Hydrologic Balance Associated with Pre-monsoon Drought in India

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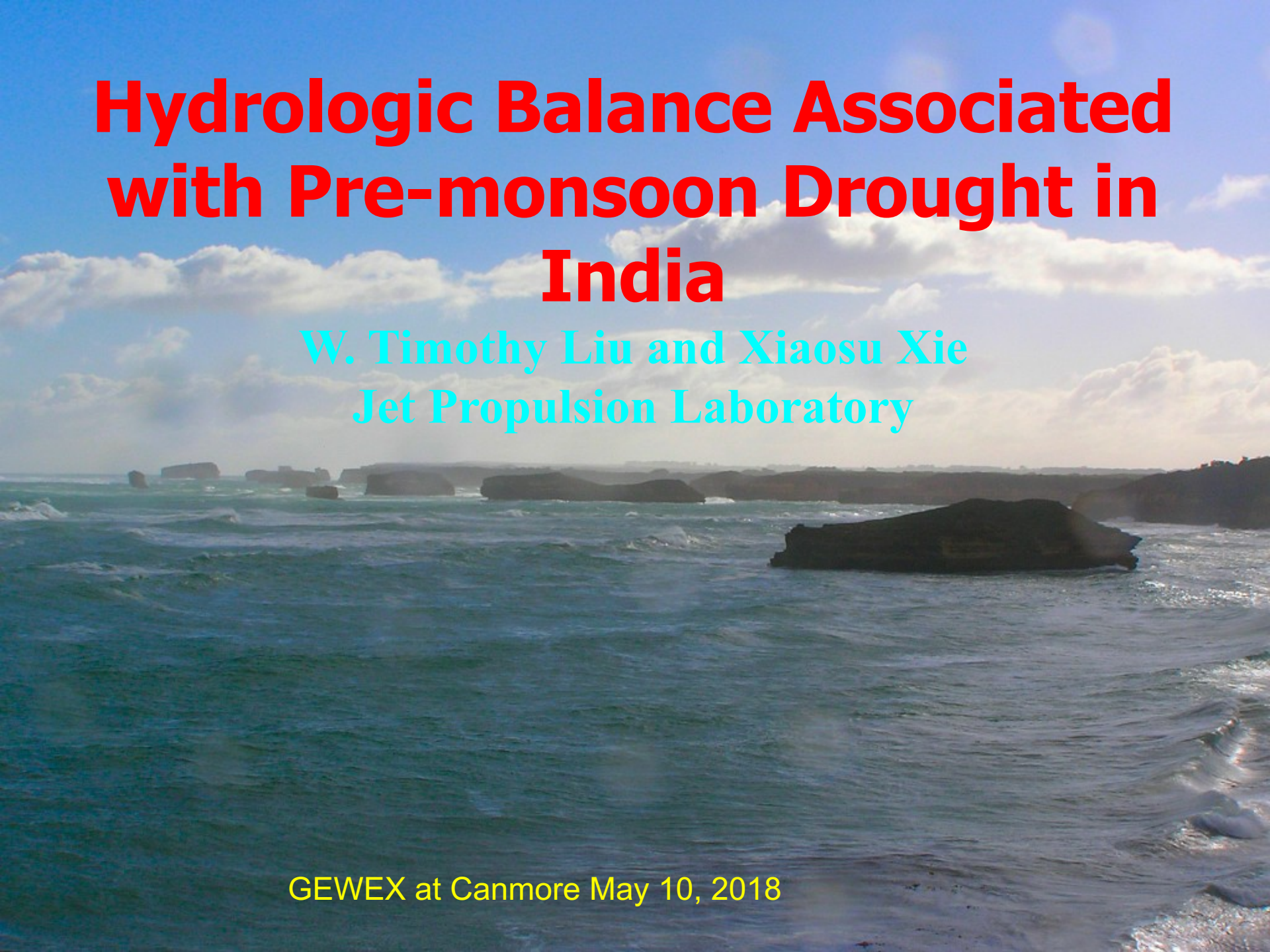


