7-2015

Forecasting the Response of Earth's Surface to Future Climatic and Land Use Changes: A Review of Methods and Research Needs

Jennifer L. Pierce
Boise State University

Michael J. Poulos
Boise State University

AGU PUBLICATIONS

Earth's Future

REVIEW

10.1002/2014EF000290

Key Points:

- We review models and data useful for forecasting Earth surface changes
- We identify key knowledge gaps required to forecast Earth surface changes
- We strategize how geomorphologists and Earth-systems modelers can collaborate

Supporting Information:

- Supporting Information S1

Corresponding author:
J.D. Pelletier, jdpellet@email.arizona.edu

Citation:
Pelletier, J. D. et al. (2015), Forecasting the response of Earth's surface to future climatic and land use changes: A review of methods and research needs, *Earth's Future*, *3*, 220–251, doi:10.1002/2014EF000290.

Received 9 DEC 2014
Accepted 22 MAY 2015
Accepted article online 26 MAY 2015
Published online 14 JUL 2015

Forecasting the response of Earth's surface to future climatic and land use changes: A review of methods and research needs

Jon D. Pelletier[1], A. Brad Murray[2], Jennifer L. Pierce[3], Paul R. Bierman[4], David D. Breshears[5], Benjamin T. Crosby[6], Michael Ellis[7], Efi Foufoula-Georgiou[8], Arjun M. Heimsath[9], Chris Houser[10], Nick Lancaster[11], Marco Marani[2,12,13], Dorothy J. Merritts[14], Laura J. Moore[15], Joel L. Pederson[16], Michael J. Poulos[3], Tammy M. Rittenour[16], Joel C. Rowland[17], Peter Ruggiero[18], Dylan J. Ward[19], Andrew D. Wickert[20], and Elowyn M. Yager[21]

[1]Department of Geosciences, University of Arizona, Tucson, Arizona, USA, [2]Division of Earth and Ocean Sciences, Nicholas School of the Environment, Duke University, Durham, North Carolina, USA, [3]Department of Geosciences, Boise State University, Boise, Idaho, USA, [4]Department of Geology, University of Vermont, Burlington, Vermont, USA, [5]School of Natural Resources and the Environment, University of Arizona, Tucson, Arizona, USA, [6]Department of Geosciences, Idaho State University, Pocatello, Idaho, USA, [7]British Geological Survey, Environmental Sciences Centre, Nottingham, UK, [8]Department of Civil Engineering, St. Anthony Falls Laboratory, University of Minnesota, Minneapolis, Minnesota, USA, [9]School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, USA, [10]Department of Geography, Texas A&M University, College Station, Texas, USA, [11]Desert Research Institute, Reno, Nevada, USA, [12]Department of Civil and Environmental Engineering, Duke University, Durham, North Carolina, USA, [13]Department of Civil, Architectural, and Environmental Engineering, University of Padova, Padova, Italy, [14]Department of Earth and Environment, Franklin & Marshall College, Lancaster, Pennsylvania, USA, [15]Department of Geological Sciences, University of North Carolina, Chapel Hill, North Carolina, USA, [16]Department of Geology, Utah State University, Logan, Utah, USA, [17]Division of Earth and Environmental Sciences, Los Alamos National Laboratory, Los Alamos, New Mexico, USA, [18]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis, Oregon, USA, [19]Department of Geology, University of Cincinnati, Cincinnati, Ohio, USA, [20]Department of Geological Sciences, University of Colorado, Boulder, Colorado, USA, [21]Department of Civil Engineering, University of Idaho, Boise, Idaho, USA

Abstract In the future, Earth will be warmer, precipitation events will be more extreme, global mean sea level will rise, and many arid and semiarid regions will be drier. Human modifications of landscapes will also occur at an accelerated rate as developed areas increase in size and population density. We now have gridded global forecasts, being continually improved, of the climatic and land use changes (C&LUC) that are likely to occur in the coming decades. However, besides a few exceptions, consensus forecasts do not exist for how these C&LUC will likely impact Earth-surface processes and hazards. In some cases, we have the tools to forecast the geomorphic responses to likely future C&LUC. Fully exploiting these models and utilizing these tools will require close collaboration among Earth-surface scientists and Earth-system modelers. This paper assesses the state-of-the-art tools and data that are being used or could be used to forecast changes in the state of Earth's surface as a result of likely future C&LUC. We also propose strategies for filling key knowledge gaps, emphasizing where additional basic research and/or collaboration across disciplines are necessary. The main body of the paper addresses cross-cutting issues, including the importance of nonlinear/threshold-dominated interactions among topography, vegetation, and sediment transport, as well as the importance of alternate stable states and extreme, rare events for understanding and forecasting Earth-surface response to C&LUC. Five supplements delve into different scales or process zones (global-scale assessments and fluvial, aeolian, glacial/periglacial, and coastal process zones) in detail.

1. Introduction

1.1. Problem Statement

Many of the most significant effects of future climatic and land use changes (C&LUC) will occur on Earth's surface, which we consider to be synonymous with the critical zone [e.g., *Anderson et al.*, 2008] and includes the near-surface environment where humans obtain, produce, and consume air, water, and food necessary for life. The delicate balance of human and ecosystem prosperity on Earth's surface is challenged by climatic variability, climate change, and unsustainable human activities.

The community of Earth-surface scientists (including, but not limited to, geomorphologists, hydrologists, physicists, and applied mathematicians who work on landform evolution) has developed powerful conceptual and mathematical models for how Earth's surface and near-surface environments are likely to respond to and feed back on potential future C&LUC. For example, models have been developed that reproduce observed recent changes in arctic permafrost landscapes [e.g., *Plug and West*, 2009], aeolian dune systems [e.g., *Pelletier et al.*, 2009], and the response of coastal and river systems to sea level rise [e.g., *Marani et al.*, 2007; *Fagherazzi et al.*, 2012] and land use change [e.g., *Kirwan et al.*, 2011]. In many cases, however, these models have not yet been systematically applied to forecasting landscape changes over large regions, which limits their potential impact.

Earth-system modelers, in contrast, excel at working at the global scale. They have successfully represented the key physical and chemical processes occurring in the atmosphere and oceans within their Earth System Models (ESMs). However, ESMs have been less successful at representing some Earth-surface processes, including the lateral redistribution of water, sediment, and nutrients near Earth's surface. For example, land models (for hydrometeorology, climate, and carbon cycle studies) often assume a globally uniform soil depth (e.g., 2 m in *Gochis et al.* [2010]) above bedrock. Even the use of an unconfined aquifer in land models implicitly assumes a global constant bedrock depth [e.g., *Lawrence et al.*, 2011]. The land model components of ESMs solve the governing equations for subsurface water flow in the vertical direction only, even though water moves in all three directions in the subsurface [e.g., *Miguez-Macho and Fan*, 2012]. Riverine sediment flux, an important control on biogeochemical processes in wetlands, is another important component of land surface processes not adequately accounted for in current ESMs. Given these limitations of current ESMs, there is much to be gained if Earth-surface scientists and Earth-system modelers collaborate more closely to assess the impacts of likely future C&LUC on human health, safety, and resource sustainability.

More basic research is also needed to further develop and refine Earth-surface response models so that they can be applied to forecasting changes in the state of Earth's surface in response to likely future C&LUC. Quantitative modeling of Earth-surface processes and testing and calibration of models against data are still in a relatively early stage of development compared with the advanced state of General Circulation Models (GCMs) that comprise the atmospheric and oceanic components of ESMs. As such, the Earth-surface scientific (ESS) community needs additional time and resources to develop models that accurately forecast how some Earth-surface processes will respond to likely future C&LUC. Alluvial rivers, for example, tend to aggrade when the ratio of sediment supply to transport capacity increases, and they tend to incise when that ratio decreases [e.g., *Bull*, 1991]. However, forecasting whether an alluvial river will aggrade or incise in response to future C&LUC scenarios is complicated by the fact that the relationships among sediment supply, transport capacity, rainfall, and vegetation cover are incompletely known. Similarly, we cannot yet forecast whether future climate change will lead to an overall increase or decrease in dust emitted to the atmosphere. Partly, this inability reflects the uncertainty in whether greater water use efficiency in a world of higher atmospheric CO_2 concentrations will outweigh the negative effect of limited water availability in areas undergoing desertification. Our inability to forecast whether the future will be more or less dusty also reflects the uncertainty associated with the relationship between vegetation cover and wind erosion. More vegetation cover leads to higher turbulent stresses near the ground and hence may be expected to increase rates of wind erosion. However, vegetation cover also acts to protect the underlying surface from erosion, and the trade-offs between providing protection and causing higher turbulent shear stresses need to be further resolved. To better forecast how dust emissions will change under future C&LUC scenarios, the portion of the ESS community working on wind erosion must also collaborate more closely with scientific communities working to predict future groundwater levels [e.g., *Scanlon et al.*, 2006] and the vegetation response to climate change in arid and semiarid regions [*Munson et al.*, 2011].

Natural experiments in the response of Earth-surface processes to C&LUC are constantly playing out across a wide range of timescales from human to geological, and across a wide variety of process zones. Such natural experiments provide essential data for developing and testing conceptual and mathematical models of how geomorphic systems will respond to likely future C&LUC. In all cases, landform responses are known to be complex, depending on the recent history (antecedence), the existence of internal system dynamics that can amplify C&LUC forcings preferentially at particular spatial and temporal scales, and the decisions made by humans at both individual and societal levels. The net effect is that landscapes are highly nonlinear systems, and the probability of particular impacts cannot be simply mapped to the state of forcing or the rate of forcing change. For example, in the North American Cordillera, tree mortality is increasing nonlinearly with temperature increases [e.g., *Preisler and Westerling*, 2007]. The geomorphic response to wildfires (e.g., debris-flow generation) is also highly nonlinear [e.g., *Cannon et al.*, 2010]. As such, there are compounding types of nonlinearity that must be accounted for in relating hillslope and/or fluvial-system responses to likely future C&LUC in mountainous regions.

From the perspective of modern climatic changes, high-level governmental discussions now acknowledge that some amount of human-induced change is occurring and more change is inevitable. As a consequence, significant effort is being steered toward the development of adaptation strategies. At the same time, climate scientists are acknowledging that a critical aspect of climate is its variability (particularly the increased frequency of extreme events) rather than its mean value [e.g., *Katz and Brown*, 1992]. Therefore, the need to develop adaptation strategies requires a rigorous understanding of how landscapes respond to both the mean and the variability of C&LUC. In turn, the state of Earth's climate depends in part on the response of landscapes to C&LUC. That is, the behavior of Earth's surface feeds back on the climate system in ways that are currently underrepresented in ESMs. Thus, a rigorous understanding of landscape response to external forcings is important in the contexts of both adaptation and mitigation to climate change.

In this paper, we argue that, first, ESMs have simplified representations of many Earth-surface processes and characteristics that could be improved with greater involvement of the ESS community in developing the next generation of ESMs. Second, many of the consequences of future C&LUC are felt locally and will depend sensitively on local topography, soil characteristics, vegetation cover, the degree of human disturbance, etc. Improving our ability to forecast Earth-surface hazards will thus require that the ESS community improve its ability to (1) work at larger (i.e., regional and global) scales and (2) develop forecasts (and hindcasts, to test models against measurements) that use the forcing variables' output by ESMs. Third, understanding and forecasting future landscape responses will require that the nonlinearities and threshold-dominated nature of Earth-surface systems be honored and better quantified. Fourth, a better understanding of the feedbacks among vegetation, sediment transport, and topographic change is central to improved forecasting in all Earth-surface process zones; hence, collaboration among geomorphologists, geographers, hydrologists, ecologists, and Earth-system modelers is needed.

1.2. Structure of This Review

In Section 2, we describe the nature of Earth-surface processes and hazards and their relationship to C&LUC forcing variables, rank Earth-surface hazards in terms of their relative risk to society, explain how Earth-surface processes and hazards relate to C&LUC forcing variables, and present a global map of where particular types of surface processes are likely to be dominant. Section 3 discusses opportunities for spatially explicit global-scale assessments of future changes in Earth's surface. Section 4 highlights the importance of nonlinearity, tipping points, and alternate stable states in Earth-surface systems. Section 5 emphasizes the importance of the couplings among vegetation, sediment transport, and topography in forecasting future landscape states. Section 6 argues for the importance of long timescales and natural experiments in the geologic record in validating landscape response models before they can be used for forecasts. Section 7 discusses how landscape response models can be useful for evaluating alternative mitigation strategies. Section 8 summarizes our recommendations how the ESS and broader geoscientific research communities could work to improve forecasts of Earth-surface response to likely future C&LUC. We also include five supplements that address specific scales and process zones. Text S1, Supporting Information, expands on Section 3 and reviews the global gridded forecasts currently available from the ESM community that the ESS community could use now to forecast Earth-surface responses to likely C&LUC. Text S1 also provides exemplar models and data that have been used or could be used to perform global-scale assessments of landscape response to C&LUC. Texts S2–S5 provide exemplar models and data that are being used or could be used to forecast landscape responses within the hillslope/fluvial, glacial/periglacial, aeolian, and coastal process zones, respectively. These supplements serve several purposes. They identify (1) the Earth-surface processes within each process domain that are most sensitive to C&LUC, (2) the models and data that have been or could be used to forecast Earth-surface responses to C&LUC, and (3) the key knowledge gaps and the suggested pathways for filling them, including the development of coupled process-based models, leveraging off of community-based code repositories/portals such as the Community Surface Dynamics Modeling System (CSDMS) and greater collaboration across disciplines.

2. The Nature of Earth-Surface Processes and Hazards

The hazards associated with Earth-surface processes include acute events (e.g., floods) in addition to more chronic events such as soil loss and the associated loss of food production potential. Examples of societally relevant landscape properties in need of better forecasting include:

1. the elevation of the land surface, including its changes in space and time (i.e., subsidence, river aggradation/incision, coastal erosion, etc.),
2. the fluxes of sediment and nutrients (as well as contaminants such as metals that impact water quality) laterally across Earth's surface,
3. the frequency and magnitudes of landslides, floods, dune encroachment, and other hazards related to mobile water and sediment at or near Earth's surface, and
4. particulate matter (PM) concentrations in the atmosphere, including those associated with fugitive dust.

Not all Earth-surface hazards and/or changes in societally relevant properties pose an equal risk to society. Therefore, it is useful to identify the most significant hazards to provide guidance on which hazards should be prioritized for the development of improved forecasting tools. The risk associated with these hazards can also be divided into a direct and an indirect risk. A direct risk is associated with loss of life and property. An indirect risk is one that does not directly threaten a large number of lives or properties but may have catastrophic effects in concert with another process (e.g., the greenhouse effect). An example of an indirect risk is the potential release of CO_2 and methane into the atmosphere associated with thawing permafrost and loss of ground ice, thus accelerating the greenhouse effect. In our ranking, we focused primarily on direct risks. The ranking is subjective, but it is broadly consistent with order-of-magnitude estimates of the financial risk posed by these different types of hazards [e.g., *Tol*, 2002, 2009]. We believe that future Earth-surface hazards can be approximately ranked in terms of their potential impact as follows: (1) coastal erosion and inundation, (2) river flooding and channel change, (3) water resource impacts (drought, desertification, and water quality), (4) erosion and soil loss (including mass wasting and wildfire hazards), and (5) cryosphere impacts (progressive thaw or melt in the cryosphere).

One challenge of forecasting Earth-surface responses to C&LUC is the fact that land surface processes depend sensitively on secondary drivers related to but distinct from the basic variables of C&LUC. Figure 1 illustrates how different Earth-surface process types relate to the primary C&LUC variables of temperature, precipitation, wind, and land use (including their mean values and their variability over a range of timescales). Secondary variables include runoff and infiltration (i.e., hydrology), land cover (including changes in the natural vegetation cover of landscapes and human disturbance, e.g., ecology and human geography), and the coastal zone forcings of sea level, storm surge, and wave heights. While the effects of climate hazards such as heat waves and droughts involve fairly direct linkages with primary climate variables, forecasting Earth-surface processes and hazards requires the translation of primary forcing variables into secondary forcing variables before any forecasting can be done. The relationships among primary and secondary variables are, in some cases, clear. For example, warming of the polar regions and continued extraction of fluids from deltaic regions will drive relative sea level rise in many regions. In other cases, the relationships are less clear. For example, how precipitation changes are likely to alter land cover in the future is complex and incompletely understood. As such, Figure 1 underscores the need for collaboration among specific geoscientific research communities, including among geomorphologists and hydrologists, ecologists, and the human geographers who forecast land cover changes.

The types of Earth-surface processes and the associated hazards that dominate landscape response to C&LUC vary regionally and globally (Figure 2). Glacial/periglacial zones are defined in Figure 2 as those with mean annual temperatures less than 0°C as determined using the WorldClim database [*Hijmans et al.*, 2005]. Increasing temperatures in such regions are likely to drive land subsidence due to thawing permafrost, leading to a release of soil carbon that feeds back on the global climate system. Aeolian/arid areas are

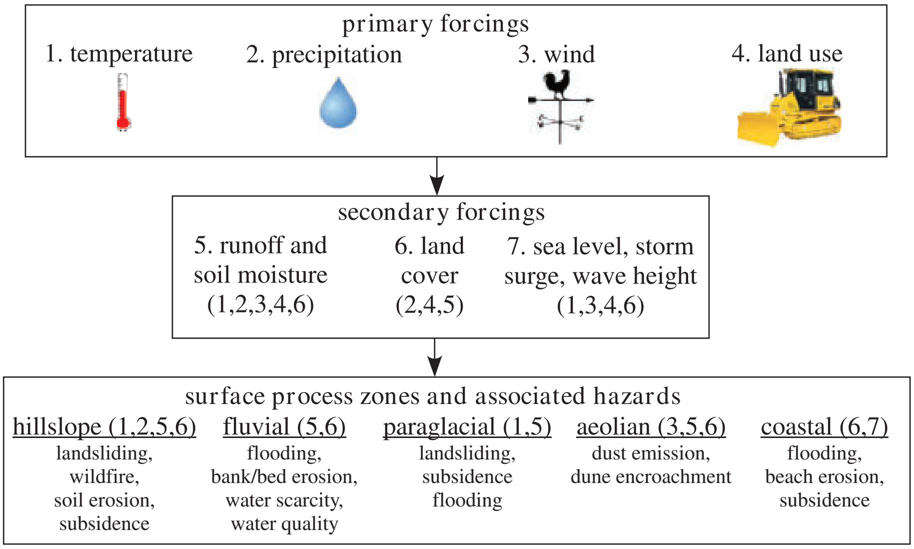


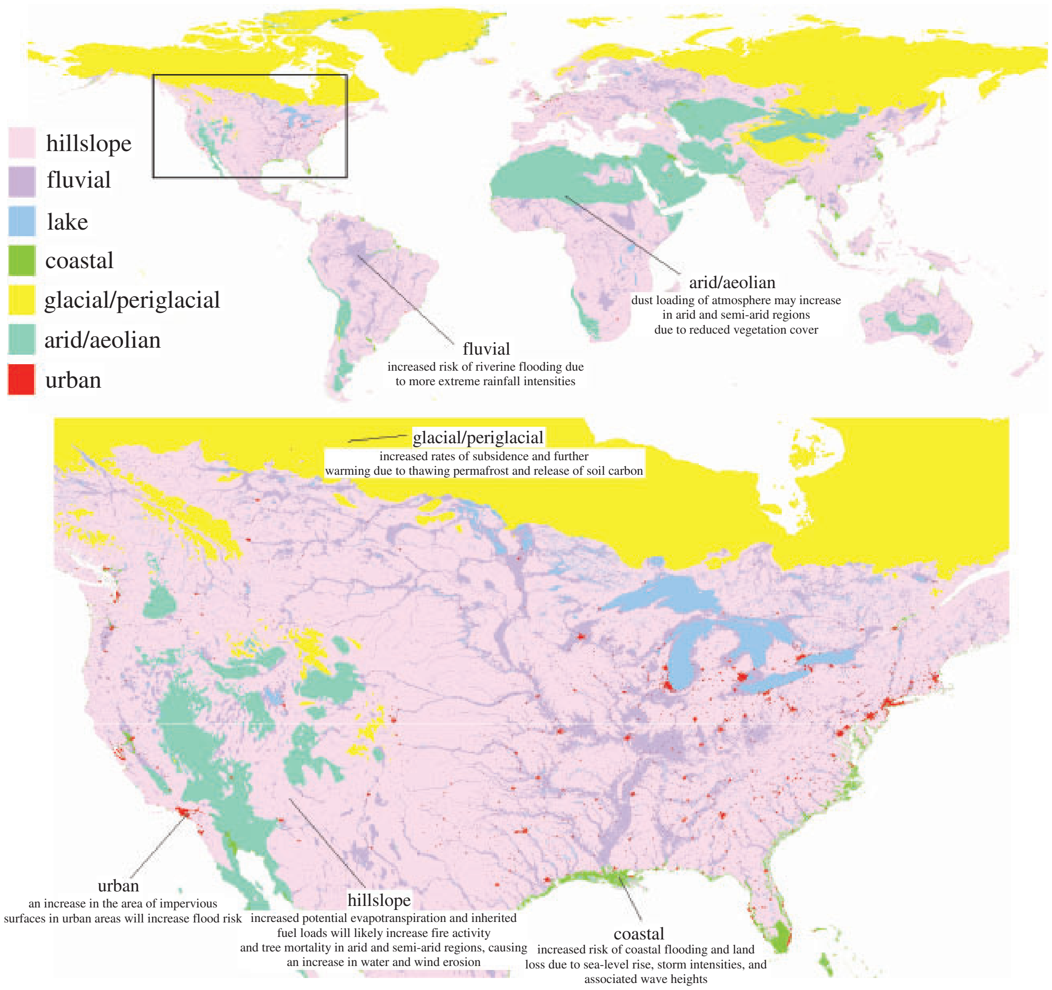
Figure 1. Conceptual diagram illustrating the linkages among the primary C&LUC forcing variables, secondary forcing variables (i.e., those that depend on the primary forcing variables but involve additional ecohydrologic and/or anthropogenic processes), and the main types of Earth-surface processes and their associated hazards. The numbers indicate dependencies. For example, the secondary forcings of sea level, storm surge, and wave height (#7) depend on global temperature changes (#1, e.g., melting polar ice), wind speeds (#3, e.g., stronger winds lead to greater storm surges and wave heights), land use (#4, e.g., fluid extraction from deltaic sediments can drive subsidence that contributes to relative sea level rise), and land cover (#6, e.g., changes in vegetation cover that can modify storm surges, dune mobility, etc.).

defined to be those with less than 200 mm a^{-1} of rainfall. Dust emission from such areas may increase in the future due to increased aridity and reduced vegetation cover. Fluvial areas are delineated by routing hypothetical extreme flows through the global 30-arc-second-resolution SRTM-derived DEM [*Farr et al.*, 2007] augmented with ASTER GDEMV2 data where SRTM data were unavailable. Such areas are likely to experience more frequent flooding in response to future increases in precipitation intensity. However, changes in sediment supply from hillslopes could cause valley floors to incise, thus decreasing flood risk in areas adjacent to valley floors. Coastal areas are considered to be areas within 10 m of sea level. Many of these areas will experience an increase in the frequency and magnitude of flooding and erosion, particularly in areas where land subsidence is occurring simultaneously with the rise in global mean sea level. Urban areas are mapped based on the Global Land Cover database [*Hansen et al.*, 1998]. As the population densities of these areas increase, it is likely that peak flood discharges will be greater due to the lower infiltration rates of impervious surfaces relative to natural surfaces. Hillslope areas are those not included in any of the other process zones. On hillslopes in arid and semiarid regions, increased potential evapotranspiration and fuel loads will likely trigger larger and more severe wildfires resulting in increased rates of soil erosion.

The thresholds of mean annual temperature, rainfall, and elevation that define the boundaries between the process zones in Figure 2 are not unique. By presenting Figure 2, we are not suggesting that there is a unique global map of process dominance. Rather, we are proposing that there is value in mapping regional "hotspots" where landscapes are likely to be most sensitive to certain types of C&LUC. Such a map will be useful in focusing research in those hotspots. In some cases, the hotspots of landscape response may occur at the boundaries between process domains. For example, it is reasonable to expect that land degradation (e.g., hillslope gullying, valley floor incision) is most likely to occur in semiarid regions that transition to arid regions, rather than in areas that are already arid.

3. Opportunities for Spatially Explicit Global-Scale Assessments of Future Changes in Earth's Surface

The ESS community has a long and successful tradition of investigation at scales from individual hillslope segments to the scale of whole watersheds. However, the ESM community necessarily works at the global scale. One of the challenges of integrating process models and data from the ESS community into ESMs



arid/aeolian
dust loading of atmosphere may increase in arid and semi-arid regions due to reduced vegetation cover

fluvial
increased risk of riverine flooding due to more extreme rainfall intensities

glacial/periglacial
increased rates of subsidence and further warming due to thawing permafrost and release of soil carbon

urban
an increase in the area of impervious surfaces in urban areas will increase flood risk

hillslope
increased potential evapotranspiration and inherited fuel loads will likely increase fire activity and tree mortality in arid and semi-arid regions, causing an increase in water and wind erosion

coastal
increased risk of coastal flooding and land loss due to sea-level rise, storm intensities, and associated wave heights

Figure 2. Map of dominant surface process zones, along with examples of the hazards and potential changes in hazards under future C&LUC scenarios. See text for a description of the criteria used to define each zone.

is the disparate scales at which most (though certainly not all) Earth-surface scientists and Earth-system modelers work. Earth-system modelers require data and process models that have global coverage and are globally applicable. Many Earth-surface scientists do not develop data or models with such global applicability in mind. In this section, we argue for enhanced collaboration between the ESS and ESM communities.

Readily available data for future climates include near-surface temperature (and its daily and seasonal variability), precipitation (and its event-scale and seasonal variability), potential evapotranspiration, and near-surface wind speeds. Readily available data for future land use changes include changes in the percent area (within 1° x 1° pixels) that will likely transition among crop, pasture, urban, primary (actively disturbed), and secondary (previously disturbed but recovering) land use types. In order to make forecasts of the Earth-surface response to C&LUC, the ESS community must further develop predictive Earth-surface response models so that they work with available input data for future C&LUC scenarios. At the same time, the ESS community needs to collaborate with Earth-system modelers and the climate and geography communities to provide the most appropriate and useful inputs for Earth-surface response models. For example, future vegetation states have been predicted, but these data usually predict vegetation type only. Few Earth-surface response models are designed to work with vegetation type. Instead, many existing models work with leaf area index (LAI) [e.g., *Pelletier*, 2012] or other quantitative measures of vegetation cover such as percent bare area. As such, the ESS community should collaborate more closely with Earth-system modelers and the climate and geography communities to ensure that data products are being produced that meet the needs of their models.

