

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°)
 - South China Sea (SCS) (0° to 25° N, 100° to 120° 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

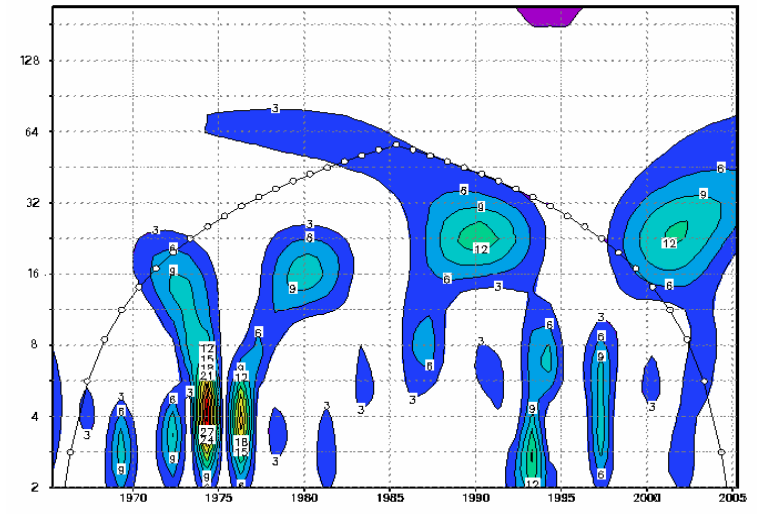
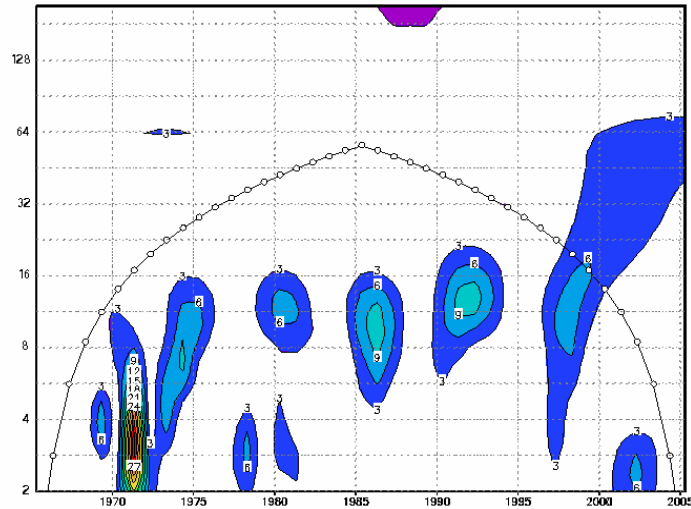
- NCEP Reanalysis data starting from 1965
- Parameters studied:
 - 850-hPa vorticity
 - 850-hPa height
 - 200-hPa – 850-hPa wind shear
 - 200-hPa divergence
 - 500-hPa height
 - Moist static energy
 - 500-hPa u-wind
- May to December, divided into 2 seasons
- Anomalies, EOF calculated

Wavelet Analysis

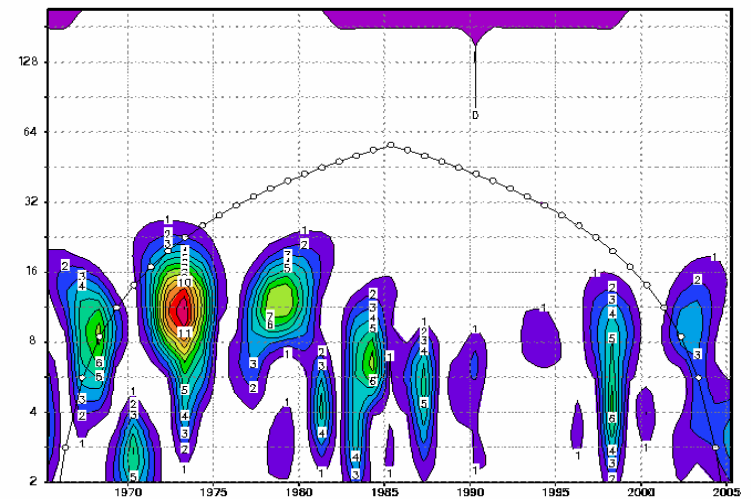
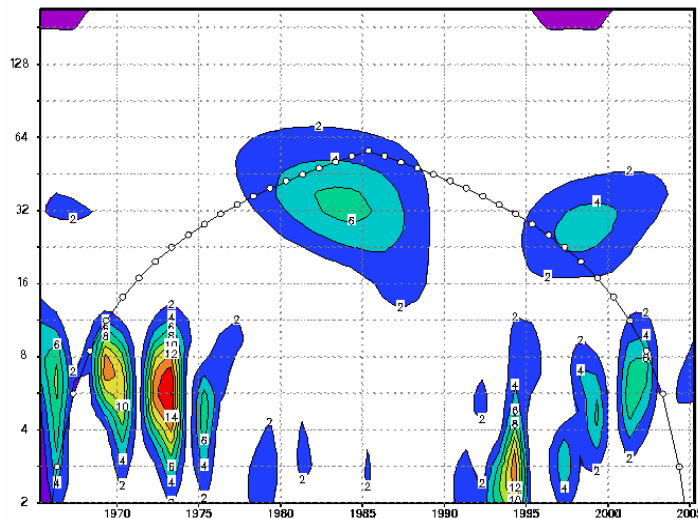
EARLY

LATE

ENT



FORM



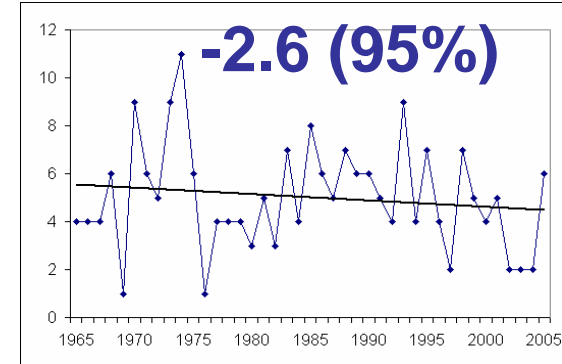
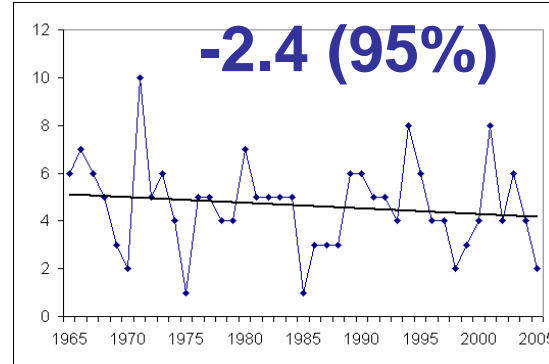
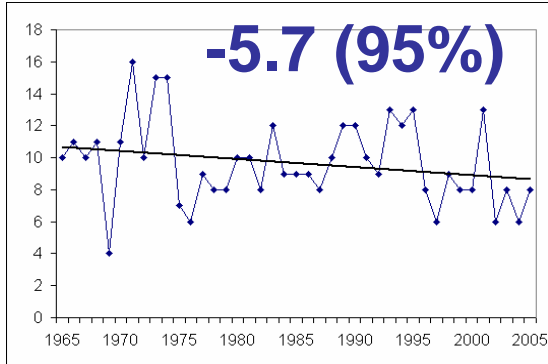
TC Trends (per 100 years)

