Observation and Simulation of the Genesis of Typhoon Fengshen (2008) in the Tropical Western Pacific

Hiroyuki Yamada[1], Wataru Yanase[2], Masaki Sato[1,2], Kunio Yoneyama[1], and Ryuichi Shirooka[1]

(1: JAMSTEC, 2: Univ. Tokyo)

Contents:

- Observed/simulated characteristics of the genesis of Fengshen (2008)
- Characteristics of the structure and background flows, which are common to Fengshen and some other tropical cyclones moving westward

Woleai Atoll, Micronesia

Background

- **Role of a large-scale background flow on TC genesis**
  - monsoon trough, monsoon gyre, easterly wave, etc.
    (Ritchie and Holland 1999)
  - *equatorial disturbance (Kelvin, Rossby, MJO)*
    (Frank and Roundy 2006)
- **Various scenarios of a role of mesoscale process**

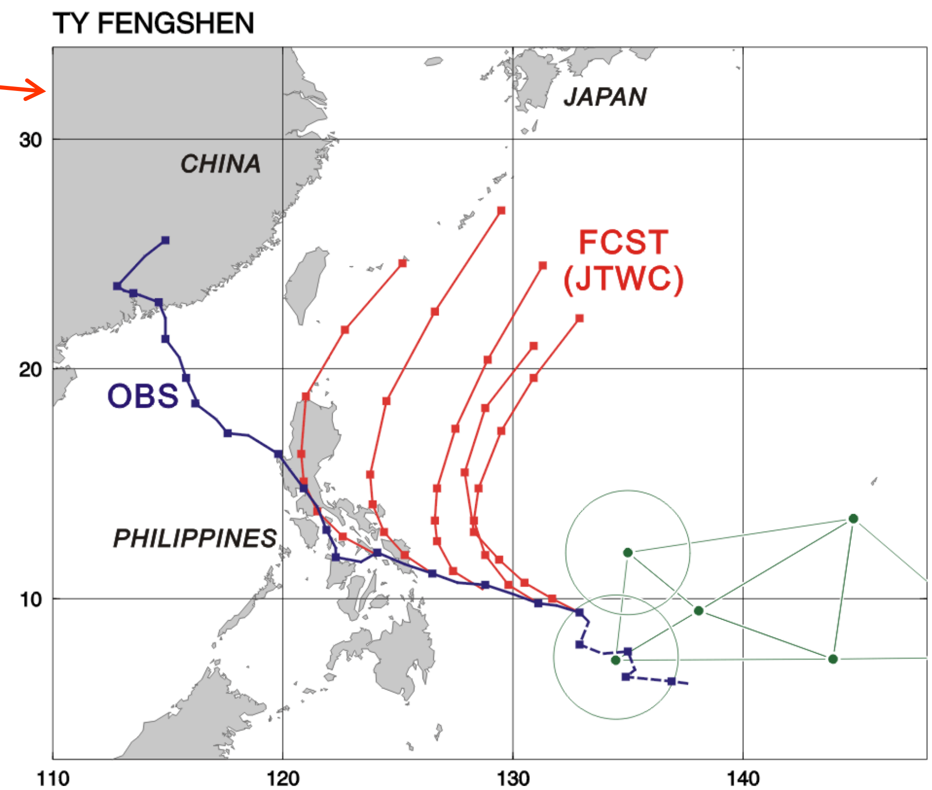
  → Evolution from a single mesoscale convective vortex (MCV)
  - top-down *(Bister and Emanuel 1997)*
  - bottom-up *(Hendricks et al. 2004; Montgomery et al. 2006)*

  → Evolution via the merger of multiple MCVs

  (Ritchie and Holland 1997; Simpson et al. 1997; Kieu and Zhang 2009)
- **Relationship between large- and meso-scale processes is important for the genesis of tropical cyclones**

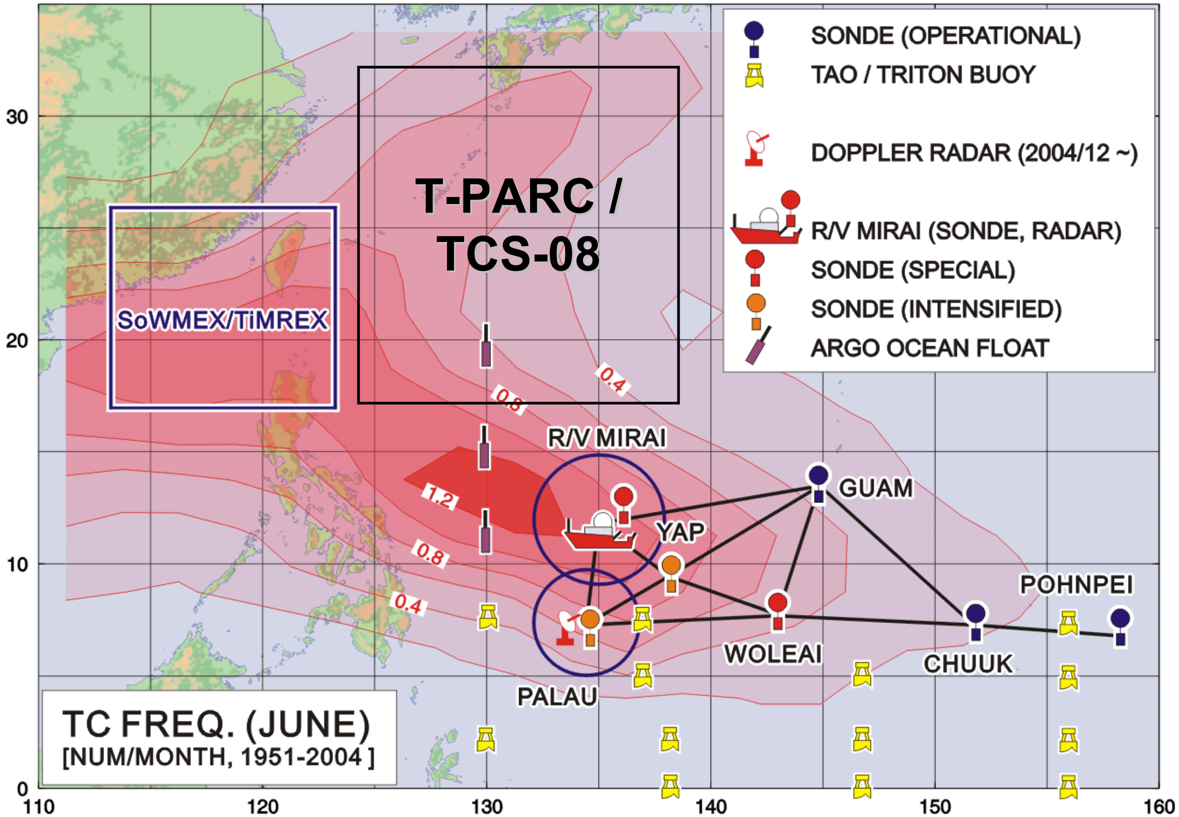
Objective of This Study

1. To understand the large-scale environmental forcing as well as internal mesoscale processes associated with the formation of Typhoon Fengshen (2008), from the combination of observations and numerical simulations.



2. To clarify the characteristics of the internal structure and large-scale flow pattern, which are common in Fengshen and the following tropical cyclones moving westward:
   - Nuri, Hagupit, and Higos during T-PARC/TCS-08
   - Durian (2006)

PALAU-2008 Field Experiment (June—July)



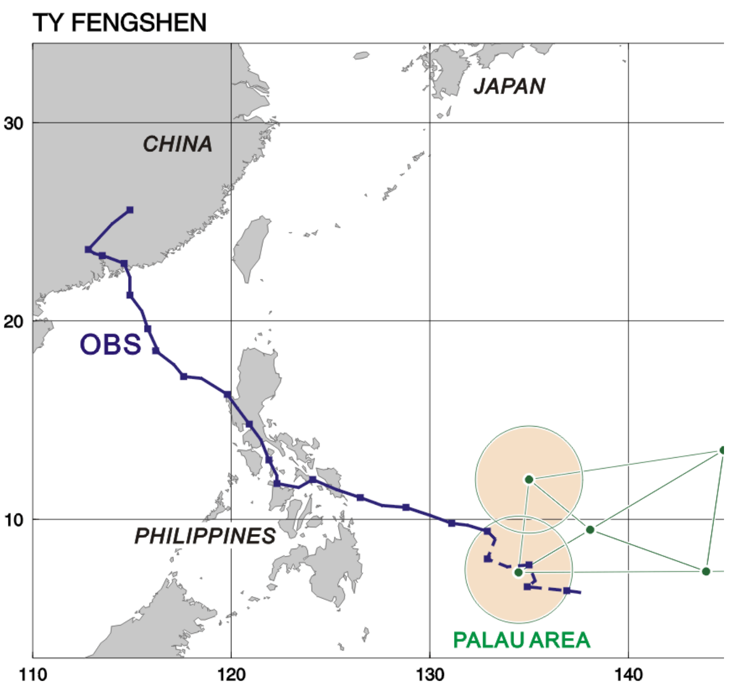
PALAU:

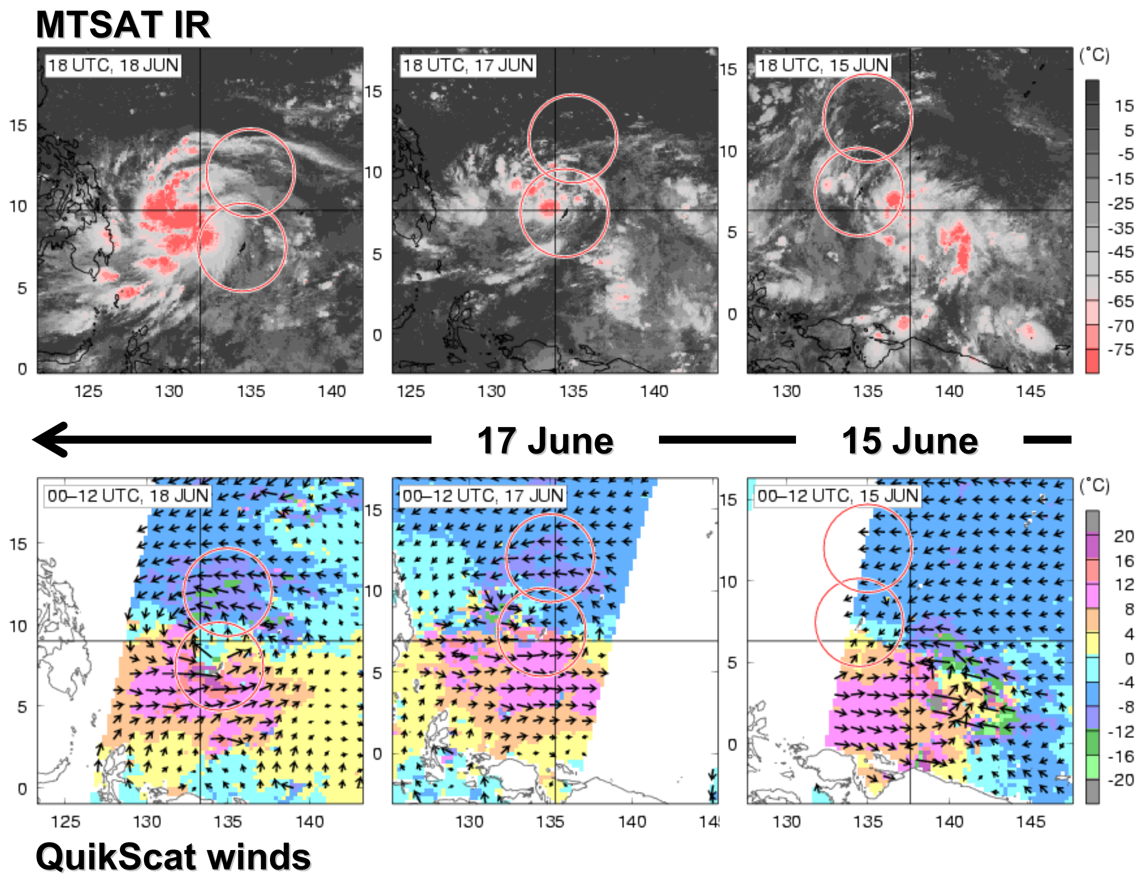
- Pacific-Area Long-term Atmospheric Obs. for Understanding Climate Change

Facilities:

- Doppler radars on R/V *Mirai* and at Palau, intensive upper-air sounding array (every 3 hours at Mirai, 6 hours at 3 stations), etc.

