Impact of sea surface temperature on COSMO forecasts of a *Medicane* over the western Mediterranean Sea

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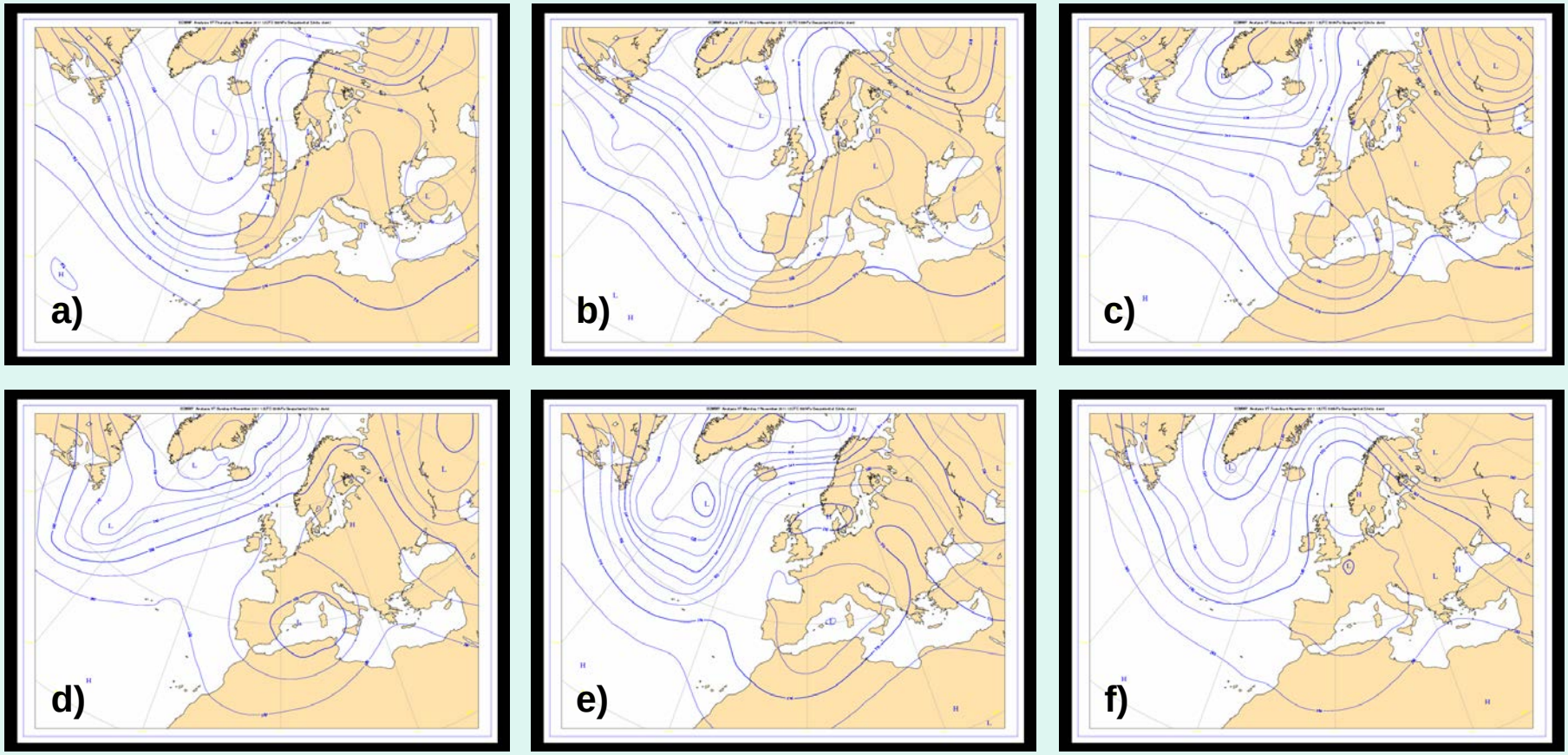
Abstract

The study describes and analyzes the sensitivity of an operational atmospheric model for several SST (Sea Surface Temperature) estimates. The model's sensitivity was studied in a *Medicane* (*Medi*terranean Hurri*cane*) test case. Numerical simulations were performed using the COSMO (COnsortium for Small-scale MOdeling) atmospheric model, in the COSMO-ME configuration. The results of the model show that the model is capable of capturing the position, timing and intensity of the cyclone.

Sensitivity experiments were carried out using different SSTs as surface boundary conditions for the COSMO forecasts. Four different experiments were carried out: the first two used SST fields obtained from the OSTIA (Operational Sea surface Temperature and sea Ice Analysis) system, while the other two used the SST analyses and forecasts from MFS (Mediterranean Forecasting System). The different boundary conditions determine differences in the main characteristics of the Medicane such as the trajectory, pressure minimum and wind intensity.

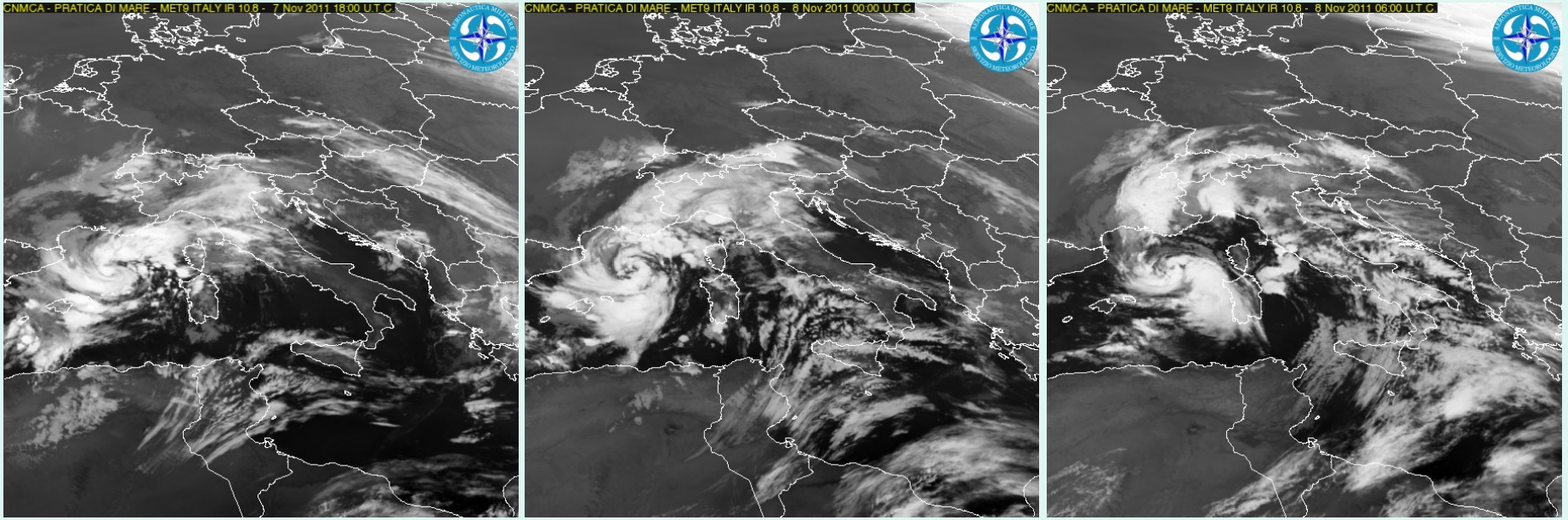
The sensitivity experiments showed that a colder than real SST field determines a weakening of the minimum pressure at the vortex center. MFS SST analyses and forecasts determine more intense heat fluxes from the sea to the atmosphere, leading to a strengthening of the vortex itself and a different trajectory for the last hours of the meteorological event.

Meteorological events



Geopotential height (500 hPa) from 3 to 8 November 2011 by ECMWF analyses at 12:00 UTC (corresponding to a) ,…, f) panels).

Meteorological events

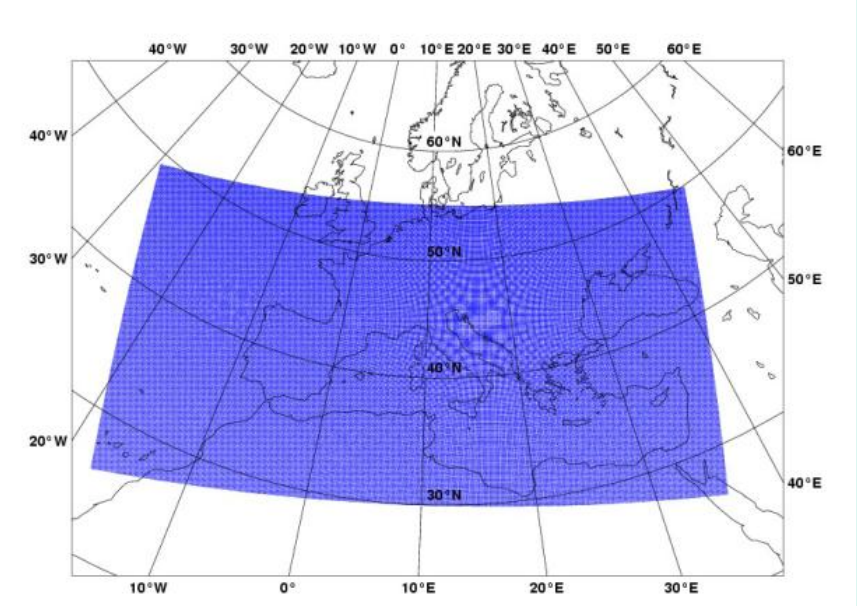


Meteosat 9 satellite observations in the infrared channel (10.8 micrometers) at 18:00 UTC on 7 November (left), at 00:00 UTC on 8 November (center), at 06:00 UTC on 8 November (right).

