Impact of ice-phase microphysics on inner-core processes in simulated extremely intense tropical cyclones

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Introduction

Most intense tropical cyclones (TCs) such as Categories 4 and 5 (Saffir-Simpson Hurricane Scale) underwent rapid intensification (RI). However, the physical mechanisms associated with RI and the inner-core processes have not been fully understood. The purpose of this study is to examine the impacts of ice-phase microphysics and boundary layer processes on the inner-core processes of an extremely intense TC with RI by using two types of 2-km mesh non-hydrostatic models (NHM2).

1. Model descriptions of 2 NHMS

JMANHM: The Japan Metrological Agency operational mesoscale model (Saito et al. 2007)

CReSS: Cloud Resolving Storm Simulator developed in HyARC, Nagoya University (Tsuboki and Sakakibara 2002)

	JMANHM	CReSS
Horizontal resolution	2km	
Equations	Non–hydrostatic and compressible	
Horizontal grid number	900～1500 ×900～1500	
Cumulus parameterization	none	
Time step	4s	4s
Initial time	1200Z23SEP2098	
Integration time	4-5 days	
Model	Atmospheric	Atmospheric-Ocean (Slab)

2. List of sensitivity experiments

model	name	Turbulence	cloud microphysics	vertical layer
AGCM	AGCM20	-	-	-
JMANHM	2LK	MYNN Level 3	2-moment: Prognostic variables [qc, qr, qi, qs, qg] and [Ni, Ns, Ng]	55
	2ddLK	Deardorff	2-moment	55
	2ddLK64	Deardorff	2-moment	64
CReSS	2CRS	Deardorff	1-moment: Prognostic variables [qc, qr, qi, qs, qg]	64
	2CRSDB	Deardorff	2-moment	64

JMANHM: 55 levels…**Higher vertical-reso. below z=1km**
20.0m, 60.0, 118.0, 194.0, 288.0, 400.0, 530.0, 678.0, 844.0

CReSS: 64 levels … **Lower vertical-reso. below z=1km**
100.0m, 311.5, 545.0, 799.2

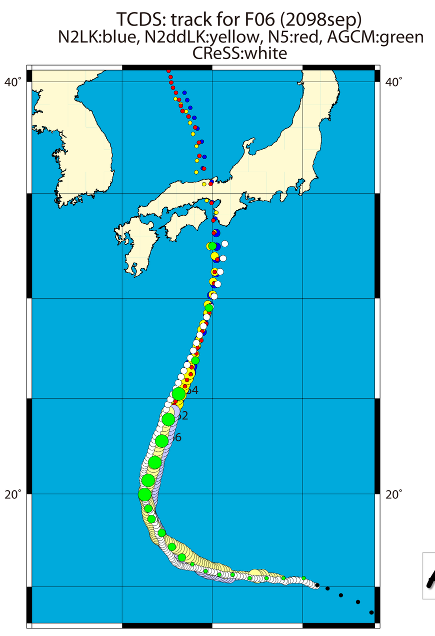
3. Initial and boundary conditions

The results of the climate experiments by a 20-km mesh atmospheric general circulation model (AGCM20).

