Pre-Monson Drought and Heat Waves in India Observed by TRMM

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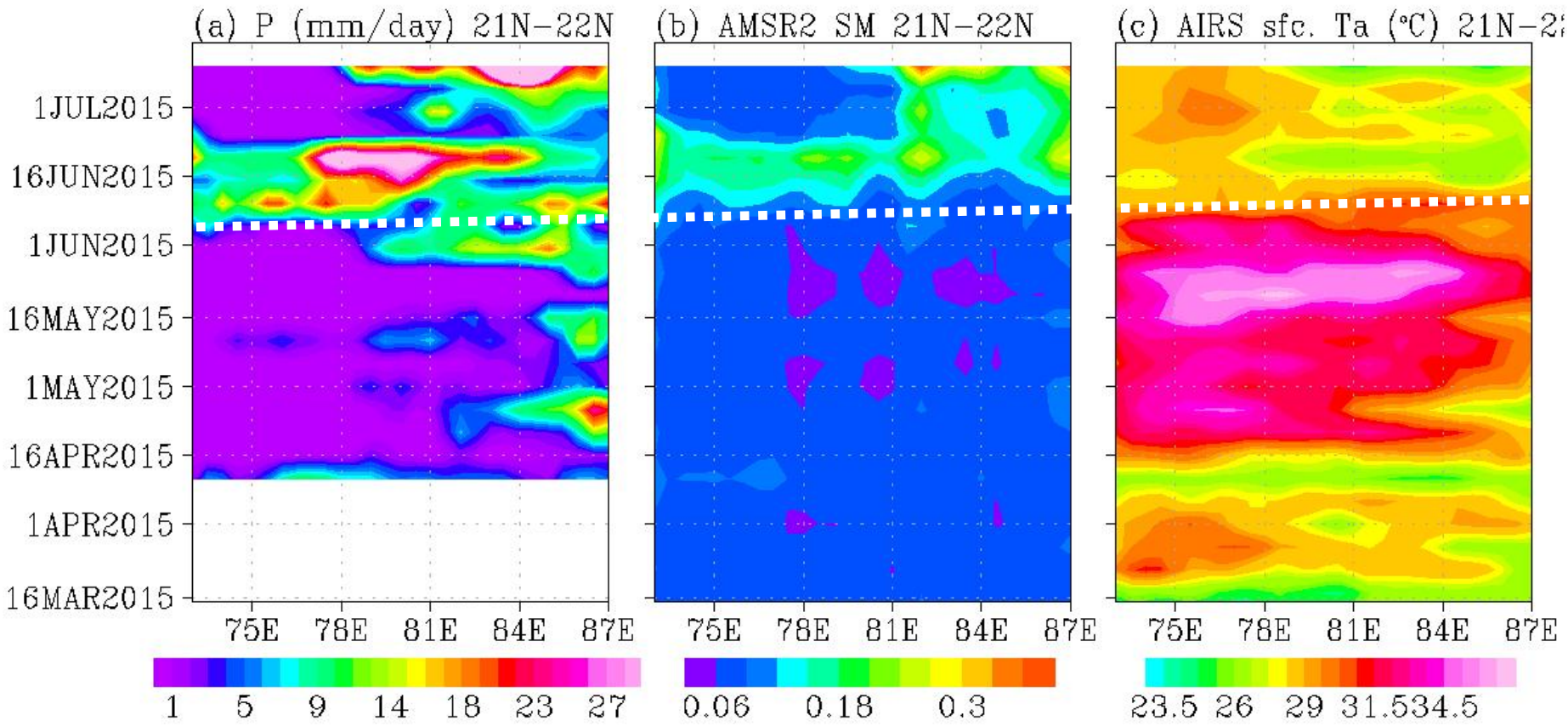
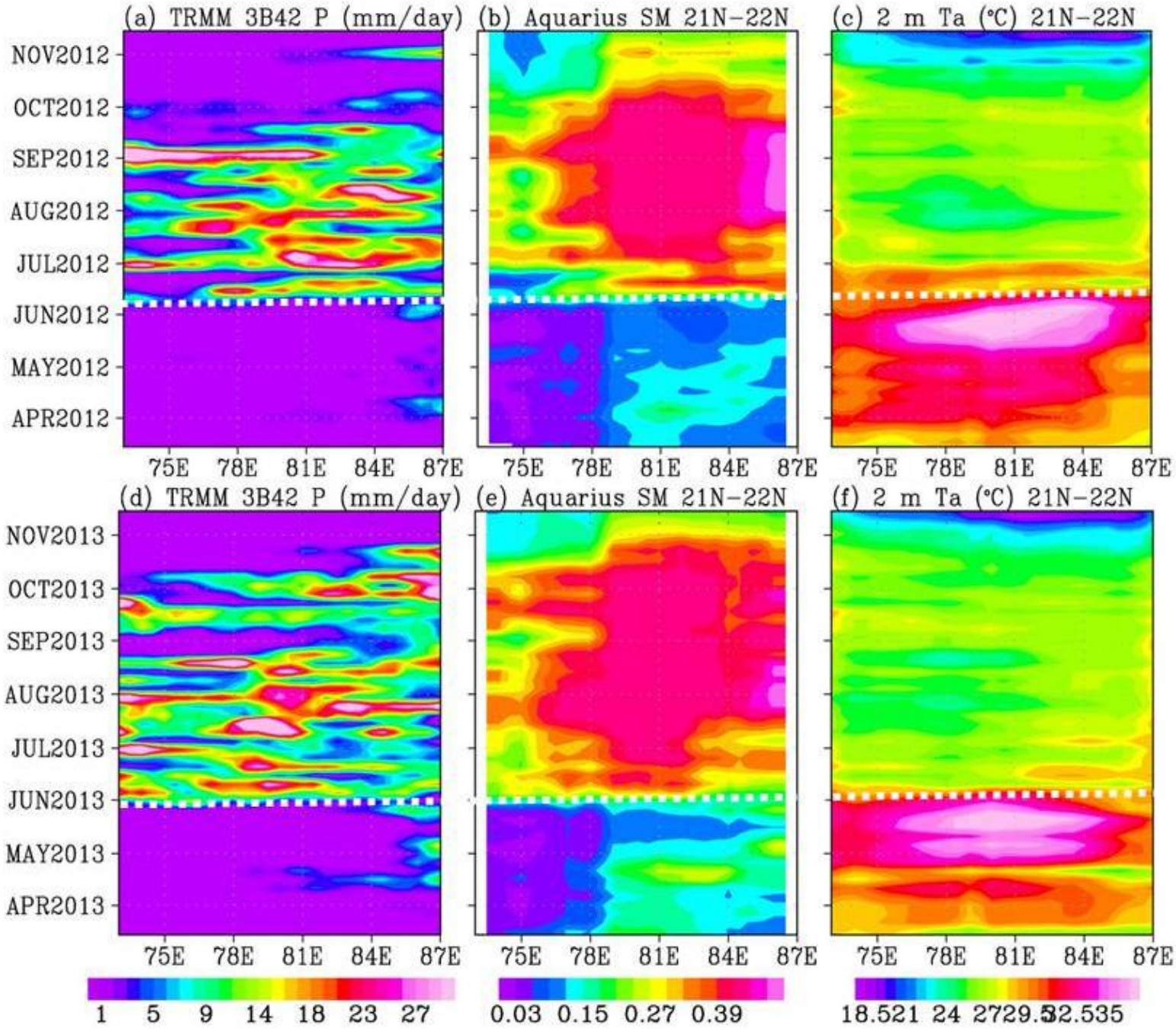
PMM Science Team Meeting July 2015 in Baltimore

