PREDICTABILITY OF THE TROPOSPHERIC NAM AND SSWS IN THE NMME PHASE-2 MODELS

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**MOTIVATION**

- Skillful subseasonal weather predictions of NH cold season extratropical weather and extreme weather events / blocking linked to the **Northern Annular Mode (NAM)**.

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*Thompson and Wallace [2001]*

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*OU The UNIVERSITY of OKLAHOMA SCHOOL OF METEOROLOGY*
USING THE STRATOSPHERE TO FORECAST THE JET STREAM?

**KEY POINTS**

- Predicting the state of the stratospheric polar vortex, we can predict the AO and thus surface temperature and storm track patterns out 20-40+ days into the future.
- Break the “10-day prediction barrier.”
## Phase 1: Seasonal Predictions (Monthly-Mean Output)

## Phase 2: Subseasonal Forecasts (Sub-daily and Daily-Mean Output)

### Research Objectives:
1. Quantify fundamental NAM characteristics in the NMME-2 models and related NAM predictability.
2. Identify model biases in the development and subsequent impacts of major sudden stratospheric warmings.

### Table: Model Information

<table>
<thead>
<tr>
<th>Model</th>
<th>Hindcast Period</th>
<th>No. of Members</th>
<th>Arrangement of Members</th>
<th>Lead (month)</th>
<th>Model resolution (atmos)</th>
<th>Model resolution (ocean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP/CFSv2</td>
<td>1982-2010</td>
<td>24 (28)</td>
<td>4 members (0, 6, 12, 18z) every 5th day</td>
<td>0-9</td>
<td>T126L64</td>
<td>MOM4L40 .25deg Eq</td>
</tr>
<tr>
<td>GFDL/CM2.1</td>
<td>1982-2010</td>
<td>10</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>2x2.5degL24</td>
<td>MOM4L50 .3deg Eq</td>
</tr>
<tr>
<td>GFDL/CM2.5 (FLOR)</td>
<td>1982-present</td>
<td>24</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>C18L32 (50km)</td>
<td>MOM5L50 0.30 deg Eq 1degPolar1.5</td>
</tr>
<tr>
<td>CMC1-CanCM3</td>
<td>1981-2010</td>
<td>10</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>CanAM3 T63L31</td>
<td>CanOM4L40 .94deg Eq</td>
</tr>
<tr>
<td>CMC1-CanCM4</td>
<td>1981-2010</td>
<td>10</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>CanAM4 T63L35</td>
<td>CanOM4L40 .94deg Eq</td>
</tr>
<tr>
<td>NCAR/CCSM4</td>
<td>1982-2010</td>
<td>10</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>0.9x1.25degL26</td>
<td>POPL60 .25deg Eq</td>
</tr>
<tr>
<td>NASA/GEOS5</td>
<td>1981-2010</td>
<td>11</td>
<td>4 mems every 5 days; 7 mems on last day of last month</td>
<td>0-9</td>
<td>1x1.25 deg L72</td>
<td>MOM4L40 .25deg Eq</td>
</tr>
<tr>
<td>NCAR/CESM1</td>
<td>1982-2010</td>
<td>10</td>
<td>All 1st of the month 0Z</td>
<td>0-11</td>
<td>0.9x1.25degL30</td>
<td>POPL60 .25deg Eq</td>
</tr>
</tbody>
</table>

*Kirtman et al., 2014*
DATA & METHODOLOGY

• **ERA-Interim Reanalysis** – ”Observations” (1982-2013)
• NMME-2 Models (CanCM3, CanCM4, CCSM4) (1982-2013)
• Focus on November – March initializations.
• Daily-mean fields.
• **NAM** defined as 1st EOF of GPH at each pressure level. Leading PC = NAM Index.
• For NMME models, NAM calculated by projecting **model** fields onto NAM characteristic patterns from **reanalysis** (avoid model biases in modes).
Part I: Fundamental Characteristics of the AO/NAM in the NMME-2 Models
SURFACE AO SIGNATURE (NDJFM SLP REGRESSED ONTO AO INDEX)

