Interannual and Interdecadal Variations of Tropical Cyclone Activity in the South China Sea

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Introduction

- Tropical Cyclones (TCs)
  - Storms with wind speeds > 40 km/h
  - Typical occurrences: May to October
  - Areas of interest:
    - Western North Pacific (WNP) (West of 180^o)
    - South China Sea (SCS) (0^o to 25^o N, 100^o to 120^o E)
- TCs in WNP
  - Occurrences affected by El-Niño Southern Oscillation (ENSO)
  - Interdecadal and interannual variations observed

Introduction

- Factors Affecting Cyclogenesis (Gray 1979)*
  - 850mb Vorticity
  - Vertical Shear of Horizontal Wind
  - Sea Surface Temperature
  - Coriolis Parameter
  - Mid-level Moisture
  - Low- to Mid-level Moist Instability

* GRAY, W.M. 1979: **Hurricanes: Their formation, structure and likely role in the tropical circulation.** *Meteorology Over Tropical Oceans. D. B. Shaw (Ed.), Roy. Meteor. Soc., James Glaisher House, Grenville Place, Bracknell, Berkshire, RG12 1BX,* pp.155-218

Introduction

- Factors Affecting Movement
  - 500mb Height Gradient
  - 500mb Wind

- TCs inside SCS
  - Formed in SCS
    - Depends on the conditions in SCS?
  - Entered SCS
    - Formed in the WNP and then moved in?

Objectives

- To study the variations in number of TCs inside the SCS;
- To determine the factors leading to changes in the frequency of TC occurrences in the SCS;
- To decide if and how large-scale atmospheric phenomena can have an effect on the factors affecting TC behaviour

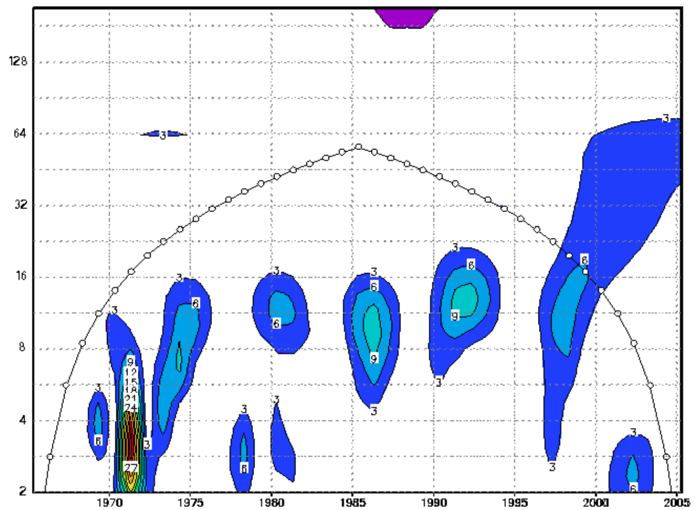
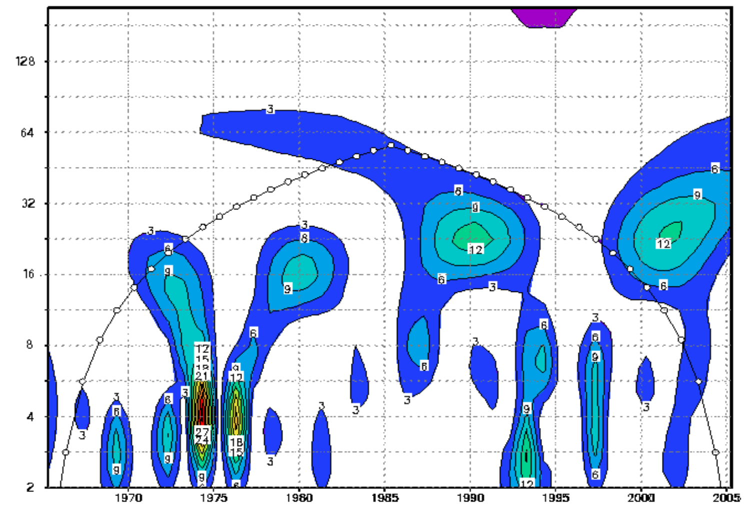
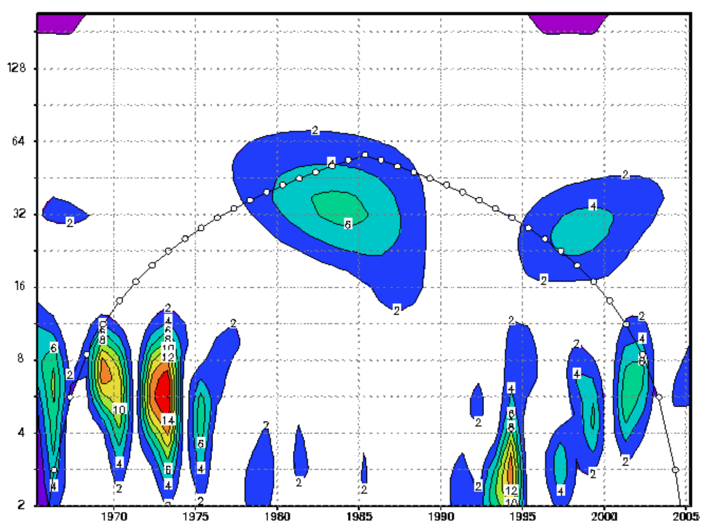
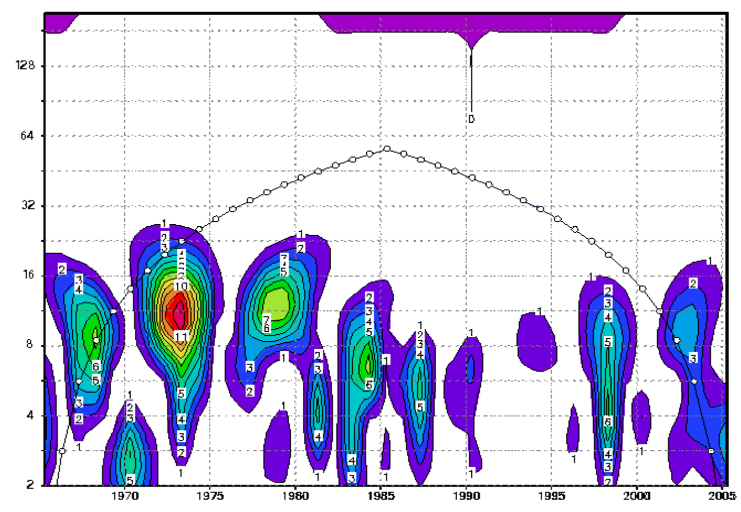
TC Data

- Hong Kong Observatory TC data from 1946 to 2005 (60 years)
- Only those after 1965 used (41 years)
- Only those with at least tropical storm strength (max winds >65 km/h) used
- Season divided into 2 halves
  - 1st: May to August
  - 2nd: September to December
- TCs can enter SCS from WNP (ENT) or formed inside SCS (FORM)

Flow Pattern Data

- NCEP Reanalysis data starting from 1965
- Parameters studied:
  - 850-hPa vorticity
  - 850-hPa height
  - 200-hPa – 850-hPa wind shear
  - 200-hPa divergence
  - 500-hPa height
  - Moist static energy
  - 500-hPa u-wind
- May to December, divided into 2 seasons
- Anomalies, EOF calculated

