SPACE-TIME PROBABILITY DENSITY OF MEDITERRANEAN HURRICANE GENESIS IN THE LIGHT OF AN EMPIRICAL TROPICAL INDEX

5ª ASAMBLEA HISPANO-PORTUGUESA DE GEODESIA Y GEOFÍSICA
(Sevilla, 30 Enero - 3 Febrero 2006)

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MOTIVATION

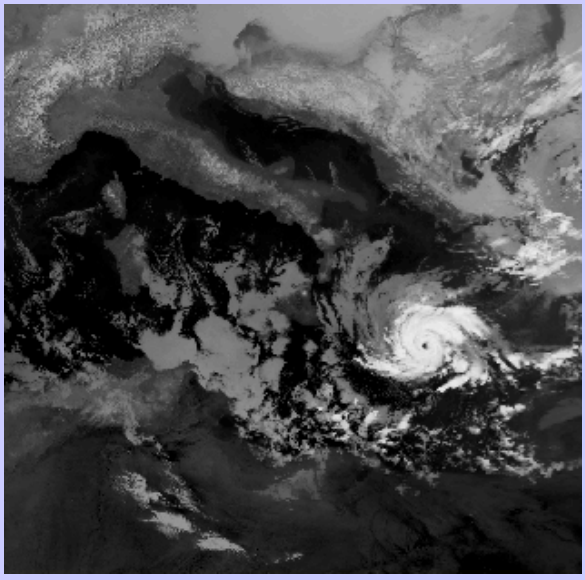
- **Fact:** Tropical-like storms (Medicanes) occasionally develop over the Mediterranean Sea, sometimes attaining hurricane intensity
- **Air-sea interaction theory:** Steady-state maintenance of tropical cyclones can be idealized as a Carnot engine. This idealized model correctly predicts the maximum 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

MEDICANES

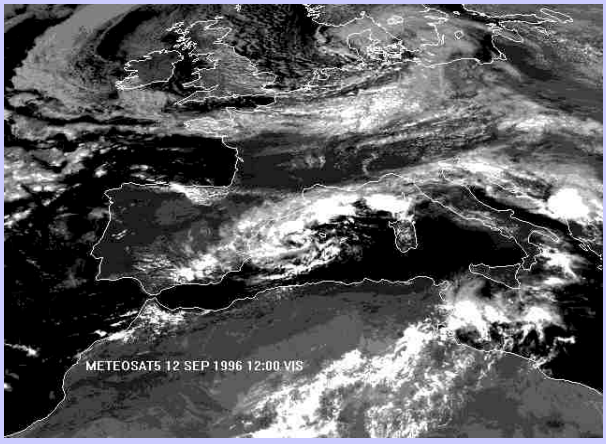
- Several per year in the Mediterranean region
- Typically develop under deep, cold cut-off cyclones aloft
- Locally large air-sea thermodynamic disequilibrium

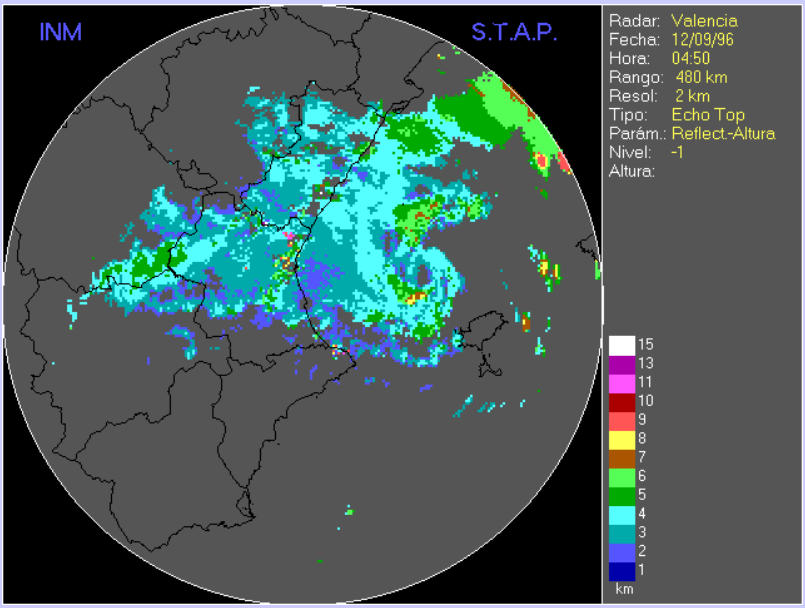
A. Jansà (INM, Spain) is acknowledged for providing the following examples …

