Tropical cyclogenesis conditions in the Southwestern Indian Ocean

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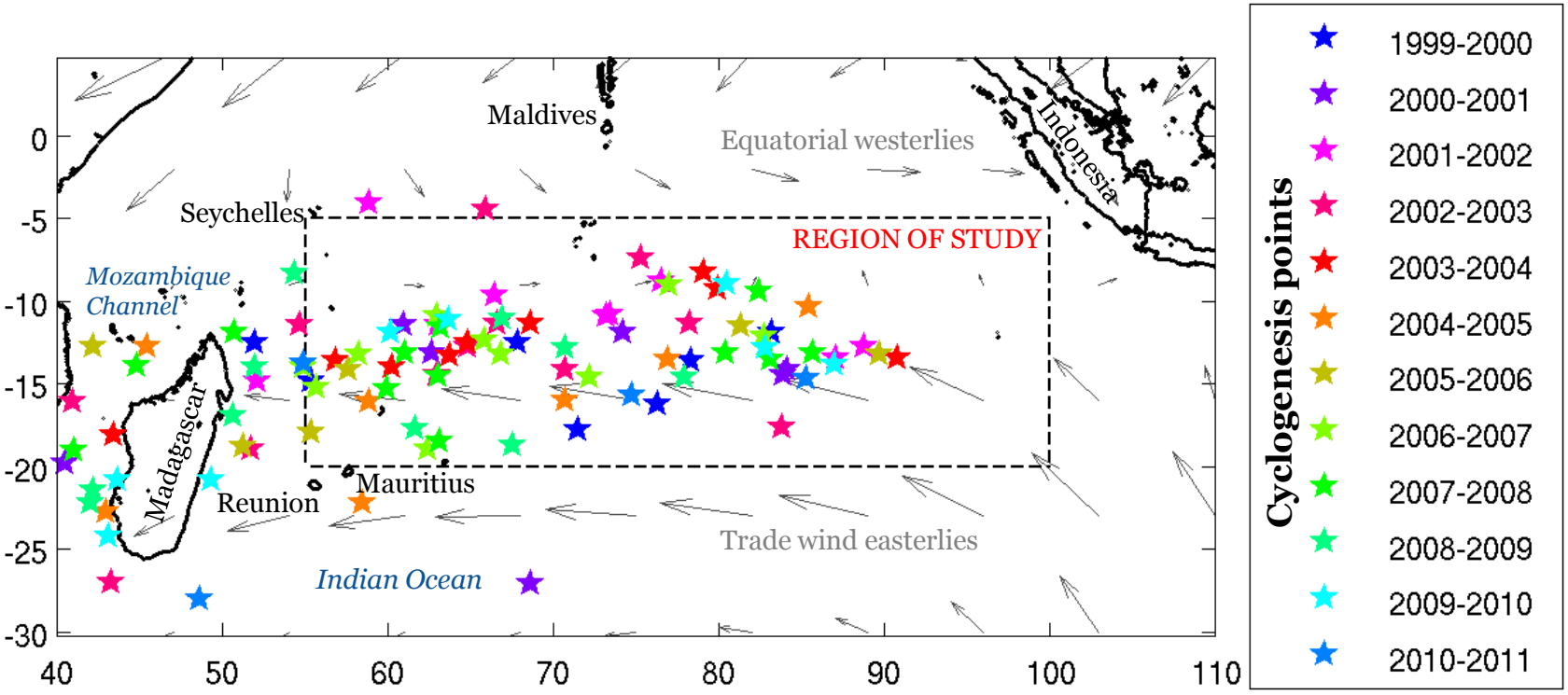
Introduction

- Southwestern Indian Ocean (SWIO) [10% of global TC activity]
- 12 cyclonic seasons [Dec 1999–Mar 2000 to Dec 2010–Mar 2011]
- Region of study [55-100°E, 5-20°S] ⚠ No Madagascar, no Mozambique Channel.



