Top-Down Solar Influence on the Madden-Julian Short-Term Climate Oscillation

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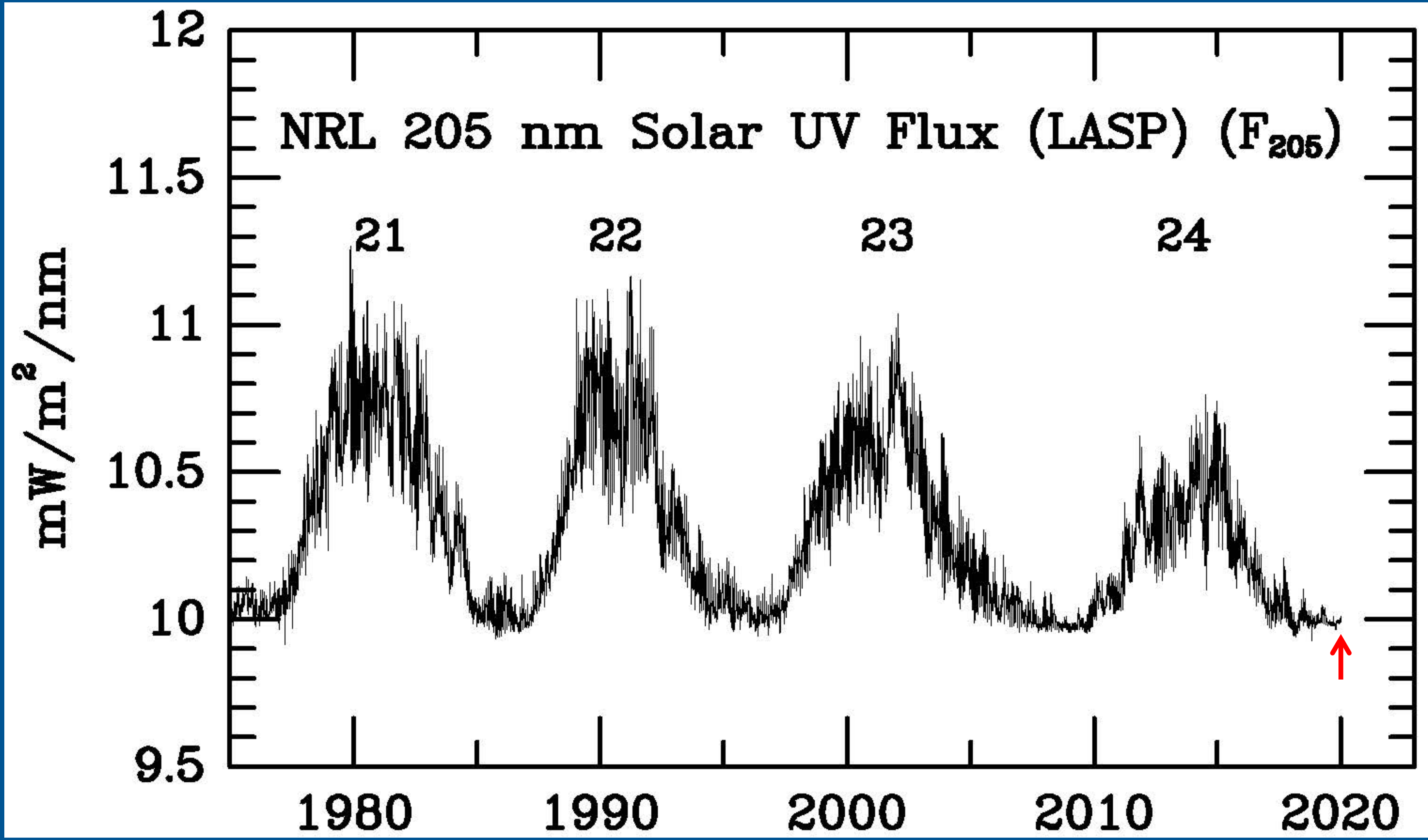
Acknowledgments: NASA LWS program, NSF Climate & Large-scale Dynamics program.

Solar UV variability occurs on time scales of both the 11-year solar cycle and the 27-day solar rotation period.



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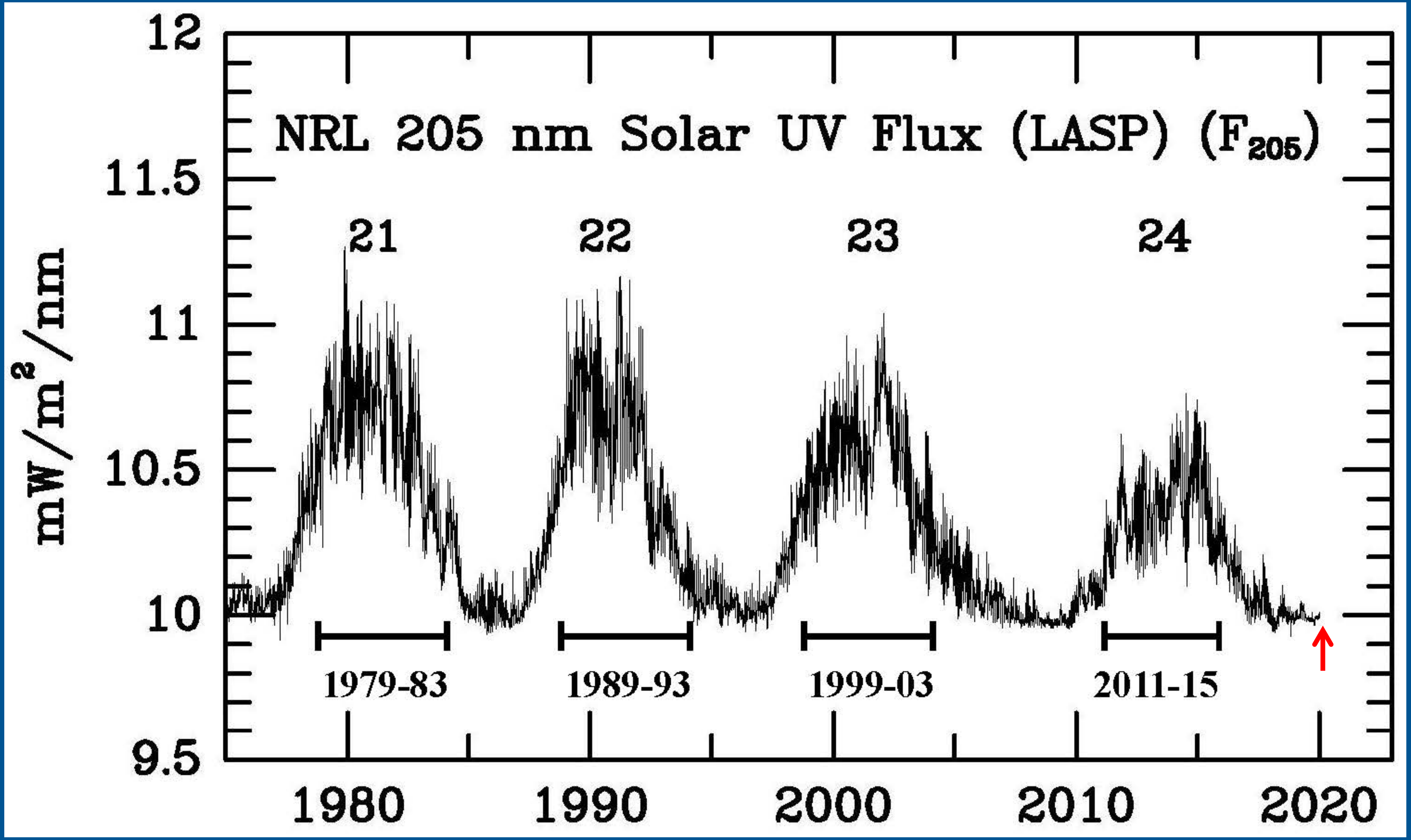
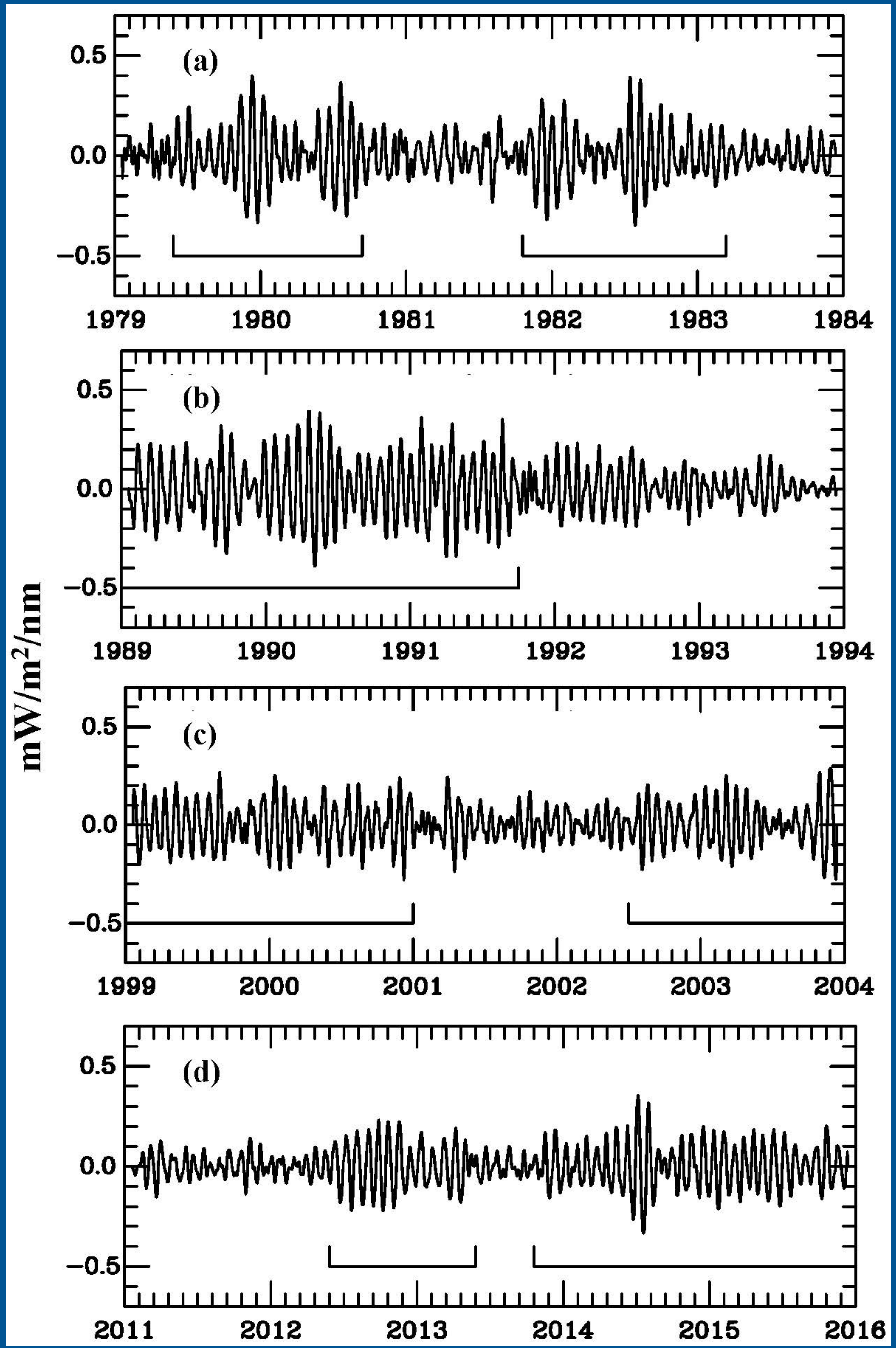