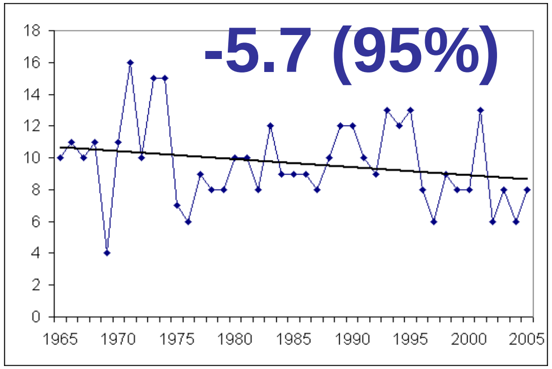
Wavelet Analysis

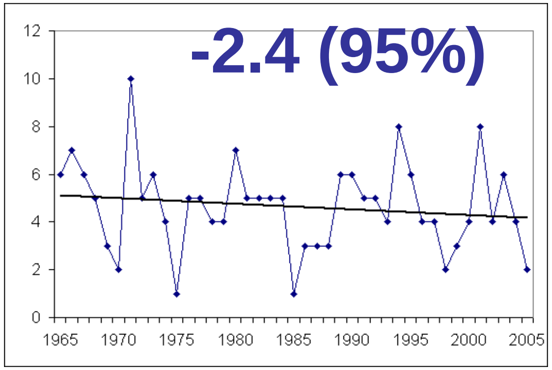
	EARLY	LATE
ENT		
FORM		

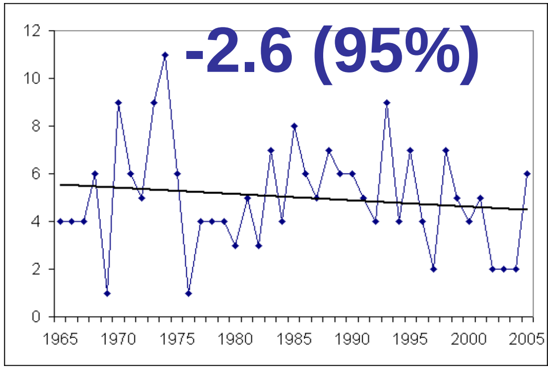
TC Trends (per 100 years)

WHOLE | EARLY | LATE

TOT







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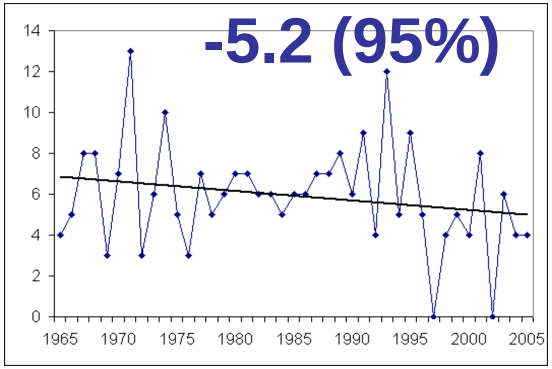

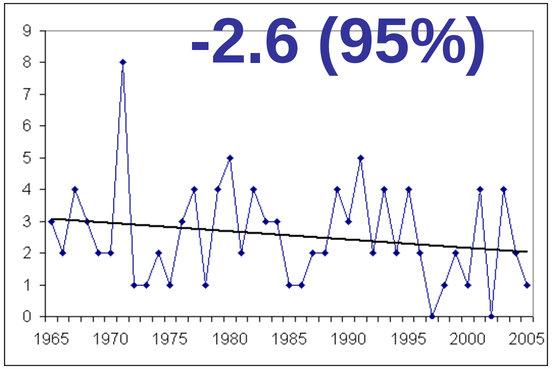

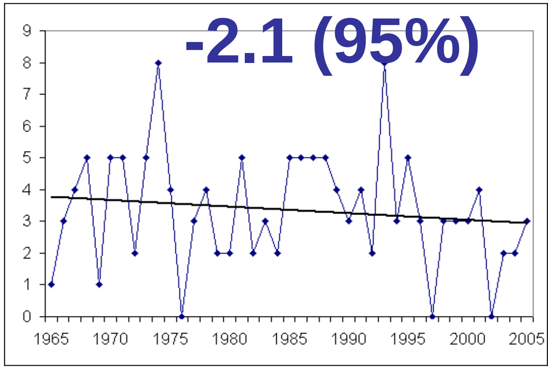

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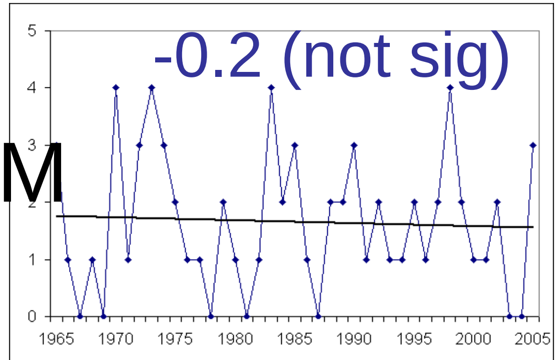
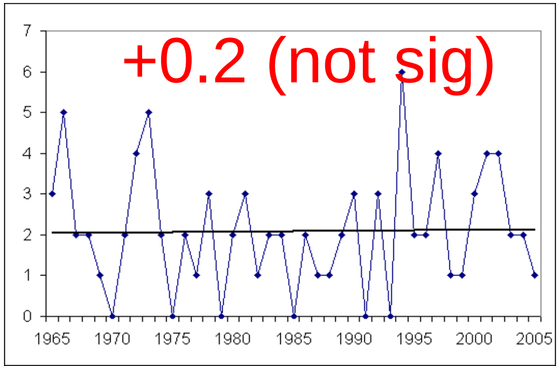
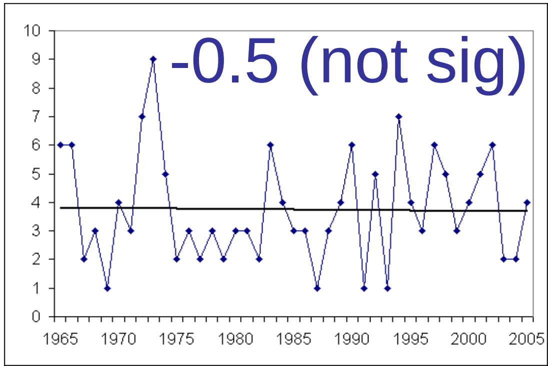






Effect of ENSO

Above/ Below	EN (12 events)			LN (10 events)		
	Whole	Early	Late	Whole	Early	Late
TOT	1/5	2/1	**0/5**	5/1	3/3	**7/0**
ENT	3/6	3/4	**2/8**	4/2	2/3	**5/1**
FORM	5/4	5/3	**2/1**	4/1	2/3	**5/1**

- Effect more prominent in late season
  - Due to ENSO peaking in winter
- Effect on ENT apparently more significant than on FORM

Effect of PDO

Above/ Below	PDO+ (16 events)			PDO- (13 events)		
	Whole	Early	Late	Whole	Early	Late
TOT	4/7	3/4	**3/6**	7/1	6/5	**5/0**
ENT	4/5	6/4	**5/10**	4/2	2/3	**5/1**
FORM	4/6	3/6	**2/3**	5/1	7/5	**4/0**

- Effect more prominent in late season
  - Due to PDO peaking in winter
- Effect of PDO similar to that of ENSO
  - Due to possible forcing of PDO by ENSO forcing?

