The role of tropical waves in the genesis of tropical cyclone Seroja

blatos@igf.edu.pl
http://beatalatos.com/

Beata Latos[1]

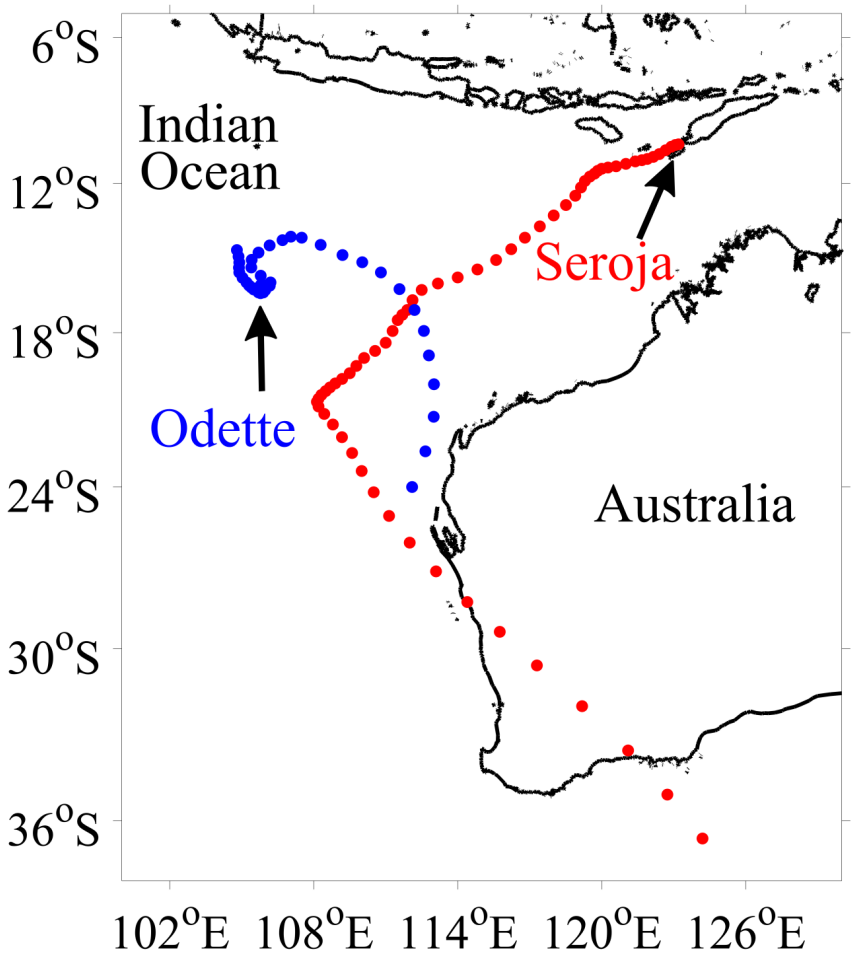
supervisor: Piotr J. Flatau[2]
co- supervisor: Dariusz Baranowski[1]

Other co-authors:

Philippe Peyrillé[3], Thierry Lefort[3], Maria K. Flatau[4],
Donaldi Permana[5], Nelly Florida[5]

[1]Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
[2]Scripps Institution of Oceanography, San Diego, CA, USA
[3]Centre National de Recherches Meteorologiques, Meteo-France, Toulouse, France
[4]Naval Research Laboratory, Monterey, CA, USA
[5]Meteorological Climatological and Geophysical Agency, Jakarta, Indonesia

Institute of Geophysics
Polish Academy of Sciences



NATIONAL SCIENCE CENTRE POLAND

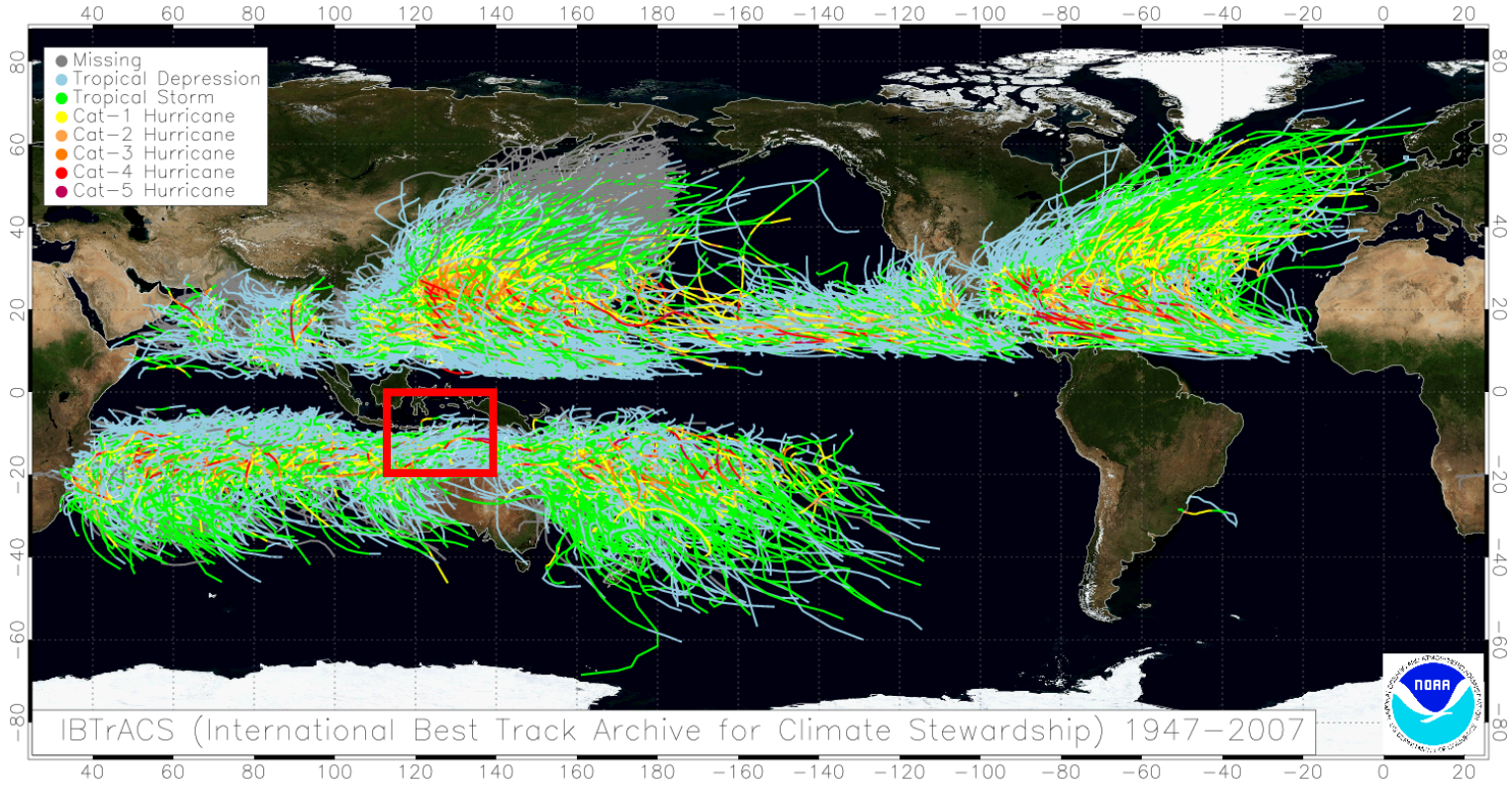
Natural Environment Research Council

This research has been supported in part by:
- NSF grant 1724741 „Equatorial Line Observations (ELO) field campaign during the International Years of Maritime Continent (YMC)". ELO is a joint US-UK project funded by National Science Foundation (NSF), USA, and NERC, UK;
- NCN grant no. 2020/37/N/ST10/03428 (Preludium);
- NCN grant no. 2019/35/B/ST10/03463 (OPUS).

Six main requirements for tropical cyclogenesis:

- warm waters,
- high moisture levels in the low and mid-troposphere,
- Coriolis force,
- a weak vertical wind shear,
- atmospheric instability
- large magnitude of relative vorticity in the lower troposphere (Gray 1986)

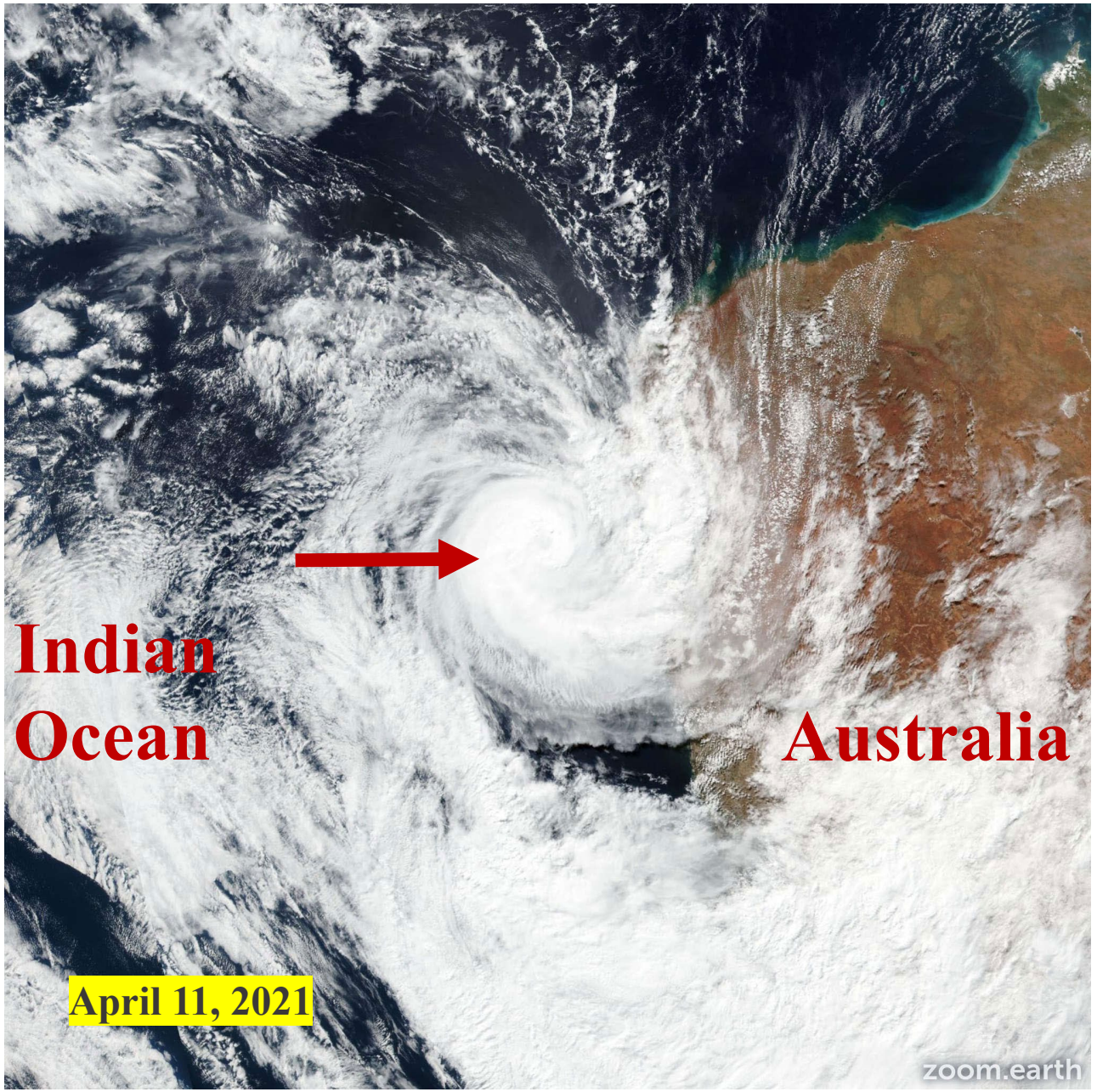
+ **perturbation**



http://www.atms.unca.edu/chennon/images/ibtracs.png

Gray, W. (1968): "Global view of the origin of tropical disturbances and storms." *Monthly Weather Review.*

In late March and early April 2021, TC Seroja impacted Indonesia, East Timor and Western Australia coast



https://zoom.earth/storms/seroja-2021/#layers=daily

According to the BMKG, Indonesia has experienced 10 Tropical Cyclones since 2008

TC Seroja was:

- **one of the first TC to have a significant impact on Indonesian land;**
- **the strongest one to form in such a close proximity to Timor Island.**

~270 people were killed by the storm in Indonesia and East Timor
Economic loss: 475+ million $
One person was killed in Australia
Economic loss: 250+ million $

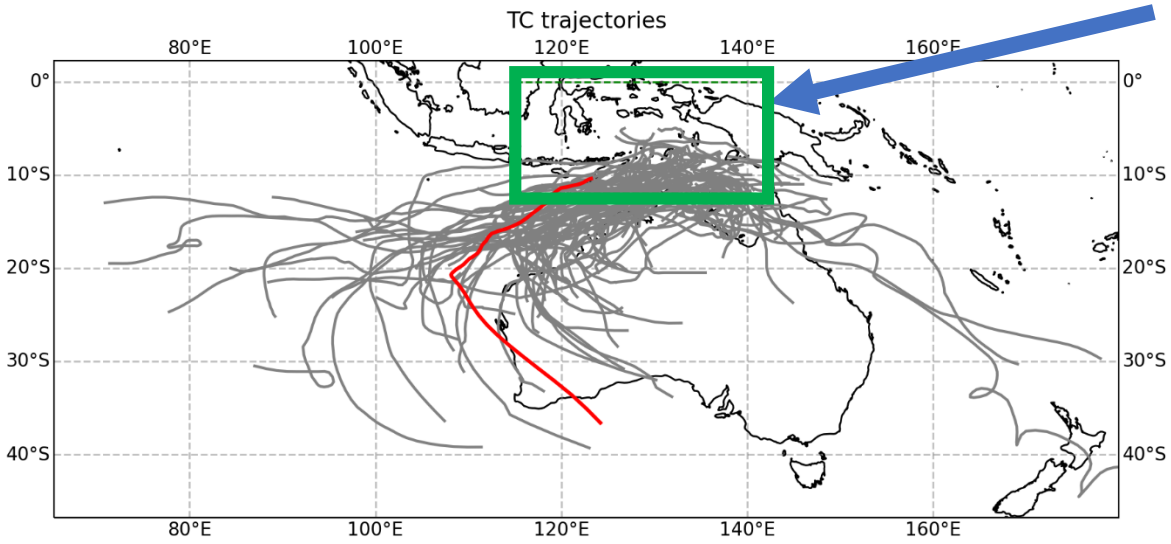
http://thoughtleadership.aon.com/Documents/20211006_analytics-if-may-global-recap.pdf

https://weather.com/news/news/2021-04-05-indonesia-east-timor-flooding-landslides-tropical-cyclone-seroja