A case of an extremely intense TC
Maximum central pressure (MCP) : 863 hPa

4. Results

i) Tracks and intensities



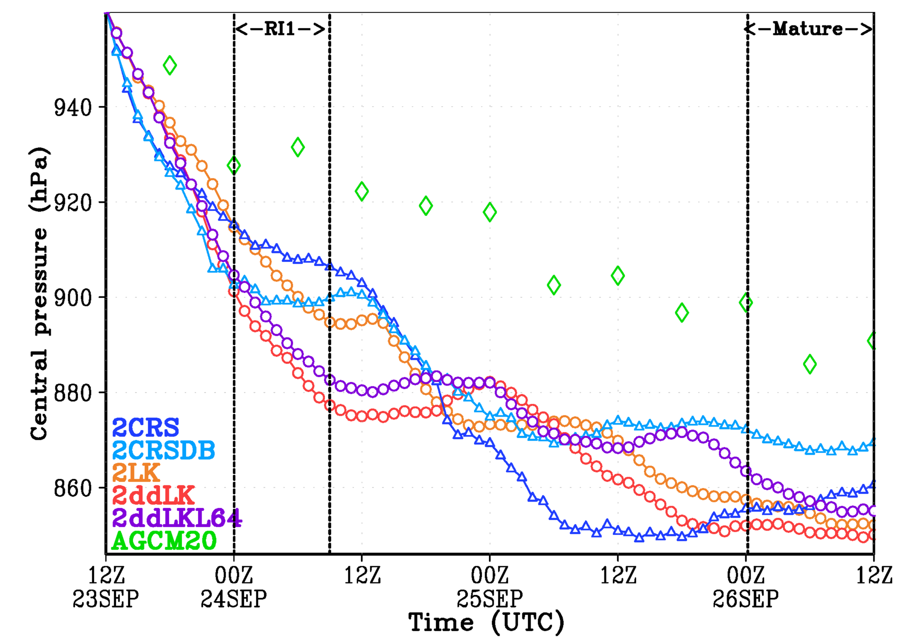
MPD: Maximum Pressure Drop

	MCP (hPa)	MWS (m/s)	MPD (hPa/24h)
AGCM20	863	79	-38
2LK	852	77	-60 (RI)
2ddLK	854	79	-73 (RI)
2ddLKL64	853	75	-73 (RI)
2CRS	851	82	-58 (RI)
2CRSDB	860	77	-53 (RI)

All NHM2 experiments underwent RI.

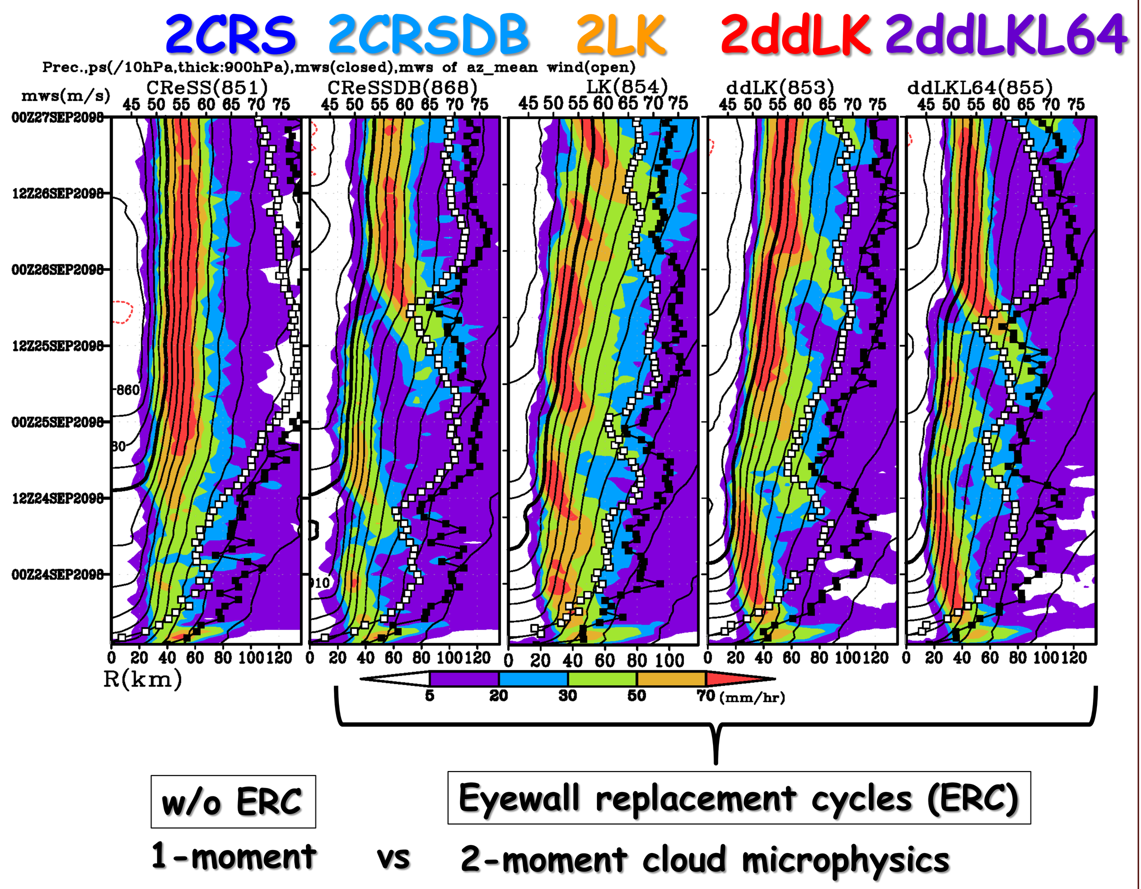
ii) General characteristics

- *Time variations of MCP*



2ddLK and 2ddLKL64 show very intense RI (Explosive RI, E-RI) during 'RI1'.