Stepwise Linear Regression

Late ENT (R=0.956)			Late FORM (R=0.955)		
Factor	% Var	Coeff	Factor	% Var	Coeff
500U1	26.72	+1.422	MSE2	13.04	+0.366
500H1	55.09	+1.333	500U1	26.72	+0.315
MSE3	10.37	+0.349	MSE1	35.18	+0.193
VOR2	13.98	+0.301	DIV1	32.17	-0.047
DIV3	11.03	+0.179	SHR3	13.16	-0.130
500H3	9.65	-0.448	DIV2	17.74	-0.188
500H2	19.22	-0.539	DIV3	11.03	-0.287
VOR1	17.08	-0.575	500U2	19.76	-0.387

- 500U: 500-hPa zonal wind, DIV: 200-hPa divergence, 500H: 500-hPa geopotential height, 850H: 850-hPa geopotential height, MSE: moist static energy, SHR: 200-850-hPa shear, and VOR: 850-hPa vorticity. The last number indicates the EOF, 1 for the first EOF, 2 for the second etc.

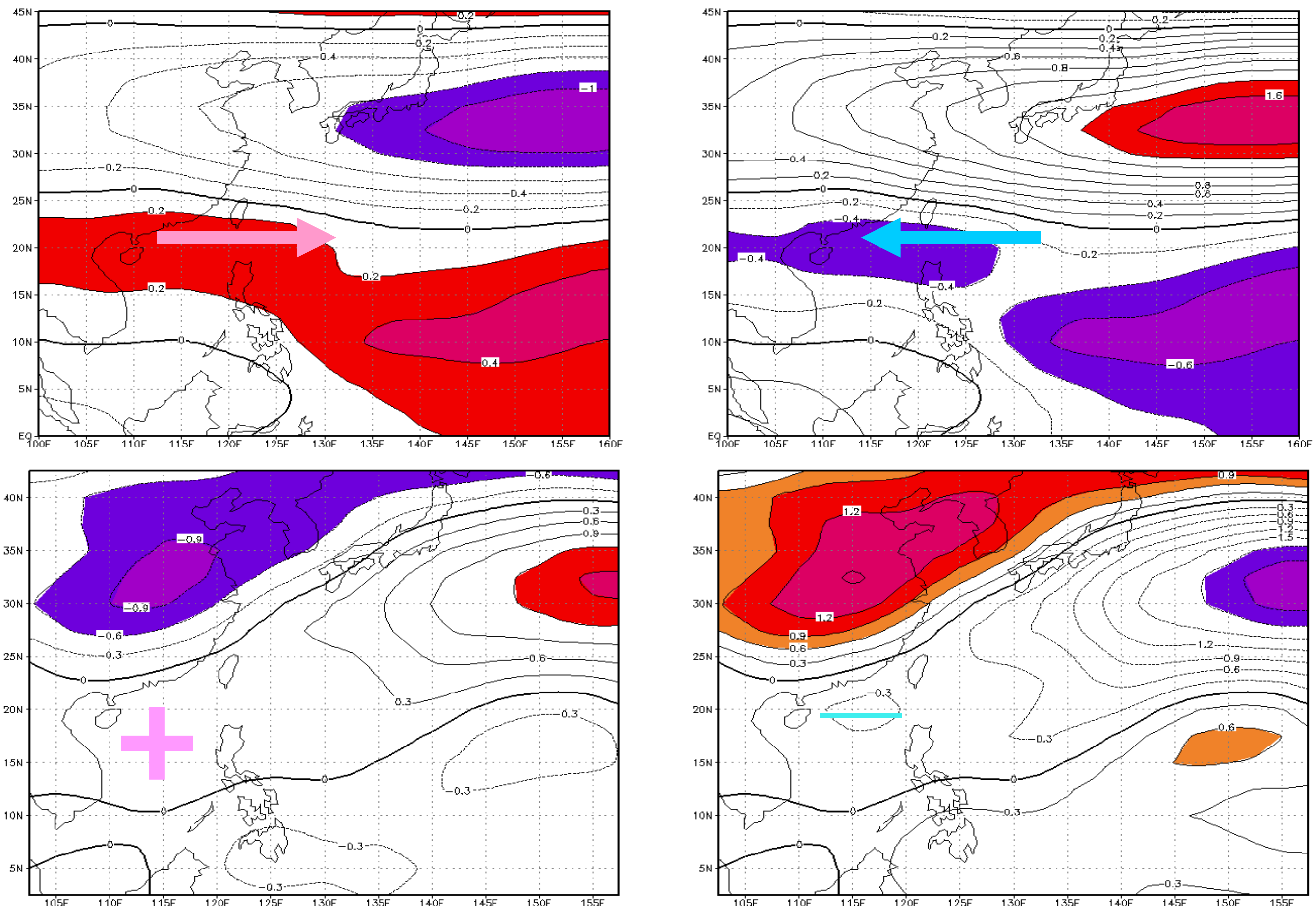
FORM in late season

FORM	EN (12 events)	LN (10 events)
Late	Above: 2, Below: 1	Above: 5, Below: 1

EN Composites **LN Composites**

500U1 (ms^{-1})

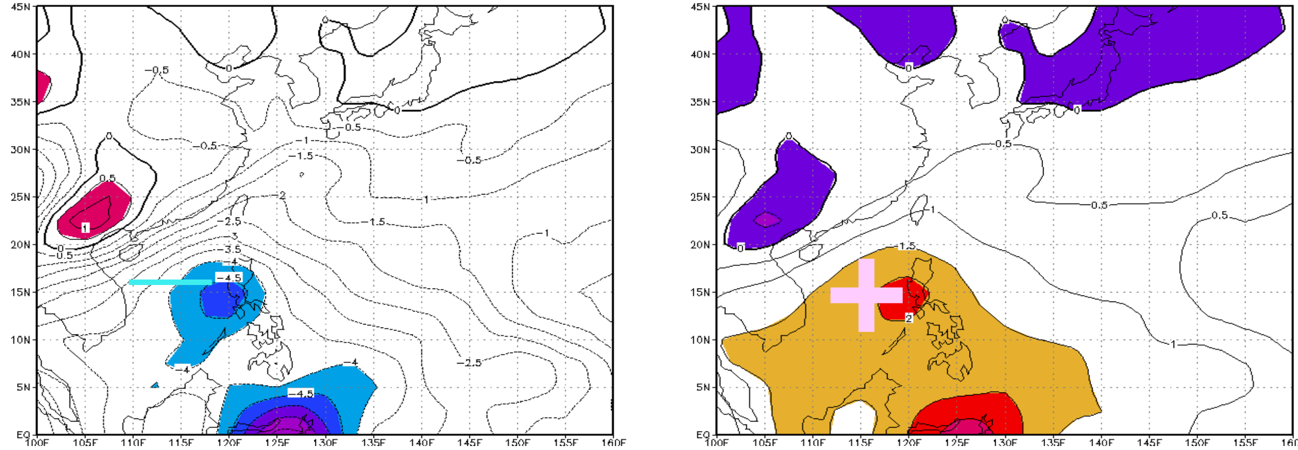
DIV3 ($\times 10^{-6}$ s^{-1})



