

Some Observed Features of Stratosphere-Troposphere Coupling

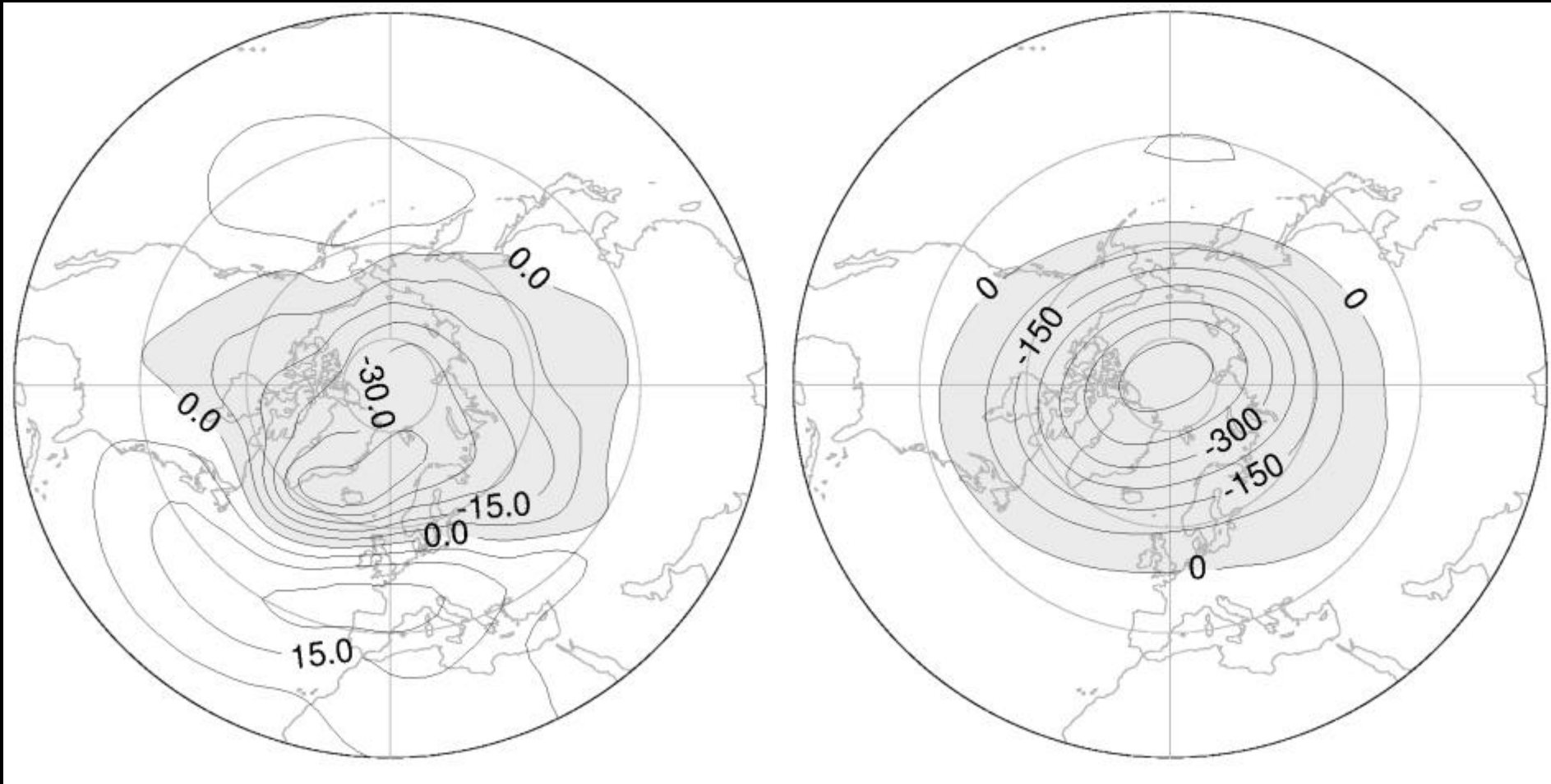
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Northern Annular Mode (NAM)

1000 hPa (Arctic Oscillation)

10 hPa



Annular mode patterns are the leading EOF of low-frequency Z variability.

Annular mode patterns are similar from Earth's surface to 50+km.

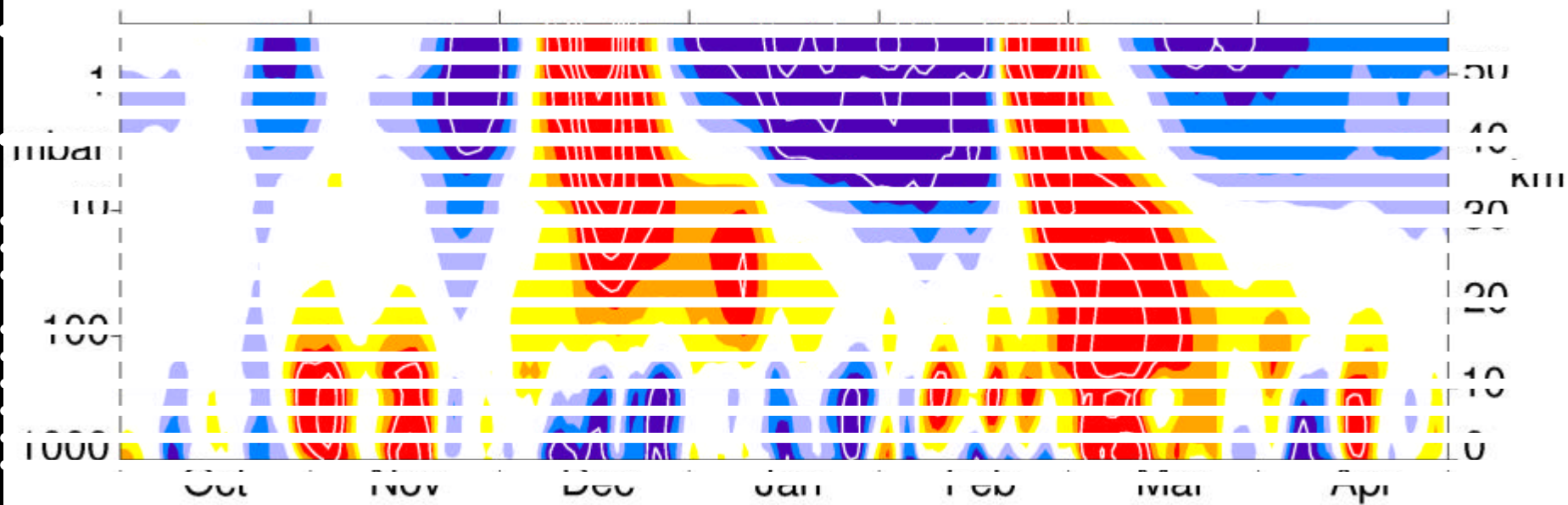
Observations show:

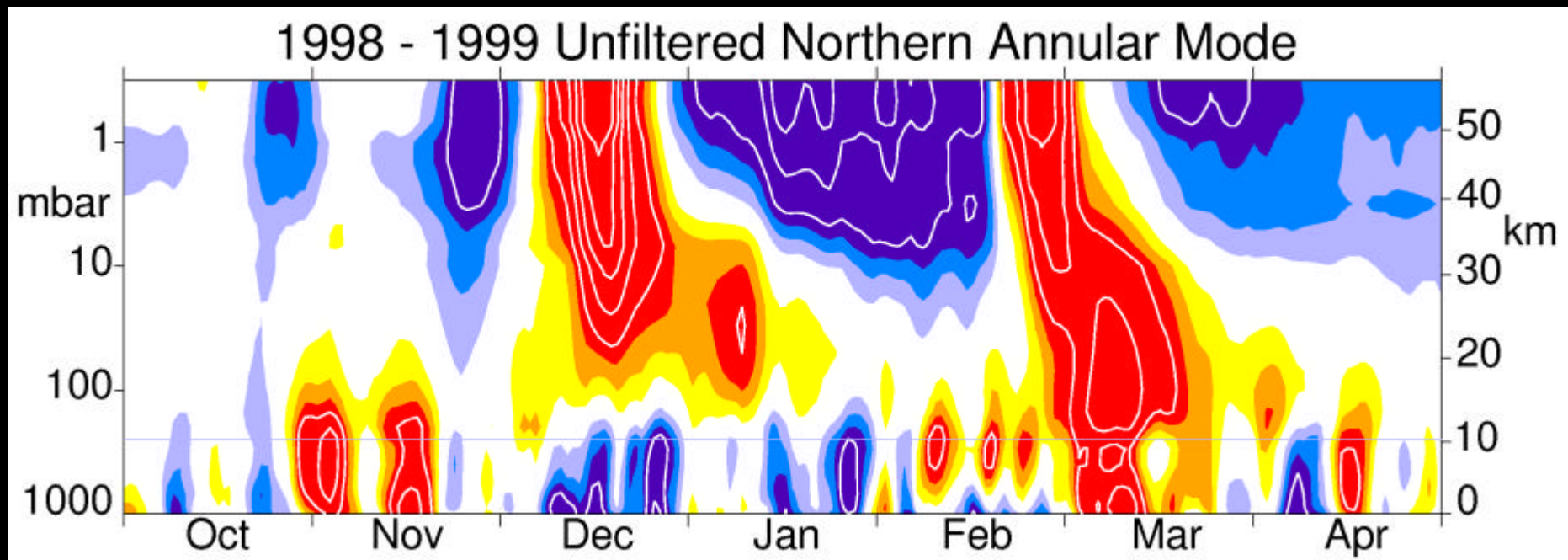
- The AO timescale is longest when NAM anomalies are largest in the lowermost stratosphere (winter).
- The NAM in the lowermost stratosphere provides better predictability of the AO than the tropospheric NAM.
- Any theory should explain these observations.

Hypothesis:

- NAM anomalies in the lowermost stratosphere affect wave propagation of (both planetary and synoptic scale) waves in the upper troposphere.
- The effect of NAM anomalies in the lowermost stratosphere is to induce AO anomalies of the same sign.
- The key level is ~ 150 hPa.
- No implication of causality.