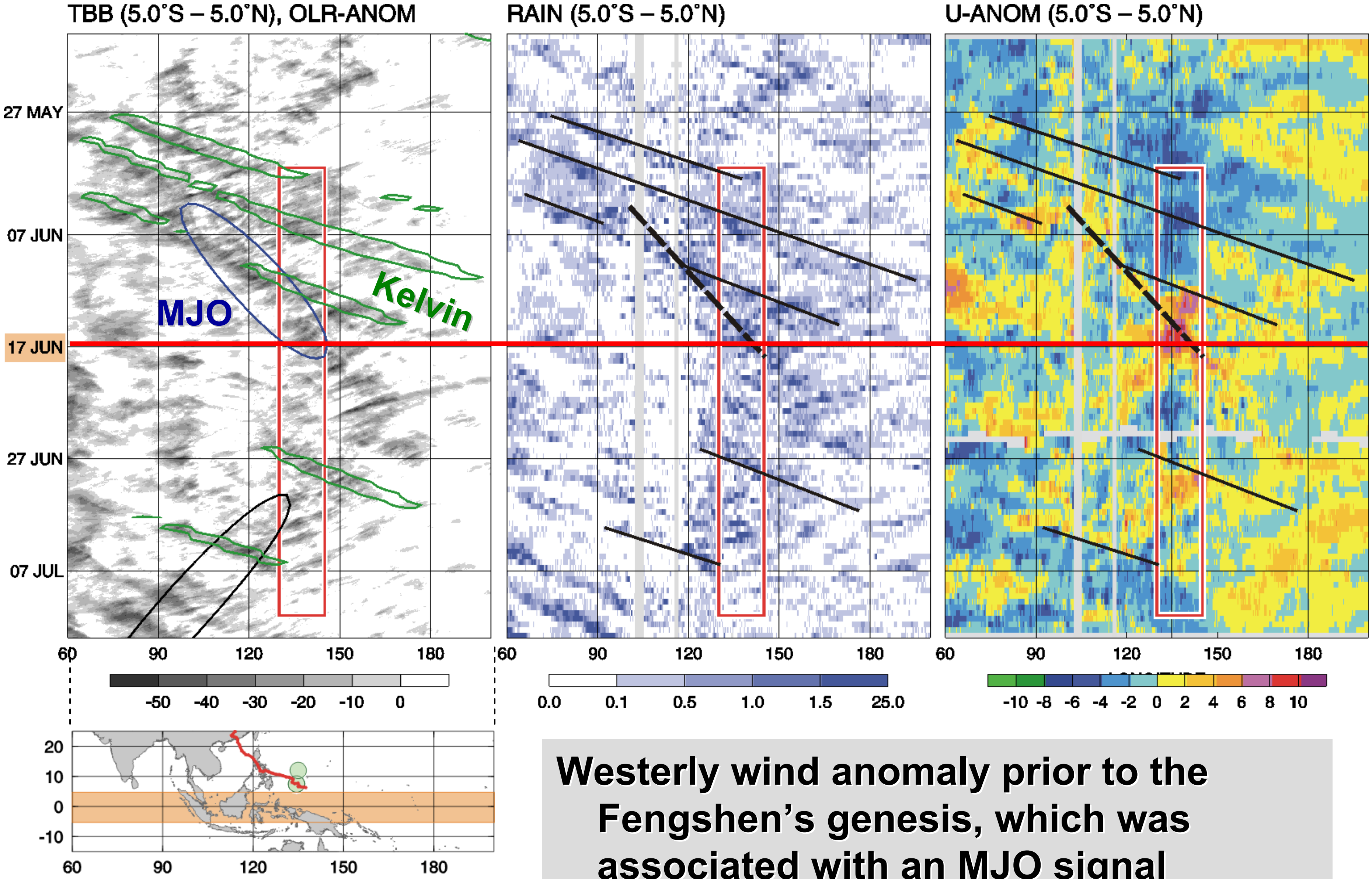
Genesis of Fengshen during a westerly wind event





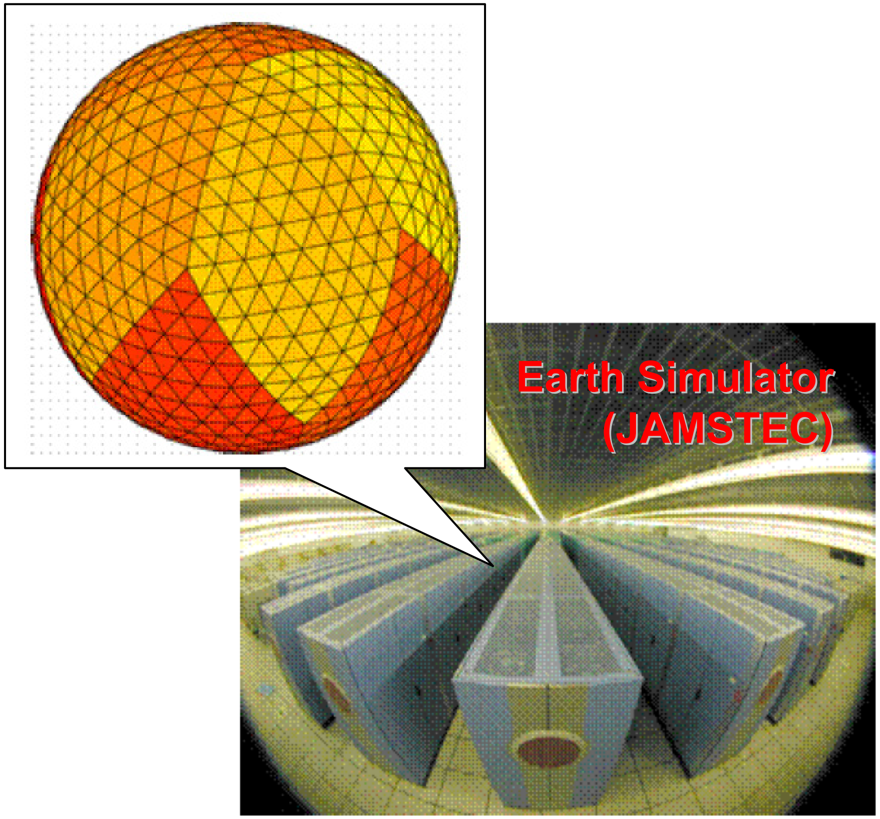
13 June	**Onset of a monsoon westerly (along the Equator)**
15 June	**First convective burst over a monsoon trough**
17-18 June	**Clouds with MCV passing over the Doppler radar area**
18-19 June	**Second convective burst and typhoon formation**

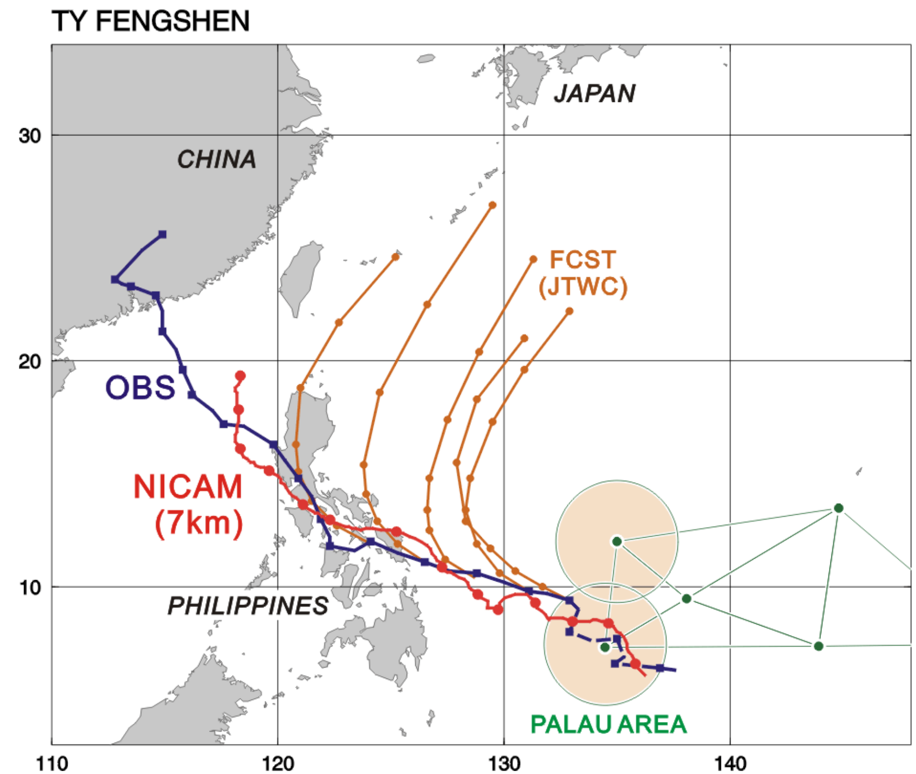
Westerly Anomaly Associated with Equatorial Waves



Westerly wind anomaly prior to the Fengshen's genesis, which was associated with an MJO signal involving three Kelvin-wave signals

Simulation Using a Global Cloud-Resolving Model





Nonhydrostatic Icosahedral Atmospheric Model (NICAM) :

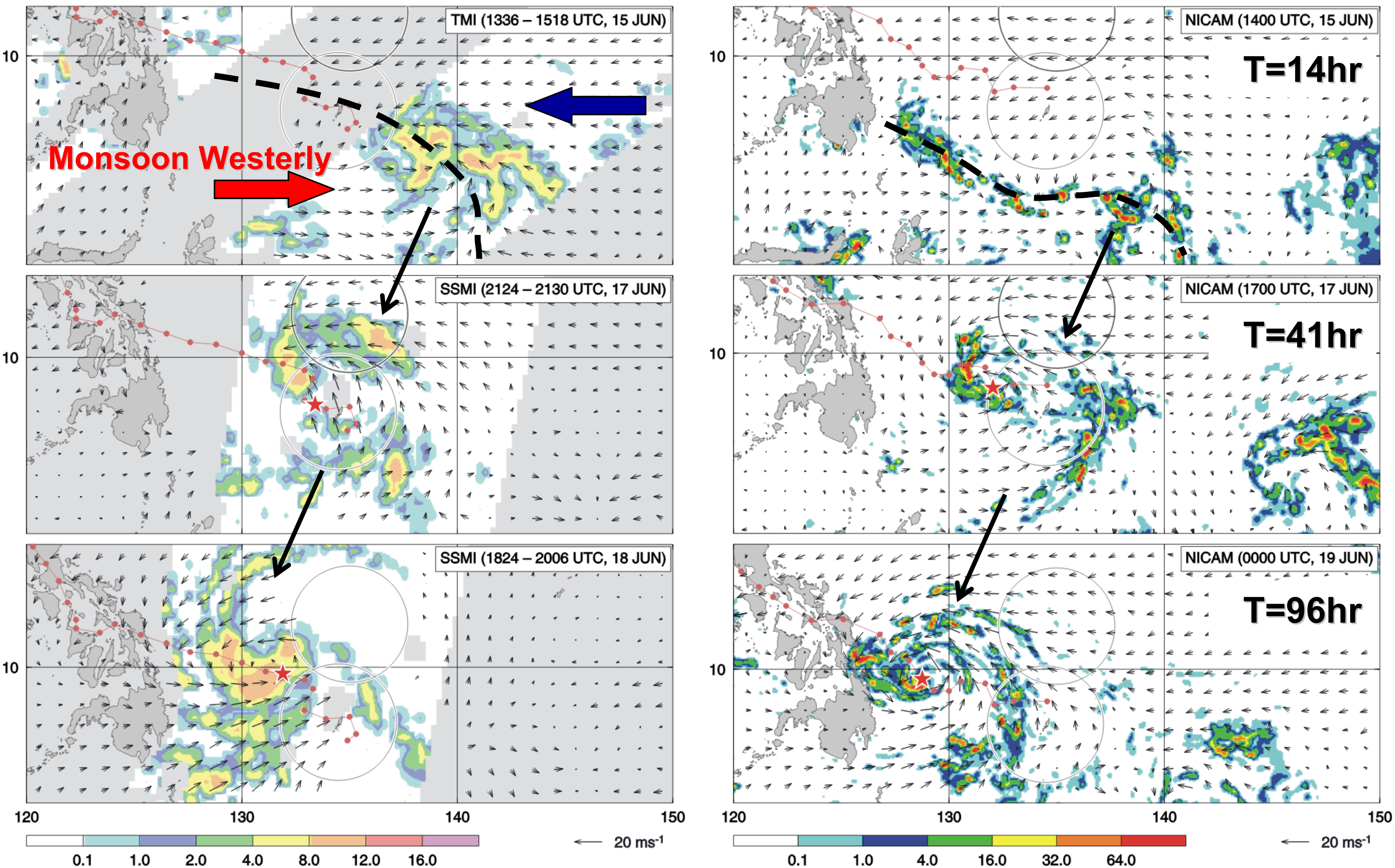
- Icosahedral grid system
- Nonhydrostatic equations
- Explicit cloud physics
- Run on "Earth Simulator"

Simulation of Fengshen (2008):

