MEDITERRANEAN TROPICAL CYCLONE REPORT

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Tropical Storm Xandra
2-3 December 2014

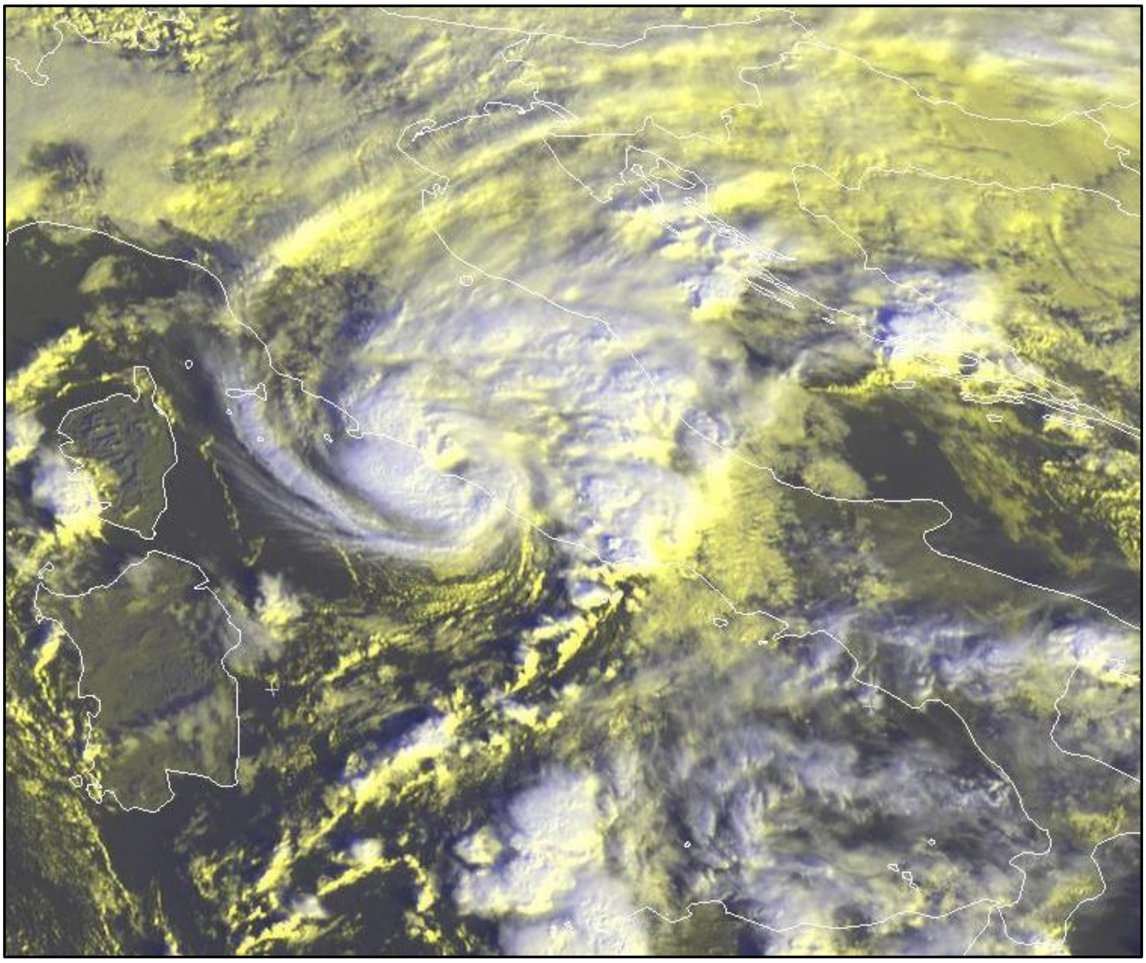

Image: EUMETSAT

Xandra (named by Freie Universität - Berlin) was a short-lived, small, but structurally well-defined tropical storm which developed from an extratropical cyclone, moved across the Tyrrhenian Sea, and made landfall in Italy.

Synoptic history

Much of the month of November, blocking pattens dominated over Europe, thanks to a very sustained and large anticyclone over far East Europe, which steered the Atlantic extratropical cyclones and their front southward, often to the Western Mediterranean Sea – this process played role in the development of Subtropical Storm Qendresa in the first half of the month. After the middle of the month the anticyclone slowly extended to west, toward Scandinavia and Central Europe, and contributed to the advection of cold, continental airmass to these areas. On 28 November a large extratropical cyclone, which got the name 'Xandra' from the Freie Universität (Berlin), reached the western parts of the Iberian Peninsula from the Atlantic Ocean. In the next 2 days the original low gradually weakened while a new one formed over the eastern side of the peninsula, which held the former one's name. This analysis starts on 30 November, when the new low's circulation became more definitive. It also gained its strength as moved over the sea and developed a warm-seclusion occlusion with an eye-like feature around midday (Fig. 3). Later on this day and on 1 December, Xandra moved slowly eastward near the Balearic Islands and caused scattered showers and thunderstorms around its center, while the fronts gradually moved away to east, northeast across Italy and the southwest parts of Central Europe – a personal note, the warm front caused high amount of freezing rain (with accumulated ice layer of 5-10 cm in some places) and severe damages in the forests in the higher areas of Nord Hungary (pictures).

Early on 2 December, despite the relatively cold (~18-19 °C) sea surface temperature, the convection increased both in coverage, organization and strength around the center of the low with cloud top temperature around -60 °C. Along with this, the fronts totally detached and mowed much more away while gradually weakened, but an elongated convergence zone still connected to the cyclone's center from west. Based on these, Xandra likely transformed into a subtropical storm by 0600 UTC as it passed through southern Sardinia. After the low reached the Tyrrhenian Sea in the afternoon, its circulation became more organized and symmetrical, and the remnants of the earlier convergence wrapped around the south and east side of the cyclone like an outer spiral rainband. Additionally, the upper-level outflow increased, especially on the northern side of the cyclone where most of the convection occurred at this time. This process led to tropical transition which completed by 1800 UTC. In the night hours, the core of the small cyclone became increasingly better organized as it gradually turned to north, and a well-defined poleward upper-level outflow channel developed on the north-northeast side of the storm (Fig. 4). By the early morning hours of 3 December, the sustained, deep convection with cloud tops around -55, -60 °C fully wrapped around the center (Fig. 5), resulted an eye, what was distinct on Italian radar maps too (Fig. 6). Three microwave satellite measurements of GMI and AMSR-2 sensors also were available between the late evening hours of 2 December and the morning hours of 3 December which present the structural evolution of the cyclone very well (Fig. 7). The firs pass at 1736 UTC 2 December already showed well-defined spiral rainbands around the low-level center, additionally a developing eyewall with deep convection on the north side of the storm. At 0144 UTC 3 December the eye became almost fully closed at the lower levels (especially on the 37 GHz image), while deep convection wrapped to the west and south side of the circulation. At 0824 UTC the low-level eyewall dissipated on the southern parts, however, the 89 GHz and 166 GHz images showed a closed ring of deep convection in line with the infrared images (Fig. 5). At this time increasing southerly vertical wind shear had already started to affect the cyclone's structure, resulting in some tilt between the lower and higher-level centers. Xandra made landfall on Italy, near *Civitavecchia* around 0830 UTC. After the landfall, the still well-defined central convective area displaced northward from the low-level center even more, and in the late morning hours the higher terrain of the Apennines disrupted the circulation, led to a more rapid weakening and finally causing the dissipation of the cyclone after 1200 UTC.

Meteorological statistics

Xandra's intensity was well estimable based on surface wind and pressure data (Table 2), ship reports (Table 3) and ASCAT measurements (Fig. 8).

