Tropical-Extratropical Transition

Extratropical Transition

- A significant number of tropical cyclones move into the midlatitudes and transform into extratropical cyclones.
- This process is generally referred to as extratropical transition (ET).
- During ET a cyclone frequently acquires increased forward motion and sometimes intensify substantially, so that such systems pose a serious threat to land and maritime activities.
- Models are predicting better, but sometimes still handled poorly
- Extratropical transition occurs in nearly every ocean basin that experiences tropical cyclones with the number of ET events following a distribution in time similar to that of the total number of tropical cyclone occurrences.
- The largest number of ET events occur in the western North Pacific while the North Atlantic basin contains the largest percentage of tropical cyclones that undergo ET with 45% of all tropical cyclones undergoing ET.

The Issue

- Tropical cyclones transform into extratropical cyclones as they move northward, usually between 30° and 40° latitude.
- Interaction with upper-level troughs or shortwaves in the westeries, and preexisting baroclinic zones is an important factor in ET.
- During extratropical transition, cyclones begin to tilt back into the colder airmass with height, and the cyclone's primary energy source converts from the release of latent heat from condensation (from convection near the center) to baroclinic processes.
- The low pressure system eventually loses its warm core and becomes a cold-core system. During this process, a cyclone in extratropical transition will invariably form or connect with nearby fronts and/or troughs. Due to this, the size of the system will usually appear to increase. After or during transition, the storm may re-strengthen, deriving energy from primarily baroclinic processes, aided by the release of latent heat.
- The cyclone will also distort in shape, becoming less symmetric with time, but sometimes retains a tight, tropical-like core.

The Other Direction As Well!

- Less frequently, an extratropical cyclone can transit into a tropical cyclone if it reaches an area of ocean with warmer waters and an environment with less vertical wind shear.
- The process known as "tropical transition" involves the usually slow development of an extratropic cold core vortex into a tropical cyclone

Big Impacts of ET

- Severe flooding associated with the ET of Tropical Storm Agnes [1972
- Hurricane Hazel (1954) resulted in 83 deaths in the Toronto area of southern Ontario, Canada. In the northwest Pacific, severe flooding and landslides have occurred in association with ET.
- An example is the ET of Tropical Storm Janis (1995) over Korea, in which at least 45 people died and 22 000 people were left homeless.
- In one southwest Pacific ET event (Cyclone Bola) over 900 mm of rain fell over northern New Zealand).
- Another event brought winds gusting to 75 m s-1 to New Zealand's capital city, Wellington (Hill 1970), resulting in the loss of 51 lives when a ferry capsized.
- Extratropical transition has produced a number of weather-related disasters in eastern Australia, due to severe flooding, strong winds, and heavy seas [e.g., Cyclone Wanda in 1974).
- Tropical systems that reintensify after ET in the North Atlantic constitute a hazard for Canada [e.g., Hurricane Earl in 1998 and for northwest Europe. The extratropical system that developed from Hurricane Lili (1996) was responsible for seven deaths and substantial economic losses in Europe.
- Many of the largest NW windstorms are ET events (Columbus Day Storm, 1981 storm and others)
- Hurricane Sandy had undergone ET right before landfall

The Differences

Tropical Cyclones	Extratropical Cyclones
non-frontal	frontal
wind max close to cyclone centre	wind max well-removed from centre
wind max in lower troposphere (< 2,000')	wind max in upper troposphere (> 30,000')
warm core vortex	baroclinic (cold) vortex
driven by latent heat release from deep convection	driven by baroclinic instability
symmetry of precipitation	precipitation left of track

Observing the Transition

NHC forecasters consider seven factors when determining whether or not a TC is undergoing extratropical transition:

Seen Best on Satellite Imagery

1. Loss of organized convection in the inner core region
2. Loss of the upper-level outflow circulation
3. Acquisition of front-like characteristics
4. Redistribution of the main precipitation area to the poleward side of the storm (also seen in suface obs and radar)

