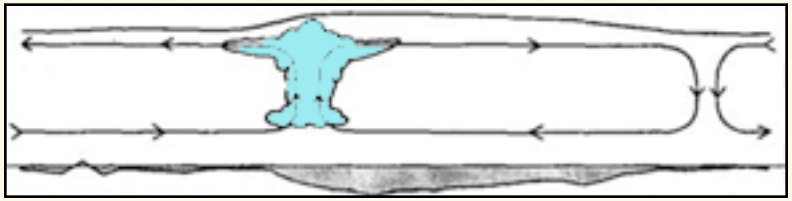
A DECOMPOSITION OF THE MADDEN-JULIAN OSCILLATION BY SATELLITE WIND PARTITIONING

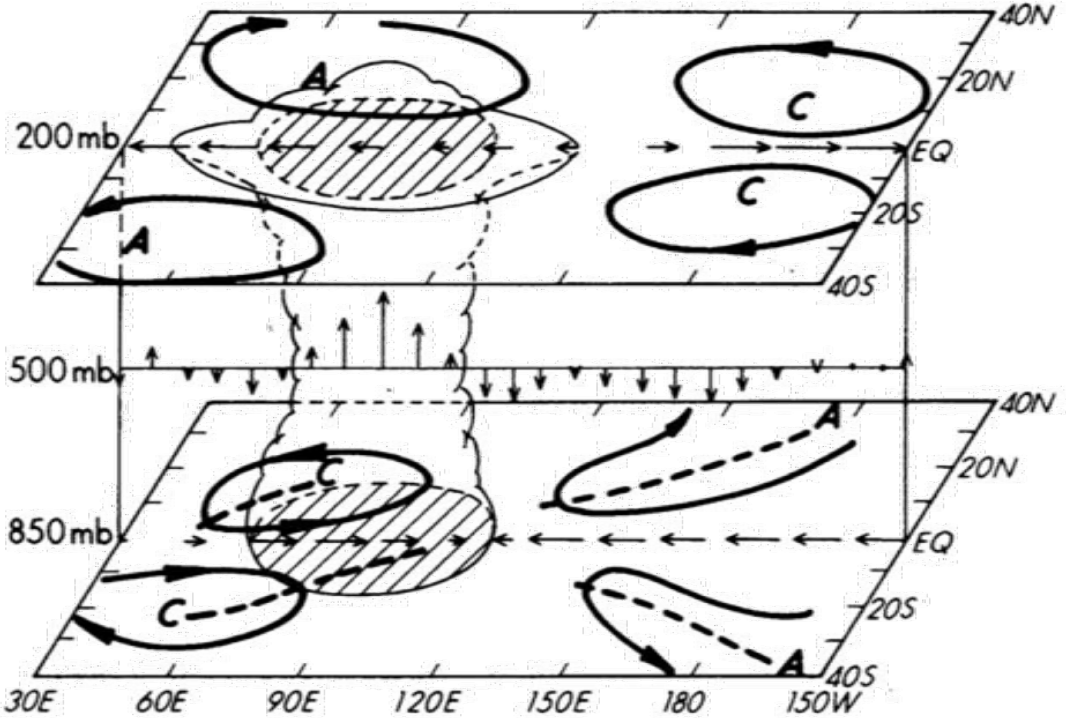
Jérôme Patoux
Ángel F. Adames-Corraliza
Ralph C. Foster

IOVWST 2012



The Madden-Julian Oscillation

- Dominant component of intraseasonal variability in the tropical atmosphere.
- Characterized by eastward-propagating (~5 m/s), convective centers.
- Local intraseasonal period of 30-90 days.



Rui and Wang [1990].

The Madden-Julian Oscillation

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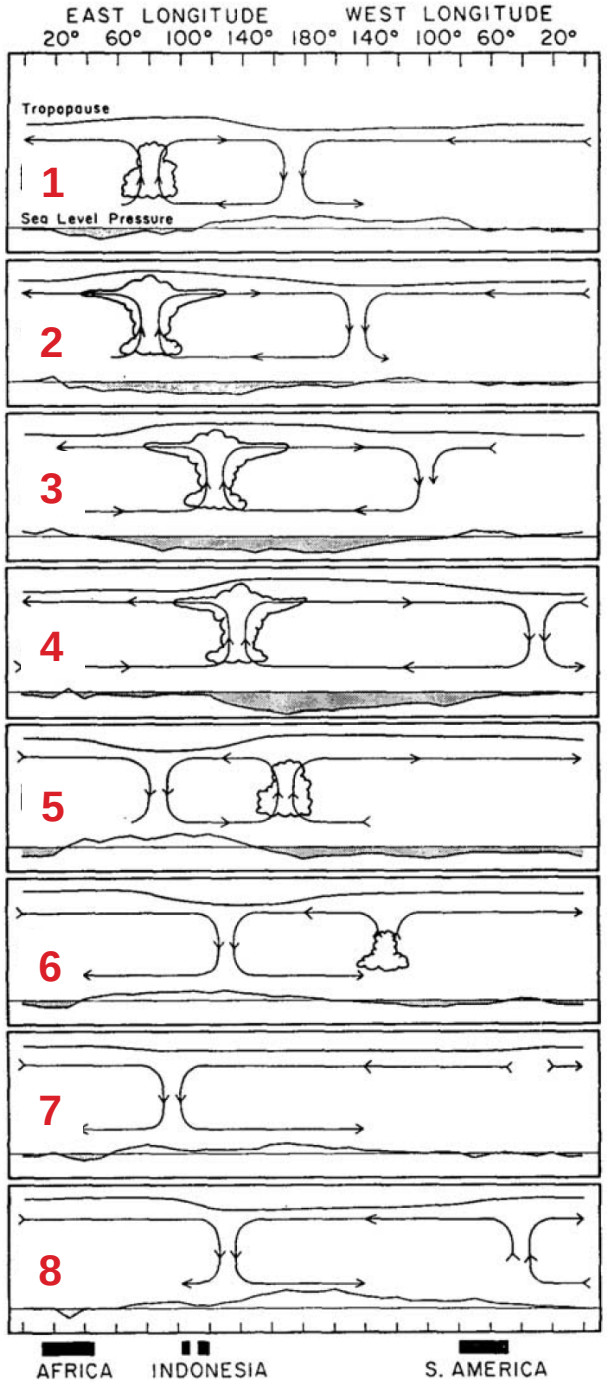
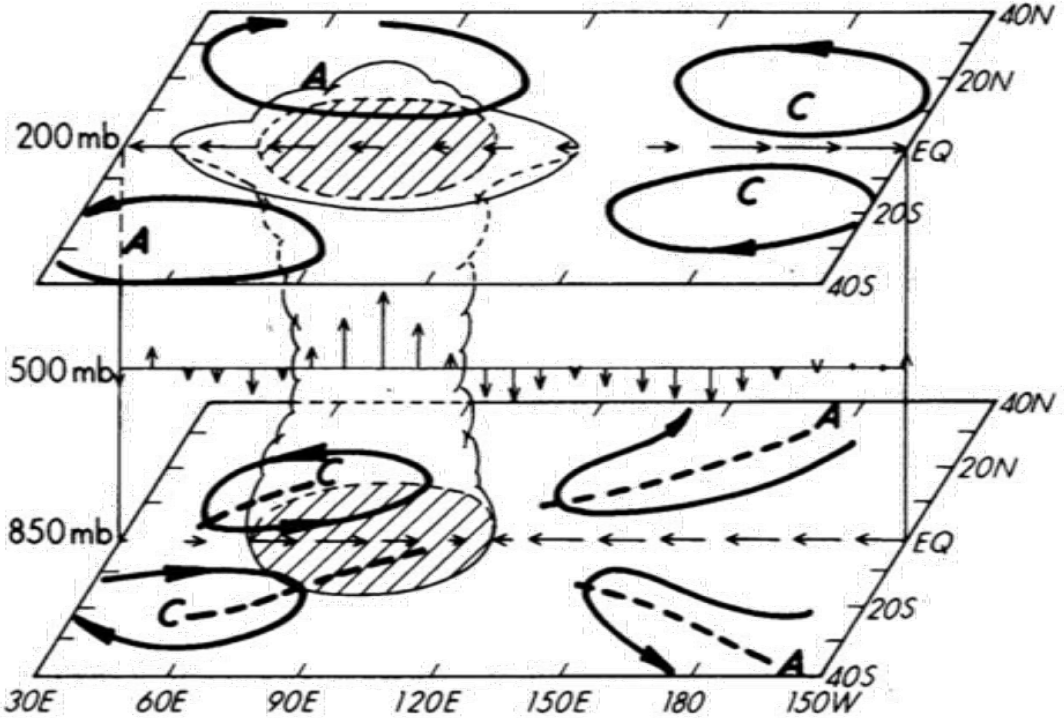
Madden and Julian [1972].



The Madden-Julian Oscillation

The MJO affects:

- The Asian-Australian Monsoon.
- Onset and evolution of the El Niño Southern Oscillation (ENSO).
- Tropical cyclone activity.
- Precipitation events in the tropics and extratropics.
- Atmospheric chemicals and aerosols.

