Structure and Maintenance of Concentric Eyewalls in Simulated Typhoon Bolaven (2012)

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Image by Digital Typhoon (http://agora.ex.nii.ac.jp/digital-typhoon/)

Introduction

- It is important for Eyewall Replacement Cycle (ERC) to suppress water vapor supply associated with the low-level inflow in PBL (Houze et al., 2007).
- Yang et al. (2013, MWR) indicated that ERC does not always occur even if Concentric Eyewall (CE) forms, using many satellite data.

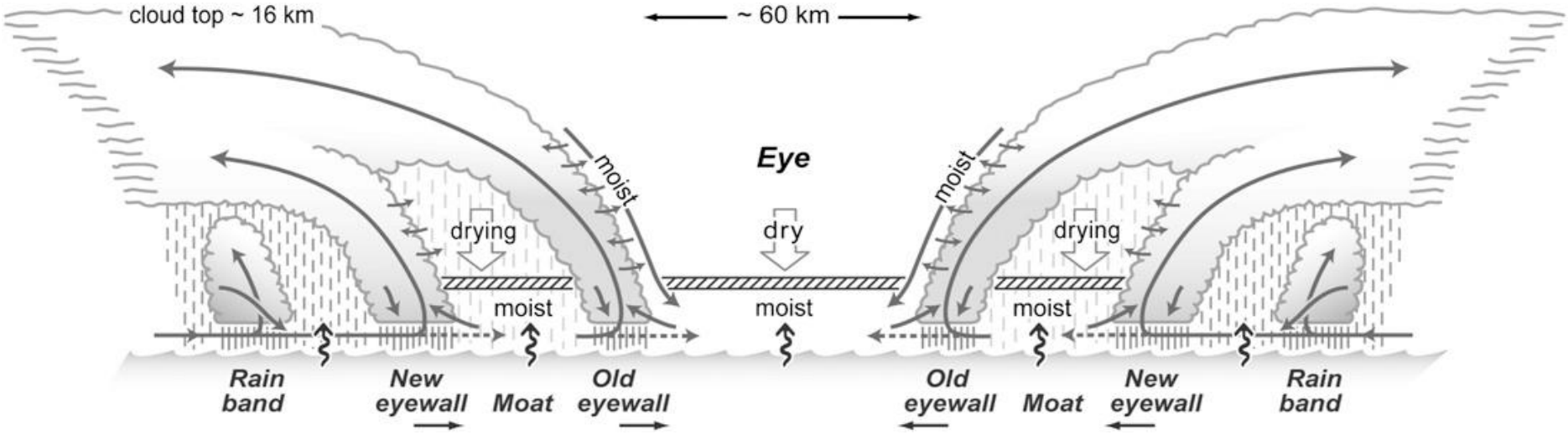
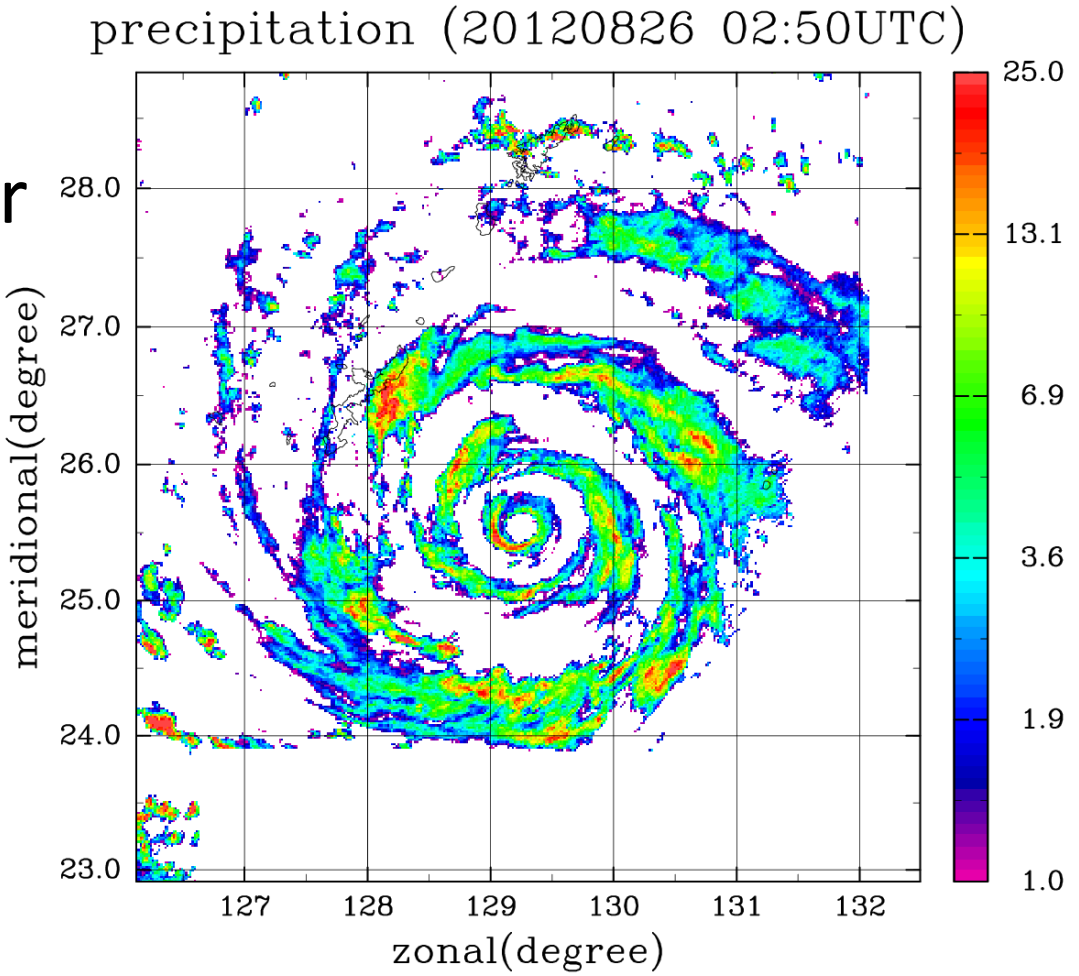


Illustration of concentric eyewalls (Houze et al., 2007).

Typhoon Bolaven (T1215)

- Clear multiple eyewalls.
- Maintaining the eyewalls for over one day.
- Without eyewall replacement cycle.