Characterize the pre-cyclonic environment and its variations
[before TS; $V_{max} < 17$ m s^{-1}] in the SWIO → 3 methods

Available data for our study

- ECMWF | ERA-Interim

SST	1.5° x 1.5°	12h	
Atmospheric variables	0.25° x 0.25°	6h	1000-100 hPa

- ESA | Meteosat-5 (1999→2007)
  Meteosat-7 (2007→2011)

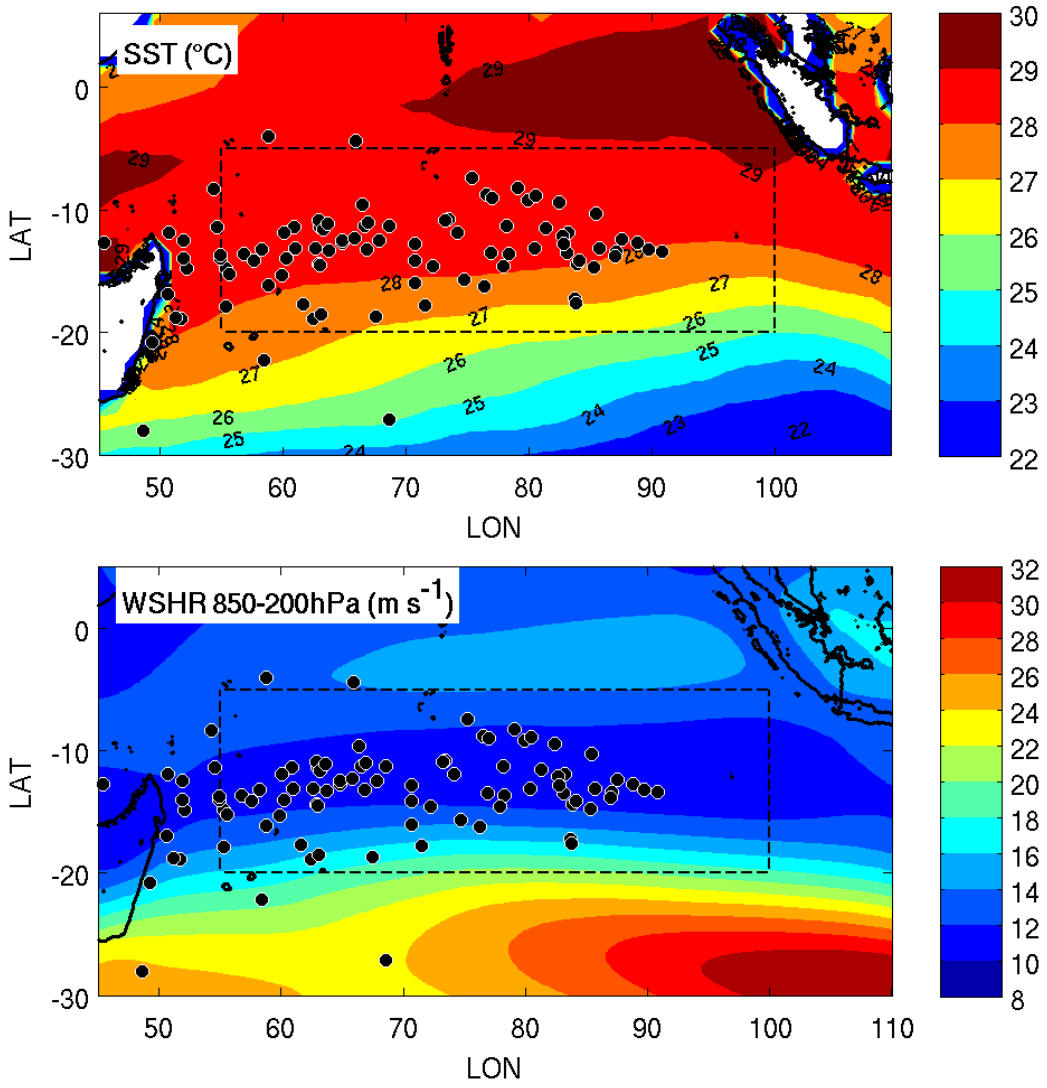
Brightness temperature in the water vapour channel (5.7 – 7.1 μm)

