Diversity of Surface Easterly Winds Along the Equator in El Niño and La Niña Events During 1997 to 2016

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Contents

- Motivation
- El Niño and La Niña Events in 1997 – 2016
- Zonal Wind Speeds in El Niño and La Niña Events Along Equator
  - Thermocline Depth
  - Upper Troposphere Zonal Wind
- Summary

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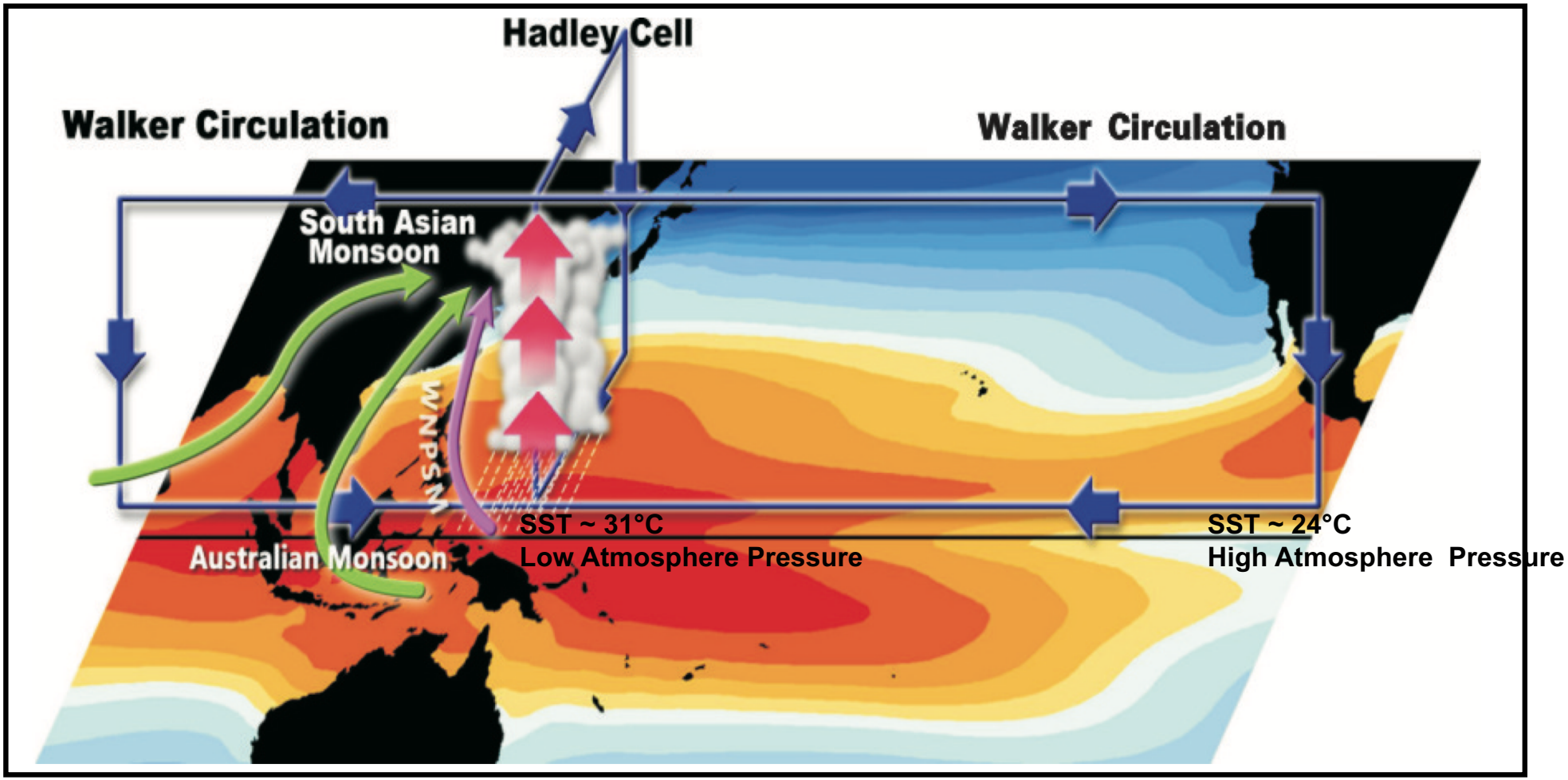
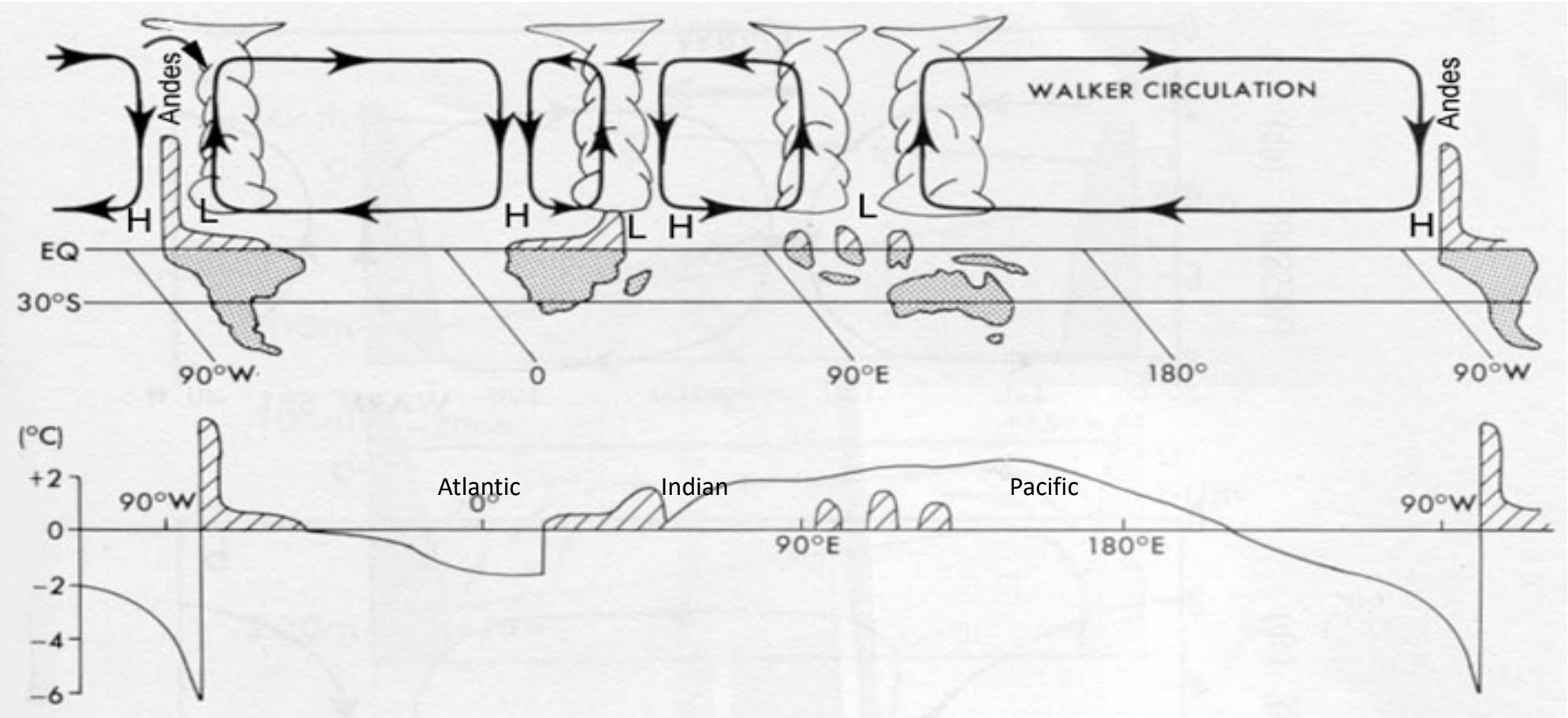
Motivation: Interaction of Atmosphere and Ocean in NPOCE



