Seminar/Workshop on Tropical and Extra Tropical Cyclones and their reporting in aviation – ICAO/SAM – 04-06/03/2024

Deep cyclones in the South Atlantic:
genesis, climatology and future perspectives

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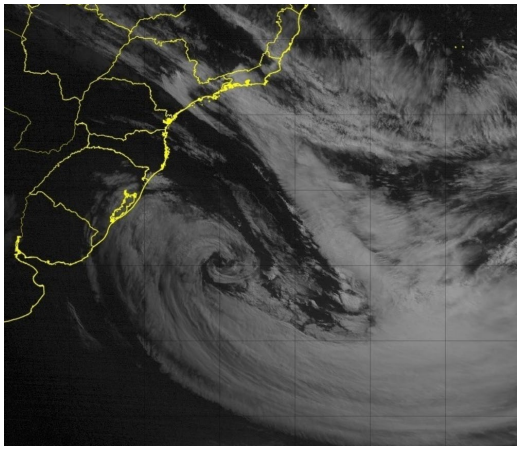
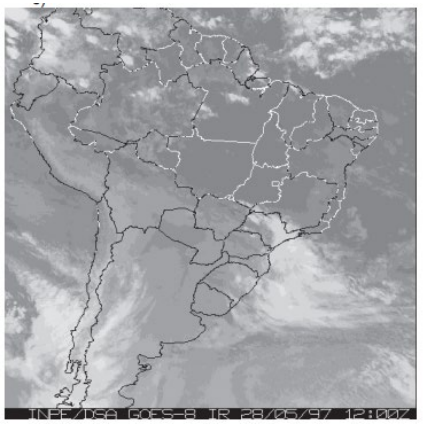
Faculdade de Ciências

Cyclones

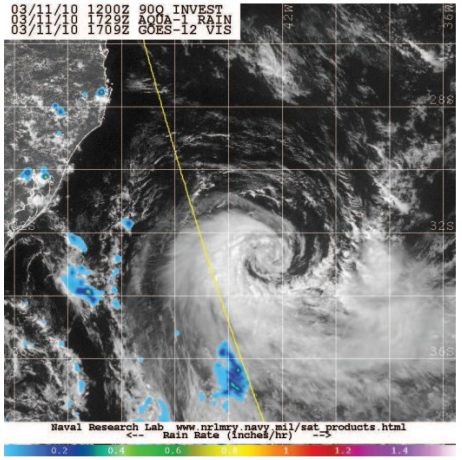
"*Deep cyclones*" = synoptic low pressure systems associated with strong winds



Norwegian explosive cyclones
(80-125 km/h, June 2020)



Shapiro-Keyser explosive cyclones
(100 km/h, May 1997)



Subtropical cyclones
(Anita, 108 km/h, March 2010)

Presented here are some results from my "cyclones' group" and some literature to context

Norwegian explosive cyclones

Explosive: i) pressure drop of at least 1 hPa in 24h, in the latitude of 60º

ii) $NDR = \left[\Delta p \left(\frac{\sin\phi}{\sin 60^\circ}\right)\right] /24\,hours$ > 1 Bergeron (Sanders and Gyakum, 1980)

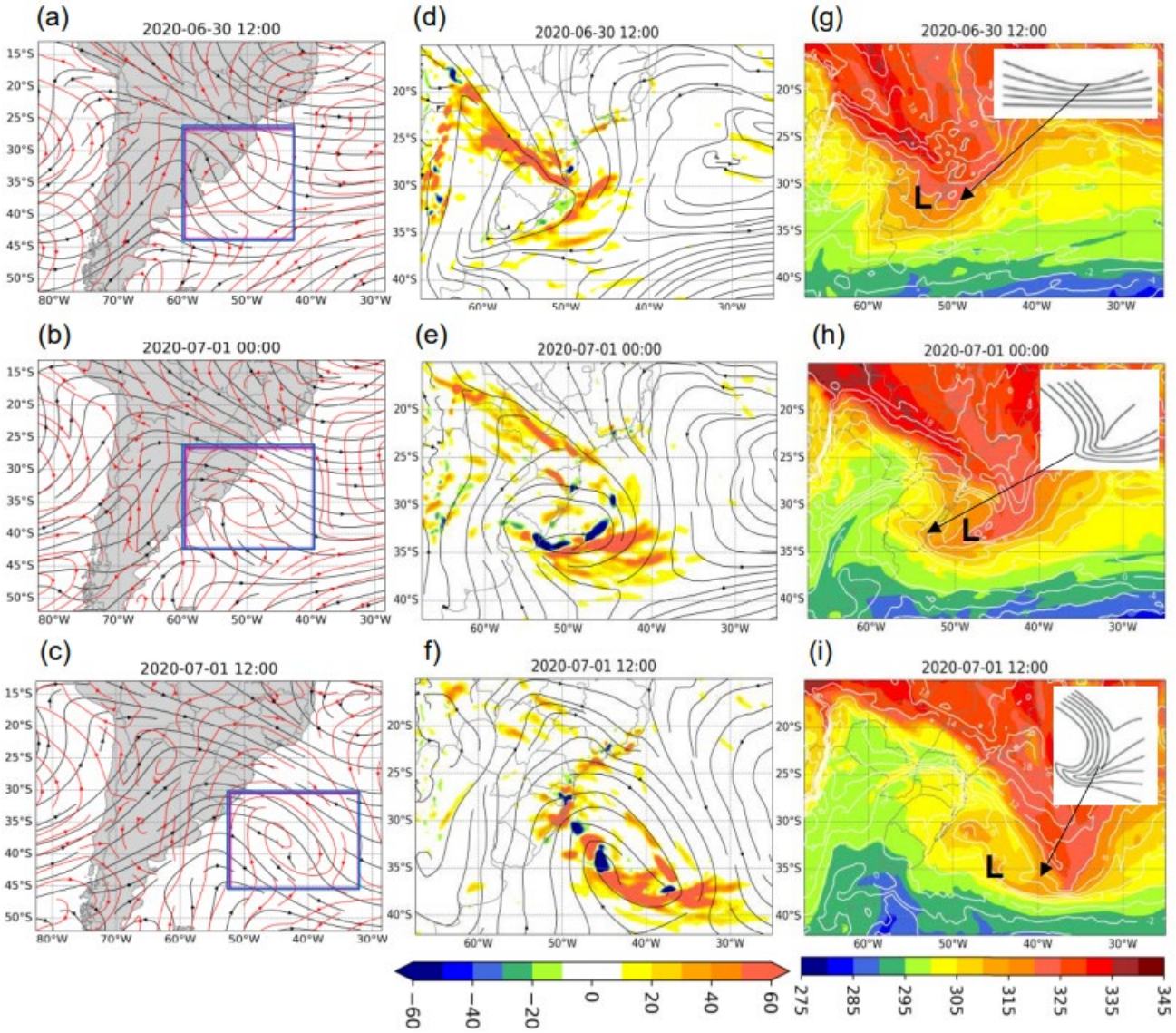
June 2020 Norwegian explosive cyclone – Fortunato et al. (2023)

(Prefeitura de Chapecó)

↓ 37 hPa / 24h = 2.6 Bergeron

(G1)

Norwegian explosive cyclones



(Fortunato et al., 2023)

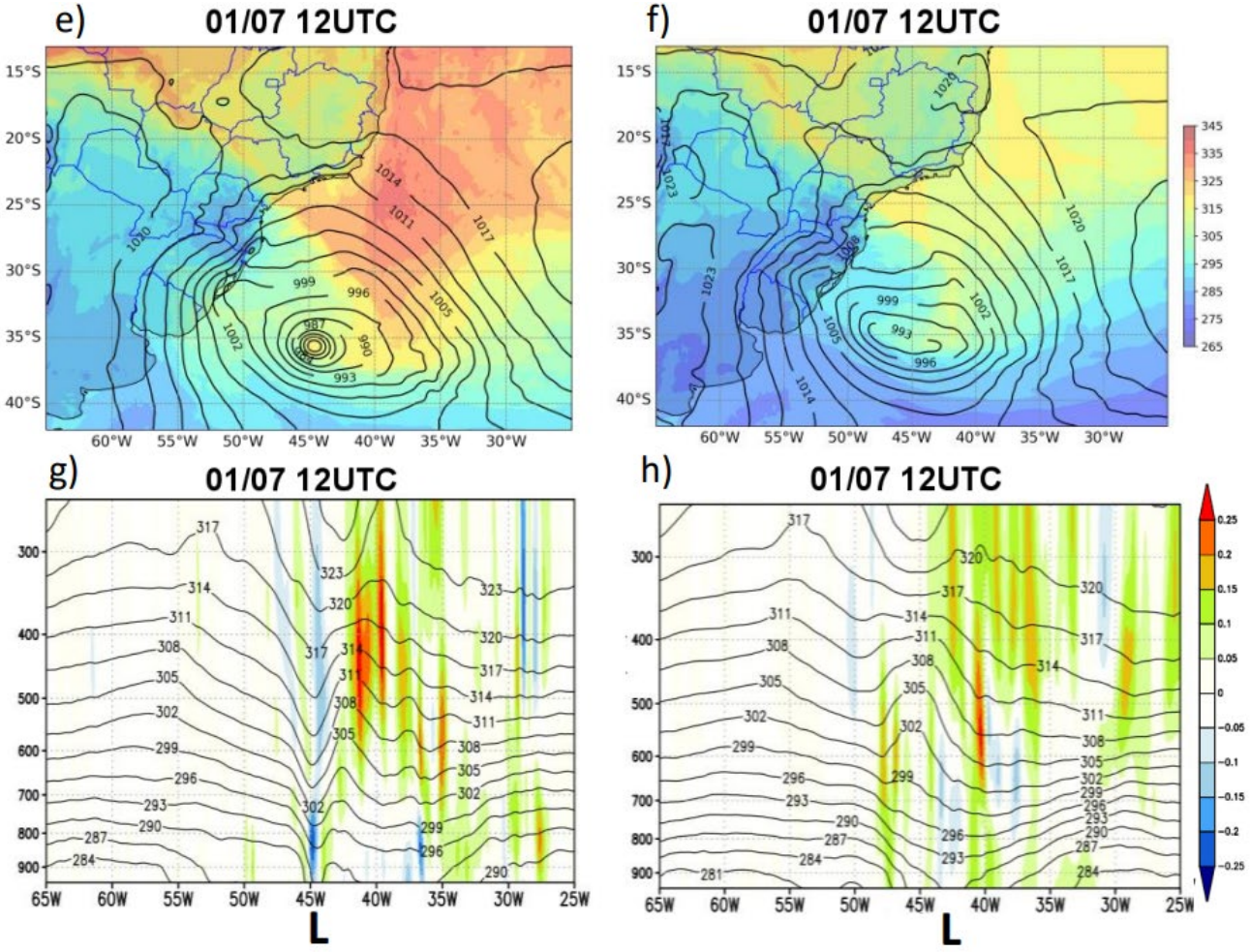
Figure 5. (**a**–**c**) Streamlines at 850 hPa (red) and at 250 hPa (black); blue box indicates the region with diffluent flow, (**d**–**f**) frontogenetic function at 850 hPa ($\times 10^{-10}$ K m^{-1} s^{-1}; shaded) and streamlines at 850 hPa (black), and (**g**–**i**) equivalent potential temperature (K, shaded) and air temperature (°C, white lines) at 850 hPa. In (**g**–**i**), (i–iii) shows a snapshot of the extratropical cyclone stages following the Bjerknes and Solberg conceptual model. The low position based on MSLP is indicated by L; the colored lines indicate the cold (dark blue) and warm (dark red) fronts.

