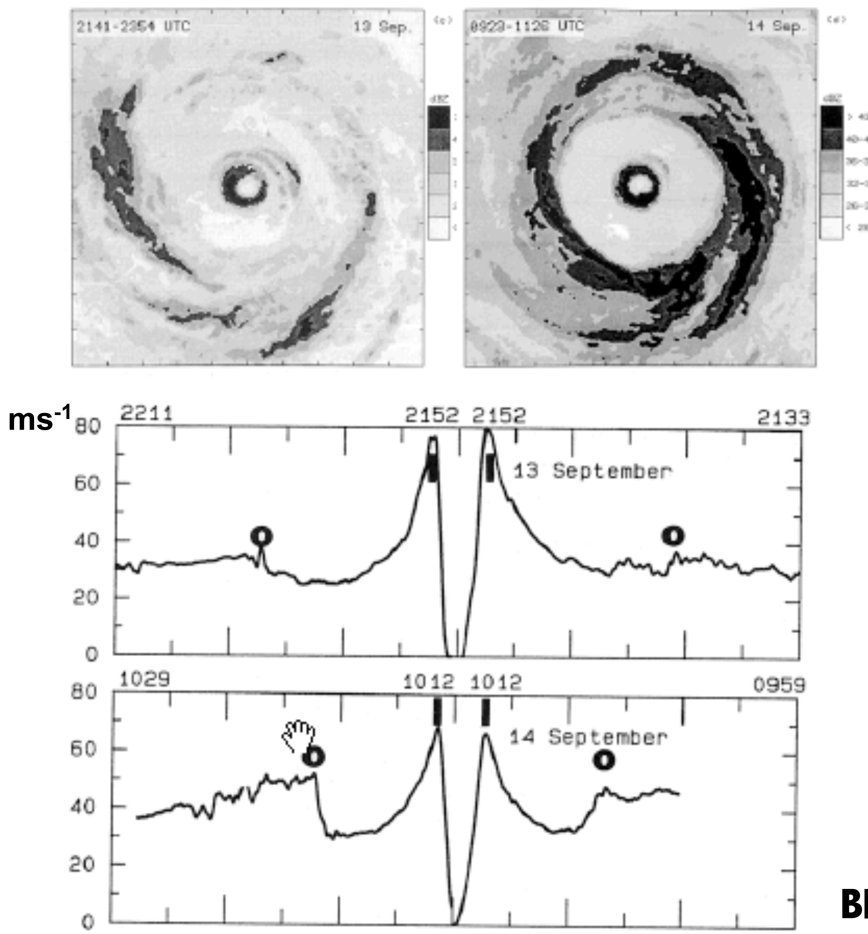
Formación de paredes convectivas concéntricas

Gilberto-88



Black y Willoughby (1992)

Perspectiva

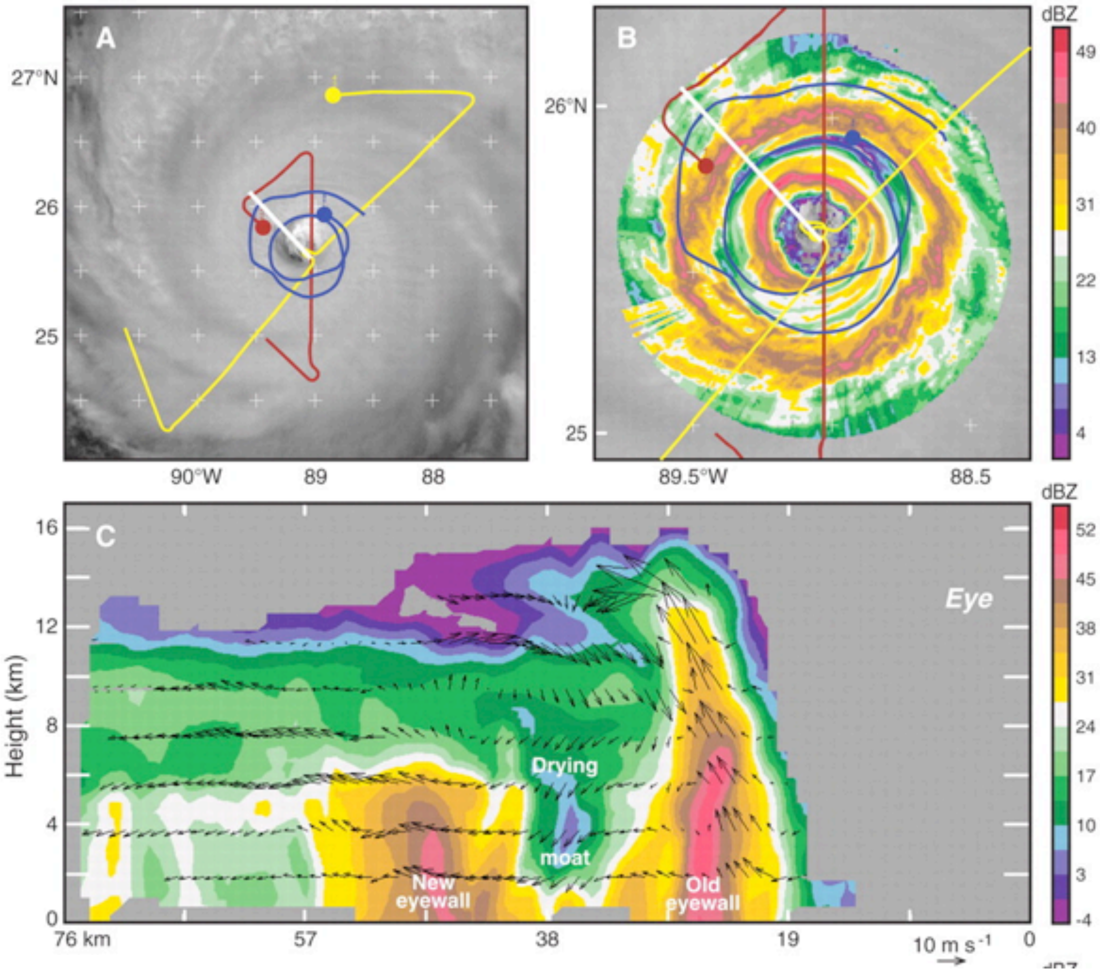
Las paredes convectivas (PC) concéntricas están vinculadas a cambios de intensidad en huracanes intensos

- Las podemos predecir?
- Si es así, qué datos hacen falta?

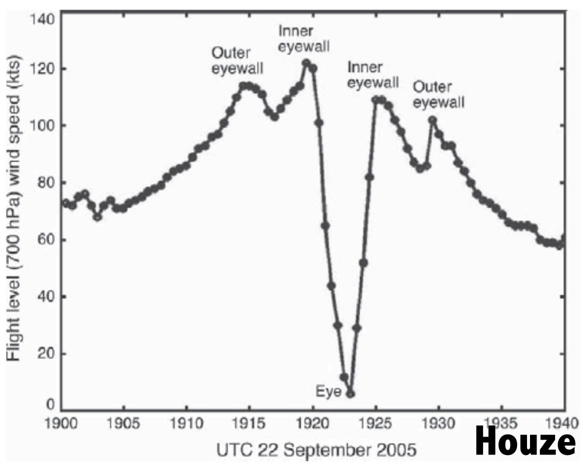
  Están éstos disponibles en las practicas observacionales contemporáneas?
- Cómo ocurre la FPC?

RAINEX, 2005

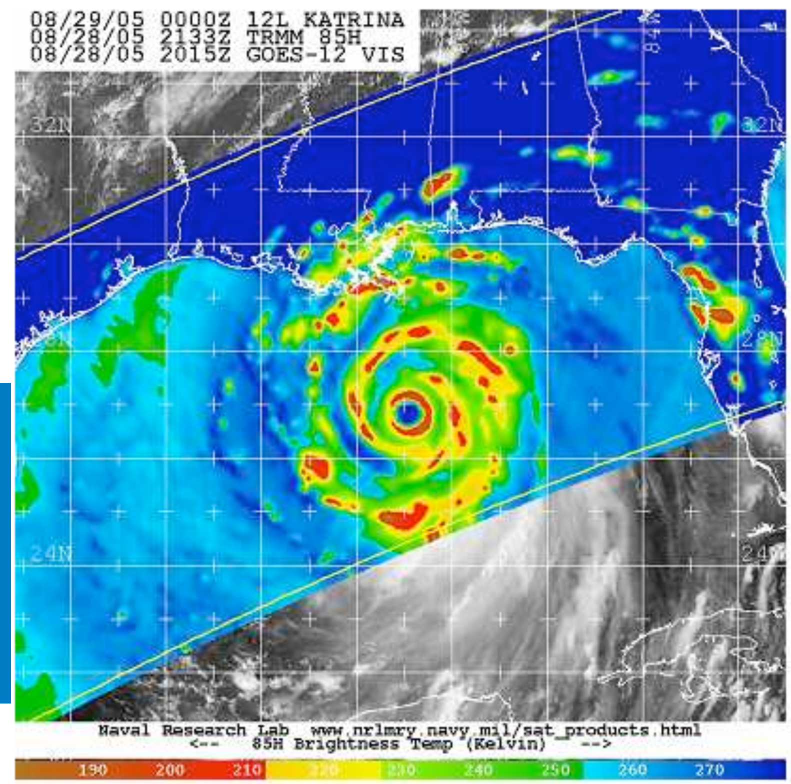
Rita y Katrina exhibieron paredes concéntricas



Houze et al. (2007)



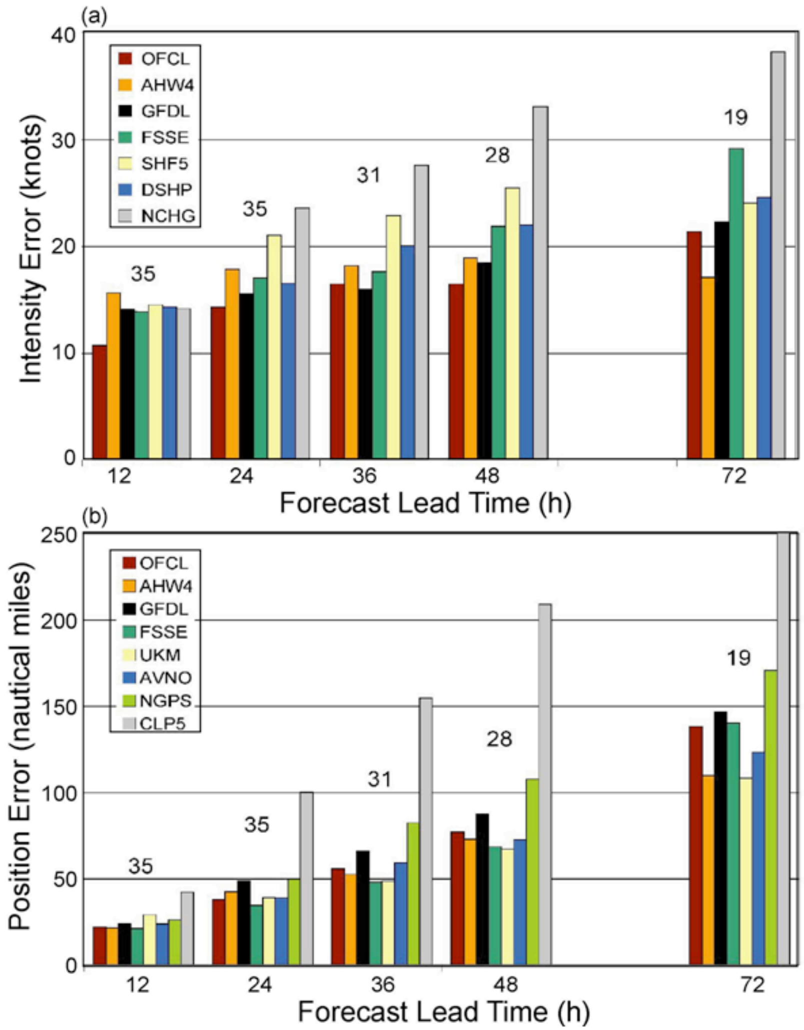
Houze et al. (2006)



