# Tropical drivers of the Antarctic atmosphere

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NSF awards ARC-1203843 and AGS-1240143
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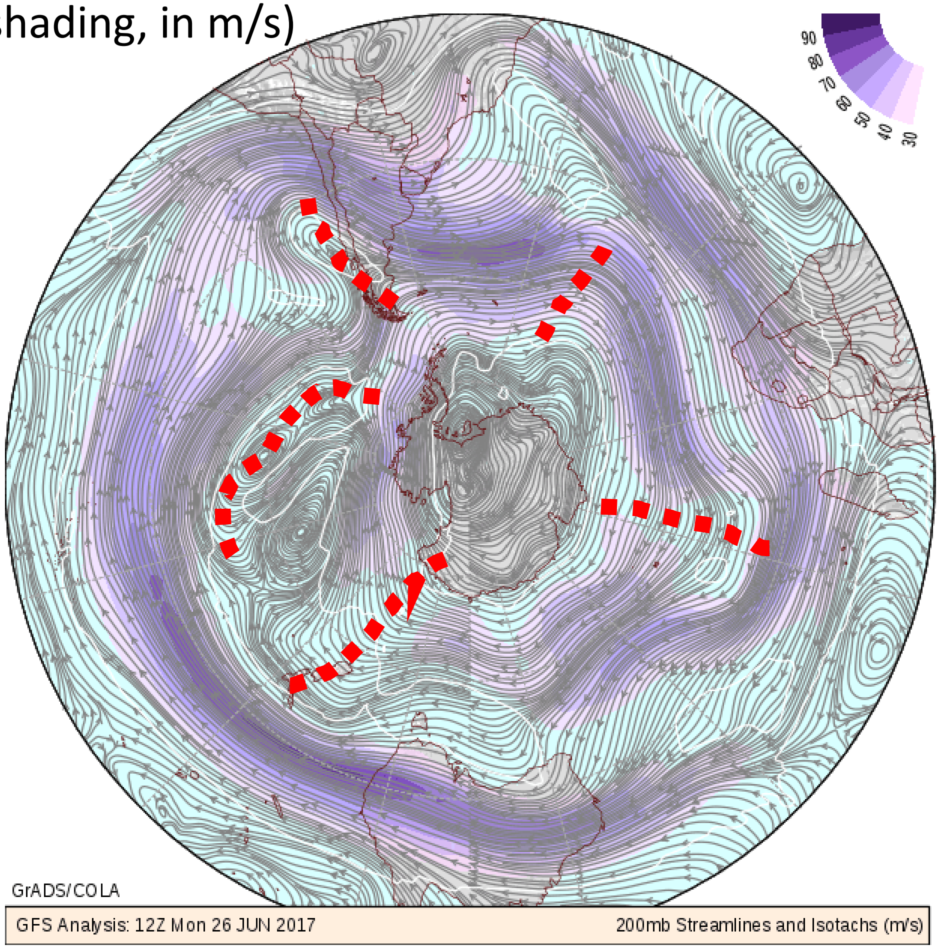
NASA award NNX16AH61G

# What is the current large-scale weather of the southern hemisphere?

1200 UTC Monday 26 June 2017:
200 mb streamlines (arrows) and wind speeds (shading, in m/s)




Four (or five) **trough axes** at 200 mb

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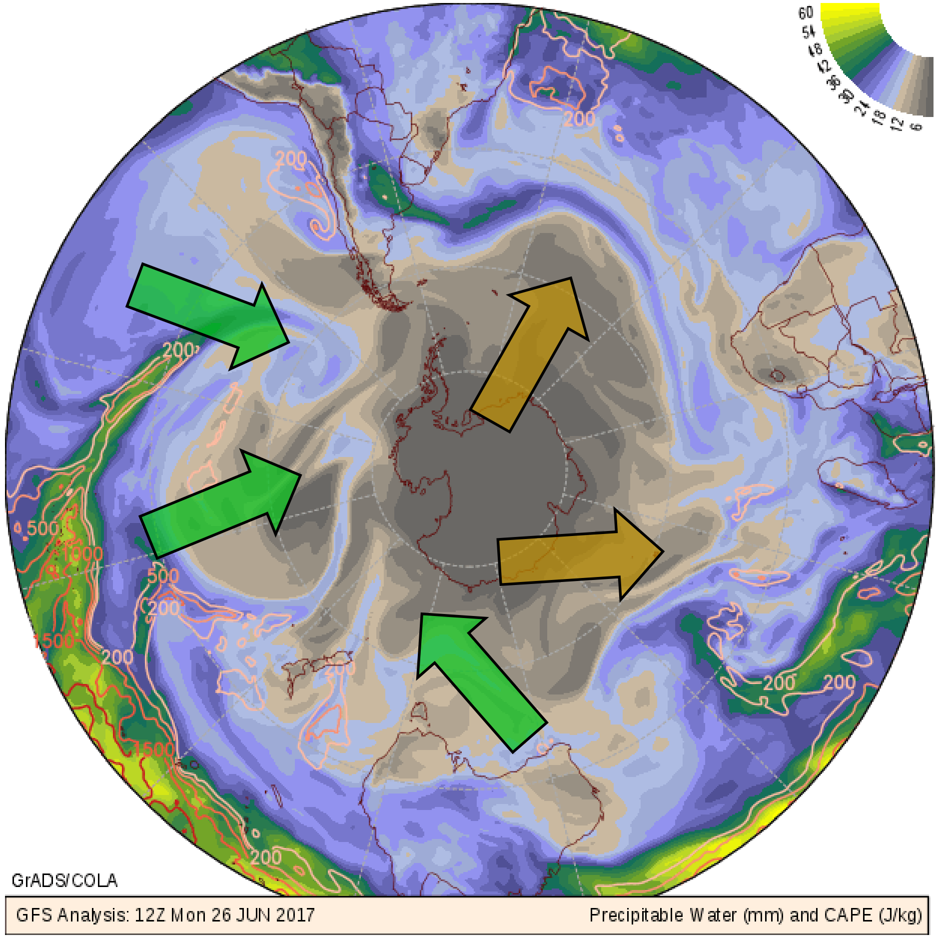


Some intrusions of **moist air** toward Antarctica, and of **dry air** away from it

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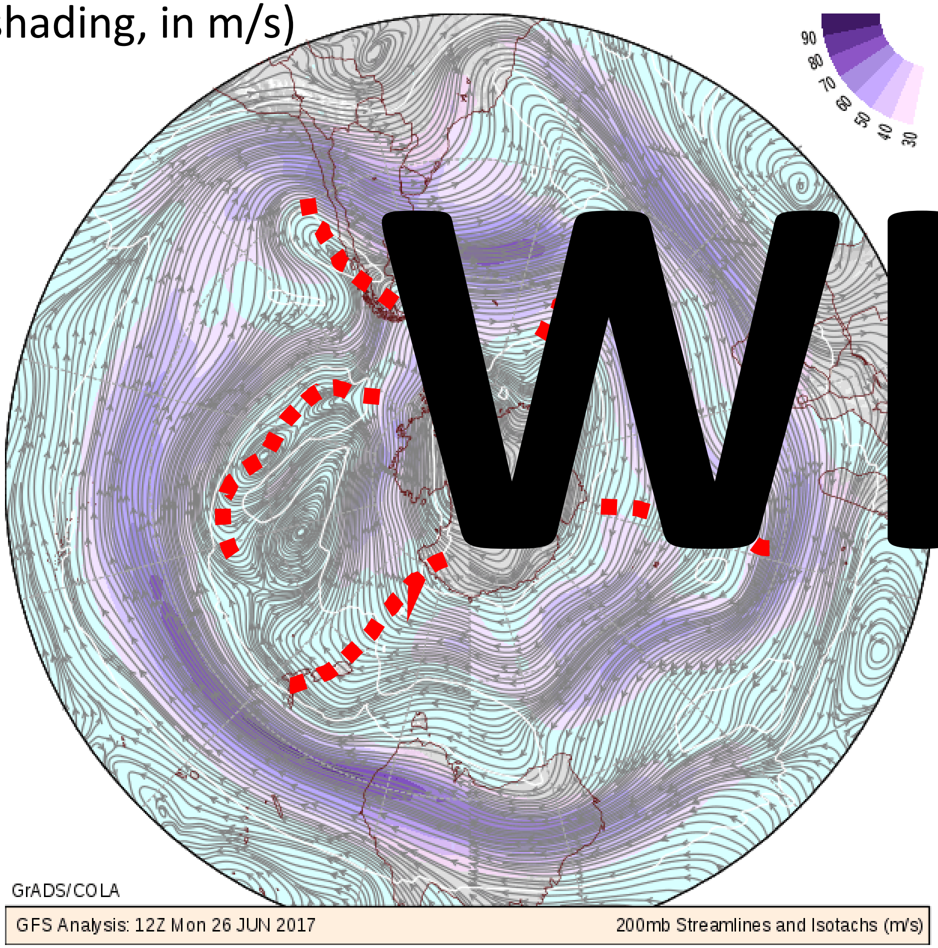


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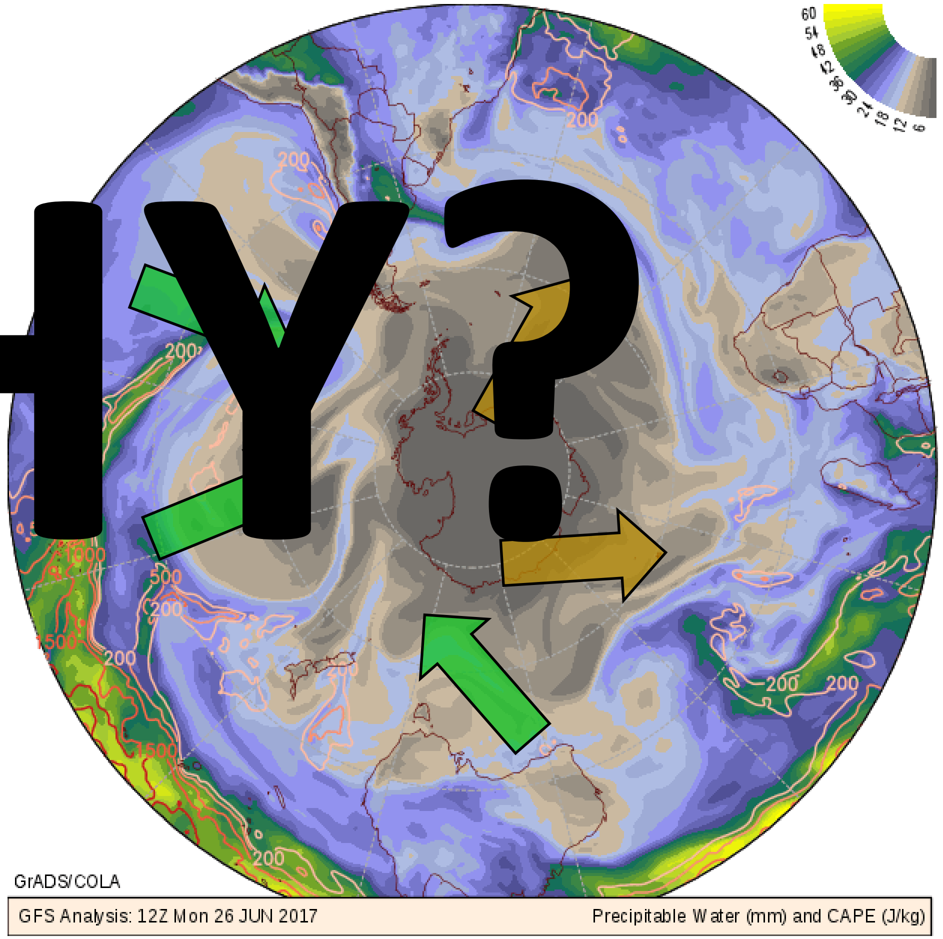


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# WHY?