The COSMO atmospheric model

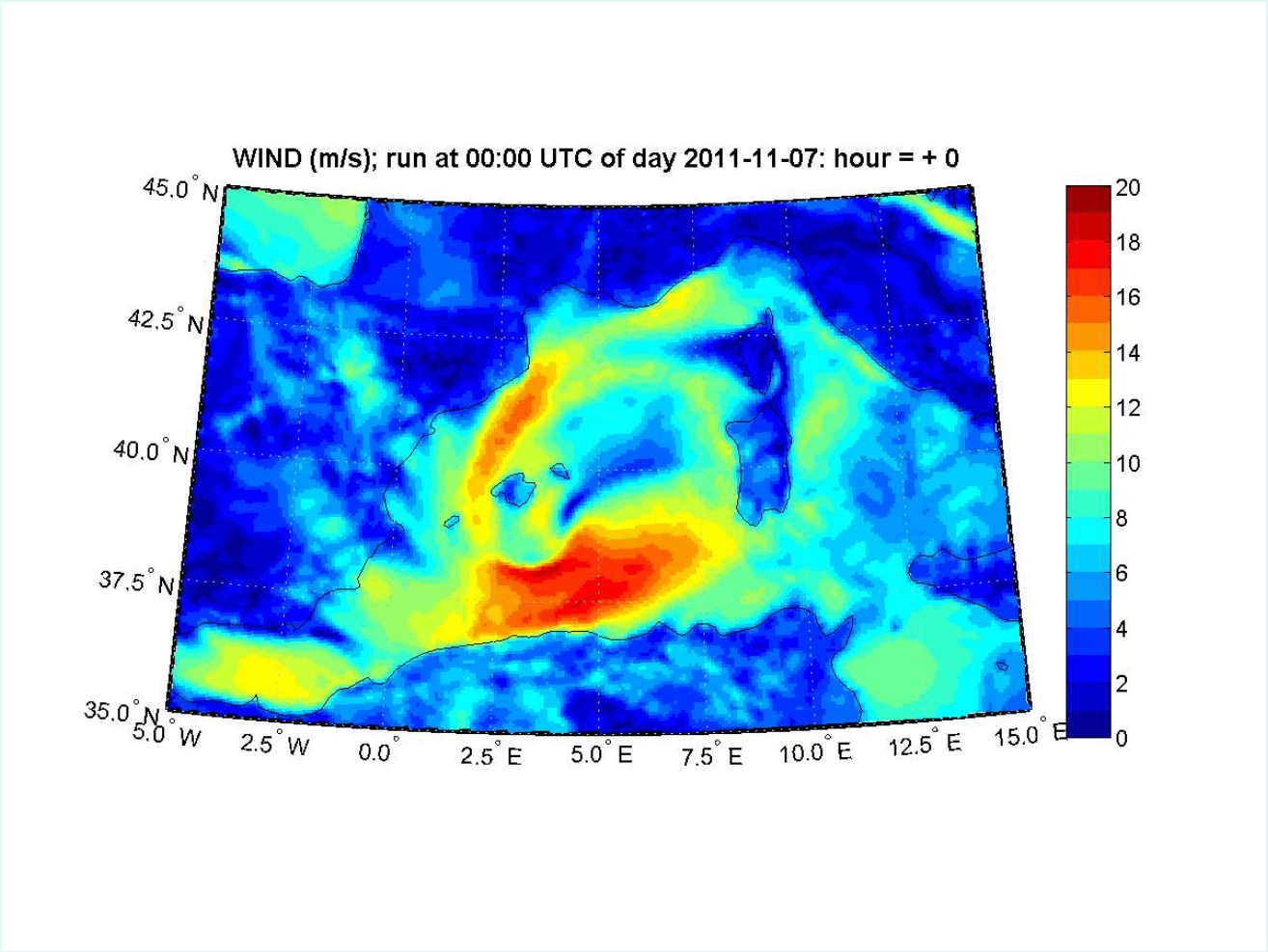
The meteorological event was simulated using the COSMO (COnsortium for Small-scale MOdeling) atmospheric model which is a limited-area, non-hydrostatic forecasting model (http://www.cosmo-model.org/). It was designed both for operational numerical weather prediction and various scientific applications at meso-β (20-200 km) and meso-γ scales (2-20 km). The basic version of the COSMO model was designed at the German weather service (DWD) and developments are carried out within the consortium formed by the national meteorological services of seven European countries: Germany, Greece, Italy, Poland, Romania, Russia and Switzerland. Operational applications of the model within COSMO mainly have a grid spacing of 1/16° (about 7 km).

The Italian Meteorological Centre (CNMCA) uses the configuration COSMO-ME which covers most of Europe with a horizontal grid of 7 km and 40 vertical levels with a top at about 22 km. The model's time integration step is 60 seconds. The operational integration of COSMO-ME is driven by the boundary conditions provided by the IFS global model (Integrated Forecast System) of ECMWF and is initialized with atmospheric analysis fields produced by the LETKF ensemble data assimilation system implemented at CNMCA. Both IFS and COSMO-ME use optimally interpolated sea surface temperatures (SSTs) from the OSTIA (Operational Sea surface Temperature and sea Ice Analysis) system, which includes satellites and in situ data. The initial SST fields are kept constant as boundary conditions during the COSMO-ME forecast time.



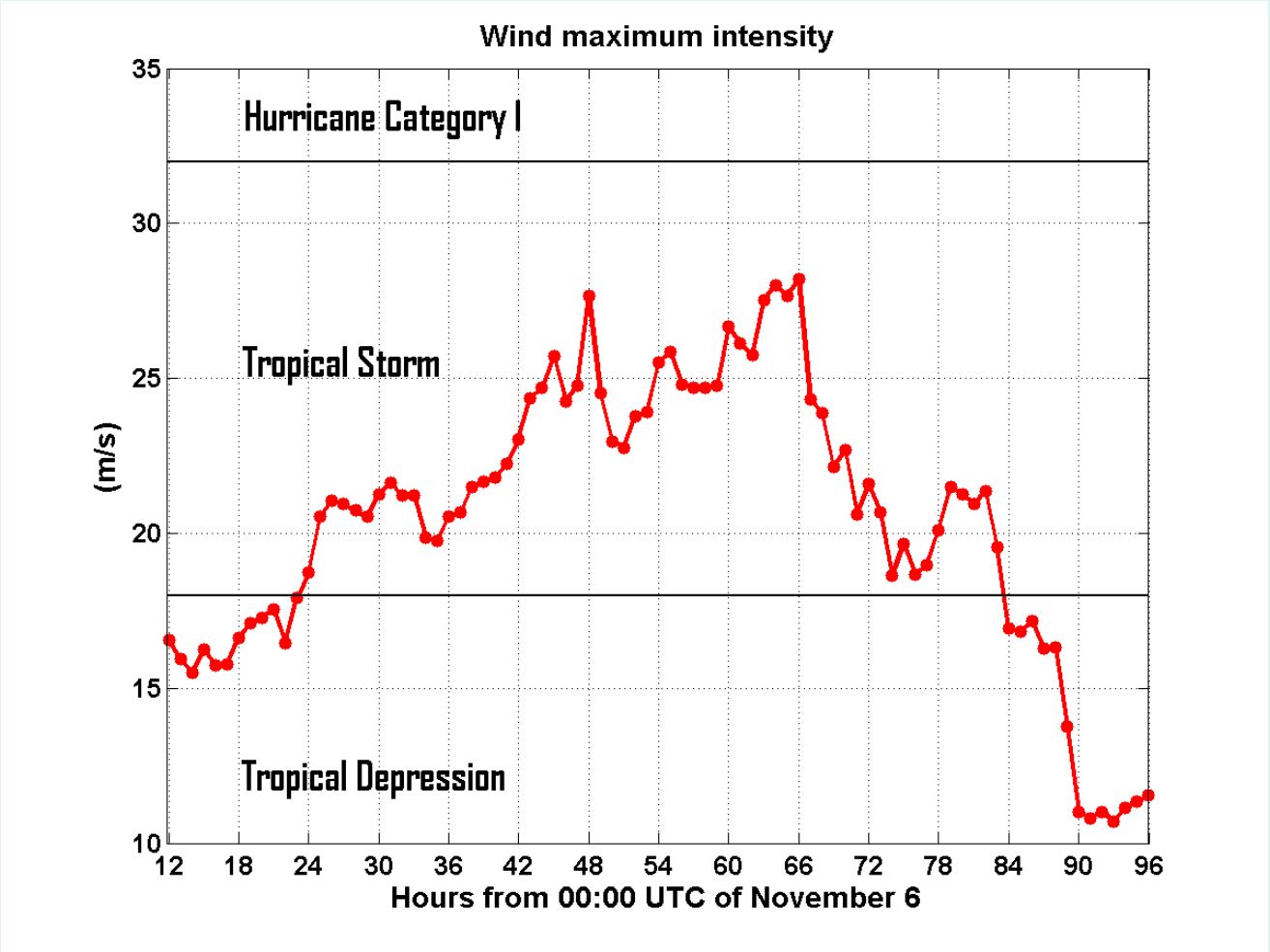
Domain of the COSMO model in the COSMO-ME configuration

