GSD Challenge #2

Toward Earth System Modeling

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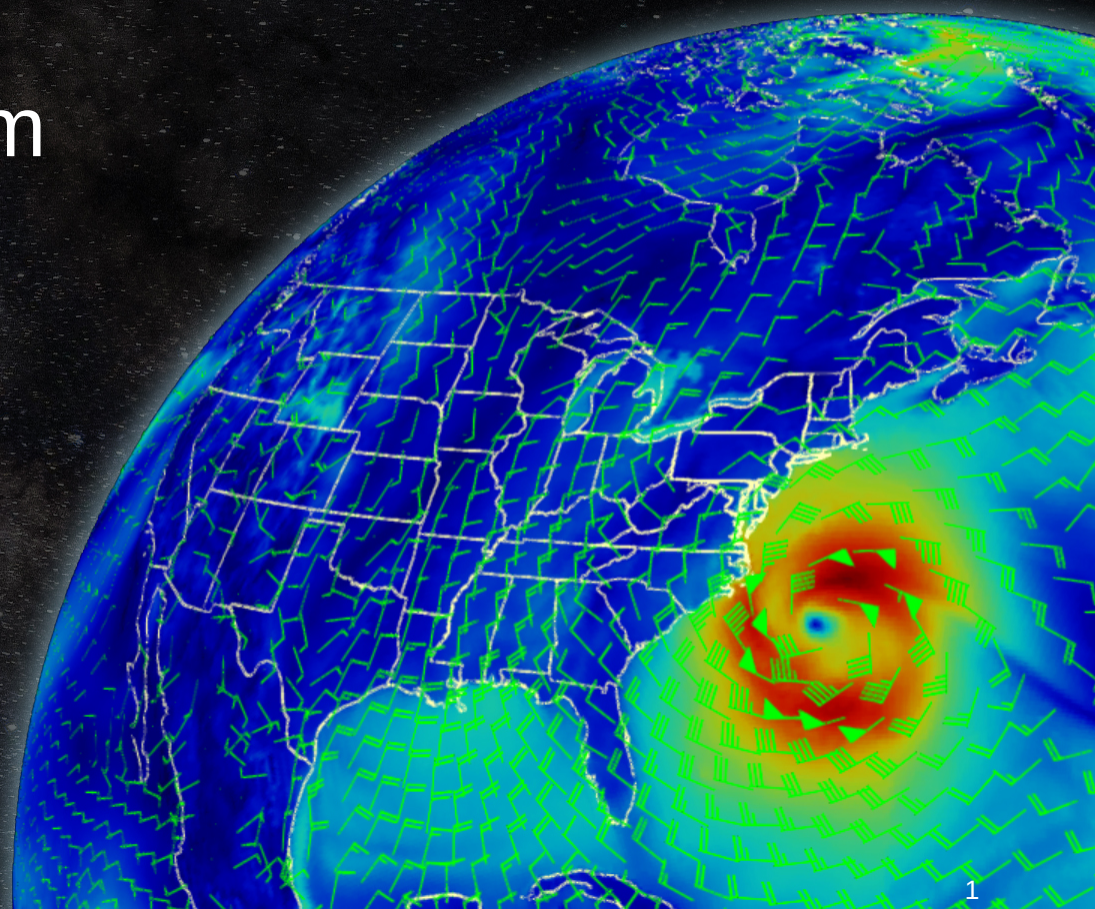
NOAA/ESRL/GSD

GSD Science Review
3-5 Nov 2015



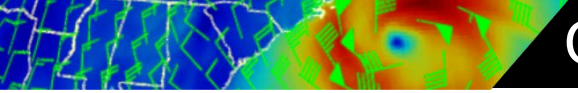
A fully coupled earth system modeling prediction capability

- Atmosphere, ocean, chemistry, ice, and land-surface components for research and potential operational applications
  - More useful **seasonal** outlooks
  - Improved **air quality** / **health** forecasts
  - **Full environmental** prediction
  - Improved **global NWP** forecasts from Day 1 – Week 4 (including ensembles/ reforecasting)
  - Global **situational awareness** – Global “Rapid Refresh”

Why Global Modeling in GSD?

- NOAA/U.S. need for improved global forecast skill
- Innovative numerical approaches for global models
- Experience with
  - optimization in high-performance computing, HPC hardware
  - data assimilation (PSD and GSD)
  - development of physical/chemistry parameterizations
- Development/verification evaluation effort similar to that used for RUC/RAP/HRRR

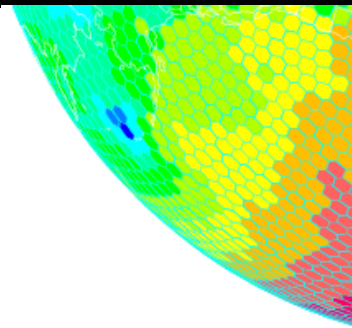
Result: GSD poised for key role with Next-Generation Global Prediction System (NGGPS) development



GSD Role in NOAA Global Modeling

- NCEP/ESRL Memorandum of Agreement – Nov 2009
  - Task 1– demonstrate contribution to GEFS from FIM within mixed-model ensemble
- High-Impact Weather Prediction Program (HIWPP)
  - Advanced hydrostatic model development, non-hydrostatic dynamic cores, physics
  - GSD/PSD, More in Session 3
- NOAA Holistic Model Consortium (EMC, GFDL, GSD/ESRL) coupled global modeling

