Tropical cyclones in present and future climates in a hierarchy of model resolutions

Malcolm Roberts, Matthew Mizielinski, Jane Strachan + Met Office
(with special thanks to Joanne Camp for the analysis tools)

Pier Luigi Vidale, Marie-Estelle Demory, Reinhard Schiemann
+ NCAS-Climate, University of Reading
Talk plan

• UPSCALE project
  – Tropical cyclone properties
    • present day and future timeslice climate

• HWG experiment results

• Conclusions
MetUM global atmosphere/coupled model climate configurations in use

Essentially the same physics/dynamics parameters used throughout model hierarchy

Explicit convection

Project to assess impact of global explicit convection
The PRACE-UPSCALE Project

UK on PRACE - weather resolving Simulations of Climate for globAL Environmental risk
Current “numerical mission” of the JWCRP High-resolution climate modelling team
PI: P.L. Vidale, NCAS-Climate, Reading

In 2011 we demonstrated our capability in effectively exploiting 4’800, and up to 12’000 CRAY XE6 cores. As an ensemble of GCMs, we could concurrently use up to 60’000 cores.

AWARD: 144 million core hours, for 1 year, 2012. Largest HPC grant at this time, in any science area, worldwide. Since superceded.

Completed:
1. HadGEM3-A multi-decadal simulations at N96 (130 km) to N512 (25 km)
   85 levels to 85km GA3.0 config (Walters et al, 2011)

- present climate simulations N96 and N512
  - forced with OSTIA SSTs 1985-2011
  - 5 ensemble members, 27 years each
- future climate simulations at N512
  - 3 ensemble member, 27 years each
  - following RCP8.5
  - SST: daily OSTIA + HadGEM2-ES RCP8.5 2100 ΔSST (global av ~ 4K)
Tropical storm tracking: TRACK

- Tropical storms are located and tracked in GloSea5 using TRACK (Hodges, 1996).

- **Tracking**: maxima in 850 hPa relative vorticity on common T42 grid

- Minimum 2 day lifetime

- Includes check for a warm core.

- Exactly the same algorithm used in all of the following (no tuning)

- Obs – HURDAT + JTWC – mainly compared model to observed hurricanes

---

Mean sea level pressure
00:00 04 August 2002

Vorticity maxima

<table>
<thead>
<tr>
<th>999</th>
<th>1002</th>
<th>1005</th>
<th>1008</th>
<th>1011</th>
<th>1014</th>
<th>1017</th>
<th>1020</th>
<th>1023</th>
</tr>
</thead>
</table>

Tracking regions

- NI
- WP
- EP
- NA
- SI
- AU
- SP
Mean NH basin counts – 1986-2010

Standard deviation indicated by line
Normalised NH basin counts – 1986-2010

Normalised basin mean TC numbers (May-Nov)

No. of TCs

- N Hemi
- N Atl
- E Pac
- W Pac
- N Ind

Legend:
- HURDAT-TS+
- HURDAT-HUR
- ERAI
- JRA25
- MERRA
- 5xn96
- 3n216
- 5n512
- 3n512_TS
Mean SH basin counts – 1986-2010

Basin mean TC numbers (Oct-May)

No. of TCs

S Hemi | S Ind | Aust | S Pac

HURDAT-TS+ | HURDAT-HUR | ERAI | JRA25 | MERRA | 5xn96 | 3n216 | 3n512 | 5n512 | 3n512_TS
Track density from model ensembles and observations

Model Tropical Storm Track Density

Global, 5xn96 N96, 1986-2010
Total tropical storms: 2399

Global, 3n216 N216, 1986-2010
Total tropical storms: 2603

Global, 5n512 N512, 1986-2010
Total tropical storms: 4798

HURDAT obs, HU+, 1986-2010
Total tropical storms: 511

Storm transits per month

0.05 0.20 0.40 0.75 1.25 1.75 3.00
Track density – Timeslice – present day

Track Density: N512 Timeslice - present day

3n512_TS N512, 1986-2010

Total tropical storms: 1592
African Easterly wave properties at N96, N216 and N512 resolutions
Western Pacific

