Report - Short Term Mission at ISAC CNR, Lecce

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Host: *Mario Marcello Miglietta – ISAC CNR*

Period: *6-17 July 2015*

As a first step, we showed each other our activities in details in order to decide how to collaborate for analysing some Medicanes case studies.

M. Miglietta provided all the cases of Medicanes in the period 2007-2014 (period of availability of high density GPS Radio Occultations (RO)) including meteorological satellites images and related papers. We have then selected GPS RO co-located with the Medicanes and analysed all the co-locations.

I have selected all the GPS ROs co-located with Medicanes in the period 2007-2014 finding a total of 20 cases (Tab. 1). Due to the small diameter (50-200 km) of Medicanes and their short life (1-2 days), it is quite difficult to get profiles into these structures; however some interesting cases have been found. Similarities with tropical cyclones in the thermal structure and in the effect on the stratosphere have been identified.

#	Medicane	RO satellite	Date and time	Co-location with CALIOP	Development area
1	Antinoo (Paul)	SACC	19/03/2007 10.10	NO	Central Mediterranean
2	Antinoo (Paul)	CHAMP	20/03/2007 19.02	NO	Central Mediterranean
3	Antinoo (Paul)	COSMIC C005	20/03/2007 20.33	NO	Central Mediterranean
4	No name	COSMIC C004	17/10/2007 21.17	NO	West Mediterranean
5	No name	SACC	25/10/2007 19.06	NO	West Mediterranean
6	No name	COSMIC C004	25/10/2007 19.23	NO	West Mediterranean
7	No name	COSMIC C005	25/10/2007 21.58	NO	West Mediterranean
8	Rolf	COSMIC C001	07/11/2011 04:38	YES	Balearic-Corsica
9	Rolf	COSMIC C001	07/11/2011 19.23	NO	Balearic-Corsica
10	Rolf	COSMIC C002	08/11/2011 04.07	NO	Balearic-Corsica
11	Lucy	Metop A	13/04/2012 11.06	NO	Tyrrhenean sea
12	Lucy	COSMIC C006	13/04/2012 16.29	NO	Tyrrhenean sea
13	Lucy	Metop A	13/04/2012 19.19	YES	Tyrrhenean sea
14	No name	COSMIC C006	16/04/2012 13.27	YES	Adriatic sea
15	No name	COSMIC C004	16/04/2012 21.55	NO	Adriatic sea
16	Cleopatra	GRACE	19/11/2013 06.09	NO	Balearic-Corsica
17	Ilona	COSMIC C005	19/01/2014 21.51	NO	Tyrrhenean-Adriatic
18	Ilona	Metop A	20/01/2014 19.19	NO	Tyrrhenean-Adriatic
19	Ilona	COSMIC C004	21/01/2014 13.14	YES	Tyrrhenean-Adriatic
20	Qendresa	COSMIC C005	07/11/2014 08.02	YES	Ionian-Adriatic

Table 1. Co-locations between medicanes and GPS ROs. Col 1-5 respectively report on: name of medicane (when available), GPS receiver acquiring the profile, date and time of the RO acquisition, availability of co-location with CALIOP, Mediterranean area of the co-location.

The GPS RO (Anthes et al., 2008) allows measurements of bending angle and atmospheric refractivity, and estimation of temperature, pressure and water vapour, with high vertical resolution (ranging between 60m in the lower troposphere and 1 km in the stratosphere), with horizontal resolution between 50 and 200 km, global coverage, high accuracy, independence on the weather conditions and processing scheme. This technique has already been extensively used for several purposes in meteorology, climatology and atmospheric physics: Huang et al. (2005) demonstrated the improvement in forecasting the tropical cyclone (TC) best tracks using the RO refractivity; Biondi et al. (2012 and 2013) showed the thermal structure of convective systems and tropical cyclones developing a new technique for detecting their cloud top altitude; Vergados et al. (2014) estimated the wind intensity of hurricanes using temperature profiles from GPS RO measurements. Biondi et al. (2015) showed the different thermal structure of TCs reaching different altitudes according to the development ocean basin. With more than 15 years of GNSS RO observation availability, these acquisitions are important and well suited for climatological studies (Foelsche et al., 2008) thanks to the RO long-term stability and self-calibrated nature, improving operational analysis and global and regional weather forecast (Cardinali, 2009).

