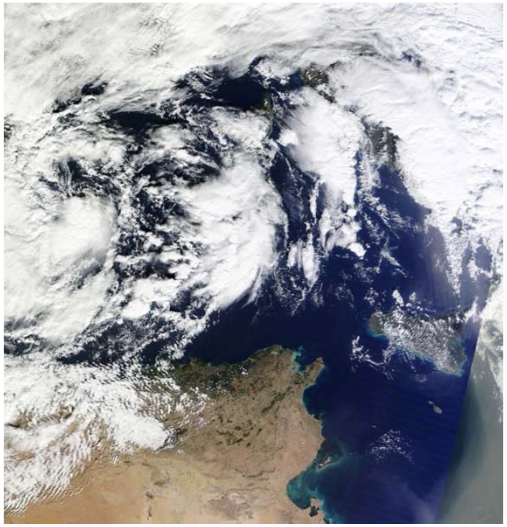
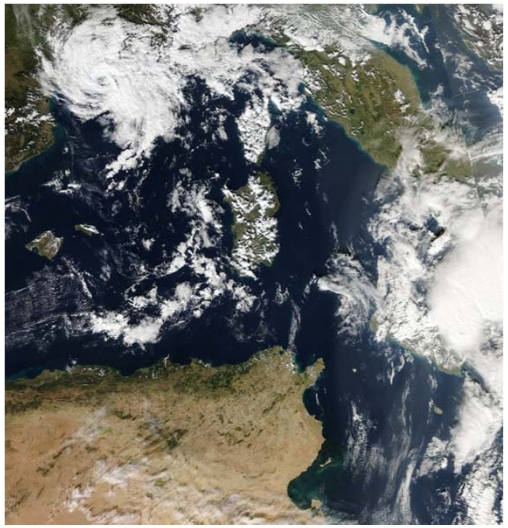


National Research Council of Italy

Institute of Atmospheric Sciences and Climate

Severe storms over the Mediterranean Sea: A satellite and model analysis

V. Levizzani, S. Laviola, A. Malvaldi, M. M. Miglietta, and E. Cattani

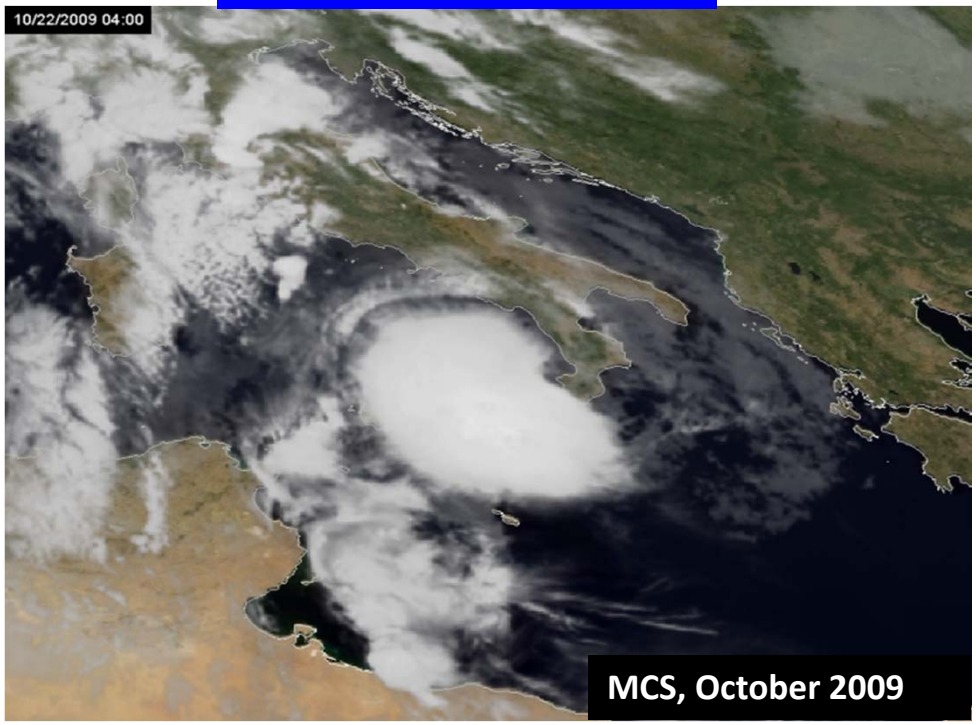
Outlines

- ✓ Focusing the attention on the Mediterranean storms
- ✓ Investigation tools
- ✓ Using MW as a proxy to classify the cloud type: the MWCC method
- ✓ Mediterranean organized systems: case studies
- ✓ A method to detect a *Mediterranean Hurricane*
- ✓ Summary & Conclusion

Focusing the attention on Mediterranean storms

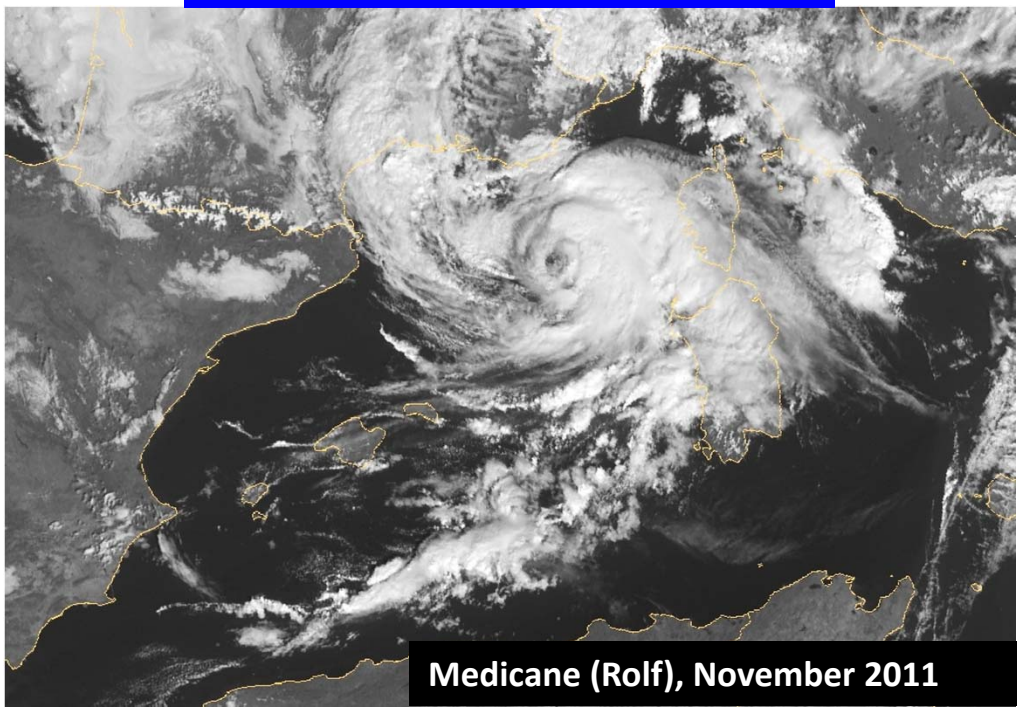
Although the Mediterranean Sea is a relatively small water body many severe meteorological phenomena usually happen in the area causing disasters or risks for the populations. When the sea surface temperature is high (>15-18 °C) the mixing of northern cold air and southern warm and wet current can generate deep systems possibly evolving up to the stage of mesoscale convective systems (MCS). In the last twenty years a subset of these meteorological systems with tropical-like characteristics was well classified as MEDICANES.

Meteosat-9 IR 10.8 Image



MCS, October 2009

Meteosat-8 HRV Image (Rapid Scan)



Medicane (Rolf), November 2011

Investigation tools

Visible (VIS) and Infrared (IR)

- Characterization of cloud systems
- Retrieval of the cloud microphysical properties
- Detection of the convective systems
- Continuous investigation of the water vapor distribution (geostationary)

Microwave (MW)

- Precipitation estimation with the method 183-WSL
- Classification of the precipitation type (stratiform/convective)
- Vertical development of clouds
- Investigation of the water vapor distribution in the target area

Blended tecniques (IR+MW)

- Advection of rain to identify the motion of the precipitating bands during the storm life cycle

