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Rapid Intensification of Tropical Cyclones in the Northwestern Pacific Ocean

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AMS 32th Hurricane and Tropical Meteorology

Motivation

RI →

- Holliday and Thompson (1979) : $\Delta_{24}P_{min} \leq$-42 hPa/day
- Kaplan and DeMaria (2003) : $\Delta_{24}V_{max} \geq$ 30 knots/day

Q1: Whether all the rapid intensification progress in WNP satisfied with these two definitions?

Q2: Which factors would affect the asynchronous change in V_{max} and P_{min}?

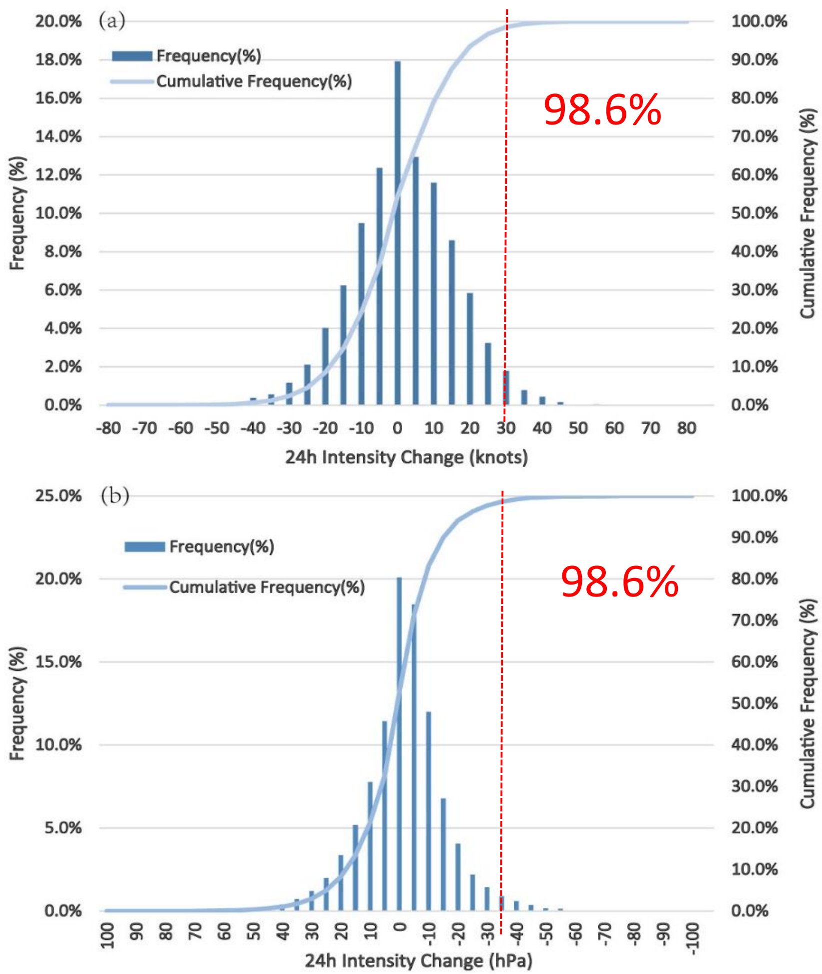
- JMA best-track dataset
- TBB data
- ECMWF reanalysis data

→ The feature of the V_{max} *and* P_{min} change in WNP from 1980 to 2013

The definition of the Rapid Intensification (RI)

Maximum wind speed

Central surface pressure



RI is defined as the 98.6% percentile of both $\Delta_{24}V_{max}$ and $\Delta_{24}P_{min}$ for all of the cases, that is

