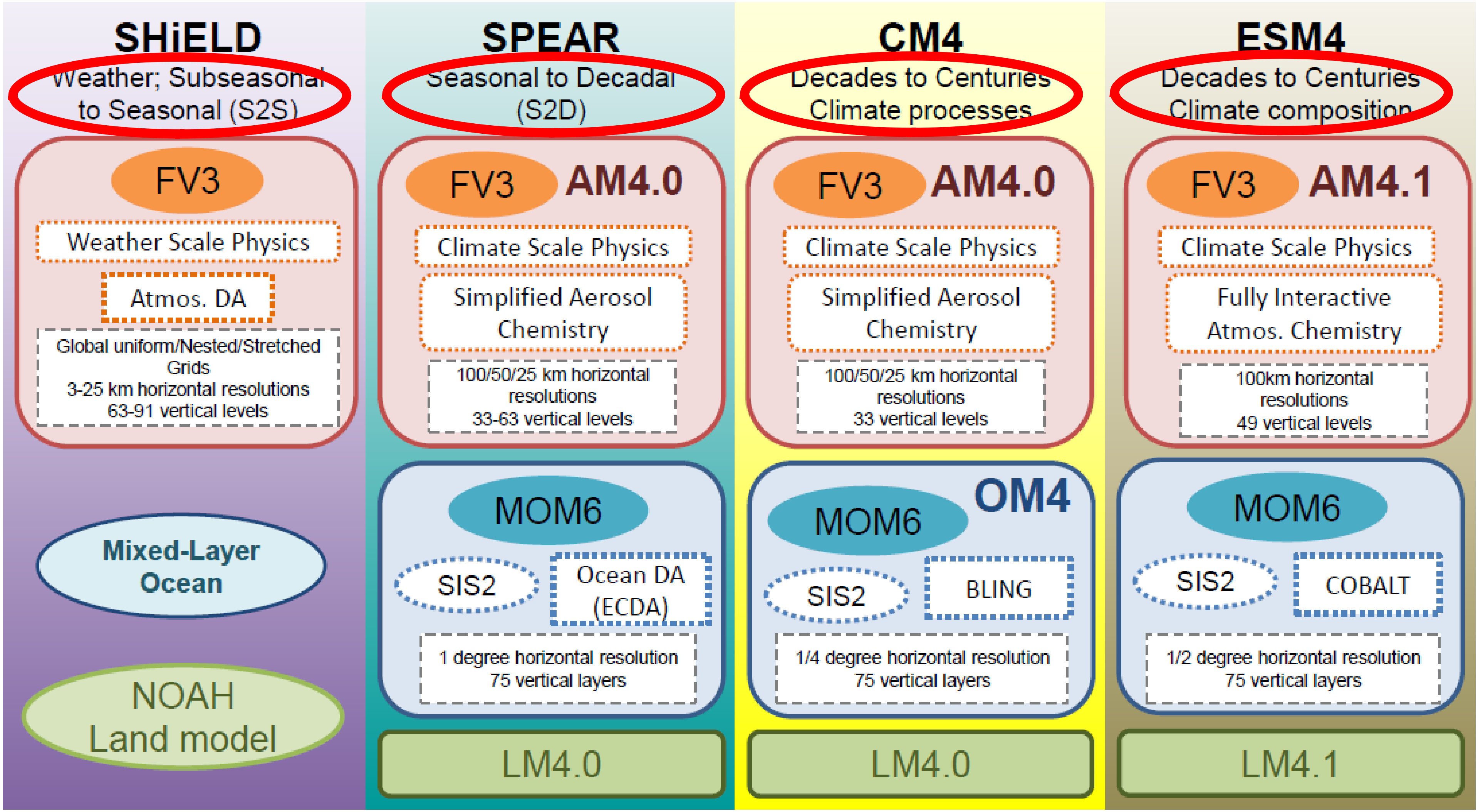
Modeling & Predictions
Where are we and
Where do we want to go?