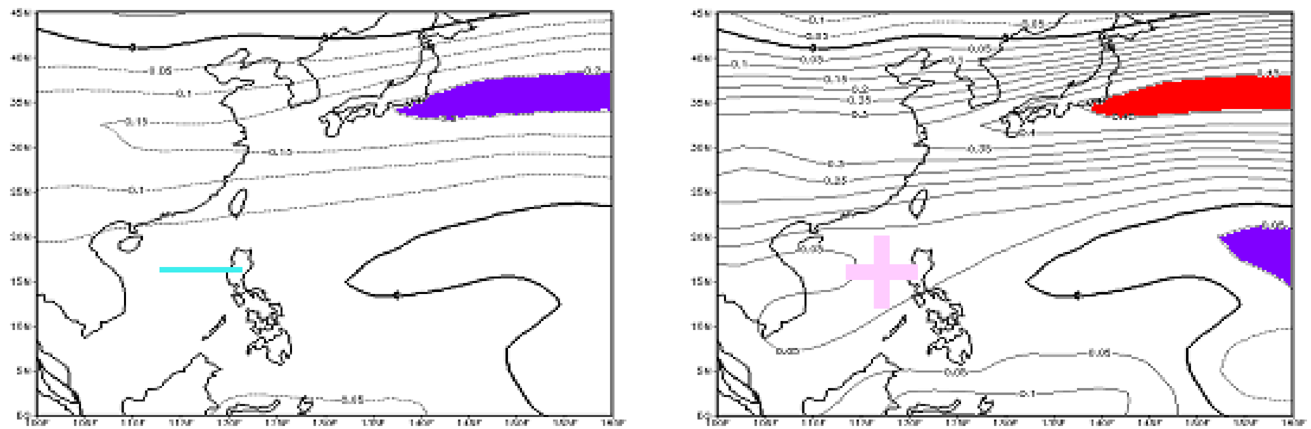
FORM in late season

EN Composites **LN Composites**

MSE1 ($\times 10^6$ Wm^{-2})



SHR3 (ms^{-1})



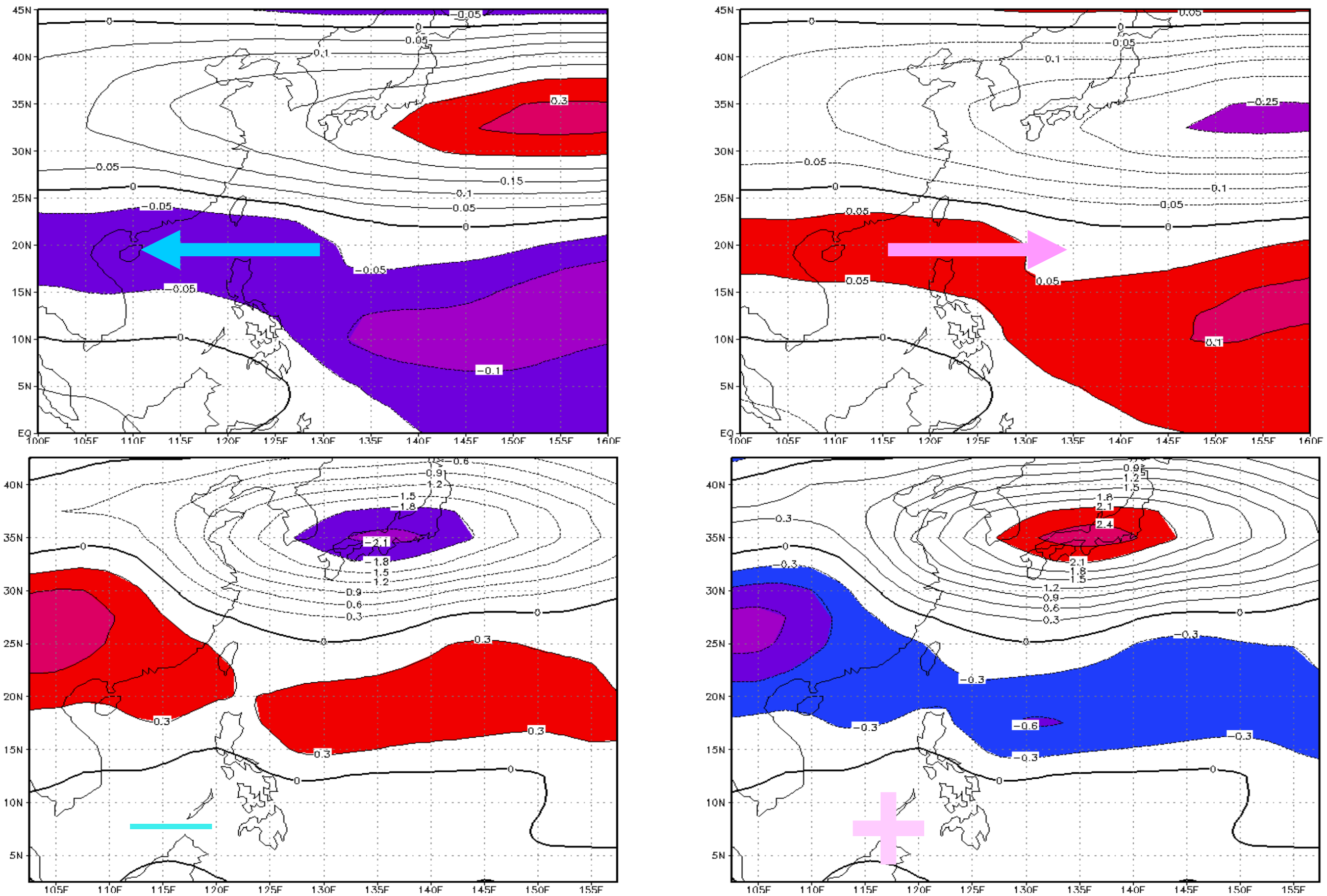
FORM in late season

FORM	PDO+ (16 events)	PDO- (13 events)
Late	Above: 2, Below: 3	Above: 4, Below: 0

PDO+ Composites **PDO- Composites**

500U1 (ms^{-1})

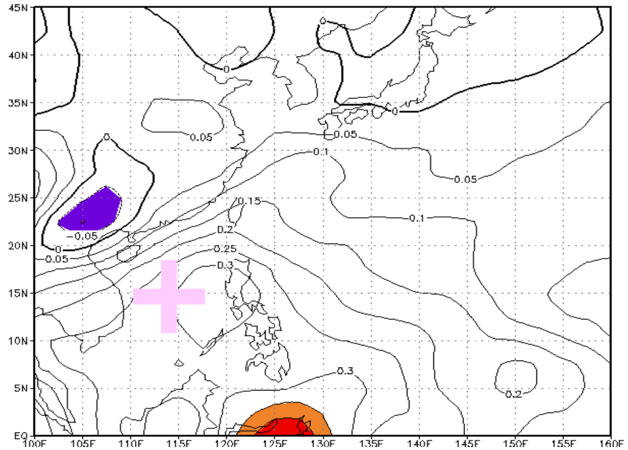
DIV2 ($\times 10^{-6}$ s^{-1})

