

A list of research products, information and services, models and model simulations, and an assessment of their impact

GFDL's principal research product is peer-reviewed publications on atmospheric and oceanic dynamics, natural climate variability, and anthropogenic change. Its publication record is discussed in Supporting Documents 1a and 1c. There are a number of other important products and services provided by GFDL that are discussed here.

Assessments

GFDL has played a major role in a number of assessments related to climate change and ozone. These include the following Intergovernmental Panel on Climate Change Assessment Reports:

- 1990 "FAR": Future projections based largely on GFDL model. 6 GFDL personnel contribute to the Report.
- 1995 "SAR": GFDL model one of ~6 models used for future projections. 9 GFDL personnel contribute to the Report.
- 2001 "TAR": GFDL model is "2nd tier" out of ~12 models. 15 GFDL personnel contribute to the Report.
- 2007 "AR4": GFDL CM models (CM2.0 and CM2.1) are two of the best out of ~24 models. 20 GFDL personnel contribute to the Report.

The Intergovernmental Panel on Climate Change, along with GFDL contributors to it, was a co-recipient of the 2007 Nobel Peace Prize for its sustained efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.

For the Intergovernmental Panel on Climate Change 5th Assessment Report (AR5) published in 2013, [GFDL contributed data](#) from new Earth System Models based on CM2.1, decadal predictions using CM2.1, results from a new coupled climate model, CM3, so-called "time slice integrations" using a high-resolution atmospheric model, and a limited number of high-resolution coupled model integrations. Over 188 terabytes of model data is available to the climate research community.

In addition to the Intergovernmental Panel on Climate Change assessments on climate change, two GFDL scientists have ongoing contributions to a set of reports on ozone:

- 1998 UNEP Scientific Assessment of Ozone Depletion
- 2002 UNEP Scientific Assessment of Ozone Depletion

- 2005 Intergovernmental Panel on Climate Change Special Report on “Safeguarding the Ozone Layer and the Global Climate System”
- 2006 UNEP Scientific Assessment of Ozone Depletion

GFDL scientists contributed to the following Synthesis and Assessment Reports (SAPs) from the Climate Change Science Program (CCSP):

- 1.1 - Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences
- 2.4 - Trends in emissions of ozone-depleting substances, ozone layer recovery, and implications for ultraviolet radiation exposure
- 3.1 - Climate Models: An Assessment of Strengths and Limitations
- 3.2 - Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols
- 3.3 - Weather and Climate Extremes in a Changing Climate
- 3.4 - Abrupt Climate Change

GFDL was the lead in the development of SAP 3.2.

Models

GFDL provides numerical models to its collaborators and the public. These models are fully described and available on GFDL's public website under the [Models menu](#).

Technology transferred to operations/application and an assessment of their significance/impact on operations

GFDL has delivered a number of products to NOAA for operational use.

Modular Ocean Model (MOM)

The Modular Ocean Model (MOM) is the canonical ocean climate model use by many researchers around the world. The model origins date back to the community code first developed by Kirk Bryan and Mike Cox in the 1960's-1980's, and to which many other ocean climate models can trace their origins. The third version of MOM (MOM3) is a z-coordinate model released in 1999 and has been the ocean component of National Centers for Environmental Prediction's (NCEP's) coupled Climate Forecast System (CFS) and Global Ocean Data Assimilation System (GODAS) since that time. The CFS became operational in 2004.

NCEP's Environmental Modeling Center (EMC) has operationalized a new version of CFS (CFS-v2) for the prediction of short-term climate out to one year. The CFS-v2 upgrades MOM3 to

MOM4, together with the NCEP atmospheric Global Forecast System (GFS), and a Global Ocean Data Assimilation System (GODAS) that includes MOM4.

MOM4 is also the ocean component for the Australian Centre for Climate and Weather Research (CAWCR) operational coastal ocean forecasting system. This system, known as Bluelink, provides ocean forecasting for regions around Australia and surrounding island nations (<http://www.bom.gov.au/oceanography/forecasts/>), though future developments are aiming to develop a global product that includes sea ice.

MOM4 formed the basis of the CM2.1, CM2M, ESM2M, and CM2.5 climate models used for high-end modeling that contributed to the IPCC AR4 and AR5 assessments.