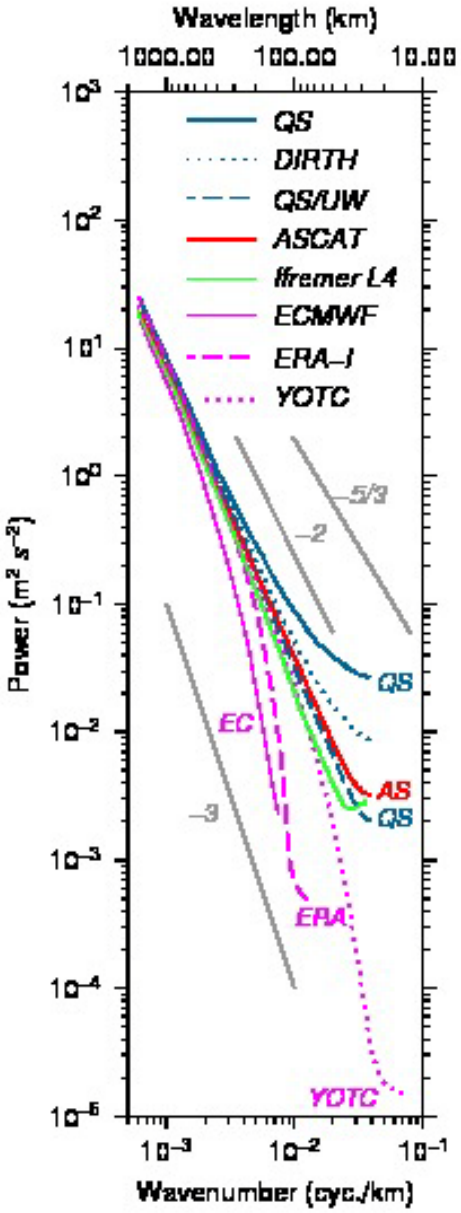


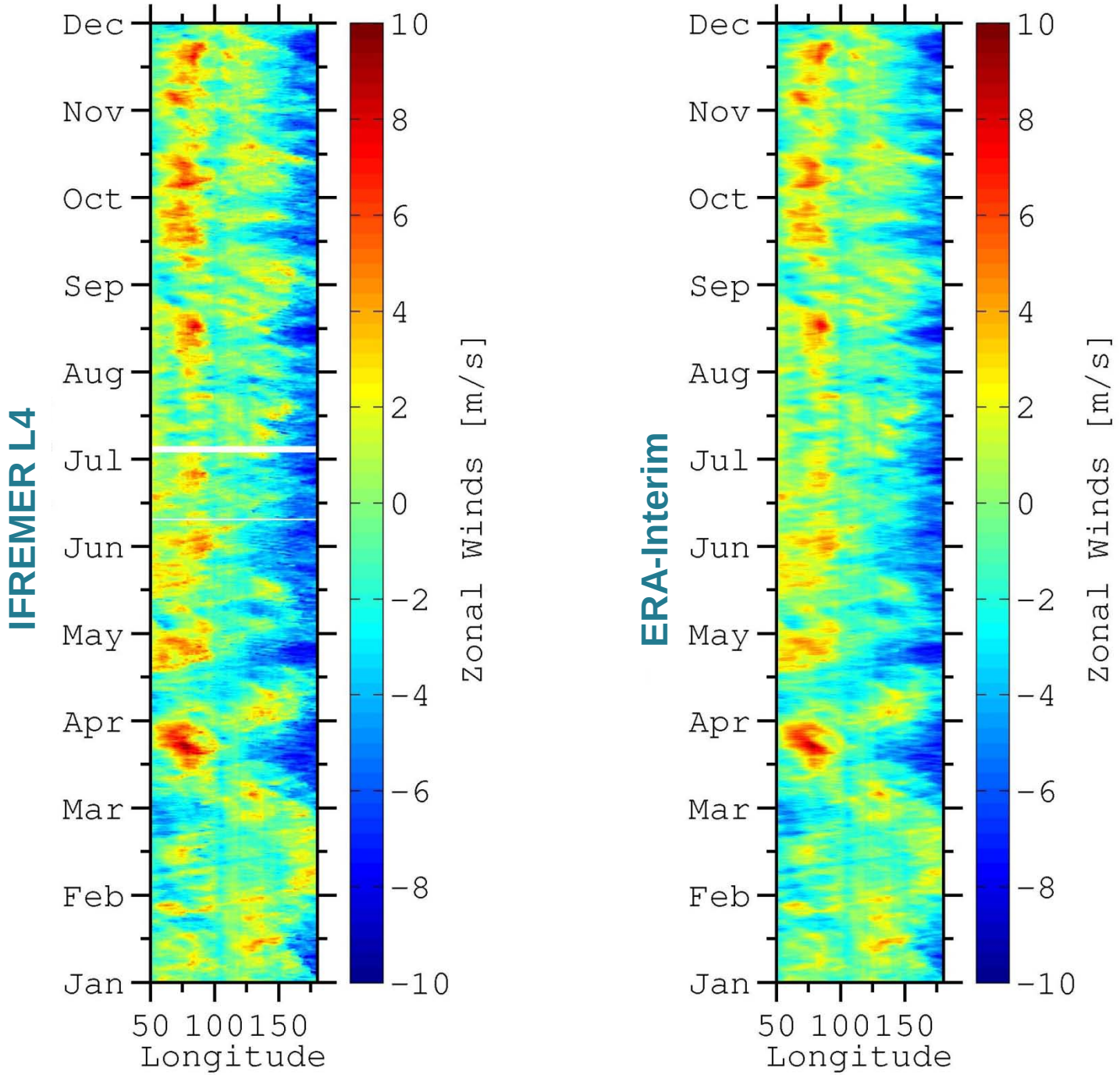
Rui and Wang [1990].

Goals

MJO events are not correctly captured by models.

- What additional information about the MJO do satellite measurements provide?
- Test some hypotheses about the role of mesoscale boundary layer processes in the initiation and propagation of the MJO using scatterometer winds and other satellite data (TRMM, SSM/I, etc.)

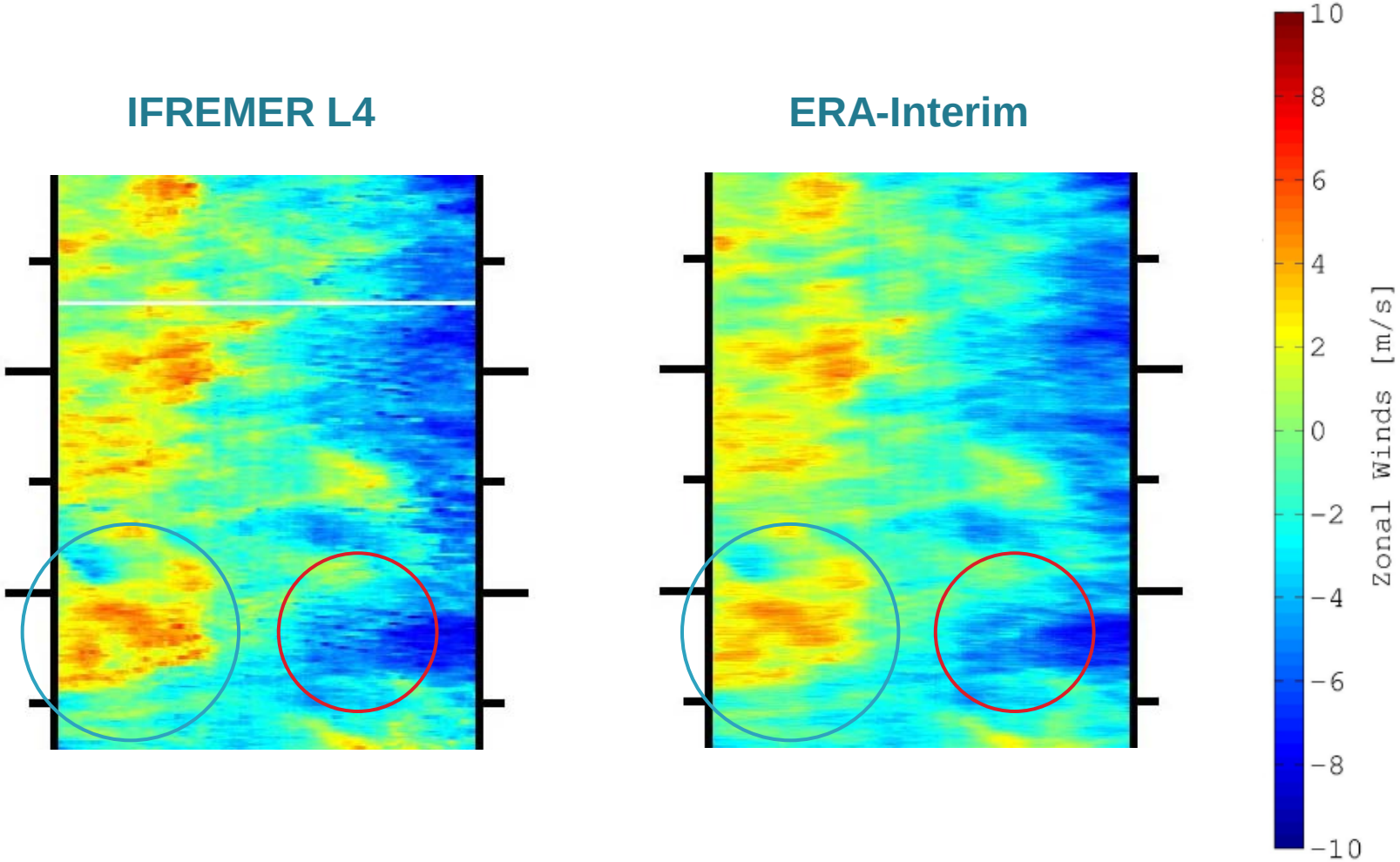



IFREMER L4
ERA-Interim
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan
50 100150
Longitude
10
8
6
4
2
0
−2
−4
−6
−8
−10
Zonal Winds [m/s]