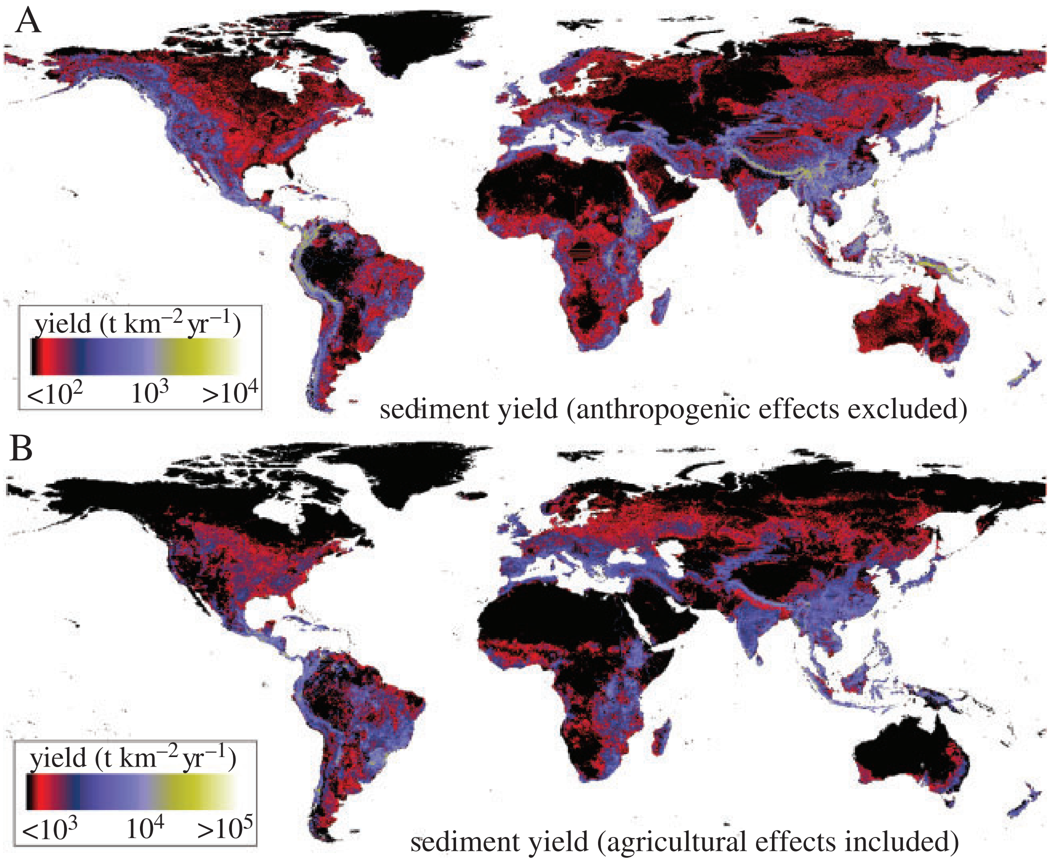


Figure 3. (a) Color map of the natural/pre-dam sediment yield as quantified by the model of *Pelletier* [2012]. (b) Sediment yield with agricultural effects included.

In this section, we use riverine sediment flux (or yield, defined as flux in mass per unit time divided by drainage basin area) as an example of an Earth-surface process for which global-scale models exist that could be used in the near future to forecast changes in response to likely future C&LUC. Quantifying sediment yield in rivers has been a central topic in geomorphology for at least a century. Sediment yields influence biogeochemical processes in wetlands [*Reddy et al.*, 2000]. Most predictive models for global sediment yield focus on the suspended load component of the total load, which is the dominant component of the total load for most large rivers. *Pelletier* [2012] developed a model that includes mean monthly precipitation, soil texture, and vegetation cover (quantified as LAI) explicitly (Figure 3). Sediment yield in this model increases in direct proportion to average rainfall and decreases exponentially with increasing LAI.

It is straightforward to include the effects of agriculture in the *Pelletier* [2012] model, at least in a simplified way, as an example of how the land use changes could be explicitly included in current land surface response models. Figure 3b illustrates the impact of modern agriculture on long-term average sediment yields, assuming that croplands are areas of bare undisturbed ground in the model framework of *Pelletier* [2012]. This is a simplified approach because croplands are bare only part of the time. Neglecting plant cover during the growing season likely leads to an overprediction of sediment yield, but this effect is somewhat counteracted by the fact that cropland soils are disturbed by tillage, thus reducing their shear strength relative to bare undisturbed surfaces. When agriculture is included in the model, the region of largest sediment yields in the U.S. shifts from the western U.S. to the eastern U.S. and the average sediment yield increases by a factor of approximately 30, consistent with the findings of *Wilkinson and McElroy* [2007].

The challenge of quantifying the geomorphic responses to land use changes reflects the uncertainty in both how sediment yield relates to land use and how land use should be quantified for input into models. Existing global gridded datasets for land use predict the locations and density of transitions between primary land

and agricultural land, but it remains unclear how best to quantify the relationships between erodibility and land use type. The effects of land use changes have been incorporated into empirical models for hillslope sediment yields such as the Universal Soil Loss Equation (USLE) [*Wischmeier and Smith*, 1978]. The effects of dams in storing sediments released from uplands have not been well quantified on a regional or global basis, but the effect is substantial. Despite the recent order-of-magnitude increase in soil erosion in the eastern U.S., the flux of sediment reaching the oceans is lower today than it has been in the past, indicating that large volumes of sediment are being stored within the fluvial system [e.g., *Walter and Merritts*, 2008; *Wisser* et al., 2013]. *Syvitski and Milliman* [2007] included anthropogenic effects on sediment yield with drainage basin–specific coefficients that depended on population density and GNP per capita. Additional research is needed to identify how best land use/land cover data types can be used to quantify sediment yield.

4. Crosscutting Importance of Nonlinearity, Tipping Points, Alternate States, and Uncertainty Propagation

Earth-surface systems are typically controlled by nonlinear and/or threshold-dominated responses to changes in external forcings [e.g., *Schumm*, 1979]. These nonlinearities imply that landscape responses to ongoing and likely future C&LUC will be both amplified and difficult to predict. Here, we provide a discussion of the basic concepts of nonlinear dynamical system theory [*Strogatz*, 2001], which provides an essential framework for understanding Earth-surface response to likely future C&LUC.

Nonlinear systems respond at a variable rate to changes in external forcings. These responses can gradually amplify the forcing, and/or they can include thresholds or "tipping points" that mark abrupt changes in the forcing–response relationship. Nonlinear relationships between forcing and response lead to disproportional responses to possibly subtle changes in forcing (Figure 4a), while feedbacks among processes governing system dynamics are often responsible for threshold responses to C&LUC (Figure 4a) and for driving some systems into one of multiple alternative equilibrium states, with the associated potential for sudden landscape/ecosystem transitions from one state to another (Figure 4b). Positive feedbacks have important implications for Earth-surface science [e.g., *Murray et al.*, 2008] (producing, for example, drainage network development [*Rinaldo et al.*, 1998], conversion of alpine glaciers into debris-covered rock glaciers [*Scherler et al.*, 2011], and river avulsions [*Slingerland and Smith*, 1998]), including these forms of rapid change and instability in the face of gradual shifts in C&LUC.

An example of gradual amplification of a forcing change is dust entrainment, which is a major player in Earth's energy balance (because dust is a radiatively important aerosol) and exerts a significance influence on human health. Dust entrainment scales approximately with the shear velocity exerted on the surface to the third power and also depends nonlinearly on moisture/water table depth [e.g., *Pelletier*, 2006]. Landsliding provides an example of a threshold-dominated behavior, in which slow soil creep can give way to catastrophic failure [*Ritter et al.*, 1999]. Bed load sediment transport rates relate to turbulent bed shear stresses in a way that is both nonlinear and threshold dominated [*Gomez and Church*, 1989]. These nonlinear responses make landscapes highly sensitive to C&LUC. In the southwestern U.S., for example, a transition from woodland to desert scrub species within elevation zones from approximately 800–1800 m above sea level caused an order-of-magnitude increase in sediment supply from watersheds during the Pleistocene-to-Holocene transition that triggered two downstream cycles of river and alluvial fan aggradation, incision, and renewed aggradation [*Pelletier*, 2014]. In recent decades, small increases in springtime temperatures have exponentially increased wildfire size and severity [*Westerling* et al., 2006], consistent with the measured correlation between modest warming and dramatically increased burn extent and severity in the western U.S. through the Holocene [*Pierce et al.*, 2004]. In many semiarid areas of the western U.S., drought-stressed forests will not recover from vapor pressure deficits that manifest in non-replacement following disturbances such as fire and insect infestations [*Williams et al.*, 2012]. This suggests that a vegetation-type conversion similar in scope to vegetation changes recorded at the Pleistocene-to-Holocene transition [*Whitlock and Bartlein*, 1997] may be ongoing now, with important consequences for flood probabilities and soil sustainability.

Recent studies of tidal marsh dynamics highlight the importance of multiple stable states, and the associated potential for instability. For example, vegetation stabilizes tidal marshes by dissipating wave energy and producing and trapping sediment. However, once sea level rise is sufficiently rapid enough to outpace this sediment production, marshes may be rapidly submerged and converted into sub-tidal platforms

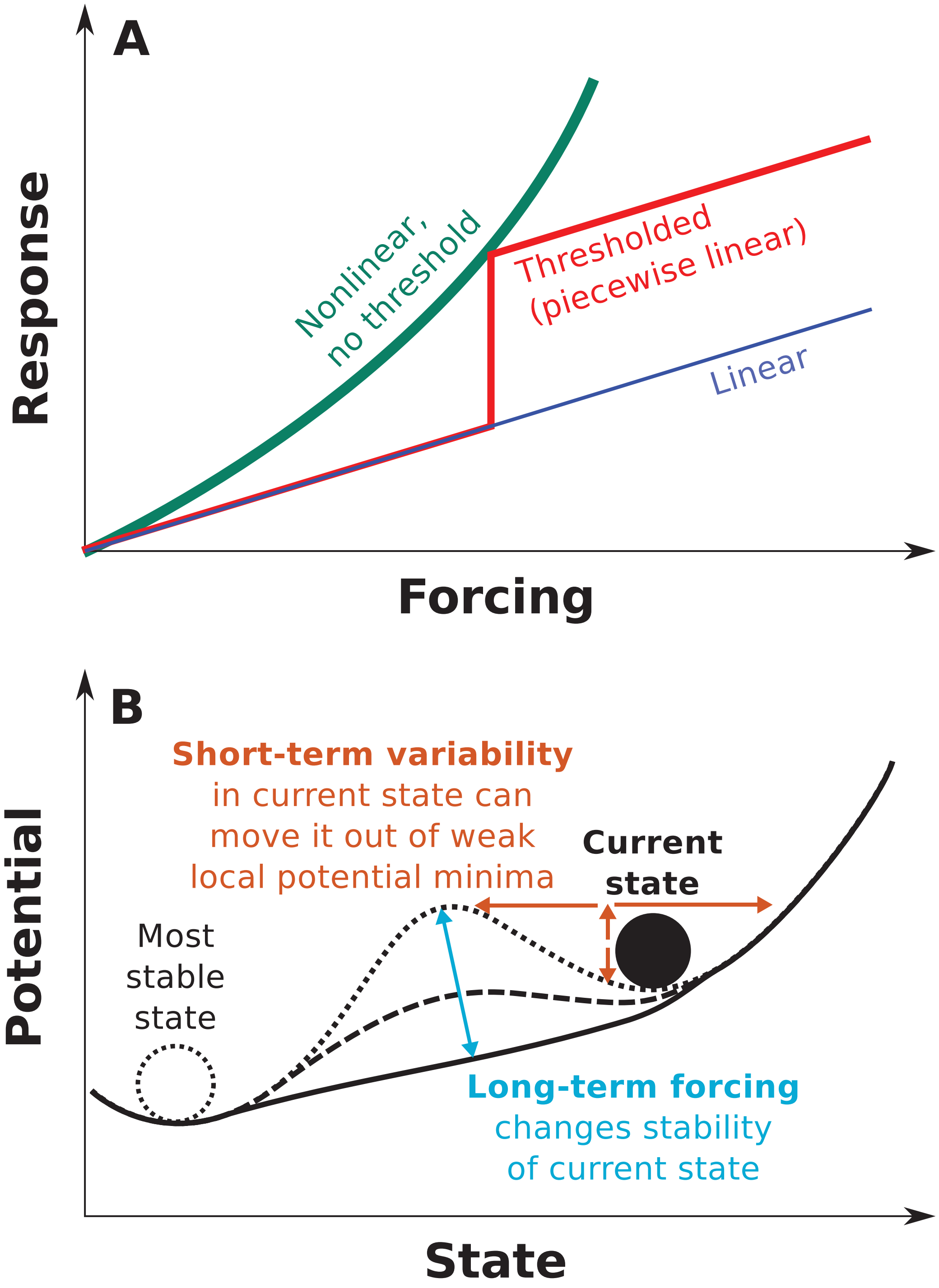


Figure 4. Schematic diagram illustrating the linear and nonlinear responses of an Earth-surface system to changes in forcing. (a) Land surface systems in the presence of a positive feedback can present several competing states. (b) Illustrates the case of a system with two possible stable states. Shifts can occur because of short-term variability in the forcing (weather) overcoming the energy barrier separating the two coexisting states or because long-term changes in the forcing (climate) change the shape of the potential defining the available stable states, making one of the states disappear and leading the system to occupy the surviving lower energy stable state.

[*Marani et al.*, 2010]. In addition, recent modeling suggests that increasing storm frequency or the rate of sea level rise can shift barrier islands from a regime with a single stable state featuring high dunes and complex ecosystems into a regime in which a wave-swept, low topography state is an alternate possibility—or even into a regime in which the high-dune state is no longer possible.

ESMs predict an increase in hydrologic variability as a result of human-induced global warming [*IPCC*, 2007, 2013], which should lead to enhanced geomorphic change [*Lane*, 2013]. However, uncertainties in future landscape forcings obtained from climate models may translate into large uncertainties in forecasts of future Earth-surface states due to nonlinear and possibly threshold-dominated geomorphic responses. Figure 5 illustrates the propagation of uncertainty from forcing forecasts to Earth-surface-system responses and finally to impacts on humans and infrastructure for two contrasting cases of linear and threshold responses, assuming Gaussian distributions of uncertainty (Figure 5b). If the geomorphic response is threshold dominated (Figure 5a), the distribution of responses is partitioned into two very distinct sets of likely responses: both minor and major geomorphic responses may become plausible, thus increasing the degree of uncertainty of the forecast (Figure 5d). The projected impact of the Earth-surface response (e.g., on ecosystems or infrastructure; Figure 5c) must be combined with the probability distribution of plausible geomorphic responses to statistically characterize the risk (Figure 5d). These schematic examples underscore how essential it is to understand the linear/nonlinear nature of the processes at play in the Earth-surface system in order to determine, and correctly interpret, the potential landscape responses to C&LUC.

5. Crosscutting Importance of Vegetation Dynamics in Future Landscape Change Forecasts

Stable landscapes reflect complex feedbacks among surface processes, climate, and vegetation. Slope stability is enhanced through lateral reinforcement by roots [*Schwarz et al.*, 2010], which allows steepening of hillslope profiles and reduction of drainage density that, in turn, may increase the intensity of erosive events when the vegetation cover is disturbed [*Collins et al*., 2004]. Vegetation cover fundamentally influences geomorphic processes and landforms, e.g., through sediment-trapping potential, influences on surface hydrology, interaction of roots and soil cohesion/erodibility, and via rock weathering and soil production. For example, the stability of barrier islands depends on the ability of foredunes to develop in both height and extent [*Houser et al.*, 2008], which, in turn, depends on the distribution and density of dune-building vegetation [*Durán and Moore*, 2013]. Resiliency of an island, therefore, is dependent on the regrowth of vegetation through the reemergence of buried plants, seed banks, and colonization from adjacent areas. Dune-building grasses can alter dune geomorphology within months, and different plant species build dunes of different shapes resulting in variable levels of exposure to coastal hazards posed by intense storms and sea level rise [*Seabloom et al.*, 2013]. The case of dune grasses also exemplifies the widely applicable point that we need to understand not just how vegetation affects physical processes, but also how vegetation responds to physical processes [e.g., *Murray et al.*, 2008].

Indirect influences of climatic changes and direct human modification of the landscape can alter vegetation cover, which can lead to a new landscape. The stability and morphology of coastal marshes as sea level rises depend on the ability of salt marsh vegetation to promote sediment deposition and limit erosion [*Morris et al.*, 2002]. If growth of the marsh surface through organic and inorganic sediments is unable to keep pace with sea level rise, there is the potential for the entire marsh surface to become unstable and irreversibly change to a tidal flat or a sub-tidal platform [*Marani et al.*, 2007], with spatially complex biogeomorphic responses [*D'Alpaos et al.*, 2007; *Kirwan and Murray*, 2007; *Marani et al.*, 2013].

More extreme modifications such as deforestation, alteration in vegetation type (e.g., in response to fire- or drought-induced tree die-off), and introduction of exotic species can cause further geomorphic changes. For example, climate-driven increases in wildfire extent and severity since the mid 1980s have also increased burn areas exponentially [e.g., *Westerling et al.* 2006]. In areas of steep topography, this has resulted in large and often damaging debris flows [*Cannon et al.*, 2010]. In central Idaho, fire-related erosional events increase the sediment yield from channels and hillslopes by almost four orders of magnitude over background rates [*Meyer et al.*, 2001], and two orders of magnitude over average Holocene rates [*Kirchner et al.*, 2001, *Meyer and Pierce*, 2003].

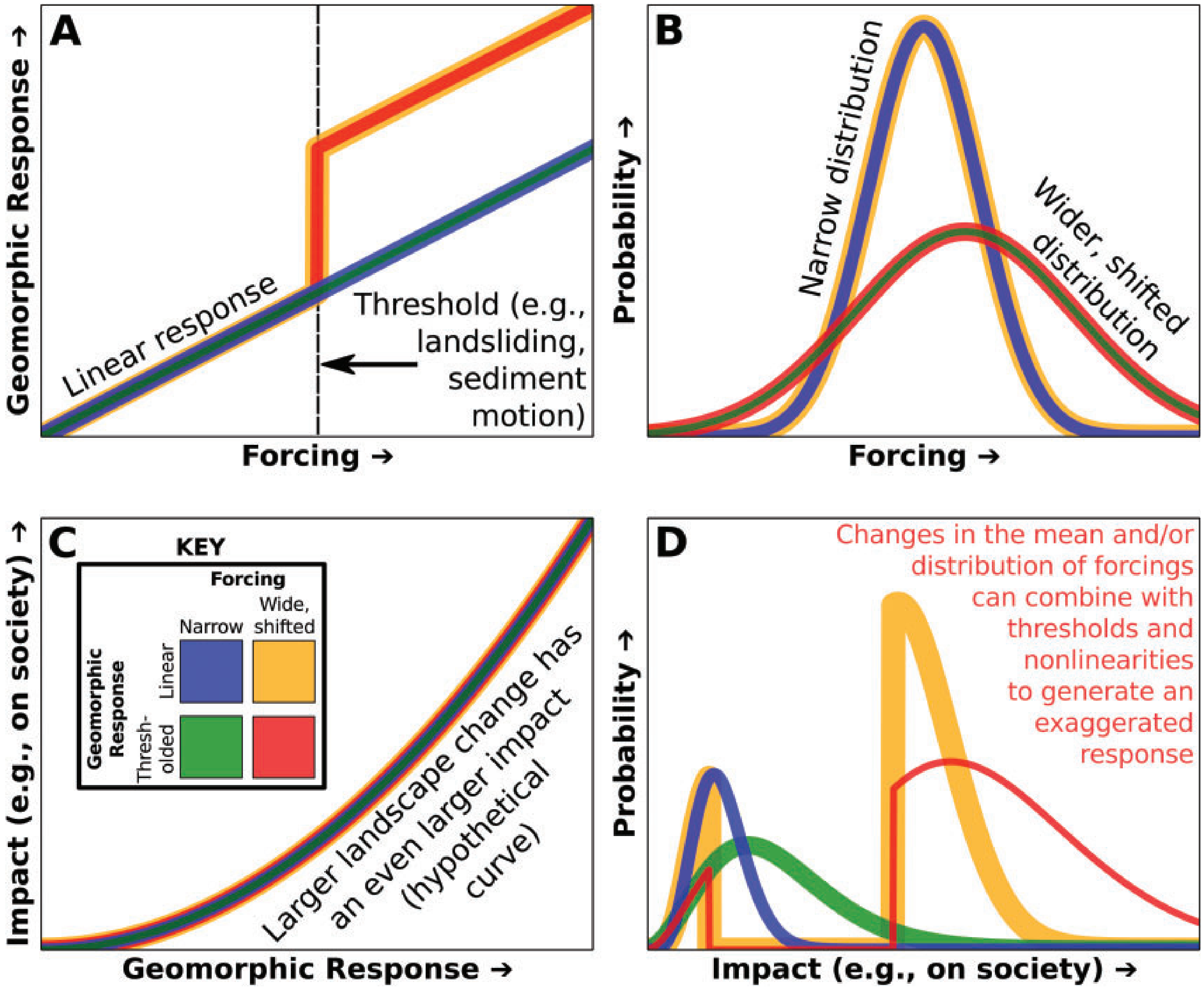


Figure 5. Schematic diagram illustrating the propagation of uncertainty from models of C&LUC to Earth-surface-system responses and societal impacts for nonlinear and/or threshold-dominated systems. Gaussian distributions of uncertainty in ESM-generated forcing of Earth-surface processes (shown in b) propagate to give very different probability distributions of responses and impacts depending on the degree of nonlinearity of Earth-surface processes. If the response is thresholded (shown in a), the probability distribution of the response is partitioned into two very distinct and widely different ranges of possible states (shown in d). The possible impacts, computed through a conventional impact function (c), are similarly distributed around two distinct possible impact ranges (shown in d).

Changes in vegetation can result from changes in sediment supply and water discharge at a distant location. For example, there has been a large loss of cottonwood trees downstream of dams because of a disconnection from the floodplain, caused by both channel incision (due to a lack of sediment supply from upstream) and lack of inundating flows (due to flow regulation) [e.g., *Polzin and Rood*, 2000; *Amlin and Rood*, 2002]. In addition to these changes, invasive species such as salt cedar have taken over in areas downstream of dams in part because of these changes in hydrology [*Friedman et al.*, 2005].

Changes in vegetation often trigger dramatic landscape responses by altering the forces both driving and resisting erosion. Changes in resisting forces effectively alter the thresholds between the stable states of landscapes, whereas changes in driving forces alter the ability of the system to overcome those thresholds. Reducing vegetation cover on hillslopes generally increases erosion by changing both the driving and resisting forces; runoff increases because interception, surface roughness, and water consumption are all reduced, while root cohesion that inhibits erosion is also reduced [e.g., *Cerda and Doerr*, 2005]. Changes in vegetation type may directly alter root cohesion, surface roughness, and geomorphic process dominance (e.g., tree throw), while indirectly altering erosive processes such as bioturbation from local fauna dependent on the vegetation (e.g., ground squirrels). Reducing vegetation cover and the associated transpiration and increased albedo and near-ground solar radiation can cause the local climate to become more arid [*Royer et al.*, 2010]. A reduction in transpiration could increase the vapor pressure deficit of the air, thereby exacerbating vegetative water stress and possibly further reducing vegetation cover through wildfire.

The importance of vegetation is quite evident in arid and semiarid environments where it limits erosion by wind and water and feeds back to the local climate through evapotranspiration. The ability of vegetation to withstand periodic drought introduces resiliency to the landscape, while the expansion and contraction of vegetation in response to prolonged changes in climate enhance low-frequency variations in rainfall [*Wang and Eltahir*, 2000] and an alternation between different vegetation states (i.e., type and/or percent cover). Specifically, the loss of vegetation through prolonged drought further limits moisture availability through a loss in soil and an increase in the vapor pressure deficit, which increases the potential for degradation through both water and wind [*Middleton and Thomas*, 1997; *Breshears et al.*, 2009]. In low-gradient arid and semiarid fluvial environments, plant mounds can lead to episodic water detention and striking patterns of vegetation banding [*Pelletier et al.*, 2012], demonstrating the bistability of ecohydrogeomorphic processes in arid and semiarid regions. Whether by water or wind, erosion tends to lead to a loss of biodiversity and soil resources, and a decrease in water-holding capacity, which, in turn, can limit primary productivity and carbon sequestration [*Chapin et al.*, 1997]. The continued loss of biodiversity may decrease system resiliency to periodic droughts, which may increase the potential for these systems to jump to an irreversible state of desertification.

Despite the importance of vegetation, direct incorporation of vegetation into geomorphic models is relatively limited. This is partly a result of the complex feedback processes among vegetation (both individual plants and communities), soil strength, fluid hydraulics, hydrology, and sediment transport. For example, in fluvial systems, vegetation is often indirectly modeled using high drag coefficients, but such simplifications do not account for the impact of vegetation on flow turbulence [*Nepf*, 1999] and the associated spatial changes in suspended sediment [*Zong and Nepf*, 2011] and bed load transport [*Yager and Schmeeckle*, 2013]. The divergence in sediment transport caused by vegetation could then lead to local scour and deposition [*Temmerman et al.*, 2007] that influence subsequent stem-scale survival [*Yager and Schmeeckle*, 2013] or vegetation patch growth [*Meire et al.*, 2014]. A better predictive understanding of these couplings—in the contexts of both air and water flows—and the importance of vegetation characteristics (e.g., species, density by area, root strength) is needed to determine how future changes in vegetation will influence geomorphic processes. Predicting vegetation dynamics is also challenging because important information on basic ecological processes such as plant mortality and its response to climate change is complex and remains highly uncertain [*McDowell et al.* 2011]. Vegetation effects on geomorphic responses can require not only predicting vegetation succession but also responses to disturbances such as drought and wildfire [*Breshears et al.*, 2012].

6. Crosscutting Importance of Long Timescales and Natural Experiments in the Geologic Record

The ESS community utilizes the geologic record as well as natural experiments of landscape dynamics that span a range of timescales from individual events (e.g., floods or wind storms) to the timescales involved in mountain building. Pertinent to understanding the effects of ongoing and future climatic changes are datasets ranging from the glacial-interglacial changes of the Quaternary epoch, to the millennial- and centennial-scale changes affecting Earth systems during the Holocene, and to the historic and ongoing natural experiments that we can monitor and study as they happen. All of these types of natural experiments have a primary role/purpose in testing conceptual and numerical models, providing essential grounding for any future forecasts.

The geologic record provides our essential understanding of past climate variability (paleoclimatology), placing the pace and magnitude of modern climatic change in context. It also provides case studies of landscape response to change and has the potential to test surface process models projecting future changes. This potential for model testing seems underdeveloped at this time, perhaps because it is only recently that multiple high-resolution geochronologic and isotopic tools have revolutionized our capabilities to study these natural archives. Now we are better able to reconstruct past change, more fundamentally, to better address the issue of what incomplete stratigraphic archives actually record in terms of process.

Often the largest changes evident in landscapes occurred in response to the glacial-interglacial oscillations of the Quaternary. For example, by reconstructing the timing and extent of former glacial advances on the ground, we have been able to model both precipitation and temperature changes through time through the glacial-interglacial transitions. Stream terrace records are, in places, approaching a level of understanding that makes them useful for testing of landscape evolution models [e.g., *Hancock and Anderson*, 2002; *Wegmann and Pazzaglia*, 2002; *Pelletier et al.*, 2011]. Yet, there is a critical need for well-constrained geologic records that link hillslopes to drainages through these large-scale changes to complete our picture of landscape response [e.g., *Harvey*, 2002; *Anders et al.*, 2005; *Enzel et al.*, 2012; *Pelletier*, 2014].

Some landscapes have been sensitive to the more moderate and recent climatic changes over the Holocene, at millennial to decadal timescales—thus recording responses to changes of the same magnitude as forecast over the upcoming century. These records caution us about the less predictable influence of catastrophic events such as high-magnitude storms and floods, which may define or reset much of the geologic record itself. Examples are alluvial records of flood magnitude/frequency and changes in sediment supply [e.g., *Macklin and Lewin*, 2008; *Harvey and Pederson*, 2011] and landsliding [*Korup et al.*, 2012].

