Modelling of Cold Surges in South China

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Abstract

Arctic warming possibly impacts the mid-latitude weather and climate system. A number of severe winters have been reported in regions of East Asia that suggest atmospheric variability leading to extremity may be linked to Arctic warming. Recent research shows that Arctic is warming and Siberian High (SH) intensity is gradually intensifying (Zhao et al., 2018). The winters in East Asia are associated with a distinct extreme weather event known as Cold Surges (CSs). Over the last decade strong CSs in South China have killed more than 129 people, displaced 1.7 million population, caused economic losses exceeding U.S. $20 billion (Zhou et al., 2011). Various criteria have also been proposed to indicate the onset of CSs though none has been universally accepted. Our analysis shows that CSs are firstly pressure gradient (PG) driven between the SH and the South China Sea (SCS). They are further influenced by intense low pressure systems near the coast of Japan that highly influences the intensity of the surges and its subsequent trajectory towards the SCS. We propose a new criteria based on PGs for identifying and forecasting the CSs at time scales of less than a week over South China.

Background & Motivation

- CSs are considered as one of the most impactful weather events for the East Asia region potentially triggering disasters (Fig.1)
- They are characterized by a succession of cold air outbursts from the SH (Fig.2) with high MSLP values.
- Modelling of CSs in South China has always been a challenge due to its geographical location which has a high influence from the surrounding air-sea interactions making the weather pattern highly complex (Fig.2).

Methods

- We used two global meteorological reanalysis datasets, the NCEP FNL and ECMWF ERA-Interim datasets.
- We used the high resolution Advanced Research Weather Research and Forecasting (WRF-ARW) model (v3.7). Two way nesting technique was employed, with a larger domain (D1) centred at the Hong Kong Observatory (HKO) Station (22^0 18' 07'' N; 114^0 10' 27'' E) at 9 x 9 km and an inner nested domain (D2) at 3 x 3 km spatial resolution.
- The model was driven via initial and lateral boundary conditions from NCEP FNL and the physics schemes was tested via sensitive experiments on the physical parameterization.
- Simulated meteorological variables were evaluated using ECMWF ERA Interim data, satellite based Advanced Scatterometer (ASCAT) data, weather charts from HKO and meteorological information derived from HKO station data.

Results and Conclusions

- An enhanced intensification and extent of the large-scale circulation effects in the SH are precursors to the outbreak of cold air mass over Siberia before it progresses towards SCS and HK regions (Fig.3 & 4).
- Low Pressure Systems (LPS) also form off Japan which affect the cold air mass trajectory. The cold air can propagate towards SCS or towards Japan as driven by PGs.
- A threshold PG value of 0.74 Pa/km between SH and SCS, maintained for at least 18 hr and subjected to the PG between SH and LPS not exceeding 1.59 Pa/km is the predictive precursor for the occurrence of CSs in South China (Table 1).

