2019 GFDL Review

State of GFDL

V. Ramaswamy

Geophysical Fluid Dynamics Laboratory Review

October 29-31, 2019

2019 GFDL Review Panel

Review Panel Members

- **Dr. Anjuli S. Bamzai** - National Science Foundation *(Chair)*
- **Dr. L. Ruby Leung** - Pacific Northwest National Laboratory
- **Dr. Masaki Satoh** - The University of Tokyo (Japan)
- **Dr. Christopher Bretherton** - University of Washington
- **Dr. Tatiana Ilyina** – Max Planck Institut für Meteorologie (Germany)
- **Dr. Jean-François Lamarque** - National Center for Atmospheric Research
- **Dr. William Large** - National Center for Atmospheric Research
- **Dr. Shang-Ping Xie** - Scripps Institution of Oceanography
- **Dr. Varavut Limpasuvan** (National Science Foundation)

NOAA Priorities

1. Reduce the impact of extreme weather and water events (Weather Act)

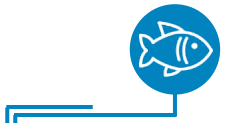
2. Increase the sustainable economic contributions of our fishery and ocean resources (Blue Economy)

OAR's vision, mission and goals

VISION: Deliver NOAA's Future

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

GOALS:



Explore the Marine Environment

Define the characteristics of the ocean, coastal areas, and their resources for mission, management, and knowledge.

Detect Changes in the Ocean & Atmosphere

Produce long-term observation records for NOAA's operational services; to identify changes in the Earth System and understand them.

Make Forecasts Better

Improve accuracy of weather, water, ocean, and climate forecasts and predictions to support a vibrant economy and save lives and property.

Drive Innovative Science

Deliver innovative research to advance NOAA's mission using the unique capabilities of NOAA's research community.

Dedication to BILL LAPENTA [1961-2019]

- **1st to recognize and push, and co-lead the 1st efforts for Integrative Modeling in NOAA synthesizing Weather and Climate efforts.**

- **Initiative to AAs and Chief Scientist (2014) ➔**

"Ram-- forwarding an outcome of our request to Louis and Craig to develop an integrated NOAA modeling strategy under the auspices of the NOAA Chief Scientist Office."

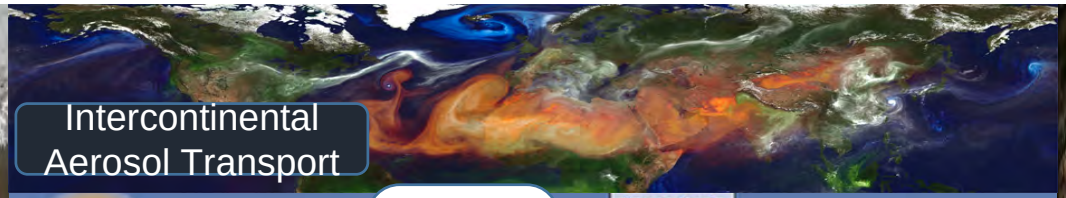
Remembering Our Colleagues

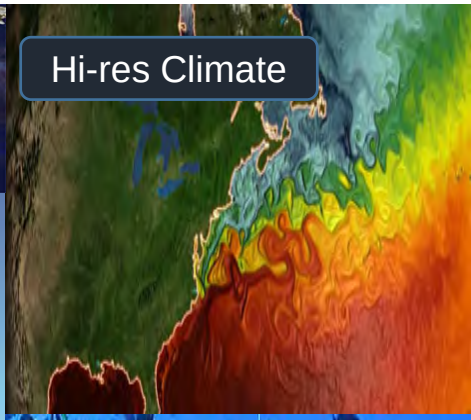
In Memoriam

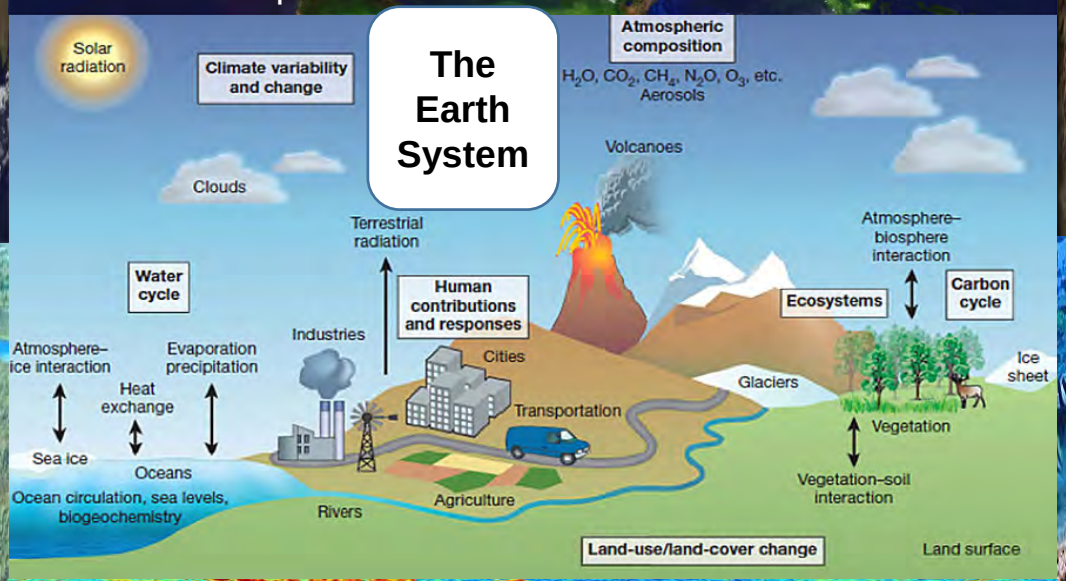
[between 2014 and 2019]

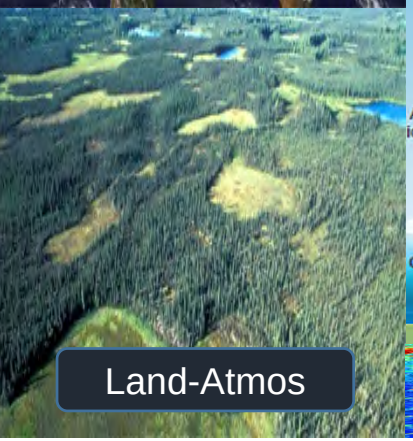
- Johann Callan
- Jean-Rene Emizet
- Joe Hand
- Amy Langenhorst
- Ants Leetmaa
- Kiku Miyakoda
- Esther Olsen
- Richard Patchen
- Gene Rasmusson
- Artem Sarkisiyan
- Joe Sirutis
- Phil Tunison
- John Wahr

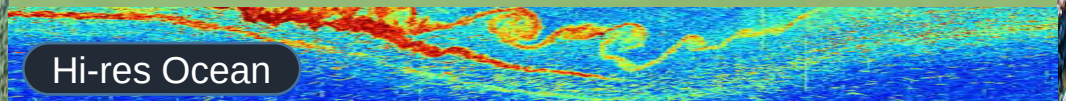
Modeling the Earth System



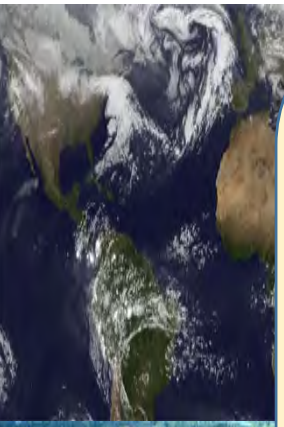


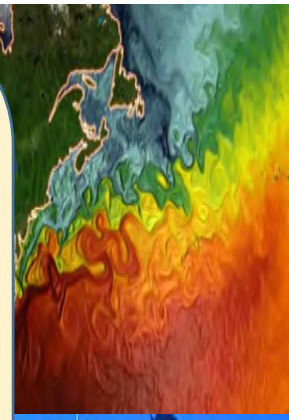






Modeling, Understanding, Predictions/Projections



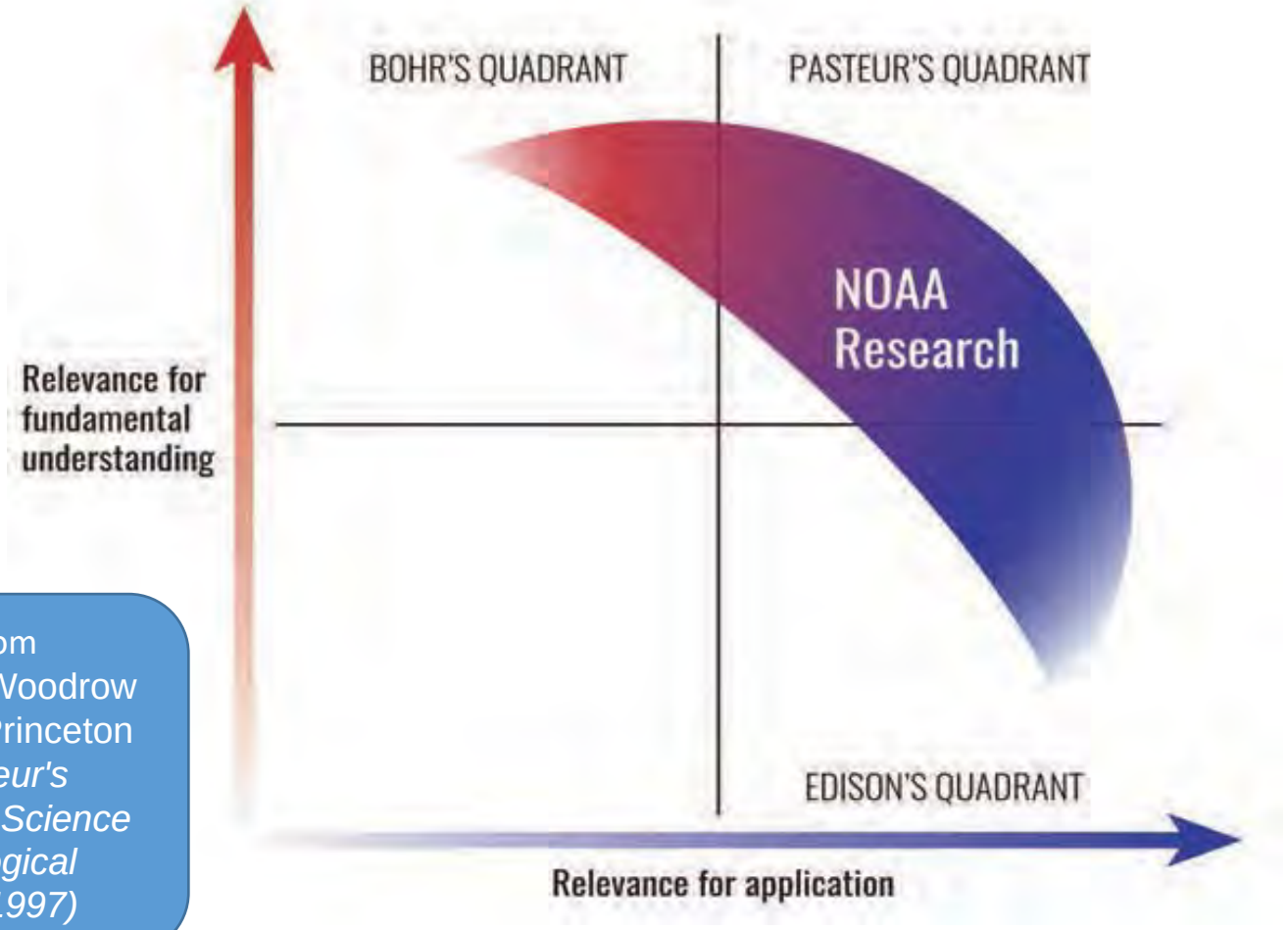



(i) Development of <u>comprehensive, integrated and unified models of the Earth system</u> comprising the atmosphere, oceans, land, biosphere, cryosphere, and ecosystems; and

(ii) <u>Application of these models for the seamless understanding, predictions and projections</u> of the Earth system, from hours to decades and from global-to-regional spatial scales, accounting for natural variations and forced changes.