Briefing to WGCM23
15 December 2020

V. Balaji based on slides from V. Ramaswamy

Geophysical Fluid Dynamics Laboratory

OAR/GFDL: Seamless Modeling of the Earth System



Understanding, Applications, Predictions & Projections

High resolution atmospheric modeling and use of observations

<u>3-5 year target:</u>

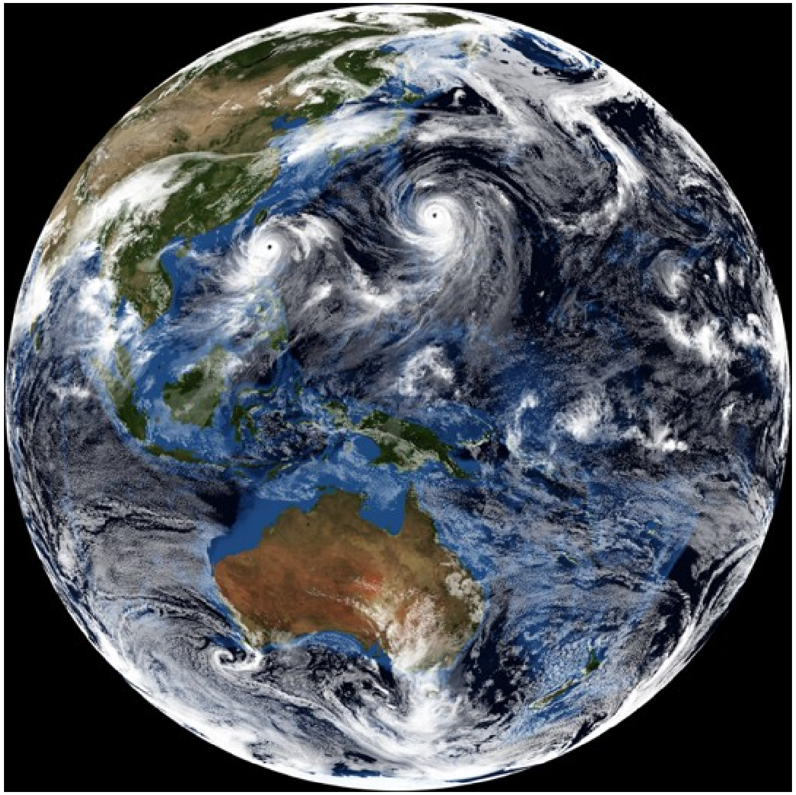
- Global cloud-system-resolving models (SHiELD).
- Quantitative evaluations of clouds, precipitation and radiation budget using satellite observations.

<u>Supporting activities:</u>

* Use new satellite data on vertical structure of cloudiness, water content,and hydrometeors at high spatial and temporal resolution (e.g. CloudSat, CALIPSO) and NESDIS data.

* Use existing diagnostic packages and develop new methods for process-oriented evaluations of clouds, precipitation, and radiation

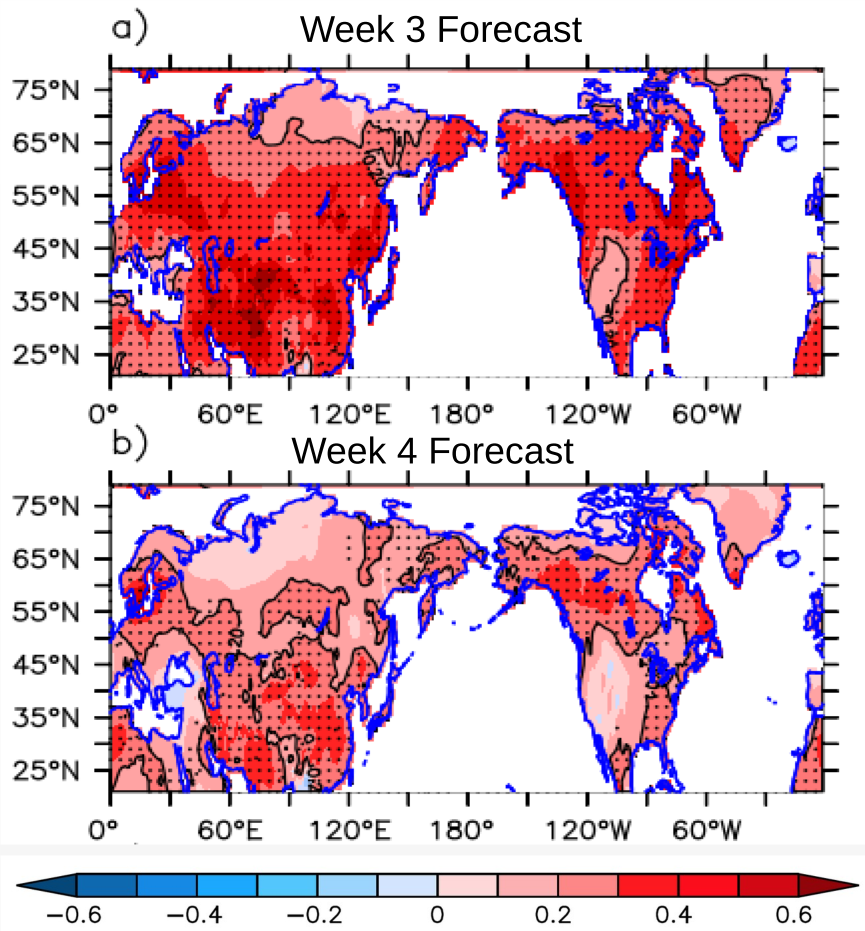
inform model parameterization development.