India heat wave kills 2,330 people as millions wait for rain

By Hilary Whiteman, CNN Updated 12:17 AM ET, Tue June 2, 2015 | Video Source: CNN


(a) P (mm/day) 21N-22N
(b) AMSR2 SM 21N-22N
(c) AIRS sfc. Ta (°C) 21N-2
1JUL2015
16JUN2015
1JUN2015
16MAY2015
1MAY2015
16APR2015
1APR2015
16MAR2015
75E 78E 81E 84E 87E
1 5 9 14 18 23 27
0.06 0.18 0.3
23.5 26 29 31.5 34.5


(a) TRMM 3B42 P (mm/day)
(b) Aquarius SM 21N-22N
(c) 2 m Ta (°C) 21N-22N
(d) TRMM 3B42 P (mm/day)
(e) Aquarius SM 21N-22N
(f) 2 m Ta (°C) 21N-22N
NOV2012
OCT2012
SEP2012
AUG2012
JUL2012
JUN2012
MAY2012
APR2012
NOV2013
OCT2013
SEP2013
AUG2013
JUL2013
JUN2013
MAY2013
APR2013
75E 78E 81E 84E 87E
1 5 9 14 18 23 27
0.03 0.15 0.27 0.39
18.521 24 2729.532.535

HYDROLOGIC BALANCE

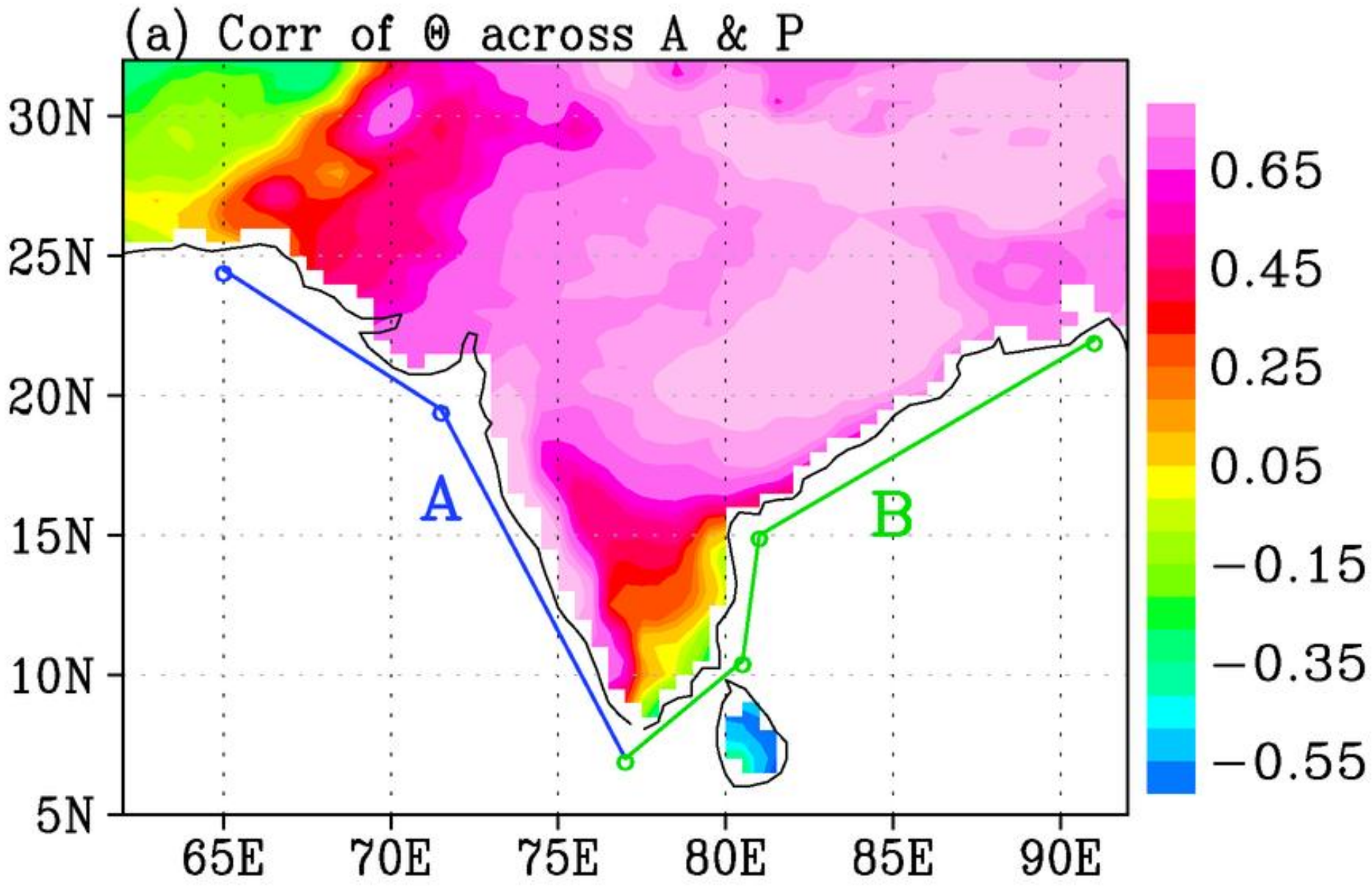
$$\frac{\partial W}{\partial t} + \nabla \bullet \Theta = E - P$$

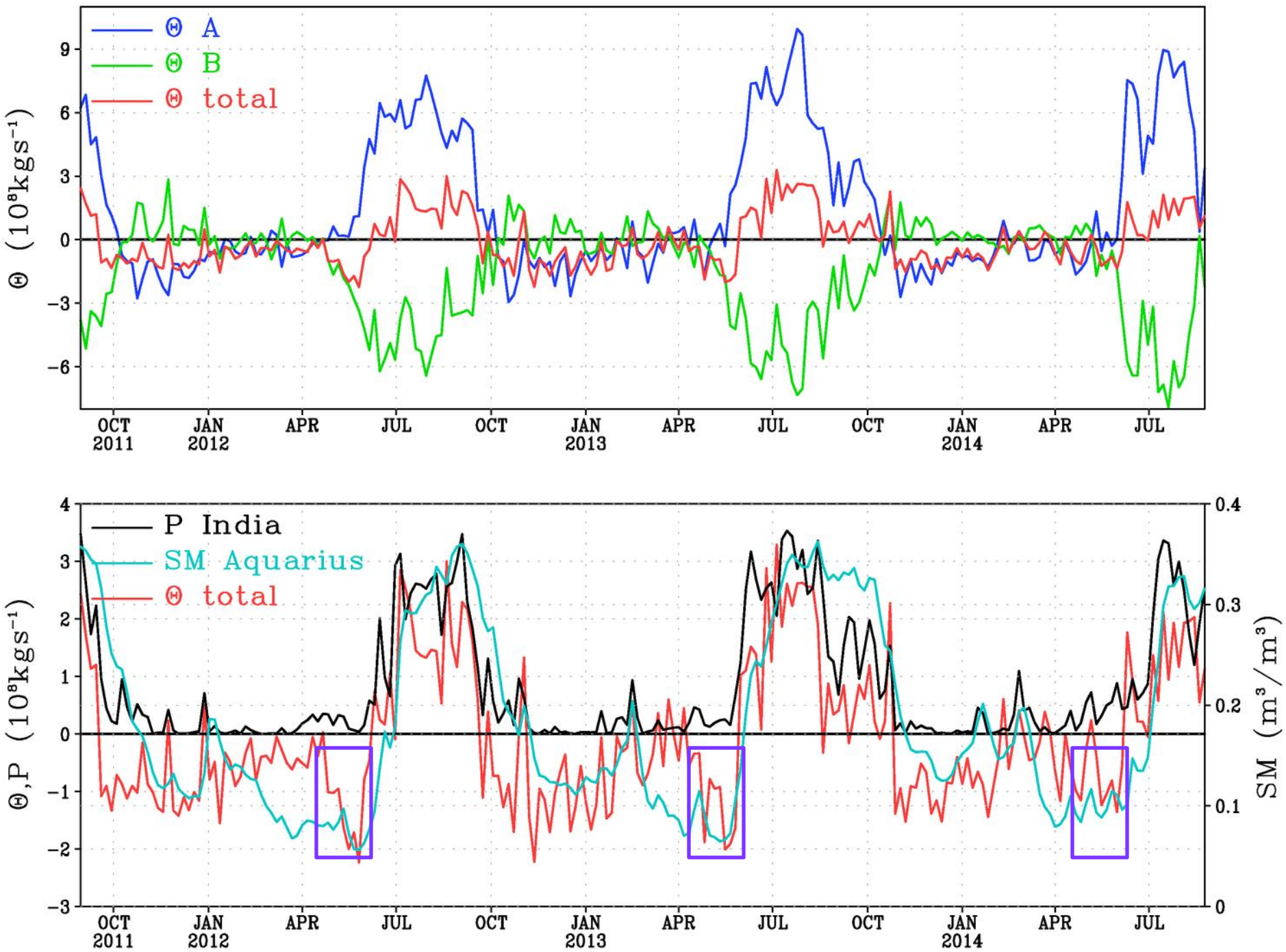
$$\Theta = \frac{1}{g}\int_0^{p0} qU\mathbf{d}p$$