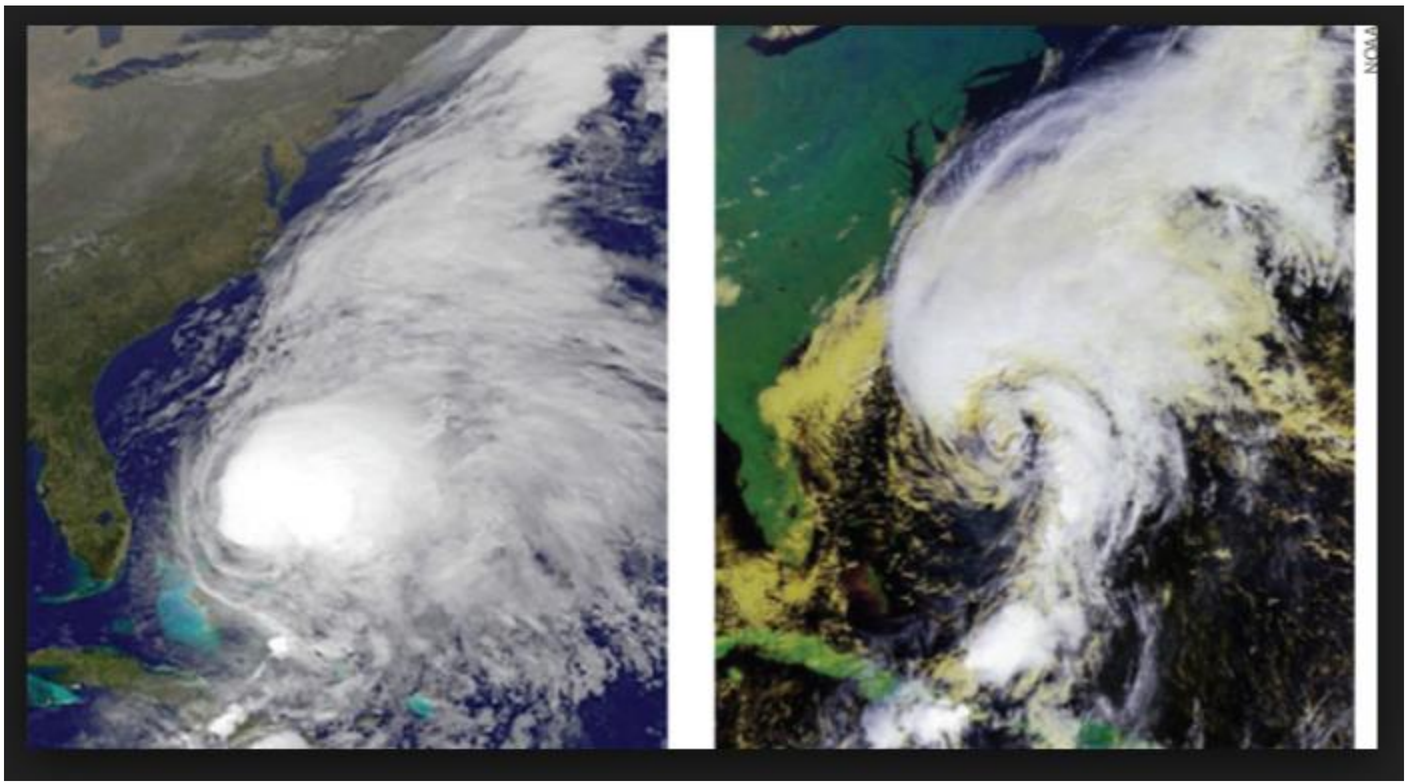
Seen Best in Surface Obs

5. Spreading out of surface wind field

Harder to Assess Operationally

6. Asymmetry in temperature and moisture fields
7. Intrusion of dry air into mid-levels of the storm

ET of Hurricane Noel (2007)