By using the bending angle anomaly technique developed by Biondi et al., (2012; 2013) we have computed the cloud top altitude of the co-located Medicanes, validated the cloud height with the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) (when available) on board of Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and finally analyzed the impact of the Medicane on the atmospheric thermal structure in comparison with the climatology in the same area. The bending angle anomaly technique computes the percentage anomaly of the bending angle profile co-located with the cyclone with respect to the climatology in the same lat/lon box (1°x1°) and then it measures a variation of 3% within an altitude range of 2 km for detecting the cloud top. Table 2 reports the cloud top altitudes evaluated with the GPS RO and measured by CALIOP for the 5 co-locations available.

#	Medicane	RO Date and time	CALIOP Date and time	RO cloud top heigh [km]	CALIOP cloud top heigh [km]
1	Rolf	07/11/2011 04:38	07/11/2011 01:58	9.7	9-10
2	Lucy	13/04/2012 19.19	14/04/2012 01.10	9.5	9-10
3	No name	16/04/2012 13.27	16/04/2012 12.05	9.5	9
4	Ilona	21/01/2014 13.14	21/01/2014 01.21	8.7	8-9
5	Qendresa	07/11/2014 08.02	07/11/2014 12.16	11.2	10-12

Table 2. Co-location of GPS RO and CALIOP during Medicanes. The cloud top altitude from CALIOP is reported with approximation in the closest area to the RO.

We report in this document the GPS RO analyses during 2 case studies chosen within the five co-locations with CALIOP (Tab. 2).

Case study 1: Rolf 07/11/2011

Rolf developed in the area between the Balearic Islands and Sardinia between the 7th and the 9th of November 2011. As shown in Miglietta et al. (2013), this Medicane exhibits a long persistence of tropical features (symmetric, warm core structure). In Fig. 1 we report an ASCAT wind map co-located with a GPS RO (blue line in southern France) and with CALIPSO track (green line). The RO was obviously at the edge of the storm, but still catching some features. Figure 2 shows the CALIOP total attenuated backscatter at 532 nm into the area of interest (shaded area) where it is clear that the cloud top was approximately ranging from 9 to 10 km of altitude.

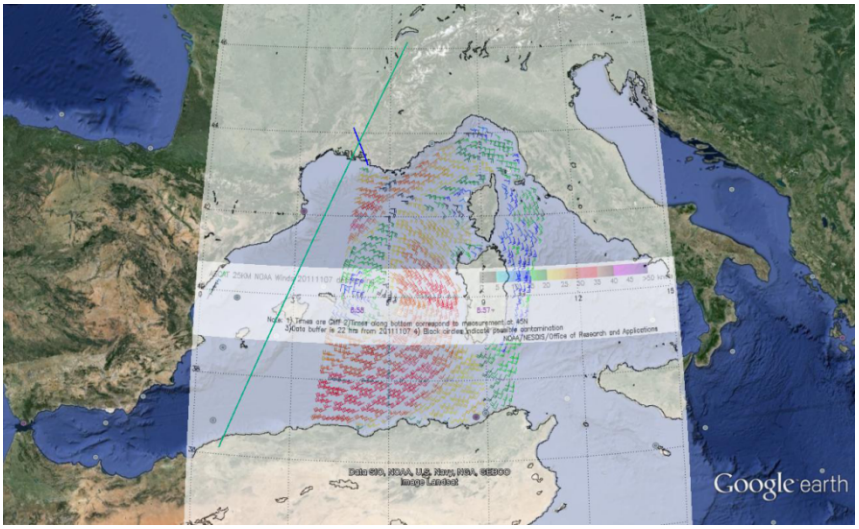

Figure 1. map showing ASCAT wind intensity, GPS RO tangent points (blue) and CALIPSO track (green)

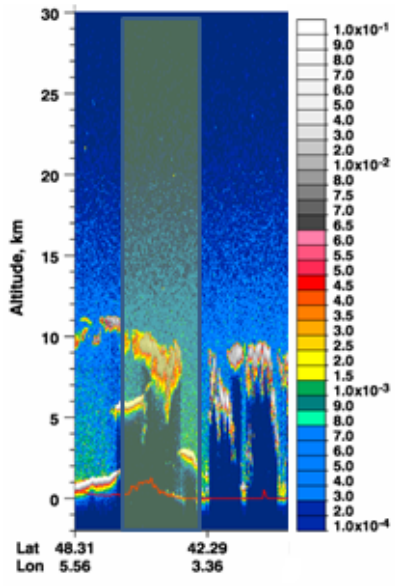

Figure 2. CALIOP total attenuated backscatter at 532 nm in the same area where the GPS RO profile was measured (shaded area).

