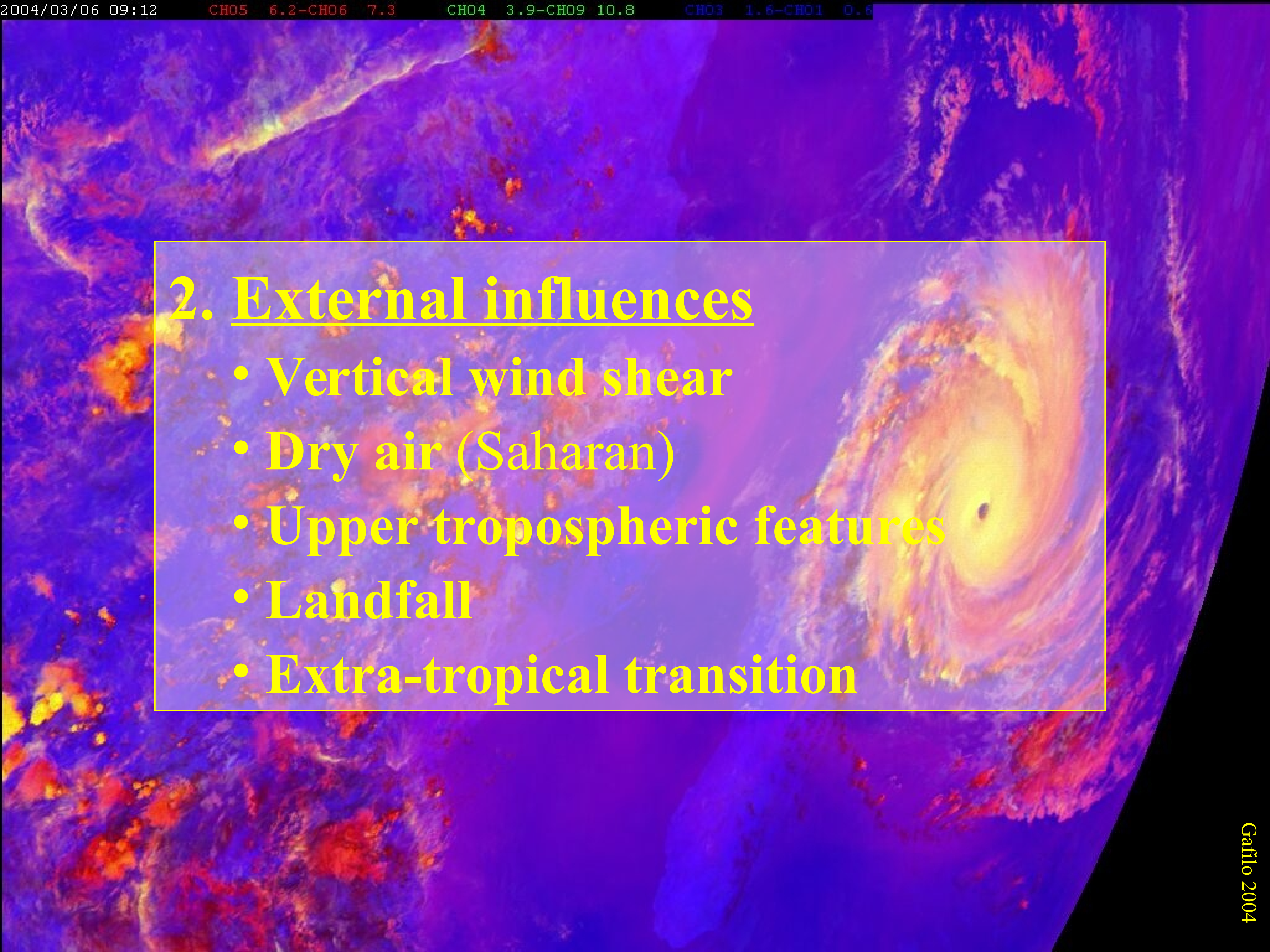
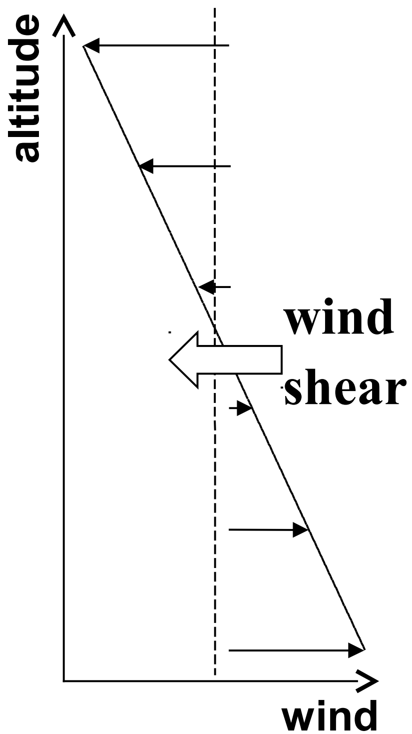


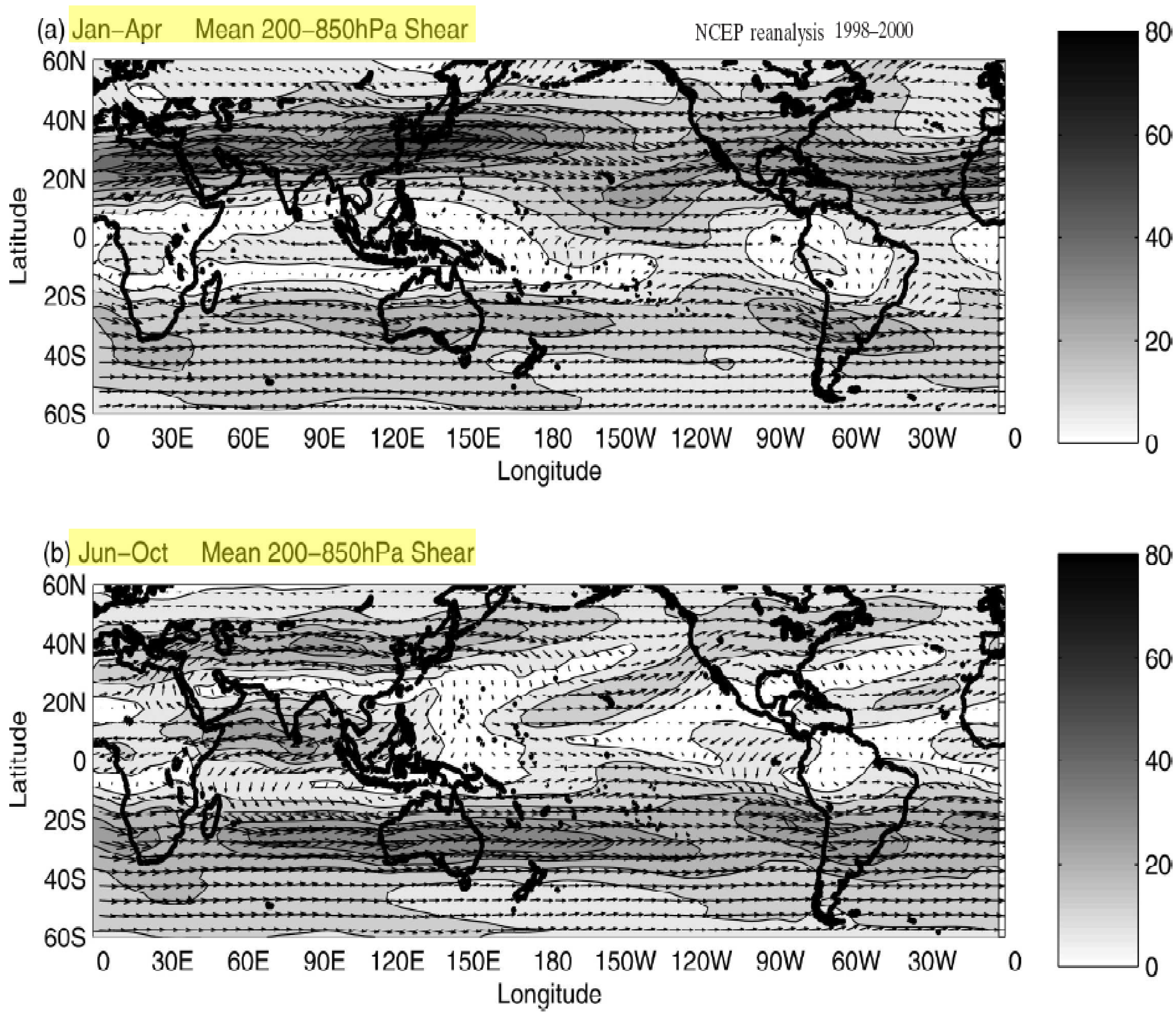
2. External influences

- **Vertical wind shear**
- **Dry air** (Saharan)
- **Upper tropospheric features**
- **Landfall**
- **Extra-tropical transition**

Gafilo 2004

VERTICAL WIND SHEAR (1)

