Direct and Indirect Impacts of Positive Subtropical Indian Ocean Dipole events on Cyclonic Activity in the South West Indian Ocean Basin

Edouard LEES, Olivier BOUSQUET, François BONNARDOT, Sébastien LANGLADE, Jimmy LECLAIR de BELLEVUE, Rui FERNANDES
Laboratoire de l'atmosphère et des cyclones, Unité mixte CNRS/Météo France/Université de la Réunion
edouard.lees@meteo.fr

Introduction

Despite an overall cyclonic activity equivalent to that of the North Atlantic basin, the South West indian Ocean (SWIO) basin (30-90 °E ; 0-40°S) is one of the less studied cyclonic area of the planet. This study investigates potential relationships between global scale climate anomalies and tropical cyclone (TC) activity from ground-based observations and model reanalyses. We focus on 4 cyclonic seasons (1999, 2006, 2011, and 2017) with a weak cyclonic activity and that also are the 4 **strongest positive Subtropical Indian Ocean Dipole (SIOD) events** of the last 20 years.

Methodology

1) Monitoring cyclonic activity :

→ Joint Typhoon Warning Center (JTWC) and CMRS La Réunion bestrack data from 1990-2017 are relied upon to retrieve TC intensity, (VMAX 10 minute averaged) **every 6 hours**
→ **The Accumulated Cyclone Energy (ACE)** is computed for each tropical cyclone, with **Vmax > 34 knots,** as the **sum of (Vmax)²**. **One unit of ACE is equal to 10^4 kn²** (where kn represents knots). This parameter provides an estimate of the kinetic energy generated by a tropical system independently of its size **(*1)**.
.→ This study is focused on two subregions : the **SWIO basin [30°E-90°E 0°S-40°S] and the eastern South Pacific basin (SPAC) [180°W-120°W 0°S-40°S]**

2) Total Column Water Vapor (TCWV) observations in the South Indian Ocean (SIO) :

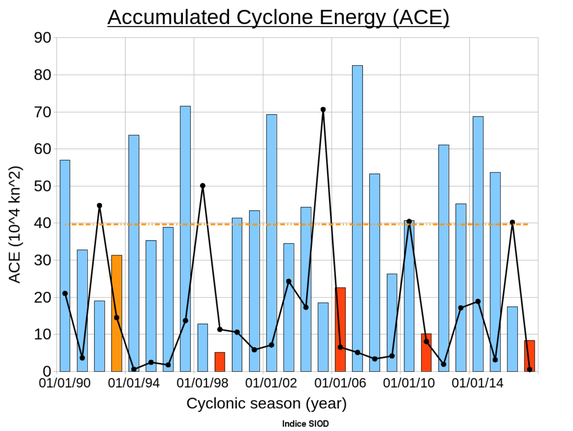
->We use TCWV derived from GNSS total zenithal delay analysis over the period 2009-2017.

3) Large scale environmental cyclogenesis conditions

→ Large scale conditions are inferred from model reanalyses (0,75*0,75° horizontal resolution) of **Sea Surface Temperature 'SST'**, **10m above surface zonal wind 'U10'**, **total column water vapor 'TCWV'** and **200 hpa Velocity Potential 'VP200' data. Due to great similarities between the** 1999, 2006, 2011 and 2017 SIOD events, a 3-month (DJF) composite analysis is computed and compared against 1980-2010 long term means.
→ **Velocity Potential** (VP) is used as **a proxy of divergent motion in the upper troposphere**. A **minimum (resp. maximum) of VP is associated with a divergent (resp. convergent) horizontal wind flow in the upper troposphere which implies upward (resp. downward or subsident) motion** due to mass conservation.

1) Monitoring cyclonic activity and SIOD intensity

-Upper Left Panel : → Accumulated Cyclone Energy (10^4 kn²) in the **SWIO** basin for DJF (pale blue and red bars) and in the **eastern SPAC basin** for NDJFMA (black line).
→ **Red/orange bars** indicate ACE values for cyclonic seasons having strong **positive SIOD (1993, 1999, 2006, 2011 and 2017)**.
→ Orange dashed line represents **1990-2017 SWIO basin ACE average for DJF**
-Lower Left Panel : SIOD index = SIOD1 – SIOD2 from 1990 to 2017. Blue (resp red) shows one (resp three) month averaged SIOD index.

