Impact of East Asian Winter (EAWM) and Australian Summer Monsoons (ASM) on the Enhanced Surface Westerlies over the Western Tropical Pacific Ocean Preceding the El Niño Onset **

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International Ocean Vector Wind Science Team Meeting
June 3rd, 2014

** For more details of this talk, please refer to the following article:
Zheng, Y., R. Zhang, and M. A. Bourassa, 2014: Impact of East Asian Winter and Australian Summer Monsoons on the Enhanced Surface Westerlies over the Western Tropical Pacific Ocean Preceding the El Niño Onset. *J. Climate,* **27**, 1928–1944.

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Outline

I. Background and motivations

Strong westerly winds over the WTP are often found before the El Nino onset, and what can cause these westerly winds? We focus on those of low frequency (>90 days but < 6 months)

II. Method and data

Composite analysis using observational data and analytic model experiments

III. Observational results

Examine the association of westerly anomaly over the WTP with EAWM and ASM in boreal winters before El Nino onset in the NCEP-NCAR reanalysis data.

IV. Model results

Seek a dynamic link of WTP westerly anomaly with EAWM and ASM to explain what we found in observations

Background and motivations

- Episodes of strong westerly winds (e.g., westerly wind bursts (WWBs) (< 90 days)) are mostly found over the western tropical Pacific Ocean (WTP) before El Niño Onset. The genesis of WWBs has been found in literatures (Lim and Chang 1981; Keen 1982, 1988;Lau et al. 1989; Kiladis and Loon 1988).

- Variation of surface winds over the WTP on the interannual time scale also plays an important role in the onset of El Niño (e.g., Rasmusson and Carpenter 1982; Zhang and Huang 1998; Rong et al. 2011)

- We examine what causes the low-frequency surface winds (> 90 days but < 6 months) before El Nino events? Here we propose that

(1) The low-frequency surface westerlies over the WTP occur mostly and are enhanced in boreal winters before El Niño Onset, and

(2) *the enhancement can be associated with the concurrent anomalous EAWM and ASM*

Method and Data

Methods

- Examine a composite of winters preceding El Nino onset
- A simple, linear, Gill-type analytic atmospheric model

Data

- NOAA ER version 3 SST (Monthly mean, 2^{o} X 2^{o}, Jan 1948–Dec 2007)
- NCAR-NCEP Reanalysis-1 product (Monthly mean, 2.5^{o} X 2.5^{o}, Jan 1948–Dec 2007): zonal and meridional surface winds, surface air temperature, surface air pressure

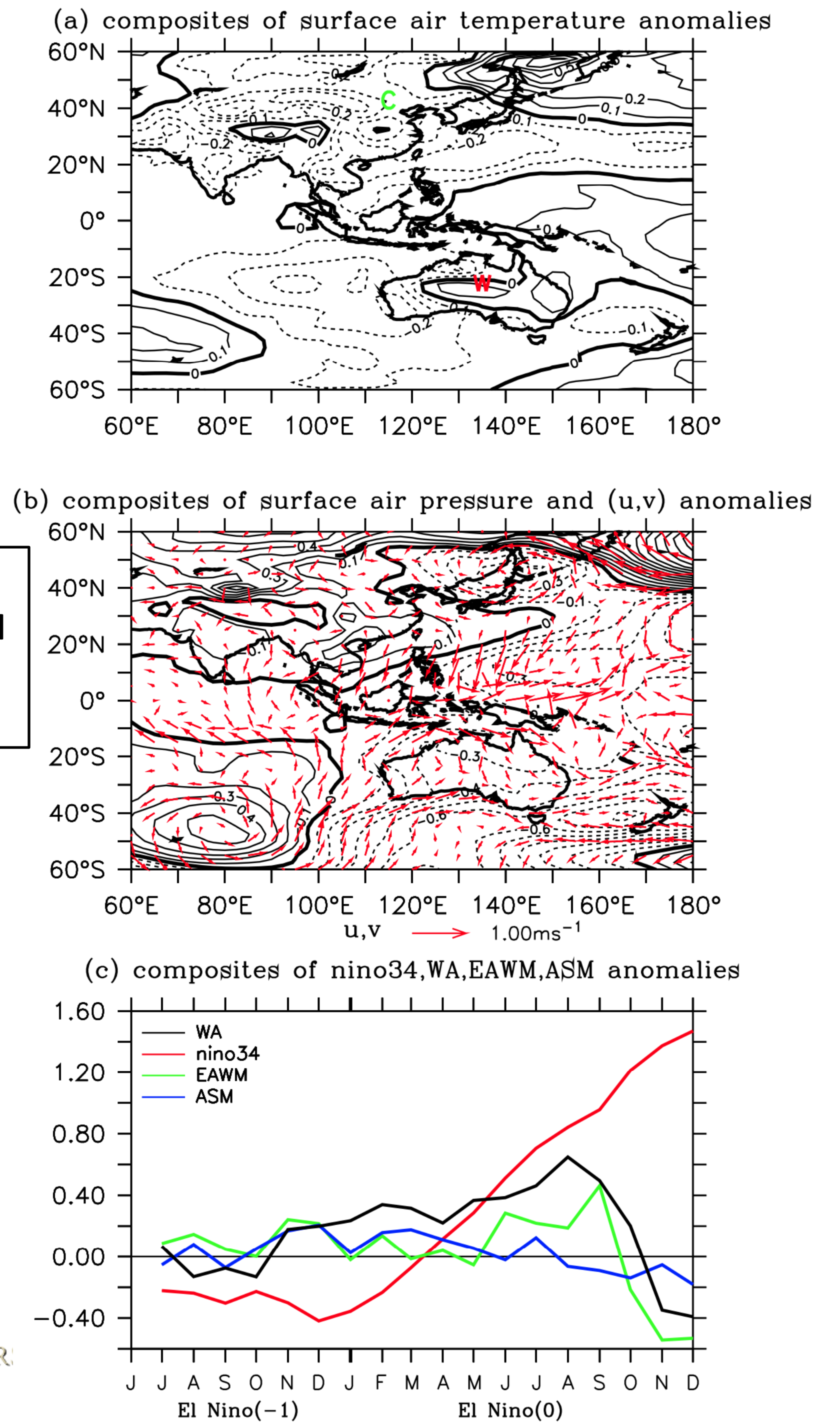
16 El Niño events during Jan 1948–Dec 2007 based on NOAA's El Niño definition*:

Begin	End	Duration (months)
Jun 1951	Dec 1951	7
Apr 1957	Jul 1958	16
May 1963	Dec 1963	8
May 1965	Mar 1966	11
Jun 1968	Jan 1970	20
Apr 1972	Feb 1973	11
Aug 1976	Jan 1977	6
May 1977	Jan 1978	9
Apr 1982	Jul 1983	16
Jul 1986	Jan 1988	19
Apr 1991	Jul 1992	16
Apr 1994	Feb 1995	11
Apr 1997	May 1998	14
Apr 2002	Feb 2003	11
May 2004	Jan 2005	9
May 2006	Jan 2007	9

NOAA's El Niño definition*: El Niño episodes over the period 1948–2007 as defined by a 3-month running mean of SST anomalies in the Nino3.4 region (5°S–5°N, 170°–120°W) and exceeding a +0.5°C threshold for at least 5 consecutive months. The anomalies are derived from the 1948–2007 SST climatology.

Composite features

Atmospheric features in horizontal space are composited according to 16 El Nino (-1) winters (November – April)



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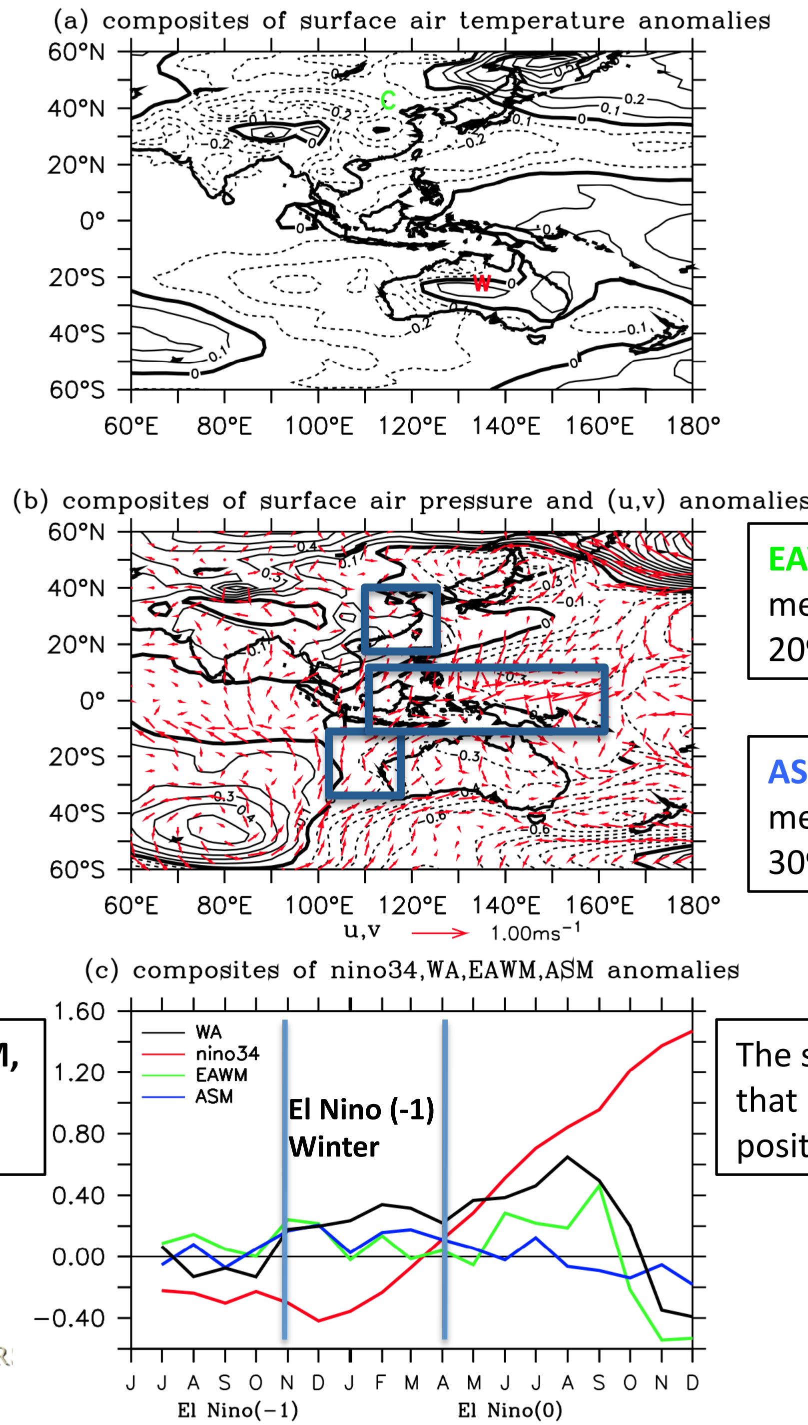


