Structures of Atmospheric Perturbations Associated with the MJO

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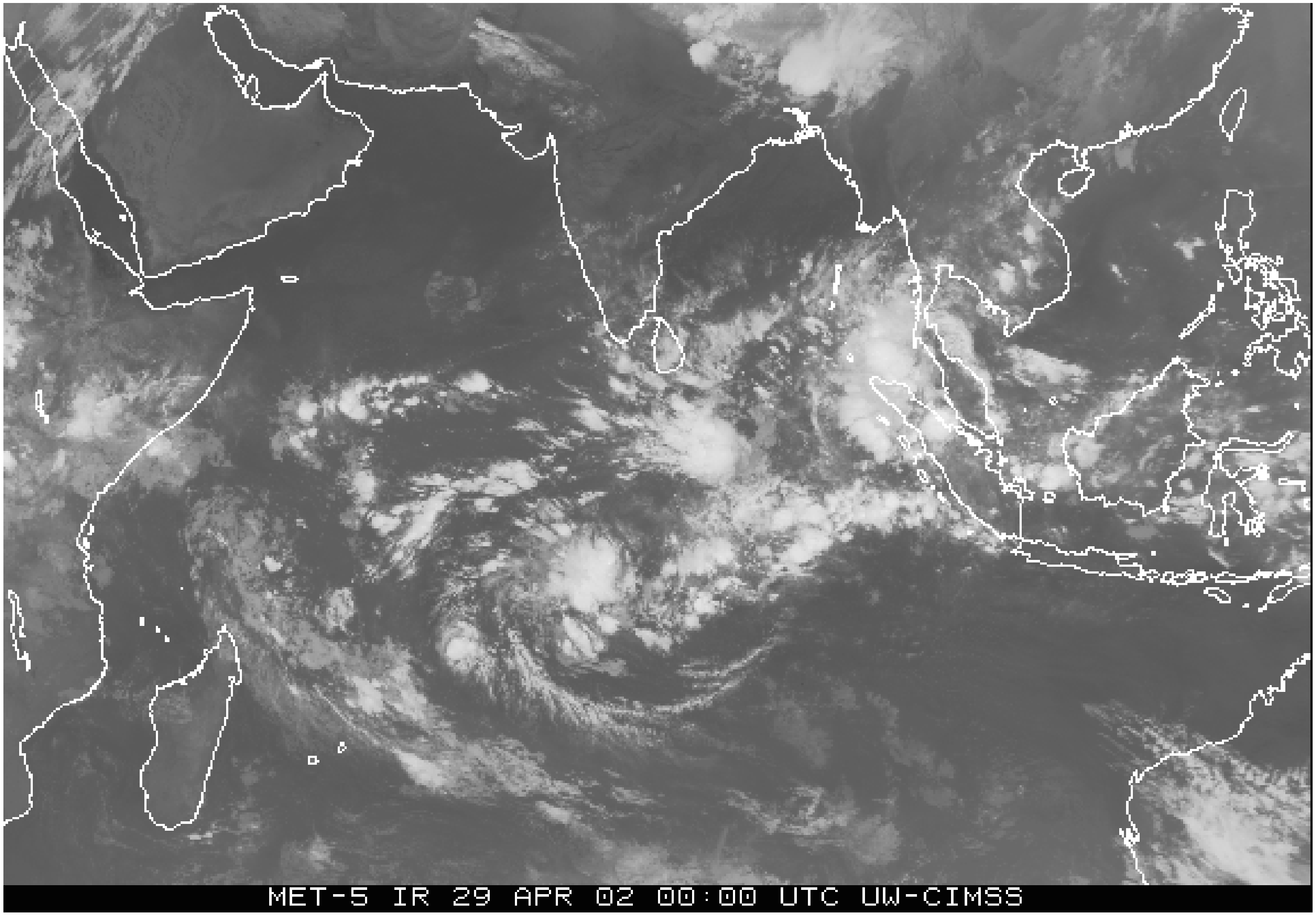
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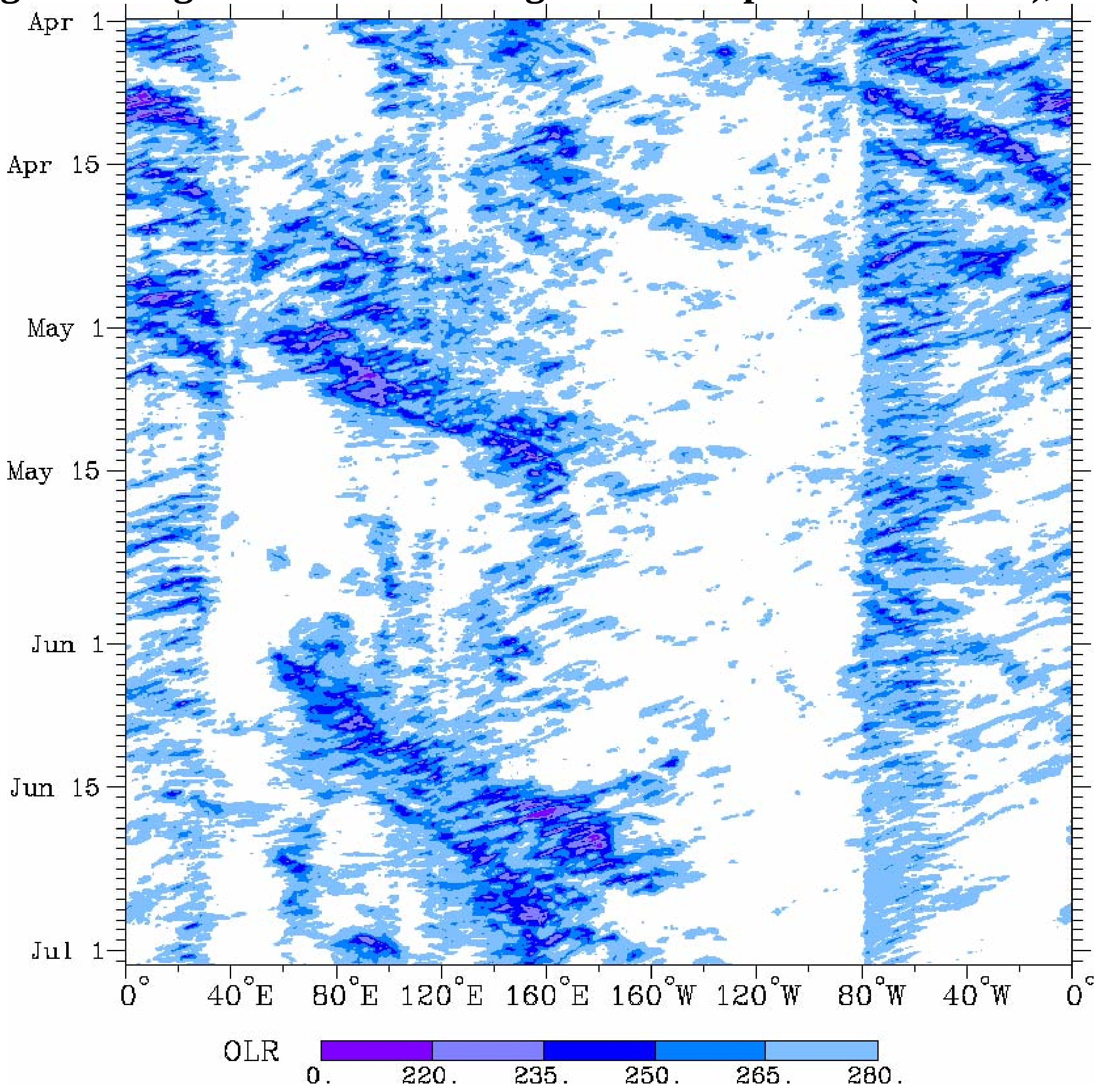
OBSERVATIONS OF WAVES WITHIN THE MJO

Time–longitude diagram of CLAUS Brightness Temperature (5S–5N), 2002



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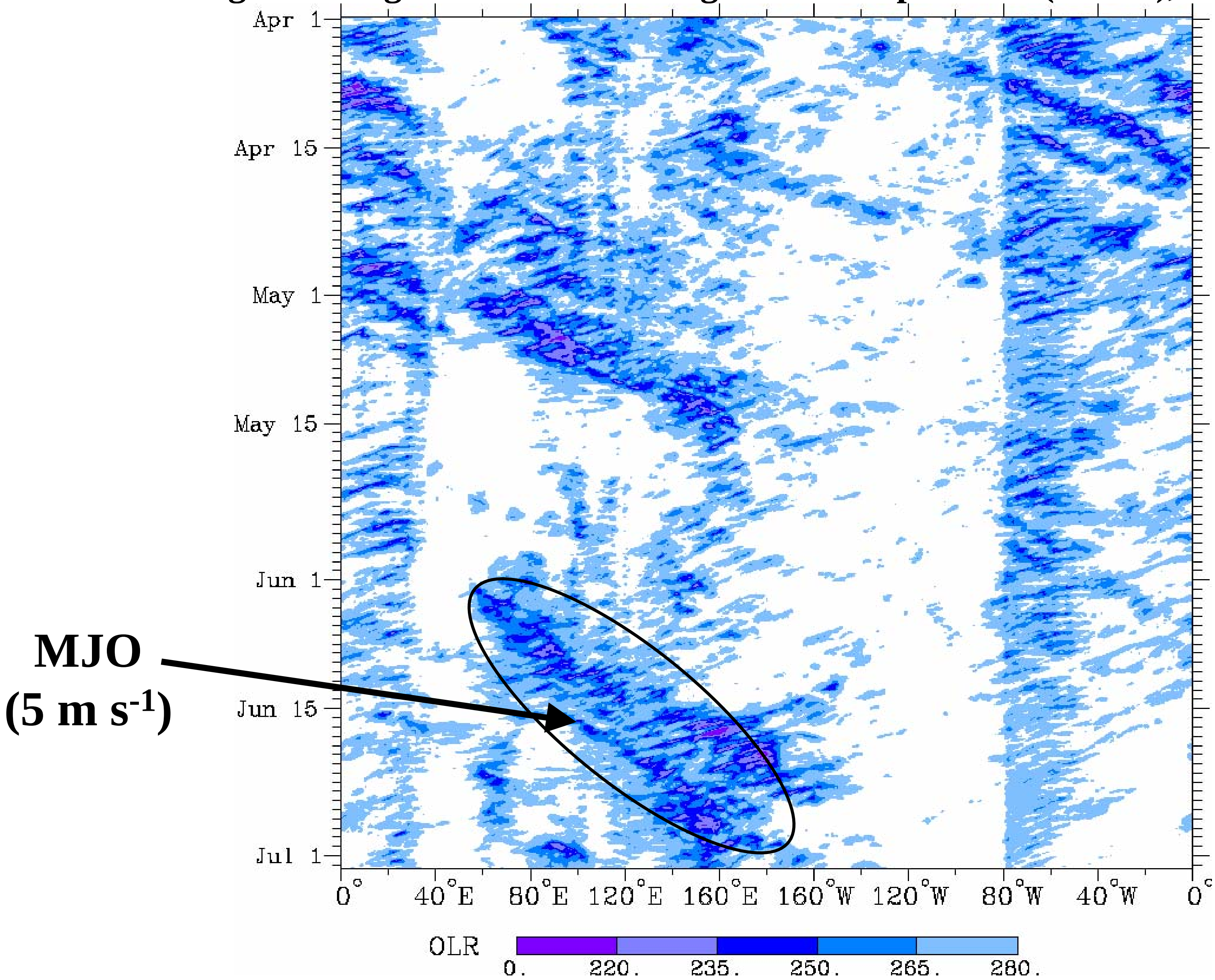

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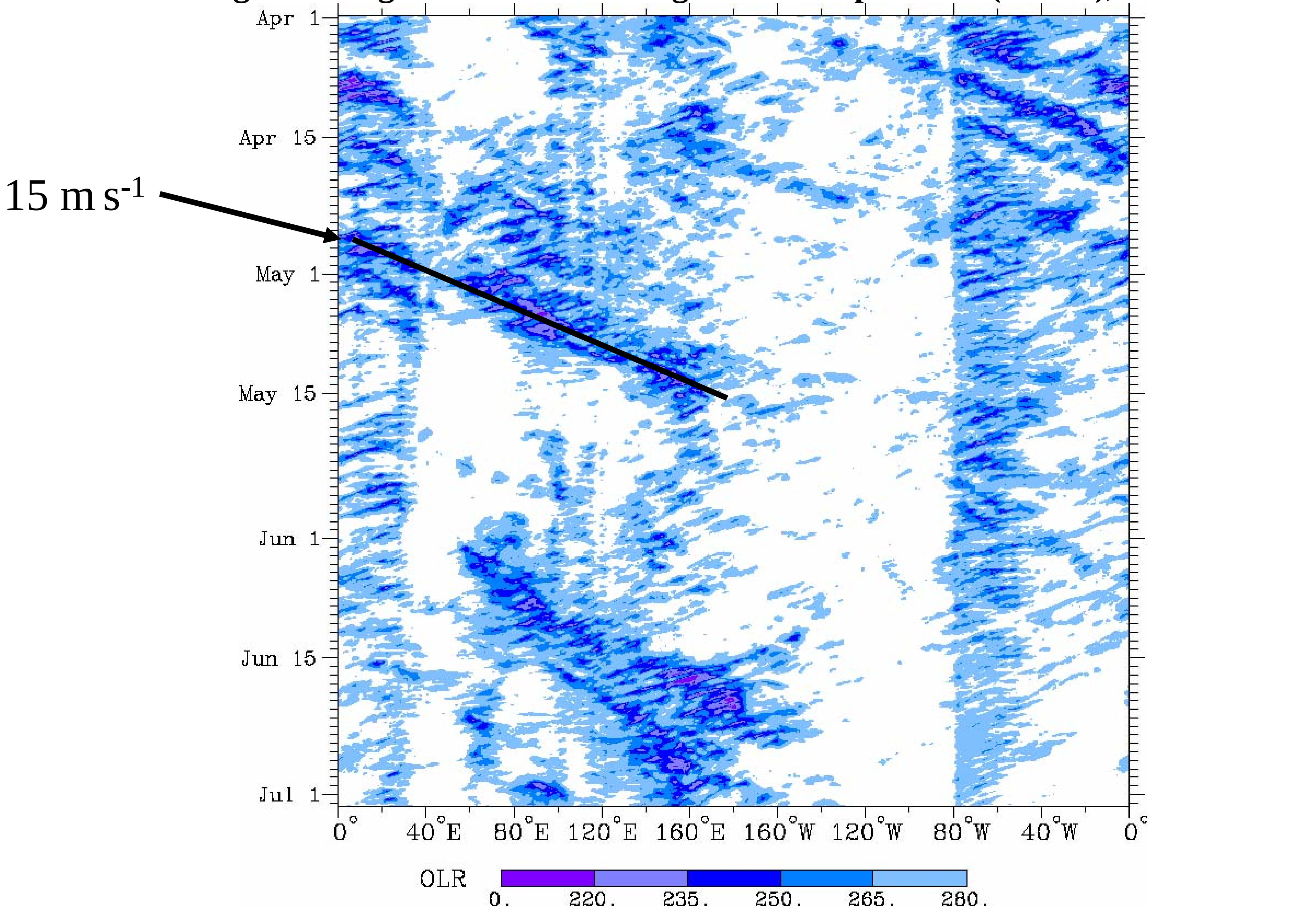

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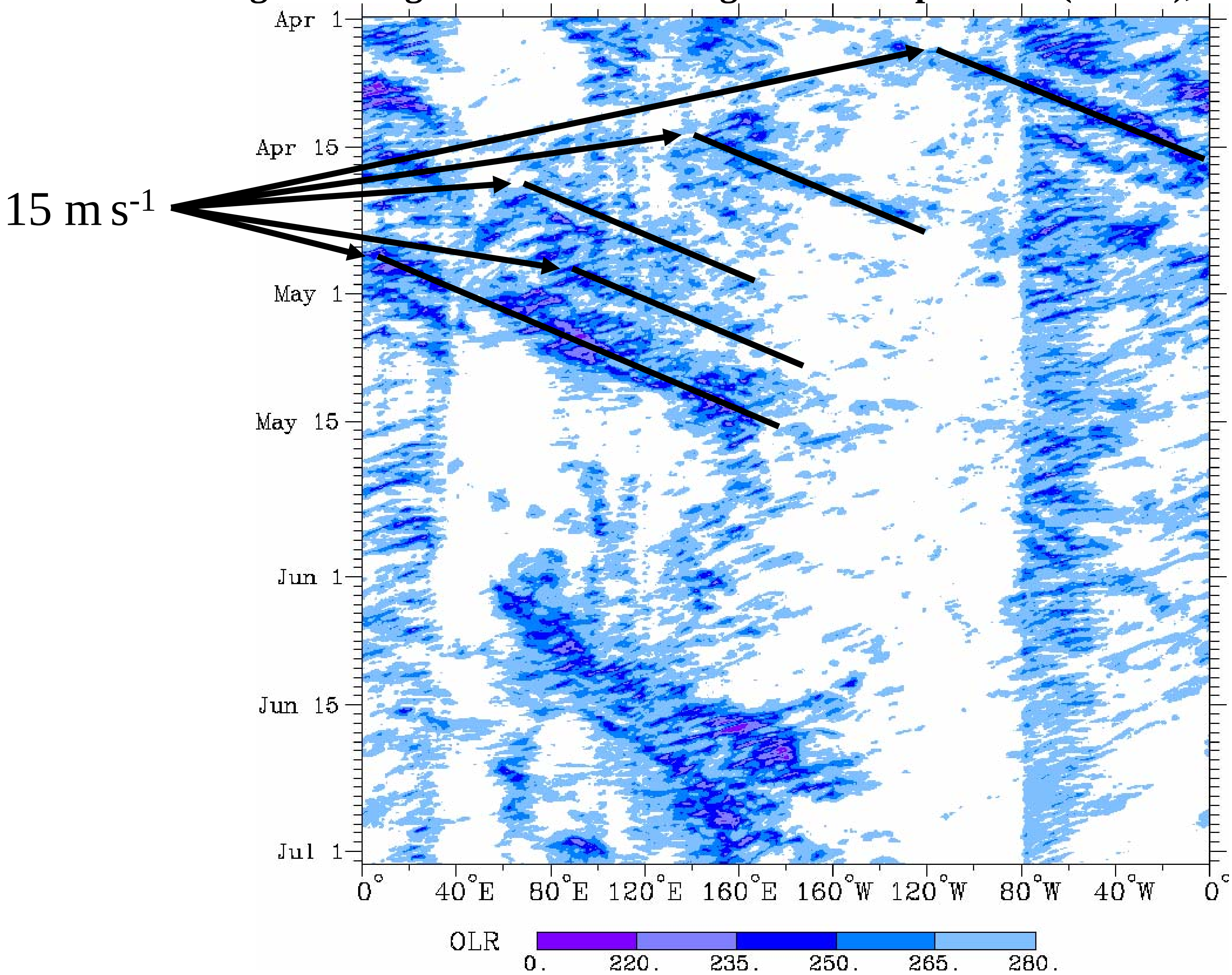