$$\Delta_{24}V_{max} \geq 30\text{knots/day}$$

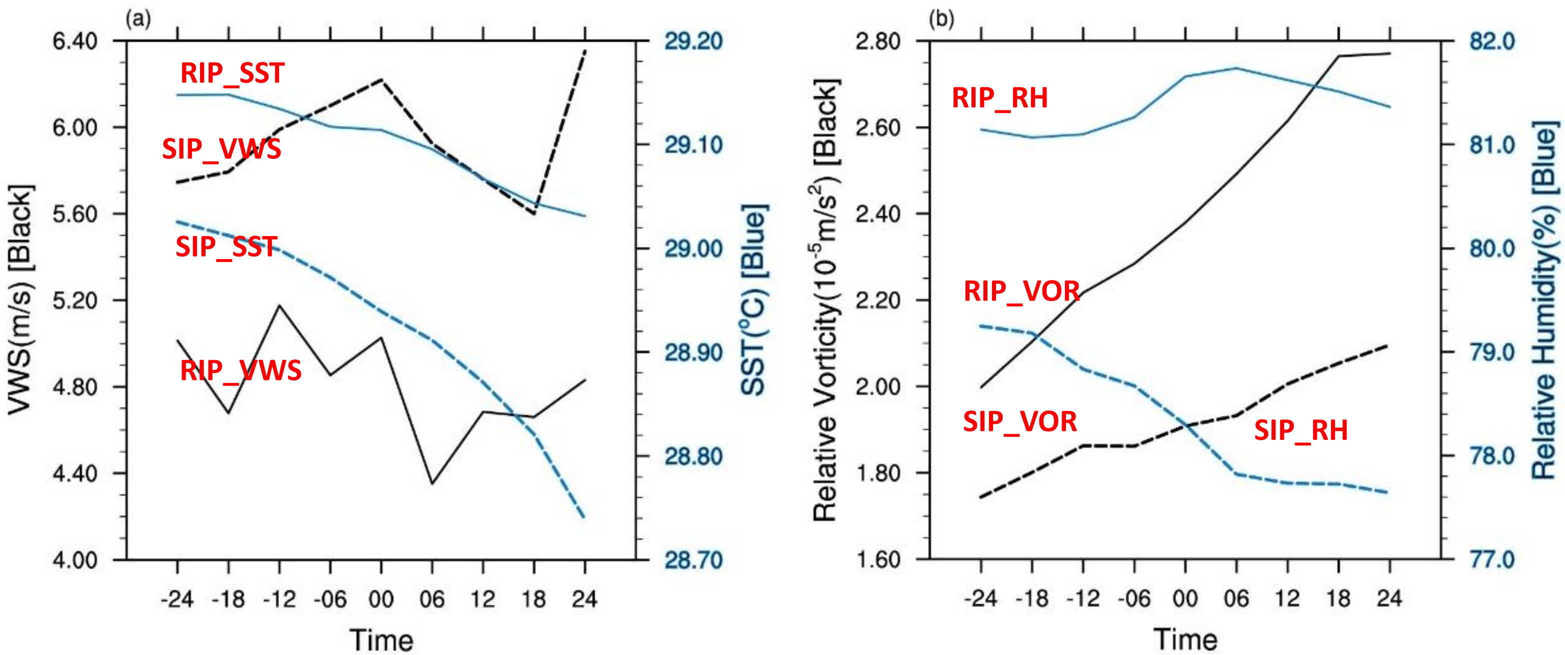
$$\Delta_{24}P_{min} \leq -35\text{hPa/day}$$

-JMA best-track data from 1980-2013

Characteristics of the TCs satisfying with two thresholds

	$\Delta V_{24} \geq 30\text{knots/day}$		$\Delta P_{24} \leq -35\text{hPa/day}$	
Number	185		170	
Ratio（/868）	21.3%		19.6%	
	SIP $\Delta P_{24} > -35\text{hPa/day}$	**RIP** $\Delta P_{24} \leq -35\text{hPa/day}$	$\Delta V_{24} \geq 30\text{knots/day}$	$\Delta V_{24} < 30\text{knots/day}$
Number	51	134	134	36
Ratio（/221）	23.1%	60.6%	60.6%	16.3%
Average Latitude	15.97°N	14.61°N	14.61°N	14.87°N
Average Longitude	134.93°E	140.13°E	140.13°E	141.82°E