EAWM: anomalous surface meridional winds averaged over 20°N–40°N, 110°–130°E

WA: anomalous surface zonal winds averaged over 10°S–10°N, 110°–160°E

ASM: anomalous surface meridional winds averaged over 30°S–10°S, 100°–120°E

Evolution of composited EAWM, ASM and WA from El Nino (-1) winters to El Nino (0) years

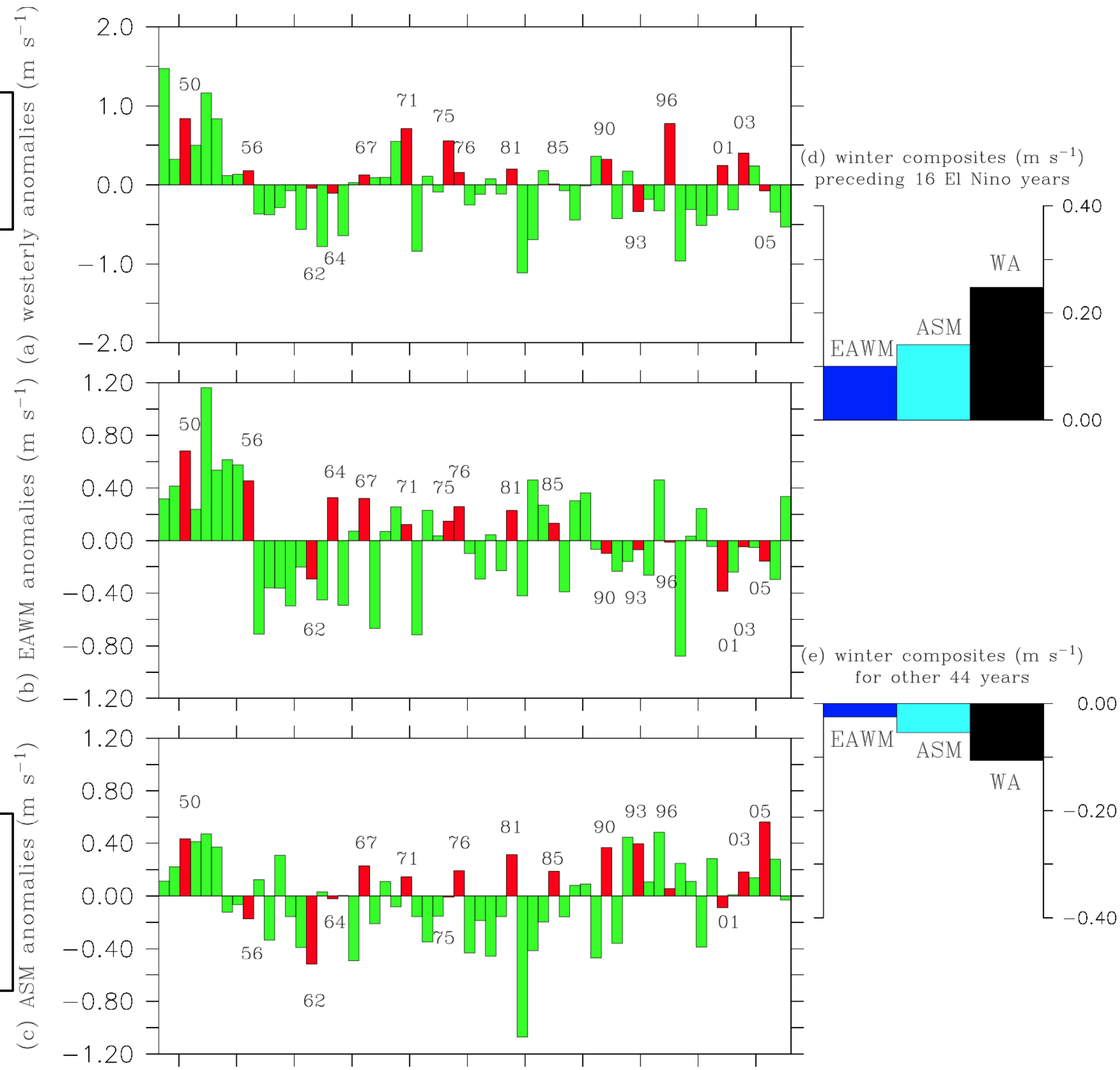
The sign of **EAWM** is reversed so that northerly anomaly is positive

