GFDL BULLETIN

WINTER 2022-2023

Research Highlights from the Geophysical Fluid Dynamics Laboratory Community

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

# PROBABILISTIC EXTREME SST AND MARINE HEATWAVE FORECASTS IN CHESAPEAKE BAY: A FORECAST MODEL, SKILL ASSESSMENT, AND POTENTIAL VALUE

**Frontiers in Marine Science** *Andrew C. Ross[1], Charles A. Stock[1]*

DOI: 10.3389/fmars.2022.896961

Extremely warm sea surface temperatures (SST) and marine heatwaves can have a range of negative impacts on ocean ecosystems, including coral bleaching, increased growth of pathogenic bacteria and harmful algal blooms, and higher fish mortality. The authors of this study developed a simple model to forecast SST in Chesapeake Bay, an estuary in the Mid-Atlantic region of the United States. They then used a scenario to assess whether model forecasts of extreme SSTs could provide economic value if used to inform management actions to reduce the impacts of heatwaves.

Although skillful marine heatwave forecasts have been demonstrated for many large-scale ocean regions, the impacts of marine heatwaves and potential mitigative actions often take place in small coastal and estuarine regions such as the Chesapeake Bay.

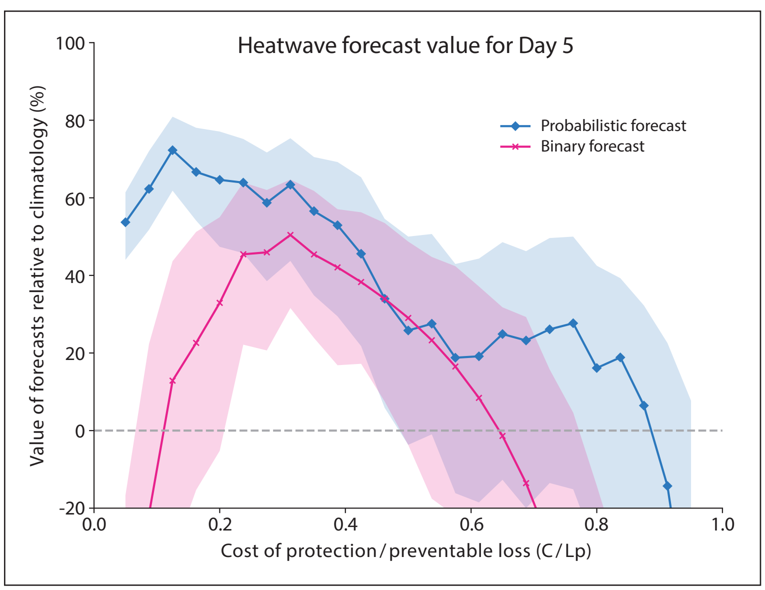
These results show that daily mean SST in Chesapeake Bay can be skillfully forecast for about two weeks in advance. Forecasts of summer extreme SST events are similarly skillful, and have substantial potential economic value compared to making decisions based on traditional practices, which lack forecasts of extreme SST. For example, some current management decisions in the Bay include always placing strict controls on oyster harvests during months when warm temperatures are common – even though that is not uniformly necessary.

The simple model developed by GFDL scientists was used to produce an extensive suite of 35-day retrospective forecasts, to assess whether skillful forecasts of SST are possible. Then they derived probabilistic forecasts of SST and extreme heat events. Finally, they assessed the potential economic benefit of applying deterministic and probabilistic forecasts to mitigate the impacts of extreme SSTs. This work shows that these forecasts could have economic value if applied to inform actions to mitigate the impacts of extreme SSTs.