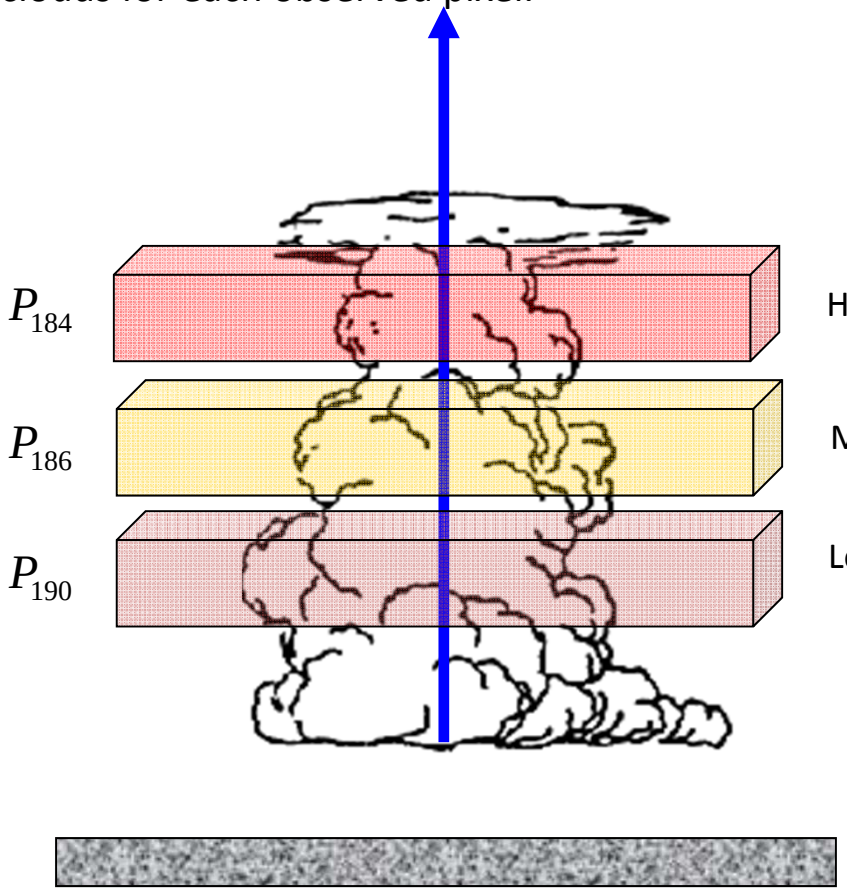
Numerical and radiative transfer models

- Weather Research and Forecasting (WRF) Model
- Local Analysis and Prediction System (LAPS)
- RTTOV

Lightning ground-based network and satellite sensors

The MW Cloud-type Classification (MWCC) method

The MWCC method is physically based on the impact of the clouds (perturbed signal) on the microwave nominal signal in a clear sky condition (unperturbed signal). The perturbation on a certain frequency is evaluated with the ratio between the measurement of radiances and its absolute maximum value (clear sky conditions). All perturbations of different frequencies are combined in a cascade test, which computes the scalar P_{MWCC} indicating the type of clouds for each observed pixel.

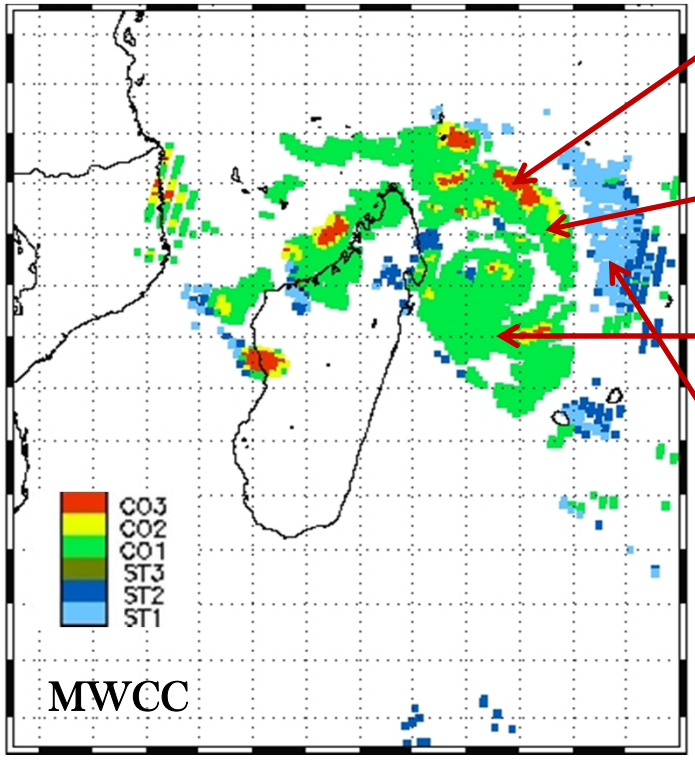


Technical details

- The MWCC method is based on the water vapor frequencies of the AMSU-B/MHS sensors. An extension to other frequencies is considered for the new version.
- The spatial resolution is ≈ 16 km (nadir)
- The sensitivity increases for clouds higher than 2 km. The retrieval of low clouds (< 2 km) is obviously problematic.
- The MWCC method has been tested at mid-latitudes and now it will be applied on the Tropics.

An example

Bingiza Tropical Storm – Madagascar, 12 February 2011 – NOAA-18



Red: strong convection (> 8 km)

Yellow: moderate convection (6-8 km)

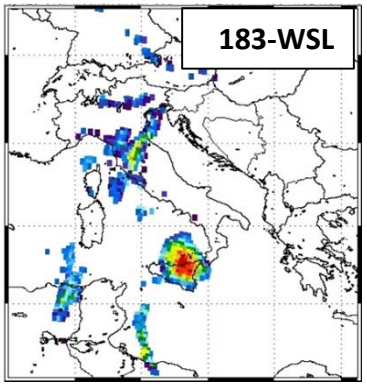
Green: light convection (4-6 km)

Cyan & Blue: low & middle stratiform clouds (2-4 km)

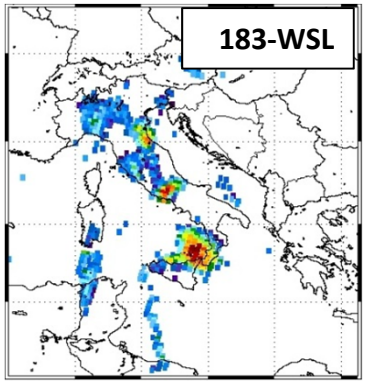
Mediterranean Mesoscale Convective System

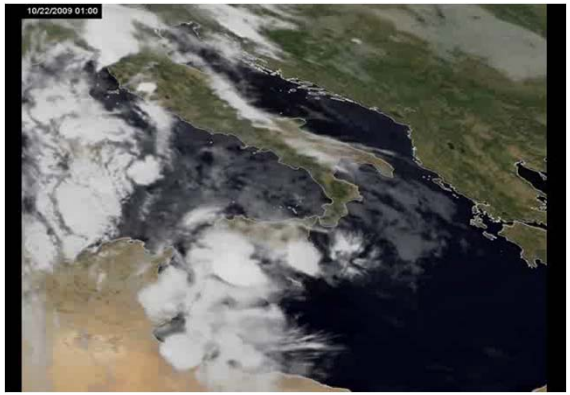
The MCS is an organized storm system either multi-cell or single cell in a compact circular shape (*Mesoscale Convective Complex, MCC*) or with a linear distribution (*squall line*) with a size of the order of 200 km. Particularly forming in fall or spring the MCSs are characterized by strong surface wind, heavy precipitation with possibly hail, and intense electric activities (lightning). The MCS horizontal dimension are usually smaller than those of extratropical cyclone and normally persist for several hours