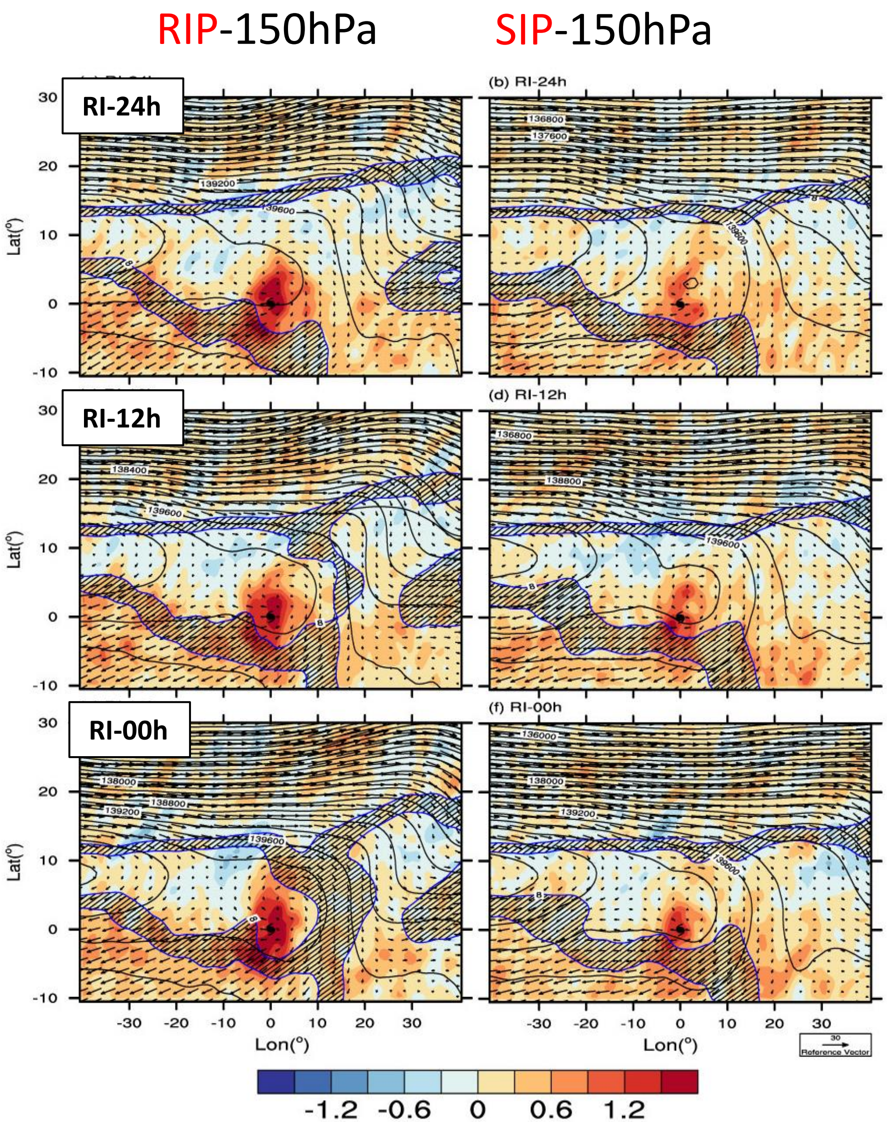
Characteristics of synoptic environment



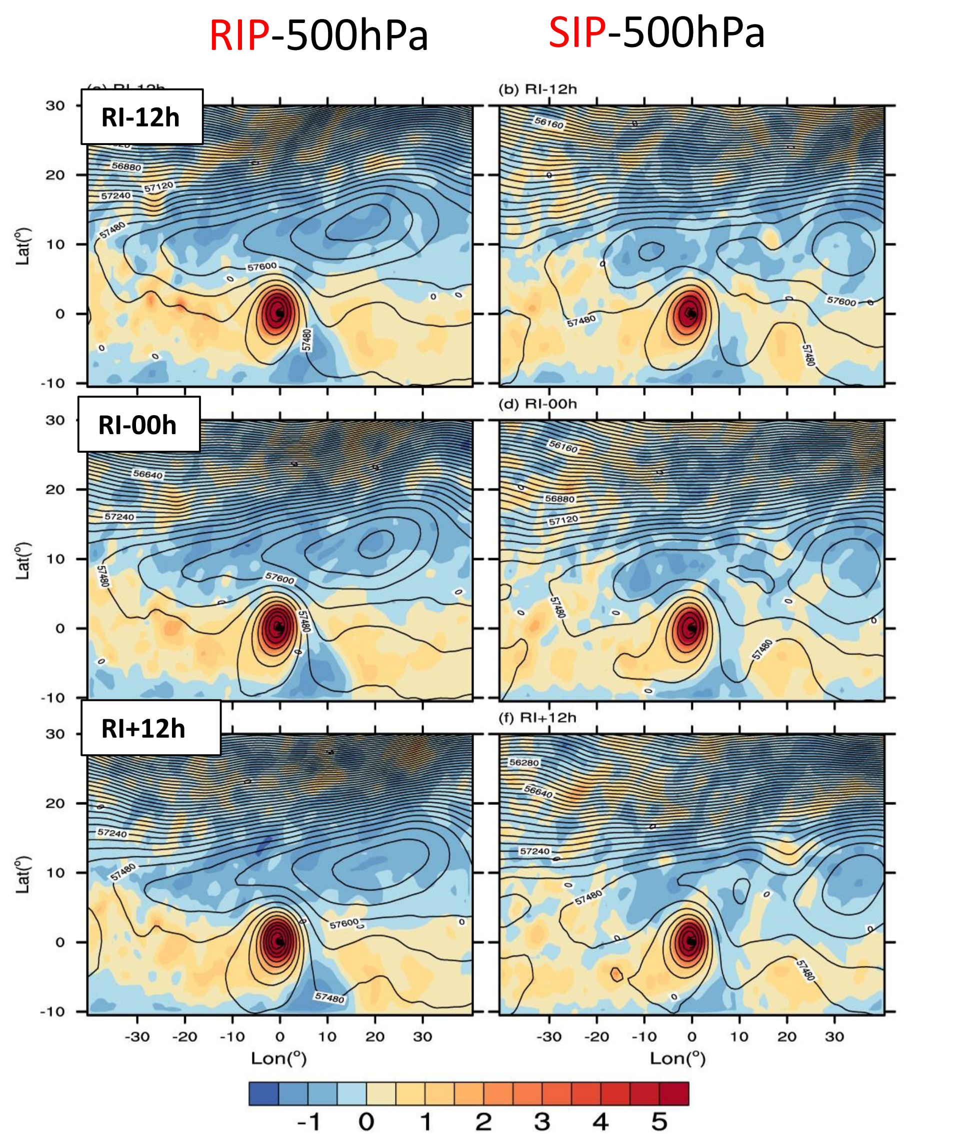
The time series of the 10.5° × 10.5° regional mean 850-200hPa VWS, SST, 850-hPa relative vorticity and the 1000-500hPa relative humidity