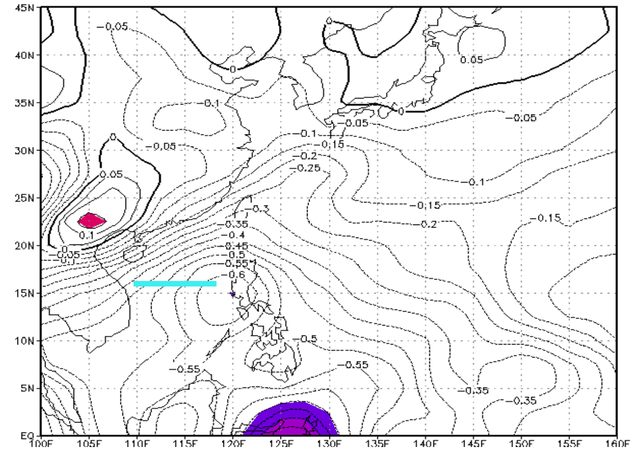


FORM in late season

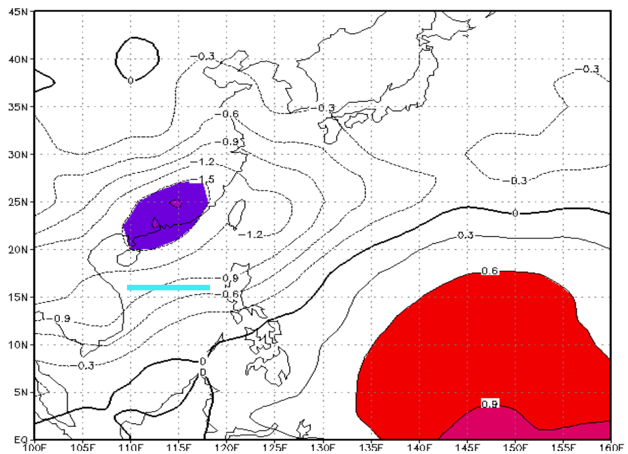
PDO+ Composites | **PDO- Composites**

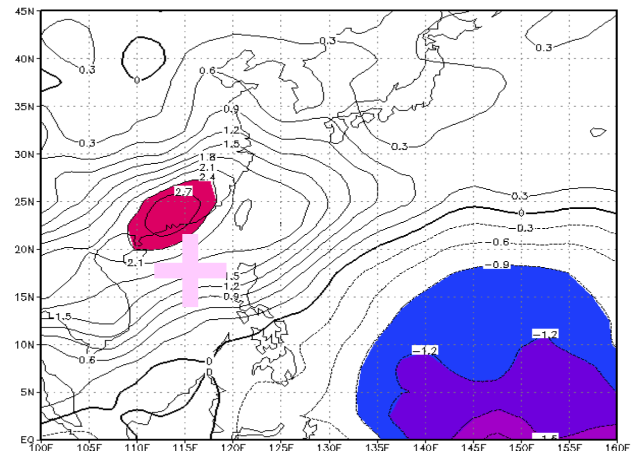
MSE1 ($\times 10^{6}$ Wm^{-2})





MSE2 ($\times 10^{6}$ Wm^{-2})



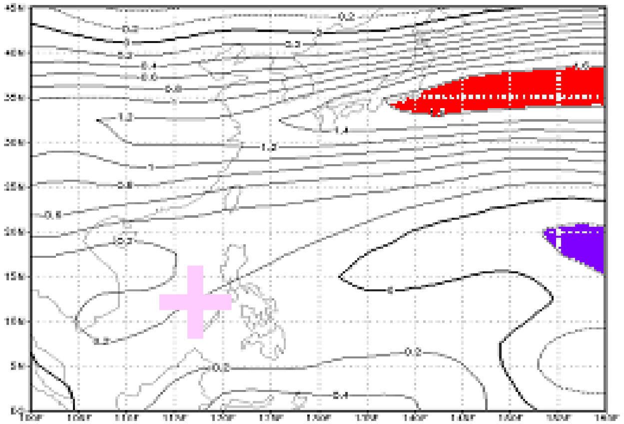


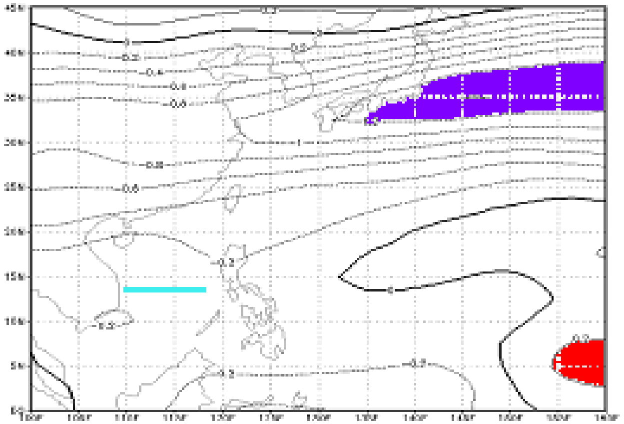
FORM in late season

PDO+ Composites

PDO- Composites

SHR3 (ms^{-1})



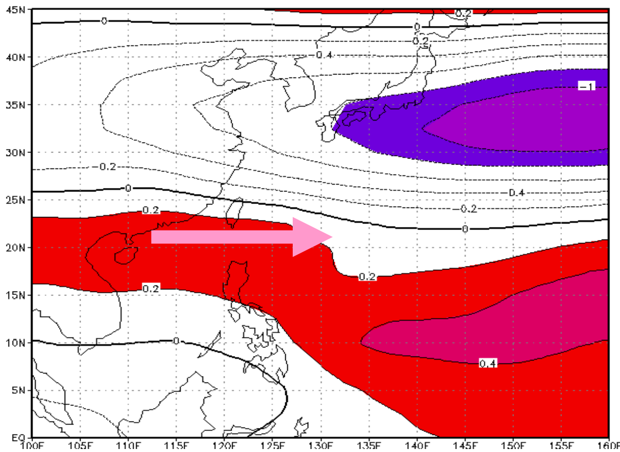


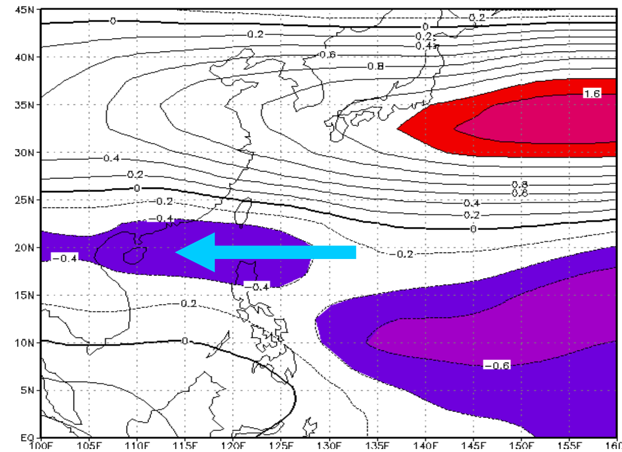
ENT in late season

ENT	EN (12 events)	LN (10 events)
Late	Above: 2, Below: 8	Above: 5, Below: 1

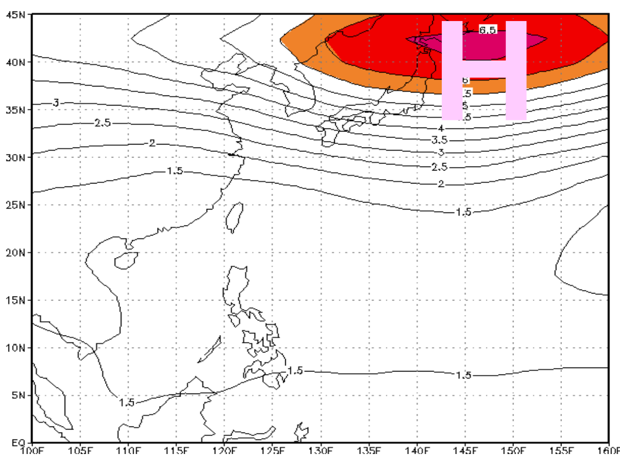
EN Composites | **LN Composites**

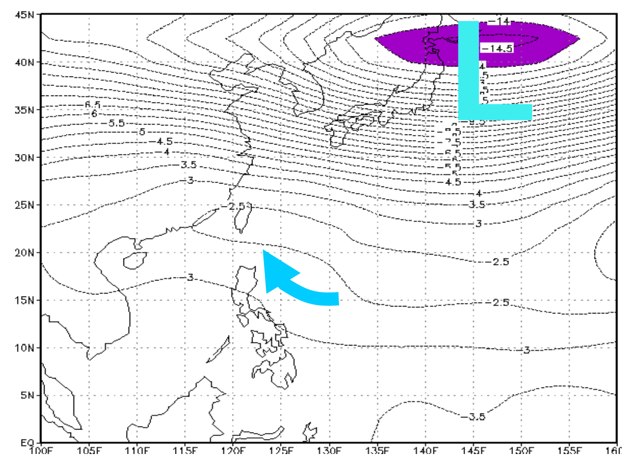
500U1 (ms^{-1})





