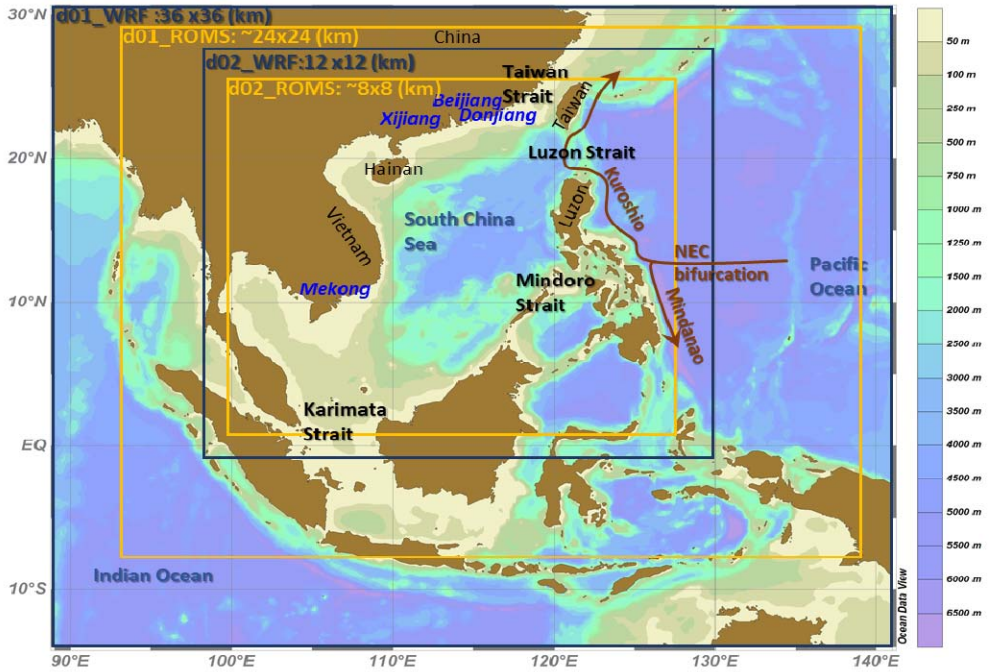
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

CODA Lab

Mesoscale ocean response and air-sea interaction in the South China Sea during ENSO decaying winter-spring modelled by a regional coupled model



Yi-Chun Kuo and Yu-heng Tseng

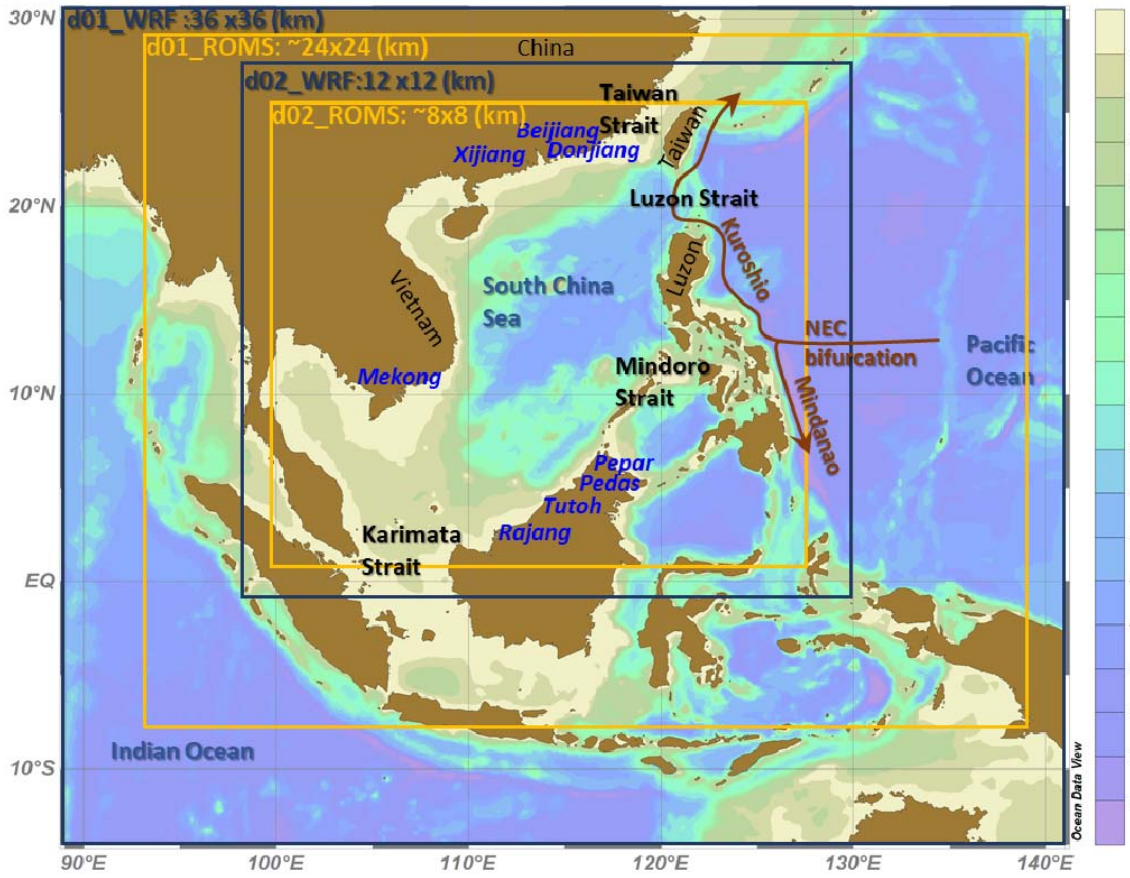
Institute of Oceanography, National Taiwan University, Taiwan

Motivations and outlines

- Provide physical background to support SCSTIMX and others
  - Ocean mesoscale structure, air-sea interaction
- Validation (Ocean/Atmosphere)
- ENSO impacts on the South China Sea
  - Ocean mesoscale feedback
  - Change of circulation
  - Change of the throughflow
  - Air-sea interaction

國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

CODA Lab



Weather Research and Forecasting Model (WRF)
Domain 1 : 36x36(km)
Domain 2 : 12x12(km)
Vertical : 36 levels

Initial/lateral BC: NCEP FNL Operational Model Global Tropospheric Analyses

Regional Ocean Modeling System (ROMS)
Domain 1 : 24x24 (km)
Domain 2 : 8x8 (km)
Vertical : 25 levels

Initial/lateral BC: HYCOM + NCODA Global 1/12° Reanalysis

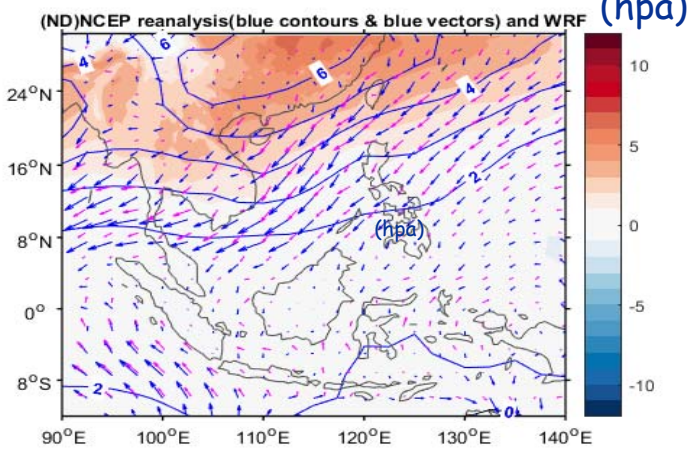
EXP1 2015/11-2016/6 El Niño
EXP2 2011/11-2012/6 La Niña

Model validation-the low level circulation

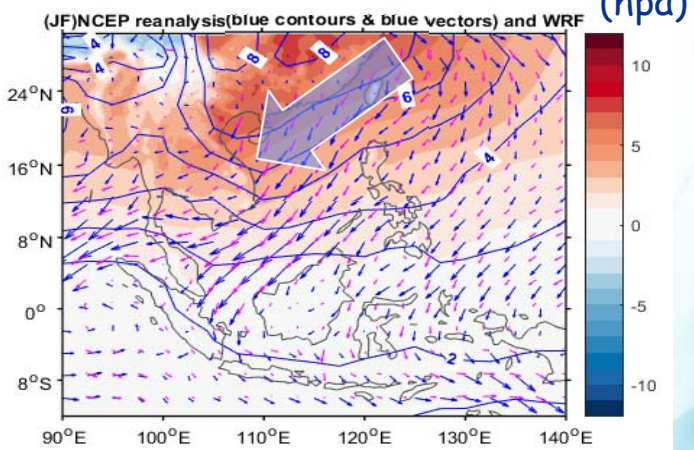
Blue contours and vectors: NCEP reanalysis.
Shaded color and pink vectors: RCM