31 cases for each group

	$\Delta_{24}P_{min}$ (hPa)	$\Delta_{24}V_{max}$ (kt)	Pressure (hPa)	30kt radius (km)	Lat (°N)	Lon (°E)
RIP group	-52.7	34.8	970	198.5	13.1	142.0
SIP group	-27.7	31.1	988	144.3	15.4	136.7



Contour: 150hPa geopotential height.
Vector: 150hPa wind
Shade: the wind speed between 8 to 12m/s
Color: divergence



Contour: 500hPa geopotential height
Color: 850hPa relative vorticity

RIP SIP

500hPa

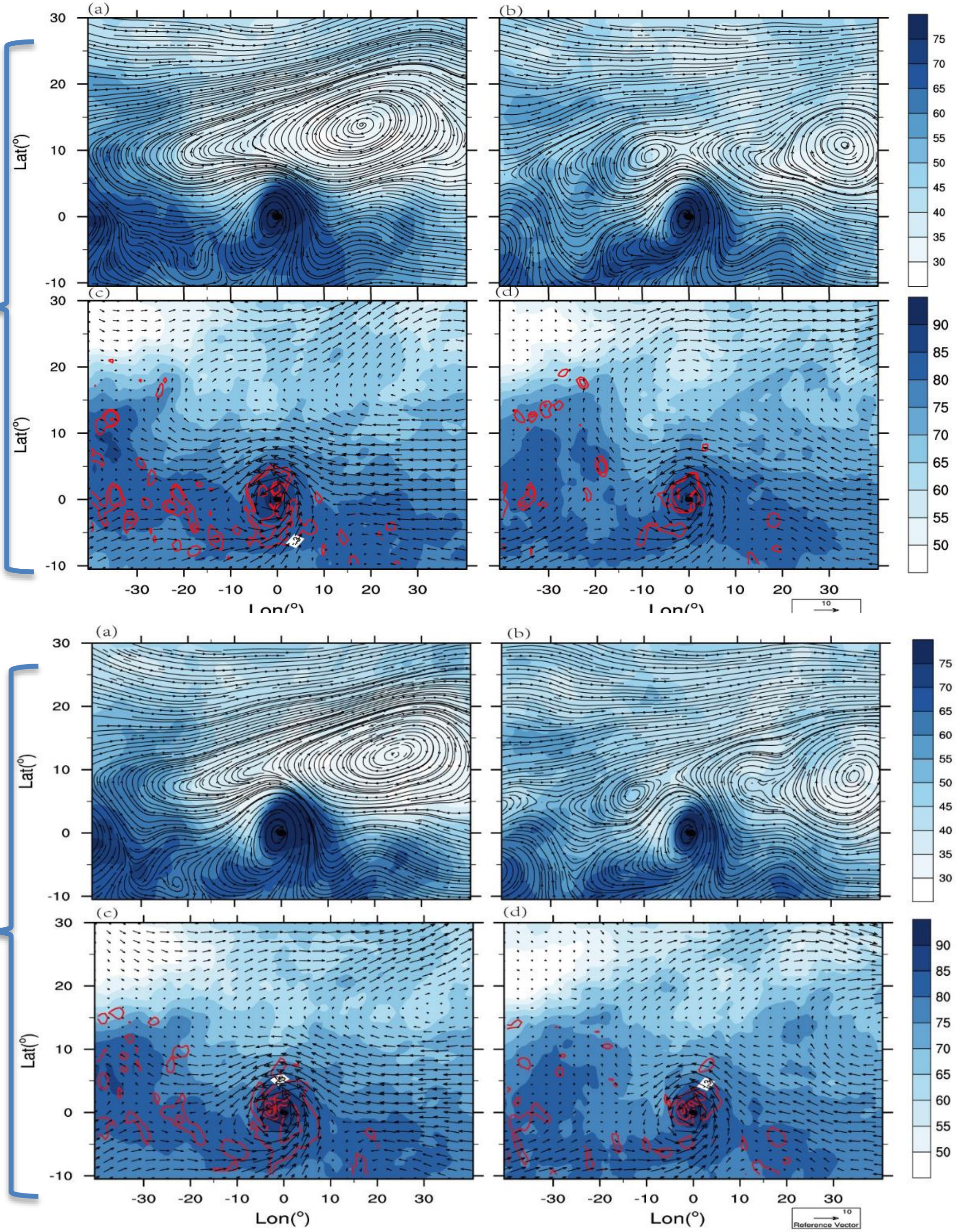
pre-RI

850hPa

500hPa

RI

850hPa



500-hPa streamlines