Figure 3 shows the temperature anomaly profile (red) and the bending angle anomaly profile acquired into the storm. It is clear the large increase of bending angle anomaly peaking at 9.7 km of altitude which satisfies the conditions of the bending angle anomaly technique for detecting the cloud top altitude (the variation within 2 km of altitude is about 6%). Assuming that 9.7 km is the cloud top altitude, just above the storm there is a large increase of temperature (about 8 K warmer compared with the global climatology computed on the entire archive 2001-2013, 6 K in comparison with the monthly mean in the same area) affecting all the Upper Troposphere-Lower Stratosphere (UTLS). In Fig. 4 we show for clarity the climatological temperature profile (blue line) computed by using all the GPS RO acquired from 2001 to 2013 in the area of interest, the dry temperature (RO artefact assuming no water vapor in the atmosphere) profile during the storm (magenta) and the temperature profile estimated by GPS RO (red). This comparison is interesting since it shows how the temperature variation at 9.7 km of altitude is not due to water vapour variation (very low at that altitude) and how the temperature during the storm diverges from the usual behavior.

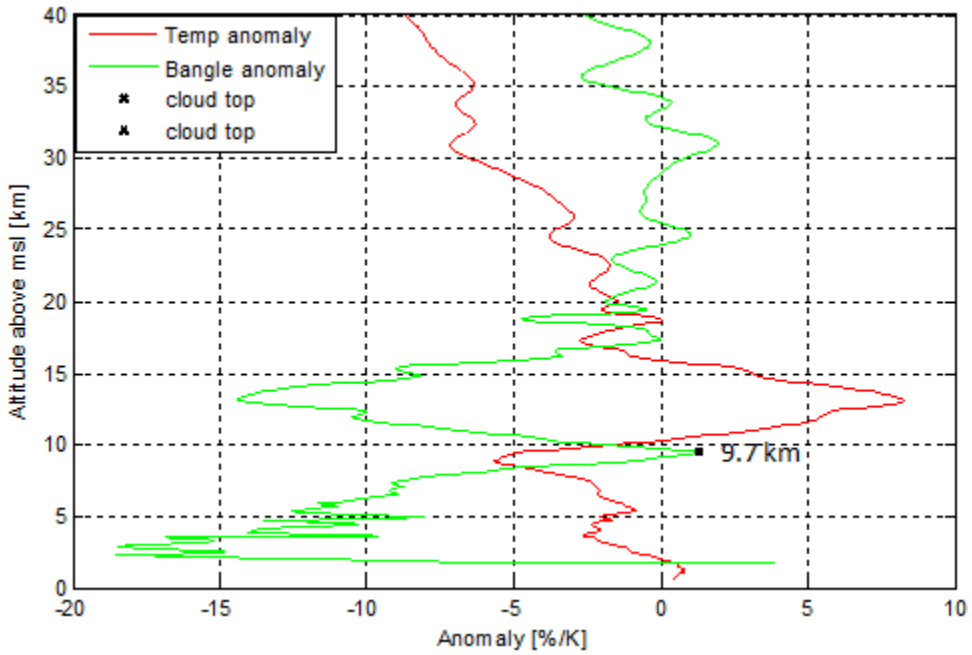

Figure 3. Temperature anomaly profile (red) and bending angle anomaly profile (green). The cloud top altitude is computed by using the bending angle anomaly technique (Biondi et al., 2013).

