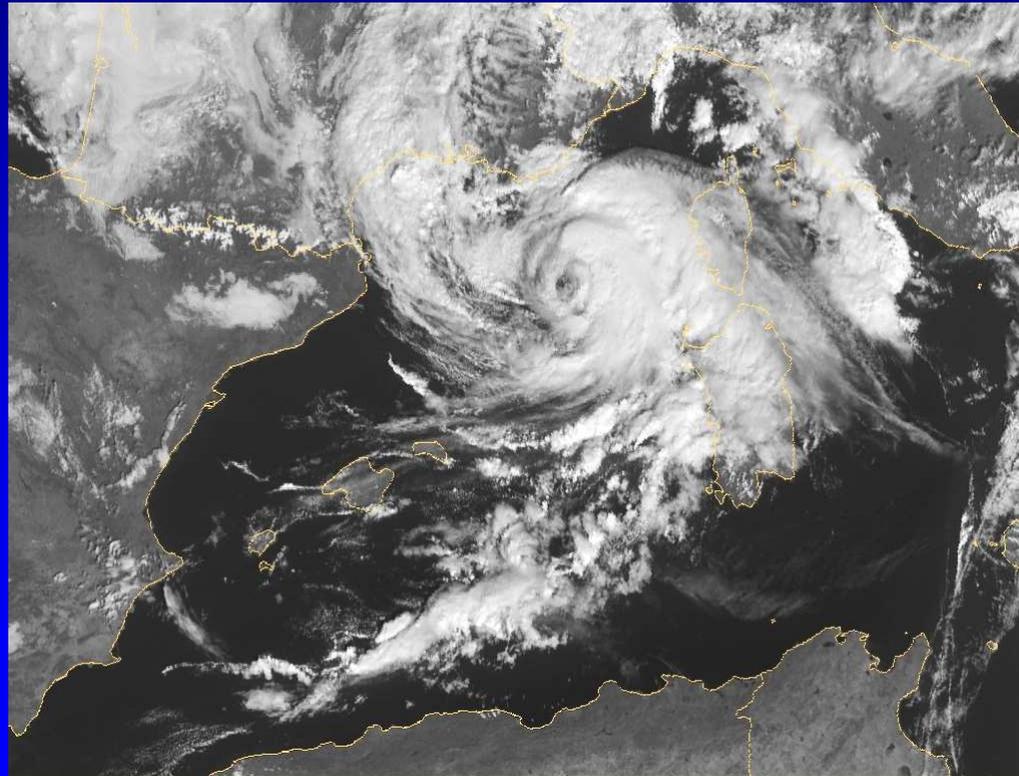


Medicanes, els "Huracans" del Mediterrani: Present i Futur

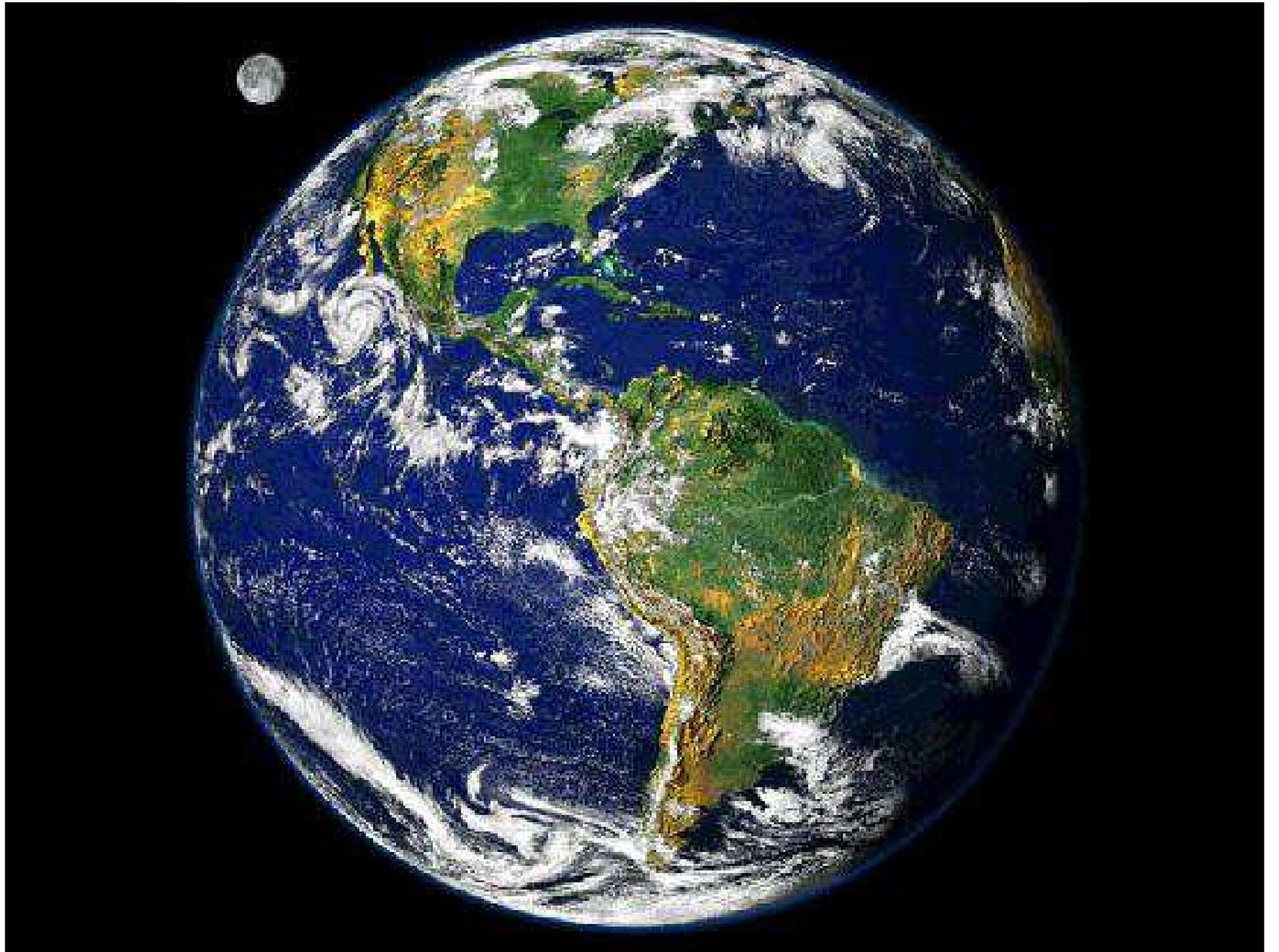


Romu Romero, Grup de Meteorologia (UIB)

ÍNDEX

- **Ciclons Tropicals: Una Mica de Física**
- **Medicanes: Observacions i Simulacions**
- **Medicanes: Risc Present i Futur**

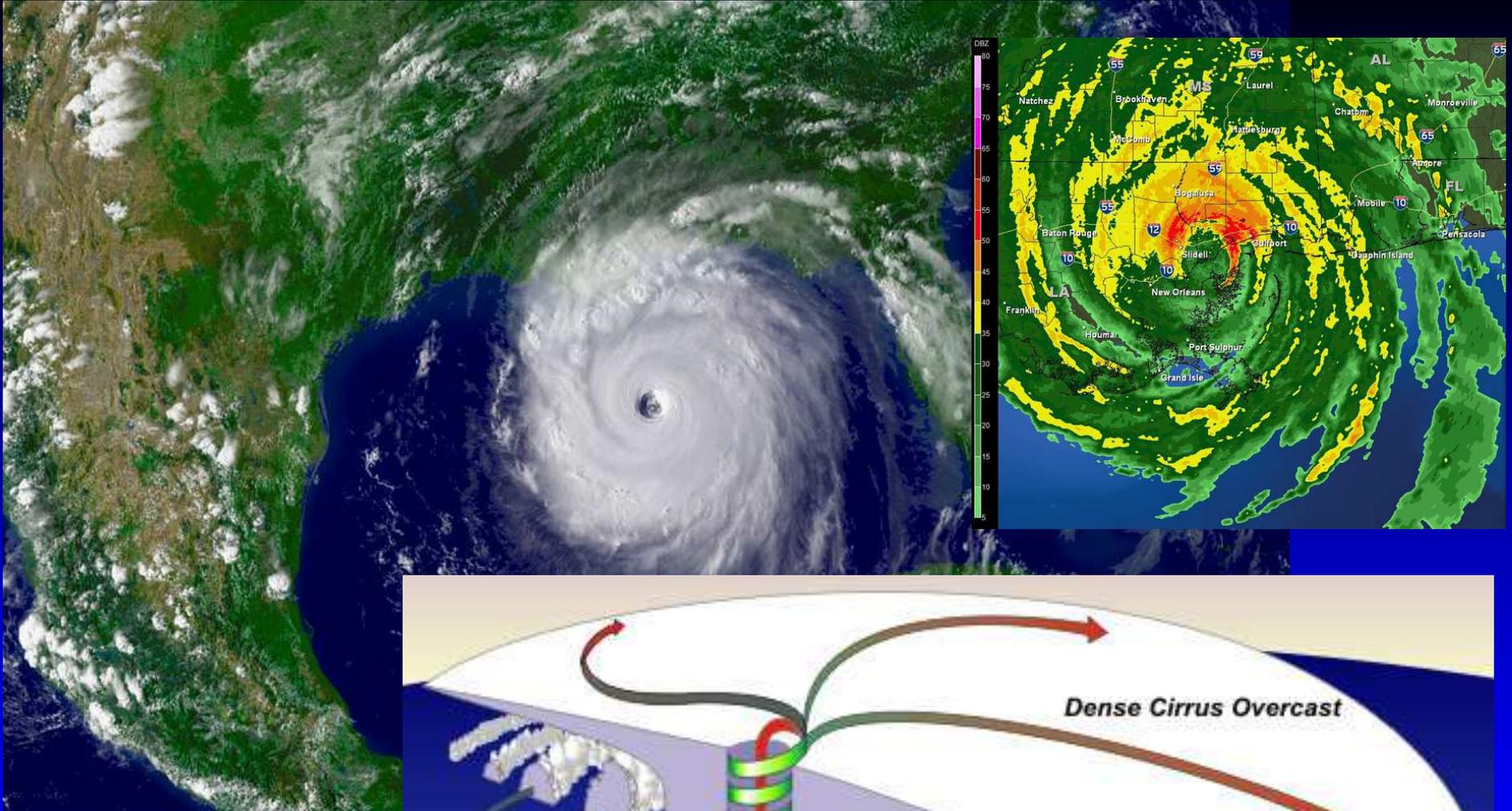
**CICLONS TROPICALS:
UNA MICA DE FÍSICA**



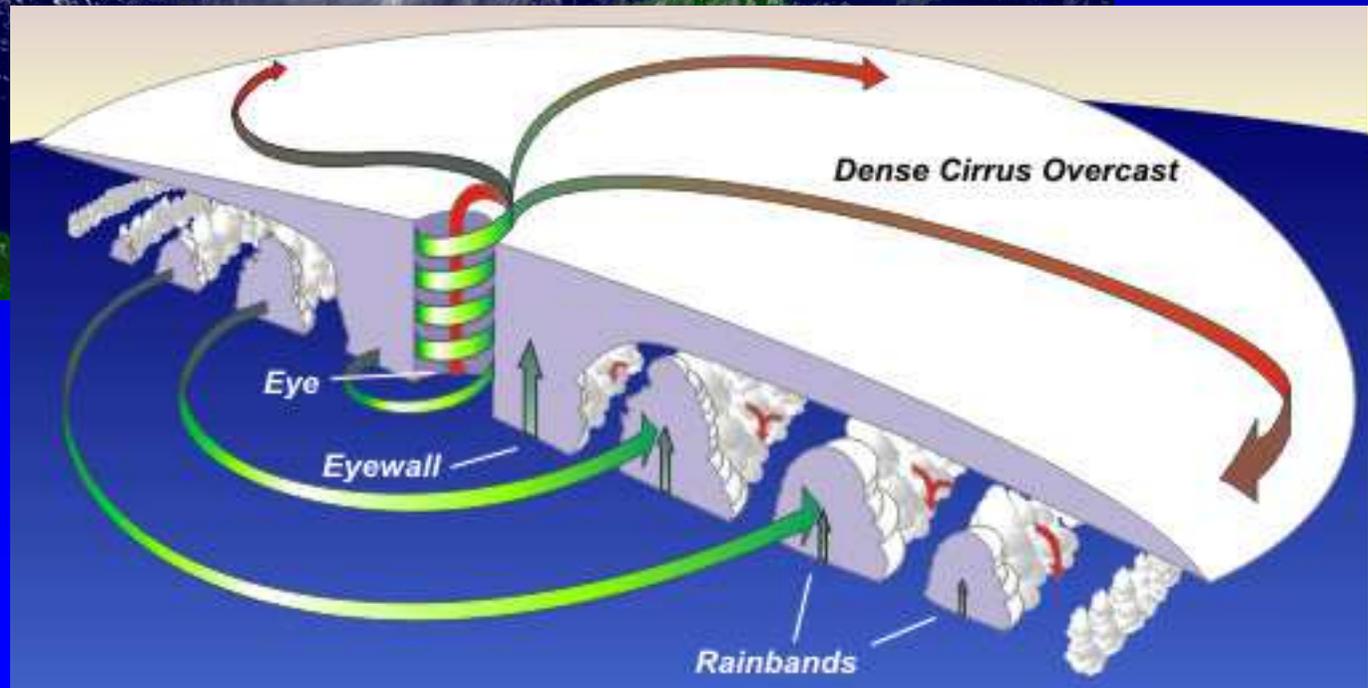
Tropical Cyclones



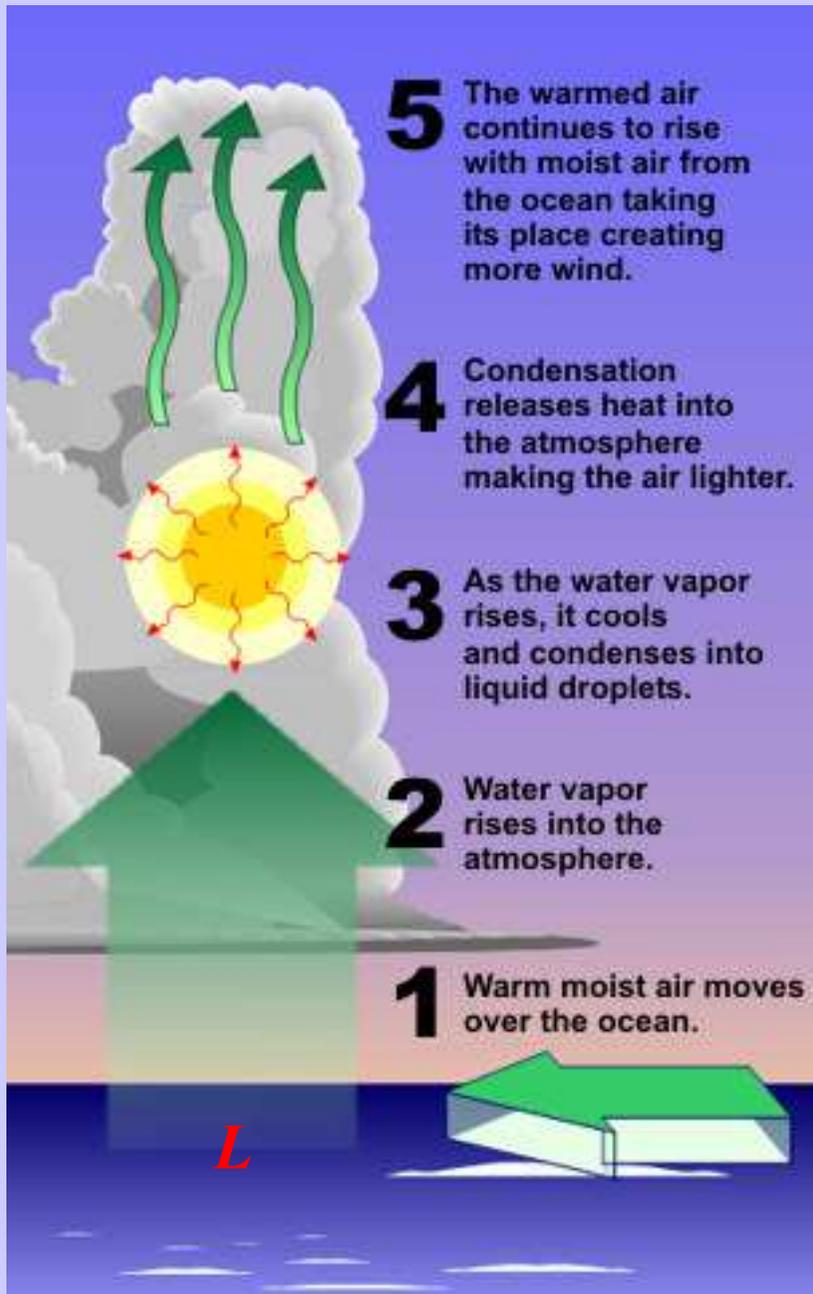
**Huracán Sandy
(Octubre 2012)**



**Huracán Katrina
(Agosto 2005)**



Mecanismo Físico



Saffir–Simpson hurricane wind scale

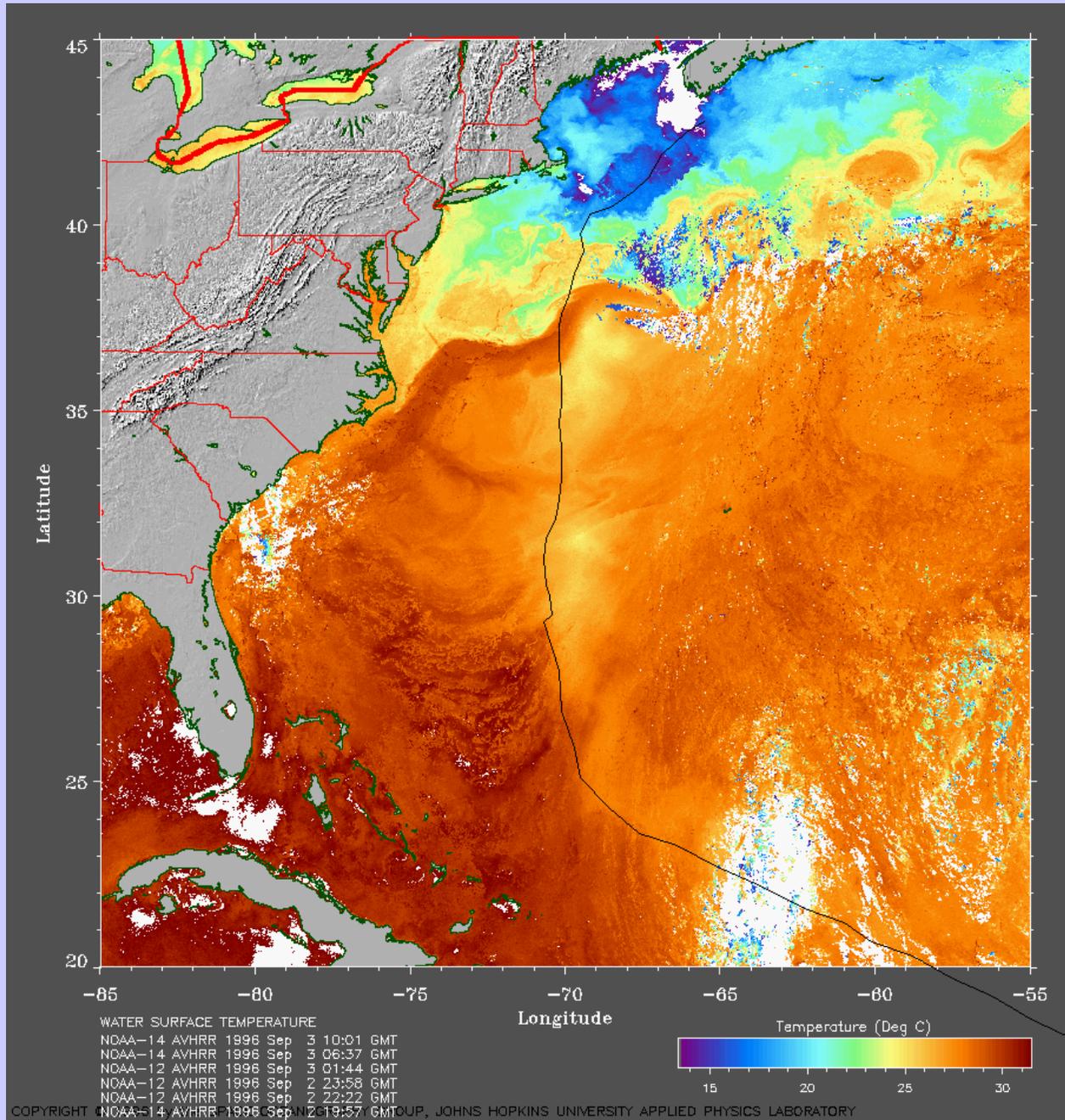
Category	Wind speeds
Five	≥70 m/s, ≥137 knots ≥157 mph, ≥252 km/h
Four	58–70 m/s, 113–136 knots 130–156 mph, 209–251 km/h
Three	50–58 m/s, 96–112 knots 111–129 mph, 178–208 km/h
Two	43–49 m/s, 83–95 knots 96–110 mph, 154–177 km/h
One	33–42 m/s, 64–82 knots 74–95 mph, 119–153 km/h

Related classifications

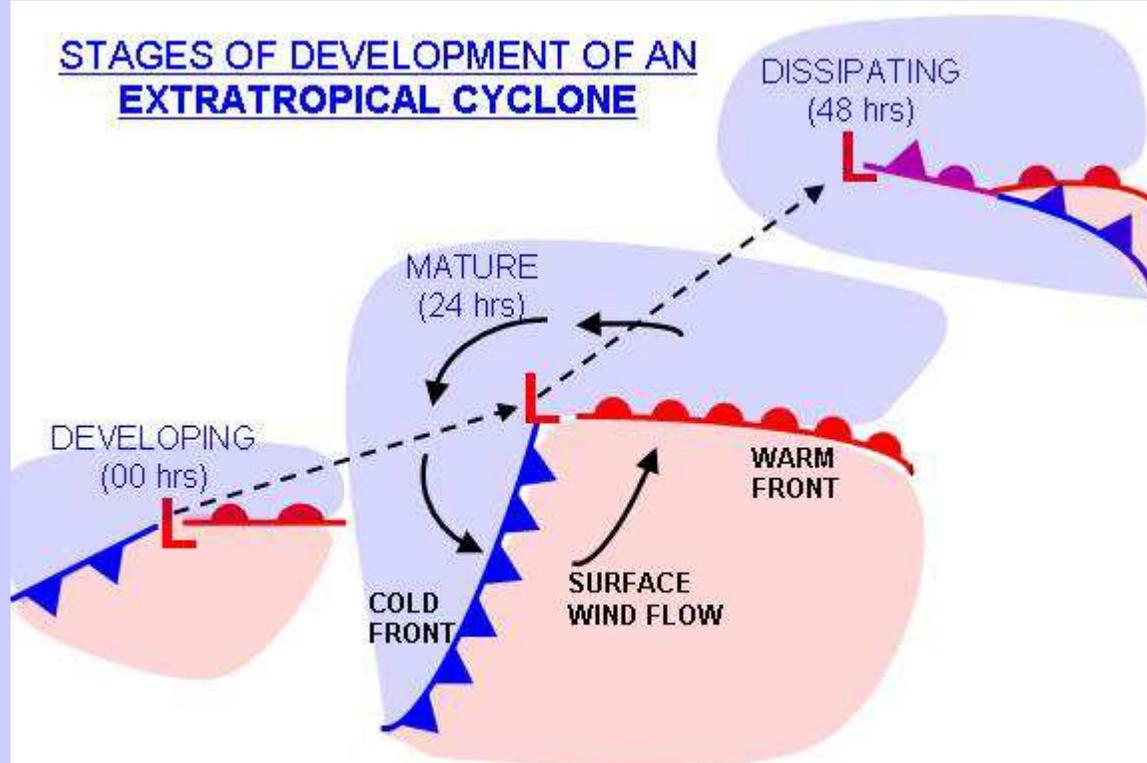
Tropical storm	18–32 m/s, 34–63 knots 39–73 mph, 63–118 km/h
Tropical depression	≤17 m/s, ≤33 knots ≤38 mph, ≤62 km/h



Redistribución de Calor en la VERTICAL



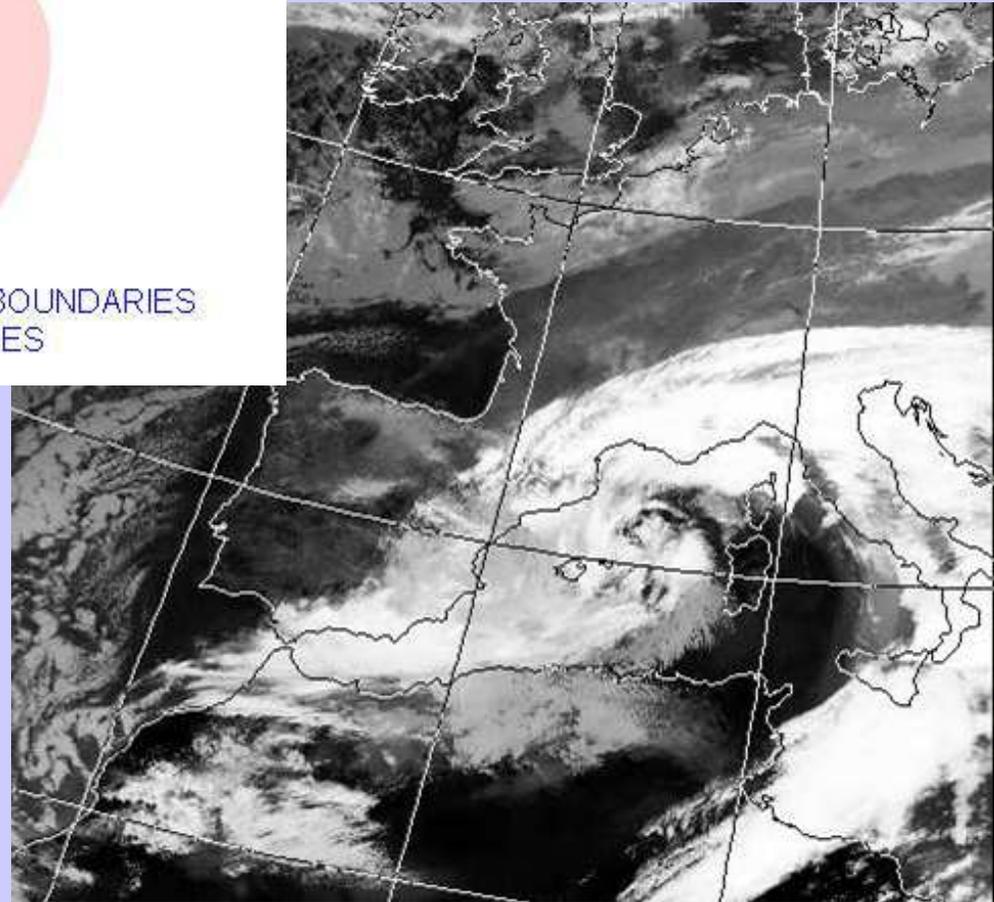
STAGES OF DEVELOPMENT OF AN EXTRATROPICAL CYCLONE



EXTRATROPICAL CYCLONES FORM ALONG THE BOUNDARIES BETWEEN COOL AND WARM AIR MASSES

**Redistribución
de Calor en la
HORIZONTAL**

**Ciclones
Extratropicales**



TEORÍA: Ciclón Tropical actúa como una Máquina Térmica (Ciclo de Carnot)