Color: 500hPa the relative humidity

Vector: 850-hPa wind field

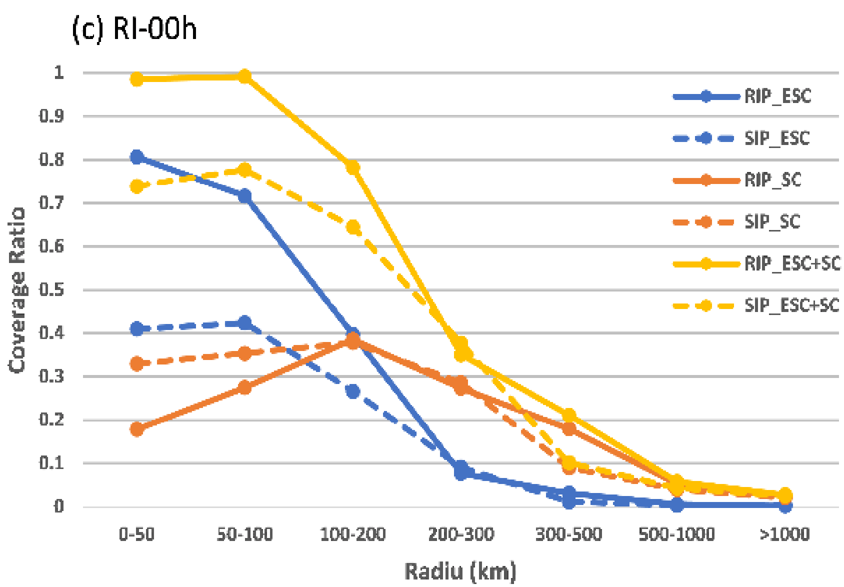
Color: 850hPa the relative humidity

Red Contour: the convergence of the water vapor flux

RIP:

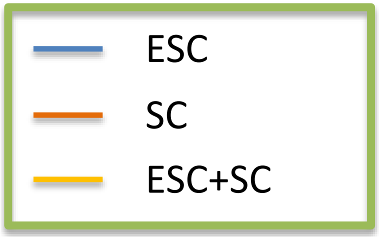
- The moisture condition on the south side of the TCs was more sufficient
- The coverage of the moisture convergence in the north and south side of the TCs was larger

Convective feature of the TCs

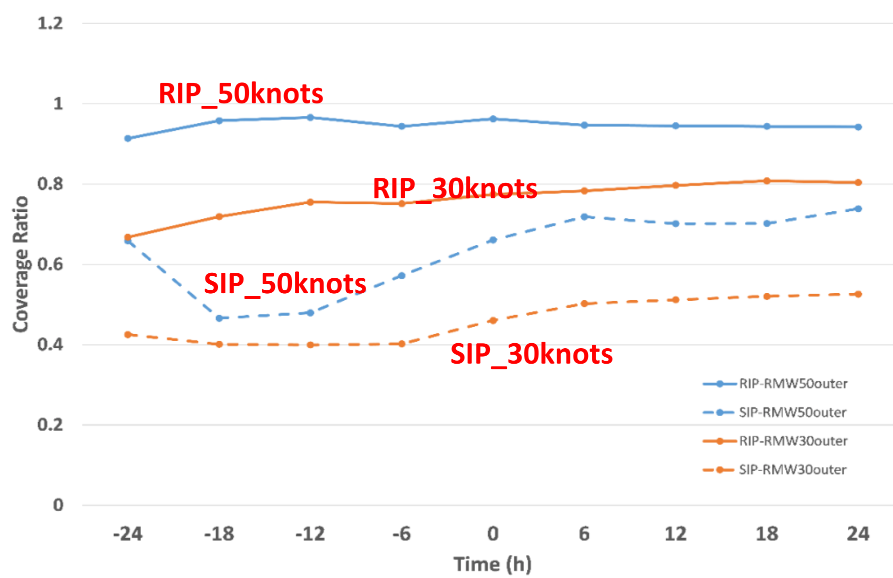


Strong convection (SC) - 5% CDF (214.7K)