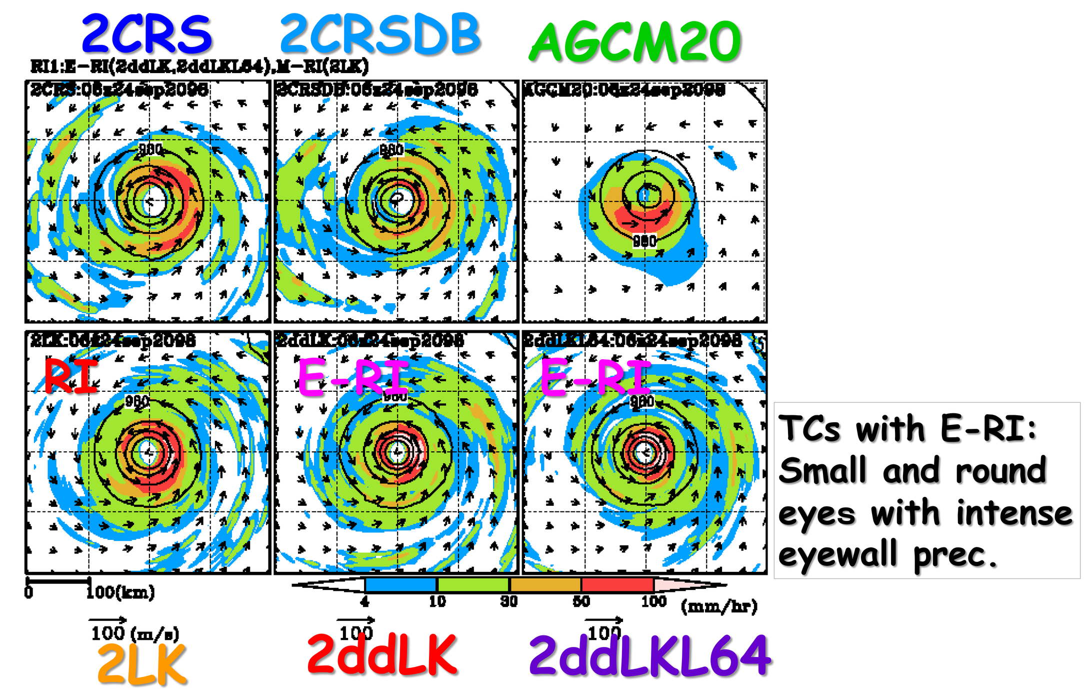
- *Hovmoller diagram of azimuthally averaged precipitation with max. 10-m wind speed*