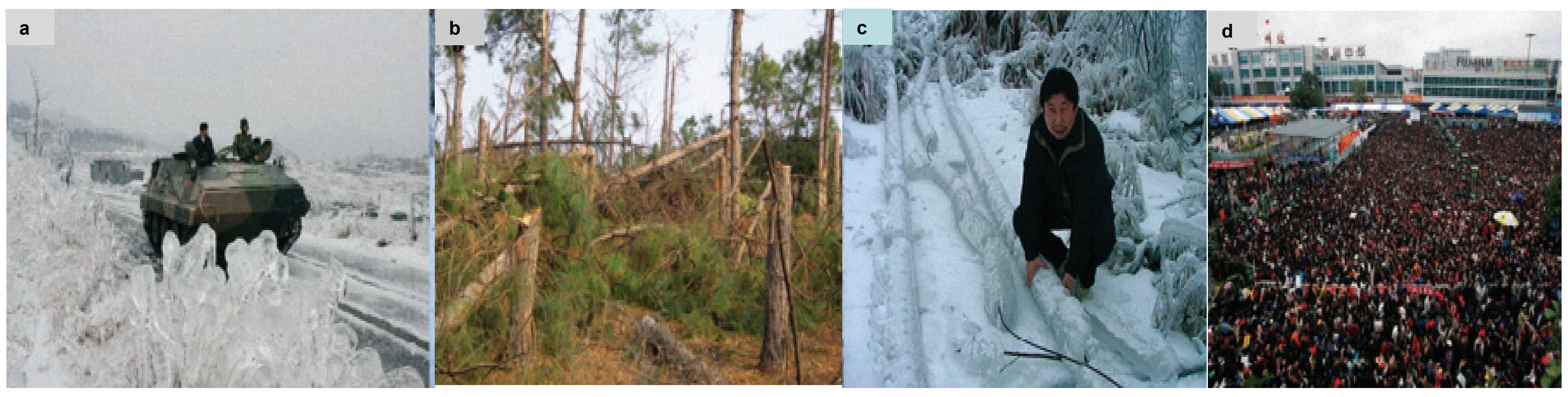

Figure 1. *Major direct impacts of CS 2008 (a) ice coated roads, (b) damaged forests (Slash Pine), (c) fallen electric lines , and (d) ice stranded travelers at Guangzhou Railway Station in the southern coastal city of Guangzhou (31st Jan 2008) (adopted from Zhou et al., 2011).*

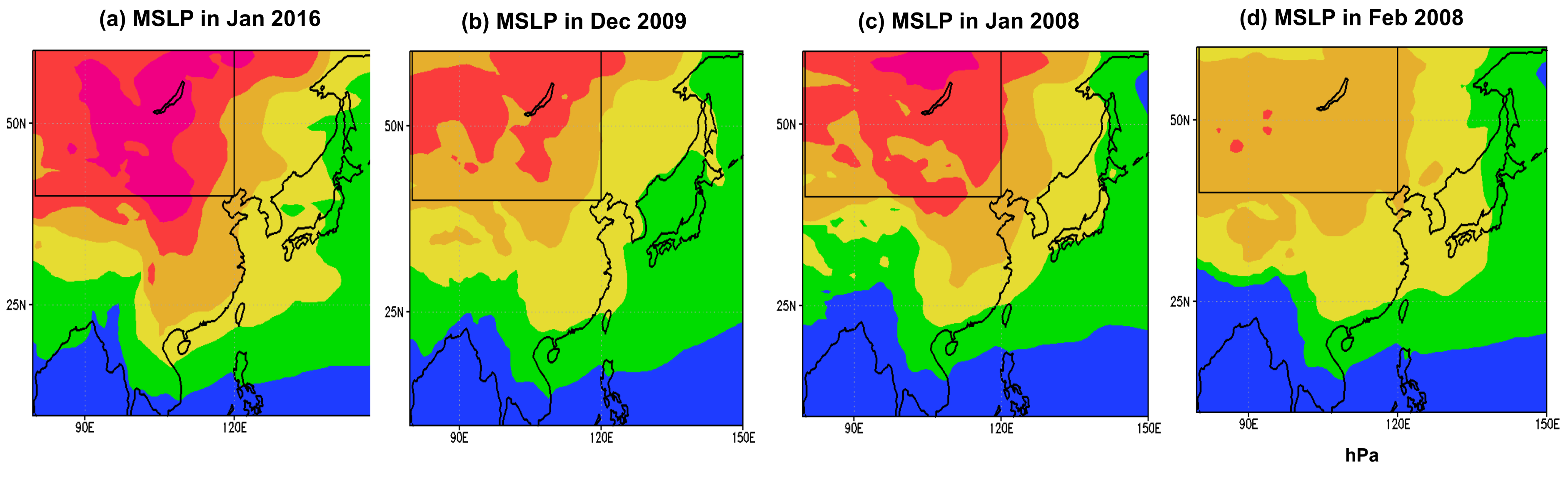
(a) MSLP in Jan 2016
(b) MSLP in Dec 2009
(c) MSLP in Jan 2008
(d) MSLP in Feb 2008

