GFDL Review 2025: Introduction

Dr. V. Ramaswamy, Director

NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY

5-Year Review
January 28-30, 2025

In Memoriam

to those past GFDLers who we have lost in the last 5 years

- Bob Smith
- Lou Umscheid
- Doug Aikin
- Lisa Goddard
- Luis Sal-Bey

WELCOME

To All Our Visitors

(*In-person and Virtual*)

Welcome to our 2025 GFDL Review Panel

Dr. David Considine - NASA *(Chair)*

Dr. Carolyn Reynolds – Naval Research Laboratory (*Vice-Chair*)

Dr. William Collins – Lawrence Berkeley Lab/ Univ. of California, Berkeley

Dr. Elizabeth Barnes – Colorado State University

Dr. Julie McLean – Scripps Institution of Oceanography

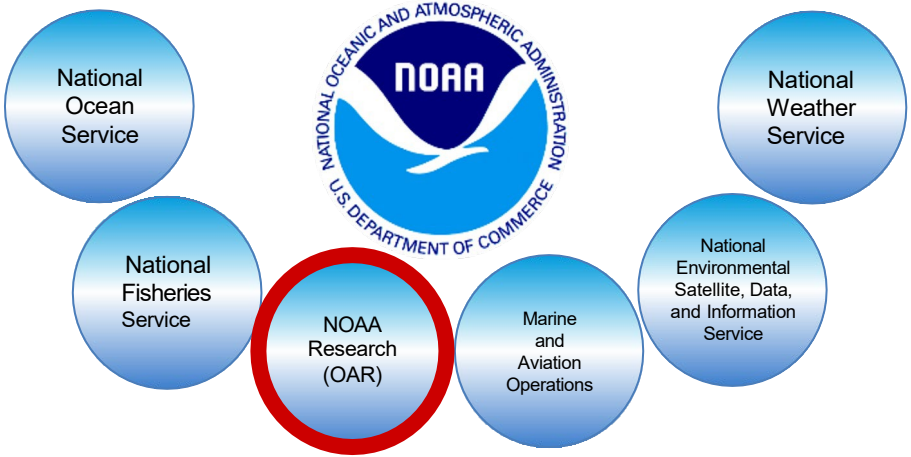
Dr. David Lawrence - National Center for Atmospheric Research

Dr. Joellen Russell – University of Arizona

Dr. Mayra Oyola-Merced – University of Wisconsin, Madison

Dr. Lori Bruhwiler – NOAA Global Monitoring Laboratory

NOAA and OAR: Organization, Mission, Strategic Goals



NOAA's Mission: Science, Service and Stewardship

- To understand and predict changes in climate, weather, ocean and coasts;
- To share that knowledge and information with others; and
- To conserve and manage coastal and marine ecosystems and resources.

NOAA Strategic Goals (2022-2026)

- Build a climate ready nation;
- Make equity central to NOAA mission;
- Accelerate growth in an information-based blue economy.

OAR Mission: Research, Develop, Transition

- Conduct research to understand and predict the Earth system;
- Develop technology to improve NOAA science, service, and stewardship; and
- Transition the results so they are useful to society.

NOAA Research: Goals and Societal Challenges

NOAA Research (2020-2026)

1 Explore the Marine Environment

Increase knowledge of the oceans, coastal areas, and Great Lakes to support resource management and public awareness.

2 Detect Changes in the Ocean and Atmosphere

Produce, analyze, and interpret observation records to understand the Earth system and inform the public.

3 Make Forecasts Better

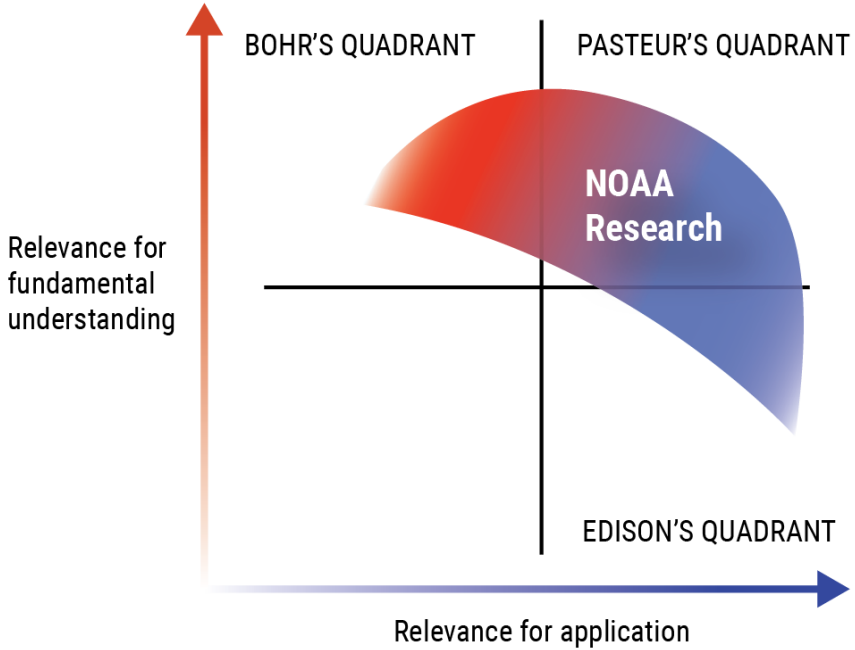
Improve accuracy, precision, and efficiency of forecasts and predictions to save lives and property and support a vibrant economy.

4 Drive Innovative Science

Cultivate and deliver mission-relevant research to lead the environmental science community.

NOAA Research Societal Challenges

NOAA Strategic Research



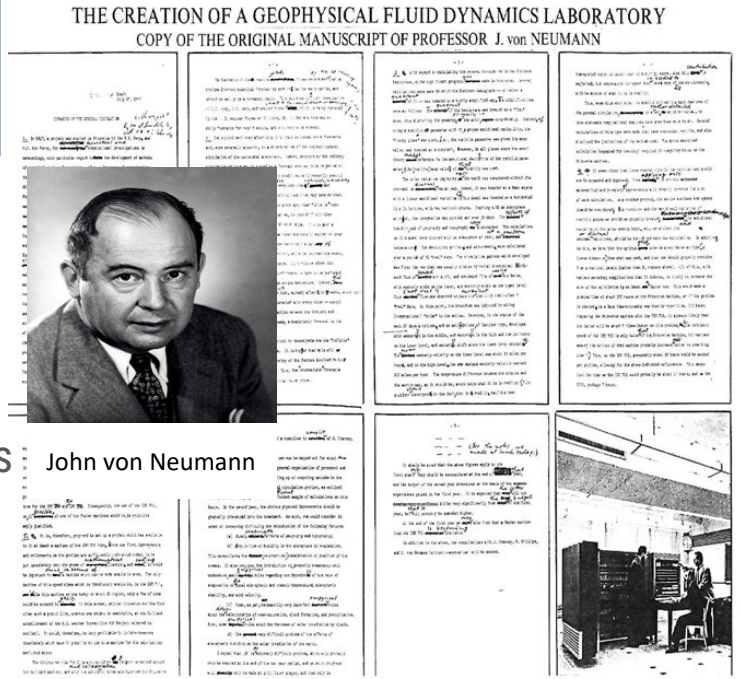
Adapted from Donald Stokes (Woodrow Wilson School, Princeton Univ.):
"Pasteur's Quadrant: Basic Science and Technological Innovation" (1997)

The Creation of GFDL

Platinum Jubilee 2025

July 29, 1955 letter by John von Neumann (Institute for Advanced Study, Princeton), after routine 24-hour numerical forecasting service became possible at the Joint Numerical Weather Prediction Unit:

- "The logical next step is to pass to longer range forecasts and to a determination of the ordinary general circulation of the terrestrial atmosphere."
- Set up project to investigate the **"infinite forecast"** i.e., general circulation or pattern.

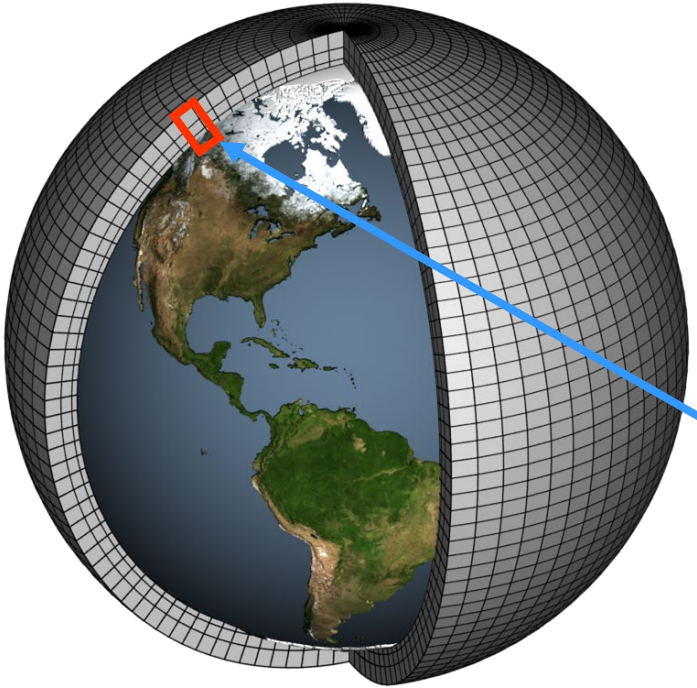


John von Neumann

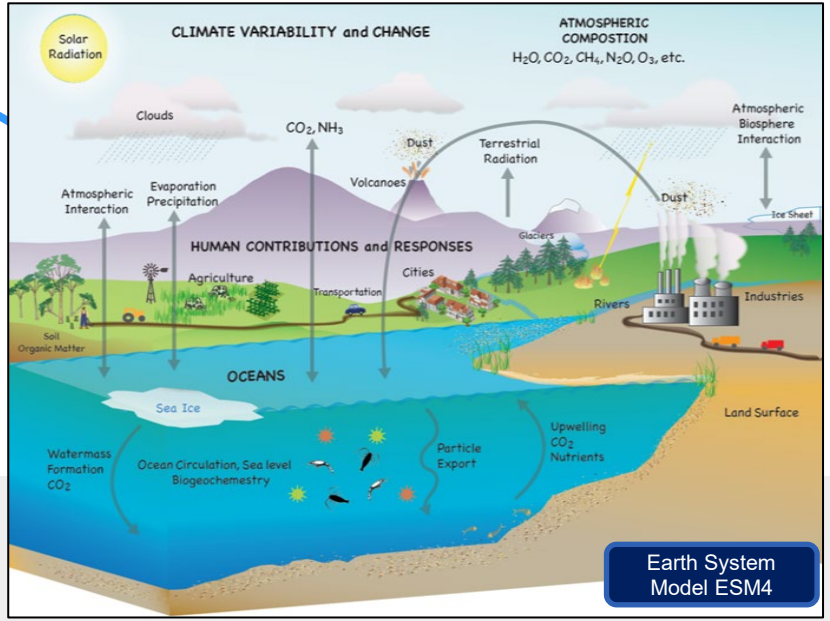
***(Smagorinsky, creation of NOAA in 1970):……investigations of the dynamics and physics of geophysical fluid systems……*mathematical modeling and computer simulation for the behavior and properties of the atmosphere and ocean**

Joseph Smagorinsky, founder and 1st Director, General Circulation Research Lab, 1955 (under US Weather Bureau, then became GFDL after NOAA was formed in 1970).