GFDL Charter (2018)

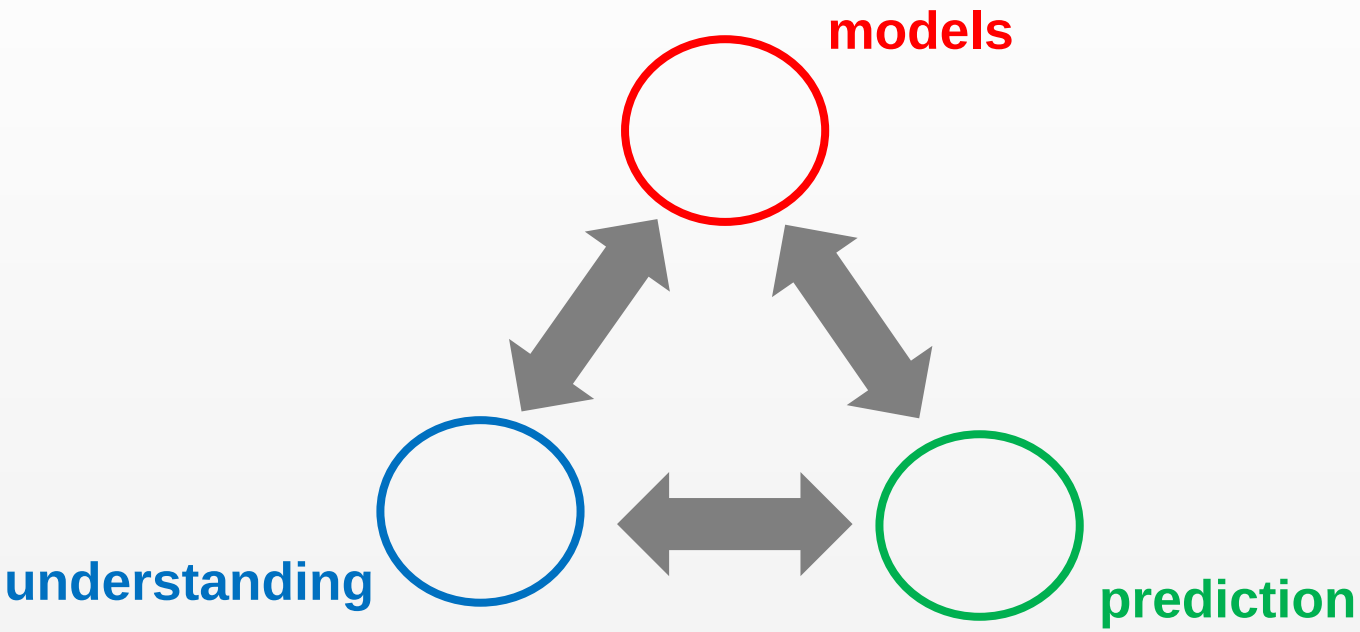
NOAA Strategic Research



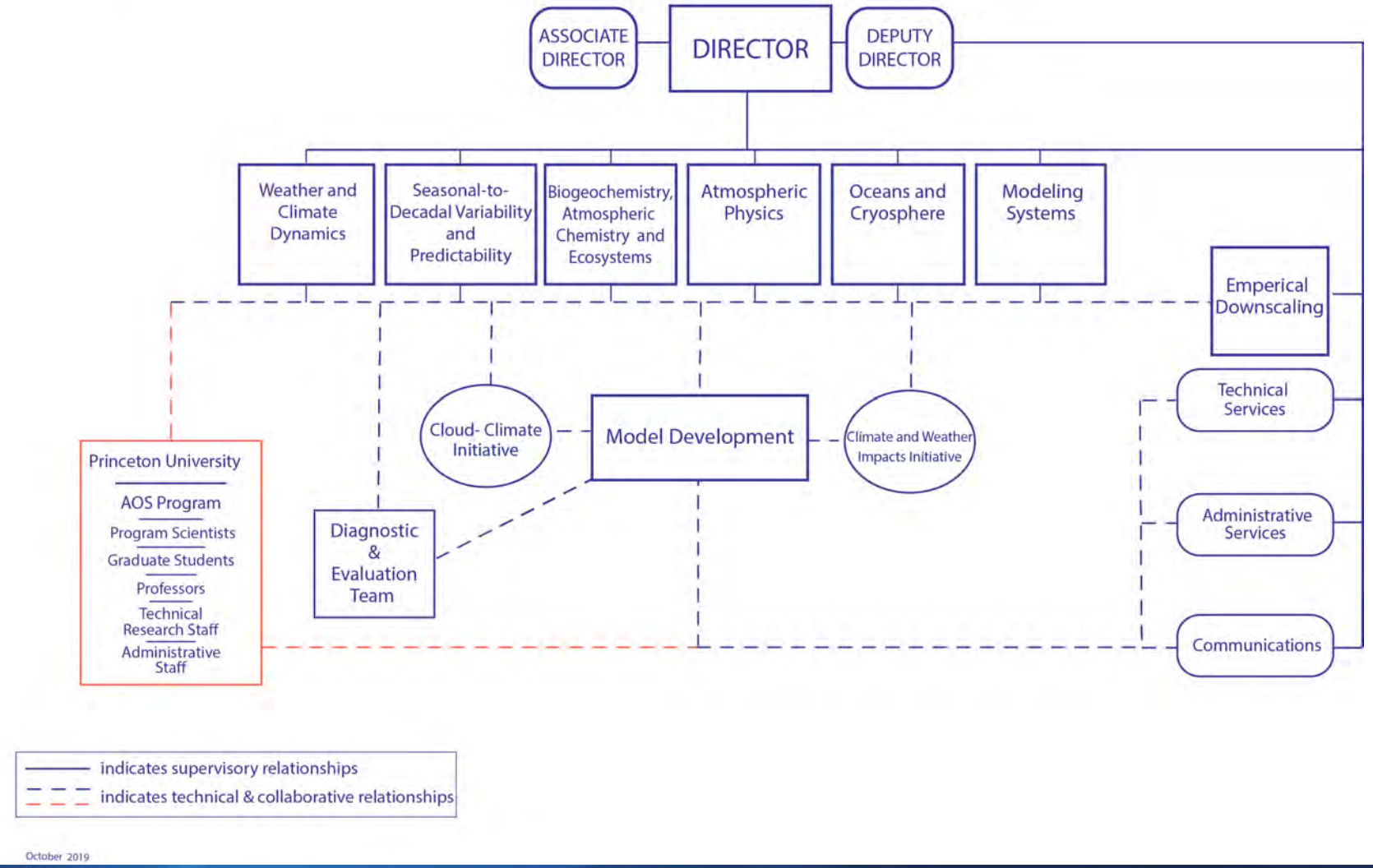
Adapted from Donald Stokes (Woodrow Wilson School, Princeton Univ.): "*Pasteur's Quadrant: Basic Science and Technological Innovation" (1997)*

Session Connections

The 2019 GFDL Strategic Science Plan outlines the use of our new model suite for understanding, predictions, and projections



GFDL Organization Chart



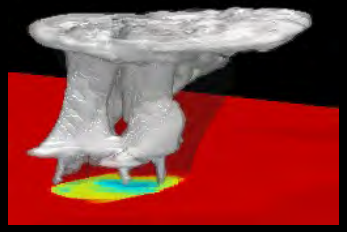
Toward a Unified Weather-Climate Prediction System

50-km GFDL-AM4

global

GFDL FV3

Regional



1-km GFDL "Super HiRAM"

Grid-stretching and nesting capabilities

Goals:

- To develop a unified modeling system for weather and climate simulations
- To unify regional (convective-scale) and global modeling systems

- July 2016:
  NOAA selected FV3 (Finite-volume core on the Cubed-Sphere) for NGGPS (Next Generation Global Prediction System)

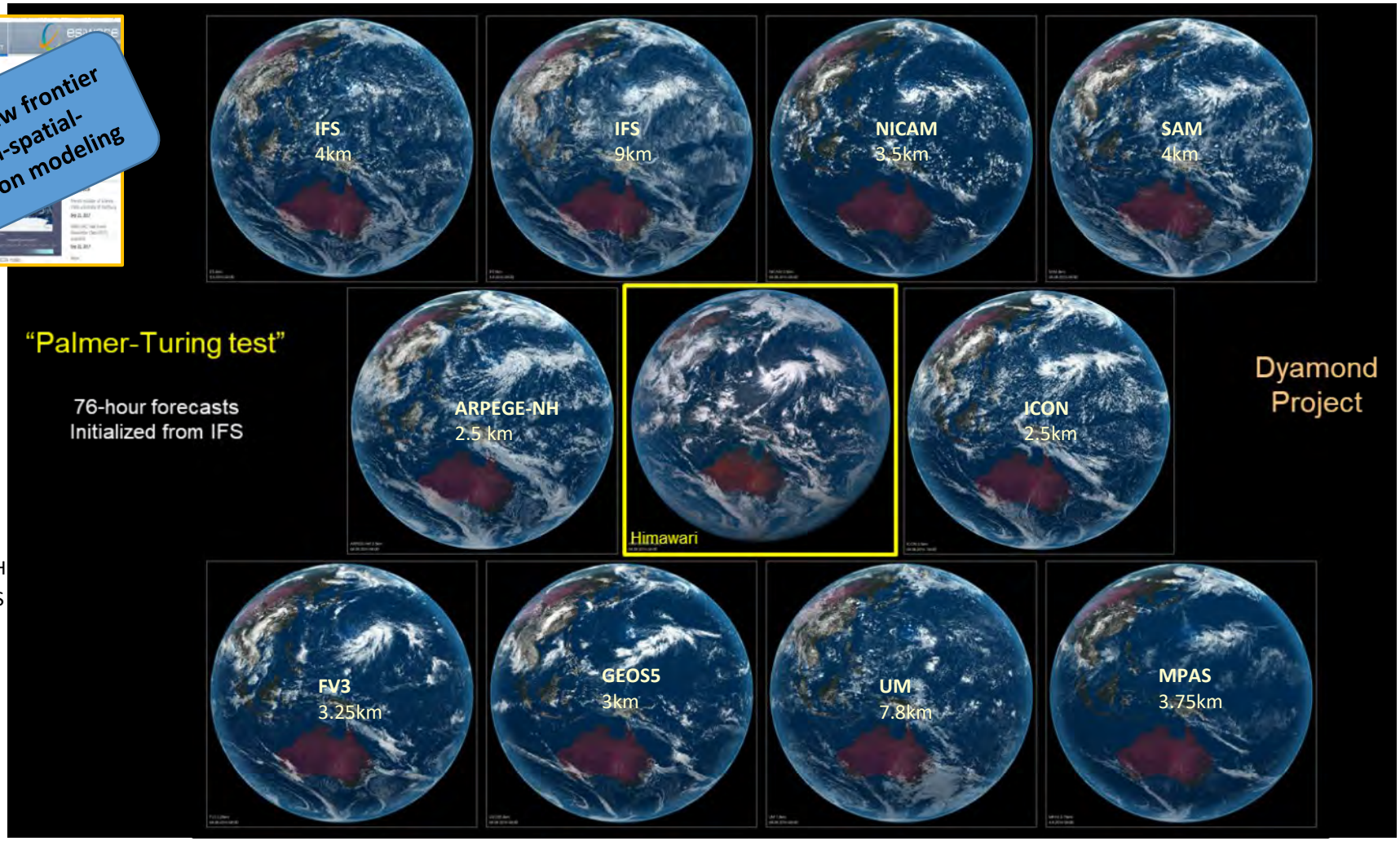
- June 2019:
  NWS operational forecasts with the "GFSv15" (with FV3 dy-core)

Credit:
S. J. Lin

NOAA/ GFDL contribution to The 40-Day "DYAMOND" Run

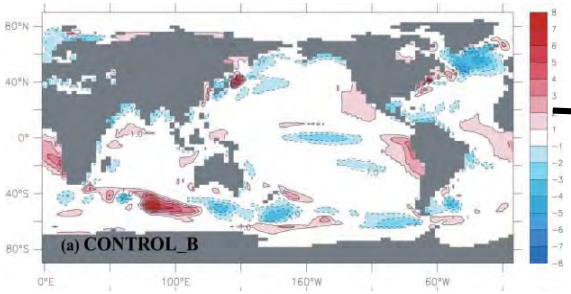
First International inter-comparison of global cloud-resolving models

- **Participants:**
  - FV3 (GFDL)
  - NICAM
  - ICON
  - UKMO-UM
  - MPAS
  - GEOS
  - ARPEGE-NH
  - ECMWF-IFS
  - SAM

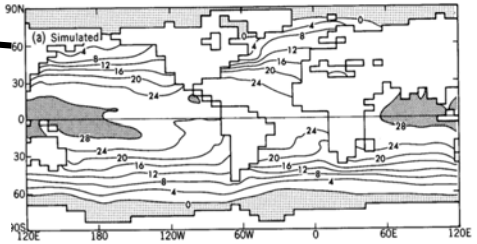


S-J Lin, Linjiong Zhou & Xi Chen

The Brief History of MOM



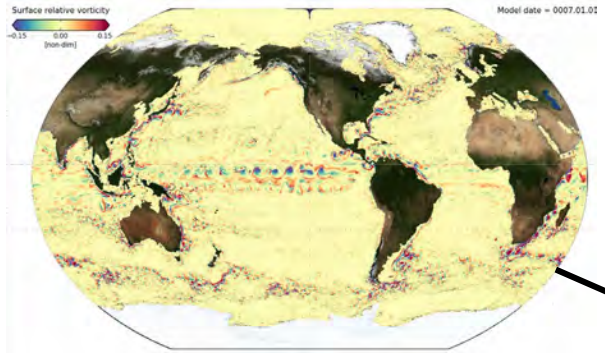
1984 Cox & Bryan code



1991 MOM1 (R30)

1996 MOM2.2

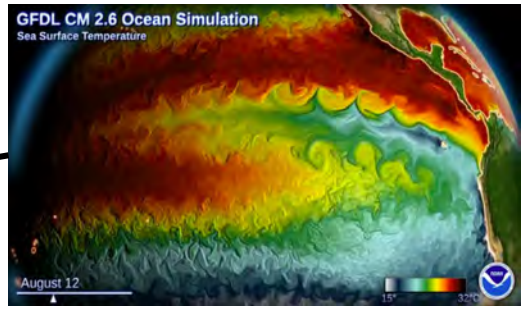
1999 MOM3



2004 MOM4.0 (CM2.1)

2006

2009 MOM4.1



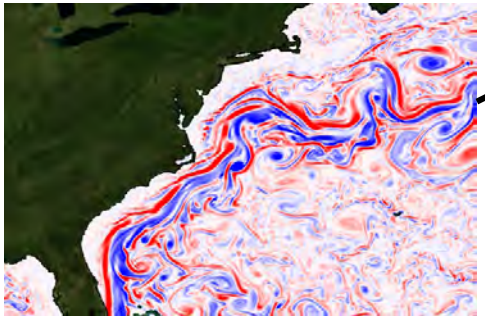
2012 MOM5.0 (CM2.6)

