京コンピュータによる台風全域LES
Large eddy simulation on whole tropical cyclone using K-computer

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LES on Tropical cyclone (TC)

Previous large eddy simulation (LES) studies:

- Nested in the coarser resolution model (e.g. Rotunno et al., 2009)
- Include local curvature of gradient wind (e.g. Nakanishi and Niino., 2012)
- Mesh concentration at TC core (e.g. Bryan et al., 2014)

This study performs **LES on whole TC** simply, despite huge computational cost

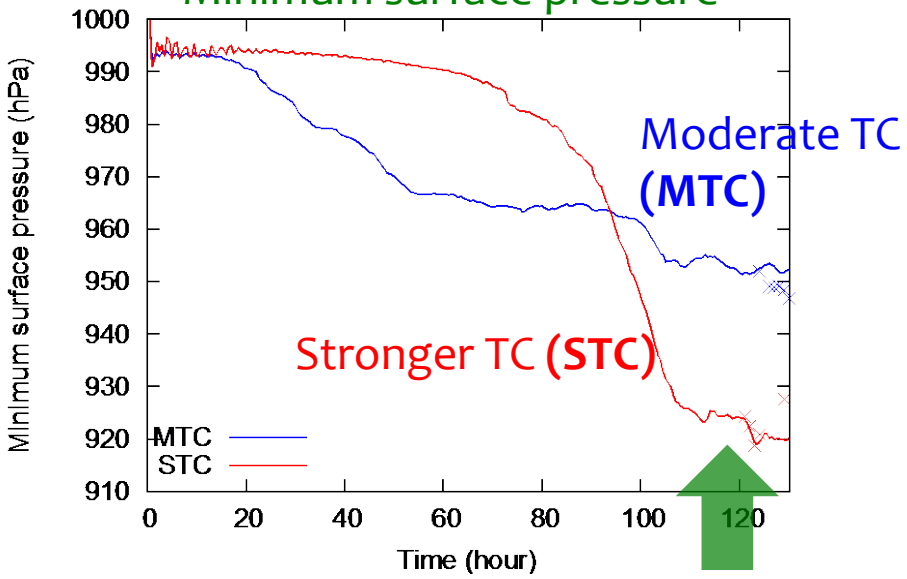
- less uncertainties
- Interactions between small and large scale structures in TC

Preliminary run (P-run) → LES-run

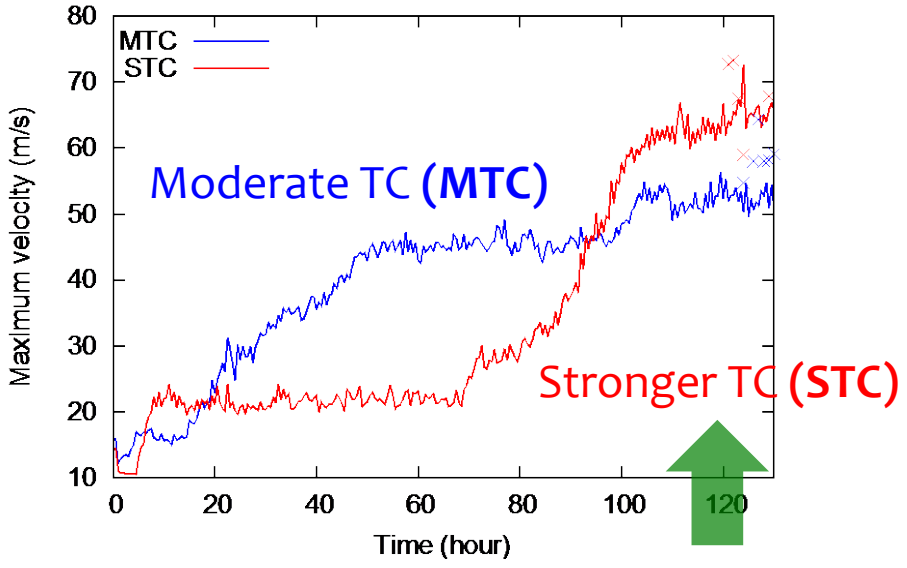
P-run to develop matured TC from an initial disturbance

