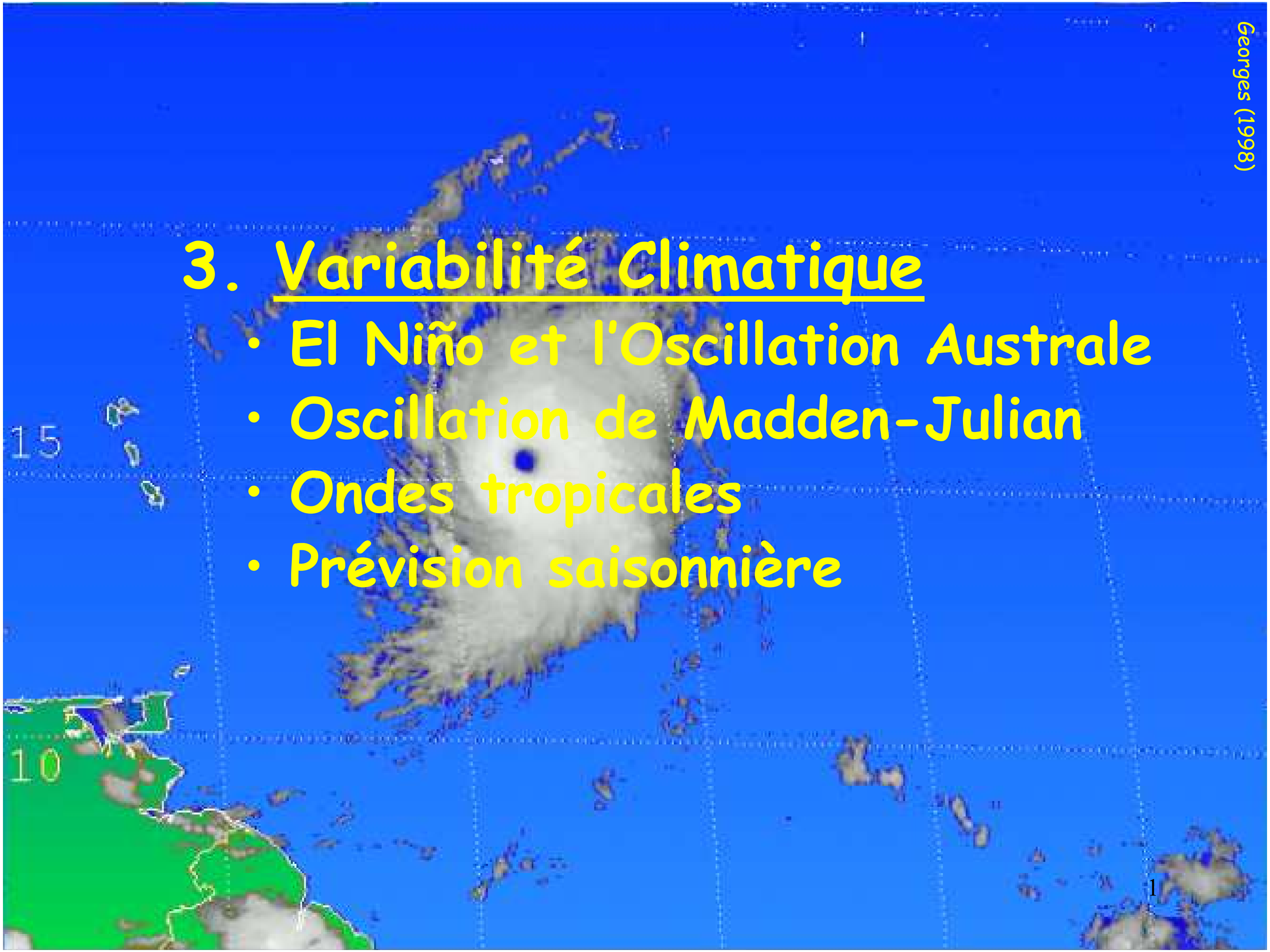
3. Variabilité Climatique

- El Niño et l'Oscillation Australe
- Oscillation de Madden-Julian
- Ondes tropicales
- Prévision saisonnière



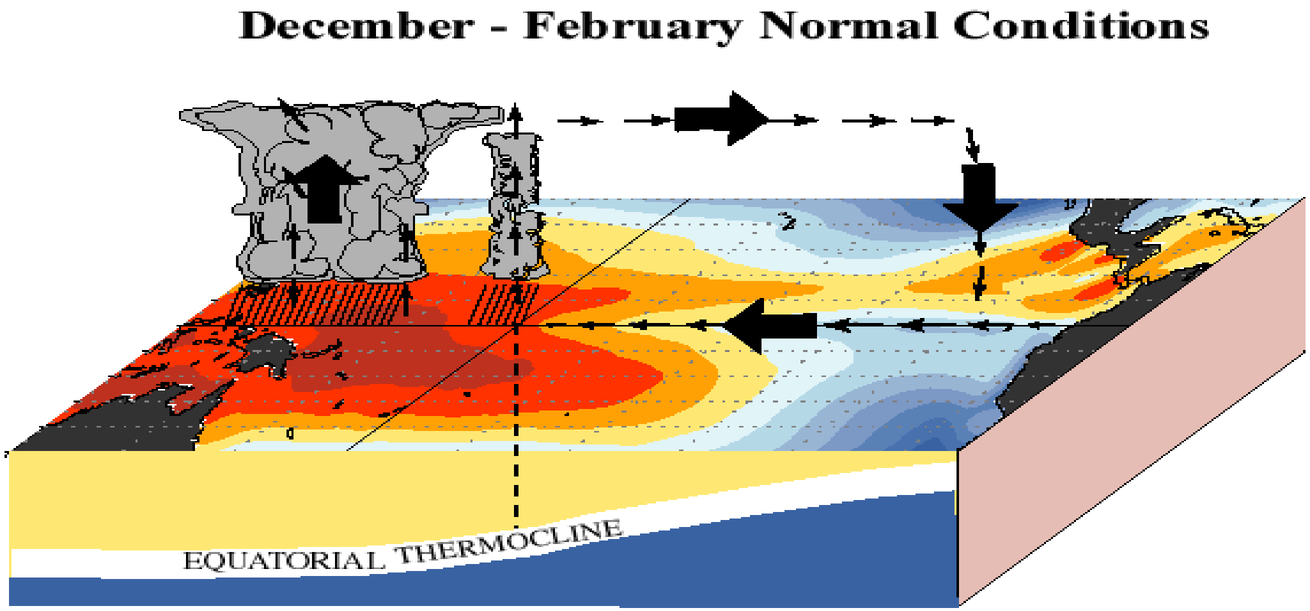
Six environmental conditions for tropical cyclones to form and grow

- Ocean surface waters warmer than 26°C ;
- An unstable atmosphere to allow convection to develop ;
- Relatively moist layers in the mid-troposphere ;
- A minimum distance of 5-10° from the equator;
- A pre-existing disturbance near the Earth's surface with sufficient cyclonic vorticity and convergence ;
- Low values of vertical wind shear between the surface and the upper troposphere .

How do variations in these conditions affect tropical cyclone activity?

- Seasonal variations in tropical cyclone activity depend on changes in one or more of the six parameters (e.g. N Indian : no TCs during the monsoon).
- Variations in these parameters (both before and during the tropical cyclone season) can be used to understand and, in some cases, predict seasonal tropical cyclone activity.

Conditions atmosphériques et océaniques « normales » sur l'océan Pacifique (1)

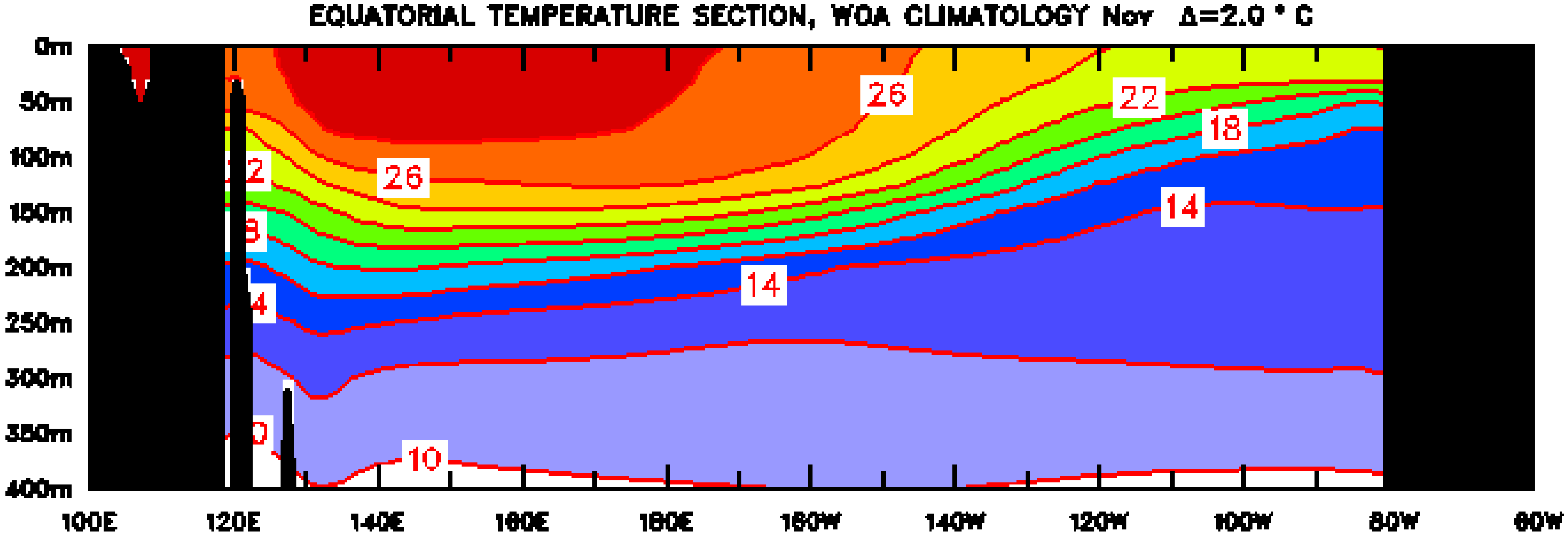


Cette répartition des températures de surface et de précipitations est associée à des vents d'Est (alizés) dans les basses couches et d'Ouest en altitude.

Sur le Pacifique Ouest et l'Indonésie, une zone de basses pressions est associée à des mouvements ascendants. A l'Est, se trouvent des hautes pressions et des mouvements descendants.

Cette « Cellule Zonale de Walker », représente la circulation de base à grande échelle sur le Pacifique tropical.

Conditions atmosphériques et océaniques « normales » sur l'océan Pacifique (2)

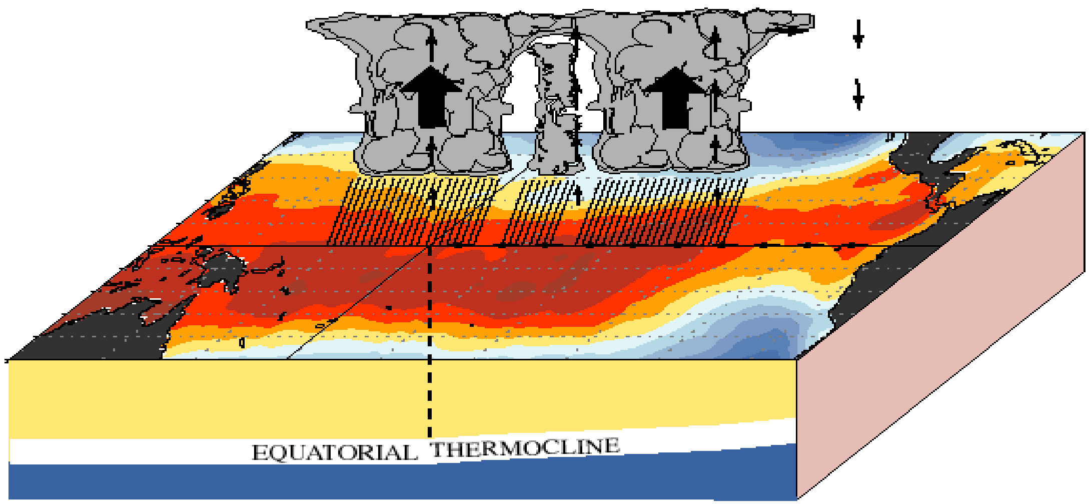


La structure thermique interne du Pacifique tropical est caractérisée par une épaisse couche d'eaux chaudes à l'Ouest , et par une couche nettement moins chaude et moins épaisse à l'Est.

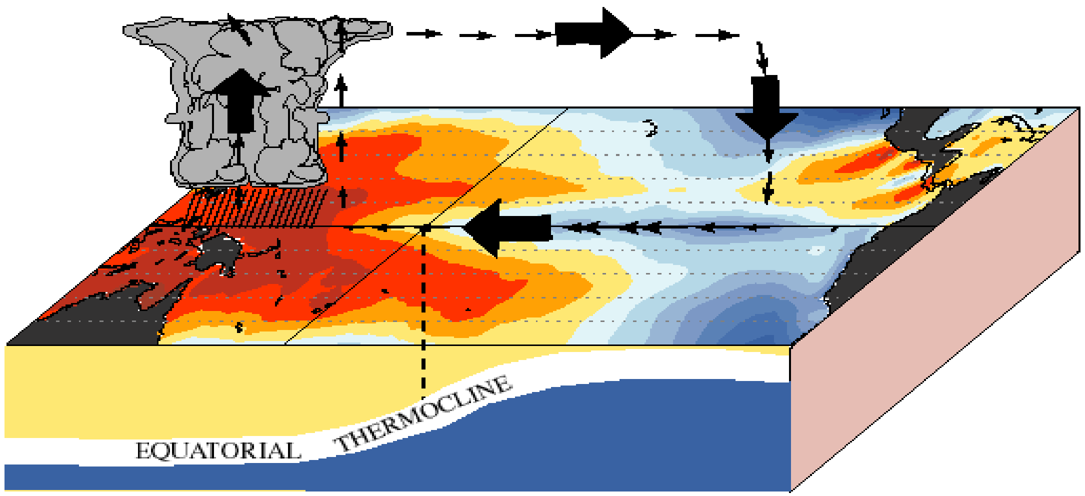
Les eaux chaudes superficielles sont séparées des eaux plus froides de fond par la thermocline, qui est située plus profondément à l'Ouest et qui remonte vers la surface à l'Est.

Conditions atmosphériques et océaniques perturbées sur l'océan Pacifique

December - February El Niño Conditions



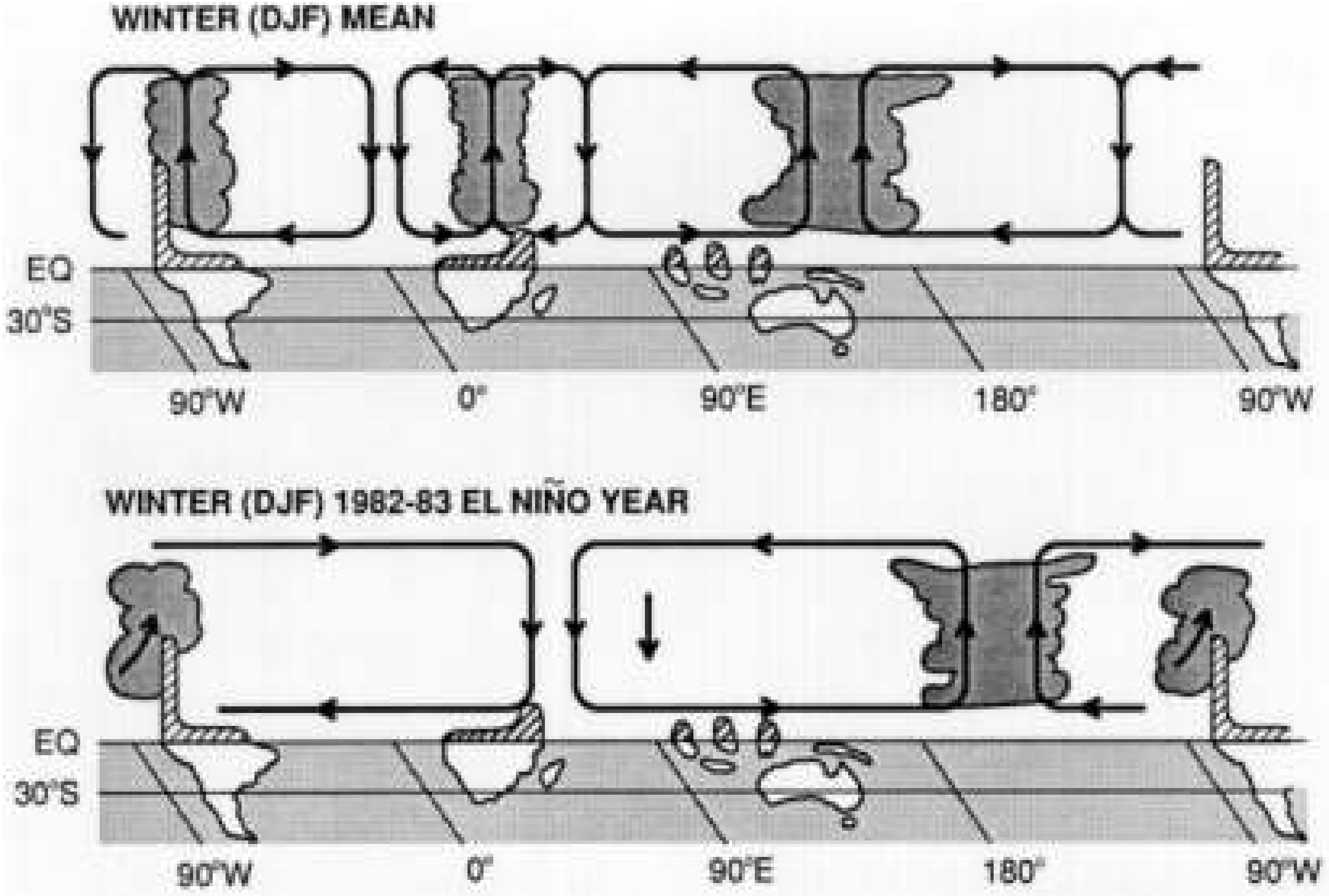
December - February La Niña Conditions



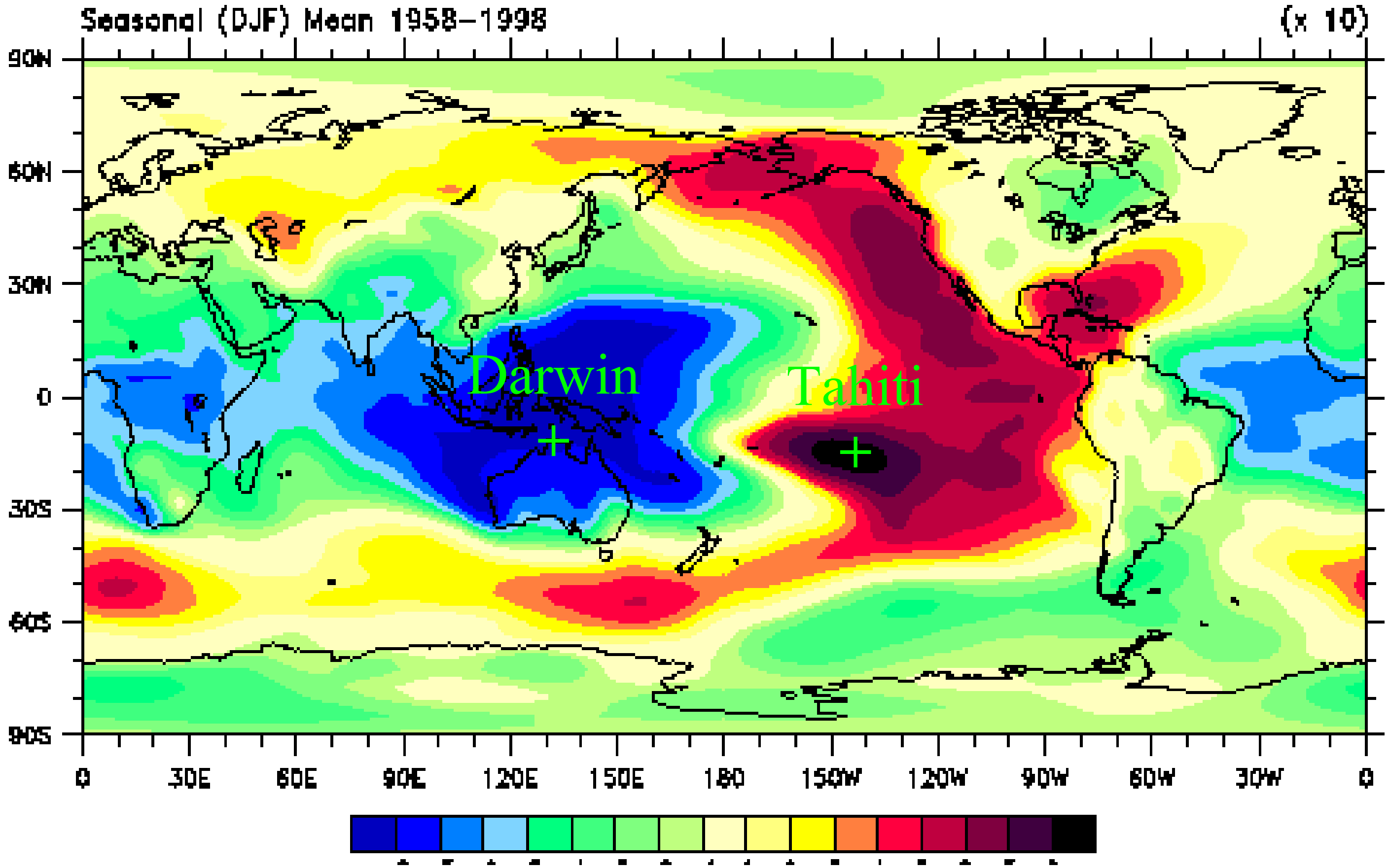
Les alizés d'Est en basse troposphère et les vents d'Ouest en haute troposphère sont réduits, traduisant une diminution d'intensité de la Circulation de Walker qui peut même disparaître totalement.

