What can real-time weather forecasts using SE and MPAS teach us about CESM?

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Weather and climate intersection

Δx ~ 5-25 km

- Required
  - Speed
  - Skill
  - “Extremes”

- Sacrifices
  - Conservation
  - Stability

Δx ~ 100-200 km

- Required
  - Conservation
  - Stability

Can CESM credibly capture evolution of “weather” state?

- Synoptic scales and finer…
Why “forecast” in CESM?

1. Evaluate CESM performance in a more traditional initialized framework (i.e., see unified modeling discussion, S2S, etc.)

2. Evaluate CAM errors/biases in “fast” processes (e.g., CAPT)

3. Given a realistic state of the atmosphere in a “weather” sense, how well can CESM reproduce transient synoptic/sub-synoptic evolution?
   • Relevant for extreme weather climatology
**CESM “forecast mode”**

- CESM 2.0.alpha07e (cam5_4_137)
- Every 24 hrs (00Z) from December 1\textsuperscript{st} 2017 to January 15\textsuperscript{th} 2018 (n = 46)
- Initialization (Zarzycki and Jablonowski, MWR, 2015)
  - **Atmosphere**: GFS analysis, forward digital filter
  - **Ocean**: Prescribed SSTs/ice (NOAA/OI analysis)
  - **Land**: active CLM5 (initial cycled spinup, then +24hr forecast used for init)
- 240 hour forecast = \(\sim\) 1 hour of wall clock time on 432 CPUs (Cheyenne)
- (not pretty, but functional) CESM “forecast” wrapper on Github, contact if interested

+006

![Map of accumulated precipitation]
Grid configurations

- CAM-SE
- 110km
- 14km

- CAM-MPASv4*
- 120km
- 15km

*MPASv4 implemented in CESM2beta “sandbox”
MPASv5 = “fresh” implementation
Sample forecasts (Jan. 4, 2018)

CAM5-SE

Valid 06Z 01 04 2018 [UTC-08]
Instant. precip. rate (shading, mm/hr), precip. type (color)

Accumulated snowfall

CAM5-MPAS

Valid 06Z 01 04 2018 [UTC-08]
Instant. precip. rate (shading, mm/hr), precip. type (color)

Accumulated Bourgoin snow (10:1 in.)
Anomaly correlation coefficient

$$ACC = \frac{\overline{(f - c) - (f - c)} \overline{(a - c) - (a - c)}}{\sqrt{\overline{(f - c) - (f - c)}^2 \overline{(a - c) - (a - c)}^2}}$$

1 = perfect spatial correlation
-1 = perfect spatial anti-correlation
0 = “noise”
~0.6 = skillful for NWP purposes

GFS +120 hr forecast

GFS

CAM-SE +120 hr forecast

CAM-SE

NHEMI, INIT
12/31/17

Z500

Analysis valid at forecast (“truth”)

0.94

0.85
How do CAM-MPAS & CAM-SE stack up?

*shading = mid-50%
Does base resolution (i.e., “boundary condition resolution”) matter?

220km -> 14km

110km -> 14km

55km -> 14km
Does background resolution matter?
Does background resolution matter?
Does topographical roughness matter?

“smooth”

“rough”
Does topography roughness matter?
Does topography roughness matter?

![Graph showing the impact of topography roughness on U850 ACC in different scenarios.](https://example.com/graph.png)
Does vertical resolution matter?

nlev=59

nlev=30
Does vertical resolution matter?

![Graph showing the impact of vertical resolution on Z500 ACC over time. The graph compares two models: hindcast_conus_30_x8_CAM5_L30 (green line) and hindcast_conus_30_x8_CAM5_L59 (red line). The Z500 ACC is measured against a horizontal line at 0.6, indicating the threshold for comparison. The shaded areas represent the range of ACC values for each model at different lead times.]
Does vertical resolution matter?
Does hyperviscosity matter?

nu=1e15

nu=2e14
Does diffusion matter?

Z500
NHEMI

Z500 ACC (nhemi)

Lead (hours)
Does parameterization suite matter?

CAM4

CAM5

CAM6
Does physics matter?
Does physics matter?

Z500 CONUS

- **hindcast_conus_30_x8_CAM4_L26_HV**
- **hindcast_conus_30_x8_CAM5_L30**
- **hindcast_conus_30_x8_CAM6_L32**
Does physics matter?

U850
NHEMI

**U850 ACC (nhemi)**

- `hindcast_conus_30_x8_CAM4_L26_HV`
- `hindcast_conus_30_x8_CAM5_L30`
- `hindcast_conus_30_x8_CAM6_L32`

**Lead (hours)**

- 12
- 24
- 36
- 48
- 60
- 72
- 96
- 120
- 144
- 168
- 192
- 216
- 240
Summary

- CAM/CLM (surprisingly?) reasonable NWP-type evolution
- In this framework...
  - **What doesn’t (seem to) matter?**
    - Explicit diffusion
    - Vertical resolution (?)
    - Topographic roughness (?)
  - **What does matter?**
    - Base resolution (at least until synoptic scales)
    - Physics!
      - CAM5 > CAM4/CAM6 \(\rightarrow\) (?)
  - Preferably would like \(\sim\) 3 months DJF, JJA, higher uniform base \(\Delta x\)?
  - Forecasts running in “real-time!”
    (http://www.colinzarzycki.com)