- Model: JMA-NHM, f=10°N
- Domain: 2000km×2000km×23km
- Grid number: 1000×1000×60
- Horizontal boundaries: doubly-cyclic
- **Horizontal resolution *dx* = 2km;** Vertical resolution *dz* ∨ ≤ 100 m in boundary layer with stretching

Minimum surface pressure



Maximum surface wind



Results at t=120 hr are Interpolated to be initial condition of LES

Preliminary run (P-run) → LES-run

- Model: JMA-NHM
- Domain: 2000km×2000km×23km
- Horizontal boundaries: doubly-cyclic

} The same as P-run

- **Horizontal resolution *dx*: 100 m**
- Grid number: 20000×20000×60
- Time Integrations up to 10 hours are completed

CPU usage: 9216 nodes × 9.5 hour × 10 times × 2case

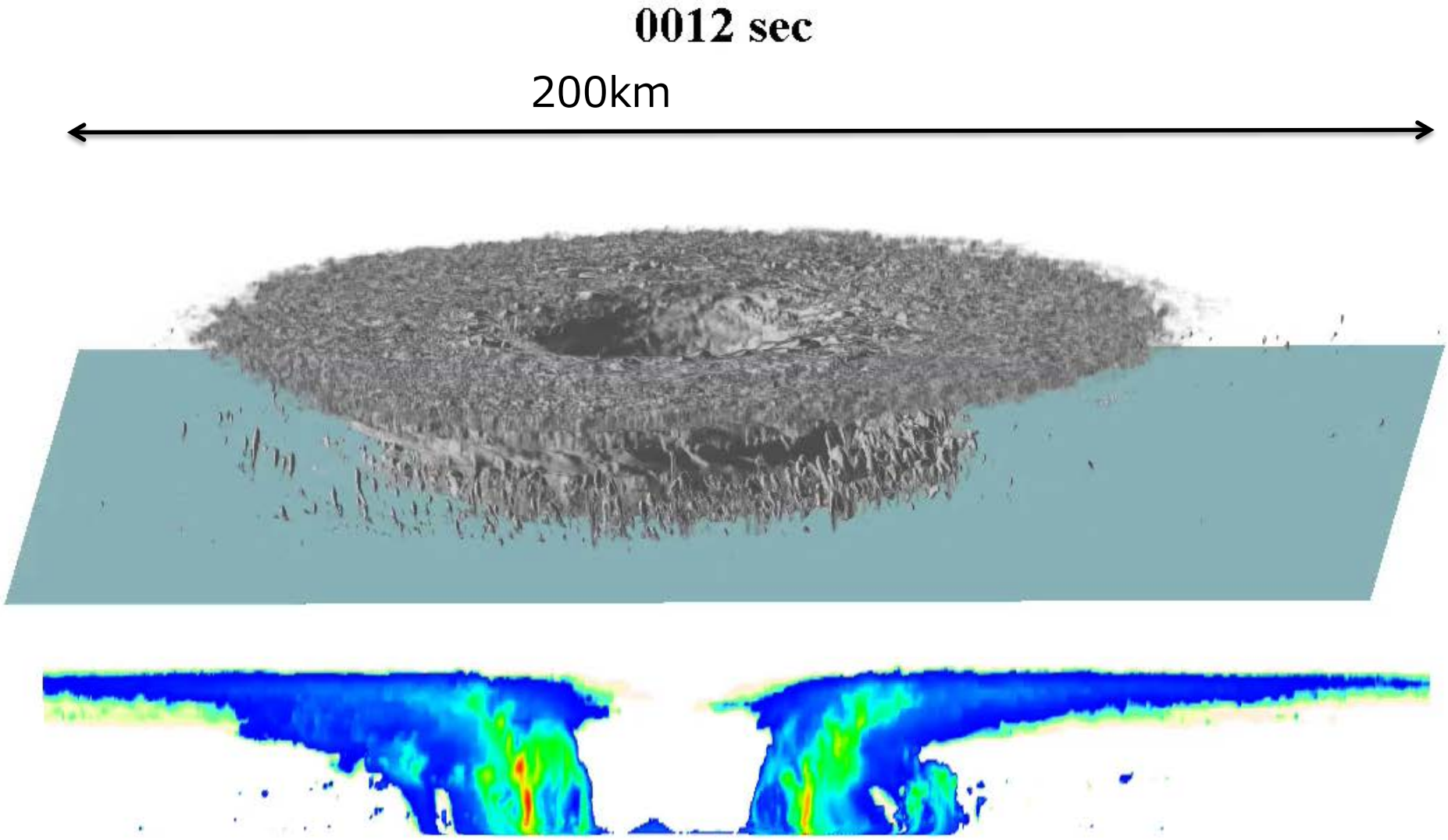
Elapse for 1 hour time integration

MTC & STC

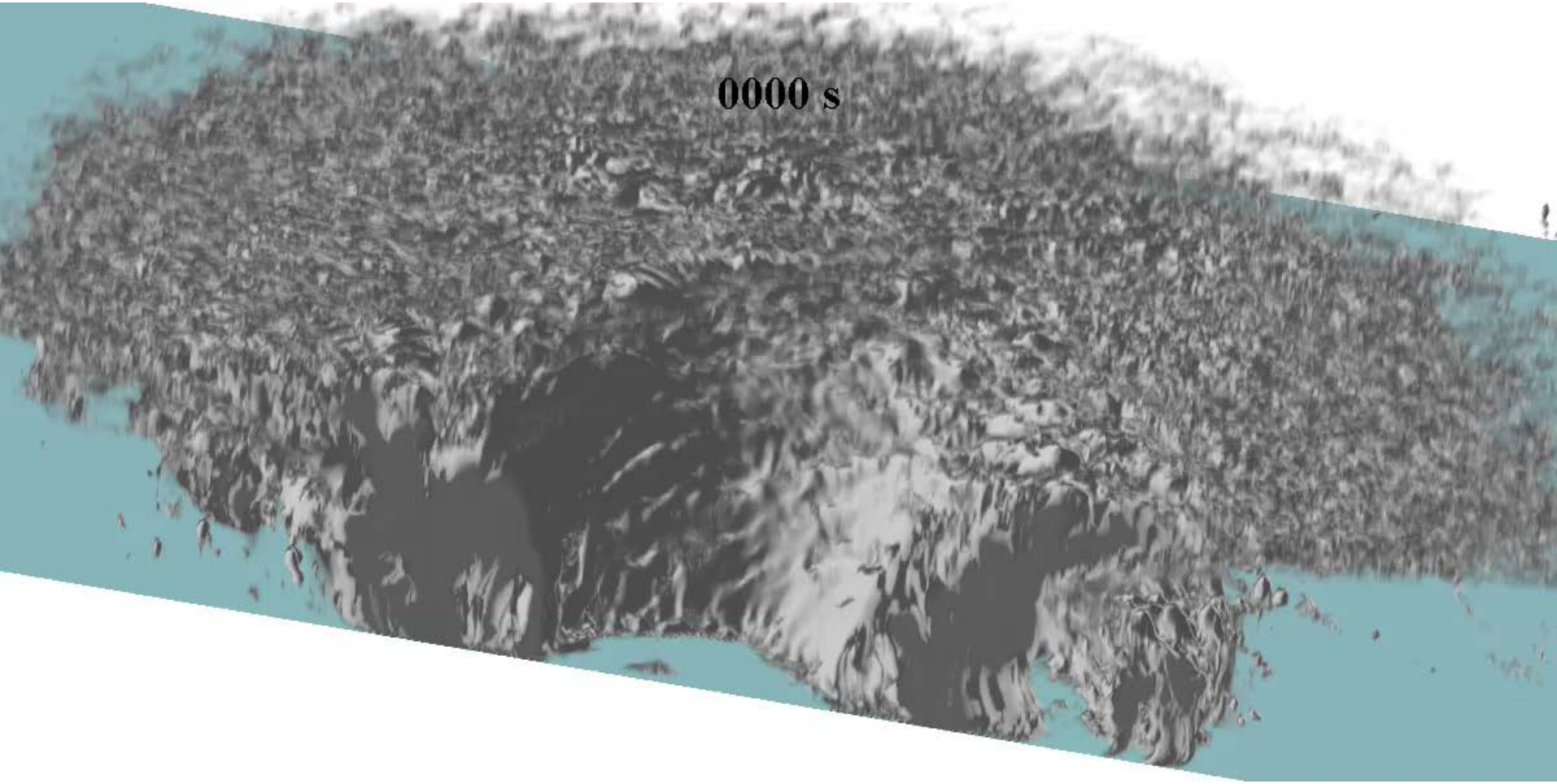
Disk usage: Restart files ~ 17 TB

Data

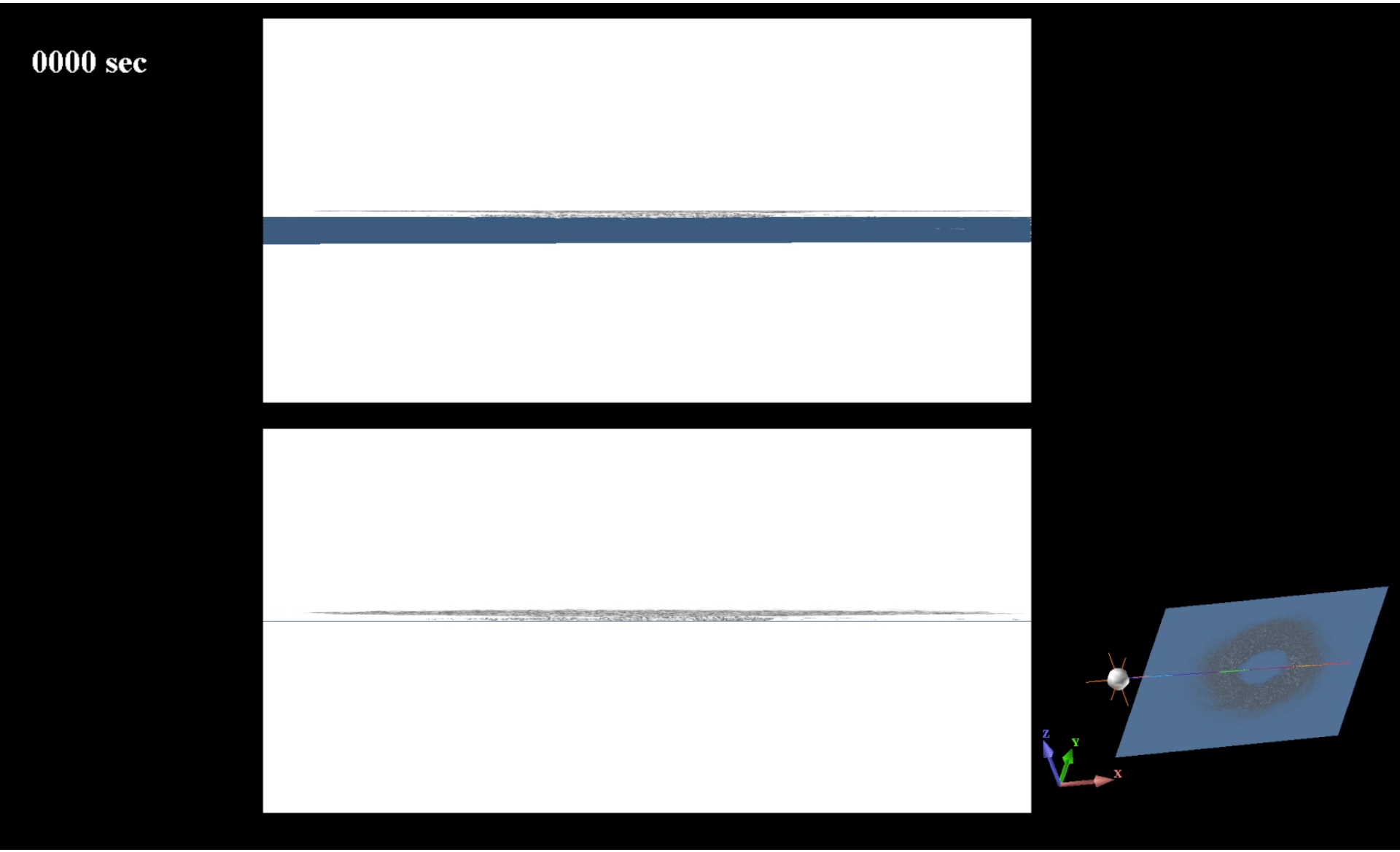
Movie 1 (Cloud water amount, 9→10 hr)