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

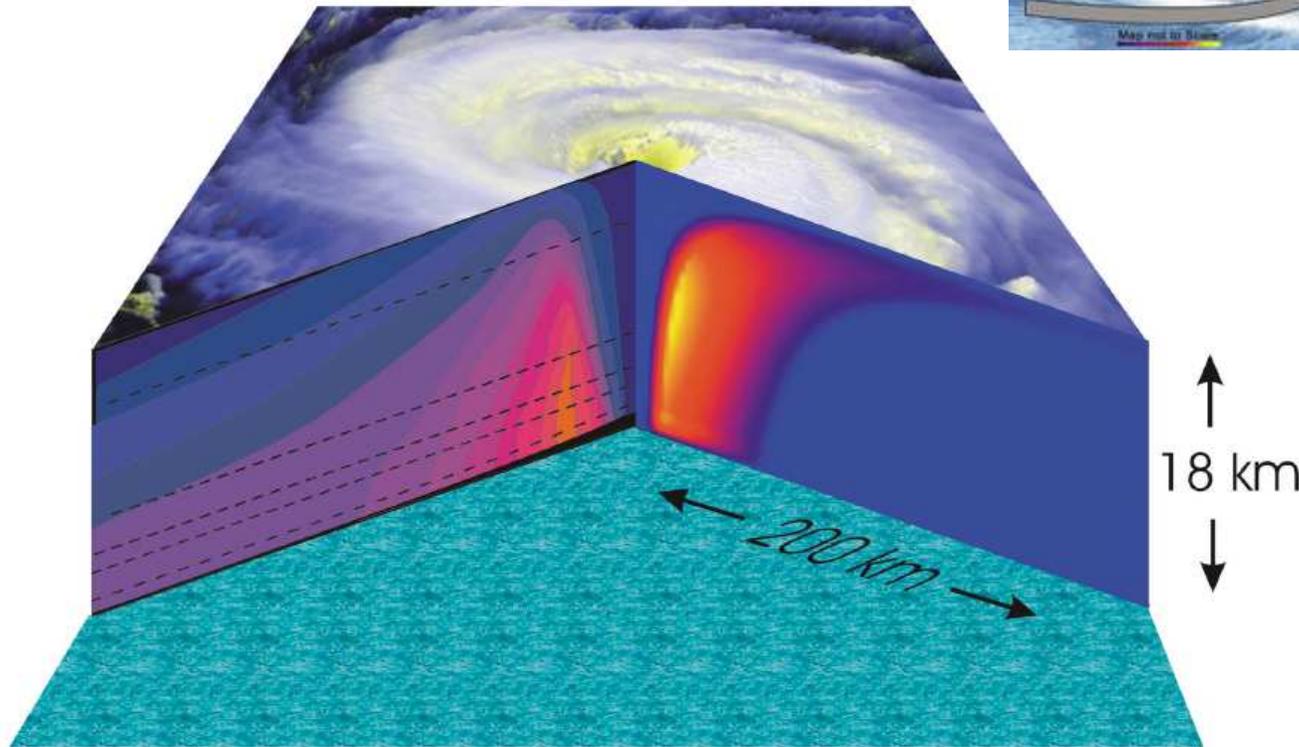
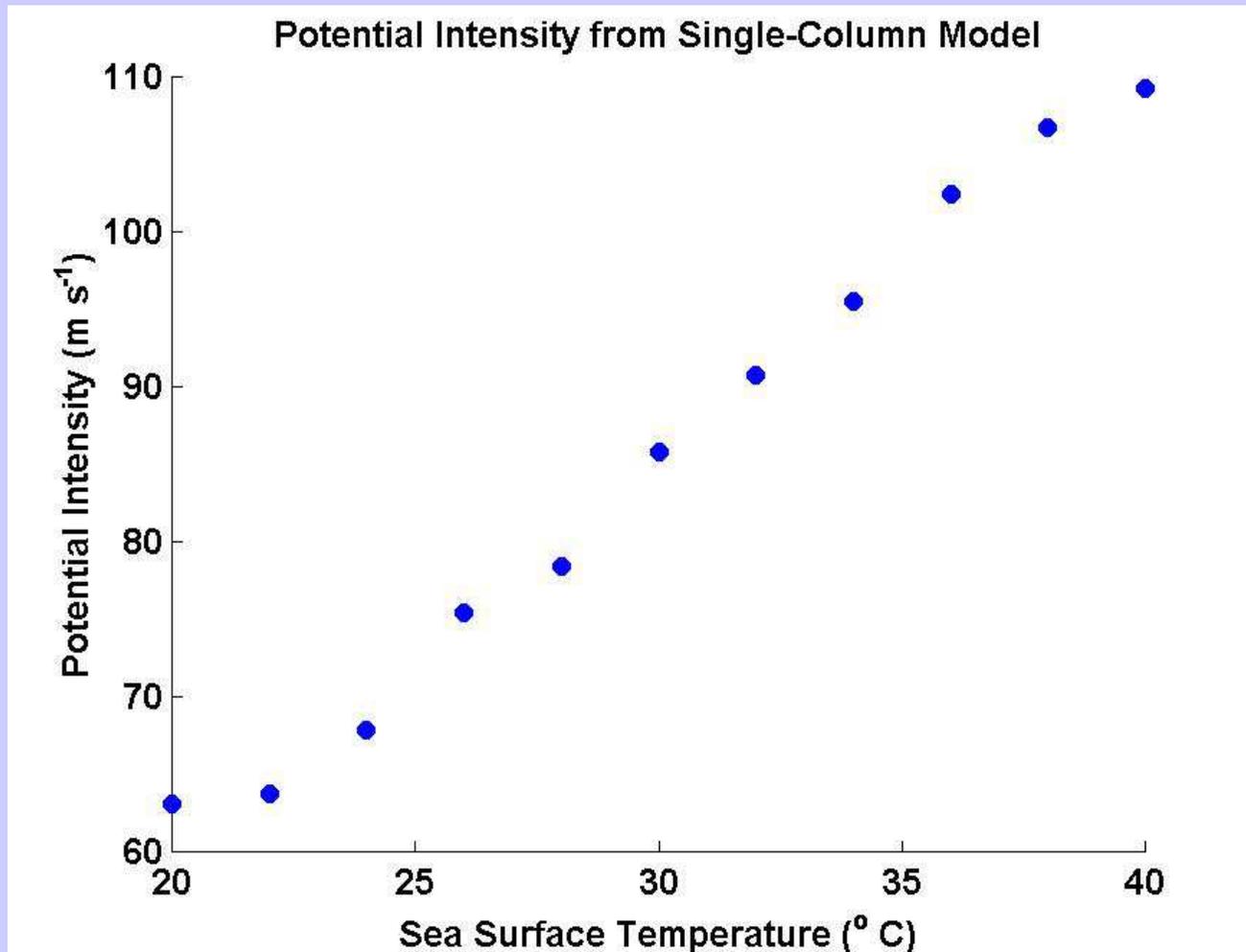


Figure 3 Cutaway view of the structure of a tropical cyclone. The top of the storm is based on a satellite photograph of the cloud structure of Hurricane Fran of 1996. The right-hand cut shows the vertical component of velocity, from a numerical simulation of a hurricane using the model of Emanuel (1995a); maximum values (yellow) are approximately 8 ms^{-1} . The left-hand cut shows the magnitude of the tangential wind component measured in Hurricane Inez of 1966 by aircraft flying at levels indicated by the black dashed lines; from Hawkins & Imbembo (1976). Maximum values are approximately 50 ms^{-1} .

TEORÍA: La Intensidad Potencial Aumenta con la SST (Emanuel, 1987)



Índice Empírico de Génesis

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

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

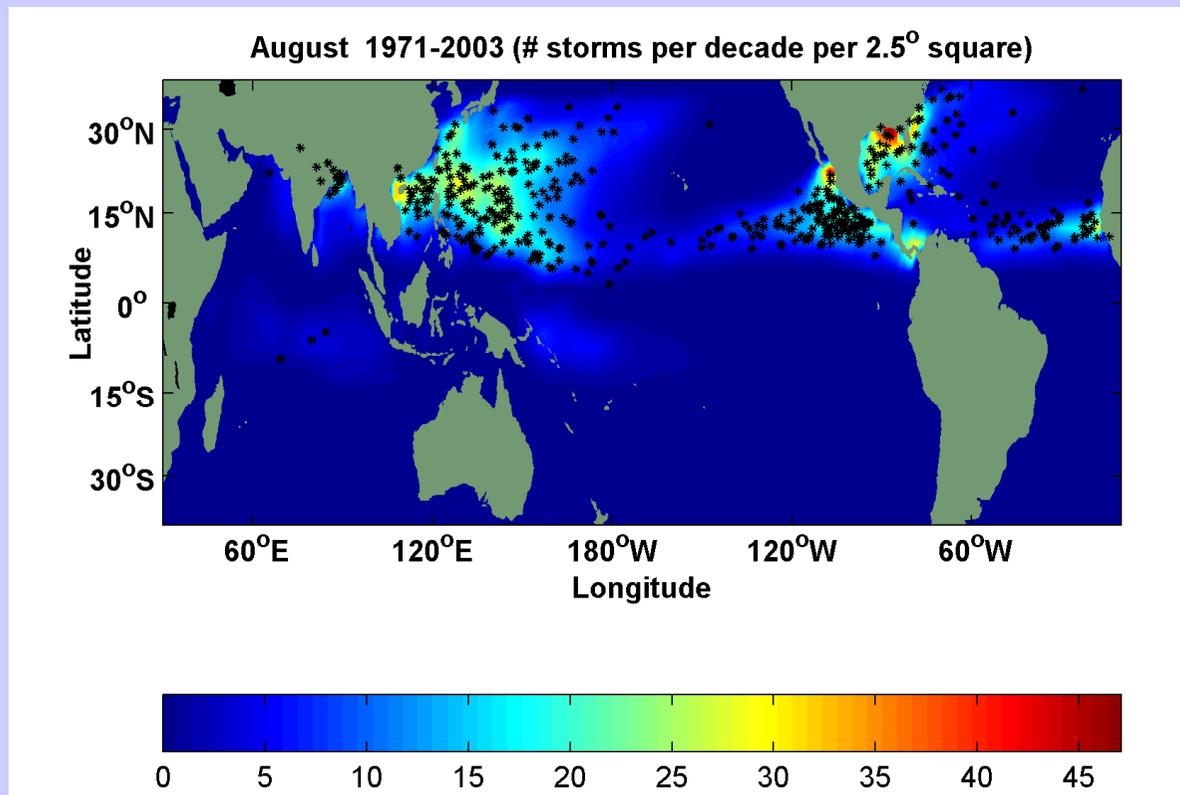
$V_{pot} \equiv \text{Potential wind speed } (ms^{-1}),$

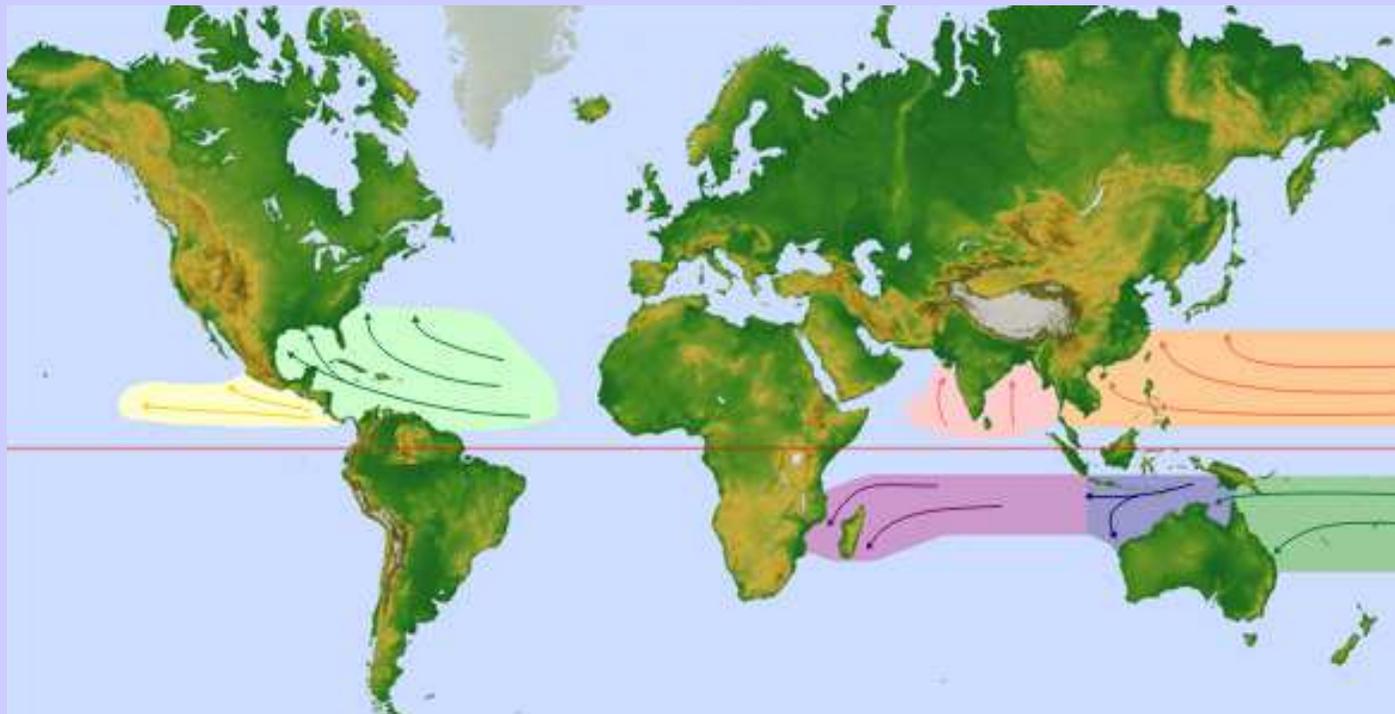
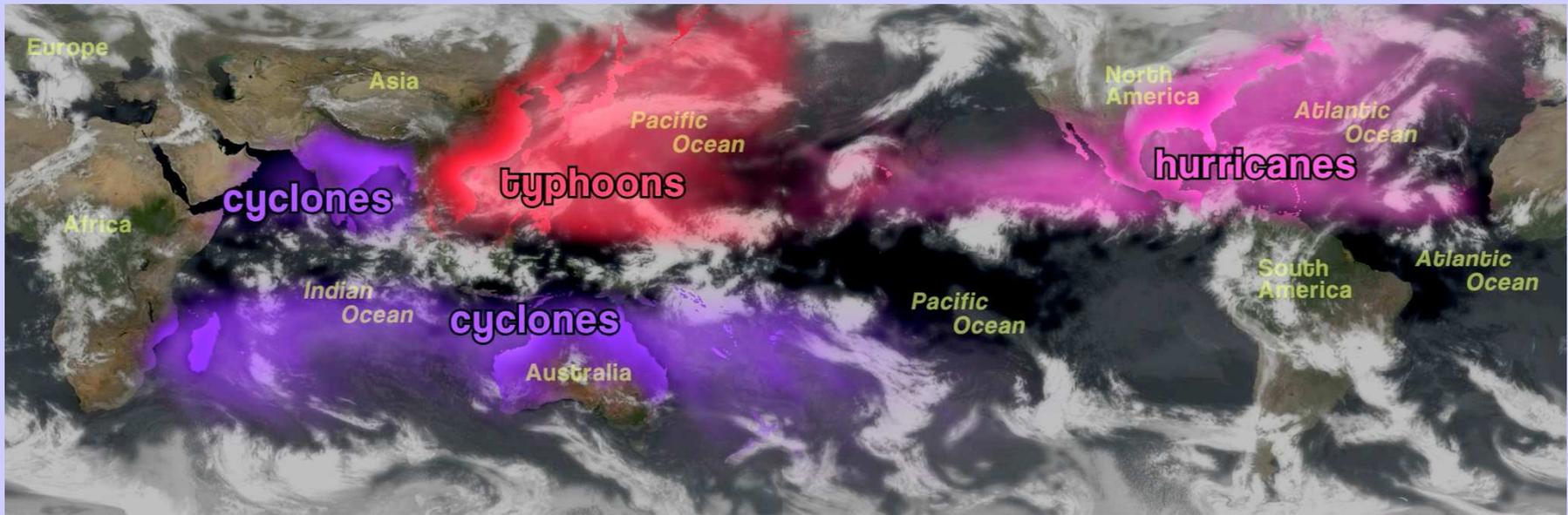
$H \equiv 600 \text{ mb relative humidity } (\%),$