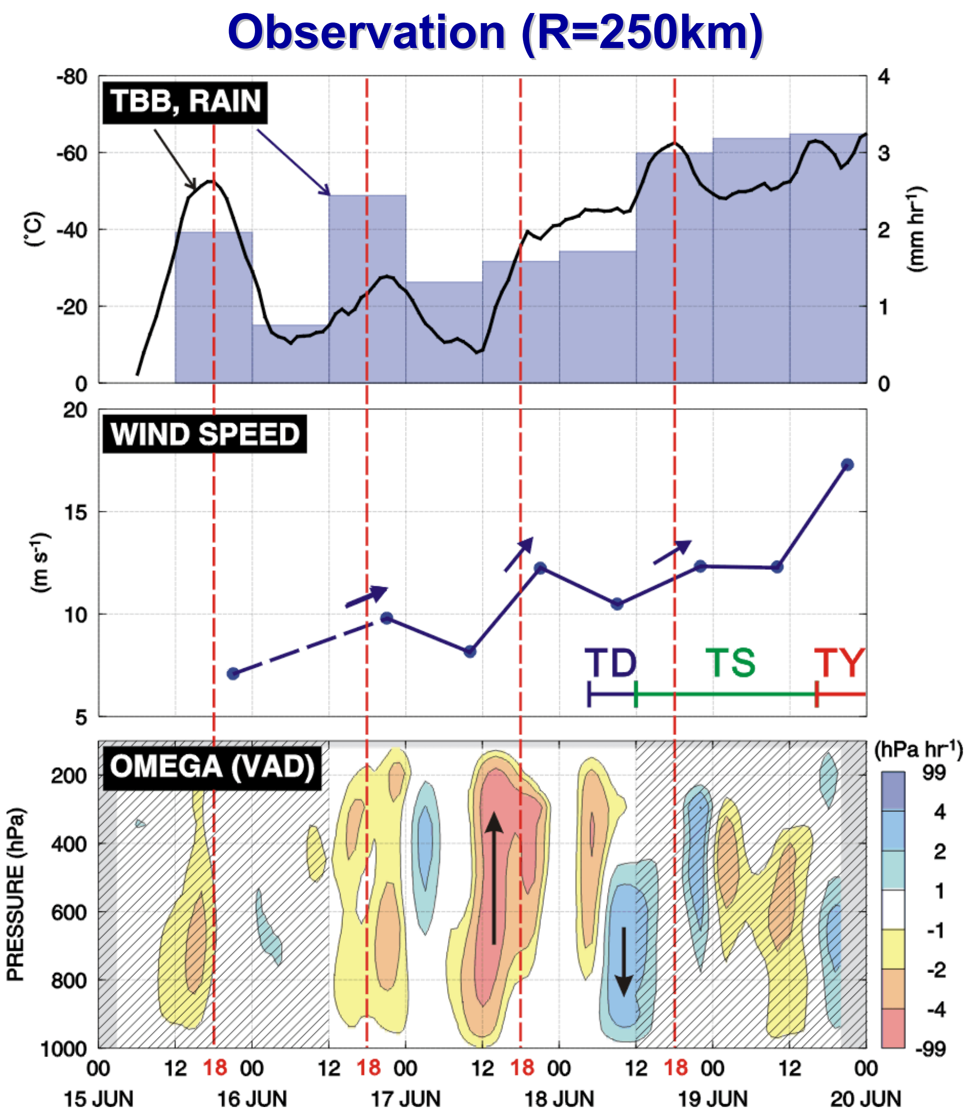
- Initialization 3 days before genesis (12 hours before the 1st conv. burst)
- Horizontal resolution of 7 km
- TC track and evolution similar to observation, while operational models showed large track error

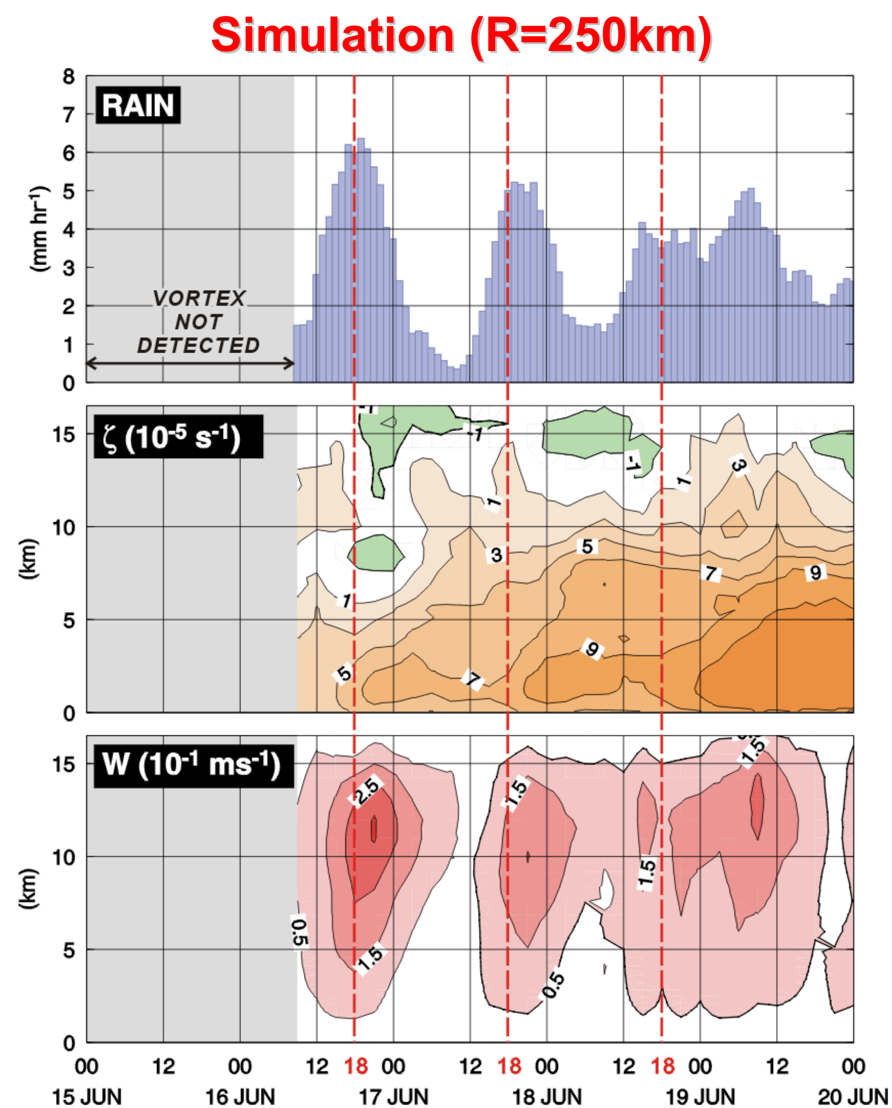
Observation vs Simulation

Obs. (MW rain, QScat winds) | **NICAM (sfc rain and winds)**



Diurnal Evolution of Convection and Vorticiy





- Nocturnal convective development, followed by vortex intensification, is seen in both observation and simulation

Observed Diurnal Change

June 17, evening

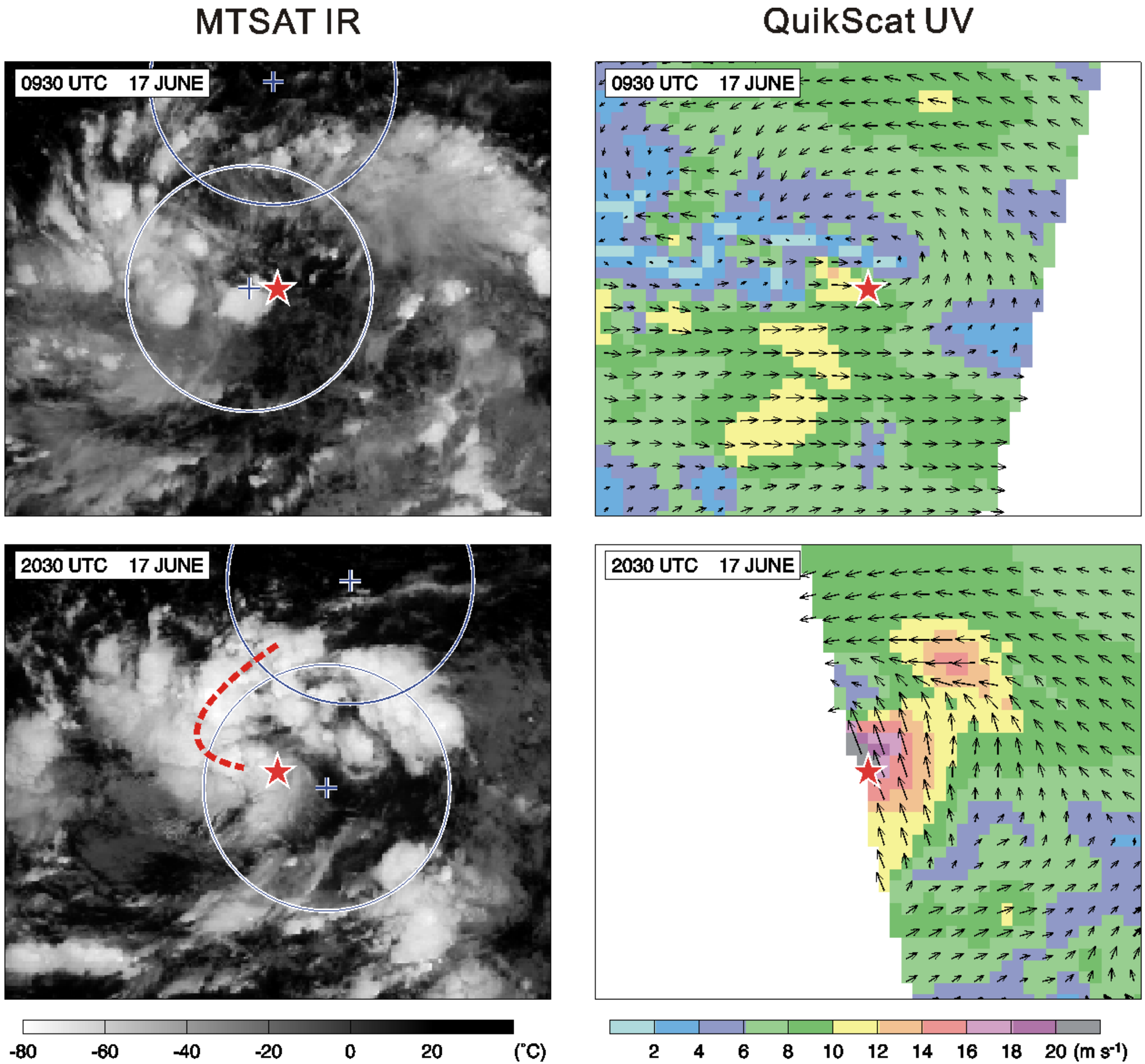
sparse deep convection

weak winds near the cyclone center

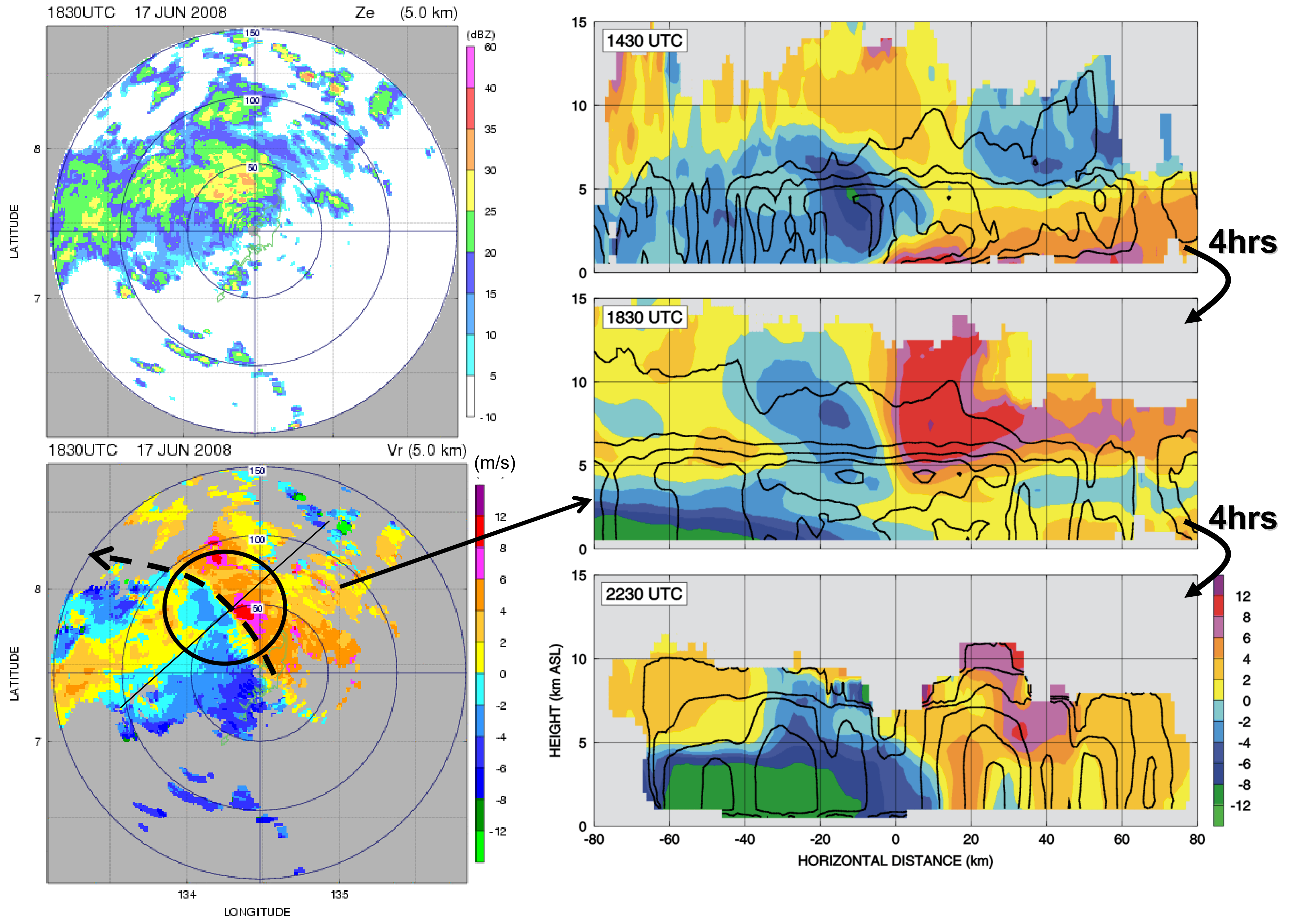
June 18, morning

Organization of a spiral rainband

Enhanced surface winds



MCV near the Cyclone Center



Axisymmetrization of Vortex (in NICAM)