Les alizés d'Est en basse troposphère et les vents d'Ouest en haute troposphère sont plus intenses, traduisant un renforcement de la Circulation de Walker .

La circulation de Walker globale perturbée

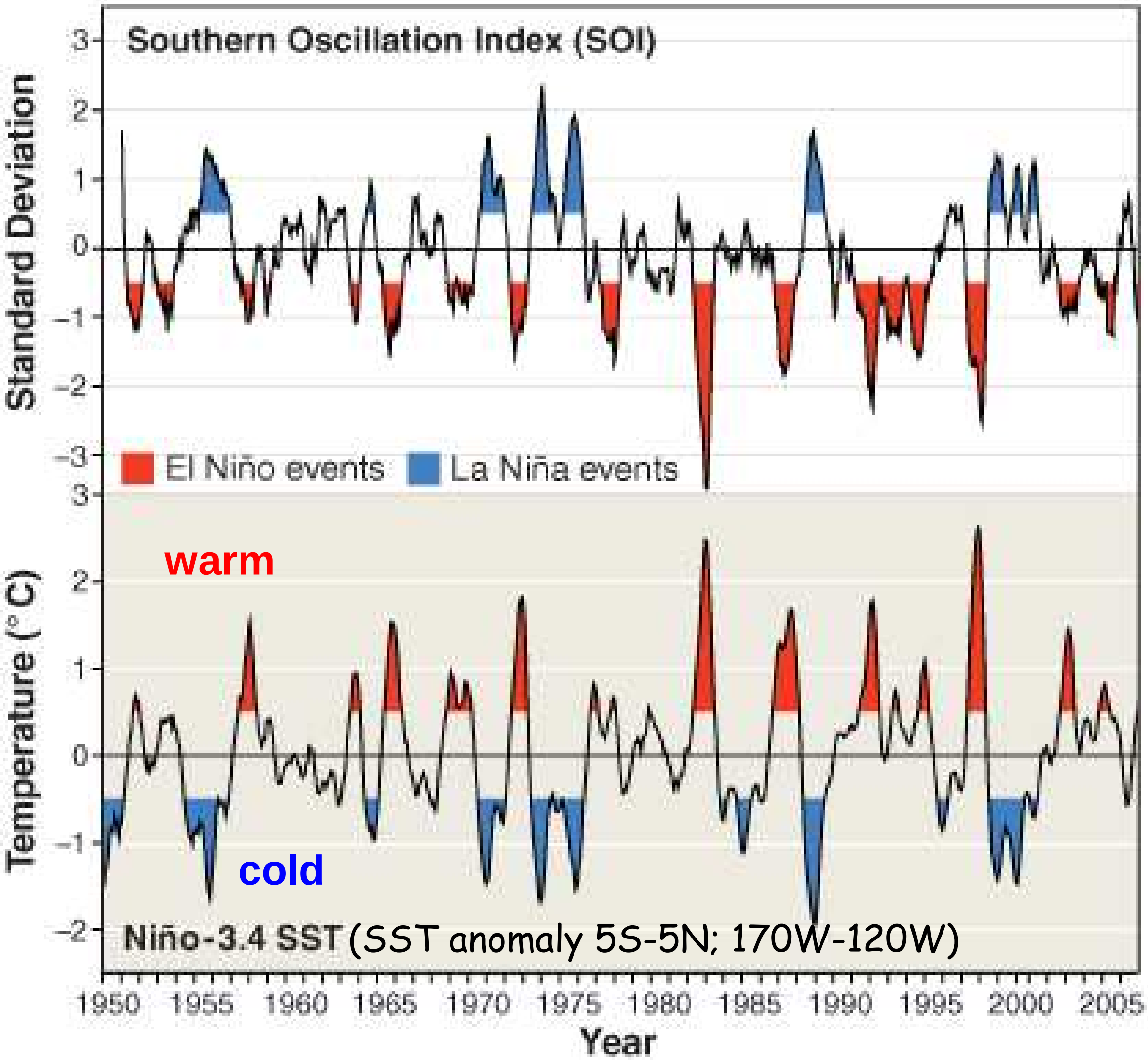


Influence globale de l'ENSO



La carte des corrélations entre les pressions de surface mesurées à Tahiti (Pacifique central : 17° 52' S - 149° 56' W) et dans le reste du monde montre la très grande zone d'influence de l'ENSO. Darwin (N Australie, 12° 28' S - 130° 51' E) peut être considéré comme le pôle opposé à Tahiti.

Southern Oscillation Index



The SOI « Southern Oscillation Index » is the standardized difference in SLP between Tahiti and Darwin.

High pressure at Darwin and low pressure at Tahiti correspond to El Niño events (SOI<0), and the opposite pressure conditions (SOI>0) correspond to La Niña events.

The influence of ENSO on Tropical Cyclones

The state of ENSO has been related to TC numbers in many regions of the world.

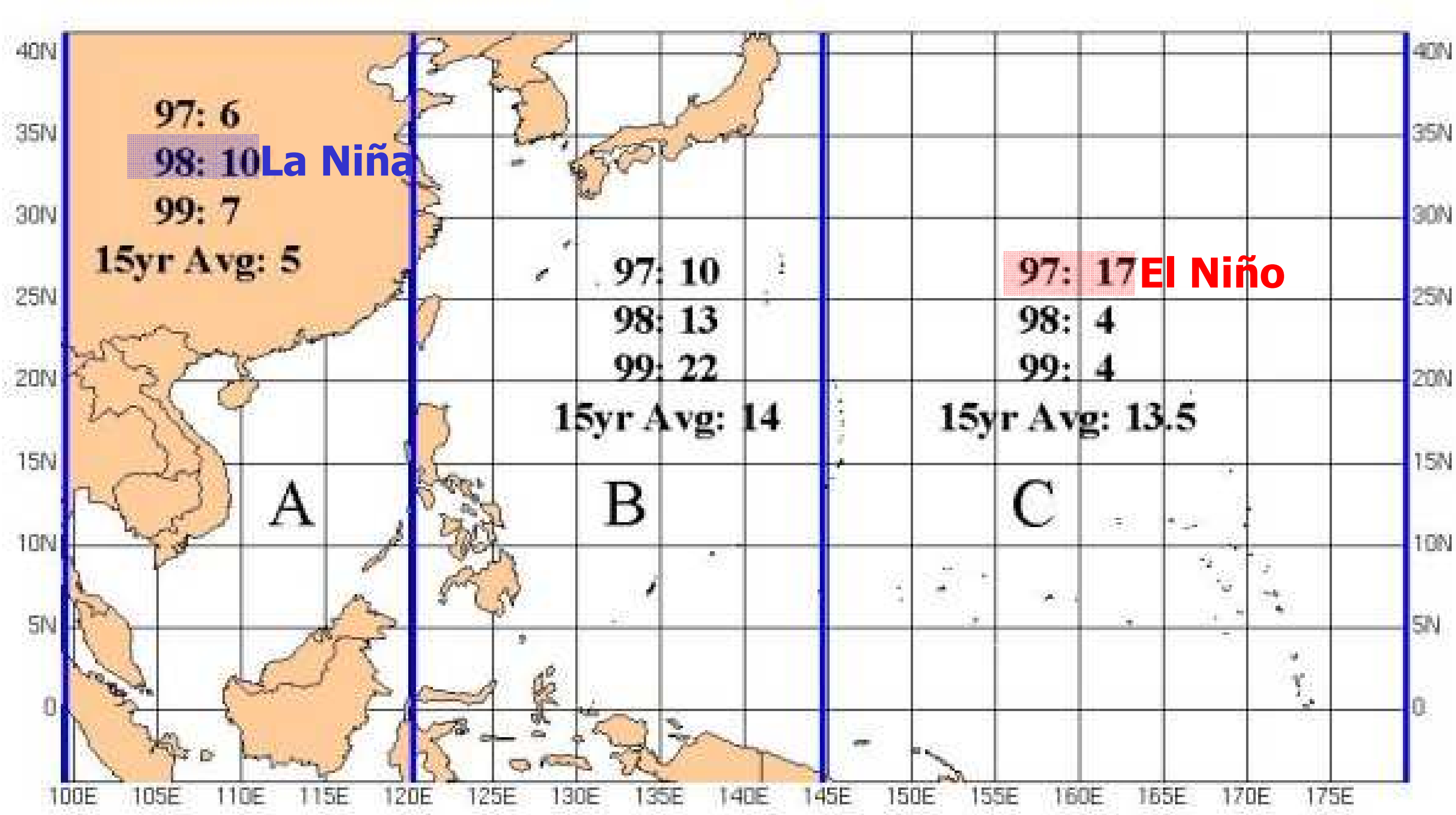
Coherent relationships between cyclone occurrence and the phase of ENSO have been found, although the dynamical reasons for the modulation appear to be quite different in the various cyclone basins of the world.

The different factors are the SST, the SLP, the tropospheric wind and humidity.

The influence of ENSO can appear through shifts in the location of cyclogenesis, and in cyclone frequency and intensity.

ENSO and Tropical Cyclones : NW Pacific

[**Chu, 2004** : « *ENSO and tropical cyclone activity. Hurricanes and Typhoons : Past, Present, and Potential* ». R.J. Murnane and K.B. Liu, Eds., Columbia Univ. Press, 297-332]



The tropical cyclogenesis location shifts eastward across 150°E in the NW Pacific during ENSO warm years.

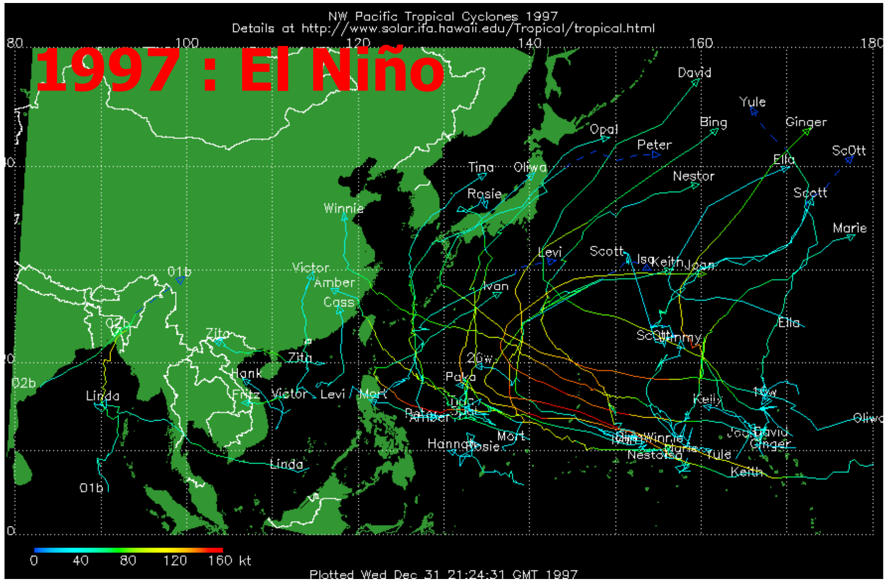
More typhoons and tropical storms occurred in the eastern part (145-180 °E) than the western part (100-145°E) during an El Niño event (eg 1997).

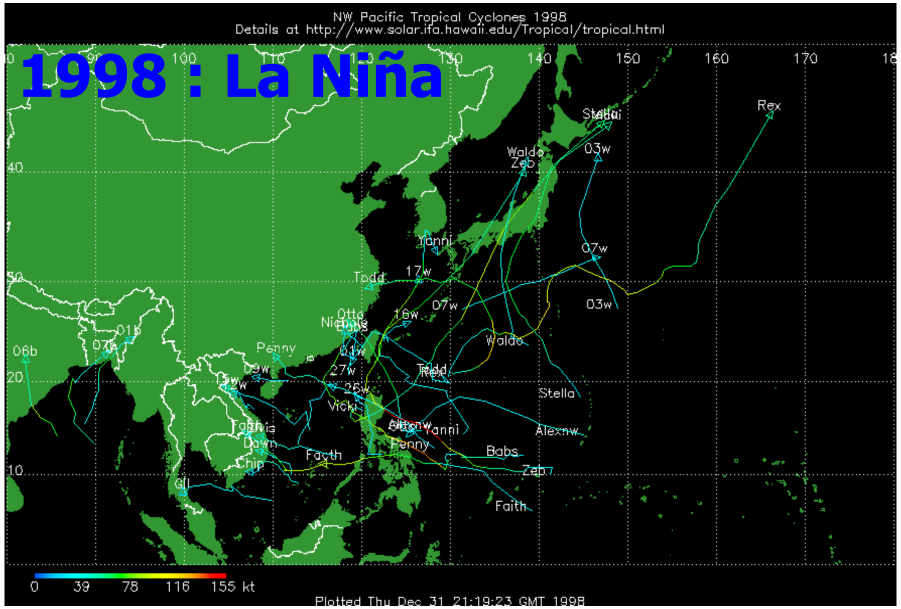
ENSO and Tropical Cyclones : **NW Pacific**

[Chu, 2004]

During El Niño years, the eastward and equatorward shift in origin location allow TCs to maintain a longer lifespan while tracking westward over open water.

Interactions with transient midlatitude synoptic systems result in more recurved trajectories, toward China, Taiwan, Japan and Korea.





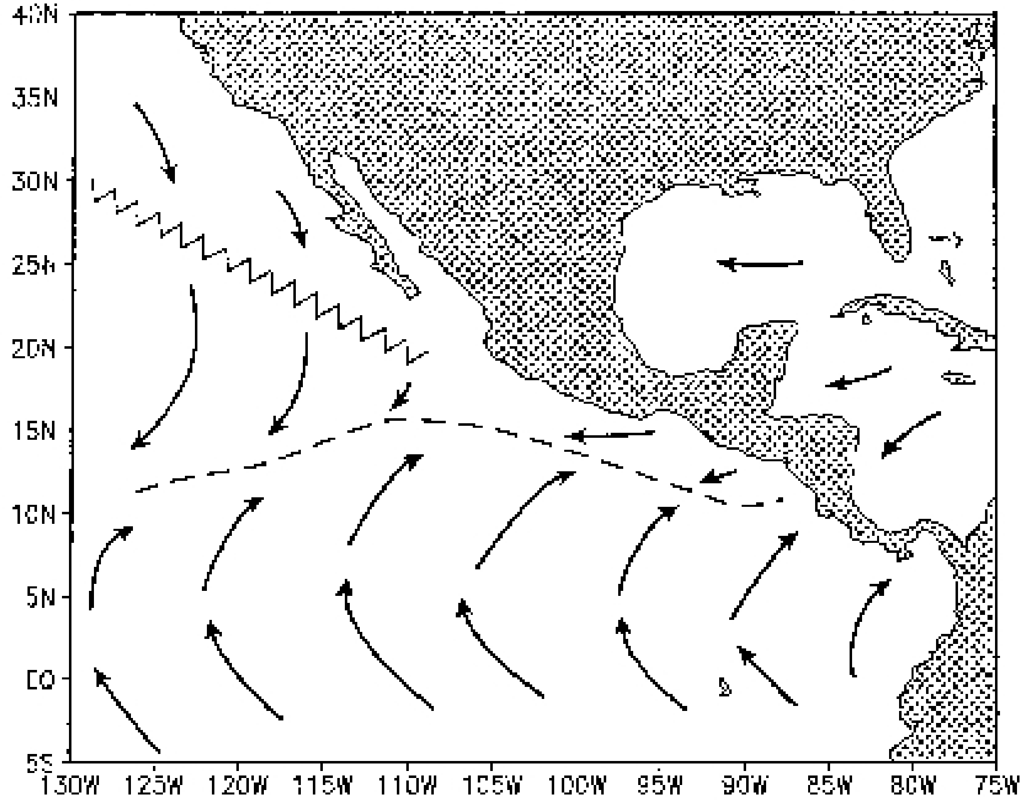
During La Niña years, the monsoon trough is short and confined in the western extreme of N Pacific.

Landfalls are more common in the northern Philippines and South China sea.

ENSO and Tropical Cyclones : **NE Pacific**

[Chu, 2004]

A majority of storms form along the axis of the <u>monsoon trough</u>, but TCs might also be triggered by <u>tropical Easterly Waves</u> from the Atlantic and West Africa.



Schematic showing the long-term mean surface circulation in August in the eastern North Pacific. The monsoon trough axis is denoted by a broken line, and the ridge axis by a zigzag line. Wind directions are indicated by arrows.

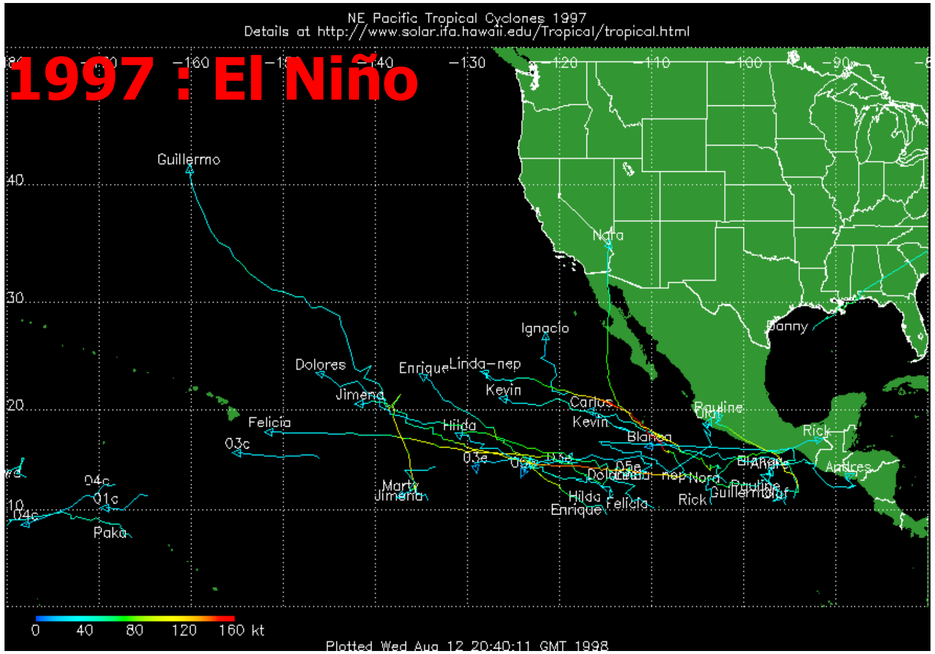
!! when TCs are <u>active in the NE Pacific</u>, they tend to be <u>suppressed over the N Atlantic</u> and vice versa !!

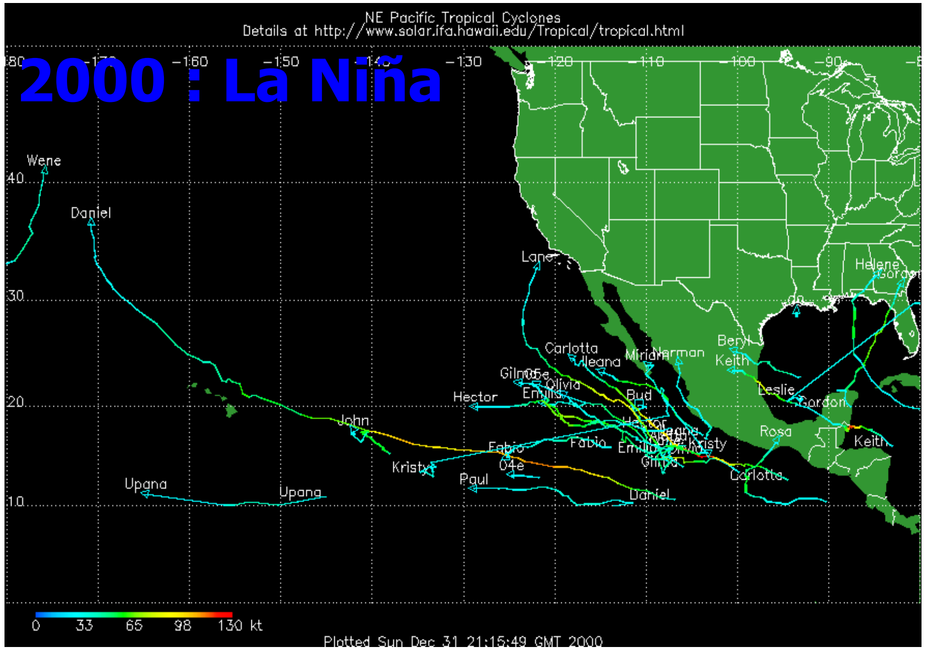
ENSO and Tropical Cyclones : **NE Pacific**

[Chu, 2004]

There is <u>no obvious impact of ENSO</u> on the overall TC frequency in the NE Pacific.