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

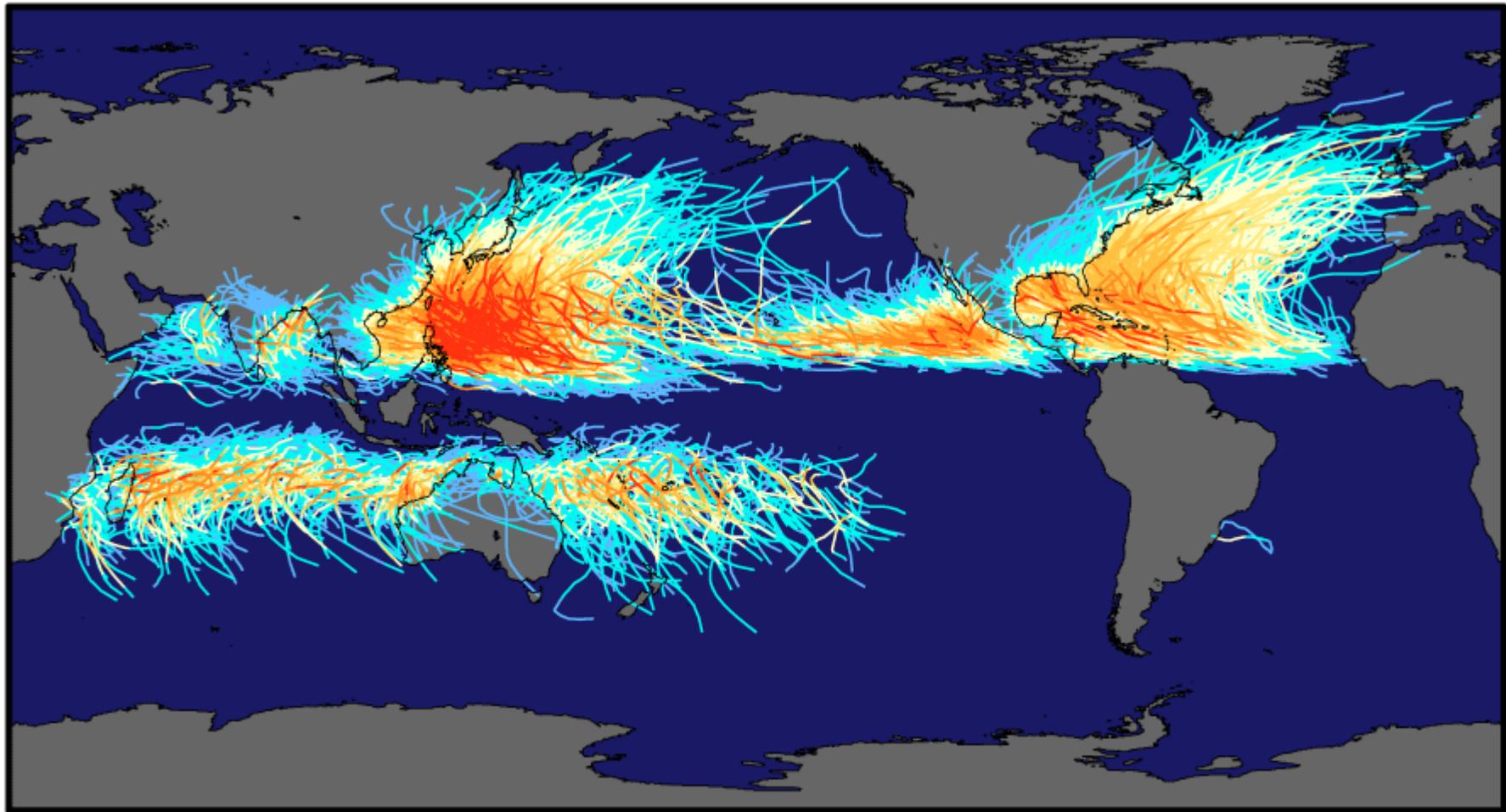
Índice Empírico de Génesis

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



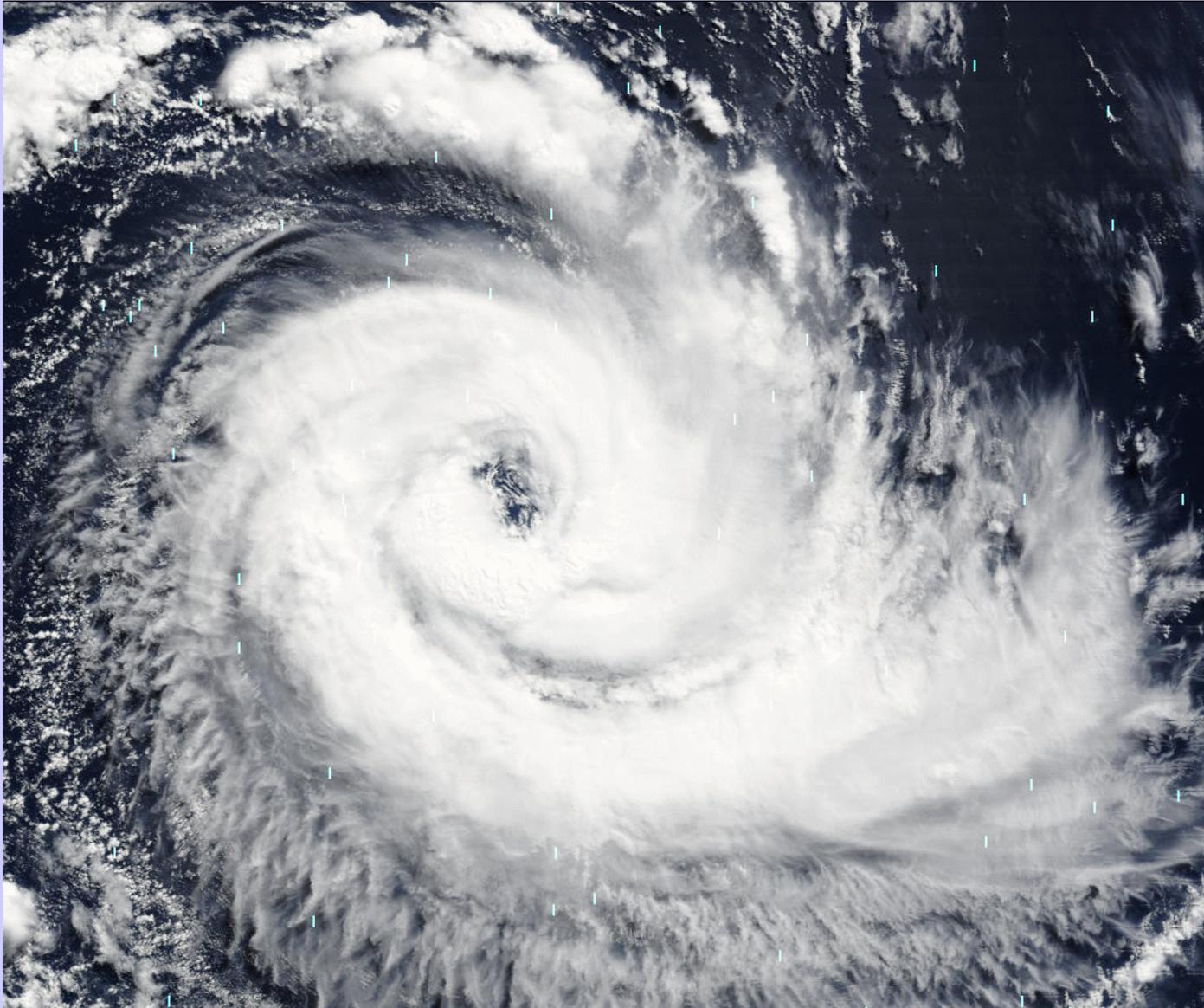


Tracks and Intensity of All Tropical Storms

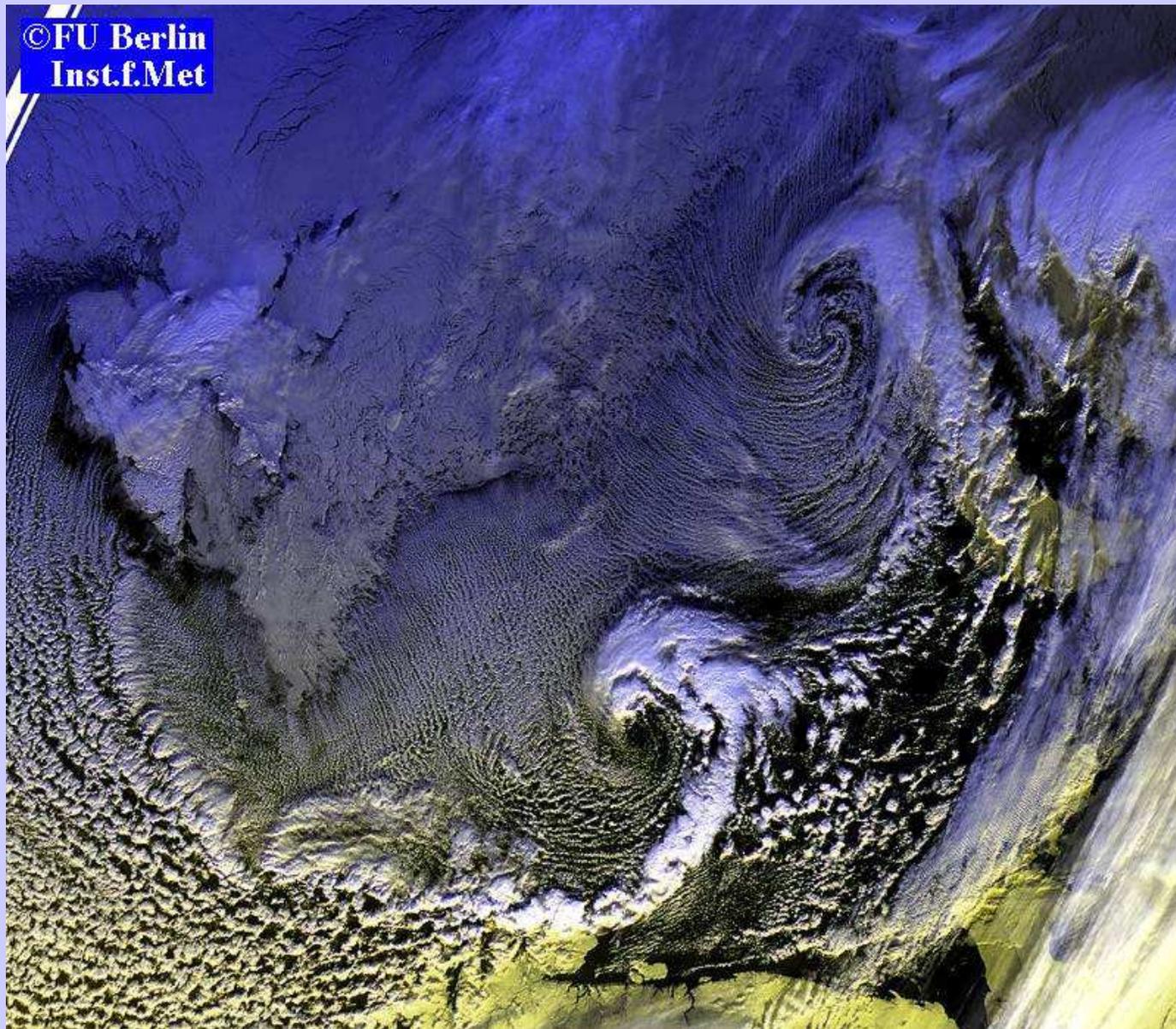


Saffir-Simpson Hurricane Intensity Scale

**Huracán Catalina (Brasil, marzo 2004),
formado a partir de una depresión fría en altura**



Bajas Polares

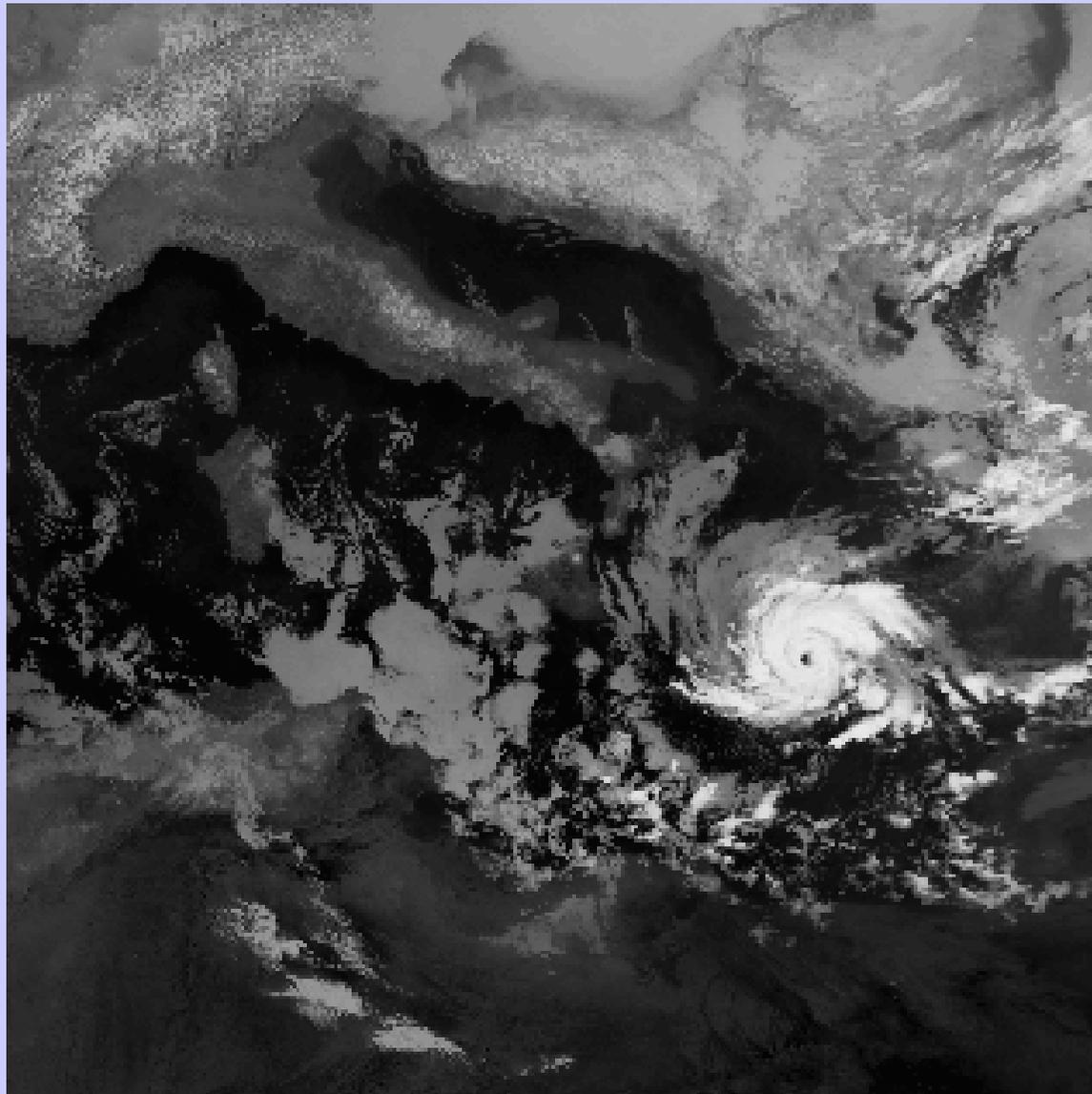


MEDICANES

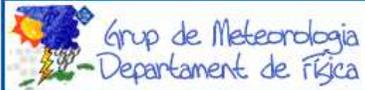
(miniciclones, ciclones cuasi/sub-tropicales ...)

- ~**1-2 por año** en el conjunto de la cuenca mediterránea, rara vez alcanzando la categoría de huracán (120 km/h).
- Típicamente, se forman bajo el efecto de una **depresión fría y aislada** en los niveles medio-altos de la troposfera.
- Se sustentan en el elevado desequilibrio termodinámico **aire-mar** propiciado por la perturbación primaria. Son más frecuentes en **otoño**.

Medicane del 15-17 Enero 1995



**MEDICANES (locals):
OBSERVACIONS I SIMULACIONS**



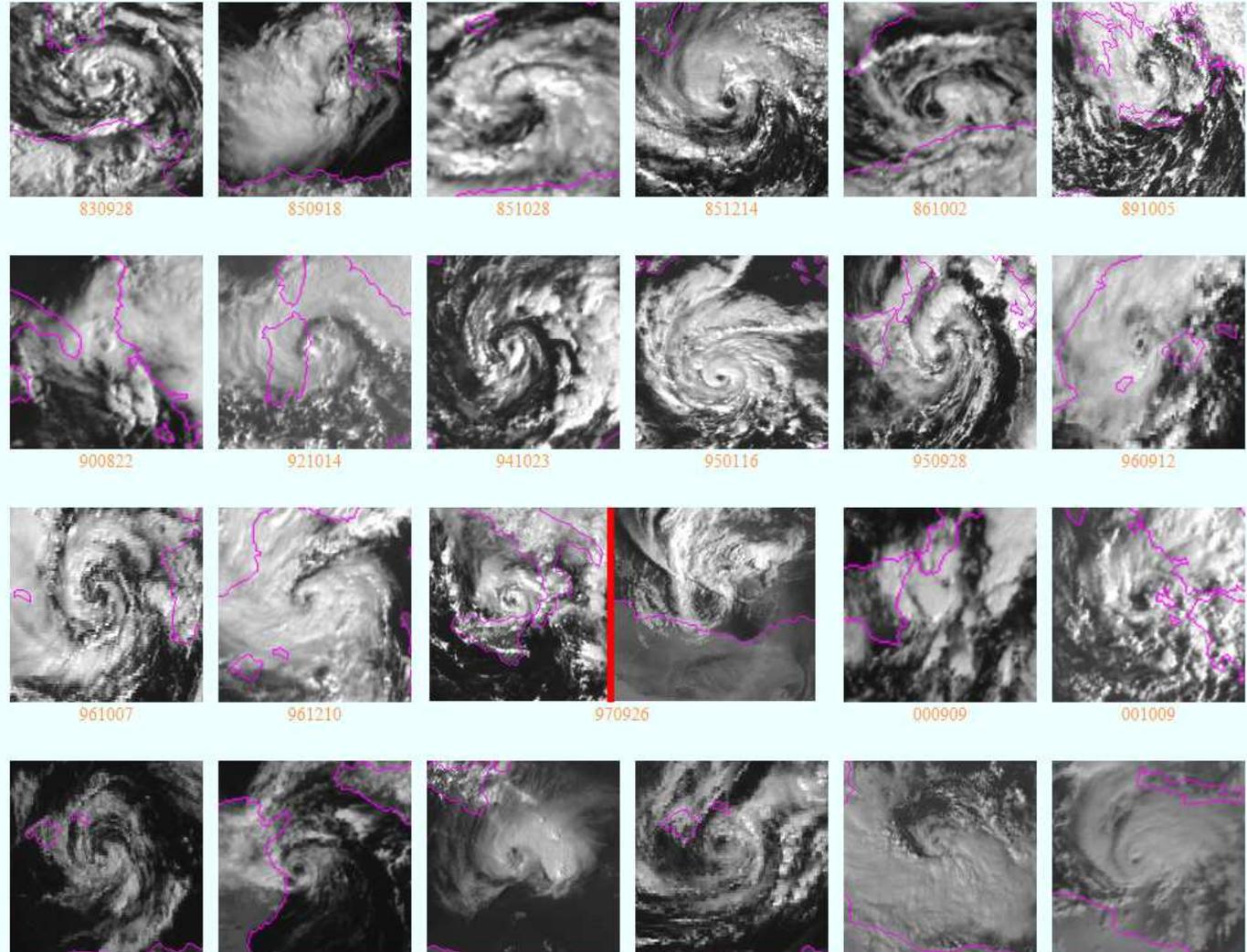
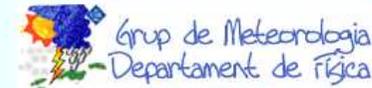
MEDICANES: Mediterranean tropical-like storms
Lluís Fita @

- Introduction
- Medicanes & Hurricanes
 - Dynamical evolutions
- Schemes
 - Evolution
 - Air-sea mechanism
- Cases
 - List of cases

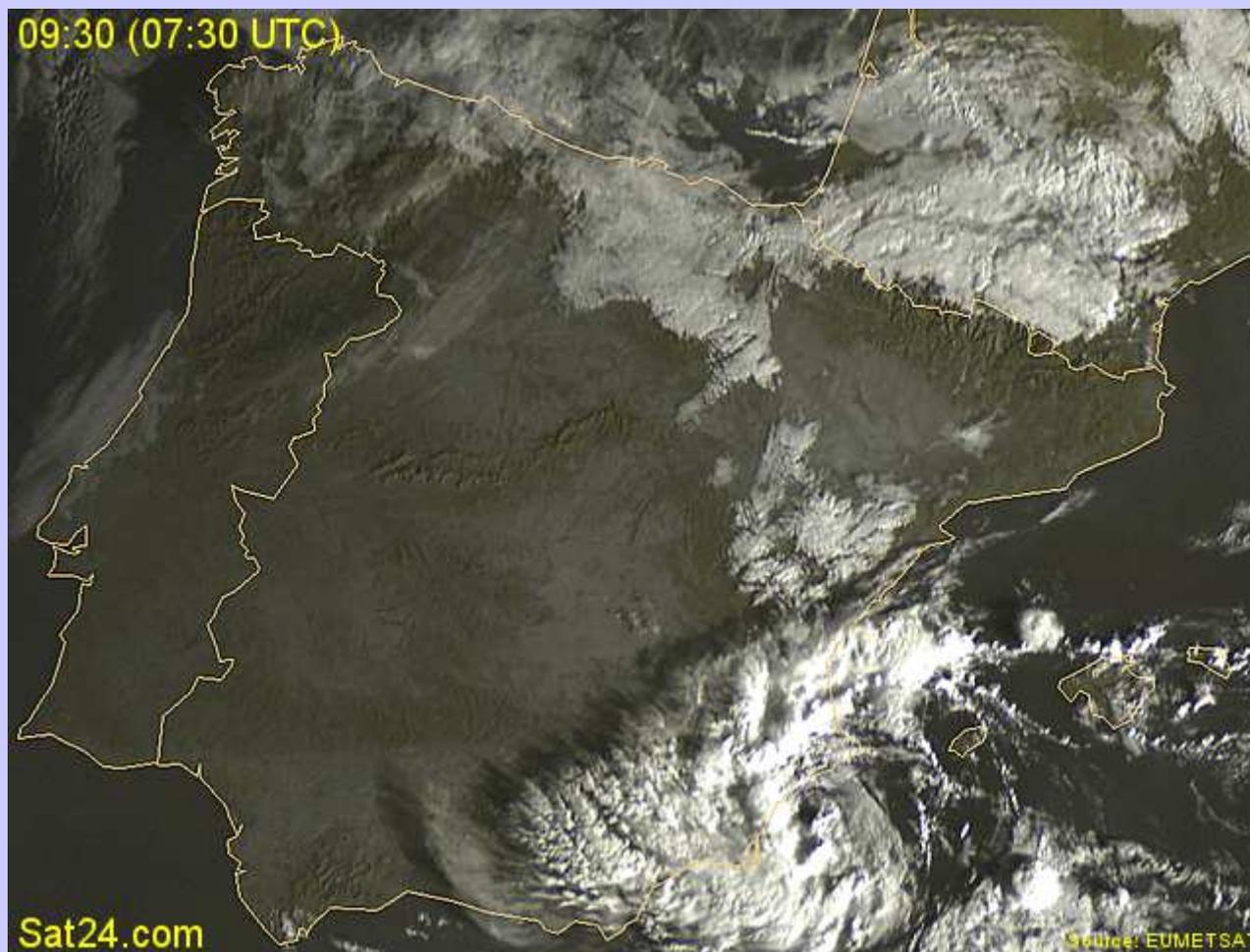
References

All images with a Eumetsat: (c)
Synoptic analyses are derived from ECMWF analyses

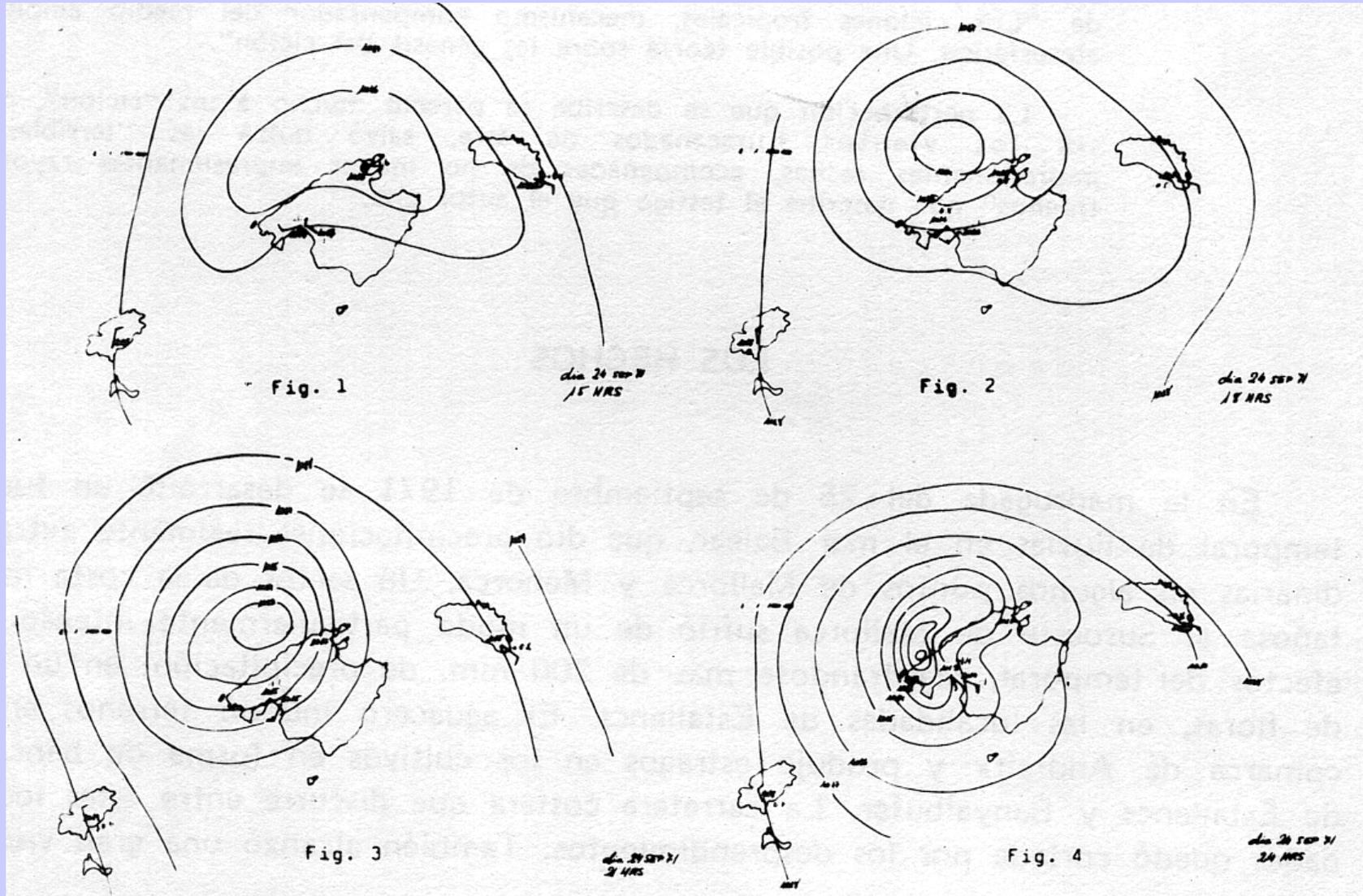
* Satellite images thanks to:
Angel Luque
* List of cases thanks to:
D. Bianchino, K. Emanuel, Iuka Milevoj and Wikipedia
* Schematic-animations thanks to:
Lorena Garcies
* Barographs thanks to:
INM-Centre Meteorologic a les Illes Balears
* QuickScat winds thanks to:
Remote Sensing Systems
* Synoptic environment thanks to:
European Centre for Medium-Range Weather Forecasts (ECMWF)



Medicane del 18 Octubre 2007

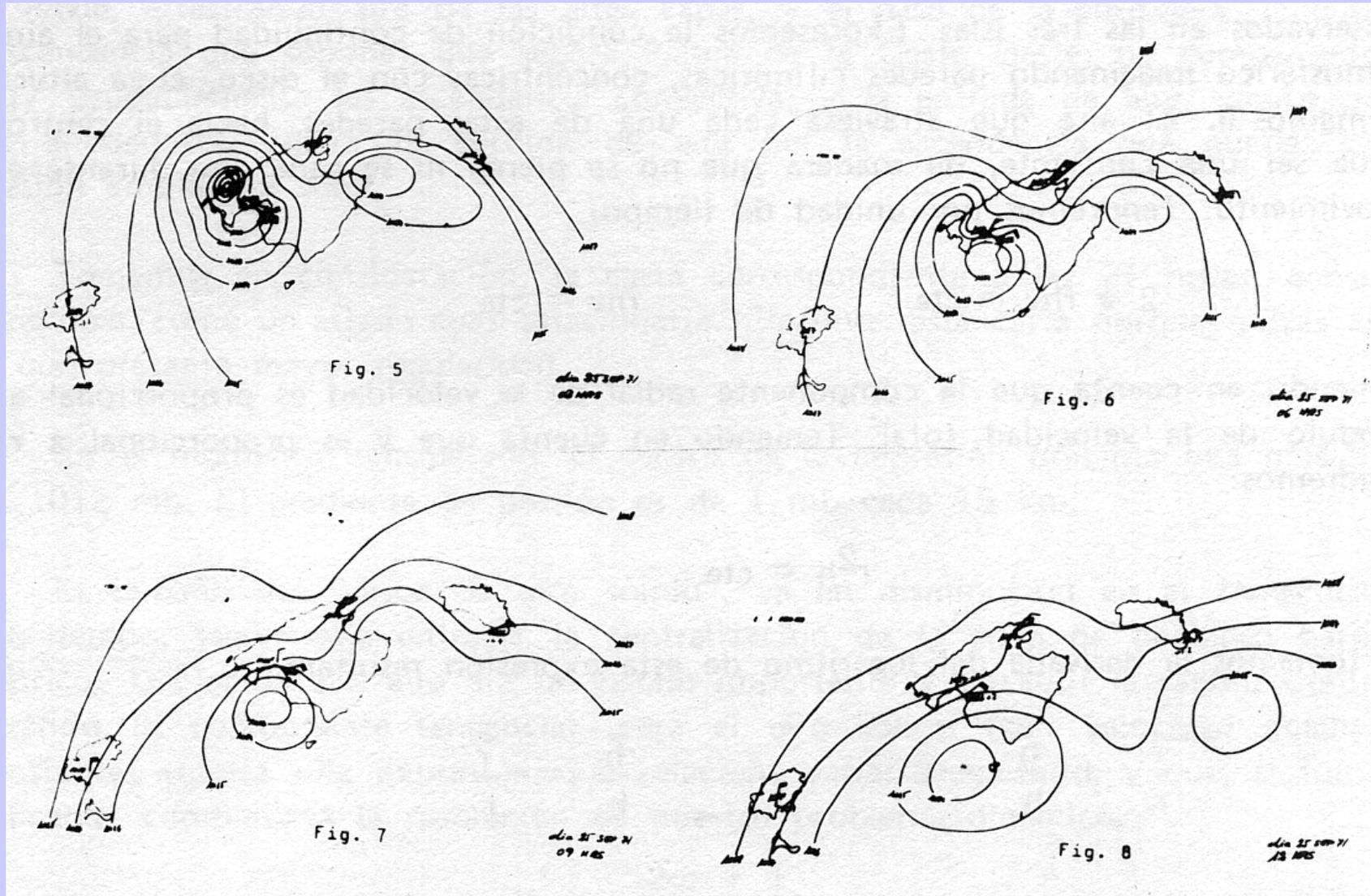


Medicane del 24-25 Septiembre 1971 ???



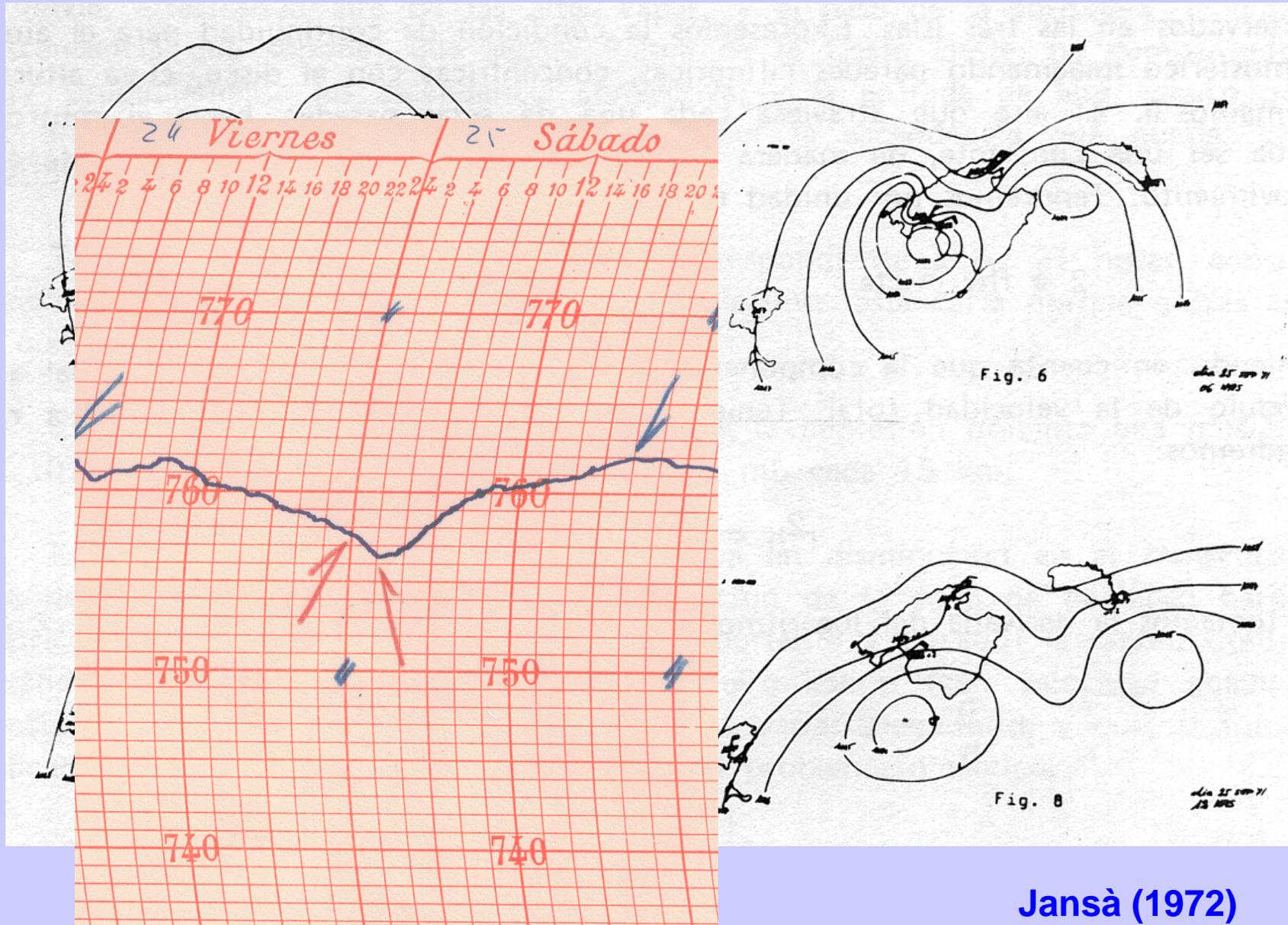
Jansà (1972)

Medicane del 24-25 Septiembre 1971 ???