WHOLE

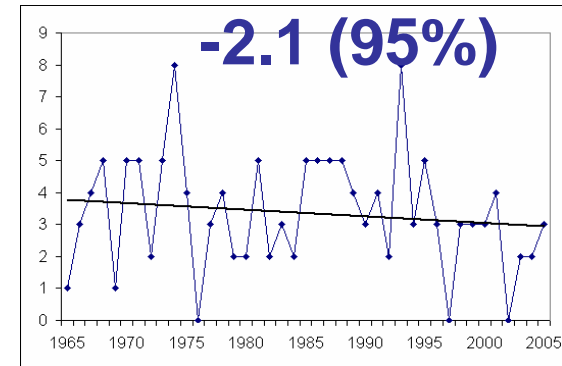
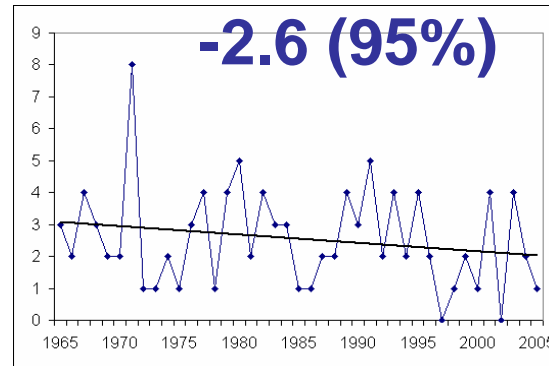
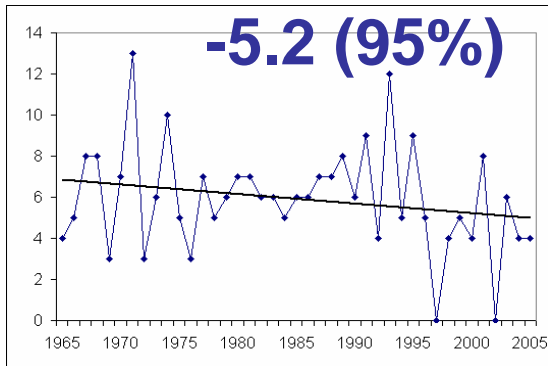
EARLY

LATE

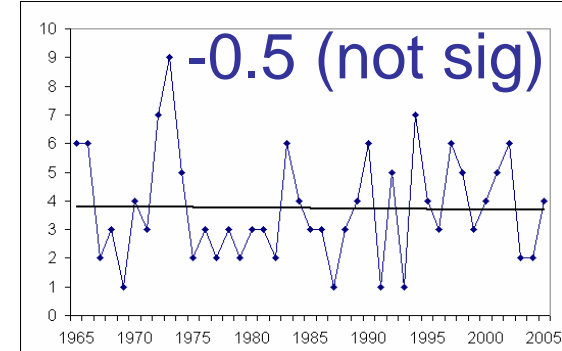
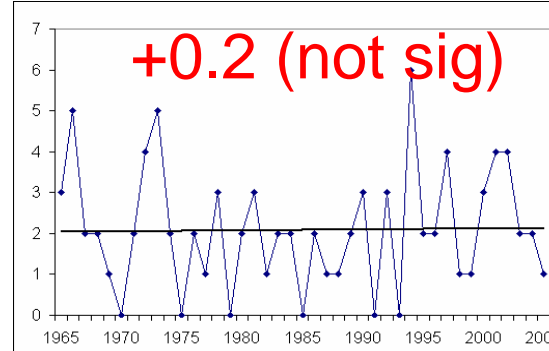
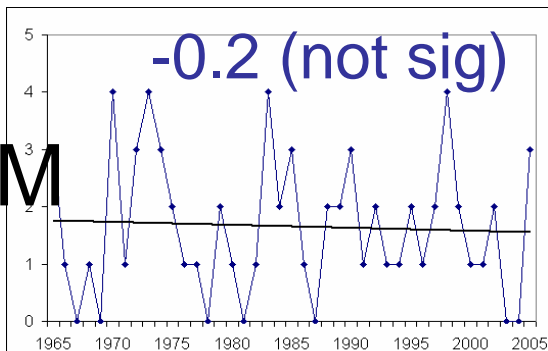
TOT



ENT



FORM



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.

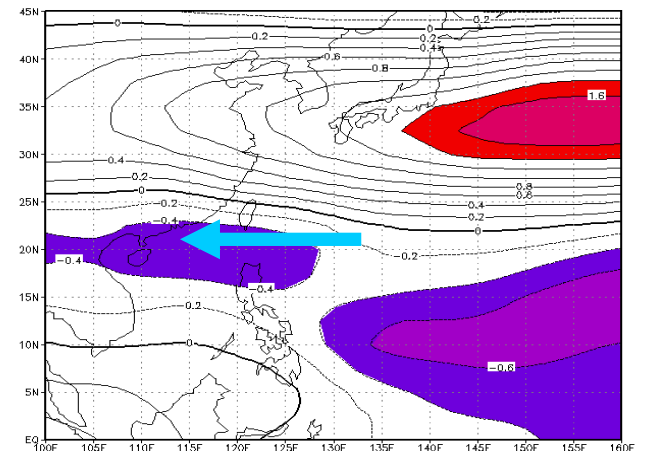
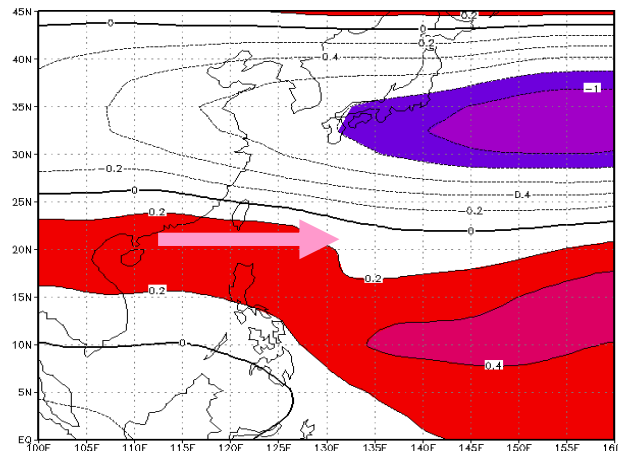
FORM in late season