Natural and artificial experiments remain the mainstay of understanding the response of landscape processes to climatic changes. Because large-scale experiments on geological timescales are not possible, much of our understanding of process response to climatic forcing is based on natural experiments. Natural experiments usually rely on a particularly well-expressed geomorphic process, or a particularly well-documented part of the geologic record. They allow us to isolate the effects of physical climate variables such as temperature and precipitation rate [e.g., *Abbühl et al.*, 2011; *Menking et al.*, 2013; *Ferrier et al.*, 2013] on specific geomorphic processes.

Finally, landscape evolution models can bridge the gap between process understanding and the geologic record. These models integrate physical understanding from natural and controlled laboratory and field experiments. A common modeling goal is to simulate how various processes interact to produce a realistic synthetic landscape (i.e., one that compares well, at least statistically, to the modern landscape and the evidence from the geologic record) [*Dietrich et al.*, 2003]. Calibrating models based on landscapes produced by an integrated history of climate change over geologic timescales runs the risk of generating false confidence in the predictive power of such models, because incomplete geological records of landscape change do not allow strong assessment of equifinality in model results [e.g., *Brazier et al.*, 2000; *Beven*, 1996]. Continual refinement of these models based on independent understanding of individual processes is required to rigorously evaluate the model outcomes and any predictions they make [*Dietrich et al.*, 2003]. The natural experiment that is anthropogenic C&LUC, and the associated rapid, measurable response of sensitive landscapes, provides an important opportunity for landscape modelers: models of landscape processes can be used to make predictions of change that will manifest on ~5–10 year timescales, and the models can be continually refined based on real-time monitoring of these processes (i.e., data assimilation) in order to improve their predictive power [*Paola et al.*, 2006].

Data are needed by numerical models to both (1) develop or improve empirically based parameterization and parameter values and (2) test diagnostic model predictions. Although the types of data needed are specific to each model context, existing data are often not complete or otherwise optimal for these two sorts of needs. More communication and collaboration between researchers developing models and those with observational expertise is needed, so that resources that go into collecting data can be better directed toward collecting the types of data that will allow modeling capabilities to advance more rapidly.

7. Adaptation Strategies

Recognizing that changes in the state of Earth's surface are an inevitable and ongoing part of Earth's dynamics, society is developing strategies for adapting to these changes. Investigations of the geomorphic processes governing landscape response to C&LUC at a variety of spatial and temporal scales are essential precursors for developing appropriate adaptation and mitigation strategies for hazards associated with Earth-surface processes. Geomorphic studies can provide guidance for direct site-specific human modification of Earth-surface systems (e.g., environmental restoration, hazard mitigation) and the development of realistic policy alternatives for future landscape and climate states. Such efforts require close collaboration between the scientific community and stakeholders (government agencies at all levels; communities, land owners, etc.) to ensure that the best available scientific knowledge is used appropriately. In some cases, knowledge gaps may need to be filled by targeted investigations (e.g., determining dust emission potentials from disturbed and undisturbed surfaces [e.g., *Macpherson et al*., 2008]). Some examples of successful adaptation strategies include:

1. An improved understanding of how fluvial systems have evolved in the northeast U.S. in response to widespread human manipulation has informed stream restoration projects in Pennsylvania. The result is that such restoration efforts now provide increased ecosystem services compared with previous practices (see text S2 for details).
2. Models of the response of coastal sediment transport to human manipulations have shown that shoreline stabilization in one location affects distant coastal communities as well as the neighboring ones, especially as climate forcing changes; this insight provides a framework for more coordinated holistic management of coastlines (as opposed to the ad hoc approach prevalent currently)—with the goal of increasing the net benefits to the stakeholders involved (see text S5 for details).
3. Coastal areas in the U.S. are beginning to incorporate adaptation to climate change impacts into their community planning. One significant example of this is the 2012 Louisiana Coastal Master Plan, available at http://coastal.la.gov/a-common-vision/2012-coastal-master-plan/. This effort involves an assessment of future system states if no new action is taken along with portfolios of policy scenarios or management solutions to guide systems toward alternate states. Such an effort incorporates a mix of coupled geomorphic/ecological/hydrodynamic models along with socioeconomic data and models to guide policy choices that will reduce coastal change and flood risk for coastal communities.

8. Next Steps

To improve our ability to forecast changes in the state of Earth's surface in response to future C&LUC, we recommend several steps. These can be divided into steps that the ESS community can take working largely within its community and work that requires collaboration with other research communities.

Steps that the ESS community can take largely independently include:

1. Develop additional process models that couple process zones that have traditionally been considered separately,
2. Develop additional datasets that can be used to test numerical models (particularly over decadal to century timescales),
3. Develop forecast models that can use existing data, and
4. Extend models developed based on one location to other locations by testing those models against data for areas having different characteristics and then updating the models so that they apply more broadly.

Tasks that require collaboration with other research communities include:

1. Develop improved input datasets and component models for Earth-surface processes in ESMs and
2. Focus on the development of datasets for testing models (particularly over decadal to century timescales).

Landscape responses to C&LUC often involve critical linkages between disparate processes in different process zones. For example, the maintenance of tidal wetland and delta landscapes depends in part on hillslope and fluvial processes that may be thousands of kilometers away. Events that occur in watersheds, such as land use change and widespread vegetation change related to climate shifts, can drastically alter the rate the sediment is delivered to the fluvial system and transported to coastal environments. Because of these linkages, we need to couple together models of processes in different environments to be able to address many key questions regarding our planet's future. The Community Surface Dynamics Modeling System (CSDMS) exists to facilitate such model coupling. More broadly, the ESS community should more fully engage with Earth-system modelers to develop ESMs that incorporate the state-of-the-art models identified in the supplement.

Acknowledgments
We wish to thank the NSF Geomorphology and Land-Use Dynamics program and its manager Paul Cutler for supporting this effort intellectually and financially through award #1250358. We also thank the many members of the broader Working Group on Predicting Landscape Response to Climatic and Land-Use Changes that commented on drafts of the manuscript at http://geomorphicprediction.geo.arizona.edu/. Data used to make any of the figures can be obtained upon request from J.D.P.

References

Abbühl, L. M., K. P. Norton, J. D. Jansen, F. Schlunegger, A. Aldahan, and G. Possnert (2011), Erosion rates and mechanisms of knickzone retreat inferred from ^{10}Be measured across strong climate gradients on the northern and central Andes Western Escarpment, *Earth Surf. Processes Landforms*, *36*, 1464–1473, doi:10.1002/esp.2164.

Ackert, R. P. (2009), Palaeoclimate: Patagonian dust machine, *Nat. Geosci.*, *2*, 244–245, doi:10.1038/ngeo485.

Ahern, M., R. S. Kovats, P. Wilkinson, R. Few, and F. Matthies (2005), Global health impacts of floods: Epidemiologic evidence, *Epidemiol. Rev.*, *27*, 36–46, doi:10.1093/epirev/mxi004.

Alessa, L., A. Kliskey, R. Lammers, C. Arp, D. White, L. Hinzman, and R. Busey (2008), The arctic water resource vulnerability index: An integrated assessment tool for community resilience and vulnerability with respect to freshwater, *Environ. Manage.*, *42*(3), 523–541, doi:10.1007/s00267-008-9152-0.

Alin, S. R., R. Aalto, M. A. Goni, J. E. Richey, and W. E. Dietrich (2008), Biogeochemical characterization of carbon sources in the Strickland and Fly rivers, Papua New Guinea, *J. Geophys. Res. Earth Surf.*, *113*(F1), F01S05, doi:10.1029/2006JF000625.

Allan, J. C., and P. Komar (2000), Are ocean wave heights increasing in the eastern North Pacific?, *Eos Trans. Am. Geophys. Union*, *81*(47), 561–567, doi:10.1029/EO081i047p00561-01.

Allan, J. C., and P. Komar (2006), Climate controls on U.S. West Coast erosion processes, *J. Coastal Res.*, *22*(3), 511–529, doi:10.2112/03-0108.1.

Allen, J. R. L. (1990), Salt-marsh growth and stratification: A numerical model with special reference to the Severn Estuary, southwest Britain, *Mar. Geol.*, *95*, 77–96, doi:10.1016/0037-0738(95)00101-8.

Amlin, N. M., and S. B. Rood (2002), Comparative tolerances of riparian willows and cottonwoods to water-table decline, *Wetlands*, *22*, 338–346, doi:10.1672/0277-5212(2002)022[0338:CTORWA]2.0.CO;2.

Anders, M. D., et al. (2005), Pleistocene geomorphology and geochronology of eastern Grand Canyon: Linkages of landscape components during climate changes, *Quat. Sci. Rev.*, *24*, 2428–2448, doi:10.1016/j.quascirev.2005.03.015.

Anderson, L., J. Birks, J. Rover, and N. Guldager (2013a), Controls on recent Alaskan lake changes identified from water isotopes and remote sensing, *Geophys. Res. Lett.*, *40*, 3413–3418, doi:10.1002/GRL.50672.

Anderson, R. S. (1998), Near-surface thermal profiles in alpine bedrock: Implications for the frost weathering of rock, *Arct. Alp. Res.*, *30*(4), 362–372, doi:10.2307/1552008.

Anderson, R. S. (2000), A model of ablation-dominated medial moraines and the generation of debris-mantled glacier snouts, *J. Glaciol.*, *46*(154), 459–469, doi:10.3189/172756500781833025.

Anderson, R. S., and N. F. Humphrey (1989), Interaction of weathering and transport processes in the evolution of arid landscapes, in *Quantitative Dynamic Stratigraphy*, edited by T. A. Cross , pp. 349–361 , Prentice-Hall, Englewood Cliffs, N. J.

Anderson, R. S., M. Dühnforth, W. Colgan, and L. Anderson (2012), Far-flung moraines: Exploring the feedback of glacial erosion on the evolution of glacier length, *Geomorphology*, *179*(15), 269–285, doi:10.1016/j.geomorph.2012.08.018.

Anderson, R. S., S. P. Anderson, and G. E. Tucker (2013b), Rock damage and regolith transport by frost: An example of climate modulation of the geomorphology of the critical zone, *Earth Surf. Processes Landforms*, *38*, 299–316, doi:10.1002/esp.3330.

Anderson, S. P. (2007), Biogeochemistry of glacial landscape systems, *Annu. Rev. Earth Planet. Sci.*, *35*, 375–379, doi:10.1146/annurev.earth.35.031306.140033.

Anderson, S. P., R. C. Bales, and C. J. Duffy (2008), Critical Zone Observatories: Building a network to advance interdisciplinary study of Earth surface processes, *Mineral. Mag.*, *72*(1), 7–10, doi:10.1180/minmag.2008.072.1.7.

Anisimov, O., J. Vandenberghem, V. Lobanov, and A. Kondratiev (2008), Predicting changes in alluvial channel patterns in North-European Russia under conditions of global warming, *Geomorphology*, *98*(3), 262–274, doi:10.1016/j.geomorph.2006.12.029.

Antinao, J. L., and E. McDonald (2013), A reduced relevance of vegetation change for alluvial aggradation in arid zones, *Geology*, *41*, 11–14, doi:10.1130/G33623.1.

Armon, J. W. (1980), Dune erosion and recovery on a northern barrier, in *Coastal Zone '80. Proceedings of the 2nd Symposium on Coastal and Ocean Management of ASCE*, pp. 1233–1250, Hollywood, Fla.

Armstrong, W. H., M. J. Collins, and N. P. Snyder (2014), Hydroclimatic flood trends in the northeastern United States and linkages with large-scale atmospheric circulation patterns, *Hydrol. Sci. J.*, *59*(9), 1636–1655, doi:10.1080/02626667.2013.862339.

Arp, C. D., M. S. Whitman, B. M. Jones, R. Kemnitz, G. Grosse, and F. E. Urban (2012), Drainage network structure and hydrologic behavior of three lake-rich watersheds on the Arctic Coastal Plain, Alaska, *Arct. Antarct. Alp. Res.*, *44*(4), 385–398, doi:10.1657/1938-4246-44.4.385.

Arsenault, A. M., and A. J. Meigs (2005), Contribution of deep-seated bedrock landslides to erosion of a glaciated basin in southern Alaska, *Earth Surf. Processes Landforms*, *30*, 1111–1125, doi:10.1002/esp.1265.

Ashkenazy, Y., H. Yizhaq, and H. Tsoar (2011), Sand dune mobility under climate change in the Kalahari and Australian deserts, *Clim. Change*, *112*(3–4), 901–923, doi:10.1007/s10584-011-0264-9.

Ashmore, P., and M. A. Church (2001), The impact of climate change on rivers and river processes in Canada, *Bull. Geol. Surv. Can.*, *555*, 58.

Ashton, A. D., and A. B. Murray (2006a), High-angle wave instability and emergent shoreline shapes: 1. Modeling of sand waves, flying spits, and capes, *J. Geophys. Res.*, *111*, F04011, doi:10.1029/2005JF000422.

Ashton, A. D., and A. B. Murray (2006b), High-angle wave instability and emergent shoreline shapes: 2. Wave climate analysis and comparisons to nature, *J. Geophys. Res.*, *111*, F04012, doi:10.1029/2005JF000423.

Ashton, A. D., and A. C. Ortiz (2011), Overwash control coastal barrier response to sea-level rise, in *Proceedings Coastal Sediments '11, Proceedings of the Seventh International Symposium on Coast Engineering and Science of Coastal Sediment Processes*, pp. 230–243, Miami, Fla.

Ashton, A. D., and L. Giosan (2011), Wave-influenced delta evolution controlled by wave approach angle, *Geophys. Res. Lett.*, *38*, L13405, doi:10.1029/2011GL047630.

Ashton, A. D., A. B. Murray, and O. Arnault (2001), Formation of coastline features by large-scale instabilities induced by high angle waves, *Nature*, *414*, 296–300, doi:10.1038/35104541.

Ashton, A. D., E. W. H. Hutton, A. J. Kettner, F. Xing, J. Kallumadikal, J. Nienhuis, and L. Giosan (2013), Progress in coupling models of coastline and fluvial dynamics, *Comput. Geosci.*, *53*, 21–29, doi:10.1016/j.cageo.2012.04.004.

Aufdenkampe, A. K., E. Mayorga, P. A. Raymond, J. M. Melack, S. C. Doney, S. R. Alin, R. E. Aalto, and K. Yoo (2011), Riverine coupling of biogeochemical cycles between land, oceans, and atmosphere, *Front. Ecol. Environ.*, *9*(1), 53–60, doi:10.1890/100014.

Austermann, J., J. X. Mitrovica, K. Latychev, and G. A. Milne (2013), Barbados-based estimate of ice volume at Last Glacial Maximum affected by subducted plate, *Nat. Geosci.*, *6*(7), 553–557, doi:10.1038/ngeo1859.

Baas, A. C. W., and J. M. Nield (2007), Modelling vegetated dune landscapes, *Geophys. Res. Lett.*, *34*, L06405, doi:10.1029/2006GL029152.

Bacon, S., and D. J. T. Carter (1991), Wave climate changes in the North Atlantic and North Sea, *Int. J. Climatol.*, *11*, 545–558, doi:10.1002/joc.3370110507.

Baker, V. R. (2009), 1. Overview of megaflooding: Earth and Mars, in *Megaflooding on Earth and Mars*, edited by D. Burr, P. A. Carling, and V. R. Baker , pp. 1–10 , Cambridge Univ. Press, New York.

Ballantyne, C. K. (2002), Paraglacial geomorphology, *Quat. Sci. Rev.*, *21*(18–19), 1935–2017, doi:10.1016/S0277-3791(02)00005-7.

Ballantyne, C. K., and J. O. Stone (2013), Timing and periodicity of paraglacial rock-slope failures in the Scottish Highlands, *Geomorphology*, *186*(15), 150–161, doi:10.1016/j.geomorph.2012.12.030.

Banerjee, A., and R. Shankar (2013), On the response of Himalayan glaciers to climate change, *J. Glaciol.*, *59*, 480–490, doi:10.3189/2013JoG12J130.

Barchyn, T. E., and C. H. Hugenholtz (2012), Aeolian dune field geomorphology modulates the stabilization rate imposed by climate, *J. Geophys. Res. Earth Surf.*, *117*, F02035, doi:10.1029/2011JF002274.

Barkwith, A., C. W. Thomas, P. Limber, M. A. Ellis, and A. B. Murray (2013a), Assessing the natural morphological sensitivity of a pinned, soft-cliff, sandy coast to a changing wave climate, *Earth Surf. Dyn.*, *1*, 855–889, doi:10.5194/esurfd-1-855-2013.

Barkwith, A., M. D. Hurst, C. W. Thomas, M. A. Ellis, P. W. Limber, and A. B. Murray (2013b), Assessing the influence of sea walls on the coastal vulnerability of a pinned, soft-cliff, sandy coastline, *Earth Surf. Dyn.*, *1*, 1127–1149, doi:10.5194/esurfd-1-1127-2013.

Barnhart, K. R., R. S. Anderson, I. Overeem, C. Wobus, G. D. Clow, and F. E. Urban (2014), Modeling erosion of ice-rich permafrost bluffs along the Alaskan Beaufort Sea coast, *J. Geophys. Res. Earth Surf.*, *119*(5), 1155–1179, doi:10.1002/2013JF002845.

Bartholomaus, T. C., R. S. Anderson, and S. P. Anderson (2008), Response of glacier basal motion to transient water storage, *Nat. Geosci.*, *1*, 33–37, doi:10.1038/ngeo.2007.52.

Battin, T. J., L. A. Kaplan, S. Findlay, C. S. Hopkinson, E. Marti, A. I. Packman, J. D. Newbold, and F. Sabater (2008), Biophysical controls on organic carbon fluxes in fluvial networks, *Nat. Geosci.*, *1*(2), 95–100, doi:10.1038/ngeo101.

Battin, T. J., S. Luyssaert, L. A. Kaplan, A. K. Aufdenkampe, A. Richter, and L. J. Tranvik (2009), The boundless carbon cycle, *Nat. Geosci.*, *2*(9), 598–600, doi:10.1038/ngeo618.

Bauer, B. O. (1991), Aeolian decoupling of beach sediments, *Ann. Assoc. Am. Geogr.*, *81*, 290–303, doi:10.1111/j.1467-8306.1991.tb01691.x.

Bauer, B. O., and R. G. D. Davidson-Arnott (2003), A general framework for modeling sediment supply to coastal dunes including wind angle, beach geometry, and fetch effects, *Geomorphology*, *49*, 89–108, doi:10.1016/S0169-555X(02)00165-4.

Bedoui, S. E., et al. (2011), Paraglacial gravitational deformations in the SW Alps: A review of field investigations, ^{10}Be cosmogenic dating and physical modeling, *Geol. Soc. London Spec. Pub.*, *351*(1), 11–25, doi:10.1144/SP351.2.

Beighley, R. E., and V. Gummadi (2011), Developing channel and floodplain dimensions with limited data: A case study in the Amazon Basin, *Earth Surf. Processes Landforms*, *36*(8), 1059–1071, doi:10.1002/esp.2132.

Belmont, P. (2011), Floodplain width adjustments in response to rapid base level fall and knickpoint migration, *Geomorphology*, *128*, 92–102, doi:10.1016/j.geomorph.2010.12.026.

Belmont, P., et al. (2011), Large shift in source of fine sediment in the Upper Mississippi River, *Environ. Sci. Technol.*, *45*, 8804–8810, doi:10.1021/es2019109.

Belnap, J., S. L. Phillips, J. E. Herrick, and J. R. Johansen (2007), Wind erodibility of soils at Fort Irwin, California (Mojave Desert), USA, before and after trampling disturbance: Implications for land management, *Earth Surf. Processes Landforms*, *32*, 75–84, doi:10.1002/esp.1372.

Beltaos, S., and T. D. Prowse (2001), Climate impacts on extreme ice-jam events in Canadian rivers, *Hydrol. Sci. J.*, *46*(1), 157–181, doi:10.1080/02626660109492807.

Berthier, E., Y. Arnaud, D. Baratoux, C. Vincent, and F. Rémy (2004), Recent rapid thinning of the "Mer de Glace" glacier derived from satellite optical images, *Geophys. Res. Lett.*, *31*, L17401, doi:10.1029/2004GL020706.

Bevan, S. L., P. R. J. North, S. O. Los, and W. M. F. Grey (2012), A global dataset of atmospheric aerosol optical depth and surface reflectance from AATSR, *Remote Sens. Environ.*, *116*(0), 199–210, doi:10.1016/j.rse.2011.05.024.

Beven, K. (1996), Equifinality and uncertainty in geomorphological modelling, in the scientific nature of geomorphology, in *Proceedings of the 27th Binghamton Symposium in Geomorphology*, edited by B. L. Rhoads and C. E. Thorn , pp. 289–313 , John Wiley & Sons Ltd., New York.

Beylich, A. A., S. F. Lamoureux, and A. Decaulne (2011), Developing frameworks for studies on sedimentary fluxes and budgets in changing cold environments, *Quaestiones Geographicae*, *30*(1), 5–18, doi:10.2478/v10117-011-0001-5.

Bhattachan, A., P. D'Odorico, M. Baddock, T. M. Zobeck, G. S. Okin, and N. Cassar (2012), The Southern Kalahari: A potential new dust source in the Southern Hemisphere?, *Environ. Res. Lett.*, *7*(2), 024001.

Bindoff, N. L., et al. (2007), Observations: Oceanic climate change and sea level, in *Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon et al., chap. 5 , pp. 385–432 , Cambridge Univ. Press, Cambridge, U. K.

Bohorquez, P., and S. Darby (2008), The use of one-and two-dimensional hydraulic modelling to reconstruct a glacial outburst flood in a steep Alpine valley, *J. Hydrol.*, *361*(3), 240–261, doi:10.1016/j.jhydrol.2008.07.043.

Bolch, T., T. Pieczonka, and D. I. Benn (2011), Multi-decadal mass loss of glaciers in the Everest area (Nepal Himalaya) derived from stereo imagery, *Cryosphere*, *5*, 349–358, doi:10.5194/tc-5-349-2011.

Bowden, W. B., M. N. Gooseff, A. Balser, A. Green, B. J. Peterson, and J. Bradford (2008), Sediment and nutrient delivery from thermokarst features in the foothills of the North Slope, Alaska: Potential impacts on headwater stream ecosystems, *J. Geophys. Res.*, *113*, G02026, doi:10.1029/2007JG000470.

Bradley, D. N., and G. E. Tucker (2013), The storage time, age, and erosion hazard of laterally accreted sediment on the floodplain of a simulated meandering river, *J. Geophys. Res. Earth Surf.*, *118*(3), 1308–1319, doi:10.1002/JGRF.20083.

Brazier, R. E., K. J. Beven, J. Freer, and J. S. Rowan (2000), Equifinality and uncertainty in physically based soil erosion models: Application of the GLUE methodology to WEPP-the Water Erosion Prediction Project-for sites in the UK and USA, *Earth Surf. Processes Landforms*, *25*, 825–845, doi:10.1002/1096-9837(200008)25:8<825::AIDESP101>3.0.CO;2-3.

Breshears, D. D., J. J. Whicker, C. B. Zou, J. P. Field, and C. D. Allen (2009), A conceptual framework for dryland aeolian sediment transport along the grassland-forest continuum: Effects of woody plant canopy cover and disturbance, *Geomorphology*, *105*, 28–38, doi:10.1016/j.geomorph.2007.12.018.

Breshears, D. D., T. B. Kirchner, J. J. Whicker, J. P. Field, and C. D. Allen (2012), Modeling aeolian transport in response to succession, disturbance and future climate: Dynamic long-term risk assessment for contaminant redistribution, *Aeolian Res.*, *3*(4), 445–457, doi:10.1016/j.aeolia.2011.03.012.

Budyko, M. I. (1974), *Climate and Life*, Academic, New York, 508 p.

Buffington, J. M., and D. R. Montgomery (1997), A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers, *Water Resour. Res.*, *33*(8), 1993–2029, doi:10.1029/96WR03190.

Bull, W. B. (1991), *Geomorphic Responses to Climatic Change*, Oxford Press, Oxford, U. K. and New York, 326 p.

Bull, W. B., and A. P. Schick (1979), Impact of climatic change on an arid watershed: Nahal Yael, southern Israel, *Quat. Res.*, *11*, 153–171, doi:10.1016/0033-5894(79)90001-2.

Bullard, J. E. (2010), Bridging the gap between field data and global models: Current strategies in aeolian research, *Earth Surf. Processes Landforms*, *35*, 496–499, doi:10.1002/esp.1958.

Bullard, J. E. (2013), Contemporary glaciogenic inputs to the dust cycle, *Earth Surf. Processes Landforms*, *38*(1), 71–89, doi:10.1002/esp.3315.

Bullard, J. E., and G. H. McTainsh (2003), Aeolian-fluvial interactions in dryland environments: Scales, concepts and Australia case study, *Prog. Phys. Geogr.*, *27*(4), 471–501, doi:10.1191/0309133303pp386ra.

Bullard, J. E., S. P. Harrison, M. C. Baddock, N. Drake, T. E. Gill, G. McTainsh, and Y. Sun (2011), Preferential dust sources: A geomorphological classification designed for use in global dust-cycle models, *J. Geophys. Res.*, *116*(F4), F04034, doi:10.1029/2011JF002061.

Burgess, E., R. Forster, and C. Larsen (2013), Flow velocities of Alaskan glaciers, *Nat. Commun.*, *4*, 2146, doi:10.1038/ncomms3146.

Burns, P., and A. Nolin (2014), Using atmospherically-corrected Landsat imagery to measure glacier area change in the Cordillera Blanca, Peru from 1987 to 2010, *Remote Sens. Environ.*, *140*, 165–178, doi:10.1016/j.rse.2013.08.026.

Cai, W., et al. (2014), Increasing frequency of extreme El Niño events due to greenhouse warming, *Nat. Clim. Change*, *4*, 111–116, doi:10.1038/nclimate2100.

Campeau, A., J.-F. Lapierre, D. Vachon, and P. A. del Giorgio (2014), Regional contribution of CO_2 and CH_4 fluxes from the fluvial network in a lowland boreal landscape of Québec, *Global Biogeochem. Cycles*, *28*, 57–69, doi:10.1002/2013GB004685.

Cannon, S. H., J. E. Gartner, M. G. Rupert, J. A. Michael, A. H. Rea, and C. Parrett (2010), Predicting the probability and volume of post wildfire debris flows in the intermountain western United States, *Geol. Soc. Am. Bull.*, *122*, 127–144.

Carrasco, R. M., J. Pedraza, D. Domínguez-Villar, J. K. Willenbring, and J. Villa (2013), Supraglacial debris supply in the Cuerpo de Hombre paleoglacier (Spanish Central System): Reconstruction and interpretation of a rock avalanche event, *Geogr. Ann. Ser. A Phys. Geogr.*, *95*, 211–226, doi:10.1111/geoa.12010.

Carrivick, J. L., and F. S. Tweed (2013), Proglacial lakes: Character, behaviour and geological importance, *Quat. Sci. Rev.*, *78*(15), 34–52, doi:10.1016/j.quascirev.2013.07.028.

Carruthers, E. A., D. P. Lane, R. L. Evans, J. P. Donnelly, and A. D. Ashton (2013), Quantifying overwash flux in barrier systems: An example from Martha's Vineyard, Massachusetts, USA, *Mar. Geol.*, *343*, 15–28, doi:10.1016/j.margeo.2013.05.013.

