

Decadal warming of the China coastal seas during winter and its coupling with monsoon and cross flows

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Motivation

Coastal oceans bear the brunt of climate changes – anthropogenic or otherwise [Halpern et al. 2008, Science; Belkin 2009, Prog. Oceanogr.]

Outline

- **Physics of cross flows**
- **Decadal coastal warming (since ~1980)**
- **Air-sea coupling**
- **Summary**

Wang, R., Zuo, T. and Wang, K., 2003: The Yellow Sea cold bottom water – an oversummering site for *Calanus sinicus* (Copepoda, Crustacea). *J. Plankton Res.*, 25, 169–183.

Zhang, G.-T., S. Sun and B. Yang, 2007: Summer reproduction of the planktonic copepod *Calanus sinicus* in the Yellow Sea. *J. Plankton Res.*, 29, 179–186

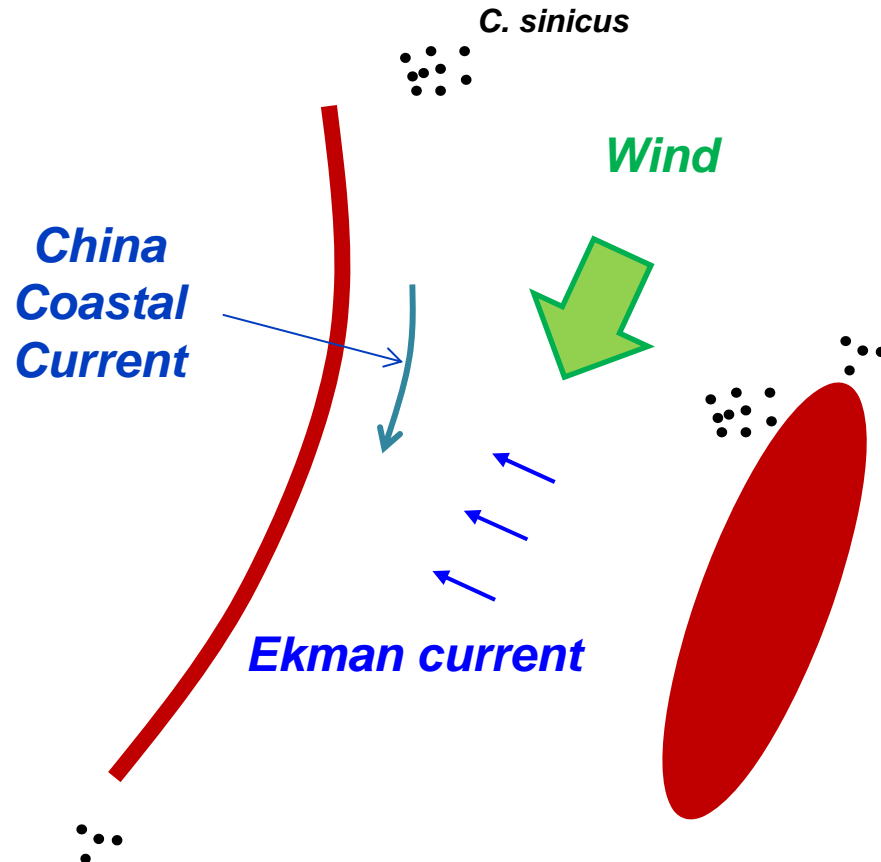
Chen, Q. C., 1992: Zooplankton of China Seas (1). Science Press, Beijing, China.

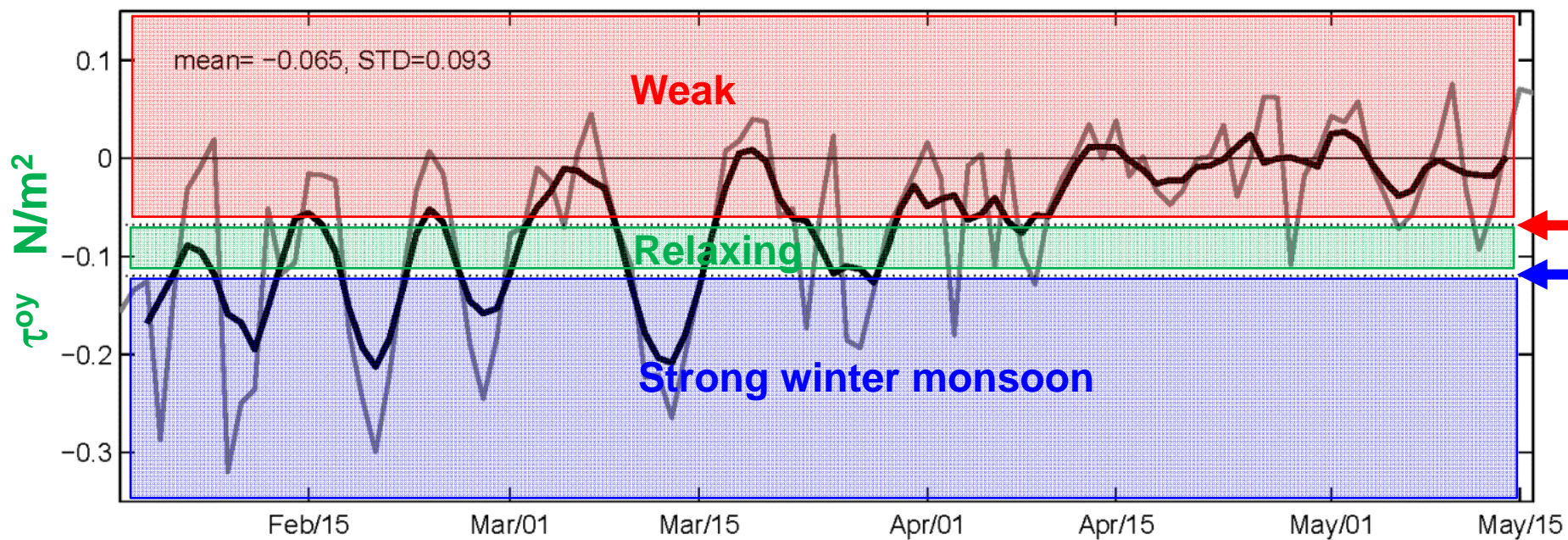
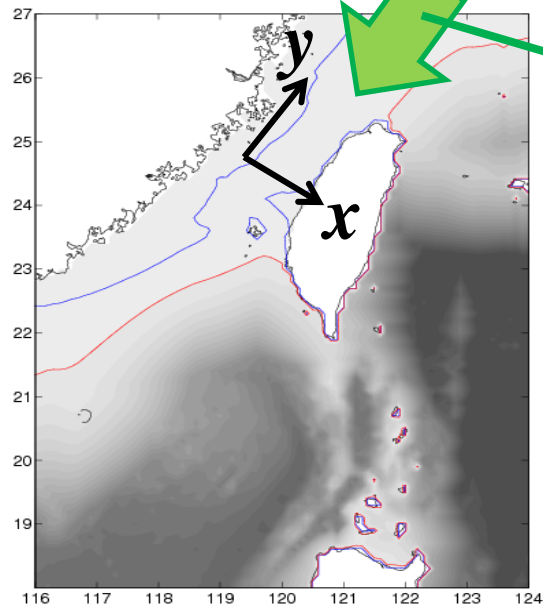
Hwang, J.-S. and C. K. Wong, 2005: The China Coastal Current as a driving force for transporting *Calanus sinicus* (Copepoda: Calanoida) from its population centers to waters off Taiwan and Hong Kong during the winter northeast monsoon period. *J. Plankton Res.* 27, 205-210.

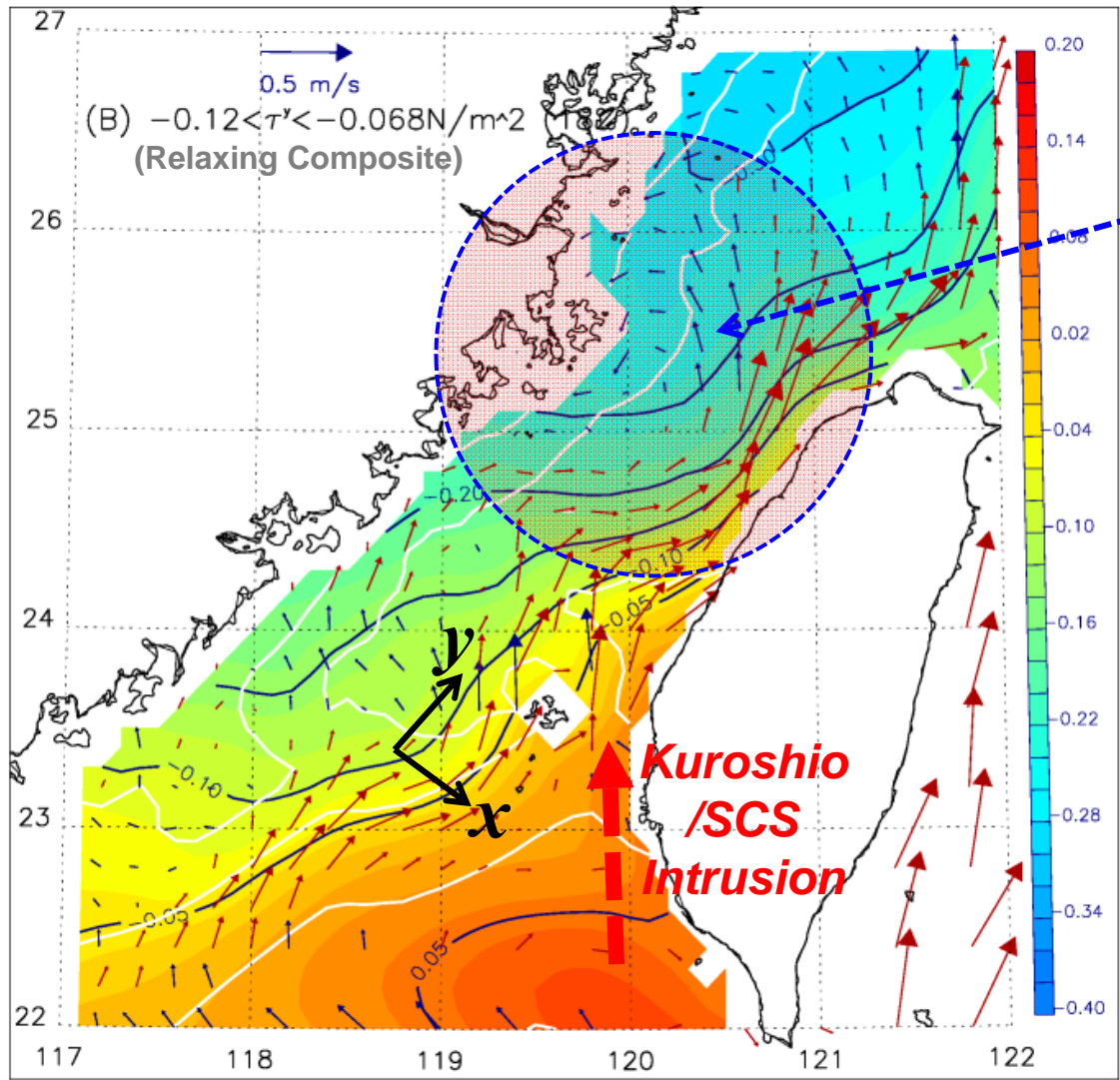
Hwang, J.-S. + 14 co-authors, 2006: A 5-year study of the influence of the northeast and southwest monsoons on copepod assemblages in the boundary coastal waters between the East China Sea and the Taiwan Strait. *J. Plankton Res.* 28, 943-958.