Hu et al. (2014) NPOCE Science / Implementation Plan

Global Walker Circulation and Sea Surface Temperature



http://biophysics.sbg.ac.at/atmo/el-scans/walker.jpg

N = 34
N = 62
N = 105

El Niño, La Niña, and Normal Time Intervals
(NOAA ONI Niño3.4 SSTA v4)

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1997	-0.5	-0.4	-0.2	0.1	0.6	1.0	1.4	1.7	2.0	2.2	2.3	2.3
1998	2.1	1.8	1.4	1.0	0.5	-0.1	-0.7	-1.0	-1.2	-1.2	-1.3	-1.4
1999	-1.4	-1.2	-1.0	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.2	-1.4	-1.6
2000	-1.6	-1.4	-1.1	-0.9	-0.7	-0.7	-0.6	-0.5	-0.6	-0.7	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	0.5	0.8	0.9	1.0
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3
2010	1.3	1.1	0.8	0.5	0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8
2012	-0.7	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2
2013	-0.4	-0.5	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
2014	-0.5	-0.6	-0.4	-0.2	0	0	0	0	0.2	0.4	0.6	0.6
2015	0.5	0.4	0.5	0.7	0.9	1.0	1.2	1.5	1.8	2.1	2.2	2.3
2016	2.2	1.9	1.5	1.1	0.6	0.2						