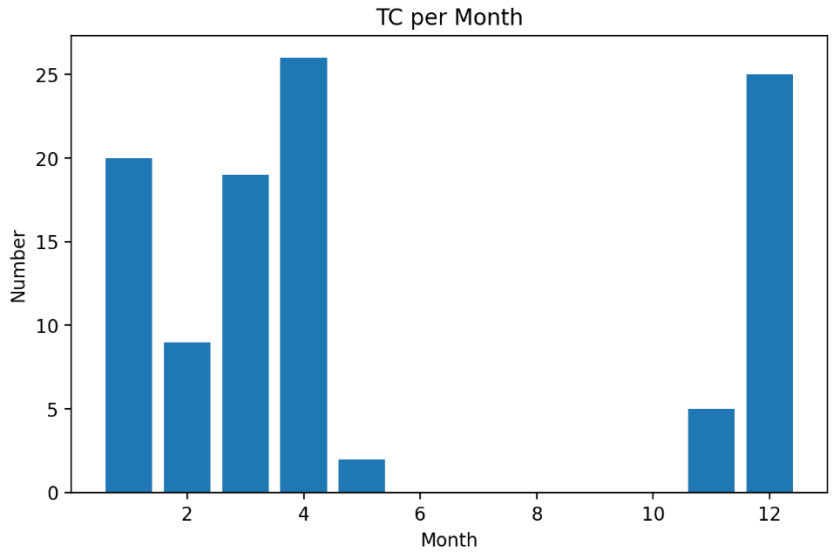
https://en.tempo.co/read/1449601/bmkg-explains-4-impacts-of-tropical-cyclone-seroja-in-indonesia

https://7news.com.au/news/weather/damage-blackouts-as-seroja-slams-wa-c-2570320

TC initiated after 1974 the box: [115, 142, -12, 0], N =106



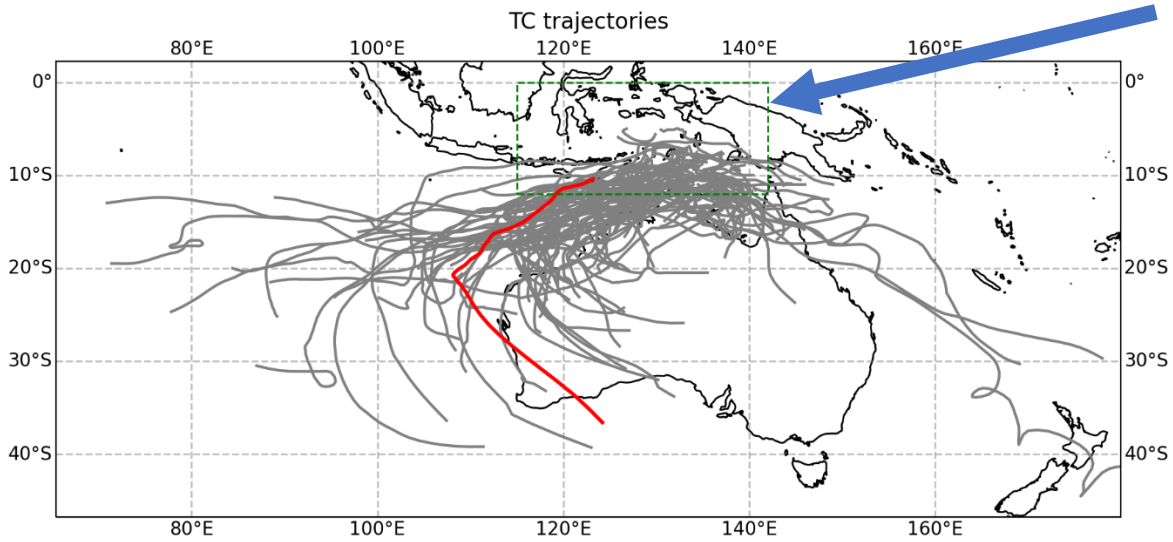
Only TCs that initiated inside this box were considered



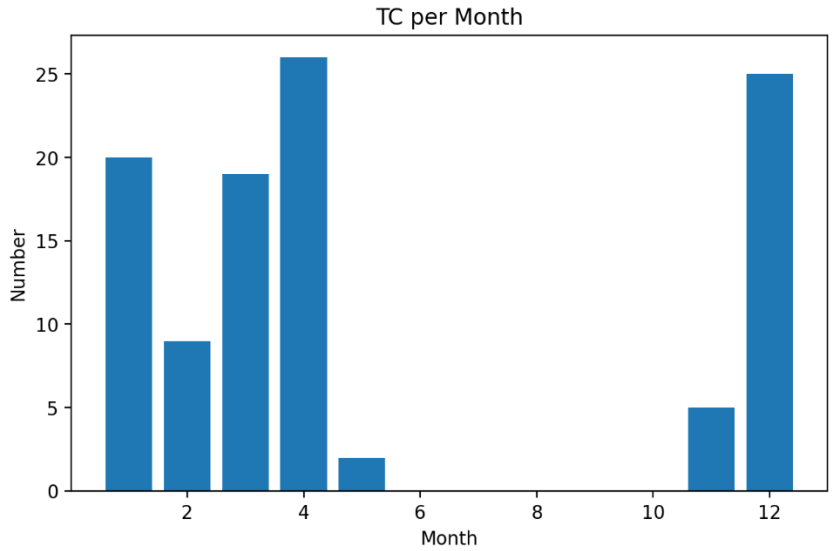
<u>INITIATION = first data point in IBTrACS</u>

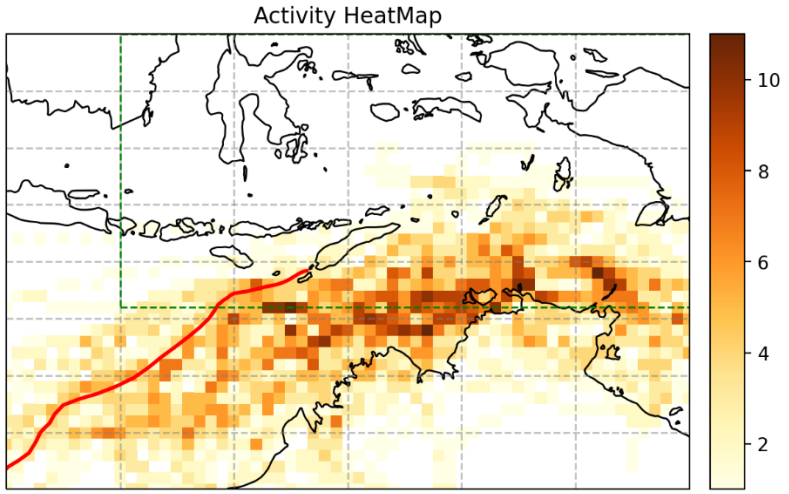
<u>First data point in in IBTrACS = when the vortex reaches the criteria of a tropical disturbance, depression or tropical storm</u>

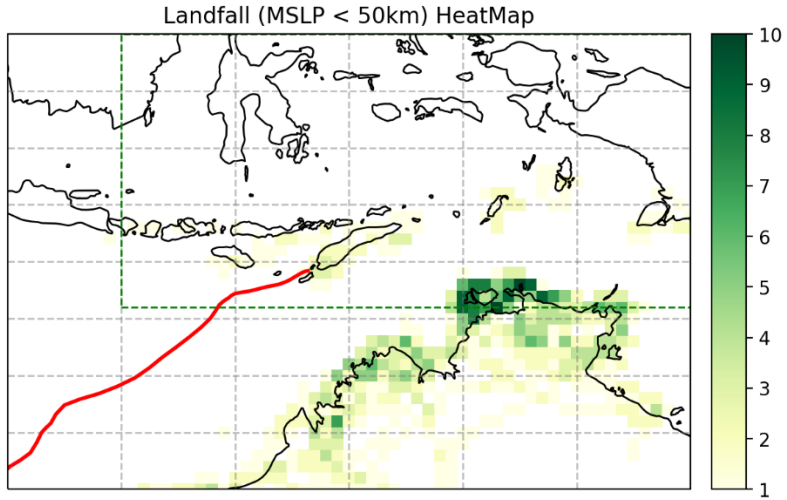
TC initiated after 1974 the box: [115, 142, -12, 0], N =106



Only TCs that initiated inside this box were considered



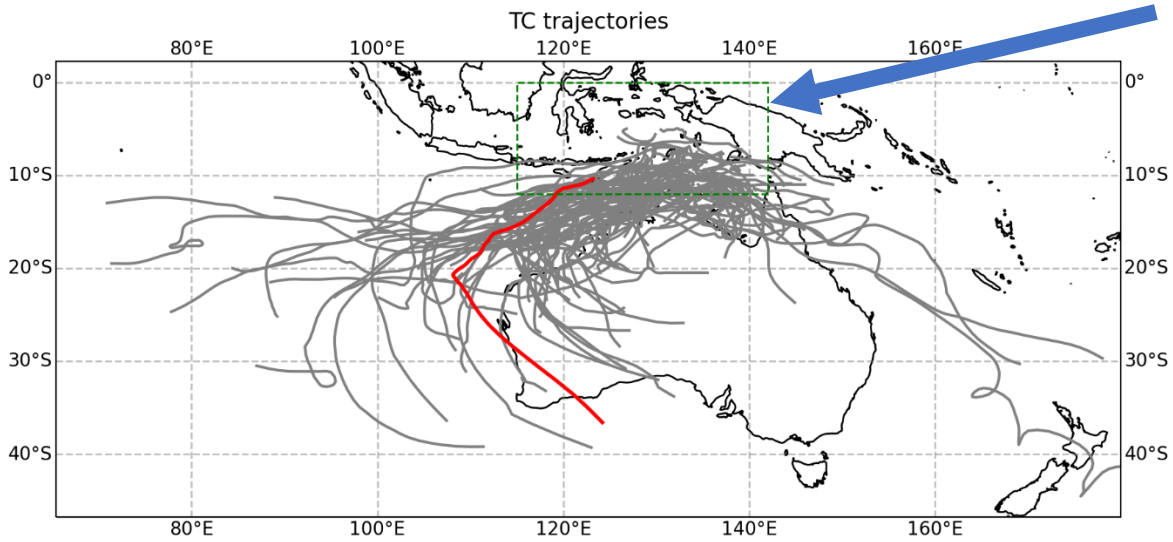




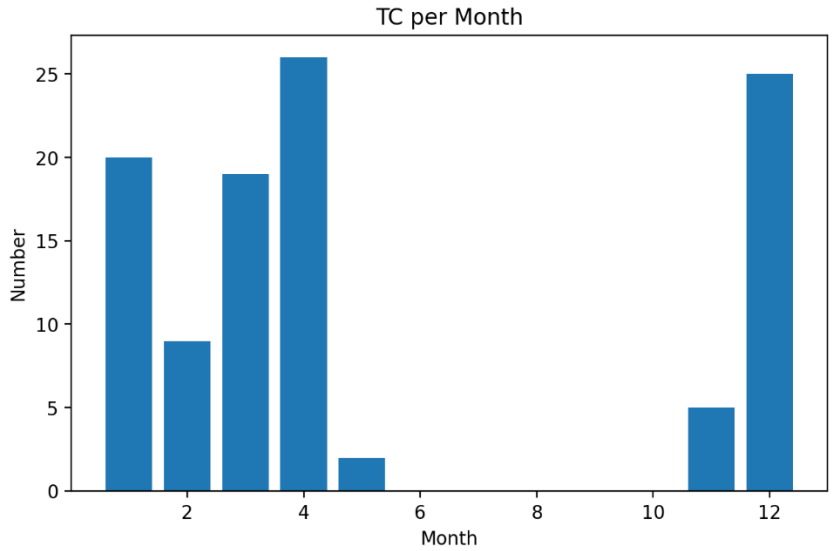
INITIATION = first data point in IBTrACS

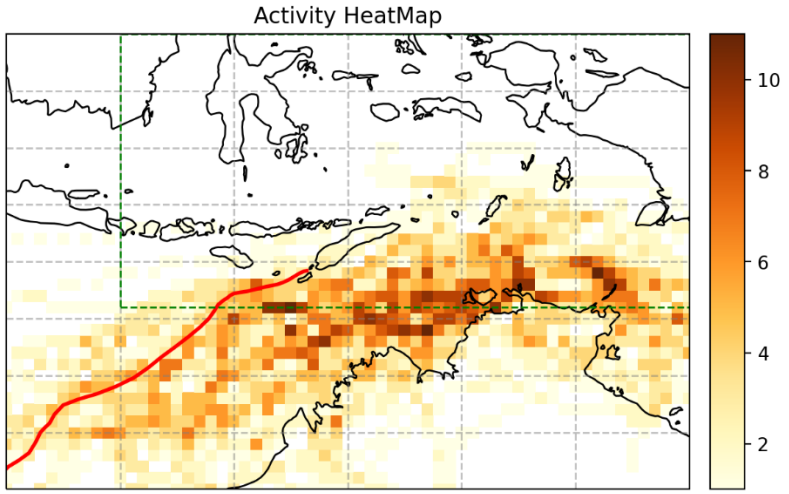
First data point in in IBTrACS = when the vortex reaches the criteria of a tropical disturbance, depression or tropical storm

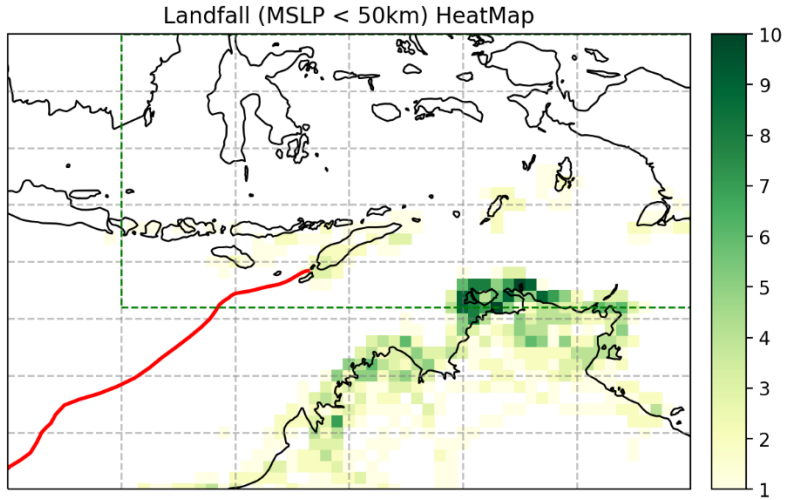
TC initiated after 1974 the box: [115, 142, -12, 0], N =106