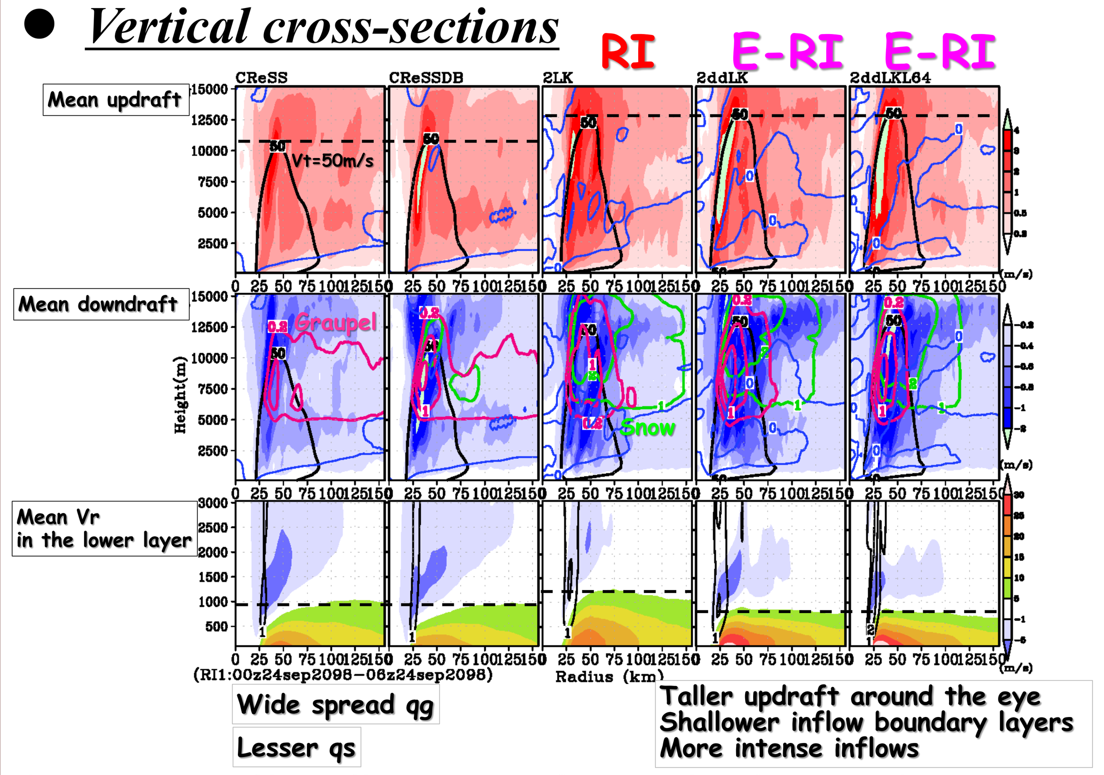
Acknowledgements: This study was supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan under the framework of the Sousei Program. Numerical simulations were performed using the Earth Simulator.