Super El Niño 1

La Niña 1

El Nino 1

El Niño 2

El Niño 3

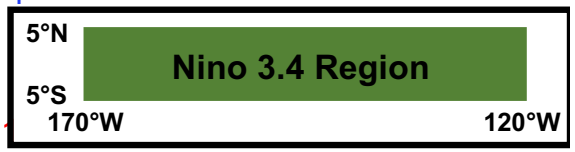
La Nina 2

El Niño 4

La Niña 3

La Niña 4

Super El Niño 2



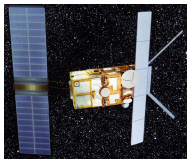
El Niño Intensity	SSTA (°C)
Weak	0.5 - 1.0
Moderate	1.0 - 1.5
Strong	1.5 - 2.0
Super	> 2.0

NPOCE

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Zonal Wind in 4 El Niño and 4 La Niña Events

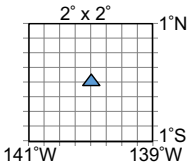
Methodology

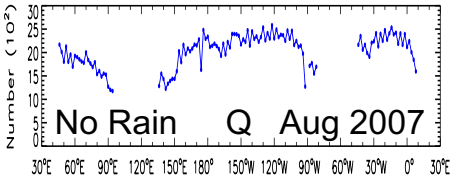


AMI-SCAT
on ERS-2

SeaWinds
on QuikSCAT

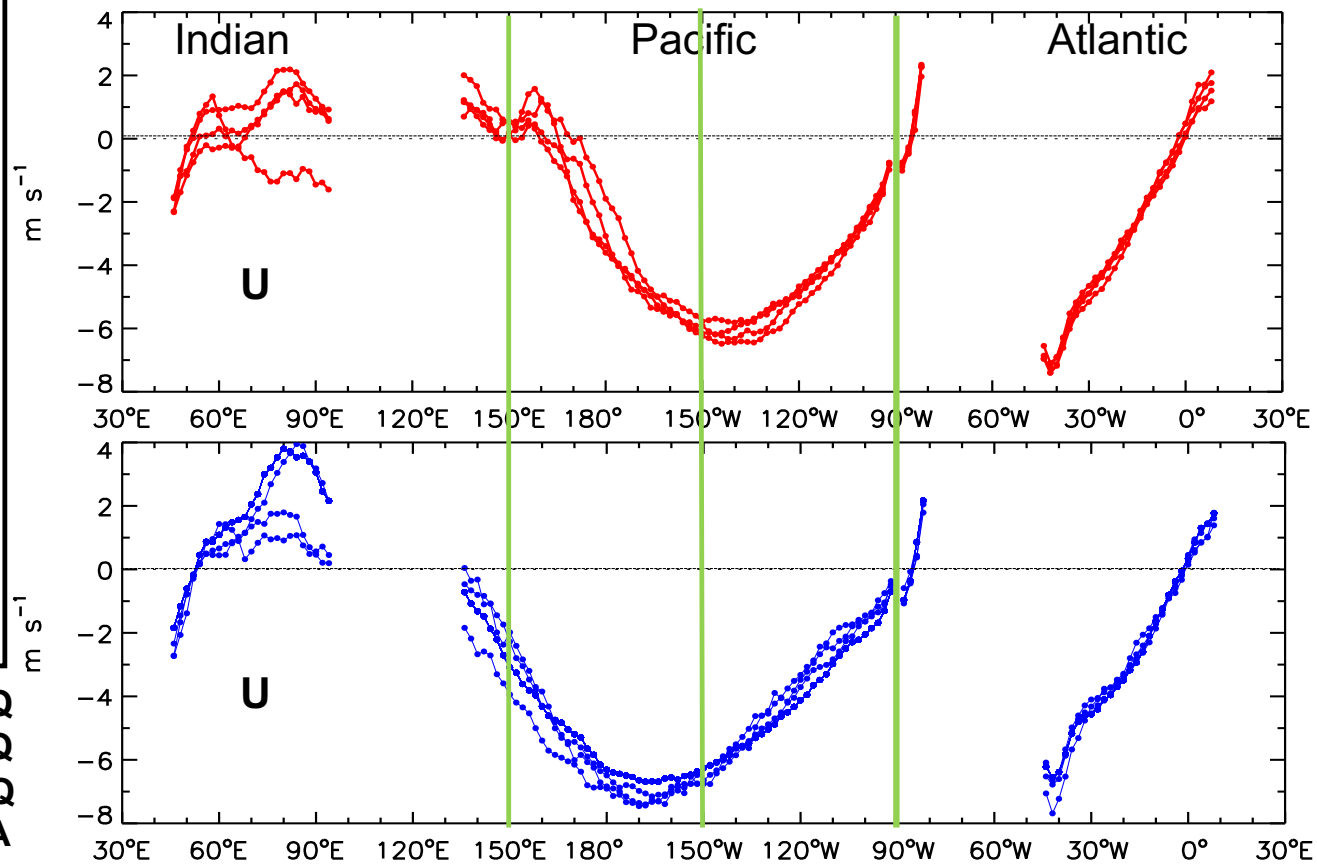
ASCAT-A
on MetOp-A





ERS-2 / QuikSCAT
KNMI v2.4 / RSS v4
17 months
$\langle \Delta U_{E-Q} \rangle = -0.18$ m s^{-1}
$\langle RMSD \rangle = 0.97$ m s^{-1}

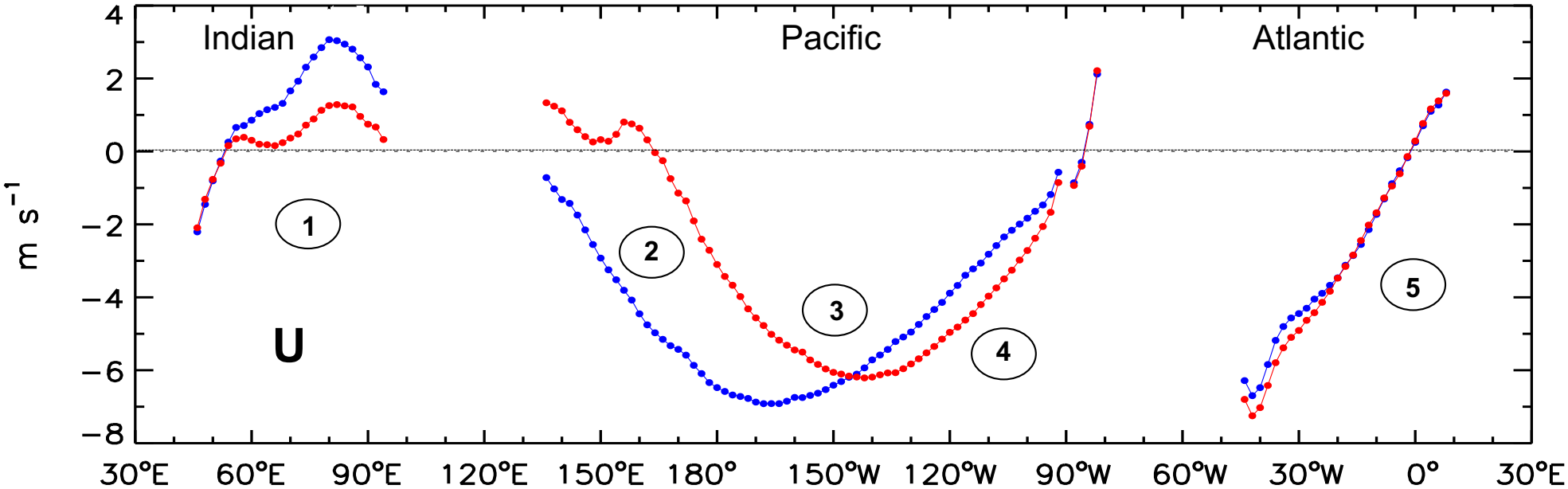
QuikSCAT/ ASCAT-A
RSS v4 / RSS v2.1
15 months
$\langle \Delta U_{A-Q} \rangle = 0.01$ m s^{-1}
$\langle RMSD \rangle = 0.36$ m s^{-1}