Forecast wind by COSMO-ME



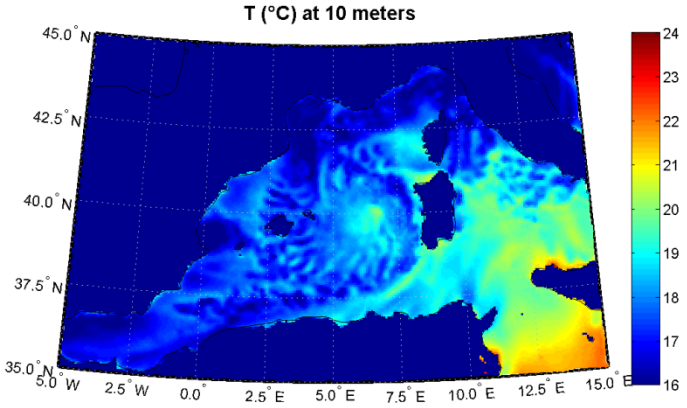
Hourly forecast wind (m/s) at 10 meters by COSMO-ME for 7-8 November (*run* at 00:00 UTC -- 7 November 2011)

Forecast wind by COSMO-ME

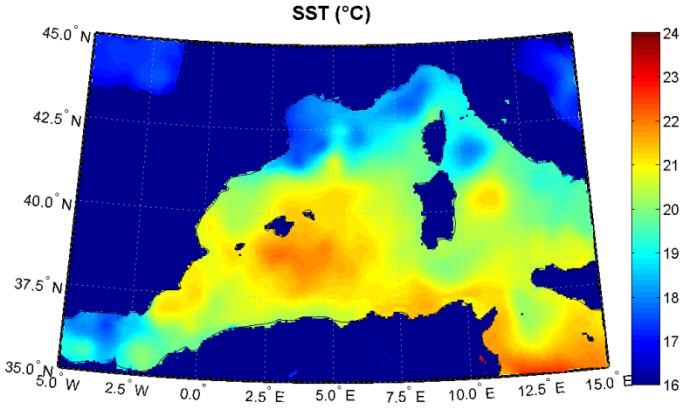


Wind maximum intensity (m/s) from 12:00 UTC on 6 November to 00:00 UTC on 10 November. Black horizontal lines mark the separation between different categories: tropical depression, tropical storm and hurricane.

Air and sea temperature

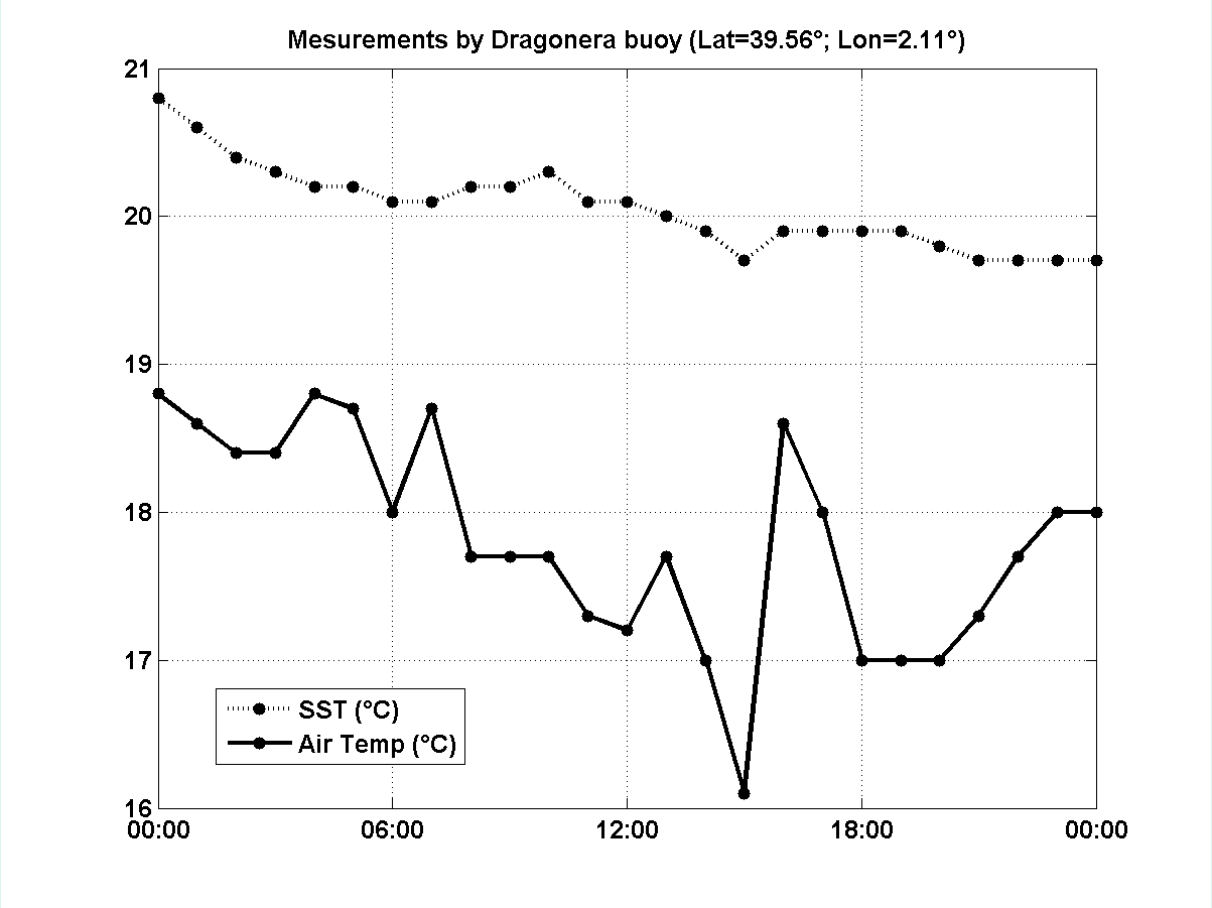


Air temperature at 10 meters obtained by LETKF data assimilation system at 12:00 UTC on 7 November.



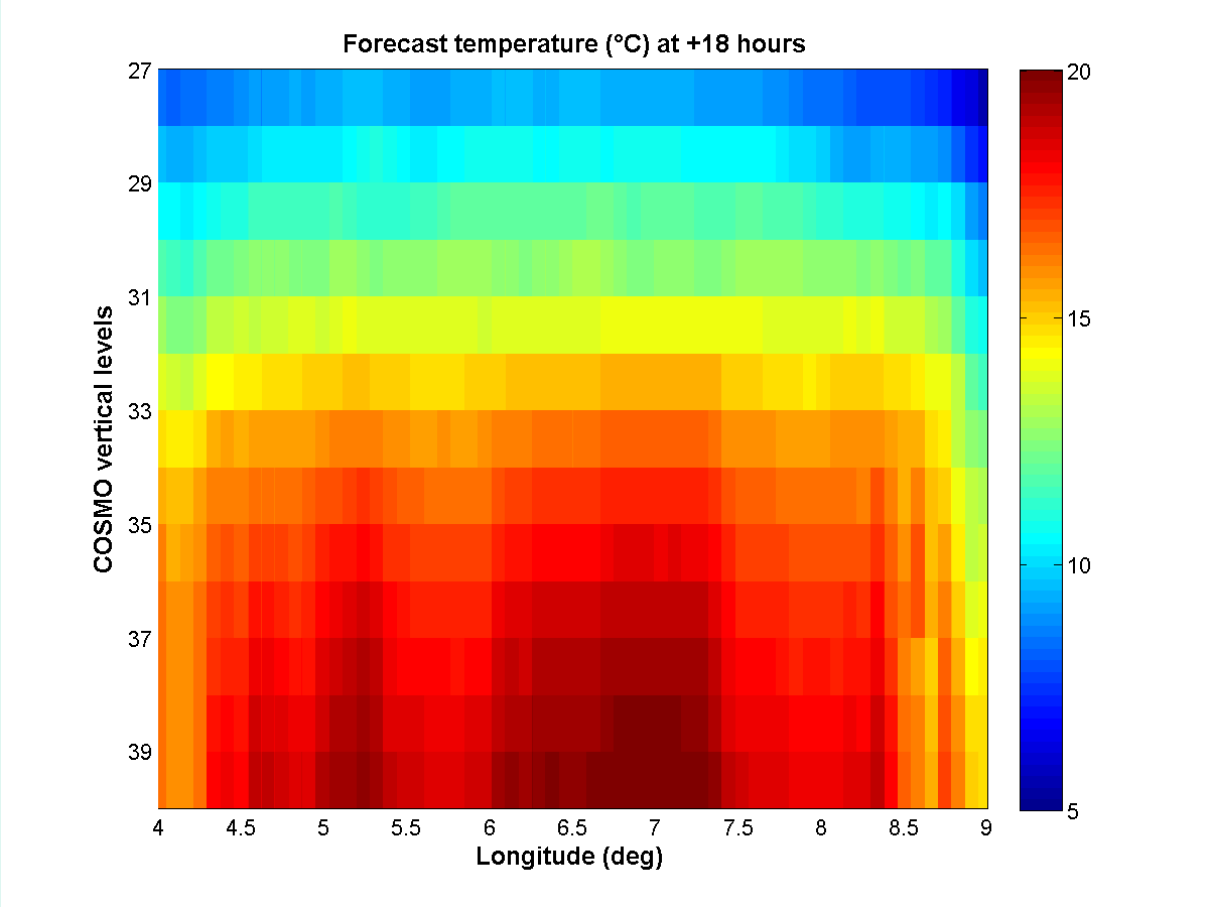
SST field by OSTIA system at 12:00 UTC on 7 November.