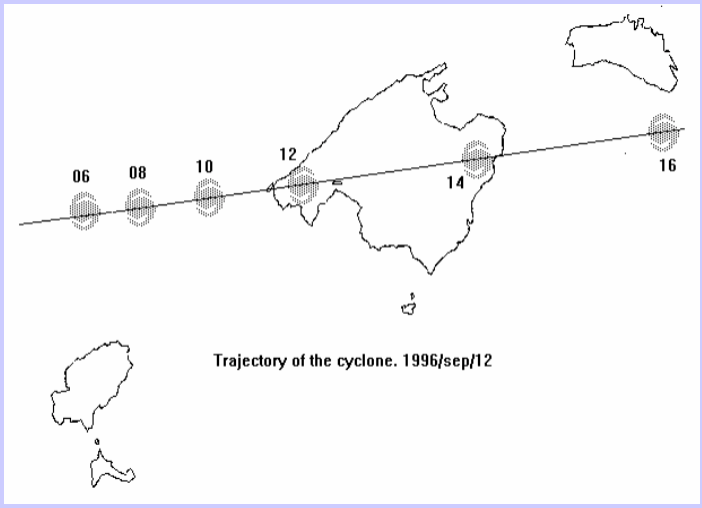
Medicane of 15-17 January 1995



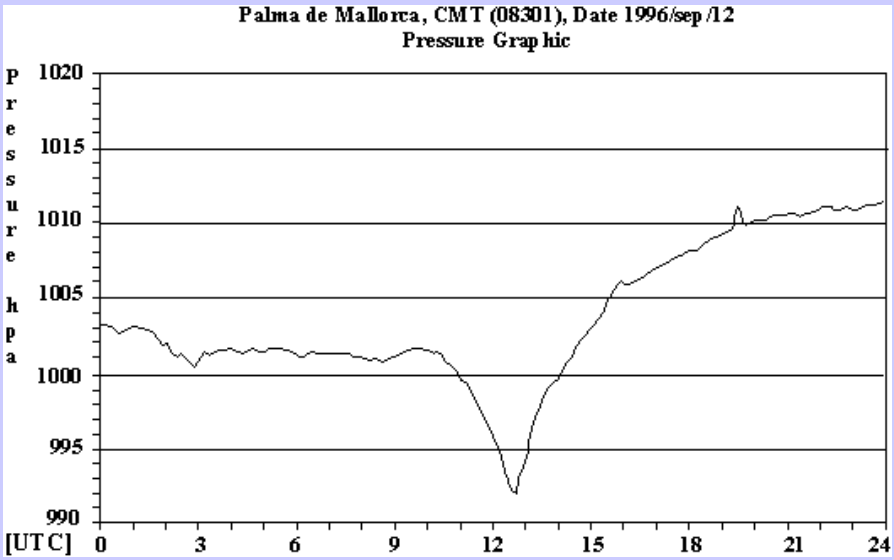
Medicane of 12 September, 1996



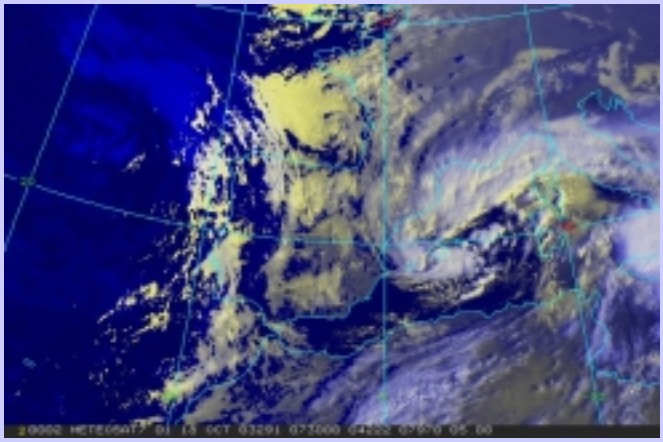


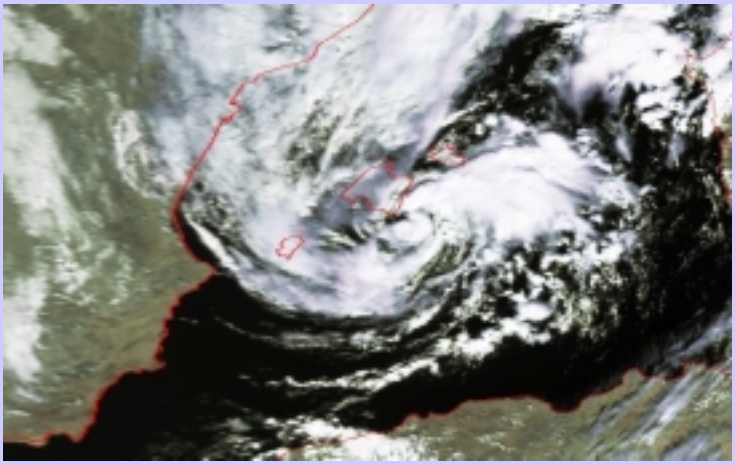


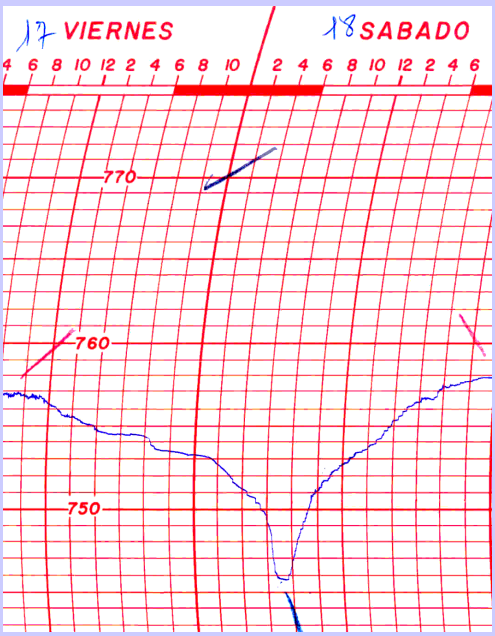
