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

David Halpern

NASA Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California 91109, USA

and

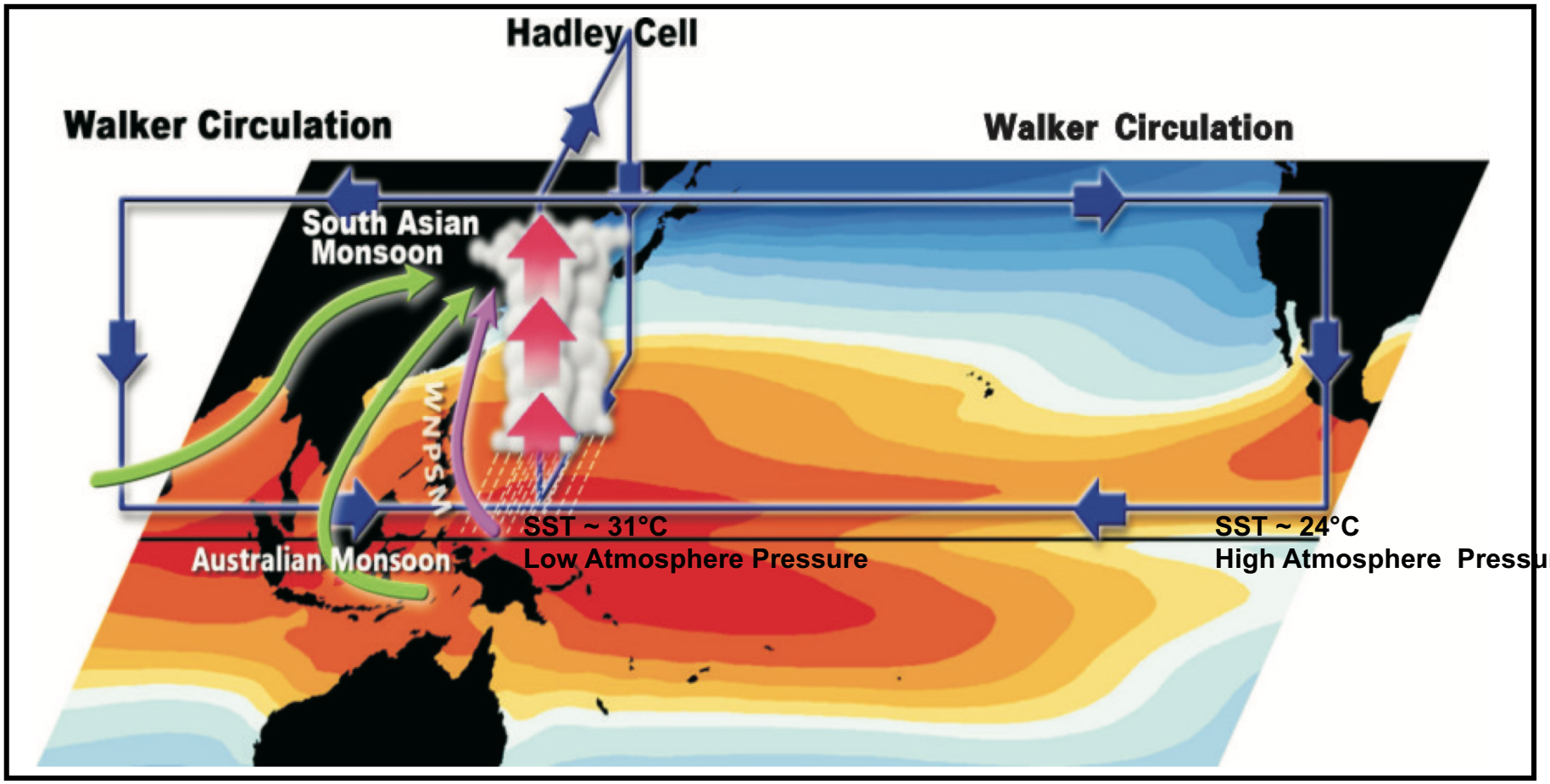
Scripps Institution of Oceanography, University of California San Diego
La Jolla, California 92093, USA

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 and Upper Troposphere Wind
- Summary and Recommendations

Copyrighted 2019 California Institute of Technology. Government sponsorship acknowledged.

