GFDL Updates (2016)

NWP

- FV3 selected as atmosphere dynamical core in NOAA/NWS Next Generation Global Prediction System (NGGPS) competition

Subseasonal-Seasonal

- Arctic Sea Ice prediction
- Ongoing contributions to NMME
- HiFLOR skillfull seasonal prediction of Category 4-5 Cyclones
- NMME based regional living marine resource (LMR) prediction

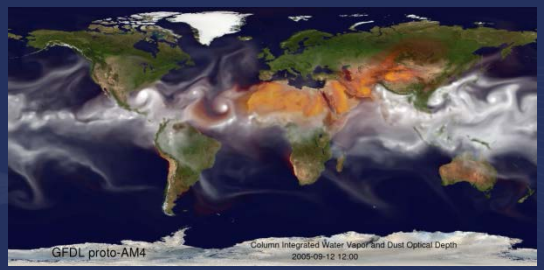
Seasonal-Centennial/CMIP6

- North Atlantic Oscillation driving Northern Hemisphere climate variability
- CM2.6/ESM2.6 (10 km ocean) for regional climate/LMR impact studies
- GFDL model development team freezes AM4.0
- Final CM4.0/ESM4.0 to be frozen in 2017 (Code, June; Configuration, Sept)

Other Accomplishments

- MOM6 selected as NCAR's next generation ocean dynamical core
- Prototype coupled ice-ocean simulation of ice sheet collapse
- Land-Atm. modeling of Earth System interactions through urban and hillslope tiling, fire, dust, N_2O emissions, and river N discharge.

Towards a unified Weather-Climate Prediction System



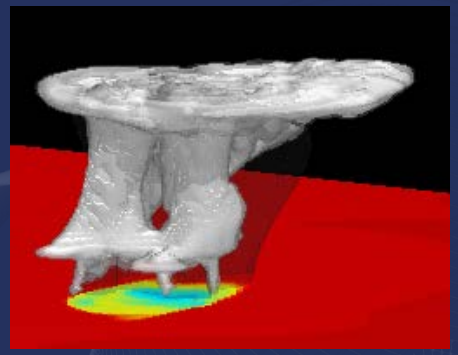
50-km GFDL-AM4

global ⟷

GFDL FV3

Grid-stretching and nesting capabilities

⟷ Regional



1-km GFDL "Super HiRAM"

Next Generation Global Prediction System (NGGPS) Goals:

- Develop a unified modeling system for weather and climate simulations
- Unify regional (convective-scale) and global modeling systems

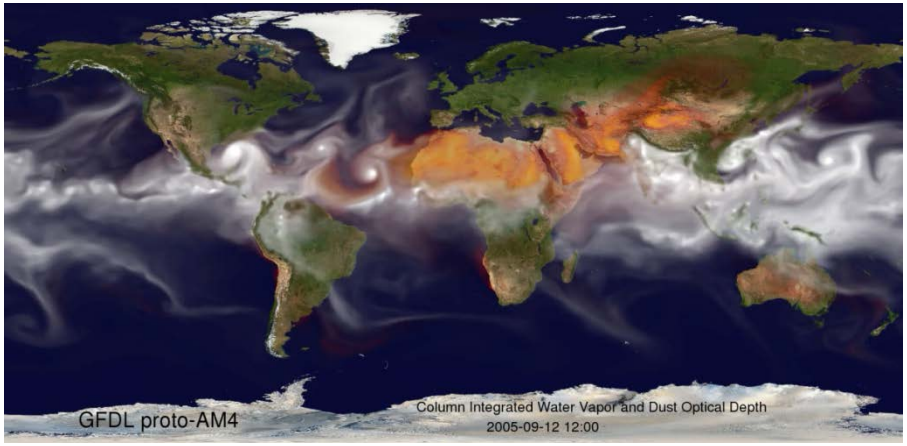
- **July 2016:**
  NOAA selected GFDL's FV3 led by S. J. Lin for NGGPS – 1st–ever open competition

  - **Significantly better forecasts than operational GFS using GFS IC**
  - **Forecasts as skillful as operational ECMWF when initialized with (spatially interpolated) Initialized Forecast System**

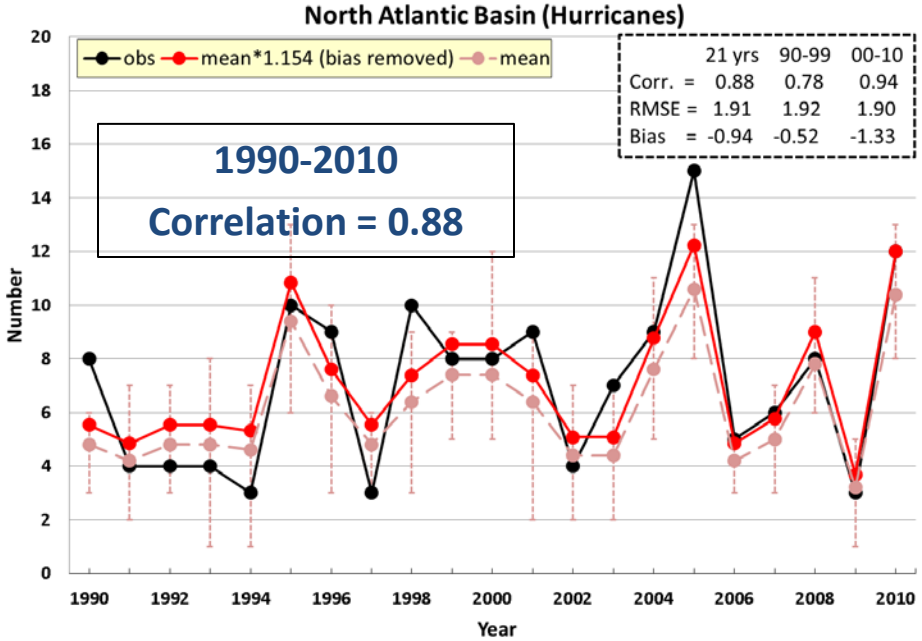
GFDL weather-climate modeling

(an unique modeling system for applications across time scales, including NWP)

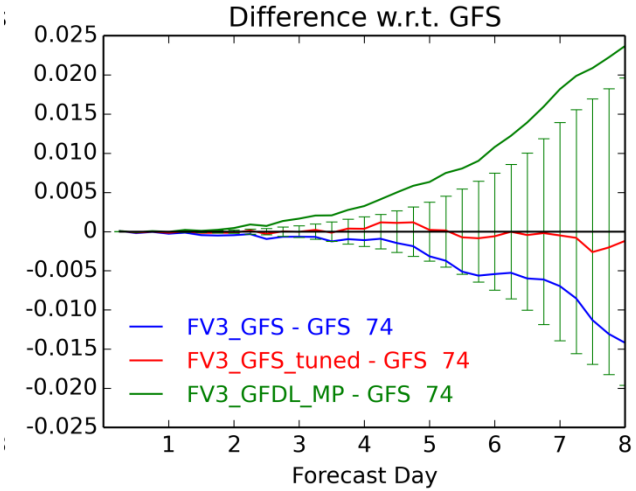
Dust (orange) and water vapor (white)
(GFDL 50-km AM4 for CMIP6)