OBSERVATIONS OF WAVES WITHIN THE "MJO"

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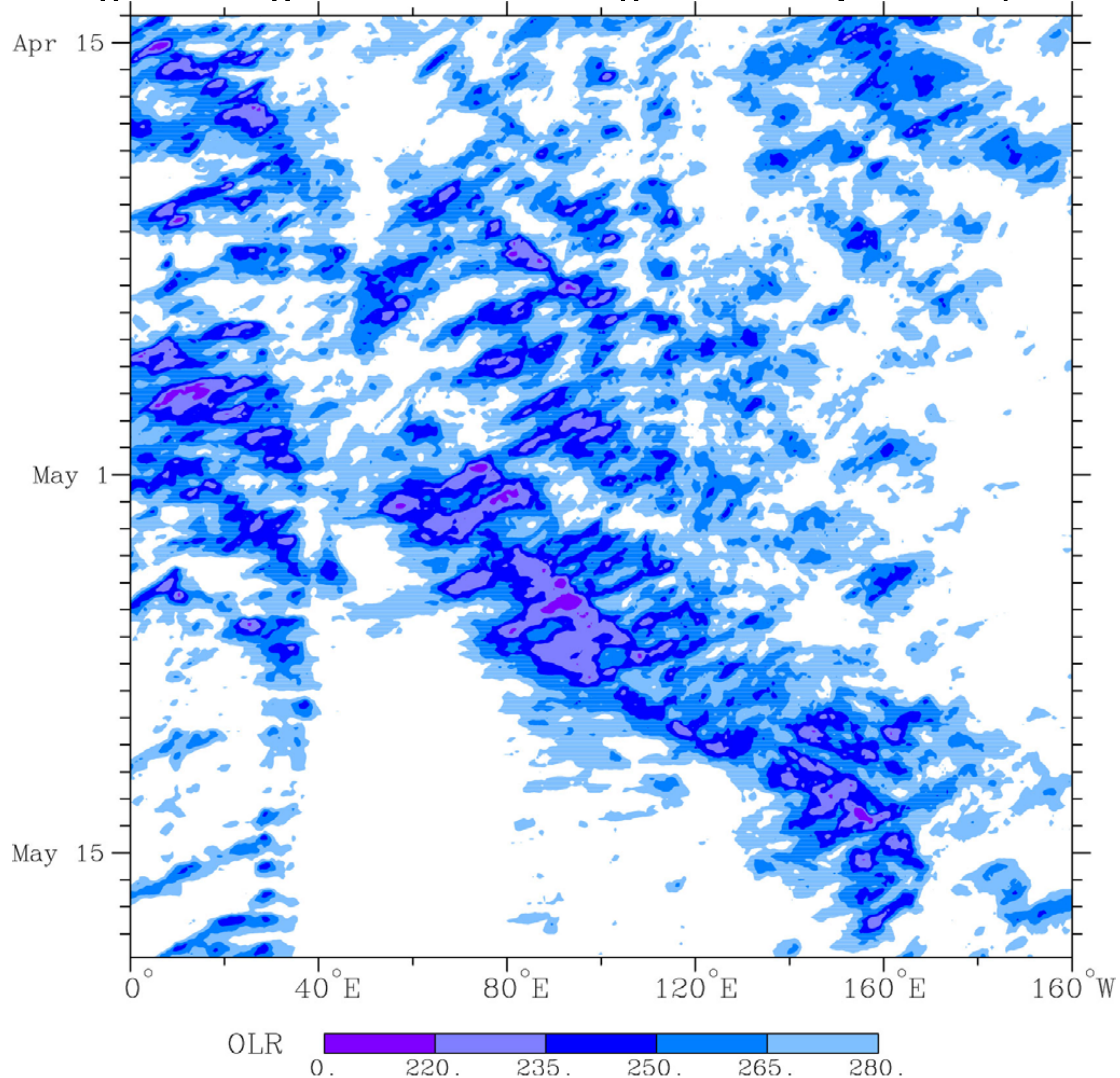

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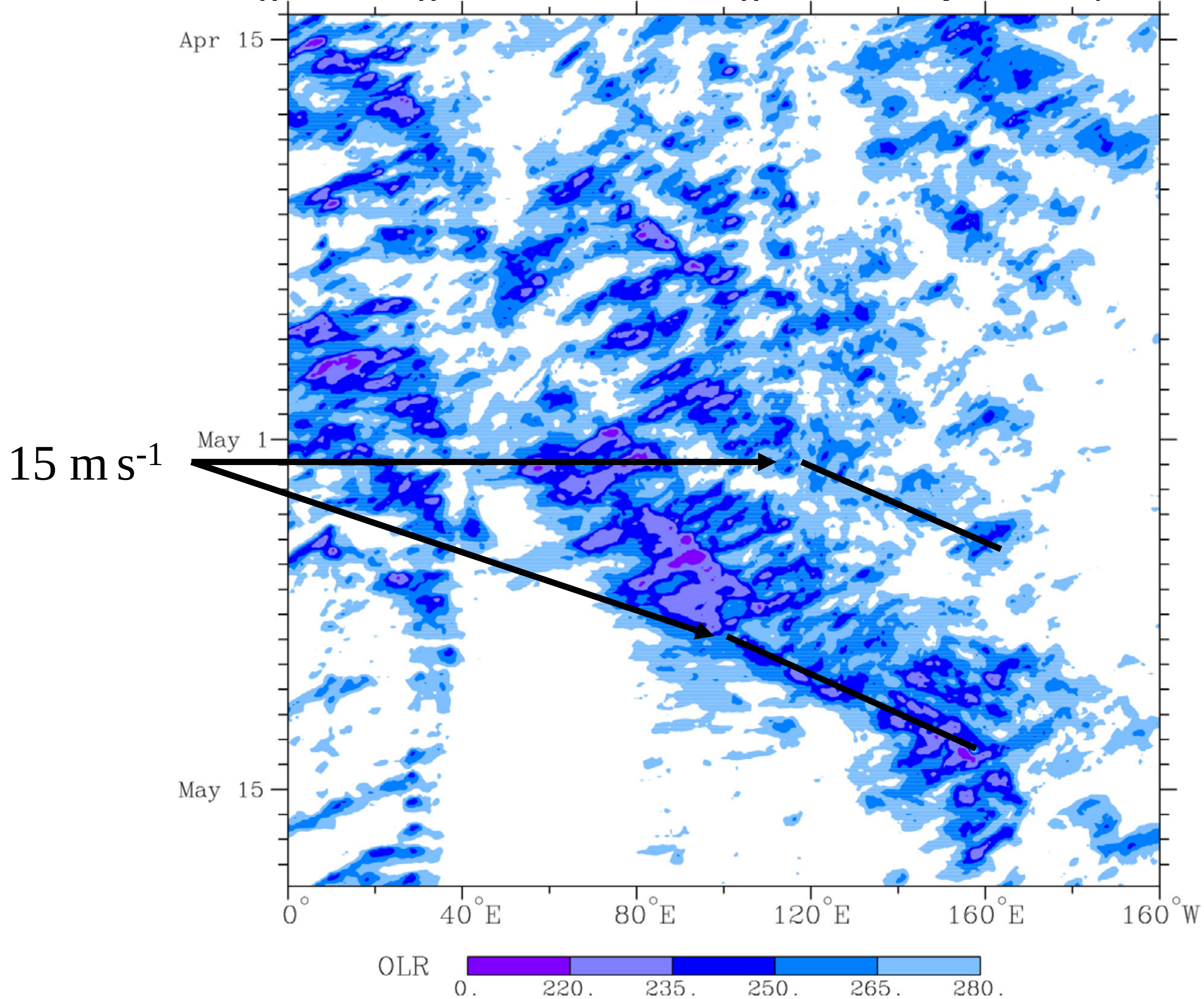

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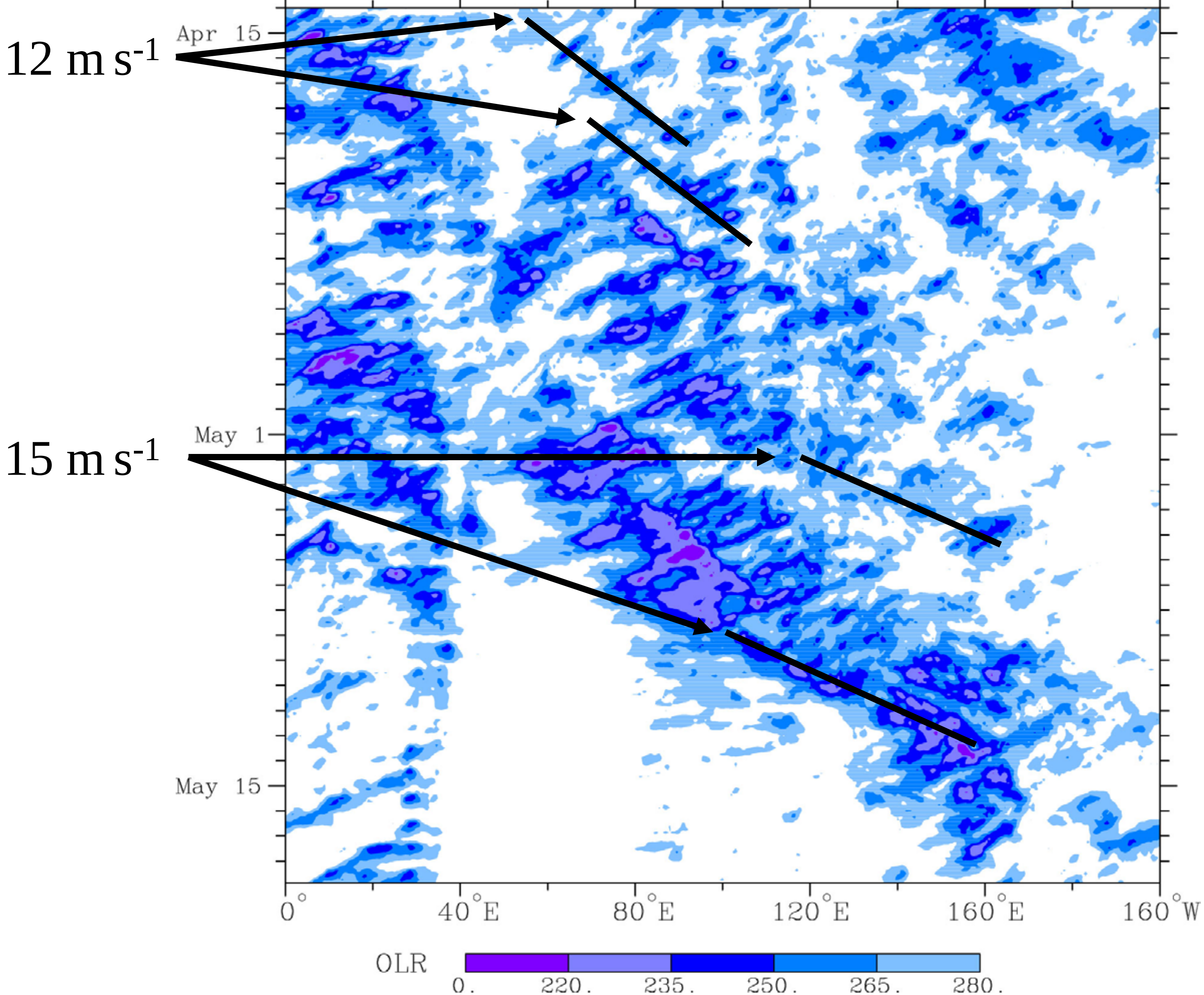

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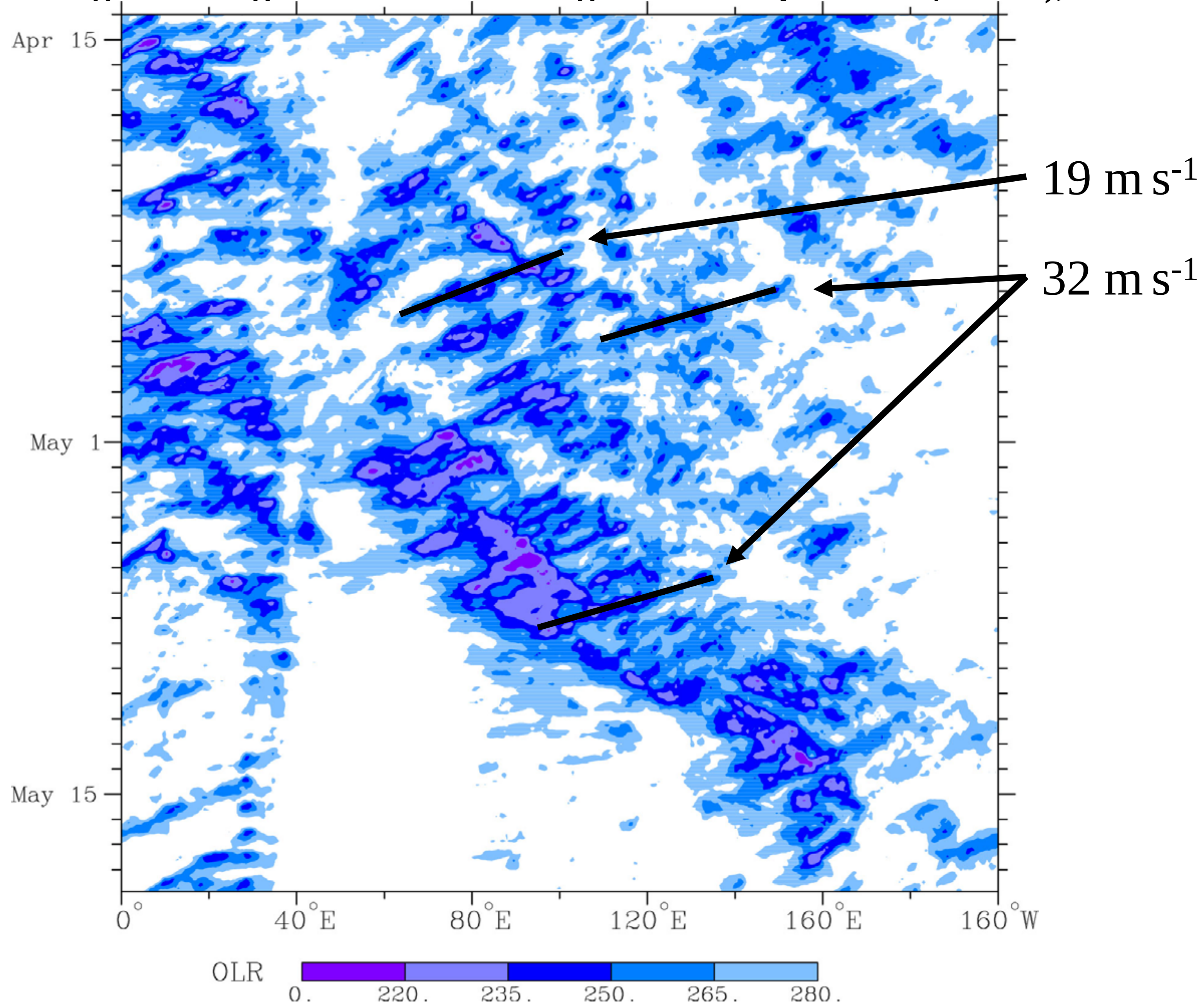
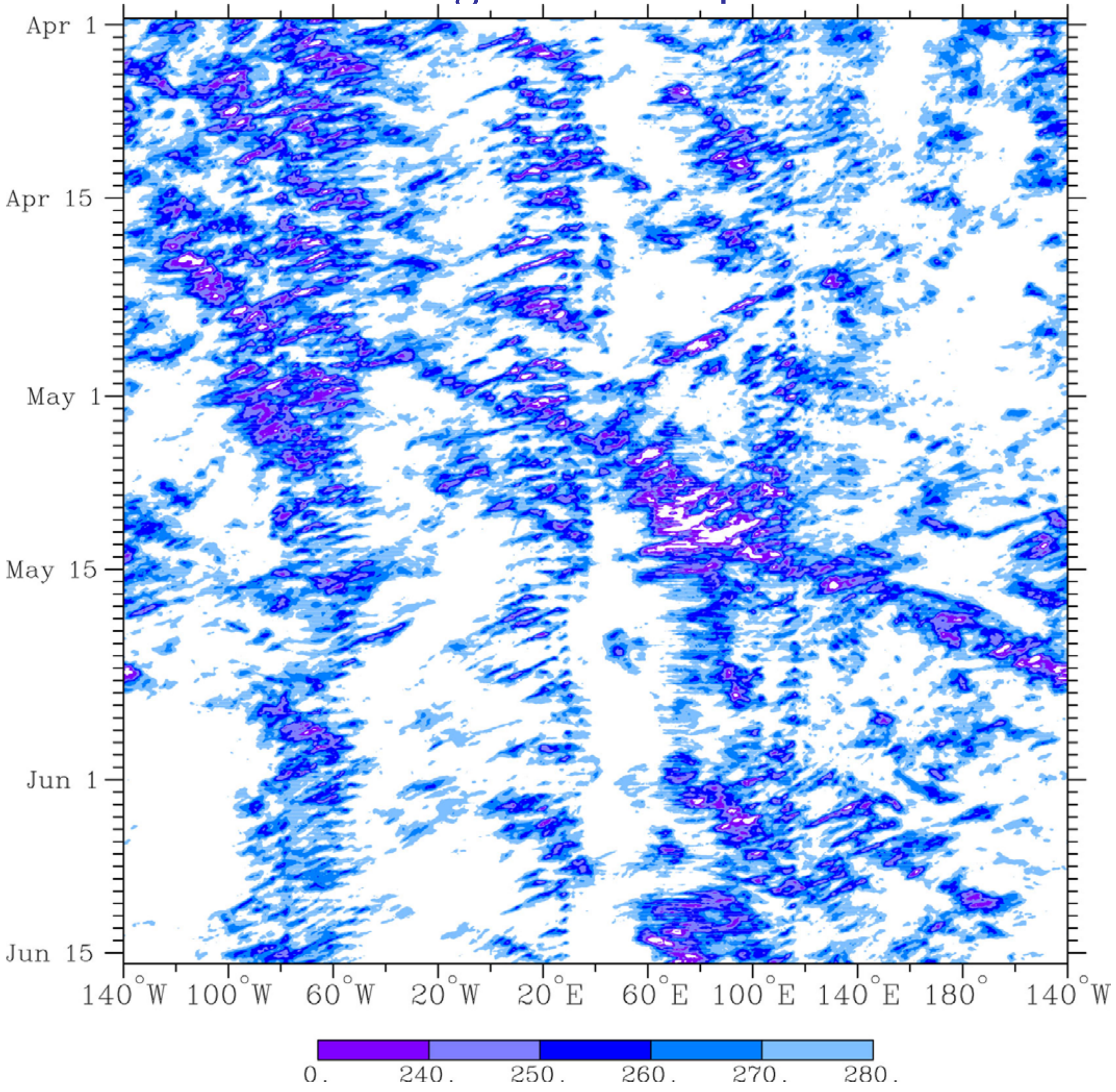
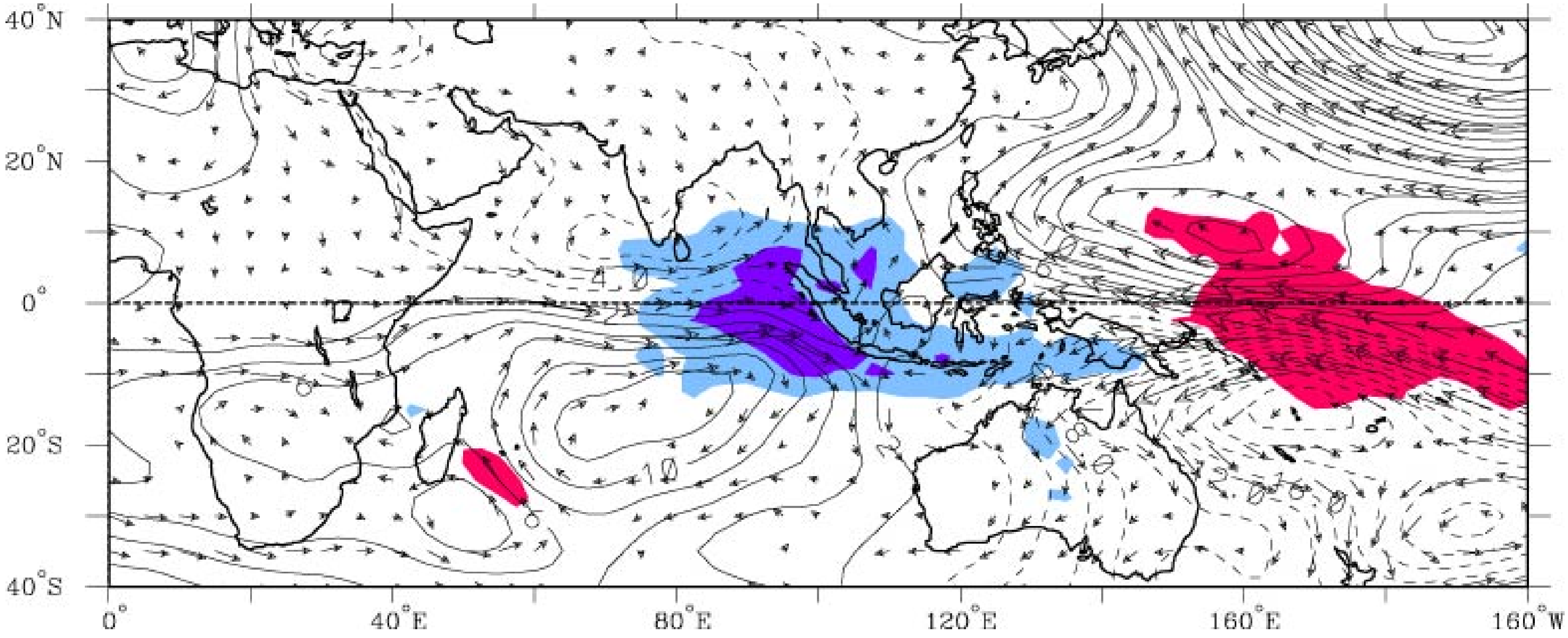