No. of TCs

Year


Western Pacific

No. of TCs

Year

### TC correlations (1985-2011) vs HURDAT

<table>
<thead>
<tr>
<th>Resolution Basin</th>
<th>N96 (5 member)</th>
<th>N216 (3 member)</th>
<th>N512 (5 member)</th>
<th>Reanalyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>0.57, 0.58, 0.47, 0.37, 0.38 (0.60)</td>
<td>0.56, 0.67, 0.41 (0.64)</td>
<td>0.65, 0.67, 0.57, 0.57, 0.69 (0.76)</td>
<td>0.78, 0.88, 0.89 (0.9)</td>
</tr>
<tr>
<td>W Pacific</td>
<td>0.58, 0.57, 0.58, 0.51 (0.71)</td>
<td>0.7, 0.52, 0.62 (0.74)</td>
<td>0.45, 0.49, 0.53, 0.42, 0.44 (0.60)</td>
<td>0.4, 0.54, 0.57 (0.69)</td>
</tr>
<tr>
<td>E Pacific</td>
<td>0.35, 0.29, 0.04, 0.34, 0.14 (0.3)</td>
<td>0.34, 0.47, 0.34 (0.5)</td>
<td>0.28, 0.34, 0.4, 0.2, 0.21 (0.33)</td>
<td>0.02, 0.56, 0.26 (0.51)</td>
</tr>
<tr>
<td>Indian</td>
<td>0.05, -0.16, -0.34, -0.06, -0.07 (-0.17)</td>
<td>0.08, -0.02, -0.16 (-0.12)</td>
<td>0.31, -0.34, -0.36, -0.44, -0.11 (-0.34)</td>
<td>0.29, 0.39, 0.39 (0.4)</td>
</tr>
</tbody>
</table>
NH tropical cyclone intensity (wind speed vs MSLP) for (top) 10m wind (bottom) 925hPa winds (HURDAT is 10m in both)
Composite structure from 10 strongest storms at peak – cross-section of wind speed from N96, N216 and N512 models
Composite structure from 10 strongest storms at peak – cross-section of temperature anomaly from N96, N216 and N512 models
Composite structure from 10 strongest storms at peak – precipitation from N96, N216 and N512 models

mm/day
Composite structure from 10 strongest storms at peak – cross-section of wind speed from (top) N512 present day and (bottom) N512 timeslice
Composite structure from 10 strongest storms at peak – cross-section of wind speed from N512 present day and N512 timeslice
Composite structure from 10 strongest storms at peak – precipitation from N512 present day and N512 timeslice
Track density difference: Nino - Nina

Tropical Storm Track Density Nino - Nina

5xn96 N96, 1986-2010

3n216 N216, 1986-2010

5n512 N512, 1986-2010

HURDAT obs 1986-2010

Total tropical storms: 992

Total tropical storms: 814

Total tropical storms: 153

Total tropical storms: 311

Storm transits per month

-3.00 -1.00 -0.60 -0.20 -0.05 0.10 0.40 0.80 2.00
Model N96_xhqn  US tropical storm crossings
June-November 1985-2011

Observed US tropical storm crossings
June-November 1985-2011

Total tropical storms: 101

Model N512_xgqxq  US tropical storm crossings
June-November 1985-2011

Total tropical storms: 35
HWG experiments

• Little analysis done
• Only 8-10 years with higher resolution models
HWG experiments
NH basin mean

Basin mean TC numbers (May-Nov)

- **NH**
- **N Atl**
- **E Pac**
- **W Pac**
- **N Ind**
HWG experiments
SH basin mean

Basin mean TC numbers (Oct-May)

- S Hemi
- S Ind
- Aust
- S Pac

Key:
- HURDAT-TS+
- HURDAT-HUR
- N96 Ctl
- N96 +2K
- N96 2xCO2
- N216 Ctl
- N216 +2K
- N216 2xCO2
- N320 Ctl
- N320 +2K
- N320 2xCO2
Tropical Storm Track Density

SST - Ctl N96, 1979-1997

2xCO2 - Ctl N96, 1979-1999

Total tropical storms: 424

Total tropical storms: 460

SST - Ctl N216, 1979-1987

2xCO2 - Ctl N216, 1979-1987

Total tropical storms: 272

Total tropical storms: 258

SST - Ctl N320, 1980-1986

2xCO2 - Ctl N320, 1980-1986

Total tropical storms: 251

Total tropical storms: 250

Storm transits per month

-2.0  -0.5  -0.1  0.1  0.5  2.0

Joint Weather and Climate Research Programme
A partnership in climate research
Summary

• General improvements at higher resolution
  – Increase in storm numbers, and slightly improved interannual correlations, particularly in Atlantic
  – US landfalling storm distribution dependent on model resolution
    • due to genesis position mainly?

• Common errors
  – Too many SH storms
  – Weak intensities
  – Too few landfalling storms in N Atlantic

• HWG experiments
  – No significant change in numbers of storms at any resolution
  – Track density changes variable
Future/ongoing work

- Further analysis of UPSCALE and HWG experiments
  - Understanding sensitivities to resolution/forcing
- Work with improved dynamical core (ENDGame)
  - Indications of some significant improvements at low resolution, high resolution ongoing
- Understand weak intensity of storms
  - PhD student working on this
Difference in surface temperature
Timeslice – present day