Winds and pressure

Since the cyclone developed associated with a deep Atlantic low-pressure system, it produced quite low central pressure already in its early lifetime. On the second half of 30 November and the first half of 1 December many stations on the Balearic Islands reported pressure around or a bit below 990 hPa, and the nearby ship 'BAREU66' also measured pressure of 988.9 hPa at 1100 UTC 30 November. The extratropical low produced gale-force winds over a large area around its center, except the north-northeast portions. An ASCAT pass at 2002 UTC 1 December showed peak winds around 85 km/h (45 kt) while the strongest wind gusts in *Ibiza* and *Menorca* also were around 80 km/h (43 kt) in this period, and some ships reported 10-minutes sustained winds of 65-70 km/h (35-38 kt). The wind slowly weakened on 2 December, but a larger area of gale-force winds still occurred north of the Baleares on the backside of the cyclone. The tightening center of the low moved across the southern parts of Sardinia, where the pressure fell to around 994-995 hPa at this time, indicated some gradual weakening since the previous day. However, in the southeastern edge of Sardinia, *Capo Carbonara* reported 10-minutes sustained winds of 70 km/h (38 kt) both in the morning and in the midday hours. As the cyclone left the island, its low-level circulation become more compact and symmetrical, confirmed by ASCAT measurements at 1942 UTC and at 0845 UTC on the next day. These showed peak winds around 55 km/h (30 kt) but based on the very small size of the cyclone and the typical undersampling of the ASCAT sensors, Xandra likely retained the tropical storm intensity at this period. Moreover, despite the lack of any available measurements, the gradually improving structure suggested at least some slight intensification until the landfall, with estimated peak intensity of 85 km/h (45 kt) around 0600 UTC. Pressure of 997.2 hPa was reported in *Civitavecchia* at 0900 UTC, about half hour after the landfall. Since the cyclone's structure already started to become more disorganized shortly before the landfall and the storm probably lost some of its strength by this time, that data may support 993 hPa central pressure at peak.

Rainfall

The precipitation of the subtropical and tropical parts of the cyclone is not easy to determine since the central system was very small, and the low caused extensive rainfall (and even snowfalls and freezing rain) across the Western and Central Mediterranean region and even in Central Europe in its extratropical phase, as usual in most of the winter Mediterranean cyclones. Thus, Table 4 contain precipitation data only from Sardinia, South Corsica and Central Italy on 1-3 December, where most of the rains likely fell associated with the small cyclonic vortex or its surrounding rainbands. In this period, the highest 3-days summaries were around 50 mm in all areas, with maximum values locally up to 70-90 mm in Italy. However, total rain above 100 mm cannot be ruled out in the coastal areas near the landfall.

Storm Surge

There was not any measurements or eyewitness videos available from the surge associated with Xandra.

Reanalysis data

Xandra had been analyzed by ECMWF-ERA5 high-resolution reanalysis data. The examined parameters were 300 hPa divergence and winds (Fig. 9), 925 hPa geopotential and 850 hPa vertical speed (Fig. 10), 850 hPa equivalent potential temperature and wind (Fig. 11), 500-1000 hPa thickness and 850 hPa relative vorticity (Fig. 12), 200-1000 hPa thickness and 300 hPa potential vorticity (Fig. 13) and vertical cross-sections of potential vorticity (Fig. 14). The analysis expanded from 0000 UTC 29 November to 2100 UTC 3 December. However, only two images are listed here: the first one is at 1200 UTC 30 November, when Xandra still was extratropical, but it developed a warm seclusion, and second one at 0600 UTC 3 December, when it reached its peak intensity as a tropical storm. An animation of all reanalysis maps is available here:

https://www.youtube.com/watch?v=PlEDgkcweXw

As it was mentioned earlier, the cyclone formed in the periphery of a weakening Atlantic extratropical system, and the synoptic pattern was very favorable to the cyclogenesis. The developing low was influenced by a strong jet stream which provided favorable upper-level divergence aloft, additionally a potent upper-level potential vorticity (PV) streamer reached the area from southwest. The significant temperature gradient (baroclinity), the lower-level relative vorticity advection and a warm conveyor belt at 850 hPa also contributed to the formation and fast deepening of the cyclone on 29 and 30 November. On the latter day the low occluded quickly and developed a warm seclusion which was visible on the 850 hPa equivalent potential temperature (EPT) and both the 500-1000 hPa and the 200-1000 hPa thickness maps. The upper-level PV streamer also wrapped into the cyclone center, and the cross section indicated the appearance of a weak low-level anomaly as well. At this time, an upper-level low moved over Xandra, causing significant weakening of the vertical wind shear, and generating divergent upper-level flow. The 850 hPa relative vorticity and updrafts became stronger around the center too, but an elongated frontal band still was visible to east, along the high temperature (thickness) gradient and the western edge of the warm conveyor belt. On 1 December this front moved away to east and gradually weakened, indicated by all parameters. The cyclone retained its warm core and the 850 hPa relative vorticity concentrated even more into the center, however the updrafts weakened around it. The upper-level low stretched to northeast and became larger as the jet stream placed over the Central-Southern Mediterranean Sea, so Xandra remained in a weak-shear, mostly moderately divergent upper-level environment, and the potential vorticity anomaly significantly decreased over it.

On 2 December the cyclone's structure temporarily become less organized as it interacted with Sardinia. The warm core weakened on the thickness and EPT maps and stretched to southwest to northeast, additionally the 850 hPa relative vorticity field took same appearance. On the second half of this day and the first half of 3 December, an approaching upper-level shortwave trough from west, which was visible well on the 300 hPa wind maps, generated stronger south to southwest flow north of the cyclone which contributed to the development of the previously mentioned poleward outflow channel. In the night and morning hours the warm core and the low-level relative vorticity filed became better defined and more symmetrical again, and stronger updraft appeared near the cyclone center. At this time, there was not any significant upper-tropospheric potential vorticity anomaly above the cyclone, only to the west-southwest associated with the shortwave trough, however, the low-level PV tower remained quite weak and shallow.

Table 1 Best track for Xandra, 30 November - 3 December 2014

Day/Time [UTC]	Latitude [°N]	Longitude [°E]	Pressure [hPa]	Wind speed [km/h *(kt)*]	Stage
30 / 0000	37.8	1.0	995	45 *(25)*	extratropical
30 / 0600	38.1	2.4	990	55 *(30)*	”
30 / 1200	38.9	1.7	988	75 *(40)*	”
30 / 1800	39.0	1.8	988	75 *(40)*	”
01 / 0000	39.0	3.0	989	85 *(45)*	”
01 / 0600	39.9	4.2	989	85 *(45)*	”
01 / 1200	39.8	4.4	990	85 *(45)*	”
01 / 1800	39.2	5.9	991	85 *(45)*	”
02 / 0000	39.2	7.0	992	75 *(40)*	”
02 / 0600	39.4	8.7	993	75 *(40)*	subtropical storm
02 / 1200	39.9	9.6	994	65 *(35)*	”
02 / 1800	40.2	10.3	995	65 *(35)*	tropical storm
03 / 0000	40.8	11.4	994	75 *(40)*	”
03 / 0600	41.7	11.8	993	85 *(45)*	”
03 / 1200	42.6	11.9	999	55 *(30)*	tropical depression
03 / 1800					dissipated
03 / 0600			993	85 *(45)*	minimum pressure and maximum wind (as tropical)
03 / 0830			995	75 *(40)*	landfall south of Civitavecchia (Italy)

