Pacific and Atlantic decadal variability reflected by the winter temperature in Taiwan during the period 1911-2010

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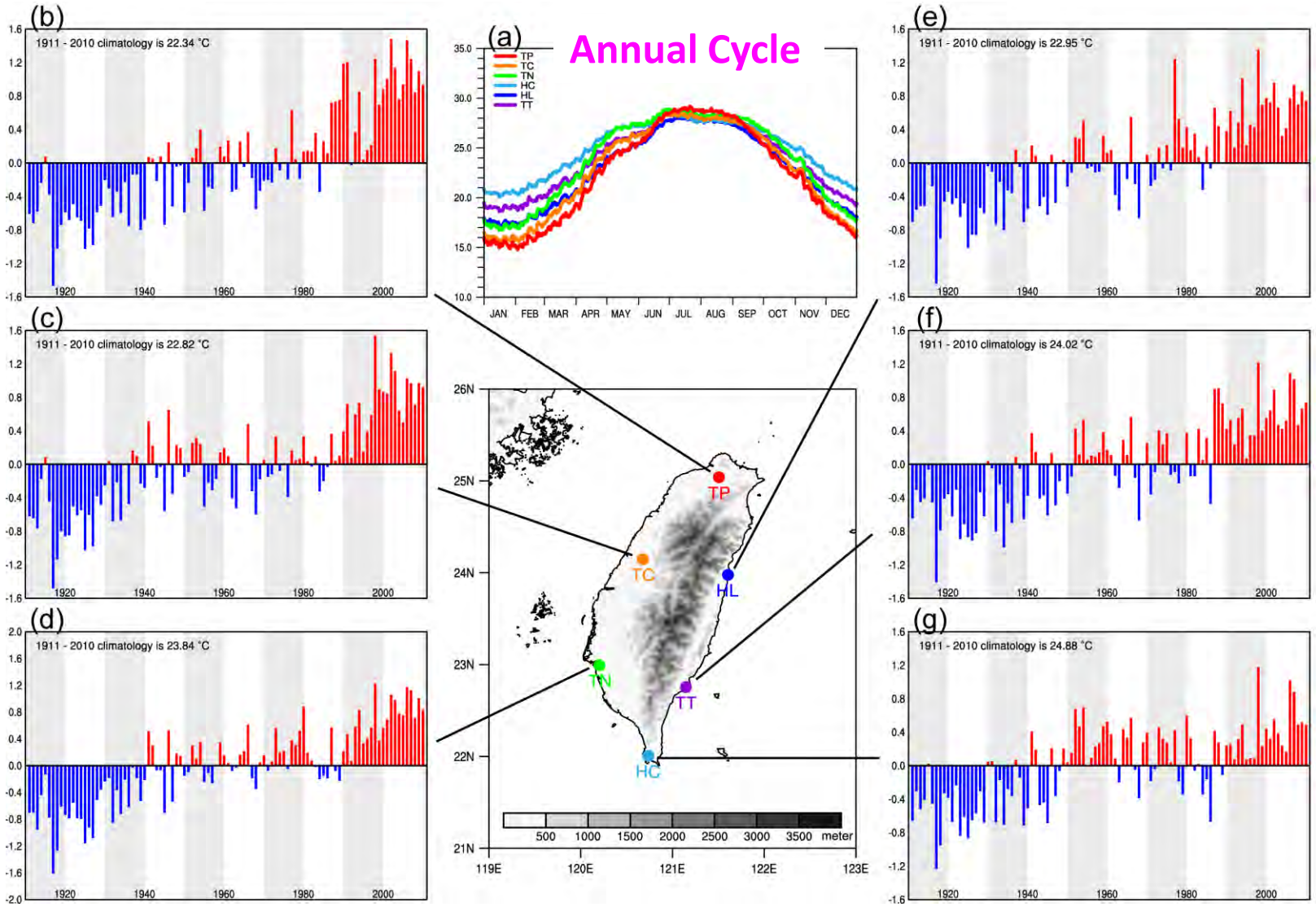
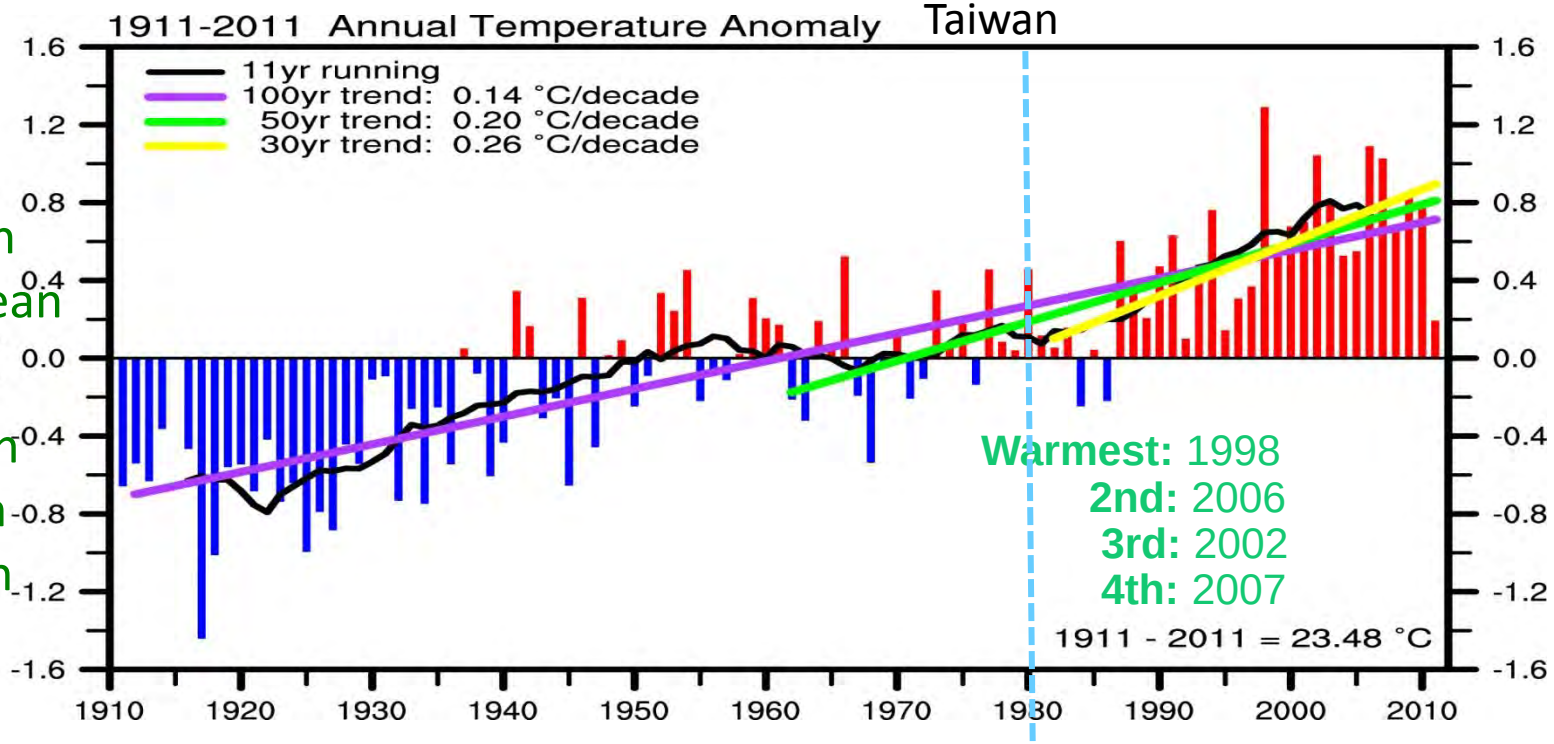
Taiwan Temperature

