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SEA BREEZE CONVERGENCE AND CONVECTIVE CLOUD FREQUENCIES FROM AVHRR DATA OVER THE ISLE OF MALLORCA

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Abstract

The short-term forecast of the timing, location and intensity of sea breeze convection is currently one of the most difficult atmospheric phenomena, as forecasting tools available are not enough. The line of Cu clouds associated with low level sea breeze convergence and sea breeze complex interactions with features of coastline, small-scale terrain and large-scale synoptic flows is the main feature of this β-mesoscale circulation over the Isle of Mallorca. The boundary layer convergence zones developed by sea breezes can trigger scattered local heavy showers and thunderstorms under conditionally unstable atmosphere, which sometimes can be extraordinarily severe, producing hailstone and gusty winds. AVHRR data from the NOAA-17 (0900-1200 UTC) and NOAA16 (1200-1500 UTC) satellites were collected during 8-month study period (March-October 2004) for computing high-resolution (1.1 km) convective cloud masks making use of a new APOLLO cloud detection algorithm. A non-eulerian numerical model is used in order to simulate the diurnal evolution of mesoscale sea breeze field and calculate wind convergence values for a high resolution grid-point basis covering the centre of the Isle of Mallorca and surrounding Mediterranean sea. This study attempts to statistically verify the impact of low-level convergence of sea breezes on convective cloud development. The two-dimensional numerical model is capable of forecasting a reasonably accurate location of most prominent convective zones mapped by the cloud detection algorithm. Three case studies on influences of different intensities of low-level sea breeze convergence upon convective development were simulated: (1) September 17th, 2004 represents an episode of weak sea breeze convergence; (2) June 17th, 2004 corresponds to a light to moderate sea breeze convergence; and (3) July 27th, 2004 illustrates a strong sea breeze convergence.

AVHRR / Numerical model

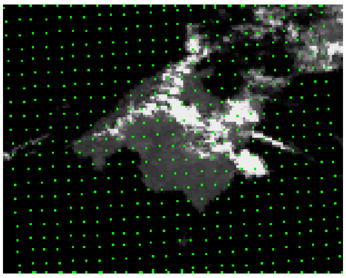
AVHRR-data

1) AVHRR data (1.1 km) from the **NOAA-17** (0900-1200 UTC) and **NOAA-16** (1200-1500 UTC) orbits were collected for the 8-month study period **March-October 2004**.

2) A set of **58** (N17) and **66** (N16) **images** were used following application of three objective criteria in order to detect true sea breeze boundaries: (a) favourable synoptic conditions, (b) air temperatures >20ºC (c) large-scale flows <13 m s^{-1}.

3) A new APOLLO cloud detection algorithm was used to compute the **cloud mask** for each image (see poster EMS2007-A-00542).

4) **Convective cloud frequencies** were calculated for a high-spatial resolution grid based on 550 points.



(Fig. 1a) Channel 2 (0.72-1.10 μm) on July 27th, 2004 (1120 UTC) showing location of the original 550 grid-points put forward by Ramis *et al.* (1990) for the non-eulerian numerical model. Convective cloud frequency values were computed for each point at a 06' lat by 08' long (7x7 pixels)

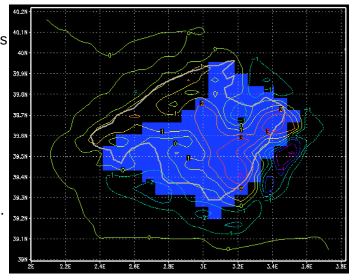
Numerical model

1) A **two-dimensional** (x, y) **numerical model** was used to simulate the β-mesoscale circulation over the Isle of Mallorca.

2) The **input data** for the model were provided by the European Centre for Medium-Range Weather Forecasts (**ECMWF**) charts, METEOSAT visible images and soundings in Palma de Mallorca and were used to establish: overall large-scale winds, stability, and cloudiness to establish, in turn pseudo-radiation.

3) **Low-level convergence values (in 1e-5 s-1 units)** were computed for the high-spatial resolution grid based on the original 550 points.

4) The **linear correlation analysis** was carried out for a set of **95 grid-points** essentially centred over the Isle of Mallorca. The NW mountain range was excluded due to block sea breezes.

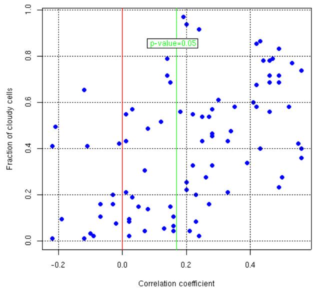


(Fig. 1b) Low-level convergence map over the Isle of Mallorca on July 27th, 2004 (1115h UTC). The original grid-basis is bounded by 38º99' and 40º22'N, and 2º00'and 3º83'E. Area coloured in blue corresponds to the set of 95 grid-points used for the linear correlation analysis

Linear correlation analysis

- **In 87 out of the 124 images** selected for both NOAA-17 and NOAA-16 satellite data the APOLLO algorithm detected **cloudy pixels** over the 95 grid-points.

- **In 50 out of the 87 cloudy images** the linear correlation coefficient (r-Pearson) is significantly greater than 0 **at the 95%** of confidence level (p-value = 0.05).