Table 2 Selected surface winds and pressure observation

Location	Minimum sea level pressure		Maximum surface wind speed		
	Day/Time [UTC]	Pressure [hPa]	Day/Time [UTC]	Sustained (10-min) [km/h *(kt)*]	Gust [km/h *(kt)*]
Ibiza / Es Codola (Sp. / Baleares)	30 / 1400	988.8	30 / 1400	48 *(26)*	80 *(43)*
Ibiza / Es Codola (Sp. / Baleares)	30 / 1600	988.3	30 / 1600	15 *(8)*	
Pal. de M. / Son S. J. (Sp. / Baleares)	01 / 0100	992.3			
Menorca / Mahon (Sp. / Baleares)	01 / 0600	990.1	01 / 0600	19 *(10)*	
Menorca / Mahon (Sp. / Baleares)	01 / 1600	993.7	01 / 1600	54 *(29)*	80 *(43)*
Decimomannu (It. / Sardinia)	02 / 0600	994.3			
Guspini (It. / Sardinia)	02 / 0600	993.5	02 / 0600	20 *(11)*	
Capoterra (It. / Sardinia)	02 / 0630	994.7			
Capo Carbonara (It. / Sardinia)			02 / 0655	70 *(38)*	
Capo Carbonara (It. / Sardinia)			02 / 1055	70 *(38)*	
Capo Carbonara (It. / Sardinia)	02 / 1155	996.0	02 / 1155	61 *(33)*	
Capo Bellavista (It. / Sardinia)	02 / 1255	994.5			
Ponza (Italy)	03 / 0000	1001.3	03 / 0000	43 *(23)*	
Pratica Di Mare (Italy)	03 / 0555	1000.7	03 / 0555	41 *(22)*	63 *(34)*
Civitavecchia (Italy)	03 / 0900	997.2	03 / 0900	31 *(17)*	
Vigna Di Valle (Italy)	03 / 1000	1000.6	03 / 1000	35 *(19)*	
Vigna Di Valle (Italy)	03 / 1100	1001.6	03 / 1100	41 *(22)*	
Viterbo (Italy)	03 / 1155	1001.2	03 / 1155	48 *(26)*	70 *(38)*
Valentano (Italy)	03 / 1200	1000.0			
Orvieto (Italy)	03 / 1330	1001.8	03 / 1330	48 *(26)*	79 *(43)*
Marsciano (Italy)	03 / 1400	1001.0			

Table 3 Selected ship reports

Day/Time [UTC]	Ship call sign	Latitude [°N]	Longitude [°E]	Wind dir/speed [km/h *(kt)*]	Pressure [hPa]
30 / 0000	WKAB	36.9	1.3	330 / 11 *(6)*	996.6
30 / 1100	BAREU66	39.2	0.8		988.9
30 / 1200	DGHX	37.5	3.4	220 / 67 *(36)*	996.0
30 / 1700	TBWUK47	36.9	0.6	260 / 65 *(35)*	998.8
30 / 1800	BATFR46	39.4	1.0	010 / 46 *(25)*	991.9
01 / 0000	DGHX	36.6	-0.8	250 / 70 *(38)*	999.0
01 / 0200	ZCEF3	41.5	4.5	090 / 33 *(18)*	995.6
01 / 0600	3ECJ7	37.8	7.1	240 / 43 *(23)*	1000.0
02 / 0200	BATFR21	42.2	7.4	050 / 48 *(26)*	999.9
02 / 1300	BATFR11	38.2	8.6	250 / 48 *(26)*	999.9
02 / 1400	BATFR11	38.4	8.9	250 / 46 *(25)*	999.4
02 / 2000	C6WK7	40.8	13.4	090 / 50 *(27)*	1003.0
03 / 0100	C6WK7	41.6	12.0	070 / 61 *(33)*	1002.0

Table 4 Selected surface rainfall observation

Location	Rain on 1 Dec. [mm]	Rain on 2 Dec. [mm]	Rain on 3 Dec. [mm]	Total rain [mm]
Decimomannu (It. / Sardinia)	23.0	22.0	0.0	45.0
Capo Bellavista (It. / Sardinia)	6.0	18.0	0.6	24.6
Capo Carbonara (It. / Sardinia)	9.0	6.0	0.8	15.8
Olbia / Costa Smeralda (It. / Sardinia)	0.0	11.6	0.0	11.6
Capo Frasca (It. / Sardinia)	4.0	0.0	2.2	6.2
Alghero (It. / Sardinia)	1.0	0.0	1.4	2.4
Capo Caccia (It. / Sardinia)	0.4	1.0	0.8	2.2
Pertusato (Fr. / Corsica)	2.6	0.8	37.5	40.9
Figari (Fr. / Corsica)	8.1	0.0	9.5	17.6
Solenzara (Fr. / Corsica)	0.4	0.0	6.6	7.0
Frosinone (Italy)	5.0	36.0	52.0	93.0
Grazzenise (Italy)	9.0	66.0	0.2	75.2
Roma / Ciampino (Italy)	38.0	21.0	3.4	62.4
Roma / Fiumicino (Italy)	31.6	22.8	3.8	58.2
Frontone (Italy)	4.0	16.0	38.0	58.0
Radifocani (Italy)	9.0	0.2	46.0	55.2
Viterbo (Italy)	16.0	3.0	17.0	36.0
Civitavecchia (Italy)	9.0	9.0	15.0	33.0
Ponza (Italy)	0.0	25.0	7.0	32.0
Forli (Italy)	0.6	1.0	26.0	27.6

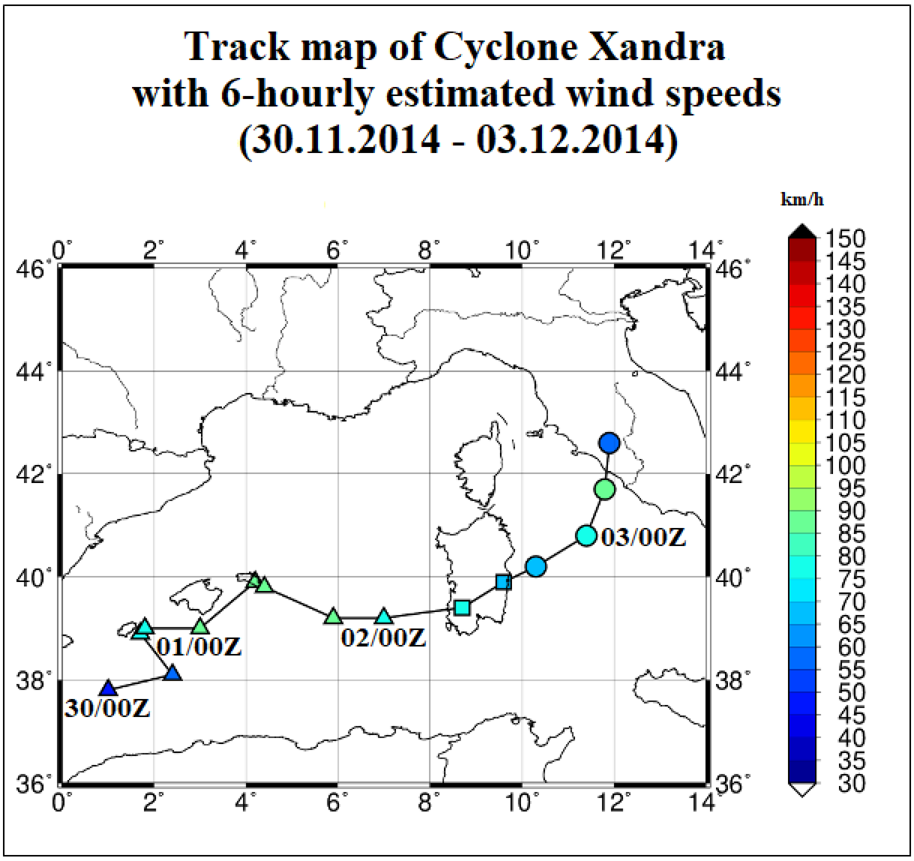

Figure 1. Best track positions for Tropical Storm Xandra, 30 November - 3 December 2014. The triangles mean extratropical, the squares subtropical and the circles tropical stage. The colors represented the estimated wind speeds (from Table 1) at the actual time. The position based on satellite images and ECMWF reanalysis.