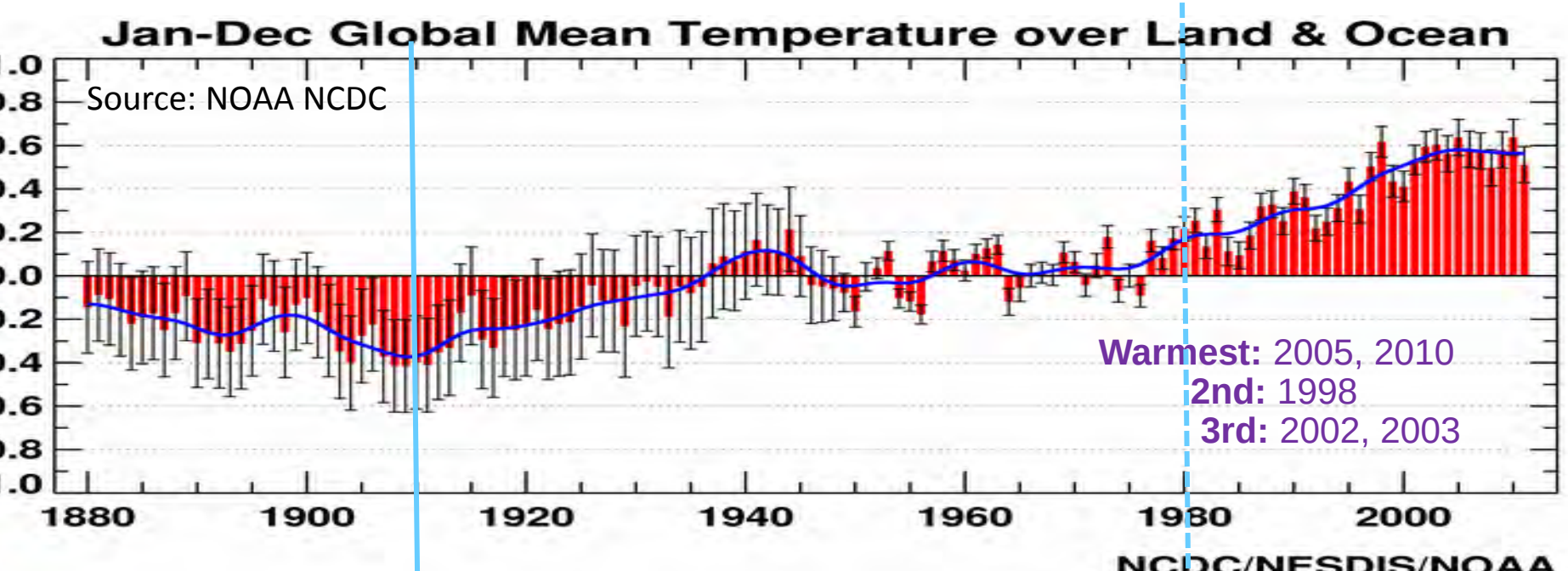


- The annual range of Taiwan temperature is less than 15°C.
- The warming trend is observed all over the island.

- Taiwan temperature shows similar warming pattern as the global mean temperature.
- The correlation between Taiwan and global mean temperature:

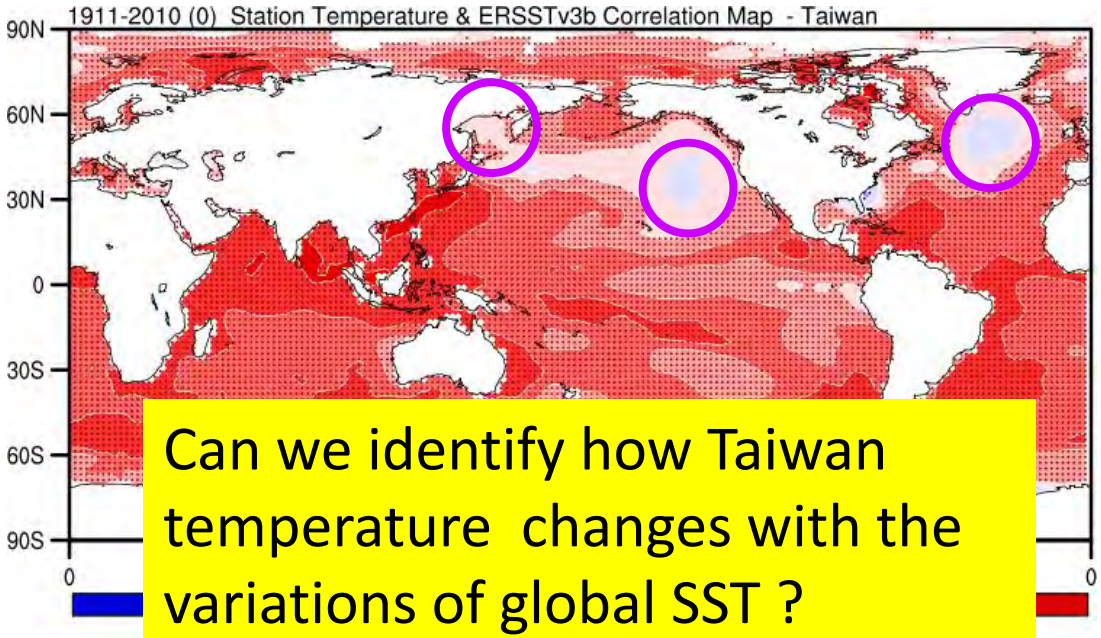
0.81



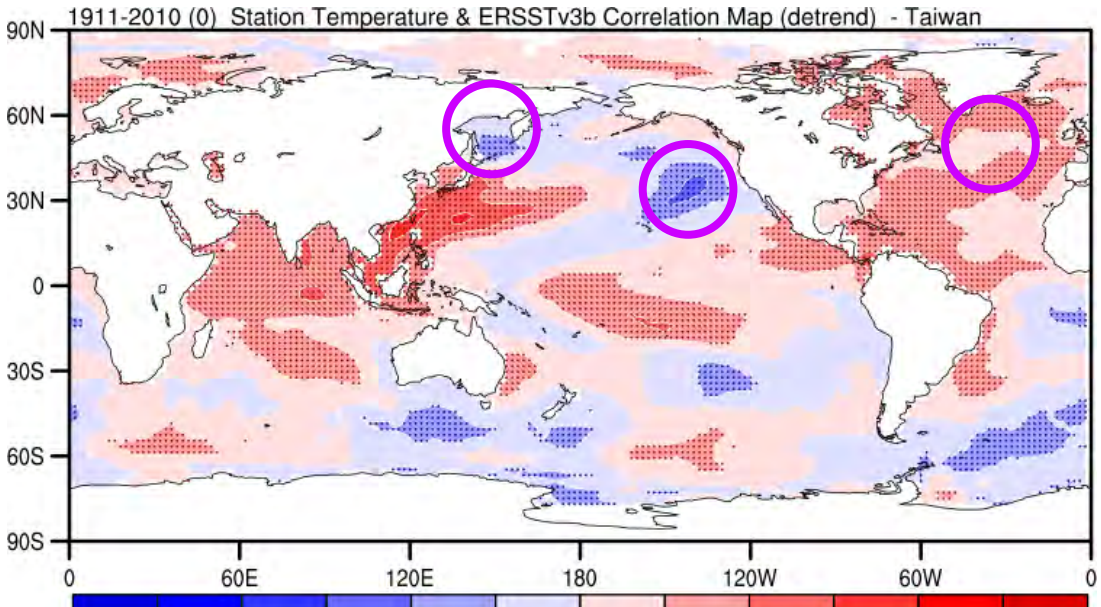


Correlation of the Annual Mean Temperature

Taiwan & Global SST (NOAA ER SST v3b)