NOAA/ GFDL Global Climate and Earth System Model



Atmosphere, Oceans, Biosphere, Cryosphere, Ecosystems



Earth System Model ESM4

Dunne, J., et al. (JAMES, 2020)

NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY

GFDL Vision and Mission (formulated by Lab in 2023-2024)

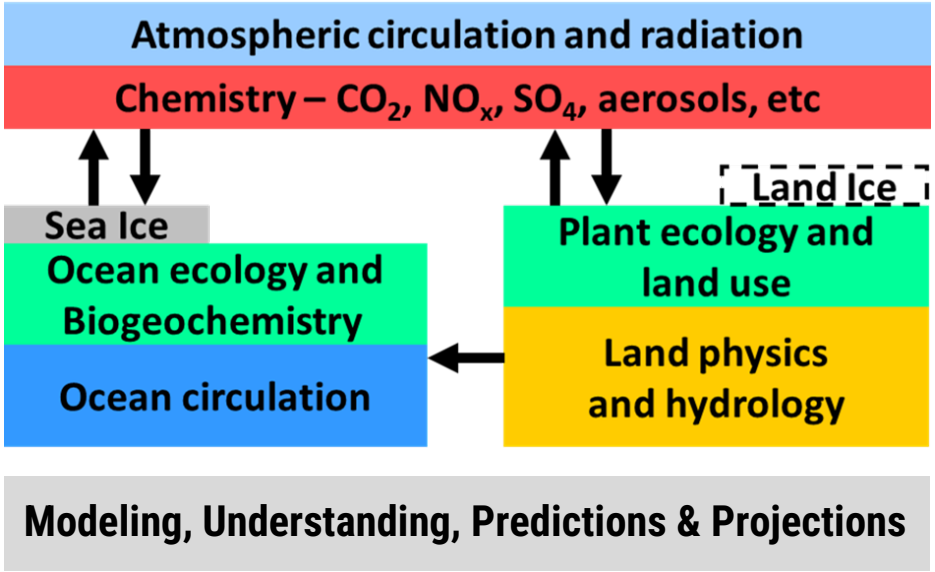
Vision: Healthy ecosystems and climate-and weather-ready communities and economies enabled by trusted and actionable earth system science.

Mission: To advance the scientific understanding, predictions and projections of the climate and earth system, and inform policy and decision-making through comprehensive computational modeling covering weather to climate timescales.

Computational Aspects

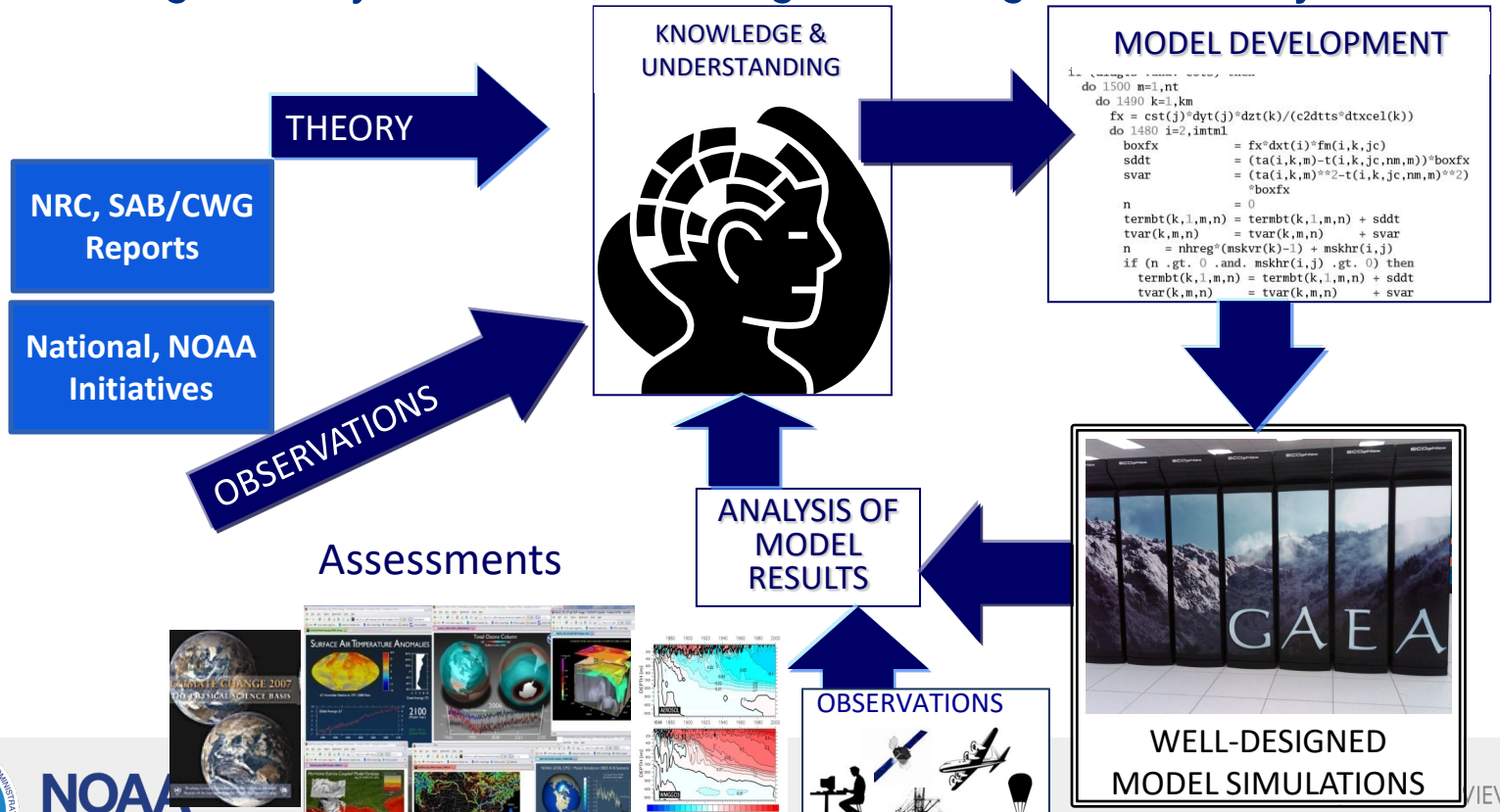
Models need to:

1. Be Realistic
2. Be Efficient
3. Quantify uncertainties

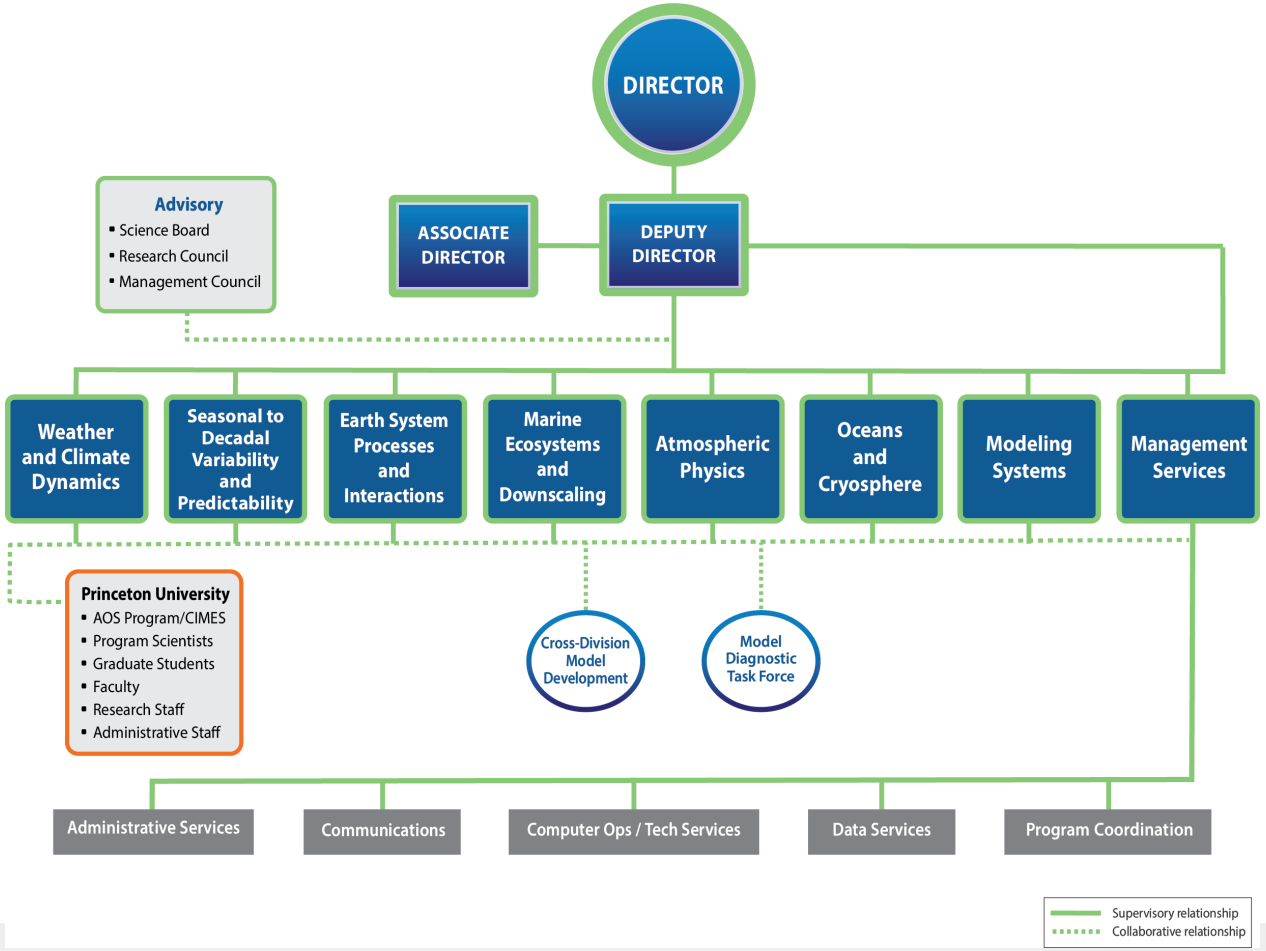


Planning, Execution, Results, Lessons

→ advancing Earth System science through modeling → NOAA Objectives



GFDL Community:
108 Federal
45 Contractors
128 CIMES/UCAR



Cooperative Institute for Modeling the Earth System (CIMES) at Princeton University (CIMES reviewed by NOAA, January 2023)

2024 CIMES Summer Interns

A vibrant, synergistic, sustained and productive relationship since 1968 resulting in:

- 10 GFDL scientists on Atmospheric and Oceanic Sciences Program Faculty, teaching, mentors on Ph.D. committees.
- 14 Ph.D. thesis (since 2019), 120 Ph.D. degrees awarded.
- 11 long-term CI scientists in key portfolios at GFDL.
- 456 Visiting Scientists since inception.
- 66 Summer Internships and 10 Faculty Exchange Fellowships including from Minority Serving Institutions (MSIs).
- Other Princeton University interactions (Geosciences, HMEI, Astrophysics, Physics, Engineering, Applied Math, Ecology, Public & International Affairs, Comp. Science, Precision Health).

Excerpts from 2019 5-10year Science Plan

GFDL model suite employs common components including the atmospheric dynamical core FV3, the Modular Ocean Model MOM6, the LM4 land model and the SIS2 sea-ice model, built upon the **Flexible Modeling System (FMS)** common infrastructure.

FMS computational and software infrastructure is the **basis for the unified modeling concept** - from weather to climate timescales. FMS-based components **contribute to community-wide weather and climate models**. They provide the basis for understanding Earth System processes and for developing a seamless prediction capability across timescales.

Exploration of innovative ways to support community model development; harness the **power of Machine Learning**; and adapt to the **rapid evolution of HPC** (e.g., novel architectures, GPUs).

Excerpts from 2019 5-10 year Science Plan

GFDL's efforts, enabled by models and observations, are organized into 4 areas: 1) *atmospheric, oceanic, biospheric and cryospheric processes*; 2) *biogeochemical processes*; 3) *weather and climate extremes*; and 4) *climate variability and change*.

By enhancing both the *realism* and *comprehensiveness* of its prediction tools, GFDL is using them to provide skillful, real-time predictions of weather and climate to deliver information on seasonal-to-multidecadal outlooks.

GFDL will push towards the goal of *seamless predictions and projections* by developing new modeling capabilities, improving predictions of high-impact events, and narrowing the gap between potential predictability and realized skill.