Quality – Innovative Global Model Development



- Accurate numerics (FIM, NIM)
- Extension to in-line chemistry – FIM-chem
- Coupling to ocean community model (HYCOM)
  - First/only NOAA global coupled model with HYCOM
- Development of non-hydrostatic icosahedral model (NIM)
- Real-data evaluation
  - Successful performance vs. GFS – deterministic (including hurricane) and mixed-model ens.
- Physical parameterizations
  - GFS physics suite within alternate dynamic core
  - Development of scale-independent and storm-scale physics suites, aerosol-chemistry

ESRL Global Icosahedral Models (FIM/NIM)

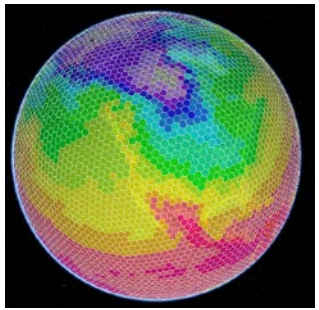
FIM: Hydrostatic

- Model candidate for NOAA global ensemble and subseasonal real-time applications.
- Backbone for ESRL Earth-System Analyzer (ESA – chem-global) research applications.

Target resolution ≥ 10 km

NIM: Nonhydrostatic

- Demonstration for actual 3km real-data global forecasting with advanced computing and numerics.

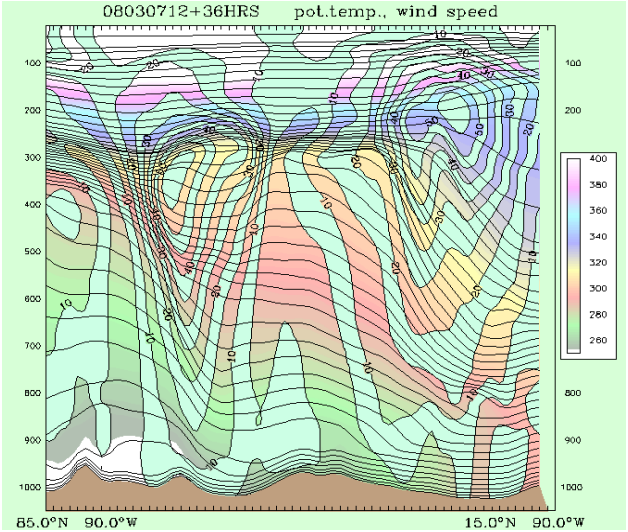


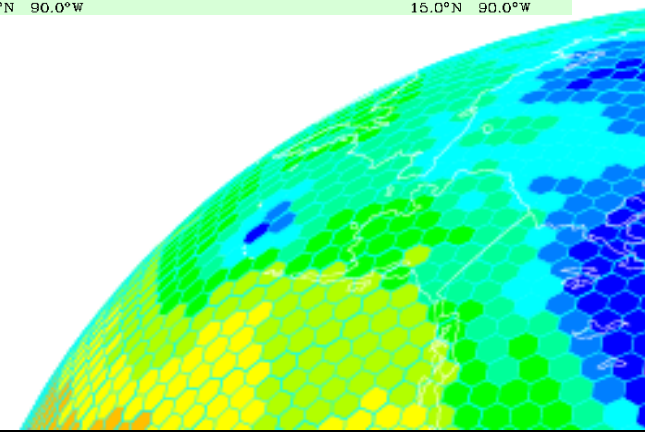
Target resolution: Down to 1 km

Why Global Modeling in GSD?

Innovative numerical approaches for global models

- Icosahedral horizontal coordinate
- Isentropic-adaptive coordinate
- Application of finite-volume approach within icosahedral and isentropic framework