500H1 (gpm)

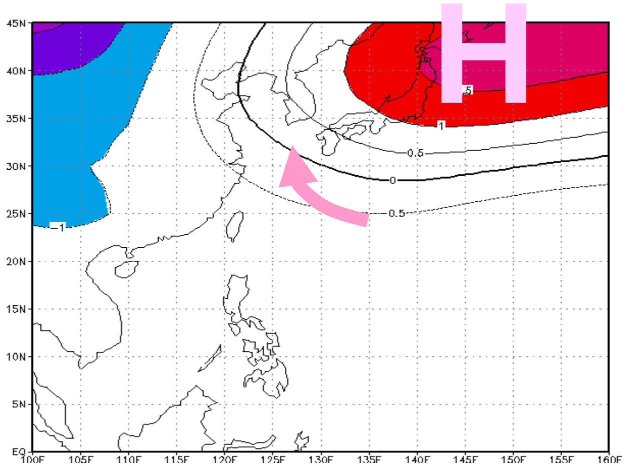


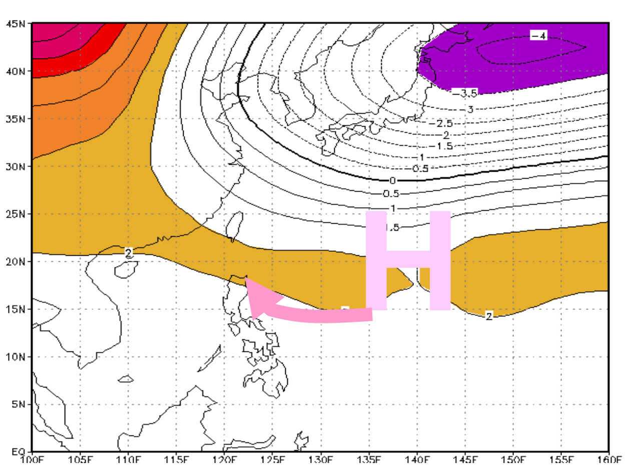


ENT in late season

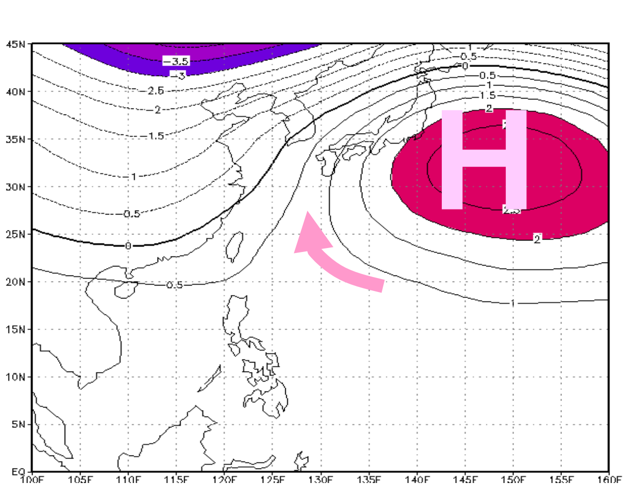
EN Composites | **LN Composites**

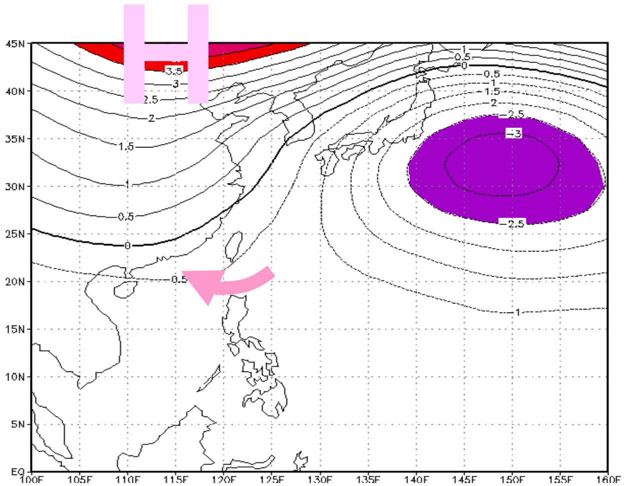
500H2 (gpm)





500H3 (gpm)

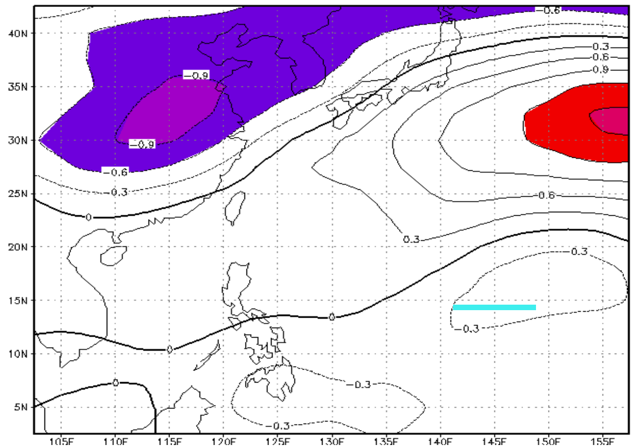


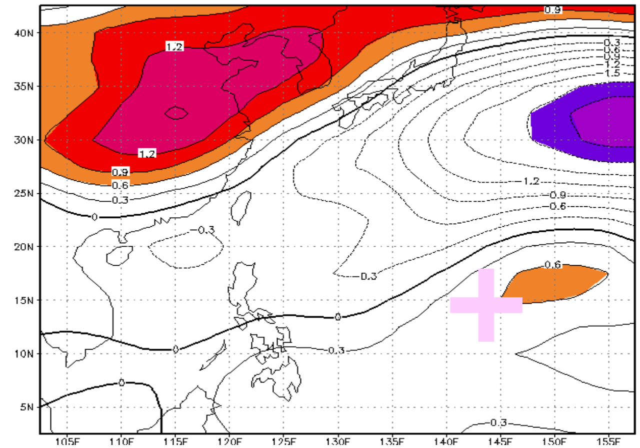


ENT in late season

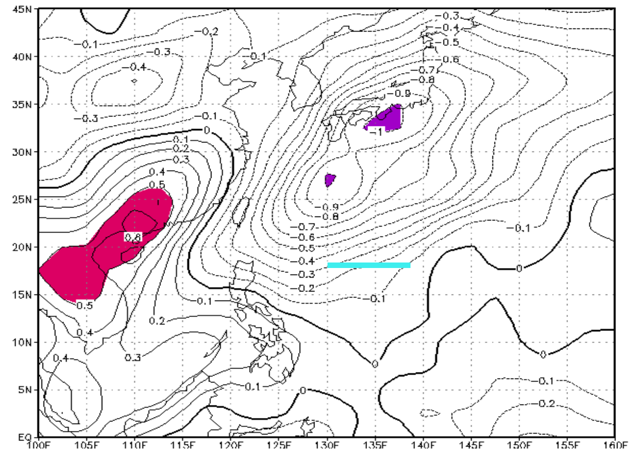
EN Composites **LN Composites**

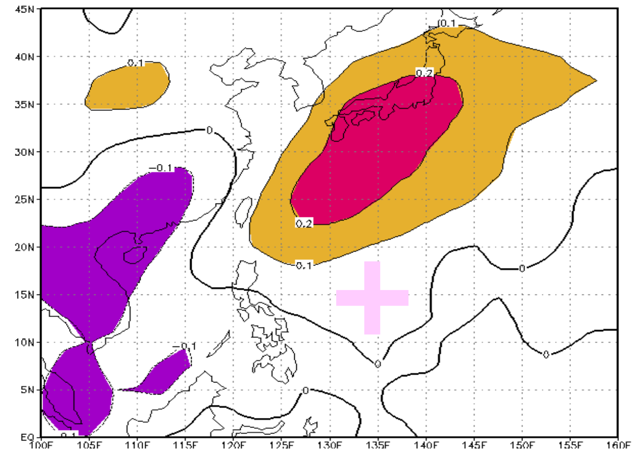
DIV3 ($\times 10^{-6}$ s^{-1})