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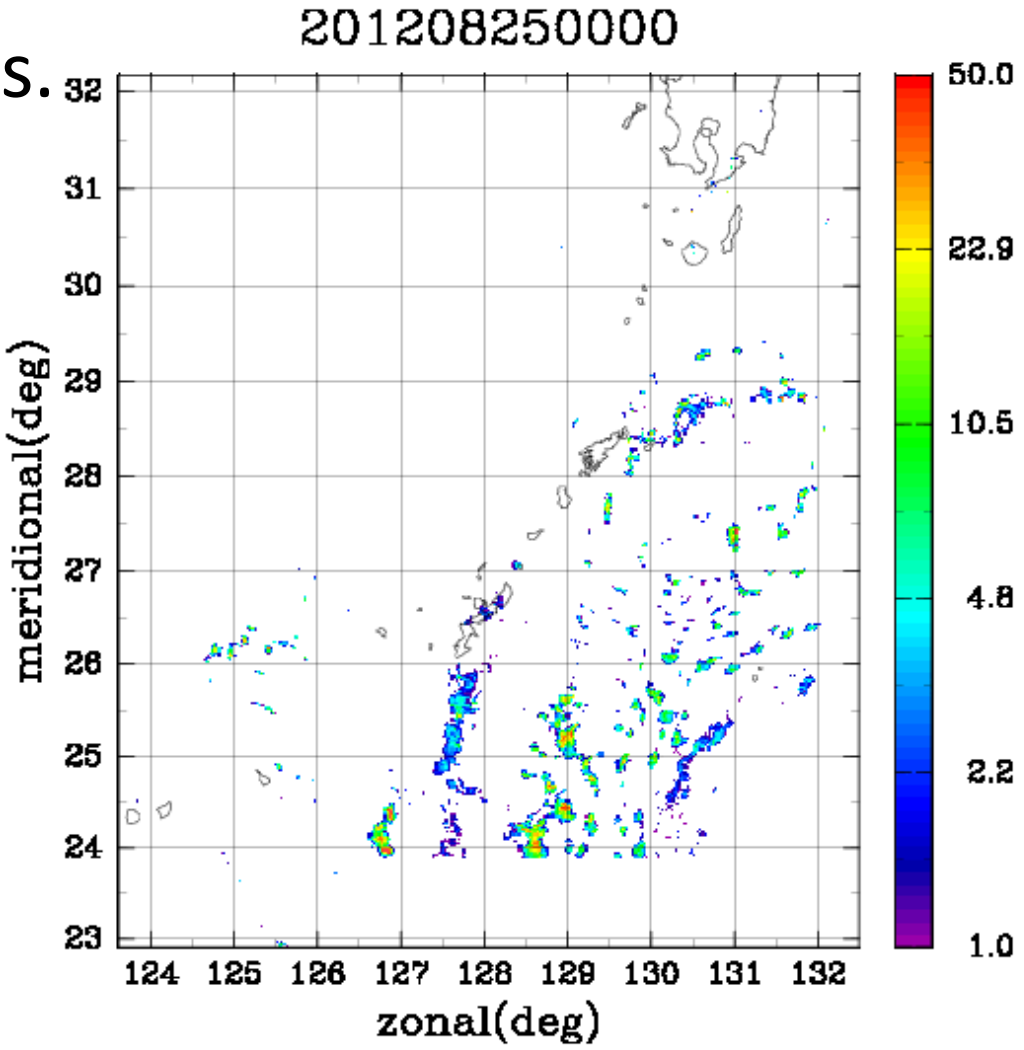
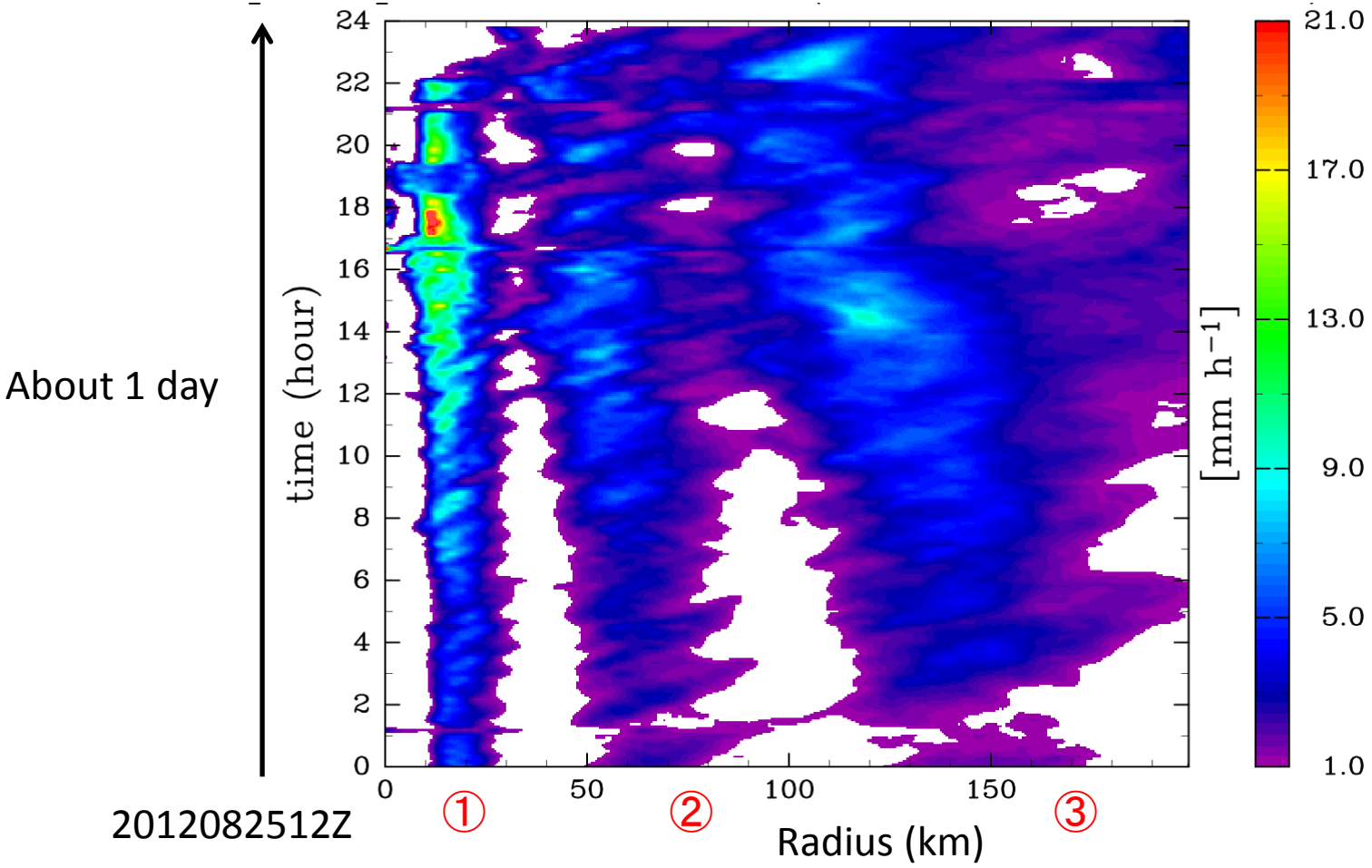


Typhoon Bolaven (T1215)

Azimuthal mean of precipitation (JMA Radar)



Motivation

- Why could CE of Bolaven maintain for over one day ?
- To understand the ERC, Maintaining CE must be also investigated.
- We investigate how the difference of CE with and without replacement has.
  - We focus on the relationship between structure and replacement of CE in TCs.