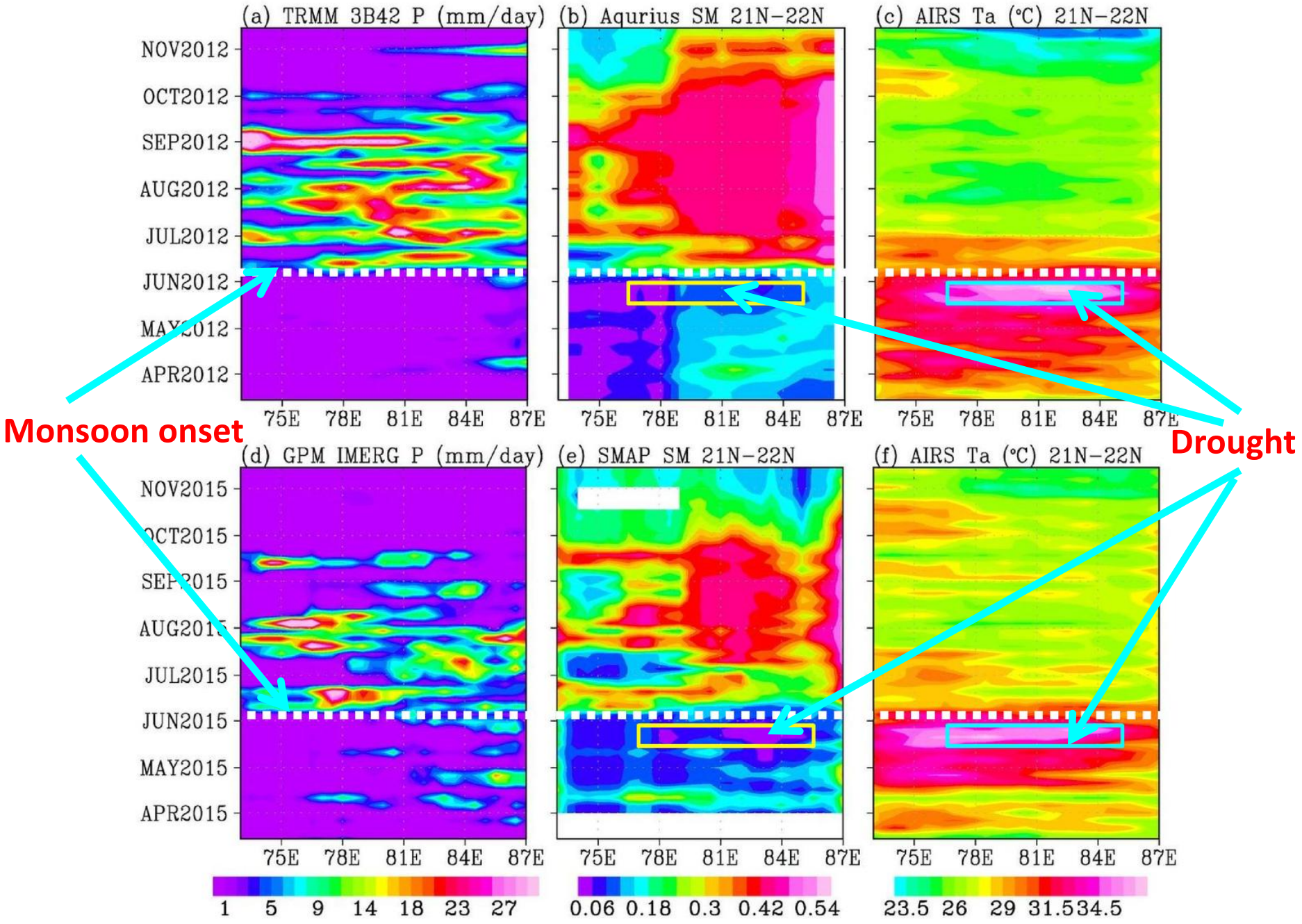
GEWEX at Canmore May 10, 2018

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

•Anecdotic descriptions of extreme dry and hot weather before summer monsoon that causes human suffering in India year after year. Most fatality in Talangana and Odisha States (central east) the week before summer rain. No documentation on the severity and postulation on the scientific reason.

•Rainfall through the dry season from March-May is low and cannot identify the weeks of severe drought. Aquarius/SMAP soil moisture provide the opportunity to study this short period, which we call ”premonsoon drought”


(a) TRMM 3B42 P (mm/day)
(b) Aqurius SM 21N-22N
(c) AIRS Ta (°C) 21N-22N
NOV2012
OCT2012
SEP2012
AUG2012
JUL2012
JUN2012
APR2012
75E 78E 81E 84E 87E
Monsoon onset
Drought
(d) GPM IMERG P (mm/day)
(e) SMAP SM 21N-22N
(f) AIRS Ta (°C) 21N-22N
NOV2015
JUL2015
JUN2015
MAY2015
APR2015
1 5 9 14 18 23 27
0.06 0.18 0.3 0.42 0.54
23.5 26 29 31.5 34.5