# Goals and objectives of this presentation

- Introduction
  - Summarize briefly the principal mode of subseasonal atmospheric variability
  - Highlight some of the important aspects of teleconnections between the tropics and the Southern Hemisphere, including around Antarctica
- Research questions:
  - At what time lags does the Antarctic atmosphere exhibit the greatest "response" to tropical convection?
    - Does the time lag vary by season (winter vs summer)?
    - Does the time lag vary by height in the atmosphere (700 mb, 500 mb, or 300 mb)?
    - Does the time lag vary by geographical location of the tropical convection?
    - Does the time lag vary spatially around the southern hemisphere?
  - What are the physical pathways responsible for these lags?
    - Is there any evidence of blocking or standing waves?
    - Is there any evidence of eastward propagation of the extratropical response?

# The Madden-Julian Oscillation: a primary mode of subseasonal variability

- MJO is seen as anomalous eastward-moving convective cloud clusters 2000-10000 km in horizontal scale
  - Convective clusters are most vigorous in eastern hemisphere (Indian Ocean, Maritime Continent, western Pacific Ocean)
  - Accompanying pressure and circulation perturbations also move east, and circumnavigate the planet along the equator
- Key MJO characteristics:
  - Period of 40-50 days
  - Progresses eastward
  - Stronger in summer (DJF) and autumn (MAM)

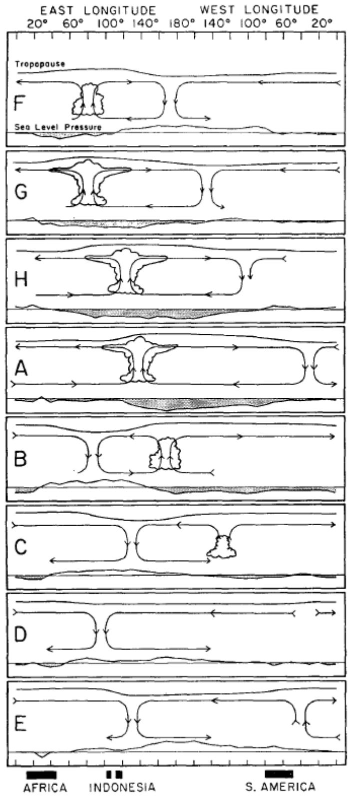

Image from *Madden and Julian* [1972].

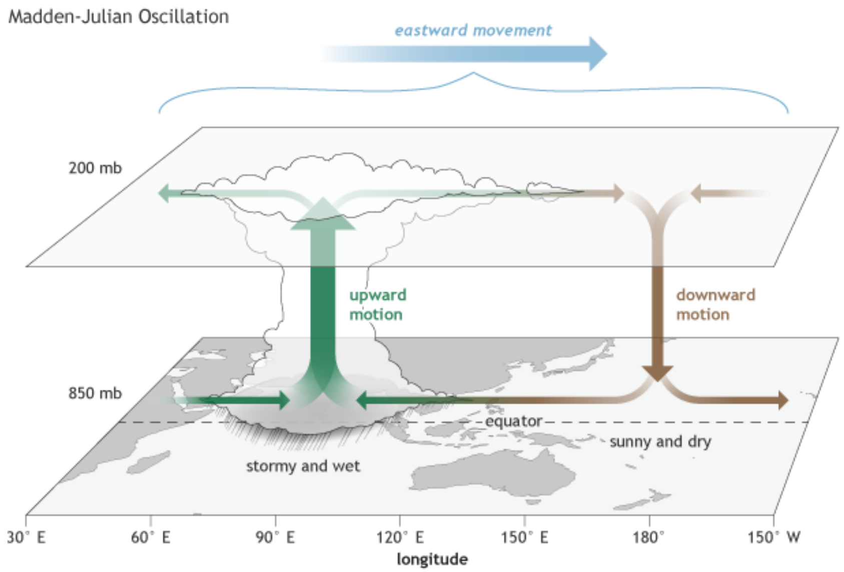

Image from *F. Martin, climate.gov*

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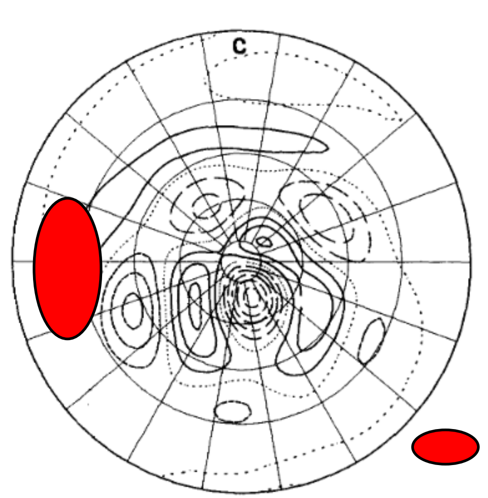


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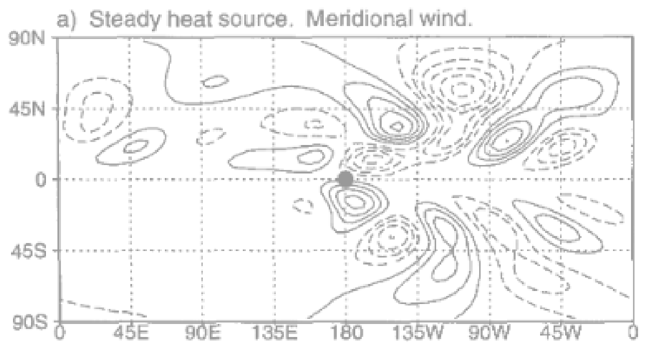


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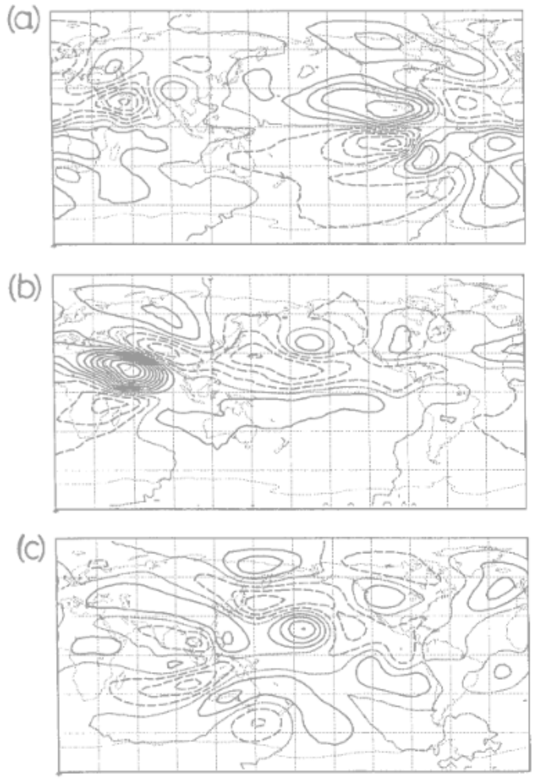


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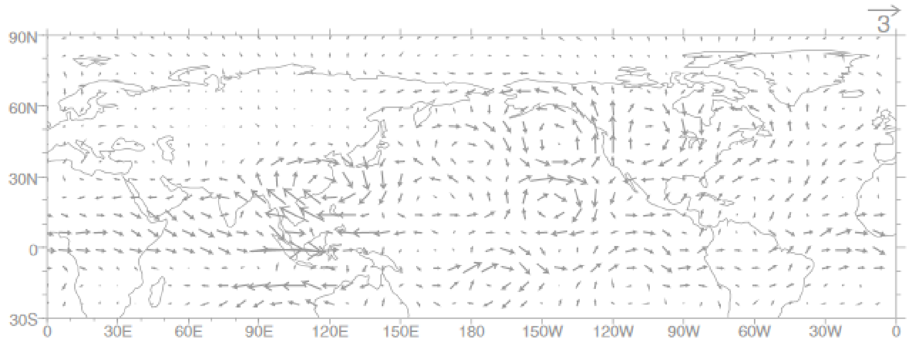


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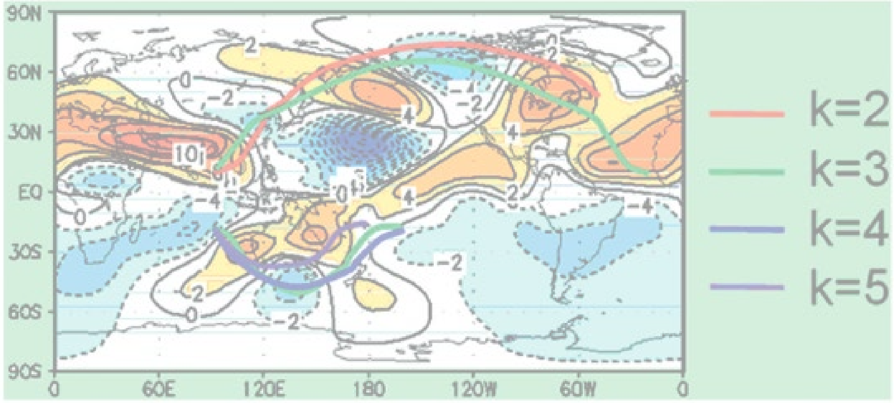


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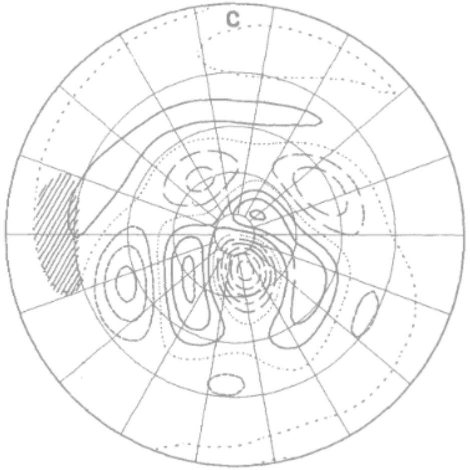


