Spring 2020

GFDL BULLETIN

Research Highlights from the Geophysical Fluid Dynamics Laboratory Community

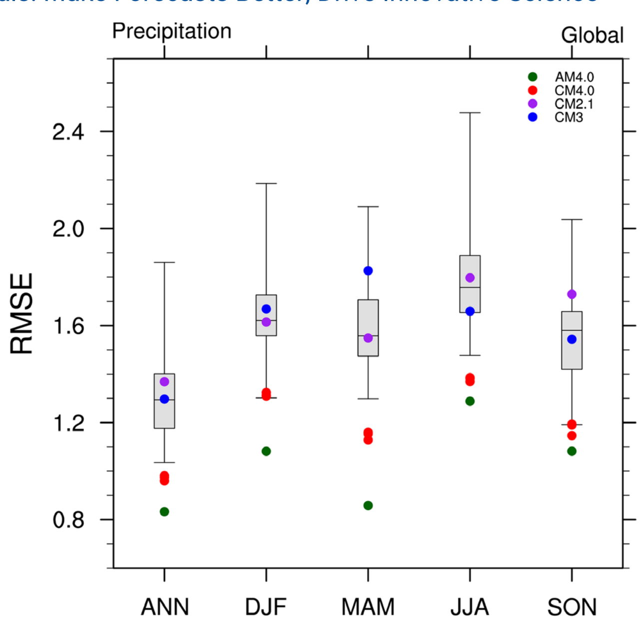
Advancing the Modeling, Understanding, and Prediction of Weather and Climate

STRUCTURE AND PERFORMANCE OF GFDL's CM4.0 CLIMATE MODEL

DOI: 10.1029/2019MS001829

GFDL's latest multi-purpose atmosphere-ocean coupled climate model, CM4.0, consists of GFDL's newest atmosphere and land models (AM4 and LM4; 100 km horizontal resolution) and newest ocean and sea ice models (MOM6 and SIS2; 25 km horizontal resolution). Model results have been extensively evaluated against observations, as well with earlier models (CM3 and CM2.1, developed in 2011 and 2006, respectively). CM4.0 ranks high among the world's state-of-the-art coupled climate models by many measures of bias in the simulated climatology and in capturing modes of climate variability, such as the El Niño-Southern Oscillation and Madden-Julian Oscillation. Other strengths include small biases in top-of-atmosphere fluxes, precipitation, Arctic Sea ice extent, and sea surface temperature. Some aspects of the simulation, such as potentially excessive Southern Ocean variability on centennial time scales, remain subjects of continuing model development.

OAR Goals: Make Forecasts Better; Drive Innovative Science



Reducing the errors in model simulation of precipitation (mm/day)

CM4 (red dots) has lowered the bias (root-mean square error, or RMSE) in the simulation of precipitation when compared with observations. This represents a significant improvement over previous GFDL models (CM3, blue dots; CM2.1, purple dots). The green dots illustrate the bias when sea-surface temperatures are prescribed from observations. The differences between the green and red dots illustrate the modest deterioration in the coupled model, in which sea surface temperatures are simulated rather than prescribed. Box and whiskers show the full spread, the 25–75% range and the median, based on the World Climate Research Program Coupled Model Intercomparison Project 5. Averages are over the Years 1980–2014.

Journal of Advances in Modeling Earth Systems

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GFDL SCIENTISTS IN THE SPOTLIGHT

Six GFDL scientists were recently honored on the
Web of Science Group's 2019 List of Highly Cited Researchers

Thomas Delworth, Andrew Wittenberg, Larry Horowitz, Vaishali Naik, John Dunne, and Elena Shevliakova

This index identifies the most influential scientists, who are authors of the papers that were most frequently cited by their peers over the last decade.