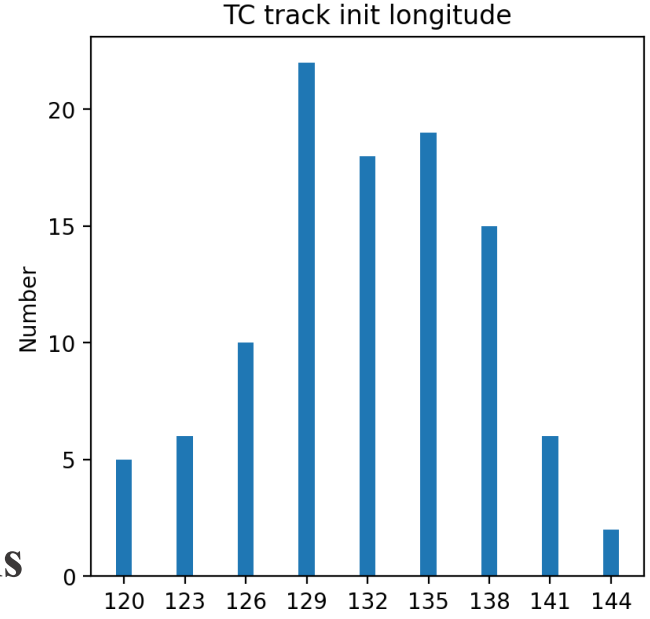


Only TCs that initiated inside this box were considered







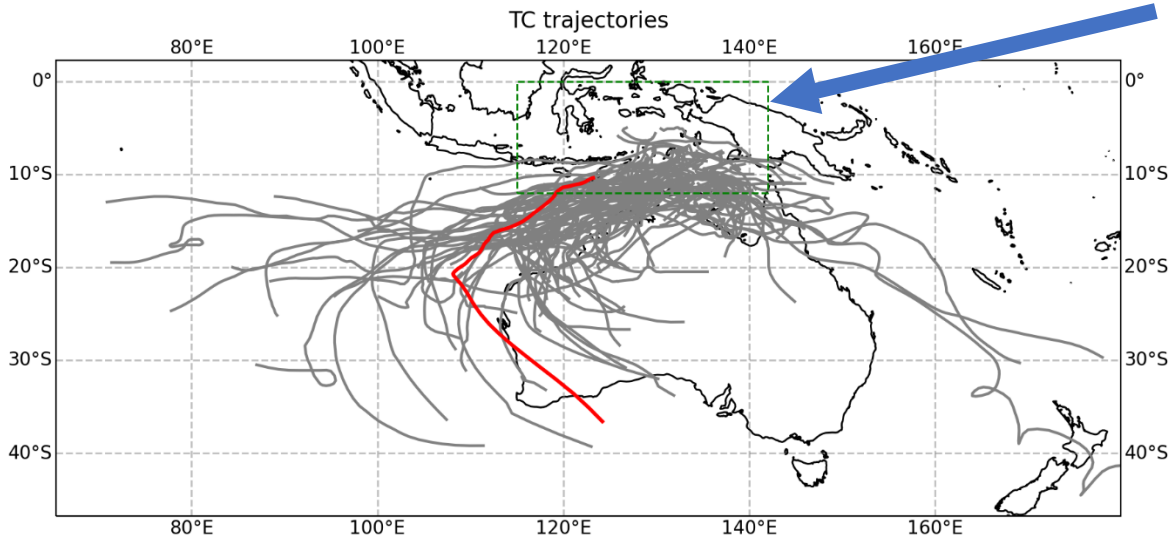


<u>INITIATION = first data point in IBTrACS</u>

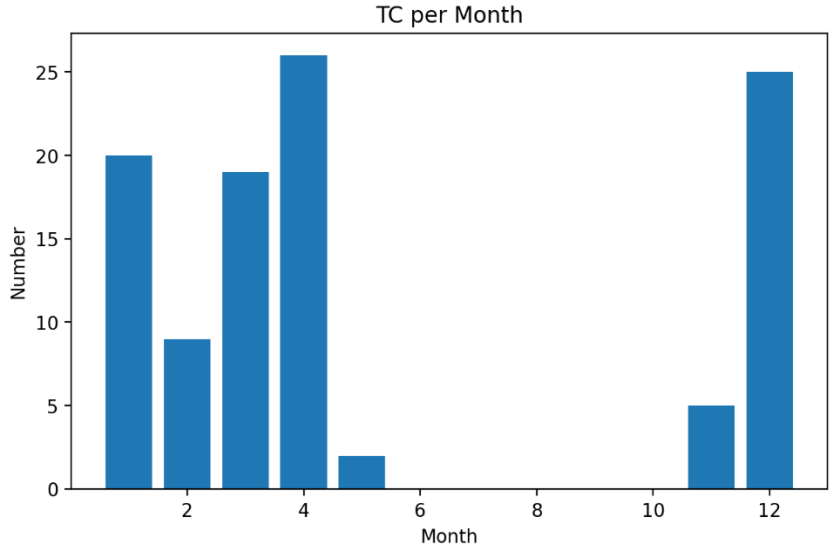
Seroja initiated at 10S, 124E, which is an outlier due to <u>longitude</u>

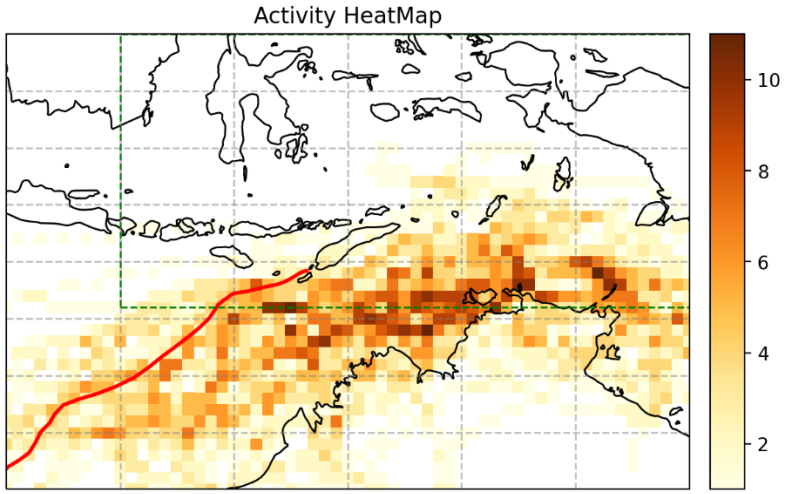
<u>First data point in in IBTrACS = when the vortex reaches the criteria of a tropical disturbance, depression or tropical storm</u>

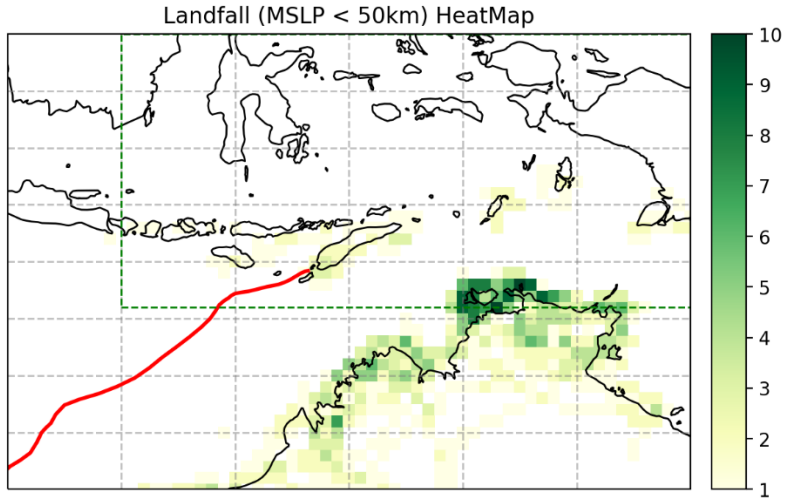
TC initiated after 1974 the box: [115, 142, -12, 0], N =106

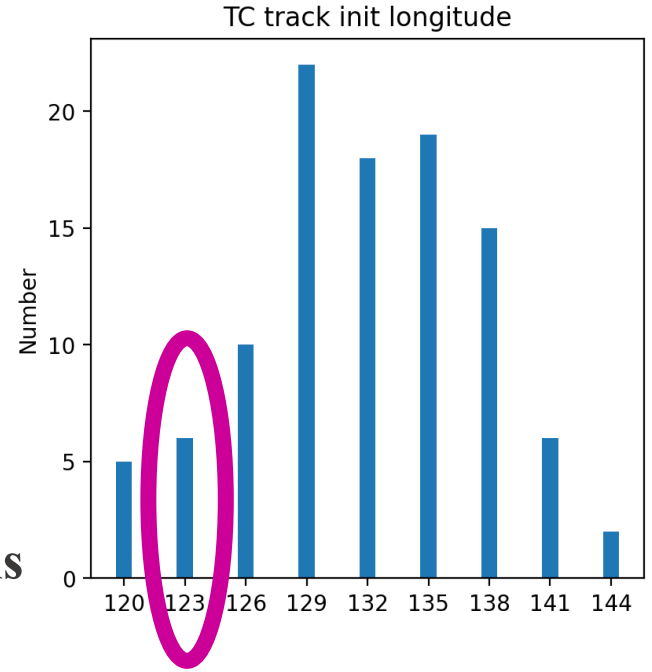


Only TCs that initiated inside this box were considered







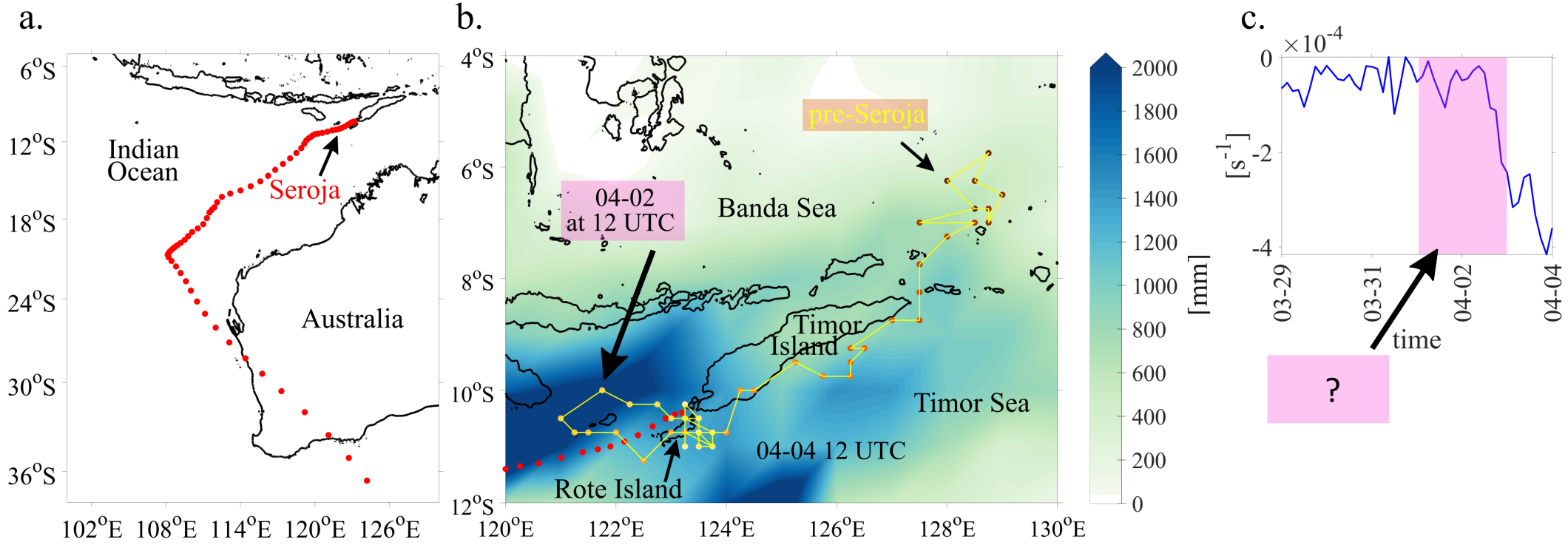


Seroja initiated at 10S, 124E, which is an outlier due to longitude

INITIATION = first data point in IBTrACS

First data point in in IBTrACS = when the vortex reaches the criteria of a tropical disturbance, depression or tropical storm

Timor Island: from 29 March to 4 April (BEFORE TC SEROJA), heavy rains across the country have caused flash floods and landslides



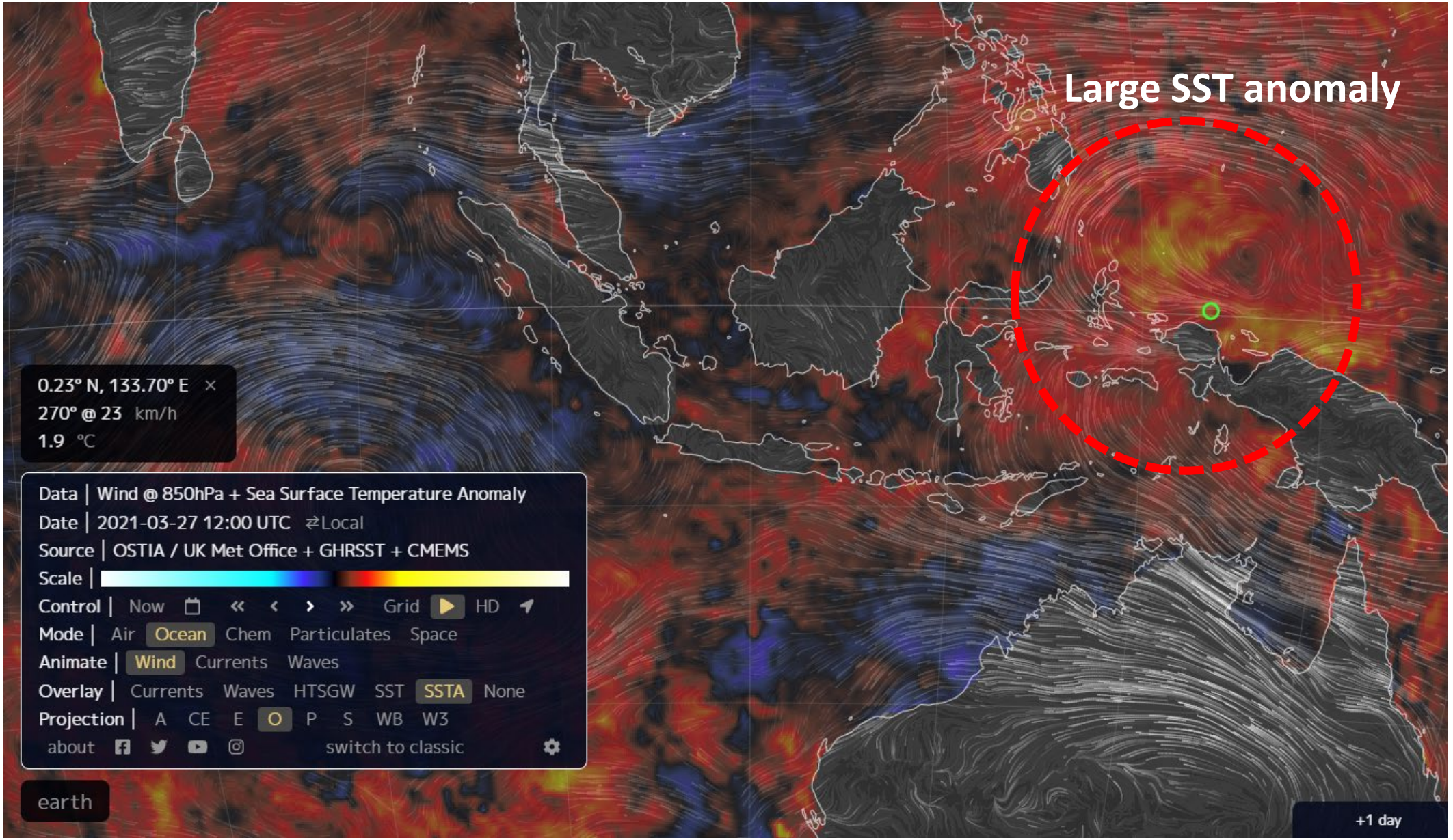
(a) TC Seroja (red dots) tracks obtained from the International Best Track Archive for Climate Stewardship (IBTrACS). Data every 3h starting at April 4, 12 UTC.

