

# Observational Evidence For The Delayed Response Of Stratospheric Polar Vortex Variability To ENSO SST Anomalies

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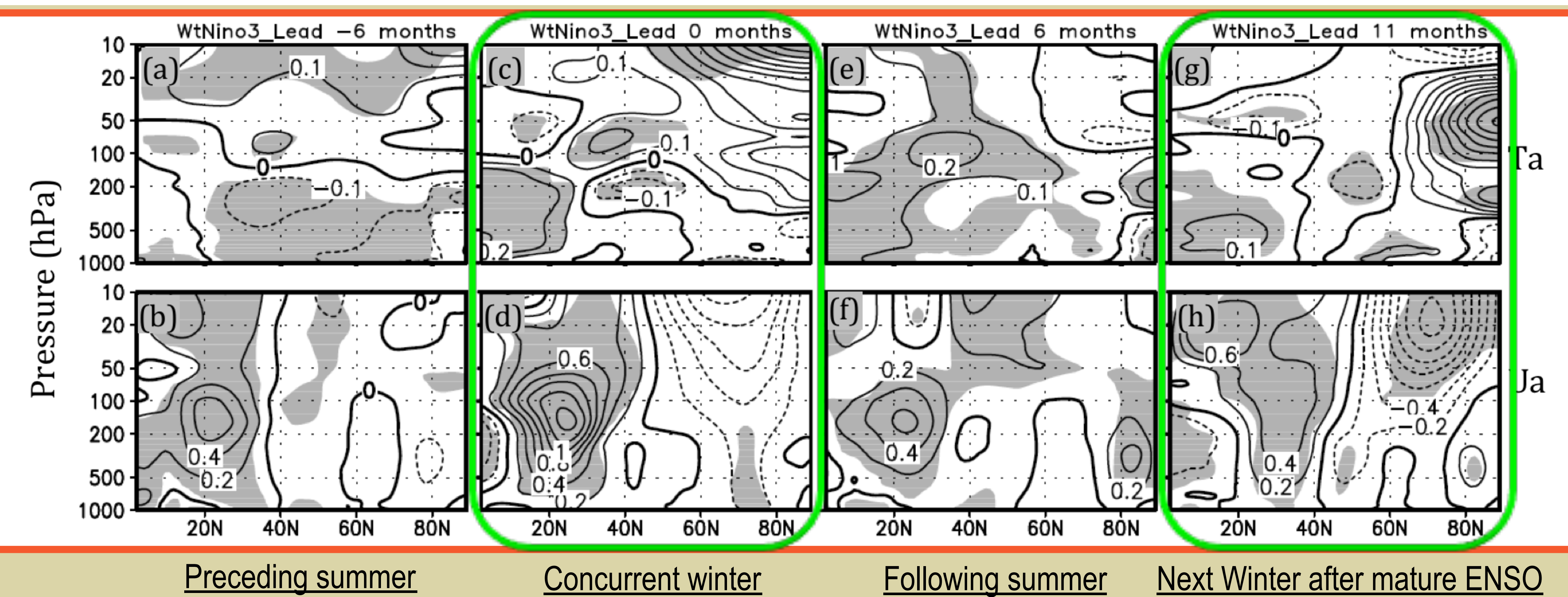
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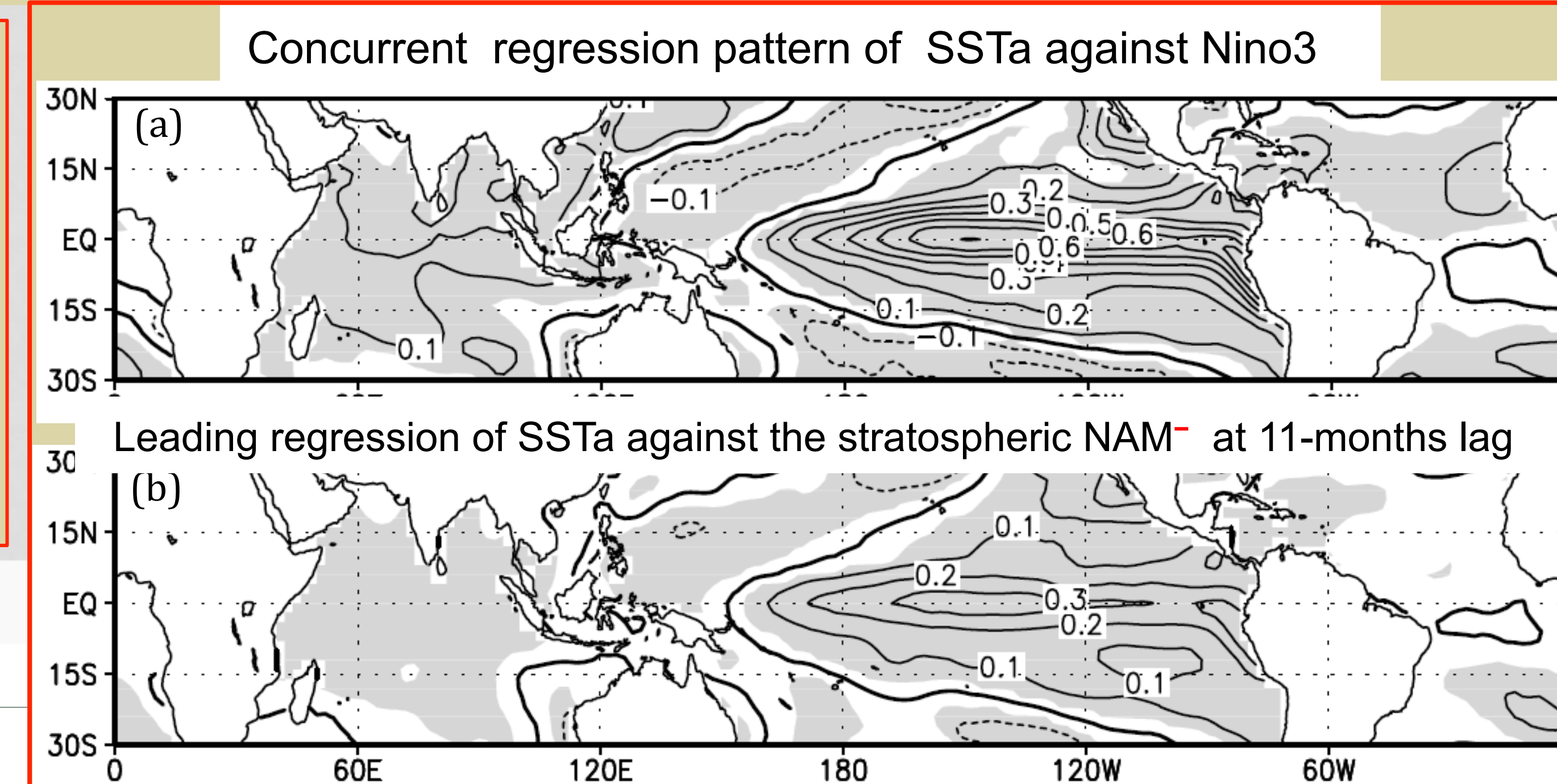
## Background and Questions:

1. Concurrent response: Warm/cold ENSO forces a weaker/stronger polar vortex (van Loon et al. 1982; Labitzke and van Loon 1989; Camp and Tung 2007; Hamilton 1995; Sassi et al. 2004; Manzini et al. 2006; Garfinkel and Hartmann 2007, 2008);
2. Possible delayed effect of ENSO
  - Stratospheric warming response lags the maximum Niño3.4 value for several months (García-Herrera et al. 2006);
  - Maximum correlation between ENSO and EP flux divergence at 30hPa appears when ENSO leads the EP flux by about three seasons (Chen et al. 2003)
3. The known delayed effect of ENSO in the troposphere Response of zonal-mean tropical temperature lags the ENSO peak by 1-2 seasons (Newell and Weare 1976; Angell 1981; Reid et al. 1989; Yulaeva and Wallace 1994), due to the tropical oceans delayed response to ENSO (Kumar and Hoerling 2003) and via the "atmospheric bridge", (Lau and Nath 2003; Klein et al. 1999) and PNA-like teleconnection (Handoh et al. 2006).
4. Is a Lagged ENSO-PVO relationship existed? How?

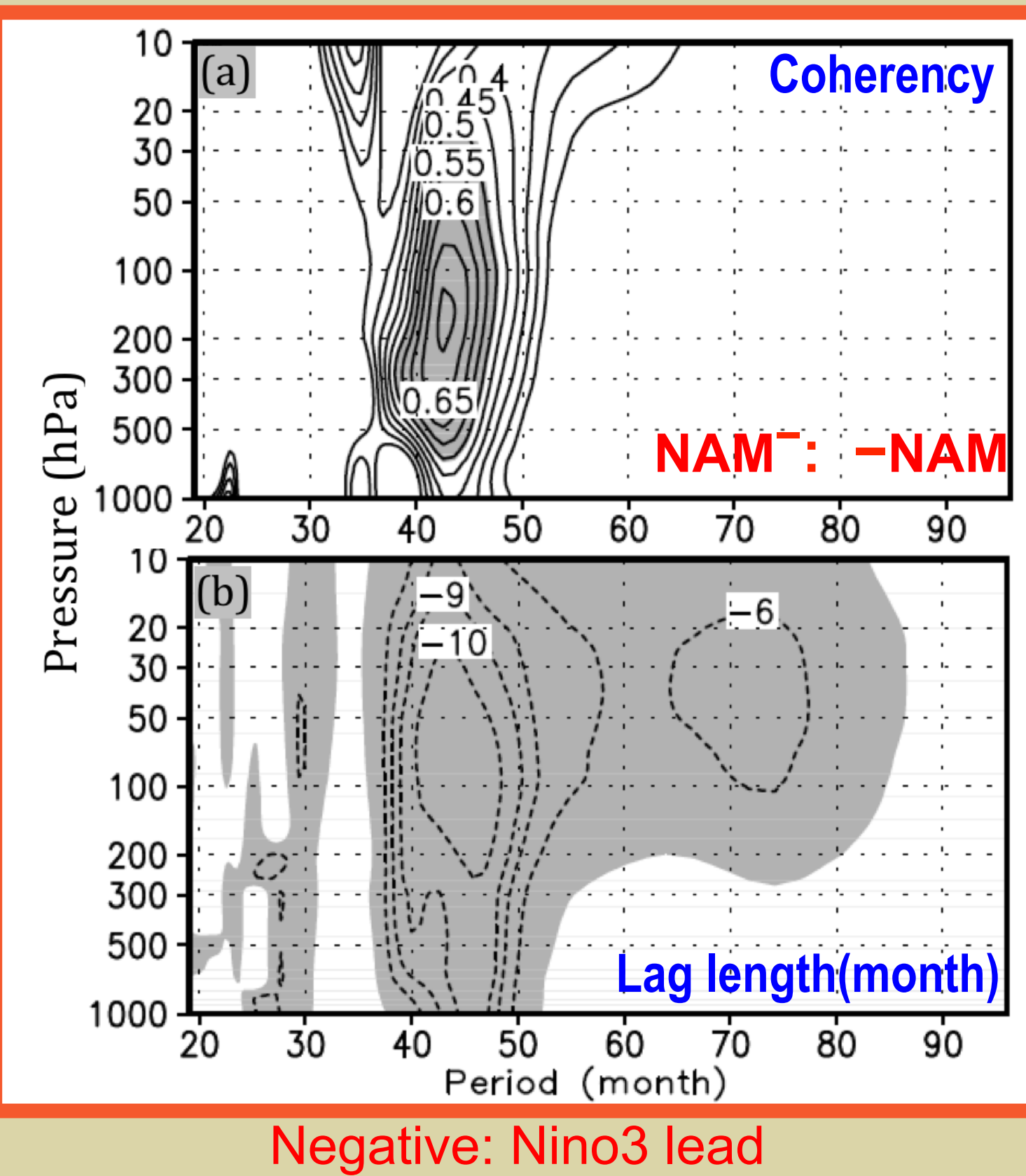
Lead/Lag Regression of Zonal-mean Ta and Ua against the winter Niño3 in 3-5 year timescale