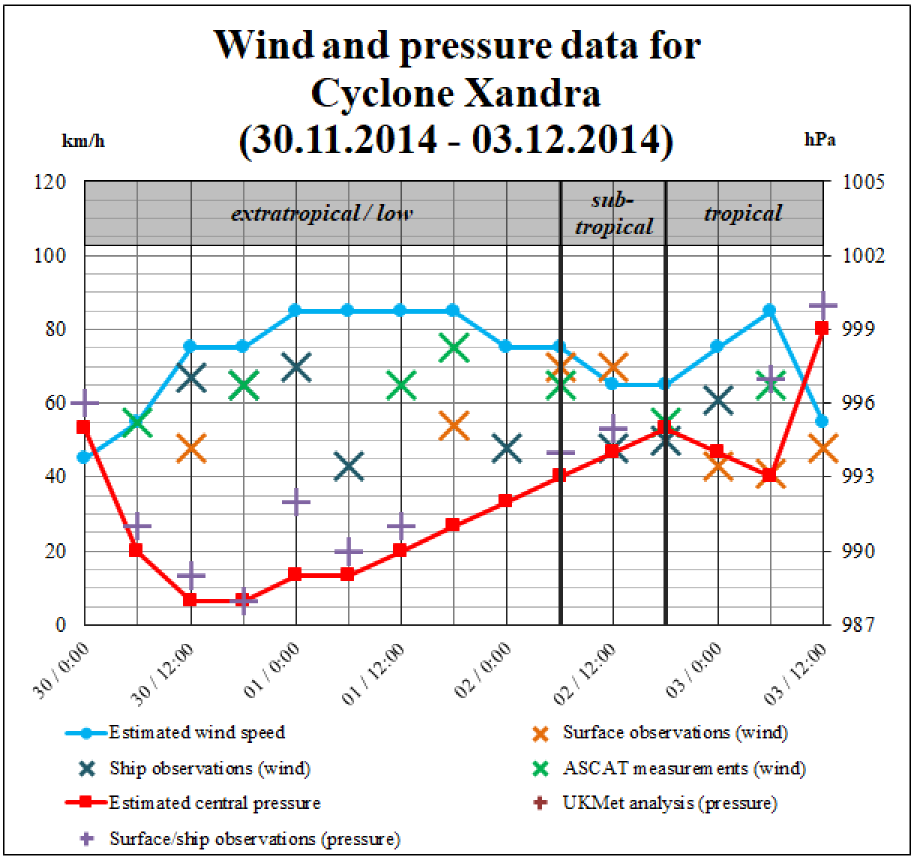

Figure 2. Selected wind and pressure observations with estimated maximum sustained wind and minimum central pressure for Tropical Storm Xandra, 30 November – 3 December 2014. The stated 6 hourly data mean the maximum sustained wind within a 3-hour interval around the marked time in case of all measurements.

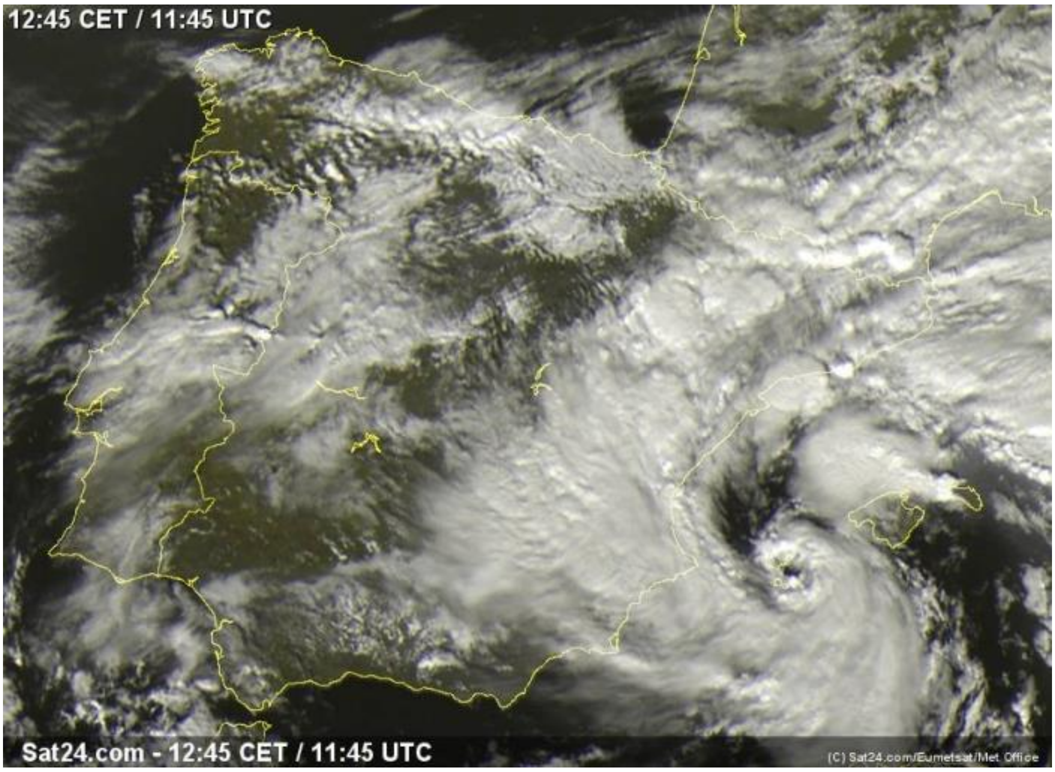

Figure 3. Visible satellite image of Xandra at 1145 UTC 30 November. The cyclone developed a warm-core occlusion head at this time with an eye-like feature. *Source: EUMETSAT / Sat24.com*

