Multidecadal variations in the modulation of high-latitude temperatures by the Madden-Julian Oscillation

Eric C. J. Oliver [1,2]

1 Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
2 Australian Research Council Centre of Excellence for Climate System Science

translating**nature**into**knowledge**

The Madden-Julian Oscillation

- The **Madden-Julian Oscillation (MJO)** is dominant mode of intraseasonal (30-90 day) variability in the Tropics
- Expressed as
  - Deep convection, cloud cover
  - Rainfall
  - Low- and high-level winds
- Develops over Indian Ocean and propagates eastward, 5-10 m/s
- Influences generation of tropical cyclones, sea level variations, extratropical air temperature, etc...

Wheeler and Hendon, MWR, 2004

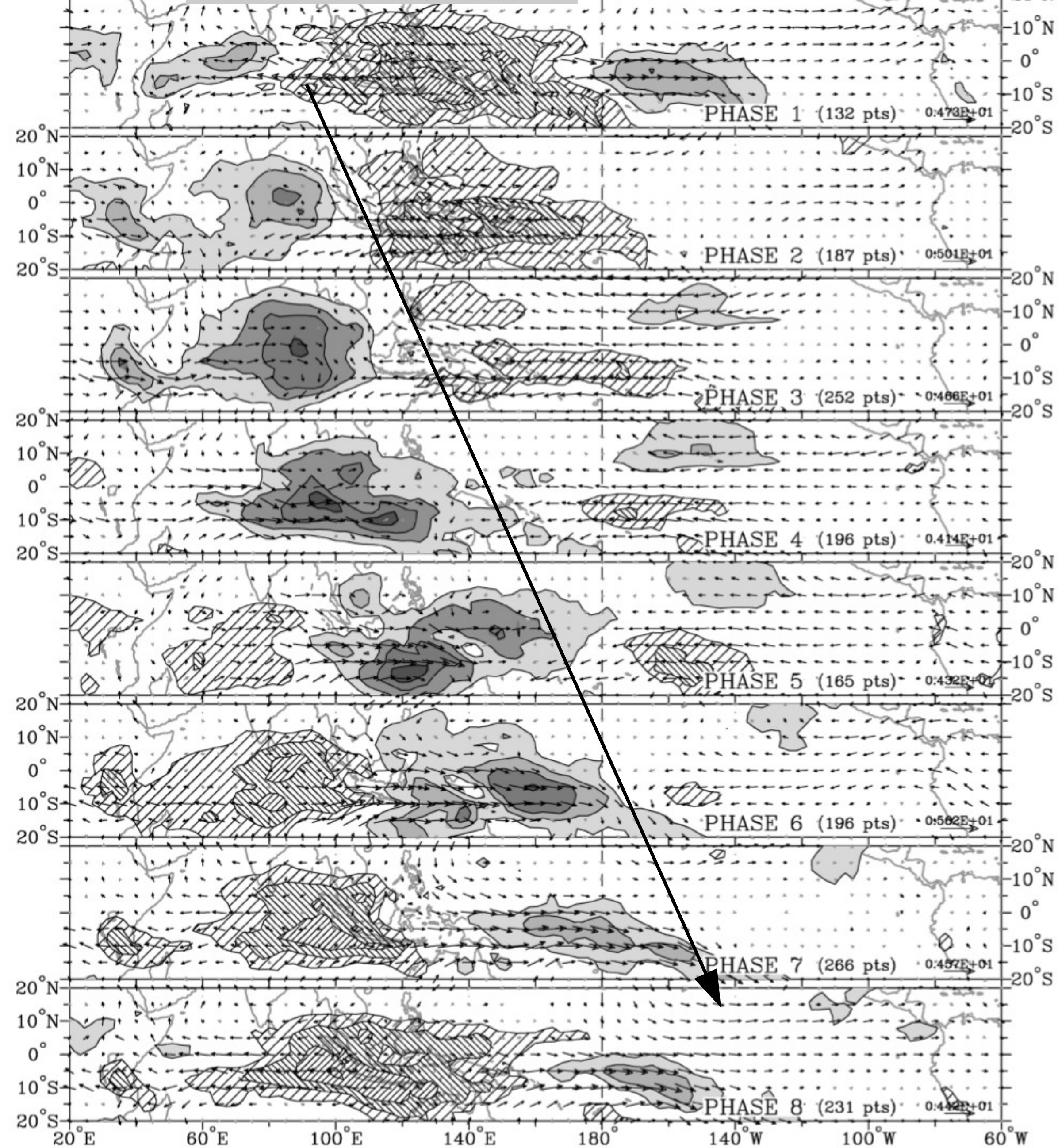


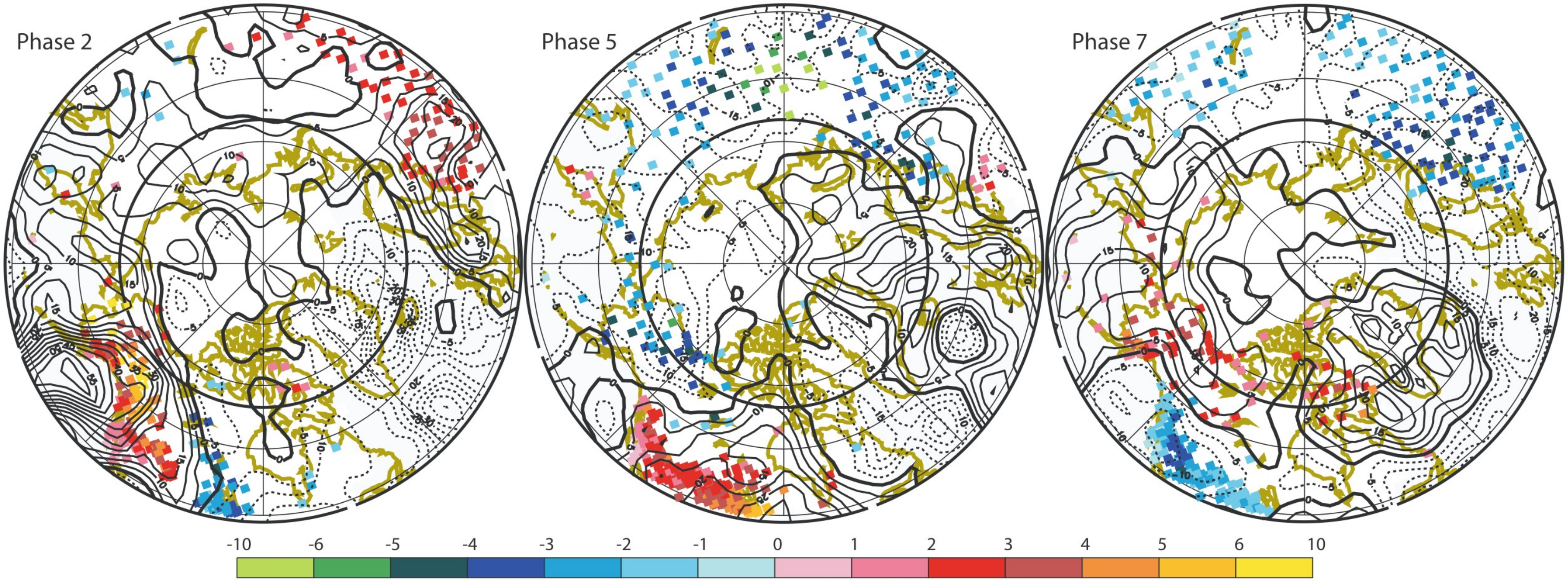
FIG. 8. DJF composite OLR[A] and 850-hPa wind vector anomalies. Shading levels denote OLR anomalies less than −7.5, −15, −22.5, and −30 W m^{-2}, respectively, and hatching levels denote OLR anomalies greater than 7.5, 15, and 22.5 W m^{-2}, respectively. Black arrows indicate wind anomalies that are statistically significant at the 99% level, based on their local standard deviation and the Student's *t* test. The magnitude of the largest vector is shown on the bottom right, and the number of days (points) falling within each phase category is given.