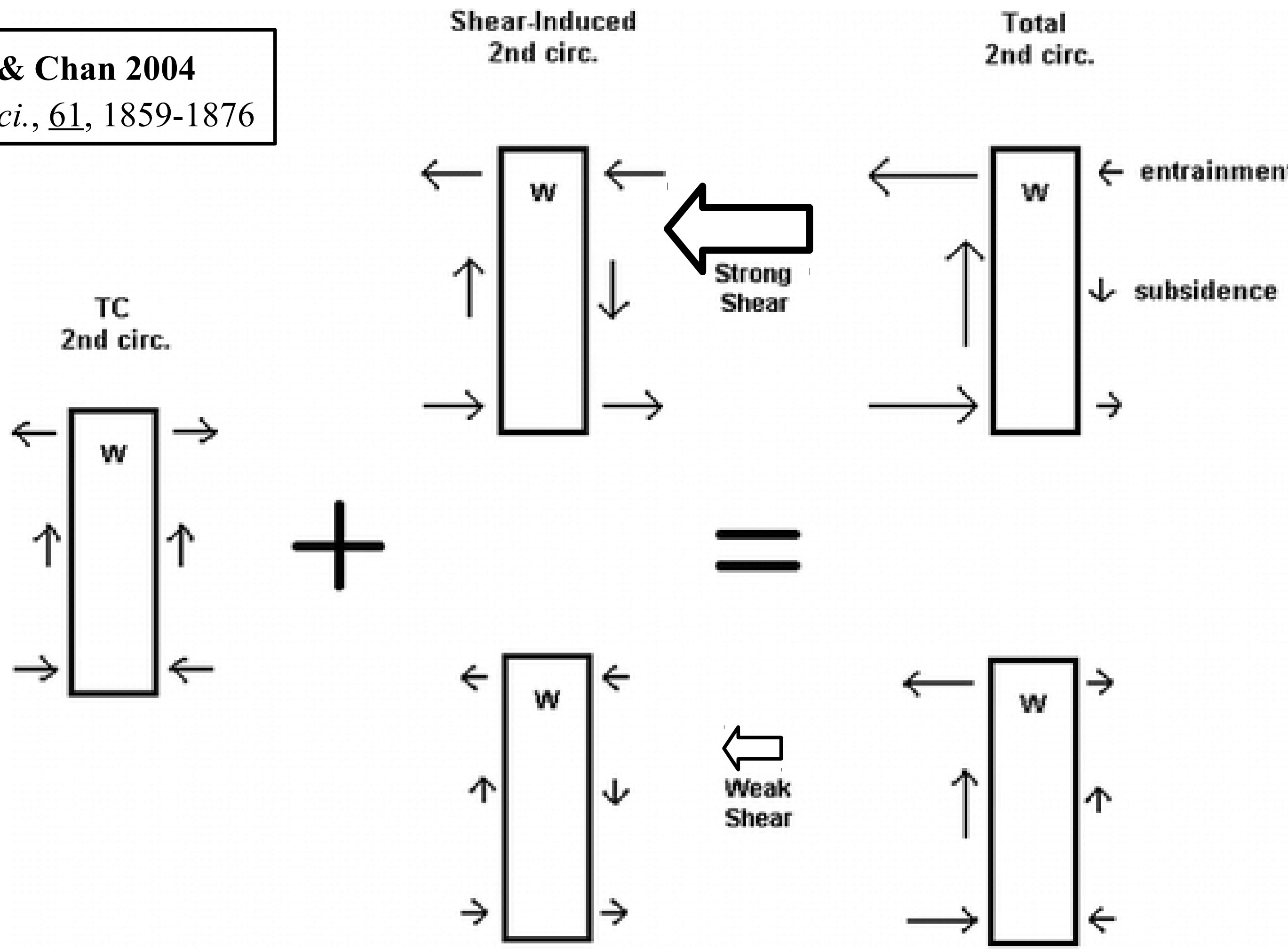




Chen *et al.* 2006
Mon. Wea. Rev., <u>134</u>,
3190-3208

VERTICAL WIND SHEAR (2)

Wong & Chan 2004
J. Atmos. Sci., 61, 1859-1876



Schematic diagram showing the secondary circulation under strong and weak environmental vertical wind shear. Arrows indicate the direction and strength of the circulation; "W" stands for the warm core at the upper levels

Braun & Wu 2007
Mon. Wea. Rev., 135, 1179-1194

VERTICAL WIND SHEAR (3)

Hurricane Erin (Sep 01)

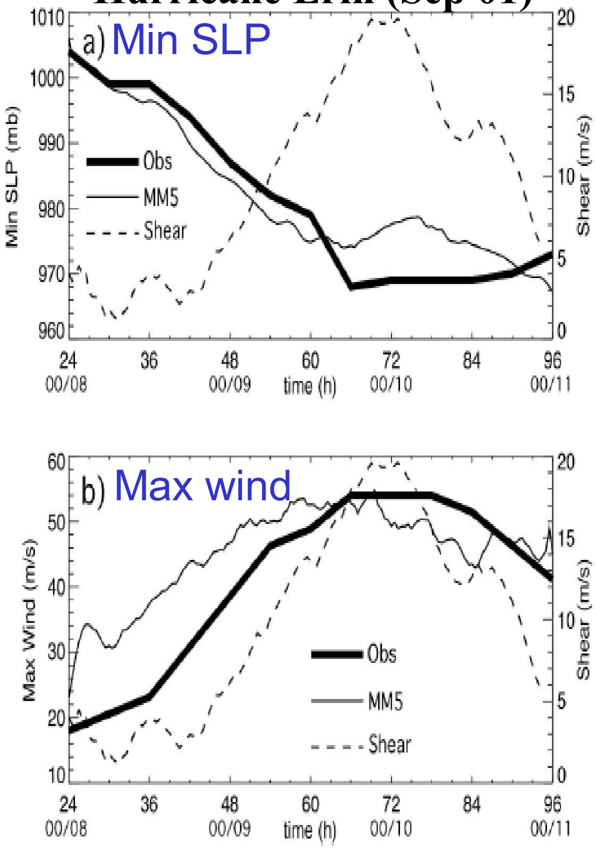


FIG. 3. Time series of simulated (thin solid line) and observed (thick line) (a) minimum sea level pressure and (b) maximum wind speed at the lowest model level. The dashed line shows the magnitude of the 850–200-mb vertical wind shear averaged over a circle of radius 300 km

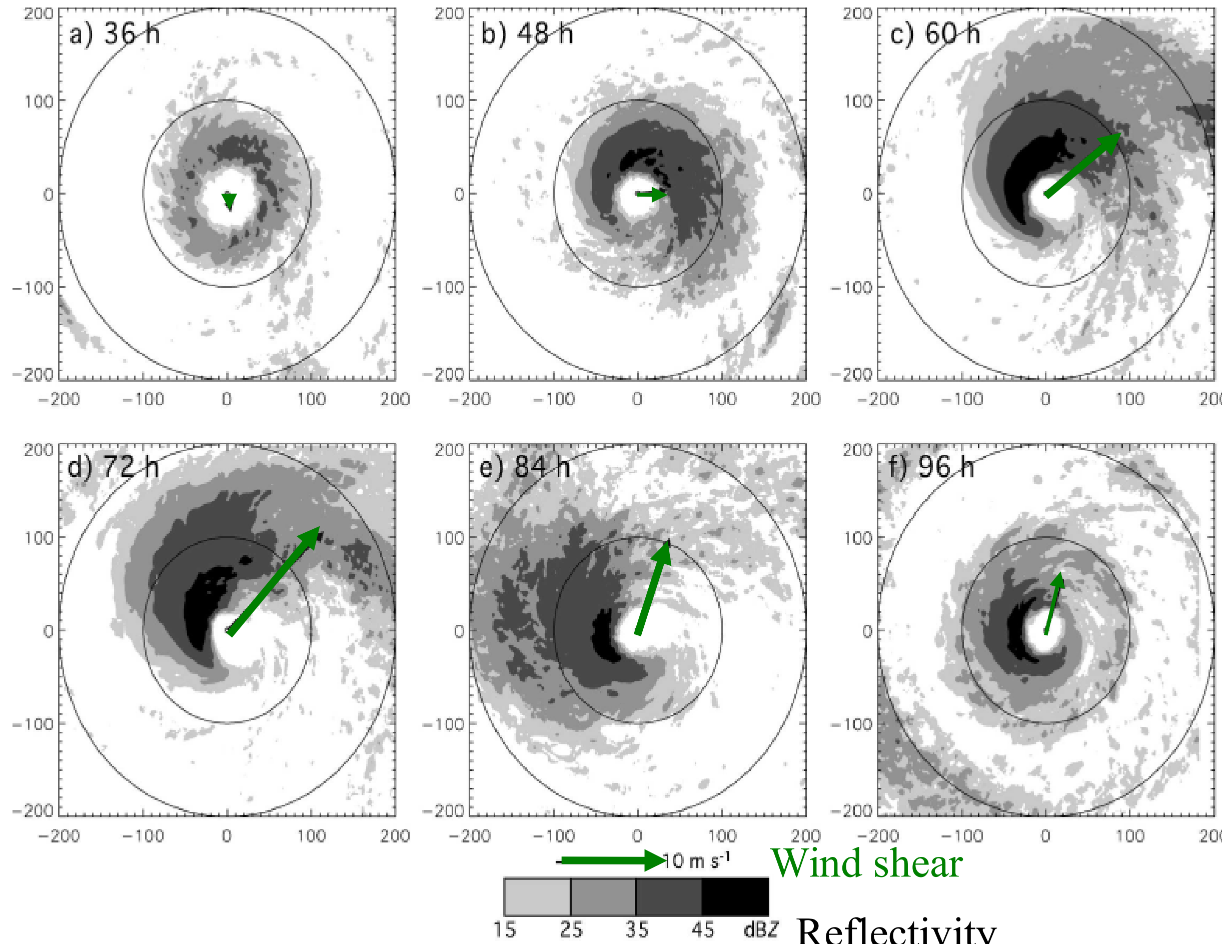
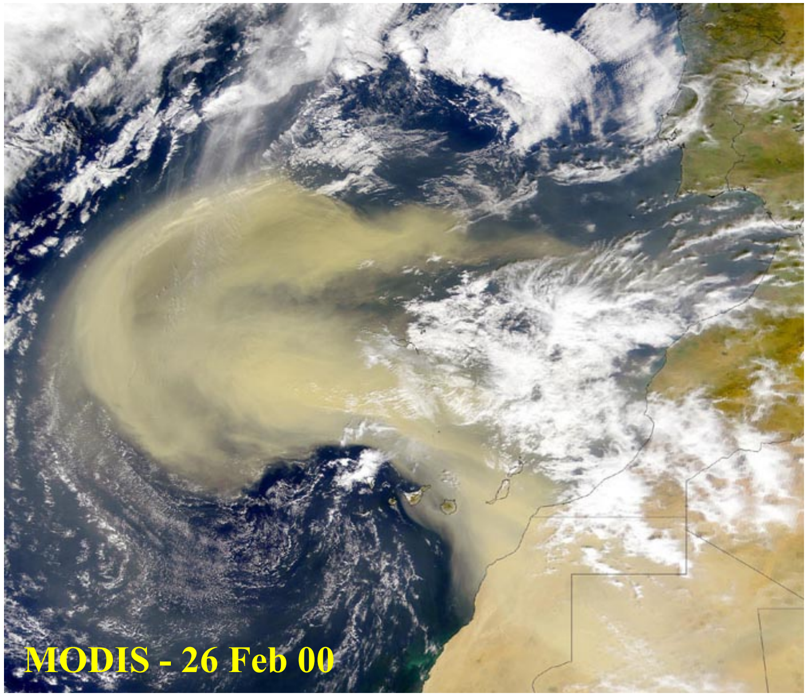