Winter-averaged (Nov – Apr) WTP's surface westerlies, EAWM, and ASM during 1948 – 2008

WA: anomalous surface zonal winds averaged over 10ºS–10ºN, 110º–160ºE

EAWM: anomalous surface meridional winds averaged over 20ºN–40ºN, 110º–130ºE

ASM: anomalous surface meridional winds averaged over 30ºS–10ºS, 100º–120ºE



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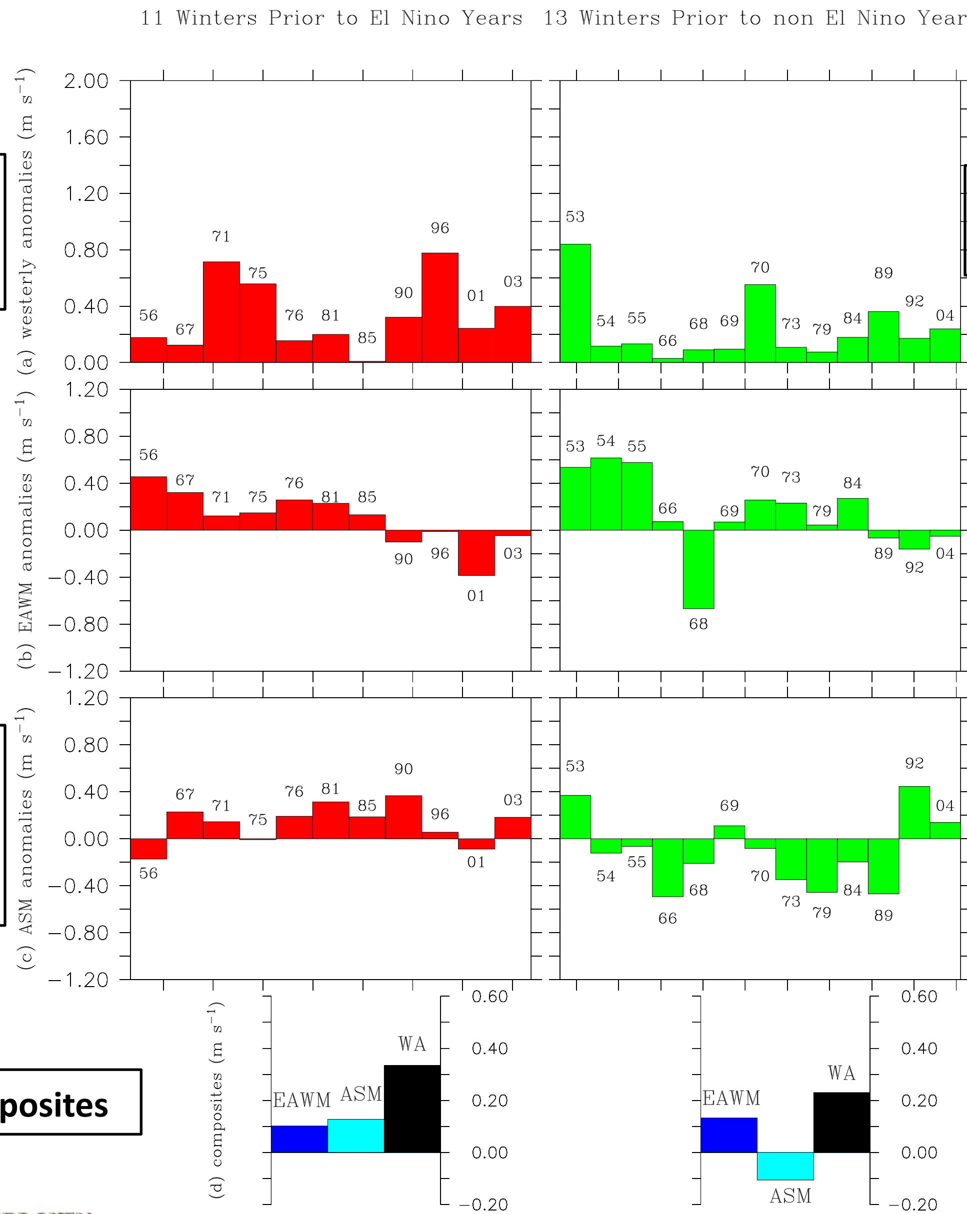
When surface westerlies over the WTP are present, then what are different features of EAWM and ASM between winters preceding El Nino onset and other winters?