Motivation: Interaction of Atmosphere and Ocean



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

N = 62
N = 62
N = 116

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	Super El Niño 1
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	La Niña 1
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	El Nino
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	El Niño 2
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	El Niño 3
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3	La Nina 2
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	El Niño 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	La Niña 3
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	La Niña 4
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	Super El Niño 2
2016	2.2	1.9	1.5	1.1	0.6	0.2							

N P O C E

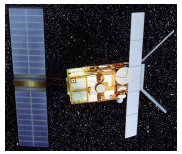
El Niño Intensity

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

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

Zonal Wind in 4 El Niño and 4 La Niña Events

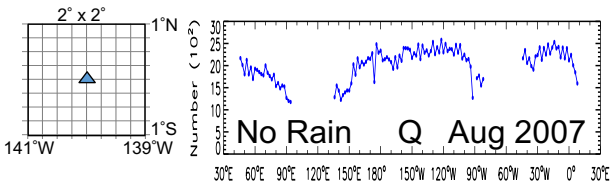
Methodology



AMI-SCAT
on ERS-2

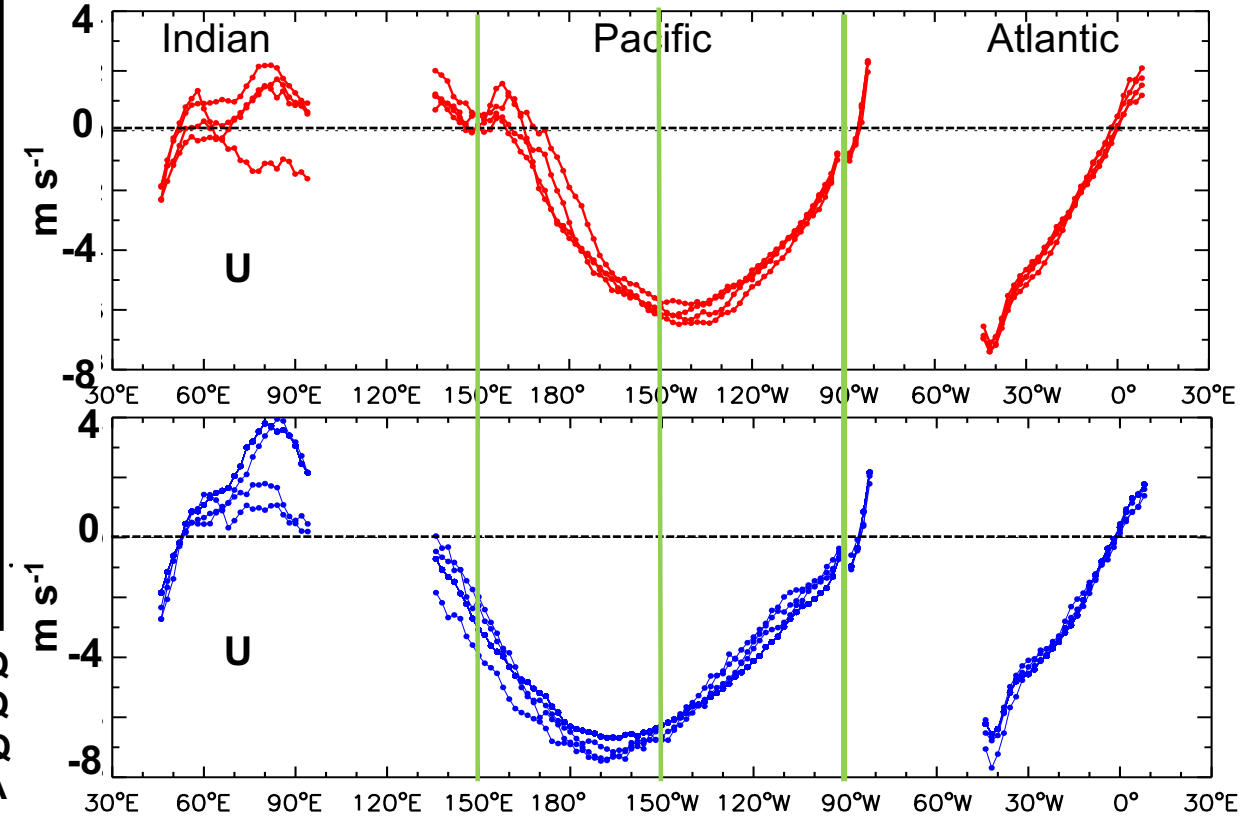
SeaWinds
on QuikSCAT

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}

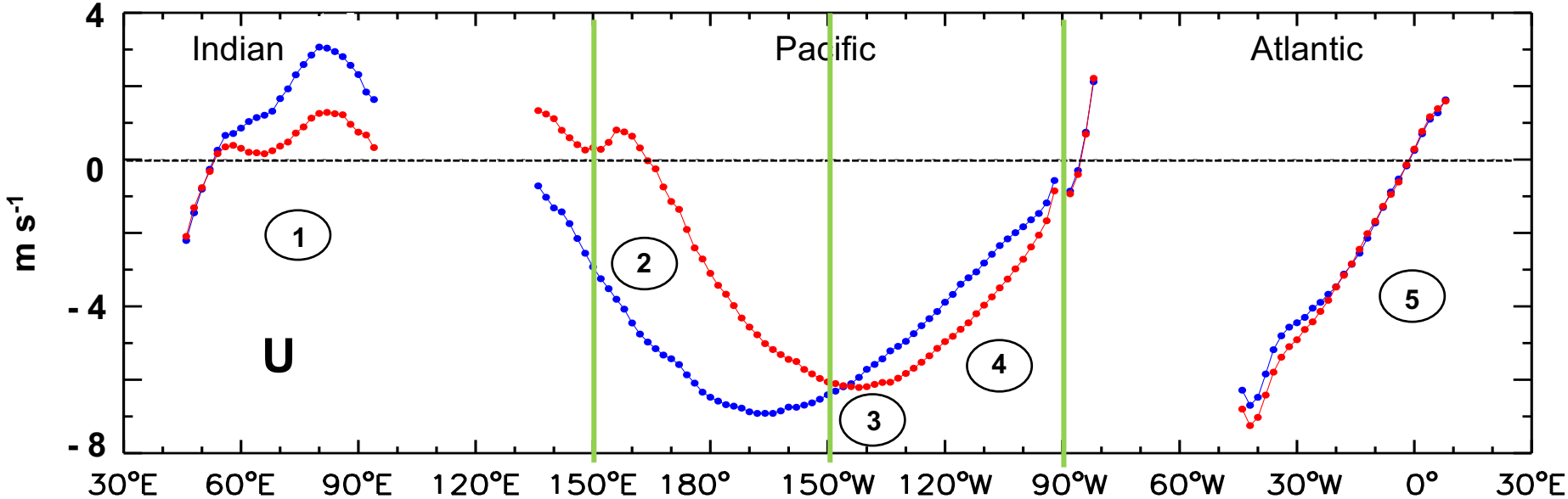
QuikSCAT/ ASCAT-A
RSS v4 / RSS v2.1
15 months
$\langle \Delta U_{A-Q} \rangle = 0.01$ m s^{-1}
$\langle RMSD \rangle = 0.36$ m s^{-1}