(b) precursor of TC Seroja identified using backward trajectory based on ERA-5 relative vorticity (dots, line, data every 3h starting at March 28, 0 UTC) and accumulation of GPM precipitation anomalies between March 28 and April 7 (shading).

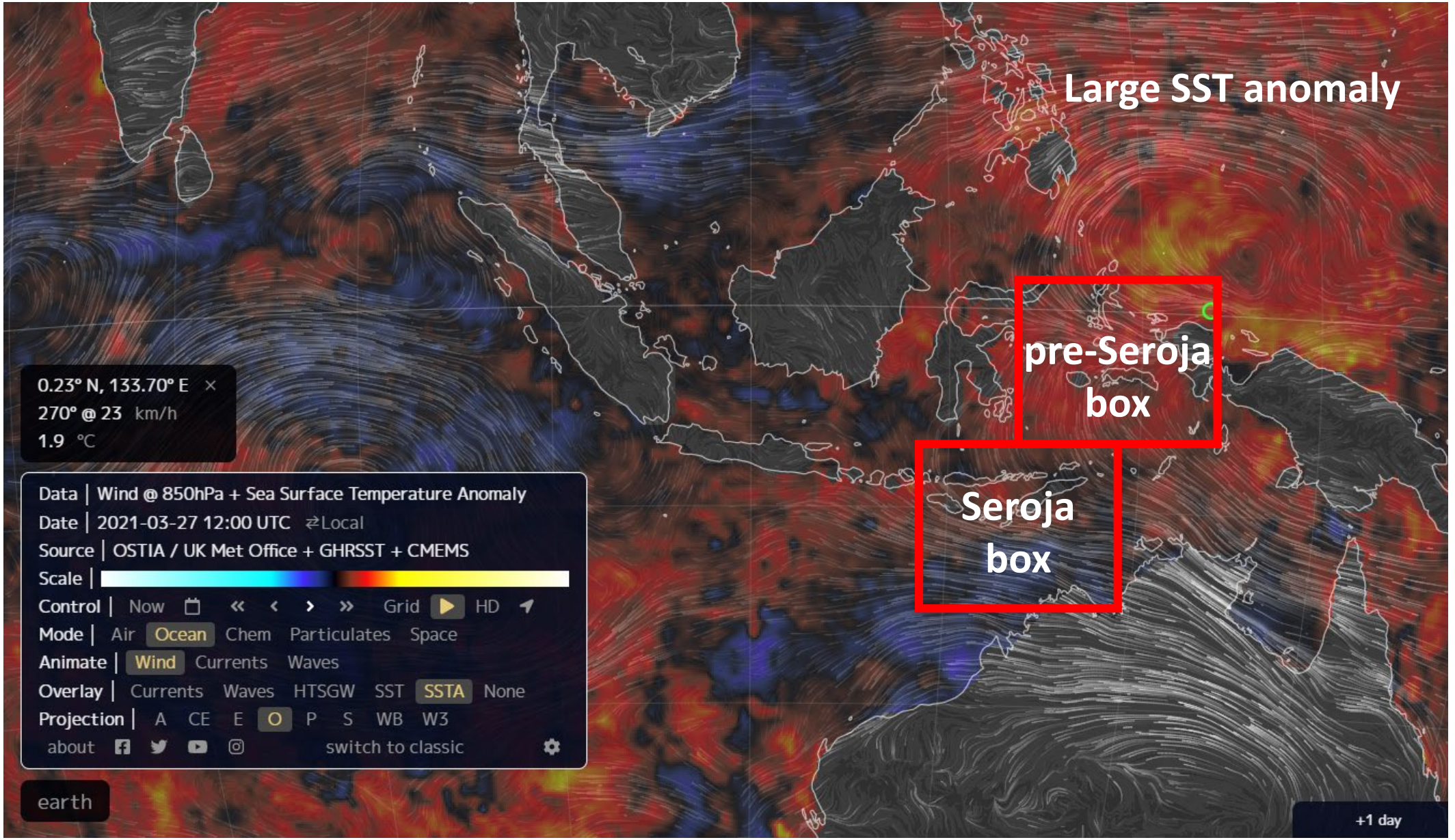
(c) integrated ERA-5 relative vorticity tracked in the precursor of TC Seroja. Data every 3~h.

Introduction & Motivation
short summary

- TC can cause great loss of life and damage
- several criteria must be fulfilled for a TC to develop
- TC Seroja was the first TC to have a significant impact on Indonesian land + the strongest one close to Timor
- floods in East Timor happened before the tropical low developped into TC (before April 4, 2021)