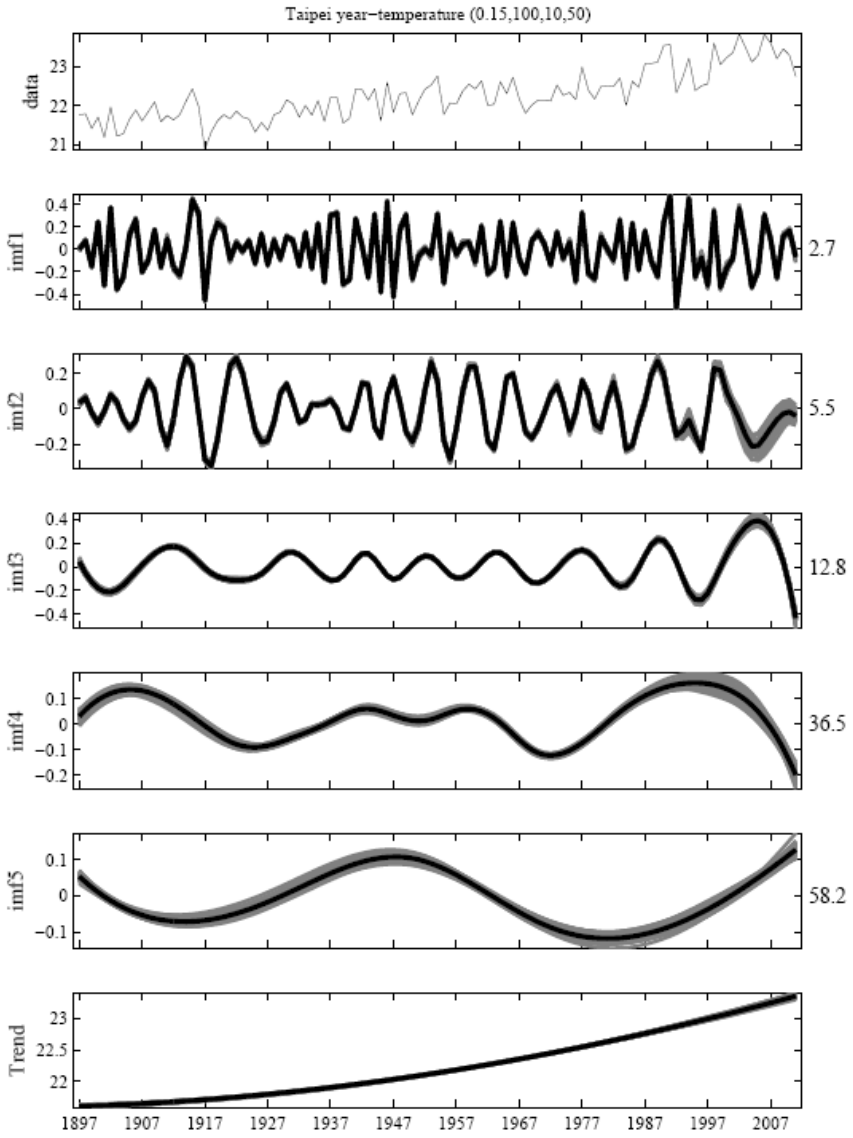


Can we identify how Taiwan temperature changes with the variations of global SST ?

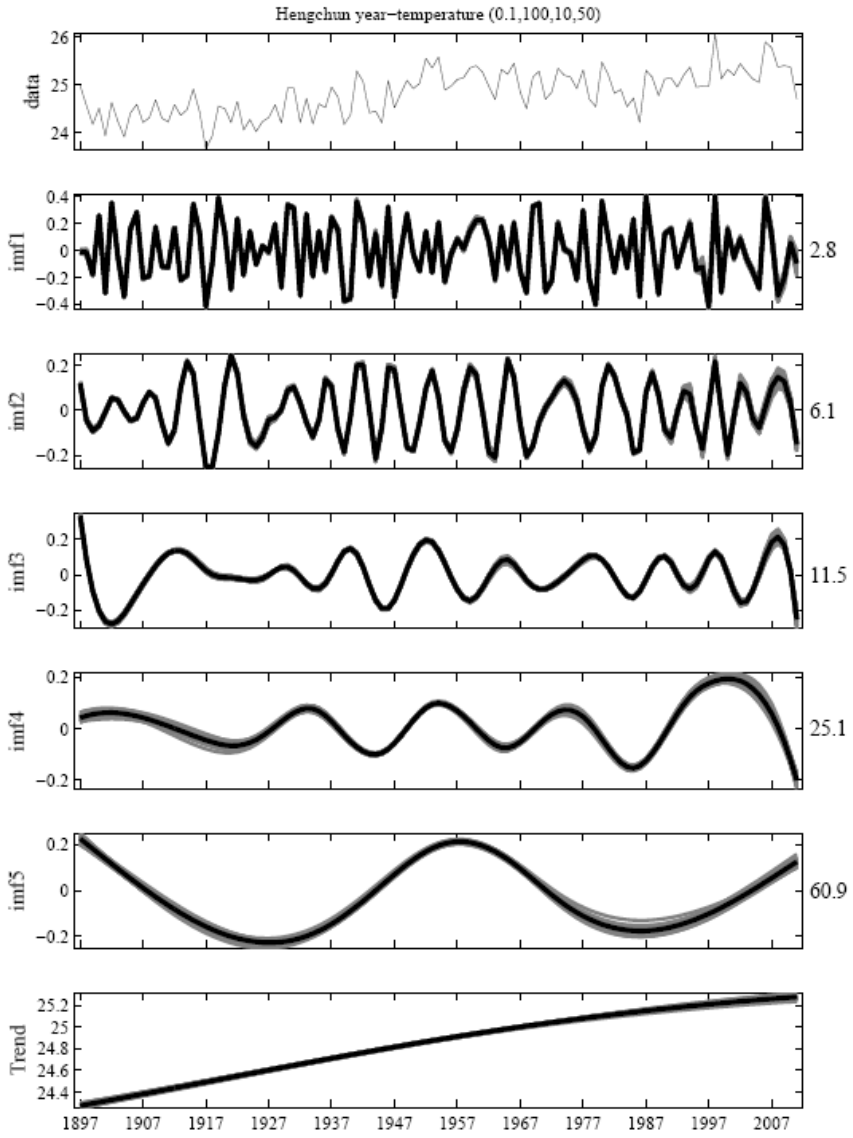


Use the EEMD method (Wu and Huang 2009) to decompose Taiwan Temperature at the six stations with data longer than 100 years

Taipei



Hengchun



Temperature-EEMD IMF 1~5 Cycle

95%

	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ	DJF	Year
Taipei	2.9	2.8	2.7	2.9	2.8	2.6	2.8	2.7	2.6	2.6	2.8	2.7	2.8
	6.6	5.8	5.2	6.2	5.5	5.8	5.8	5.2	5.8	5.2	5.5	6.2	6.2
	14.1	11	11	11	9	9.9	9.9	9.9	11	11	11	14.1	12.4
	44	22.7	25.2	33.6	32.6	27.4	26	24.9	31.3	30.2	29.8	42.9	33.1
	87.6	79.7	51.1	73.4	48.2	98.1	50.7	53.5	89.8	63.6	49.9	53.7	49.1
Hualien	2.9	3	2.6	2.8	3.2	2.8	2.8	2.8	2.6	2.8	2.9	2.5	2.7
	6.6	6.2	5.2	5.2	6.2	5.8	6.2	5.8	5	5.8	5.8	6.2	5.8
	12.4	12.4	12.4	9.9	12.4	12.4	11	11	11	12.4	12.4	12.4	11
	28.2	29.3	27.5	22.2	33.2	29.3	26	27.3	24.7	29.2	29.1	27.1	26
	92.8	70.8	43.5	90.9	87.3	88.8	49.5	54.5	52.8	49.8	58.4	89.7	47.9
Tainan	2.8	2.8	2.8	2.6	2.8	3	2.6	2.8	2.6	2.8	2.8	2.6	2.9
	6.2	5.2	6.2	5.2	5.8	5.2	5.5	5.5	5.2	5.2	5.5	5.8	6.2
	12.4	9.9	12.4	11	9.9	11	9.9	11	11	9.9	11	14.1	12.4
	30	22.5	37.1	21.9	21.8	34.8	35.6	34.3	32.7	29.3	28.5	29.7	32.6
	93.1	50.1	50.1	50.4	49.4	93.7	83.9	51.2	89.1	96.2	96.7	91.1	85.6
Taichung	2.8	2.8	2.6	2.8	3	2.9	2.8	2.5	2.8	2.6	2.8	2.5	2.8
	6.2	5.2	5.5	5.8	5.8	6.6	5.8	6.6	6.2	5.2	5.5	5.8	7.1
	12.4	11	14.1	9.9	12.4	9.9	11	11	9.9	12.4	11	9.9	12.4
	37.1	22.8	31.4	23.3	34.7	26.9	23.8	34.6	30	29.5	29.8	24.4	41.8
	77.9	49.8	49.5	90.6	77.3	87.6	90.8	90.9	94.4	96.8	93.7	48	96.4
Hengchun	2.7	3	2.8	2.8	2.7		3	2.9	2.7	2.5	2.7	2.8	2.8
	5.2	5.5	5.5	5.2	5.8		5.5	6.6	6.2	5.5	5.8	5.8	6.2
	11	9.9	11	12.4	12.4	*	11	11	9.9	11	11	12.4	11
	26.2	29	30.2	39.5	33.6		23.7	29.9	18.4	23.4	27.4	23.2	20.6
	70.8	88.3	92.3	51.7	91.1		49.3	49.8	49.3	51.5	52.6	49.5	49.5
Taitung	2.9	3.1	2.8	2.8	2.8	3	3	2.8	2.8	2.7	2.8	2.8	2.8
	6.2	6.2	6.6	5.8	5.5	6.2	5.8	6.2	5.5	5.8	5.8	6.6	5.8
	12.4	11	14.1	11	12.4	12.4	11	11	9.9	12.4	11	14.1	11
	37.6	46.2	29.7	30.7	28.2	28.3	31.5	22.9	25.2	22.5	29.4	35.7	39.1
	66	71.1	52.9	50.5	88.2	82.5	50.4	53.9	81.8	69.7	82.9	54.5	69.9