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

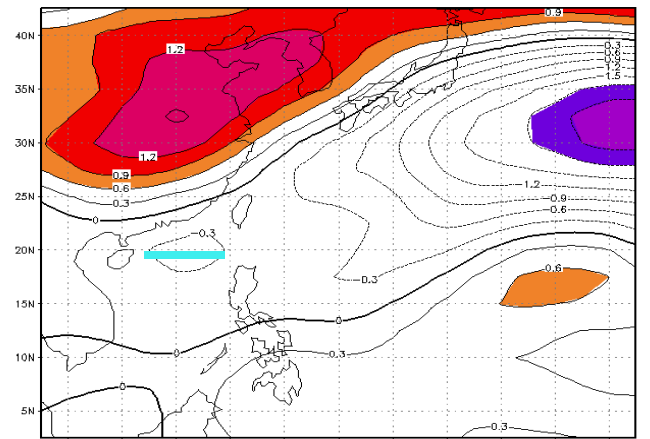
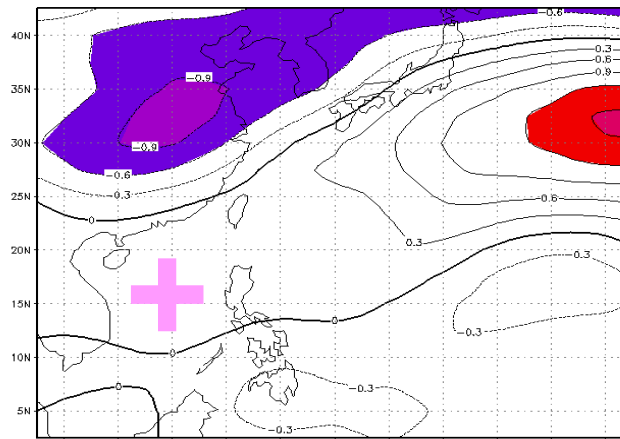
EN Composites

LN Composites

500U1 (ms⁻¹)



DIV3 (x10⁻⁶ s⁻¹)

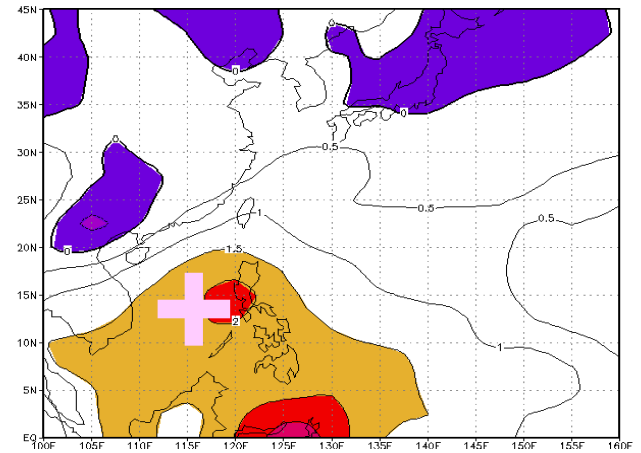
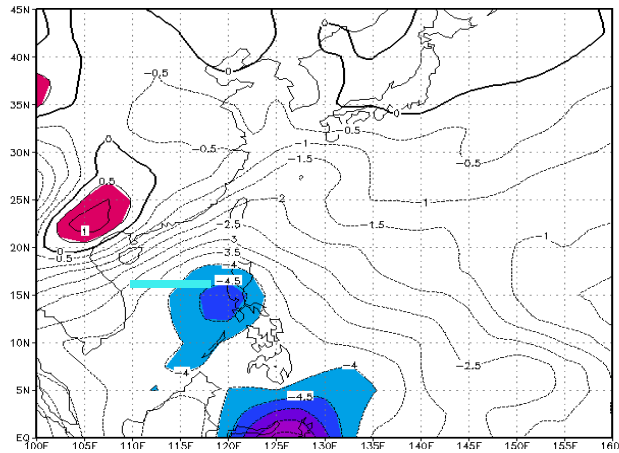


FORM in late season

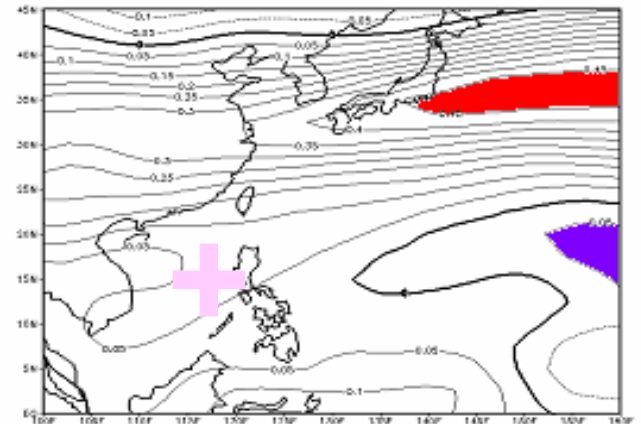
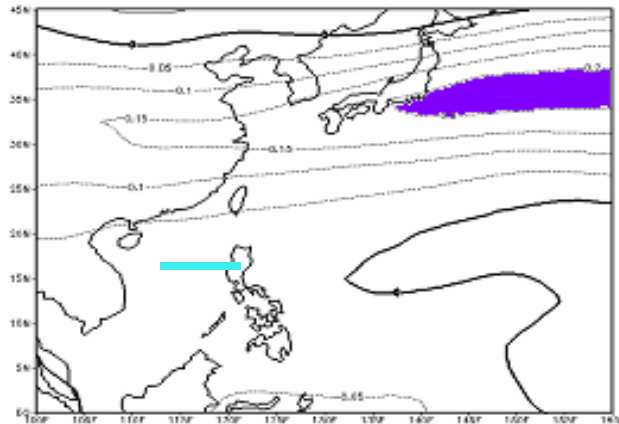
EN Composites

LN Composites

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



SHR3 (ms^{-1})



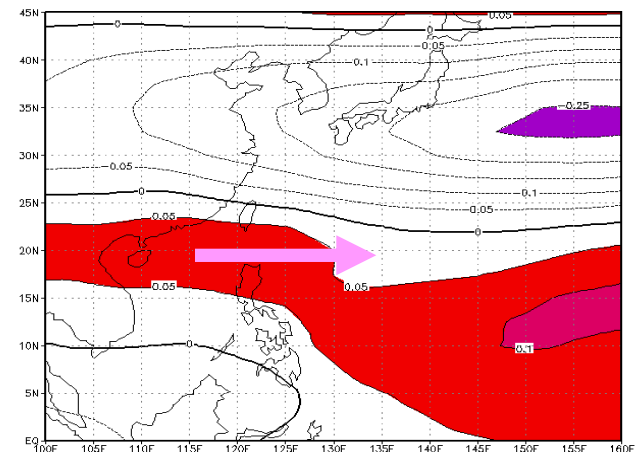
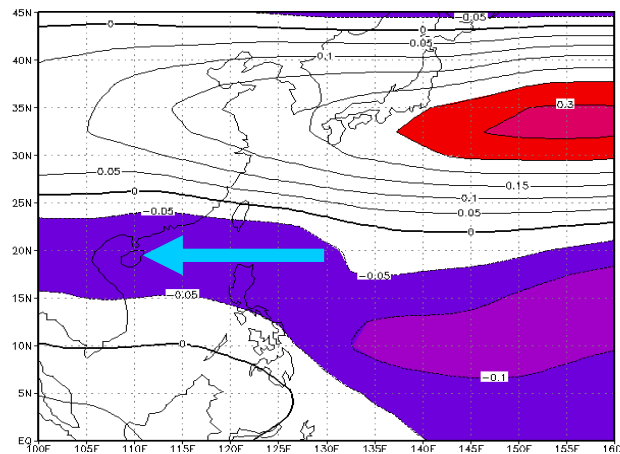
FORM in late season