WA: anomalous surface zonal winds averaged over 10ºS–10ºN, 110º–160ºE

EAWM: anomalous surface meridional winds averaged over 20ºN–40ºN, 110º–130ºE

ASM: anomalous surface meridional winds averaged over 30ºS–10ºS, 100º–120ºE



Positive: westerly anomaly

Positive: northerly anomaly

Composites

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Summary of observational analyses

- *The low-frequency surface westerlies over the WTP occur mostly and are enhanced in boreal winters before El Niño Onset (i.e., El Niño(-1) winters)*

- *When surface westerlies in El Niño (-1) winters are present, they are mostly accompanied by the concurrent EAWM (i.e., anomalous northerly) and ASM anomalies (i.e., anomalous southerly).*

- *In other winters, when surface westerlies are present, they are not overall accompanied by the concurrent EAWM and ASM anomalies.*

Experimental Design using Gill-type model

I. Steady atmospheric response to an anomalous cooling over Northeast Asia:

$Q(x, y) = 2.5 \exp(-\lambda^2(y - y_c)^2 - \alpha^2(x - x_c)^2)$, where $\lambda = \alpha = 0.5$, $(x_c, y_c) = (-0.5, 4.0)$
the cooling center approximately located at (115°E, 40°N)***

II. Steady atmospheric response to a weak anomalous warming over Australia:

$Q(x, y) = -1.5 \exp(-\lambda^2(y - y_c')^2 - \alpha^2(x - x_c')^2)$, where $\lambda = \alpha = 0.5$, $(x_c', y_c') = (1.5, -2.5)$ the warming center approximately located at (135°E, 25°S)***

III. Steady atmospheric response to an anomalous cooling over Northeast Asia and a weak anomalous warming over Australia concurrently:

$Q(x,y) = 2.5 \exp(-\lambda^2(y - y_c)^2 - \alpha^2(x - x_c)^2) - 1.5 \exp(-\lambda^2(y - y_c')^2 - \alpha^2(x - x_c')^2)$

*****:** The real location (120°E, 0°) is taken to represent (0,0) in the model

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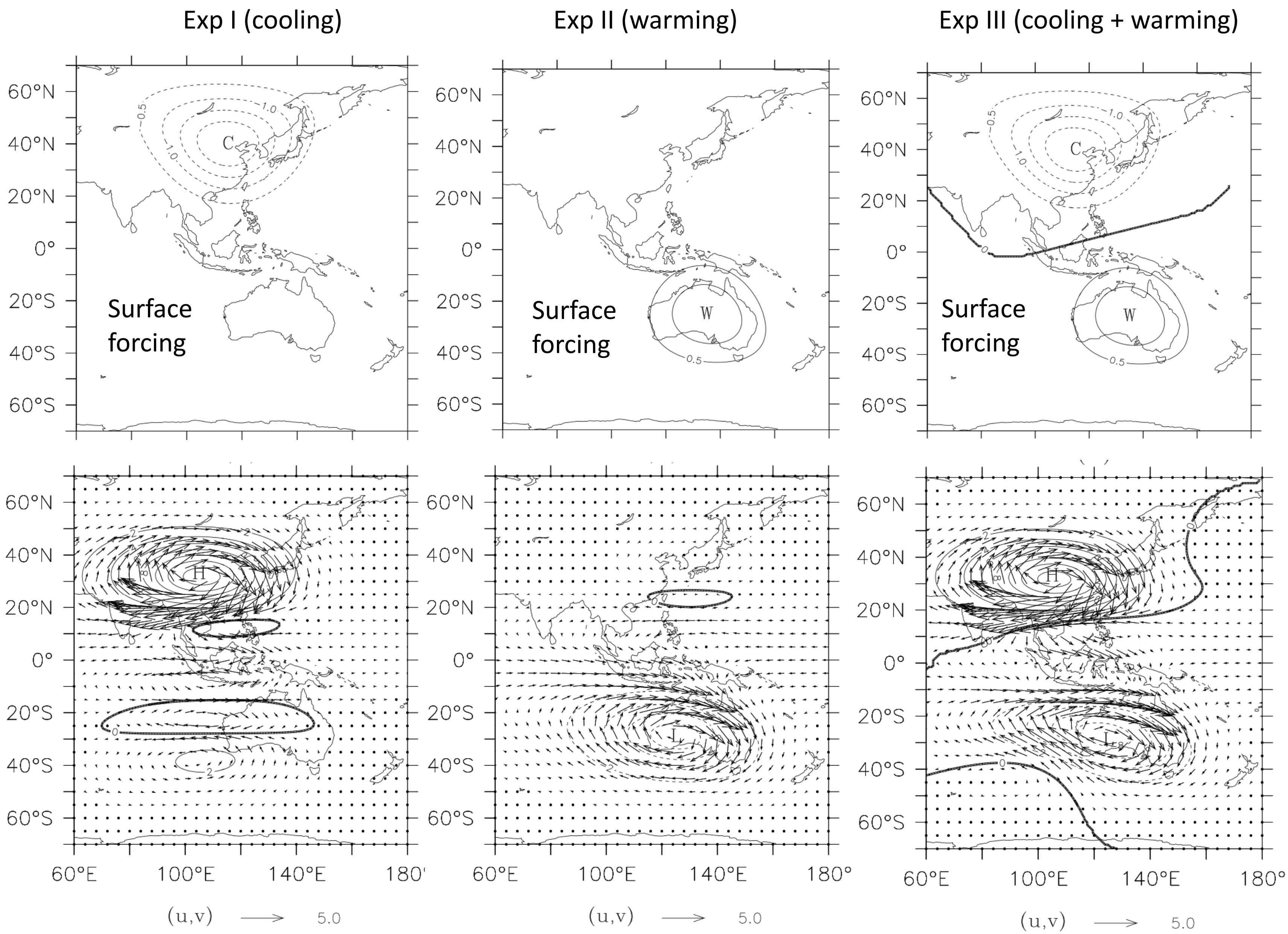

Surface winds in vectors and geopotential (ϕ) in contours

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Summary of model experiments

Strength of westerly anomaly (WA) averaged over the regions (110°–160°E, 10°S–10°N) in response to thermal forcing in three experiments.