The El Niño case (2015/11-2016/6)

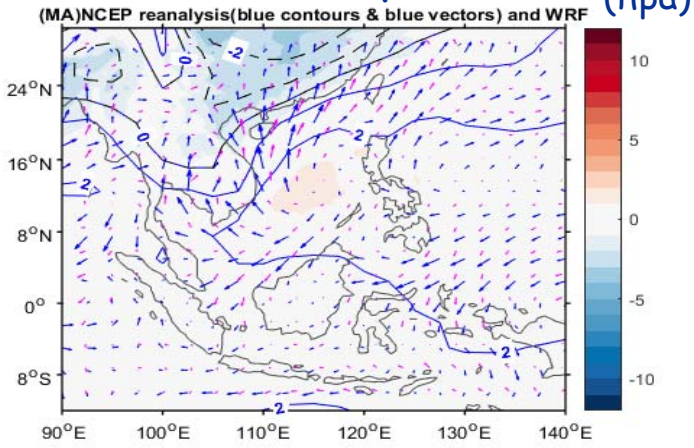
Nov-Dec



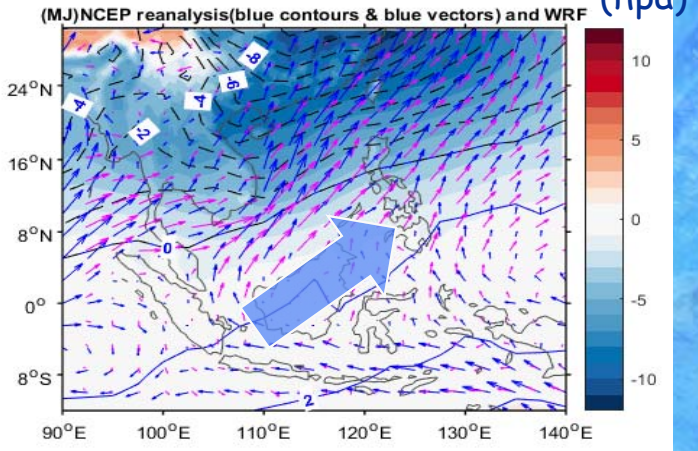
Jan-Feb



Mar-Apr



May-Jun



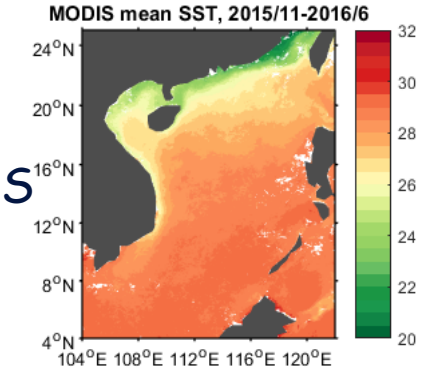
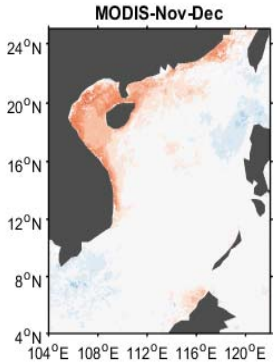
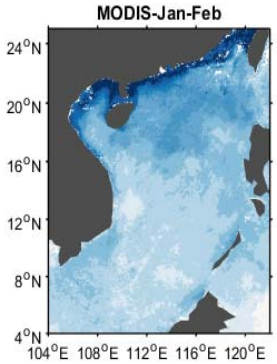
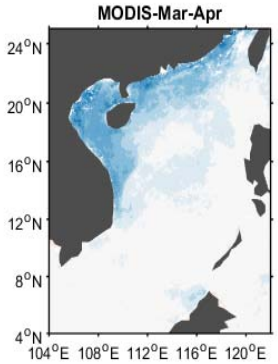
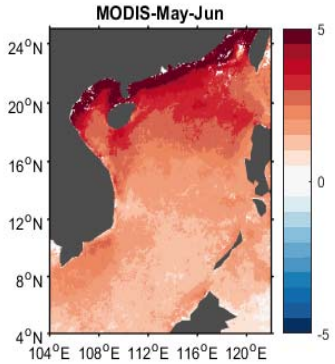
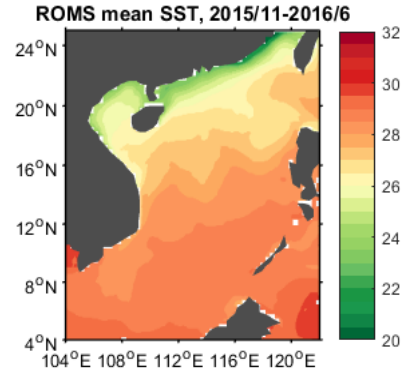
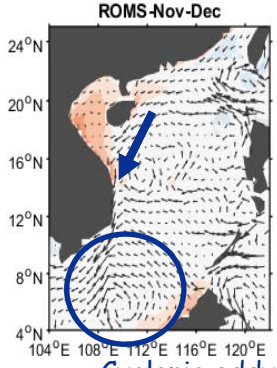
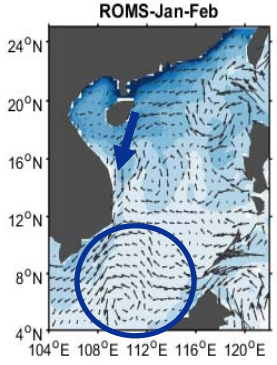
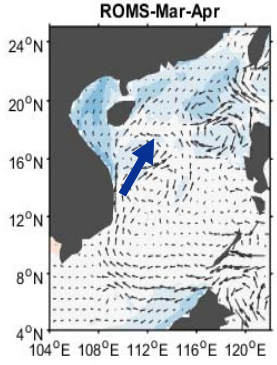
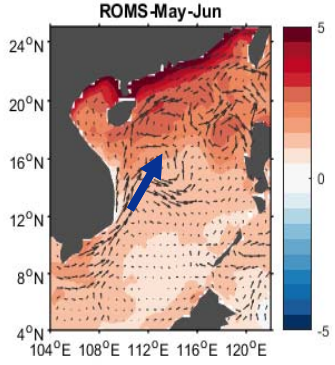
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

CODA Lab

Model validation-SST (2015/16)

8-month mean SST pattern

consecutive 2-month averaged SST deviation

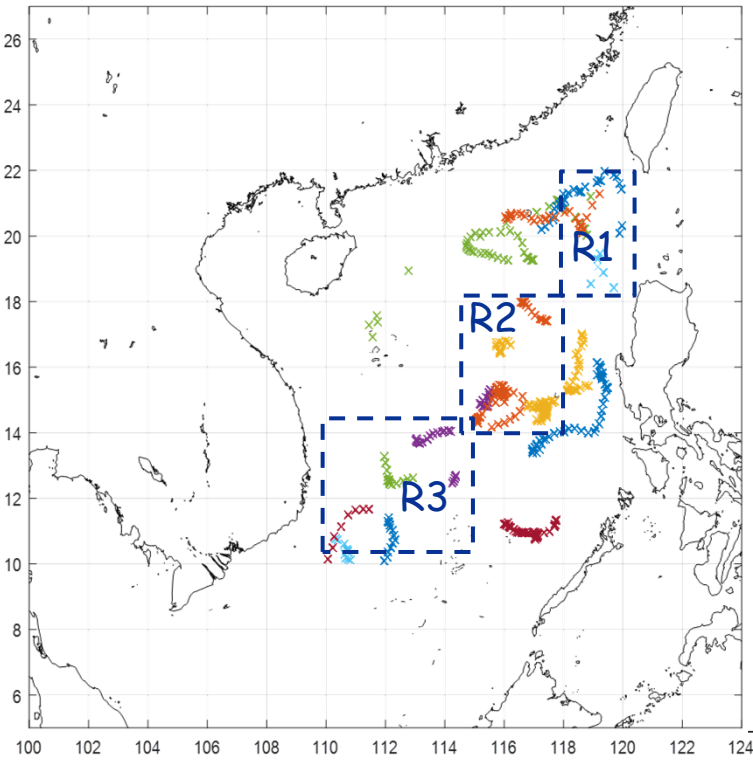
	Nov-Jun	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun
MODIS					
model					

