Seamless Predictions and Projections of the Earth's Climate System

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Why seamless?

- Earth's climate system is highly interconnected across time and space scales
- Successful prediction of phenomena on shorter time scale may increase confidence in projected response to radiative forcing changes on longer time scales – and vice-versa

<u>Examples:</u>

- ➢ Successful seasonal hurricane predictions used to assess the role of radiative forcing changes
- ➢ Decadal predictability of the ocean can shed light on interpreting observed ocean changes under climate change

Consistent with OAR Mission:

"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."

What do we mean by “seamless” prediction and projection?

A unified set of modeling tools *that can make predictions and projections across synoptic to centennial scales.*

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

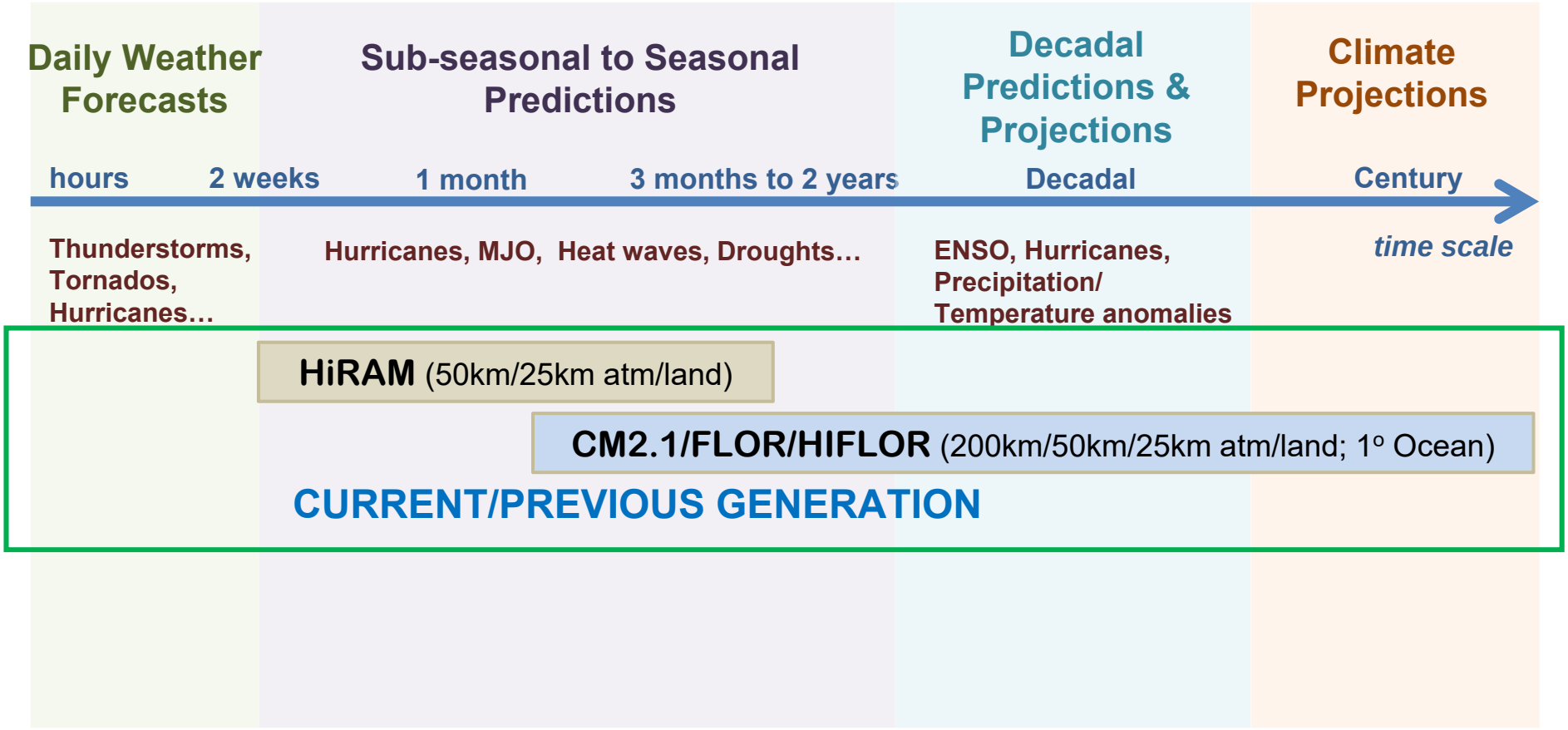
Initial Value Problem (synoptic to seasonal to decadal prediction)