X-SHiELD. Credit: S.-J. Lin, Xi Chen, and Linjiong Zhou
www.gfdl.noaa.gov/visualizations-mesoscale-dynamics/

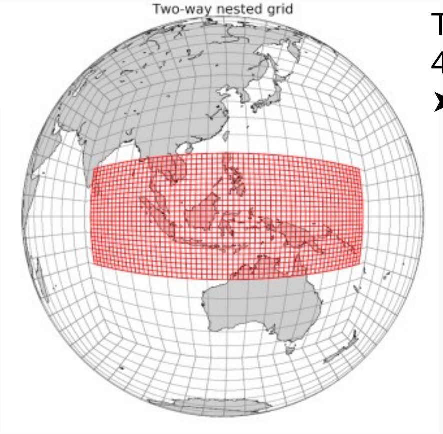
Subseasonal-to-Seasonal Prediction

Effective coupled S2S

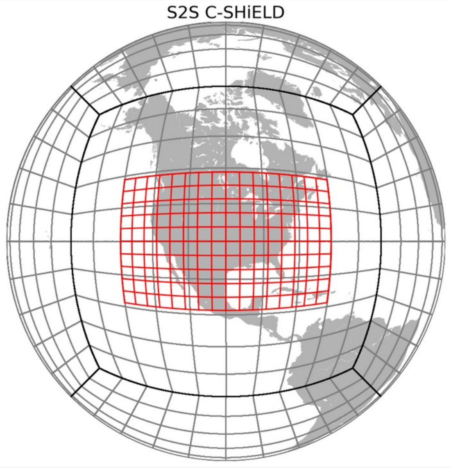


ACC (1 is perfect) of wintertime 2-m temp forecasts with 50-km proto-SPEAR
Xiang et al., GRL 2019

Efficient convective-scale S2S



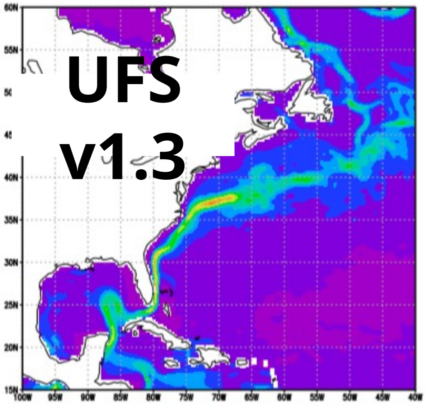
T-SHiELD 16 & 4-km
40 days of MJO skill
➤ 40 days in 8 hours with 4K cores