Trajectory of the cyclone. 1996/sep/12



Medicane of 18 October, 2003






17 VIERNES
18 SABADO
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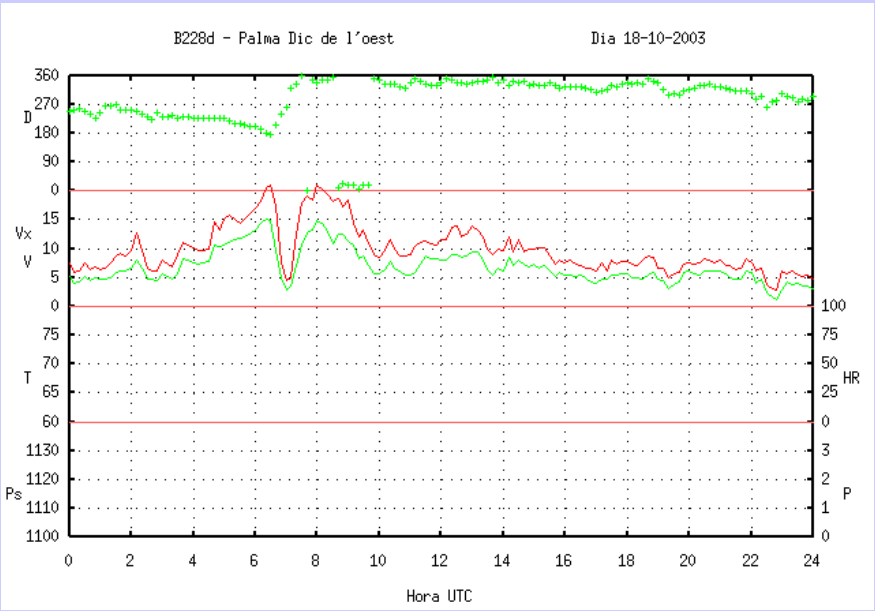
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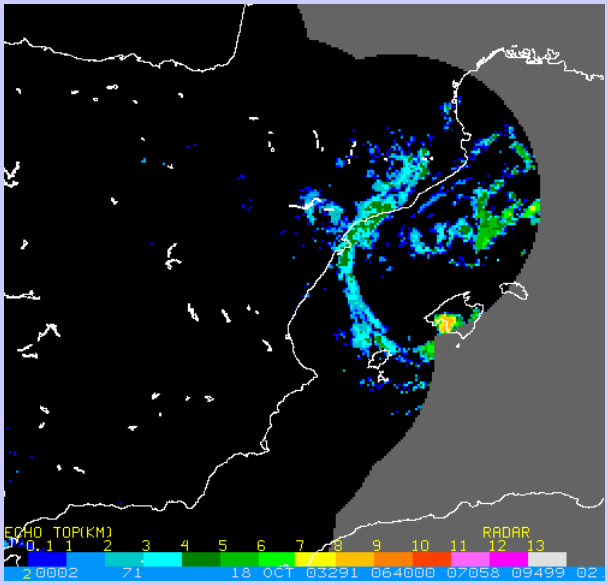
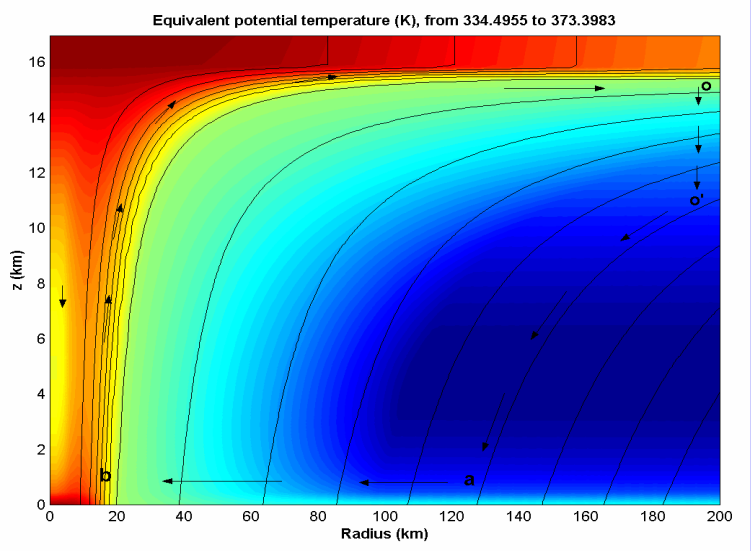