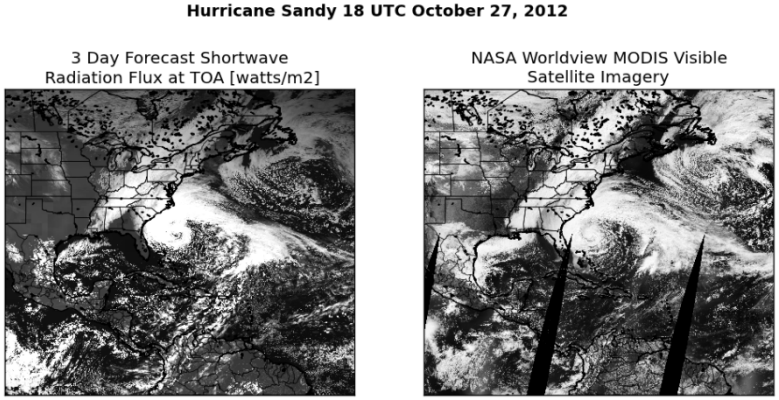
Seasonal Hurricane Prediction (25-km HiRAM)



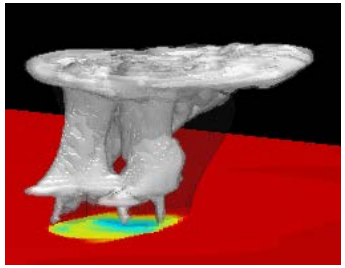
Medium-range NWP (13-km, phase-2 NGGPS)



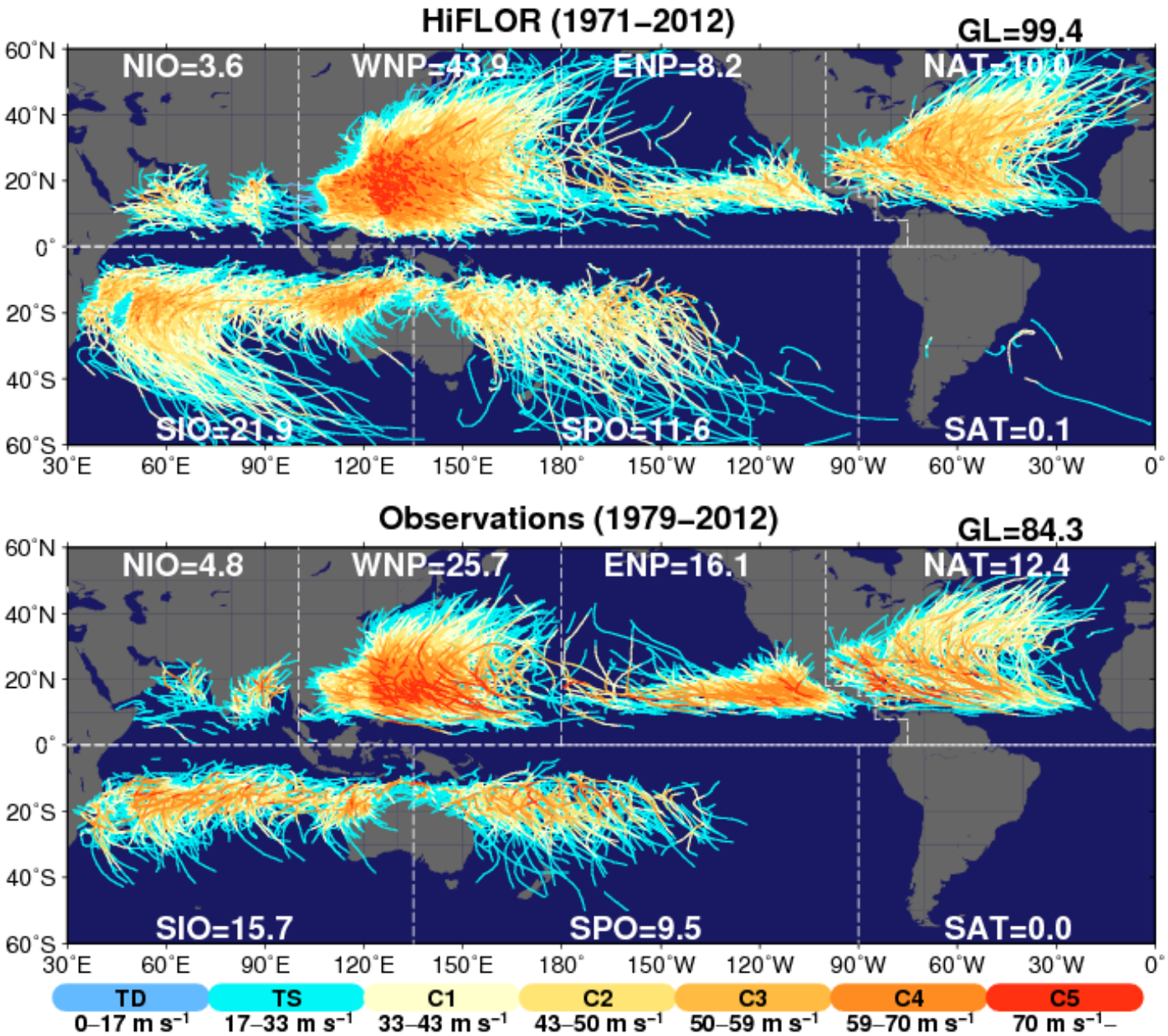
Global cloud-permitting Predictions (3-km, phase-1 NGGPS)



Severe Storm prediction (1 km, Super HiRAM)