From http://www.weatherwise.org/Archives/Back%20Issues/2015/Marh-April%202015/wind_full.html

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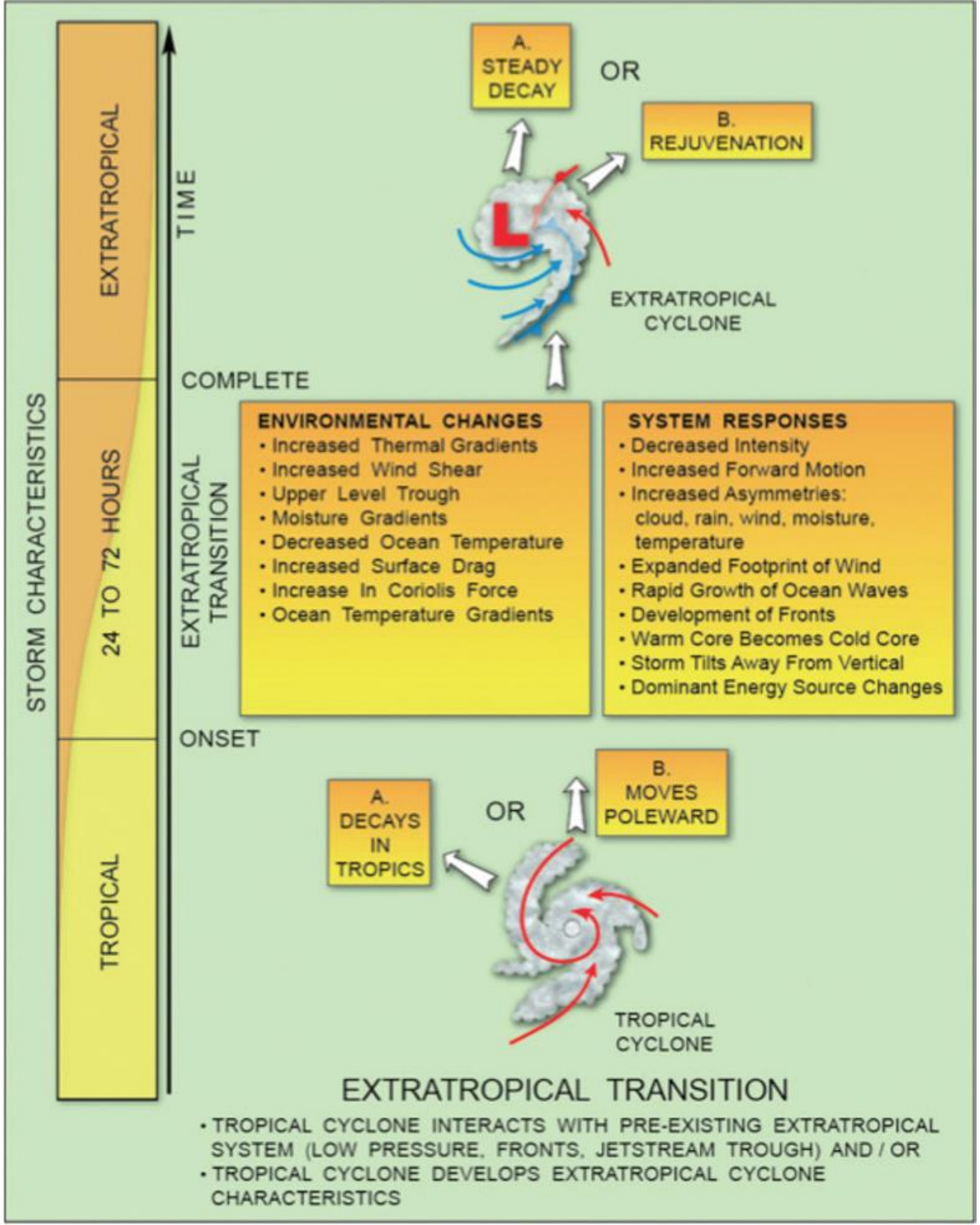


Movement of ET Storms

Track

- Storms frequently accelerate rapidly after recurvature
  - under the influence of the midlatitude flow
  - 10 kts to 50 kts not abnormal
- Tropical Cyclones are steered by the deep layer mean flow aloft
  - flow at 500 mb good estimation
  - storms transitioning to ET are moving between 50 and 100% of 500 mb flow

Intensity

- An ET storm generally first weakens and then can strengthen substantially..