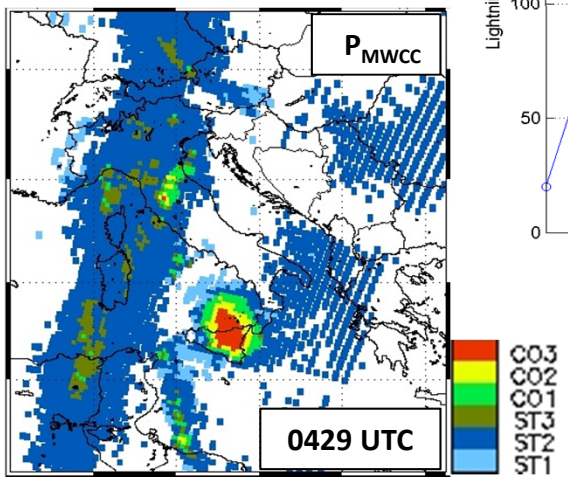
20091022 – 0429 UTC

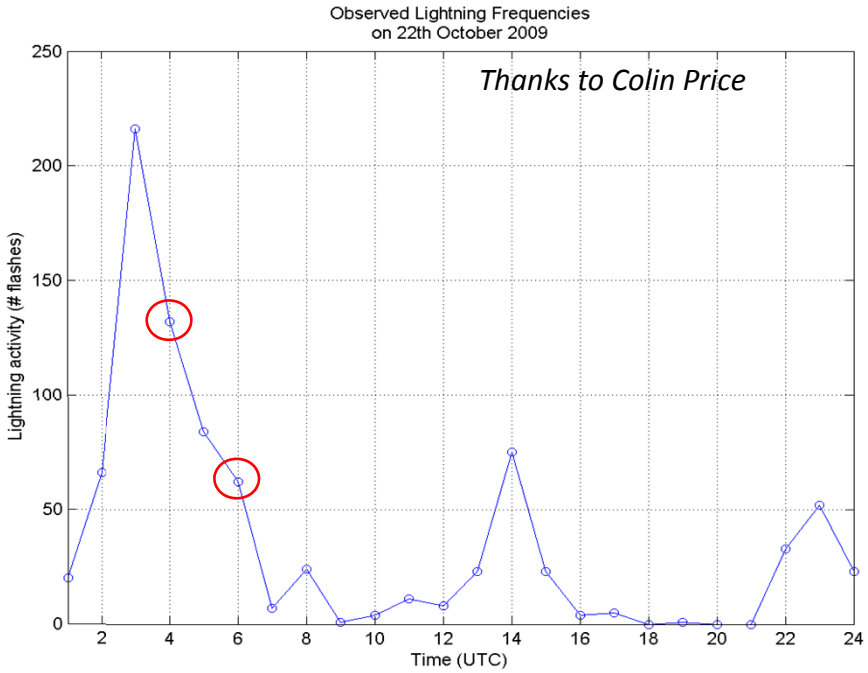


20091022 – 0602 UTC







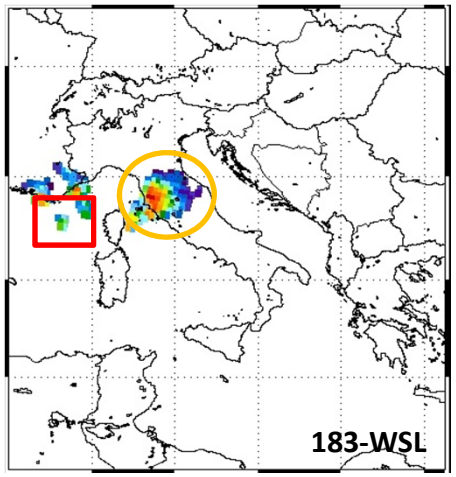


MCS over Italy: 183-WSL & MWCC

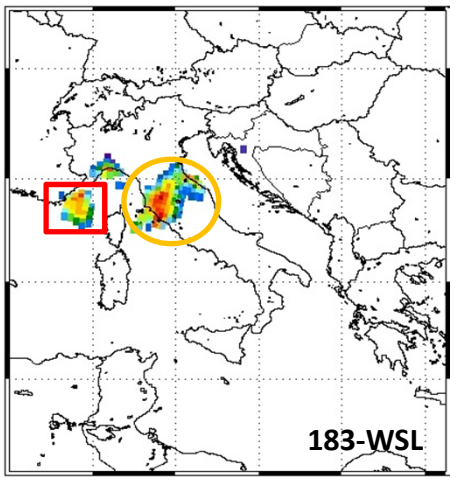
Marta river flood, 15/11/2005

The convective system was persistent over the Marta river basin for whole day

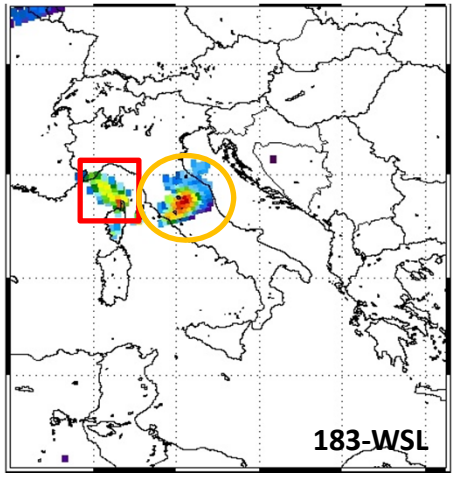
20051115– 0556 UTC

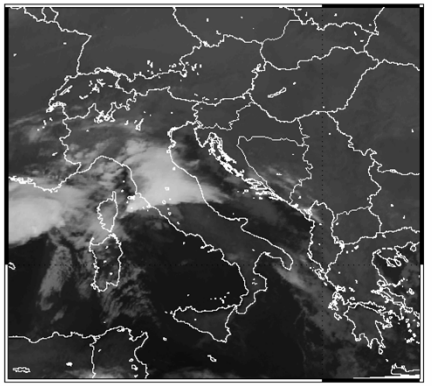


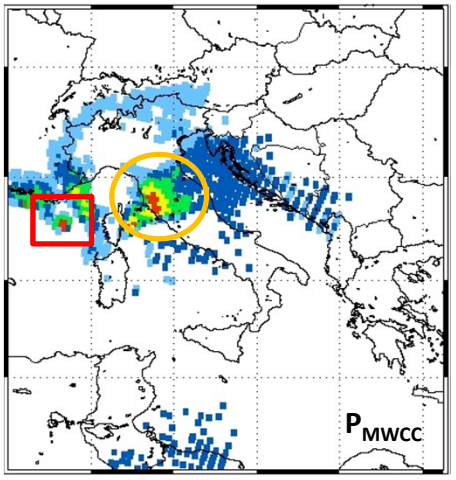
20051115– 0957 UTC

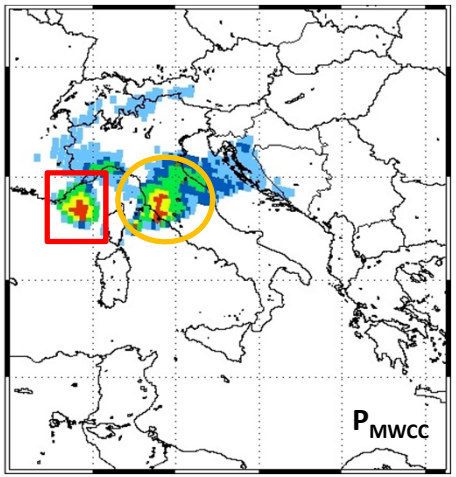


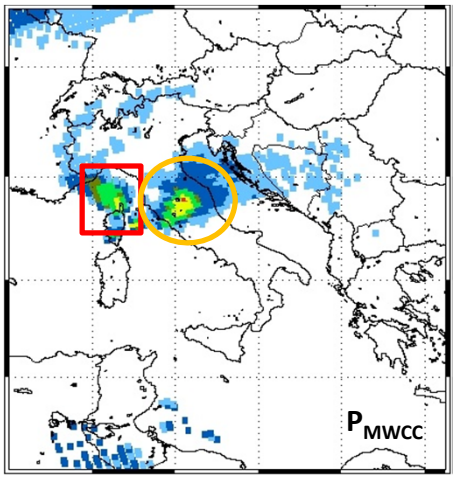
20051115– 1319 UTC











Decreasing (Mature convection with intense rain tends to decrease)

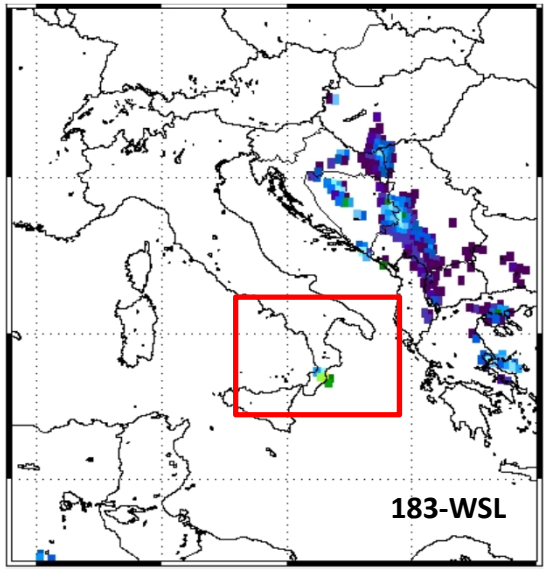
Increasing (Small convection with moderate rain tends to increase)

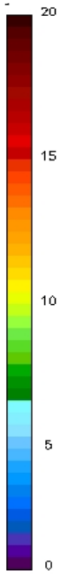
Max RR [mm h^{-1}]	Max P_{MWCC}
15.78	**60**
15.88	**60**
16.67	**60**