Extremely strong convection (ESC) - 1% CDF (199.3K)



- **The strong convection of TCs in RIP group exhibited nearly symmetric distribution in the inner-core area**



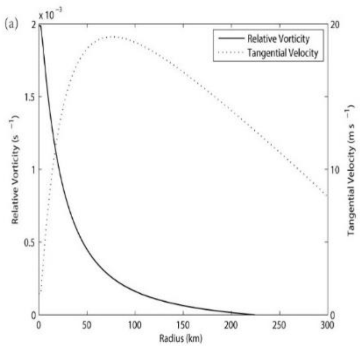
The time series of convective coverage ratio

- The 24-h changes of V_{max} *and* P_{min} could be asynchronous in the RI processes in Northwestern Pacific Ocean.

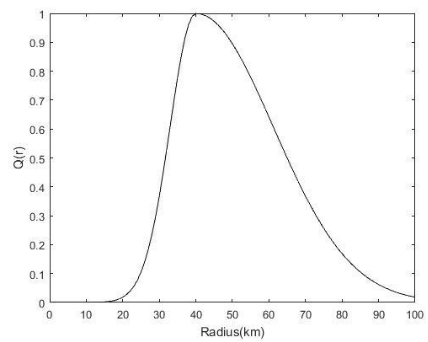
- Possible reasons:
  - **Symmetric or Asymmetric heating**
  - **Strength of diabatic heating**
  - **Initial vortex strength**
  - **Initial vortex size**
  - **Coriolis force**

The dry idealized simulation

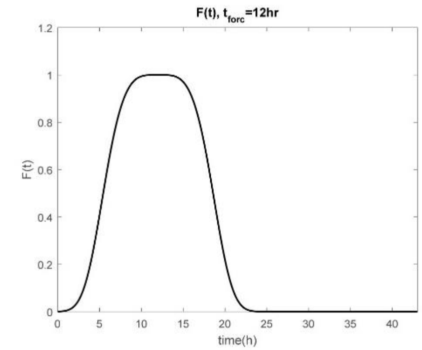
Initial vortex



Radial distribution of the heating



Time evolution of the heating



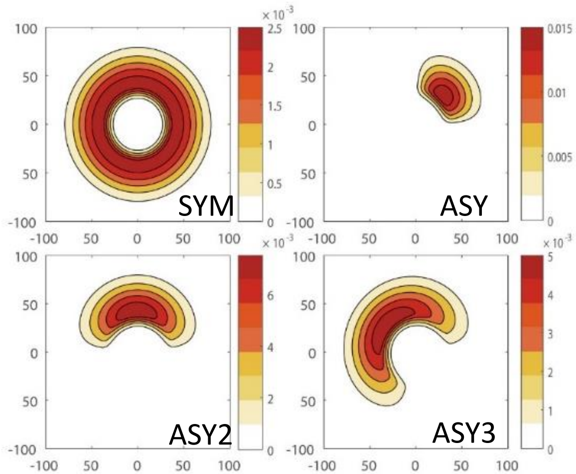
	Heating structure	Qmax	Initial Vmax	Initial 15m/s radius	f
Ctrl	SYM	10	20m/s	182km	5.0E-5
A	ASY	10	20m/s	182km	5.0E-5
B	SYM	{var}	20m/s	182km	5.0E-5
C	SYM	10	{var}	182km	5.0E-5
D	SYM	10	20m/s	{var}	5.0E-5
E	SYM	10	20m/s	182km	{var}

Model Parameters:

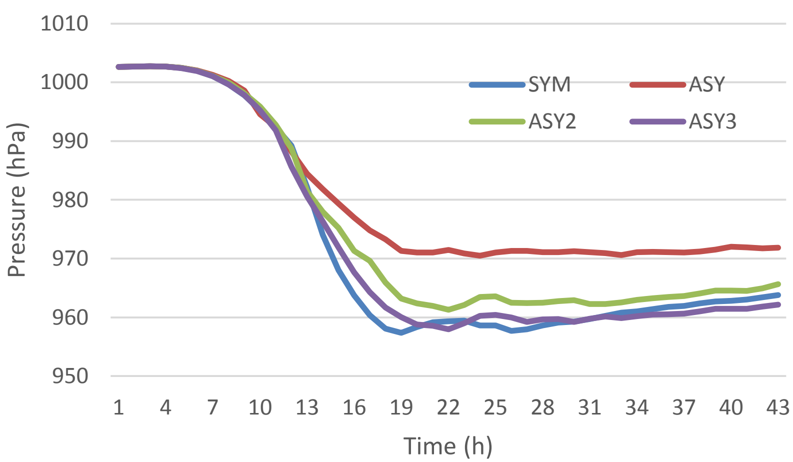
- WRF 3.6
- 35 vertical levels
- 900 × 900 grid points
- Horizontal resolution: 2km
- No boundary layer scheme & microphysics parameterization

