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SEASONAL FORECAST OF TC ACTIVITY ON SWIO BASIN

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Météo-France DIROI/EC

WMO RA-I Training course 2023

Outline

- **Interannual variability**
  - Seasonal cycle of the Indian Ocean
  - Working with « anomalies »
  - Evidence of climate interannual variability

- **Main drivers of the interannual variability**
  - ENSO, IOD, SIOD
  - Regional climate response

- **Focus on TC activity**
  - Interannual variability no the SWIO TC activity
  - Impact based approach

- **Seasonal forecast applications at regional scale**
  - SWIOCOF activity
  - TC outlook mini-forum

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What is interannual variability ?

- Year to year variation of a specifc climat index, pattern.

- The identification of interannual variability based on the measured anomaly with respect to a climatic reference (normal values, average seasonal cycle, etc.).

- Interannual variability is generally assimilated to so-called "low-frequency" variability modes. Most of the time, this low-frequency signal is embedded in higher-frequency variations (intra-seasonal or sub-seasonal variability, or even day to day variability).

Why are we looking at interannual variability?

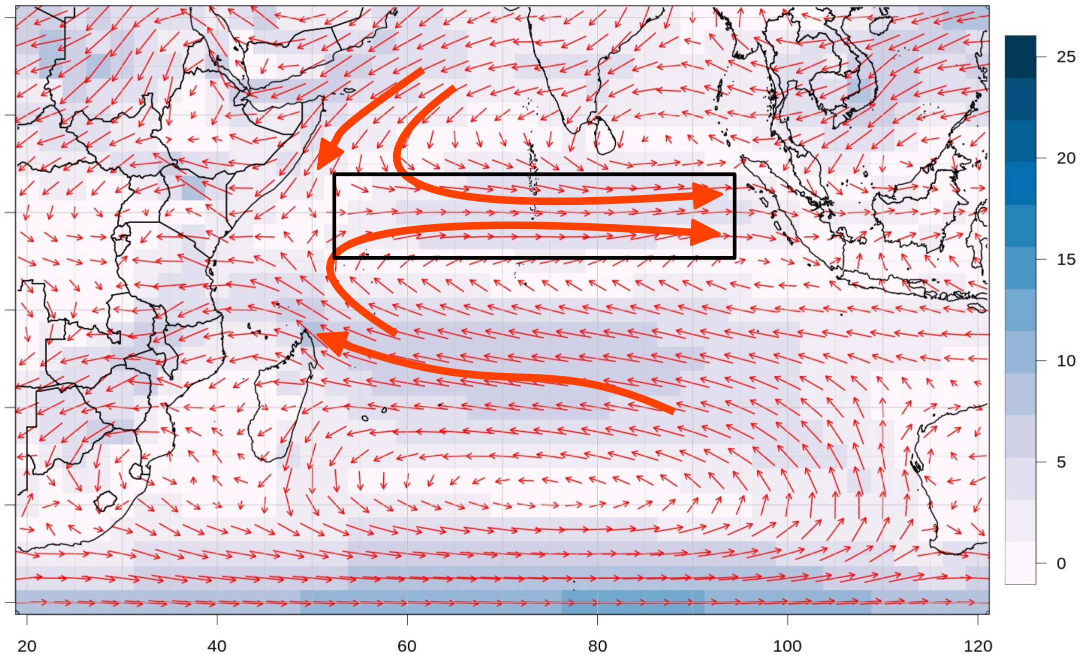
Identifying and understanding the modes of variability (drivers) that drive this variability makes it possible to :

- establish a "context" or "background landscape" for the analysis of a given weather or climate situation,
- anticipate possible climatic anomalies (seasonal or sub-seasonal forecasts) when these drivers are predictable. These are known as sources of predictability

Working with « anomalies »

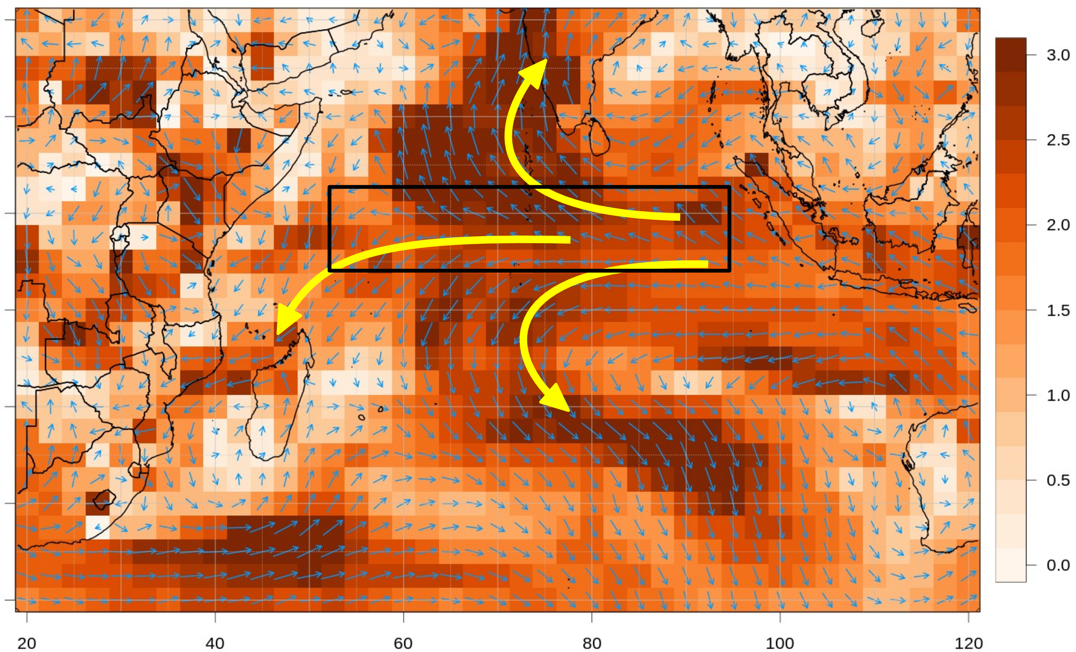
- On a climate scale, we mostly reason in terms of anomalies with respect to an average value or configuration.
- For seasonal forecast or monitorting, the standard scale is the quater (JFM, AMJ, JAS, OND...)
- Example : 850 hpa wind (OND quater)

ERA5 Wind 850 Avg. : OND



1993-2016

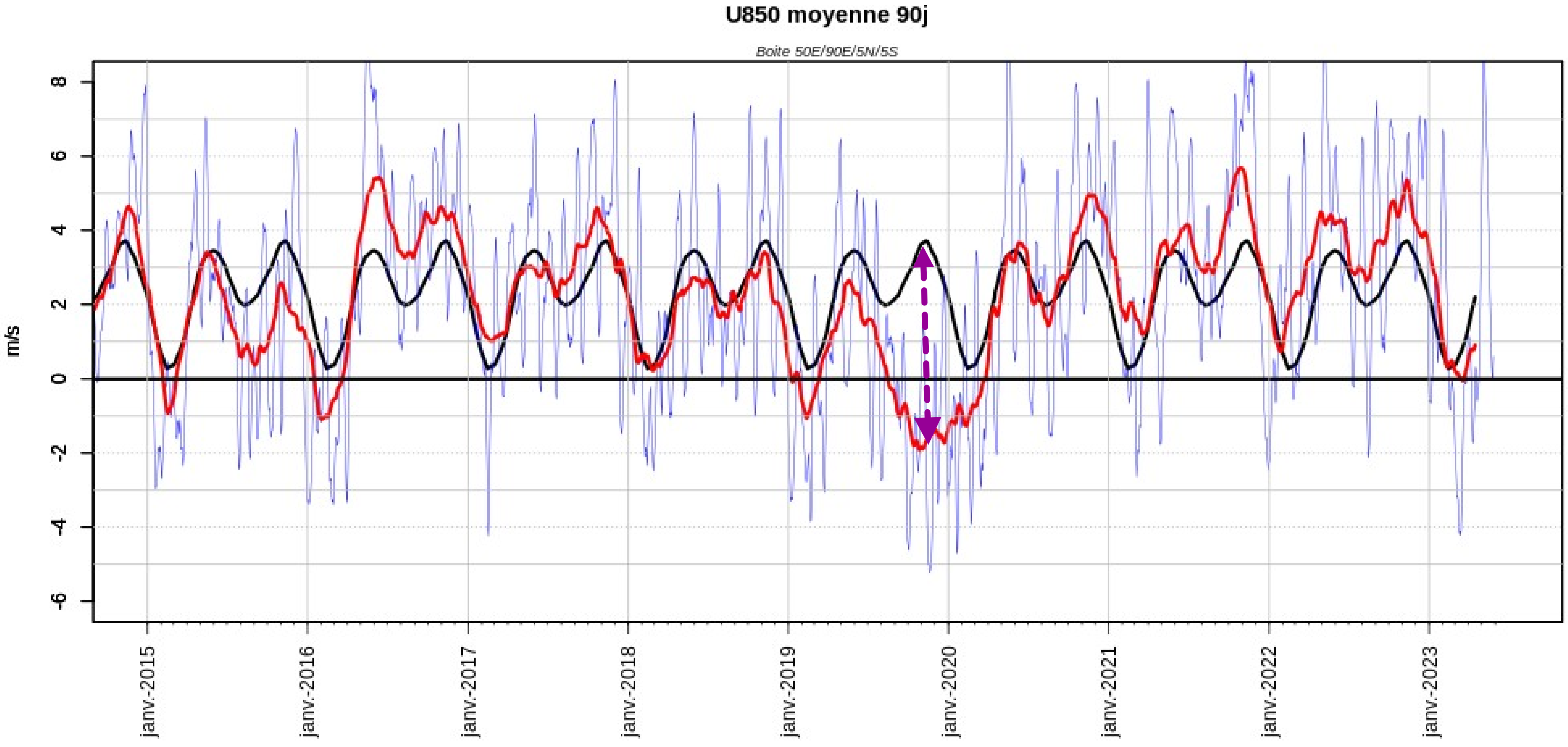
ERA5 850hPa Wind anomaly : OND 2019



Ref: 1993-2016

Working with « anomalies »

- U850 (box 50E/90E/5N/5S) from 2015 to 2023
  - Black line : climatology
  - Blue line : 7 days averaged rolling period
  - Red line : 90 days averaged rolling period



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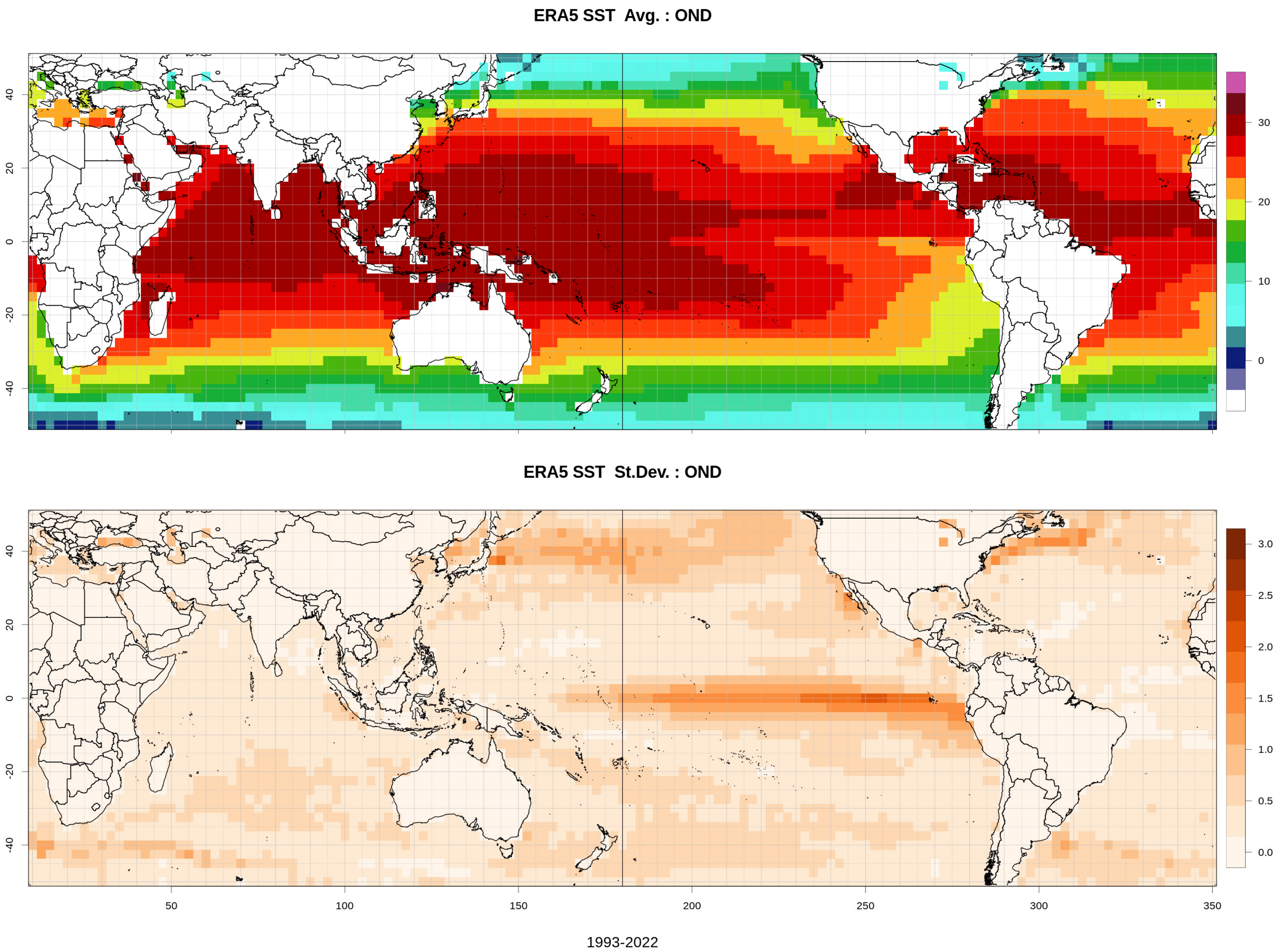
Pacific Ocean: main driver of the global climate interannual variability at interannual



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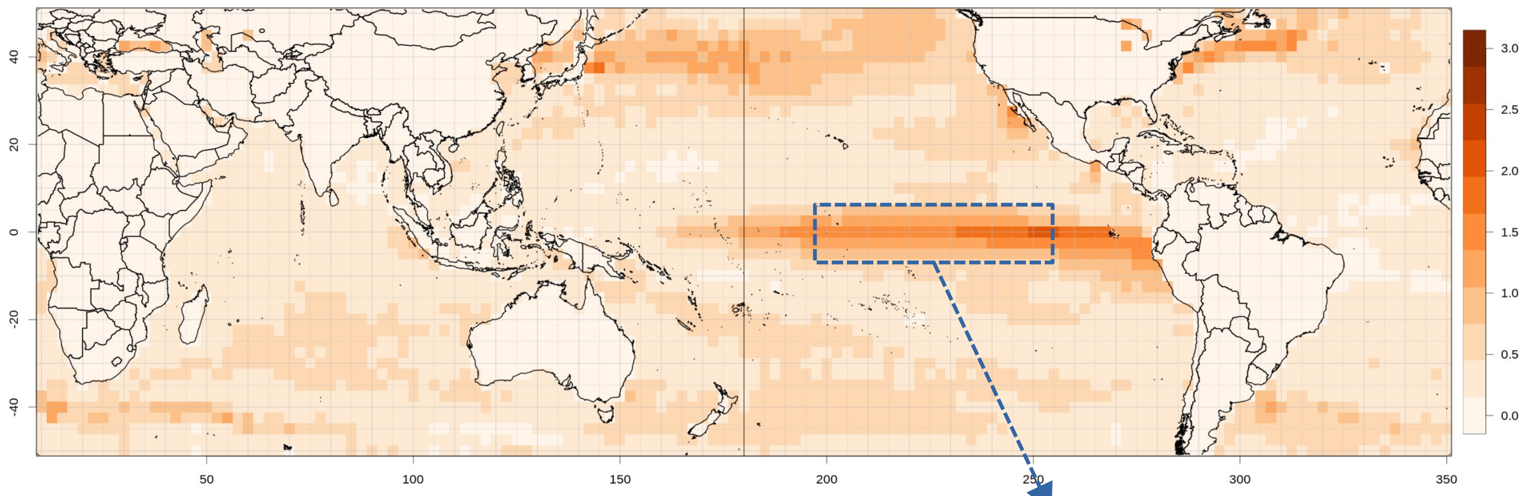
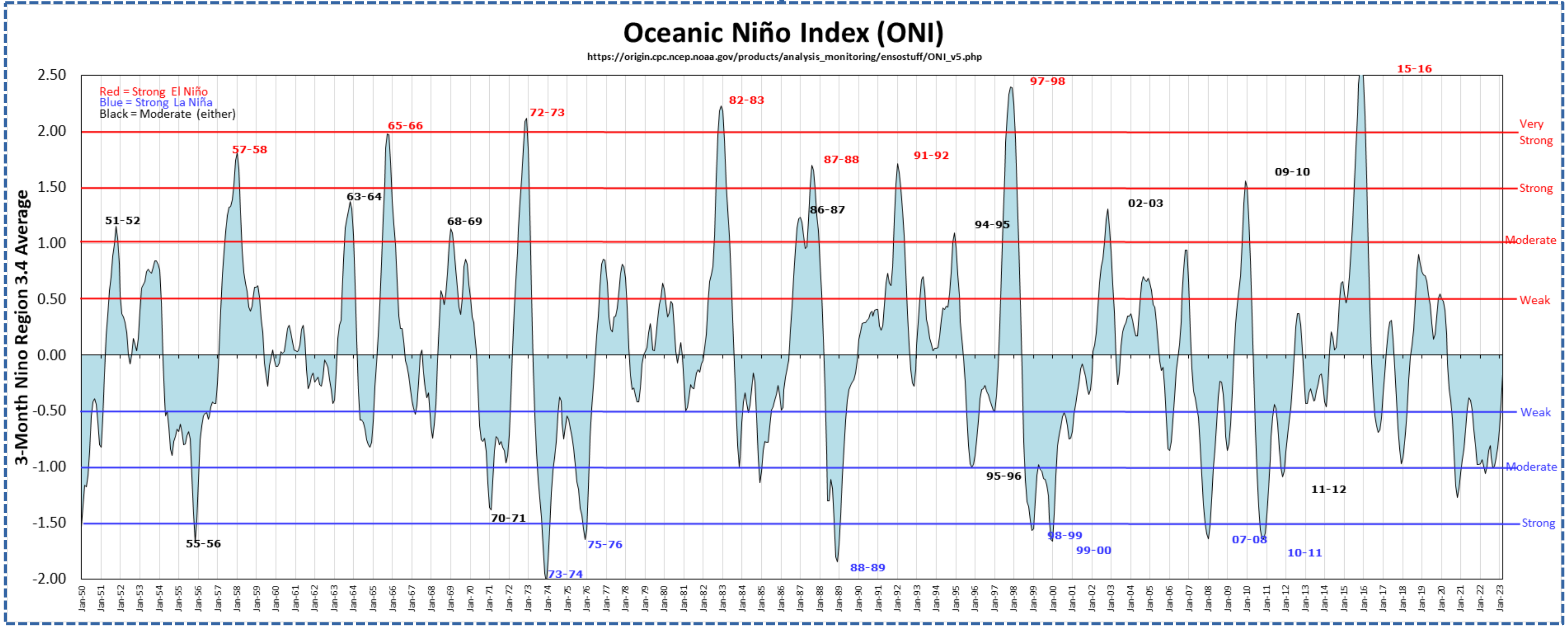
ENSO : El Niño Southern Oscillation

ERA5 SST St.Dev. : OND





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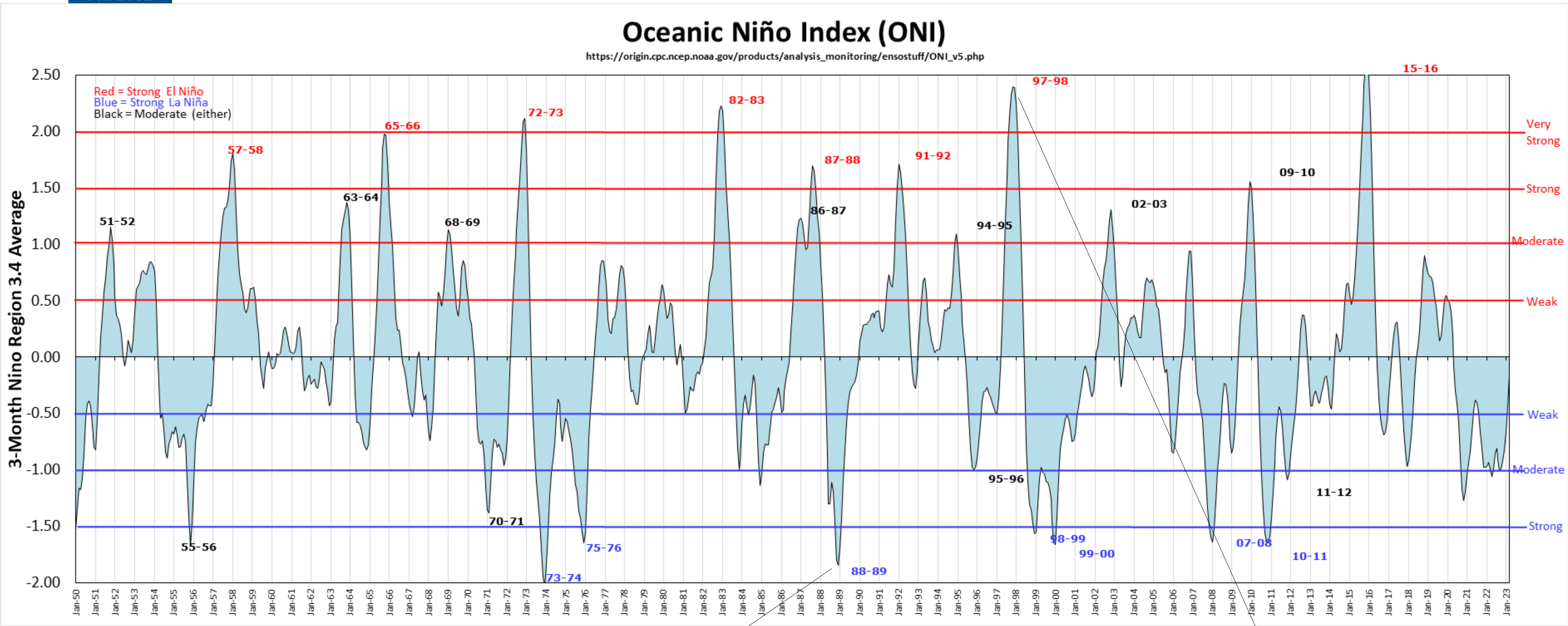
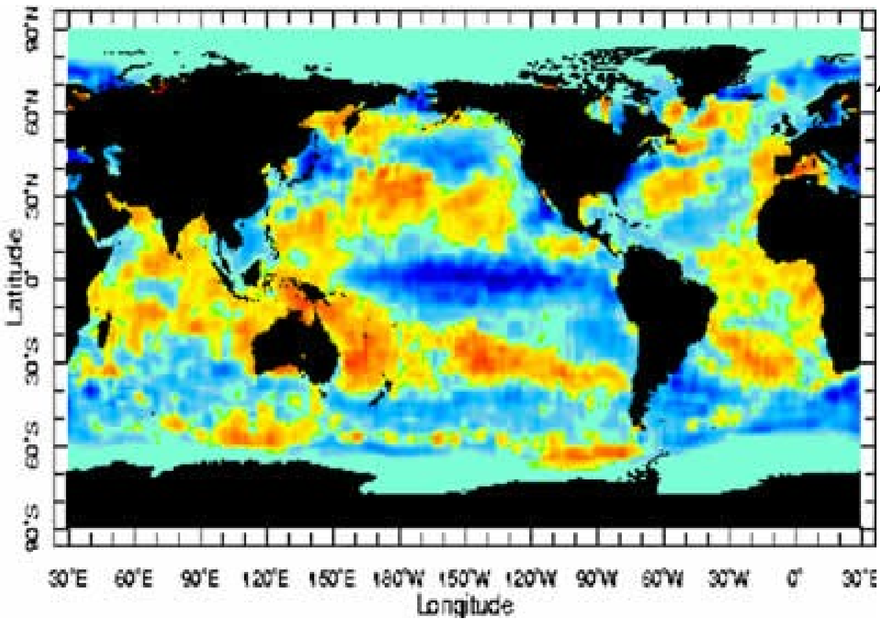
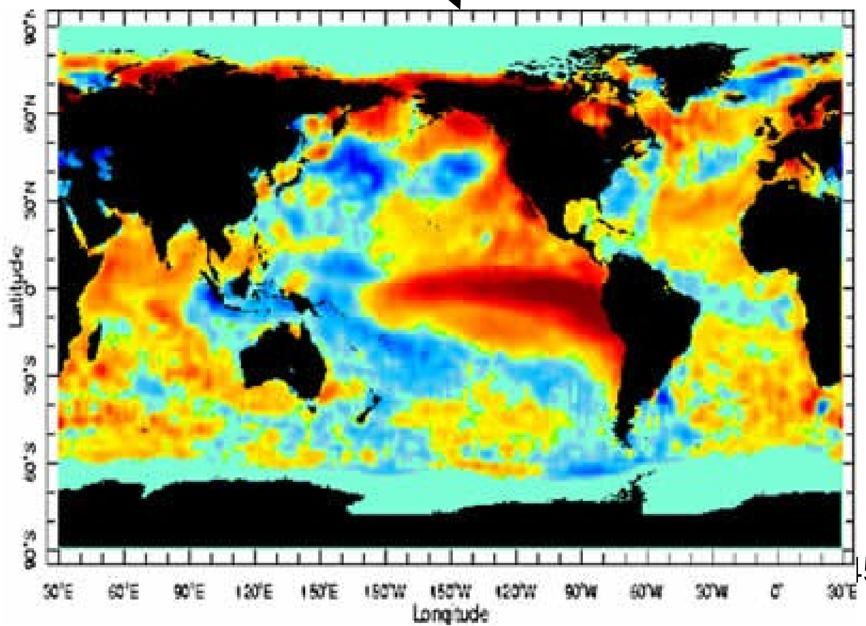
ENSO : El Niño Southern Oscillation

