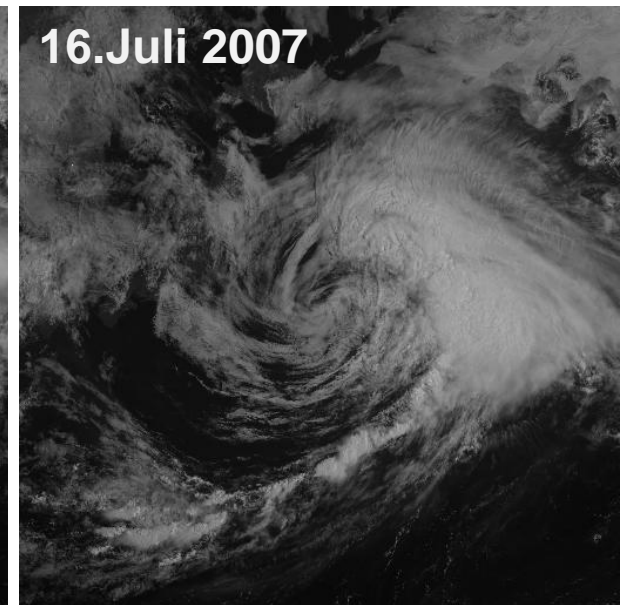
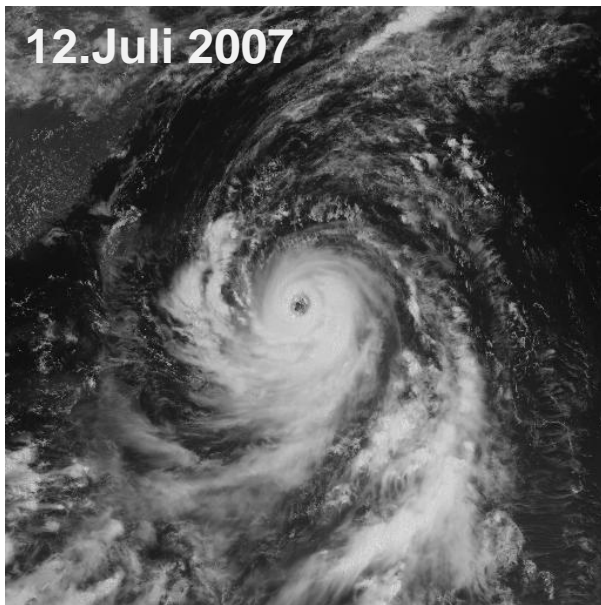


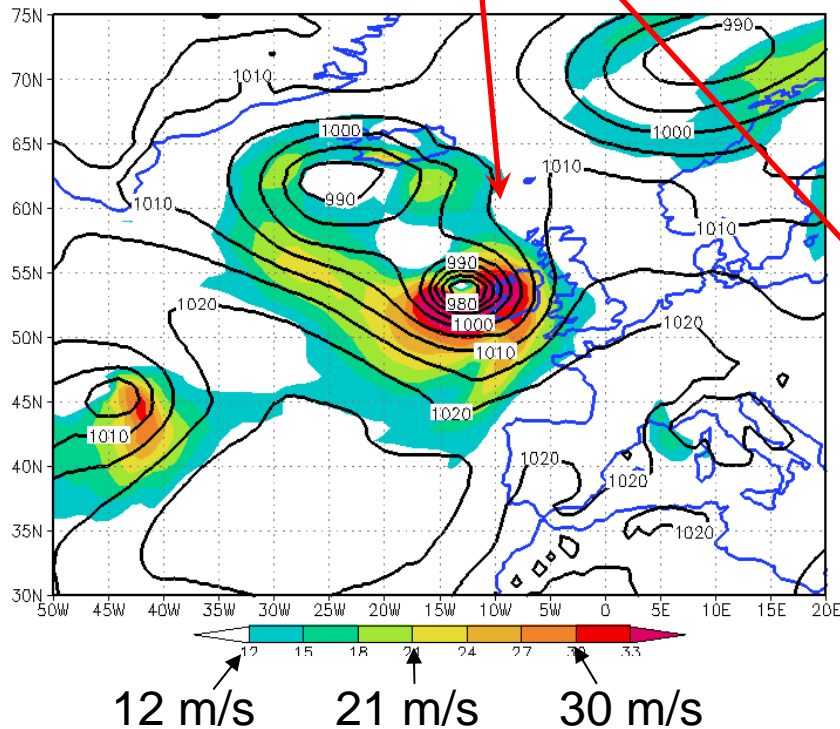
# Impact of air-sea interaction on extratropical transition of tropical cyclones

Sarah Jones

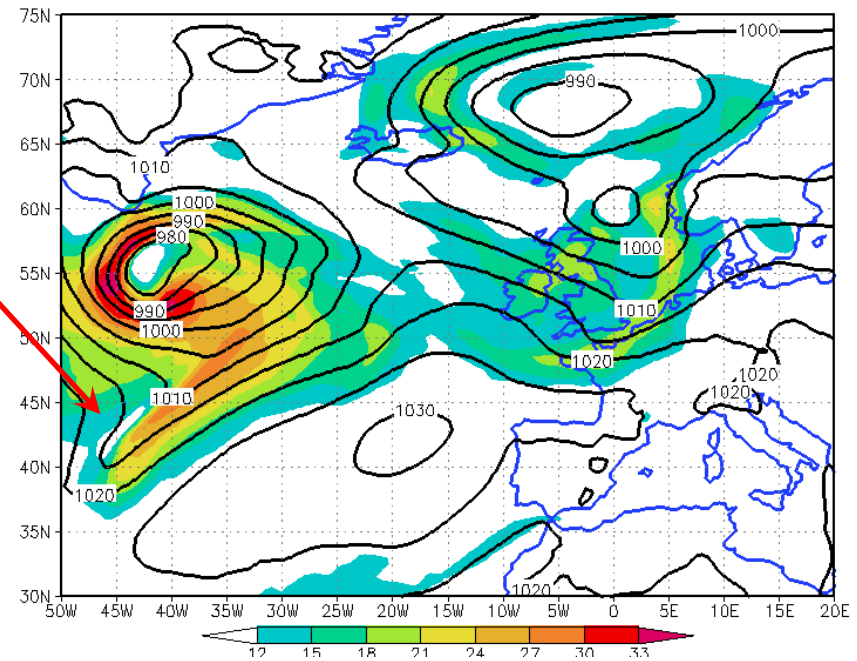


## Ex-Hurricane Philippe: a storm ... or not a storm?

6 day forecast valid 12 UTC 29 Sep



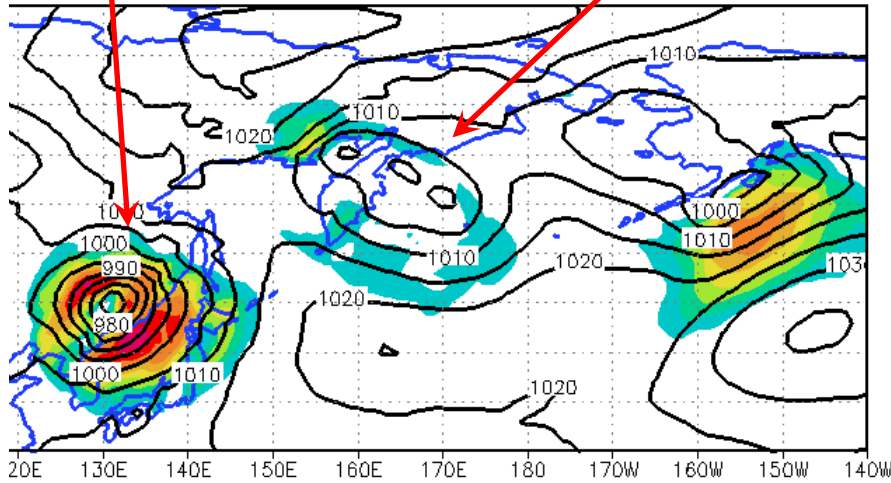
Analysis 12 UTC 29 SEP 2005



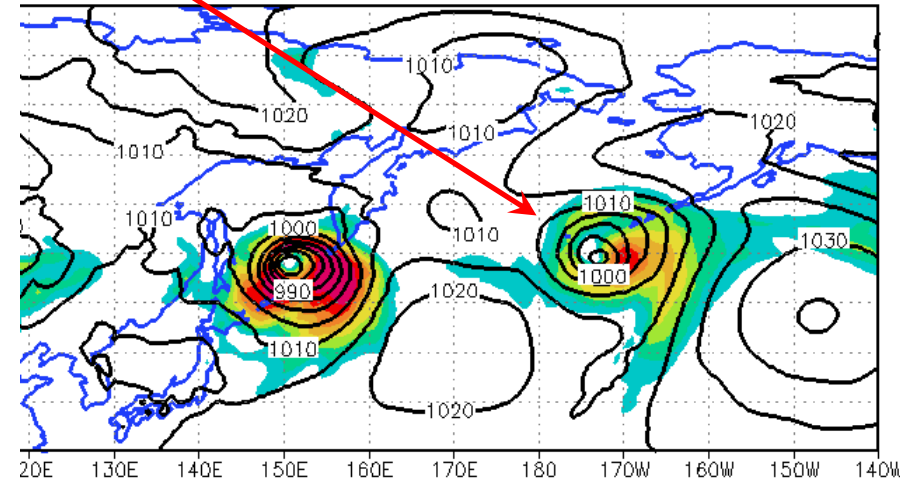
Anwender, Harr and Jones (2008)

## Ex-Typhoon Nabi Downstream low

6 day forecast valid 12 UTC 8 Sept. 2005

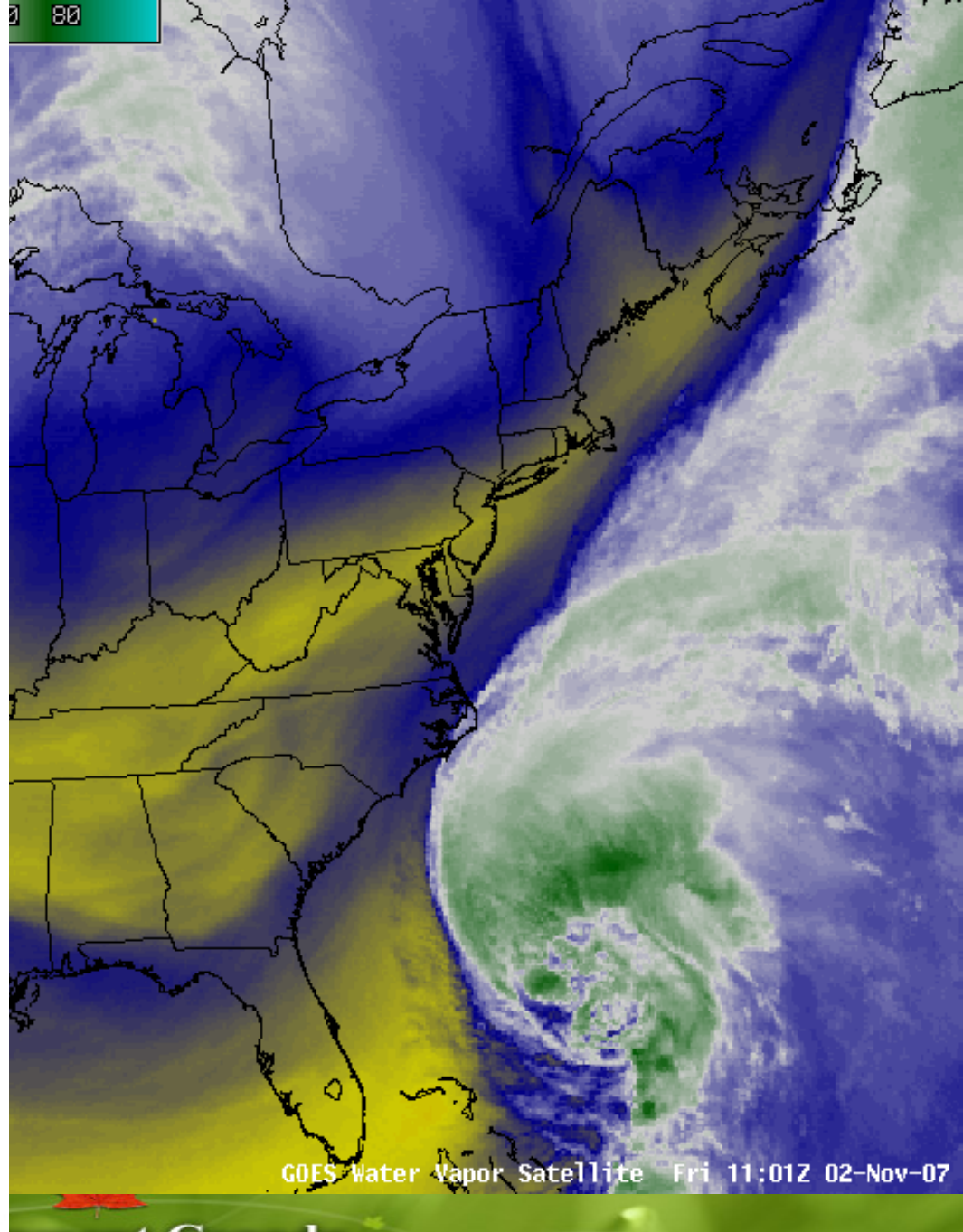
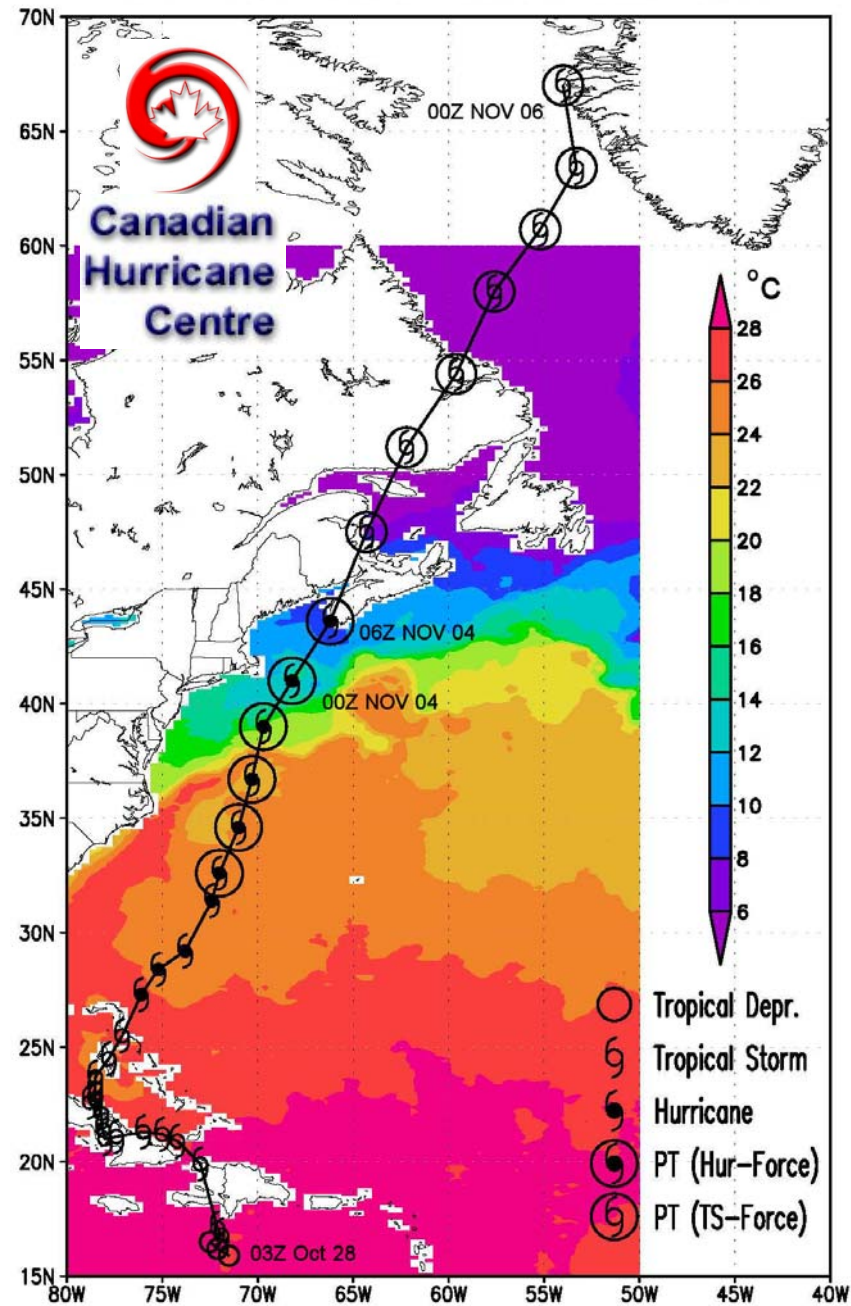