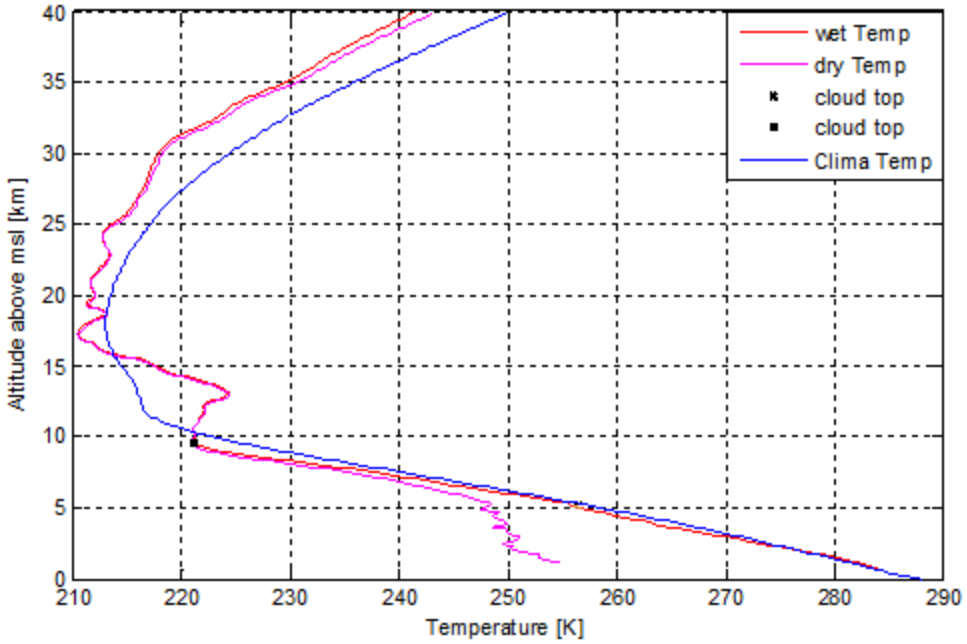

Figure 4. Climatological temperature profile (blue), dry temperature profile (magenta) and temperature profile (red). All these profile are estimated by using GPS ROs.

Case study 2: Lucy, April 2012

Lucy developed in the area between the Tyrrhenean sea and Adriatic sea between the 12th and the 14th of April 2012. Again, this case showed tropical-like features, according to Miglietta et al. (2013). This case was very interesting since we got 3 different GPS ROs in the same day (13th of April) co-located with the storm and we were lucky to find also a CALIPSO track overpassing the storm with few hours of delay. Figure 5 shows the clouds from meteosat with the GPS RO tanget points (blue) acquired at 19.19 UTC and the CALIPSO track (green) 5 hours later. Figure 6 shows the CALIOP total attenuated backscatter at 532 nm in the closest area (shaded area) to the RO, highlighting a cloud top altitude ranging between 9 and 10 km. As shown in Fig. 7, all the 3 RO bending angle anomaly profiles are really consistent with the CALIOP cloud top measurement. The bending angle anomaly algorithm reports on cloud top altitudes respectively of 9.8 km, 9.9 km and 9.5 km. Also in this case study a clear warming above the cloud tops is evident.

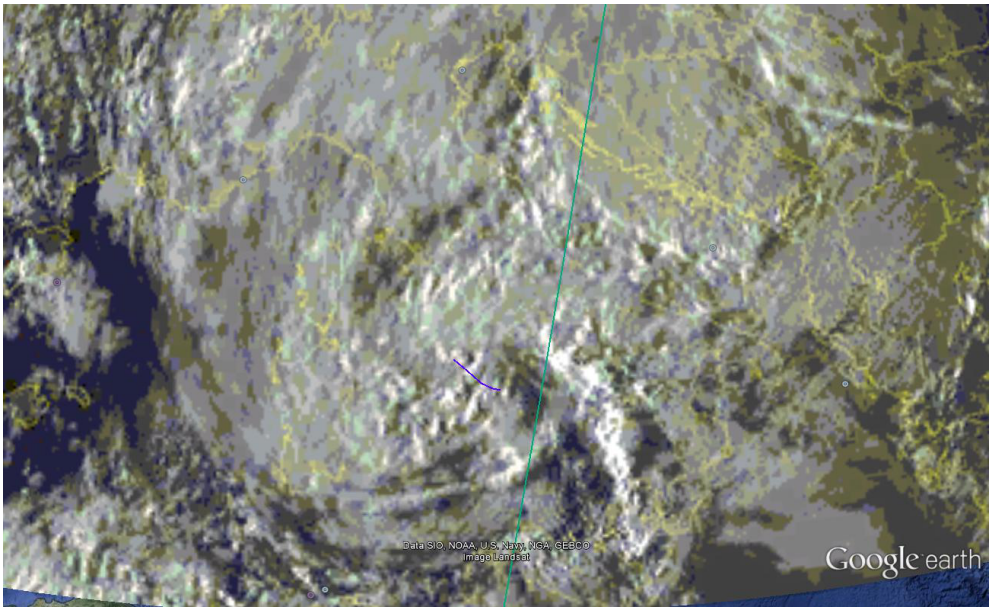

Figure 5. Meteosat cloud image (13th of April at 19.00 UTC) co-located with GPS RO (13th of April at 19.19 UTC) tangent points (blue) and CALIPSO track (14th of April at 01.00 UTC).