Norwegian explosive cyclones

WRF Sensitivity experiments

FLX

NOFLX



θe and MSLP

θe and ω

(Fortunato et al., 2023)

Norwegian explosive cyclones

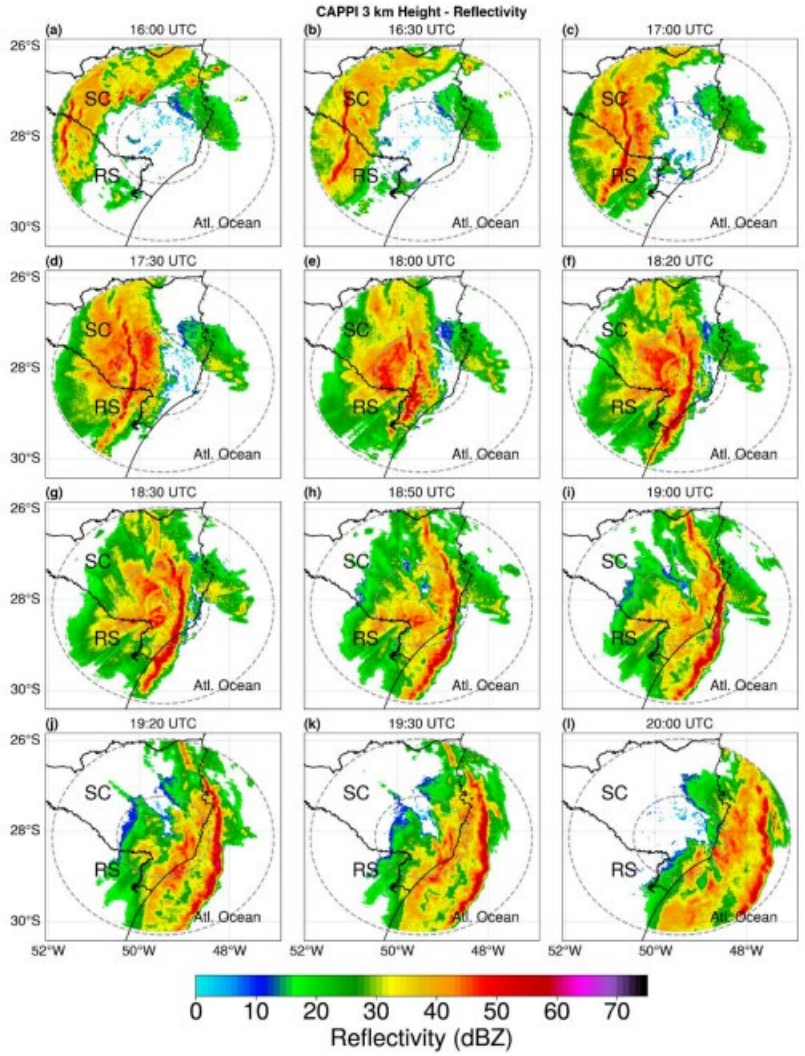


Figure 12. (a–l) Constant Altitude Plan Position Indicator (CAPPI) at 3 km height of reflectivity from Morro da Igreja radar from 1600 to 2000 UTC on 30 June 2020.

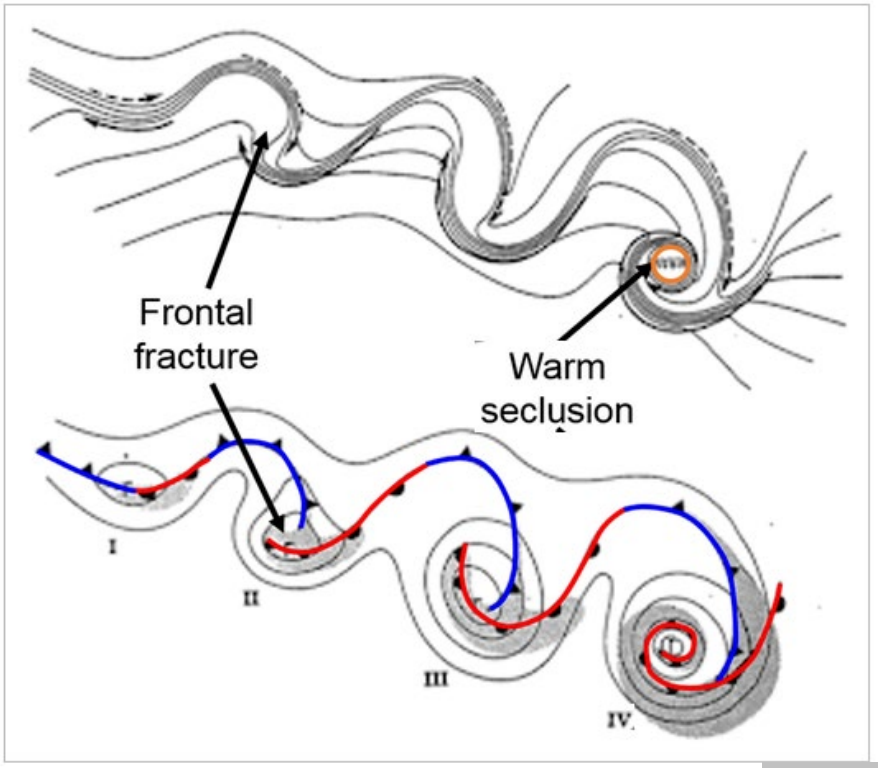
Squall line organized along the cyclone's cold front was responsible for the most destructive winds

Ongoing research: how the absence of surface fluxes impacts fronts and the squall line?

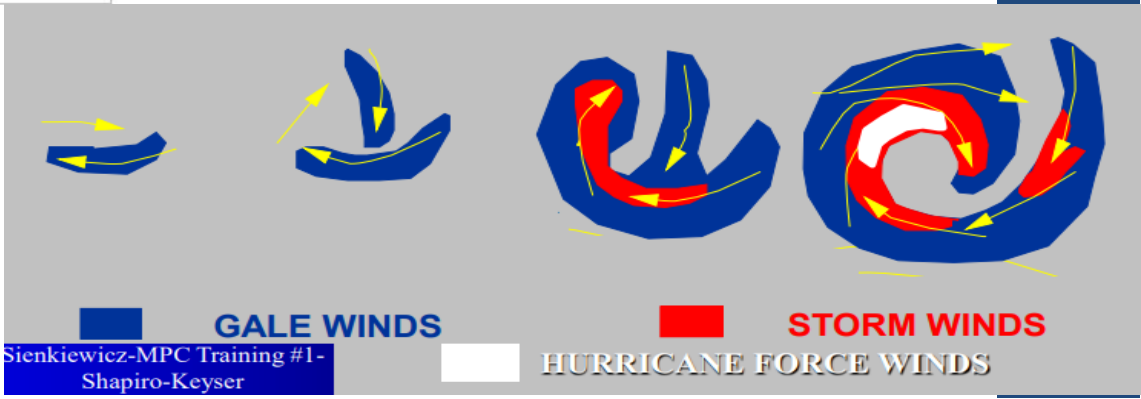
(Fortunato et al., 2023)

Shapiro-Keyser explosive cyclones

The majority of explosive cyclones develop following the Shapiro-Keyser (1990) model



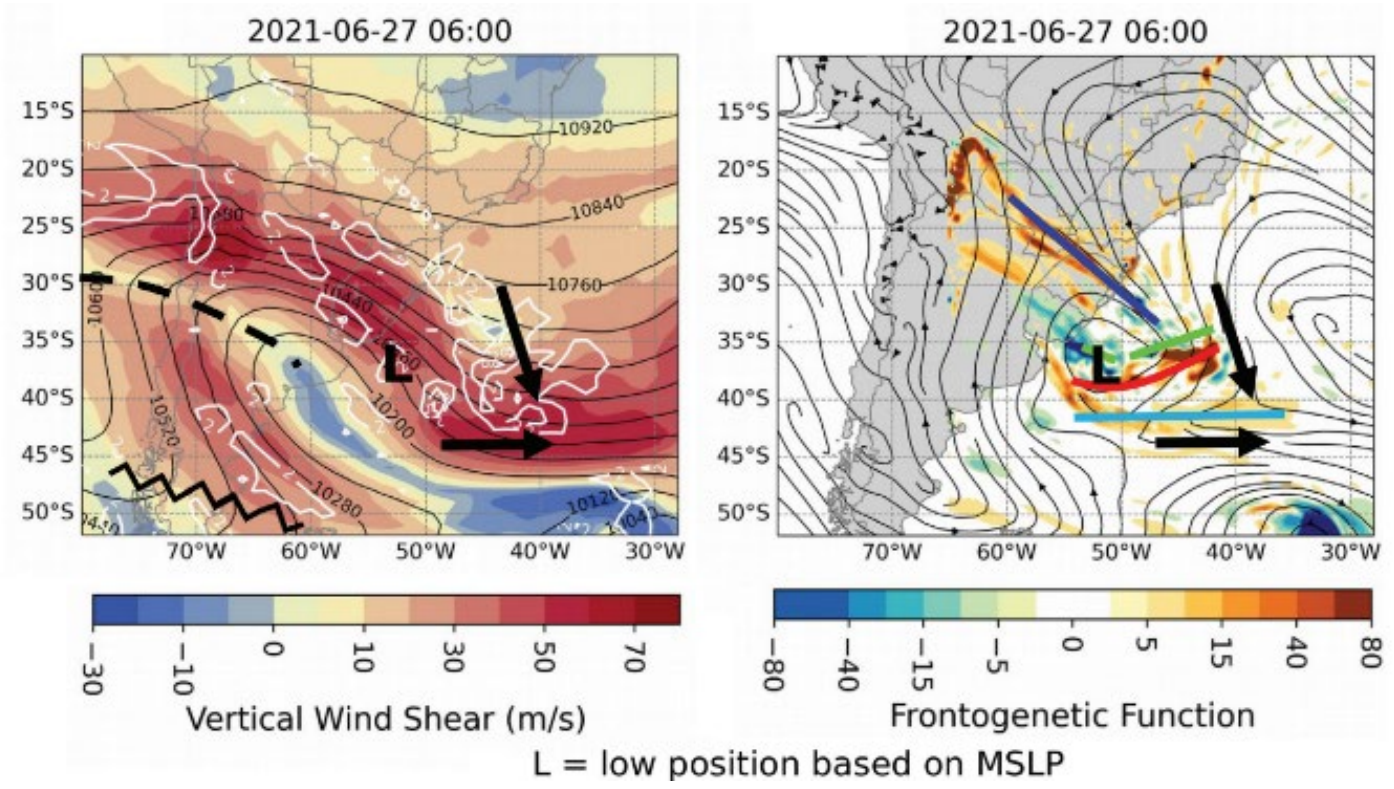
(Adapted from Shapiro and Keyser, 1990; Dacre, 2020)