Comparison of time-longitude zonal wind speed

IFREMER L4

ERA-Interim

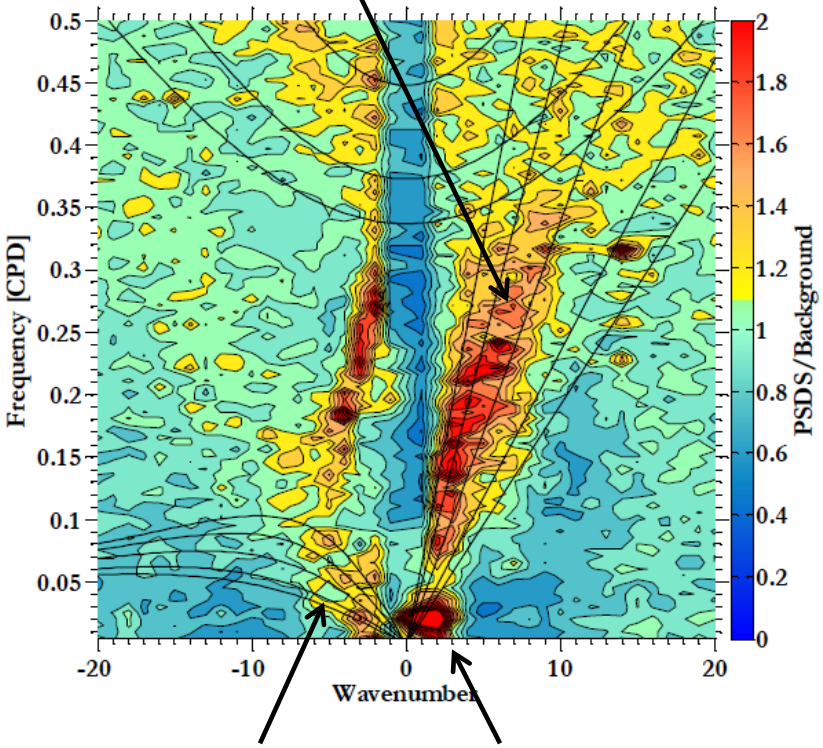


Equatorial waves: 2D Fourier analysis and ω-k spectra

$\omega_K = ck$

$c = \sqrt{gh_e}$

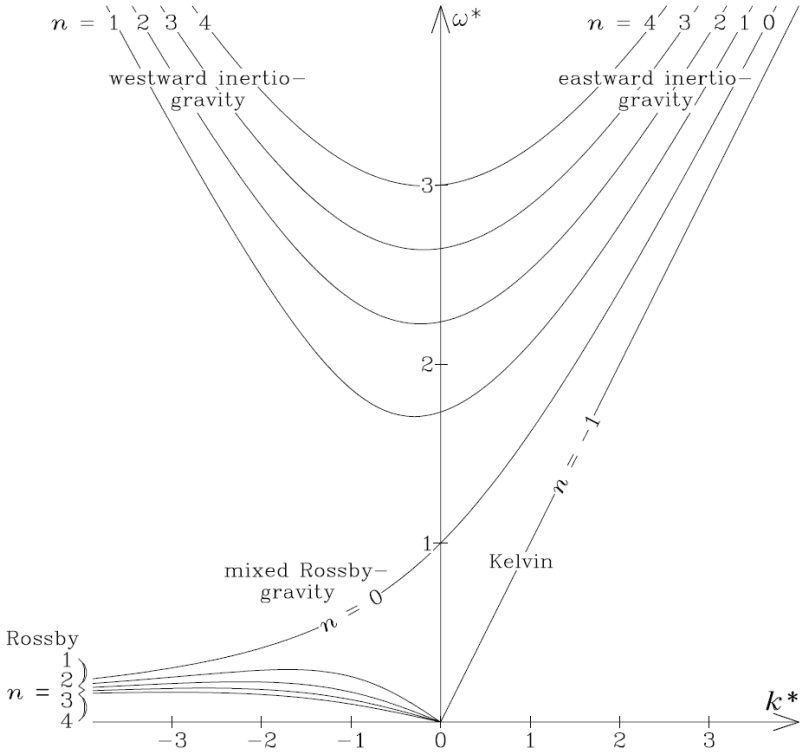
Kelvin



eq. Rossby

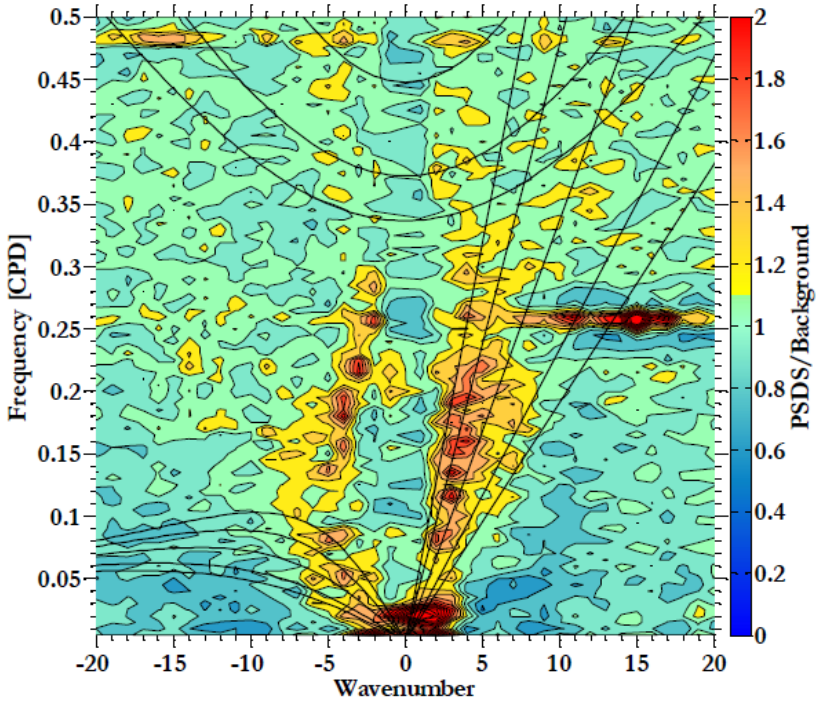
MJO

$$\omega_R = \frac{-\beta k}{k^2 + (2n+1)\beta/c}$$



Comparison of ω-k spectra

IFREMER L4



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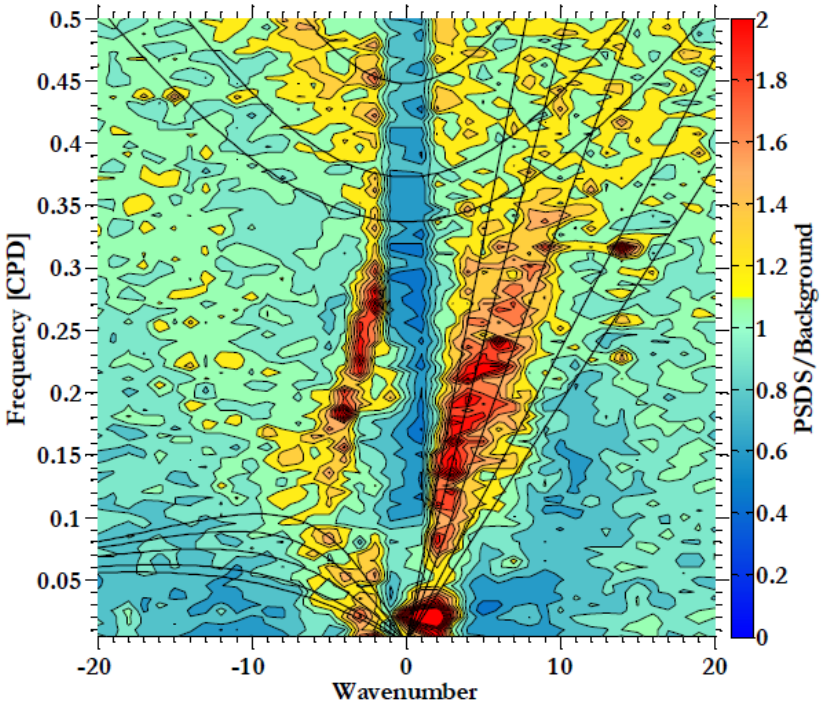
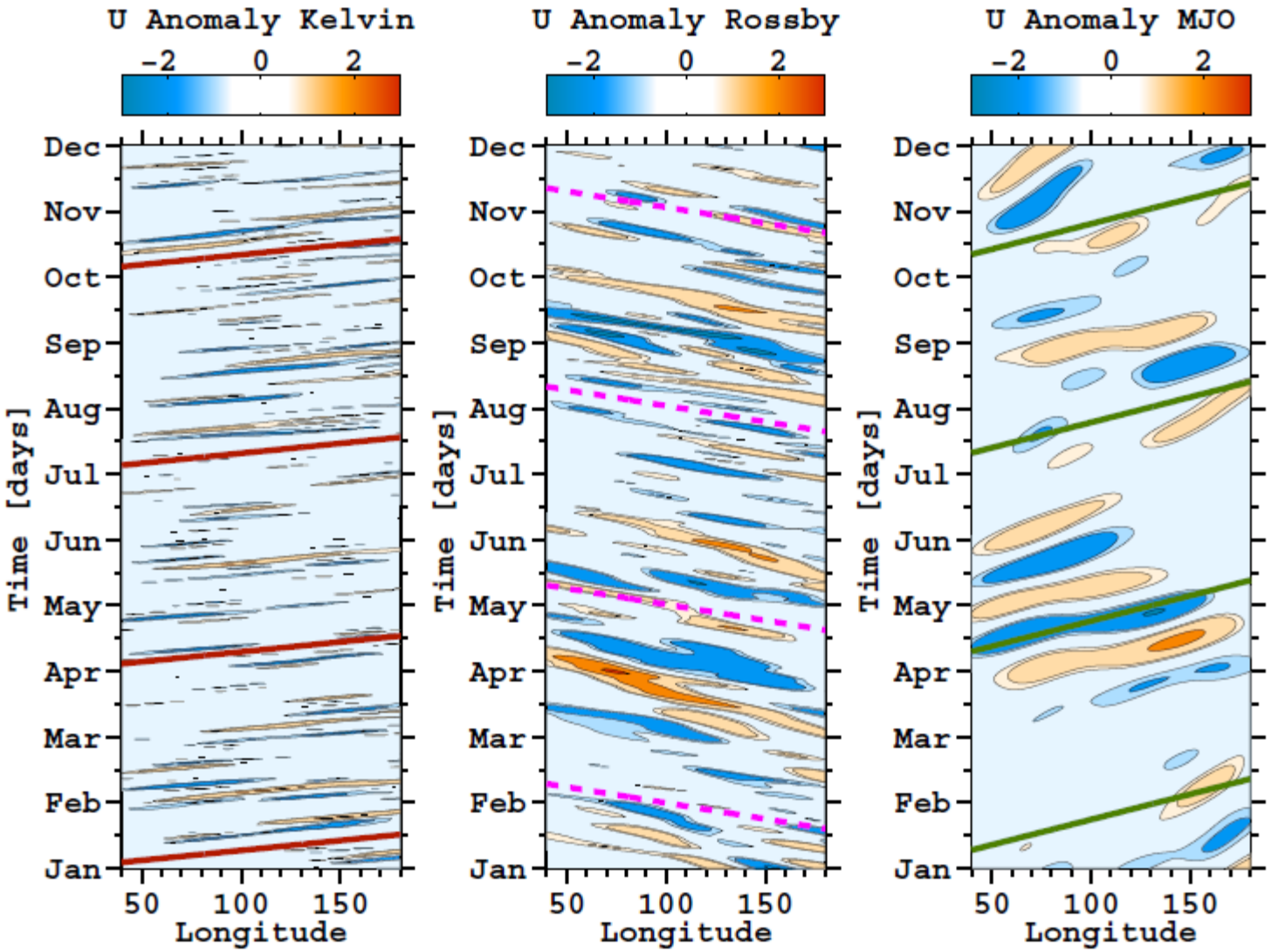
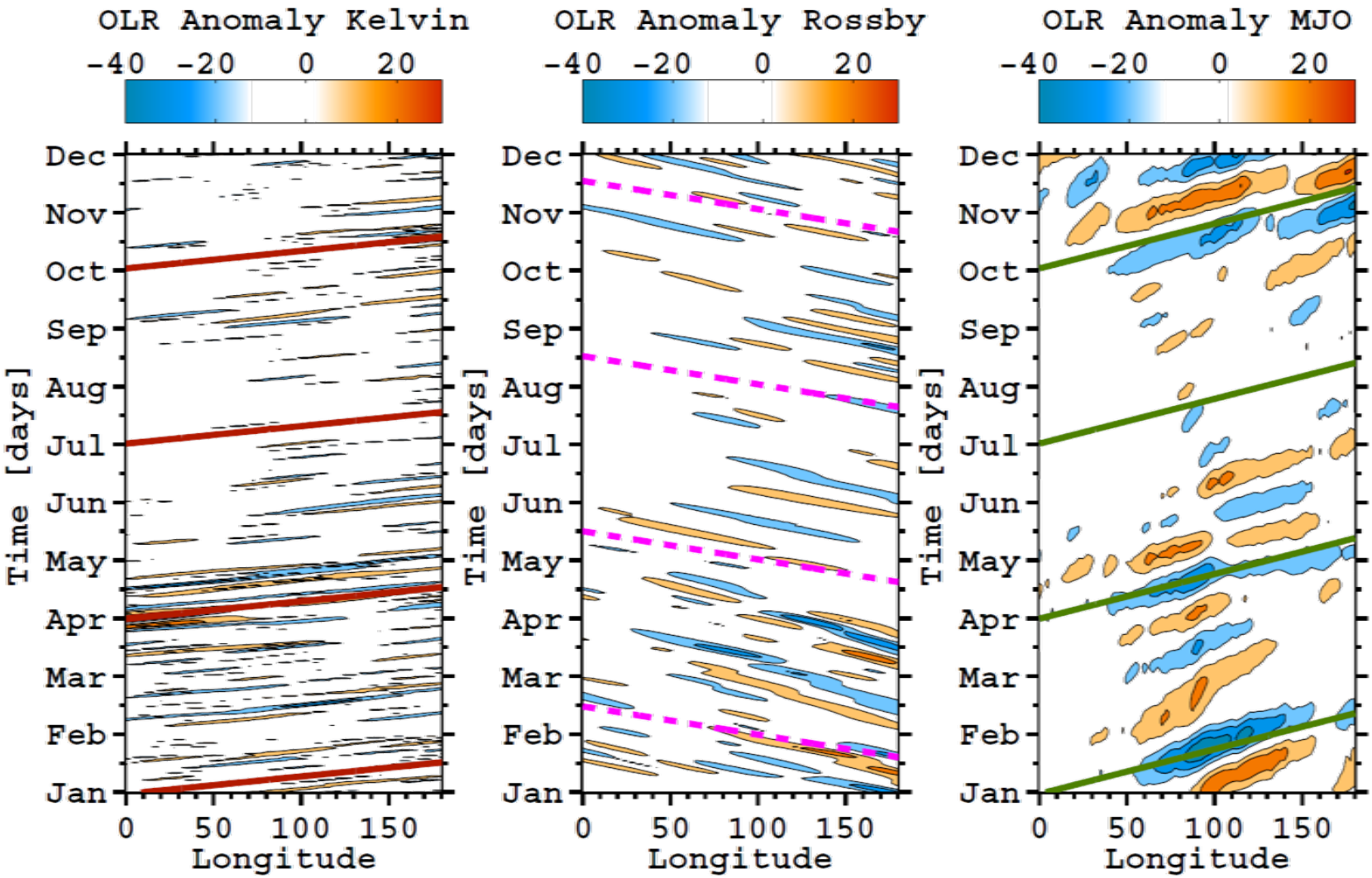
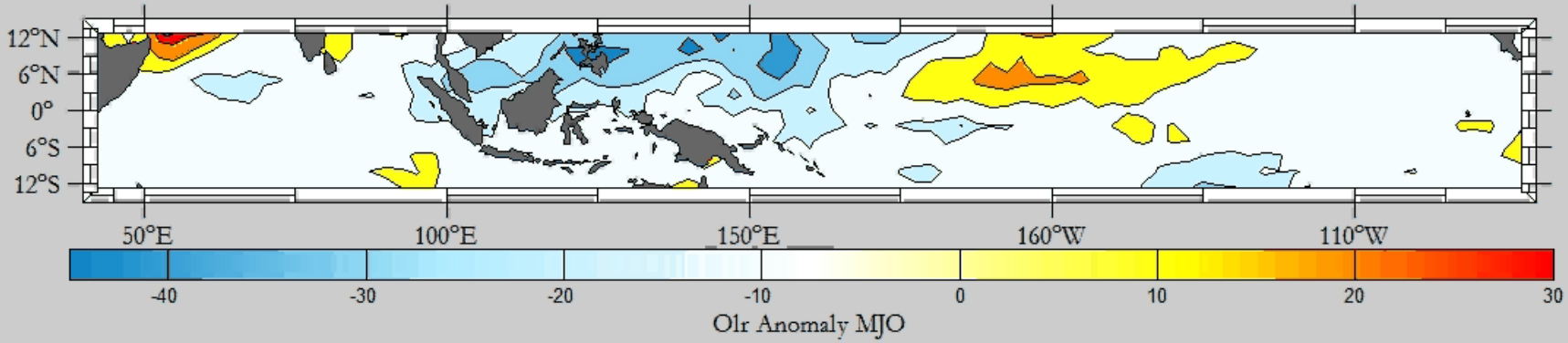