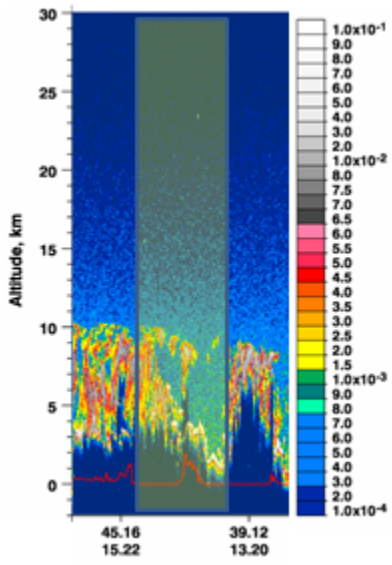

Figure 6. CALIOP total attenuated backscatter at 532 nm in the area of interest.

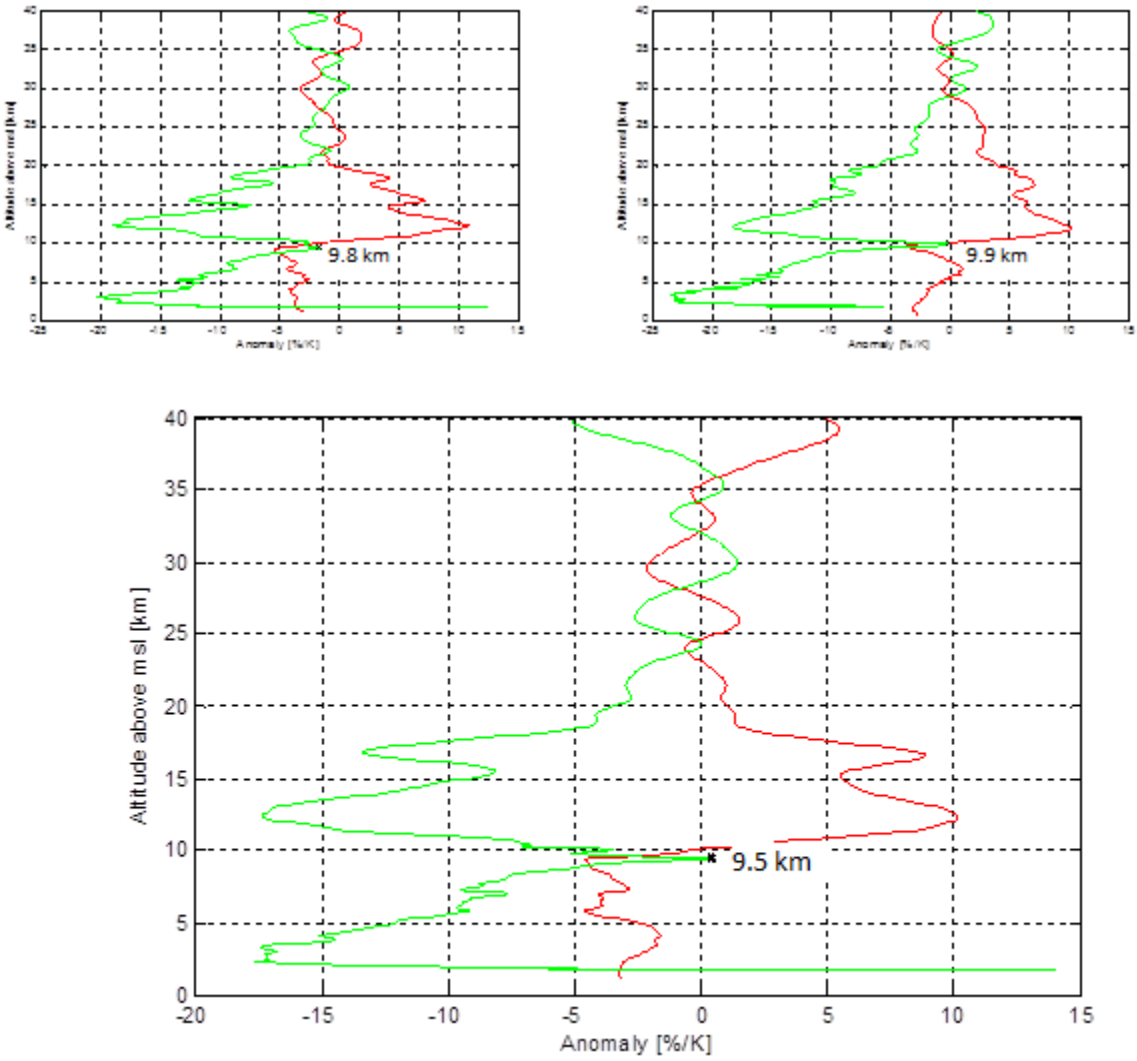

Figure 7. Temperature anomaly profiles (red) and bending angle anomaly profiles (green) co-located with Lucy. Top-left: GPS RO at 11.06 UTC. Top-right: GPS RO at 16.29 UTC. Bottom: GPS RO at 19.19 UTC.

Conclusions and future work

As shown for the 2 case studies reported in this document, the GPS RO bending angle anomaly technique confirms its capabilities for detecting the cloud top altitudes also during Medicanes. The most important feature that must be highlighted is the large warming that we have found above all the storms and this is interesting especially on the light of the results just published by Biondi et al. 2015 (Fig. 8, left panel) reporting such kind of warming characterizing tropical cyclones in the northern hemisphere. This can suggest that the impact of the Medicanes on the UTLS thermal structure is very similar to the impact of tropical