Boundary Value Problem (decadal to centennial projection)

Synoptic to seasonal to decadal to multi-decadal predictions and projections

GFDL Seamless Modeling System – Predictions and Projections

MOM4, AM2,
LM2/3, SIS



GFDL Seamless Modeling System – Predictions and Projections

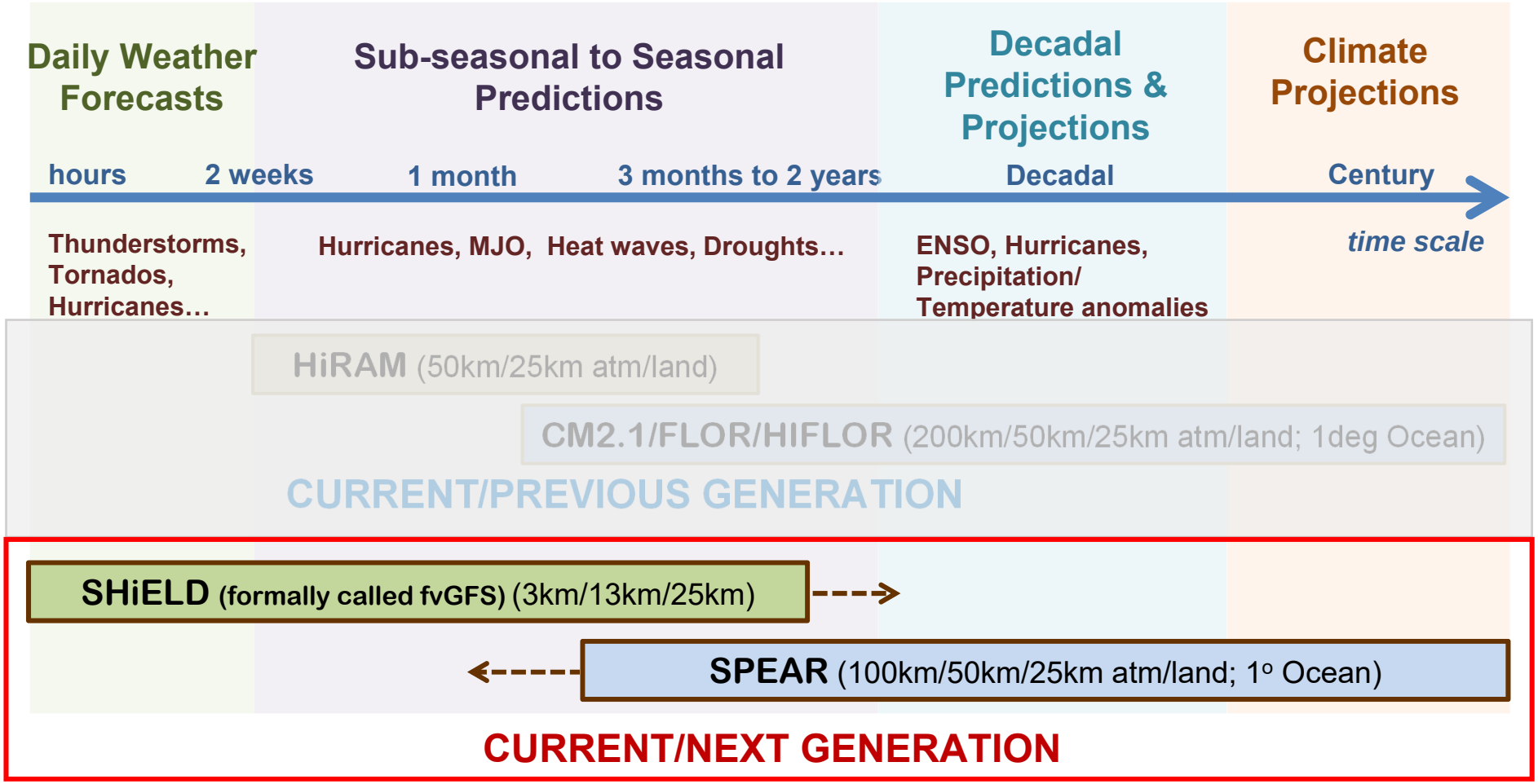
	Atmosphere resolution	Ocean resolution
CM2.1	200 km	1º
FLOR	50 km	1º
HIFLOR	25 km	1º