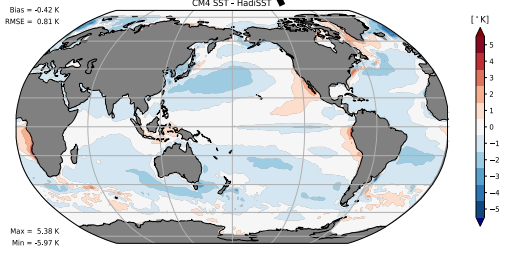
2013 MOM6 first commit on GitHub

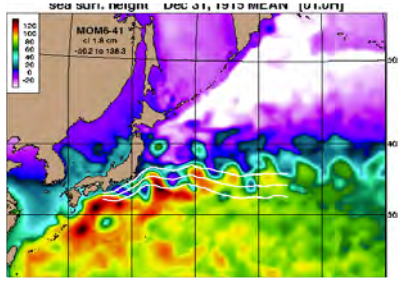
2017 NCAR forks MOM6

2019 Developing regional capabilities (w/ Rutgers)

2019 CM4



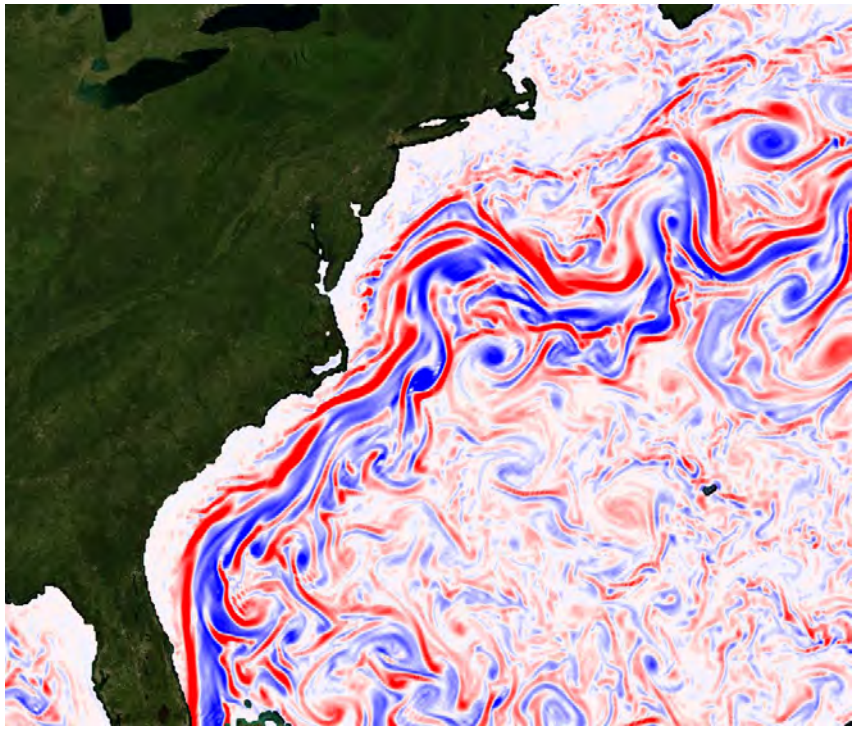




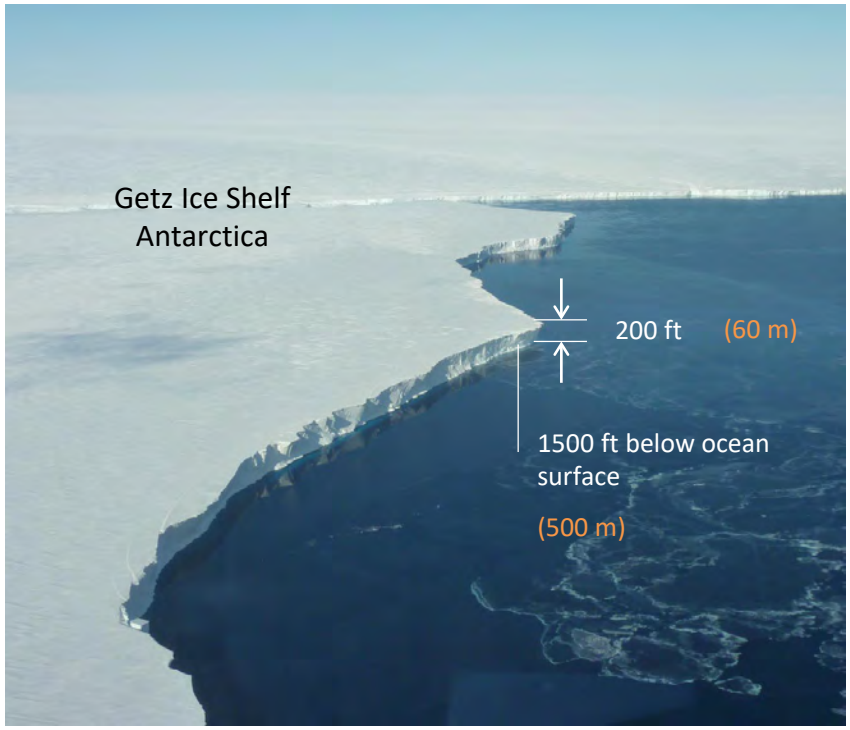
Navy 1/12° Global MOM6 Configuration (“Hycom3”)

Frontiers in ocean/ice-sheet modeling: MOM6

Role of ocean eddies in climate/earth system



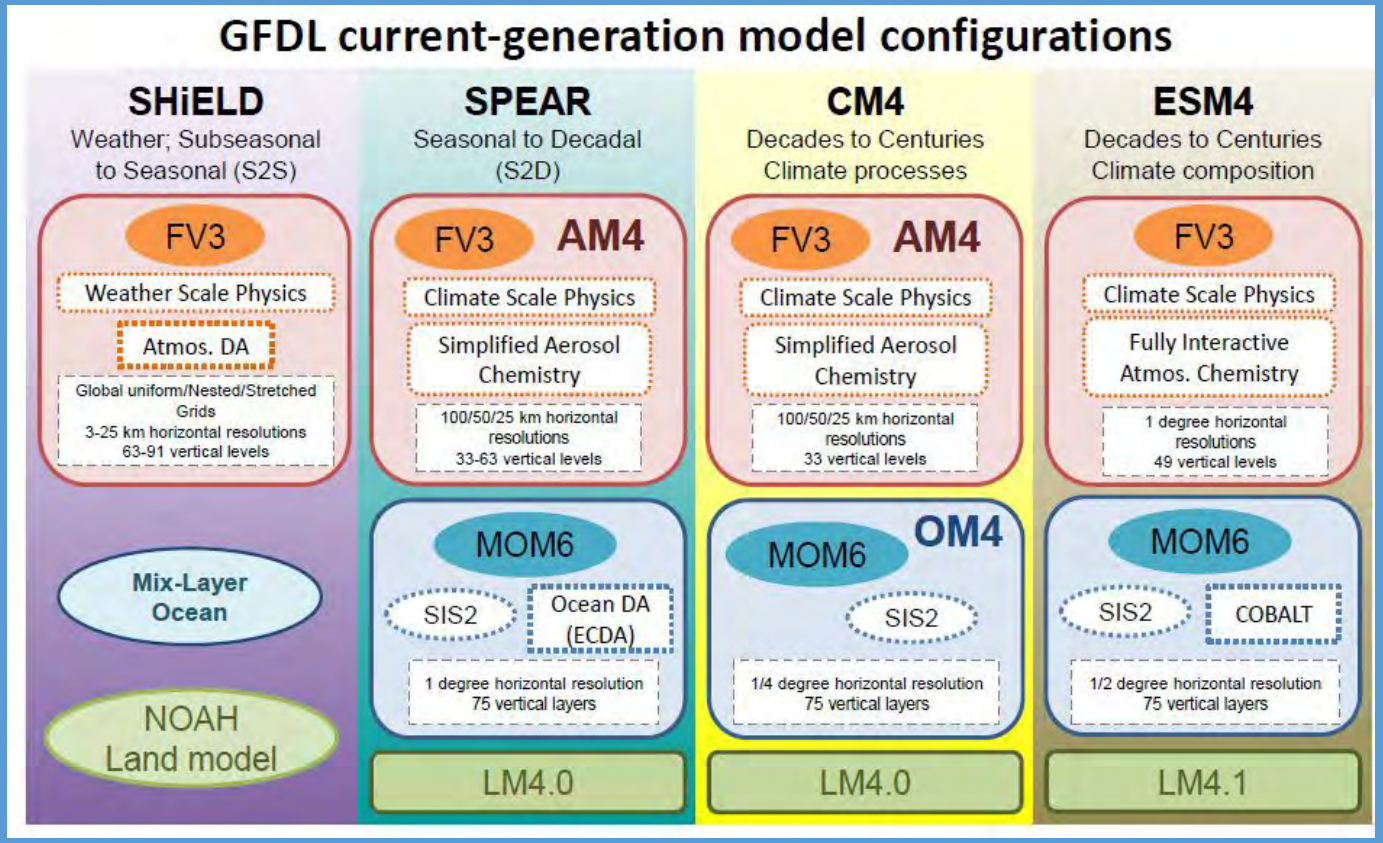
Sea-level rise and ice-sheet/ocean interaction



Courtesy: A. Adcroft, S. Griffies, R. Hallberg

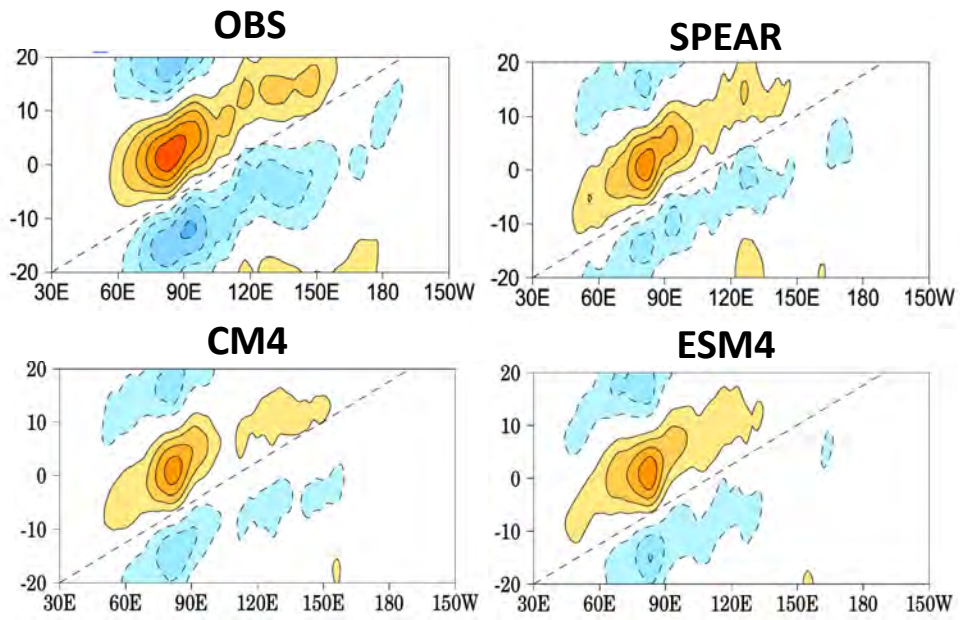
Unified Modeling System

Flexible Modeling System (FMS)



Series-4 Models: Reduction of biases

MJO Eastward Propagation



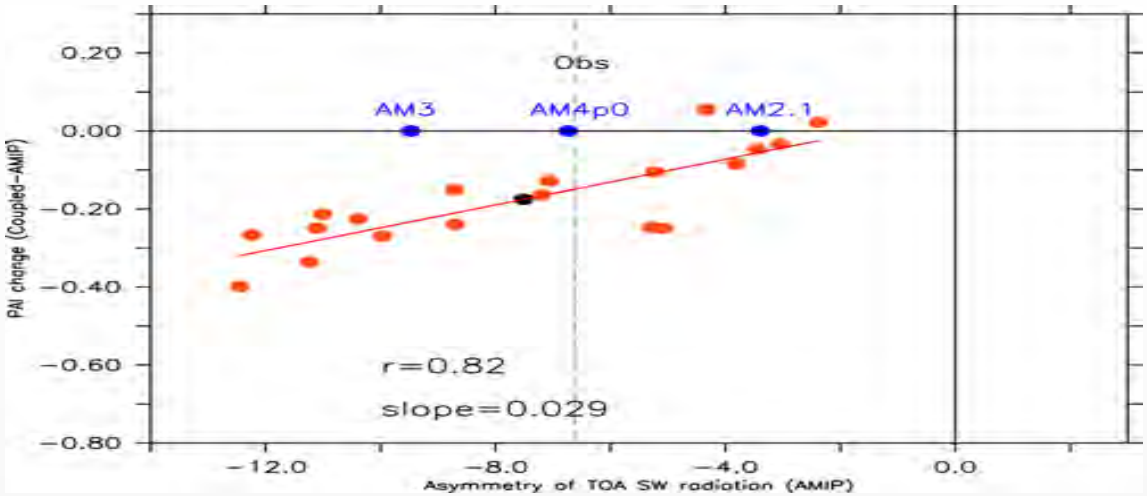
AMIP RMSE Comparison (SST coupled)

Model	CM2/AM2	CM3/AM3	CM4/AM4
(CM) SST (K)	1.2	1.1	0.84
OLR (W/m2)	7.3	8.3	4.3
TOA SW (W/m2)	12.7	11.4	7.6
Precipitation (mm/day)	1.14	1.03	0.84
NH DJF SLP (hPa)	2.39	1.87	1.84
Zonal mean zonal wind (m/s)	1.52	1.52	0.76