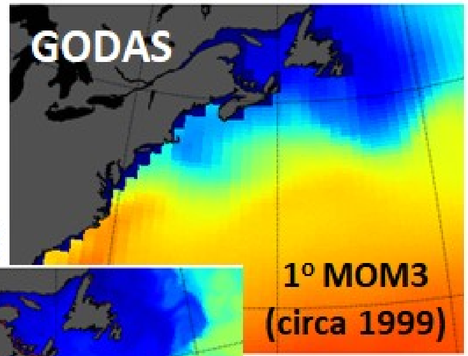


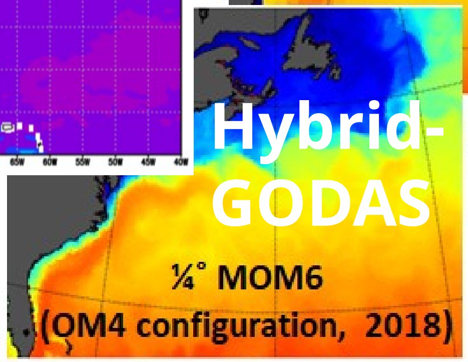
C-SHiELD 16 & 5 km
Week 3–4 Severe Wx
➤ 30 days in 8 hours with 2112 cores

Next: convective-scale regional climate prediction?

MOM6 across NOAA, and beyond

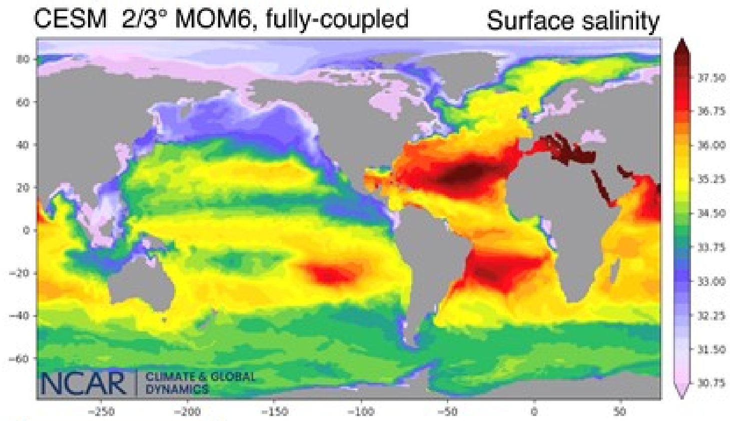






Courtesy
Yan Xue, NCEP-CPC

Courtesy *Gustavo Marques*, NCAR



NOAA-EMC

NCAR

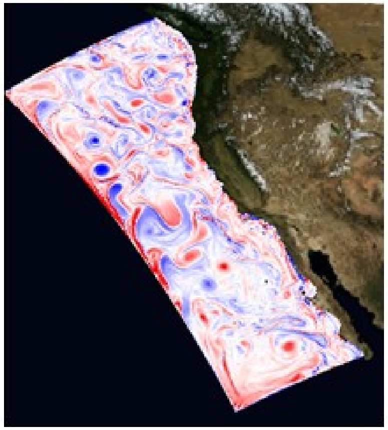
MOM6

(GFDL)