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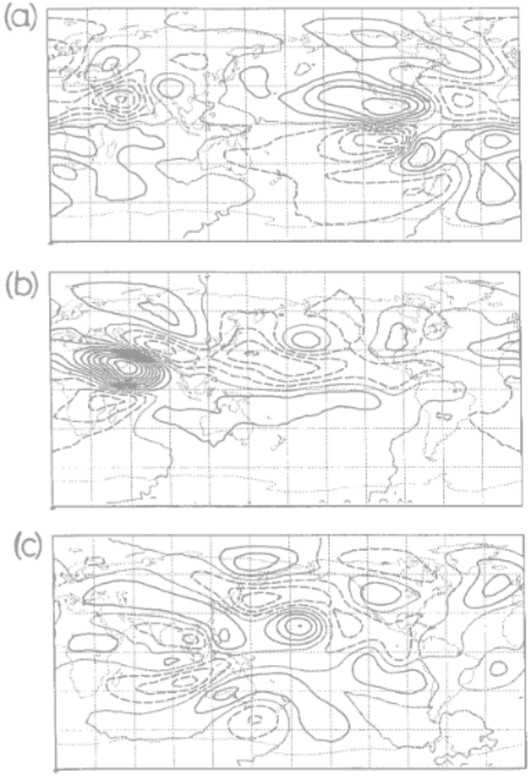


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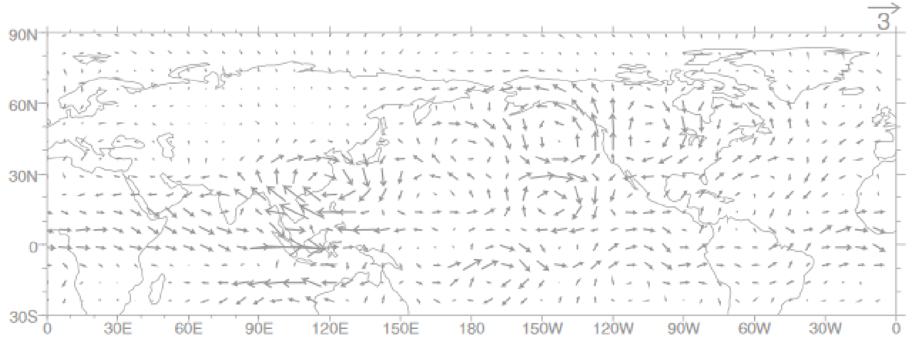


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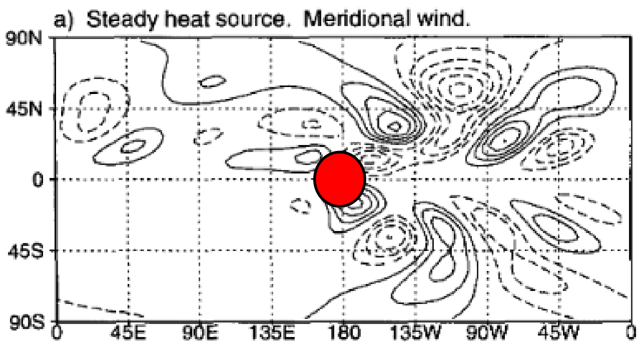
**upper-tropospheric heat source**

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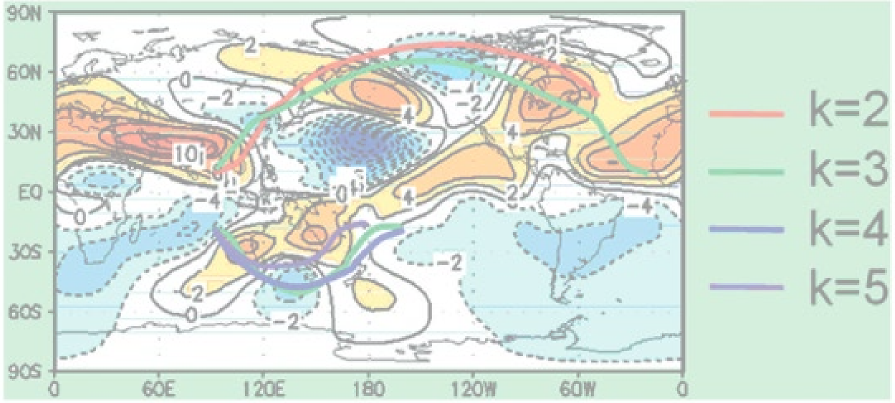


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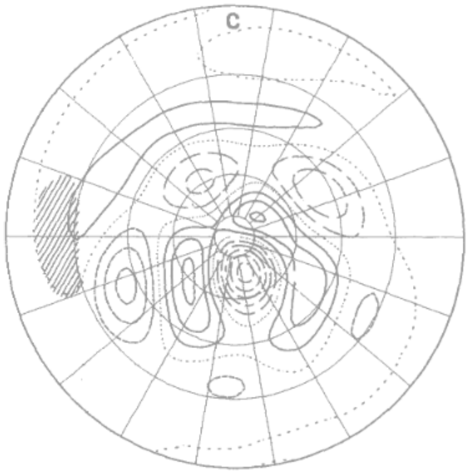


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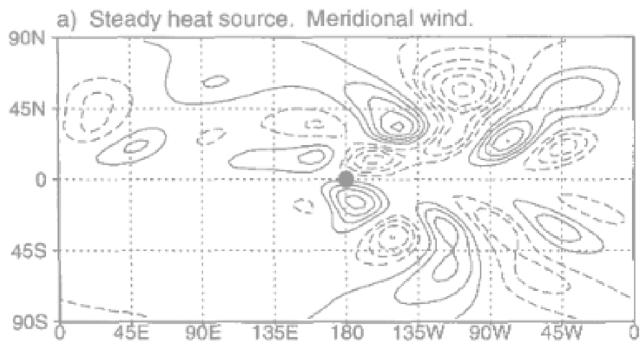


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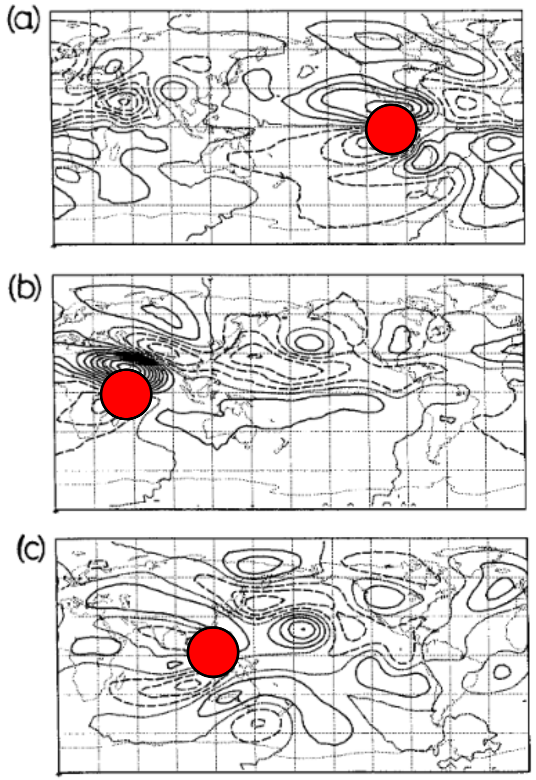


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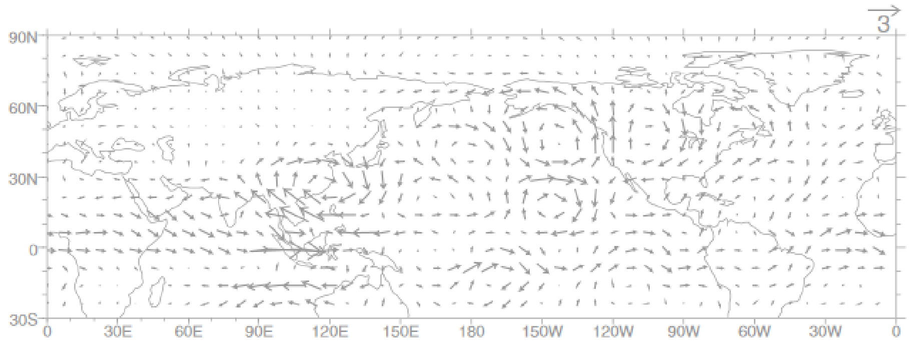


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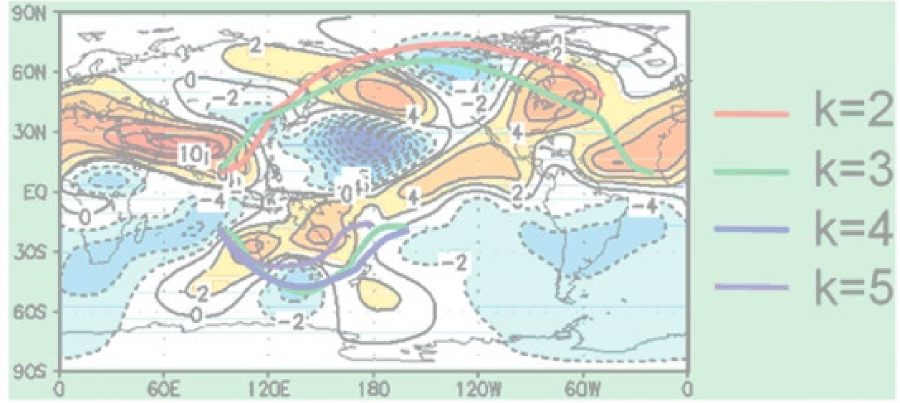


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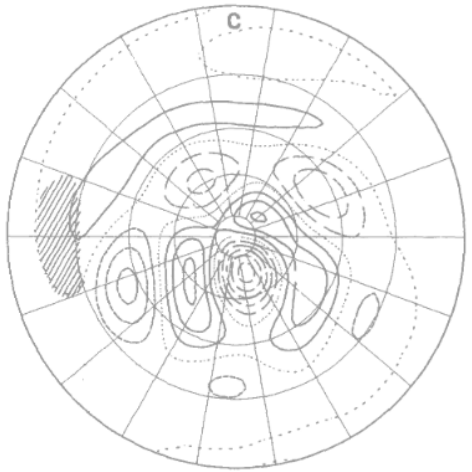


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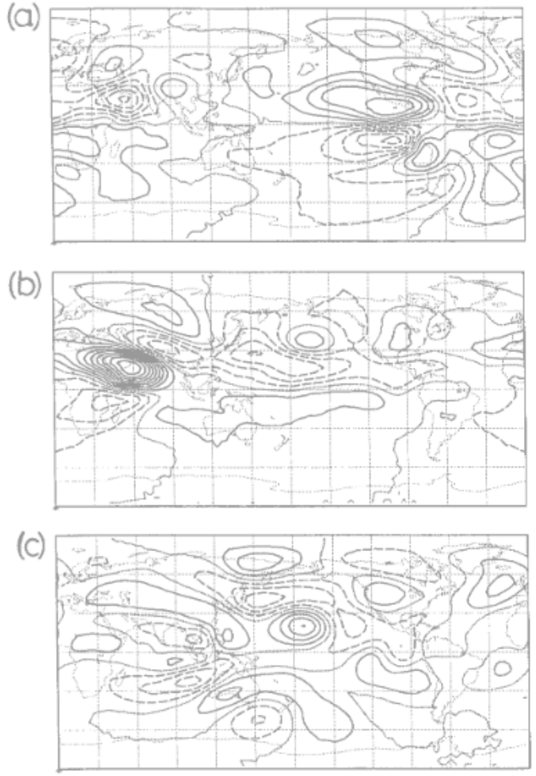