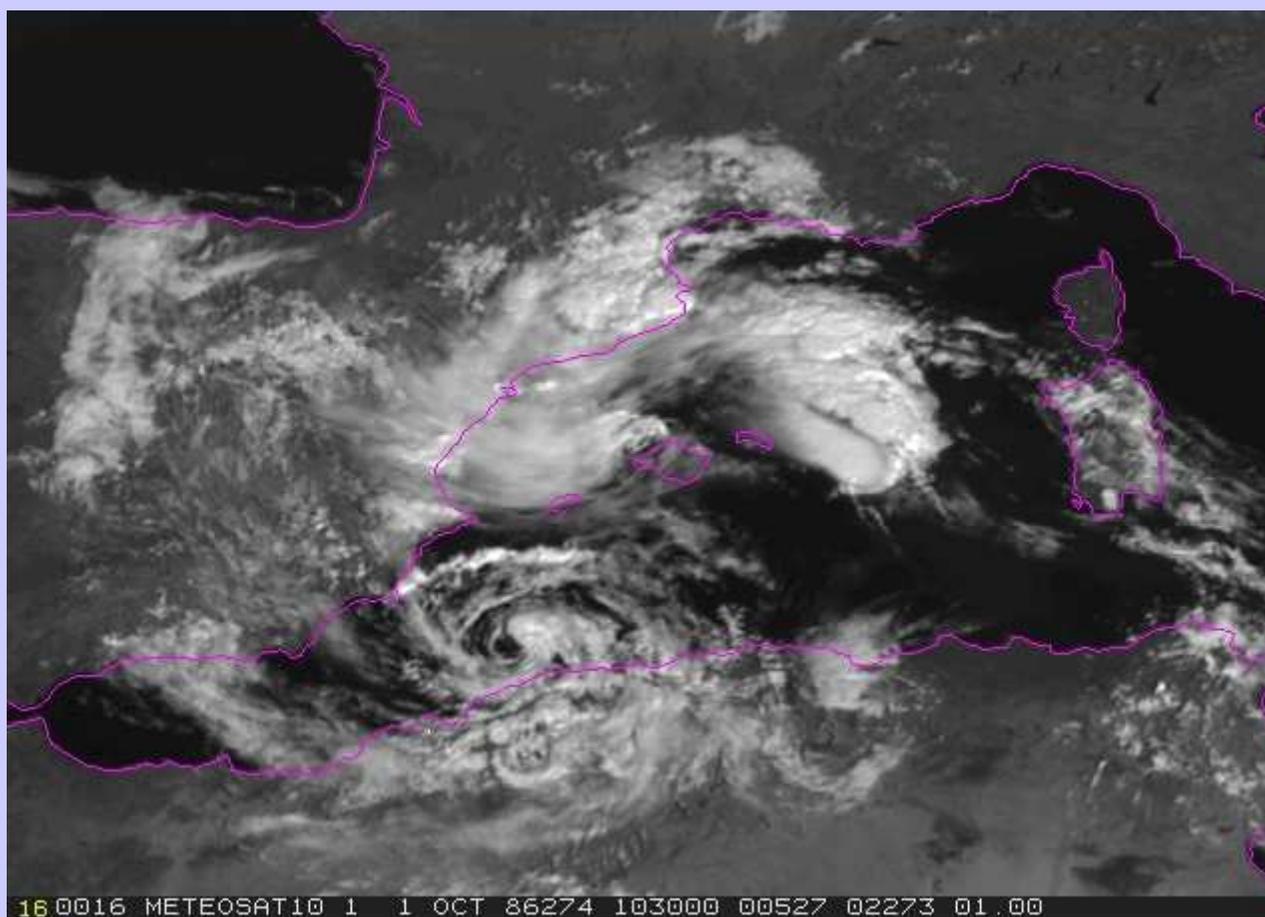
Jansà (1972)

Medicane del 24-25 Septiembre 1971 ???

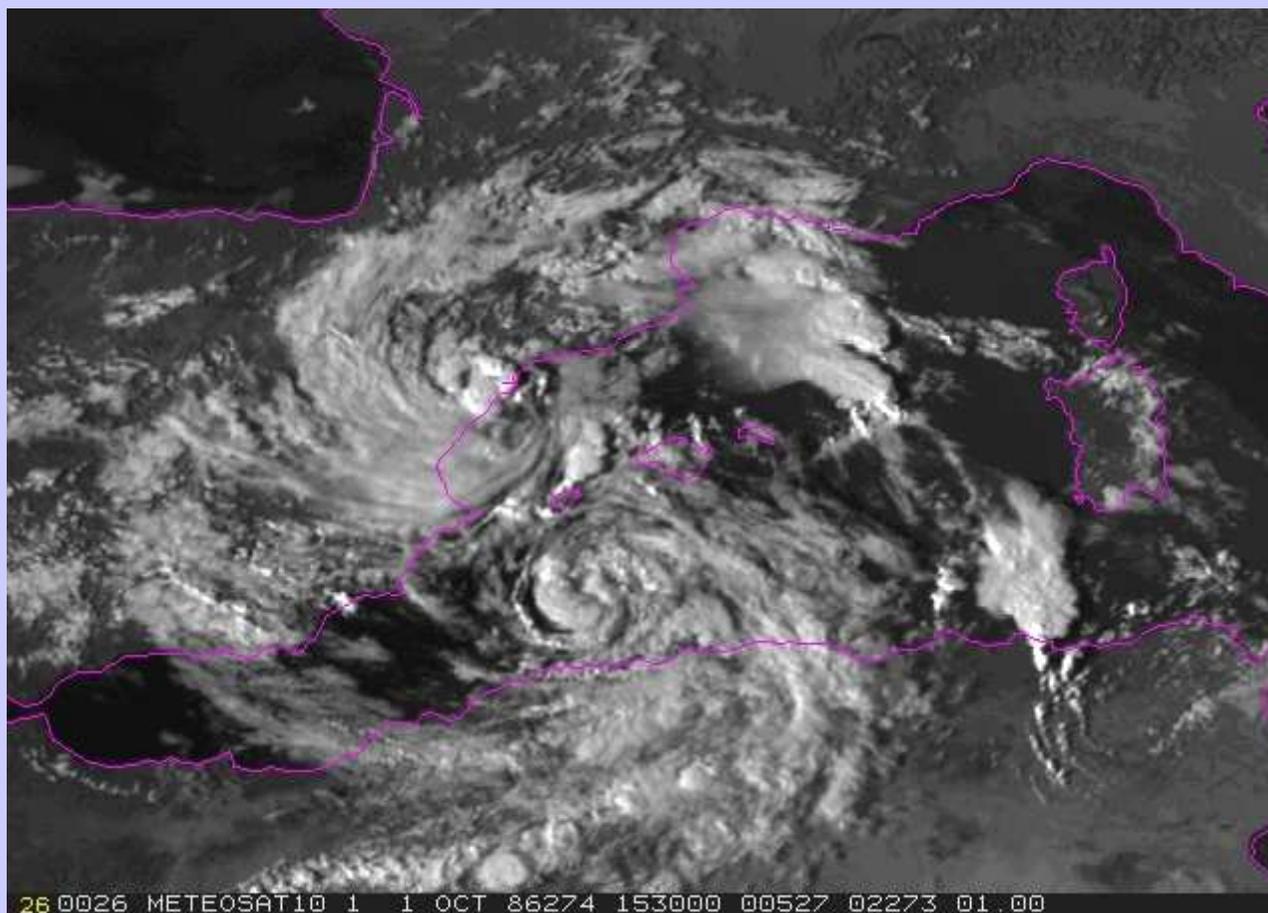


Jansà (1972)

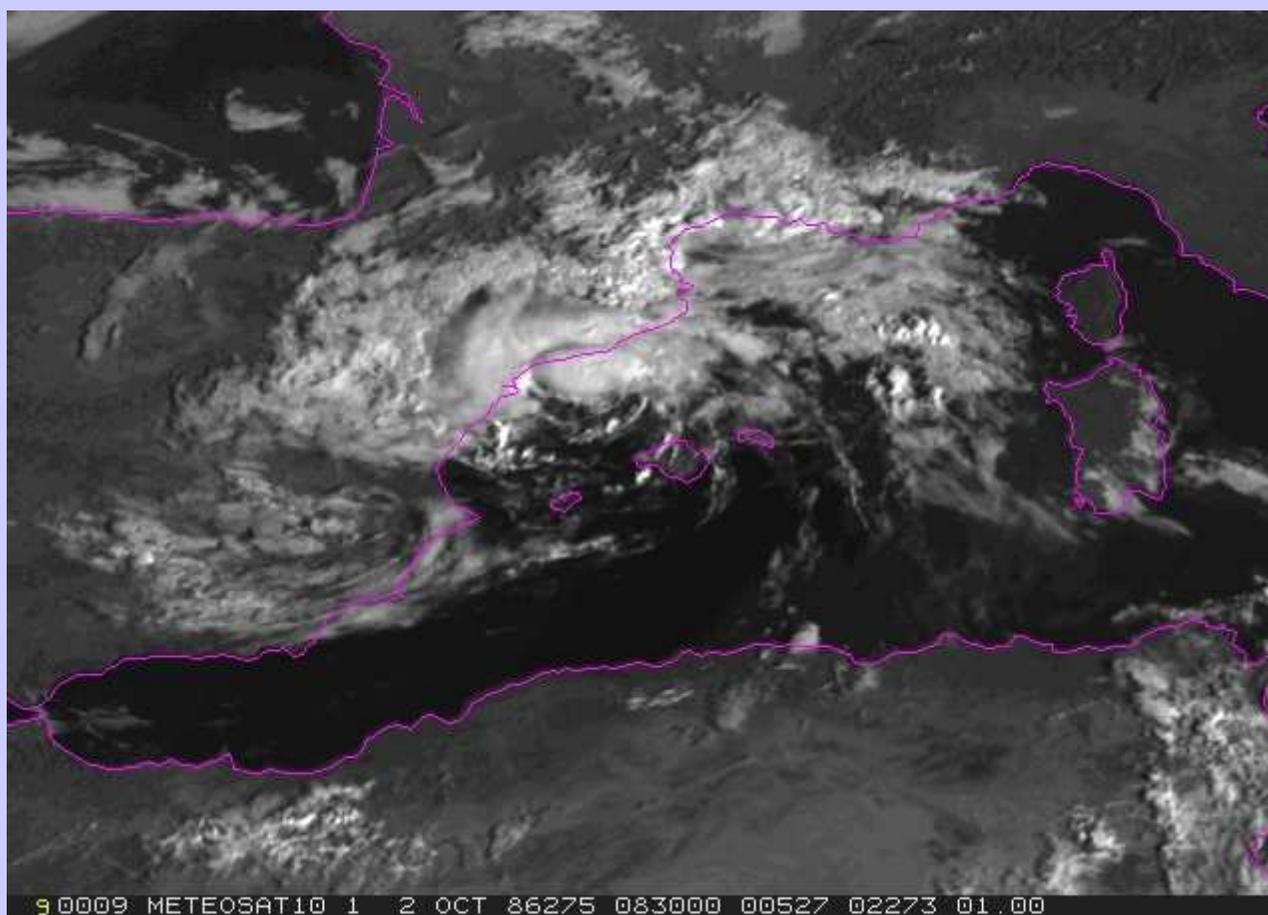
Medicane del 2 Octubre 1986



Medicane del 2 Ottobre 1986



Medicane del 2 Ottobre 1986



Medicane del 2 Octubre 1986

Diario de Ma

Palma, viernes 5 de octubre de 1986

Año XXXIV - N.º 16.661 - Precio 50 Ptas. - V.A. incluido - Editora Relsar, S.A. - Calle 1.ª - Tel. 716.443 - C.I.

Las pérdidas, aunque no han sido evaluadas, podrían ascender a varios cientos de millones

El ciclón destruyó unos veinte barcos de recreo en el Paseo Marítimo



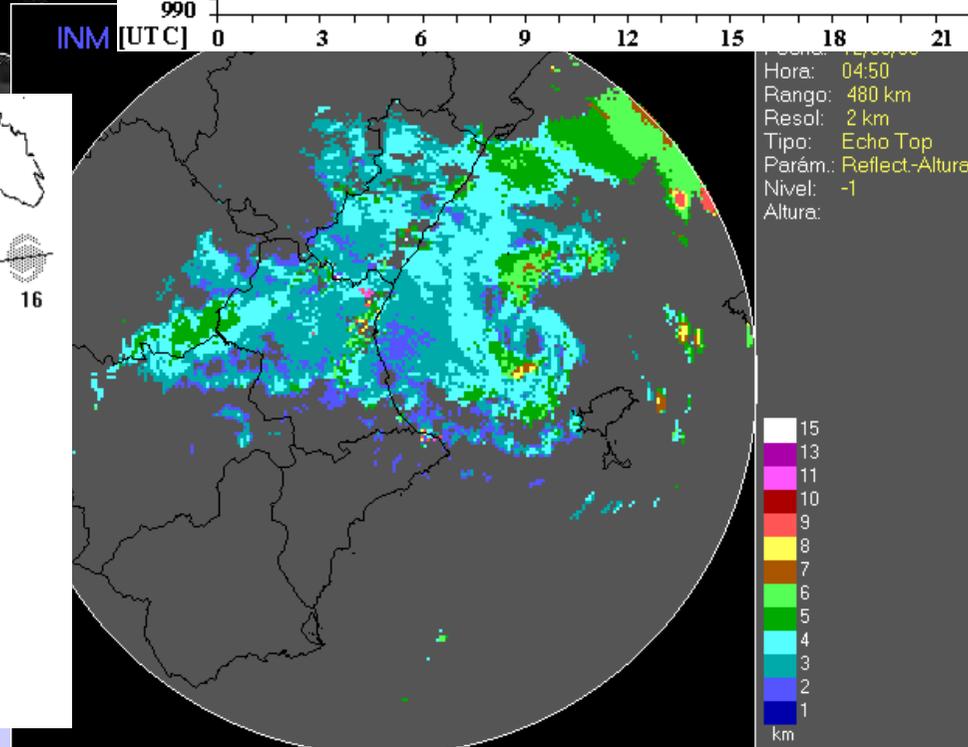
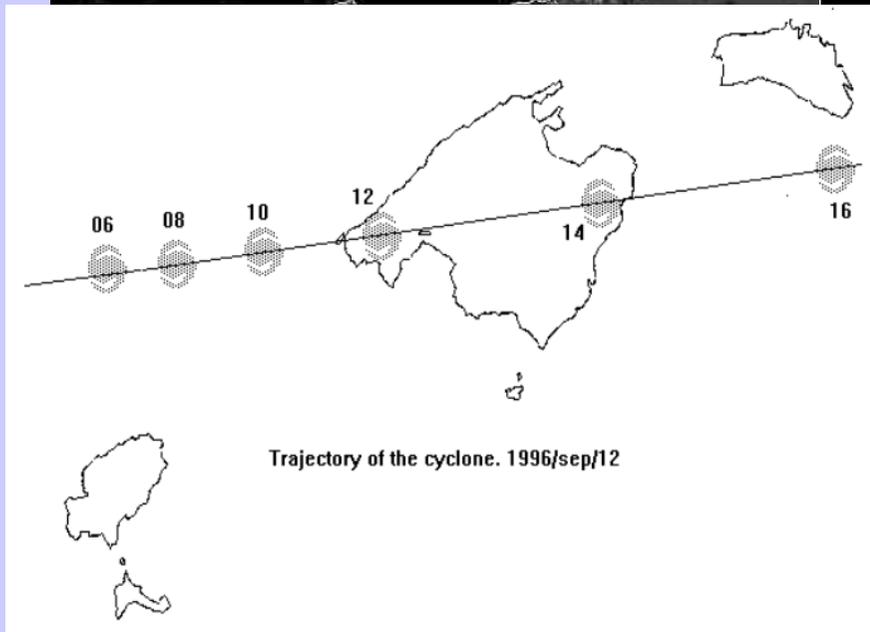
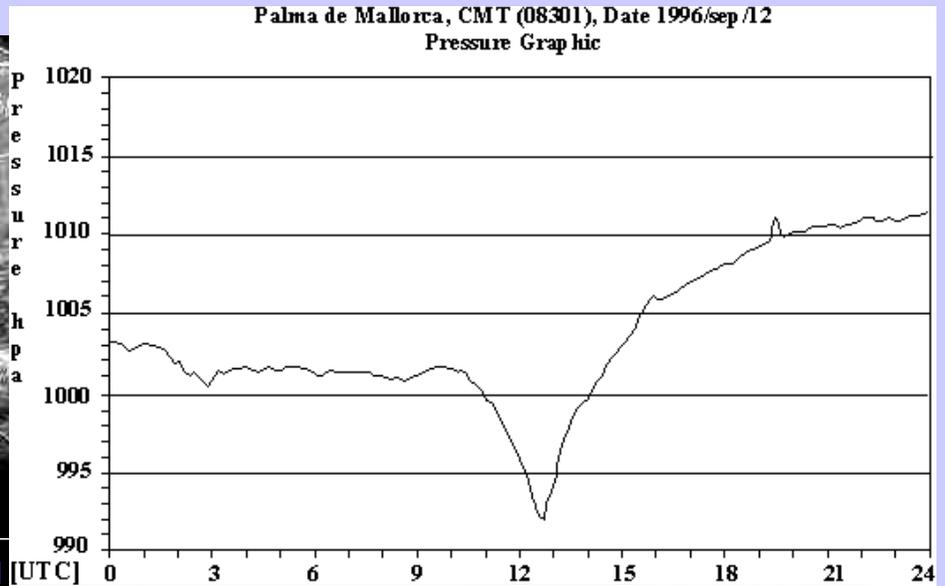
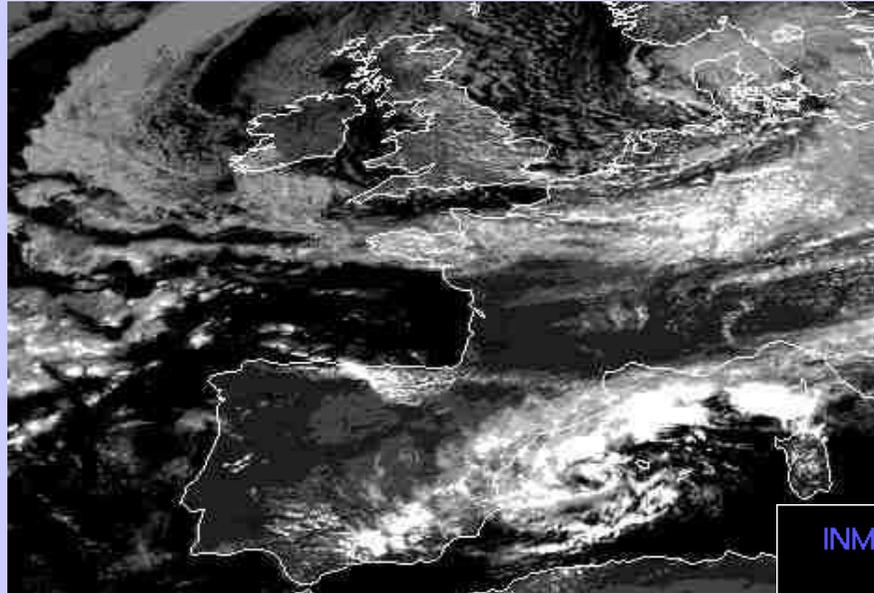
Mallorca se vió ayer sorprendida, a horas de la madrugada, con un viento llo que llegó a alcanzar en ocasiones los 100 kilómetros por hora, y que causó serios daños en distintos puntos de la isla, afectando especialmente al Paseo Marítimo de Palma, donde se produjeron numerosos daños a una veintena de barcos allí amarrados. El viento comenzó a estragarse en la isla alrededor de las 10 horas de la madrugada. Los daños causados pese a haber sido evaluados pueden ascender a varios cientos de millones. El fuerte viento estuvo acompañado de fuertes precipitaciones que llegaron a alcanzar en la zona de Sóller los 100 litros por metro cuadrado. Tanto los bomberos de Palma como los efectivos de la Policía Local se vieron obligados a llevar a cabo un trabajo desde las tres de la madrugada hasta bien entrada la tarde. Las previsiones de los bomberos como de la Unidad de Inteligencia Inmediata, se vieron desbordadas, a causa del fenómeno climatológico. Dentro de Palma la mayor actividad estuvo motivada por la caída de árboles y postes del tendido eléctrico y teléfono que afectaron a doce turismo aparcados en el paseo. Según las previsiones del Instituto Nacional de Meteorología, la "gota fría" puede afectar a la isla en las próximas horas.

(Página 1)

Destrozos en el puerto. - En el puerto el pequeño ciclón causó estragos en embarcaciones. Algunas se hundieron, otras, a causa de la fuerza del viento, rompieron amarras y sufrieron posteriores y violentas colisiones contra los pantalanes de otros barcos, resultaron seriamente dañadas. Igualmente, se dañaron las instalaciones de "Bañoares Náutica", las cuales quedaron prácticamente desmanteladas. (Foto Lorenzo)



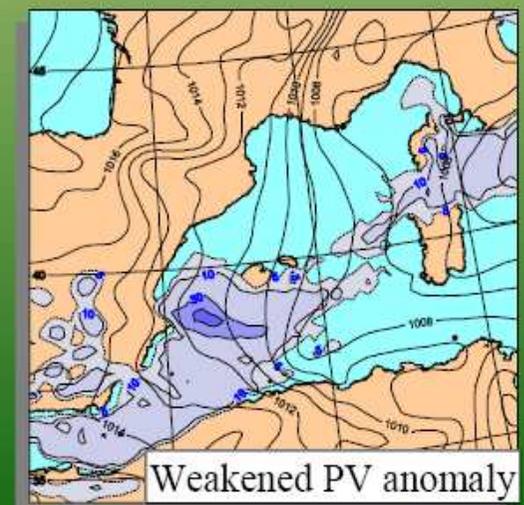
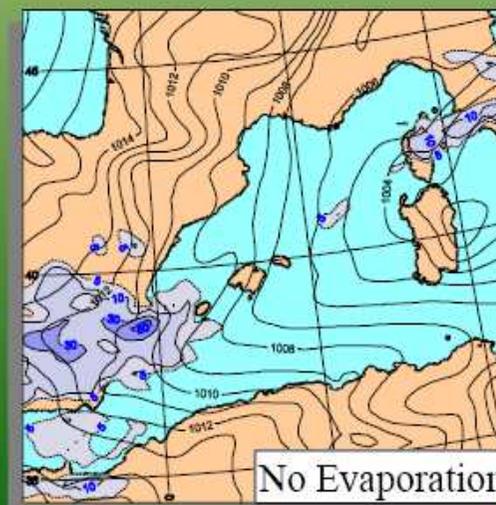
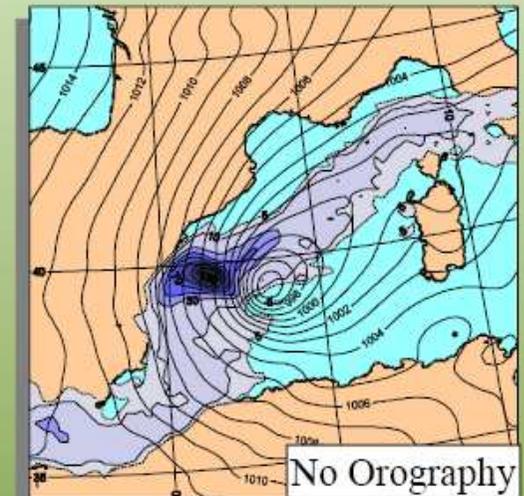
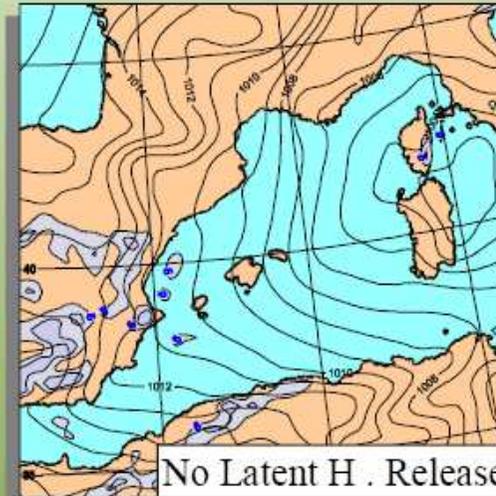
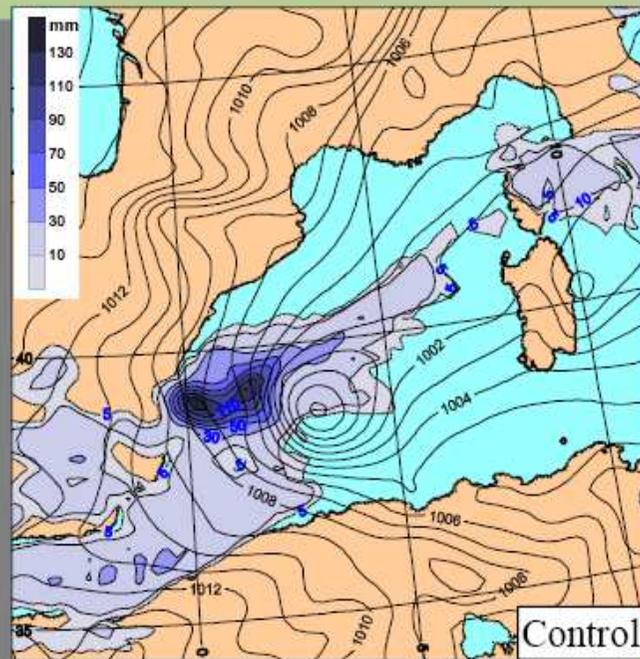
Medicane del 12 de Septiembre 1996