Biological data suggests a cross-strait drift of *C. sinicus* by the surface currents, some 100-200 km across the Taiwan Strait in winter-early spring;

→ **How?**



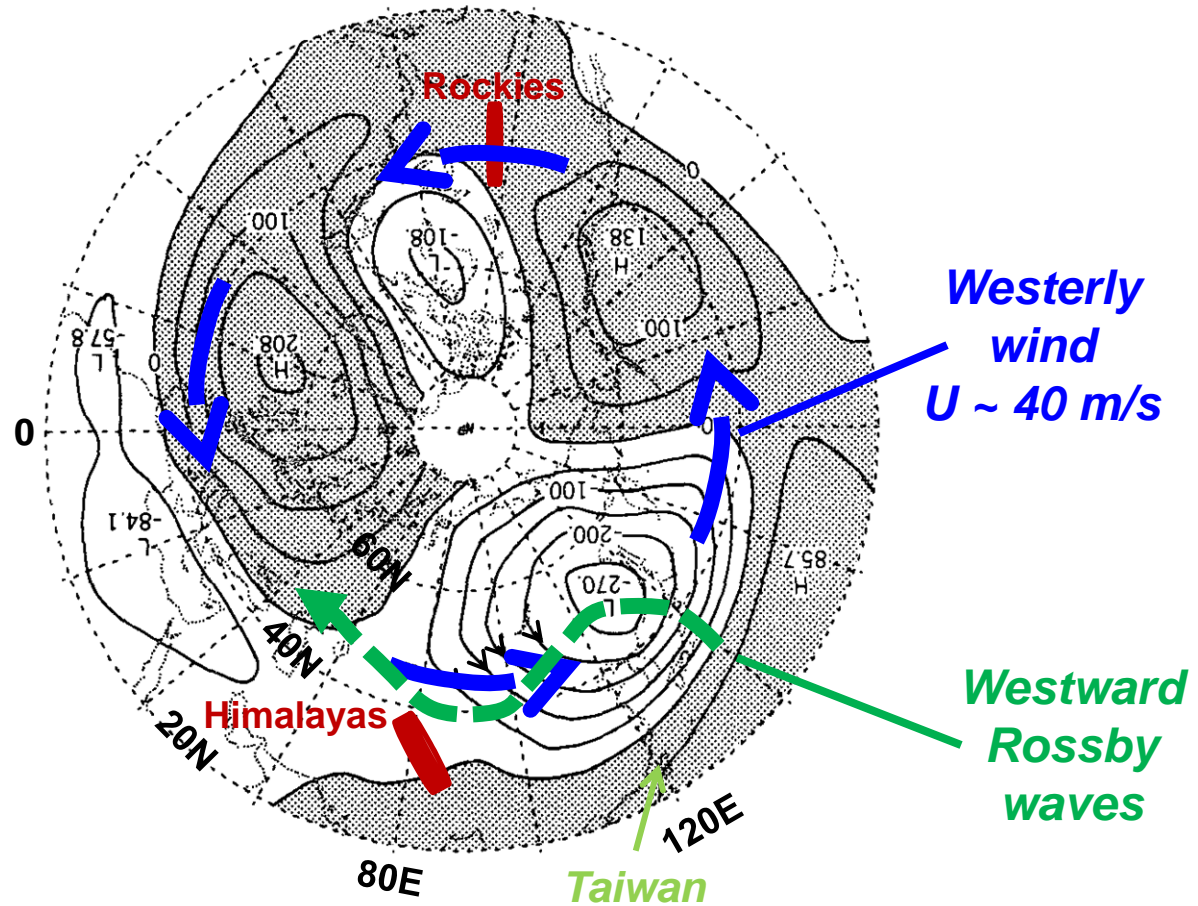




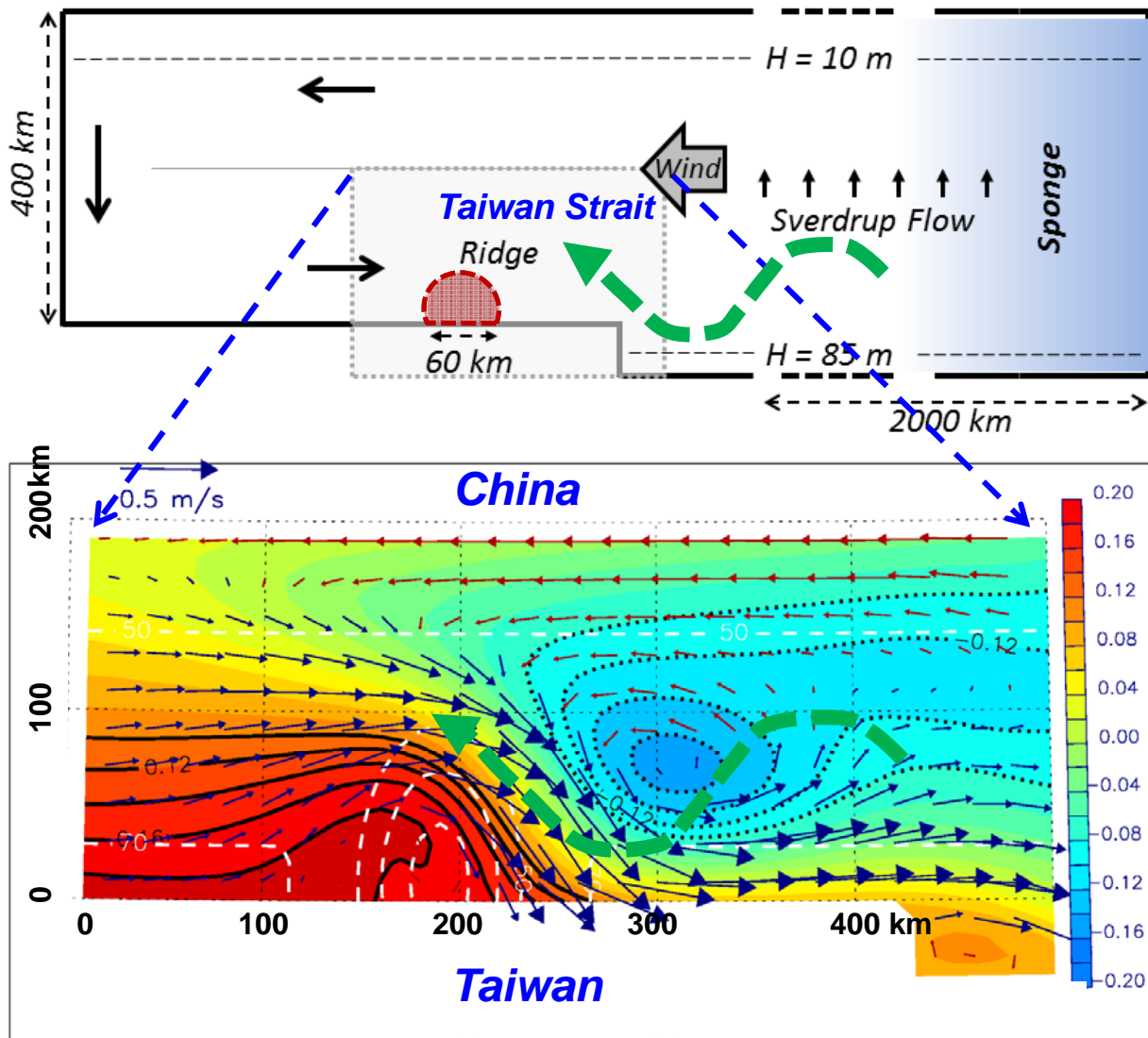
Cross flow: cyclone
downstream of the
Changyun Ridge

**Why
cross flows?**

Standing Wavelength $\lambda_{\text{atmos}} = 2\pi (U_{\text{atmos}} / \beta)^{1/2} \approx 8,000\text{km}$