MCS over Southern Italy: 183-WSL

Vibo Valentia (South Italy)
03/07/2006

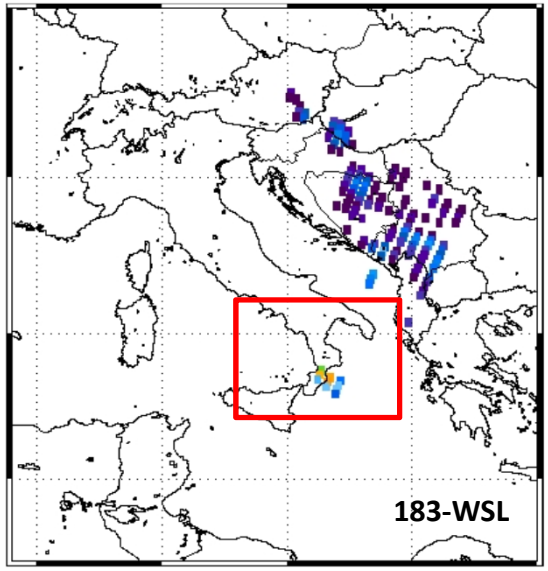
03 July 2006 - 0452 UTC





mm h^{-1}

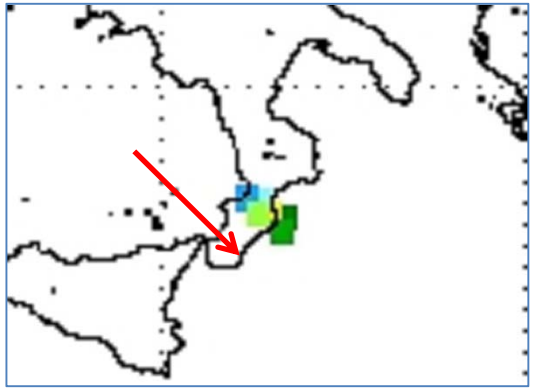
03 July 2006 - 1018 UTC

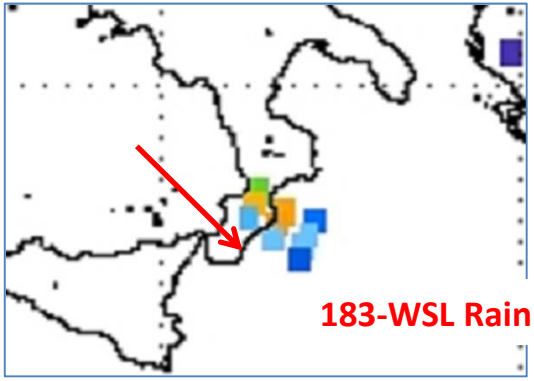


Extremely localized convective system (≈10 km^2) with a short-lived heavy precipitation

Storm life cycle≈ **2h**

Accumulated rain (08:00-13:00)≈ **202.6 mm**



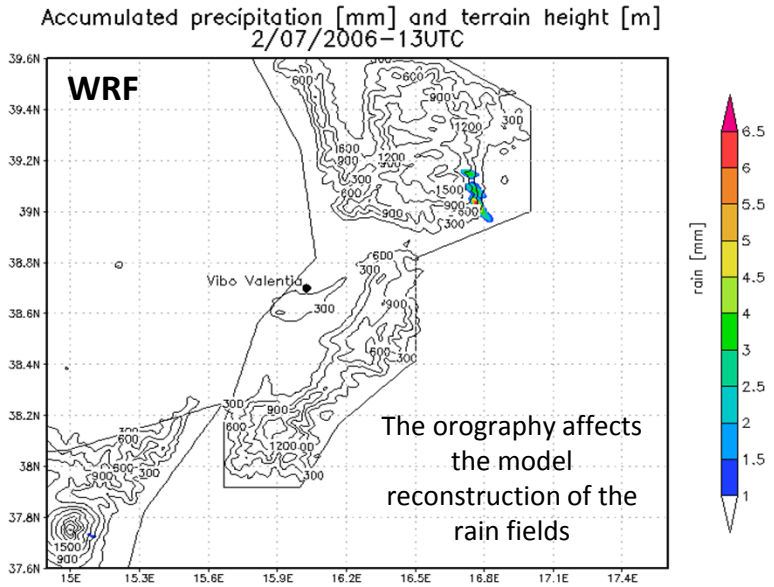


183-WSL Rain Rate≈ 18 mm h^{-1}

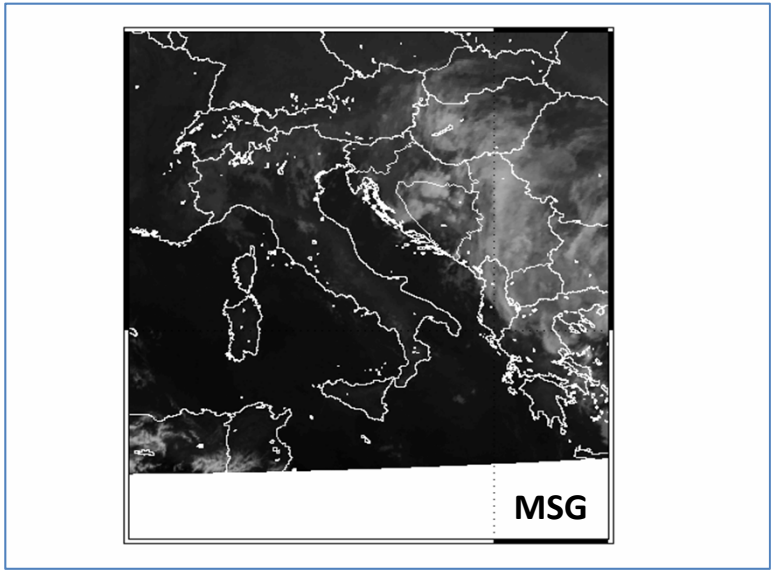
Reference: **Chiaravalloti F. & S. Gabriele**, 2009: *Vibo Valentia flood and MSG rainfall evaluation*, Atmos. Research, 93, 286-294