Carter, D., and L. Draper (1988), Has the north-east Atlantic become rougher?, *Nature*, *332*, 494, doi:10.1038/332494a0.

Cazenave, A., and W. Llovel (2010), Contemporary sea level rise, *Annu. Rev. Mar. Sci.*, *2*, 145–173, doi:10.1146/annurev-marine-120308-081105.

Cellino, M., and W. H. Graf (1999), Sediment-laden flow in open-channels under noncapacity and capacity conditions, *J. Hydraul. Eng.*, *125*(5), 455–462, doi:10.1061/(ASCE)0733-9429(1999)125:5(455).

Cerda, A., and S. H. Doerr (2005), Influence of vegetation recovery on soil hydrology and erodibility following fire: An 11-year investigation, *Int. J. Wildland Fire*, *14*, 423–437, doi:10.1071/WF05044.

Chapin, F. S., III, B. H. Walker, R. J. Hobbs, D. U. Hooper, J. H. Lawton, O. E. Sala, and D. Tilman (1997), Biotic control over the functioning of ecosystems, *Science*, *277*, 500–504, doi:10.1126/science.277.5325.500.

Chase, B. (2009), Evaluating the use of dune sediments as a proxy for palaeo-aridity: A southern African case study, *Earth Sci. Rev.*, *93*(1–2), 31–45, doi:10.1016/j.earscirev.2008.12.004.

Chatanantavet, P., and G. Parker (2009), Physically based modeling of bedrock incision by abrasion, plucking, and macroabrasion, *J. Geophys. Res.*, *114*(F4), F04018, doi:10.1029/2008JF001044.

Chen, M., J. C. Rowland, C. J. Wilson, G. L. Altmann, and S. P. Brumby (2012), Temporal and spatial pattern of thermokarst lake area changes at Yukon Flats, Alaska, *Hydrol. Processes*, *28*, 837–852, doi:10.1002/hyp.9642.

Chen, M., J. C. Rowland, C. J. Wilson, G. L. Altmann, and S. P. Brumby (2013), The importance of natural variability in lake areas on the detection of permafrost degradation: A case study in THE Yukon flats, Alaska, *Permafrost Periglac. Processes*, *24*, 224–240, doi:10.1002/ppp.1783.

Chiarle, M., and G. Mortara (2009), Geomorphological impact of climate change on Alpine Glacial and Periglacial areas, in *INTERPRAEVENT 2008 – Conference Proceedings*, *2*, 111–122.

Chiarle, M., S. Iannotti, G. Mortara, and P. Deline (2007), Recent debris flow occurrences associated with glaciers in the Alps, *Global Planet. Change*, *56*(1), 123–136, doi:10.1016/j.gloplacha.2006.07.003.

Chmura, G. L., S. C. Anisfeld, D. R. Cahoon, and J. C. Lynch (2003), Global carbon sequestration in tidal, saline wetland soils, *Global Biogeochem. Cycles*, *17*(4), 1111, doi:10.1029/2002GB001917.

Christiansen, M. B., and R. Davidson-Arnott (2004), Rates of landward sand transport over the Foredune at Skallingen, Denmark and the role of dune ramps, *Geografisk Tidsskrift-Danish J. Geogr.*, *104*, 31–43, doi:10.1080/00167223.2004.10649502.

Church, J. A., and N. J. White (2006), A 20th century acceleration in global sea-level rise, *Geophys. Res. Lett.*, *33*, L01602, doi:10.1029/2005GL024826.

Church, M. (2006), Bed material transport and the morphology of Alluvial River channels, *Annu. Rev. Earth Planet. Sci.*, *34*(1), 325–354, doi:10.1146/annurev.earth.33.092203.122721.

Claessens, L., J. M. Schoorl, P. H. Verburg, L. Geraedts, and A. Veldkamp (2009), Modelling interactions and feedback mechanisms between land use change and landscape processes, *Agric. Ecosyst. Environ.*, *129*(1–3), 157–170, doi:10.1016/j.agee.2008.08.008.

Clague, J. J. (2009), Climate change and slope instability, in *Landslides–Disaster Risk Reduction*, edited by S. Kyoji and P. Canuti, pp. 557–572 , Springer-Verlag, Berlin.

Clague, J. J., and S. G. Evans (2000), A review of catastrophic drainage of moraine-dammed lakes in British Columbia, *Quat. Sci. Rev.*, *19*(17), 1763–1783, doi:10.1016/S0277-3791(00)00090-1.

Clark, P. U., A. S. Dyke, J. D. Shakun, A. E. Carlson, J. Clark, B. Wohlfarth, J. X. Mitrovica, S. W. Hostetler, and A. M. McCabe (2009), The last glacial maximum, *Science*, *325*(5941), 710–714, doi:10.1126/science.1172873.

Clarke, M. E., and H. M. Rendell (1998), Climatic change impacts on sand supply and the formation of desert sand dunes in the south-west U.S.A., *J. Arid Environ.*, *39*(3), 517–532, doi:10.1006/jare.1997.0372.

Clarke, M., H. Rendell, J. Tastet, B. Clave, and L. Masse (2002), Late-Holocene sand invasion and North Atlantic storminess along the Aquitaine coast, southwest France, *Holocene*, *12*, 231–238, doi:10.1191/0959683602hl539rr.

Clemmensen, L. B., and A. Murray (2006), The termination of the last major phase of aeolian sand movement, coastal dunefields, Denmark, *Earth Surf. Processes Landforms*, *31*, 795–808, doi:10.1002/esp.1283.

Clemmensen, L., K. Pye, A. Murray, and J. Heinemeier (2001), Sedimentology, stratigraphy and landscape evolution of a Holocene coastal dune system, Lodbjerg, NW Jutland, Denmark, *Sedimentology*, *48*, 3–27, doi:10.1111/j.1365-3091.2001.00345.x.

Coe, M. T., M. H. Costa, and E. A. Howard (2008), Simulating the surface waters of the Amazon River basin: Impacts of new river geomorphic and flow parameterizations, *Hydrol. Processes*, *22*(14), 2542–2553, doi:10.1002/hyp.6850.

Cogley, J. G. (2010), A more complete version of the World Glacier Inventory, *Ann. Glaciol.*, *50*(53), 32–38, doi:10.3189/172756410790595859.

Cole, J., Y. Prairie, N. Caraco, W. McDowell, L. Tranvik, R. Striegl, C. Duarte, P. Kortelainen, J. Downing, and J. Middelburg (2007), Plumbing the global carbon cycle: Integrating inland waters into the terrestrial carbon budget, *Ecosystems*, *10*(1), 172–185, doi:10.1007/s10021-006-9013-8.

Colgan, W., H. Rajaram, R. Anderson, K. Steffen, J. Zwally, T. Phillips, and W. Abdalati (2012), The annual glaciohydrology cycle in the ablation zone of the Greenland ice sheet: Part 2. Observed and modeled ice flow, *J. Glaciol.*, *58*, 51–64, doi:10.3189/2012JoG11J081.

Collins, D. B. G., R. L. Bras, and G. E. Tucker (2004), Modeling the effects of vegetation-erosion coupling on landscape evolution, *J. Geophys. Res.*, *109*, F03004, doi:10.1029/2003JF000028.

Cooke, R. U., and R. W. Reeves (1976), *Arroyos and Environmental Change*, Clarendon Press, Oxford, U. K., 213 p.

Cossart, E., and M. Fort (2008), Sediment release and storage in early deglaciated areas: Towards an application of the exhaustion model from the case of Massif des Écrins (French Alps) since the Little Ice Age, *Nor. Geogr. Tidsskr.*, *62*, 115–131, doi:10.1080/00291950802095145.

Cossart, E., R. Braucher, M. Fort, D. L. Bourlès, and J. Carcaillet (2008), Slope instability in relation to glacial debuttressing in alpine areas (Upper Durance catchment, southeastern France): Evidence from field data and ^{10}Be cosmic ray exposure ages, *Geomorphology*, *95*(1), 3–26, doi:10.1016/j.geomorph.2006.12.022.

Costard, F., L. Dupeyrat, E. Gautier, and E. Carey-Gailhardis (2003), Fluvial thermal erosion investigations along a rapidly eroding river bank: Application to the Lena River (central Siberia), *Earth Surf. Processes Landforms*, *28*(12), 1349–1359, doi:10.1002/esp.592.

Costard, F., E. Gautier, D. Brunstein, J. Hammadi, A. Fedorov, D. Yang, and L. Dupeyrat (2007), Impact of the global warming on the fluvial thermal erosion over the Lena River in Central Siberia, *Geophys. Res. Lett.*, *34*, L14501, doi:10.1029/2007GL030212.

Coulthard, T. J., G. R. Hancock, and J. B. C. Lowry (2012), Modelling soil erosion with a downscaled landscape evolution model, *Earth Surf. Processes Landforms*, *37*(10), 1046–1055, doi:10.1002/esp.3226.

Coulthard, T. J., J. C. Neal, P. D. Bates, J. Ramirez, G. a. M. de Almeida, and G. R. Hancock (2013), Integrating the LISFLOOD-FP 2D hydrodynamic model with the CAESAR model: Implications for modelling landscape evolution, *Earth Surf. Processes Landforms*, *38*(15), 1897–1906, doi:10.1002/esp.3478.

Cowell, P. J., et al. (1995), Simulation of large-scale coastal change using a morphological-behaviour model, *Mar. Geol.*, *126*, 45–61, doi:10.1016/ 0025-3227(95)00065-7.

Crawford, J. T., R. G. Striegl, K. P. Wickland, M. M. Dornblaser, and E. H. Stanley (2013), Emissions of carbon dioxide and methane from a headwater stream network of interior Alaska, *J. Geophys. Res. Biogeosci.*, *118*, 482–494, doi:10.1002/JGRG.20034.

Crawford, J. T., N. R. Lottig, E. H. Stanley, J. F. Walker, P. C. Hanson, J. C. Finlay, and R. G. Striegl (2014), CO_2 and CH_4 emissions from streams in a lake-rich landscape: Patterns, controls, and regional significance, *Global Biogeochem. Cycles*, *28*, 197–210, doi:10.1002/2013GB004661.

Cromwell, J. (1973), Barrier coast distribution: A world-wide survey, in *Barrier Islands*, edited by M. L. Schwartz , pp. 407–408 , Dowden Hutchinson Ross, Stroudsburg, Pa.

Crouvi, O., K. Schepanski, R. Amit, A. R. Gillespie, and Y. Enzel (2012), Multiple dust sources in the Sahara Desert: The importance of sand dunes, *Geophys. Res. Lett.*, *39*(13), L13401, doi:10.1029/2012GL052145.

Curry, A. M., T. B. Sands, and P. R. Porter (2009), Geotechnical controls on a steep lateral moraine undergoing paraglacial slope adjustment, *Geol. Soc. London Spec. Pub.*, *320*, 181–197, doi:10.1144/SP320.12.

D'Alpaos, A., S. Lanzoni, M. Marani, and A. Rinaldo (2007), Landscape evolution in tidal embayments: Modeling the interplay of erosion, sedimentation, and vegetation dynamics, *J. Geophys. Res.*, *112*, F01008, doi:10.1029/2006JF000537.

Da Lio, C., A. D'Alpaos, and M. Marani (2013), The secret gardener: Vegetation and the emergence of biogeomorphic patterns in tidal environments, *Philos. Trans. R. Soc. A*, *371*, 2004, doi:10.1098/rsta.2012.0367.

Dadson, S. J., and M. Church (2005), Postglacial topographic evolution of glaciated valleys: A stochastic landscape evolution model, *Earth Surf. Processes Landforms*, *30*, 1387–1403, doi:10.1002/esp.1199.

Daly, C., G. H. Taylor, W. P. Gibson, T. Parzybok, G. L. Johnson, and P. A. Pasteris (1998), Development of high-quality spatial climate datasets for the United States. in *Proceedings of 1st International Conference on Geospatial Information in Agriculture and Forestry*, pp. 512–519, Lake Buena Vista, Fla.

Davidson-Arnott, R. G. D. (2005), A conceptual model of the effects of sea-level rise on sandy coasts, *J. Coastal Res.*, *21*, 1166–1172, doi:10.2112/03-0051.1.

Decharme, B., H. Douville, C. Prigent, F. Papa, and F. Aires (2008), A new river flooding scheme for global climate applications: Off-line evaluation over South America, *J. Geophys. Res.*, *113*, D11110, doi:10.1029/2007JD009376.

Dendy, F. E., and G. C. Bolton (1976), Sediment yield-runoff-drainage area relationships in the United States, *J. Soil Water Conserv.*, *31*, 264–266.

Derose, R. C., N. A. Trustrum, and P. M. Blaschke (1993), Post-deforestation soil loss from steepland hillslopes in Taranaki, New Zealand, *Earth Surf. Processes Landforms*, *18*(2), 131–144, doi:10.1002/esp.3290180205.

Déry, S. J., M. A. Hernández-Henríquez, J. E. Burford, and E. F. Wood (2009), Observational evidence of an intensifying hydrological cycle in northern Canada, *Geophys. Res. Lett.*, *36*, L13402, doi:10.1029/2009GL038852.

Dickson, M. E., M. J. A. Walkden, and J. W. Hall (2007), Systemic impacts of climate change on an eroding coastal region over the twenty-first century, *Clim. Change*, *84*, 141–166, doi:10.1007/s10584-006-9200-9.

Dietrich, W. E. (1982), Settling velocity of natural particles, *Water Resour. Res.*, *18*(6), 1615–1626, doi:10.1029/WR018I006P01615.

Dietrich, W. E., R. Reiss, M.-L. Hsu, and D. R. Montgomery (1995), A process-based model for colluvial soil depth and shallow landsliding using digital elevation data, *Hydrol. Processes*, *9*, 383–400, doi:10.1002/hyp.3360090311.

Dietrich, W. E., D. G. Bellugi, L. S. Sklar, J. D. Stock, A. M. Heimsath, and J. J. Roering (2003), Geomorphic transport laws for predicting landscape form and dynamics, in *Prediction in Geomorphology*, edited by P. R. Wilcock and R. M. Iverson, Am. Geophys. Union, Washington, D. C., doi:10.1029/135GM09.

Diolaiuti, G. A., D. Maragno, C. D'Agata, C. Smiraglia, and D. Bocchiola (2011), Glacier retreat and climate change: Documenting the last 50 years of Alpine glacier history from area and geometry changes of Dosde Piazzi glaciers (Lombardy Alps, Italy), *Prog. Phys. Geogr.*, *35*(2), 161–182, doi:10.1177/0309133311399494.

Dixon, J. C. (2013), Response of periglacial geomorphic processes to global change, *Treatise on Geomorphology*, edited by J. Shroder, L. A. James, C. P. Harden, and J. J. Clague, *13*, pp. 176–189, Academic, San Diego, Calif., doi:10.1016/B978-0-12-374739-6.00351-1.

Dobhal, D. P., M. Mehta, and D. Srivastava (2013), Influence of debris cover on terminus retreat and mass changes of Chorabari Glacier, Garhwal region, central Himalaya, India, *J. Glaciol.*, *59*(217), 961–971, doi:10.3189/2013JoG12J180.

Douglas, I. (1996), Impact of land-use changes, especially logging, shifting cultivation, mining and urbanization on sediment yields in humid tropical Southeast Asia: A review with special, in *Erosion and Sediment Yield: Global and Regional Perspectives: Proceedings of an International Symposium Held at Exeter, UK*, *from 15 to 19 July 1996*, edited by D. E. Walling, and B. Webb, pp. 463–471.

Dühnforth, M., A. L. Densmore, S. Ivy-Ochs, and P. A. Allen (2008), Controls on sediment evacuation from glacially modified and unmodified catchments in the eastern Sierra Nevada, California, *Earth Surf. Processes Landforms*, *33*(10), 1602–1613, doi:10.1002/esp.1694.

Durán, O., and L. J. Moore (2013), Vegetation controls on the maximum size of coastal dunes, *Proc. Natl. Acad. Sci. U. S. A.*, *110*(43), 17,217–17,222, doi:10.1073/pnas.1307580110.

Durán, V. O., and L. J. Moore (2015), Barrier island instability induced by biophysical interactions, *Nat. Clim. Change*, *5*, 158–162, doi:10.1038/nclimate2474.

Dussaillant, A., G. Benito, W. Buytaert, P. Carling, C. Meier, and F. Espinoza (2010), Repeated glacial-lake outburst floods in Patagonia: An increasing hazard?, *Nat. Hazards*, *54*(2), 469–481, doi:10.1007/s11069-009-9479-8.

Egholm, D. L., M. F. Knudsen, C. D. Clark, and J. E. Lesemann (2011), Modeling the flow of glaciers in steep terrains: The integrated second-order shallow ice approximation (iSOSIA), *J. Geophys. Res.*, *116*, F02012, doi:10.1029/2010JF001900.

Egholm, D. L., V. K. Pedersen, M. F. Knudsen, and N. K. Larsen (2012), Coupling the flow of ice, water, and sediment in a glacial landscape evolution model, *Geomorphology*, *141–142*(1), 47–66, doi:10.1016/j.geomorph.2011.12.019.

Egiazaroff, I. V. (1965), Calculation of nonuniform sediment concentrations, *J. Hydraul. Div. Am. Soc. Civ. Eng.*, *91*, 225–247.

Einstein, H. A. (1950), The bed-load function for sediment transportation in open channel flows. *Tech. Bull. U. S. Department of Agriculture, Soil Conservation Service*, *1026*, pp. 78.

Ells, K., and A. B. Murray (2012), Long-term, non-local coastline responses to local shoreline stabilization, *Geophys. Res. Lett.*, *39*, L19401, doi:10.1029/2012GL052627.

Emanuel, K. (2005), Increasing destructiveness of tropical cyclones over the past 30 years, *Nature*, *436*, 686–688, doi:10.1038/nature03906.

Emanuel, K. A. (2013), Downscaling CMIP5 climate models shows increased tropical cyclone activity over the 21st century, *Proc. Natl. Acad. Sci. U. S. A.*, *110*(30), 12,219–12,224, doi:10.1073/pnas.1301293110.

Engelstaedter, S., and R. Washington (2007), Temporal controls on global dust emissions: The role of surface gustiness, *Geophys. Res. Lett.*, *34*, L15805, doi:10.1029/2007GL029971.

Engelstaedter, S., I. Tegen, and R. Washington (2006), North African dust emissions and transport, *Earth Sci. Rev.*, *79*, 73–100, doi:10.1016/j.earscirev.2006.06.004.

Enzel, Y., R. Amit, T. Grodek, A. Ayalon, J. Lekach, N. Porat, P. Bierman, J. D. Blum, and Y. Erel (2012), Late Quaternary weathering, erosion, and deposition in Nahal Yael, Israel: An "impact of climatic change on an arid watershed?", *Geol. Soc. Am. Bull.*, *124*, 705–722, doi:10.1130/B30538.1.

Ettema, J., M. R. van den Broeke, E. van Meijgaard, W. J. van de Berg, J. L. Bamber, J. E. Box, and R. C. Bales (2009), Higher surface mass balance of the Greenland ice sheet revealed by high-resolution climate modeling, *Geophys. Res. Lett.*, *36*, L12501, doi:10.1029/2009GL038110.

Evans, D. J. A. (2010), Controlled moraine development and debris transport pathways in polythermal plateau icefields: Examples from Tungnafellsjökull, Iceland, *Earth Surf. Processes Landforms*, *35*(12), 1430–1444, doi:10.1002/esp.1984.

Evans, S. G., and J. J. Clague (1994), Recent climatic change and catastrophic geomorphic processes in mountain environments, *Geomorphology*, *10*(1–4), 107–128, doi:10.1016/0169-555X(94)90011-6.

Fagherazzi, S., L. Carniello, L. D'Alpaos, and A. Defina (2006), Critical bifurcation of shallow microtidal landforms in tidal flats and salt marshes, *Proc. Natl. Acad. Sci. U. S. A.*, *103*(22), 8337–8341, doi:10.1073/pnas.0508379103.

Fagherazzi, S., et al. (2012), Numerical models of salt marsh evolution: Ecological, geomorphic, and climatic factors, *Rev. Geophys.*, *50*, RG1002, doi:10.1029/2011RG000359.

Farr, T. G., et al. (2007), The shuttle radar topography mission, *Rev. Geophys.*, *45*, RG2004, doi:10.1029/2005RG000183.

Favre, A., and A. Gershunov (2006), Extra-tropical cyclonic/anticyclonic activity in North-Eastern Pacific and air temperature extremes in Western North America, *Clim. Dyn.*, *26*, 617–629, doi:10.1007/s00382-005-0101-9.

Fennel, K., J. Hu, A. Laurent, M. Marta-Almeida, and R. Hetland (2013), Sensitivity of hypoxia predictions for the northern Gulf of Mexico to sediment oxygen consumption and model nesting, *J. Geophys. Res. Oceans*, *118*, 990–1002, doi:10.1002/JGRC.20077.

Ferguson, R. I., and M. Church (2004), A simple universal equation for grain settling velocity, *J. Sediment. Res.*, *74*(6), 933–937, doi:10.1306/051204740933.

Ferrier, K., K. Huppert, and J. T. Perron (2013), Climatic control of bedrock river incision, *Nature*, *496*, 206–209, doi:10.1038/nature11982.

Field, J. P., D. D. Breshears, and J. J. Whicker (2009), Toward a more holistic perspective of soil erosion: Why aeolian research needs to explicitly consider fluvial processes and interactions, *Aeolian Res*, *1*(1–2), 9–17, doi:10.1016/j.aeolia.2009.04.002.

Field, J. P., D. D. Breshears, J. J. Whicker, and C. B. Zou (2011), On the ratio of wind- to water-driven sediment transport: Conserving soil under global-change-type extreme events, *J. Soil Water Conserv.*, *66*(2), 51A–56A, doi:10.2489/jswc.66.2.51A.

Finnegan, N. J., and W. E. Dietrich (2011), Episodic bedrock strath terrace formation due to meander migration and cutoff, *Geology*, *39*(2), 143–146.

Finnegan, N. J., R. Schumer, and S. Finnegan (2014), A signature of transience in bedrock river incision rates over timescales of 10^4-10^7 years, *Nature*, *505*, 391–394.

Fischer, L., F. Amann, J. Moore, and C. Huggel (2010), Assessment of periglacial slope stability for the 1988 Tschierva rock avalanche, *Eng. Geol.*, *116*(1–2), 32–43, doi:10.1016/j.enggeo.2010.07.005.

Fischer, L., C. Huggel, A. Kääb, and W. Haeberli (2013), Slope failures and erosion rates on a glacierized high-mountain face under climatic changes, *Earth Surf. Processes Landforms*, *38*(8), 836–846, doi:10.1002/esp.3355.

FitzGerald, D. M., I. V. Buynevich, M. S. Fenster, and P. A. McKinlay (2000), Sand dynamics at the mouth of a rock-bound, tide-dominated estuary, *Sed. Geol.*, *131*, 25–29, doi:10.1016/S0037-0738(99)00124-4.

Florsheim, J. L., and J. F. Mount (2002), Restoration of floodplain topography by sand-splay complex formation in response to intentional levee breaches, Lower Cosumnes River, California, *Geomorphology*, *44*(1–2), 67–94, doi:10.1016/S0169-555X(01)00146-5.

Florsheim, J. L., and J. F. Mount (2003), Changes in lowland floodplain sedimentation processes: Pre-disturbance to post-rehabilitation, Cosumnes River, CA, *Geomorphology*, *56*(3–4), 305–323, doi:10.1016/S0169-555X(03)00158-2.

Ford, J. D., and P. Tristan (2010), What we know, do not know, and need to know about climate change vulnerability in the western Canadian Arctic: A systematic literature review, *Environ. Res. Lett.*, *5*(1), 014008, doi:10.1088/1748-9326/5/1/014008.

Forman, S. L., L. Marin, J. Pierson, J. Gomez, G. H. Miller, and R. S. Webb (2005), Aeolian sand depositional records from western Nebraska: Landscape responses to droughts in the past 1500 years, *Holocene*, *15*(7), 973–981, doi:10.1191/0959683605hl871ra.

Fortier, D., and M. Allard (2004), Late Holocene syngenetic ice-wedge polygons development, Bylot Island, Canadian arctic archipelago, *Can. J. Earth Sci.*, *41*(8), 997–1012, doi:10.1139/e2012-015.

Fortier, D., M. Allard, and Y. Shur (2007), Observation of rapid drainage system development by thermal erosion of ice wedges on Bylot Island, Canadian Arctic Archipelago, *Permafrost Periglac. Processes*, *18*(3), 229–243, doi:10.1002/ppp.595.

Fraser, B. (2012), Melting in the Andes: Goodbye glaciers, *Nature*, *491*(7423), 180–182, doi:10.1038/491180a.

French, H. M. (2007), *The Periglacial Environment*, John Wiley and Sons, Ltd, Hoboken, N. J., 480 p.

Frey, K. E., and J. W. McClelland (2009), Impacts of permafrost degradation on arctic river biogeochemistry, *Hydrol. Processes*, *23*(1), 169–182, doi:10.1002/hyp.7196.

Friedman, J. M., G. T. Auble, P. B. Shafroth, M. L. Scott, M. F. Merigliano, M. D. Freehling, and E. R. Griffith (2005), Dominance of non-native riparian trees in western USA, *Biol. Invasions*, *7*, 747–751, doi:10.1007/s10530-004-5849-z.

Fyke, J. G., A. J. Weaver, D. Pollard, M. Eby, L. Carter, and A. Mackintosh (2011), A new coupled ice sheet/climate model: Description and sensitivity to model physics under Eemian, Last Glacial Maximum, late Holocene and modern climate conditions, *Geosci. Model Dev.*, *4*, 117–136, doi:10.5194/gmd-4-117-2011.

Gabet, E. J., and T. Dunne (2003), Sediment detachment by rain power, *Water Resour. Res.*, *39*(1), 1002, doi:10.1029/2001WR000656.

Galloway, W. (1975), Process framework for describing the morphologic and stratigraphic evolution of deltaic depositional systems, in Deltas: Models for exploration, pp. 87–98.

García, M. (2006), ASCE manual of practice 110—Sedimentation engineering: Processes, measurements, modeling, and practice, in *Examining the Confluence of Environmental and Water Concerns: Proceedings of the World Environmental and Water Resource Congress 2006*, edited by R. Graham, 94, doi:10.1061/40856(200)94, Am. Soc. of Civ. Eng., Reston, Va.

Gardelle, J., Y. Arnaud, and E. Berthier (2011), Contrasted evolution of glacial lakes along the Hindu Kush Himalaya mountain range between 1990 and 2009, *Global Planet. Change*, *75*(1–2), 47–55, doi:10.1016/j.gloplacha.2010.10.003.

Gardelle, J., E. Berthier, Y. Arnaud, and A. Kääb (2013), Region-wide glacier mass balances over the Pamir-Karakoram-Himalaya during 1999–2011, *Cryosphere*, *7*, 1263–1286, doi:10.5194/tc-7-1263-2013.

Gardner, A., et al. (2013), A reconciled estimate of glacier contributions to sea level rise: 2003 to 2009, *Science*, *340*(6134), 852–857, doi:10.1126/science.1234532.

Gares, P., and S. A. White (2005), Volumetric analysis of overwash fans resulting from tropical storms on North Hatteras Island, North Carolina, *Southeast. Geogr.*, *45*, 1–15, doi:10.1353/sgo.2005.0006.