MJO/high-latitude links

- MJO links with mid- and high-latitude variability
  - **North Atlantic Oscillation** – Cassou (2008, Nature), Lin et al. (2008, J Clim)
  - **Rainfall over Pacific Northwest USA** – Bond and Vecchi (2003, WAF)
  - **Snow cover over North America** – Barrett et al. (2015, J Clim)
  - **Rainfall in Argentina** – Giovannettone et al. (2013, Aqua-LAC)
  - **Precipitation in Chile** – Barrett et al. (2012, J Clim), Julia et al. (2012 , J Clim)
- Specifically, **MJO links with high-latitude air temperature**
  - Vecchi and Bond (2004, GRL): wintertime, Northern Hemisphere
  - Lin and Brunet (2009, MWR): wintertime, Canada
  - Zhou et al. (2011, MWR): teleconnection mechanism
  - Nauman and Vargas (2010, WAF): summer, South America
  - Alvarez et al. (2015, Clim Dyn): all seasons, South America
  - Jacques-Coper et al. (2015, JGR): summer heatwaves in Patagonia

MJO and high-lat SAT

- Vecchi and Bond (2004, GRL)
- Composites of DJF SAT from stations (1970-1990)



Shaded: 90% Sign. 1979-1990 DJF Composite MJO Surface Air Temperature Anom. (Deg C). Contours: Composite 700 hPa Specific Humidity Anom. (10^{-5} kg/kg)

- Strong response, particularly in Alaska

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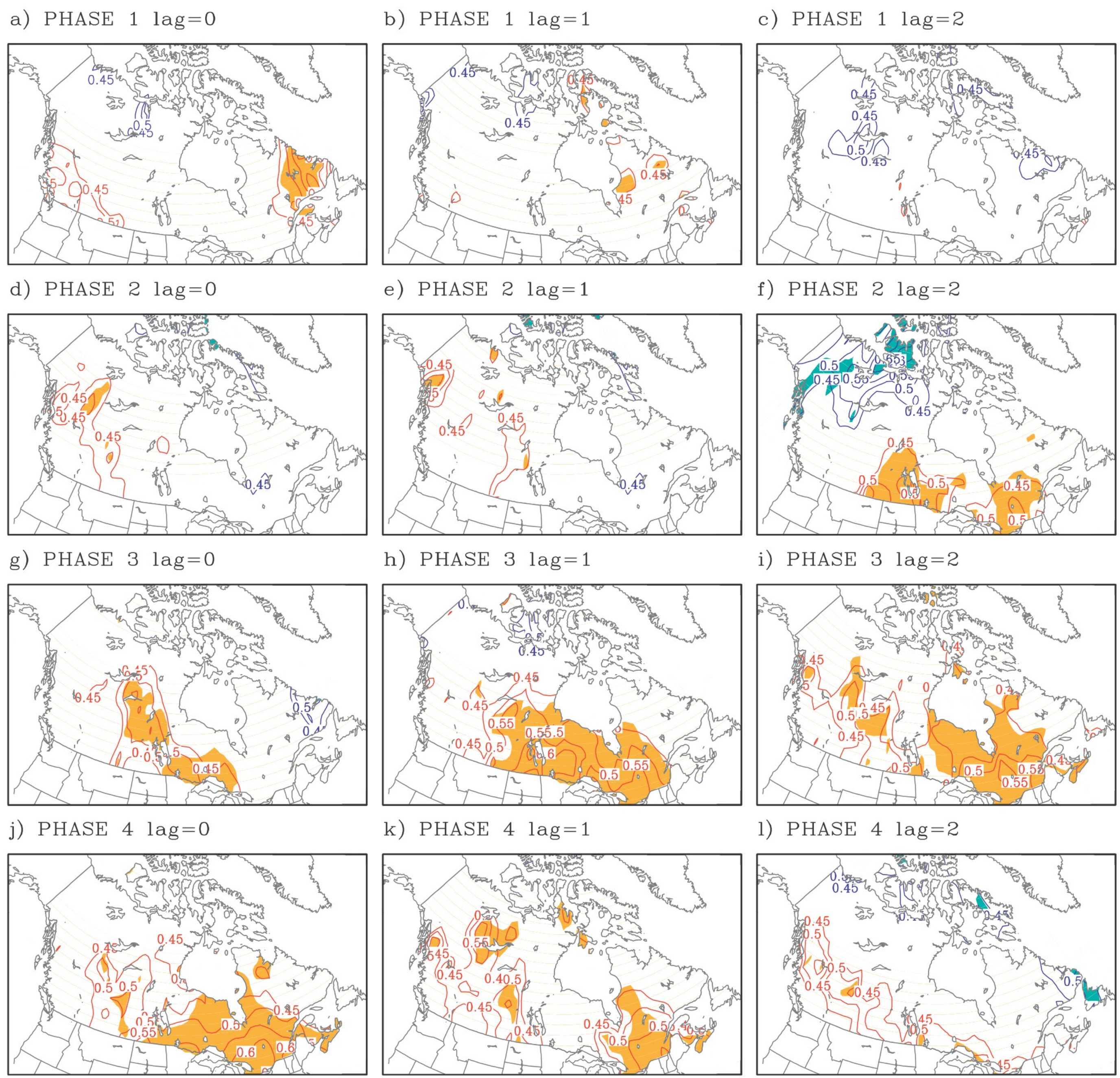
MJO and high-lat SAT

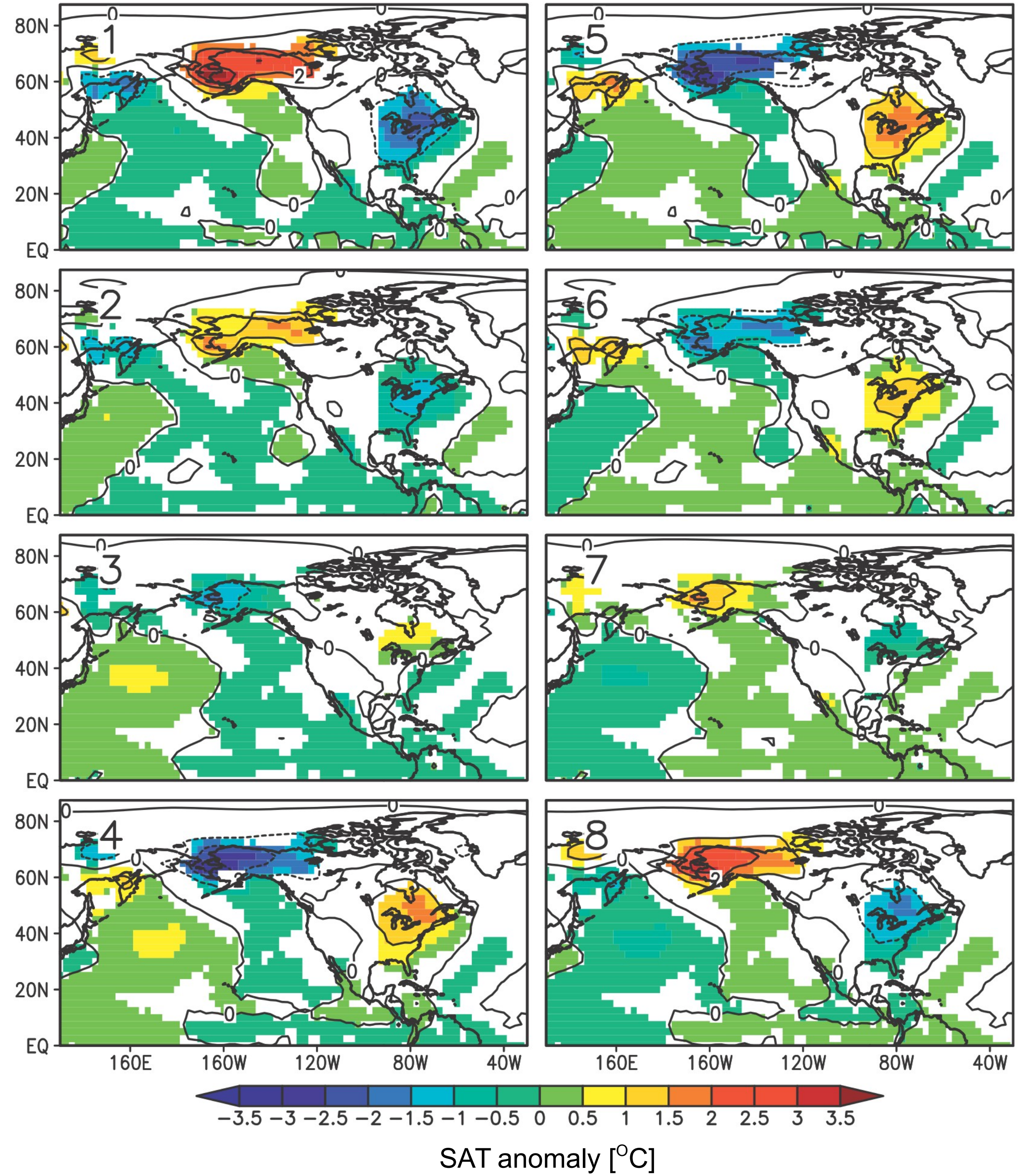
UTAS

- Lin and Brunet (2009, MWR)
- Lagged probabilities of upper-tercile DJF SAT from gridded observations (1979-2004)
- Consistent signal in SE Canada to Vecchi and Bond (2004)