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

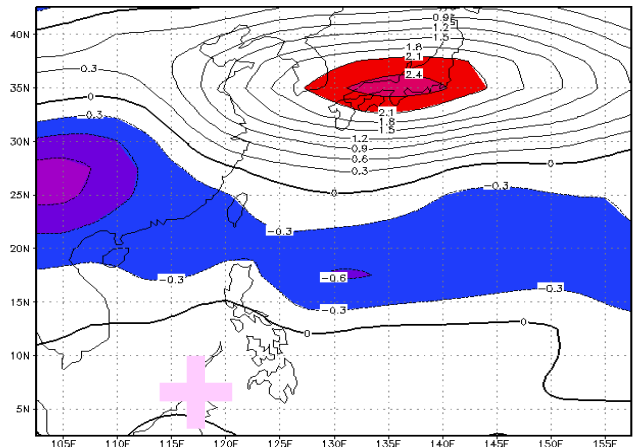
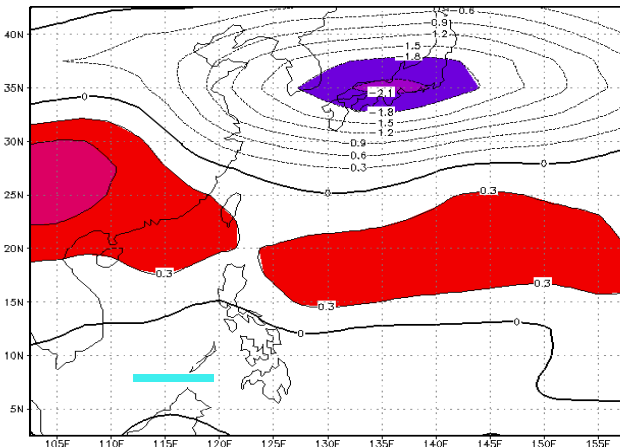
PDO+ Composites

PDO- Composites

500U1 (ms^{-1})



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

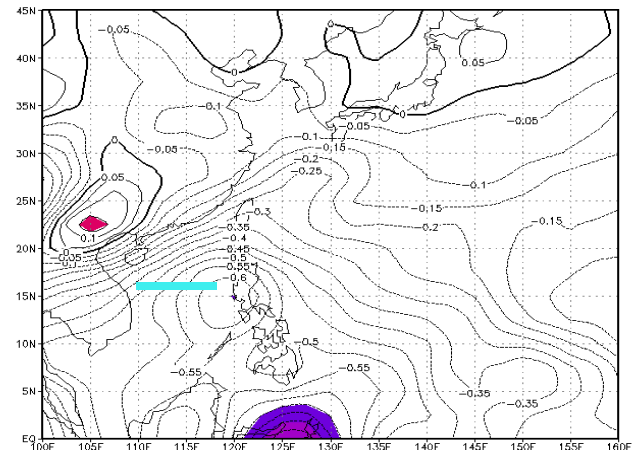
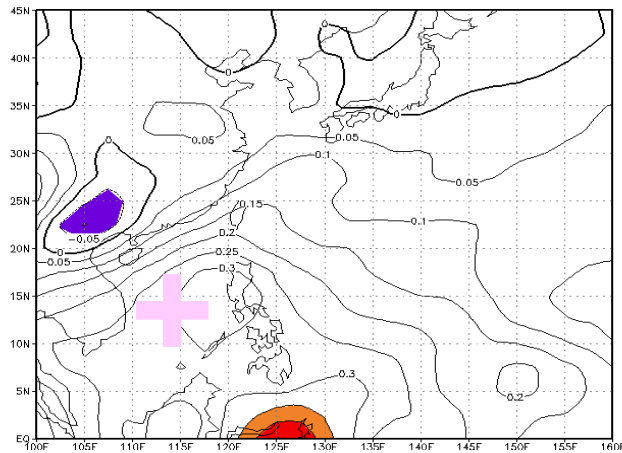


FORM in late season

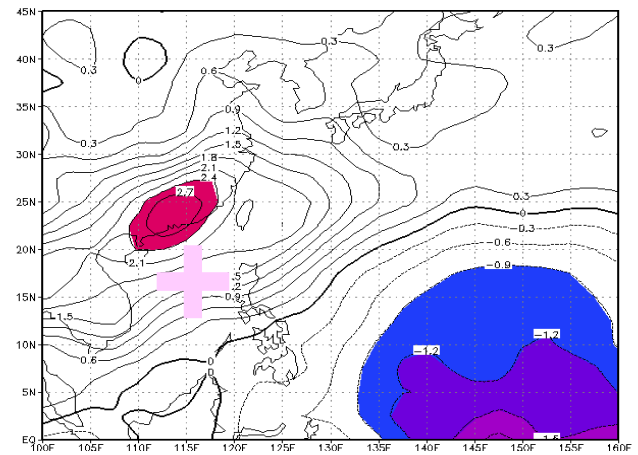
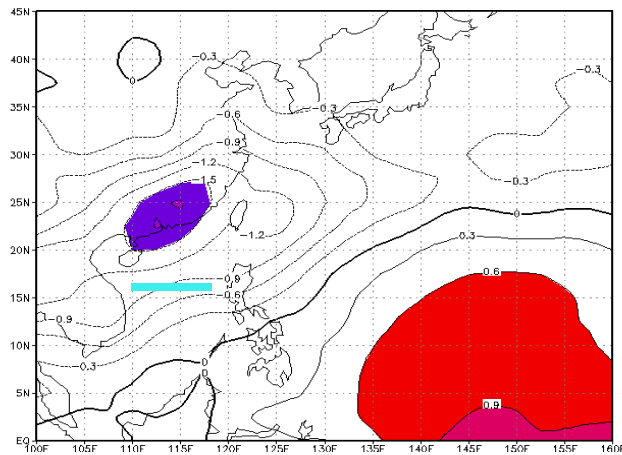
PDO+ Composites