1996 - 1999 Unfiltered Northern Annular Mode

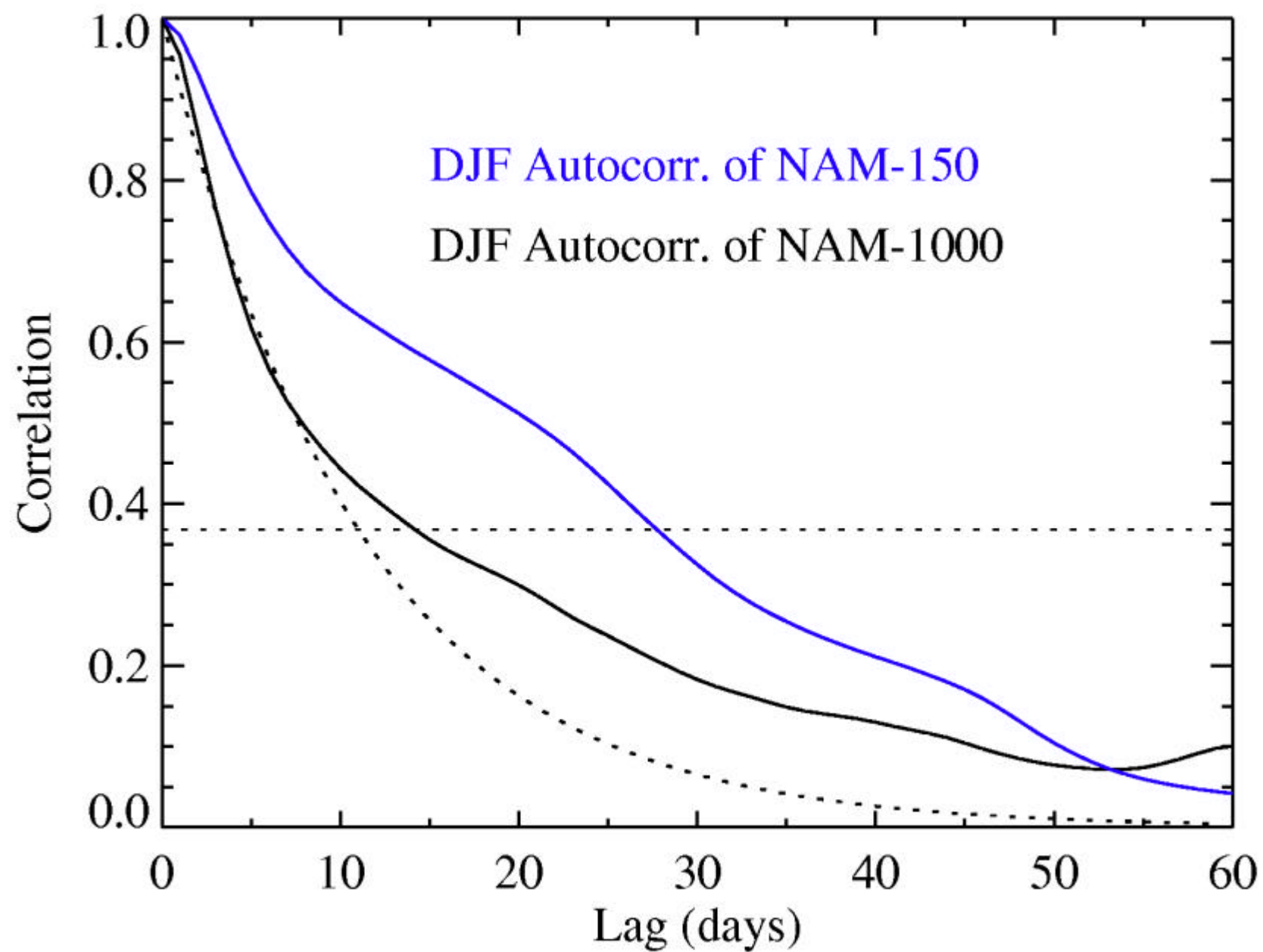




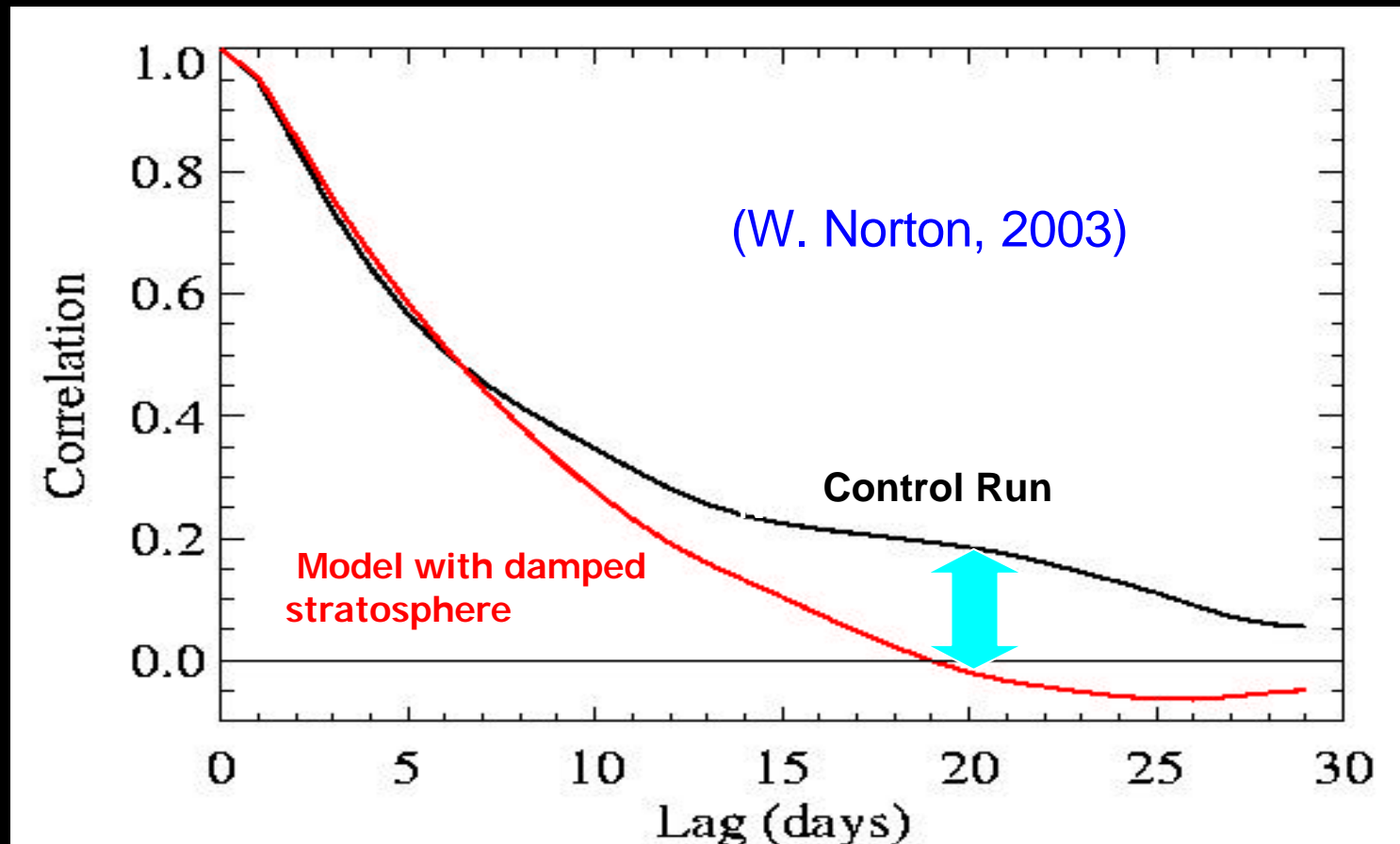
Daily data.

The AO is the 1000-hPa NAM.

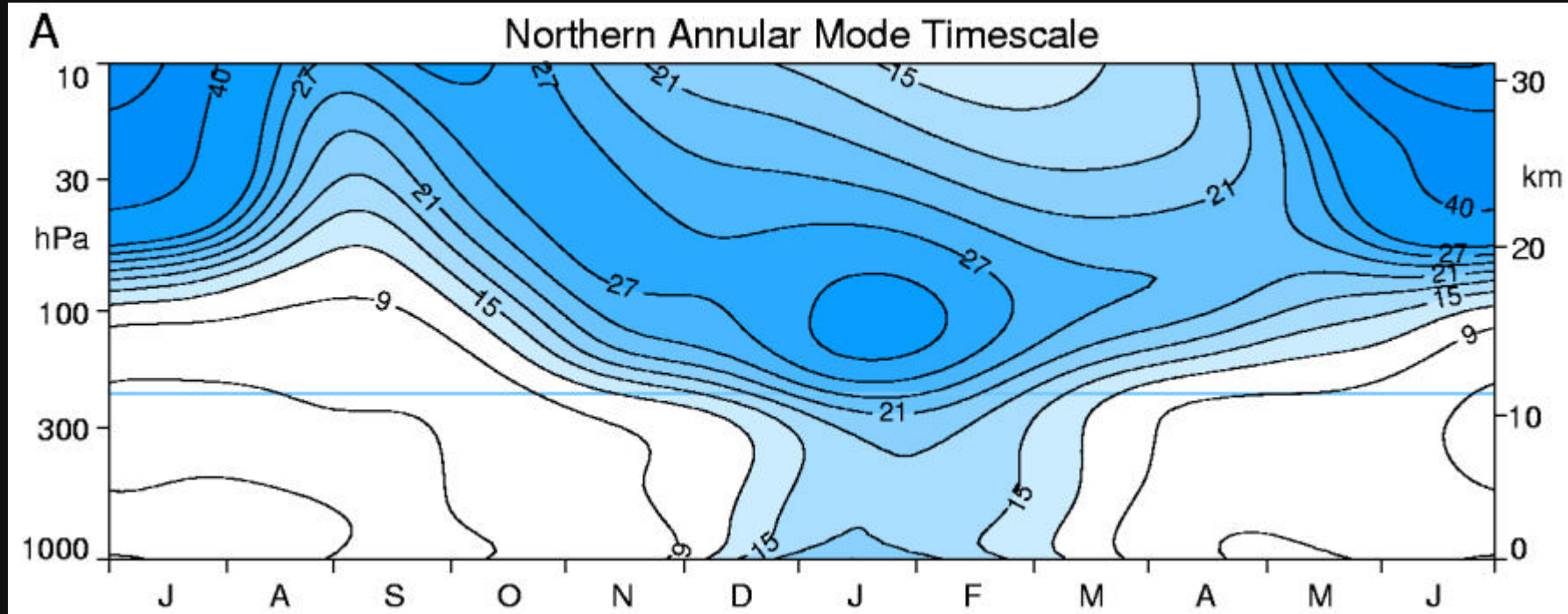
Why is S/T coupling emphasized by annular modes?