Lau, N.-C., 1979: The observed structure of tropospheric stationary waves and the local balances of vorticity and heat. *J. Atmos. Sci.*, 36, 996-1016

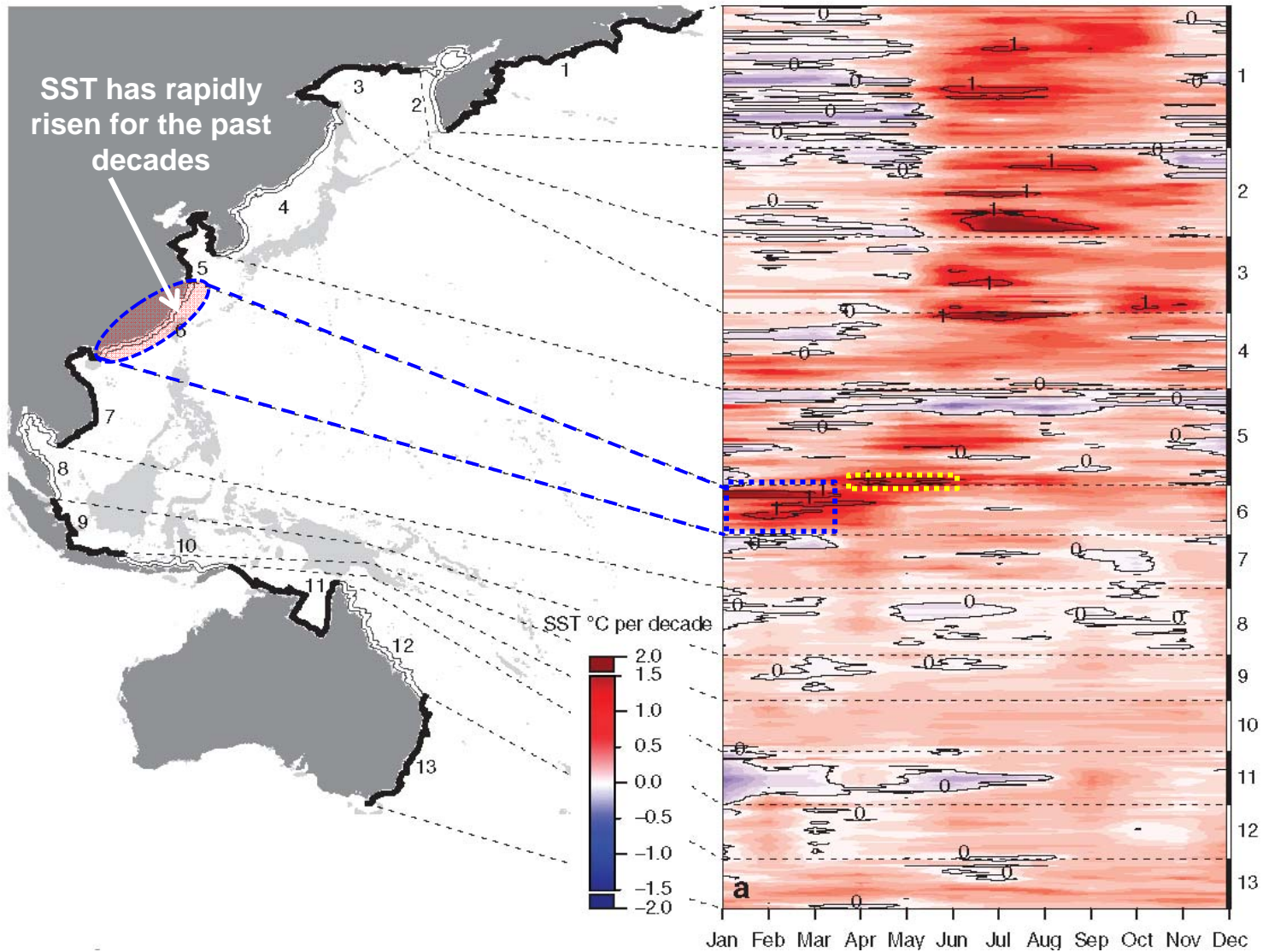


Standing wavelength $\lambda \sim (U/\beta)^{1/2}$;

$$\lambda_{\text{ocean}} = [(0.2/40) * (2/27)]^{1/2} \sim 0.07 * 0.3 * 8,000 \text{ km} \sim 170 \text{ km}$$

Coastal warming

Decadal coastal warming

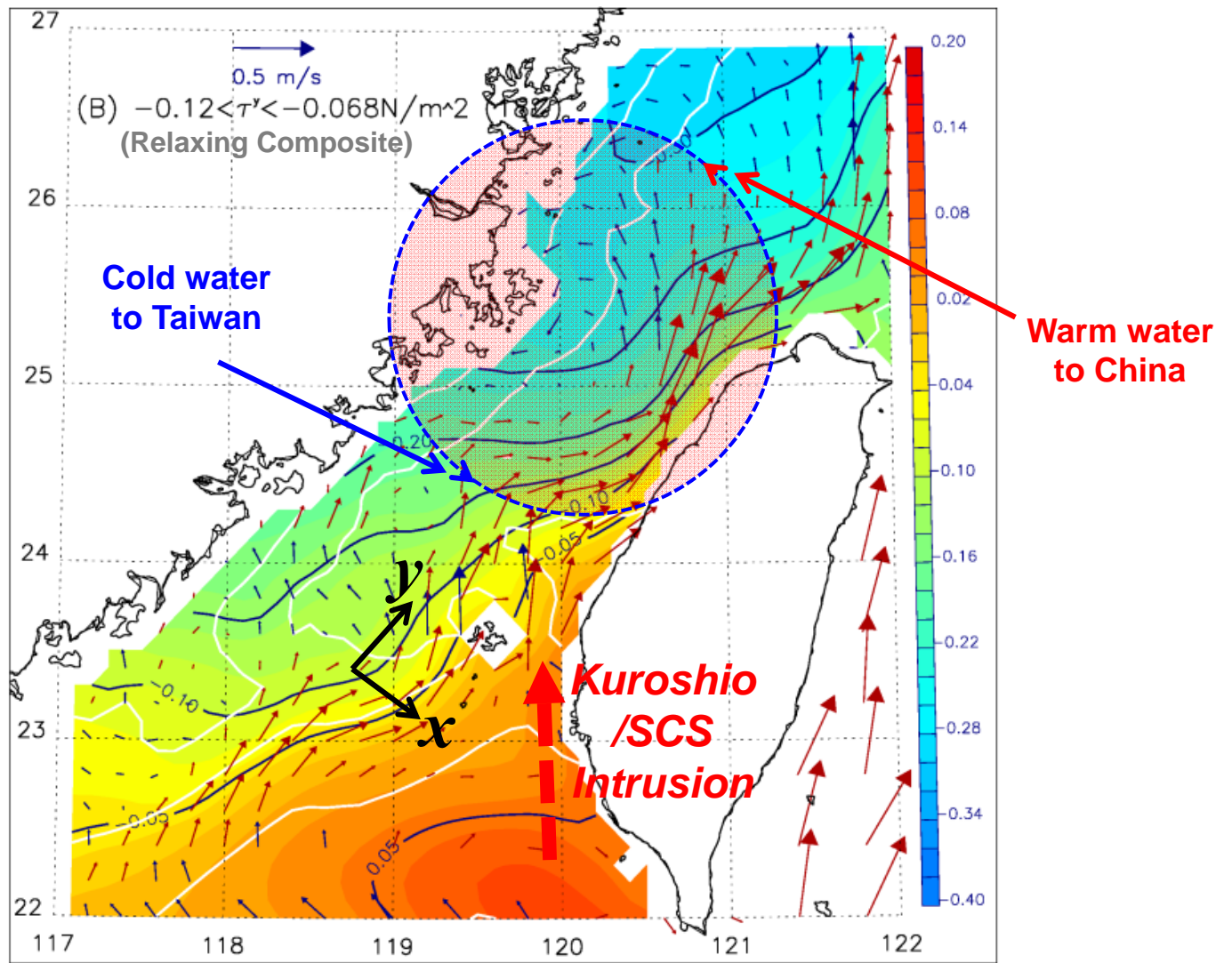


[Lima, F. P. and D. S., Wethey, 2012: Three decades of high- resolution coastal sea surface temperatures reveal more than warming. *Nature Communications* 3,704.](#)

See also:

[Belkin, I. M., 2009: Rapid warming of large marine ecosystems. *Prog. Oceanogr.* 81, 207–213.](#)