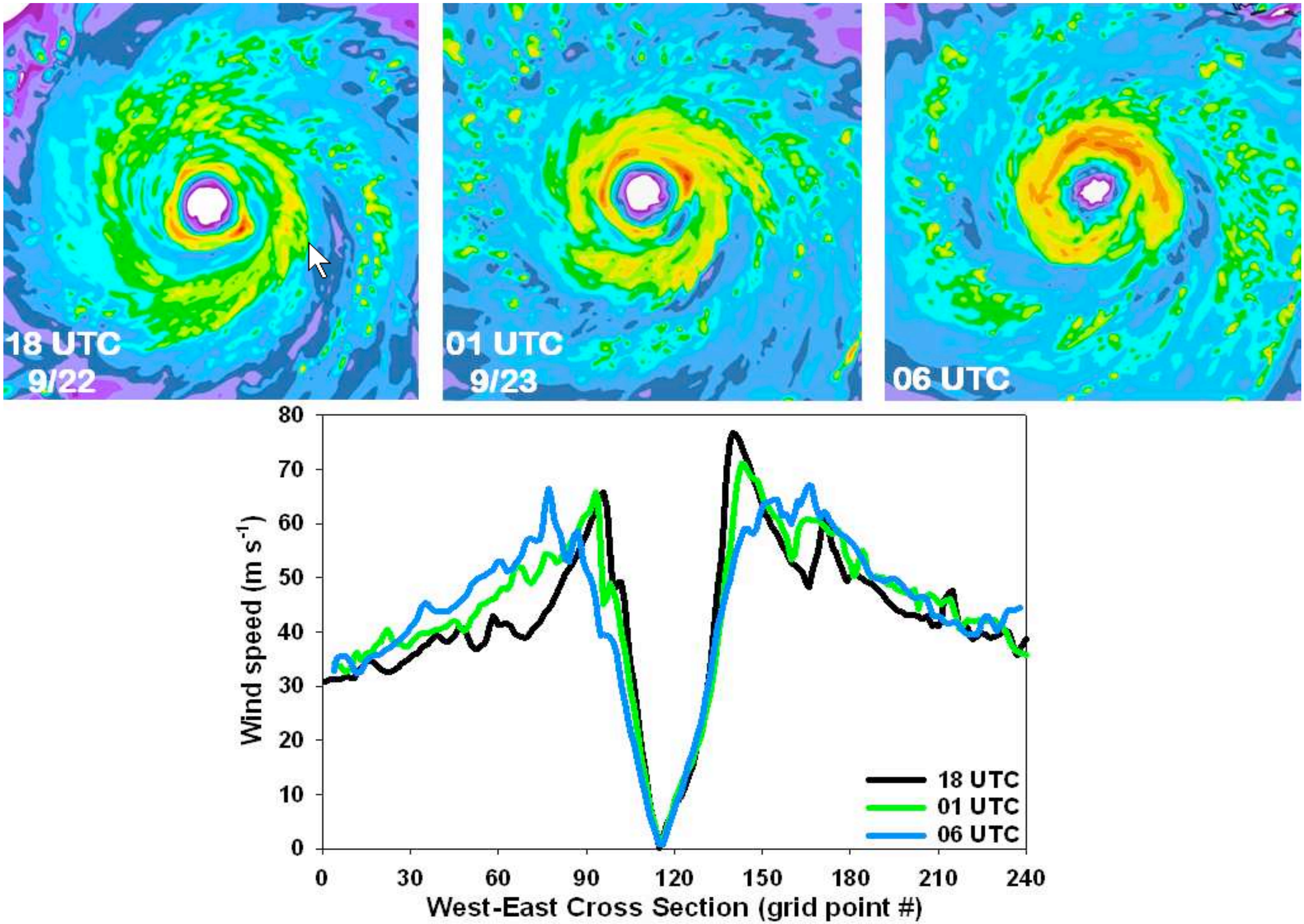
Advanced Hurricane WRF

- Simulaciones en tiempo real en NCAR (desde 2004)
- Dos o tres dominios (12, 4 y 1.33km) con mallas interactivas
- Inicializado con datos de GFDL y/o GFS a las 00 y/o a las 12 UTC
- Kain-Fritsch parametrización de Cu (12Km sólamente); WSM3,5 microfísica, esquema de CLP de SYU, flujos superficiales (carlson-Boland) para CT
- ~ Tan bueno como el pronóstico oficial

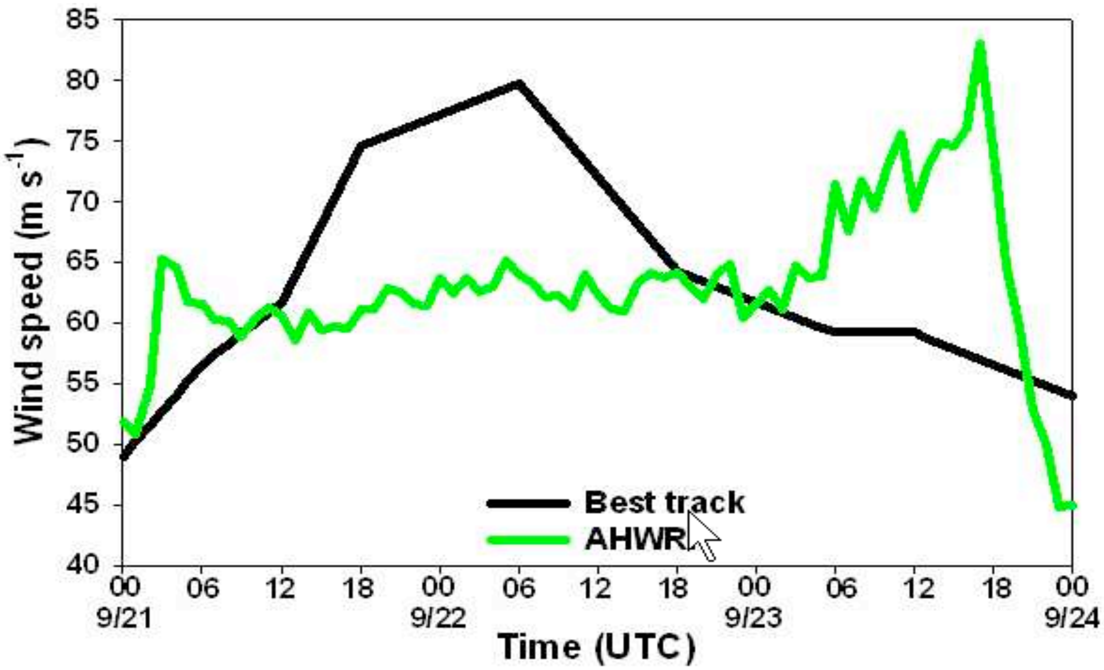
Desempeño, 2005 (7 CT)

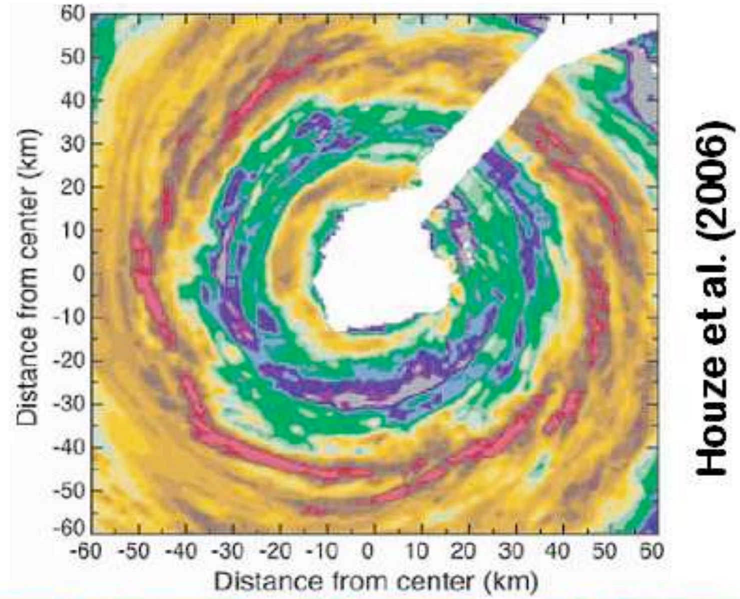


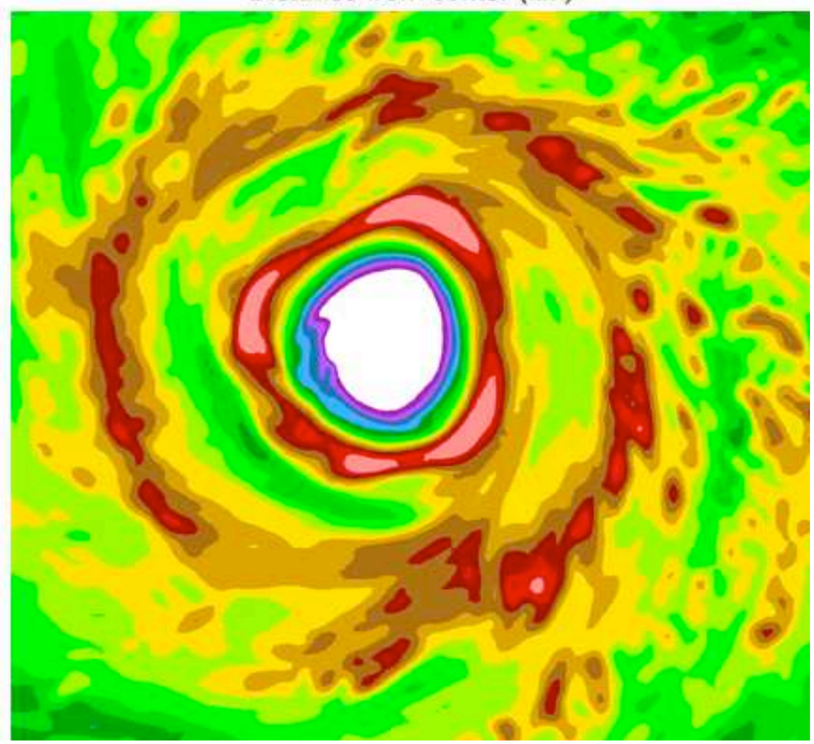
Davis et al. (2008)



18 UTC
9/22
01 UTC
9/23
06 UTC
Wind speed (m s-1)
West-East Cross Section (grid point #)
18 UTC
01 UTC
06 UTC

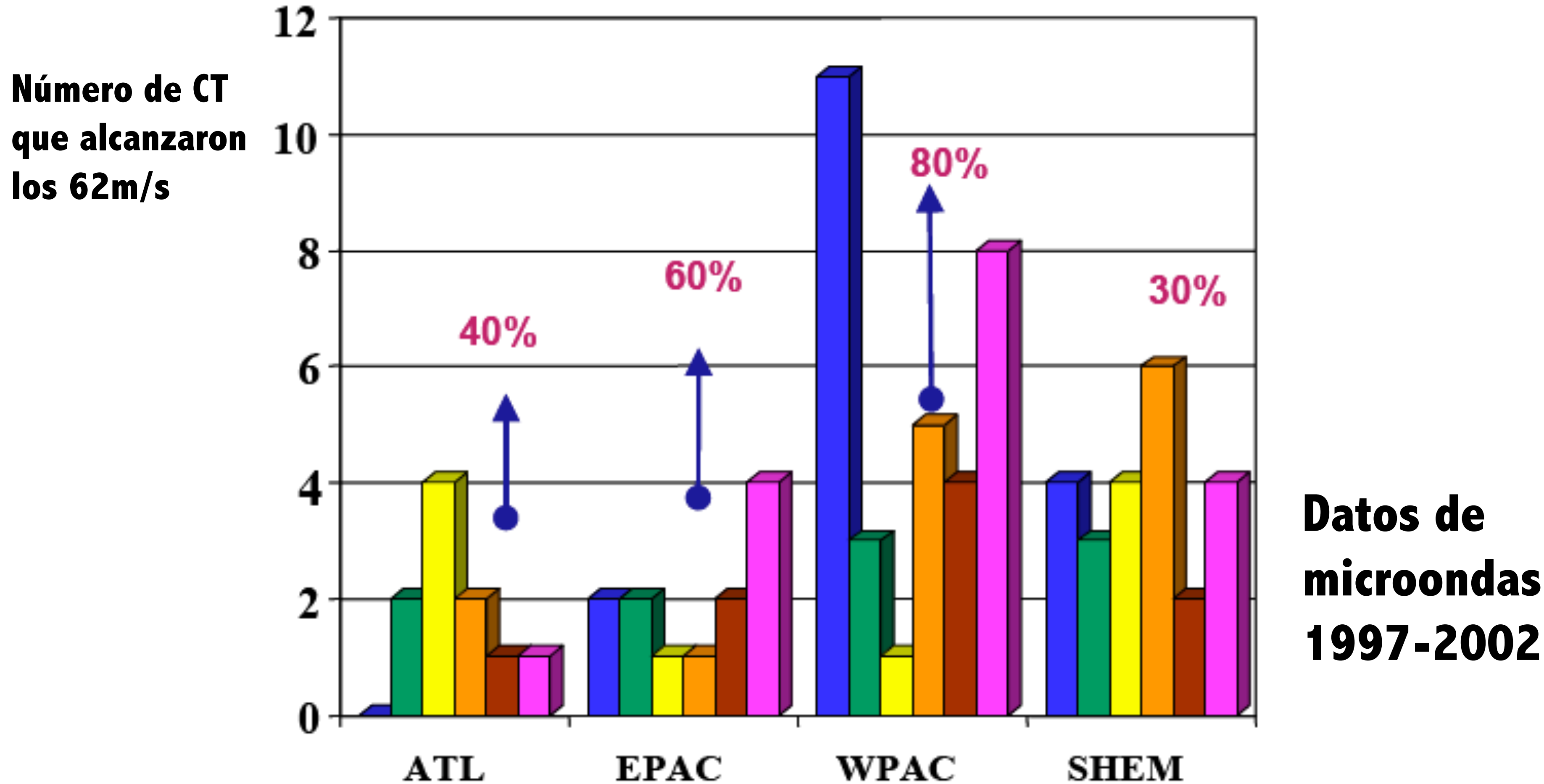






Reflectividad del radar ELDORA (arriba)
17 UTC 9-22

1.33 km AHWRF (abajo)
Agua precipitable
23 UTC 9/22

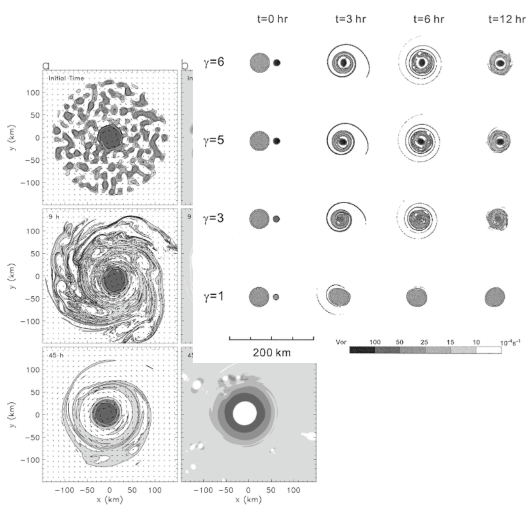


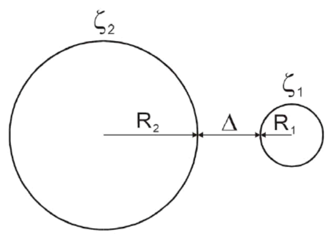
FPC ocurren con frecuencia en CT suficientemente intensos