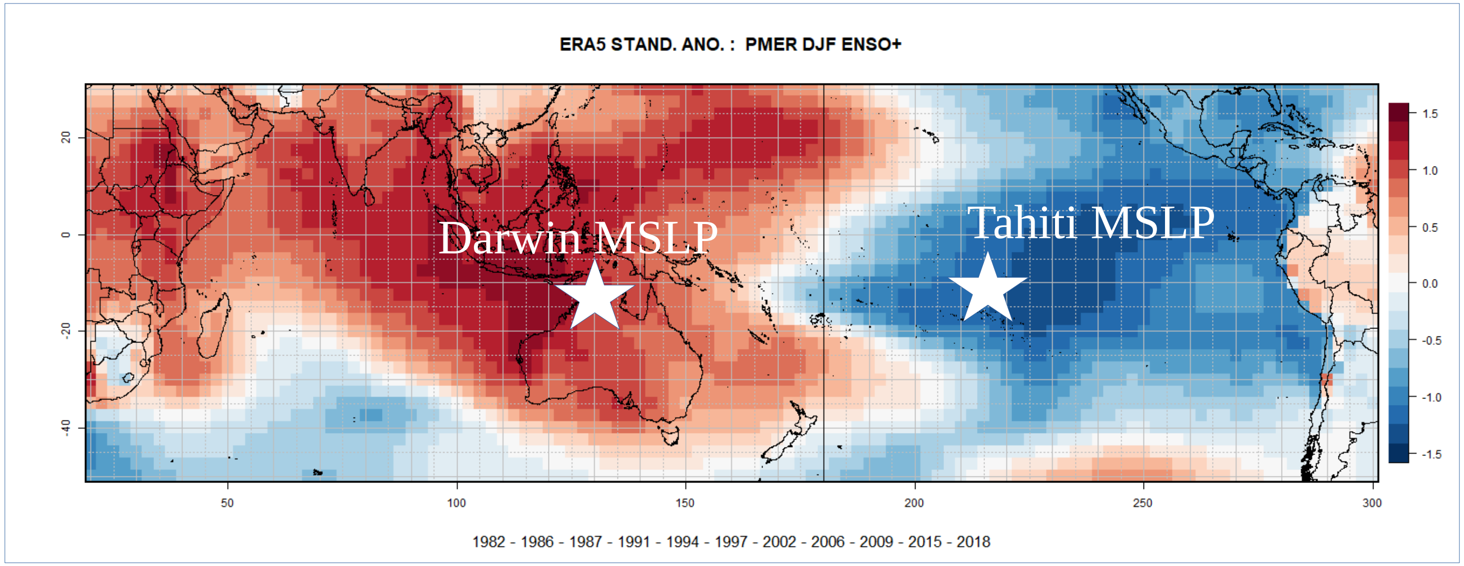




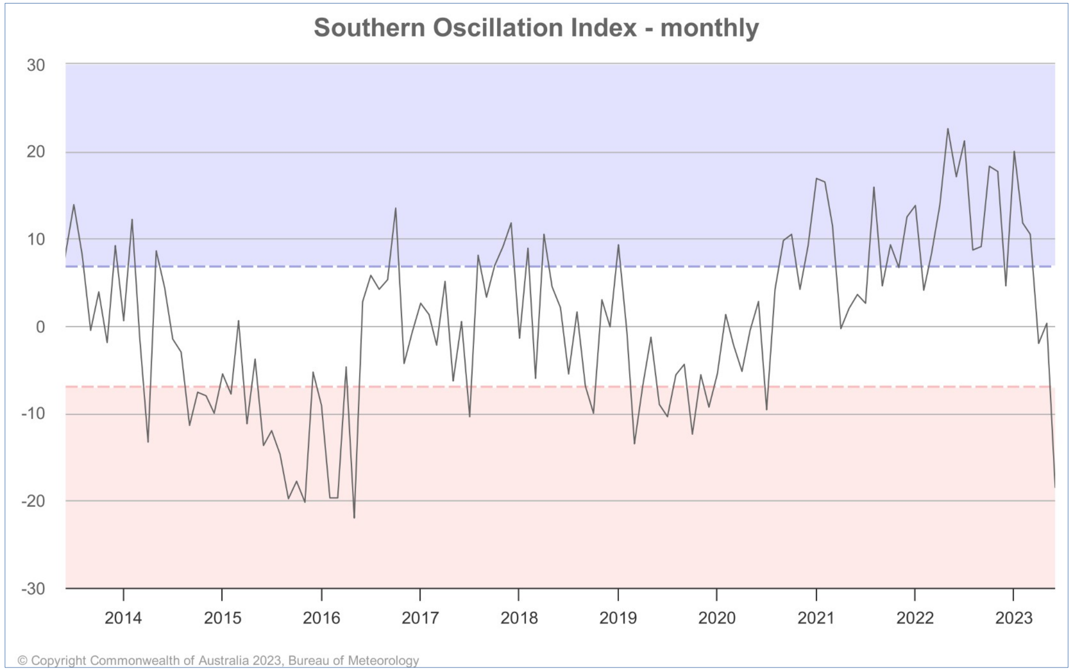


ENSO : El Niño Southern Oscillation

Atmpospheric signature (response) : SOI index (Southern Oscillation Index)
Standardized anomaly on the mean sea level pressure difference between Tahiti et



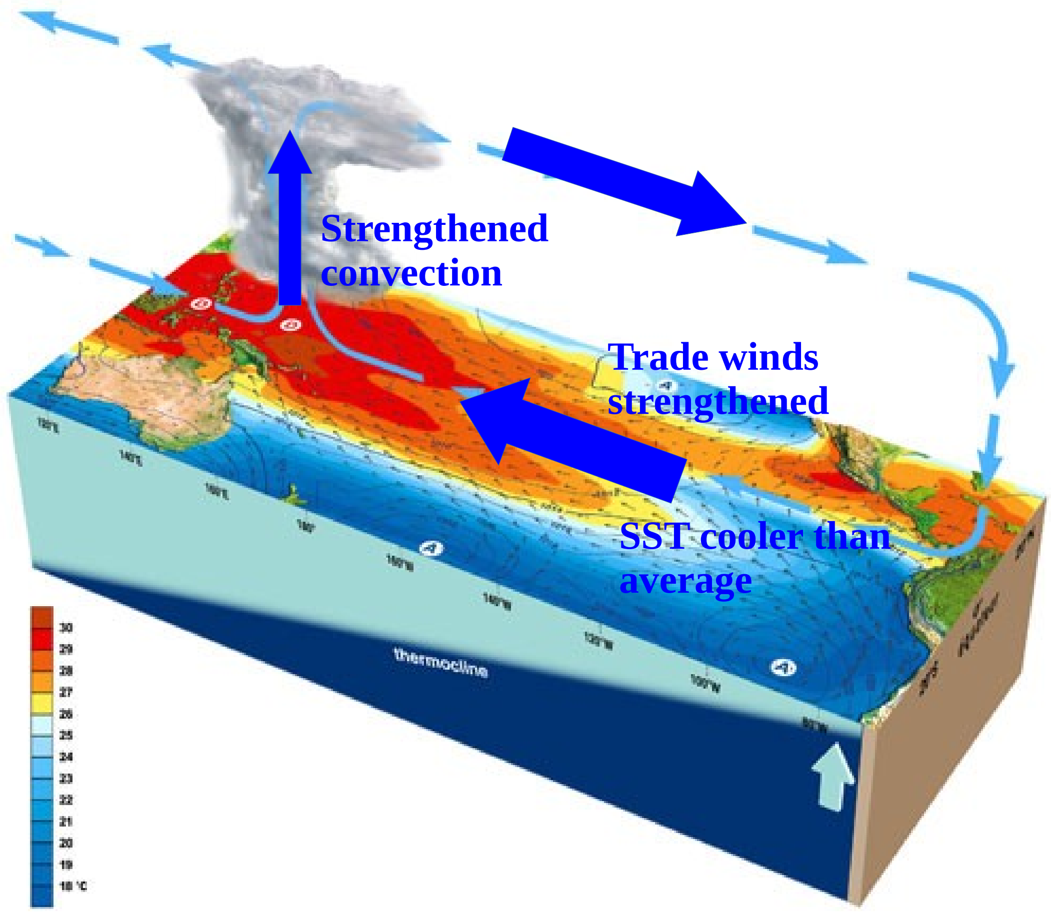
SOI = MSLP tahiti – MSLP darwin



ENSO : El Niño Southern Oscillation

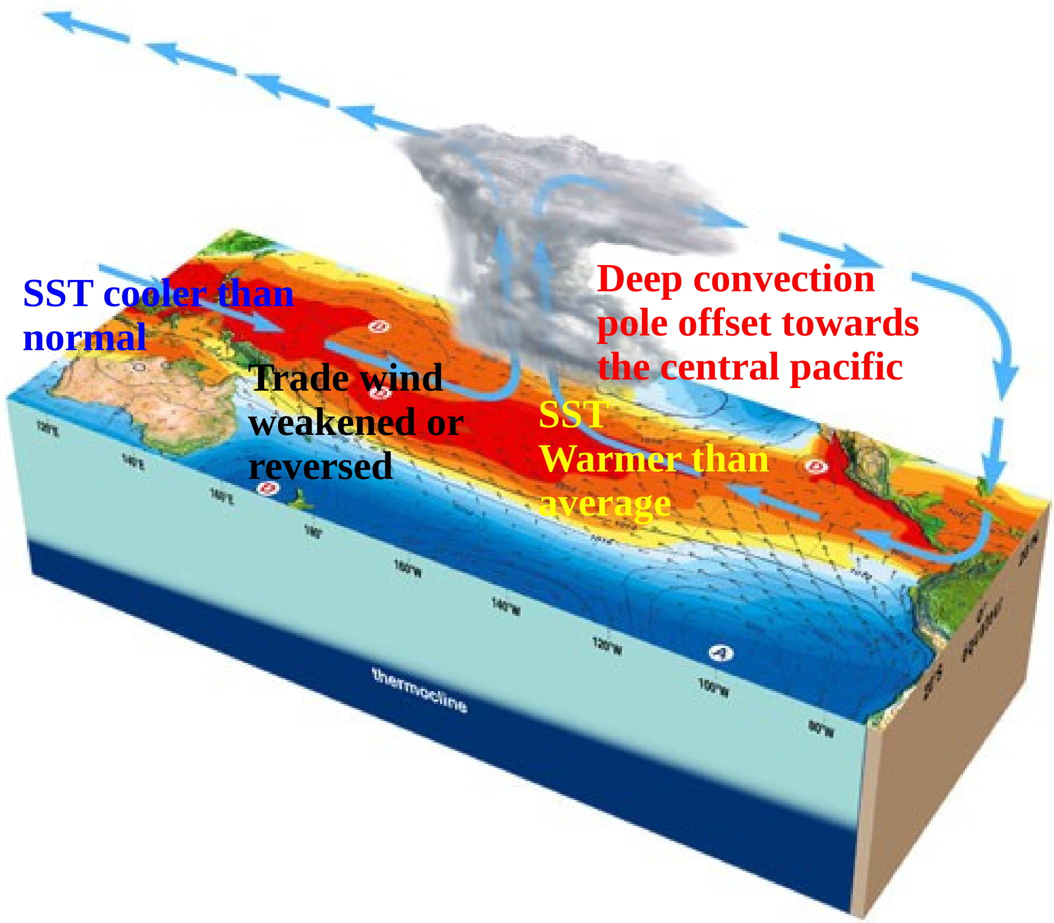
- Coupled variability mode (Ocean-Atmosphere couplind process).
- Heat content charging-discharging of the warm pool