Analysis 12 UTC 08 SEPT 2005



Harr, Anwender and Jones (2008)

# PT NOEL 2007 Track and SST



Courtesy of Pete Boywer and Chris Fogarty

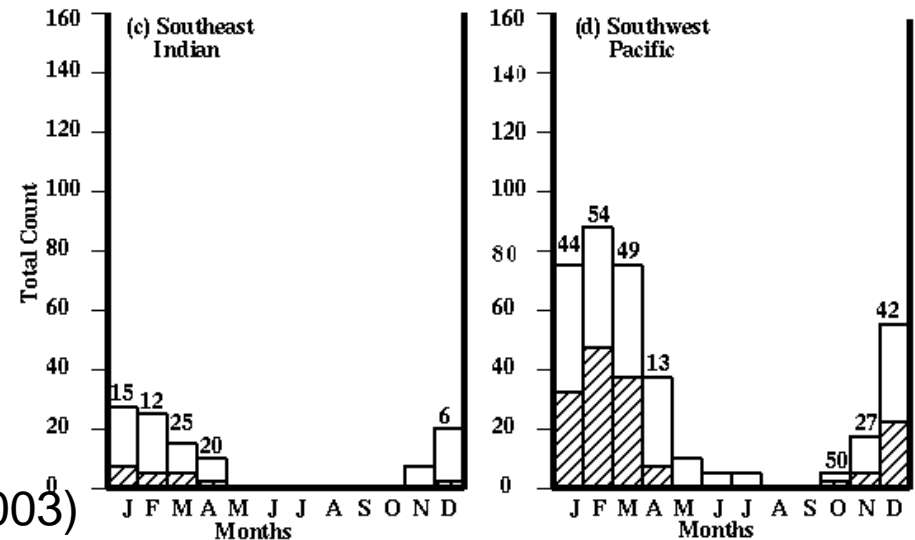
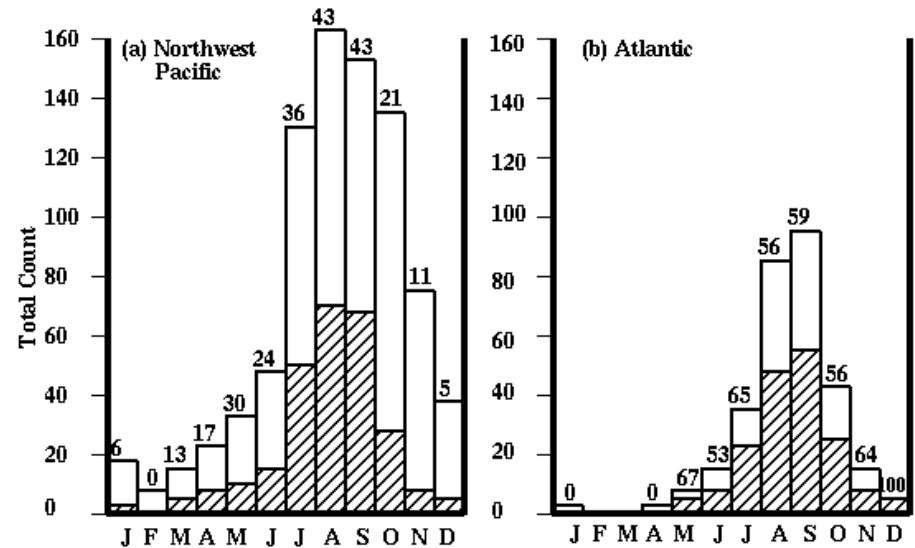
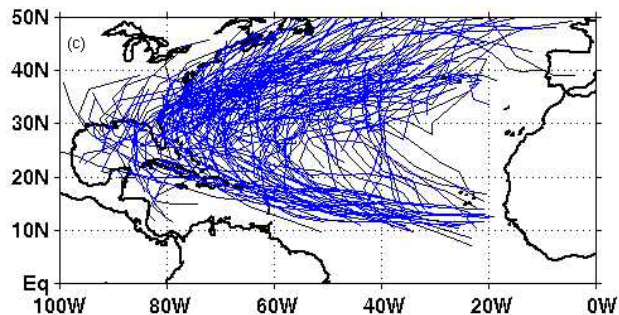
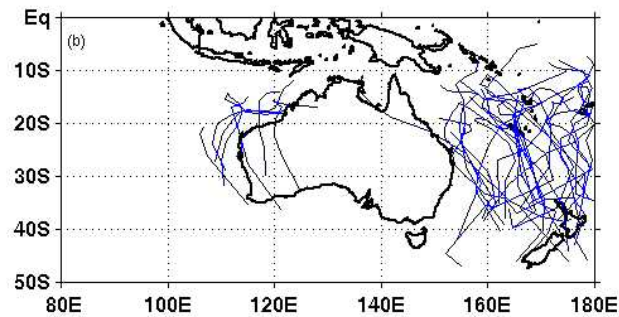
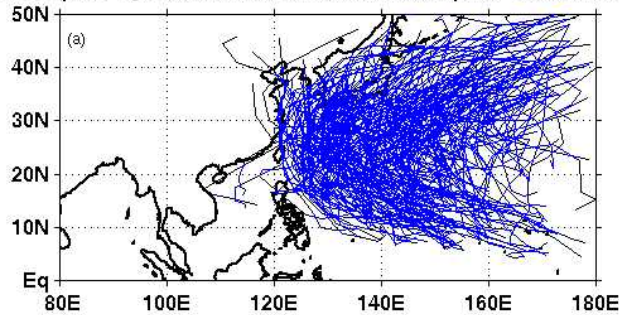
Review Article in Weather and Forecasting (2003):

Jones, Harr, Abraham, Bosart, Bowyer, Evans, Hanley, Hanstrum, Hart, Lalaurette, Sinclair, Smith, and Thorncroft ,The extratropical transition of tropical cyclones: forecast challenges, current understanding, and future directions

***„Considerable effort has been devoted to studying the surface–atmosphere interaction for both tropical and extratropical cyclones, but the implications for ET have received little attention”***

# Where and when does ET occur?

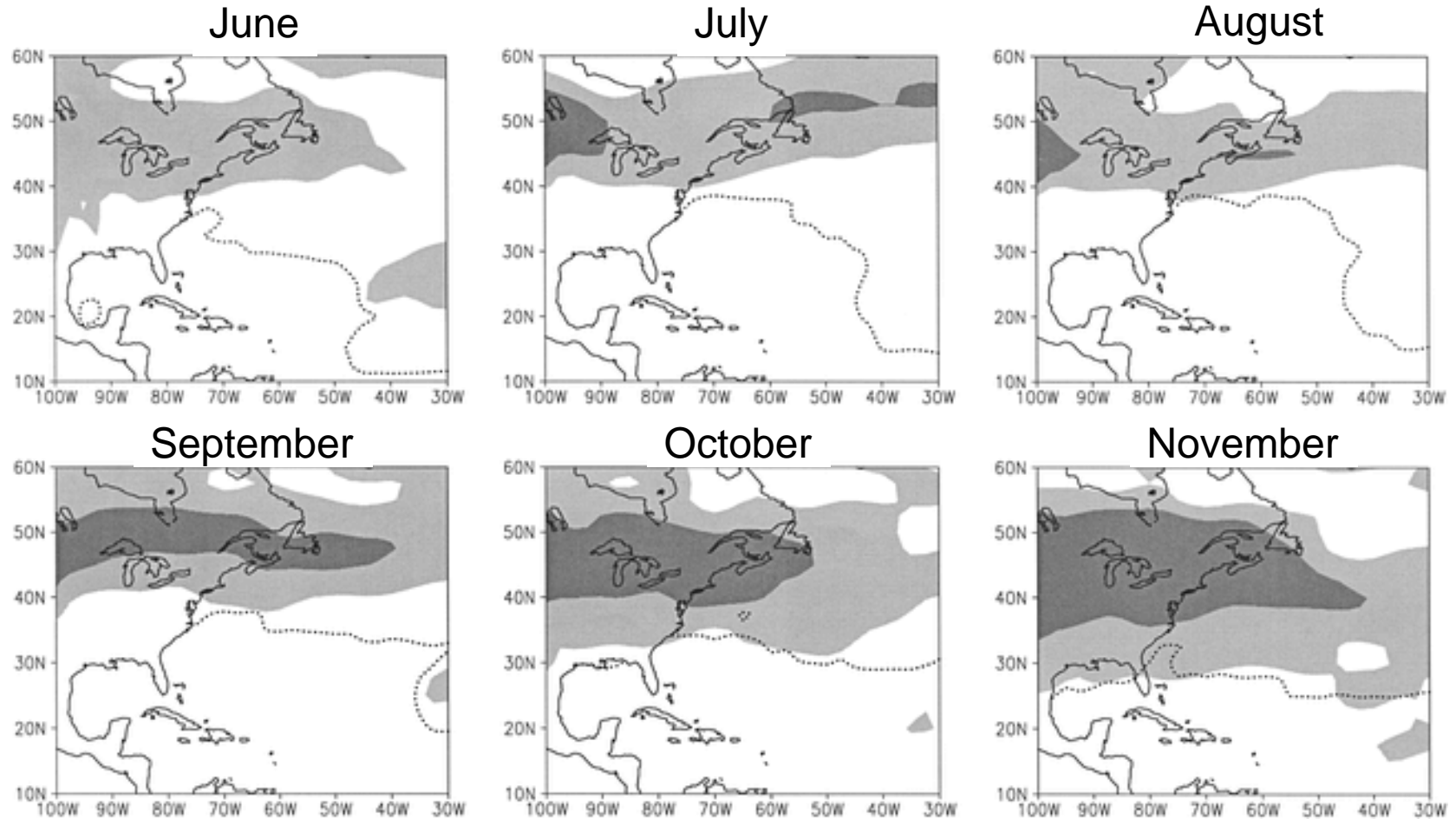
Tracks of Tropical Cyclones that Underwent Extratropical Transition: 1970–1999



Jones, Harr, Abraham and co-authors (2003)

# Tropical or extratropical reintensification?

Hart and Evans (2001)



Dotted line: Minimum pressure of 960 hPa from Emanuel's MPI theory  
Shading: Eady growth rate of 0.25 and 0.5 day<sup>-1</sup>