About 136 strong peaks and 128 strong minima are selected for analysis

Deviations from the 35-day running mean:

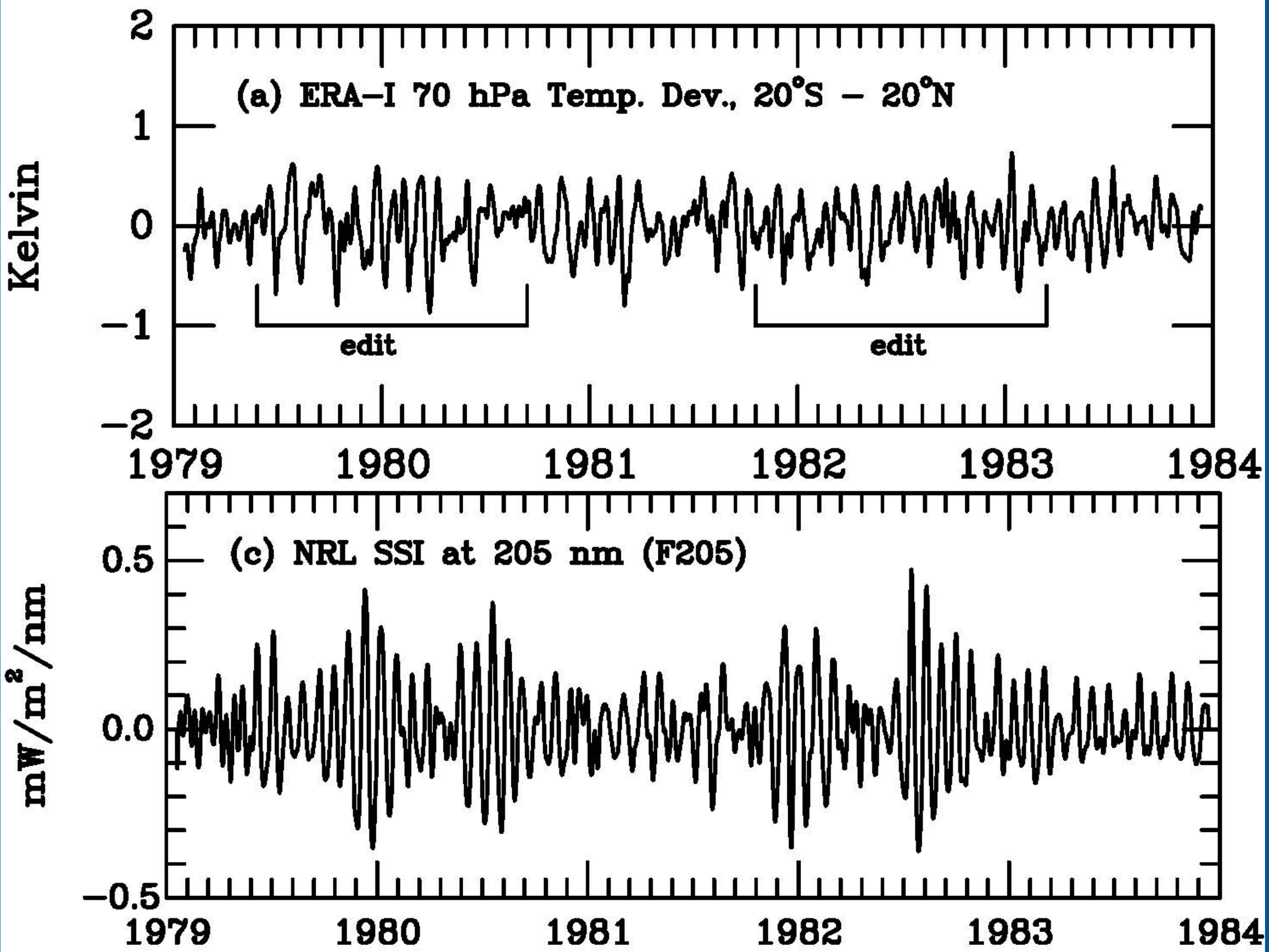
1. Filtering

2. Editing



First, consider just the tropical thermal response to 27-day solar UV variations:

Carry out cross-correlation and regression analyses to investigate the existence of a tropical thermal response



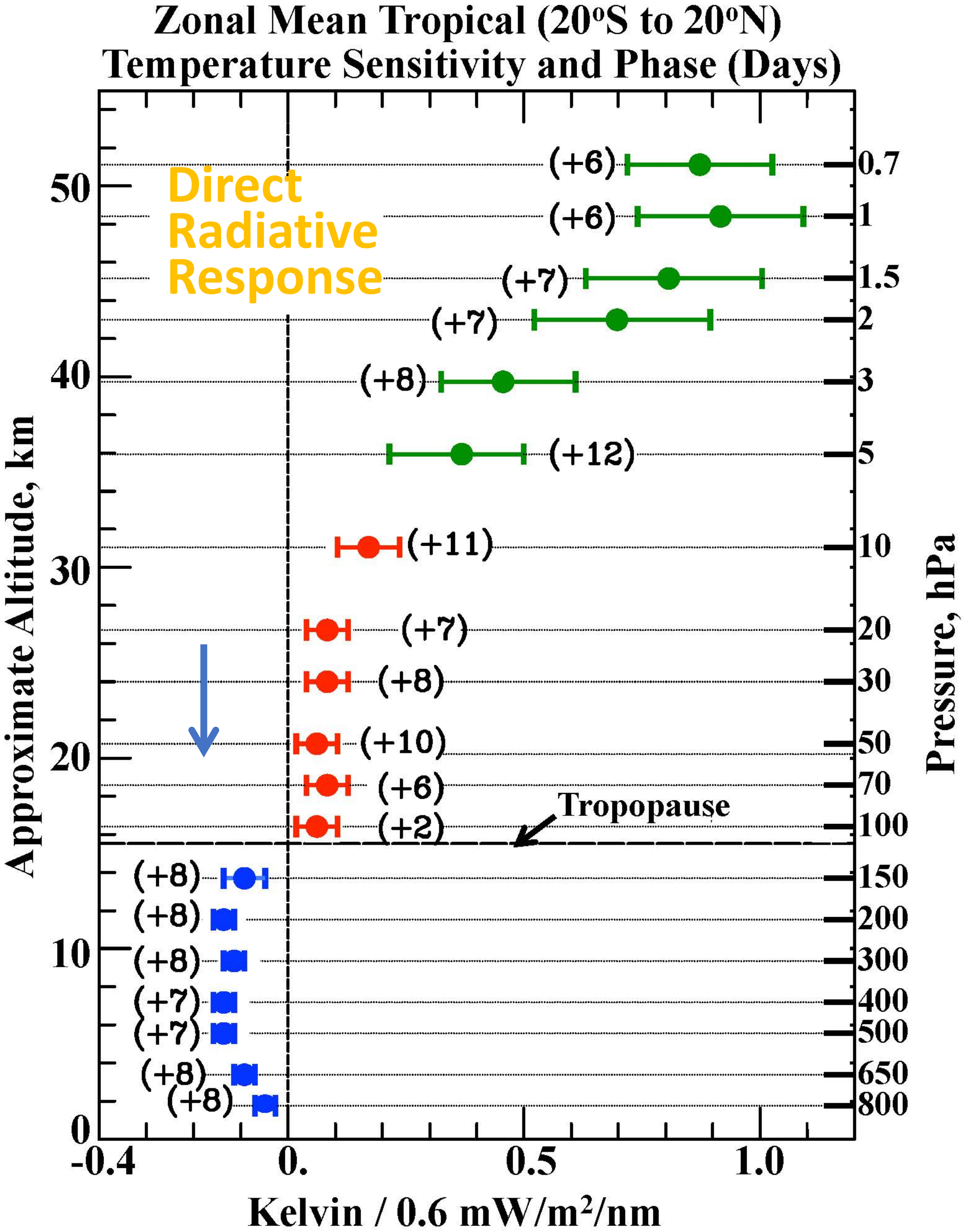
Deviations from the 35-day running mean:

From Hood (GRL, 2016)

Lagged Stratospheric and Tropospheric Thermal Response to 27-day Solar UV Forcing