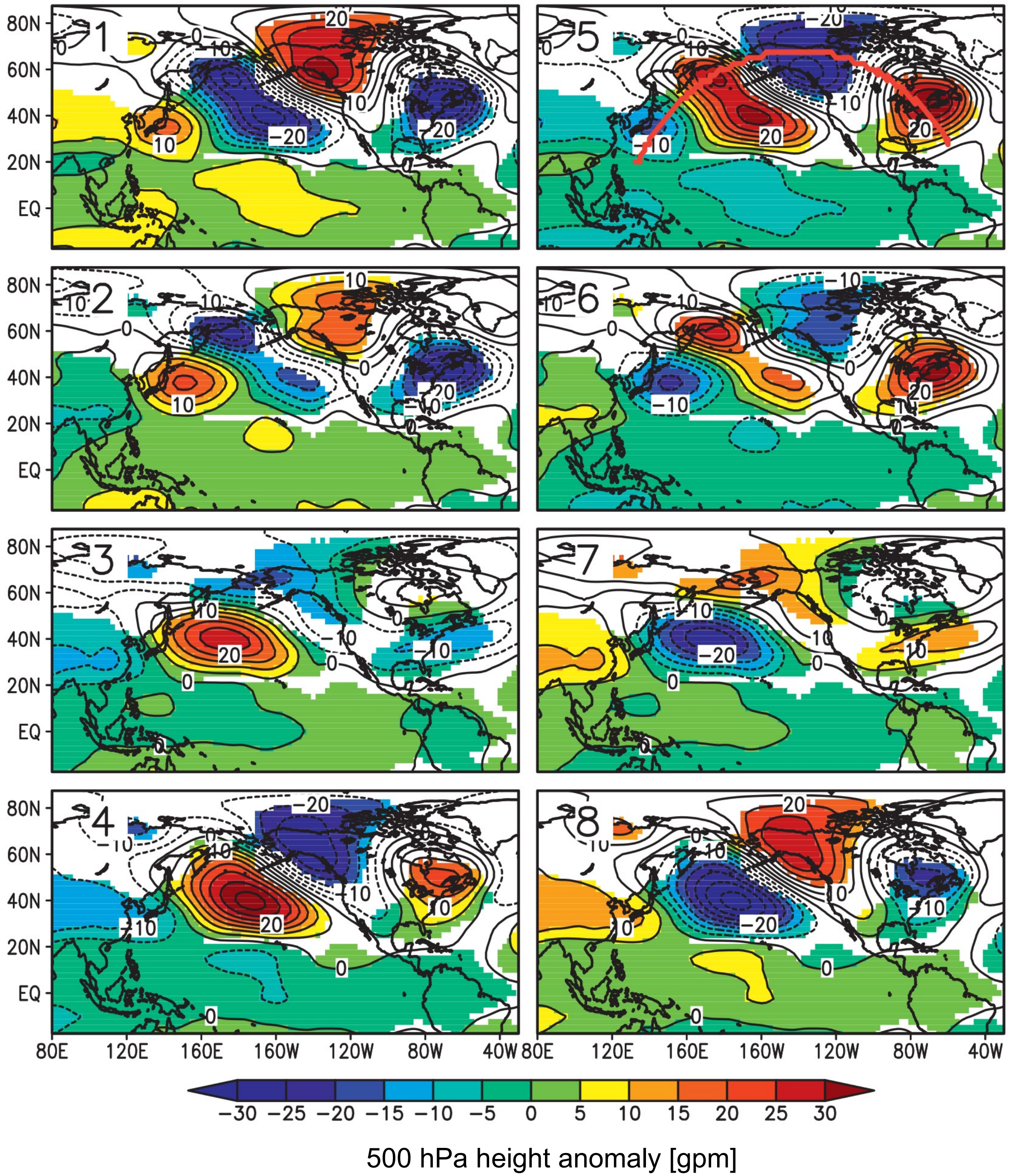
MJO and high-lat SAT

- Zhou, Thompson, and Lu (2011, MWR)
- Composites from NCEP R1 (1979-2008) over DJF
- Surface air temperature (SAT)



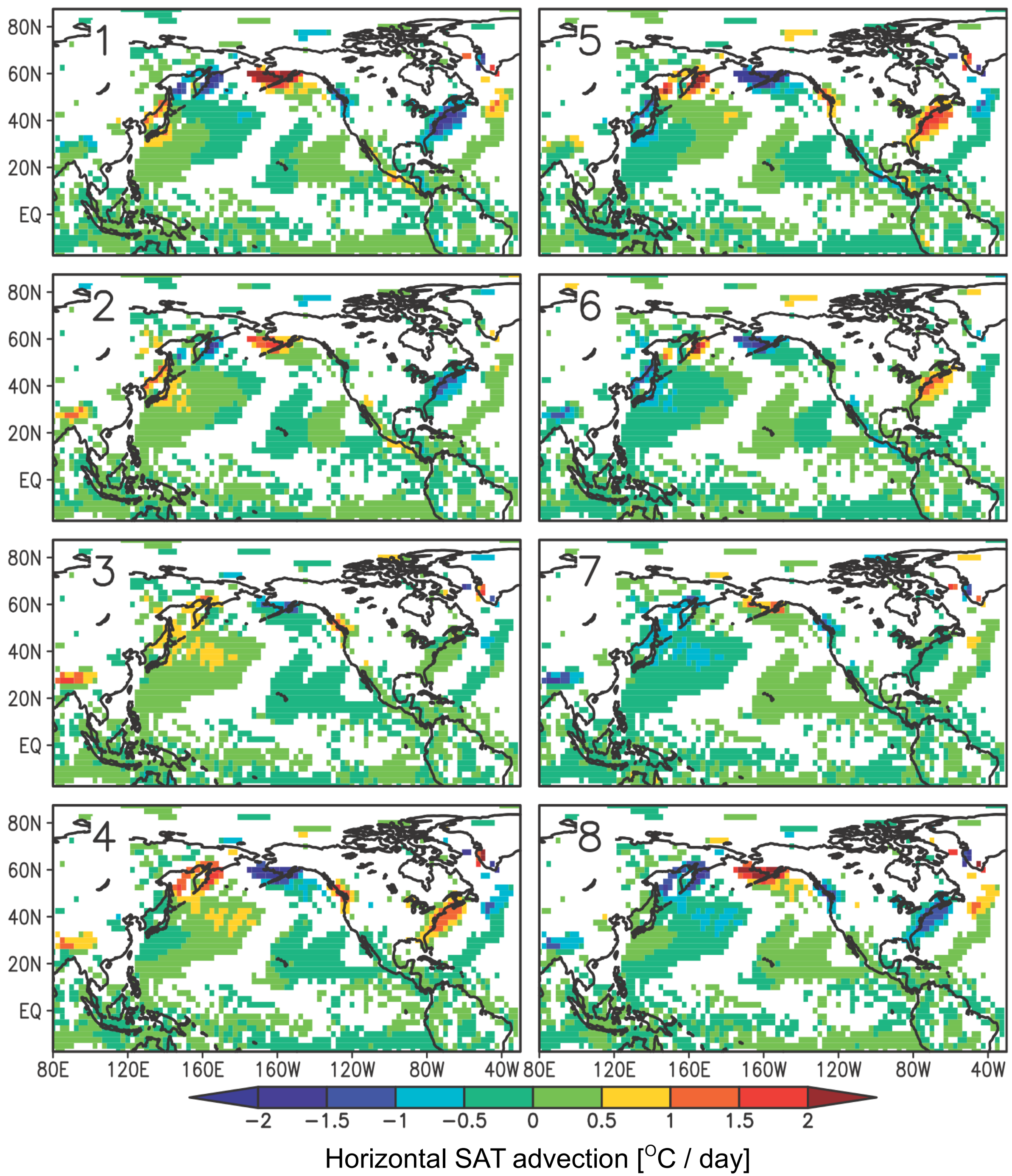
MJO and high-lat SAT

- Zhou, Thompson, and Lu (2011, MWR)
- Composites from NCEP R1 (1979-2008) over DJF
- Surface air temperature (SAT)
- 500 hPa geopotential height