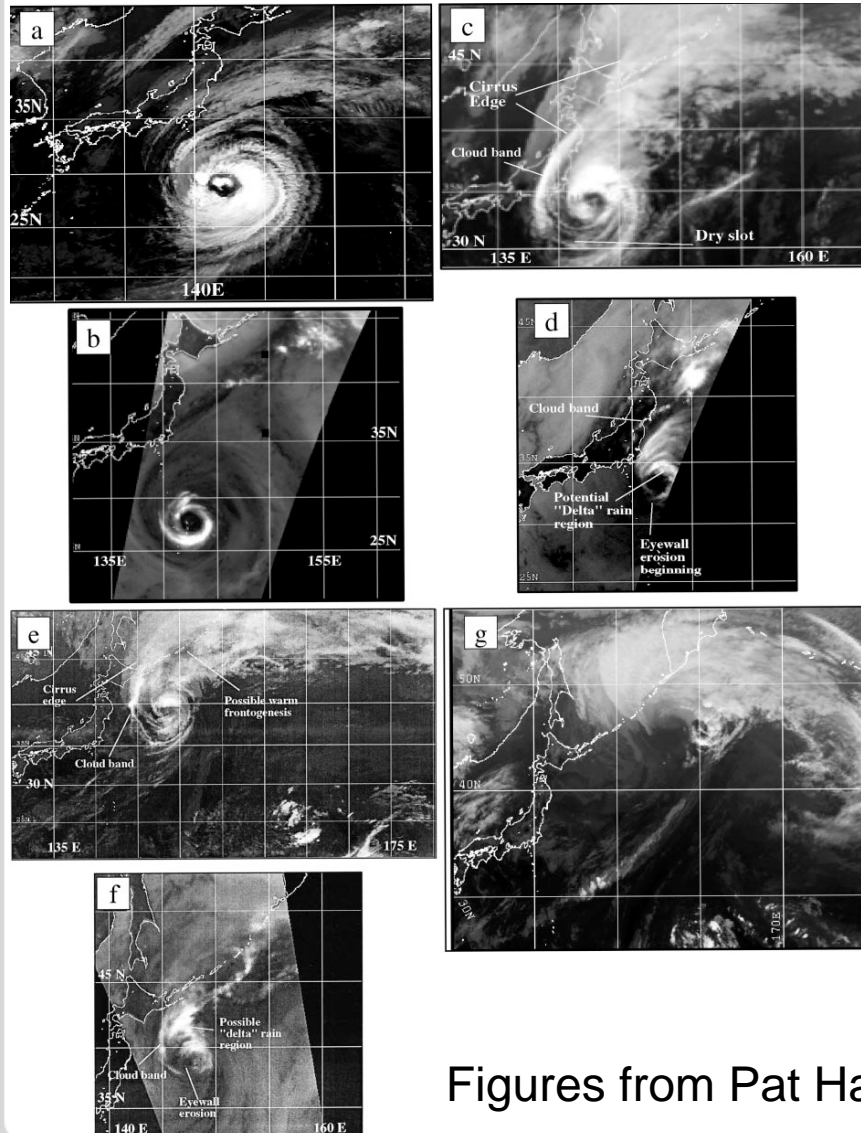
# Classification of ET

Klein, Harr and Elsberry (2000)

**Tropical Stage**

**Transformation Stage**







**Reintensification (extratropical) stage**



Figures from Pat Harr



# Characteristics of ET

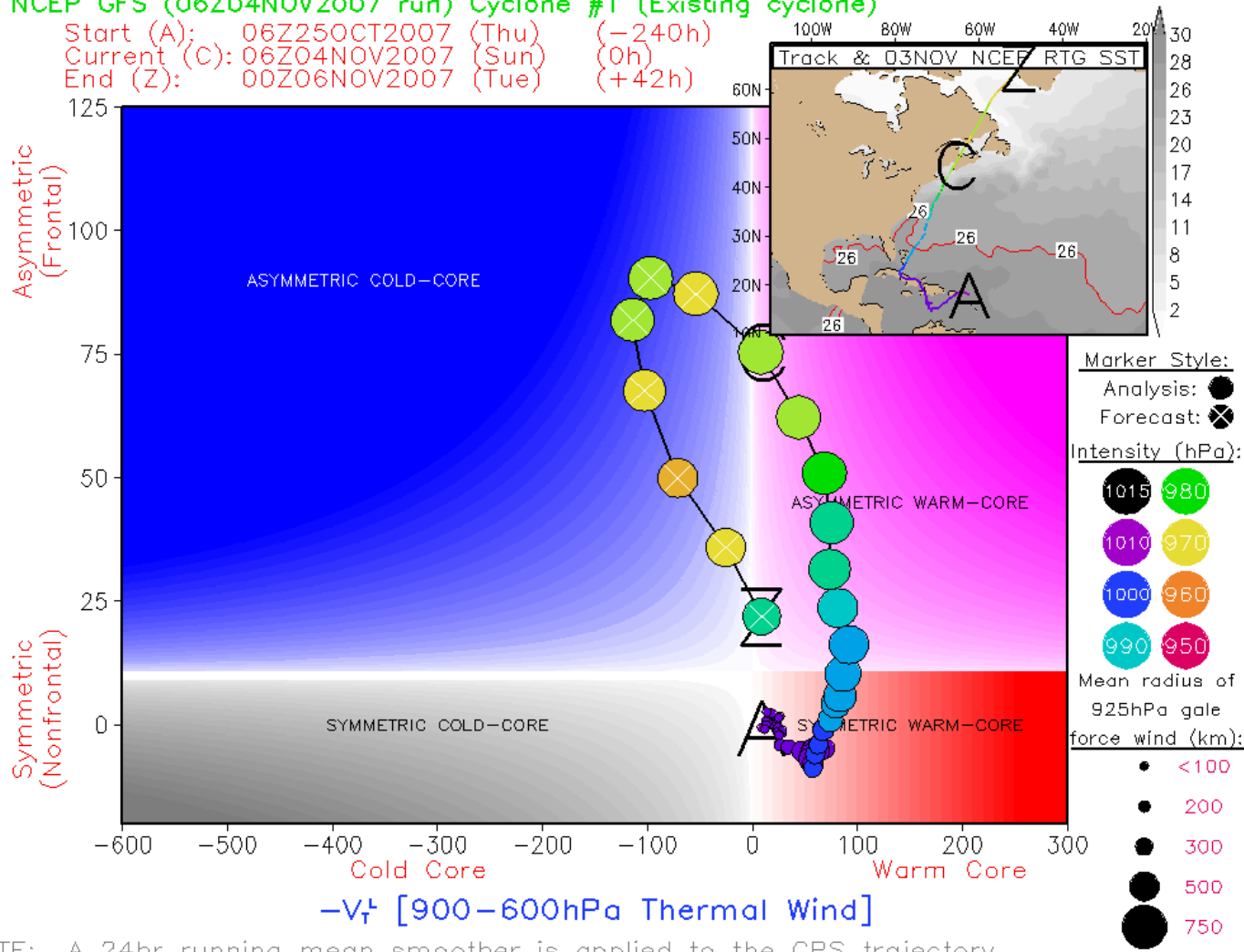
-  Increased forward speed
-  Increased asymmetry of cloud, precipitation and wind fields
  - Winds strongest right (left) of track in NH (SH)
  - Precipitation strongest left (right) of track in NH (SH)
-  Expansion of areal coverage of strong winds
-  Decreased SST / strong SST gradients
-  Strong warm frontogenesis & enhanced latent heat release
-  Transformation from warm to cold core system

# Cyclone phase space diagram for Noel (2007)

0.5° NCEP GFS (06Z04NOV2007 run) Cyclone #1 (Existing cyclone)

Start (A): 06Z25OCT2007 (Thu) (-240h)  
 Current (C): 06Z04NOV2007 (Sun) (0h)  
 End (Z): 00Z06NOV2007 (Tue) (+42h)

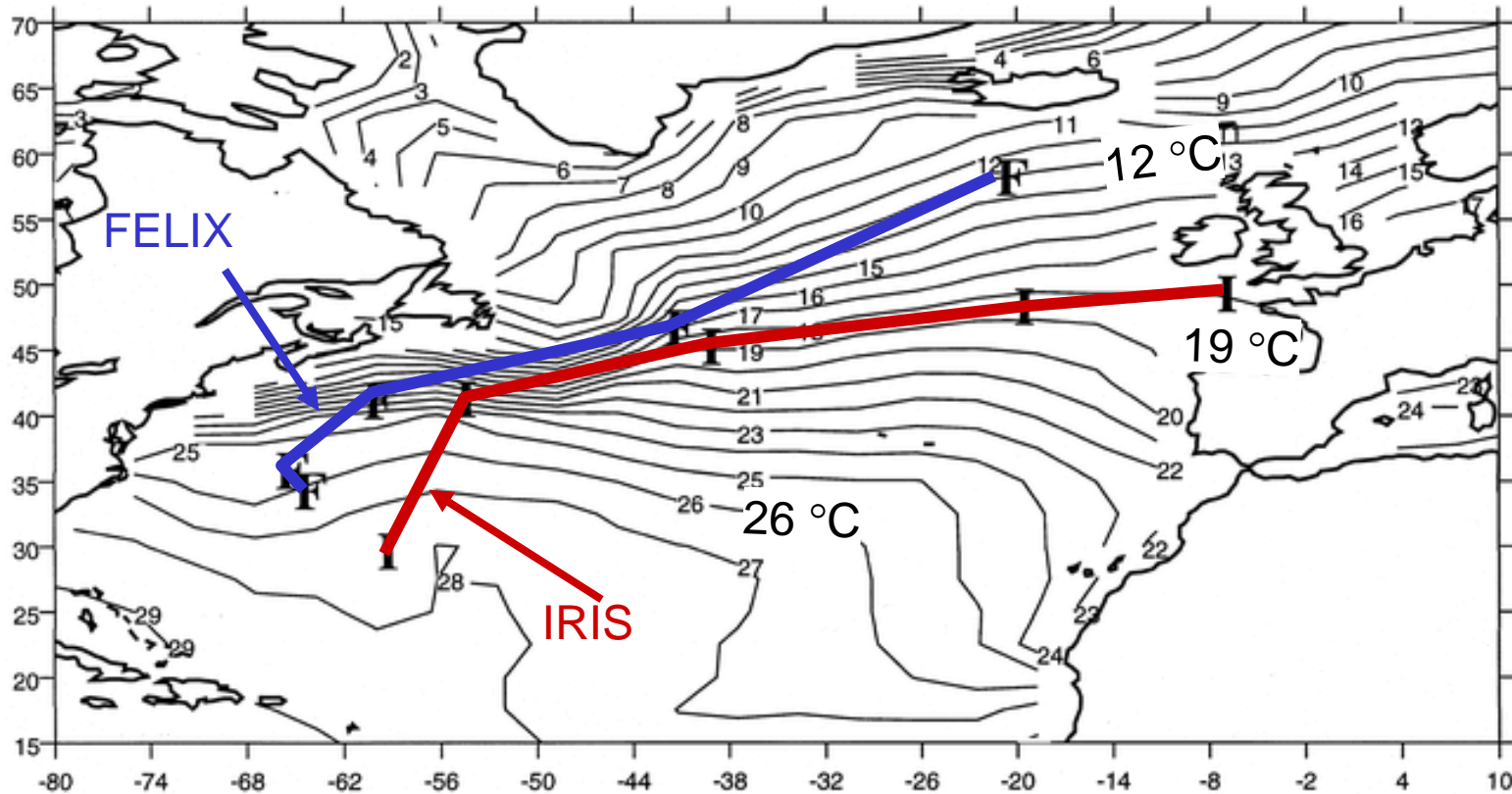
B [900–600hPa Storm–Relative Thickness Symmetry]



NOTE: A 24hr running mean smoother is applied to the CPS trajectory.

Courtesy of Bob Hart and Jenni Evans

# A tale of two storms in 1995

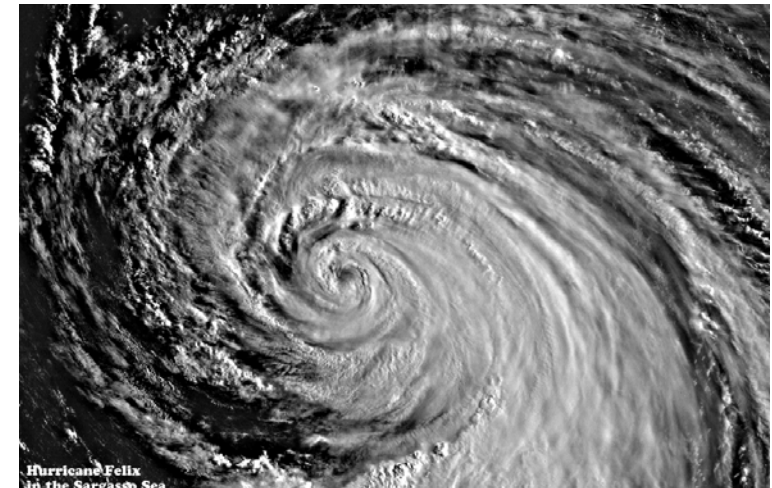
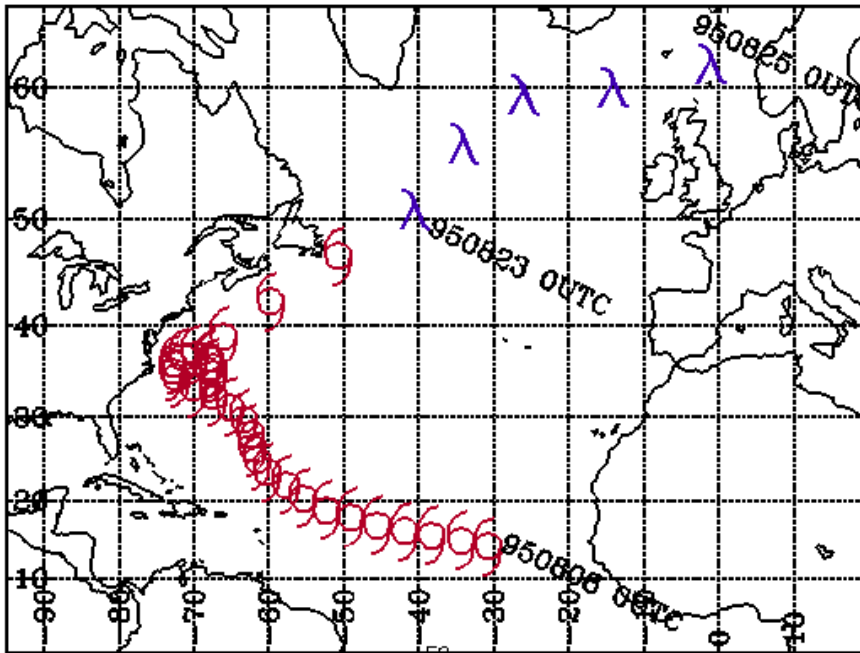