Normal situation

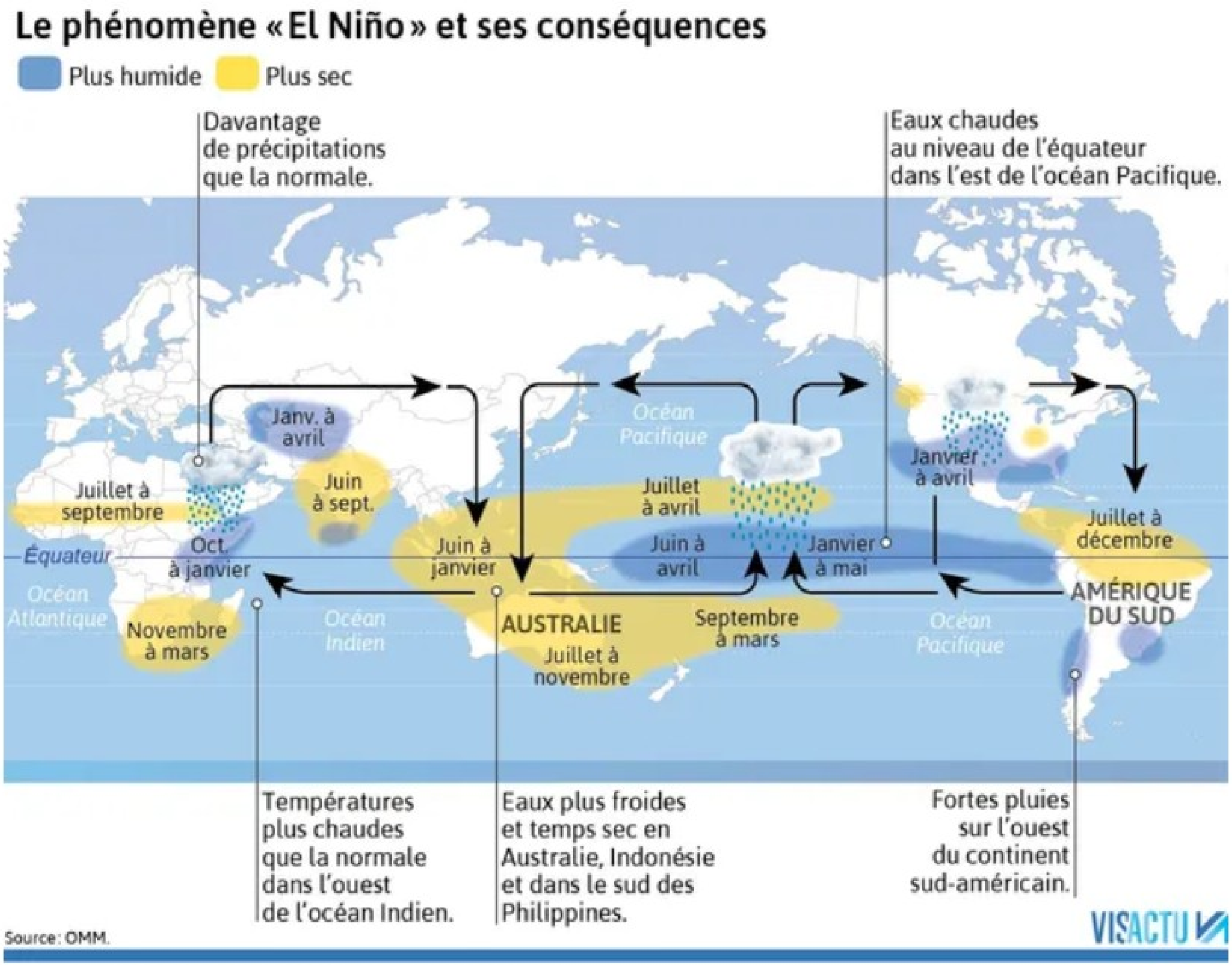


La Niña : normal circulation reinforced

- **El Niño**

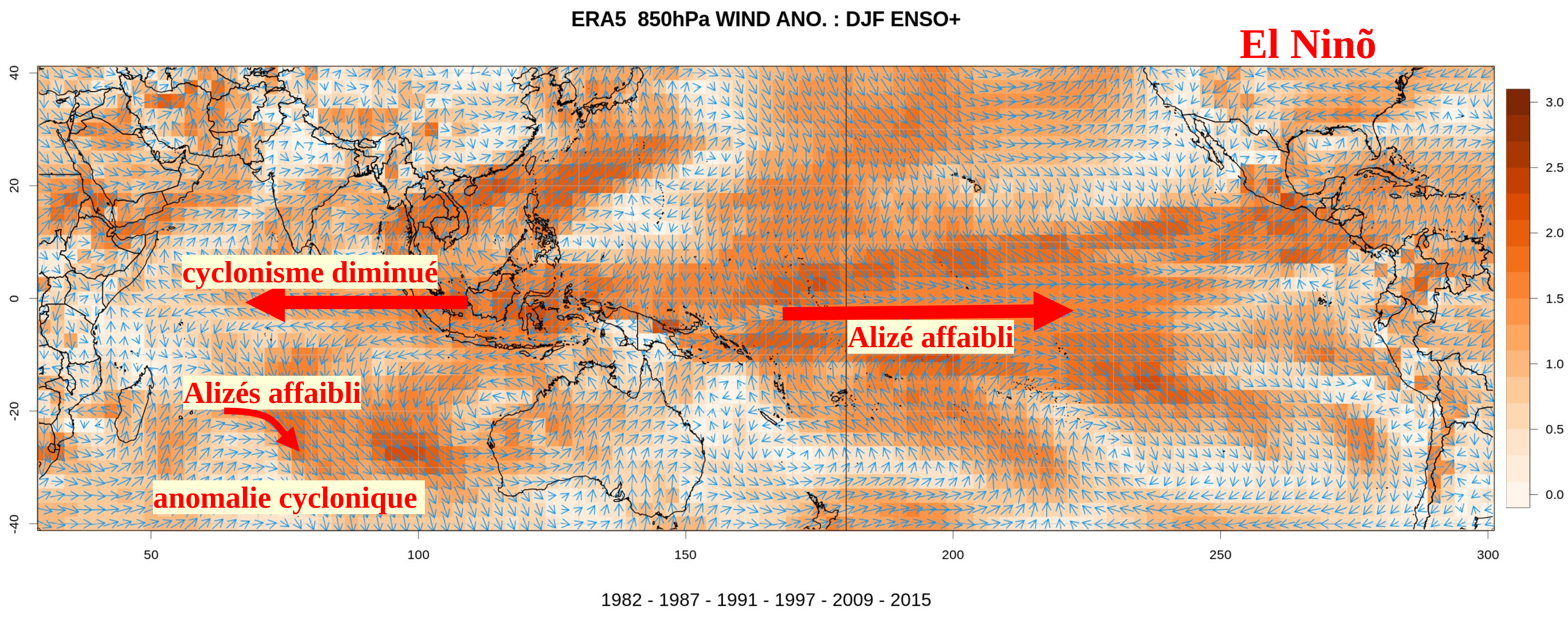


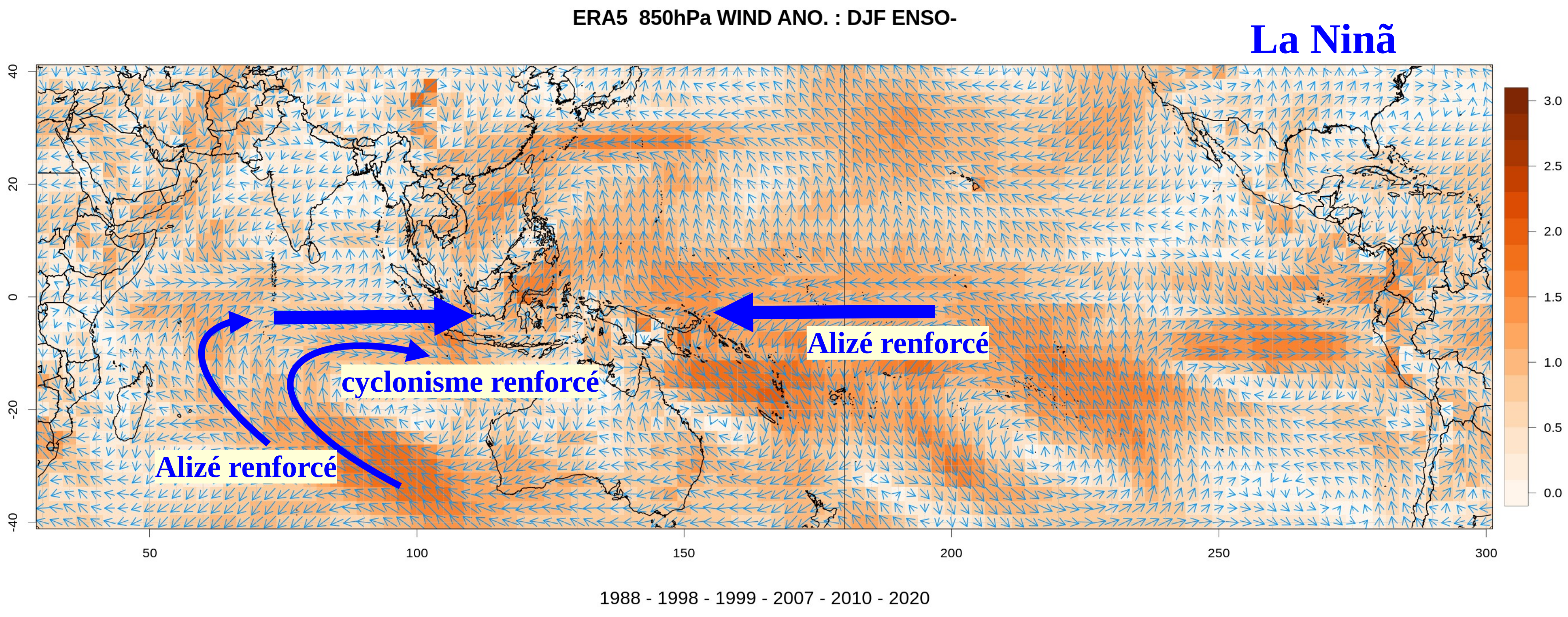
Conséquences planétaires



Le phénomène El Niño et ses conséquences © Visactu

ENSO+ : El Niño vs La Niña





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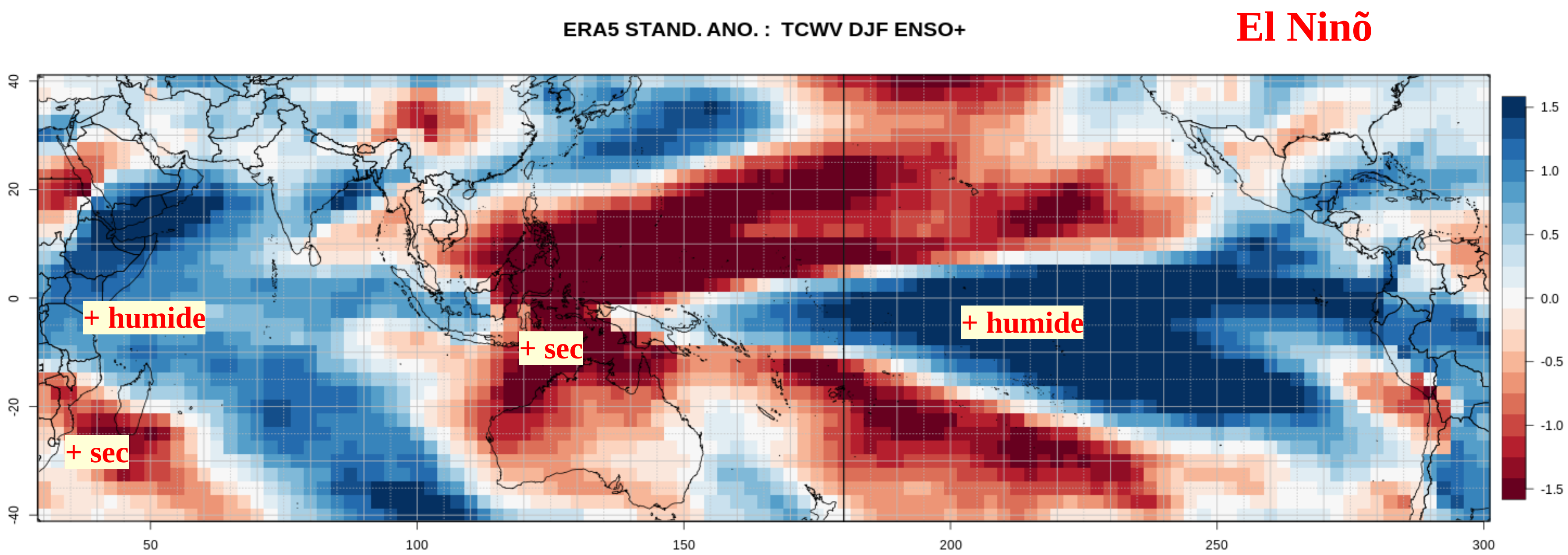
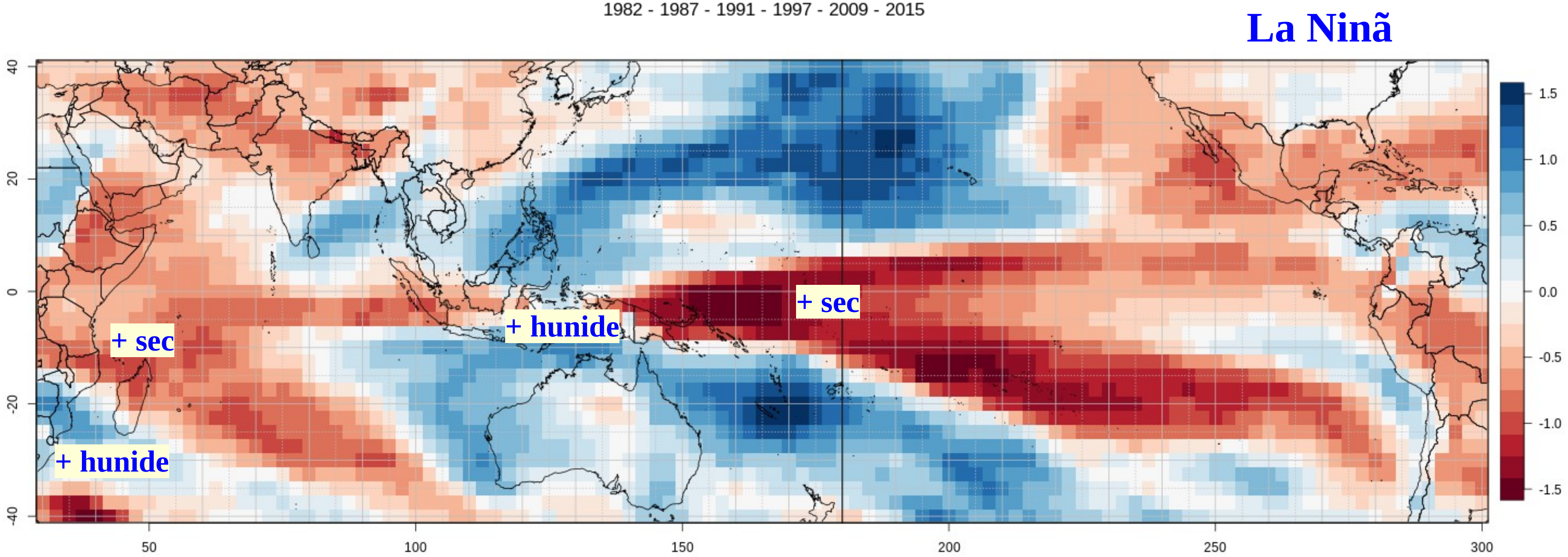
ENSO+ : El Niño vs La Niña



1982 - 1987 - 1991 - 1997 - 2009 - 2015



1988 - 1998 - 1999 - 2007 - 2010 - 2020

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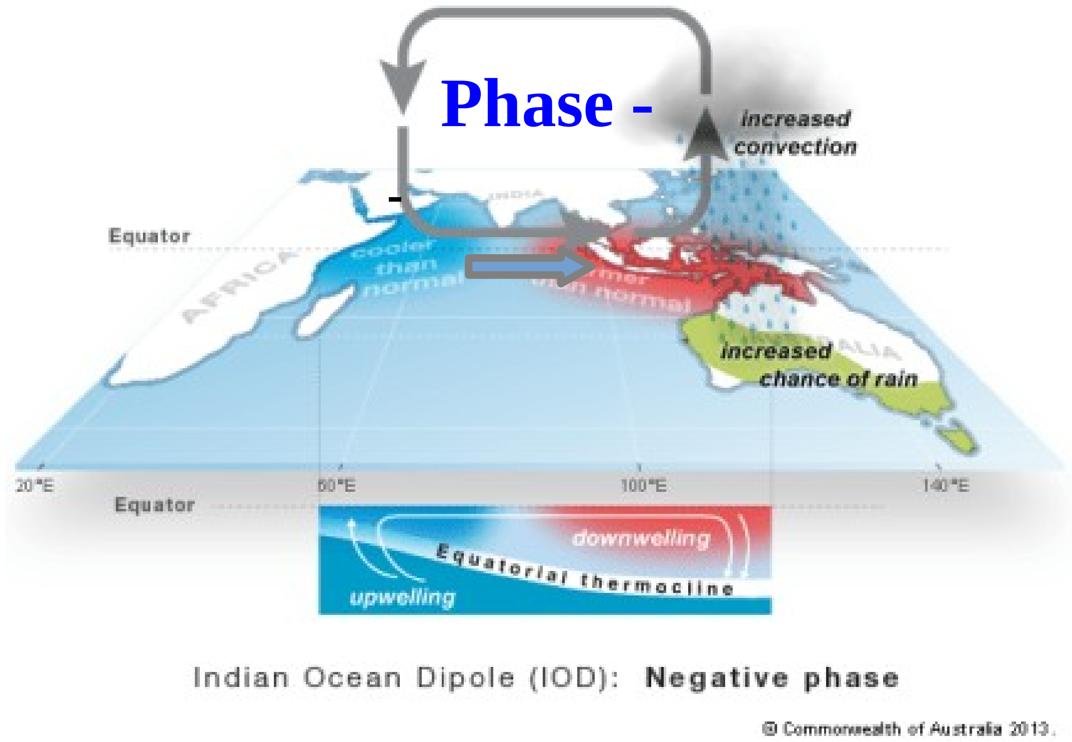
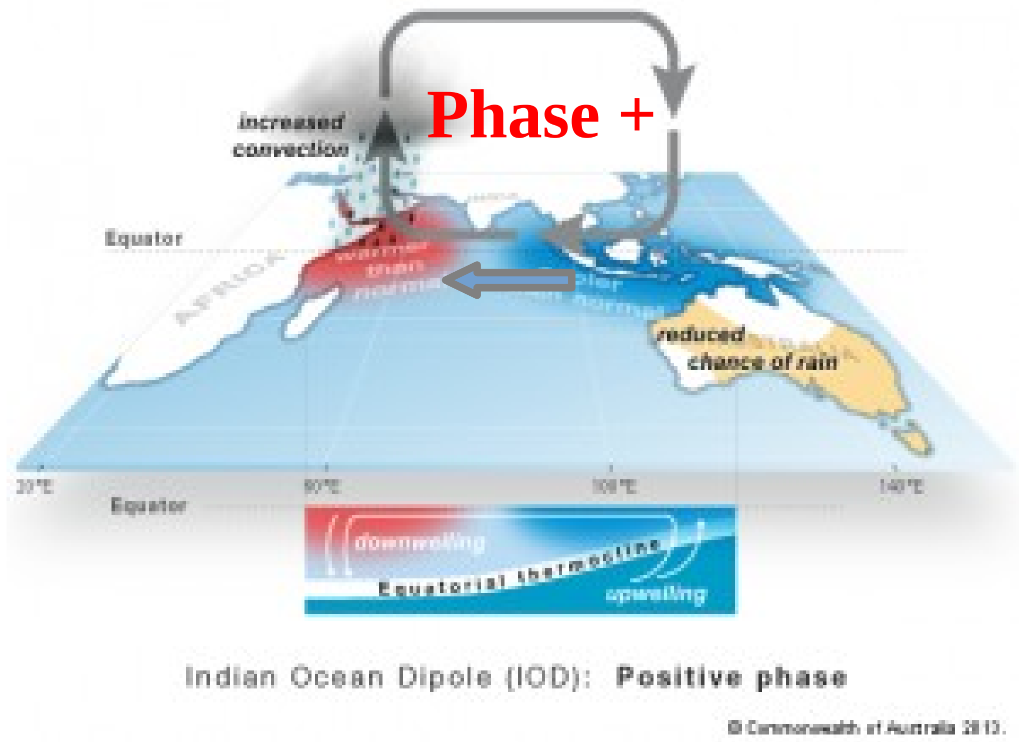
Source de variabilité dans l'Océan Indien

IOD : Indian Ocean Dipole

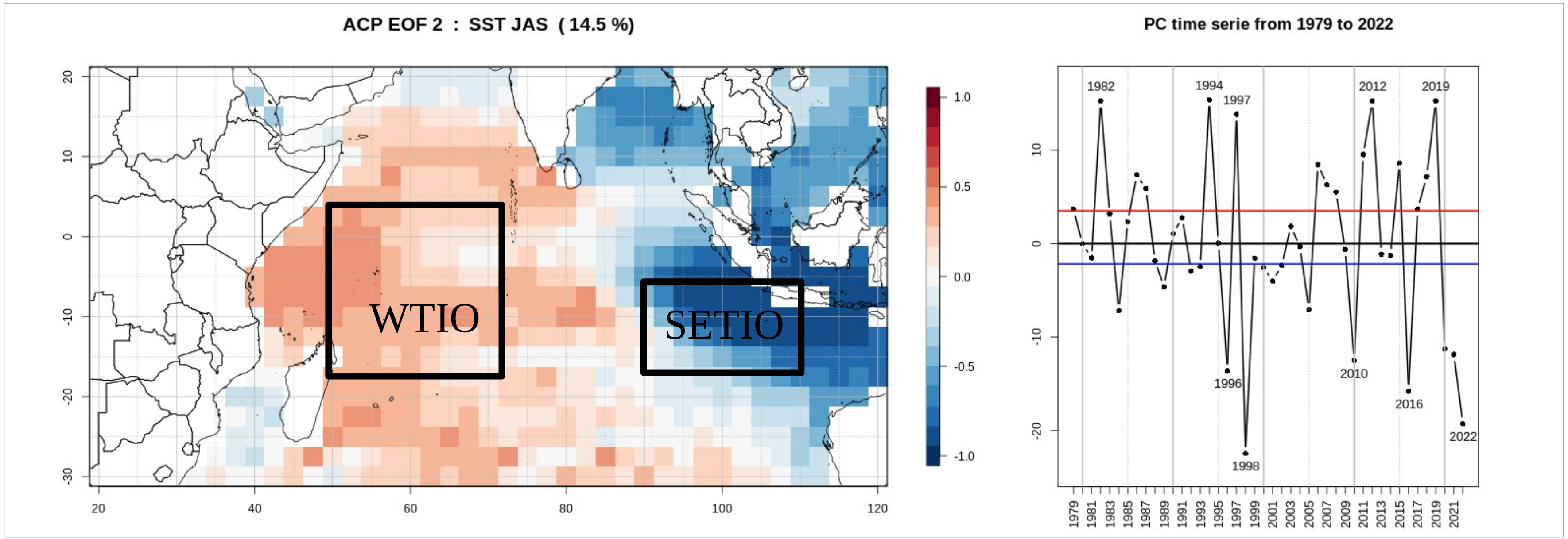




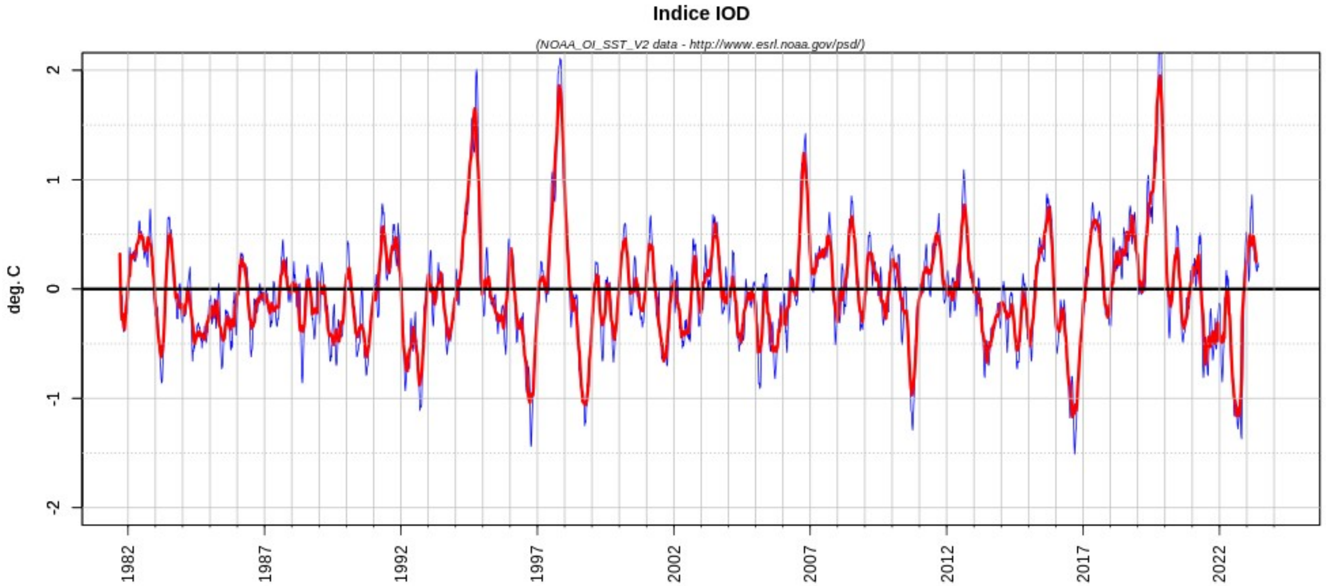
- Mode de variabilité couplé Océan-Atmosphère
- Des liens avec l'ENSO (IOD+/El Niño – IOD-/La Niña)
- Actif principalement durant le deuxième semestre de l'année

Oscillation modes of the Indian Ocean

IOD : Indian Ocean Dipole

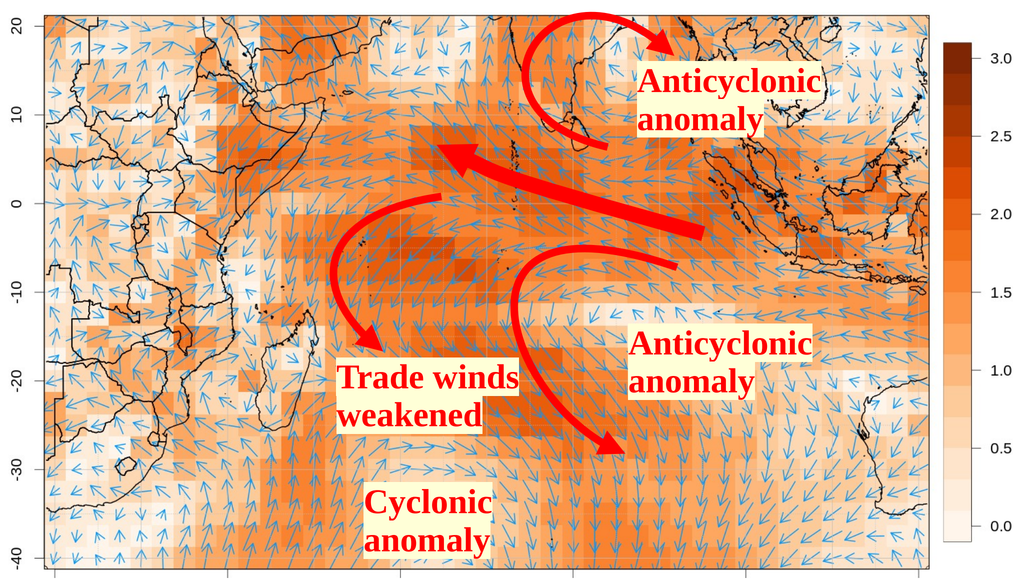


DMI = SST anomaly WTIO box – SST anomaly SETIO box

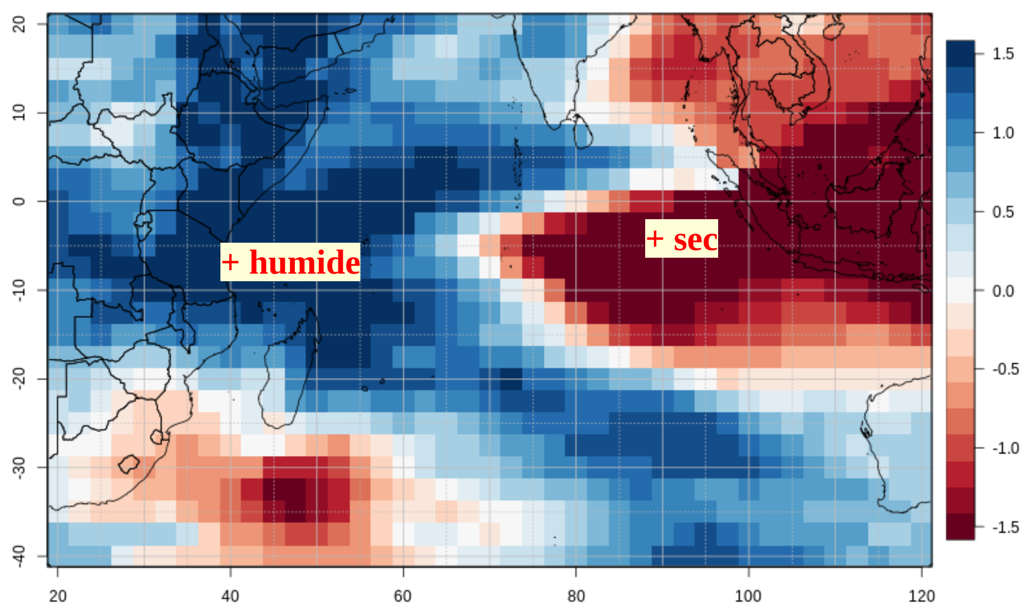


Regional atmospheric response IOD +

ERA5 850hPa WIND ANO. : SON IOD+

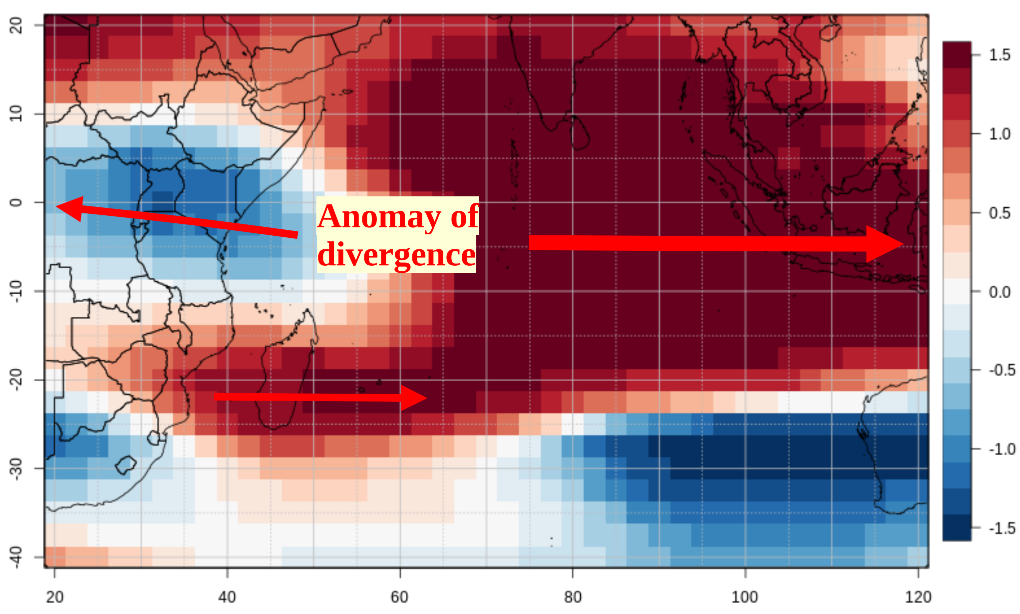


ERA5 STAND. ANO. : TCWV SON IOD+



1982 - 1994 - 1997 - 2006 - 2019

ERA5 STAND. ANO. : U200 SON IOD+



1982 - 1994 - 1997 - 2006 - 2019

- Equatorial westerlies weakened or reversed
- Lower level convergence and vorticity diminished in the NET over the eastern part of the basin
- Subtropical high and trade winds weakened
- Humid conditions over the western Indian Ocean basin