Ge, S., M. Liu, N. Lu, J. W. Godt, and G. Luo (2009), Did the Zipingpu Reservoir trigger the 2008 Wenchuan earthquake?, *Geophys. Res. Lett.*, *36*(20), L20315, doi:10.1029/2009GL040349.

Gelfenbaum, G., C. R. Sherwood, C. D. Peterson, G. Kaminsky, M. Buijsman, D. Twichell, P. Ruggiero, A. Gibbs, and C. Reed (1999), The Columbia River littoral cell: A Sediment budget overview, in *Proc. of Coastal Sediments '99, ASCE*, pp. 1660–1675.

Gemmrich, J., B. Thomas, and R. Bouchard (2011), Observational changes and trends in northeast Pacific wave records, *Geophys. Res. Lett.*, *38*, L22601, doi:10.1029/2011GL049518.

Gilbert, G. K. (1877), *Report on the geology of the Henry Mountains (Utah)*, United States Geological Survey, Washington, D. C.

Gillette, D. A., and W. Chen (2001), Particle production and aeolian transport from a "supply-limited" source area in the Chihuahuan desert, New Mexico, United States, *J. Geophys. Res.*, *106*(D6), 5267–5278, doi:10.1029/2000JD900674.

Gillette, D. A., D. W. Fryrear, T. E. Gill, T. Ley, T. A. Cahill, and E. A. Gearhart (1997), Relation of vertical flux of particles smaller than 10 μm to total aeolian horizontal mass flux at Owens Lake, *J. Geophys. Res.*, *102*(D22), 26009–26015, doi:10.1029/97JD02252.

Gillies, J., W. G. Nickling, and J. King (2007), Shear stress partitioning in large patches of roughness in the atmospheric inertial sublayer, *Bound. Lay. Meteorol.*, *122*, 367–396, doi:10.1007/s10546-006-9101-5.

Glaeser, J. D. (1978), Global distribution of barrier islands in terms of tectonic setting, *J. Geol.*, *86*, 283–298.

Gochis, D. J., E. R. Vivoni, and C. J. Watts (2010), The impact of soil depth on land surface energy and water fluxes in the North American Monsoon Region, *J. Arid Environ.*, *74*(5), 564–571, doi:10.1016/j.jaridenv.2009.11.004.

Godin, E., D. Fortier, and C. R. Burn (2012), Geomorphology of a thermo-erosion gully, Bylot Island, Nunavut, Canada, *Can. J. Earth Sci.*, *49*(8), 979–986, doi:10.1139/e2012-015.

Goelzer, H., P. Huybrechts, J. J. Fürst, F. M. Nick, M. L. Andersen, T. L. Edwards, X. Fettweis, A. J. Payne, and S. Shannon (2013), Sensitivity of Greenland ice sheet projections to model formulations, *J. Glaciol.*, *59*, 733–749, doi:10.3189/2013JoG12J182.

Goldberg, D. N., C. M. Little, O. V. Sergienko, A. Gnanadesikan, R. Hallberg, and M. Oppenheimer (2012), Investigation of land ice-ocean interaction with a fully coupled ice-ocean model: 1. Model description and behavior, *J. Geophys. Res.*, *117*, F02037, doi:10.1029/2011JF002246.

Gomez, B., and M. Church (1989), An assessment of bed load sediment transport formulae for gravel bed rivers, *Water Resour. Res.*, *25*(6), 1161–1186, doi:10.1029/WR025I006P01161.

Gomez, B., Y. Cui, A. J. Kettner, D. H. Peacock, and J. P. M. Syvitski (2009), Simulating changes to the sediment transport regime of the Waipaoa River, New Zealand, driven by climate change in the twenty-first century, *Global Planet. Change*, *67*(3–4), 153–166, doi:10.1016/j.gloplacha.2009.02.002.

Goni, M. A., M. B. Yunker, R. W. Macdonald, and T. I. Eglinton (2005), The supply and preservation of ancient and modern components of organic carbon in the Canadian Beaufort Shelf of the Arctic Ocean, *Mar. Chem.*, *93*(1), 53–73, doi:10.1016/j.marchem.2004.08.001.

Goodfellow, B. W. and J. Boelhouwers (2013), Hillslope processes in cold environments: An illustration of high-latitude mountain and hillslope processes and forms, *Treatise on Geomorphology*, *7*, J. Shroder, R. A. Marston, and M. Stoffel, 320–336, Academic, San Diego, Calif, doi:10.1016/B978-0-12-374739-6.00181-0.

Gooseff, M. N., A. Balser, W. B. Bowden, and J. B. Jones (2009), Effects of hillslope thermokarst in Northern Alaska, *Eos Trans. AGU*, *90*(4), 29–30, doi:10.1029/2009EO040001.

Gordeev, V. V. (2006), Fluvial sediment flux to the Arctic Ocean, *Geomorphology*, *80*, 94–104, doi:10.1016/j.geomorph.2005.09.008.

Goudie, A. S., and N. J. Middleton (2006), *Desert Dust in the Global System*, Springer, Berlin, 287 pp.

Graham, N. E., and H. F. Diaz (2001), Evidence for intensification of North Pacific winter cyclones since 1948, *Bull. Am. Meteorol. Soc.*, *82*, 1869–1893, doi:10.1175/1520-0477(2001)082<1869:EFIONP>2.3.CO;2.

Grosse, G., B. M. Jones, and C. D. Arp (2013), Thermokarst lake, drainage, and drained basins, in *Treatise on Geomorphology*, edited by J. Shroder, R. Giardino, and J. Harbor , pp. 1–29 , Elsevier Academic Press, San Diego, Calif.

Gruber, S., and W. Haeberli (2007), Permafrost in steep bedrock slopes and its temperature-related destabilization following climate change, *J. Geophys. Res. Earth Surf.*, *112*, F02S18, doi:10.1029/2006JF000547.

Gu, Y., and B. K. Wylie (2010), Detecting ecosystem performance anomalies for land management in the Upper Colorado River basin using satellite observations, climate data, and ecosystem models, *Remote Sens.*, *2*, 1880–1891, doi:10.3390/rs2081880.

Guimberteau, M., G. Drapeau, J. Ronchail, B. Sultan, J. Polcher, J. M. Martinez, C. Prigent, J. L. Guyot, G. Cochonneau, and J. Espinoza (2012), Discharge simulation in the sub-basins of the Amazon using ORCHIDEE forced by new datasets, *Hydrol. Earth Syst. Sci.*, *16*(3), 911–935, doi:10.5194/hessd-8-11171-2011.

Guo, L., and R. W. Macdonald (2006), Source and transport of terrigenous organic matter in the upper Yukon River: Evidence from isotope (δ^{13}C, Δ^{14}C, and δ^{15}N) composition of dissolved, colloidal, and particulate phases, *Global Biogeochem. Cycles*, *20*, GB2011, doi:10.1029/2005GB002593.

Hack, J. T. (1942), The changing physical environment of the Hopi Indians of Arizona, *Peabody Museum Papers, 25*(1), 85 p., 12 plates.

Hacker, S., P. Zarnetske, E. Seabloom, P. Ruggiero, J. Mull, S. Gerrity, and C. Jones (2012), Subtle differences in two non-native congeneric beach grasses significantly affect their colonization, spread, and impact, *Oikos*, *121*, 138–148, doi:10.1111/j.1600-0706.2011.01887.x.

Hales, T. C., and J. J. Roering (2005), Climate-controlled variations in scree production, Southern Alps, New Zealand, *Geology*, *33*, 701–704, doi:10.1130/G21528.1.

Hales, T. C., and J. J. Roering (2007), Climatic controls on frost cracking and implications for the evolution of bedrock landscapes, *J. Geophys. Res. Earth Surf.*, *112*, F02033, doi:10.1029/2006JF000616.

Halfen, A. F., and W. C. Johnson (2013), A review of Great Plains dune field chronologies, *Aeolian Res*, *10*, 135–160, doi:10.1016/j.aeolia.2013.03.001.

Hancock, G. R., T. J. Coulthard, C. Martinez, and J. D. Kalma (2011), An evaluation of landscape evolution models to simulate decadal and centennial scale soil erosion in grassland catchments, *J. Hydrol.*, *398*(3–4), 171–183, doi:10.1016/j.jhydrol.2010.12.002.

Hancock, G. S., and R. S. Anderson (2002), Numerical modeling of fluvial strath-terrace formation in response to oscillating climate, *Geol. Soc. Am. Bull.*, *114*, 1131–1142, doi:10.1130/0016-7606(2002)114<1131:NMOFST>2.0.CO;2.

Hancock, G. S., R. S. Anderson, and K. X. Whipple (1998), Beyond power: Bedrock River incision process and form, in *Rivers Over Rock: Fluvial Processes in Bedrock Channels*, edited by K. J. Tinkler and E. E. Wohl , pp. 35–60 , AGU, Washington, D. C.

Hanna, E., et al. (2013), Ice-sheet mass balance and climate change, *Nature*, *498*(7452), 51–59, doi:10.1038/nature12238.

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, and J. R. G. Townshend (2013), High-resolution global maps of 21st-century forest cover change, *Science*, *342*(6160), 850–853, doi:10.1126/science.1244693.

Hansen, M., R. DeFries, J. R. G. Townshend, and R. Sohlberg (1998), *UMD Global Land Cover Classification, 1 Kilometer, 1.0*, Department of Geography, Univ. of Maryland, College Park, Md., 1981–1994.

Hansom, J. D. (2001), Coastal sensitivity to environmental change: A view from the beach, *Catena*, *42*, 291–305, doi:10.1016/S0341-8162(00)00142-9.

Harig, C., and F. Simons (2012), Mapping Greenland's mass loss in space and time, *Proc. Natl. Acad. Sci. U. S. A.*, *109*(49), 19,934–19,937, doi:10.1073/pnas.1206785109.

Harrison, S. (2009), Climate sensitivity: Implications for the response of geomorphological systems to future climate change, *Geol. Soc. London Spec. Pub.*, *320*, 257–265, doi:10.1144/SP320.16.

Harvey, A. M. (2002), Effective timescales of coupling within fluvial systems, *Geomorphology*, *44*, 175–201, doi:10.1016/S0169-555X(01)00174-X.

Harvey, A. M., and S. G. Wells (2003), Late Quaternary variation in alluvial fan sedimentologic and geomorphic processes, Soda Lake Basin, Eastern Mojave Desert, California, in *Paleoenvironments and Paleohydrology of the Mojave and Southern Great Basin Deserts*, edited by Y. Enzel, S. G. Wells, and N. Lancaster, pp. 207–230, Geol. Soc. Am. Spec. Pap. 368, Boulder, Colo.

Harvey, J. E., and J. L. Pederson (2011), Reconciling arroyo-cycle and paleoflood approaches to alluvial records in drylands, *Quat. Sci. Rev.*, *30*, 855–866, doi:10.1016/j.quascirev.2010.12.025.

Hay, C. C., E. Morrow, R. E. Kopp, and J. X. Mitrovica (2013), Estimating the sources of global sea level rise with data assimilation techniques, *Proc. Natl. Acad. Sci. U. S. A.*, *110*(Suppl), 3692–3699, doi:10.1073/pnas.1117683109.

Heimsath, A. M., W. E. Dietrich, K. Nishiizumi, and R. C. Finkel (1997), The soil production function and landscape equilibrium, *Nature*, *388*, 358–361.

Held, I. M., and B. J. Soden (2006), Robust responses of the hydrological cycle to global warming, *J. Clim.*, *19*(21), 5686–5699, doi:10.1175/JCLI3990.1.

Hequette, A., and M. H. Ruz (1991), Spit and barrier island migration in the southeastern Canadian Beaufort Sea, *J. Coastal Res.*, *7*(3), 677–698.

Hesp, P. A. (2002), Foredunes and blowouts: Initiation, geomorphology and dynamics, *Geomorphology*, *48*, 245–268, doi:10.1016/S0169-555X(02)00184-8.

Hesp, P. A., and I. J. Walker (2013), Coastal dunes, in *Treatise on Geomorphology*, edited by J. F. Shroder , pp. 328–355 , Elsevier Academic Press, San Diego, Calif.

Heuvelink, G. B. M., J. M. Schoorl, A. Veldkamp, and D. J. Pennock (2006), Space–time Kalman filtering of soil redistribution, *Geoderma*, *133*(1–2), 124–137, doi:10.1016/j.geoderma.2006.03.041.

Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, and A. Jarvis (2005), Very high resolution interpolated climate surfaces for global land areas, *Int. J. Clim.*, *25*, 1965–1978, doi:10.1002/joc.1276.

Hinkel, J., R. J. Nicholls, S. J. Tol, Z. B. Wang, J. M. Hamilton, G. Boot, A. T. Vafeidis, L. McFadden, A. Ganopolski, and R. J. T. Klein (2013), A global analysis of erosion of sandy beaches and sea-level rise: An application of DIVA, *Global Planet. Change*, *111*, 150–158, doi:10.1016/j.gloplacha.2013.09.002.

Hinkel, K. M., B. M. Jones, W. R. Eisner, C. J. Cuomo, R. A. Beck, and R. Frohn (2007), Methods to assess natural and anthropogenic thaw lake drainage on the western Arctic coastal plain of northern Alaska, *J. Geophys. Res. Earth Surf.*, *112*, F02S16, doi:10.1029/2006JF000584.

Hinzman, L. D., et al. (2005), Evidence and implications of recent climate change in northern Alaska and other arctic regions, *Clim. Change*, *72*(3), 251–298, doi:10.1007/s10584-005-5352-2.

Hoelzle, M., T. Chinn, D. Stumm, F. Paul, M. Zemp, and W. Haeberli (2007), The application of glacier inventory data for estimating past climate change effects on mountain glaciers: A comparison between the European Alps and the Southern Alps of New Zealand, *Global Planet. Change*, *56*(1–2), 69–82, doi:10.1016/j.gloplacha.2006.07.001.

Holm, K., M. Bovis, and M. Jakob (2004), The landslide response of alpine basins to post-Little Ice Age glacial thinning and retreat in southwestern British Columbia, *Geomorphology*, *57*(3–4), 201–216, doi:10.1016/S0169-555X(03)00103-X.

Hooke, R. L., and J. F. Martín-Duque (2012), Land transformation by humans: A review, *GSA Today*, *12*(12), 4–10, doi:10.1130/GSAT151A.1.

Houser, C. (2009), Synchronization of transport and supply in beach-dune interaction, *Prog. Phys. Geogr.*, *33*, 733–746, doi:10.1177/0309133309350120.

Houser, C. (2012), Role of ridge and swale bathymetry in barrier island transgression, *Geomorphology*, *173–174*, 1–16.

Houser, C., and B. Greenwood (2005), Profile response of a lacustrine multiple-barred nearshore to a sequence of storm events, *Geomorphology*, *69*, 118–137, doi:10.1016/j.geomorph.2004.12.005.

Houser, C., and B. Greenwood (2007), Onshore migration of a swash bar during a storm, *J. Coastal Res.*, *23*(1), 1–14, doi:10.2112/03-0135.1.

Houser, C., and S. Hamilton (2009), Sensitivity of post-hurricane beach and dune recovery to event frequency, *Earth Surf. Processes Landforms*, *34*, 613–628, doi:10.1002/esp.1730.

Houser, C., and S. Mathew (2011), Variability in foredune height depends on the alongshore correspondence of transport potential and sediment supply, *Geomorphology*, *125*, 62–72.

Houser, C., C. Hapke, and S. Hamilton (2008), Controls on coastal dune morphology, shoreline erosion and barrier island response to extreme storms, *Geomorphology*, *100*, 223–240, doi:10.1016/j.geomorph.2007.12.007.

Howard, A. D., and T. R. Knutson (1984), Sufficient conditions for river meandering: A simulation approach, *Water Resour. Res.*, *20*(11), 1659–1667, doi:10.1029/WR020I011P01659.

Hugenholtz, C. H., and S. A. Wolfe (2005), Biogeomorphic model of dunefield activation and stabilization on the northern Great Plains, *Geomorphology*, *70*, 53–70, doi:10.1016/j.geomorph.2005.03.011.

Hugenholtz, C. H., and T. E. Barchyn (2010), Spatial analysis of sand dunes with a new global topographic dataset: New approaches and opportunities, *Earth Surf. Processes Landforms*, *35*(8), 986–992, doi:10.1002/esp.2013.

Huggel, C., A. Kääb, W. Haeberli, and B. Krummenacher (2003), Regional-scale GIS-models for assessment of hazards from glacier lake outbursts: Evaluation and application in the Swiss Alps, *Nat. Hazards Earth Syst. Sci.*, *3*(6), 647–662, doi:10.5194/nhess-3-647-2003.

Huggel, C., A. Kääb, and N. Salzmann (2004), GIS-based modeling of glacial hazards and their interactions using Landsat-TM and IKONOS imagery, *Nor. Geogr. Tidsskr.*, *58*, 61–73, doi:10.1080/00291950410002296.

Huggel, C., A. Kääb, and N. Salzmann (2006), Evaluation of QuickBird and IKONOS imagery for assessment of high-mountain hazards, *EARSeL eProc.*, *5*(1), 51–62.

Huggel, C., J. J. Clague, and O. Korup (2012), Is climate change responsible for changing landslide activity in high mountains?, *Earth Surf. Processes Landforms*, *37*, 77–91, doi:10.1002/esp.2223.

Hurst, M. D., M. A. Ellis, K. R. Royse, K. A. Lee, and K. Freeborough (2013), Controls on the magnitude-frequency scaling of an inventory of secular landslides, *Earth Surf. Dyn.*, *1*, 67–78, doi:10.5194/esurf-1-67-2013.

Hurtt, G. C., et al. (2011), Harmonization of land-use scenarios for the period 1500–2100: 600 years of global gridded annual land-use transitions, wood harvest, and resulting secondary lands, *Clim. Change*, *109*, 117–161, doi:10.1007/s10584-011-0153-2.

Inman, D. L., and C. E. Nordstrom (1971), On the tectonic and morphologic classification of coasts, *J. Geol.*, *79*, 1–21.

IPCC, AR4 (2007), *Climate Change 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by S. Solomon et al., Cambridge Univ. Press, Cambridge, U. K. and New York.

IPCC, AR5 (2013), *Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. Stocker et al., Cambridge Univ. Press, Cambridge, U. K. and New York. [Available at https://www.ipcc-wg1.unibe.ch/.]

Iturrizaga, L. (2011), Glacier lake outburst floods, in *Encyclopedia of Snow, Ice and Glaciers,* edited by V. P. Singh, P. Singh, and U. K. Haritashya, pp. 381–399, Springer, Dordrecht, doi:10.1007/978-90-481-2642-2.

Iverson, N. R. (2012), A theory of glacial quarrying for landscape evolution models, *Geology*, *40*, 679–682, doi:10.1130/G33079.1.

Jepsen, S. M., C. I. Voss, M. A. Walvoord, B. J. Minsley, and J. Rover (2013), Linkages between lake shrinkage/expansion and sublacustrine permafrost distribution determined from remote sensing of interior Alaska, USA, *Geophys. Res. Lett.*, *40*, 882–887, doi:10.1002/GRL.50187.

Jerolmack, D. J. (2009), Conceptual framework for assessing the response of delta channel networks to Holocene sea level rise, *Quat. Sci. Rev.*, *28*(17–18), 1786–1800, doi:10.1016/j.quascirev.2009.02.015.

Jewell, P. W., and K. Nicoll (2011), Wind regimes and aeolian transport in the Great Basin, U.S.A., *Geomorphology*, *129*(1–2), 1–13, doi:10.1016/j.geomorph.2011.01.005.

Johnson, J. M., L. J. Moore, K. Ells, A. B. Murray, P. N. Adams, R. A. MacKenzie III, and J. M. Jaeger (2014), Recent shifts in coastline change and shoreline stabilization linked to storm climate change, *Earth Surf. Processes Landforms*, *40*, 569–585, doi:10.1002/esp.3650.

Jomelli, V., V. P. Pech, C. Chochillon, and D. Brunstein (2004), Geomorphic variations of debris flows and recent climatic change in the French Alps, *Clim. Change*, *64*, 77–102, doi:10.1023/B:CLIM.0000024700.35154.44.

Jones, B. M., C. D. Arp, M. T. Jorgenson, K. M. Hinkel, J. A. Schmutz, and P. L. Flint (2009), Increase in the rate and uniformity of coastline erosion in Arctic Alaska, *Geophys. Res. Lett.*, *36*, L03503, doi:10.1029/2008GL036205.

Jones, B. M., G. Grosse, C. D. Arp, M. C. Jones, K. M. Walter Anthony, and V. E. Romanovsky (2011), Modern thermokarst lake dynamics in the continuous permafrost zone, northern Seward Peninsula, Alaska, *J. Geophys. Res.*, *116*, G00M03, doi:10.1029/2011JG001666.

Jones, J. A., I. F. Creed, K. L. Hatcher, R. J. Warren, M. B. Adams, M. H. Benson, and M. W. Williams (2012), Ecosystem processes and human influences regulate streamflow response to climate change at long-term ecological research sites, *BioScience*, *62*(4), 390–404.

Jorgenson, M. T., and T. E. Osterkamp (2005), Response of boreal ecosystems to varying modes of permafrost degradation, *Can. J. Forest Res.*, *35*, 2100–2111, doi:10.1139/x05-153.

Jorgenson, M. T., Y. L. Shur, and E. R. Pullman (2006), Abrupt increase in permafqrost degradation in Arctic Alaska, *Geophys. Res. Lett.*, *33*, L02503, doi:10.1029/2005GL024960.

Joughin, I., R. Alley, and D. Holland (2012), Ice-sheet response to oceanic forcing, *Science*, *338*(6111), 1172–1176, doi:10.1126/science.1226481.

Junk, W. J., S. An, C. M. Finlayson, B. Gopal, J. Kvet, S. A. Mitchell, W. J. Mitsch, and R. D. Robarts (2013), Current state of knowledge regarding the world's wetlands and their future under global climate change: A synthesis, *Aquatic Sci.*, *75*(1), 151–167, doi:10.1007/s00027-012-0278-z.

Kääb, A., R. Frauenfelder, and I. Roer (2007), On the response of rock glacier creep to surface temperature increase, *Global Planet. Change*, *56*, 172–187, doi:10.1016/j.gloplacha.2006.07.005.

Kaminsky, G. K., P. Ruggiero, M. C. Buijsman, and G. Gelfenbaum (2010), Historical evolution of the Columbia River littoral cell, *Mar. Geol.*, *273*(1–4), 96–126, doi:10.1016/j.margeo.2010.02.006.

Kaminsky, G., P. Ruggiero, and G. Gelfenbaum (1998), Monitoring coastal change in Southwest Washington and Northwest Oregon during the 1997/98 El Niño, *Shore Beach*, *66*(3), 42–51.

Kaser, G. (1999), A review of the modern fluctuations of tropical glaciers, *Global Planet. Change*, *22*(1), 93–103, doi:10.1016/S0921-8181(99)00028-4.

Kattelmann, R. (2003), Glacial lake outburst floods in the Nepal Himalaya: A manageable hazard?, *Nat. Hazards*, *28*, 145–154, doi:10.1023/A:1021130101283.

Katz, R. W., and B. G. Brown (1992), Extreme events in a changing climate: Variability is more important than averages, *Clim. Change*, *21*, 289–302, doi:10.1007/BF00139728.

Kendall, R. A., J. X. Mitrovica, and G. A. Milne (2005), On post-glacial sea level--II. Numerical formulation and comparative results on spherically symmetric models, *Geophys. J. Int.*, *161*(3), 679–706, doi:10.1111/j.1365-246X.2005.02553.x.

Kershaw, J. A., J. J. Clague, and S. G. Evans (2005), Geomorphic and sedimentological signature of a two-phase outburst flood from moraine-dammed Queen Bess Lake, British Columbia, Canada, *Earth Surf. Processes Landforms*, *30*, 1–25, doi:10.1002/esp.1122.

Khalsa, S. J. S., M. B. Dyurgerov, T. Khromova, B. H. Raup, and R. G. Barry (2004), Space-based mapping of glacier changes using ASTER and GIS tools, *IEEE Trans. Geosci. Remote Sens.*, *42*, 2177–2183, doi:10.1109/TGRS.2004.834636.

Kingslake, J., and F. Ng (2013), Quantifying the predictability of the timing of jökulhlaups from Merzbacher Lake, Kyrgyzstan, *J. Glaciol.*, *59*, 805–818, doi:10.3189/2013JoG12J156.

Kirchner, J. W., R. C. Finkel, C. S. Riebe, D. E. Granger, J. L. Clayton, J. G. King, and W. F. Megahan (2001), Mountain erosion over 10 yr, 10 k.y., and 10 m.y. time scales, *Geology*, *29*(7), 591–594, doi:10.1130/0091-7613(2001)029<0591:MEOYKY>2.0.

Kirschbaum, D. B., R. Adler, Y. Hong, and A. Lerner-Lam (2009), Evaluation of a preliminary satellite-based landslide hazard algorithm using global landslide inventories, *Nat. Hazards Earth Syst. Sci.*, *9*, 673–686, doi:10.5194/nhess-9-673-2009.

Kirwan, M. L., and A. B. Murray (2007), A coupled geomorphic and ecological model of tidal marsh evolution, *Proc. Natl. Acad. Sci. U. S. A.*, *104*, 6118–6122, doi:10.1073/pnas.0700958104.

Kirwan, M. L., A. B. Murray, J. P. Donnelly, and D. R. Corbett (2011), Rapid wetland expansion during European settlement and its implication for marsh survival under modern sediment delivery rates, *Geology*, *39*(5), 507–510, doi:10.1130/G31789.1.

Klijn, J. A. (1990), The younger dunes in the Netherlands: Chronology and causation, in *Dunes of the European Coasts*, edited by T. W. M. Bakker, P. D. Jungerius, and J. A. Klijn, *Catena Suppl.*, *18*, 89–100.

Kneisel, C., C. Rothenbühler, F. Keller, and W. Haeberli (2007), Hazard assessment of potential periglacial debris flows based on GIS-based spatial modelling and geophysical field surveys: A case study in the Swiss Alps, *Permafrost Periglac. Processes*, *18*, 259–268, doi:10.1002/ppp.593.

Knox, J. (2001), Agricultural influence on landscape sensitivity in the Upper Mississippi River Valley, *Catena*, *42*(2–4), 193–224, doi:10.1016/S0341-8162(00)00138-7.

Knox, J. C. (1983), Response of river systems to Holocene climates, in *Late Quaternary Environments of the United States, vol. 2, The Holocene*, edited by H. E. Wright Jr. , pp. 26–41 , Univ. of Minn. Press, Minneapolis.

Knox, J. C. (2006), Floodplain sedimentation in the Upper Mississippi Valley: Natural versus human accelerated, *Geomorphology*, *79*(3–4), 286–310, doi:10.1016/j.geomorph.2006.06.031.

Knutson, T. R., et al. (2010), Tropical cyclones and climate change, *Nat. Geosci.*, *3*(3), 157–163, doi:10.1038/ngeo779.

Kochel, R. C., and J. M. Trop (2012), Active processes, morphology, and dynamics of icy debris fans: Landform evolution along rapidly degrading escarpments in alpine regions undergoing recent deglaciation, *Geomorphology*, *151*, 59–76, doi:10.1016/j.geomorph.2012.01.014.

Kocurek, G., and N. Lancaster (1999), Aeolian system sediment state: Theory and Mojave Desert Kelso dune field example, *Sedimentology*, *46*, 505–515, doi:10.1046/j.1365-3091.1999.00227.x.