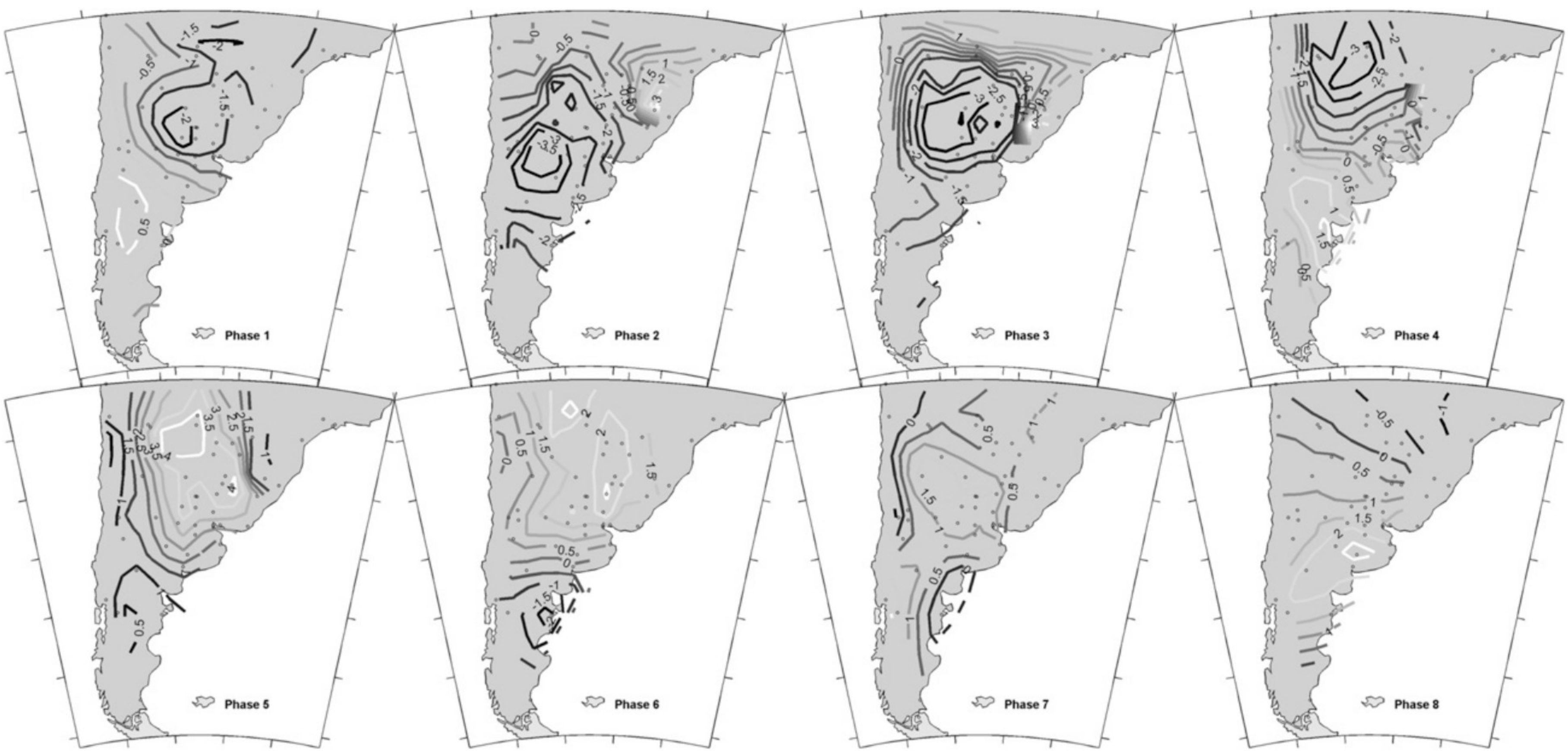
MJO and high-lat SAT

- Zhou, Thompson, and Lu (2011, MWR)
- Composites from NCEP R1 (1979-2008) over DJF
- Surface air temperature (SAT)
- 500 hPa geopotential height
- Temperature advection (-v.∇T)



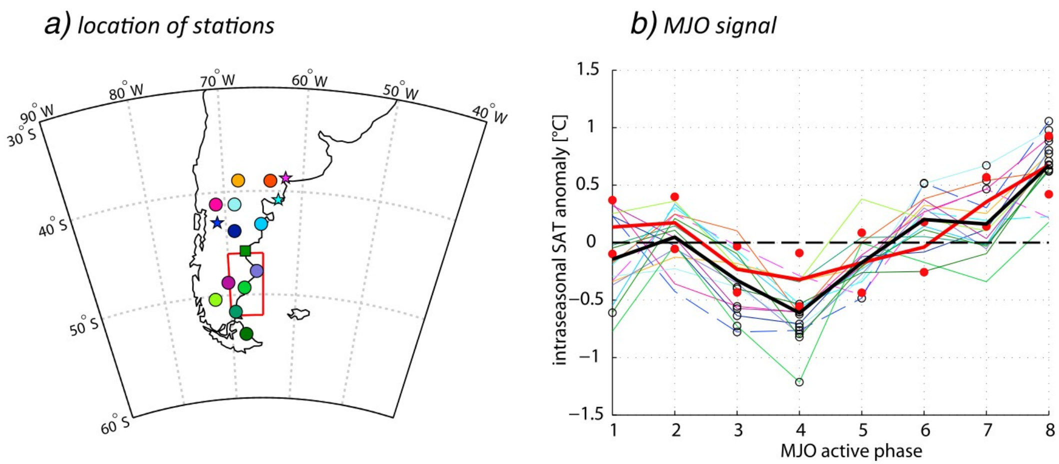
MJO and high-lat SAT

- Naumann and Vargas (2010, WAF)
- Composites of JJA SAT from stations (1975-2004)

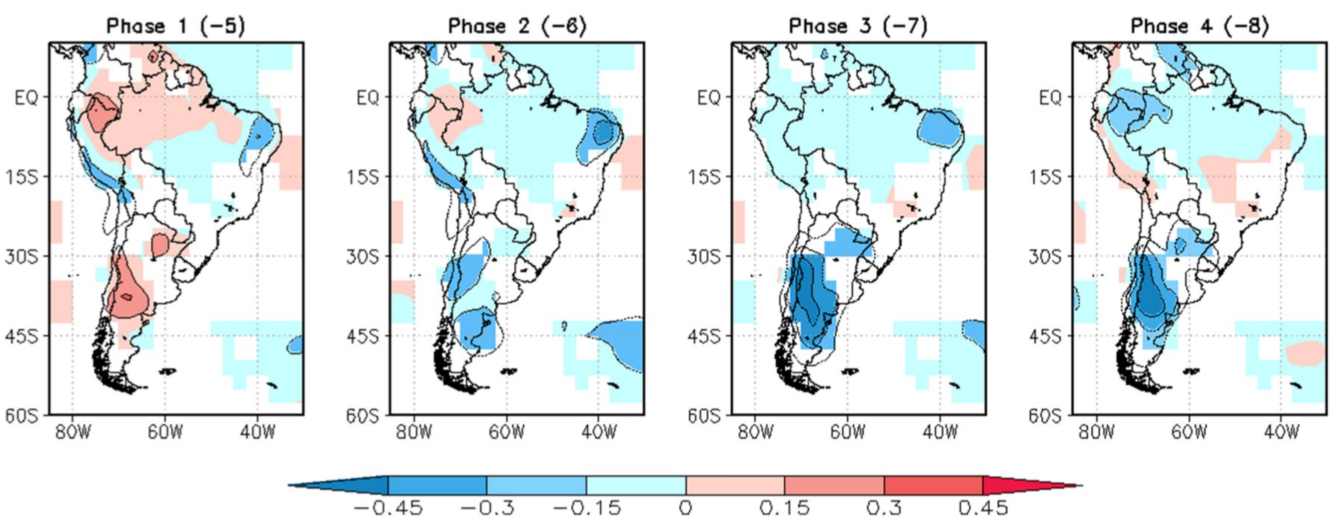


MJO and high-lat SAT

- Jacques-Coper et al. (2015, JGR)
- Composites of DJF SAT from stations (1957-2008)

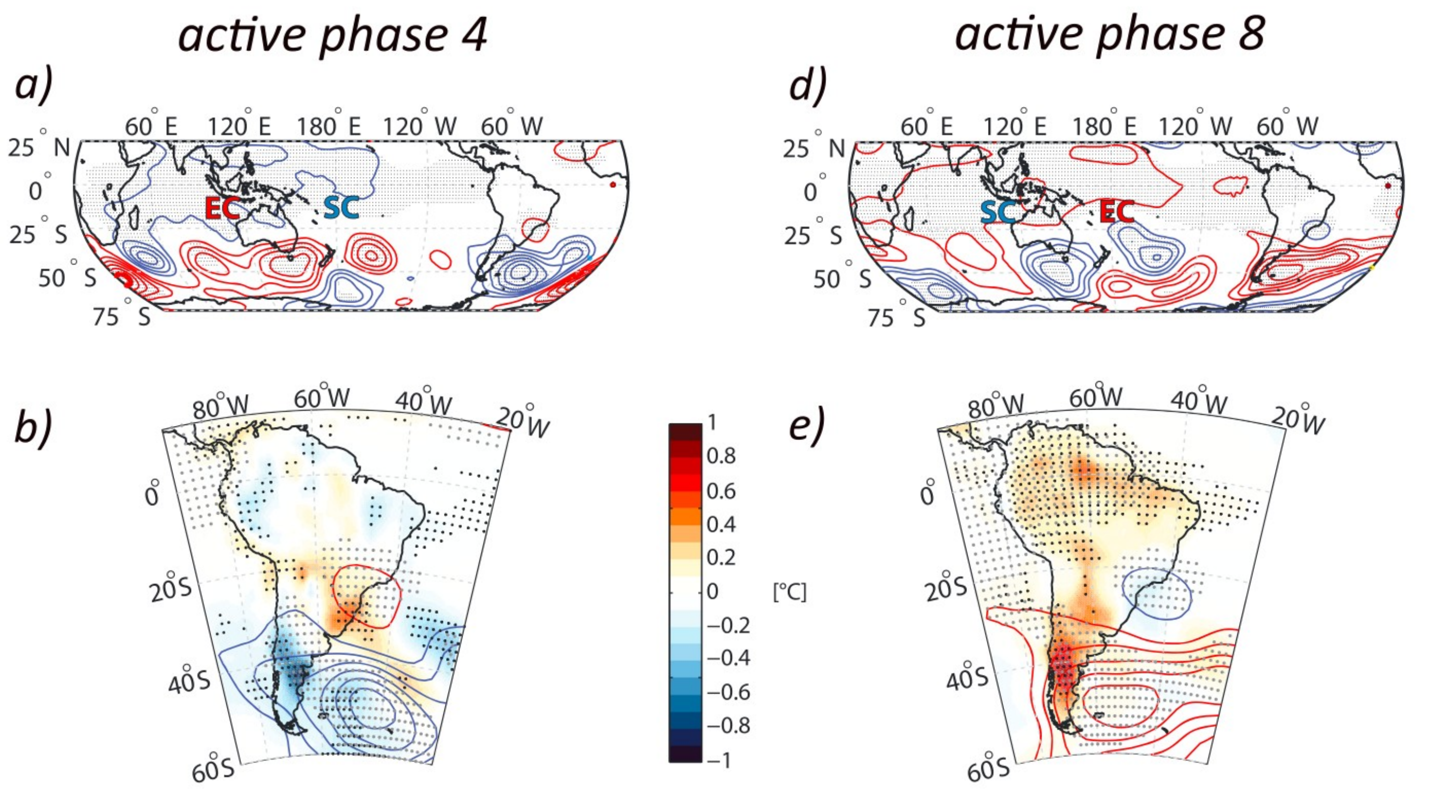


- Alvarez et al. (2015, Clim Dyn)
- Composites of DJF SAT from NCEP R1 (1979-2012)