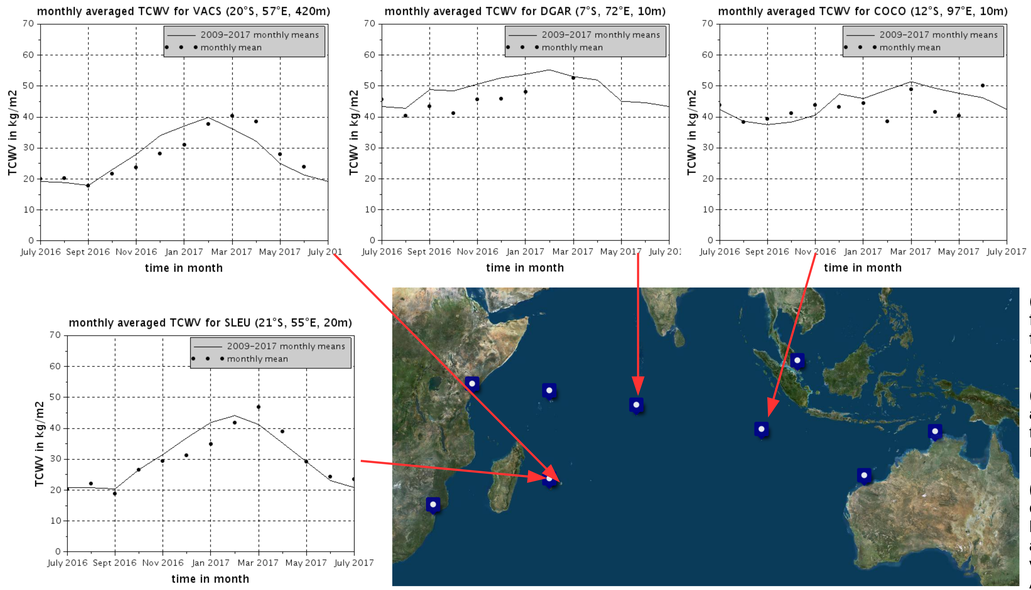


-Upper Right Panel : example of positive SIOD (Jan 2017) with SSTs anomaly and SIOD1/SIOD2 boxes used to compute the SIOD index.
-Table : number of storms reaching at least the intensity of a **Tropical Storm** (TS vmax>34kt), **Strong Tropical Storm** (STS, vmax > 50kt), **Tropical cyclone** (TC, vmax>64kt), **Strong Tropical cyclone** (STC, vmax>90kt) for **SWIO basin in DJF.**

	DJF 1992/1993	DJF 1998/1999	DJF 2005/2006	DJF 2010/2011	DJF 2016/2017	1990-2017 DJF average
Nb TS	4	4	3	2	2	5,4
Nb STS	3	2	3	2	2	4,3
Nb TC	3	0	2	2	2	3,1
Nb STC	1	0	1	0	0	1,9

→ **A Positive SIOD event usually reaches its peak intensity in DJF** (*2). According to ACE data, cyclonic seasons featuring **strong positive SIOD events** show **very weak cyclonic activity in DJF** except for 1993 season due to an early peaking SIOD event in Dec92 and a quick damping in Jan93**.** We don't take into account 1993 in the rest of this study.
→ **Strong positive SIOD events** show low number of both Tropical Storm and Tropical Cyclone in DJF for the SWIO basin.
→ **Strong positive SIOD events** are often following cyclonic seasons with higher than normal activity in the eastern SPAC basin.

2) Total Water Vapor Column observation during 2017 event in the South Indian Ocean