PDO- Composites

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

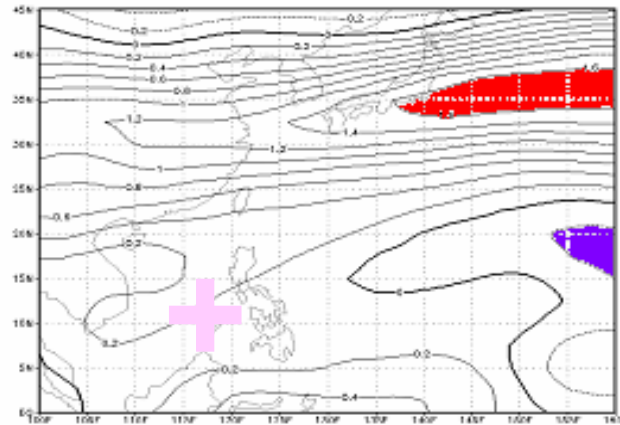


MSE2 ($\times 10^6 \text{ Wm}^{-2}$)

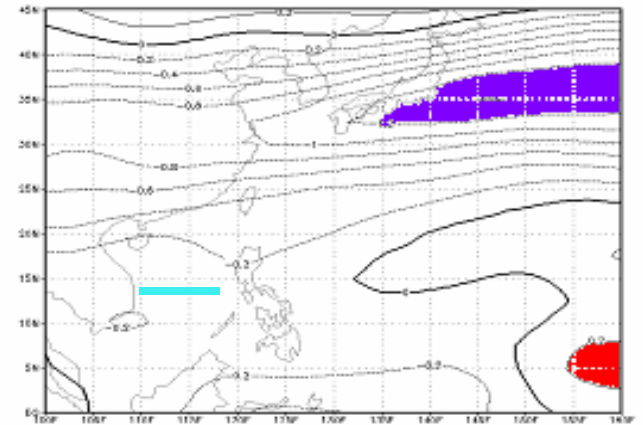


FORM in late season

PDO+ Composites



PDO- Composites

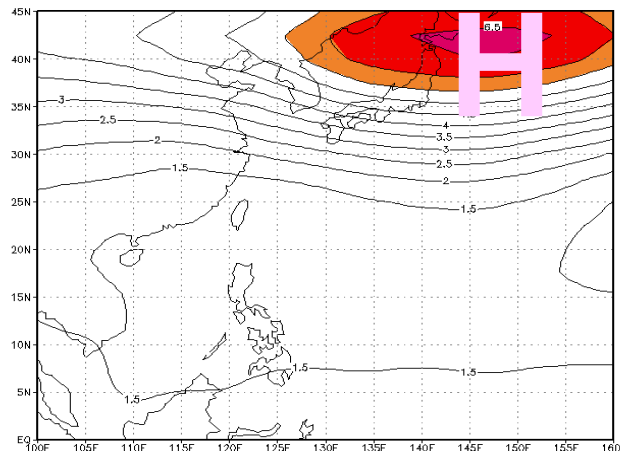
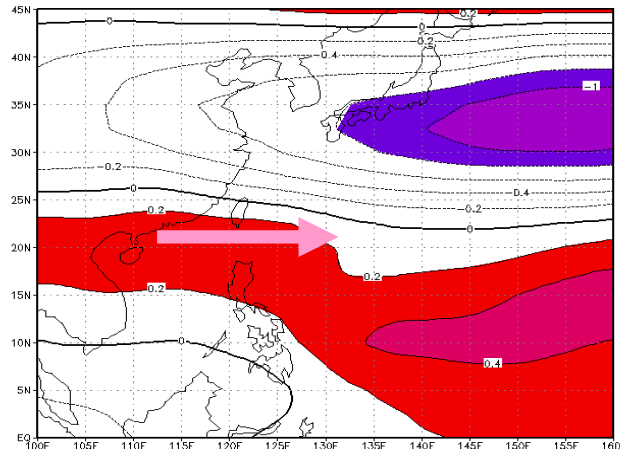


SHR3 (ms⁻¹)

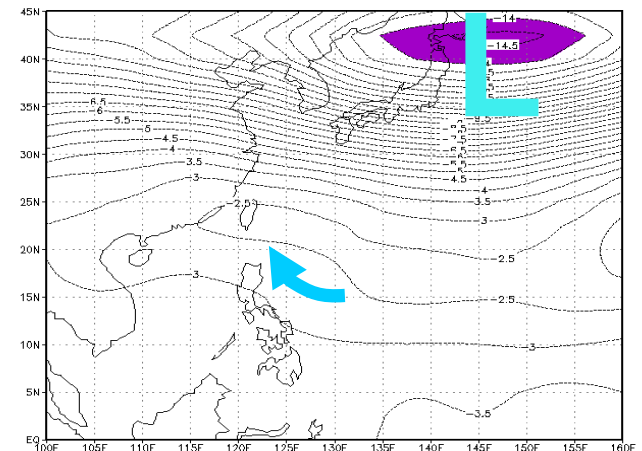
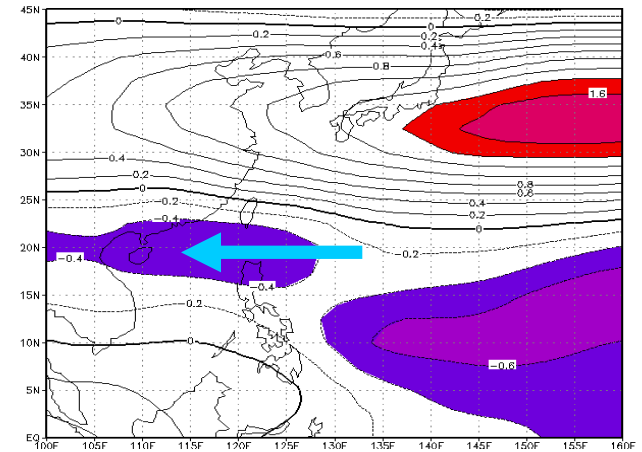
ENT in late season

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

EN Composites



LN Composites

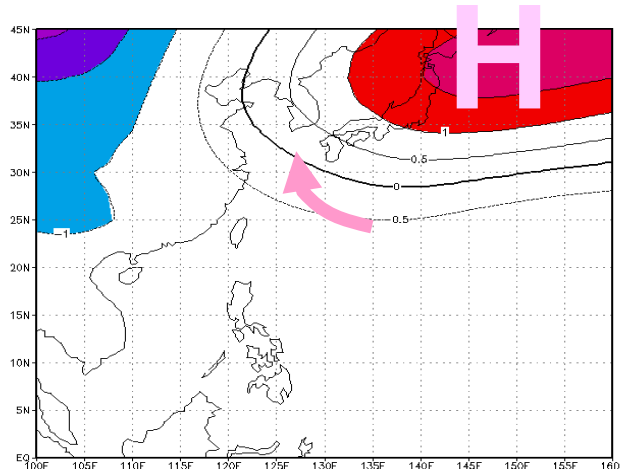


500U1 (ms⁻¹)

500H1 (gpm)

