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Reviews of Geophysics

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A. Bellucci, R. Haarsma,
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(DOI 10.1002/2014RG000473)

ADVANCEMENTS IN DECADEAL CLIMATE PREDICTABILITY: THE ROLE OF NONOCEANIC DRIVERS

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We review recent progress in understanding the role of sea ice, land surface, stratosphere, and aerosols in decadal-scale predictability and discuss the perspectives for improving the predictive capabilities of current Earth system models (ESMs). These constituents have received relatively little attention because their contribution to the slow climatic manifold is controversial in comparison to that of the large heat capacity of the oceans. Furthermore, their initialization as well as their representation in state-of-the-art climate models remains a challenge. Numerous extraoceanic processes that could be active over the decadal range are proposed. Potential predictability associated with the aforementioned, poorly represented, and scarcely observed constituents of the climate system has been primarily inspected through numerical simulations performed under idealized experimental settings. The impact, however, on practical decadal predictions, conducted with realistically initialized full-fledged climate models, is still largely unexploited. Enhancing initial-value predictability through an improved model initialization appears to be a viable option for land surface, sea ice, and, marginally, the stratosphere. Similarly, capturing future aerosol emission storylines might lead to an improved representation of both global and regional short-term climatic changes. In addition to these factors, a key role on the overall predictive ability of ESMs is expected to be played by an accurate representation of processes associated with specific components of the climate system. These act as “signal carriers,” transferring across the climatic phase space the information associated with the initial state and boundary forcings, and dynamically bridging different (otherwise unconnected) subsystems. Through this mechanism, Earth system components trigger low-frequency variability modes, thus extending the predictability beyond the seasonal scale.

Jérôme Faillettaz,
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(DOI 10.1002/2014RG000466)

AVALANCHING GLACIER INSTABILITIES: REVIEW ON PROCESSES AND EARLY WARNING PERSPECTIVES

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Avalanching glacier instabilities are gravity-driven rupture phenomena that might cause major disasters, especially when they are at the origin of a chain of processes. Reliably forecasting such events combined with a timely evacuation of endangered inhabited areas often constitute the most efficient action. Recently, considerable efforts in monitoring, analyzing, and modeling such phenomena have led to significant advances in destabilization process understanding, improving early warning perspectives. The purpose of this paper is to review the recent progress in this domain. Three different types of instabilities can be identified depending on the thermal properties of the ice/bed interface. If cold (1), the maturation of the rupture is associated with a typical time evolution of surface velocities and passive seismic activity. A prediction of the final break off is possible using these precursory signs. For the two other types, water plays a key role in the development of the instability. If the ice/bed interface is partly temperate (2), the presence of meltwater may reduce the basal resistance, which promotes the instability. No clear and easily detectable precursory signs are known in this case, and the only way to infer any potential instability is to monitor the temporal evolution of the thermal regime. The last type of instability (3) concerns steep temperate glacier tongues switching for several days/weeks during the melting season into a so-called “active phase” followed in rare cases by a major break-off event. Although the prediction of such events is still far from being achievable, critical conditions promoting the final instability can be identified.

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(DOI 10.1002/2014RG000460)

WESTERN DISTURBANCES: A REVIEW

Cyclonic storms associated with the midlatitude Subtropical Westerly Jet (SWJ), referred to as Western Disturbances (WDs), play a critical role in the meteorology of the Indian subcontinent. WDs embedded in the southward propagating SWJ produce extreme precipitation over northern India and are further enhanced over the Himalayas due to orographic land-atmosphere interactions. During December, January, and February, WD snowfall is the dominant precipitation input to establish and sustain regional snowpack, replenishing regional water resources. Spring melt is the major source of runoff to northern Indian rivers and can be linked to important hydrologic processes from aquifer recharge to flashfloods. Understanding the dynamical structure, evolution-decay, and interaction of WDs with the Himalayas is therefore necessary to improve knowledge which has wide ranging socioeconomic implications beyond short-term disaster response including cold season agricultural activities, management of water resources, and development of vulnerability-adaptive measures. In addition, WD wintertime precipitation provides critical mass input to existing glaciers and modulates the albedo characteristics of the Himalayas and Tibetan Plateau, affecting large-scale circulation and the onset of the succeeding Indian Summer Monsoon. Assessing the impacts of climate variability and change on the Indian subcontinent requires fundamental understanding of the dynamics of WDs. In particular, projected changes in the structure of the SWJ will influence evolution-decay processes of the WDs and impact Himalayan regional water availability. This review synthesizes past research on WDs with a perspective to provide a comprehensive assessment of the state of knowledge to assist both researchers and policymakers, and context for future research.