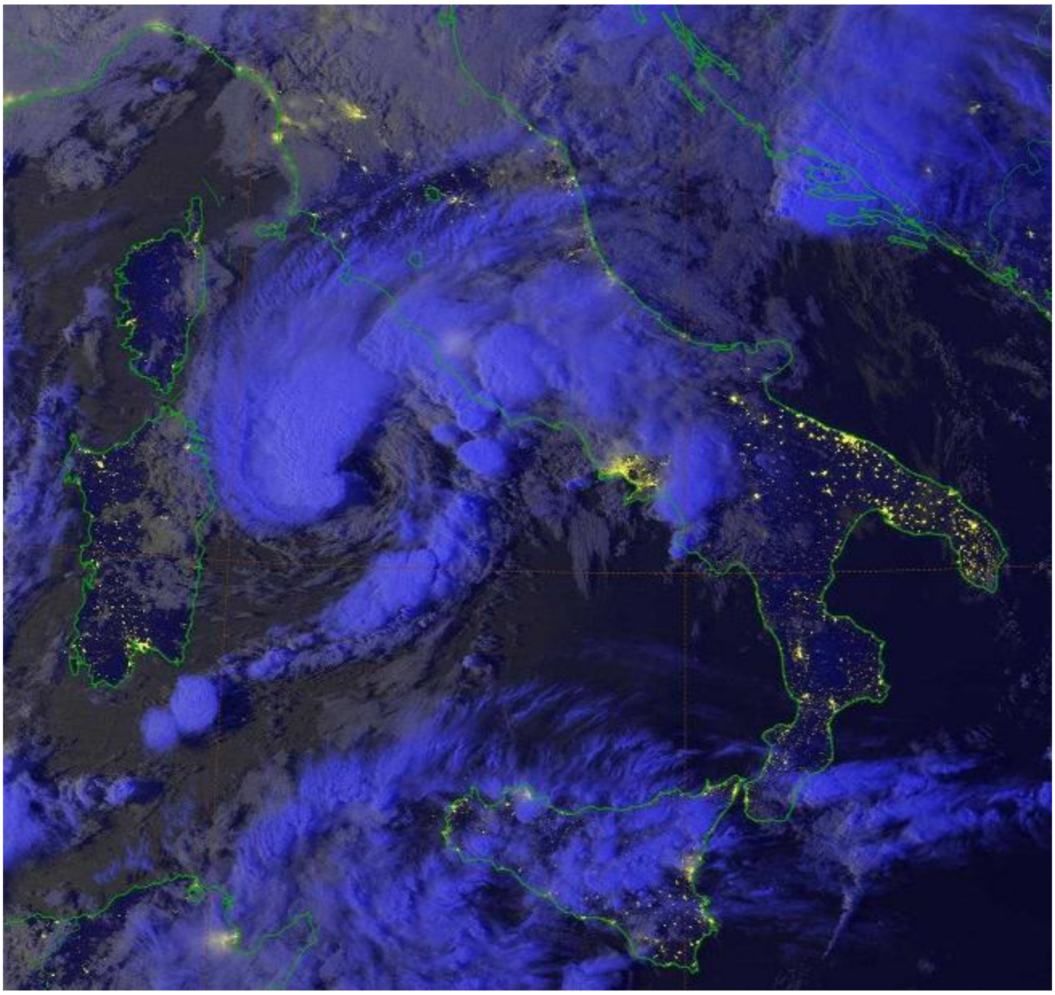

Figure 4. Nighttime visible satellite image of Xandra at 0030 UTC 3 December. The deep convection wrapped around the tight, well-defined center almost halfway by this time and a poleward outflow channel also developed to north, northeast. An outer band with scattered showers and thunderstorms also connected to the cyclone on its southern and eastern side. *Source: NRL Navy NexSat*

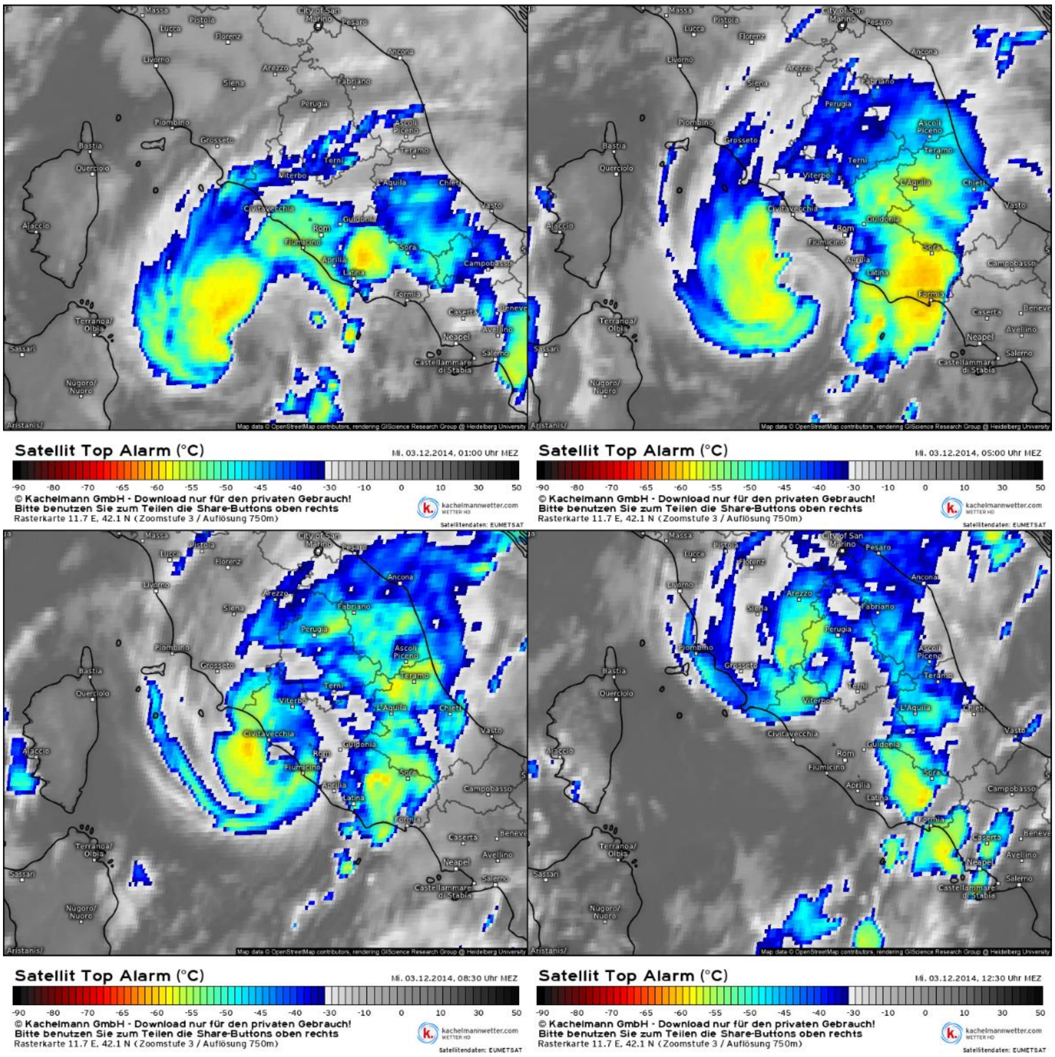

Figure 5. Infrared (cloud top temperature) satellite images of Xandra at 0000 UTC, 0400 UTC, 0730 UTC and 1130 UTC 3 December. Sustained, deep convection gradually wrapped around the center, led to the formation of an eye near the landfall, and a mid-level eye-like feature was still visible some hours later despite the cyclone moved well inland. *Source: EUMETSAT / Kachelmannwetter*

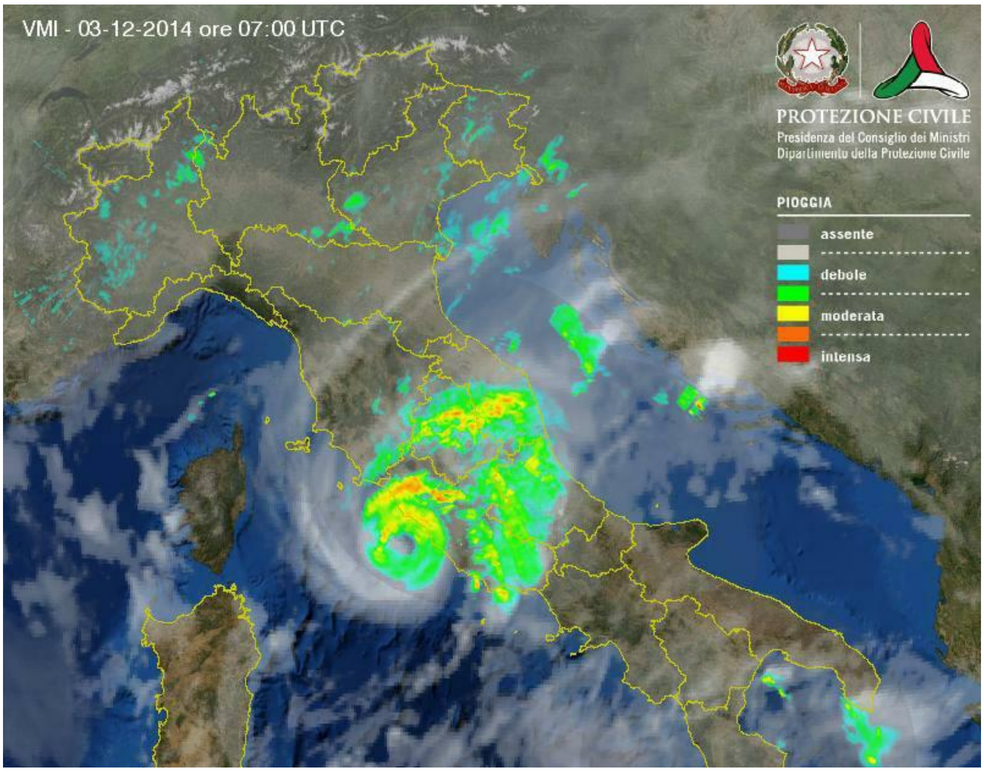

Figure 6. Combined satellite and radar image of Xandra at 0700 UTC 3 December, shortly before the landfall. The cyclone reached its best structural appearance at this time with a well-defined eye and spiral bands around it to east and north. *Source: Girovaghi*