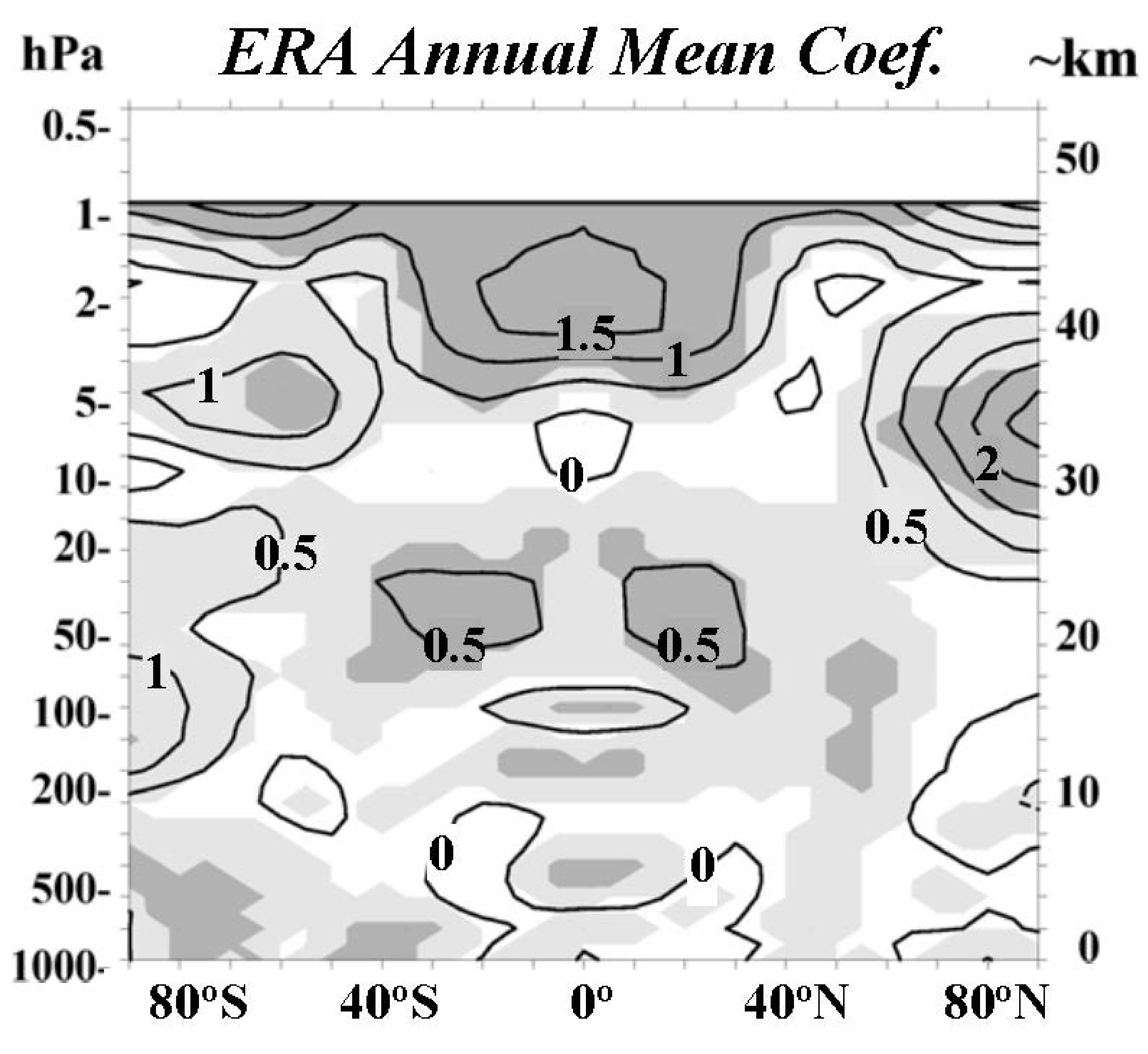
Secondary Dynamical Response

Cooling Response in the Troposphere



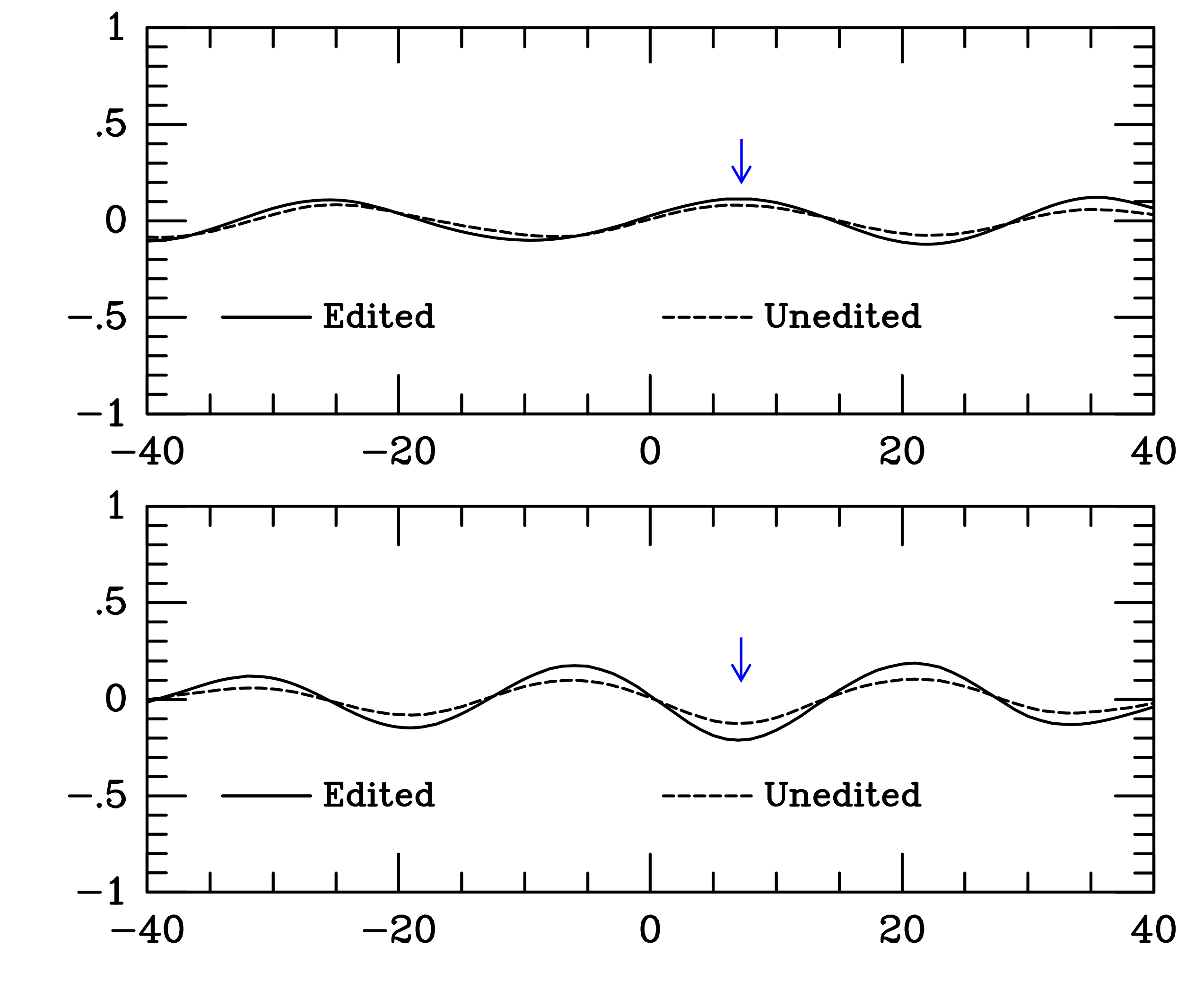
From Hood (GRL, 2016)

11-year solar temperature response derived from ERA-Interim reanalysis data over the 1979-2012 period

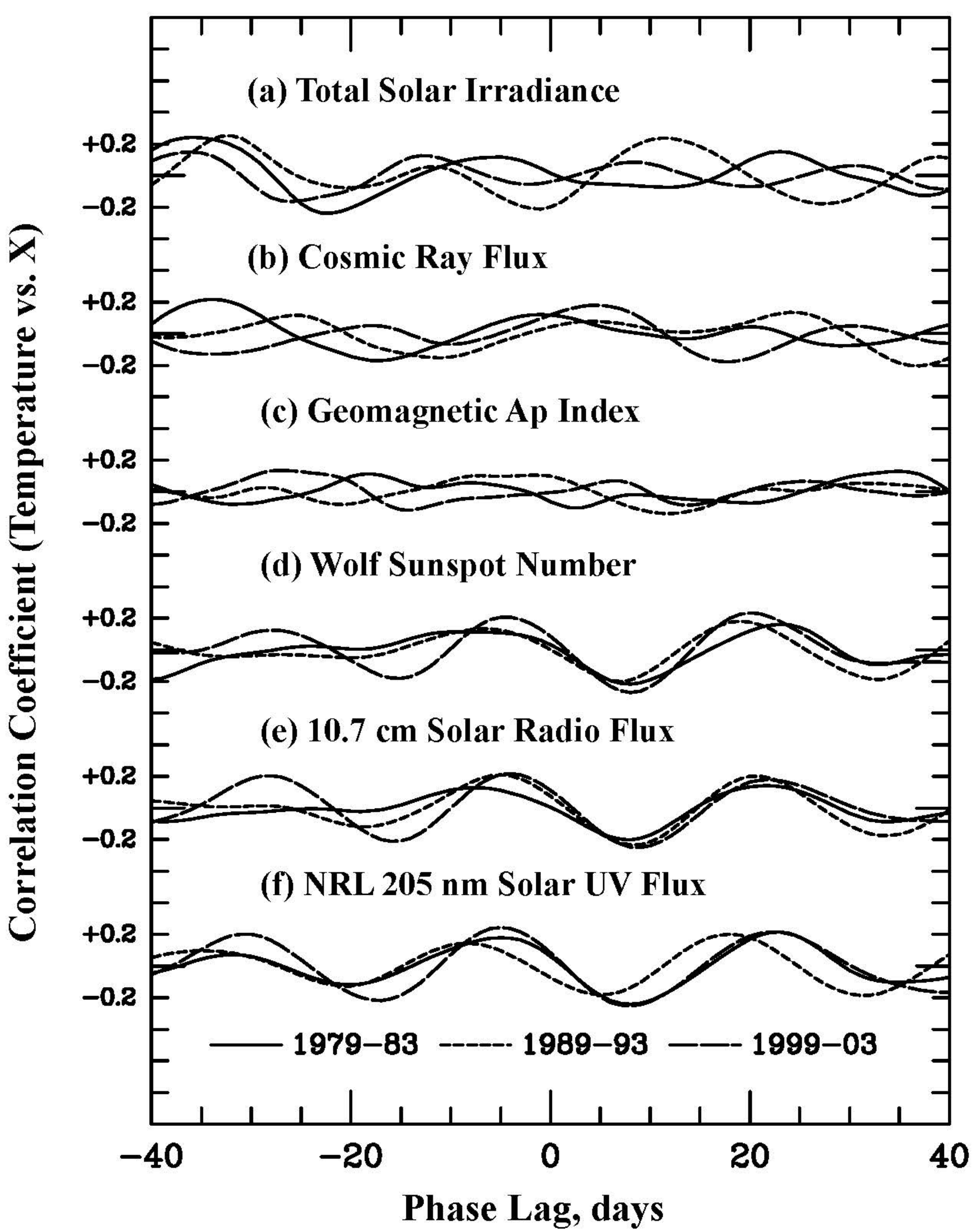


From Hood et al., QJRMS, 2015

Cross-correlation functions between ERA-Interim zonally averaged tropical temperature deviations for three solar maximum periods (1979-83; 1989-93; 1999-2003) and F205 for (a) a pressure level in the lower stratosphere; and (b) a level in the mid-troposphere.

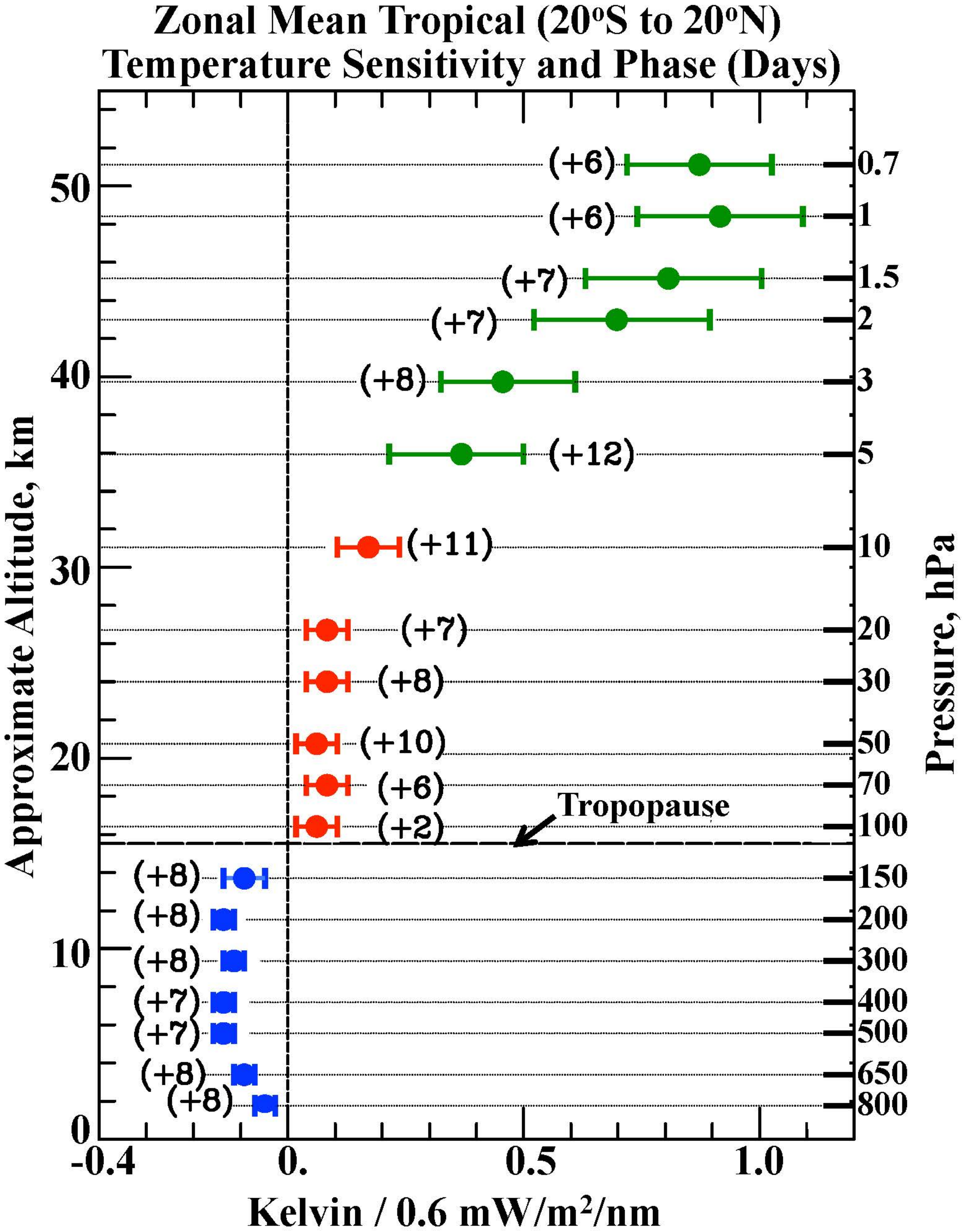


Cross-correlation functions between ERA-Interim zonally averaged tropical temperature deviations at 500 hPa for three solar maximum periods (1979-83; 1989-93; 1999-2003) and a series of possible solar forcing functions. The most consistent correlations are obtained when using solar UV proxies such as F205 and F10.7cm.