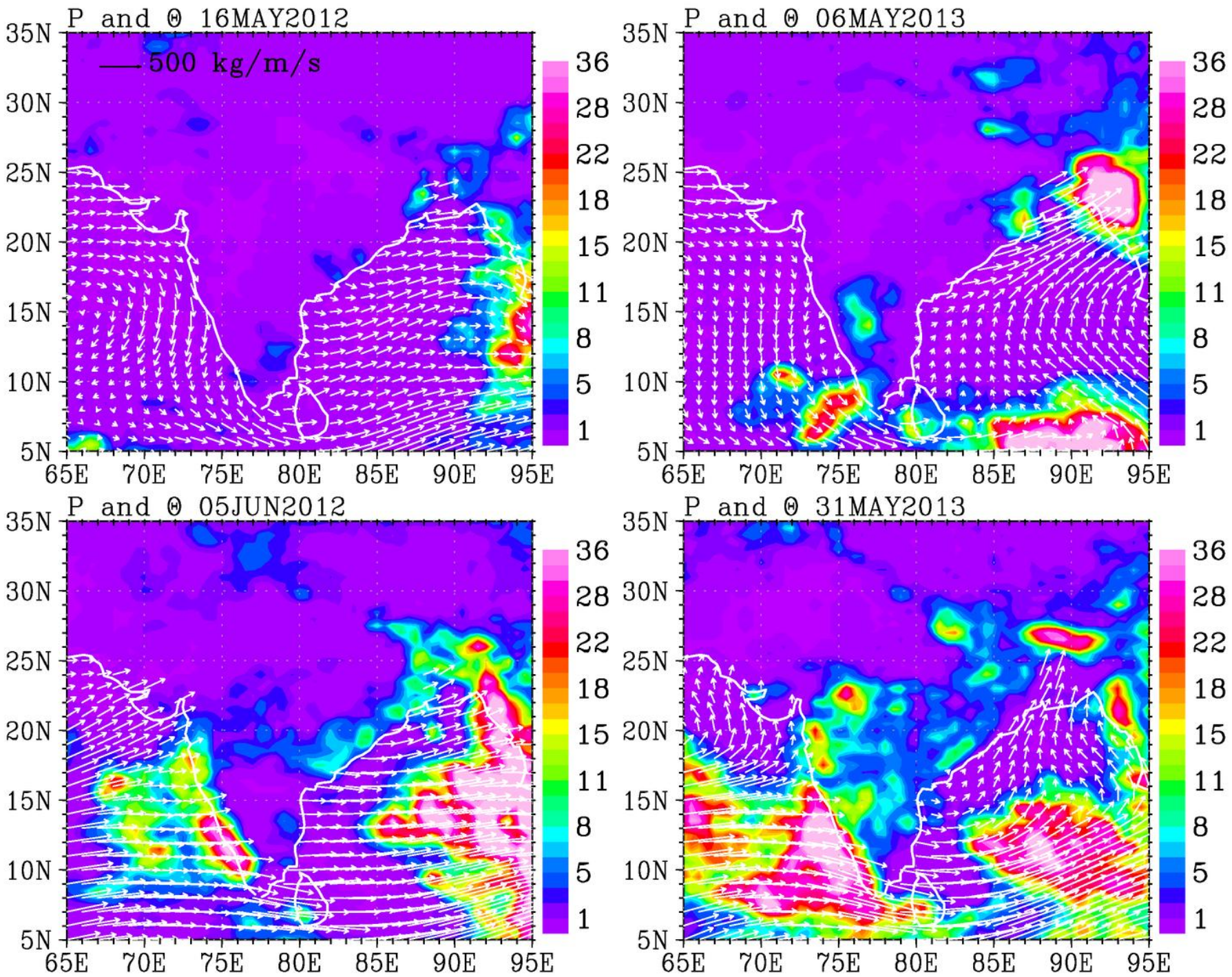
$$W = \frac{1}{g}\int_0^{p0} q\mathbf{dp}$$