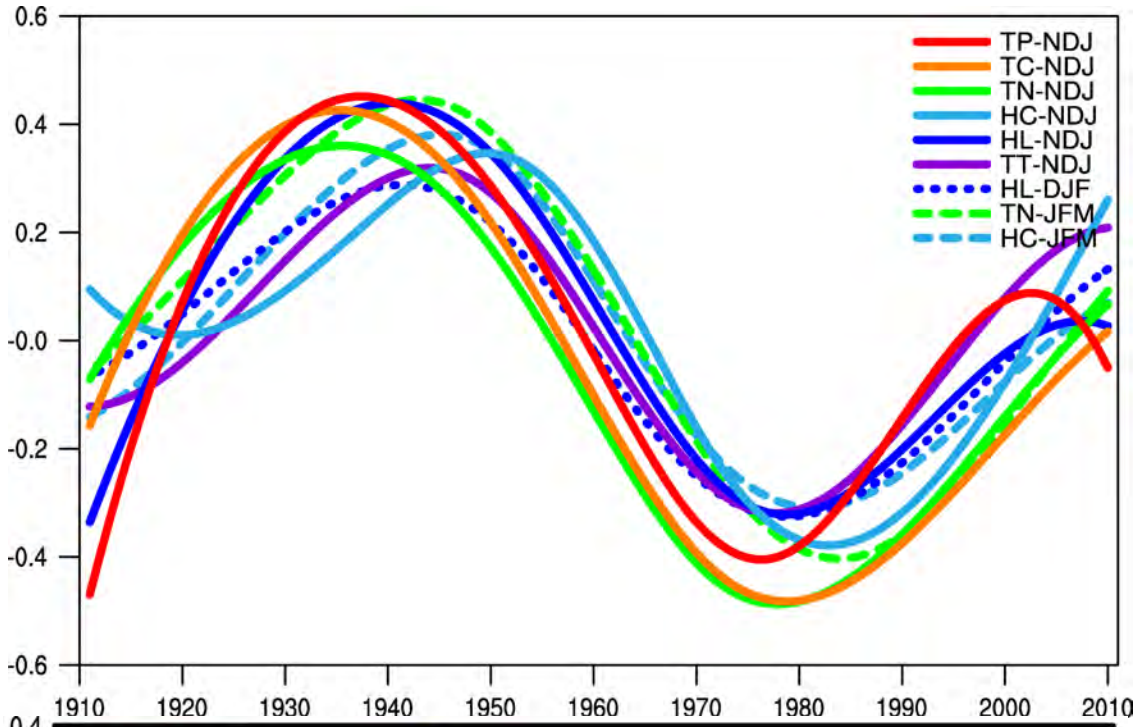
Significant Multi-decadal Modes of Taiwan Temperature Variations

period > 40 years

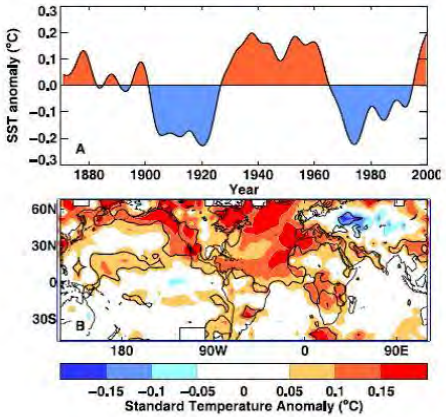
Station	Annual	Season											
		OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON
Taipei			IMF5(50)			IMF5(81)							IMF5(91)
Taichung	IMF5(94)	IMF5(98)	IMF5(92)					IMF5(91)			IMF5(94)	IMF5(92)	IMF5(67)
Tainan	IMF5(86)	IMF5(97)	IMF5(92)		IMF5(94)					IMF5(96)	IMF5(82)		IMF5(86)
Hengchun	IMF5(50)		IMF5(91)	IMF5(91)	IMF5(92)	IMF5(86)	IMF5(95)		IMF5(93)		IMF5(50)		
Taitung	IMF4(43)		IMF5(85)					IMF5(85)		IMF5(83)			
Hualien			IMF5(67)	IMF5(97)				IMF5(95)		IMF5(91)			

- Taiwan temperature shows significant multi-decadal variations.
- The most robust multi-decadal signal appears in winter temperature averaged over November, December and January three months.

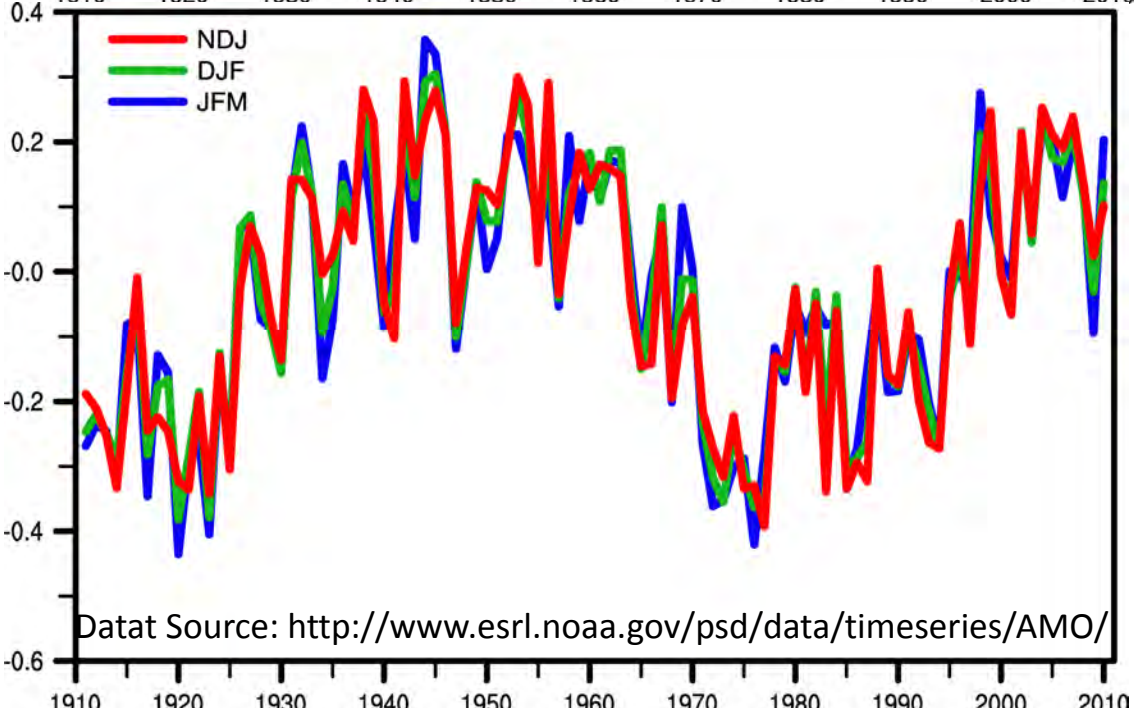
Multi-decadal Modes -
Taiwan Winter Temperature



Multi-decadal Mode -
Atlantic Multidecadal Mode (AMO)