Series-4 Models: AM4, CM4, ESM4:
NOAA models for WCRP CMIP6

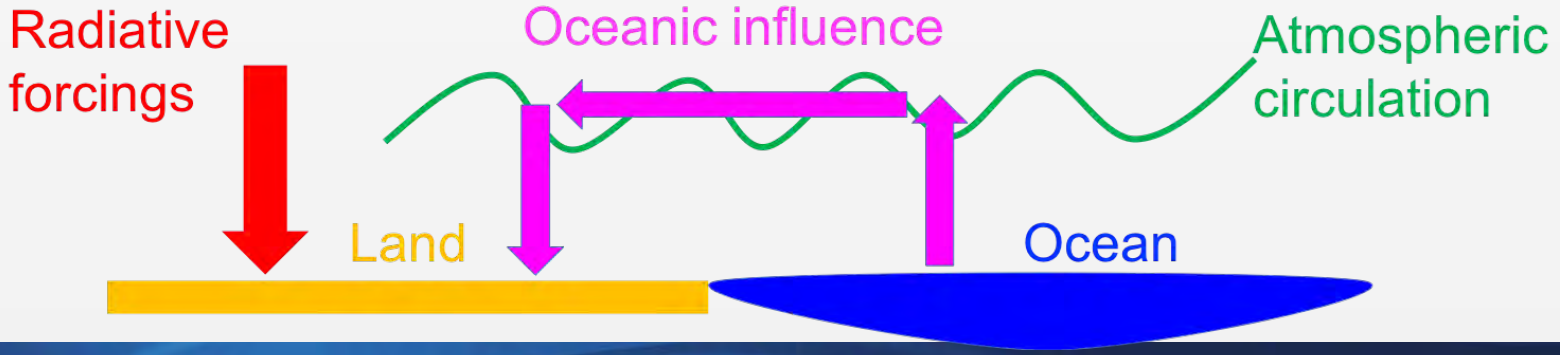
Credit: Ming Zhao

Double ITCZ linked to TOA radiative balance



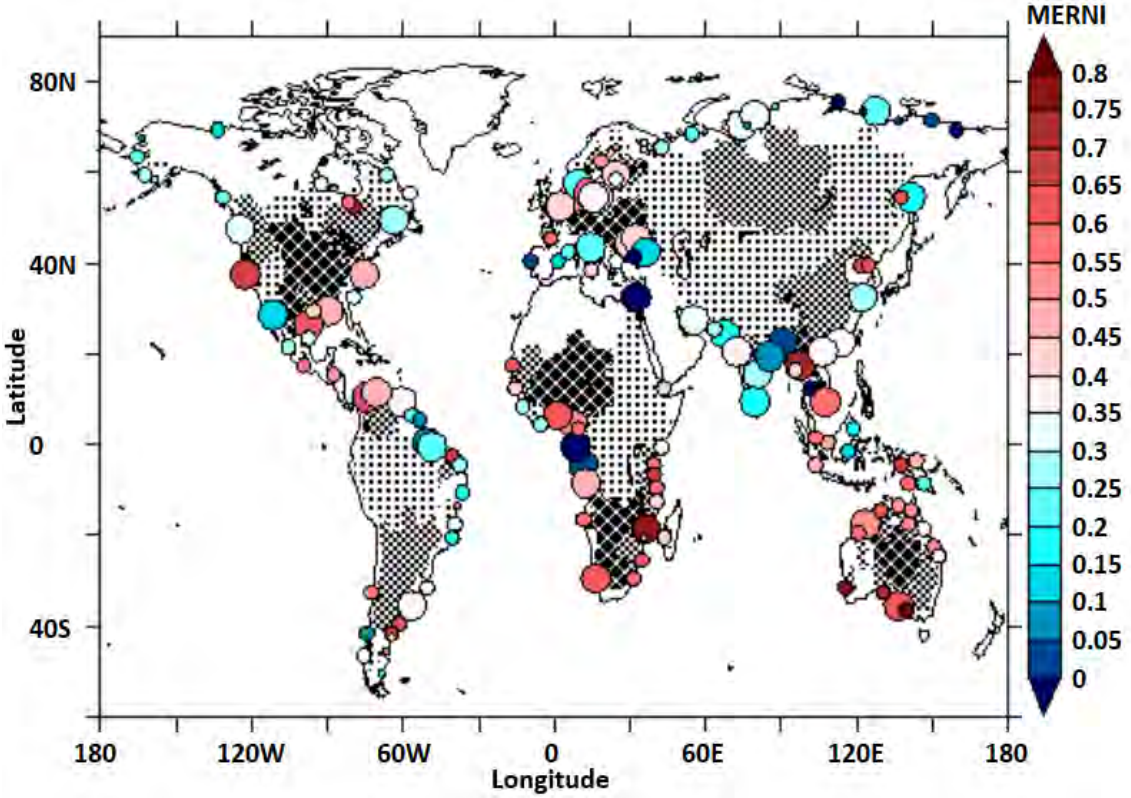
- Severity of double ITCZ in coupled models (CM) deduced from the atmospheric model (AM) TOA simulation.

Constraining aerosol forcing and climate sensitivity with historical temperature records

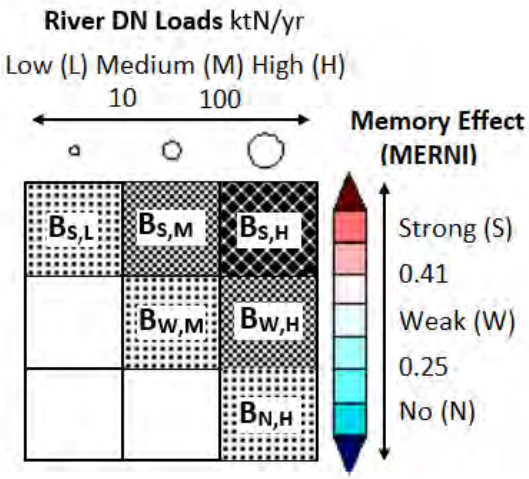


Land N Memory Effect on Coastal Eutrophication

- A land N memory effect can significantly amplify extremes of river N loads.
- The effect is prevalent globally and varies widely in strength across the globe.
- Strong effects can produce 25 (4-79)% higher N loads than would otherwise be expected from simple scaling between river discharges and N loads.

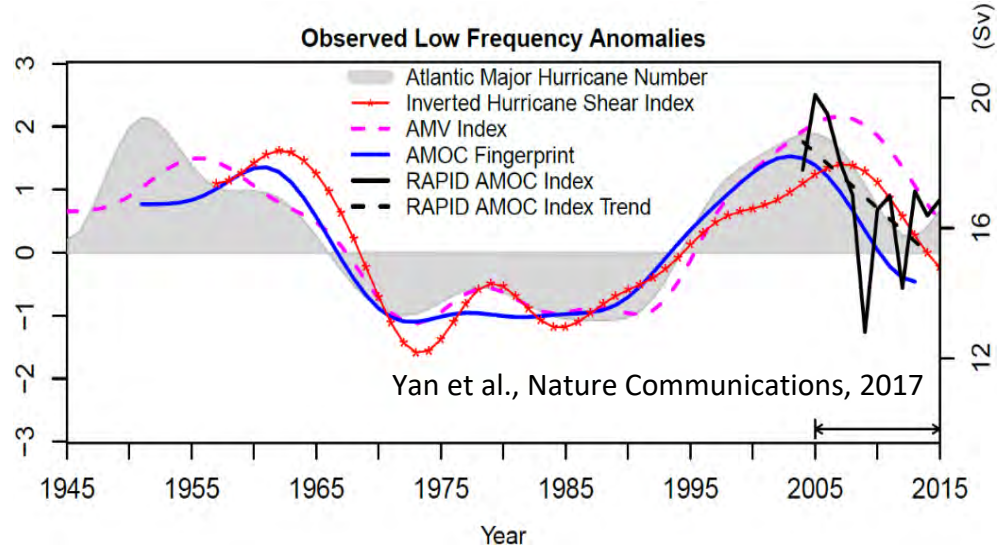


Memory-Effect-on-River-N Index (**MERNI**), with a larger MERNI indicating a stronger memory effect



Lee et al., GRL, 2016; Lee et al., In Prep

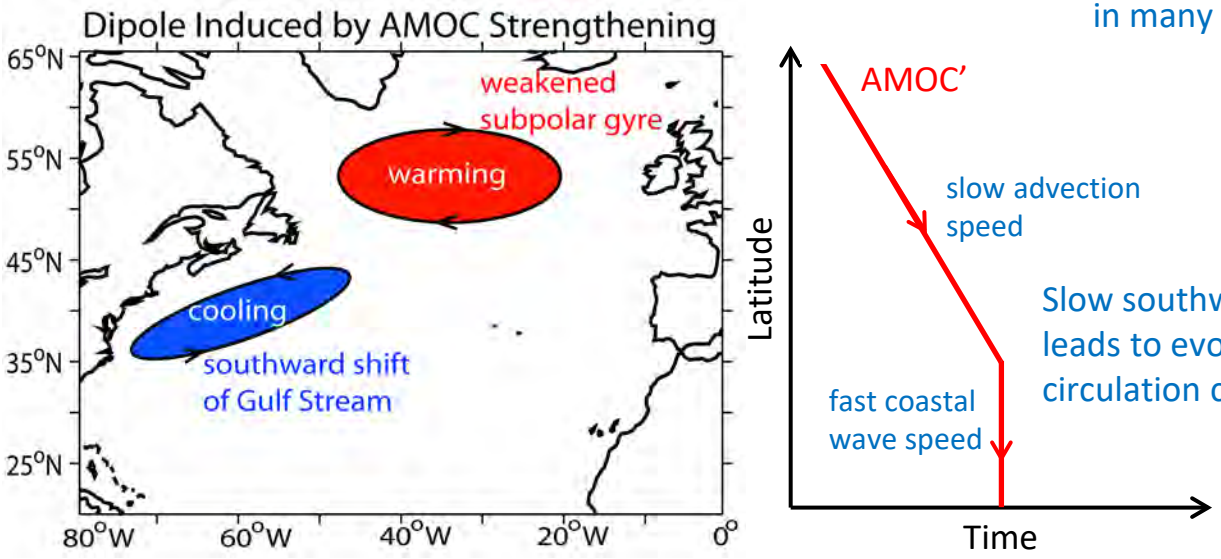
Key Role of AMOC in Atlantic Hurricane Activity and Decadal Predictability



Observations and ESM2G control simulation suggest a key role of AMOC in AMV and multidecadal variability of Atlantic major hurricane frequency

AMOC fingerprint is used to reconstruct historical AMOC variations, consistent with recent direct observations

- Role of AMOC in AMV, related impacts, and decadal predictability has been underestimated in many climate models (Yan et al., GRL, 2018)



Slow southward propagation of AMOC anomalies leads to evolution of AMOC fingerprint (gyre circulation changes) and decadal predictability of AMV

Zhang, GRL, 2008; Sanchez-Franks and Zhang; Zhang and Zhang, GRL, 2015

Components of Research Modeling Systems for the Study of Seamless Variability, Predictability and Projections

- **Observing Systems**
- **Assimilation Systems**
- **Models**
- **Changing radiative forcing**

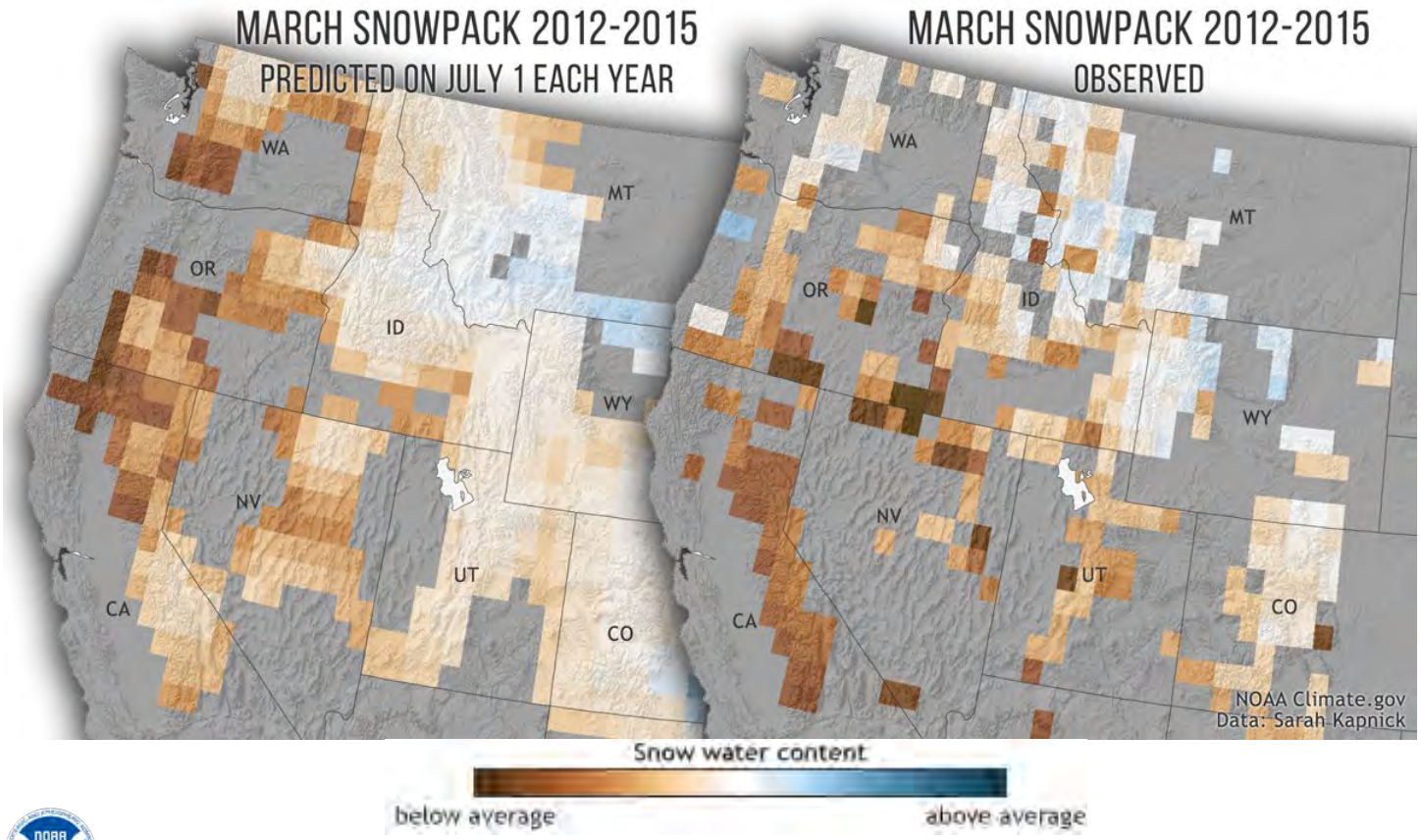
Initial Value Problem
(synoptic to seasonal prediction)