Hawkins and Helveston (2004)

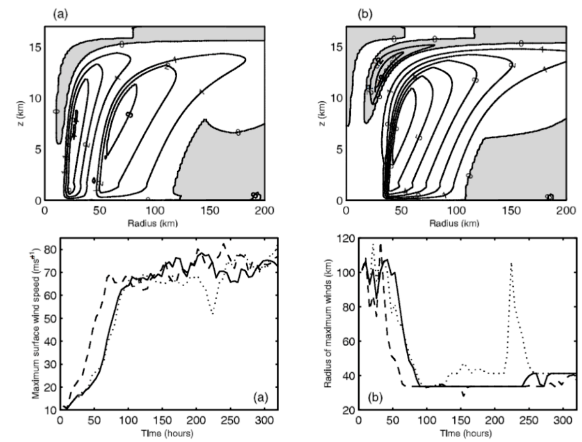
Hipótesis de FPC:

Interacciones barotrópicas entre vórtices

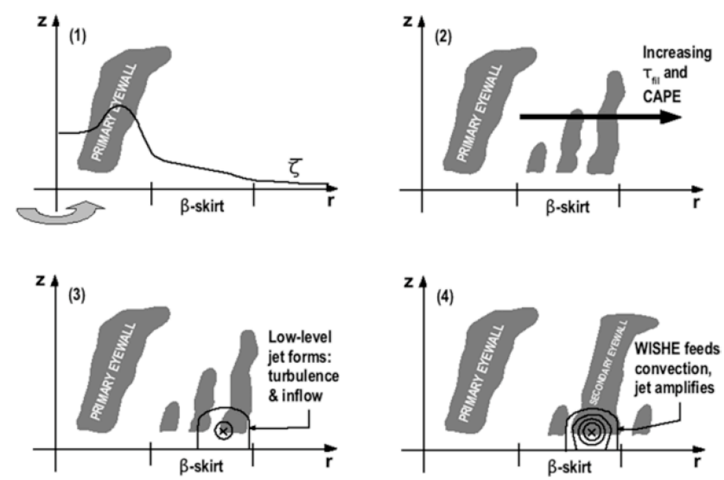




Inestabilidad WISHE (amplitud finita)



β-Falda



Interacciones Barotrópicas entre vórtices

Kuo, Lin, Chang and Williams; 2004
Kuo, Schubert, Ling and Kuo; 2008

Diseño de experimentos

$$\frac{\partial \zeta}{\partial t} + \frac{\partial(\psi,\ \zeta)}{\partial(x,\ y)} = \nu \nabla^2 \zeta,$$

$$\zeta = \nabla^2 \psi$$

$$u = -\partial\psi/\partial y$$

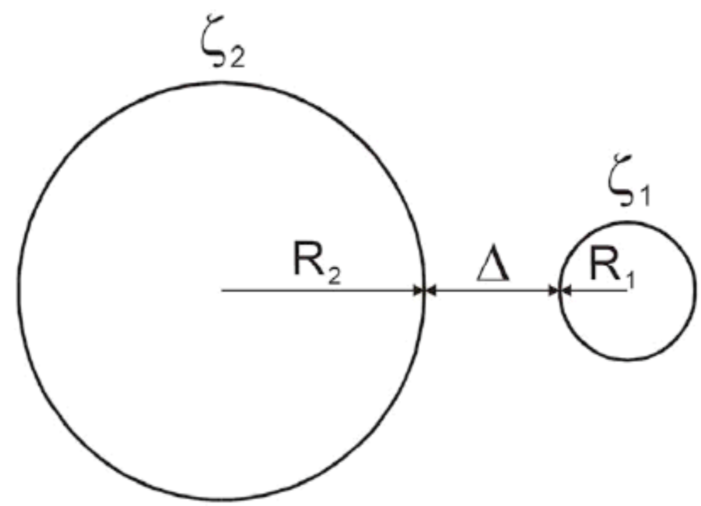
$$v = \partial\psi/\partial x$$

Dritschel y Waugh (1992)

$$r = \frac{R_1}{R_2}$$

$$\Delta / R_1$$

$$\gamma = \frac{\zeta_1}{\zeta_2}$$



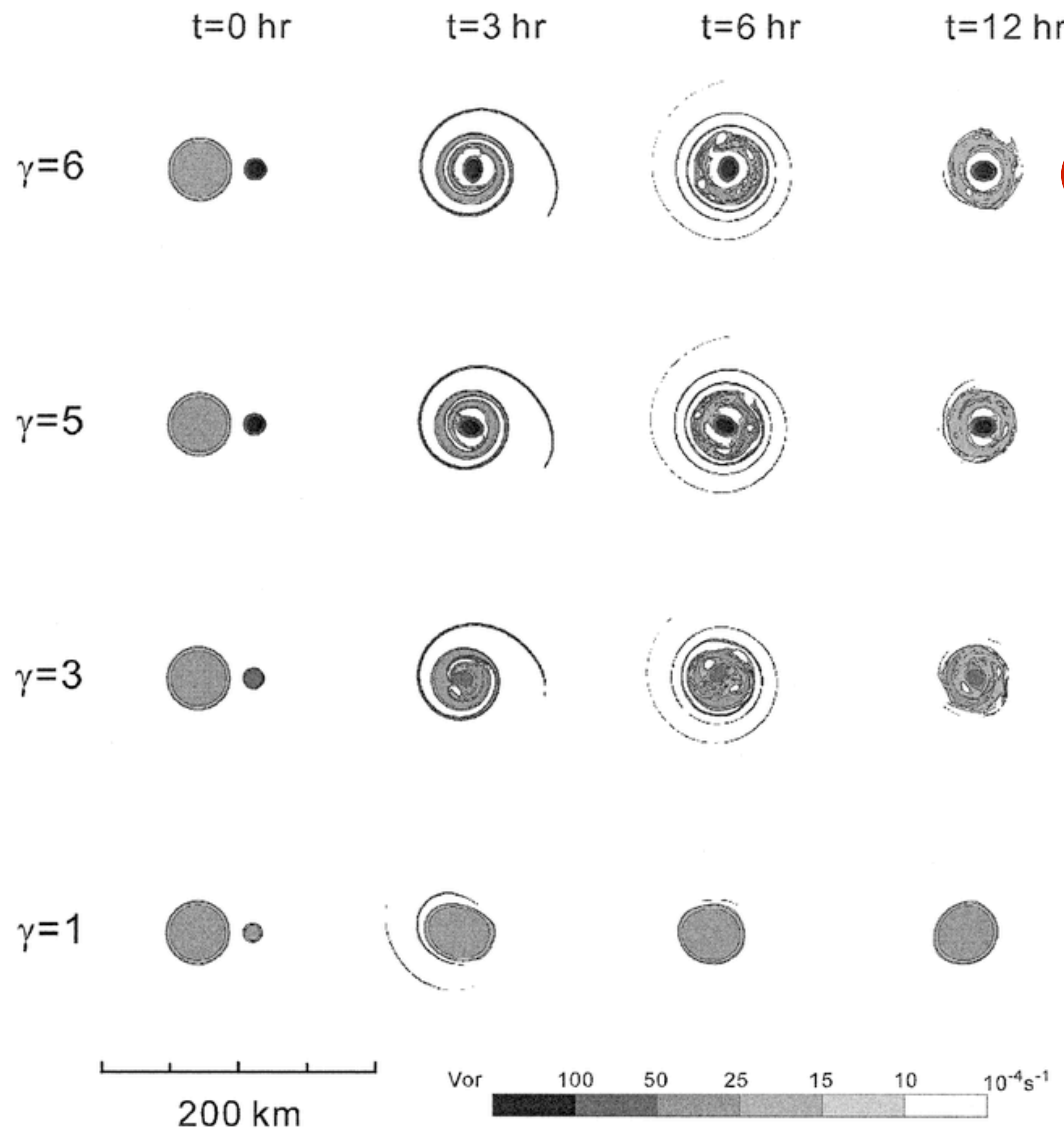
Vórtices Rankine

Kuo et al. (2004)

$$\gamma = \frac{\zeta_1}{\zeta_2}$$

$r=1/3$

$\Delta/R_1=1$

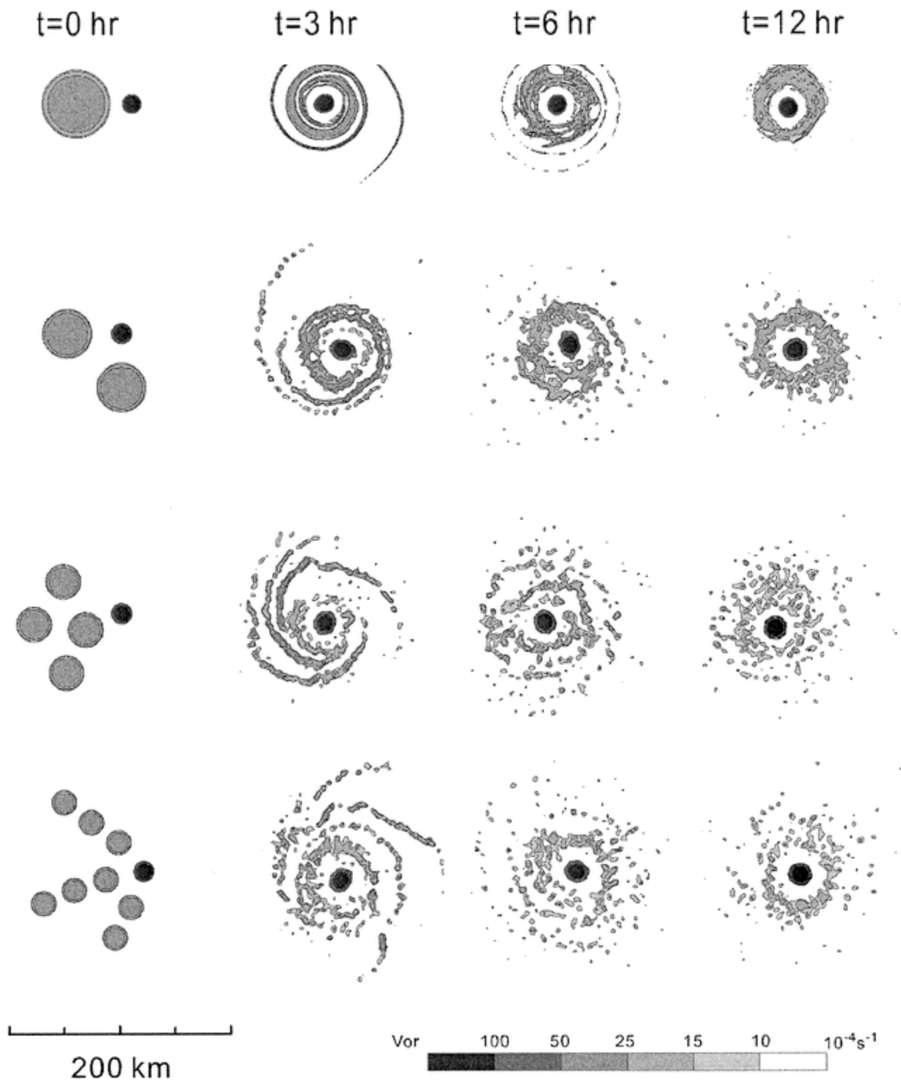


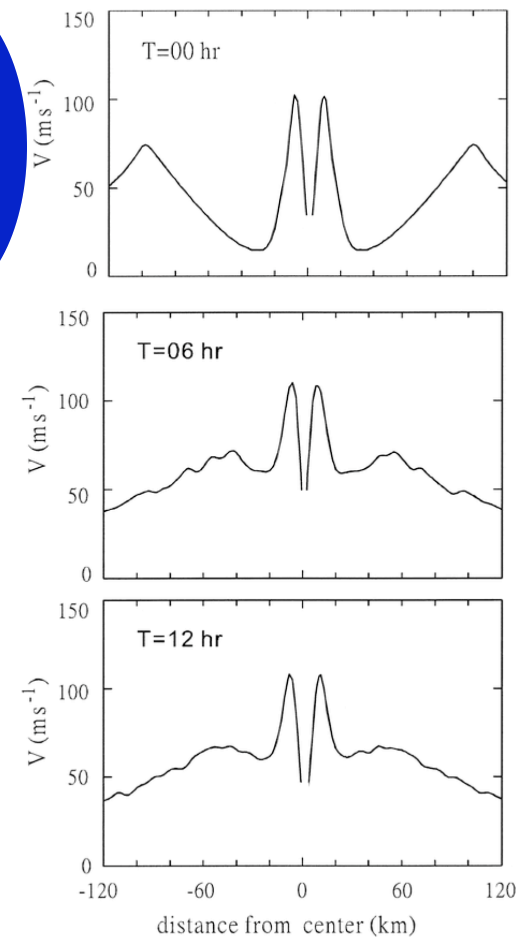
CONCENTRICAS

Fusión

Kuo et al. (2004)