Rutgers

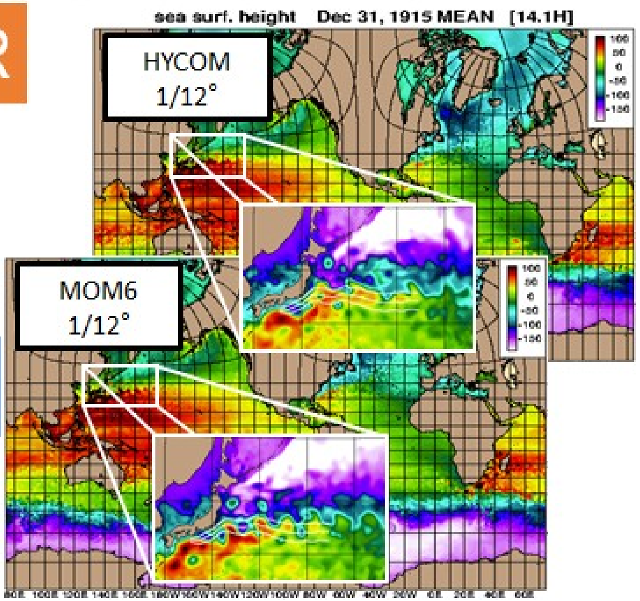
FSU/Navy

ESPC



CCS from *Curchitser & Hedstrom*, Rutgers/UAF

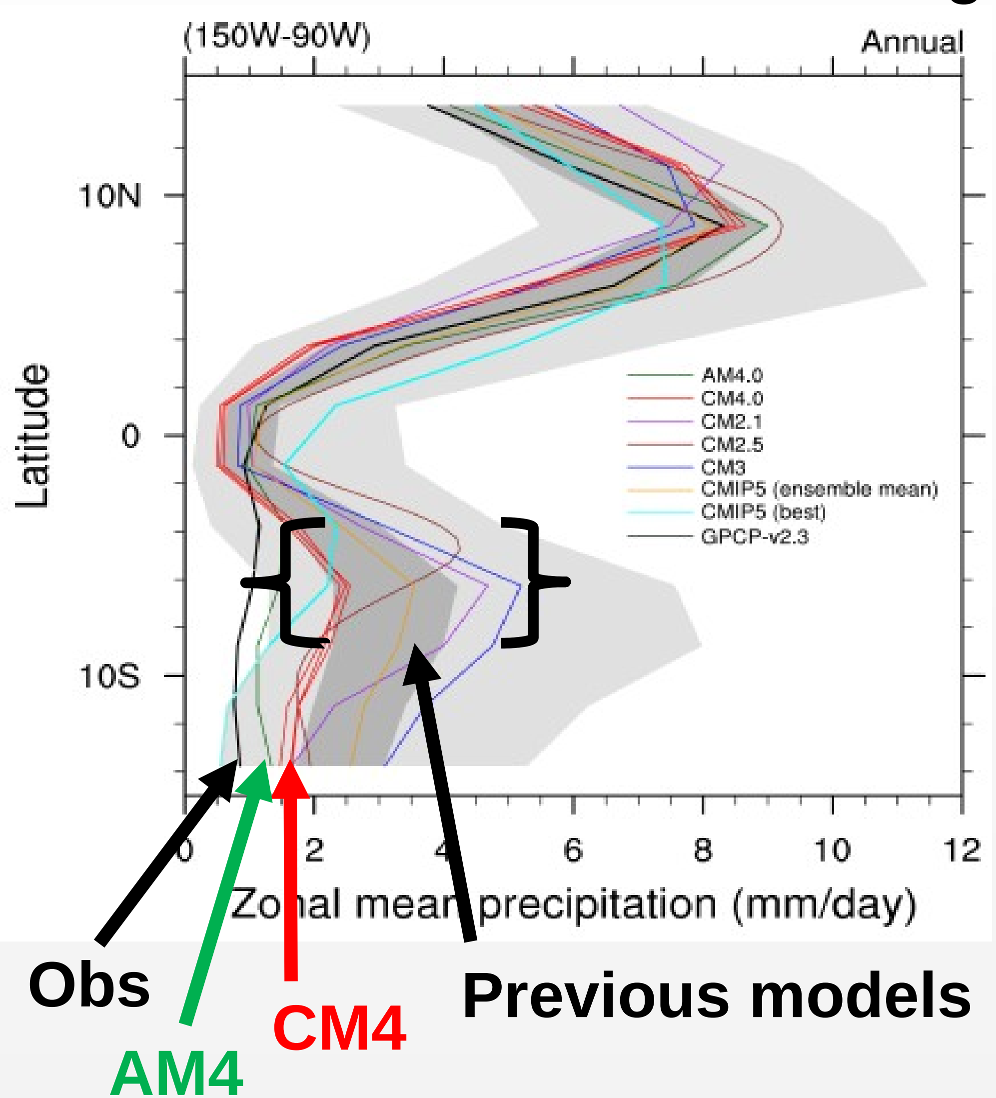