TB	5 km x 5 km	3h

- NOAA/NCDC | IBTrACS
  → RSMC La Réunion (Météo-France)
  → Already developed perturbations

Mean climatic conditions in the SWIO

Over 12 seasons



Cyclogenesis in the SWIO generally occurs when:

- SST above 27 °C
- WSHR below 15 m s^{-1}

Identification of developing TS in ERA-Interim

An objective analysis from Picornell et al. (2001)

1st method

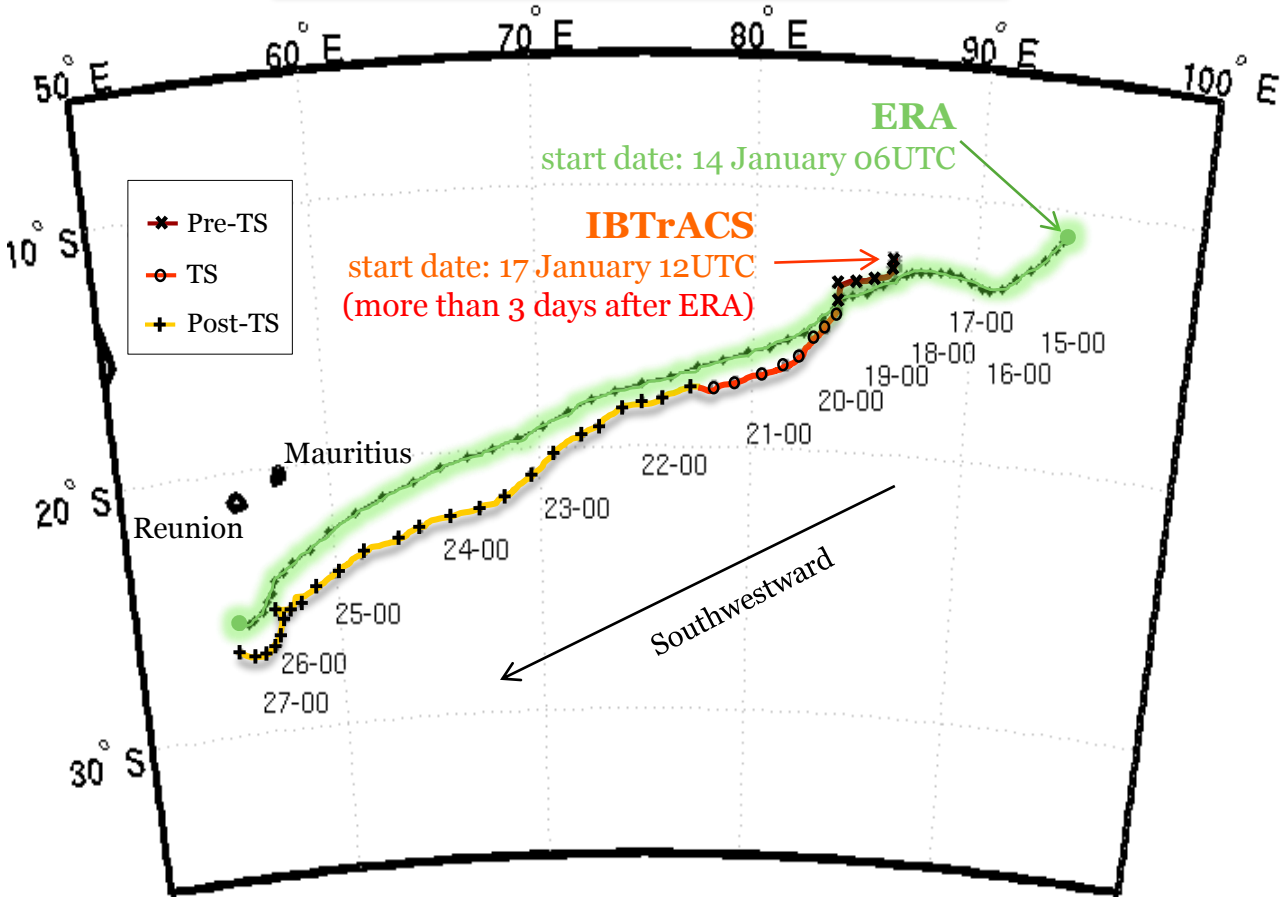
Method

- Minimum Z
  < 1000hPa
- Surface cyclonic circulations
  > 5 10^6 m^2 s^{-1}
- Vertical and temporal continuity

Results

- Identification of all the 63 IBTrACS TS/TC in ERA-Interim
- Average location error: ~100km
- 6 hours to 6 days before the first fix in IBTrACS

SEASON DEC2000 — MAR2001



Example: Tropical cyclone CHARLY in January 2001

Intraseasonal cyclogenesis index for the SWIO

A two-step objective method

2nd method

Step 1

Identification of relevant variables for tropical cyclogenesis

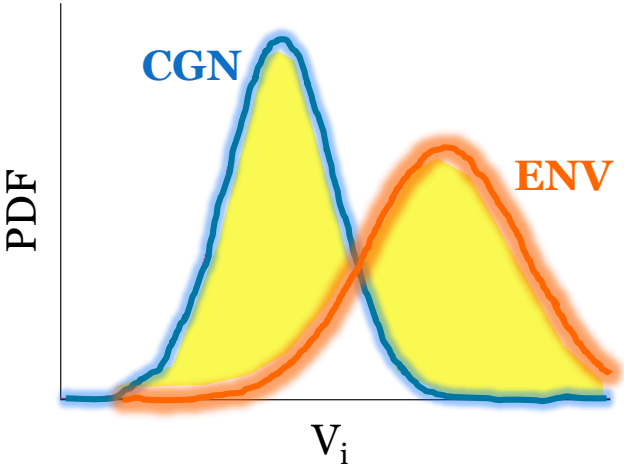
Step 2

Optimum linear combination of these selected variables that accurately identifies favorable environmental conditions for cyclogenetic evolution at an intraseasonal time scale

Step 1: Selection of relevant variables

- 12 thermodynamic and dynamic variables
- Probability distribution functions (PDFs) for each variable V_i over the 12 seasons in 2 domains based on 1st method:
  - CGN: points within 500 km of developing cyclonic systems
  - ENV: excluding CGN and points near developed storms and remnants
- Discriminating factor

$$\delta_i = \frac{\int \left| \mathrm{PDF(CGN)} - \mathrm{PDF(ENV)} \right| dV_i}{\int \mathrm{PDF(CGN)} dV_i + \int \mathrm{PDF(ENV)} dV_i} \geq 0.3$$



- 9 relevant variables
  - 7 selected with $\delta_i \geq 0.3$
    - TB, RVOR1000-800, RIH1000-800, DIV1000-800,
      RVOR700-500, RIH700-500, DIV400-200
  - + 2 others:
    - SST, WSHR850-200

Step 2: Optimum combination of relevant variables

Selected variables V_i + Cyclogenesis criterion C (∝ storm intensification)

Normalization with mean and std dev over all 12 seasons,

$$V_i^* = \frac{V_i - M(V_i)}{\sigma(V_i)} \text{ and } C^* = \frac{C - M(C)}{\sigma(C)}$$

Principal Component Analysis

First component gives a unique combination

Cyclogenesis index γ for the SWIO

$$\forall n = \{\text{lat, lon, t}\}, \quad C^*(n) \approx \gamma(n) = -0.13\,TB^*(n) + 0.09\,SST^*(n)$$
$$- 0.13\,RVOR^*_{1000\text{–}800}(n) - 0.12\,DIV^*_{1000\text{–}800}(n) + 0.13\,RIH^*_{1000\text{–}800}(n)$$
$$- 0.12\,RVOR^*_{700\text{–}500}(n) + 0.14\,RIH^*_{700\text{–}500}(n)$$
$$+ 0.11\,DIV^*_{400\text{–}200}(n)$$

Coefficient for $WSHR^*_{850\text{-}200} < 0.01$ → already favorable?