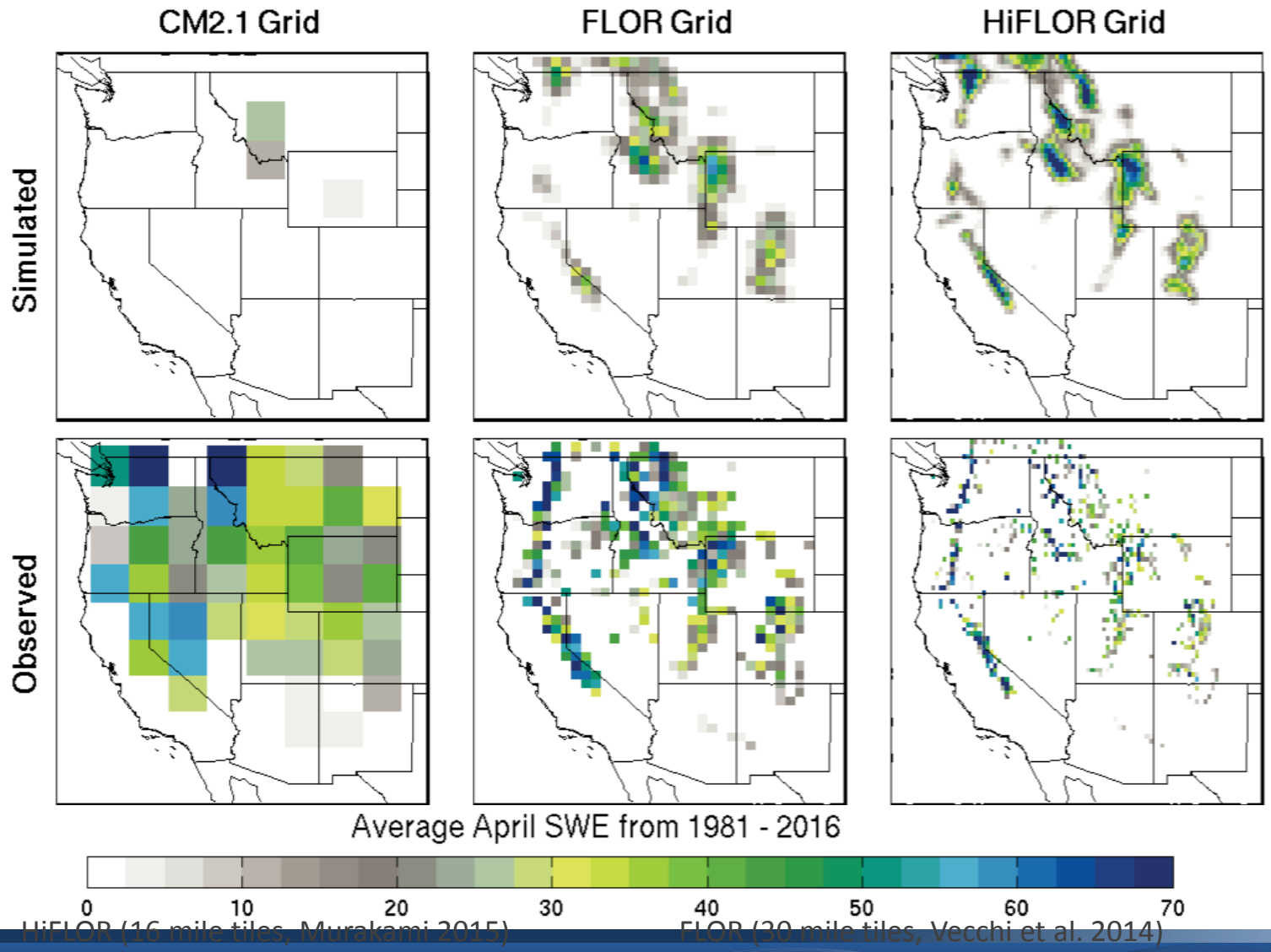


HiFLOR: first global climate model to simulate & predict Cat. 4-5 TCs (most destructive storms)



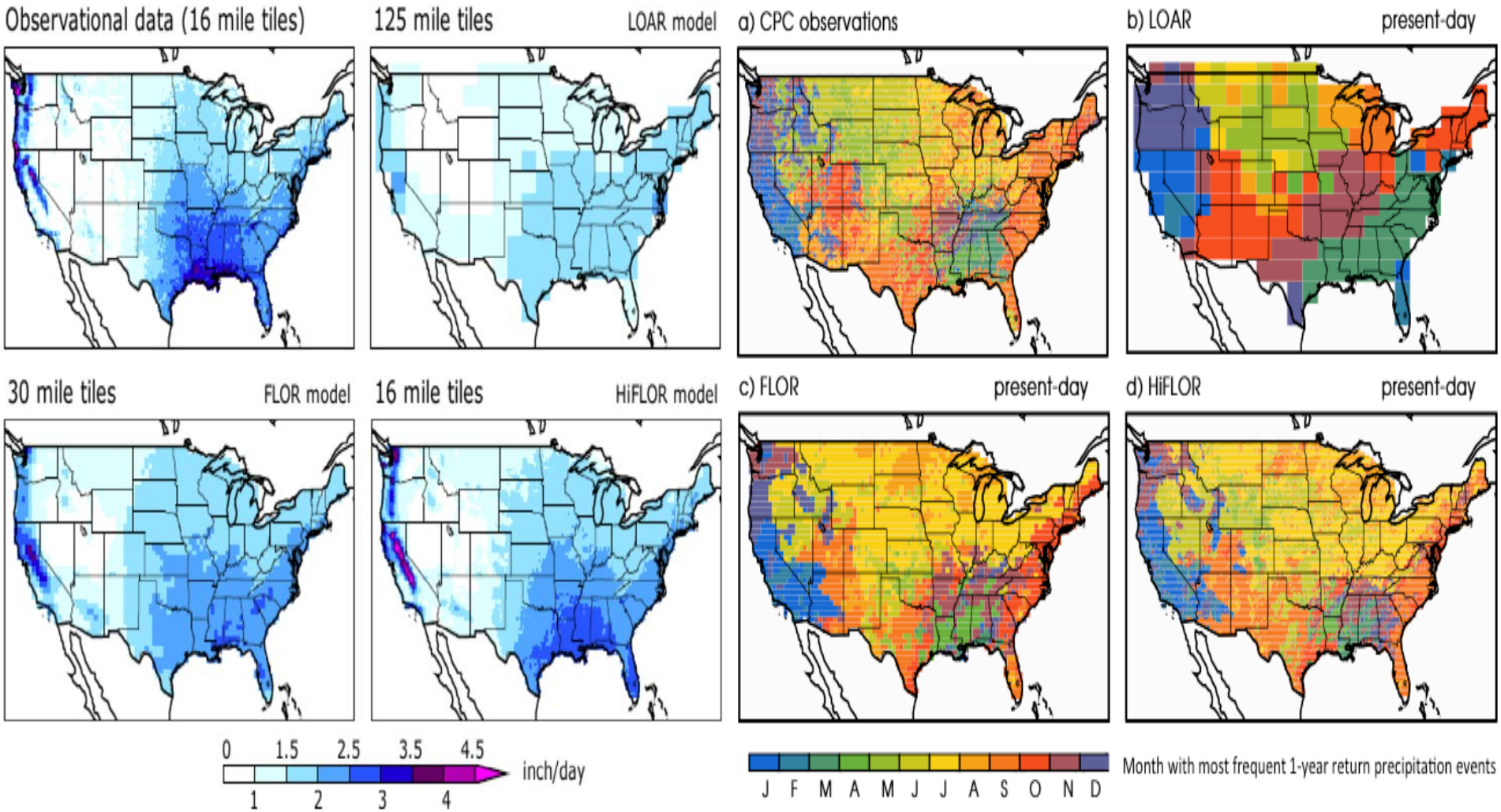
Murakami et al. (2015, J. Climate)