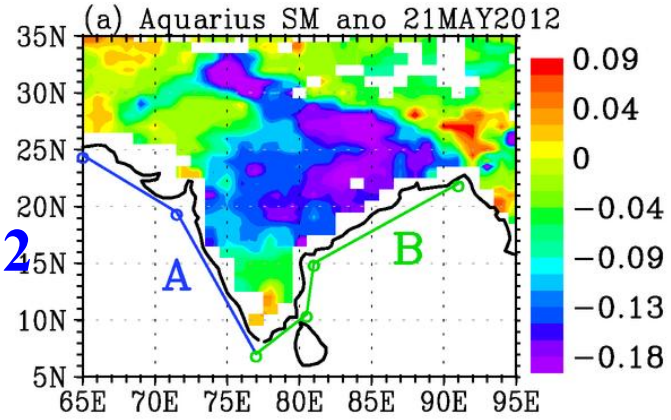
Aquarius SM

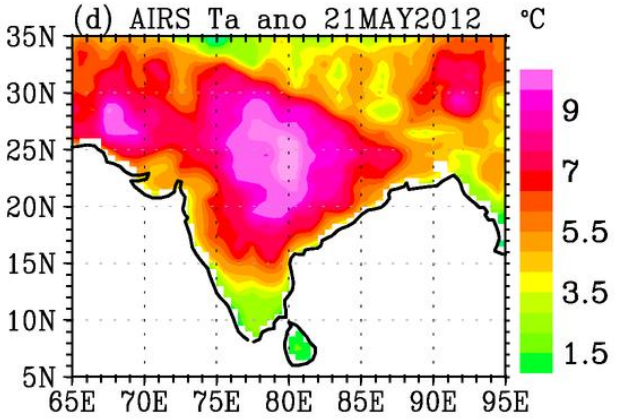
AIRS Ta

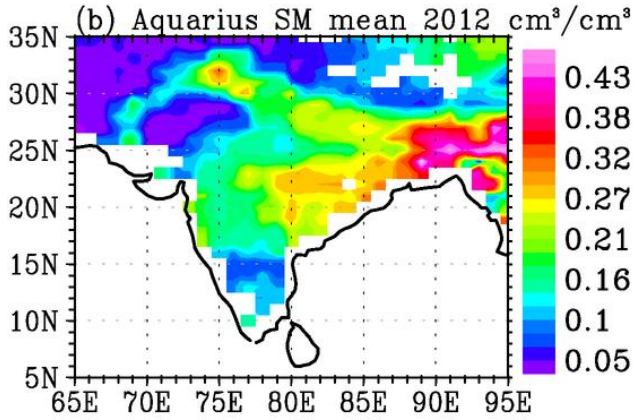
Anomaly 5/21-25/2012

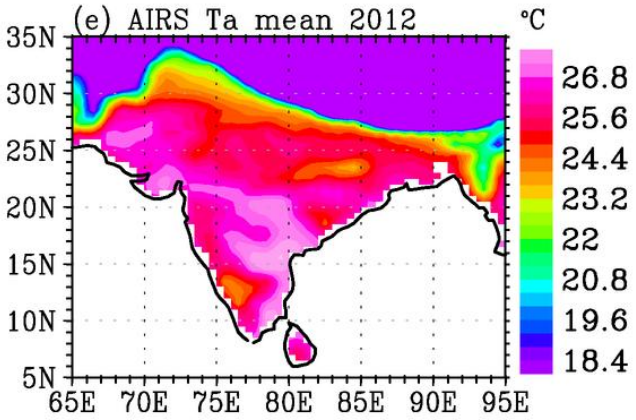
2012 mean

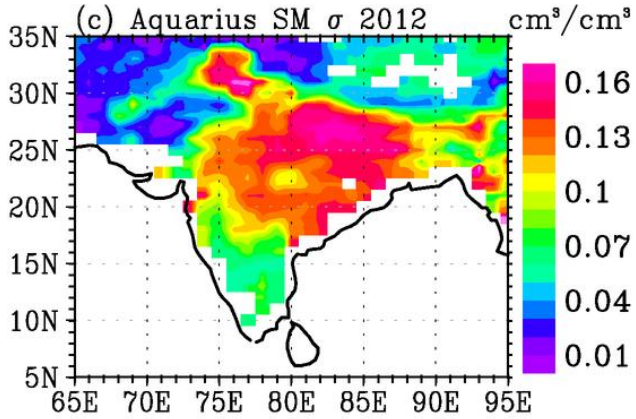
Standard deviation

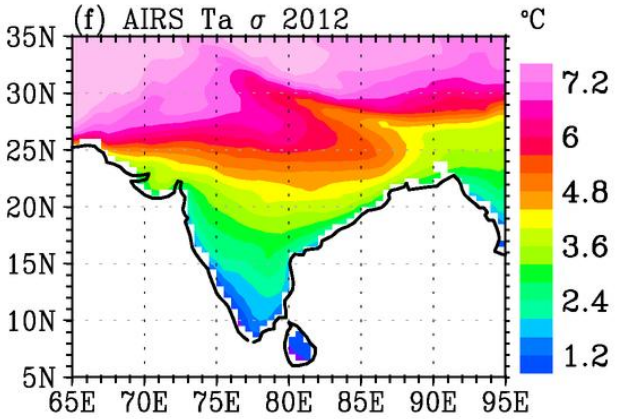


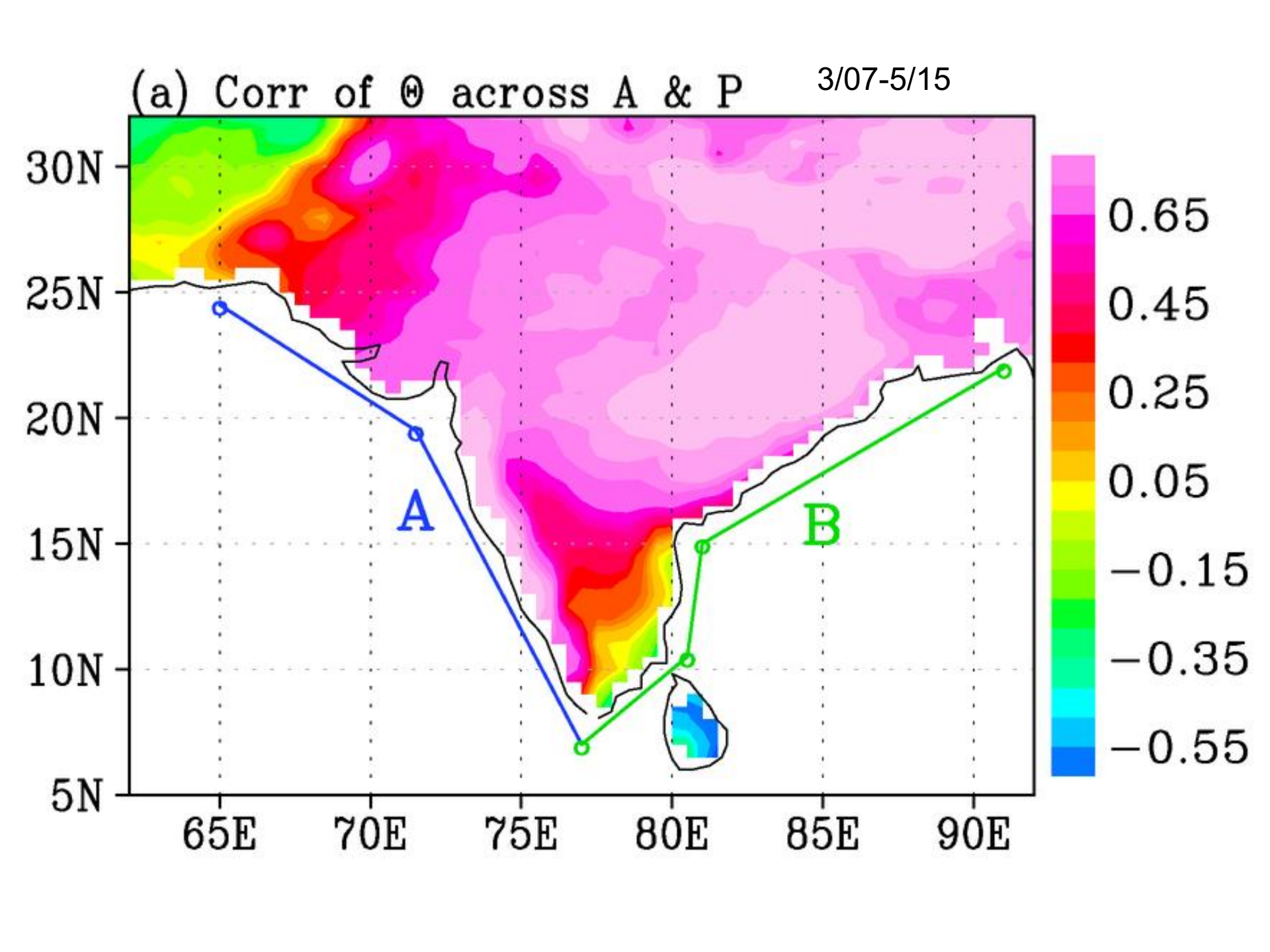


