# SPACE-TIME PROBABILITY DENSITY OF MEDITERRANEAN HURRICANE GENESIS IN THE PRESENT AND FUTURE CLIMATE

8th PLINIUS CONFERENCE ON MEDITERRANEAN STORMS AND EXTREME EVENTS IN AN ERA OF CLIMATE CHANGE
(Dead Sea, Israel, 17 - 20 October 2006)

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## MOTIVATION

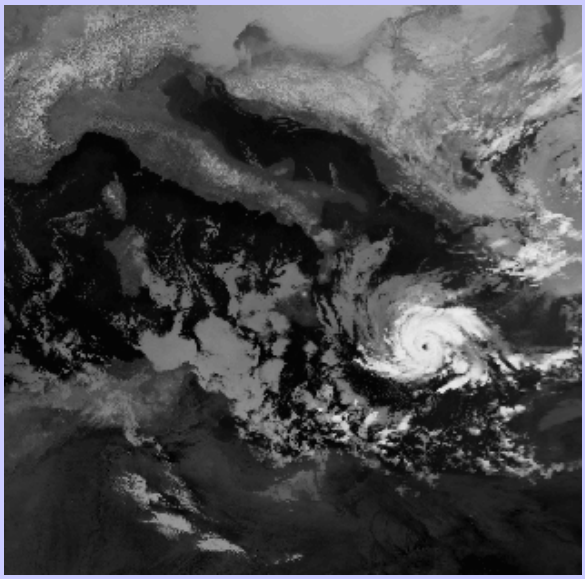
- **Fact:** Tropical-like storms (Medicanes) occasionally develop over the Mediterranean Sea, sometimes attaining hurricane intensity
- **Air-sea interaction theory:** Steady-state maintenance of tropical cyclones can be idealized as a Carnot engine. This idealized model correctly predicts the maximum wind speed –or minimum central pressure– achievable in real events (Potential Intensity)
- **Genesis:** Empirical genesis index successfully tested against the true space-time probability of tropical cyclone genesis
- **Objective:** To apply the above ideas to the Mediterranean region where the record of Medicanes is too sparse to allow any kind of robust statistical analysis of real data / How will climate change affect this issue ???

# MEDICANES

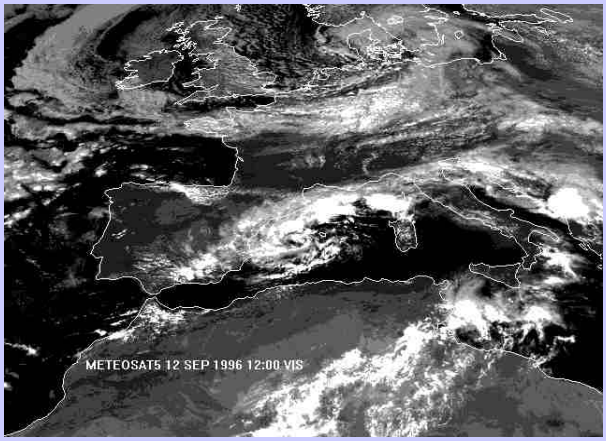
- Several per year in the Mediterranean region
- Typically develop under deep, cold cut-off cyclones aloft
- Locally large air-sea thermodynamic disequilibrium