GFDL's Coupled Model Output for Seasonal-to-Interannual Research

GFDL delivers coupled model output to NCEP/EMC in a collaborative effort to develop a multi-model ensemble for operational seasonal-interannual prediction. The model used is CM2.1, one of the GFDL models used in the Intergovernmental Panel on Climate Change's (IPCCs) Fourth Assessment Report (AR4). The output is in the form of one-year hindcasts starting each month from 1982 to the present.

Towards a similar purpose, in 2004 GFDL began collaborating with the International Research Institute (IRI) for Climate and Society to produce real-time seasonal forecasts as part of their monthly Multi-model ensemble (MME) seasonal prediction system. The predictions of the individual atmospheric general circulation models (AGCM) are objectively combined into a multi-model ensemble probability forecast, where weights assigned to the individual models are based on historical hindcast performance using prescribed, observed SST for the season and location. In addition, GFDL's coupled model sea surface temperature (SST) predictions are now being used at IRI in two ways: 1) As part of the plume of SST forecasts for the Nino 3.4 region, and 2) By being combined with other coupled model SST predictions to enhance the SST forcing fields used by all of the AGCMs in the IRI MME seasonal prediction system. Results are posted at the [IRI website](#). The IRI MME provides guidance for the Climate Prediction Center (CPC) operational long lead forecasts. Recently, GFDL has begun contributing to the US National Multi-Model Ensemble ([NMME](#)), an experimental multi-model seasonal forecasting system consisting of coupled models from US modeling centers including NOAA/NCEP, NOAA/GFDL, IRI, NCAR, and NASA.

Real-time seasonal forecasts over North America are also available at GFDL's website (<http://gfdl.noaa.gov/seasonal-to-interannual-experimental-predictions>), as is a description of GFDL's Seasonal Forecast System (http://gfdl.noaa.gov/SI_Exp_Predictions).

GFDL's Hurricane Forecast System

The dynamical model used in the prediction system is an outgrowth of a research model, the construction of which began in 1970 at GFDL. The research model was used in a number of idealized numerical experiments and produced results that demonstrated a high degree of simulation capability. The performance of the research model suggested a substantial potential benefit from application of the model to forecasting real tropical cyclones.

The work to convert the research model to a comprehensive prediction system started in the mid-1980s. The prediction capability of the GFDL hurricane model was first investigated using global analysis data of the National Centers for Environmental Prediction (NCEP) for cases of Hurricane Gloria 1985. The results were quite promising and indicated that a prediction system had to include a model initialization process, in addition to a process to link the model with the database. During the early 1990s, the model showed substantial improvement over the available operational track guidance, notably by successfully forecasting the sharp recurving of Hurricane Emily near the North Carolina Outer Banks. The model was transferred to NCEP in 1994 for a parallel mode test. Intensive effort was made in this step to improve throughput efficiency so that the system would meet a demand that the entire procedure for making a 72-h prediction be completed in less than 20 min. Prompted by the skill demonstrated by the system in the 1994 season, NOAA's National Weather Service (NWS) officially adopted the GFDL system in 1995 for use as a guidance tool for hurricane prediction.

Since that time, continuous improvements have included coupling the atmospheric component with the Princeton Ocean Model, which became operational in 2001, major physics upgrades implemented in 2003 and 2006, and increases in both the vertical resolution in 2003 and the horizontal resolution in 2002 and 2005. During the 2003-2006 seasons, GFDL track errors were the lowest of all the dynamical model guidance available to the NWS Tropical Prediction Center in both the Atlantic and eastern Pacific basins. It will also be shown that the GFDL model has exhibited a steady reduction in its intensity errors during the past five years, and can now provide skillful intensity forecasts. The introduction of a cloud microphysics package and an improved air-sea momentum flux parameterization in 2006 led to a significant improvement in the model's reliability and skill for forecasting intensity that occurred in 2006.

Most recently, upgrades to the GFDL prediction system have centered on the version used by the United States Navy and will support this through its end-of-life. GFDL continues to conduct research into the structure and prediction of hurricanes through NOAA's Hurricane Forecast Improvement Project.

Data

Public data sets from GFDL are made available through the [GFDL Data Portal](#). The Data Portal is designed to allow one to download files, display data file attributes, and graphically display the data. One can download complete files via "http" and "ftp" access. One can also display data file attributes that provide information about file contents without having to download the file itself. Continued development of the Live Access Server is ongoing to enhance the ability of a remote user to graphically display the data.

Registration for the GFDL Data Files is free. Users are requested to complete the Registration Form for Public Data Files (found on the right hand menu) when they first begin using the data portal. Information from this form will be used to provide registered users with news on when additional public data becomes available and when corrections are made to existing public data. The information gathered will not be used for any purposes other than to send notices about GFDL Data Portal Services.