Lagged Stratospheric and Tropospheric Thermal Response to 27-day Solar UV Forcing

Reduced Convection and Latent Heat Release



Hood, GRL, 2016;
ERA-Interim Reanalysis Data

Hypothesized Mechanism:

Stratopause

Direct Effects of Solar UV Increases On Ozone and Radiative Heating in the Tropical Upper Stratosphere

Positive Perturbation of Zonal Wind; Indirect Effects on Wave Absorption at Lower levels in the Extratropics

$\nabla \cdot F > 0$

$\partial u / \partial t > 0$

$\Delta w^* > 0$

Increased Static Stability

$\Delta w^* < 0$

$dT/dt > 0$

$dO_3/dt > 0$

Tropopause

F = Planetary Wave Flux

Reduced Convection and Latent Heat Release

Vertically Propagating, Planetary-scale Rossby Waves

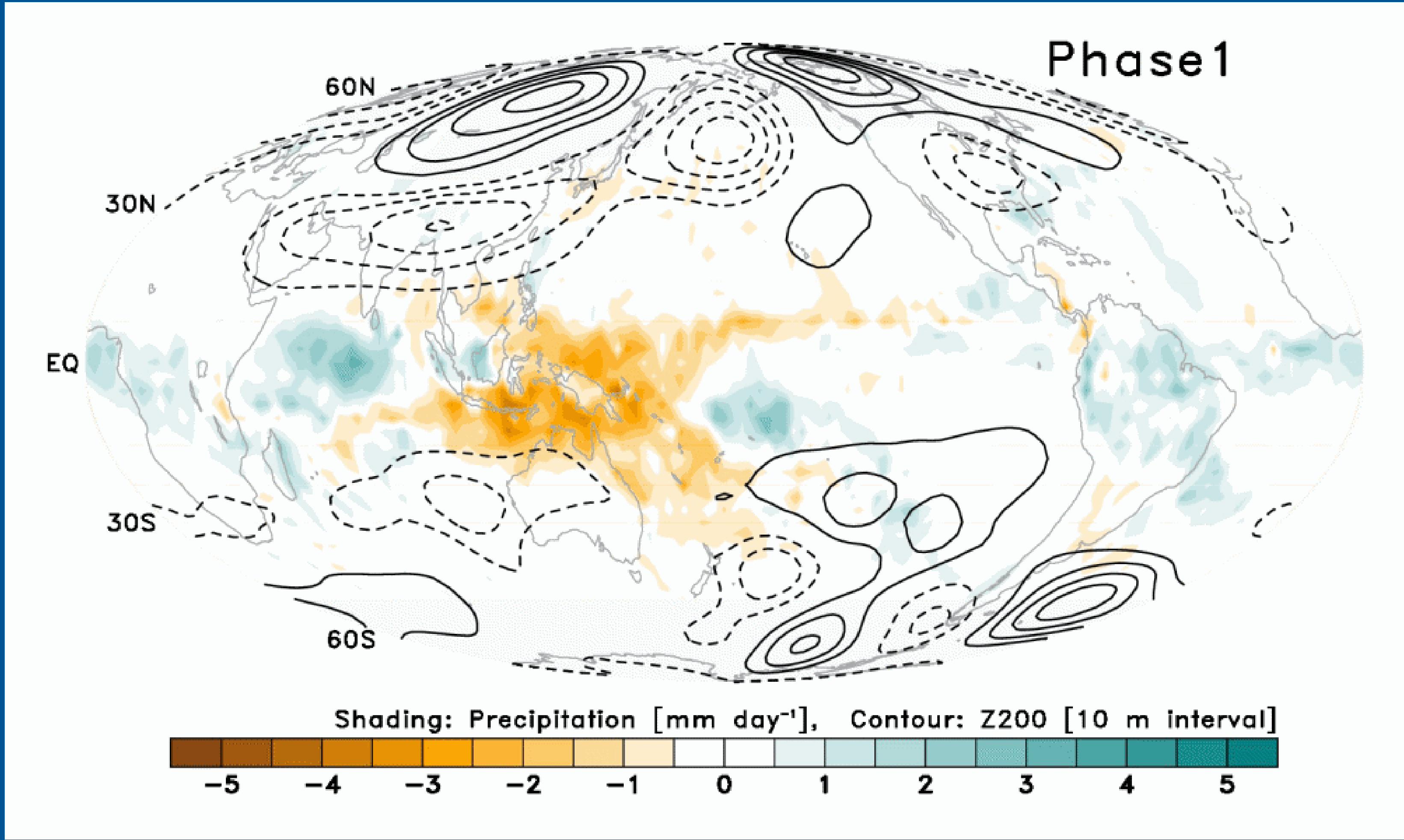
Surface

Equator

Winter Hemisphere

Pole

- *The Madden-Julian Oscillation (MJO), also known as the 30 to 60 day oscillation, is a an eastward propagating pattern of alternately intense and weak tropical convection and precipitation primarily in the Indo-Pacific region.*
- *It is the strongest of the subseasonal climate oscillations and has important effects on extratropical circulation and subseasonal climate, including effects on extreme rainfall in the U.S.*



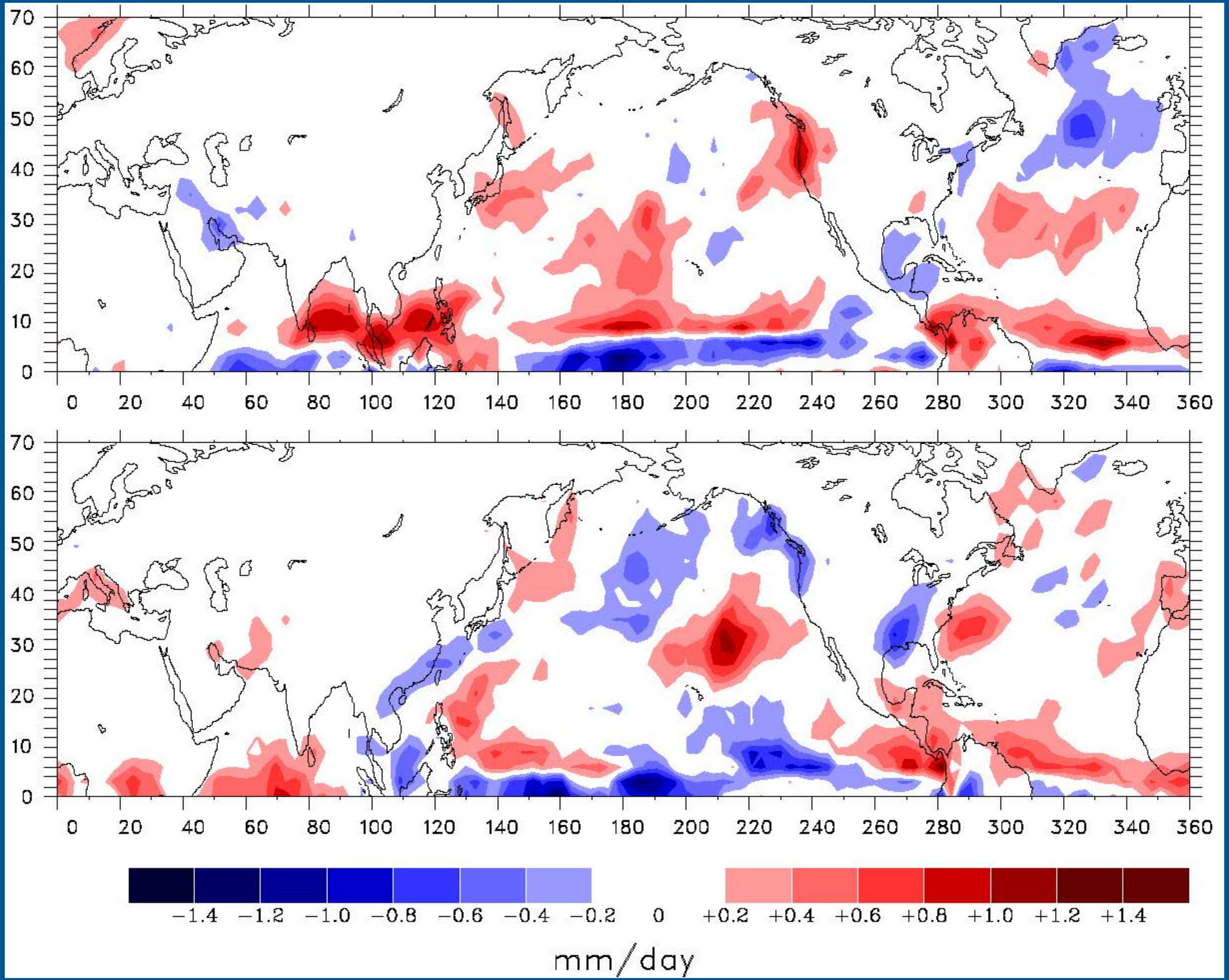
20-100-day filtered variables
Shading: Precipitation
Contour: GPH200 (solid: +, dashed: -)

Video kindly provided by
Dr. Min-Seop Ahn, Univ. of Washington

Effect on Precipitation of a Weak MJO Event (Amp. ~ 1 s.d.)