April Western U.S. Snowpack Climatology Simulation Improvements with Resolution

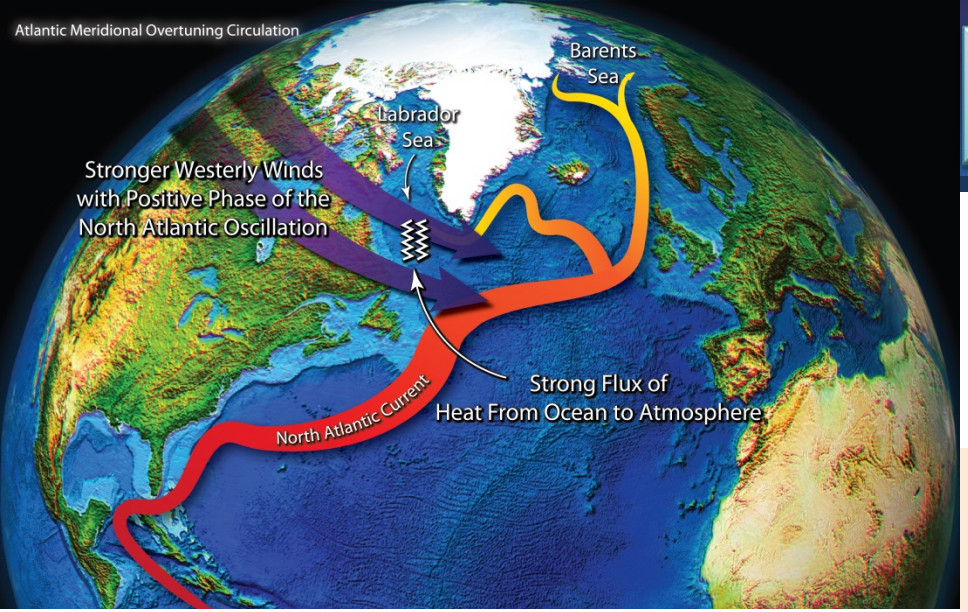


Source: Kapnick et al. (in prep.)

Resolution Dependence of Extreme Precipitation and its Seasonality



van der Wiel, K., Kapnick, S.B., Vecchi, G.A., Cooke, W.F., Delworth, T.L., Jia, L., Murakami, H., Underwood, S. and Zeng, F., 2016. The Resolution Dependence of Contiguous US Precipitation Extremes in Response to CO_2 Forcing. *Journal of Climate*.



Multidecadal NAO variations influence NH climate by altering Atlantic ocean circulation

Potential contribution to observed multidecadal changes in:

- *Atlantic ocean temperature*
- *Arctic sea ice*
- *Northern Hemisphere temperature*
- *Atlantic tropical storm activity*
- *African rainfall*

1. Delworth and Zeng, 2016, J Climate: Idealized study showing decadal-scale NAO drives North Atlantic ocean (AMOC) changes with hemispheric scale climate impact (Atlantic ocean, Arctic sea ice, precipitation, tropical circulation)

2. Delworth et al., 2016, Nature Geoscience: Exploration of observed multidecadal NAO changes in driving climate variations through Atlantic ocean circulation. These include rapid Atlantic warming, Arctic sea ice changes, tropical precipitation changes, and tropical cyclones.

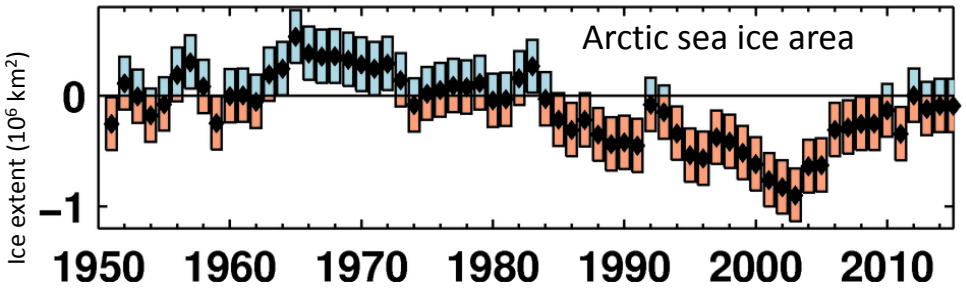


Figure caption: Simulated impact of multidecadal NAO variations on NH surface air temperature due to ocean circulation changes