**How may China
coastal seas
become
warm in winter?**



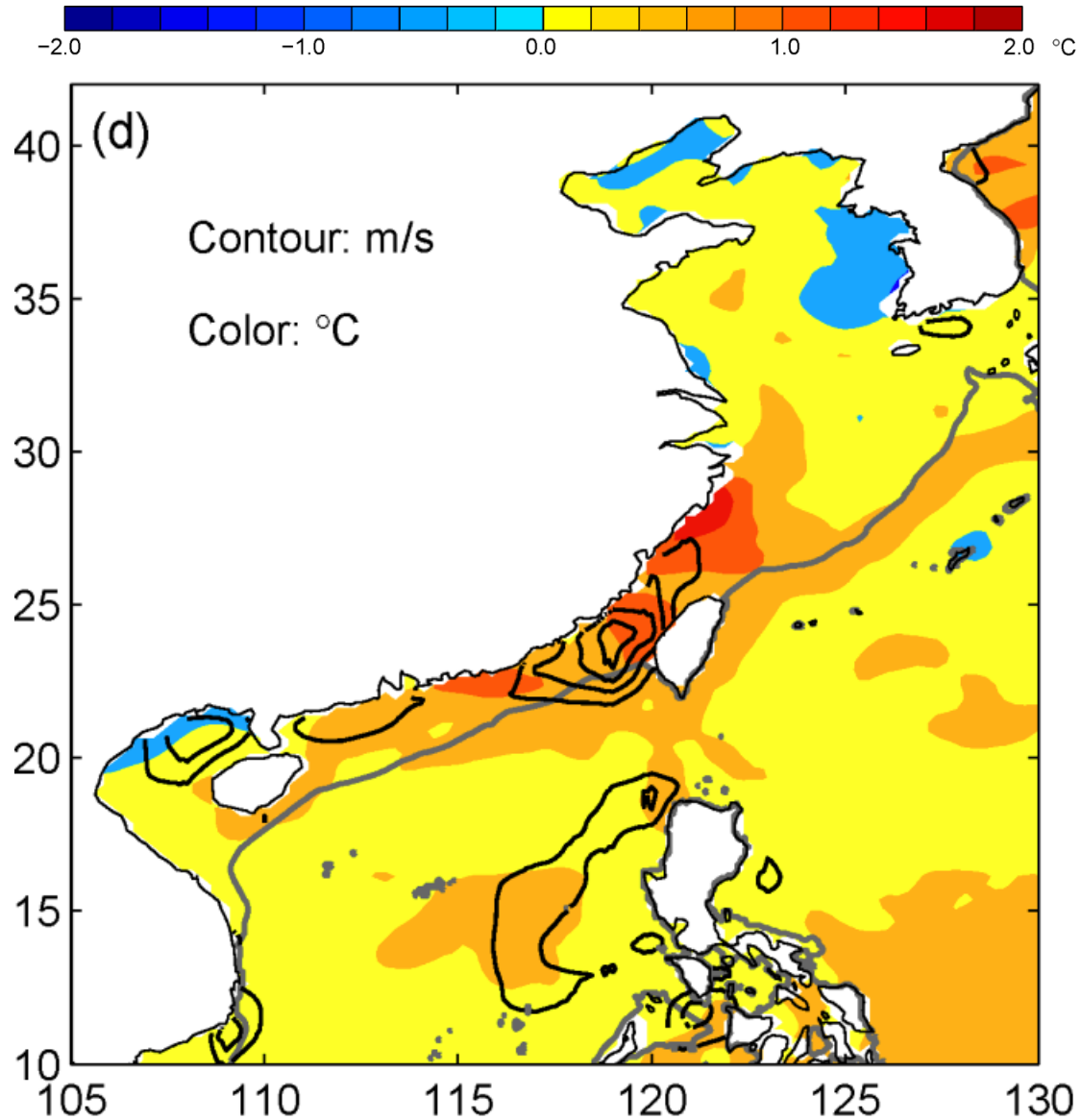
Warm parcels to China Cold to Taiwan

So net heat flux is: Taiwan → China

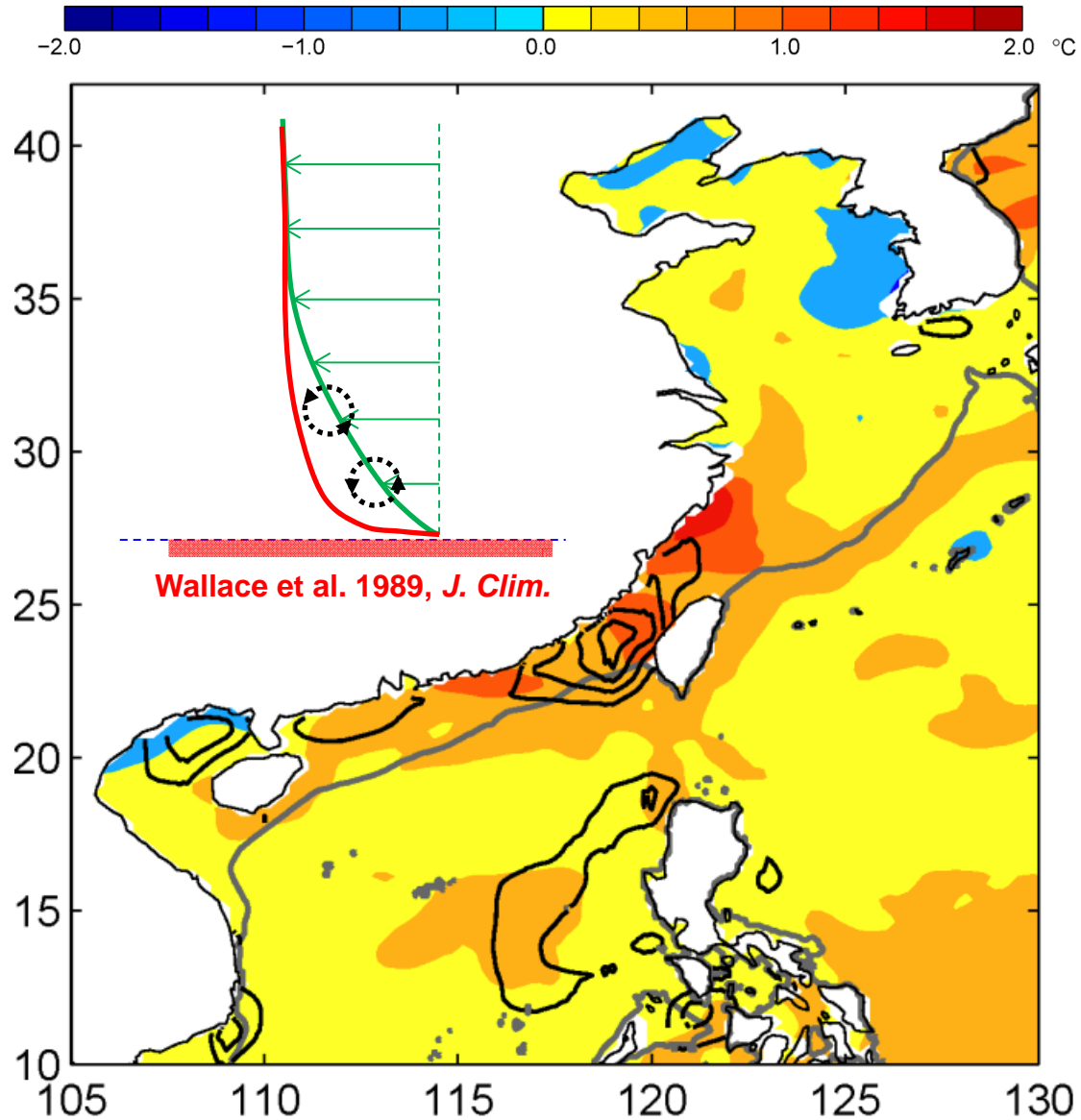
tending to warm China's coastal region

**.. but why has
coastal SST
been rising in
past decades?**

Contours are $\delta(\text{WindSpeed})$ in m/s, 1999-2009 JFM minus 1988-1998 JFM
Color is $\delta(\text{SST})$ in $^{\circ}\text{C}$, 1998-2009 JFM minus 1987-1997 JFM



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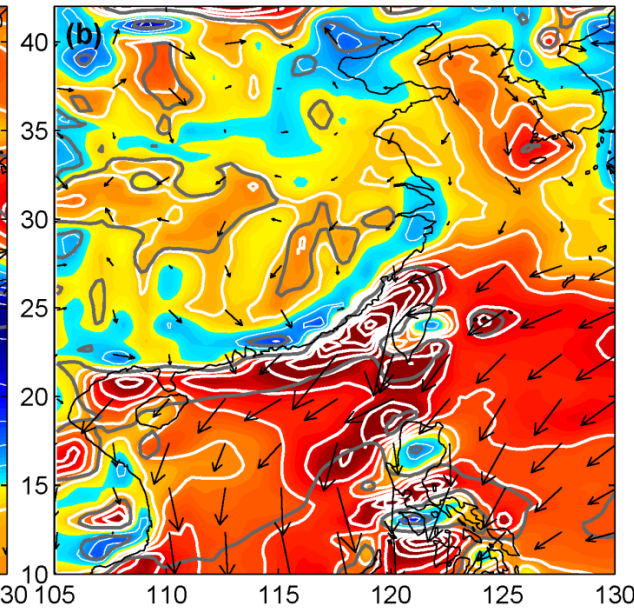
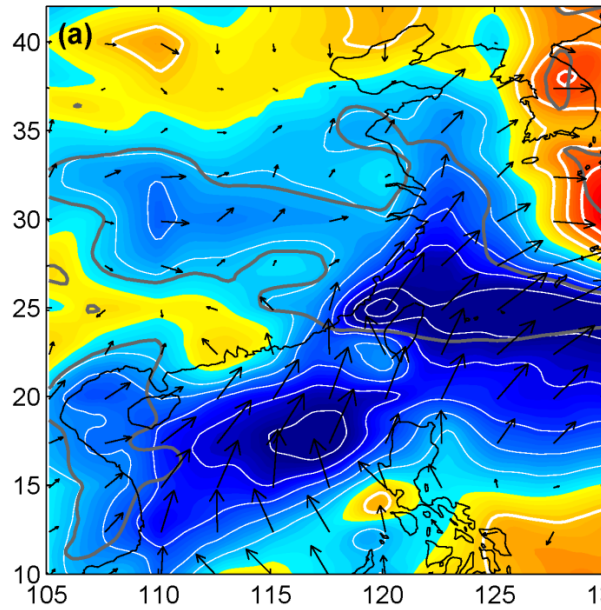




-1.50 -1.20 -0.90 -0.60 -0.30 0.00 0.30 0.60 0.90 1.20 1.50 m/s/10yr
-2.0 -1.0 0.0 1.0 2.0 °C