If only <u>intense storms</u> (Saffir-Simpson category ≥3) are considered, the <u>ratio during El Niño to La Niña years is about 1.7</u>.





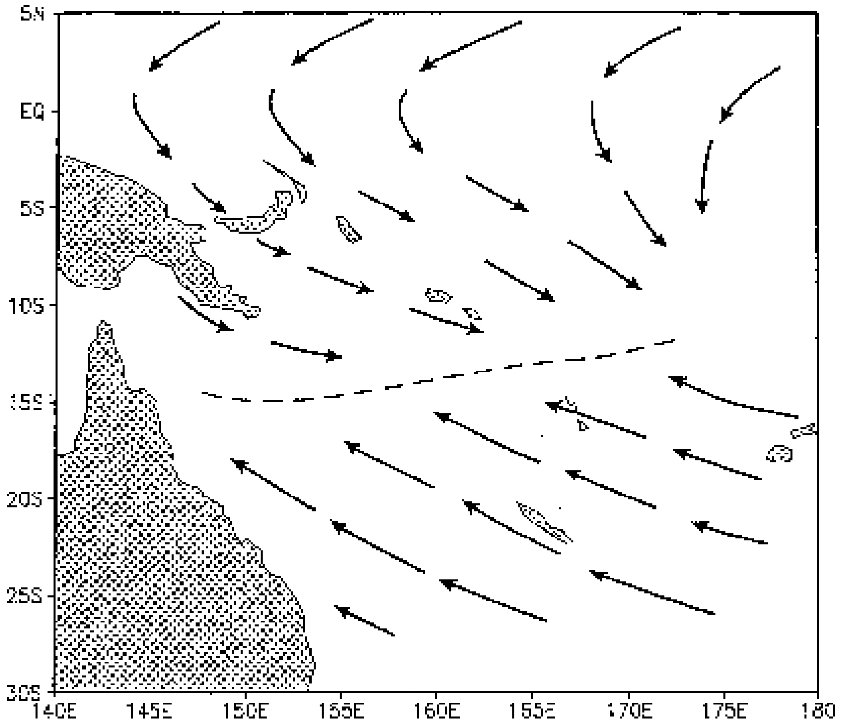
TC tracks <u>expand westward</u> during El Niño years, and <u>retreat eastward</u> during La Niña.

ENSO and Tropical Cyclones : **SW Pacific**

[Chu, 2004]

There is a strong correlation between the SOI and TC days around the Australian region (105°E – 165°E).

Higher SLP, cooling of ocean surface, and the sinking branch of the Walker circulation during El Niño years combine to produce unfavourable conditions for TC formation.

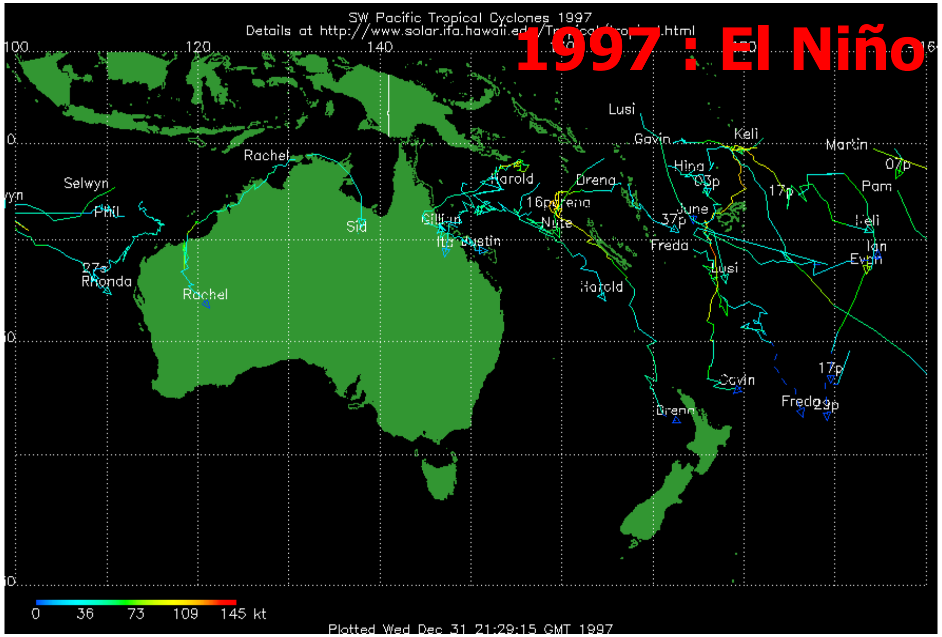


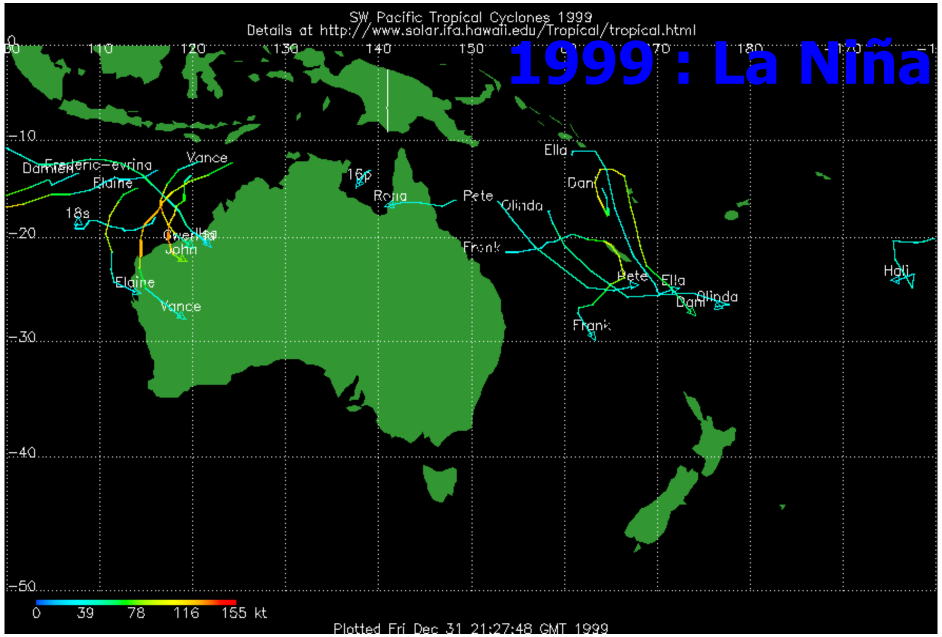
Schematic showing the long-term mean surface circulation in February in the southwestern Pacific. The monsoon trough axis is indicated by a broken line. Wind directions are indicated by arrows.

For the SW Pacific, the eastern end of the monsoon trough is usually near 175°E, but it can extend as far east as 140°W during El Niño years.

ENSO and Tropical Cyclones : **SW Pacific**

[Chu, 2004]



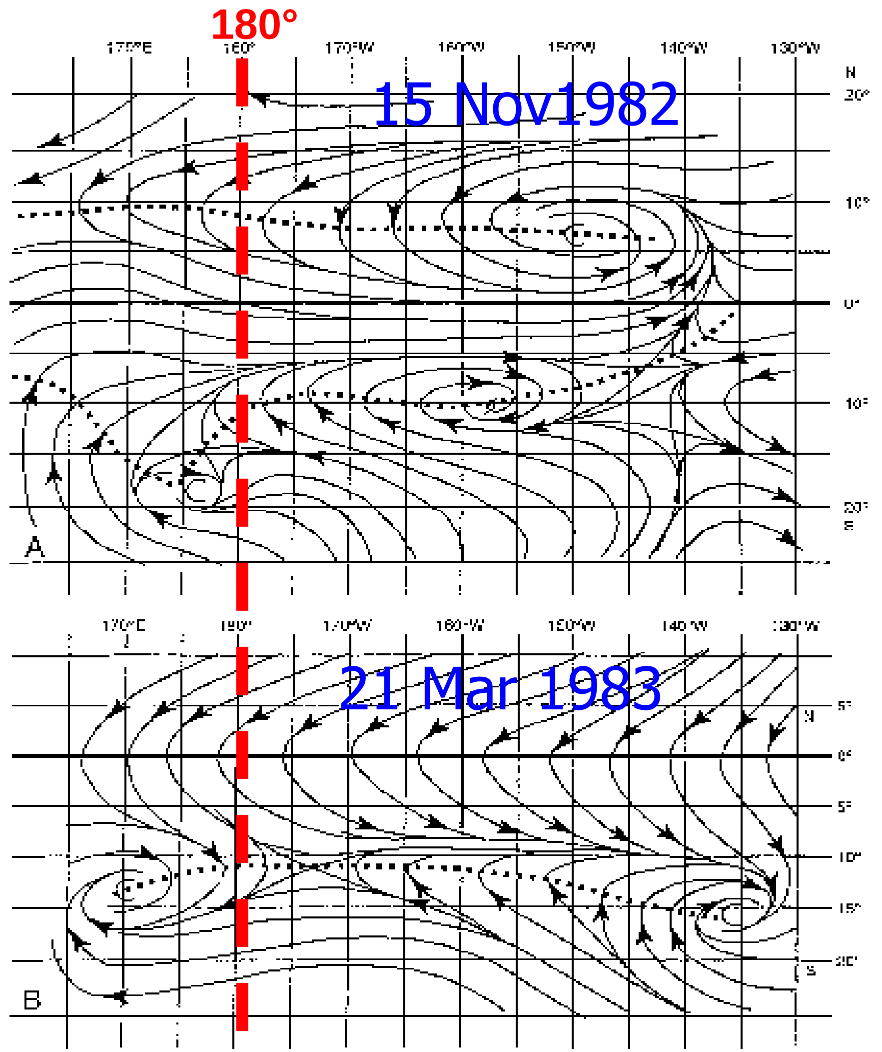


During El Niño years, the median location of TC genesis points is about 20° eastward from the climatological mean.

During La Niña years, TCs form more closer to Australia with a higher risk of landfall.

ENSO and Tropical Cyclones : **SW Pacific**

[Chu, 2004]

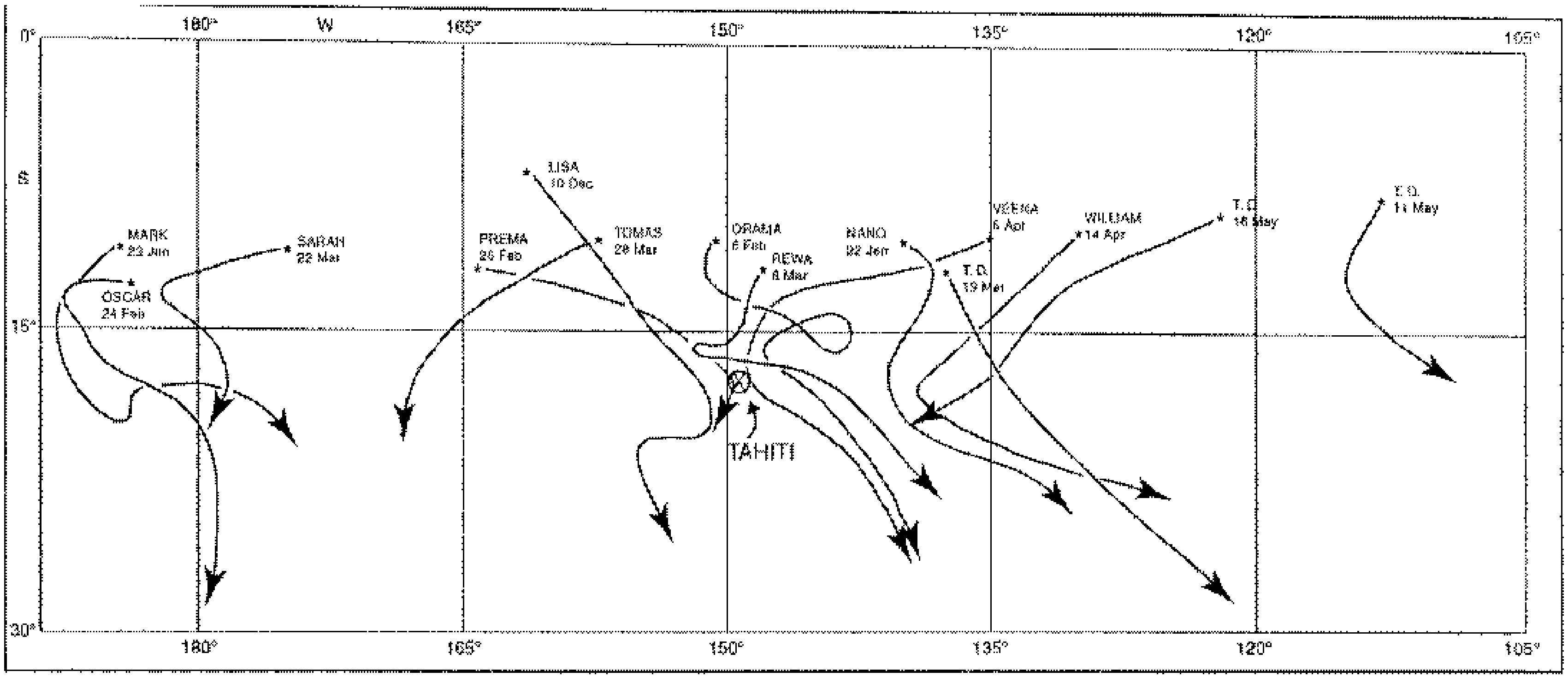


Surface streamline analyses for (A) November 15, 1982, and (B) March 21, 1983. The trough lines are indicated by dots. Note that in (A) the equatorial westerlies in the central Pacific are embedded between the double trough, one in each hemisphere, and that the tropical depression near Penryhn in the South Pacific (~158°W) is indicated. In (B), westerlies lie between the trough (dotted line) and the equator. Note the trough extends as far east as 135°W (adapted from Sadler, 1983, with permission).

During the very strong 1982-1983 El Niño, the South Pacific trough was almost 60° of longitude (≈6000 km) east of its mean climatological position.

ENSO and Tropical Cyclones : **SW Pacific**

[Chu, 2004]

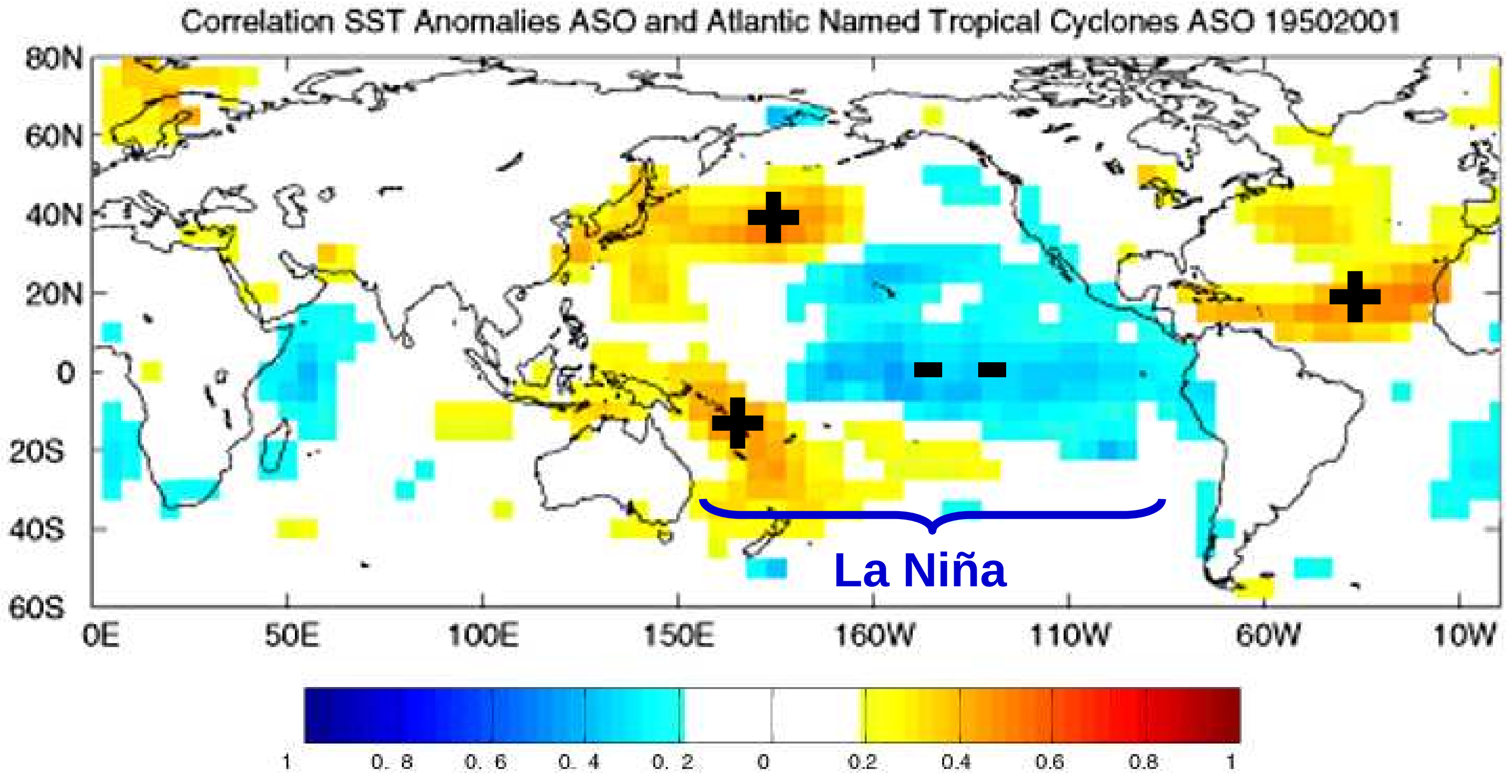


Tracks of southeastern Pacific tropical cyclones from December 1982 to May 1983. Asterisk indicates origin points of tropical depression (adapted from Sadler 1983, with permission).

During the very strong 1982-1983 El Niño, anomalous conditions caused TCs to occur in French Polynesia that is not generally regarded as a cyclone-prone area (due to strong vertical wind shear).