SST and TC tracks

Thorncroft and Jones (2000)

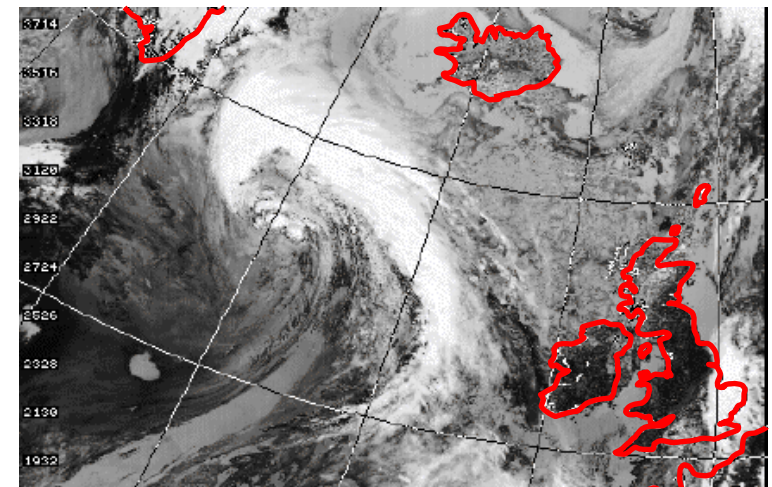
# A tale of two storms

## NHC Best Track for Felix 5.8. - 25.8.1995



Hurrikan Felix

13.8.1995



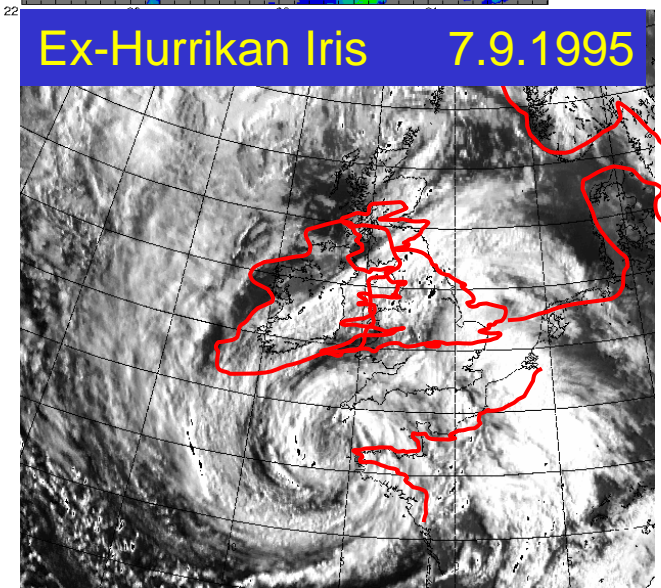
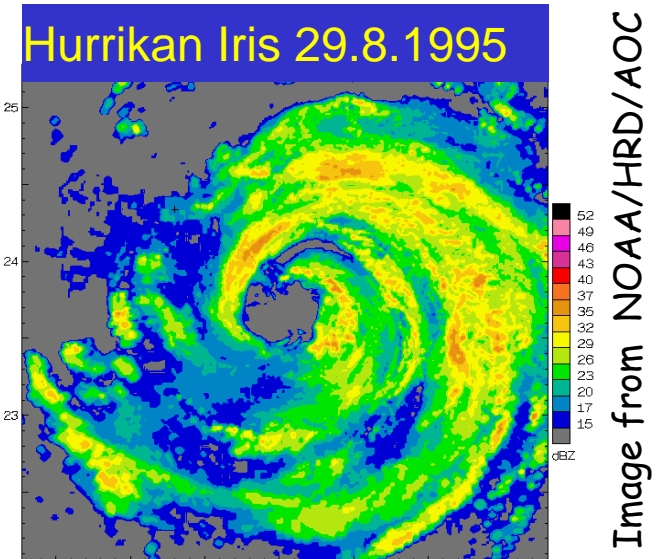
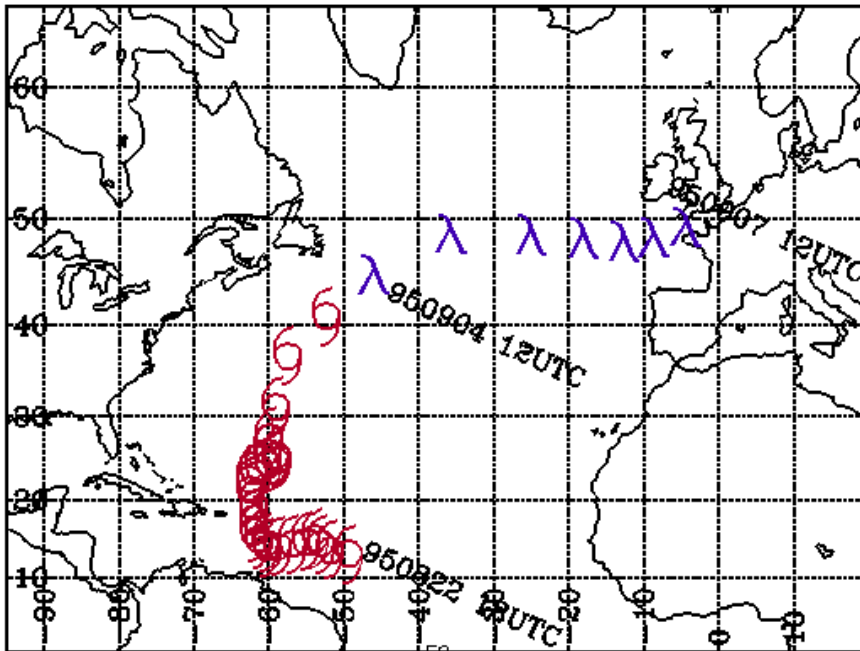
Ex-Hurrikan Felix

23.8.1995

Thorncroft and Jones (2000)

# A tale of two storms

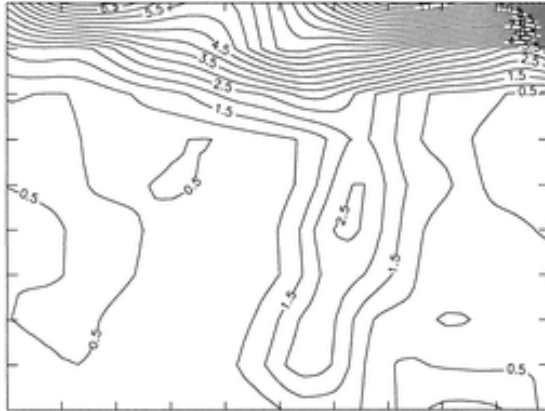
## NHC Best Track for Iris 22.8. - 7.9.1995



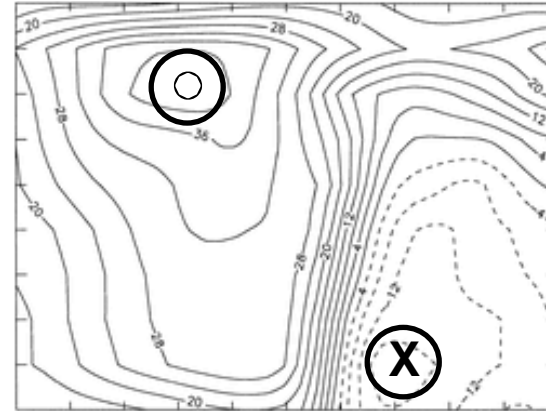
Thorncroft and Jones (2000)

# Structure of Felix after ET

PV



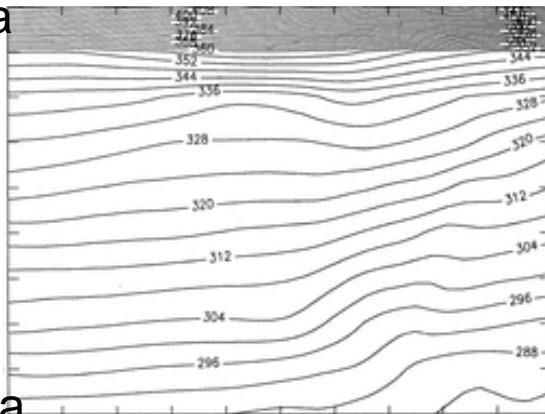
U



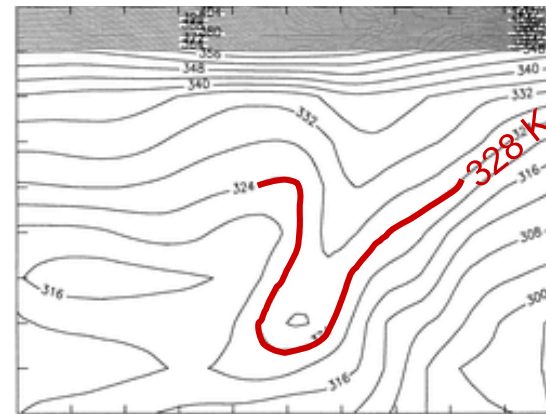
FELIX 24/8/1995 00 UTC

$\theta$

100 hPa



$\theta_e$



1000 hPa

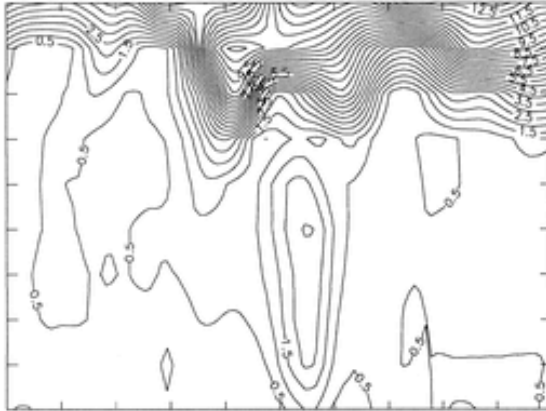
50 N

65 N

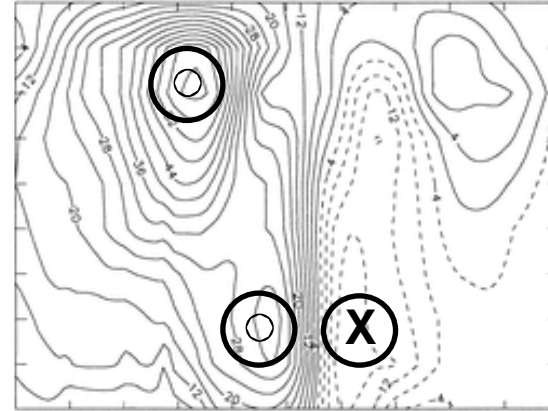
Thorncroft and Jones (2000)

# Structure of Iris after post-ET reintensification

PV



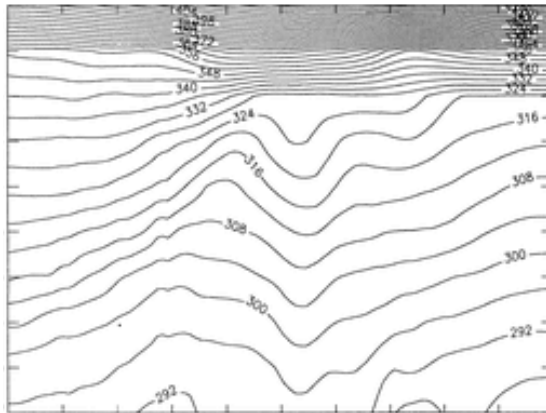
U



IRIS 7/9/1995 00 UTC

$\theta$

100 hPa



$\theta_e$



1000 hPa

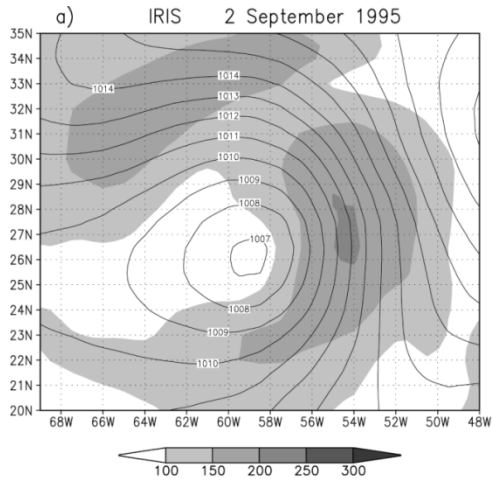
35 N

60 N

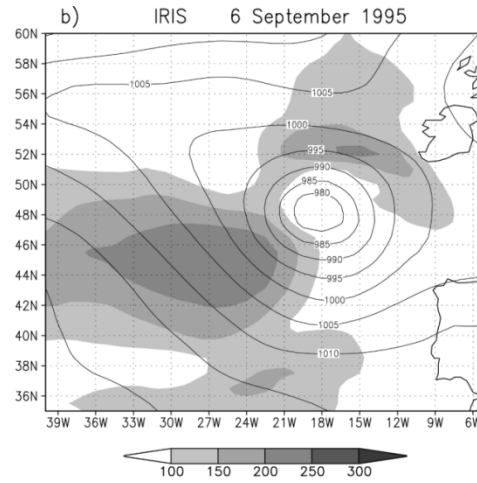
Thorncroft and Jones (2000)