1998 CLAUS Brightness Temperature 5ºS-5º N



Horizontal Structure of the MJO

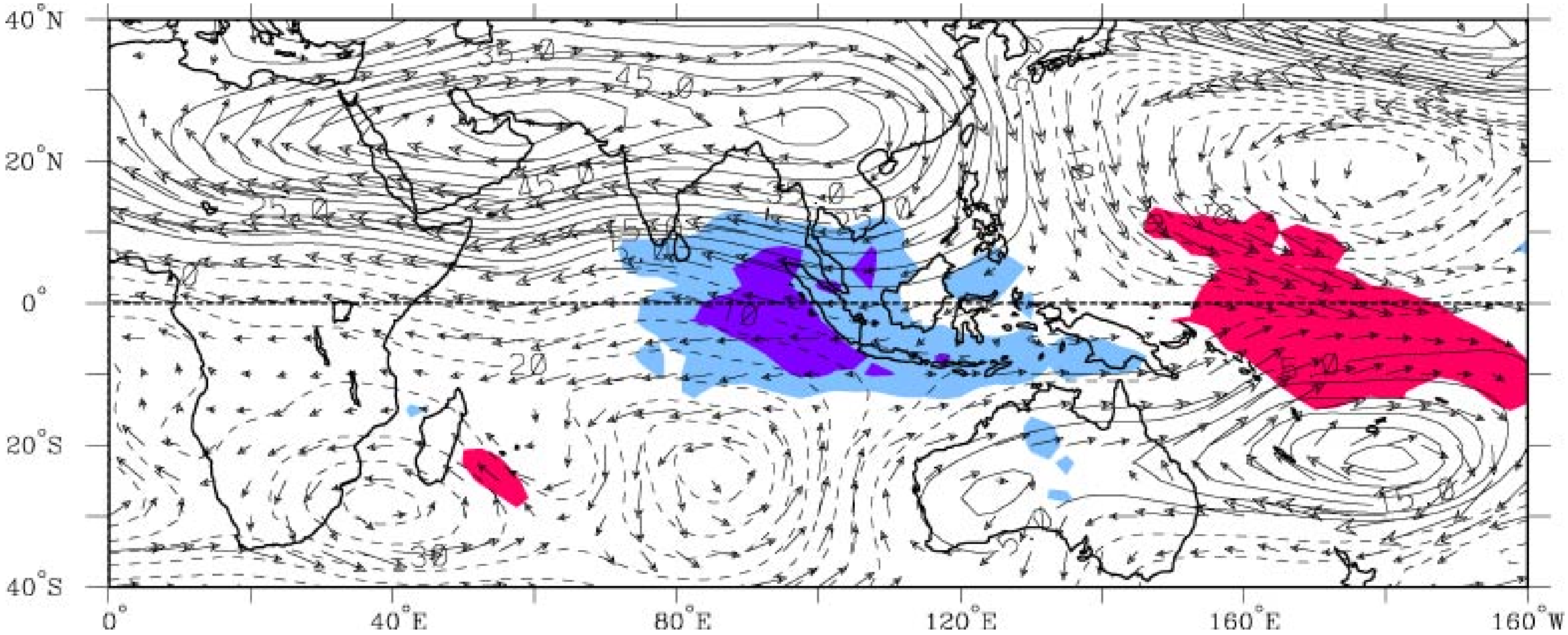
OLR and 850 hPa Flow Regressed against MJO-filtered OLR (scaled -40 W m^2) at eq, 155°E, 1979-1993



Day-15

Streamfunction (contours 2 X 10^5 m^2 s^{-1})
Wind (vectors, largest around 4 m s^{-1})
OLR (shading starts at +/- 6 W s^{-2}), negative blue

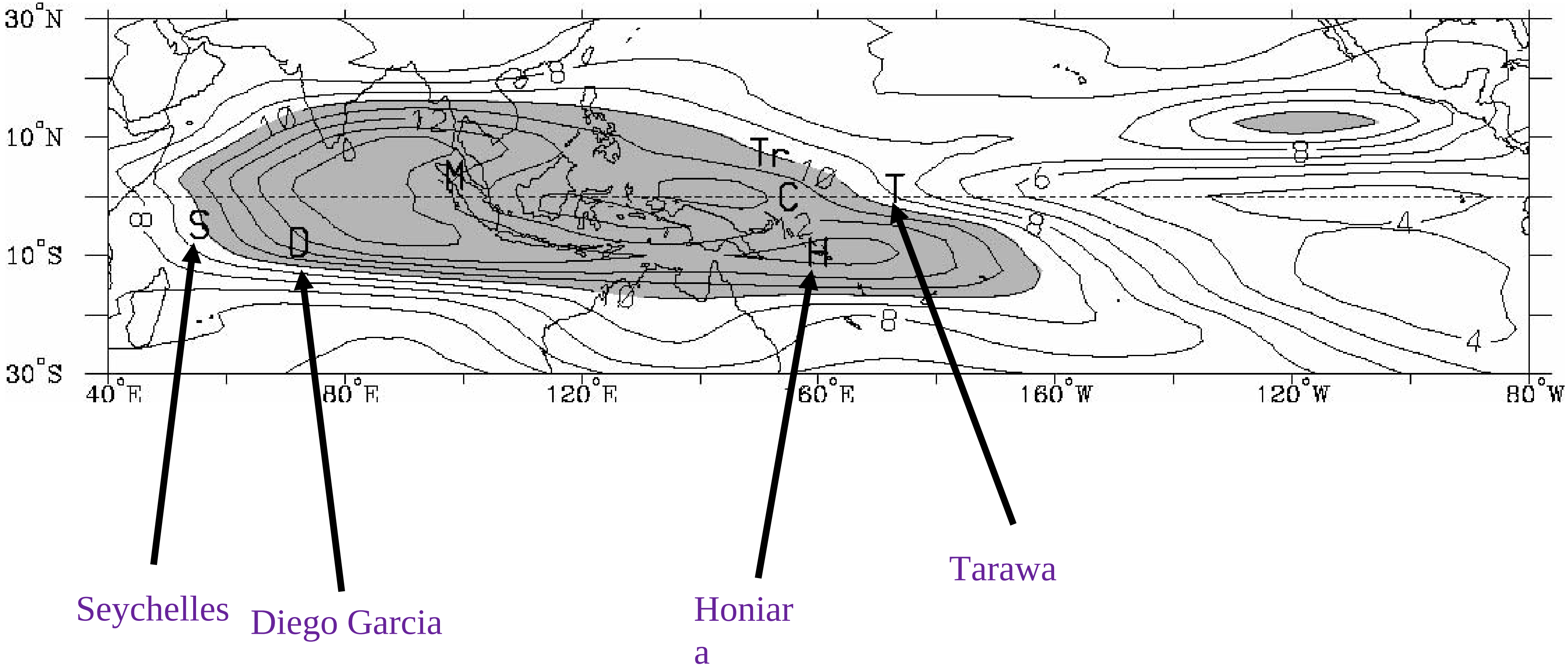
OLR and 850 hPa Flow Regressed against MJO-filtered OLR (scaled -40 W m^2) at eq, 155°E, 1979-1993



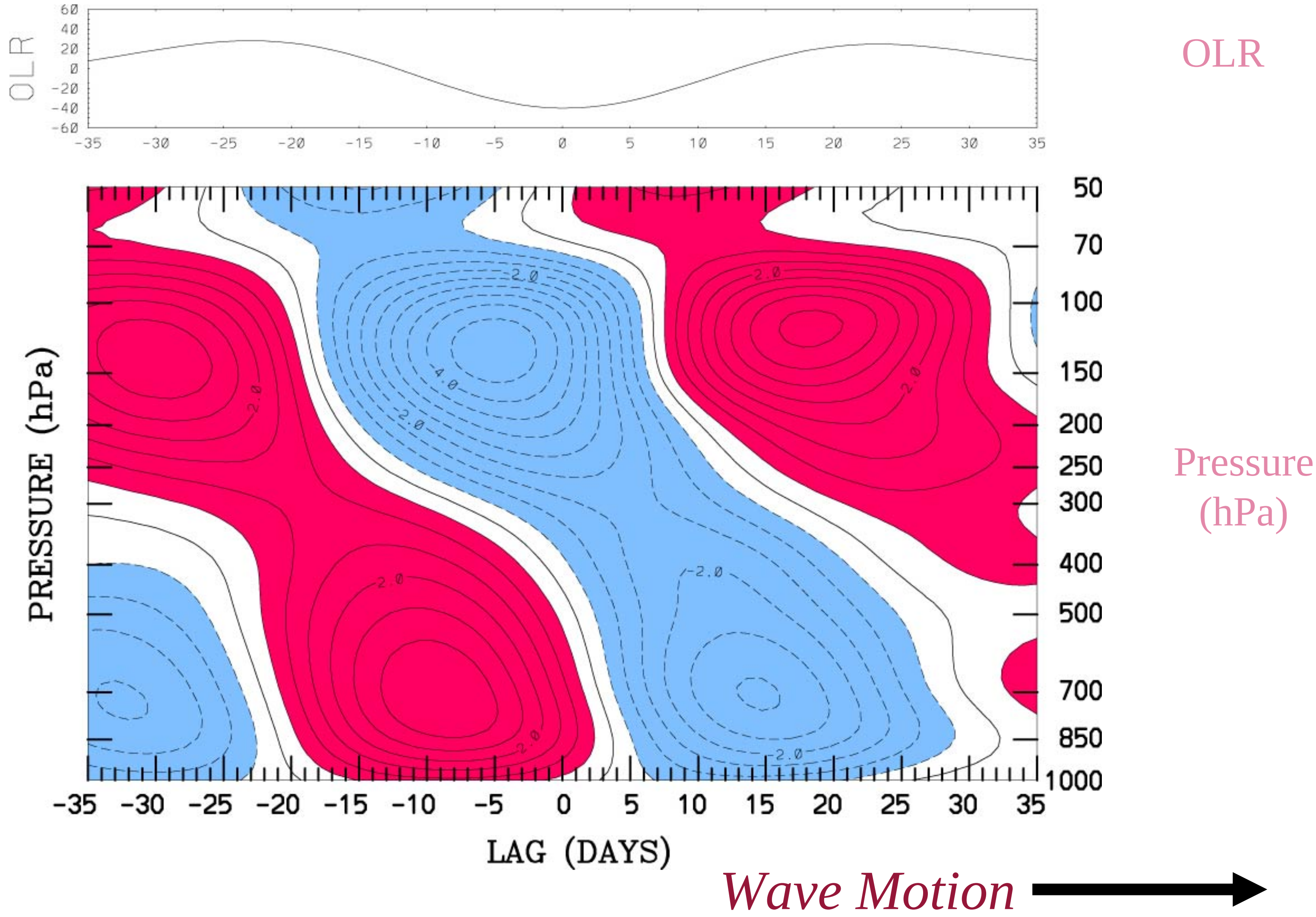
Day-15

Streamfunction (contours 5 X 10^5 m^2 s^{-1})
Wind (vectors, largest around 4 m s^{-1})
OLR (shading starts at +/- 6 W s^{-2}), negative blue

Vertical Structure of the MJO and other Equatorial Waves


30°N
10°N
10°S
30°S
40°E
80°E
120°E
160°E
160°W
120°W
80°W
S
D
M
Tr
C
T
H
10
12
8
6
4
Seychelles
Diego Garcia
Honiar
a
Tarawa

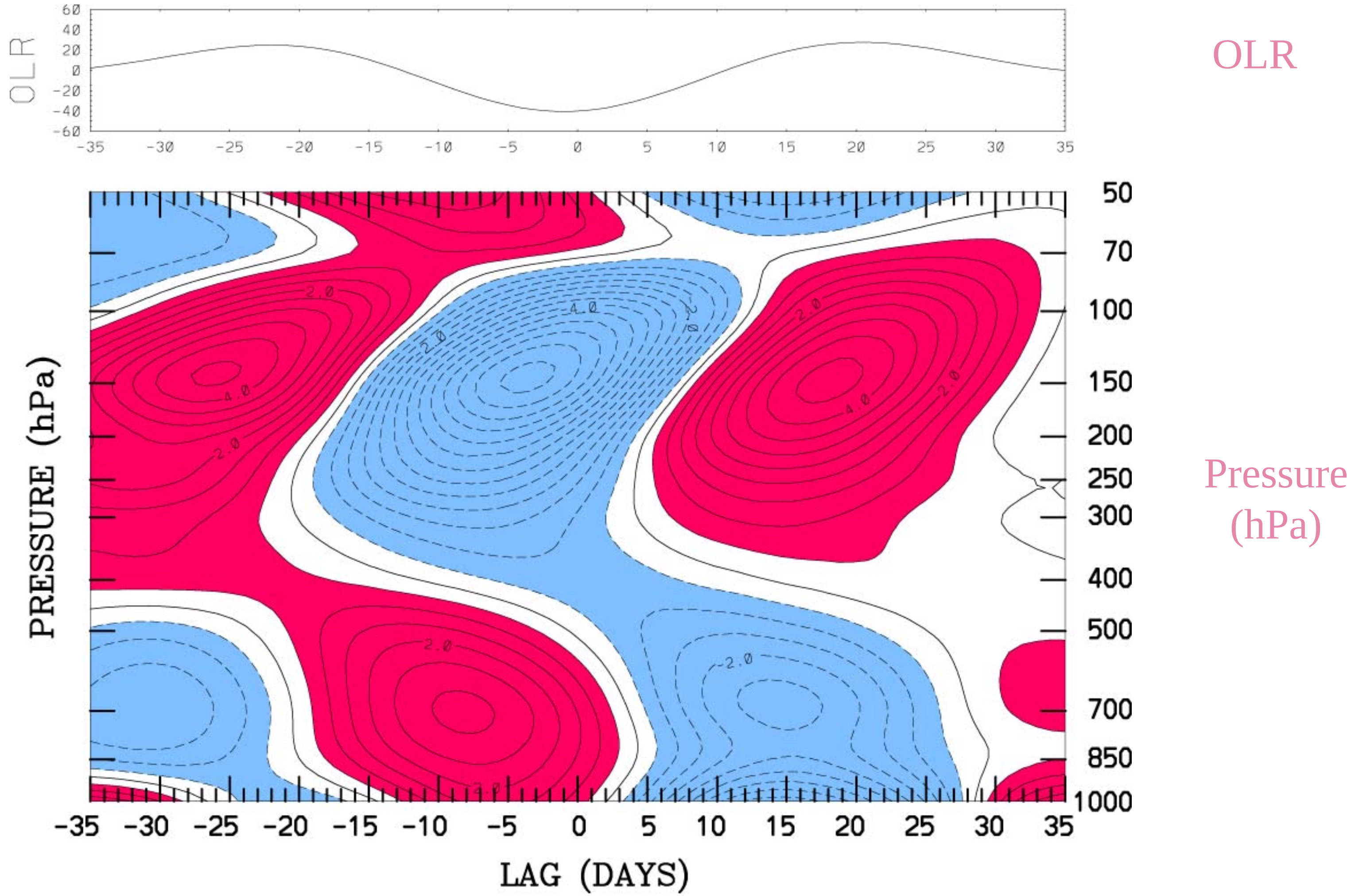
Zonal Wind at Honiara (10°S, 160°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR (top, Wm^{-2})
U Wind (contours, .5 m s^{-1}), red positive

from Kiladis et al. 2005

Zonal Wind at Tarawa (1.4°N, 173°E) Regressed against MJO-filtered OLR (scaled -40 W m2) for 1979-1999