2019 Review Findings (excerpts)

- GFDL is in great shape. **Unique aspects** of the Lab: GFDL addresses NOAA's mission goals in weather, climate and earth system modeling.
- Long-standing intellectual capabilities to **address fundamental processes** in climate physics. Meaningful contributions through its Earth System models by **providing societally relevant predictions and projections** consistent with NOAA and OAR missions.
- Personnel combine scientific inquiry with **forward-thinking model development** – a combination that truly sets GFDL apart from other NOAA labs.
- Coupling its scientific and technical expertise with a **team-science approach**, GFDL has produced world-class model products. Components such as FV3 are crucial to NOAA. Open development approach of MOM6 a new strength that can be widely adopted.
- GFDL's progress toward a **unified modeling framework for prediction and projection** an emerging strength.

2019 GFDL Review Recommendations and Response

Recommendation	Action	Progress
R3: Be ready to reach out to outside entities	GFDL will pursue strategic opportunities in the enhancement of its models through community involvement. This will include attempts to identify additional funding streams in OAR and elsewhere to pursue new collaborations with external entities to benefit NOAA mission.	Multiple implementations: **OAR labs, private industry, and international partners**: 1. GFDL-initiated **Global Nested model** proposal funded by NOAA (from FY22) ➔ funding for other OAR labs ➔ collaborative weather modeling. 2. Collaboration with the **Allen Institute for Artificial Intelligence (AI2)** ➔ treatment of moist processes using ML techniques in SHiELD model. Also, development of AI-Enhanced and AI-Emulator models. Latest venture: coupled modeling using MOM6 (collaboration with Schmidt Foundation). 3. **Sofar Ocean**: improved coupled data assimilation using high-spatial-density ocean observations for weather forecasts. 4. CPO model diagnostic task force (MDTF) has new diagnostic packages for atmospheric model evaluation, involving the external community. 5. Interactions with **WMO/ WCRP** ➔ GFDL provides decadal climate predictions each year to the UK Met Office (WCRP Decadal Climate Prediction). 6. Leadership role in formulation and execution of Regional Ocean modeling under **NOAA Climate Ecosystems and Fisheries Initiative**. 7. Data to **Amer. Soc. Civil Engineers for analyzing climate impacts**.
R3: Be ready to reach out to outside entities	A plan focusing on stratospheric chemistry, dynamics, and radiation, and their interactions, will be undertaken and used to guide GFDL's future modeling work in the understanding and predictability of weather and climate.	1. An integrative approach synthesizing stratospheric chemistry, dynamics, and radiation under **OAR/CSL Earth Radiation Budget initiative** ➔ upgrade of the Climate model to study the influence of stratospheric aerosols and ozone. 2. GFDL is part of an **NOAA-funded land Climate Process Teams** on Surface Radiation and Coupling of Land And Atmosphere Subgrid Parameterization. 3. NWS/EMC scientists embedded at GFDL for modeling of atmosphere and ocean.
R3: Be ready to reach out to outside entities	GFDL will finalize and publish Fair Use Policy for GFDL model configurations, code, and data to provide clear guidance for collaborators.	**Fair Use Policy** finalized and published in FY21. Co-development of science with partners (Federal, academic).

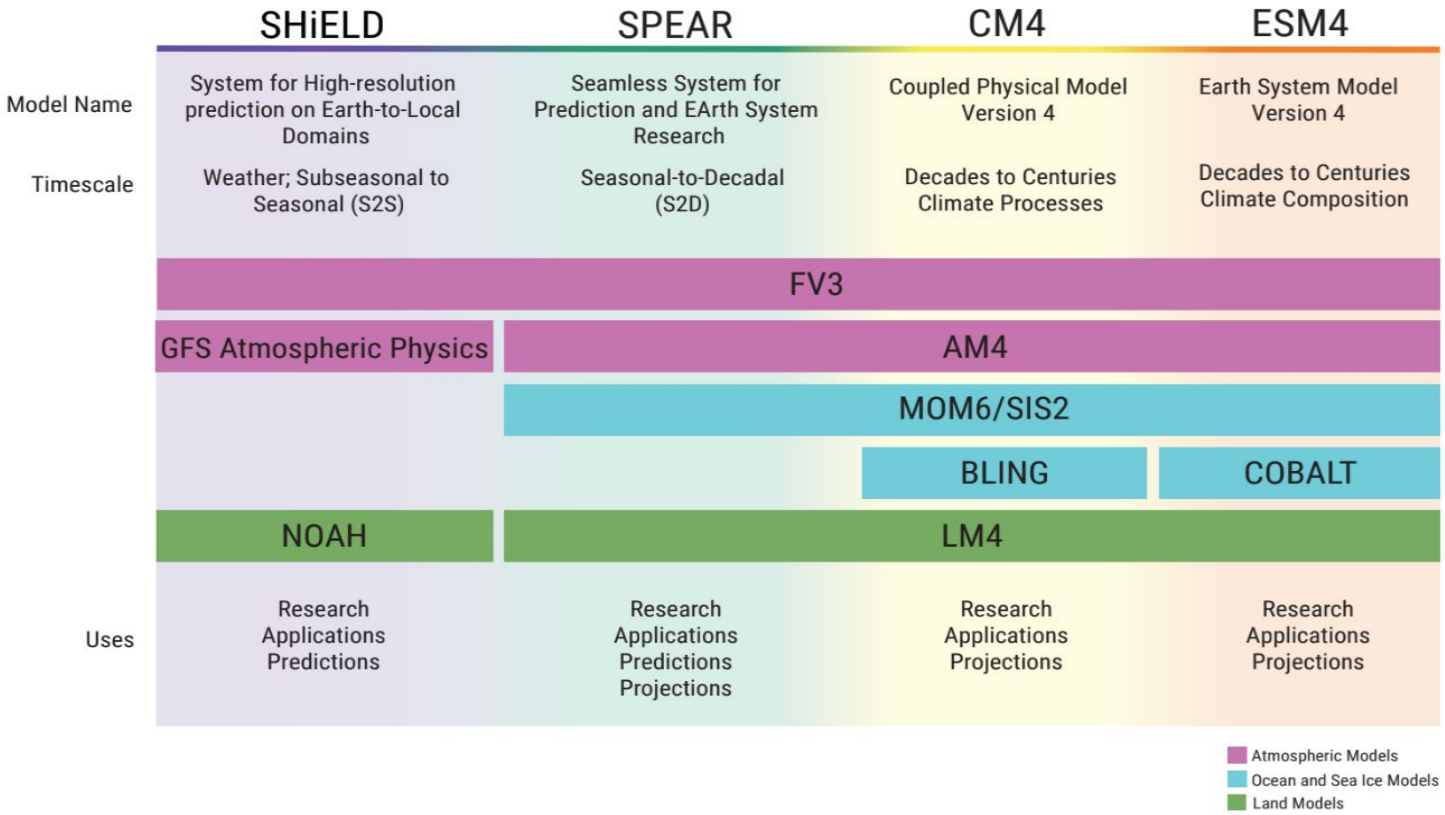
2019 GFDL Review Recommendations and Response

Recommendation	Action	Progress
R4: Increase engagement with other NOAA efforts	Outreach and collaboration with other NOAA efforts, including workshops, will continue to be an ongoing effort.	1. **Joint workshops with AOML and GSL**. Two weather portfolio funded projects with AOML. 2. GFDL co-led development of the Climate and Fisheries Initiative. 3. GFDL participates in NOAA's Earth Radiation Budget Project: Stratospheric Chemistry and Marine Cloud Brightening. ARL effort with LM4 for local scale modeling/observational analysis. 4. GFDL has significantly expanded public availability and **open development of codes and configurations e.g., FV3 and FMS** now have a significant amount of community resources available through their respective web portals and GitHub code repositories. 5. Collaboration with PSL to develop new methods for model-analog predictions. 6. Interactions with **PSL, NCEI, CPC for real-time attribution of climate extremes**. 7. Providing GFDL high-resolution model outputs as **contribution to NOAA ATLAS-15**. 8. Providing SPEAR-simulated **sea-level predictions** to PSL, improve sea-level rise estimate 9. Liaison established between OAR and NESDIS with GFDL scientist a poc in Silver Spring
R5: Define appropriate scope toward model development	Future model development will be based on the recently developed GFDL Science Plan focused on NOAA/OAR objectives and will target key areas, including those articulated in the Review comments, while cognizant of resource and personnel constraints.	1. **Next-Generation Atmospheric Model (AM5)** task force and core development team formed to guide the development of AM5 2. **SPEAR began providing predictions to NOAA/NWS/NMME in March 2021**, replacing FLOR (which was operating since 2015 and continues to be run for specific cases) 3. ESM integrating land, cryosphere and ecosystem. 4. Establish a **cross-OAR capacity** to co-develop and run regional MOM6+BGC. 5. Integrate SHiELD into the FMS Full Coupler ➔ unifying capabilities of SHiELD and AM5 as per the Atmospheric Modeling Task Force. 6. HiFLOR model simulations **contribute to NHC's seasonal hurricane outlook**.
R5: Define appropriate scope toward model development	GFDL will continue to contribute our model components to the UFS as well as weather- and climate- forecast-oriented innovations.	1. Regular **public releases of FV3, FMS, SHiELD** made through public GitHub repositories. 2. Developing NUOPC Cap for **LM4(with dynamic vegetation) for use in UFS**. 3. Establishing NOAA capability to run regional MOM6. 4. With EPIC, developing **ocean/atmosphere coupling** strategy for configurations **in UFS**.

2019 GFDL Review Recommendations and Response

Recommendation	Action	Progress
R7: High Performance Computing (HPC) challenges and opportunities	GFDL will continue to optimize the utilization of current HPC assets via: Code optimization, workflow analysis and improvement, resource management (allocations, quotas), and exploration of new and novel platforms, architectures, and technologies.	GFDL is collaborating with **AI2, NASA, and GSL to port our models to GPU-accelerated supercomputers**, with a focus on the development of the GT4py Domain-Specific Language (DSL) for performance-portability between GPU and traditional CPU architectures.
R7: High Performance Computing (HPC) challenges and opportunities	Creation of a new initiative at GFDL to explore the use of machine learning and artificial intelligence in enhancing GFDL's mission.	GFDL is supporting **AI2 efforts to use Global Storm Resolving Model** and other high-resolution models for ML-corrected and ML-emulated climate model for improved extreme event prediction and projection.
R7: High Performance Computing (HPC) challenges and opportunities	GFDL will explore and invest (pending funding availability) in HPC assets outside of NOAA R&D HPCS, to facilitate external collaborations.	HPC has been procured at **Princeton. "Stellar" HPC** phase one was implemented. This allows us to negotiate firewall issue and barrier to collaborations.