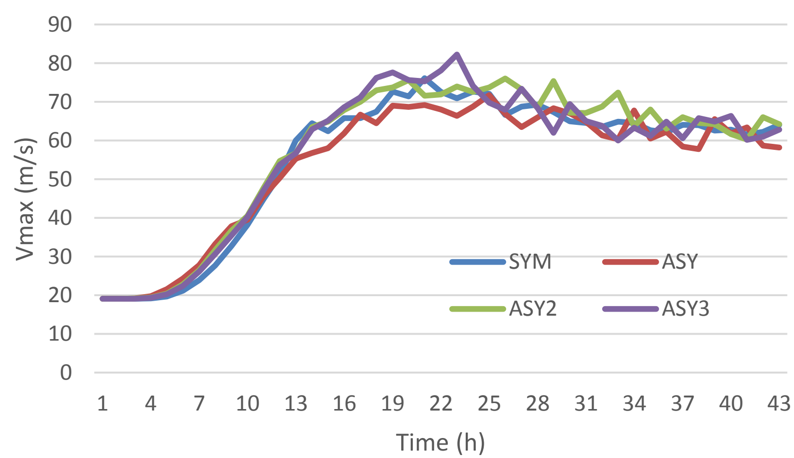
A

Different horizontal structure of heating



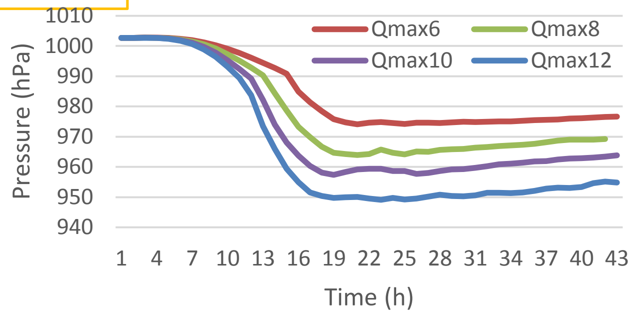
	SYM	ASY	ASY2	ASY3	Difference
ΔP_{24}	-43.97	-31.58	-39.04	-42.19	12.39
ΔV_{24}	53.00	52.68	54.67	50.67	2.33

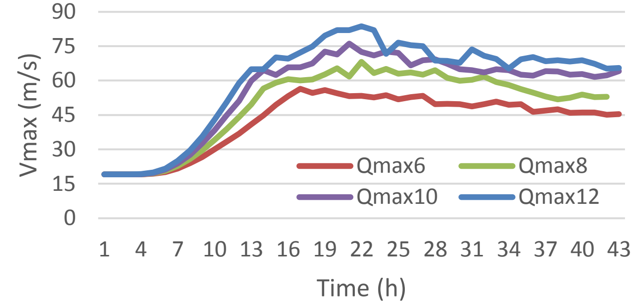




B Different strength of heating

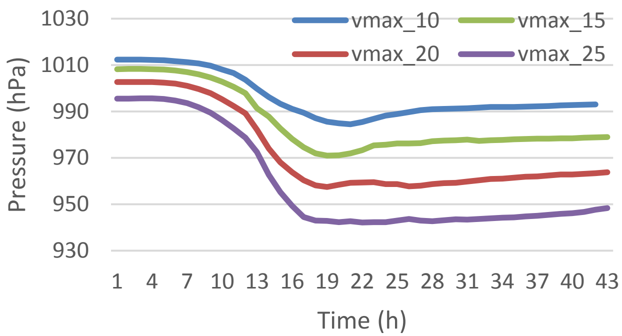
Qmax	6	8	10	12	Difference
ΔP_{24}	−28. 39	−38. 42	−43. 97	−53. 35	24. 96
ΔV_{24}	32. 72	43. 93	53. 00	57. 40	24. 68