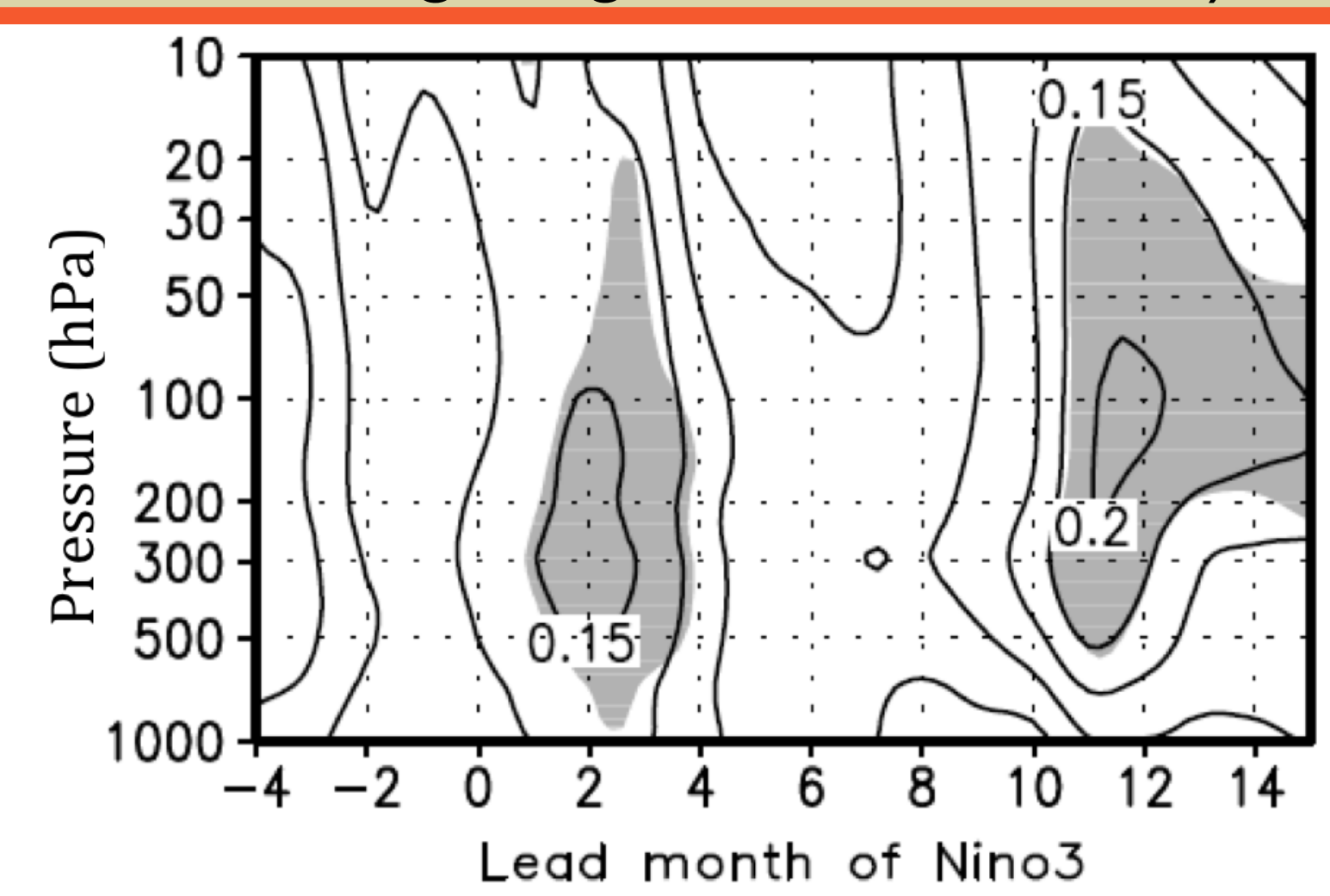
Other than in the concurrent winter, the ENSO-related strongest response is in the next winter after ENSO peak; A canonical ENSO SST pattern is in the previous winter before PVO.