➔ Seasonal to decadal predictions and climate change projections

- CM2.1 and FLOR: North American Multi-Model Ensemble (NMME)
- Output provided to NCEP to inform their seasonal outlooks
  - FLOR and HIFLOR for hurricanes
  - CM2.1 and FLOR for other climate outlooks, including ENSO, precipitation and temperature
- Seasonal sea ice predictions provided routinely (Sea Ice Prediction Network, NSF)
- Ocean reanalysis provided to NCEP for Multiple Ocean Reanalysis Project
- Decadal predictions as part of international coordinated program through UK Met Office

GFDL Seamless Modeling System – Predictions and Projections

MOM6, AM4, LM4, SIS2



SPEAR: Seamless system for Prediction and EArth system Research

➔ Using latest generation component models:
AM4 (atmosphere), **MOM6** (ocean), **SIS2** (sea ice), **LM4** (land)

	Atmosphere resolution	Ocean resolution	
SPEAR_LO	100 km	1º	*Global scale climate, decadal prediction*
SPEAR_MED	50 km	1º	*Regional hydroclimate and extremes, seasonal prediction*
SPEAR_HI	25 km	1º	*Major hurricanes, seasonal prediction*

Future plans:

- Higher resolution atmosphere with refined mesh over North America (SHiELD)
- Higher resolution ocean, especially for coastal processes
- Incorporating Earth System Model components (biogeochemistry, carbon, marine ecosystems)

New initialization system

New initialization systems using latest model components.

a) New Ensemble Coupled Data Assimilation system using MOM6 (Feiyu Lu)

b) Atmospheric initialization (see poster by Liwei Jia)

c) Innovative sea level pressure (SLP) based assimilation system for initialization of decadal predictions (see poster by Xiaosong Yang)

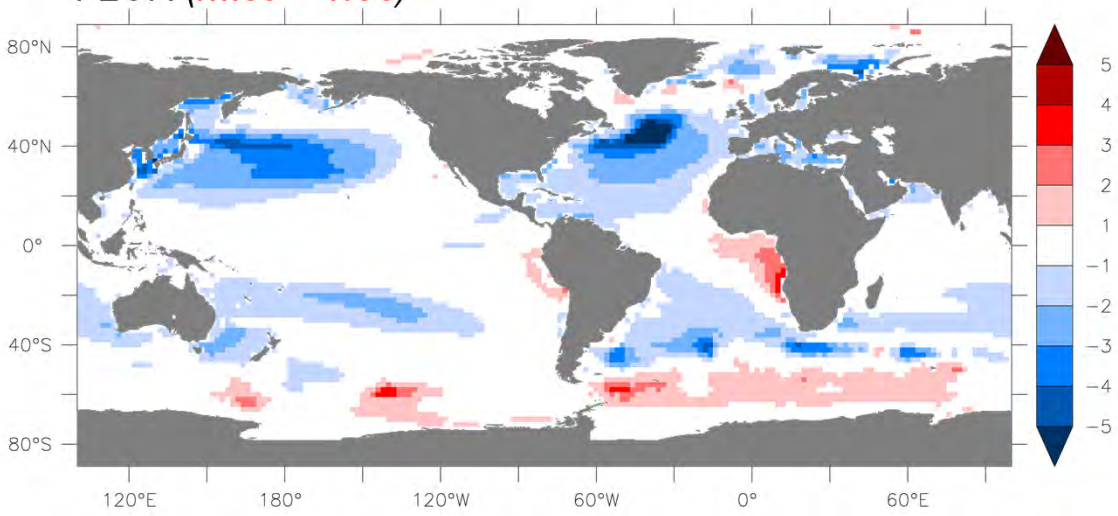
Very encouraging results to date!