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REPRESENTATION OF MICROPHYSICAL PROCESSES IN CLOUD-RESOLVING MODELS: SPECTRAL (BIN) MICROPHYSICS VERSUS BULK PARAMETERIZATION

Most atmospheric motions of different spatial scales and precipitation are closely related to phase transitions in clouds. The continuously increasing resolution of large-scale and mesoscale atmospheric models makes it feasible to treat the evolution of individual clouds. The explicit treatment of clouds requires the simulation of cloud microphysics. Two main approaches describing cloud microphysical properties and processes have been developed in the past four and a half decades: bulk microphysics parameterization and spectral (bin) microphysics (SBM). The development and utilization of both represent an important step forward in cloud modeling. This study presents a detailed survey of the physical basis and the applications of both bulk microphysics parameterization and SBM. The results obtained from simulations of a wide range of atmospheric phenomena, from tropical cyclones through Arctic clouds using these two approaches are compared. Advantages and disadvantages, as well as lines of future development for these methods are discussed.

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A REVIEW ON REGIONAL CONVECTION-PERMITTING CLIMATE MODELING: DEMONSTRATIONS, PROSPECTS, AND CHALLENGES

Regional climate modeling using convection-permitting models (CPMs; horizontal grid spacing $<4\text{ km}$) emerges as a promising framework to provide more reliable climate information on regional to local scales compared to traditionally used large-scale models (LSMs; horizontal grid spacing $>10\text{ km}$). CPMs no longer rely on convection parameterization schemes, which had been identified as a major source of errors and uncertainties in LSMs. Moreover, CPMs allow for a more accurate representation of surface and orography fields. The drawback of CPMs is the high demand on computational resources. For this reason, first CPM climate simulations only appeared a decade ago. In this study, we aim to provide a common basis for CPM climate simulations by giving a holistic review of the topic. The most important components in CPMs such as physical parameterizations and dynamical formulations are discussed critically. An overview of weaknesses and an outlook on required future developments is provided. Most importantly, this review presents the consolidated outcome of studies that addressed the added value of CPM climate simulations compared to LSMs. Improvements are evident mostly for climate statistics related to deep convection, mountainous regions, or extreme events. The climate change signals of CPM simulations suggest an increase in flash floods, changes in hail storm characteristics, and reductions in the snowpack over mountains. In conclusion, CPMs are a very promising tool for future climate research. However, coordinated modeling programs are crucially needed to advance parameterizations of unresolved physics and to assess the full potential of CPMs.

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(DOI 10.1002/2014RG000457)

UNDERSTANDING COASTAL MORPHODYNAMIC PATTERNS FROM DEPTH-AVERAGED SEDIMENT CONCENTRATION

This review highlights the important role of the depth-averaged sediment concentration (DASC) to understand the formation of a number of coastal morphodynamic features that have an alongshore rhythmic pattern: beach cusps, surf zone transverse and crescentic bars, and shoreface-connected sand ridges. We present a formulation and methodology, based on the knowledge of the DASC (which equals the sediment load divided by the water depth), that has been successfully used to understand the characteristics of these features. These sand bodies, relevant for coastal engineering and other disciplines, are located in different parts of the coastal zone and are characterized by different spatial and temporal scales, but the same technique can be used to understand them. Since the sand bodies occur in the presence of depth-averaged currents, the sediment transport approximately equals a sediment load times the current. Moreover, it is assumed that waves essentially mobilize the sediment, and the current increases this mobilization and advects the sediment. In such conditions, knowing the spatial distribution of the DASC and the depth-averaged currents induced by the forcing (waves, wind, and pressure gradients) over the patterns allows inferring the convergence/divergence of sediment transport. Deposition (erosion) occurs where the current flows from areas of high to low (low to high) values of DASC. The formulation and methodology are especially useful to understand the positive feedback mechanisms between flow and morphology leading to the formation of those morphological features, but the physical mechanisms for their migration, their finite-amplitude behavior and their decay can also be explored.