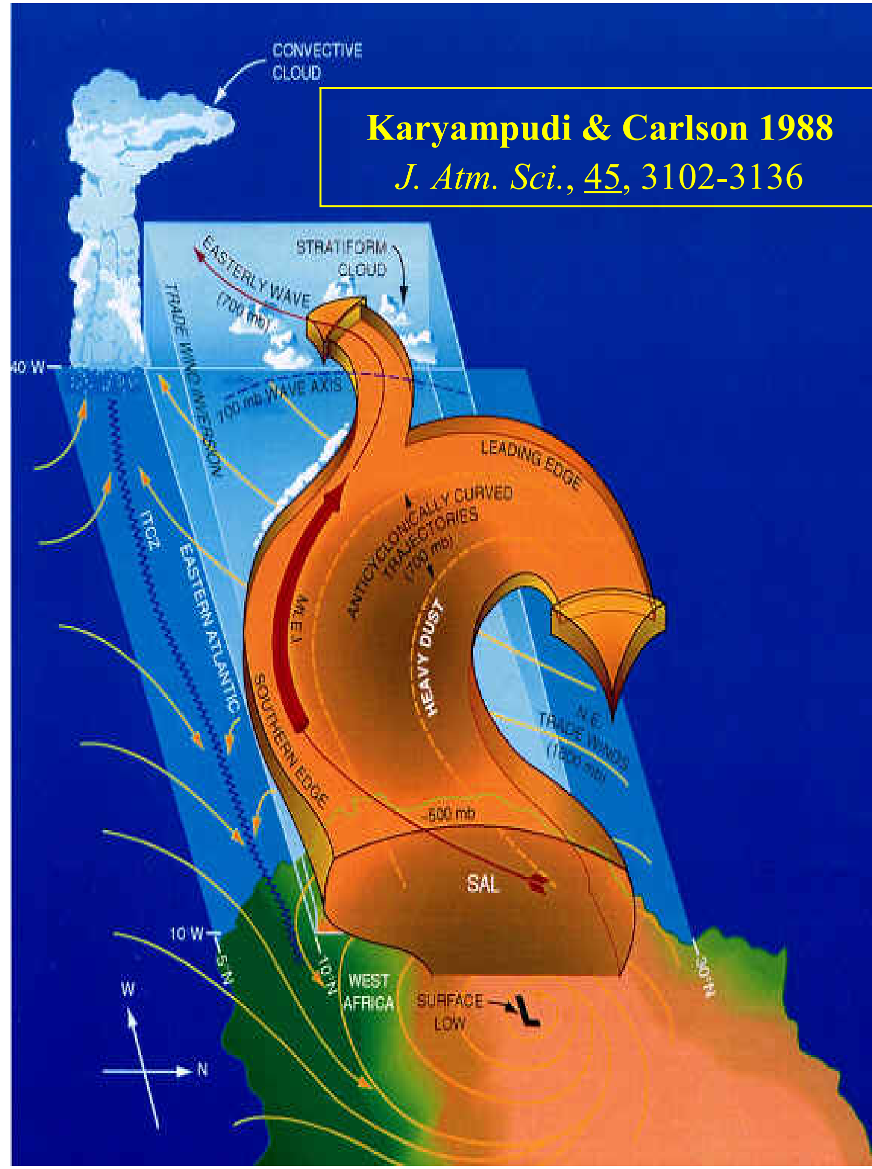
FIG. 5. Simulated radar reflectivity structure at the lowest model level (38 m). Contours show the simulated radar reflectivity averaged over the 6-h period ending at the indicated time. Arrows show the 6-h-averaged 850–200-mb vertical wind shear vector. Axis labels are in km with the origin at the storm center.

(SAHARAN) **DRY AIR**



Large zones with very dry air (RH <50%), loaded with aerosols, emerge sporadically from Sahara and propagate westward over the tropical Atlantic.

These air masses extend from 1500 to 6000 m (900-500 hPa) and they are associated with strong winds (10-25 ms^{-1}).



Dunion & Velden 2004
Bull. Amer. Meteor. Soc., 84, 353-365

Impact on Atlantic hurricanes :

- Low-level inversion with $\Delta T_{SAL} \approx$ 5-10°C
- Dry air intrusion at 850-600 hPa
- Stronger vertical wind shear
  (stronger African Easterly Jet near 700 hPa)
- Influence of aerosols on microphysics ?
- Saharan air propagate over large distances, without major changes of its characteristics
- Satellite images help to detect such events

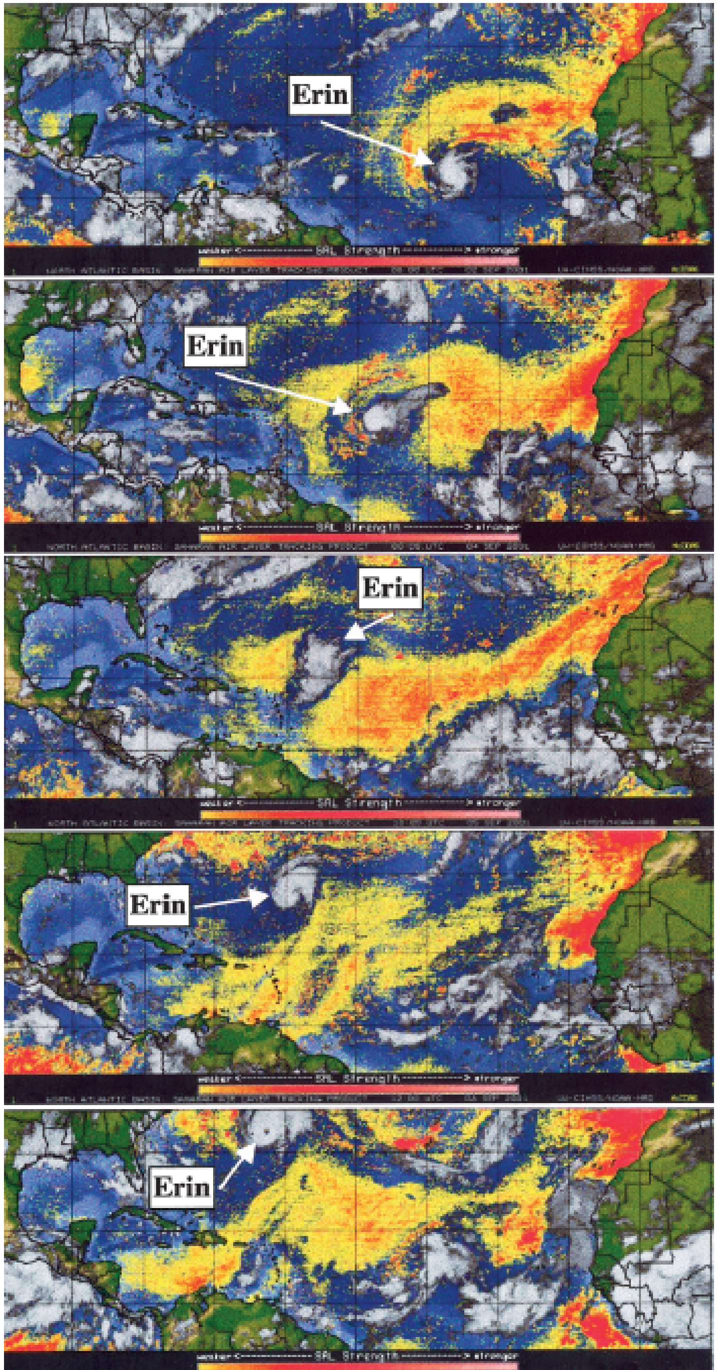
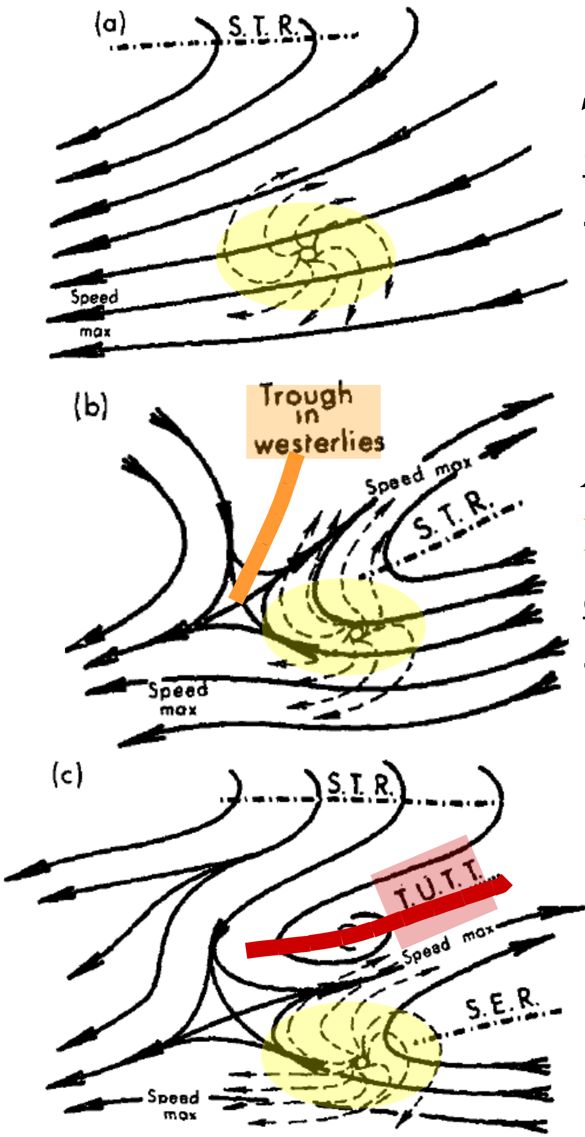