ENSO and Tropical Cyclones : **N Atlantic**

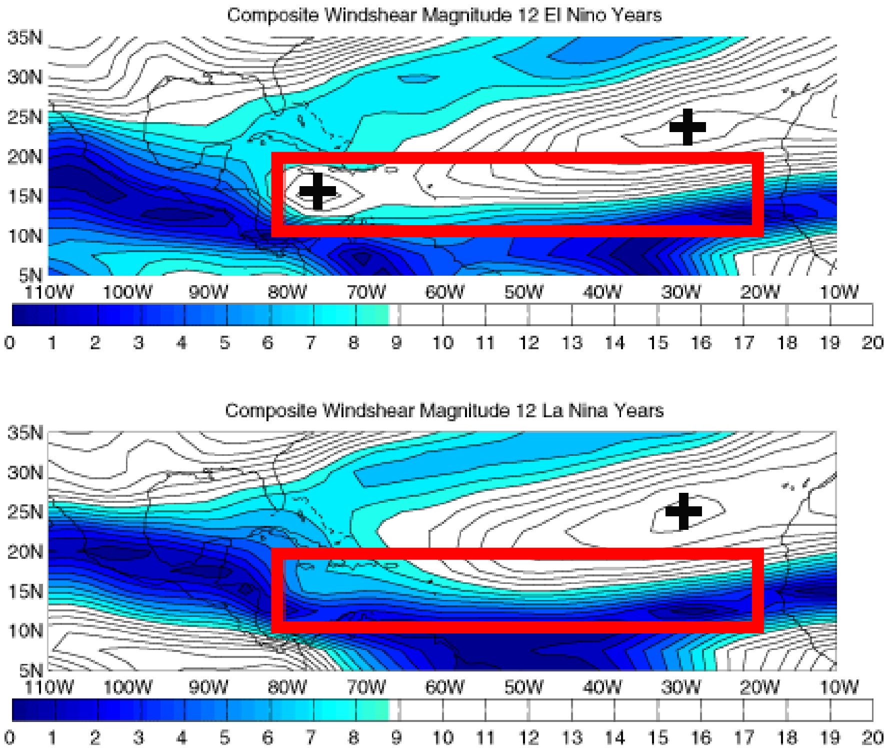
[Chu, 2004]

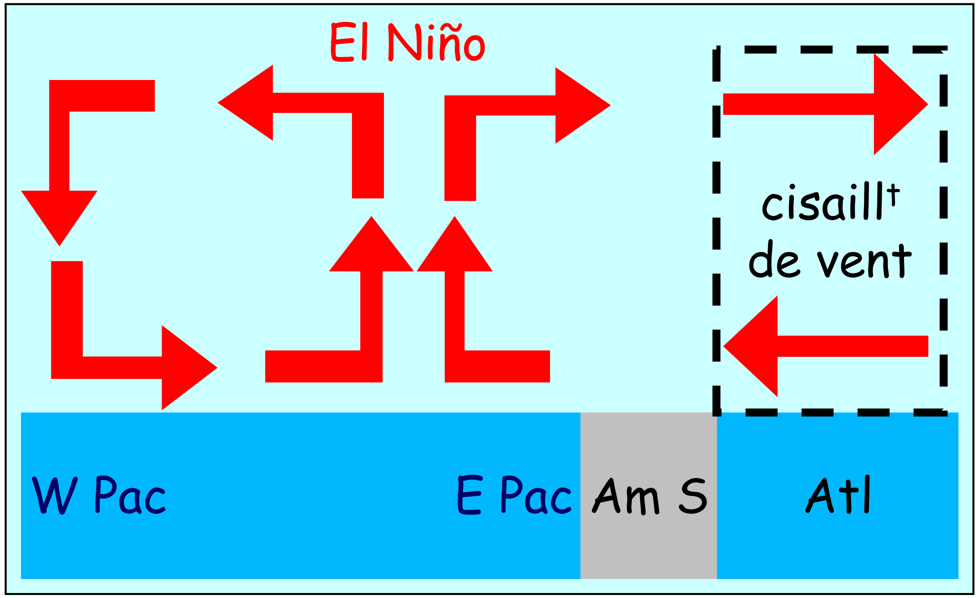


There are <u>more storms</u> in the north Atlantic during La Niña years than during El Niño years

ENSO and Tropical Cyclones : **N Atlantic**

[Chu, 2004]

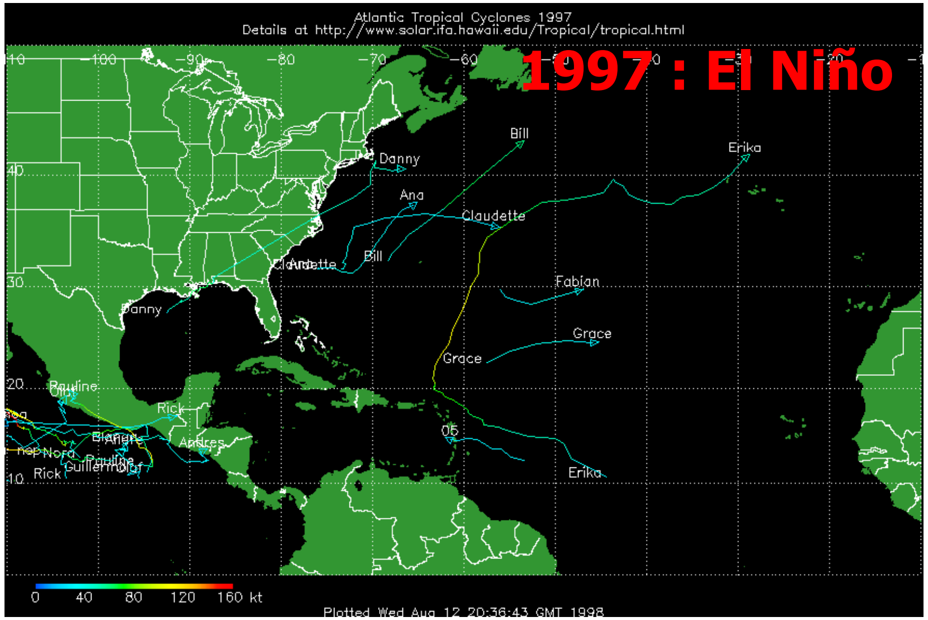




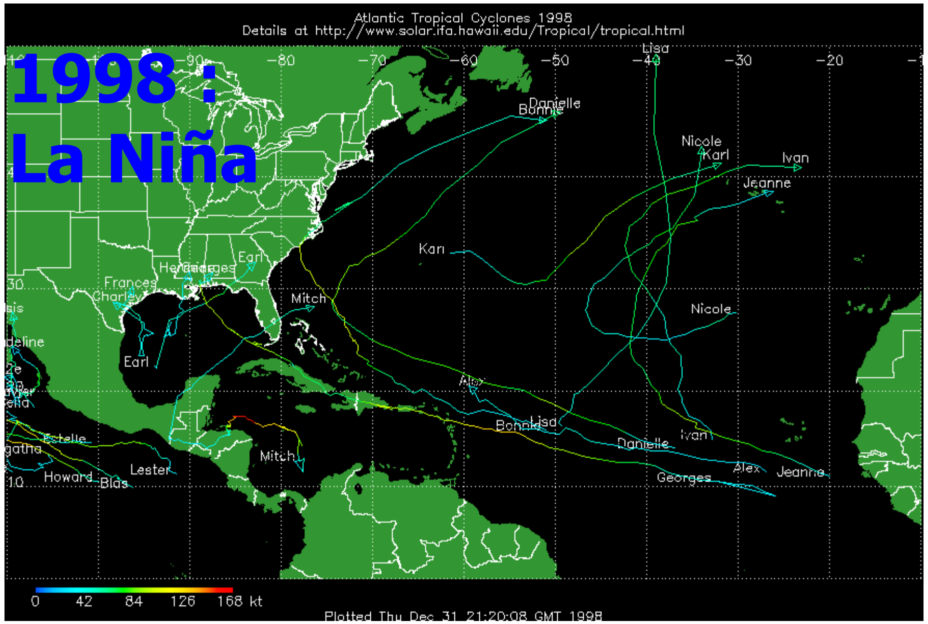
Changes in the vertical wind shear are the most important environmental factor in modulating the TC activity.

ENSO and Tropical Cyclones : N Atlantic

[Chu, 2004]



During "El Niño", the warm pool and tropical convection shift eastward to the NE Pacific. The enhanced upper-level divergent outflows from deep cumulus convection cause subsidence and upper-level westerly winds intensifying the vertical wind shear, over the Caribbean and tropical Altantic.



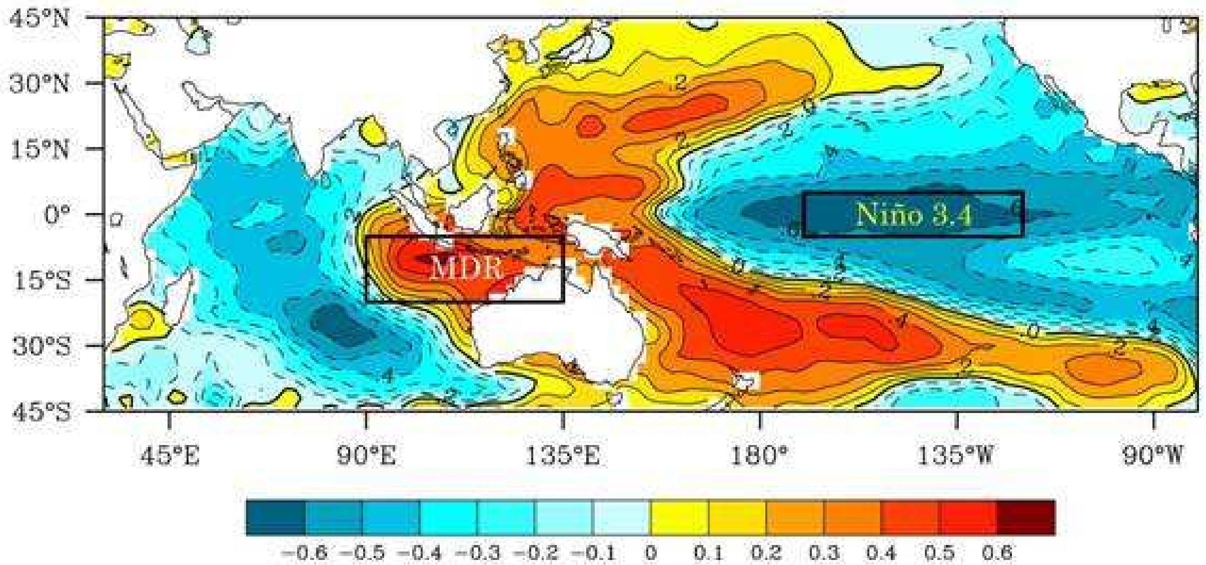
"La Niña" has a profound impact on hurricane number, intensity and landfall probability. There is a 20:1 ratio in median damage per year during the opposite phases (3 billion USD in La Niña vs. 150 million USD in El Niño.

ENSO and Tropical Cyclones : **S Indian**

[Chu, 2004]

Statistical analysis of the records for the last 40 years of tropical cyclones in the Indian Ocean indicates no obvious systematic, ENSO related variations of seasonal tropical cyclone frequency or location in the North and South Indian Oceans.

However, more careful studies of Indian Ocean cyclones are needed. It is likely that meaningful seasonal influences are present and may be elucidated in more detailed analyses.

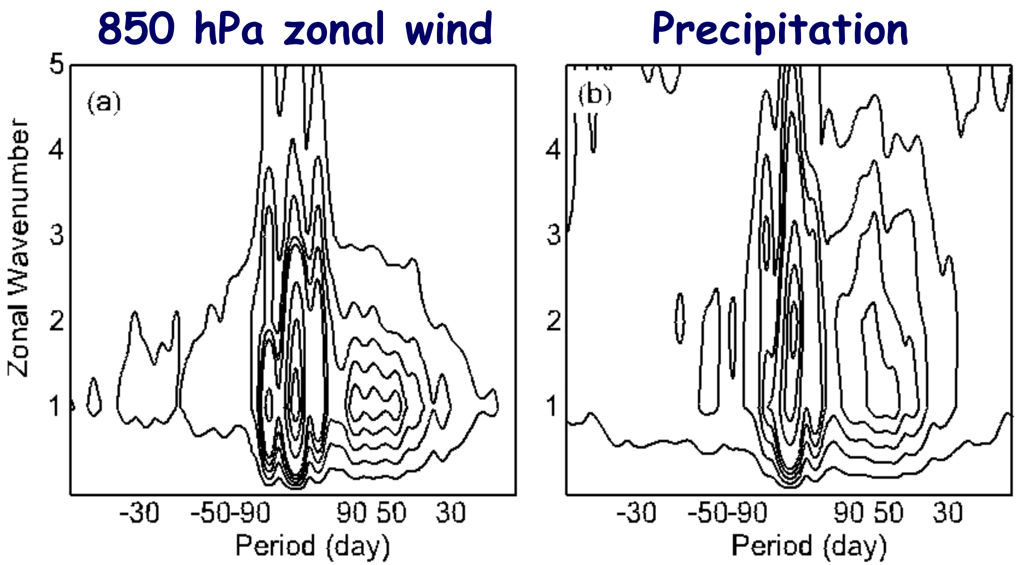


ENSO related SST anomaly (K)

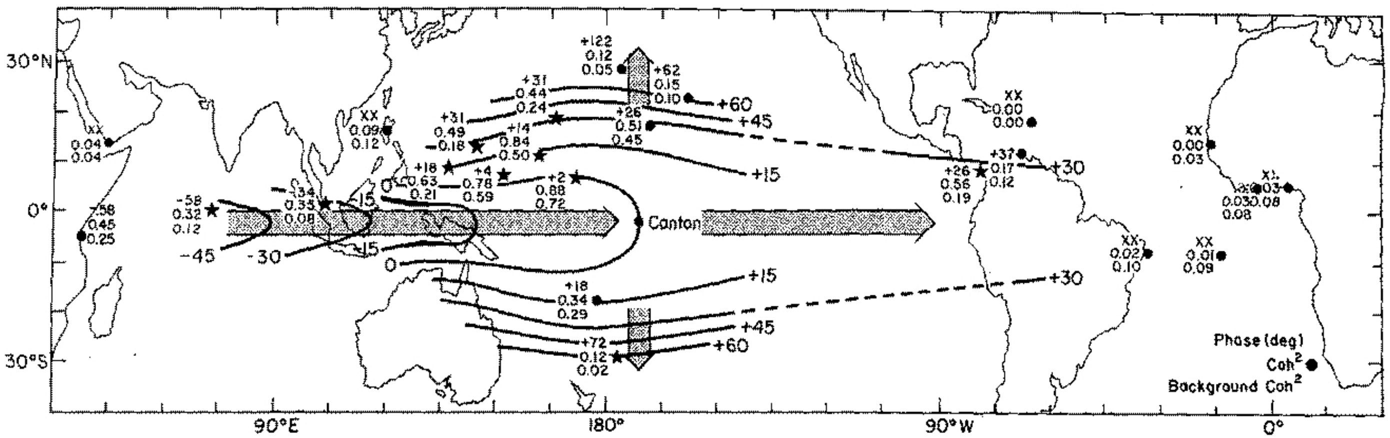
Cyclone Basin	El Niño Years		La Niña Years	
	Frequency	Intensity	Frequency	Intensity
N Atlantic	Large Decrease	Small Decrease	Small Increase	Small Increase
NE Pacific	Slight Increase	Increase	Slight Decrease	Decrease
NW Pacific E Part W Part	 Increase Decrease	 *No Change* *No Change*	 Decrease Increase	 *No Change* *No Change*
N Indian	*No Change*	*No Change*	*No Change*	*No Change*
S Indian	*No Change*	*No Change*	*No Change*	*No Change*
Austr. Region Western Central & East	 Slight Decrease Decrease	 *No Change* Slight Decrease	 Slight Increase Increase	 *No Change* Slight Increase
S & Central Pacific (>160ºE)	Increase	Increase	Decrease	Slight Decrease

Madden & Julian [1972 : JAS, 29, 1109-1123 + 1994 : MWR, 122, 814-837] ;
Zhang, 2005 [Rev. Geophys., 43, 1-36]

Madden-Julian Oscillation (MJO)

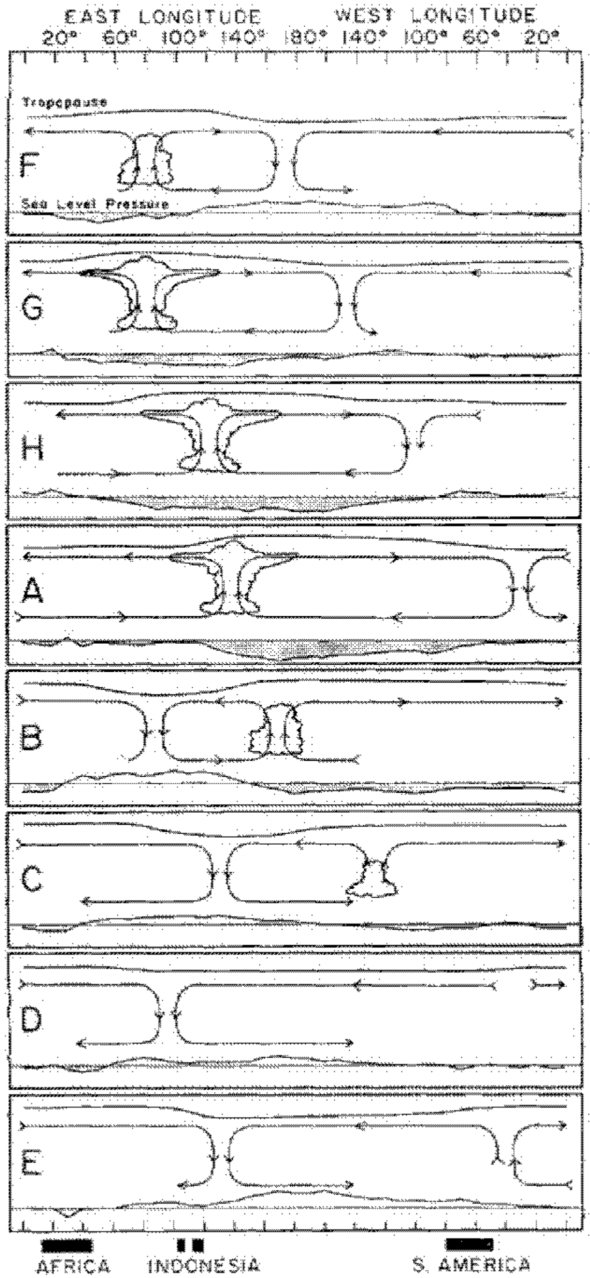


Time-space power spectra of (a) 850 hPa zonal wind (NCEP/NCAR reanalysis) and (b) precipitation [*Xie and Arkin*, 1997] for 1979 through 1998, averaged over 20°N–20°S and 60°–180°E. Positive (negative) periods correspond to eastward (westward) propagating power. Data resolutions for the spectra are pentad in time and 10° in longitude.

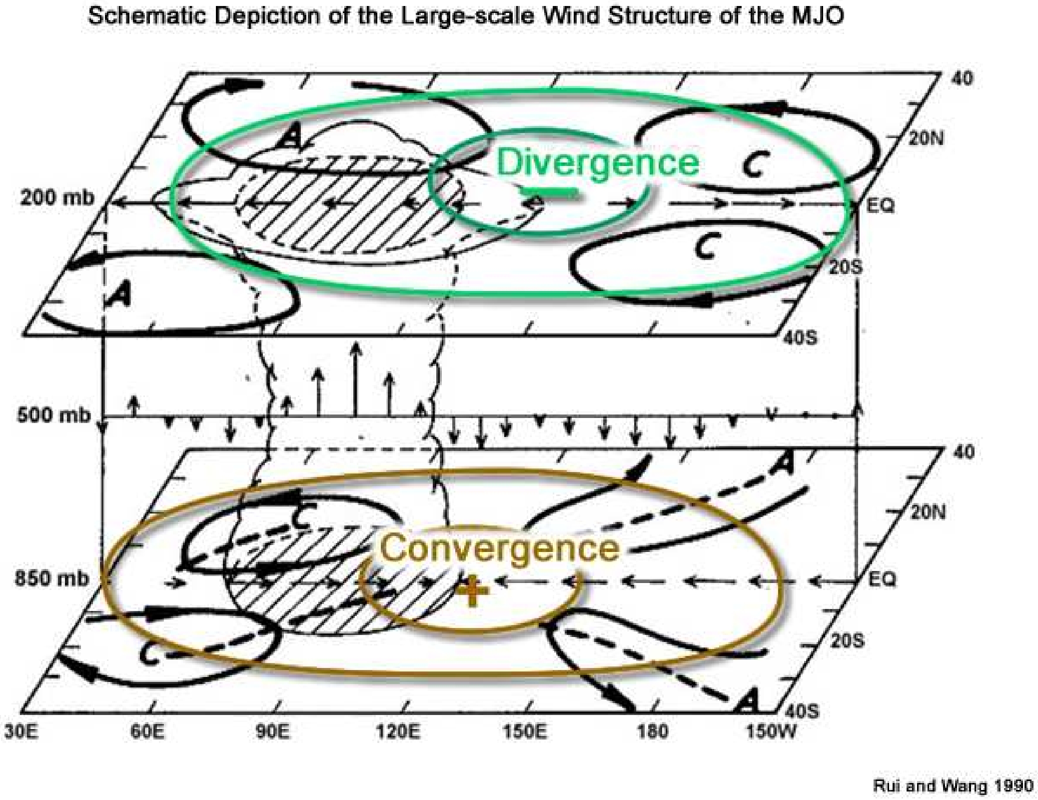


Mean phase angles (deg), coherence squares, and background coherence squares for approximately the 36–50-day period range of cross spectra between surface pressures at all stations and those at Canton. The plotting model is given in the lower right-hand corner. Positive phase angle means Canton time series leads. Stars indicate stations where coherence squares exceed a smooth background at the 95% level. Mean coherence squares at Shemya (52.8°N, 174.1°E) and Campbell Island (52.6°S, 169.2°E) (not shown) are 0.08 and 0.02, respectively. Both are below their average background coherence squares. Values at Dar es Salaam (0.8°S, 39.3°E) are from a cross spectrum with Nauru. The arrows indicate propagation direction (adapted from Madden and Julian 1972).