# Latent heat fluxes from ECMWF Modell

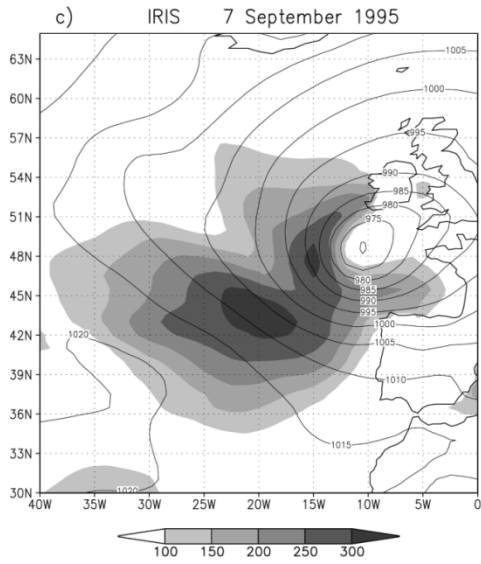
Iris  
2 Sept



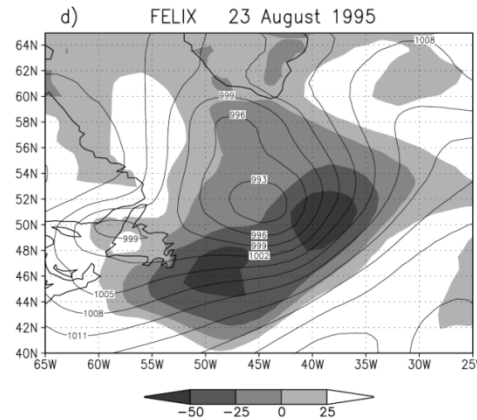
Iris  
6 Sept



Iris  
7 Sept



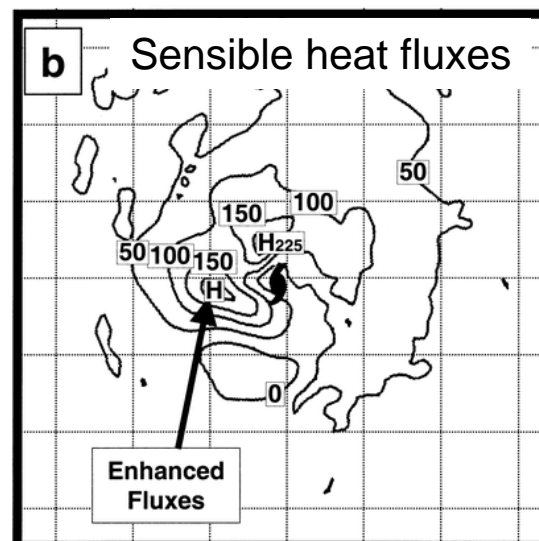
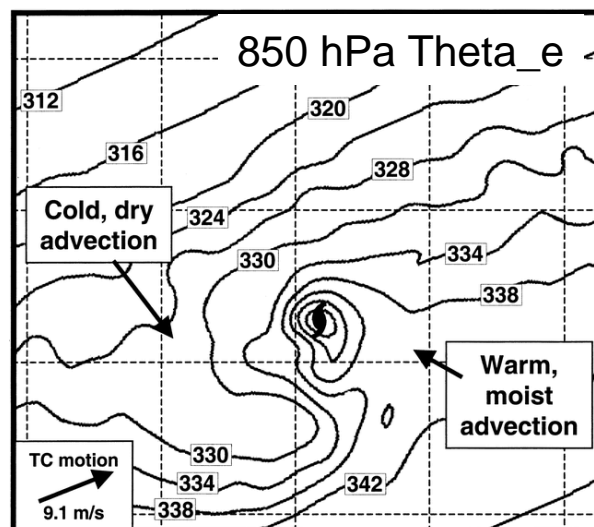
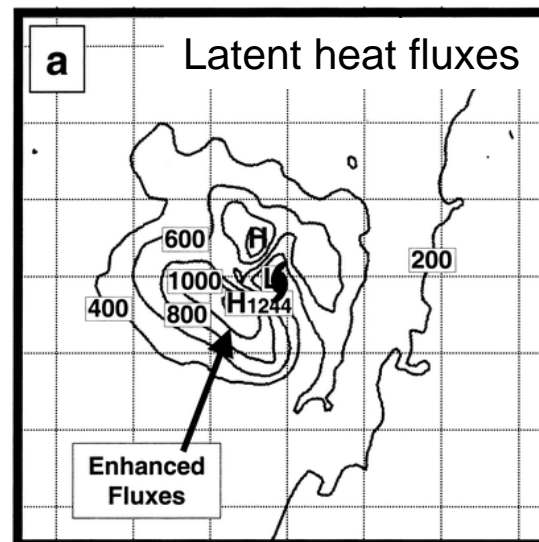
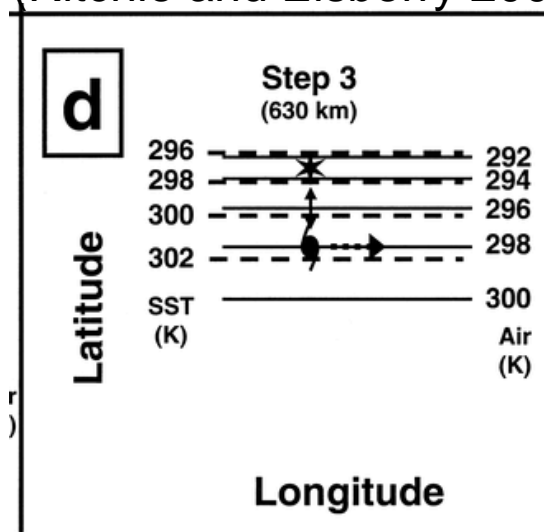
Felix  
23 August





# Idealised modelling of transformation stage of ET

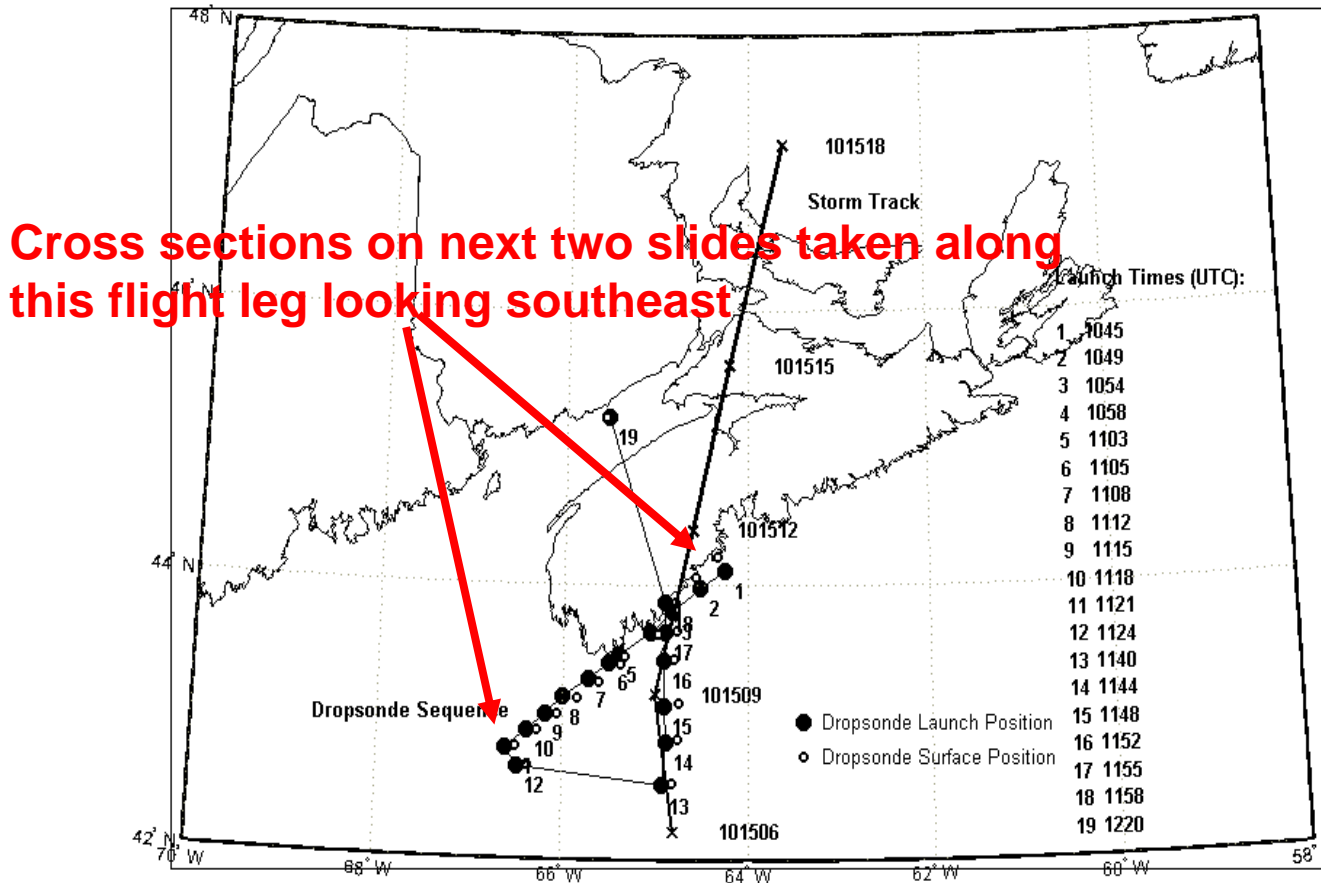
(Ritchie and Elsberry 2001)