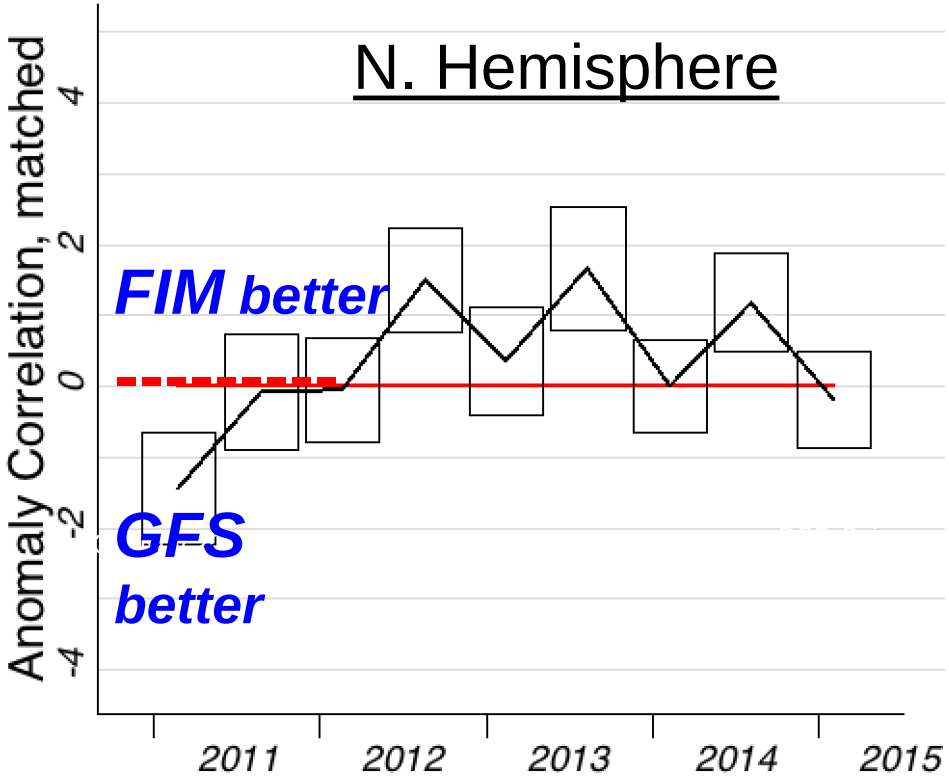


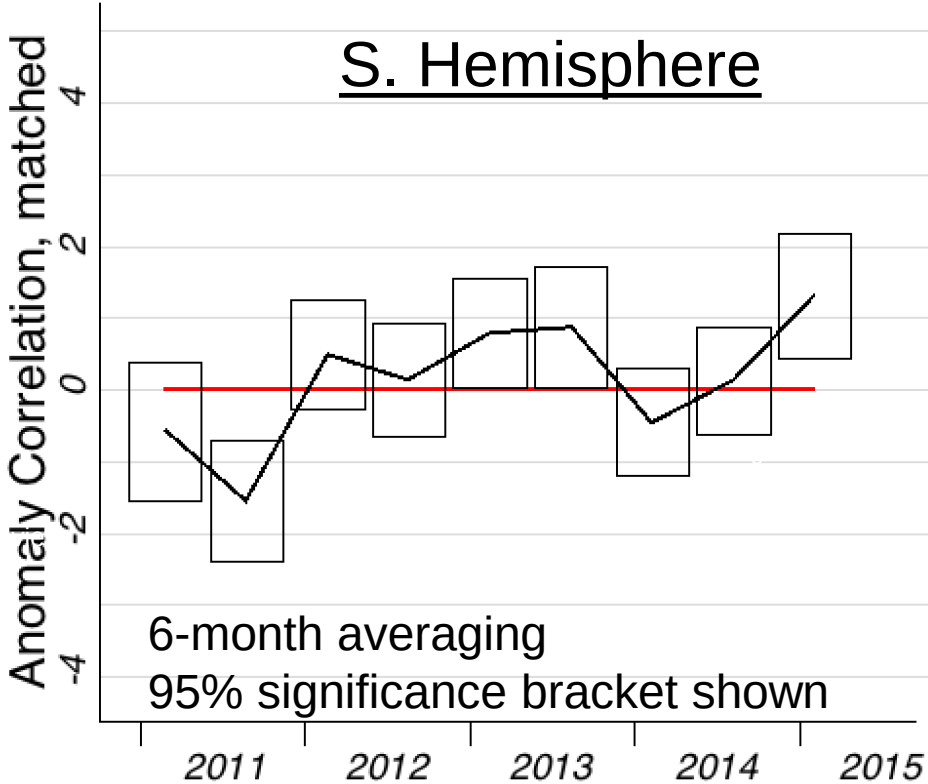


Experience with physical parameterizations

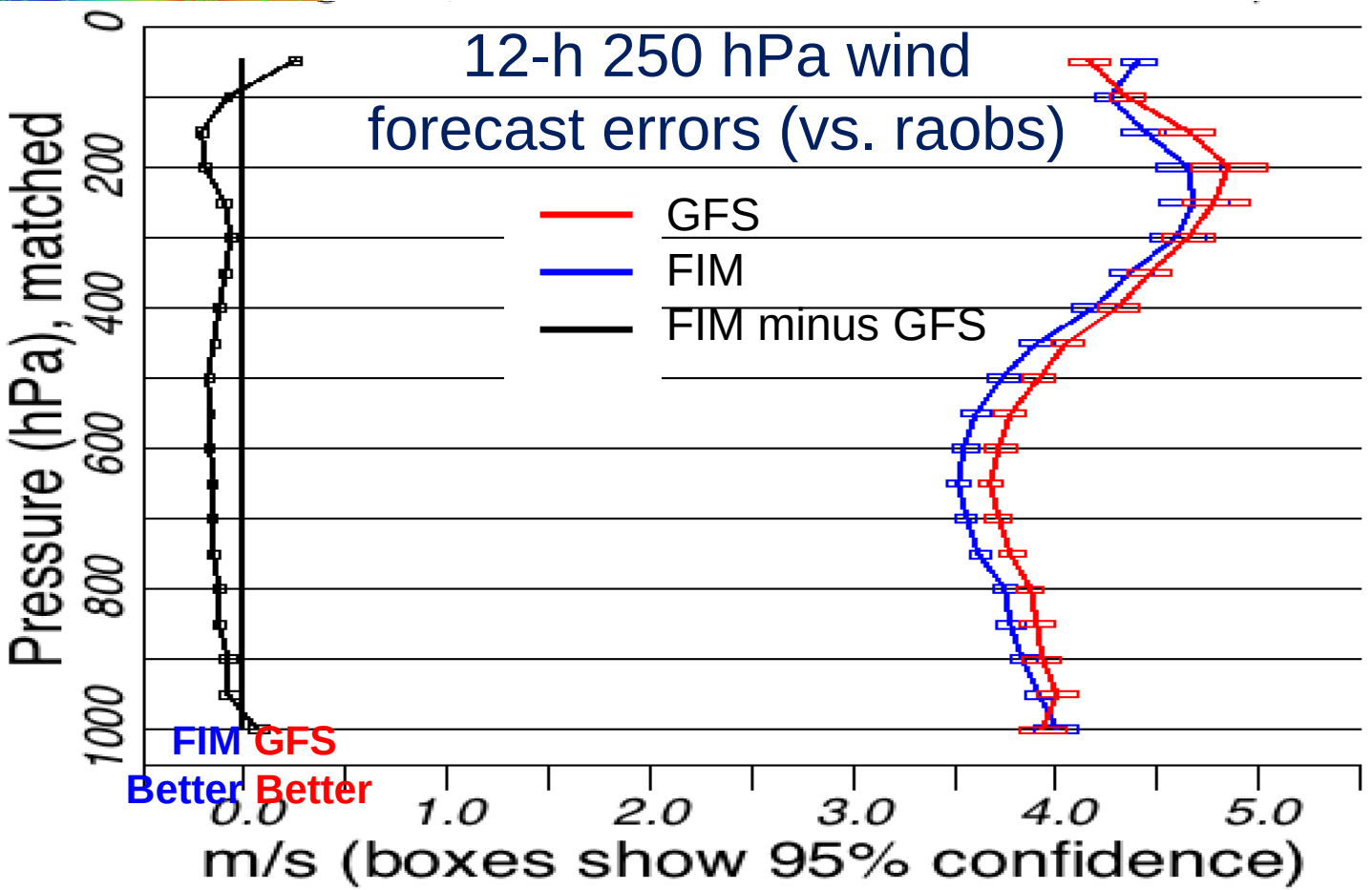
- Successful incorporation of GFS physics (2008, 2011, 2015 versions) into alternate dynamic core global models.
- Development of alternative scale-aware deep cumulus parameterization (Grell), sub-grid-scale cloud effects (Grell,Olson)
- Development and demonstration of HRRR-RAP physics suite (main NOAA development for storm-scale physics suite)
- Aerosol-aware physics, aerosol chemistry (smoke, volcanic ash)
- Collaboration with WRF, WRF-Chem, Climate Processes Team, NGGPS Global Modeling Test Bed

