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A satellite analysis: Comparing Two Medicanes

G. Ciardullo[1], L. Primavera[1], F. Ferrucci[1], F. Lepreti[1], V. Carbone[1]

1 Department of Physics, University of Calabria, 87036 Rende (CS), Italy

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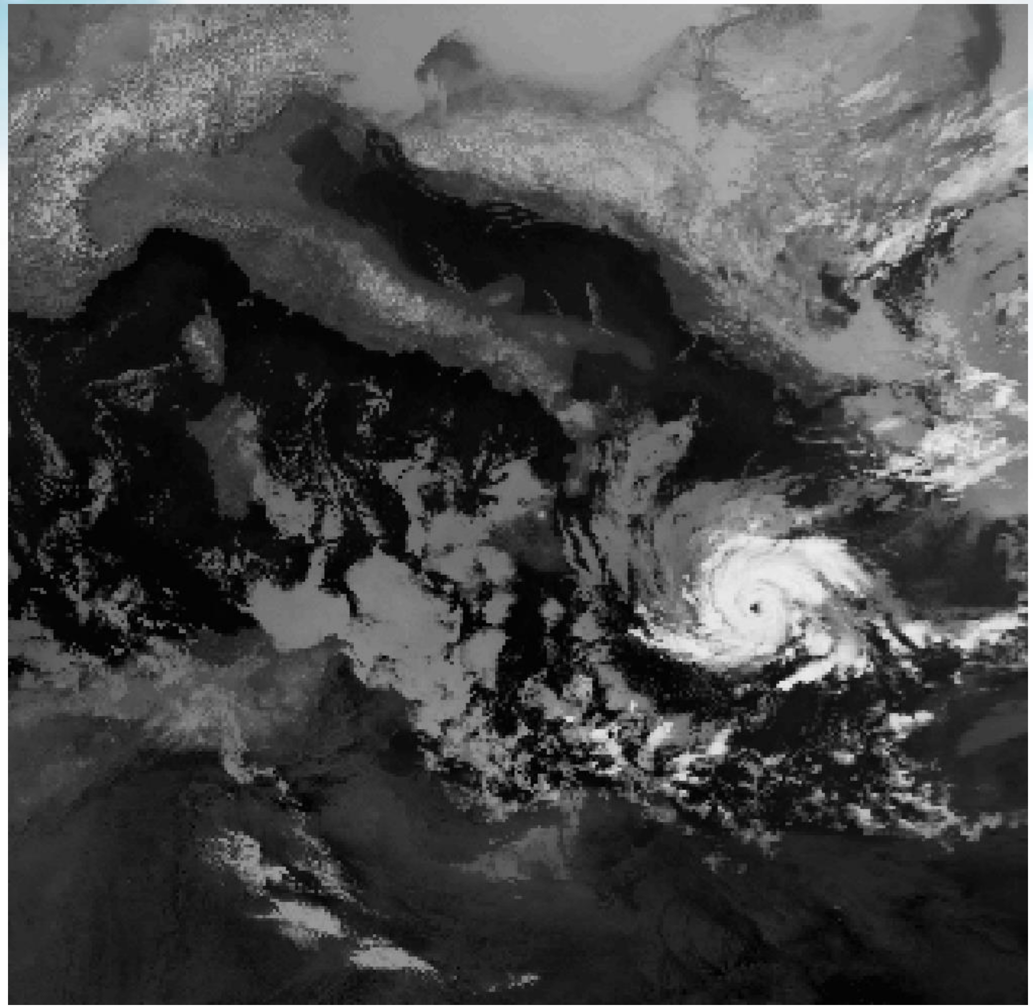
Introduction



Mediterranean Hurricane on 15 January 1995 *[Emanuel, 2005]*.

Medicane is the term recently adopted for indicating peculiar cases of intensification of Mediterranean cyclones.

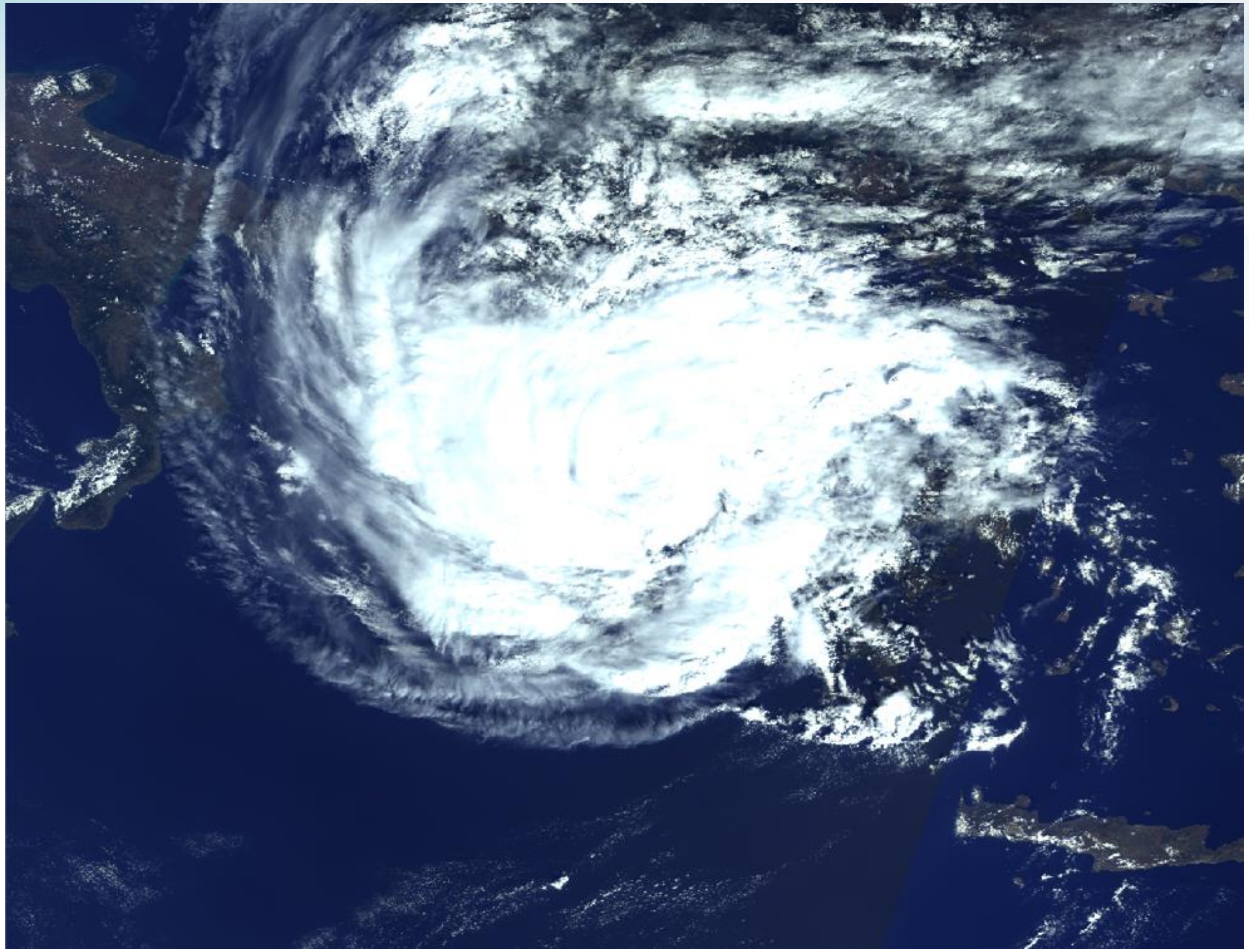
Categorization of Medicanes with their dynamical characteristic features are summarized in *[Miglietta, 2019]* and *[Dafis, 2020]*. Three main groups can identify these objects:

1. Strong initial depression from baroclinic instability. Warm seclusion explains the presence of warm core. Convection is the major responsible of the intensification.
2. Baroclinicity is relevant only in the initial stage, while WISHE effect is the major contribution during mature stages, after the occurrence of tropical transition.
3. Upper-level PV streamer before the tropical transition trigger convection, under a strong control of SST and powerful release of latent heat.