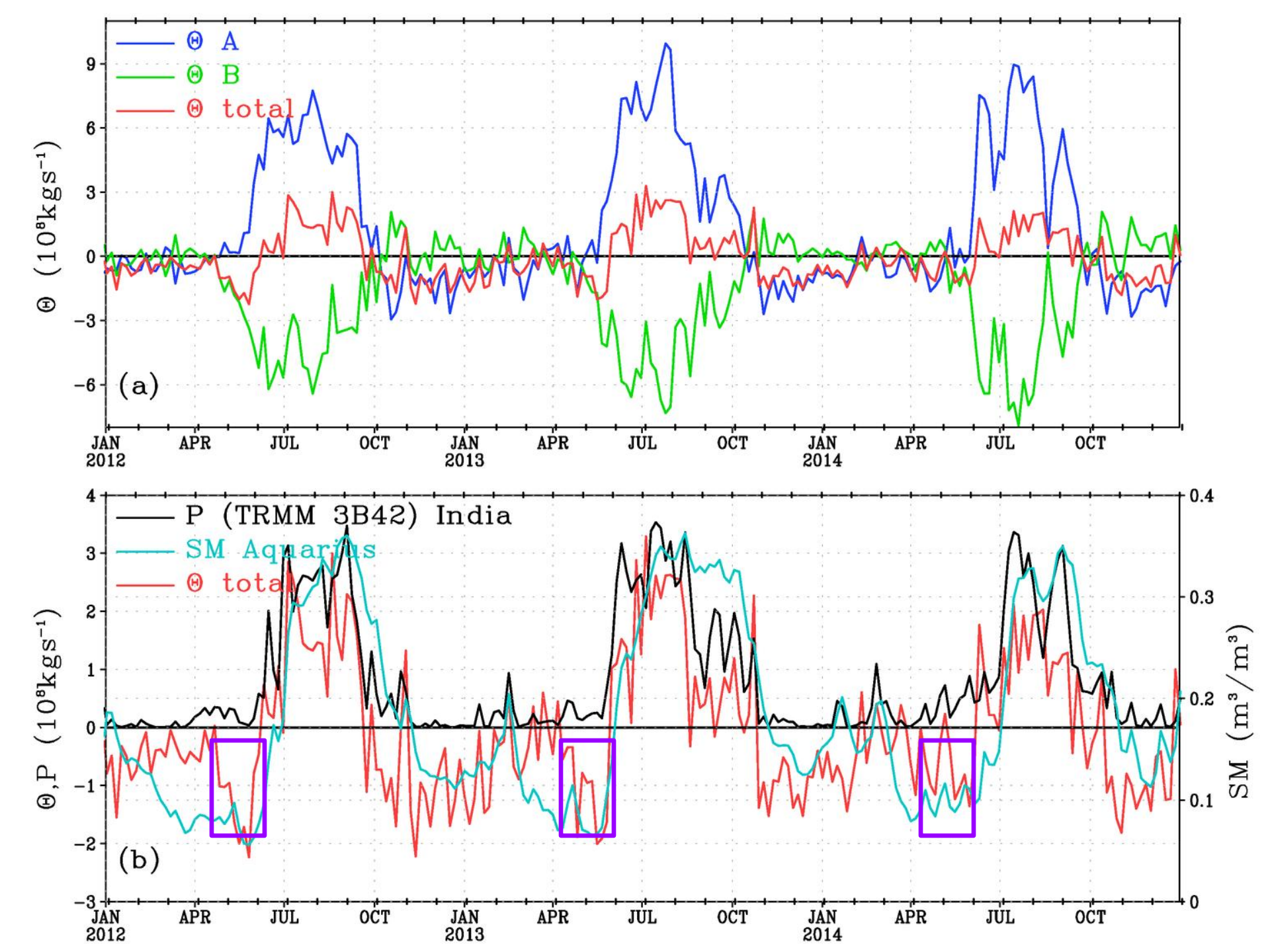


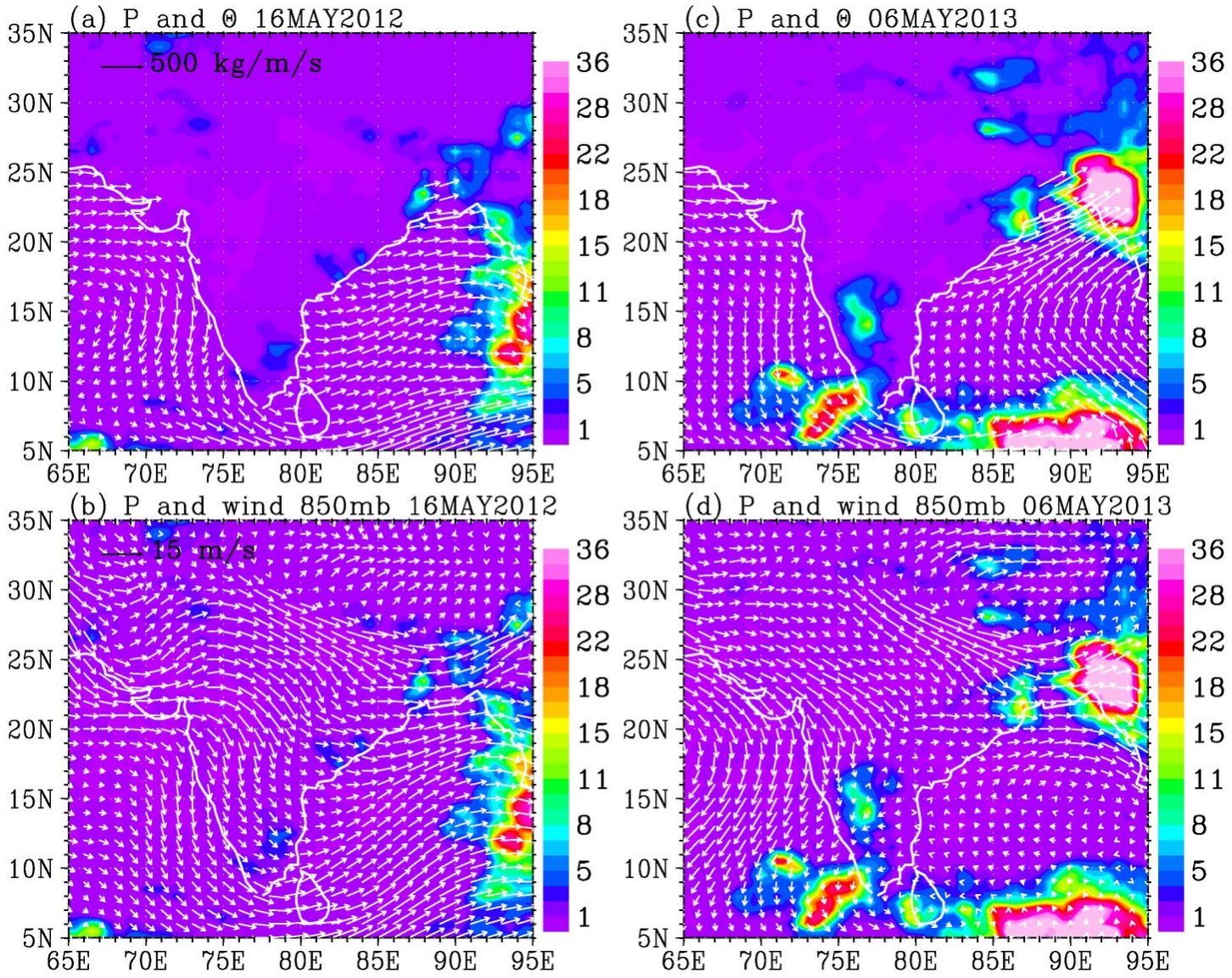




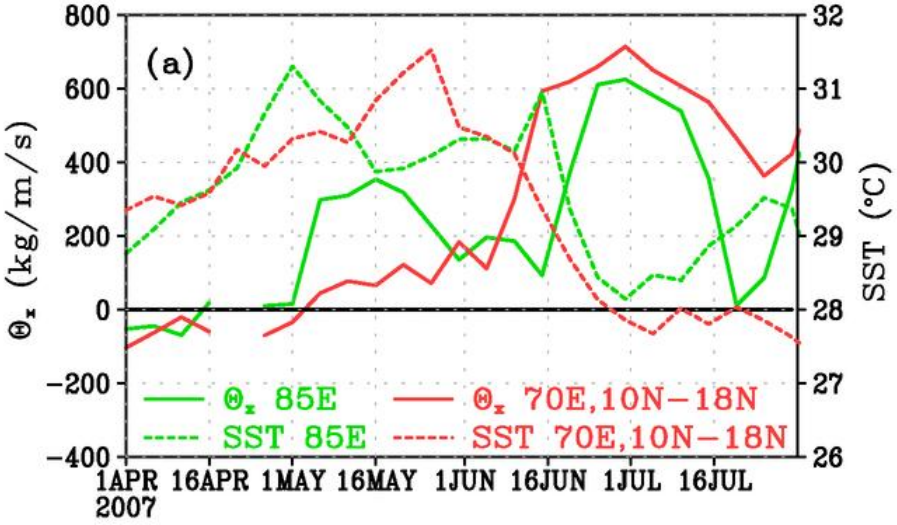


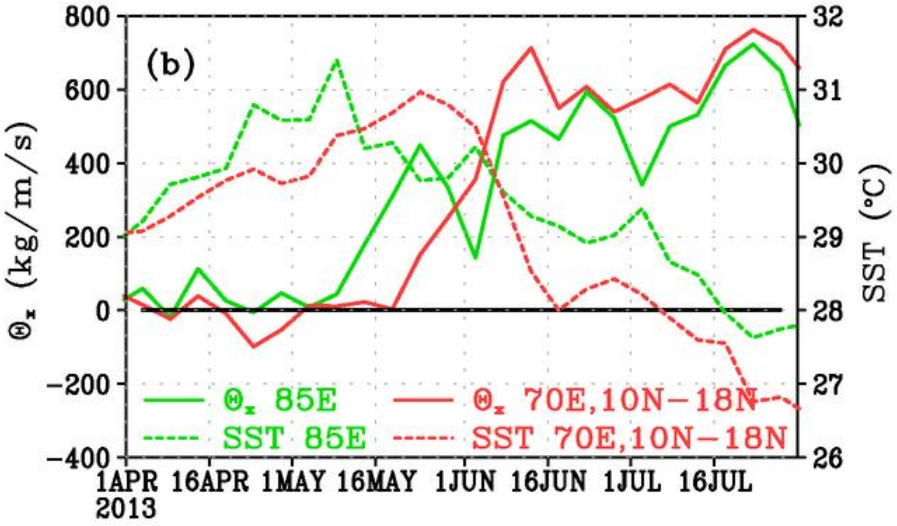

(a) Corr of Θ across A & P
3/07-5/15
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
A
B
0.65
0.45
0.25
0.05
−0.15
−0.35
−0.55

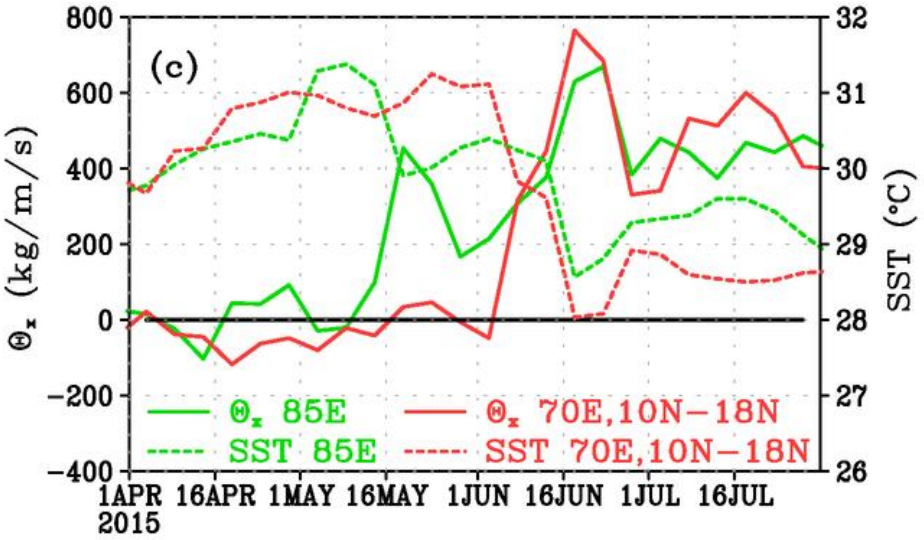

Θ A
Θ B
Θ total
Θ (10⁸kgs⁻¹)
(a)
JAN 2012
APR
JUL
OCT
JAN 2013
APR
JUL
OCT
JAN 2014
APR
JUL
OCT
P (TRMM 3B42) India
SM Aquarius
Θ total
Θ,P (10⁸kgs⁻¹)
SM (m³/m³)
(b)



Atmospheric transports during pre-monsoon drought. (a) **Θ** and (b) 850 mb wind, averaged between May 16-20, 2012, both represented by white arrows, superimposed by precipitation in color. (c) and (d) are the same as (a) and (b), except for May 6-10, 2013.