MJO *[Madden & Julian 1972+1994 ; Zhang 2005]*

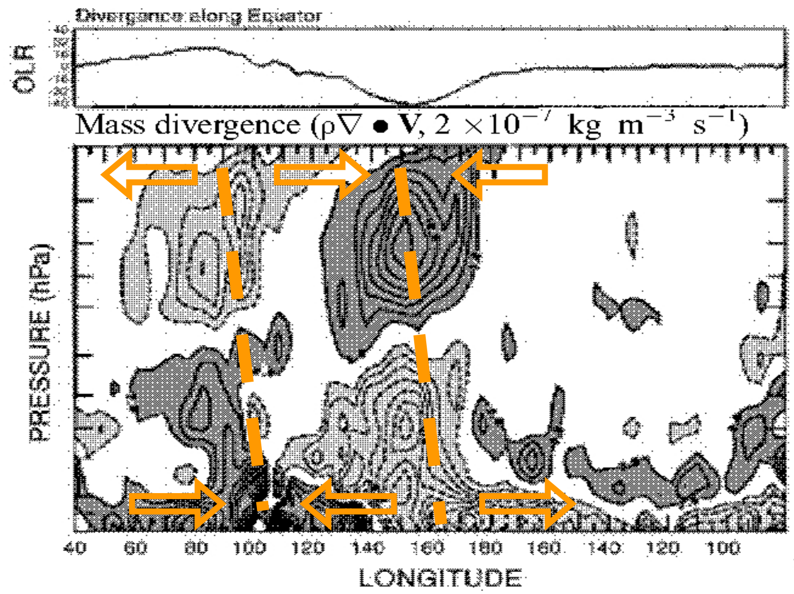


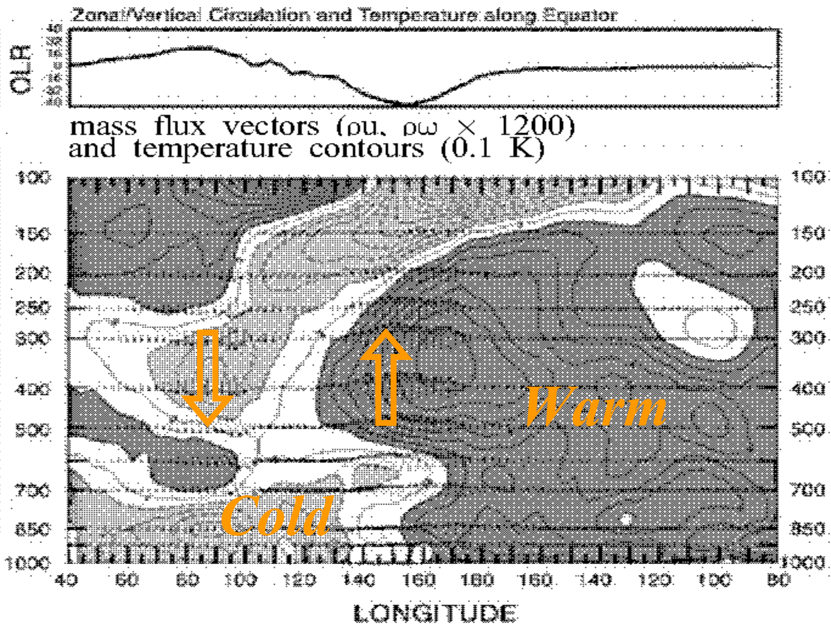
Longitude-height schematic diagram along the equator illustrating the fundamental large-scale features of the Madden-Julian Oscillation (MJO) through its life cycle (from top to bottom). Cloud symbols represent the convective center, arrows indicate the zonal circulation, and curves above and below the circulation represent perturbations in the upper tropospheric and sea level pressure.

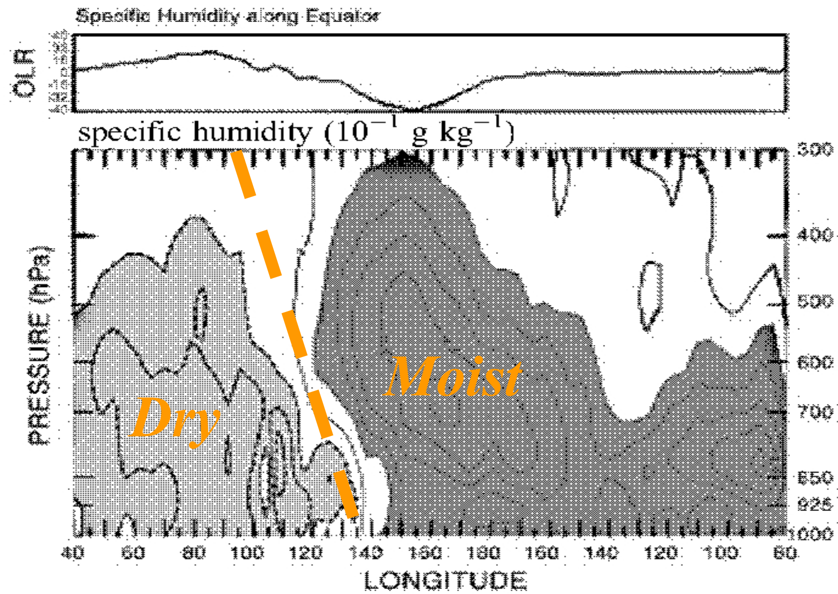


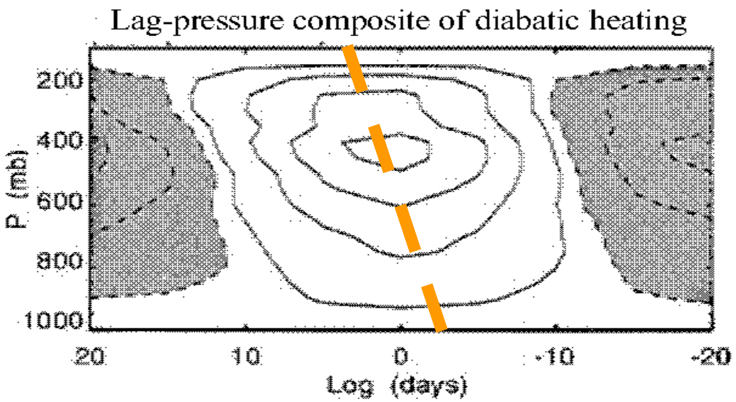
Schematic depiction of the large-scale wind structure of the MJO. The cloud symbol indicates the convective center. Arrows represent anomalous winds at 850 and 200 hPa and the vertical motions at 500 hPa. "A" and "C" mark the anticyclonic and cyclonic circulation centers, respectively. Dashed lines mark troughs and ridges. From *Rui and Wang* [1990].

MJO *[Madden & Julian 1972+1994 ; Zhang 2005]*

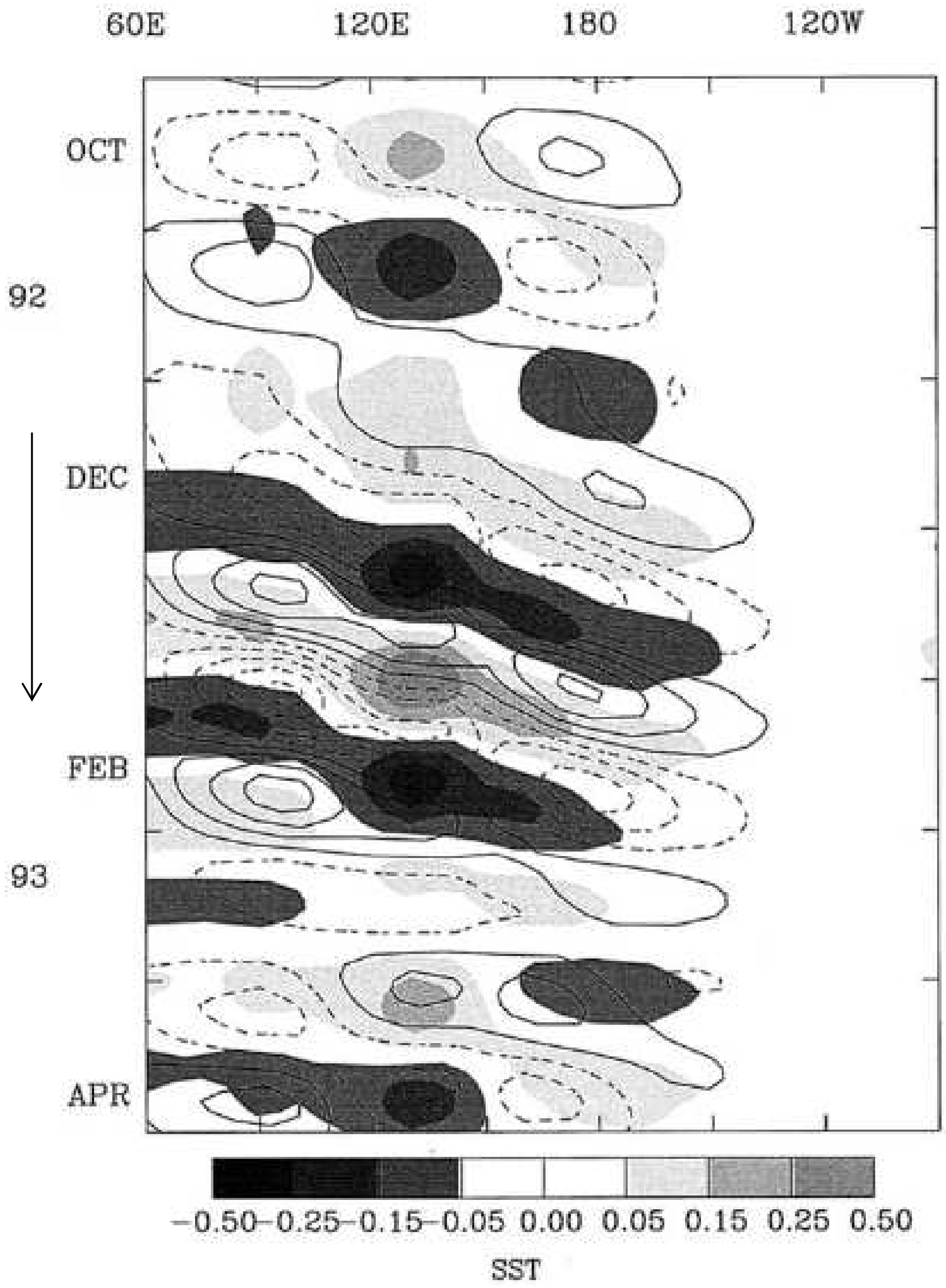








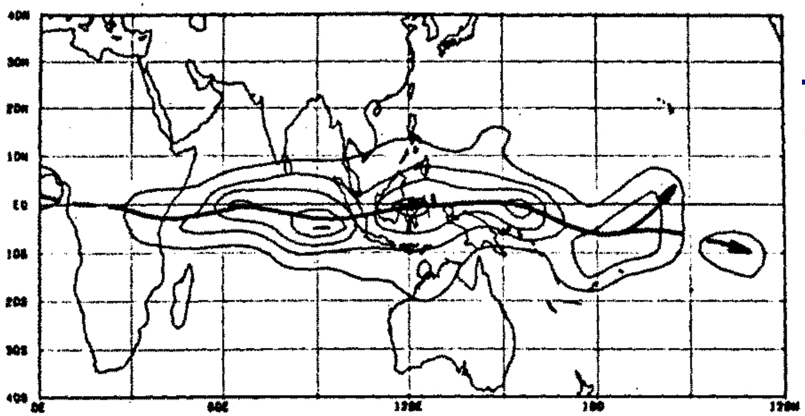
MJO *[Madden & Julian 1972+1994 ; Zhang 2005]*



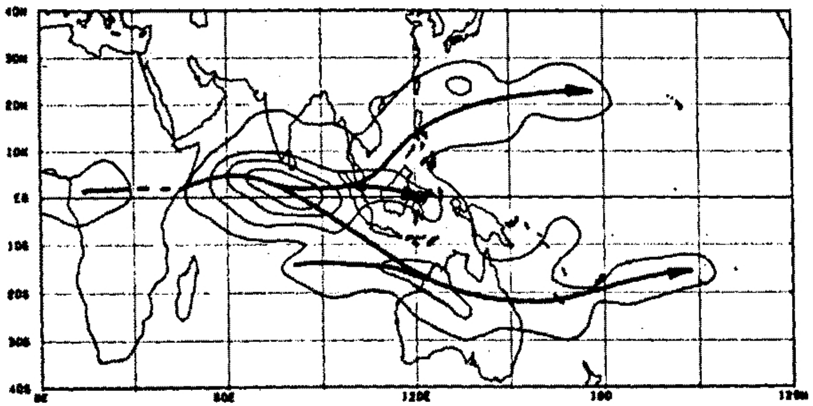
As a consequence of surface cooling in the convective centers of the MJO and warming outside, fluctuations in SST propagate eastward in tandem with the MJO, with the maximum SST and thermocline depth leading the convective centers.

Time-longitude diagram of anomalies in OLR (contours with interval of 10 W m^{-2}) and SST (shaded, °C) associated with MJO along 5°S for 1 October 1992 to 15 April 1993.
[from Hendon and Glick, 1997]

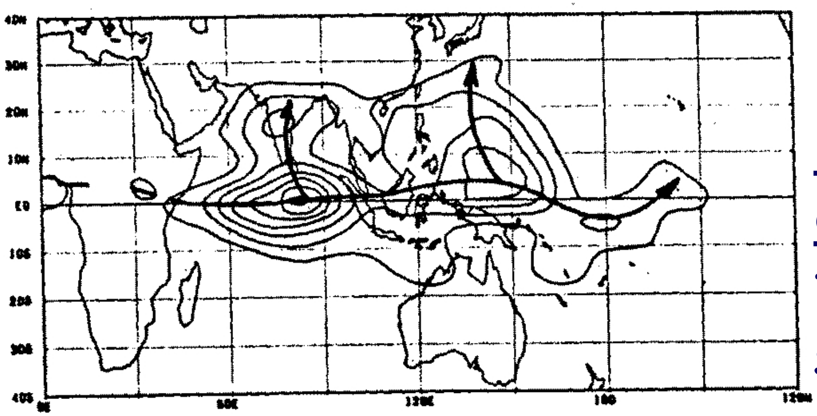
MJO *[Madden & Julian 1972+1994 ; Zhang 2005]*



Strickly eastward-moving cloud complexes



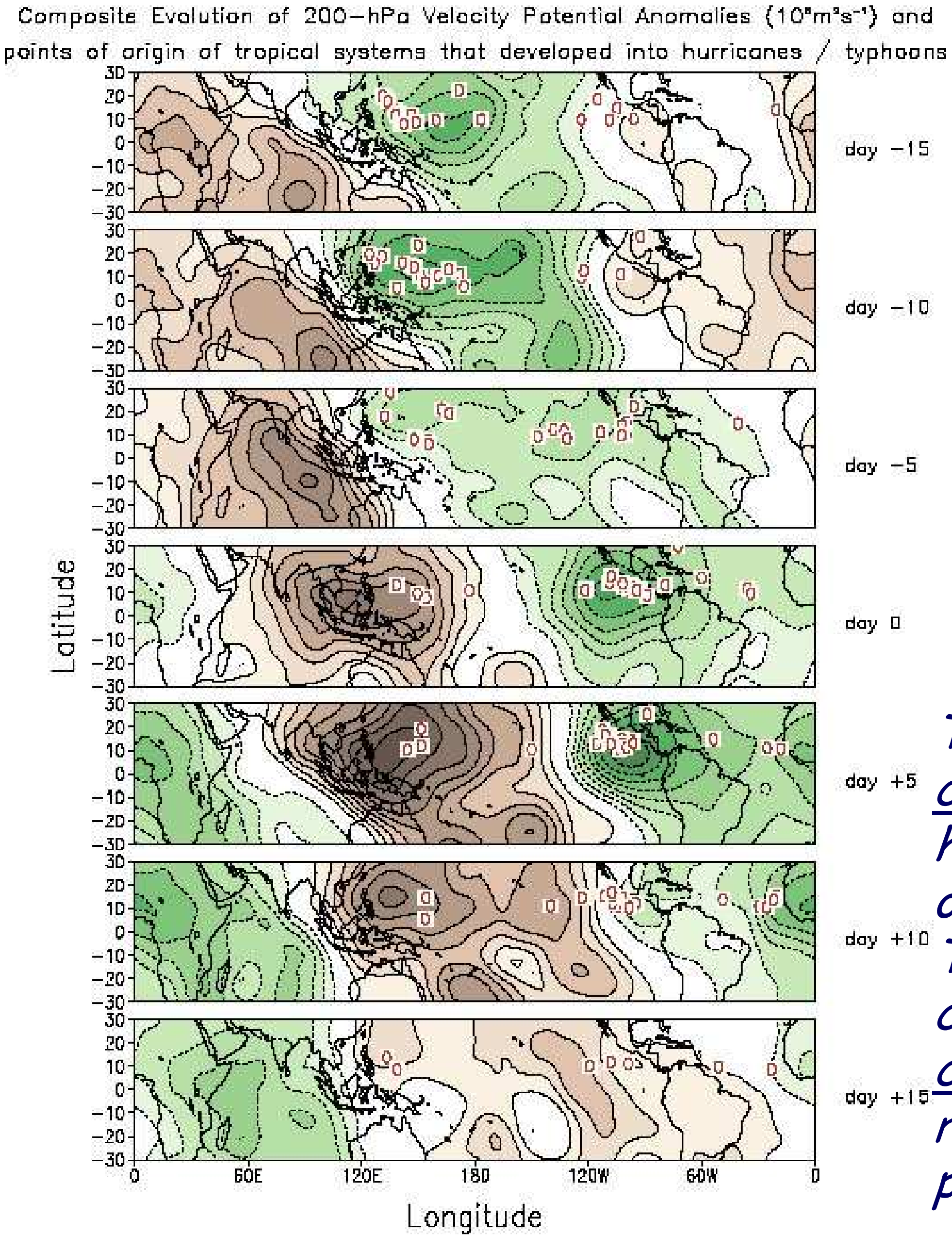
Eastward complexes that split either to the north over to the south over the Indian ocean



Eastward complexes that are connected with cloud systems that move northward into southern Asia

MJO and Tropical Cyclones

Higgins & Shi, 2001
[J. Climate, 14, 403-417]

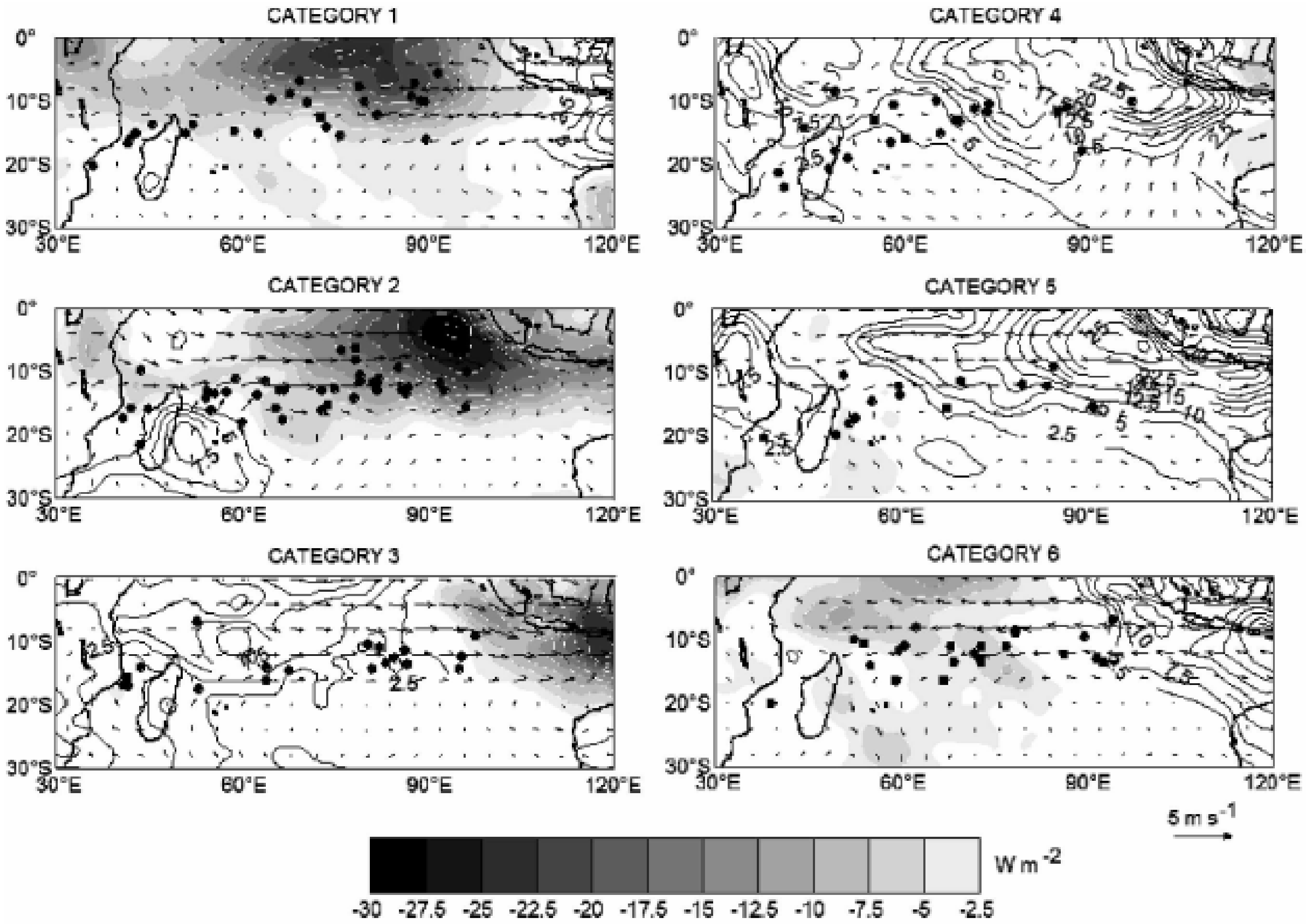


The MJO produce a strong modulation of TC activity, in relation with associated variations in low- and upper-level winds, vertical wind shear, atmospheric humidity and temperature, organized convection, SST, …

The points of origin of tropical cyclones that developed into hurricanes / typhoons ar shown as open circles.
The green (brown) shading roughly corresponds to regions where convection is favored (suppressed) as represented by 200-hPa velocity potential anomalies.