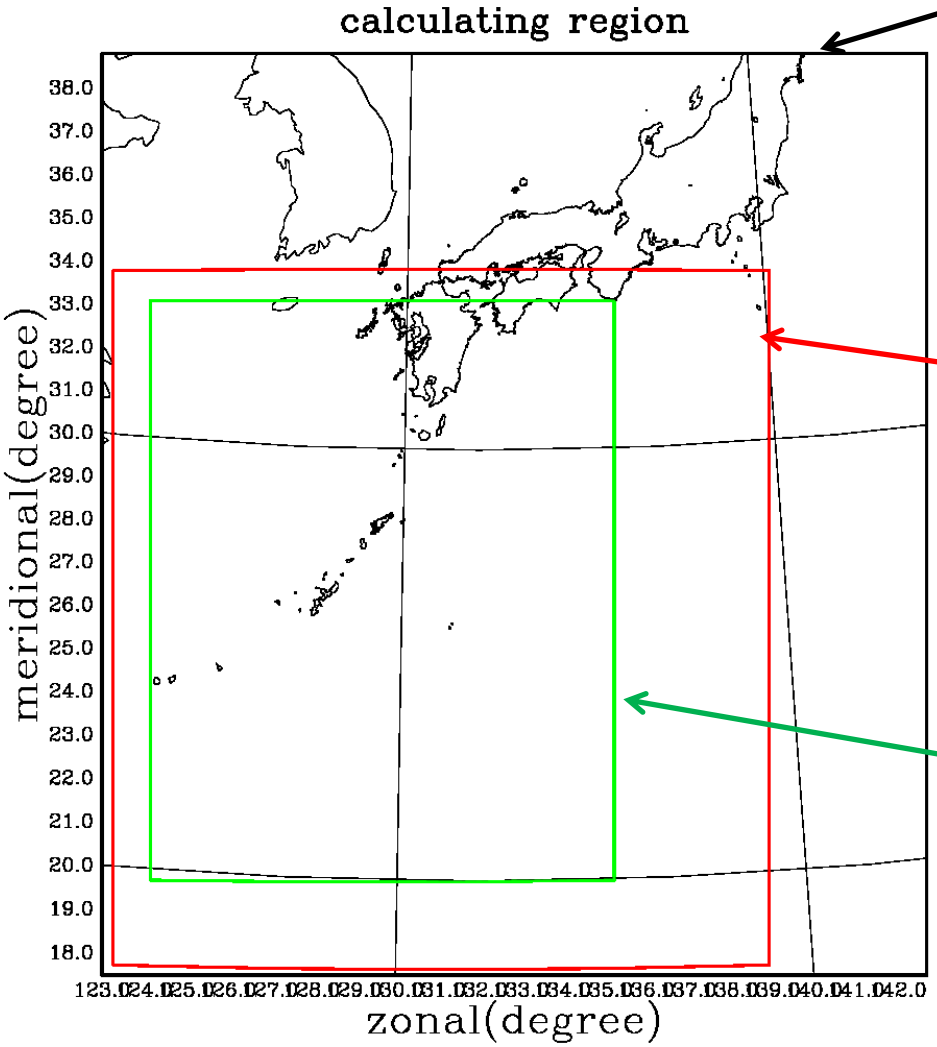
Contents

- Numerical experiment of Bolaven's CE.
  - Three-dimensional non-hydrostatic model (CReSS).
- The characteristic structure of Bolaven's CE.
- A hypothesis of CE maintenance.
  - On the basis of Sawyer-Elliassen response and Rossby deformation radius.
- Idealized experiment of replacement of CE.

Model setting

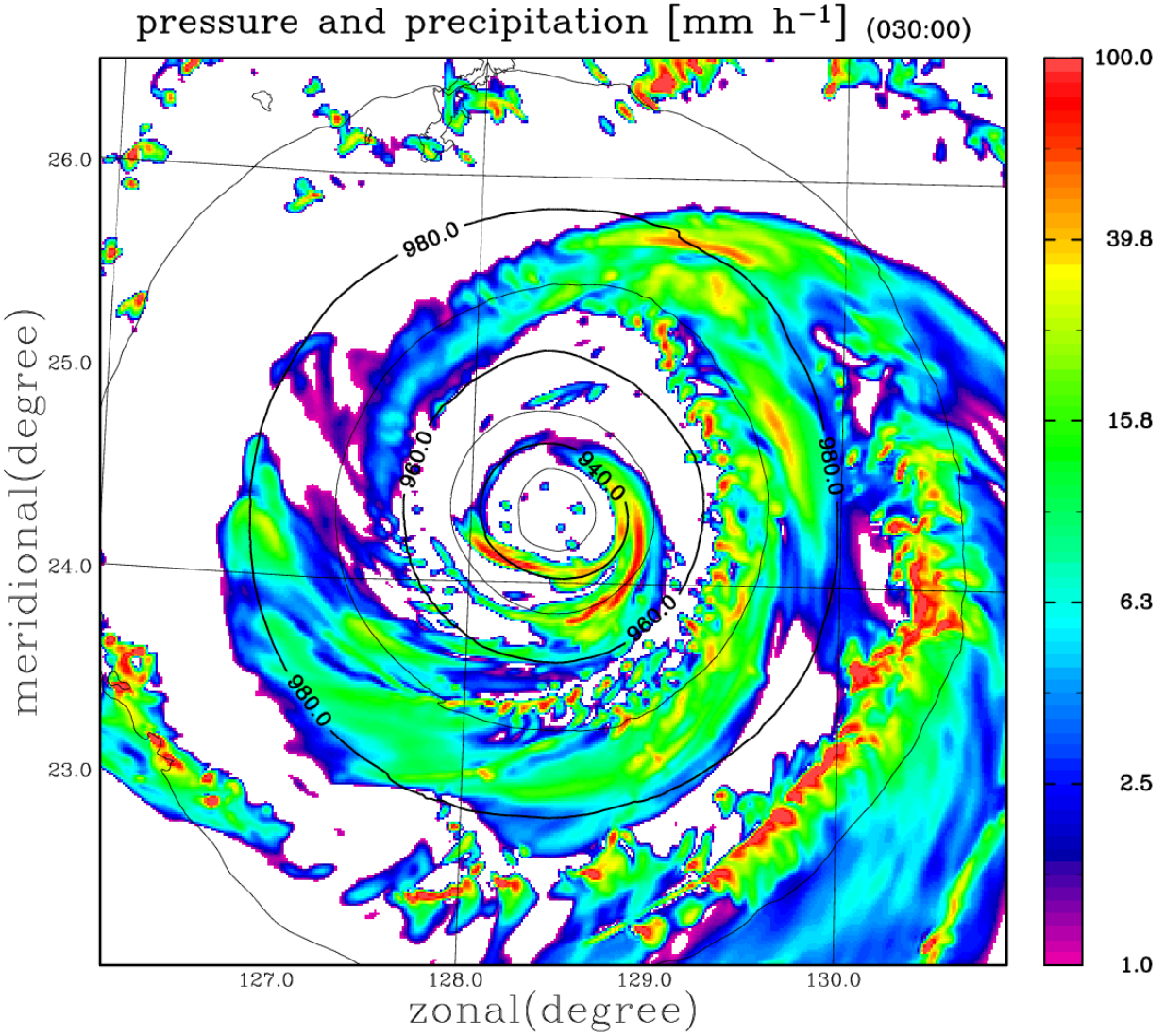
- Physical process
  - Surface process : Bulk aerodynamic formula (Kondo (1975)).
  - Ocean : one-dimensional, vertical mixing process.
  - Turbulence : 1.5-order closure of turbulent kinetic energy.
  - Cloud physics : Parameterization of the bulk cold rain.
    (calculating mixing ratio and number concentration).
- Data set
  - Terrain : NASA SRTM 30 data.
  - SST : JMA MGDSST data.