Shapiro-Keyser explosive cyclones

These cyclones form and develop associated with:

Confluent upper-level large-scale flow



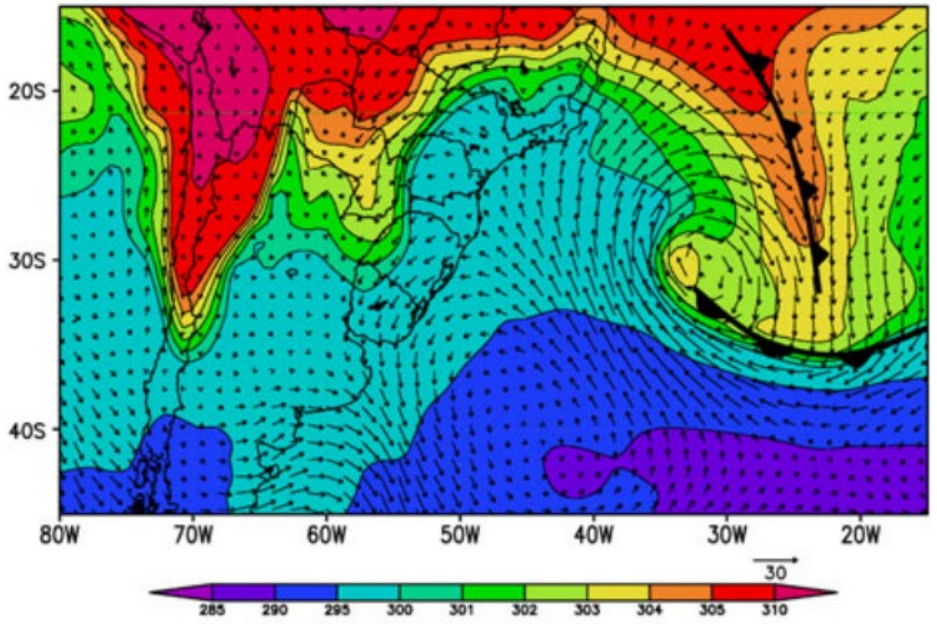
(Reboita et al., 2022)

Shapiro-Keyser explosive cyclones

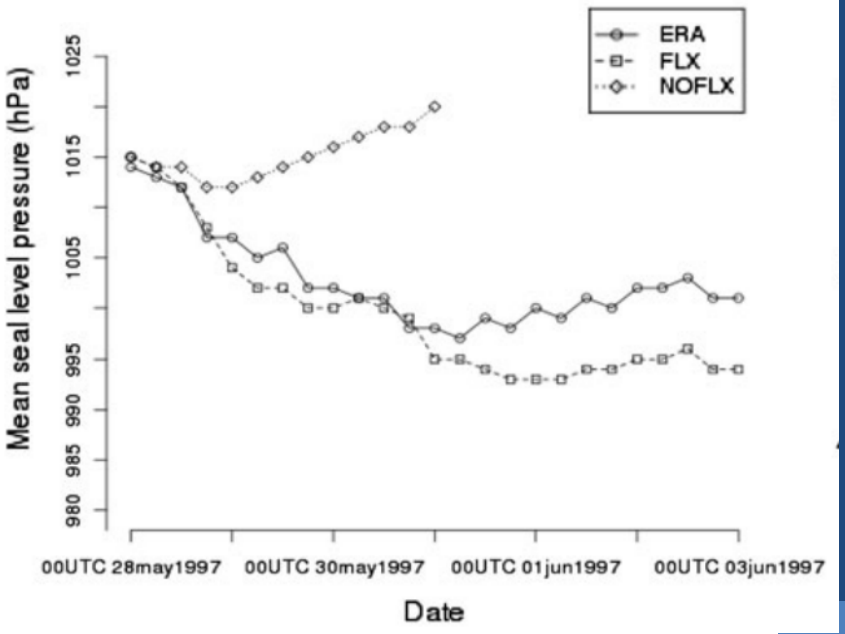
These cyclones form and develop associated with:

Strong surface sea-air turbulent heat fluxes

Gozzo and da Rocha (2013): sensitivity experiments to study the role of surface latent and heat fluxes in the development of a Shapiro-Keyser cyclone



ERAInt θe and 925 hPa winds



No fuel to convection, damps pressure drop

Shapiro-Keyser explosive cyclones

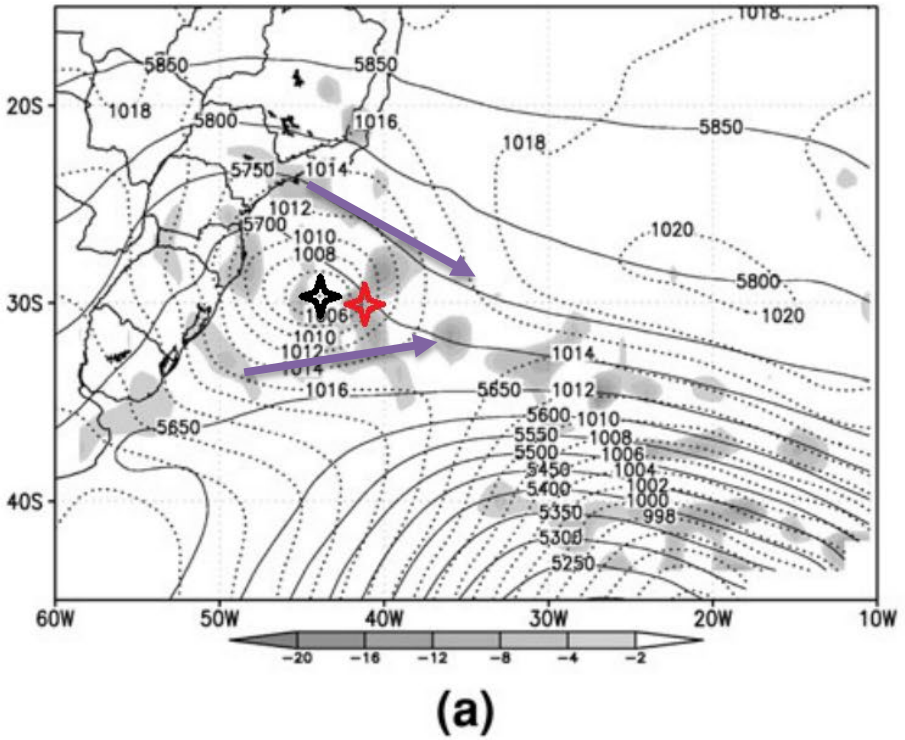
These cyclones form and develop associated with:

Strong surface sea-air turbulent heat fluxes

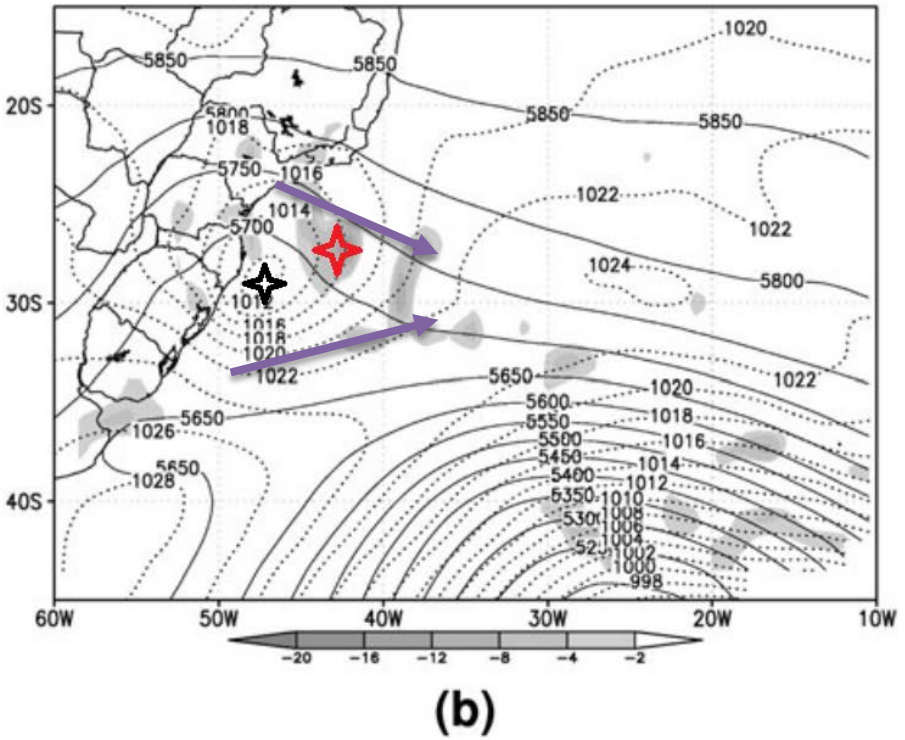
Gozzo and da Rocha (2013): sensitivity experiments to study the role of surface latent and heat fluxes in the development of a Shapiro-Keyser cyclone