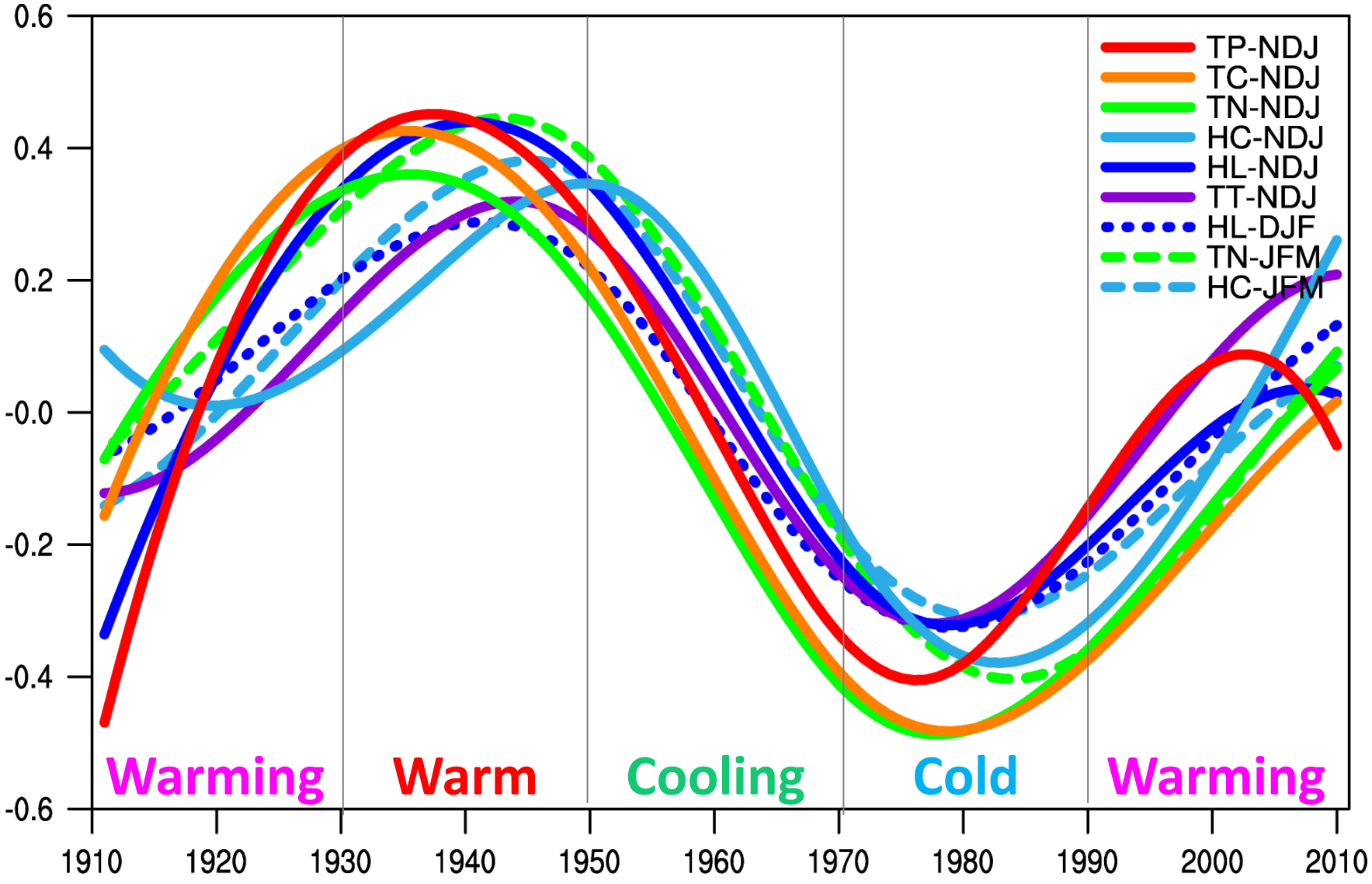


Knight et al. (GRL 2005)



Datat Source: http://www.esrl.noaa.gov/psd/data/timeseries/AMO/

Warm and Cold Regimes of TW Winter Multi-decadal Mode



SST Anomalies

Warm Phase

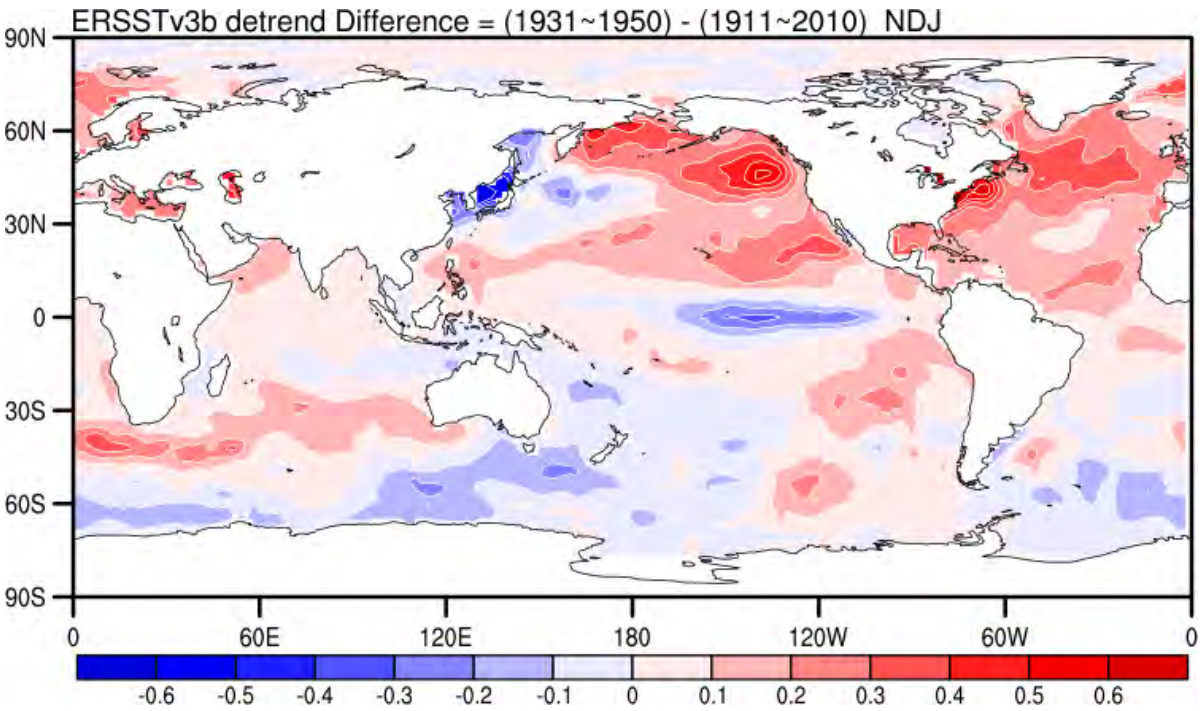
1931-1950 (NDJ)

Note:

South China Sea (+)

Sea of Japan (-)

Sea of Okhotsk (-)



Cold Phase

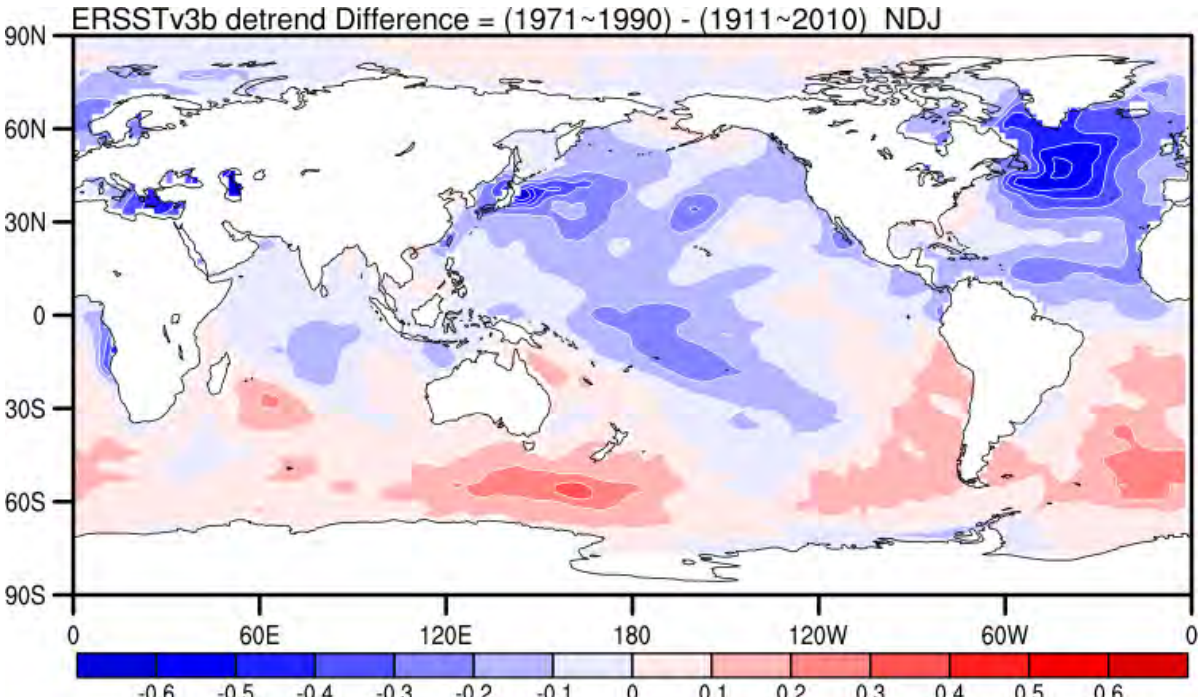
1971-1990 (NDJ)