MJO and Tropical Cyclones : **SW Indian**

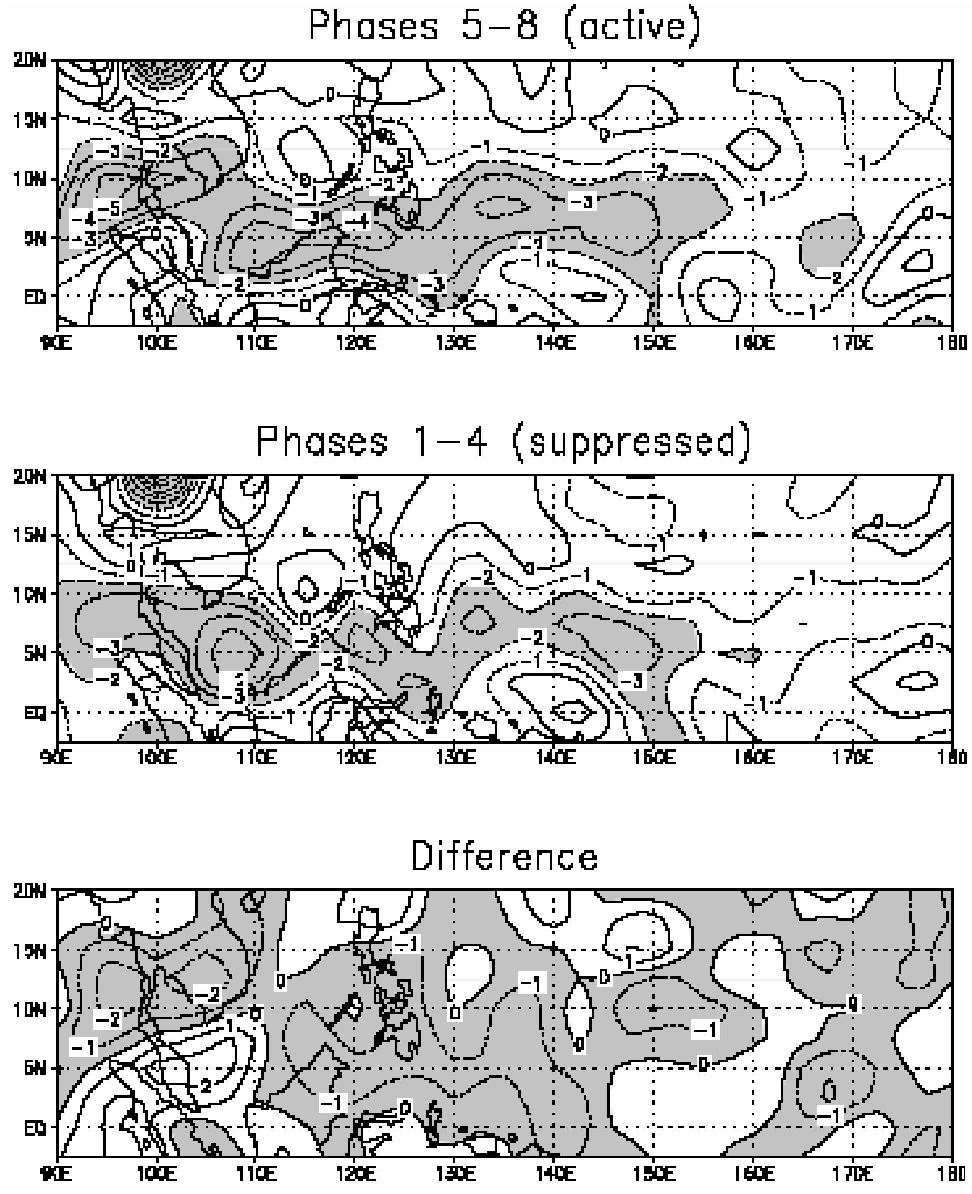
*[**Bessafi & Wheeler, 2006** : Mon. Wea. Rev., 134, 638-656]*



Composite 850-hPa wind anomalies (vectors) and unfiltered OLR anomalies (<0 : shading, >0 : contours) for **each category of MJO**. Dots represent the TC genesis location for each category

MJO and Tropical Cyclones : **NW Pacific**

*[**Sobel & Maloney, 2000** : Geophys. Res. Lett., 27, 1739-1742]*



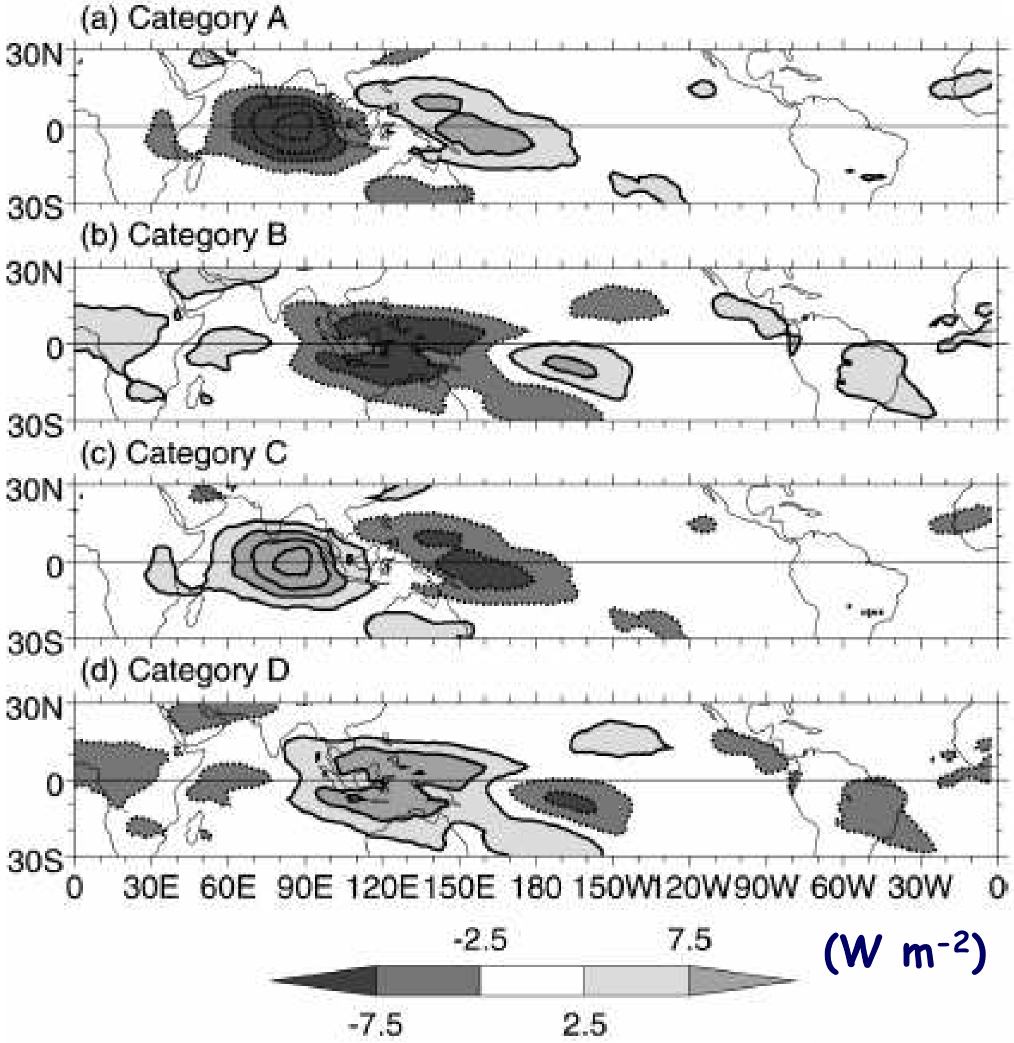
Convergence is larger in the active MJO phase than during the suppressed phase by an amount of order 1 x 10^{-6} s^{-1}. The tongue of large convergence also shifts slightly northward in the active phase.

NW Pacific tropical cyclones are more frequent during the active phase, because of the existence of a larger number of precursor depressions rather than because of any invrease in the percentage which undergo cyclogenesis.

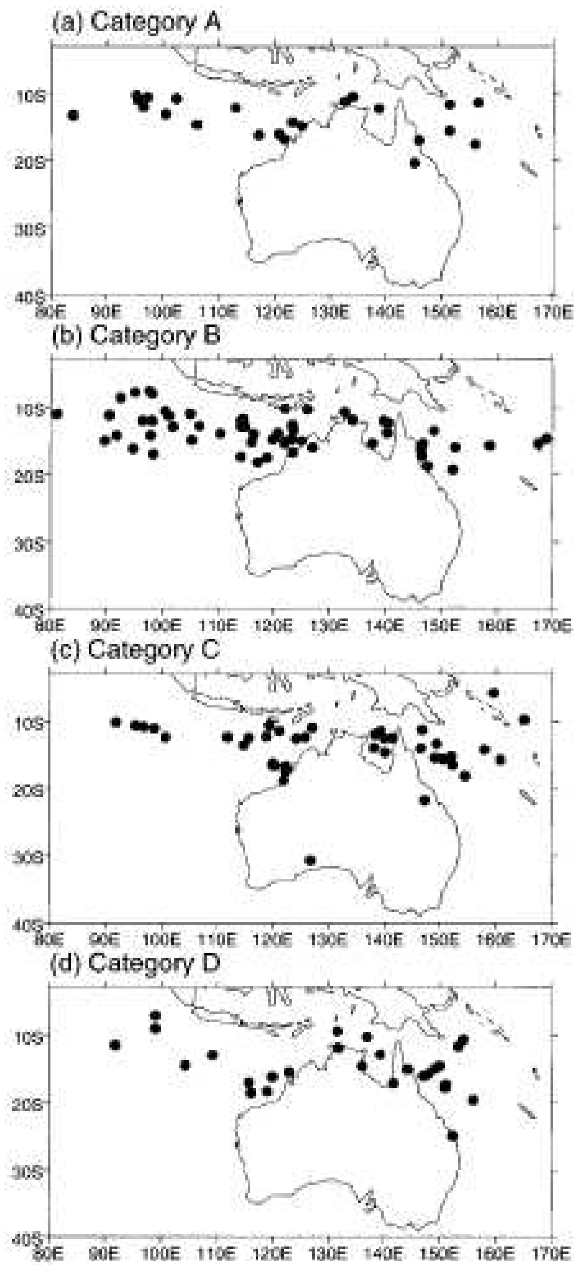
Group velocity divergence at 850 hPa composited over the active (top) and suppressed (middle) phase of the MJO, in units of 10^{-6} s^{-1}.

MJO and Tropical Cyclones :
SW Pacific

*[**Hall et al., 2001** : Mon. Wea. Rev., <u>129</u>, 2970–2982]*



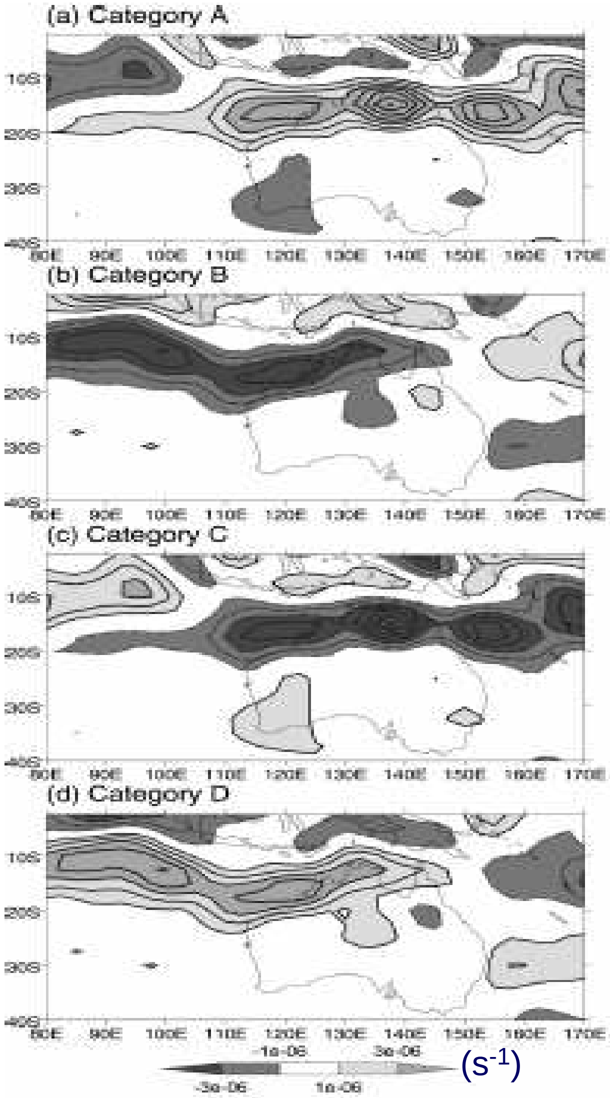
Anomaly maps of OLR for MJO category



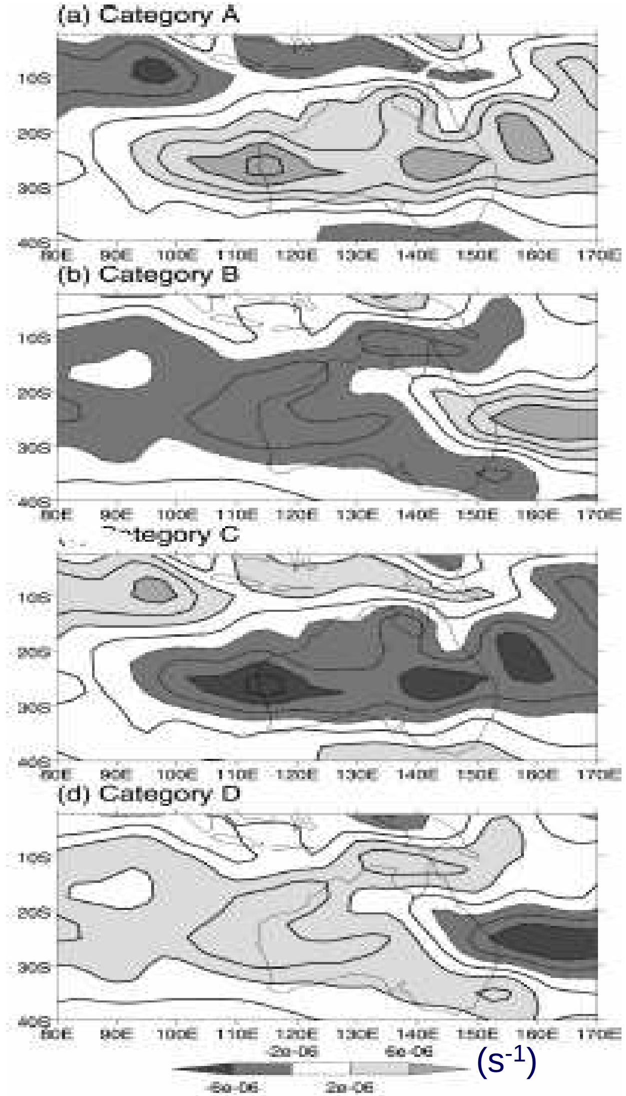
TC genesis locations for MJO category

MJO and Tropical Cyclones : **SW Pacific**

[Hall et al., 2001]



Anomaly maps of 850-hPa vorticity for MJO category



Anomaly maps of $(\xi_{850} - \xi_{200})$ for MJO category

MJO and Tropical Cyclones : **NE Pacific**

*[**Maloney & Hartmann, 2000** : Science , 287 , 2002-2004]*

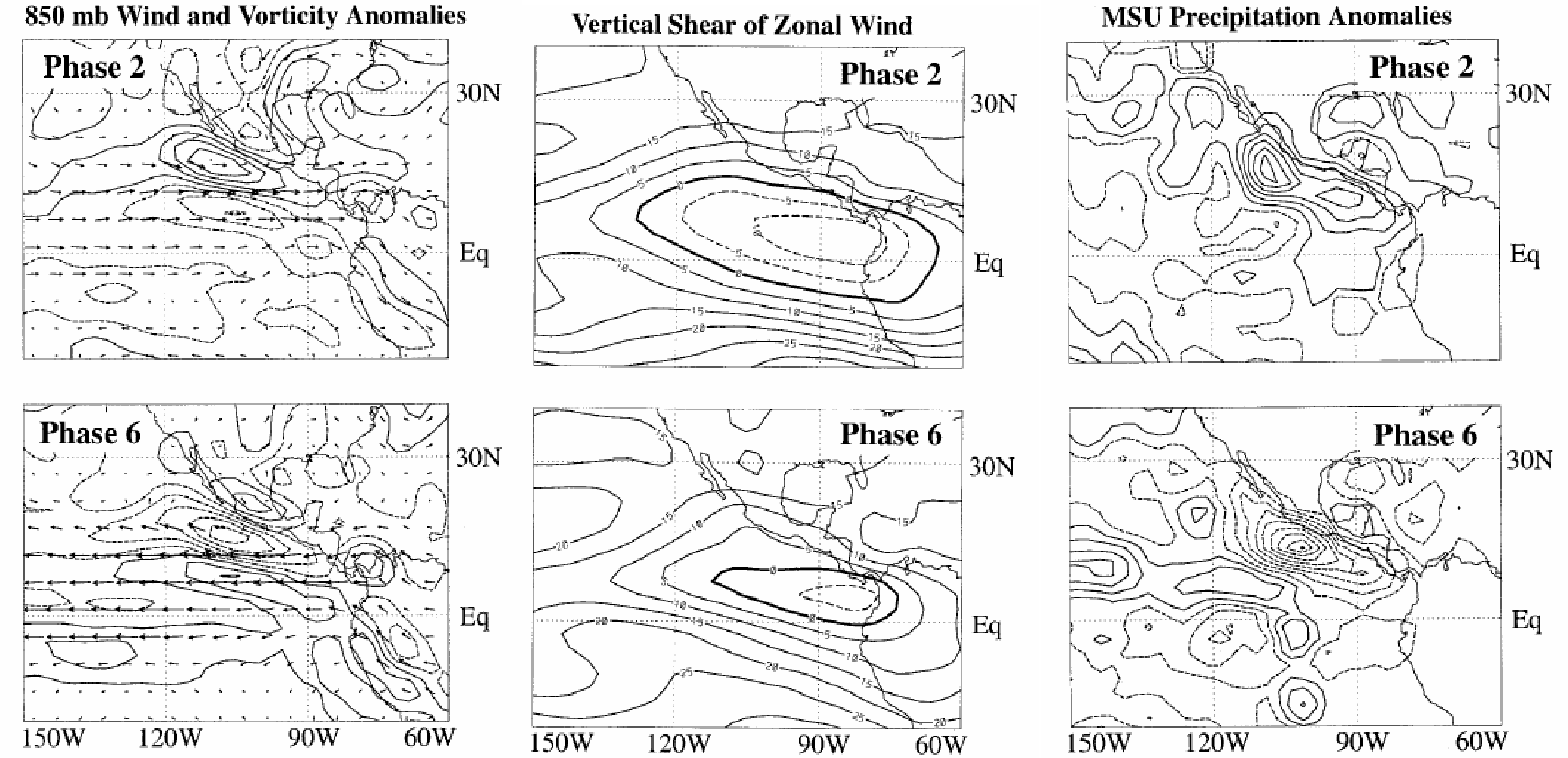


FIG. 5. The 850-mb bandpassed wind anomalies and 850-mb re ative vorticity anomalies during May–Nov 1979–95 for phases 2 an 6. Maximum vectors are 3.0 m s^{-1}. Contours are every 1.2 × 10 s^{-1} starting at 0.6 × 10^{-6} s^{-1}. Negative contours are dashed.

FIG. 9. The 200-mb zonal wind minus 850-mb zonal wind during May–Nov 1979–95 for phases 2 and 6. Values are not anomalies but total shear values. Contours are every 5.0 m s^{-1} starting at 0.0 m s^{-1}. Negative contours are dashed. Positive values mean that 200-mb winds are more westerly than 850-mb winds.

FIG. 6. MSU precipitation anomalies during May–Nov 1979–95 for phases 2 and 6. Contours are every 0.6 mm day^{-1} starting at 0.3 mm day^{-1}. Negative contours are dashed. No smoothing is used. The precipitation product is valid only over ocean areas.

The MJO composites show more favorable low-level vorticity, vertical wind shear and convection for E Pacific hurricane development during 850-hPa equatorial westerly anomalies (Phase 2) than during easterly anomalies (Phase 6).