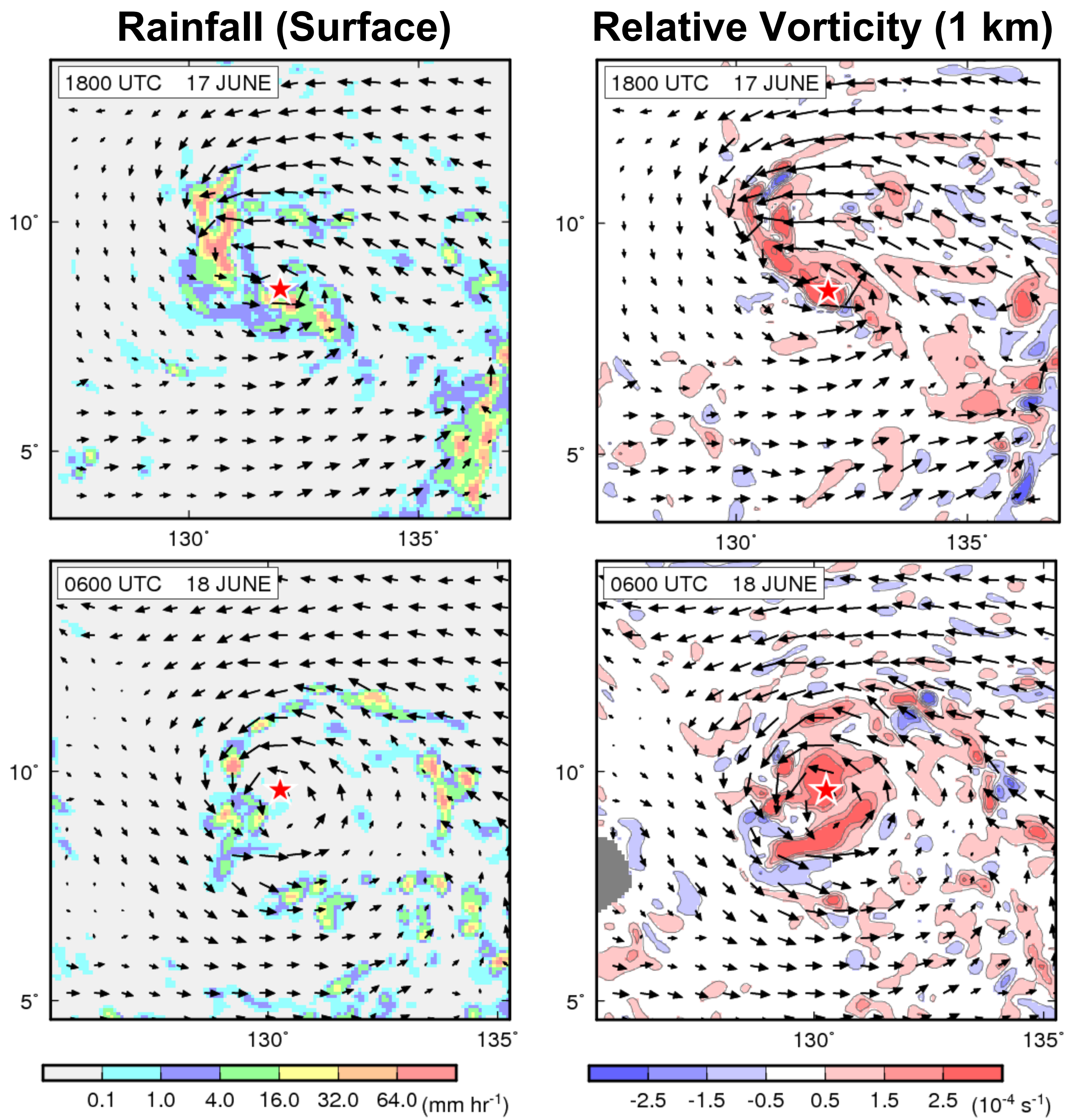
June 18, morning

Evolution of a spiral rainband

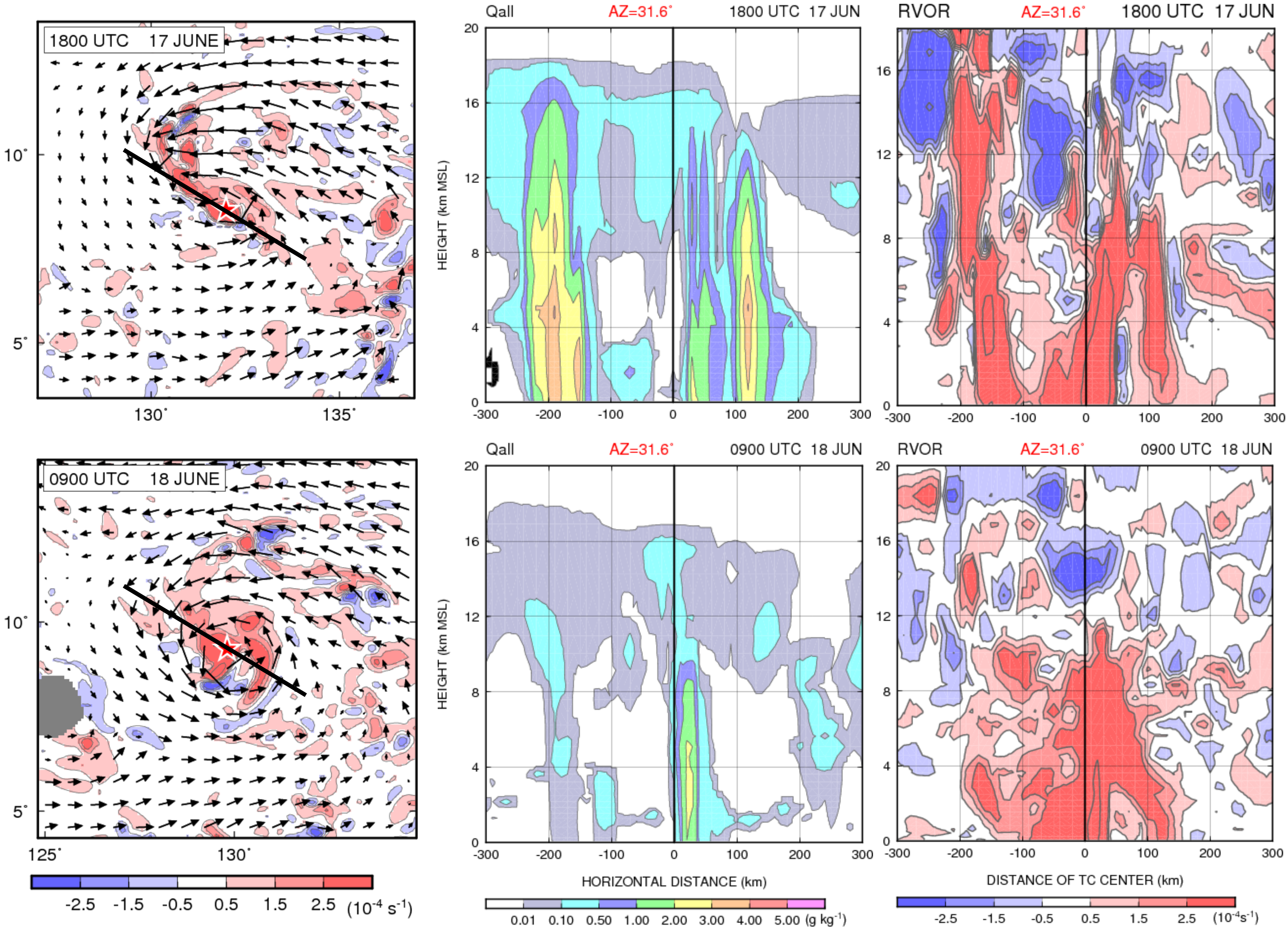
Asymmetric vorticity distribution

June 18, evening

Axisymmetrization of vorticity distribution under a weak convective activity

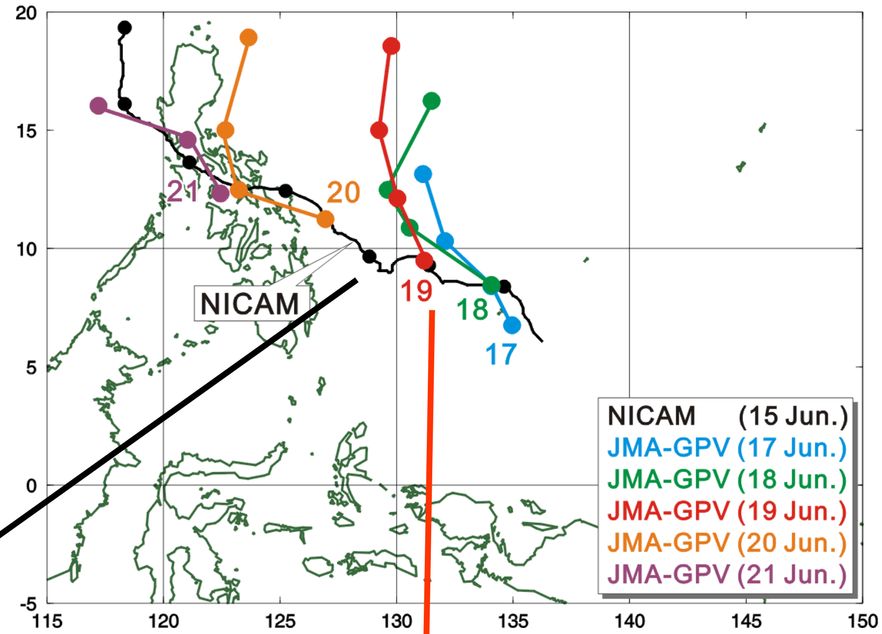


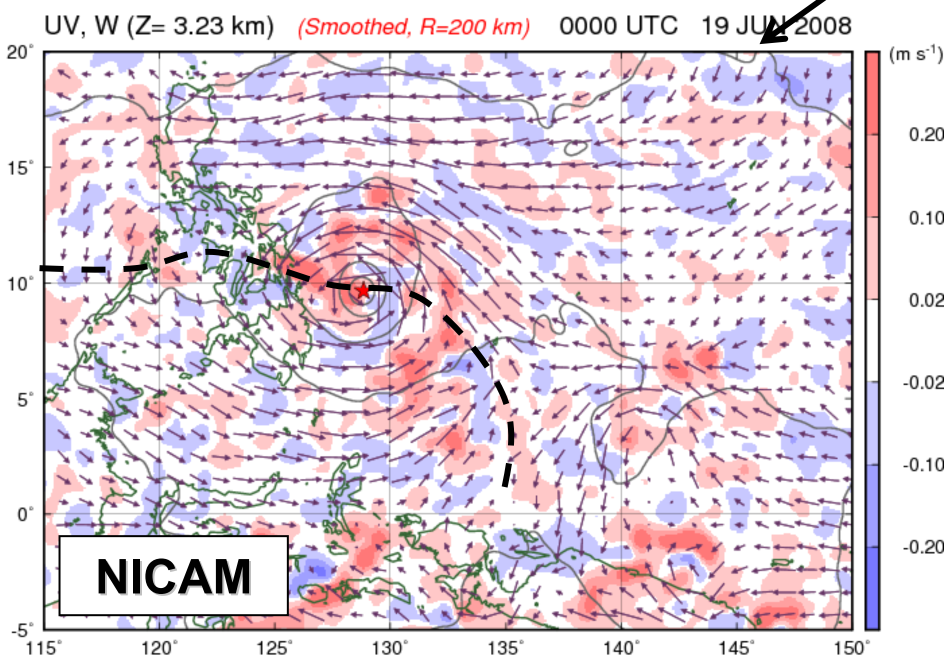
Axisymmetrization of Vortex (in NICAM)

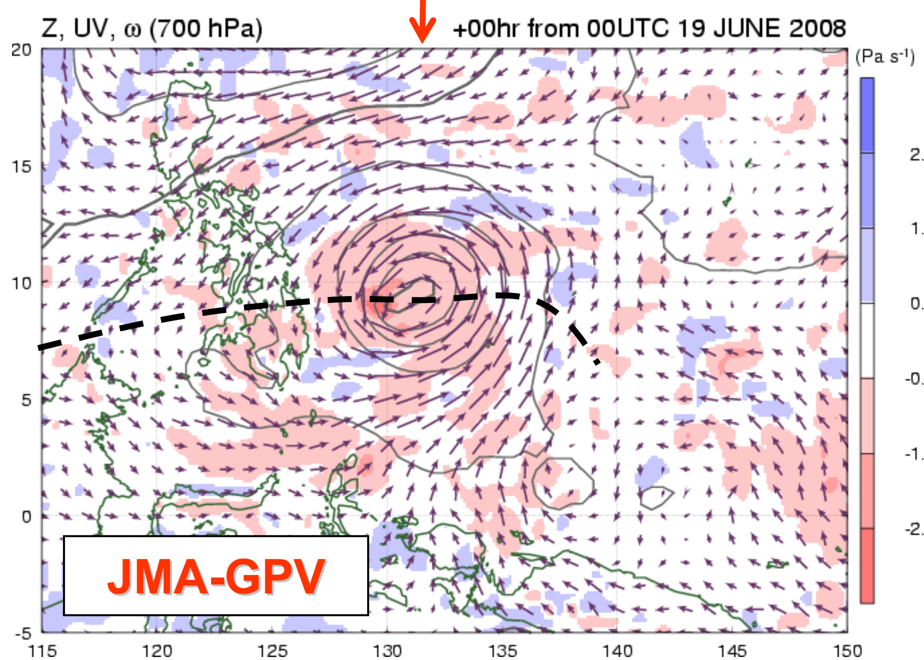


Track Error in JMA-GPV

- *The largest track error at the initial time of 19 June (mostly northward from the initial time)*
- *The distribution of vertical velocity is rather symmetric in JMA-GPV, as compared with that in NICAM*