The German Meteorological Service proposed an unofficial classification based on the Saffir-Simpson scale for the tropical cyclones *[Wieczorek, 2018]*, in which a Medicane can be classified in the first category of intensity.

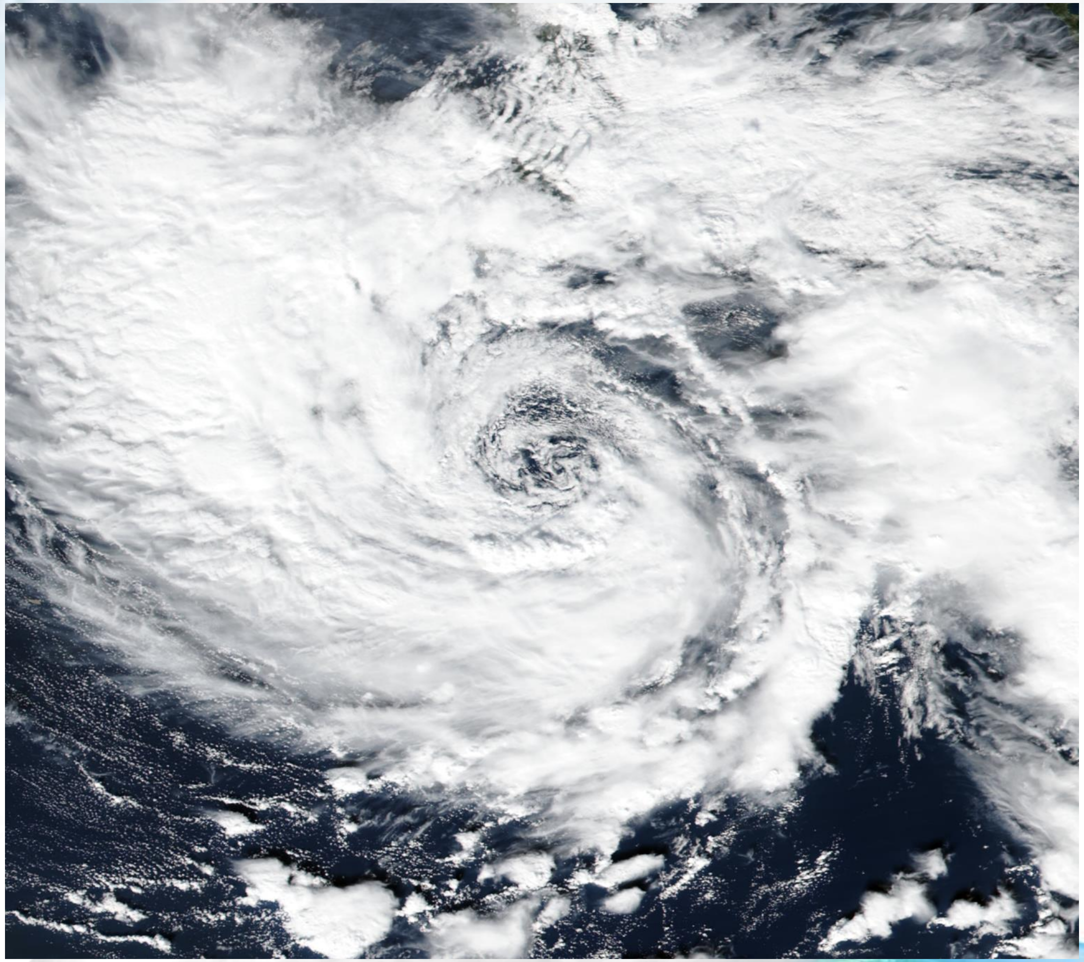
Overview - comparison between two medicanes

IANOS



OLCI – Sentinel 3 image of Ianos, 18 sep. 2020, 15.36 h UTC.
Credits to Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus/#/home

APOLLO



VIIRS – Suomi NPP image of Apollo, 29 oct. 2021, 00.00 h UTC.
Credits to Level-1 and Atmosphere Archive & Distribution System Distributed Active Archive Center: https://ladsweb.modaps.eosdis.nasa.gov/search/

Databases and analysis

- Database with high spatial resolution from two Low-Earth orbit (LEO) platforms.
- Study of remote sensed different atmospheric parameters *[Ciardullo et al., 2023]* extracted from five-days evolution of Ianos and Apollo.
- Comparison of physical quantities and medicanes observations.

Satellite platform	Sentinel - 3	Suomi NPP
Radiometer	SLSTR	VIIRS
Short name of the type of image	S3A_SL_1_RBT	VNP46A1
Bands spatial resolution (TIR)	1 Km	0.75 Km
Time resolution	Daily	Daily
Number of images	10	10

Type of image	Sensor	Bands	Date (d-m-y)	Sensing time (h UTC)
S3ASL1RBT	SLSTR	S8-S9	15-09-2020	21.01*
S3ASL1RBT	SLSTR	S8-S9	16-09-2020	09.17
S3ASL1RBT	SLSTR	S8-S9	17-09-2020	08.51
S3ASL1RBT	SLSTR	S8-S9	18-09-2020	20.21*
S3ASL1RBT	SLSTR	S8-S9	19-09-2020	08.38
VNP46A1	VIIRS	M15-M16	15-09-2020	00.00*
VNP46A1	VIIRS	M15-M16	16-09-2020	00.00*
VNP46A1	VIIRS	M15-M16	17-09-2020	00.00*
VNP46A1	VIIRS	M15-M16	18-09-2020	00.00*
VNP46A1	VIIRS	M15-M16	19-09-2020	00.00*

Space born imagery acquired from the polar satellites for this study.

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Remote sensing study procedure:

1) Pre-processing phase of *Nearest Neighbour* pixel resampling *[Van Ha, 2018]* on all the images

2) From brightness temperature *Tb* raw data of channel TIR2, computation of cloud-top altitude *H* and temperature *T* using recorded data of daily air temperature at 2 m a.s.l. *Tamb*

3) Vertical temperature gradient ∇T assessment using *T* and *SST* daily value:

$$\nabla T = \frac{|T - SST|}{H}$$

4) Atmospheric pressure field *P* calculation using *H*, standard level pressure $P_0 = 1013.25\ hPa$ and scale height $a = 8000\ m$:

$$P = P_0 e^{-H/a}$$

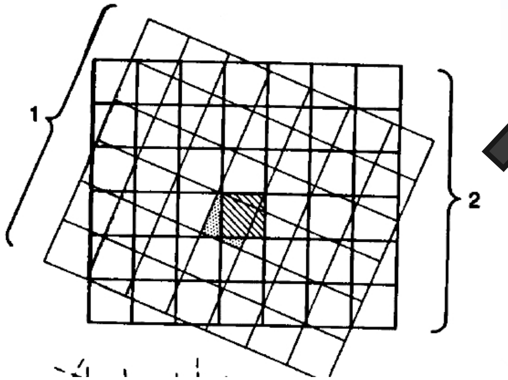
5) Deep convection clouds pixels *DCCP* assessment from the clouds in temperature range 230-240 K, from TIR1 spectral channels *[Dafis et al., 2020]*.