Filtered zonal wind anomalies

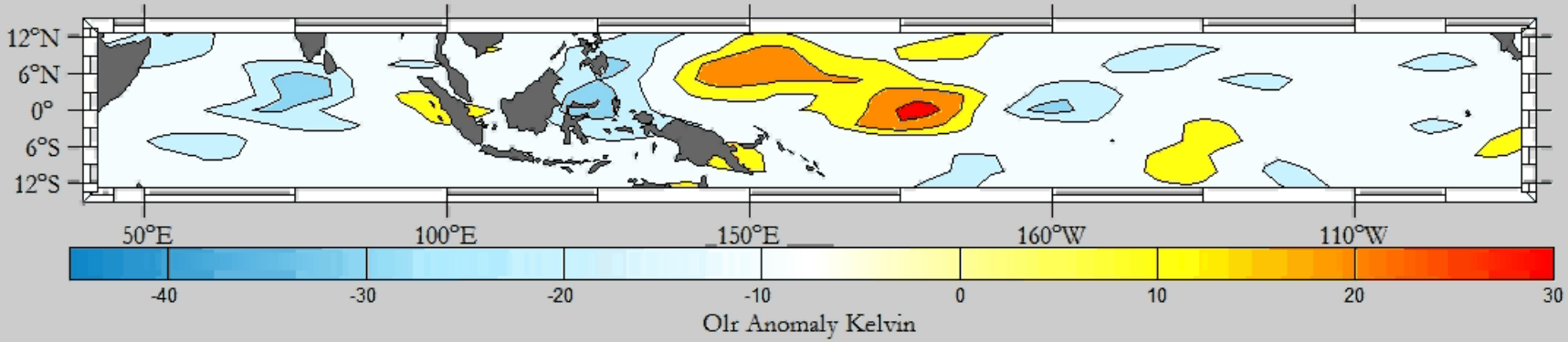


Filtered OLR anomalies

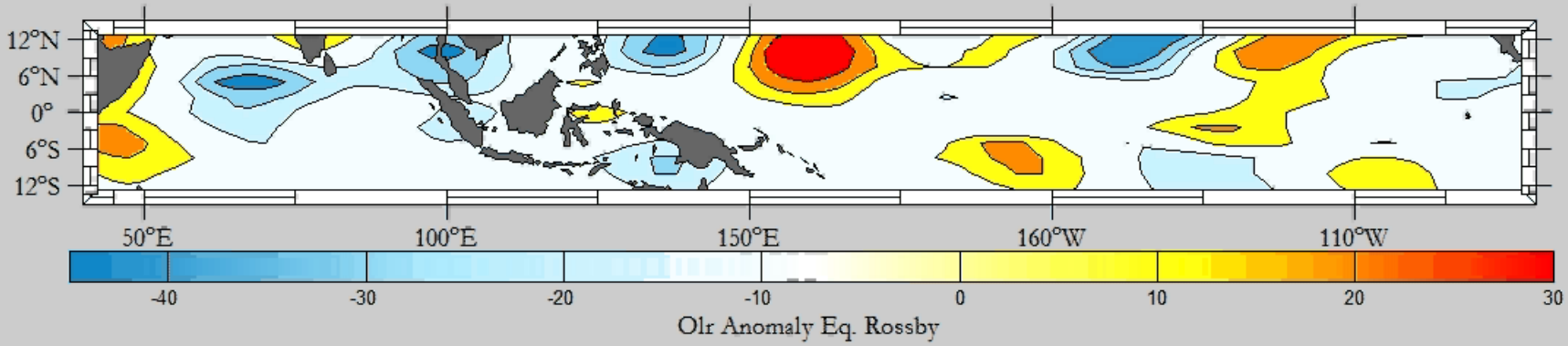




Olr Anomaly MJO



Olr Anomaly Kelvin



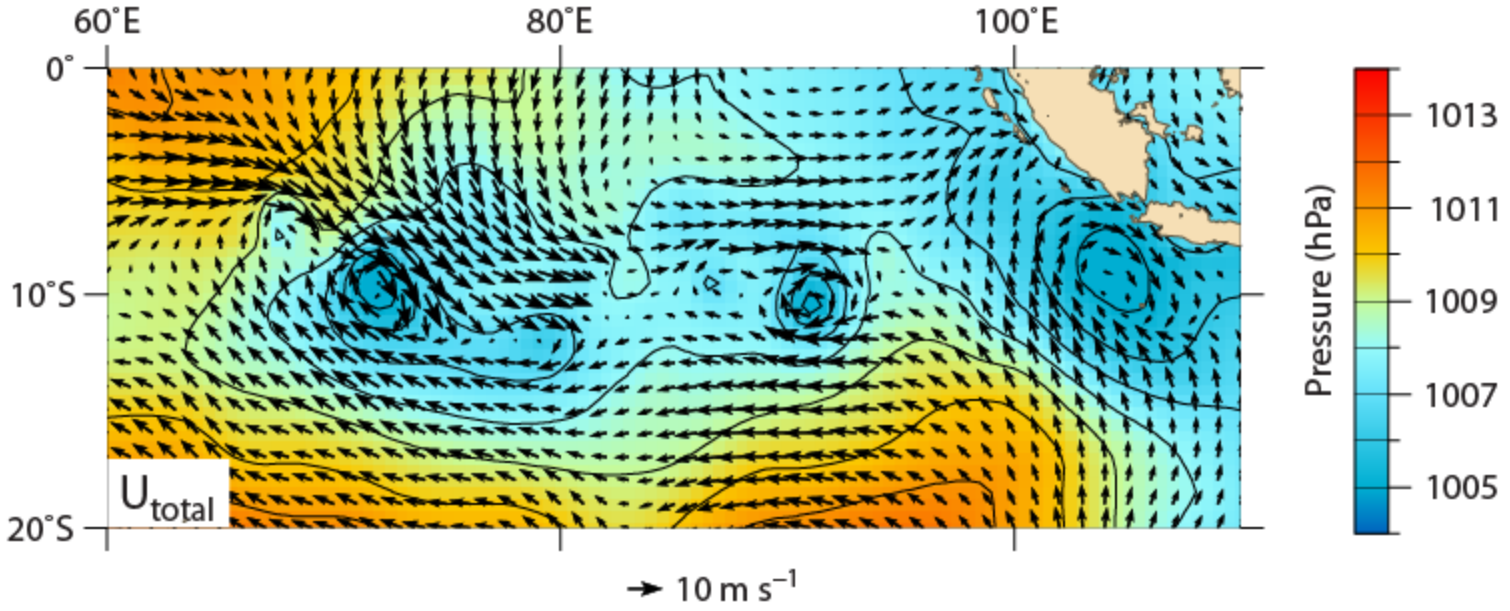
Olr Anomaly Eq. Rossby

Wind partitioning

The total wind ($\mathbf{U_{tot}}$) is partitioned by attributing individual elements of vorticity and divergence in the tropical belt (using free-space Green's functions) to separate wind components:

- a non-divergent component $\mathbf{U_{\psi}}$ (carrying the rotational part of the wind field);
- an irrotational component $\mathbf{U_{\chi}}$ (carrying the convergent part of the wind field);
- a background flow $\mathbf{U_{\theta}} = \mathbf{U_{tot}} - \mathbf{U_{\psi}} - \mathbf{U_{\chi}}$ characterizing the environment in which the rotational and convergent elements are embedded – the background flow can be thought of as resulting from vorticity and divergence elements outside of the tropical belt.