Alan Wallcraft
FSU



Courtesy Alistair Adcroft

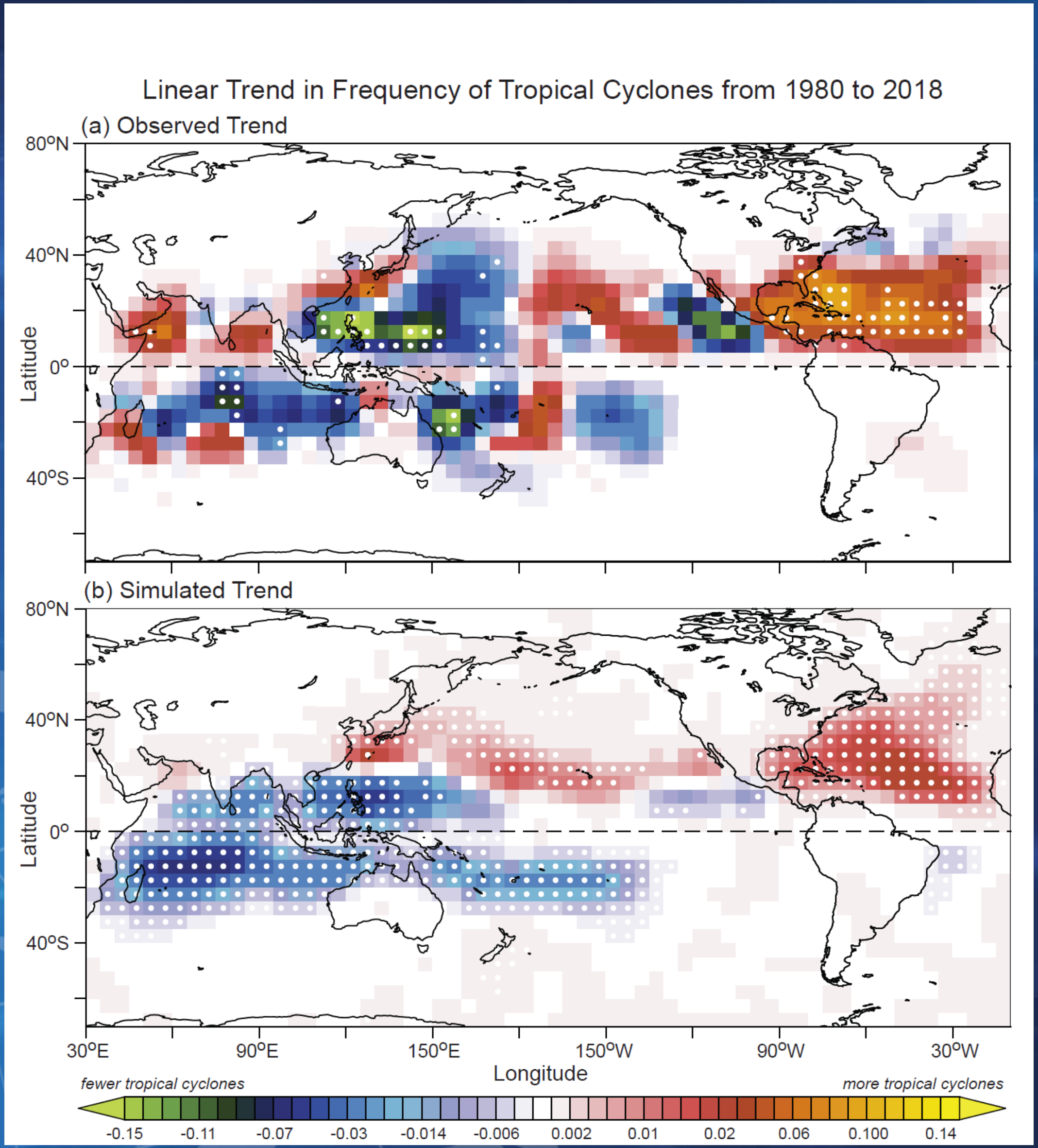
Strongly Improved Regional Precipitation