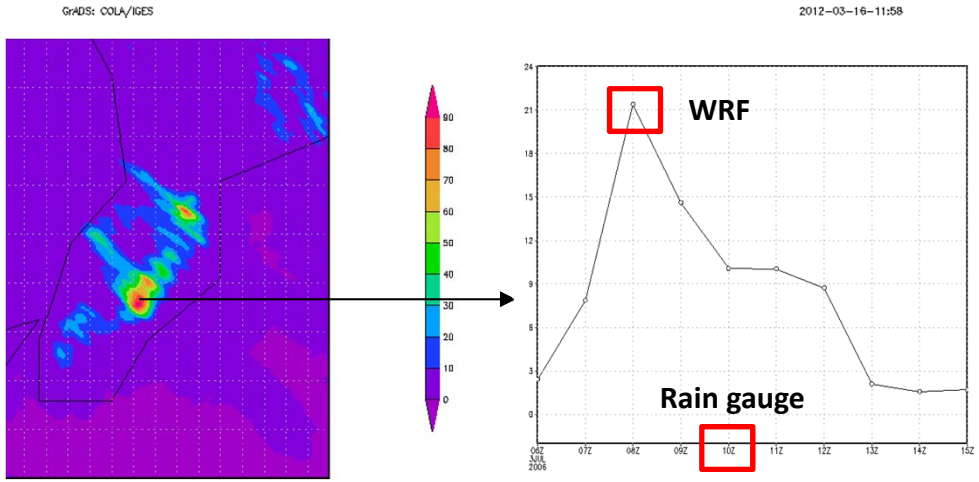
MCS over Southern Italy: WRF & CMORPH

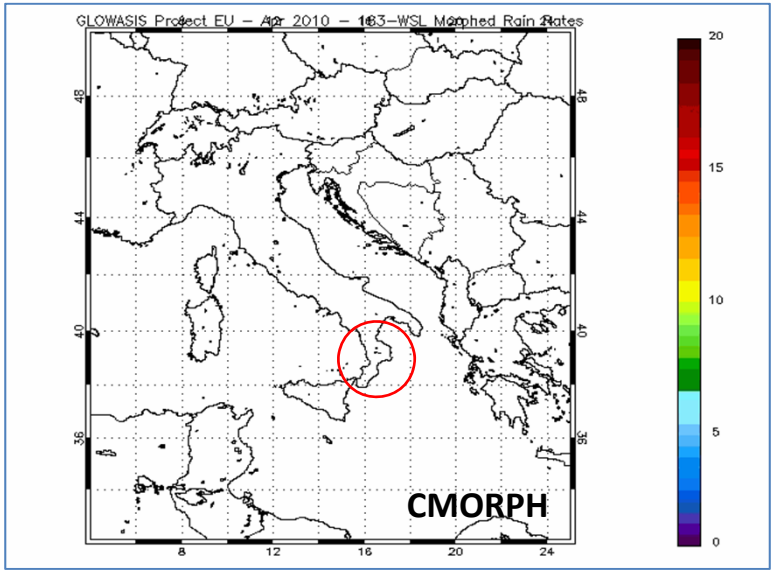
Vibo Valentia, 03/07/2006



The orography affects the model reconstruction of the rain fields





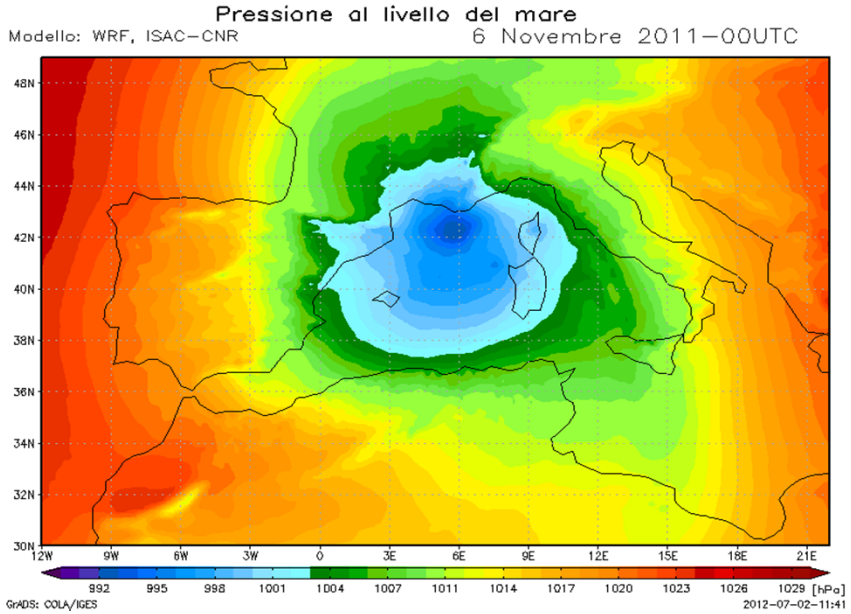


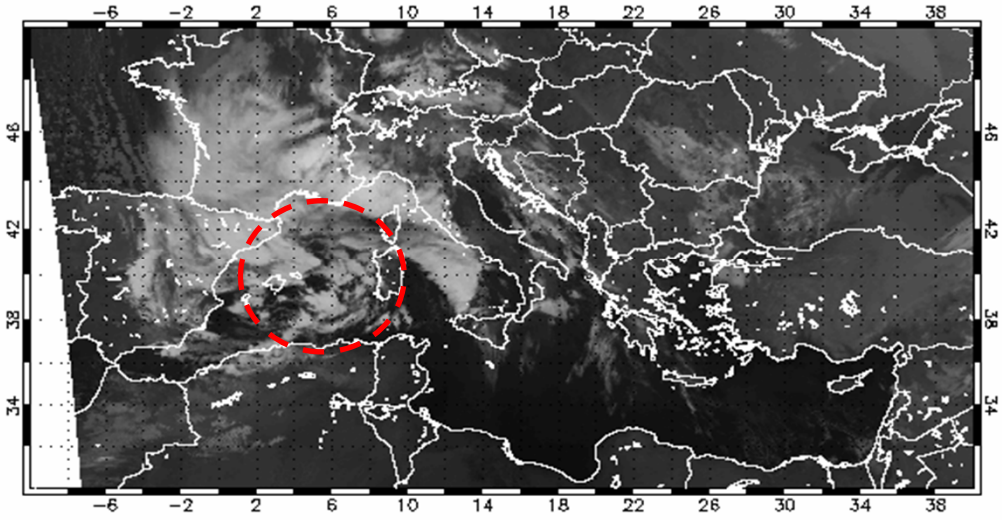
The rain amount is **underestimated** and the maximum is shifted **2 hr before**

Tropical-like system: the Medicane (***Medi***terranean Hurri***cane***)

The Medicanes or Tropical-like Cyclones (TLC) are low pressure systems with a tropical-like cyclone structure, which can *occasionally* form over the Mediterranean sea. Although the environmental conditions of the Mediterranean sea are completely different with respect to tropical oceans, the mechanisms of triggering based on the thermal instability of the sea level air are the same of those of tropical cyclones.

Balearic Islands, 06-08/11/2011





Detection method of the Medicanes with the WRF model

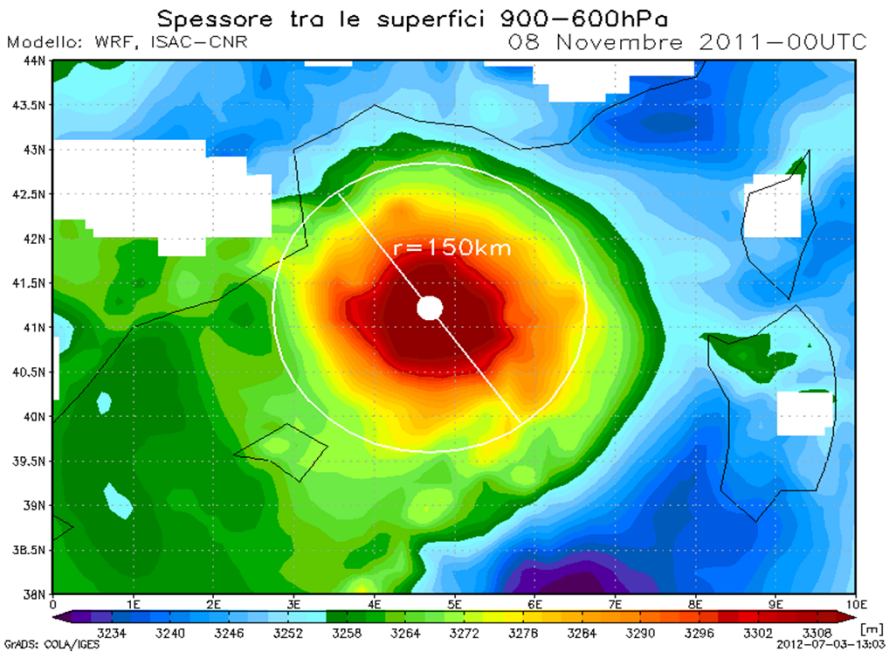
The detection of the environmental characteristics and the classification as a possible Medicane is based on the *Hart* algorithm.

The methodology is based on coupled tests: a geometric test which evaluates the symmetry of the system and a thermodynamic test which computes the difference between the geopotential in the middle and high atmosphere

1) Thermal symmetry: $$B = h\left(\overline{Z_{600hPa} - Z_{900hPa}}|_R - \overline{Z_{600hPa} - Z_{900hPa}}|_L\right)$$ [R= 100 ÷ 300 Km]

2) Thermal wind:

$$\begin{cases} -|V_T^L| = \dfrac{\partial(\Delta Z)}{\partial \ln p}\Big|_{900\ hPa}^{600\ hPa} \\ -|V_T^U| = \dfrac{\partial(\Delta Z)}{\partial \ln p}\Big|_{600\ hPa}^{300\ hPa} \end{cases}$$



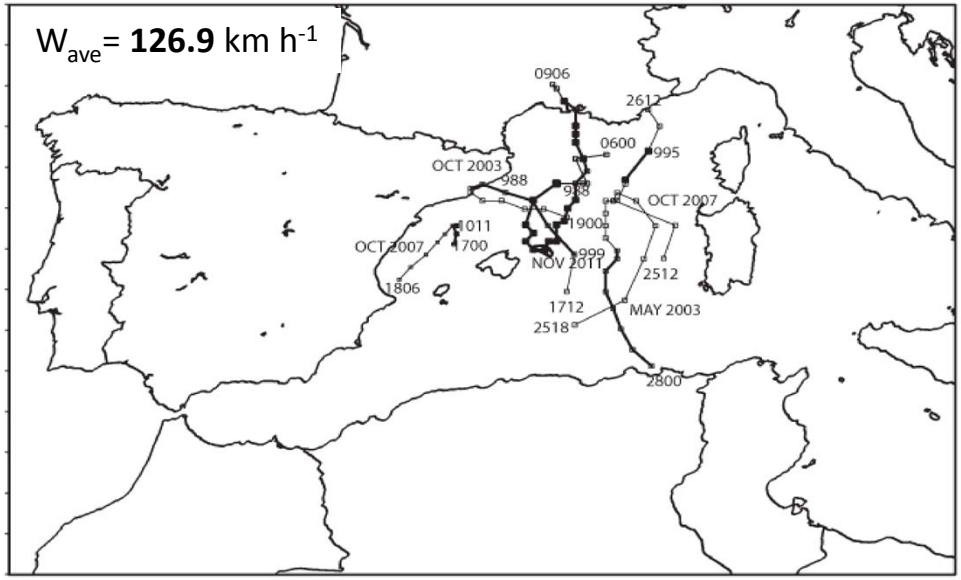
Selection criteria:

$$\begin{cases} B < 10 \\ -|V_T^L| > 0 \\ -|V_T^U| > 0 \end{cases}$$

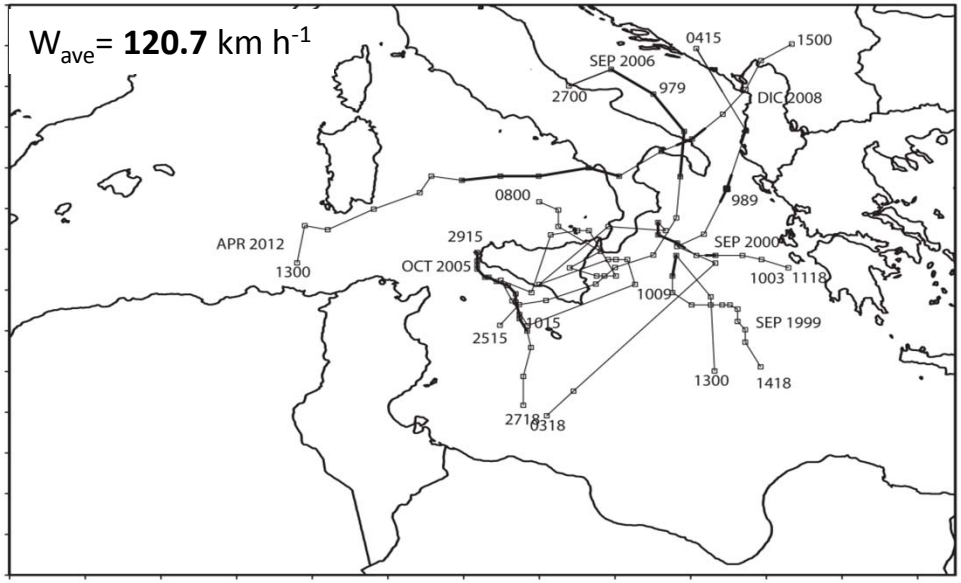
Hart, R. E., 2003: *A cyclone phase space derived from thermal wind and thermal asymmetry.* Monthly Weather Review , 131, 585-616

Mediterranean basin (1999-2012): 17 Medicane

Western Area (5)



Central Area (5)

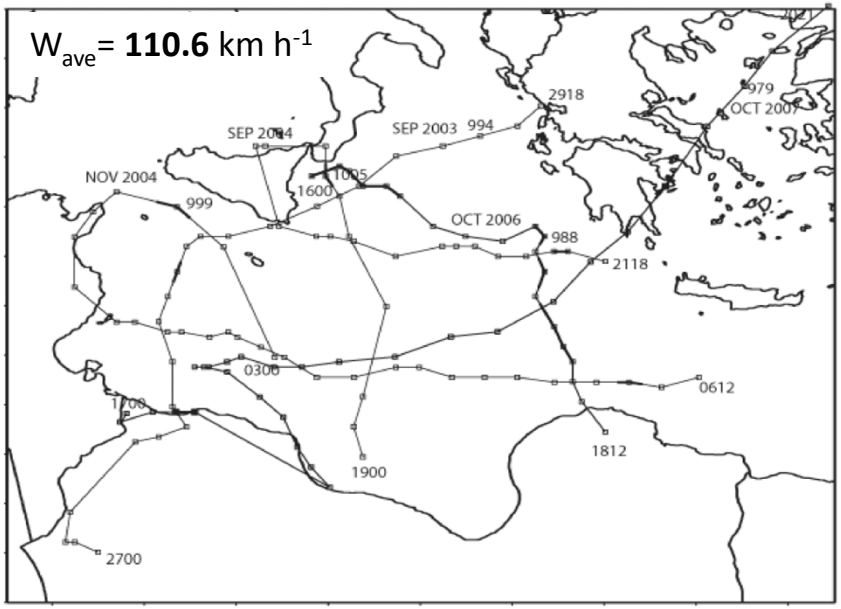


Date	Wind (km/h)	Life time (h)	Max wind
20030525	101	24	113.6
20031017	148.4	18	148.4
20071016	78.7	18	80.9
20071024	129.7	6	129.7
20111106	161.9	63	161.9

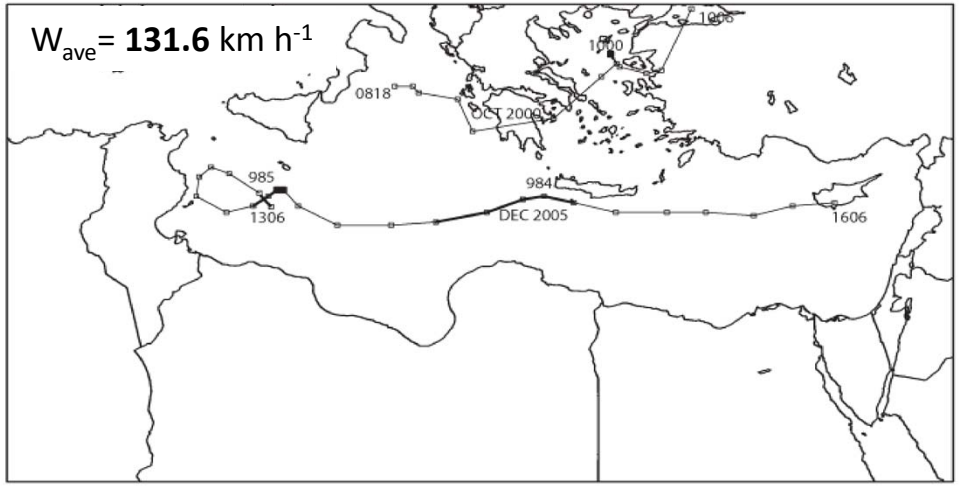
Date	Wind (km/h)	Life time (h)	Max wind
19990913	78.3	6	78.3
20000907	70.5	12	110.7
20060926	152.5	12	152.5
20081202	137.4	3	137.4
20120413	124.6	18	124.6

Mediterranean basin (1999-2012): 17 Medicane

Southern Area (4)



Eastern Area (3)



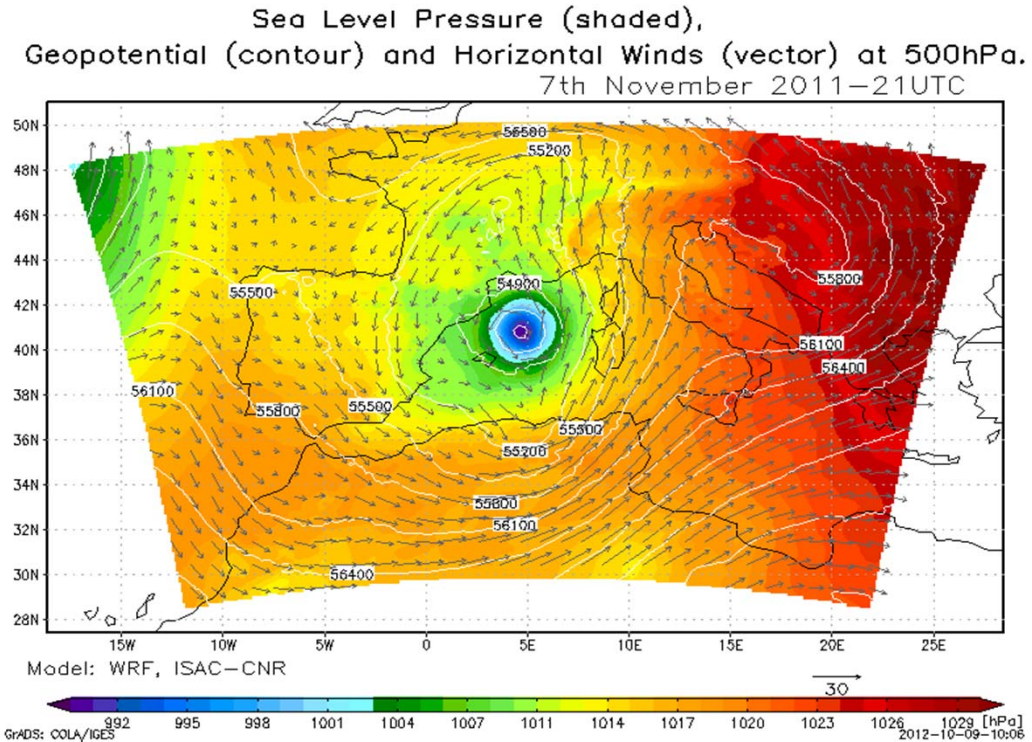
Date	Wind (km/h)	Life time (h)	Max wind
20030927	68.8	3	110.6
20040919	84 ~ 72.4	3 ~ 6	84
20041102	98.6 ~ 79.8	3 ~ 3	107.6
20061015	127.2 ~ 140.1	18 ~ 18	140.4

