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An analysis on observed and simulated PNA associated atmospheric diabatic heating

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An analysis on observed and simulated PNA associated atmospheric diabatic heating

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1. Introduction
2. Data and Methods
3. Results
   a. Diabatic heating
   b. Dynamical aspects
4. Summary
Excitation of the PNA by the atmospheric heating

- Relating atmospheric heating to SST anomalies
  (eg, Horel & Wallace, 1981; Wallace & Jiang, 1987; Renwick & Wallace, 1996; Trenberth et al., 1998; Held et al., 2002)

- ENSO related SST forcing
  a. ENSO forcing can selectively amplify natural forms of internal variability but cannot generate new structures
     (eg, Lau, 1997; Hoerling et al., 1997; Palmer, 1999);
  b. Climate variability on the PNA sector is not strongly related to ENSO
     (eg, Deser & Blackmon, 1995; Zhang et al., 1996).
     Particularly, ENSO forces a circulation pattern quite distinct from the internally generated PNA variability
     (Straus & Shukla, 2002).
● Maintenance of long-lived atmospheric anomalies
  ○ Interaction between the anomalies and the time-mean flow
    (eg, Branstator, 1992; Hoskins & Karoly, 1981; Branstator, 1983; Simmons et al., 1983; Trenberth, 1986)
  ○ Transient eddy feedbacks
    (eg, Branstator, 1992; Hoskins et al., 1983; Lau, 1988; Nakamura & Wallace, 1990; Trenberth et al., 1998)

● Objective

Analyze thermodynamic and dynamic aspects responsible for the PNA variability by linearly isolating the influence of ENSO.
● Analysis data

a. NCEP/NCAR and ERA-40 reanalyses
   (Sept.1957-Aug.2002; Kistler et al., 2001; Uppala et al., 2005)

b. CCCma’s CGCM 1000-yr control simulation
   (AGCM: 3.75*3.75L10, OGCM: GFDL-MOM 1.8*1.8L29; Flato et al., 2000; Boer et al., 2000)

● Diagnostic methods

a. Diabatic heating
   ○ 3D diabatic heating (e.g., Hoskins et al., 1989; Nigam, 1994)
   ○ vertically integrated heating and energy transport
     (Boer, 1986; Trenberth et al., 1994; Yu & Boer, 2002)

b. Dynamical aspects
   ○ interaction between synoptic eddies and time-mean flow
     (e.g., Hoskins et al., 1983; Trenberth, 1986; Lau, 1988)
   ○ Rossby wave source (Sardesmukh & Hoskins, 1988)
Time series

Spectra

Corr. = 0.51

PNA: JISAO/NOAA, UW
Niño3.4: CPC/NCEP/NOAA
Time series

Spectra
List of DJF winters for PNA and Niño3.4 composites

|-------|--------------------------------------------------|

a) Years are labeled on January of the DJF winters.
b) PNAa indicates the index after removing the Niño3.4 contribution.
$\Phi_{500}$ anomalies (+PNA minus −PNA)

Removing ENSO
Correlations of vertically integrated heating $\tilde{Q}$ with the indices

$$\tilde{Q} = R_T - F_S + L(P - E)$$
Vertically integrated heating anomalies

(+PNAa minus –PNAa)

$\tilde{Q} = R_T - F_S + L(P - E)$

5% sig. test

NCEP

ERA40
Diabatic heating anomalies
(+PNAa minus –PNAa)

\[ Q_d \approx Q_{TAM} + Q_{Eddy} \]

5% sig. test
Vertical structure of heating anomalies (180-120W) (+PNAa minus -PNAa)
Lag-Corr. between PNAa and $Q_d(35-45N,180-120W)$

DJF months

entire series
Positive phase of PNAa (Aleutian Low)

200 hPa
Div > 0

600 hPa
Q_d > 0
Φ^- Pcp^+
TAM^+ ED^-

1000 hPa
Q_d < 0
Div < 0
SSTa < 0
T'_Q'sfc > 0
Atmos. generates T'

T'Q' > 0
$E = (\bar{v'}^2 - \bar{u'}^2, -\bar{u'}\bar{v}')$ and $\nabla \cdot E$ at 200hPa
Synoptic eddy feedbacks
(+PNAa minus -PNAa)

\[ \frac{\partial \Phi}{\partial t} \approx f \nabla^{-2} \left[ -\nabla \cdot (u^t \xi^t) \right] \]
Lag-Corr. between -PNAa and HF-eddy forcing over (35-45N, 180-120W)

Forcing leads                                -PNAa leads
-3        -2        -1          0         1          2         3
Lag time (months)

NCEP

-0.4  -0.2    0.0    0.2    0.4    0.6    0.8
-3   -2    -1   0     1     2     3
Lag time (months)

200hPa
500hPa

ERA40

-0.4  -0.2    0.0    0.2    0.4    0.6    0.8
-3   -2    -1   0     1     2     3
Lag time (months)

200hPa
500hPa
Rossby wave sources ($S$) at 200hPa
(+PNA minus -PNA)

\[ S = -\nabla \cdot \left[ (\zeta + f) V_x \right] \]

5% sig. test
Positive phase of PNAa

HF Feedback

LF Dynamics
Vertically integrated heating $\tilde{Q}$ anomalies

(based on a 1000yr-CGCM simulation, heating regressed on PNA)
Summary

a. PNA-related diabatic heating
   ○ is dominated by a north-south dipole structure in the eastern Pacific.
   ○ The heating anomalies change sign with height in mid-latitudes, and have the same sign throughout the troposphere in the subtropics.
   ○ The independence of the PNA on ENSO from the heating viewpoint.

b. Over the North Pacific
   ○ The mid-latitude depression leads to enhanced precipitation.
   ○ The anomalous heating is supported by the anomalous advection of potential temperature by the time average motions.
   ○ The atmospheric heating contributes a positive feedback to the PNA.

c. Rossby wave sources exhibit a PNA-like train of forcing anomalies.
   The enhanced eddy activity over the NP is accompanied by eastward acceleration. The synoptic eddies feedback positively on the PNA centers of action.