Pacific Double ITCZ Challenge



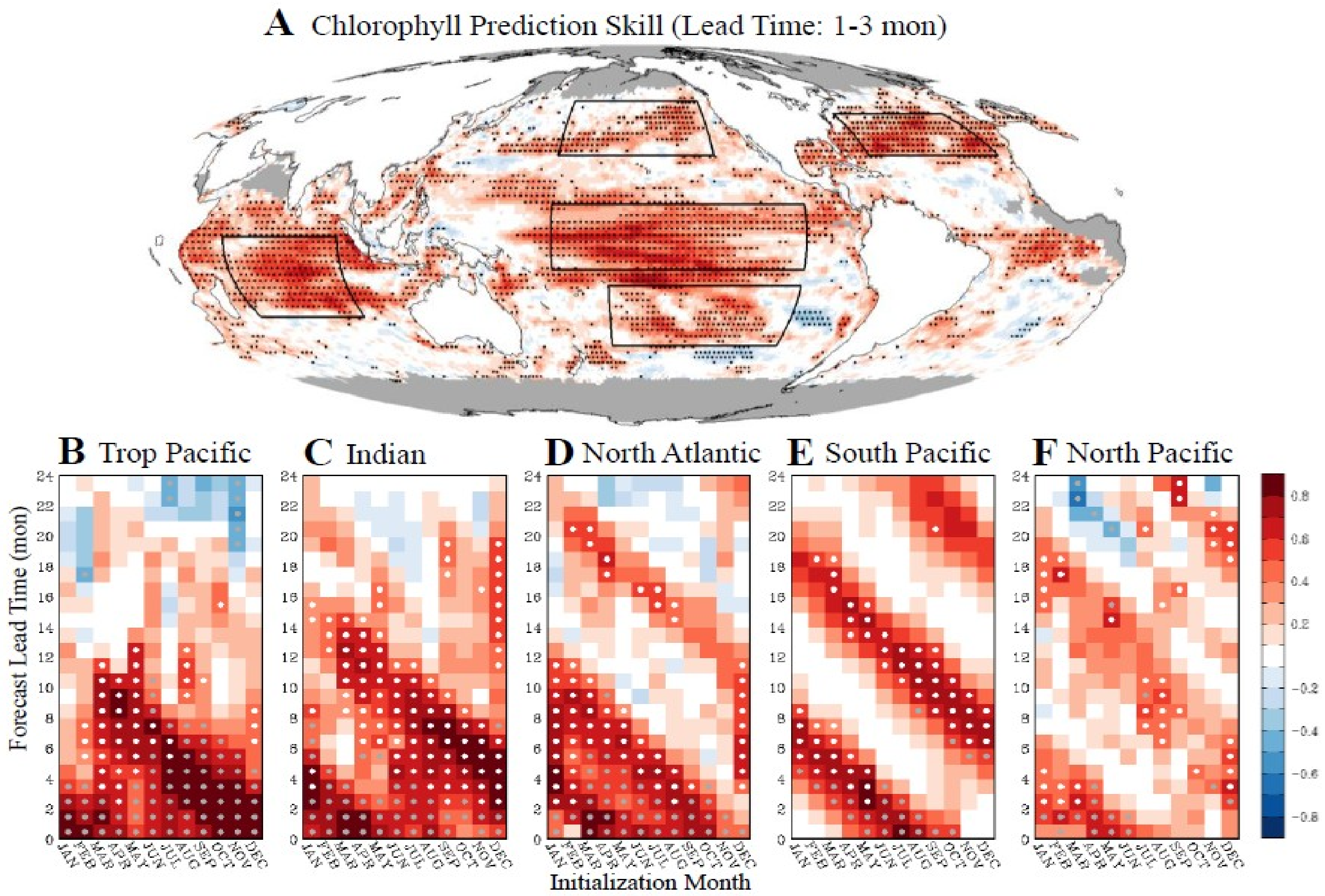
tected climatic change in global distribution of tropical cyclo

Murakami et al., 2020



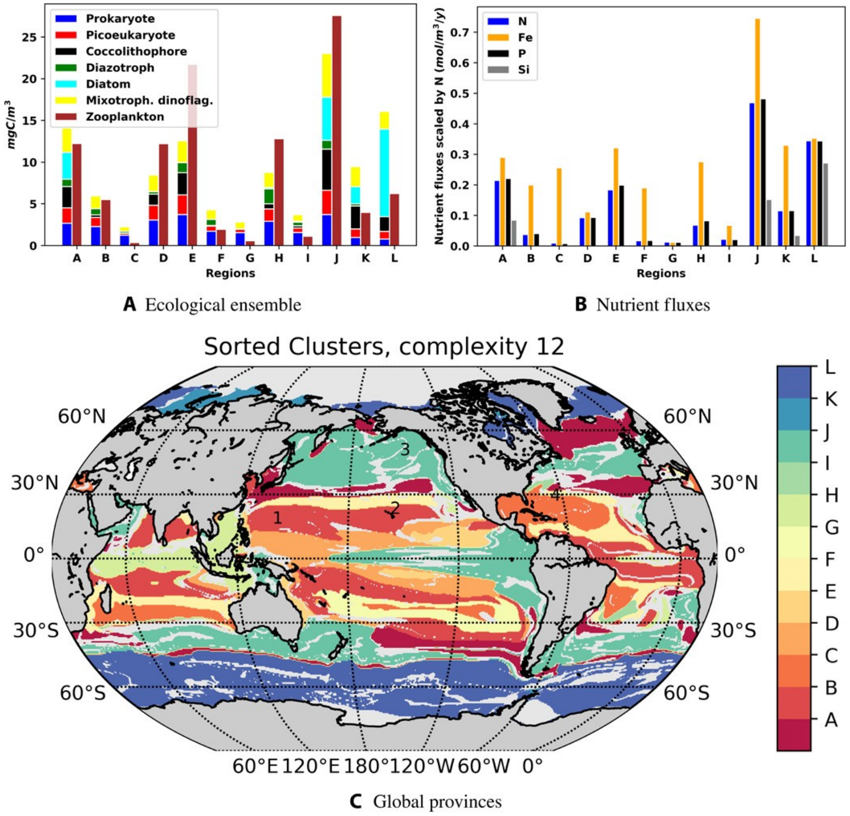
This study demonstrates that a signal of change in the global distribution of tropical cyclones has already emerged in observations and may in part be attributable to the increase in greenhouse gas emissions.