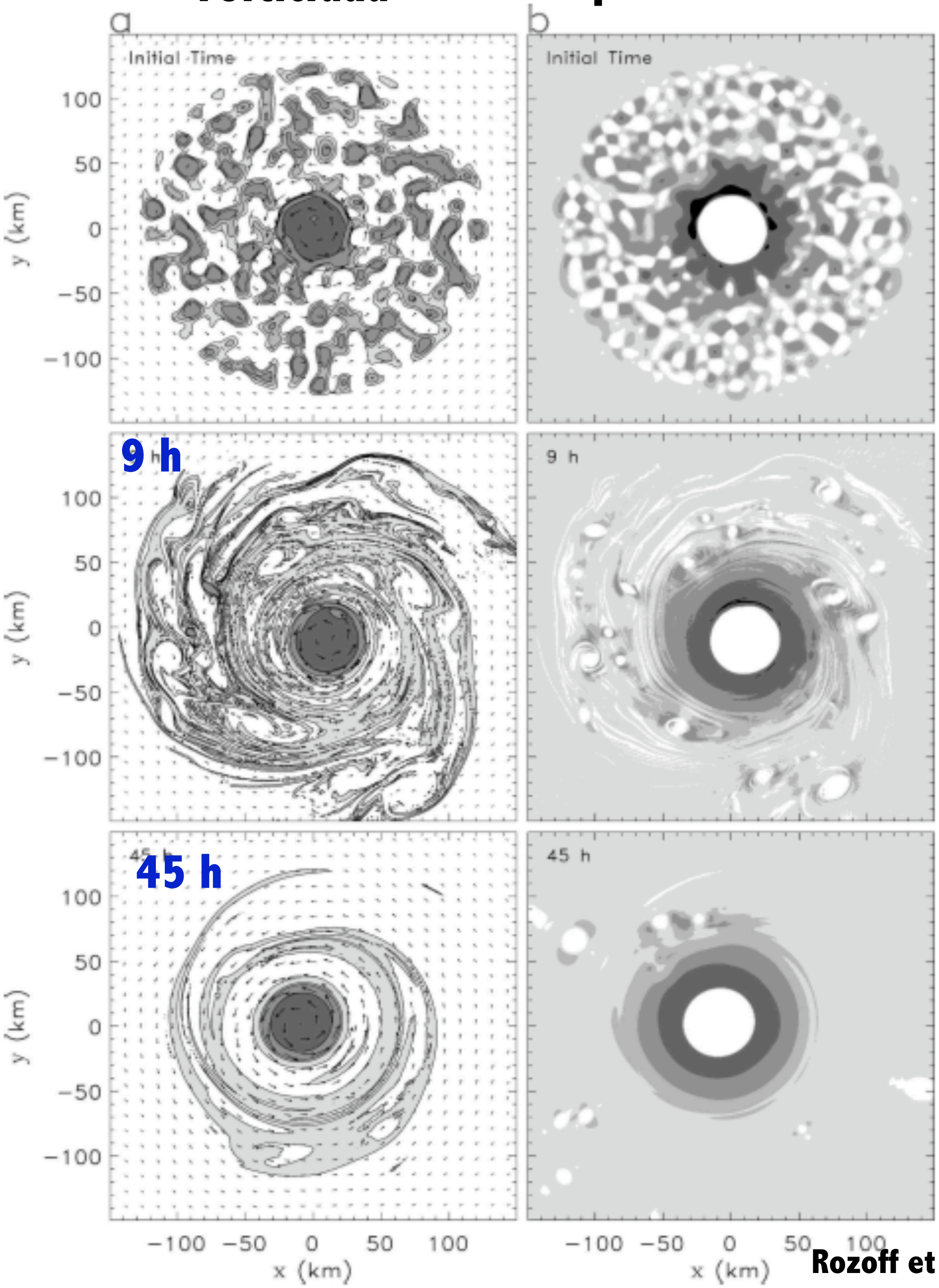
Estructuras concéntricas en todas las configuraciones





Contracción de la estructura secundaria

Vorticidad Tiempo de filamentación



Rozoff et al. (2006)

Tiempo de filamentación

$$2(S_1^2+S_2^2-\zeta^2)^{-1/2}$$

S_1 **Deformación "strain"**

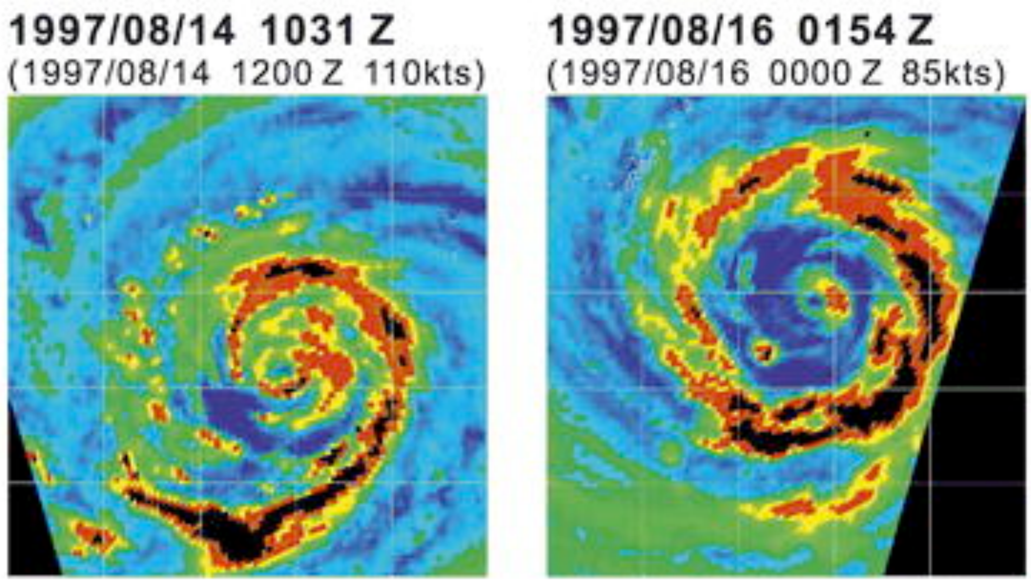
S_2 **Deformación por sizalla**

Estructuras concéntricas también resultan de aglomeraciones de vorticidad aleatoriamente distribuídas

Conclusiones

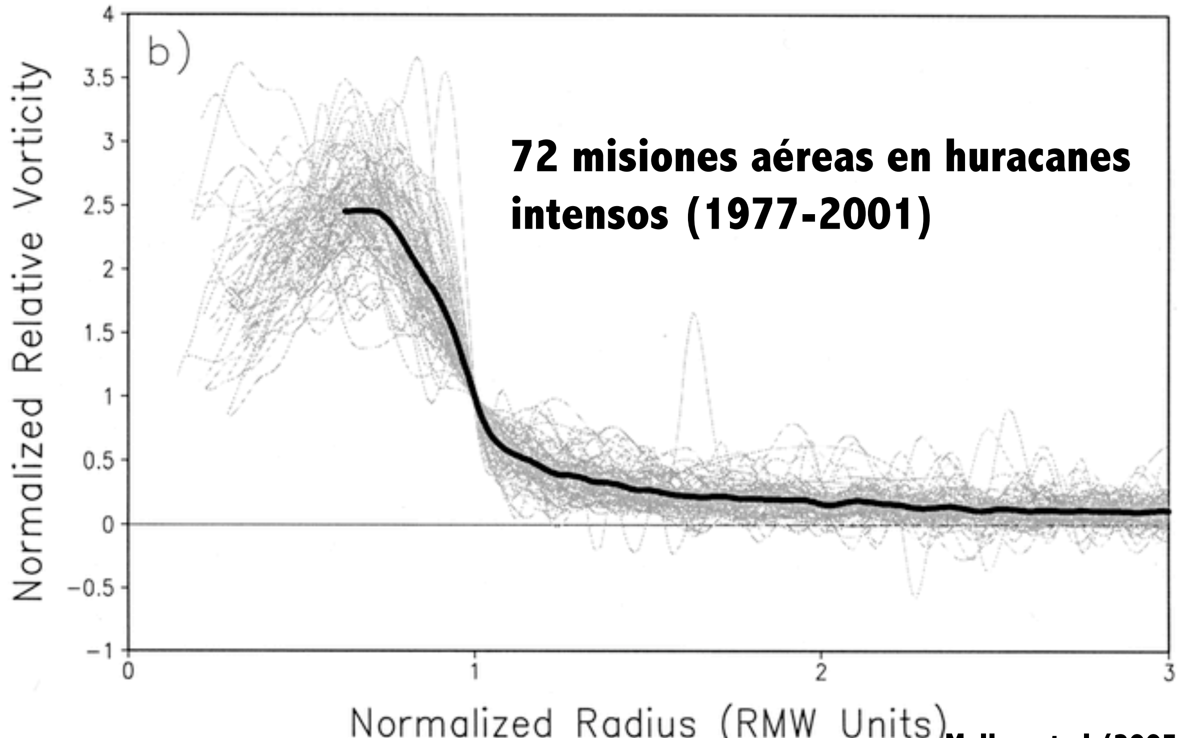
- La formación de estructuras concéntricas requiere:
  - Vórtice 6 veces más fuerte que las aglomeraciones de vorticidad que lo rodean
  - La distancia entre los vórtices debe ser menor a 3-4 veces el radio del vórtice pequeño
- La contracción del máximo secundario de vientos puede ser un resultado de interacción de vórtices barotrópicos

Winnie
(1997)



Kuo et al. (2008)

FPS @
R ~ 270Km!



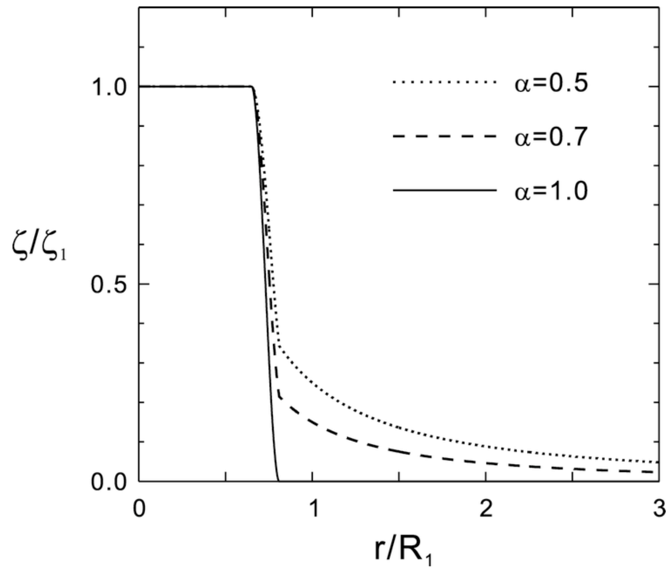
Mallen et al (2005)

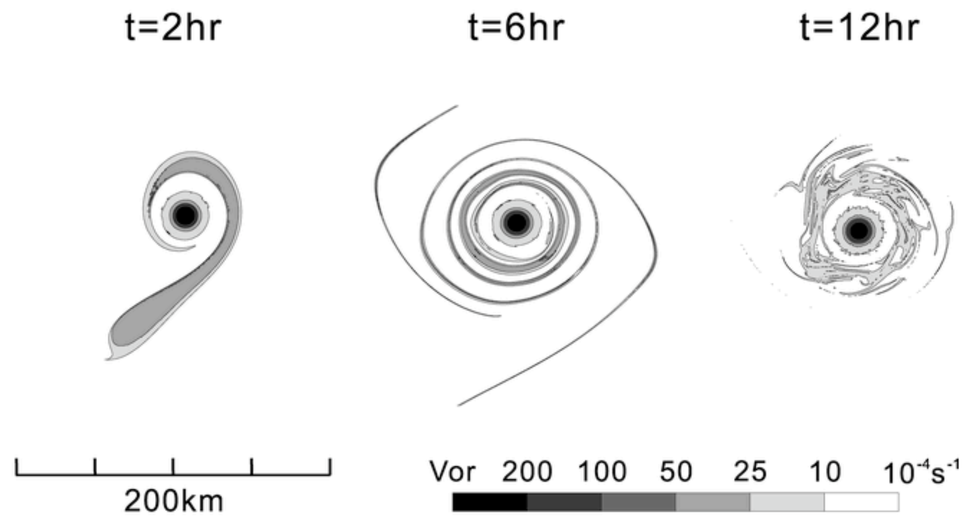
¡Los huracanes intensos no son vórtices Rankine!