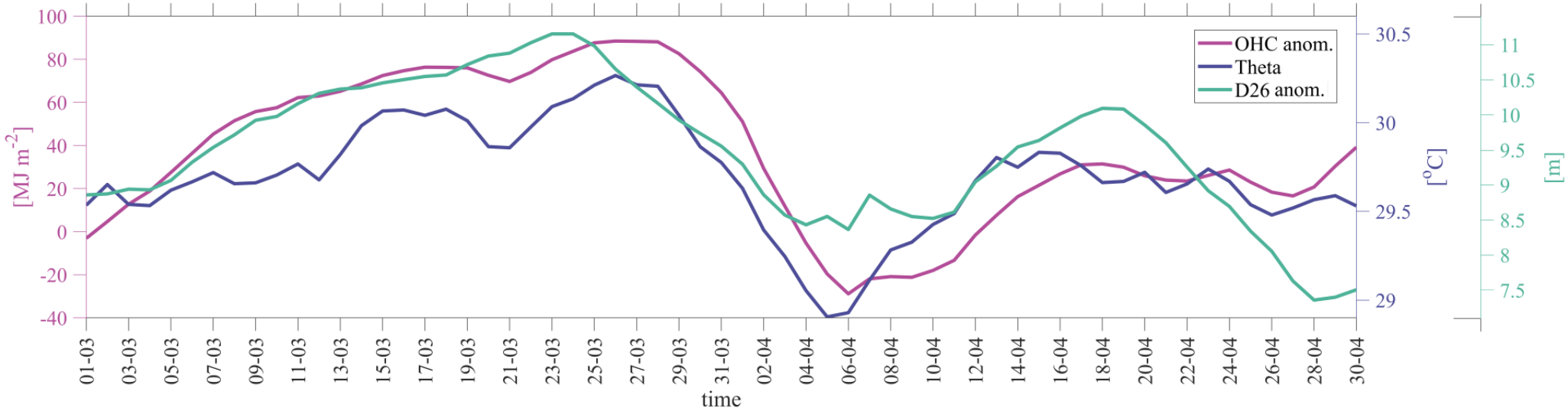


https://earth.nullschool.net/

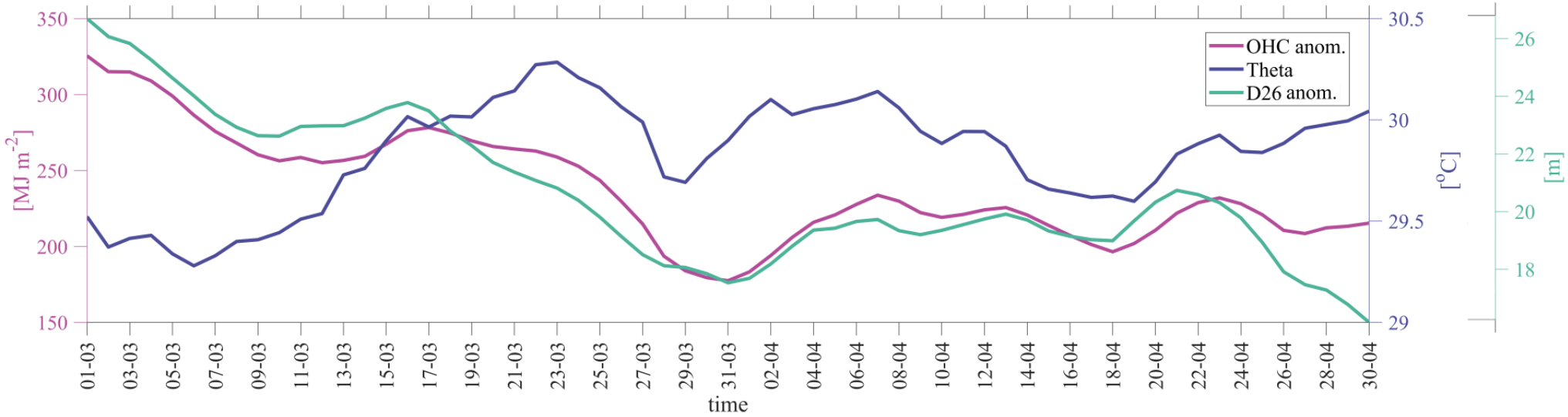


https://earth.nullschool.net/

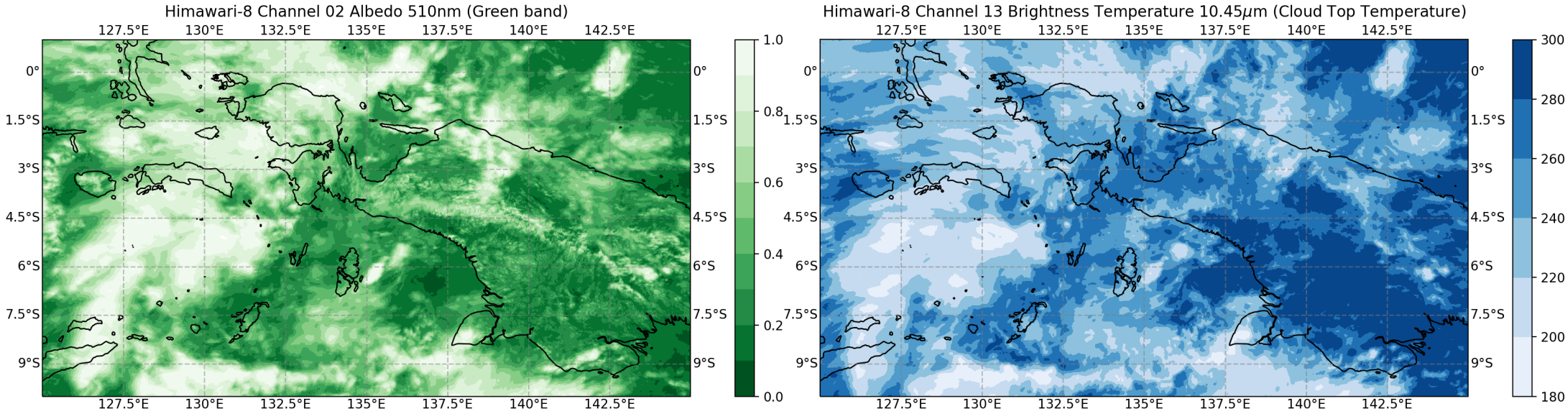
a) Seroja box



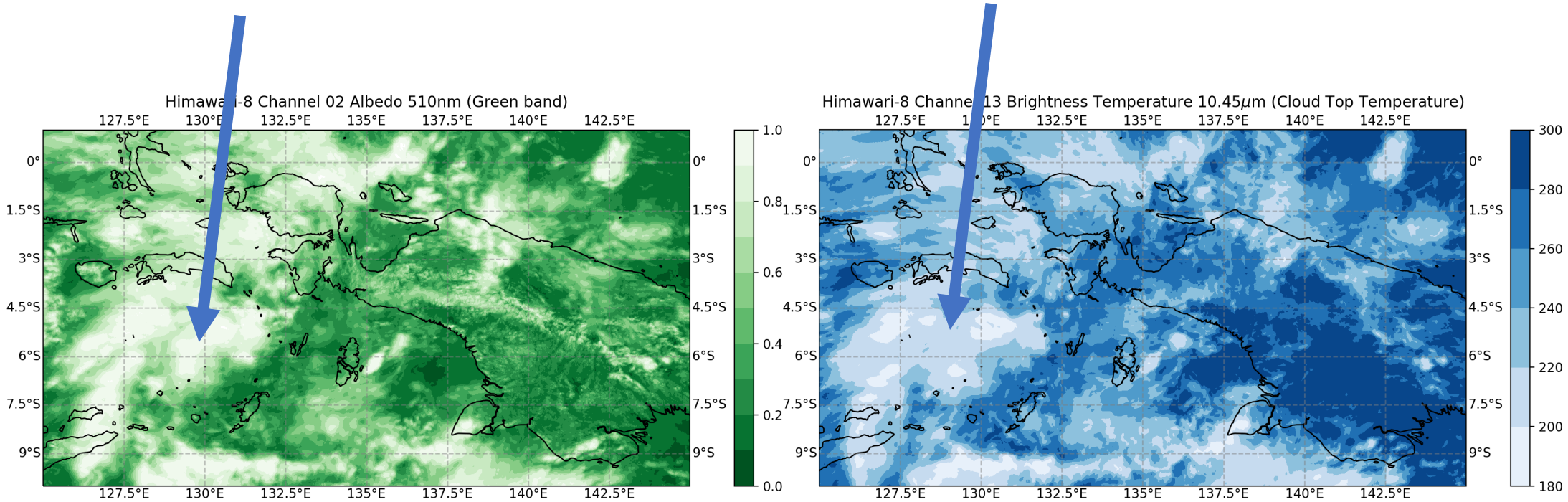
b) pre-Seroja box



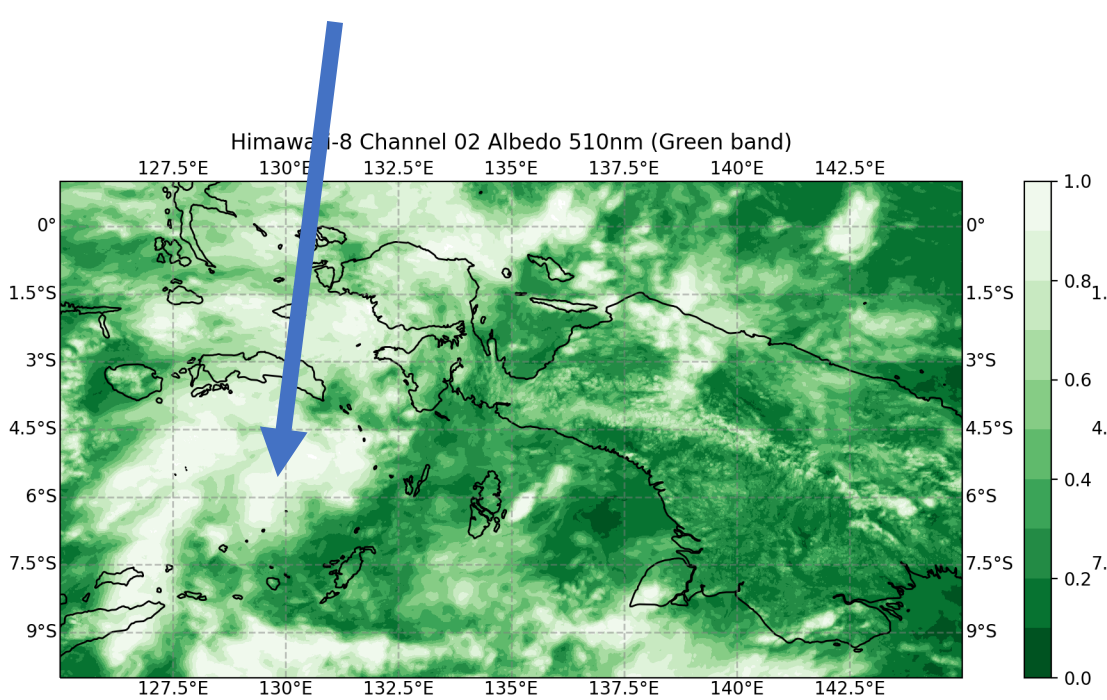
Himawari-8 on 2021-03-28T03 UTC

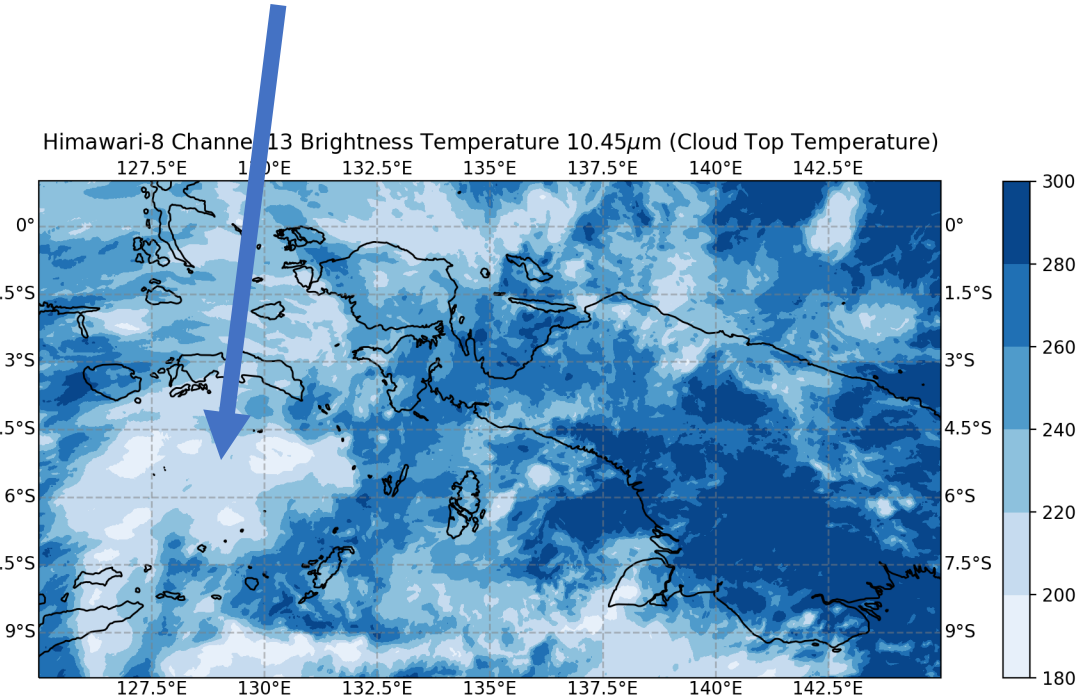


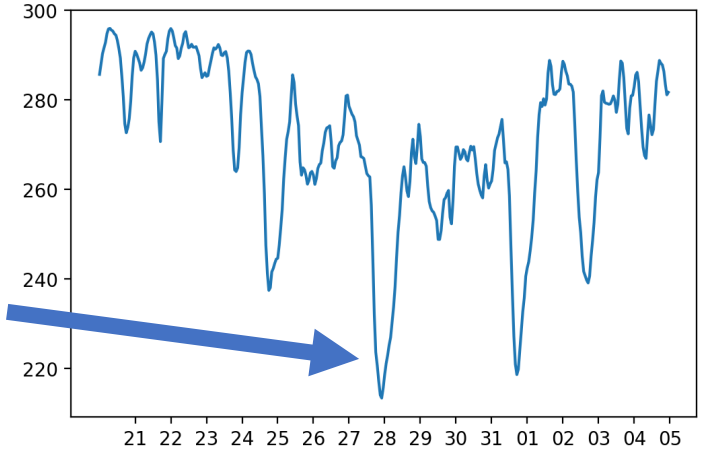
Himawari-8 on 2021-03-28T03 UTC



Himawari-8 on 2021-03-28T03 UTC

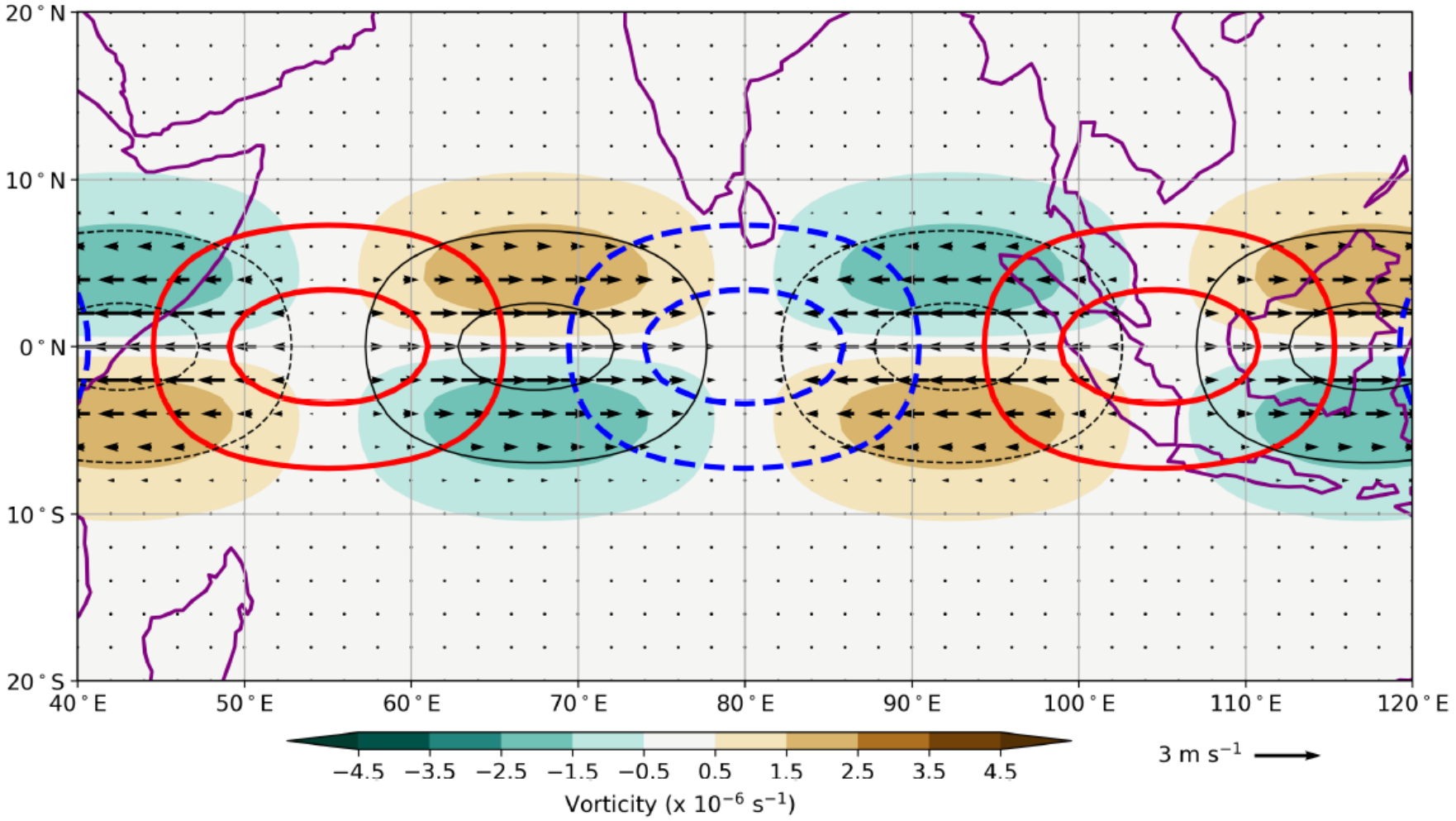






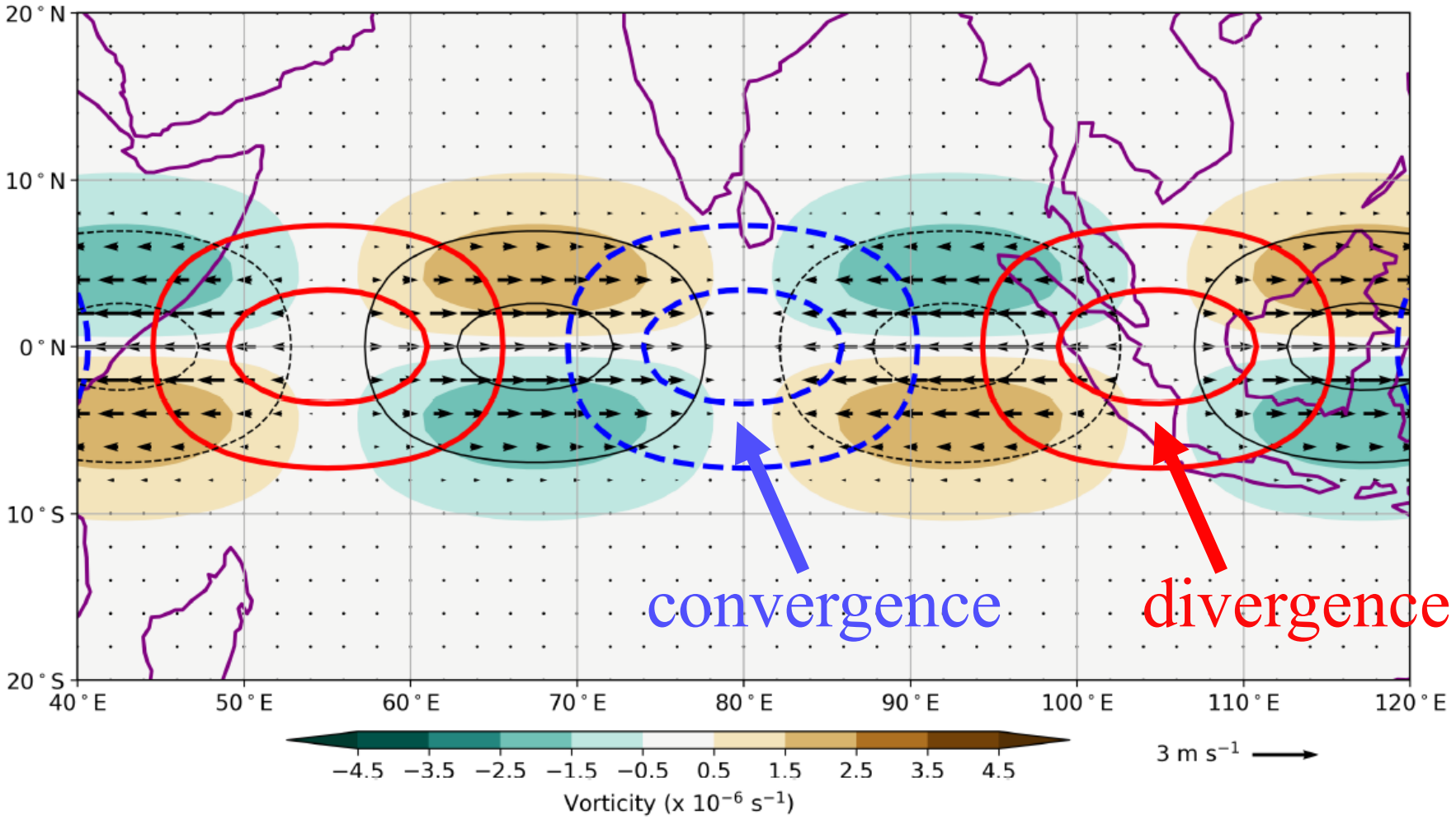
Ocean forcing
short summary

- positive SST and OHC anomalies provided energy to support convection
- we defined “pre-Seroja box” and “Seroja box”
- visible channel of Himawari 8 data as well as infrared data show extensive Equatorial Convection which developed in the area of high SSTs



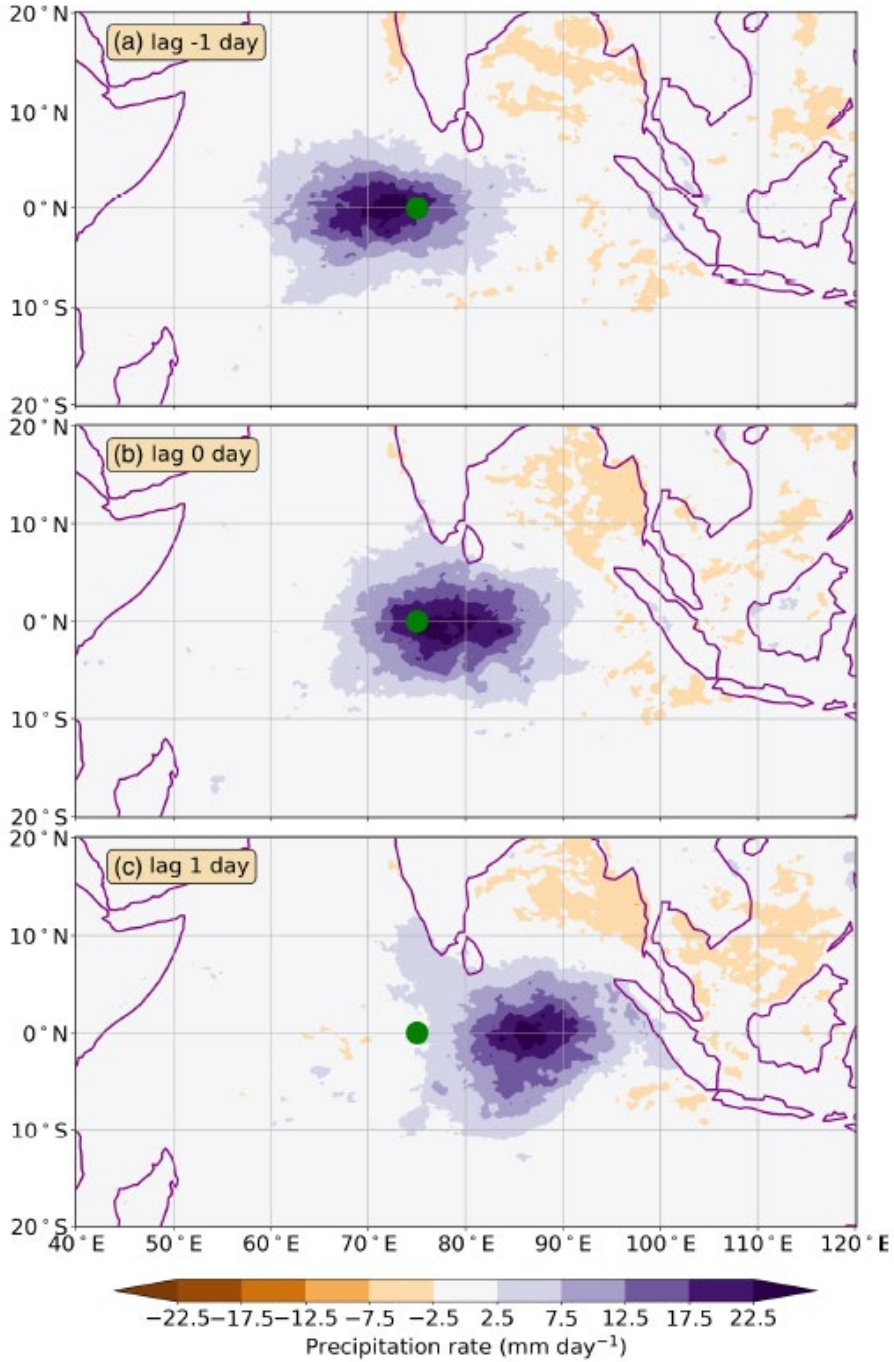
Matthews A. (2021): "Dynamical propagation and growth mechanisms for convectively coupled equatorial Kelvin waves over the Indian Ocean". *Q. J. R. Meteorol. Soc.*

Structure of a sample theoretical equatorial **Kelvin wave**. Horizontal wind vectors are shown by the black arrows. Relative vorticity is colour shaded.