But it does not seem to be the only effect of no surface fluxes…

FLX



NOFLX

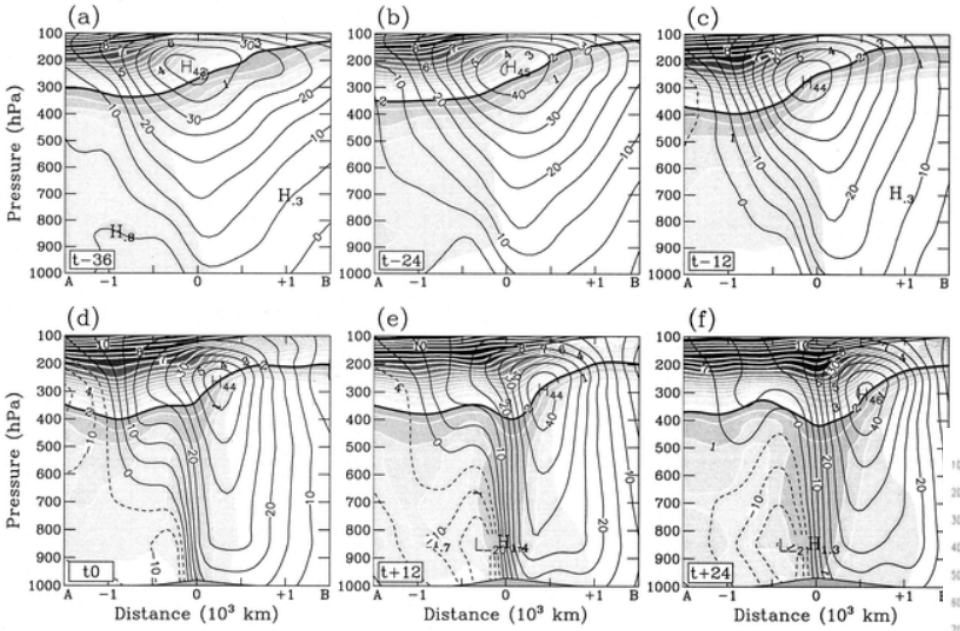


Absence of fluxes halts the surface low displacement, “detaching” it from the upper levels

Shapiro-Keyser explosive cyclones

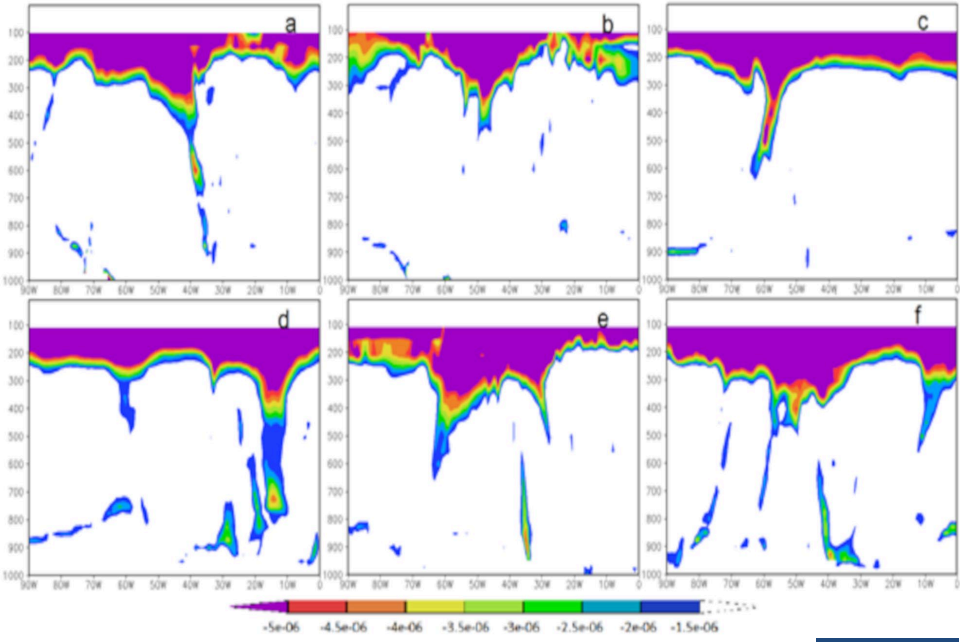
They are associated with:

Remarkable lowering of the tropopause level ("tropopause folding")



(Wang and Rogers, 2001)

(Composite analysis of 18 SK cases in Northern Hemisphere)

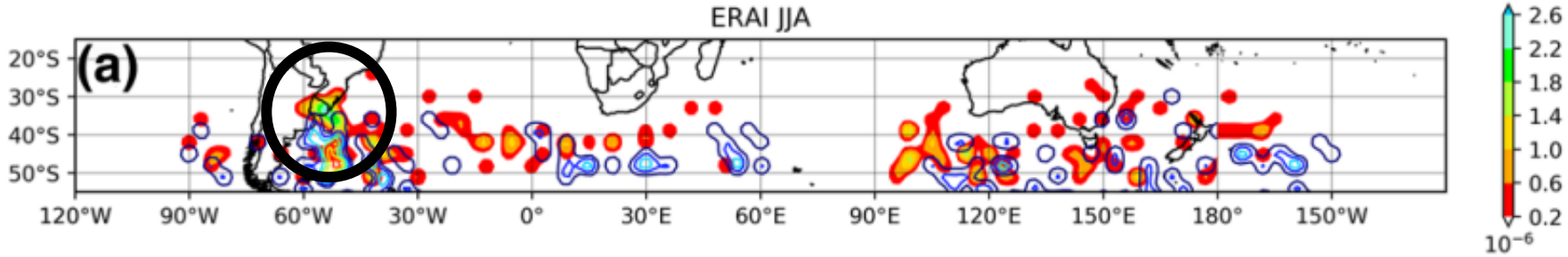


(Ávila et al., 2021)

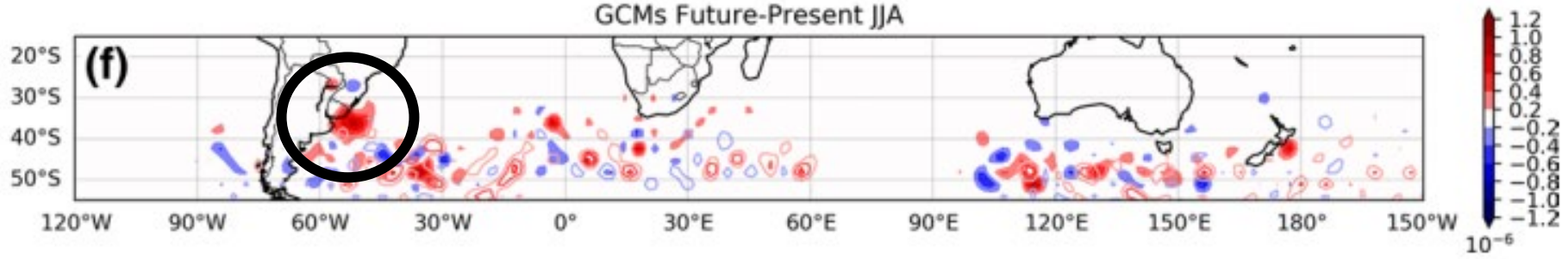
(6 SK case studies over the South Atlantic, during winter)

Climatology and projected future changes in explosive cyclones

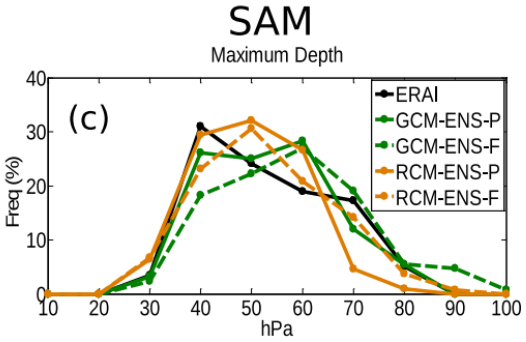
The main cyclogenetic region for winter explosive cyclones near South America is the La Plata Region…



… and their frequency is projected to increase by the end of this century…



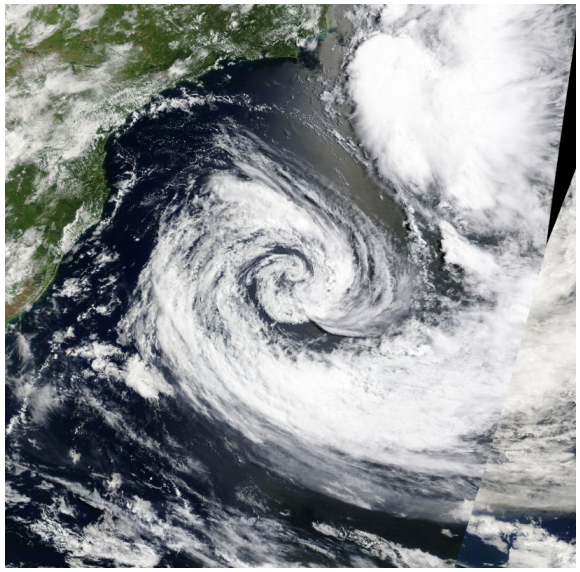
… with deeper cyclones (diabatic processes!)



(Reboita et al., 2021)

Subtropical cyclones

"Low pressure system (…) nonfrontal, with a low tropospheric warm core and an upper-level cold core. They can be formed with such characteristics and maintain them throughout the cyclone lifetime, or they may originate as an intermediary stage in a tropical or extratropical transition"



(Cyclone Akará – 2024)

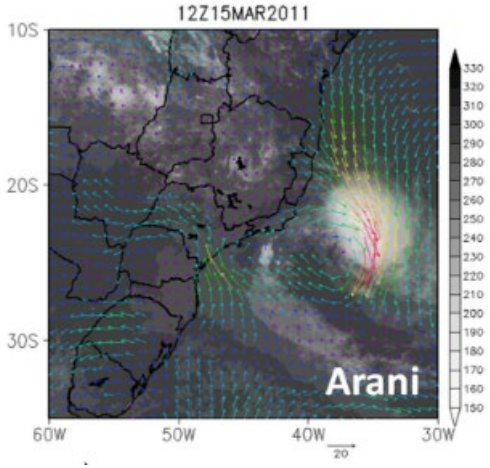
- ✓ Formation between latitudes 20º and 40º;
- ✓ Thermal symmetry and warm core for more than 36 hours;
- ✓ Not necessarily attain gale-force winds (but most of them do!)