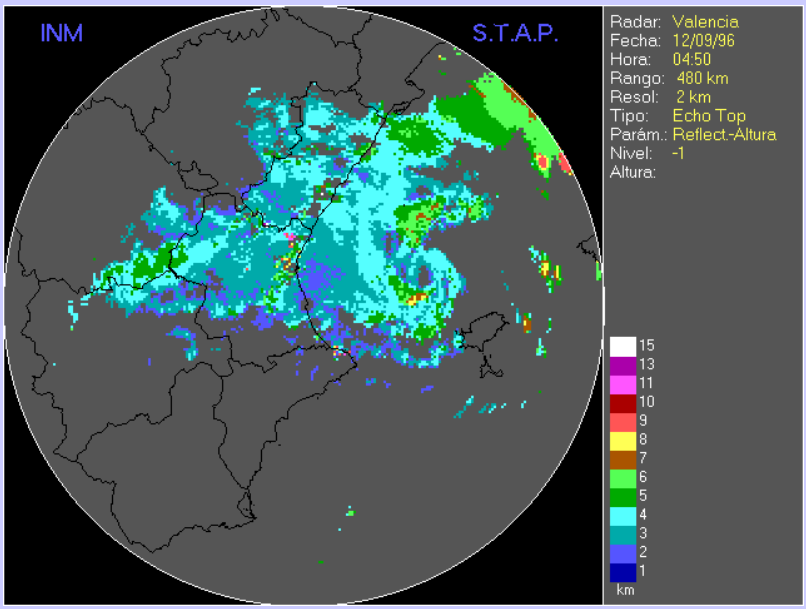
**A. Jansà (INM, Spain) is acknowledged for providing the following examples …**