OAR Goals: Explore the Marine Environment, Make Forecasts Better, Drive Innovative Science

## Economic value of decisions made based on probabilistic forecasts

*The potential economic value of decisions made based on the forecasts developed in this study, expressed as a percent improvement over decisions made using the long-term climatology instead of forecasts. Forecast values above 0% indicate an improvement over the long-term climatology, and a perfect forecast has a value of 100%. The values of the forecasts are evaluated over a range of different ratios between the cost of taking protective action against heatwaves and the preventable loss that will occur in a heatwave without protection. The probabilistic forecast gives information about the percent chance of a heatwave, whereas the binary forecast only predicts if a heatwave will occur or not.*




[1]NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ

# ENHANCED DUST EMISSION FOLLOWING LARGE WILDFIRES DUE TO VEGETATION DISTURBANCE

**Nature Geoscience** *Yan Yu[1], Paul Ginoux[2]*

DOI: 10.1038/s41561-022-01046-6

Large wildfires reduce vegetation cover and soil moisture, leaving the degraded landscapes an emergent source of dust emission. In addition to the instantaneous societal disruptions and health risks, drought and resultant wildfires set the stage for dust storms even weeks after burning. This research shows that the intensification of wildfires over the past 18 years has caused a one-day elongation of post-fire dust events. With predicted intensification of regional wildfires and concurrent droughts in the upcoming decades, we can expect enhancement of sequential fire and dust extremes along with their societal and ecological impacts, according to the authors.

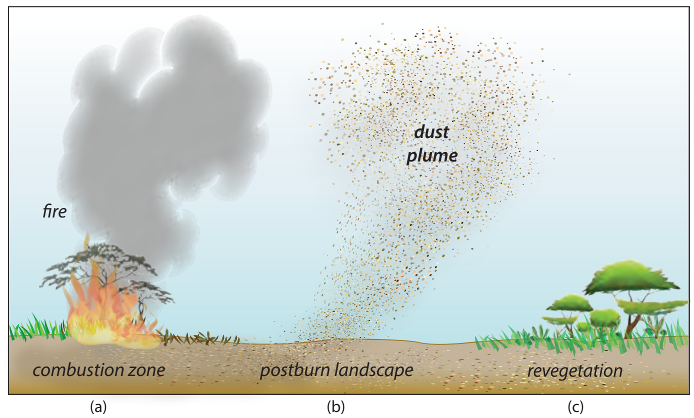
The occurrence and duration of post-fire dust emission was found to be determined primarily by the extent of the wildfires and resultant vegetation anomalies. Drought conditions seen prior to the fires were a secondary factor.

Using satellite measurements of active fires, aerosol abundance, vegetation cover and soil moisture from 2003 to 2020, the authors found that more than half of large wildfires are followed by enhanced dust emission, producing substantial dust emissions for days to weeks over normally dust-free regions. The robustness of these results comes from the very large number of cases analyzed (~150,000 wildfires), and the wide variety of elements (dust, greenness, soil moisture and surface wind) measured from independent instruments.

Compared with dryland dust storms, the post-fire dust storms may cause even larger socioeconomic and health impacts, due to their closer location to populated areas and possible mixing of harmful combustion residuals into the post-fire dust storms. The emitted soil particles from these disturbed lands may enter the global dust cycle, altering the radiation budget, cloud and precipitation patterns, as well as oceanic and terrestrial biogeochemistry.

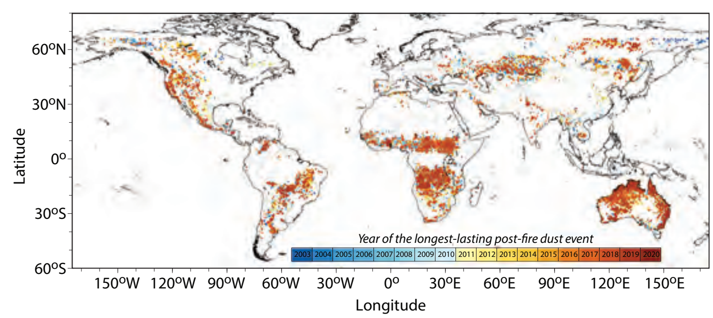
OAR Goals: Detect Changes in the Ocean and Atmosphere, Drive Innovative Science

## Sequence of Events Following Extreme Wildfires




- *Vegetation is burnt down by the wildfire, leaving soil nearly bare.*
- *Bare soil surface is prone to dust emissions as soon as the wind uplifts soil particles.*
- *Vegetation is slow to recover, and that recovery is what reduces the possibility of dust emission.*

## Year of the Longest Duration Post-Fire Dust Event




*Each dot shows the year of the longest lasting post-fire dust event between 2003 and 2020. The preponderance of such events in recent years (shades of orange) show that these dust events are becoming elongated. This analysis was based on more than 150,000 wildfire events.*