MSE3 ($\times 10^{6}$ Wm^{-2})

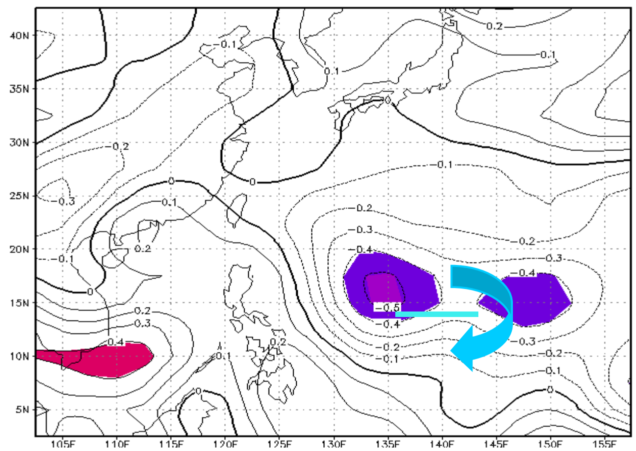




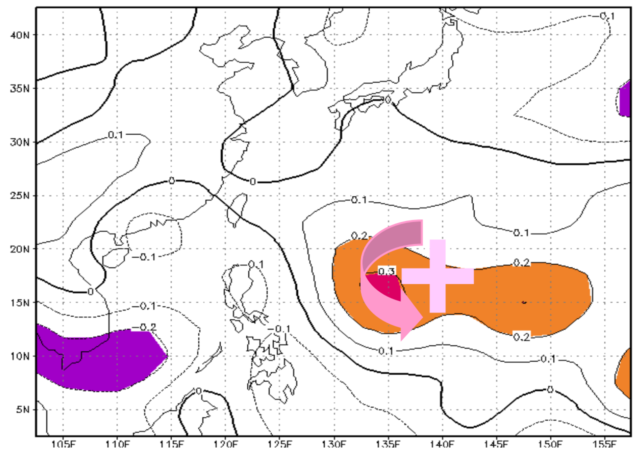
ENT in late season

VOR2 ($\times 10^{-6}$ s^{-1})

EN Composites

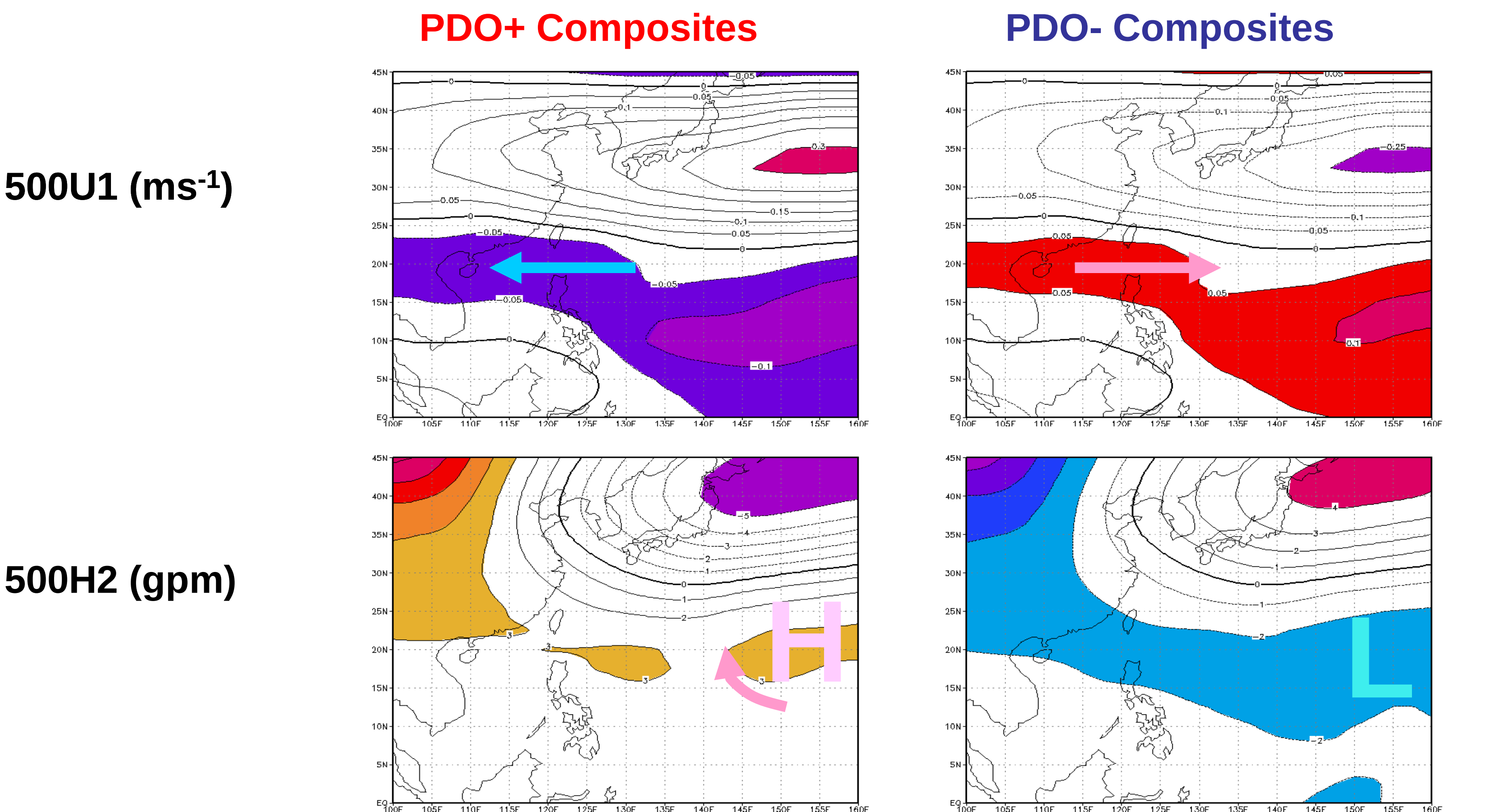


LN Composites



ENT in late season

ENT	PDO+ (16 events)	PDO- (13 events)
Late	Above: 5, Below: 10	Above: 5, Below: 1