Wind partitioning: an example in the Indian Ocean

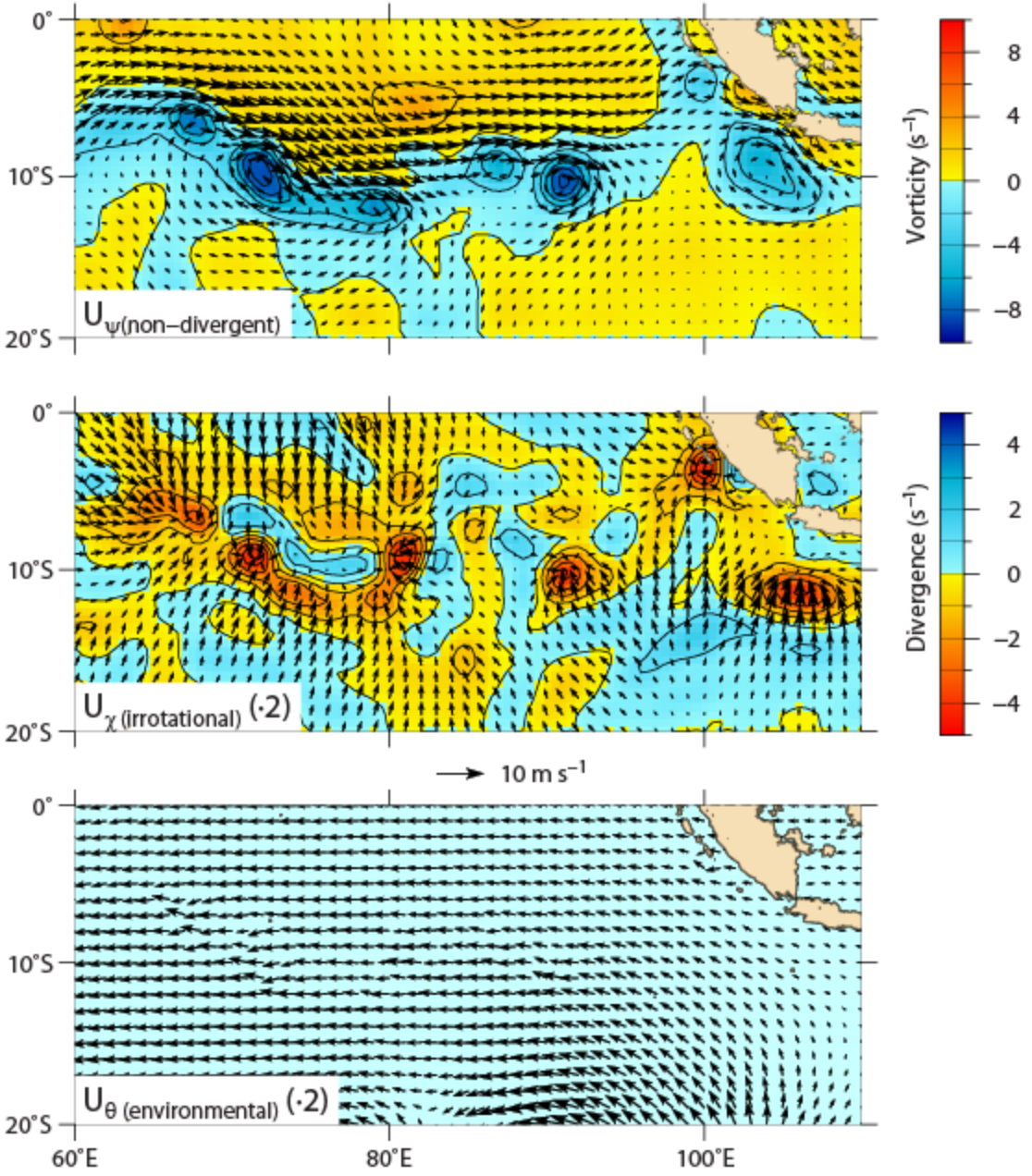


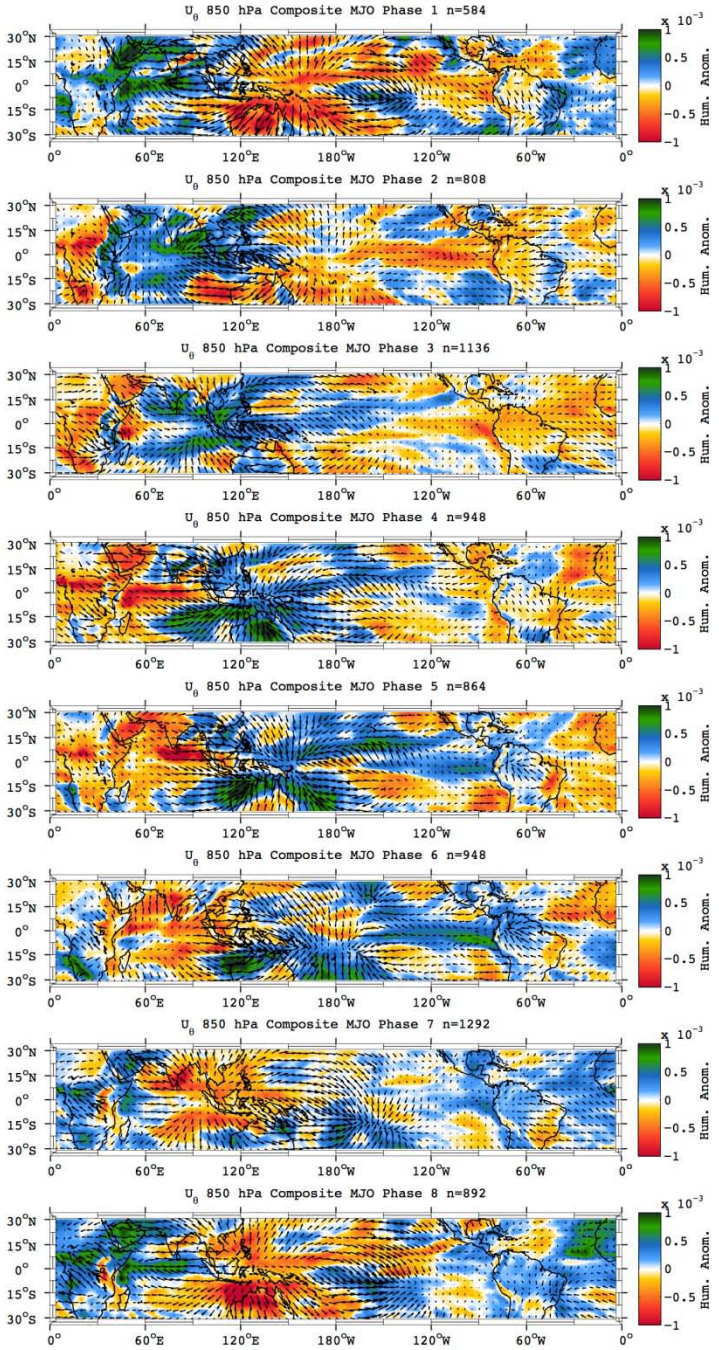
Wind partitioning

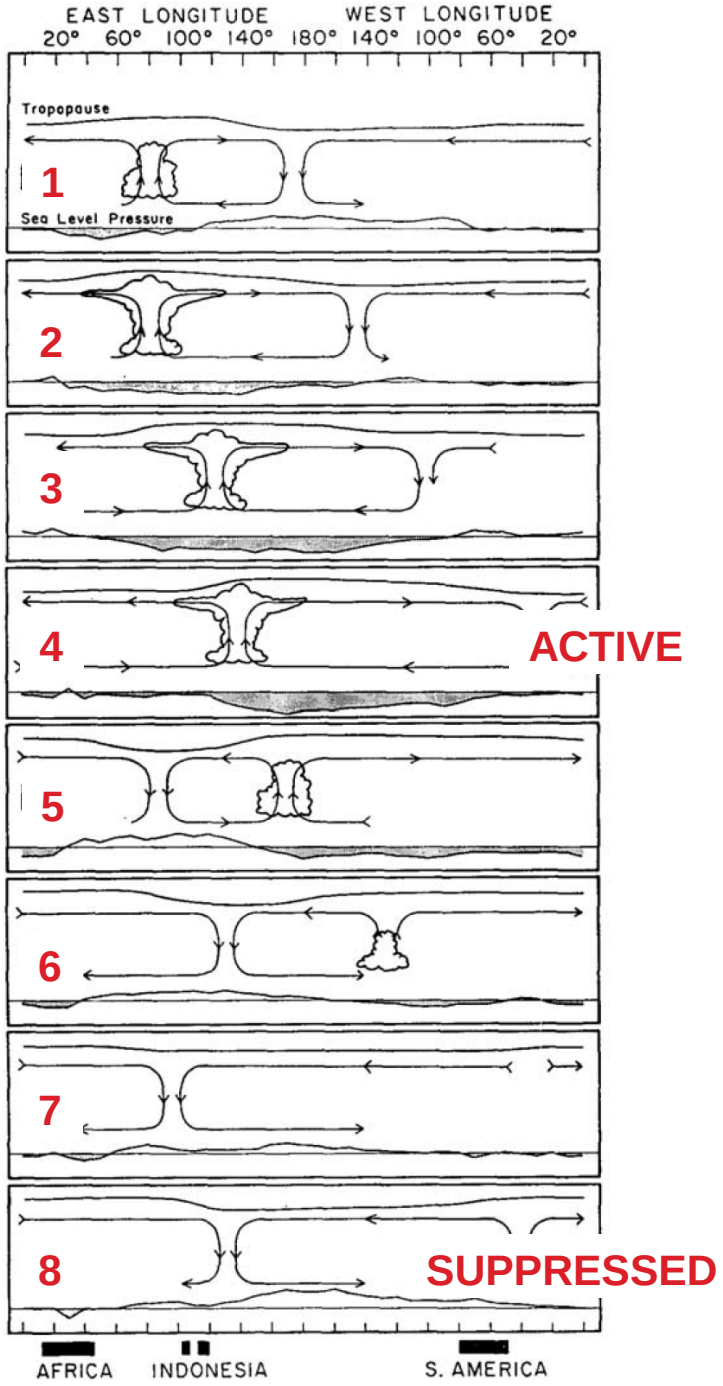
non-divergent component $\mathbf{U_\psi}$

irrotational component $\mathbf{U_\chi}$

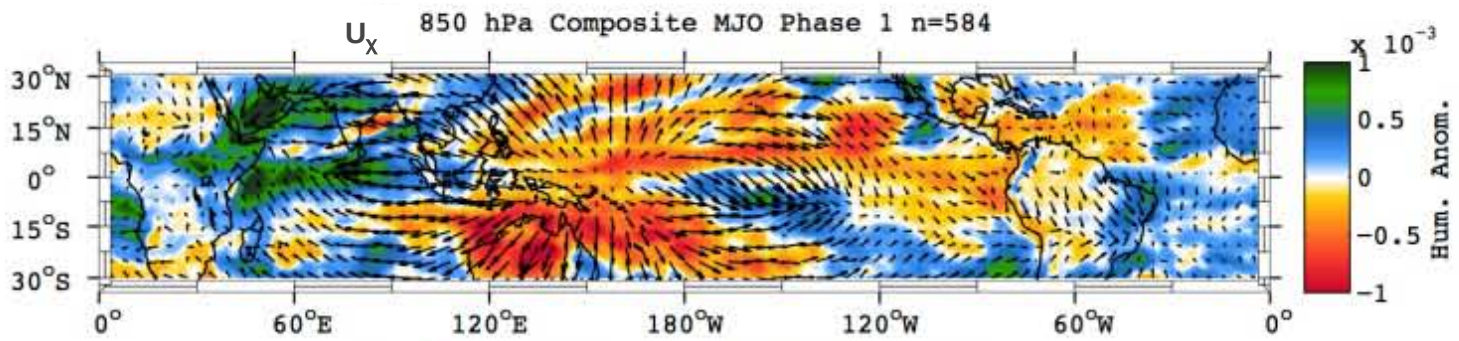
background flow $\mathbf{U_\theta}$



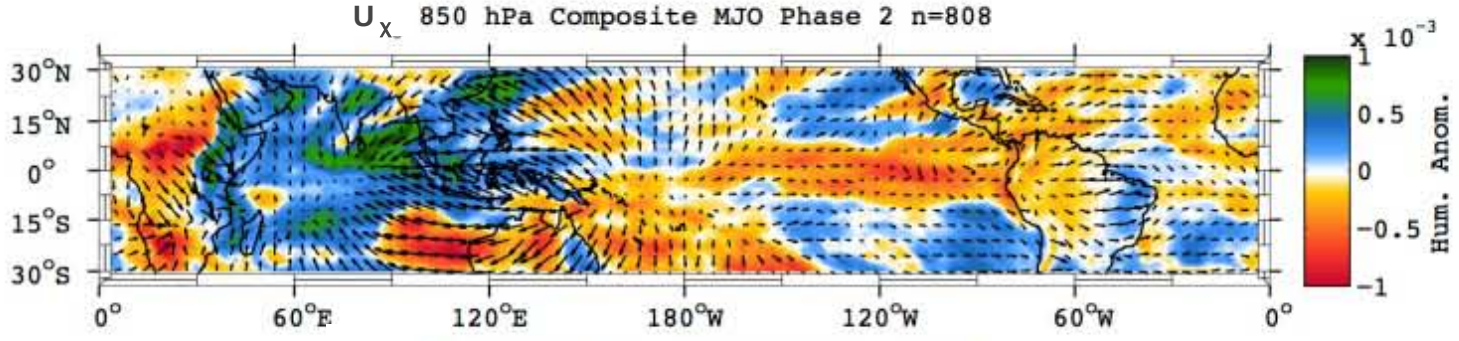

U$_\theta$ 850 hPa Composite MJO Phase 1 n=584
U$_\theta$ 850 hPa Composite MJO Phase 2 n=808
U$_\theta$ 850 hPa Composite MJO Phase 3 n=1136
U$_\theta$ 850 hPa Composite MJO Phase 4 n=948
U$_\theta$ 850 hPa Composite MJO Phase 5 n=864
U$_\theta$ 850 hPa Composite MJO Phase 6 n=948
U$_\theta$ 850 hPa Composite MJO Phase 7 n=1292
U$_\theta$ 850 hPa Composite MJO Phase 8 n=892
30°N
15°N
0°
15°S
30°S
0°
60°E
120°E
180°W
120°W
60°W
0°
x 10^{-3}
1
0.5
0
−0.5
−1
Hum. Anom.