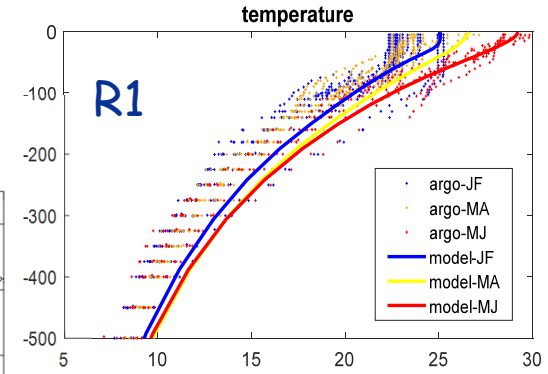
Cyclonic eddy

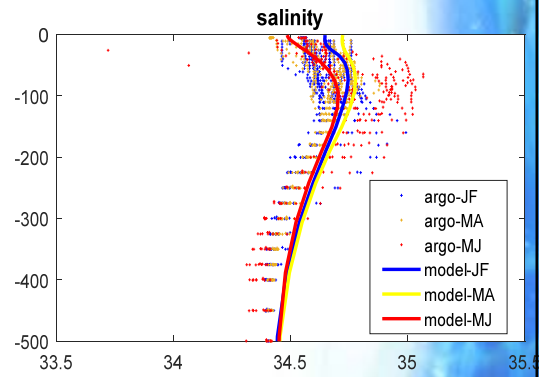
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

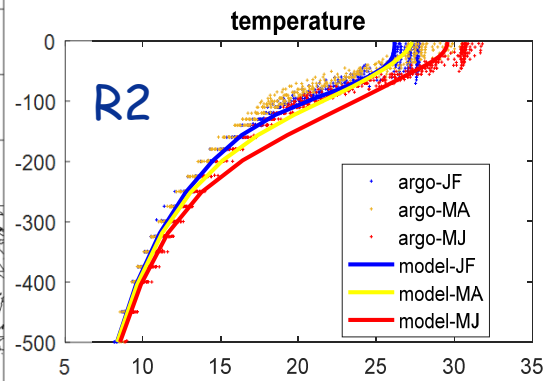
CODA Lab

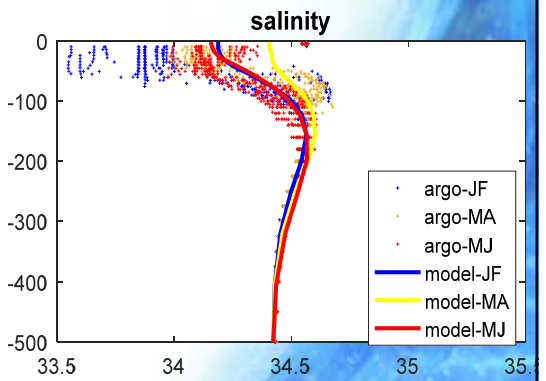
Model validation-TS profiles vs Argo Floats

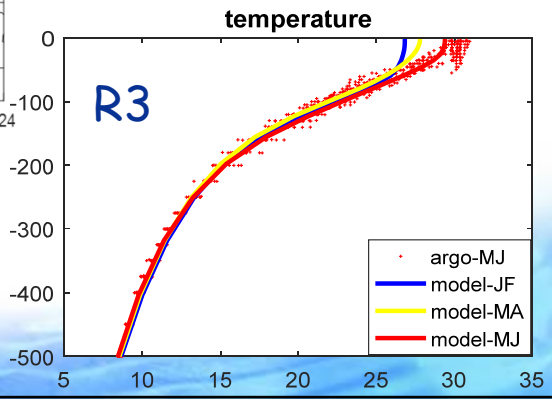


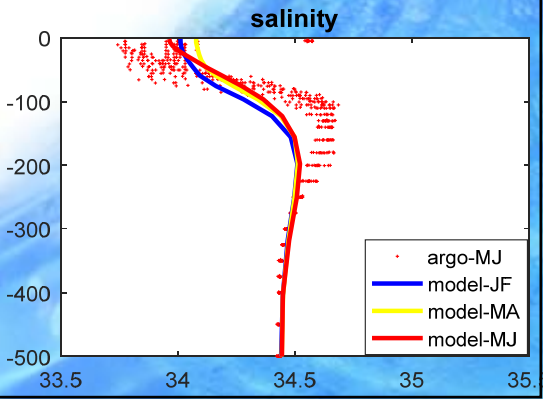












2015/16 minus 2011/2

Low-level atm. circulation between El Niño & La Niña

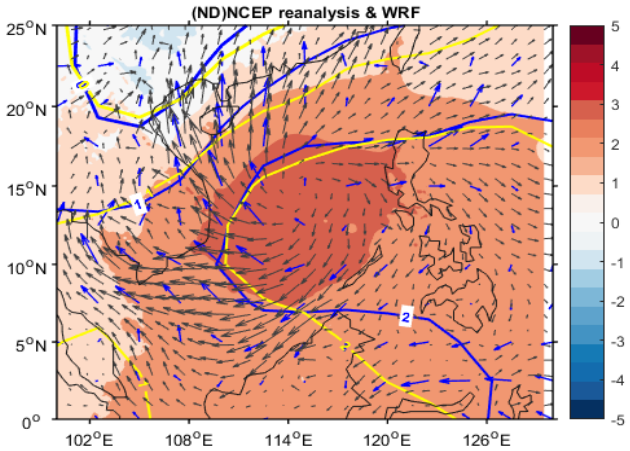
Blue contours and vectors: NCEP reanalysis

Yellow: mean SLP diff. from recent 6 strongest ENSO (3 El Niño and 3 La Niña)