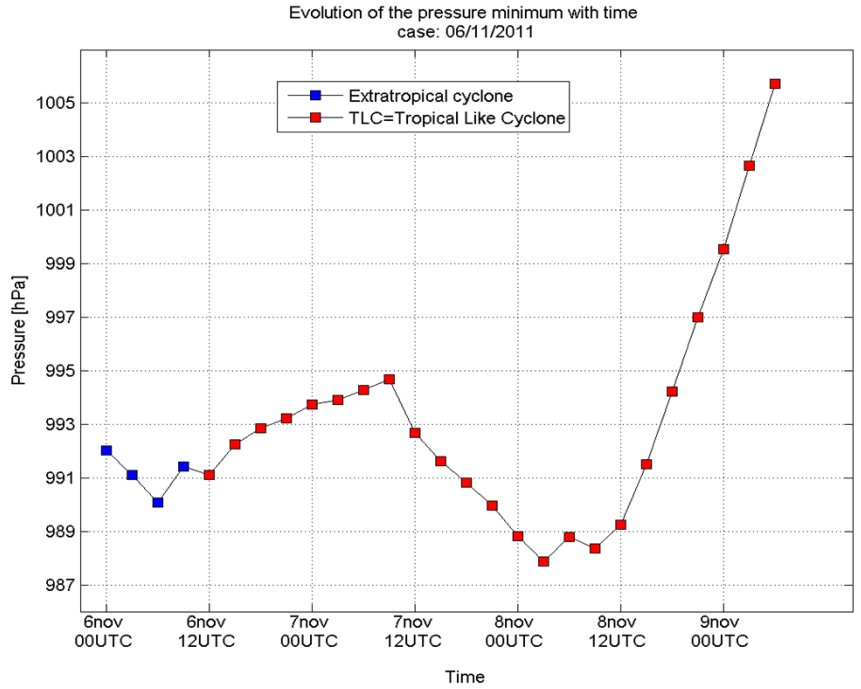
Date	Wind (km/h)	Life time (h)	Max wind
20001008	74.6	3	83
20051213	122.4 ~ 136.6 ~ 121.6	6 ~ 12 ~ 15	137.7
20071014	82.3 ~ 135.5	6 ~ 3	174

Medicane analysis with WRF

Balearic Islands, 06-08/11/2011

The cyclone developed over Western Mediterranean close to the Balearic Islands on 6 November 2011 as a result of the combination of a low pressure system over Spain and France, and a mid-tropospheric through (see left map). When the Mediterranean cyclone formed, the polar jet was lying over northern Algeria and the sea level pressure minimum was underneath a cold cut-off low at upper levels. The system made landfall on 8 Novembre 2011 over Southern France and then decayed.

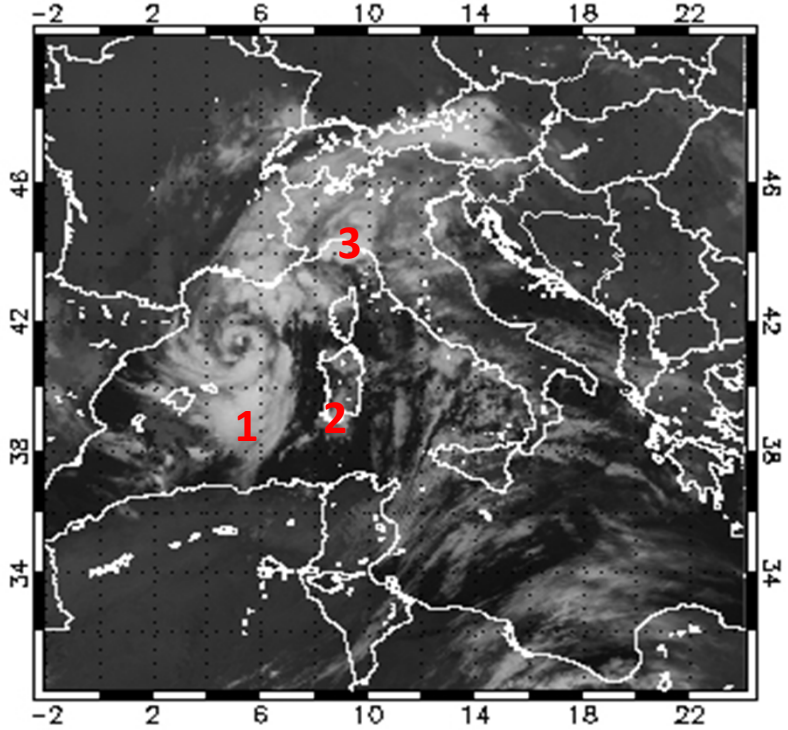


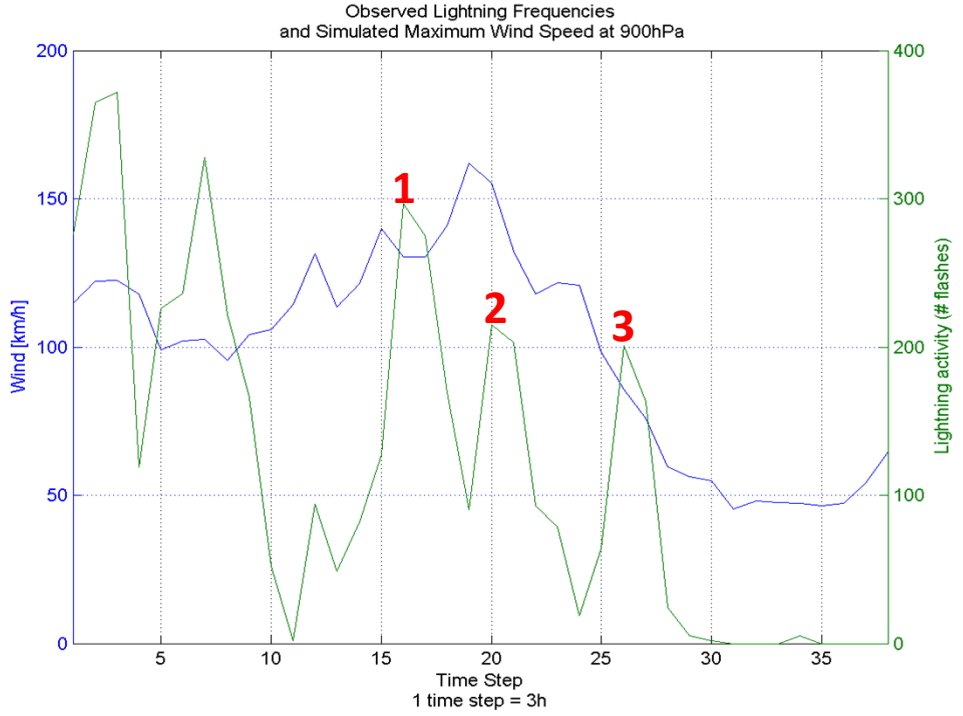


Medicane analysis with WRF

Balearic Islands, 06-08/11/2011

An analysis of the evolution of maximum winds and total lightning frequency every 3 h during the entire lifetime of the *medicane* was conducted. The diagram of lightning frequency *vs* maximum surface wind reveals an intense electric activity before (≈ 30 hr) the formation of the medicane. In the mature stage of the cyclone (numbered peaks) the measured strokes are related to other cloud systems far away from the main cyclone body.





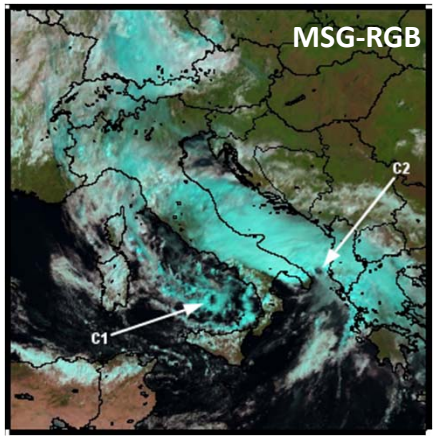
(Price, C., Asfur, M., and Yair, Y. (2009). Maximum hurricane intensity preceded by increase in lightning frequency. *Nature Geoscience, DOI:10.1038/NGEO477*)

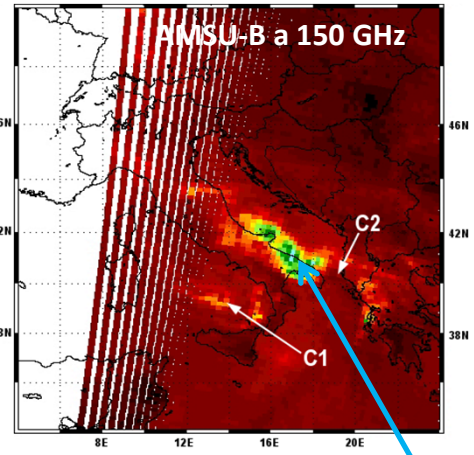
Medicane analysis with MSG, 183-WSL & WRF