GFDL Principal Current-generation Modeling Configuration



FV3: Finite-Volume Cubed-Sphere Dynamical Core
GFS: Global Forecast System
AM4: Atmospheric Model version 4
MOM6: Modular Ocean Model version 6
SIS2: Sea Ice Simulator version 2
BLING: Biology Light Iron Nutrient and Gas
COBALT: Carbon, Ocean Biogeochemistry and Lower Trophics
NOAH: Noah Land Surface Model
LM4: Land Model version 4

Major Scientific Developments

Foundational science, including new frontiers and novel explorations, leading to:

➔ Applications to challenging scientific problems

➔ Addressing NOAA objectives, including Operational

➔ Information/ Data in the societal context

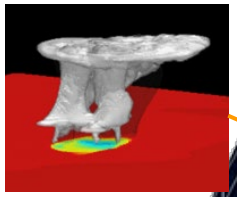
Global-Nested Project → Digital Twin

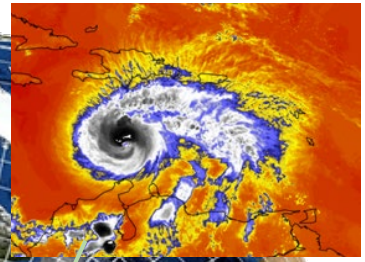
Convective-scale holistic, integrated modeling of weather and climate

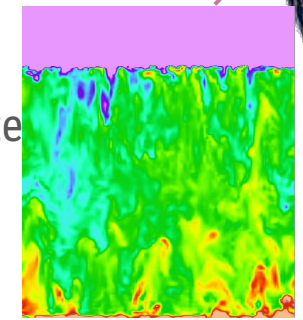
- Global-to-regional CONUS-nested models
- Global Storm Resolving Models (2–5 km) and sub-km

Prediction of extreme events and their impacts →
West coast atmospheric rivers, severe thunderstorm outbreaks, east coast winter storms, hydroclimate extremes, hurricanes

➔ Applicable to changed/warmed climate climate risk and hydroclimate extremes, climate downscaling, and assessment







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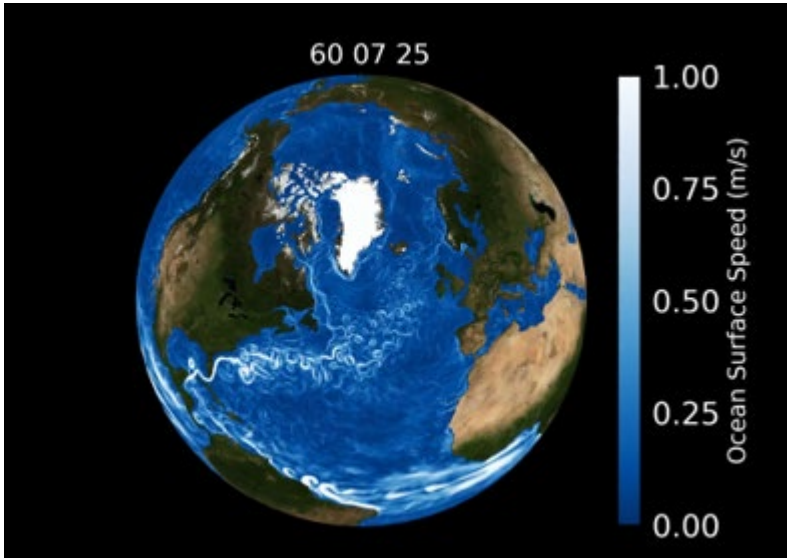
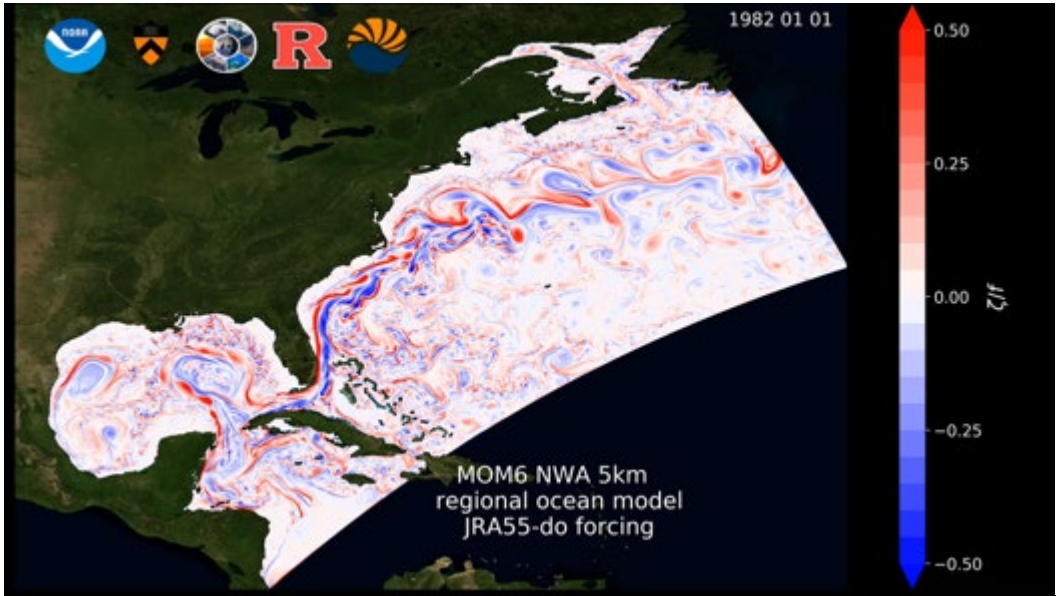
FV3 is the Atmospheric dynamical core (“engine”) of NOAA and NASA models

Oceans, Coasts, and Cryosphere



Modular Ocean Model, v.6 (MOM6): 1/8° (~12km)



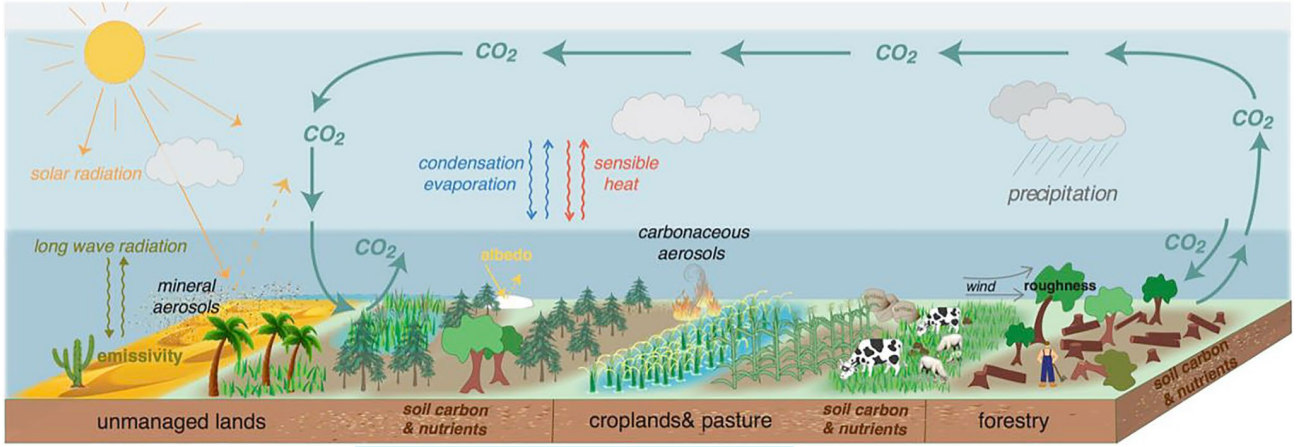
Regional MOM6, Coastal, Ecosystem

Sea level along US coast to rise by 0.3m over the next 3 decades, as much as over the last 100 years.

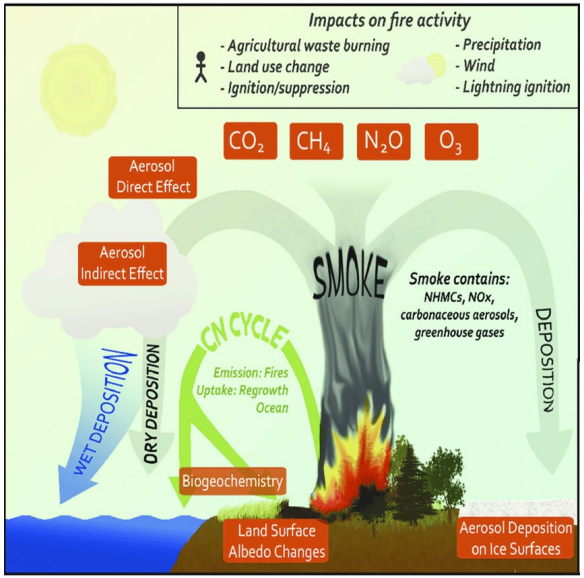
NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY

MOM6 is the Ocean component of NOAA, NCAR and NASA models

GFDL Modeling: Interactions between Atmosphere, Land, and Terrestrial Ecosystem using Land Model LM4



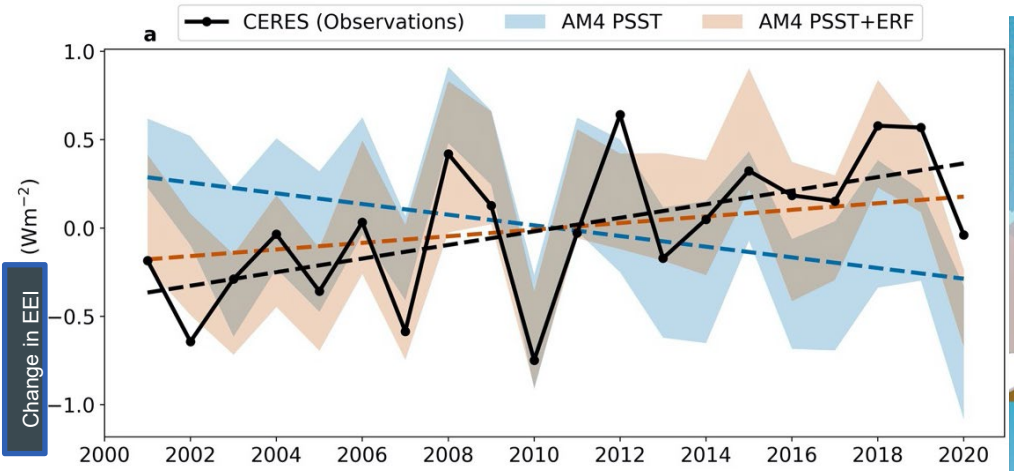
Land – River – Coast



Fires – Weather – Climate

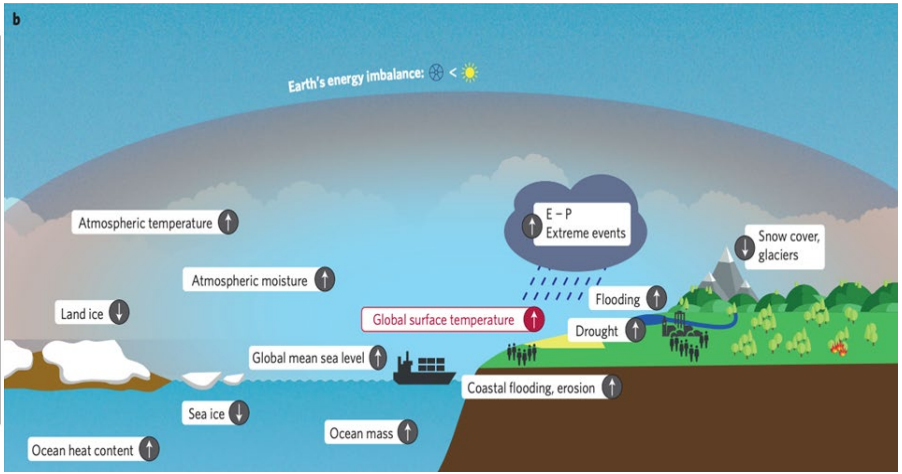
LM4 is land component in NOAA's weather, climate, and earth system models

Earth Radiation Budget: Observed Change and Significance



CERES Satellite-observed trend in Earth's Energy Imbalance (**EEI**) ➔ increase in energy trapped by the Earth system over the past two decades.