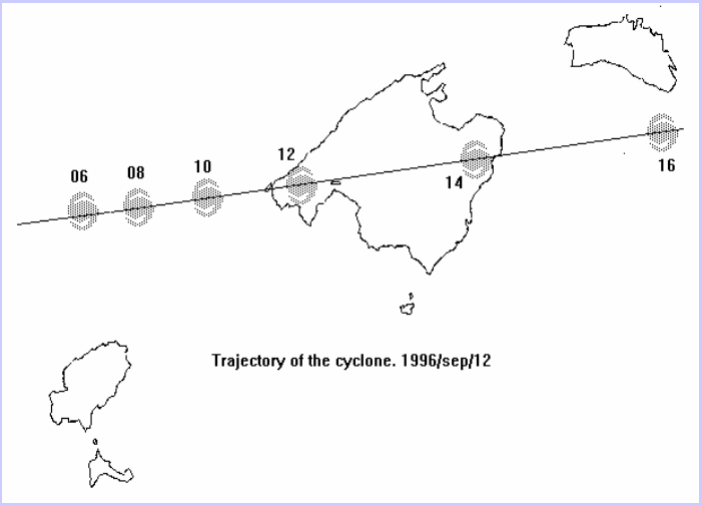
## Medicane of 15-17 January 1995



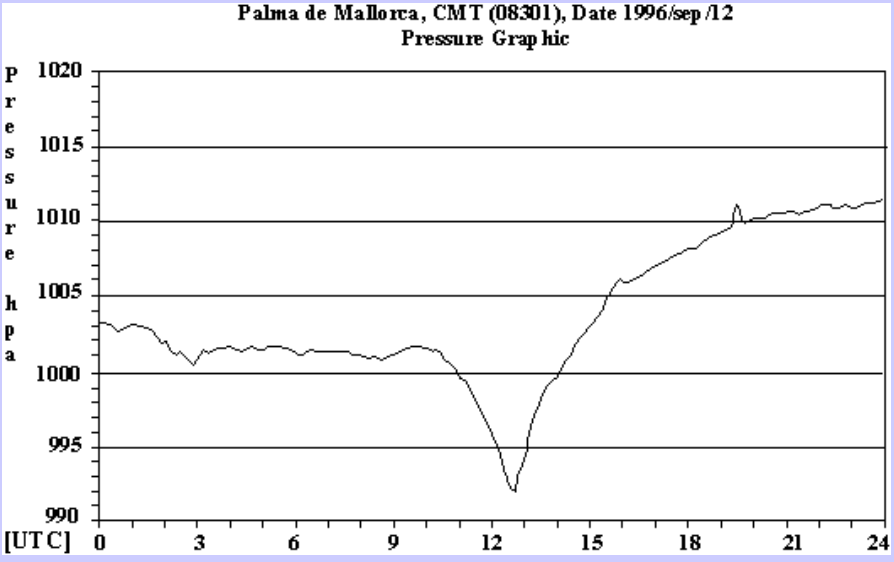
## Medicane of 12 September, 1996



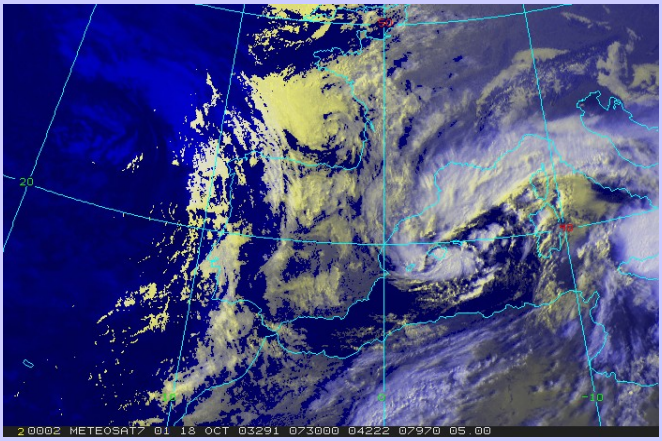



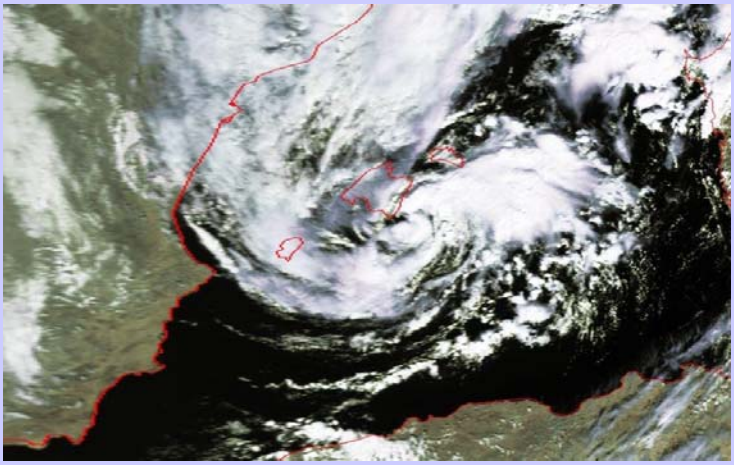


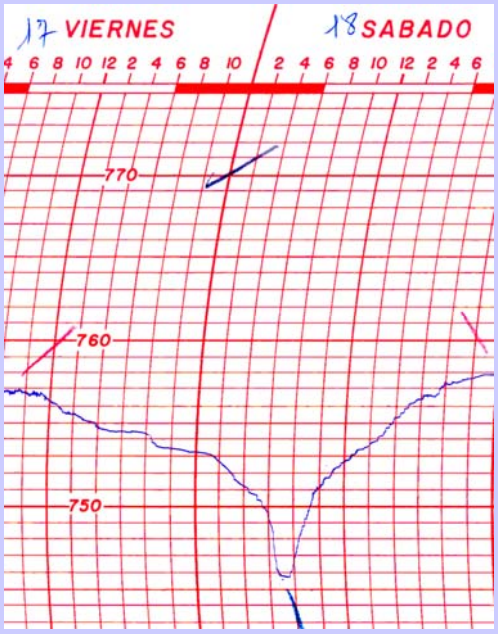

Trajectory of the cyclone. 1996/sep/12



## Medicane of 18 October, 2003

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18 SABADO