Boundary Value Problem
(multi-decadal to centennial projection)

Hours to subseasonal to
Seasonal to
Decadal to
Multi-decadal
Predictions
and
Projections

Goal: ***Seamless system for improved understanding leading to predictions and projections across Weather and Climate time scales.***

Low March snowpack case study: 2012-15
Yearly predictions made July 1 (50 km model) vs. observed



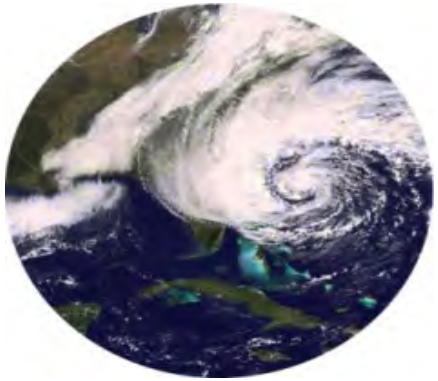
Source: Climate.gov image adapted from Kapnick et al., Proc. Natl. Acad. Sci. 2018

Scientific Challenges [Weather, Water, Climate]

- How can we improve the simulation and prediction of important weather and climate phenomena, including extremes, through advances in science and technology?
- How do aerosols, clouds, microphysics, convection, boundary layer and radiation impact weather, water and climate?
- How can we improve the understanding and simulation of the atmosphere, oceans, and cryosphere, and the interactions to more confidently project heat and carbon uptake, and sea level rise?
- How do terrestrial and ocean biogeochemical cycles influence the atmospheric abundances of greenhouse gases, aerosols and other climate forcing agents, and *vice versa*?
- How can we best use observations from diverse platforms to evaluate Earth System models, including ecosystems, perform initialized predictions, and reduce uncertainty in future projections?

Cooperative Institute for Modeling the Earth System (CIMES), Princeton University
➔ A Vibrant, Synergistic, Sustained and Productive Relationship

CIMES



NOAA competition and selection of CI:
CIMES (initiated 2018); CICS (2003-2008; 2008-2019)

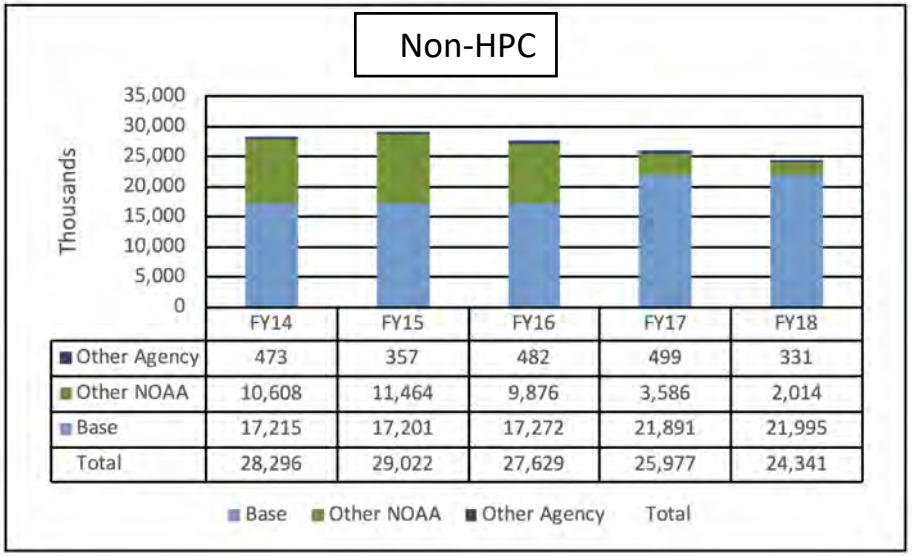
Summer Interns - 2019

- **Graduate Teaching, Education & Visiting Scientists Programs (since 1968)**
  - 10 GFDL scientists on Atmospheric and Oceanic Sciences Program Faculty, teaching courses, and mentors on Ph. D. committees.
  - 27 Ph. D. theses (since 2014). AOS Program: 120 Ph. D. degrees awarded.
  - 9 long-term CICS/CIMES scientists in key portfolios at GFDL.
  - 83 Visiting Scientists (since 2014). 369 Visiting Scientists since inception.
  - Summer internships and Faculty Exchange Fellowships (including a focus on recruitment from minority-serving institutions)

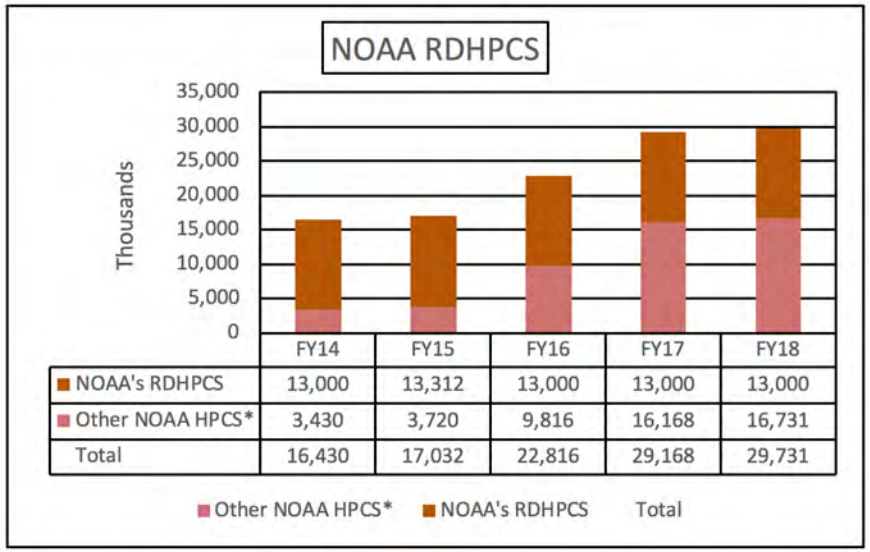
Earth System Research leverage: Ocean Biogeochemistry, Land-Surface Modeling, Ecosystems.
Leveraging PU Carbon Mitigation Initiative (BP) – Carbon sources and sinks; weather and climate extremes.
SOCCOM – Southern Ocean Carbon and Climate Observations and Modeling Project. Ocean Biogeochemical Data, Model Analysis.

❑**AOS Program (Geosciences), Princeton Environmental Institute, Princeton International Institute for Regional Studies**
❑**Departments**: Ecology and Evolutionary Biology, Civil and Environmental Engineering, Mechanical Engineering, Applied Mathematics, Woodrow Wilson School for Economics and Public Policy, PICSciE (computational science).

Budget



	FY14	FY15	FY16	FY17	FY18
Other Agency	473	357	482	499	331
Other NOAA	10,608	11,464	9,876	3,586	2,014
Base	17,215	17,201	17,272	21,891	21,995
Total	28,296	29,022	27,629	25,977	24,341

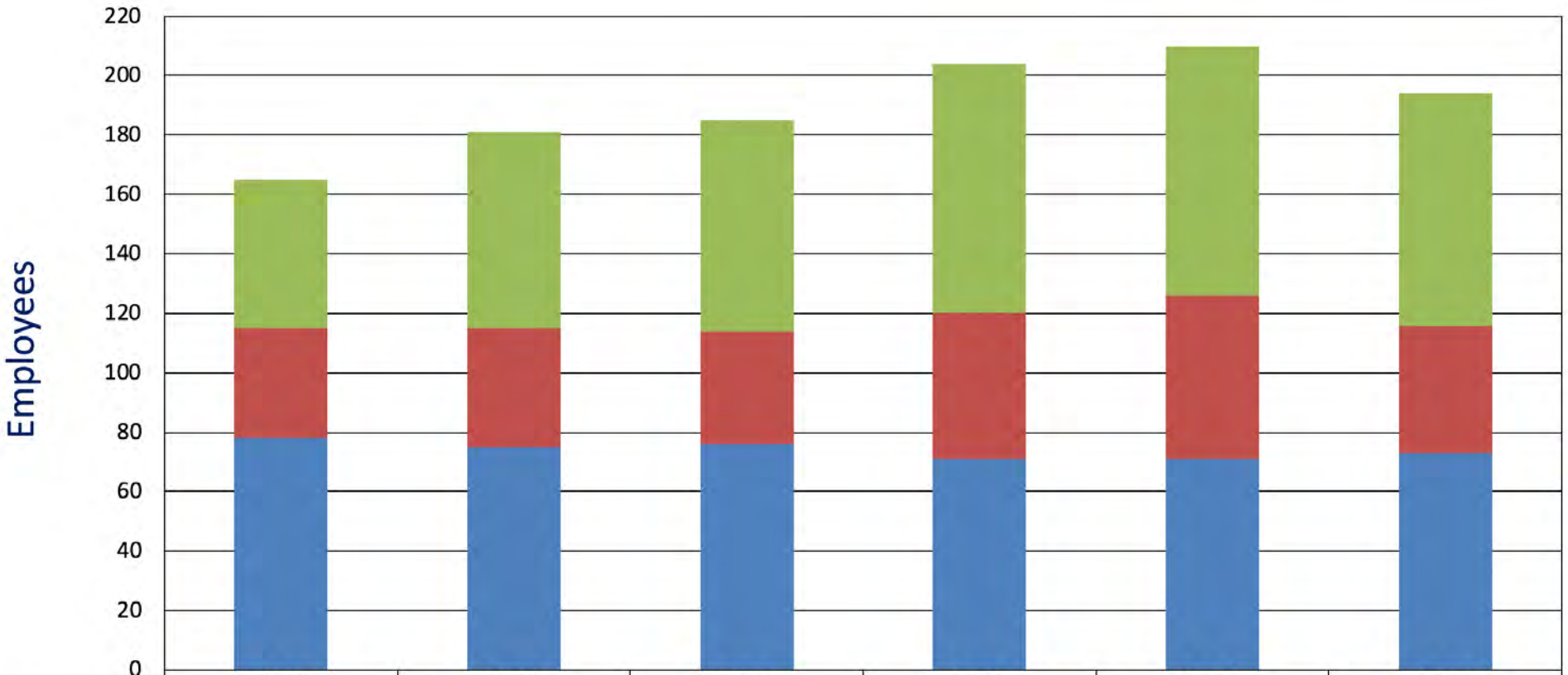


	FY14	FY15	FY16	FY17	FY18
NOAA's RDHPCS	13,000	13,312	13,000	13,000	13,000
Other NOAA HPCS*	3,430	3,720	9,816	16,168	16,731
Total	16,430	17,032	22,816	29,168	29,731