OLR (top, Wm^{-2})
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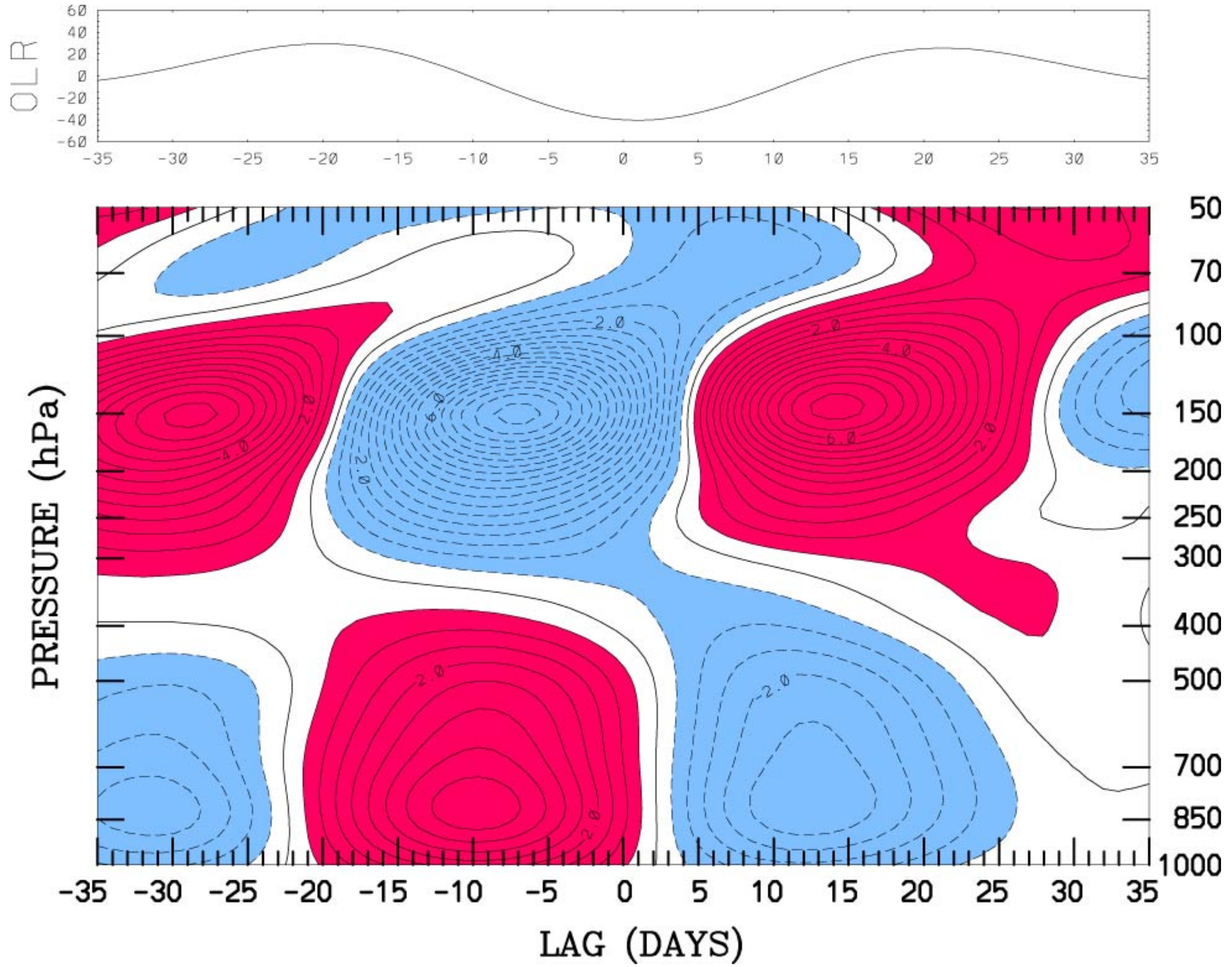
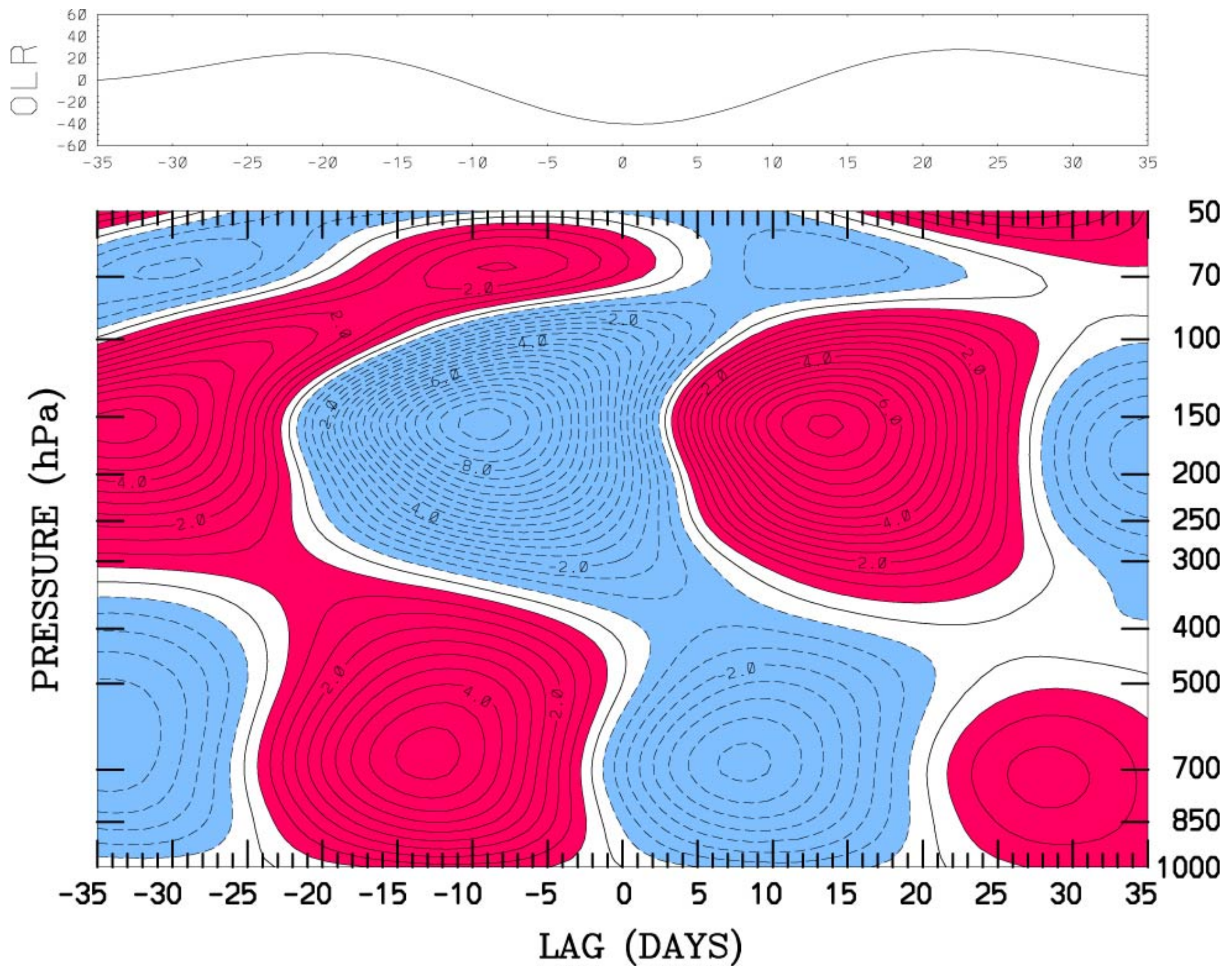
Zonal Wind at Diego Garcia (7.7°S, 72.4°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR (top, Wm^{-2})
U Wind (contours, .5 m s^{-1}), red positive

from Kiladis et al. 2005

Zonal Wind at Seychelles (4.7°S, 55.5°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



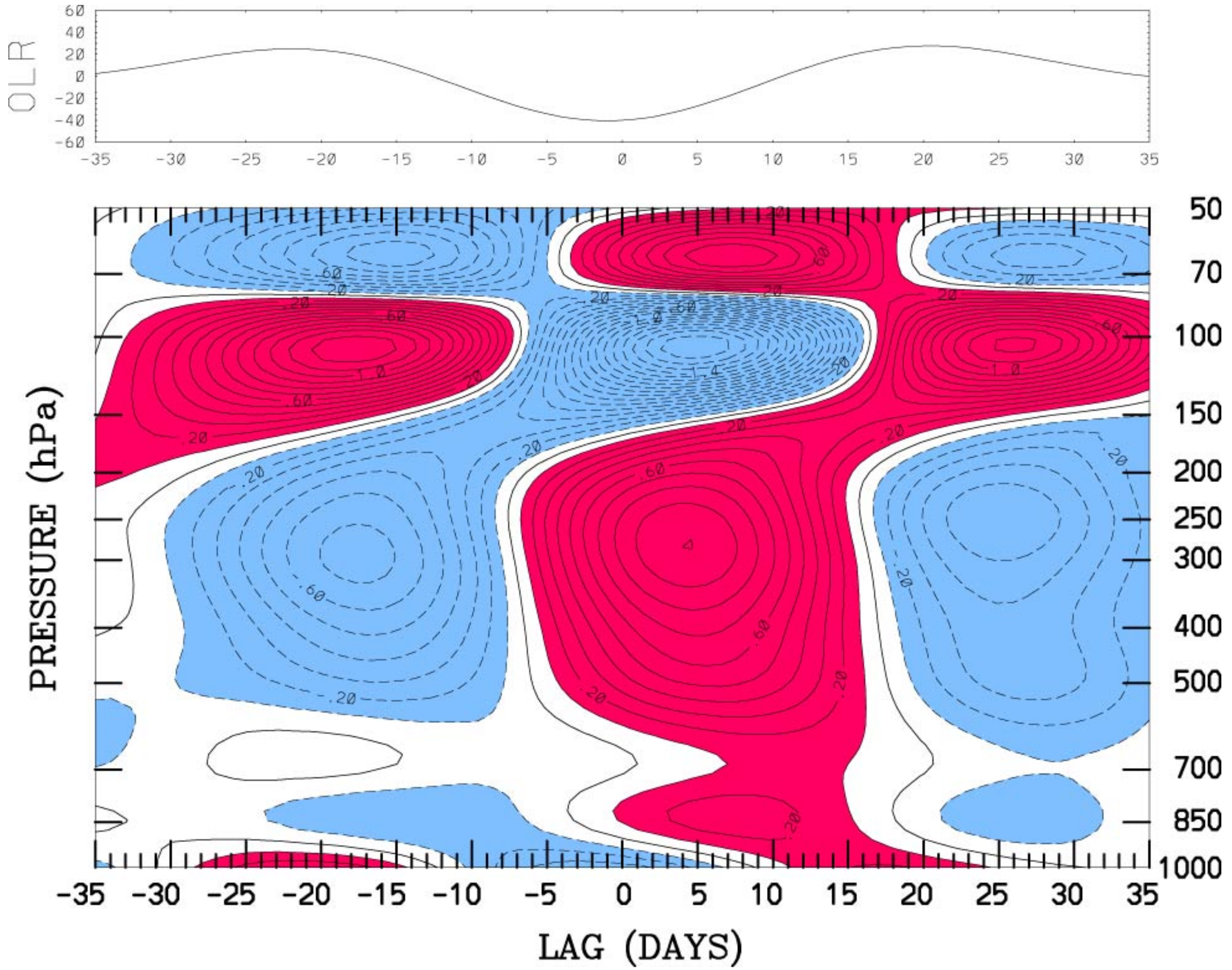
OLR

Pressure (hPa)

OLR (top, Wm^{-2})
U Wind (contours, .5 m s^{-1}), red positive

from Kiladis et al. 2005

Temperature at Tarawa (1.4°N, 173°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR

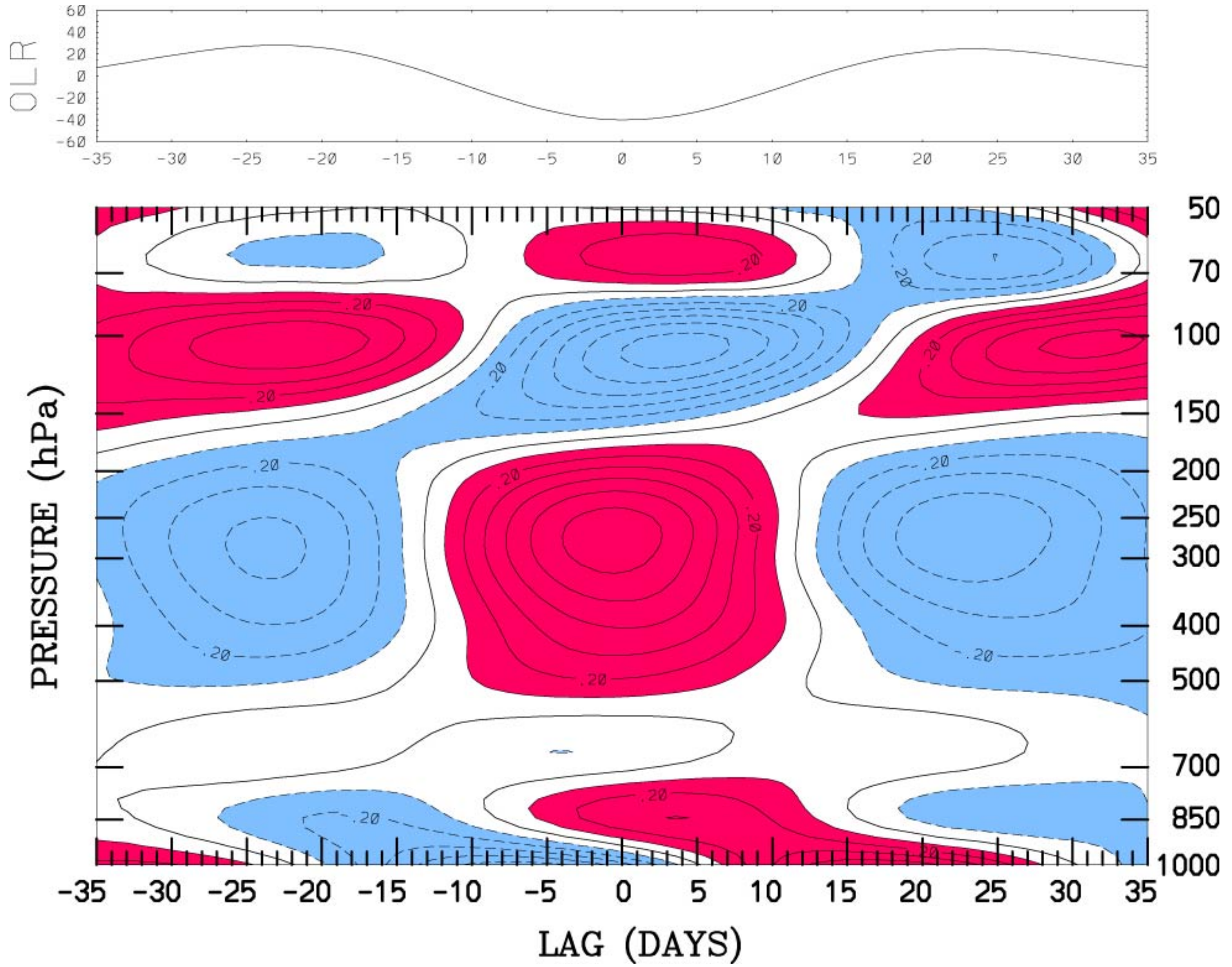
Pressure (hPa)

Wave Motion

OLR (top, Wm^{-2})
Temperature (contours, .1 °C), red positive

from Kiladis et al. 2005

Temperature at Honiara (10°S, 160.0°E) Regressed against MJO-filtered OLR (scaled -40 W m2) for 1979-1999



OLR

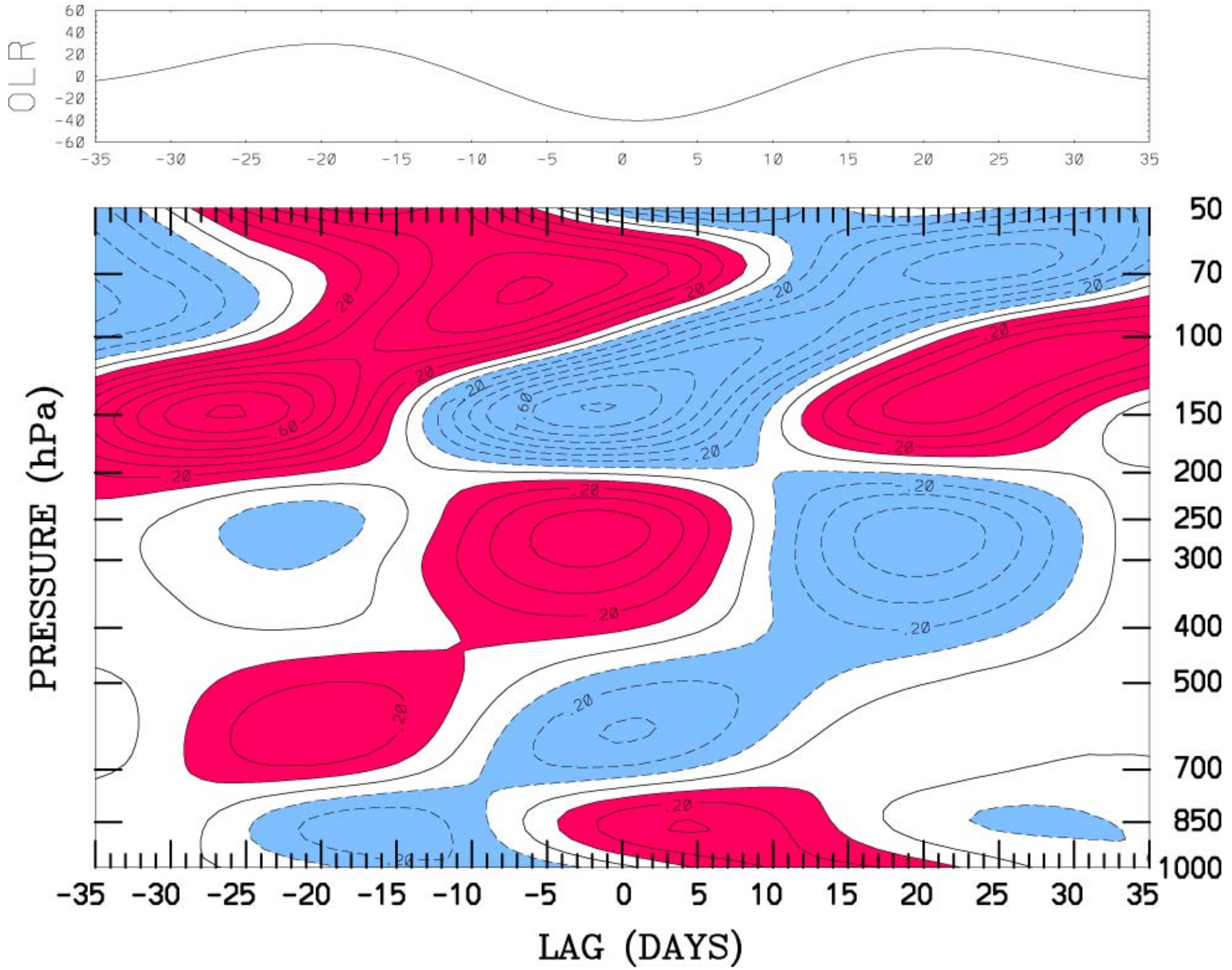
Pressure (hPa)