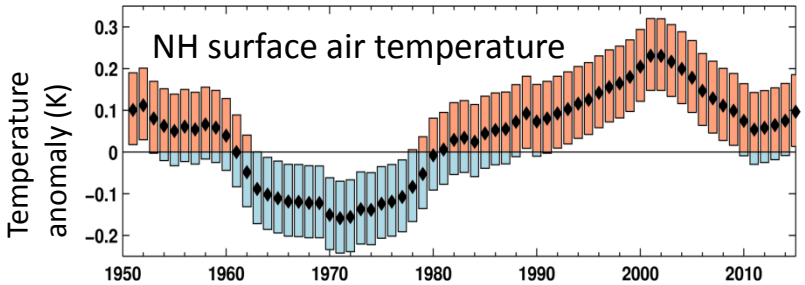


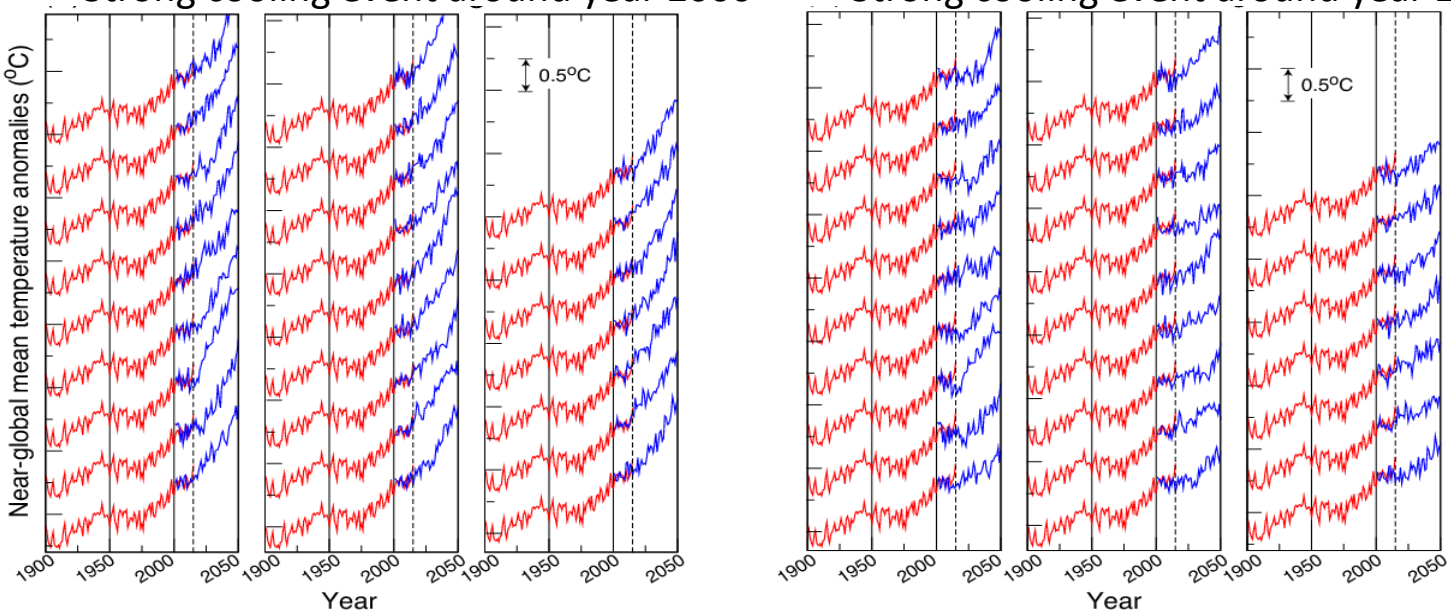
Figure caption: Simulated impact of multidecadal NAO variations on NH surface air temperature due to ocean circulation changes

3. Delworth et al., 2017, J Climate: Explicit analysis comparing ocean dynamics versus surface flux forcing in generating AMO-like North Atlantic multidecadal variability.

How might global temperature evolve in coming decades?

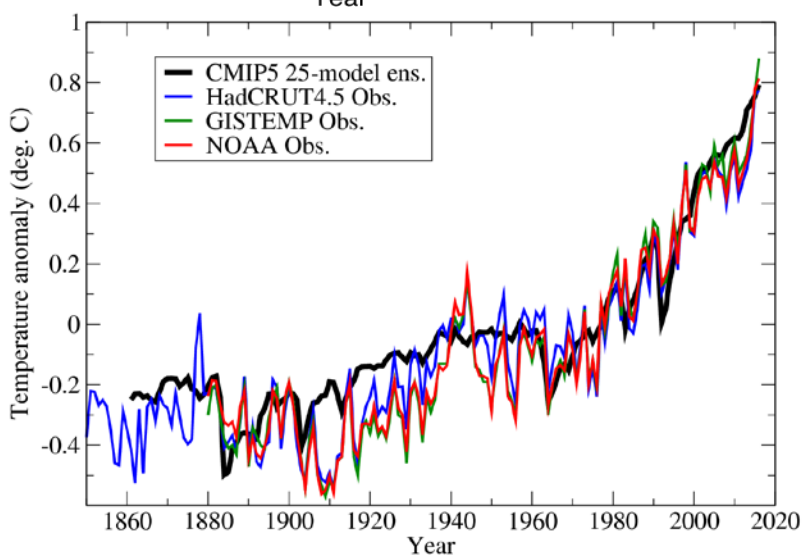
A: - Future warming rate in CMIP5 (RCP8.5)
- Strong cooling event around year 2000

B: - Future warming rate **50%** of CMIP5 (RCP8.5)
- Strong cooling event around year 2000



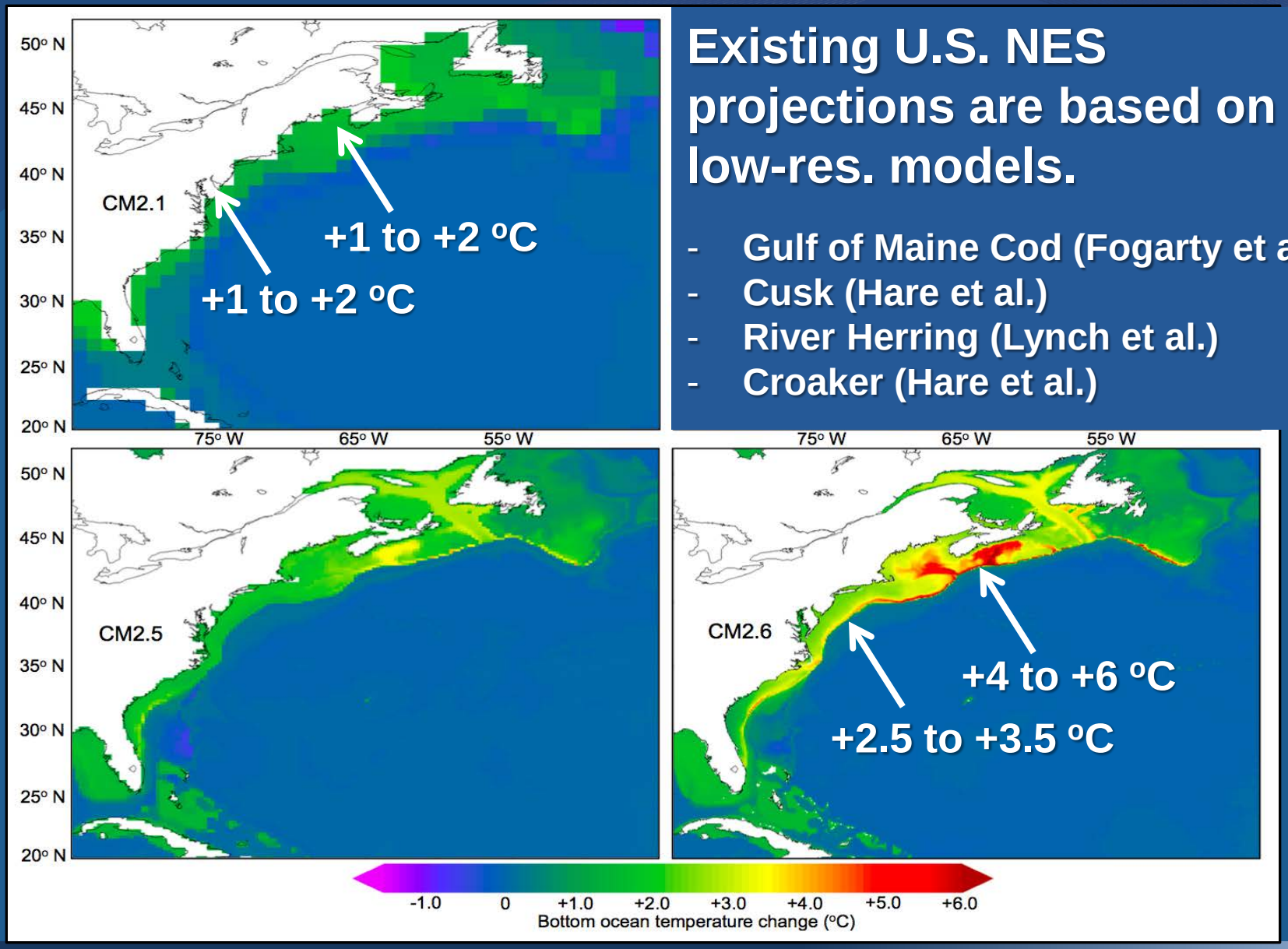
Note: Internal multidecadal cooling events from GFDL CM3…the most highly variable among CMIP5 models.