Energy Production (Carnot cycle)

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



Steady State Energy Balance

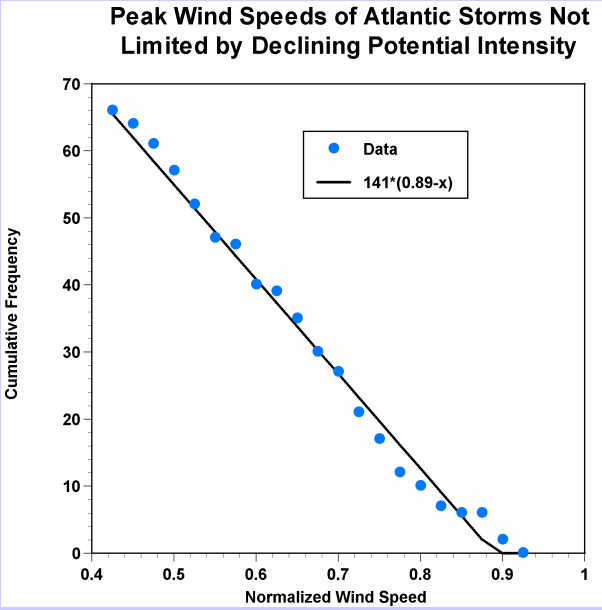
$$\text{☆} = 2\pi \frac{T_s - T_o}{T_s} \int_a^b \left[C_k \rho |V| \left(k_0^* - k \right) + C_D \rho |V|^3 \right] r dr$$