Wave Motion →

OLR (top, Wm^{-2})
Temperature (contours, .1 °C), red positive

from Kiladis et al. 2005

Temperature at Diego Garcia (8°S, 72.4°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR

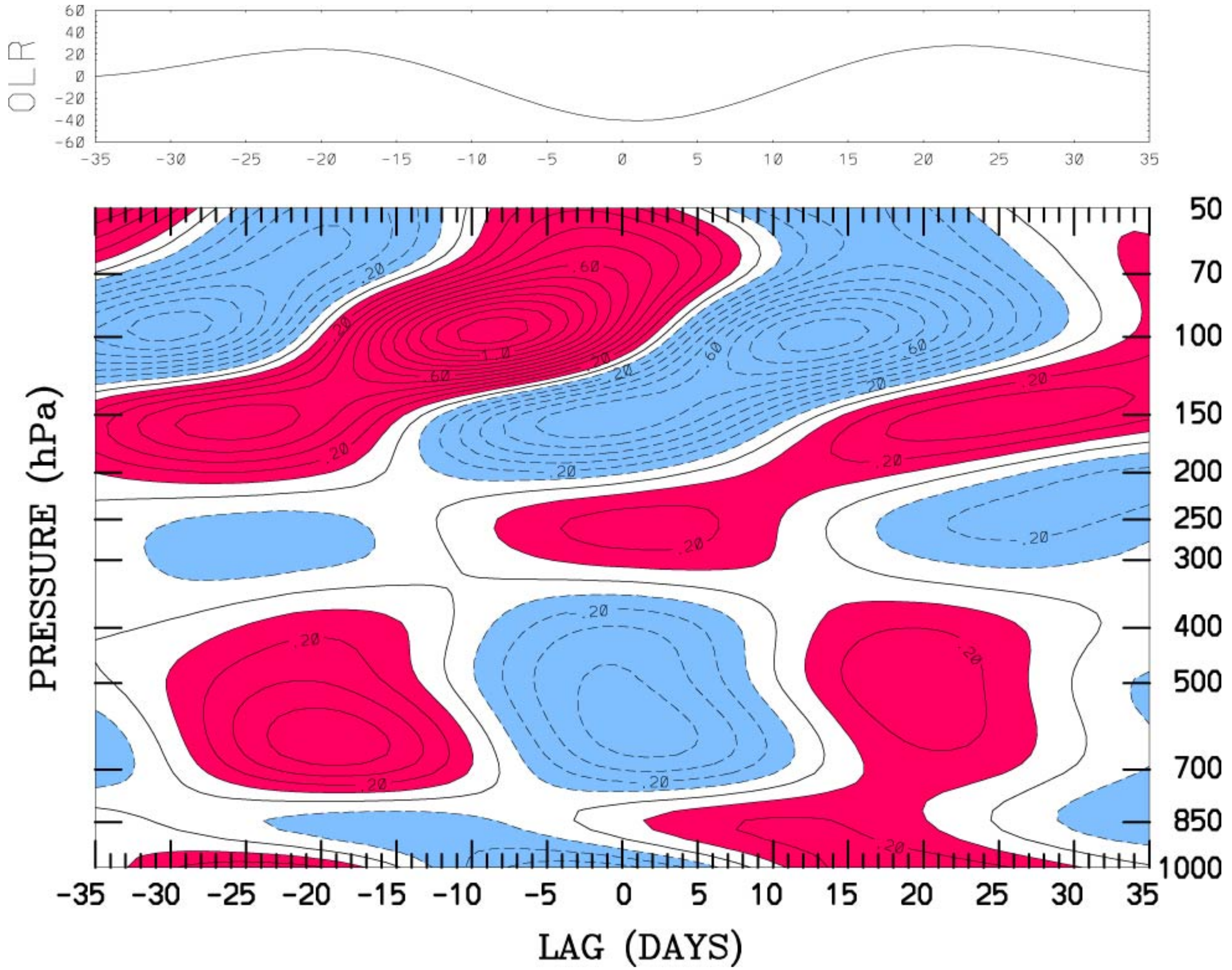
Pressure (hPa)

Wave Motion →

OLR (top, Wm^{-2})
Temperature (contours, .1 °C), red positive

from Kiladis et al. 2005

Temperature at Seychelles (8°S, 72.4°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR

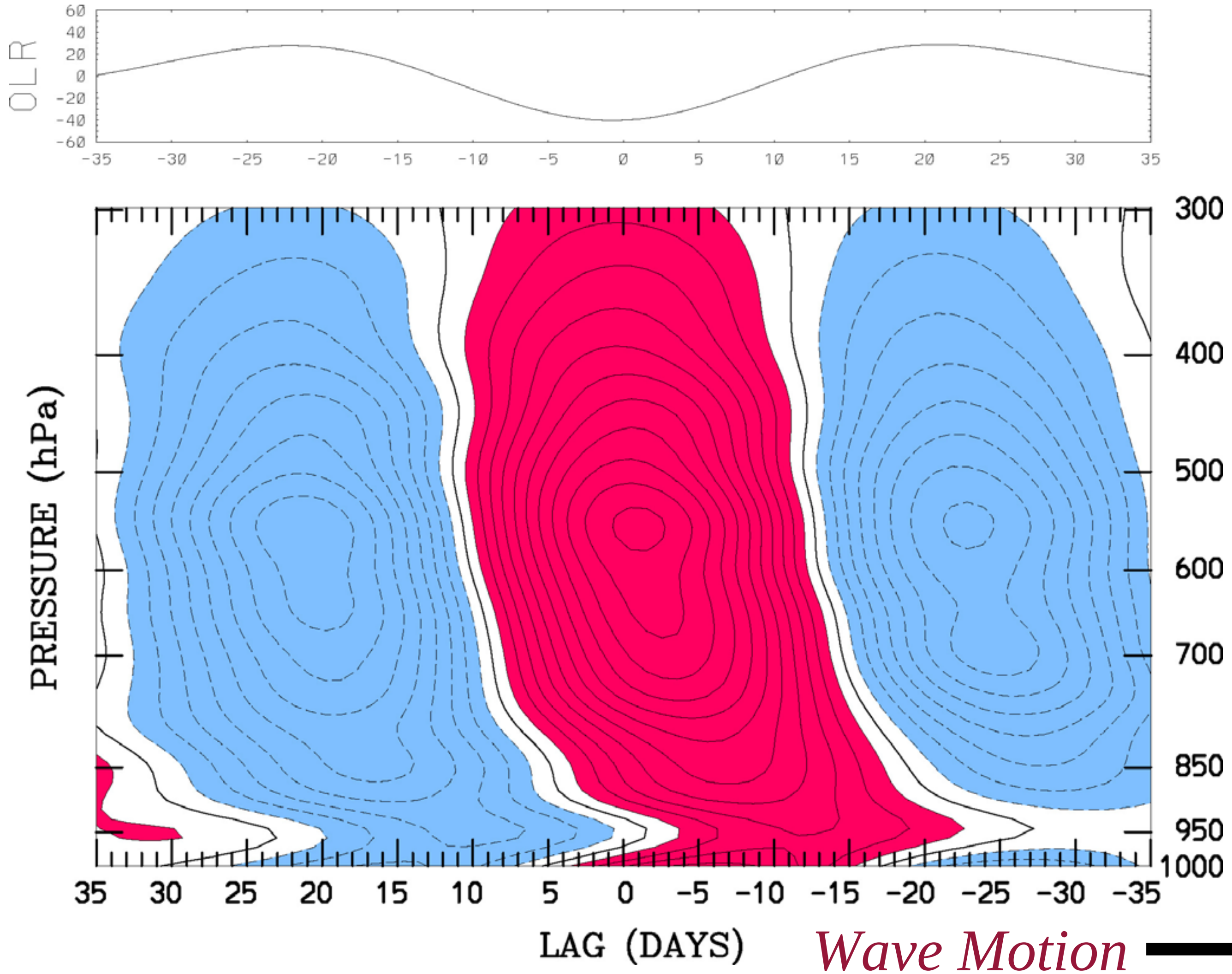
Pressure (hPa)

Wave Motion →

OLR (top, Wm^{-2})
Temperature (contours, .1 °C), red positive

from Kiladis et al. 2005

Specific Humidity at Truk (7.5°N, 152.5°E) Regressed against MJO-filtered OLR (scaled -40 W m^2) for 1979-1999



OLR

Pressure (hPa)

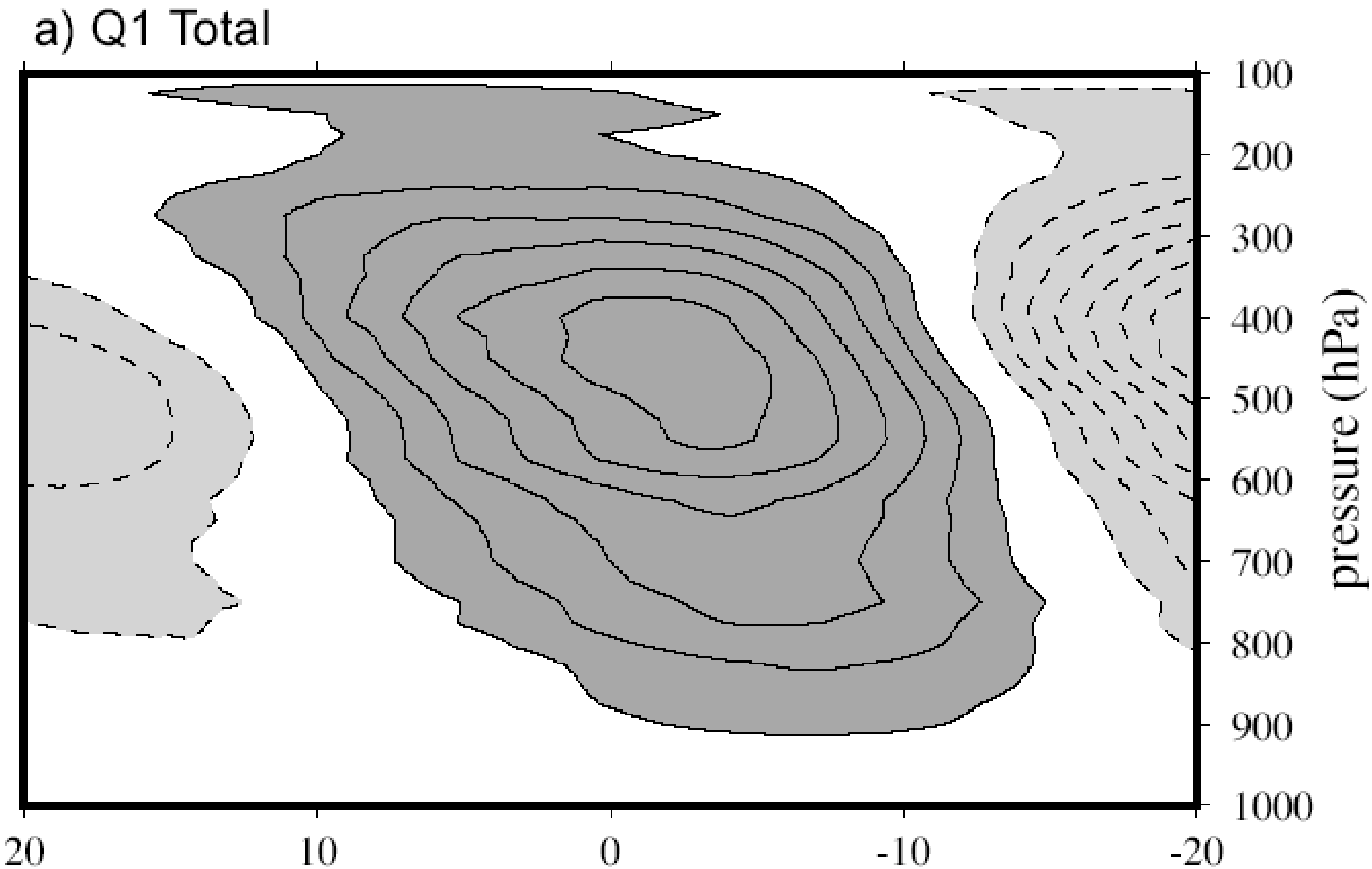
Wave Motion

OLR (top, Wm^{-2})