Calculating domain



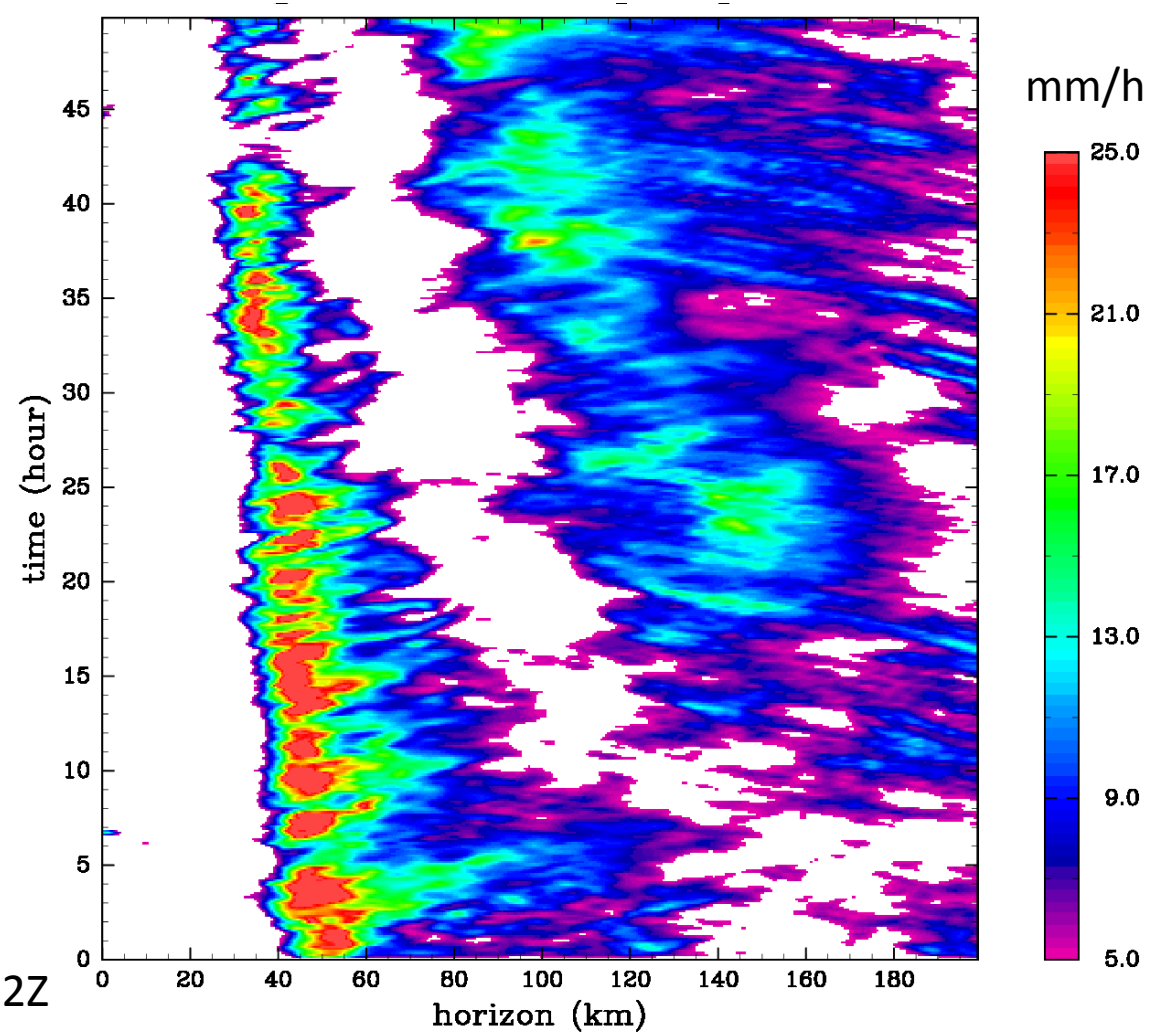
- 1st domain
  - 5km x 5km
  - JMA-GSM
    - 2012/08/22 00Z
  - 6 days
- 2nd domain
  - 2.5km x 2.5km
  - 1st domain
    - 2012/08/23 06Z
  - 4 days
- 3rd domain
  - 1km x 1km
  - 2nd domain
    - 2012/08/24 12Z
  - 2.5 days