MJO Phases 3 to 6:

MJO Phases 1,2,7,8:

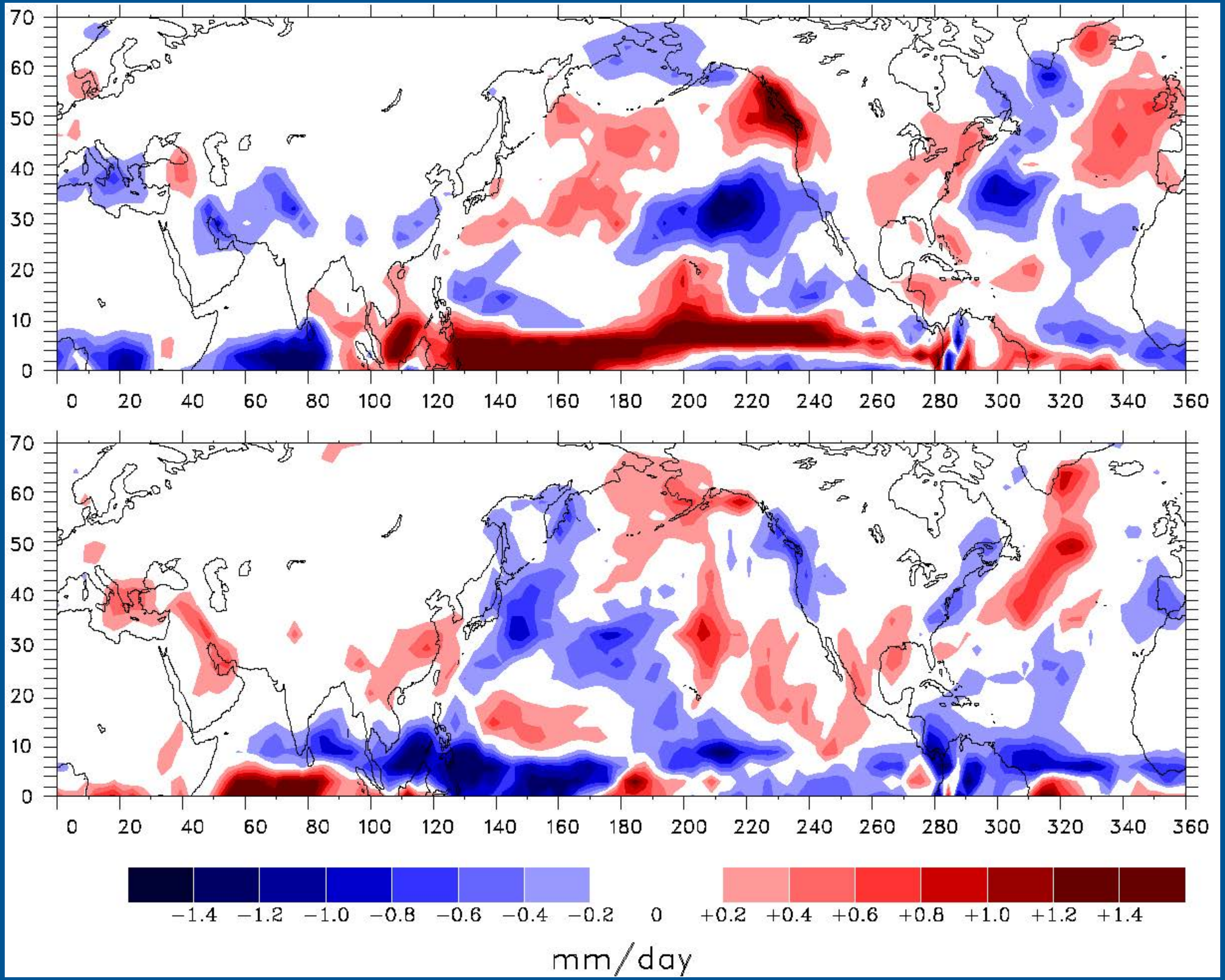


ERA Interim Reanalysis Data

Effect on Precipitation of a Strong MJO Event (Amp. ~ 2 s.d.)

MJO Phases 3 to 6:

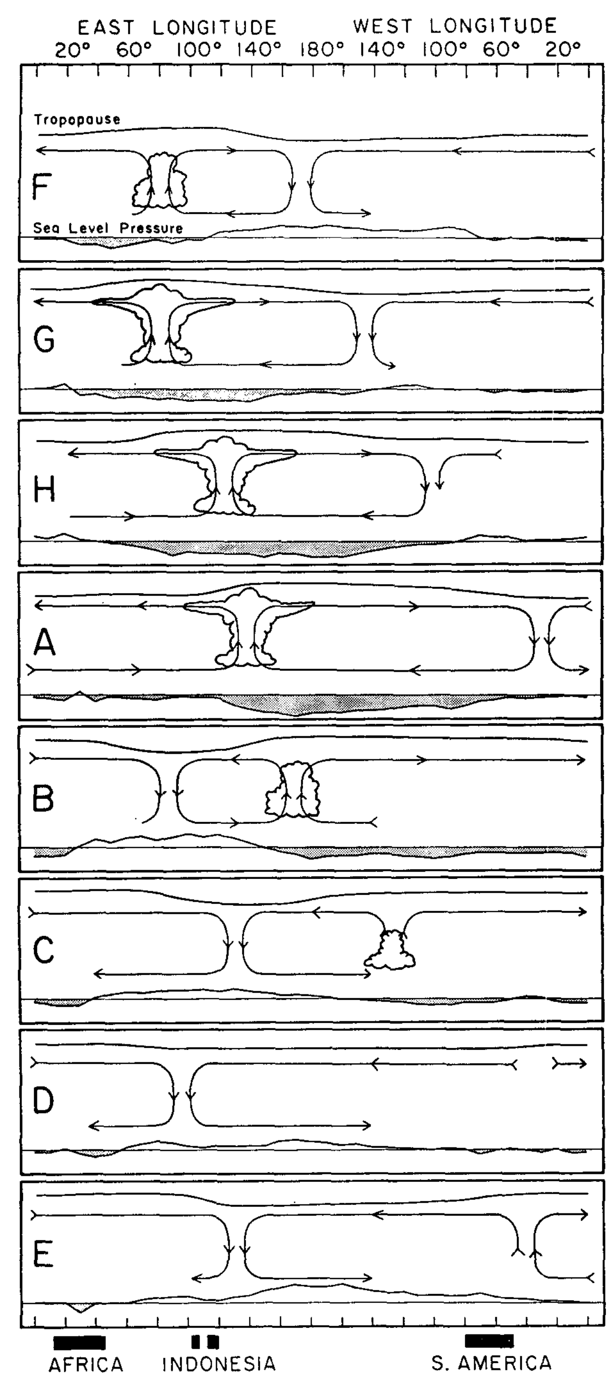
MJO Phases 1,2,7,8:



ERA Interim Reanalysis Data

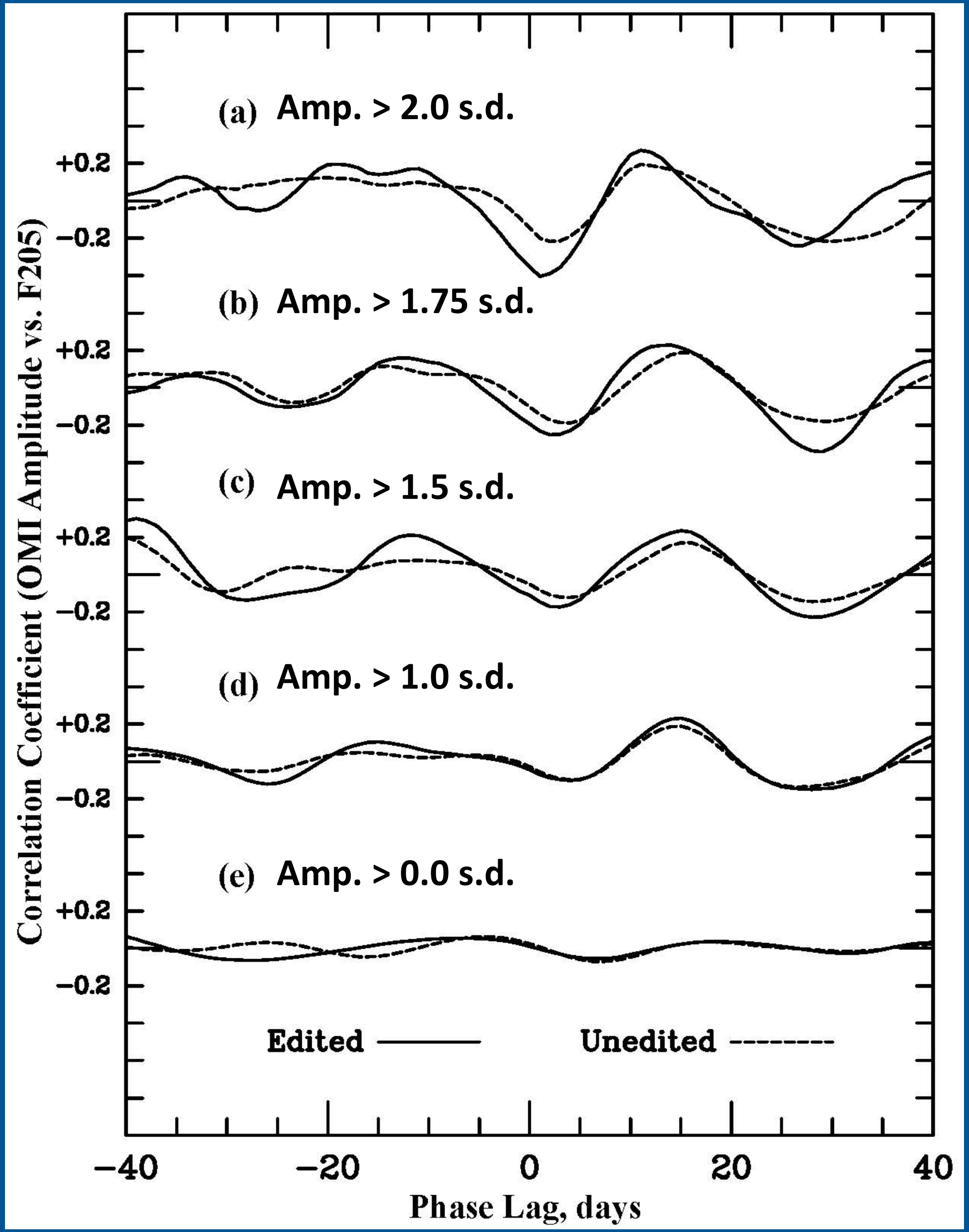
The MJO can be regarded as a vertically trapped Kelvin wave-like disturbance (e.g., Chang, 1977; Hayashi and Sumi, 1986).

It extends vertically into the uppermost troposphere so it is possible that conditions at its upper boundary can affect its eastward propagation and intensity. An MJO event can potentially be amplified by favorable conditions (e.g., reduced static stability) in the lowermost stratosphere.



Credit: Madden & Julian, 1972

Analyses of daily MJO amplitude data indicate a reduction of MJO amplitudes following peaks in 27-day solar UV flux. This is especially true when only days with relatively large MJO amplitudes are considered.