ET and Precipitation

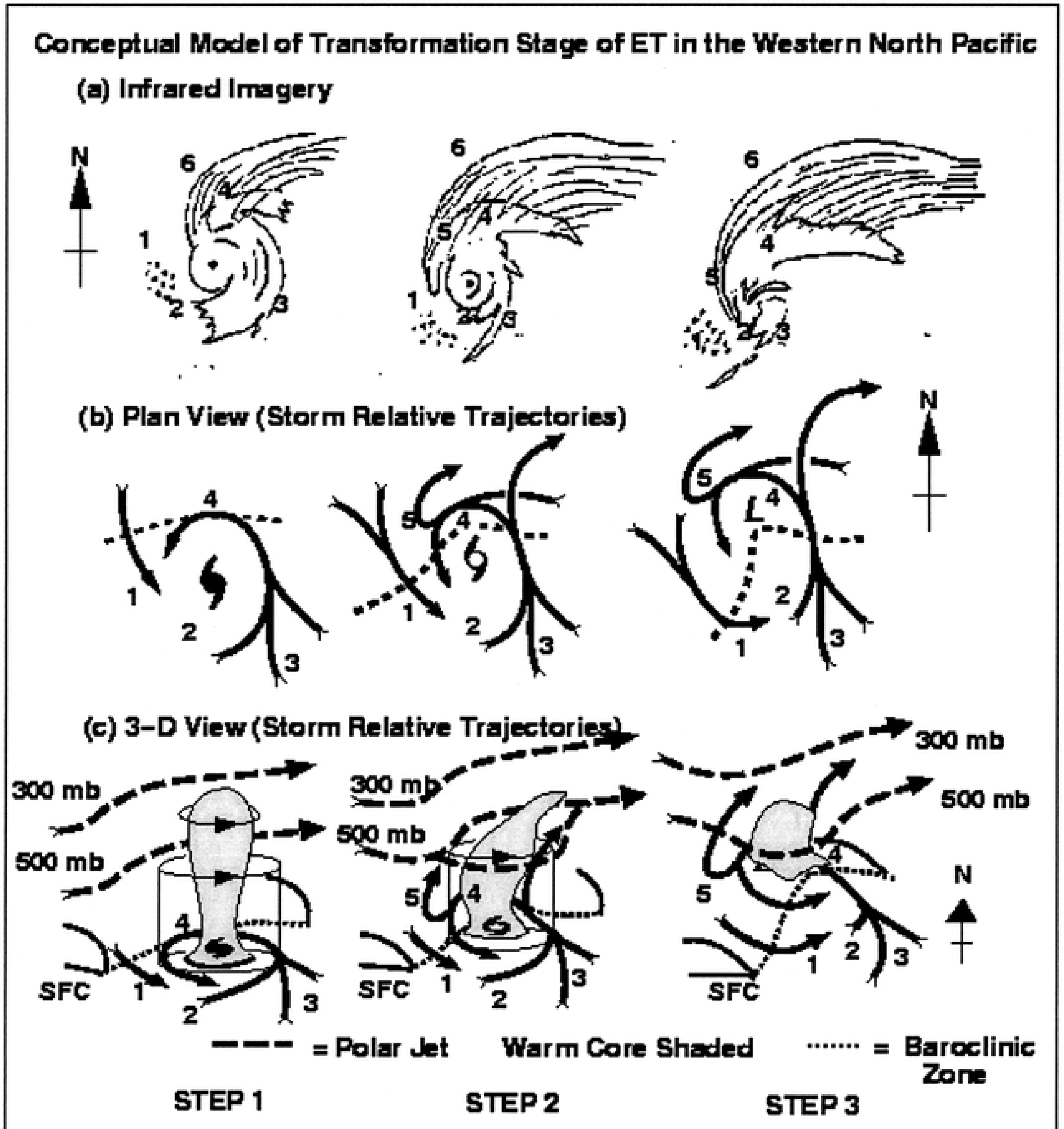
- During an ET event the precipitation expands poleward of the center and is typically maximum to the left (right) of the track in the Northern (Southern) Hemisphere. The change in the structure of the precipitation field from the more symmetric distribution in a tropical cyclone to the asymmetric distribution during ET can be attributed to increasing synoptic-scale forcing of vertical motion associated with midlatitude baroclinic features
- Ets have been associated with extraordinarily large precipitation amounts and associated flooding.