7-day 500 hPa height anomaly correlation

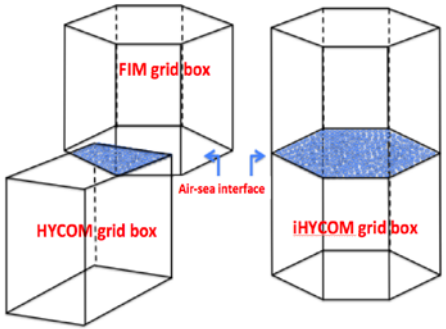




Performance in Global Modeling

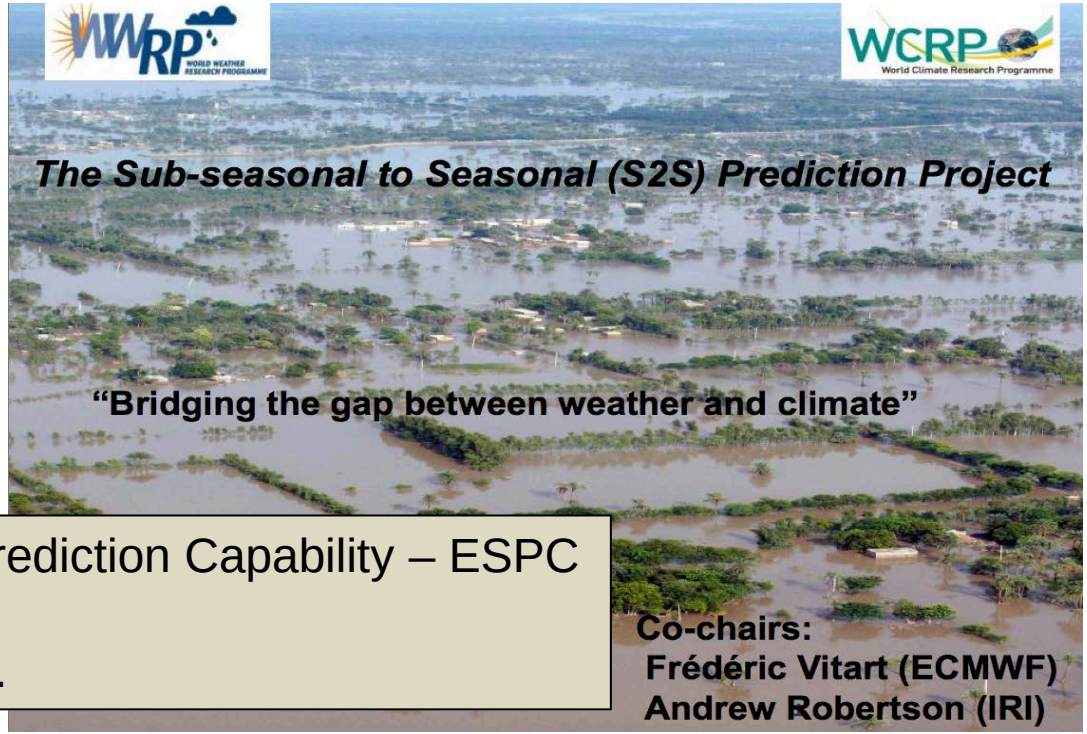


Subseasonal National Multi-Model Ensemble (S-NMME) – Week 3-4



Coupled FIM-HYCOM

- *atmosphere-ocean model*
- *testing down to 15km*



Component of Earth System Prediction Capability – ESPC

- NOAA, Navy, DoD
- Focus Areas – Blocking, etc.