- **“Hard” fund component ~87%**
- **All Fed employees on “Hard” funds**

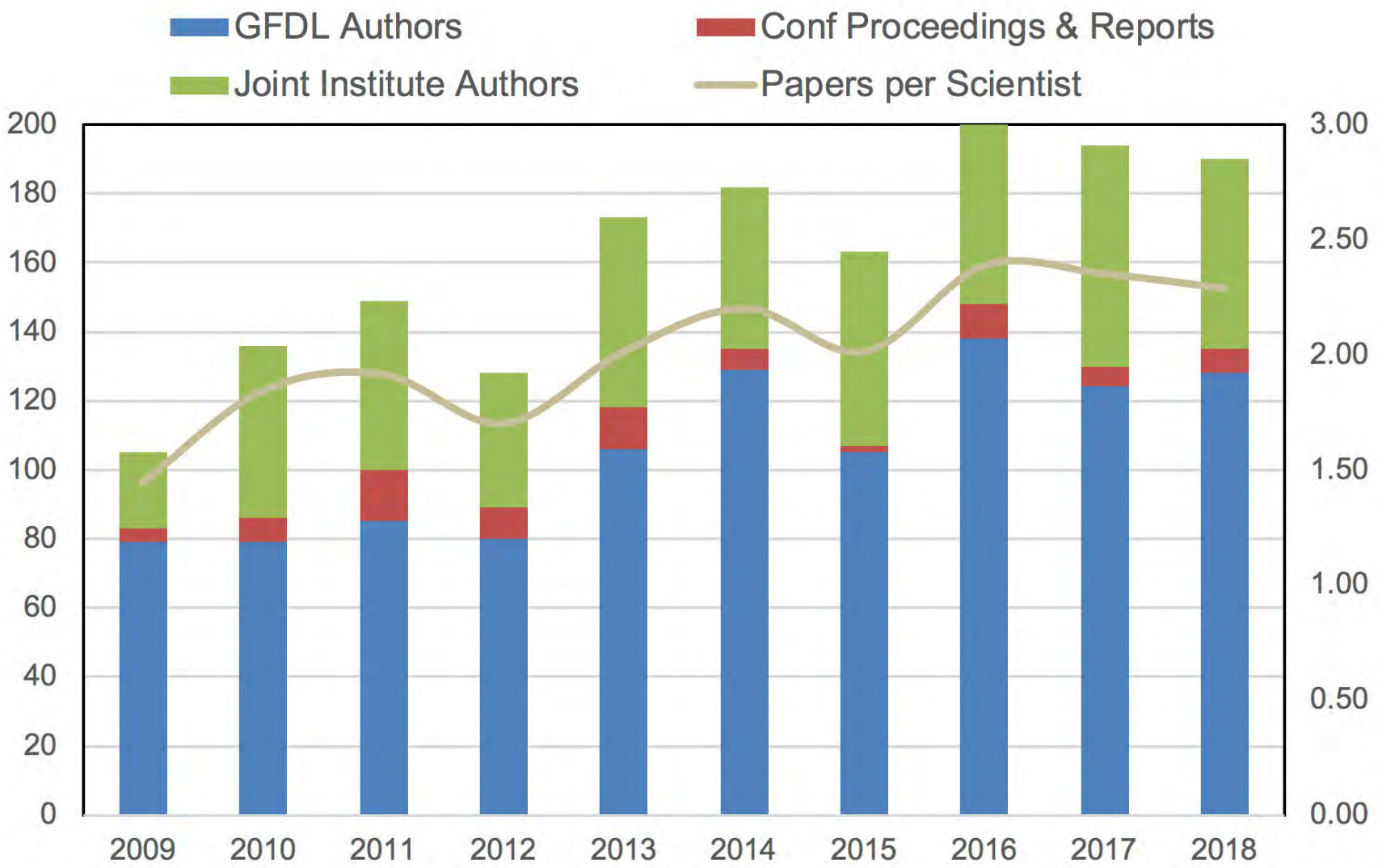
Staffing

Geophysical Fluid Dynamics Laboratory
10-Year Staffing Profile (FTE) as of July 2019

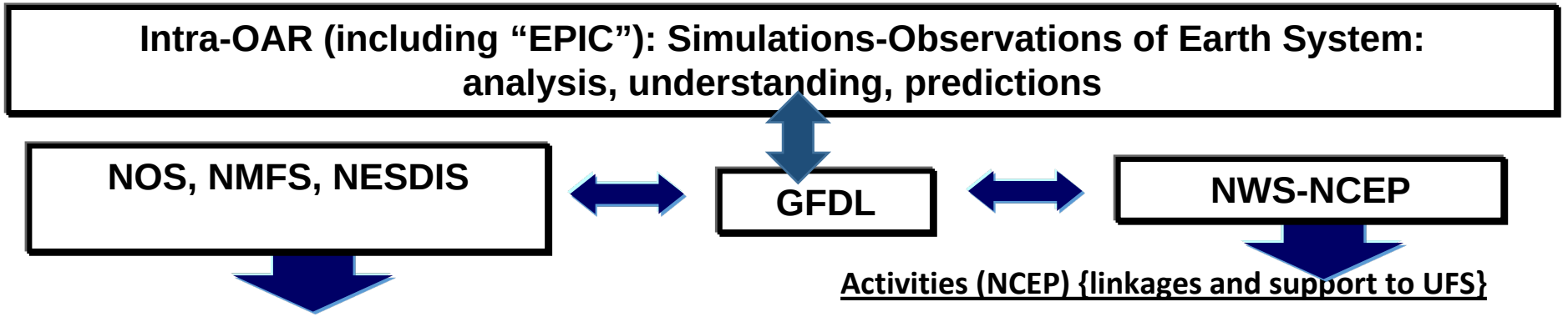


	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18
CI/CA	50	66	71	84	84	78
Contractor	37	40	38	49	55	43
Federal	78	75	76	71	71	73

Publications



GFDL's modeling and linkages with NOAA LOs



Activities (NOS):
- NCCOS

Activities (NMFS):
- Climate and Fisheries
- Climate and Marine Ecosystems

Activities (NESDIS):
- Coral bleaching. Phytoplankton
- Radiative transfer (potential future)
- Microphysics and radiances

Activities (NCEP) {linkages and support to UFS}
- GFSv15 – Operational model (with FV3)
- Atmosphere models (AM4) {*CM4 shortly*}
- FLOR seasonal prediction model.
- Coupled data assimilation scheme.
- Seasonal-Interannual
  - Experimental forecasts (NMME)
  - Seasonal hurricane outlook
  - ENSO outlook
- Modular Ocean Model 6 (MOM6)
- Land model (LM)

GFDL's Modeling Collaborators, Stakeholders [Federal Agencies]

R & D, applications: Modeling. Use of models, simulations, and data.

DOE, NASA, NSF(NCAR), Navy, USDA, USGS*, USAF, USACE, State ⟷ **GFDL**

Activities:

- Dynamical cores. Model development, intercomparisons
- Understanding model biases
- Community based modeling framework
- Ocean models.
- Joint projects on high resolution models, model-observation (satellite, surface, aircraft) comparisons
- Projects on climate, chemistry, carbon cycle, and Earth System modeling
- Weather-climate Impacts and extremes
- Exascale computing and other novel HPC architectures

Inter-agency modeling links → USGCRP - IGIM

GFDL's products and contributions

- **Peer-reviewed papers** (**~180/yr**). Contributions to National (NCA) and International (IPCC) Assessments
- **State-of-the-art Climate & Earth System Models**: Components; Process modules; Model output. Publicly available after vetting process. Data via GFDL's Data Portal
- **R2X** ➔ Research leading to: Advanced model developments; Operational usage; Sectoral applications; Information for management and policy decision-making
- **Transitions to Operational agency usage and Applications:**

  FV3 ⇨ NCEP, NCAR, NASA, Taiwan. Universities: E.g.., Harvard, U. Mich., Univ. of Oklahoma.
  MOM ⇨ NCEP, NCAR, NASA, Navy. Australia, Brazil, India, South Africa
  Hurricane model ⇨ NCEP, U.S. Navy
  CM2.1 and FLOR ⇨ North American MultiModel Ensemble [NMME]
  Hi-res atmospheric model ⇨ Taiwan
  Dust-generation model ⇨Air Force

- **Leadership**: National Research Council reports; major national and international Advisory Boards
- **IPCC Special Report**: Climate and Land (Convening Lead Author, and SPM); Oceans and Cryosphere (1 Lead Author, and SPM)
- **IPCC 6th Assessment Report WG1** ⇨ 2 Lead Authors; 1 Review Editor
- **WMO Tropical Cyclone Assessment** (led by GFDL scientist)
- **Presentations**: Academic; National, International (> **400** since 2014)

GFDL Research ➔ Experimental Prediction

- GFDL is advancing GFSv15 research, and participating with **NWS** and **OAR** Labs in improving operational forecasts of extreme weather e.g., Atlantic hurricanes, Midwest storms, using FV3 and microphysics packages.
- GFDL contributes to the NMME prediction system, and provides real-time experimental seasonal predictions to **NCEP**.
- GFLD makes ocean reanalysis (used in its NMME forecasts) available to the **Real Time Multiple Ocean Reanalysis Intercomparison**.
- GFDL contributes to the NWS seasonal Atlantic hurricane predictions by providing forecasts to the **National Hurricane Center**.
- GFDL performs simulation predictions of the summertime Arctic sea-ice extent, and delivers the predictions to the **Sea-Ice Prediction Network**.
- GFDL performs decadal simulations (including radiative forcings), and contributes to multi-Center decadal predictions organized by **UK Met Office**.
- GFDL model results are used by **NOAA Fisheries** and other partners to translate Earth system variability into vulnerability and impact assessments.
- GFDL participates in the **WCRP** activities organized by WGCM and WGNE such as CMIP6 and in climate data distribution in the Earth System Grid Federation.

GFDL's Collaborations/Partnerships

NOAA and other Programs

- **Climate Process Teams** ["CPTs" on Atmosphere, Oceans, Land, Ice]. **OWAQ** projects.
- **Field campaigns** [ICARTT, CalNex, SENEX, SOCRATES]
- **Workshops** [NOAA (Grand Challenges, CPO, NMFS, CINAR)]. Summer school at GFDL.
- **South Central Climate Science Center** [University of Oklahoma, Dept. of Interior]
- **Model and data programs** [NSF/NCAR; DOE; NASA; Navy; USGS; Agriculture; EPA]
- **US Federal and non-Federal partners**: **114**.

- **UCAR** [**41** Visiting Scientists]
- **Internships** [**102**. NOAA (Hollings, NCAS/CREST), Princeton, MPOWIR,…]

International

- **WMO**: WWRP, WCRP (*CLIVAR, GEWEX, SPARC, CLiC*) , IGBP, UNEP
- **Modeling, simulations, data** [Australia, Taiwan, South Korea, India, Japan, UK, France, Germany, Brazil, Switzerland]
- **Institutions abroad, including governmental and non-governmental**: **98**

Private sector

- BP/CMI, Atmos. Research, Willis Re, ExxonMobil, Vulcan

Honors, Awards (2014 and after)

NATIONAL

- Presidential Distinguished Rank
- AGU Revelle Medal
- AGU Hydro. Sciences (USGS)
- Franklin medal (Emeritus)
- AGU Fellow
- 4 AMS Fellows
- AGU Horton Lecturer (USGS)
- 36 Highly cited scientists (Thompson/ Clarivate, 2014-2018)
- AGU Ascent (3)
- AMS Houghton
- AMS Meisinger
- AMS Bernhard Haurwitz Lecturer
- AMS Roberts Lecturer
- AGU Cryosphere Early Career
- Houghton Lecturer (MIT)
- AGU James Holton Young Scientist (3)
- AMS Banner Miller
- EEO Diversity Award
- Air &Waste Mgmt.
- 4 Journal Editors' citations
- Student presentation honors (AMS, AGU)
- 100 IT Leaders (2015)
- ABA Stevie Award
- Theodore Roosevelt Government-Academic Leadership (CICS)
- Finalist, Service to America (Career Achievement) (2019)

DOC / NOAA /OAR

- 12 DOC Gold Medalists
- 2 DOC Silver Medalists
- 32 DOC Bronze Medals
- 12 NOAA Admin (12)
- 3 Distinguished Career
- Albritton Communicator
- Linda Winner Memorial
- 2 Employee of the Year
- Outstanding Paper (10)
- OAR Graduate Program
- Green Steward
- EEO Counselor
- Energy and Water Management (9)
- State Dept. Certificate of Recognition
- 2 Amy Langenhorst (GFDL internal)
- Green Grant Funding
- Electronic Stewardship Project
- OAR Deemed Exports
- Order of Sherman's Lagoon (2)

INTERNATIONAL

- Crafoord Prize (Sweden; Emeritus)
- BBVA Frontiers of Science (Emeritus; Spain)
- 3 WMO Norbert Gerbier-MUMM Awardees
- EGU Nansen Medal (Europe)
- Distinguished Lectures (U. of Toronto, KAUST, U. of Illinois, SUNY-Stony Brook, IISc-Bangalore)
- Wei Lun Distinguished Visiting Professor (Hong Kong)
- SPARC Conference paper
- Toastmaster – Communicator
- WCRP Model Development (Honorable Mention)
- Princeton Technical Achievement
- Chair, WCRP-CLIVAR-GLASS Panel
- Princeton University Stripe Award
- Princeton Arnold Guyot Prize (AOS)

Challenges in sustaining world-leading science and mission goals

- State-of-the-art, high-end, climate and Earth System modeling and applications ➔ *science, service, and stewardship* ➔ science-based, evidence-tested, and pre-eminent.
- Increasing demand ➔ realism/complexity, regional details, improved quantification, more data and information.
- Uncertain & unsteady budgets, especially for critical science developments.
- Meeting Lab internal and external expectations.
- Federal-level shakiness: shutdown/furlough, science-management tension.
- Hiring process and time duration; inordinate, inexplicable delays.
- Foreign National and physical+computing access, and security measures.
- NOAA's R&D HPC acquisition over-reliant on disaster fund supplemental.
- Shrinking physical space in the 51-year old GFDL building.
- Terminology impeding clarity of purpose e.g., "weather vs climate"; "seamless"; "Earth system".

Strive for Excellence [Diversity, Inclusion, and Advancement]

Recruiting, retaining, developing, and advancing scientists, administrators and technical/computational experts, and having a high priority for diversity and inclusivity, are critical to achieve the Strategic Science Plan and 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. Actively seek candidates from, and promote collaborations with, underrepresented minority communities and minority-serving institutions including NOAA's Cooperative Science Centers.
- Foster an environment that maintains high standards of excellence, while achieving a greater degree of inclusivity and sustainable work-life balance.
- Maintain resources (human and computational) to provide the tools for world-class climate and Earth System research, modeling, predictions, and projections.
- Foster a collegial setting in the Lab that is conducive to the collaborative, integrated efforts essential for climate and Earth System sciences and to accomplish the NOAA mission goals.