Kohfeld, K., and S. P. Harrison (2001), DIRTMAP: The geological record of dust, *Earth Sci. Rev.*, *54*(1–3), 81–114, doi:10.1016/S0012-825s2(01)00042-3.

Kokelj, S. V., and M. T. Jorgenson (2013), Advances in Thermokarst Research, *Permafrost Periglac. Processes*, *24*, 108–119, doi:10.1002/ppp.1779.

Kokelj, S. V., B. Zajdlik, and M. S. Thompson (2009), The impacts of thawing permafrost on the chemistry of lakes across the subarctic boreal-tundra transition, Mackenzie Delta region, Canada, *Permafrost Periglac. Processes*, *20*, 185–199, doi:10.1002/ppp.641.

Kokelj, S. V., D. Lacelle, T. C. Lantz, J. Tunnicliffe, L. Malone, I. D. Clark, and K. S. Chin (2013), Thawing of massive ground ice in mega slumps drives increases in stream sediment and solute flux across a range of watershed scales, *J. Geophys. Res. Earth Surf.*, *118*, 681–692, doi:10.1002/JGRF.20063.

Komar, P. D. (1998), *Beach Processes and Sedimentation*, Prentice Hall, Saddle River, N. J., 544 p.

Korup, O., and F. Schlunegger (2009), Rock-type control on erosion-induced uplift, eastern Swiss Alps, *Earth Planet. Sci. Lett.*, *278*, 278–285, doi:10.1016/j.epsl.2008.12.012.

Korup, O., and F. Tweed (2007), Ice, moraine, and landslide dams in mountainous terrain, *Quat. Sci. Rev.*, *26*(25), 3406–3422, doi:10.1016/j.quascirev.2007.10.012.

Korup, O., T. Gorum, and Y. Hayakawa (2012), Without power? Landslide inventories in the face of climate change, *Earth Surf. Processes Landforms*, *37*, 92–99, doi:10.1002/esp.2248.

Labrecque, S., D. Lacelle, C. R. Duguay, B. Lauriol, and J. Hawkings (2009), Contemporary (1951–2001) evolution of lakes in the old crow basin, Northern Yukon, Canada: Remote sensing, numerical modeling, and stable isotope analysis, *Arctic*, *62*(2), 225–238, doi:10.14430/arctic134.

Lacelle, D., J. Bjornson, and B. Lauriol (2010), Climatic and geomorphic factors affecting contemporary (1950–2004) activity of retrogressive thaw slumps on the Aklavik Plateau, Richardson Mountains, NWT, Canada, *Permafrost Periglac. Processes*, *21*, 1–15, doi:10.1002/ppp.666.

Lachenbruch, A. H. (1962), Mechanics of thermal contraction cracks and ice-wedge polygons in permafrost, *Geol. Soc. Am. Spec. Pub.*, *70*, 1–66, doi:10.1130/SPE70-p1.

Lamb, M. P., and M. A. Fonstad (2010), Rapid formation of a modern bedrock canyon by a single flood event, *Nat. Geosci.*, *3*(7), 477–481, doi:10.1038/ngeo894.

Lamoureux, S. F., and M. J. Lafrenière (2009), Fluvial impact of extensive active layer detachments, Cape Bounty, Melville Island, Canada, *Arct. Antarct. Alp. Res.*, *41*, 59–68, doi:10.1657/1523-0430-41.1.59.

Lancaster, N. (1988), Development of linear dunes in the southwestern Kalahari, southern Africa, *J. Arid Environ.*, *14*, 233–244.

Lancaster, N. (1997), Response of eolian geomorphic systems to minor climatic change: Examples from the southern California deserts, *Geomorphology*, *19*, 333–347, doi:10.1016/S0169-555X(97)00018-4.

Lancaster, N., and A. Baas (1998), Influence of vegetation cover on sand transport by wind: Field studies at Owens Lake, California, *Earth Surf. Processes Landforms*, *23*, 69–82, doi:10.1002/(SICI)1096-9837(199801)23:1<69::AID-ESP823>3.0.CO;2-G.

Lancaster, N., and P. Helm (2000), A test of a climatic index of dune mobility using measurements from the southwestern United States, *Earth Surf. Processes Landforms*, *25*, 197–207, doi:10.1002/(SICI)1096-9837(200002)25:2<197::AID-ESP82>3.0.CO;2-H.

Lane, S. N. (2013), 21st century climate change: Where has all the geomorphology gone?, *Earth Surf. Processes Landforms*, *38*(1), 106–110, doi:10.1002/esp.3362.

Langbein, W. B., and S. A. Schumm (1958), Yield of sediment in relation to mean annual precipitation, *Trans. Am. Geophys. Union*, *39*, 1076–1084, doi:10.1029/TR039i006p01076.

Langley, J. A., K. L. Mckee, D. R. Cahoon, J. A. Cherry, and J. P. Megonigal (2009), Elevated CO_2 stimulates marsh elevation gain, counterbalancing sea level rise, *Proc. Natl. Acad. Sci. U. S. A.*, *106*, 6182–6186, doi:10.1073/pnas.0807695106.

Lantuit, H., and W. Pollard (2008), Fifty years of coastal erosion and retrogressive thaw slump activity on Herschel Island, southern Beaufort Sea, Yukon Territory, Canada, *Geomorphology*, *95*(1), 84–102, doi:10.1016/j.geomorph.2006.07.040.

Lau, W. K. M., H. T. Wu, and K. M. Kim (2013), A canonical response of precipitation characteristics to global warming from CMIP5 models, *Geophys. Res. Lett.*, *40*, 3163–3169, doi:10.1002/GRL.50420.

Lauer, J. W., and G. Parker (2008a), Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meandering river: Application to the Clark Fork River, Montana, *Water Resour. Res.*, *44*, W08404, doi:10.1029/2006WR005529.

Lauer, J. W., and G. Parker (2008b), Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meandering river: Theory, *Water Resour. Res.*, *44*, W04425, doi:10.1029/2006WR005528.

Lawrence, D., et al. (2011), Parameterization improvements and functional and structural advances in Version 4 of the Community Land Model, *J. Adv. Model. Earth Syst.*, *3*, M03001, doi:10.1029/2011MS000045.

Lazarus, E., and A. B. Murray (2011), An integrated hypothesis for regional patterns of shoreline change along the Northern North Carolina Outer Banks, USA, *Mar. Geol.*, *281*, 85–90, doi:10.1016/j.margeo.2011.02.002.

Lazarus, E. D., and A. B. Murray (2007), Process signatures in regional patterns of shoreline change on annual to decadal timescales, *Geophys. Res. Lett.*, *34*, L19402, doi:10.1029/2007GL031047.

Lazarus, E., A. Ashton, and A. B. Murray (2011), Cumulative versus transient shoreline change: Dependencies on temporal and spatial scale, *J. Geophys. Res. Earth Surf.*, *116*, F022014, doi:10.1029/2010JF001835.

Leatherman, S. P. (1976), Barrier island dynamics: Overwash processes and aeolian transport, in *Proc. 15th Coastal Engr. Conf. ASCE*, New York, pp. 1958–1974.

Leatherman, S. P. (1979), Barrier dune systems: A reassessment, *Sed. Geol.*, *24*, 1–16, doi:10.1016/0037-0738(79)90025-3.

Leopold, L. B., and T. Maddock (1953), *The Hydraulic Geometry of Stream Channels and Some Physiographic Implications*, United States Geological Survey, Washington, D. C.

Lewis, K. C., G. A. Zyvoloski, B. Travis, C. Wilson, and J. Rowland (2012), Drainage subsidence associated with Arctic permafrost degradation, *J. Geophys. Res. Earth Surf.*, *117*, F04019, doi:10.1029/2011JF002284.

Lewkowicz, A. G., and C. Harris (2005), Frequency and magnitude of active-layer detachment failures in discontinuous and continuous permafrost, northern Canada, *Permafrost Periglac. Processes*, *16*, 115–130, doi:10.1002/ppp.522.

Li, H., M. S. Wigmosta, H. Wu, M. Huang, Y. Ke, A. M. Coleman, and L. R. Leung (2013), A physically based runoff routing model for land surface and earth system models, *J. Hydrometeor.*, *14*(3), 808–828, doi:10.1175/JHM-D-12-015.1.

Liljedahl, A. K., L. D. Hinzman, and J. Schulla (2012), Ice-wedge polygon type controls low-gradient watershed scale hydrology, in *Proceedings of the Tenth International Conference on Permafrost, vol. 1: International Contributions*, edited by K. M. Hinkel , pp. 231–236 , The Northern Publisher, Salehard, Russia.

Limber, P. W., and A. B. Murray (2011), Beach and sea cliff dynamics as a driver of rocky coastline evolution and stability, *Geology*, *39*, 1147–1150, doi:10.1130/G32315.1.

List, J. H., and A. D. Ashton (2007), A circulation modeling approach for evaluating the conditions for shoreline instabilities, in *Coastal Sediments 2007* , pp. 327–340 , Am. Soc. of Civ. Eng., Reston, Va.

Luoto, M. (2007), New insights into factors controlling drainage density in subarctic landscapes, *Arct. Antarct. Alp. Res.*, *39*(1), 117–126, doi:10.1657/1523-0430(2007)39[117:NIIFCD]2.0.CO;2.

MacDonald, L. A., K. W. Turner, A. M. Balasubramaniam, B. B. Wolfe, R. I. Hall, and J. N. Sweetman (2012), Tracking hydrological responses of a thermokarst lake in the Old Crow Flats (Yukon Territory, Canada) to recent climate variability using aerial photographs and paleolimnological methods, *Hydrol. Processes*, *26*, 117–129, doi:10.1002/hyp.8116.

Mackay, J. R. (1990), Some observations on the growth and deformation of epigenetic, syngenetic and anti-syngenetic ice wedges, *Permafrost Periglac. Processes*, *1*, 15–29, doi:10.1002/ppp.3430010104.

Mackintosh, A. N., A. J. Dugmore, and A. L. Hubbard (2002), Holocene climatic changes in Iceland: Evidence from modelling glacier length fluctuations at Sólheimajökull, *Quat. Int.*, *91*(1), 39–52, doi:10.1016/S1040-6182(01)00101-X.

Macklin, M. G., and J. Lewin (2008), Alluvial responses to the changing Earth System, *Earth Surf. Processes Landforms*, *33*, 1374–1395, doi:10.1002/esp.1714.

MacLean, R., M. W. Oswood, J. G. Irons, and W. H. McDowell (1999), The effect of permafrost on stream biogeochemistry: A case study of two streams in the Alaskan (USA) taiga, *Biogeochemistry*, *47*(3), 239–267, doi:10.1007/BF00992909.

Macpherson, T., W. G. Nickling, J. A. Gillies, and V. Etyemezian (2008), Dust emissions from undisturbed and disturbed supply-limited desert surfaces, *J. Geophys. Res. Earth Surf.*, *113*, F02S04, doi:10.1029/2007JF000800.

Magliocca, N. R., D. E. McNamara, and A. B. Murray (2011), Long-term, large-scale morphodynamic effects of artificial dune construction along a barrier island coastline, *J. Coastal Res.*, *27*, 918–930, doi:10.2112/JCOASTRES-d-10-00088.1.

Mahowald, N. M., and C. Luo (2003), A less dusty future?, *Geophys. Res. Lett.*, *30*, 1903, doi:10.1029/2003GL017880.

Mahowald, N. M., D. R. Muhs, S. Levis, P. J. Rasch, M. Yoshioka, C. S. Zender, and C. Luo (2006), Change in atmospheric mineral aerosols in response to climate: Last glacial period, preindustrial, modern, and doubled carbon dioxide climates, *J. Geophys. Res.*, *111*, D10202, doi:10.1029/2005JD006653.

Marani, M., A. D'Alpaos, S. Lanzoni, L. Carniello, and A. Rinaldo (2007), Biologically-controlled multiple equilibria of tidal landforms and the fate of the Venice lagoon, *Geophys. Res. Lett.*, *34*, L11402, doi:10.1029/2007GL030178.

Marani, M., A. D'Alpaos, S. Lanzoni, L. Carniello, and A. Rinaldo (2010), The importance of being coupled: Stable states and catastrophic shifts in tidal biomorphodynamics, *J. Geophys. Res.*, *115*, F04004, doi:10.1029/2009JF001600.

Marani, M., A. D'Alpaos, S. Lanzoni, and M. Santalucia (2011), Understanding and predicting wave erosion of marsh edges, *Geophys. Res. Lett.*, *38*, L21401, doi:10.1029/2011GL048995.

Marani, M., C. De Lio, and A. D'Alpaos (2013), Vegetation engineers marsh morphology through multiple competing stable states, *Proc. Nat. Acad. Sci. U. S. A.*, *110*, 3259–3263, doi:10.1073/pnas.1218327110.

Marîn, L., S. L. Forman, A. Valdez, and F. Bunch (2005), Twentieth century dune migration at the Great Sand Dunes National Park and Preserve, Colorado, relation to drought variability, *Geomorphology*, *70*, 163–183, doi:10.1016/j.geomorph.2005.04.014.

Mariotti, G., and S. Fagherazzi (2013), Critical width of tidal flats triggers marsh collapse in the absence of sea-level rise, *Proc. Natl. Acad. Sci. U. S. A.*, *110*(14), 5353–5356, doi:10.1073/pnas.1219600110.

Mariotti, G., and S. Fagherazzi (2010), A numerical model for the coupled long-term evolution of salt marshes and tidal flats, *J. Geophys. Res. Earth Surf.*, *115*, F01004, doi:10.1029/2009JF001326.

Marren, P. M. (2005), Magnitude and frequency in proglacial rivers: A geomorphological and sedimentological perspective, *Earth Sci. Rev.*, *70*(3), 203–251, doi:10.1016/j.earscirev.2004.12.002.

Marren, P. M., A. J. Russell, and O. Knudsen (2002), Discharge magnitude and frequency as a control on proglacial fluvial sedimentary systems, *Int. Assoc. Hydrol. Sci.*, *276*, 297–303.

Mars, J., and D. Houseknecht (2007), Quantitative remote sensing study indicates doubling of coastal erosion rate in past 50 yr along a segment of the Arctic coast of Alaska, *Geology*, *35*(7), 583–586, doi:10.1130/G23672A.1.

Marsh, P., and N. N. Neumann (2001), Processes controlling the rapid drainage of two ice-rich permafrost-dammed lakes in NW Canada, *Hydrol. Processes*, *15*, 3433–3446, doi:10.1002/hyp.1035.

Marsh, P., M. Russell, S. Pohl, H. Haywood, and C. Onclin (2009), Changes in thaw lake drainage in the Western Canadian Arctic from 1950 to 2000, *Hydrol. Processes*, *23*, 145–158, doi:10.1002/hyp.7179.

Marticorena, B., et al. (2006), Surface and aerodynamic roughness in arid and semiarid areas and their relation to radar backscatter coefficient, *J. Geophys. Res. Earth Surf.*, *111*, F03017, doi:10.1029/2006JF000462.

Matsuoka, N. (2001), Solifluction rates, processes and landforms: A global review, *Earth Sci. Rev.*, *55*(1), 107–134, doi:10.1016/S0012-8252(01)00057-5.

Matsuoka, N., and H. Sakai (1999), Rockfall activity from an alpine cliff during thawing periods, *Geomorphology*, *28*(3), 309–328, doi:10.1016/S0169-555X(98)00116-0.

Matsuoka, N., and J. Murton (2008), Frost weathering: Recent advances and future directions, *Permafrost Periglac. Processes*, *19*, 195–210, doi:10.1002/ppp.620.

Matthews, J. A., and K. R. Briffa (2005), The 'Little Ice Age': Reevaluation of an evolving concept, *Geogr. Ann. Ser. A Phys. Geogr.*, *87*, 17–36, doi:10.1111/j.0435-3676.2005.00242.x.

McClelland, J. W., S. J. Déry, B. J. Peterson, R. M. Holmes, and E. F. Wood (2006), A pan-arctic evaluation of changes in river discharge during the latter half of the 20th century, *Geophys. Res. Lett.*, *33*, L06715, doi:10.1029/2006GL025753.

McClelland, J. W., A. Townsend-Small, R. M. Holmes, F. Pan, M. Stieglitz, M. Khosh, and B. J. Peterson (2014), River export of nutrients and organic matter from the North Slope of Alaska to the Beaufort Sea, *Water Resour. Res.*, *50*, 1823–1839, doi:10.1002/2013WR014722.

McColl, S. T. (2012), Paraglacial rock-slope stability, *Geomorphology*, *153*, 1–16, doi:10.1016/j.geomorph.2012.02.015.

McDonald, E. V., L. D. McFadden, and S. G. Wells (2003), Regional response of alluvial fans to the Peistocene–Holocene climate transition, Mojave Desert, California, in *Paleoenvironments and Paleohydrology of the Mojave and Southern Great Basin Deserts*, edited by Y. Enzel, S. G. Wells, and N. Lancaster , pp. 189–205 , Geological Society Am. Special Pap. 368, Boulder, Co.

McDowell, N. G., D. J. Beerling, D. D. Breshears, R. A. Fisher, K. F. Raffa, and M. Stitt (2011), The interdependence of mechanisms underlying climate-driven vegetation mortality, *Trends Ecol. Evol.*, *26*, 523–532, doi:10.1016/j.tree.2011.06.003.

McKillop, R. J., and J. J. Clague (2007), Statistical, remote sensing-based approach for estimating the probability of catastrophic drainage from moraine-dammed lakes in southwestern British Columbia, *Global Planet. Change*, *56*, 153–171, doi:10.1016/j.gloplacha.2006.07.004.

McLeod, E., et al. (2011), A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2, *Front. Ecol. Environ.*, *9*, 552–560, doi:10.1111/j.1365-2699.2007.01806.x.

McNamara, D. E., and B. T. Werner (2008), Coupled barrier island–resort model: 1. Emergent instabilities induced by strong human-landscape interactions, *J. Geophys. Res. Earth Surf.*, *113*, F01016, doi:10.1029/2007JF000840.

McNamara, J. P. (2012) Is there a Northern signature on fluvial form?, in *Gravel-Bed Rivers: Processes, Tools, Environments*, edited by M. Church, P. M. Biron and A. G. Roy, John Wiley & Sons, Ltd, Chichester, U. K., doi:10.1002/9781119952497.ch38.

McNamara, J. P., and D. L. Kane (2009), The impact of a shrinking cryosphere on the form of arctic alluvial channels, *Hydrol. Processes*, *23*, 159–168, doi:10.1002/hyp.7199.

McNamara, J. P., D. L. Kane, and L. D. Hinzman (1999), An analysis of an arctic channel network using a digital elevation model, *Geomorphology*, *29*(3), 339–353, doi:10.1016/S0169-555X(99)00017-3.

McNinch, J. E. (2004), Geologic control in the nearshore: Shore-oblique sandbars and shoreline erosional hotspots, Mid-Atlantic Bight, USA, *Mar. Geol.*, *211*, 121–141, doi:10.1016/j.margeo.2004.07.006.

Meier, M., M. Dyurgerov, U. Rick, S. O'neel, W. Pfeffer, R. Anderson, S. Anderson, and A. Glazovsky (2007), Glaciers dominate eustatic sea-level rise in the 21st century, *Science*, *317*(5841), 1064–1067, doi:10.1126/science.1143906.

Meire, D., J. Kondziolka, and H. Nepf (2014), Interaction between neighboring vegetation patches: Impact on flow and deposition, *Water Resour. Res.*, *50*(5), 3809–3825, doi:10.1002/2013WR015070.

Melack, J. (2011), Biogeochemistry: Riverine carbon dioxide release, *Nat. Geosci.*, *4*(12), 821–822, doi:10.1038/ngeo1333.

Mendez, F. J., M. Menendez, A. Luceno, and I. J. Losada (2006), Estimation of the long-term variability of extreme significant wave height using a time-dependent Peak Over Threshold (POT) model, *J. Geophys. Res.*, *111*, C07024, doi:10.1029/2005JC003344.

Menéndez, M., F. J. Méndez, I. J. Losada, and N. E. Graham (2008), Variability of extreme wave heights in the northeast Pacific Ocean based on buoy measurements, *Geophys. Res. Lett.*, *35*, L22607, doi:10.1029/2008GL035394.

Menking, J. A., J. Han, N. M. Gasparini, and J. P. L. Johnson (2013), The effects of precipitation gradients on river profile evolution on the Big Island of Hawai'I, *Geol. Soc. Am. Bull.*, *125*, 594–608, doi:10.1130/B30625.1.

Meyer, G. A., and J. L. Pierce (2003), Climatic controls on fire-induced sediment pulses in Yellowstone National Park and Central Idaho: a long-term perspective, *For. Ecol. Manage.*, *178*, 89–104, doi:10.1016/S0378-1127(03)00055-0.

Meyer, G. A., and S. G. Wells (1997), Fire-related sedimentation events on alluvial fans, Yellowstone National Park, USA, *J. Sed. Res.*, *67*(5), 776–791.

Meyer, G. A., J. L. Pierce, S. H. Wood, and A. J. T. Jull (2001), Fire, storms, and erosional events in the Idaho batholith, *Hydrol. Processes*, *15*(15), 3025–3038, doi:10.1002/hyp.389.

Meyer-Peter, E., and R. Müller (1948), Formulas for bed-load transport, in *Proceedings of the 2nd Meeting of the International Association for Hydraulic Structures Research*, 39–64.

Middleton, N. J., and D. S. G. Thomas (1997), *World Atlas of Desertification*, 2nd ed. , pp. , UNEP, Geneva, 182 p.

Miguez-Macho, G., and Y. Fan (2012), The role of groundwater in the Amazon water cycle: 1. Influence on seasonal streamflow, flooding and wetlands, *J. Geophys. Res. Atmos.*, *117*, D15113, doi:10.1029/2012JD017539.

Millar, S. (2013), Mass movement processes in the periglacial environment, in *Treatise on Geomorphology*, vol. *8*, edited by J. Shroder, R. Giardino, and J. Harbor , pp. 374–391 , Academic Press, San Diego, Calif.

Miller, D. A., and R. A. White (1998), A conterminous United States multilayer soil characteristics dataset for regional climate and hydrology modeling, *Earth Interact.*, *2*(2), 1–26, doi:10.1175/1087-3562(1998)002<0001:ACUSMS>2.3.CO;2.

Mitrovica, J. X., and G. A. Milne (2003), On post-glacial sea level: I. General theory, *Geophys. J. Int.*, *154*(2), 253–267, doi:10.1046/j.1365-246X.2003.01942.x.

Mitrovica, J. X., N. Gomez, and P. U. Clark (2009), The sea-level fingerprint of West Antarctic collapse, *Science*, *323*(5915), 753, doi:10.1126/science.1166510.

Mitrovica, J. X., N. Gomez, E. Morrow, C. Hay, K. Latychev, and M. E. Tamisiea (2011), On the robustness of predictions of sea level fingerprints, *Geophys. J. Int.*, *187*(2), 729–742, doi:10.1111/j.1365-246X.2011.05090.x.

Molnar, P., R. S. Anderson, and S. P. Anderson (2007), Tectonics, fracturing of rock, and erosion, *J. Geophys. Res. Earth Surf.*, *112*, F03014, doi:10.1029/2005JF000433.

Moore, J. R., A. Boleve, J. W. Sanders, and S. D. Glaser (2011), Self-potential investigation of moraine dam seepage, *J. Appl. Geophys.*, *74*(4), 277–286, doi:10.1016/j.jappgeo.2011.06.014.

Moore, J. R., J. Egloff, J. Nagelisen, M. Hunziker, U. Aerne, and M. Christen (2013a), Sediment transport and bedrock erosion by wet snow avalanches in the Guggigraben, Matter Valley, Switzerland, *Arct. Antarct. Alp. Res.*, *45*(3), 350–362, doi:10.1657/1938-4246-45.3.350.

Moore, L. J., J. H. List, S. J. Williams, and D. Stolper (2010), Complexities in barrier island response to sea level rise: Insights from numerical model experiments, North Carolina Outer Banks, *J. Geophys. Res. Earth Surf.*, *115*, F03004, doi:10.1029/2009JF001299.

Moore, L. J., D. E. McNamara, A. B. Murray, and O. Brenner (2013b), Observed changes in hurricane-driven waves explain the dynamics of modern cuspate shorelines, *Geophys. Res. Lett.*, *40*, 5867–5871, doi:10.1002/2013GL057311.

Moore, R. D., S. W. Fleming, B. Menounos, R. Wheate, A. Fountain, K. Stahl, K. Holm, and M. Jakob (2009), Glacier change in western North America: Influences on hydrology, geomorphic hazards and water quality, *Hydrol. Processes*, *23*, 42–61, doi:10.1002/hyp.7162.

Morris, J. T. (2006), Competition among marsh macrophytes by means of geomorphological displacement in the intertidal zone, *Estuarine Coastal Shelf Sci.*, *69*(3–4), 395–402, doi:10.1016/j.ecss.2006.05.025.

Morris, J. T., P. V. Sundareshwar, C. T. Nietch, B. Kjerfve, and D. R. Cahoon (2002), Responses of coastal wetlands to rising sea level, *Ecology*, *83*, 2869–2877, doi:10.1890/0012-9658(2002)083[2869:ROCWTR]2.0.CO;2.

Morton, R. A. (2002), Factors controlling storm impacts on coastal barrier sand beaches: A preliminary basis for near real-time forecasting, *J. Coastal Res.*, *18*, 486–501.

Morton, R. A., and J. G. Paine (1985), Beach and vegetation-line changes at Galveston Island, Texas. Erosion, deposition, and recovery from Hurricane Alicia, *Bureau of Economic Geology Geological Circular, 85*, The Univ. of Texas, Austin, Tex.

Moulin, C., C. E. Lambert, F. Dulac, and U. Dayan (1997), Control of atmospheric export of dust by the North Atlantic Oscillation, *Nature*, *387*, 691–694.

Muhs, D. R., and P. B. Maat (1993), The potential response of eolian sands to greenhouse warming and precipitation reduction on the great plains of the United States, *J. Arid Environ.*, *25*(4), 351–361.

Muhs, D. R., and V. T. Holliday (1995), Active dune sand on the Great Plains in the 19th century: Evidence from accounts of early explorers, *Quat. Res.*, *43*, 118–124.

Mulitza, S., et al. (2010), Increase in African dust flux at the onset of commercial agriculture in the Sahel region, *Nature*, *466*(7303), 226–228.

Munson, S. M., J. Belnap, and G. S. Okin (2011), Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau, *Proc. Natl. Acad. Sci. U. S. A.*, *108*(10), 3854–3859, doi:10.1073/pnas.1014947108.

Munson, S. M., R. H. Webb, J. Belnap, J. A. Hubbard, D. E. Swann, and S. Rutman (2012), Forecasting climate change impacts to plant community composition in the Sonoran Desert region, *Global Change Biol.*, *18*, 1083–1095, doi:10.1111/j.1365-2486.2011.02598.x.

Murray, A. B., M. A. F. Knaapen, M. Tal, and M. L. Kirwan (2008), Biomorphodynamics: Physical-biological feedbacks that shape landscapes, *Water Resour. Res.*, *44*, W11301, doi:10.1029/2007WR006410.

Murray, A. B., S. Gopalakrishnan, D. E. McNamara, and M. D. Smith (2013), Progress in coupling models of human and coastal landscape change, *Comput. Geosci.*, *53*, 30–38, doi:10.1016/j.cageo.2011.10.010.