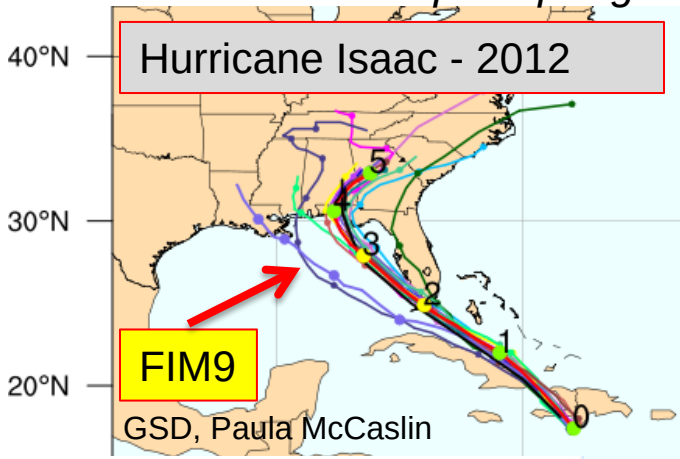
Subseasonal NMME Participants

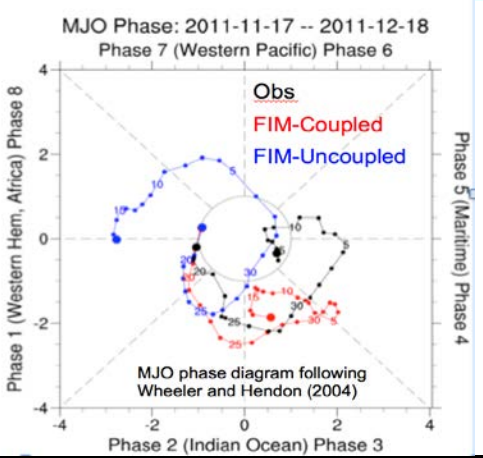
	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-32	T639/319L91	51	2/week	On the fly	Past 18y	2/weekly	11
UKMO	D 0-60	N96L85	4	daily	On the fly	1989-2003	4/month	3
NCEP	D 0-45	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-35	0.6x0.6L40	21	weekly	On the fly	Past 15y	weekly	4
CAWCR	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-34	T159L60	50	weekly	Fix	1979-2009	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1992-now	daily	4
Met.Fr	D 0-60	T127L31	51	monthly	Fix	1981-2005	monthly	11
CNR	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10
FIM/HYC	**0-32**	**30kmL64 OL32**	**10**	**weekly**	**Fix**	**1999-2014**	**weekly**	**4**

Relevance in GSD Global Modeling

- Hurricane Forecast Improvement Project
- HIWPP – 15km FIM out to 14 days, hourly output
- ESPC – blocking
- NMME – subseasonal forecasting – coupled FIM-HYCOM

HFIP website http://hfip.org





Relevance: To NOAA Administrator's Priorities

Community Resiliency

- **Global model demos - readiness for 15➔ 10➔ 3km**
- **GSD - vanguard for NOAA high-res global modeling**

Evolve the Weather Service

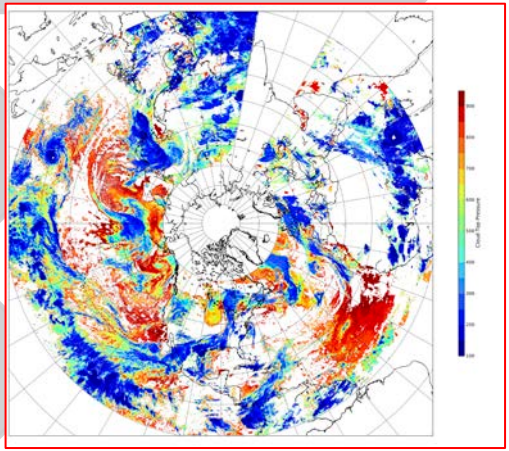
- **Experimental FIM demo real-time runs for HFIP, HIWPP – use in NWS**