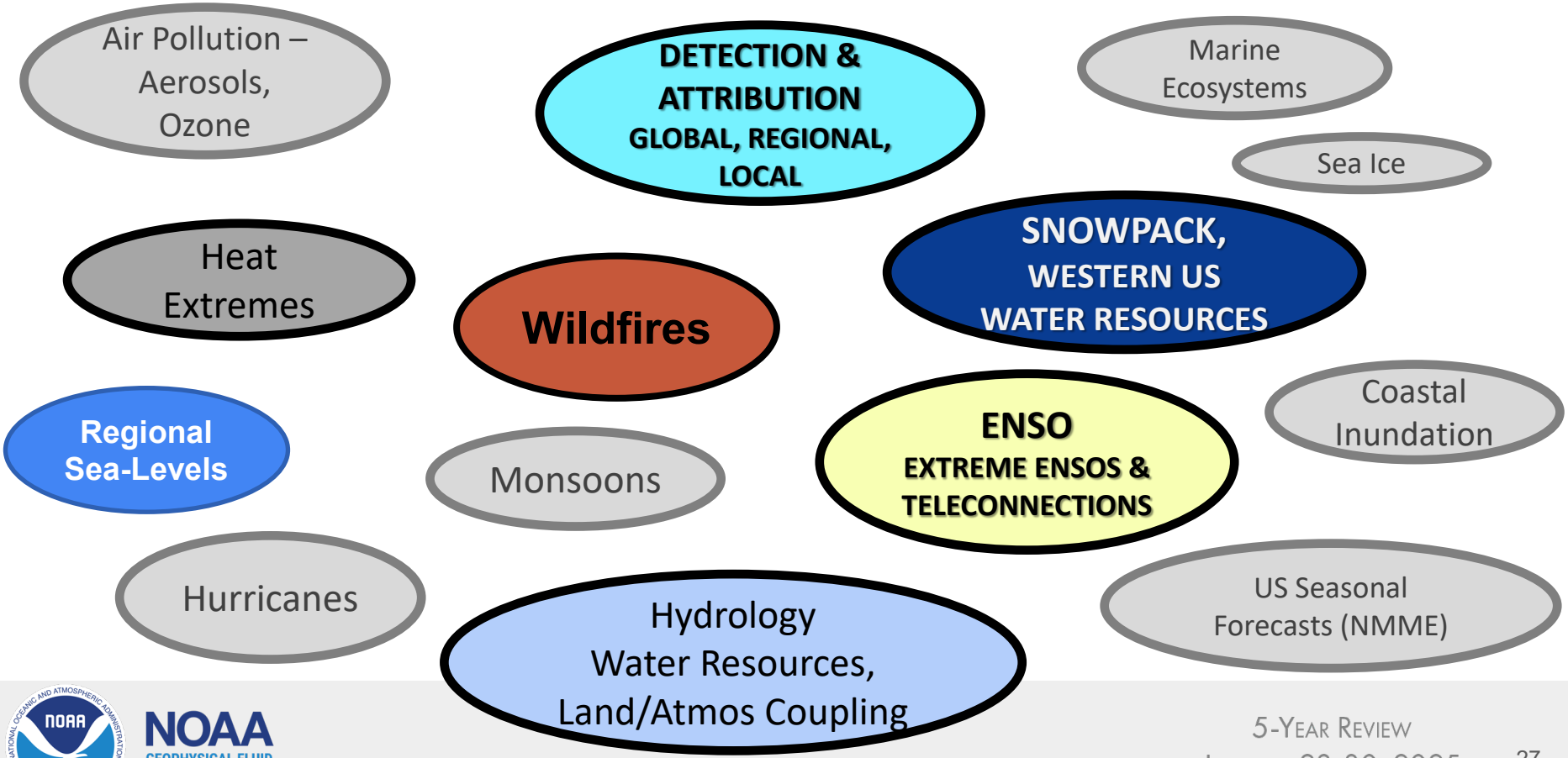
GFDL model results illustrate that **changes in atmospheric composition**, **anthropogenic forcing and feedback** can account for the observed trend.



Increasing imbalance in the radiation budget leads to changes in the climate system.

Raghuraman et al. (Science, 2021)

GFDL model suite ➔Regional extremes and impacts on Seasonal-to-Multidecadal timescales

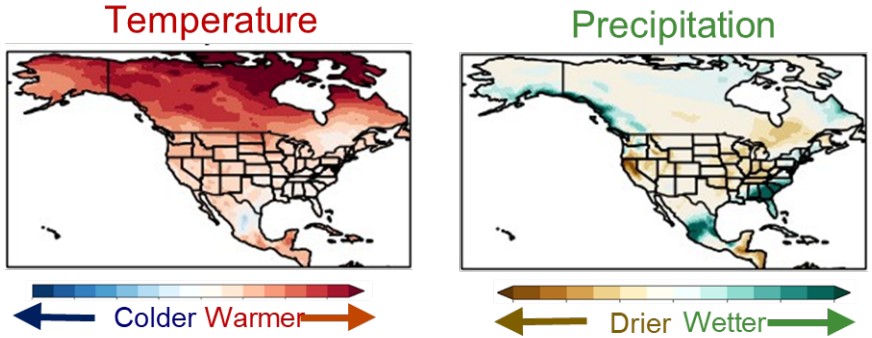


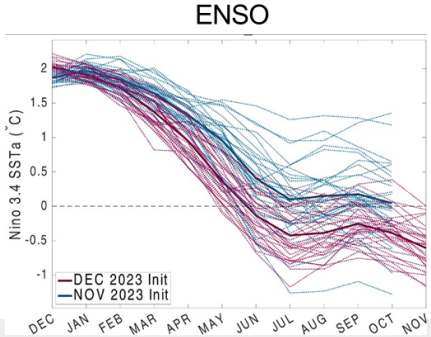
GFDL “SPEAR” model yields real-time seasonal predictions:

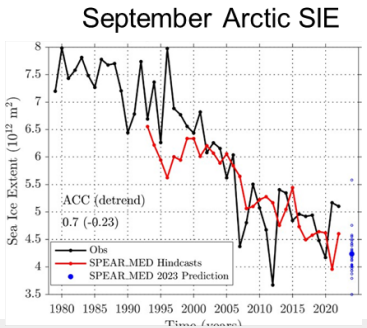
The North American Multi-Model Ensemble (NMME)

- GFDL is one of five centers that produces and delivers experimental seasonal forecasts to NOAA via the NMME.
- GFDL’s SPEAR seasonal forecasts provide guidance for NOAA’s seasonal outlooks.
  - El Niño-Southern Oscillation (ENSO) Outlook
  - Seasonal Temperature and Precipitation Outlooks
  - Atlantic Hurricane Season Outlook
- SPEAR seasonal predictions also contribute to community experimental forecast products (e.g. seasonal sea level and sea ice predictions)
- Ocean reanalysis provided to NCEP for the Multi ocean Reanalysis Intercomparison

SPEAR Predictions (1 Dec Init)
DJF 23/24





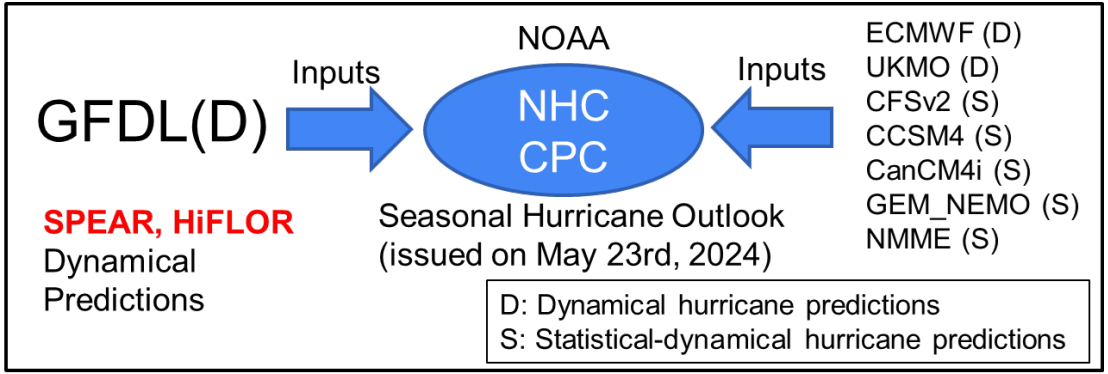


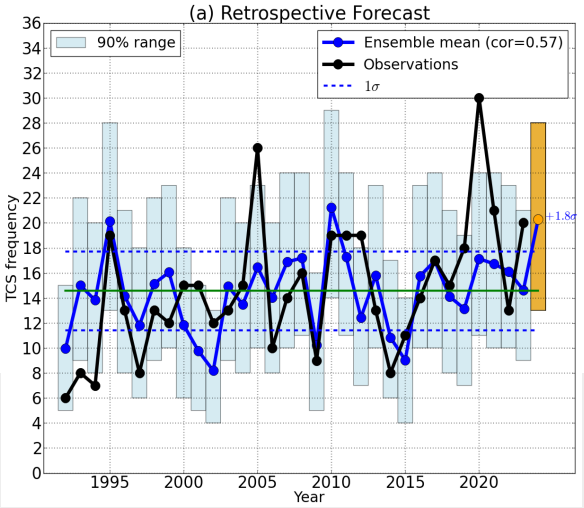
GFDL "SPEAR" Seasonal Hurricane Predictions

- GFDL has been supporting NWS/ NHC,CPC since 2017 for hurricane season outlooks.

- OAR/GFDL is the only U.S. institution that provides **dynamical** hurricane seasonal forecasts.

SPEAR system ALSO delivers climate predictions/ projections from seasonal-to-centennial

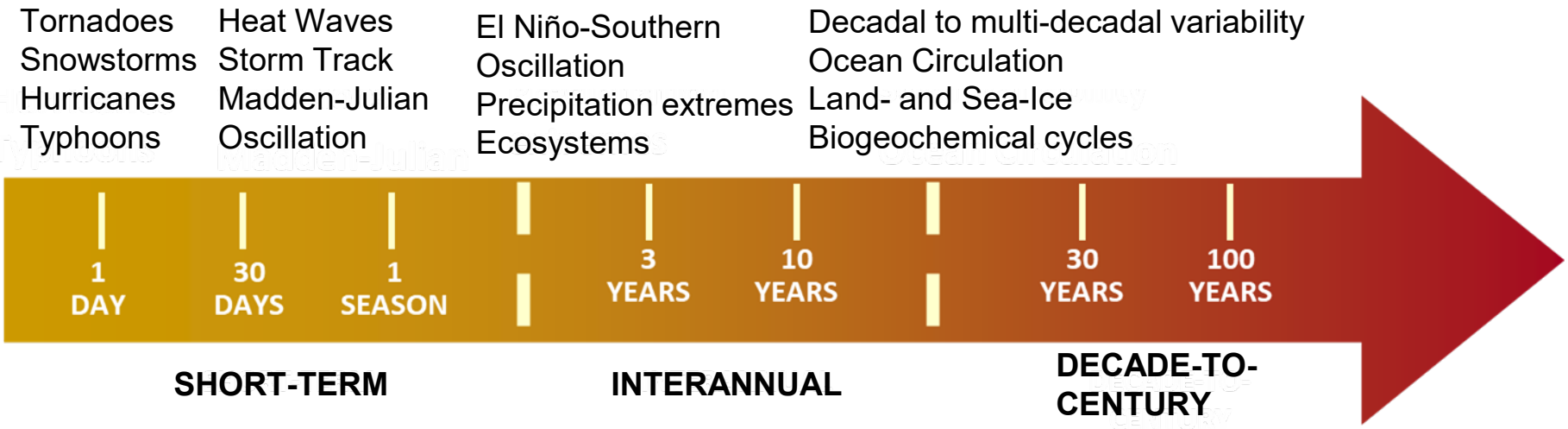




Predicted frequency of named storms in the North Atlantic for the 2024 summer by the GFDL models from the May 1st initial conditions (orange), with indicated uncertainty.

Weather and Climate, including Extremes, in the 21st Century

Seamless modeling system



Weather to Climate a Continuum….