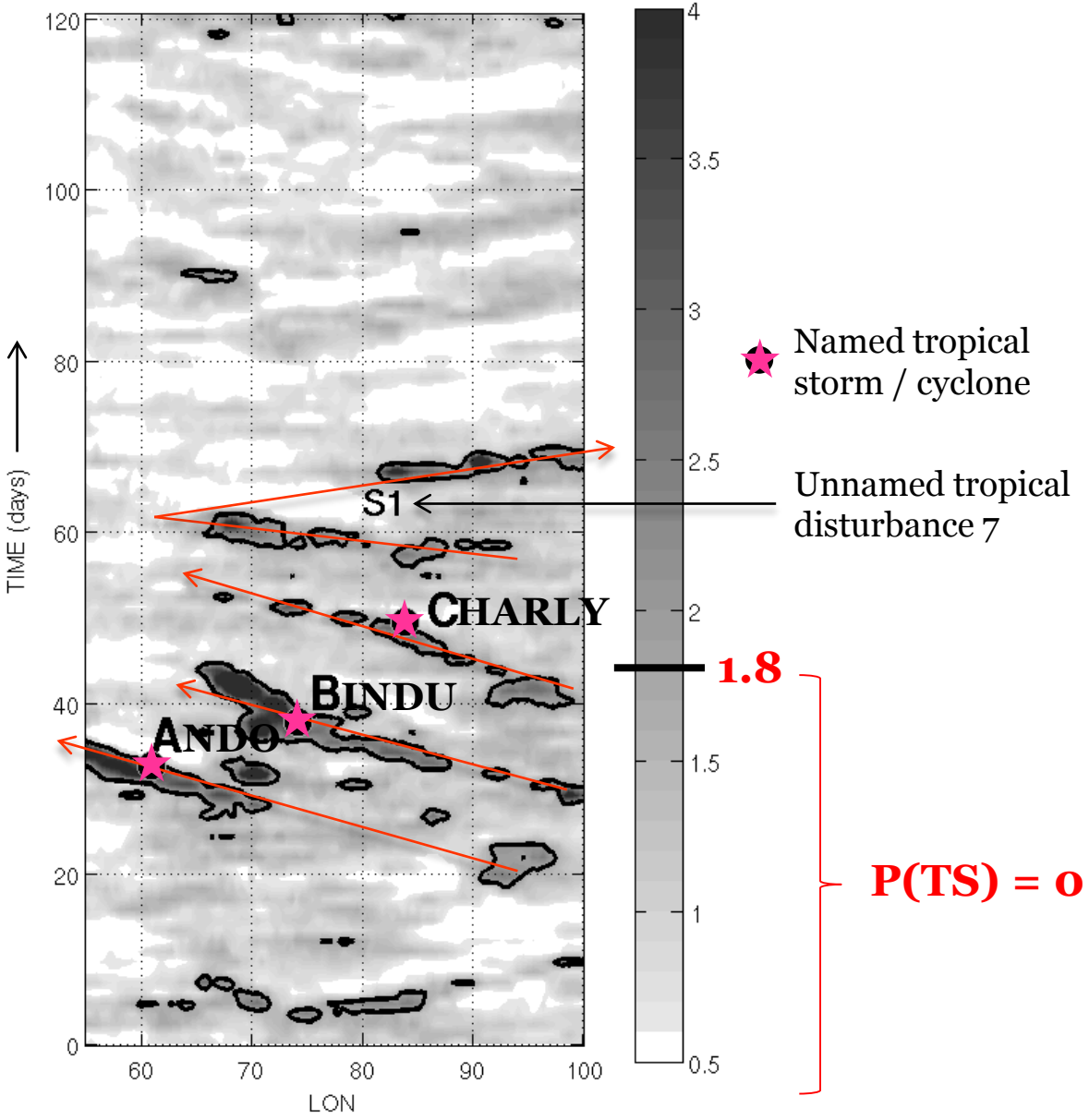
Example: Cyclogenesis index γ

SEASON DEC2000 – MAR2001

Hovmöller diagram of **max(γ)** over 5-20°S