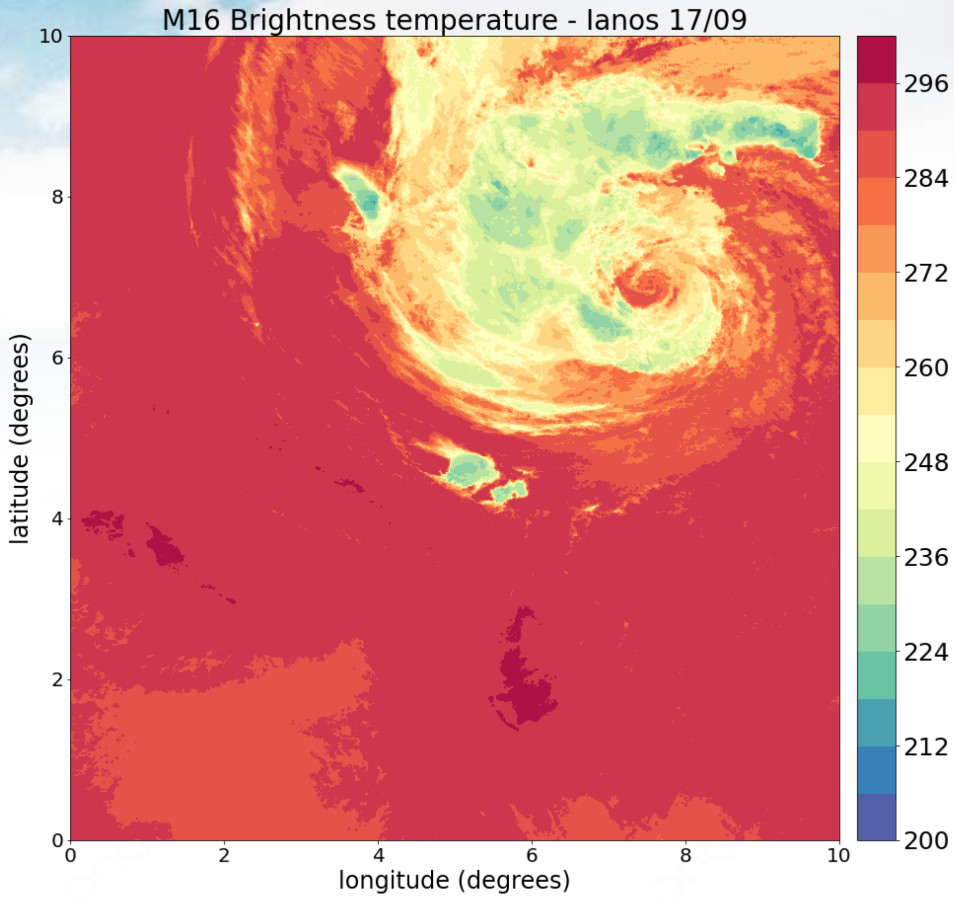
6) Ice percentage in the clouds assessment using Split Window technique:

$$SW = Tb(TIR2) - Tb(TIR1)$$

with $-1 < SW < 0$ values in the images.

Results - resampling





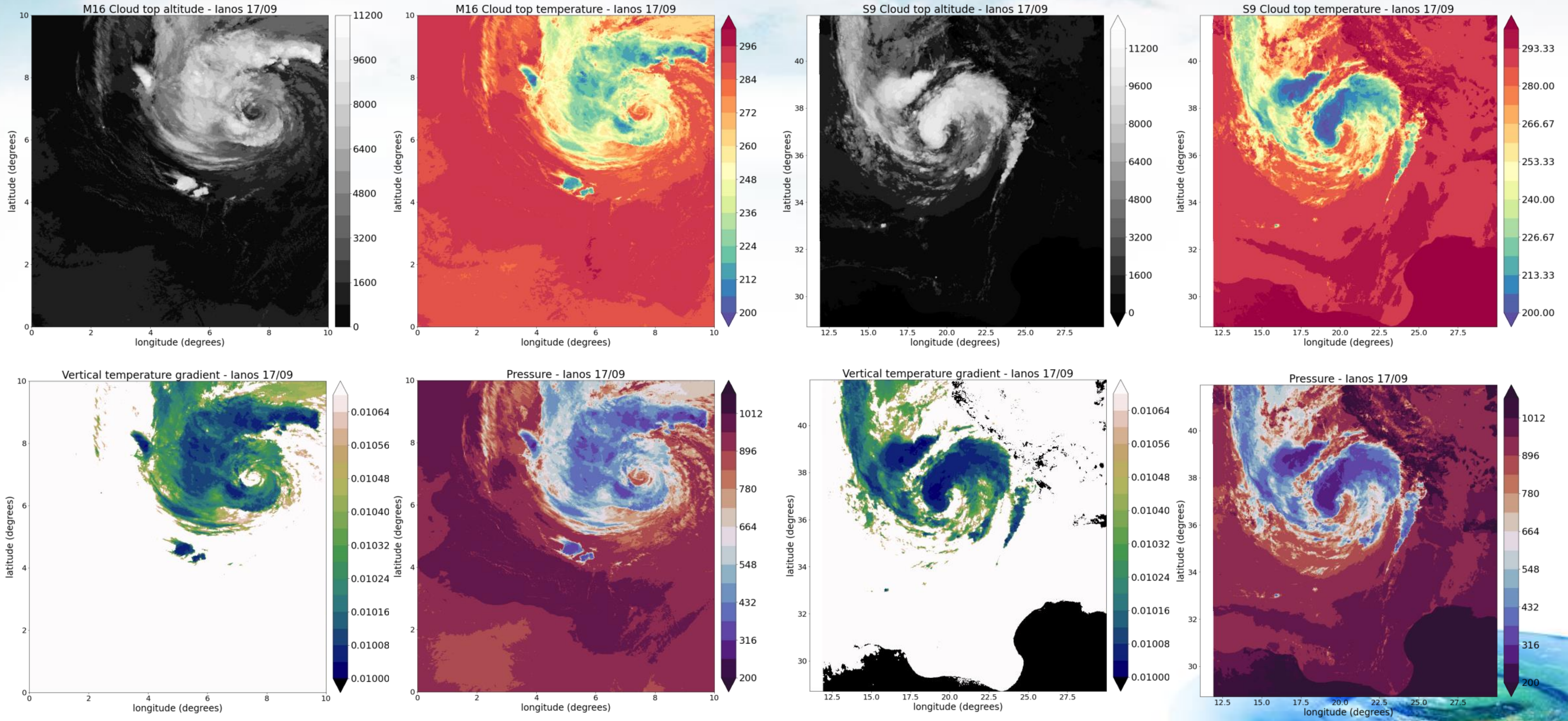
Nearest Neighbour interpolation algorithm is used for resampling pixels of the satellite images: output pixels replace the input ones closest to the location of the corresponding coordinates.

The nominal value of the pixel is not altered, values are geometrically redistributed and reprojected on the ellipsoid system UTM WGS-84.