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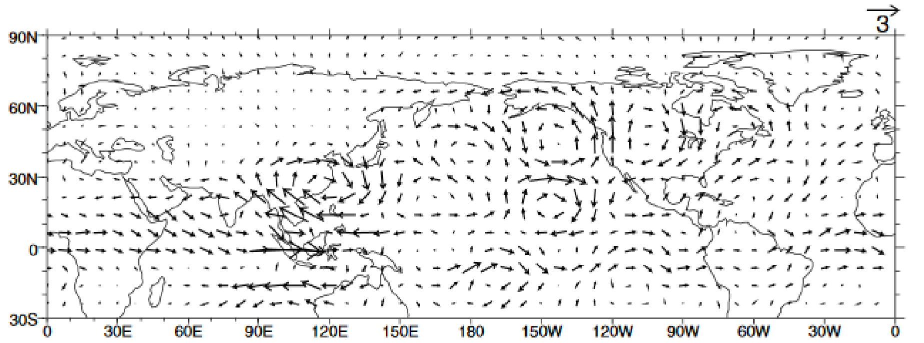


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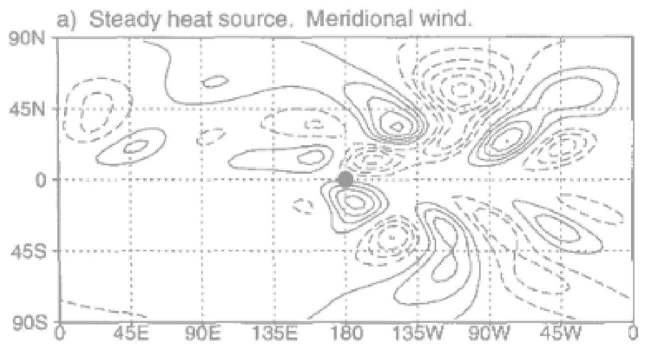


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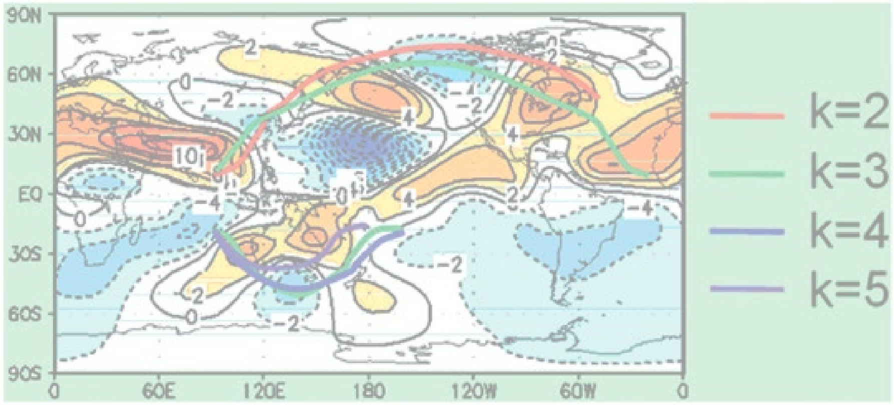


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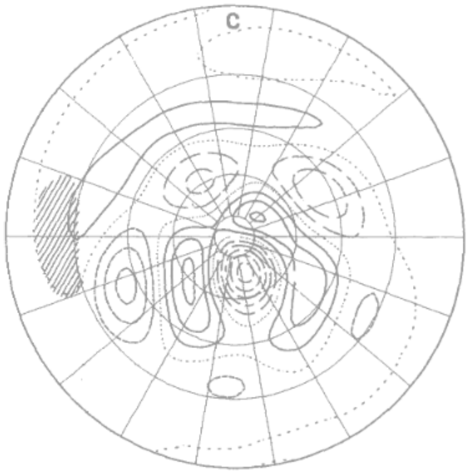


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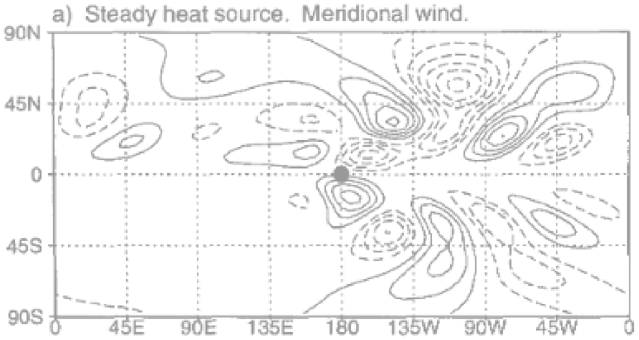


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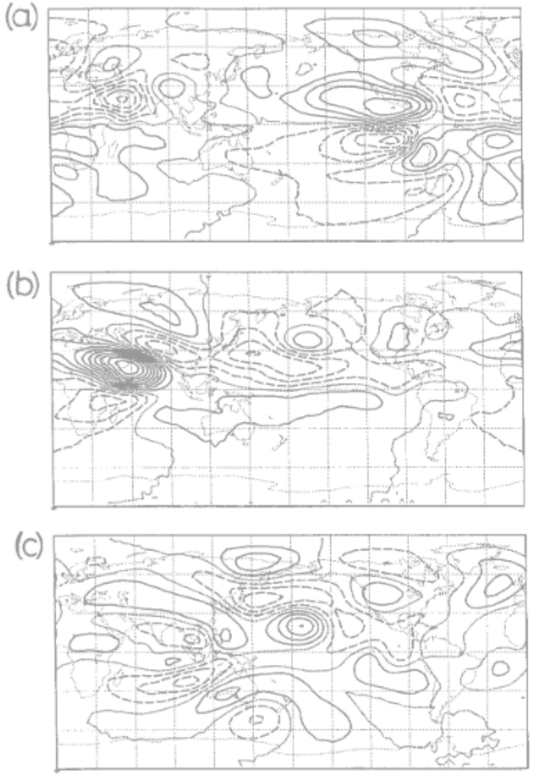


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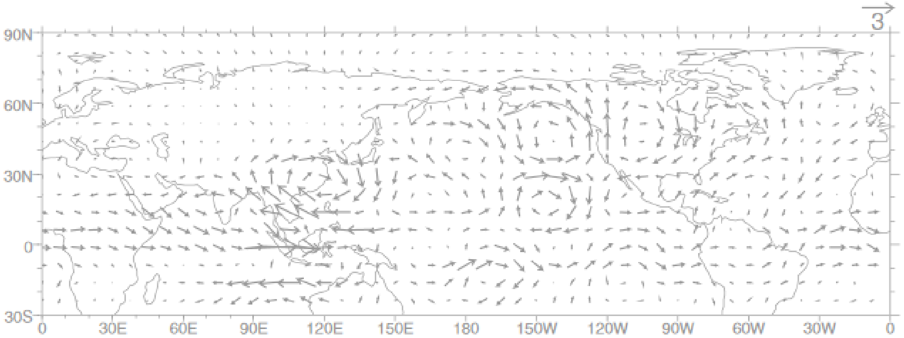


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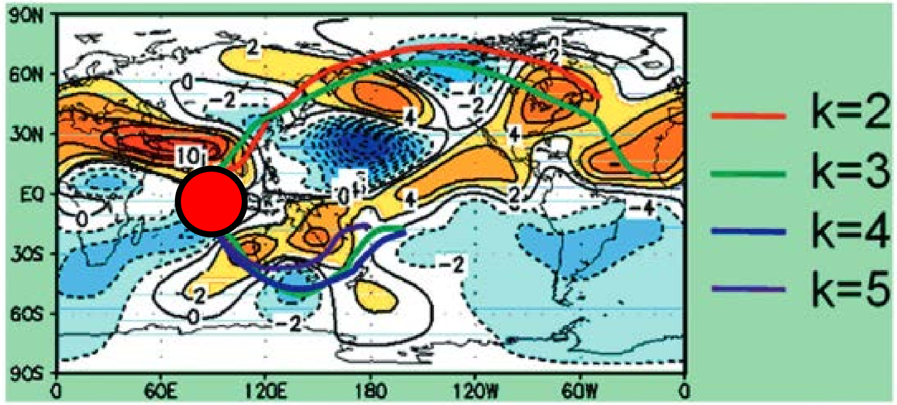


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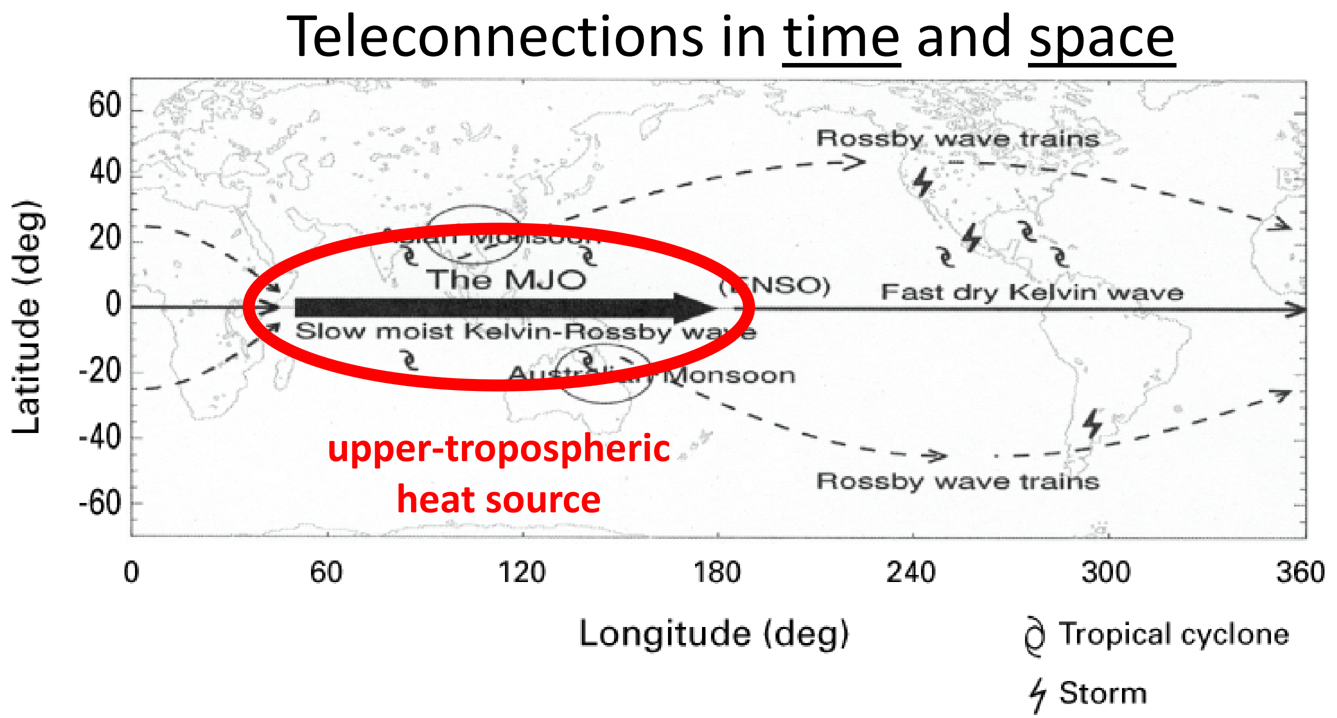
# A framework for the extratropical response to tropical MJO heating