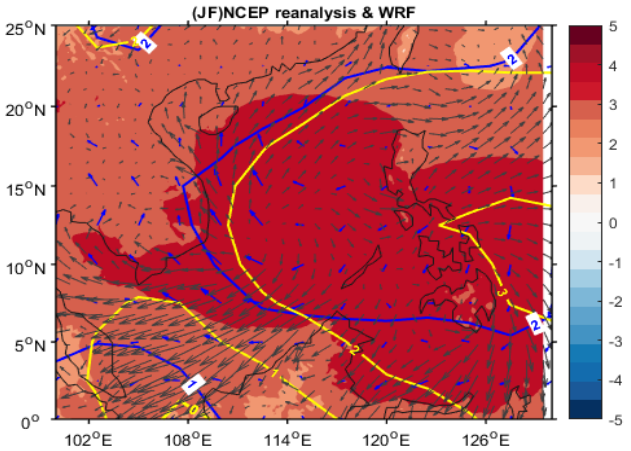
North SCS:
Weaker EAWM

South SCS:
Stronger EAWM

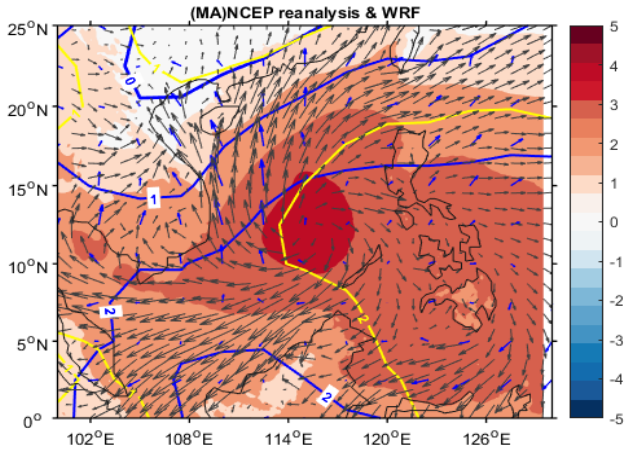
Nov-Dec



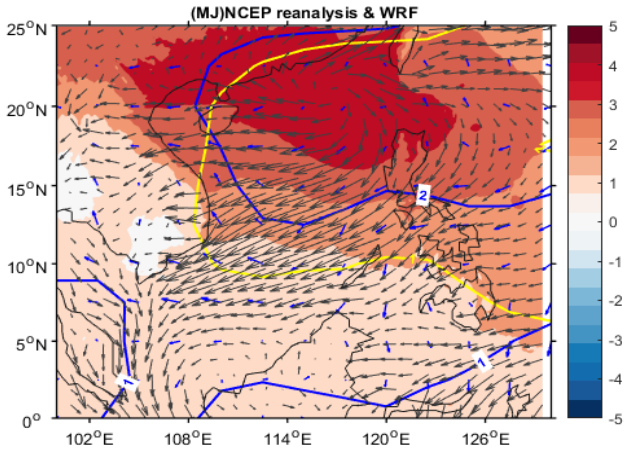
Jan-Feb



Mar-Apr

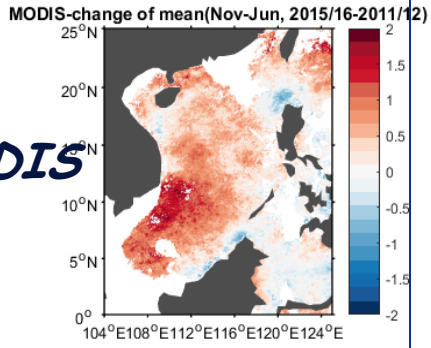
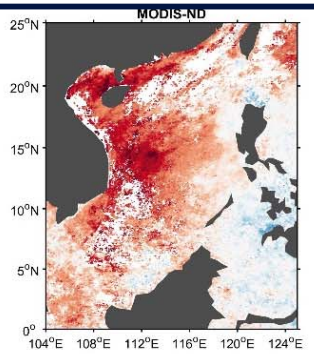
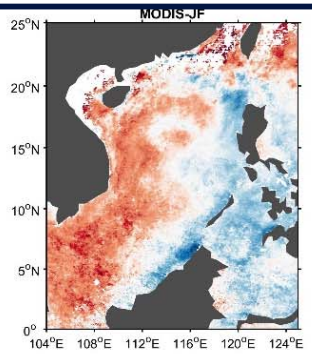
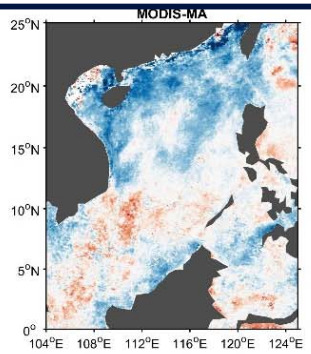
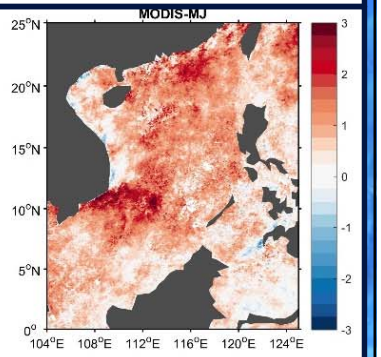
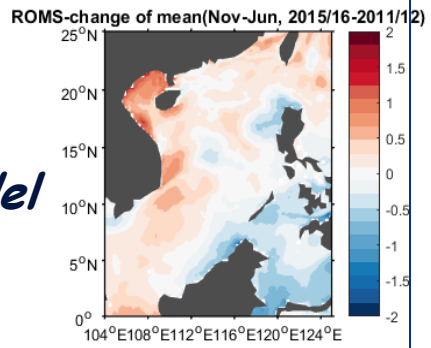
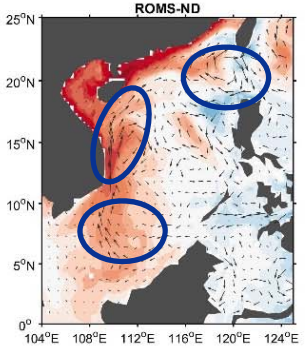
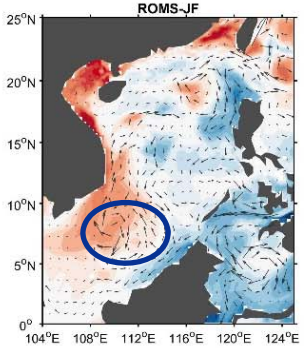
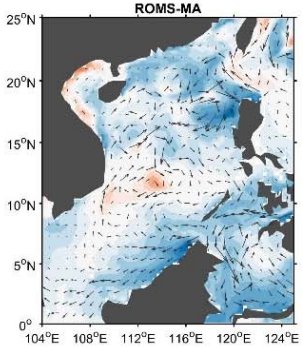
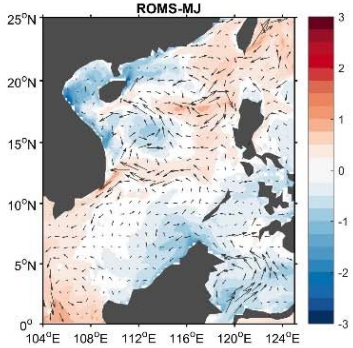


May-Jun



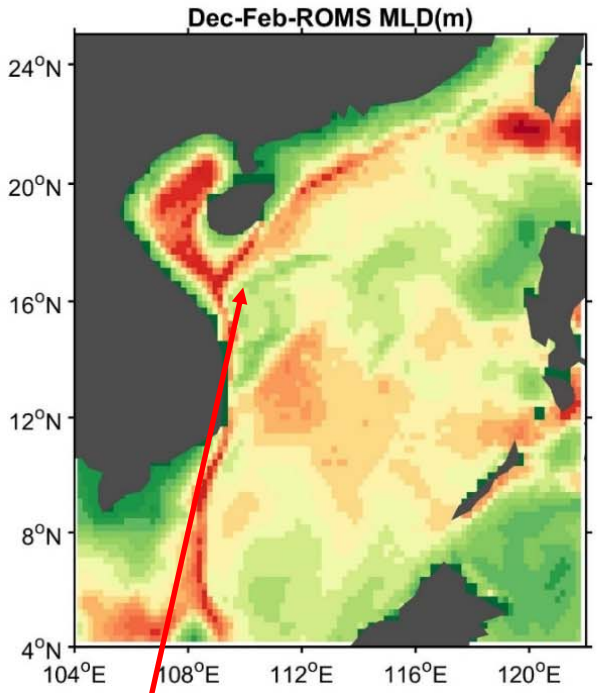
Surface SCS response to ENSO (El Niño-La Niña)

averaged SST diff.

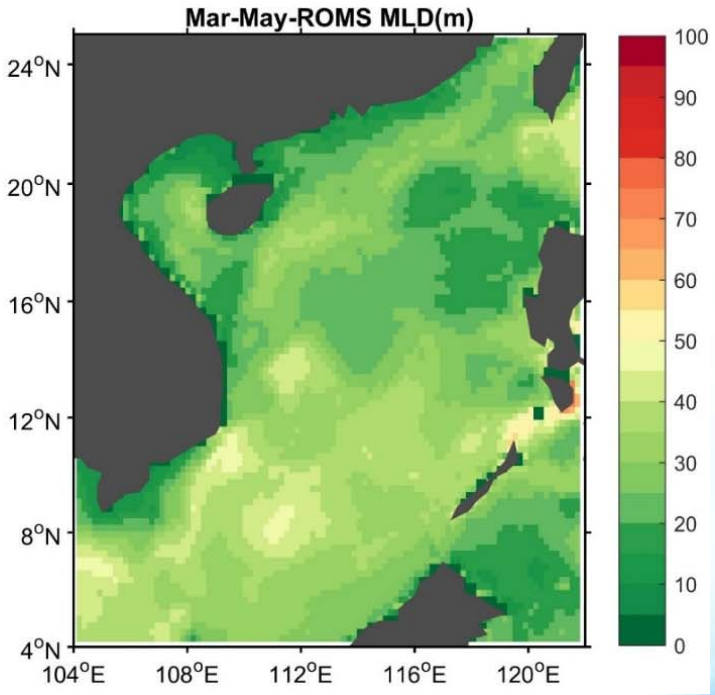
	Nov-Jun	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun
MODIS					
model					

Subsurface SCS response to ENSO (MLD)