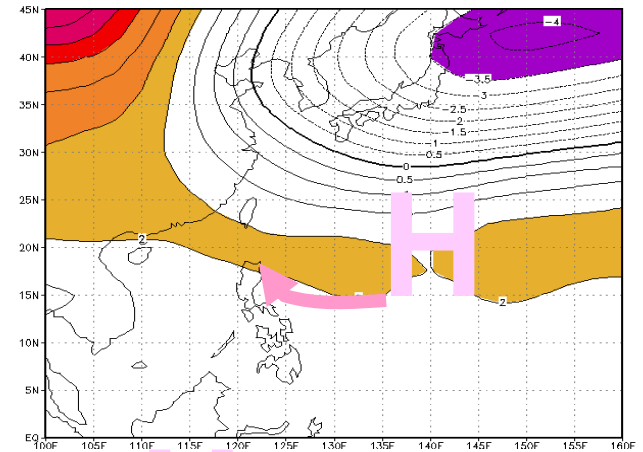
ENT in late season

EN Composites

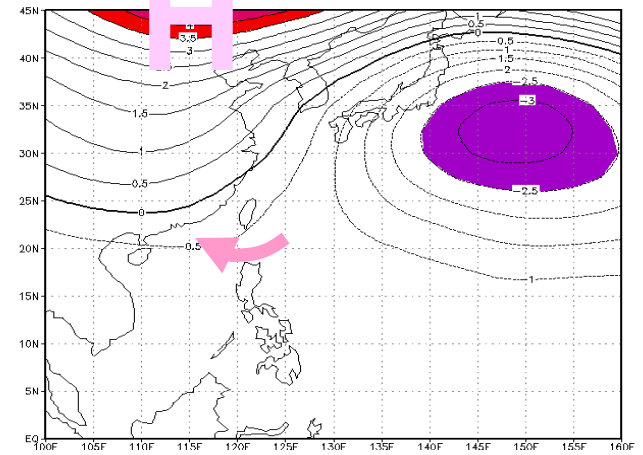
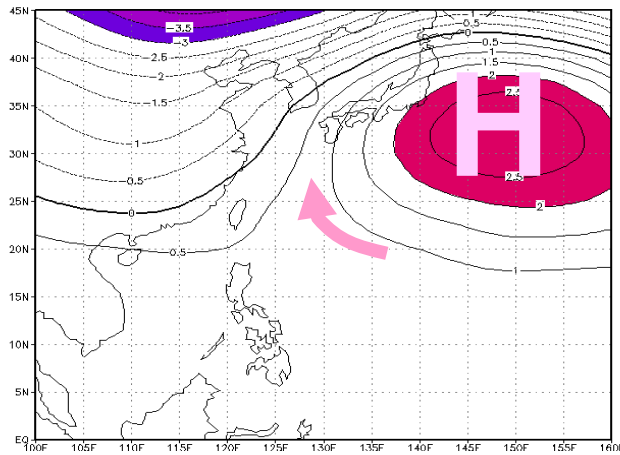


500H2 (gpm)

LN Composites

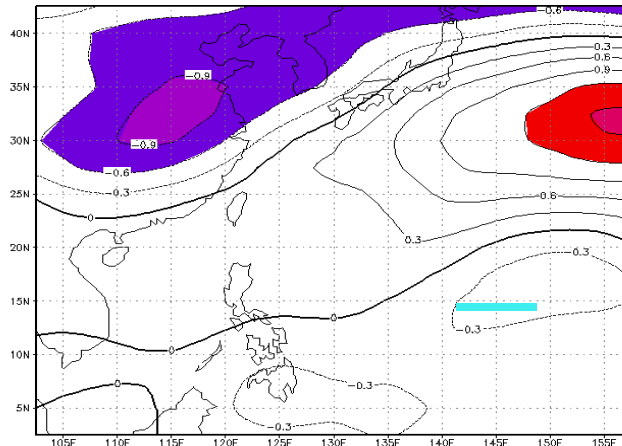


500H3 (gpm)

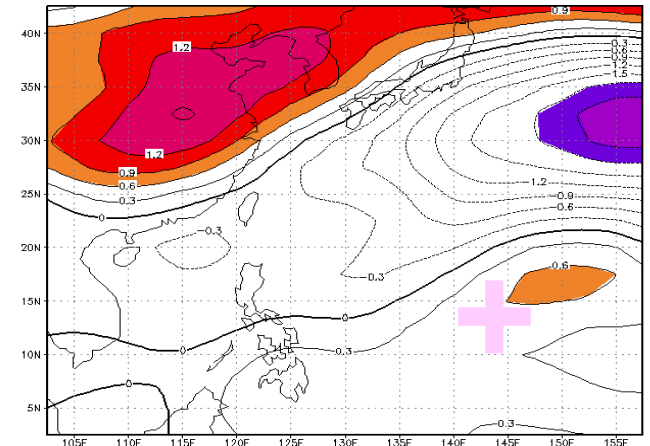


ENT in late season

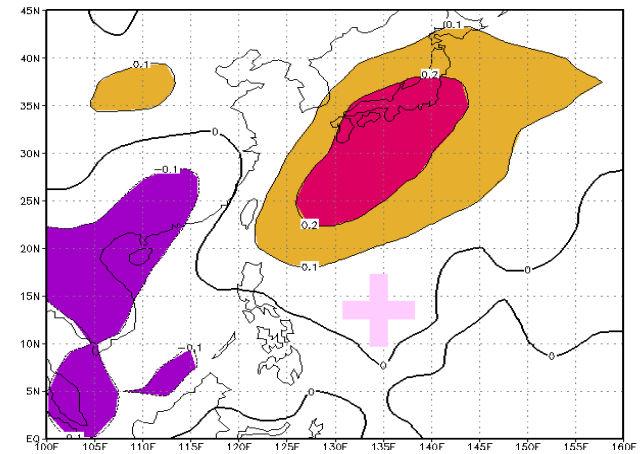
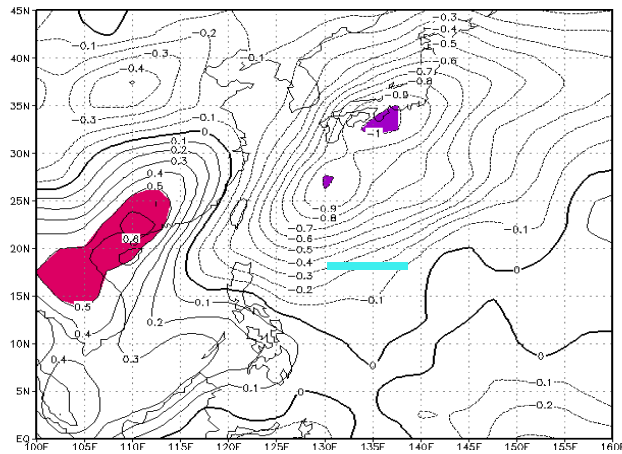
EN Composites