Corrective Machine Learning trained on SHiELD simulation

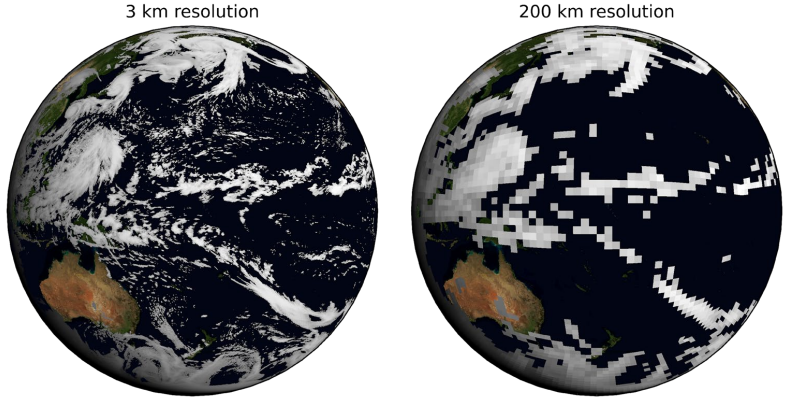
AI2 Climate Modeling + FV3 Team

Train an ML correction to enable 200 km FV3GFS to better track GFDL's 1-year 3 km SHiELD 'digital-twin' reference simulation

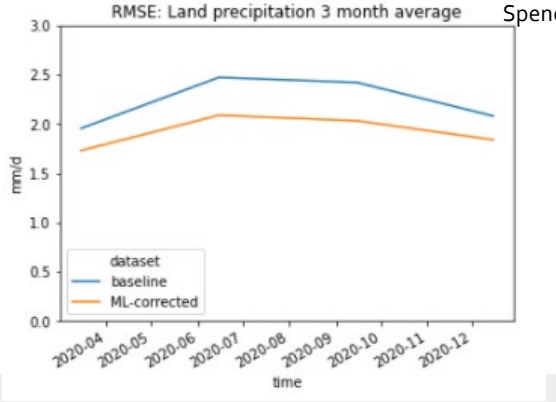
Extends/corroborates a recent study[2] based on shorter 40 day training dataset

Outputs from inline coarse-graining stored to Google Cloud for ML workflow

Year-long simulation including ML correction improves land precip pattern by 15% in all seasons vs. no-ML baseline



Spencer Clark (AI2/GFDL)



Anna Kwa(AI2)

GFDL's Collaborations and Partnerships [External]

NOAA, Other Programs

- **OAR** [All Labs]
- **Other NOAA** [NOS (NCCOS), NWS (EMC, NHC, CPC, NMME (*providing guidance*)), NESDIS (NCEI), NMFS].
- **Climate Process Teams** ["CPTs" on Oceans, Atmosphere, Land]. **WPO** projects [EPIC, UFS]
- **USGCRP** [NCA, National Security WG].
- **Field campaigns** [AEROMMA. NASA-NOAA-FIREX]
- **Modeling & Data** [NOAA (ERB, MAPP); NSF/NCAR; DOE; NASA; Navy; DOD; USGS; Agriculture; EPA; Sea-Ice Pred. Network]
- **UCAR** [CPAESS]
- **Internships** [NOAA (Hollings, NCAS/CREST), Princeton, MPOWIR, EPA]

Academic partners: Rutgers, UW, U. Mich., U. Miami, U. Arizona, CCNY, URI, UC (Berk., Irvine, LA, SB, SC, SD), Harvard, Texas A&M, Penn State, Cornell, UNH, MIT, U. Chicago, NYU, WHOI, Columbia, Florida State, Temple, U. Wis., UIUC, Hawaii, Clemson, CSU, Duke…..

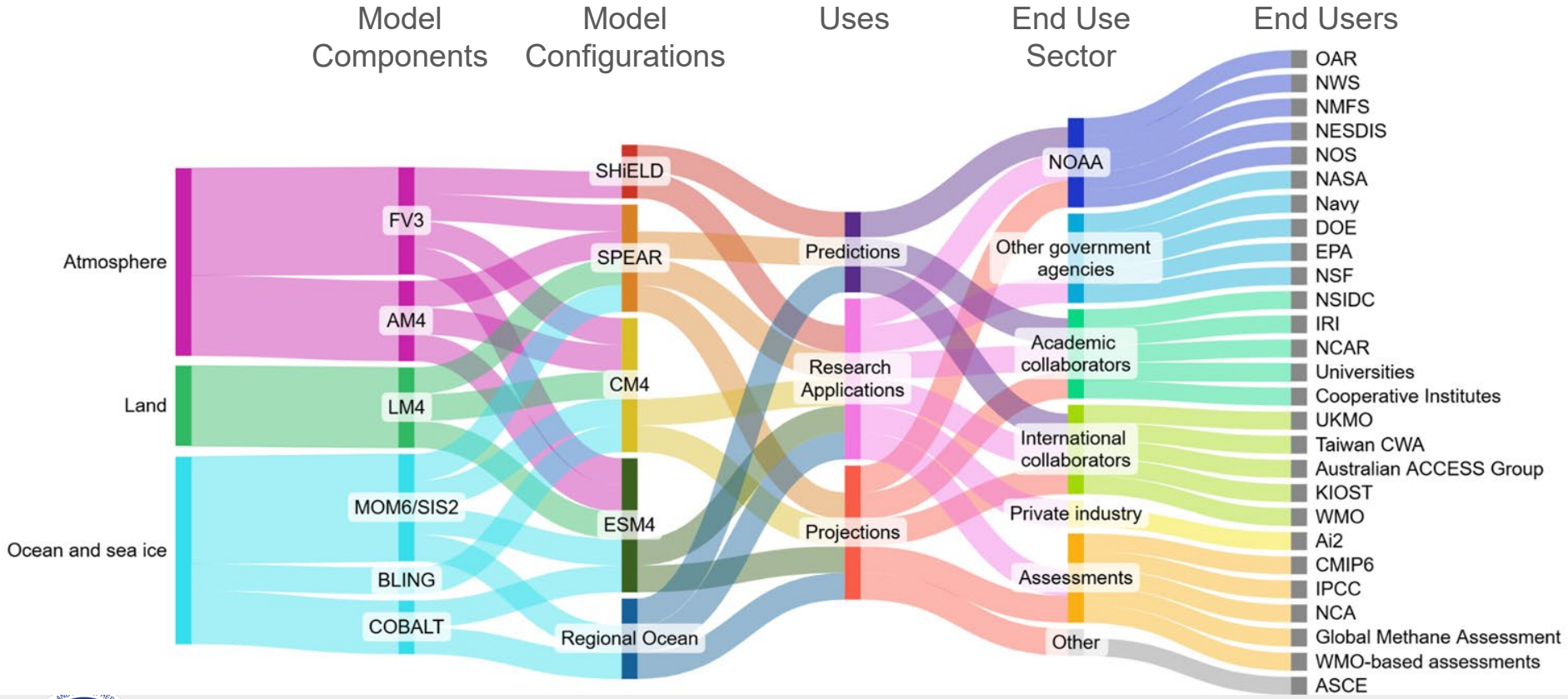
International

- **WMO**: WWRP, WCRP (*CLIVAR, GEWEX, APARC, CLiC*). **WMO, IPCC, TOAR Assessments** [Coordinating Lead Authors, Review Editors]
- **Modeling, simulations, data (governmental and non-governmental)** [Australia, Taiwan, South Korea, Israel, India, Japan, UK, France, Germany, Brazil, Chile, Switzerland]

Private sector

- **AI2**, **Schmidt Science**, AER, **Amer. Soc. Civil Eng, Sofar Ocean**, Nvidia, Microsoft, **NWRA**, Western US Water (Economic Valuation)

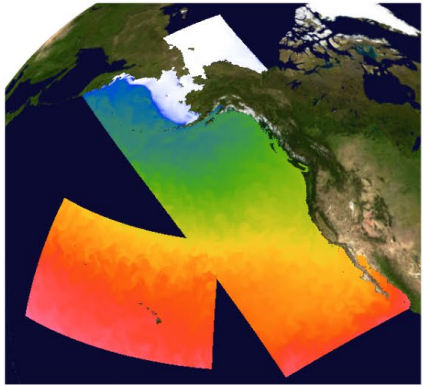
NOAA GFDL Model Application Products (across timescales)



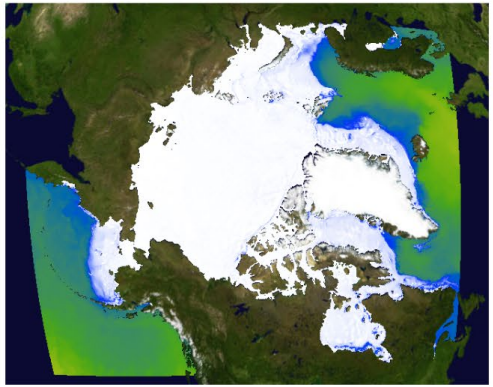
MOM6 Regional Modeling and Marine Ecosystems

Toward a nationally integrated regional ocean/BGC modeling and prediction system to support marine resource decisions - key for NOAA's Climate, Ecosystems, and Fisheries Initiative (CEFI)