Matthews A. (2021): "Dynamical propagation and growth mechanisms for convectively coupled equatorial Kelvin waves over the Indian Ocean". *Q. J. R. Meteorol. Soc.*

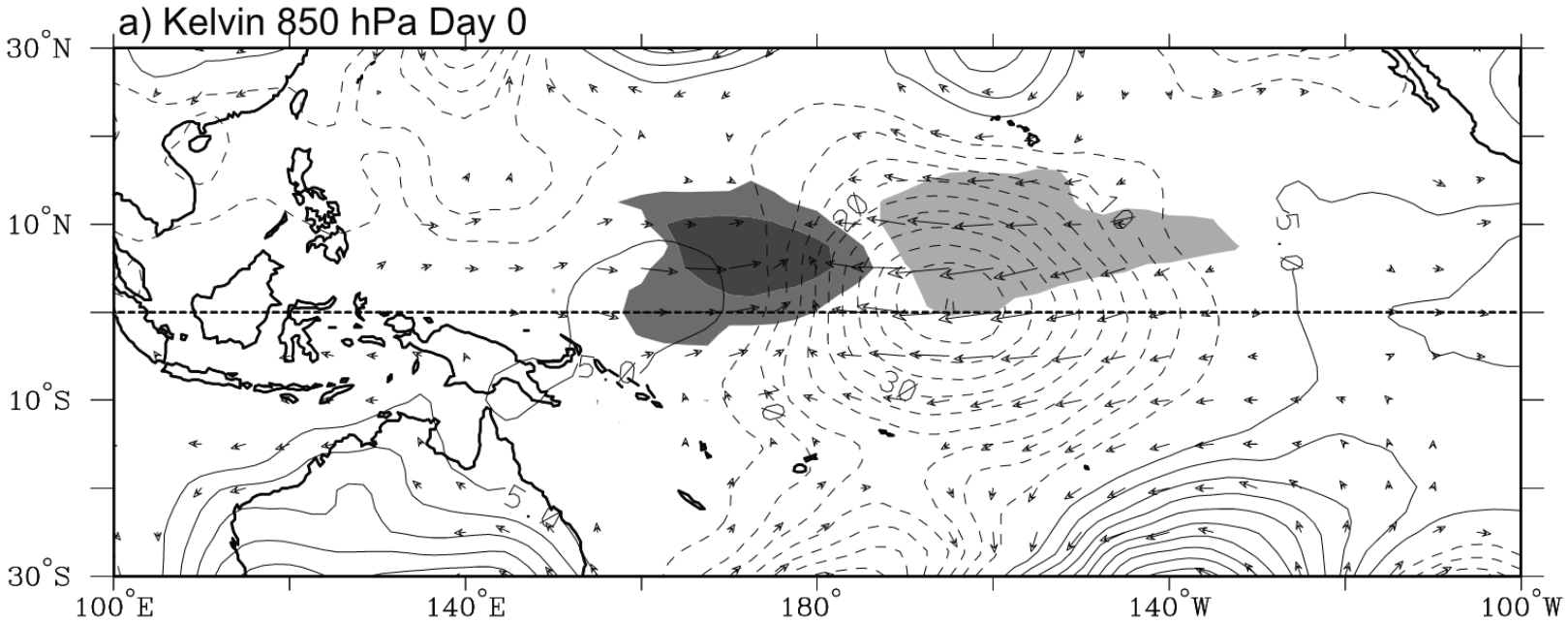
Structure of a sample theoretical linear equatorial **Kelvin wave**. Horizontal wind vectors are shown by the black arrows. Relative vorticity is colour shaded.



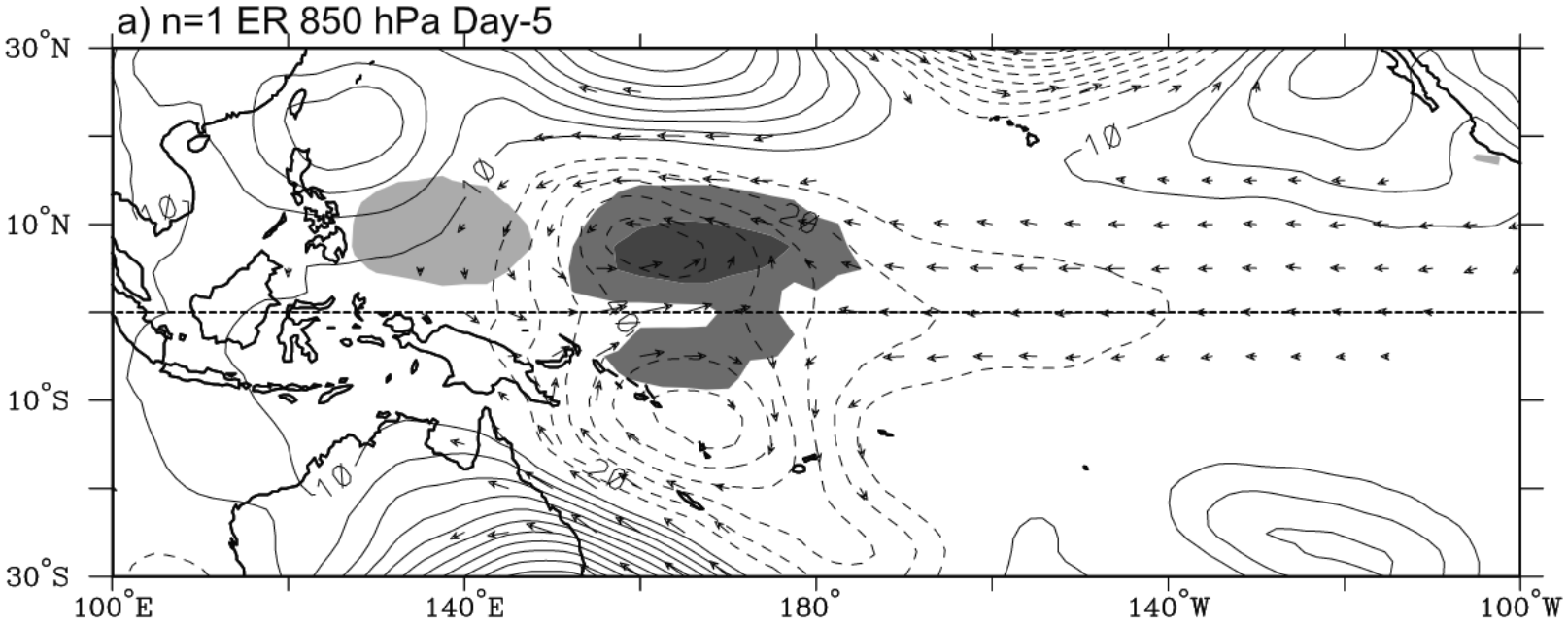
Matthews A. (2021): "Dynamical propagation and growth mechanisms for convectively coupled equatorial Kelvin waves over the Indian Ocean". *Q. J. R. Meteorol. Soc.*

Lagged composite maps of TRMM (satellite) **precipitation anomalies of Kelin waves**, with basepoint at 75degE (indicated by the green circle), for day (a) −1, (b) 0, (c) +1.

Kelvin wave
DIVERGENT



Rossby wave
ROTATIONAL



Kiladis, G. et al. (2009): "Convectively coupled equatorial waves." *Reviews of Geophysics.*

Introduction to MJO and tropical waves short summary

- the Madden-Julian Oscillation (MJO) is the major fluctuation in tropical weather on weekly to monthly timescales
- tropical waves are „building blocks” of an active MJO. They modulate convective activity moving across the tropics. Here Kelvin and Rossby waves are considered.
- tropical waves trigger natural hazard such as heavy rainfall and floods

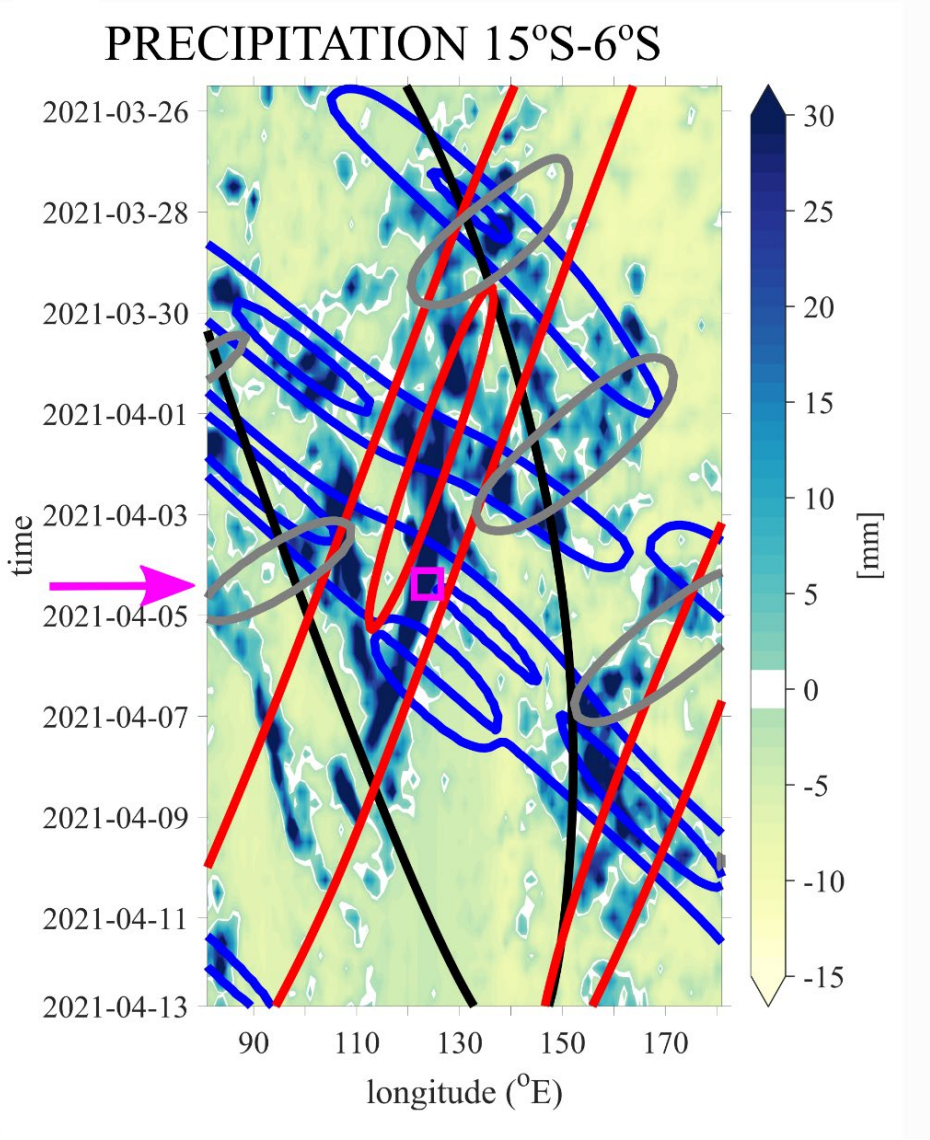
Hovmöller diagram confirms tropical waves activity

Rossby Wave:
- rotational
- propagates westward
- comes back every 10 – 48 days
- have a scale of 2000–3000 km

Madden-Julian Oscillation
- divergent
- propagates eastward
- comes back every 30 - 90 days
- have a scale of ~ 1500 km in latitude

and 4500 km in longitude

Kelvin waves
- divergent
- propagates eastward
- comes back every 5 - 20 days
- have a scale of ~ 1000 km in longitude