Red: Observations (HadCRUT4) through 2015.
Blue: Synthetic model projections.



Knutson, T., R. Zhang and L. Horowitz 2016, Prospects for a prolonged slowdown in global warming in the early 21st century. *Nature Communications*.

Northwest Atlantic 2xCO_2 Projection



Existing U.S. NES projections are based on low-res. models.

- Gulf of Maine Cod (Fogarty et al.)
- Cusk (Hare et al.)
- River Herring (Lynch et al.)
- Croaker (Hare et al.)

Saba et al. 2015

Ocean Modeling with MOM6/SIS2

- **MOM6 unifies GFDL's ocean modeling efforts - best of MOM5 and GOLD**
- **SIS2 modernizes our sea-ice model**
- **Scalable on large parallel computers**
- C-grid discretization (replaces B-grid)
  - No "Checkerboard" null mode
  - Less smoothing of forcing required
- **Better representation of topography and narrow channels**
  - No need for "Cross-land mixing"
- **MOM6 and SIS2 are basis of OM4 ocean/ice component of CM4**
- **Open development model (MOM6+SIS2)**
  - All activity visible via *GitHub*

- **NCEP/CFS uses MOM**
- **NCAR/CESM2 adopting MOM6 code base**

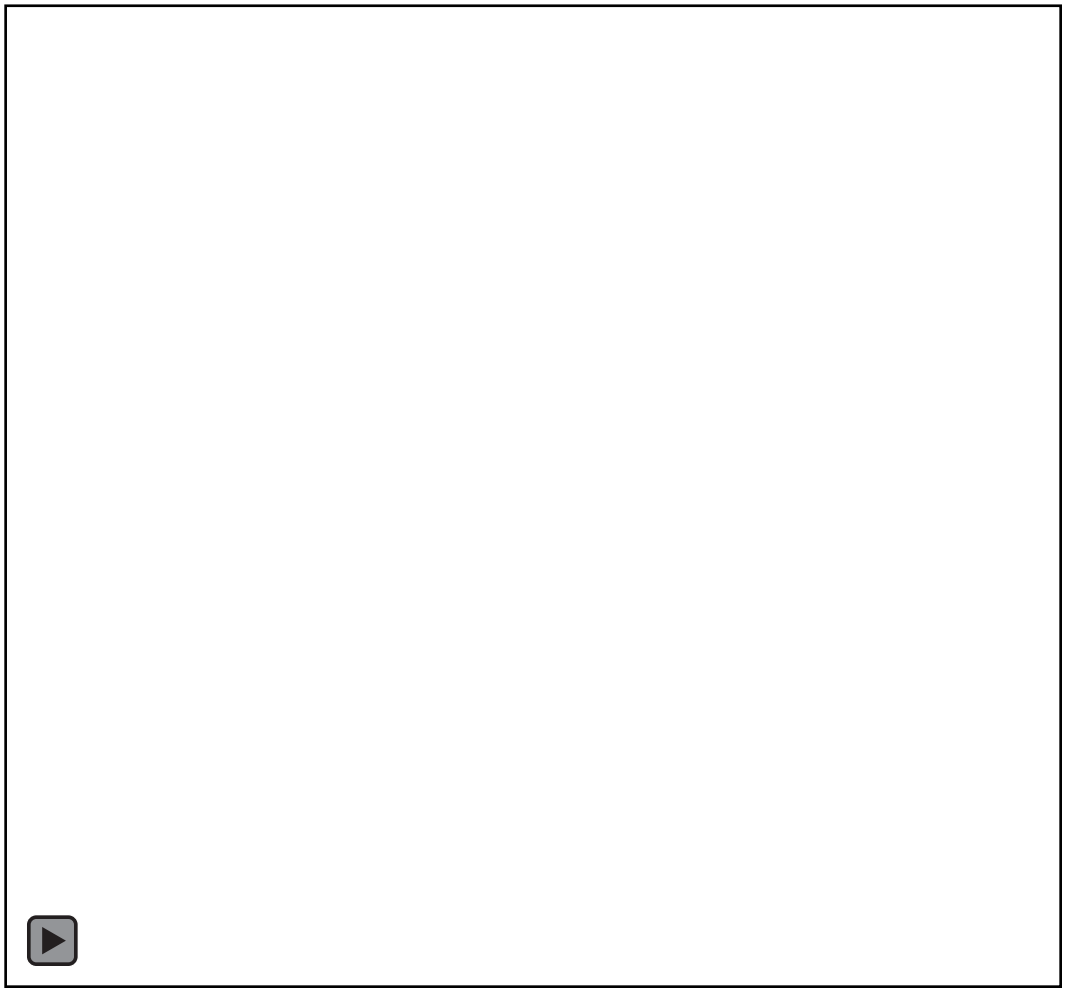
Lagrangian Vertical Dynamics

- Arbitrary Lagrangian-Eulerian method (ALE)
- Tracer advection is not required for gravity wave dynamics
- Able to use a wide range of vertical coordinates

- Implicit remapping replaces vertical advection
  - No vertical CFL limit on time steps
  - Ultra-fine vertical resolution possible
- **Permits sub-cycled gravity-wave dynamics vs. tracer advection**
  - Reduces cost to add tracers.
- **Handles wetting and drying, and evolving geometry conservatively**