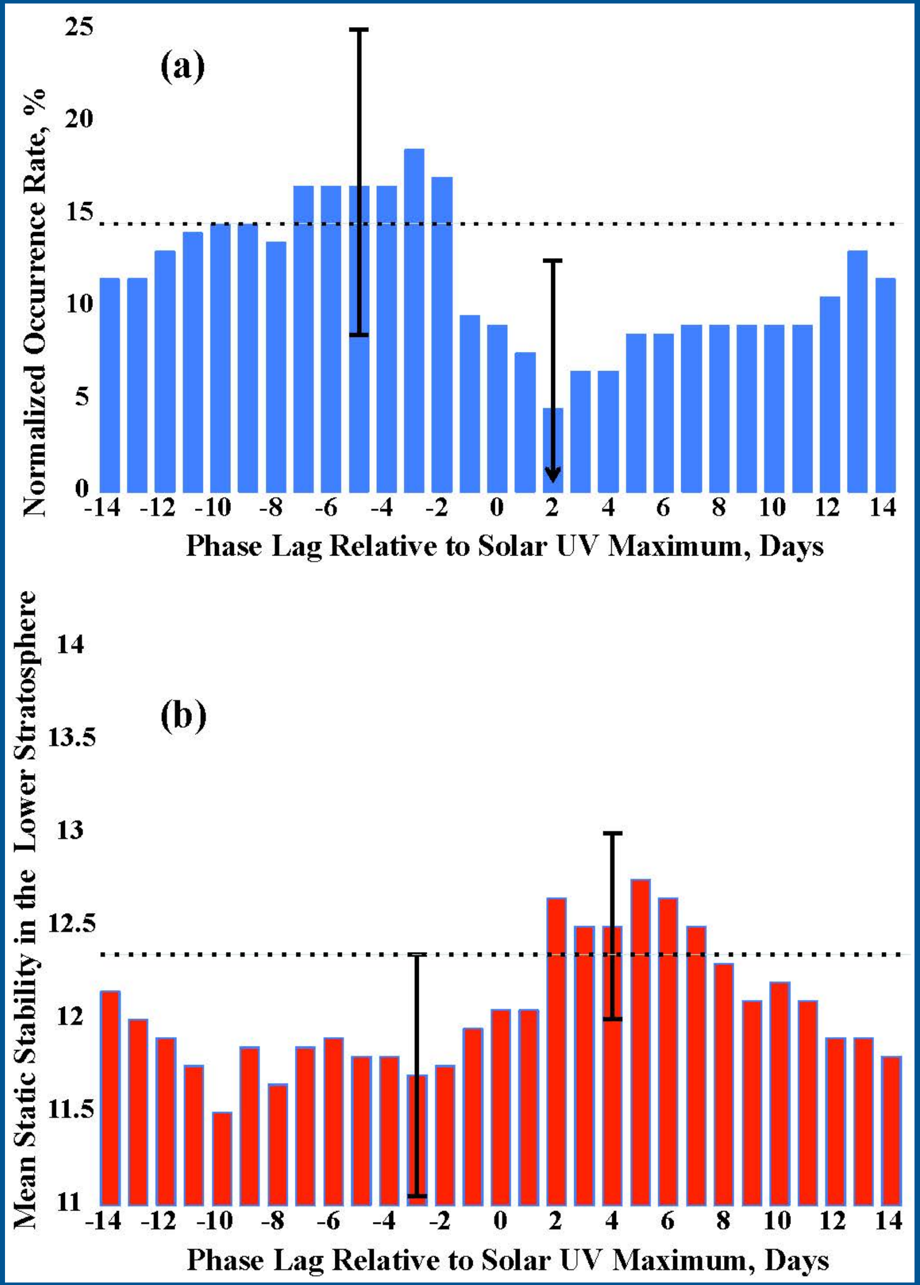


Hood, JAS, 2018

Calculate Normalized Occurrence Rates of MJO events with <u>amplitudes > 2.0</u> versus phase lag relative to 64-68 solar UV peaks. <u>Only days in DJFMAM are considered.</u>

Also, calculate corresponding mean static stabilities in the lower stratosphere (70 to 100 mb), averaged over the warm pool region where MJO amplitudes are largest.

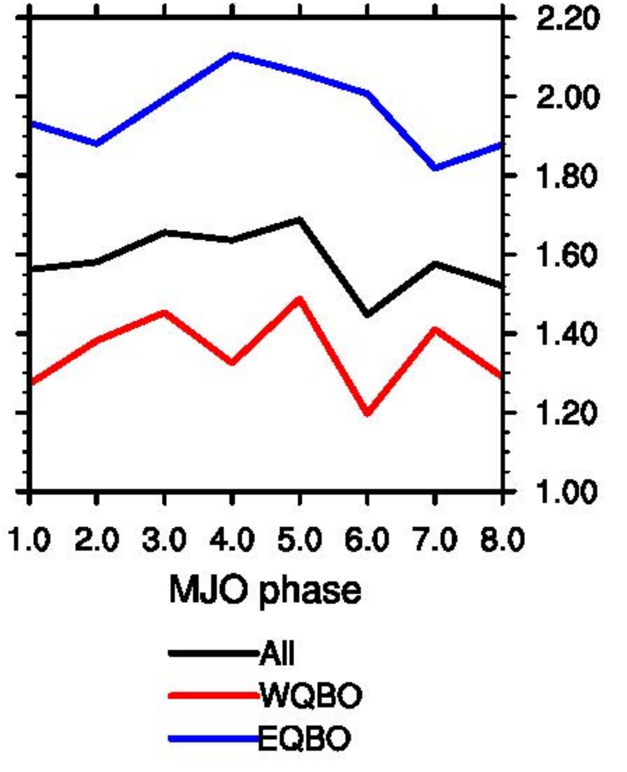
<u>A Significant Response</u>

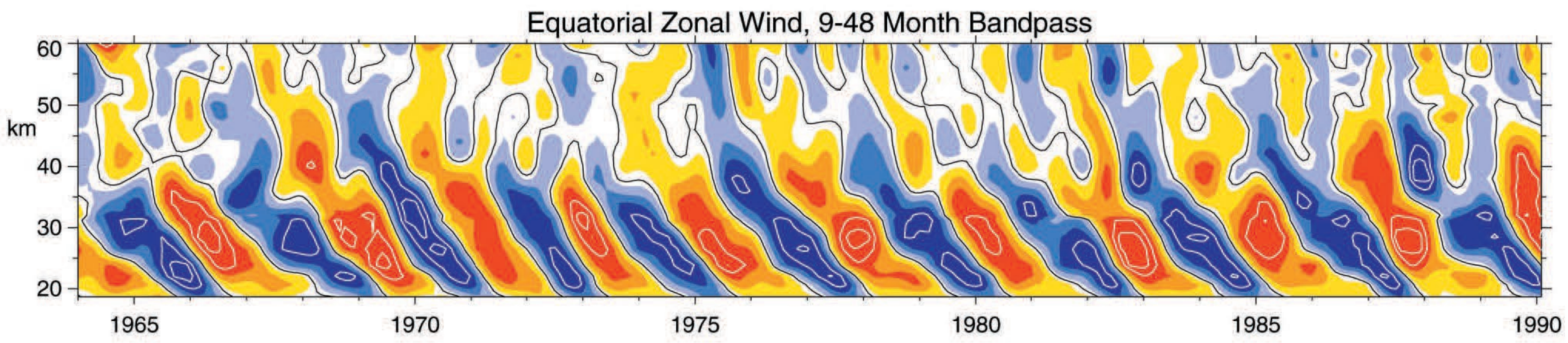


Beginning about 4 years ago, it was realized that the amplitude and occurrence rate of MJO events differs significantly depending on the phase of the stratospheric quasi-biennial oscillation during boreal winter (DJF).

MJO Amplitude, Standard Deviations:

Yoo and Son, GRL, 2016:



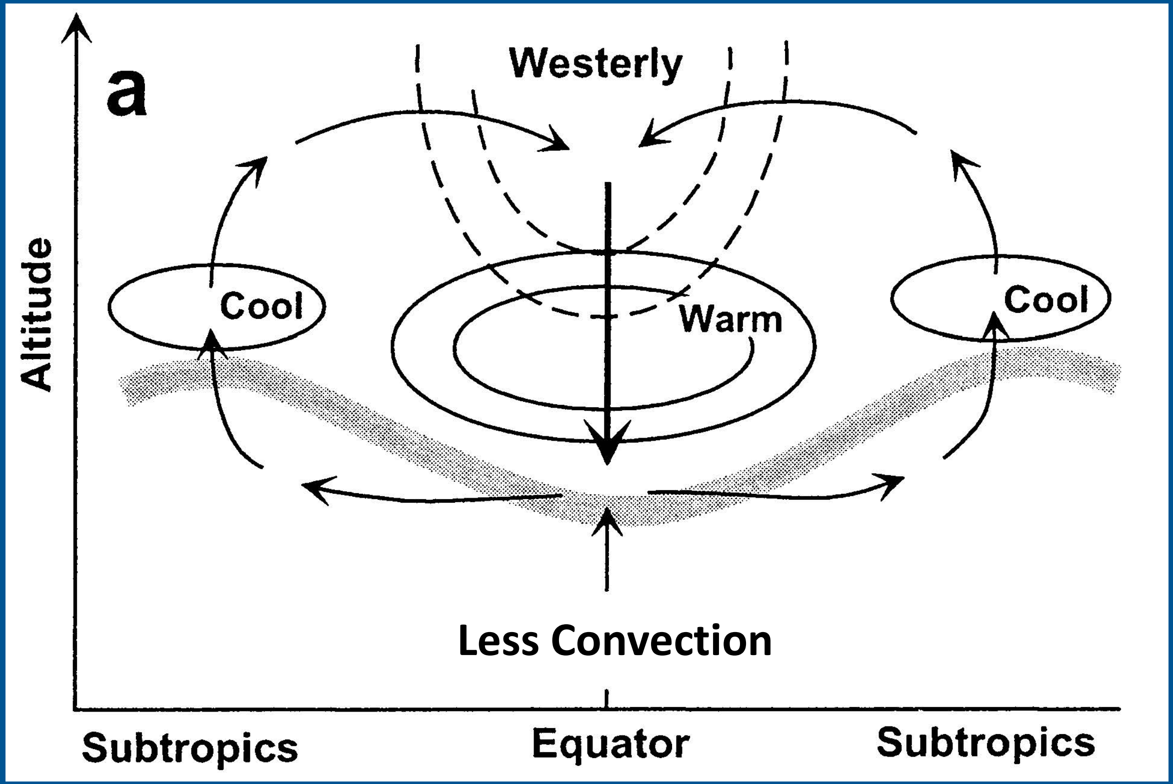


Credit: Baldwin et al. 2001

A Possible Mechanism: Relative downwelling (upwelling) in the tropical lowermost stratosphere during the QBOW (QBOE) phase