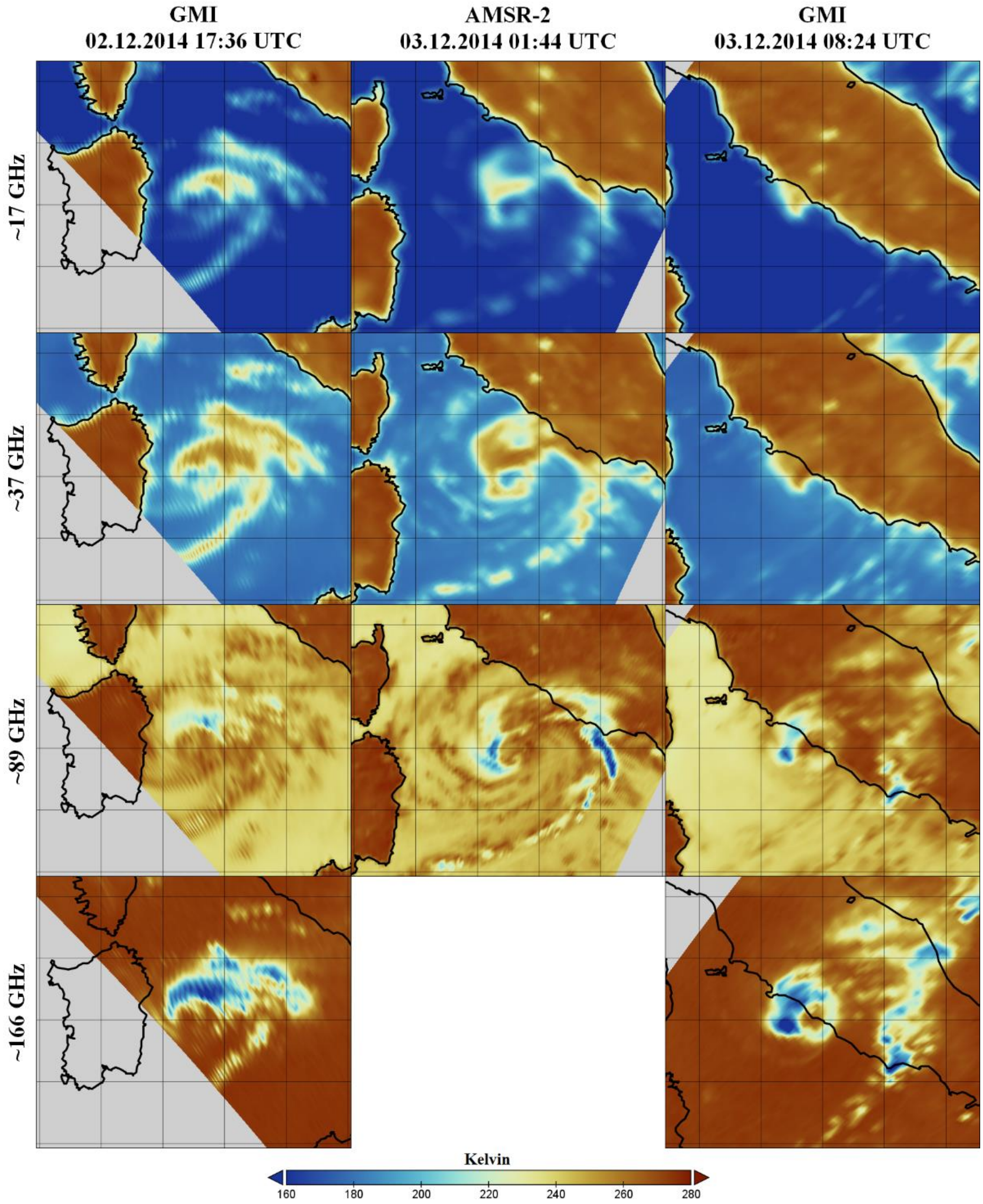

Figure 7. Microwave satellite measurements of Xandra on 2-3 December at the indicated times and frequencies (composites of horizontal and vertical polarizations), provided by GMI and AMSR-2 sensors. *Source: NASA EOSDIS*

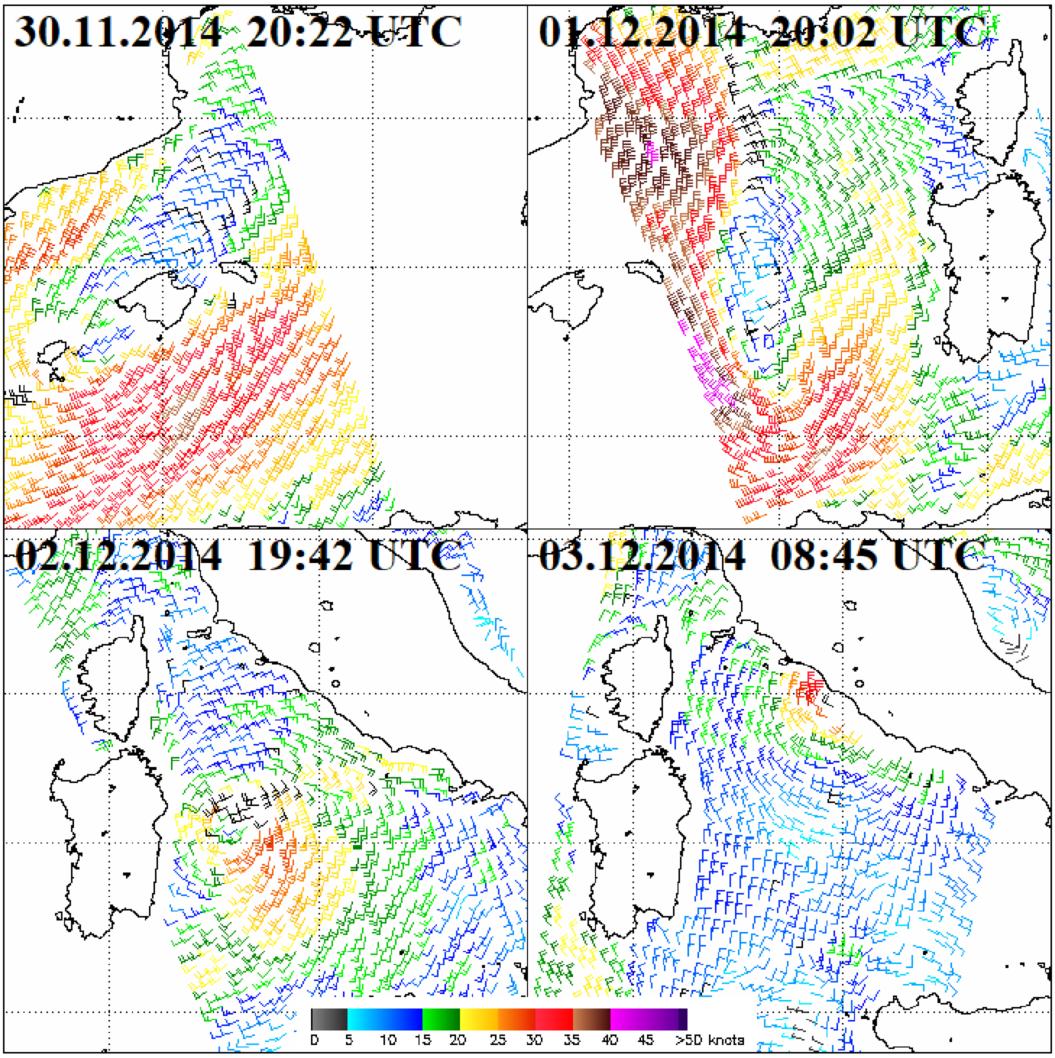

Figure 8. Satellite-based wind data of Xandra between 30 November and 3 December measured by ASCAT-A and ASCAT-B sensors. *Source: NOAA NESDIS*

