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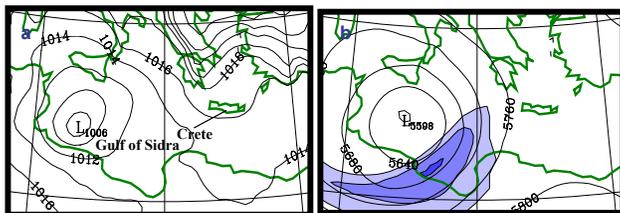
Introduction

The Mediterranean is an area where significant cyclone activity occurs, mainly during the cold period of the year. As the major number of these cyclones is formed over the sea, an especially useful tool for the observation of these systems is the use of spaceborne platforms. Moreover, during the cold period of the year, lightning usually occurs over the relatively warm surface waters and thus the study of the evolution of convective systems can be also assisted by the use of data from lightning detection devices.

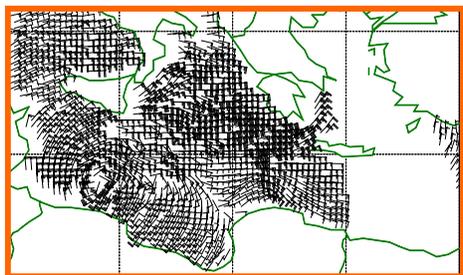
Data and Methodology

1. The data explored are those provided by the lightning detection network ZEUS operated by NOA and by TRMM satellite.
2. An example study of a storm over the Mediterranean (4/11/2004) is presented
3. For the same case high-resolution model simulations with MM5 model are validated against the same set of observations.

A Synoptic set-up



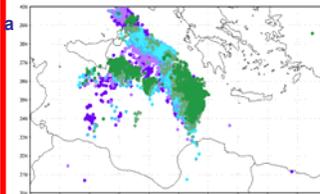
ECMWF analysis valid at 0000 UTC 04 November 2004 of:
(a) mean-sea-level pressure (solid lines at 3 hPa interval) and of 500 hPa geopotential height (dashed lines at 40 m interval) and of 300 hPa wind speed (shaded contours at 10 ms^{-1} interval, only values exceeding 30 ms^{-1} are shown).



10-m wind field provided by QUIKscat scatterometer (one pennant: 25 ms^{-1} , one barb: 5 ms^{-1} , one half-barb: 2.5 ms^{-1}), valid at ~0300 UTC 04 November 2004.

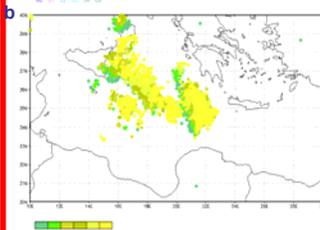
The significant pressure gradient at sea level was associated with important surface winds. Wind speeds exceed 15 ms^{-1} around the low center, while, very strong eastern winds prevail over the maritime area northeastwards of the low center.

B Lightning by ZEUS network



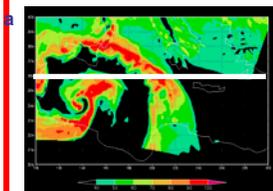
Lightning activity as sensed by ZEUS:
(a) from 0000-0600 UTC 04 November 2004.
(b) From 0600-1200 UTC 04 November 2004.

Lightning activity was very strong from 0000 to 1200 UTC 4 November showing also a slow eastward progression of the activity. The lightning activity is very weak around the low-pressure-center, while it is much more pronounced over the maritime area northeast from the low-center, in the area where QUIKscat winds show an important convergence zone.



ZEUS network is operated by the National Observatory of Athens during the last three years. ZEUS network consists of five very-low frequency (VLF) sensors installed across Europe.

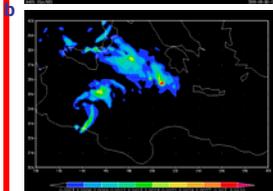
D MM5 model simulations



MM5 results at 9km resolution (grid 2) valid at 0000 UTC 04 November 2004:

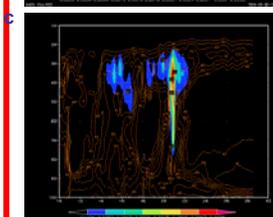
(a) 700 hPa relative humidity field (at 10% interval, only values exceeding 40% are shown).

- The model reproduces:
- the high humidity area around the low-pressure center
 - the band of high relative humidity values over the area of maximum lightning activity.
 - the dry area between the low center and the major band in the northeast.



(b) Column integrated ice mixing ratio (shaded contours at 0.3 gkg^{-1} interval).

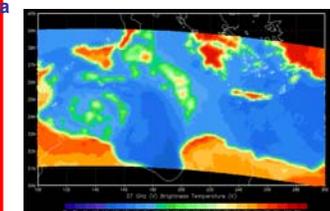
Significant ice concentrations can be depicted in good agreement with the low brightness temperature values at high frequencies and the significant lightning activity



(c) Vertical cross section of graupel and ice concentration (shaded contours at 0.1 gkg^{-1} intervals) and of relative humidity (solid lines at 10% intervals) along the white line in (a).

The significant amount of graupel and ice concentrations aloft, as well as the high relative humidity values and the associated strong updraft motions (not shown) create the necessary conditions for charge separation within the cloud and the production of the observed significant lightning activity.

C TRMM data



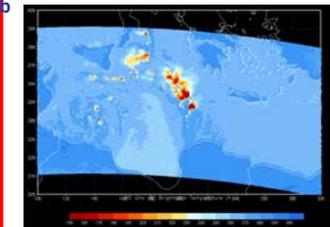
TRMM brightness temperature at ~0000 UTC 04 November 2004:

(a) from the 37 GHz vertical polarization channel

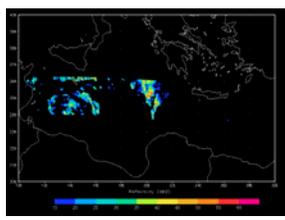
Spirally distributed rainbands are evident around the low-pressure system, with a rain-free area over the maritime area northeast from the low center, coinciding with the area of significant lightning activity

(b) for the 85.5 GHz vertical polarization channel.

Figure b provides an additional evidence of the good correlation between ice presence and lightning activity



Horizontal cross-section of the TRMM-PR reflectivity field (at 5 dBZ interval) at 3 km height.



E Remarks

The synergetic use of various space borne and ground based instruments can be useful for the observation of mid-latitude weather systems over the sea.

This set of data is important for the validation of high-resolution model results but also for the buildup of the necessary confidence in model outputs during the forecasting procedure of Mediterranean storms.