cyclones. As next step we would like to compare/validate the cloud top altitudes evaluated with the GPS RO with cloud top altitudes evaluated by using meteorological satellites algorithms (Levizzani and Laviola, 2011) and to investigate the reasons of the warming above the storm.

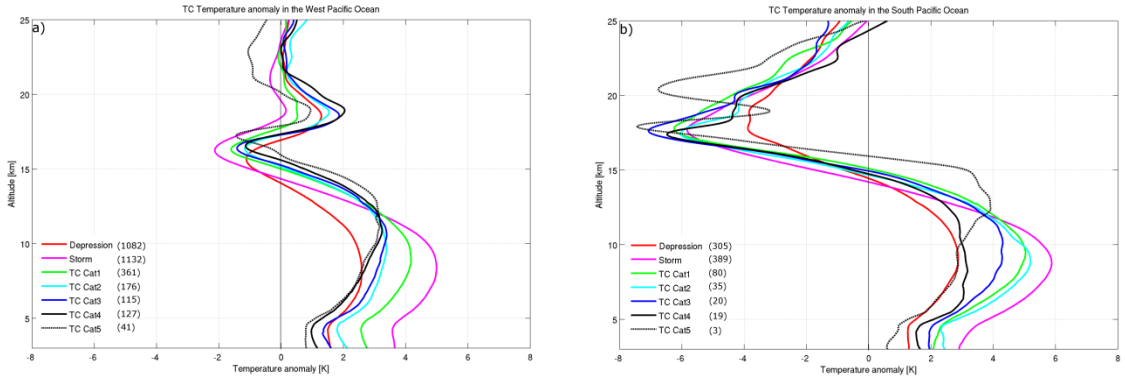

Figure 8. Biondi et al., 2015: Mean temperature anomalies for different storm categories shown for: (a) West Pacific Ocean and (b) South Pacific Ocean. Numbers in brackets denote the numbers of observations.

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Laviola, S., and V. Levizzani (2011), The 183-WSL fast rain rate retrieval algorithm Part I: Retrieval design, Atmos. Res., 99, 443–461.

Miglietta, M. M., S. Laviola, A. Malvaldi, D. Conte, V. Levizzani, and C. Price (2013), Analysis of tropical-like cyclones over the Mediterranean Sea through a combined modeling and satellite approach, Geophys. Res. Lett., 40, 2400–2405, doi:10.1002/grl.50432.

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