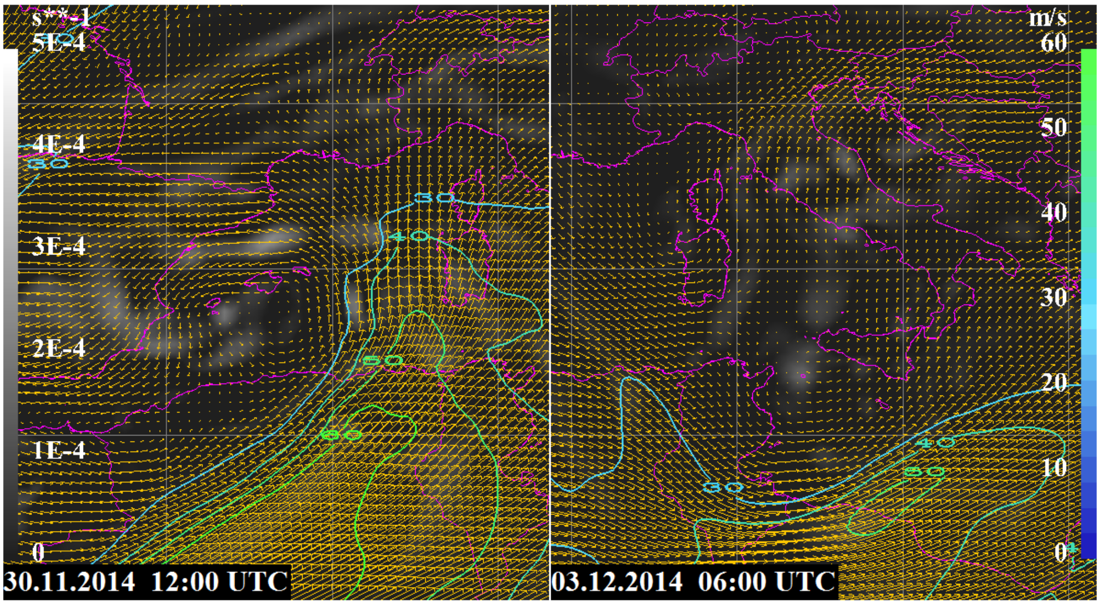

Figure 9. 300 hPa divergence (shaded) and winds (vectors and contours per 10 m/s from 30) over the Western and Central Mediterranean Sea at 1200 UTC 30 November and 0600 UTC 3 December. *Data source: ECMWF/Copernicus*

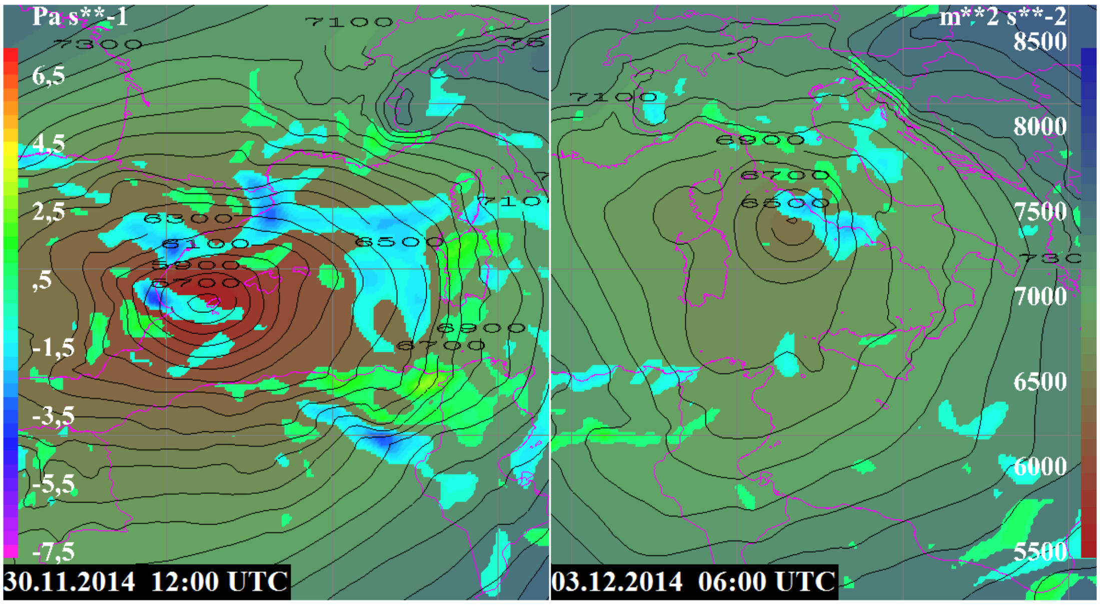

Figure 10. 925 hPa geopotential (shaded with black contours) and 850 hPa vertical speed (shaded patches, without the -0,5 to 0,5 Pa/s range) over the Western and Central Mediterranean Sea at 1200 UTC 30 November and 0600 UTC 3 December. *Data source: ECMWF/Copernicus*

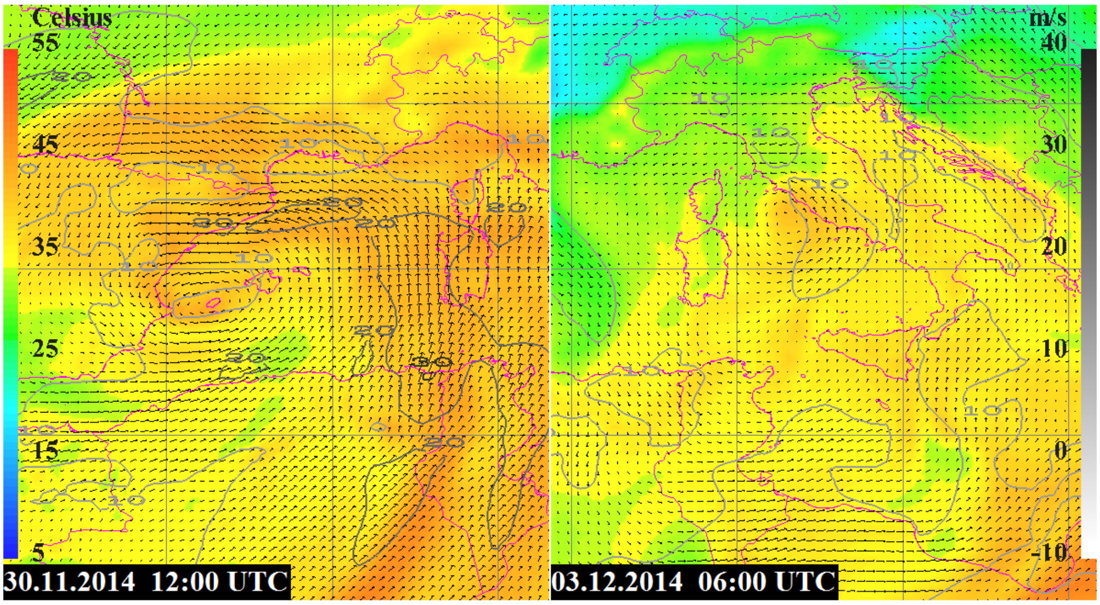

Figure 11. 850 hPa equivalent potential temperature (shaded) and winds (vectors and contours per 10 m/s) over the Western and Central Mediterranean Sea at 1200 UTC 30 November and 0600 UTC 3 December. *Data source: ECMWF/Copernicus*