MJO and Tropical Cyclones : **NE Pacific**

[Maloney & Hartmann, 2000]

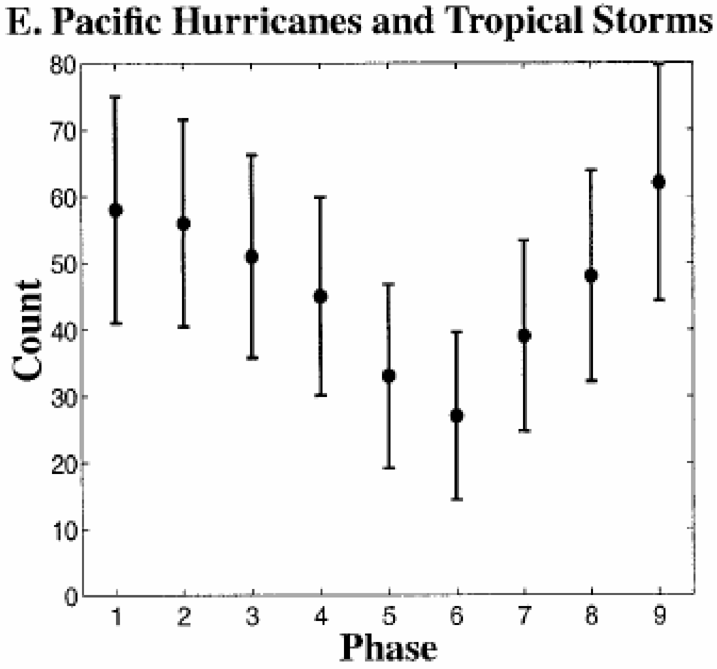


FIG. 10. Number of hurricanes and tropical storms as a function of MJO phase for the eastern Pacific Ocean hurricane region during May–Nov 1979–95. Error bars represent 95% confidence limits.

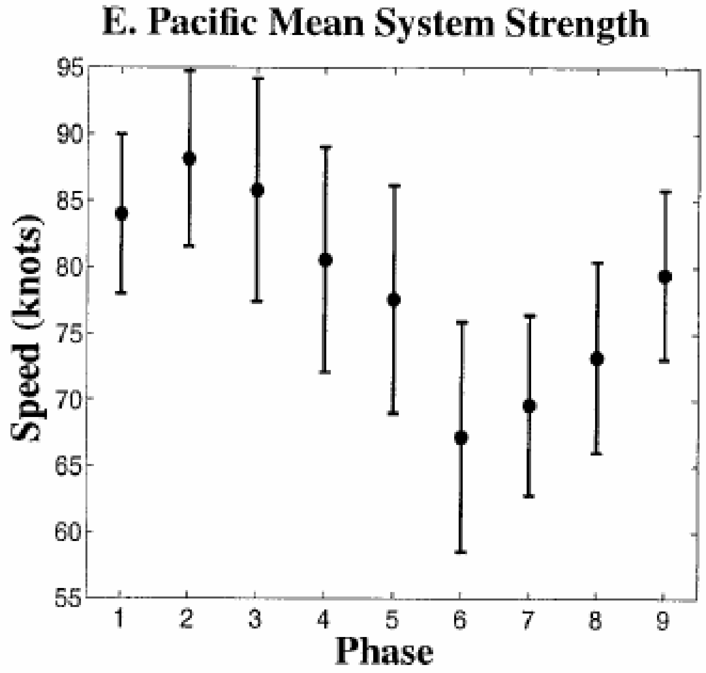


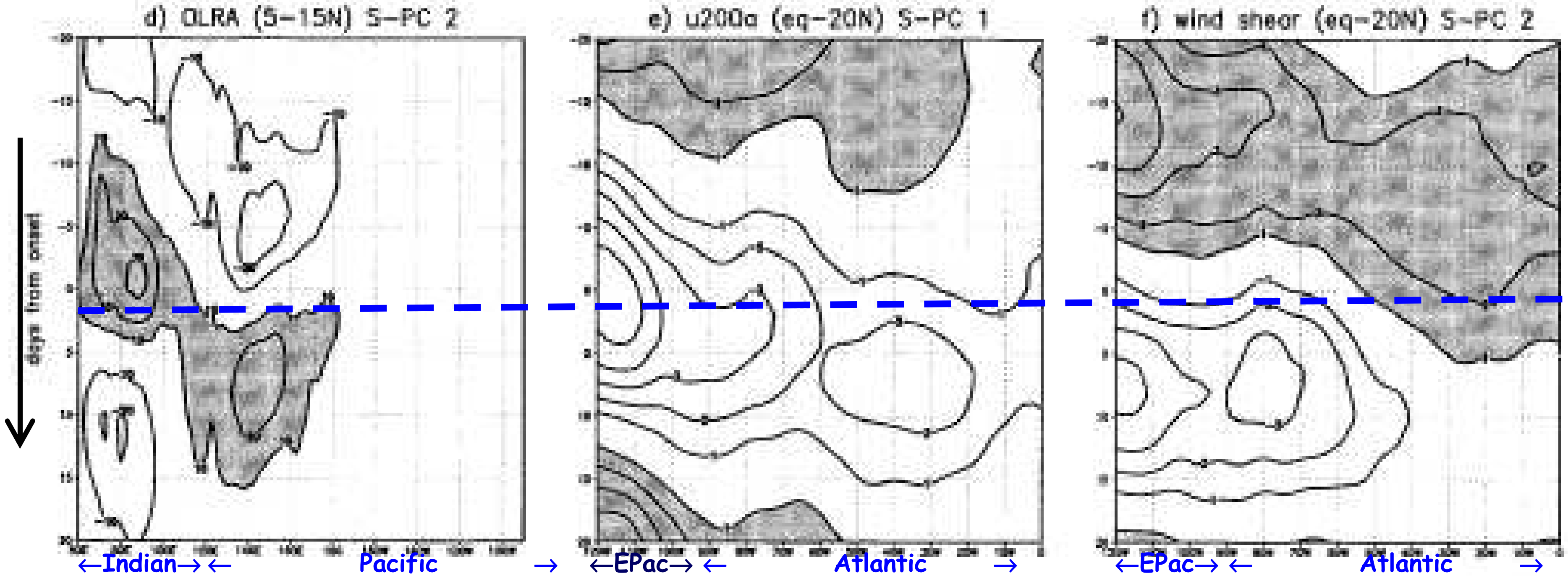
FIG. 11. Average strength (kt) of hurricanes and tropical storms as a function of MJO phase for the eastern Pacific Ocean hurricane region during May–Nov 1979–95. Error bars represent 95% confidence limits.

Over twice the number of named tropical systems exist in both Phase 1 and Phase 2. An identical analysis using genesis events produces a similar result.

A pronounced cycle in system strength is also seen during the progression through the phases.

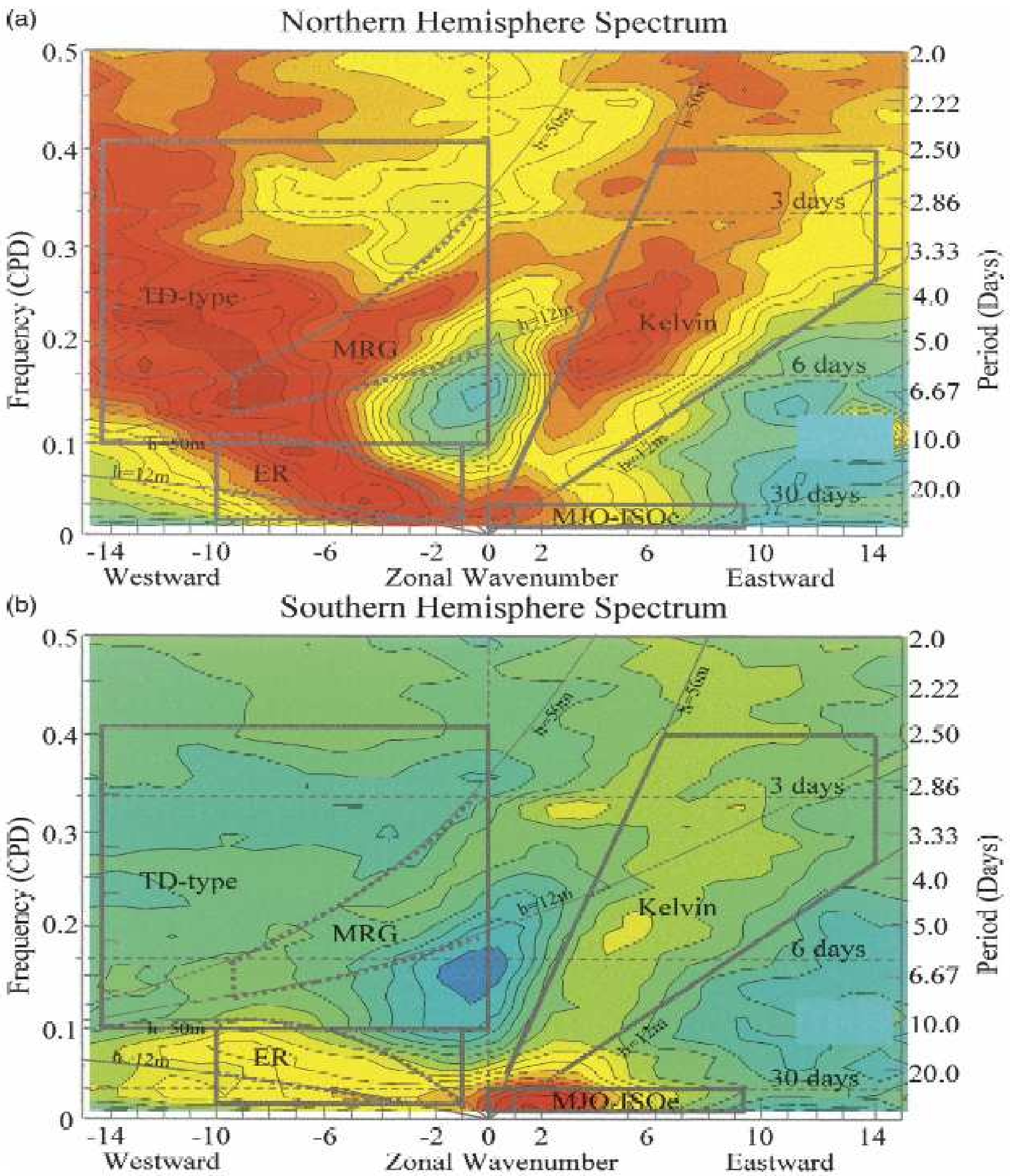
MJO and Tropical Cyclones : **N Atlantic**

*[**Mo, 2000** : Mon. Wea. Rev., 128, 4097-4107]*



Tropical storms in the Atlantic are more likely to occur when convection in the Indian Ocean is enhanced.

The response of the wind shear in the Main Development Region (5-15°N ; 30-120°W) is remotely forced by Tropical Intraseasonal Oscillations from the Pacific.

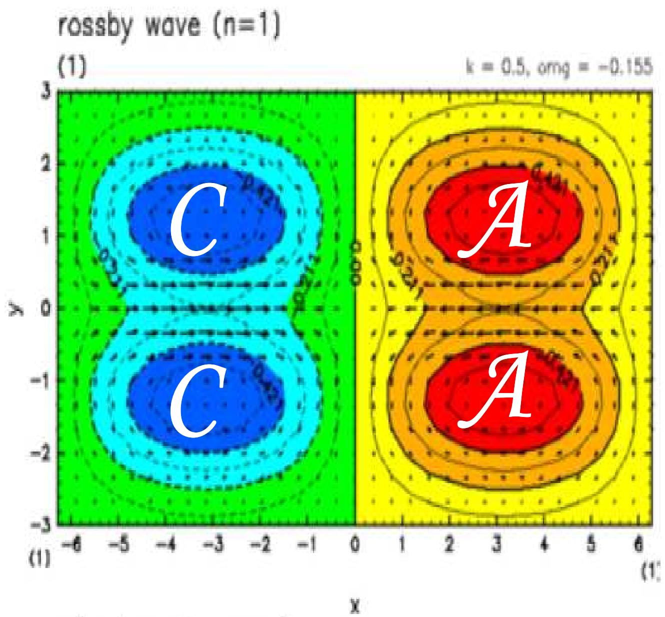


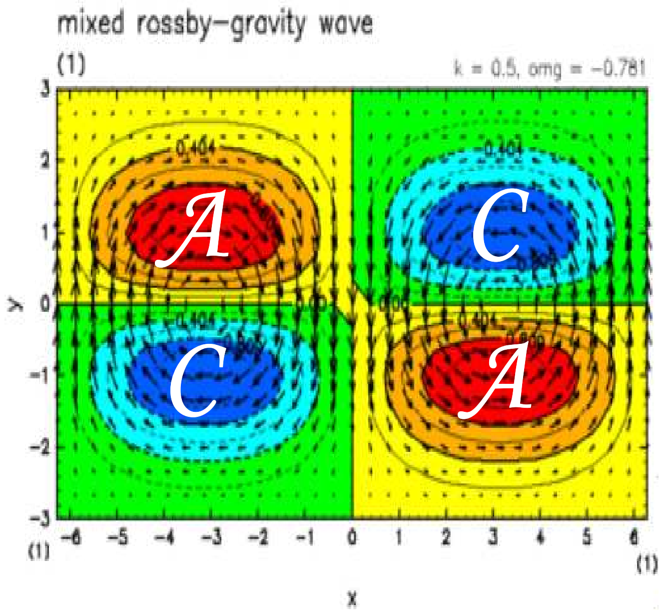
Frank & Roundy, 2006 :
Mon. Wea. Rev., 134, 2397-2417

The MJO is by far the most active wave type in the Southern Hemisphere. Higher-frequency tropical waves are all much more prominent in the Northern Hemisphere.

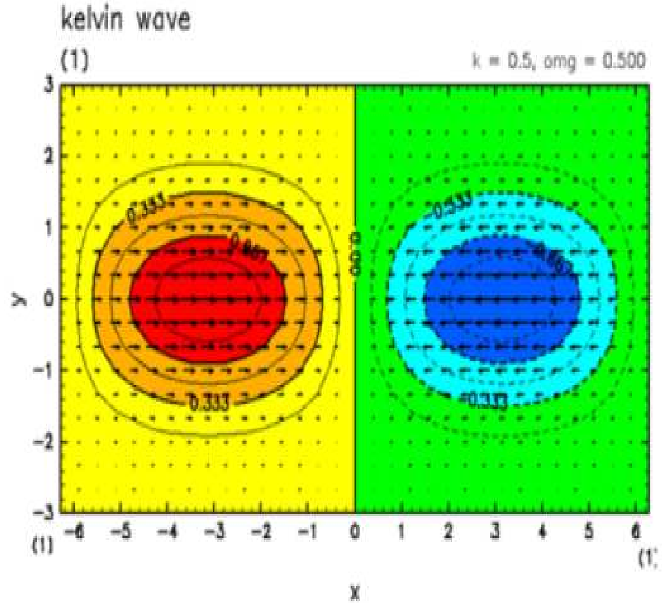
Tropical waves

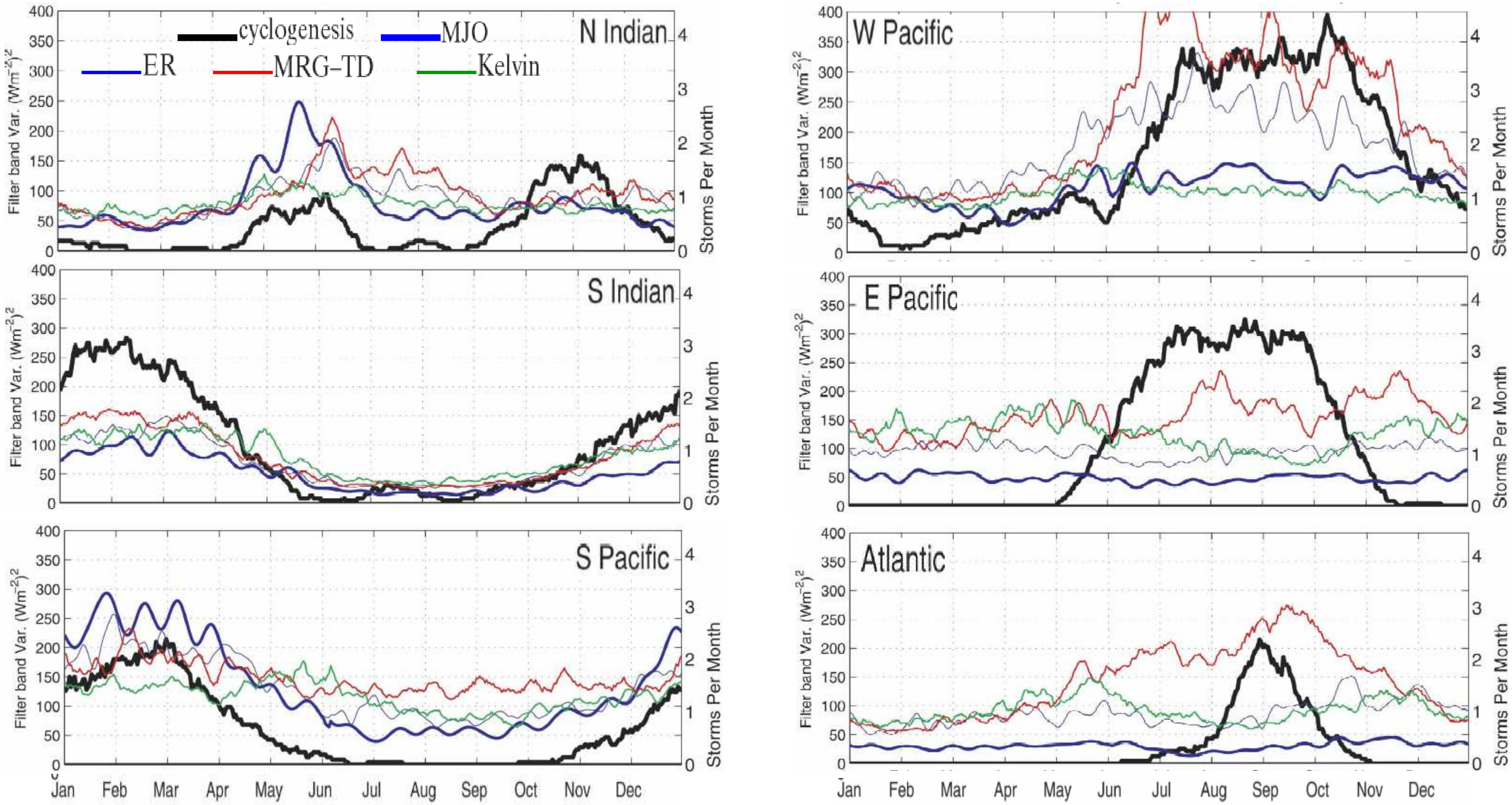
Westward





Eastward



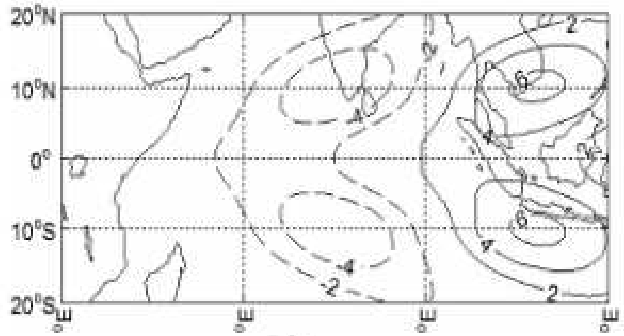


Comparing Figs. 2 and 4 it is clear that the low-frequency MJO band and ER band variances that dominate the Southern Hemisphere spectrum are strongly seasonal, and they vary in phase with the cyclone season in the two Southern Ocean basins and for the first peak of the North Indian season. Activity in the Kelvin band tends to follow the same pattern, though the cycles are somewhat less distinct than for the MJO and ER bands.