Note:

South China Sea (-)

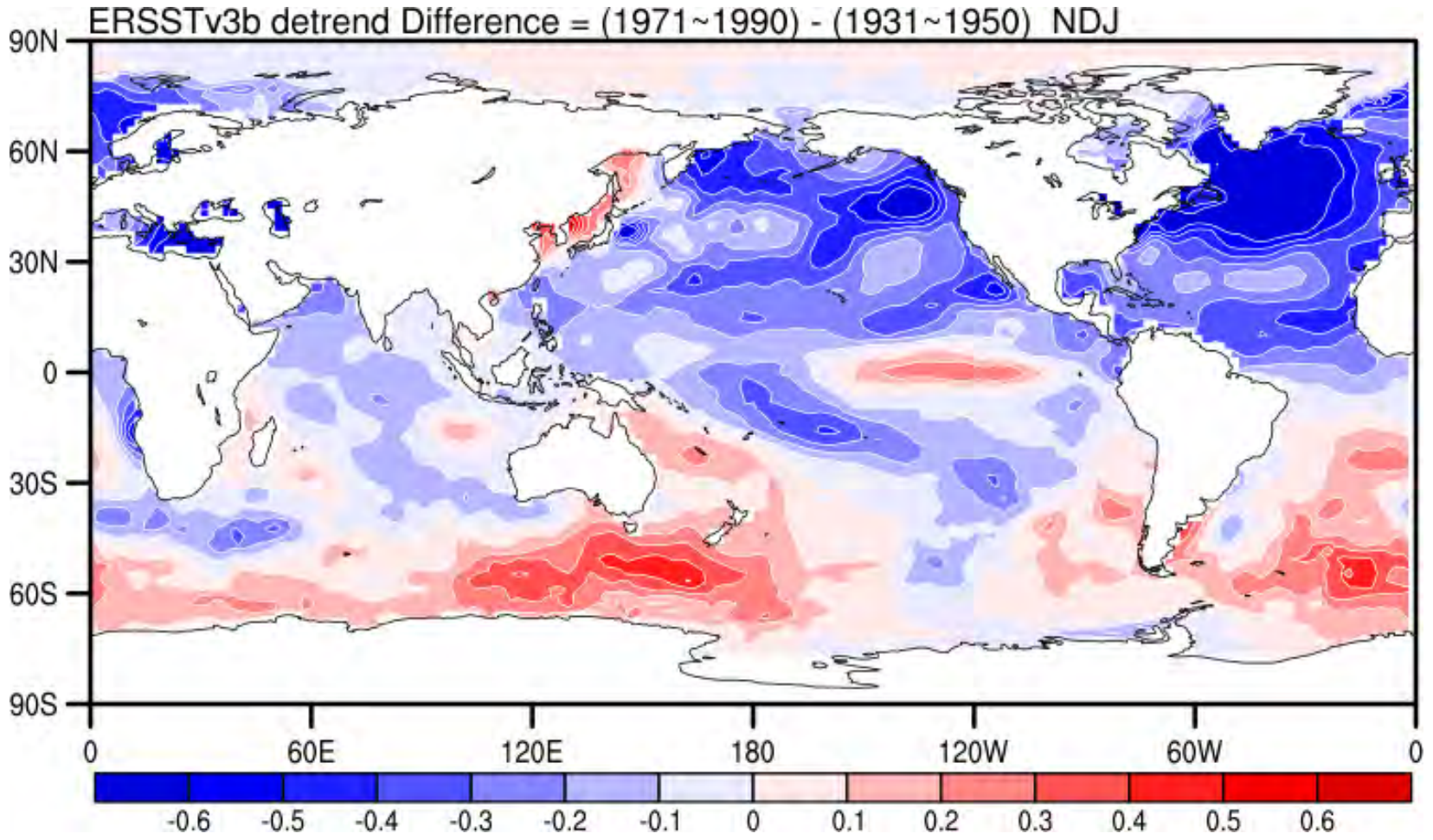
Sea of Japan (-)

Sea of Okhotsk (-)



SST Multi-decadal Contrast during the 20th Century

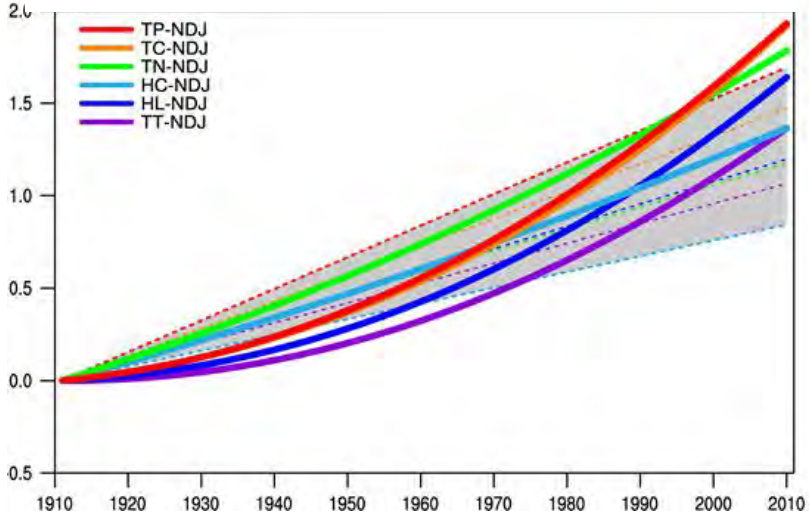
Cold *minus* Warm



Last thought – The centennial warming trend ?

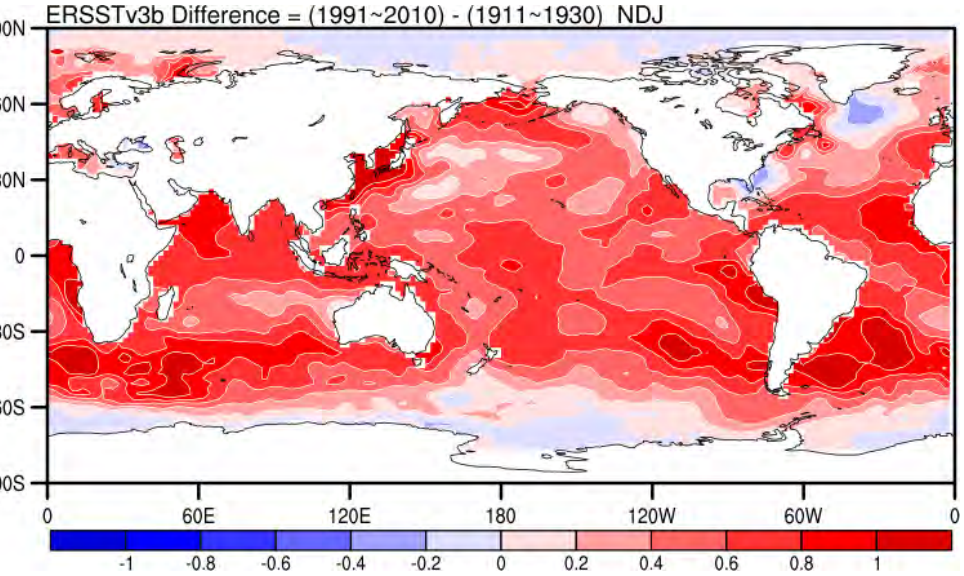
The data adaptive trend shows larger warming rate after 1970.