Movie 2 (Cloud water amount, 9→10 hr)



Movie 3 (Cloud water amount, 9→10 hr)



Comparison of surface wind intensity

MTC STC

Surface wind speed

P-run
(dx=2km)

LES-run
(dx=100m)

↔

*Color scales are different

- Surface wind speed → Almost the same or a little weaker in LES-run
- Fine scale variations in LES-run

Roll structure (Type A and B)

Vertical velocity near the surface (Shading) in MTC

Green contours:
surface wind >55m/s

Outer
70>r>40km

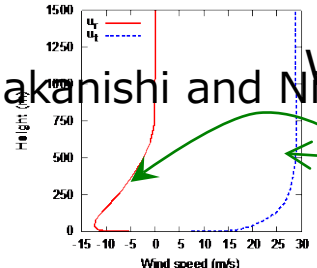
Core
-15>r>15km

Type-B roll

Type-A roll

Type-A roll

Type-A roll: Inflection point instability



Wind profiles @ r=50km (c.f. Nakanishi and Niino 2012)

$\partial^2 u/\partial z^2=0$

Type-B roll: ~~Shear Instability~~
Parallel Instability

(Lilly 1962; Foster 2005)

Downdrafts of Type-B accompany the maximum surface wind of TC

Changes in large scale structure

Differences in **[LES-run] – [P-run]** are shown

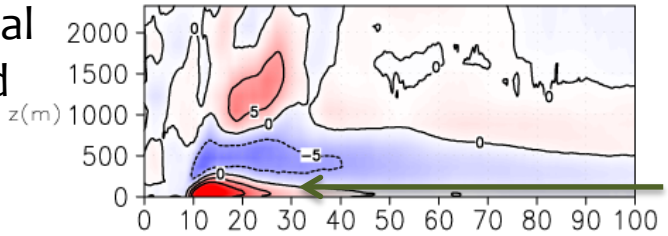
Turbulent momentum flux

Resolved Type-A rolls in LES-run increase eddy viscosity

Larger turbulent momentum flux

Larger Ekman transport

Radial wind



Tangential wind

Larger inflow

Cloud water amount

Shrink of TC

Conclusions

- JMA-NHM in LES mode on whole TC has been performed on K-computer
- Results are demonstrated in 3D animations
- Fine scale structures in boundary layer
  - **Type-A roll** in exterior of radius of maximum wind (RMW)
    - Inflection point instability
    - Intensify inflow → Shrink TC radius
  - **Type-B roll** only near RMW
    - Parallel instability
    - Associated with the maximum surface wind

Future subjects

- Quantitative analysis for instability (semi analytical- solution with LES-run data?)
- Energy spectral
- Structures above boundary layer (e.g. Cumulus convection), but vertical resolution is coarser (dz >> dx) in upper layers
- LES-run in vertical shear (tornadoes in super-cell are possible?)

Thank you for your attention!