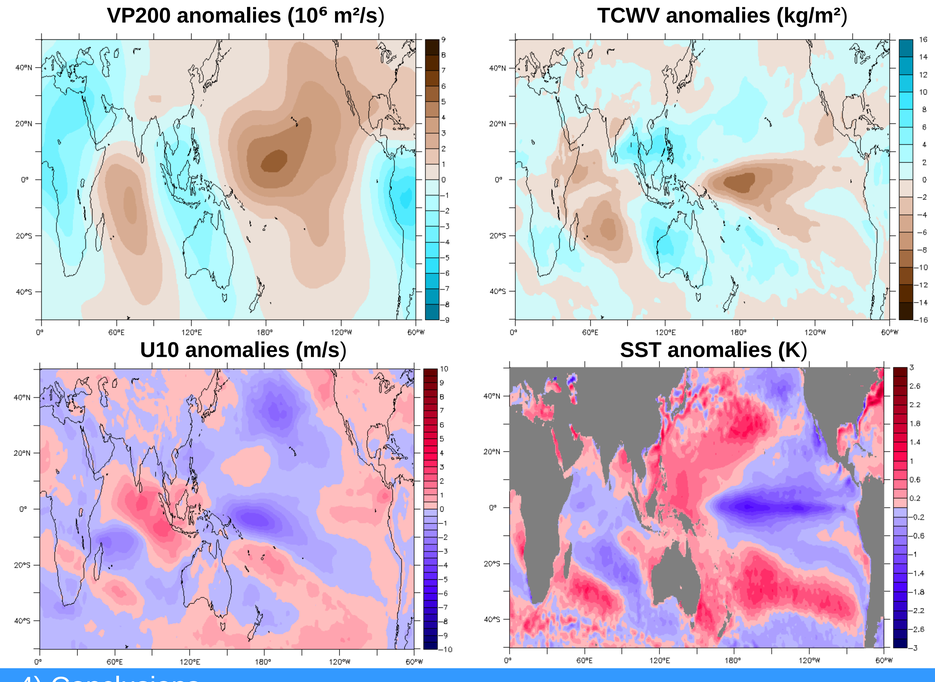
Monthly averaged **Total Column Water Vapor** obtained from GNSS Zenithal total delay (ZTD) for year 2016/2017 (dots) and for 2009/2017 period (black line)

From left to right : **Reunion island (SLEU) and Mauritius island (VACS) i**n the **south west** of South Indian Ocean, **Chagos archipelago (DGAR)** in the **center** of South Indian Ocean, and **keeling island (COCO)** on the eastern edge of the basin.

→ **In the eastern part of the basin** (COCO) a **wet anomaly can be seen from September to November, followed by a** dry anomaly in austral summer.
→ **In the center** part of the basin (DGAR) a **dry anomaly remains around 10 to 15 % of the normal** on the 2009/2017 period from august to march.
→ **In the western part of the basin (SLEU, VACS), the dry anomaly extends from November to February and peaks in January with a 20 % deficit** in agreement with the very low cyclonic activity seen in DJF. A **wet anomaly takes place in March/April**

3) Large scale environmental cyclogenesis conditions

Composites of anomalies for the trimester december-january-february of years 1999, 2006, 2011 and 2017



→ **Positive 200 hpa VP anomaly => large scale subsidence anomaly** over the SWIO basin (west of 90°E).

→ **Drier than normal enviromnent** in the center and west part of South Indian Ocean.

→ **Positive surface pressure anomaly around 20°S-60°E** (not shown) due to large scale subsidence anomaly

=> **Easterly (resp westerly) surface wind anomaly** west of 100°E and between 5°S and 20°S (resp. south of 20°S) instead **of the climatological northwesterly (resp. southeasterly)** surface wind flow

→ **Reduced surface wind convergence west of 90 °E between 5°S and 15°S.**

→ West of 90°E we have due to surface winds anomaly **positive (resp. negative) anomaly of latent heat flux, and deeper (resp. shallower) ocean mixing layer**

=> **Lower (resp. higher) sensitivity to seasonnal short wave flux (*3)** north (resp. south) of 20°S :

=> **Lower (resp. higher) than normal SSTs north of (resp. south of) 20°S and west of 90°E**

The combination of these two SSTs anomalies are called a positive SIOD.

4) Conclusions

Austral cyclonic seasons 1999, 2006, 2011 and 2017 were characterized with both **strong positive SIOD events** and a **very low cyclonic activity during the DJF trimester**. TCWV observations show the presence of **a dry anomaly over the central and western part of the South Indian Ocean from Nov to Feb 2017, with a peak intensity in Jan**. Model reanalysis data suggest that this dry anomaly in Nov/Feb 2016/2017 is also occuring for the 3 other seasons and is due to **large subsidence anomaly over SWIO basin**. This subsidence anomaly is also **reducing surface wind convergence** in the northern part of SWIO basin by creating a positive surface pressure anomaly around 20°S 60°E. **Large scale subsidence, dry environment and lack of low level convergence** are all unfavorable conditions for cyclogenis. The combination of these 3 conditions thus explains why these 4 seasons show such a low cyclonic activity. An interesting point deserving further investigation is that these 4 seasons all follow very active cyclonic seasons in the eastern SPAC basin.

(*1) **Climate Assessment for 1999,** Bell et al., 2000
(*2) **Subtropical SST dipole events in the southern Indian Ocean**, Swadhin K. Behera and Toshio Yamagata, 2001
(*3) **Climate variability in the southern Indian Ocean as revealed by self-organizing maps**, Yushi Morioka, Tomoki Tozuka, Toshio Yamagata, 2010