Results – atmospheric parameters

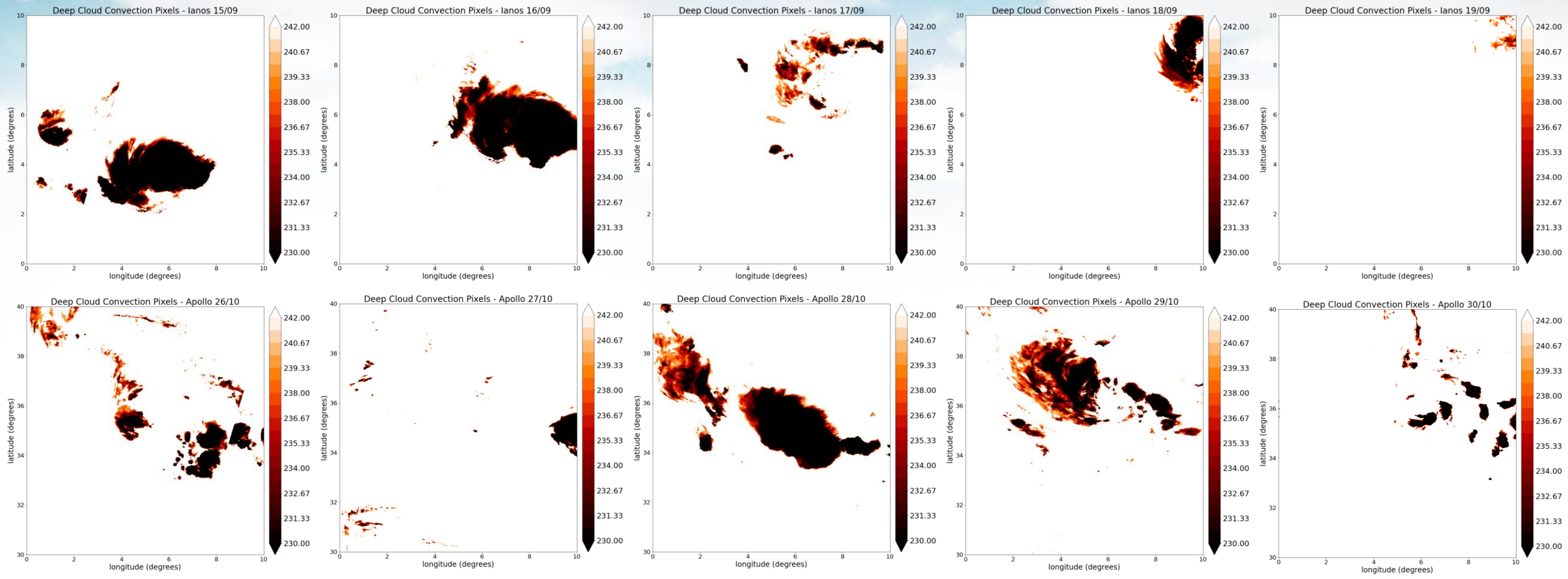
VIIRS, 17/09/20, 00.00 UTC

SLSTR,17/09/20, 08.51 UTC



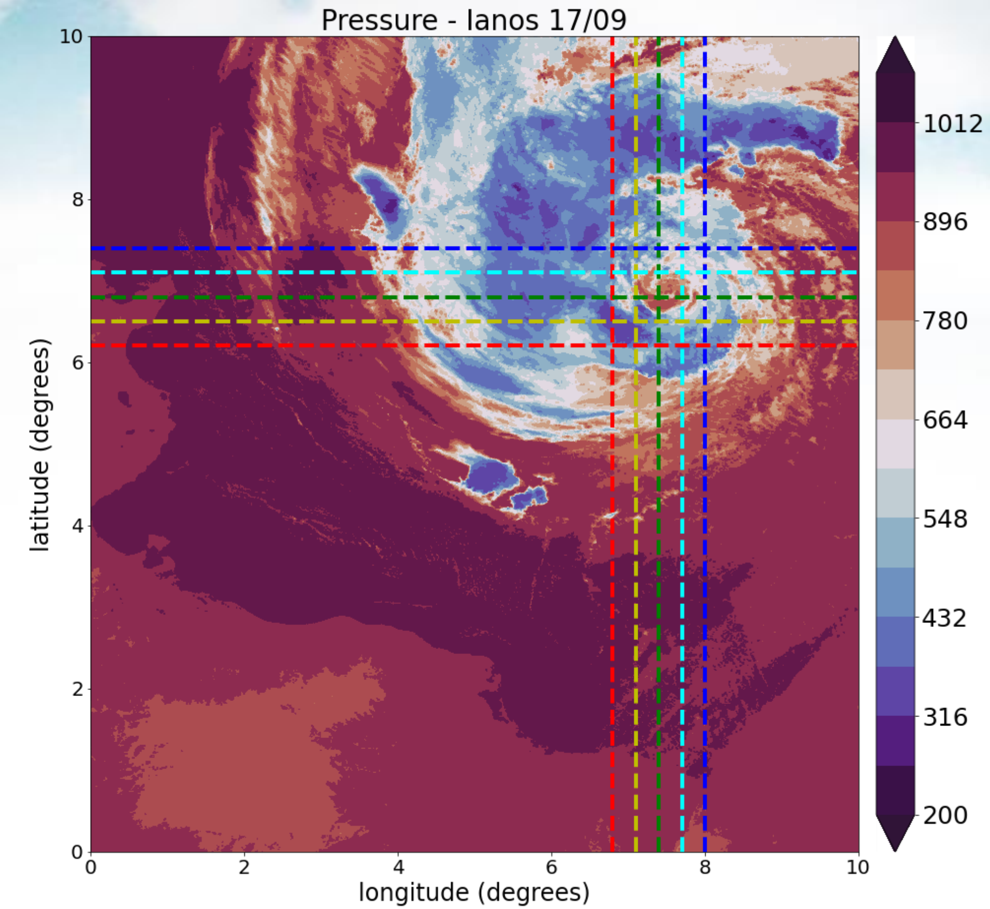
Atmospheric parameters visualization of Ianos Medicane evolution in the day of september the 17th. Comparison between VIIRS and SLSTR observations.