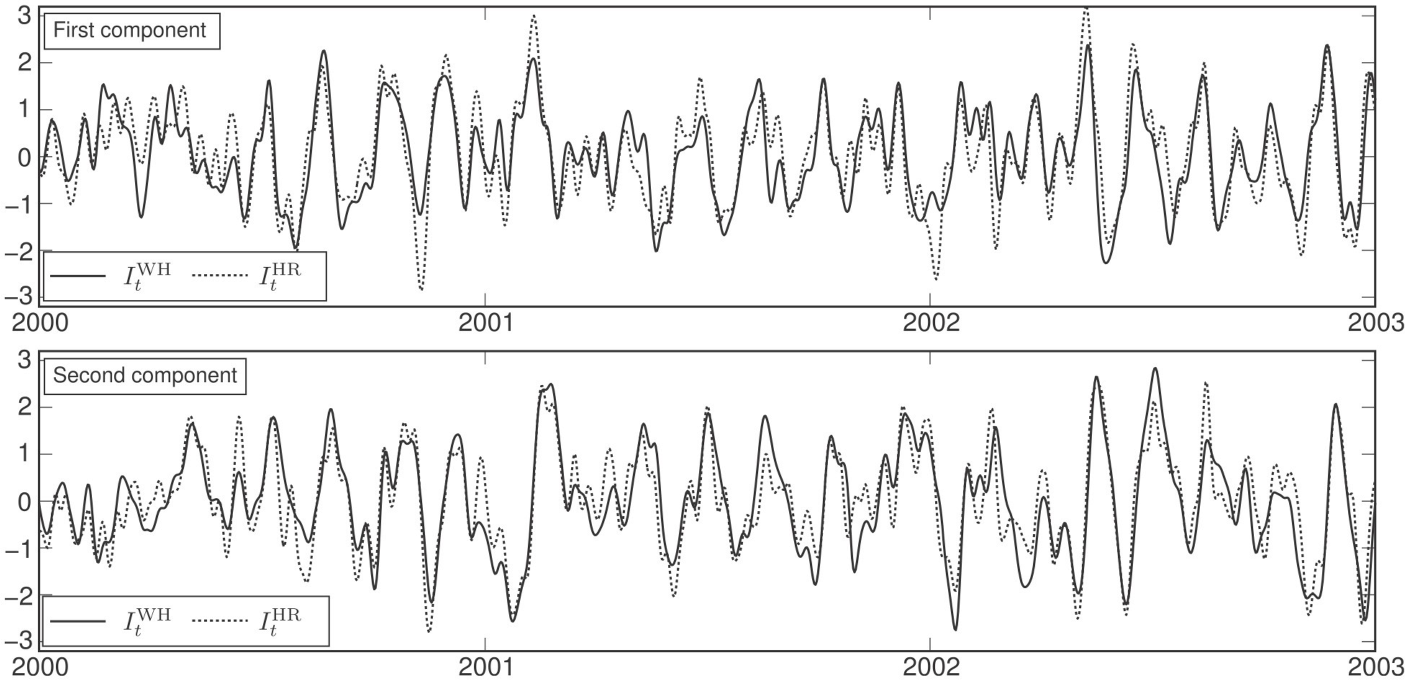
MJO and high-lat SAT

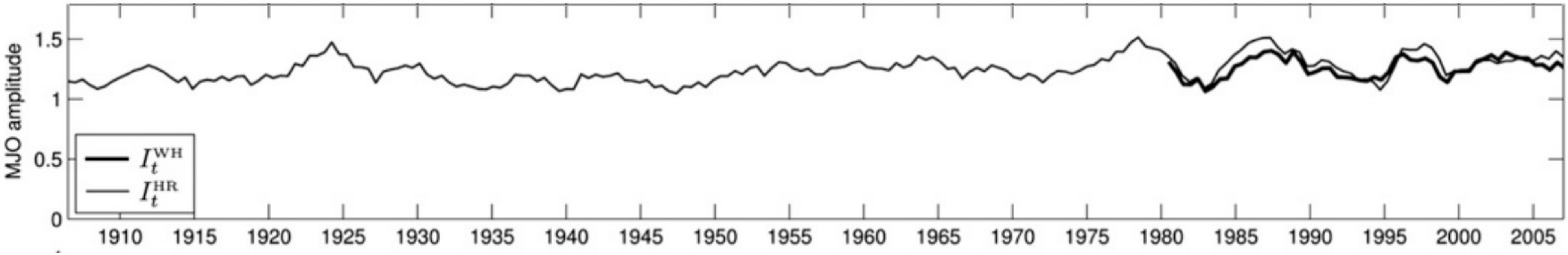
- Jacques-Coper et al. (2015, JGR)
- Composites of 500 hPa geopotential height from NCEP 20CR (1905-2008)



100+ year MJO record

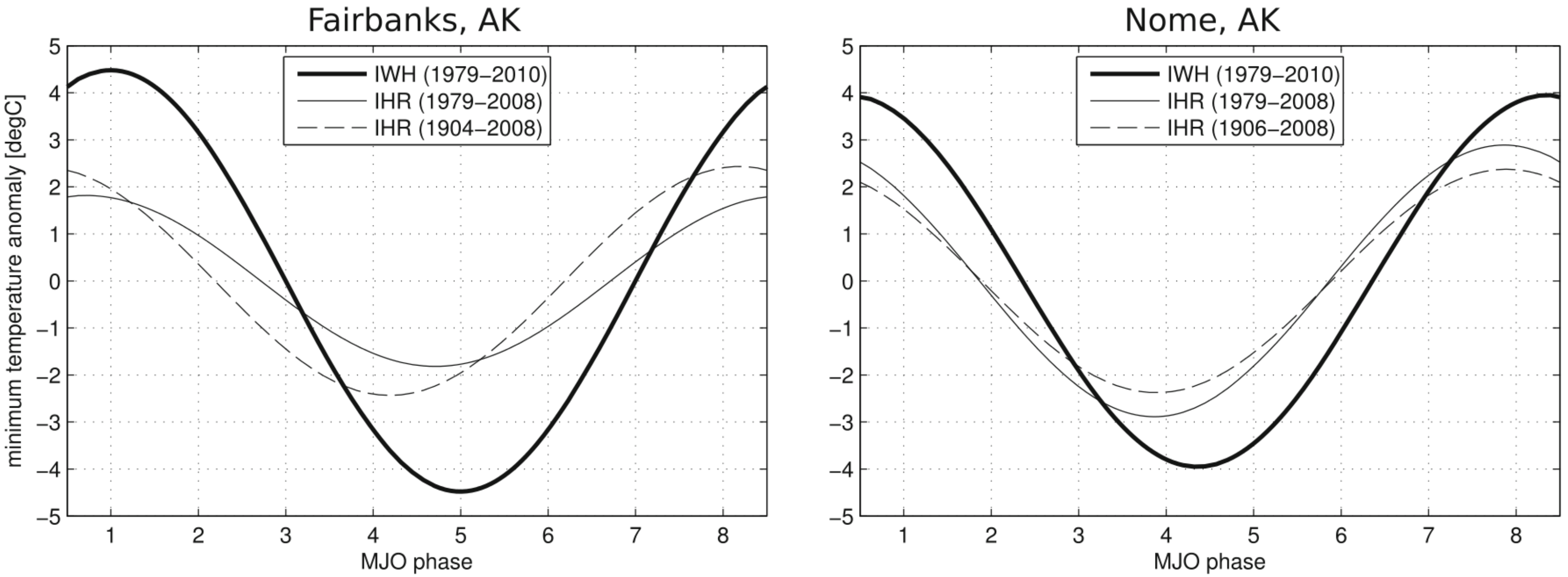
- Oliver and Thompson (2012, J Clim) reconstructed the Wheeler and Hendon (2004) MJO index
- Used NCEP 20CR tropical pressures back to 1905 as predictors for MJO index
- Provides a record of the MJO over 1905-2008+, has been extensively validated
- Download index: `http://passage.phys.ocean.dal.ca/~olivere/histmjo.html`