➔ Anticipate that SPEAR based prediction system will join the NMME in 2020

SPEAR model performance

SST BIAS (MODEL – OBS)

FLOR (rmse = 1.36)

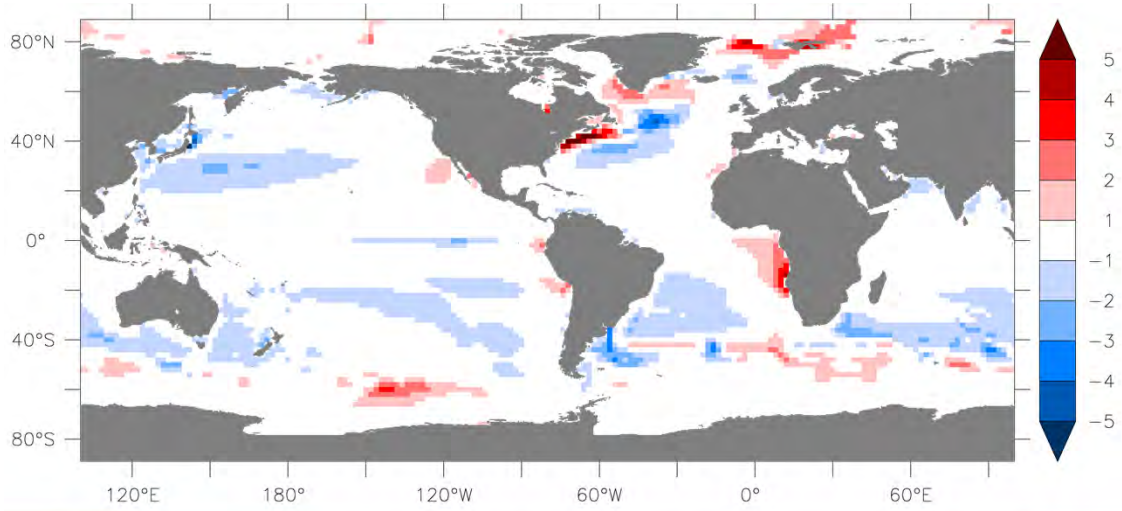


35% reduction in SST error (FLOR → SPEAR)

- Improvements from AM4
- MOM6, including hybrid coordinates

Also improvement in simulation of precipitation, tropical storms

SPEAR (rmse = 0.89)