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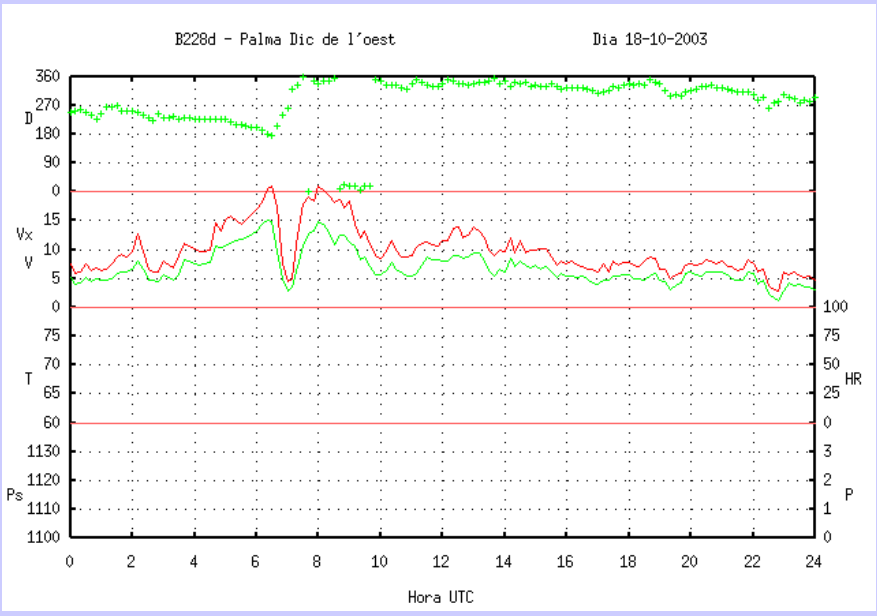
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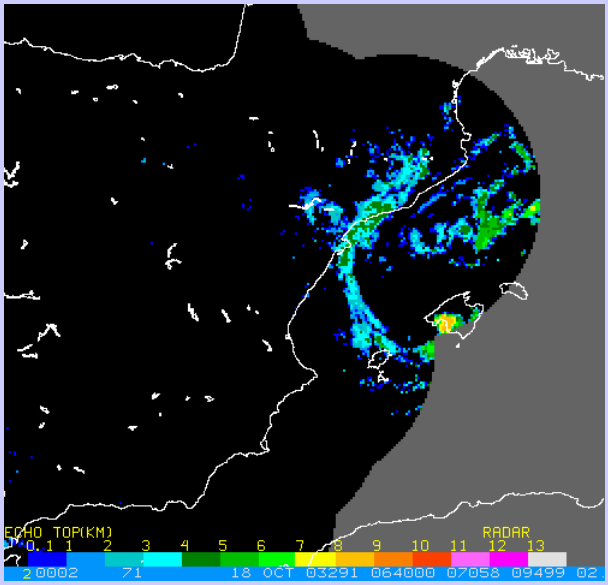
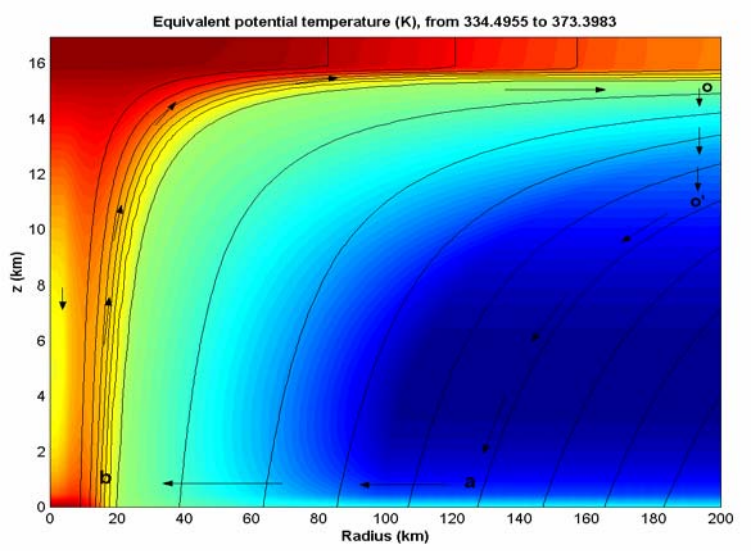



# Energy Production (Carnot cycle)

**a-b**: Isothermal expansion **b-o**: Adiabatic expansion **o-o'**: Isothermal compression **o'-a**: Adiabatic compression



