OAR/GFDL: Seamless Modeling of the Earth System

**SHiELD**
- Weather: Subseasonal to Seasonal (S2S)
- FV3
  - Weather Scale Physics
  - Atmos. DA
  - Global uniform/Nested/Stretched Grids
  - 3-25 km horizontal resolutions
  - 63-91 vertical levels

**SPEAR**
- Seasonal to Decadal (S2D)
- FV3 AM4.0
  - Climate Scale Physics
  - Simplified Aerosol Chemistry
  - 100/50/25 km horizontal resolutions
  - 33-63 vertical levels

**CM4**
- Decades to Centuries
  - Climate processes
  - FV3 AM4.0
  - Climate Scale Physics
  - Simplified Aerosol Chemistry
  - 100/50/25 km horizontal resolutions
  - 33 vertical levels

**ESM4**
- Decades to Centuries
  - Climate composition
  - FV3 AM4.1
  - Climate Scale Physics
  - Fully Interactive Atmos. Chemistry
  - 100km horizontal resolutions
  - 49 vertical levels

**Mixed-Layer Ocean**
- MOM6
  - SIS2
  - Ocean DA (ECDA)
  - 1 degree horizontal resolution
  - 75 vertical layers

**NOAH Land model**
- LM4.0

**Understanding, Applications, Predictions & Projections**
3-5 year target:
- Global cloud-system-resolving models (SHiELD).
- Quantitative evaluations of clouds, precipitation and radiation budget using satellite observations.

Supporting activities:
- 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 to inform model parameterization development.

X-SHiELD. Credit: S.-J. Lin, Xi Chen, and Linjong Zhou
www.gfdl.noaa.gov/visualizations-mesoscale-dynamics/
Subseasonal-to-Seasonal Prediction

Effective coupled S2S

- Week 3 Forecast
- 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

UFS v1.3

GODAS

1° MOM3 (circa 1999)

Hybrid-GODAS

¾° MOM6
(OM4 configuration, 2018)

NOAA-EMC

NCAR

MOM6 (GFDL)

Rutgers

FSU/Navy

ESPC

 Courtesy Alistair Adcroft

CESM 2/3° MOM6, fully-coupled

Surface salinity

Courtesy Gustavo Marques, NCAR

HYCOM 1/12°

MOM6 1/12°
Strongly Improved Regional Precipitation

Pacific Double ITCZ Challenge

Latitude

Zonal mean precipitation (mm/day)

10N

10S

(150W-90W)

Annual

Obs

AM4

CM4

Previous models

CM4.0

CM4.0

CM4.0

CM2.1

CM2.5

CM3

CMIP5 (ensemble mean)

CMIP5 (best)

GPCP-v2.3

Previous models
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

A Chlorophyll Prediction Skill (Lead Time: 1-3 mon)

ML: combining theory and observations

- Tracking such features of dynamics and ecology in historical simulations and model projections (ongoing and future work).

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

Decadal to Multi-decadal Variability, Cryospheric, Solar Variability

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

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.