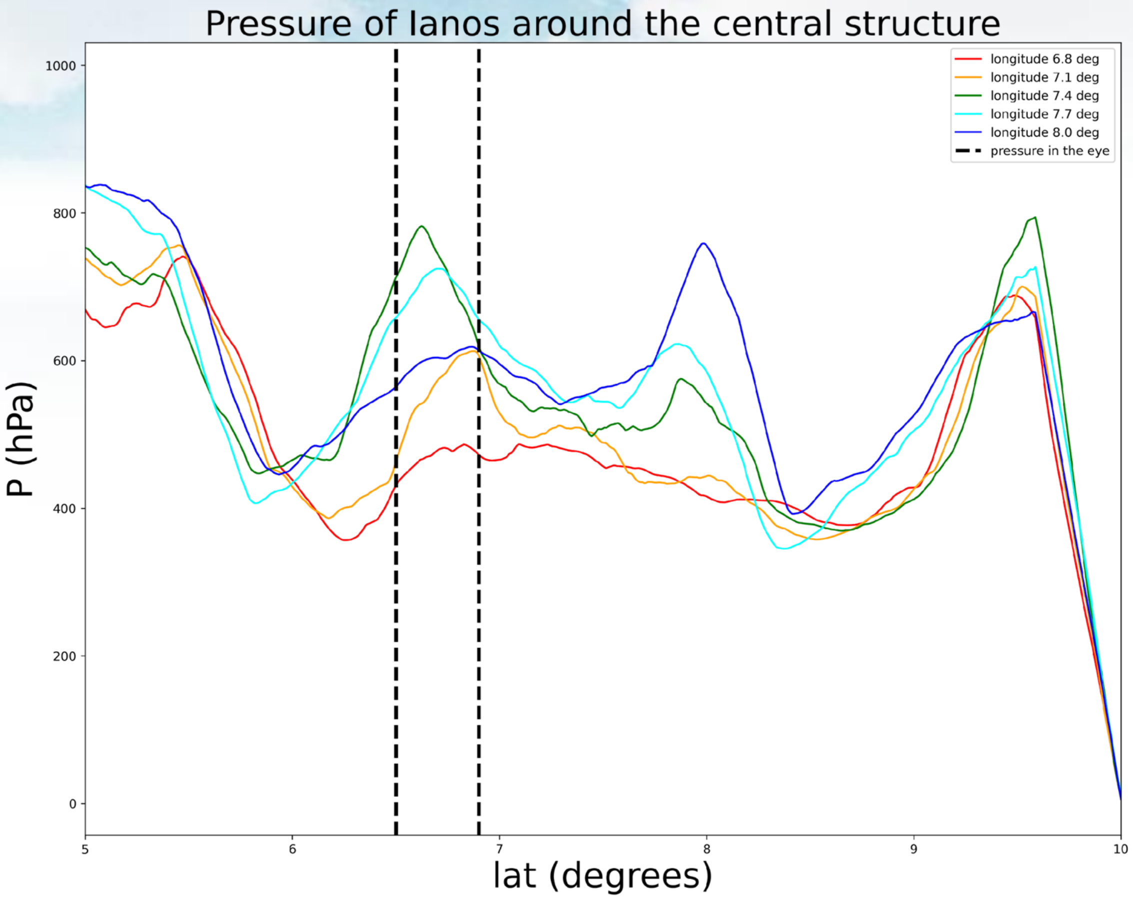
Results – pixels and time-displacement reconstructions



Daily evolution of deep cloud convection pixels of Ianos (top row) and Apollo (bottom row), from all the VIIRS products.
Evolutions are represented in the same grid (lon,lat), showing the displacement in their impact geographical areas.

Results – Longitudinal assessment of Ianos pressure



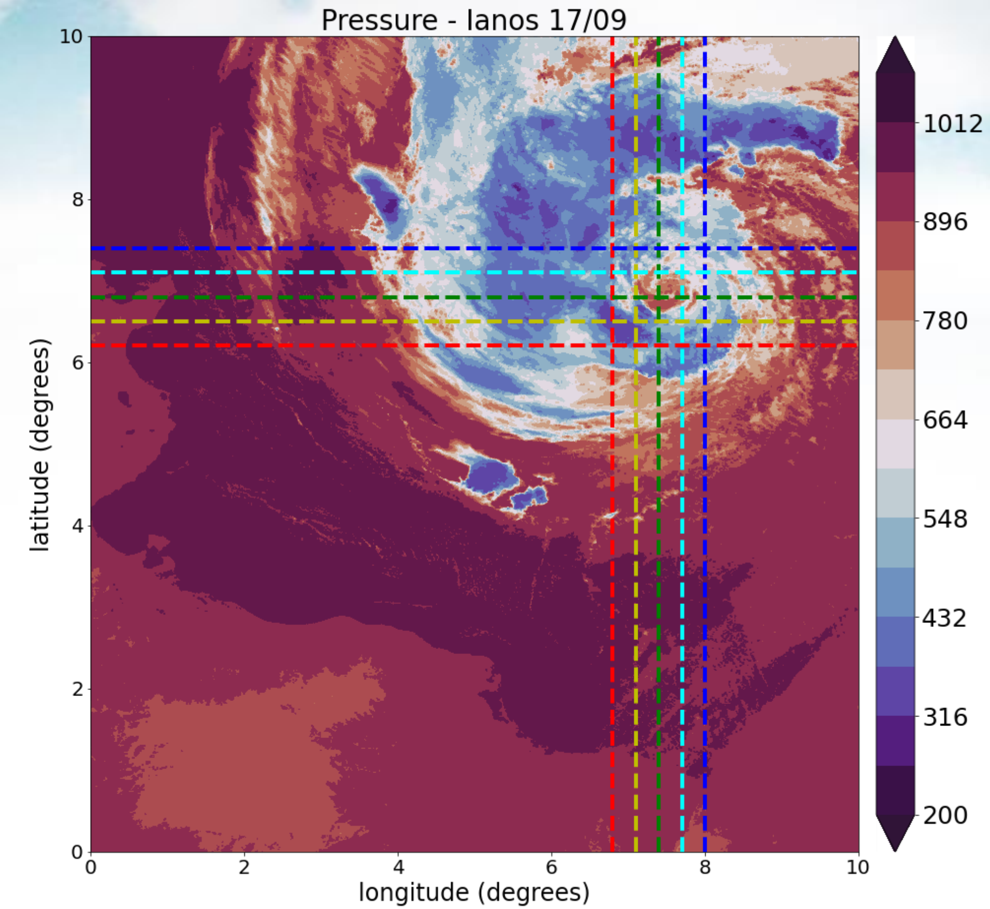


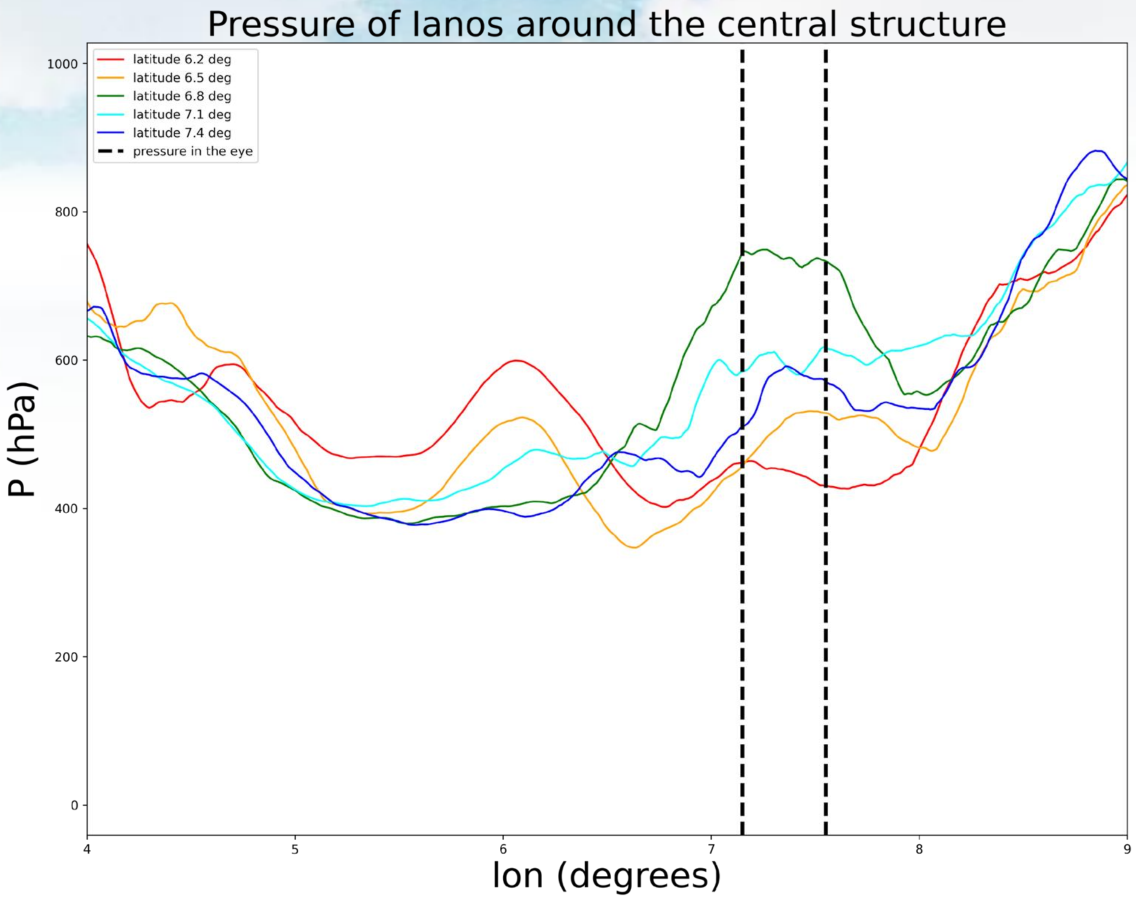
Atmospheric pressure trend in the space, focus around the central structure of Ianos medicane in the VIIRS product of 17/09/2020, 00.00 UTC, at fixed longitude values.