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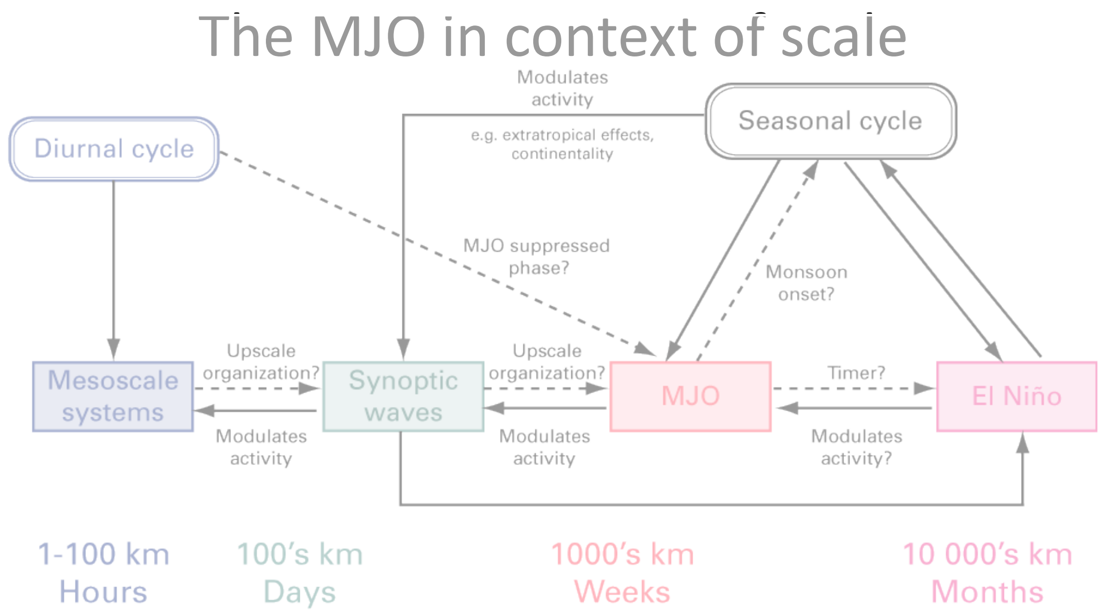


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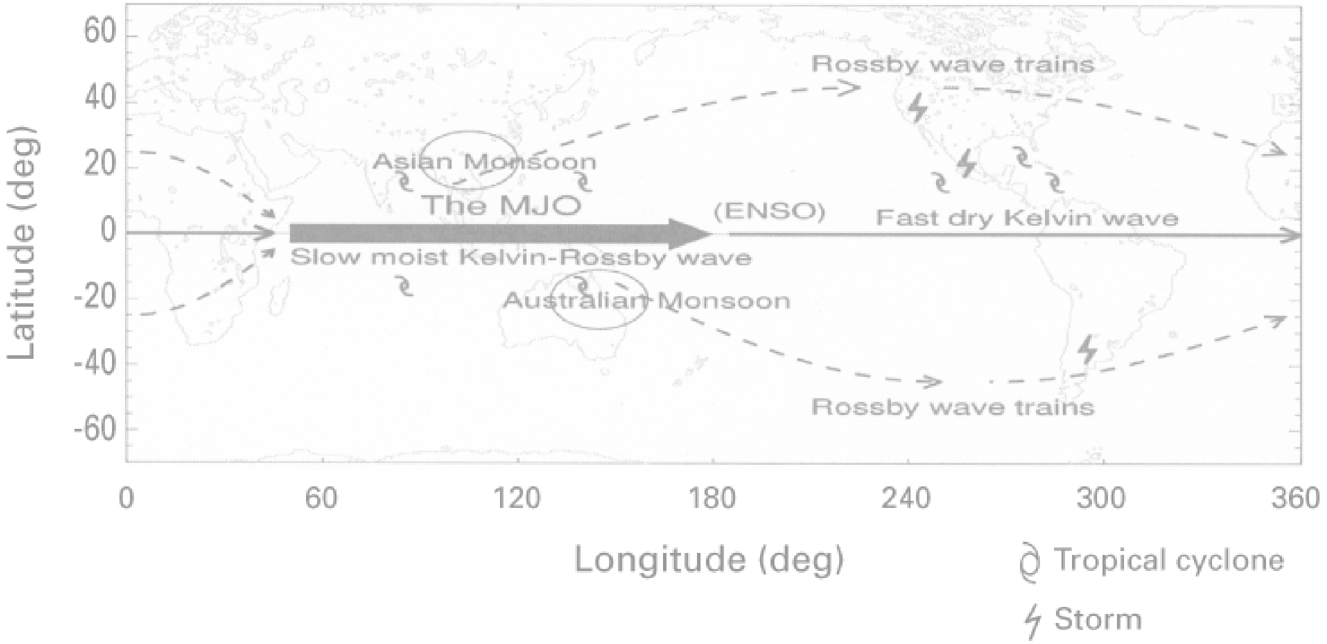
# A framework for the extratropical response to tropical MJO heating

Teleconnections in time and space

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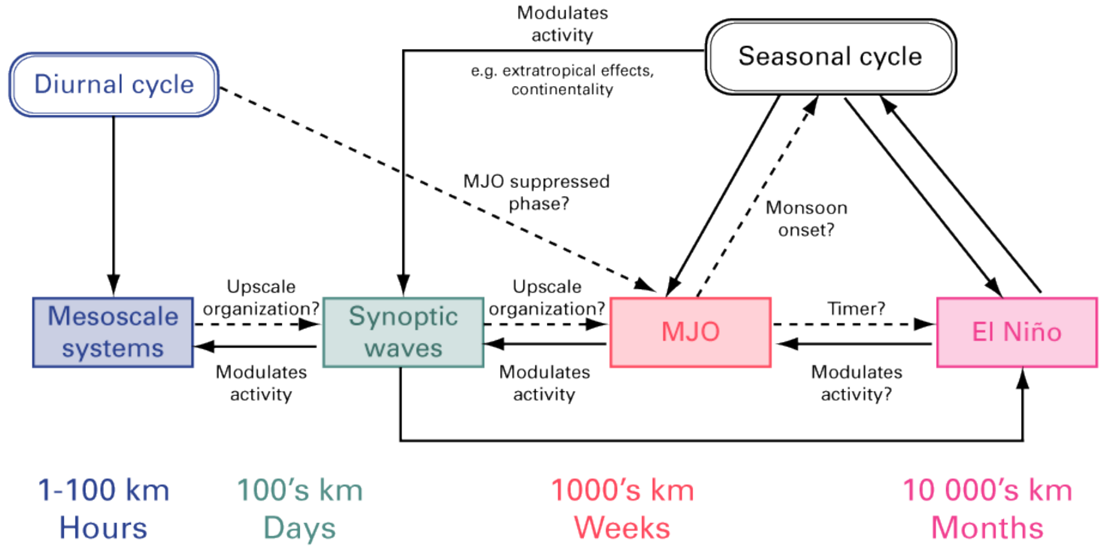
The MJO in context of scale

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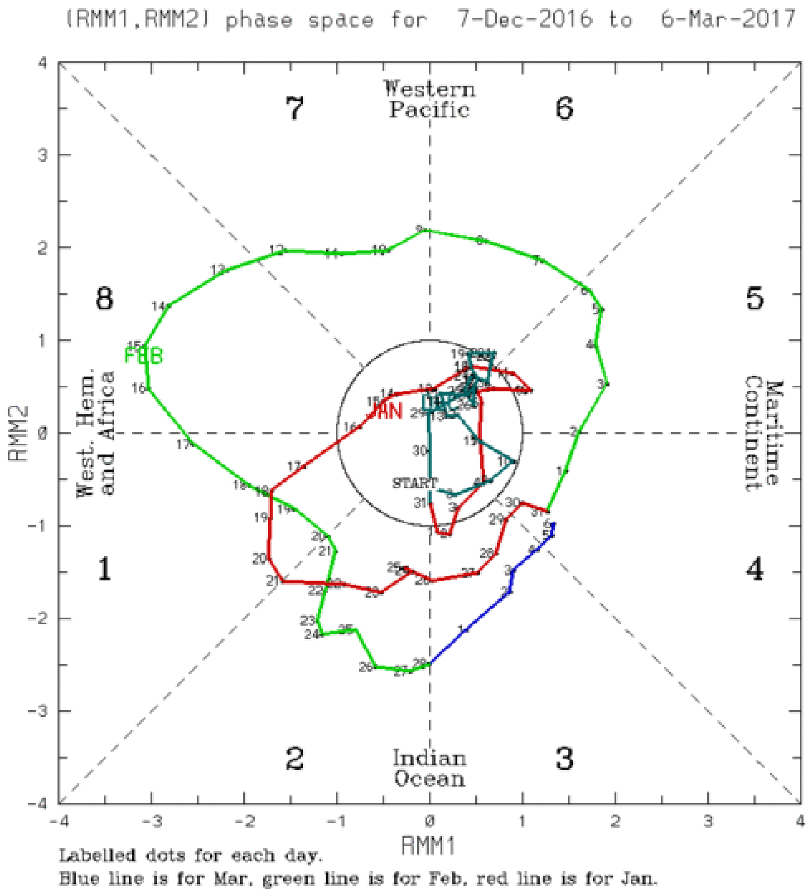
MJO & precip: Barrett et al. 2012 (*J Climate*)
MJO & air quality: Barrett et al. 2012 (*Atmos Environ*), Ragsdale et al. 2013 (*Atmos Environ*)
MJO & weather regimes: Fauchereau et al. 2016 (*J Climate*)

# An index that represents the location and intensity of the MJO

- One method to locate the MJO and determine its intensity was developed by Wheeler and Hendon (2004)
  - They used principal component analysis of three variables: outgoing longwave radiation, zonal wind at 850 mb, and zonal wind at 200 mb, all between 15°S and 15°N
- Their index is called the Real-time Multivariate MJO (RMM) index
- The two leading principal components (RMM1 y RMM2) form a phase space for the MJO
  - It is posible to assign a phase and an intensity using this phase space
  - Wheeler and Hendon developed 8 phases for the MJO




Fuente: http://www.bom.gov.au/climate/mjo/

# Data and methods

<u>Methods</u>

- Create composites of atmospheric variables by MJO phase
  - Focus here on geopotential height
  - Analyze 3 vertical levels: 700 mb, 500 mb, and 300 mb
  - Only consider MJO events with RMM amplitude > 1.0 (e.g., only consider "active" MJOs)
- Lag the composites from 0-30 days after each active MJO phase
  - Flatau and Kim (2012 *J. Climate*) suggested up to a 15-day lag between MJO convection and greatest response in the Antarctic Oscillation (AAO) index
  - Cassou (2008 *Nature*) suggested a peak response in the Northern Hemisphere to MJO convection at 7 days