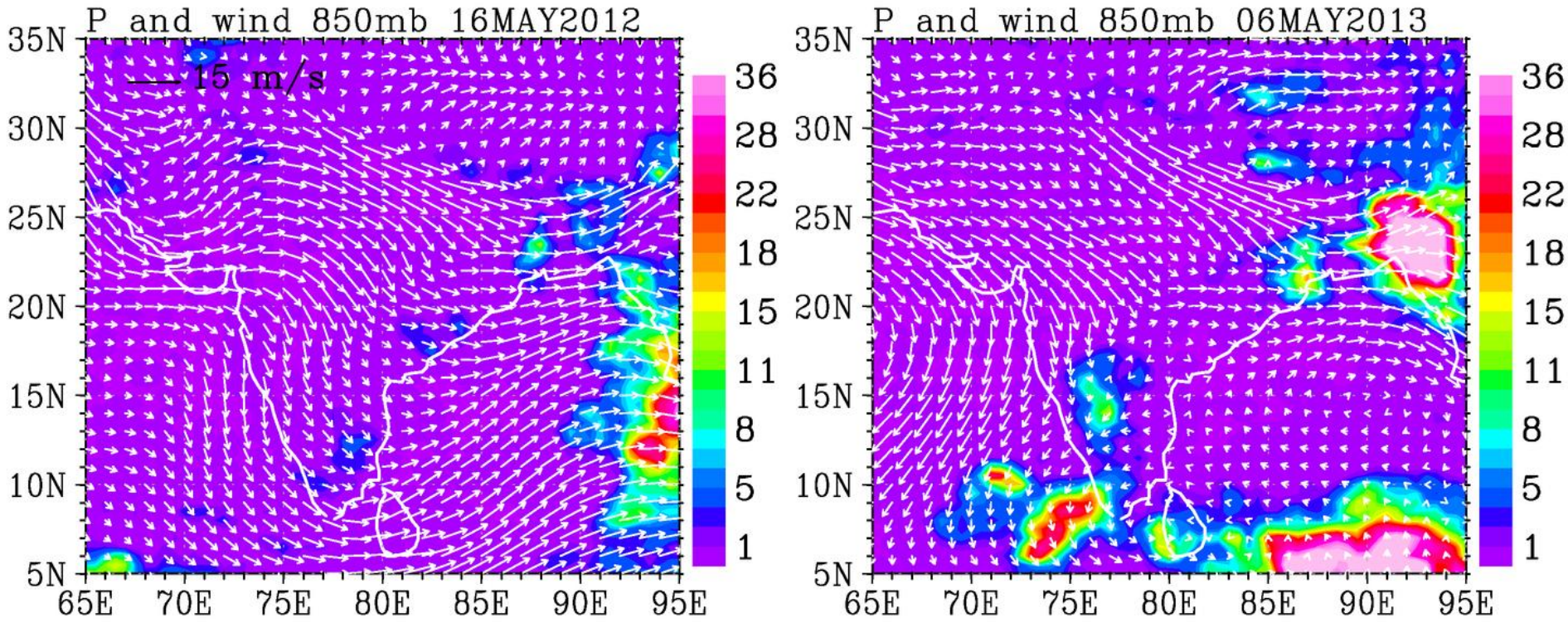
$$\Theta = \mathbf{Ue}\ W$$

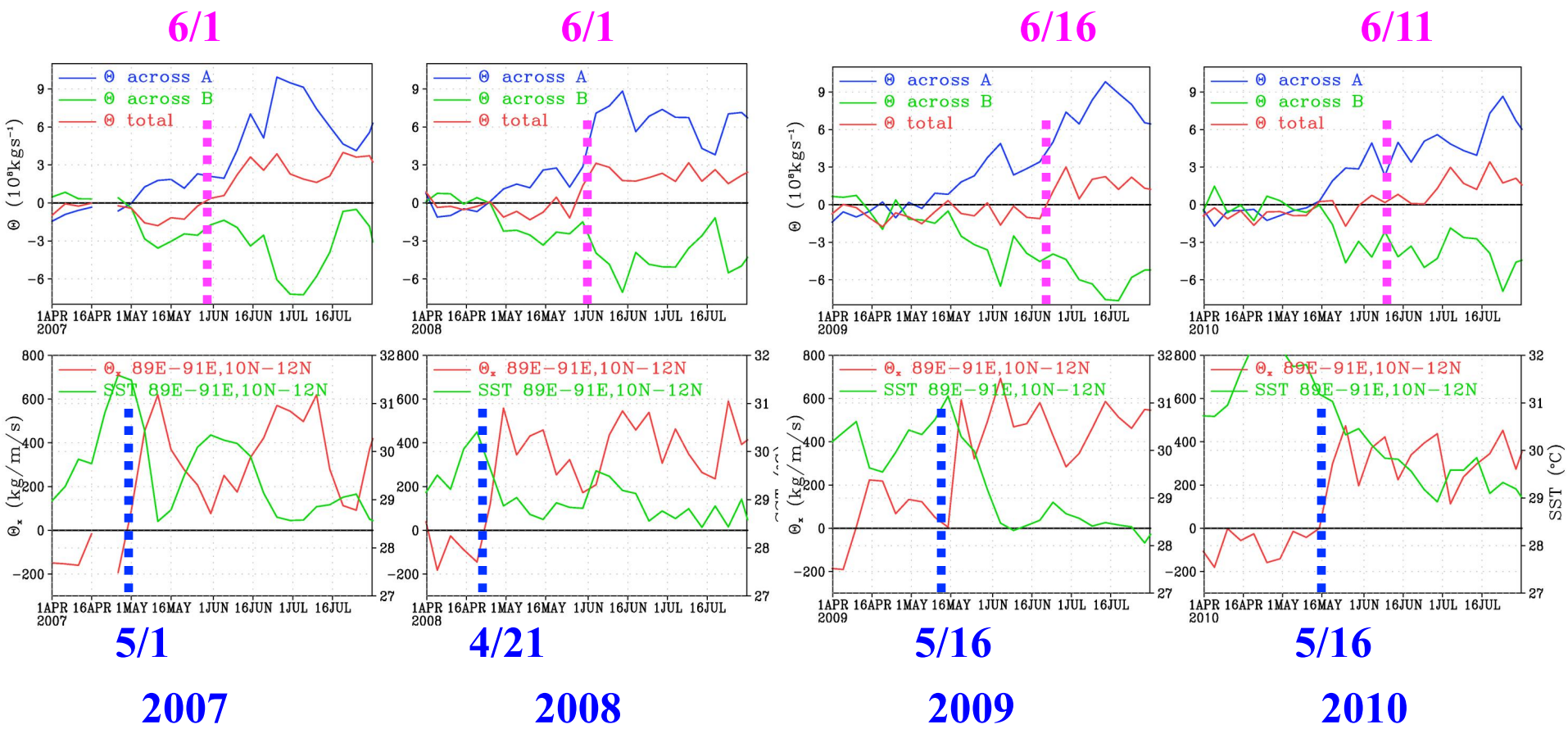
Θ is equivalent to column water vapor W advected by Ue.
Ue is the depth-averaged wind weighted by humidity
We use SVR to relate Ue to wind at two levels:
1. U_N: scatterometer surface wind stress
2. U_{850mb}: cloud drift wind (free-stream wind)