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Lapo Boschi
and Cornelis Weemstra
(DOI 10.1002/2014RG000455)

STATIONARY-PHASE INTEGRALS IN THE CROSS CORRELATION OF AMBIENT NOISE

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The cross correlation of ambient signal allows seismologists to collect data even in the absence of seismic events. "Seismic interferometry" shows that the cross correlation of simultaneous recordings of a random wavefield made at two locations is formally related to the impulse response between those locations. This idea has found many applications in seismology, as a growing number of dense seismic networks become available: cross-correlating long seismic records, the Green's function between instrument pairs is "reconstructed" and used, just like the seismic recording of an explosion, in tomography, monitoring, etc. These applications have been accompanied by theoretical investigations of the relationship between noise cross correlation and the Green's function; numerous formulations of "ambient noise" theory have emerged, each based on different hypotheses and/or analytical approaches. The purpose of this study is to present most of those approaches together, providing a comprehensive overview of the theory. Understanding the specific hypotheses behind each Green's function recipe is critical to its correct application. Hoping to guide nonspecialists who approach ambient noise theory for the first time, we treat the simplest formulation (the stationary-phase approximation applied to smooth unbounded media) in detail. We then move on to more general treatments, illustrating that the "stationary-phase" and "reciprocity theorem" approaches lead to the same formulae when applied to the same scenario. We show that a formal cross correlation/Green's function relationship can be found in complex, bounded media and for nonuniform source distributions. We finally provide the bases for understanding how the Green's function is reconstructed in the presence of scattering obstacles.

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(DOI 10.1002/2014RG000456)

REMOTE SENSING OF DROUGHT: PROGRESS, CHALLENGES AND OPPORTUNITIES

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This review surveys current and emerging drought monitoring approaches using satellite remote sensing observations from climatological and ecosystem perspectives. We argue that satellite observations not currently used for operational drought monitoring, such as near-surface air relative humidity data from the Atmospheric Infrared Sounder mission, provide opportunities to improve early drought warning. Current and future satellite missions offer opportunities to develop composite and multi-indicator drought models. While there are immense opportunities, there are major challenges including data continuity, unquantified uncertainty, sensor changes, and community acceptability. One of the major limitations of many of the currently available satellite observations is their short length of record. A number of relevant satellite missions and sensors (e.g., the Gravity Recovery and Climate Experiment) provide only a decade of data, which may not be sufficient to study droughts from a climate perspective. However, they still provide valuable information about relevant hydrologic and ecological processes linked to this natural hazard. Therefore, there is a need for models and algorithms that combine multiple data sets and/or assimilate satellite observations into model simulations to generate long-term climate data records. Finally, the study identifies a major gap in indicators for describing drought impacts on the carbon and nitrogen cycle, which are fundamental to assessing drought impacts on ecosystems.

This paper reviews measurement techniques and corresponding devices used to determine the physical properties of the seasonal snowpack from distances close to the ground surface. The review is placed in the context of the need for scientific observations of snowpack variables that provide inputs for predictive hydrological models that help to advance scientific understanding of geophysical processes related to snow in the near-surface cryosphere. Many of these devices used to measure snow are invasive and require the snowpack to be disrupted, thereby precluding the possibility for multiple measurements to be made at the same sampling location. Moreover, many devices rely on the use of empirical calibration equations that may not be valid at all geographic locations. The spatial density of observations with most snow measurement devices is often inadequate. There is a need for improved automation of snowpack measurement instrumentation with an emphasis on field-based feedback of measurement validity in lieu of postprocessing of samples or data at a lab or office location. The scientific future of snow measurement instrumentation thereby requires a synthesis between science and engineering principles that takes into consideration geophysics and the physics of device operation.

Tropical cyclone-generated storm surges are among the world's most deadly and destructive natural hazards. This paper provides the first comprehensive global review of tropical storm surge data sources, observations, and impacts while archiving data in SURGEDAT, a global database. Available literature has provided data for more than 700 surge events since 1880, the majority of which are found in the western North Atlantic (WNA), followed by Australia/Oceania, the western North Pacific (WNP), and the northern Indian Ocean (NIO). The Bay of Bengal (BOB) in the NIO consistently observes the world's highest surges, as this subbasin averages five surges ≥ 5 m per decade and has observed credible storm tide levels reaching 13.7 m. The WNP observes the highest rate of low-magnitude surges, as the coast of China averages 54 surges ≥ 1 m per decade, and rates are likely higher in the Philippines. The U.S. Gulf Coast observes the second highest frequency of both high-magnitude (≥ 5 m) and low-magnitude (≥ 1 m) surges. The BOB observes the most catastrophic surge impacts, as 59% of global tropical cyclones that have killed at least 5000 people occurred in this basin. The six deadliest cyclones in this region have each killed at least 140,000 people, and two events have killed 300,000. Storm surge impacts transportation, agriculture, and energy sectors in the WNA. Oceania experiences long-term impacts, including contamination of fresh water and loss of food supplies, although the highest surges in this region are lower than most other basins.