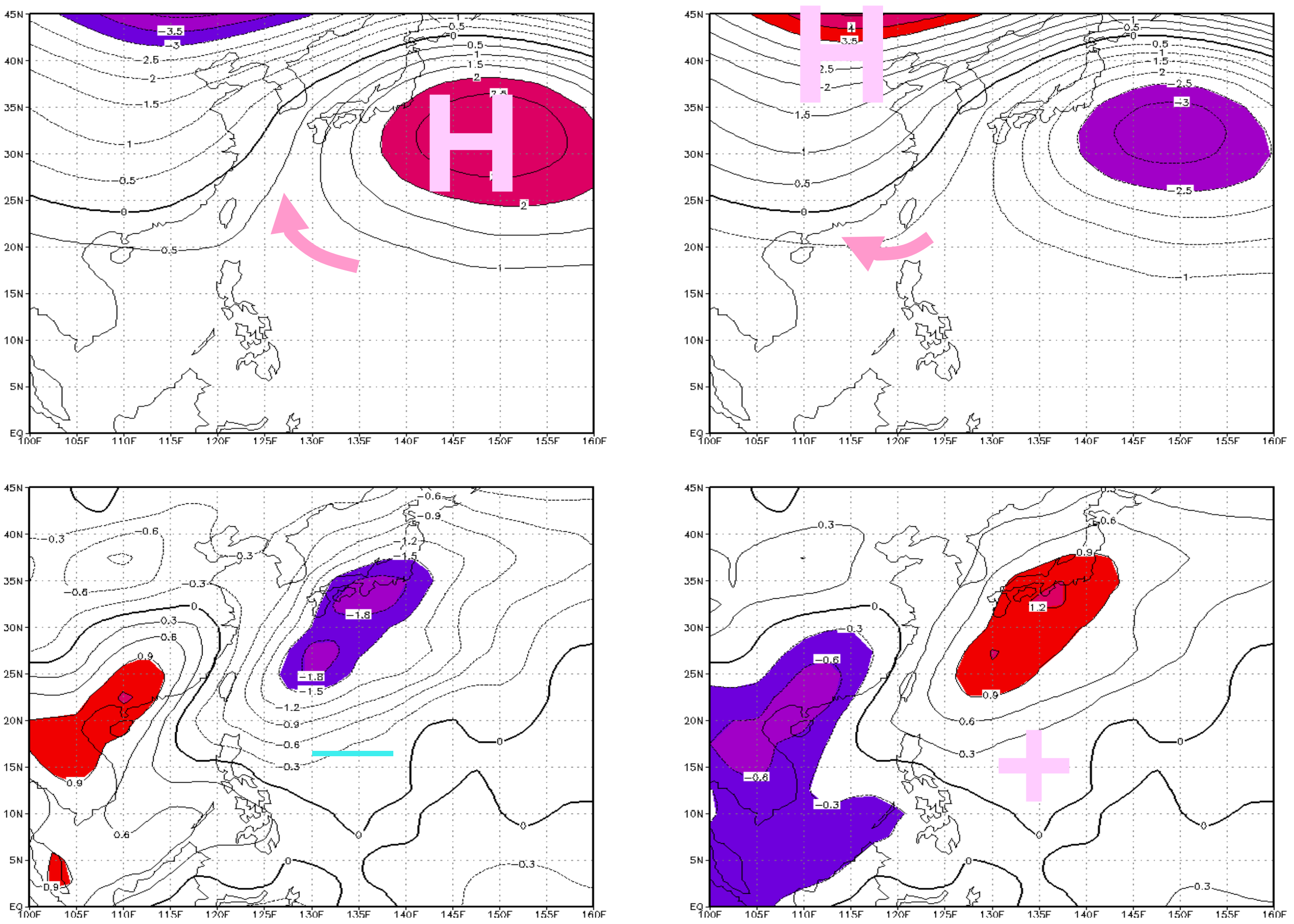
ENT in late season

PDO+ Composites

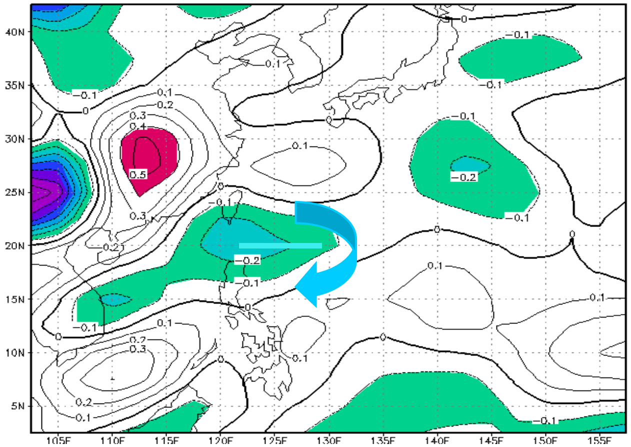
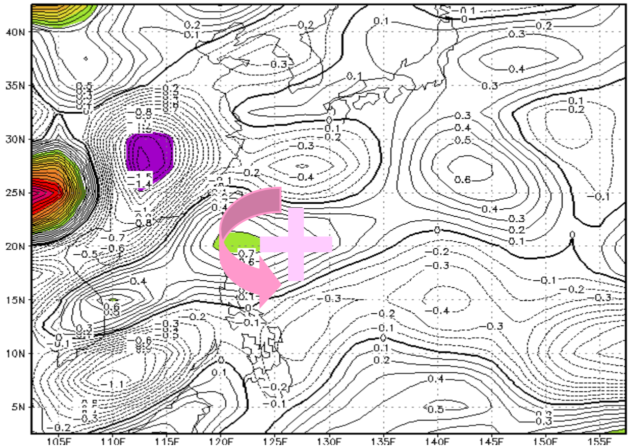
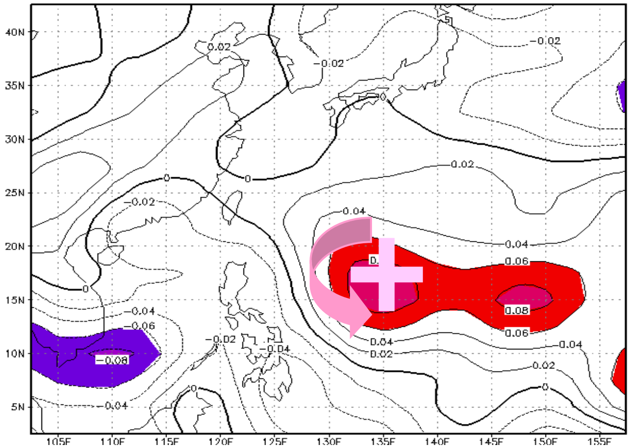
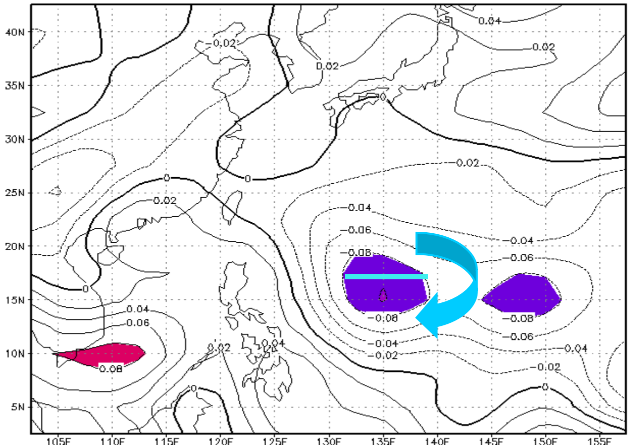
PDO- Composites

500H3 (gpm)

MSE3 ($\times 10^6$ Wm^{-2})



ENT in late season

	PDO+ Composites	PDO- Composites
VOR1 ($\times 10^{-6}$ s^{-1})		
VOR2 ($\times 10^{-6}$ s^{-1})		

Summary

- SCS TCs show interannual and interdecadal variations
- ENT: Decreasing trend, FORM: no trend
- ENT:
  - EN, PDO+: Below-normal
    - WNP formation inhibited, TCs recurve
  - LN, PDO-: Above-normal
    - WNP formation, easterly flow prevail

Summary

- FORM:
  - EN vs LN:
    - Below-normal vs Above-normal
    - SCS formation inhibited vs preferred
    - Location & strength of monsoon trough

      → North-South discrepancy
  - PDO+ vs PDO-:
    - Below-normal vs Above-normal
    - Difference more due to dynamical factors
    - Monsoon trough virtually constant

      → No North-South discrepancy

Conclusion

ENSO and PDO

Variations in factors affecting TC activities

Interannual and interdecadal variations in SCS TCs

THANK YOU