Autocorrelation of daily surface AO index



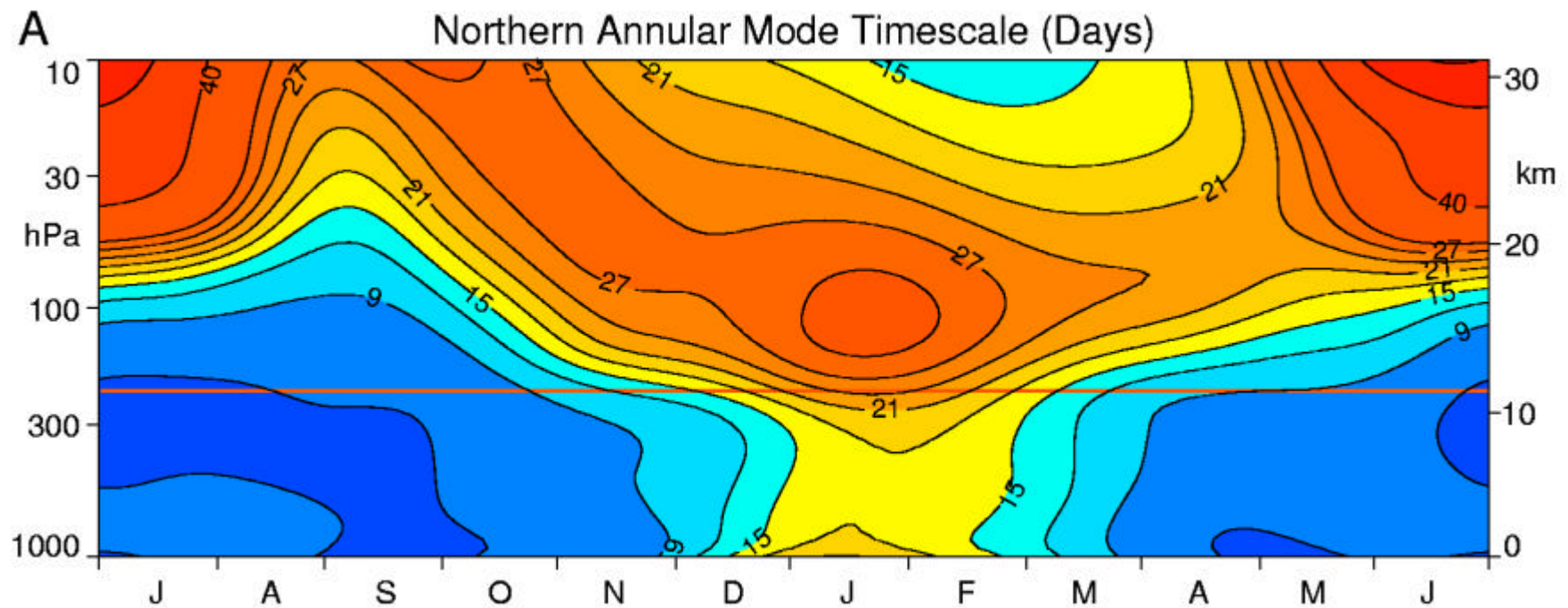
- Without stratospheric variability, the timescale of the surface AO is shorter



NAM e-folding timescale in days.

The stratospheric NAM timescale is much longer.

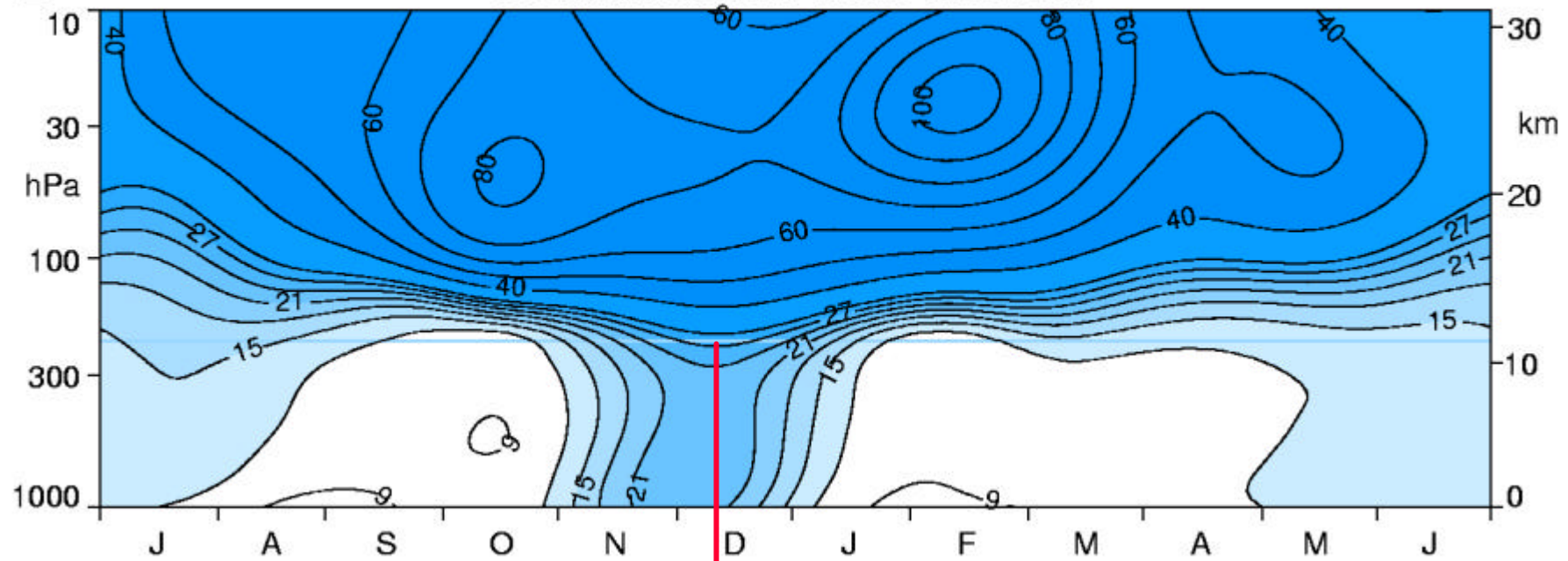
In the troposphere the longest timescale occurs during winter.



In the troposphere the longest timescale occurs during winter. Does this effect depend on the stratosphere, or is it simply an annual cycle?