Skillful chlorophyll prediction beyond 1 year



Park et al., 2019. Seasonal to multiannual marine ecosystem prediction with a global Earth system model. Science. 365 (6450) 284-288.

ML: combining theory and observations



- From [Sonnewald et al, *Science Advances* (2020)], highlighted in Eos, [How Machine Learning Redraws the Map of Ocean Ecosystems].
- Tracking such features of dynamics and ecology in historical simulations and model projections (ongoing and future work).

Other examples from GFDL: Muhling et al (2018) , Muhling et al (2017), Ross and Stock (2019), Chaney et al (2018)

Multiple weather-climate phenomena
Variability, extremes, and change

National Research Council (2012) Recommendation:
"Unified" modeling approaches

Internal Variability, External Forcings

Tornadoes
Snowstorms
Hurricanes
Typhoons

Heat Waves
Storm Track Variations
Madden-Julian Oscillation

El Niño-Southern Oscillation
Precipitation extreme
Intra- & Inter-season Variation
Changes in the Arctic

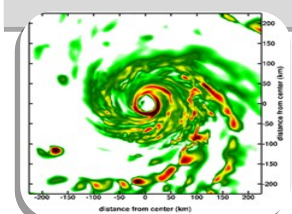
Decadal to Multi-decadal Variability
Cryospheric
Solar Variability

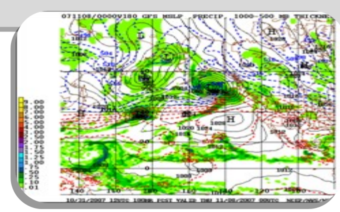
Ocean: Circulation, SLR, Heat Content
Greenhouse Gases and Aerosols

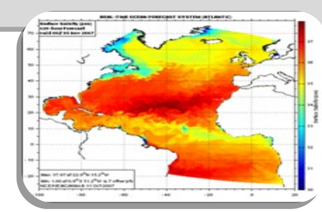
1 DAY | 30 DAYS | 1 SEASON | 3 YEARS | 10 YEARS | 30 YEARS | 100 YEARS

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

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







Weather to Climate is "Seamless"

Where do we want to be in the future?

- The GFDL modeling suite will provide the opportunity to diagnose the more realistic submesoscale processes that are missing in current models and their impacts on weather, precipitation, ocean heat uptake, sea level rise, and ocean-ice interactions
- Novel and more realistic parametrizations of ocean, ice, and atmosphere processes and air-sea exchanges will be extracted using ML to advance prediction skills of extreme events (e.g. hurricanes and storm surges) and of weather/climate systems across timescales
- The very high resolution coupled simulations will also advance applications to coastal inundation and coastal marine ecosystems, and align with activities for the UN Decade of Ocean Science for Sustainable Development
- The innovations achieved from the coupled kilometer-scale resolution simulations in conjunction with ML can be seamlessly transitioned into NOAA operational models
- The newly-developed parameterizations will be adapted for improving operational scale coupled simulations and the advances will be conveyed to NWS, NMFS, and NOS