Specific Humidity (contours, 1 X 10^{-1} g kg^{-1}), red positive

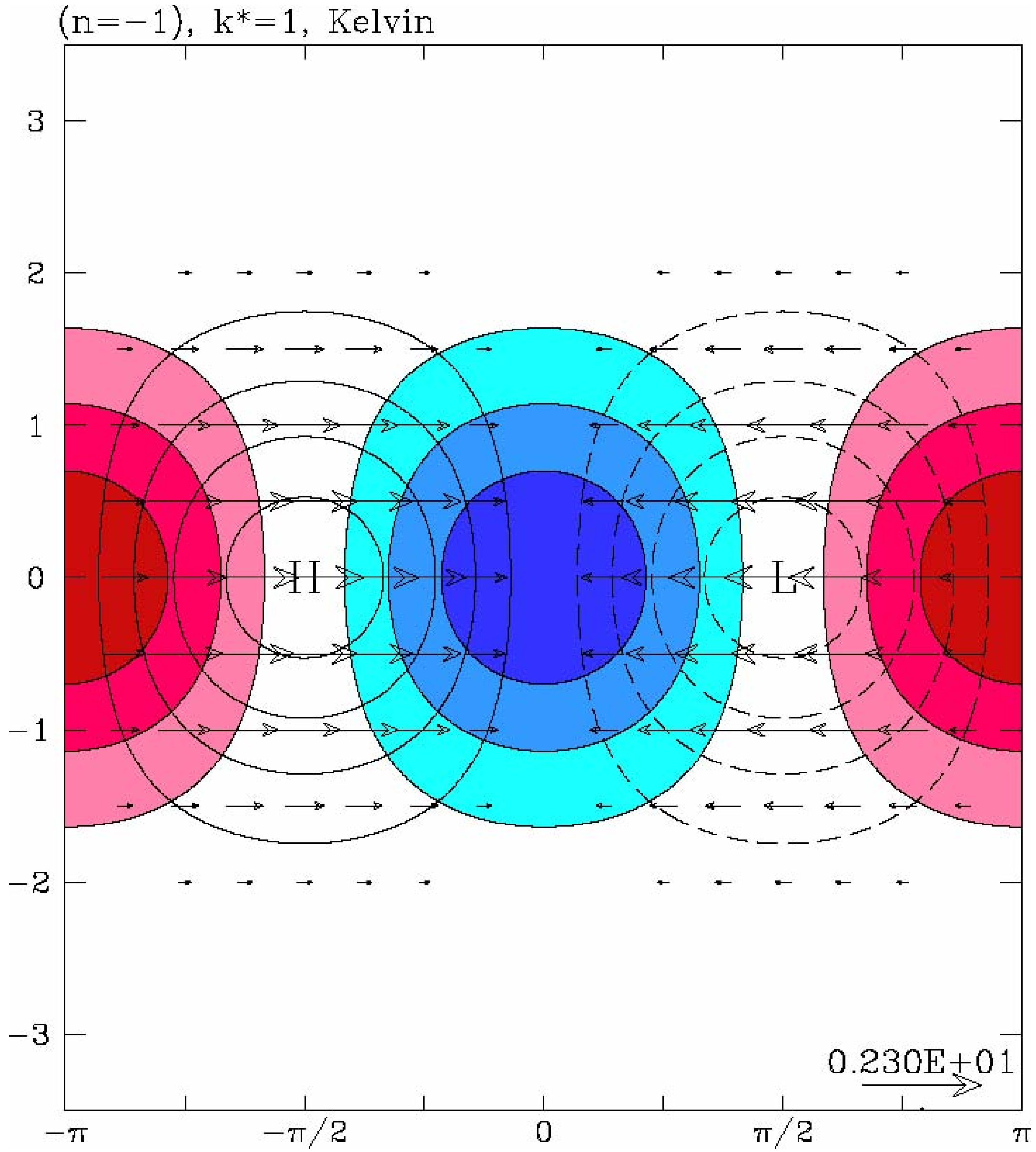
from Kiladis et al. 2005

Q1 Regressed against MJO-filtered OLR over the IFA during COARE



from Kiladis et al. 2005

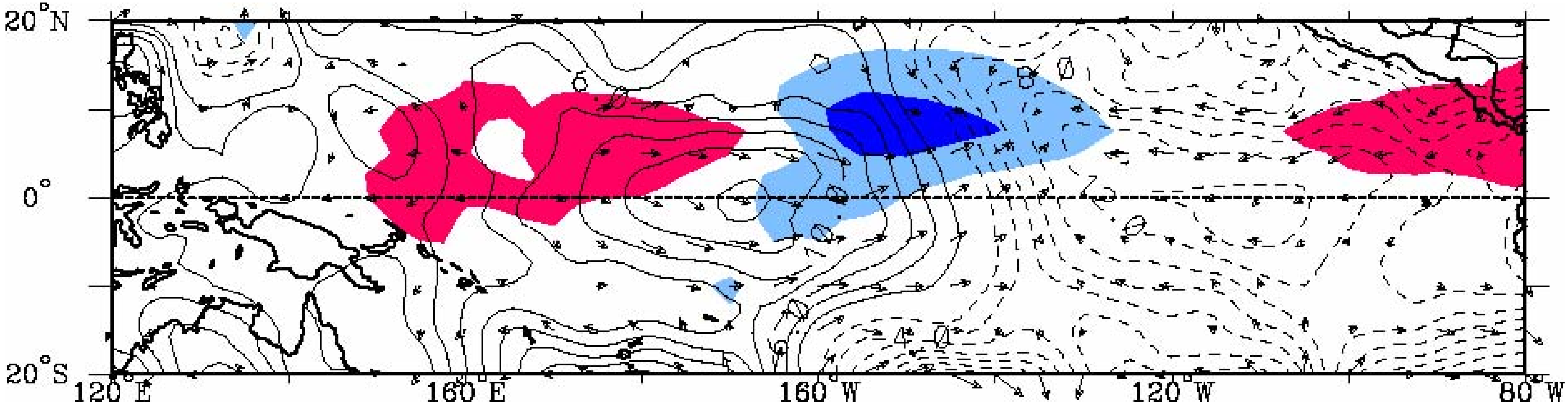
Kelvin Wave Theoretical Structure



Wind, Pressure (contours),
Divergence, blue negative

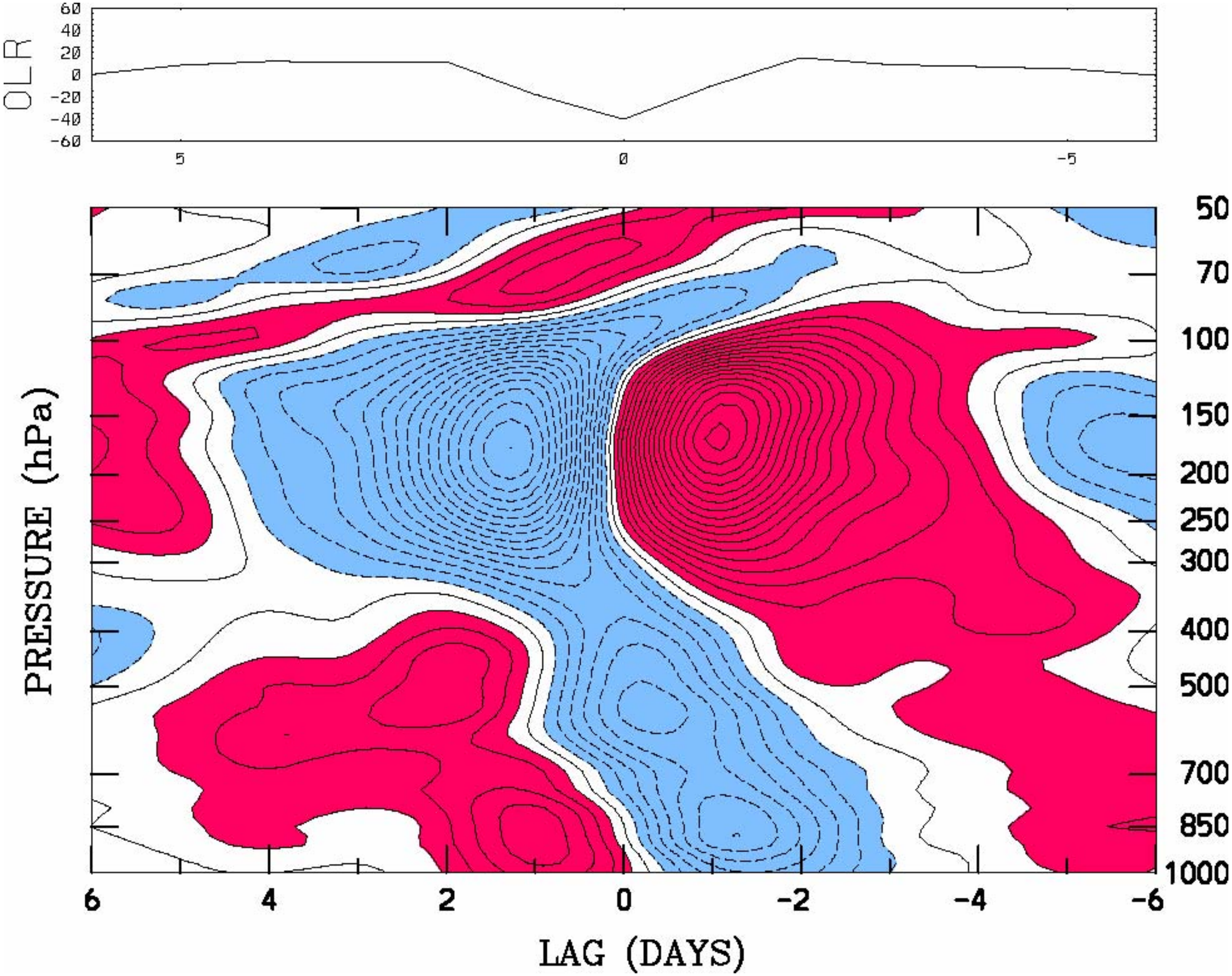
OLR and 1000 hPa Flow Regressed against Kelvin-filtered OLR (scaled -20 W m^2) at 10°N, 150°W for June-Aug. 1979-2004

Day 0



Geopotential Height (contours 2 m)
Wind (vectors, largest around 5 m s^{-1})
OLR (shading starts at +/- 6 W s^{-2}), negative blue

Zonal Wind at Majuro (7°N, 171°E) Regressed against Kelvin-filtered OLR (scaled -40 W m2) for 1979-1999

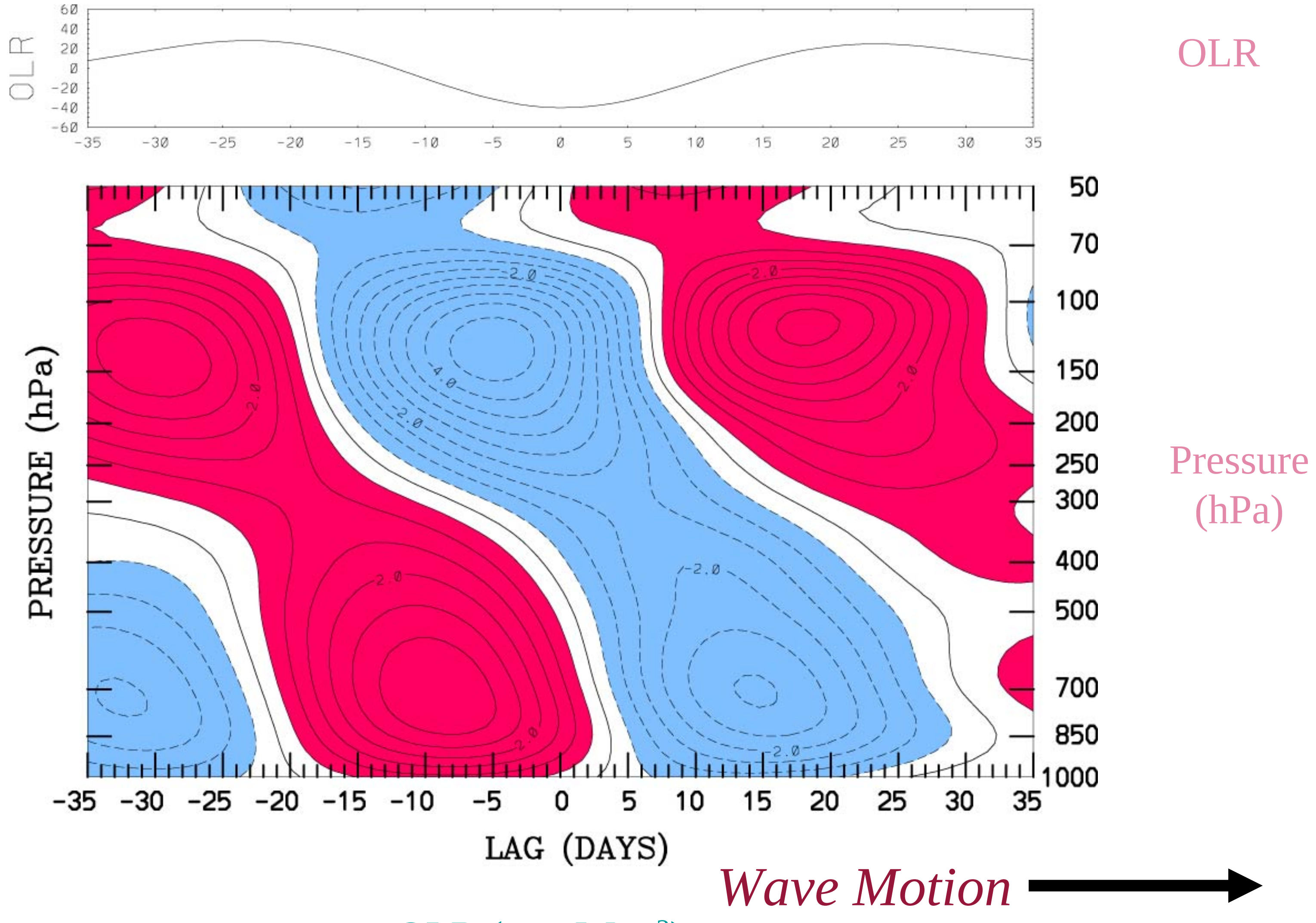


from Straub and Kiladis 2002

OLR (top, Wm^{-2})

Zonal Wind (contours, .25 $m\,s^{-1}$), red positive

Zonal Wind at Honiara (10°S, 160°E) Regressed against MJO-filtered OLR (scaled -40 W m2) for 1979-1999



OLR (top, Wm^{-2})
U Wind (contours, .5 m s^{-1}), red positive

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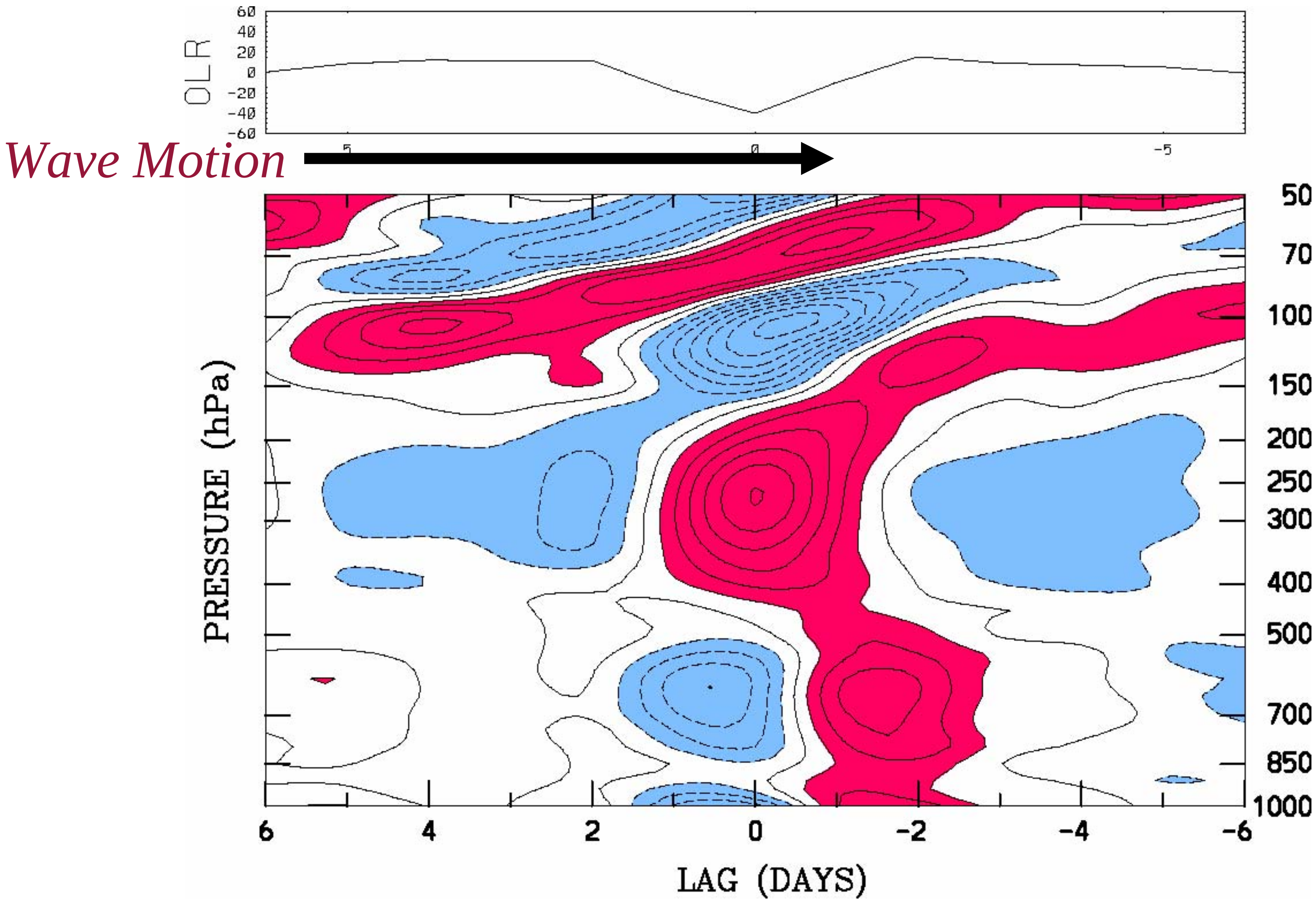
Temperature at Majuro (7°N, 171°E) Regressed against Kelvin-filtered OLR (scaled -40 W m^2) for 1979-1999

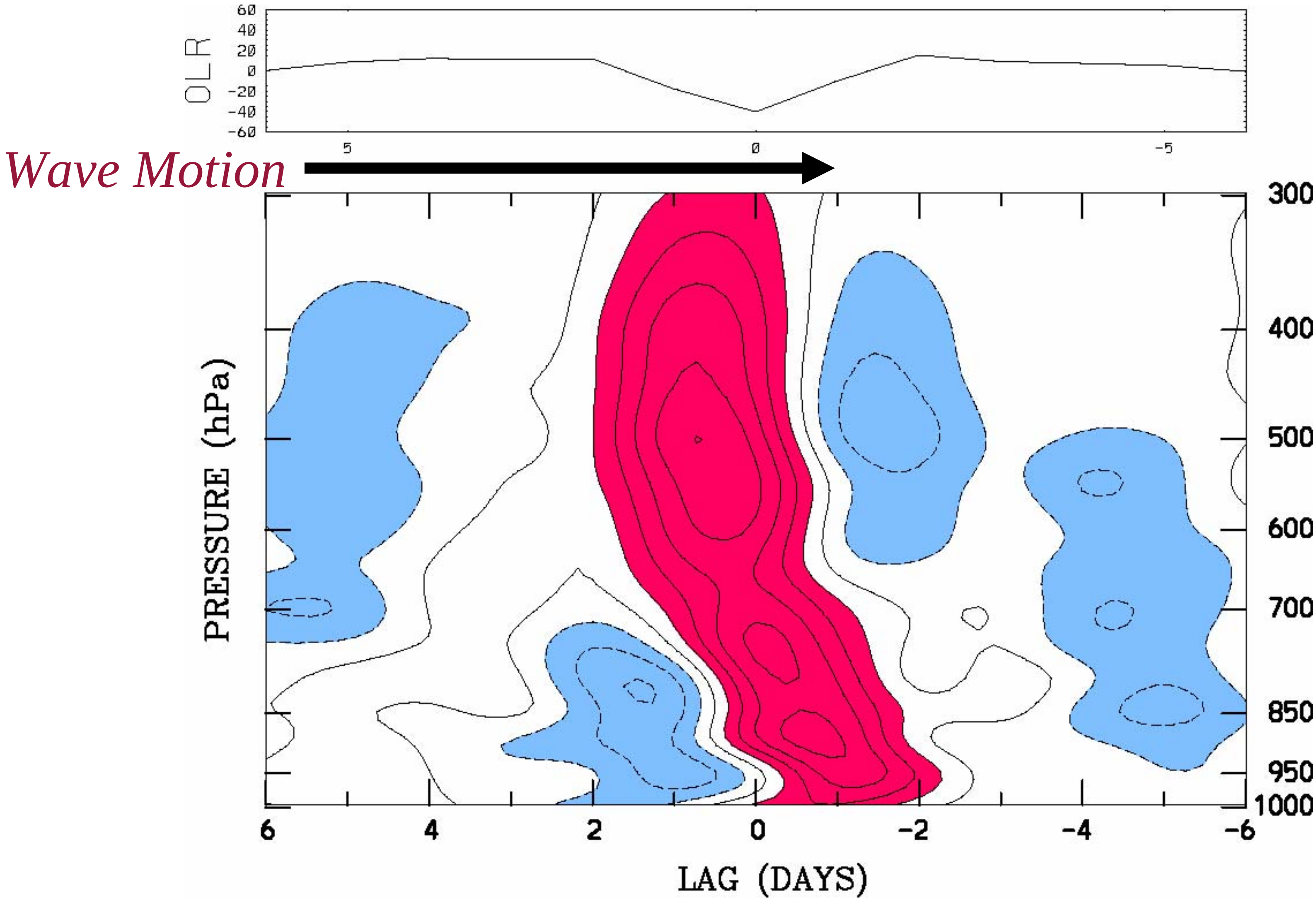


from Straub and Kiladis 2002

OLR (top, Wm^{-2})

Temperature (contours, .1 °C), red positive

Specific Humidity at Majuro (7°N, 171°E) Regressed against Kelvin-filtered OLR (scaled -40 W m^2) for 1979-1999

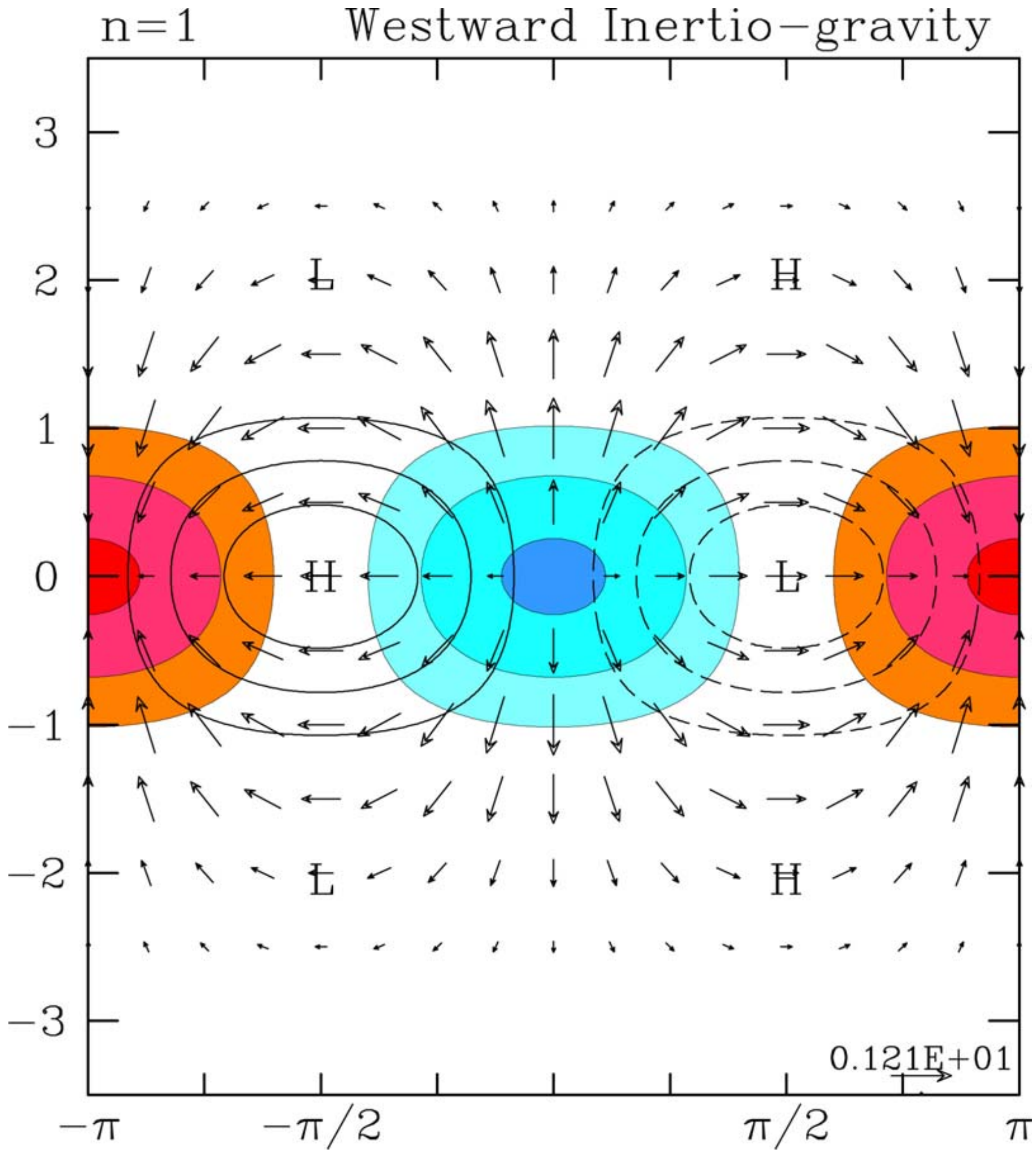


from Straub and Kiladis 2002

OLR (top, Wm^{-2})