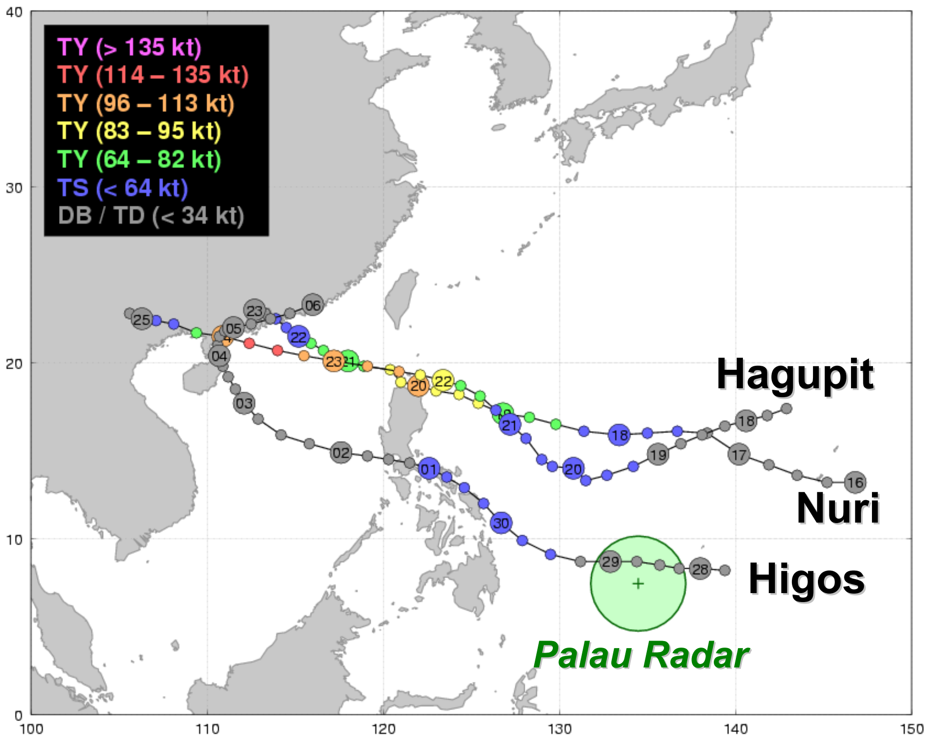


Summary (1)

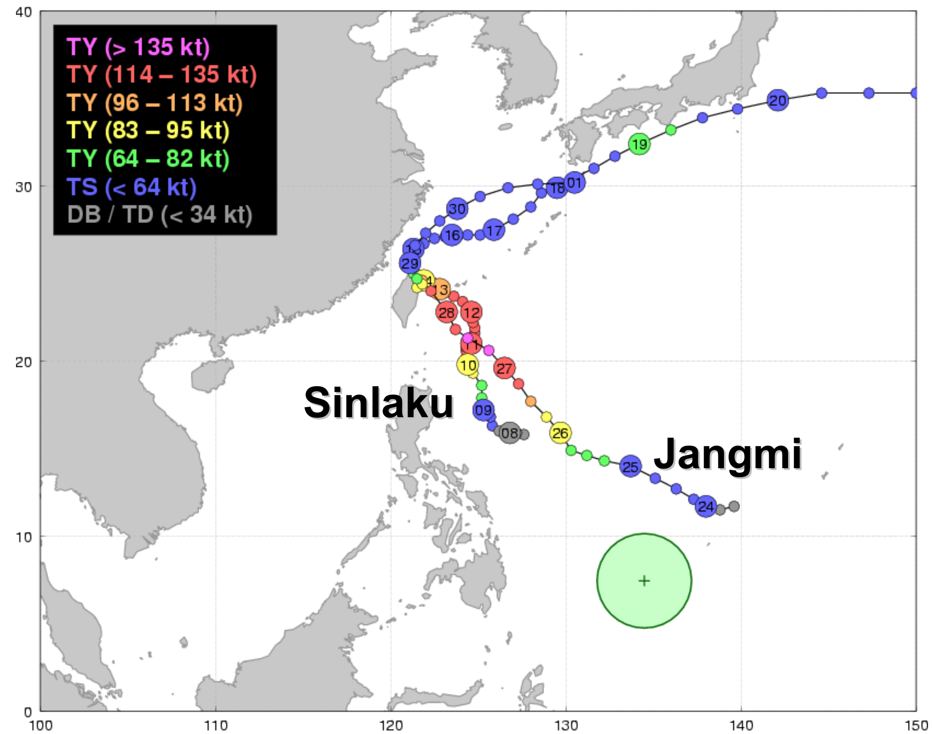
- We succeeded to observe/simulate the genesis of TY Fengshen during the PALAU-2008 field experiment, whose processes are briefly characterized as follows:
  - Initiation of an incipient vortex along a monsoon trough under the influence of an eastward-propagating equatorial disturbances/waves.
  - Diurnal change in convective activity and vortex enhancement:
    1. Evolution of a spiral rainband in the nighttime
    2. Axisymmetrization of vorticity distribution in the daytime
  - Westward movement along the monsoon trough

Tropical Cyclones during T-PARC/TCS-08

Westward-moving TCs (3)



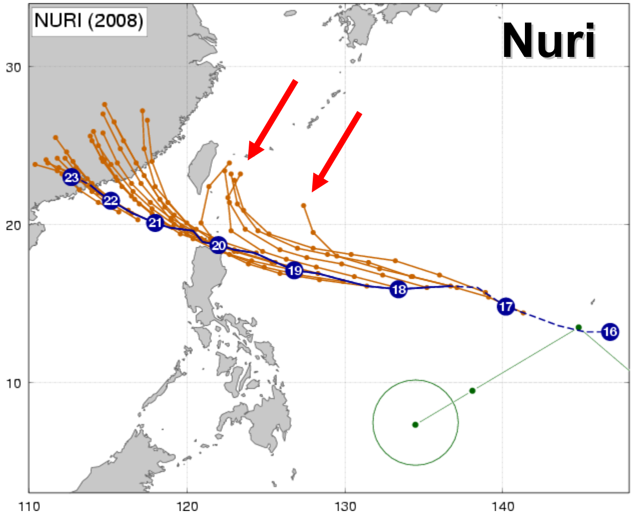
Northward-moving TCs (2)

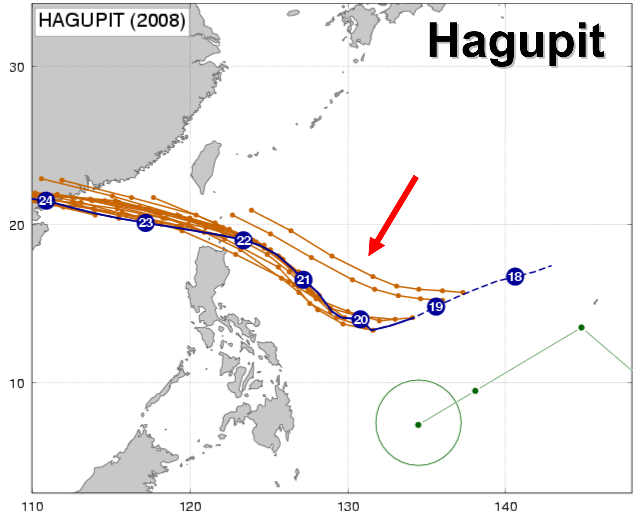


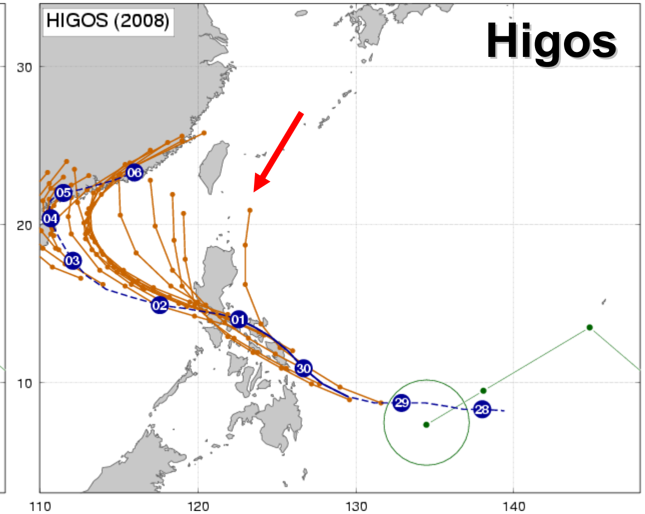
Similar track to Fengshen (2008)

Track forecast (by JTWC)

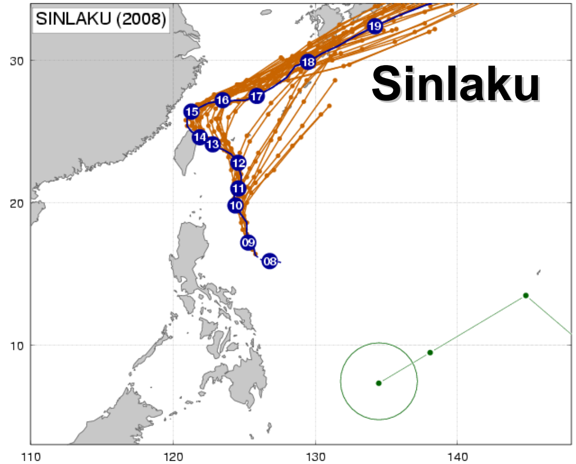
Westward-moving cases – northward bias in the formation stage

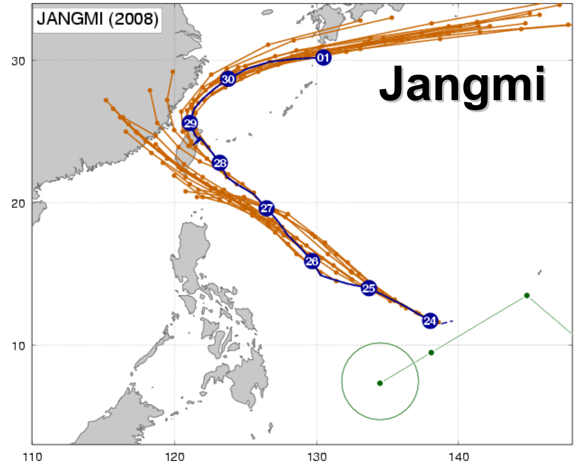






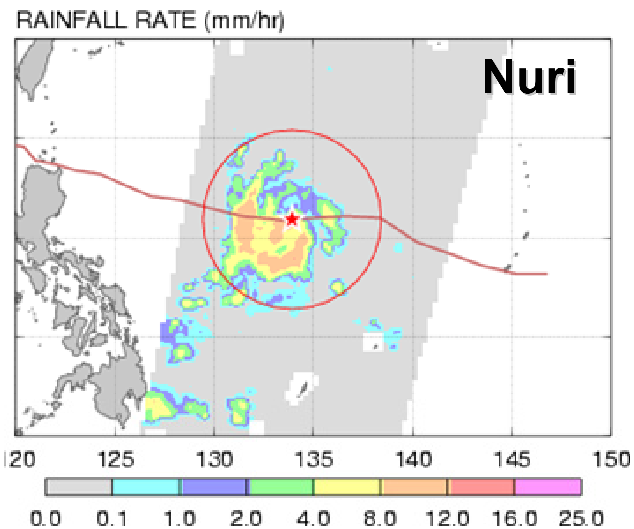
Northward-moving cases – small bias in the formation stage

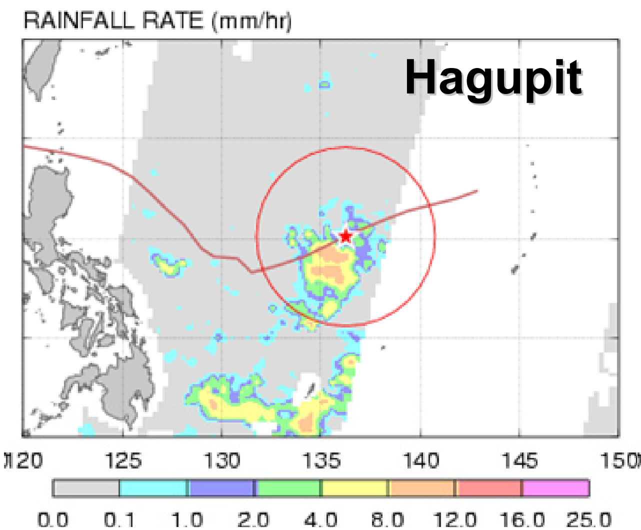


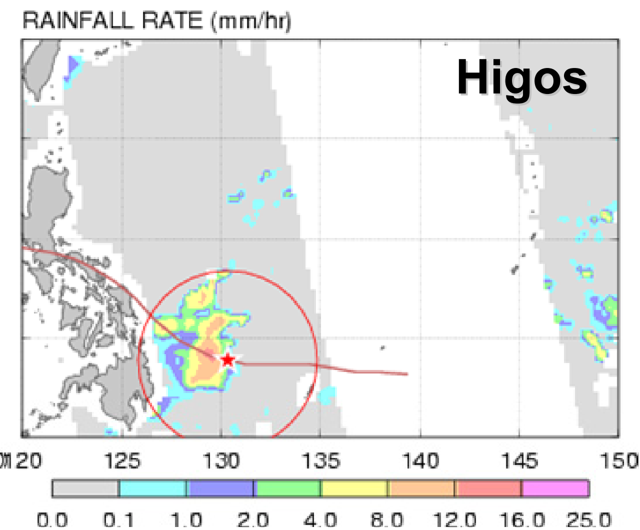


Rainfall patterns of TCs during T-PARC

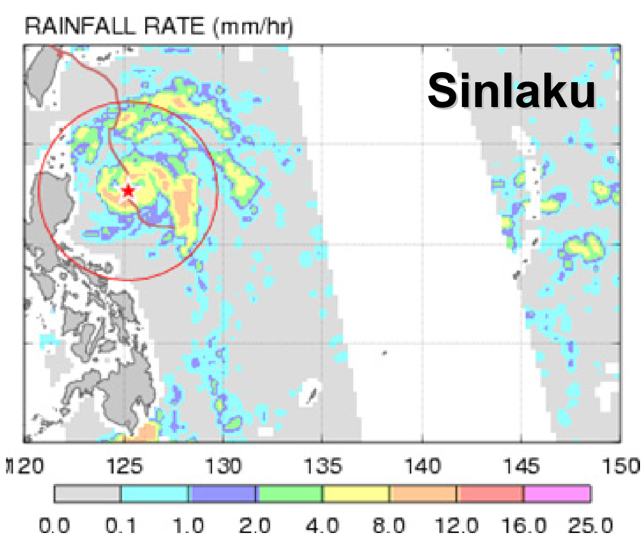
Westward-moving cases – asymmetric with a southwestern peak