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RESPONSE OF STORM-RELATED EXTREME SEA LEVEL ALONG THE U.S. ATLANTIC COAST TO COMBINED WEATHER AND CLIMATE FORCING

Journal of Climate *J. Yin[1], S.M. Griffies[2,3], M. Winton[2], M. Zhao[2], L. Zanna[4]*

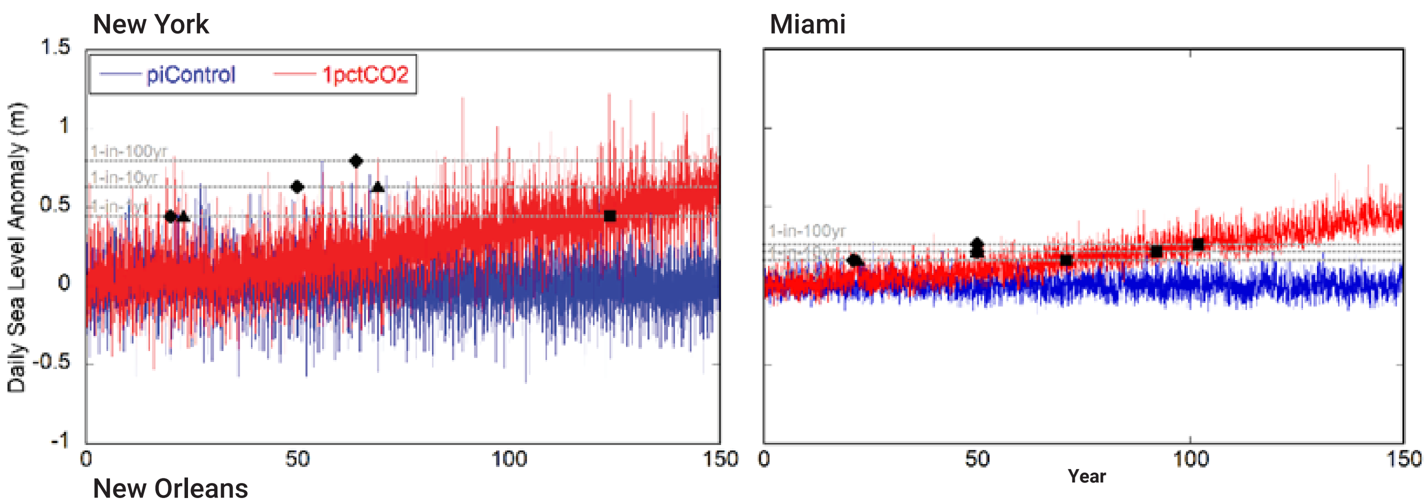
DOI: 10.1175/JCLI-D-19-0551.1

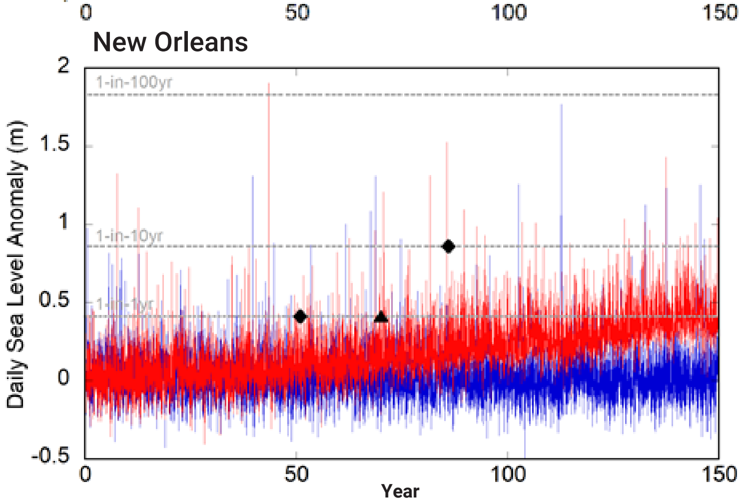
The U.S. East and Gulf Coasts differ in how ocean and atmospheric circulation and sea level interact to produce storm surges, and both regions will experience greater storm surges as global warming progresses, according to new research. Stronger hurricanes will affect the Gulf Coast and increased sea level will affect the East Coast.