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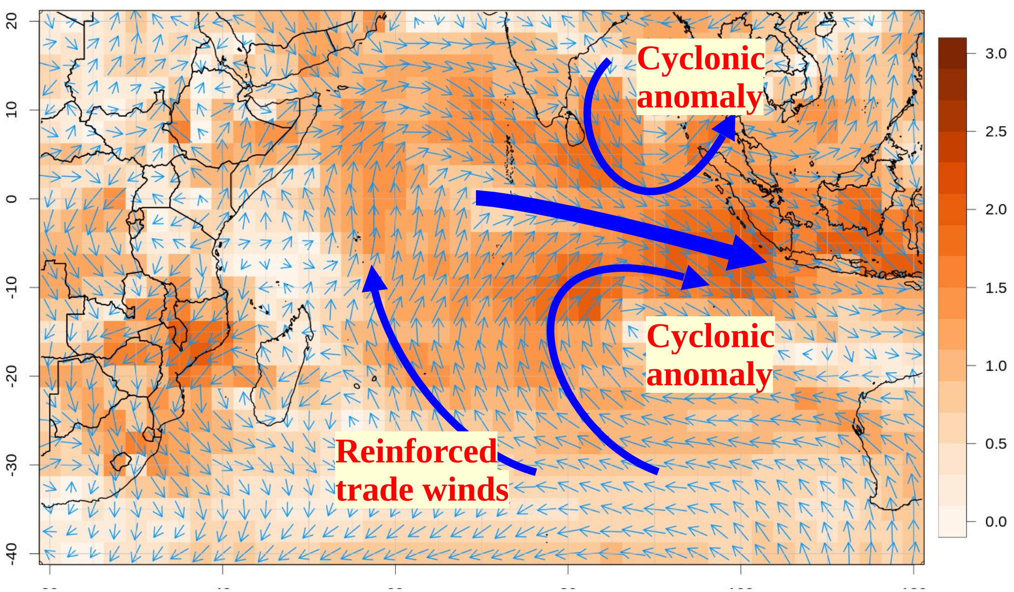
Regional atmospheric response IOD -

ERA5 850hPa WIND ANO. : SON IOD-



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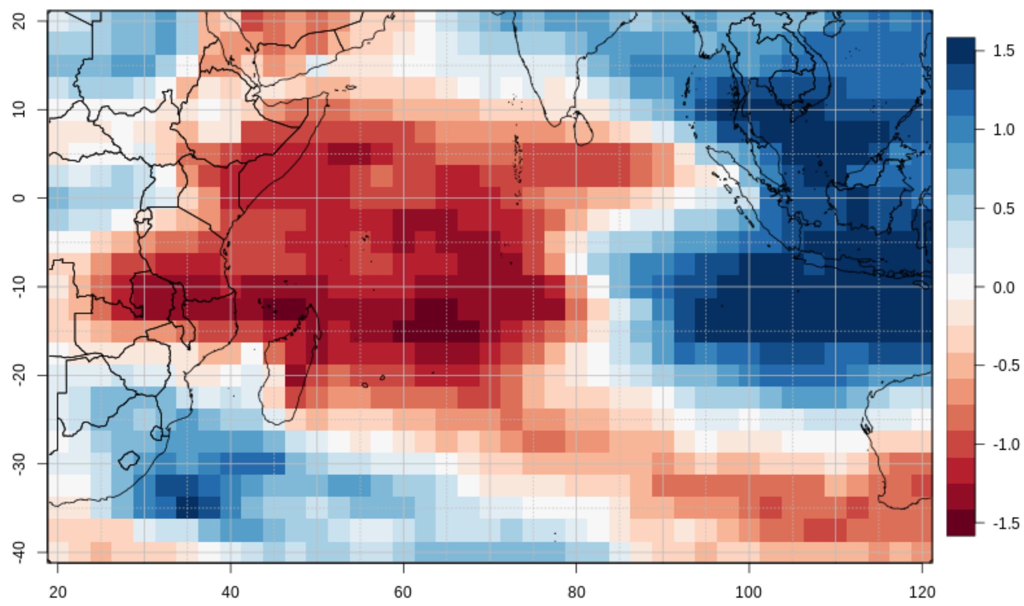
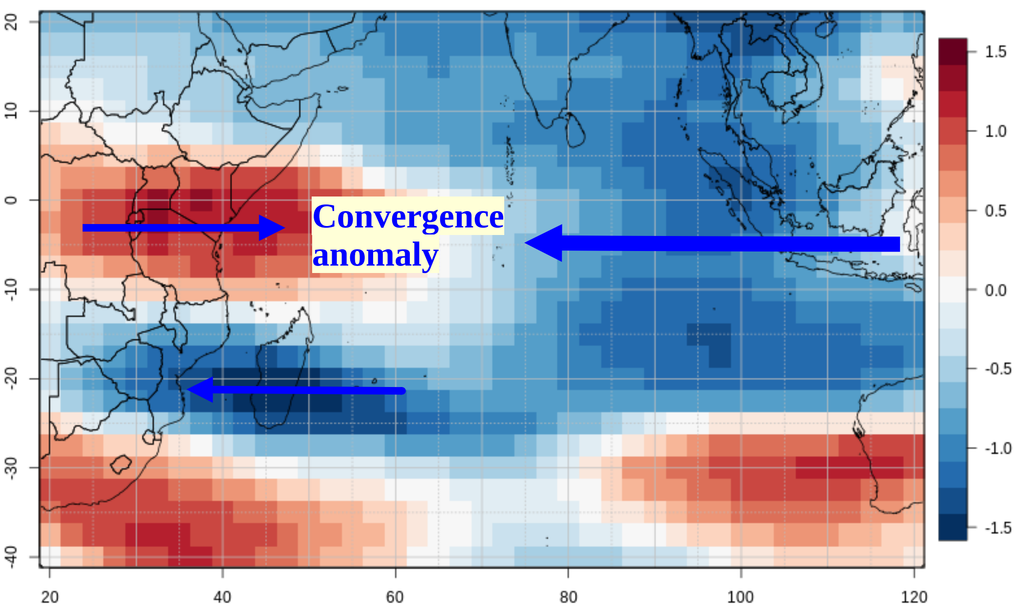


1996 - 1998 - 2010 - 2016 - 2022

ERA5 STAND. ANO. : U200 SON IOD-



1996 - 1998 - 2010 - 2016 - 2022

- Reinforced equatorial westerlies
- Lower level convergence et vorticity strengthened within the NET over the eastern part of the basin
- Subtropical high reinnforced
- Reinforced trade winds
- Dry conditions over the western Indian Ocean basin

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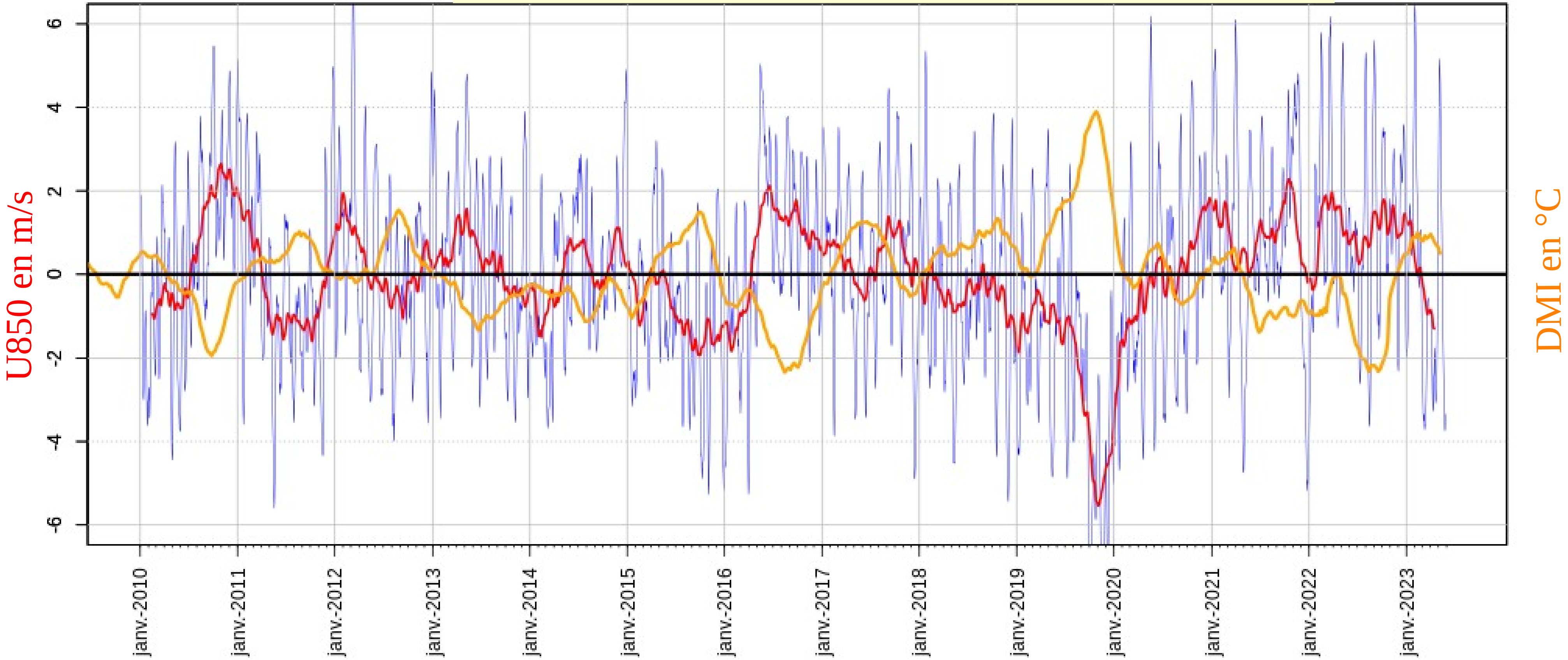
Oscillation modes of the Indian Ocean

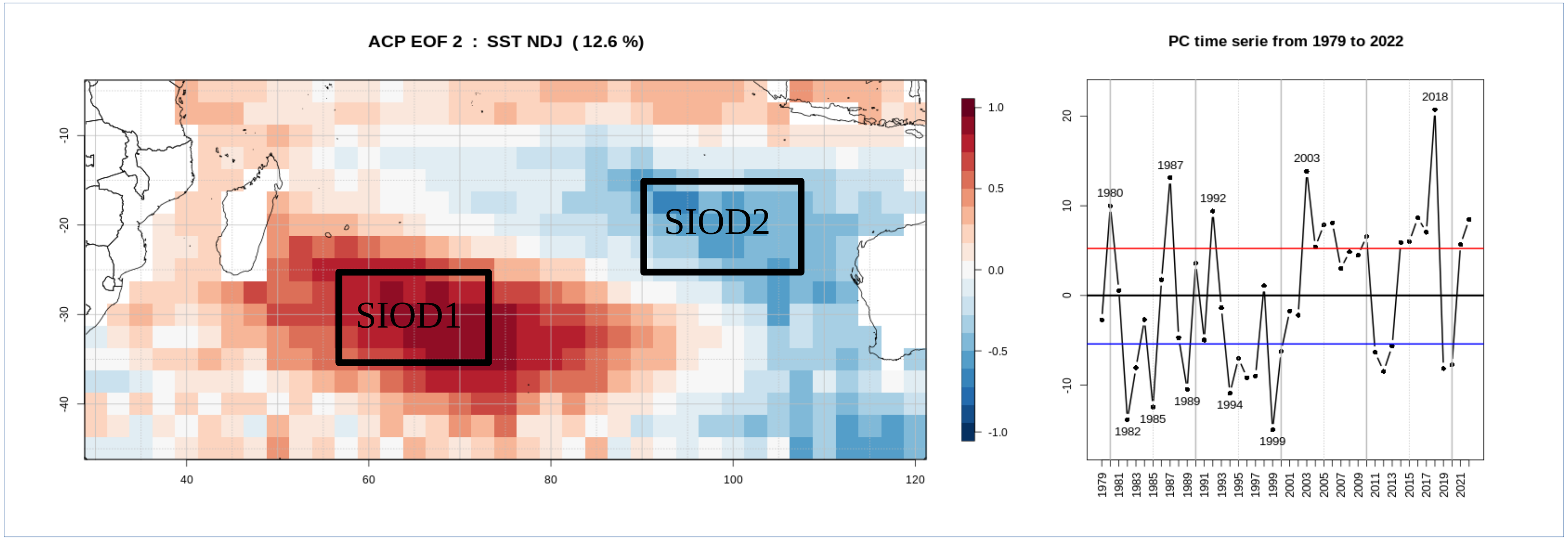
IOD : Indian Ocean Dipole

Ocean-Atmosphere coupling
U850 (Equatorial box) vs DMI (Oceanic Index)

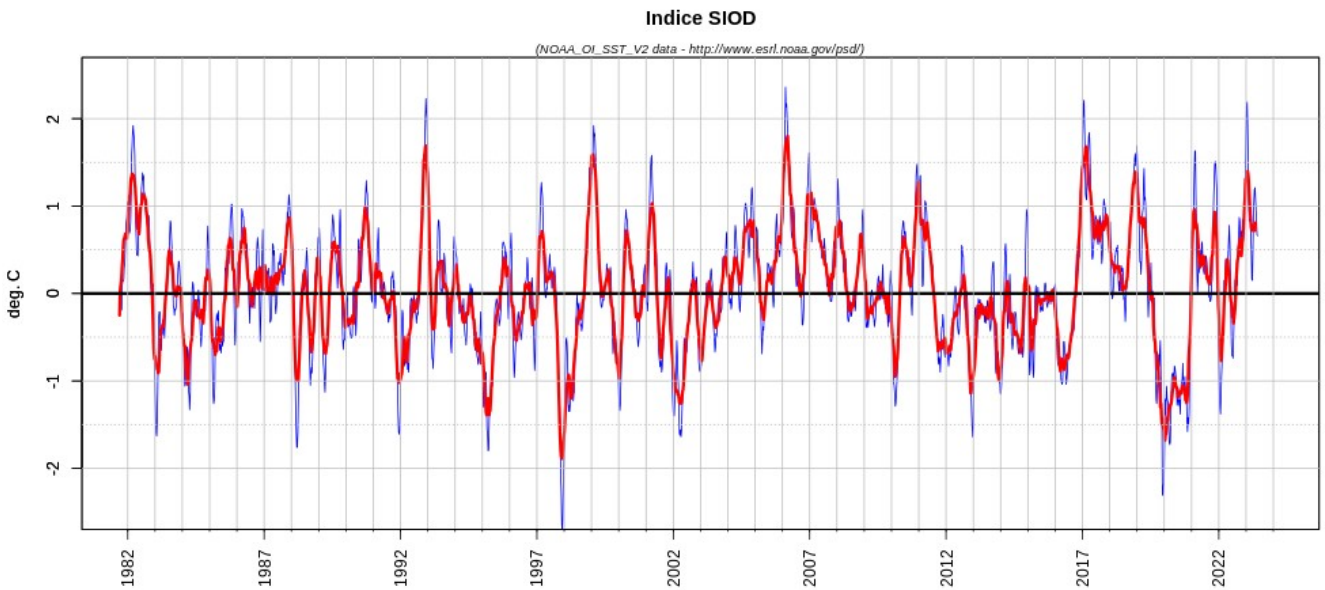


Oscillation modes of the Indian Ocean

SIOD : Subtropical Indian Ocean Dipole

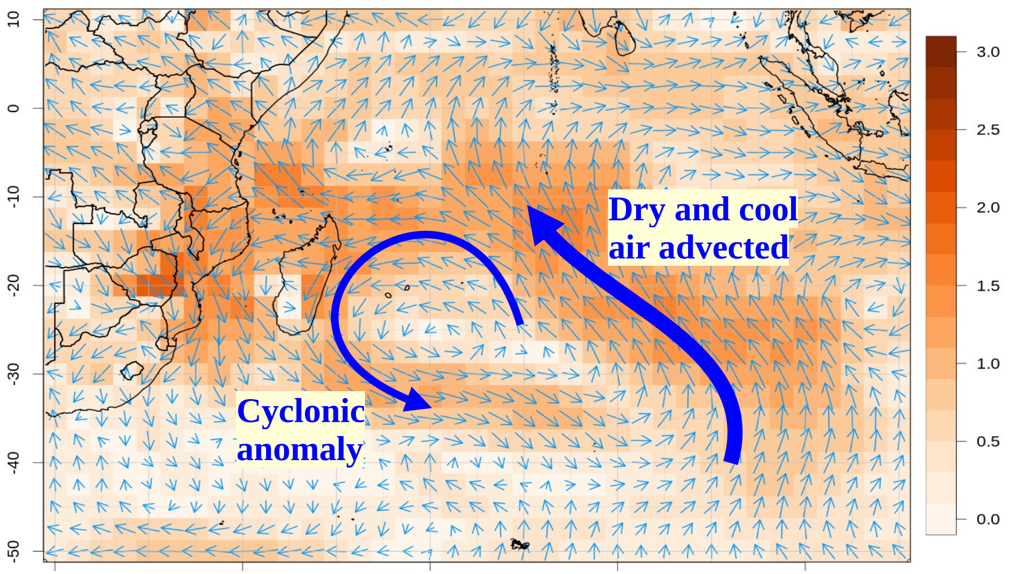


SIOD index = SST anom SIOD1 box – SST anom SIOD2 box

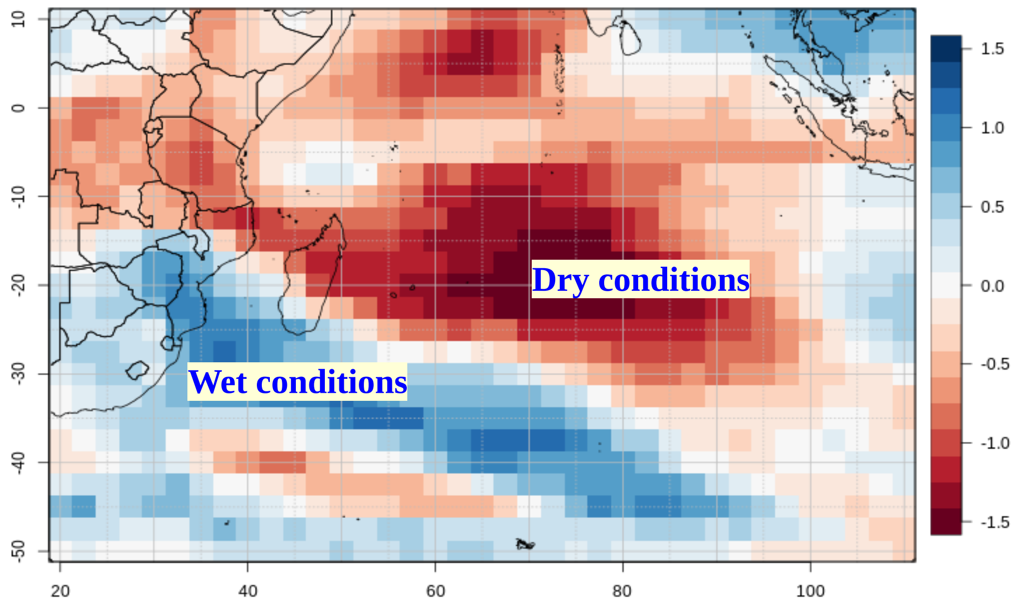


Impact régional SIOD +

ERA5 850hPa WIND ANO. : DJF SIOD+

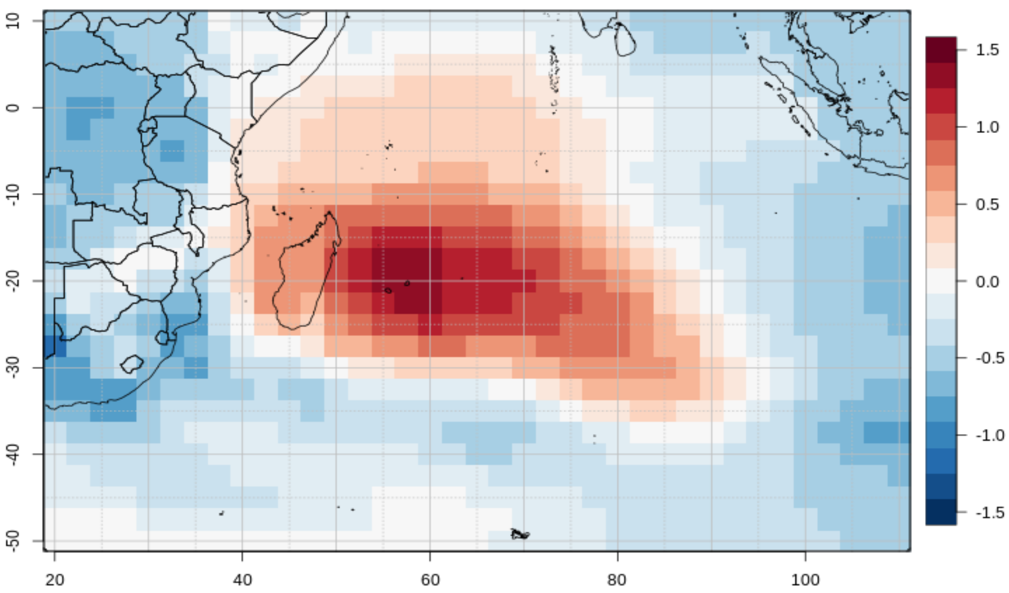


ERA5 STAND. ANO. : TCWV DJF SIOD+



1992 - 1998 - 2005 - 2010 - 2016 - 2022

ERA5 STAND. ANO. : PMER DJF SIOD+



1992 - 1998 - 2005 - 2010 - 2016 - 2022

- Stengthened subtropical high
- Dry and cool air advected with the prefered area of cyclogenesis
- Wet conditions over the South-West of the region