FIG. 9. GOES SAL-tracking imagery time series showing Hurricane Erin's interaction with the SAL at (top to bottom) 0000 UTC 2 Sep 2001, 0000 UTC 4 Sep 2001, 1800 UTC 5 Sep 2001, 1200 UTC 8 Sep 2001, and 1800 UTC 9 Sep 2001. The yellow–red shading indicates likely SAL regions with increasing amounts of dust content and dry lower-tropospheric air, as detected by the GOES imagery.

UPPER TROPOSPHERIC FEATURES (1)

Sadler 1976
Mon. Wea. Rev., 104, 1266-1278



S of Sub-Tropical Ridge →the NE flow leads to <u>stronger wind shear</u> & <u>weakened divergent anticylonic circulation</u> to the north
→<u>**Unfavourable conditions**</u>

Autumn :
E of a mid-latitude trough →the SW flow leads to <u>stronger divergent anticylonic circulation</u> to the north
→<u>**Favourable conditions**</u>

<u>Summer</u> :
« Tropical Upper Tropospheric Trough » north of a TC, the divergent anticylonic circulation aloft is stronger
→<u>**Favourable conditions**</u>

UPPER TROPOSPHERIC FEATURES (2)

Hanley *et al.* 2001
Mon. Wea. Rev., 129, 2570-2584

TUTT – TC interactions

Favorable factors :

- enhanced divergent flow in altitude
- angular moment flux convergence

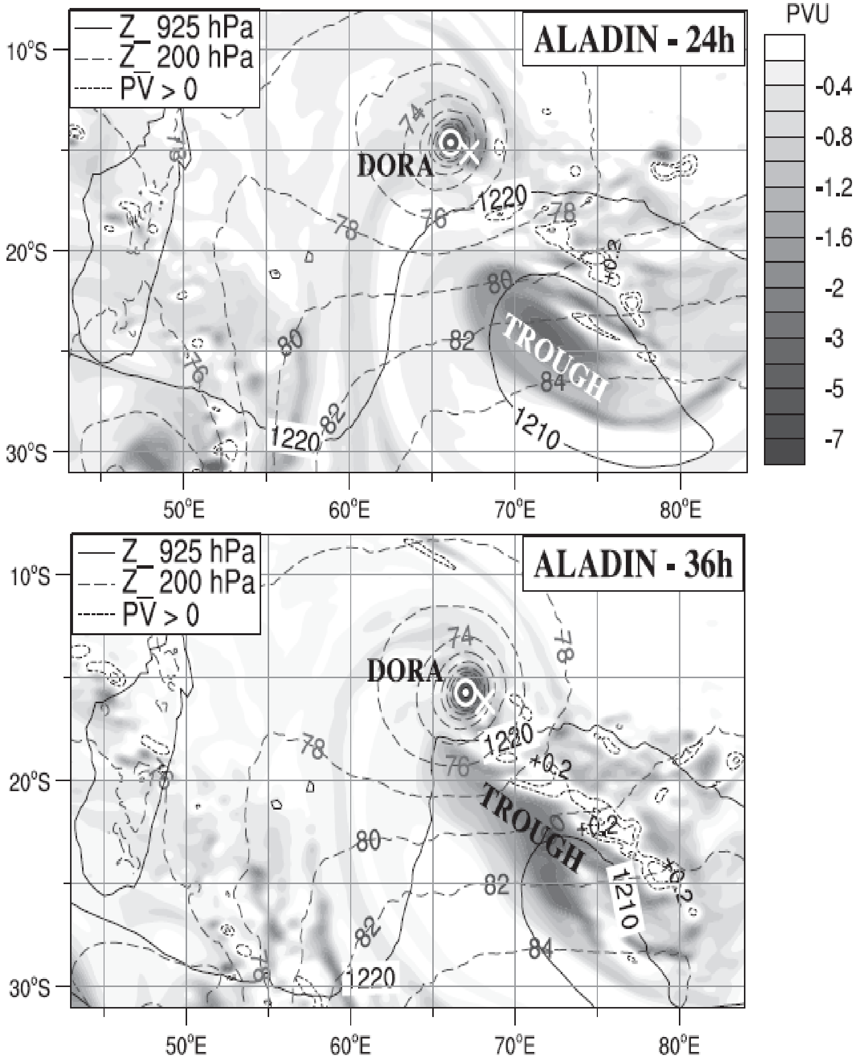
Unfavorable factors :

- stronger vertical wind shear

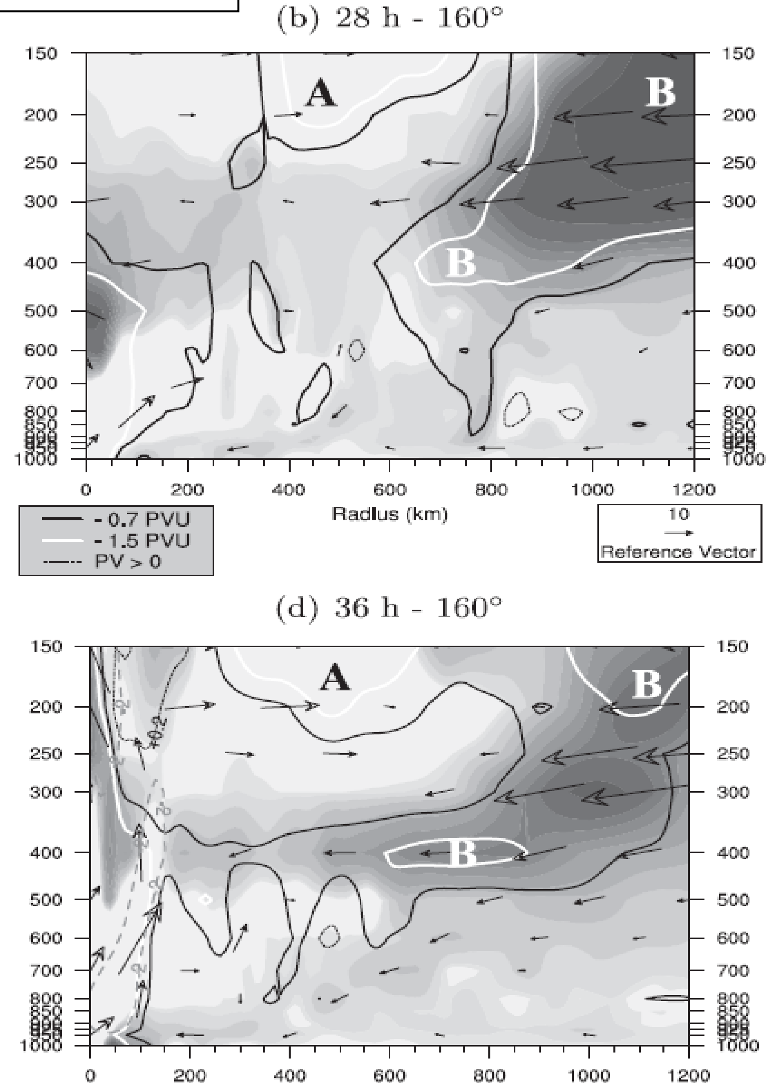
No definite conclusion (geometry is important …)

UPPER TROPOSPHERIC FEATURES (3)

Leroux *et al.* 2013
J. Atmos. Sci., 70, 2547-2565



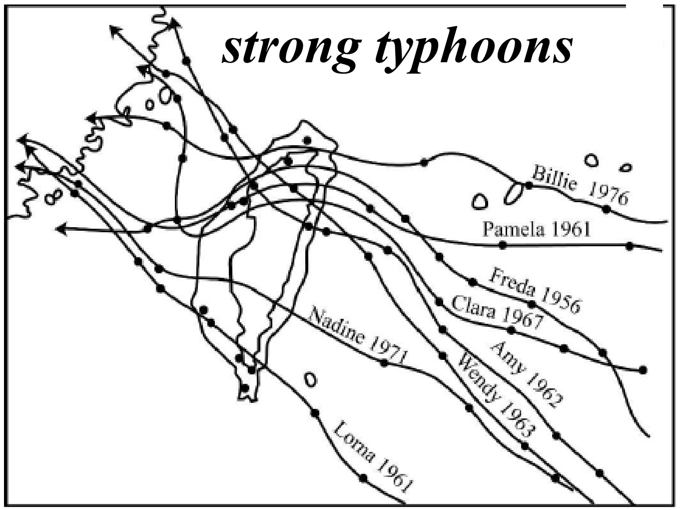
Aladin-Reunion forecast for TC Dora from 0600 UTC 31 Jan 2007