This research is the first to compare how different parts of the Atlantic Coast might fare during storms. GFDL scientists and university collaborators examined the impacts of both tropical cyclones and extra-tropical cyclones (i.e., nor'easters) by using a new GFDL climate model (CM4) that allowed them to combine information on weather, climate and sea level in a fully integrated way. The scientists studied the coastline from Halifax, Nova Scotia, to Houston, Texas – home to more than 60 million people. Between 2000 and 2017, those regions were hit by 13 hurricanes that each caused more than $10 billion in damages.

Even in the absence of global warming, the Gulf Coast, and especially New Orleans, is particularly vulnerable to storm surge. As the climate warms, the Gulf Coast will be even more susceptible to extreme storm surges as hurricane winds increase. For the U.S. East Coast, especially in the Northeast, the maximum storm surge is mainly influenced by the background sea level rise from warming waters, as well as through impacts from changes to the Gulf Stream and the associated meridional overturning circulation.

OAR Goals: Make Forecasts Better; Drive Innovative Science





Time of emergence of the anthropogenic signal in storm related extreme sea level for New York, Miami, and New Orleans

*In response to a 1% per year atmospheric CO2 increase (**1pctCO2**), anthropogenic signals (relative to **piControl**) in daily surge height and frequency can emerge from the background variability in as little as 20 years along the Northeast and Southeast coast. It is delayed along the Gulf of Mexico coast because of the large natural variability. Blue and red colors denote the daily sea level anomaly in the unperturbed (**piControl**) and perturbed (**1pctCO2**) simulations, respectively. Horizontal dashed lines denote the return levels of 1-, 10-, and 100-year events in the 150-year unperturbed simulation. Triangles and diamonds indicate time of emergence in extreme sea level height and frequency, respectively. Rectangles denote permanent exceedance by the rising mean sea level.*

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SPEAR: THE NEXT GENERATION GFDL MODELING SYSTEM FOR SEASONAL TO MULTIDECADAL PREDICTION AND PROJECTION

Journal of Advances in Modeling Earth Systems

T.L. Delworth[1,2], W.F. Cooke[3], A. Adcroft[4], M. Bushuk[3], J.-H. Chen[3], K.A. Dunne[5], P. Ginoux[1], R. Gudgel[1], R.W. Hallberg[1,2], L. Harris[1], M.J. Harrison[1], N. Johnson[1], S.B. Kapnick[1], S.-J. Lin[1], F. Lu[4], S. Malyshev[1], P.C. Milly[5], H. Murakami[3], V. Naik[1], S. Pascale[6], D. Paynter[1], A. Rosati[3], M.D. Schwarzkopf[1], E. Shevliakova[1], S. Underwood[1], A.T. Wittenberg[1], B. Xiang[3], X. Yang[3], F. Zeng[1], H. Zhang[7], L. Zhang[4], M. Zhao[1]