Winter



Spring

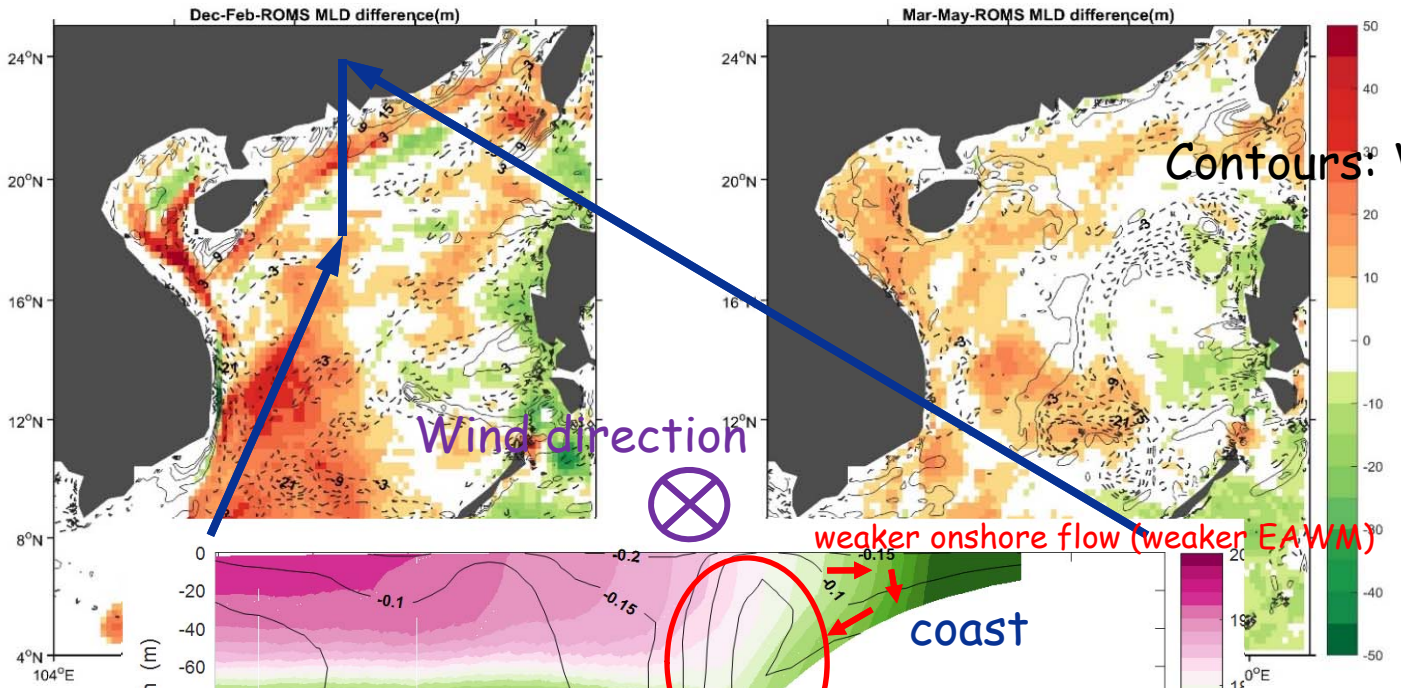


Thicker MLDs in WBCs (stronger downward momentum flux enhances the vertical mixing)

Subsurface SCS response to ENSO (MLD, El Niño-La Niña)

Winter

Spring



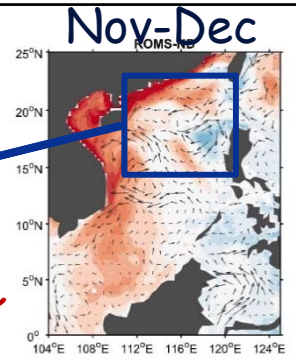
2015/16
El Niño

2011/12
La Niña

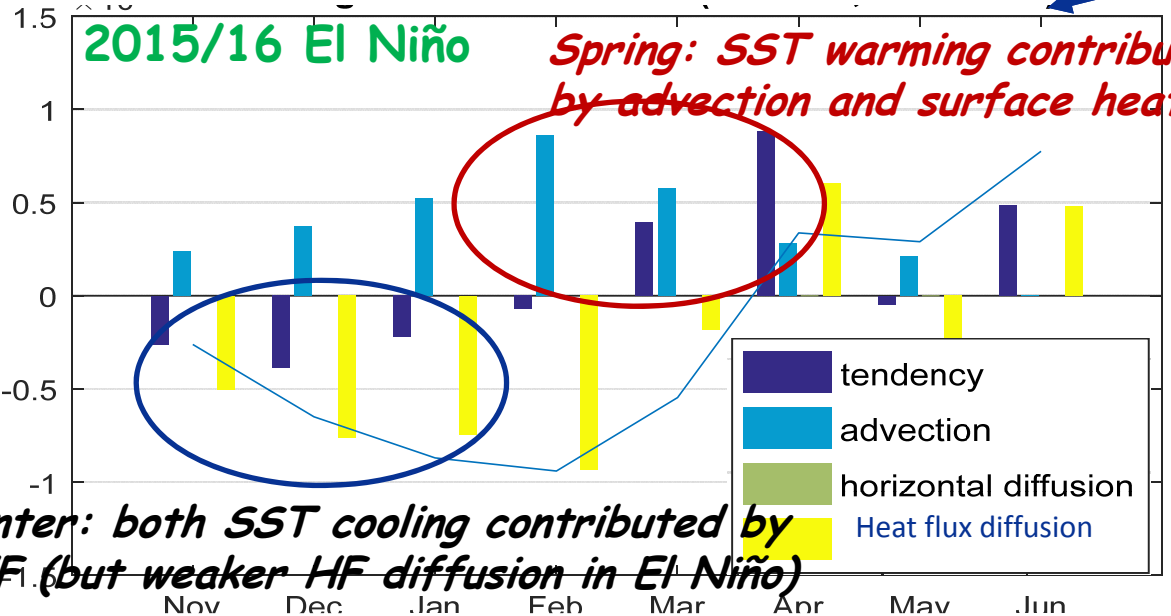
drive more bottom cooler water offshore

國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

Heat budget

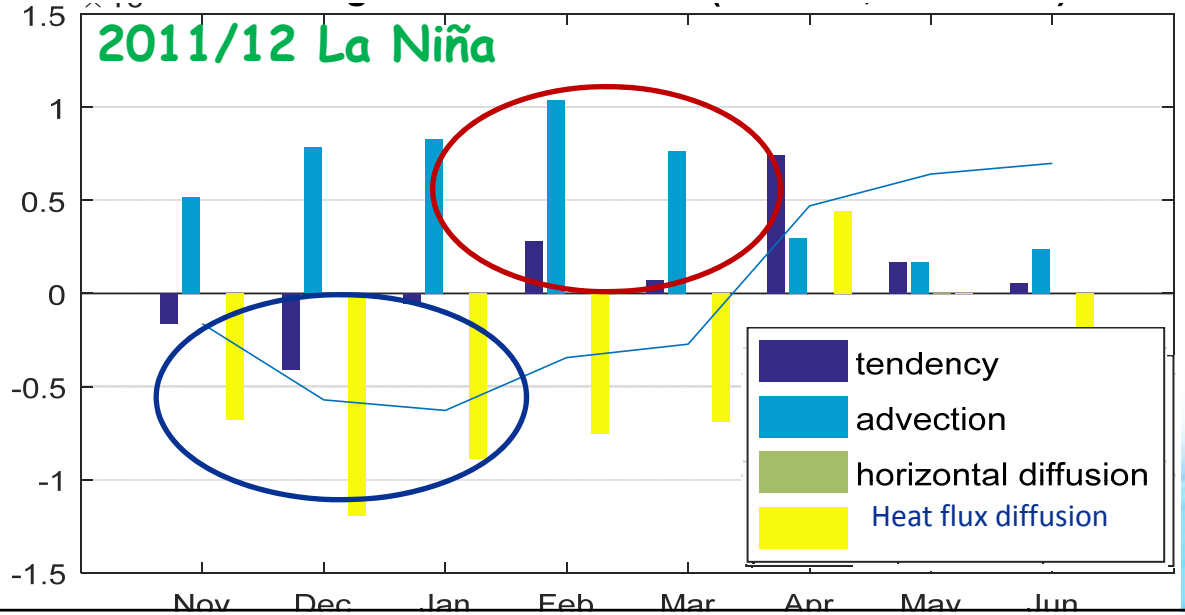


CODA Lab

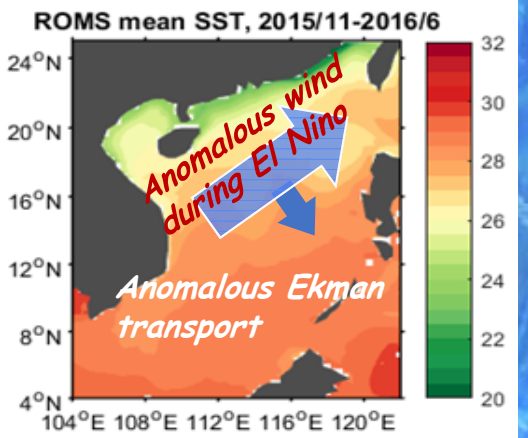


Spring: SST warming contributed by advection and surface heat flux

Winter: both SST cooling contributed by SHF (but weaker HF diffusion in El Niño)