Large zones of $\gamma \geq 0.5$

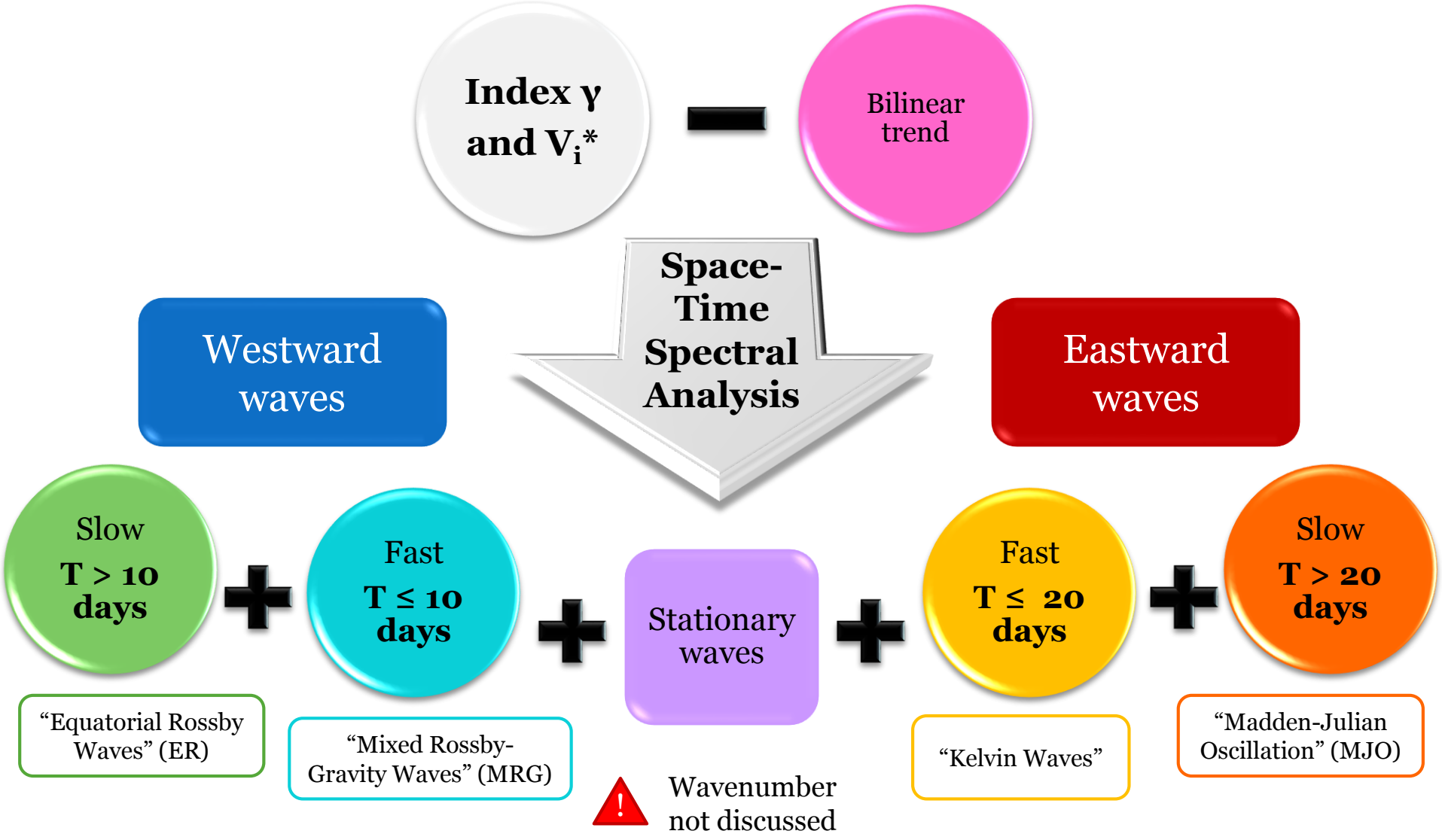
Smaller areas of **$\gamma \geq 1.8$** associated with tropical perturbations