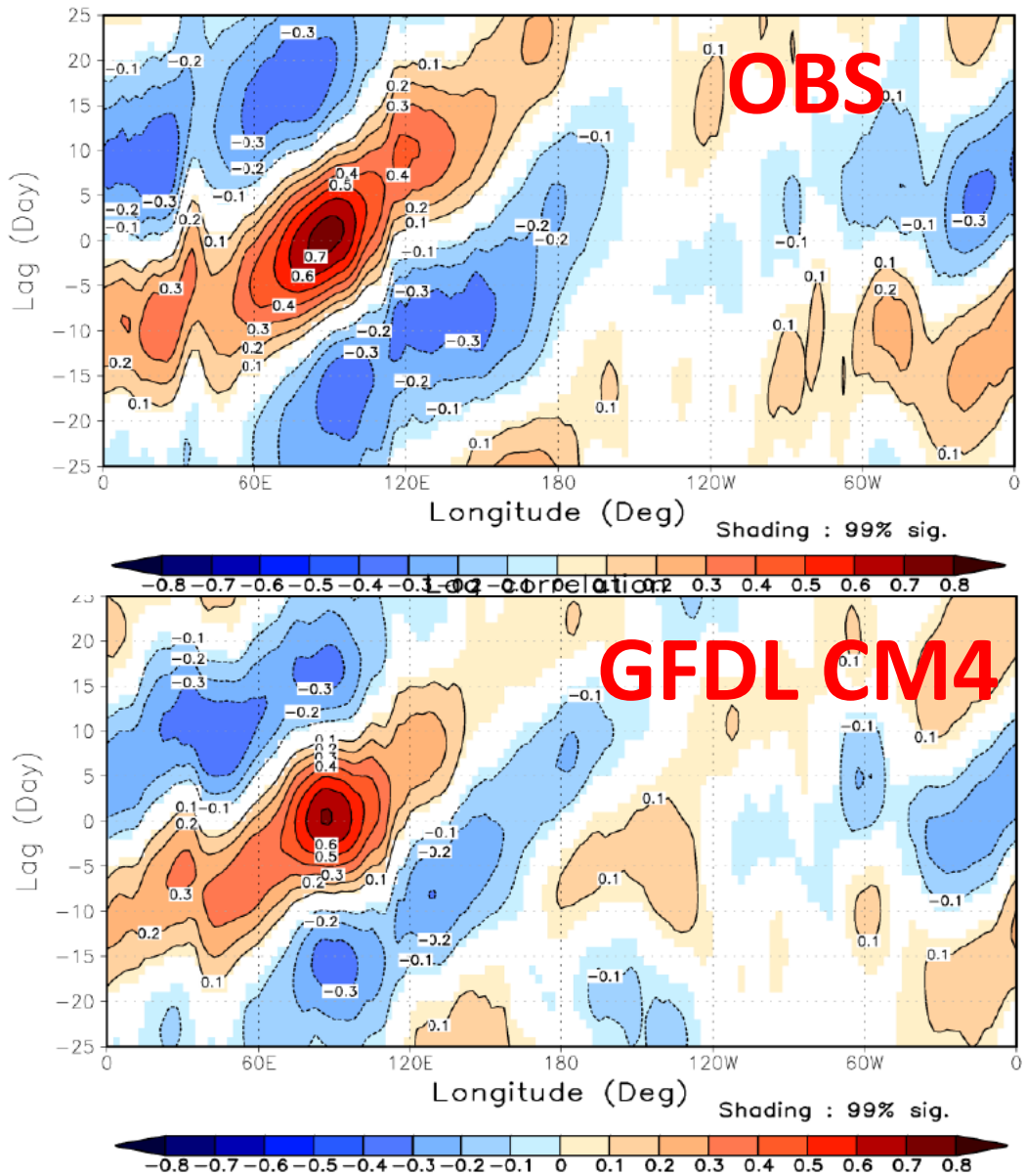
  e.g., moving ice-shelf grounding line

Iceshelf of tabular icebergs coupled to MOM6 ocean



Alon Stern &
Gustavo Marques

MJO Eastward Propagation and Comparative Metrics



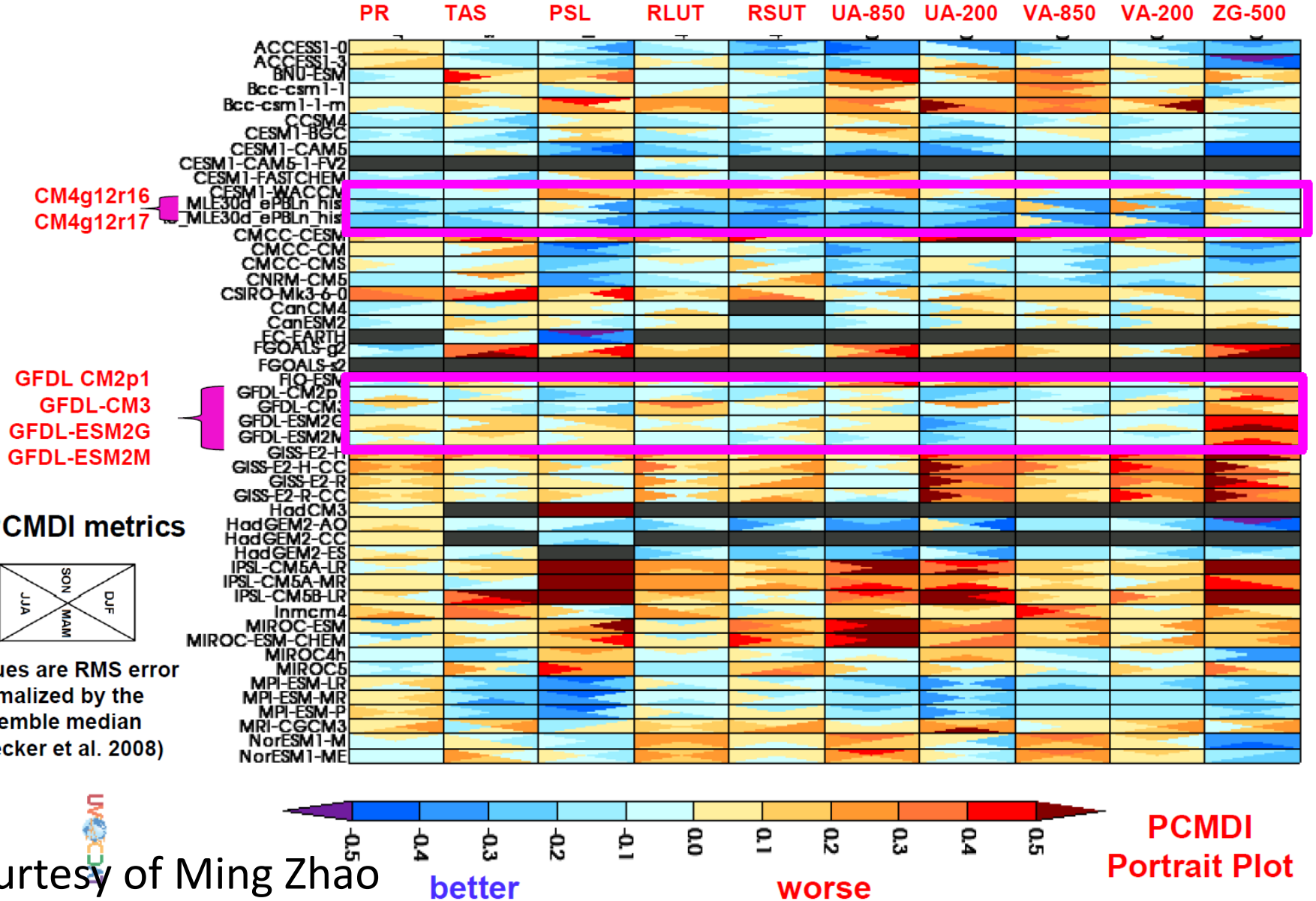
AMIP RMSE Comparison (SST cpld)