ΘBay of Bengal

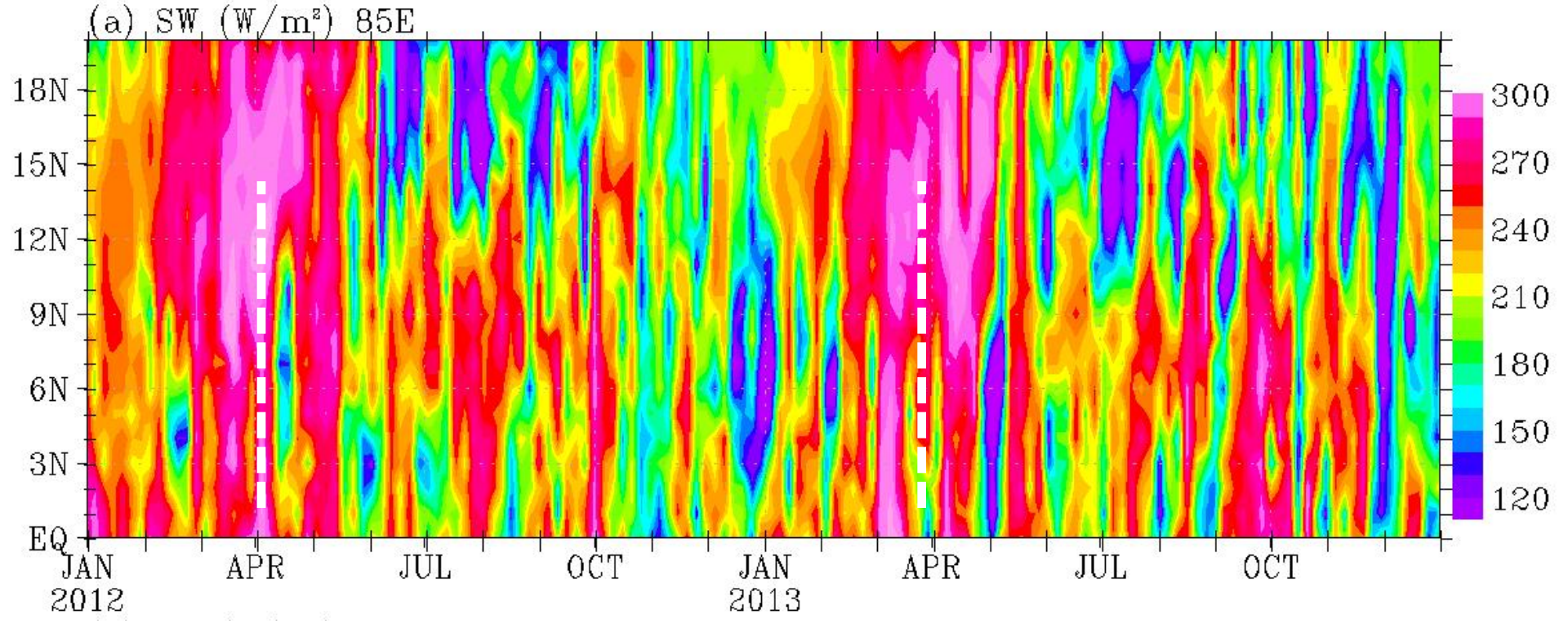
SST

Θ Arabian Sea

SST

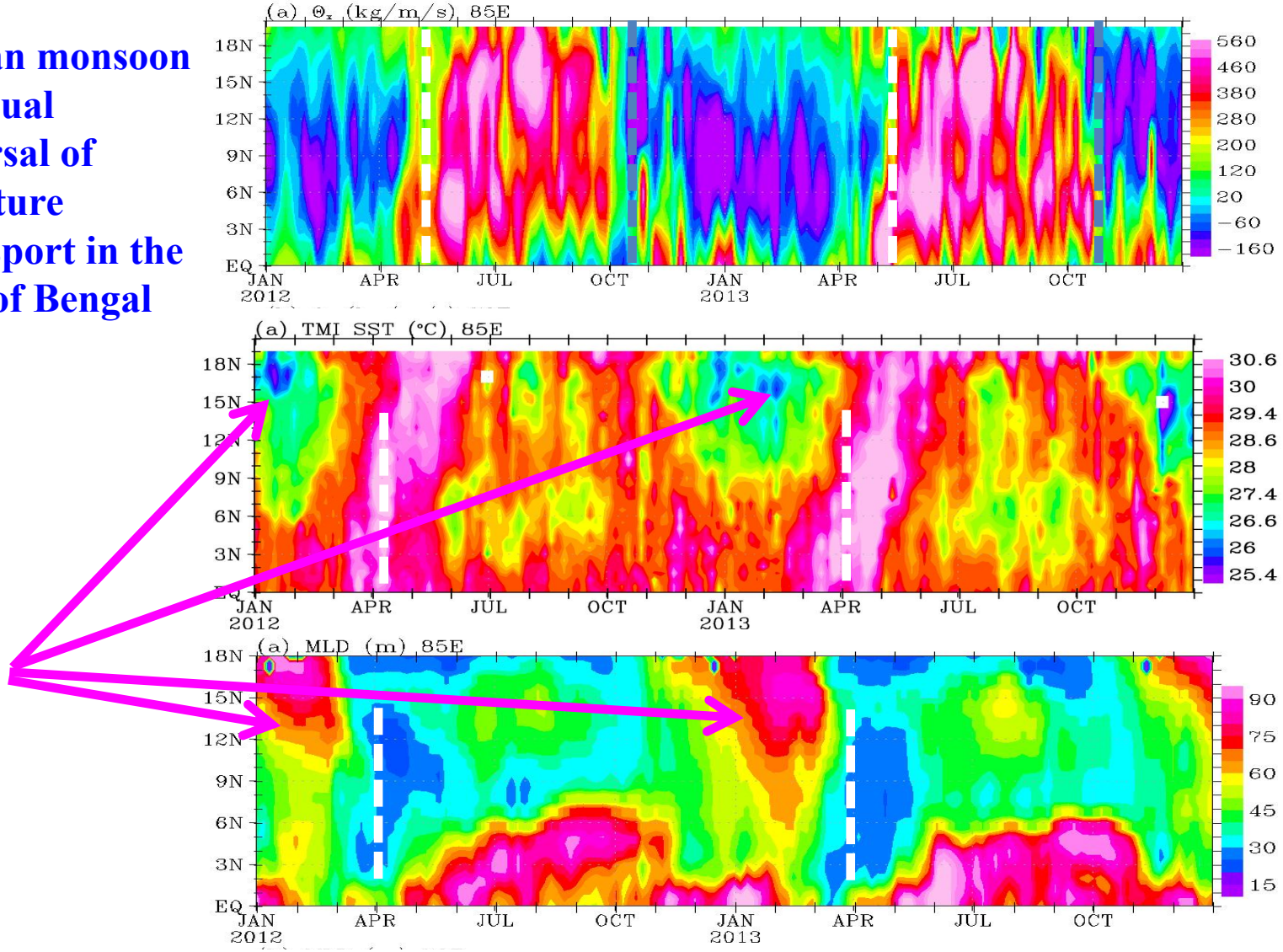
Summer monsoon starts at the peak of SST rise, in both AS and BB. BS changes earlier than AS