Nachtergaele, L., H. van Velthuize, L. Verelst, N. Batjes, K. Dijkshoorn, V. van Engelen, G. Fischer, A. Jones, L. Montanarella, M. Petri, S. Prieler, E. Teixeira, D. Wiberg, and X. Shi (2012), *Harmonized World Soil Database, Version 1.2*, FAO/IIASA/ISRIC/ISS-CAS/JRC, Rome.

Nakawo, M., and B. Rana (1999), Estimate of ablation rate of glacier ice under a supraglacial debris layer, *Geogr. Ann. Ser. A Phys. Geogr.*, *81*, 695–701, doi:10.1111/1468-0459.00097.

Nelson, F. E., O. A. Anisimov, and N. I. Shiklomanov (2001), Subsidence risk from thawing permafrost, *Nature*, *410*(6831), 889–890, doi:10.1038/35073746.

Nepf, H. M. (1999), Drag, turbulence, and diffusion in flow through emergent vegetation, *Water Resour. Res.*, *35*, 479, doi:10.1029/1998WR900069.

Neupane, S., and E. M. Yager (2013), Numerical simulation of the impact of sediment supply and streamflow variations on channel grain sizes and Chinook salmon habitat in mountain drainage networks, *Earth Surf. Processes Landforms*, *38*, 1822–1837, doi:10.1002/esp.3426.

Nicholas, A. P., and D. E. Walling (1997), Modelling flood hydraulics and overbank deposition on river floodplains, *Earth Surf. Processes Landforms*, *22*(1), 59–77, doi:10.1002/(SICI)1096-9837(199701)22:1<59::AID-ESP652>3.0.CO;2-R.

Nicholas, A. P., D. E. Walling, R. J. Sweet, and X. Fang (2006), New strategies for upscaling high-resolution flow and overbank sedimentation models to quantify floodplain sediment storage at the catchment scale, *J. Hydrol.*, *329*(3–4), 577–594, doi:10.1016/j.jhydrol.2006.03.010.

Nickling, W. G., and C. K. McKenna Neuman (1995), Development of deflation lag surfaces, *Sedimentology*, *42*(3), 403–414, doi:10.1111/j.1365-3091.1995.tb00381.x.

Nickling, W. G., and M. Ecclestone (1981), The effects of soluble salts on the threshold shear velocity of fine sand, *Sedimentology*, *28*, 505–510, doi:10.1111/j.1365-3091.1981.tb01698.x.

Nield, J. M., and A. C. W. Baas (2008), Investigating parabolic and nebkha dune formation using a cellular automaton modelling approach, *Earth Surf. Processes Landforms*, *33*, 724–740, doi:10.1002/esp.1571.

Nott, J. (2006), Tropical cyclones and the evolution of the sedimentary coast of Northern Australia, *J. Coastal Res.*, *22*, 49–62, doi:10.2112/05A-0005.1.

Oerlemans, J. (1994), Quantifying global warming from the retreat of glaciers, *Science*, *264*(5156), 243–245, doi:10.1126/science.264.5156.243.

Okin, G. S., and M. C. Reheis (2002), An ENSO predictor of dust emission in the southwestern United States, *Geophys. Res. Lett.*, *29*(9), 46–41, doi:10.1029/2001GL014494.

Okin, G. S., J. E. Bullard, R. L. Reynolds, J.-A. C. Ballantine, K. Schepanski, M. C. Todd, J. Belnap, M. C. Baddock, T. E. Gill, and M. E. Miller (2011), Dust: Small-scale processes with global consequences, *Eos Trans. Am. Geophys. Union*, *92*(29), 241–242, doi:10.1029/2011EO290001.

Old, G. H., D. M. Lawler, and A. Snorrason (2005), Discharge and suspended sediment dynamics during two jökulhlaups in the Skaftá River, Iceland, *Earth Surf. Processes Landforms*, *30*, 1441–1460, doi:10.1002/esp.1216.

Orford, J., J. Cooper, D. Jackson, G. Malvarez, and D. White (1999), Extreme storms and thresholds on foredune stripping at Inch Spit, South-West Ireland, in *Coastal Sediments '99*, *1–3*, pp. 1852–1866.

Orwin, J. F., S. F. Lamoureux, J. Warburton, and A. Beylich (2010), A framework for characterizing fluvial sediment fluxes from source to sink in cold environments, *Geogr. Ann. Ser. A Phys. Geogr.*, *92*(2), 155–176, doi:10.1111/j.1468-0459.2010.00387.x.

Osti, R., S. Egashira, and Y. Adikari (2013), Prediction and assessment of multiple glacial lake outburst floods scenario in Pho Chu River basin, Bhutan, *Hydrol. Processes*, *27*, 262–274, doi:10.1002/hyp.8342.

Ouimet, W. B., K. X. Whipple, L. H. Royden, Z. Sun, and Z. Chen (2007), The influence of large landslides on river incision in a transient landscape: Eastern margin of the Tibetan Plateau (Sichuan, China), *Geol. Soc. Am. Bull.*, *119*(11–12), 1462–1476, doi:10.1130/B26136.1.

Owen, G., J. F. Hiemstra, J. A. Matthews, and L. J. Mcewen (2010), Landslide-glacier interaction in a neoparaglacial setting at Tverrbytnede, Jotunheimen, Southern Norway, *Geogr. Ann. Ser. A Phys. Geogr.*, *92*, 421–436, doi:10.1111/J.1468-0459.2010.00405.X.

Paola, C., E. Foufoula-Georgiou, W. E. Dietrich, M. Hondzo, D. Mohrig, G. Parker, M. E. Power, I. Rodriguez-Iturbe, V. Voller, and P. Wilcock (2006), Toward a unified science of the Earth's surface: Opportunities for synthesis among hydrology, geomorphology, geochemistry, and ecology, *Water Resour. Res.*, *42*, W03S10, doi:10.1029/2005WR004336.

Parajuli, S. P., Z.-L. Yang, and G. Kocurek (2014), Mapping erodibility in dust source regions based on geomorphology, meteorology, and remote sensing, *J. Geophys. Res. Earth Surf.*, *119*, 1977–1994, doi:10.1002/2014JF003095.

Parker, G., P. C. Klingemen, and D. L. McLean (1982), Bedload and size distribution in paved gravel-bed streams, *J. Hydraul. Div. Am. Soc. Civ. Eng.*, *108*, 544–571.

Paul, F., A. Kääb, and W. Haeberli (2007a), Recent glacier changes in the Alps observed by satellite: Consequences for future monitoring strategies, *Global Planet. Change*, *56*(1–2), 111–122, doi:10.1016/j.gloplacha.2006.07.007.

Paul, F., M. Maisch, C. Rothenbühler, M. Hoelzle, and W. Haeberli (2007b), Calculation and visualisation of future glacier extent in the Swiss Alps by means of hypsographic modelling, *Global Planet. Change*, *55*(4), 343–357, doi:10.1016/j.gloplacha.2006.08.003.

Peckham, S. D., E. W. H. Hutton, and B. Norris (2013), A component-based approach to integrated modeling in the geosciences: The design of CSDMS, *Comput. Geosci.*, *53*, 3–12, doi:10.1016/j.cageo.2012.04.002.

Pelletier, J. D. (2006), Sensitivity of playa windblown-dust emissions to climatic and anthropogenic change, *J. Arid Environ.*, *66*, 62–75, doi:10.1016/j.jaridenv.2005.10.010.

Pelletier, J. D. (2012), A spatially-distributed model for the long-term suspended sediment discharge and delivery ratio of drainage basins, *J. Geophys. Res. Earth Surf.*, *117*, F02028, doi:10.1029/2011JF002129.

Pelletier, J. D. (2014), The linkage between hillslope vegetation changes, elevation, and late-Quaternary fluvial-system aggradation in the Mojave Desert revisited, *Earth Surf. Dyn.*, *2*, 535–574, doi:10.5194/esurf-2-455-2014.

Pelletier, J. D., H. Mitasova, R. S. Harmon, and M. Overton (2009), The effects of interdune vegetation changes on eolian dune field evolution: A numerical-modeling case study at Jockey's Ridge, North Carolina, USA, *Earth Surf. Processes Landforms*, *34*, 1245–1254, doi:10.1002/esp.1809.

Pelletier, J. D., J. Quade, R. J. Goble, and M. S. Aldenderfer (2011), Widespread hillslope gullying on the southeastern Tibetan Plateau: Human or climate-change induced?, *Geol. Soc. Am. Bull.*, *123*, 1926–1938, doi:10.1130/B30266.1.

Pelletier, J. D., S. B. DeLong, C. A. Orem, P. Becerra, K. Compton, K. Gressett, J. Lyons-Baral, L. A. McGuire, J. Molaro, and J. Spinler (2012), How do vegetation bands form in drylands? Insights from numerical modeling and field studies in southern Nevada, U.S.A., *J. Geophys. Res. Earth Surf.*, *117*, F04026, doi:10.1029/2012JF002465.

Pendergrass, A. G., and D. L. Hartmann (2014a), The atmospheric energy constraint on global-mean precipitation change, *J. Clim.*, *27*(2), 757–768, doi:10.1175/JCLI-D-13-00163.1.

Pendergrass, A. G., and D. L. Hartmann (2014b), Changes in the distribution of rain frequency and intensity in response to global warming, *J. Clim.*, *27*, 8372–8383, doi:10.1175/JCLI-D-14-00183.1.

Pierce, J. L., G. A. Meyer, and A. J. T. Jull (2004), Fire-induced erosion and millennial-scale climate change in northern ponderosa pine forests, *Nature*, *432*(7013), 87–90, doi:10.1038/nature03058.

Pinter, N. (2005), One step forward, two steps back on US floodplains, *Science*, *308*(5719), 207–208, doi:10.1126/science.1108411.

Plug, L. J., and J. J. West (2009), Thaw lake expansion in a two-dimensional coupled model of heat transfer, thaw subsidence, and mass movement, *J. Geophys. Res. Earth Surf.*, *114*, F01002, doi:10.1029/2006JF000740.

Pluis, J. L. A. (1992), Relationships between deflation and near surface wind velocity in a coastal dune blowout, *Earth Surf. Processes Landforms*, *17*, 663–673, doi:10.1002/esp.3290170703.

Plummer, M. A., and F. M. Phillips (2003), A 2-D numerical model of snow/ice energy balance and ice flow for paleoclimatic interpretation of glacial geomorphic features, *Quat. Sci. Rev.*, *22*(14), 1389–1406, doi:10.1016/s0277-3791(03)00081-7.

Polzin, M. L., and S. B. Rood (2000), Effects of damming and flow stabilization on riparian processes and black cottonwoods along the Kootenay River, *Rivers*, *7*, 221–232.

Pope, C. A., J. Schwartz, and M. R. Ransom (1992), Daily mortality and PM10 pollution in Utah Valley, *Arch. Environ. Health*, *47*, 211–217, doi:10.1080/00039896.1992.9938351.

Preisler, H. K., and A. L. Westerling (2007), Statistical model for forecasting monthly large wildfire events in Western United States, *J. Appl. Meteorol. Climatol.*, *46*, 1020–1030, doi:10.1175/JAM2513.1.

Prigent, C., F. Papa, F. Aires, W. B. Rossow, and E. Matthews (2007), Global inundation dynamics inferred from multiple satellite observations, 1993–2000, *J. Geophys. Res.*, *112*, D12107, doi:10.1029/2006JD007847.

Prospero, J. M., P. Ginoux, O. Torres, S. E. Nicholson, and T. E. Gill (2002), Environmental characterization of global sources of atmospheric soil dust identified with the NIMBUS 7 Total ozone mapping spectrometer (TOMS) absorbing aerosol product, *Rev. Geophys.*, *40*(1), 2-1–2-31, doi:10.1029/2000RG000095.

Prowse, T. D., and S. Beltaos (2002), Climatic control of river-ice hydrology: A review, *Hydrol. Processes*, *16*, 805–822, doi:10.1002/hyp.369.

Psuty, N. P. (1993), Foredune morphology and sediment budget, in *The Dynamics and Environmental Context of Aeolian Sedimentary System*, edited by K. Pye , pp. 145–157 , Geological Society, London.

Pye, K. and A. Neal (1993), Late Holocene dune formation on the Sefton Coast, Northwest England, *Dynamics and Environmental Context of Aeolian Sedimentary Systems*, *72*(1), 201–217, Geological Society of London Special Publications, Bath, U. K., doi:10.1144/GSL.SP.1993.072.01.17.

Quincey, D. J., S. D. Richardson, A. Luckman, R. M. Lucas, J. M. Reynolds, M. J. Hambrey, and N. F. Glasser (2007), Early recognition of glacial lake hazards in the Himalaya using remote sensing datasets, *Global Planet. Change*, *56*, 137–152, doi:10.1016/j.gloplacha.2006.07.013.

Rabatel, A., P. Deline, S. Jaillet, and L. Ravanel (2008), Rock falls in high-alpine rock walls quantified by terrestrial lidar measurements: A case study in the Mont Blanc area, *Geophys. Res. Lett.*, *35*, L10502, doi:10.1029/2008GL033424.

Rachold, V., F. E. Are, D. E. Atkinson, G. Cherkashov, and S. M. Solomon (2005), Arctic coastal dynamics (ACD): An introduction, *Geo Mar. Lett.*, *25*(2), 63–68, doi:10.1007/s00367-004-0187-9.

Rahmstorf, S. (2007), A semi-empirical approach to projecting future sea-level rise, *Science*, *315*(5810), 368–370, doi:10.1126/science.1135456.

Raj, B. K. G., W. K. Kumar, and S. N. Remya (2013), Remote sensing-based inventory of glacial lakes in Sikkim Himalaya: Semi-automated approach using satellite data: Geomatics, *Nat. Hazards Risks*, *4*, 241–253, doi:10.1080/19475705.2012.707153.

Ranasinghe, R., R. McLoughlin, and A. D. Short (2004), The Southern Oscillation Index, wave climate, and beach rotation, *Mar. Geol.*, *204*, 273–287, doi:10.1016/S0025-3227(04)00002-7.

Randriamazaoro, R., L. Dupeyrat, F. Costard, and E. C. Gailhardis (2007), Fluvial thermal erosion: Heat balance integral method, *Earth Surf. Processes Landforms*, *32*, 1828–1840, doi:10.1002/esp.1489.

Raup, B., A. Racoviteanu, S. J. S. Khalsa, C. Helm, R. Armstrong, and Y. Arnaud (2007), The GLIMS geospatial glacier database: A new tool for studying glacier change, *Global Planet. Change*, *56*, 101–110, doi:10.1016/j.gloplacha.2006.07.018.

Ravi, S., D. D. Breshears, T. E. Huxman, and P. D'Odorico (2010), Land degradation in drylands: Interactions among hydrologic-aeolian erosion and vegetation dynamics, *Geomorphology*, *116*(3–4), 236–245, doi:10.1016/j.geomorph.2009.11.023.

Ravi, S., et al. (2011), Aeolian processes and the biosphere, *Rev. Geophys.*, *49*, RG3001, doi:10.1029/2010RG000328.

Reddy, K. R., E. M. D'Angelo, and W. G. Harris (2000), Biogeochemistry of wetlands, in *Handbook of Soil Science*, edited by M. E. Sumner, pp. G89–G119 , CRC Press.

Rees, W. G., and N. S. Arnold (2007), Mass balance and dynamics of a valley glacier measured by high-resolution LiDAR, *Polar Record*, *43*(4), 311–319, doi:10.1017/S0032247407006419.

Refsnider, K. A., B. J. C. Laabs, M. A. Plummer, D. M. Mickelson, B. Singer, and M. W. Caffee (2008), Last glacial maximum climate inferences from cosmogenic dating and glacier modeling of the western Uinta ice field, Uinta Mountains, Utah, *Quat. Res.*, *69*(1), 130–144, doi:10.1016/j.yqres.2007.10.014.

Regnier, P., et al. (2013), Anthropogenic perturbation of the carbon fluxes from land to ocean, *Nat. Geosci.*, *6*(8), 597–607, doi:10.1038/ngeo1830.

Reitz, M. D., D. J. Jerolmack, R. C. Ewing, and R. L. Martin (2010), Barchan-parabolic dune pattern transition from vegetation stability threshold, *Geophys. Res. Lett.*, *37*, L19402, doi:10.1029/2010GL044957.

Reynolds, R. L., J. C. Yount, M. Reheis, H. Goldstein, P. Chavez, R. Fulton, J. Whitney, C. Fuller, and R. M. Forester (2007), Dust emission from wet and dry playas in the Mojave Desert, USA, *Earth Surf. Processes Landforms*, *32*, 1811–1827, doi:10.1002/esp.1515.

Richey, J. E., J. I. Hedges, A. H. Devol, P. D. Quay, R. Victoria, L. Martinelli, and B. R. Forsberg (1990), Biogeochemistry of carbon in the Amazon River, *Limnol. Oceanogr.*, *35*(2), 352–371.

Riggs, S. R., et al. (1995), Influence of inherited geological framework on barrier shoreface morphology and dynamics, *Mar. Geol.*, *126*, 213–234, doi:10.1016/0025-3227(95)00079-E.

Rinaldo, A., W. E. Dietrich, G. Vogel, R. Rigon, and I. Rodriguez-Iturbe (1995), Geomorphological signatures of varying climate, *Nature*, *374*, 632–636, doi:10.1038/374632a0.

Rinaldo, A., I. Rodriguez-Iturbe, and R. Rigon (1998), Channel networks, *Annu. Rev. Earth Planet. Sci.*, *26*(1), 289–327, doi:10.1146/annurev.earth.26.1.289.

Riordan, B., D. Verbyla, and A. D. McGuire (2006), Shrinking ponds in subarctic Alaska based on 1950–2002 remotely sensed images, *J. Geophys. Res.*, *111*, G04002, doi:10.1029/2005JG000150.

Ritter, D. F., R. C. Kochel, and J. R. Miller (1999), The disruption of Grassy Creek: Implications concerning catastrophic events and thresholds, *Geomorphology*, *29*(3–4), 323–338, doi:10.1016/S0169-555X(99)00022-7.

Roach, J. K., B. Griffith, D. Verbyla, and J. Jones (2011), Mechanisms influencing changes in lake area in Alaskan boreal forest, *Global Change Biol.*, *17*, 2567–2583, doi:10.1111/j.1365-2486.2011.02446.x.

Roach, J. K., B. Griffith, and D. Verbyla (2013), Landscape influences on climate-related lake shrinkage at high latitudes, *Global Change Biol.*, *19*, 2276–2284, doi:10.1111/gcb.12196.

Roberson, S. (2008), Structural composition and sediment transfer in a composite cirque glacier: Glacier de St. Sorlin, France, *Earth Surf. Processes Landforms*, *33*, 1931–1947, doi:10.1002/esp.1635.

Rose, S., and N. E. Peters (2001), Effects of urbanization on streamflow in the Atlanta area (Georgia, USA): A comparative hydrological approach, *Hydrol. Processes*, *15*(8), 1441–1457, doi:10.1002/hyp.218.

Rotschky, G., O. Eisen, F. Wilhelms, U. Nixdorf, and H. Oerter (2004), Spatial distribution of surface mass balance on Amundsenisen plateau, Antarctica, derived from ice-penetrating radar studies, *Ann. Glaciol.*, *39*, 265–270, doi:10.3189/172756404781814618.

Rover, J., L. Ji, B. K. Wylie, and L. L. Tieszen (2012), Establishing water body areal extent trends in interior Alaska from multi-temporal Landsat data, *Remote Sens. Lett.*, *3*(7), 595–604, doi:10.1080/01431161.2011.643507.

Rowland, J. C., B. J. Travis, and C. J. Wilson (2011), The role of advective heat transport in talik development beneath lakes and ponds in discontinuous permafrost, *Geophys. Res. Lett.*, *38*, L17504, doi:10.1029/2011GL048497.

Roy, D. P., J. Ju, K. Kline, P. L. Scaramuzza, V. Kovalskyy, M. C. Hansen, T. R. Loveland, E. F. Vermote, and C. Zhang (2010), Web-enabled landsat data (WELD): Landsat ETM+ composited mosaics of the conterminous United States, *Remote Sens. Environ.*, *114*, 35–49.

Royer, P. D., D. D. Breshears, C. B. Zou, N. S. Cobb, and S. A. Kurc (2010), Ecohydrological energy inputs in semiarid coniferous gradients: Responses to management- and drought-induced tree reductions, *Forest Ecol. Manage.*, *260*, 1646–1655, doi:10.1016/j.foreco.2010.07.036.

Ruggiero, P. (2013), Is the intensifying wave climate of the U.S. Pacific Northwest increasing flooding and erosion risk faster than sea level rise?, *J. Waterw. Port. Coastal Am. Soc. Civil Eng.*, *139*(2), 88–97, doi:10.1061/(ASCE)WW.1943-5460.0000172.

Ruggiero, P., P. D. Komar, and J. C. Allan (2010a), Increasing wave heights and extreme-value projections: The wave climate of the U.S. Pacific Northwest, *Coastal Eng.*, *57*, 539–552, doi:10.1016/j.coastaleng.2009.12.005.

Ruggiero, P., M. C. Buijsman, G. Kaminsky, and G. Gelfenbaum (2010b), Modeling the effect of wave climate and sediment supply variability on large-scale shoreline change, *Mar. Geol.*, *273*, 127–140, doi:10.1016/j.margeo.2010.02.008.

Ruggiero, P., J. Mull, P. Zarnetske, S. Hacker, and E. Seabloom (2011), Interannual to decadal foredune evolution, in *Proceedings of Coastal Sediments 2011*, *3*, 698–711, World Scientific, Hackensack, N. J.

Rupper, S., and G. Roe (2008), Glacier changes and regional climate: A mass and energy balance approach, *J. Clim.*, *21*(20), 5384–5401, doi:10.1175/2008JCLI2219.1.

Sallenger, A. H., Jr. (2000), Storm impact scale for barrier islands, *J. Coastal Res.*, *16*, 890–895.

Salzmann, N., A. Kääb, C. Huggel, B. Allgöwer, and W. Haeberli (2004), Assessment of the hazard potential of ice avalanches using remote sensing and GIS-modelling, *Nor. Geogr. Tidsskr.*, *58*, 74–84, doi:10.1080/00291950410006805.

Salzmann, N., C. Frei, P. L. Vidale, and M. Hoelzle (2007), The application of Regional Climate Model output for the simulation of high-mountain permafrost scenarios, *Global Planet. Change*, *56*(1–2), 188–202, doi:10.1016/j.gloplacha.2006.07.006.

Scanlon, B. R., K. E. Keese, A. L. Flint, L. E. Flint, C. B. Gaye, W. M. Edmunds, and I. Simmers (2006), Global synthesis of groundwater recharge in arid and semiarid regions, *Hydrol. Processes*, *20*, 3335–3370, doi:10.1002/hyp.6335.

Schaefer, M., H. Machguth, M. Falvey, and G. Casassa (2013), Modeling past and future surface mass balance of the Northern Patagonia Icefield, *J. Geophys. Res. Earth Surf.*, *118*, 571–588, doi:10.1002/JGRF.20038.

Schaub, Y., W. Haeberli, C. Huggel, M. Künzler, and M. Bründl (2013), Landslides and new lakes in deglaciating areas: A risk management framework, in *Landslide Science and Practice*, edited by C. Margottini, P. Canuti, and K. Sassa , pp. 31–38 , Springer, Berlin.

Scherler, D., S. Leprince, and M. Strecker (2008), Glacier-surface velocities in alpine terrain from optical satellite imagery—Accuracy improvement and quality assessment, *Remote Sens. Environ.*, *112*, 3806–3819, doi:10.1016/j.rse.2008.05.018.

Scherler, D., B. Bookhagen, and M. R. Strecker (2011), Spatially variable response of Himalayan glaciers to climate change affected by debris cover, *Nat. Geosci.*, *4*(3), 156–159, doi:10.1038/ngeo1068.

Schomacker, A. (2010), Expansion of ice-marginal lakes at the Vatnajökull ice cap, Iceland, from 1999 to 2009, *Geomorphology*, *119*, 232–236, doi:10.1016/j.geomorph.2010.03.022.

Schoorl, J. M., M. P. W. Sonneveld, and A. Veldkamp (2000), Three-dimensional landscape process modelling: The effect of DEM resolution, *Earth Surf. Processes Landforms*, *25*(9), 1025–1034, doi:10.1002/1096-9837(200008)25:9<1025::AID-ESP116>3.0.CO;2-Z.

Schoorl, J. M., A. Veldkamp, and J. Bouma (2002), Modeling water and soil redistribution in a dynamic landscape context, *Soil Sci. Soc. Am. J.*, *66*(5), 1610, doi:10.2136/sssaj2002.1610.

Schoorl, J. M., C. Boix Fayos, R. J. de Meijer, E. R. van der Graaf, and A. Veldkamp (2004), The 137Cs technique applied to steep Mediterranean slopes (part II): Landscape evolution and model calibration, *Catena*, *57*(1), 35–54, doi:10.1016/j.catena.2003.08.002.

Schumm, S. (1979), Geomorphic thresholds: The concept and its applications, *Trans. Inst. Br. Geogr.*, *4*(4), 485–515.

Schumm, S. A., and R. S. Parker (1973), Implications of complex response of drainage systems for Quaternary alluvial stratigraphy, *Nature*, *243*, 99–100, doi:10.1038/physci243099a0.

Schumm, S. A. (1969), River metamorphosis, *J. Hydraul. Div. Am. Soc. Civ. Eng.*, *95*(HY1), 255–273.

Schupp, C. A., J. E. McNinch, and J. H. List (2006), Nearshore shore-oblique bars, gravel outcrops and their correlation to shoreline change, *Mar. Geol.*, *233*, 63–79, doi:10.1016/j.margeo.2006.08.007.

Schwarz, M., P. Lehmann, and D. Or (2010), Quantifying lateral root reinforcement in steep slopes – From a bundle of roots to tree stands, *Earth Surf. Processes Landforms*, *35*, 354–367, doi:10.1002/esp.1927.

Seabloom, E., P. Ruggiero, S. Hacker, J. Mull, and P. Zarnetske (2013), Invasive grasses, climate change, and flood risk in coastal ecosystems, *Global Change Biol.*, *19*, 824–832, doi:10.1111/gcb.12078.

Selby, M. J. (1992), *Hillslope Materials and Processes*, 2nd ed. , pp. , Oxford Univ. Press, Oxford, U. K, 451 p.

Seymour, R. J. (2011), Evidence for changes to the northeast Pacific wave climate, *J. Coastal Res.*, *27*(1), 194–201, doi:10.2112/JCOASTRES-D-09-00149.1.

Shepherd, A., et al. (2012), A reconciled estimate of ice-sheet mass balance, *Science*, *338*, 1183–1189, doi:10.1126/science.1228102.

Sherman, D. J., B. Li, J. T. Ellis, E. J. Farrell, L. P. Maia, and H. Granja (2013), Recalibrating aeolian sand transport models, *Earth Surf. Processes Landforms*, *38*(2), 169–178, doi:10.1002/esp.3310.

Shields, A. (1936), Arwendung der Aenlich-keits-mechanik and der Turbulenz-forschung auf die Geshienbebewegung. Versuch-sanstalt fur Wasserbau and Schiffsbau, Berlin, Heft 26, p. 26, Mitteilungen der Preussischen.

Short, A., and P. Hesp (1982), Wave, beach and dune interactions in Southeastern Australia, *Mar. Geol.*, *48*, 259–284, doi:10.1016/0025-3227(82)90100-1.