iii) RI1 stage

- ***Hourly precipitation***

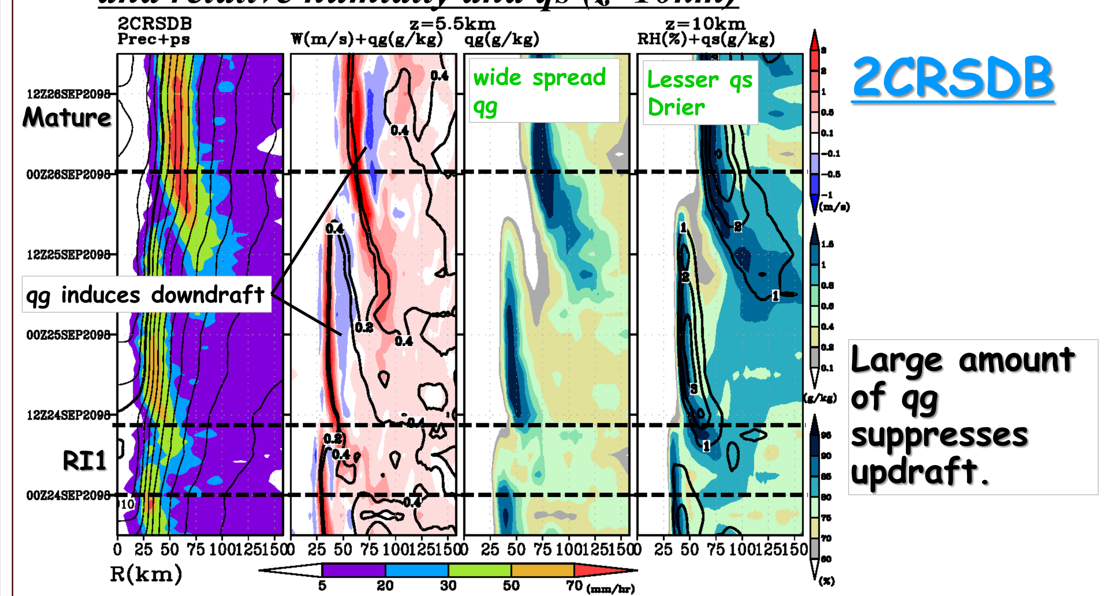


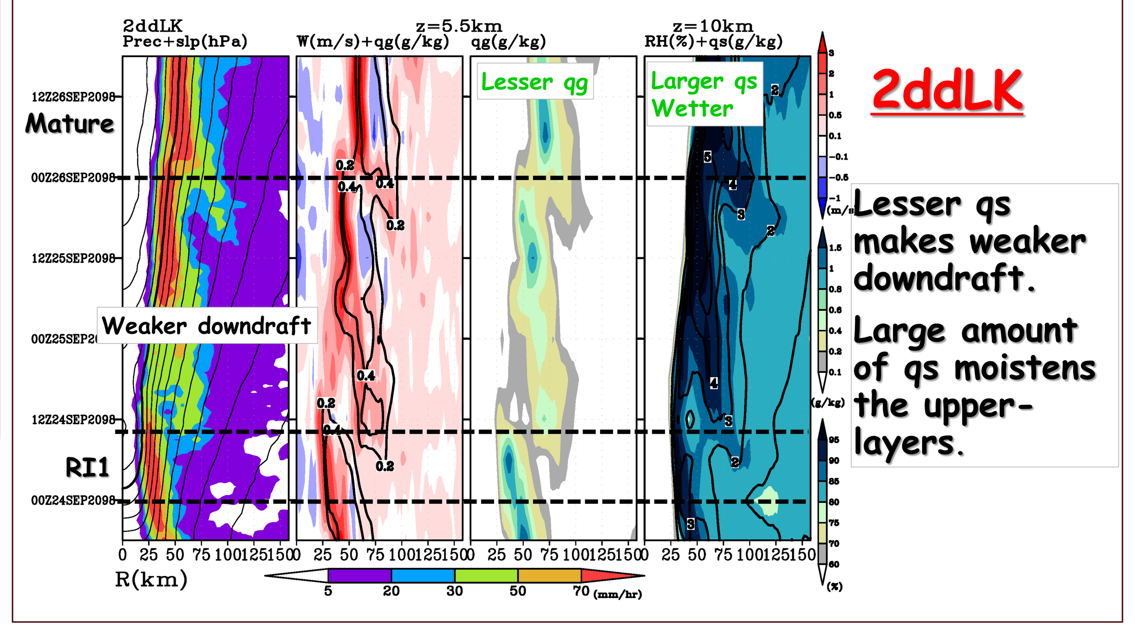
- ***Vertical cross-sections***



iv) Hovmoller diagrams for typical experiments

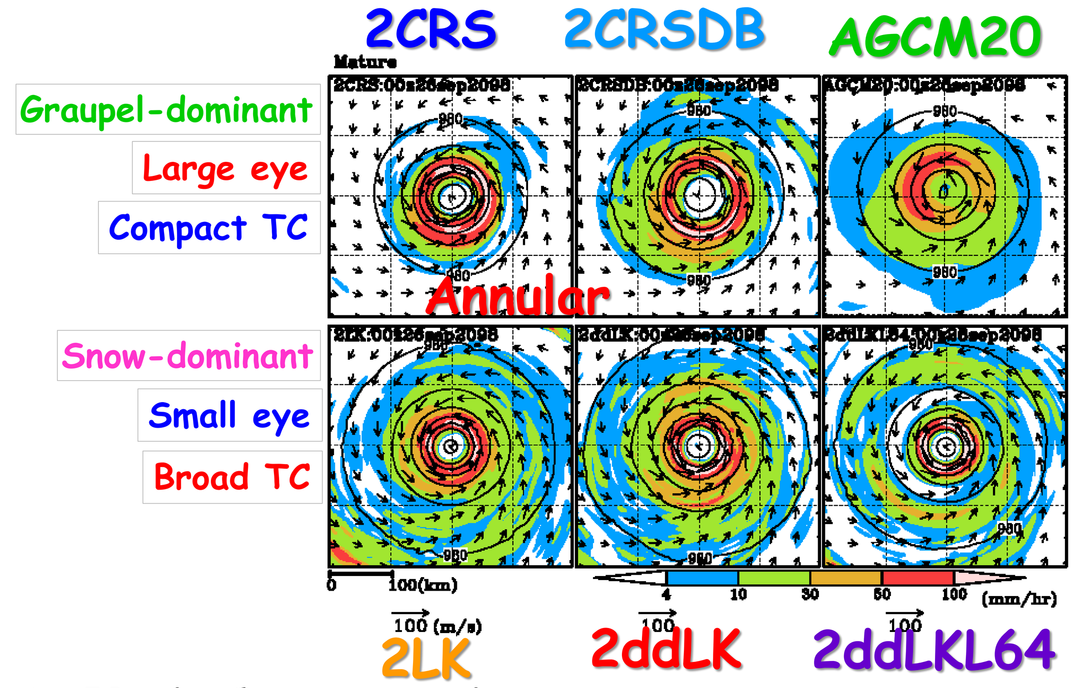
- *Azimuthally averaged vertical velocity and qg (z=5.5km) and relative humidity and qs (z=10km)*