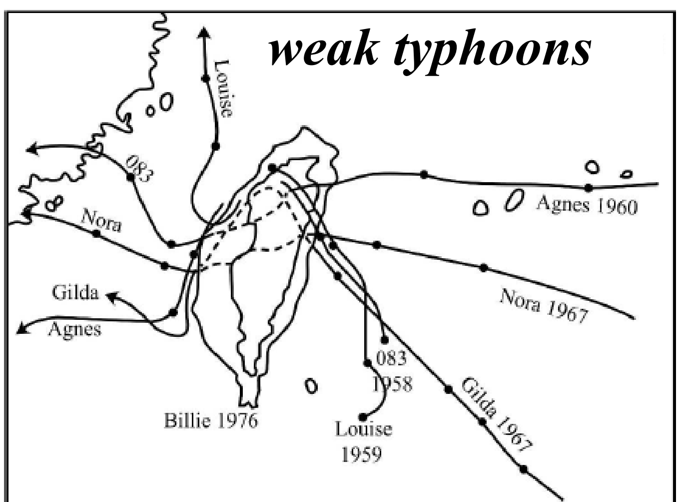


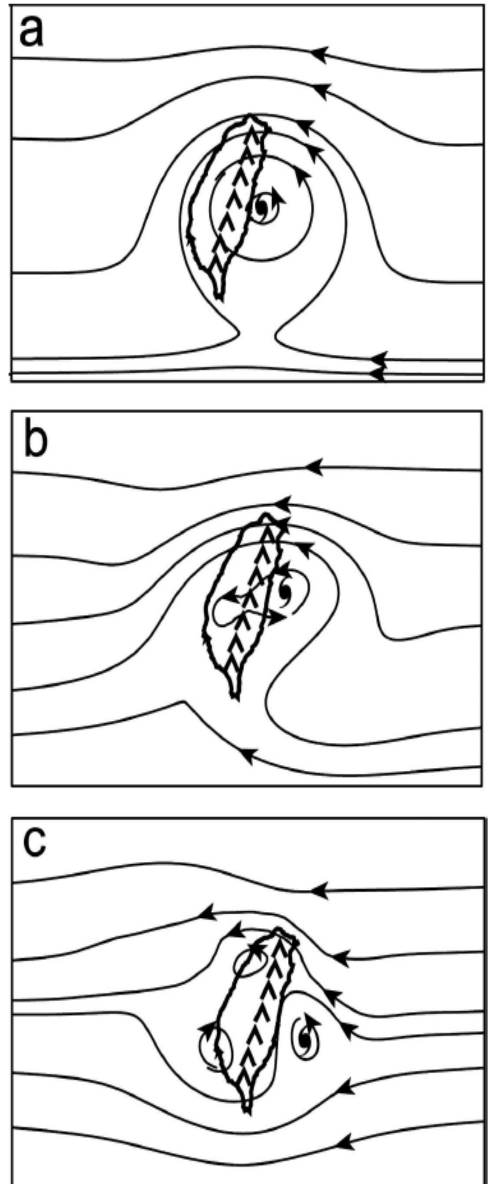
Radius–pressure cross sections of PV radial advection

LANDFALL : influence of orography (1)

Lin *et al.* 2006
Mon. Wea. Rev., 134, 3509-3538







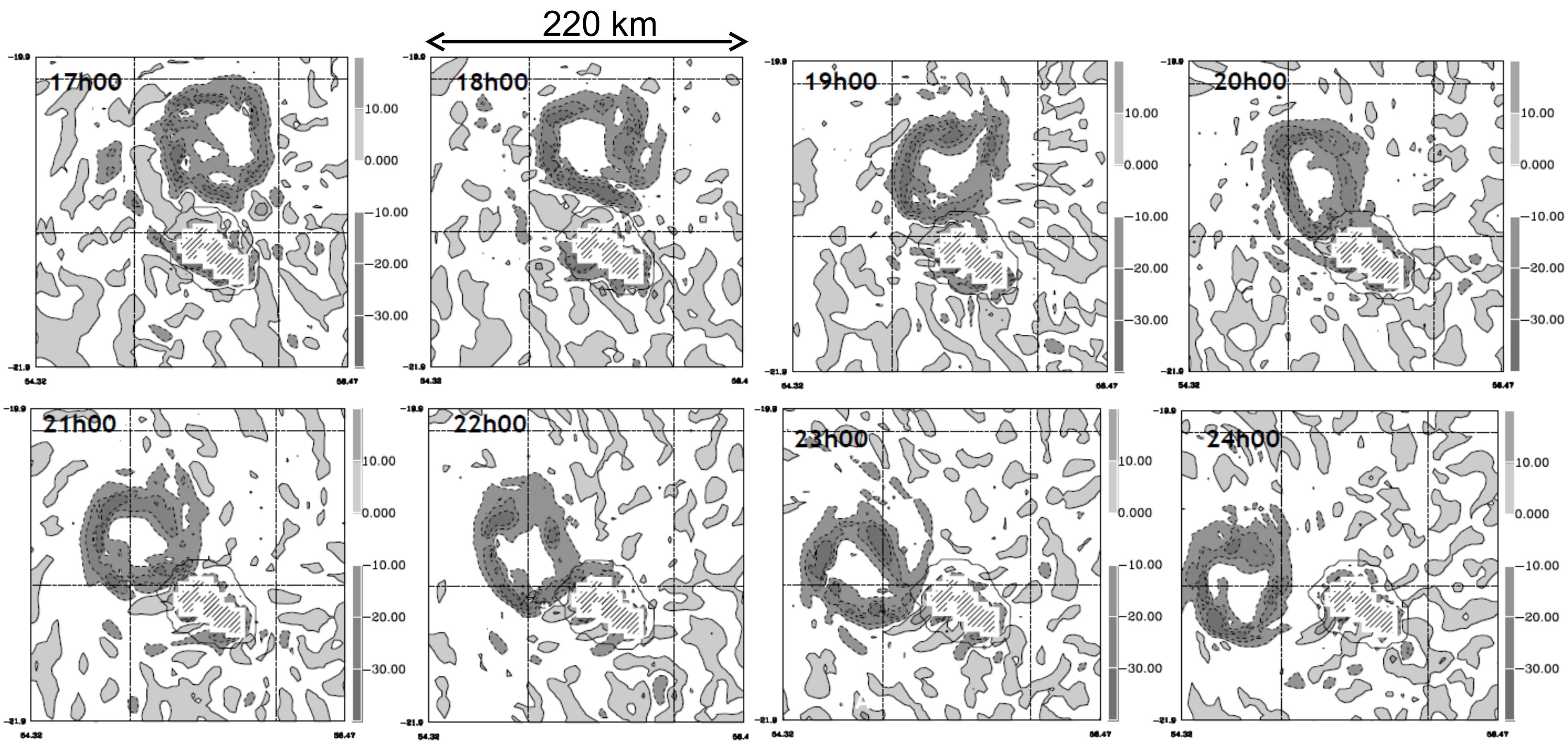
Weak blocking : *northward upstream, then southward downstream deflection, continuous track.*

Moderate blocking : *northward upstream deflection, secondary vortex on the lee side, discontinuous track.*

Strong blocking : *souththward upstream deflection, secondary vortices on the lee side, discontinuous track.*

LANDFALL : influence of orography (2)

Jolivet *et al.* 2013 [*Ann. Geophys.*, 31, 107-125]
« A numerical study of orographic forcing on TC Dina (2002) in SW Indian ocean »

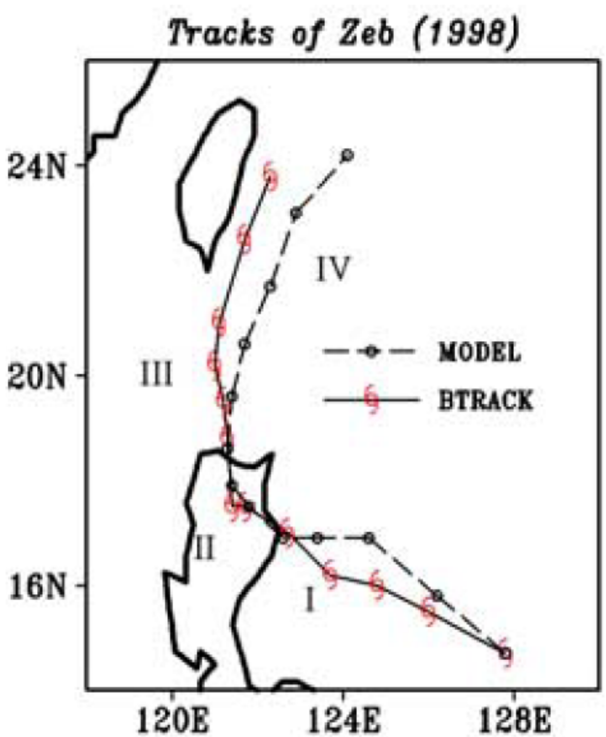


Potential vorticity fields (shaded = cyclonic, PVU = 10^{-6} m^2 s^{-1} K kg^{-1})
from the 4-km model at 1000 m altitude