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**

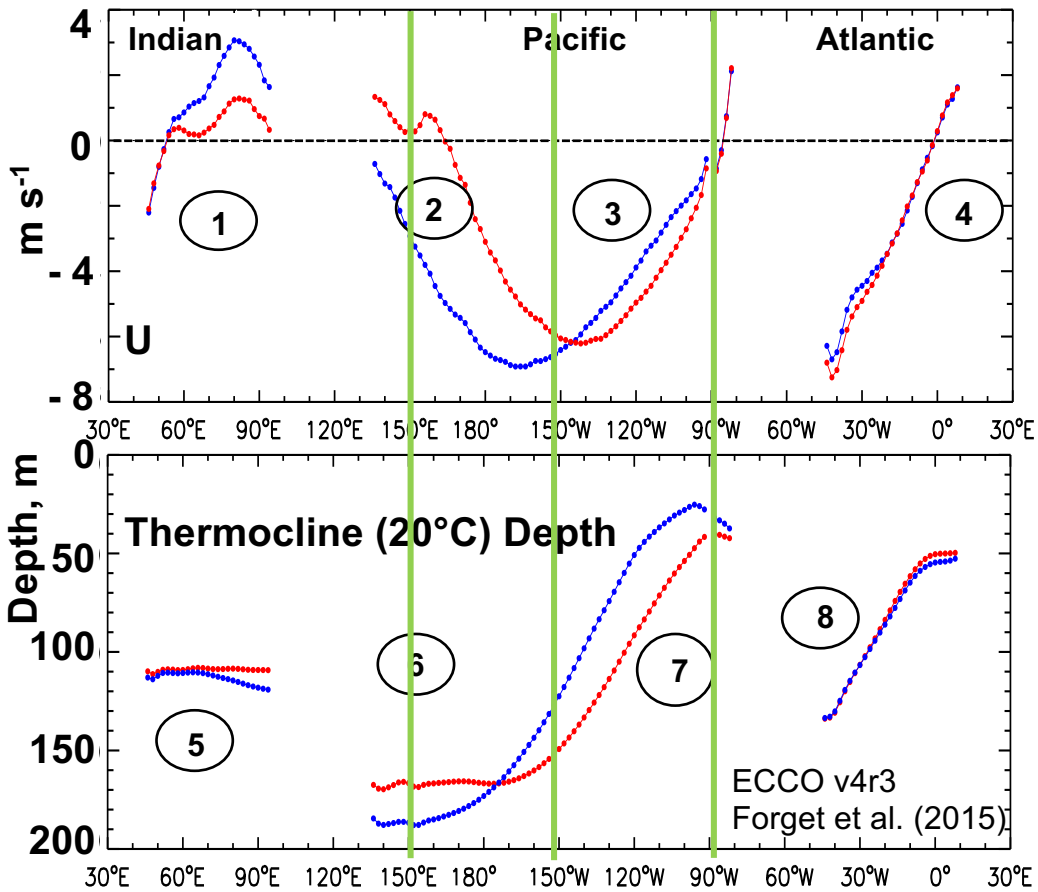
- **Similarity of each El Niño event in Pacific and Atlantic**
- **Similarity of each La Niña event in Pacific and Atantic**
- **Zonal wind collapse in west Pacific in each El Niño event**

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



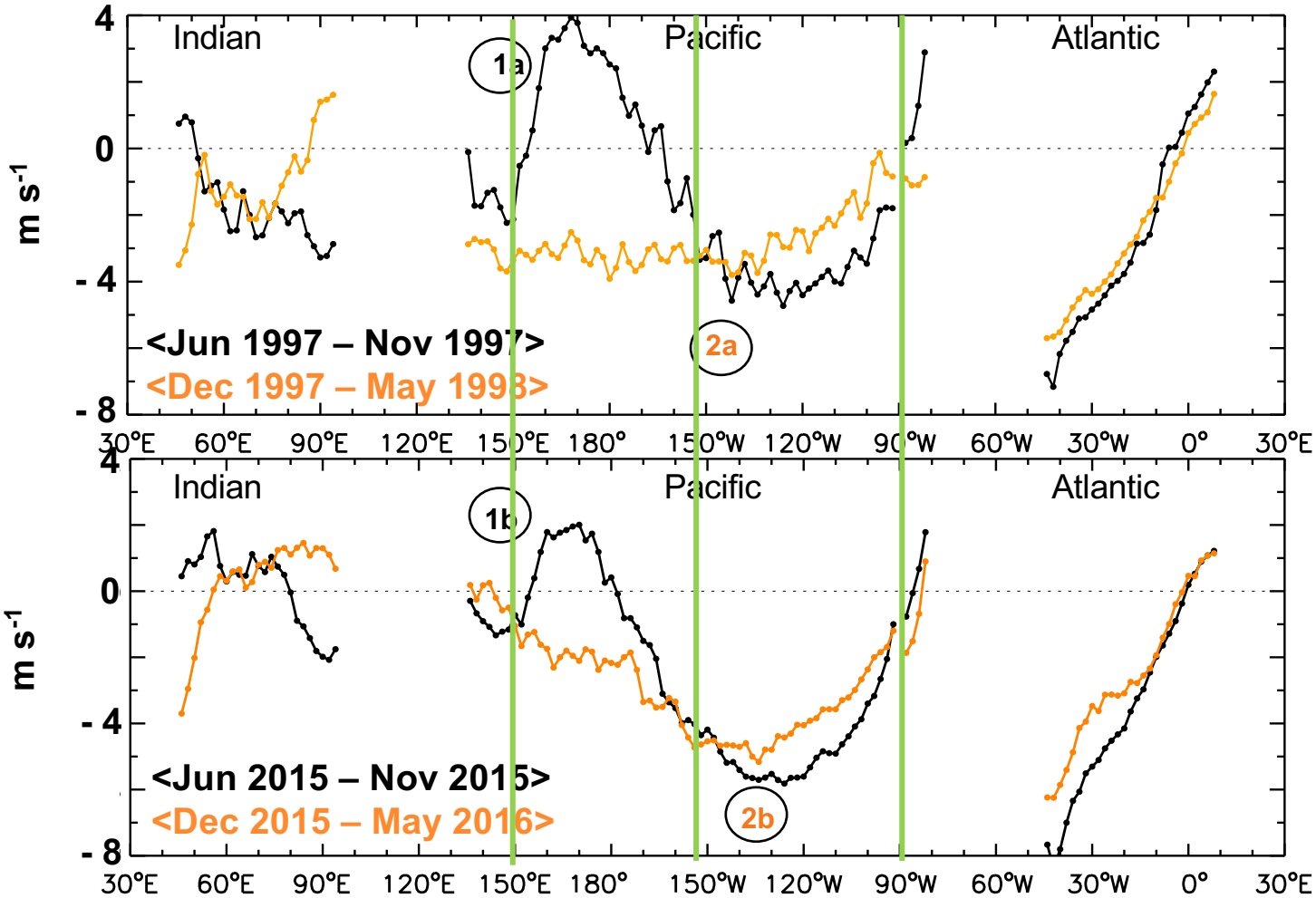
1. Westward wind speed west of 60°E and eastward wind direction east of 60°E
2. **Uwestward** < **Uwestward** in west Pacific by **3** m s^{-1}
3. **Uwestward max** was > 35° longitude to the west of **Uwestward max** (indicating an eastward movement of surface limb of Walker Cell in **El Niño** compared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