Result（30 hour）



Time series of CE

Azimuthal mean precipitation



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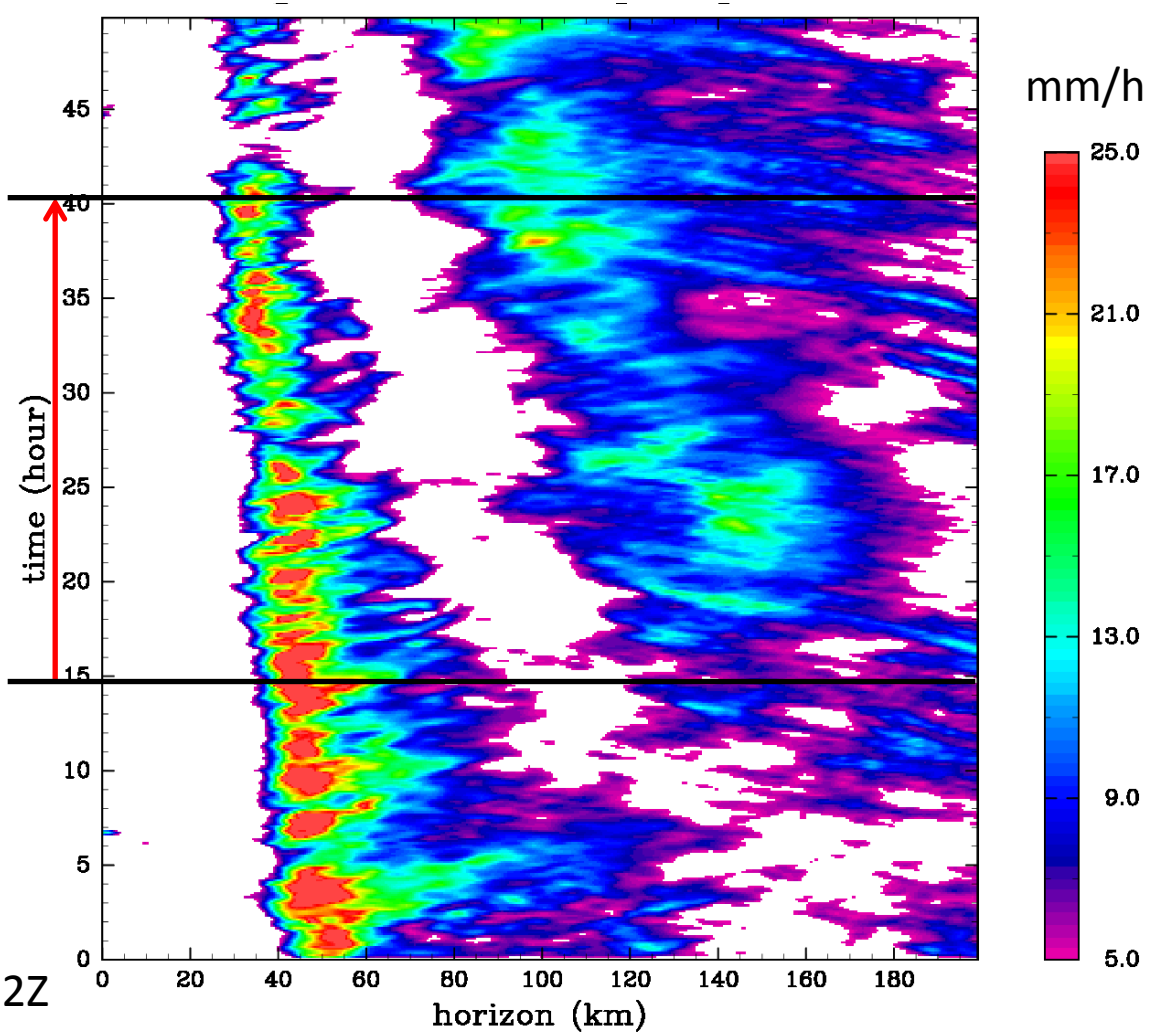
Time series of CE