Observation Infrastructure

- **advanced global use of sat data**
- **situational awareness**

Organizational Excellence

- **FIM/NIM/HPC coordination across ESRL to NGGPS, NMME**



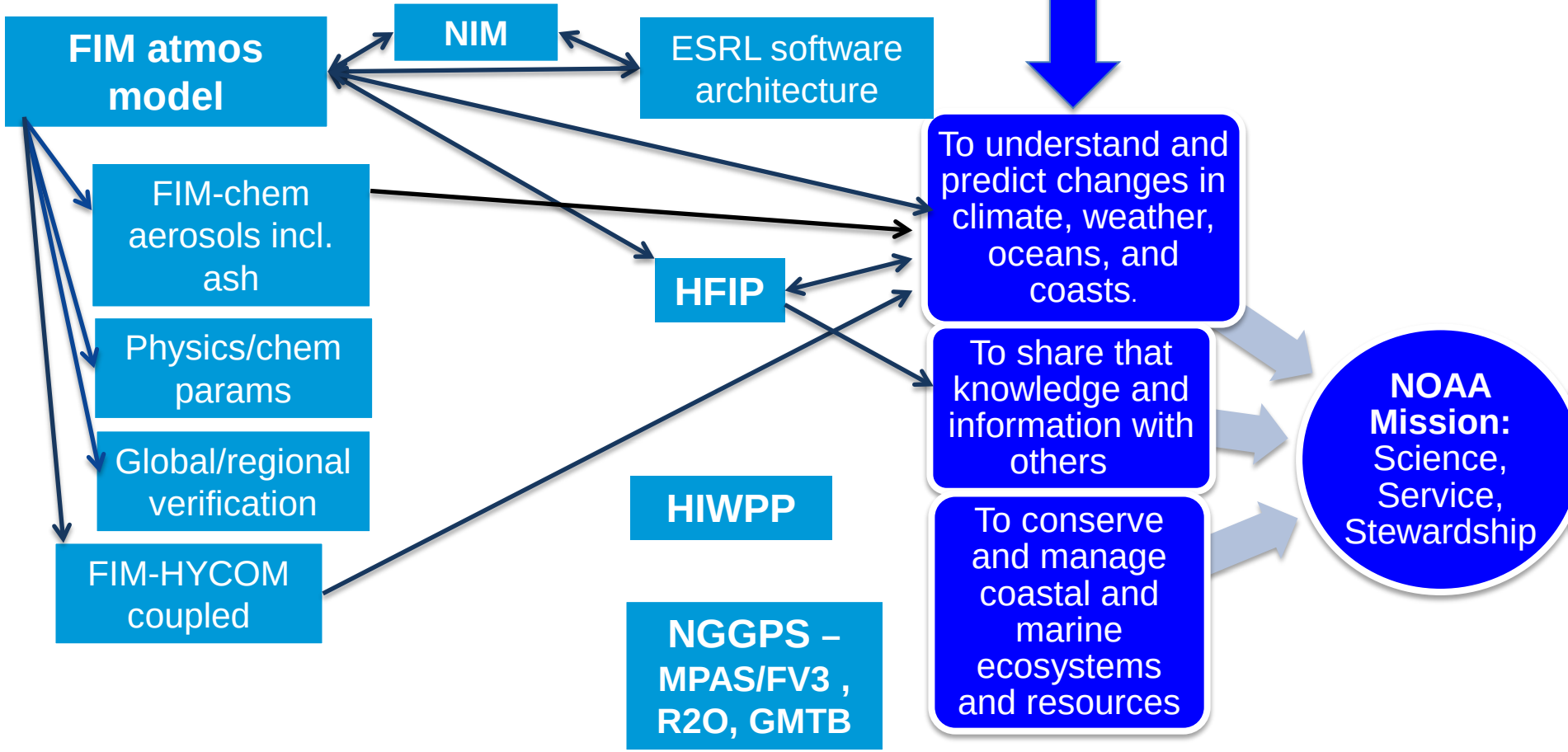
GSD global cloud analysis increment using GSI

What improvements to observing systems, analysis approaches and models will allow us to better analyze and predict the atmosphere, ocean, and hydrological land processes?

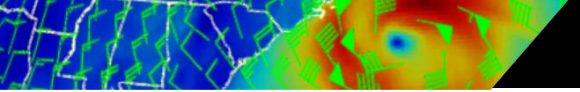
ESRL/GSD role:

- Develop new or improved models and assimilation techniques
  - improve prediction and understanding of phenomena
  - support operational forecasting and research
- Apply those “sharpened tools” to --
  - aviation, severe weather, hydrology, energy, others

Relevance to NOAA 5-year Research Plan



Relevance to NOAA 5-year Research Plan



FIM atmos model

NIM

ESRL software architecture

HIWPP
NGGPS era

FIM-chem aerosols incl. ash

Physics/chem params

Global/regional verification

FIM-HYCOM coupled

HFIP

HIWPP

NGGPS – MPAS/FV3 , R2O, GMTB

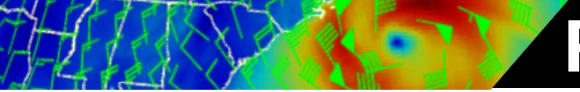
To understand and predict changes in climate, weather, oceans, and coasts.

To share that knowledge and information with others

To conserve and manage coastal and marine ecosystems and resources

NOAA Mission: Science, Service, Stewardship

Relevance to NOAA 5-year Research Pla



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NOAA Mission: Science, Service, Stewardship