Day	*BOLAM* mean sea level pressure (hPa)	Warm core pressure from VIIRS (hPa)	Warm core pressure from SLSTR (hPa)
15-09-2020	1010.00 ± 1.00	957.64 ± 53.44	920.67 ± 75.44
16-09-2020	1003.00 ± 1.00	939.92 ± 52.34	889.71 ± 76.56
17-09-2020	991.00 ± 1.00	924.25 ± 52.36	862.85 ± 77.36
18-09-2020	994.00 ± 1.00	947.96 ± 53.76	908.10 ± 76.01
19-09-2020	1005.00 ± 1.00	961.58 ± 52.94	938.84 ± 75.98

Atmospheric pressure values around the Ianos eye extracted from VIIRS and SLSTR products for all sensing times. Comparison with BOLAM recorded data of daily mean sea level pressure.

Results – Latitudinal assessment of Ianos pressure





Atmospheric pressure trend in the space, focus around the central structure of Ianos medicane in the VIIRS product of 17/09/2020, 00.00 UTC, at fixed latitude values.

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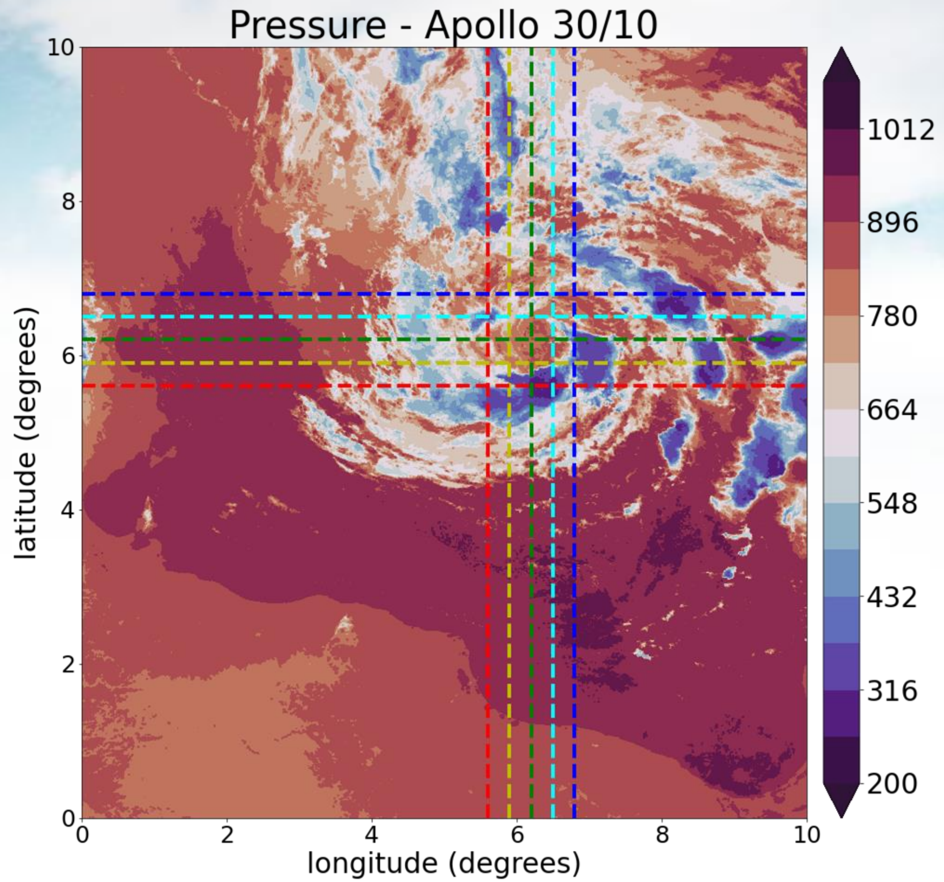
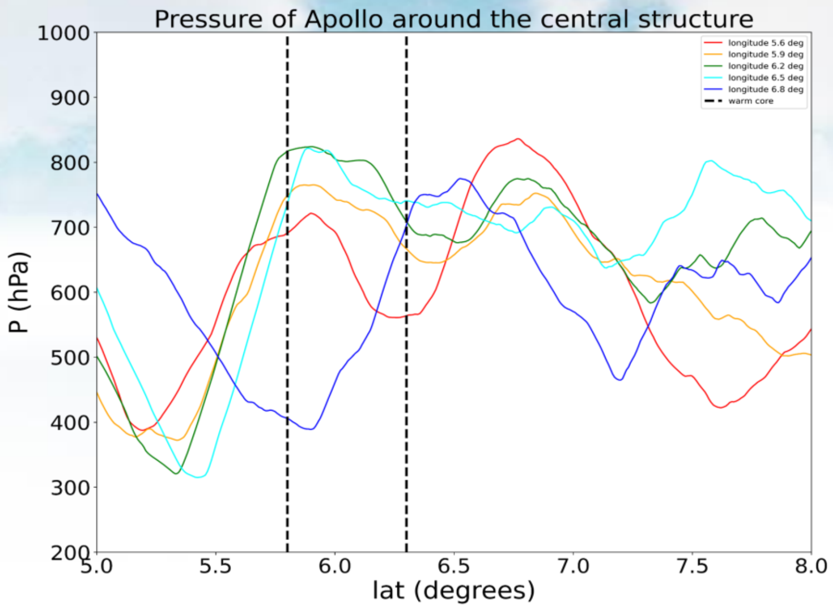
Atmospheric pressure values around the Ianos eye extracted from VIIRS and SLSTR products for all sensing times. Comparison with BOLAM recorded data of daily mean sea level pressure.