Alaska SAT/MJO connection

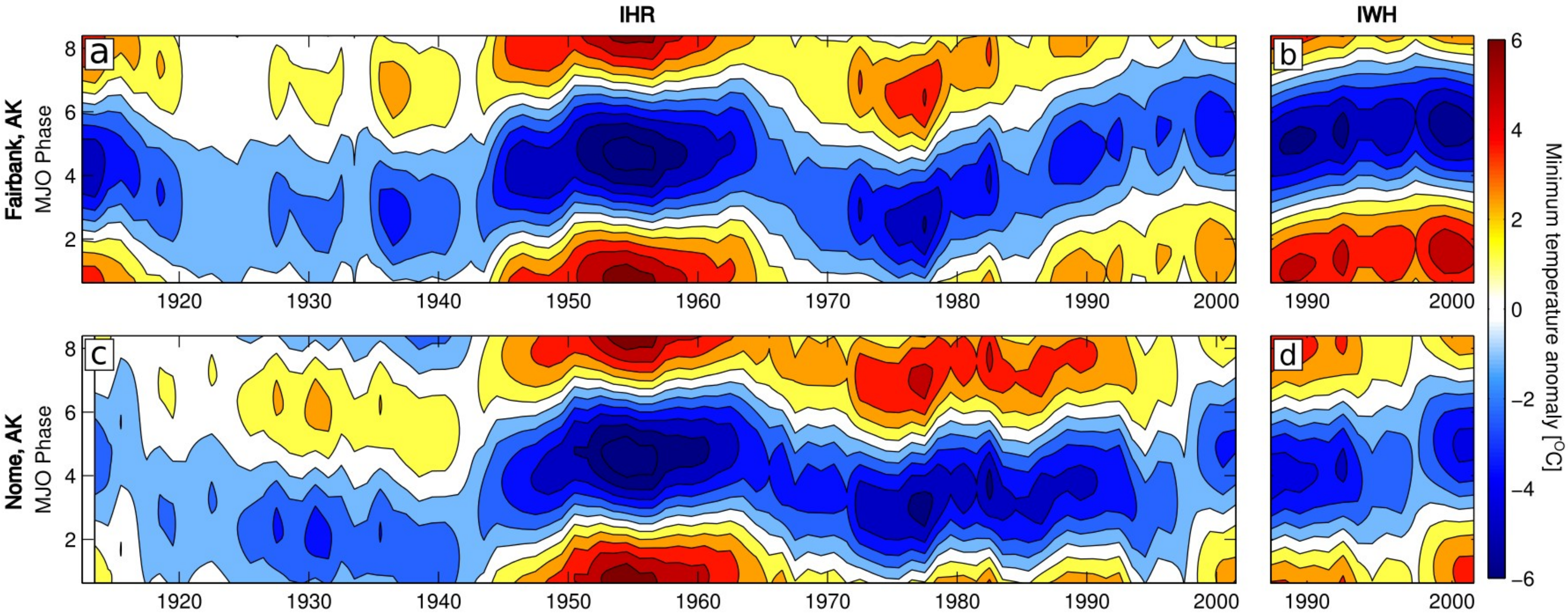
- Does the MJO/SAT connection vary in time?
- Check this using MJO index and long, independent, daily records of Alaska SAT
  - Fairbanks: (64°50' N, 147°43' W), 1904-2010 (107 years), <1% missing data
  - Nome: (64°30' N, 165°24' W), 1906-2010 (105 years), <1% missing data
- Get SAT response to MJO using linear regression
  - $SAT = \beta_0 + \beta_1 I_1 + \beta_2 I_2 + \varepsilon$
  - "Ideal" MJO response simulated using $(I_1, I_2) = (a \cos \phi, a \sin \phi)$ with $a = 1.5$ and $\phi = [0 \ldots 2\pi]$
- MJO-SAT connection exists over 100+ year record:



Oliver (2014), *Theoretical and Applied Climatology*, **121**: 1-11

Multidecadal Variability

- SAT response in moving 15-year blocks shows multidecadal variations
- This is not due to variations in MJO amplitude (relatively steady, technique controls for this)



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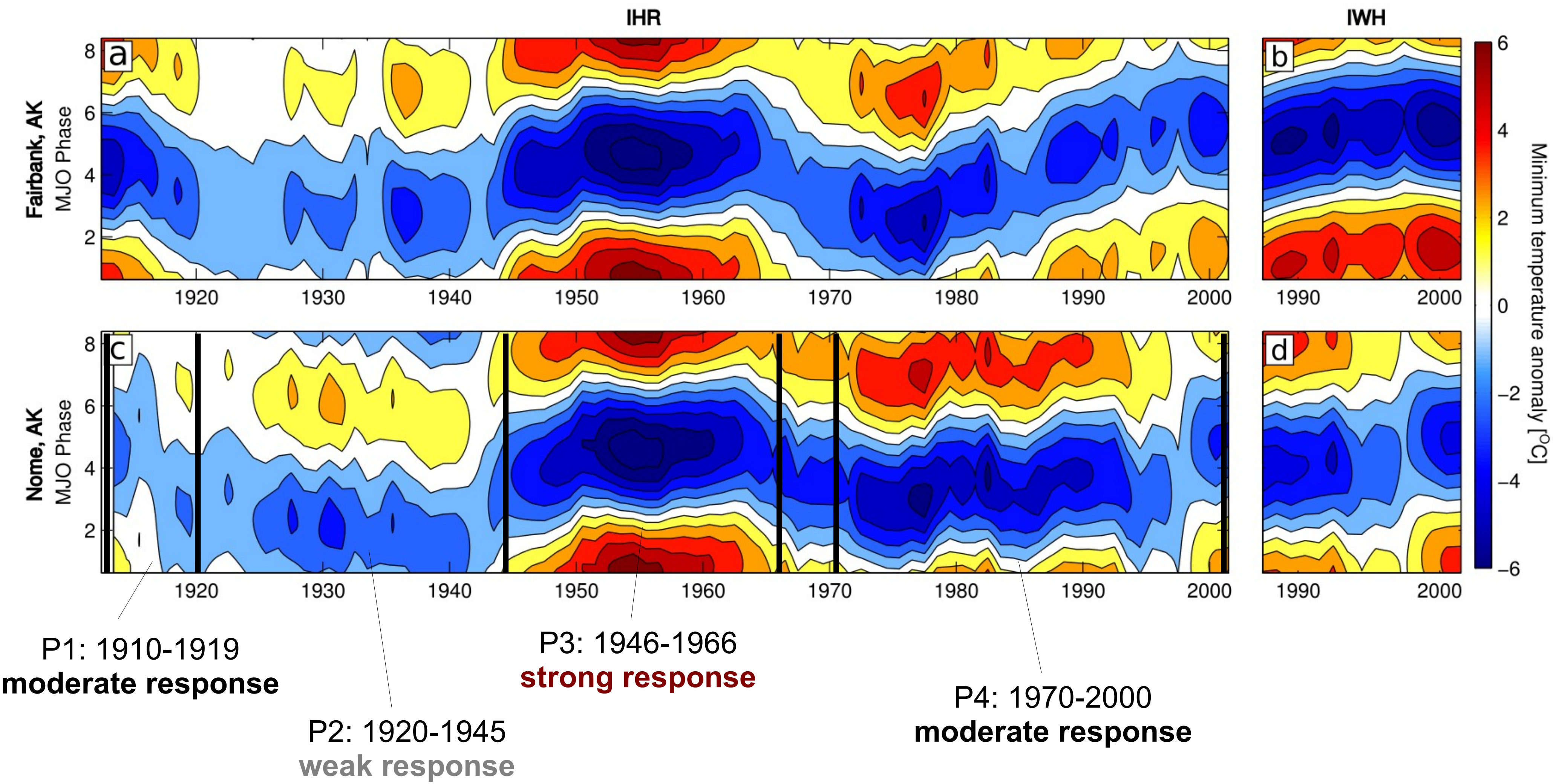