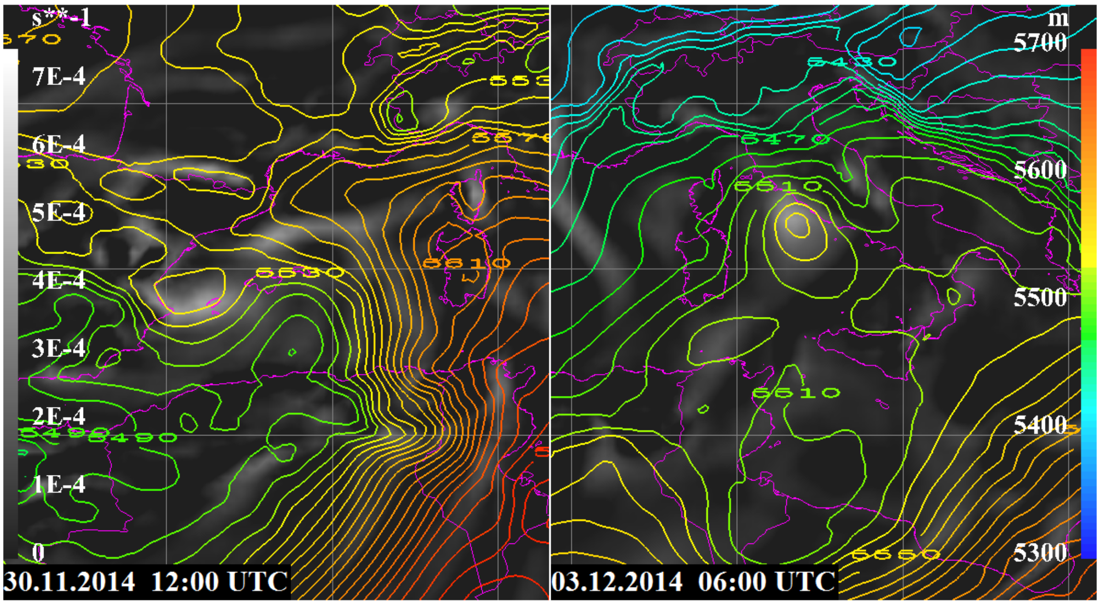

Figure 12. 500-1000 hPa thickness (contours per 10 m) and 850 hPa relative vorticity (shaded) over the Western and Central Mediterranean Sea at 1200 UTC 30 November and 0600 UTC 3 December. *Data source: ECMWF/Coperncus*

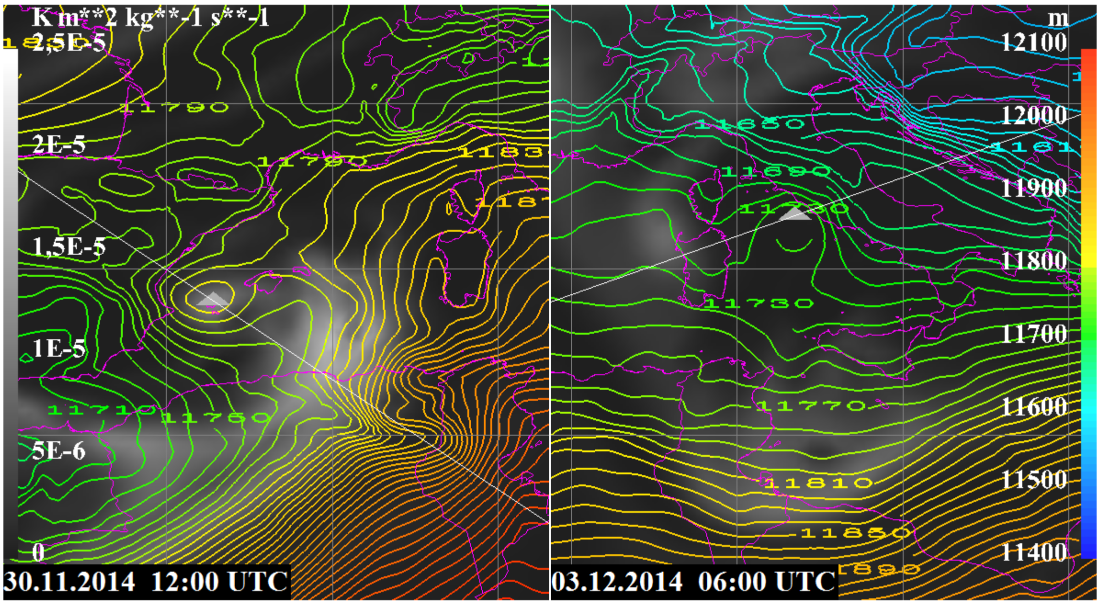

Figure 13. 200-1000 hPa thickness (contours per 10 m) and 300 hPa potential vorticity (shaded) over the Western and Central Mediterranean Sea at 1200 UTC 30 November and 0600 UTC 3 December. *Data source: ECMWF/Copernicus*

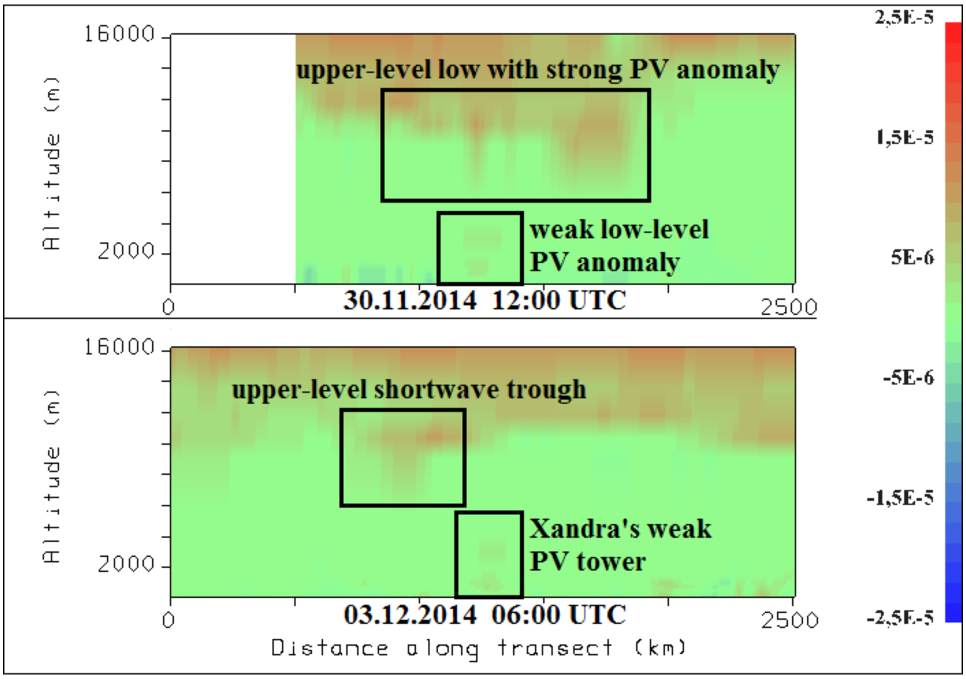

Figure 14. Potential vorticity vertical crosses through the center of Xandra and its environment at 1200 UTC 30 November and 0600 UTC 3 December. The cross-sections marked with thin white lines on Figure 13. *Data source: ECMWF/Copernicus*