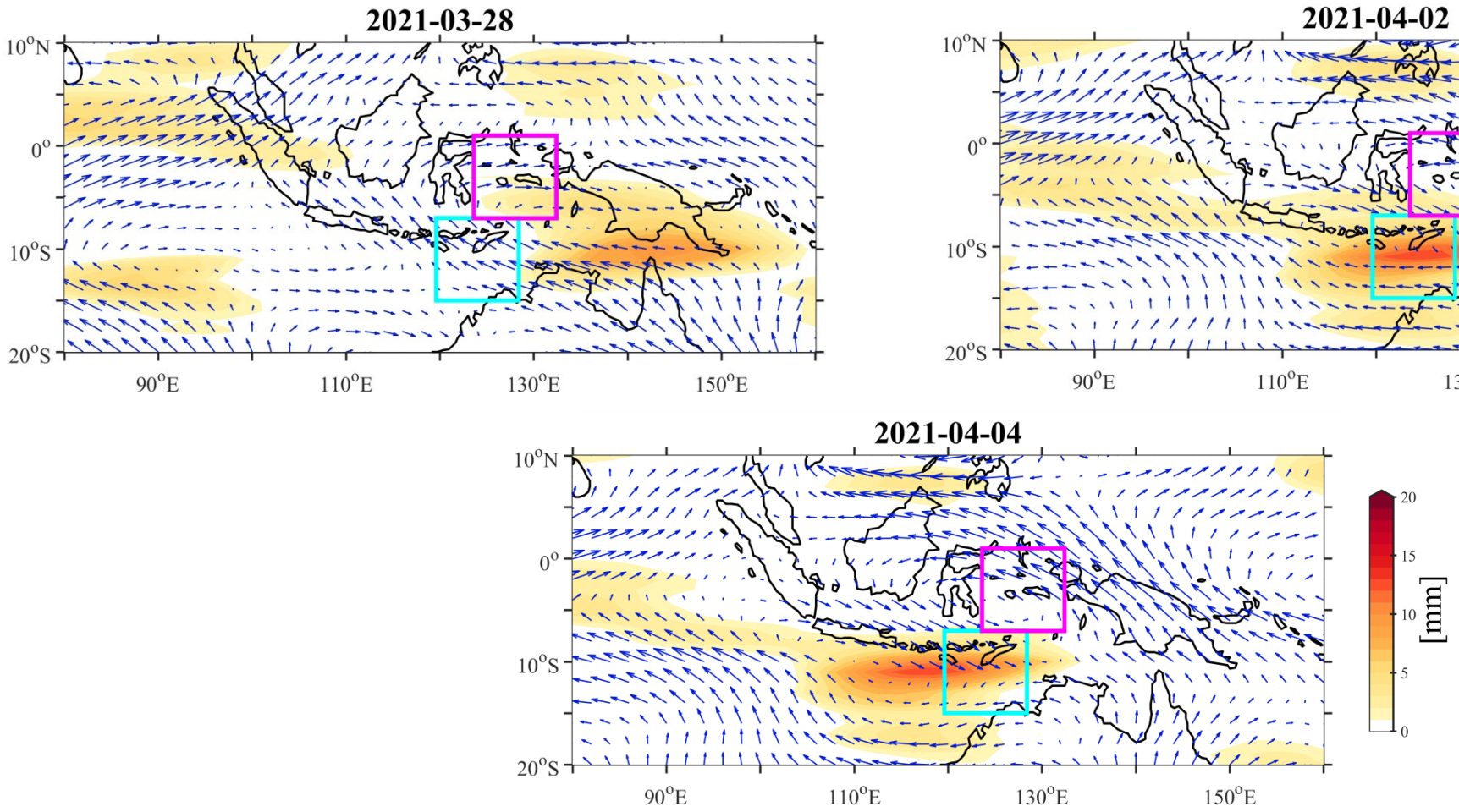


Red = Rossby Wave

Blue = Kelvin Wave

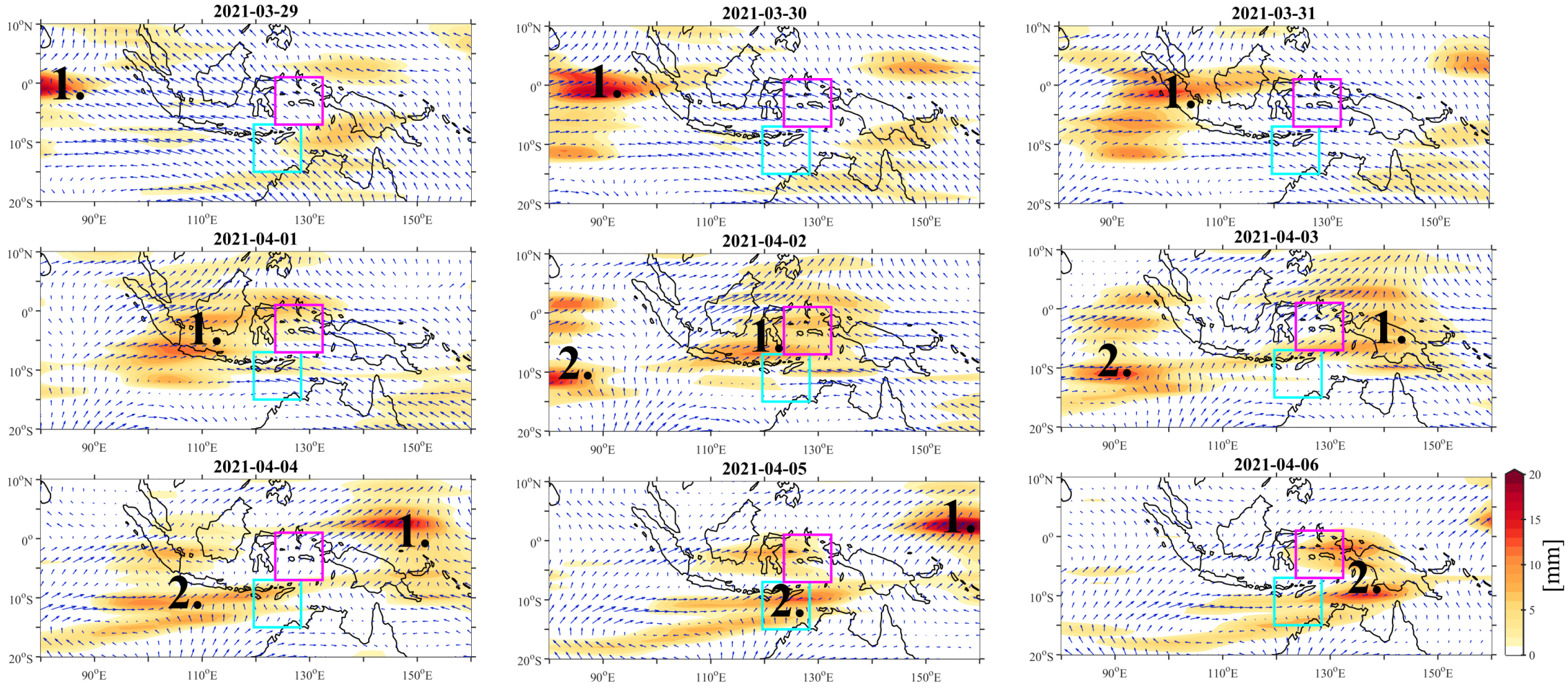
Black = MJO

Rossby wave added environmental vorticity



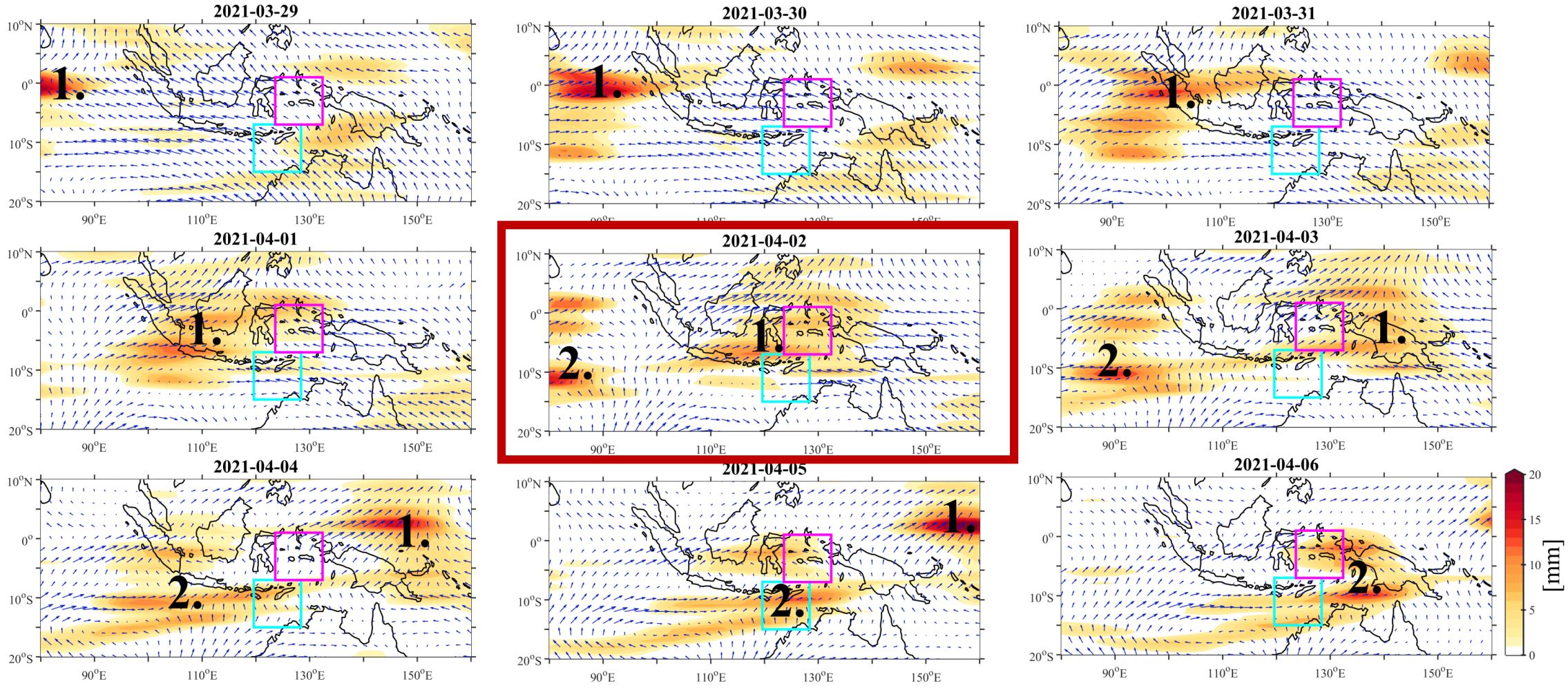
Rossby wave-filtered precipitation and low-level ERA-5 winds

Kelvin Waves were active during TC Seroja genesis



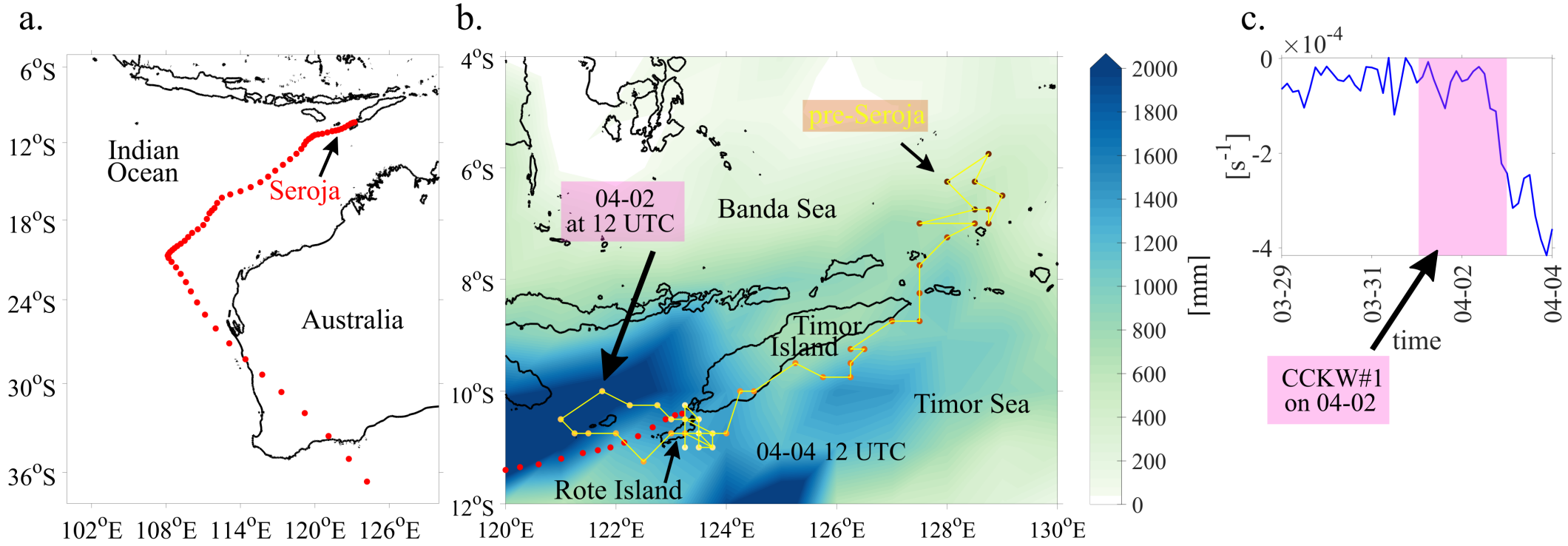
Kelvin Wave-filtered precipitation and low-level ERA-5 winds

Kelvin Waves were active during TC Seroja genesis



Kelvin Wave-filtered precipitation and low-level ERA-5 winds

Kelvin Wave #1 could support strenghtening of pre-Seroja vortex by a positive vorticity tendency

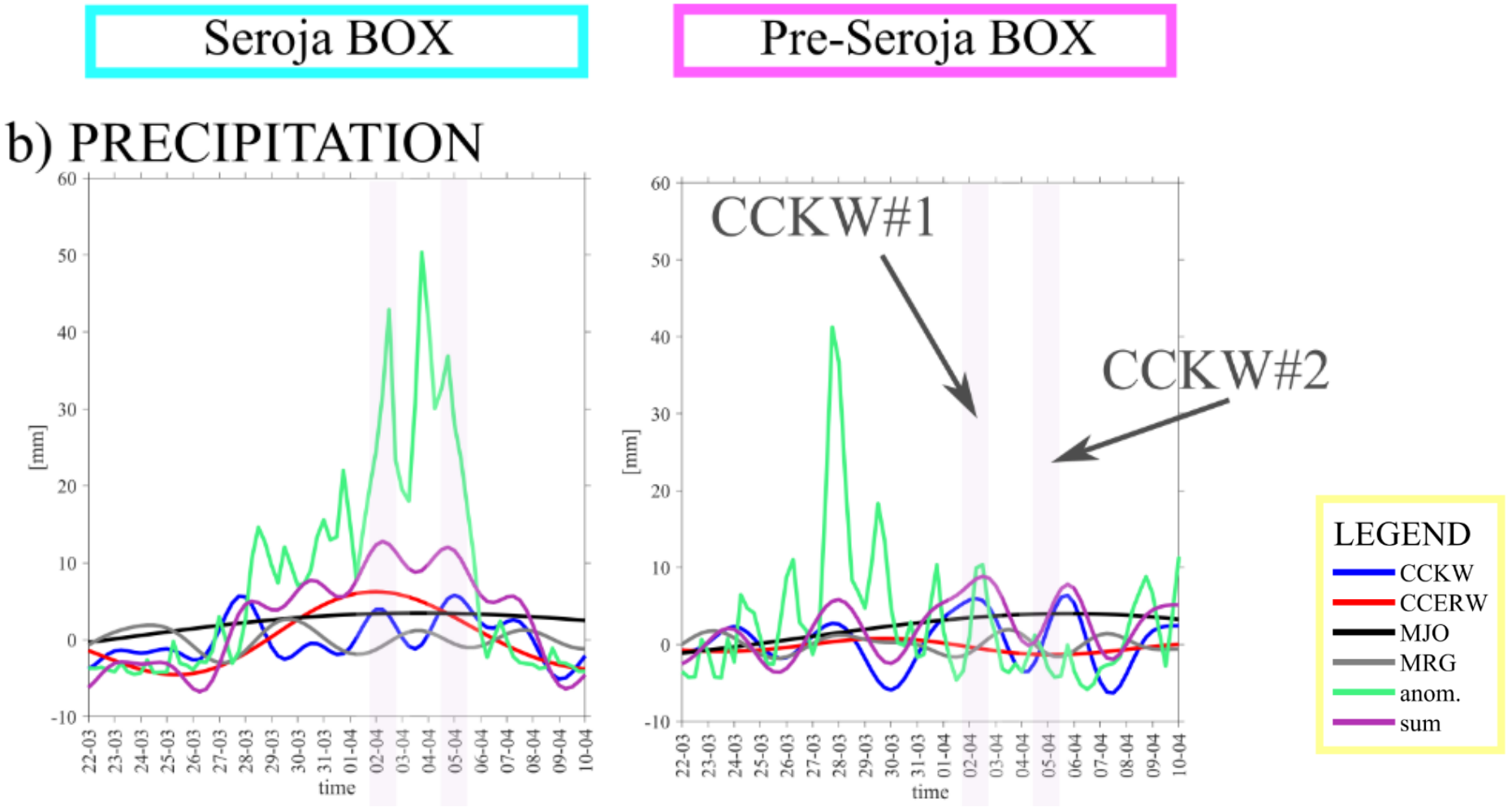


(a) TC Seroja (red dots) tracks obtained from the International Best Track Archive for Climate Stewardship (IBTrACS). Data every 3h starting at April 4, 12 UTC.