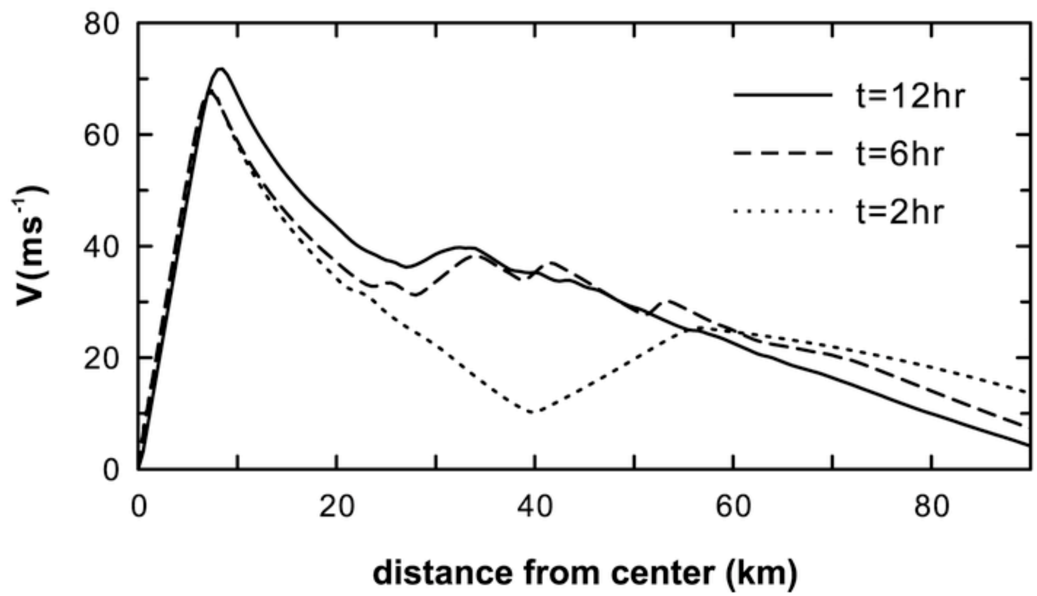
Formación de paredes concéntricas

$\alpha = 0.7 \quad r=1/4$

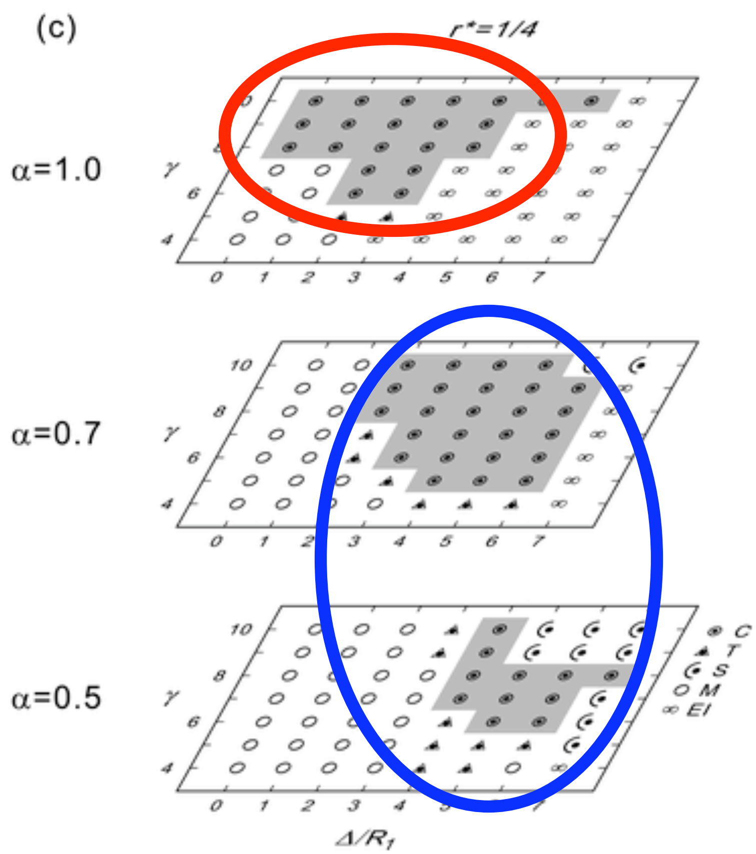
$\gamma=7 \quad \Delta/R_1=5$







Dinámica advectiva en 2D podría explicar la contracción de la pared secundaria



Las estructuras concéntricas son favorecidas:

- $\alpha = 1$ cerca del vórtice fuerte
- $\alpha = 0.7, 0.5$: lejos del vórtice fuerte

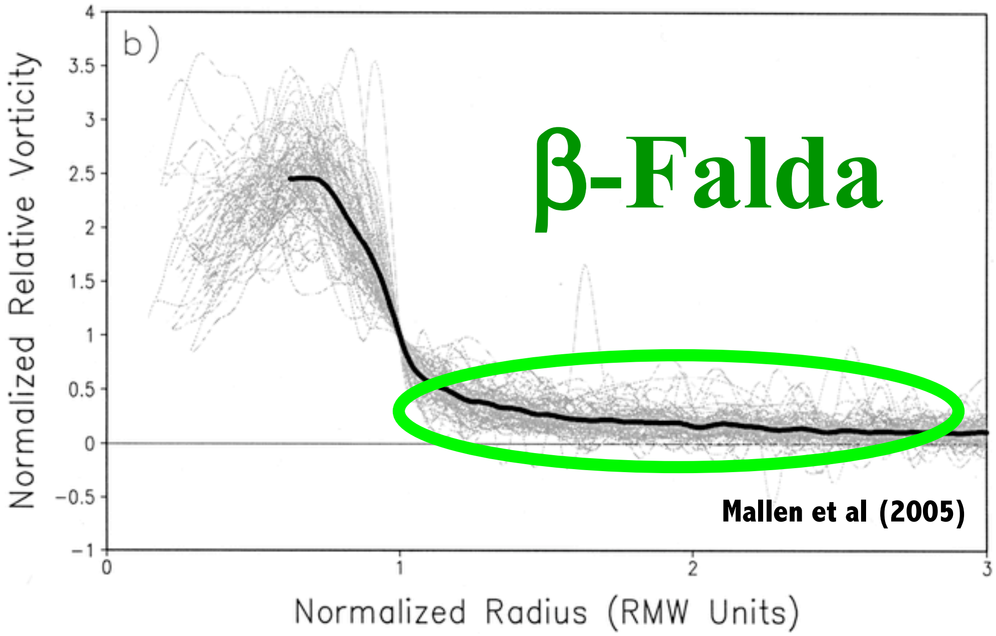
Hipótesis

- FPS resulta de dinámica advectiva en 2D
- Ocurre cuando un vórtice “grande y débil” está relativamente cerca del centro del CT