EAST LONGITUDE
WEST LONGITUDE
20° 60° 100° 140° 180° 140° 100° 60° 20°
Tropopause
Sea Level Pressure
1
2
3
4
5
6
7
8
ACTIVE
SUPPRESSED
AFRICA
INDONESIA
S. AMERICA

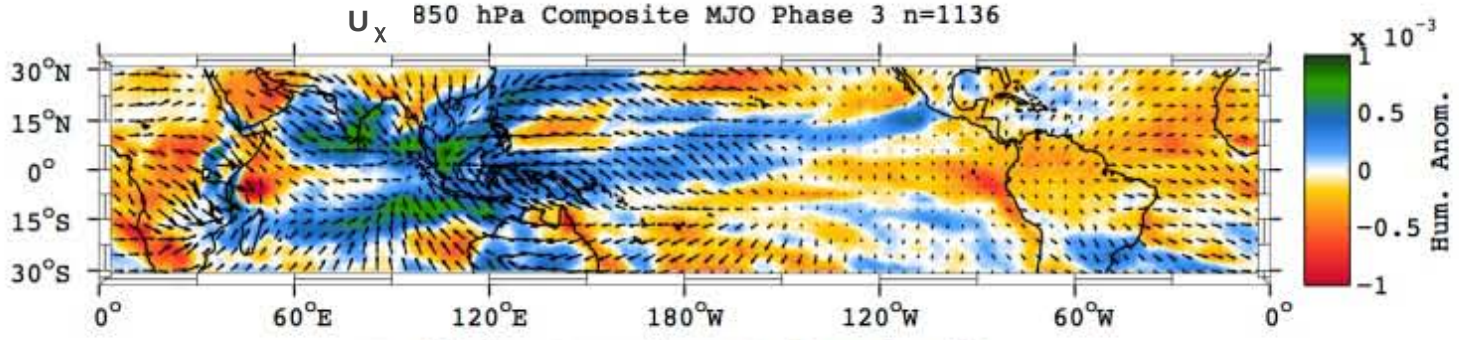
1


U_X 850 hPa Composite MJO Phase 1 n=584
30°N
15°N
0°
15°S
30°S
0°
60°E
120°E
180°W
120°W
60°W
0°
x 10⁻³
1
0.5
0
−0.5
−1
Hum. Anom.

2

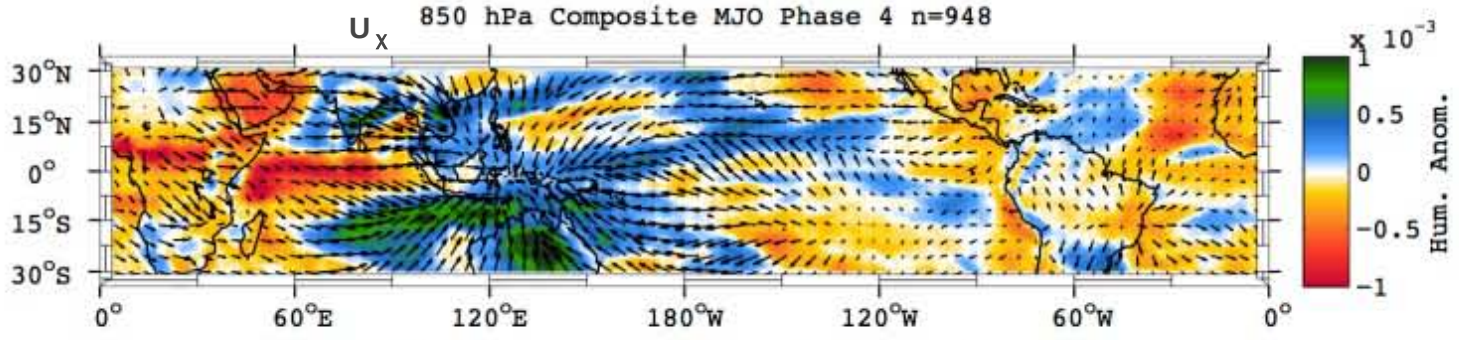

U_X 850 hPa Composite MJO Phase 2 n=808
30°N
15°N
0°
15°S
30°S
0°
60°E
120°E
180°W
120°W
60°W
0°
x 10⁻³
1
0.5
0
−0.5
−1
Hum. Anom.

3

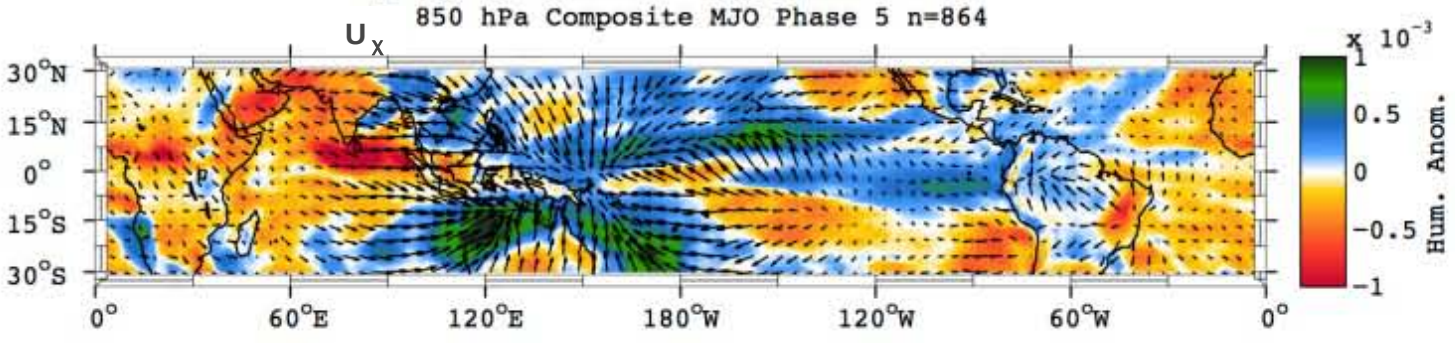

U_X 850 hPa Composite MJO Phase 3 n=1136
30°N
15°N
0°
15°S
30°S
0°
60°E
120°E
180°W
120°W
60°W
0°
x 10⁻³
1
0.5
0
−0.5
−1
Hum. Anom.

4

ACTIVE


U_X 850 hPa Composite MJO Phase 4 n=948
30°N
15°N
0°
15°S
30°S
0°
60°E
120°E
180°W
120°W
60°W
0°
x 10⁻³
1
0.5
0
−0.5
−1
Hum. Anom.

5



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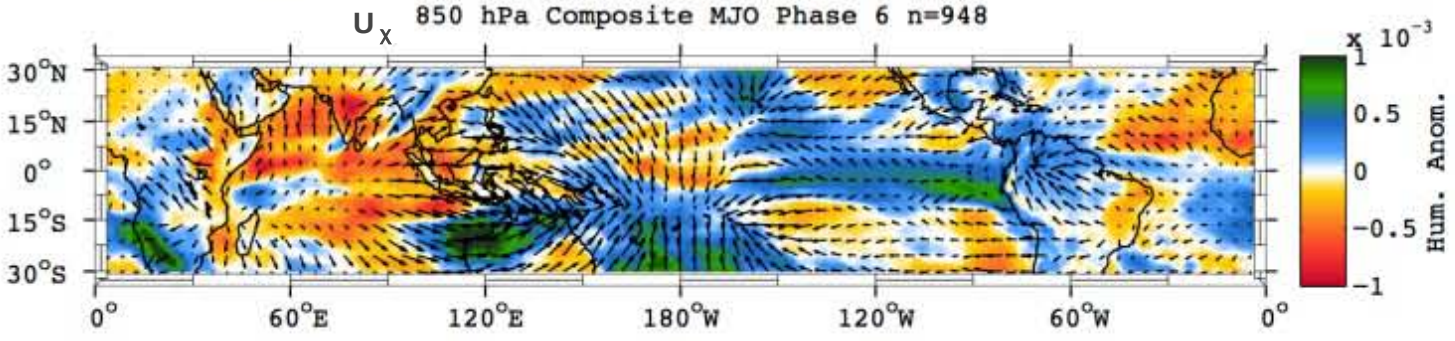
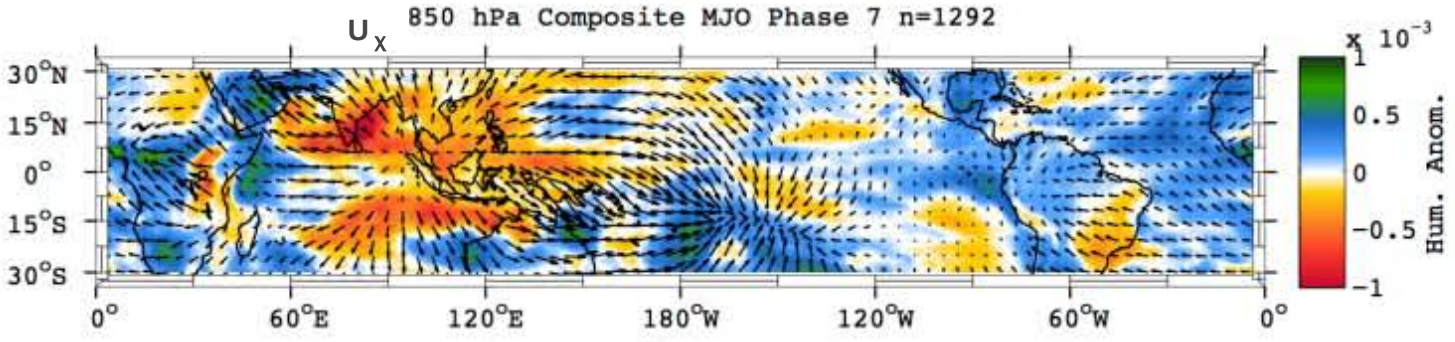
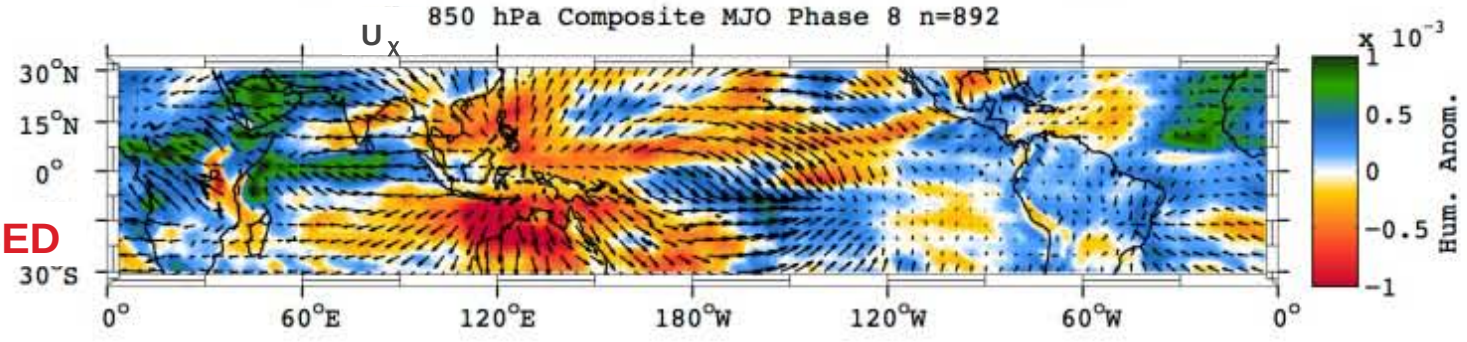


