Wind errors due to physics computation grid in high-resolution simulations

Colin M. Zarzycki
National Center for Atmospheric Research

Kevin A. Reed, Julio Bacmeister, Anthony P. Craig, Susan C. Bates, Nan A. Rosenbloom, John Truesdale

Physics-Dynamics Coupling 2016
Motivation

- High-resolution climate models capable of producing very intense features
  - Ex: tropical cyclones, characterized by small scales and intense near-surface wind speeds
CESM and data components

CESM = Community Earth System Model
CESM and data components

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OBS

land ice G-CISM

land CLM

coupler CPL

atmosphere CAM

solar radiation

natural emissions

anthropogenic emissions

land use changes
Data ocean framework in CESM

ATM

CAM-SE grid

“OLD”

Dynamic ocean model (POP) grid

OCN
Data ocean framework in CESM

"OLD"

CAM-SE grid

ATM

Dynamic ocean model (POP) grid

DOES IT MATTER?

"NEW"

OCN
Experimental configuration

- Two 26-year CESM AMIP simulations (1980-2005)
- Identical forcing (SSTs, prescribed chemistry, solar insolation)
- ATM DYN: ne120 CAM-SE (~0.25°)
- Only difference is “data ocean” grid
  - CESM gx1v6 grid (~1°)
  - CAM-SE ne120 grid (~0.25°)
- Prescribed HadSSTs at ~1°
  - Data “well-resolved” on either grid
Large-scale climatology

ANN Global

Standardized Deviations (Normalized)

Correlation

ATM OCN

ne120_gx1v6
ne120_ne120

1 - PSL
2 - U200
3 - U850
4 - RH600
5 - TMQ
6 - PRECT
7 - T500

Zarzycki et al., 2016, GMD
Tropical cyclone pressure-wind

Minimum Surface Pressure (hPa)

Maximum Wind Speed (m/s)

- IBTrACS
- ne120_gx1v6
- ne120_ne120

Zarzycki et al., 2016, GMD
Coupling on **low-resolution grid** produces **6x** 50 m/s exceedances than **high-res**

- **~250** 59 m/s exceedances for **low-res**, **zero** (25 year simulation) for **high-res**
Surface fluxes in CESM

- Parameterized surface fluxes calculated in model coupler
- CESM “default” is to calculate fluxes on the ocean grid
- Fairly standard construct for global climate models

\[ \tau = \rho_A C_D v^2 \]
\[ E = \rho_A C_E v \Delta q \]
\[ H = \rho_A C_H v \Delta \theta \]
Surface coupling schematic

a) Winds calculated by \textit{atm dynamics}

b) Winds passed to CPL-> remapped to \textit{ocn grid}

c) Parameterized fluxes computed

d) Fluxes remapped back to \textit{atm dynamics}

e) Dynamics proceeds
Deterministic forecasts

- Run CESM in “forecast mode”
  - Initialize with observations
- Can use **identical initial conditions to isolate changes in model behavior** for short-term processes
- Run same configs as climate (**low-res ocn, high-res ocn**)
Deterministic forecasts

-ne240_gx1v6
Sfc. wind (black), sfc. stress (red)

-ne240_ne240
Sfc. wind (black), sfc. stress (red)

stress / wind

LH + SH flx
W/m²

d.

LH + SH flx
W/m²
e.
Deterministic forecasts

Weaker/misaligned stress (red), stronger winds (black)

Zarzycki et al., 2016, GMD
High-resolution climate models generally run with prescribed SSTs!

**Ocean = (Heat \times \infty)**

**Why?**
- **Expensive** at high resolution
- **Potential SST biases** harm mean climate
- **Community inertia**
- Lack of “process coupling”
- TCs cool ocean surface (flux extraction + turbulent mixing) -> unrepresented negative feedback

Data ocean frameworks

[Image](http://www.remss.com/storm-watch)

Typhoon Ioke (2006)
Oceans in GCMs: a hierarchy of complexity

- fixed SST
- thermodynamic slab
- empirical mixing slab
- 1D mixing
- 3D dynamic ocean

Increasing ocean complexity

Fig. courtesy Brian Medeiros, NCAR
The simplest cold wake parameterization™?

\[ \frac{\partial SST}{\partial t} = \frac{1}{\tau} (SST_{clim} - SST) + \frac{1}{\rho_o c_p h} F_{net} - X_{cool} R_{cool} \left( \frac{SST - T_{deep}}{\Delta T_o} \right) \left( \frac{h_o}{h} \right) \]

“Traditional slab”

LARGE-SCALE RESTORATION

SURFACE FLUXES

VERT. MIXING/UPWELLING

Needed for TCs!

Lack of “process coupling” -> errors

10-m Wind PDF

PDF (%)

Wind speed (m/s)

15% reduction

Lack of “process coupling” -> errors

• Prescribed SSTs -> large intensity bias for TCs
• Need to reevaluate lack of atm-ocn coupling in high-res sims
• See “Tropical cyclone intensity errors associated with lack of two-way ocean coupling in high-resolution global simulations” in JClim (EOR)
Summary

- When using low-res physics computation grids, filtering occurs, but not uniformly between dycore and physics
  - Ex: leads to misaligned surface drag in TCs, which leads to bias in surface winds (positive feedback)
- Trivial fix? - maybe, maybe not...
  - Can we average in presence of mesoscale variation?
  - Variable-resolution grid that straddles a uniform grid?
  - Exchange grids?
- Prescribed SST frameworks should be reconsidered in high-resolution climate extreme modeling