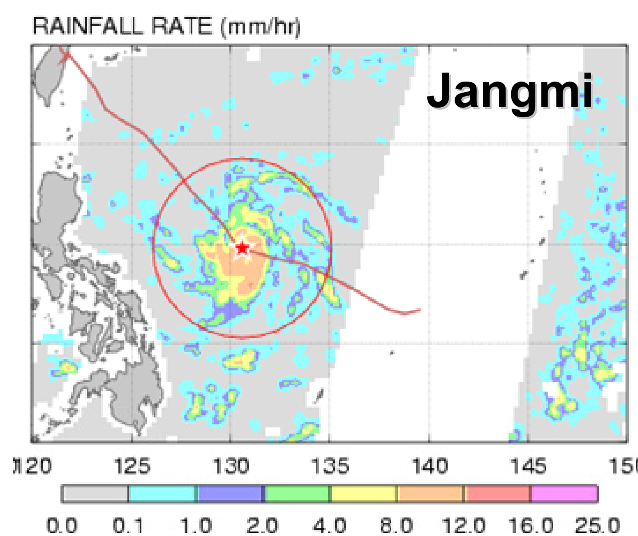




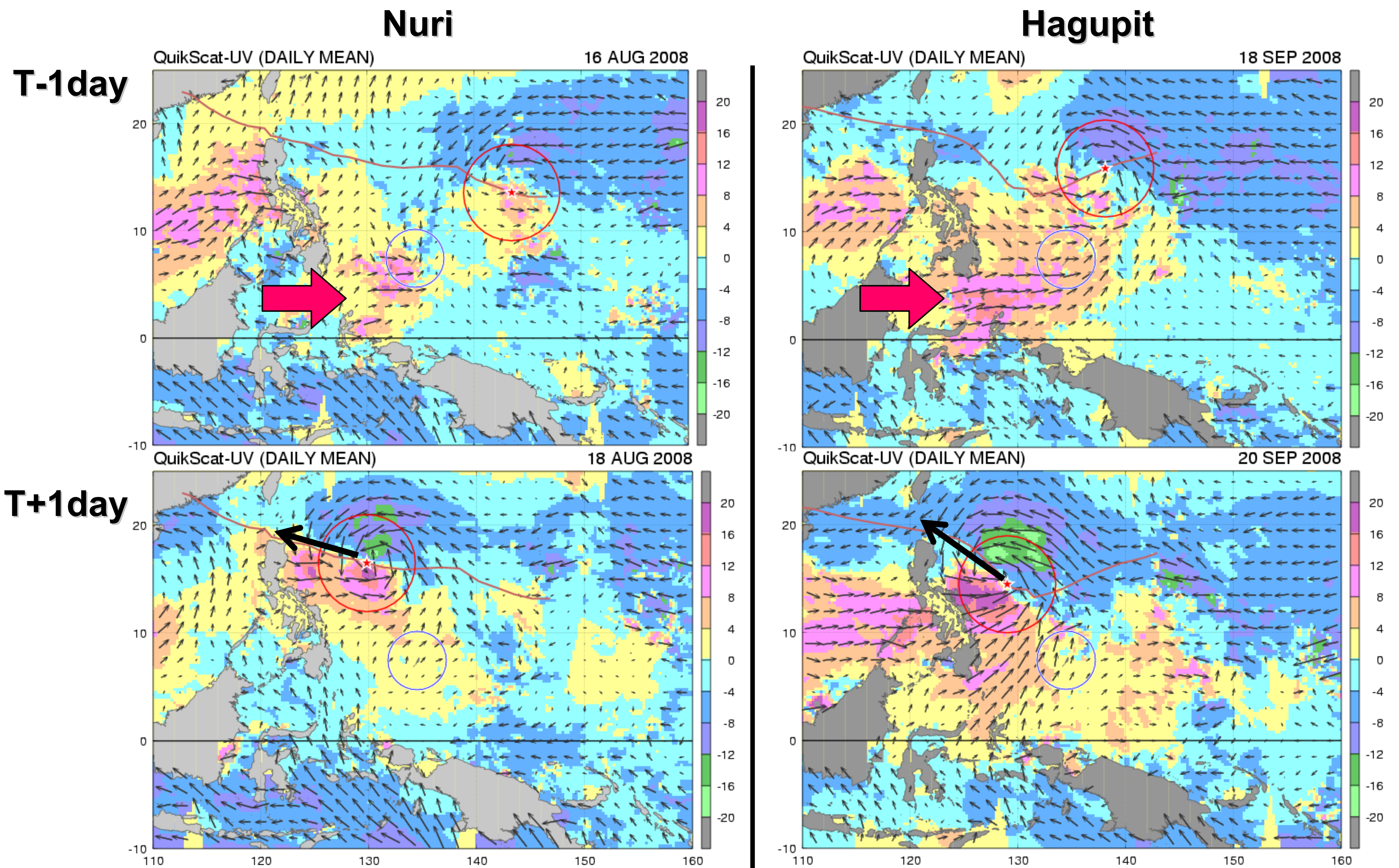


Northward-moving cases – rather axisymmetric inner core



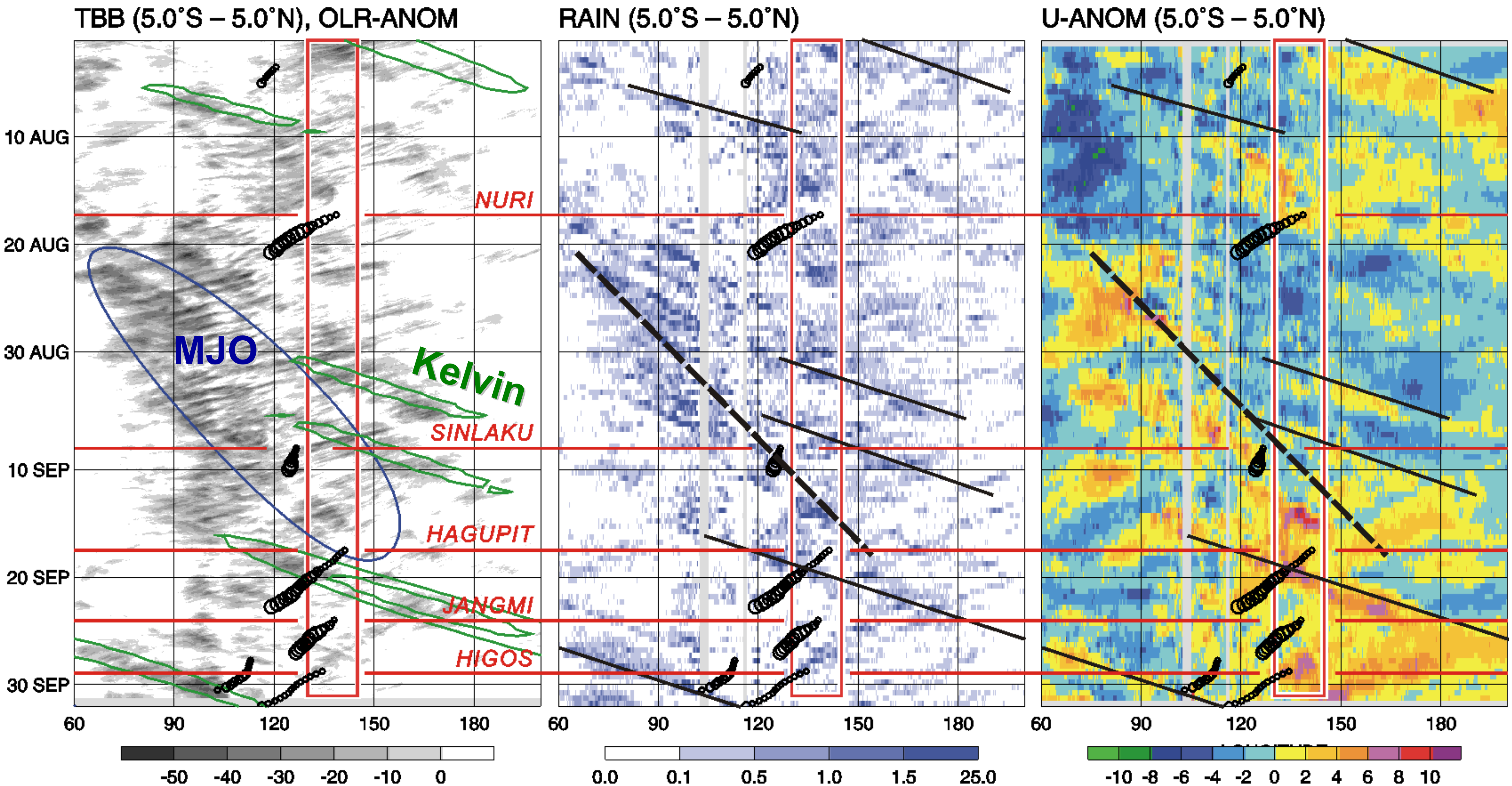


Surface winds (during the genesis of W-moving TCs)



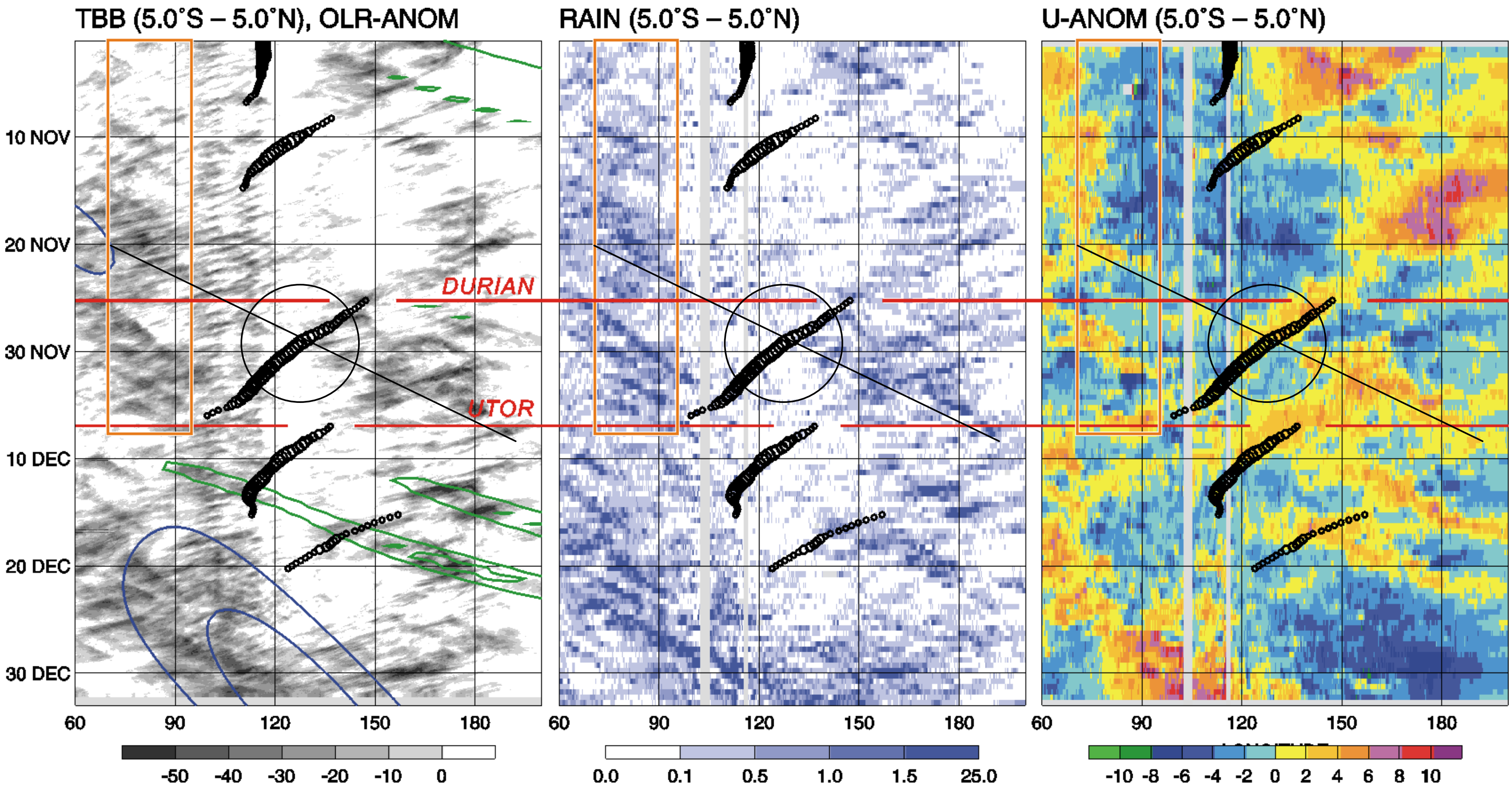
- Westerly flow prevails near the equator before the genesis of TCs
- TCs moved along a shearline between westerly and easterly