Area Averaged WA	EXP I (Cooling)	EXP II (Heating)	EXP III (Heating+Cooling)
(110°–160°E, 10°S–10°N)	0.104	0.347	0.451

Simple model experiments show that when anomalous northerlies from the EAWM converge with anomalous southerlies from the ASM, westerly anomalies over the WTP are enhanced as a result of the Kelvin wave response.

Thanks ☺

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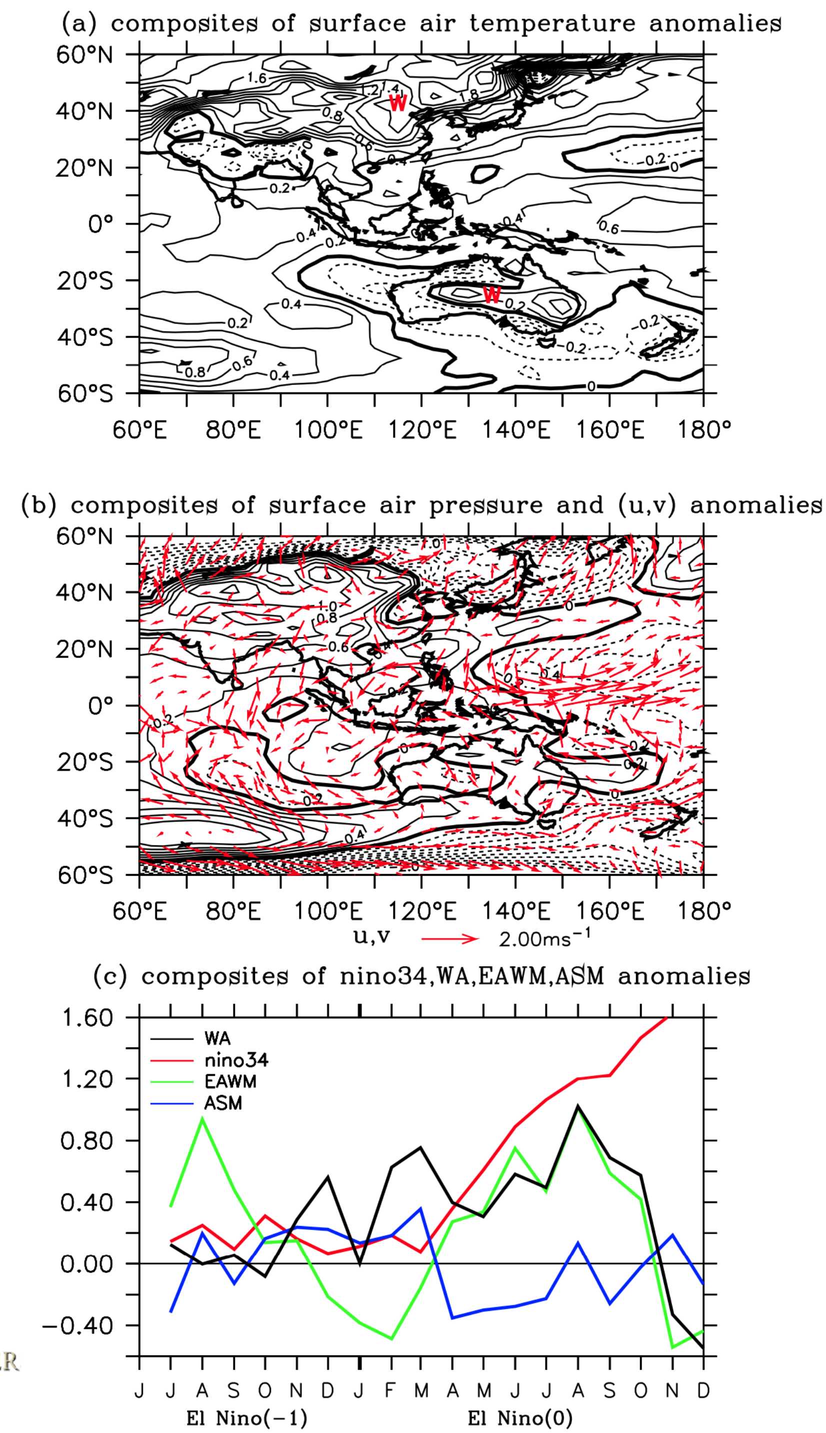