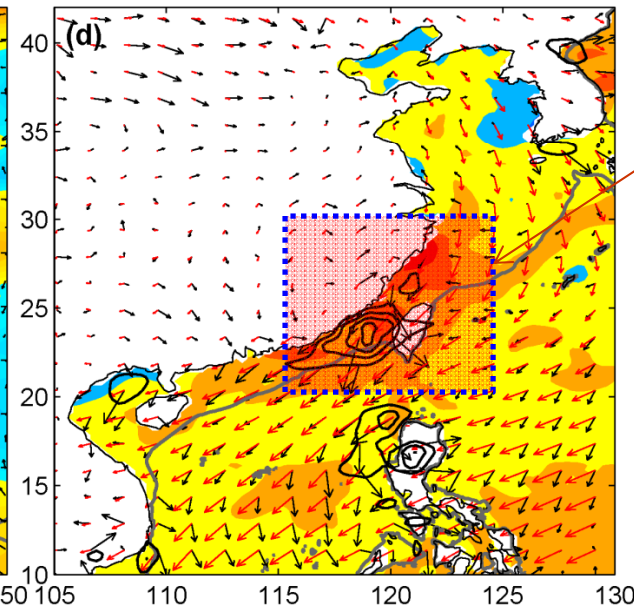
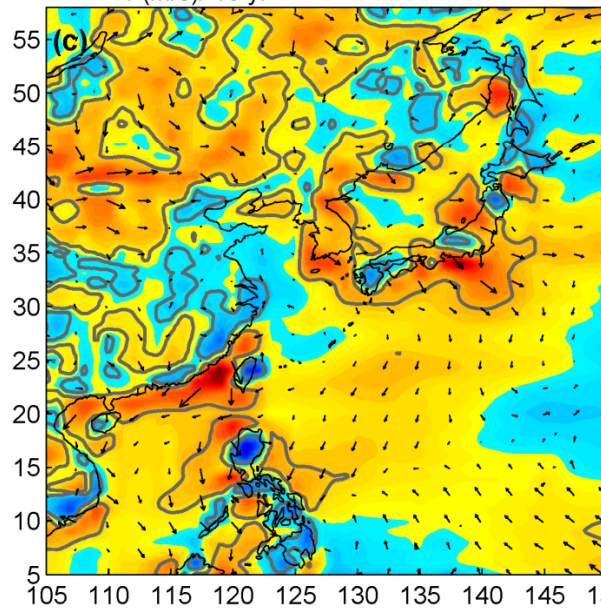
→ 1 (m/s)/ 10 yr **1988-1998 Trend**

→ 1 (m/s)/ 10 yr **1998-2009 Trend**

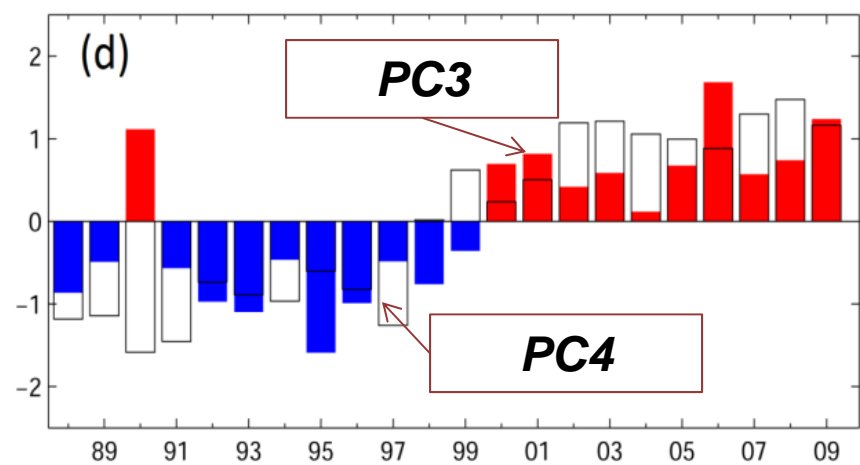
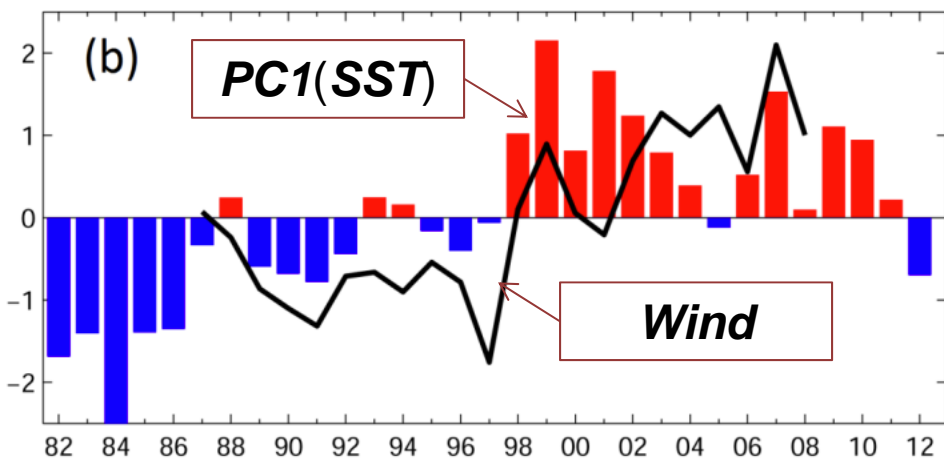
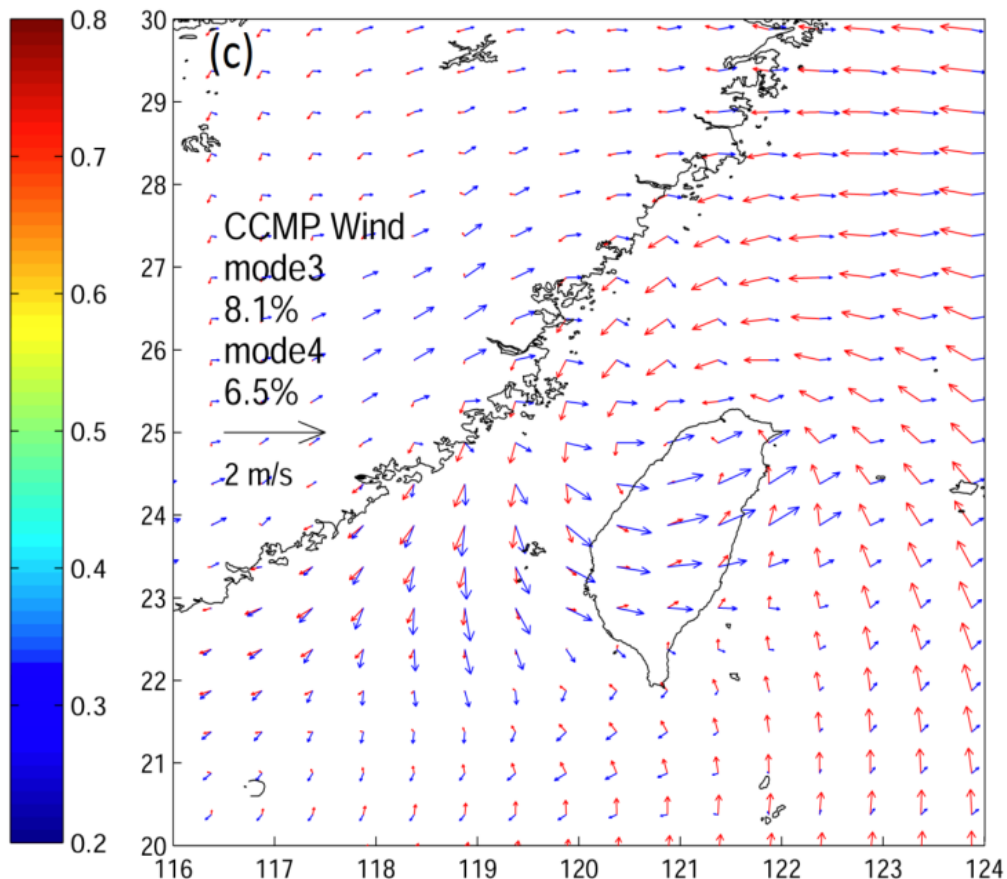
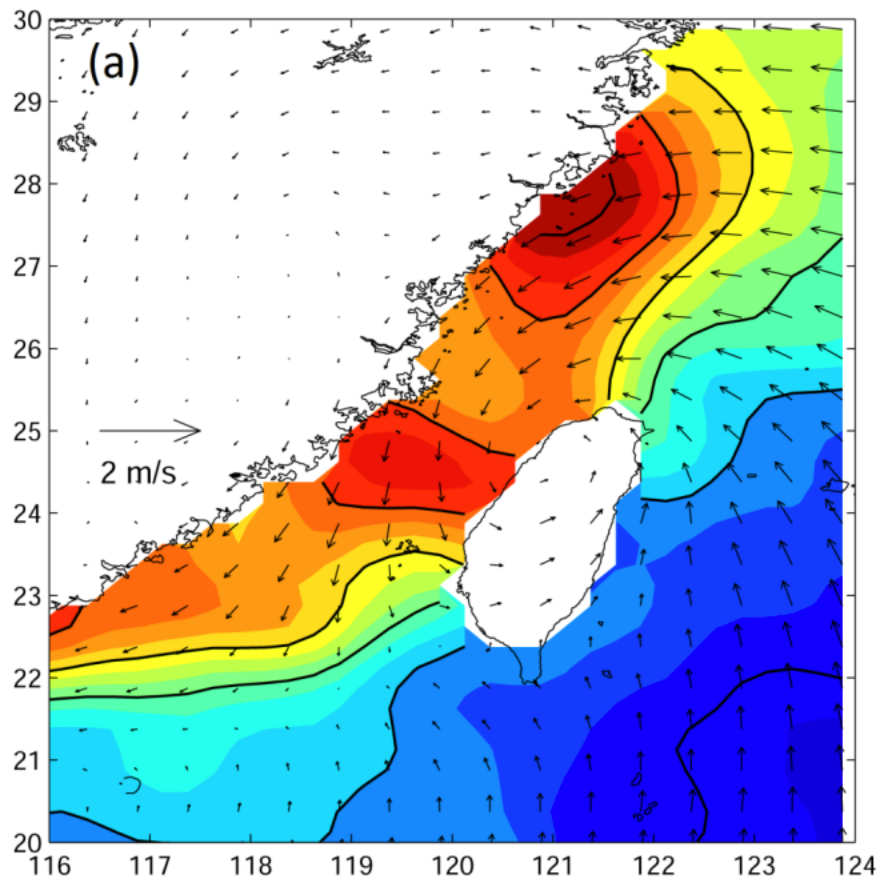