- Model bias toward **east-based** NAO.
- Much **stronger** Pacific loading center than obs (especially in CanCM4 and CCSM4 models).
- High spatial correlations (> 0.7).
**POSITVE vs. NEGATIVE AO FREQUENCY**

- Underestimate frequency of AO regimes past ~day 7
- Significant ‘bump’ for –AO duration Days 10-16 in observations not matched by models.
MAX JET LATITUDE

Histogram of Max Jet Latitude (OBS)

Mean Lat: 49.3 N

Histogram of Max Jet Latitude (CANCM3)

Mean Lat: 45.8 N

Histogram of Max Jet Latitude (CANCM4)

Mean Lat: 46.7 N

Histogram of Max Jet Latitude (CCSM4)

Mean Lat: 49.4 N
NDJFM 50 MB HEIGHTS REGRESSED ONTO AO INDEX

- Annular-like in most models (except CCSM4).
- Important symmetry and regional differences in center and structure of vortex.
22-28% lower variability compared to reanalysis

- Models underestimate variability in NH polar vortex.
- Likely due to weaker and more infrequent SSWs.
- Issue known with low-top models [e.g., Charlton-Perez et al. 2013; Furtado et al. 2015].
Part II: *Simulated* Major SSWs: Precursors and Post-SSW Impacts

- Define a **major sudden stratospheric warming (SSW)** as done in *Charlton and Polvani* [2007] and *Butler and Polvani* [2011].
- For **ERA-Interim**, 20 events from 1982-2013.
- For **models**, apply definition per ensemble member (starting month = November). For **statistics**, randomly choose 10 simulated SSWs per run (N = 100 – less for CCSM4 because of lack of major SSW frequency – Factor of 3 less).
PRECURSOR PATTERNS—DAYS -30 TO -15
COMPOSITE 500 MB MAP

- Common features include **negative NPO/EPO** and **Northern Eurasian ridge**.
- CCSM4 has almost the complete opposite pattern.
PRECURSOR PATTERNS – VERTICAL EP FLUX (WAVE FORCING)

EPz (40-80 N) PreCursor to Major SSWs
(All Runs)

- Observations
- CanCM4
- CCSM4
- CanCM3

$EPz \times 10^3 \text{ J/m}^2$

Lag [Days]

-30 -25 -20 -15 -10 -5 0 5
POST-SSW IMPACTS – DAYS +5 TO +60
COMPOSITE 500 MB GPH

NAO signature present but slight-east bias in models.

Little agreement in Pacific sector.
POST-SSW IMPACTS
- DAYS +5 TO +60
COMPOSITE SFC T

ERA-INTERIM

CanCM3

CanCM4

CCSM4
LAG NAM COMPOSITES FOR MAJOR SSWS

CanCM3 and CCSM4 plots agree with most other coupled models [Furtado et al., 2015]

ERA-Interim

CanCM3

CanCM4

CCSM4
• Negative tendency clearly seen in the observations for near-surface AO.
• Models have a very weak / near neutral signal.
WHY NO DOWNWARD PROPAGATION? – WAVE FLUXES

Anomalous div-EP AFTER Major SSWs (Days +5 to +30) (ERA-Interim)

EP FLUX DIVERGENCE
JET DISPLACEMENT EQUATORWARD

EP FLUX DIVERGENCE
STRENGTHENING PV
WHY NO DOWNWARD PROPAGATION? – WAVE FLUXES
CONCLUSIONS

• NMME Phase-2 models have fundamental flaws in the general structure of the NAM (frequency of regimes, east-based NAO).
• Downward propagation of signal from the stratosphere $\rightarrow$ troposphere remains a problem (CanCM4 an exception).
• S/T coupling biases be tied to incorrect wave-mean flow interactions in the troposphere following major SSWs.
• **Ongoing Work:**
  • Model-skill scores for *observed* SSWs and their post-SSW impacts on lower tropospheric conditions.
  • Closer look into case studies for insight into wave propagation or other associated errors/model bias.
THANK YOU!

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