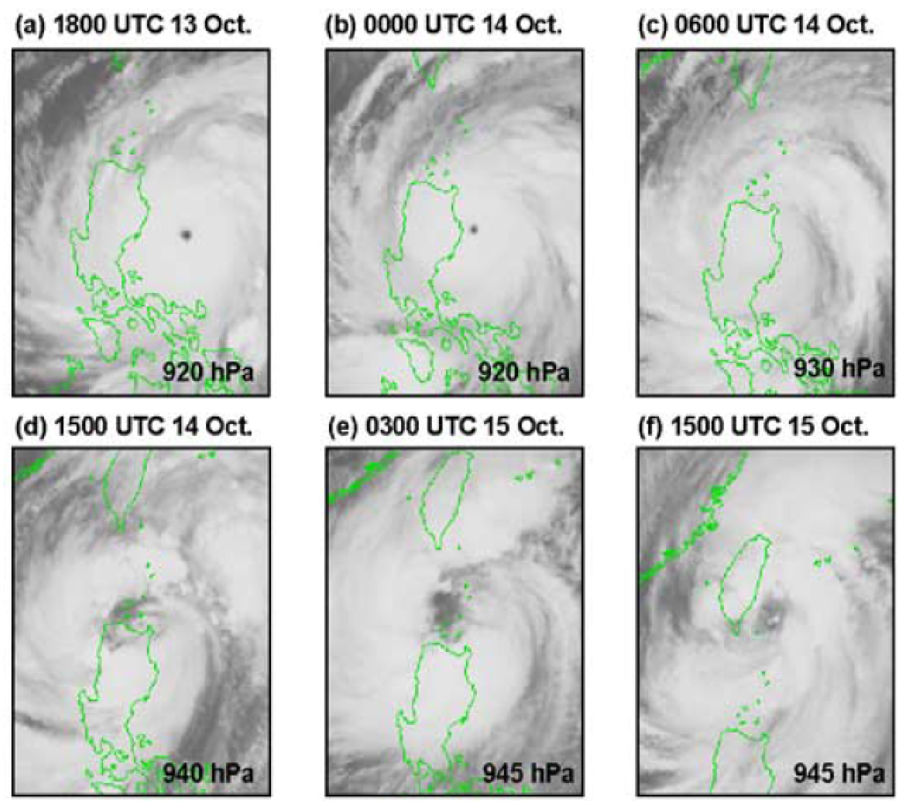
LANDFALL : decay and intensification (1)

Wu *et al.* 2003 [*Geophys. Res. Let.*, 30, 6.1-4]

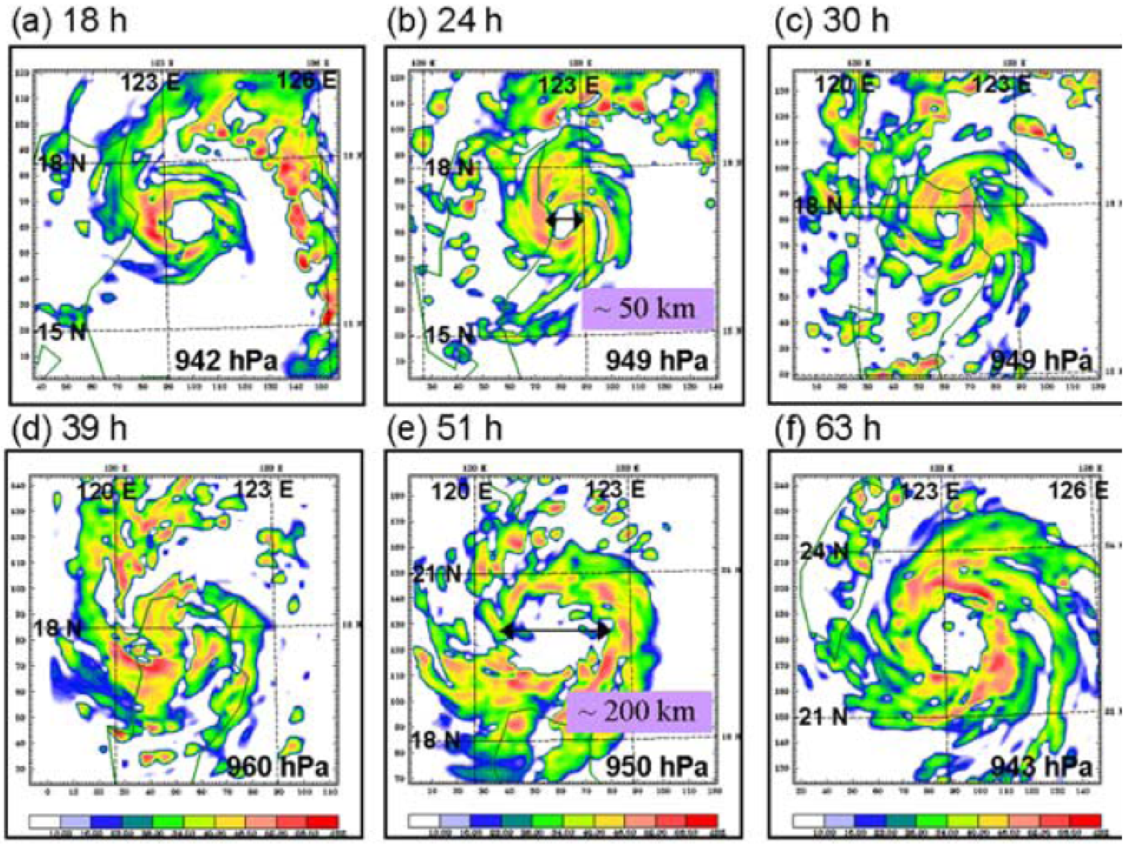
- Evolution of typhoon Zeb (1998) before, during and after its landfall at Luzon documented with satellite observations and MM5 (45 / 15 / 5 km, 72 h simulation starting 00 UTC 13 Oct 98, 24 h prior to landfall)
- The terrain plays a critical role in the observed evolution : eyewall contraction just before landfall, a following breakdown, and eyewall reformation after the storm returned to the ocean



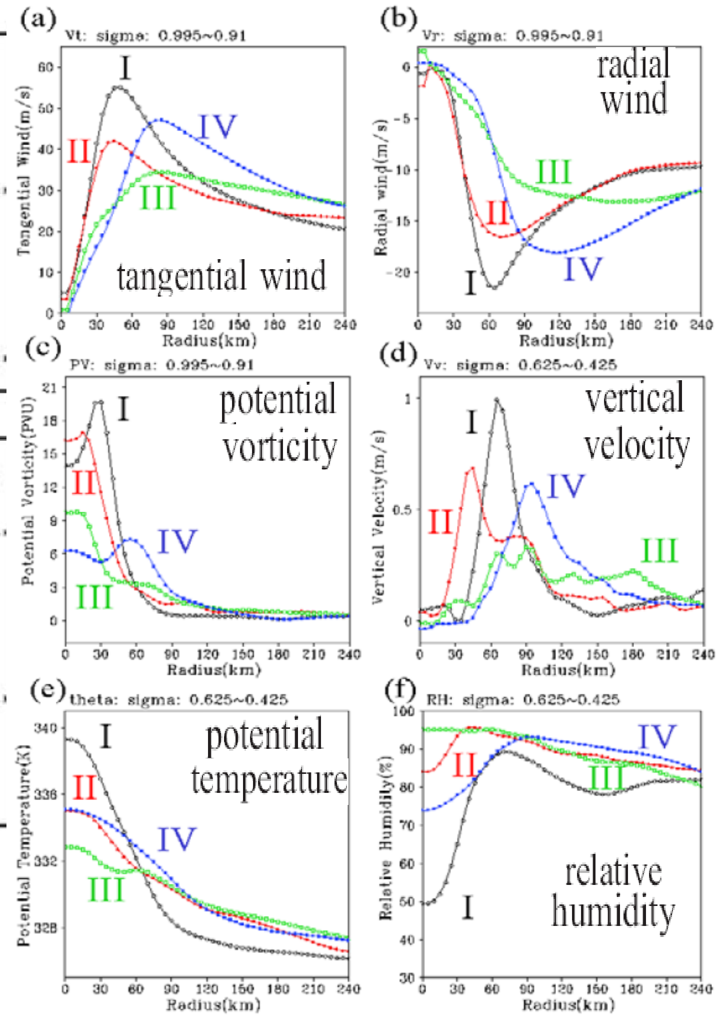
GMS satellite IR images



LANDFALL : decay and intensification (2)



model-simulated radar reflectivity (dBZ) at 700 hPa



Time, azimuthal and vertical average

I : before landfall , **II** : landfall begins ,
III : inland , **IV** : return to the ocean

(i) What are the key parameters determining the evolutionary processes of a landfalling TC?

(ii) How does the eddy (the asymmetric component) interact with the mean flow (the symmetric component)