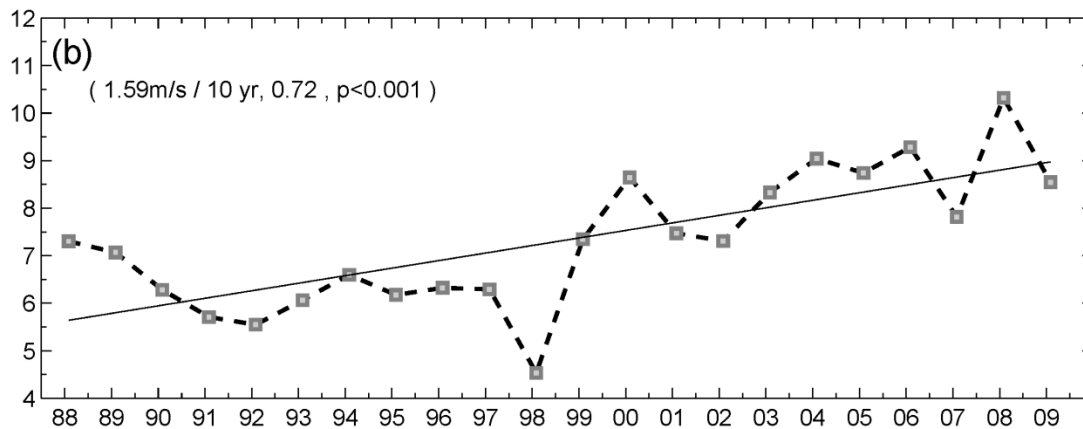
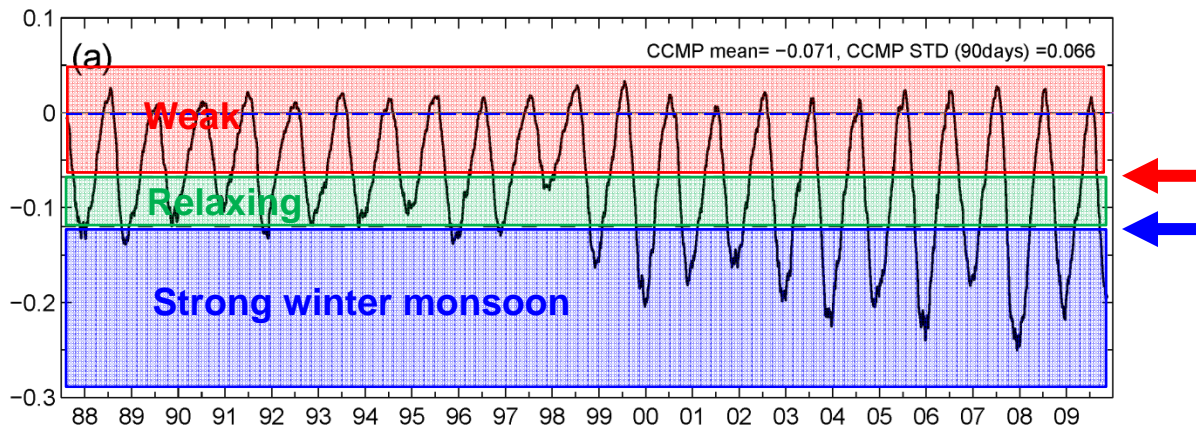
→ 1 (m/s)/ 10 yr **1988-2009 Trend**

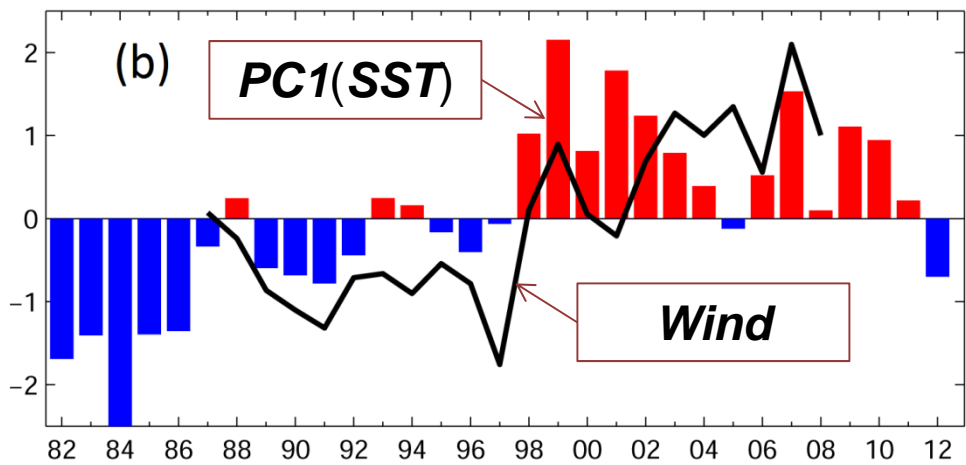
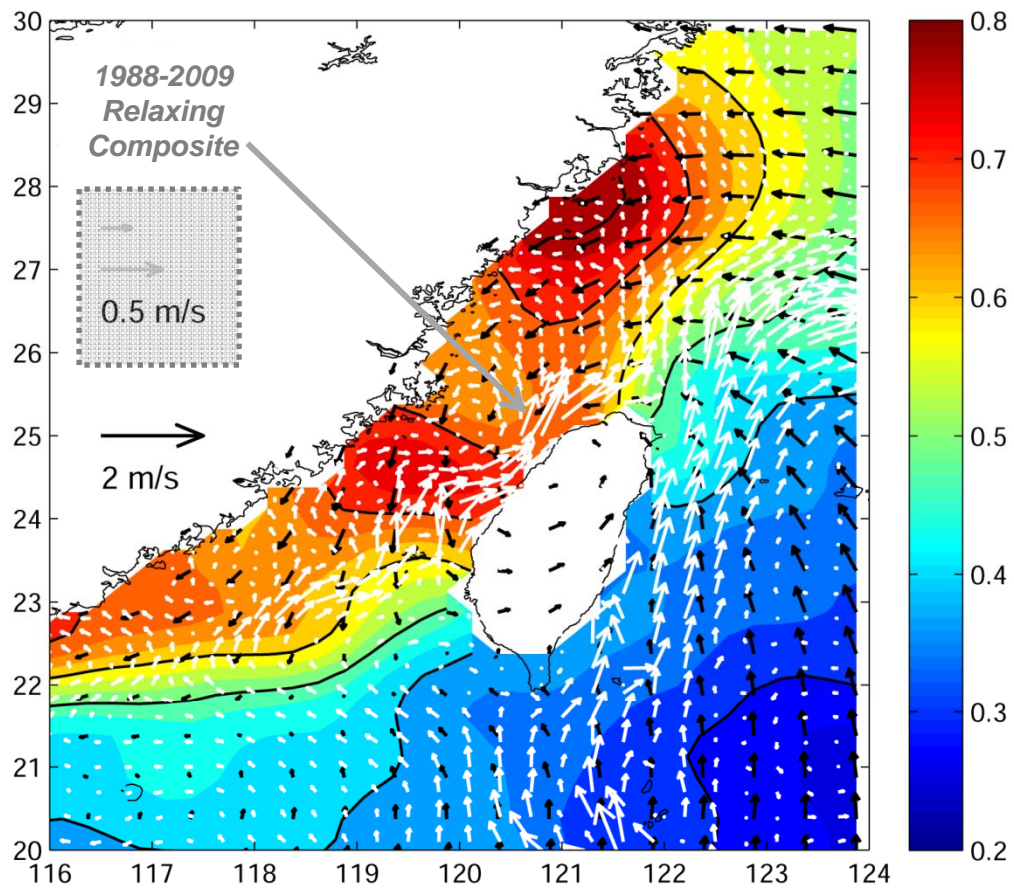
→ 1m/s — 5m/s