β-falda

Terwey and Montgomery; 2008

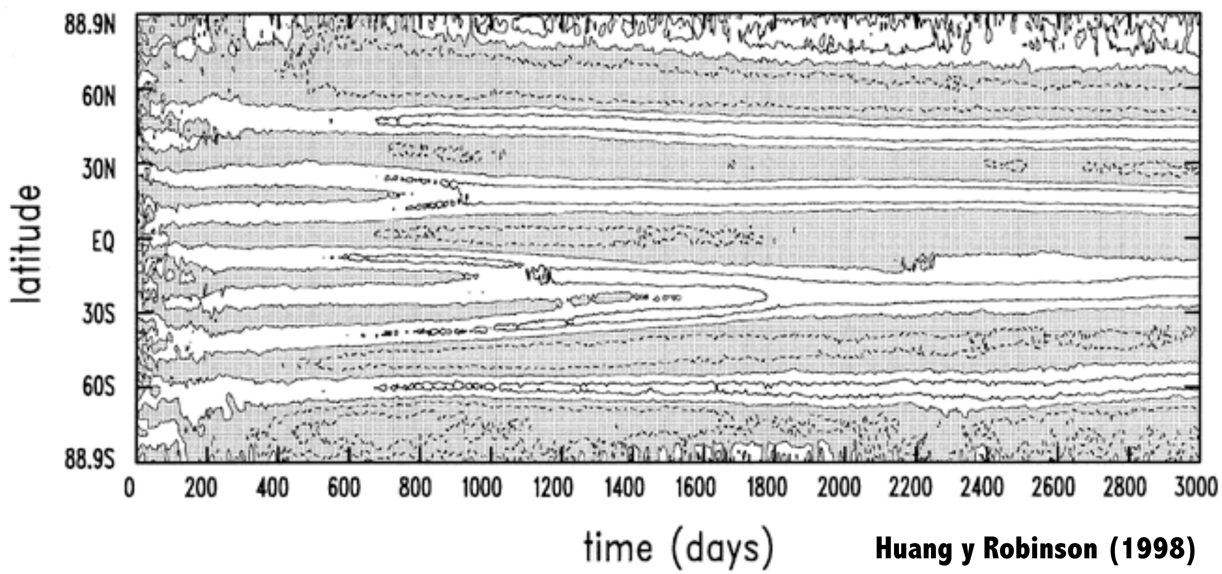
Vorticidad relativa media-azimutal



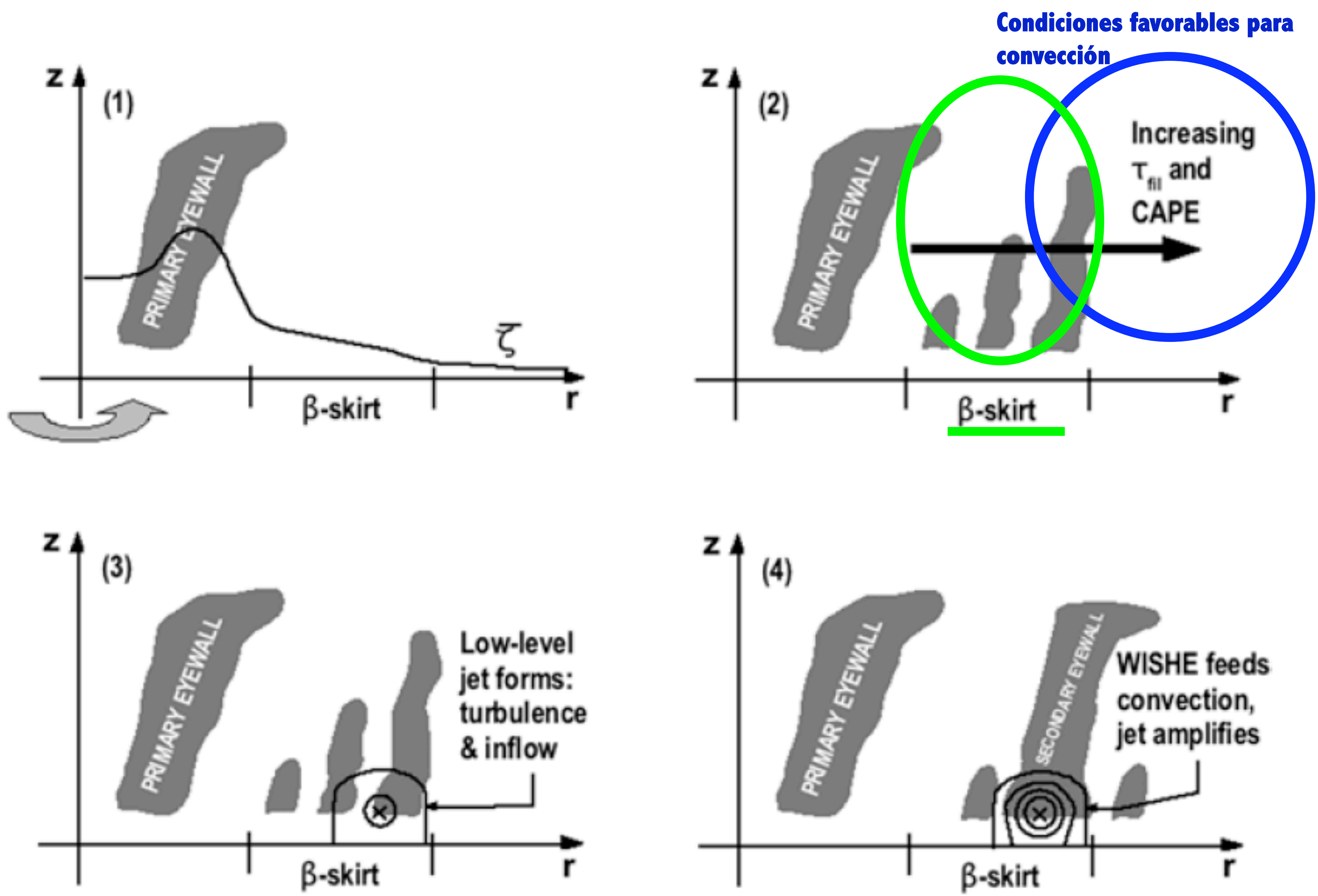
Viento medio zonal

Turbulencia 2D en una esfera

- C.I. Perturbaciones
- Organización del flujo en jets zonales



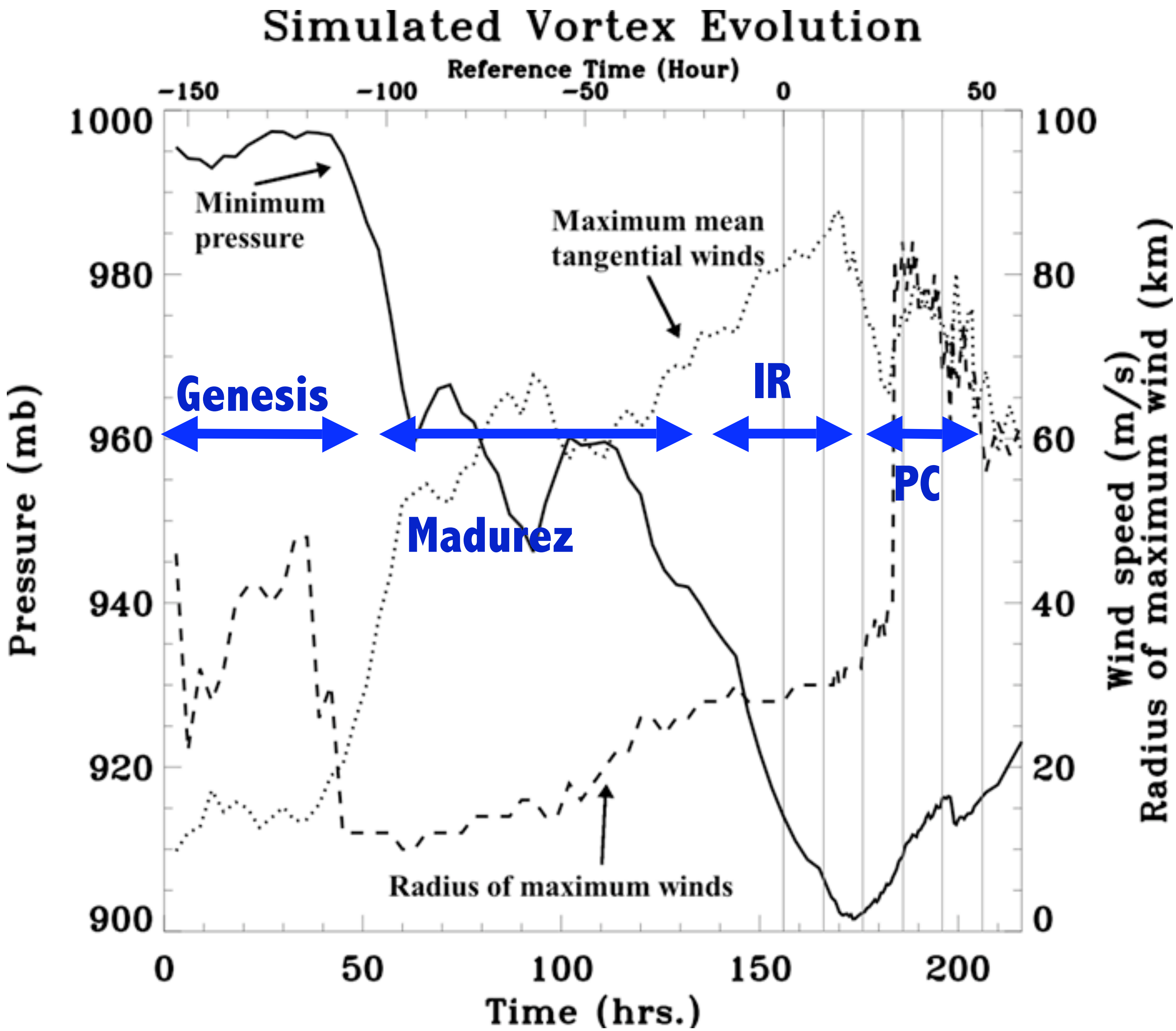
Huang y Robinson (1998)

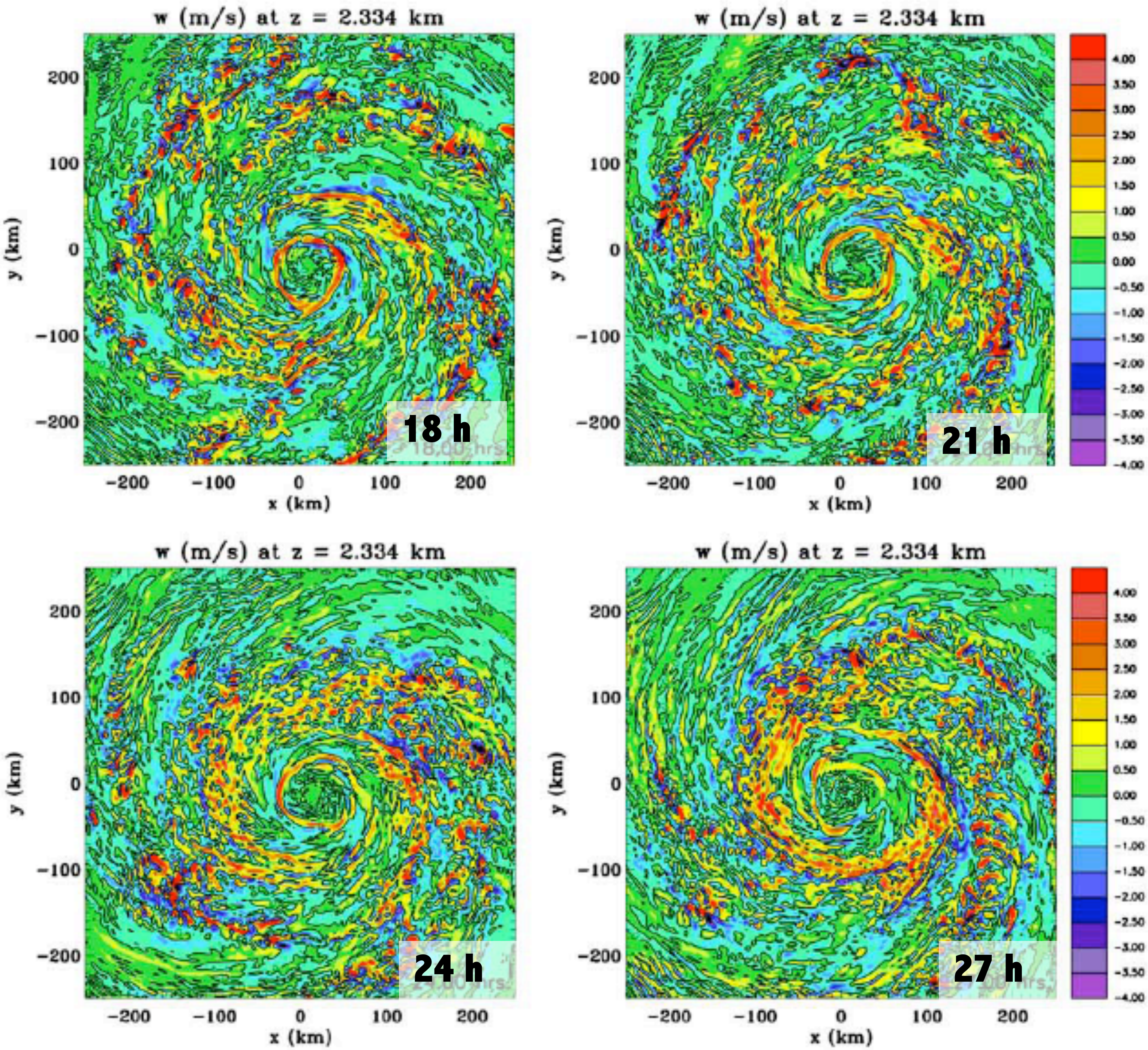


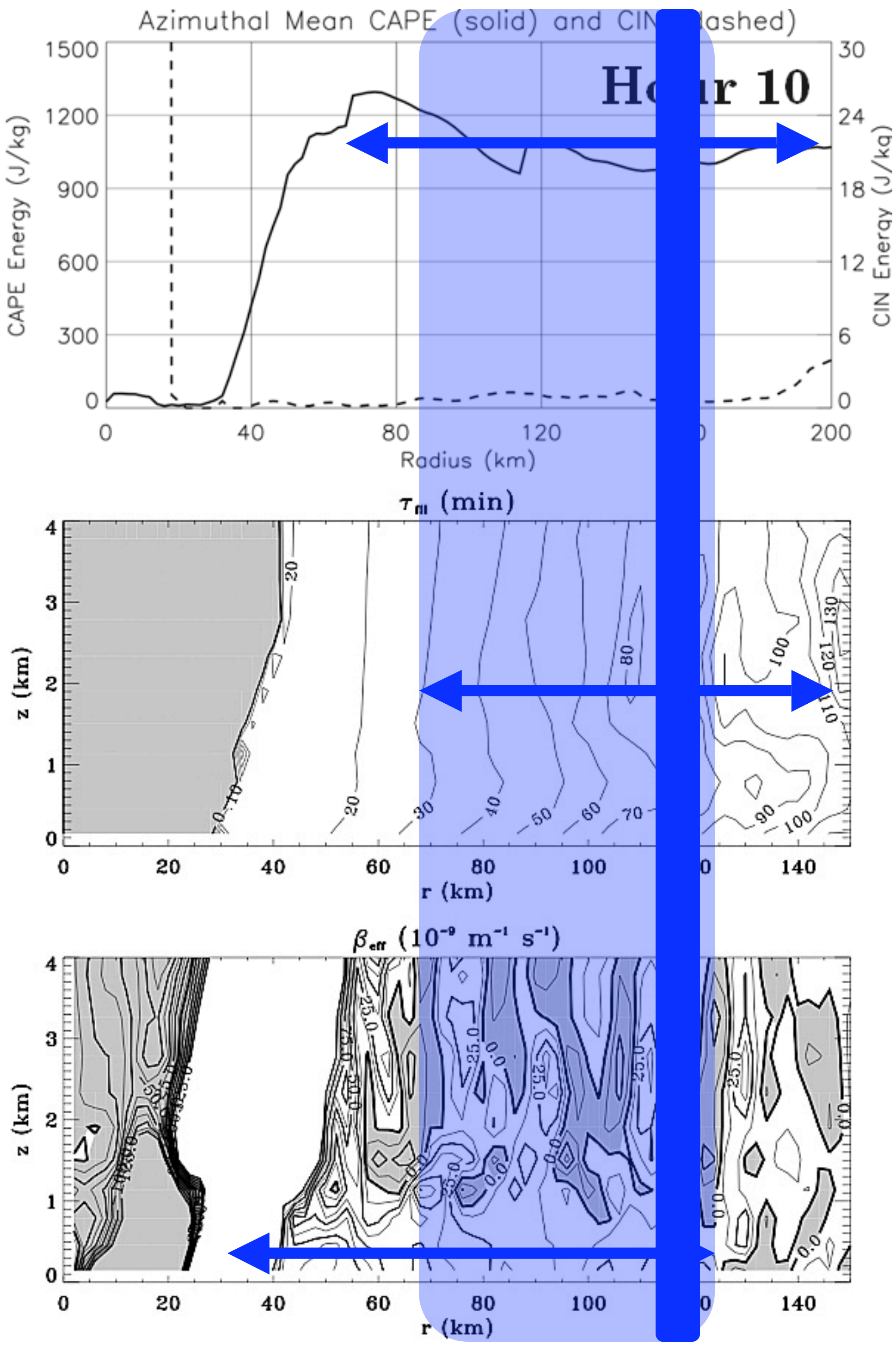
Condiciones favorables para convección
z
(1)
PRIMARY EYEWALL
ζ
β-skirt
r
(2)
Increasing
τ_{fil} and
CAPE
(3)
Low-level
jet forms:
turbulence
& inflow
(4)
SECONDARY EYEWALL
WISHE feeds
convection,
jet amplifies

Detalles de la simulación

- RAMS versión 2.9
- 3 Dominios (2,6 and 24 km)
  - Condiciones de frontera periódicas (laterales)
- F constante, 15^0
- 28^0C TSM
- Inicialización con vórtice de mesoescala
  - V_{max}~10 m/s a 75 km
  - Jordan (1958) sondeo medio (humedecido cérca del centro)
- 204 horas de simulación


Simulated Vortex Evolution
Reference Time (Hour)
−150
−100
−50
0
50
1000
980
960
940
920
900
100
80
60
40
20
0
Minimum pressure
Maximum mean tangential winds
Radius of maximum winds
Genesis
Madurez
IR
PC
Pressure (mb)
Wind speed (m/s)
Radius of maximum wind (km)
0
50
100
150
200
Time (hrs.)


w (m/s) at z = 2.334 km
w (m/s) at z = 2.334 km
w (m/s) at z = 2.334 km
w (m/s) at z = 2.334 km
18 h
21 h
24 h
27 h
y (km)
x (km)
200
100
0
−100
−200
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
−0.50
−1.00
−1.50
−2.00
−2.50
−3.00
−3.50
−4.00