# Observations of ET of Karen

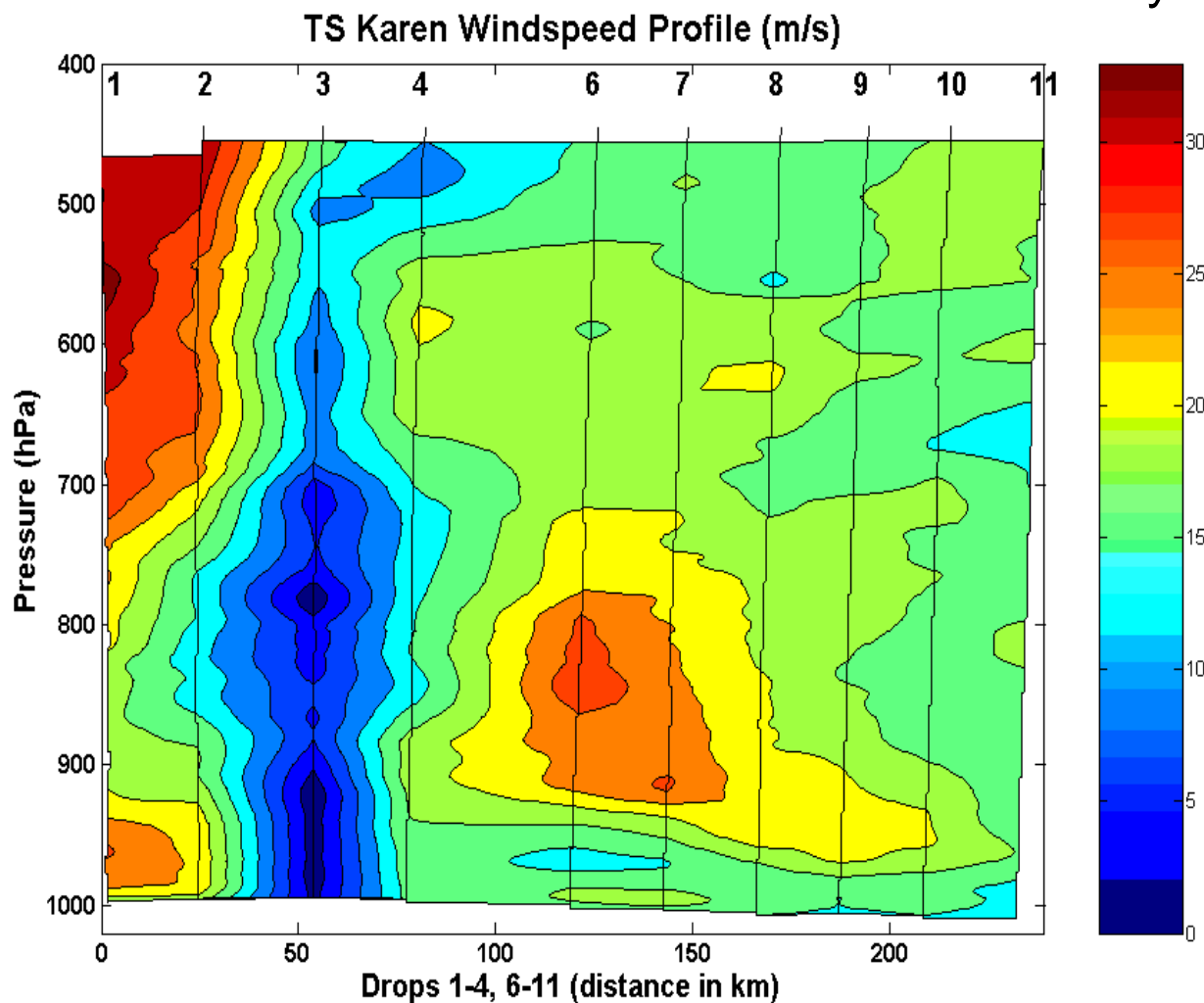
Courtesy of Chris Fogarty

Tropical Storm Karen Dropsonde Sequence and Storm Track



# Observations of ET of Karen

Courtesy of Chris Fogarty

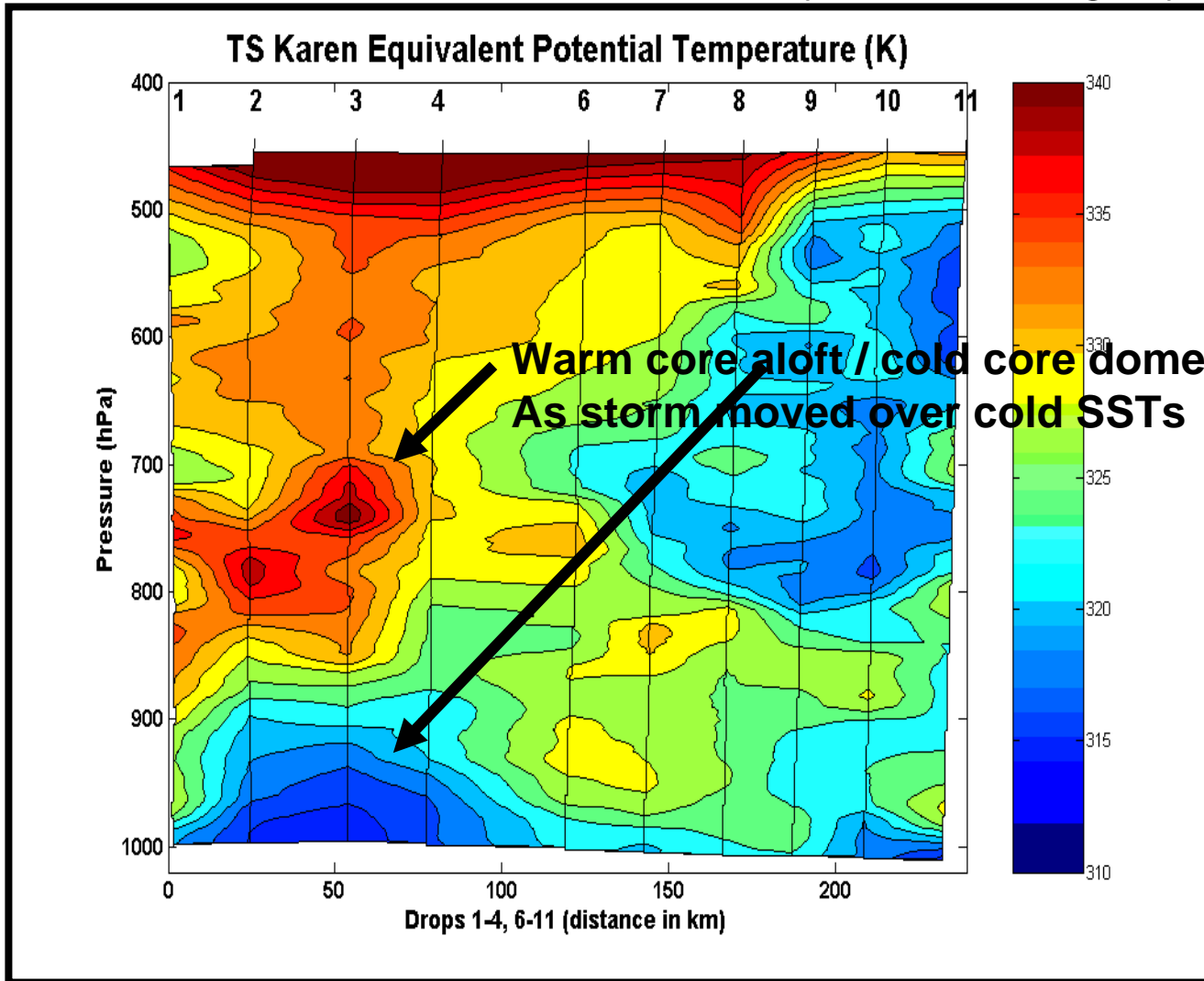


# Observations of ET of Karen

Courtesy of Chris Fogarty



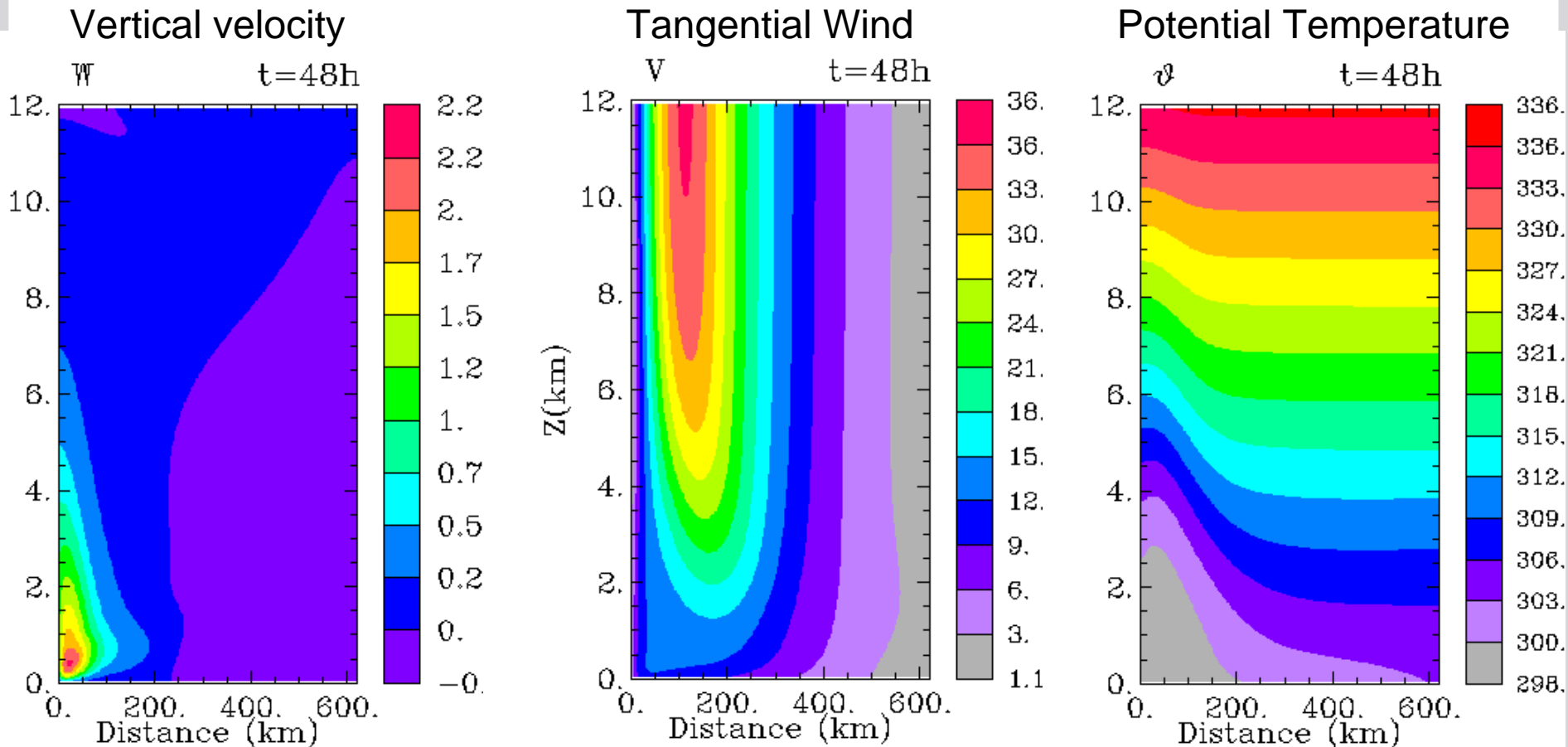
Canadian  
Hurricane  
Centre



See also Modelling study in Fogarty (2006), Fogarty, Greatbatch, Ritchie (2006, 2007)

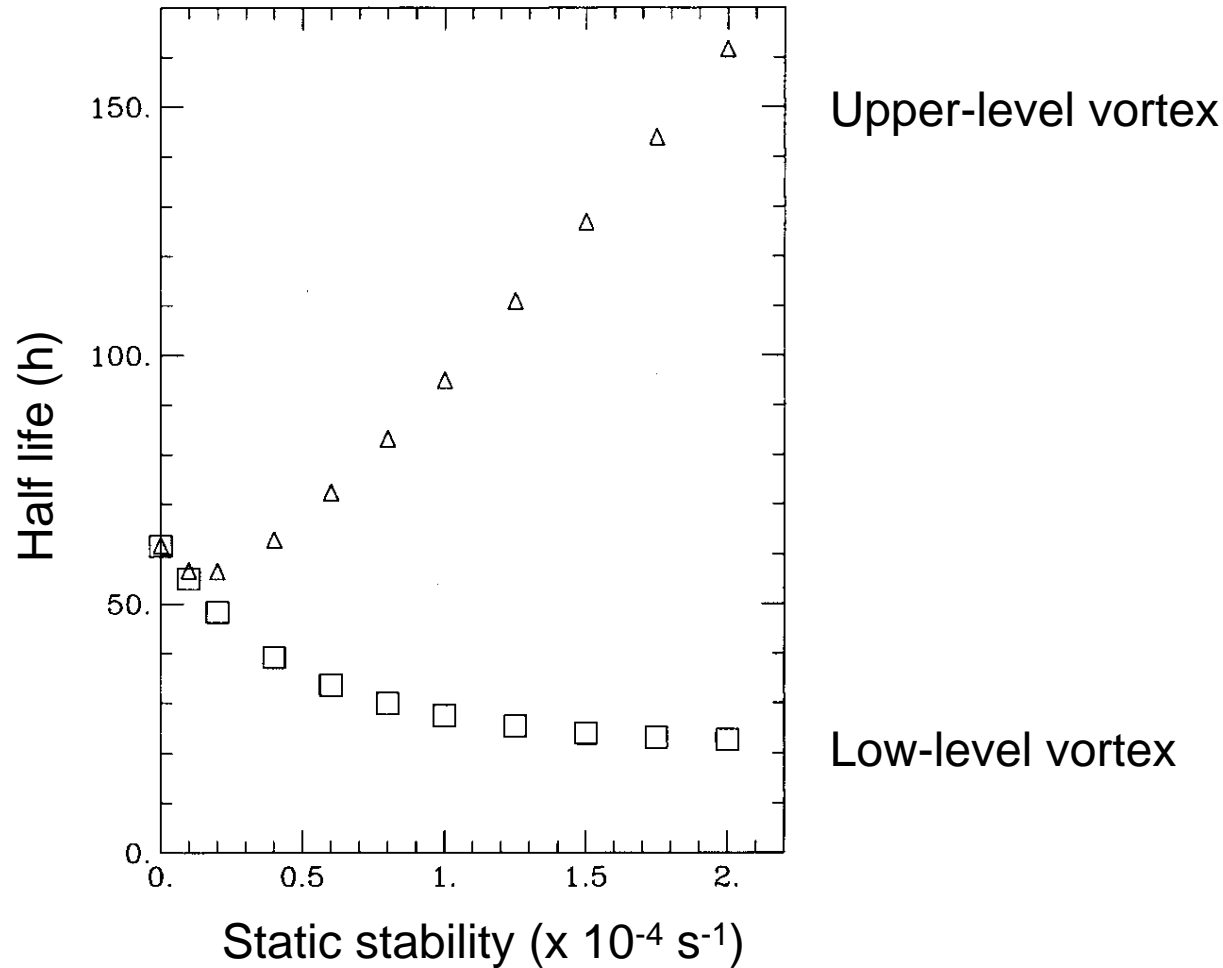
# Longevity of a tropical cyclone vortex after ET

## Spin down of an initially-barotropic axisymmetric vortex



(Jones und Thorncroft 2000)

# Longevity of a tropical cyclone vortex after ET

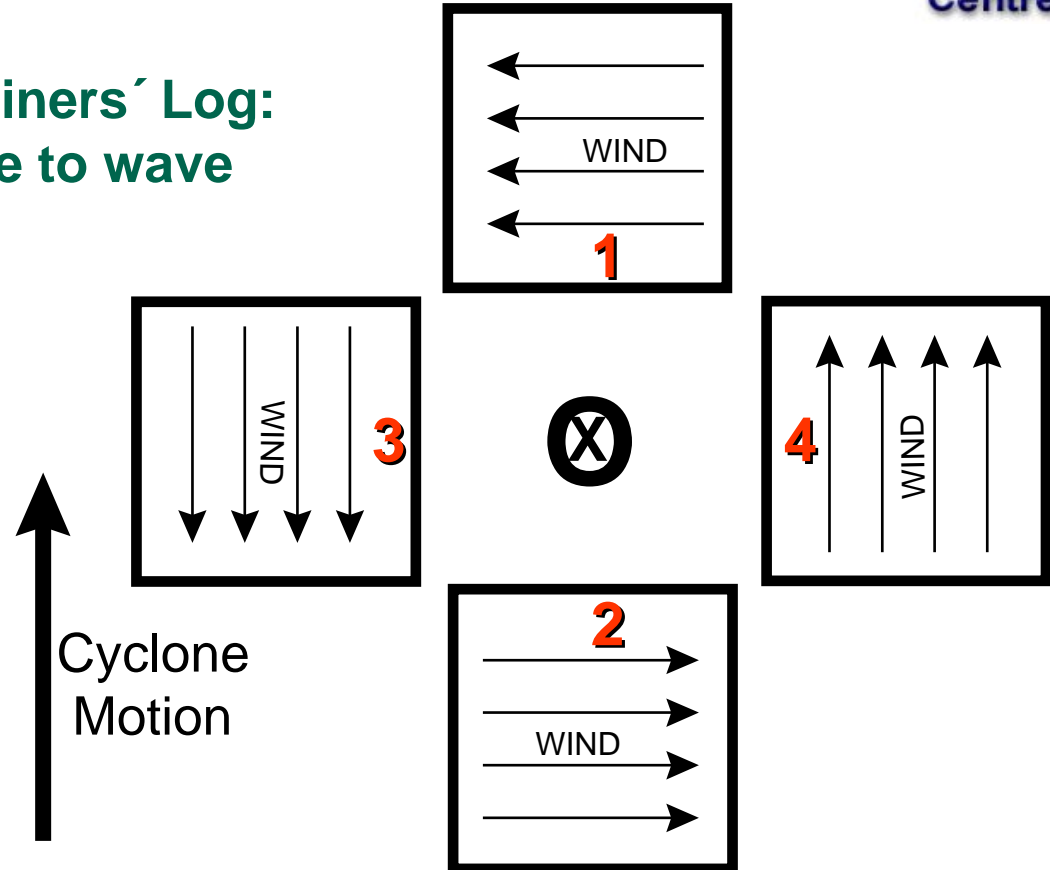


(Jones und Thorncroft 2000)