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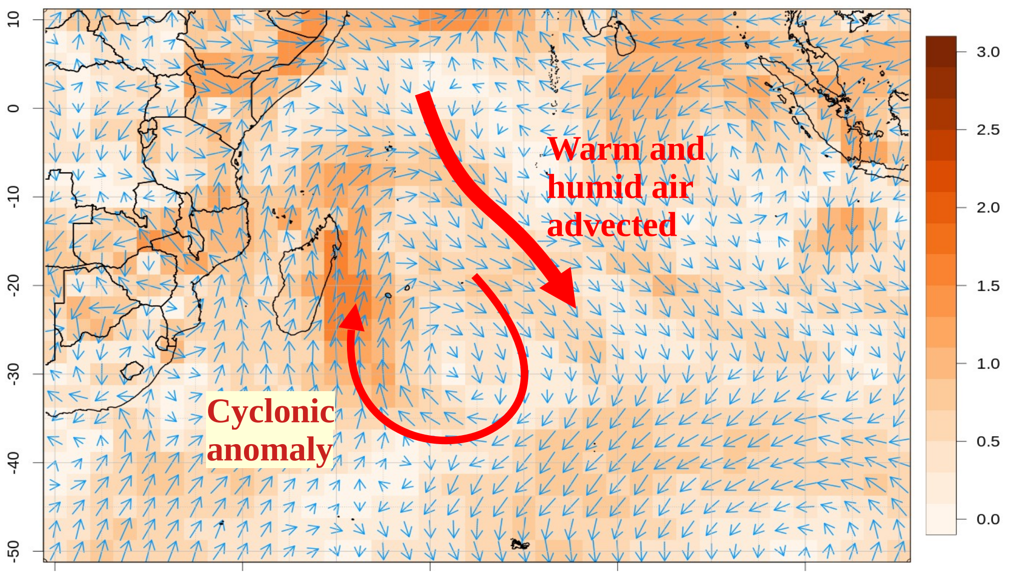
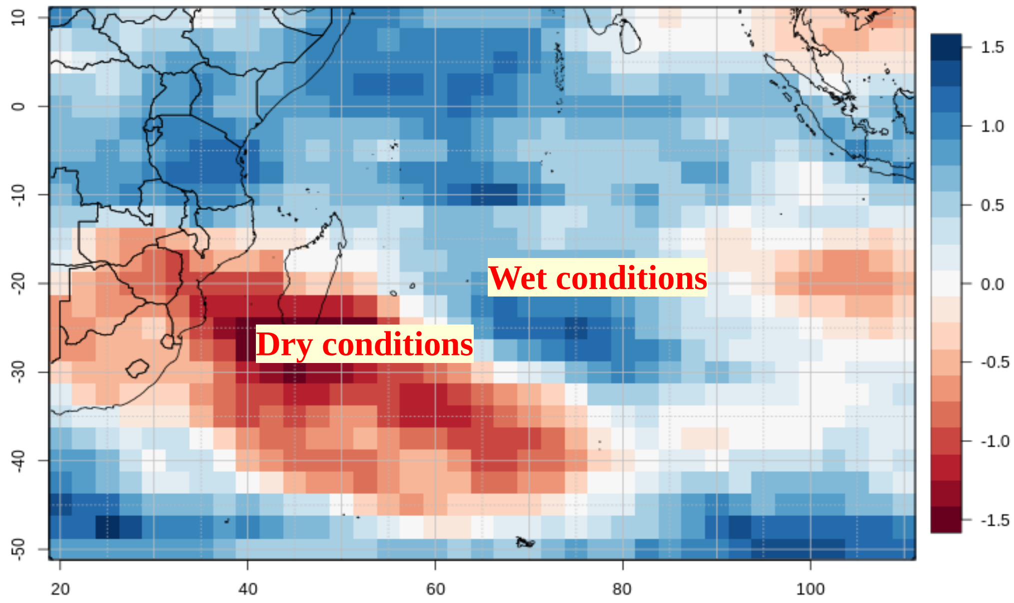
Impact régional SIOD -

ERA5 850hPa WIND ANO. : JFM SIOD-

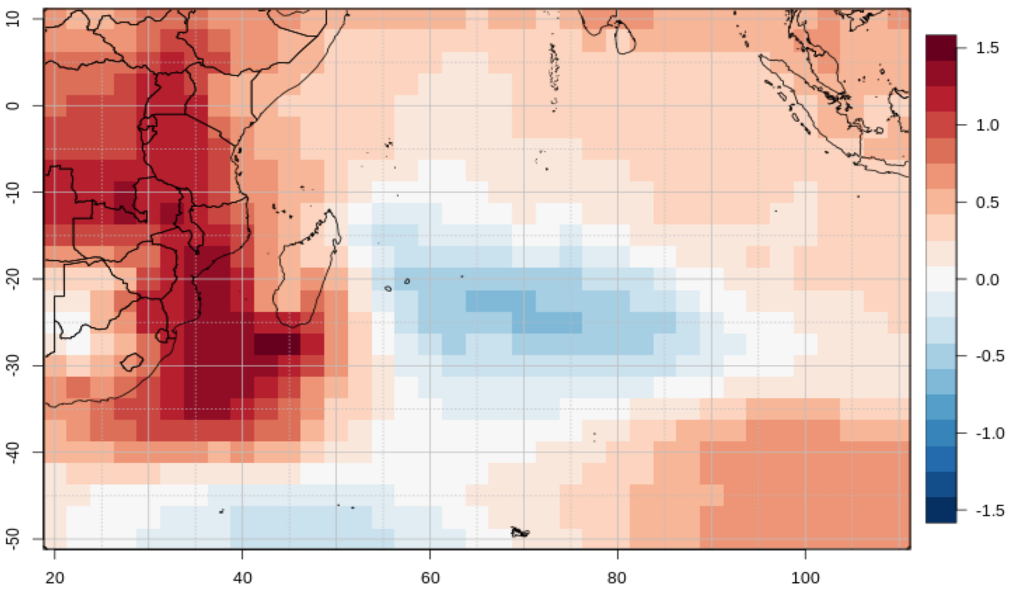


ERA5 STAND. ANO. : TCWV JFM SIOD-



1995 - 2002 - 2013 - 2020

ERA5 STAND. ANO. : PMER JFM SIOD-



1995 - 2002 - 2013 - 2020

- Dry conditions over the South-West part of the region
- Weakened subtropical high
- Warm and humid air advected from equatorial regions in the central part of the basin.

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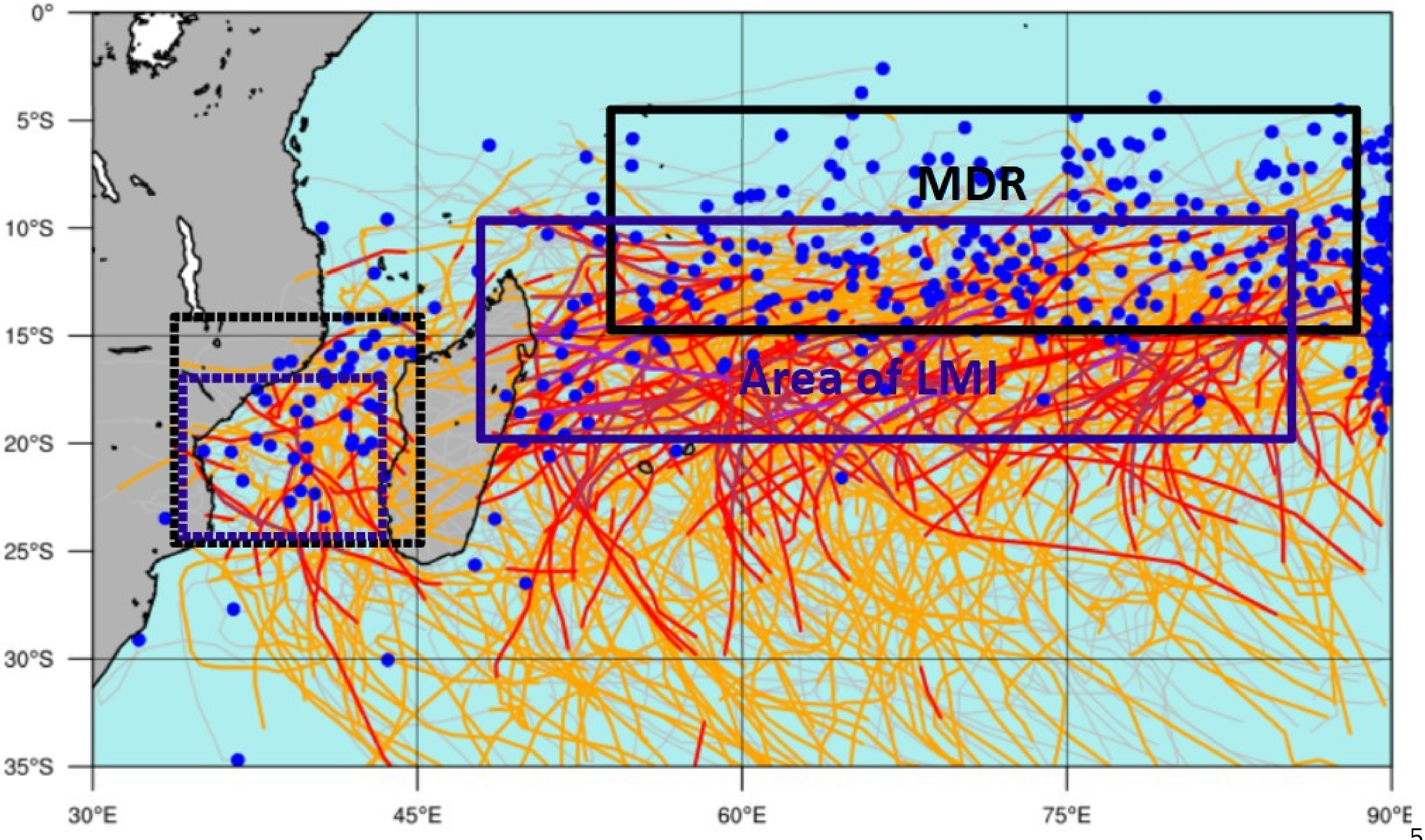
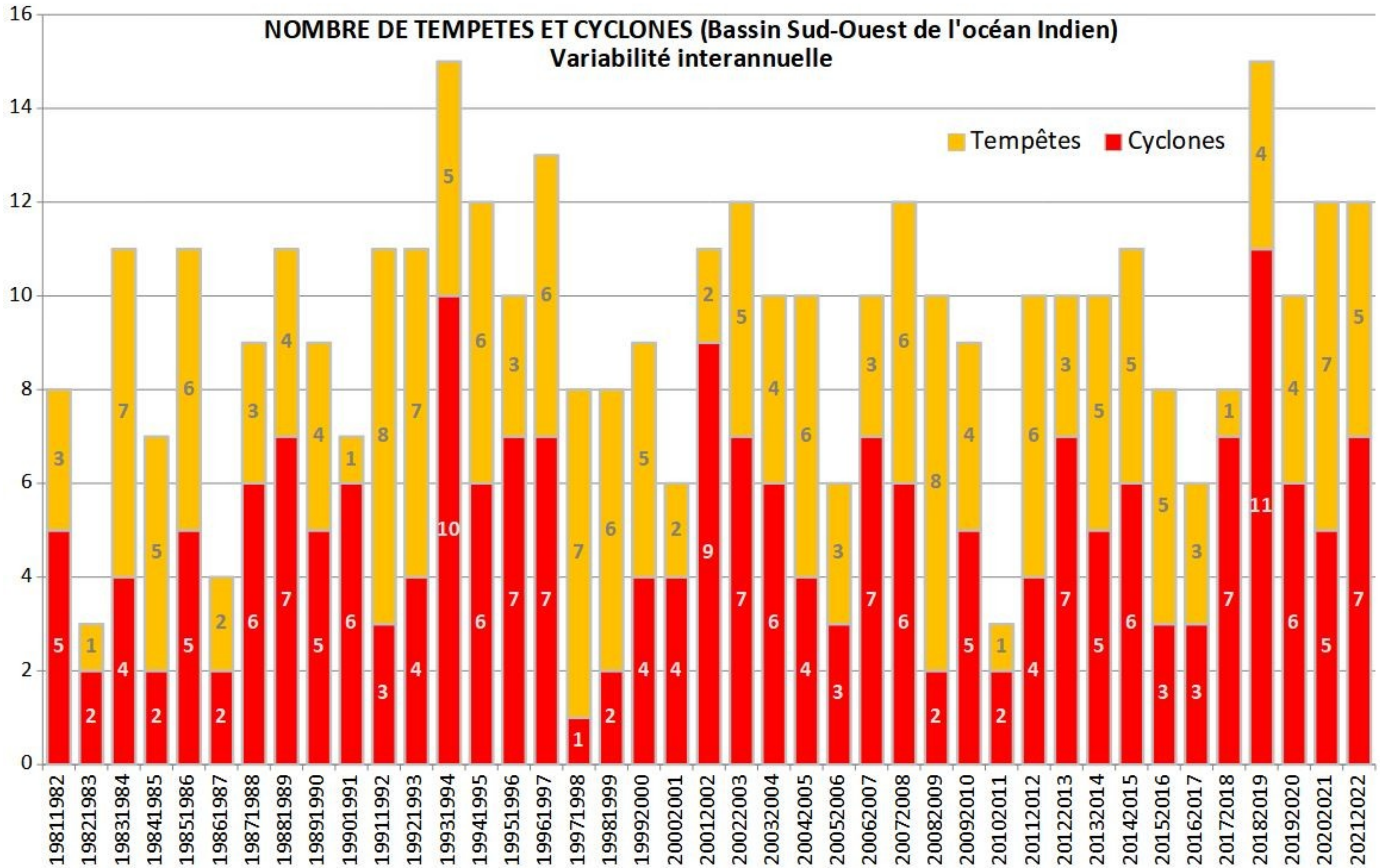
Interannual variability of SWIO basin TC activity

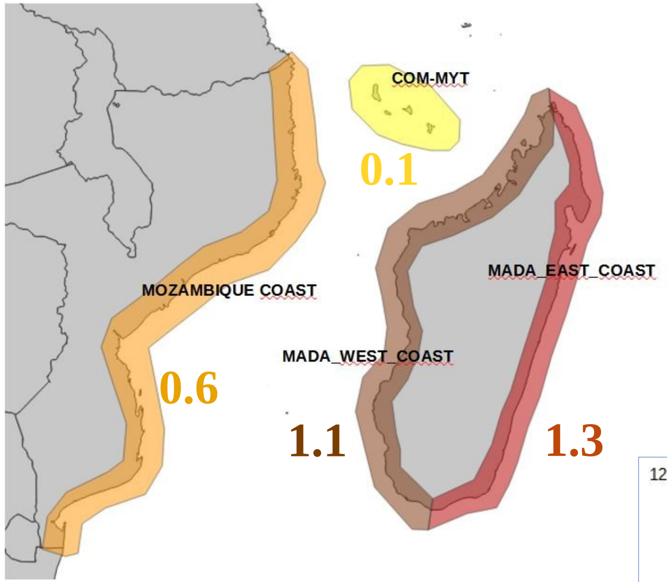


Interannual variability of SWIO basin TC activity

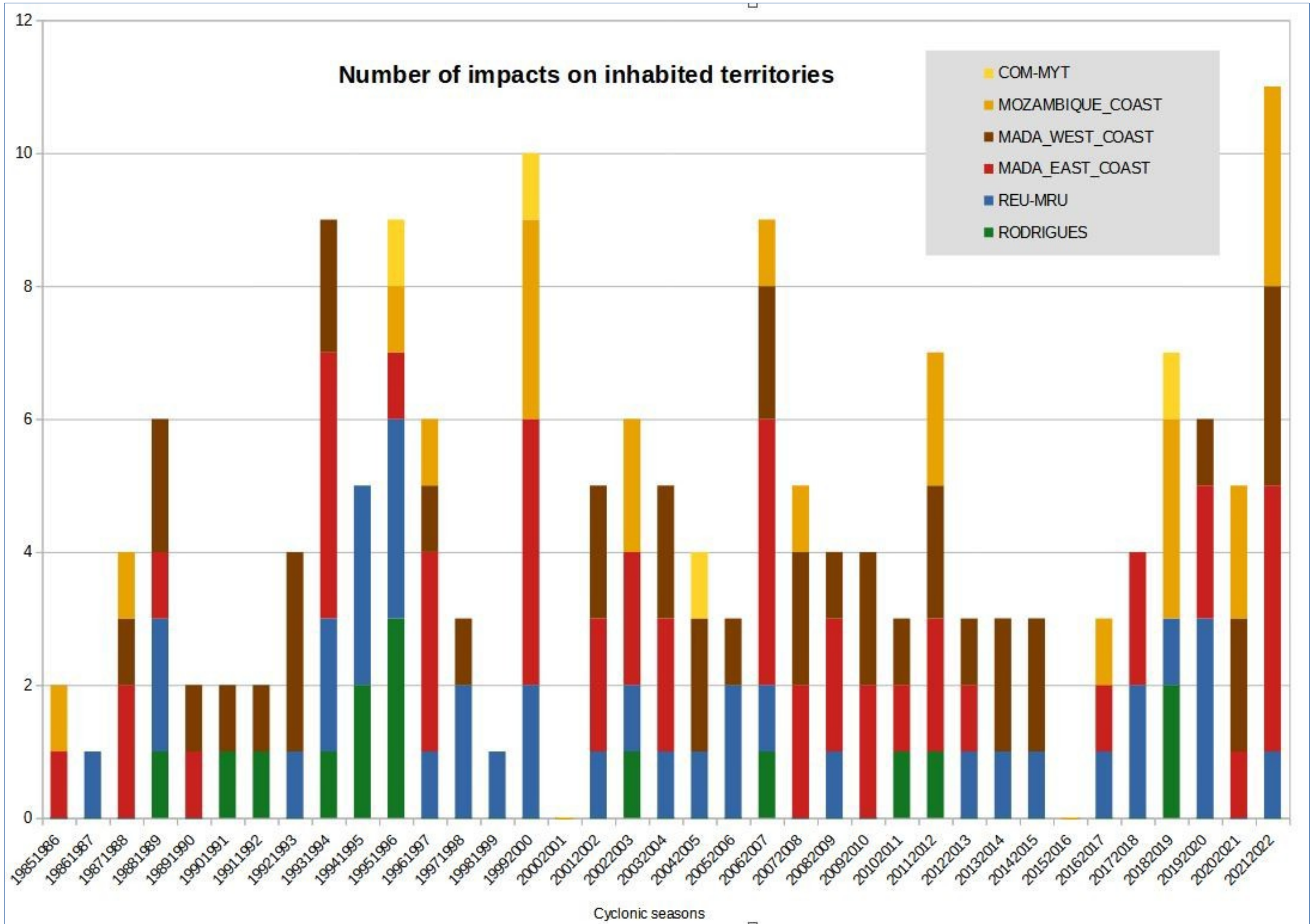
	Tropical storms-cyclones > 33kt	Tropical cyclones > 63kt	Intense tropical cyclones > 89kt	Very intense tropical cyclones > 115kt
Average annual numbers	9,8	5,1	3,3	0,7
Ratio	100 %	52 %	34 %	7 %



Interannual variability with repect to impacts on inhabited areas

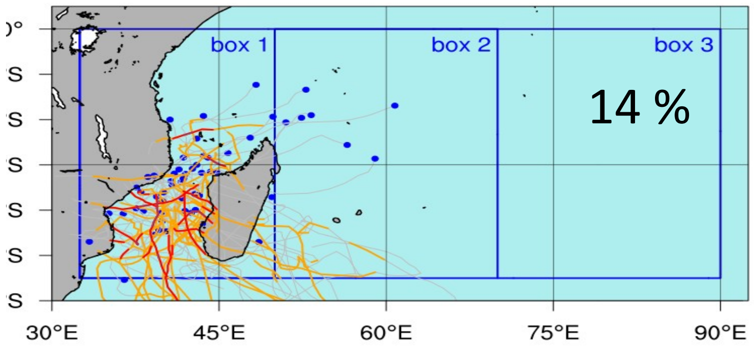


about 4.5 impacts/year

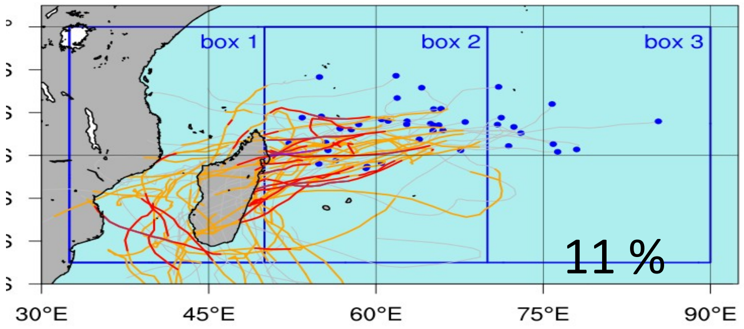


Interannual variability with repect to impacts on inhabited areas
TC tracks classification

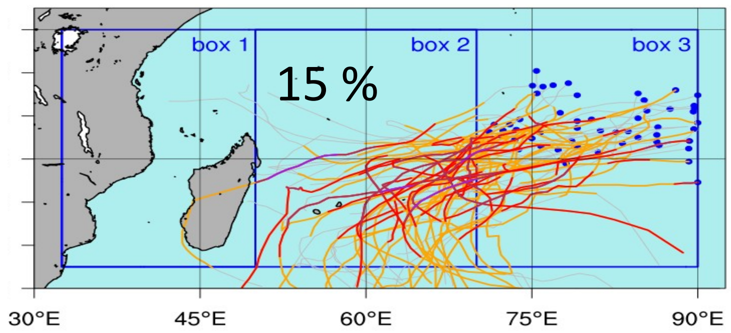
Track classe : 111 (1986-2022)



Track classe : 212 (1986-2022)



Track classe : 323 (1986-2022)



Classification of tracks with respect to :

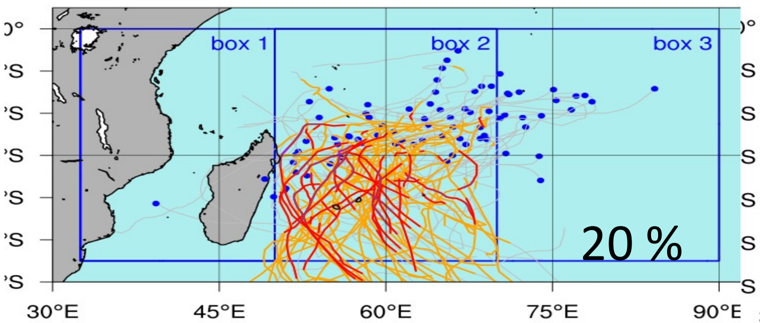
- start longitude (box 1,2,3)
- min longitude (box 1,2,3)
- max longitude (box 1,2,3)

with

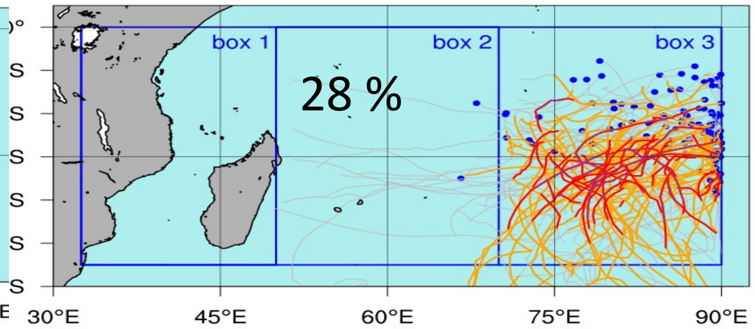
Vmax ≥ 34kt (10 minutes avg wind)