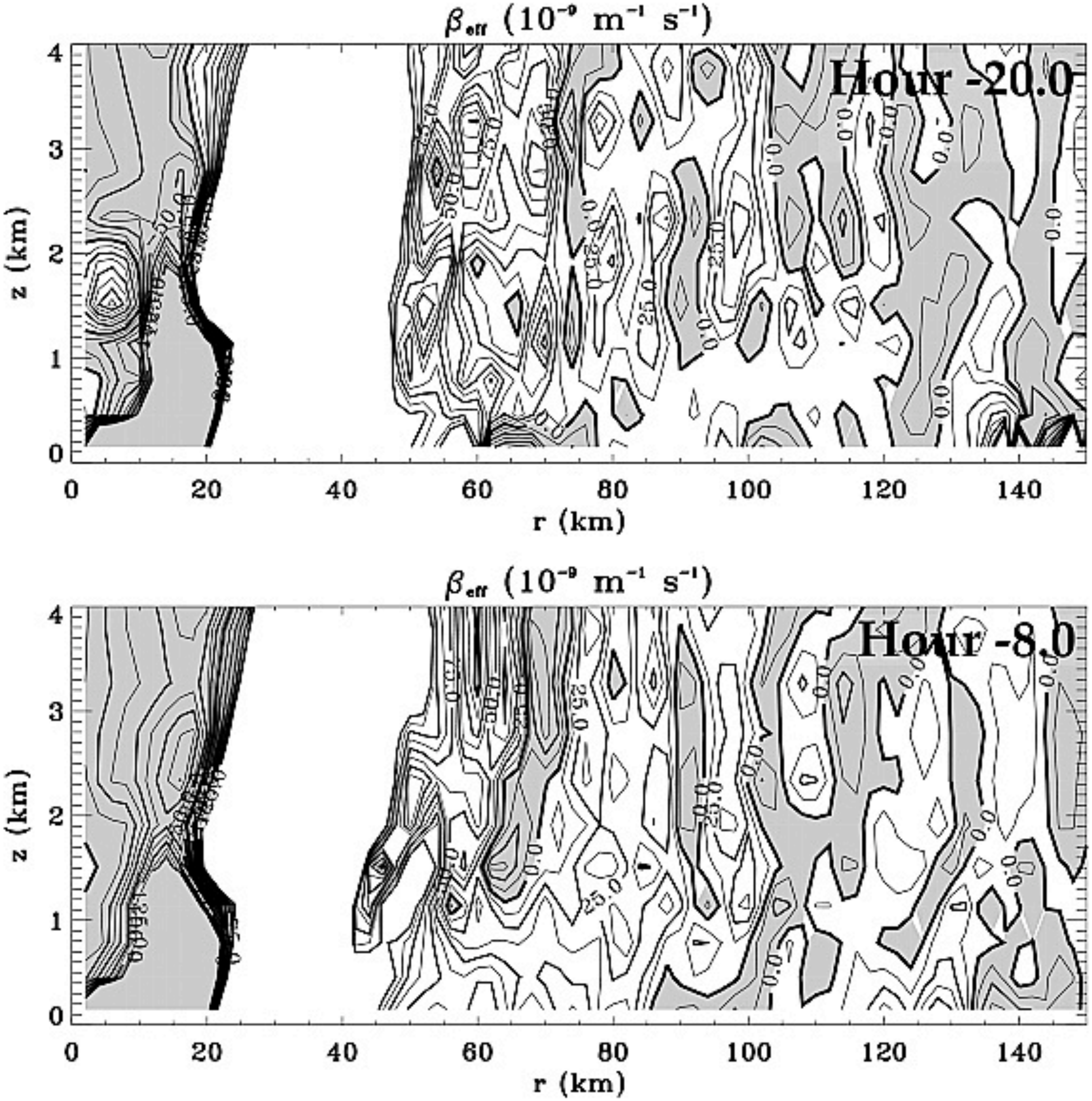


Condiciones favorables para convección:

CAPE y CIN @~60Km

Tiempo de filamentación @~70Km

FPC puede ocurrir entre ~70-120Km



β_{eff} (10^{-9} m^{-1} s^{-1})
Hour -20.0
z (km)
r (km)
0 1 2 3 4
0 20 40 60 80 100 120 140
β_{eff} (10^{-9} m^{-1} s^{-1})
Hour -8.0
z (km)
r (km)
0 1 2 3 4
0 20 40 60 80 100 120 140

Hipótesis

FPC ocurre en regiones dónde:

- Ocurre convección (alto potencial convectivo)
- ß-falda está presente, forma un Jet

Jet evoluciona a una pared concéntrica a través de WISHE

Inestabilidad de WISHE de amplitud finita

Nong y Emanuel; 2003

Descripción del 1er modelo

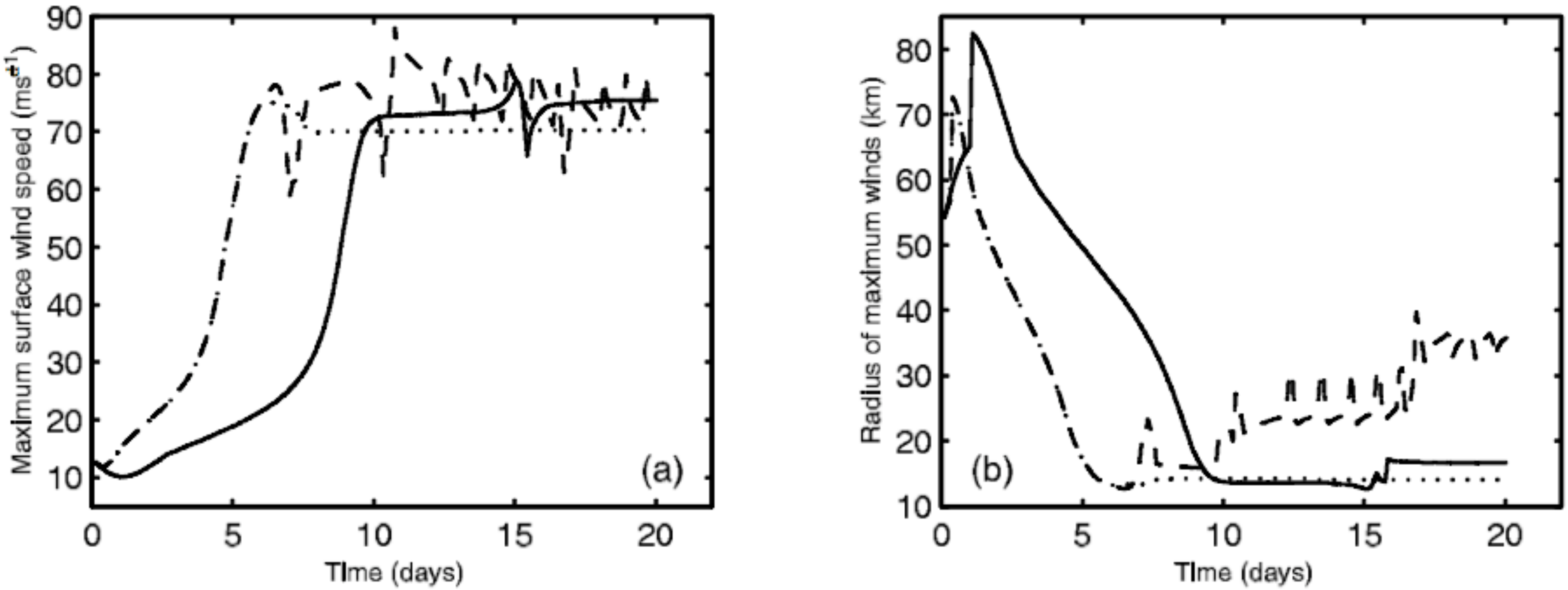
- **Simétrico con respecto al eje de rotación**
- **2 capas**
  - **Debajo de las nubes**
  - **Resto de la troposfera**
- **Dinámica en balance**
- **Convección parametrizada**

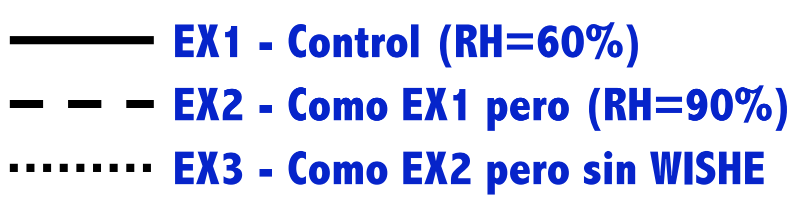
Vórtice inicial

•R_{vm} = 60 km
•$R_{\text{vientos cesan}}$ = 400 km
•Viento máximo = 10m s^{-1}

EX1	Control
EX2	$\mathcal{H}_m$ increased from 60% to 90% in the lower troposphere
EX3	Same as EX2 except that surface wind at 8 days is used in the calculations of surface entropy fluxes after 8 days
EX4	Same as EX1 except that Gaussian random perturbations with zero mean and standard deviation of 5 are instantly added to the surface entropy fluxes at 9.4 days in the entire model domain
EX5	Same as EX4 except that the random perturbations begin at 9.4 days and last 7.5 hours in the entire model domain

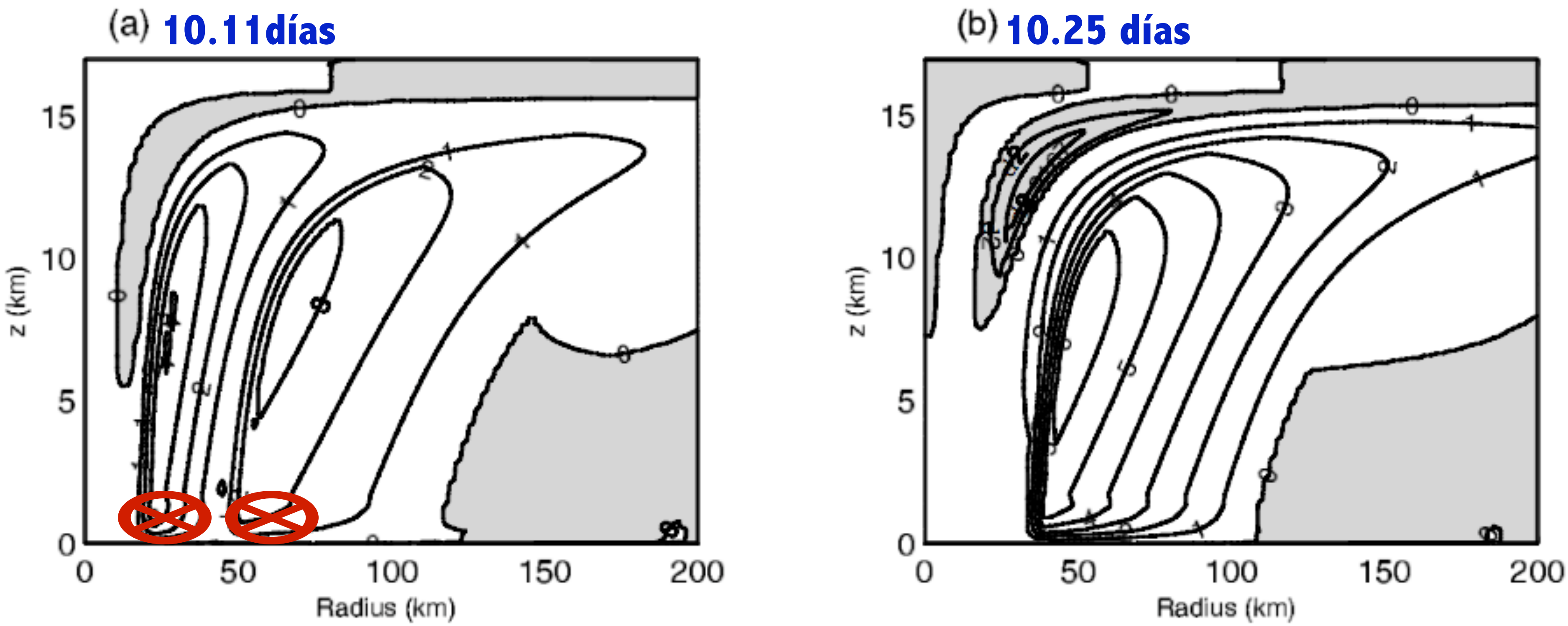
Resultados del 1er modelo





Nong y Emanuel (2003)

Resultados del 1er modelo

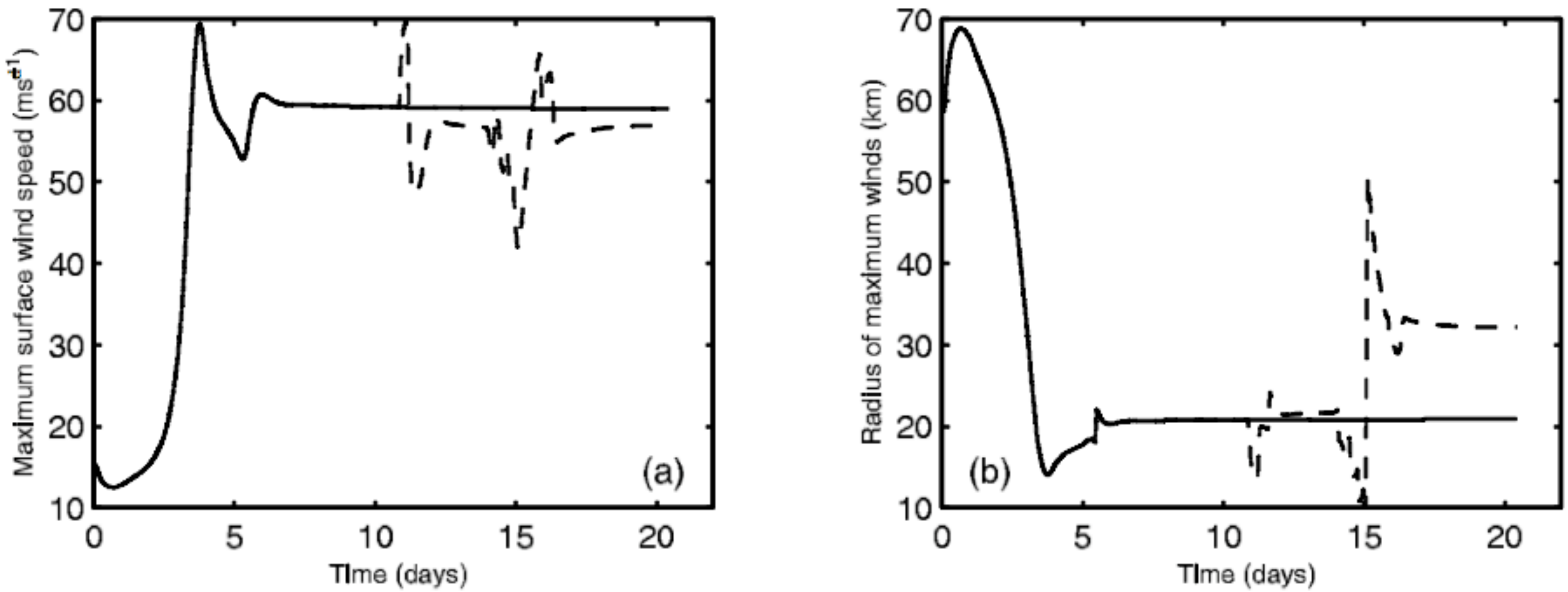


EX2 Velocidad vertical [m s^{-1}]