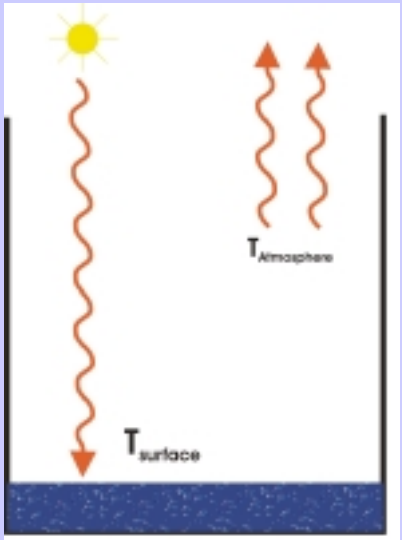
$$\text{⌘} = 2\pi \int_a^b C_D \rho |V|^3 r dr$$

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

→ 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

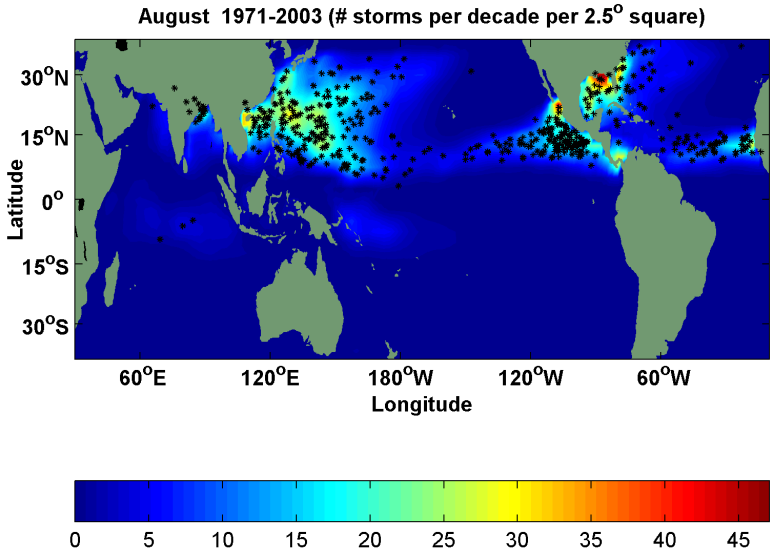
$$I = \left|10^5 \eta\right|^{3/2} \left(\frac{H}{50}\right)^3 \left(\frac{V_{pot}}{70}\right)^3 \left(1+0.1V_{shear}\right)^{-2},$$

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

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

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

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



METEOROLOGICAL DATA

- **Climatology:** **Reanalysis data base from ERA40, available at 00, 06, 12 and 18 UTC on standard pressure levels with a spatial resolution of 1.25^0 (September 1957 – August 2002)**
- **Events:** **ECMWF grid analyses, available at 00, 06, 12 and 18 UTC on standard pressure levels with a spatial resolution of 0.3^0 (from beginning of 80's)**
- **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 1958-2001, based on the average 00-06-12-18 UTC daily state:**
  - **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

PROJECT ON MEDITERRANEAN HURRICANES

http://medicanes.uib.es

CONCLUSIONS

- **Main result:** **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**
- **Open question:** **Which are the appropriate thresholds and extra information that should be used to avoid excessive false alarms ?**
- **Future research:** **Long term risk of these violent Mediterranean windstorms under current climate and global warming? … use of synthetic meteorological analyses to construct genesis/trajectory scenarios**