The data files on the data portal are stored in netCDF (network Common Data Form). The files are intended to be compliant with the COARDS conventions for the standardization of netCDF files.

From March 2006 through February 2014, the GFDL Data Portal has served 2,590,000 requests for files, roughly 2,440,000 via HTTP the rest via FTP to 6,950 distinct hosts. These requests were for 840,000 distinct files (a "distinct file" is a distinct file served to a distinct host). These files total 1,120 terabytes of netCDF data. In 2013 alone, GFDL is sending out an average of ~14 TB of data per month, or about 105,000 fulfilled requests monthly.

Simulations

Model output and documentation from a set of multi-century experiments performed using GFDL's CM2.0 and CM2.1 models are available to the public (<http://nomads.gfdl.noaa.gov/CM2.X/>). Data sets accessible from the GFDL Data Portal include those from CM2.X experiments associated with the Intergovernmental Panel on Climate Change's 4th and 5th Assessment Report (IPCC AR4 and AR5 respectively) and the US Climate Change Science Program (US CCSP). A subset of the AR4 data was sent to the Department of Energy's Program for Climate Model Data and Intercomparison (PCMDI), the central data repository in support of the Intergovernmental Panel on Climate Change AR4. The AR5 data is served as a federated dataset through the [CMIP5 Data Access](#) site.

GFDL has been pushing the envelope in high-resolution seasonal prediction, enabling predictions of regional tropical cyclone activity, and temperature and precipitation over land. We have produced the first high-resolution semi-operational seasonal prediction system in the

Nation, with a 50km atmospheric model coupled to a relatively low-resolution ocean model for efficiency. This is among the (if not the) highest resolution currently being used in the world. We are making these predictions available to the NWS and world every month through the [NMME](#). Experimental long-lead time predictions of seasonal hurricane activity using a hybrid statistical dynamical technique are publicly available at the [website for the Hybrid Hurricane Forecast System \(HyHuFS\)](#).

Real-time seasonal forecasts over North America are available at GFDL's website (<http://gfdl.noaa.gov/seasonal-to-interannual-experimental-predictions>) as a research product.

Presentations

GFDL scientists share their findings and results through active participation at national and international conferences. On the pages that follow is a table of GFDL paid talks and posters at various conferences and workshops, all during Fiscal Year 2013:

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GFDL-paid Talks -- Invited and Not-Invited				
DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
9/23/2013	Ginoux, Paul	Modeling anthropogenic dust: a new approach	12th International Aerocom Conference	Hamburg, Germany
9/17/2013	Bewtra, Ron	Chief information officers council	Brief CIO Council and other meetings in HQ	Silver Spring, MD
9/16/2013	Harris, Lucas	High-resolution and enhanced-resolution modeling at GFDL	Seminar at University of Albany, Dept. of Earth and Atmospheric Sciences	Albany, NY
9/10/13 - 9/13/13	Stock, Charles	The response of marine ecosystems to climate forcing: causes and consequences	University of Washington: Climate Change Summer Institute	Friday Harbor, WA
8/12/13 - 8/16/13	Dixon, Keith	Examining the stationary assumption: perfect model experiments & evaluations	NCPP's "Quantitative Evaluation of Downscaling" workshop	Boulder, CO
8/6/2013	Sentman, Lori	Reducing uncertainty in the global carbon cycle from land use application: implications for initialized earth system models	Advanced Studies Program (ASP) at NCAR	Boulder, CO
7/30/13 - 8/1/13	Vecchi, Gabriel	Construction, visualization and verification of ensemble-based predictions from sub-second to ISI timescales	Environmental Satellite Processing Center and National Unified Operational Prediction Capability Workshops	San Diego, CA
7/31/2013	Knutson, Tom	The global warming hiatus: perspectives from the CMIP5 multi-model ensemble	National Academics Ocean Sciences Board	Monmouth, NJ
7/25/2013	Stock, Charles	Climate change and conservation of marine species: bridging the gap between ecology, climate science and policy	International Congress for Conservation Biology (ICCB)	Baltimore, MD
7/17/13 - 7/18/13	Delworth, Thomas	Dynamics and impact	US AMOC/UK RAPID International Science Meeting	Baltimore, MD