Air and sea temperature



Air temperature at 2 meters (continuos line, °C) and SST (dot line, °C) observed by the Dragonera buoy (Lat.=39.56°; Lon.=2.11°) on 7 November 2011

Thermal structure of the vortex



Temperature (°C) vertical section along parallel 40.0° at hour 18:00 UTC on 7 November by COSMO-ME (run at 00:00 UTC on 7 November).

The vertical section ranges between 1000 hPa and 815 hPa, about 1700 m.

Sensitivity experiments

Four different numerical experiments were carried out by using several SST fields as boundary conditions:

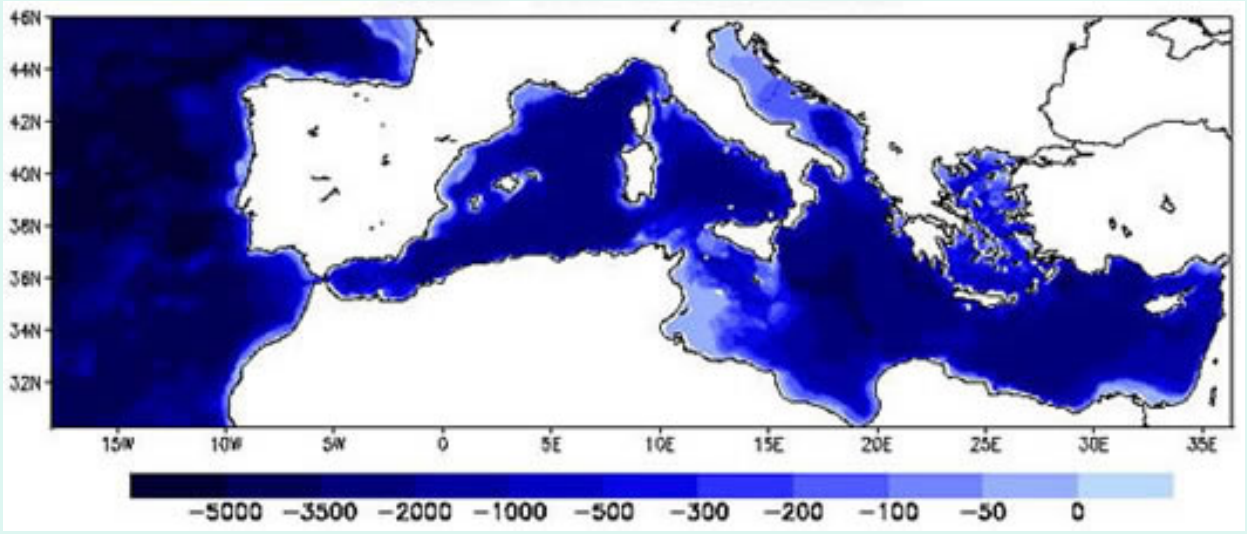
Experiments	SST boundary conditions
EXP1	SST from OSTIA (operational configuration)
EXP2	SST fields by OSTIA lowered by 2°C
EXP3	SST fields from MFS (fixed to initial values)
EXP4	SST fields from MFS (variable)

Boundary conditions for the 4 different numerical experiments. Simulations started at 00:00 UTC on 7 November 2011, and lasted for 72 h.

Mediterranean Forecasting System

SST forecast fields produced by the Mediterranean Forecasting System (MFS) were also used as initial and boundary conditions. MFS (http://gnoo.bo.ingv.it/mfs) is an operational forecasting system consisting of a near real-time observation system with satellite and in situ elements, a numerical ocean forecasting model at a basin scale, based on a primitive equation model and a data assimilation scheme.

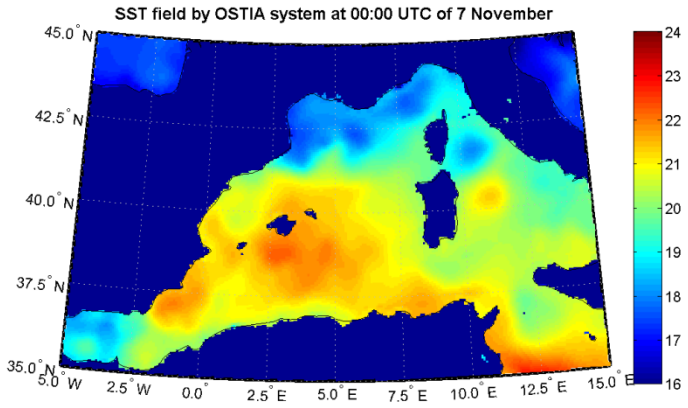
The numerical ocean model has a resolution of 1/16°×1/16° on the horizontal and 72 unevenly spaced vertical levels. The system produces ten-day ocean forecasts and ocean analyses using a daily assimilation cycle where a different optimally interpolated SST from satellites is used to constrain the surface temperature of the model.



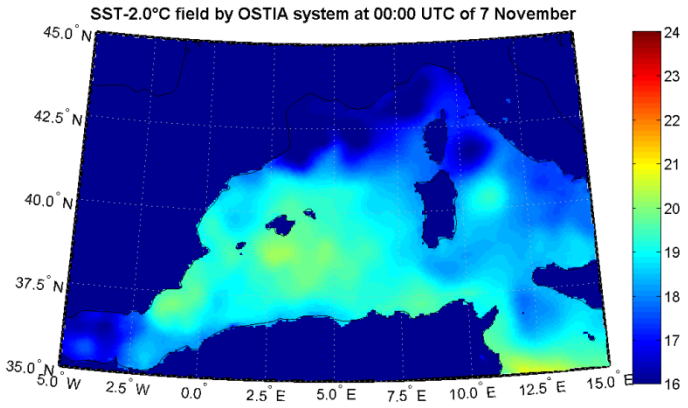
Domain and bathymetry (m) of the Mediterranean Forecasting System