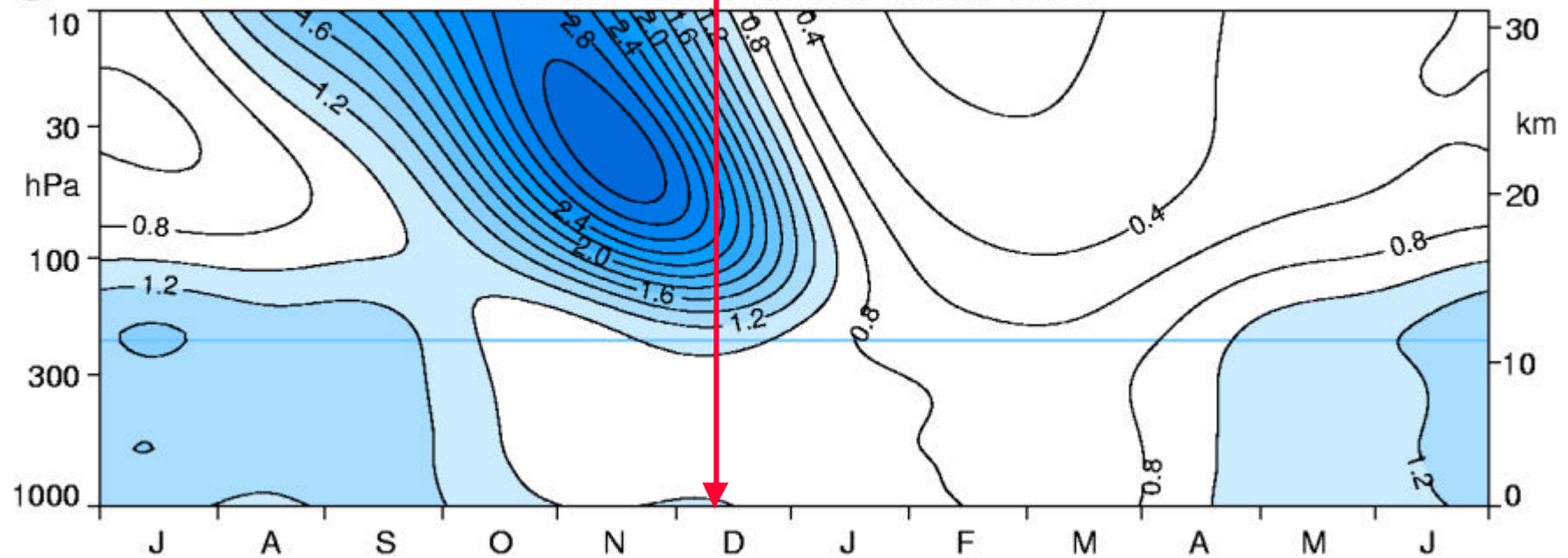
B

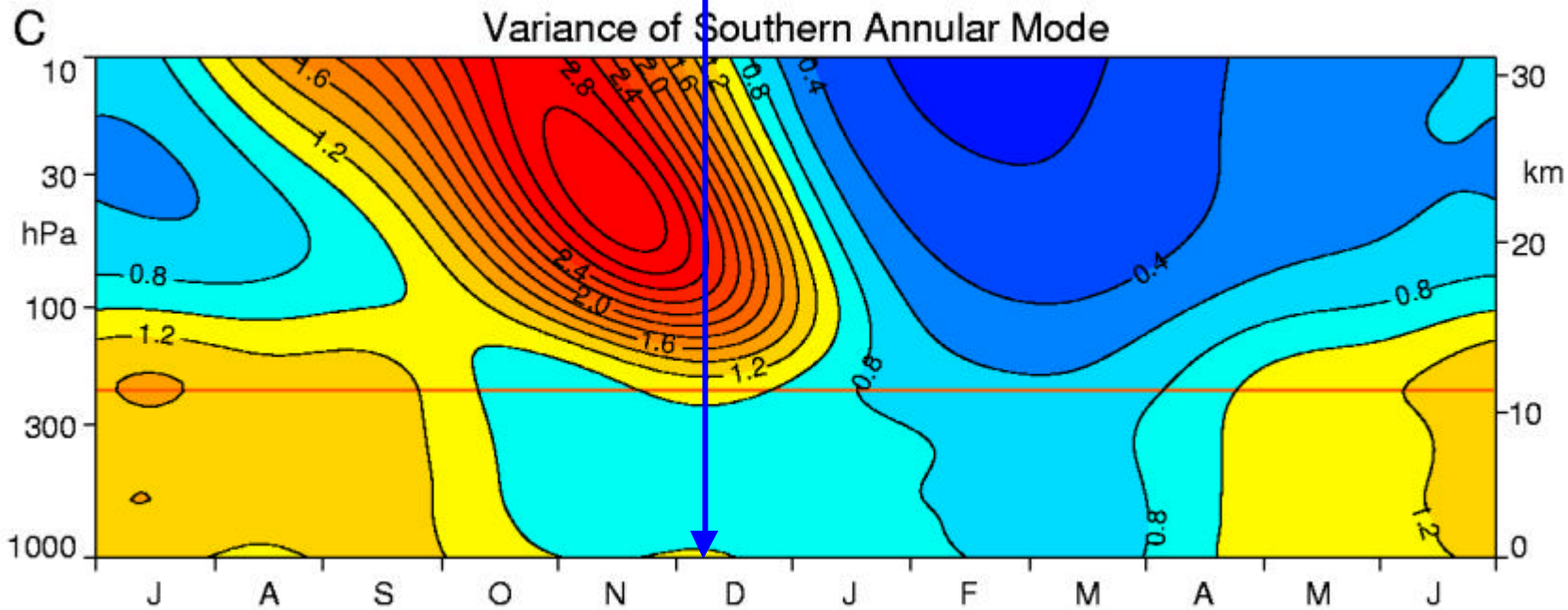
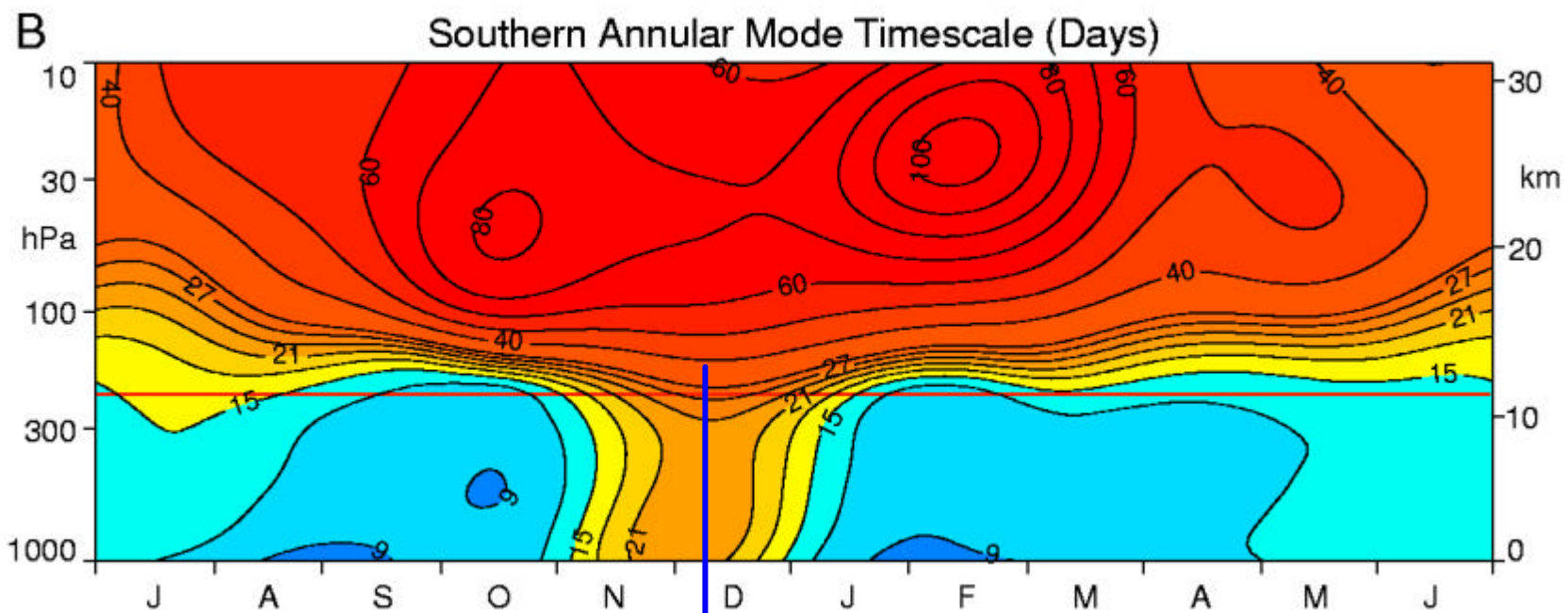
Southern Annular Mode Timescale