## Steady State Energy Balance

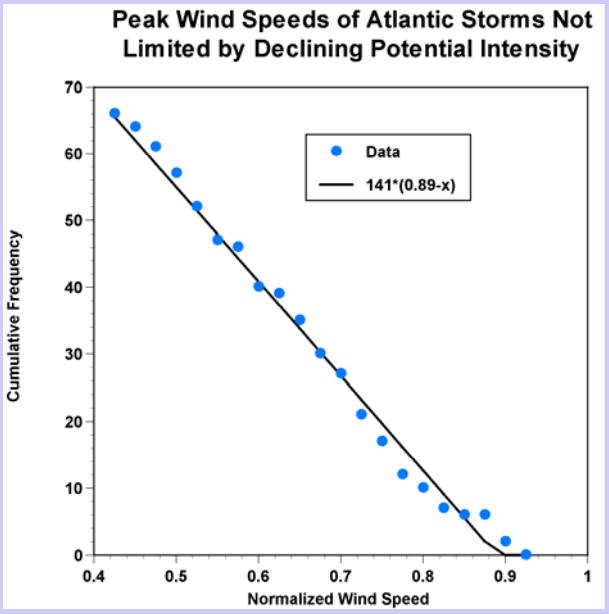
$$P = 2\pi \frac{T_s - T_o}{T_s} \int_a^b \left[ C_k \rho |V| \left( k_0^* - k \right) + C_D \rho |V|^3 \right] r dr$$

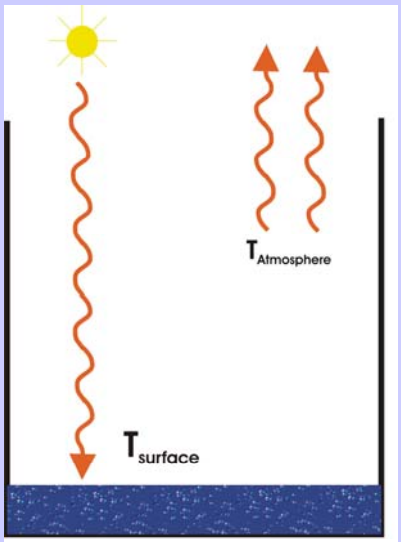
$$D = 2\pi \int_a^b C_D \rho |V|^3 r dr$$

$$\rightarrow |V_{max}|^2 \cong \frac{C_k}{C_D} \frac{T_s - T_o}{T_o} \left( k_0^* - k \right)$$

- $P_{min}$ using the gradient-wind relationship

**When peak storm intensity is normalized by potential intensity and events are counted, a universal distribution function becomes apparent**






Entropy Export to Space = $[\frac{1}{T_{Atmos}} - \frac{1}{T_s}]\dot{Q}$

Entropy Export = Production
≈ Dissipation

## Empirical Genesis Index

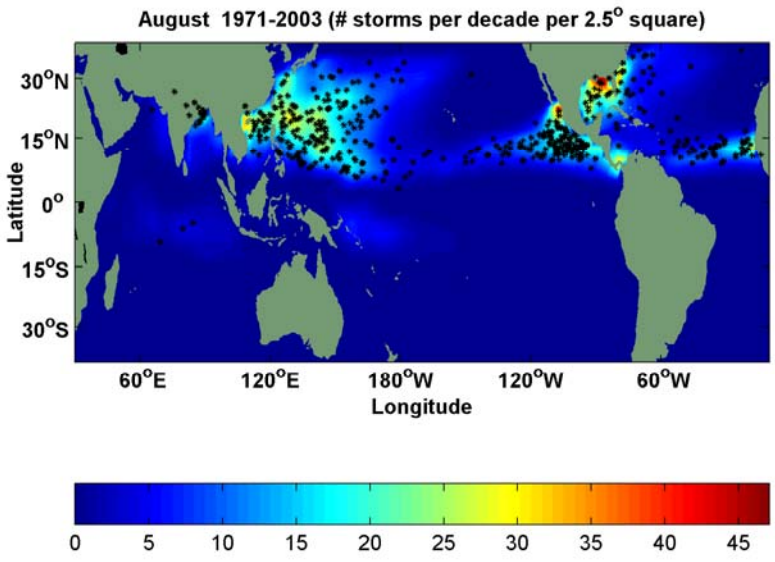
$$I = \left|10^5 \eta\right|^{3/2} \left(\frac{H}{50}\right)^3 \left(\frac{V_{pot}}{70}\right)^3 \left(1+0.1V_{shear}\right)^{-2},$$