GFDL-paid Talks -- Invited and Not-Invited				
DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
7/16/13 - 7/19/13	Delworth, Thomas	Hemispheric-scale impacts of centennial-scale AMOC variations in the GFDL CM2.5 high-resolution couple model	US AMOC/UK RAPID International Science Meeting	Baltimore, MD
7/1/13 - 7/3/13	Knutson, Tom	Multi-decadal assessment of trends in regional surface temperature and Arctic Sea ice extent	International Detection/Attribution Group (IDAG)	Boulder, CO
6/10/13 - 6/11/13	Stern, William	Representation of tropical intra-seasonal activity in climate prediction GCMs at GFDL and assessing sensitivity to resolution, coupling, convective parameterization and initialization	Nature of the MJO at George Mason University	Fairfax, VA
5/27/13-5/31/13	Westley, Marian	Development of a web-based document repository on ocean fertilization	London Convention Scientific Groups Meeting	Buenos Aires, Argentina
5/29/2013	Knutson, Tom	Dynamical downscaling projections of late 21st century Atlantic hurricane activity: CMIP3 and CMIP5 model-based scenarios	Northeast Tropical Conference	Rensselaerville, NY
5/21/13 - 5/23/13	Hallberg, Robert	"Resolution-dependent eddy parametrizations for large-scale ocean models" and "sensitivity of 21st century steric sea level rise to ocean model formulation"	2013 Layered Ocean Model Workshop	Ann Arbor, MI
5/21/2013	Ramaswamy, V.	Anthropogenic weakening of Asian monsoon	WMO Norbert Gerbier-Mumm Award Ceremony	Geneva, Switzerland
5/13/2013	Ming, Yi	Reconciling the observed surface temperature and precipitation trends in the satellite era	AGU Meeting of the Americas	Cancun, Mexico
5/6/2013	Siebers, Bernie	Review of AOU-reproducibility's and data issues at GFDL	IEEE Mass Storage Conference	Long Beach, CA

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DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
5/1/2013	Ginoux, Paul	Dust from agriculture and natural sources: Implications for air quality and climate	Stony Brook University	Long Island, NY
4/26/2013	Knutson, Tom	The Science of climate change	Jacksonville Presbyterian Church	Jacksonville, NJ
4/16/2013	Donner, Leo	Biases and errors in physical parameterizations: new issues raised by the first-generation treatments of cloud-aerosol interactions in GCMs	Working group on numerical experimentation 4th Workshop on Systematic Errors in Weather and Climate Models	Exeter, United Kingdom
4/2/2013	Bewtra, Ron	High performance computing at NOAA	Dell High Performance Workshop	Philadelphia, PA
3/28/2013	Dunne, John	Heat stress reduces labor capacity under climate warning	Seminar at NOAA Headquarters	Silver Spring, MD
3/28/2013	Ramaswamy, V.	Modeling of regional climate	National Academics- Board on Atmospheric Sciences and Climate	Silver Spring, MD
3/20/13 - 3/22/13	Vecchi, Gabriel	High-resolution models for prediction and projection	Climate 2013	Berkeley, CA
3/5/2013	Lin, Shian-Jiann	GFDL's unified regional-global non-hydrostatic modeling system	2013 Tropical Cyclone Research Forum	College Park, MD
2/27/2013	Harris, Lucas	Grid refinement in the GFDL HiRam: stretched and nested grid	SIAM Conference on Computational Science and Engineering	Boston, MA
2/22/2013	Vecchi, Gabriel	Predicting and projecting hurricane activity	Lamont Doherty Earth Observatory	Palisades, NY
2/17/2013	Stock, Charles	Global-scale carbon and energy flows through the planktonics food web: an analysis with a coupled physical - biological model	2013 Aquatic Sciences Meeting	New Orleans, LA