C

Variance of Southern Annular Mode



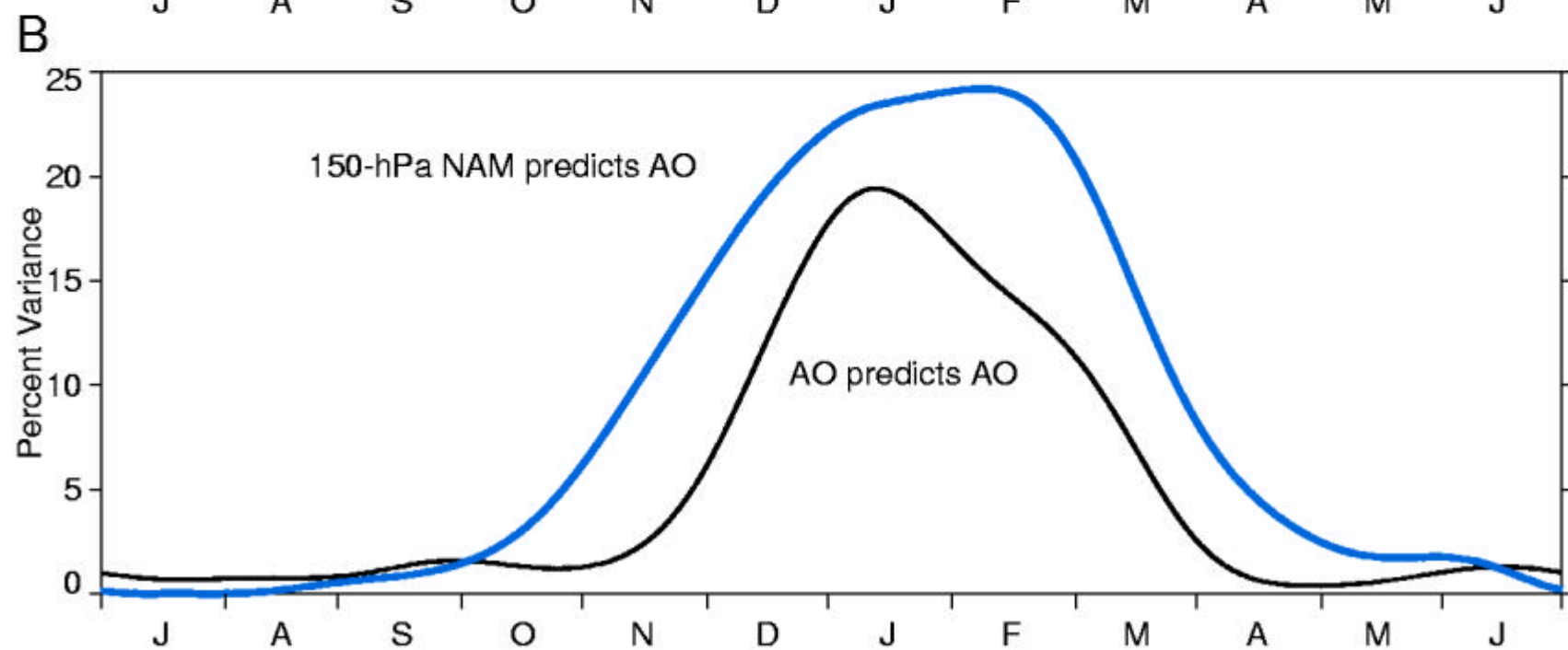
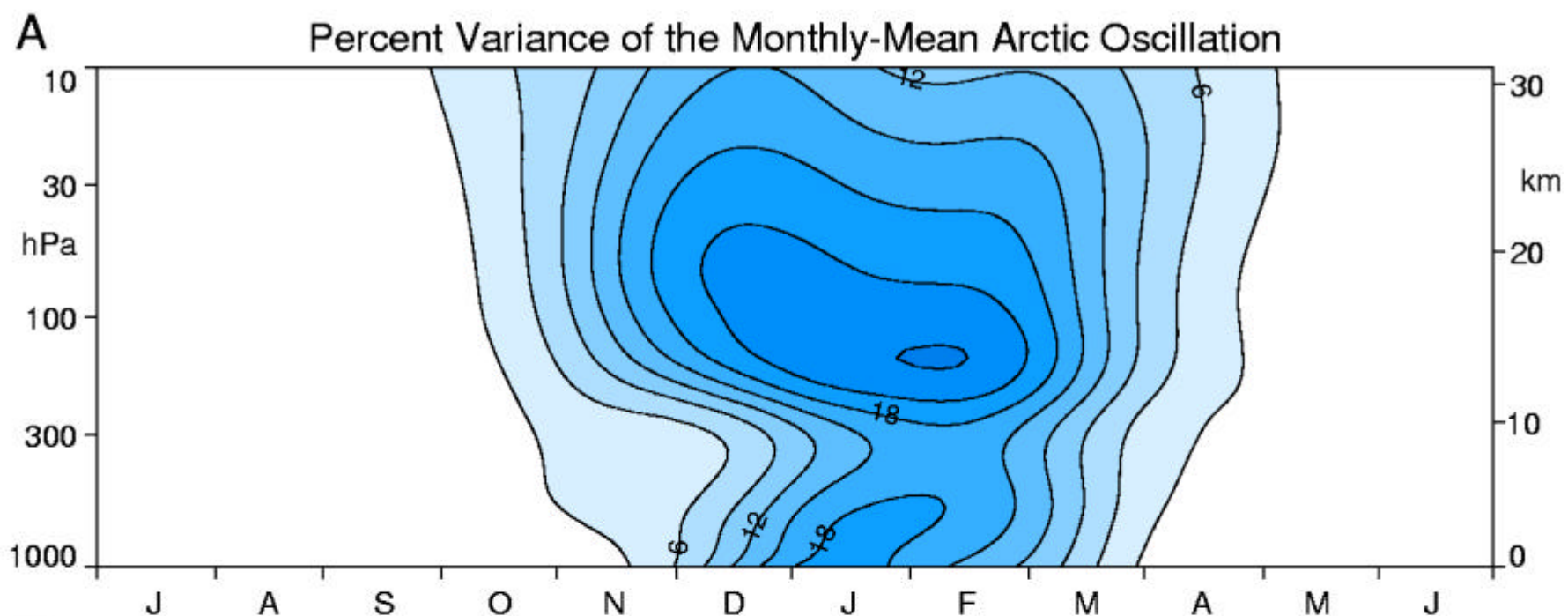


Timescale of the tropospheric NAM/SAM

- Is longest when there are large AM anomalies just above the tropopause.
- Why? Do AM anomalies in the lowermost stratosphere induce changes to the surface AM?

Statistical AO Forecasts

- Exploit the enhanced timescale of the AO during winter.
- Predict the average AO during a future time period, such as 10–40 days.
- Predictors:
 - 1) The present value of the AO
 - 2) The present values of the annular modes at all other levels, including the stratosphere.