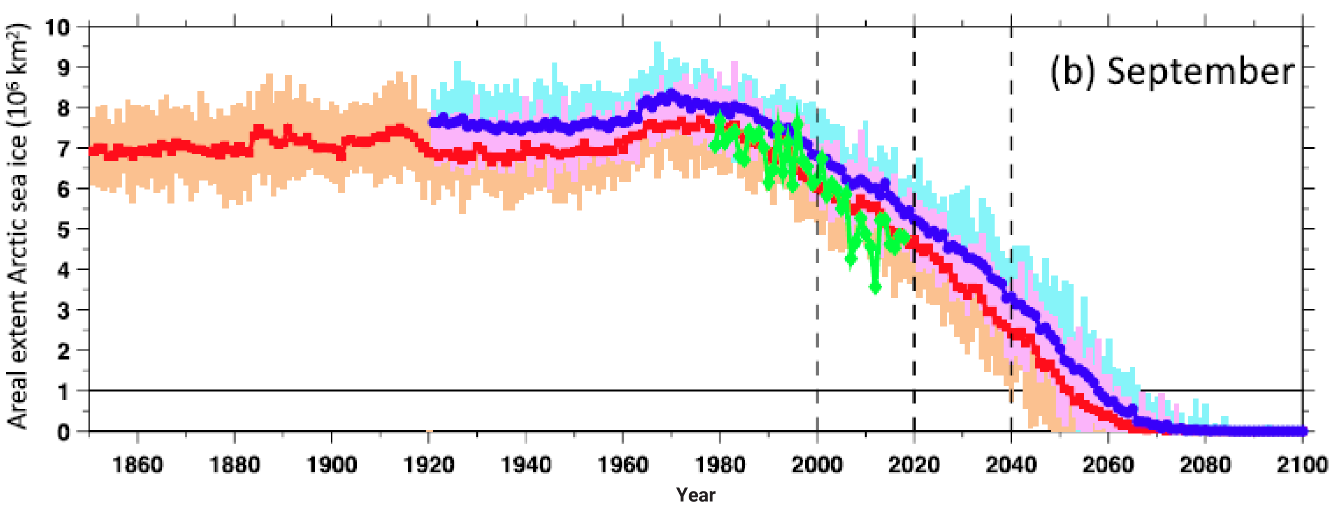
DOI: 10.1029/2019MS001895

GFDL's next-generation seasonal to multi-decadal prediction and projection system called the "Seamless system for Prediction and EArth system Research" (SPEAR) takes advantage of many recent modeling advancements, including the FV3 dynamical core, MOM6 ocean code, LM4 land model, and SIS2 sea ice model. Analyses show that SPEAR is able to simulate many aspects of Earth's climate system with a high degree of fidelity, including regional precipitation and extremes, the El Niño-Southern Oscillation, the Pacific Decadal Oscillation, the Atlantic Meridional Overturning Circulation, and more.

It is anticipated that this new modeling system will become a part of the North American Multi-Model Ensemble system for seasonal prediction. This model will also be used in experimental decadal prediction, as well as a suite of research activities on seasonal to centennial time scales.

SPEAR has already been used to conduct large ensembles of climate change simulations and projections spanning the period 1851 to 2100 (see figure below), totaling more than 20,000 model simulated years. These simulations are being used for risk assessment in the context of changing climate extremes. The simulations also highlight the influence of the near-surface climate over Antarctica on deep-water formation in the Southern Ocean, and important characteristics of the global ocean circulation. A more realistic representation of the surface energy budget over Antarctica resulted in much improved aspects of the global ocean circulation, as well as reduced model drift.

OAR Goals: Make Forecasts Better; Drive Innovative Science



Observed and simulated areal extent of September Arctic sea ice

Time series of areal extent of Arctic sea ice for September, demonstrating the ability of the model to simulate both natural climate variability and the response of climate to changing radiative conditions. Observations in green. Sea ice units are millions of square kilometers. The red line and symbols are the 30-member ensemble mean from SPEAR_LO (lower resolution model version), while the blue line and symbols are the 30-member ensemble mean from SPEAR_MED (higher resolution version). The tan (light blue) shading shows the range of values each year across the ensemble members from SPEAR_LO (SPEAR_MED), showing the impact of natural variability each year. The magenta shading indicates where the distributions of SPEAR_LO and SPEAR_MED overlap. The three vertical dashed lines are for ease of reference to identify years 2000, 2020, and 2040. The thick green line and symbols show the observed sea ice extent for 1979 to 2018.