Space-time spectral analysis

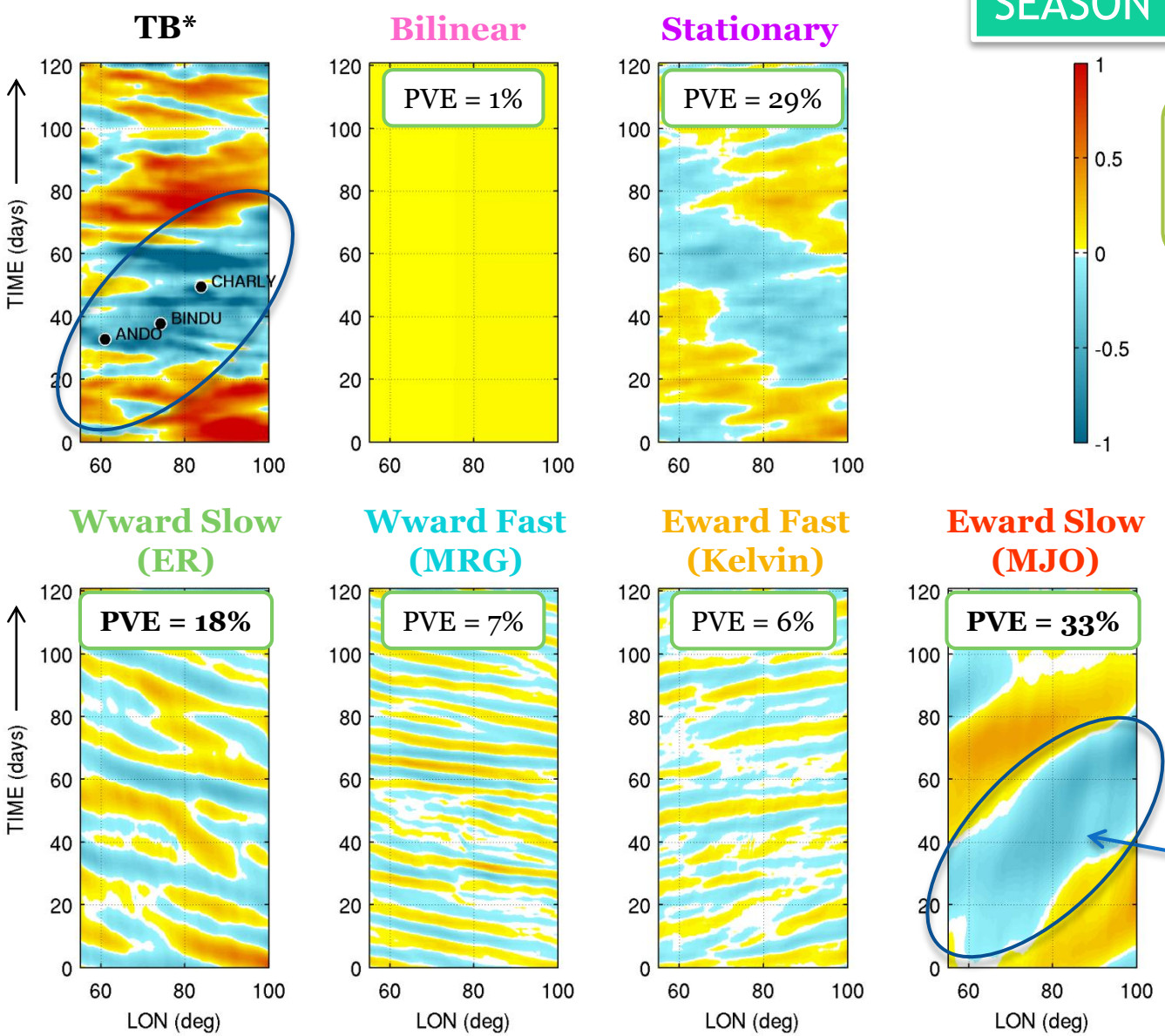
Hayashi (1971), Wheeler and Kiladis (1999), Roundy (2012), …