Specific Humidity (contours, 1×10^{-1} g kg^{-1}), red positive

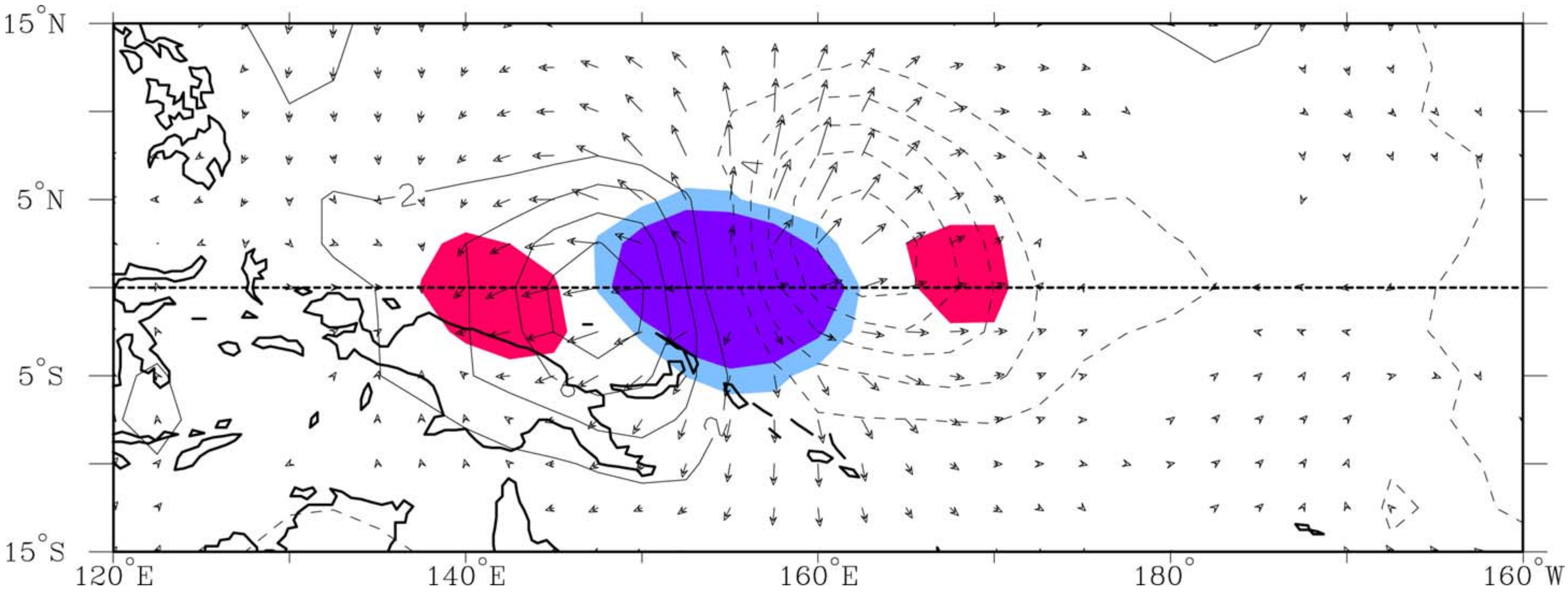
n=1 Westward Inertio-gravity Wave Theoretical Structure



Wind, Pressure (contours),
Divergence, blue positive

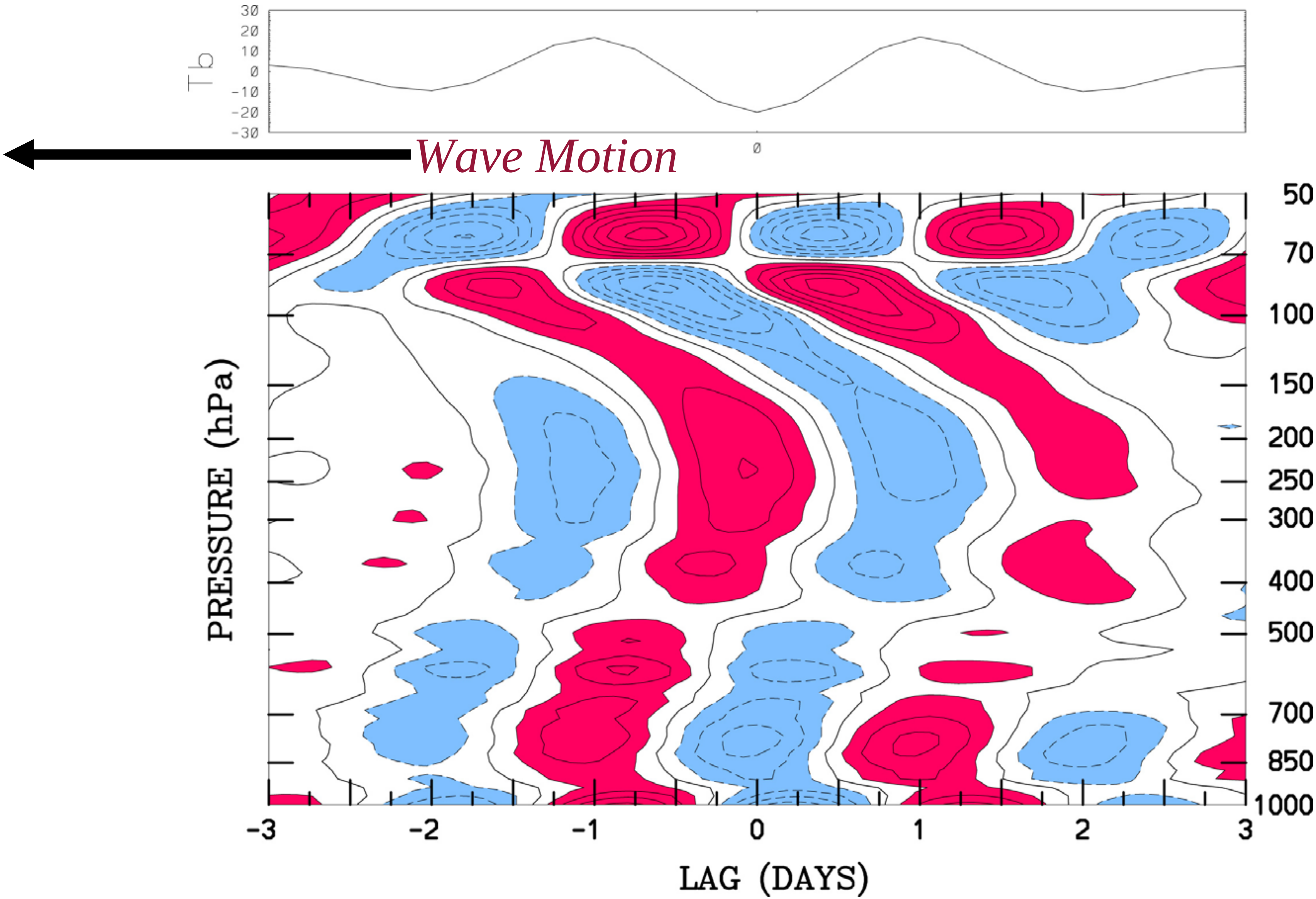
OLR and 200 hPa Flow Regressed against WIG-filtered OLR (scaled -20 W m^2) at 10°N, 150°W for June-Aug. 1979-2004

Day 0



Geopotential Height (contours 2 m)
Wind (vectors, largest around 5 m s^{-1})
Brightness T (shading starts at +/- 3 K), blue negative

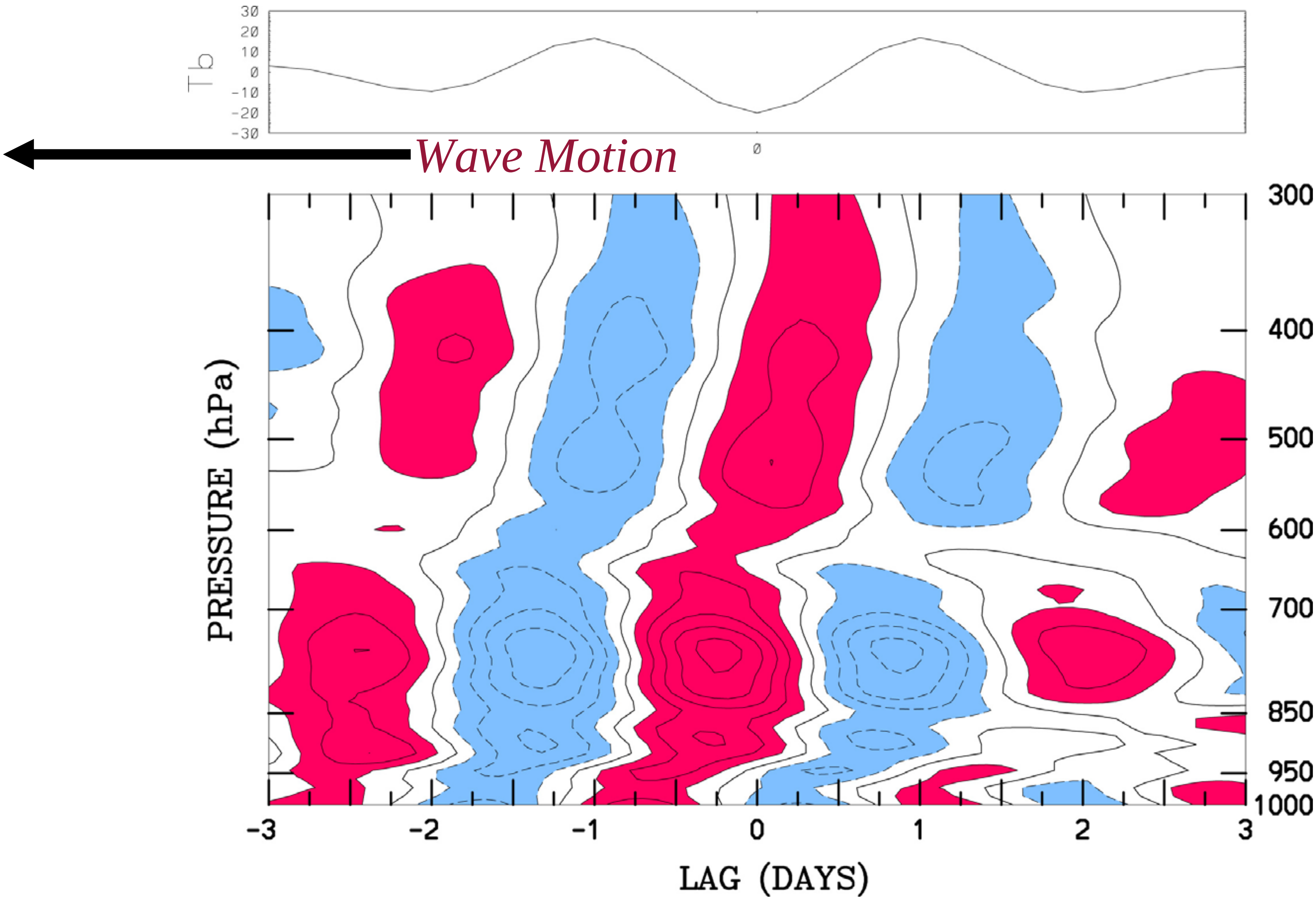
TOGA COARE Temperature (2°S, 155°E) Regressed against Westward Inertio Gravity-filtered OLR (scaled -40 W m^2)



Haertel and Kiladis 2004

Temperature (contours, .1 °C), red positive

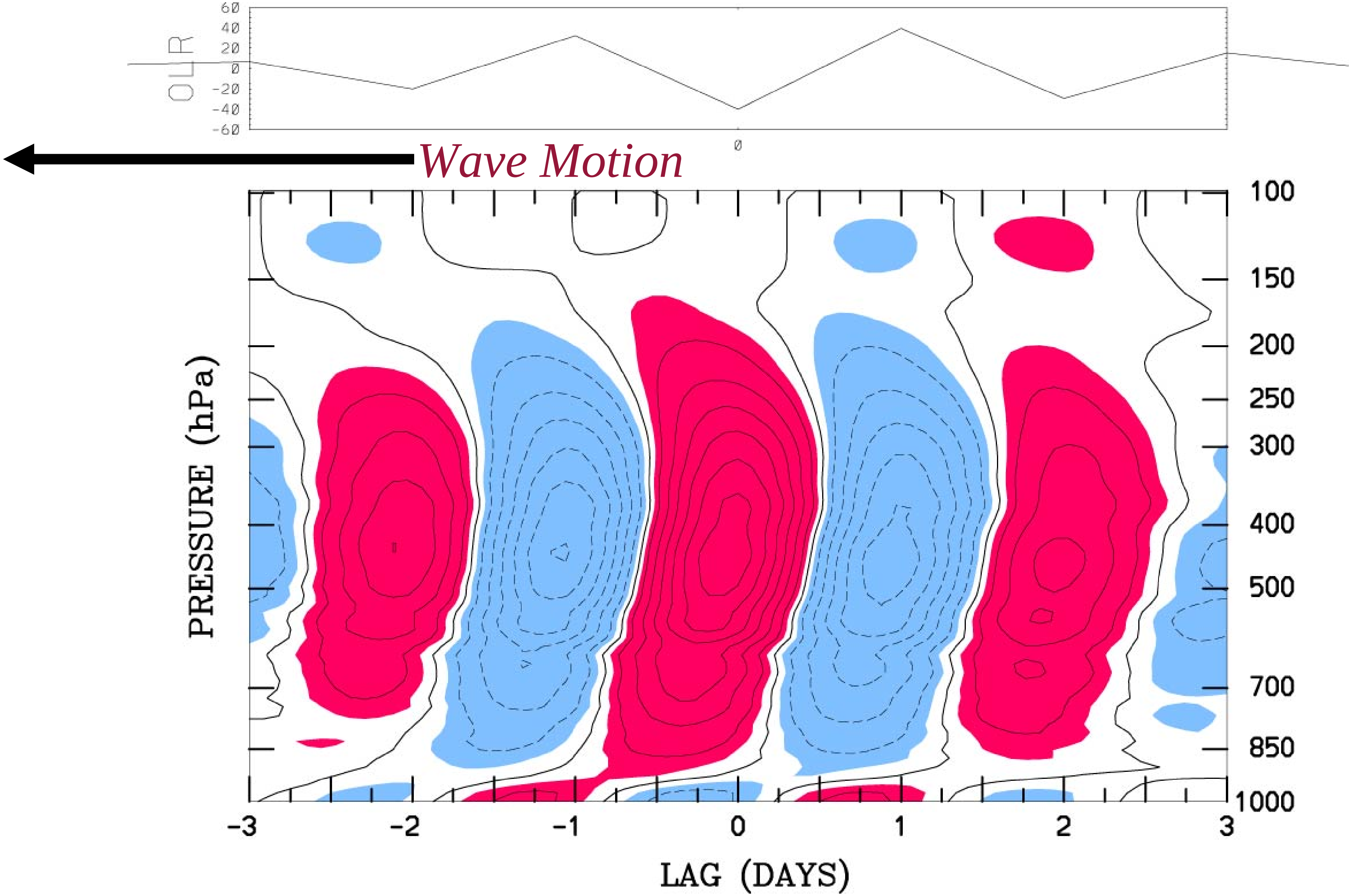
TOGA COARE Specific Humidity (2°S, 155°E) Regressed against Westward Inertio Gravity-filtered OLR (scaled -40 W m^2)



Haertel and Kiladis 2004

Specific Humidity (contours, 1 X 10^{-1} g kg^{-1}), red +

TOGA COARE Diabatic Heating Q1 (2°S, 155°E) Regressed against Westward Inertio Gravity-filtered OLR (scaled -40 W m^2)