THE CREATION OF A GEOPHYSICAL FLUID DYNAMICS LABORATORY

COPY OF THE ORIGINAL MANUSCRIPT OF PROFESSOR J. von NEUMANN

July 29, 1955 letter by John von Neumann (*Institute for Advanced Study (IAS), Princeton*) to the **US Weather Bureau**

…..after routine 24-hour numerical forecasting service became possible at the *Joint Numerical Weather Prediction (JNWP) 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."**
- **"What atmospheric conditions will generally prevail when they have become, due to the lapse of very long time intervals, causally and statistically independent of whatever initial conditions may have existed."**
- **Set up project to investigate the "infinite forecast" i.e., general circulation.**

Adopting National Research Council (2012) Recommendation: *Unified modeling approaches*

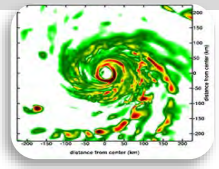
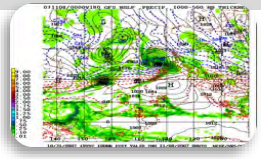
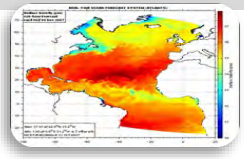
Internal Variability and External Forcings

Tornadoes	Heat Waves	El Niño-Southern Oscillation	Decadal to Multi-decadal Variability	Ocean: Circulation, SLR, Heat Content
Snowstorms	Storm Track Variations	Precipitation extreme	Cryospheric	Greenhouse Gases and Aerosols
Hurricanes	Madden-Julian Oscillation	Intra- & Inter-season Variation	Solar Variability	
Typhoons		Changes in the Arctic		

1 DAY | 30 DAYS | 1 SEASON | 3 YEARS | 10 YEARS | 30 YEARS | 100 YEARS

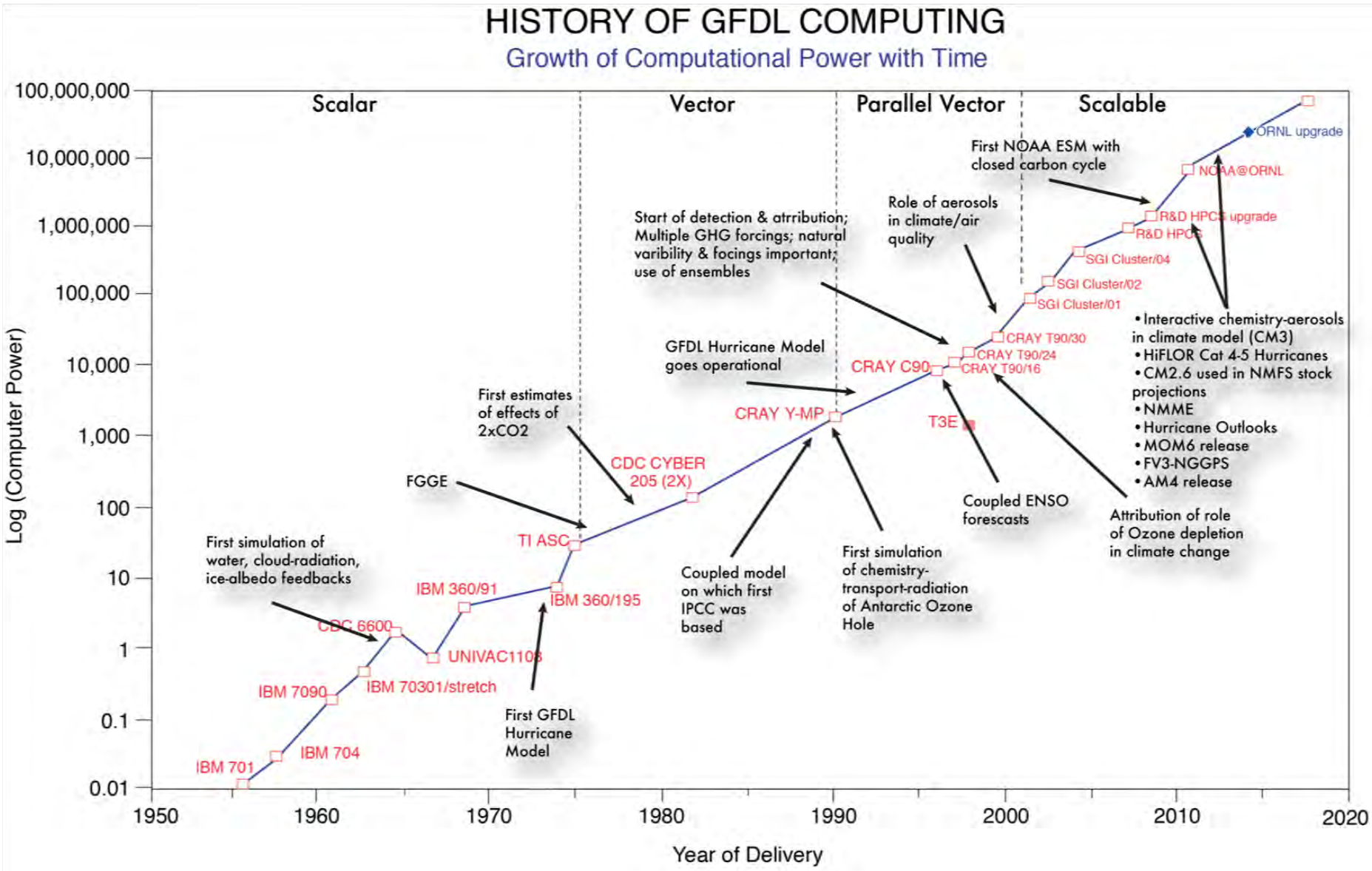
WEATHER | SHORT-TERM | INTERANNUAL | DECADE-TO-CENTURY

Sub-seasonal-to - Seasonal	Seasonal-to-Interannual	Interannual-to-Decadal	Decadal-to-Multidecadal

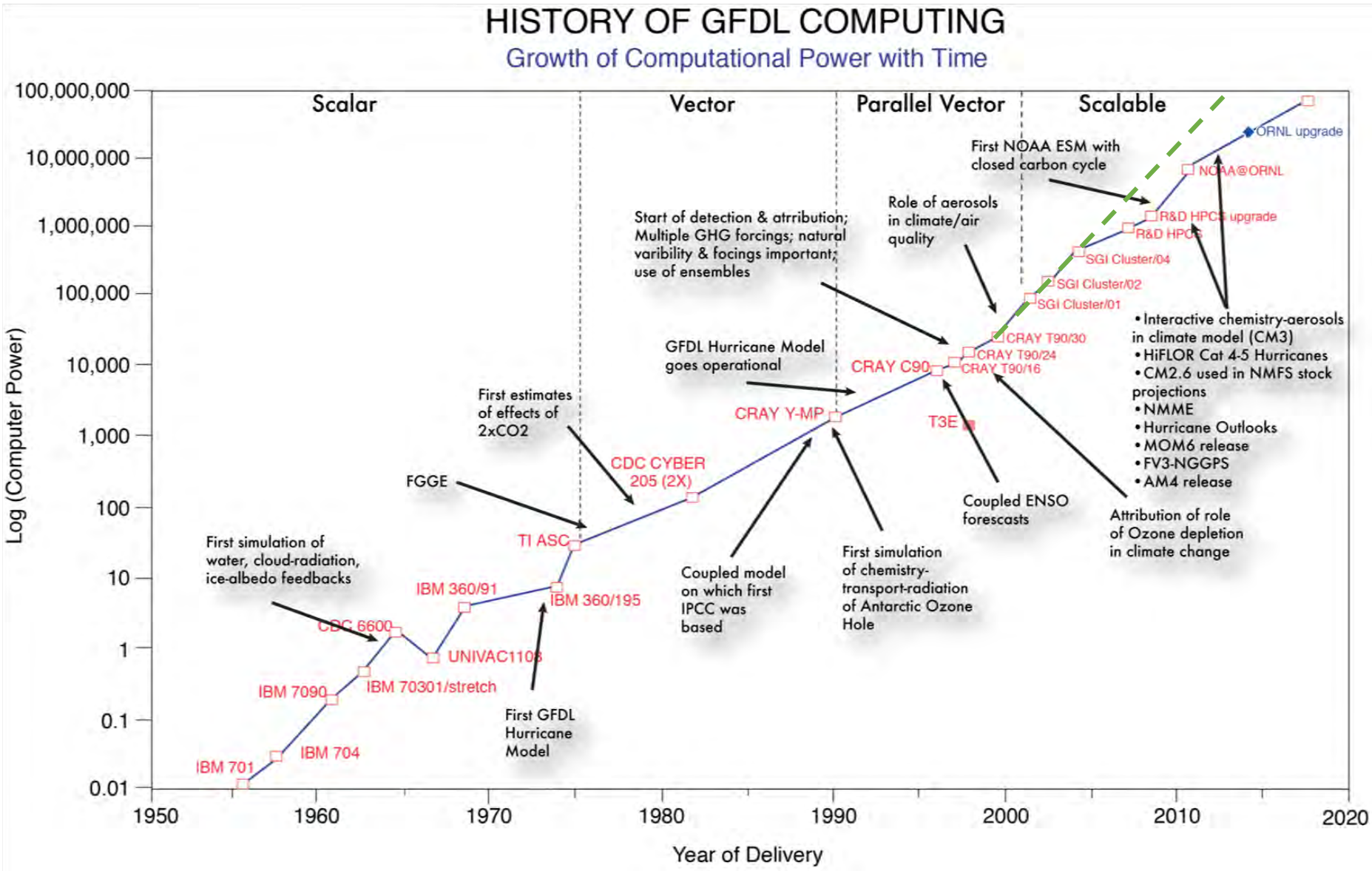




Weather to Climate: *Seamless*

Sustained Innovation for NOAA's Mission



Sustained Innovation for NOAA's Mission



Next NOAA HPC ➔ Hi-res *seamless* Earth System Modeling

Multiple phenomena and interactions, and societal needs

Nonstationarity of weather and climate regimes

ASPIRATION…… The case for investment is there!

AGENDA in Brief (OPEN sessions on Oct. 29,30)

- **Theme 1: Modeling the Earth System**
- **Theme 2: Advancing the Understanding of the Earth System: Phenomena, Processes, Variability and Change**
- **Theme 3: Earth System Predictions and Projections**

- **High-Performance Computing**
- **Climate Assessments & Analysis**

==========

➢Q&A after each presentation

➢Extended discussions at the end of the 1st four sessions

AGENDA in Brief (Closed sessions)

➔ Meetings of the Review Panel with groups:

- Early-Mid careers
- Recent Arrivals
- Poster sessions
- Stakeholders
- Model development, implementation, and data management
- AOS graduate students
- CIMES Leadership
- GFDL Administrative and Technical services
- GFDL scientific governance and management

➔ Meeting of the NOAA Line Office representatives with a subset of GFDL scientists

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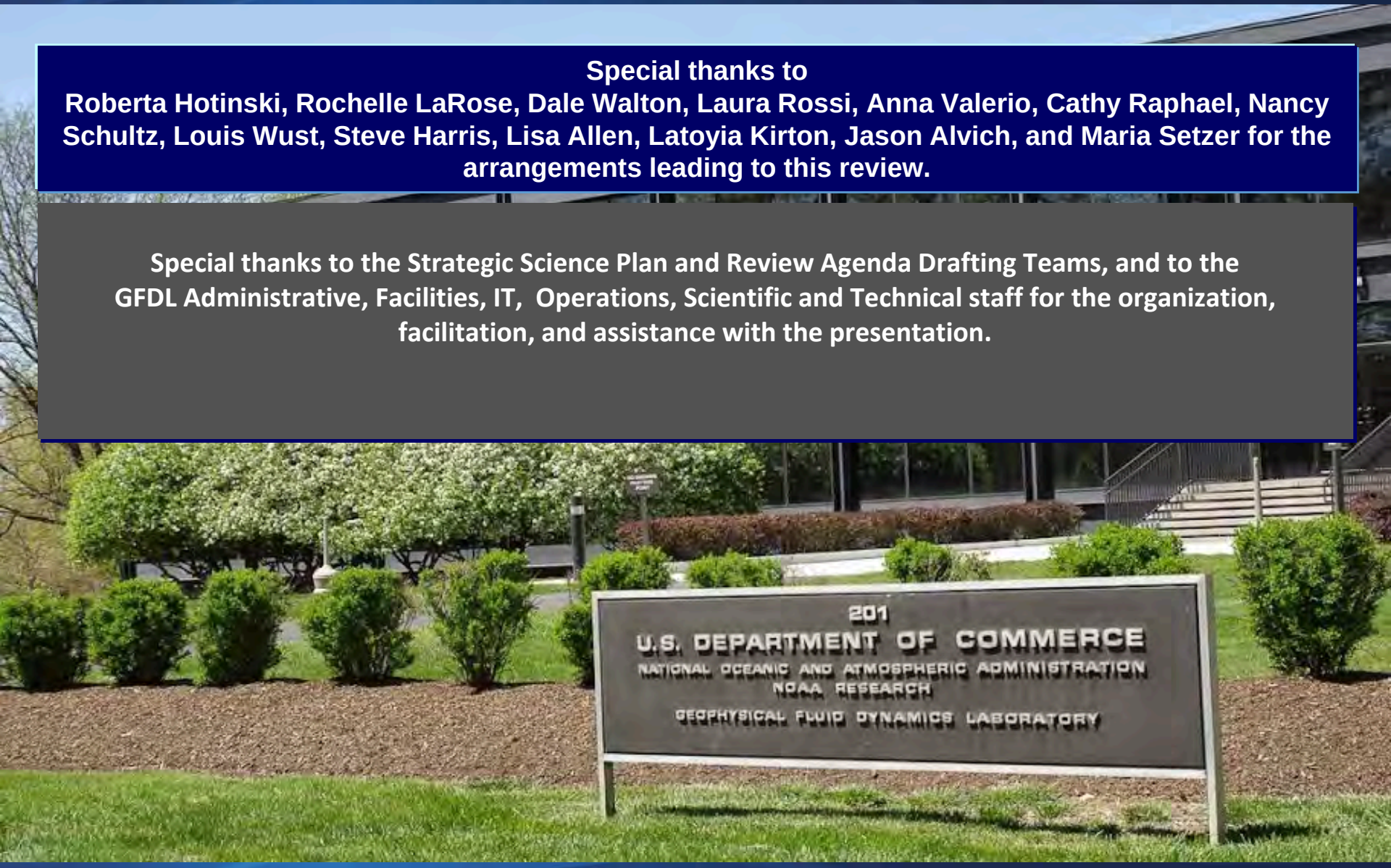