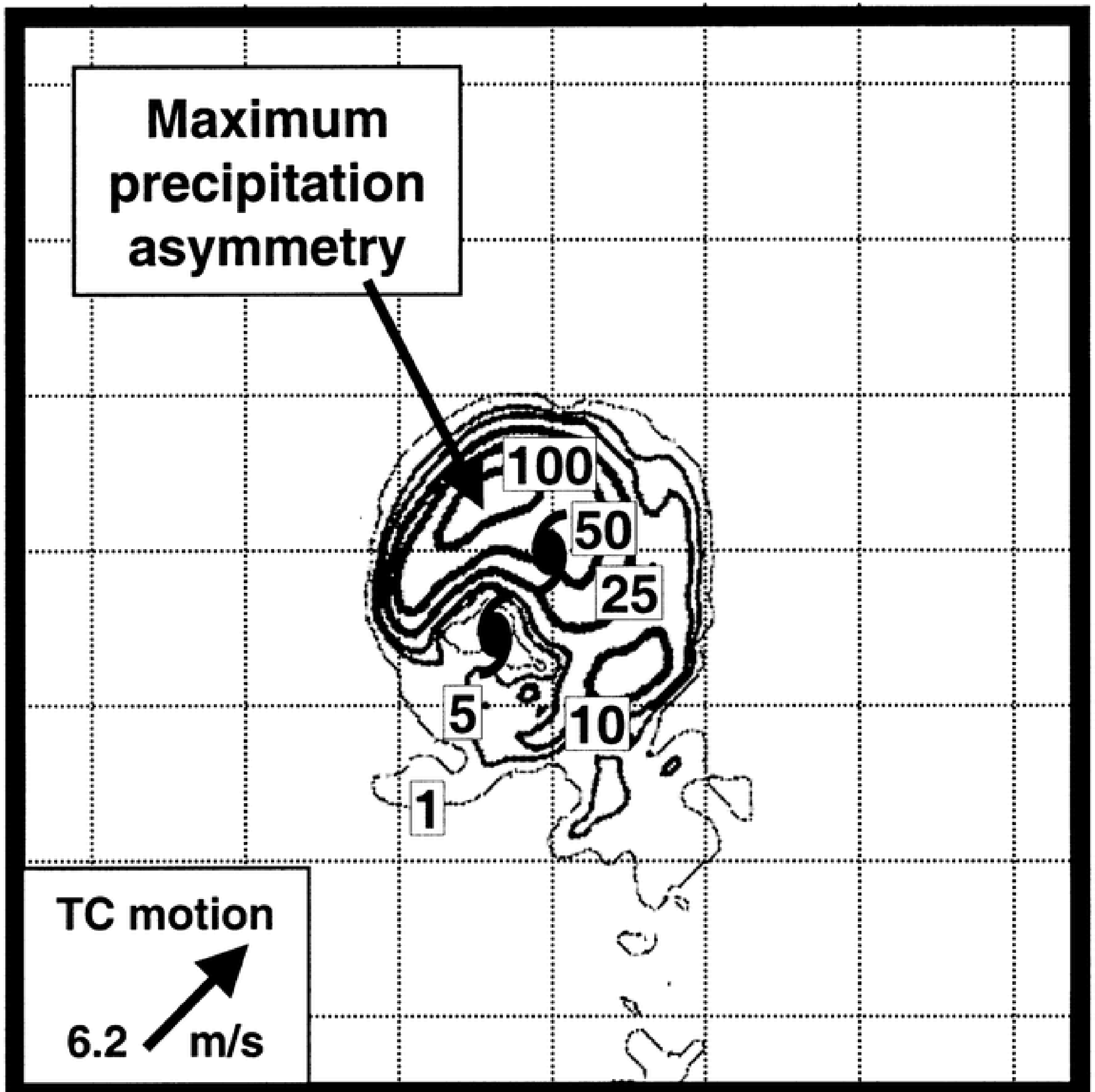
The Details of ET

- The physical mechanisms associated with the transformation stage of the extratropical transition of a tropical cyclone were simulated with a mesoscale model by Ritchie and Elsberry (2001, MWR).
- There appears to be three steps in the transformation, which compares well with available observations.
- During step 1 of transformation when the tropical cyclone is just beginning to interact with the midlatitude baroclinic zone, the main environmental factor that affects the tropical cyclone structure appears to be the decreased sea surface temperature. The movement of the tropical cyclone over the lower sea