Extratropical transition of North Atlantic tropical cyclones in variable-resolution CAM5

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CAM-SE Variable Resolution

- SE dynamical core with unstructured mesh
  - 1° coarse region
  - 0.5° transition region
  - 0.25° high-resolution region over Atlantic basin
- Prescribed SSTs and chemistry
- Coupled to 0.9° x 1.25° CLM

- Compared to NCEP Climate Forecast System Reanalysis (CFSR)
  - 0.5° x 0.5° latitude-longitude grid

- 6-hourly output over 1980-2002 for both data sets
Extratropical Transition

Tropical Cyclone (TC)
- Warm Core
- Symmetric about eye
- Energy from latent heat of warm ocean

Extratropical Cyclone
- Cold Core
- Asymmetric
- Energy from horizontal temperature gradients
Extratropical Transition

Phase Space Parameters (Hart 2003)

Cyclone asymmetry ($B$): storm-relative 900-600 hPa geopotential thickness difference between the right and left sides of the cyclone over a 500 km radius

$$B = h \left( \frac{Z_{600 \text{ hPa}} - Z_{900 \text{ hPa}}}{R} - \frac{Z_{600 \text{ hPa}} - Z_{900 \text{ hPa}}}{L} \right)$$

Cyclone thermal wind ($-V_T$): vertical derivative of the geopotential height perturbation for the lower troposphere ($-V_T^L$) and upper troposphere ($-V_T^U$)

$$-V_T^L = \frac{\partial (\Delta Z)}{\partial \ln p} \bigg|_{600 \text{ hPa}} \quad -V_T^U = \frac{\partial (\Delta Z)}{\partial \ln p} \bigg|_{300 \text{ hPa}}$$

$$\Delta Z = Z_{\text{max}} - Z_{\text{min}}$$
Example of Extratropical Transition

Date: 1986 10 04 18 hrs

Pressure at Sea Level

hPa

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Pressure at Sea Level

hPa
Objective Cyclone Tracking

CAM-SE Variable Resolution Storm Trajectories

June - November

TCs: 220  
ETs: 138  
62.7% undergo ET
Objective Cyclone Tracking

NCEP Reanalysis Storm Trajectories
June - November

TCs: 144  ETs: 77  **53.5%** undergo ET
Climatology

CAM-SE Variable Resolution

NCEP Reanalysis

Diana Thatcher

CESM Workshop

6/17/2015
• CAM-SE has more TCs
  • A greater fraction of TCs transitions on average

• NCEP CFSR has greater variance between years
  • 0 to 100% of TCs undergo ET

• Both data sets over-predict transitions compared to observations
  • 63% in CAM-SE
  • 54% in NCEP CFSR
  • 46% of North Atlantic TCs undergo ET (Hart and Evans 2001)
• CAM-SE (0.25° resolution) is able to produce intense hurricanes, including category 3-5

• NCEP CFSR (0.5° resolution) does not produces intense hurricanes
Both data sets have similar phase space distributions

CAM-SE:
- Higher standard deviation in all parameters
- More storms have stronger deep warm core
- Fewer storms have weaker deep warm core

<table>
<thead>
<tr>
<th>Data Set</th>
<th>$B$</th>
<th>$-V_F^L$</th>
<th>$-V_F^U$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAM-SE</td>
<td>9.4 ± 18.6</td>
<td>44.9 ± 123.5</td>
<td>−19.4 ± 146.1</td>
</tr>
<tr>
<td>Reanalysis</td>
<td>8.2 ± 13.7</td>
<td>56.4 ± 85.1</td>
<td>3.9 ± 106.3</td>
</tr>
</tbody>
</table>
Transition Duration

- In both data sets, most storms transition in under 24 hours
  - NCEP CFSR has higher fraction of storms transition in under 6 hours
  - CAM-SE has several storms that take over 4 days to transition

- CAM-SE is comparable to ECMWF reanalysis (Evans and Hart 2003)
  - Mean = 33.4 hour
  - Median = 18.0 hours
  - Standard Deviation = 40 hours

Mean = 26.1 hours
Median = 12 hours
Std. Dev. = 32.7 hours

Mean = 16.1 hours
Median = 6 hours
Std. Dev. = 20.4 hours

0.25° -> 0.5°

0.5°

1°
Summary

CAM-SE successfully produces extratropical transitions of tropical cyclones compared to observations

– No impact from variable resolution mesh
– A greater fraction of TCs undergo ET in CAM-SE than in the subjective analysis of historical records

CAM-SE results are similar to NCEP CFSR, but the coarser resolution of the reanalysis data makes direct comparison impossible

– CAM-SE has a greater number of TCs and higher fraction of TCs that undergo ET compared to NCEP CFSR
– Phase space distributions for both data sets are similar
– Transition duration is similar to other studies

Future areas of study

– Precipitation distribution, especially for landfalling storms
– Interactions with midlatitude baroclinic systems
– Reintensification after extratropical transition
References