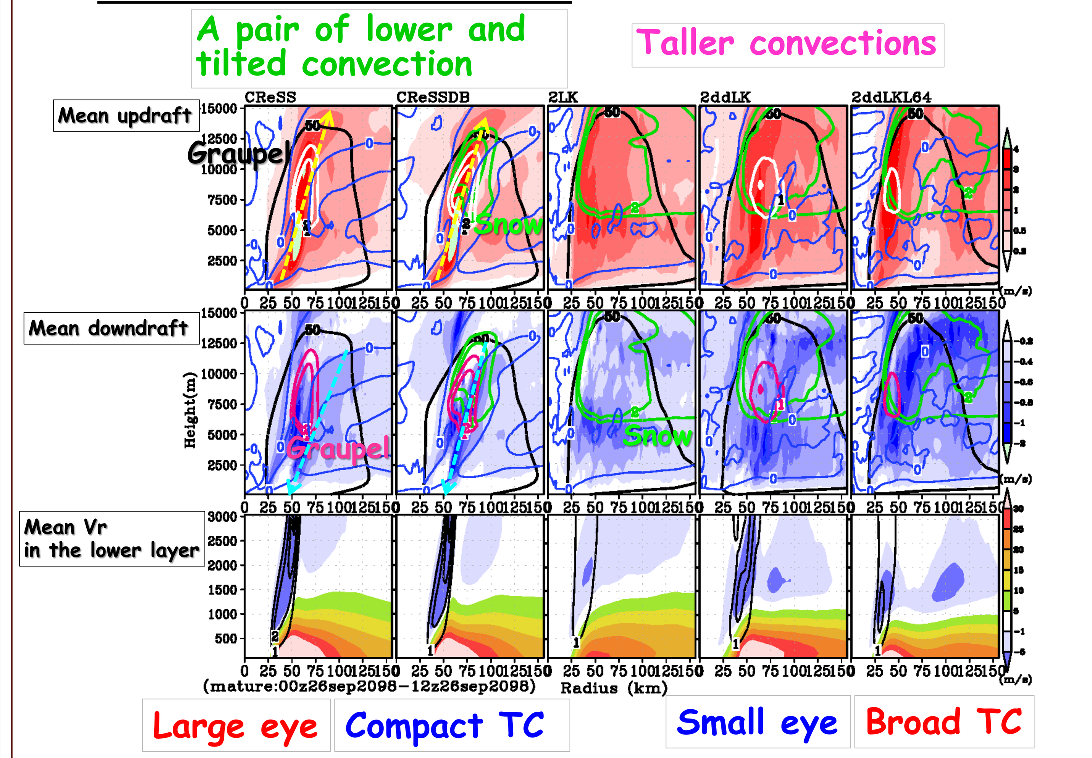


v) Mature stage

- ***Hourly precipitation***



- ***Vertical cross-sections***



5. Summaries

i) *In all experiments by NHM2s, TCs underwent RI.*

ii) *Cloud microphysics and ERC;*

- CReSS with a 1-moment microphysics: w/o ERC
- All experiments with a 2-moment microphysics: with ERC

iii) *Favorite situations for intense RI;*

- Tall and intense updraft, an axisymmetric small eyewall and shallower inflow boundary layer with intense near-surface inflow.

iv) *Cloud microphysics and the horizontal scale;*

- Graupel-dominant experiments (CReSSs): A compact TC with large eye.
- Snow-dominant experiments (JMANHMs): A broad TC with small eye.

!! The cloud microphysics and PBL processes are closely related to the inner-core structures and evolutions of simulated extremely intense TCs.