HIWPP NGGPS era

- - - → indirect

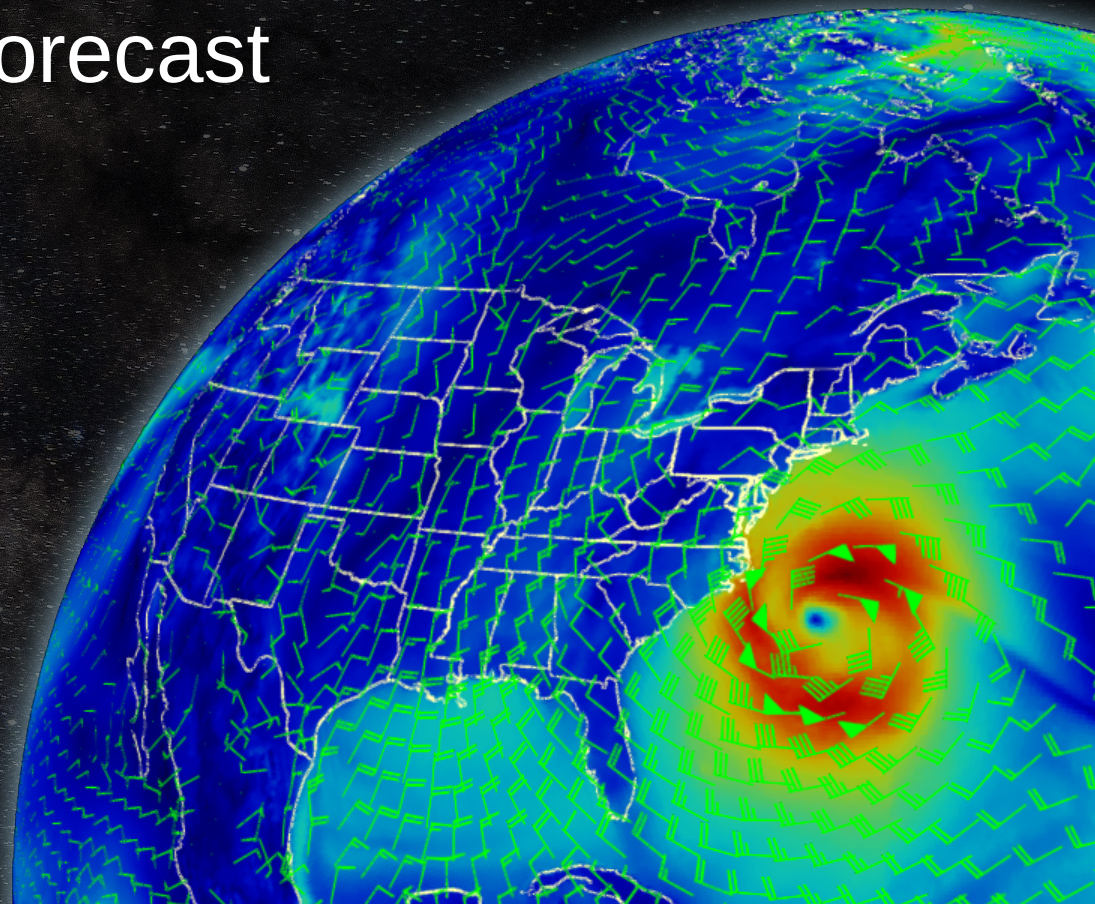
——→ direct

NWP Session 2 Posters – Science Highlights

Presenter	Electronic Poster	Station
Stan Benjamin	FIM atmospheric global model for medium-range forecast applications	**1**
Georg Grell	Impact of composition and chemistry on weather forecasting	**2**
Shan Sun	Coupled atmospheric-ocean earth system modeling for sub-seasonal prediction	**3**
Jin Lee	Development of non-hydrostatic global modeling - NIM	**4**
Tom Henderson	High-performance software engineering	**5**
John Brown	Physics for global non-hydrostatic applications	**6**

FIM Atmospheric Global Model for Medium-Range Forecast Applications

Stan Benjamin
NOAA/ESRL/GSD



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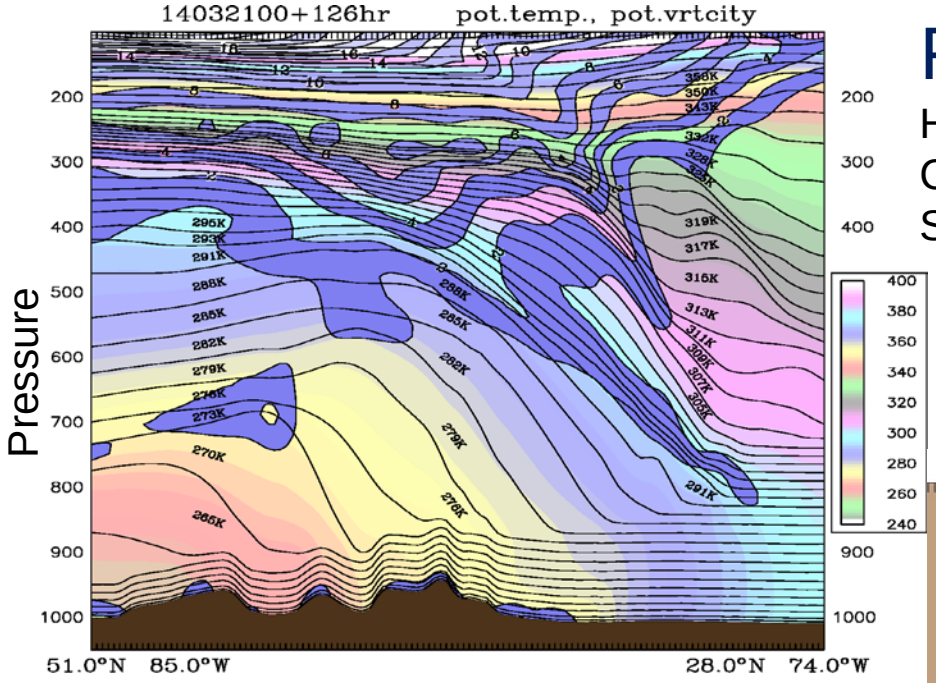
al model
64 levels