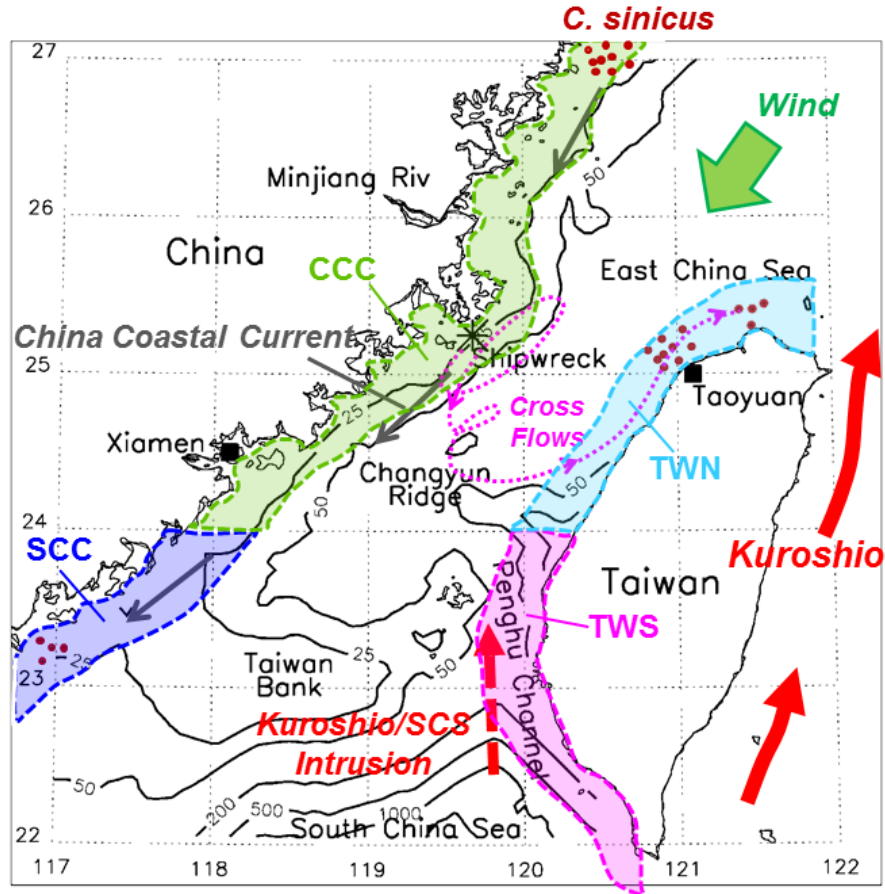


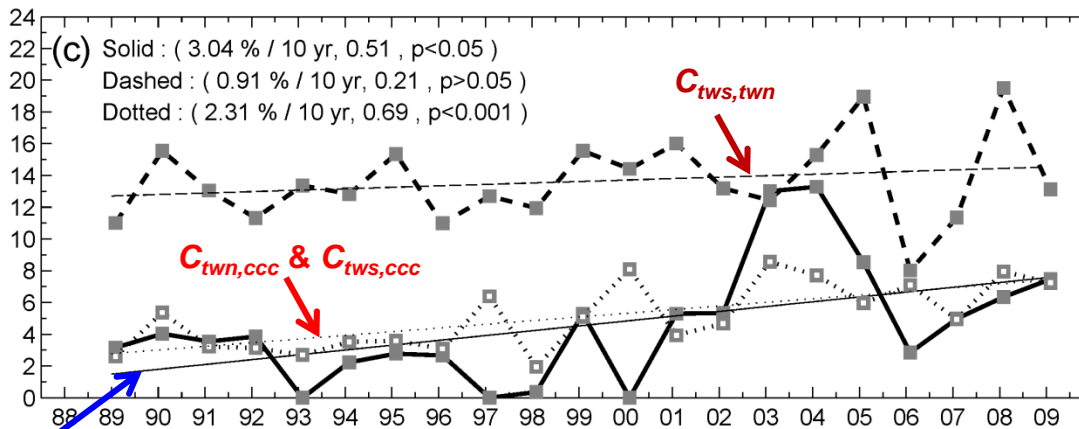
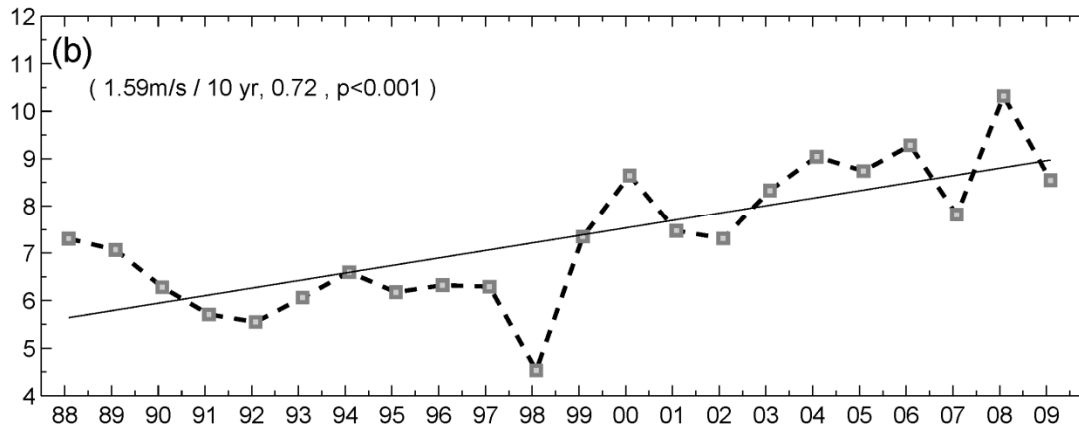
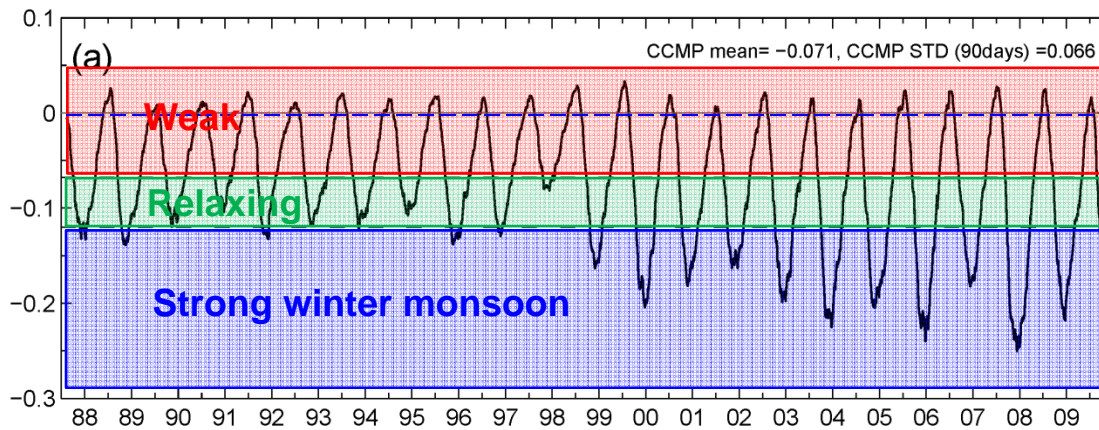
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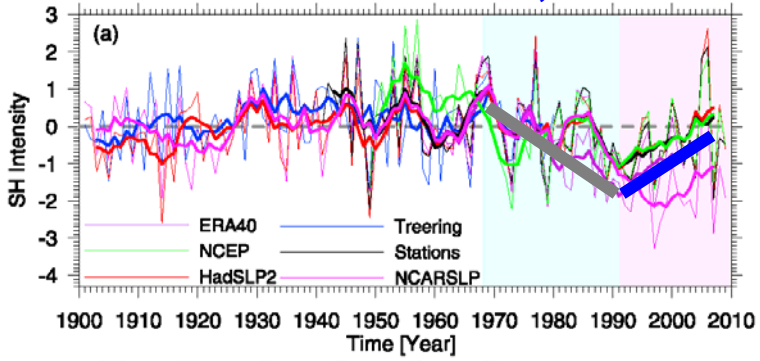


**Far-reaching
impact of
coastal warming
on EAWM**

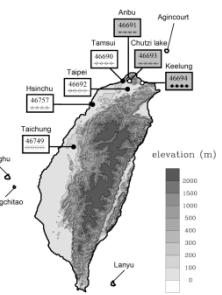
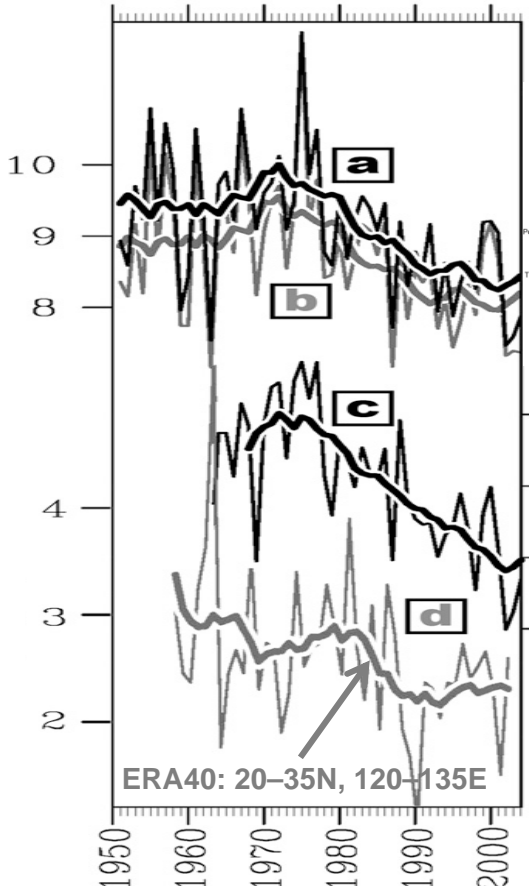
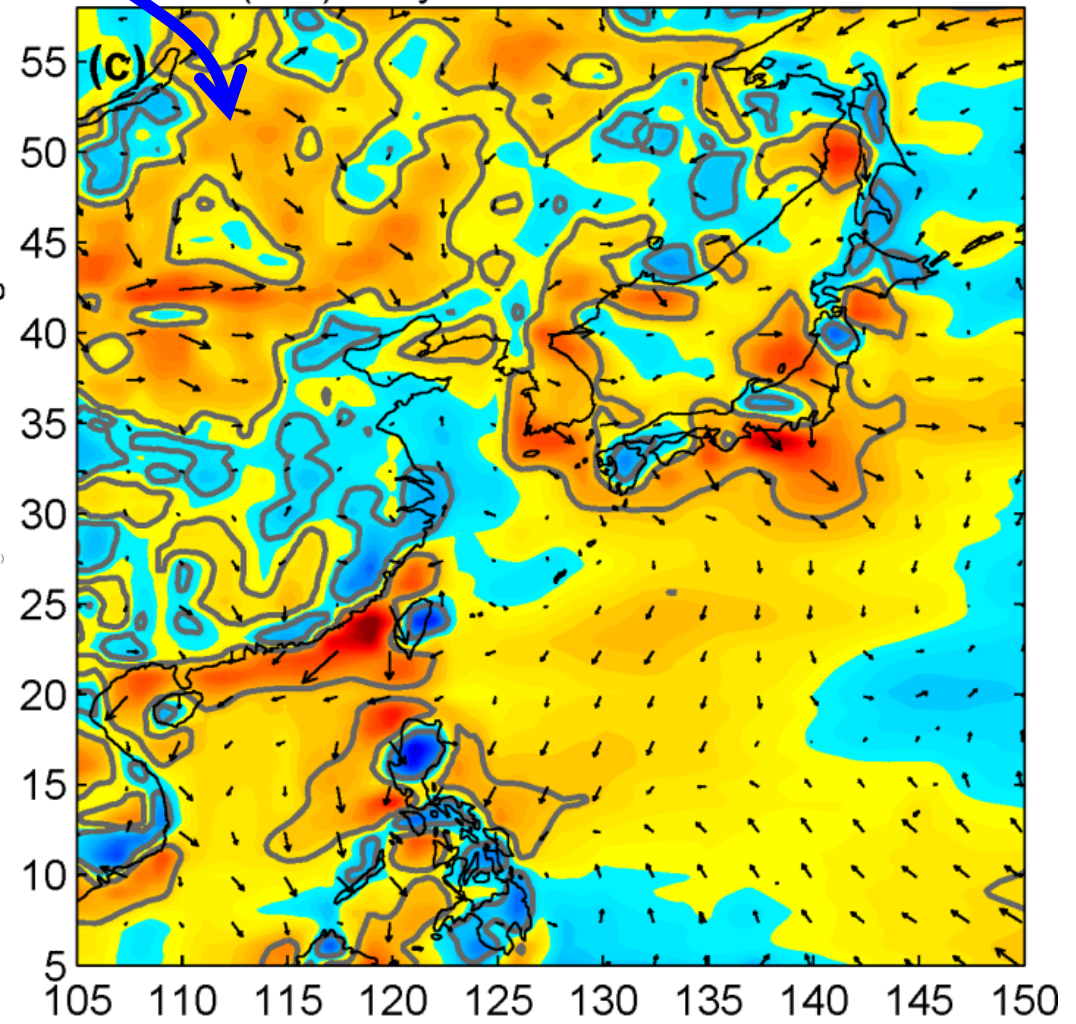
Jeong, J.-H., et al. 2011: [Recent recovery](#) of the Siberian High intensity, *J. Geophys. Res.*, 116, D23102, doi:10.1029/2011JD015904