# Impact of ET: Trapped Fetch Waves

## Validation of Canadian Buoy Data in ex-Hurricane Luis

Report from QEI in Mariners' Log:  
„Visibility reduced due to wave  
height“



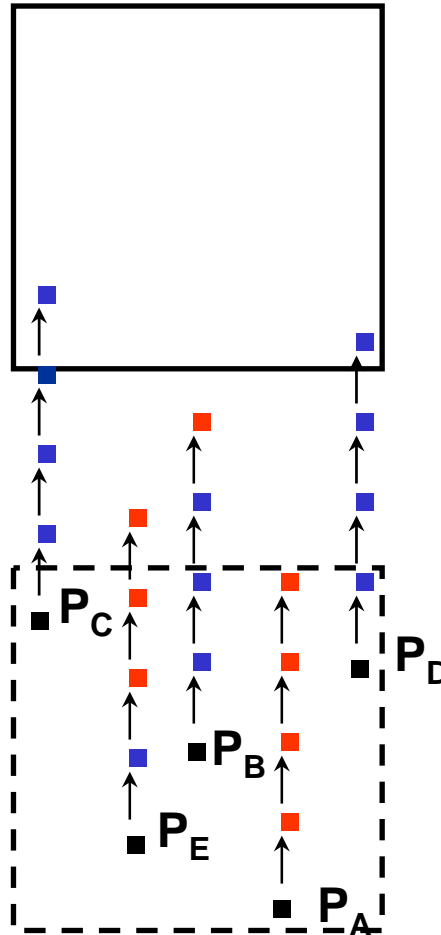
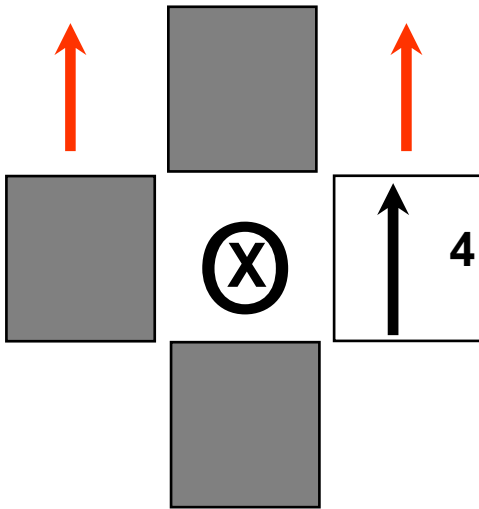
Courtesy of Pete Bowyer

# Impact of ET: Trapped Fetch Waves



Canadian  
Hurricane  
Centre

Winds With  
Fetch Motion



Time  $T_4$

Waves from  
 $P_C$  &  $P_D$   
are still growing  
after 4 time-steps

Time  $T_0$

Bowyer and Macafee; Macafee and Bowyer (2005)

Courtesy of Pete Bowyer

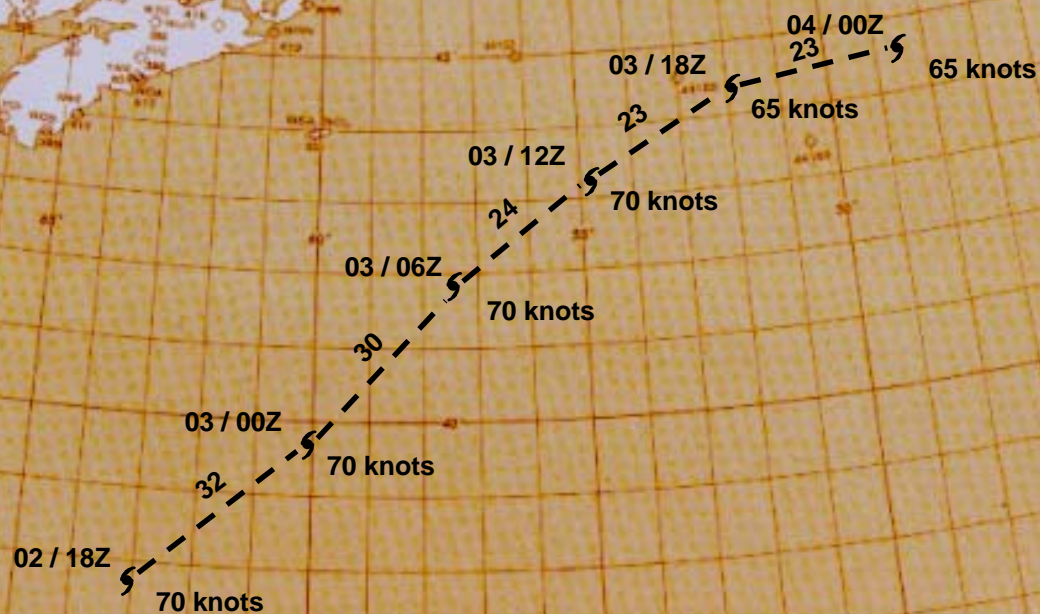


# Impact of ET: Trapped Fetch Waves



Canadian  
Hurricane  
Centre

**HURRICANE  
DANIELLE  
Sept. 2-3, 1998**



Courtesy of Pete Bowyer

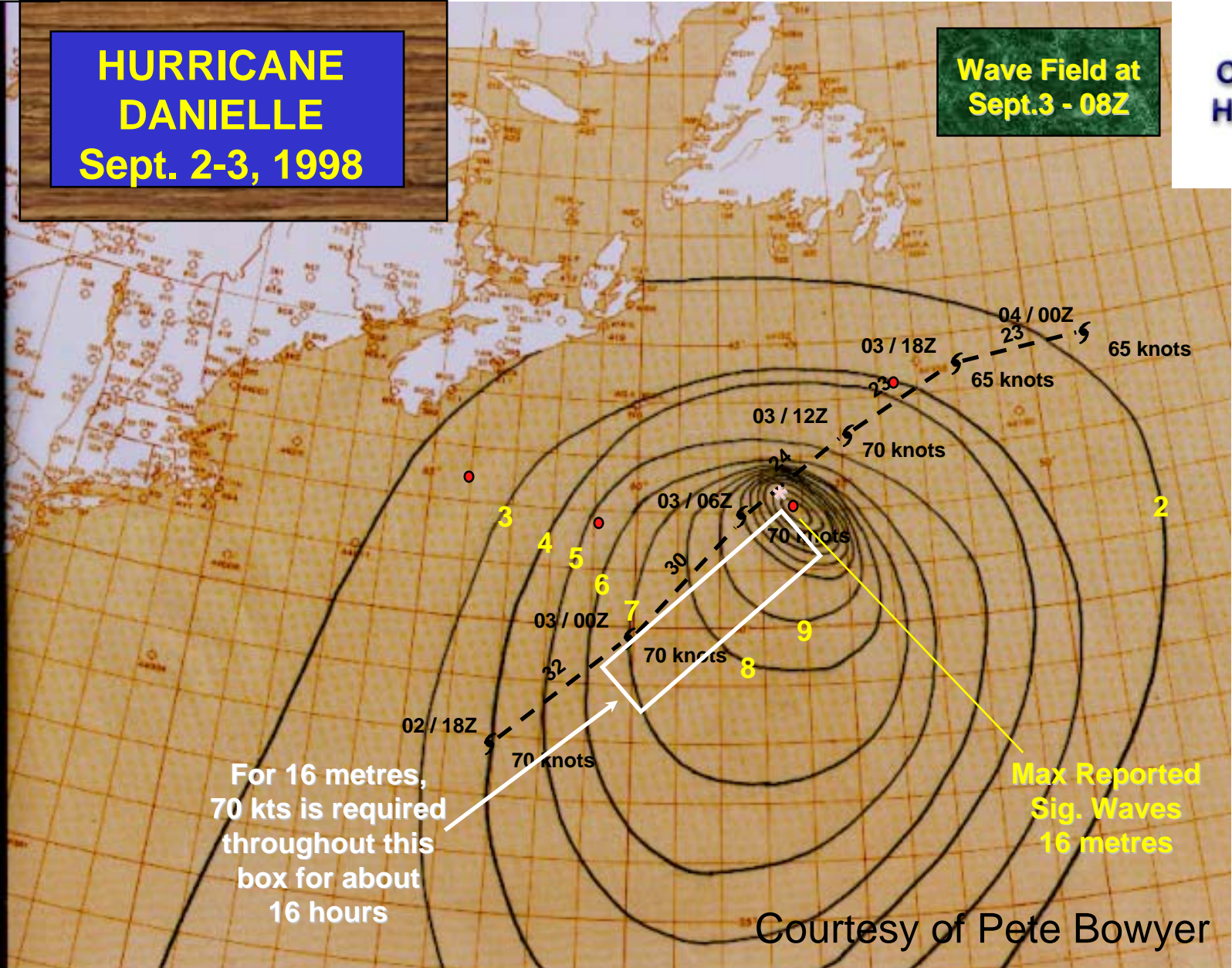
# Impact of ET: Trapped Fetch Waves



Canadian  
Hurricane  
Centre

**HURRICANE  
DANIELLE  
Sept. 2-3, 1998**

**Wave Field at  
Sept.3 - 08Z**



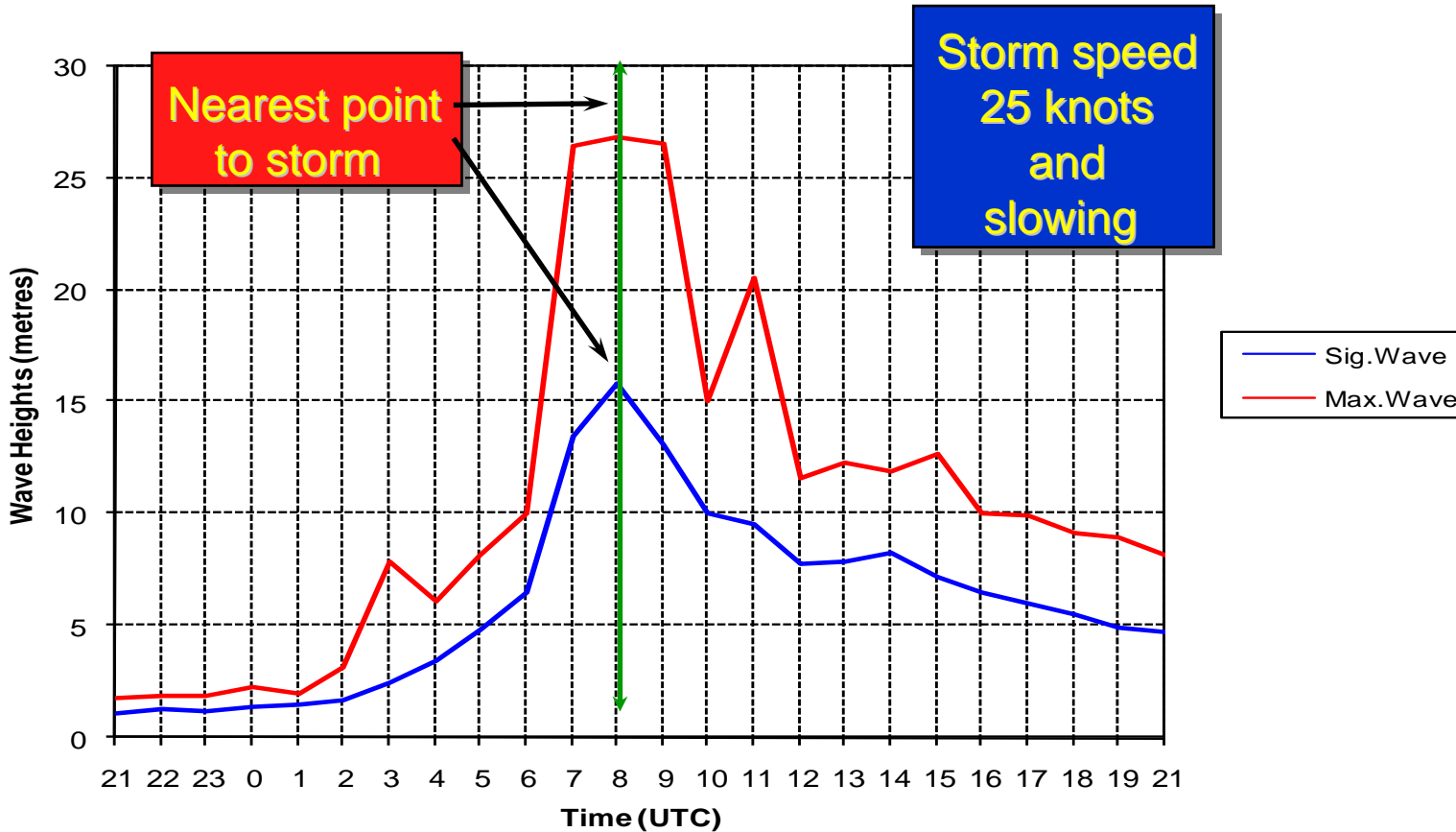
Courtesy of Pete Bowyer

# Impact of ET: Trapped Fetch Waves



Canadian  
Hurricane  
Centre

Significant & Maximum Wave Heights at Buoy 44141  
During Hurricane Danielle  
September 2-3, 1998