SST fields as boundary conditions

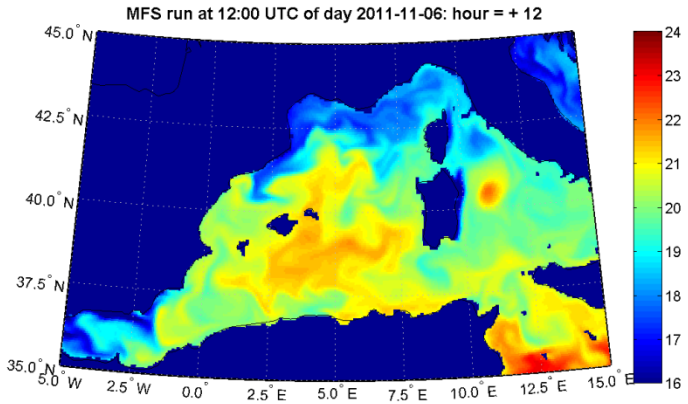
EXP1



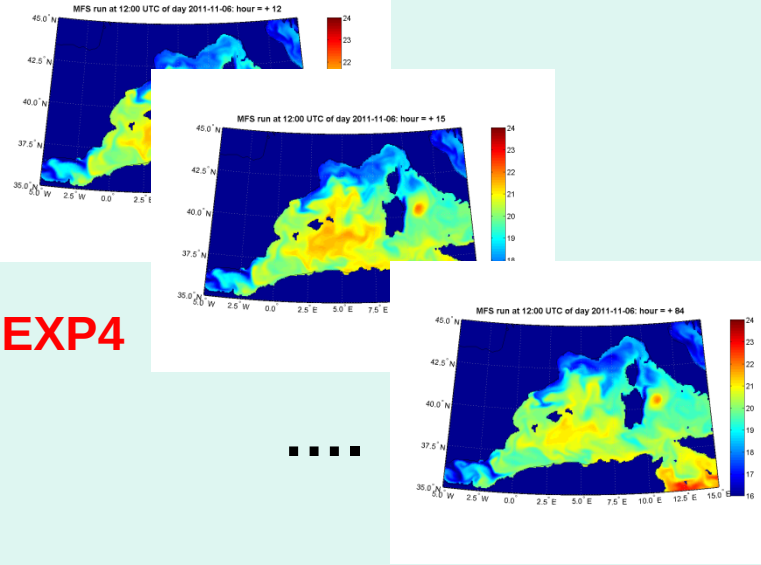
EXP2



EXP3



EXP4



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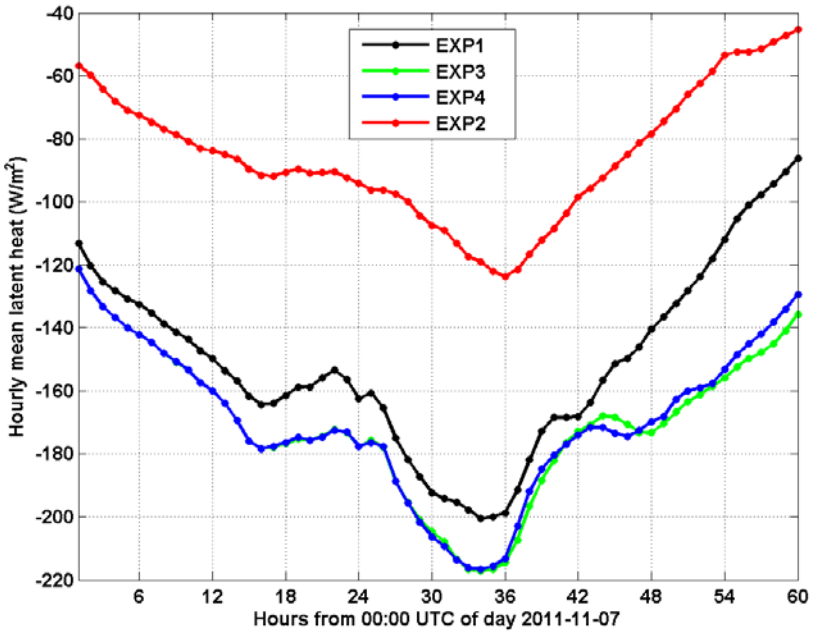
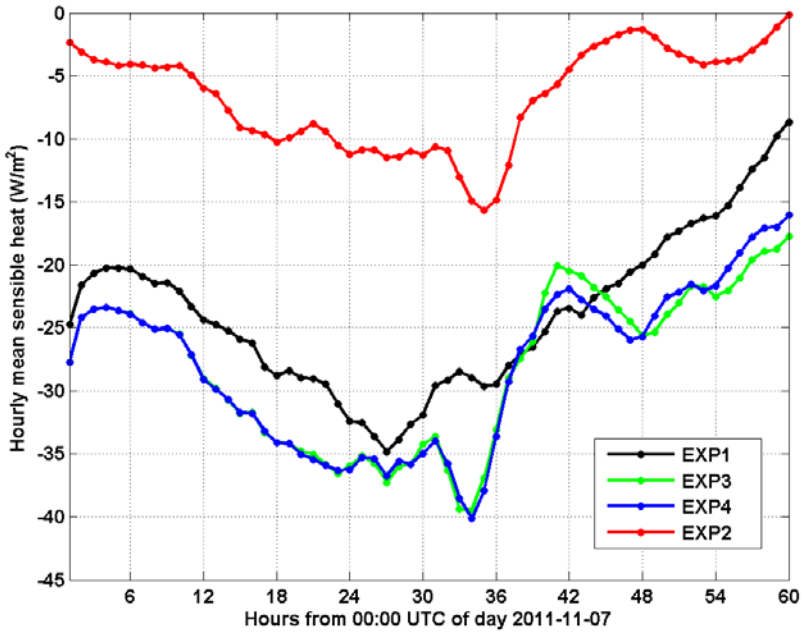
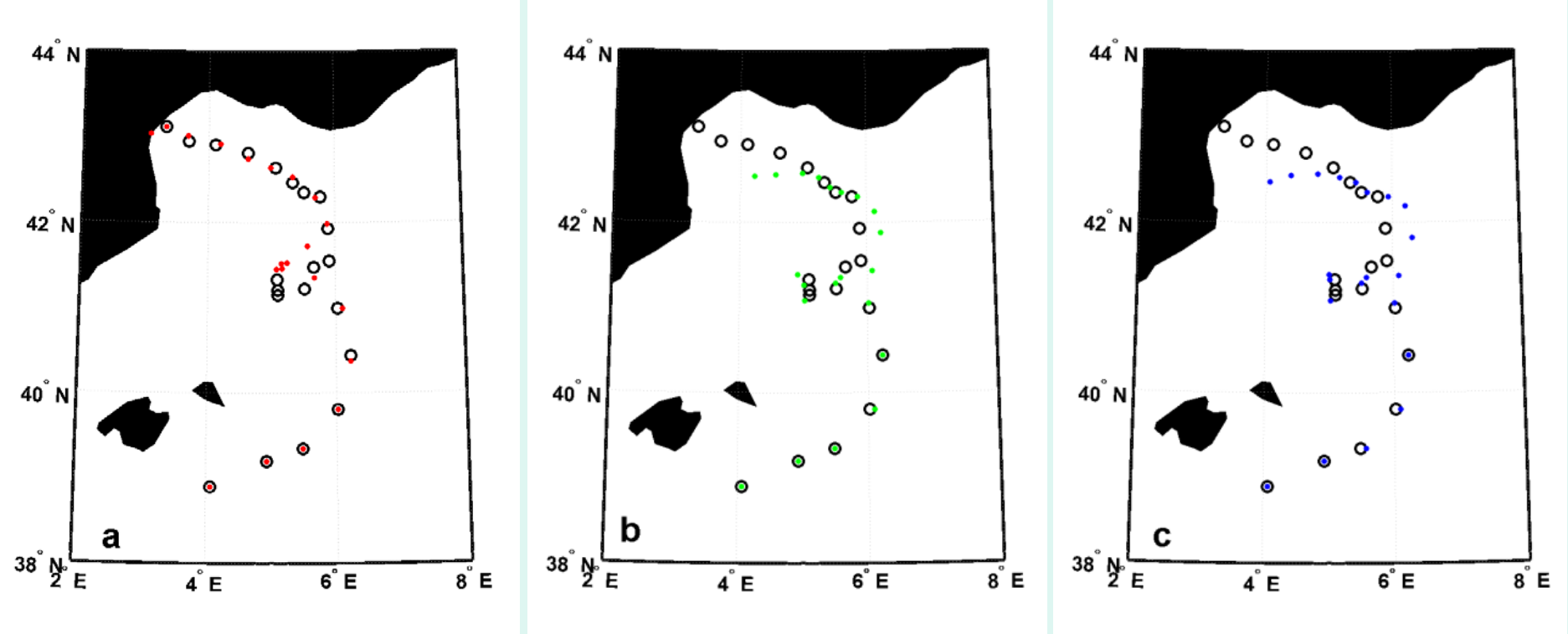
Results: latent and sensible heat fluxes





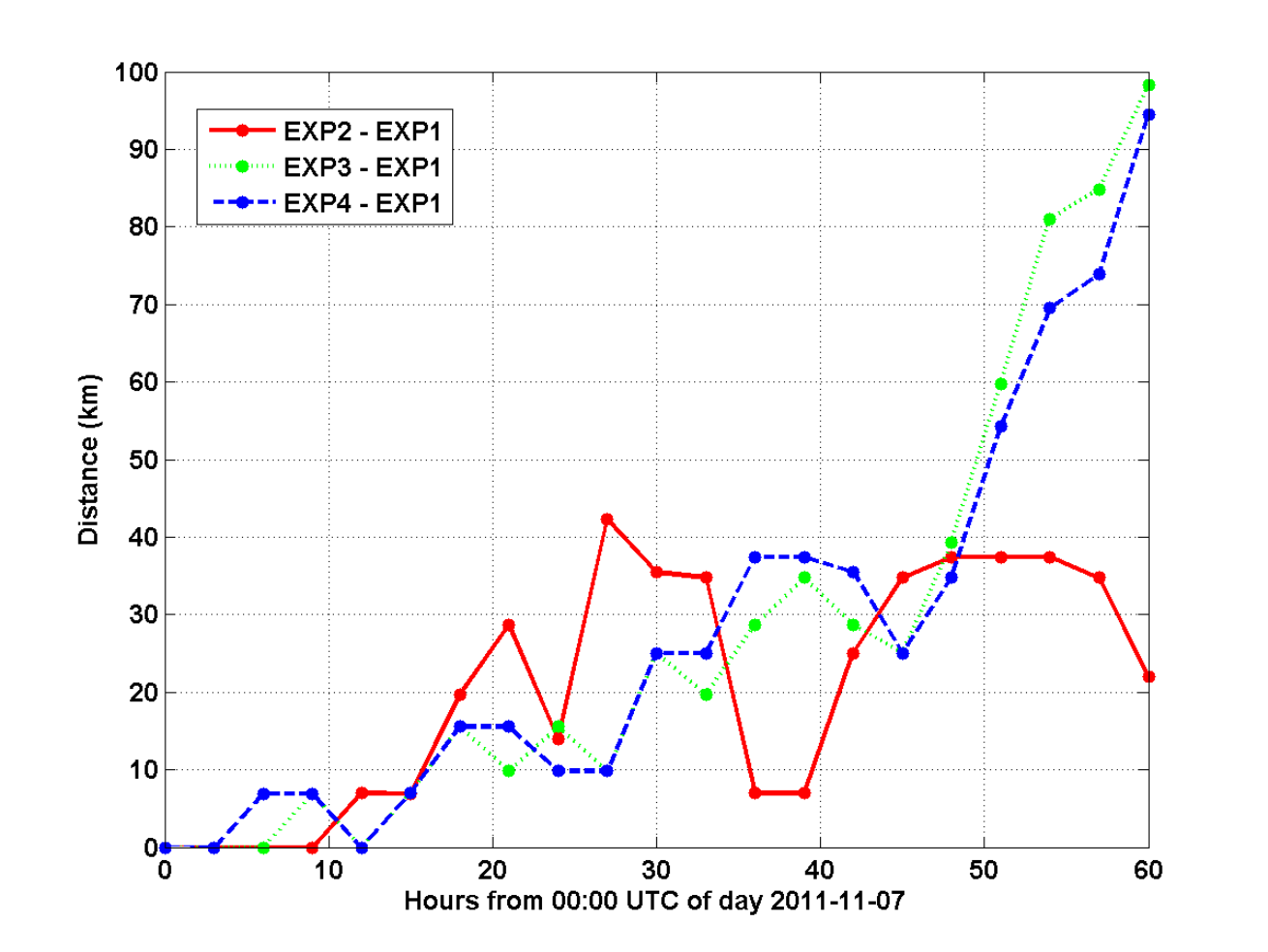
Hourly mean latent (left) and sensible (right) heat fluxes for the 4 different experiments. Average domain: 41°<Lat<44°, 3.0°<Lon<7.0°.