Equatorial Waves during T-PARC



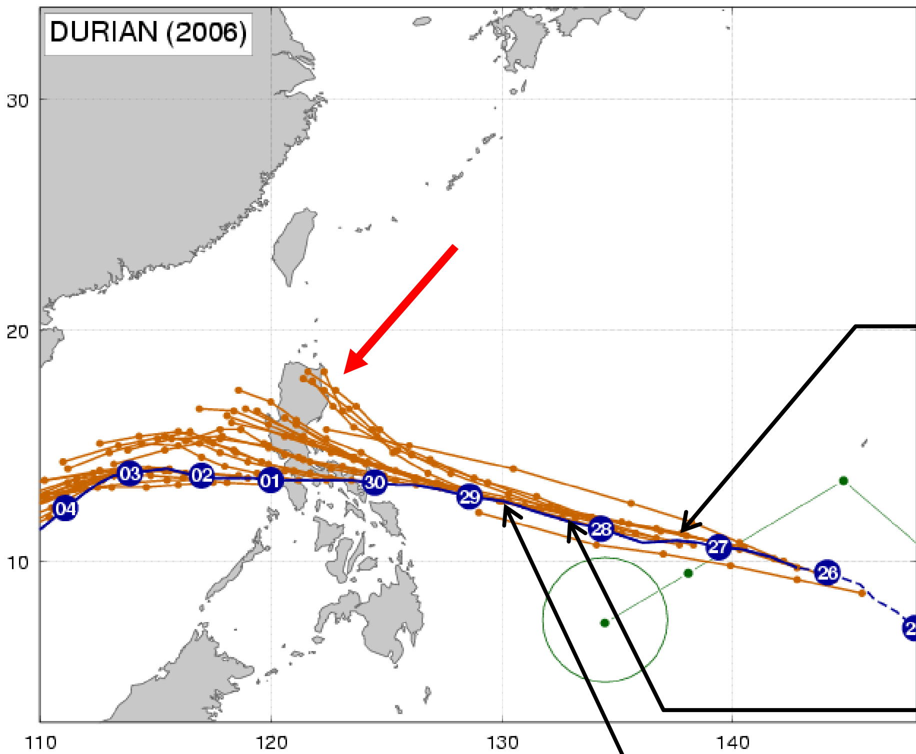
- TCs during the T-PARC formed during which westerly anomaly became strong over the equator
- They concentrate in the later half of a MJO event

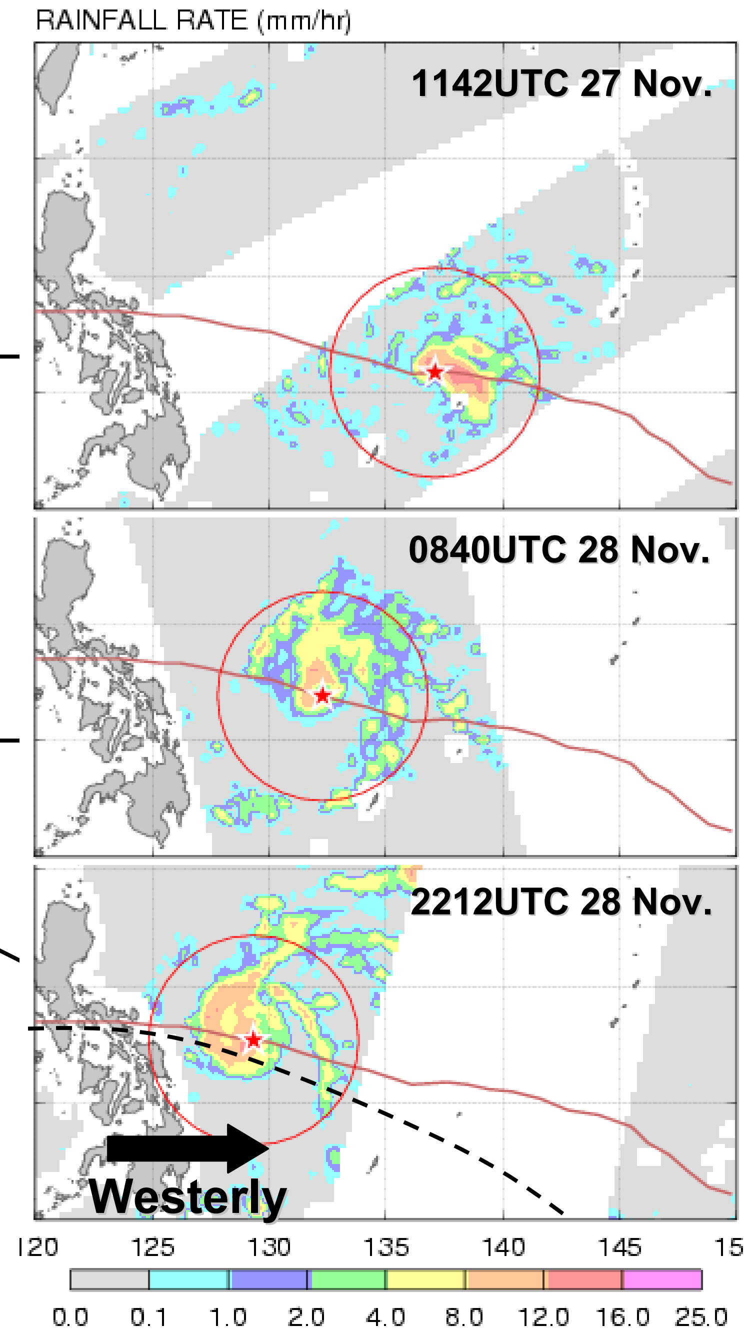
Equatorial Wave Activity and TY Durian (2006)



- An eastward-propagating signal of westerly anomaly intersected with Durian (2006) during its intensification stage
- This signal was not identified as MJO or Kelvin using wavenumber-frequency spectrum analysis

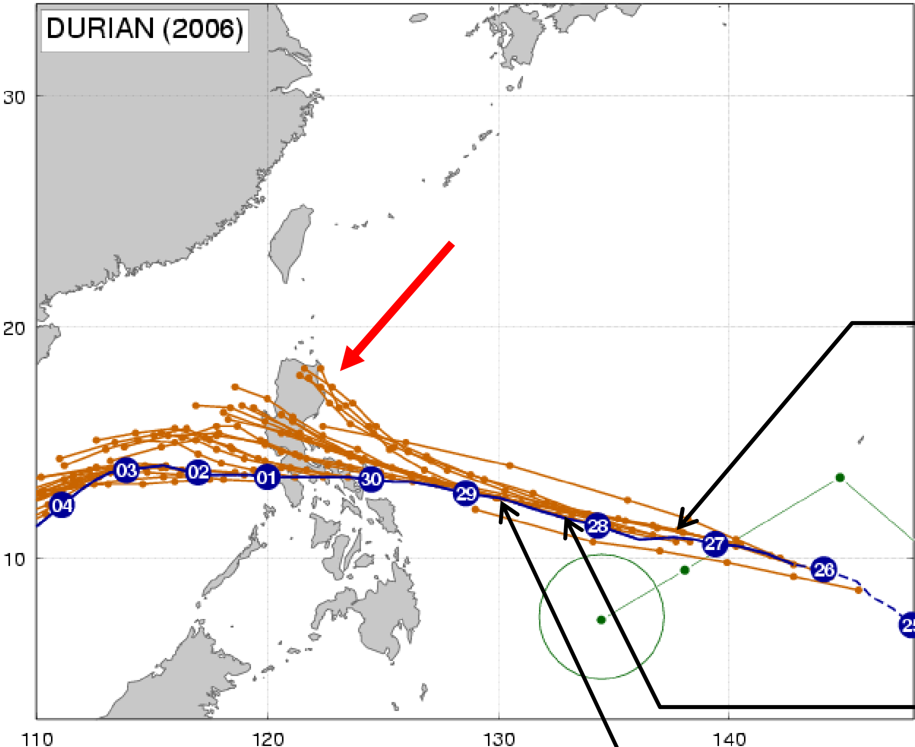
Forecast Track (by JTWC) and Structure of Durian (2006)

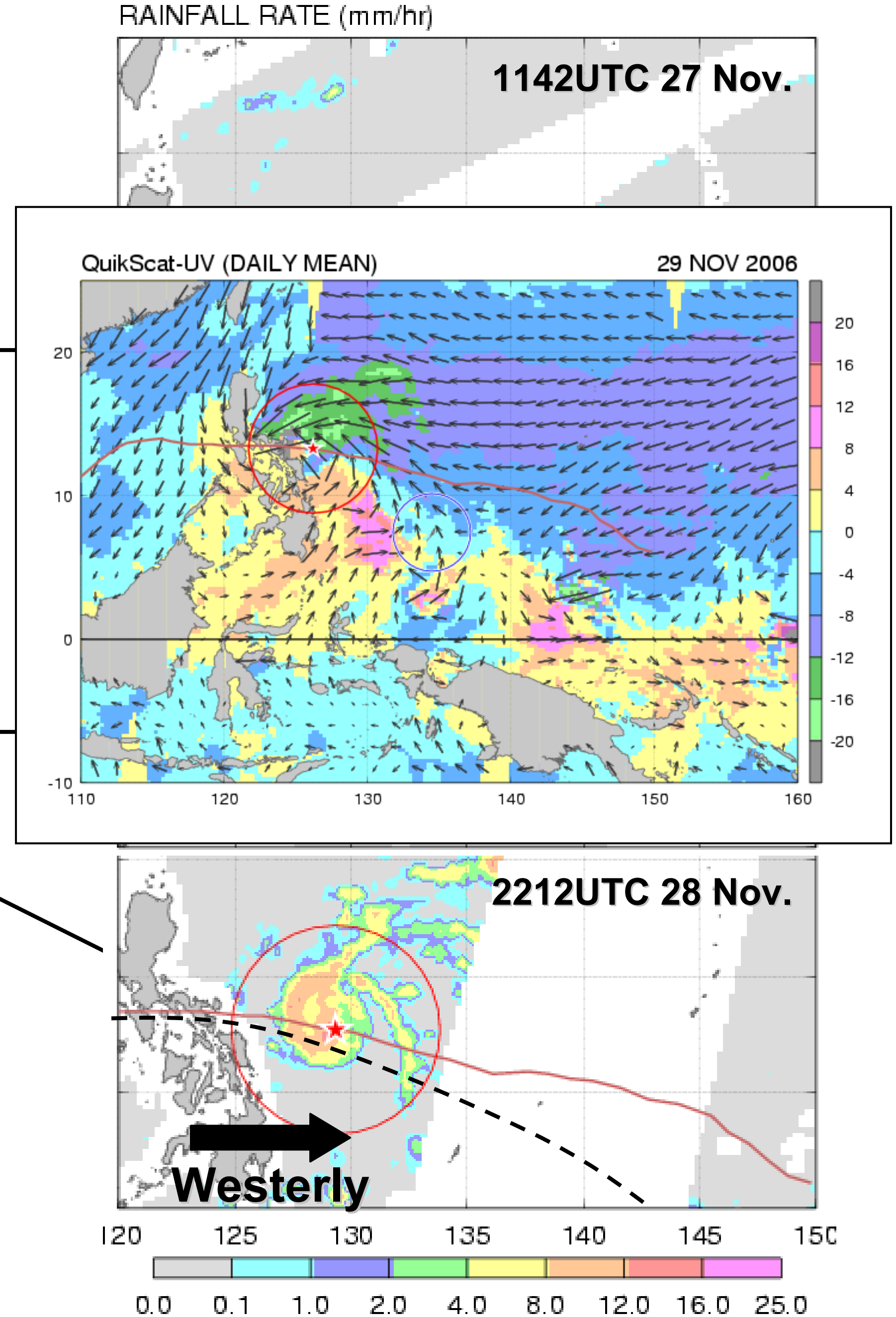




- Northward bias in TC track predicted on 28-29 Nov. (when eastward-propagating westerly anomaly approached)
- Significant change in a rainfall peak (from east to west) during this period

Forecast Track (by JTWC) and Structure of Durian (2006)