25°S ≤ latitude ≤ 0°

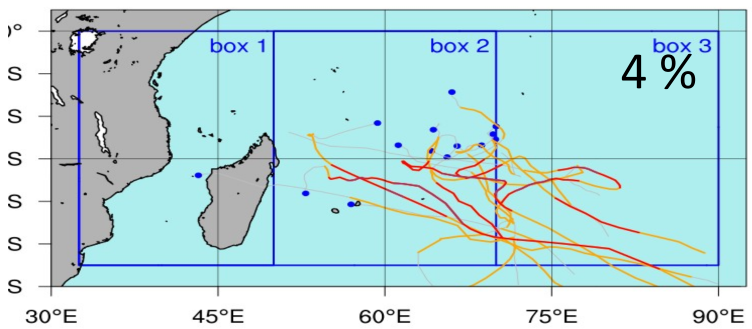
Track classe : 222 (1986-2022)



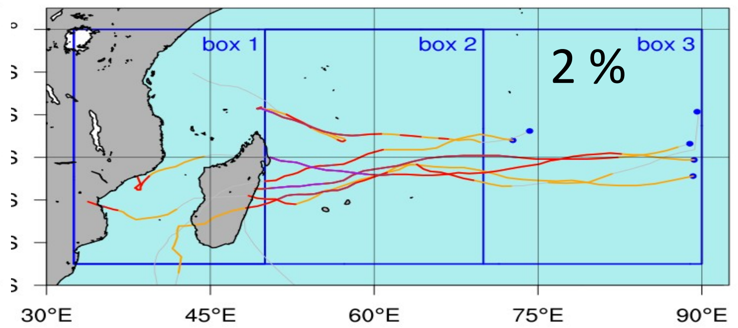
Track classe : 333 (1986-2022)



Track classe : 223 (1986-2022)

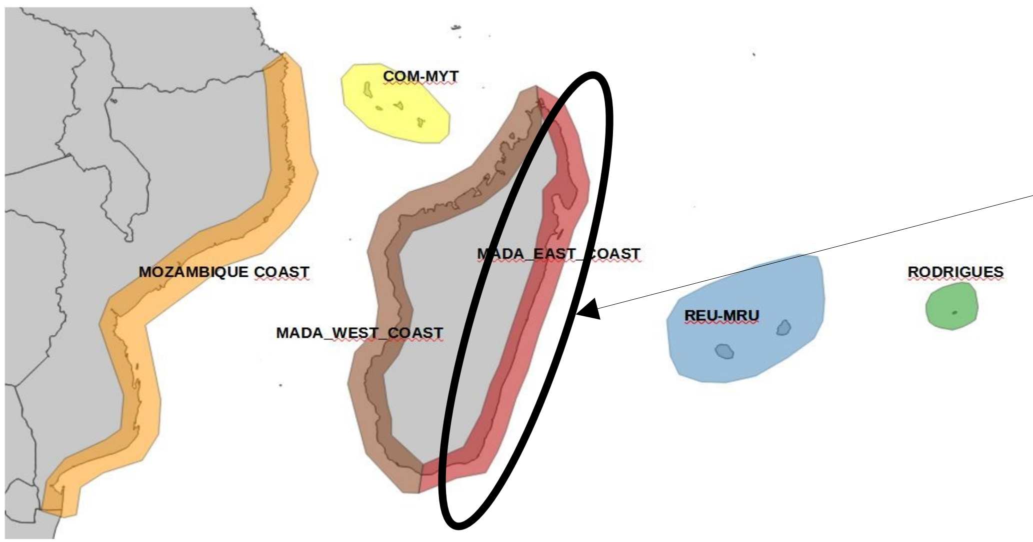


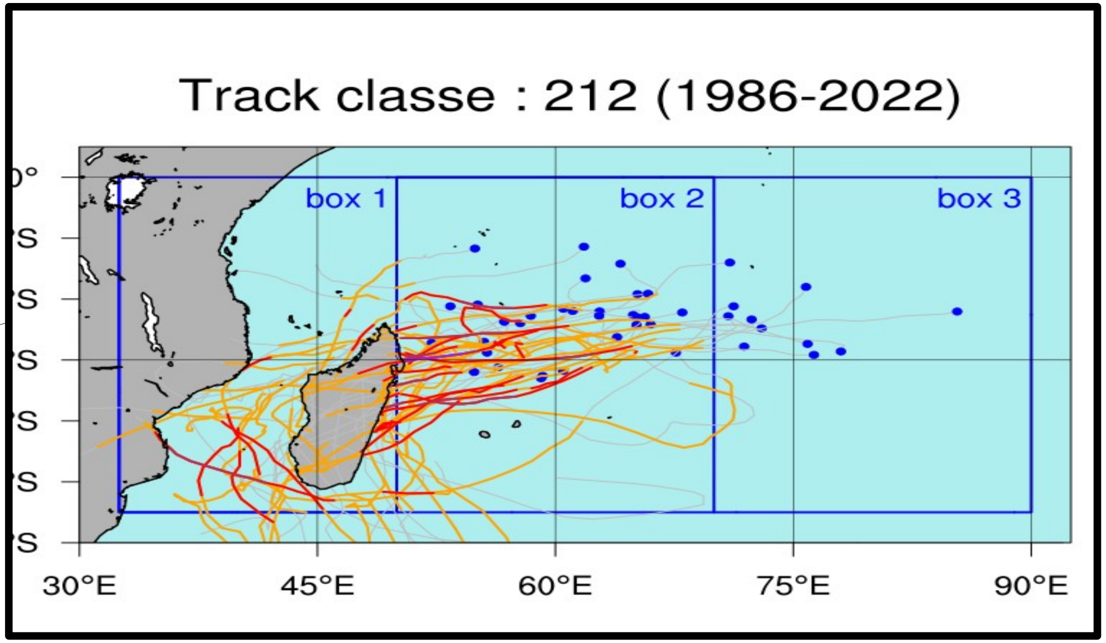
Track classe : 313 (1986-2022)



Interannual variability with repect to impacts on inhabited areas
TC tracks classification

%	RODRIGUES	REU-MRU	MADA_EAST_COAST	MADA_WEST_COAST	MOZAMBIQUE_COAST	COM-MYT
111	0	0	12,8	61	63,6	75
212	6,7	5,4	68,1	39	27,3	25
222	26,7	70,3	6,4	0	0	0
223	6,7	5,4	0	0	0	0
313	0	5,4	10,6	0	9,1	0
323	60	13,5	2,1	0	0	0
333	0	0	0	0	0	0





Interannual variability with repect to impacts on inhabited areas
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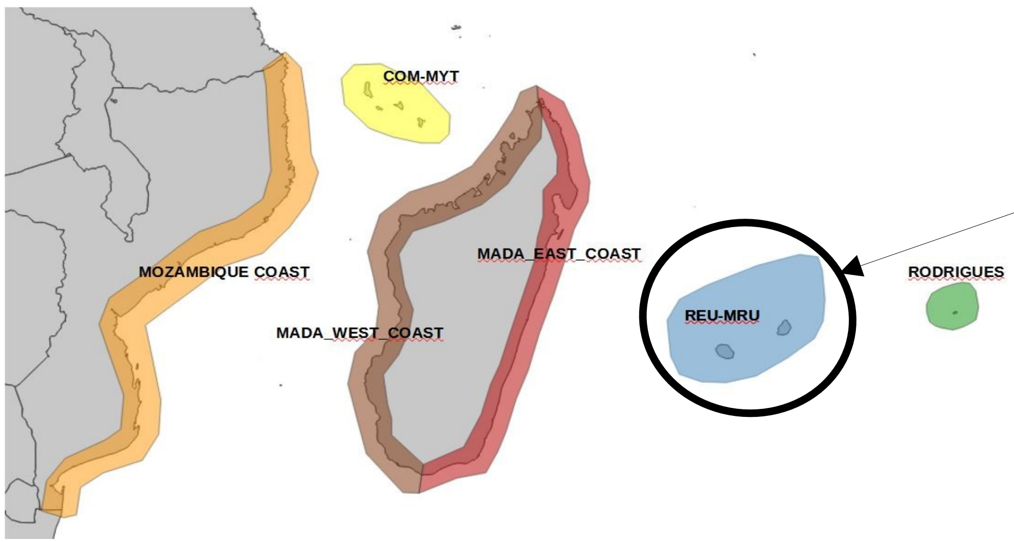
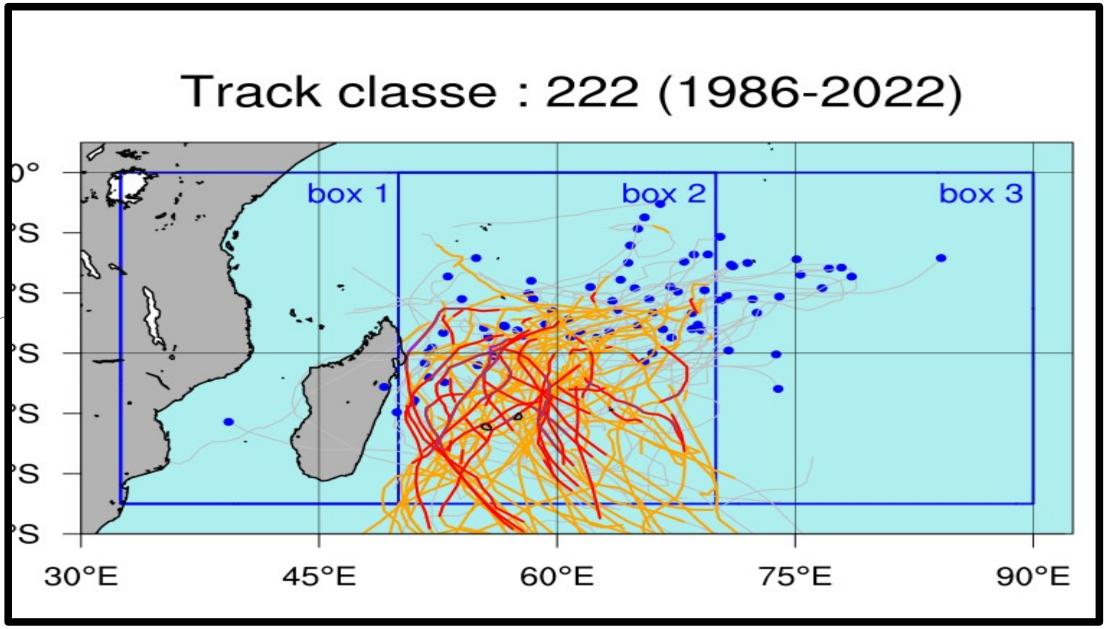
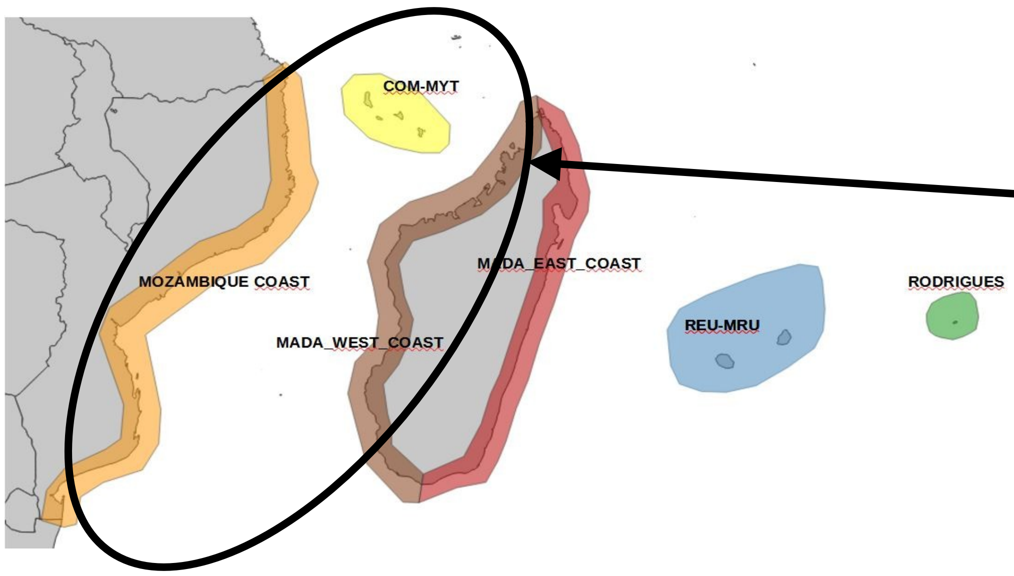
223	6,7	5,4	0	0	0	0
313	0	5,4	10,6	0	9,1	0
323	60	13,5	2,1	0	0	0
333	0	0	0	0	0	0

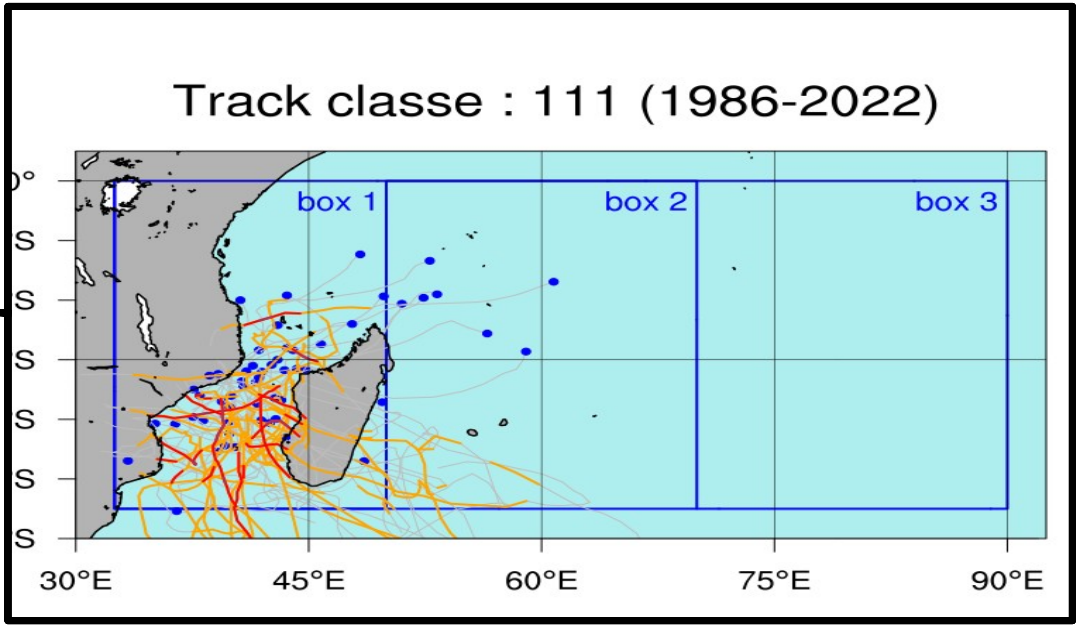




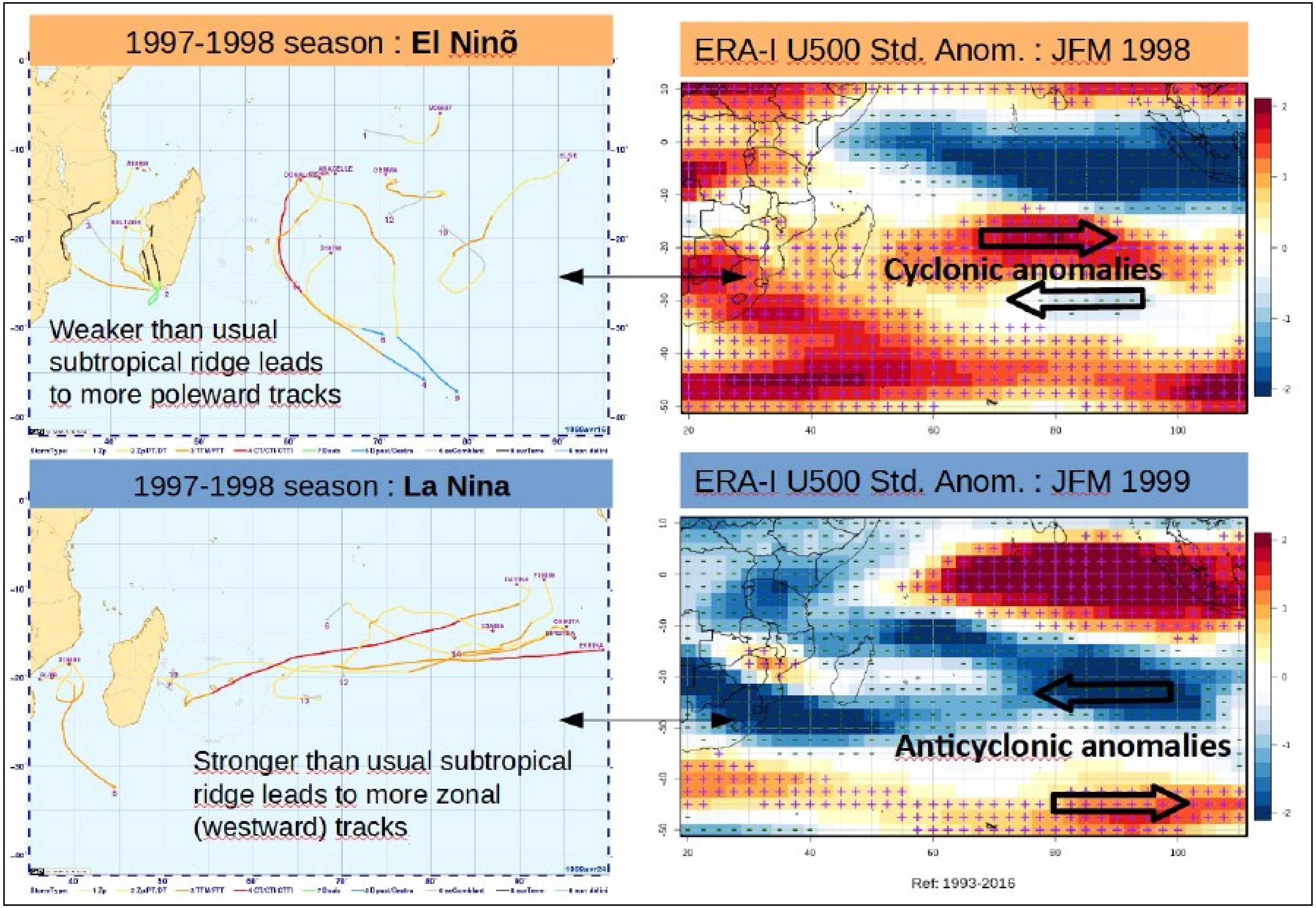
Interannual variability with repect to impacts on inhabited areas
TC tracks classification

%	RODRIGUES	REU-MRU	MADA_EAST_COAST	MADA_WEST_COAST	MOZAMBIQUE_COAST	COM-MYT
111	0	0	12,8	61	63,6	75
212	6,7	5,4	68,1	39	27,3	25
222	26,7	70,3	6,4	0	0	0
223	6,7	5,4	0	0	0	0
313	0	5,4	10,6	0	9,1	0
323	60	13,5	2,1	0	0	0
333	0	0	0	0	0	0





Modulation of the TC activity with repect to the « low frequency » variability modes



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Modulation of the probability to observe an active system from december to march (core of the season)

Climate conf.	Number of Weeks	Probability %	Anomaly %
ALL	641	45,7	0
NINA	139	42,4	-3,3
NINO	134	43,3	-2,4
SIOD-	105	52,4	6,7
SIOD+	114	36,8	-8,9
NINA - SIOD+	32	28,1	-17,6
NINA - SIOD-	10	90	44,3
NINA – IOD-SIOD Neutral	89	44,9	-0,8
NINO - SIOD+	16	50	4,3
NINO - SIOD-	33	45,5	-0,2
NINO – IOD-SIOD Neutral	71	38	-7,7
ENSOneutral - SIOD+	66	37,9	-7,8
ENSOneutral - SIOD-	62	56,5	10,8
IOD-	39	59	13,3
IOD+	25	32	-13,7
NINA - IOD-	5	40	-5,7
NINA - IOD+	5	40	-5,7
NINO - IOD-	13	7,7	-38
NINO - IOD+	10	10	-35,7
ENSOneutral - IOD+	10	40	-5,7
ENSOneutral - IOD-	21	61,9	16,2
All Neutral	223	48,4	2,7

Modulation of the probability to observe an active system from october to january (first half of the season)

Climate conf.	Number of Weeks	Probability %	Anomaly %
ALL	650	27,5	0
NINA	183	23,5	-4
NINO	151	25,8	-1,7
SIOD-	83	41	13,5
SIOD+	110	24,5	-3
NINA - SIOD+	36	19,4	-8,1
NINA - SIOD-	19	36,8	9,3
NINA – IOD-SIOD Neutral	104	29,8	2,3
NINO - SIOD+	21	42,9	15,4
NINO - SIOD-	26	30,8	3,3
NINO – IOD-SIOD Neutral	83	24,1	-3,4
ENSOneutral - SIOD+	53	20,8	-6,7
ENSOneutral - SIOD-	38	55,3	27,8
IOD-	72	13,9	-13,6
IOD+	63	14,3	-13,2
NINA - IOD-	29	0	-27,5
NINA - IOD+	1	0	-27,5
NINO - IOD-	4	0	-27,5
NINO - IOD+	40	12,5	-15
ENSOneutral - IOD+	22	18,2	-9,3
ENSOneutral - IOD-	39	23,1	-4,4
All Neutral	183	48,4	20,9

Modulation of the probability to observe an active system from february to april (second half of the season)

Climate conf.	Number of Weeks	Probability %	Anomaly %
ALL	636	30,7	0
NINA	89	34,8	4,1
NINO	93	38,7	8
SIOD-	84	35,7	5
SIOD+	69	43,5	12,8
NINA - SIOD+	9	33,3	2,6
NINA - SIOD-	3	100	69,3
NINA - IOD-SIOD Neutral	60	33,3	2,6
NINO - SIOD+	4	50	19,3
NINO - SIOD-	20	45	14,3
NINO - IOD-SIOD Neutral	56	30,4	-0,3
ENSOneutral - SIOD+	56	44,6	13,9
ENSOneutral - SIOD-	61	29,5	-1,2
IOD-	57	38,6	7,9
IOD+	36	13,9	-16,8
NINA - IOD-	13	15,4	0
NINA - IOD+	5	40	0
NINO - IOD-	14	0	0
NINO - IOD+	0		0
ENSOneutral - IOD+	31	6,5	-24,2
ENSOneutral - IOD-	30	30	-0,7
All Neutral	286	26,6	-4,1