Taiwan Winter Temperature

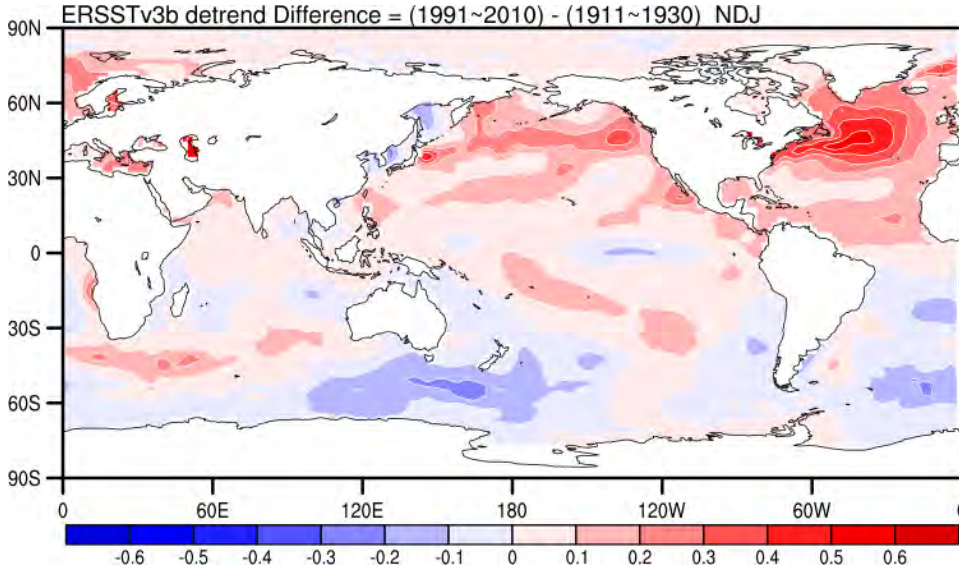


(1991-2010) minus (1911-1930)

Before detrend



After detrend



SST Tendency

Warming

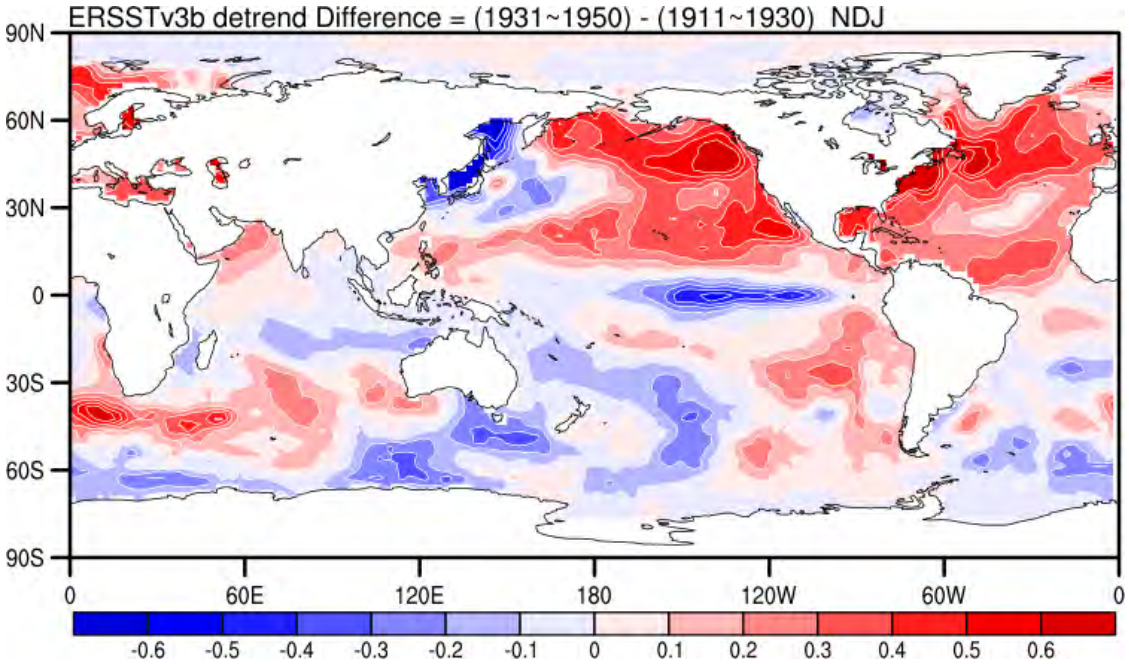
Early 20th Century

Note:

South China Sea (+)

Sea of Japan (-)

Sea of Okhotsk (-)



Warming

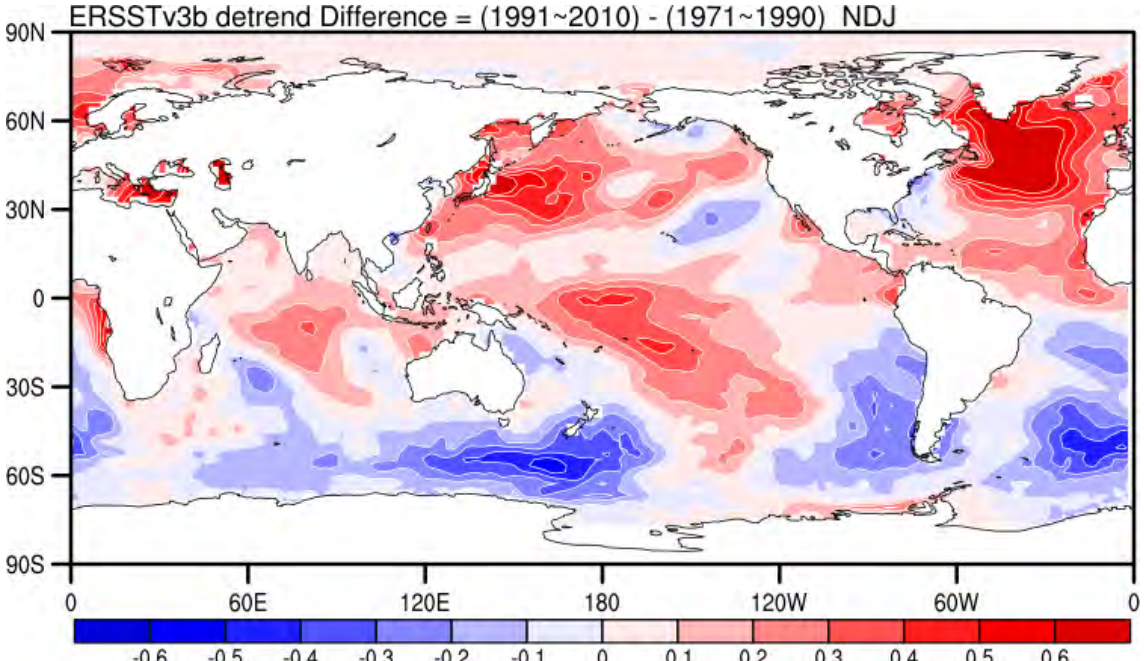
After 1990

Note:

South China Sea (+)

Sea of Japan (+)

Sea of Okhotsk (+)



Summary

- The cycles and centennial trend and their seasonal dependence of Taiwan temperature during the period of 1910-2010 are investigated using EEMD method.
- The statistically significant multi-decadal modes are robust in winter. Based on the multi-decadal mode, a warm regime during the 1930s and 1940s and a cold regime during 1970s and 1980s are identified.
- The multi-decadal mode shows a transition from cold to ward phase after 1990. The warming phase has not reached the peak yet. It suggests that warm winters will be easier to occur than the cold ones before 2020.
- The SST patterns over the western Pacific and Indian Oceans during the warming phase after 1990 are very different from the patterns of the warming phase during early 20th century, except over the North Atlantic Ocean.

On-going Work

- The ST obtained from EEMD analysis shows a warming rate that surpasses the linear trend after 1990. This is possibly due to the cooling of the SST around Taiwan associated with the phase change of the Pacific Decadal (20-40 year) mode such as NPGO that changed from the negative phase to positive during 1990s.