Medicane del 12 de Septiembre 1996

Sensitivity

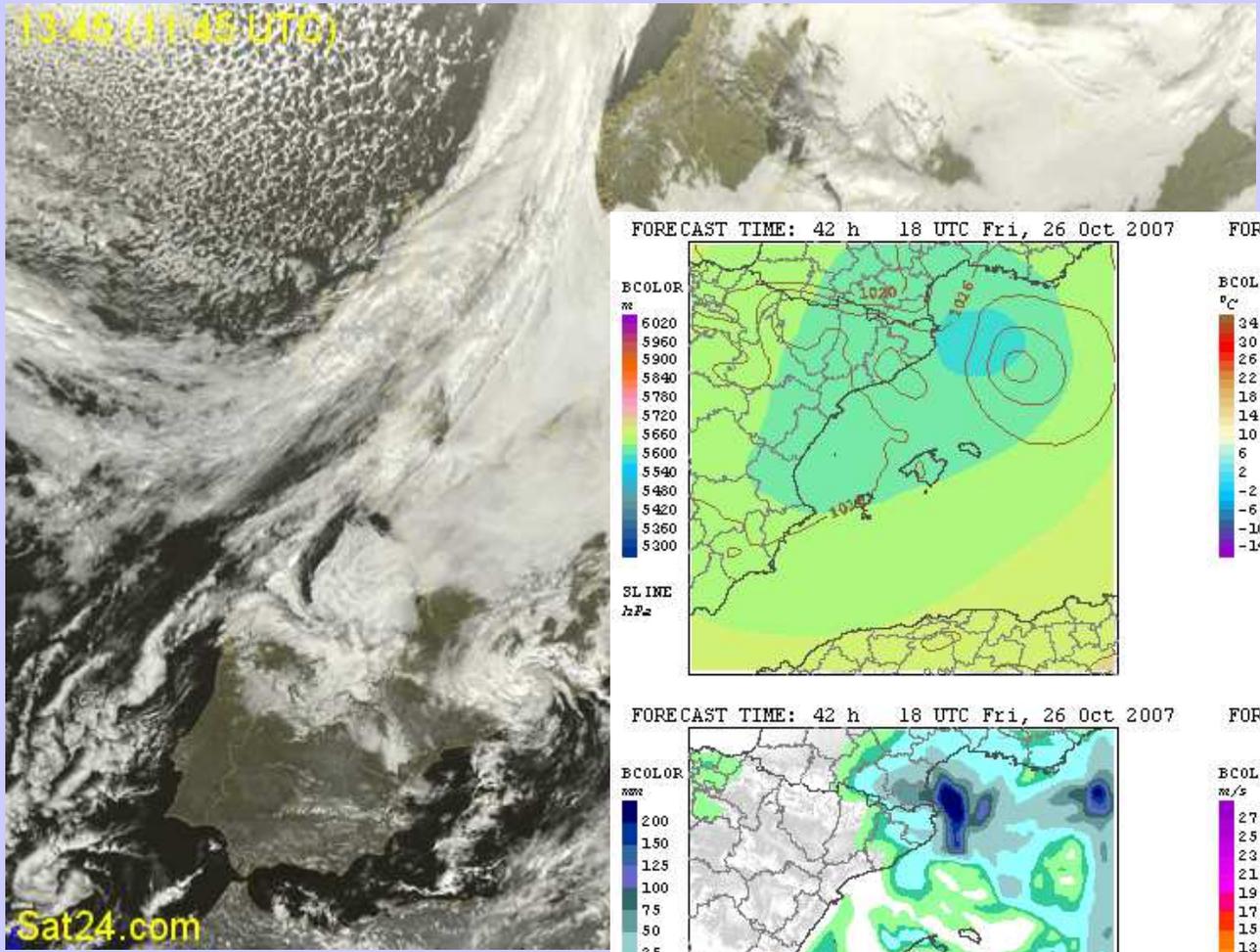
● Results of the sensitivity experiments in terms of surface pressure and accumulated precipitation at 1200 UTC:



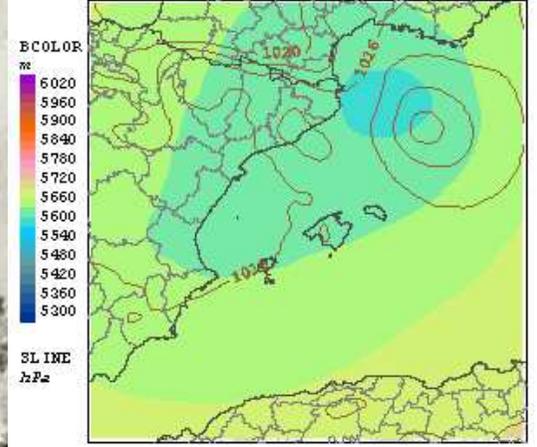
Homar et al.
(2003)

Medicane del 26 Octubre 2007

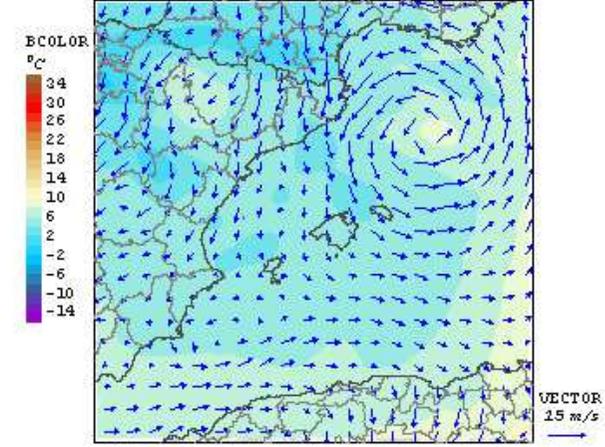
13:45 (11:45 UTC)



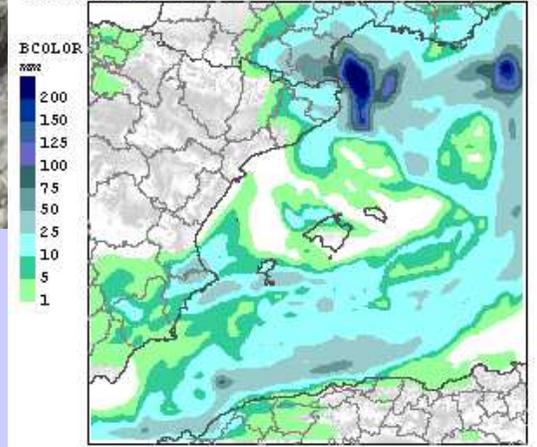
FORECAST TIME: 42 h 18 UTC Fri, 26 Oct 2007



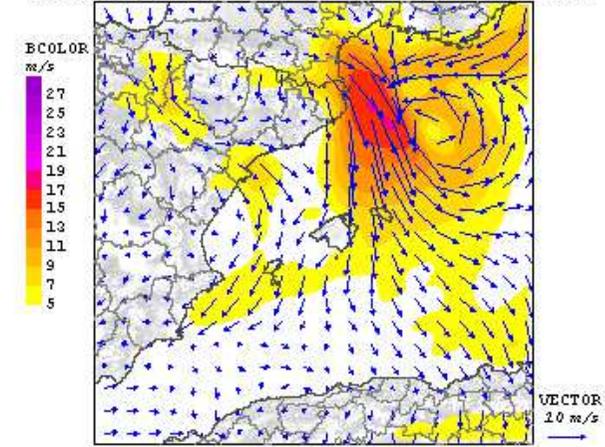
FORECAST TIME: 42 h 18 UTC Fri, 26 Oct 2007



FORECAST TIME: 42 h 18 UTC Fri, 26 Oct 2007

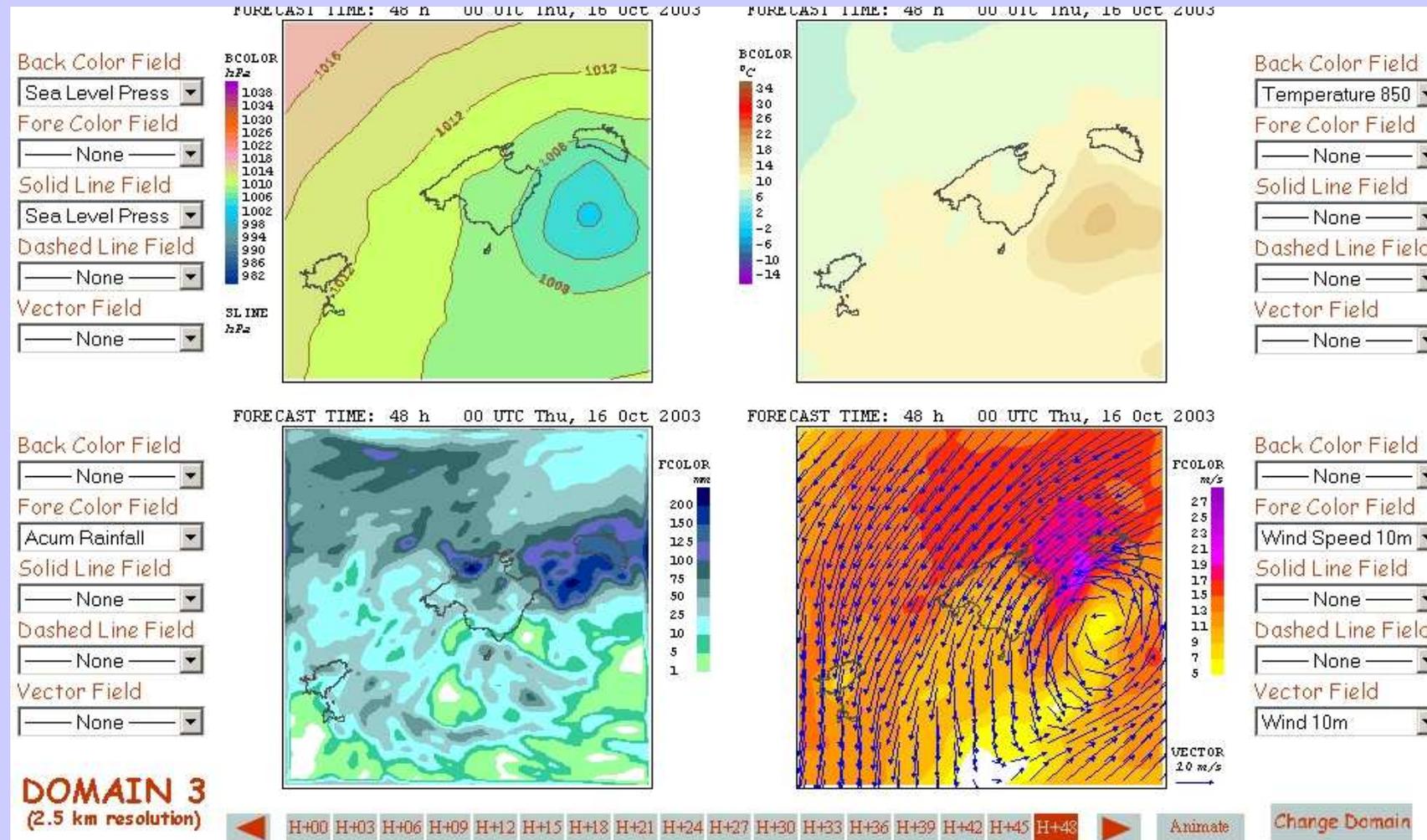


FORECAST TIME: 42 h 18 UTC Fri, 26 Oct 2007

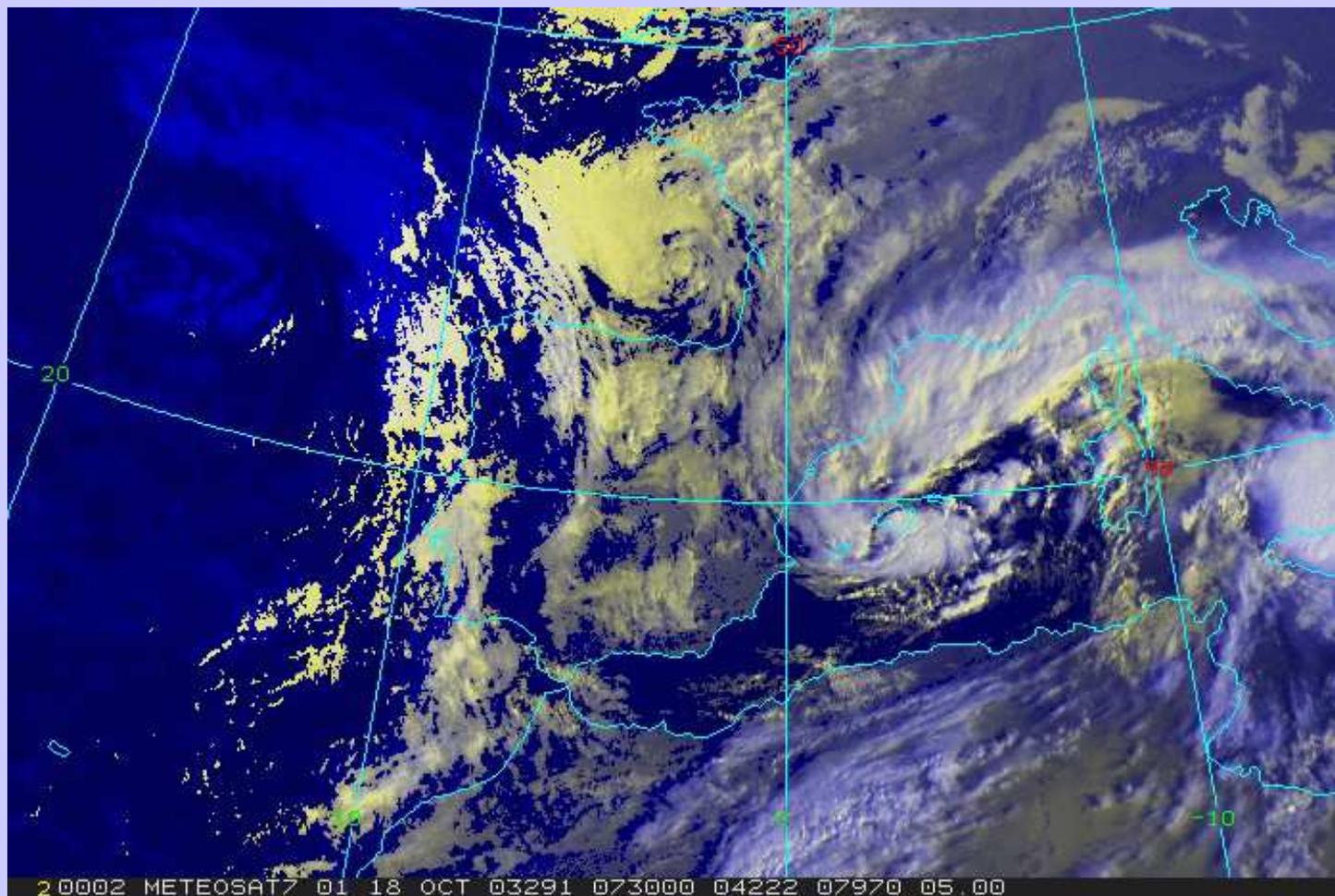


◀ H+00 H+03 H+06 H+09 H+12 H+15 H+18 H+21 H+24 H+27 H+30 H+33 H+36 H+39 H+42 H+45 H+48 ▶ Animate

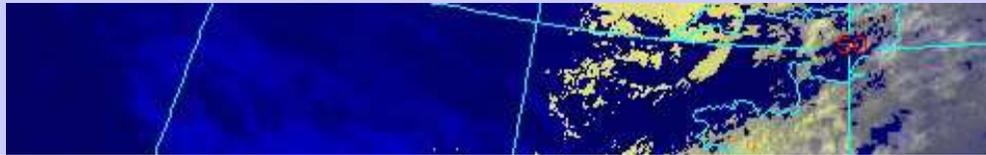
FALSO Medicane del 16 Octubre 2003



... PERO Medicane el 18 Octubre 2003

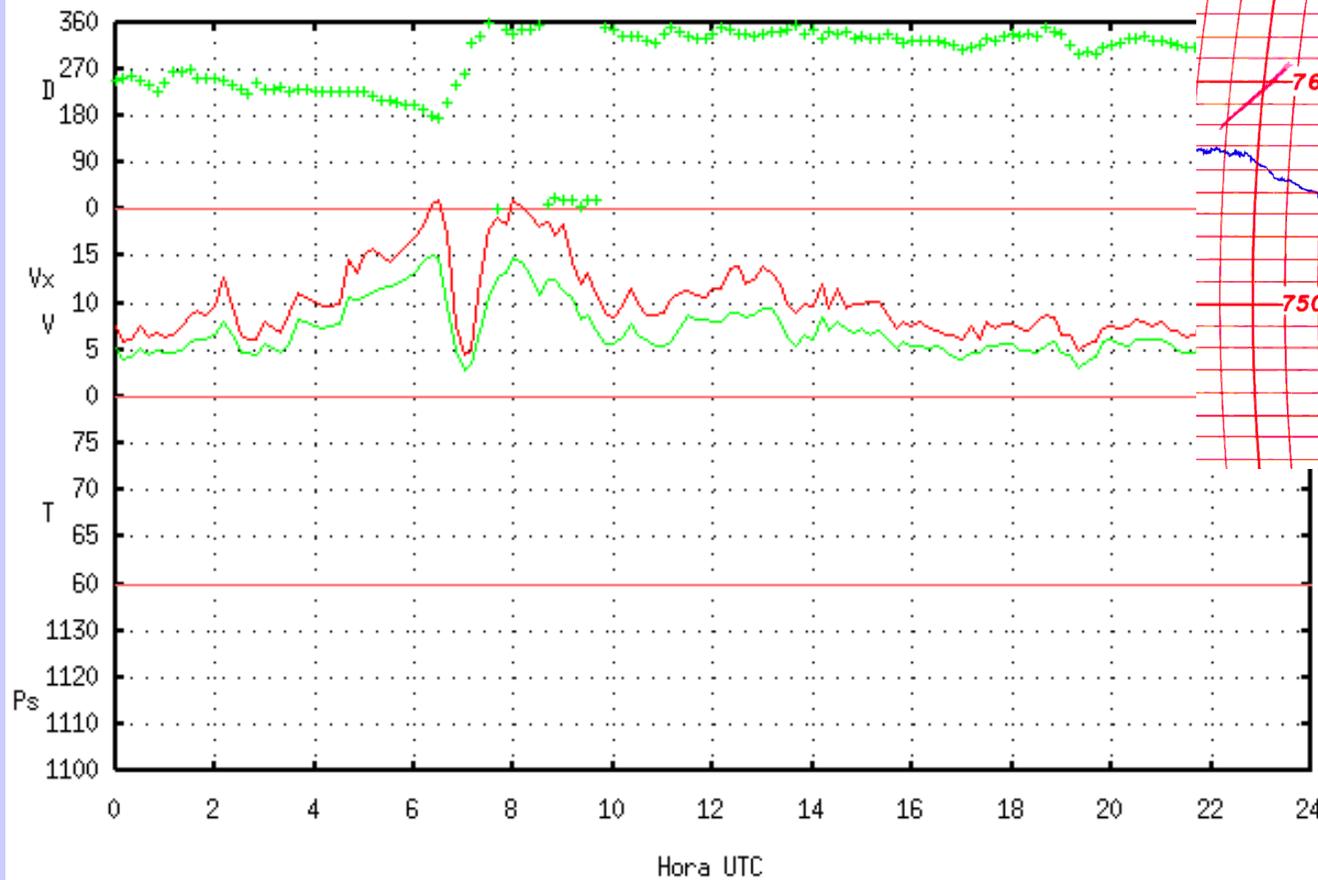


... PERO Medicane el 18 Octubre 2003

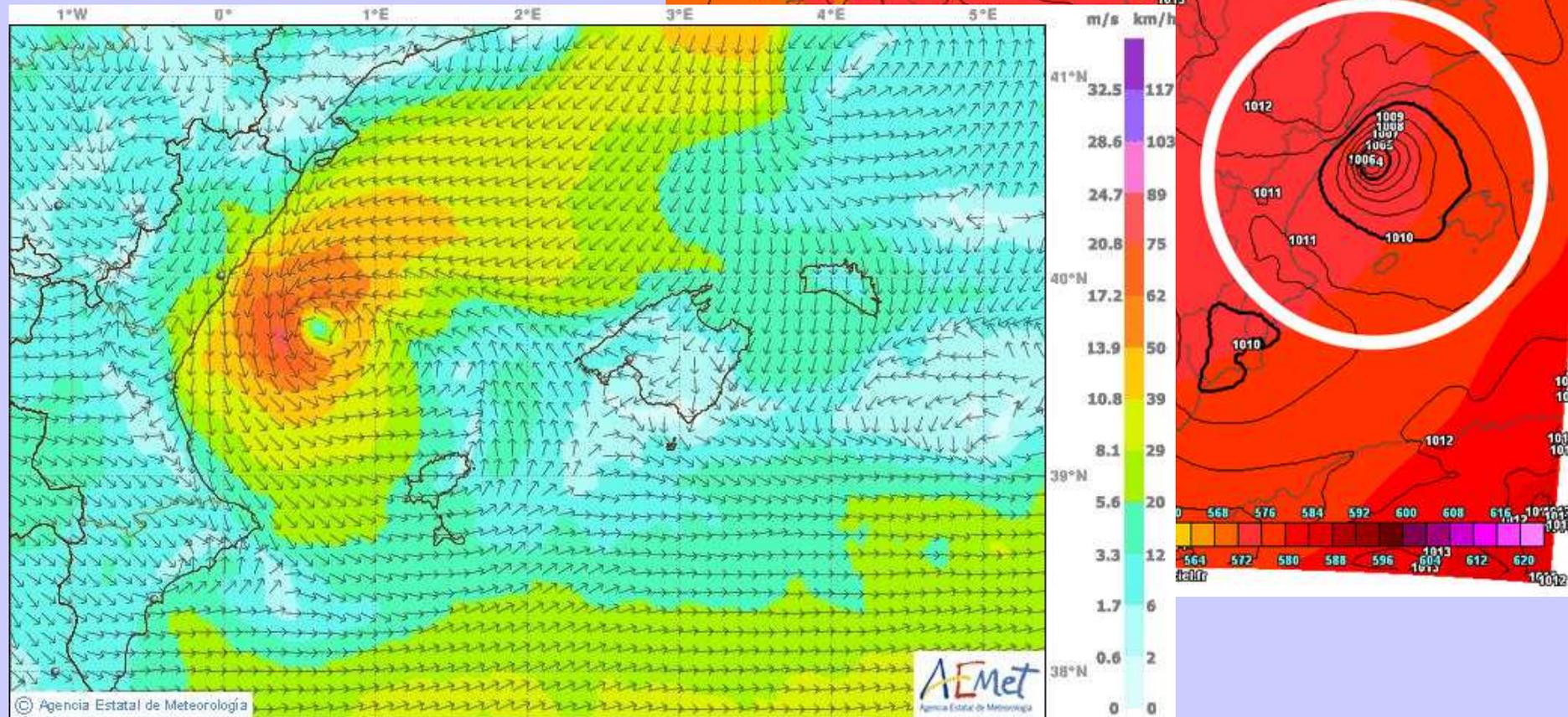
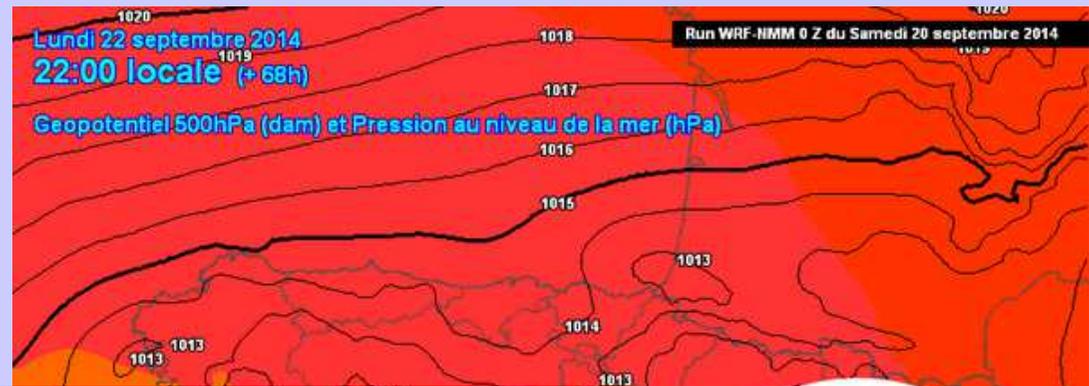


B228d - Palma Dic de l'oest

Dia 18-10-2003



FALSO Medicane del 22-23 Septiembre 2014

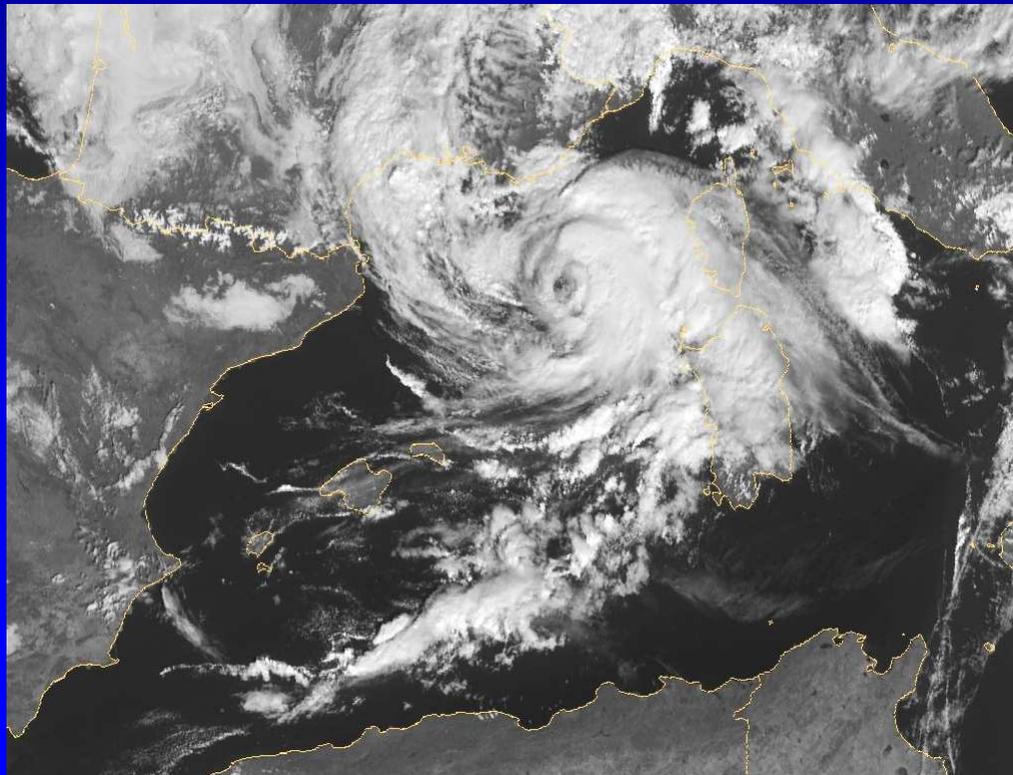


**MEDICANES:
RISC PRESENT I FUTUR**

MOTIVACIÓN

Los **Medicanes** son tempestades marítimas **potencialmente violentas** y que pueden afectar a las **islas y zonas costeras** del Mediterráneo:

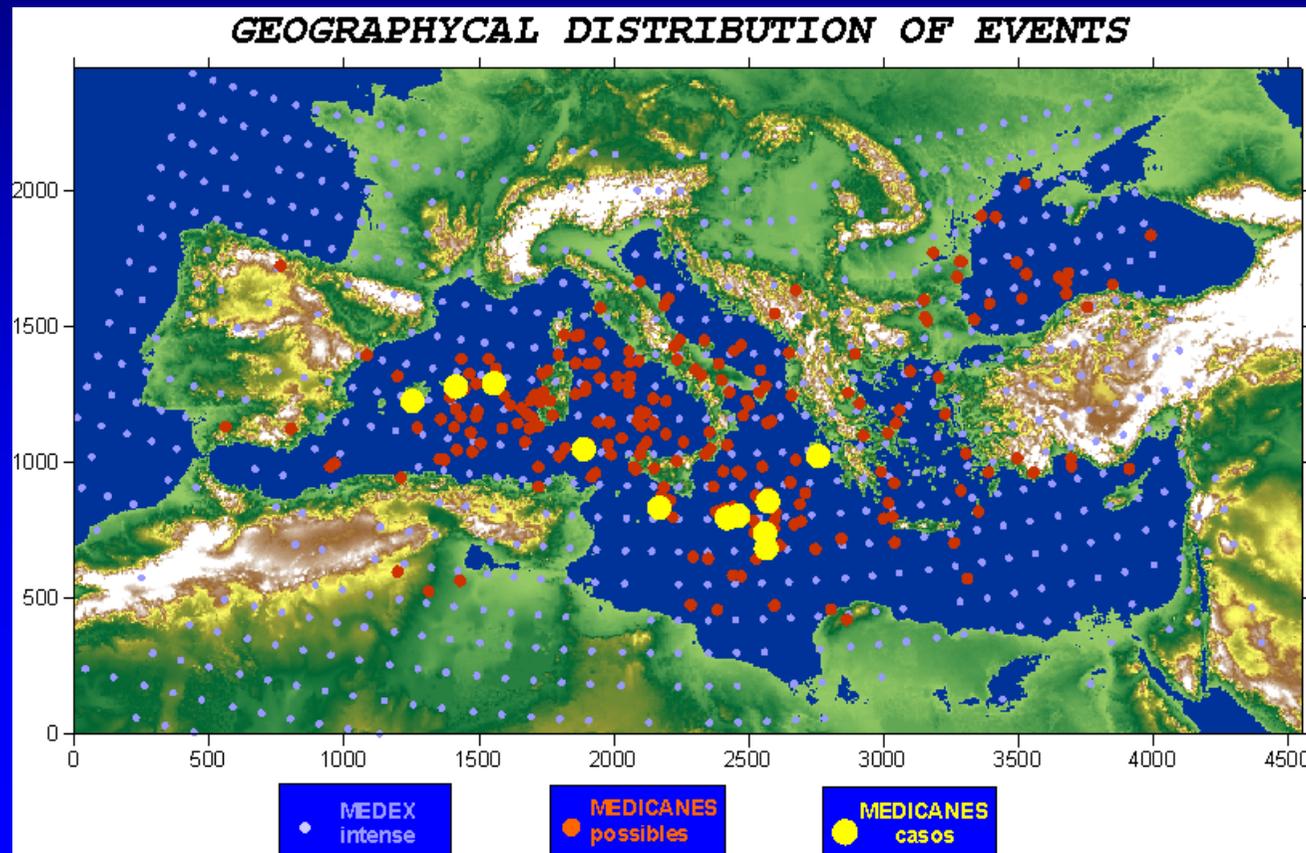
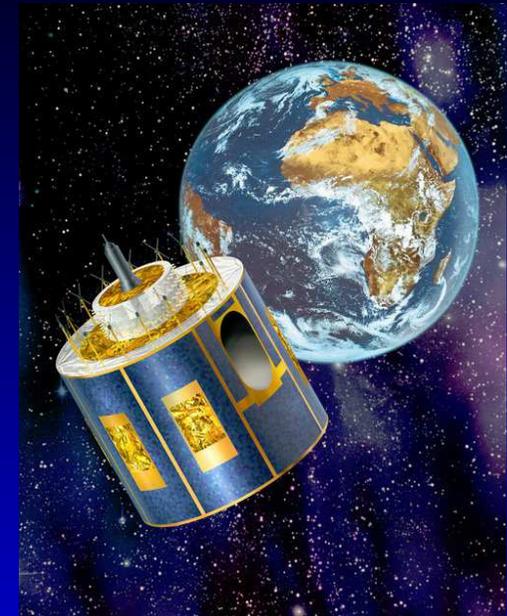
- **Existen zonas preferentes para el desarrollo de medicanes ?**
- **Qué intensidad pueden llegar a alcanzar ?**
- **Cambiará su frecuencia e intensidad con el cambio climático ?**



8 Noviembre 2011
(NOAA: INVEST 01M)

RIESGO DE MEDICANES ???