Anomalous Ekman transport causes the cooler water to move toward the southeast



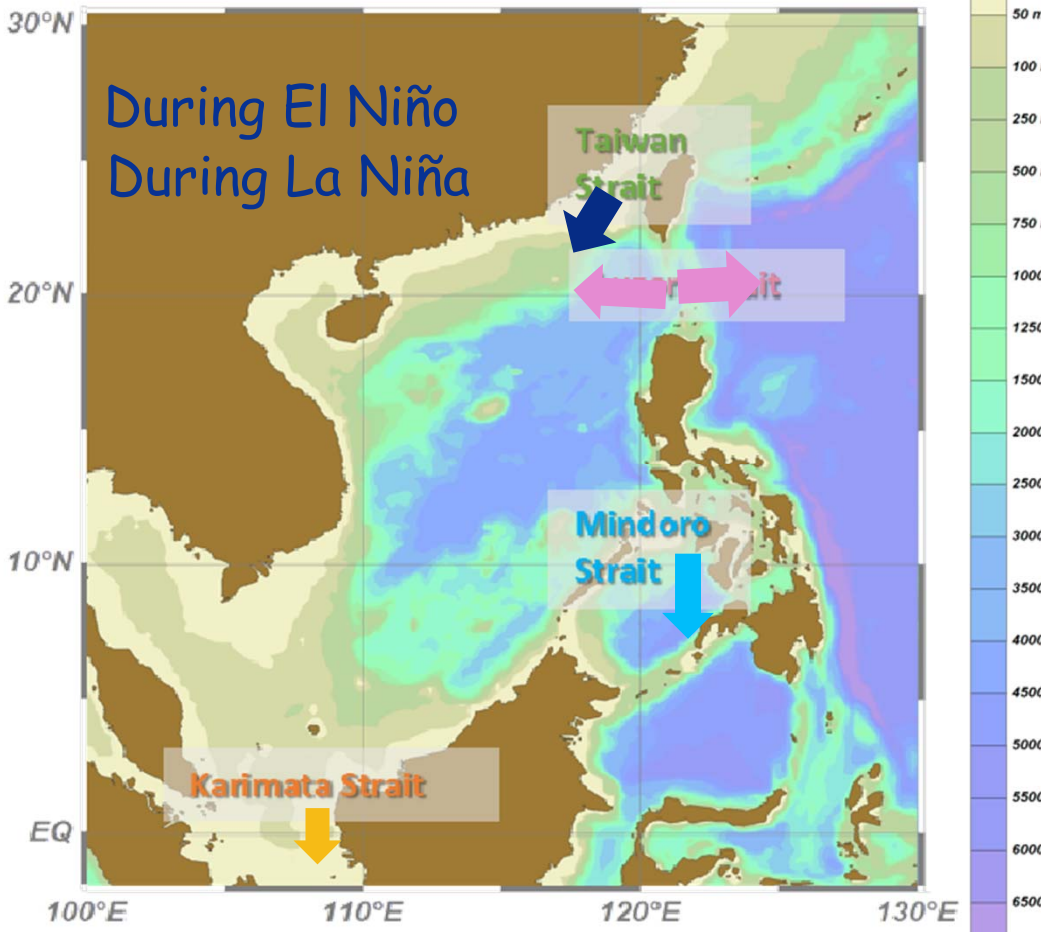
Winter: upward SHF causes cooler SST during La Niña and El Niño

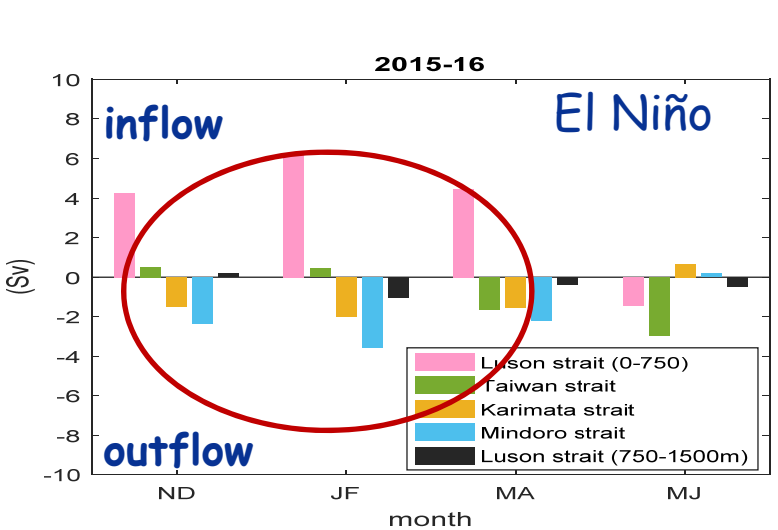
Spring: the advection causes cooler SST during the El Niño than La Niña

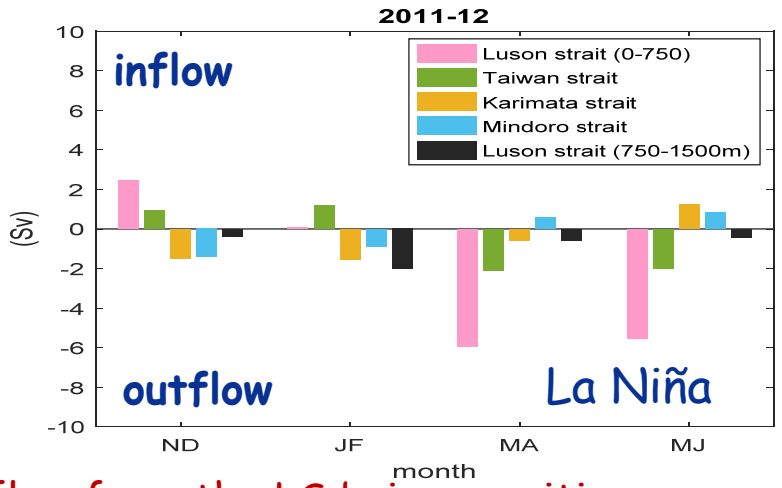
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

Water exchange in the SCS

CODA Lab







Dominant vorticity source through LS

$$\Omega^{cor} = \int_{Si} f\bar{u}dSi + \int_{Sj} f\bar{v}dSj$$

Gan et al. (2016)

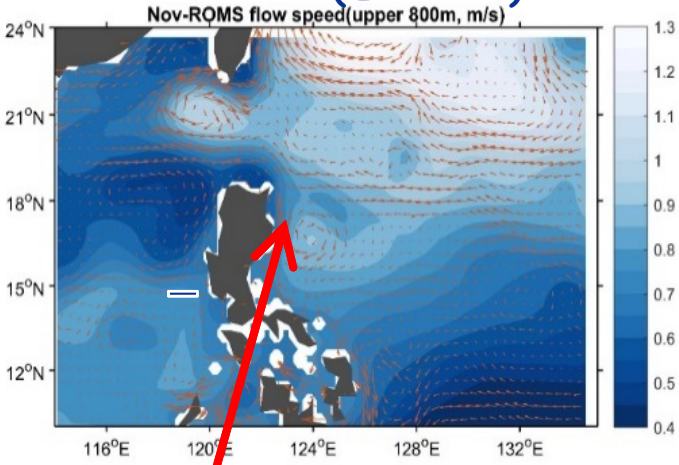
anomalous inflow from the LS brings positive planetary vorticity flux due to a higher latitude of the LS (larger *f*)

Si and *Sj* are the positive inward of the enclosed SCS.

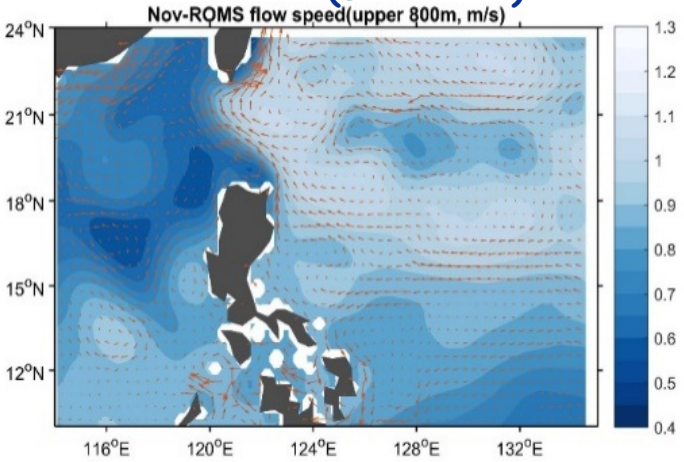
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