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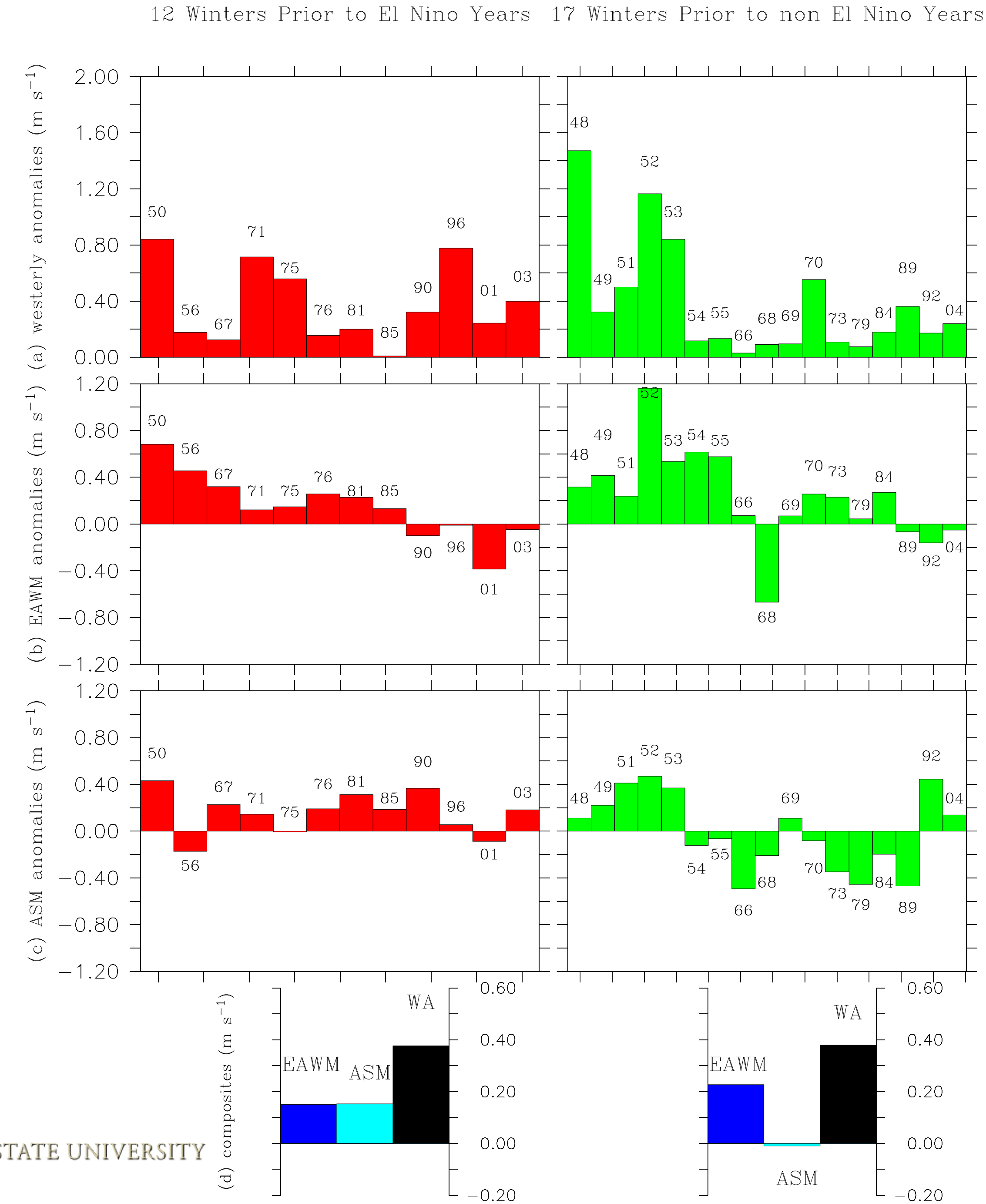

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Lau and Lim (1982)