$\eta \equiv 850\,hPa\ absolute\ vorticity\ (s^{-1})$,

$V_{pot} \equiv Potential\ wind\ speed\ (ms^{-1})$,

$H \equiv 600\,mb\ relative\ humidity\ (\%)$,

$V_{shear} \equiv \left|\mathbf{V}_{850} - \mathbf{V}_{250}\right|\ (ms^{-1})$.




## METEOROLOGICAL DATA

- **Climatology:** **ECMWF reanalysis data base (ERA40), available at 00, 06, 12 and 18 UTC on standard pressure levels with a spatial resolution of $1.125^0$**
- **Events:** **ECMWF grid analyses, available at 00, 06, 12 and 18 UTC on standard pressure levels with a spatial resolution of $0.3^0$**
- **Parameters:**
  - **SST:** Sea surface temperature ($^0$C)
  - **MINCP:** Minimum central pressure (hPa) achievable by the cyclone according to air-sea interaction theory
  - **MAXWS:** Maximum wind speed (m/s) achievable by the cyclone according to air-sea interaction theory, or potential intensity
  - **GENPDF:** Probability density of genesis (no units) according to the empirical tropical index

## STATISTICAL PRODUCTS

- **Climatology: Monthly basis for the period 1981-2000, based on the 00-06-12-18 UTC daily-mean atmosphere:**
  - **MEAN:** Mean value
  - **QT25:** 25% percentile value
  - **QT75:** 75% percentile value
  - **IQR:** Inter-quartile range (QT75-QT25)
  - **THRS1, THRS2, THRS3, THRS4:** Number of days over thresholds 1, 2, 3, 4
  - **Western Region:** Histograms for the bulk of the western Mediterranean
  - **Central Region:** …… central Mediterranean
  - **Eastern Region:** …… eastern Mediterranean
- **Events (currently 12 quasi-tropical Mediterranean cyclones):**
  - **3-day period centered in the closest synoptic time to mature storm**
  - **Synoptic scenario:** Sea level pressure (hPa) and 500 hPa Geopotential height (m)
  - **"Tropical" diagnosis:** SST, MINCP, MAXWS and GENPDF fields

## CLIMATE CHANGE EFFECTS

- **GCMs: Same statistical products as for the ERA-40 climatology, but using the daily-mean atmospheres of the following models:**
  - **CSIRO-Mk3.0 (Australia):** $1.875^0$ x $1.865^0$ horizontal resolution in (lon,lat)
  - **ECHAM5/MPI-OM (Germany):** $1.875^0$ x $1.865^0$
  - **GFDL-CM2.1 (USA):** $2.5^0$ x $2.01^0$
- **Present and future climate: A 20-year time slice is extracted from two different runs of the GCMs:**
  - **1981-2000:** Climate of the 20th century experiment (20C3M)
  - **2081-2100:** High emission scenario experiment (SRESA2)

## PROJECT ON MEDITERRANEAN HURRICANES

http://medicanes.uib.es

## CONCLUSIONS

- **Events:** **High values of the empirical index are invariably obtained for the available cases, indicating that such an index can be a good candidate to estimate –or forecast– the likelihood of Medicane genesis. However, appropriate thresholds and extra information must be defined to avoid excessive false alarms**
- **Climatology:** **Highest monthly values are obtained for autumn, especially in October. Mean fields emphasize the western and central basin as the main cyclogenetic areas, but the occurrence of extremes might follow a different pattern**
- **Climate change effects:** **The GCMs exhibit some problems to simulate the regional climate (e.g. CSIRO). In spite of the large increase of SST imposed by global warming , the long term risk of these violent Mediterranean windstorms is not clear: CSIRO and GFDL indicate an enhanced risk, while ECHAM5 a reduced risk. Again, extreme values rather than mean fields should be analysed**