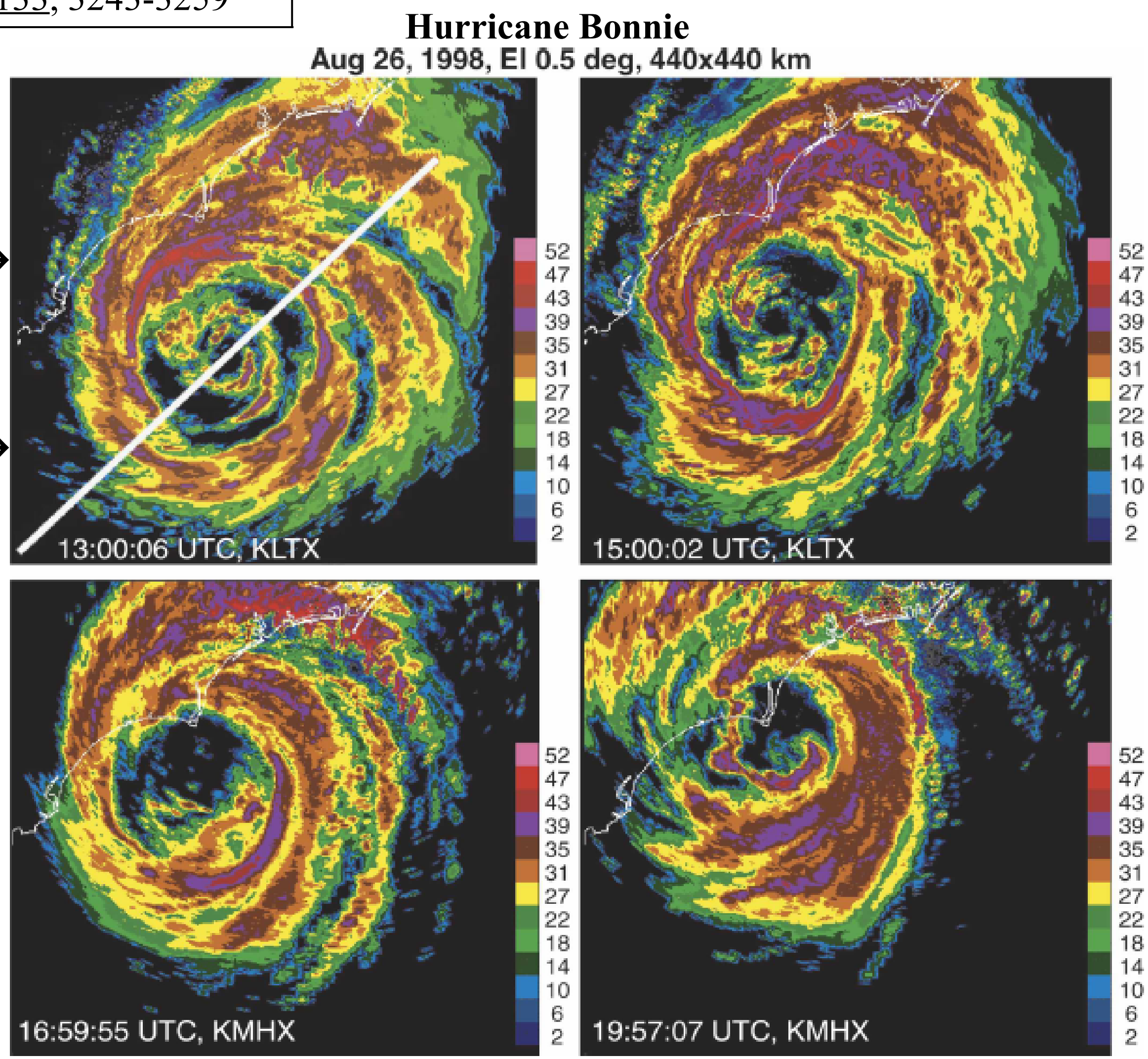
(iii) What kind of roles do the terrain, surface drag, and ocean heat flux play relative to those eyewall processes?

LANDFALL : decay and intensification (3)

Schneider & Barnes, 2005
Mon. Wea. Rev., 133, 3243-3259

Land (N Carolina) →

Atlantic Ocean →



Enhanced convergence over land → NW part of the storm intensifies

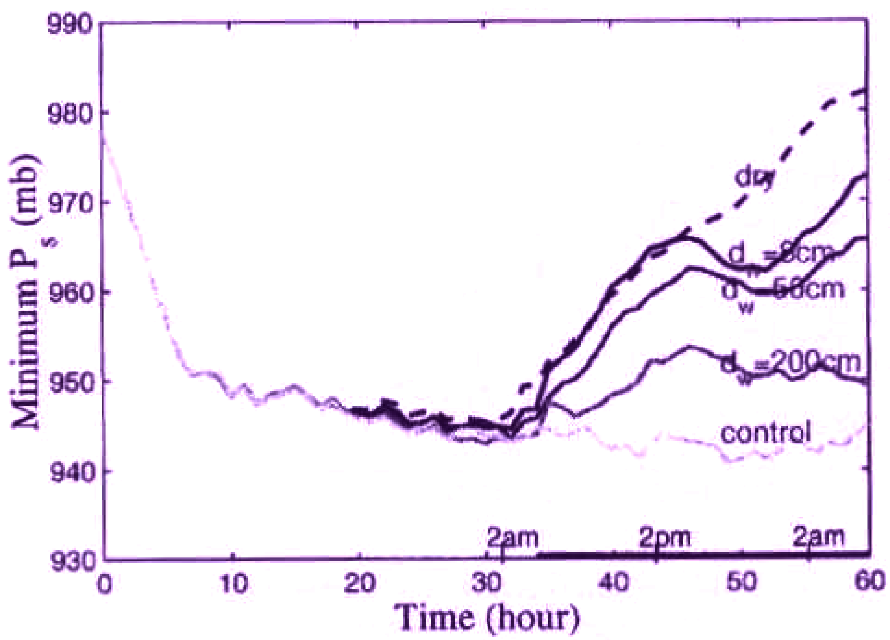
Eyewall structure disorganizes

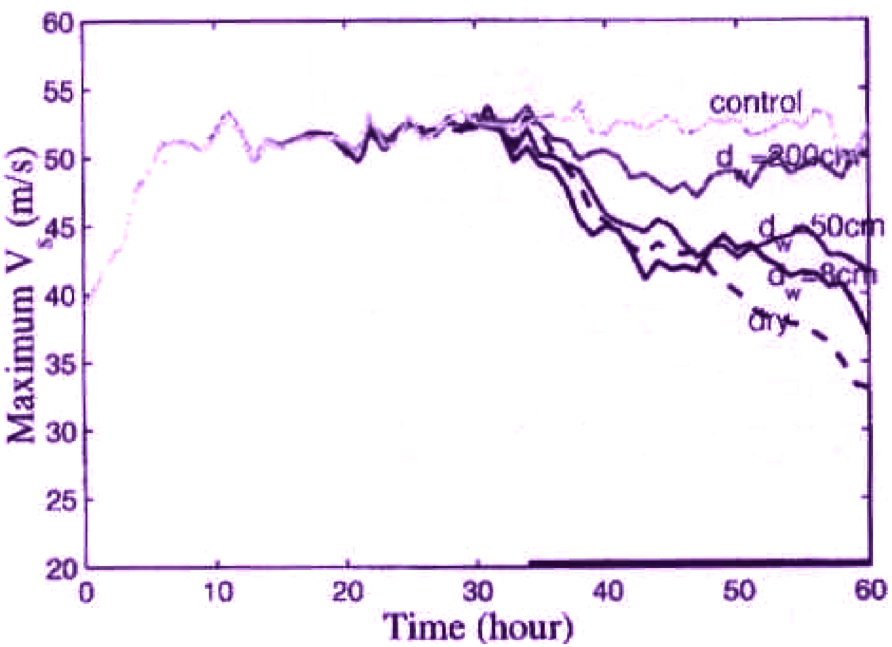
Inland rainband weakens and SE part of the storm intensifies

LANDFALL : decay and intensification (4)

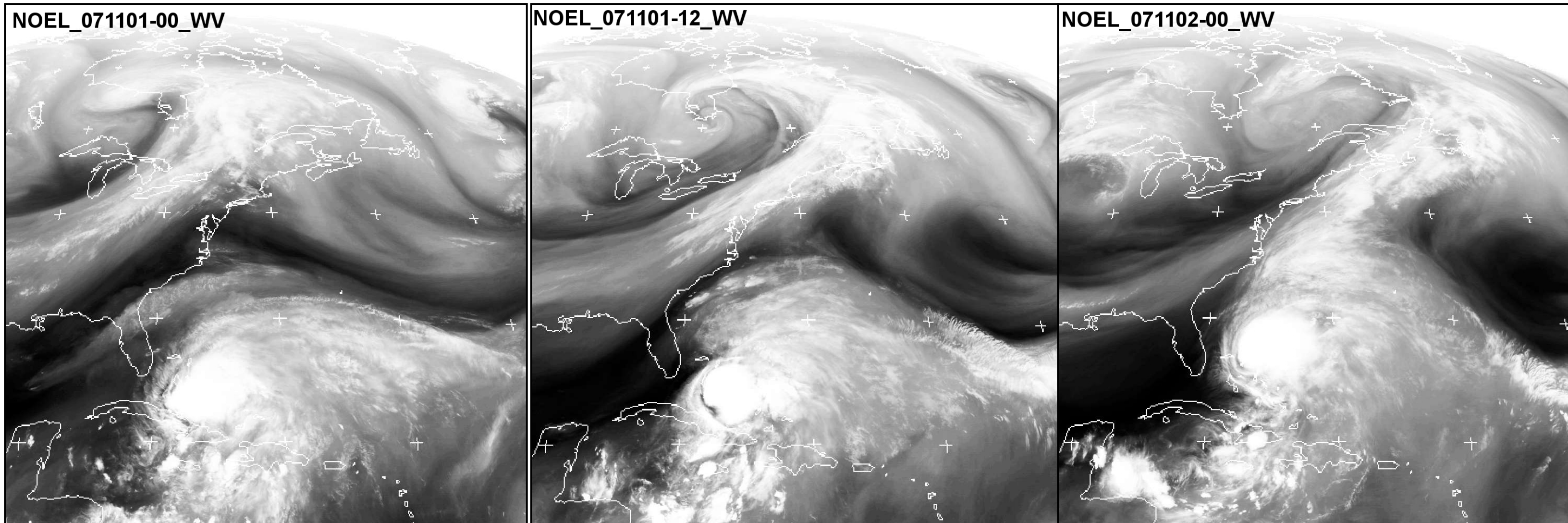
Shen *et al.* 2002 [*J. Atmos. Sci.*, 59, 789-802]

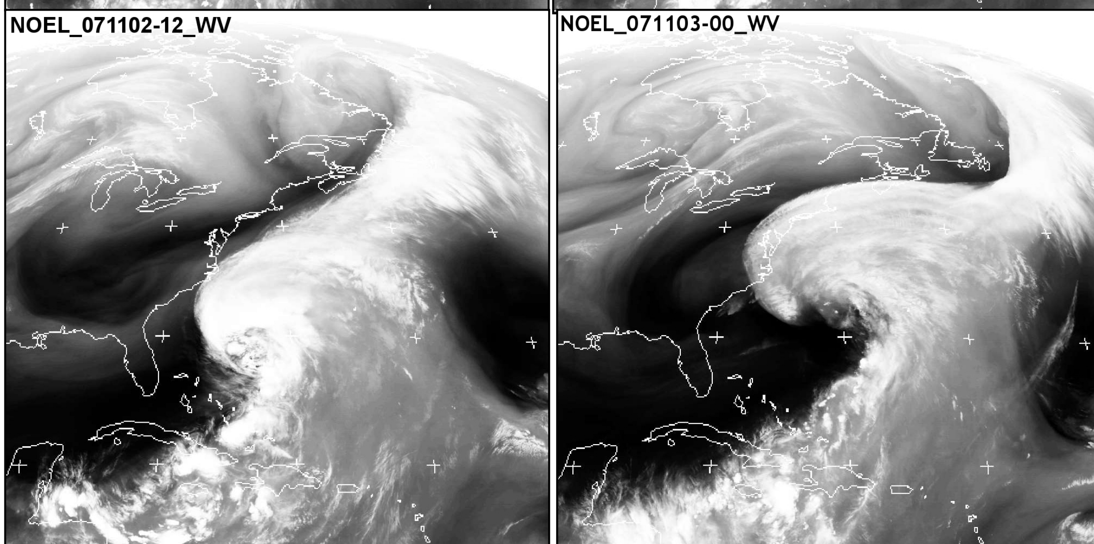
- Little is known on the effect of surface water over land during decay of a landfalling tropical cyclone.
- Different water depths and surface conditions are considered [GFDL model, 1° + 1/3° + 1/6°]
- a layer of 0.5 m water can noticeably reduce landfall decay
- increase of surface roughness reduces the surface winds, but barely change the surface temperature and evaporation patterns.