Results: trajectories



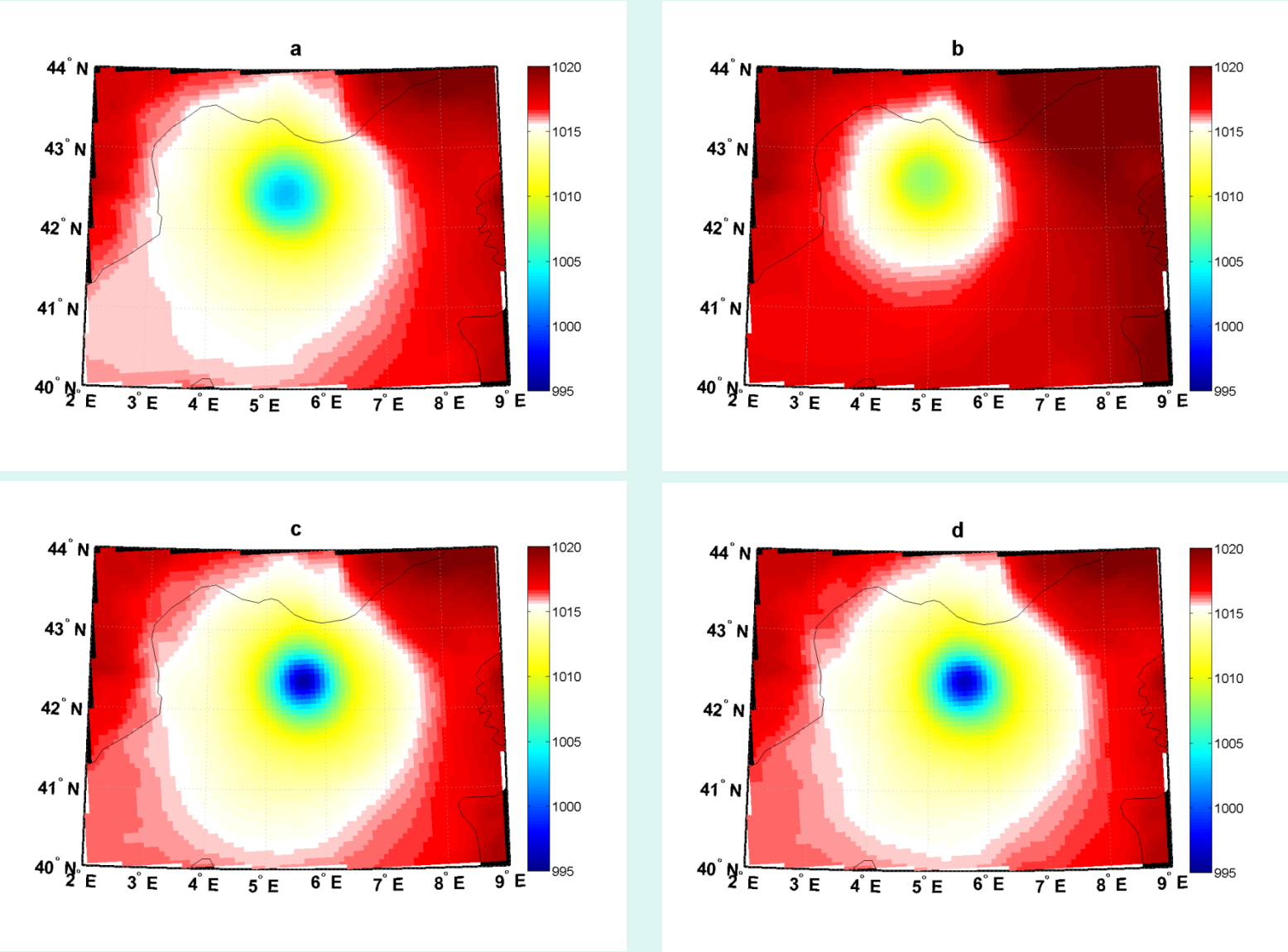
Trajectories from 00:00 UTC on 7 November every 3 hours until 12:00 UTC on 9 November for three different COSMO experiments with respect to the default experiment (circles): EXP2 (a, red), EXP3 (b, green), EXP4 (c, blue).

Results: trajectories



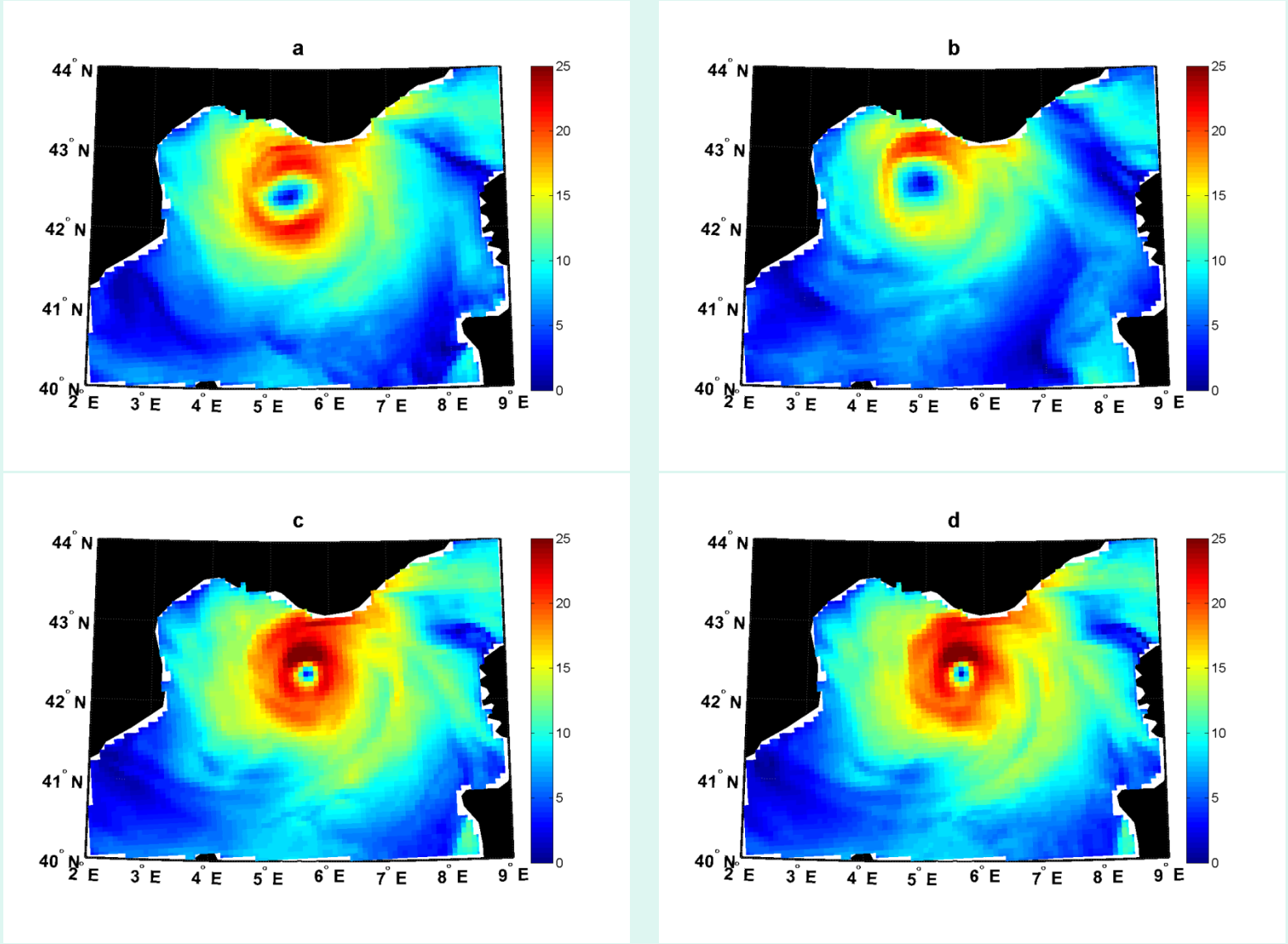
Distances (km) of the minimum pressure positions vis-a-vis EXP1, every 3 hours from 00:00 UTC on 7 November: EXP2 (red line), EXP3 (green dot line) and EXP4 (blue dash line).