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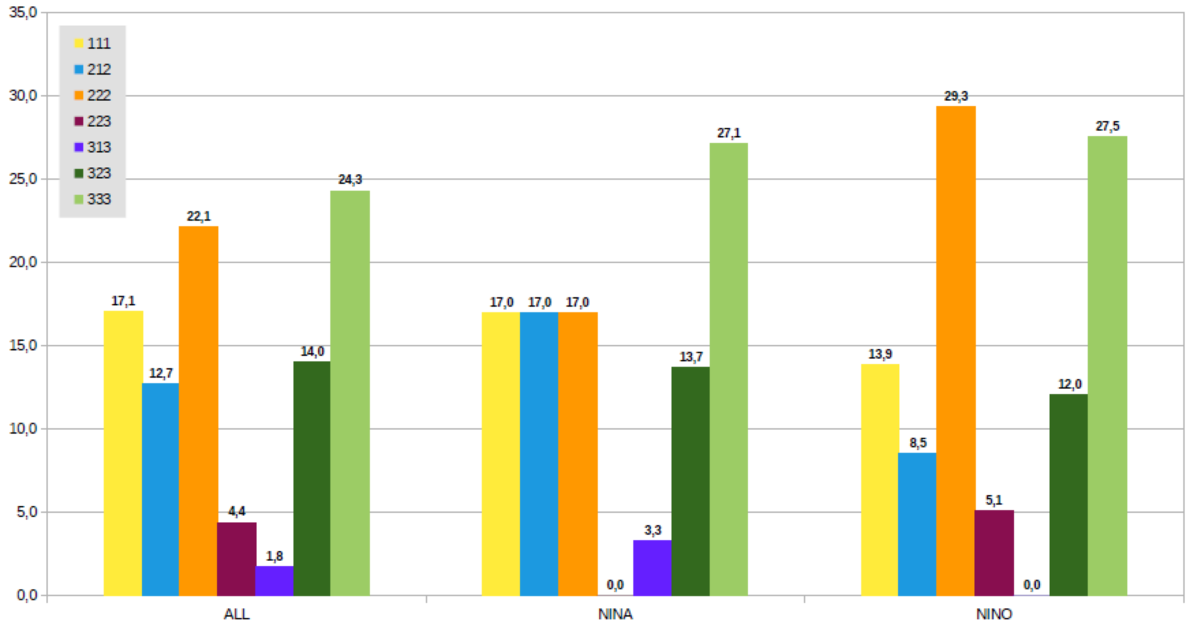
Modulation des types de trajectoire par l'ENSO

a) ENSO



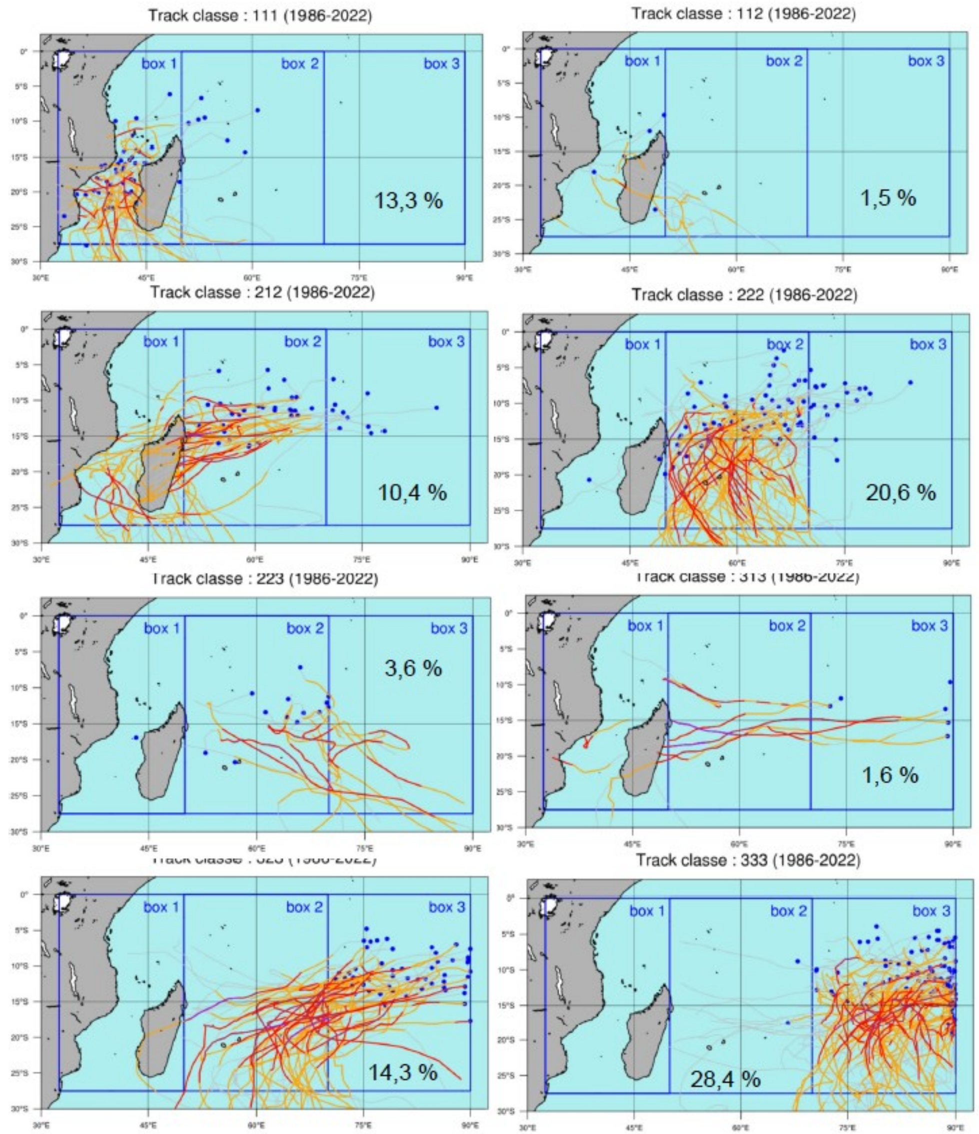


Figure 11 : Modulation of classes proportion with respect to ENSO phases during the core of the cyclonic season (December to March). Proportions are expressed in %

Modulation des types de trajectoire par l'ENSO

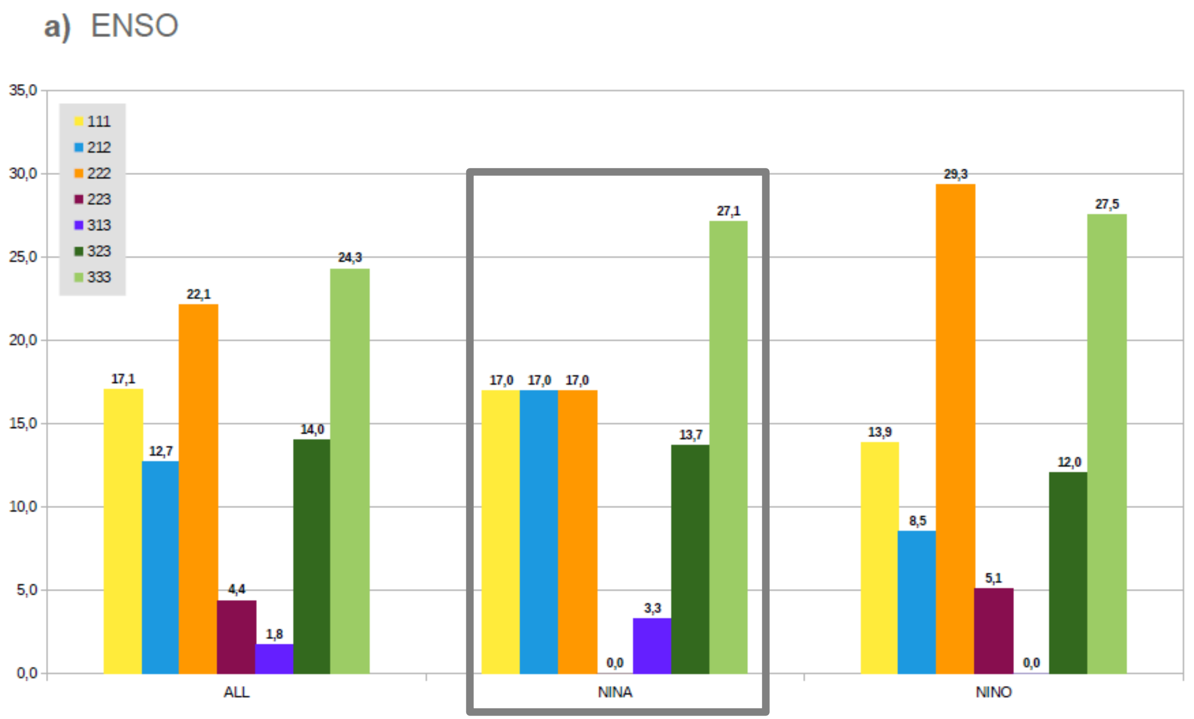
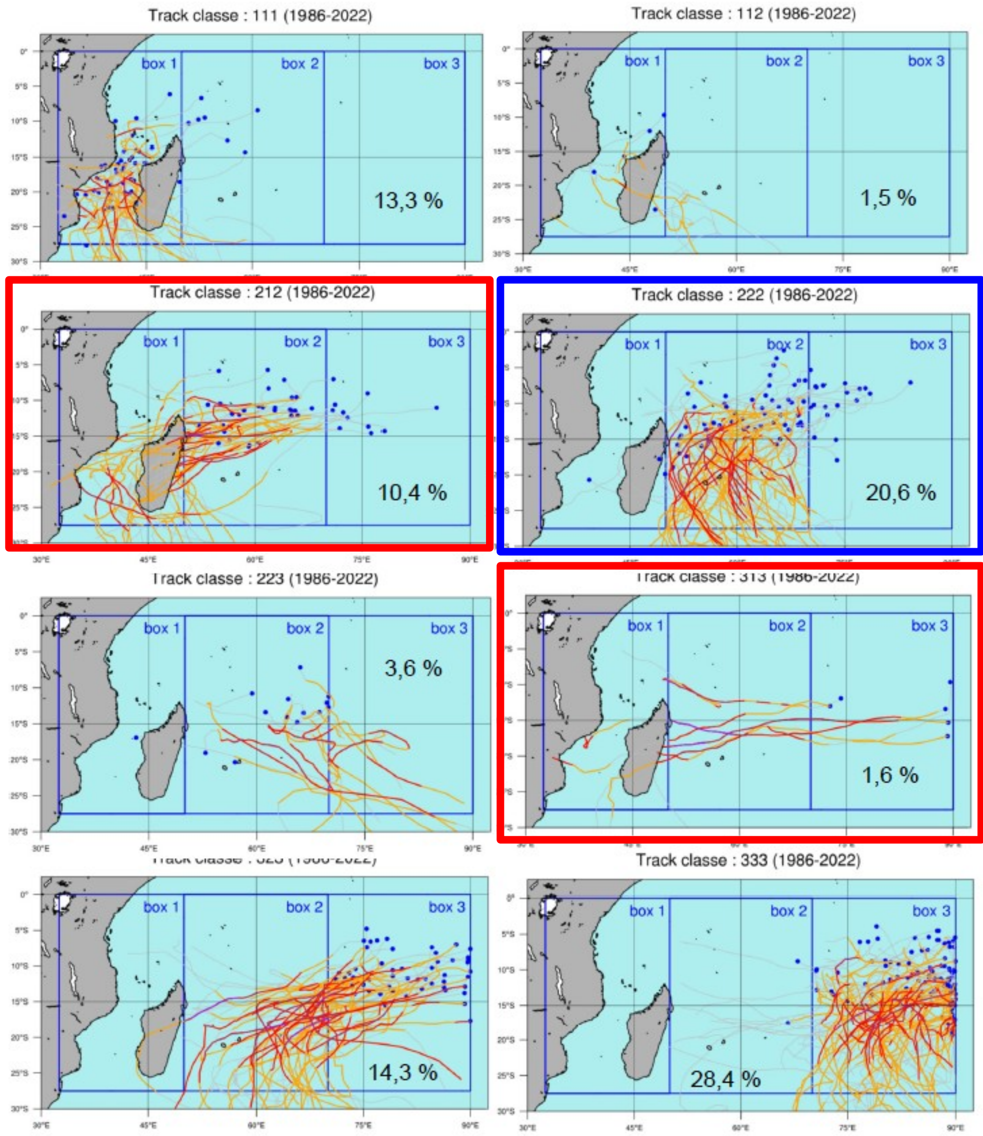


Figure 11 : Modulation of classes proportion with respect to ENSO phases during the core of the cyclonic season (December to March). Proportions are expressed in %



NINA
212, 313 favored
222 reduced

Modulation des types de trajectoire l'ENSO

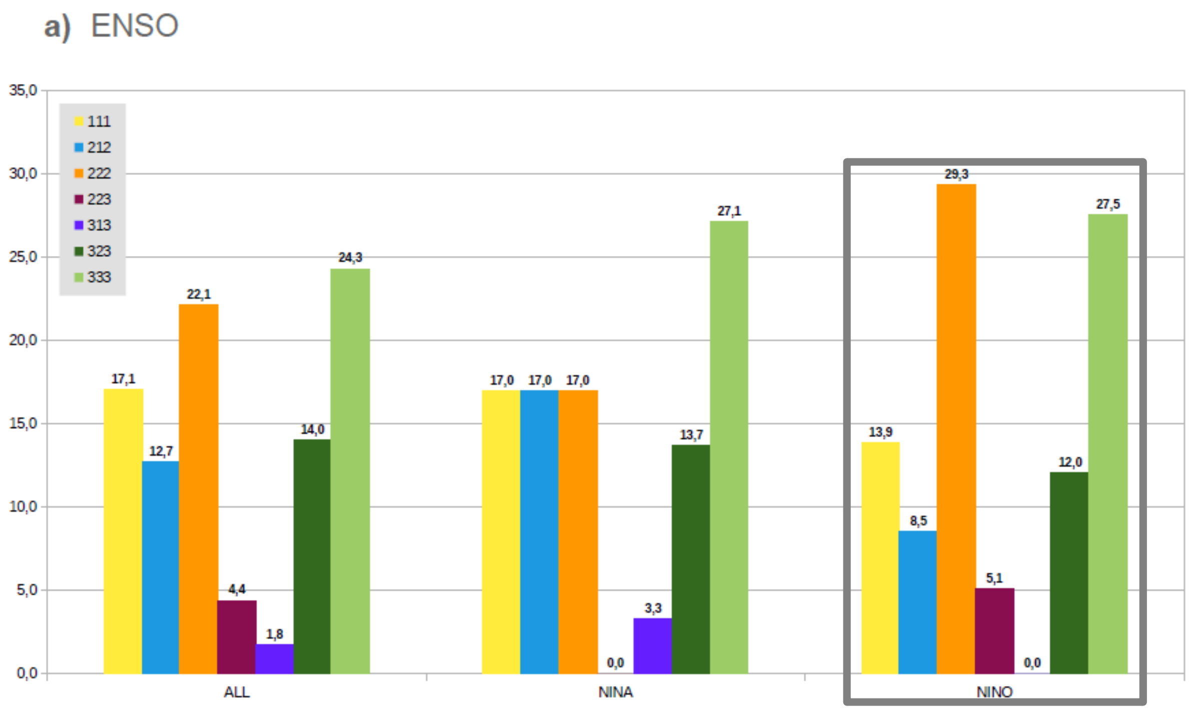
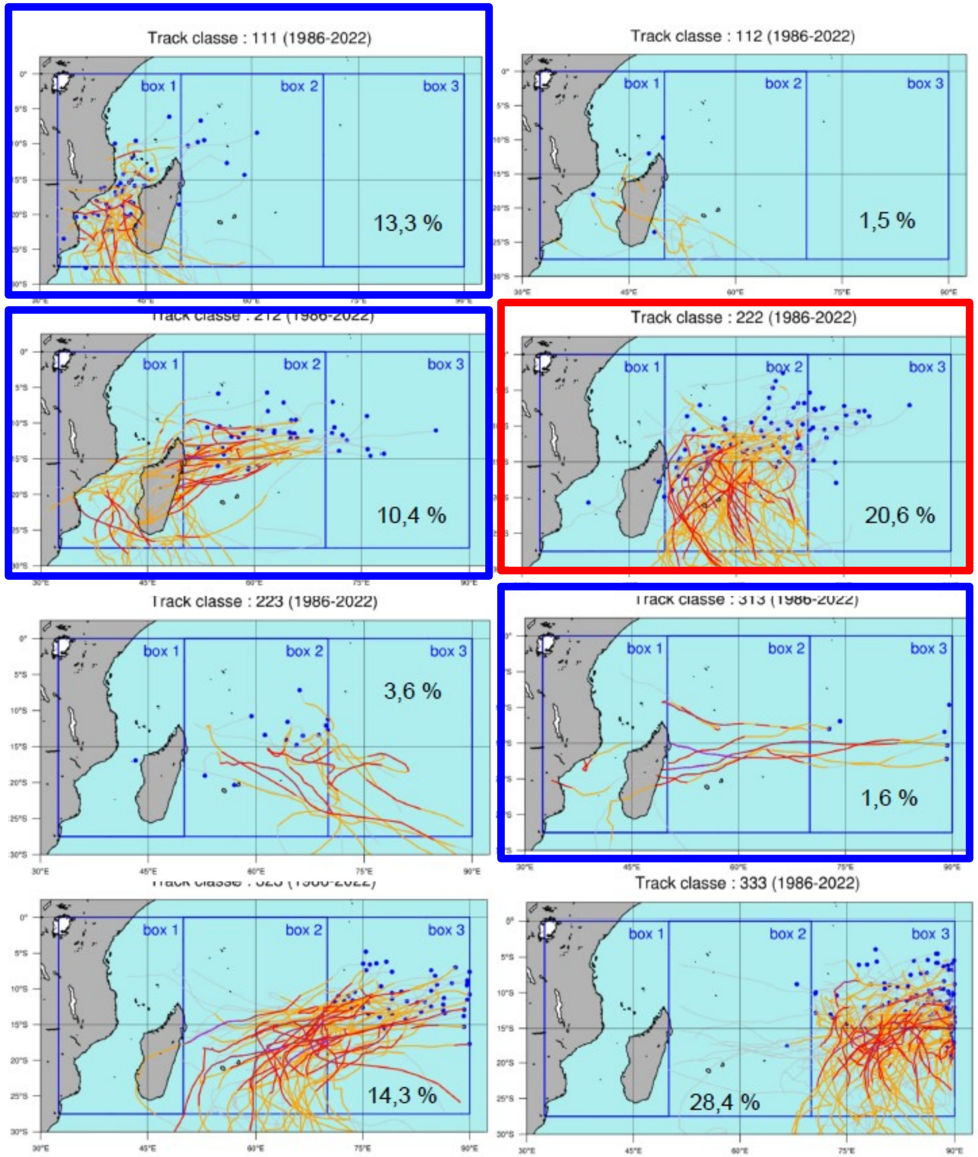
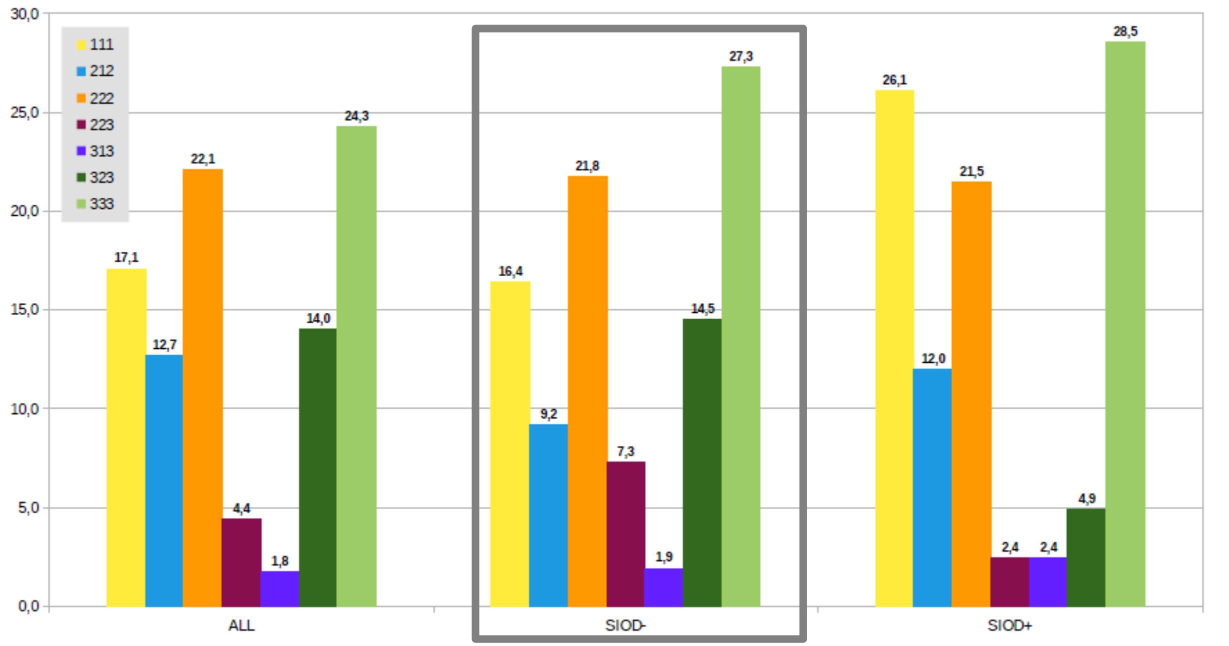


Figure 11 : Modulation of classes proportion with respect to ENSO phases during the core of the cyclonic season (December to March). Proportions are expressed in %