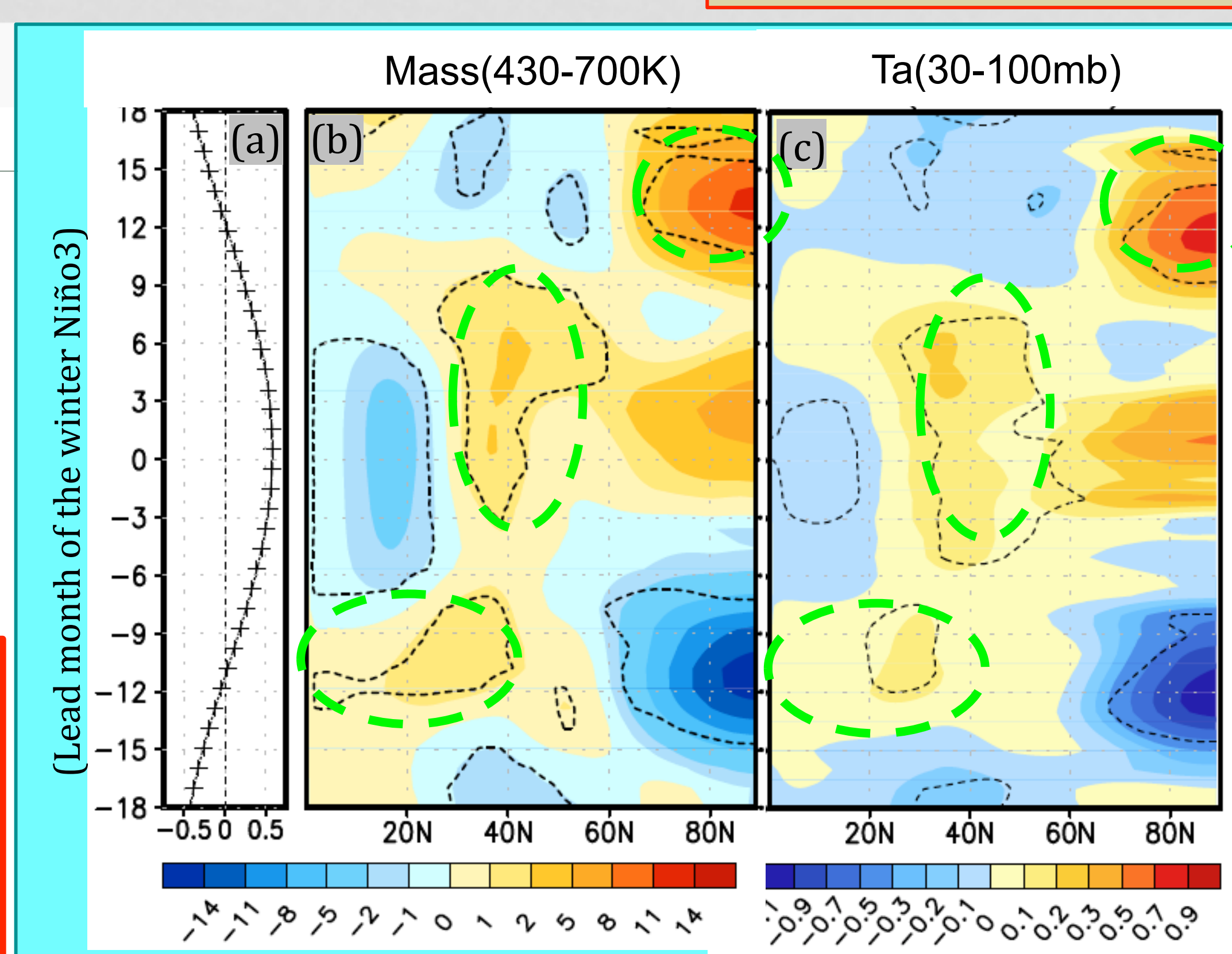
Cross Spectrum (Niño3 & NAM)