Results: pressure fields



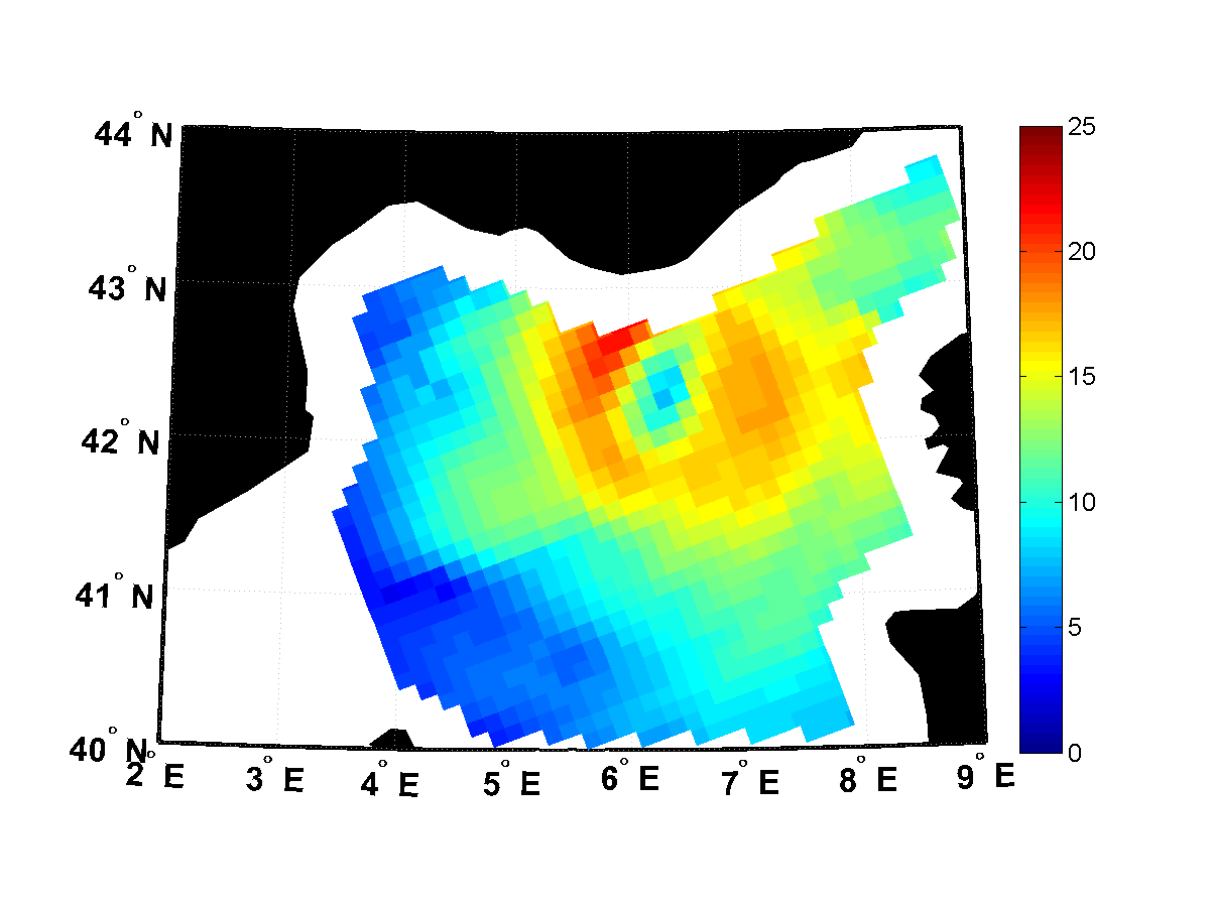
Forecast mean sea level pressure (hPa) at 21:00 UTC on 8 November for EXP1, EXP2, EXP3 and EXP4 (respectively a, b, c, d panel).

Results: wind fields



Forecast wind intensity (m/s) at 21:00 UTC on 8 November for EXP1, EXP2, EXP3 and EXP4 (respectively a, b, c, d panel).

Results: comparison with ASCAT data



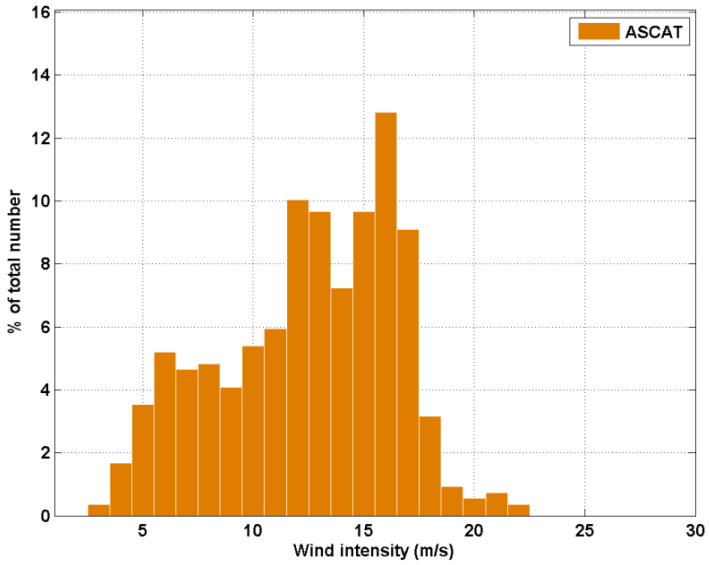
Wind intensity estimate (m/s) from ASCAT sensors on board of MetOp-A satellite at 20:39 UTC on 8 November 2011.

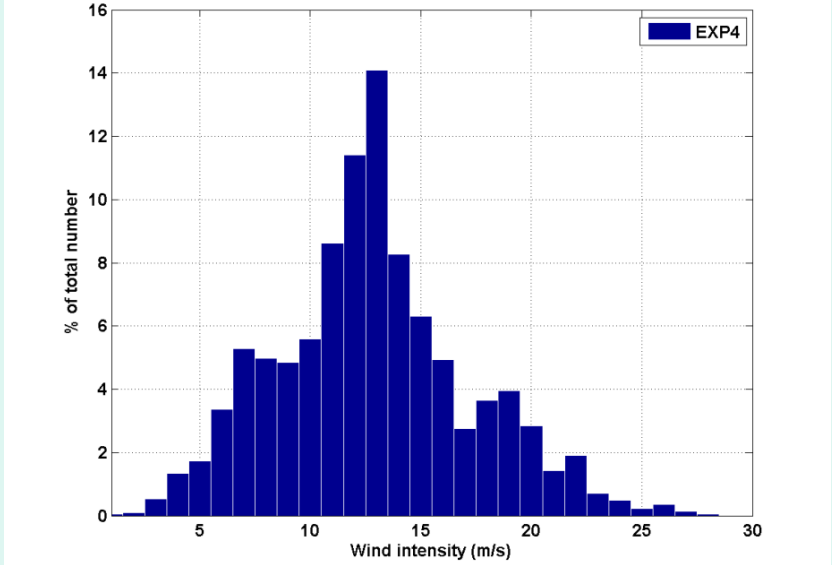
Results: position and size of the vortex

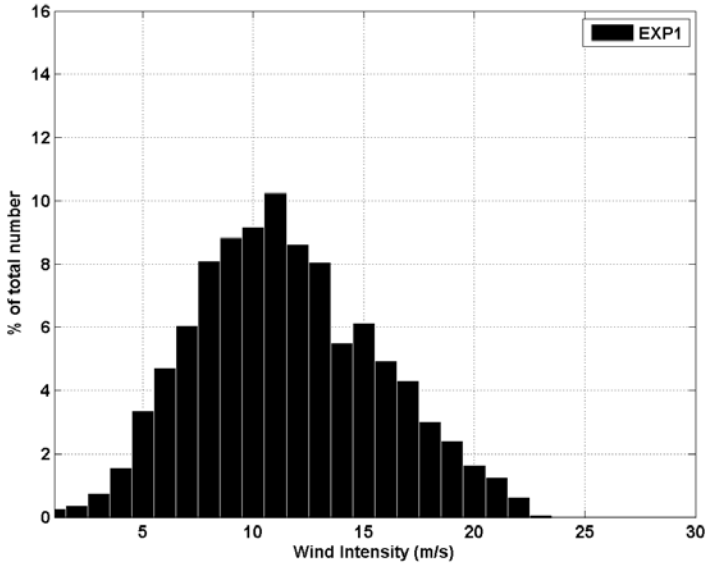
Experiments	Lat (deg)	Lon (deg)	Mean radius (km)
EXP1	42.405°	5.342°	126
EXP2	42.577°	4.989°	117
EXP3	42.352°	5.601°	128
EXP4	42.352°	5.601°	129
ASCAT	42.230°	6.285°	144

Positions and sizes of the Medicane for the four COSMO-ME experiments (at 21:00 UTC) and for the ASCAT satellite measurements (at 20:39 UTC).