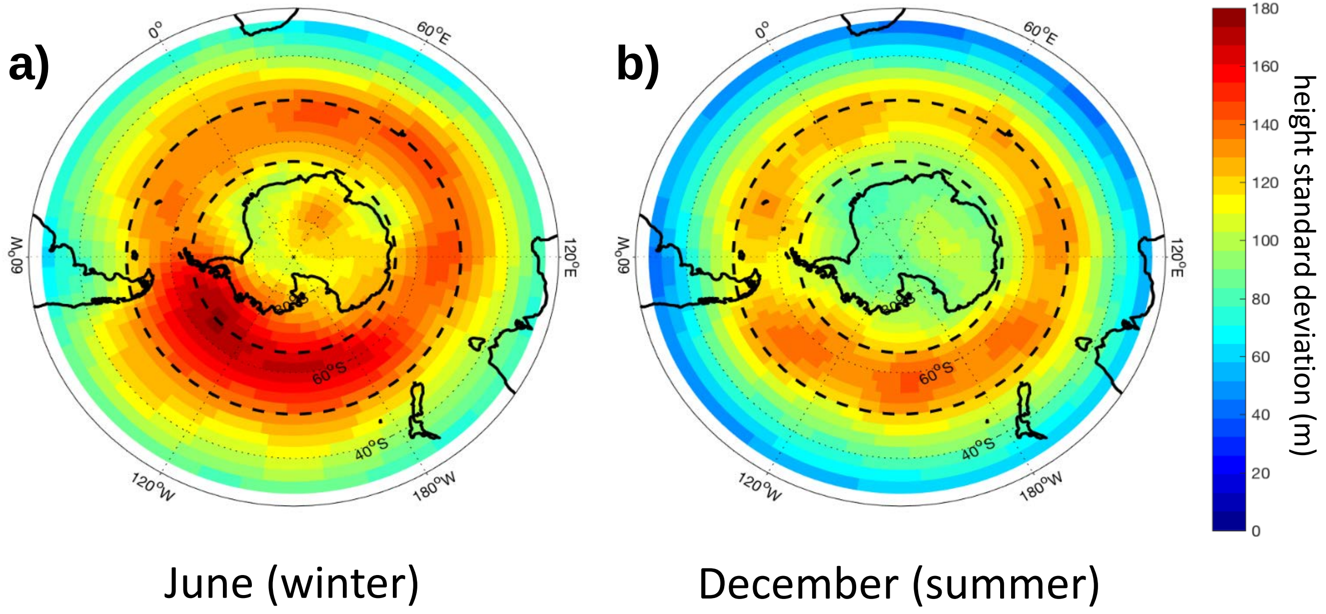
<u>Data</u>

- NCEP-DOE Reanalysis II
  - 1979-2014
  - Focus on June (winter) and December (summer)
  - Standardize anomalies (divide anomalies by standard deviation)
- Wheeler and Hendon (2004 *MWR*) MJO index

# Data and methods

- Examine height anomalies along annular *swaths* around Antarctica
    - Choose the swath latitudes to capture greatest variability in the Antarctic atmosphere
- Greatest variability in height field is not over Antarctica itself but between ~50°S-65°S
    - Dashed circles in Figure 1 show this latitude band
- Examined four other swaths, in addition to the 50°S-65°S one:
    - 55°S-70°S
    - 55°S-80°S
    - 45°S-65°S
    - 55°S-65°S

Figure 1: Standard deviation (color shading) in 500-mb height field, 1979-2014, for (a) June and (b) December. Dashed lines highlight swath from 50°S-65°S.

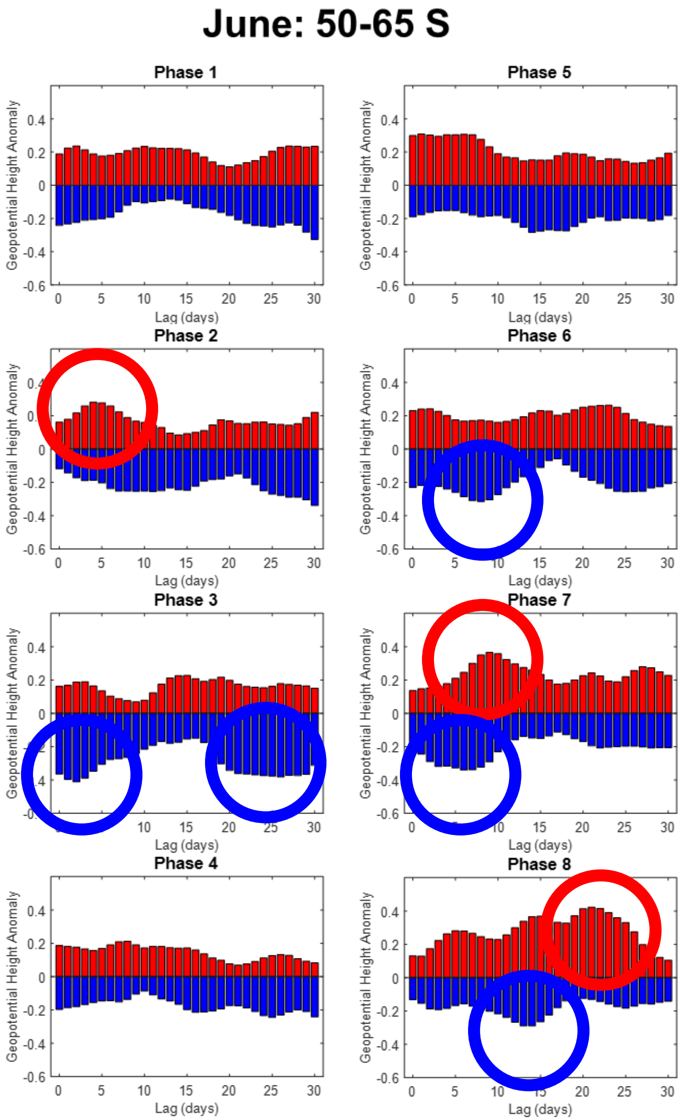


# Result #1

Figure 2: Standard anomalies at 500 mb, from 0-30 days after each MJO phase 1-8, for June (winter), for 50°S-65°S

**Red: positive 500 mb anomaly**

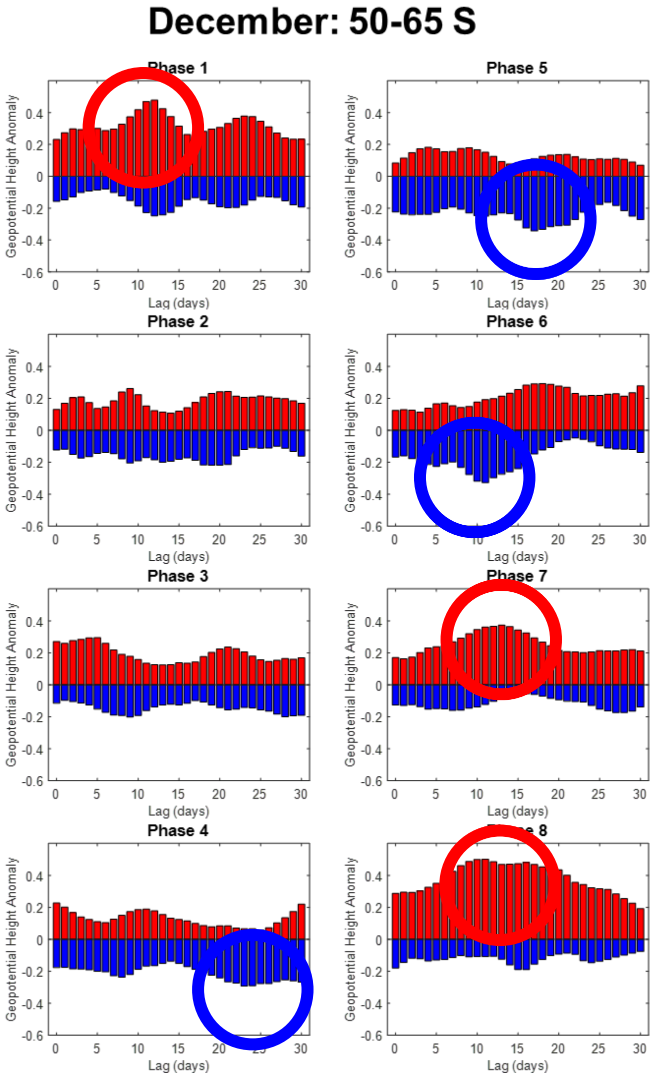
**Blue: negative 500 mb anomaly**




- Antarctic atmosphere exhibited variability from 0-30 days after tropical MJO convection (Fig. 2) in June
  - Some phases exhibited stronger "peaks" after MJO tropical convection
    - Phases 2 and 3 (Indian Ocean)
    - Phases 6, 7, and 8 (Western Pacific and Western Hemisphere)
  - Other phases (Phase 1, Phase 4) exhibited relatively smaller "peaks" after MJO convection
- The greatest response peaks varied by MJO phase
  - Some peaks were seen ~5 days after MJO convection (Indian Ocean), others ~10 days after (western Pacific Ocean), and others ~20-25 days after (western Hemisphere)
  - Some phases (Indian Ocean) showed dual peaks (~5 and ~20 days)

# Result #1, continued

Figure 3: Standard anomalies at 500 mb, from 0-30 days after each MJO phase 1-8, for December (summer) from 50°S-65°S
**Red: positive 500 mb anomaly**
**Blue: negative 500 mb anomaly**




- Antarctic atmosphere also exhibited variability from 0-30 days after tropical MJO convection (Fig. 3) in December
  - Peak magnitude, and timing of greatest peaks, were different from June
    - Eg, after Phase 1 in December, strongest positive height anomalies were seen ~12 days after convection, but in June, no discernable peak was seen
    - Similar to Phases 7 and 8: peaks in height anomalies were noted 10-15 days after MJO convection in December, but in June, greatest peak was < 10 days for Phase 7 and > 20 days for Phase 8
  - Similar patterns were seen in the negative anomaly “peaks”
    - Phases 2 and 3 saw very little negative height anomalies in December, but much more negative height anomalies in June

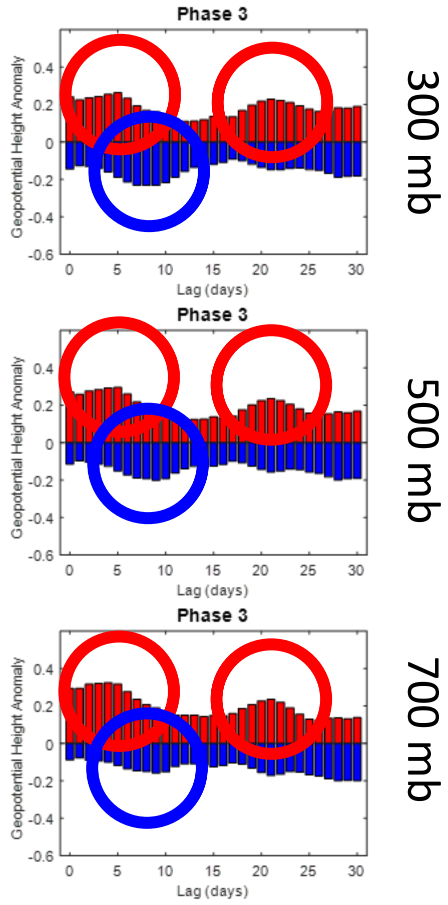
# Result #2

Figure 4: Standard anomalies at 500 mb, from 0-30 days after MJO phase 3 for December (summer), for 700 mb, 500 mb, and 300 mb, from 50°S-65°S