El Niño 1, Jun 2002 – Feb 2003 (9 mo) **Q**
El Niño 2, Jul 2004 – Apr 2005 (10 mo) **Q**
El Niño 3, Sep 2006 – Jan 2007 (5 mo) **Q**
El Niño 4, Jul 2009 – Apr 2010 (10 mo) **A**
La Niña 1, Jul 1998 – Mar 2001 (32 mo) **E+Q**
La Niña 2, Aug 2007 – Jun 2008 (11 mo) **Q**
La Niña 3, Jul 2010 – Apr 2011 (10 mo) **A**
La Niña 4, Aug 2011 – Mar 2012 (9 mo) **A**

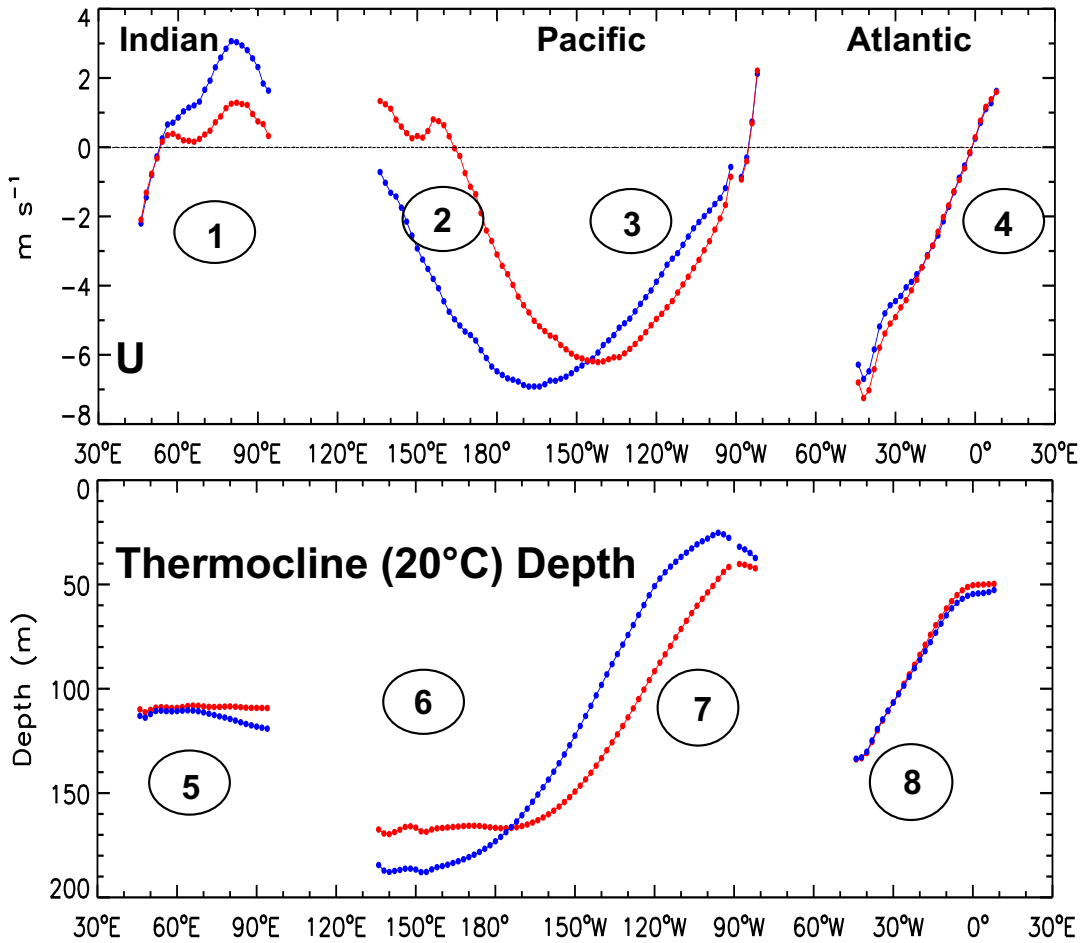
- **Similarity of each El Niño event in Pacific and Atlantic**
- **Similarity of each La Niña event in Pacific and Atantic**
- **Zonal wind collapse in west Pacific in each El Niño event**