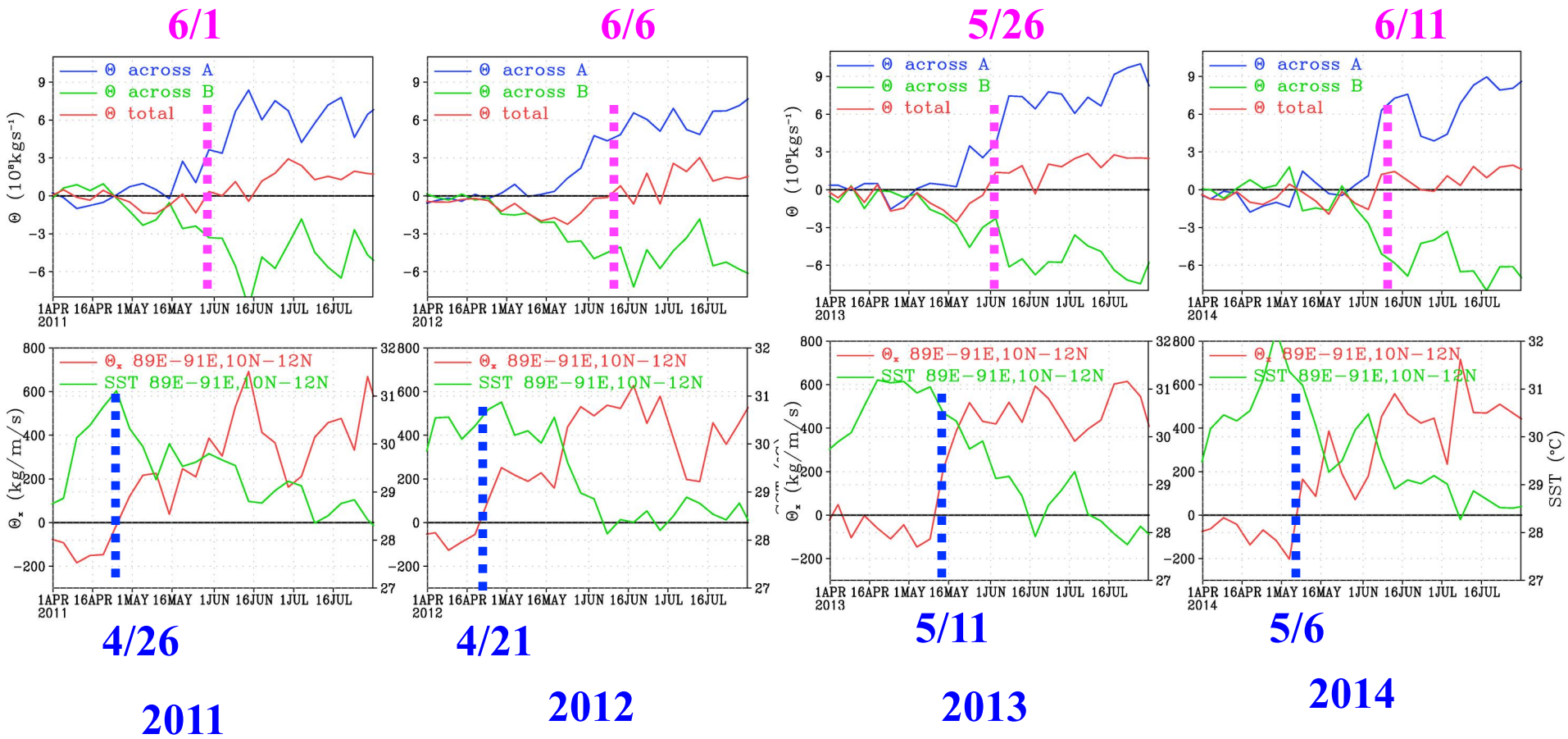

(a) Corr of Θ across A & P
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
A
B
0.65
0.45
0.25
0.05
−0.15
−0.35
−0.55


Θ A
Θ B
Θ total
Θ (10⁸kgs⁻¹)
9
6
3
0
−3
−6
OCT 2011
JAN 2012
APR
JUL
OCT
JAN 2013
APR
JUL
OCT
JAN 2014
APR
JUL
P India
SM Aquarius
Θ total
Θ,P (10⁸kgs⁻¹)
SM (m³/m³)
4
3
2
1
0
−1
−2
−3
0.4
0.3
0.2
0.1
0


P and Θ 16MAY2012
500 kg/m/s
P and Θ 06MAY2013
P and Θ 05JUN2012
P and Θ 31MAY2013
35N
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
95E
36
28
22
18
15
11
8
5
1

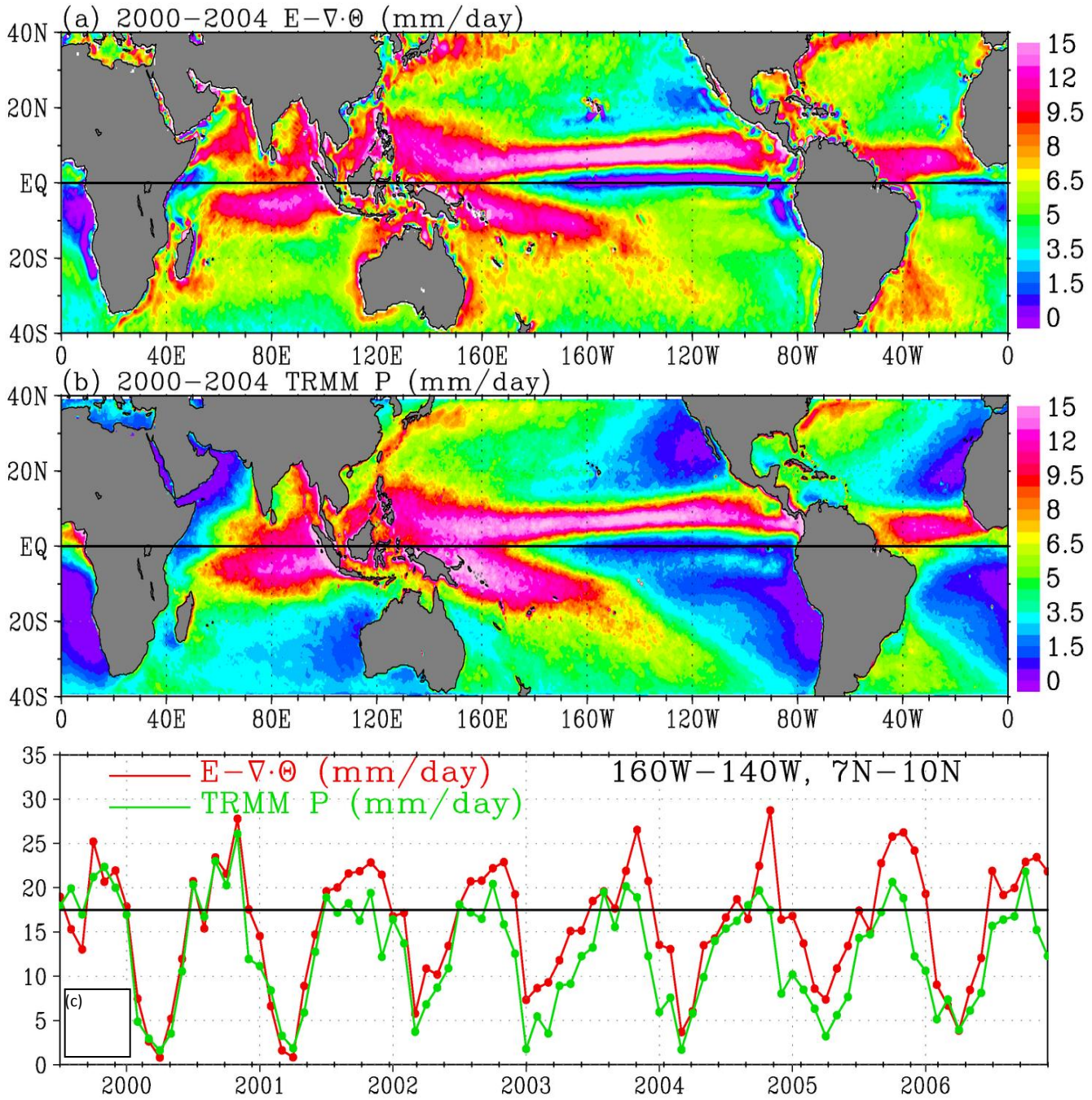

P and wind 850mb 16MAY2012
15 m/s
35N
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
95E
36
28
22
18
15
11
8
5
1
P and wind 850mb 06MAY2013
35N
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
95E
36
28
22
18
15
11
8
5
1