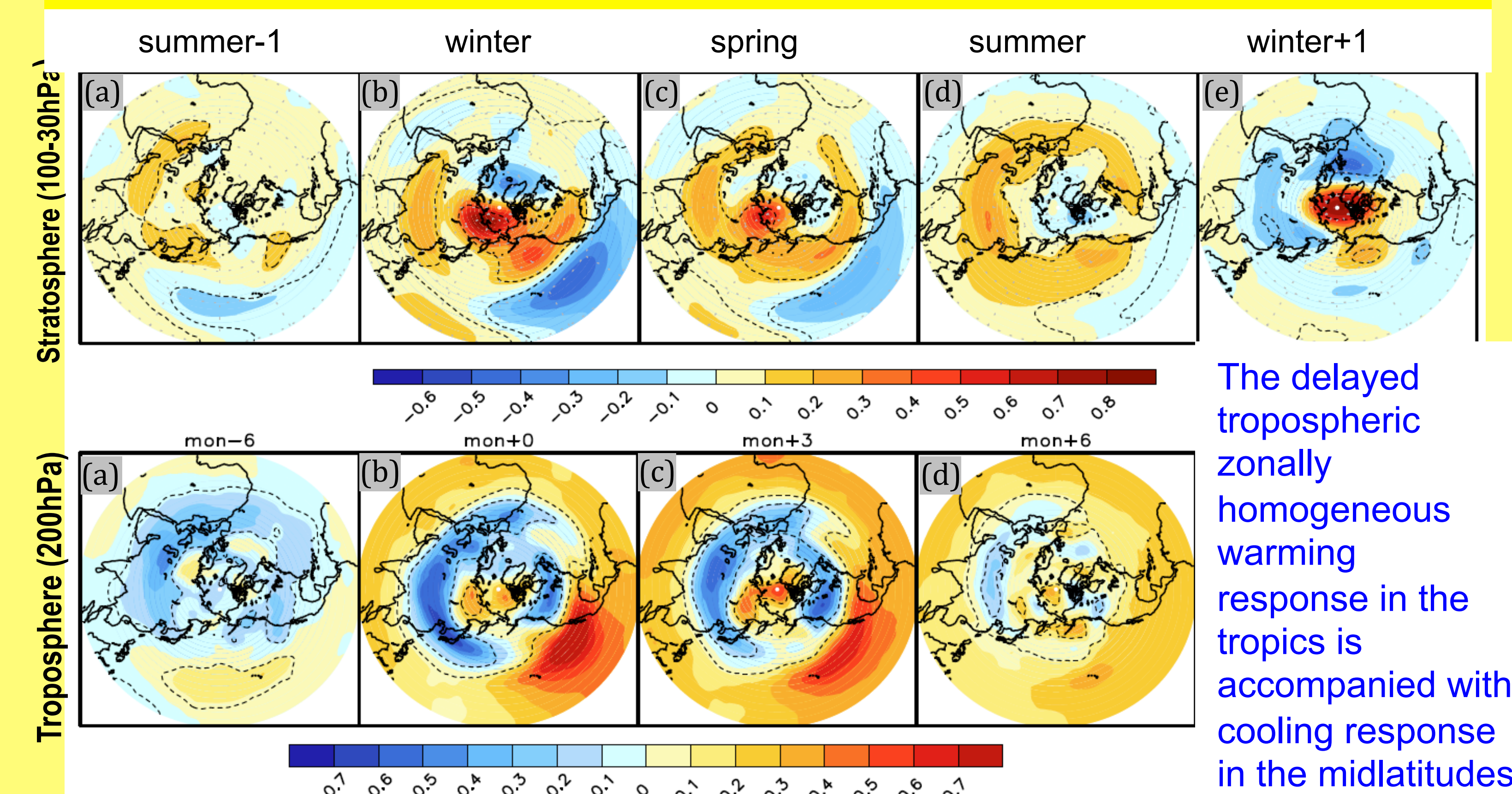
Lead/Lag Regression of NAM



• ENSO-PVO, a lagged relationship, at 3-5 year timescale, maximum response lags ENSO about one year.