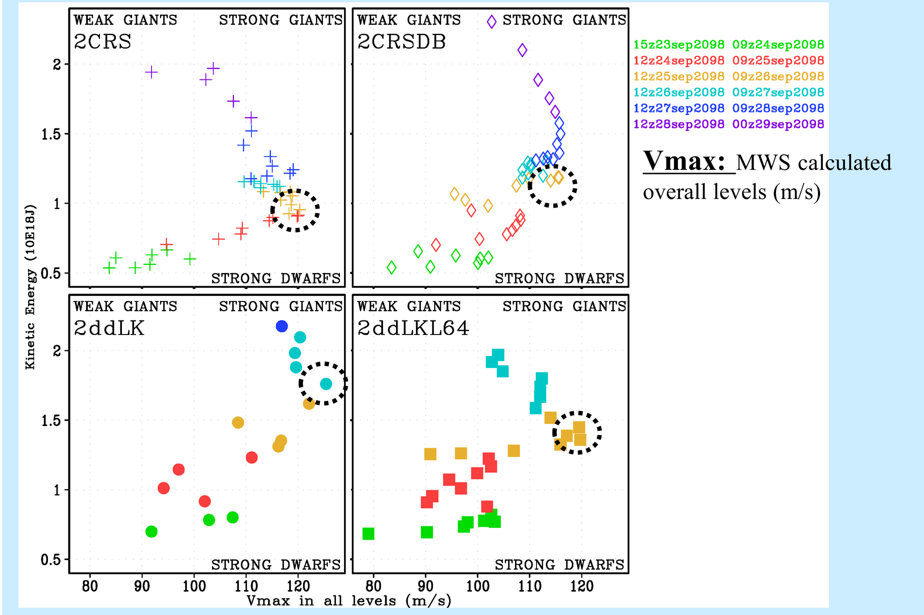
!! Even TCs with similar MCP or MWS, the characteristics of the TCs (including the inner-core and horizontal expansions) differed among NHMs

Issues to be solved in the future

- **RI or not**: Why can only NHM2kms realize RI? *i.e.* the processes or structures for RI that only NHM2kms can represent [AGCM20 vs NHM2kms]
- **Favorite conditions for intense RI:** Relationship between RI and the inner-core structures (e.g. tall and intense updraft around the eye, an axisymmetric small eyewall and shallower inflow boundary layer with intense near-surface inflow) [CReSS vs JMANHM]

Appendix

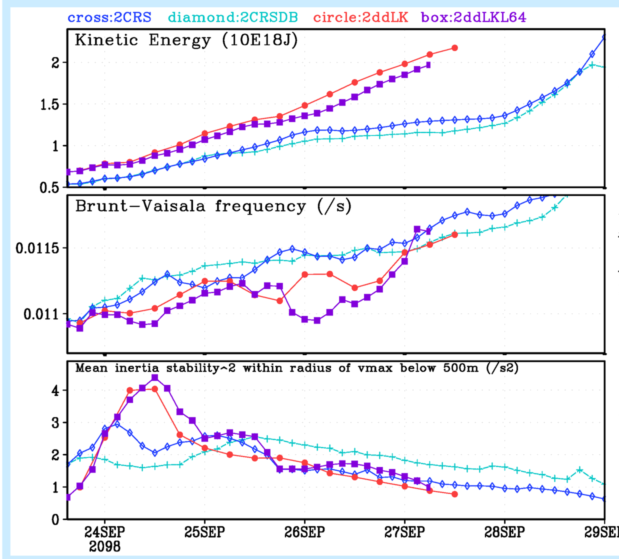
- ***K-Vmax diagram***



Vmax: MWS calculated overall levels (m/s)

2CRS: A strong and compact TC at its mature stage
2ddLK: A strong and broad (large) TC at its mature stage

- ***Time variations of K_E, N and I^2***



Total kinetic energy (K_E) within R < 800km (10E18J)
JMANHMs > CReSSs
(broad vs compact TCs?)

Mean Brunt-Vaisala frequency (N) within R < 800km (/s)
CReSSs > JMANHMs

Mean inertia stability (I^2) within radius of Vmax below 500m (/s^2)
JMANHMs > CReSSs

Larger N (vertical stability) with smaller (I^2) in CReSS experiments (2CRS and 2CRSDB) could be related to lower and tilted convection (larger eye) ?