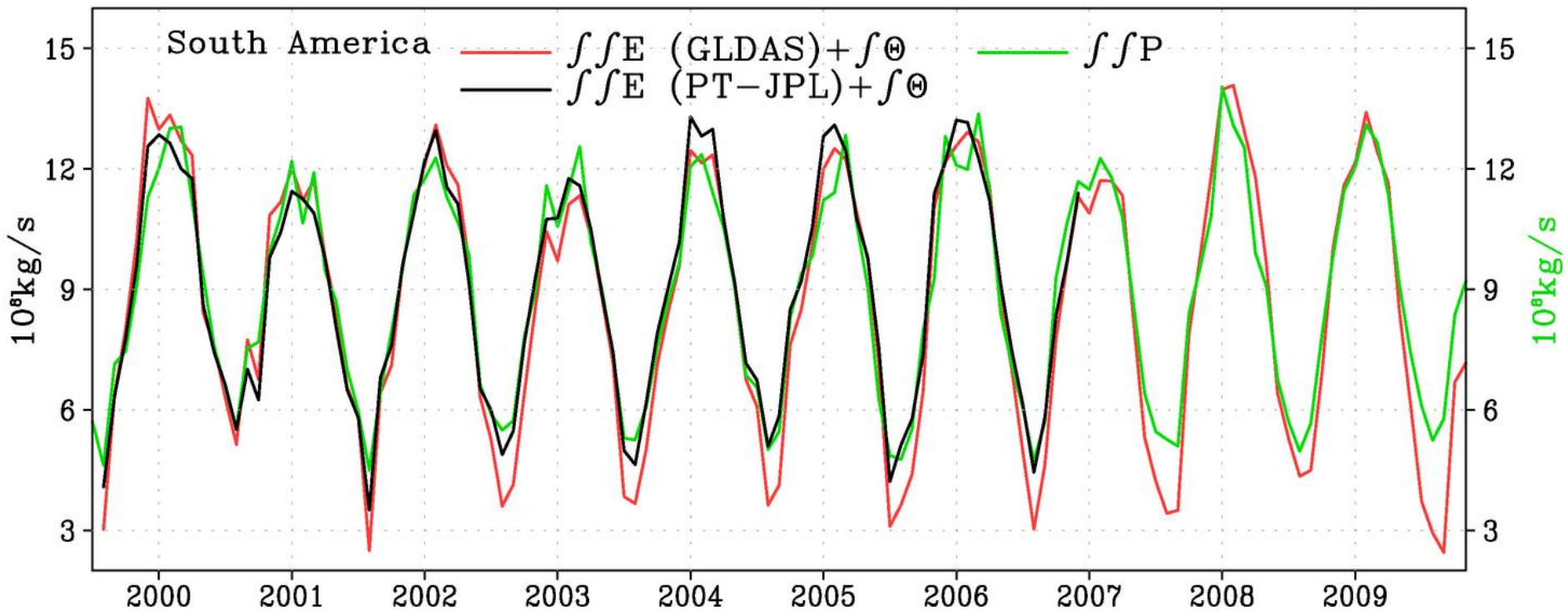

6/1
6/1
6/16
6/11
Θ across A
Θ across B
Θ total
Θ (10⁸kgs⁻¹)
1APR 16APR 1MAY 16MAY 1JUN 16JUN 1JUL 16JUL
2007
2008
2009
2010
Θx 89E-91E,10N-12N
SST 89E-91E,10N-12N
Θx (kg/m/s)
SST (°C)
5/1
4/21
5/16
5/16
2007
2008
2009
2010


6/1
6/6
5/26
6/11
Θ across A
Θ across B
Θ total
Θ (10⁸kgs⁻¹)
1APR 16APR 1MAY 16MAY 1JUN 16JUN 1JUL 16JUL
2011
2012
2013
2014
Θx 89E−91E,10N−12N
SST 89E−91E,10N−12N
Θx (kg/m/s)
SST (°C)
4/26
4/21
5/11
5/6
2011
2012
2013
2014

- The dryest and hotest week in the India is often found when dry air is suck out to the Bay of Bengal (BB) before moisture is drawn in from the Arabian Sea (AS), starting of summer monsoon in India. Summer monsoon starts earlier in BB than AS, drawing dry air out of India, following sharp rise in sea surface temperature in BB.

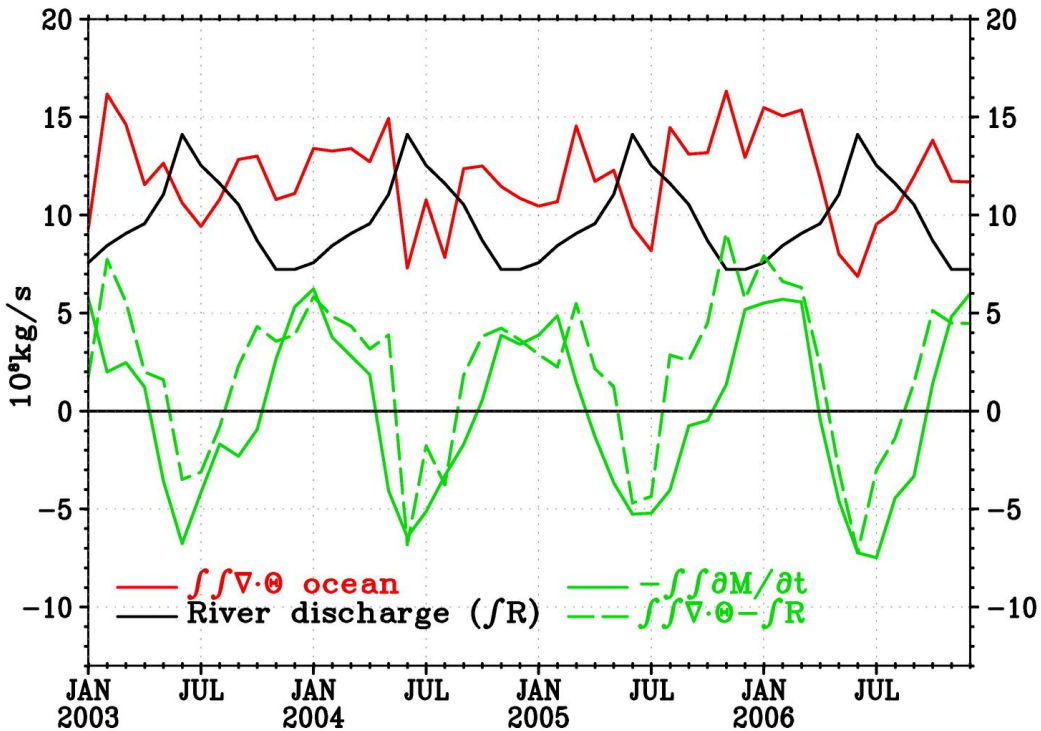
- Backup


(a) 2000−2004 E−∇·Θ (mm/day)
40N
20N
EQ
20S
40S
0
40E
80E
120E
160E
160W
120W
80W
40W
0
15
12
9.5
8
6.5
5
3.5
1.5
0
(b) 2000−2004 TRMM P (mm/day)
E−∇·Θ (mm/day)
TRMM P (mm/day)
160W−140W, 7N−10N
(c)
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006