< Zonal Wind Speed > During 4 El Niño Events and 4 La Niña Events



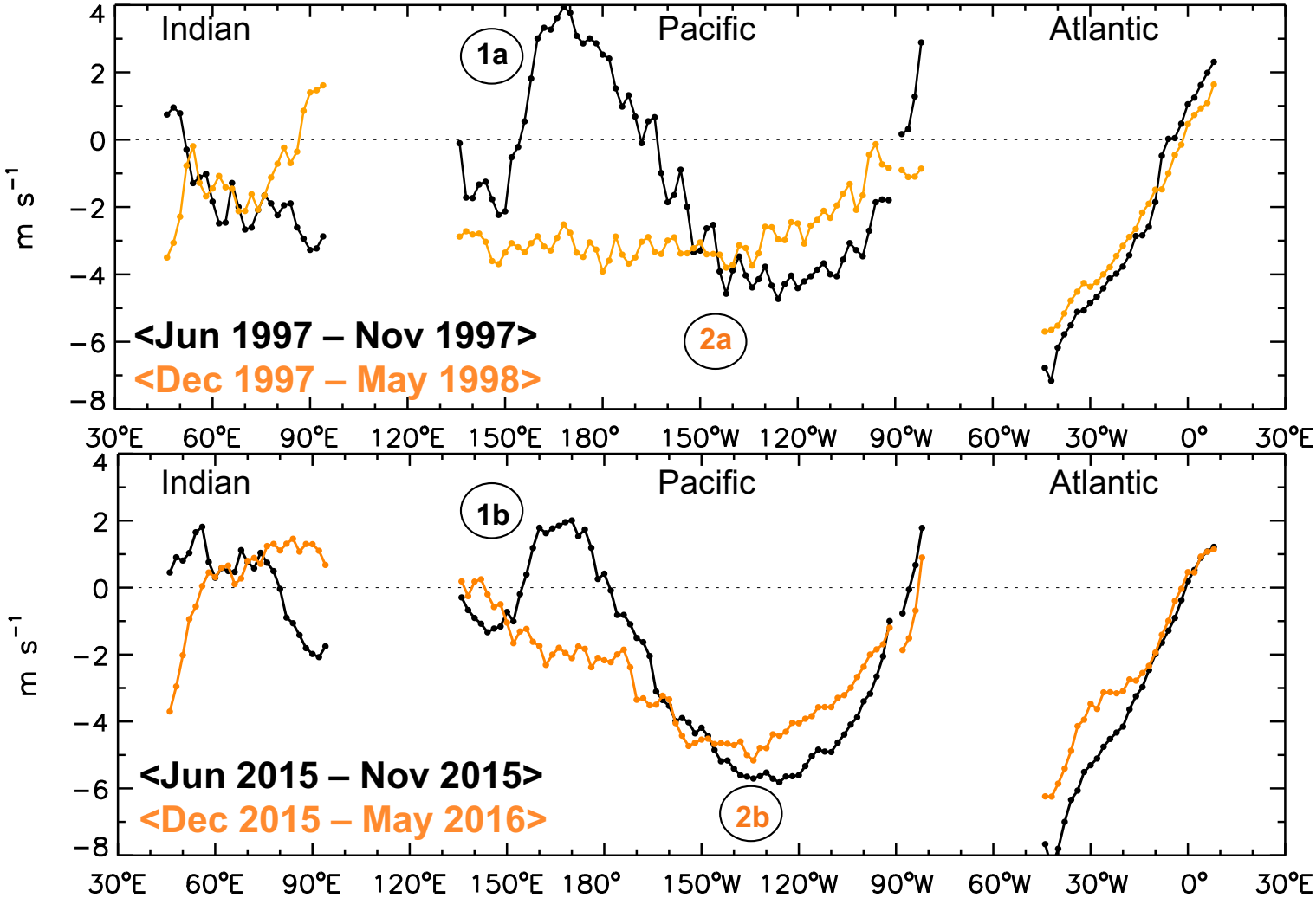
1. Westward wind speed west of 60°E and eastward wind direction east of 60°E
2. **Uwestward** < **Uwestward** in west Pacific by **3** m s^{-1}
3. **Uwestward max** was > 35° longitude to the west of **Uwestward max** (indicating an eastward movement of surface limb of Walker Cell in **El Niño** compared to **La Niña**)
4. **Uwestward** > **Uwestward** in east Pacific by **1** m s^{-1}
5. **U** is independent of **El Niño** or **La Niña**

< Zonal Wind Speed > and < Thermocline Depth>
in 4 El Niño Events and 4 La Niña Events



1) Westward wind speed west of 60°E and eastward wind direction east of 60°E
2) $U_{El\ Nino} < U_{La\ Nina}$ in west Pacific by 3 m s^{-1}
3) $U_{El\ Nino} > U_{La\ Nina}$ in east Pacific by 1 m s^{-1}
4) U is independent of **El Niño** or **La Niña**
5) Stronger **La Niña** eastward wind should produce more downwelling & deeper thermocline
6) Weaker **El Niño** westward wind should produce less downwelling at western boundary and shallower thermocline
7) Stronger **El Niño** westward wind in east Pacific [3] <u>should</u> produce more upwelling and shallower thermocline compared to **La Niña** – **not observed**
8) Westward wind speed should produce downwelling in west Atlantic and a deeper thermocline compared to east Atlantic