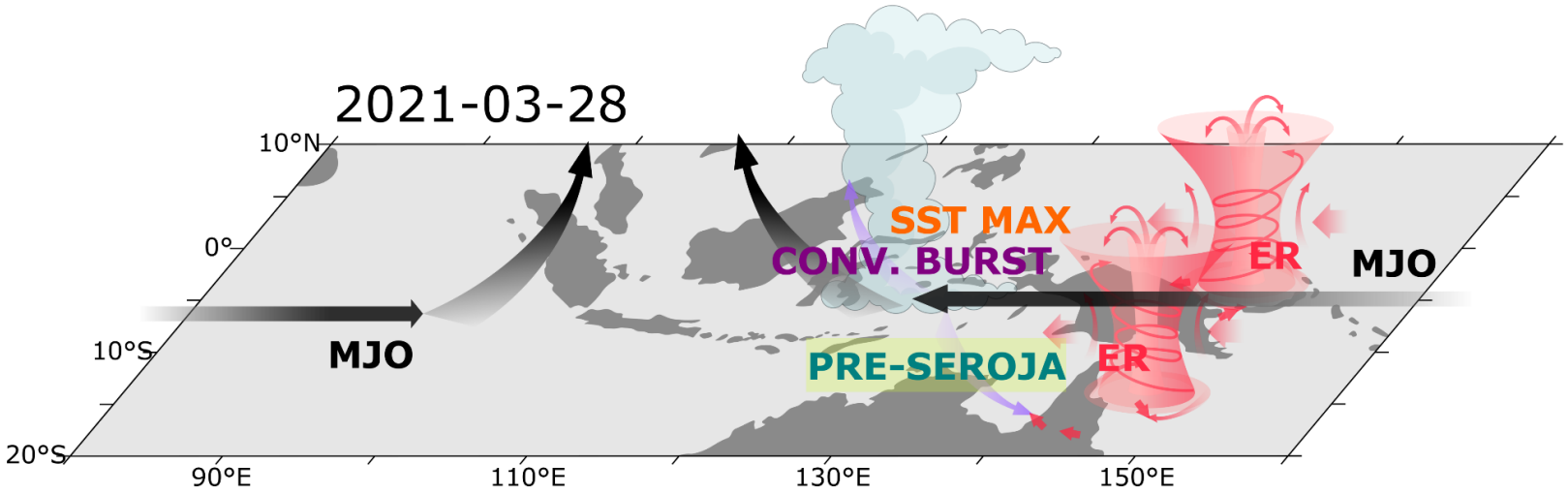
(b) precursor of TC Seroja identified using backward trajectory based on ERA-5 relative vorticity (dots, line, data every 3h starting at March 28, 0 UTC) and accumulation of GPM precipitation anomalies between March 28 and April 7 (shading).

(c) integrated ERA-5 relative vorticity tracked in the precursor of TC Seroja. Data every 3~h. The line indicate the period of the first Convectively Coupled Kelvin Wave.

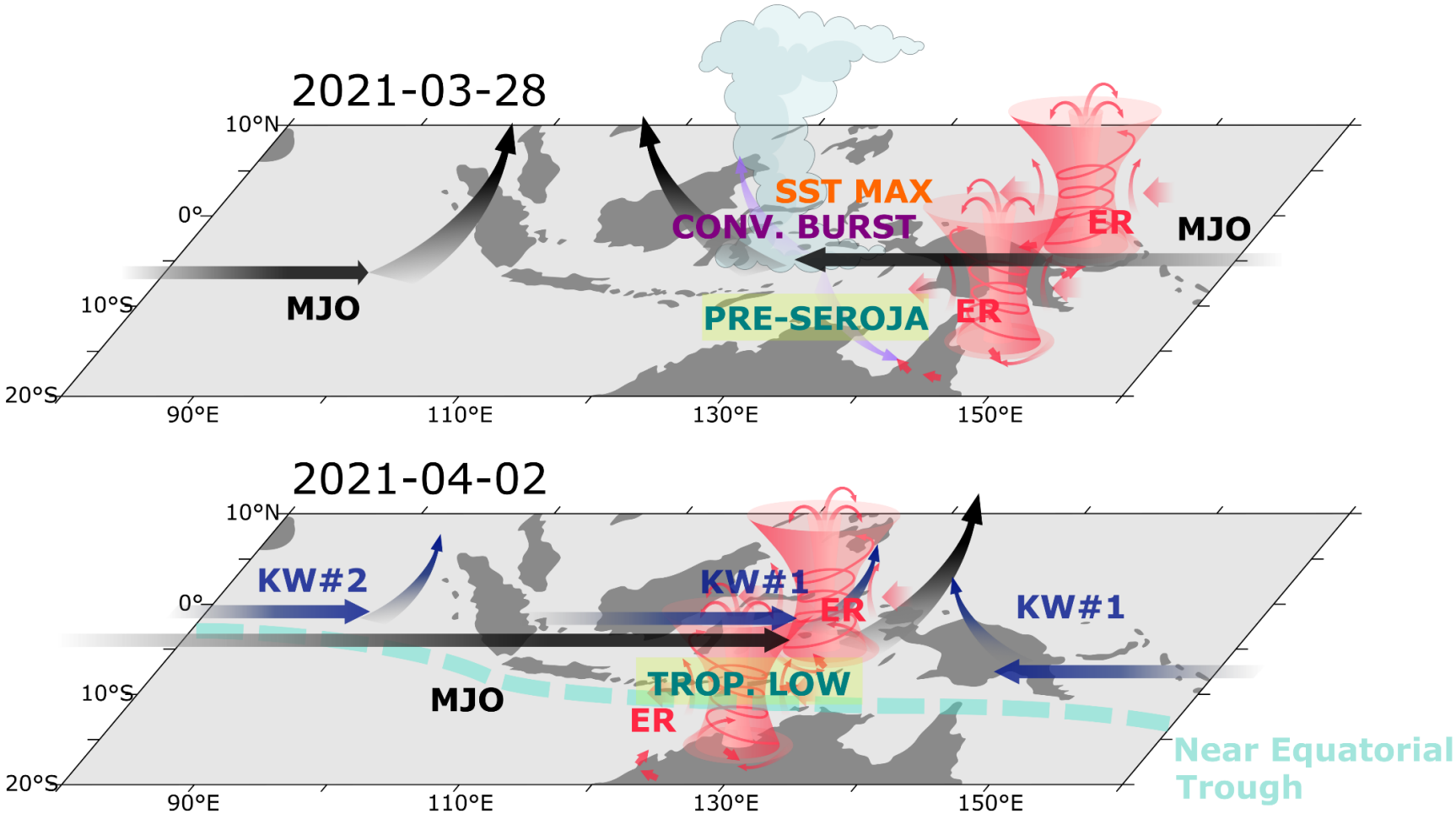
The two Kelvin waves significantly modulate local conditions



Schematic depiction of the key processes responsible for TC Seroja genesis

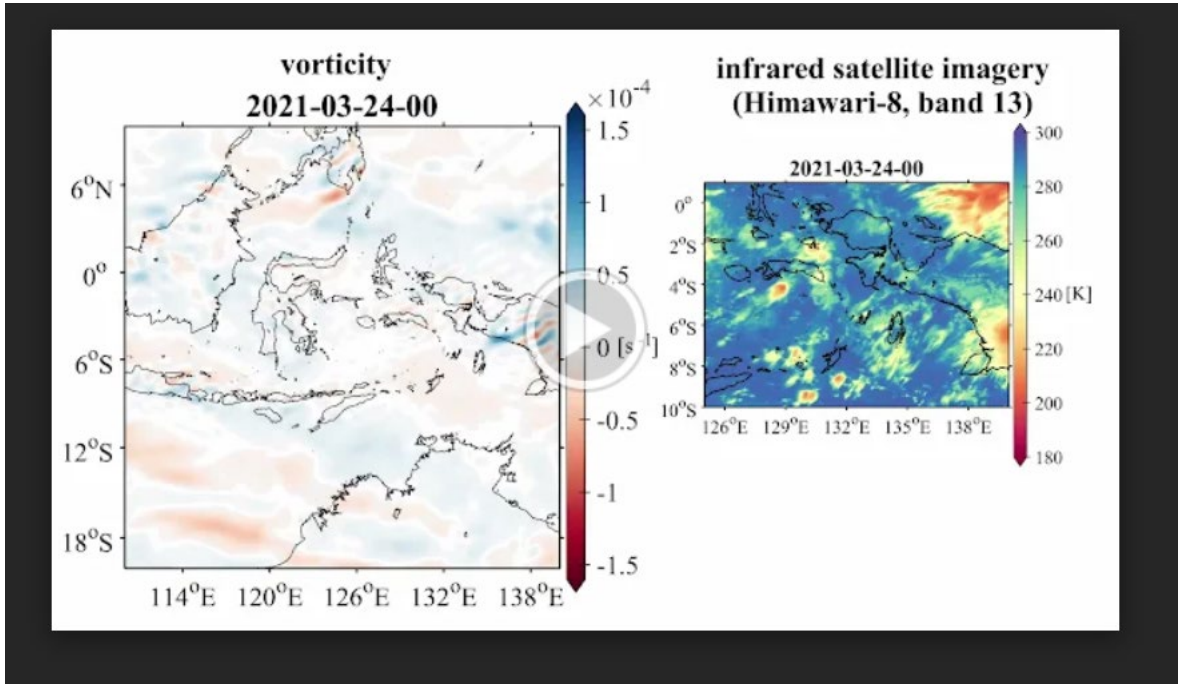


Schematic depiction of the key processes responsible for TC Seroja genesis



Animation

https://bit.ly/3svvOjJ



Summary & Conclusions

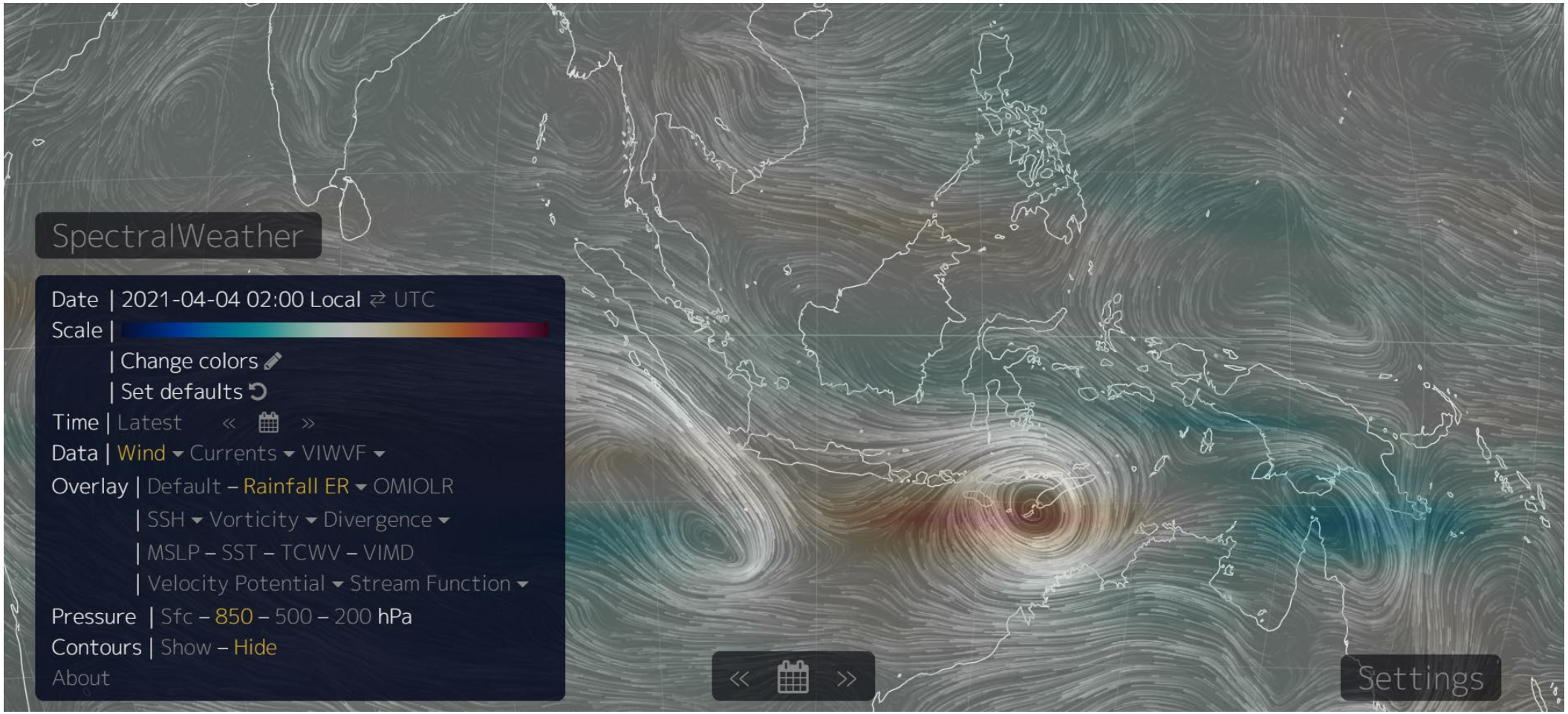
- **cyclogenesis in the Indonesian region of Timor and Suvu Seas was associated with enhanced equatorial convection on March 28, 2021 which was preceded by warm sea surface anomalies and OHC build-up in that region (ahead of MJO)**

- **the initial equatorial convection moved southwest, boosted by environmental cyclonic vorticity associated with Rossby Wave. Kelvin Wave that arrived over the Maritime Continent helped in strengthening vorticity and structuring the convection**

- **the interaction between convectively coupled equatorial Rossby wave and two convectively coupled Kelvin waves embedded within the larger-scale envelope of the MJO was crucial in this case and provided supportive environment for this extreme event**

- **forecasting of TCs genesis and tracks should consider the dynamics of tropical waves in the Maritime Continent**

Total winds + Rossby Wave precipitation at https://spectralweather.ucsd.edu/



The role of tropical waves in the genesis of tropical cyclone Seroja

Institute of Geophysics
Polish Academy of Sciences

blatos@igf.edu.pl
http://beatalatos.com/

Beata Latos

THANK YOU