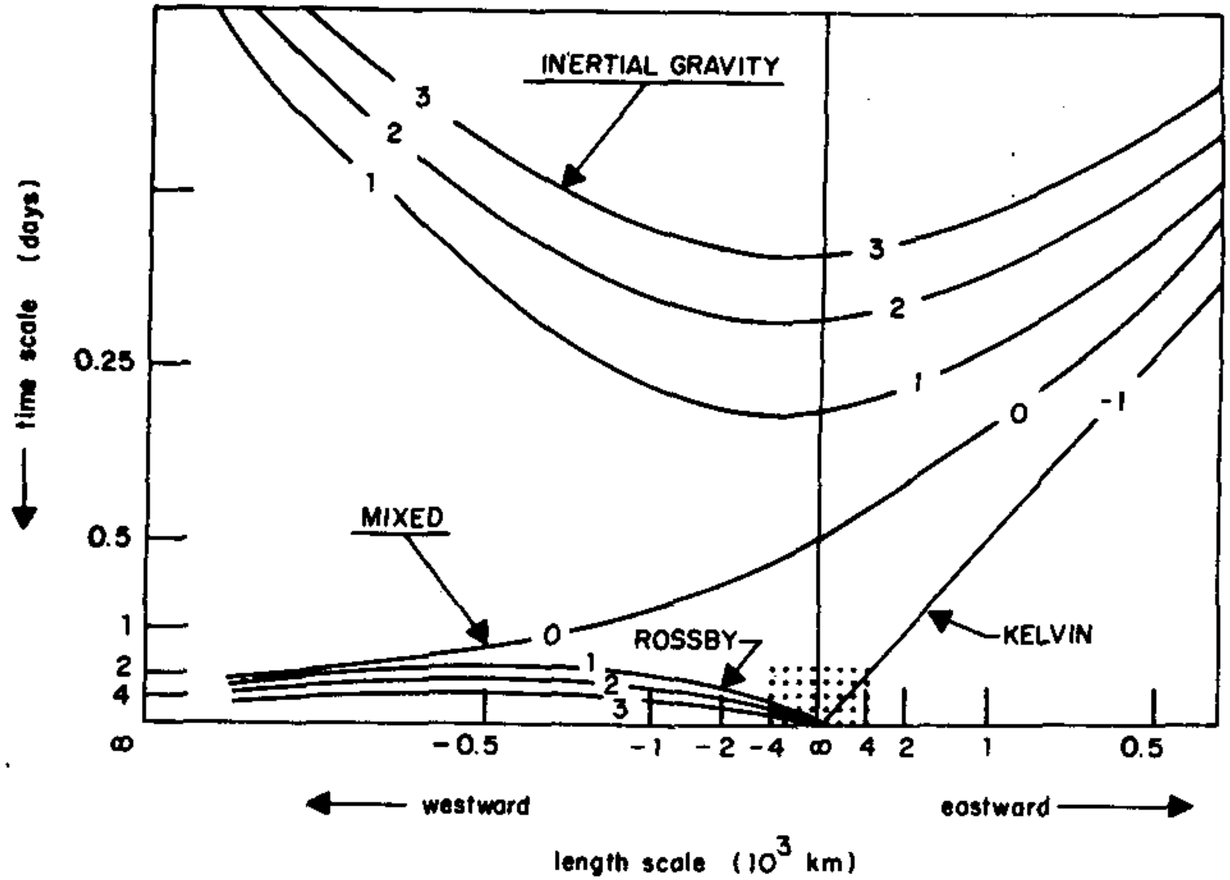

FIG. 1. Dispersion relation for the real part of the eigenfrequency and the wavelengths in an equatorial β-plane. The region within which the longwave approximation remains valid is indicated by stippling.

A simplified, linear, Gill-type analytic atmospheric Model

For slow and large-scale waves, small friction parameters, and assuming long wave approximation, the non-dimensional, linearized, steady state equatorial β-plane shallow water equations with no mean flow, are simplified as below:

$$\varepsilon u - \frac{1}{2} y v + \frac{\partial \phi}{\partial x} = 0$$

$$\frac{1}{2} y u + \frac{\partial \phi}{\partial y} = 0$$

$$\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + \varepsilon \phi = Q$$

Where *u* and *v* are the perturbations of low-level zonal and meridional winds, respectively. Other variables and parameters are defined as follows: ϕ is the geopotential height perturbation; *ε* is both the Rayleigh friction coefficient and the Newtonian cooling coefficient; *Q* is the forcing (i.e., diabatic heating/cooling rate) whereas a negative/positive *Q* implies heating/cooling when the model equations describe the behaviors of the lower layer of the atmosphere in this study.

To seek steady response to a prescribed steady surface forcing,
Gill's Methods (1980) ➔

$\Psi = \phi + u$, $\mathrm{X} = \phi - u$

$$(\Psi, \mathrm{X}, v, Q)(x,y) = \sum_{n=0}^{\infty} (\Psi_n, \mathrm{X}_n, v_n, Q_n)(x) D_n(y), \quad D_n(y) = (-1)^n \exp\left(\frac{1}{4}y^2\right) \frac{d^n}{dy^n} \exp\left(-\frac{1}{2}y^2\right)$$

The equations are

$$\frac{\partial \Psi_0}{\partial x} + \varepsilon \Psi_0 = Q_0$$

🡐Kelvin wave moving eastward with unit phase speed

$$\left(-\frac{1}{2n+1}\right)\frac{\partial \Psi_{n+1}}{\partial x} + \varepsilon \Psi_{n+1} = \frac{nQ_{n+1} + Q_{n-1}}{2n+1},$$

🡐 Rossby waves moving westward with phase speed 1/(2n+1)

$$\Psi_1 = 0, \quad v_0 = -Q_1, \quad v_n = \frac{2(n+1)}{2n+1}\frac{\partial \Psi_{n+1}}{\partial x} - \frac{(n+1)Q_{n+1} - Q_{n-1}}{2n+1}$$

$$\mathrm{X}_{n-1} = (n+1)\Psi_{n+1}, \ (n \geq 1)$$

Approximate solutions to the simplified Gill-type analytic atmospheric Model

$$u = \frac{1}{2}\left(\sum_{n=0}^{4}\left(\Psi_n D_n(y) - \mathrm{X}_n D_n(y)\right) + \sum_{n=5}^{6}\Psi_n D_n(y)\right)$$

$$\phi = \frac{1}{2}\left(\sum_{n=0}^{4}\left(\Psi_n D_n(y) + \mathrm{X}_n D_n(y)\right) + \sum_{n=5}^{6}\Psi_n D_n(y)\right)$$

$$v = \sum_{n=0}^{5} v_n D_n(y)$$

The Solution is expressed by the summation of a series of Rossby and Kelvin waves