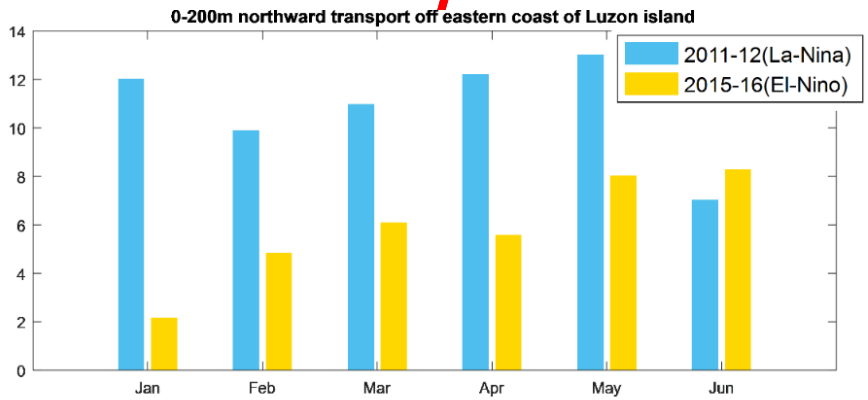
CODA Lab

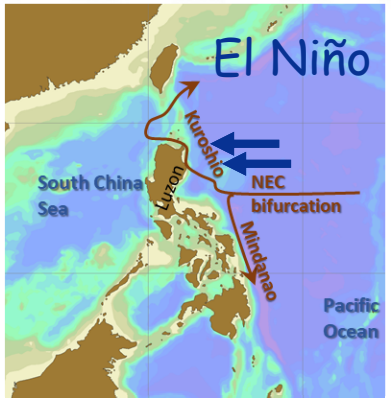
2015-16 (El Niño)

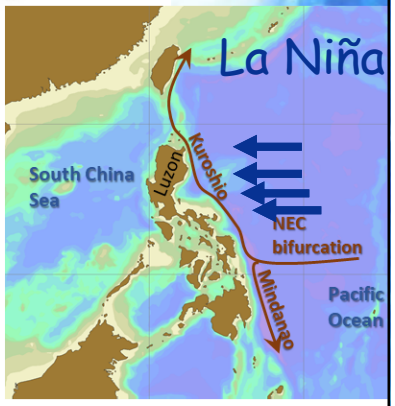


2011-12(La Niña)

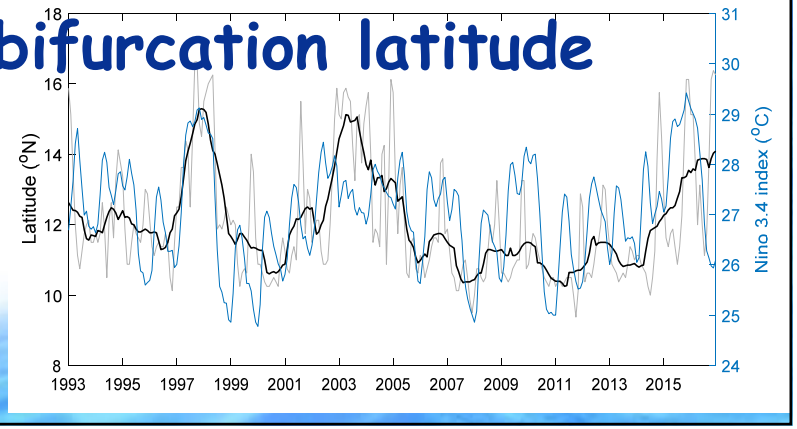








NEC bifurcation latitude



gray line: monthly value;
black line: 12-month moving ave.
Blue: Niño3.4 index

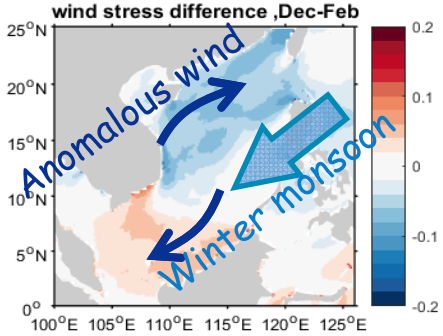
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

Air-sea heat exchange

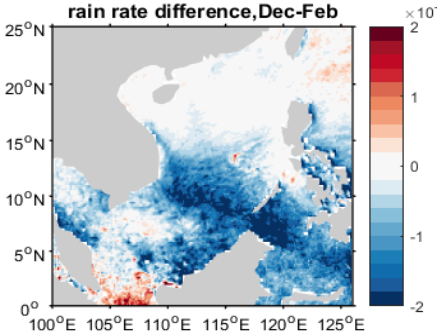
CODA Lab

seasonal mean diff. (El Niño-La Niña)

Winter(Dec-Feb)

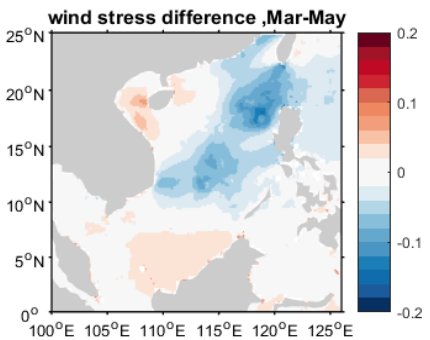


Wind stress

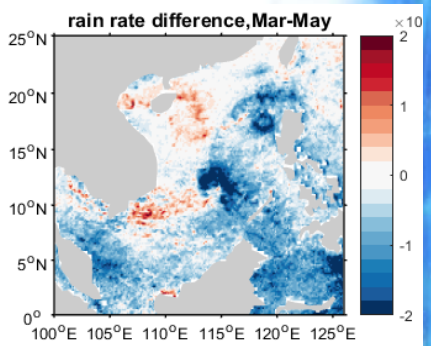


Rain rate

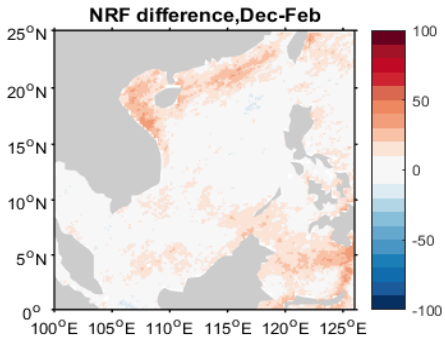
Spring (Mar-May)



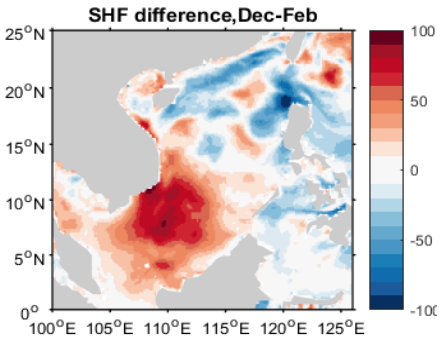
Wind stress



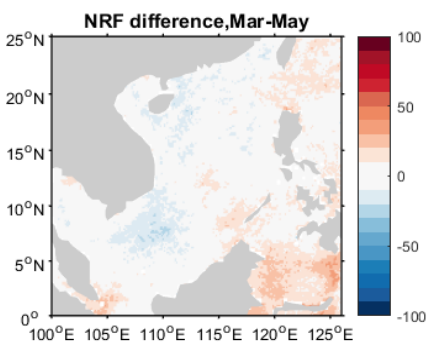
Rain rate



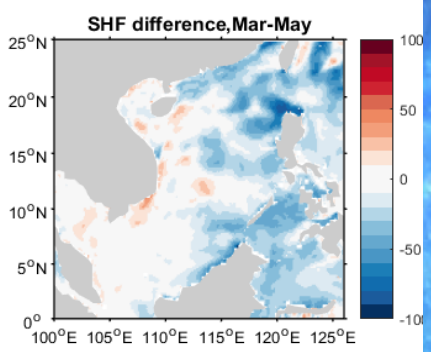
Net radiative HF



SHF



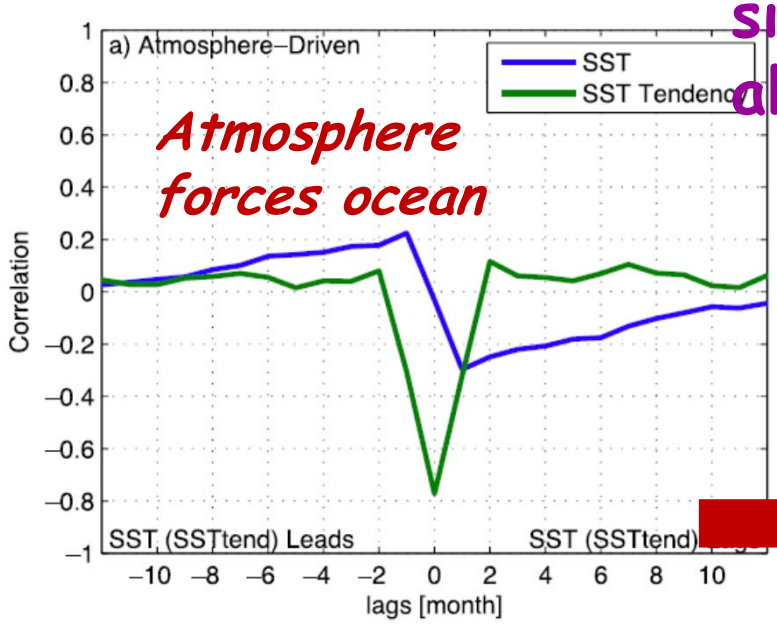
Net radiative HF



SHF

Positive: upward heat flux

SST and SHF relation in the simple stochastic models (Wu et al. 2006)