Short wave radiation in Bay of Bengal



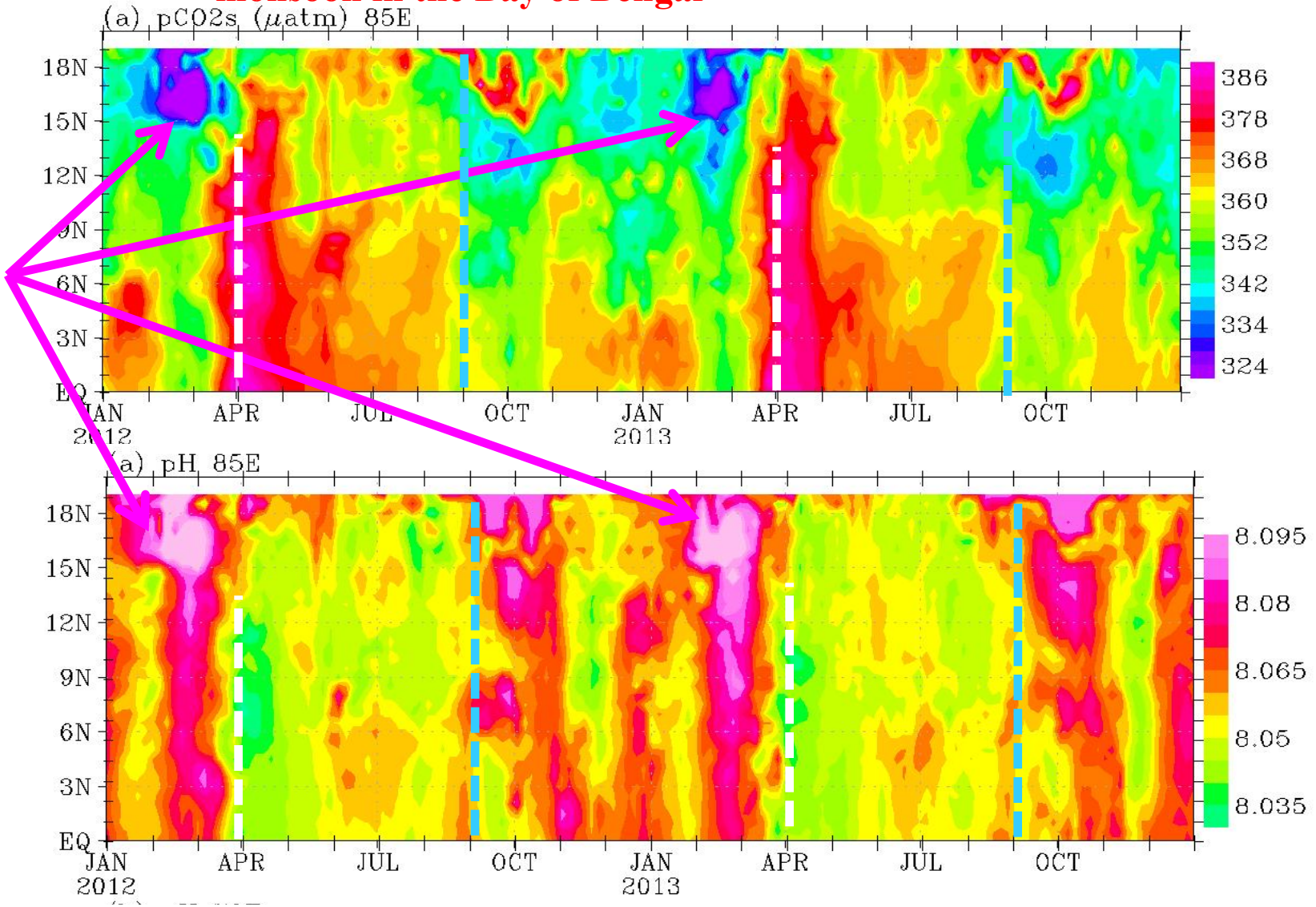
Thermal dynamics and ocean stratification in Bay of Bengal

Indian monsoon - annual reversal of moisture transport in the Bay of Bengal



Preceding the change of pCO2s and pH in February, ocean mixed layer deepens and sea water becomes colder in January/February, followed by much shallower mixed layer and sharp SST rise in April.

Annual variation of ocean acidity associated with Indian monsoon in the Bay of Bengal



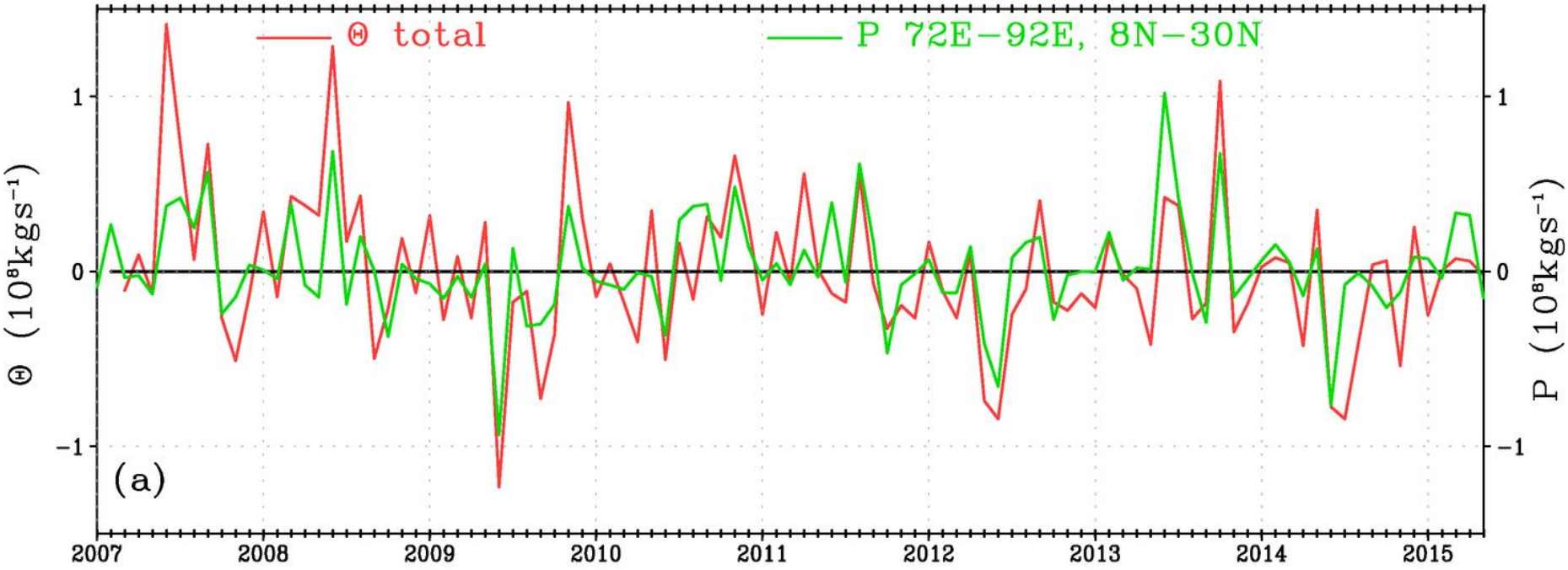
Sharp decrease of pCO2s and increase of pH (more alkaline, less acid sea water) in late January and February, followed by increase of pCO2s and decrease of pH (more acid sea water) in April.