3rd method



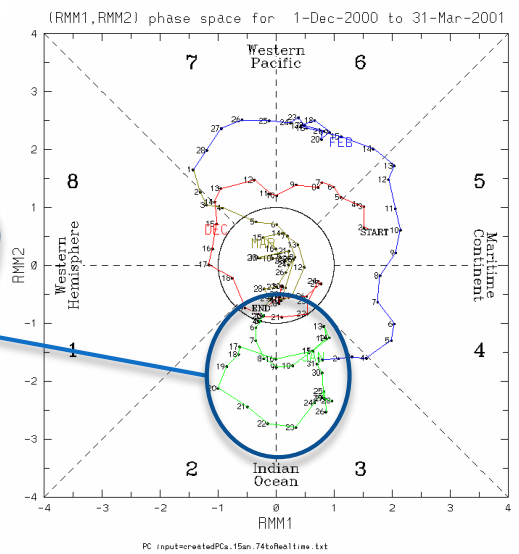
Example: Wave mode decomposition

SEASON DEC2000 — MAR2001



PVE: Percentage of TB* variance explained by each of the 6 modes

MJO active phase identified on Wheeler's diagram (RMM1, RMM2)
http://cawcr.gov.au/staff/mwheeler/maproom/RMM/



Influence of wave modes on cyclogenesis

Percentage of γ and V_i* variance explained by each of the 6 modes

SEASON DEC2000 – MAR2001

Variable	Weight in γ	Bi-linear	Statio-nary	Wward Slow **ER**	Wward Fast MRG	Eward Fast Kelvin	Eward Slow **MJO**	Σ
γ		1	29	27	9	4	26	96
TB*	-0.13	1	29	18	7	6	33	94
SST*	+0.09	54	13	21	0	1	13	104
RVOR*1000-800	-0.13	11	19	40	20	6	11	107
DIV*1000-800	-0.12	7	29	28	12	12	17	105
RIH*1000-800	+0.13	3	29	35	11	5	17	100
RVOR*700-500	-0.12	18	19	35	17	5	12	106
RIH*700-500	+0.14	5	27	29	7	2	27	97
DIV*400-200	+0.11	3	29	19	10	11	34	106

~70% of the variance of γ in 2000-2001 is controlled by wave phenomena

Similar results over the 12 seasons in the SWIO:
65% wave phenomena, of which **28% ER**, **8% MRG**, **6% Kelvin** and **23% MJO**

≥ 40%
≥ 30%
≥ 20%

Conclusion

- 3 objective methods for the SWIO
  - Identification of developing cyclonic perturbations in ERA-Interim data
    → A longer cyclogenesis phase
  - Creation of an intraseasonal index as a linear combination of relevant environmental variables
    → Favorable conditions for cyclogenesis
  - Space-time spectral analysis on index and relevant variables
    → Links between tropical cyclogenesis and equatorial waves

- Further possible work
  - Other basins? North Atlantic?
  - Other reanalyses? NCEP/NCAR? MERRA?

Thank you.

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