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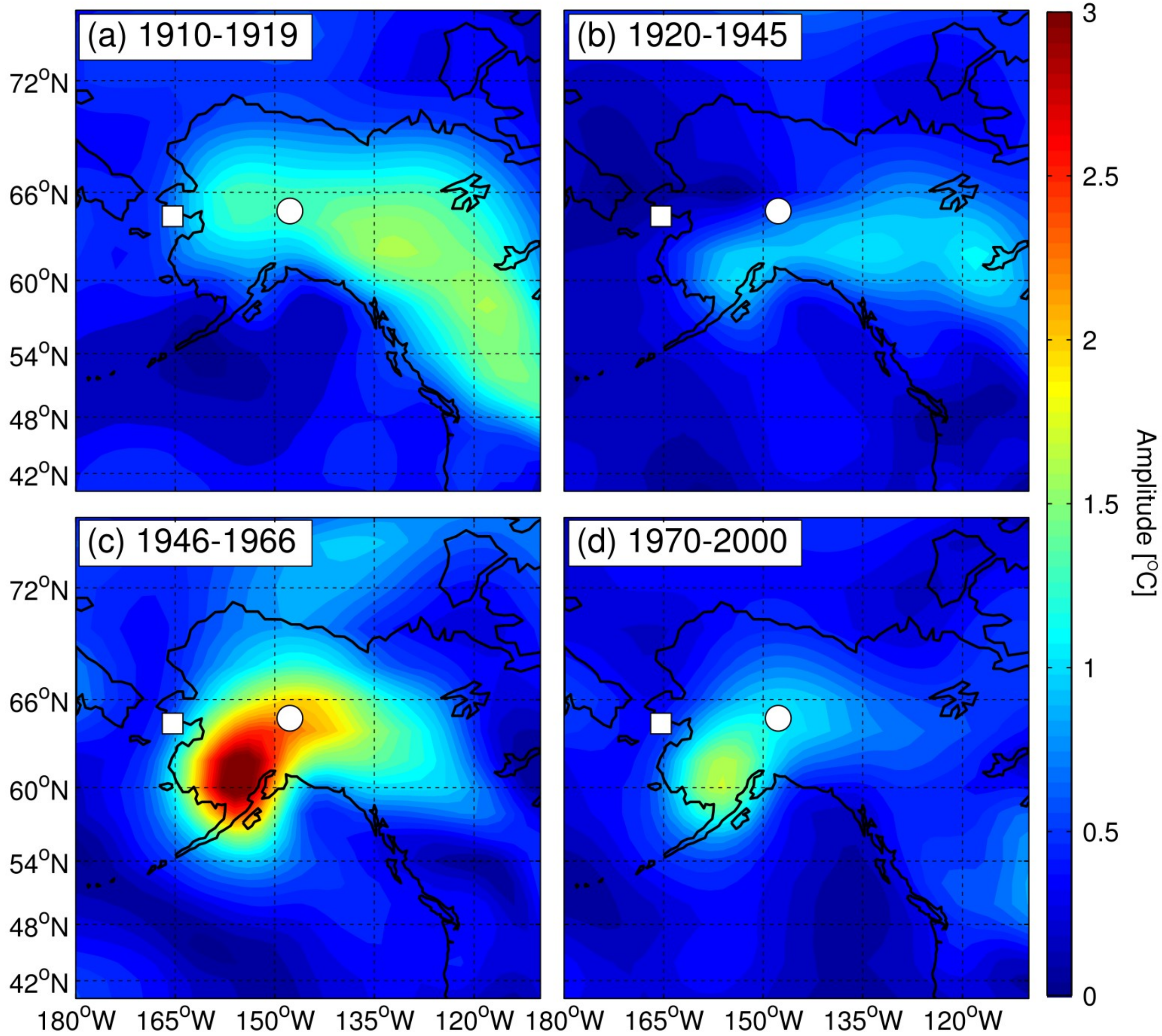
Teleconnection mechanism

- Consistent with amplitude of 20CR SAT response to MJO:



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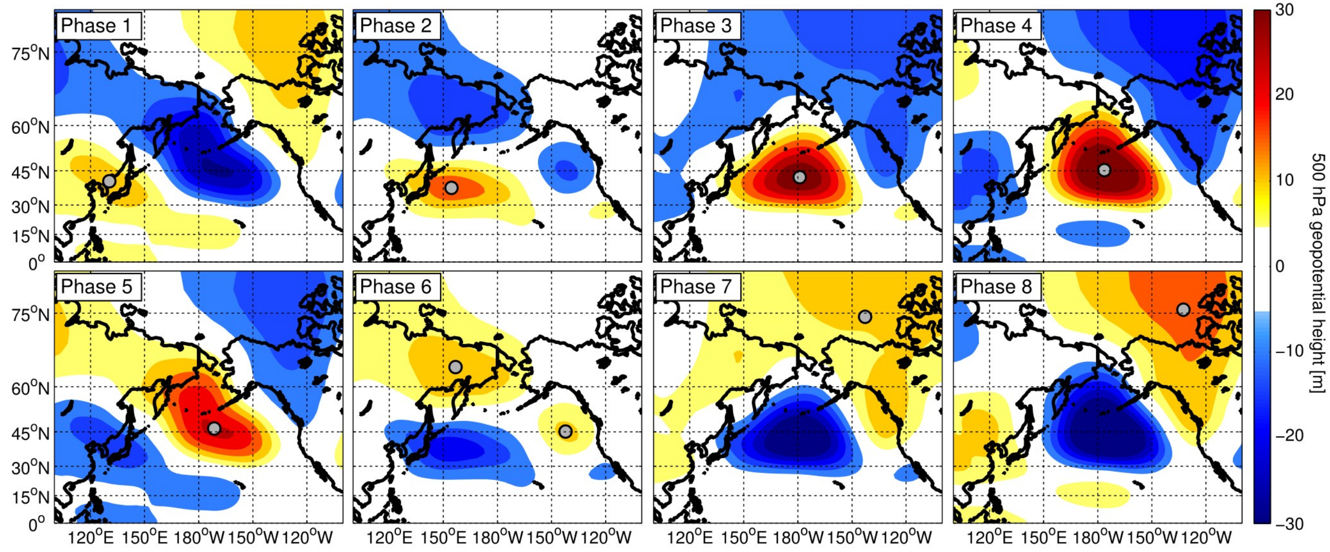
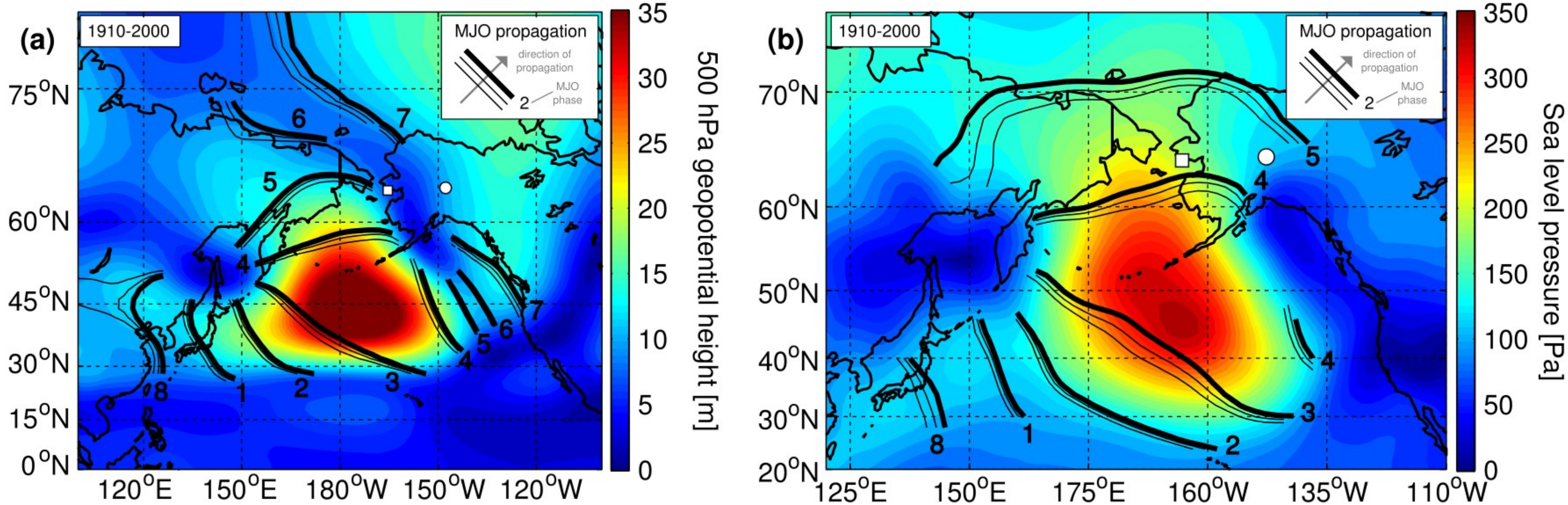
Teleconnection mechanism

- MJO Composites Rossby wave train propagation (500 hPa gp height):



- Can summarise using an amplitude / phase plot, also see propagation in SLP:



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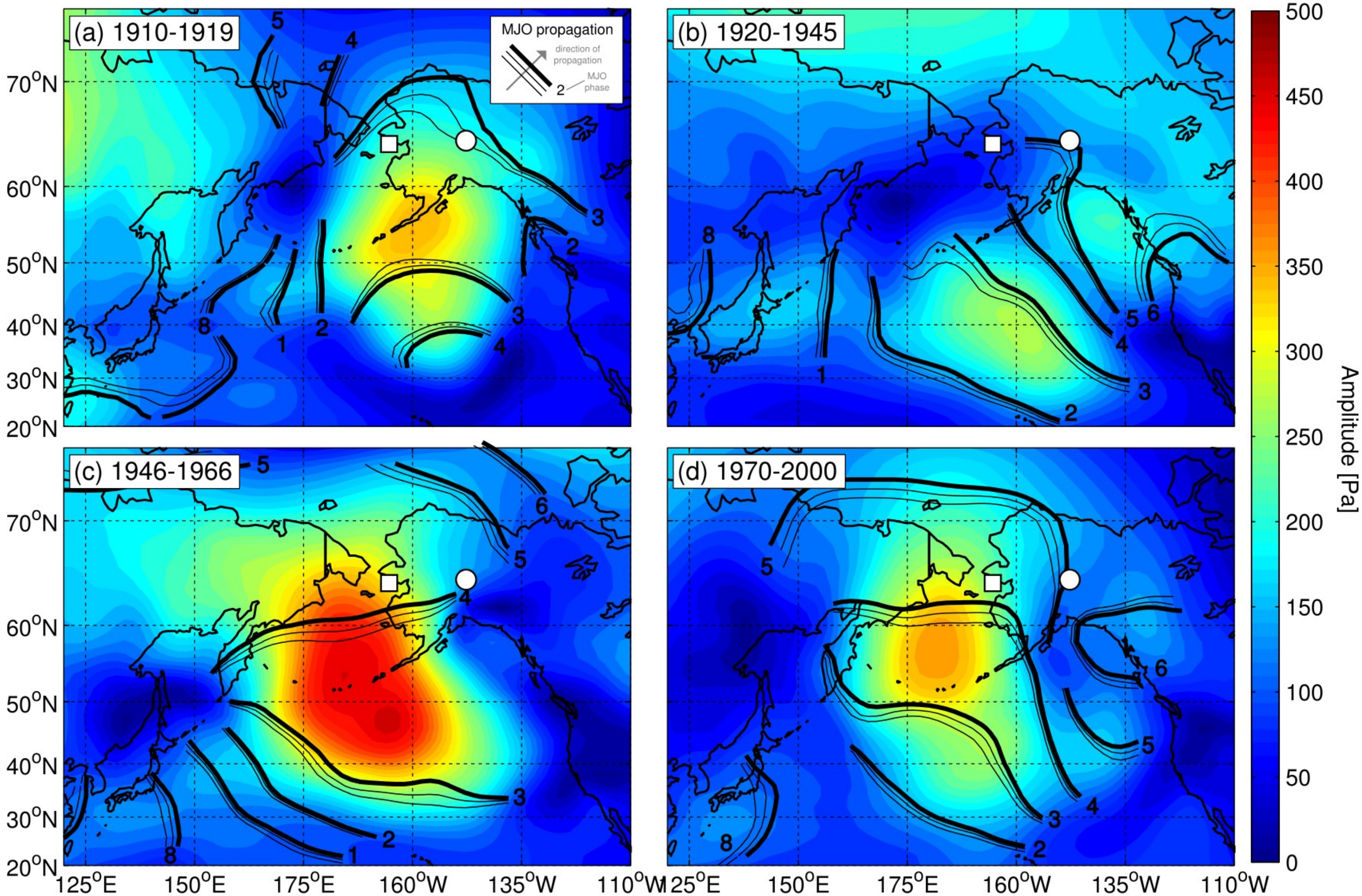
Teleconnection mechanism

- This teleconnection mechanism appears to have varied over time
- Time periods match well with SAT response



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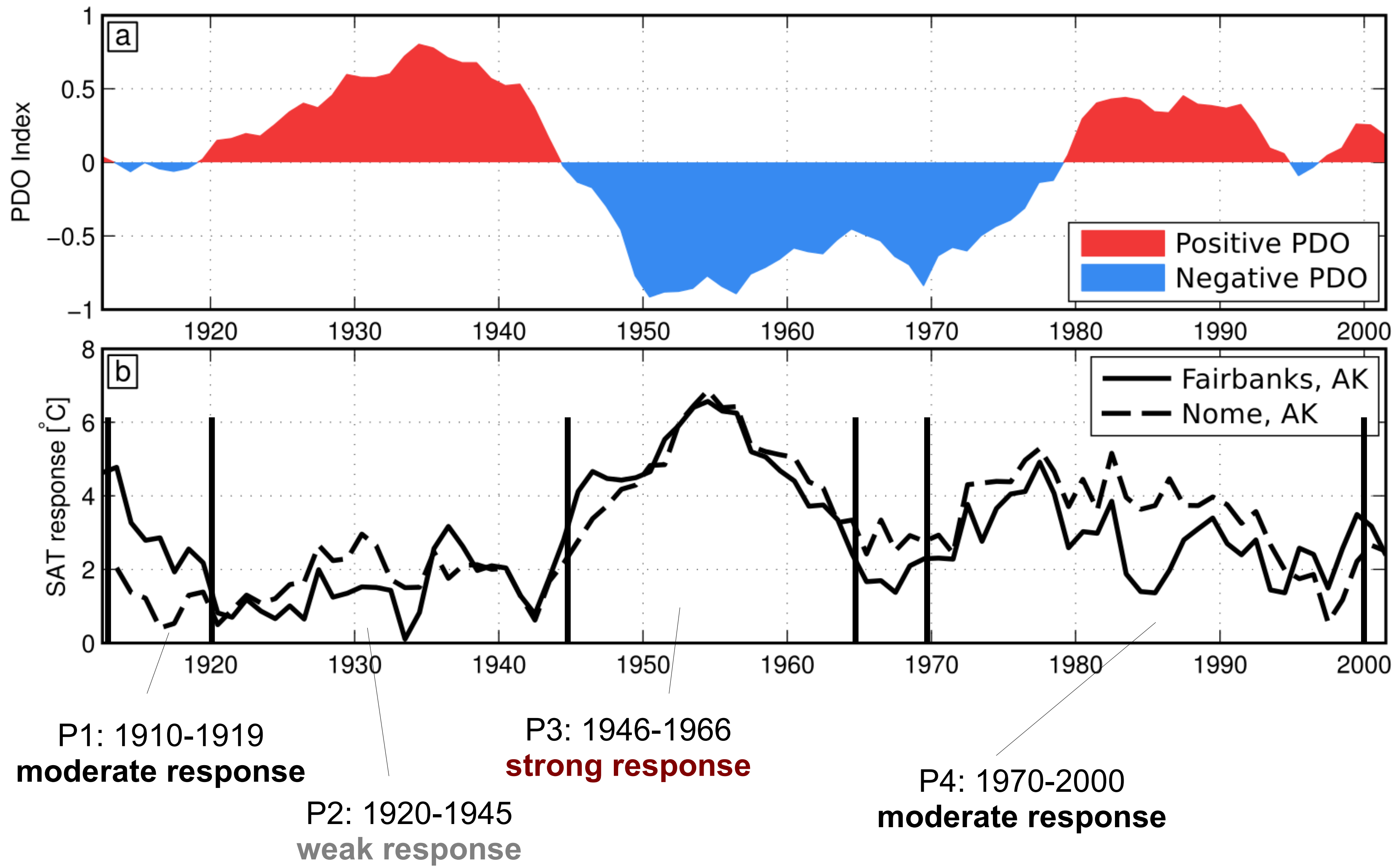
Pacific Decadal Oscillation

- Amplitude of MJO response seems related to PDO
- Correlation is -0.64 (Fairbanks) and -0.56 (Nome)



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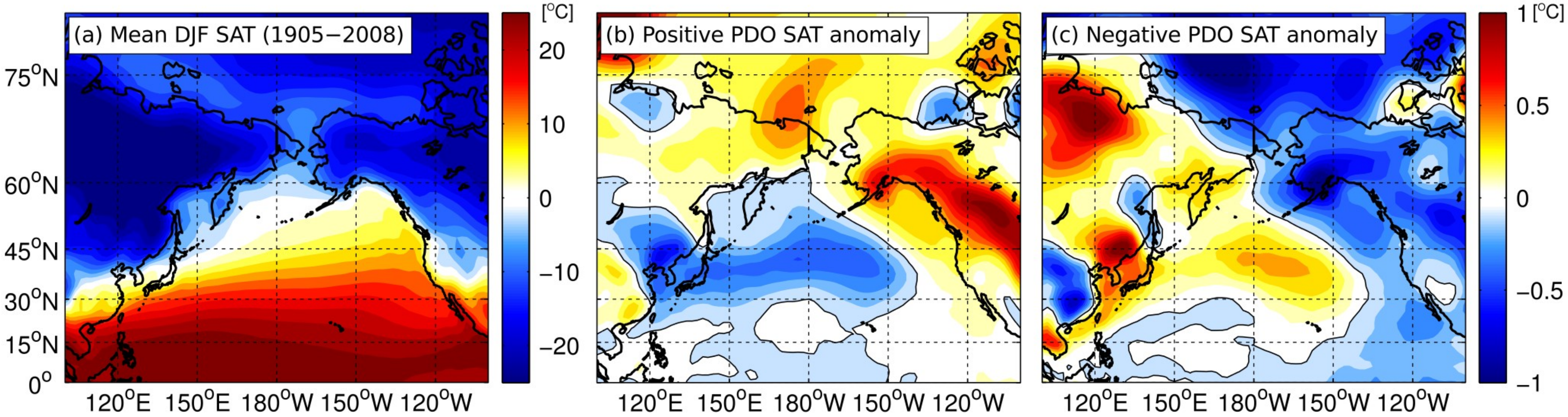
Pacific Decadal Oscillation

- PDO influences cross-shore temperature gradient (and thus temp. advection)



- Role of PDO in influencing dynamical teleconnection mechanism (Rossby wave train) unclear

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Summary

- Connection between MJO and high-lat SAT variability subject to multidecadal variability
  - MJO modulation of SAT varies from nearly 0 to up to +/- 6°C
- Strength and direction of teleconnection mechanism has varied through time
  - Not due to variations in the MJO
- PDO appears to be play a role, but this is not the whole story
  - No late 1970s climate shift...
- Interesting example of interaction across scales...
  - Intraseasonal variability, which varyies on multidecadal time scales

Oliver (2014), *Theoretical and Applied Climatology*, **121**: 1-11