SHI = winter SLP 40-65°N, 80-120°E



1 (m/s)/ 10 yr 1988-2009 Trend



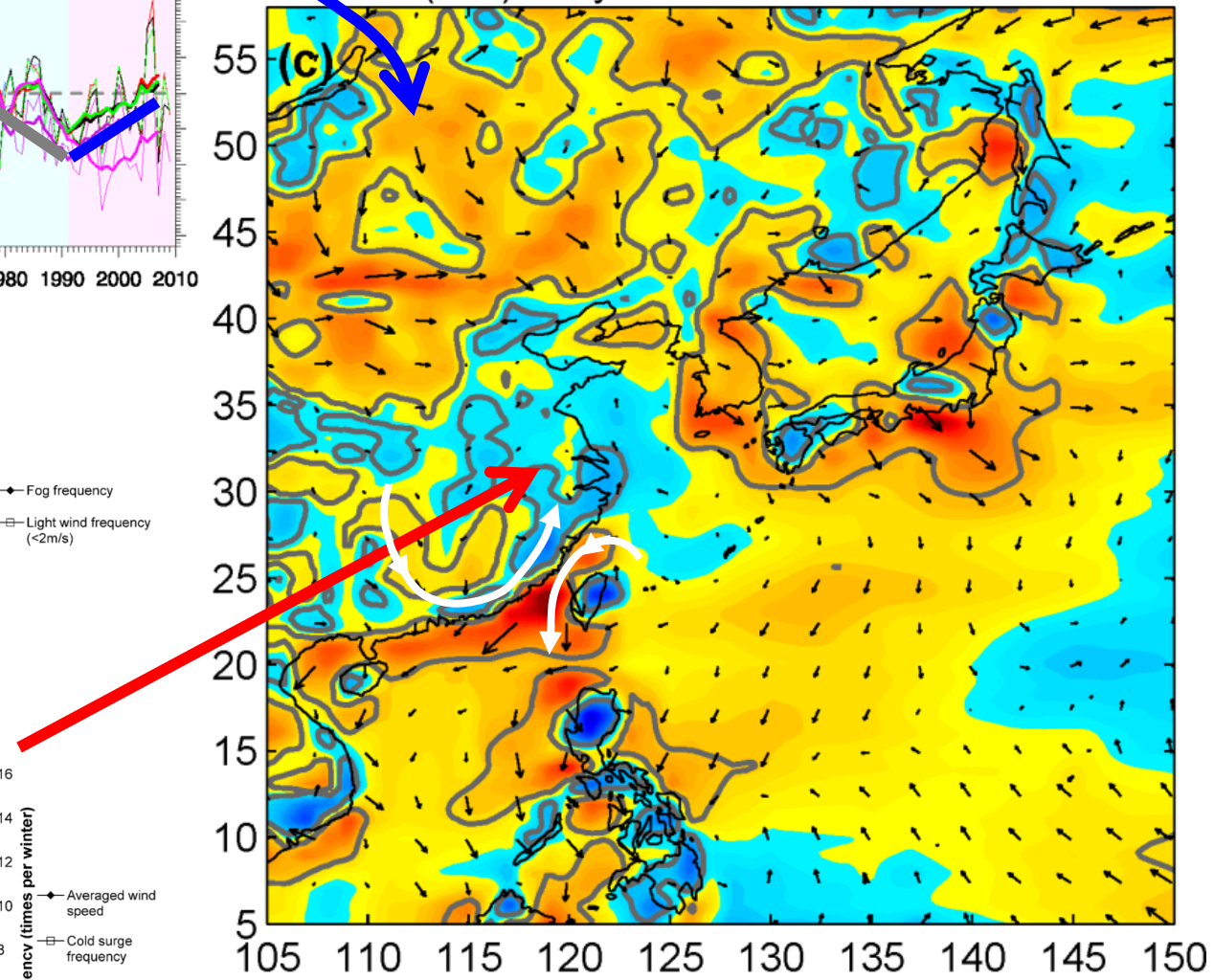
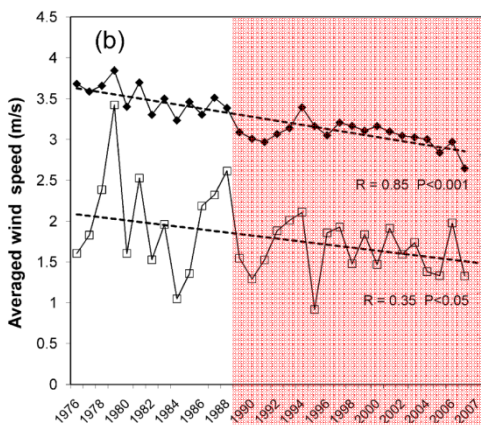
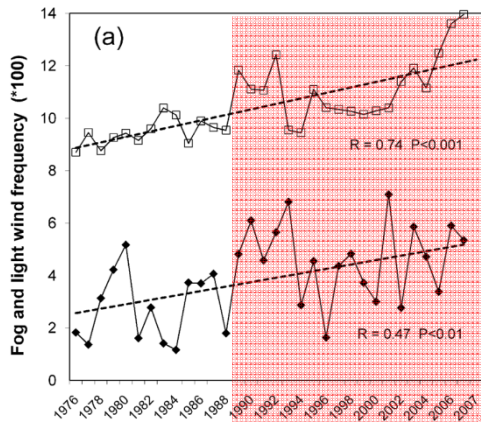
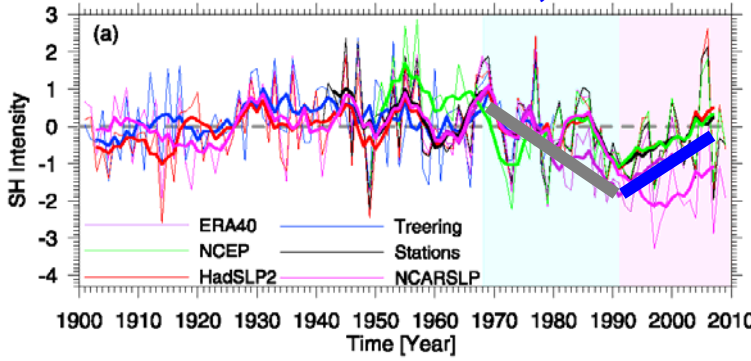
Hung, C.-W. and P.-K. Kao, 2010: Weakening of the winter monsoon and increase of winter rainfalls over northern Taiwan and southern China in early 1980s. *J. Clim*, 23, 2357-2367

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SHI = winter SLP 40-65°N, 80-120°E

— 1 (m/s)/ 10 yr **1988-2009 Trend**



Niu, F. et al. 2010: Increase of wintertime fog in China: Potential impacts of weakening of the Eastern Asian monsoon circulation, J. Geophys. Res., 115, D00K20

Summary

- ❖ **Cross flows in Taiwan Strait transport heat to China coast**
- ❖ **Coastal warming produces stronger northeasterly wind**
- ❖ **Resulting in more frequent cross flows → heat flux, in a positive feedback**
- ❖ **EAWM over China is fundamentally altered and decoupled from SH**

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