- Northward bias in TC track predicted on 28-29 Nov. (when eastward-propagating westerly anomaly approached)
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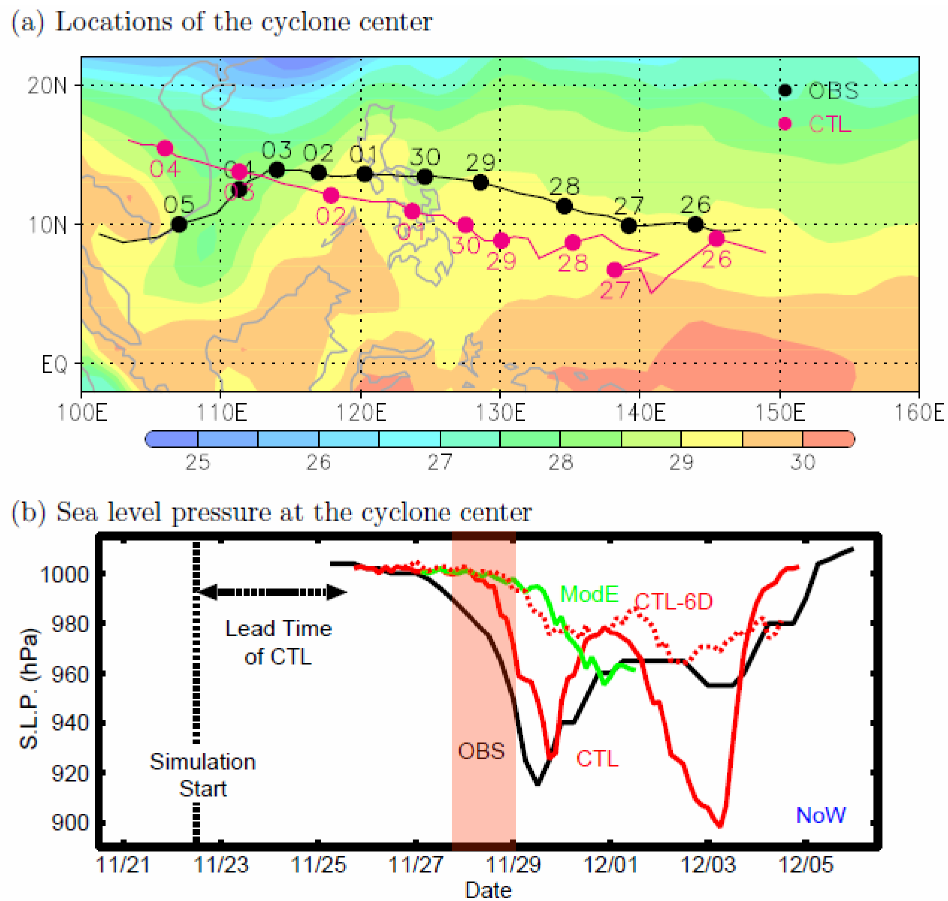
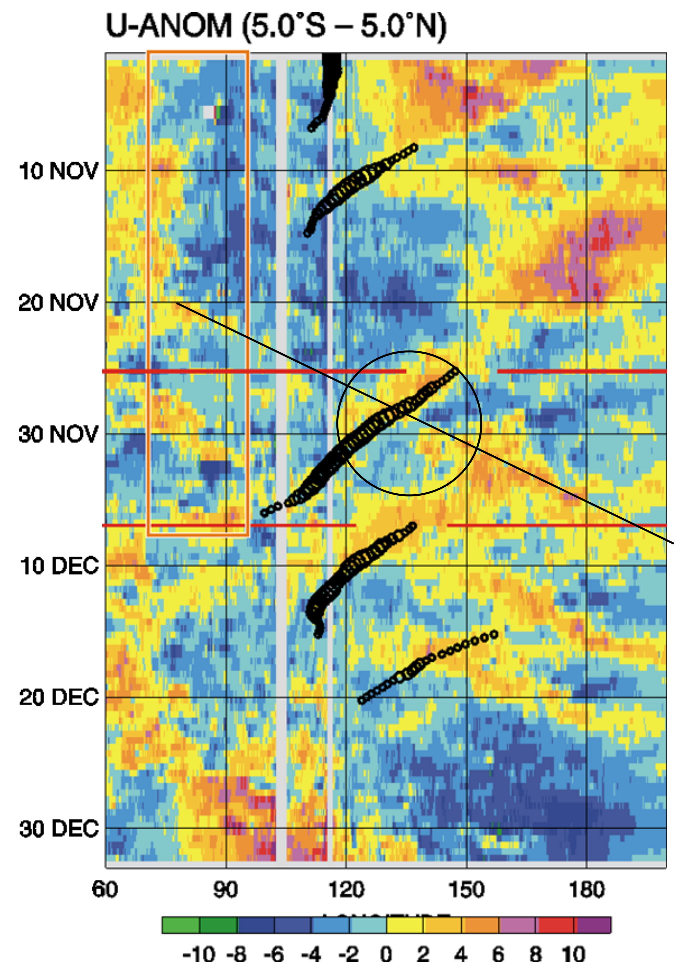
Simulation of Typhoon Durian (2006)



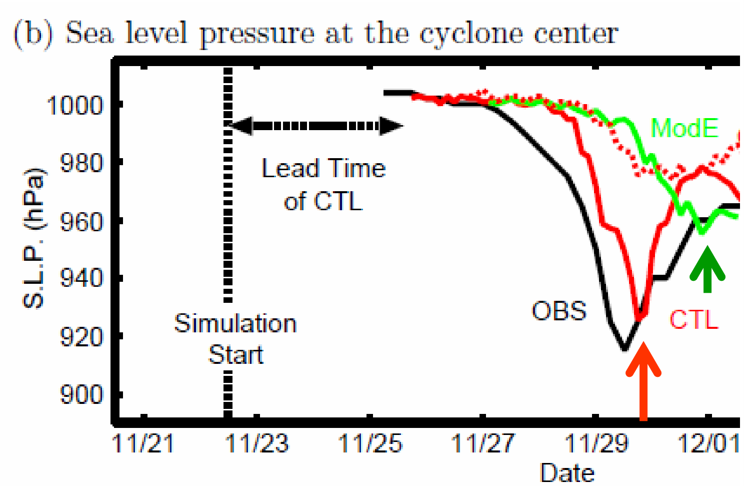


- Westward movement both in observation and NICAM simulation
- Intensification to the east of Phillippines in 28-29 Nov.

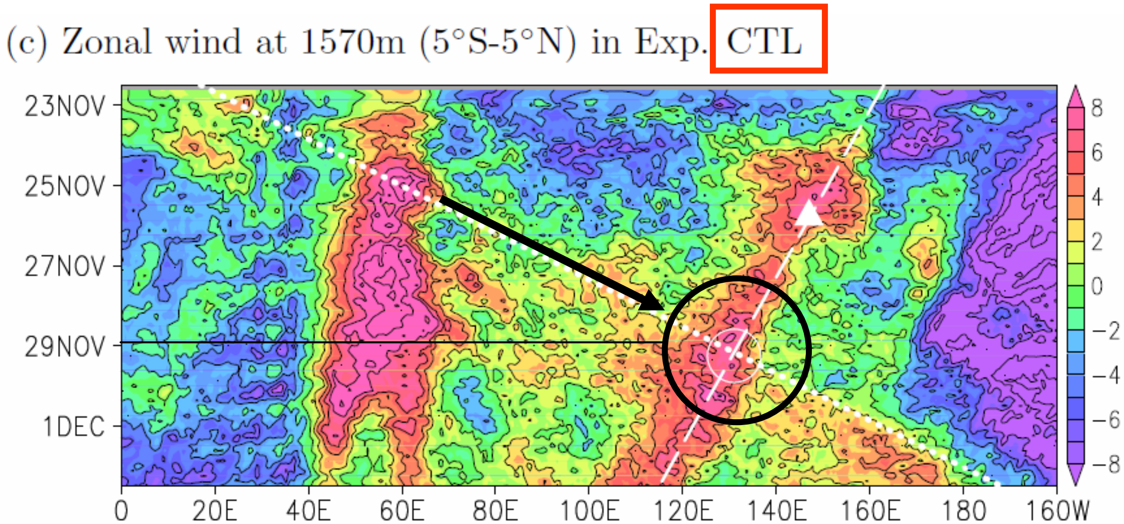
Yanase et al. (to be submitted)

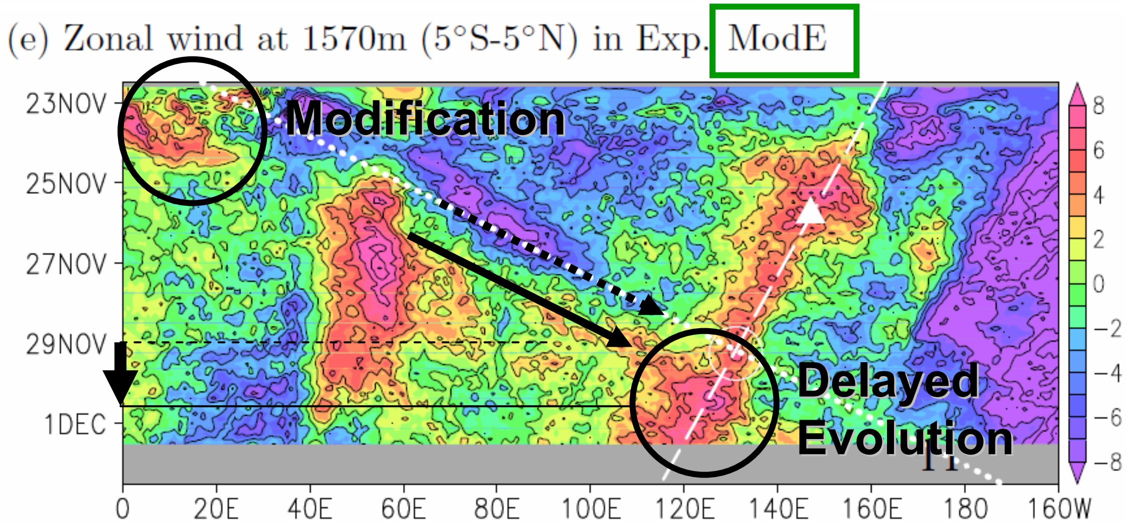
Sensitivity of TC Intensity to a Wave

Minimum pressure



Hovmöller of zonal winds





- Timing of intensification is delayed as the arrival of an equatorial westerly is delayed artificially in a sensitivity experiment (Mod-E)
- This shows a significant impact of equatorial waves on TC evolution

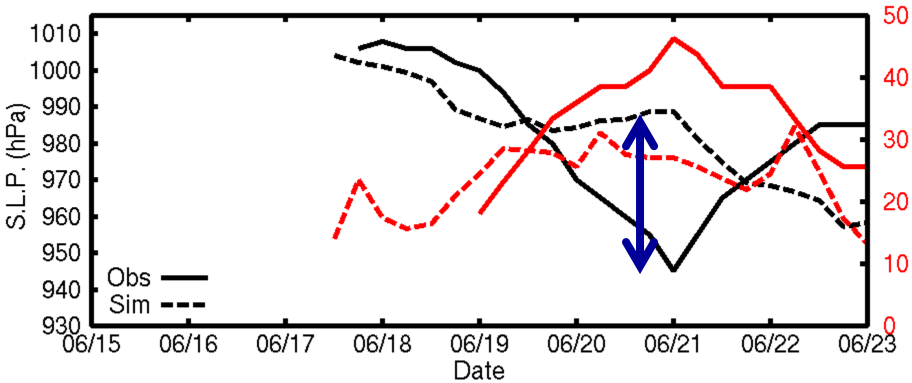
Yanase et al. (to be submitted)

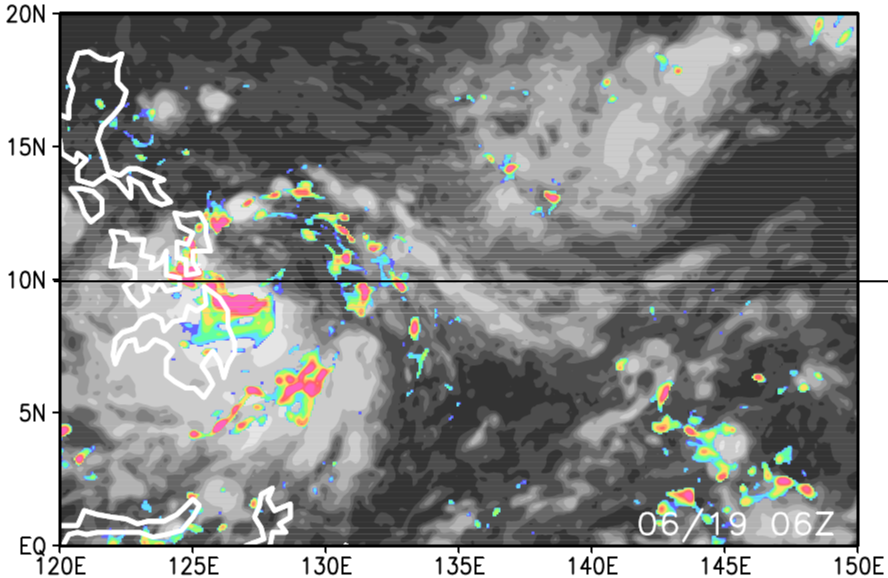
Summary (2)

- Westward-moving TCs (Fengshen, Nuri, Hagupit, Higos in 2008, and Durian in 2006) showed common characteristics:
  - Northward bias of predicted TC track to the east of Philippines
  - Asymmetric rainfall distribution with a peak in the western side
  - Predominance of westerly flow to the south of TC, which propagates eastward along the equator from the Indian Ocean
  - TC moves along a westerly-easterly shear (monsoon trough), suggesting that TC track is controlled by lower-tropospheric large-scale flows
- A numerical study of TY Durian (2006) using global cloud-resolving model (NICAM) shows a role of a convectively-coupled equatorial wave on the intensification of this cyclone.
- It is necessary to better represent the propagation of convectively-coupled equatorial waves, including short ones (~2,000 km), for better predictions of TC genesis and track.

NICAM simulations (dx=7km → 3.5km)

Streached grids, dx(min)=7km





A 3.5km full-grid run is scheduled to be conducted in December

Streached grids, dx(min)=3.5km