**Red: positive 500 mb anomaly**

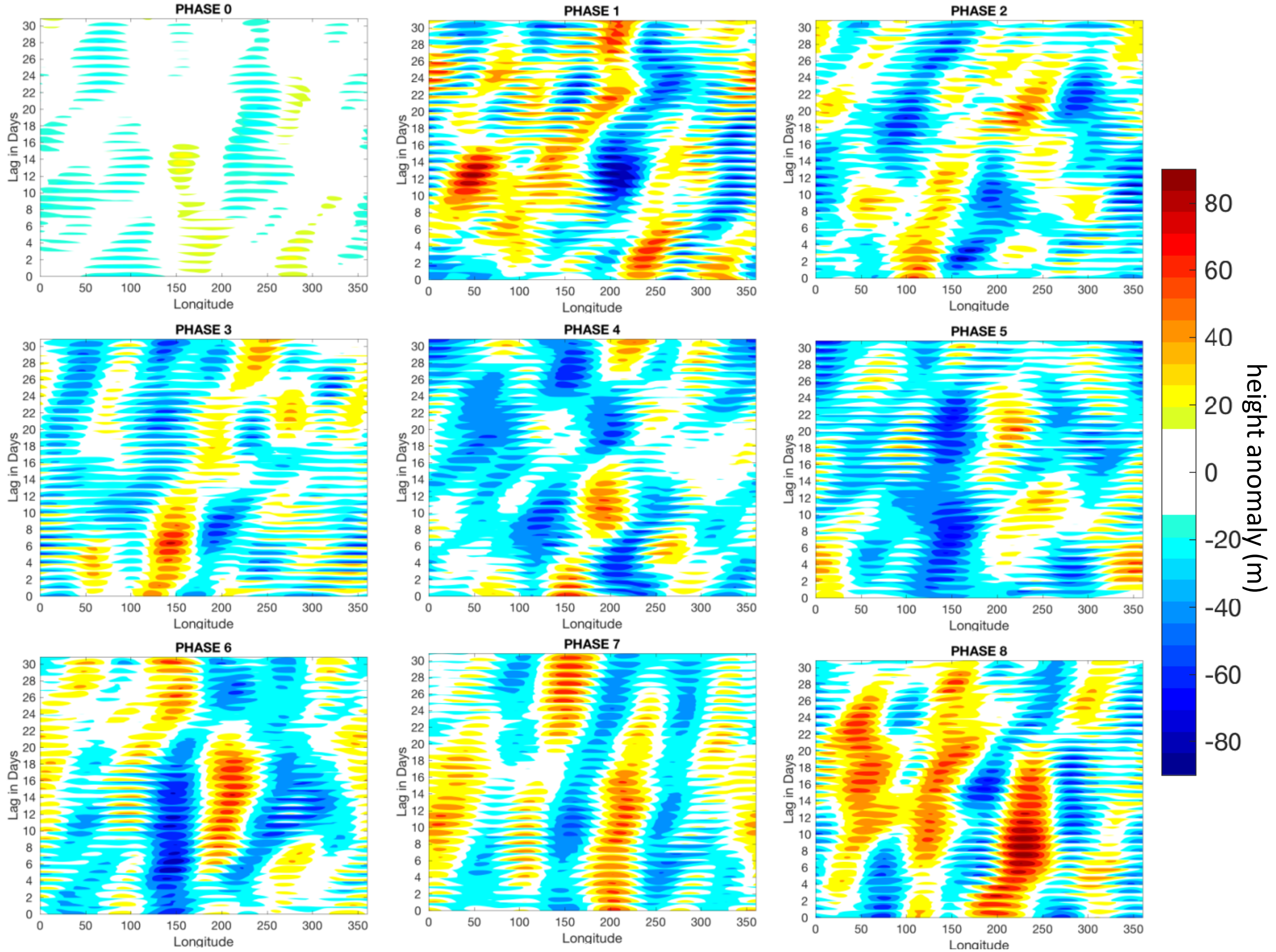
**Blue: negative 500 mb anomaly**

- Choice of vertical level (700 mb, 500 mb, 300 mb) did not seem to matter to the amplitude or lag of the height response peaks
- Fig. 4 shows the 700, 500, and 300-mb height response 0-30 days after MJO Phase 3 response (convection in the Indian Ocean)
  - All three vertical levels show peaks in response at ~5 days and ~20 days
  - All 8 phases behaved very similarly to phase 3



# Result #3

Figure 5: Height anomalies (in m) at 500 mb between 50°S-65°S from 0-30 days after December active MJO convection (phases 1-8; phase 0 represents inactive MJO).




- In December, 500-mb heights in the 50°S-65°S swath organized into responses with wavenumber 3 or 4 (Fig. 5)
  - 500 mb heights progressed eastward after MJO convection for some phases
    - Up to 30 days after Phases 1, 2, and 3 (Western Hemisphere and Indian Ocean), anomalies progressed steadily eastward
  - 500 mb heights exhibited a blocking (or a standing wave) pattern after MJO convection for other phases
    - Phases 6, 7 and 8 exhibited standing wave patterns from 150°E-110°W

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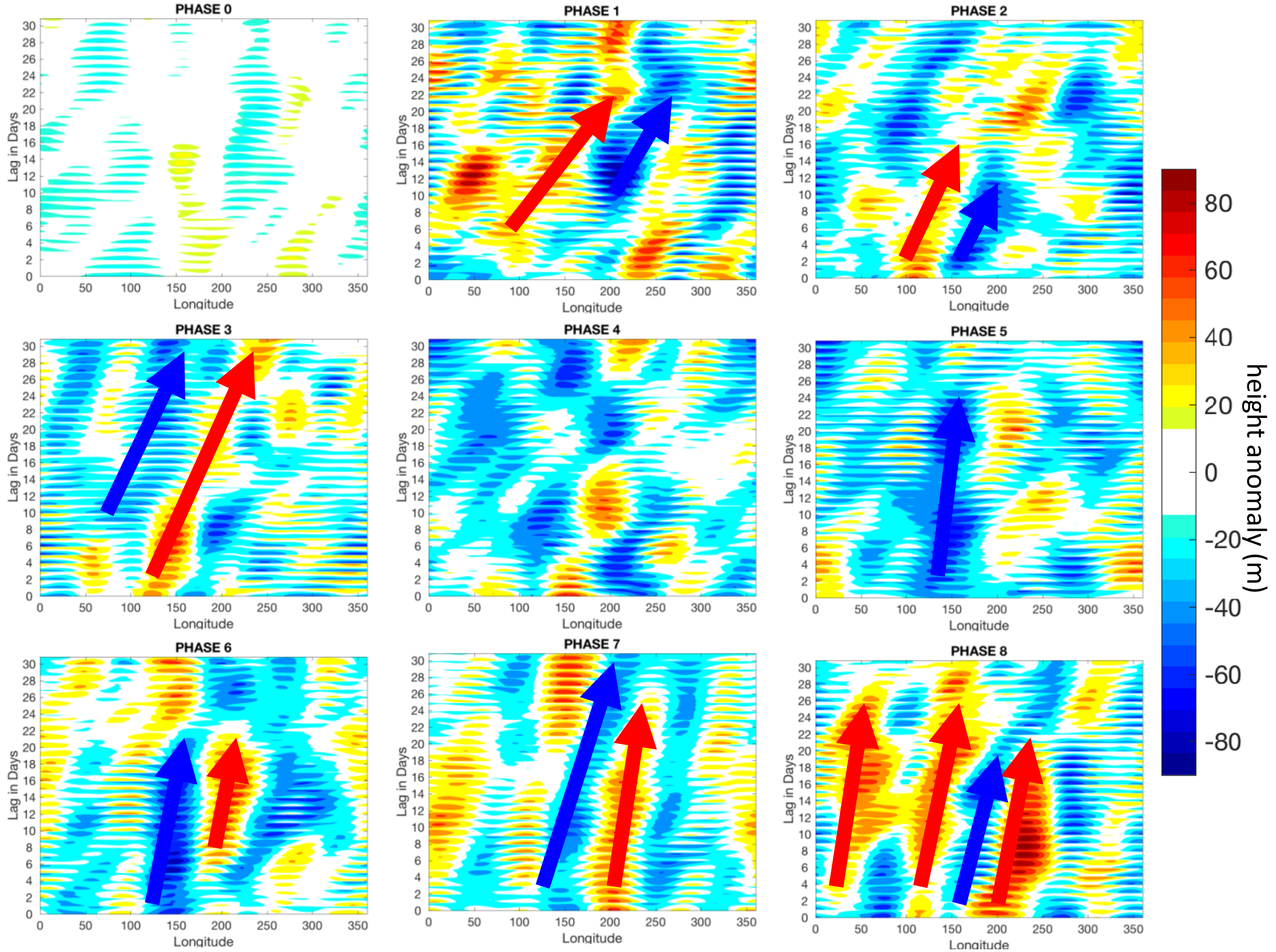