7



8

SUPPRESSED

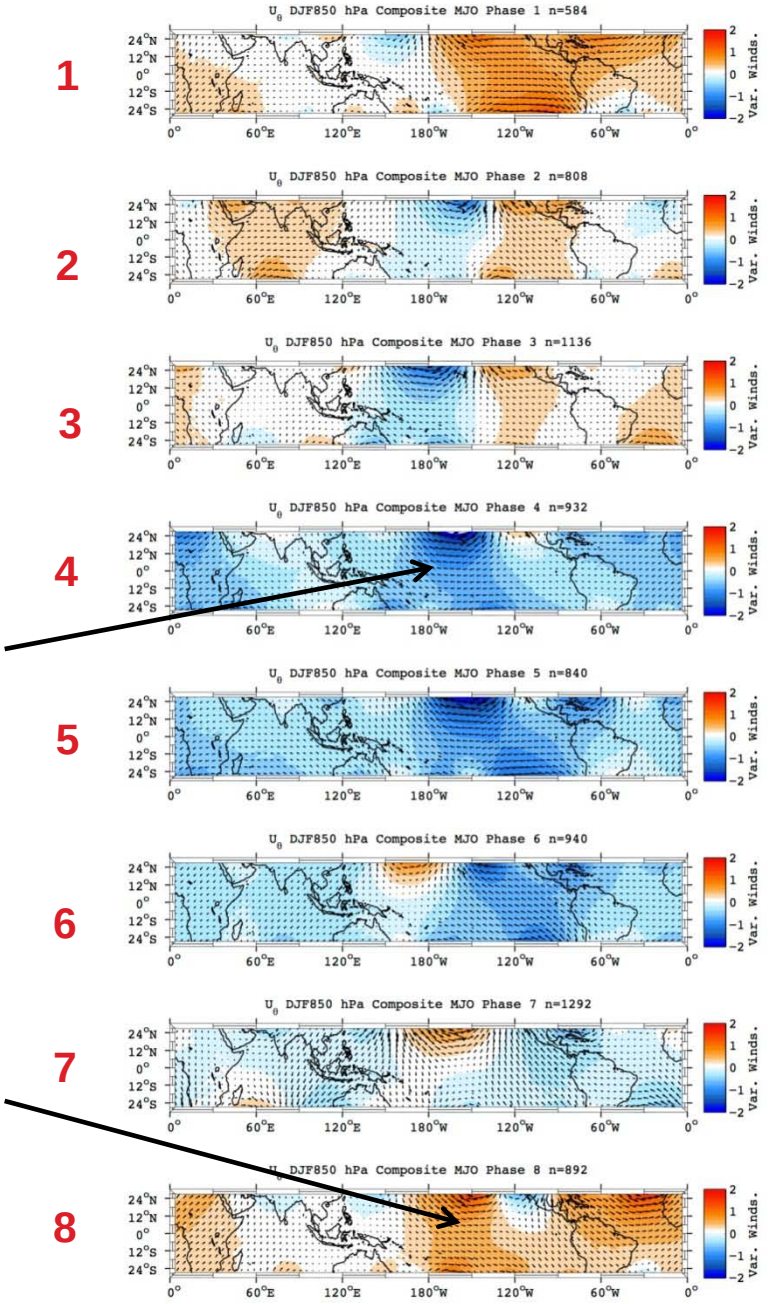


Background flow

There is a reversal of the background flow when composited on the MJO phases.

active phase = easterly

suppressed phase = westerly



Conclusion and future work

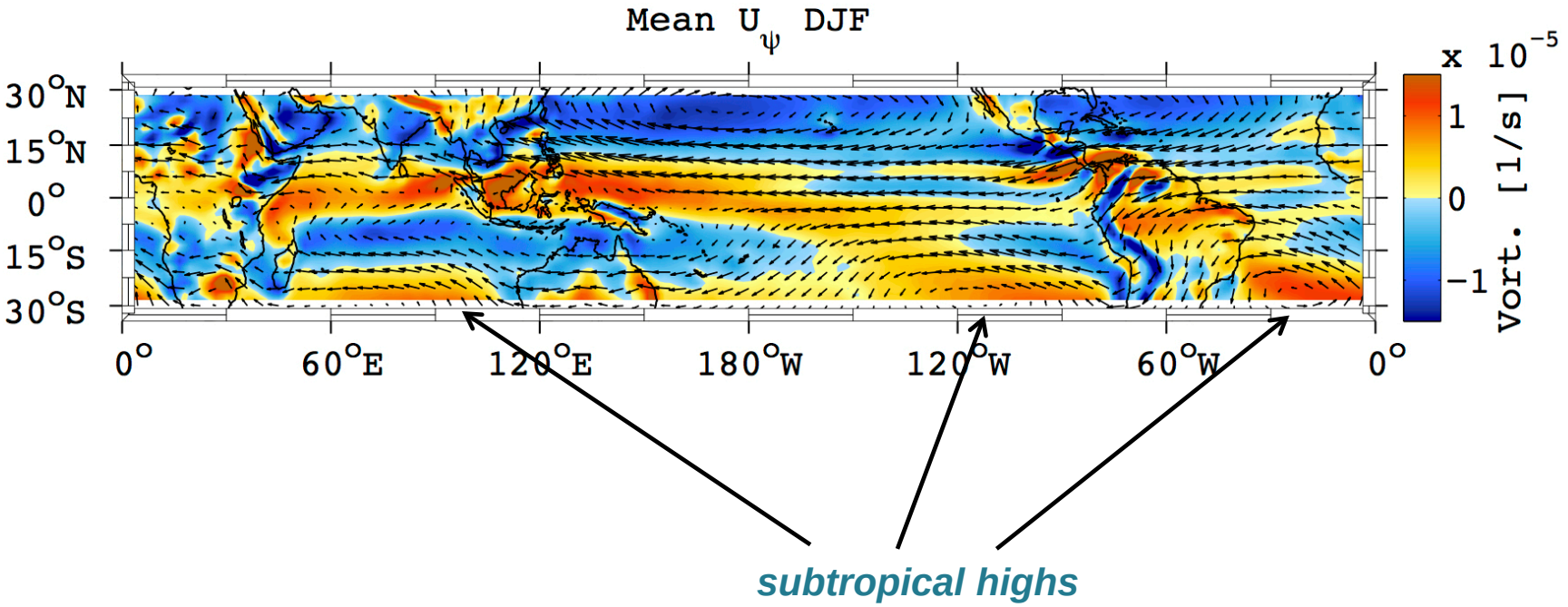
- There are differences between model and satellite winds in the equatorial Indian Ocean, of which we want to take advantage to better characterize and understand the MJO.

- We are particularly interested in the non-divergent and irrotational components of the wind field, thought to be related to Rossby and Kelvin waves, respectively. We are currently looking at evaporation and advection of moisture by each component.

- The reversal of the background flow when composited on the MJO phases suggests that the MJO (an equatorial/ tropical phenomenon) excites specific modes of variability in the extratropics that, in turn, modulate the tropical background flow. We are currently investigating possible feedbacks of this background flow on the MJO itself.

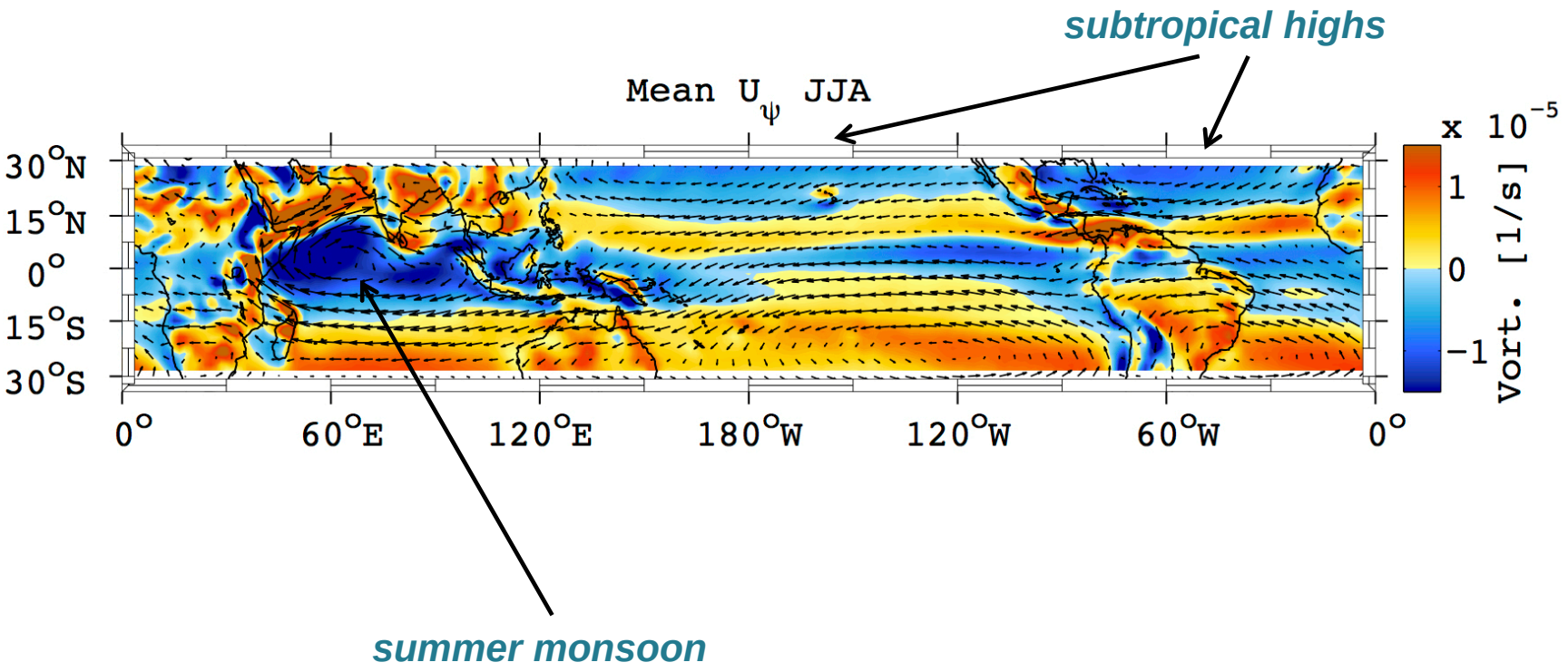
Mean rotational (non-divergent) wind component

WINTER



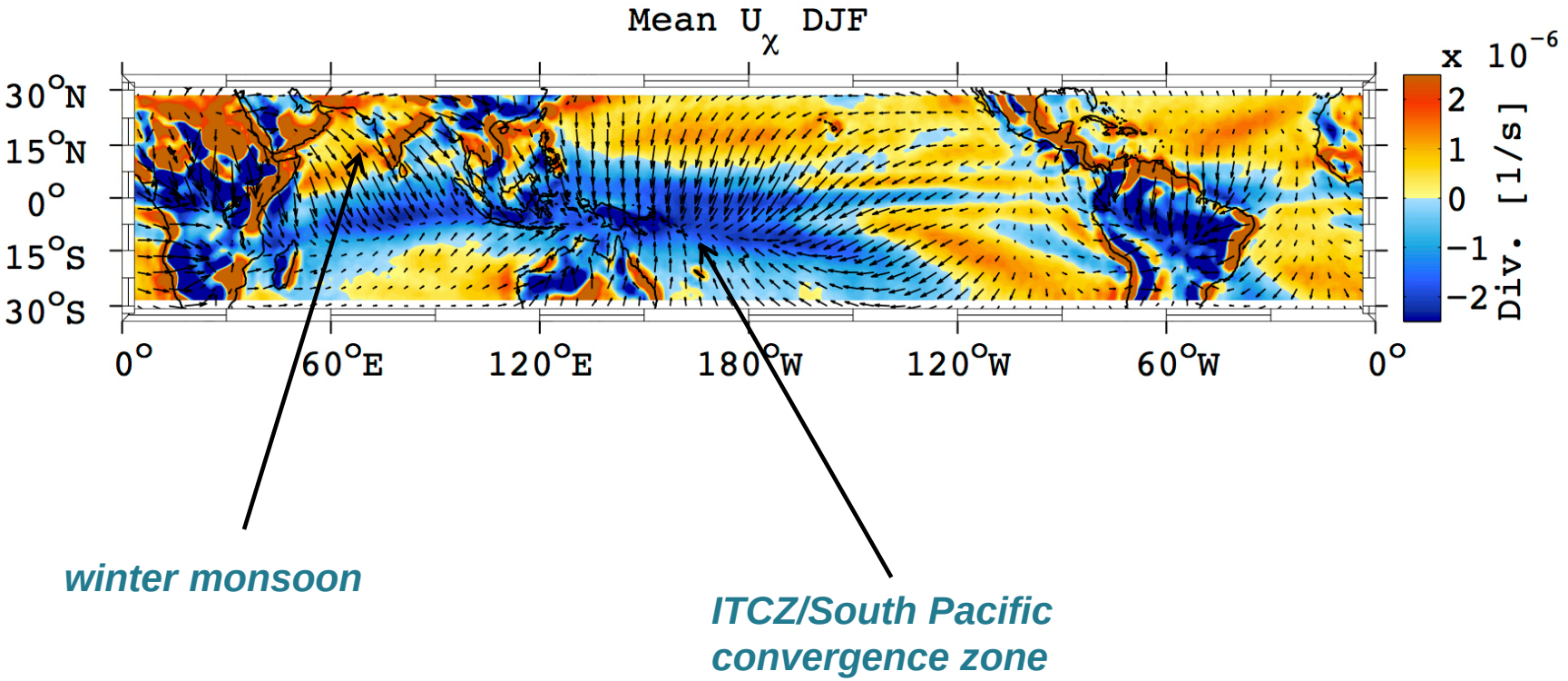
Mean rotational (non-divergent) wind component