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[2]NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, NJ

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# OCEAN CURRENTS BREAK UP A TABULAR ICEBERG

## Science Advances

*Alex Huth[1], Alistair Adcroft[1], Olga Sergienko[1], Nuzhat Khan[2]*

DOI: 10.1126/sciadv.abq6974

Iceberg size and iceberg breakup affect where they drift and deposit meltwater, which influences ocean circulation, sea-ice formation, and biological productivity. Giant icebergs with lengths exceeding 18.5 km comprise the vast majority of the total Antarctic iceberg volume. However, they are not represented in existing Earth system models (ESMs) due to a lack of appropriate methods to represent bergs larger than a grid cell, and because rift calving (iceberg breakup into large fragments) is poorly understood.

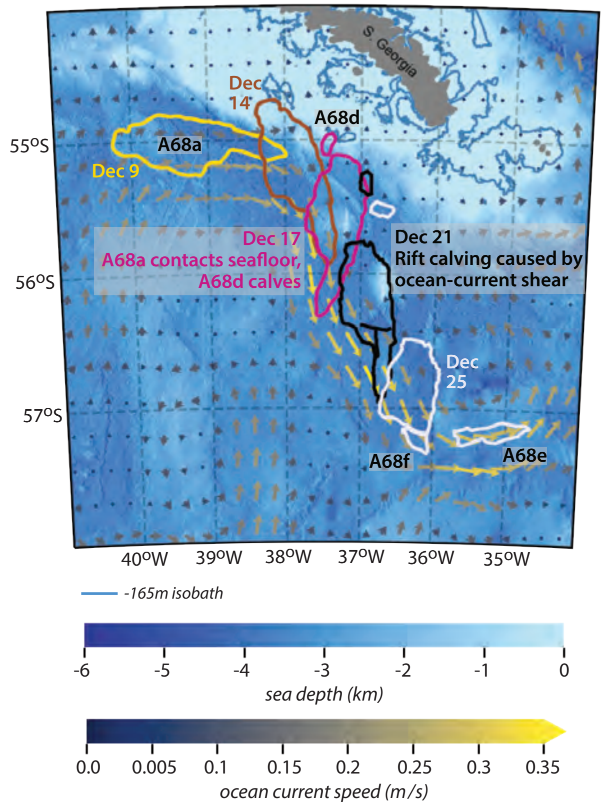
From model simulations, the authors discovered that deep-ocean rift calving can be triggered by a previously unknown mechanism of iceberg breakup: "ocean-current shear", where the iceberg overlapped strong and weak ocean currents simultaneously, inducing enough tension along its body to snap it into pieces.

Rift calving can occur when icebergs collide with the seafloor, but also occurs in ocean deeper than iceberg keels, for unknown reasons. In December 2020, giant iceberg A68a broke up in open ocean much deeper than its keel, indicating that the breakage was not immediately caused by collision with the seafloor.

This research demonstrated that an iceberg module developed at GFDL, Kinematic Iceberg Dynamics (iKID), can represent the drift, decay, and breakup of giant icebergs in Earth system models; and that iKID can simulate the observed December 2020 drift and rift calving events of iceberg A68a. Importantly, this research also shows that the iKID framework is computationally efficient enough to incorporate it within ESMs.

The impact of icebergs on climate cannot be assessed without an accurate representation of their drift trajectories, breakup, and meltwater distribution. Consequently, this study will improve our projections of where iceberg meltwater is deposited into the ocean and its impact on climate. It also may improve our ability to predict iceberg drift for the purpose of risk assessment to offshore structures and ships.