Increased static stability in the tropical lowermost stratosphere

Decreased static stability in the tropical lowermost stratosphere



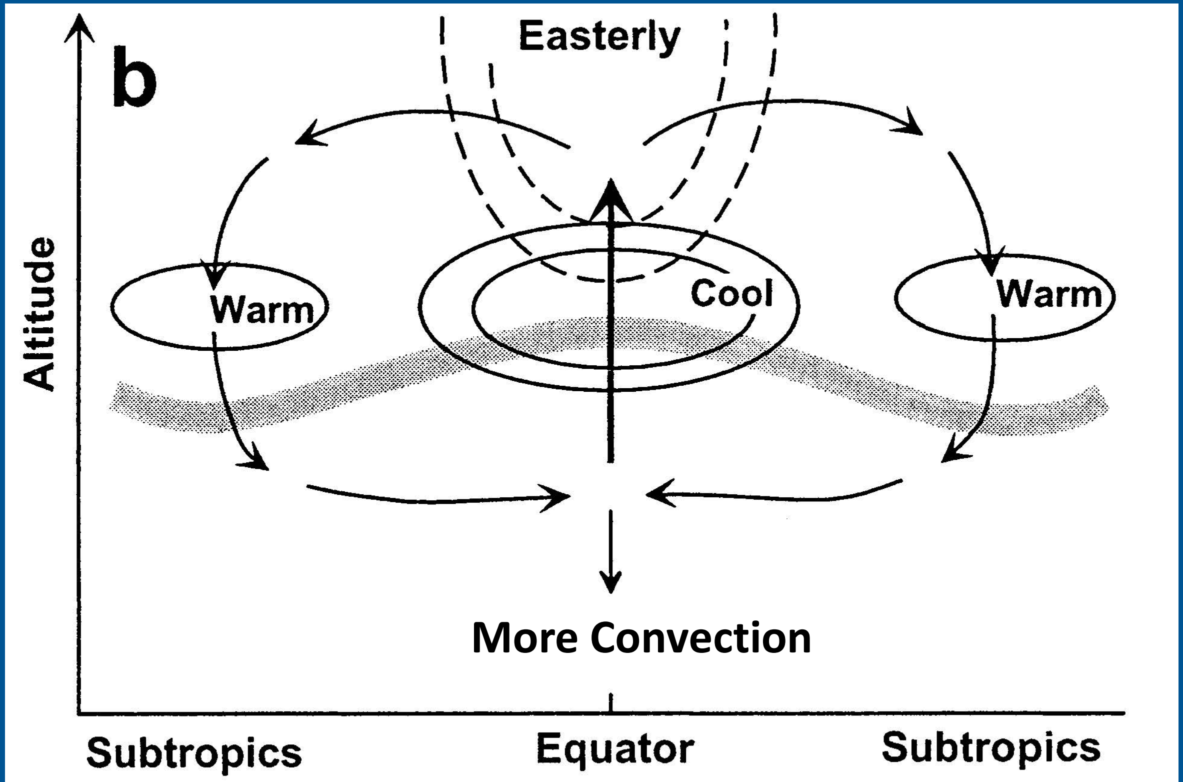
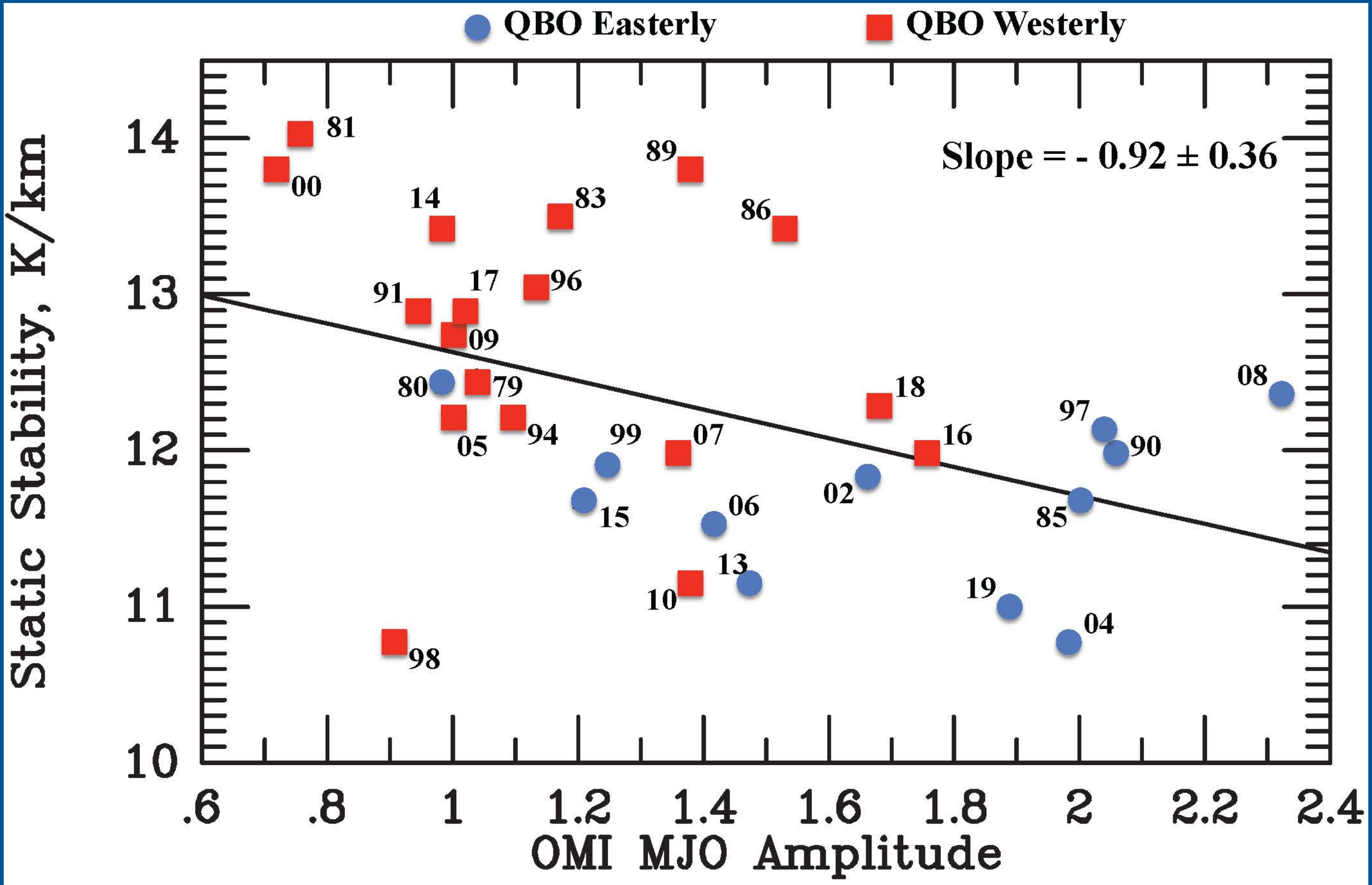


Figure taken from Collimore et al., "On the Relationship Between the QBO and Tropical Deep Convection", J. of Climate, 2003.

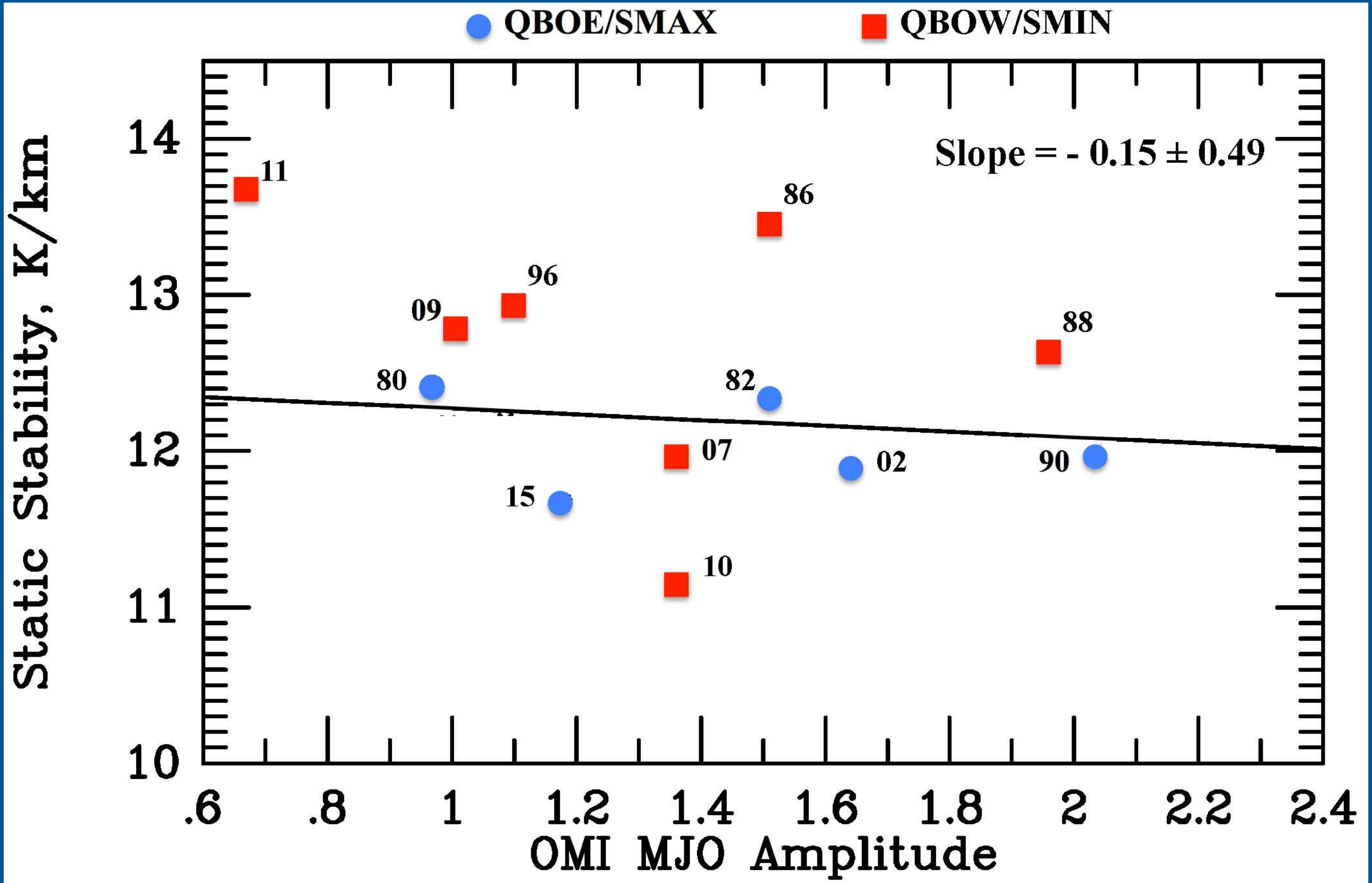
Plot of mean MJO amplitude in DJF vs. mean static stability in the tropical lower stratosphere over the warm pool region.

Updated from Yoo and Son, GRL, 2016 and Hood, GRL, 2017



First, consider only those winters when the two forcings are opposing one another: QBOE/SMAX; QBOW/SMIN.