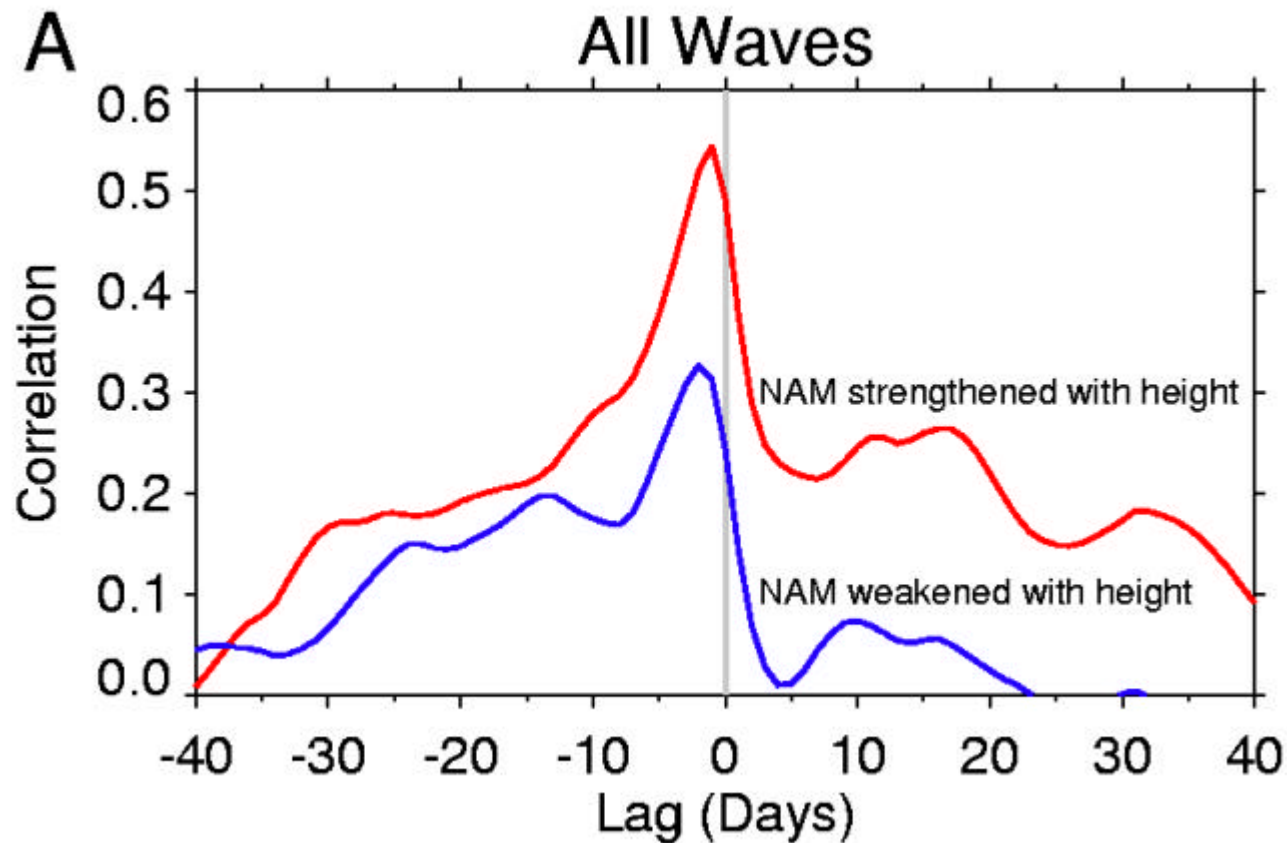
Cross-validated AO Forecasts

- Remove one winter at a time; forecast the remaining winter.
- 150-hPa NAM only during DJF: skill is reduced from 20% to 18%.
- AO predicts AO: cross-validated skill is 12%
- Adding the the AO as a second predictor does not improve skill.

Why does the stratosphere provide predictability?

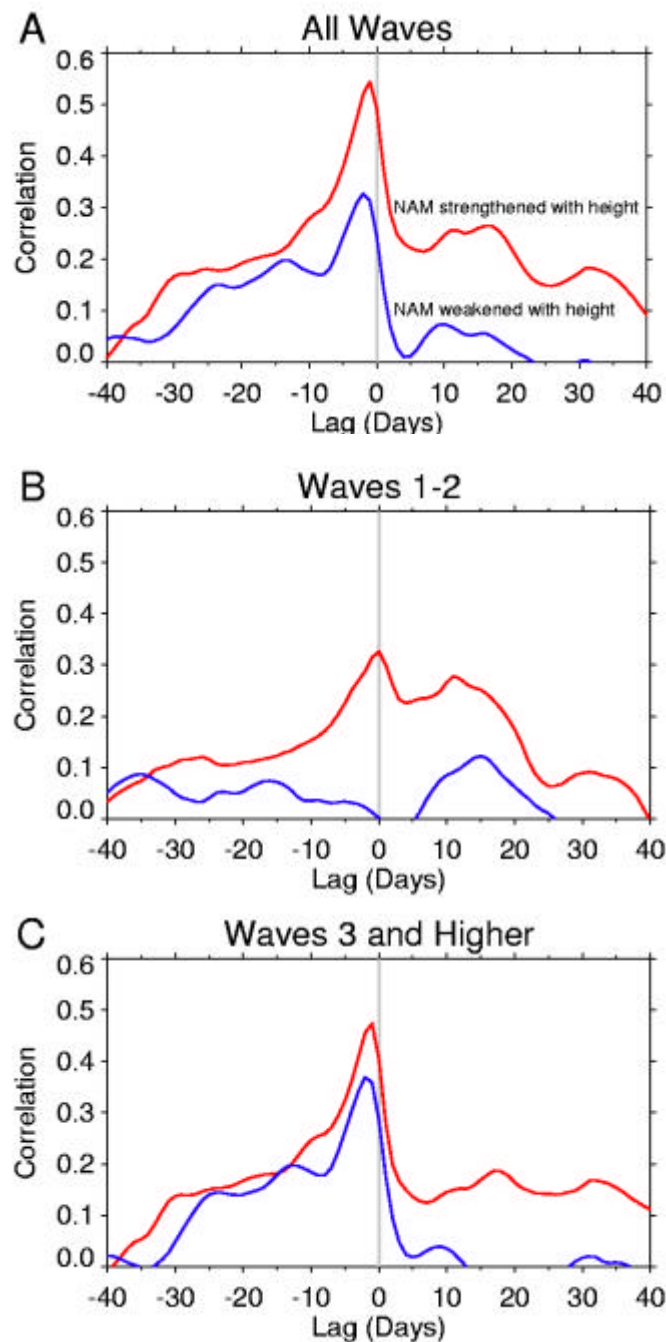
- NAM anomalies in the lowermost stratosphere are long lived.
- NAM anomalies in the lowermost stratosphere affect wave propagation in the upper troposphere (region of overlap).
- Altered wave propagation creates a N-S dipole in momentum forcing (drives tropospheric NAM anomalies)
- Which waves?