### Breakup of Iceberg A68a
### Mid-December 2020




*The yellow, brown, pink, black, and white outlines show the shape and location of the iceberg through time.*

*The first breakup event (Dec. 17) occurs when the iceberg collides with the ocean bottom. The second breakup (Dec. 21) is caused by shear in ocean currents, a new breakup mechanism not previously reported.*

*https://www.gfdl.noaa.gov/iceberg-a68a/*

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

[1]AOS Program, Princeton University, Princeton, NJ;[2]Macaulay Honors College at Hunter College, City University of New York, NY

Photo Credit: Weddell Sea, Antarctica / 66 North, Unsplash

# INTEGRATED DYNAMICS-PHYSICS COUPLING FOR WEATHER TO CLIMATE MODELS

**Geophysical Research Letters** *Linjiong Zhou[1], Lucas Harris[2]*

DOI: 10.1029/2022GL100519

A new integrated dynamics-physics coupling framework developed at GFDL can significantly improve weather prediction skills. Implemented in GFDL's System for High-resolution prediction on Earth-to-Local Domains (SHiELD) model, it shows significant improvements to weather prediction, and indicates promise for improved simulation of high-impact weather events such as hurricanes.

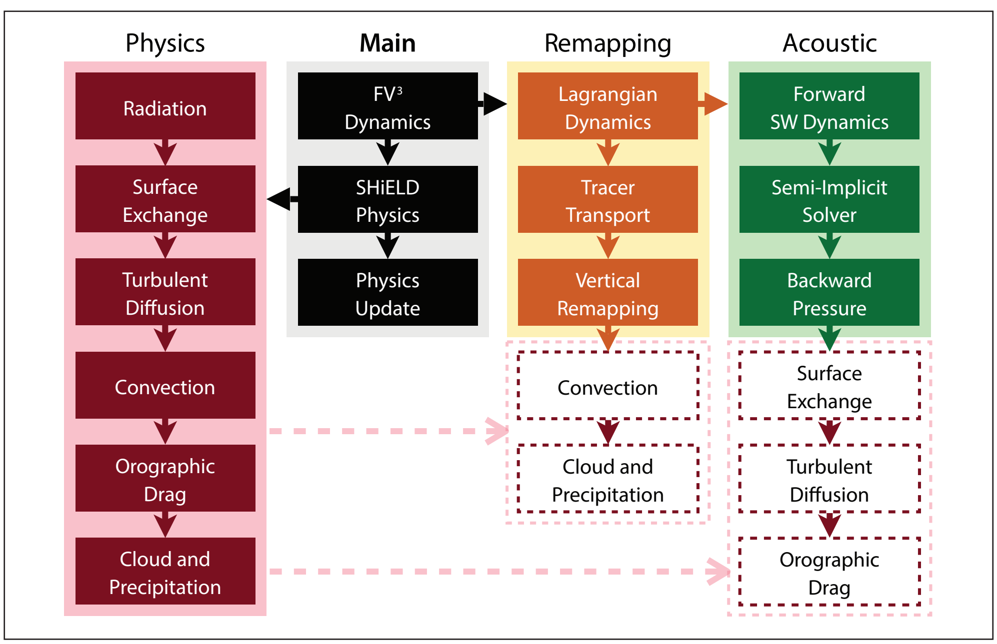
Resolved-scale air flow ("dynamics") and sub-grid parameterizations ("physics") are two essential components of a weather or climate model. They work together through dynamics-physics coupling in the models. Traditionally, dynamics and physics are each engineered in isolation and developed independently. As a result, many parts of the physics run at a physically-inappropriate time frequency, or with heat transfers that are inconsistent with the dynamics, leading to errors. Dynamical and physical processes have different physical time scales, and the design of the dynamical core and dynamics-physics coupling should reflect this difference.

The authors developed a novel integrated framework designed to enhance dynamics-physics interaction and thermodynamic consistency. The cloud and precipitation physics integrated within the dynamics in SHiELD is the first example that demonstrates the improvements. When a large number of 10-day forecasts are run, the version with integrated cloud and precipitation physics shows significantly lower errors and higher skill, especially for large-scale weather patterns, compared to a traditionally-coupled physics scheme.

The integrated physics also shows promise for improved simulation of high-impact weather events such as hurricanes. In addition, while the feasibility of this framework was proven in a global weather model, it should also be beneficial in climate models and regional models because the dynamics-physics coupling frameworks are similar. Improving weather forecast accuracy will save lives and property, and support a vibrant economy.