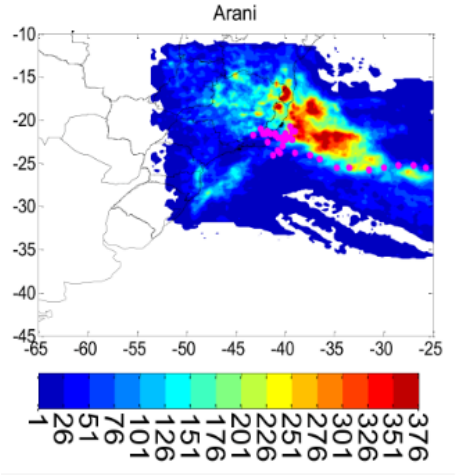
(Gozzo et al., 2014)

Subtropical cyclones

Active research topic in Brazilian Meteorological community because…

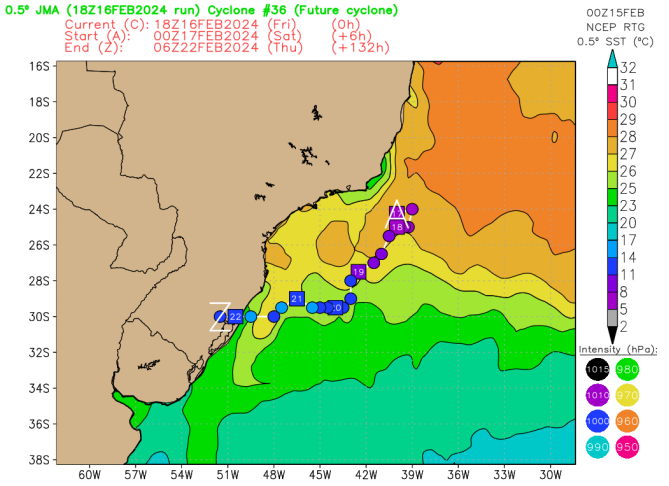
…they cause high low-level winds and rainfall…

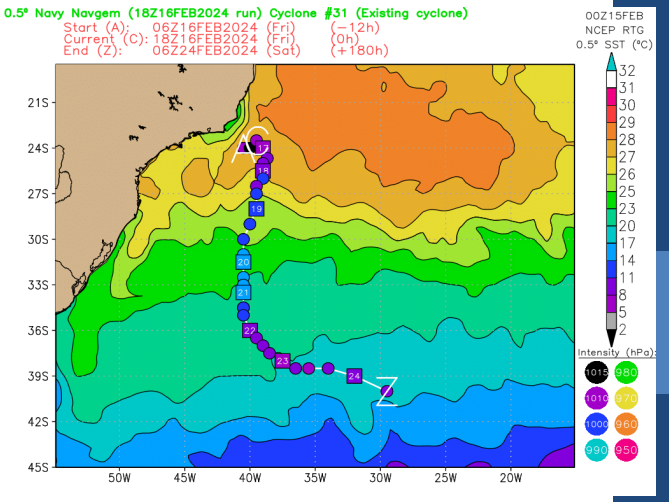




(Reboita et al., 2018)

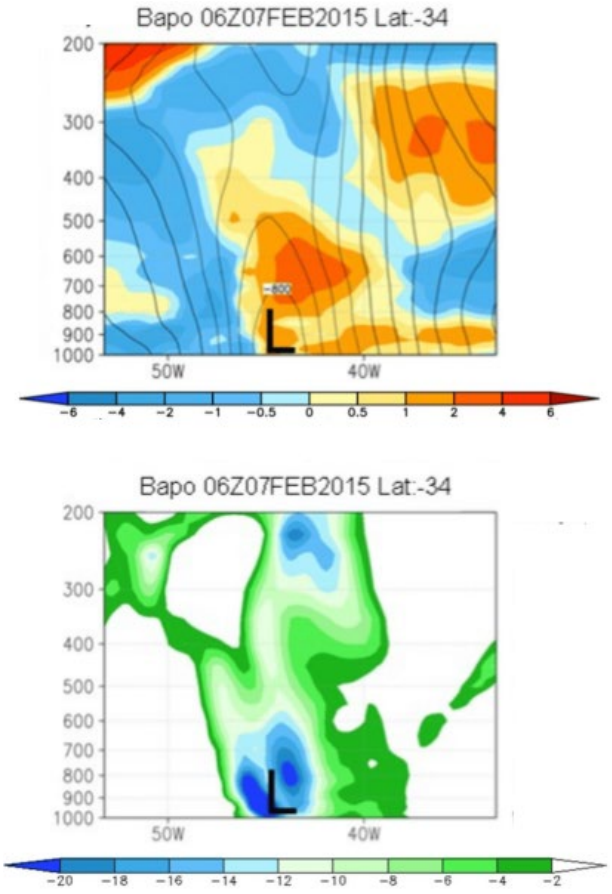
… and models still struggle to forecast/reproduce them!





Subtropical cyclones

Neither extratropical, nor tropical systems, but hybrid!



(Reboita et al., 2018)

Low-level warm core, barotropic ("stacked") structure and stronger low-level winds… tropical features!

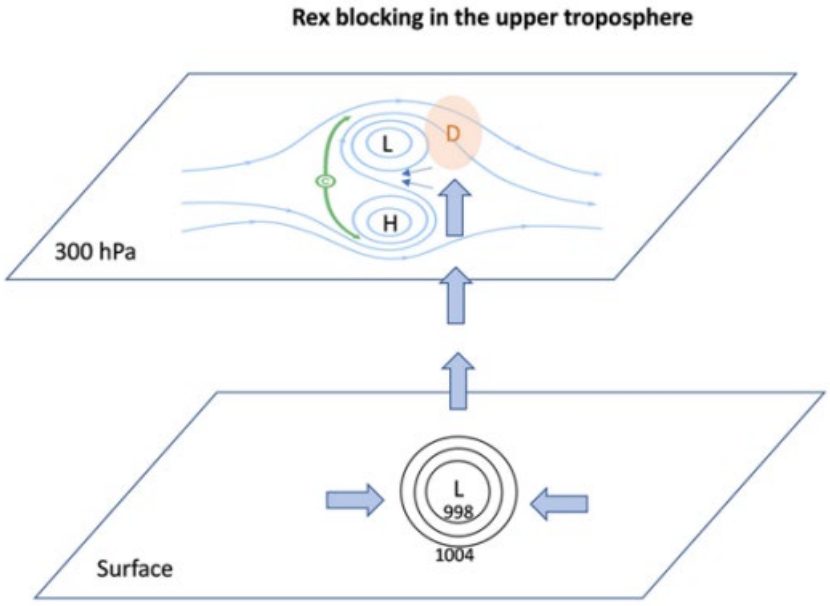
Upper-level cold core, formation in midlatitudes and tropopause folding signal… extratropical features!

Being partly tropical, these cyclones need two ingredients to develop: **weak vertical wind shear** and **abundant moisture to feed convection**!

Subtropical cyclogenesis

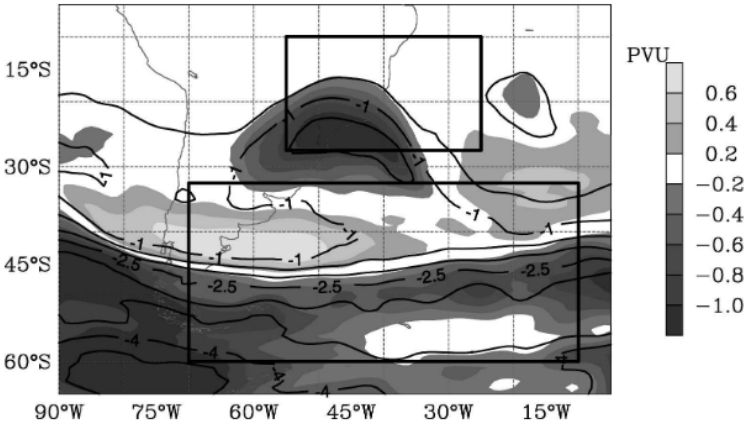
Weak vertical wind shear

- Upper-level dipole blocking



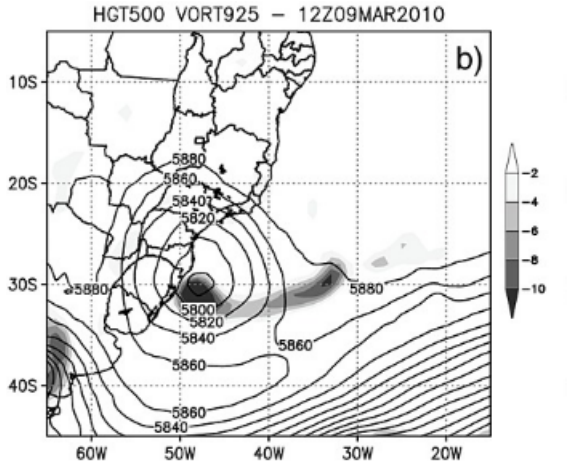
(da Rocha et al., 2019)

Cyclone Catarina (2004)



(McTaggart-Cowan et al., 2006)

Cyclone Anita (2010)

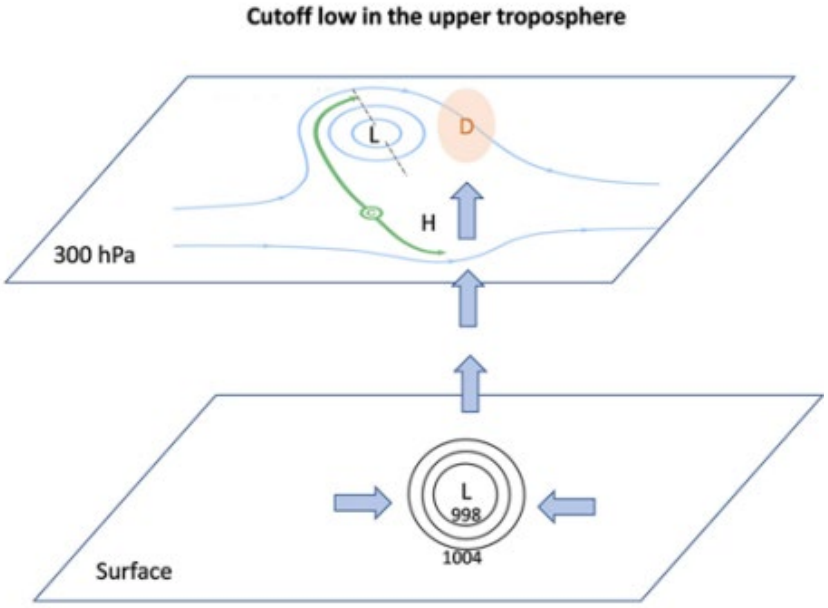


(Dias-Pinto et al., 2013)