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[7]NOAA/GFDL, Princeton, NJ, and Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY

CHANGES IN EXTREME PRECIPITATION AND LANDSLIDES OVER HIGH MOUNTAIN ASIA

Geophysical Research Letters *D. Kirschbaum[1], S.B. Kapnik[2], T. Stanley[1], S. Pascale[3]*

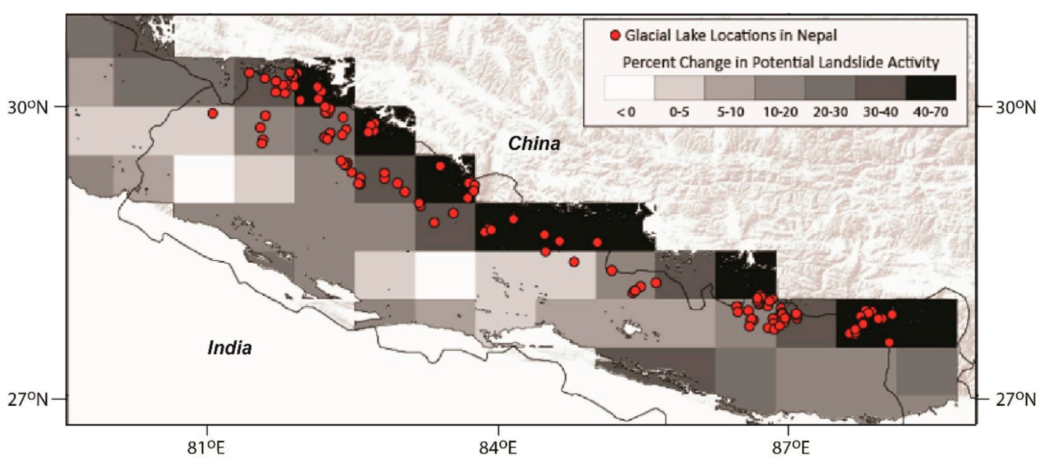
DOI: 10.1029/2019GL085347

High Mountain Asia is home to both monsoonal rains and the largest concentration of glaciers outside the North and South Poles. Heavy rainfall will increase with climate change, especially in mountains near glaciers and glacial lakes. This will make landslides more likely and could present new hazards of landslides releasing a wall of water from glacial lakes, impacting communities and infrastructure located downstream.

This research shows that extreme precipitation will occur more frequently in the high mountain Asia region by the end of this century, in turn leading to increases in landslide risks. Locations with the greatest increase in landslide risk are collocated with regions having a high concentration of glacial lakes, increasing the likelihood for cascading hazards (e.g., a landslide breaching a lake, causing massive flooding downstream). The most significant projected increases in potential landslide activity occur in the transition zone between the Himalayan Mountains and Tibetan Plateau along the Nepal-China border, with the largest changes during the summer months when the monsoon brings the majority of the extreme rainfall.

This novel, interdisciplinary investigation melded the unique strengths of NOAA and NASA, combining a landslide database and dynamic landslide model developed at NASA, satellite data, and a high resolution GFDL global climate model. This study provides both relevant scientific results and a new framework for combining a large ensemble of global climate model simulations with satellite data and a landslide model.

OAR Goals: Detect Changes in the Ocean and Atmosphere; Drive Innovative Science



Projected Changes in Landslide Activity in High Mountain Asia

Percent change in potential landslide activity comparing the present (1961–2000) and future scenarios (2061–2100) using the GFDL FLOR model. A positive value indicates an increase in potential landslide activity toward the end of the century. The current locations of 131 glacial lakes are shown in red.

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RECENTLY HONORED SCIENTISTS

Baoqiang Xiang (GFDL & CIMES)
has been awarded the **International Prize for Model Development from the World Meteorological Organization** for his skill in developing multiple modeling systems, and in particular for leading the development of GFDL's model for weather and subseasonal predictions.

Leo Donner (GFDL)
has been named a **Fellow of the American Association for the Advancement of Science** (AAAS), an honor bestowed upon AAAS members by their peers, based on their distinguished efforts to advance science or its applications.

Morris Bender (retired, GFDL)
has received the **2020 Richard H. Hagenmeyer Award in Tropical Meteorology** from the National Weather Service for his leadership role that has contributed to significant advances in the numerical modeling of tropical systems.