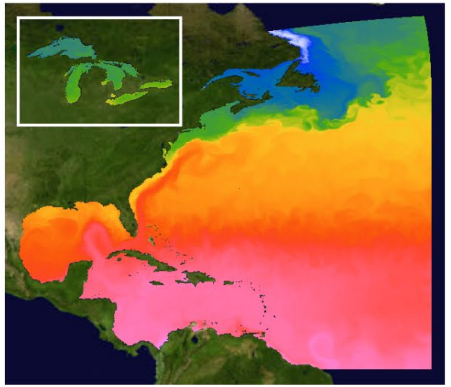
MOM6-NEP

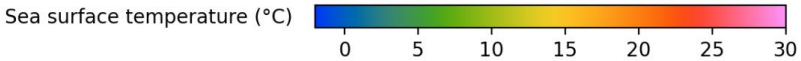


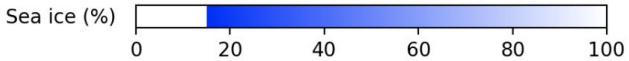
MOM6-Arctic



MOM6-NWA



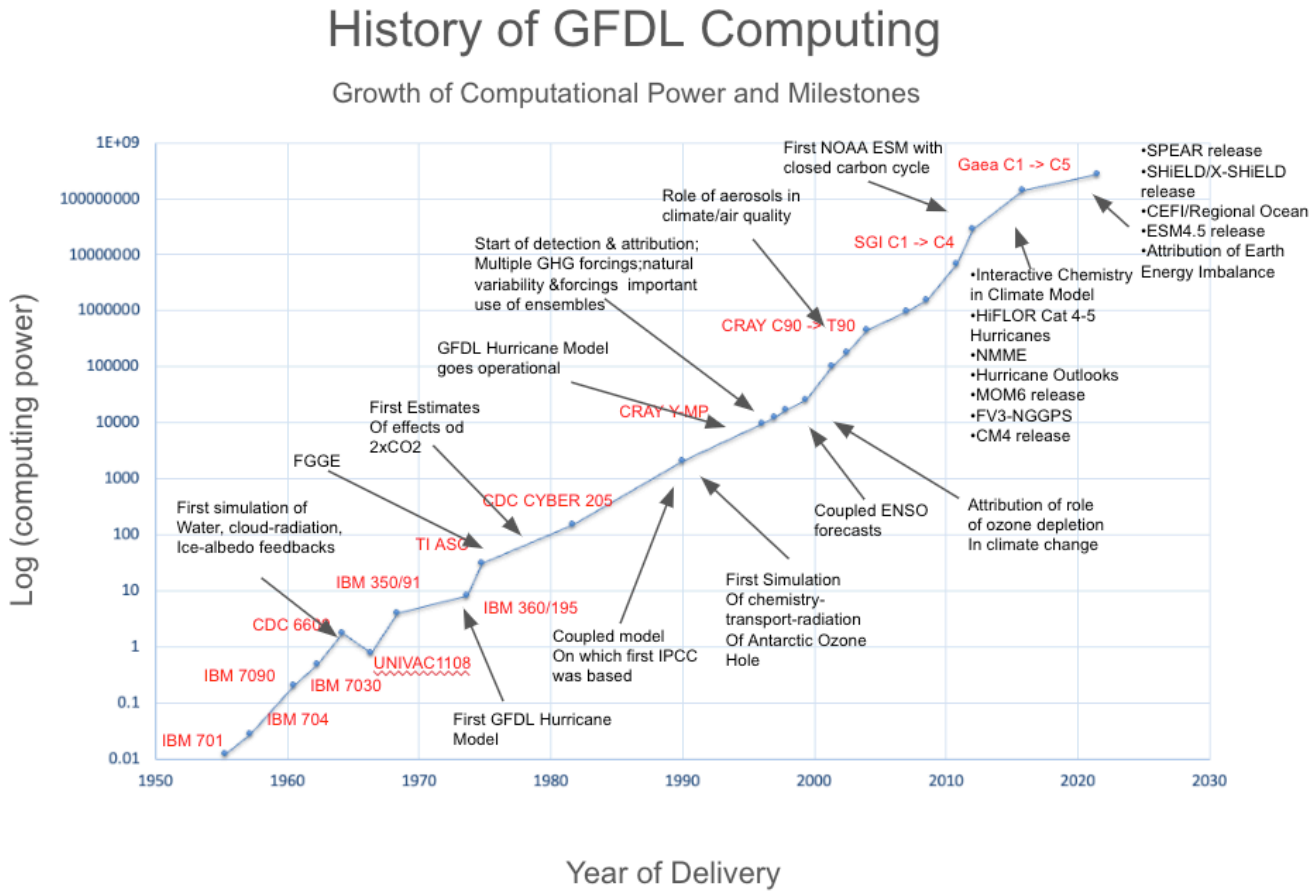




Courtesy Regional MOM6 Team

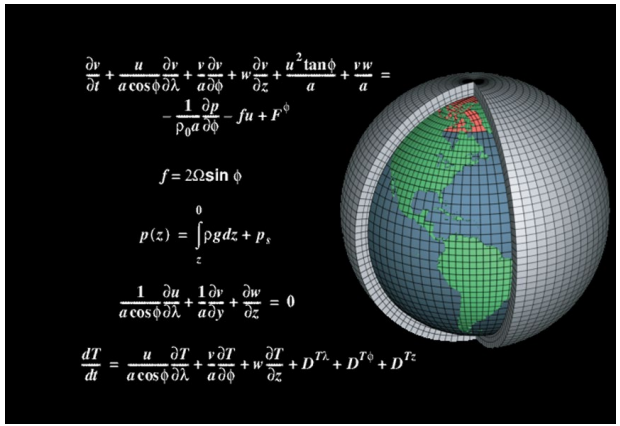
PRINCETON UNIVERSITY
RUTGERS
UNIVERSITY OF ALASKA FAIRBANKS

Sustained Innovation for NOAA's Mission



Modeling of the Earth System on High-Performance Computers

OAR Flexible Modeling System (FMS) → Infrastructure for 20+ years of Earth System Modeling



Fundamental equations applied to the global system.

NOAA's Research and Development HPC "Gaea" located at Oak Ridge National Laboratory in Tennessee

GFDL Throughput and Data Storage

2010:
0.5 petaflop (Pflop*)
80M files on GFDL archive
17.6 petabytes of data

2024:
10+ Pflops
400+ petabytes of data

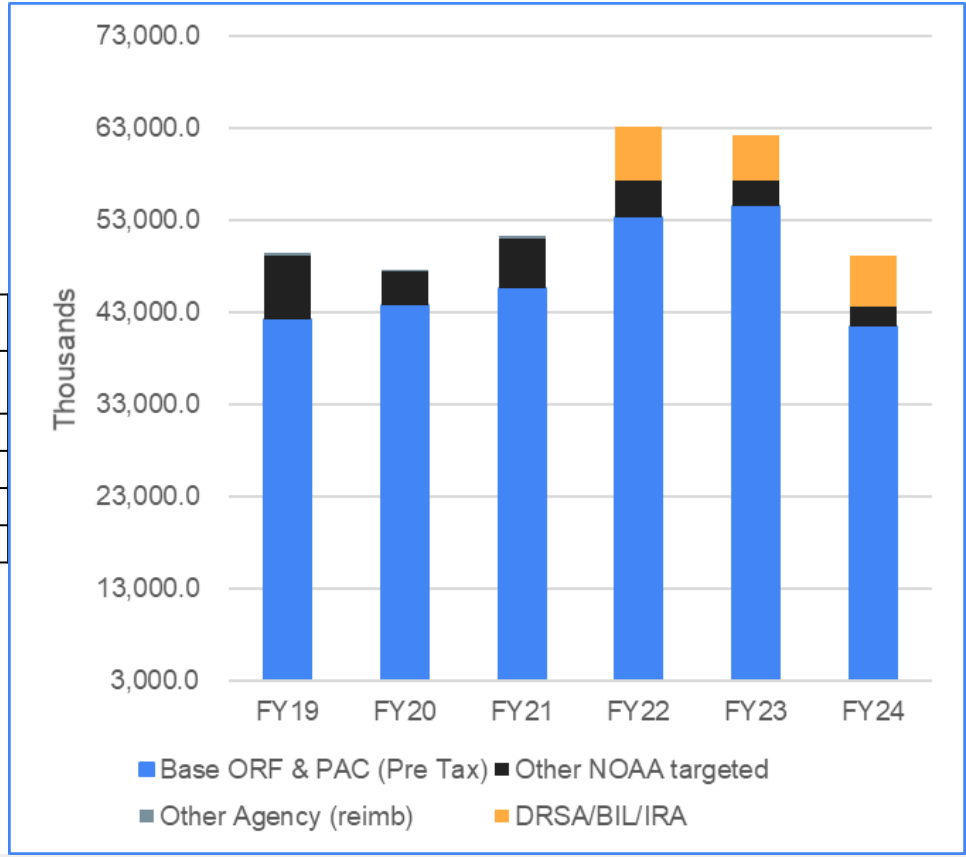
***1 Pflop = 10^{15} calculations/second**

Major Management Accomplishments

- **20-year lease signed between NOAA/GFDL and Princeton University (through 2044)**
- GFDL IT experts performing IT security Assessments for other OAR Labs
- GFDL **Facility Engineer a consultant for OAR building needs and restoration/renovation**
- Major building renovations completed at GFDL
- Formal document on **Manuscript Submission Policy** and Implementation
- **GFDL formulates Data DOI policy and partnership with Princeton University Library to mint Data DOI's**
- Fair Use Policy implemented

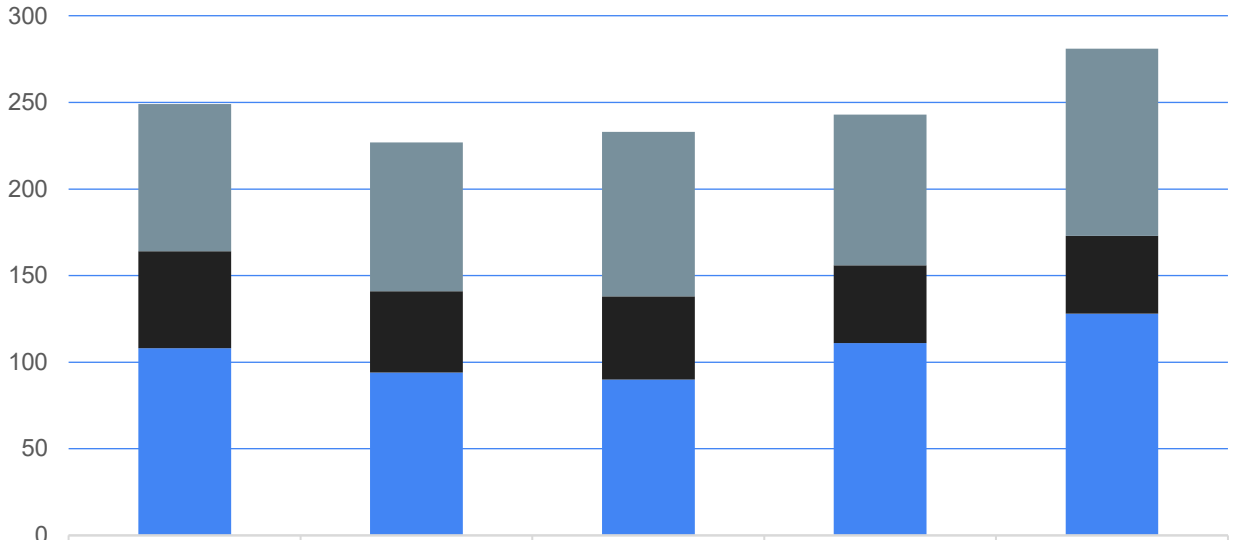
Budget 5 year overview

	FY19	FY20	FY21	FY22	FY23	FY24
Base ORF & PAC (Pre Tax)	42,269.9	43,772.0	45,592.0	53,280.0	54,528.6	41,407.2*
Other NOAA targeted	6,932.0	3,673.8	5,417.0	4,009.0	2,777.0	2,184.7
Other Agency (reimb)	266.5	36.1	302.0	7.0	88.6	-
DRSA/BIL/IRA	-	-	-	5,901.0	4,824.7	5,584.0
Total	49,468.4	47,481.9	51,311.0	63,197.0	62,218.9	49,175.9



*Part of reduction reflects direct external allotments due to BAS challenges

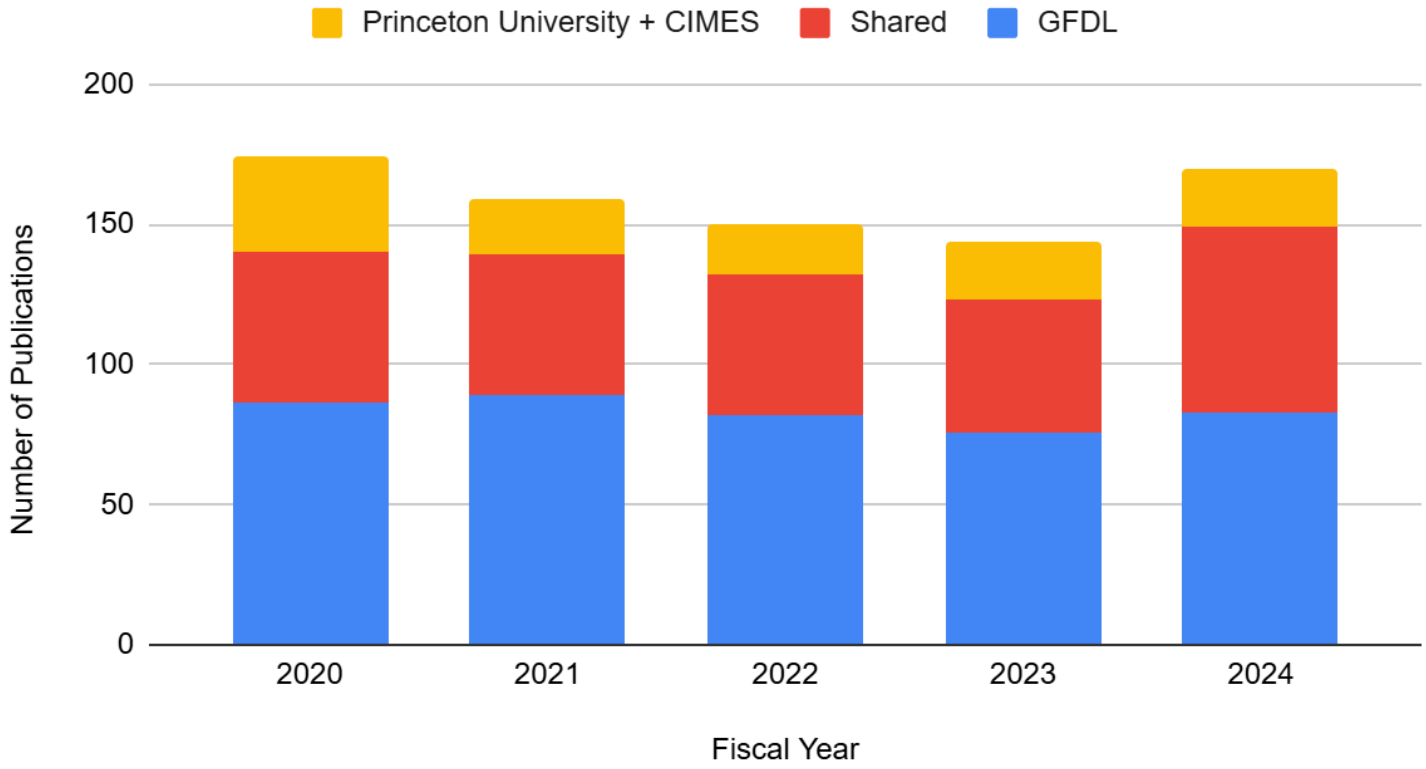
5-Year Staffing Profile



	FY20	FY21	FY22	FY23	FY24
Federal	85	86	95	87	108
Contractor	56	47	48	45	45
CIMES/UCAR	108	94	90	111	128