Subtropical cyclogenesis

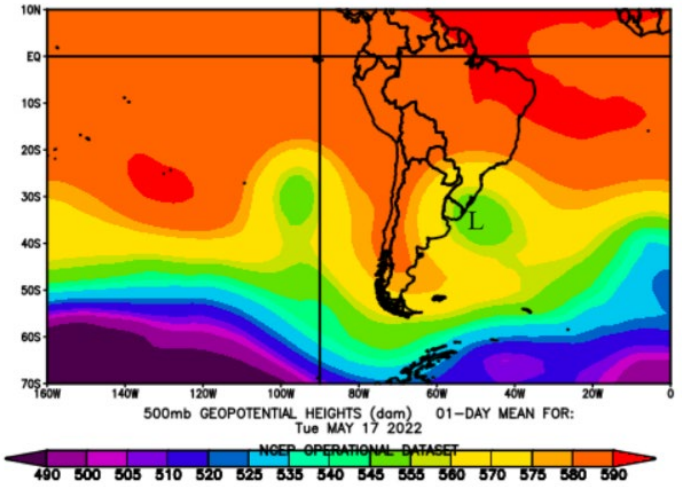
Weak vertical wind shear

- Upper-level cutoff low

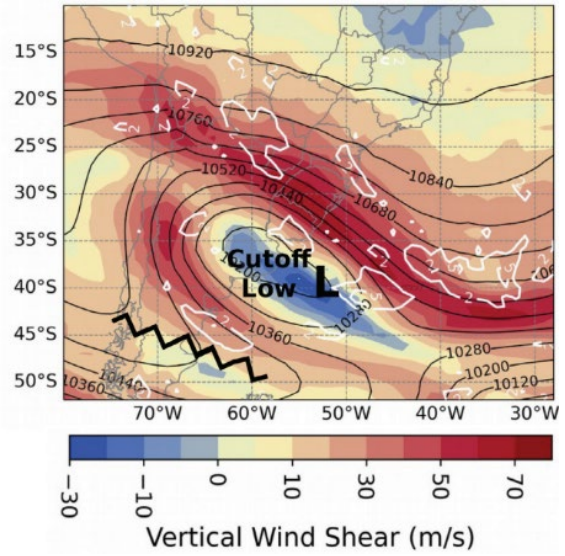


(Adapted from da Rocha et al., 2019)

Cyclone Yakecan (2022)



Cyclone Raoni (2021)

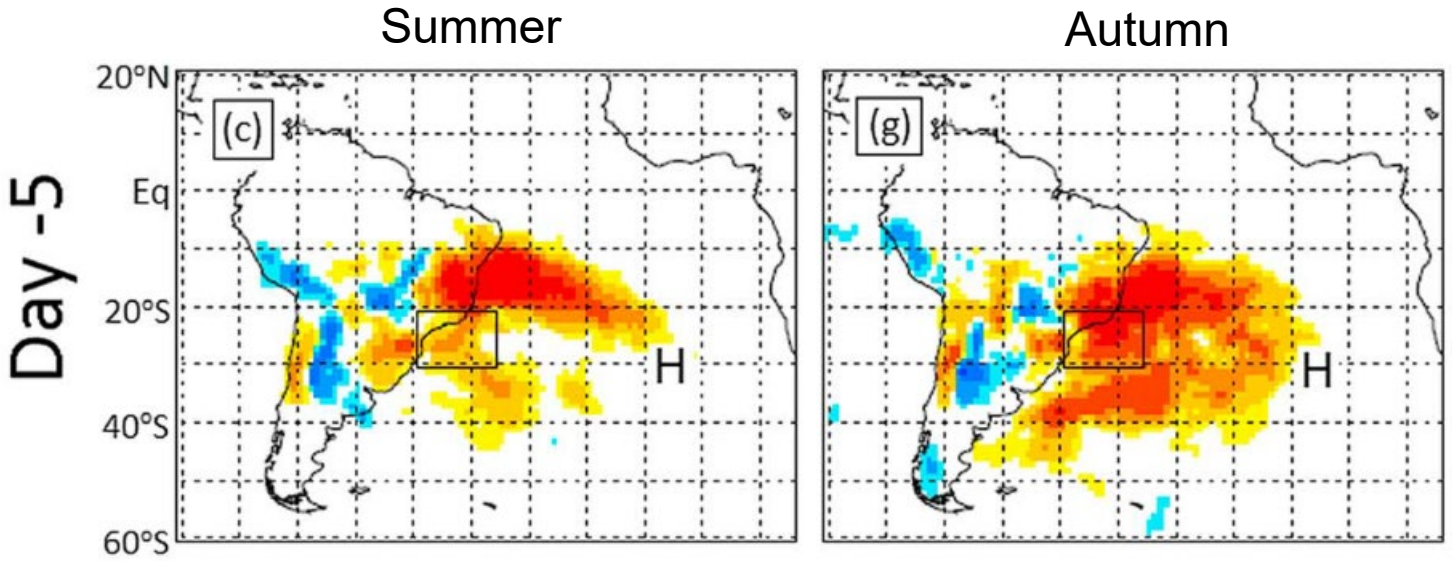


(Reboita et al., 2022)

Abundant moisture

Sea-air latent heat flux (evaporation) is the main moisture source, as occurs in the extratropical explosives and in hurricanes, BUT…

Water vapor source 5 days before subtropical cyclones

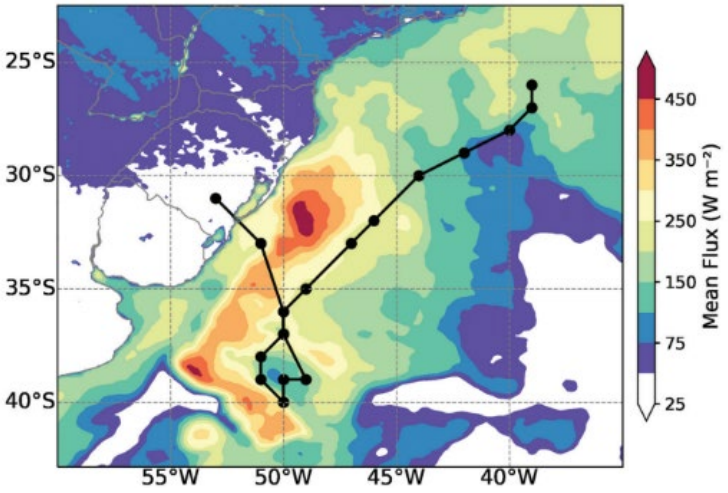


(Gozzo et al., 2017)

… not only local evaporation feed the subtropical cyclones, but also remote water vapor transport!

Abundant moisture

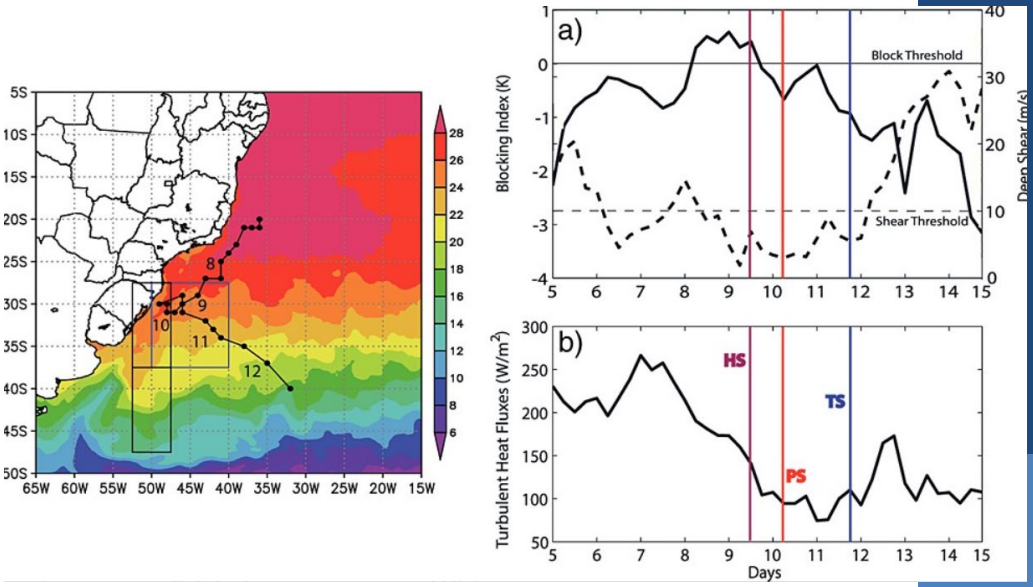
Cyclone Raoni (2021): surface fluxes strengthened a warm seclusion!



(Reboita et al., 2022)

A difference to tropical systems: atmospheric column destabilization may be high even with moderate surface fluxes and relatively low SST!

Cyclone Anita (2010)

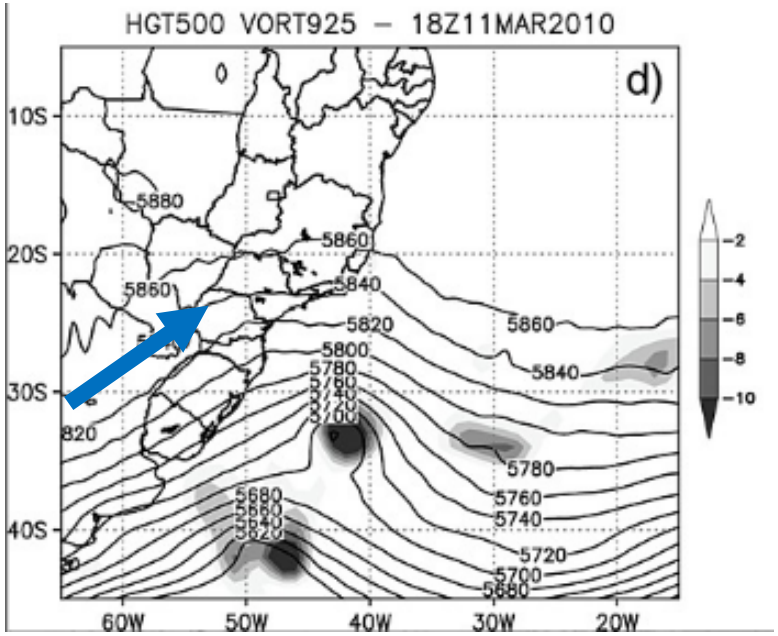


(Dias-Pinto et al., 2013)