Shroder, J. F. (2013), *Treatise on Geomorphology*, Elsevier Academic Press, San Diego, Calif.

Sklar, L. S., and W. E. Dietrich (2001), Sediment and rock strength controls on river incision into bedrock, *Geology*, *29*(12), 1087–1090, doi:10.1130/0091-7613(2001)029<1087:SARSCO>2.0.CO;2.

Sklar, L. S., and W. E. Dietrich (2004), A mechanistic model for river incision into bedrock by saltating bed load, *Water Resour. Res.*, *40*(6), W06301, doi:10.1029/2003WR002496.

Slater, A. G., and D. M. Lawrence (2013), Diagnosing present and future permafrost from climate models, *J. Clim.*, *26*, 5608–5623, doi:10.1175/JCLI-D-12-00341.1.

Slingerland, R., and N. D. Smith (1998), Necessary conditions for a meandering-river avulsion, *Geology*, *26*(5), 435–438, doi:10.1130/0091-7613(1998)026<0435:NCFAMR>2.3.CO;2.

Slott, J. M., A. B. Murray, A. D. Ashton, and T. J. Crowley (2006), Coastline responses to changing storm patterns, *Geophys. Res. Lett.*, *33*, L18404, doi:10.1029/2006GL027445.

Smith, L. C., Y. Sheng, G. M. MacDonald, and L. D. Hinzman (2005), Disappearing Arctic lakes, *Science*, *308*(5727), 1429, doi:10.1126/science.1108142.

Stallins, J. A., and A. J. Parker (2003), The influence of complex systems interactions on barrier island dune vegetation pattern and process, *Ann. Assoc. Am. Geogr.*, *93*, 13–29, doi:10.1111/1467-8306.93102.

Stendel, M., V. E. Romanovsky, J. H. Christensen, and T. Sazonova (2007), Using dynamical downscaling to close the gap between global change scenarios and local permafrost dynamics, *Global Planet. Change*, *56*, 203–214, doi:10.1016/j.gloplacha.2006.07.014.

Stevenson, S. L. (2012), Significant changes to ENSO strength and impacts in the twenty-first century: Results from CMIP5, *Geophys. Res. Lett.*, *39*, L17703, doi:10.1029/2012GL052759.

Stockdon, H. F., A. H. Sallenger, R. A. Holman, and P. A. Howd (2007), A simple model for the spatially-variable coastal response to hurricanes, *Mar. Geol.*, *238*, 1–20, doi:10.1016/j.margeo.2006.11.004.

Stoffel, M., and C. Huggel (2012), Effects of climate change on mass movements in mountain environments, *Prog. Phys. Geogr.*, *36*, 421–439, doi:10.1177/0309133312441010.

Stoffel, M., I. Lièvre, D. Conus, M. A. Grichting, H. Raetzo, H. W. Gärtner, and M. Monbaron (2005), 400 years of debris-flowactivity and triggering weather conditions: Ritigraben, Valais, Switzerland, *Arct. Antarct. Alp. Res.*, *37*(3), 387–395, doi:10.1657/1523-0430(2005)037[0387:YODAAT]2.0.CO;2.

Stoffel, M., M. Bollschweiler, and M. Beniston (2011), Rainfall characteristics for periglacial debris flows in the Swiss Alps: Past incidences and potential future evolutions, *Clim. Change*, *105*(1–2), 263–280, doi:10.1007/s10584-011-0036-6.

Stone, G. W., B. Liu, D. A. Pepper, and P. Wang (2004), The importance of extratropical and tropical cyclones on the short-term evolution of barrier islands along the northern Gulf of Mexico, USA, *Mar. Geol.*, *210*, 63–78, doi:10.1016/j.margeo.2004.05.021.

Storms, J. E. A., G. J. Weltje, J. J. van Dijke, C. R. Geel, and S. B. Kroonenberg (2002), Process-response modeling of wave-dominated coastal systems: Simulating evolution and stratigraphy on geological timescales, *J. Sediment. Res.*, *7*, 226–239, doi:10.1306/052501720226.

Strogatz, S. H. (2001), *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering*, Westview Press, New York, 512 p.

Stutz, M. L., and O. H. Pilkey (2011), Open-ocean barrier islands: Global influence of climatic, oceanographic, and depositional settings, *J. Coastal Res.*, *27*, 207–222, doi:10.2112/09-1190.1.

Sunamura, T. (1976), Feedback relationship in wave erosion of laboratory rocky coast, *J. Geol.*, *84*, 427–437, doi:10.1086/628209.

Sunamura, T. (1982), A wave tank experiment on the erosional mechanism at a cliff base, *Earth Surf. Processes Landforms*, *7*, 333–343, doi:10.1002/esp.3290070405.

Surian, N., and M. Rinaldi (2003), Morphological response to river engineering and management in alluvial channels in Italy, *Geomorphology*, *50*(4), 307–326, doi:10.1016/S0169-555X(02)00219-2.

Sweeney, M. R., E. V. McDonald, and C. E. Markley (2013), Alluvial sediment or playas: What is the dominant source of sand and silt in desert soil Av horizons, southwest USA, *J. Geophys. Res. Earth Surf.*, *118*, 257–275, doi:10.1002/JGRF.20030.

Syvitski, J. P. M. (2002), Sediment discharge variability in Arctic rivers: Implications for a warmer future, *Polar Res.*, *21*(2), 323–330, doi:10.1111/j.1751-8369.2002.tb00087.x.

Syvitski, J. P. M., and J. D. Milliman (2007), Geology, geography, and humans battle for dominance over the delivery of fluvial sediment to the coastal ocean, *J. Geol.*, *115*, 1–19, doi:10.1086/509246.

Syvitski, J. P. M., S. D. Peckham, R. Hilberman, and T. Mulder (2003), Predicting the terrestrial flux of sediment to the global ocean: A planetary perspective, *Sed. Geol.*, *162*, 5–24, doi:10.1016/S0037-0738(03)00232-X.

Syvitski, J. P. M., C. J. Vörösmarty, A. J. Kettner, and P. Green (2005), Impact of humans on the flux of terrestrial sediment to the global coastal ocean, *Science*, *308*(5720), 376–380, doi:10.1126/science.1109454.

Tal, M., and C. Paola (2007), Dynamic single-thread channels maintained by the interaction of flow and vegetation, *Geology*, *35*(4), 347–350, doi:10.1130/G23260A.1.

Tal, M., and C. Paola (2010), Effects of vegetation on channel morphodynamics: Results and insights from laboratory experiments, *Earth Surf. Processes Landforms*, *35*(9), 1014–1028, doi:10.1002/esp.1908.

Tal, M., Gran, K., Murray, A. B., Paola, C. and Hicks, D. M. (2004) Riparian vegetation as a primary control on channel characteristics in multi-thread rivers, in *Riparian Vegetation and Fluvial Geomorphology* (eds S. J. Bennett and A. Simon), American Geophysical Union, Washington, D. C. doi: 10.1029/008WSA04

Tegen, I., M. Werner, S. P. Harrison, and K. E. Kohfeld (2004), Relative importance of climate and land use in determining present and future global soil dust emission, *Geophys. Res. Lett.*, *31*, L05105, doi:10.1029/2003GL019216.

Temme, A. J. A. M., J. E. M. Baartman, and J. M. Schoorl (2009), Can uncertain landscape evolution models discriminate between landscape responses to stable and changing future climate? A millennial-scale test, *Global Planet. Change*, *69*(1–2), 48–58, doi:10.1016/j.gloplacha.2009.08.001.

Temme, A. J. A. M., L. Claessens, A. Veldkamp, and J. M. Schoorl (2011), Evaluating choices in multi-process landscape evolution models, *Geomorphology*, *125*(2), 271–281, doi:10.1016/j.geomorph.2010.10.007.

Temmerman, S., T. J. Bouma, J. Van de Koppel, D. Van der Wal, M. B. De Vries, and P. M. J. Herman (2007), Vegetation causes channel erosion in a tidal landscape, *Geology*, *35*, 631–635, doi:10.1130/G23502A.1.

Tennant, C. J., B. T. Crosby, and S. E. Godsey (2014), Elevation-dependent responses of streamflow to climate warming, *Hydrol. Processes*, *29*, 991–1001, doi:10.1002/hyp.10203.

Thieler, E. R., and R. S. Young (1991), Quantitative evaluation of coastal geomorphological changes in South Carolina after Hurricane Hugo, *J. Coastal Res.*, *8*, 187–200.

Thomas, D. S. G., M. Knight, and G. F. S. Wiggs (2005), Remobilization of southern African desert dune systems by twenty-first century global warming, *Nature*, *435*, 1218–1221, doi:10.1038/nature03717.

Thonon, I., K. de Jong, M. van der Perk, and H. Middelkoop (2007), Modelling floodplain sedimentation using particle tracking, *Hydrol. Processes*, *21*, 1402–1412, doi:10.1002/hyp.6296.

Timmons, E. A., A. B. Rodriguez, C. R. Mattheus, and R. DeWitt (2010), Transition of a regressive to a transgressive barrier island due to back-barrier erosion, increased storminess, and low sediment supply: Bogue Banks, North Carolina, USA, *Mar. Geol.*, *278*, 100–114, doi:10.1016/j.margeo.2010.09.006.

Tockner, K., and J. A. Stanford (2002), Riverine flood plains: Present state and future trends, *Environ. Conserv.*, 308–330, doi:10.1017/S037689290200022X.

Tol, R. S. J. (2002), Estimates of the damage costs of climate change. Part 1. Benchmark estimates, *Environ. Resour. Econ.*, *21*, 47–73, doi:10.1.1.175.6038.

Tol, R. S. J. (2009), The economic effects of climate change, *J. Econ. Pers.*, *23*(2), 29–51, doi:10.1257/jep.23.2.29.

Topping, D., J. C. Schmidt, and L. E. Vierra Jr. (2003), Computation and analysis of the instantaneous-discharge record for the Colorado River at Lees Ferry, Arizona, May 8, 1921, through September 30, 2000, *U.S. Geol. Surv. Prof. Pap. 1677*, U.S. Geological Survey, Reston, Va.

Tormey, D. (2010), Managing the effects of accelerated glacial melting on volcanic collapse and debris flows: Planchon and Peteroa Volcano, Southern Andes, *Global Planet. Change*, *74*(2), 82–90, doi:10.1016/j.gloplacha.2010.08.003.

Tucker, G. E., and G. R. Hancock (2010), Modelling landscape evolution, *Earth Surf. Processes Landforms*, *35*(1), 28–50, doi:10.1002/esp.1952.

Tucker, G. E., and R. Slingerland (1997), Drainage basin responses to climate change, *Water Resour. Res.*, *33*(8), 2031–2047, doi:10.1029/97WR00409.

Tweed, F. S. (2000), Jökulhlaup initiation by ice-dam flotation: The significance of glacier debris content, *Earth Surf. Processes Landforms*, *25*, 105–108, doi:10.1002/(SICI)1096-9837(200001)25:1<105::AID-ESP73>3.0.CO;2-B.

van Huissteden, J., C. Berrittella, F. J. W. Parmentier, Y. Mi, T. C. Maximov, and A. J. Dolman (2011), Methane emissions from permafrost thaw lakes limited by lake drainage, *Nat. Clim. Change*, *1*(2), 119–123, doi:10.1038/nclimate1101.

Van Rijn, L. C. (2007), Unified view of sediment transport by currents and waves. II: Suspended transport, *J. Hydraul. Eng.*, *133*(6), 668–689, doi:10.1061/(ASCE)0733-9429(2007)133:6(668).

Vandenberghe, J. (2002), The relation between climate and river processes, landforms and deposits during the quaternary, *Quat. Int.*, *91*(1), 17–23, doi:10.1016/S1040-6182(01)00098-2.

Vandenberghe, J., and M. K. Woo (2002), Modern and ancient periglacial river types, *Prog. Phys. Geogr.*, *26*(4), 479–506, doi:10.1191/0309133302pp349ra.

Verhaar, P. M., P. M. Biron, R. I. Ferguson, and T. B. Hoey (2010), Numerical modelling of climate change impacts on Saint-Lawrence River tributaries, *Earth Surf. Processes Landforms*, *35*(10), 1184–1198, doi:10.1002/esp.1953.

Viles, H. A., and A. S. Goudie (2003), Interannual, decadal and multi-decadal scale climatic variability and geomorphology, *Earth Sci. Rev.*, *61*, 105–131, doi:10.1016/S0012-8252(02)00113-7.

Vilímek, V., M. L. Zapata, J. Klimeš, Z. Patzelt, and N. Santillán (2005), Influence of glacial retreat on natural hazards of the Palcacocha Lake area, Peru, *Landslides*, *2*, 107–115, doi:10.1007/s10346-005-0052-6.

Vonk, J. E., B. E. van Dongen, and Ö. Gustafsson (2010), Selective preservation of old organic carbon fluvially released from sub-Arctic soils, *Geophys. Res. Lett.*, *37*, L11605, doi:10.1029/2010GL042909.

Walder, J. S., and B. Hallet (1986), The physical basis of frost weathering: Toward a more fundamental and unified perspective, *Arct. Alp. Res.*, *18*(1), 27–32, doi:10.2307/1551211.

Walkden, M. J. A., and J. W. Hall (2005), A predictive mesoscale model of the erosion and profile development of soft rock shores, *Coastal Eng.*, *52*, 535–563, doi:10.1016/j.coastaleng.2005.02.005.

Walter, R. C., and D. J. Merritts (2008), Natural streams and the legacy of water-powered mills, *Science*, *319*(5861), 299–304, doi:10.1126/science.1151716.

Wang, G., and E. A. B. Eltahir (2000), Role of vegetation dynamics in enhancing the low-frequency variability of the Sahal rainfall, *Water Resour. Res.*, *36*(4), 1013–1021, doi:10.1029/1999WR900361.

Wang, X. L., and V. R. Swail (2006), Climate change signal and uncertainty in projections of ocean wave heights, *Clim. Dyn.*, *26*, 109–126, doi:10.1007/s00382-005-0080-x.

Wang, X. L., F. W. Zwiers, and V. R. Swail (2004a), North Atlantic ocean wave climate change scenarios for the twenty-first century, *J. Clim.*, *17*, 2368–2383, doi:10.1175/1520-0442(2004)017<2368:NAOWCC>2.0.CO;2.

Wang, X., Z. Dong, J. Zhang, and L. Liu (2004b), Modern dust storms in China: An overview, *J. Arid Environ.*, *58*, 559–574, doi:10.1016/j.jaridenv.2003.11.009.

Wang, X., Y. Yang, Z. Dong, and C. Zhang (2009), Responses of dune activity and desertification in China to global warming in the twenty-first century, *Global Planet. Change*, *67*(3–4), 167–185, doi:10.1016/j.gloplacha.2009.02.004.

Ward, D. J., R. S. Anderson, Z. S. Guido, and J. P. Briner (2009), Numerical modeling of cosmogenic deglaciation records, Front Range and San Juan mountains, Colorado, *J. Geophys. Res. Earth Surf.*, *114*, F01026, doi:10.1029/2008JF001057.

Warren, A., A. Chappell, M. C. Todd, C. S. Bristow, N. A. Drake, S. Engelstaedter, V. Martins, S. M'Bainayel, and R. Washington (2007), Dust-raising in the dustiest place on earth, *Geomorphology*, *92*(1–2), 25–37, doi:10.1016/j.geomorph.2007.02.007.

Webster, P. J., G. J. Holland, J. A. Curry, and H. R. Chang (2005), Changes in tropical cyclone number, duration, and intensity in a warming environment, *Science*, *309*(5742), 1844–1846, doi:10.1126/science.1116448.

Wegmann, K., and F. Pazzaglia (2002), Holocene strath terraces, climate change, and active tectonics: The Clearwater River basin, Olympic Peninsula, Washington State, *Geol. Soc. Am. Bull.*, *114*, 731–744, doi:10.1130/0016-7606(2002)114<0731:HSTCCA>2.0.CO;2.

Wellman, T. P., C. I. Voss, and M. A. Walvoord (2013), Impacts of climate, lake size, and supra- and sub-permafrost groundwater flow on lake-talik evolution, Yukon Flats, Alaska (USA), *Hydrogeol. J.*, *21*(1), 281–298, doi:10.1007/s10040-012-0941-4.

Welsh, K. E., J. A. Dearing, R. C. Chiverrell, and T. J. Coulthard (2009), Testing a cellular modelling approach to simulating late-Holocene sediment and water transfer from catchment to lake in the French Alps since 1826, *Holocene*, *19*(5), 785–798, doi:10.1177/0959683609105303.

Werner, B. T., and D. E. McNamara (2007), Dynamics of coupled-human landscapes, *Geomorphology*, *91*(3–4), 393–407, doi:10.1016/j.geomorph.2007.04.020.

West, J. J., and L. J. Plug (2008), Time-dependent morphology of thaw lakes and taliks in deep and shallow ground ice, *J. Geophys. Res. Earth Surf.*, *113*, F01009, doi:10.1029/2006JF000696.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam (2006), Warming and earlier spring increase western U.S. forest wildfire activity, *Science*, *313*, 940–943, doi:10.1126/science.1128834.

Whipple, K. X. (2004), Bedrock rivers and the geomorphology of active orogens, *Annu. Rev. Earth Planet. Sci.*, *32*(1), 151–185, doi:10.1146/annurev.earth.32.101802.120356.

Whipple, K. X., G. S. Hancock, and R. S. Anderson (2000), River incision into bedrock: Mechanics and relative efficacy of plucking, abrasion, and cavitation, *Geol. Soc. Am. Bull.*, *112*(3), 490–503, doi:10.1130/0016-7606(2000)112<490:RIIBMA>2.0.CO;2.

White, D. M., S. C. Gerlach, P. Loring, A. C. Tidwell, and M. C. Chambers (2007a), Food and water security in a changing arctic climate, *Environ. Res. Lett.*, *2*(4), 045018, doi:10.1088/1748-9326/2/4/045018.

White, D., et al. (2007b), The arctic freshwater system: Changes and impacts, *J. Geophys. Res.*, *112*, G04S54, doi:10.1029/2006JG000353.

Whitlock, C., and P. J. Bartlein (1997), Vegetation and climate change in northwest America during the past 125 kyr, *Nature*, *388*, 57–61.

Wickert, A. D., J. M. Martin, M. Tal, W. Kim, B. Sheets, and C. Paola (2013), River channel lateral mobility: Metrics, time scales, and controls, *J. Geophys. Res. Earth Surf.*, *118*, 396–412, doi:10.1029/2012JF002386.

Wieczorek, G. F., and T. Glade (2005), Climatic factors influencing occurrence of debris flows, in *Debris-flow Hazards and Related Phenomena*, edited by M. Jakob and O. Hungr , pp. 325–362 , Springer, Berlin.

Wiggs, G. F. S., D. S. G. Thomas, J. E. Bullard, and I. Livingstone (1995), Dune mobility and vegetation cover in the Southwest Kalahari desert, *Earth Surf. Processes Landforms*, *20*(6), 515–529, doi:10.1002/esp.3290200604.

Wilcock, P. R., and J. C. Crowe (2003), Surface-based transport model for mixed-size sediment, *J. Hydraul. Eng.*, *129*(2), 120–128, doi:10.1061/(ASCE)0733-9429(2003)129:2(120).

Wilkinson, B., and B. McElroy (2007), The impact of humans on continental erosion and sedimentation, *Geol. Soc. Am. Bull.*, *119*(1/2), 140–156, doi:10.1130/B25899.1.

Williams, A. P., C. D. Allen, C. Millar, T. Swetnam, J. Michaelsen, C. J. Still, and S. W. Leavitt (2010), Forest responses to increasing aridity and warmth in southwestern North America, *Proc. Natl. Acad. Sci. U. S. A.*, *107*, 21,289–21,294.

Williams, A. P., et al. (2012), Temperature as a potent driver of regional forest drought stress and tree mortality, *Nat. Clim. Change*, *3*, 292–297, doi:10.1038/NCLIMATE1693.

Wilson, P., J. D. Orford, J. Knight, S. M. Braley, and A. G. Wintle (2001), Late-Holocene [post-4000yr BP] coastal dune development in Northumberland, northeast England, *Holocene*, *11*(2), 215–229, doi:10.1191/095968301667179797.

Wilson, P., J. McGourty, and M. Bateman (2004), Mid- to late-Holocene coastal dune event stratigraphy for the north coast of Northern Ireland, *Holocene*, *14*, 406–416, doi:10.1191/0959683604hl716rp.

Winkelmann, R., M. A. Martin, M. Haseloff, T. Albrecht, E. Bueler, C. Khroulev, and A. Levermann (2011), The Potsdam Parallel Ice Sheet Model (PISM-PIK) – Part 1: Model description, *Cryosphere*, *5*, 715–726, doi:10.5194/tc-5-715-2011.

Wischmeier, W. H., and D. D. Smith (1978), *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning, Agriculture Handbook No. 537*, pp. 58, USDA/Science and Education Administration, U.S. Govt. Printing Office, Washington, D. C.

Wisser, D., S. Frolking, S. Hagen, and M. F. P. Bierkens (2013), Beyond peak reservoir storage? A global estimate of declining water storage capacity in large reservoirs, *Water Resour. Res.*, *49*, 5732–5739, doi:10.1002/WRCR.20452.

Wolfe, S. A., and C. H. Hugenholtz (2009), Barchan dunes stabilized under recent climate warming on the northern Great Plains, *Geology*, *37*(11), 1039–1042, doi:10.1130/G30334A.1.

Wolfe, S. A., and W. G. Nickling (1996), Shear stress partitioning in sparsely vegetated desert canopies, *Earth Surf. Processes Landforms*, *21*(7), 607–619, doi:10.1002/(SICI)1096-9837(199607)21:7<607::AID-ESP660>3.0.CO;2–1.

Wolinsky, M. A., and A. B. Murray (2009), A unifying framework for shoreline migration: 2. Application to wave-dominated coasts, *J. Geophys. Res. Earth Surf.*, *114*, F01009, doi:10.1029/2007JF000856.

Wolner, C. V., L. J. Moore, D. R. Young, S. T. Brantley, S. N. Bissett, and R. A. McBride (2013), Ecomorphodynamic feedbacks and barrier island response to disturbance: Insights from the Virginia Barrier Islands, Mid-Atlantic Bight, USA, *Geomorphology*, *199*, 115–128, doi:10.1016/j.geomorph.2013.03.035.

Woo, M. K. (2012), Rivers in cold regions, in *Permafrost Hydrology* , pp. 407–454 , Springer, Berlin, Heidelberg.

Wright, L. D., J. Chappell, B. G. Thom, M. P. Bradshaw, and P. Cowell (1979), Morphodynamics of reflective and dissipative beach and inshore systems: Southeastern Australia, *Mar. Geol.*, *32*, 105–140, doi:10.1016/0025-3227(79)90149-X.

Wunsch, C., R. M. Ponte, and P. Heimbach (2007), Decadal trends in sea level patterns: 1993–2004, *J. Clim.*, *20*(24), 5889–5911, doi:10.1175/2007JCLI1840.1.

Yager, E. M., W. E. Dietrich, J. W. Kirchner, and B. W. McArdell (2012), Predictions of sediment transport in step-pool channels, *Water Resour. Res.*, *48*, W01541, doi:10.1029/2011WR010829.

Yager, E. M., and M. W. Schmeeckle (2013), The influence of vegetation on turbulence and bedload transport, *J. Geophys. Res. Earth Surf.*, *118*, 1585–1601, doi:10.1002/JGRF.20085.

Yamazaki, D., S. Kanae, H. Kim, and T. Oki (2011), A physically based description of floodplain inundation dynamics in a global river routing model, *Water Resour. Res.*, *47*, W04501, doi:10.1029/2010WR009726.

Yanites, B. J., and T. A. Ehlers (2012), Global climate and tectonic controls on the denudation of glaciated mountains, *Earth Planet. Sci. Lett.*, *325–326*, 63–75, doi:10.1016/j.epsl.2012.01.030.

Yin, J., S. M. Griffies, and R. J. Stouffer (2010), Spatial variability of sea level rise in twenty-first century projections, *J. Clim.*, *23*(17), 4585–4607, doi:10.1175/2010JCLI3533.1.

Yizhaq, H., Y. Askenazy, and H. Tsoar (2007), Why do active and stabilized dunes coexist under the same climatic conditions, *Phys. Rev. Lett.*, *98*, 188001, doi:10.1103/PhysRevLett.98.188001.

Yizhaq, H., Y. Ashkenazy, and H. Tsoar (2009), Sand dune dynamics and climate change: A modeling approach, *J. Geophys. Res. Earth Surf.*, *114*, F01023, doi:10.1029/2008JF001138.

Yoshikawa, K., and L. D. Hinzman (2003), Shrinking thermokarst ponds and groundwater dynamics in discontinuous permafrost near council, Alaska, *Permafrost Periglac. Processes*, *14*, 151–160, doi:10.1002/ppp.451.

Young, I. R., S. Zieger, and A. V. Babanin (2011), Global trends in wind speed and wave height, *Science*, *332*, 451–455, doi:10.1126/science.1197.

Zaitchik, B. F., M. Rodell, and F. Olivera (2010), Evaluation of the global land data assimilation system using global river discharge data and a source-to-sink routing scheme, *Water Resour. Res.*, *46*, W06507, doi:10.1029/2009WR007811.

Zarnetske, P. L., S. D. Hacker, E. W. Seabloom, P. Ruggiero, J. R. Killian, T. B. Maddux, and D. Cox (2012), Biophysical feedback mediates effects of invasive grasses on coastal dune shape, *Ecology*, *93*(6), 1439–1450, doi:10.1890/11-1112.1.

Zemp, M., M. Hoelzle, and W. Haeberli (2007), Distributed modelling of the regional climatic equilibrium line altitude of glaciers in the European Alps, *Global Planet. Change*, *56*, 83–100, doi:10.1016/j.gloplacha.2006.07.002.

Zender, C. S., and E. Y. Kwon (2005), Regional contrasts in dust emission responses to climate, *J. Geophys. Res.*, *110*, D13201, doi:10.1029/2004JD005501.

Zender, C. S., H. Bian, and D. Newman (2003), Mineral Dust Entrainment and Deposition (DEAD) model: Description and 1990s dust climatology, *J. Geophys. Res.*, *108*, 4416, doi:10.1029/2002JD002775, D14.

Zhao, M., and S. W. Running (2010), Drought-induced reduction in global terrestrial net primary production from 2000 through 2009, *Science*, *329*, 940–943, doi:10.1126/science.1192666.

Zobeck, T. M., M. C. Baddock, and R. S. Van Pelt (2013), Anthropogenic Environments, in *Treatise on Geomorphology*, edited by J. F. Shroder, pp. 395–413, Academic Press, San Diego, Calif, doi:10.1016/B978-0-12-374739-6.00310-9.

Zoet, L. K., B. Carpenter, M. Scuderi, R. B. Alley, S. Anandakrishnan, C. Marone, and M. Jackson (2013), The effects of entrained debris on the basal sliding stability of a glacier, *J. Geophys. Res. Earth Surf.*, *118*, 656–666, doi:10.1002/JGRF.20052.

Zollweg, J. A., W. J. Gburek, and T. S. Steenhuis (1996), SMoRMod – A GIS-integrated rainfall-runoff model, *Trans. Am. Soc. Agric. Eng.*, *39*(4), 1299–1307.

Zong, L., and H. Nepf (2011), Spatial distribution of deposition within a patch of vegetation, *Water Resour. Res.*, *47*, W03516, doi:10.1029/2010WR009516.