surface temperatures results in reduced surface heat and moisture fluxes, which weakens the core convection and the intensity decreases.

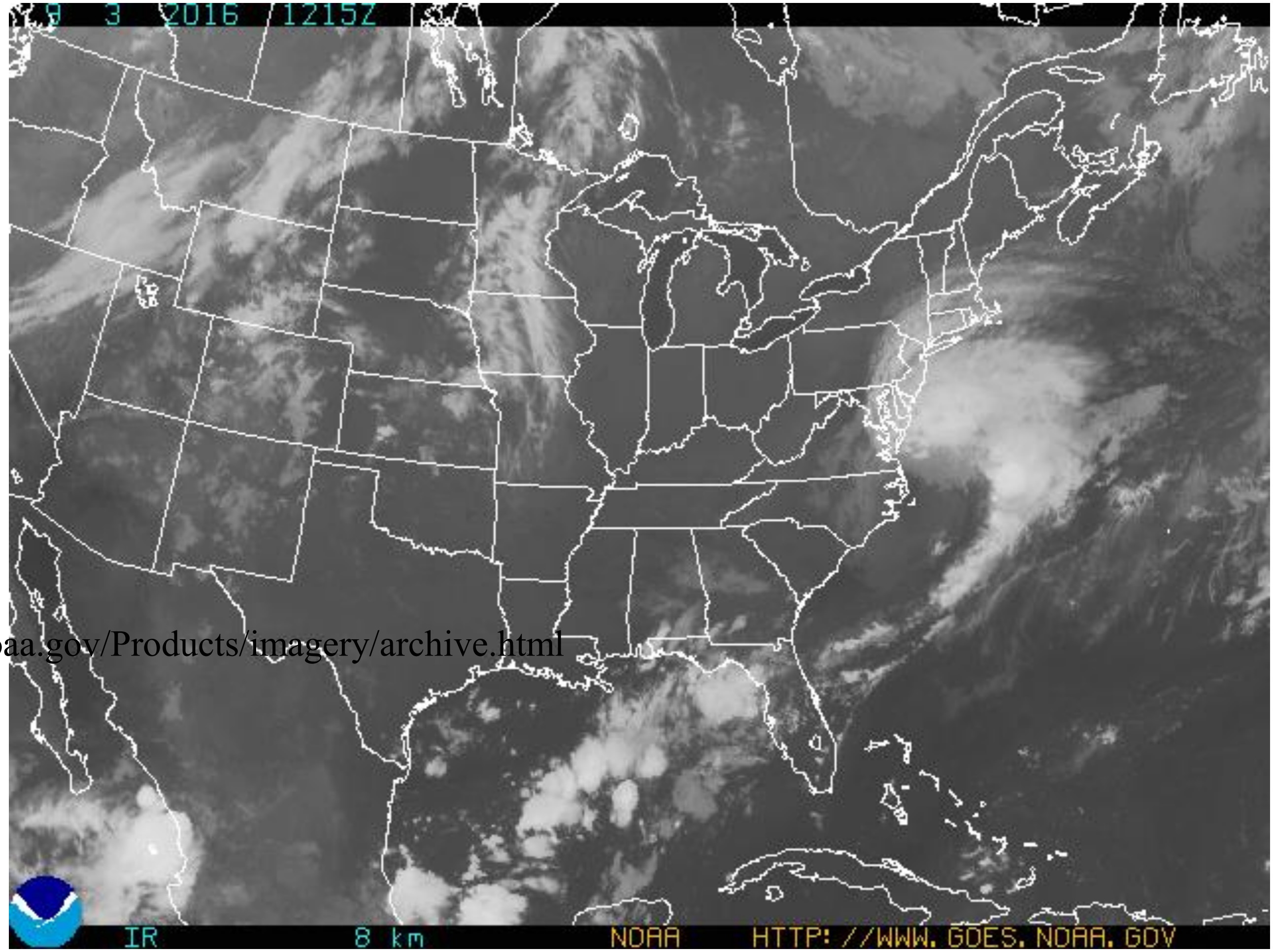
- During step 2 of transformation, the low-level temperature gradient and vertical wind shear associated with the baroclinic zone begin to affect the tropical cyclone.
- Main structural changes include the development of cloud-free regions on the west side of the tropical cyclone, and an enhanced rain region to the northwest of the tropical cyclone center. Gradual erosion of the clouds and deep convection in the west through south sectors of the tropical cyclone appear to be from subsidence.