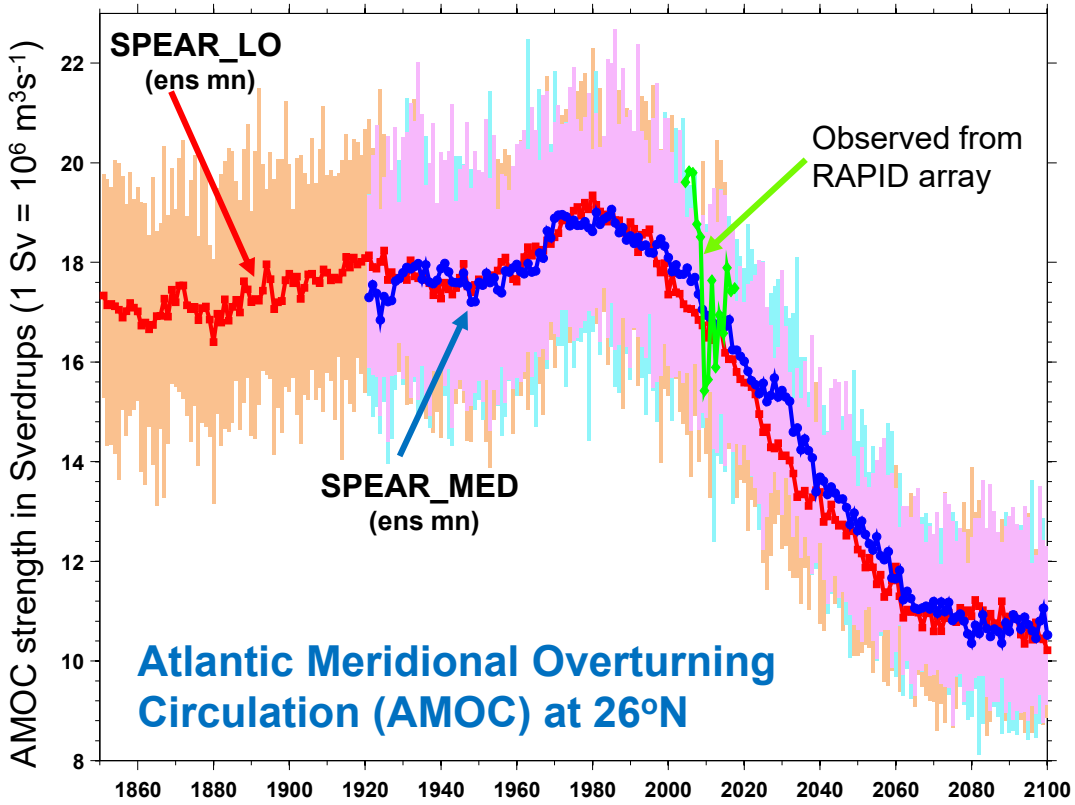


Delworth et al, JAMES, submitted

SPEAR Large Ensembles

As part of seamless system, same model used for seasonal prediction is used to generate 30-member ensembles of projections for 1851-2100.

- 1851-2010: Use observed atmospheric composition
- 2011-2100: Use projected atmospheric composition from SSP5-85



30-member ensembles using both SPEAR_LO (100 km atmosphere) and SPEAR_MED (50 km atmosphere)

Observations from RAPID array fall within model spread.

New studies with SPEAR ensembles:

- *Extreme rainfall and flooding over NE US*
- *"Day Zero" events in South Africa*
- *plus many others …*

Preview of what is to come in this session

1. Short time-scale weather and SHiELD *(Jan-Huey Chen)*
2. Subseasonal predictability *(Baoqiang Xiang)*
3. GFDL and the North American MultiModel Ensemble (NMME*) (Nat Johnson)*
4. Hydroclimate variability, predictability and extremes *(Sarah Kapnick)*
5. Tropical cyclone prediction and attribution *(Hiro Murakami)*
6. Ocean data assimilation and applications for next generation systems *(Feiyu Lu)*

7. Sea ice predictability *(Mitch Bushuk)*
8. Marine ecosystem prediction *(Charles Stock)*
9. Decadal variability and predictability *(Liping Zhang)*
10. Ocean heat uptake *(John Krasting)*
11. Regional climate change and fisheries *(Vincent Saba)*

Summary

- GFDL has developed a next generation research system for seamless prediction and projection (SHiELD and SPEAR)

  - Synoptic to seasonal to decadal to centennial

- Leading edge GFDL developments are at the heart of this system

  - FV3, refined mesh, AM4, MOM6, new assimilation, LM4, SIS2

- Further development is planned to incorporate atmospheric refined mesh, higher resolution ocean, and Earth System Components

- Powerful tool for attribution analysis