Zonal Wind Speed in 1997-1998 and 2015-2016 Super El Niño Events



Collapse of easterly wind in west Pacific

- 1a – very large in speed and longitude
- 1b – not as large in speed and longitude

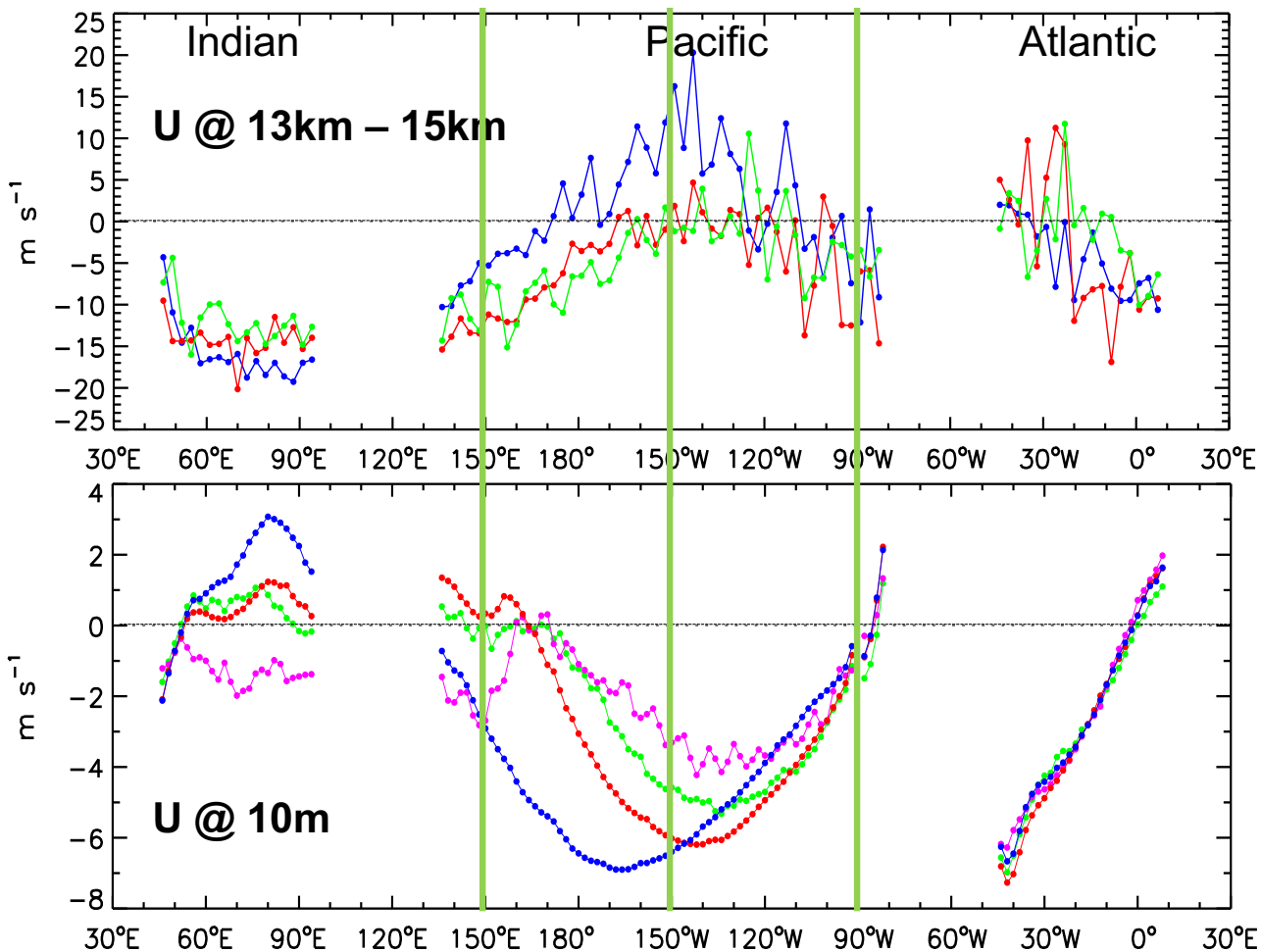
Longitudinal shape of U

- 2a – no bell-shape
- 2b – small bell shape

Maximum SSTA

- 2.3°C in 1997-1998 (2 months)
- 2.3C in 2015-2016 (1 month)