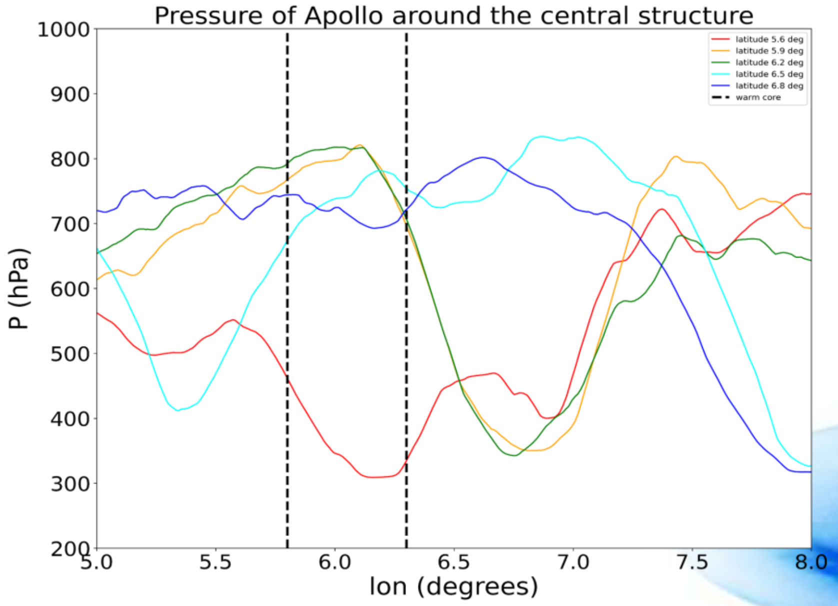
Results – Spatial assessment of Apollo pressure



Day	*BOLAM* Mean Sea Level Pressure (hPa)	Warm Core Pressure from VIIRS (hPa)	Warm Core Pressure from SLSTR (hPa)
26-10-2021	1007.00 ± 1.00	1008.15 ± 27.05	986.94 ± 47.40
27-10-2021	1002.00 ± 1.00	992.11 ± 29.01	1001.54 ± 47.99
28-10-2021	1005.00 ± 1.00	997.91 ± 28.27	1001.22 ± 46.08
29-10-2021	999.00 ± 1.00	963.18 ± 25.43	965.27 ± 47.11
30-10-2021	997.00 ± 1.00	967.08 ± 28.22	971.51 ± 53.64

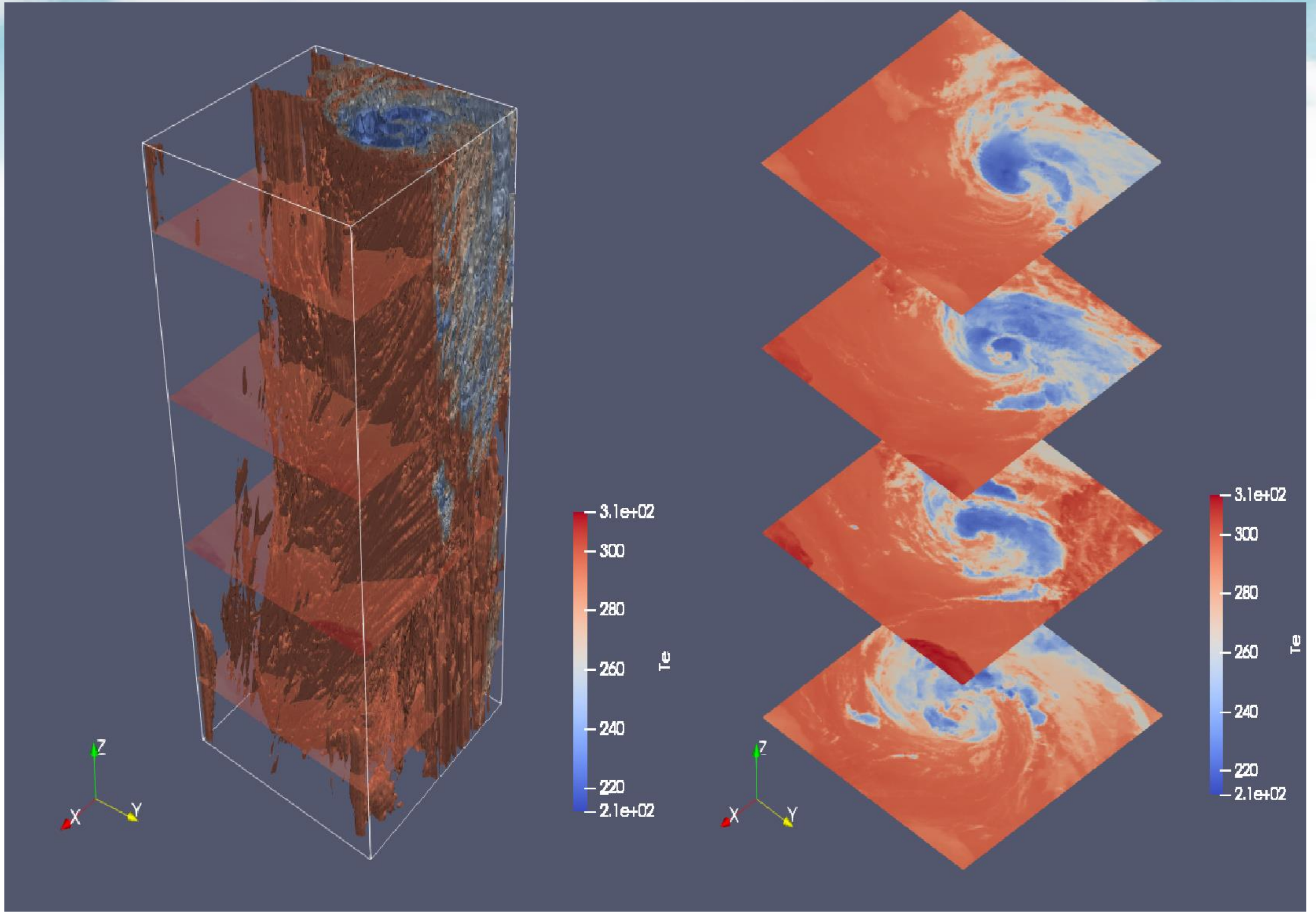
Atmospheric pressure values around the Apollo eye extracted from VIIRS and SLSTR products for all sensing times. Comparison with BOLAM recorded data of daily mean sea level pressure.





Atmospheric pressure trend in the space, focus around the central structure of Apollo medicane in the VIIRS product of 30/10/2021, 00.00 UTC, at fixed longitude (up) and latitude (down) values.

Results – 3D view



3D view of Ianos one-day temporal evolution: 2D Rapid Scan High-Rate SEVIRI images of temperature field, setting time as z-axis, by considering 5 minutes timestep.

Satellite platform	Meteosat Second Generation – 11
Radiometer	Rapid Scan High Rate SEVIRI (RSS)
Specifics of the dataset:	• Number of images available: **N** = 384; • Image dimension: **ΔR** = $N_{lon}xN_{lat}$ = 350x350 $pixel^2$ • Pixel dimension: **PS** = 3x3 Km^2 • Total sensing period: **P** = 24 hours • Sensing timestep: **Δt** = 5 min = 0.083 hours;

Imagery used for 3D characterization of medicanes.

Preliminary results – Spatio-temporal analysis of Ianos dynamics

- Proper Orthogonal Decomposition (POD) is a procedure for extracting empirical bases for a modal decomposition from an ensemble of signals. It was introduced in a context of turbulence for investigating dynamical systems without nonlinear or numerical limitation [Lumley, 1981].

  - Extraction of optimal empirical basis with maximum energy content with POD technique is given as solutions of Fredholm integral equation **(1)** [Alfonsi et al., 2003, Alfonsi et al., 2007].

  - POD solutions have orthonormal eigenfunctions ϕ_j and temporal coefficients a_j , factorizing spatial and temporal component separately.