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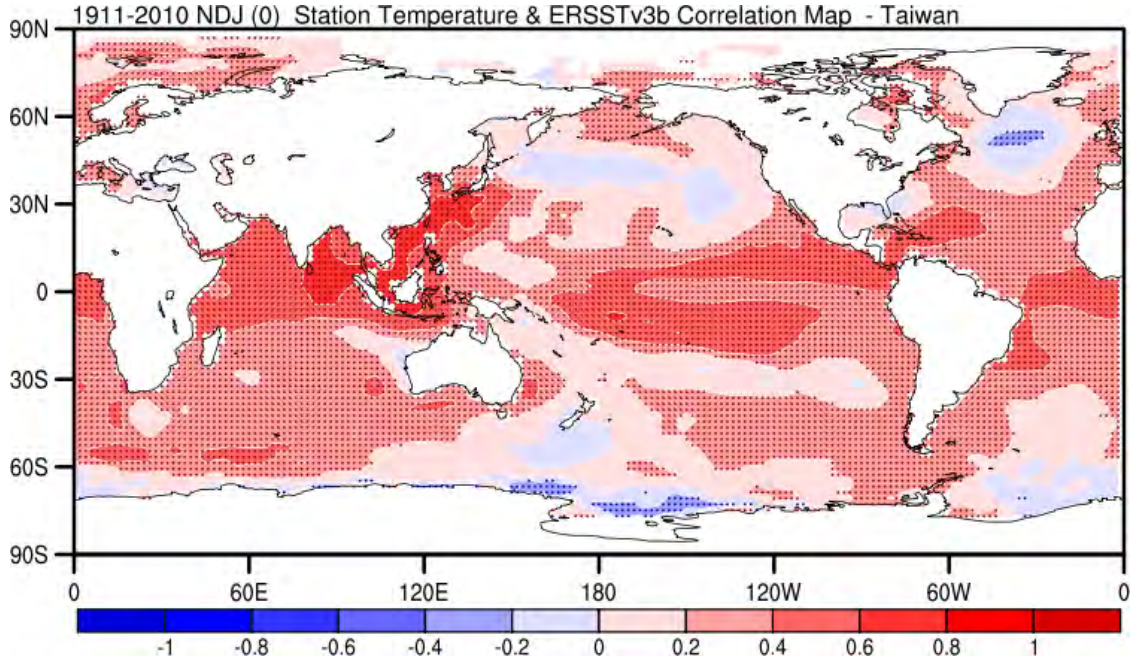
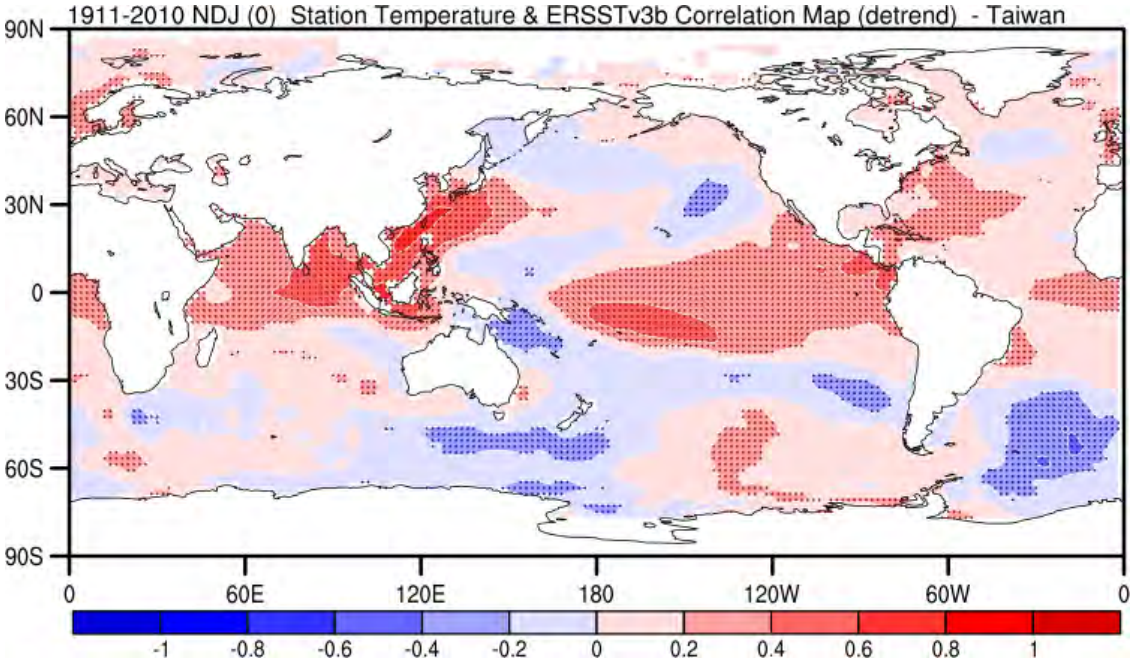
Taiwan Temperature & Global SST Correlation

Winter (NDJ) – before detrend



Winter (NDJ) – after detrend



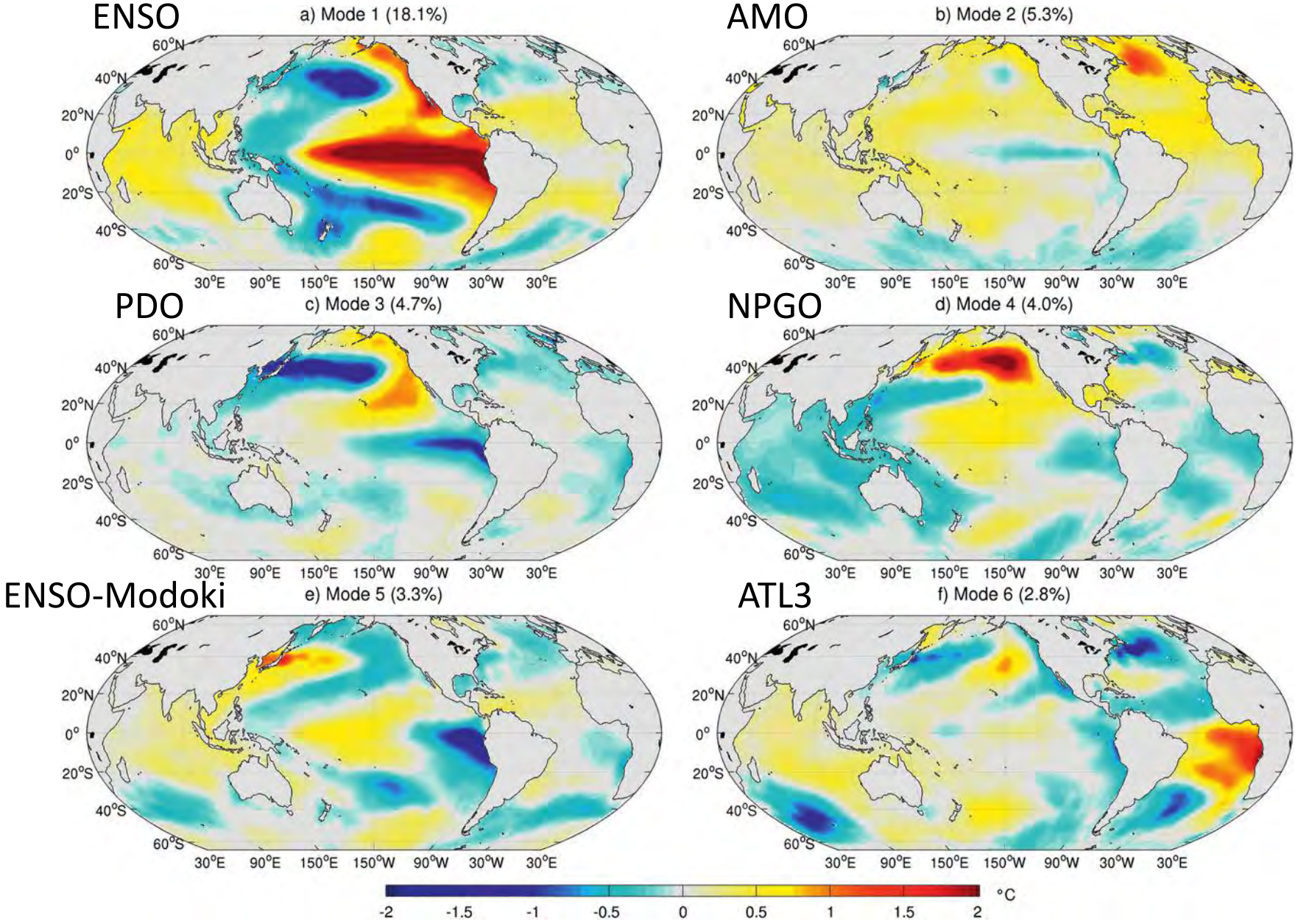


FIG. 4. Global EOF spatial patterns of the first six SST modes calculated for the 1910–2009 period.

Messié and Chavez (J Climate,2011)