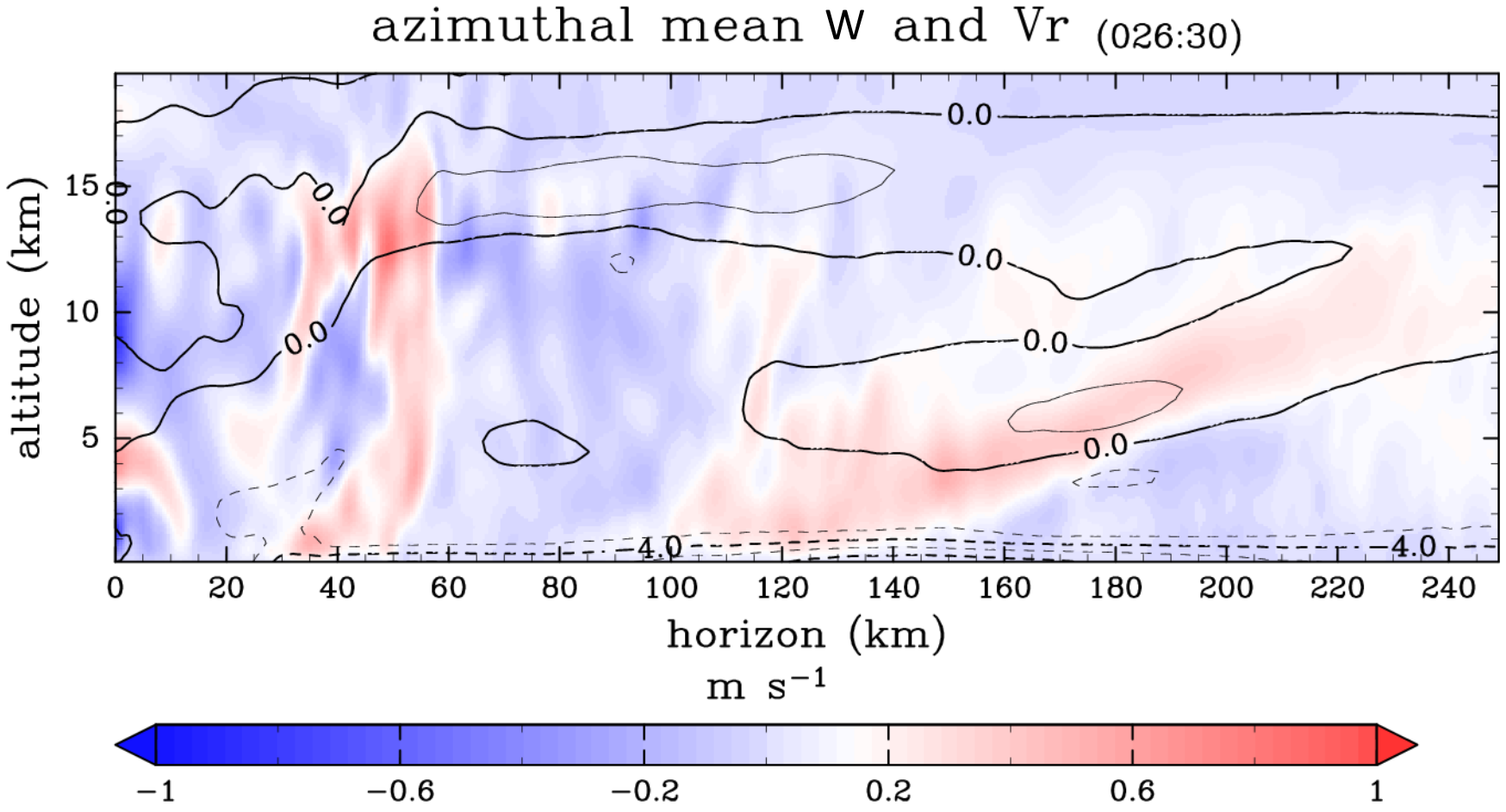
Azimuthal mean precipitation



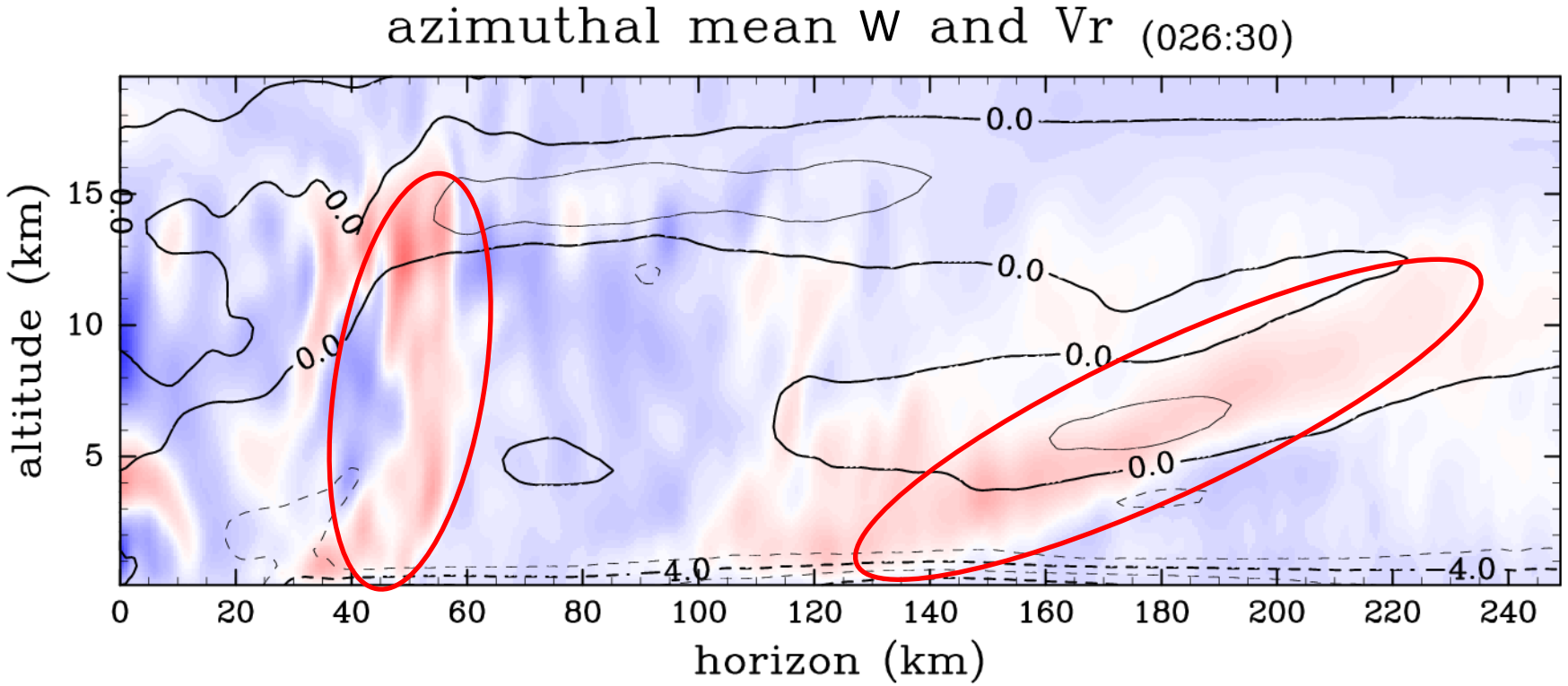
Maintaining the CE for over “one day”.

20120824 12Z

Structure of simulated Bolaven's CE



Structure of simulated Bolaven's CE



After forming the outer eyewall…

- The outer eyewall is tilted outward, relative to the inner eyewall.
- The vertical flow (W) of the outer eyewall is weaker than that of the inner eyewall.
  - Weak W of the outer is related to supply of watar vapor into the inner continuously.
- These characters are consistent with the result of Yang et al. (2013).

A hypothesis of maintaining CE

- Based on Sawyer-Eliassen response -

- Rossby deformation radius : $R \sim \frac{N}{I}$

N = vertical stability, $I \sim \frac{v}{r}$ & $\frac{\zeta}{r}$ = horizontal stability

Around the outer eyewall…

- R = large ➔ u / w = large ➔ outward tilted
  ➔ maintenance (without replacement),
- R = small ➔ u / w = small ➔ more upright
  ➔ replacement.

Thus , a condition of maintaining CE is that (for TCs of sub-equal intensity)

- the vertical stability is strong,
- the position of the outer eyewall is far from the center of TC.

Idealized Experiments

- Weak axisymmetric vortex.
  - Terwey and Montgomery (2008).
- Tropical sounding data.
  - Jordan (1958).
- SST = 302 K (Constant).
- Horizontal grid interval = 2 km.
- f – plane (15 degree N)

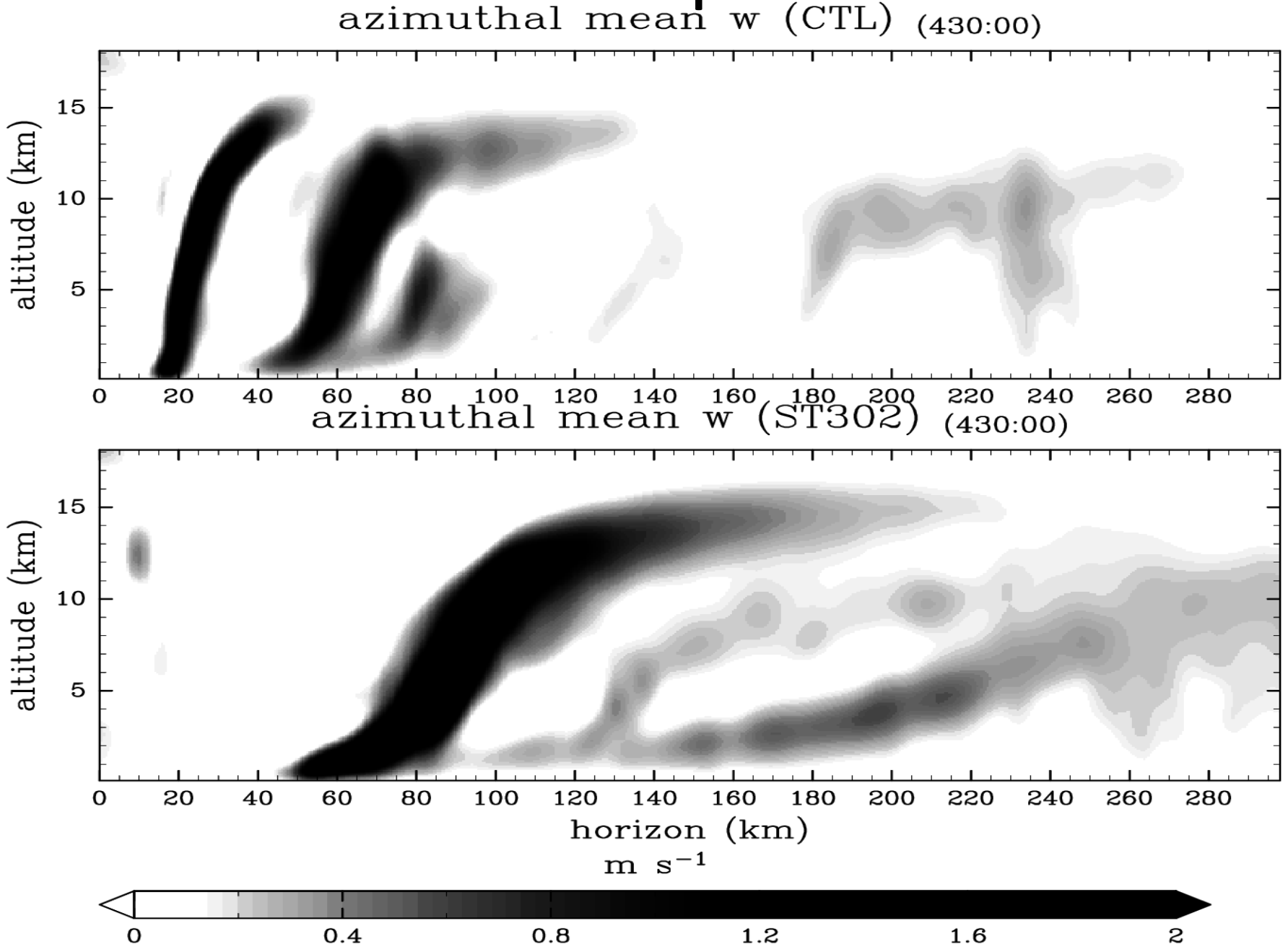
Sweeping parameter is sounding temperature.