(Fig. 2) Scatterplot of the fraction of cloudy cells in relation to the linear correlation coefficient. Confidence level at the 95% (solid green line) is drawn

- **The percentage of accuracy** of the sea breeze convergence values in the localisation of the convective cloudiness **is 57.5%.**

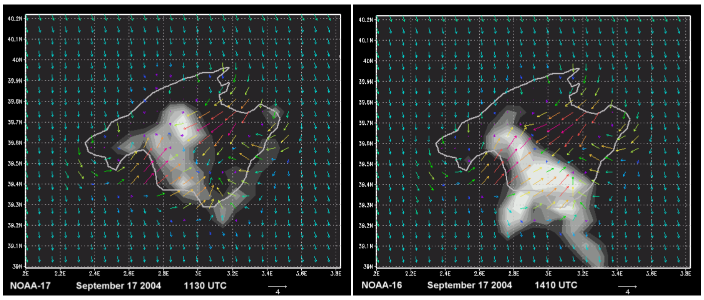
- However, the values of the **coefficient of determination** (or squared correlation coefficient; r^2) **are <0.30**, which means that <30.0% of total variation in cloud convective frequencies is explained by the linear relationship. This may be due to a misplacement of the convergence zones by the model, which can dramatically affect the bulk correlation coefficient.

Low-level sea breeze simulations and convective cloud masks

(1) WEAK SEA BREEZE CONVERGENCE

NUMERICAL SIMULATIONS

Sea breeze flows from the SW (**Bay of Palma**) and NE (**Bay of Alcúdia**) coastlines produce a sea breeze convergence zone (**SBCZ**) with **convective clouds** (Cu and Cb) near the centre of the Isle of Mallorca. This SBCZ is the **main feature of the sea breeze in Mallorca** as has been reported by many theoretical and observational studies



(Fig. 3) Mesoscale sea breeze field and convective cloud mask for (a) NOAA-17 and (b) NOAA-16 orbits. The arrow corresponds to 4 m s^{-1}

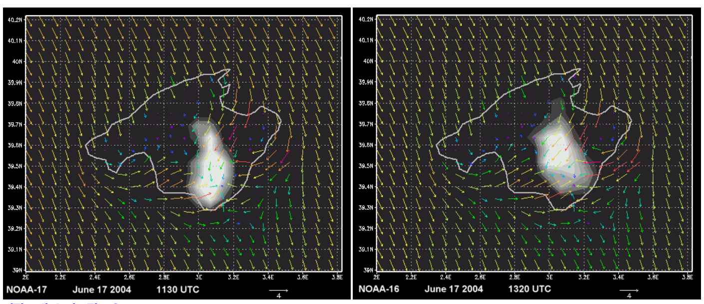
DIURNAL EVOLUTION

- **Sea breezes** from both bays **are well-developed** at 1130 and 1410 UTC, the sea breezes from the Bay of Alcúdia being the most intense ones.

- Sea breezes from the Bay of Alcúdia penetrate further inland and the **collision of sea breezes** is organized in the **SW part** of the isle.

- Convective cloud areas of **little-to-moderate vertical development** are observed along the SBCZ.

(2) LIGHT TO MODERATE SEA BREEZE CONVERGENCE



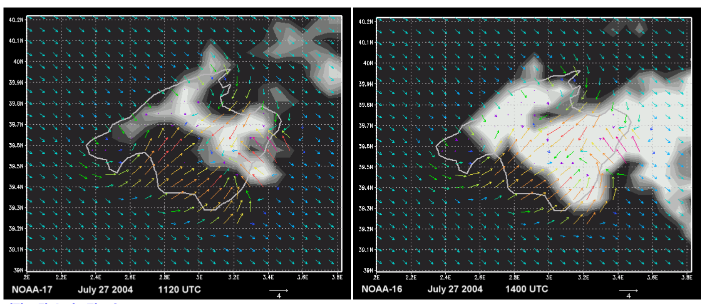
(Fig. 4) As in Fig. 3

- **Light to moderate sea breezes** from both bays and from the southeast coast **are well-established** from the morning orbits.

- Moist northeasterly, easterly and southwesterly **sea breezes collided in the S part** of the isle for the morning simulation, propagating inland as the day progressed.

- **A well defined convective cloud area** is developed in the **centre of the island** for the afternoon simulation.

(3) STRONG SEA BREEZE CONVERGENCE



(Fig. 5) As in Fig. 3

- **Moderate to strong sea breezes** from the NE, SW and SE coast **are well-developed**, the sea breezes from the Bay of Alcúdia being less intense.

- **Sea breezes** from the three coastlines **collided in the NE part** of the isle for the morning orbits. A **secondary SBCZ** with convective clouds is observed over the NW (**Tramuntana mountain range**).

- The SBCZ was enhanced and **Cu became Cb** throughout the afternoon, with **widespread convection** over the isle of Mallorca.

Future

*** Further simulations employing input data of high spatial and temporal resolution (geostationary satellite imagery; MSG2) should be undertaken to determine the impact of low-level convergence of sea breezes on the timing, location and intensity of convection.**

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