Lag correlation between 300-hPa NAM and 300-hPa momentum flux

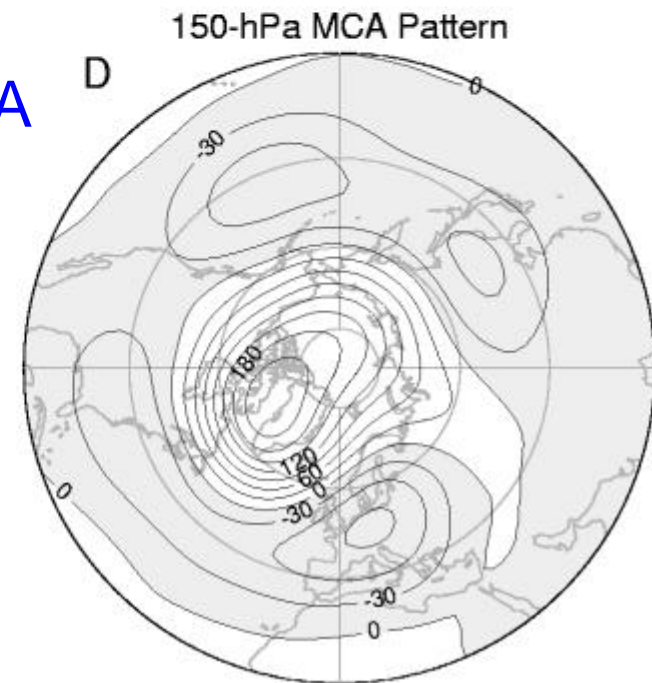
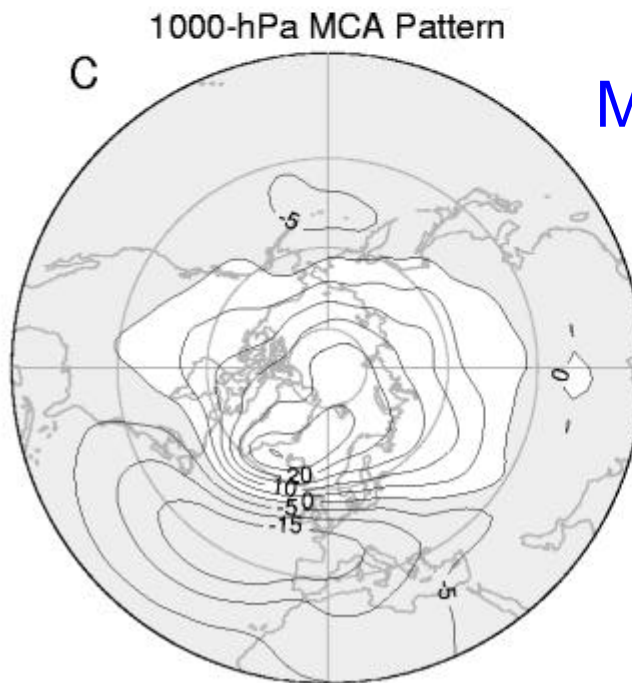
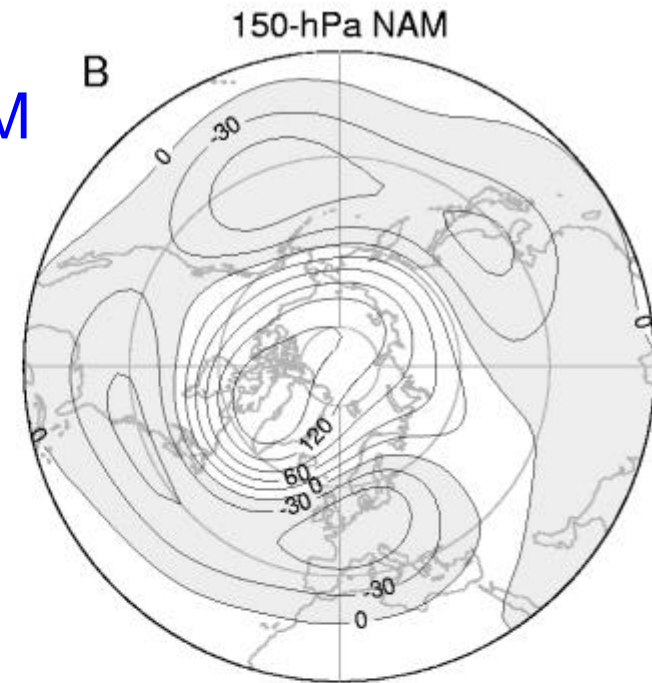
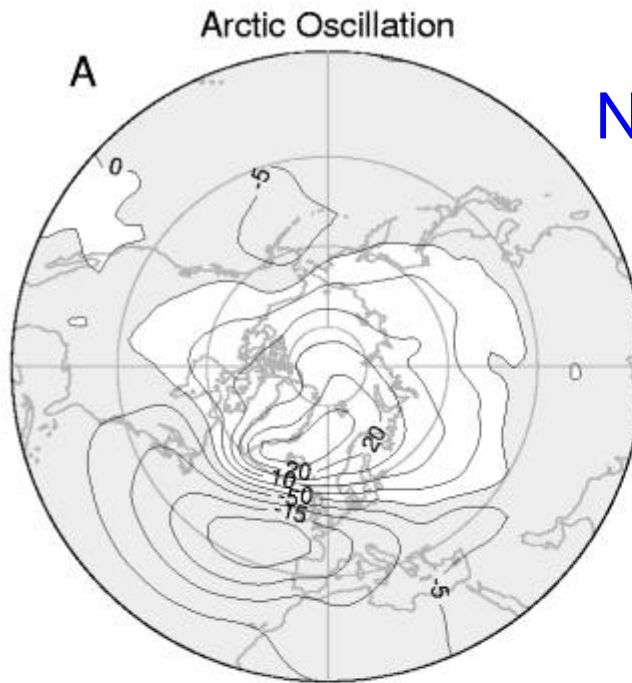


The NAM at 150 hPa affects waves at 300 hPa.

Lag correlation between 300-hPa NAM and 300-hPa momentum flux

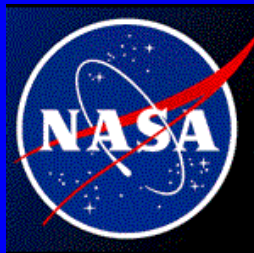


Lagged
MCA
between
daily 150-
hPa Z and
monthly-
mean 1000-
hPa Z
beginning
10 days
later yields
patterns
nearly
identical to
the NAM.



Conclusions

- Persistence *and predictability* of the AO depends on the long timescale of large circulation anomalies in the lowermost stratosphere.
- Hypothesis: NAM anomalies in the lowermost stratosphere affect waves in the upper troposphere, inducing AO changes.



Numerical Forecasts that include stratospheric effects

- Would use a stratosphere-troposphere forecast model
- Ensembles of 60–90 day integrations should capture stratospheric effects
- Perform ensemble forecasts daily during winter
- Subseasonal forecasts would be updated daily

Conclusions

- The lower stratosphere during winter changes slowly, and affects the troposphere through wave propagation. The details are not well understood.
- Persistence *and predictability* of the the troposphere involves 1) waves and 2) the long timescale found in the lowermost stratosphere
- Extended-range (>10 days) predictability of the AO using the stratosphere represents a new source of forecasting information.
- Forecast models that do not simulate stratospheric dynamics will not be able to exploit this effect.



Predictability Beyond 10 Days

- Boundary Conditions (SSTs, Snow and Ice, Soil Moisture, etc.)
- Persistent Atmospheric Phenomena (MJO, QBO, ENSO, etc.)
- Persistent stratospheric anomalies—can they affect the troposphere?