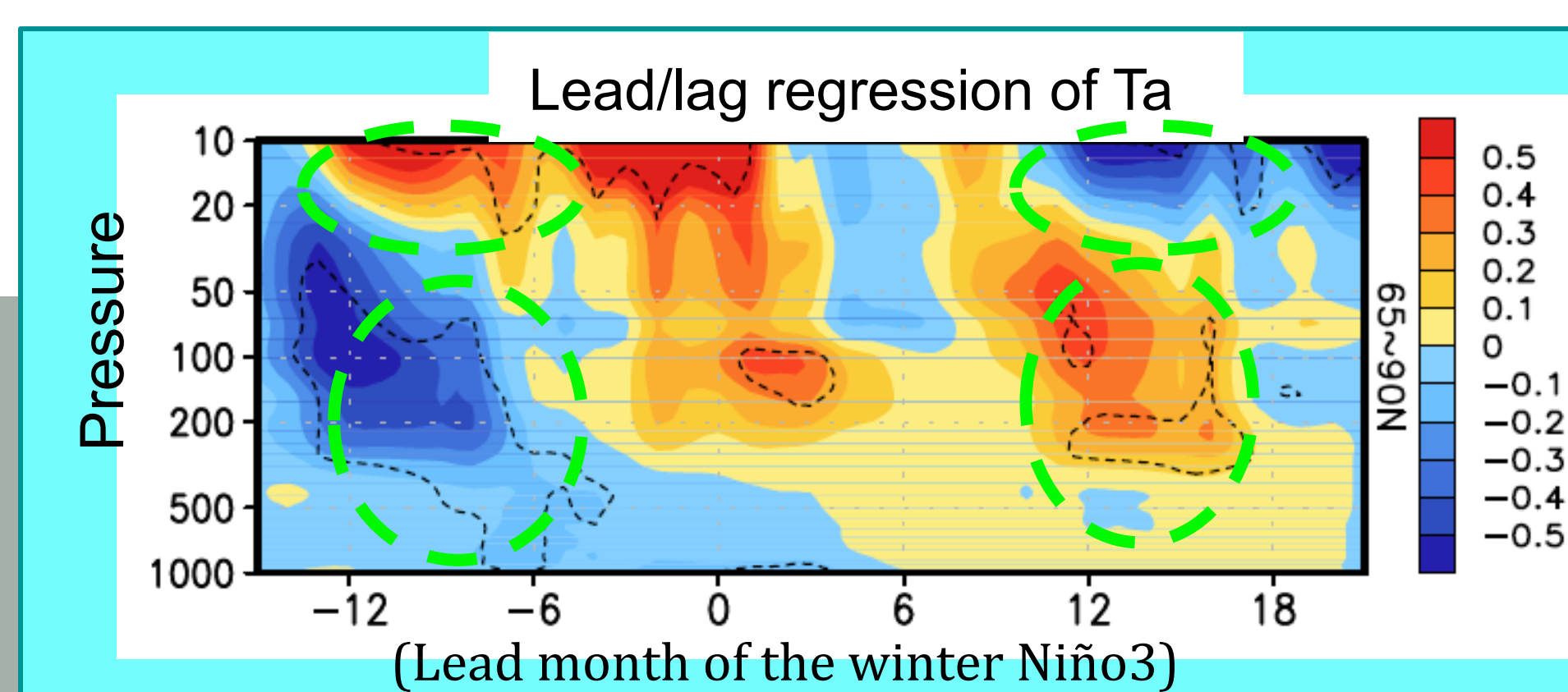


The delayed warming response in the midlatitude stratosphere to warm ENSO



The delayed tropospheric zonally homogeneous warming response in the tropics is accompanied with cooling response in the midlatitudes

• Warm ENSO is related to poleward propagation of positive mass and temperature anomalies from the tropics to the polar area and from the initiating stage (previous winter) to the ending stage (next winter) of the ENSO, manifesting the strengthening of the mass circulation in the stratosphere. The polar warming in the next winter is much stronger and with deeper vertical structure.

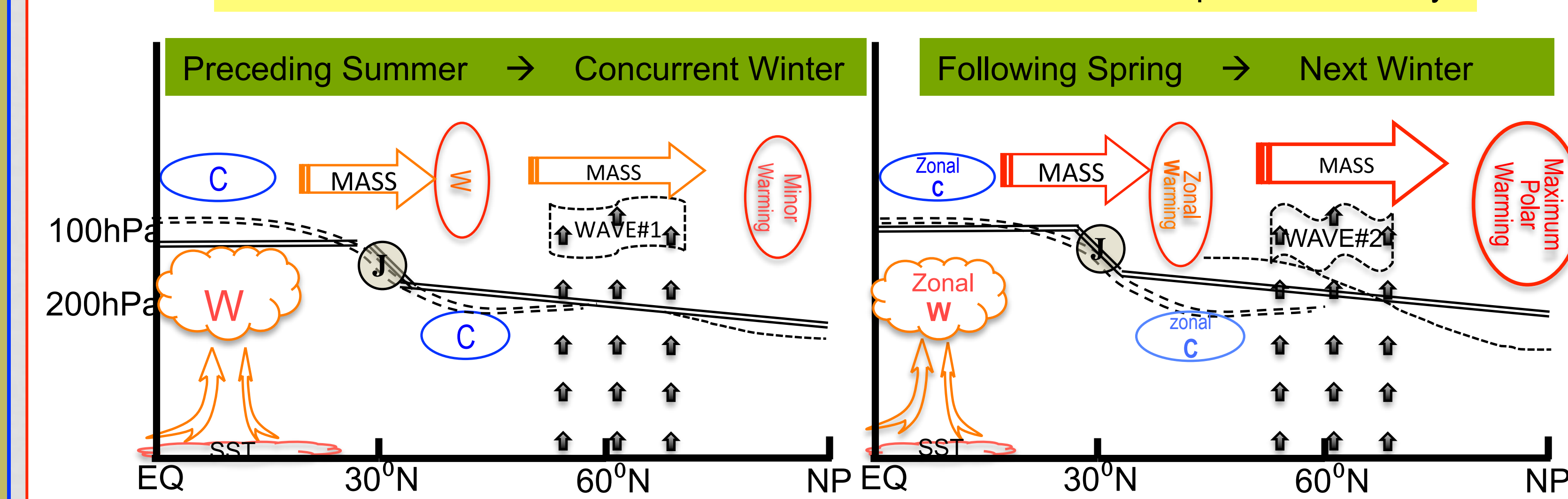


• Following warm ENSO, there is zonally homogeneous warm anomalies persisting in the midlatitude stratosphere from the preceding summer to the following summer, which is coupled with the cooling anomalies just below in the upper troposphere.