Mean difference	standard deviation (x10^8 kg/s)
0.29	0.82
0.047	0.69

Global Ocean Water Balance



$$\iint \frac{\partial M}{\partial t} = \int R - \iint \nabla \cdot \Theta$$

GRACE Dai/Trenberth Liu/Xie

$$\iint (E-P) = \int \Theta = \iint \nabla \cdot \Theta$$

Four-year Means in cm/yr

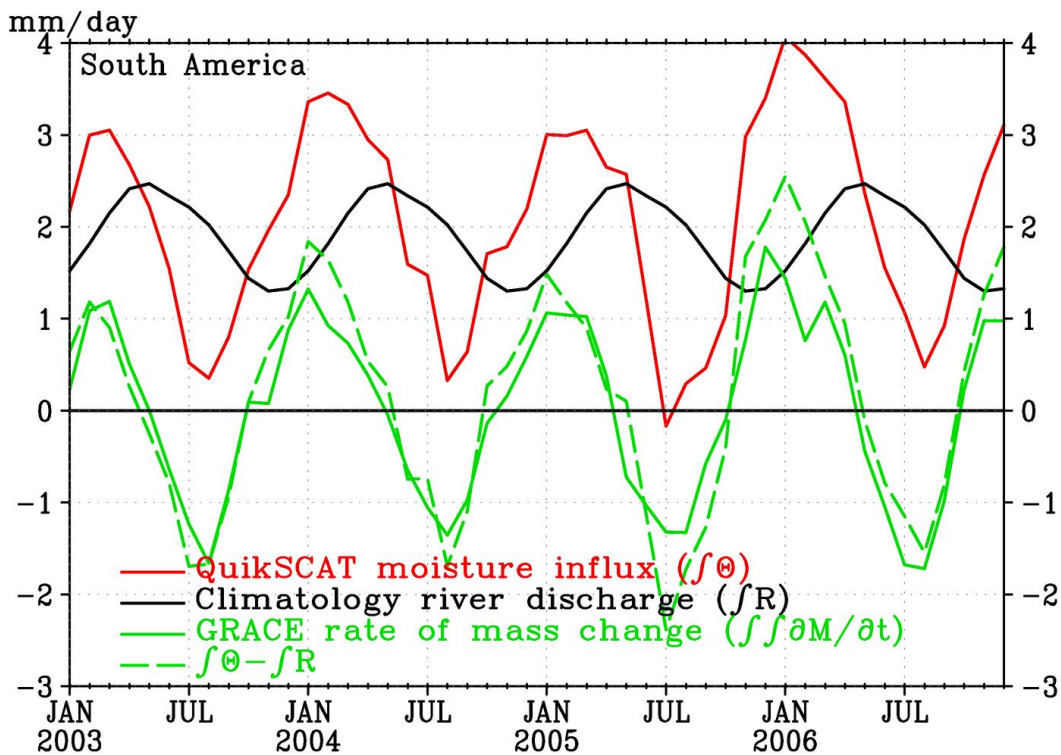
div of water transport

Liu	10.6
Hilburn	21.9
E-P	
Merra	10.6
NEWS	10
River Discharge	
Dai	8.6

18% undertainty

Liu and Xie, 2014

Water Balance over South America



$$\iint \frac{\partial M}{\partial t} = \int \Theta - \int R$$

GRACE Liu/Xie Dai/Trenberth

$$\iint (P-E) = \int \Theta$$

Four-year Means in cm/yr

Moisture into continent

Liu 76.1

Hilburn 154.5

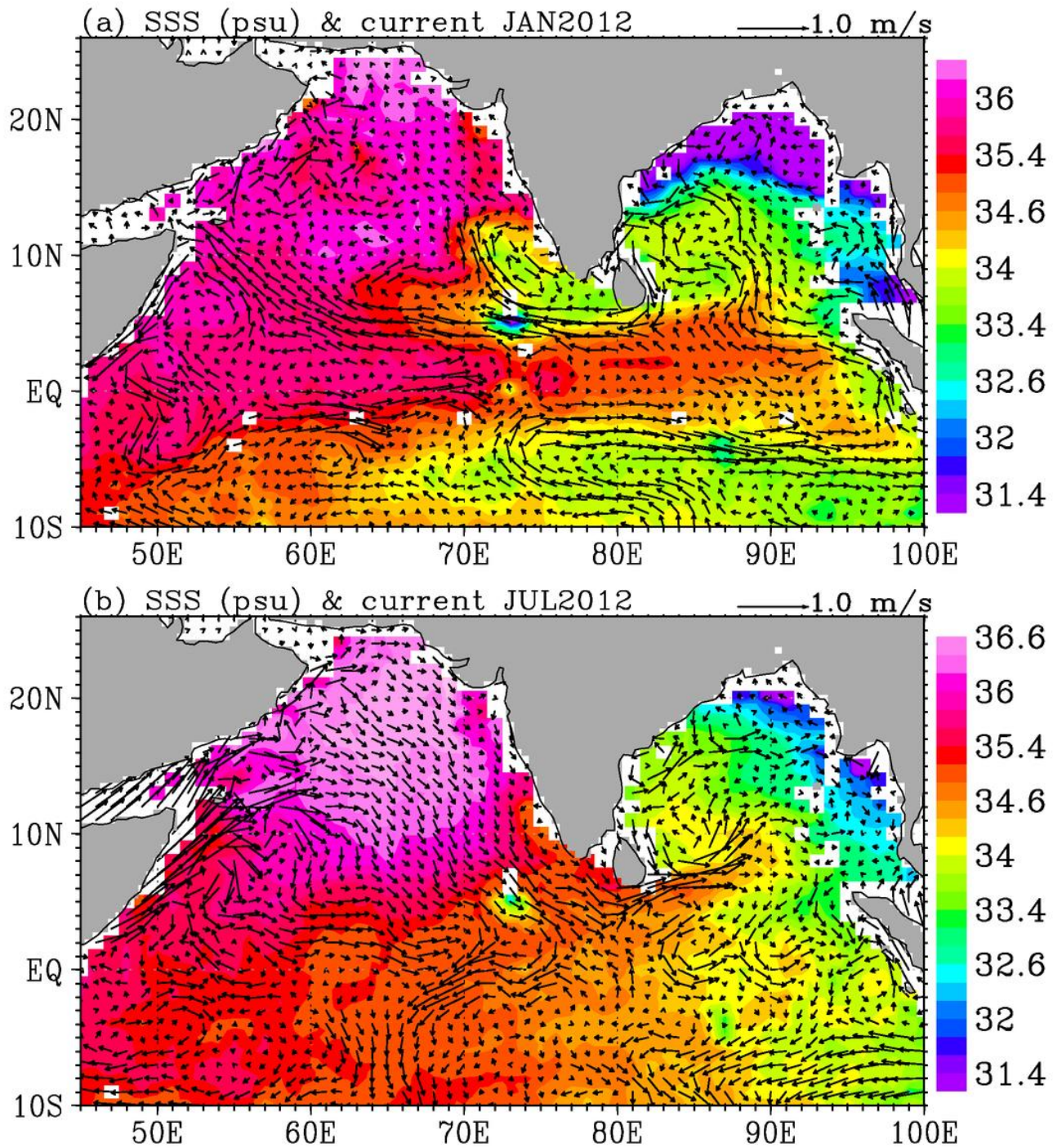
P-E

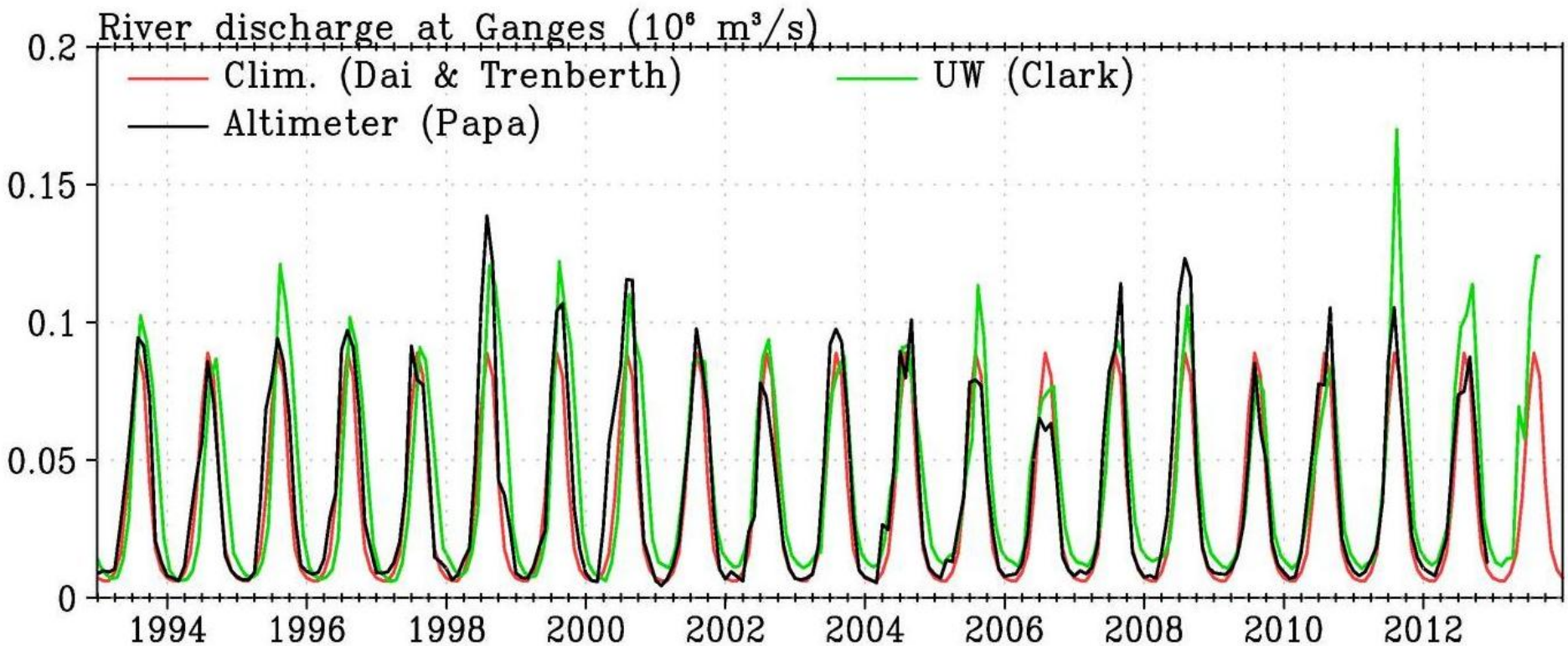