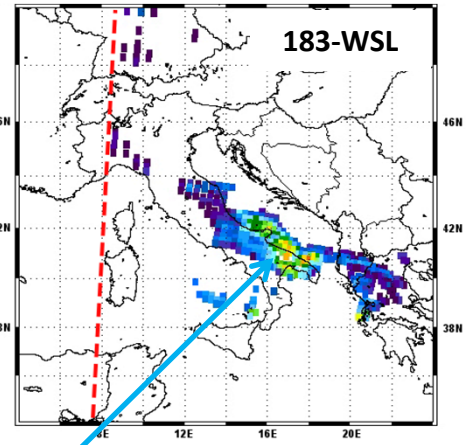
Apulia, 26/09/2006

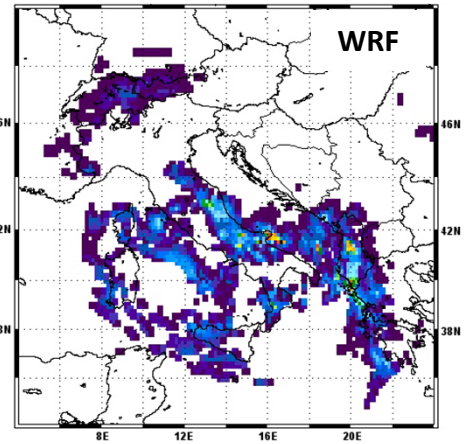
This mesoscale system was formed as a consequence of the orographic lifting by the Atlas Mountains and on the Central Mediterranean generated a complex cyclogenesis with a twin structures localized on the Adriatic and Tyrrhenian Seas. (*Laviola et al., 2011*)

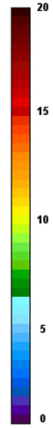
20060926 – 0925 UTC

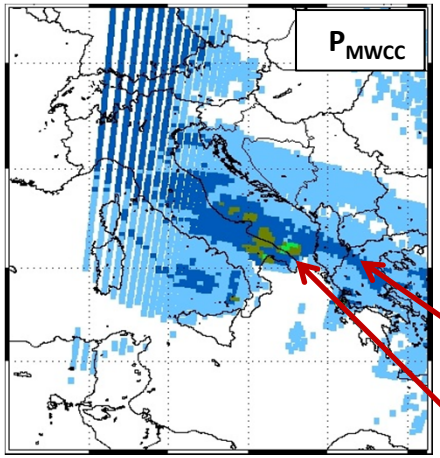












High scattering, moderate to intense rain rates

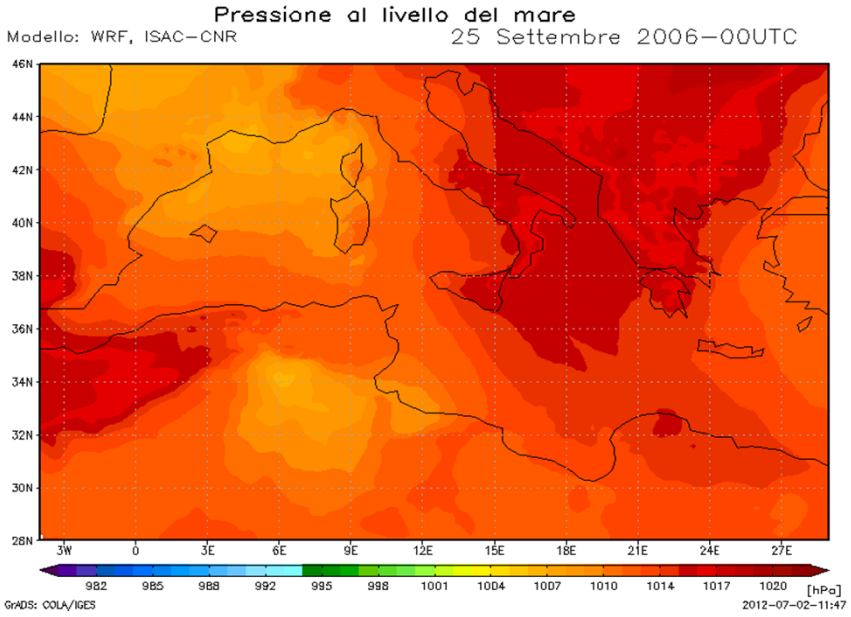
Precipitation corresponds to stratiform clouds

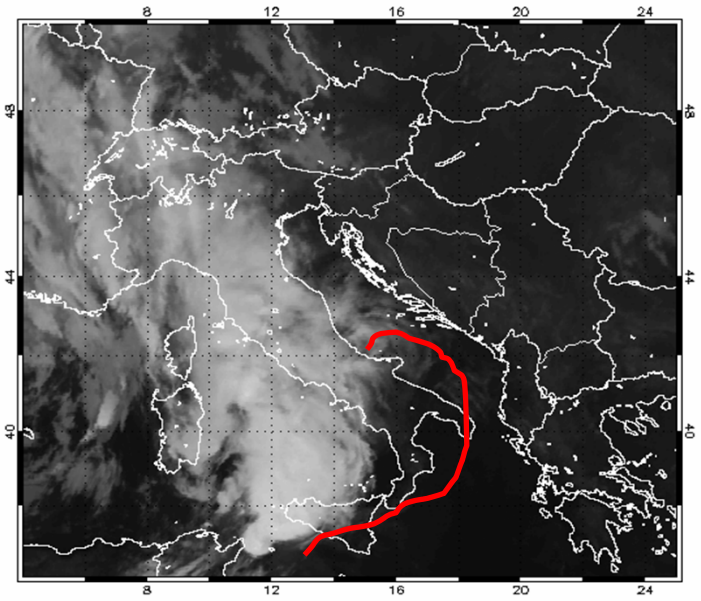
Considerations

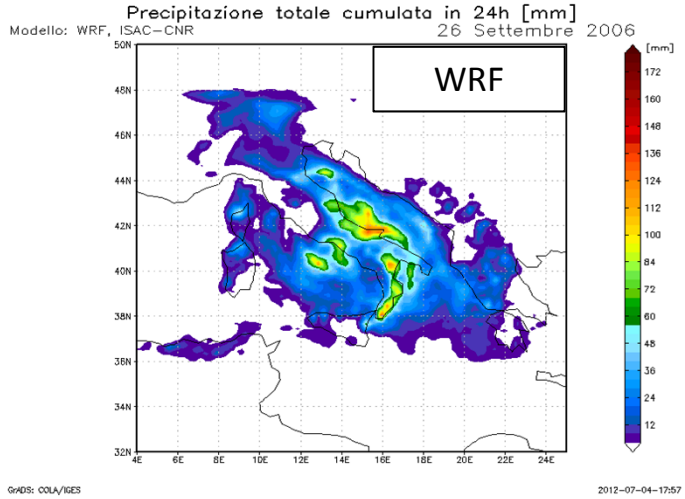
- The WRF model reconstructs a cyclone dynamic delayed of 2 hr
- The spatial domain is overestimated
- The model tends to classify several non-precipitating areas as low precipitation areas
- The rain rates is overestimated a bit more than 1 mm h^{-1}

WRF trajectory verification with MSG images

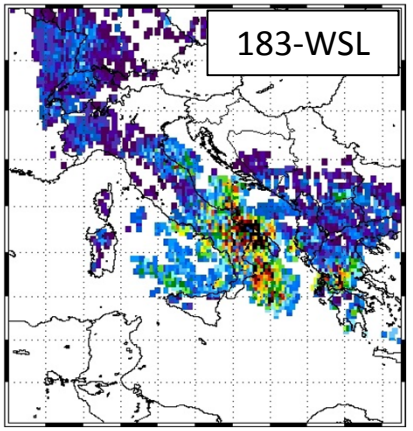
Apulia, 26/09/2006







Accumulated rainfalls



Laviola et al., 2011: *Satellite and numerical model investigation of two heavy rain events over Central Mediterranean.* J. Hydrometeor., 12, 634-649

Summary & Conclusion

✓ Our analysis was focused on 12 years (1999-2012) of Mediterranean storms classified as *MCS* and *Medicane.*

✓ To improve our investigation we combine satellite and modeling resources. In particular, the WRF model was supported by the 183-WSL method (*Laviola & Levizzani, 2011*) and by a recently developed method for cloud classification based on microwave radiation. The method classifies the observed clouds in stratiform and convective types by using a categorization that gives an indication on cloud altitude.

✓ The MWCC method reveals also as a good indicator for the evolutionary stage of clouds. With a satellite overpass sequences it is possible to track the system evolution in time.

✓ By applying the Hart algorithm to the WRF simulation 17 medicanes were classified during the study period identifying four different impacting areas on the Mediterranean basin:

- *Western area*: low number of medicanes with long life cycle and most intense storms;
- *Central+Southern area*: highest number of medicanes and life cycle < 6 hr;
- *Eastern area*: rare medicane formation and long life cycle.

✓ The lighting analysis reveals a marked signature in the early stage of the medicane. Therefore, the knowledge of the distribution of the lightning flashes is fundamental to characterize the environment for the formation of the medicane.

✓ A complete scheme for the detection of medicanes is now being tested where the satellite information mainly supports the selection of the observed system.