- “ST302” experiment = sounding temperature + 3 K.
  - ST302 is more stable than CTL.

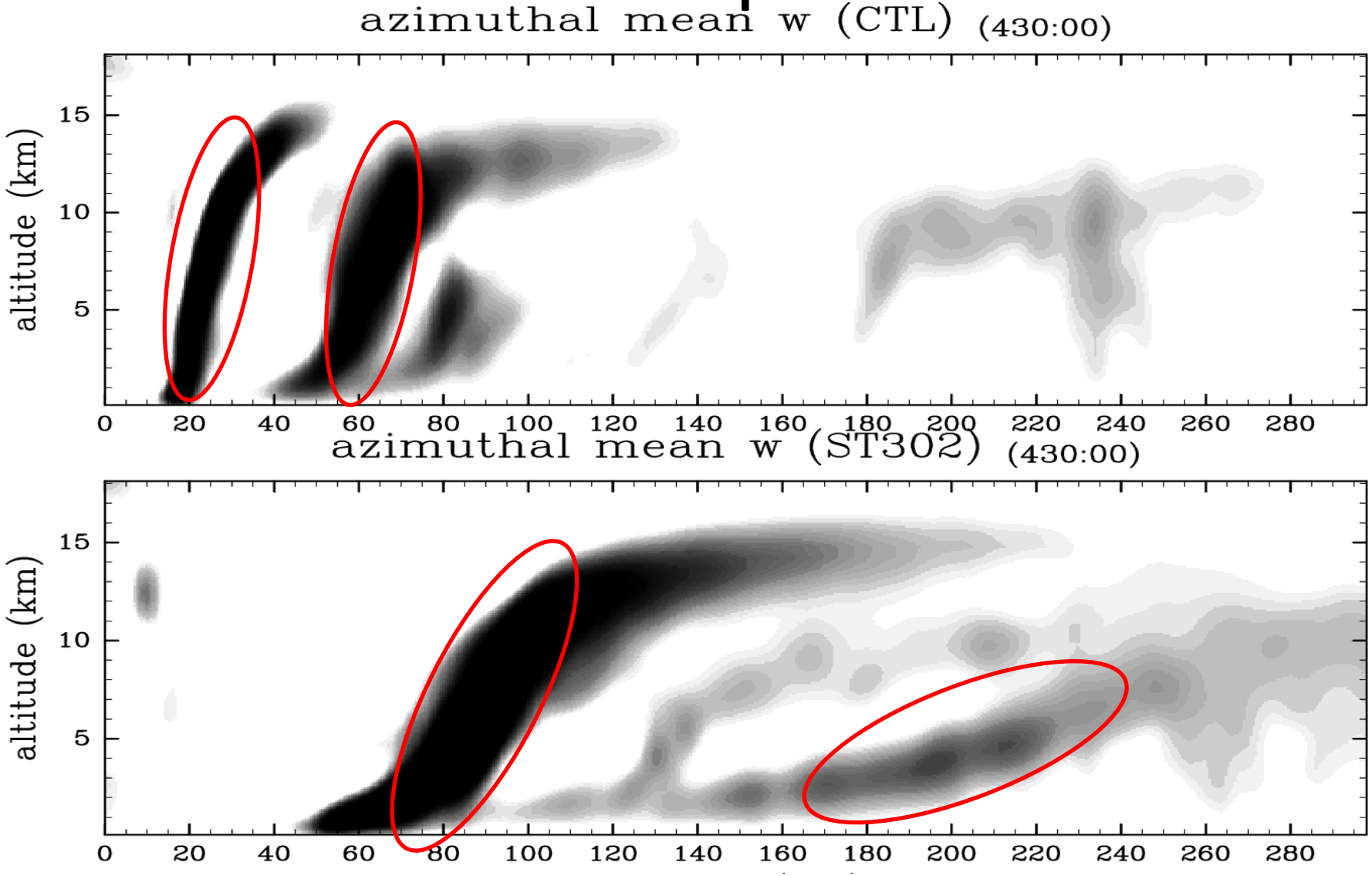
    The definition of our vertical stability : T_{top} —SST

    T_{top} is the temperature of the tropopause.