**Number includes transient persons (postdocs, students, interns, visiting positions, etc.)*

Total Peer-Reviewed Publications



2007 and 2021: NOAA, OAR, GFDL Share in Nobel Prizes

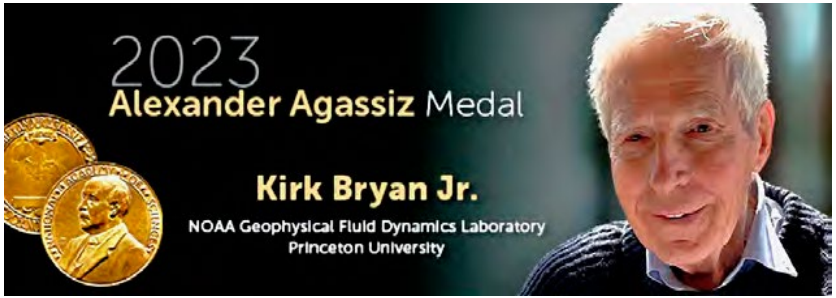
The importance of steady sustained research and robust R2X

2007: The Nobel Peace Prize was awarded jointly to the Intergovernmental Panel on Climate Change (IPCC) and Al Gore Jr. *"for their efforts to build up and disseminate greater knowledge about man-made climate change"*. Scientists from across NOAA worked on the IPCC (1990-2007) climate assessment reports and were recognized as contributing to the 2007 Award including 26 persons from GFDL (most from any NOAA center).

2021: The Nobel Physics Prize was shared by Drs. Syukuro Manabe and Klaus Hasselmann (Germany) *"for the physical modeling of Earth's climate…and reliably predicting global warming"*. Dr. Manabe, currently with Princeton University and a NOAA Affiliate, spent his research career in the US Weather Bureau and then NOAA from 1958 to 1997.

Image: Dr. Syukuro Manabe, pioneer of the mathematical modeling of climate

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.

Honors, Awards, and Recognitions (2019 - present)

NATIONAL

- Presidential Rank Award - Meritorious
- Presidential Rank Award - Distinguished
- Service to America Medal (Finalist)
- National Academy of Engineering
- National Academy of Science
- American Academy of Environmental Engineers and Scientists
- American Association for the Advancement of Science (2)
- AGU-Bert Bolin Award and Lecture
- AGU James R Holton Award
- AGU-Outstanding Review
- AGU-Ocean Sciences Award
- AGU-Atmospheric Sciences Ascent Award (2)
- AGU-Science for Solutions Award
- AGU Outstanding Student Award
- AGU-Outstanding Student Presentation (2)
- AGU-Robert E Horton Medal
- AGU-Fellow (3)
- AGU-Jule Charney Lecture
- AGU-Piers J Sellers Global Environmental Change Mid-Career Award

NATIONAL (con't)

- AMS-Carl-Gustaf Rossby Research Medal
- AMS-Syukuro Manabe Climate Research
- AMS-Best Student Presentation and Poster Award-16th Symposium
- AMS-Bernhard Haurwitz Lecture
- AMS-Henry G. Houghton Award
- American Physical Society - Fellow
- Science Research Honor Society (Sigma Xi)
- Web of Science Group - Highly Cited Researchers (6) 2019
- Governmental Executive Magazine-Theodore Roosevelt Government Leadership Award
- Princeton University-Robert H Socolow Carbon Mitigation Initiative Best Paper Award for Postdoc
- Research.com-Top 1000 Environmental Sciences Worldwide 2020 (14), 2022 (10), 2023 (33)
- Global Biogeochemical Cycles (Certificate of Achievement)
- Clarivate-Highly Cited Researchers 2020 (1), 2022 (6)
- Clarivate Analytics-World's Most Influential Scholars 2023

DOC/NOAA/OAR/GFDL

- DOC Silver Medal (9)
- DOC Bronze Medals (5)
- DOC Class of Sustainability, Energy and Environmental (SEE) Ambassador (2)
- DOC Gold Medal (9)
- NOAA Bronze Medal (4)
- NOAA Administrator Award (25)
- NOAA Distinguished Career (4)
- NOAA 50 Years of Service (2)
- NOAA AGO 2020 HUBZone Small Business of the Year Award (3)
- NOAA Richard H. Hagemeyer Award in Tropical Meteorology
- NOAA Order of Sherman's Lagoon (5)
- OAR Dr. Daniel L. Albritton Outstanding Science Communicator Award
- OAR Employee of the Year (21)
- OAR Team Member of the Year (5)
- OAR EEO/Diversity Award (4)
- GFDL Amy Langenhorst (12)
- Patent & Trademark Office – Climate Science and Prediction

INTERNATIONAL

- 2021 Royal Swedish Academy of Science-Nobel prize in Physics
- Calouste Gulbenkian Foundation-Gulbenkian Price for Humanity (3)
- World Climate Research Programme (2)
- Intergovernmental Panel on Climate Change
- iCACGP-IGAC Joint Conference (early career)
- Korean Society of Oceanography (outstanding thesis)

Challenges in sustaining world-leading science and mission goals (1)

- Taking on the **demanding scientific problems that require long lead-time R&D**, including addressing unresolved and novel issues for applications, operations and service

- Increasing the **realism of models**, with optimization, by:
  - Capturing the comprehensiveness of the system
  - Capturing the regional and, increasingly, local details of the weather and climate system
  - Increased ensemble member integrations

- Characterizing and quantifying the **key scientific uncertainties**

- **Advances in ML/AI techniques – in tandem with advances in foundational modeling** – to increase the accuracy, reliability, trustworthiness, and efficiency of predictions and projections

Challenges in sustaining world-leading science and mission goals (2)

- The necessary **foundational science (including infrastructural)** to underpin NOAA products, data, information.
- Model components utilizing state-of-the-art knowledge, observations (satellite, ground, *in situ*, reanalyses), and available resources ➔ **Credible state-of-the-art models**.
- **Critical diagnostic analyses** from observations and models ➔ publications, assessments ➔ feedbacks with users on the judicious application of observations and model data.
- Meeting **operational needs**, and **major assessment and report** requirements.
- Meeting the increasing **demand for reliable, timely knowledge**, and providing **authoritative, trustworthy information and data** to decision-makers.
- Effective **communication and dissemination of information** through interactions with users, stakeholders and planners.

Challenges in sustaining world-leading science and mission goals (3)

- **Uncertain, unsteady budgets**, especially for critical science developments.
- **Federal-level uncertainties**: shutdown/furlough, shifts in priorities etc.
- Hiring process and time duration (*improving*).
- **Meeting Lab internal and external expectations** (e.g., multiple employers among GFDL community).
- **Foreign Nationals and physical+computing access**.
- **GFDL building is 56 years old**.

- **Computing capacity**. R&D HPC acquisition over-reliant on supplemental funds; timely increases needed in base funding to keep up with science advances and societal demands.
- Maintaining a healthy **Science-Ware TO Computational-Ware** ratio.
- Balancing **short-term demands against rigor+clarity** to deliver actionable R&D information.

Strive for Continued Advancement and Excellence

Recruitment and retention of scientists, administrative and technical/ computational experts, is critical to achieve the NOAA/OAR objectives. GFDL is striving for excellence in four main areas:

- Create opportunities for all **employees to develop new skills and grow into leadership roles**.
- Foster an environment that maintains **high standards of excellence**.
- **Maintain resources (human and computational)** to provide the tools for world-class climate and Earth System research, modeling, predictions, and projections.
- Sustain a **collegial setting for collaborative, team efforts** essential for climate and Earth System R&D, to accomplish the NOAA mission goals and address the OAR-led societal challenges.

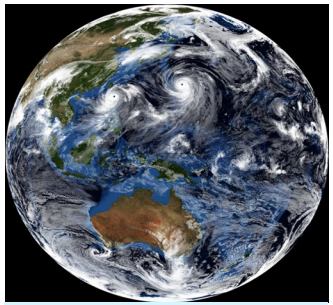
A.I.M. ➔➔ Weather, Climate and Earth System in the 21st Century

Seamless modeling, understanding, and predictions/ projections

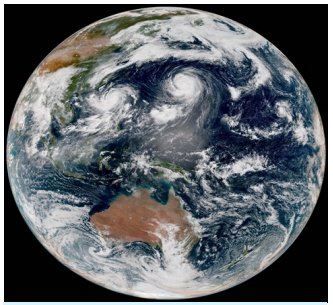
Aspiration

"infinite forecast (von Neumann)"

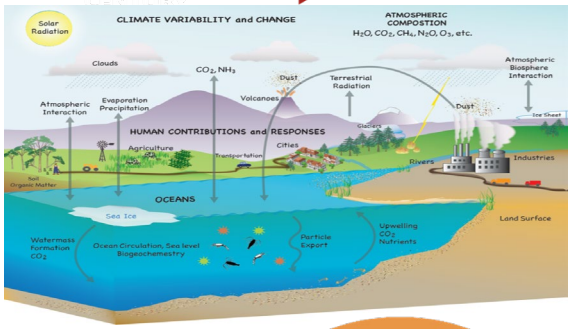
Inspiration



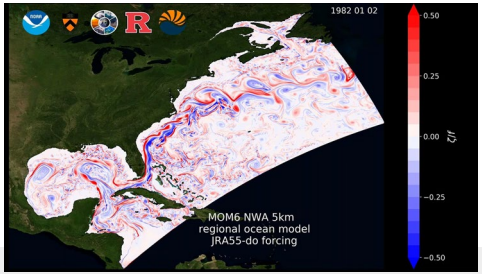
3km model



Himawari satellite



Motivation



NOAA GEOPHYSICAL FLUID DYNAMICS LABORATORY

Acknowledgements

Special thanks to
Lauren Koellermeier (Chair) and Rong Zhang (Vice-Chair) of the Review Organizing Committee

Many thanks to the Members of the Review Organizing Committee and all the Presenters,

AND

to the entire GFDL Community for the superb work over the past 5 years which leads into the reporting and discussions at this Review

AND THE

GFDL Administrative, Facilities, IT, and Operations, for the facilitation

Review Structure

The five-year review agenda is structured around four questions. The five-year review questions are intended to address various aspects of GFDL's mission, science plan, and strategic goals. GFDL's questions are as follows:

Question 1: Concerning GFDL's core strength of building and improving models of the weather, oceans, and climate for societal benefits, how can GFDL leverage advances in science and computational capabilities to improve its key models? What are the strengths, gaps, and new frontiers?

Question 2: Concerning NOAA's key mission element of understanding, predicting, and projecting changes in the Earth System, how can GFDL drive further advances in these areas, including extremes and environmental hazards, through scientific innovation based on observations, theory, and modeling? Where are the strengths, gaps, and new frontiers?

Question 3: How can GFDL research and modeling be further utilized to meet NOAA stakeholder needs and enhance research partnerships to ensure GFDL's success?

Question 4: How can GFDL build on its work environment for the continued pursuit of world-class science? How can GFDL continue to ensure a skilled workforce for its future activities towards NOAA's goals through effective recruitment and retention?

You can find all the presentations presented this week and prerequisite slides here: https://www.gfdl.noaa.gov/2025review/

Thank you for your attention!

Questions?