LN Composites



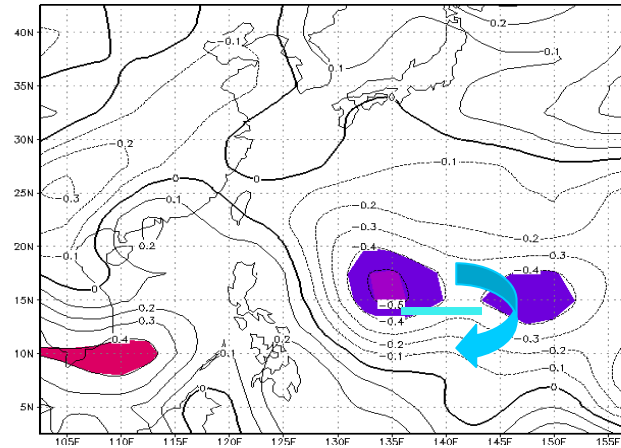
DIV3 ($\times 10^{-6} \text{ s}^{-1}$)



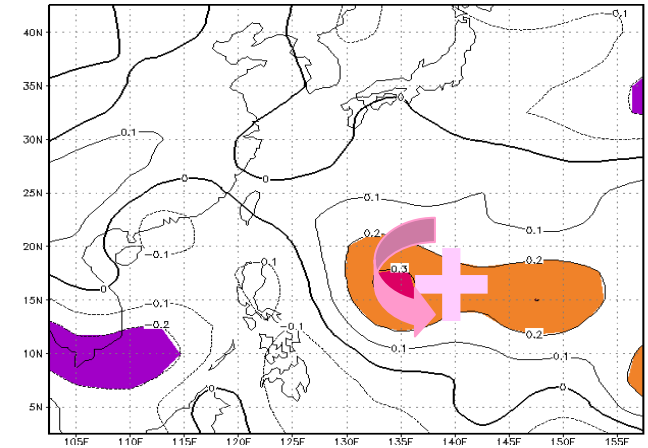
MSE3 ($\times 10^6 \text{ Wm}^{-2}$)

ENT in late season

EN Composites



LN Composites



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

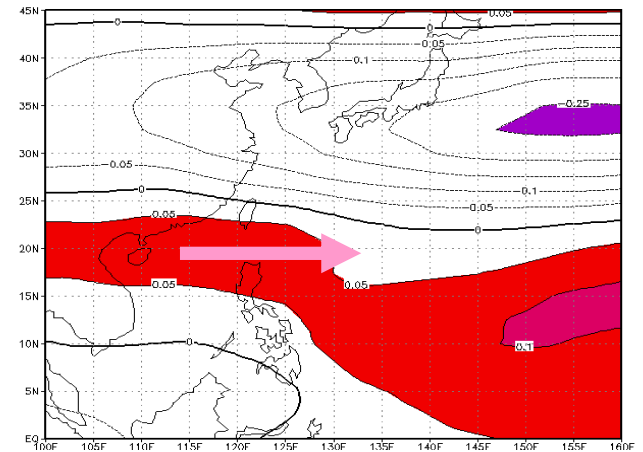
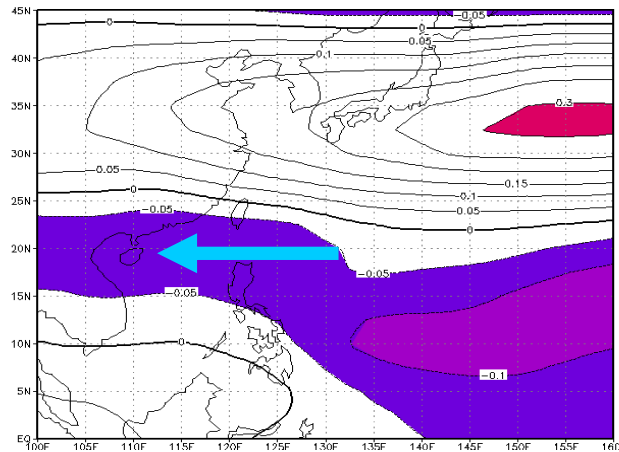
ENT in late season

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

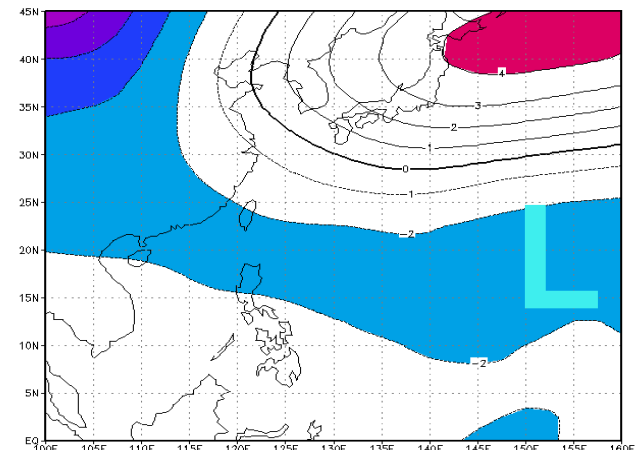
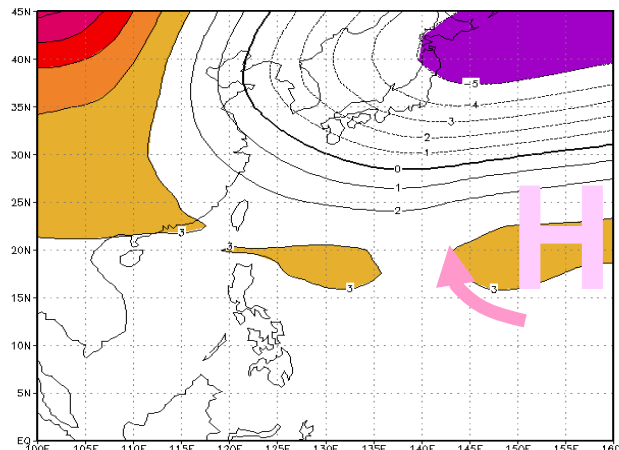
PDO+ Composites

PDO- Composites

500U1 (ms⁻¹)



500H2 (gpm)

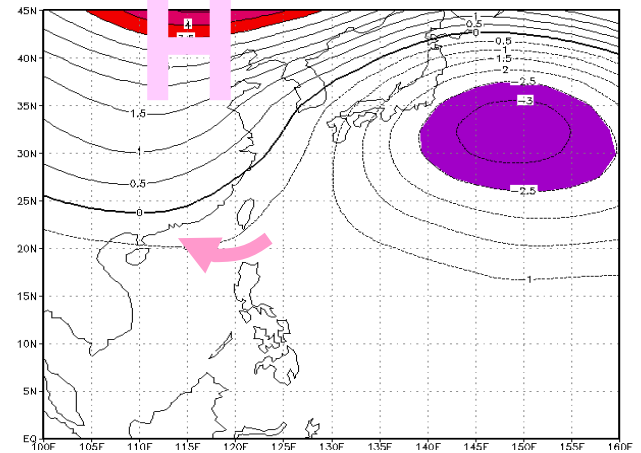
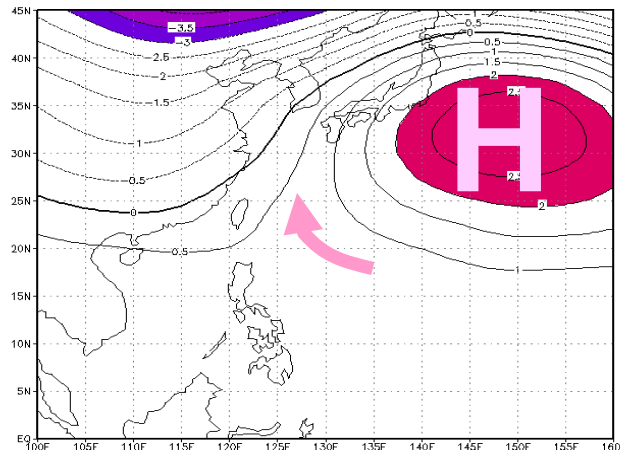