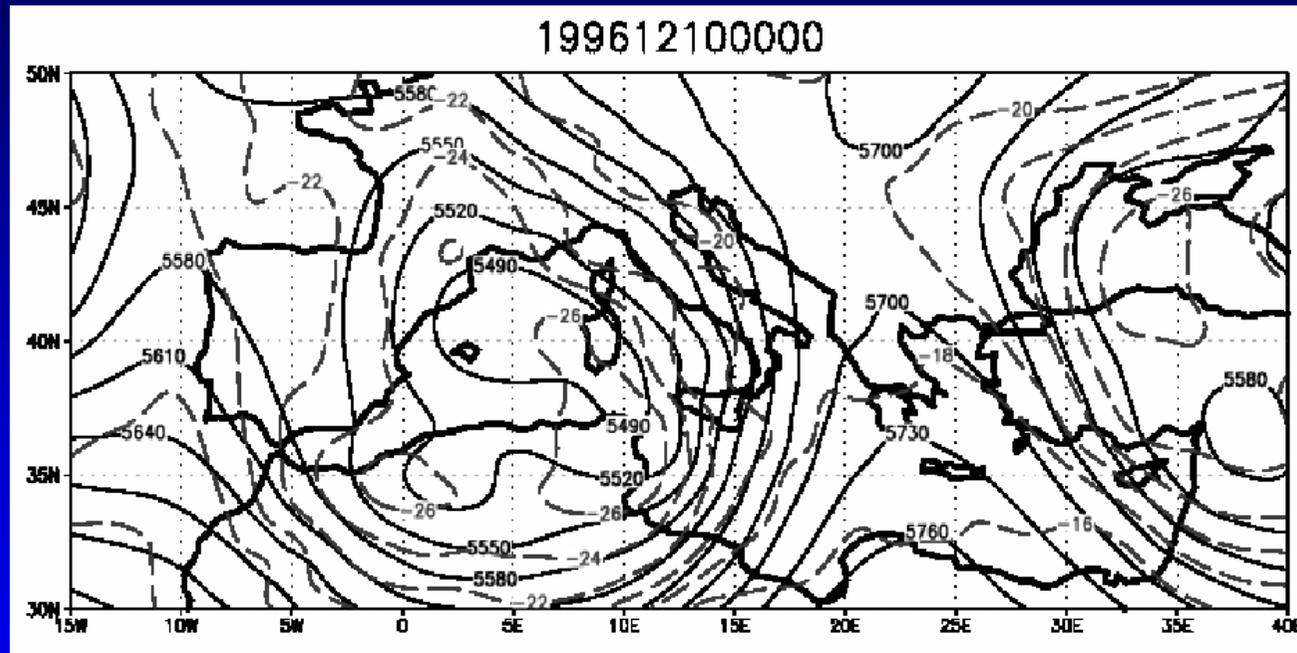
- Solo 1-2 casos por año !!!
- Cuantificación **difícil** con métodos clásicos



Base de datos (satélite)
(Tous and Romero, 2012)

APROXIMACIÓN: Ingredientes de gran escala

- **Bajas aisladas y frías** en la media y alta troposfera:



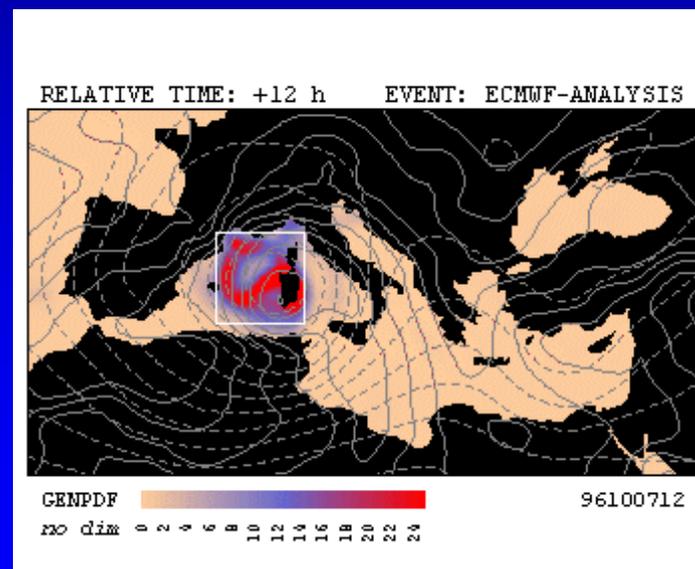
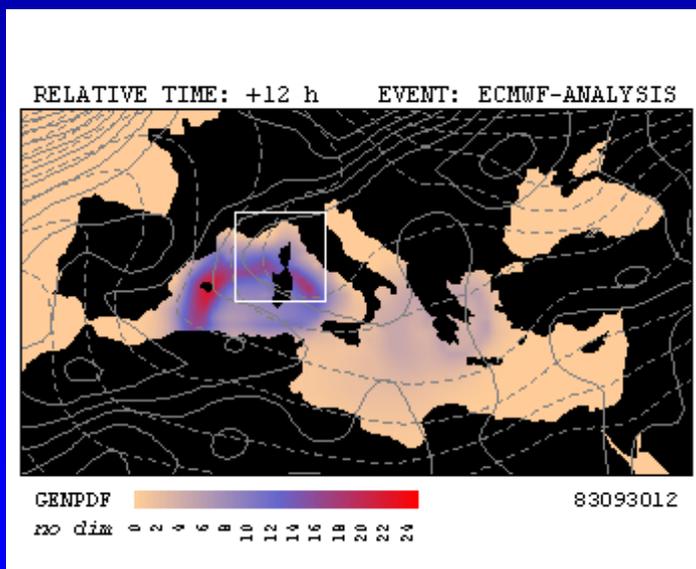
- **Pero** dada la rareza del fenómeno, deben existir **otras condiciones meteorológicas adicionales y muy especiales ...**

APROXIMACIÓN: Ingredientes de gran escala

- Aplicación del **índice empírico de génesis**:

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

Parámetro GENIX
(Emanuel and Nolan, 2004)

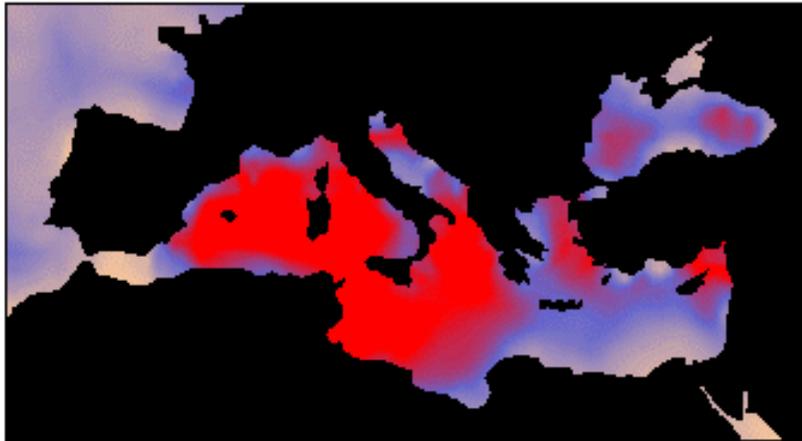


- Ingredientes **necesarios pero no suficientes ...**

APROXIMACIÓN: *Aplicación*

MONTH: Oct

REANALYSIS: ERA-40 1981-2000



GEMPDF

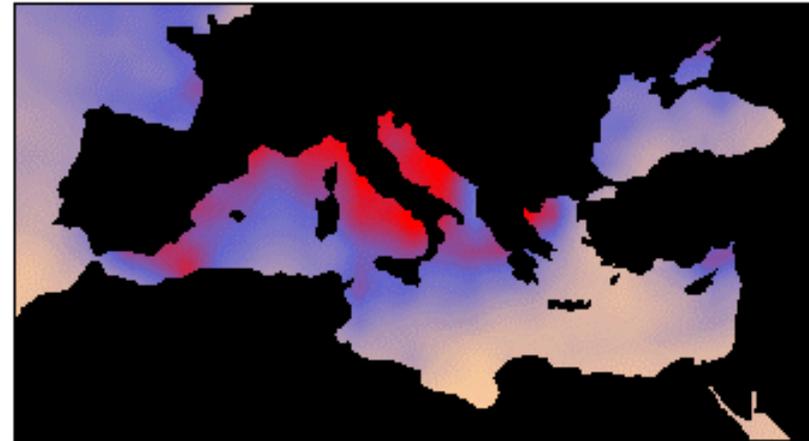
no dim



MEAN

MONTH: Oct

GCM: CSIRO-20C3M 1981-2000



GEMPDF

no dim

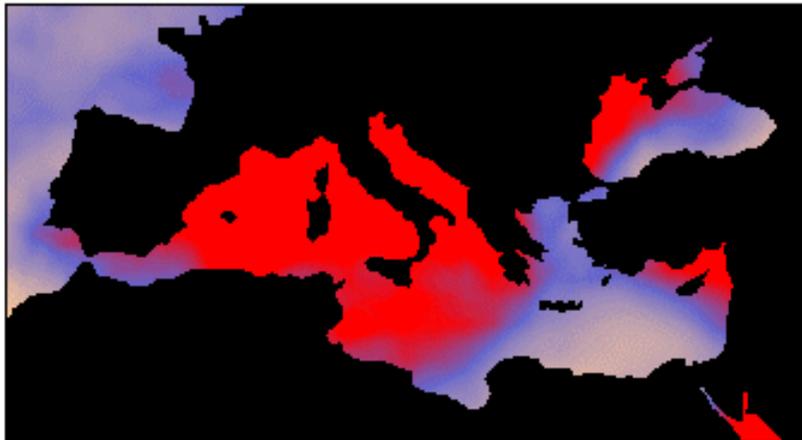


MEAN

GENIX Presente

MONTH: Oct

GCM: ECHAM5-20C3M 1981-2000



GEMPDF

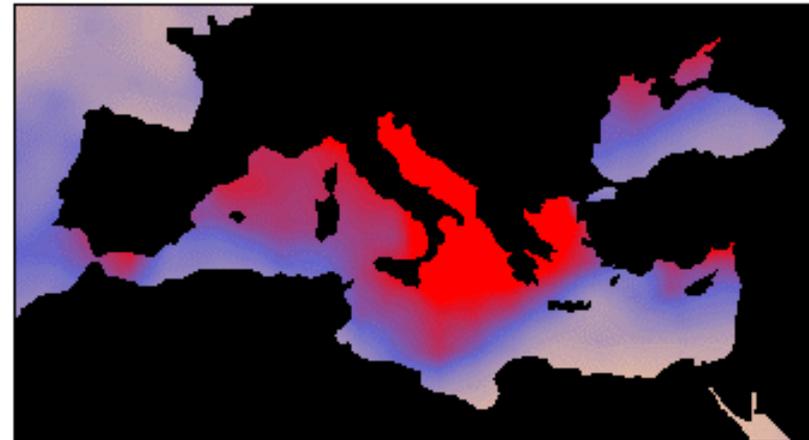
no dim



MEAN

MONTH: Oct

GCM: GFDL-20C3M 1981-2000



GEMPDF

no dim

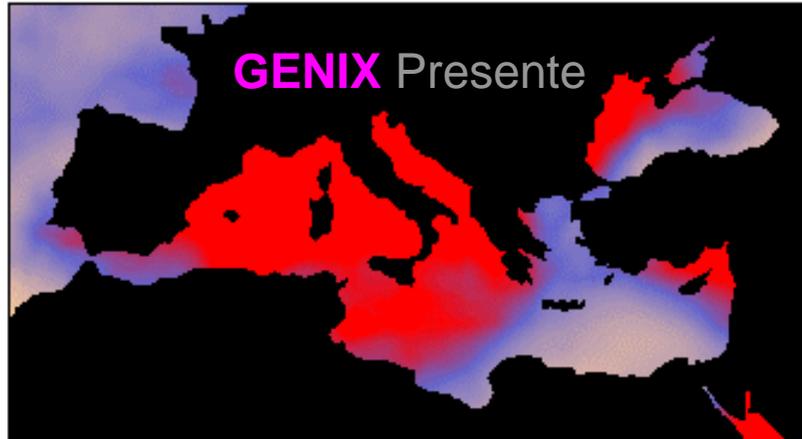


MEAN

APROXIMACIÓN: *Aplicación*

MONTH: Oct

GCM: ECHAM5-20C3M 1981-2000



GENPDF MEAN
no dim 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4

MONTH: Oct

GCM: ECHAM5-20C3M 1981-2000

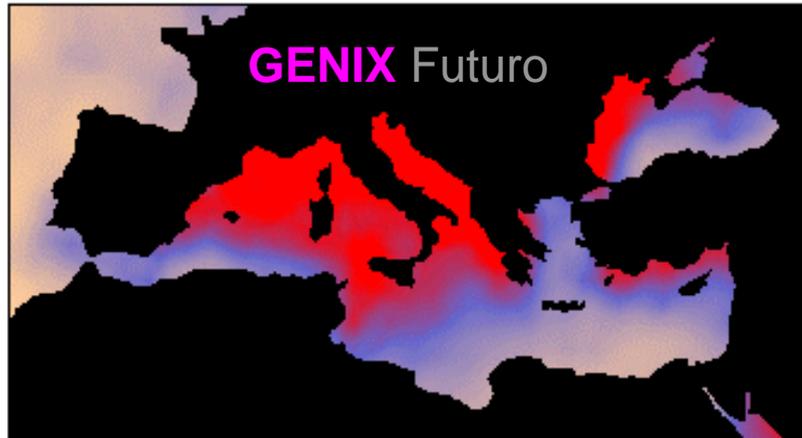


SST MEAN
°C 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

↓ + 3 °C

MONTH: Oct

GCM: ECHAM5-SRESA2 2081-2100



GENPDF MEAN
no dim 0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4

MONTH: Oct

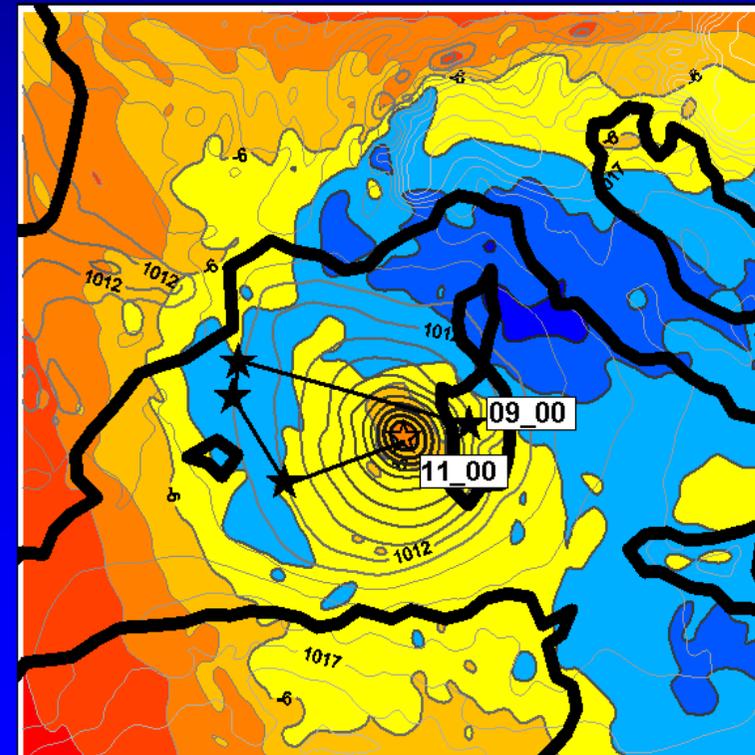
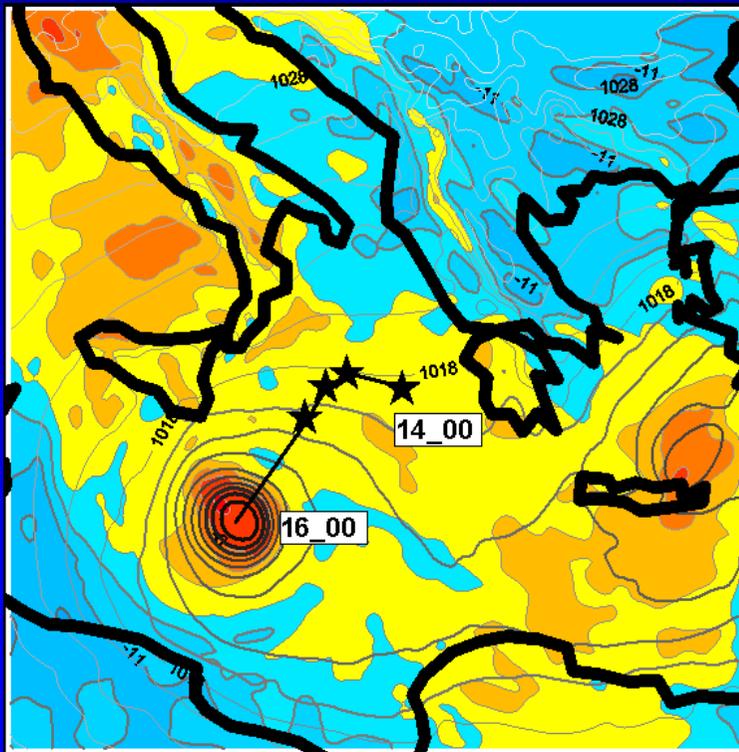
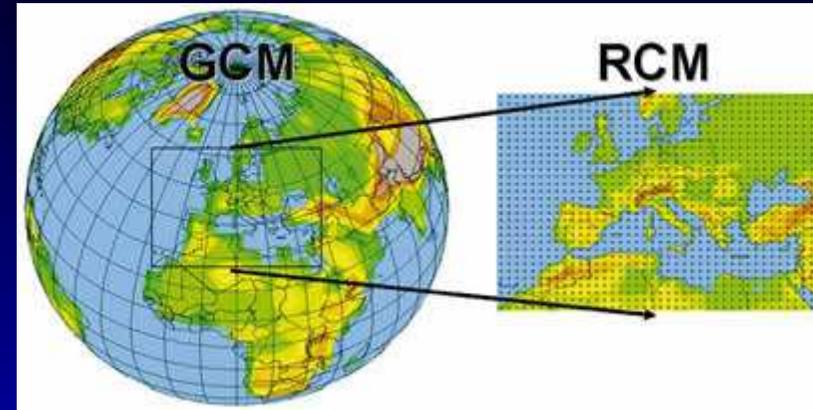
GCM: ECHAM5-SRESA2 2081-2100



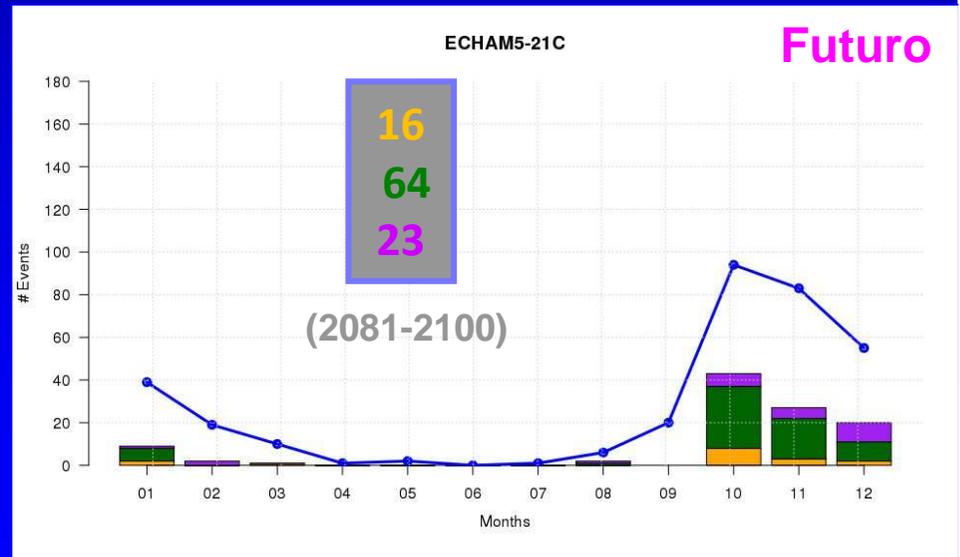
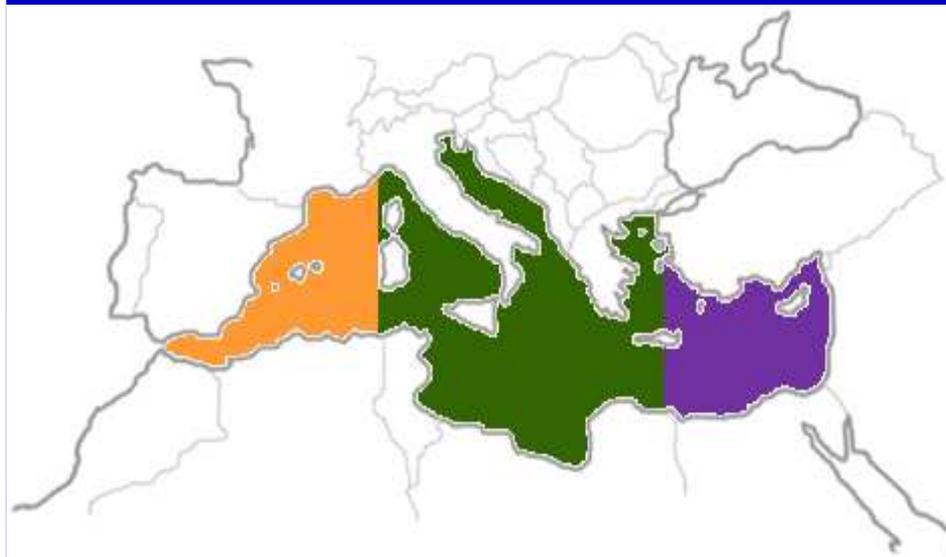
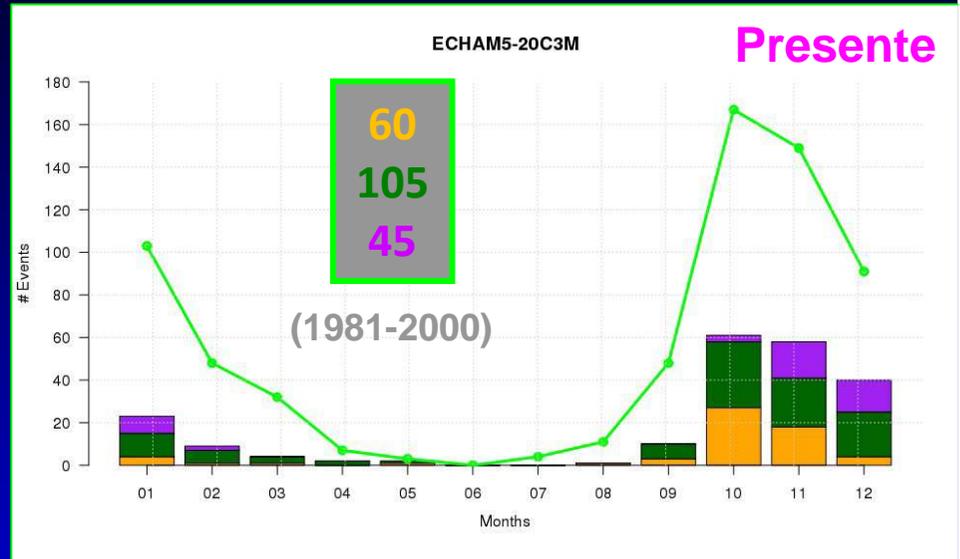
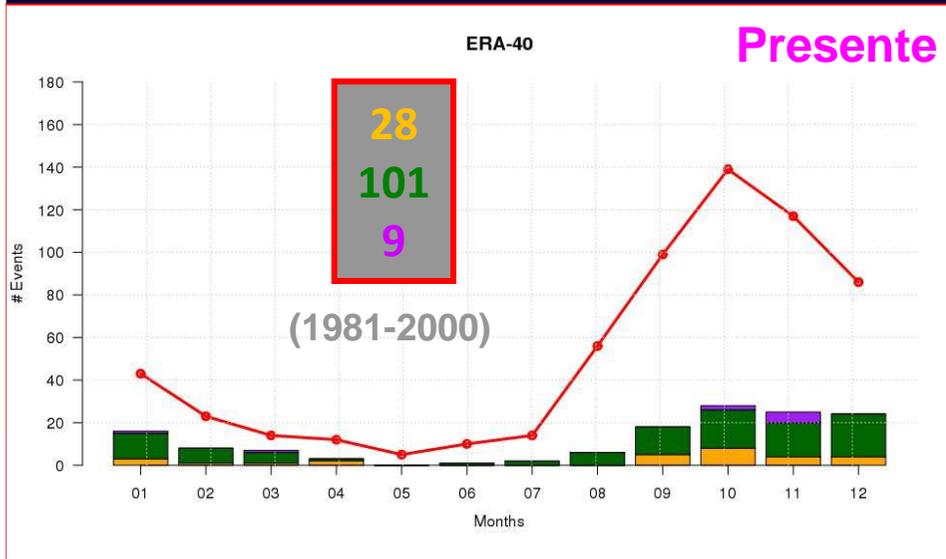
SST MEAN
°C 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