Biochemical annual change is one month prior to the monsoon reversal.

• Satellite soil moisture allows us to characterize pre-monsoon drought (PMD).

- PMD is an annual occurrence, may be amplified by interannual variation of monsoon onset but not driven by it.
- It occurs when moisture advects out to BB earlier than coming in from AS.
- Southwest wind (summer monsoon) starts earlier in BB and sucks air out of India, replaced by air from the NW desert before monsoon moisture comes from AS
- Summer monsoon is found to start at the peak of sea surface temperature (SST) rise, above deep convection threshold in both AS and BB
- Solar heating is high through the spring season, but the shallowing of ocean mixed layer coincident with SST rise.
- Ocean thermal- and hydrodynamics have strong signatures in ocean biogeochemistry during monsoon onsets.

backup


Θ total
P 72E−92E, 8N−30N
Θ (10⁸kgs⁻¹)
P (10⁸kgs⁻¹)
1
0
−1
(a)
2007
2008
2009
2010
2011
2012
2013
2014
2015

HYDROLOGIC BALANCE

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

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

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

$$\Theta = \mathbf{U_e}\, W$$

Θ is equivalent to column water vapor W advected by Ue.

Ue is the depth-averaged wind weighted by humidity

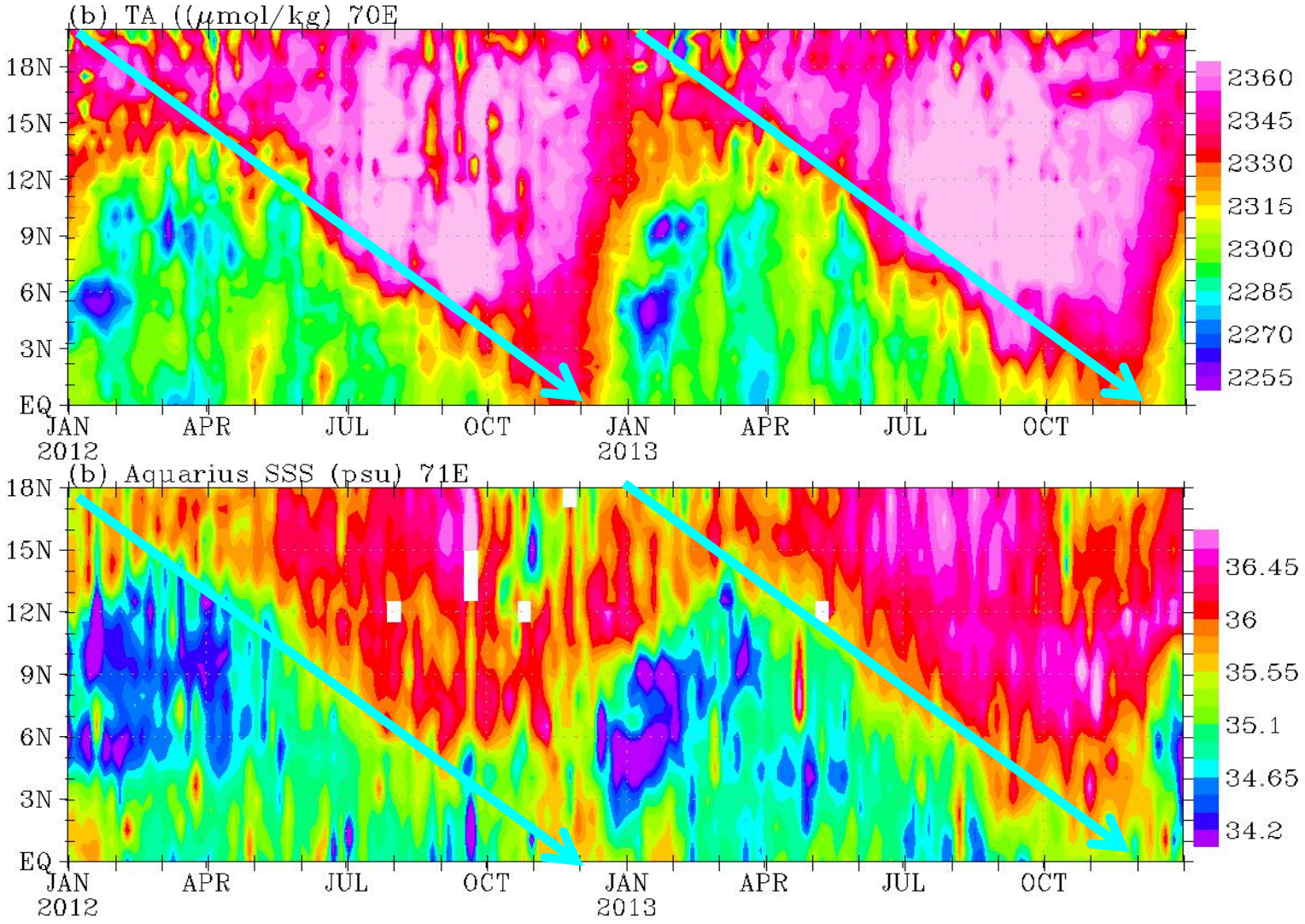
Before 2005, Ue is related to Un only

From 2005, 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)

Hydrodynamics and biochemestry in the Arabian Sea



The annual variations of TA, pCO2s, and pH (next slide) closely follow the change of SSS in the Arabian Sea, which clearly reflects the annual movement of fresh water flux between the Bay of Bengal and the Arabian Sea, associated with the Indian summer and winter monsoon.

pCO2s and pH in the Arabian Sea