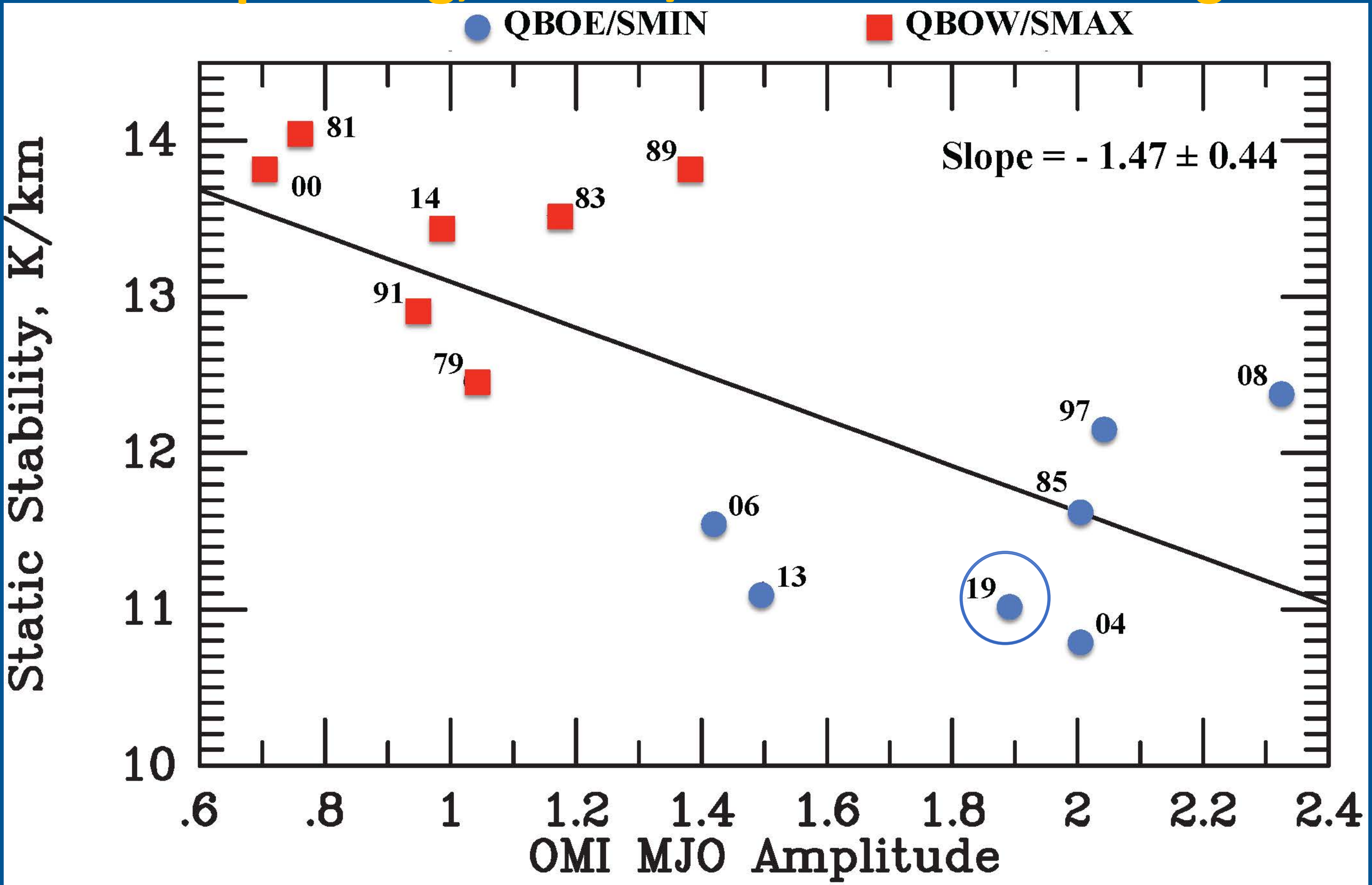
DJF mean lower stratospheric static stability plotted vs. MJO amplitude for QBOE/SMIN and QBOW/SMAX conditions



From Hood, GRL, 2017

Next, consider only those winters when the two forcings are working together: QBOE/SMIN= Upwelling; QBOW/SMAX=Downwelling.

DJF mean lower stratospheric static stability plotted vs. MJO amplitude for QBOE/SMIN and QBOW/SMAX conditions



Updated from Hood, GRL, 2017

Effect on Air Temp. of a Weak MJO Event (Amp. ~ 1 s.d.)

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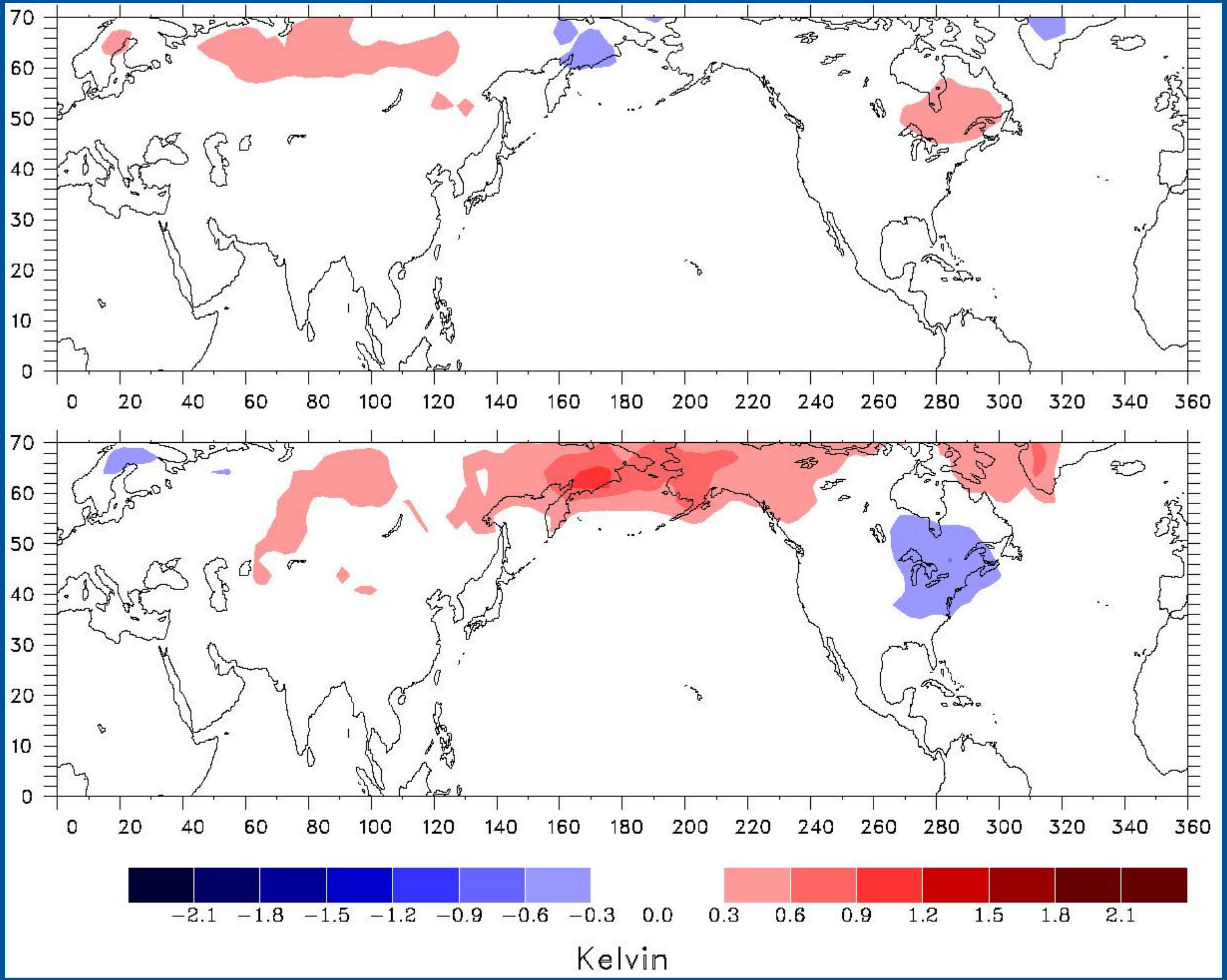
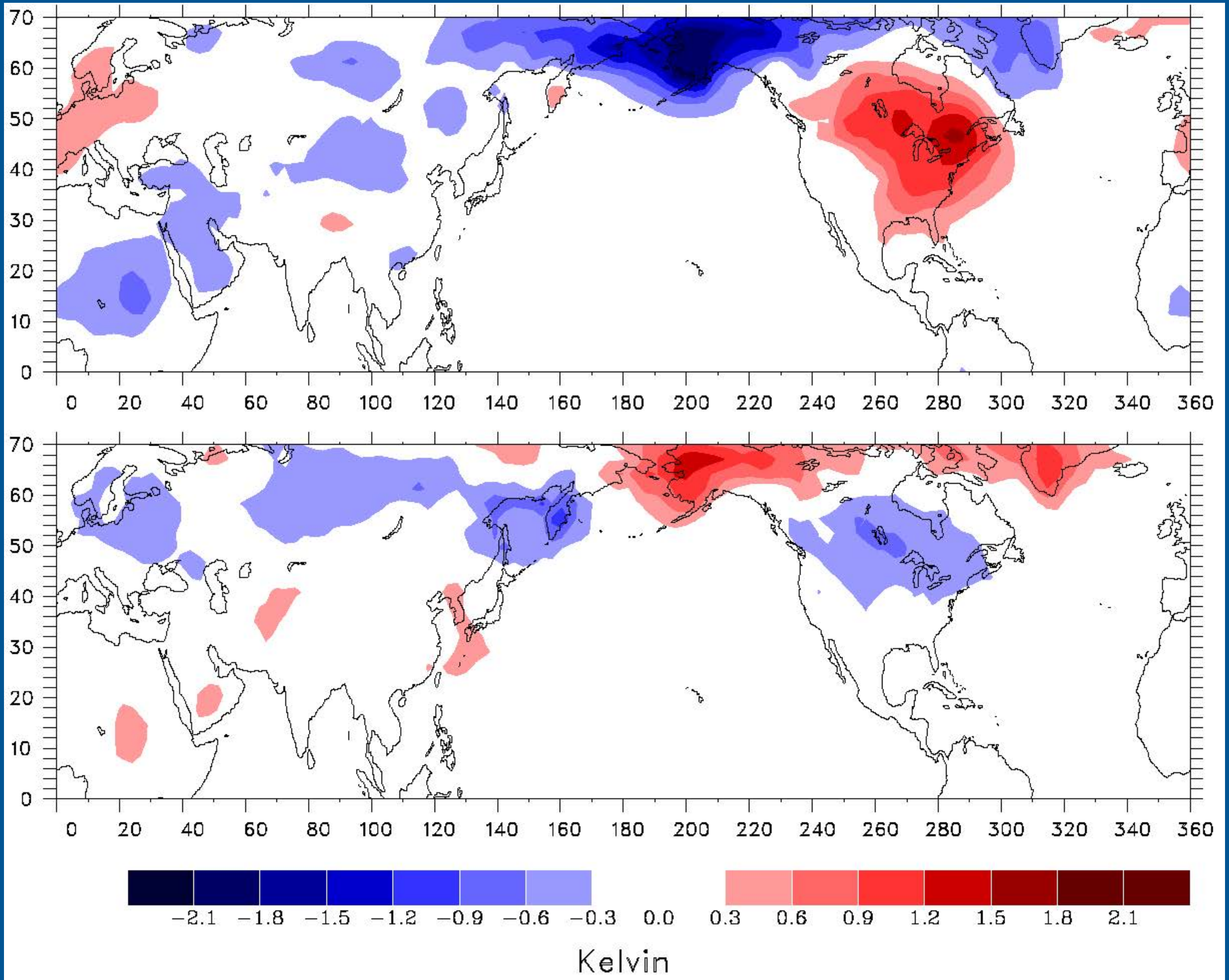


ERA Interim Reanalysis Data

Effect on Air Temp. of a Strong MJO Event (Amp. ~ 2 s.d.)

MJO Phases 3 to 6:

MJO Phases 1,2,7,8:



ERA Interim Reanalysis Data

Conclusions

- On the 27-day time scale, there is significant statistical evidence for a top-down (stratospheric) influence of solar UV spectral irradiance variations on both tropical tropospheric temperature and the occurrence rate of Madden-Julian oscillation events in boreal winter (DJF).
- On the 11-year time scale, there is evidence for a secondary influence of the 11-year solar cycle (in addition to an influence of the stratospheric QBO) on the occurrence rate of relatively strong MJO events.
- Especially large mean MJO amplitudes in boreal winter (DJF) occur under combined QBO easterly and solar minimum conditions. Especially low amplitudes occur under QBO westerly and solar maximum conditions.