PRIMER MÉTODO: Regionalización climática

- **Alto coste computacional !!!**
(incluso para simulaciones guiadas)
- Solo un **número limitado** de casos
(aunque varios GCMs y escenarios)

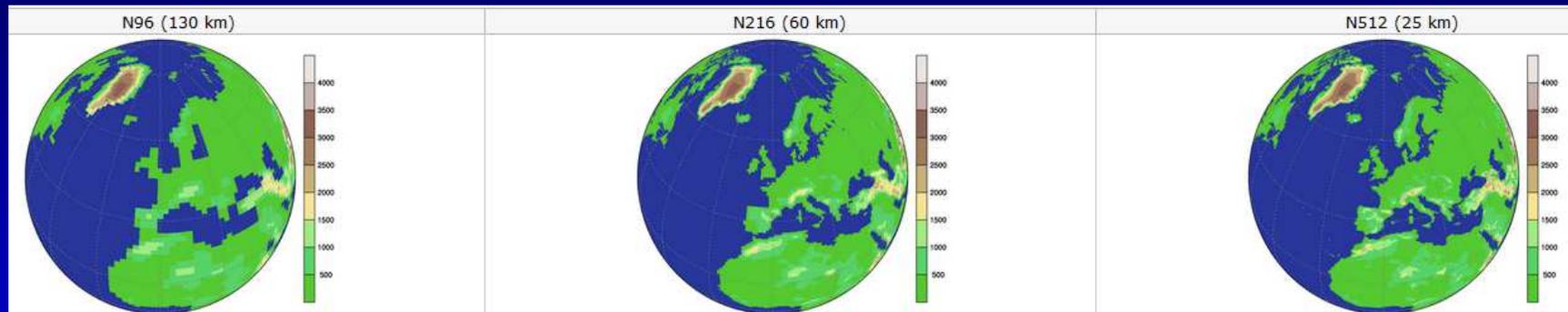


PRIMER MÉTODO: Aplicación

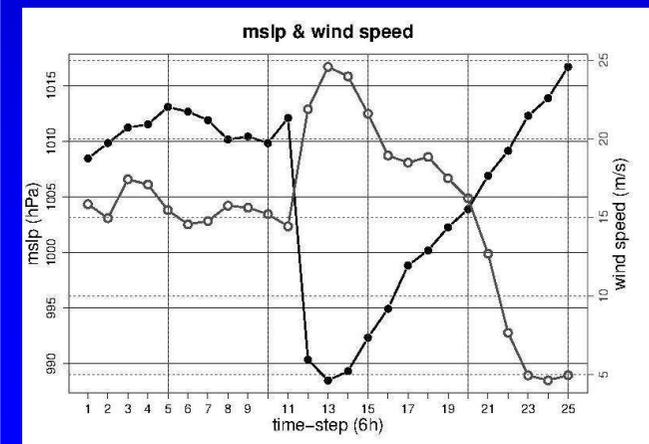
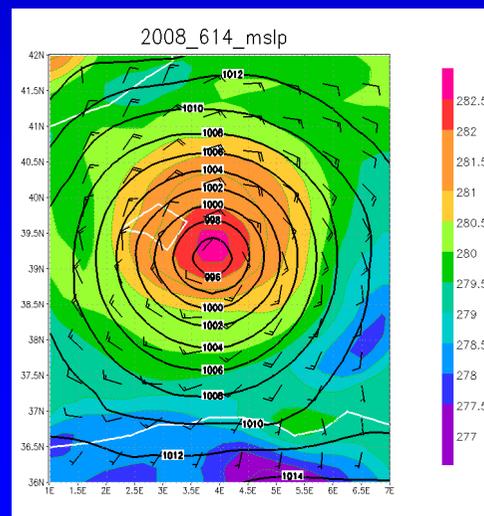
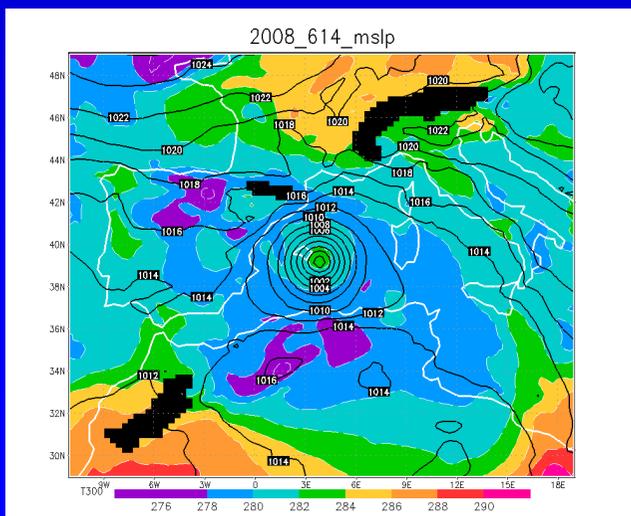


SEGUNDO MÉTODO: Simulaciones climáticas globales (HR)

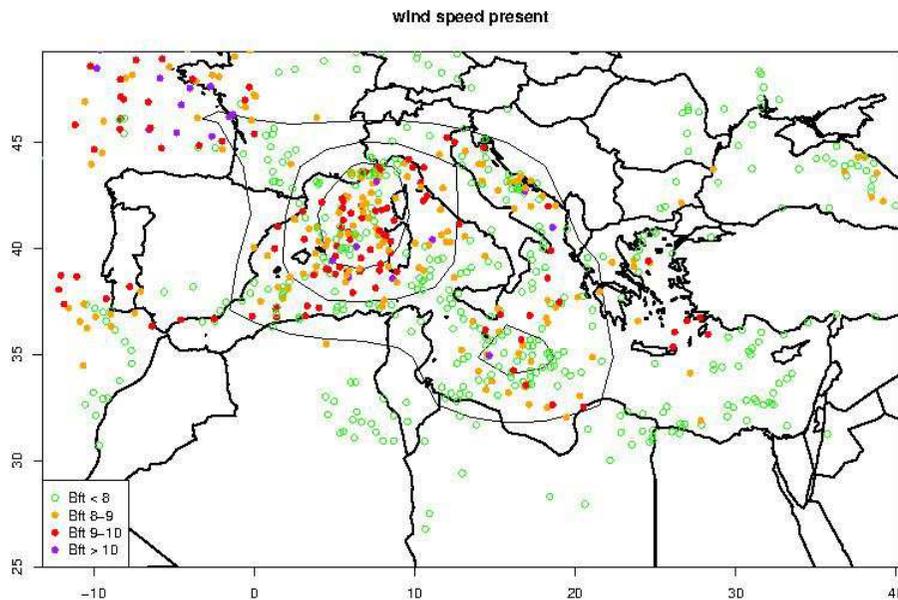
- **Detección** de perturbaciones ciclónicas intensas, simétricas y con núcleo cálido (i.e. **medicanes**) generadas en las simulaciones globales del modelo **HadGEM3 N512 (resolución 25 km)** (proyecto **UPSCALE**)



- A pesar de la **HR**, solo se capturan **medicanes grandes/potentes ...**

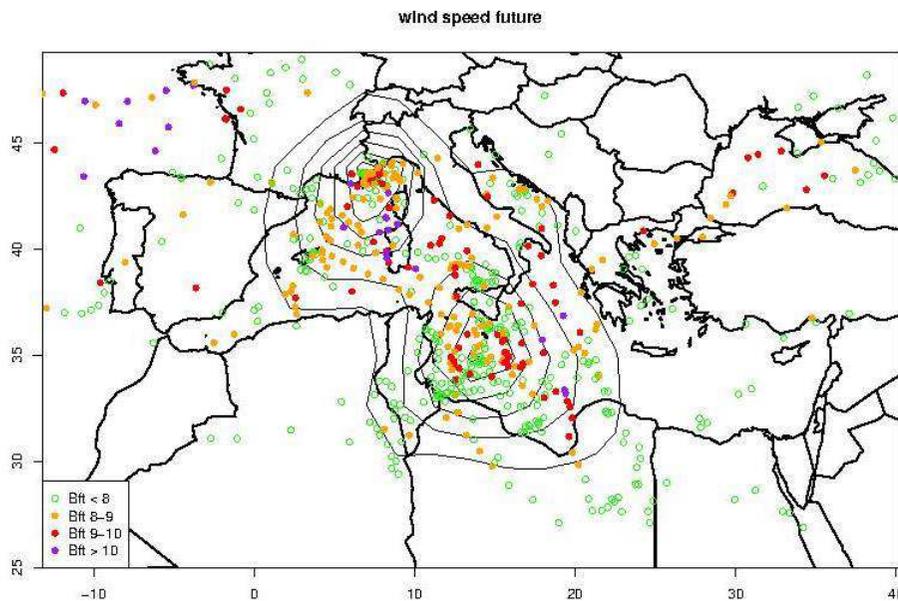


SEGUNDO MÉTODO: *Aplicación*



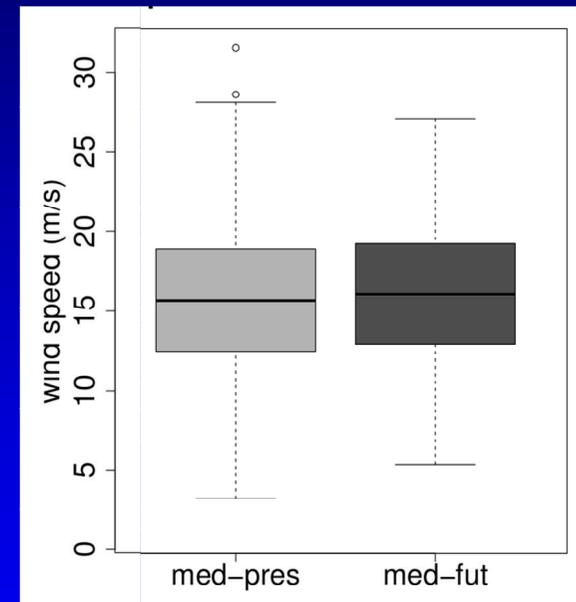
PRESENTE

65 med / 26 yr



FUTURO

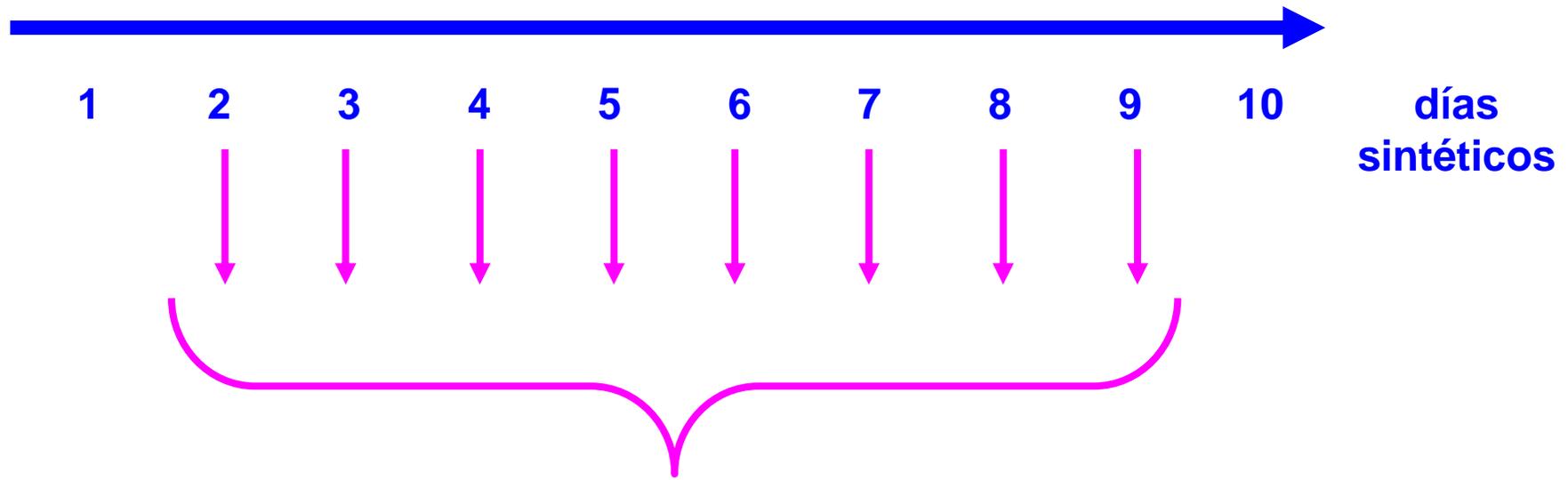
44 med / 26 yr



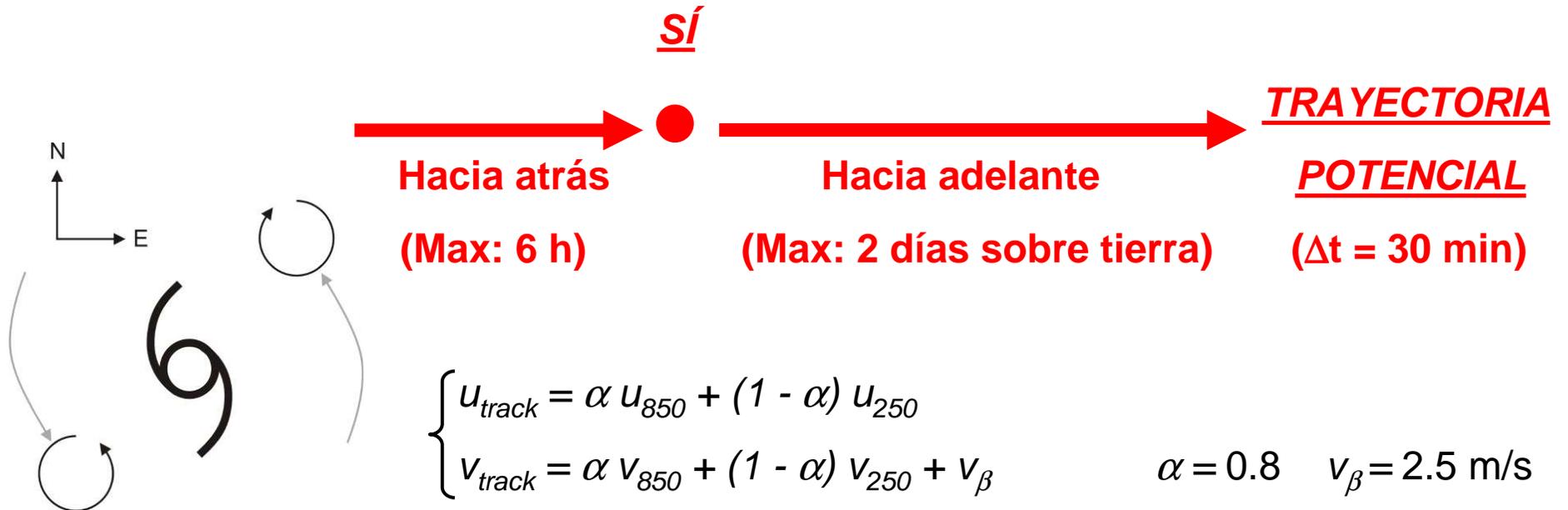
TERCER MÉTODO: Método dinámico-estadístico

- Adaptación del método pionero de **Kerry Emanuel** (MIT, USA)
- Generación de **miles de huracanes sintéticos** a bajo coste !!!
- Evaluación del riesgo con **gran robustez estadística** (p.e. **períodos de retorno** viento extremo)





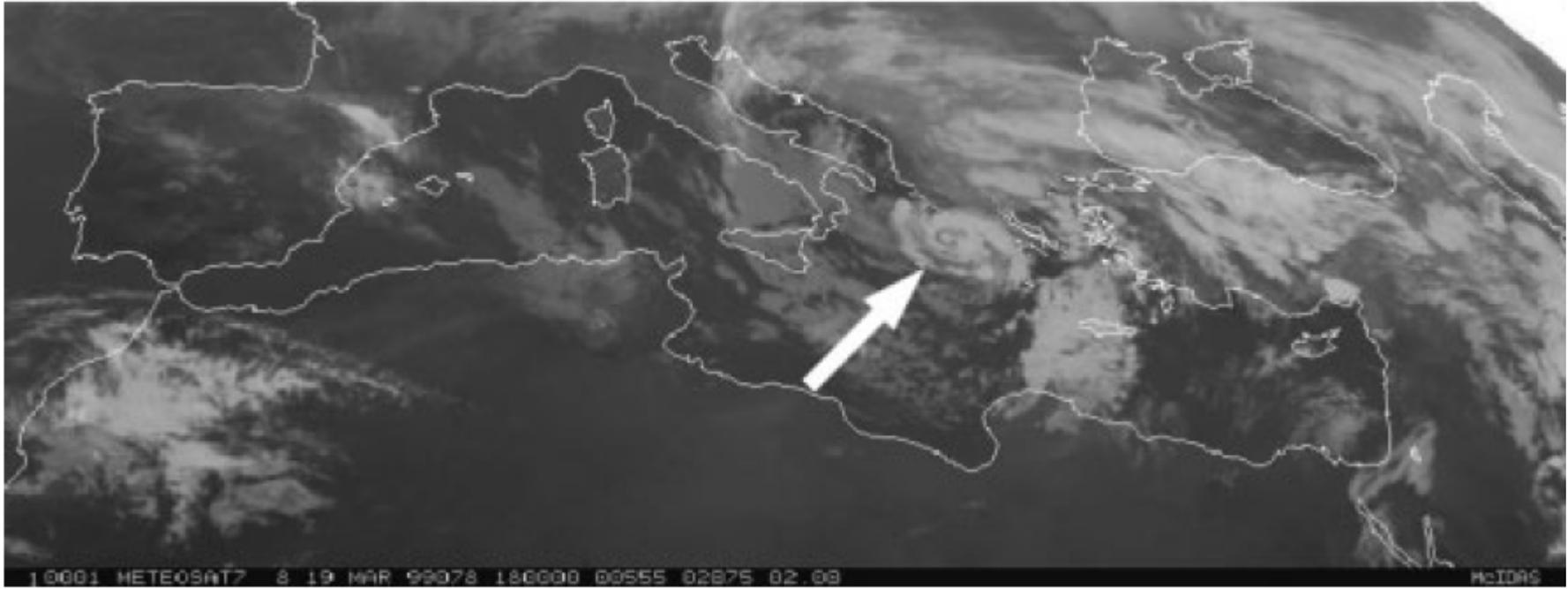
MAR ABIERTO + MAX DE GENIX > 20 + VOR ABS > 10 unidades ???



**EJEMPLO PARA UN
EPISODIO REAL**

(d)

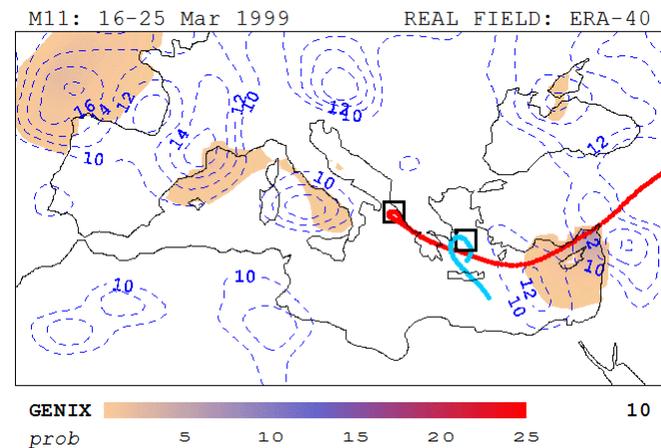
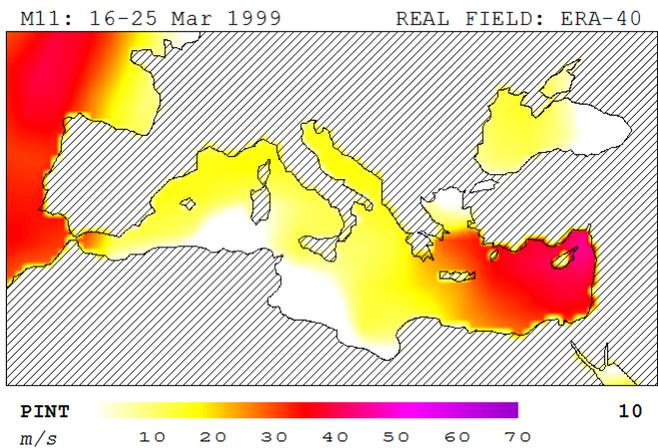
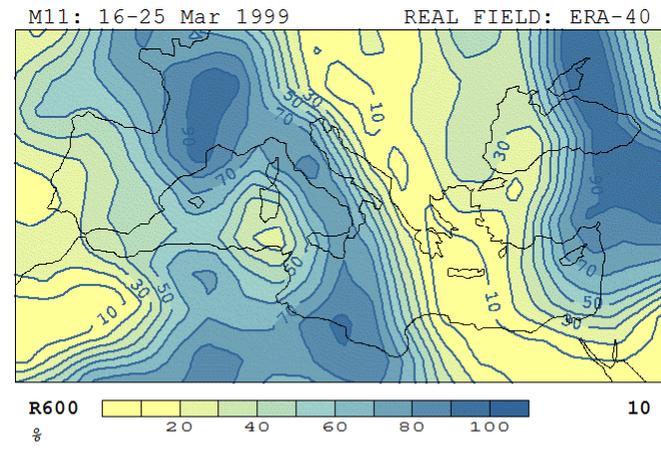
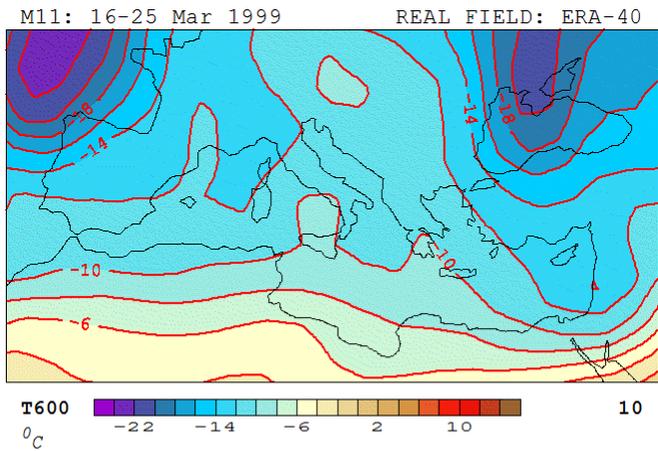
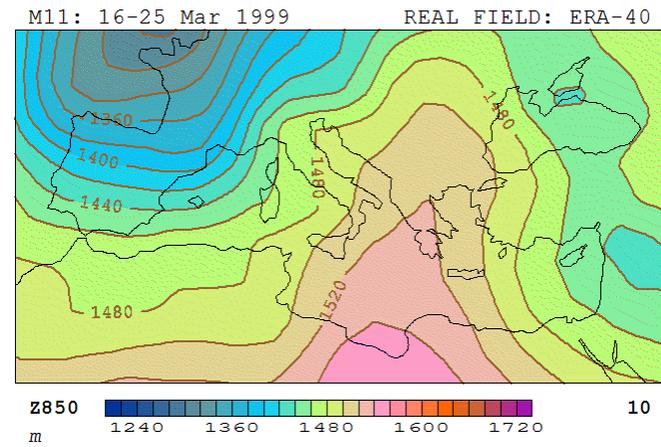
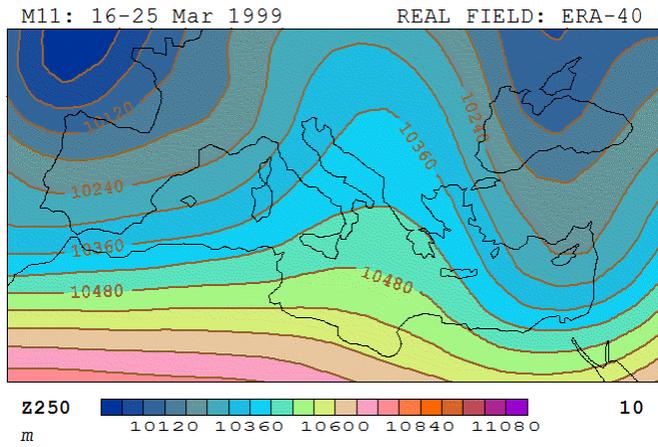
19-March-1999, 18 UTC