Surface and Upper Troposphere Zonal Wind Speeds



<4 Typical El Niño Events>

<4 Typical La Niña Events>

<May 1997 – May 1998>

<Mar 2015 – May 2016>

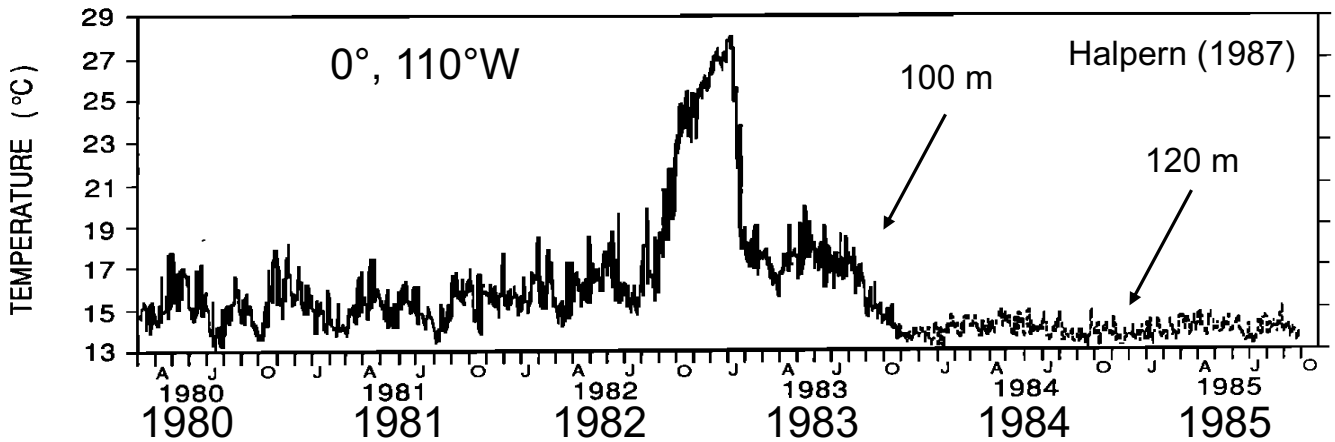
- In west Pacific, weaker vertical shear in **El Niño** would produce larger number of tropical storms (in NPOCE region). In **2015**, 27 tropical storms, 18 typhoons, and 9 super typhoons occurred in west Pacific. **[other years]**
- Weakest vertical shear in west Pacific occurred in super **El Niño**
- Walker Cell was stronger in **La Niña** than in **El Niño**

Summary

- Zonal Surface Wind
  - In west Pacific, westward surface wind collapsed in all **El Niño** events
    - Wind collapse was strongest in 6-month onset phase of super **El Niño** events
    - In super **El Niño** events, wind collapse extended to 165°W
  - In central and east Pacific, westward wind weaker in super **El Niño** compared to typical **El Niño**
  - In west Pacific, westward wind was 3 m s^{-1} smaller in **El Niño** compared to **La Niña**
  - In east Pacific, westward wind was 1 m s^{-1} larger in **El Niño** compared to **La Niña** **[puzzling]**
  - In the Atlantic, no evidence of **El Niño** and **La Niña** events
- Thermocline Depth
  - In west Pacific, thermocline depth in **El Niño** consistent with downwelling at Maritime Continent
  - In east Pacific, thermocline depth in **El Niño** not consistent with Ekman upwelling **[puzzling]**
- Zonal Surface and Upper Troposphere Winds
  - Pacific Walker Circulation Cell shifted east about 40° longitude in **El Niño** compared to **La Niña**
  - Fewer typhoons in west Pacific in **El Niño** compared to **La Niña** **[to be confirmed]**

Suggestions for Additional Research

- Use Numerical Weather Prediction Analyses (e.g., ECMWF and CMA Reanalysis)
  - Compare results obtained with satellite-derived surface and upper troposphere winds
  - Use NWP data to extend results to super **El Niño** event of April 1982 – June 1983



Super **El Niño** Event in April 1982 – June 1983, when maximum ONI SSTA was 2.1°C in Nov 1982, Dec 1982 and Jan 1983

Only 3 super **El Niño** events occurred since 1950

- Analyze satellite and NWP meridional and zonal wind components in 1997 – 2016 in NPOCE domain

THANK YOU