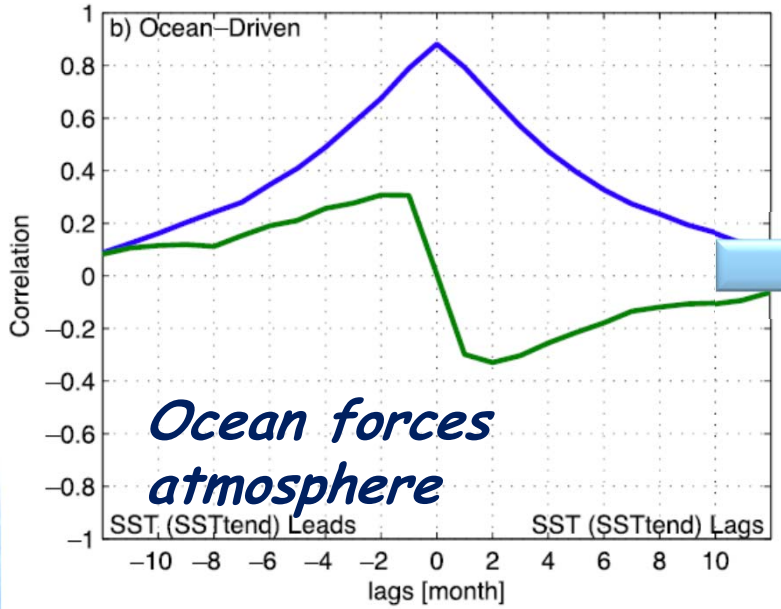
Atmosphere forces ocean

Positive: upward SHF

$$\frac{dT_a}{dt} = \alpha(SST - T_a) - \gamma_a T_a + N_a;$$

$$\frac{dSST}{dt} = \beta(T_a - SST) - \gamma_o SST + \cancel{N_o}^{0}$$

$\frac{dSST}{dt}$ ***is negatively correlated with SHF***



Ocean forces atmosphere

Positive: upward SHF

$$\frac{dT_a}{dt} = \alpha(SST - T_a) - \gamma_a T_a + \cancel{N_a}^{0};$$

SST is positively correlated with SHF

$$\frac{dSST}{dt} = \beta(T_a - SST) - \gamma_o SST + N_o$$

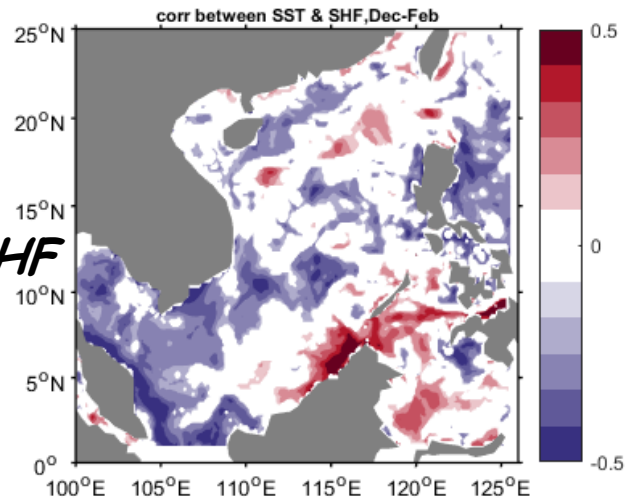
國立臺灣大學 海洋研究所
Institute of Oceanography, National Taiwan University

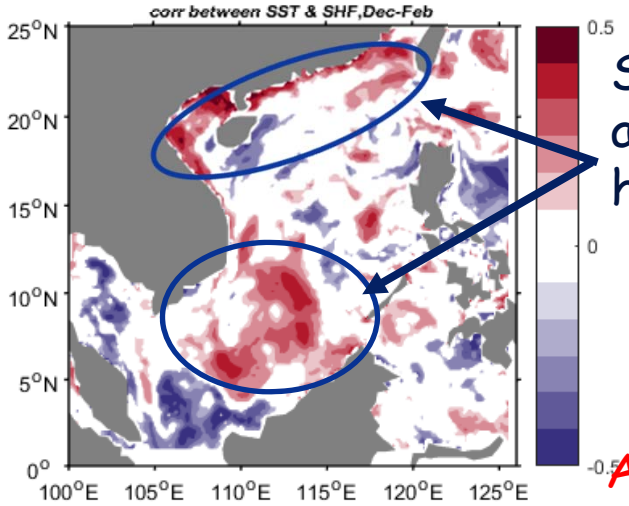
CODA Lab

Correlation between SST/SST tendency and SHF anomaly

2015 El Niño winter　　2011 La Niña winter

SST & SHF

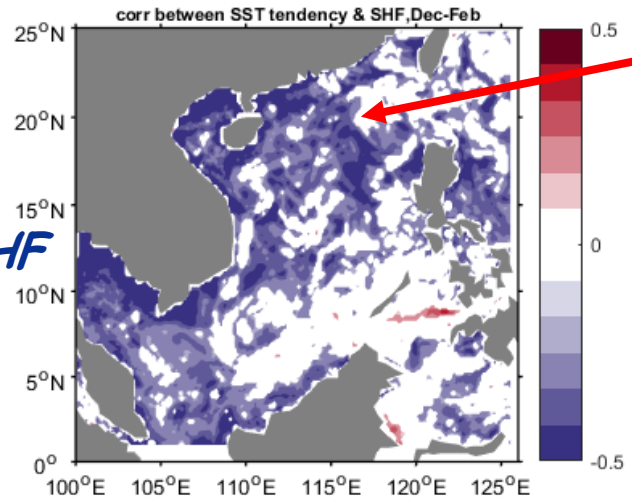


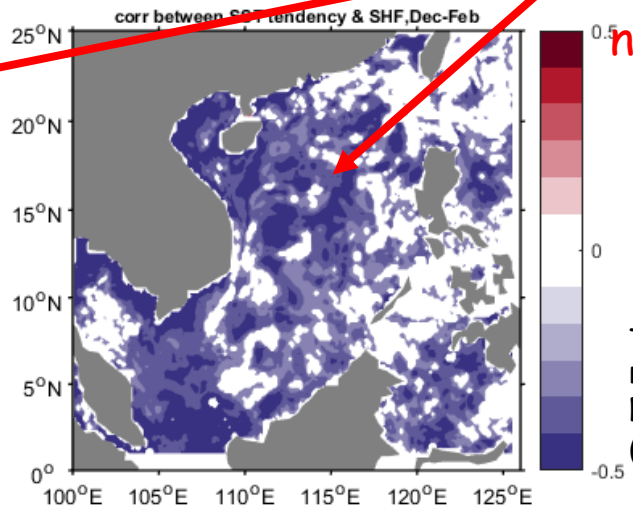


SST forces the anom. air-sea heat flux

ATM forcing dominates the anom. SHF in the northern SCS

$\frac{dSST}{dt}$ & SHF





the monthly clim. is removed by subtracting NCEP reanalysis mean (1979-2009)

Conclusion

Northern SCS during ENSO

NEC bifurcation moves northward/southward during El Niño/La Niña

Larger/smaller inflow through the Luzon strait

Gain/lose planetary vorticity flux

Modifies the 3-layer circulation

Anomalous southwesterly/northeasterly wind during El Niño/La Niña

Weaker/stronger wind-driven China coastal current during winter

Warmer/cooler SST in the western SCS during winter

anomalous Ekman drift

Cooler/warmer SST during spring

Weaker/stronger onshore flow convergence along the western coast winter

Thicker/Thinner MLD along the western coast

Anomalous negative/positive wind curl during El Niño/La Niña

Thicker/thinner MLD to the southwest of Taiwan

Southern SCS during ENSO

Weaker/stronger southward boundary current during El Niño/La Niña

Reduced/enhanced planetary vorticity flux

Weaker/stronger cyclonic circulation during winter

Higher/lower SST

Thicker/thinner MLD during winter

Anomalous negative/positive wind curl during El Niño/La Niña

Thicker/thinner MLD in the southern SCS

Anomalous descending/ ascending during El Niño/La Niña

sed/ enhanced rainfall