M11

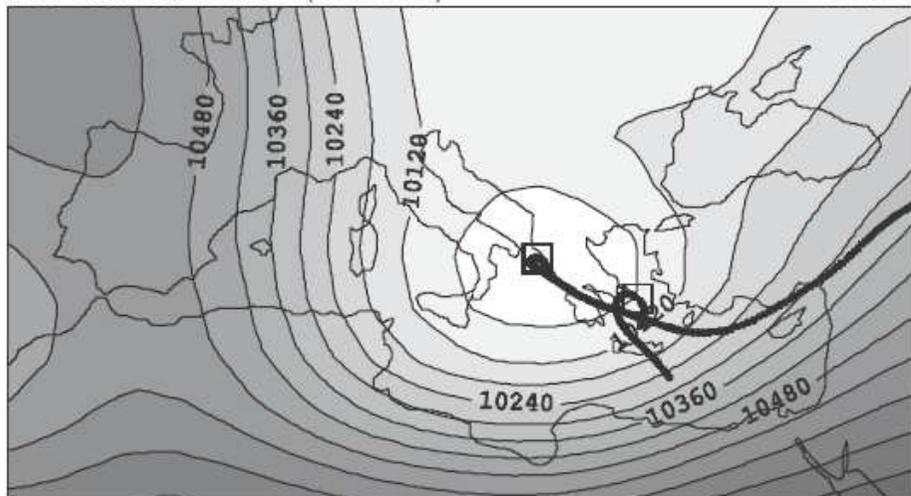


ERA-40
2 tracks



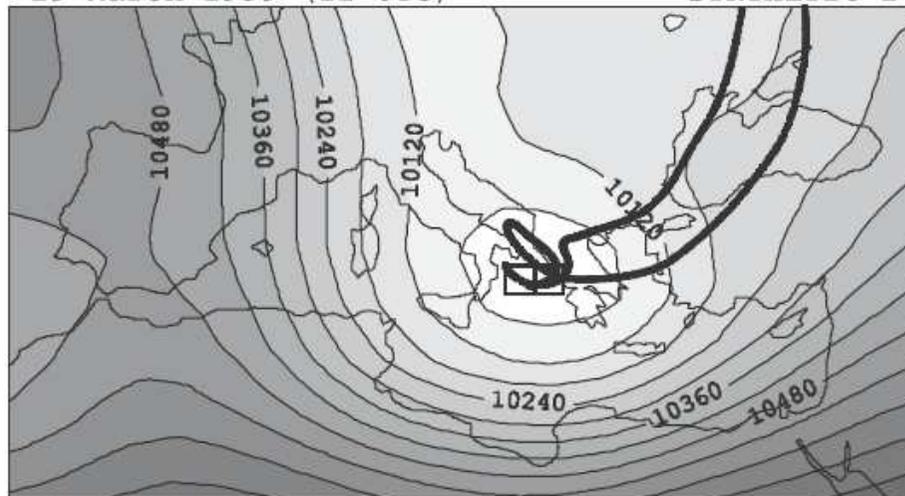
19 March 1999 (12 UTC)

REAL



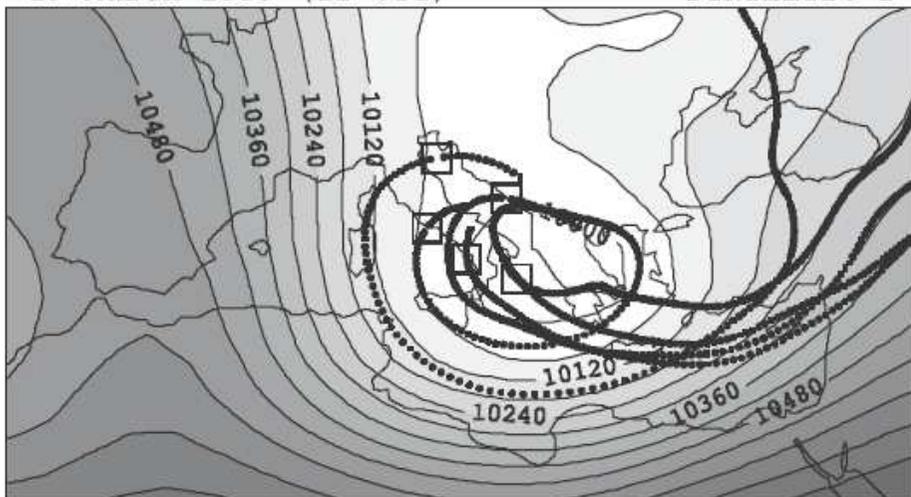
19 March 1999 (12 UTC)

SYNTHETIC 1



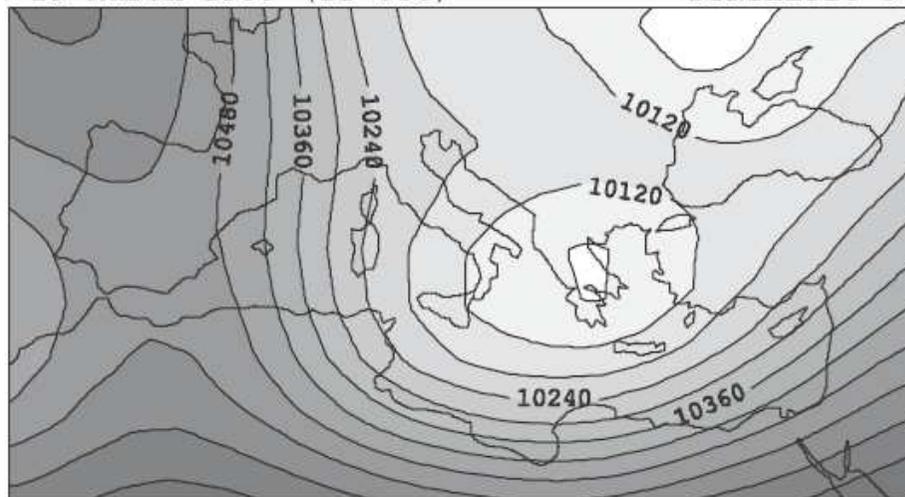
19 March 1999 (12 UTC)

SYNTHETIC 2



19 March 1999 (12 UTC)

SYNTHETIC 3

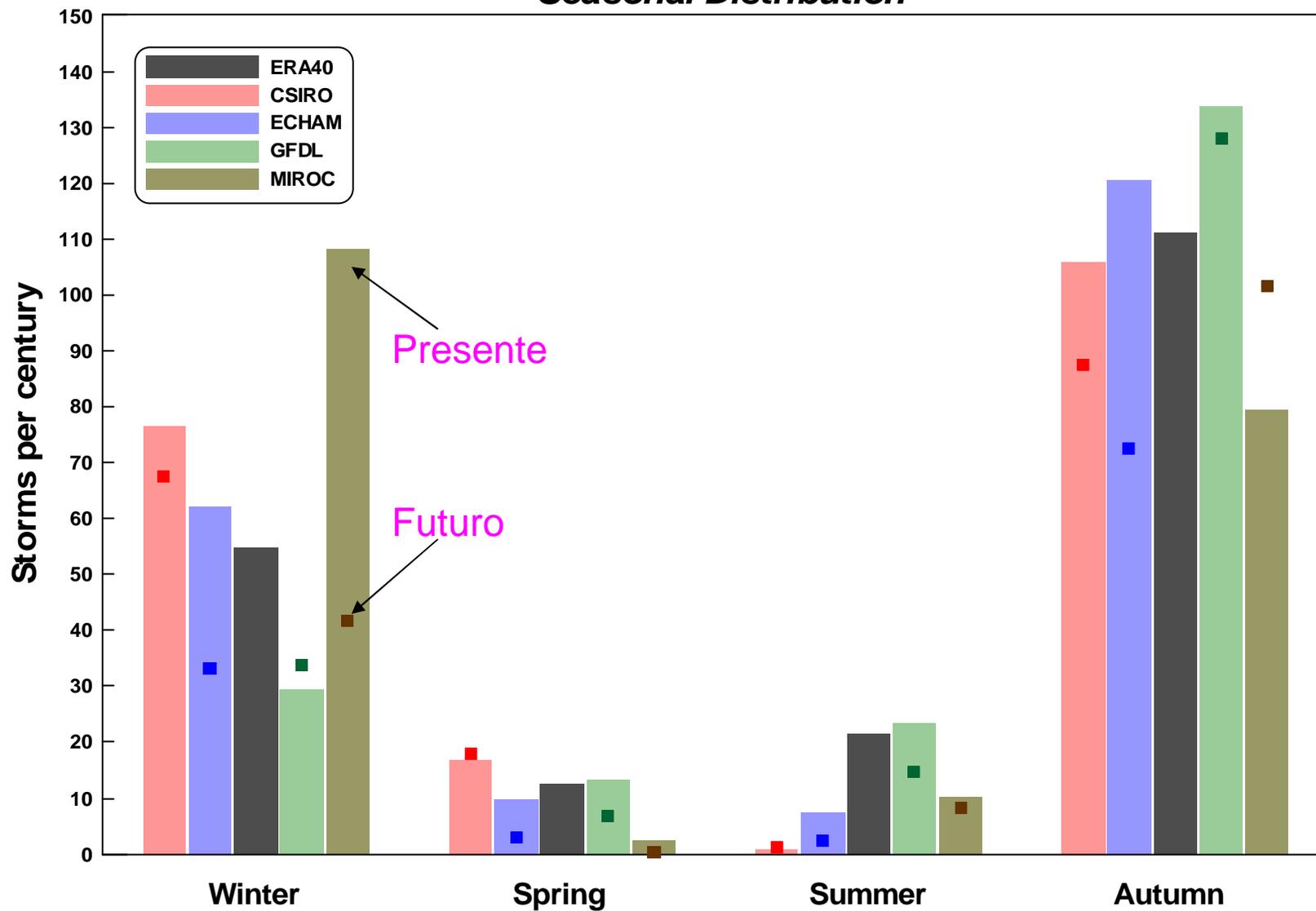


TERCER MÉTODO: *Aplicación*

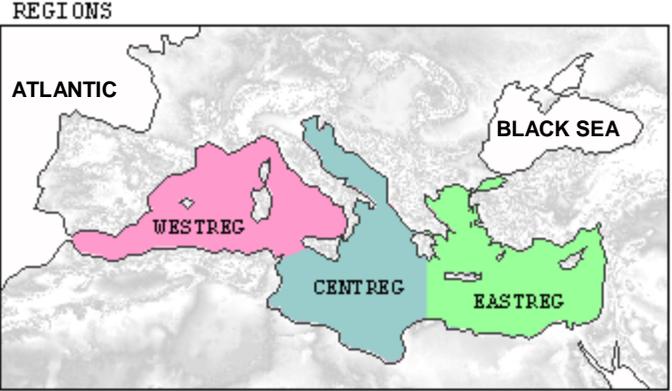
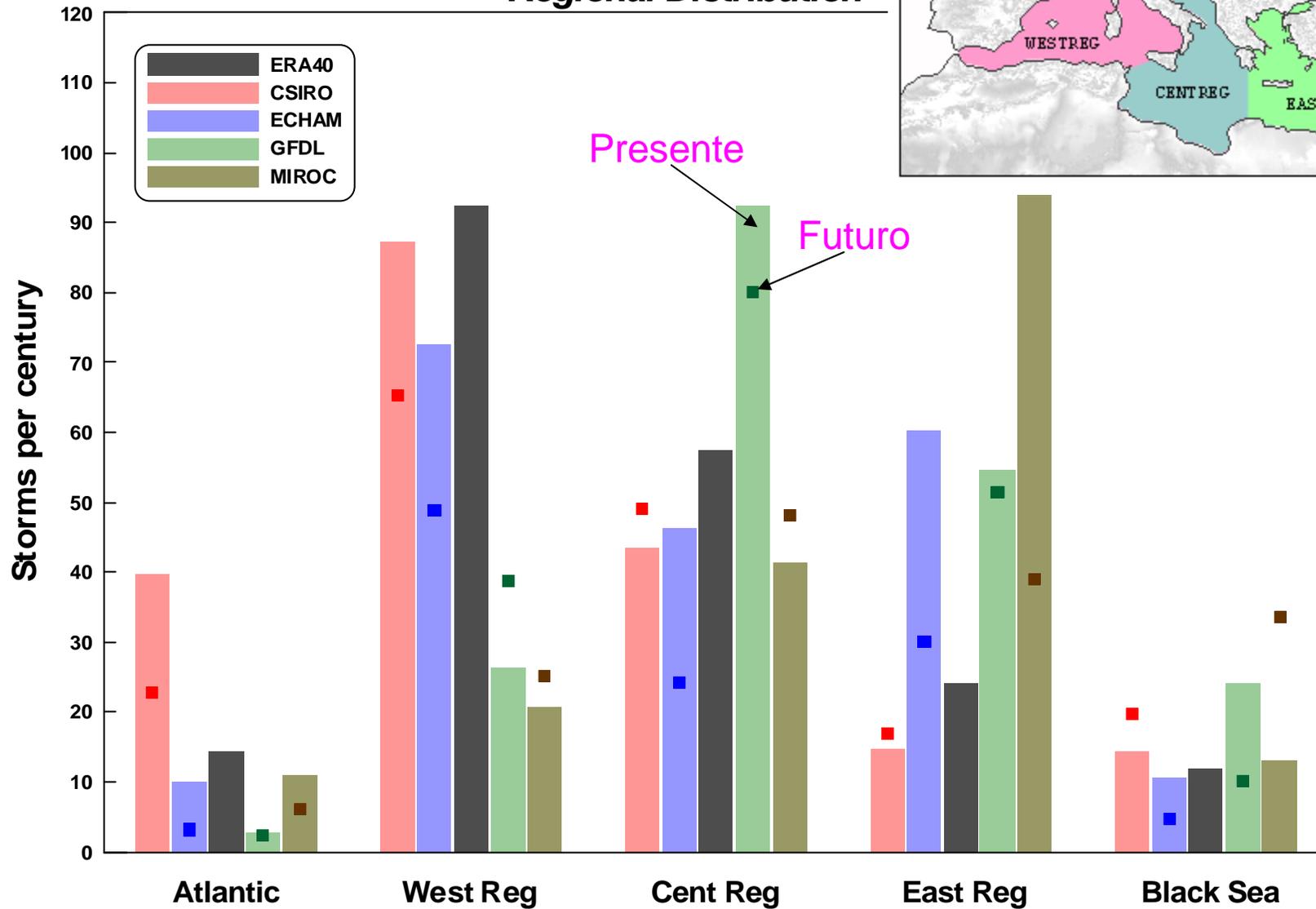
- A partir de *~15000 trayectorias* de posibles medicanes:

<i>Escenario Climático</i>	<i>Reanálisis o GCM</i>	<i>Medicanes efectivos</i>	<i>Medicanes por siglo</i>
<i>PRESENTE</i> <i>1981 – 2000</i>	<i>ERA40</i>	3048	200
	<i>CSIRO</i>	3286	200
	<i>ECHAM</i>	1924	200
	<i>GFDL</i>	1343	200
	<i>MIROC</i>	1567	200
<i>FUTURO</i> <i>2081 – 2100</i> <i>SRES A2</i>	<i>CSIRO</i>	2857	174
	<i>ECHAM</i>	1072	111
	<i>GFDL</i>	1226	183
	<i>MIROC</i>	2389	152

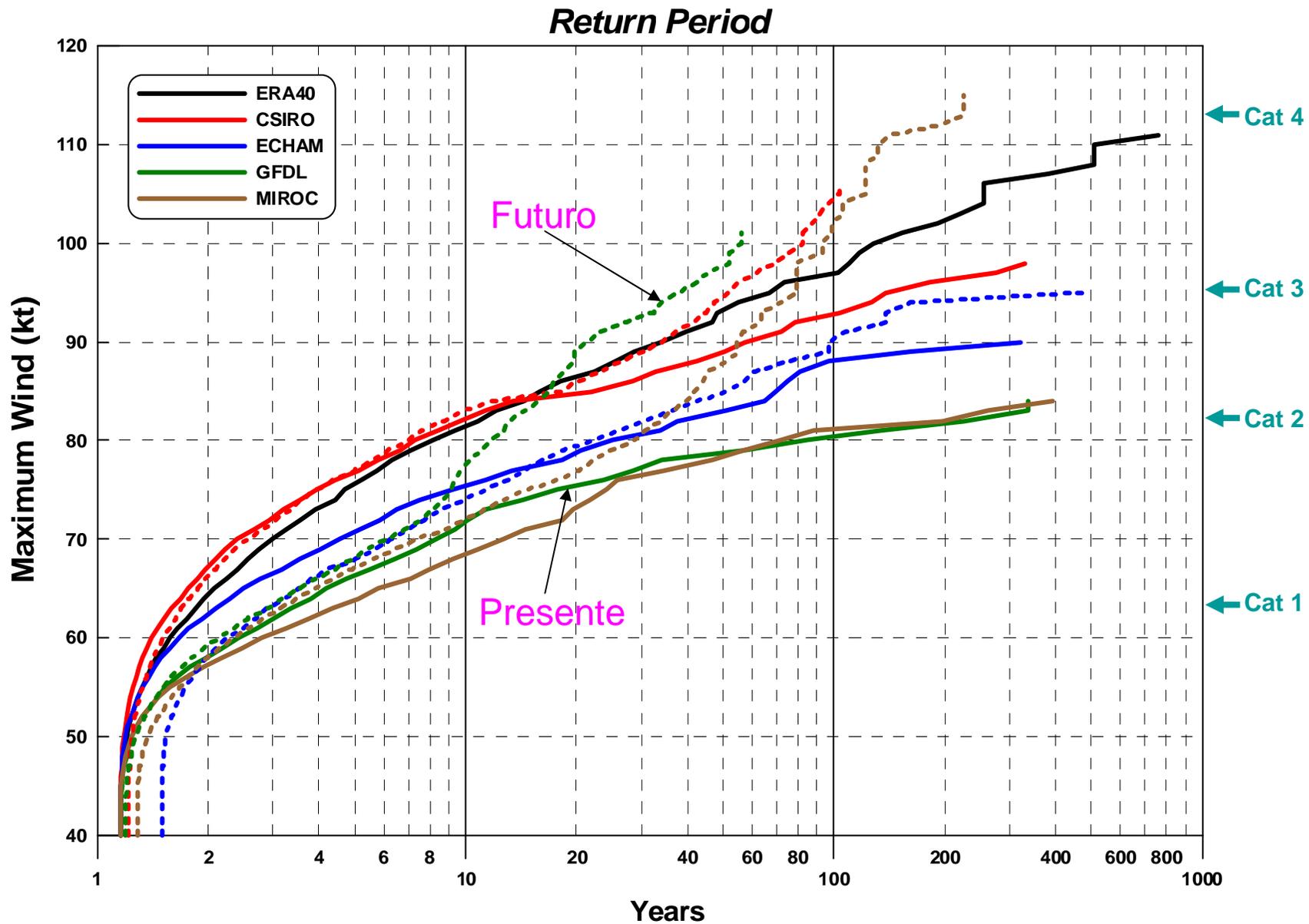
Seasonal Distribution



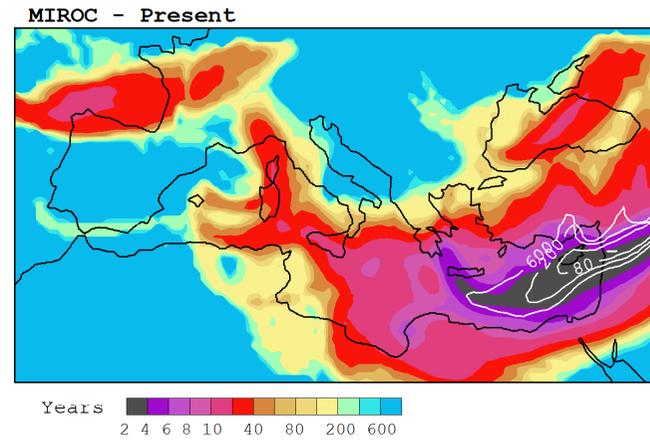
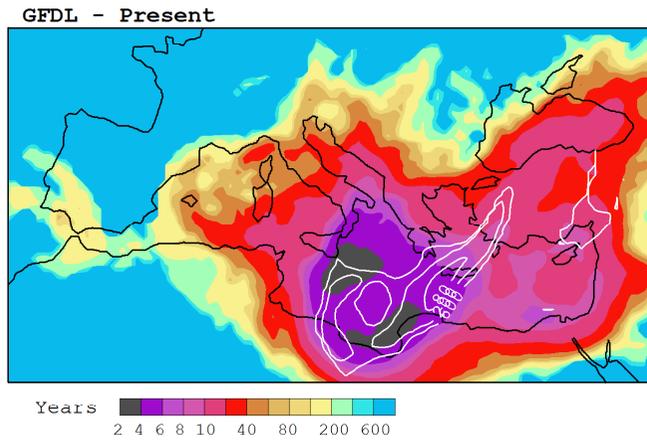
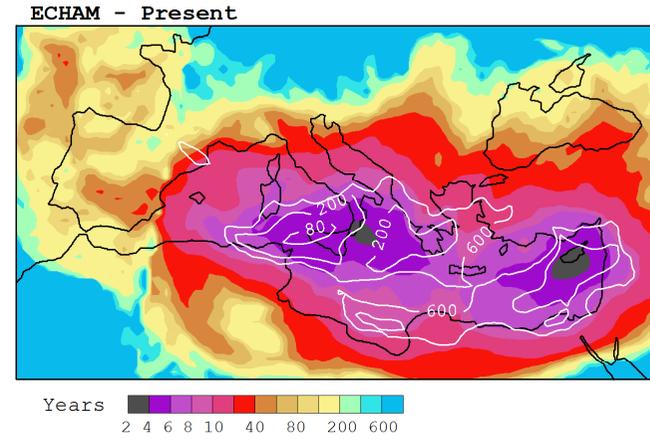
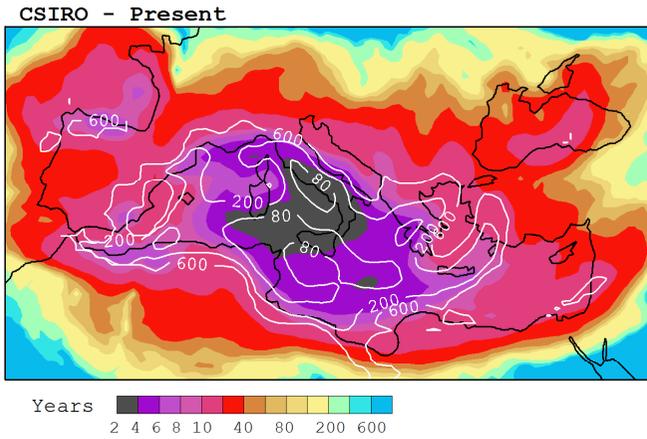
Regional Distribution



Presente
Futuro

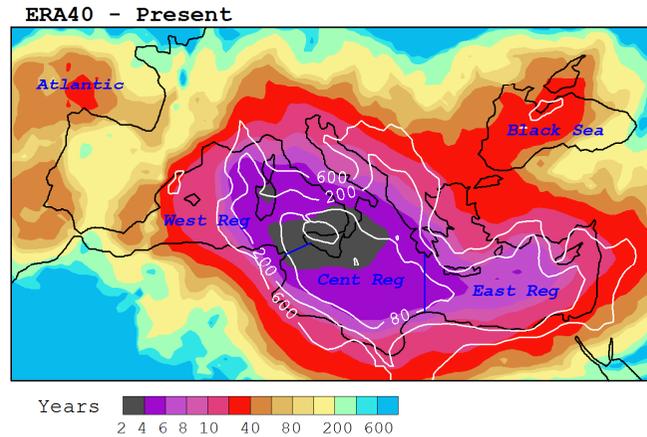


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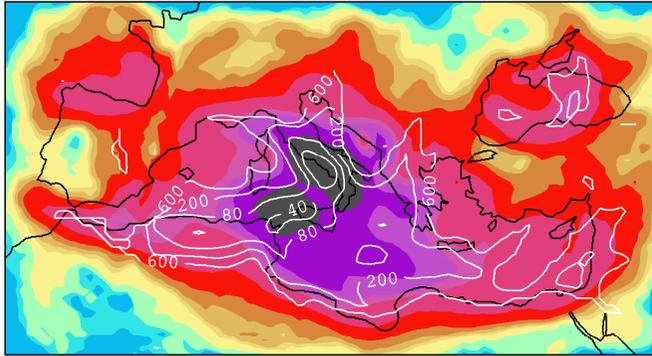
> 34 kt

> 60 kt



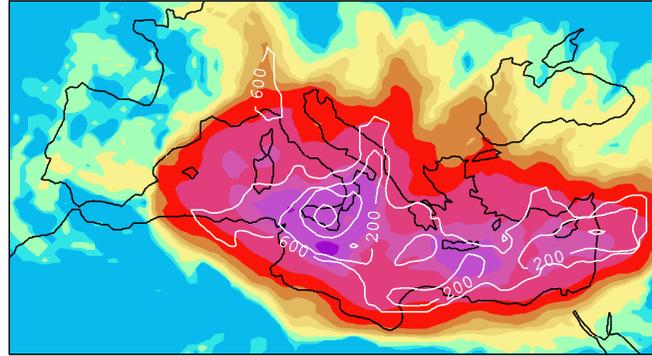
FUTURO

CSIRO - Future



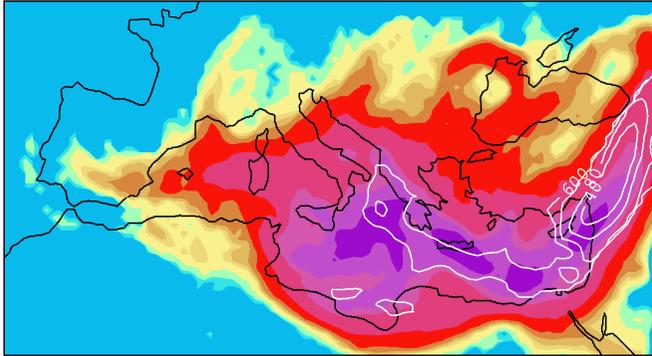
Years 2 4 6 8 10 40 80 200 600

ECHAM - Future



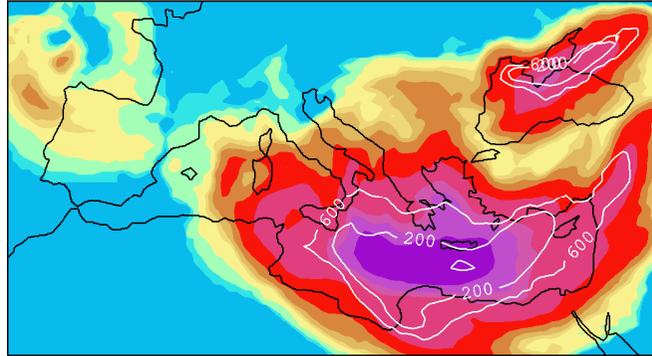
Years 2 4 6 8 10 40 80 200 600

GFDL - Future



Years 2 4 6 8 10 40 80 200 600

MIROC - Future



Years 2 4 6 8 10 40 80 200 600

> 34 kt

> 60 kt

A satellite image of a hurricane over the Atlantic Ocean. The hurricane is a large, swirling cloud system with a distinct eye. A yellow outline of the continent of South America is overlaid on the image, showing the continent's position relative to the hurricane. The text "GRÀCIES PER LA VOSTRA ATENCIÓ !!!" is written in yellow, bold, serif font across the center of the image.

**GRÀCIES PER
LA VOSTRA ATENCIÓ !!!**