Idealized Experiments

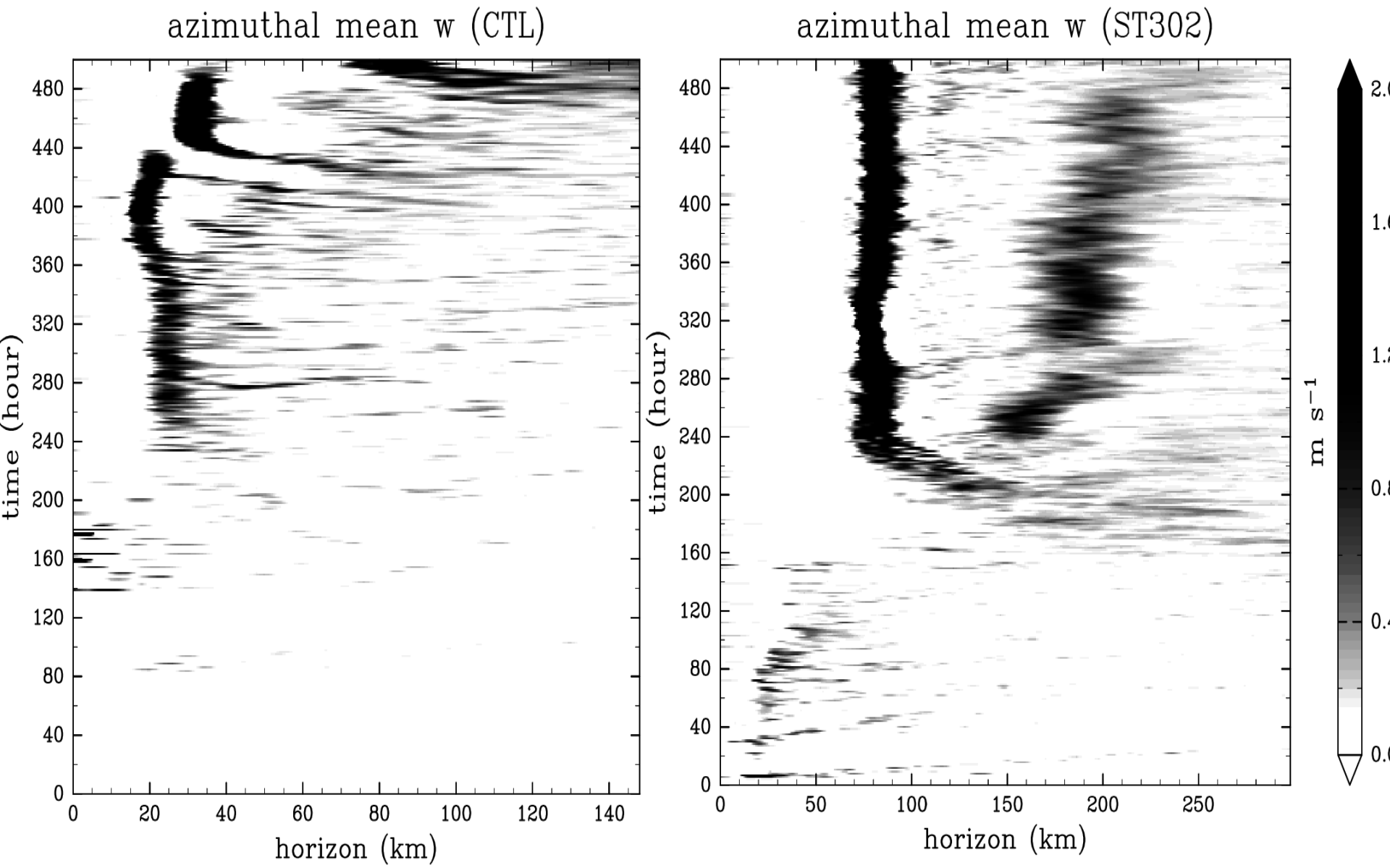


Idealized Experiments



In ST302, the structure of the outer eyewall is similar to that of Bolaven.

Idealized Experiments



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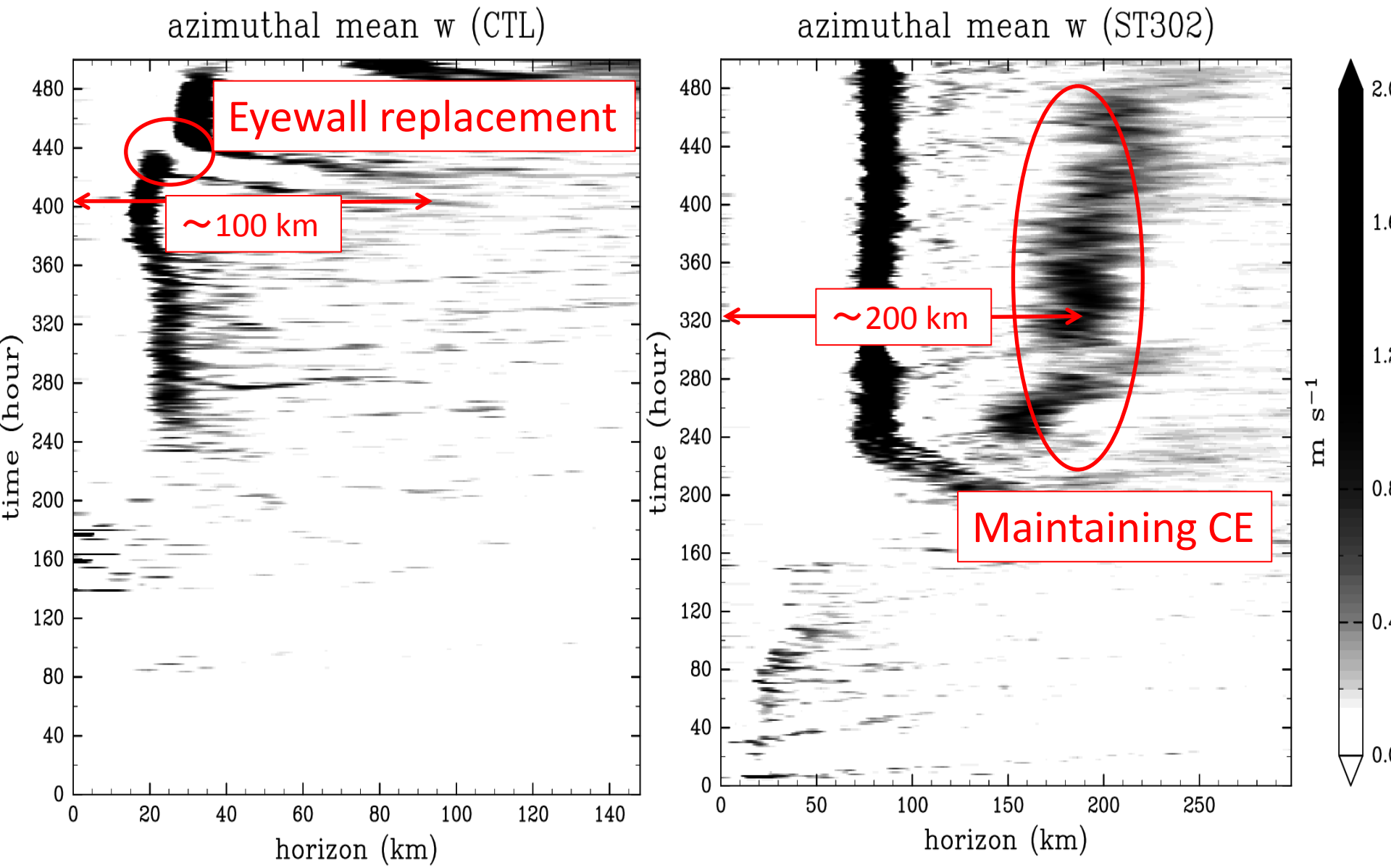

Summary

- We conducted numerical experiment of Bolaven, using CReSS model.
  - Simulated CE maintained for over one day (without eyewall replacement).
- Simulated Bolaven's outer eyewall was (relative to the inner eyewall)
  - outward tilted,
  - weak updraft.
- A hypothesis of maintaining CE, based on Sawyer-Eliassen response.
  - Vertical stability is strong.
  - The position of the outer eyewall is far from the center of TC.
- Idealized experiments of CE.
  - CE of the maintaining experiment had the same structure of Bolaven's CE.