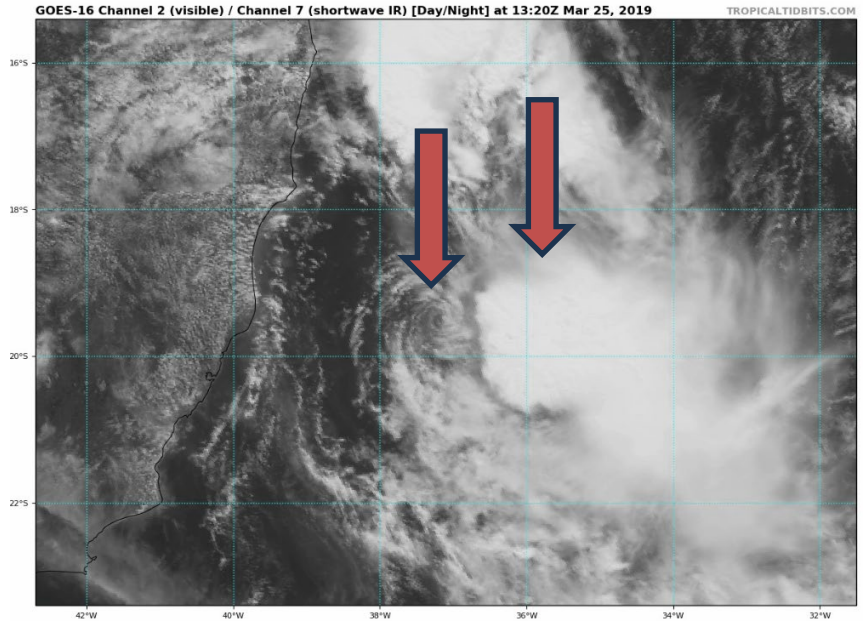
Vertical temperature gradient with cold cutoff is key!!

Subtropical cyclolysis

- Increased wind shear (trough approaching)



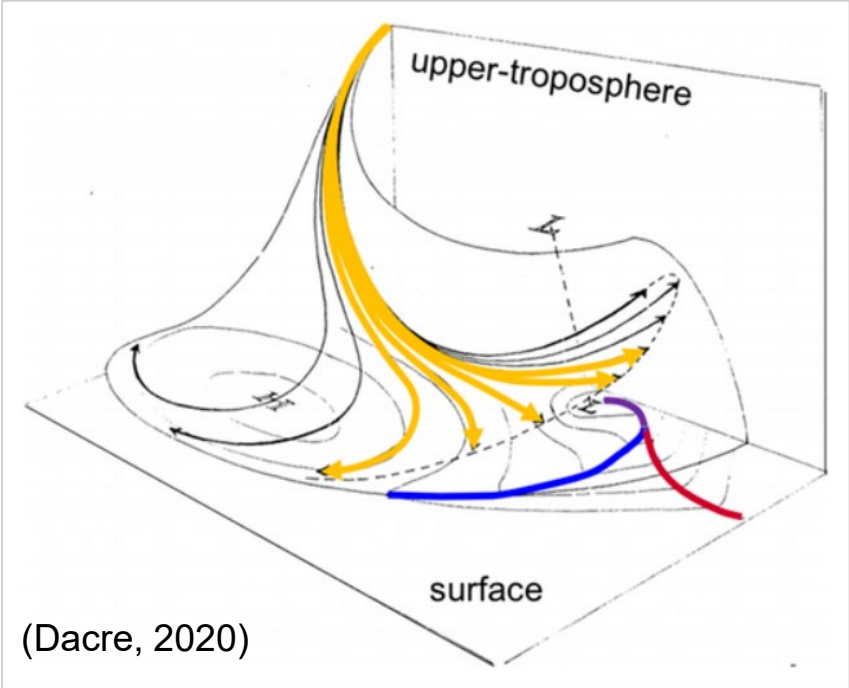
Cyclone Anita
(Dias-Pinto et al., 2013)



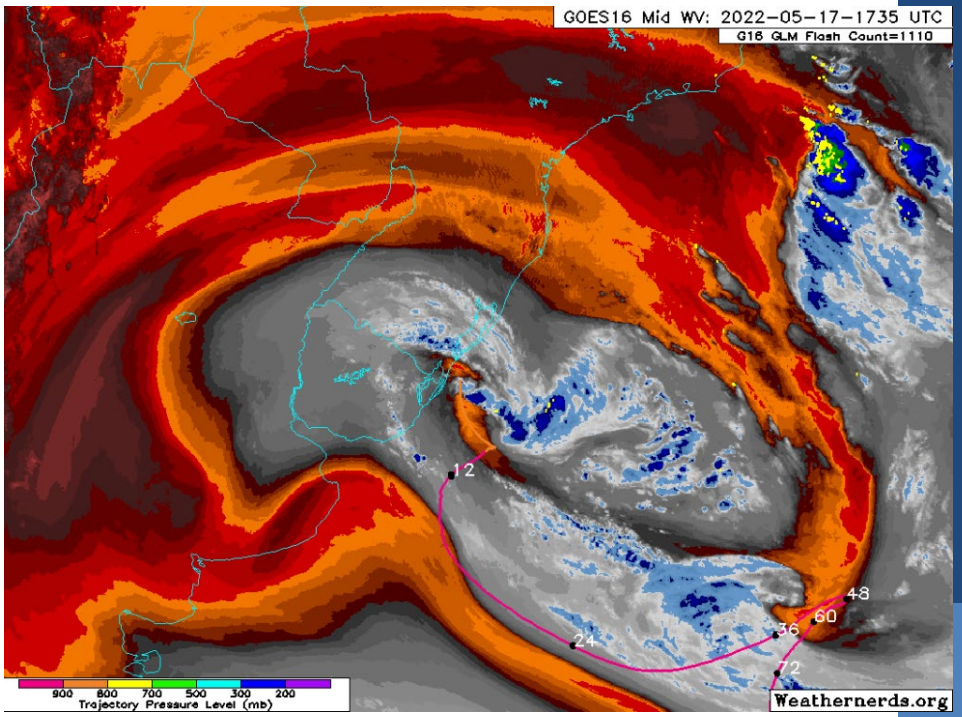
Cyclone Iba (2019)

Subtropical cyclolysis

- Dry intrusion



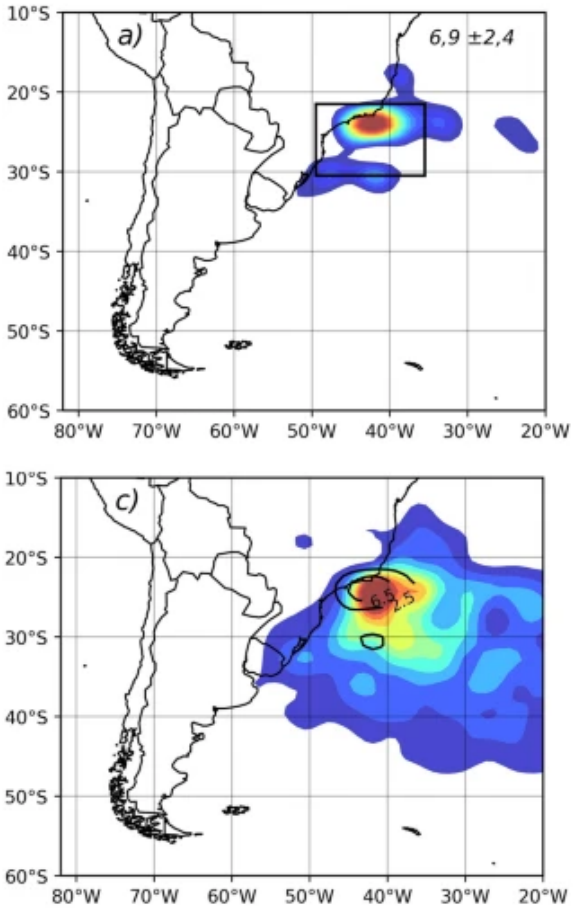
(Dacre, 2020)