Model	CM2	CM3	CM4
SST	1.2	1.1	0.83
OLR	7.21	8.56	4.27
TOA SW	12.59	11.26	7.70
Precip	1.13	1.02	0.86
NH DJF SLP	19.4	19.2	18.4
Zonal wind	1.95	1.85	0.94

Courtesy of Ming Zhao

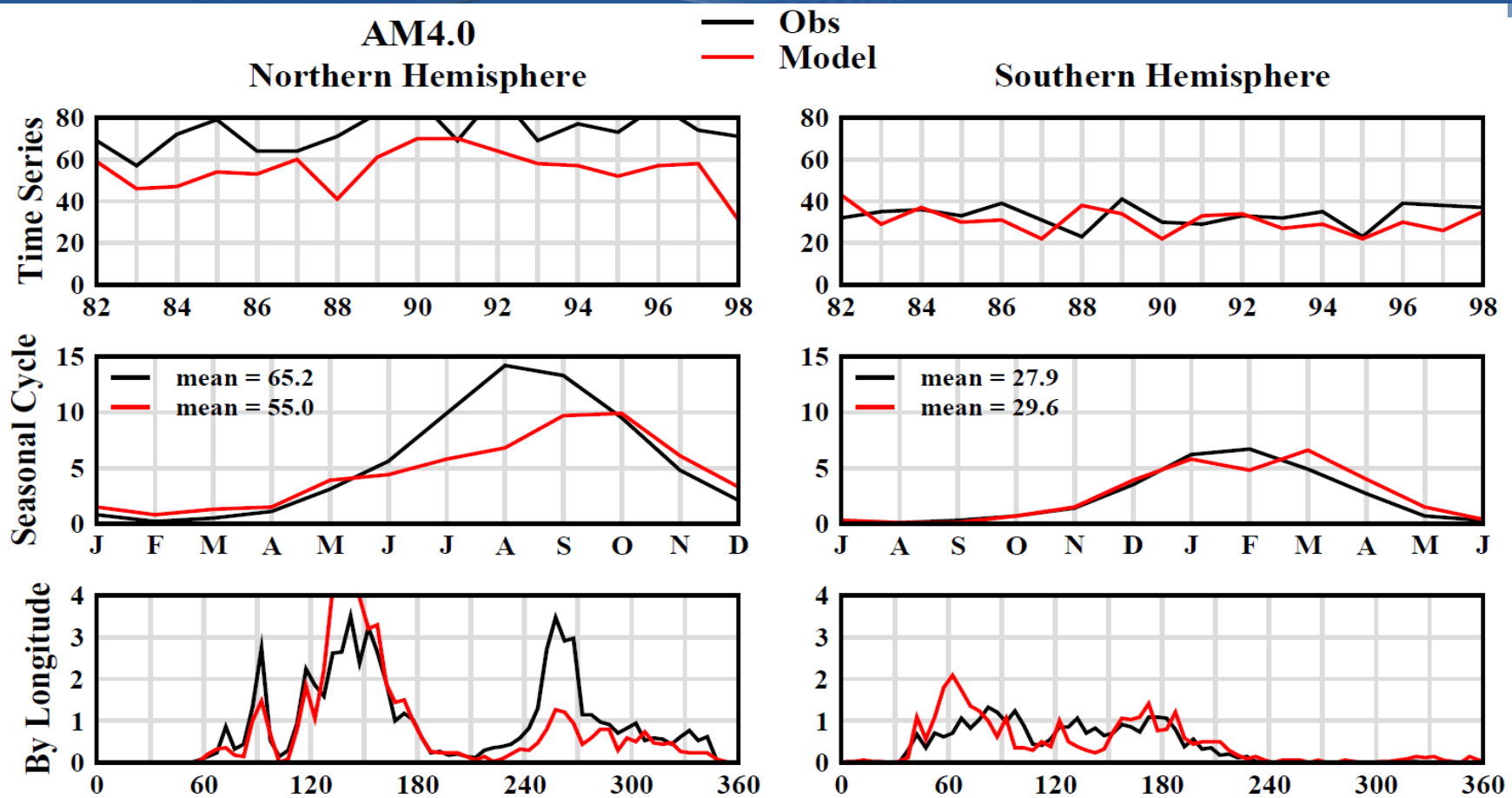
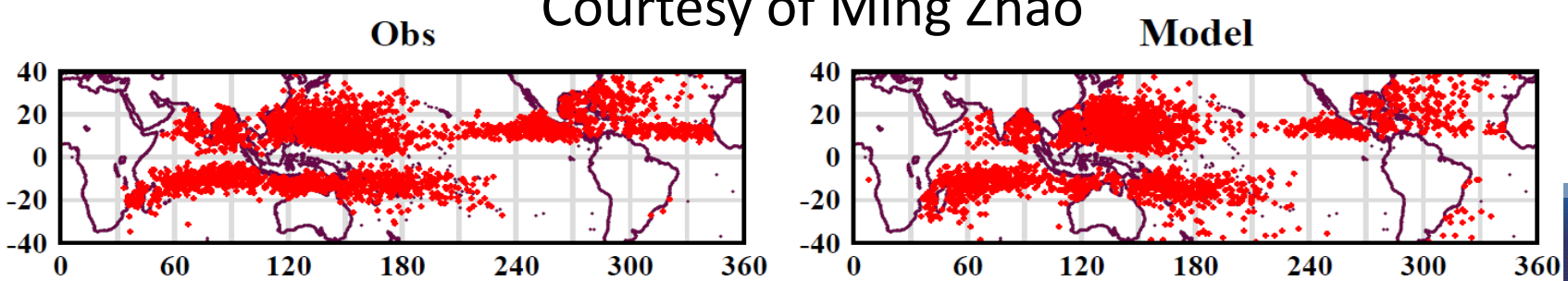
Comparison of CM4 with CMIP5 models in historical simulations

PR: Precipitation; **TAS**: Surface air temperature; **PSL**: Sea-level pressure; **RLUT**: Outgoing LW radiation; **RSUT**: reflected SW radiation at TOA; **UA-850 & UA200**: 850 and 200hPa zonal wind; **VA-850 & VA-200**: 850 and 200hPa meridional wind; **ZG-500**: 500hPa geopotential height.



Courtesy of Ming Zhao

Tracking Tropical Cyclones Distributions in AM4



Courtesy of Ming Zhao