NEWS 61.3

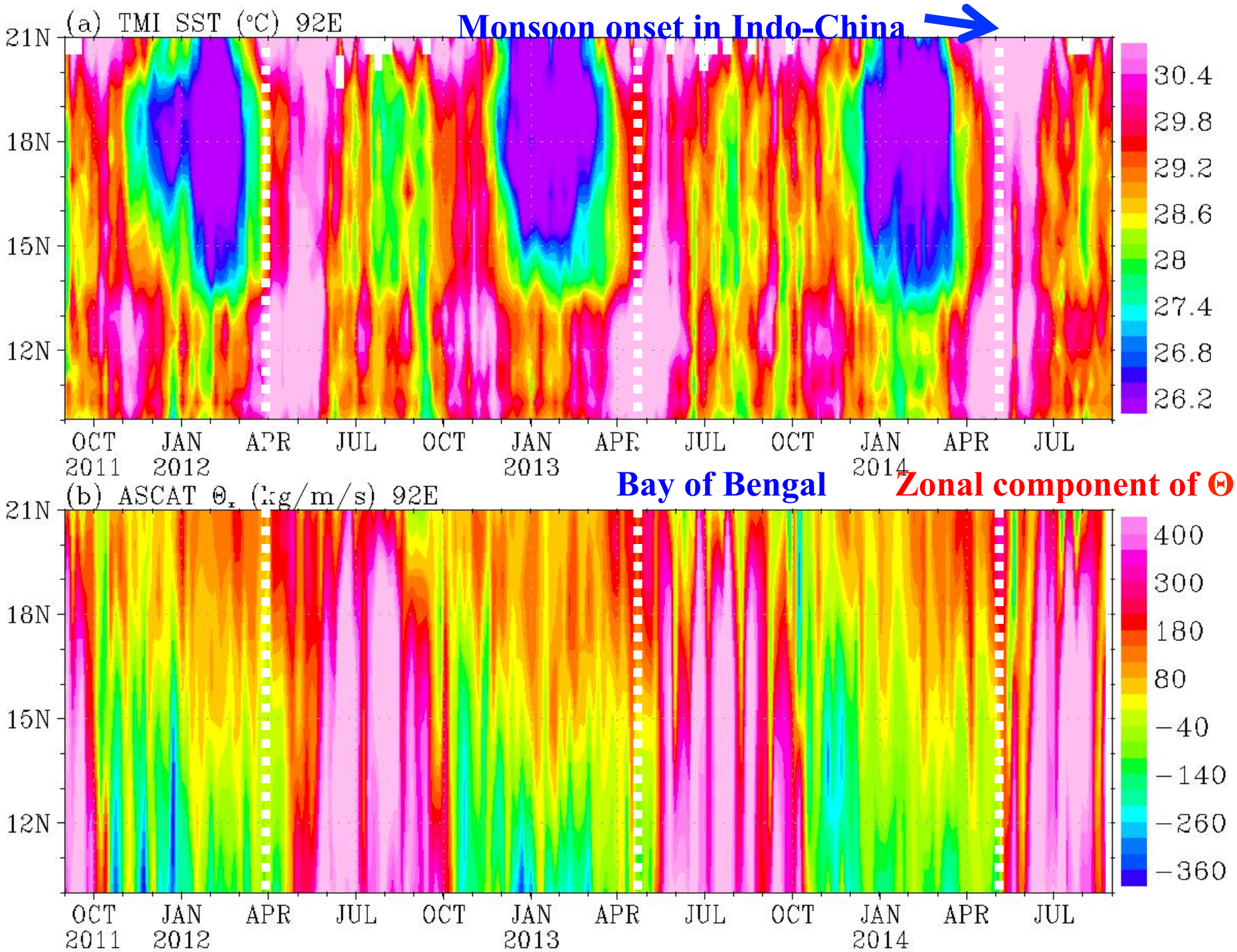
River Discharge

Dai 69.2

7% unertaintis


(a) SSS (psu) & current JAN2012
1.0 m/s
20N
10N
EQ
10S
50E
60E
70E
80E
90E
100E
36
35.4
34.6
34
33.4
32.6
32
31.4
(b) SSS (psu) & current JUL2012
1.0 m/s
20N
10N
EQ
10S
50E
60E
70E
80E
90E
100E
36.6
36
35.4
34.6
34
33.4
32.6
32
31.4


River discharge at Ganges (10⁶ m³/s)
Clim. (Dai & Trenberth)
UW (Clark)
Altimeter (Papa)
0.2
0.15
0.1
0.05
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012


(a) TMI SST (°C) 92E
Monsoon onset in Indo-China
21N
18N
15N
12N
30.4
29.8
29.2
28.6
28
27.4
26.8
26.2
OCT 2011
JAN 2012
APR
JUL
OCT
JAN 2013
APR
JUL
OCT
JAN 2014
APR
JUL
(b) ASCAT Θx (kg/m/s) 92E
Bay of Bengal
Zonal component of Θ
400
300
180
80
−40
−140
−260
−360