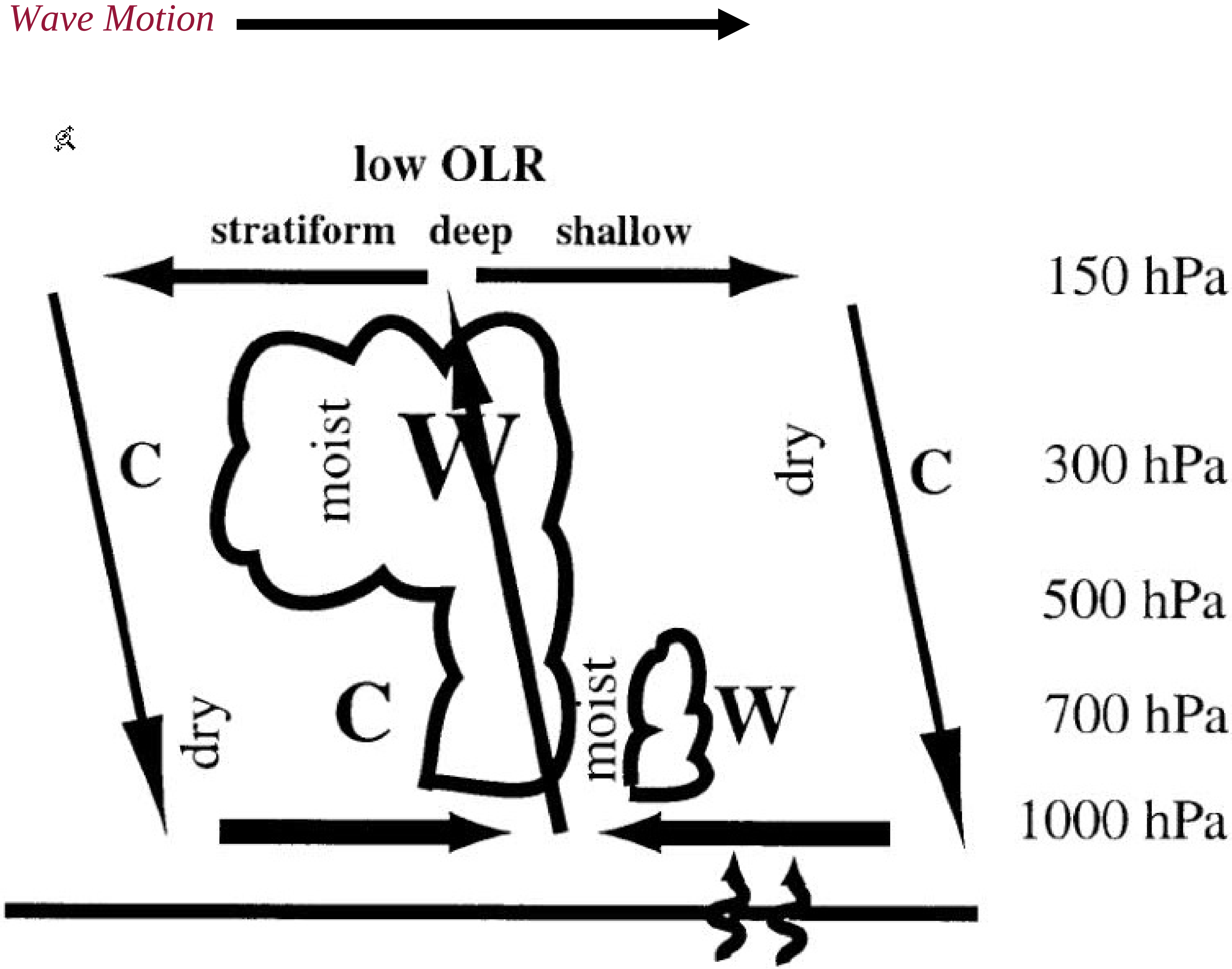


Haertel and Kiladis 2004

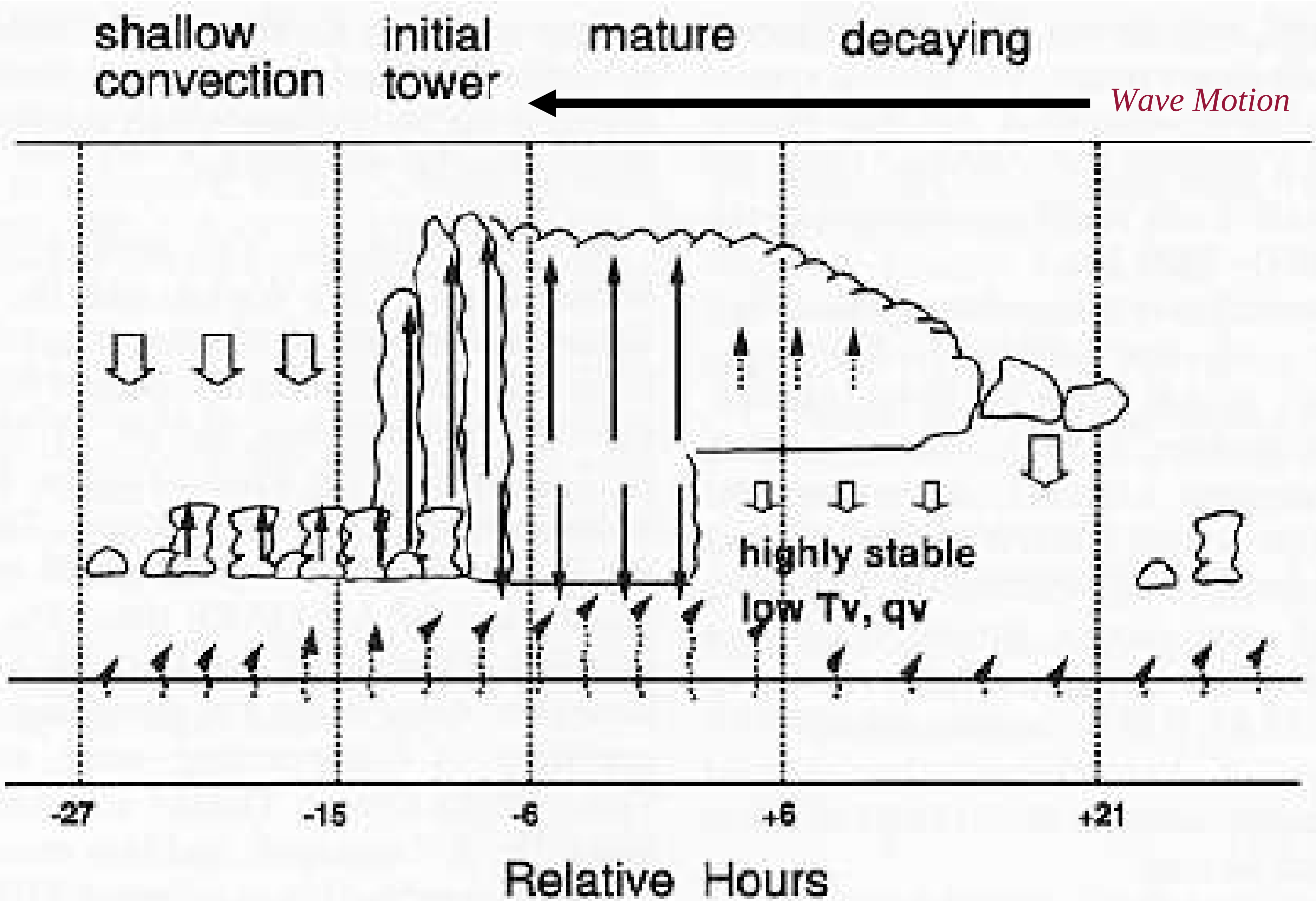
Diabatic Heating (contours, °K/day), red +

Observed Kelvin wave morphology (from Straub and Kiladis 2003)

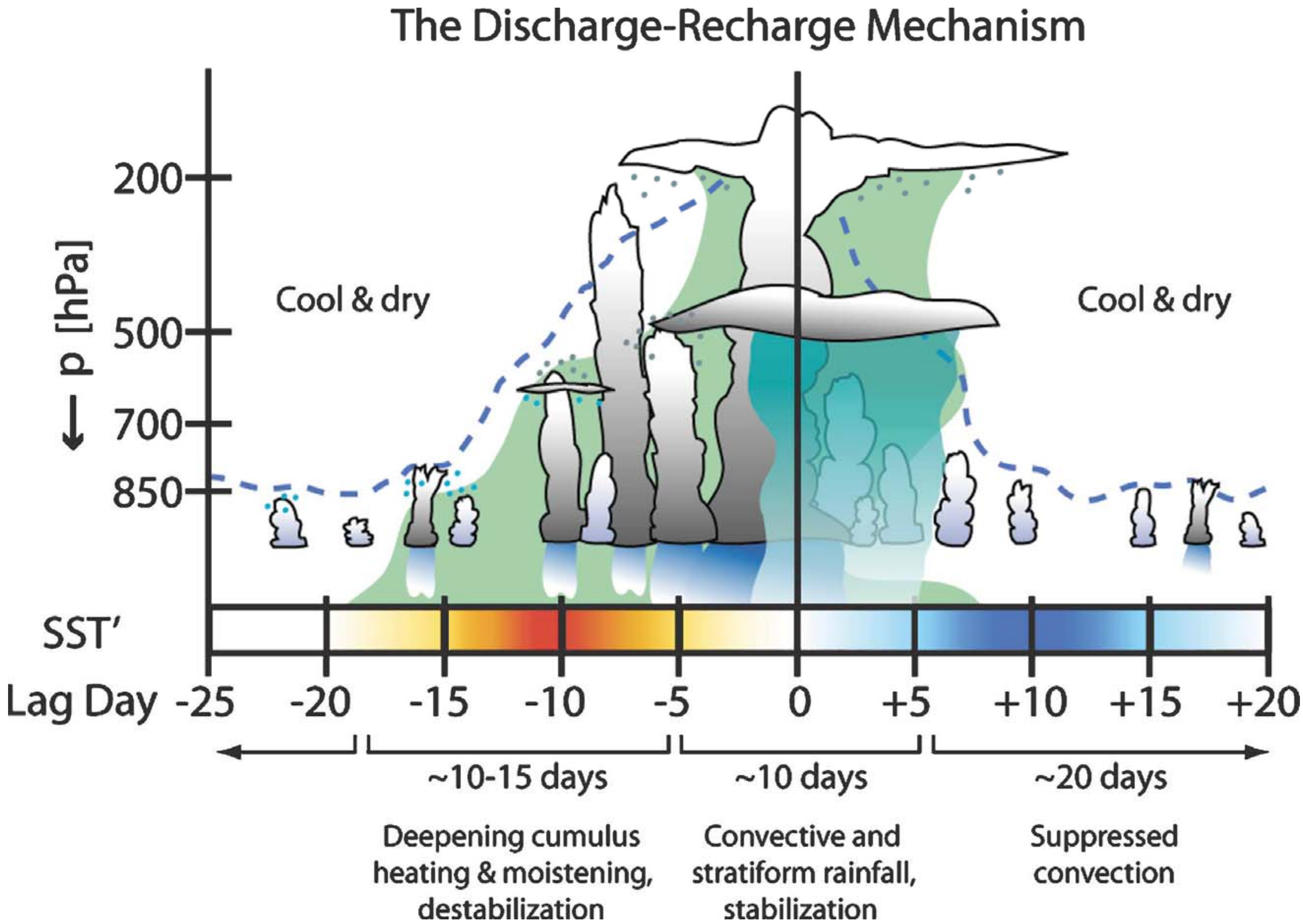
Wave Motion



Two day (WIG) wave cloud morphology (from Takayabu et al. 1996)



MJO Propagation

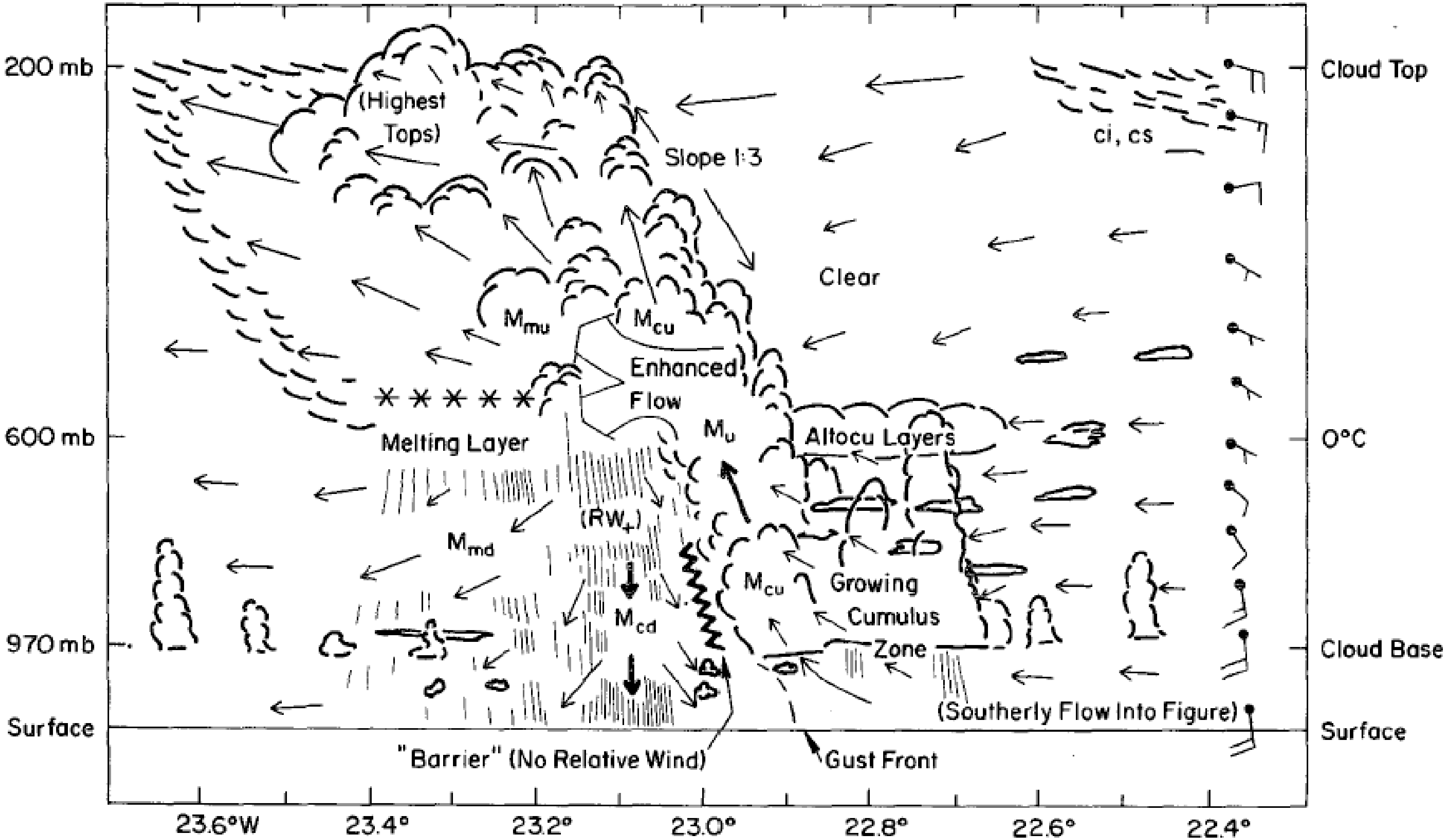


from Benedict and Randall, 2007

Morphology of a Tropical Mesoscale Convective Complex in the eastern Atlantic during GATE (from Zipser et al. 1981)

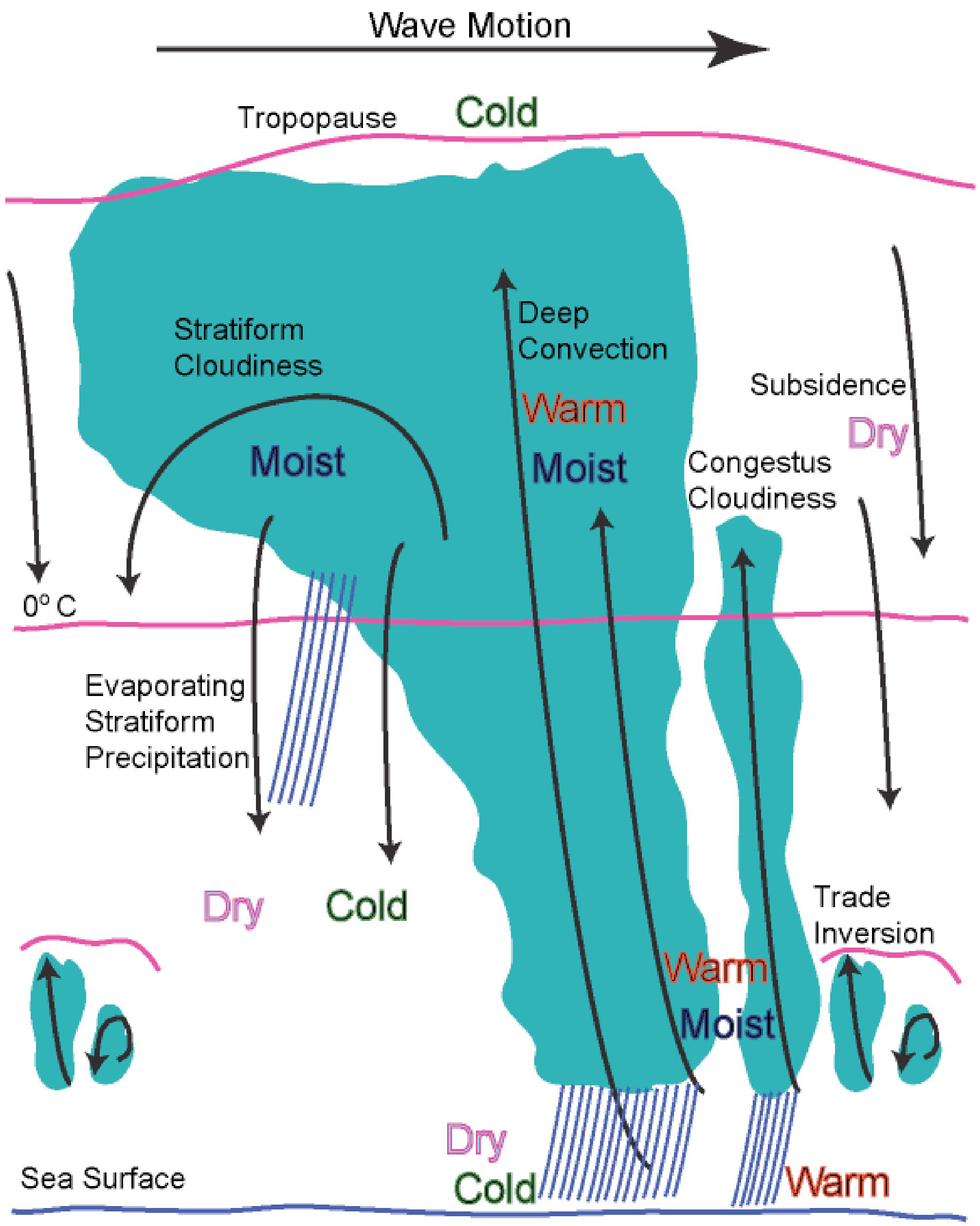
Storm Motion →

SCHEMATIC CROSS-SECTION THROUGH 14 SEPT. CLOUD SYSTEM (Composite)



System Motion Is Left to Right at 3 m s^{-1}. Arrows Show Relative Wind.

Generalized Evolution of a Convectively Coupled Equatorial Wave



from Kiladis et al., 2009

***Conclusion 1:* Large scale atmospheric waves modulate waves and convection (along with the diurnal cycle) on smaller scales**

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Conclusion 5: ***Equatorial wave cloud morphology is consistent with a progression from shallow to deep convection, followed by stratiform rain during the passage of the wave***

Summary and Question

All waves examined have broadly self-similar vertical structures in terms of their dynamical fields (temperature, wind, pressure, diabatic heating, cloud morphology)

This is consistent with a progression of shallow to deep convection, followed by stratiform precipitation from the mesoscale on up to the MJO

Suggests a fundamental interaction between wave dynamics and convection across a wide range of scales

Summary and Question

All waves examined have broadly self-similar vertical structures in terms of their dynamical fields (temperature, wind, pressure, diabatic heating, cloud morphology)

This is consistent with a progression of shallow to congestus and then deep convection, followed by stratiform precipitation from the mesoscale on up to the MJO

Suggests a fundamental interaction between wave dynamics and convection across a wide range of scales

Is a systematic cascade of energy from the mesoscale on up to the planetary scale crucial for the maintenance of equatorial waves?