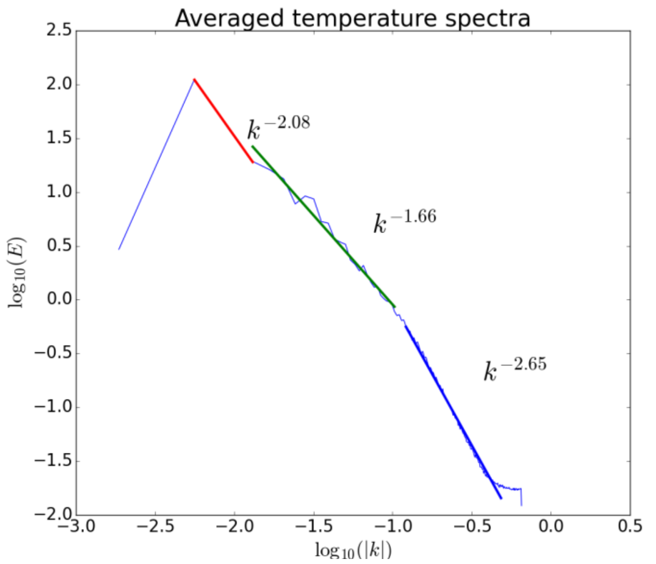
  - Original field T can be reconstructed at the different range scales *s*, using partial sums **(2).**

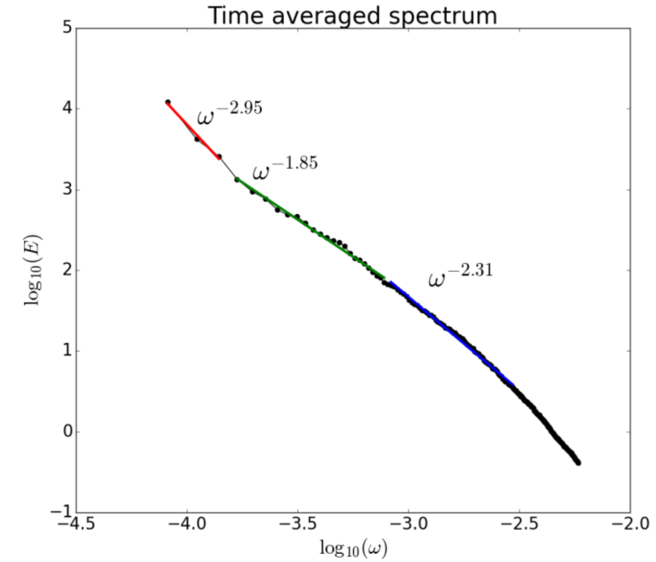
$$\int_\Omega dx'dy' < T(x,y,t_k)T^*(x',y',t_k) >_{t_k} \phi_j(x',y') = \lambda_j \phi_j(x,y) \quad (1)$$

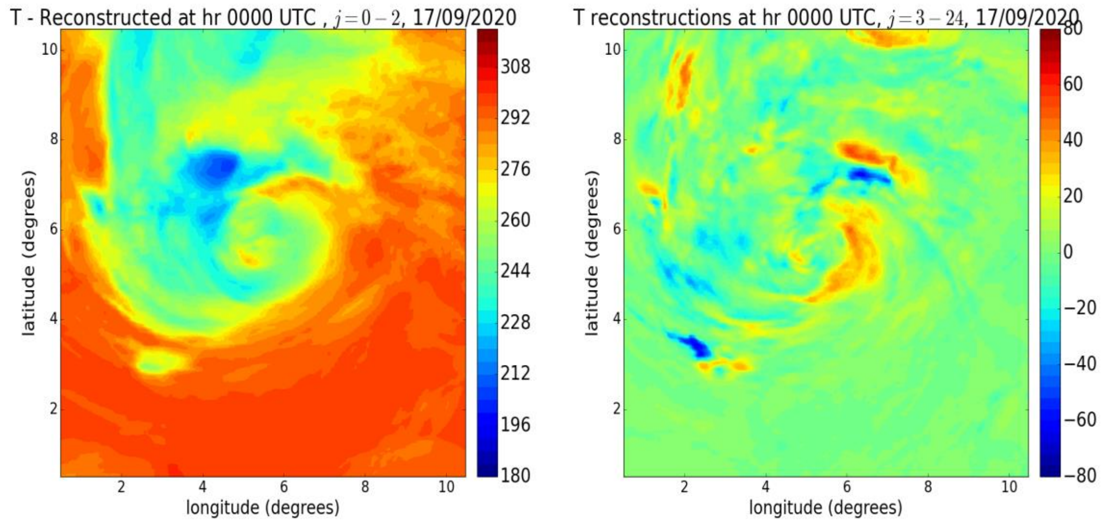
$$T_s(x,y,t_k) = \sum_{s_{init} \leq j \leq s_{final}} a_j(t_k)\phi_j(x,y) \quad (2)$$

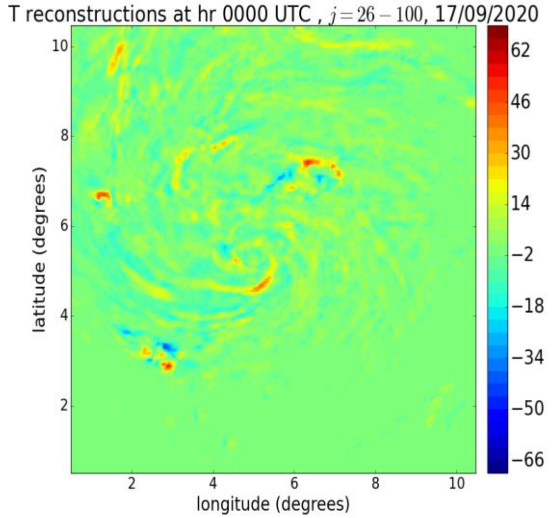
Preliminary results – POD expansion on Ianos temperature field

POD spectra obtained from the application on temperature field of Ianos, for spatial (up) and temporal (down) component, separately. Dataset is taken RSS of MSG - 11, with the same specifics of 3D view.









POD reconstructions of Ianos temperature field at 00.00 UTC of 17/09, for three characteristic scale ranges (large, intermediate and small scales), obtained from the spectral slopes.

Conclusions and future works

Key results:

- Satellite remote sensing allows understanding the evolution of *medicanes* through clouds observation, thermal variations and rotating air masses structure.
- TIR spectral channels provide significant physical aspects in large and intermediate scales of cyclonic observation in general atmospheric circulation, by confirming the results of *[Ciardullo et al, 2022]*.
- Local stratification, atmospheric instability degree and identification of the warm-core central area are exploited in both medicanes, by combining the extracted parameters with BOLAM recorded data.
- Results about deep convection detection can provide a qualitative contribution to the dynamical features of medicanes cloud systems, by replicating the procedure used in *[Hong et al., 2006, Dafis et al. 2020]*.

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New starting points:

- Explore new satellite data for going beyond current extracted parameters: try to measure the impact of relative humidity and wind speeds in the cyclonic system, as proposed in *[Quartly and Guymer, 2007]*.
- Complementary analysis from a dynamic point of view of the medicanes evolution, by exploiting spectral decomposition of geostationary satellite images, started in *[Ciardullo et al., in submission for Earth Syst Environ]*.
- Analysis of the same parameters computed from numerical simulations.
- Understanding the role of convection and moist static energy during the early stages of such events, as studied for standard atmospheric evolution in *[Muller and Bony, 2015]*.

Thank you for your attention!

Giuseppe Ciardullo

giuseppe.ciardullo11@unical.it