Upper Stratosphere Lower Mesosphere (USLM) Disturbances

- Strong baroclinic conditions near stratopause
- Elevated stratopause temperatures in excess of 290 K
- Stratopause located at 42 km +/- 2 km
- Strong positive temperature gradient below 40 km
- Concentrated latitudinal and longitudinal extent
- Rapid Development
Data and Analysis Methods

**Observations**
- TIMED/SABER
- Lidar
- Rockets

**Assimilated Data: MetO**
- October 1991 to 27 December 2010
- Once daily (12Z)
- Temperature, winds, and geopotential heights
- 2.5° latitude by 3.75° longitude
- 1000 to 0.3 hPa (0.1 hPa after late 2003) pressure surfaces

**Model: WACCM4**
- 42 year run; 2 year spin-up
- CESM framework
- Hybrid vertical scale: 66 levels
  - isobaric above ~100 hPa
  - vertical resolution increases from 1.75 km around 50 km to 3.5 km above ~65 km
- 1.9 degrees latitude by 2.5 degrees longitude
- MOZART3
- Year 2000 SST
- Orographic gravity waves parameterized based on *McFarlane* [1987]
- Solar Max conditions
USLM Criteria and Event Identification

- Search for maximum temperature at 2.0 hPa between 40° and Pole
- Fit season function with annual and semi-annual variation
- Examine periods of significant temperature excursion from function >15K

(a) MetO Time Series

(b) WACCM4 Time Series
Validity and Logic of 2.0 hPa (42 km) Criteria Level

Figure 4. Vertical temperature profiles [°C] from several northern hemisphere rocket and lidar stations on the climax of different stratospheric warming events; crosses indicate the CIRA 1986 mean January profile at 70°N; squares denote a profile from the Berlin TSM GCM.

Von Zahn [1998]
Results of Search for USLM and SSW events in MetO and WACCM

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Duration</th>
<th>NH</th>
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<tbody>
<tr>
<td><strong>MetO Data Set</strong></td>
<td>19.545 years</td>
<td>44 total USLM events</td>
<td>30 total USLM events</td>
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<td>2.25 USLM events/year</td>
<td>1.535 USLM events/year</td>
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<td>18 total SSW events</td>
<td>1 SSW event</td>
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<td>0.921 SSW events/year</td>
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<tr>
<td><strong>WACCM Data Set</strong></td>
<td>40.0 years</td>
<td>118 total USLM events</td>
<td>89 total USLM events</td>
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<td>2.95 USLM events/year</td>
<td>2.225 USLM events/year</td>
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<td>27 total SSW events</td>
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<td>0.67 SSW events/year</td>
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*Dates of USLM event onset 1991-current available for those interested*
Distribution of USLM conditions throughout the year
USLM Event Duration

MetO USLM Event Duration

WACCM USLM Event Duration

- Northern Hemisphere
- Southern Hemisphere

Fractional Frequency

USLM Event Duration [days]
Geographical Preference of T anomaly & relationship with Polar Vortex

MetO

WACCM4

Frequency [days per year]

0.00 0.35 0.70 1.05 1.40 1.75 2.10 2.45 2.80 3.15 3.50

0.00 0.35 0.70 1.05 1.40 1.75 2.10 2.45 2.80 3.15 3.50
USLM disturbances relationship with development of major SSW

MetO and WACCM histograms of lag between USLM event onset and major SSW conditions onset. **A** events are USLM events that dissipated without a subsequent SSW event, **B** events are major SSW events that were final warmings.
Discussion

• Future WACCM explorations of USLM Disturbances
  – Baroclinic Instability Analysis
  – Planetary Wave Activity in development of USLM
  – Ageostrophic Circulations
  – Energy Transfers
  – Other Ideas?

• Use of TIME-GCM
  – Planetary wave forcing
  – In-situ generation of gravity waves?
  – Poor performance at low Stratopause level

• What attributes of the models might benefit this study?

Questions, Ideas, Suggestions?
Northern Hemisphere 2.154 hPa Pressure Surface

Event Progression

Onset: Polar Vortex displaced off pole, regions of inverted dq/dy develop in jet region

Day-1

Day-0

Day 1

Peak: Maximum event temperatures, region of inverted dq/dy dissipates

Day 2

Day 3

Decline

Equation:

\[ q = \int_A \frac{\partial^2 \psi}{\partial^2 x} + \frac{\partial^2 \psi}{\partial^2 y} + \frac{\partial}{\partial p} \left( \frac{f_0^2}{c} \frac{\partial \psi}{\partial p} \right) \]