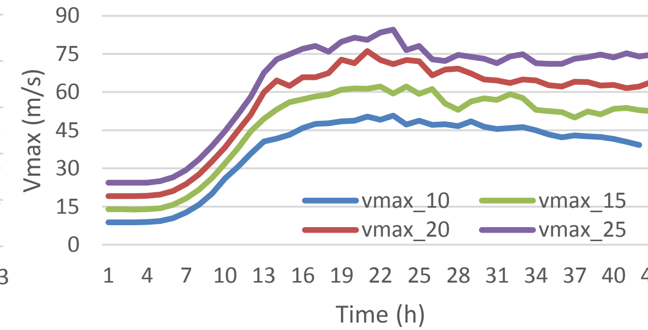




C Different initial V_{max}

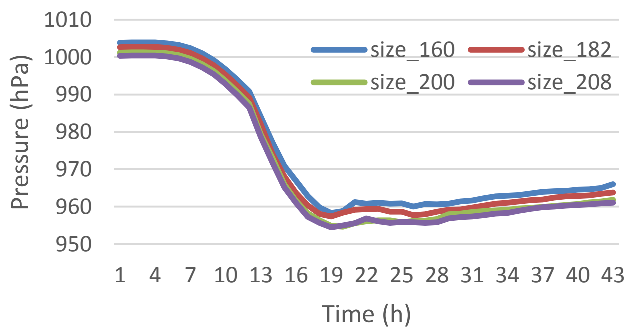
Vmax	10	15	20	25	Difference
ΔP_{24}	−23. 37	−32. 11	−43. 97	−52. 60	29. 23
ΔV_{24}	39. 90	45. 35	53. 00	53. 78	13. 88

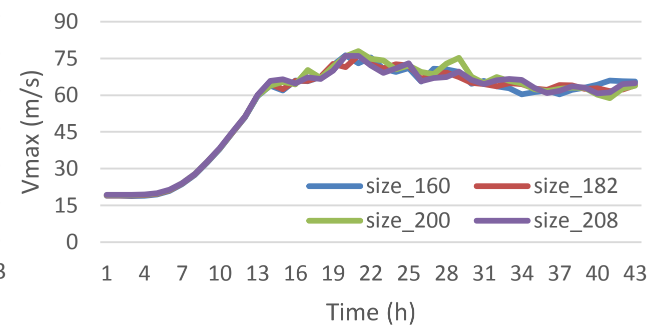




D Different initial size

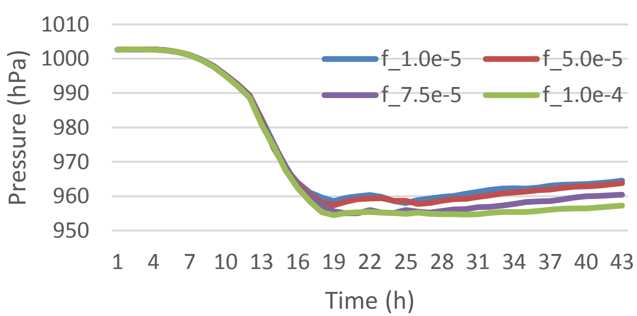
15m/s radius	160	182	200	208	Difference
ΔP_{24}	−42. 97	−43. 97	−45. 31	−44. 41	2. 34
ΔV_{24}	52. 11	53. 00	52. 87	53. 76	1. 65

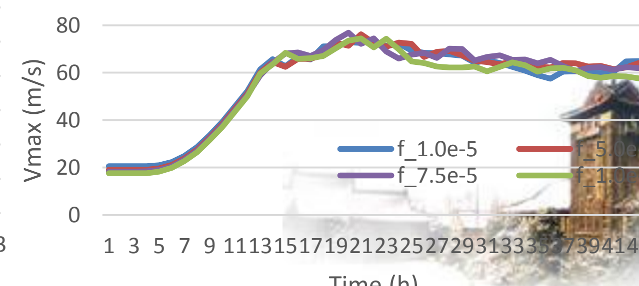




E Different f

f	1e-5	5e-5	7.5e-5	1e-4	Difference
ΔP_{24}	−44. 62	−43. 97	−46. 59	−47. 75	3. 13
ΔV_{24}	48. 72	53. 00	49. 32	47. 12	5. 88





Conclusion Remarks

- ✓ The 24-h changes of V_{max} and P_{min} could be asynchronous in the RI processes in Northwestern Pacific Ocean.

- ✓ The synoptic environment of RI with rapid change in P_{min} (RIP group):
  - "dual-channel outflow"
  - Strong western Pacific subtropical high
  - Sufficient low-to-mid moisture
  - Small vertical wind shear

  The favorable synoptic factors lead to more symmetric and stronger convection in inner-core of TCs.

- ✓ The asymmetric structure of inner-core convection and the initial vortex intensity could affect the asynchronous variations of P_{min} and V_{max} in TCs.

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Thank you !!!