Results: distribution of wind velocity







Histograms (% of total number) of wind intensity (m/s) for ASCAT (top left), EXP1 (bottom left) and EXP4 (top right) at 21:00 UTC on 8 November for the model and at 20:39 UTC for the ASCAT observations.

Modal value

ASCAT: 16 m/s

EXP1: 11 m/s

EXP4: 13 m/s

Conclusions

- The different SSTs impacted the trajectory of the vortex, changing its direction by about half a degree in longitude, with EXP4 reproducing the ASCAT position better than EXP1.

- Latent and sensible heat flux intensities varied up to 60 W/m^2 and 10 W/m^2 respectively (in EXP1, EXP3 and EXP4 experiments).

- The wind intensity and its horizontal distribution is the major difference between EXP1 and EXP4, with the latter better reproducing the ASCAT data. The mean size of the vortex, in the range of 125-130 km, was quite similar between the different experiments.

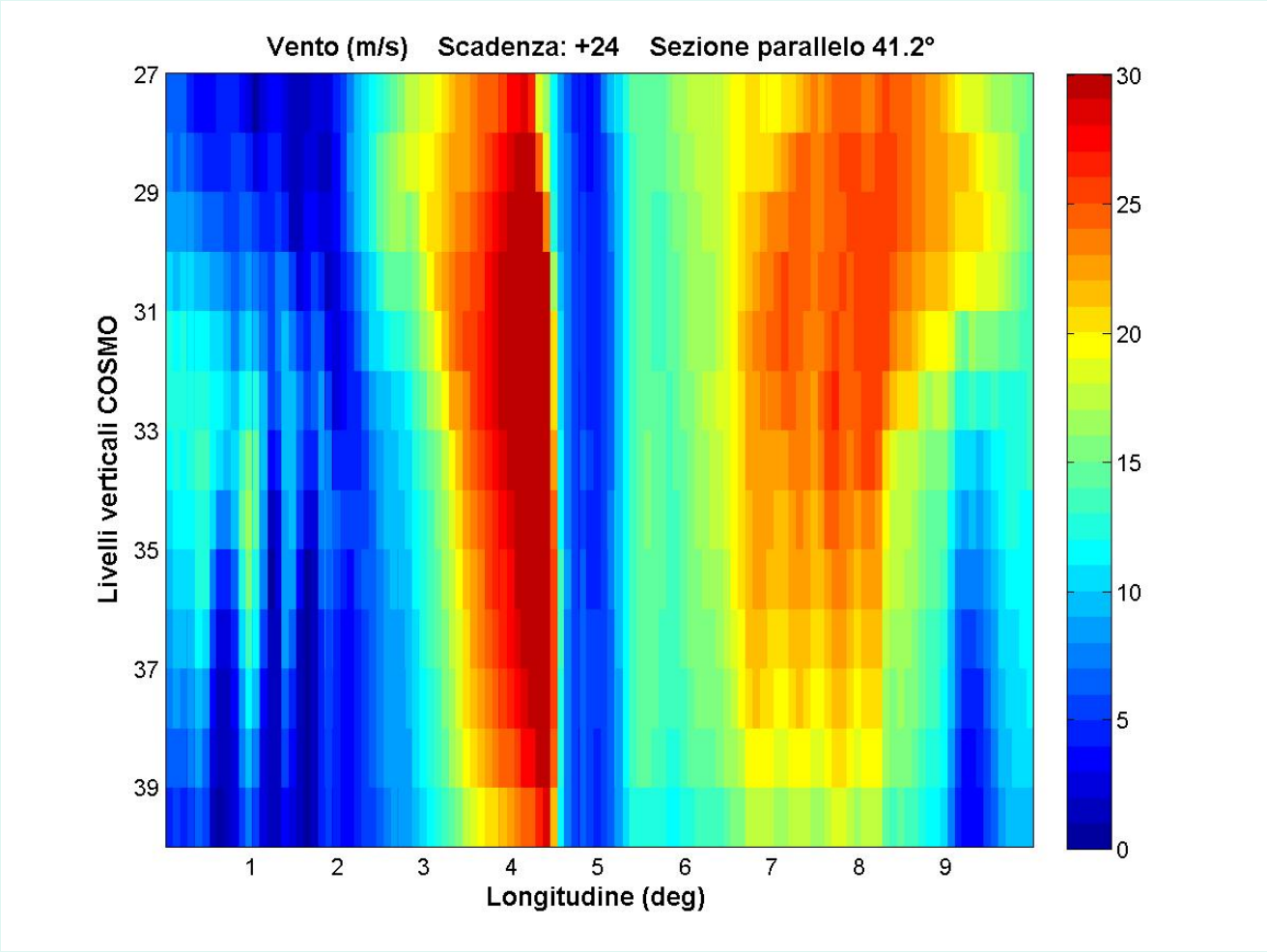
- Our results highlight that the type and value of the SST boundary conditions play an important role in determining the distribution of forecast wind velocities, minimum pressure and location of the cyclone eye. A three-hour forecast SST from the operational MFS ocean forecasting model seems to increase the accuracy of Medicane forecasts with respect to available measurements.

Thank you for your attention!

Acknowledgements

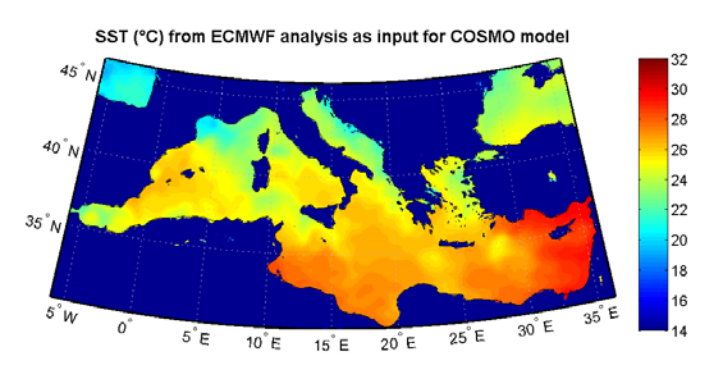
This work was supported by the European Commision MyOcean 2 Project (FP7-SPACE-2011-1-Prototype Operational Continuity for the GMES Ocean Monitoring and Forecasting Service, GA 283367) and by the Italian Project RITMARE, la RIcerca iTaliana per il MARE (MIUR-Progetto Bandiera 2012-2016).

Appendix 1: Wind vertical section



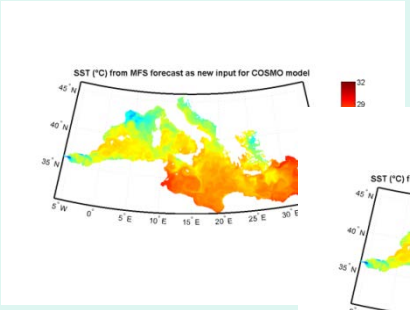
Wind (m/s) vertical section along parallel 41.2°, every 3 hours, for days 7-8 November by COSMO-ME (run at 00:00 UTC on 7 November).

Appendix 2: Weak coupling between MFS and COSMO

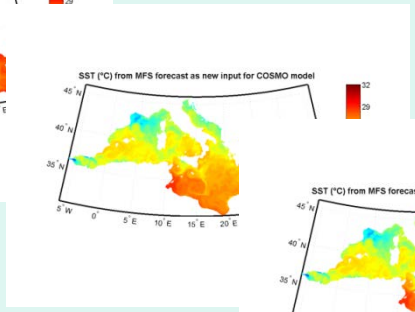


Operational runs: the SST used as boundary condition is constant during the model integration (only a SST analysis field by OSTIA system for a COSMO-ME run).

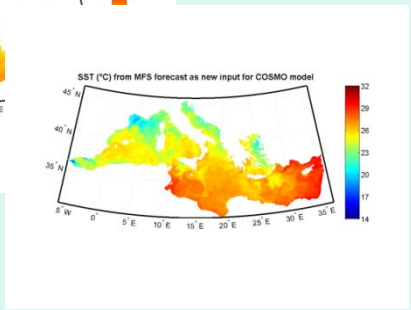
Experiments: forecast SST fields by MFS system at 3 hours time-step for each COSMO-ME run.



Δt = 0 h (analysis)



Δt = 3 h



Δt = 6 h

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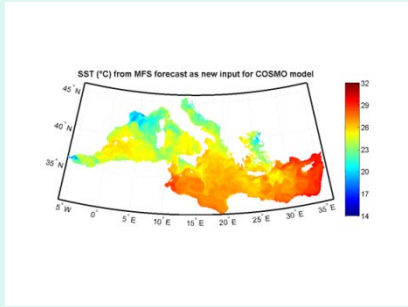

Δt = 72 h