OAR Goals: Make Forecasts Better, Drive Innovative Science

**Proposed schematic of the integrated dynamics-physics coupling framework in SHiELD**




*From left to right are SHiELD's physical parameterizations; main components of SHiELD; remapping (outer) loop in the FV3 dynamics; and acoustic (inner) loop in the Lagrangian dynamics. In the completed integrated framework, the surface exchange, turbulent diffusion, and orographic drag are relatively fast processes that would be moved from the physics loop into the acoustic loop. The convection and cloud and precipitation are intermediate-timescale processes that would be moved from the physics loop into the remapping loop.*

[1]Cooperative Institute for Modeling the Earth System, Program on Atmospheric and Oceanic Sciences, Princeton University, Princeton, NJ; [2]NOAA/GFDL, Princeton, NJ

# NATIONAL ACADEMY OF SCIENCE HONORS GFDL'S KIRK BRYAN FOR PIONEERING OCEAN AND CLIMATE SCIENCE


Former GFDL scientist Kirk Bryan Jr., Ph.D, has been named winner of the **2023 National Academy of Science's (NAS) Alexander Agassiz Medal** for his pioneering work in oceanography and climate science. He led the GFDL Ocean Division from 1961 until his retirement in 1995.

Bryan is widely recognized as the founder of numerical ocean modeling, and his work in the late 1960s at GFDL led to the first-of-its-kind general circulation climate model – combining both oceanic and atmospheric processes to bring forth insights into how the ocean and atmosphere interact with each other to influence climate. The model also predicted how changes in the natural factors that control climate such as ocean and atmospheric currents and temperature could lead to climate change. Earlier knowledge of the oceanic and atmospheric circulation, and their interactions, was based purely on theory and observation.

"When my career began, the tendency was to describe the ocean in more or less qualitative terms, tracing water masses around from one part of the ocean to another," Bryan said. "I'm enormously proud of the work we did to expand the quantitative knowledge of things, and pleased to accept this award and grateful to have our breakthroughs recognized this way."

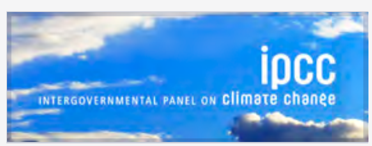
The work was especially impressive given the computing limitations of the day. The computer used to develop and run the first model Bryan developed ran with just half a megabyte of memory—not enough to store a modern high-resolution digital picture in 2023. In contrast, NOAA's modern supercomputer used by GFDL today provides more than 100,000 times the computing power of that early machine.

The Alexander Agassiz Medal is only presented once every five years and honors original contributions in the science of oceanography. The award will be presented during the NAS annual meeting on April 30 and will be webcast live.

## GFDL Scientists Lead the Charge in Climate Change Understanding Through IPCC Sixth Assessment Contributions: IPCC Honored with The Gulbenkian Prize for Humanity

GFDL scientists recently earned recognition for their pivotal role in advancing the understanding of climate change impacts. This recognition came through their participation in the Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC). AR6 was awarded the highly coveted 2022 Gulbenkian Prize for Humanity.

The Gulbenkian Prize for Humanity recognizes the crucial role of the IPCC, a global group of scientists advancing knowledge of climate change, and highlights the substantial contributions made by GFDL's scientists. This award is a testament to GFDL's commitment to improving our understanding of the impacts posed by climate change, and the vital work done by its dedicated scientists.




**As a world-renowned institution in climate science, GFDL has played a central role in each IPCC assessment since 1990. In AR6, GFDL serves as one of several international modeling centers, providing 5 models for the report's climate assessments, with 11 scientists contributing in various roles for 7 chapters, and another 10 GFDL scientists contributing as expert reviewers in the Working Group I report. GFDL also contributed 168 TB of data from experiments, equal to 1,700,000 hours of music, to the global climate science community.**

**Mitch Bushuk**
**John Dunne**
**Michelle Frazer**
**Paul Ginoux**
**Robert Hallberg**
**Jian He**
**Larry Horowitz**
**Thomas Knutson**
**Sonya Legg**
**P.C.D. (Chris) Milly**
**Vaishali Naik**
**Fabien Paulot**
**Aparna Radhakrishnan**
**V. "Ram" Ramaswamy**
**Olga Sergienko**
**Elena Shevliakova**
**Michael Winton**