NINO
222 favored
212, 313, 111 reduced

Modulation des types de trajectoire par le SIOD



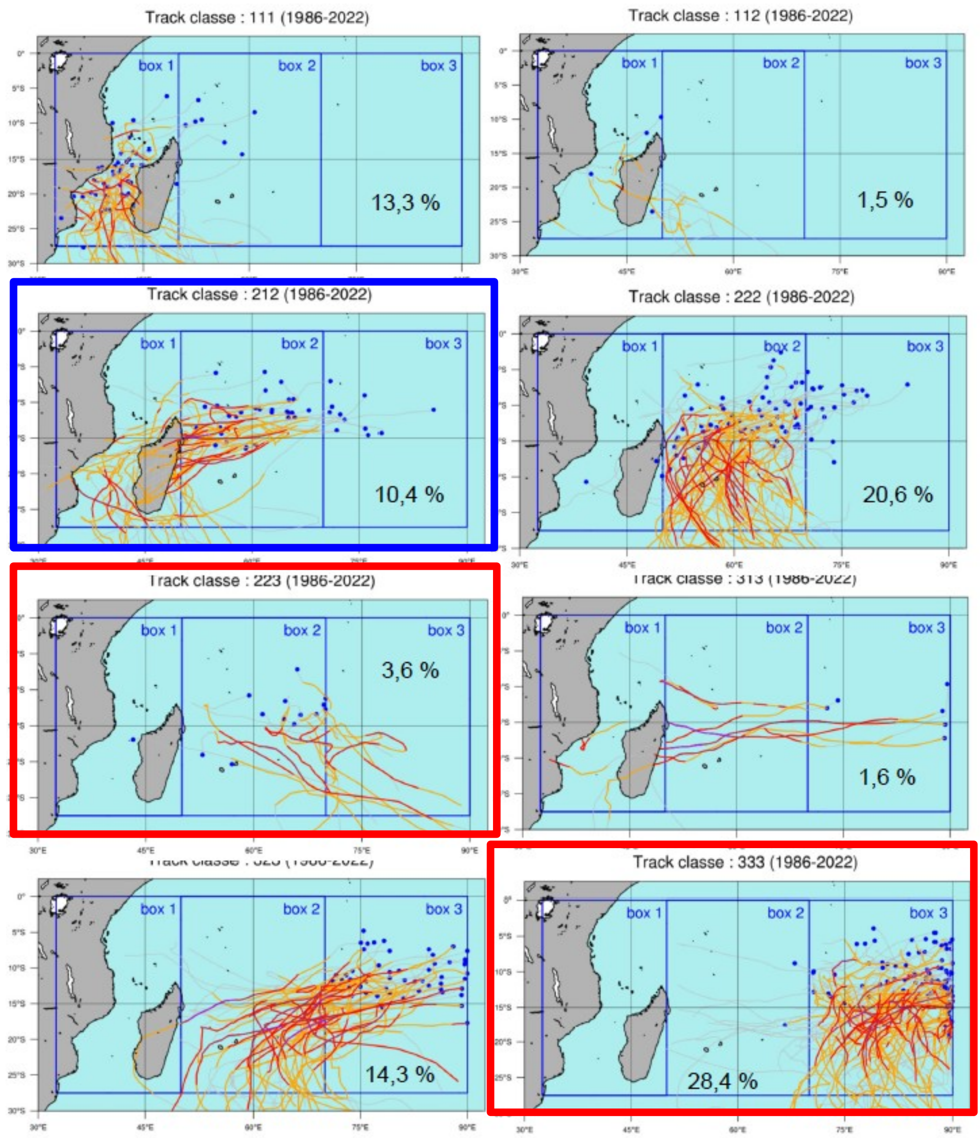


Figure 12 : Modulation of classes proportions with respect to SIOD phases during the core of the cyclonic season (December to March). Proportions are expressed in %

SIOD -
223, 333 favored
212 reduced

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Modulation des types de trajectoire par le SIOD

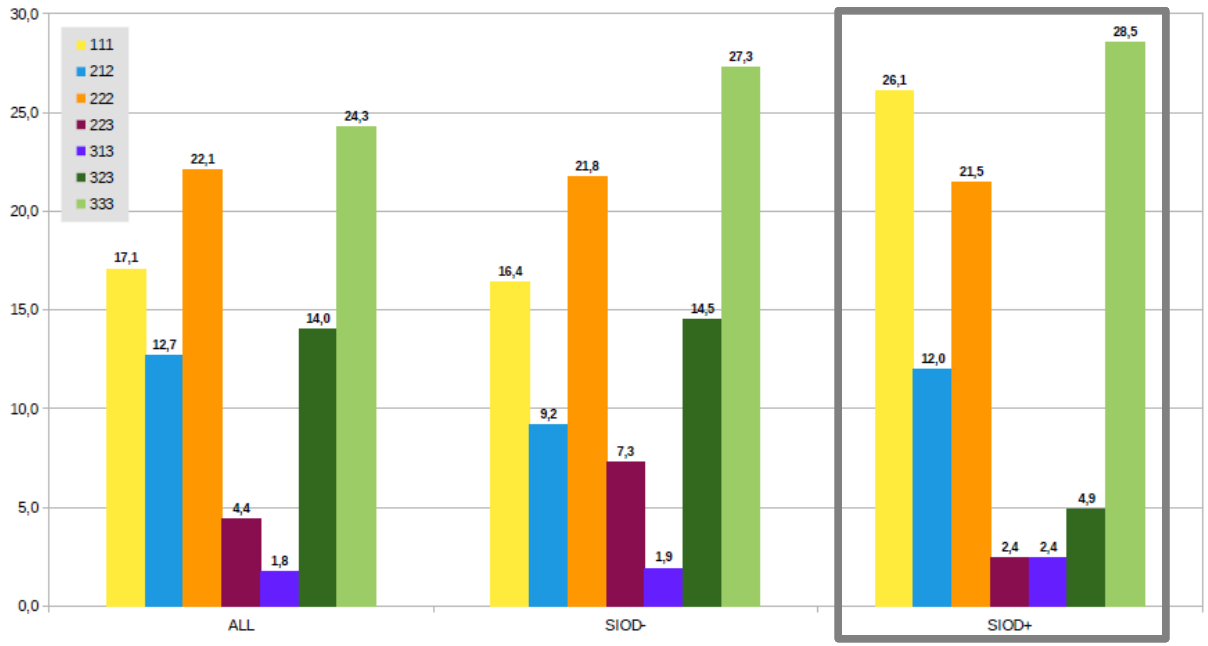
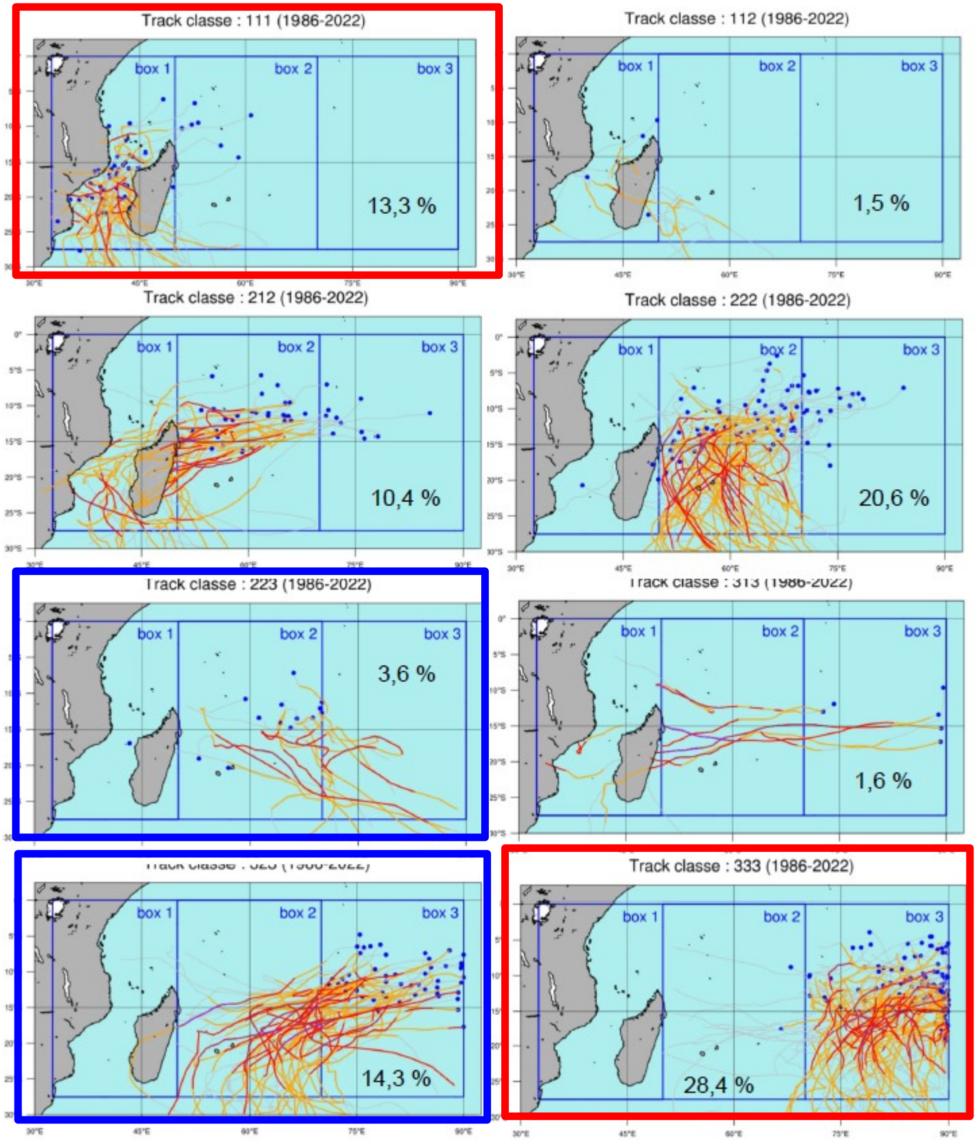


Figure 12 : Modulation of classes proportions with respect to SIOD phases during the core of the cyclonic season (December to March). Proportions are expressed in %



SIOD +
111, 333 favored
323, 223 reduced

Modulation des types de trajectoire par l'IOD

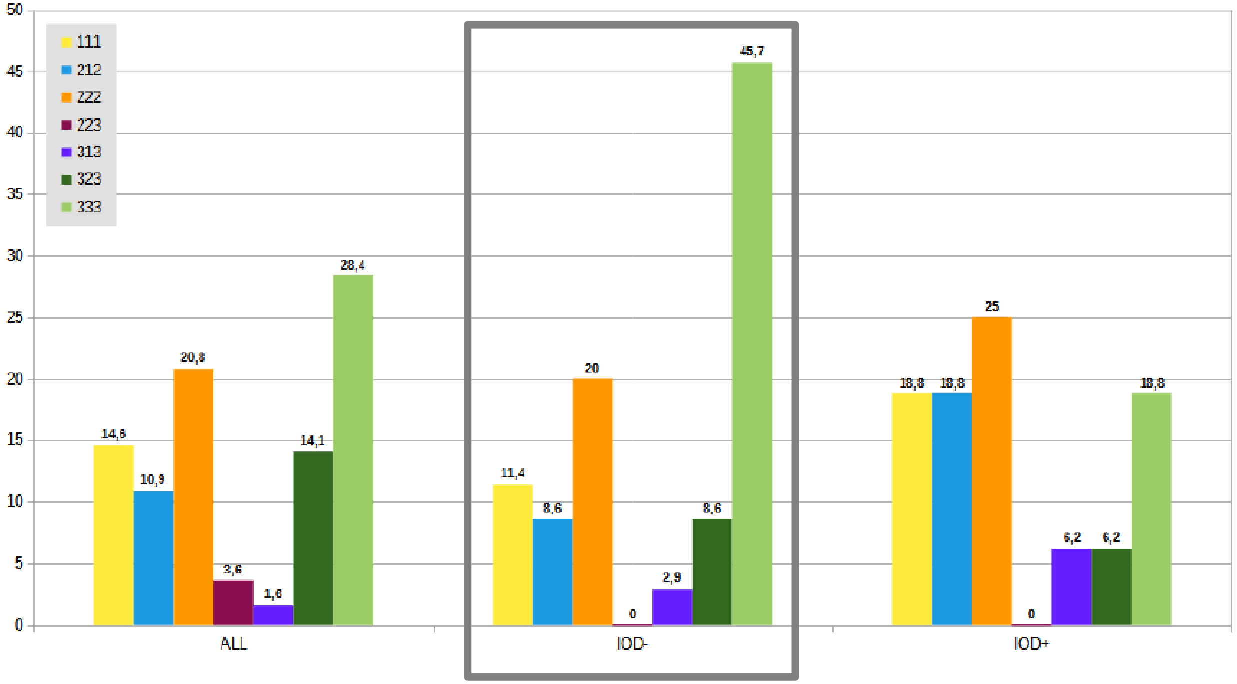
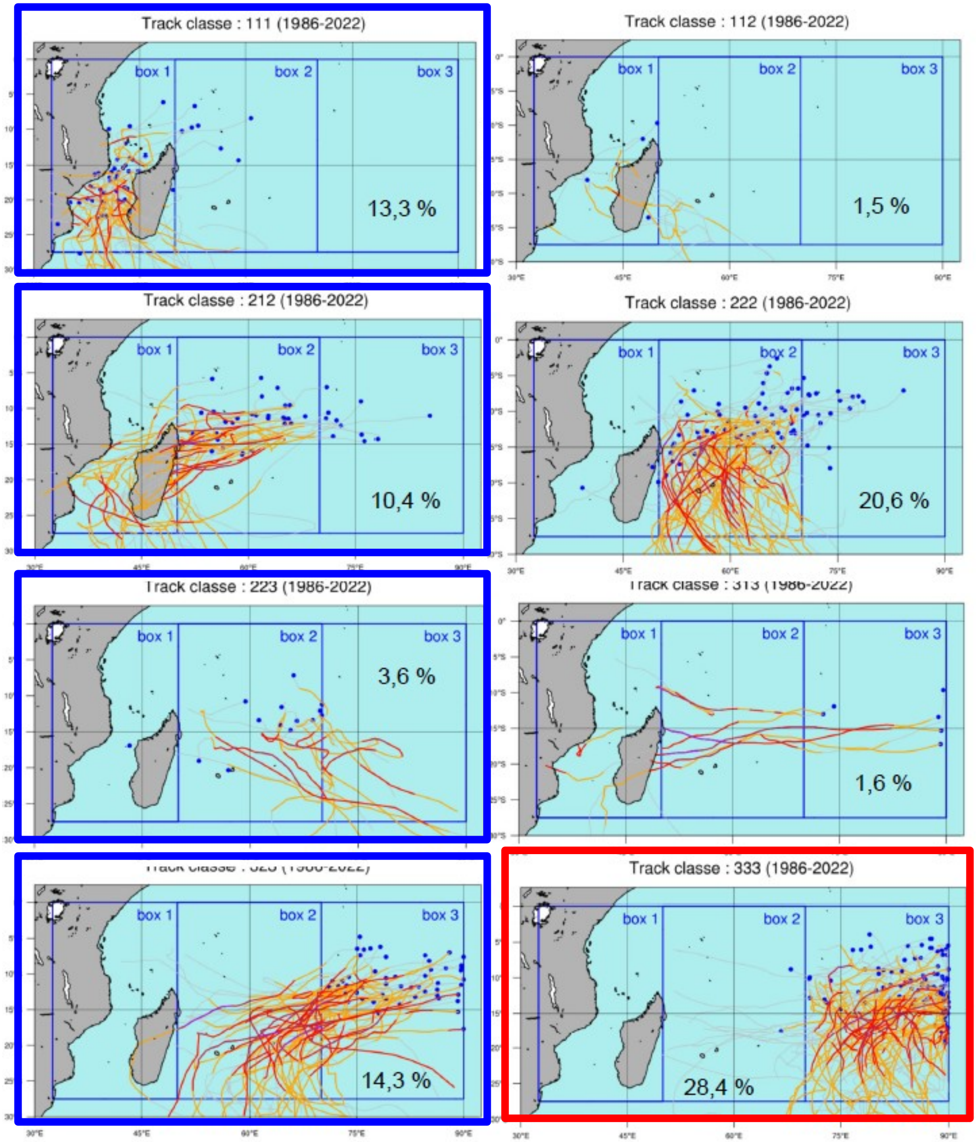


Figure 13 : Modulation of classes proportions with respect to IOD phases during the first half of the cyclonic season (October to January). Proportions are expressed in %



IOD -

333 strongly favored

323, 223 reduced

Modulation des types de trajectoire par l'IOD

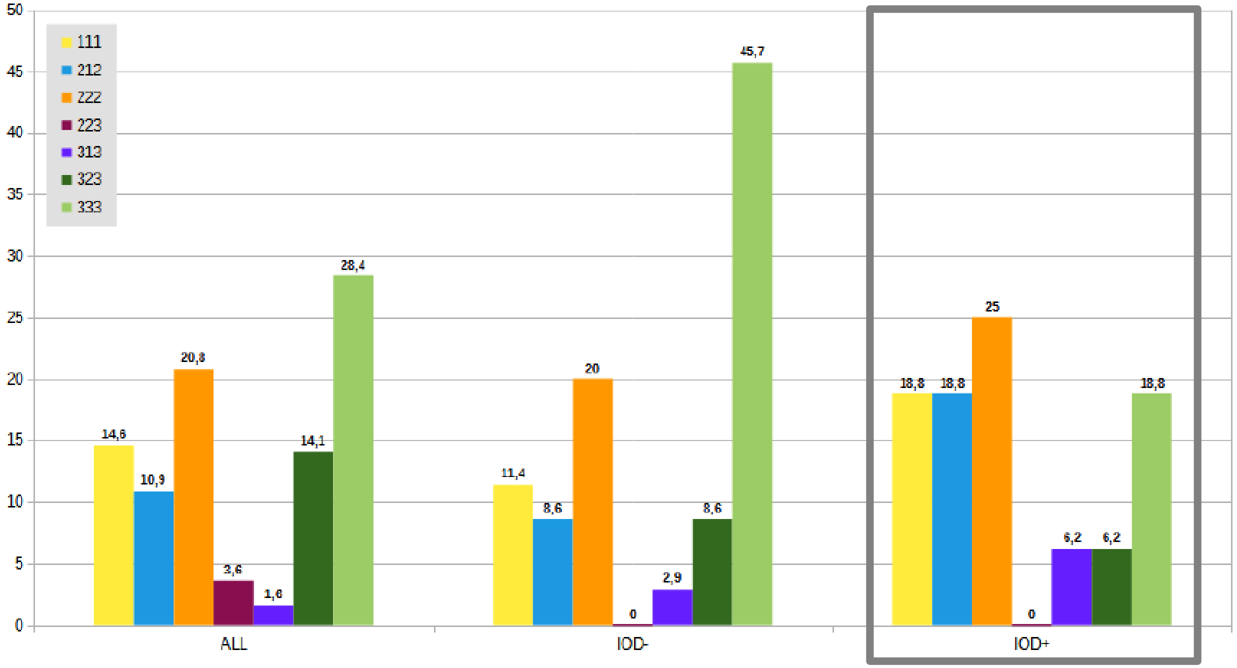
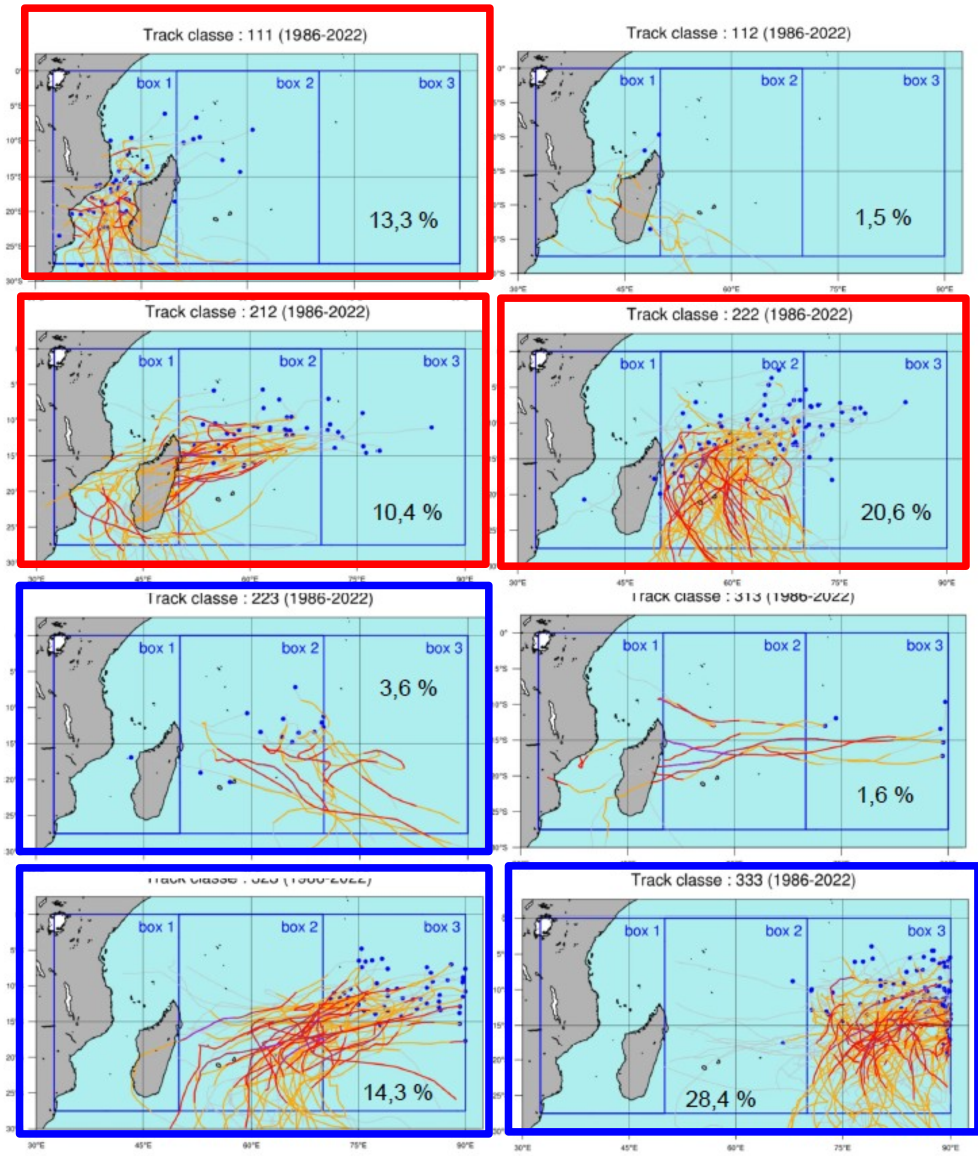


Figure 13 : Modulation of classes proportions with respect to IOD phases during the first half of the cyclonic season (October to January). Proportions are expressed in %



IOD +

111, 212, 222 favored

333, 223, 323 reduced

Risk modulation with respect to the climate

	NINO	NINA	SIOD-	SIOD+
Territories with increased risk	Rodrigues	**Madagascar** **Mozambique**	**Reunion-Maurice**	**Mozambique** Mayotte-Comores
Territories with reduced risk	**Madagascar** **Mozambique** Mayotte-Comores Reunion-Maurice	Reunion-Maurice	Mozambique Madagascar côte ouest	Madagascar côte est

	NINO/SIOD-	NINA/SIOD+	IOD-	IOD+
Territories with increased risk	**Rodrigues** **Reunion-Maurice**		Reunion-Maurice	Mozambique Mayotte-Comores
Territories with reduced risk	**Madagascar** **Mozambique** Mayotte-Comores Reunion-Maurice	**All SWIO territories**	Mayotte-Comores Mozambique	**All SWIO territories**

Outline

- **Interannual variability**
  - Seasonal cycle of the Indian Ocean
  - Working with « anomalies »
  - Evidence of climate interannual variability
- **Main drivers of the interannual variability**
  - ENSO, IOD, SIOD
  - Regional climate response
- **Focus on TC activity**
  - Interannual variability no the SWIO TC activity
  - Impact based approach
- **Seasonal forecast applications at regional scale**
  - SWIOCOF activity
  - TC outlook mini-forum