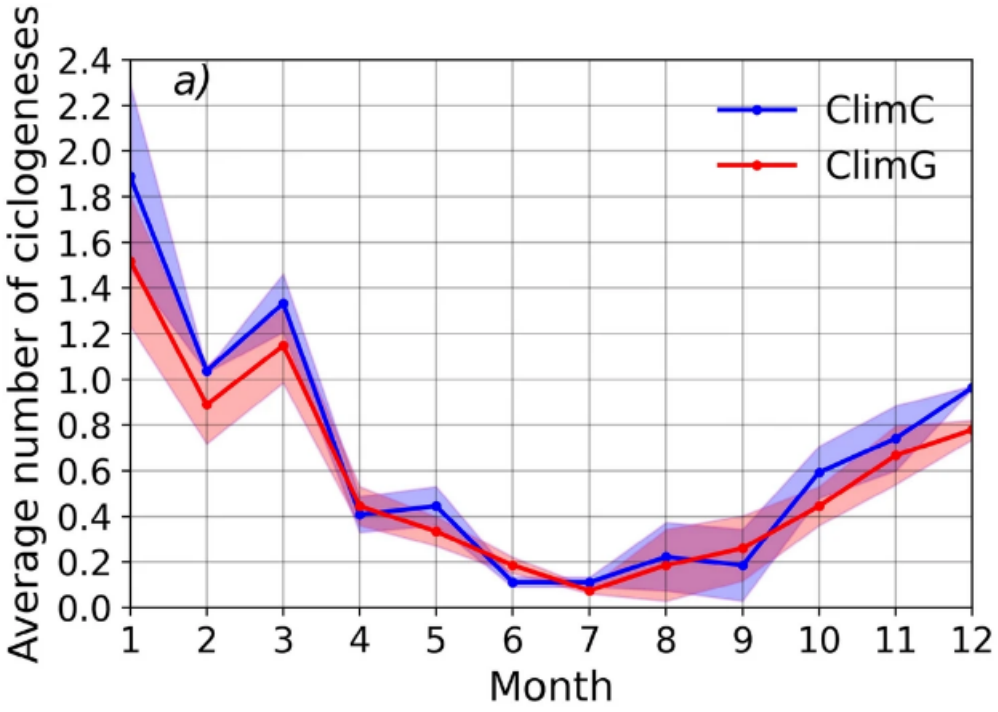
Cyclone Yakecan – 2022

Climatology and projected future changes in subtropical cyclones

Cyclogenesis density and trajectories



Mean monthly frequency

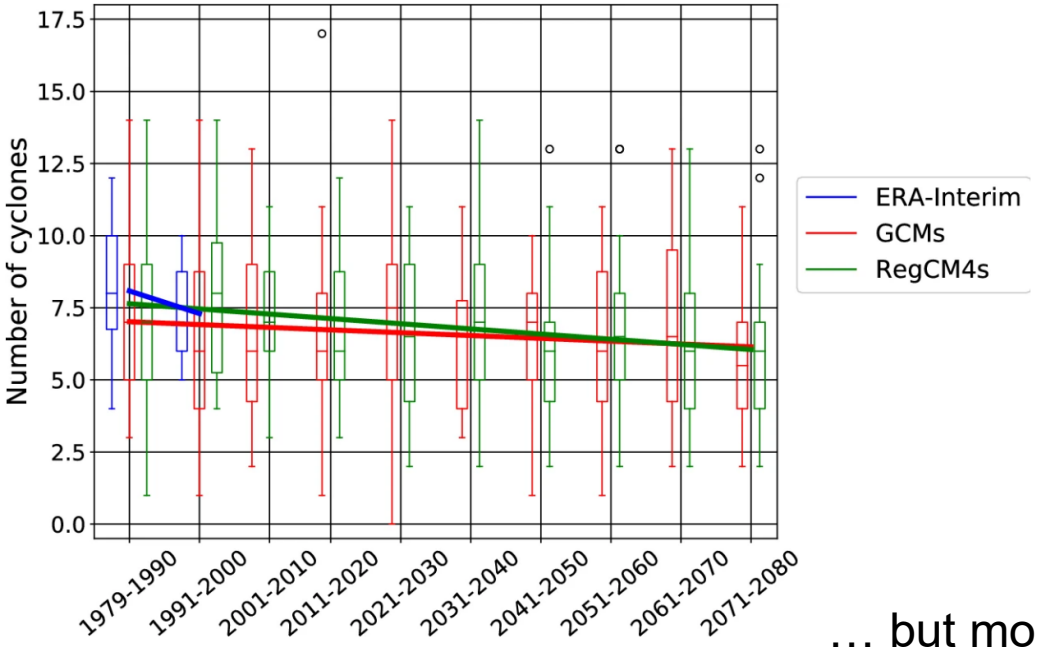


(Gozzo et al., 2014; de Jesus et al., 2021)

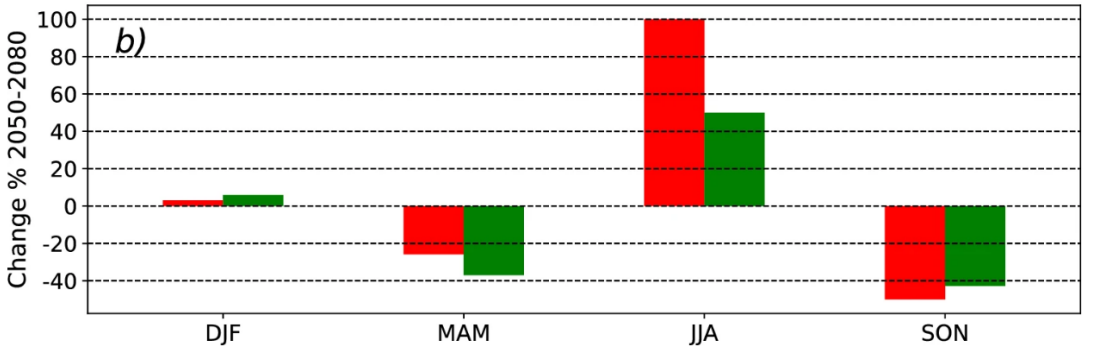
Climatology and projected future changes in subtropical cyclones

By the end of 21st century, near Southeastern Brazil:

Less subtropical cyclones per year…



… but more winter systems (more “Raoni”s)

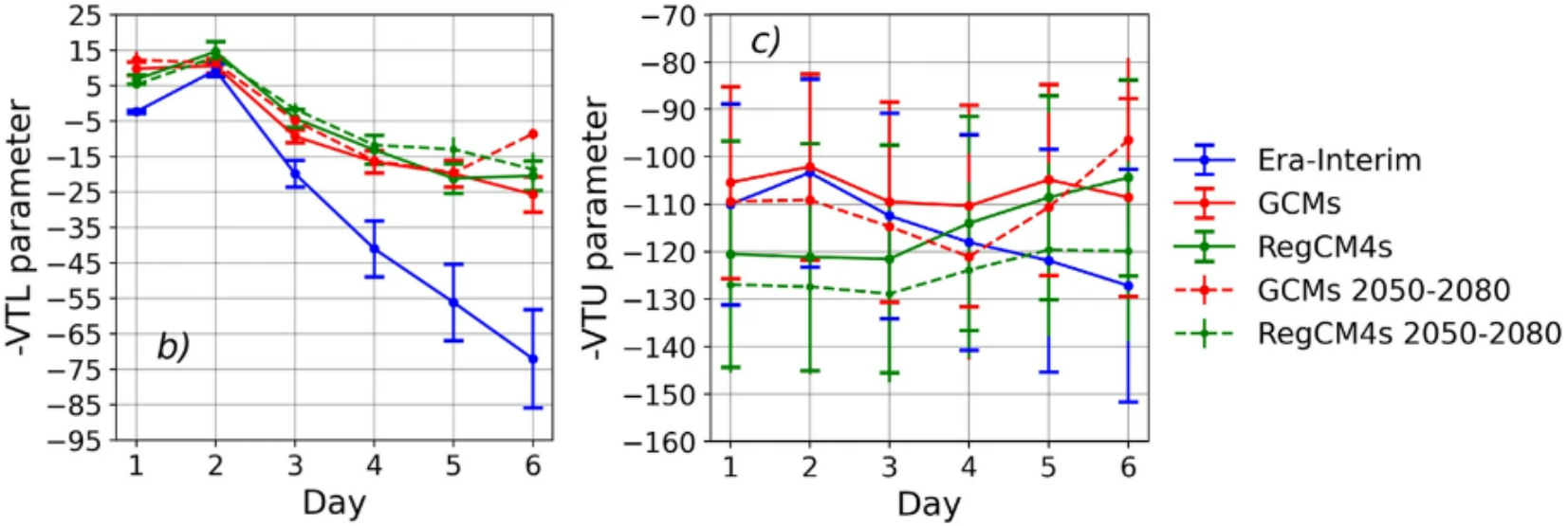


(de Jesus et al., 2021)

Climatology and projected future changes in subtropical cyclones

By the end of 21st century, near Southeastern Brazil:

Warmer low-levels AND warmer upper-levels



(de Jesus et al., 2021)

Brazilian southeastern coast may see less frequent but ‘more tropical’ subtropical cyclones in the future!

More subtropical and tropical cyclones in the future?

- Poleward shift of the upper-level jets reducing wind shear (Solman & Orlanski, 2014 – and references therein)

- Sea surface temperature warming – trend is already a fact, and it is projected to continue increasing

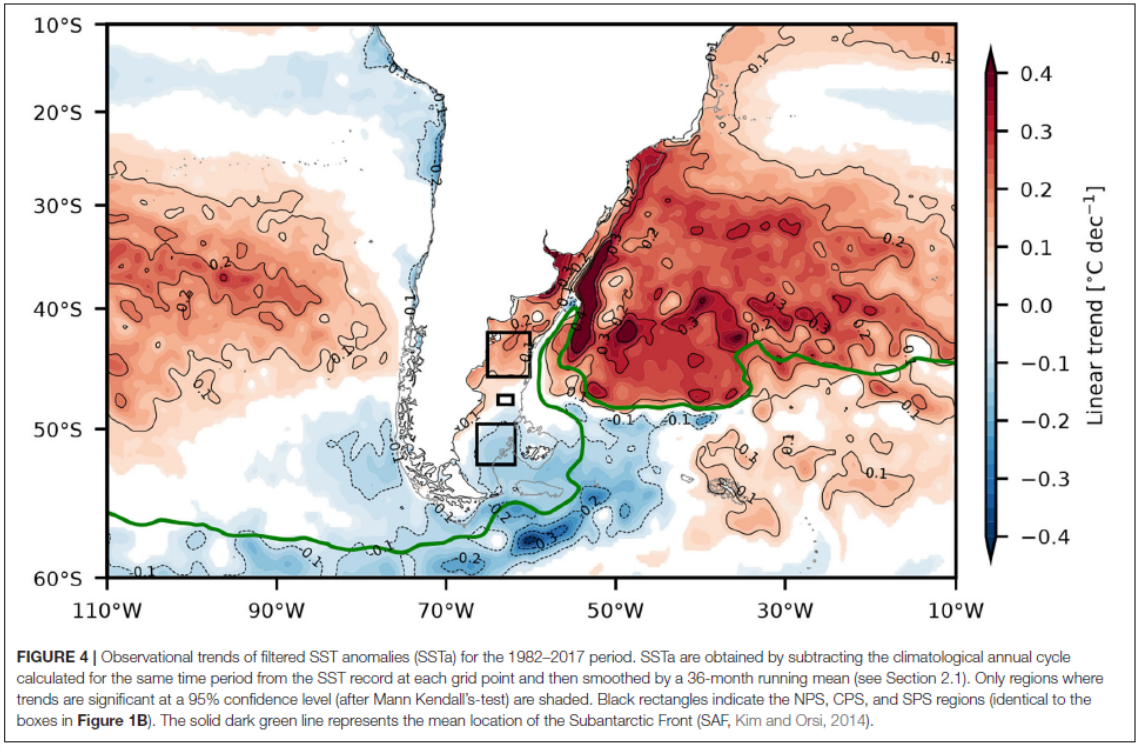


FIGURE 4 | Observational trends of filtered SST anomalies (SSTa) for the 1982–2017 period. SSTa are obtained by subtracting the climatological annual cycle calculated for the same time period from the SST record at each grid point and then smoothed by a 36-month running mean (see Section 2.1). Only regions where trends are significant at a 95% confidence level (after Mann Kendall's-test) are shaded. Black rectangles indicate the NPS, CPS, and SPS regions (identical to the boxes in **Figure 1B**). The solid dark green line represents the mean location of the Subantarctic Front (SAF, Kim and Orsi, 2014).

(Risaro et al., 2022)

References

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da Rocha, R. P., Reboita, M. S., Gozzo, L. F., Dutra, L. M. M., & de Jesus, E. M. (2019). Subtropical cyclones over the oceanic basins: a review. *Annals of the New York Academy of Sciences*, *1436*(1), 138-156.

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Thanks / Muchas gracias / Obrigado!!

Questions?

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