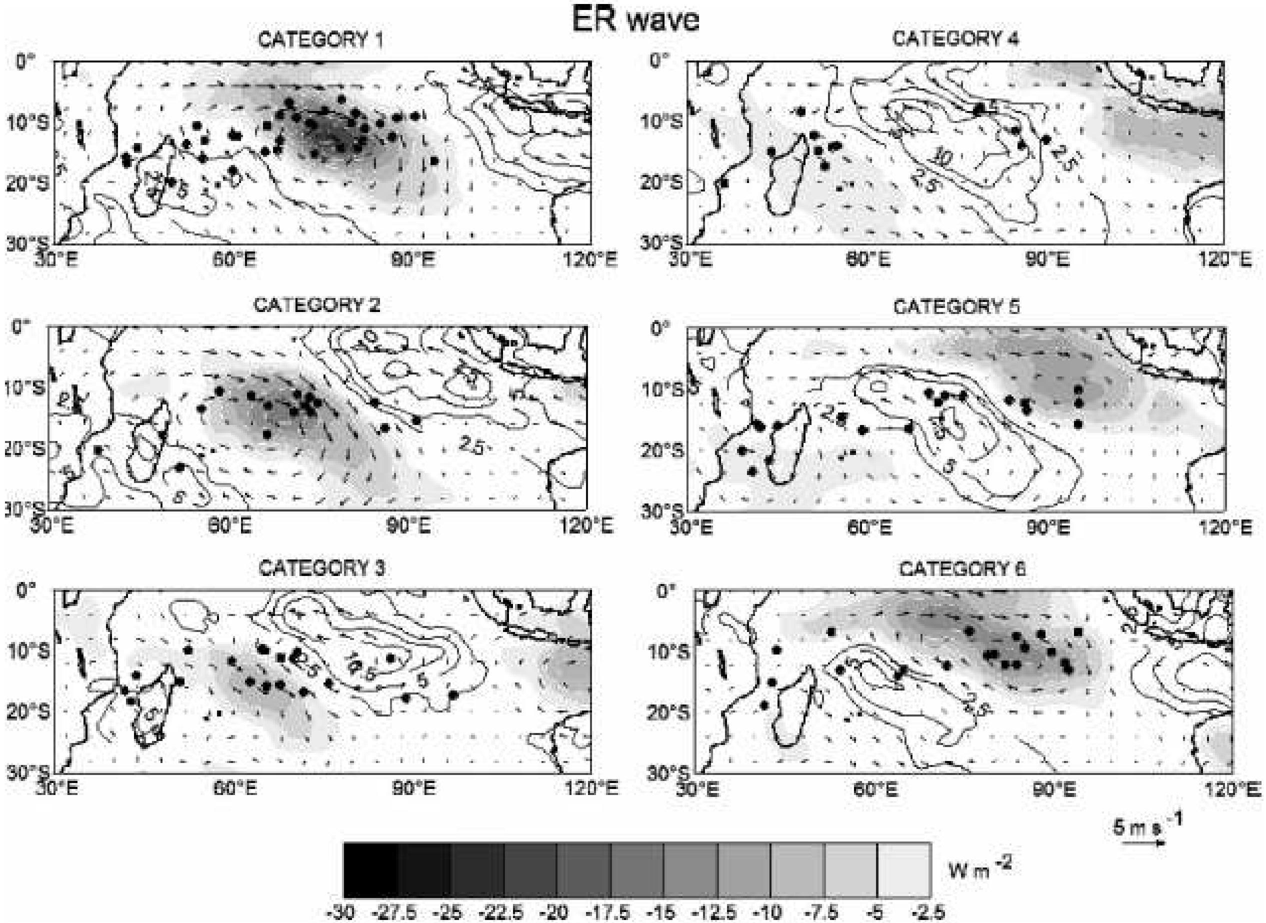
All of the wave types (except the MJO) are more active in the Northern than in the Southern Hemisphere. This is particularly true for the MRG–TD-type band, which varies strongly and in phase with the cyclone season in the North Atlantic and the northwest Pacific.

ISO and Tropical Cyclones : **SW India**

[Bessafi & Wheeler, 2006]



First EOF of the **n=1 Equatorial Rossby wave-filtered** OLR in W m^{-2}

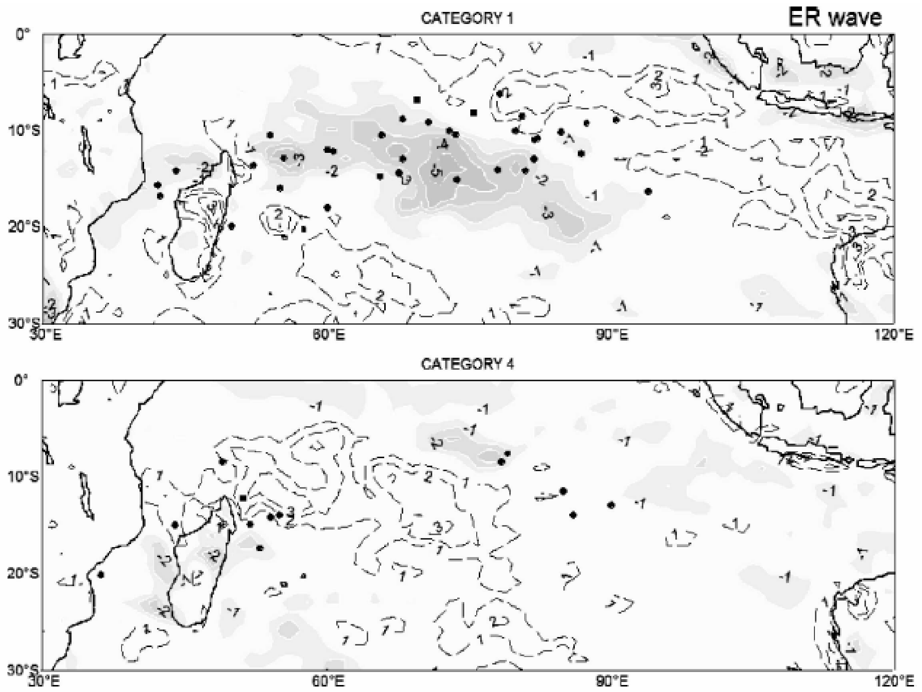


Composite 850-hPa wind (vectors) and unfiltered OLR anomalies (<0 : shading, >0 : contours) for **each category of the ER-wave**. Dots represent the TC genesis location for each category

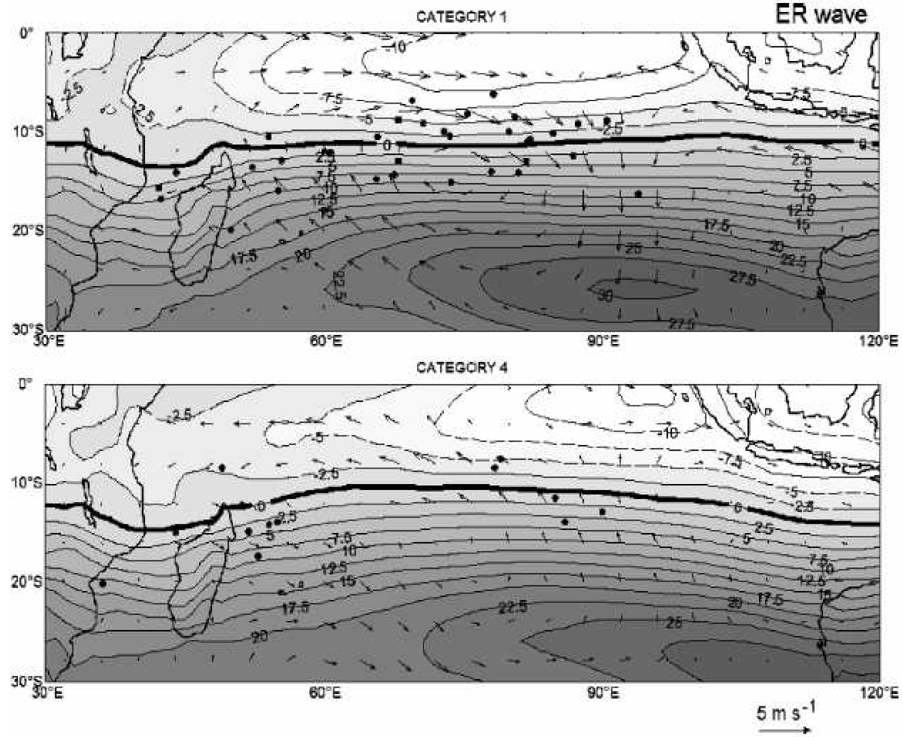
ISO and Tropical Cyclones : **SW Indian**

[Bessafi & Wheeler, 2006]

850-hPa vorticity anomaly & TC genesis



850-hPa wind anomaly & wind shear



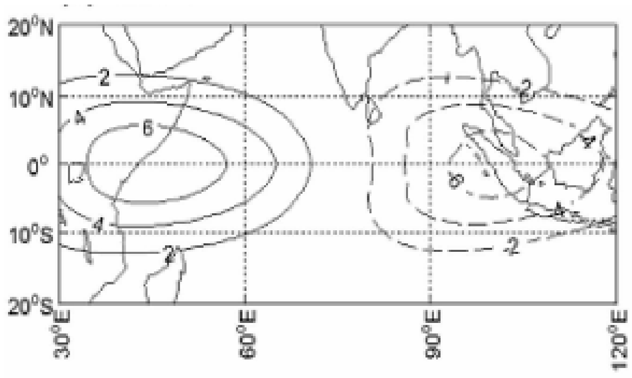
The large modulation of TC genesis in the SW Indian ocean by the ER-waves seems attributable to the <u>large variation of the low-level vorticity and coincidence with enhanced convection</u>.

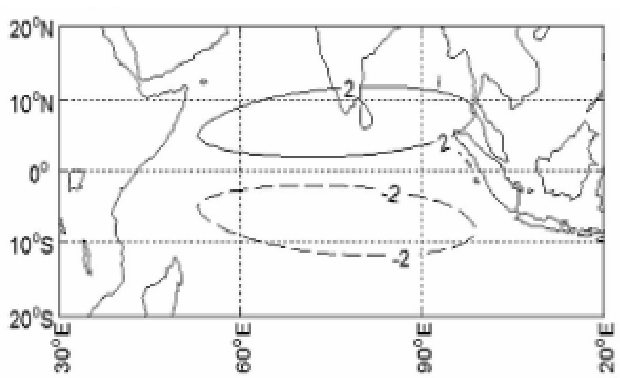
The relatively <u>smaller changes in vertical wind shear</u> appears less important.

ISO and Tropical Cyclones : **SW Indian**

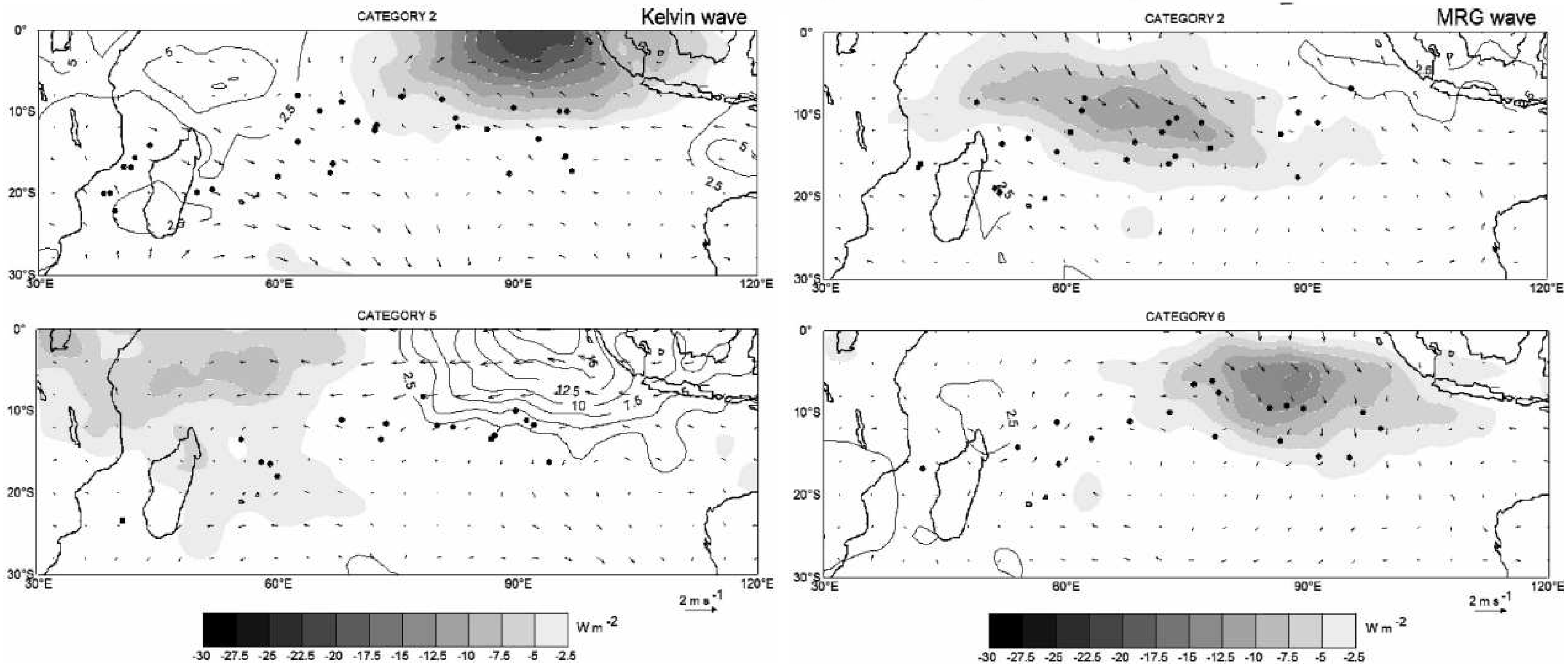
[Bessafi & Wheeler, 2006]

First EOF of the **Kelvin wave-filtered** OLR in W m^{-2}





First EOF of the **mixed Rossby-Gravity wave-filtered** OLR in W m^{-2}



For Kelvin and MRG waves, despite producing less significant TC modulation, attribution could be made to vorticity and OLR.

CONCLUSIONS

- TC genesis in the different basins has a clear modulation signal by large-scale atmospheric variability.
- Intraseasonal and interannual disturbances have some predictability. These time scales could be relevant for extending the current TC predictability.
- More research is needed however to more completely understand the interactions among various space and time scales …

Tropical cyclone season outlook

*[**Gray, 1968** : Mon. Wea. Rev. 96, 669-700 ; …]*

A statistical scheme for forecasting TC activity in the Atlantic basin by 1 April is based on different predictors :

- ***QBO*** *: vertical wind shear is weaker during the westerly phase*

- ***West African rainfall*** *: more tropical easterly waves during wet years ;*

- **ENSO** : La Niña enhances Atlantic hurricane activity ;
- **PNA (Pac N Am)** : eastward-shifted positive PNA is typically associated with El Niño event during the following year ;
- **NAO / AO** : negative values are correlated with weaker trade winds and reduced tropospheric wind shear over the tropical Atlantic ;
- **SLP in the Gulf of Mexico** : lower-than-normal values are favorable for more TC activity.

N Atlantic seasonal forecast

[http://hurricane.atmos.colostate.edu]

Forecast Parameter and 1981-2010 Median (in parentheses)	4 April 2012	Update 1 June 2012	Update 3 Aug 2012	Observed 2012 Total	% of 1981-2010 Median
Named Storms (NS) (12.0)	10	13	14	19	158%
Named Storm Days (NSD) (60.1)	40	50	52	99.50	166%
Hurricanes (H) (6.5)	4	5	6	10	154%
Hurricane Days (HD) (21.3)	16	18	20	26.00	122%
Major Hurricanes (MH) (2.0)	2	2	2	1	50%
Major Hurricane Days (MHD) (3.9)	3	4	5	0.25	6%
Accumulated Cyclone Energy (ACE) (92)	70	80	99	129	140%
Net Tropical Cyclone Activity (NTC) (103%)	75	90	105	121	117%

The 2012 Atlantic hurricane season was quite unusual, with near record-high numbers of named storms and named storm days observed. Conversely, the season was associated with a negligible amount of major hurricane activity.

This year's seasonal forecasts were somewhat of an under-prediction.

Table I — Seasonal tropical cyclone forecasts: groups that issue the forecasts, regions in which the forecasts are issued, forecast type, Website where the forecast is available.

Group	*Basins*	*Type*	*Website*
City University of Hong Kong, China (CityU)	Western North Pacific	Statistical	http://aposf02.cityu.edu.hk
Colorado State University, USA (CSU)	Atlantic	Statistical	http://hurricane.atmos.colostate.edu
Cuban Meteorological Institute (INSMET)	Atlantic	Statistical	http://www.met.inf.cu
European Centre for Medium-Range Weather Forecasts (ECMWF)	Atlantic Australian Eastern North Pacific North Indian South Indian South Pacific Western North Pacific	Dynamical	http://www.ecmwf.int (collaborating agencies only)
International Research Institute for Climate and Society (IRI)	Atlantic Australia Eastern North Pacific South Pacific Western North Pacific	Dynamical	http://iri.columbia.edu/forecast/tc_fcst/
Macquarie University, Australia	Australia / southwest Pacific	Statistical	http://www.iges.org/ellfb/past.html
Meteorological Office, United Kingdom (MetOffice)	North Atlantic	Dynamical	http://www.metoffice.gov.uk/weather/tropicalcyclone/northatlantic
National Meteorological Service, Mexico (NSM)	Eastern North Pacific	Statistical	http://smn.cna.gob.mx
National Climate Centre, China	Western North Pacific	Statistical	http://bcc.cma.gov.cn
NOAA hurricane outlooks	Atlantic Eastern North Pacific Central North Pacific	Statistical	http://www.cpc.noaa.gov http://www.cpc.noaa.gov http:// www.prh.noaa.gov/hnl/cphc
Tropical Storm Risk (TSR)	Atlantic Western North Pacific Australian region	Statistical	http://tsr.mssl.ucl.ac.uk

Group	Predictors	Outputs
CityU	1. ENSO 2. Extent of the Pacifc subtropical ridge 3. Intensity of India-Burma trough	1. Number of TCs 2. Number of named TCs 3. Number of typhoons
CSU	1. SST North Atlantic 2. SST South Atlantic 3. SLP South Pacific 4. ENSO 5. Atlantic meriodinal Mode	1. Number of named TCs 2. Named of named TC days 3. Number of hurricanes 4. Number of hurricane days 5. Number of major hurricanes 6. Named of major hurricane days 7. Accumulated cyclone energy 8. Net tropical cyclone energy
INSMET	1. North Atlantic winds 2. ENSO 3. Intensity of the Atlantic subtropical ridge 4. SST North Atlantic 5. Quasi Biennial Oscillation	1. Number of named TCs 2. Number of hurricanes 3. Number of named TCs in the Atlantic MDR, Caribbean and Gulf of Mexico (separately) 4. First day with TC genesis in the season 5. Last day with a TC active in the season 6. Number of named TCs that form in the Atlantic MDR and impact the Caribbean
ECMWF	1. Coupled dynamical model 2. Model TCs identified and tracked	1. Number of named TCs 2. Mean location of TC genesis
IRI	1. Various SST forecast scenarios. 2. Atmospheric models 3. Model TCs identified and tracked.	1. Number of named TCs 2. Accumulated cyclone energy (northern hemisphere only) 3. Mean location of TCs (western North Pacific only)
Macquarie U.	1. SOI index 2. Equivalent potential temperature gradient	1. Number of TCs 2. Number of TCs in the Coral Sea
Met Office	1. Coupled dynamical model 2. Model TCs identified and tracked	1. Number of named TCs

Group	Predictors	Outputs
SMN	1. SST anomalies 2. Equatorial wind anomalies 3. Equatorial Pacific OLR	1. Number of TCs 2. Number of tropical storms 3. Number of hurricanes 4. Number of major hurricanes
NOAA (Atlantic and Eastern Pacific)	1. ENSO 2. Tropical multi-decadal mode 3. Atlantic SST	1. Number of named TCs 2. Number of hurricanes 3. Number of major hurricanes 4. Accumulated cyclone energy
NOAA (Central Pacific)	1. ENSO 2. Pacific Decadal Oscillation	1. Number of TCs
Tropical Storm Risk (TSR)	1. Trade winds 2. MDR SST 3. ENSO 4. Sea-level pressure central Northern Pacific	1. Number of named TCs 2. Number of hurricanes 3. Number of major hurricanes 4. Accumulated Cyclone Energy 5. ACE landfalling TCs 6. Number of landfalling named TCs 7. Number of landfalling hurricanes 8. Number of landfalling major hurricanes

N Atlantic seasonal forecast

Several forecasts of hurricane activity are issued by national meteorological services, scientific agencies, and noted hurricane experts [e.g. *NOAA's National Hurricane and Climate Prediction Center, Colorado State University, Tropical Storm Risk, the United Kingdom's Met Office* , …]

Predictions of tropical activity in the 2012 season

Source	Date	Named storms	Hurricanes	Major hurricanes
	Average (1981–2010)	12.1	6.4	2.7
	Record high activity	28	15	8
	Record low activity	4	2	0
TSR	December 7, 2011	14	7	3
WSI	December 21, 2011	12	7	3
CSU	April 4, 2012	10	4	2
TSR	April 12, 2012	13	6	3
TWC	April 24, 2012	11	6	2
TSR	May 23, 2012	13	6	3
UKMO	May 24, 2012	10*	N/A	N/A
NOAA	May 24, 2012	9–15	4–8	1–3
FSU COAPS	May 30, 2012	13	7	N/A
CSU	June 1, 2012	13	5	2
TSR	June 6, 2012	14	6	3
NOAA	August 9, 2012	12–17	5–8	2–3
	Actual activity	19	10	2

** June–November only: 17 storms observed in this period.*

NW Pacific seasonal prediction

Seasonal forecasts for the NW Pacific are issued by *the Tropical Storm Risk (TSR) Consortium of the University College London, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and the Taiwan's Central Weather Bureau.* During previous seasons the *Guy Carpenter Asia-Pacific Climate Impact Centre* also issued forecasts, however they did not issue a forecast this year as it had been overestimating how many tropical cyclones would develop during the last few seasons.

Prediction of tropical activity in the 2012 season

Forecast Center	Date	Tropical storms	Total Typhoons	Intense TCs
Average(1965–2011)		26.2	16.3	8.4
TSR	April 13, 2012	25.5	15.6	7.3
CMA-STI	April 26, 2012	22 - 25	N/A	N/A
TSR	May 5, 2012	25.5	15.6	8.5
CWB	June 29, 2012	23 - 26	N/A	N/A
TSR	July 9, 2012	26.8	16.7	9.2
TSR	August 6, 2012	27.4	17.4	9.3
JMA	Actual activity	25	14	7
JTWC	Actual activity	25	16	7