ENT in late season

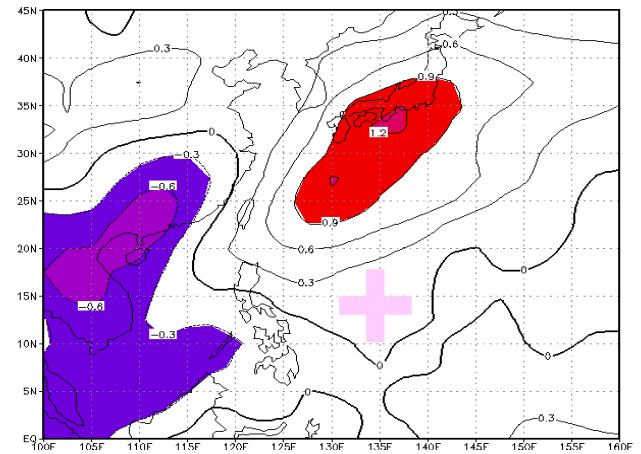
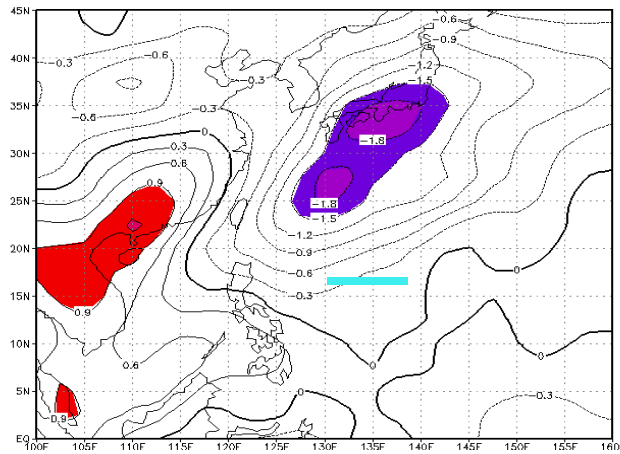
PDO+ Composites

PDO- Composites

500H3 (gpm)



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

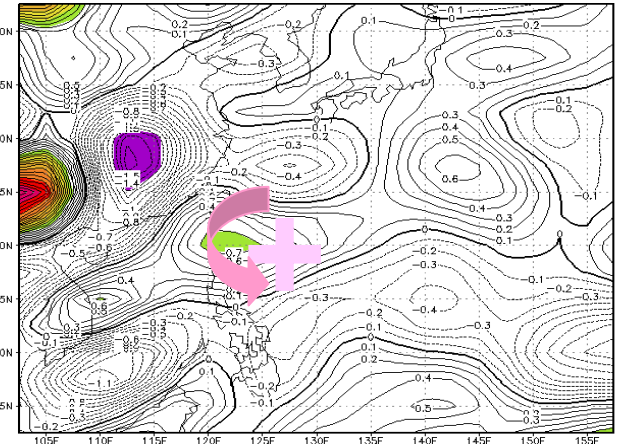
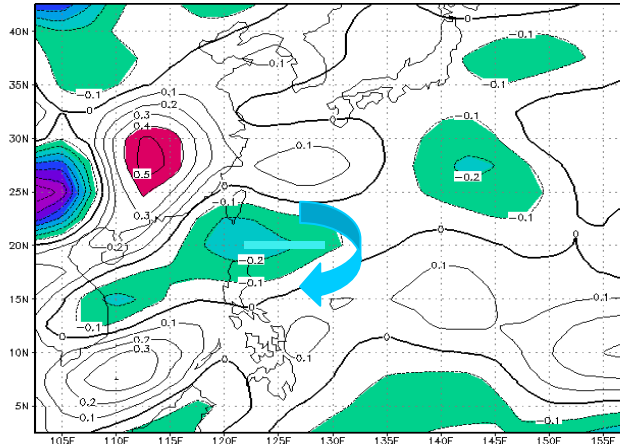


ENT in late season

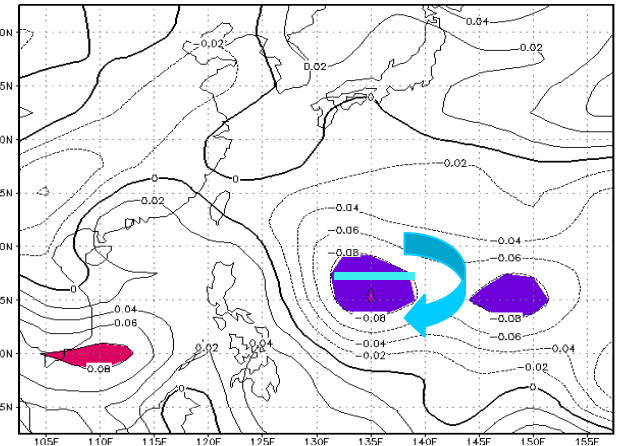
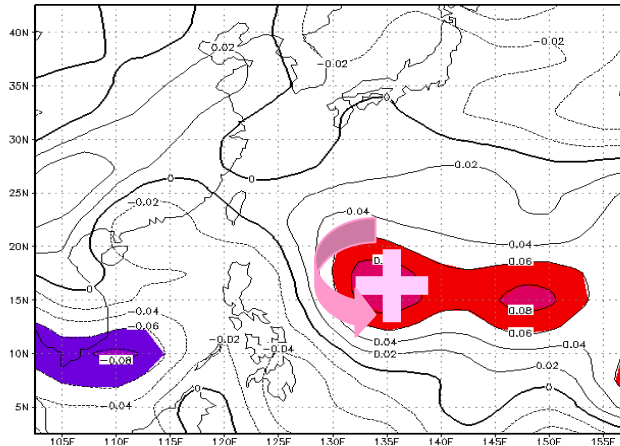
PDO+ Composites

PDO- Composites

VOR1 ($\times 10^{-6} \text{ s}^{-1}$)



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



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

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graph TD; A[ENSO and PDO] --> B[Variations in factors affecting TC activities]; B --> C[Interannual and interdecadal variations in SCS TCs];
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Variations in factors affecting TC activities

Interannual and interdecadal variations in SCS TCs

THANK YOU