- Step 3. Even though the tropical cyclone circulation aloft has dissipated, a broad cyclonic circulation is maintained below 500 mb. Whereas some precipitation is associated with the remnants of the northern eyewall and some cloudiness to the north-northeast, the southern semicircle is almost completely clear of clouds and precipitation.


Conceptual Model of Transformation Stage of ET in the Western North Pacific
(a) Infrared Imagery
N
6
4
1
2
3
5
(b) Plan View (Storm Relative Trajectories)
(c) 3-D View (Storm Relative Trajectories)
300 mb
500 mb
SFC
N
= Polar Jet
Warm Core Shaded
= Baroclinic Zone
STEP 1
STEP 2
STEP 3


Maximum precipitation asymmetry
100
50
25
10
5
1
TC motion
6.2 m/s

Extratropical Cyclone Hermine IR satellite, 9/3/16 1215Z



From
http://www.ospo.noaa.gov/Products/imagery/archive.html

Last 3 day Animation

http://cimss.ssec.wisc.edu/goes/blog/archives/21931

A Few References

- Sarah C. Jones, Patrick A. Harr, Jim Abraham, Lance F. Bosart, Peter J. Bowyer, Jenni L. Evans, Deborah E. Hanley, Barry N. Hanstrum, Robert E. Hart, François Lalaurette, Mark R. Sinclair, Roger K. Smith and Chris Thorncroft. 2003: The Extratropical Transition of Tropical Cyclones: Forecast Challenges, Current Understanding, and Future Directions. Weather and Forecasting: Vol. 18, No. 6, pp. 1052–1092.

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- Patrick A. Harr and Russell L. Elsberry. 2000: Extratropical Transition of Tropical Cyclones over the Western North Pacific. Part I: Evolution of Structural Characteristics during the Transition Process. Monthly Weather Review: Vol. 128, No. 8, pp. 2613–2633.