High Resolution Earth System Modeling using Blue Waters Capabilities

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NCAR collaborators: Nan Rosenbloom, Warren Washington, Julio Bacmeister, Colin Zarzycki, Kevin Reed, Rich Neale, John Truesdale, Cecile Hannay, Gary Strand

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Why Blue Waters?

• 0.25° atmos/land – only (30 years)
  o 12K node-hours per model year = 0.36M node-hours for one simulation
  o 4 present day – 8 future scenarios (~4.3M)

• Fully-coupled 0.5° atmos/land - 1° ocean/sea ice
  o 1 PI control, 3 20th Century, 12 future scenarios

• Fully-coupled 0.25° atmos/land - 1° ocean/sea ice
  o 10-12K node-hours per model year = 1-1.8M node-hours for one simulation
  o 1 PI control, 2 climate sensitivity, 3 20th Century, 6 future scenarios (~12M-21M)

• Fully-coupled 0.25° atmos/land – 0.1° ocean/sea ice
  o 32.3K node-hours per model year = 3.23M node-hours for one simulation
  o 1 PI control, 1 20th Century, 2 future scenarios (~13M)
Comparison Between Present and Future Precipitable Water

CAM Precipitable Water (TMQ)

Present (1990)

Future (2090, RCP8.5)

Jan 01
Tropical Cyclone (TC) Tracks

Observations: IBTrACS

Tropical cyclone algorithm and tracker follows Zhao et al. (2009) using 3-hourly model output.

Courtesy Kevin Reed, see also Wehner et al. (2014, JAMES)
Extra-tropical Storm (ETC) Tracks
(for one model year)

0.25° atmos-only

Extratropical cyclone tracks and storm properties are found using TempestExtremes (Ullrich and Zarycki, 2016).
Present Day and Future ETC Storm Count

0.25° atmos-only

- **Global**
  - Present Day 1985-2005
  - Present Day 1985-2005 (modified dust)
  - Future RCP8.5 2070-2090
  - Future RCP8.5 2070-2090 (modified SST)

- **Atlantic**

- **S. Hemisphere**

- **Pacific**

- **Ensemble Member**
Present Day and Future ETC Track Density

0.25° atmos-only

All storms

Units are average hours per year in which a storm is found within a 4° x 4° gridbox
Eady Growth Rate (850mb)

0.25° atmos-only

Units = day$^{-1}$

Present Day

Future
High Resolution Ocean

0.25° atmos - 0.10° ocean

1° atmos – 1° ocean
High Resolution Ocean

0.25° atmos - 0.10° ocean
Ocean Resolution

0.25° atmosphere
1° vs 0.10° ocean

Sample UK Events,
TMQ

Movies of 1 year’s worth of AR events strung together

1 degree
0.1 degree
Ocean Warming Trends

Pershing et al. (2015)
Compared to 1° CESM

1° atmos – 1° ocean

1° atmos - 0.10° ocean

Courtesy Justin Small
Future Changes in Days that exceed 95°F

12km atmos

RCP4.5 – Present Day

RCP8.5 – Present Day
Regional Maximum Temperature

12km atmos

Midwest

Northeast

Southeast
Publications


Definitions

Tracking Algorithm

\[ ZN = |Q_{\text{threshold}}| \geq |Q_{\text{mean}}| + 0.3( |Q_{\text{max}}| - |Q_{\text{mean}}| ) \]

Mean = zonal mean and Max = zonal maximum  \( ZN = \) Zhu and Newell (1998)

- Pineapple Express
  - 850 mb Wind Speed \( \geq \) 10 m/s
  - 270° > Wind Direction > 180°
  - \( \frac{DY}{DX} \geq 2 \) (minimum DY = 200km)

- UK Storms
  - 850 mb Wind Speed \( \geq \) 25 m/s
  - 360° > Wind Direction > 180°
  - \( \frac{DY}{DX} \geq 2 \) (minimum DY = 200km)

- France/Iberian Peninsula
  - 850 mb Wind Speed \( \geq \) 15 m/s
  - 360° > Wind Direction > 180°
  - \( \frac{DY}{DX} \geq 2 \) (minimum DY = 200km)
Summary of High Res Ocean

- Improvements with resolution
  - Atmosphere - TCs, Extreme precip, eastern boundary SST
  - Ocean – eddies, western boundary SST, small scale air-sea interaction
  - ENSO

- Stays same with resolution
  - Southern ocean wind bias
  - Subsurface warming

- Gets worse with high resolution
  - ITCZ too strong

- Caveat: results apply to CESM.
Tropical Cyclone (TC) Tracks

Observations

IBTRACS

0.25° atm/lnd – 0.1° ocn/sea ice

CESM-H

Small et al., 2014 (JAMES)
Eddy Kinetic Energy
(500mb)

Units = m²/s²

Future

Present Day

0.25° atmos-only

Courtesy Rich Neale