- **Doble máximo de viento en la superficie**

Nong y Emanuel (2003)

Resultados del 1er modelo



EX4 - Como EX1, con perturbaciones aleatorias a los 9.4 días

EX5 - Como EX4, pero la perturbación dura 7.5 horas

Nong y Emanuel (2003)

Conclusiones

- **El modelo simple produce FPC**
  - **Sin forzamiento externo**
  - **Siempre y cuando la tropósfera sea lo suficientemente húmeda**
    - **En una tropósfera más seca, una perturbación de amplitud finita es necesaria para FPC**
- **WISHE es responsable de la FPC**

Modelo que resuelve nubes (CRM)

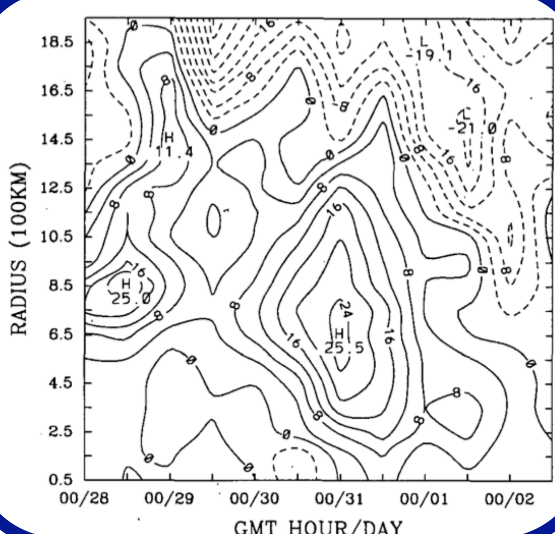
$$\frac{du}{dt}-\left(f+\frac{v}{r}\right)v=-c_p\bar{\theta}_v\frac{\partial \pi}{\partial r}+D_u$$

$$\frac{dv}{dt}+\left(f+\frac{v}{r}\right)u= D_v + \boxed{F_v=\frac{1}{r^2}\frac{\partial}{\partial r}\left(-\overline{r^2u'v'}\right)}$$

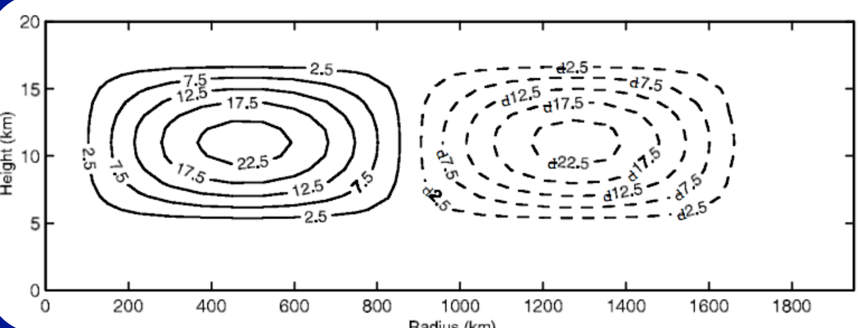
$$\frac{dw}{dt}=-c_p\bar{\theta}_v\frac{\partial \pi}{\partial z}+D_w + g\left\{\frac{\theta-\bar{\theta}}{\bar{\theta}}+0.61(q_v-\bar{q}_v)-q_l\right\}$$

EXP1	No eddy forcing is added
EXP2	Same as EXP1 but initial relative humidity is 90% from 1.875 to 9.375 km altitude
EXP3	Same as EXP1 with eddy forcing turned on for 60 h
EXP4	Same as EXP3 but the WISHE mechanism is turned off by using the surface winds at 130 h in the calculations of surface heat fluxes between 130 h and 230 h. After 230 h the WISHE mechanism is switched on again
EXP5	Same as EXP3 but without ice processes
EXP6	Same as EXP3 but no negative spin-up
EXP7	Same as EXP3 but no positive spin-up
EXP8	Same as EXP3 but $A_{\mathrm{efc}} = 15$ m s^{-1}d^{-1}
EXP9	Same as EXP3 but $A_{\mathrm{efc}} = 35$ m s^{-1}d^{-1}
EXP10	Same as EXP3 but $A_{\mathrm{efc}} = 35$ m s^{-1}d^{-1} but the WISHE mechanism turned off
EXP11	Same as EXP3 but $r_0 = 160$ km
EXP12	Same as EXP3 but $r_0 = 300$ km
EXP13	Same as EXP3 but $l_r = 1000$ km and $r_b = 3000$ km
EXP14	Same as EXP3 but $z_0 = 7$ km
EXP15	Same as EXP3 but $l_z = 10$ km
EXP16	Same as EXP3 but $t_{\mathrm{max}} = 115$ h, $l_t = 15$ h

$$F_v=\frac{1}{r^2}\frac{\partial}{\partial r}\left(-\overline{r^2u'v'}\right)$$

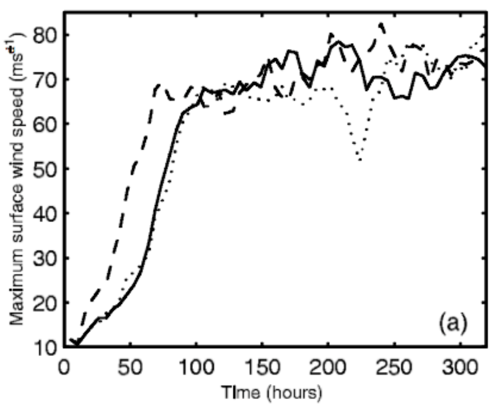


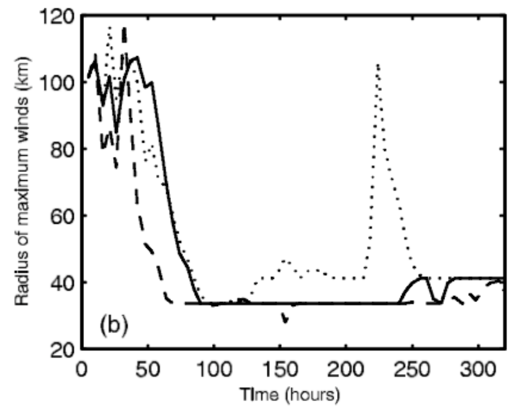
Molinari y Vollaro (1990)



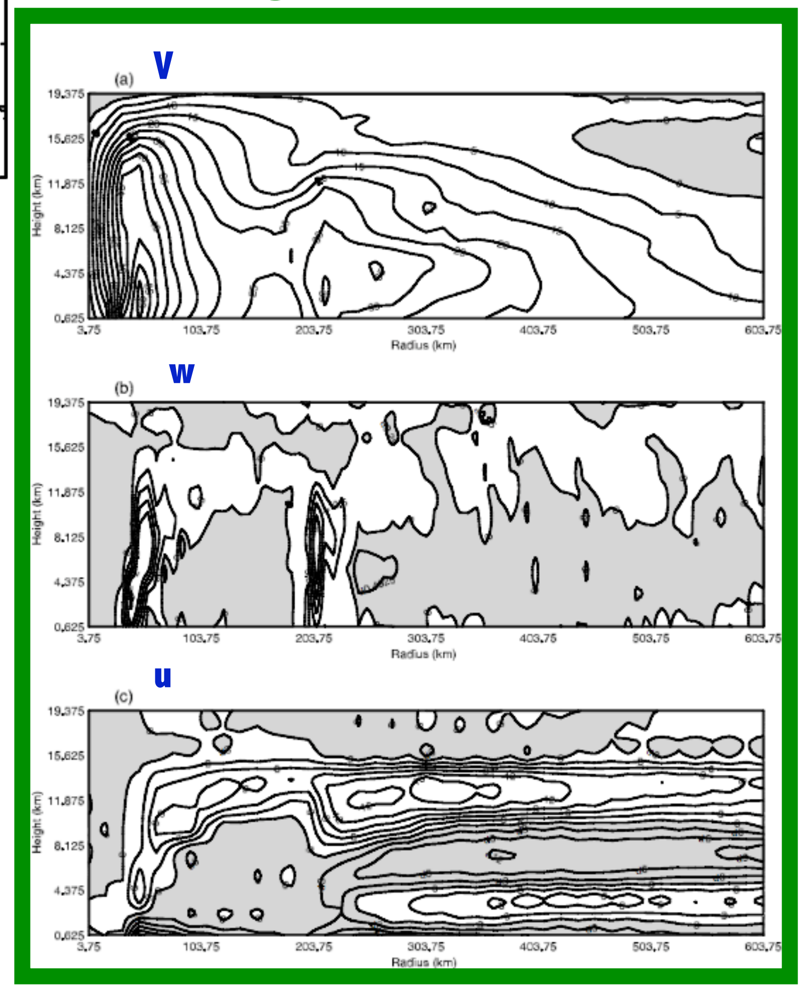
Nong y Emanuel (2003)

Resultados del 2do modelo





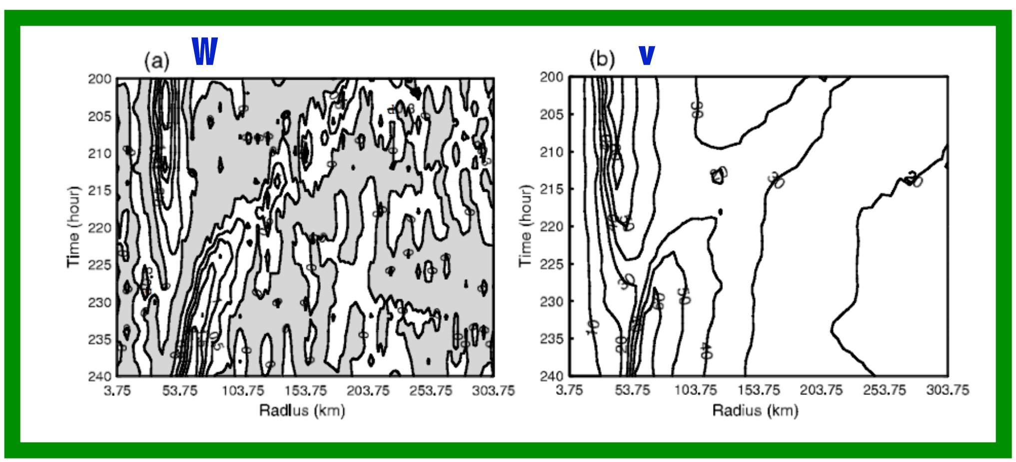
@ hr=200



EX1 - Sin forzamiento por remolinos

EX2 - Como EX1 RH=90% (~2-10Km)

EX3 - Como EX1 con forzamiento por remolinos



Results Model 2

TABLE 2. DESCRIPTION OF EXPERIMENTS WITH THE FULL-PHYSICS MODEL

EXP1	No eddy forcing is added
EXP2	Same as EXP1 but initial relative humidity is 90% from 1.875 to 9.375 km altitude
EXP3	Same as EXP1 with eddy forcing turned on for 60 h
EXP4	Same as EXP3 but the WISHE mechanism is turned off by using the surface winds at 130 h in the calculations of surface heat fluxes between 130 h and 230 h. After 230 h the WISHE mechanism is switched on again
EXP5	Same as EXP3 but without ice processes
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EXP9	Same as EXP3 but $A_{efc} = 35$ m s^{-1}d^{-1}
EXP10	Same as EXP3 but $A_{efc} = 35$ m s^{-1}d^{-1} but the WISHE mechanism turned off
EXP11	Same as EXP3 but $r_0 = 160$ km
EXP12	Same as EXP3 but $r_0 = 300$ km
EXP13	Same as EXP3 but $l_r = 1000$ km and $r_b = 3000$ km
EXP14	Same as EXP3 but $z_0 = 7$ km
EXP15	Same as EXP3 but $l_z = 10$ km
EXP16	Same as EXP3 but $t_{max} = 115$ h, $l_t = 15$ h

Sin-WISHE

Forzamiento

FPC

FPC ocurre sólo cuando:

- **WISHE se permite**
- **El forzamiento por remolinos actúa**
  - **Lo suficientemente fuerte**
  - **FPC multiples**

Hipótesis

- Lo que produce la FPC es una retroalimentación de WISHE
- Algún forzamiento "externo" es necesario

+ $$\boxed{F_v = \frac{1}{r^2}\frac{\partial}{\partial r}(-\overline{r^2 u' v'})}$$

Conclusiones

- No está claro cuáles son los procesos físicos que generan FPC
- FPC ocurre en un ambiente altamente convectivo.
- Una teoría completa de FPC debe basarse en un modelo realista

En nuestras simulaciones se observan:

- β-falda antes de FPC?
  - La convección en la región es activa?
  - Se forma un jet?

- Podemos identificar regiones de vorticidad que pudieran actuar como un vórtice “grande y débil”?

- Hay sistemas sinópticos que interactúan con el CT antes o durante la FPC?