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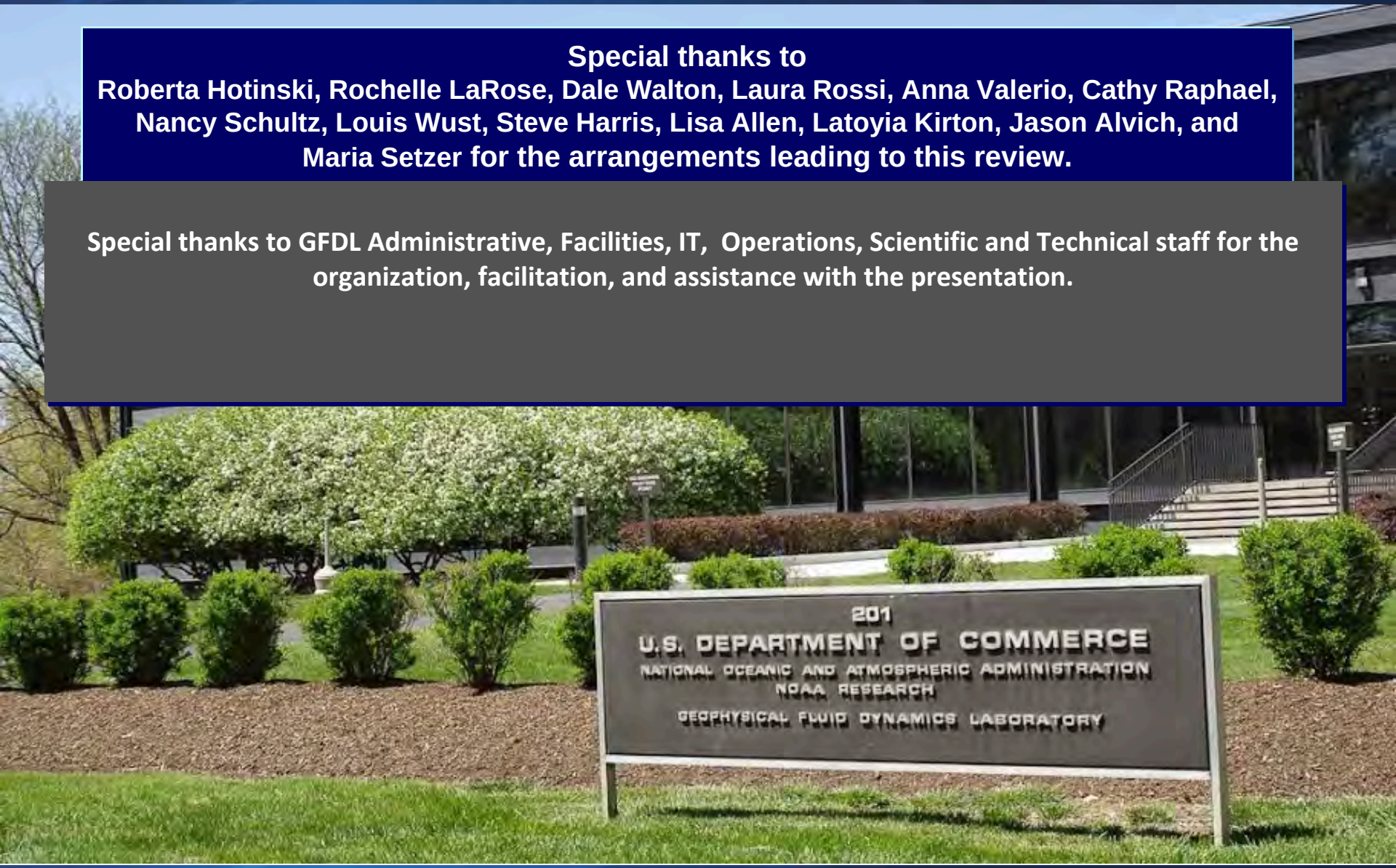


GFDL Scientific Governance [from 2018, revised 2019]

SCIENCE BOARD (SB)

Aim ➔ Advisory body.

- Guide Lab's overarching and long-term scientific horizons.
- Have oversight of the Lab's scientific progress.
- Management of science including recommendations on hires, allocations, budgets.

Composition ➔ a subset of the Lab's senior scientists.

- Director
- Deputy Director
- Senior Technical ("ST")
- Division Leaders

GFDL Scientific Governance [from 2018, revised 2019]

Research Council (RC)

Aim ➔ Facilitating body.

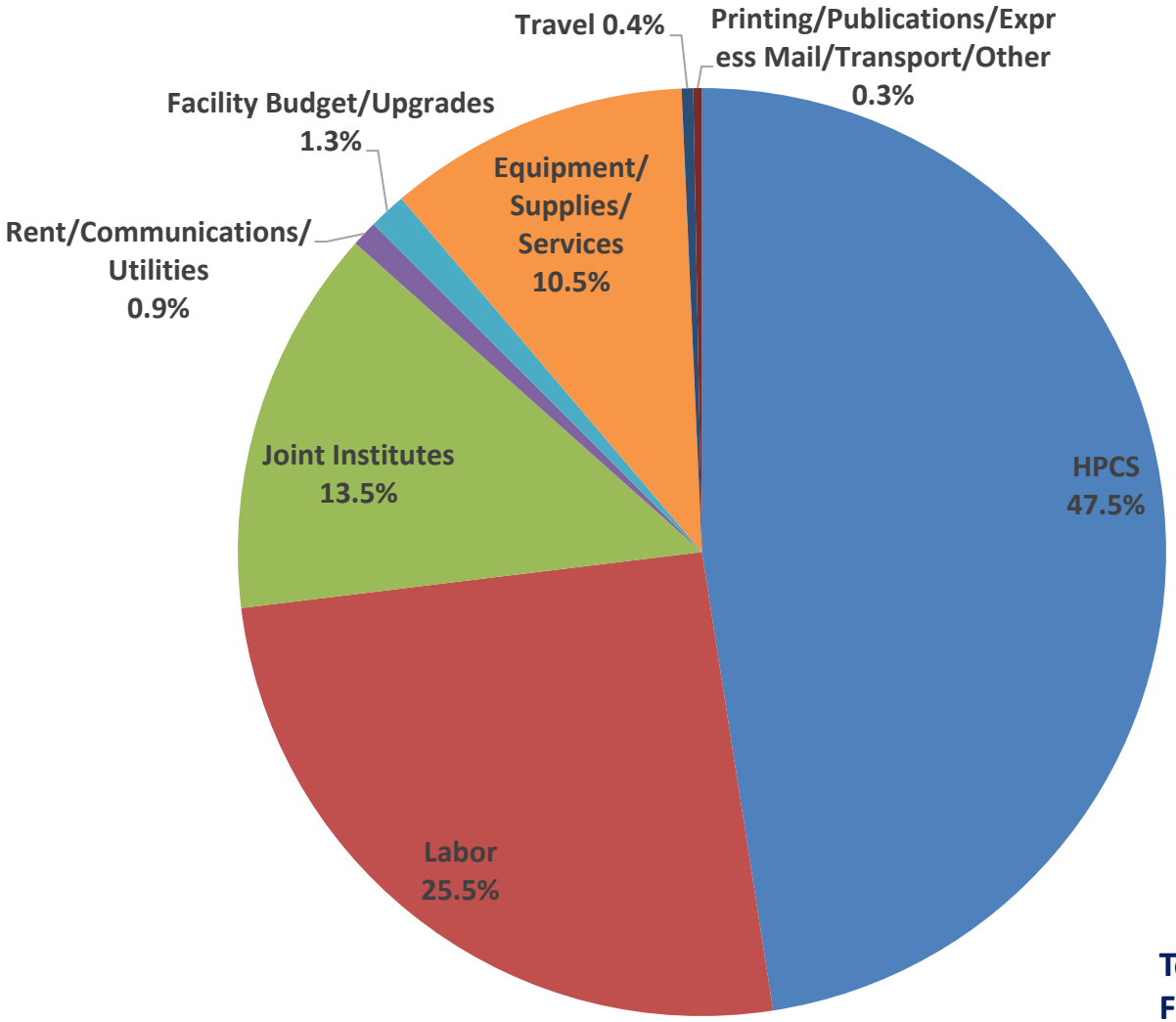
- Work together with the Division Leads**.**
- Focus on Lab's science goals; plans, implementation, and execution.
- Communicate/ inform the scientific research across Divisions and Lab.
- Coordinate cross-Divisional collaborations to enhance the Lab's objectives.

Composition ➔ a subset of the Lab's senior and mid-career scientists.

- Deputy Director (Chair)
- Associate Director (Vice Chair) {*position vacant currently*}
- Deputy Division Leaders
- Leader (Liaison for Lab models and simulation data)
- Leaders of Initiatives (Clouds-Climate Initiative. Impacts Initiative)

Budget

Geophysical Fluid Dynamics Laboratory FY 2018 Expenditures



Total Obligations in FY 2018 (in K): $54,074

Staffing

Geophysical Fluid Dynamics Laboratory
5-Year Staffing Profile (FTE) as of July 2019

Ethnicity

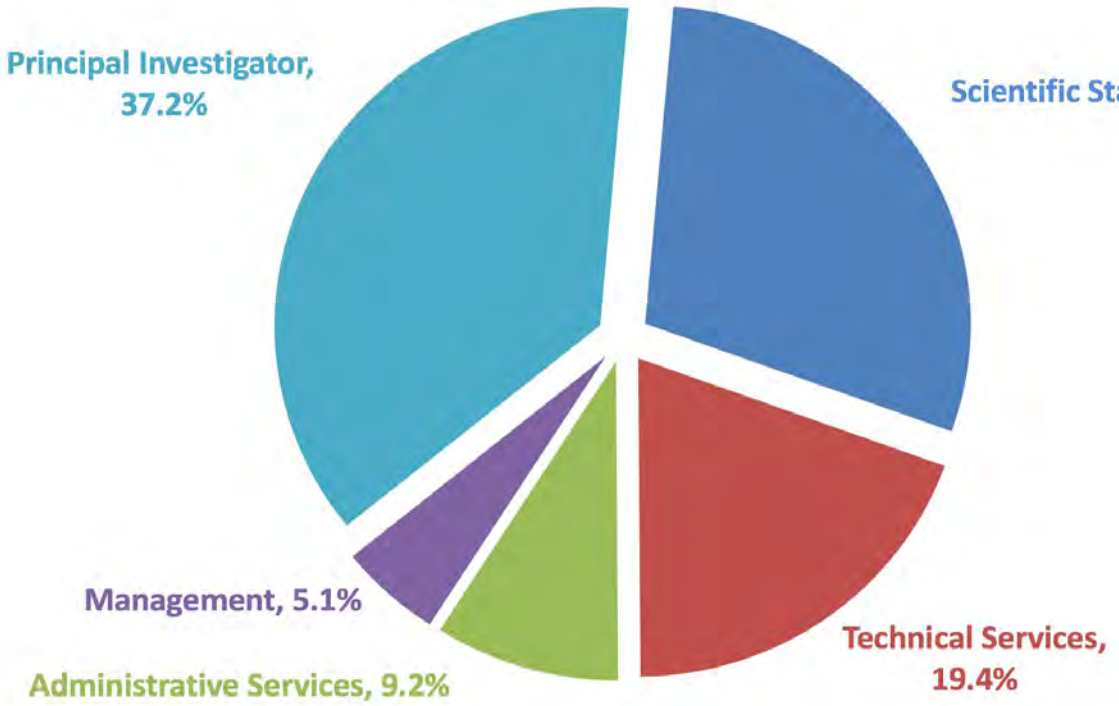
	Federal Employee Hires Last 5 Years	Federal Employee Total	CIMES & UCAR	Contractors & OPS-Interns	Total
Native American	1	1	0	0	1
Asian	7	13	27	9	49
African American	3	4	3	1	8
Caucasian	15	55	39	44	138
Latino	0	0	1	0	1
Other	1	1	1	0	2
Total	27	74	71	54	199

Gender

	Federal Employee Hires Last 5 Years	Federal Employee Total	CIMES & UCAR	Contractors & Fed- Interns	Total
Male	16	57	44	43	144
Female	11	17	27	11	55
Total	27	74	71	54	199

Staffing – FY18

TOTAL GFDL, PRINCETON, UCAR, CONTRACTOR, and Other Staff: 199



Definitions:
Principal Investigators: Scientists at Associate Research Scholar, pay band ZP-4, or higher, or equivalent

Scientific Staff: Scientists at pay band of ZP-3 or lower, post-docs, visiting scientists and other shorter-term university personnel, and graduate students