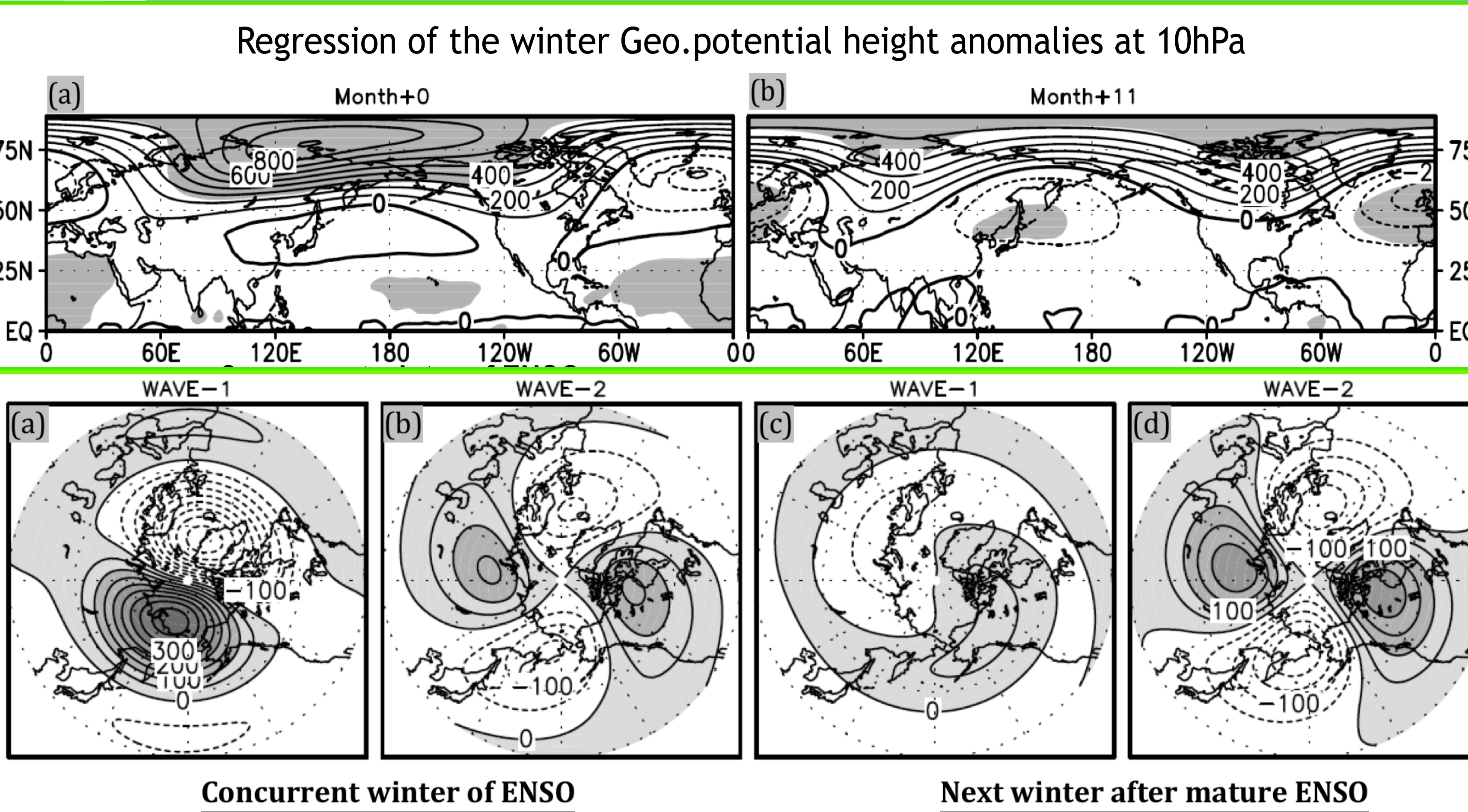
## Summary and Conclusion:

1. Significant lagged relationship between ENSO and PVO exists in 3-5 year timescale. Maximum response of PVO is in the next winter after ENSO peak.
2. The global mass circulation strengthens during Warm ENSO, exhibiting poleward and downward propagation.
3. Planetary wave-1/wave-2 in the concurrent/next winter following ENSO.

Schematics for the connection between ENSO and the stratospheric variability



4. Warm and positive mass anomalies persists in the midlatitude stratosphere from the preceding to the following summer following warm ENSO. (REN et al., 2011, *Cli. Dyn.*, DOI: 10.1007/s00382-011-1137-7)



Concurrent winter of ENSO

Next winter after mature ENSO

Positive height anomalies in both winters. An anomalous Aleutian high in the concurrent winter increasing wavenumber-1 of planetary wave; in the next winter after ENSO peak, wavenumber-2 dominates.