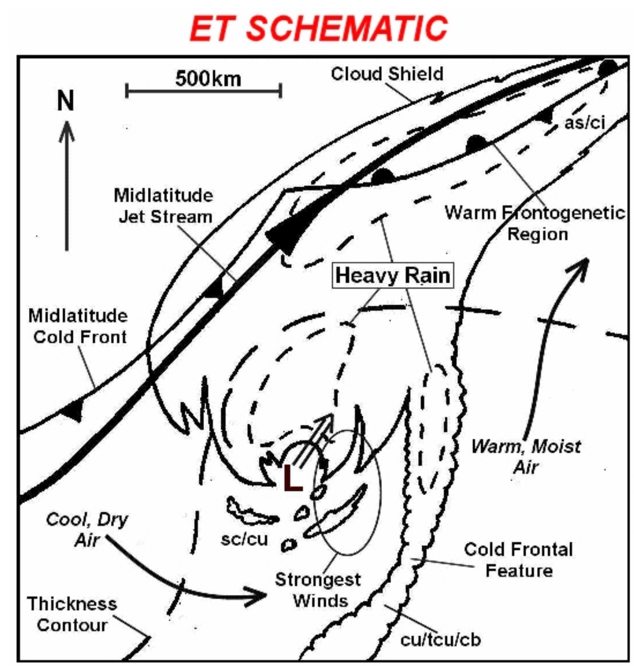




EXTRA-TROPICAL TRANSITION (1)

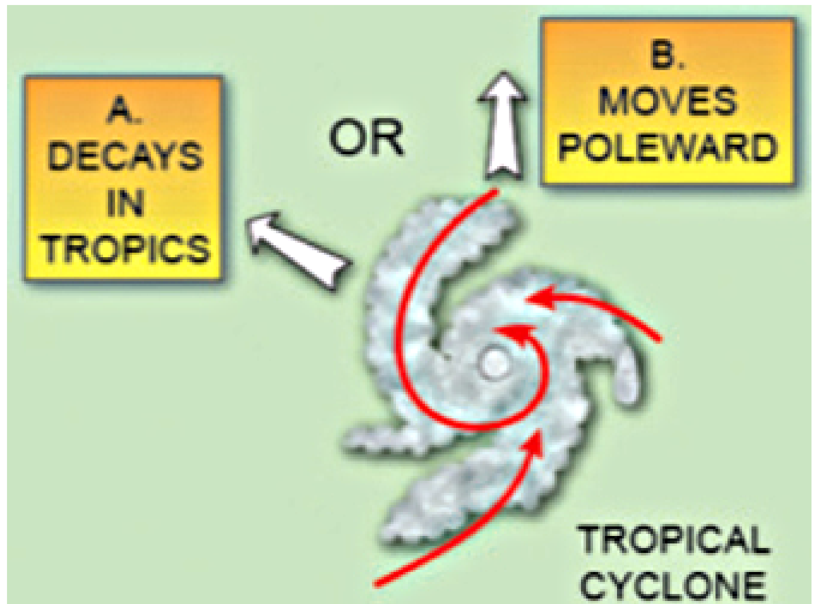






EXTRA-TROPICAL TRANSITION (2)

Halverson, 2015
Weatherwise, March-April issue



EXTRATROPICAL TRANSITION

- TROPICAL CYCLONE INTERACTS WITH PRE-EXISTING EXTRATROPICAL SYSTEM (LOW PRESSURE, FRONTS, JETSTREAM TROUGH) AND / OR
- TROPICAL CYCLONE DEVELOPS EXTRATROPICAL CYCLONE CHARACTERISTICS

EXTRA-TROPICAL TRANSITION (3)

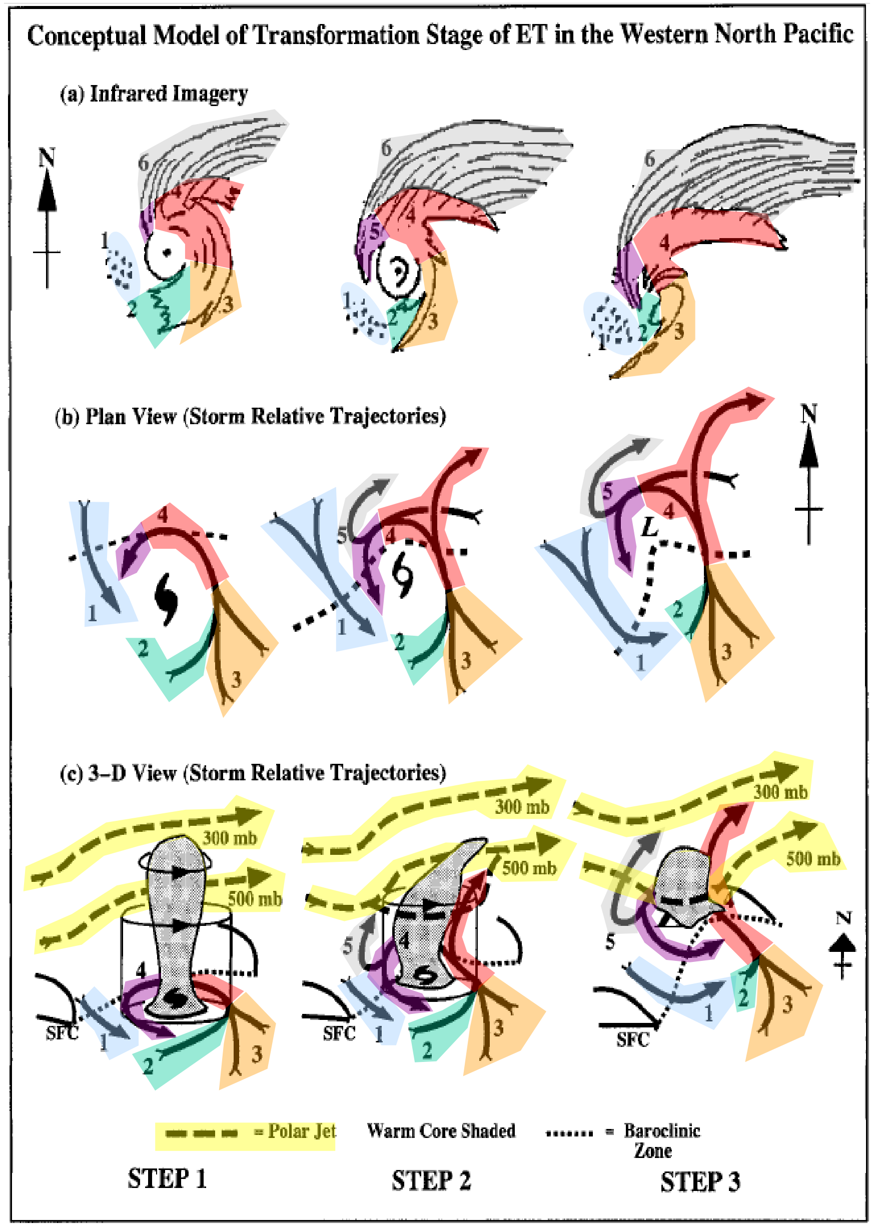
ENVIRONMENTAL CHANGES

- Increased Thermal Gradients
- Increased Wind Shear
- Upper Level Trough
- Moisture Gradients
- Decreased Ocean Temperature
- Increased Surface Drag
- Increase In Coriolis Force
- Ocean Temperature Gradients

SYSTEM RESPONSES

- Decreased Intensity
- Increased Forward Motion
- Increased Asymmetries: cloud, rain, wind, moisture, temperature
- Expanded Footprint of Wind
- Rapid Growth of Ocean Waves
- Development of Fronts
- Warm Core Becomes Cold Core
- Storm Tilts Away From Vertical
- Dominant Energy Source Changes

EXTRA-TROPICAL TRANSITION (4)



1. Environmental equatorward flow of cooler, drier air with associated low-level convection ;
2. Decreased tropical cyclone convection in the western quadrant (the « dry slot » progressively extends throughout the southern quadrant) ;
3. Environemental poleward flow of warm, moist air maintains convection in the eastern quadrant and results in an asymmetric distribution of cloud and precipitation ;
4. Ascent of warm and moist inflow over the tilted isentropic surfaces associated with baroclinic zone (« warm front ») ;
5. Wrapping ascent produces cloudbands westward and equatorward around the storm center ; dry-adiabatic descent close to the circulation center erodes the eyewall convection in STEP 3
6. Cirrus shied with a sharp cloud edge extends poleward.

EXTRA-TROPICAL TRANSITION (5)