forecast init
Mar 2014

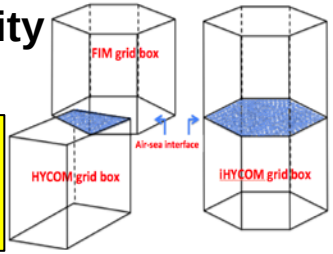
2015, *Mon.Wea.Rev.*,

FIM / HYCOM – Adaptive Vertical Coordinates

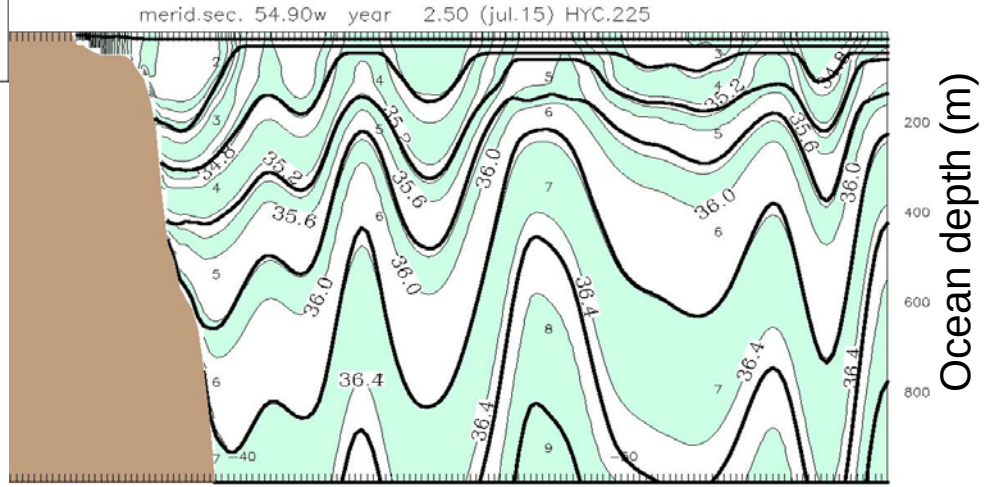


FIM atmospheric model

Heavy black lines: **coordinate surfaces**
Colored field: **potential temperature** (K)
Shaded contours: **potential vorticity**



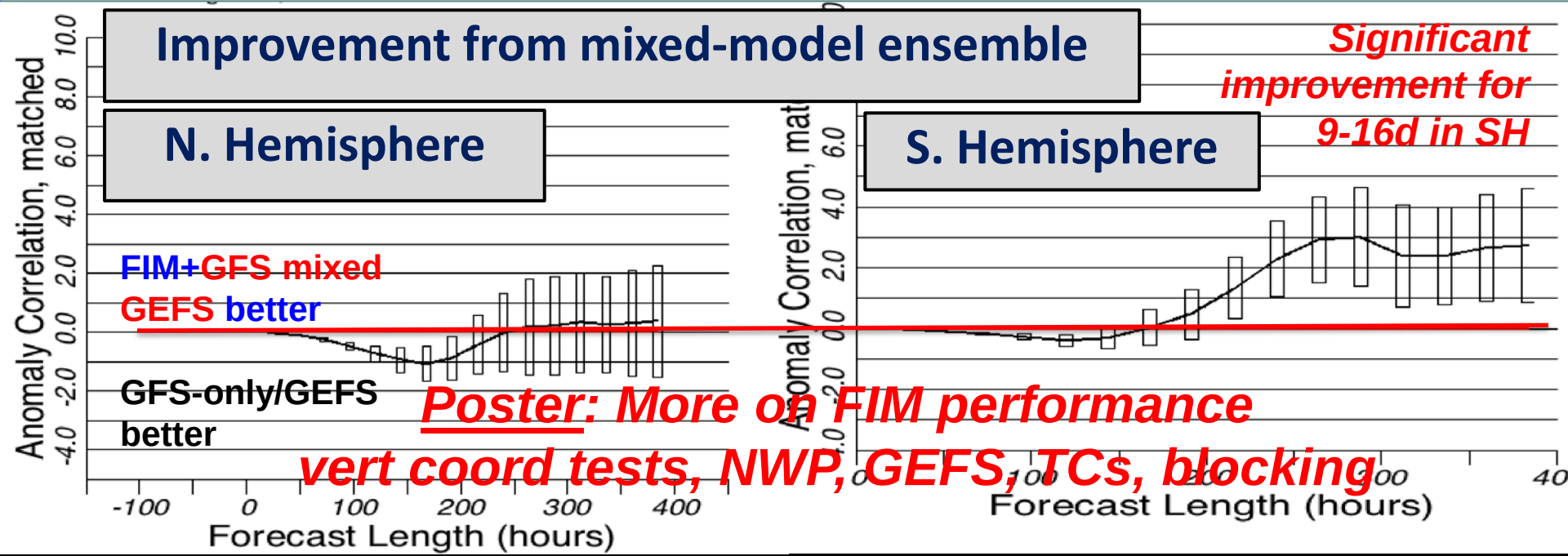
Improved transport minimizing vertical diffusion



iHYCOM ocean model

Heavy black lines: **coordinate surfaces**
Shaded contours: **potential density** (s2)

500Z Anomaly Correlation – ensemble mean
Jan-Dec 2014 – 0-16 day forecasts (2015 version of GEFS
Skill of 10FIM+10GFS ens vs. default GEFS (20 GFS members)



Poster: More on FIM performance vert coord tests, NWP, GEFS, TCs, blocking