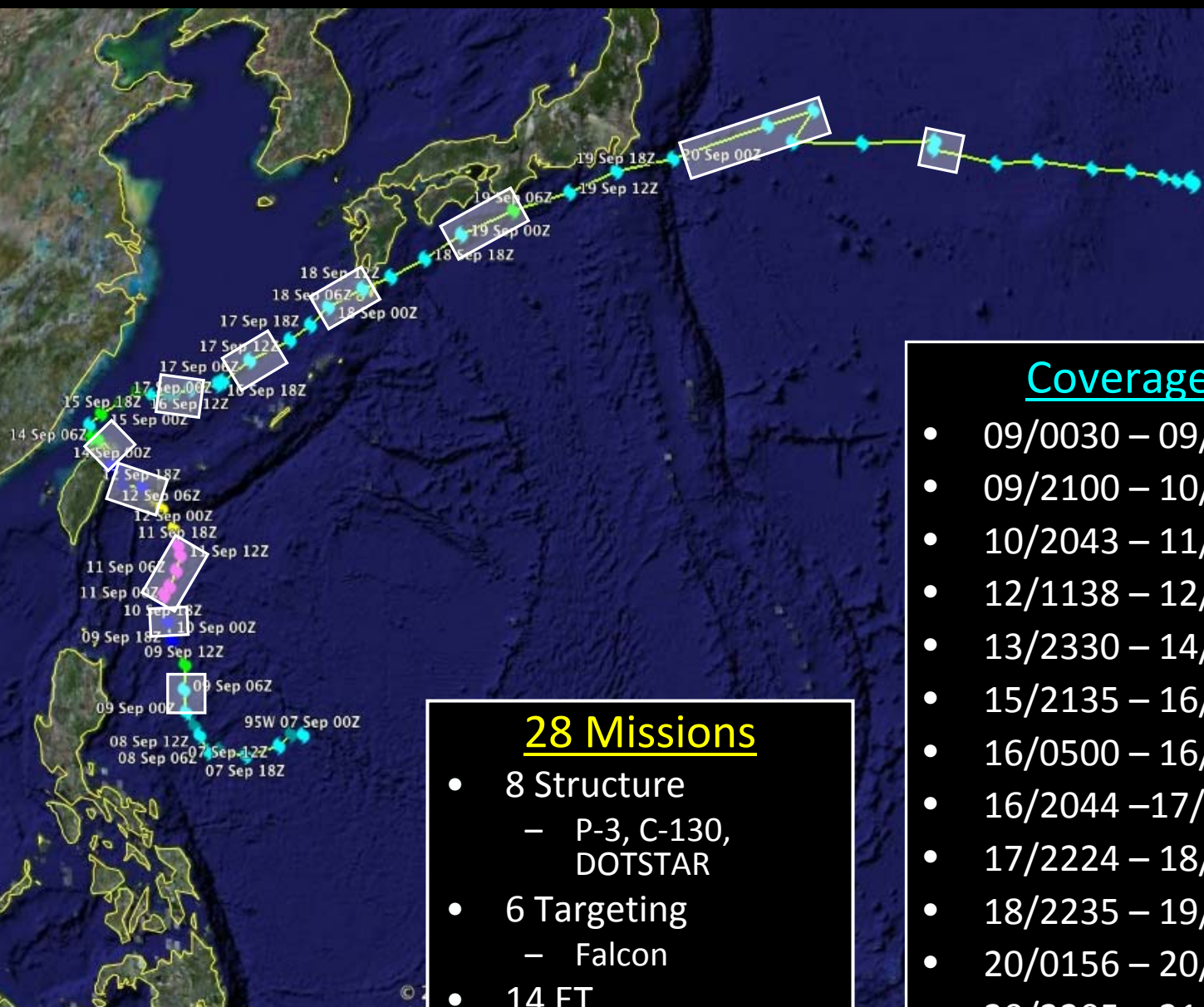
Courtesy of Pete Bowyer

# In summary: some thoughts and questions

Accurate track forecast essential to forecast ET but how well do we need to know TC intensity and structure directly before ET?

- TC structure and intensity change at high latitudes / over SST gradients

# TY Sinlaku (TCS-033 / TD15W) in T-PARC / TCS08



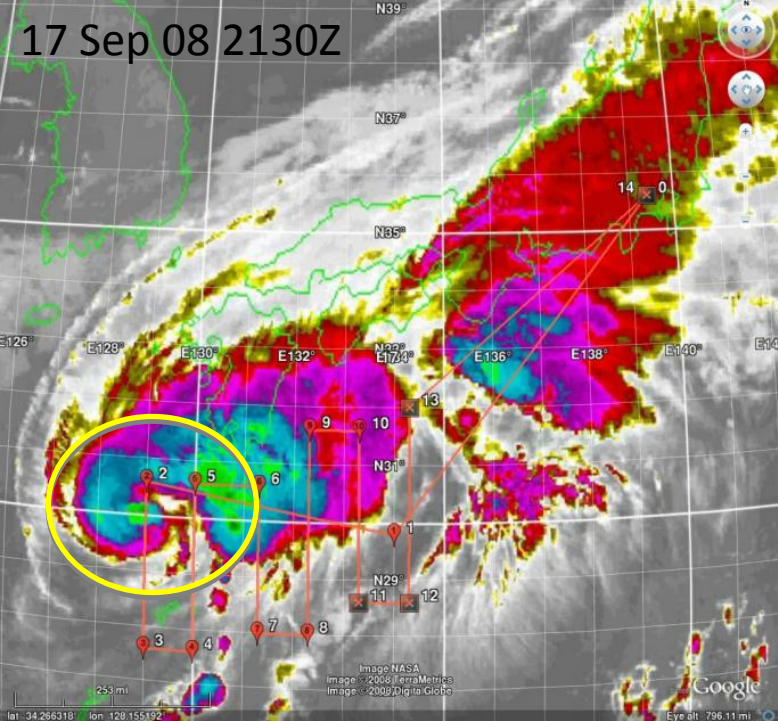
## Coverage

- 09/0030 – 09/1045
- 09/2100 – 10/1225
- 10/2043 – 11/1828
- 12/1138 – 12/2318
- 13/2330 – 14/0555
- 15/2135 – 16/0205
- 16/0500 – 16/0800
- 16/2044 – 17/1115
- 17/2224 – 18/0720
- 18/2235 – 19/0725
- 20/0156 – 20/1206
- 20/2205 – 21/0205

## 28 Missions

- 8 Structure
  - P-3, C-130, DOTSTAR
- 6 Targeting
  - Falcon
- 14 ET
  - P-3, C-130, Falcon

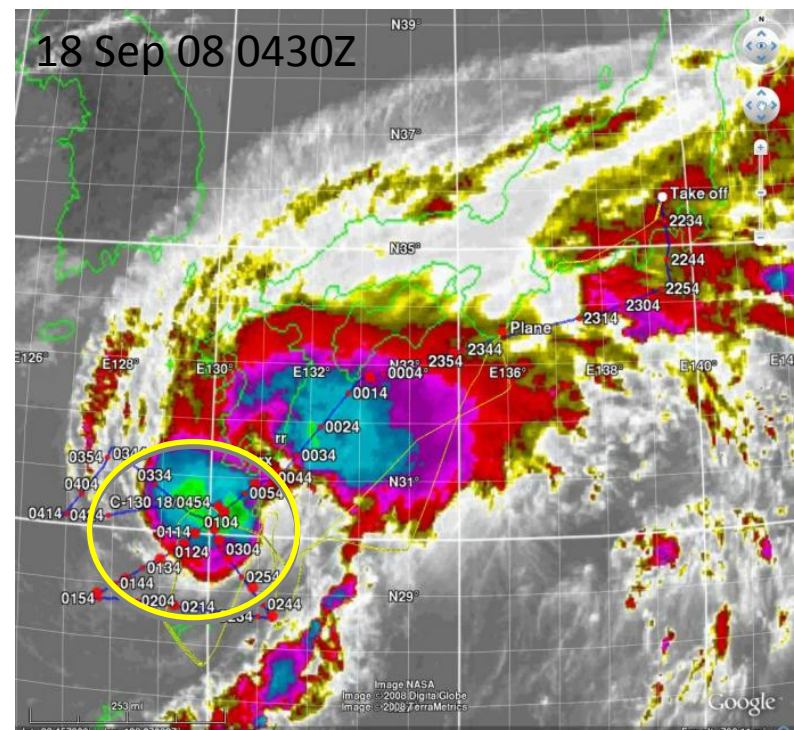
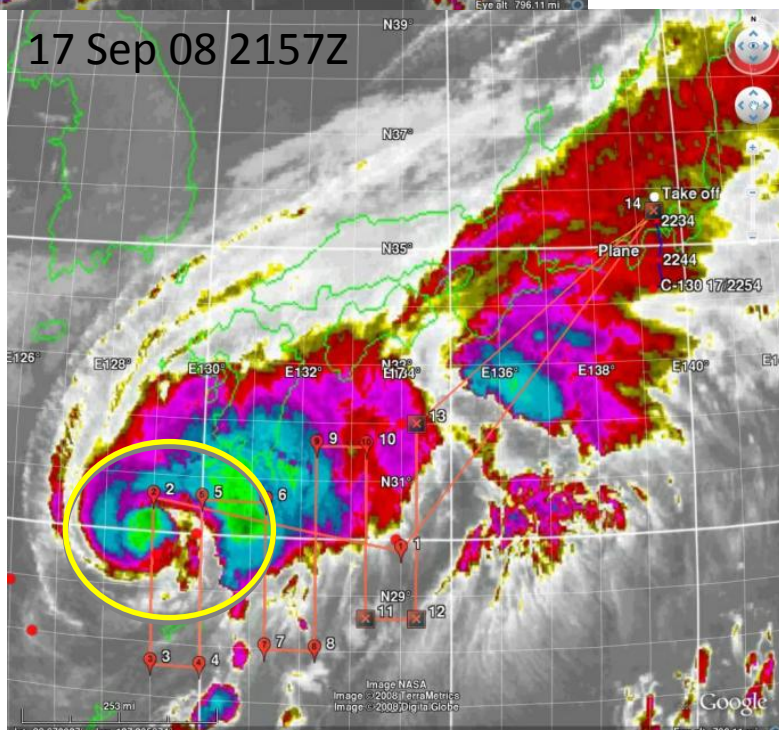
Courtesy of Beth Sanabia & Pat Harr



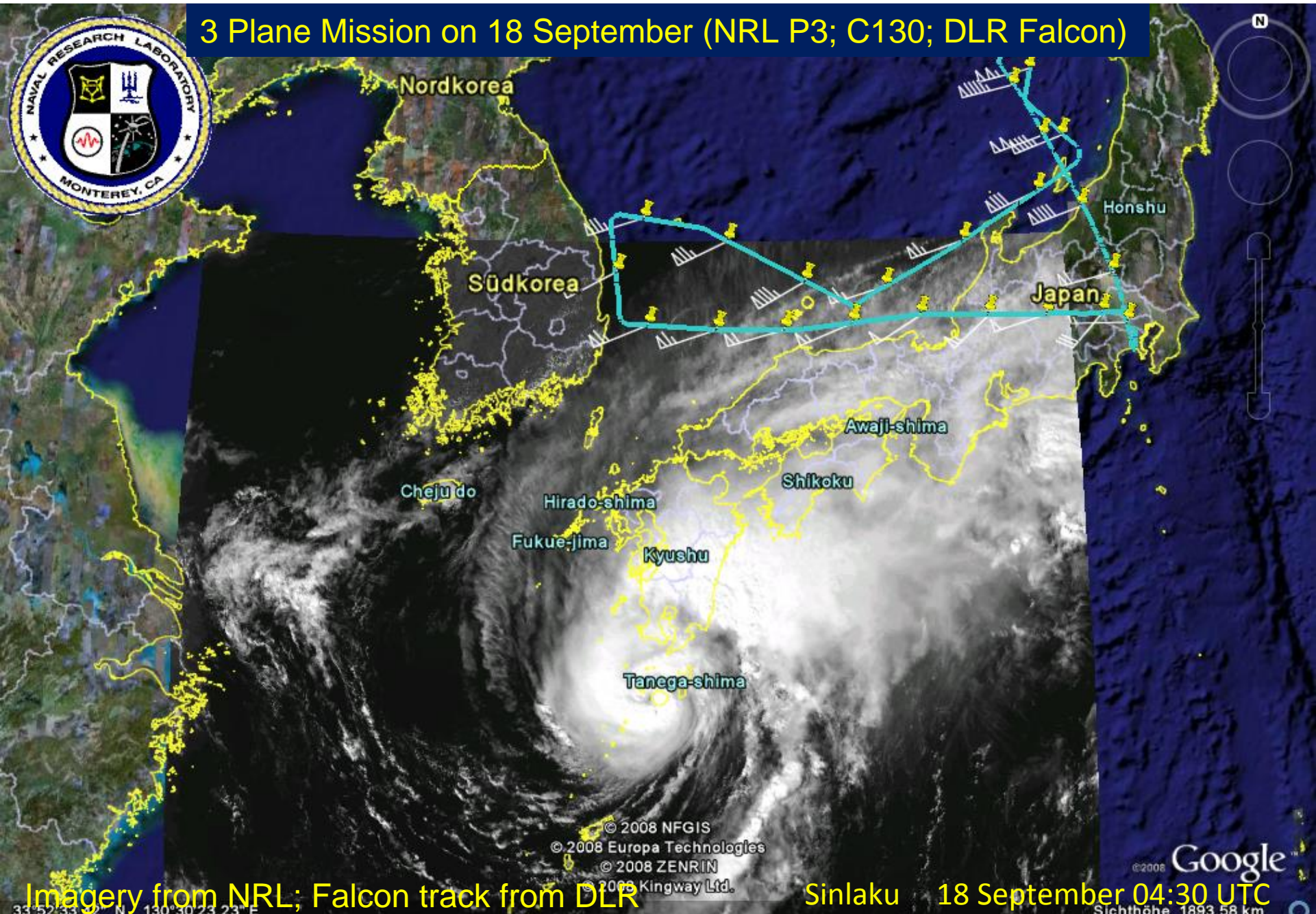
# Reintensification of TY Sinlaku

## T-PARC / TCS08

(Courtesy of Beth Sanabia, NPS;  
Imagery from NRL)



3 Plane Mission on 18 September (NRL P3; C130; DLR Falcon)



Imagery from NRL; Falcon track from DLR

Sinlaku 18 September 04:30 UTC

Sichtöhe. 1893 58 km

# Summary: some thoughts and questions

Accurate track forecast essential to forecast ET but how well do we need to know TC intensity and structure directly before ET?

- TC structure and intensity change at high latitudes / over SST gradients

How well do we need to know structure of TC remnants after ET?

- Spin down of TC vortex over cold water

What about waves?

Role of asymmetries?

Does ocean-atmosphere interaction differ from extratropical system after ET?

- Modification by TC remnants (PV tower, warm and moist inner core)?

Is coupled modelling important or just accurate representation of SST?

Impact of Extratropical Transition on ocean?