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DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
2/15/2013	Griffies, Stephen	Sea level in a suite of global ocean-ice models	WCRP	Sydney, Australia
2/5/2013	Wittenberg, Andrew	ENSO diversity in the GFDL coupled GCMs	ENSO Diversity Workshop	Boulder, CO
1/29/13 - 1/31/13	Stock, Charles	Connecting ecosystems and climate progress and challenges	NOAA Leadership/NOAA Science Day	Washington, DC
1/28/2013	Griffies, Stephen	Couple climate modeling with ocean eddies	DRAKKAR Ocean Modeling Meeting	Grenoble, France
1/28/2013	Hallberg, Robert	Resolution dependent parameterizations of ocean eddies	MIT Meeting on the Dynamics of the Southern Ocean	Cambridge, MA
1/22/2013	Donner, Leo	Aerosols, clouds, and climate: the global modeling challenge	University of Pennsylvania	Philadelphia, PA
1/21/2013	Ramaswamy, V.	Climate change in the 20th and 21st centuries	University of New South Wales	Sydney, Australia
1/7/2013	Knutson, Tom	Dynamical downscaling projections of late 21st century Atlantic hurricane activity	AMS Fall Meeting	Austin, TX
1/6/2013	Dixon, Keith	Examining the stationary assumption in statistical downscaling of climate projections: is past performance an indication of future results?	AMS Fall Meeting	Austin, TX
1/6/2013	Golaz, Jean-Christophe	Cloud tunings in a coupled climate model and their impact on 20th century warming	AMS Fall Meeting	Austin, TX
1/6/2013	Knutson, Tom	Multi-model assessment of regional surface temperature trends: CMIP3 vs. CMIP5 historical runs	AMS Fall Meeting	Austin, TX
1/6/2013	Ming, Yi	Nonlocal component of radiative flux perturbation	AMS Fall Meeting	Austin, TX

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DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
1/6/2013	Ramaswamy, V.	Earth system modeling for scientific understanding, information, and applications to climate impacts and predictability	AMS Fall Meeting	Austin, TX
12/17/2012	Golaz, Jean-Christophe	Clouds in the GFDL CM3 global climate model: recent developments	LMD	Paris, France
12/16/2012	Lin, Shian-Jiann	GFDL's unified regional-global modeling system	Frontier in Computational Physics: Modeling the Earth System	Boulder, CO
12/3/12 - 12/7/12	Harris, Lucas	Nested-grid simulations in the GFDL HiRam model	AGU Annual Meeting	San Francisco, CA
12/5/2012	Wittenberg, Andrew	Variation of ENSO teleconnections	AGU Fall Meeting	San Francisco, CA
12/3/2012	Donner, Leo	The aerosol indirect effect in climate models: where is it? Where should it be? Where should it not be?	AGU Fall Meeting	San Francisco, CA
12/3/2012	Dunne, John	Sensitivity of ocean carbon uptake to baseline ocean simulation and circulation Interior biogeochemistry and sediment calcite feedbacks	AGU Fall Meeting	San Francisco, CA
12/3/2012	Ginoux, Paul	Global anthropogenic dust sources associated with agriculture and hydrology	AGU Fall Meeting	San Francisco, CA
12/3/2012	Ming, Yi	Inferring the transient climate response from observed warming	AGU Fall Meeting	San Francisco, CA
12/3/2012	Ramaswamy, V.	Anthropogenic aerosols, climate forcing and climate change	AGU Fall Meeting	San Francisco, CA
12/3/2012	Schwarzkopf, Daniel	The impact of aerosol direct and indirect effects on climate	AGU Fall Meeting	San Francisco, CA
12/3/2012	Wilson, John	Water ice clouds and thermal structure of the Mars atmosphere: observations and modeling	AGU Fall Meeting	San Francisco, CA

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DATES	SPEAKER	TITLE OF PRESENTATION	MEETING	PLACE (CITY)
11/30/2012	Griffies, Stephen	The GFDL modular ocean model	GFDL/NCEP ocean modeling workshop	College Park, MD
11/29/2012	Wilson, John	Modeling of atmospheric rides with the GFDL Mars GCM	Mars Climate Sounder Team Meeting	Pasadena, CA
11/16/2012	Rosati, Anthony	SAB Board	NOAA Climate Test Bed - Science advisory board	College Park, MD
11/11/12-11/16-12	Indiviglio, Frank	"NOAA grid scheduling", "Big data discussion panel" and "Deputy-chair elect extreme large site computing group"	SC12	Salt Lake City, UT
10/29/2012	Donner, Leo	Mesoscale organization associated with deep convection and its representation in global models	DOE Atmospheric System Research Meeting	Rockville, MD
10/17/2012	Delworth, Thomas	Review of mechanisms of decadal to centennial AMOC variability as simulated in climate models	Global Decadal Hydroclimate Predictability, Variability and Change: A Data-Enriched Modeling Study	Palisades, NY
10/17/2012	Zhang, Rong	Atlantic multidecadal variability: internal variability vs. response to external forcing	Atlantic Sector Variability and Change Meeting	Lamont, Palisades, NY
10/8/2012	Ramaswamy, V.	The challenge of understanding trends, variances, and extremes in climate	Yale Climate and Energy Institute Series	New Haven, CT