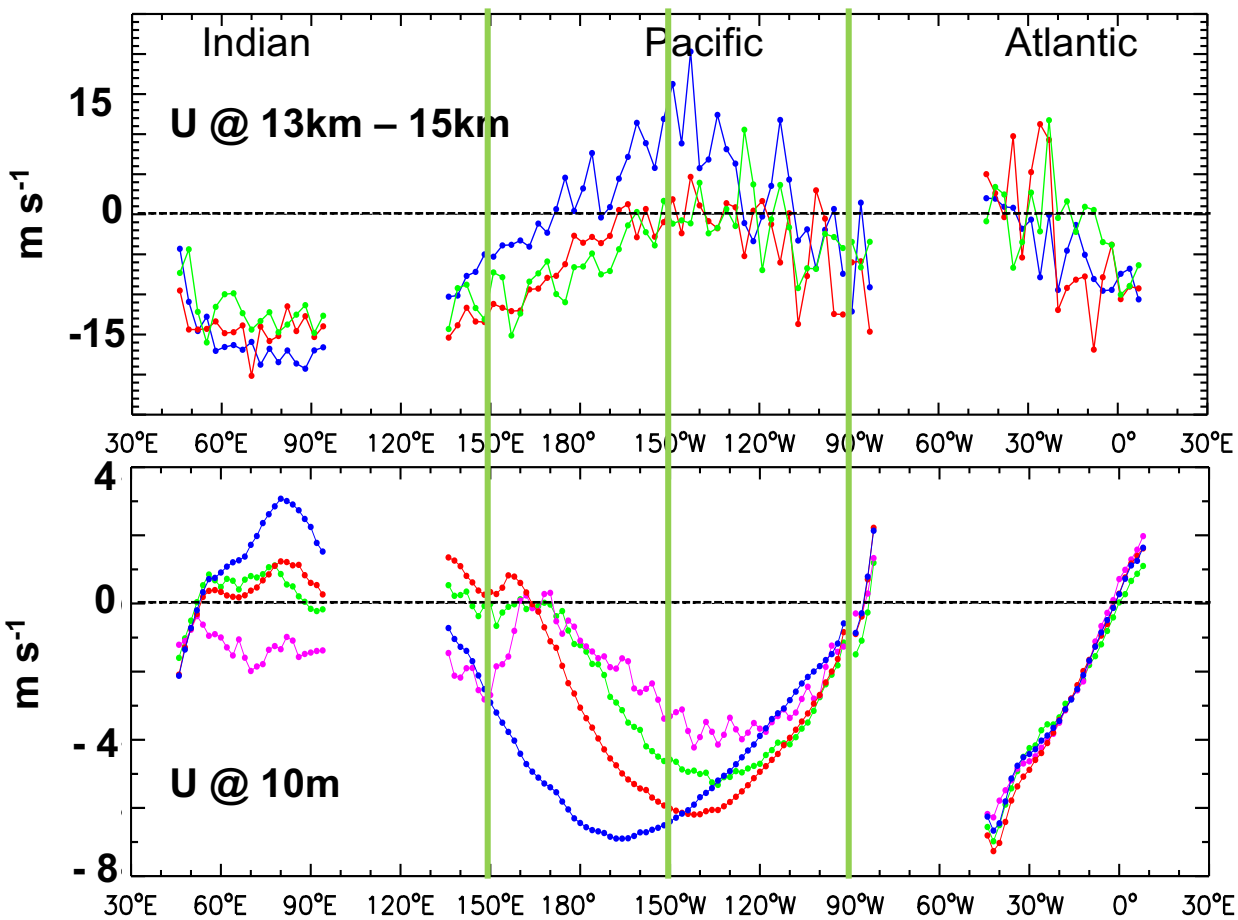
Longitudinal shape of U

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

Maximum SSTA

- 2.3°C in 1997-1998 (2 months)
- 2.3°C 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>

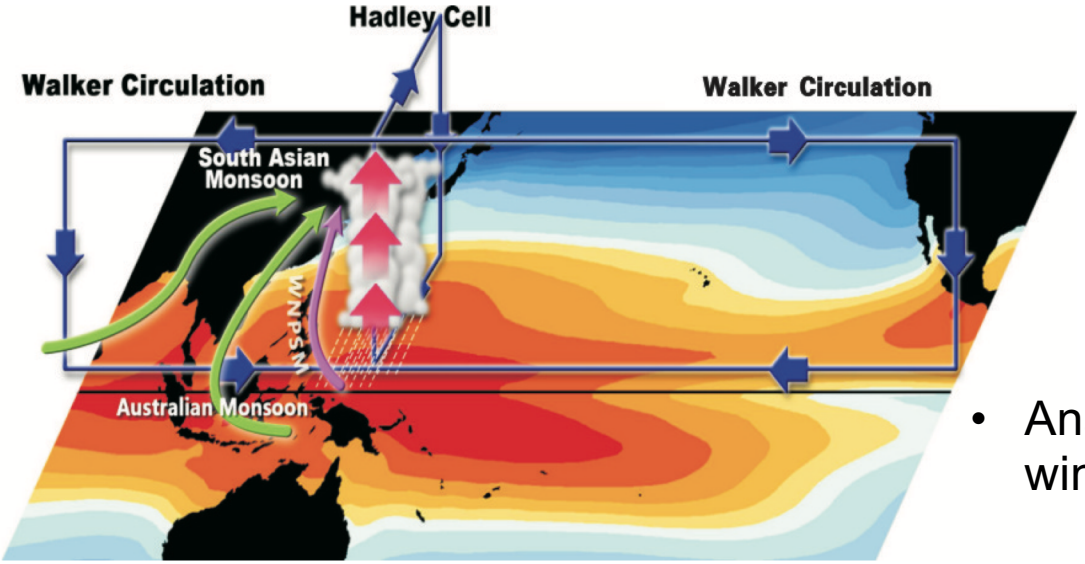
<Mar 2015 – May 2016>

- 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, extended to 165°E
    - 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 typical **El Niño** compared to typical **La Niña**
  - In east Pacific, westward wind was 1 m s^{-1} larger in typical **El Niño** compared to **La Niña** **[puzzling]**
  - Normal condition was the average of **El Niño** and **La Niña** conditions
  - 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]**

Recommendations



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

- Use NWP analyses to extend results to super **El Niño** event of April 1982 – June 1983
  - Only 3 super **El Niño** events have occurred
- Analyze satellite and NWP meridional wind components in 1997 – present