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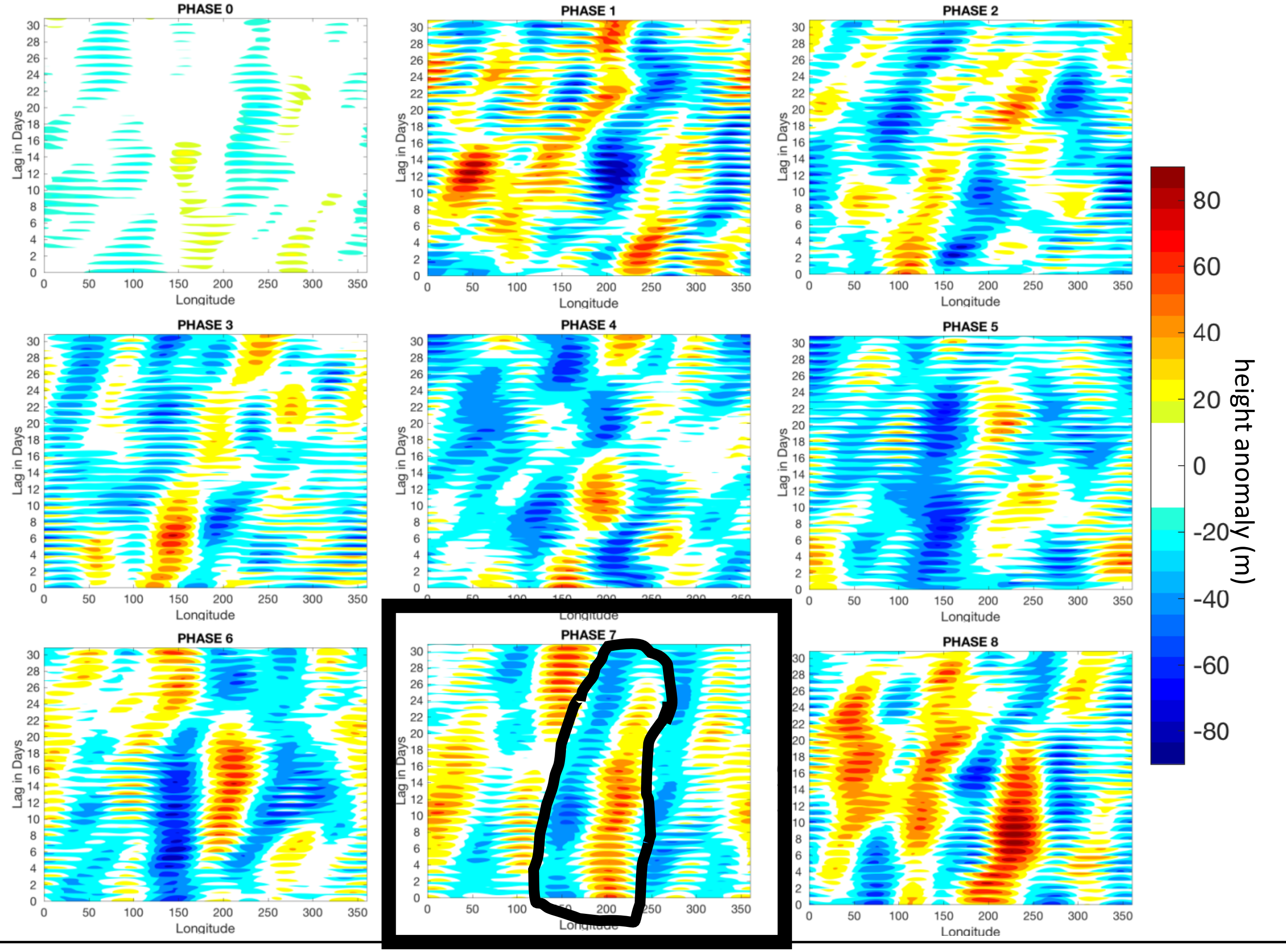
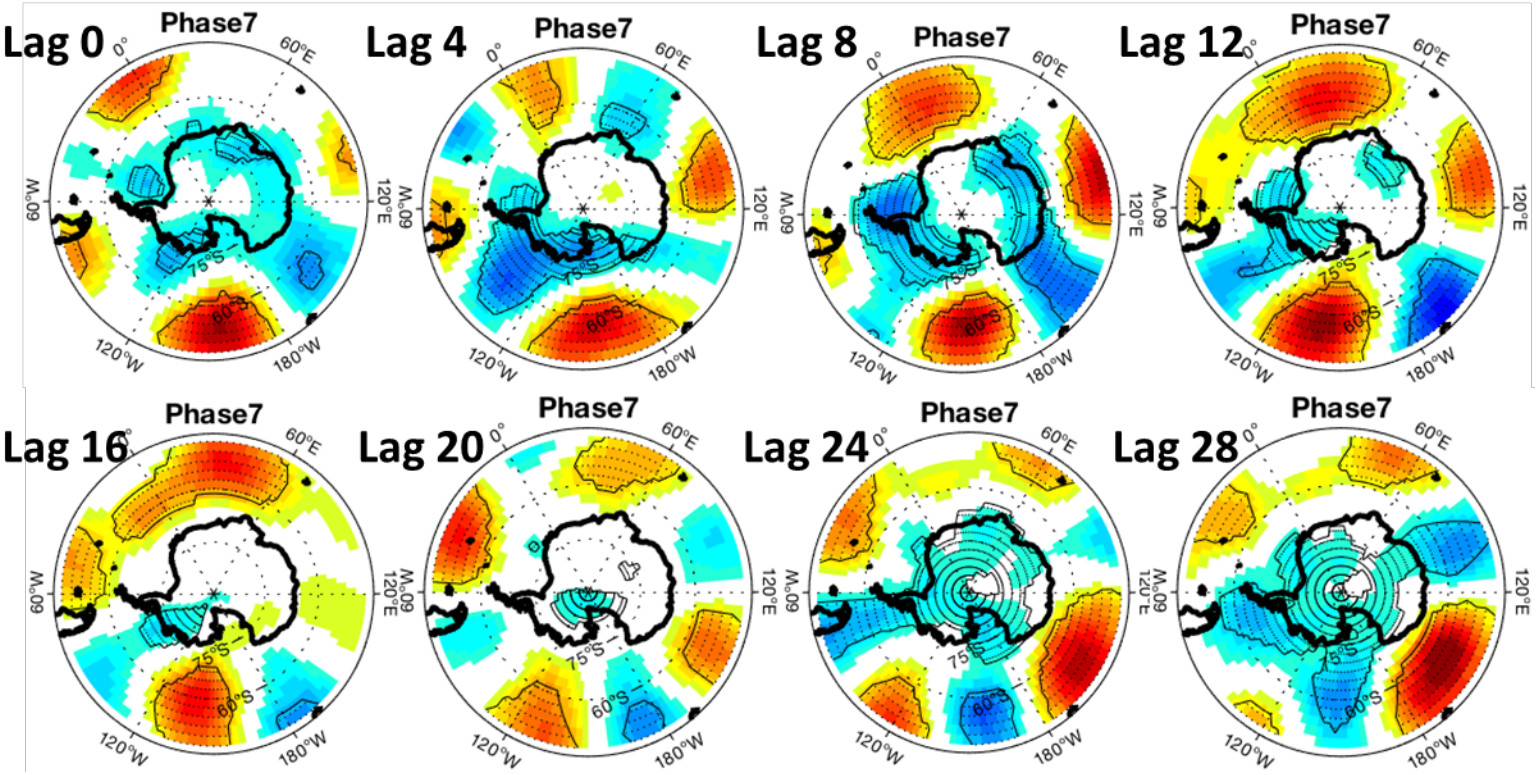


# Result #3, continued

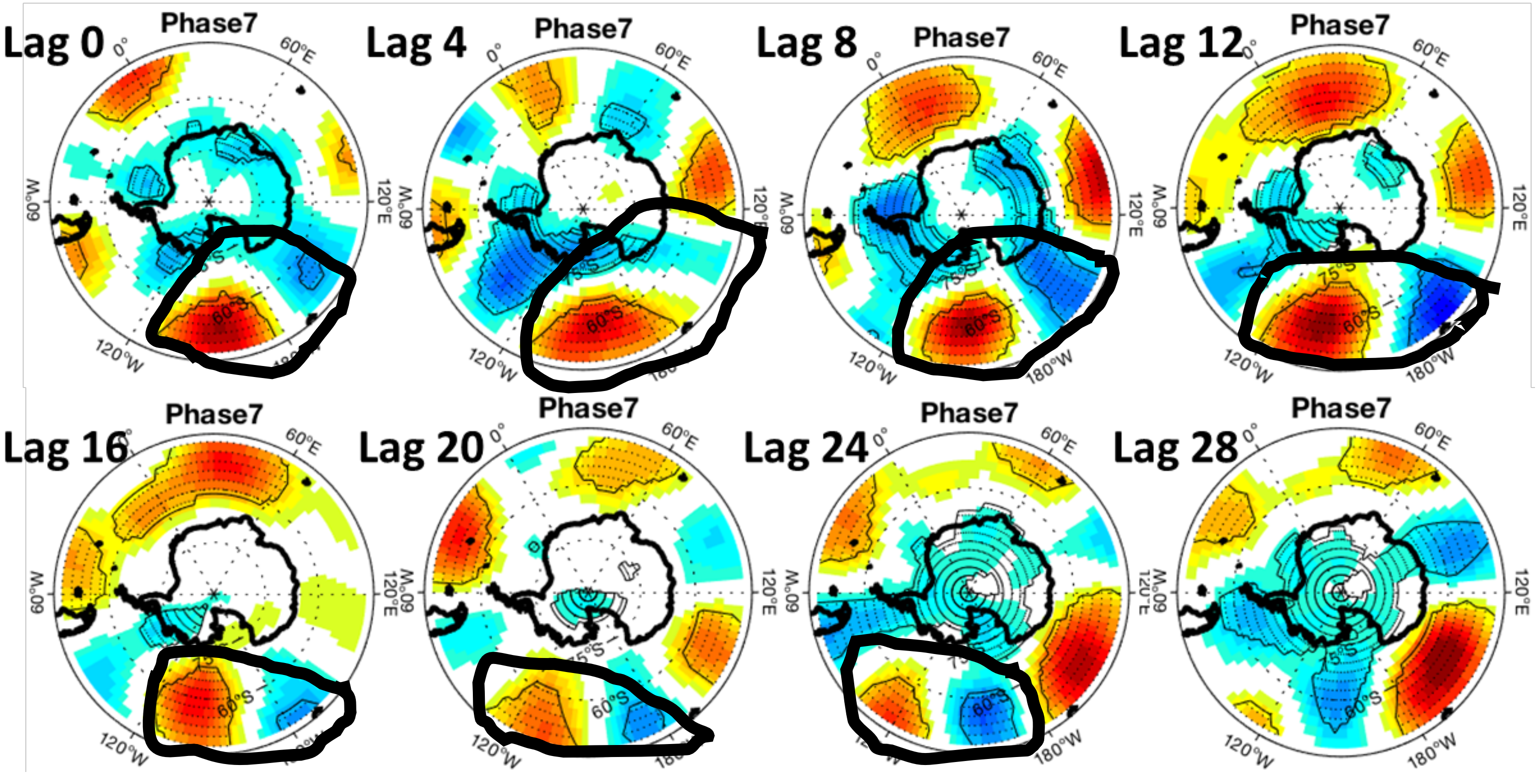
<u>Figure 6</u>: Height anomalies (in m) at 500 mb from 0-28 days after active MJO convection in the tropical western Pacific Ocean (phase 7).

- Physical context of the height lags for MJO phase 7 (Fig. 6), showing the blocking (standing wave) pattern:
  - Positive heights / red colors from 180°W-120°W up to 20 days after MJO convection in Western Pacific ocean
  - Positive anomalies slowly move to near 120°W by day 24, and weaken by day 28



# Result #3, continued

Figure 6: Height anomalies (in m) at 500 mb from 0-28 days after active MJO convection in the tropoical western Pacific Ocean (phase 7).




- Physical context of the height lags for MJO phase 7 (Fig. 6), showing the blocking (standing wave) pattern:
  - Positive heights / red colors from 180°W-120°W up to 20 days after MJO convection in Western Pacific ocean
  - Positive anomalies slowly move to near 120°W by day 24, and weaken by day 28

# Conclusions

- MJO convection affects the southern hemisphere atmosphere around Antarctica
  - Greatest response exhibits temporal lags between 3-25 days, depending on the month (June vs December) and MJO phase (1-8)
  - Different phases are associated with different modulations
- Despite different temporal lags, response was fairly even at different vertical levels (700, 500, and 300 mb) and different swaths around Antarctica
- Some MJO phases excite 500-mb height responses that resemble progressive waves
- Other MJO phases excite 500-mb height responses that resemble blocking / standing waves

# Thank you very much for your attention!

Collaborations welcome!

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