SUMMER



Mean convergent (irrotational) wind component

WINTER

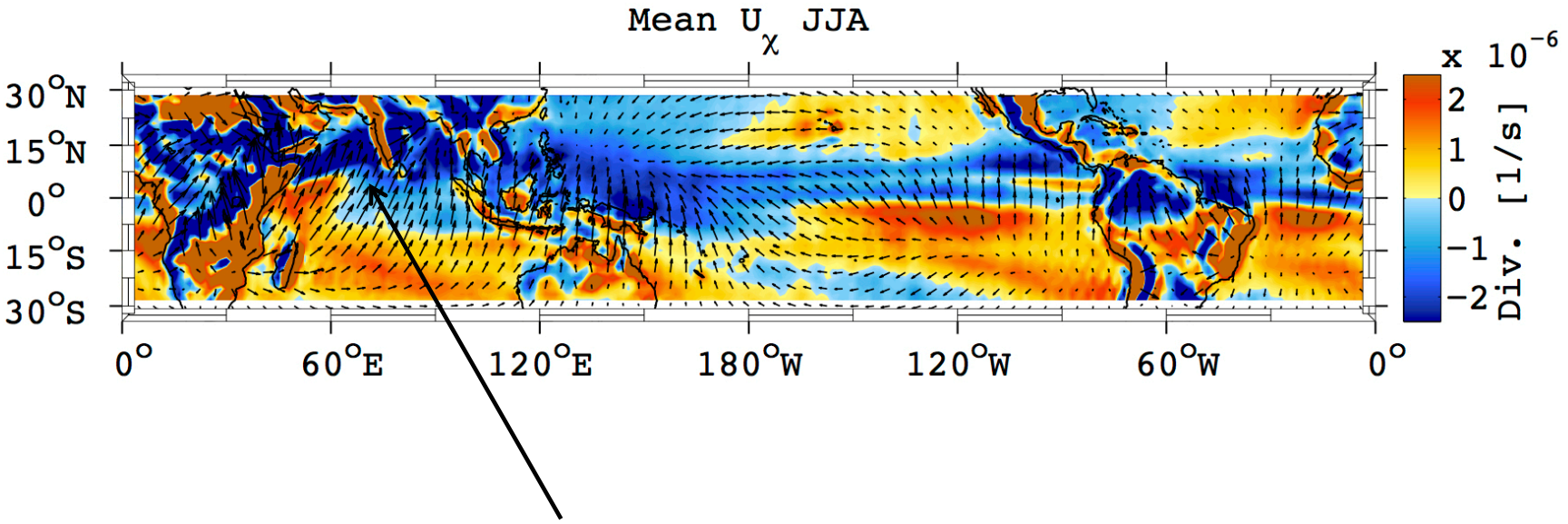


winter monsoon

ITCZ/South Pacific convergence zone

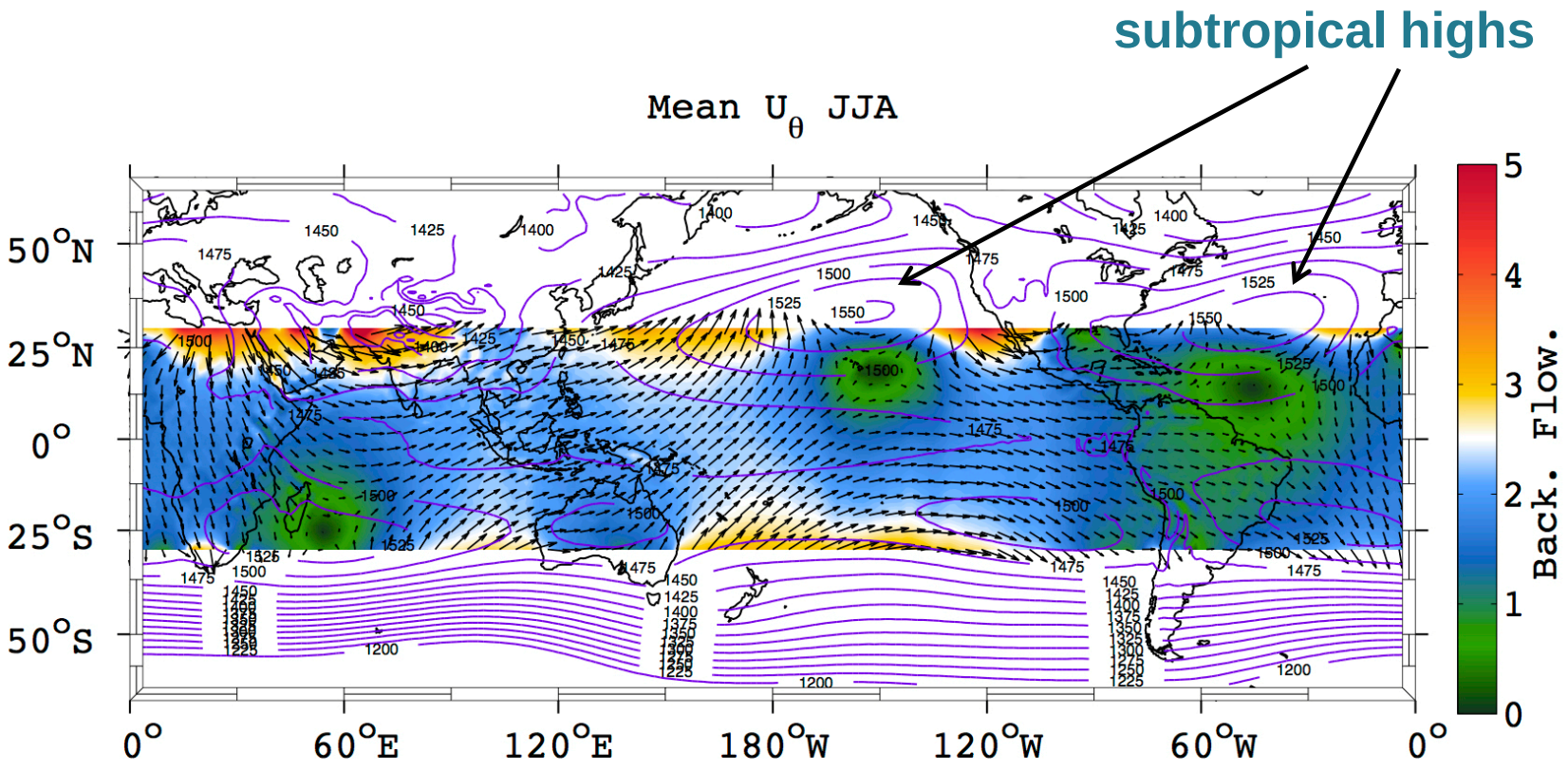
Mean convergent (irrotational) wind component

SUMMER



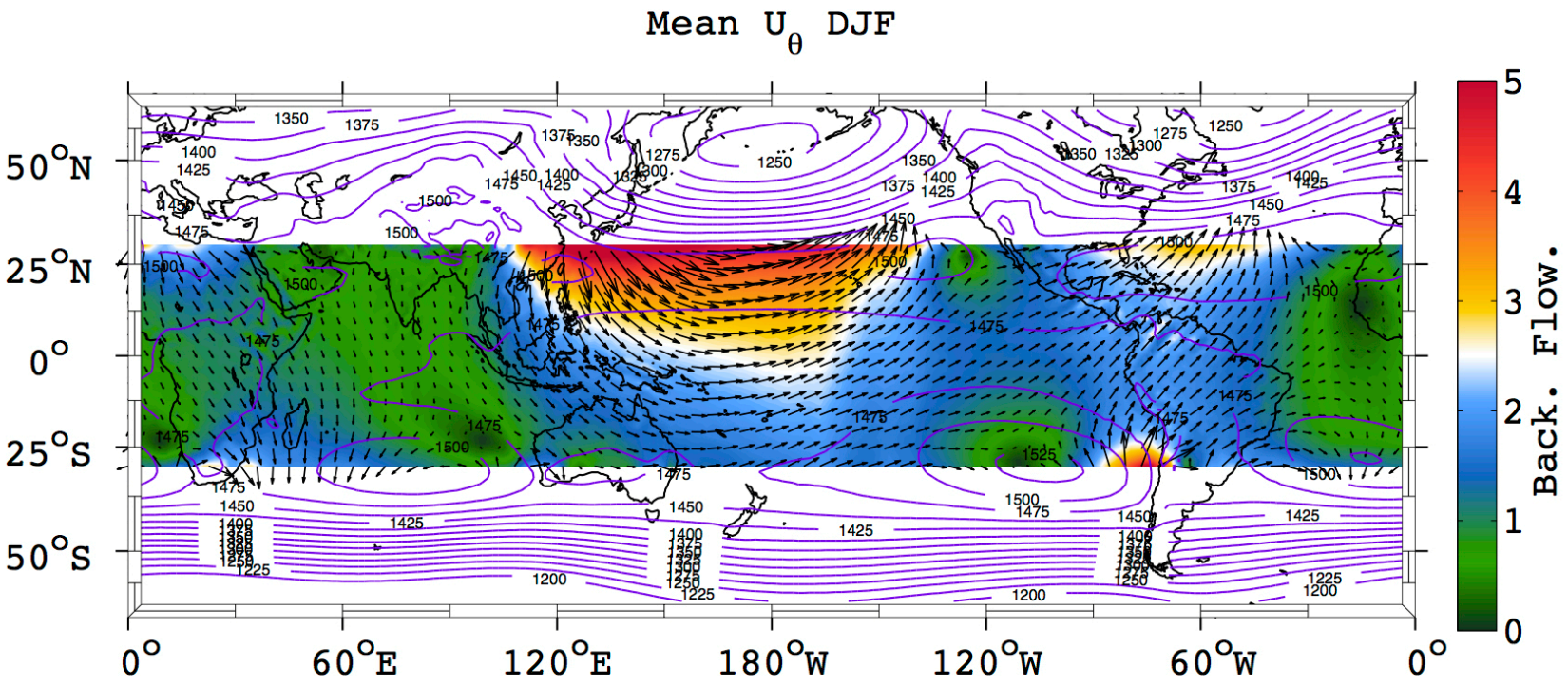
summer monsoon

Mean background flow: summer



We can think of the background flow as a signature/result of vorticity and divergence elements outside the tropics, i.e., the extratropics.

Mean background flow: winter



We can think of the background flow as a signature/result of vorticity and divergence elements outside the tropics, i.e., the extratropics.