Figure 2. *MSLP (hPa) (a) Jan 2016, (b) Dec 2009, (c) Jan 2008, and (d) Feb 2008 computed from daily maximum values over 00 UTC, 06 UTC, 12 UTC, and 18 UTC. The black box indicates the defined SH domain within 40 ^{0}N-60 ^{0}N and 80 ^{0}E-120 ^{0}E. Coastal boundaries are represented by black thick lines. Data used ECMWF, ERA Interim.*

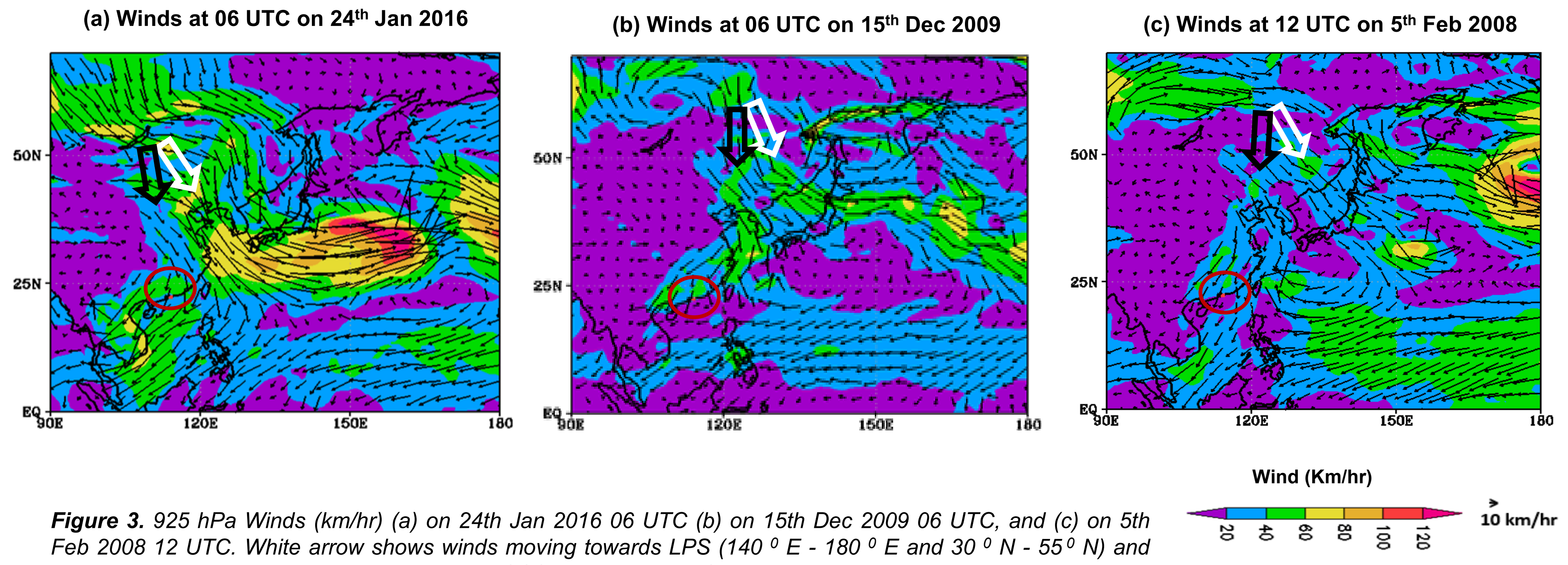
(a) Winds at 06 UTC on 24th Jan 2016
(b) Winds at 06 UTC on 15th Dec 2009
(c) Winds at 12 UTC on 5th Feb 2008

Figure 3. *925 hPa Winds (km/hr) (a) on 24th Jan 2016 06 UTC (b) on 15th Dec 2009 06 UTC, and (c) on 5th Feb 2008 12 UTC. White arrow shows winds moving towards LPS (140 ^{0} E - 180 ^{0} E and 30 ^{0} N - 55 ^{0} N) and black arrow shows winds moving towards SCS. Data used ECMWF, ERA Interim. Hong Kong region is represented with a red dot.*

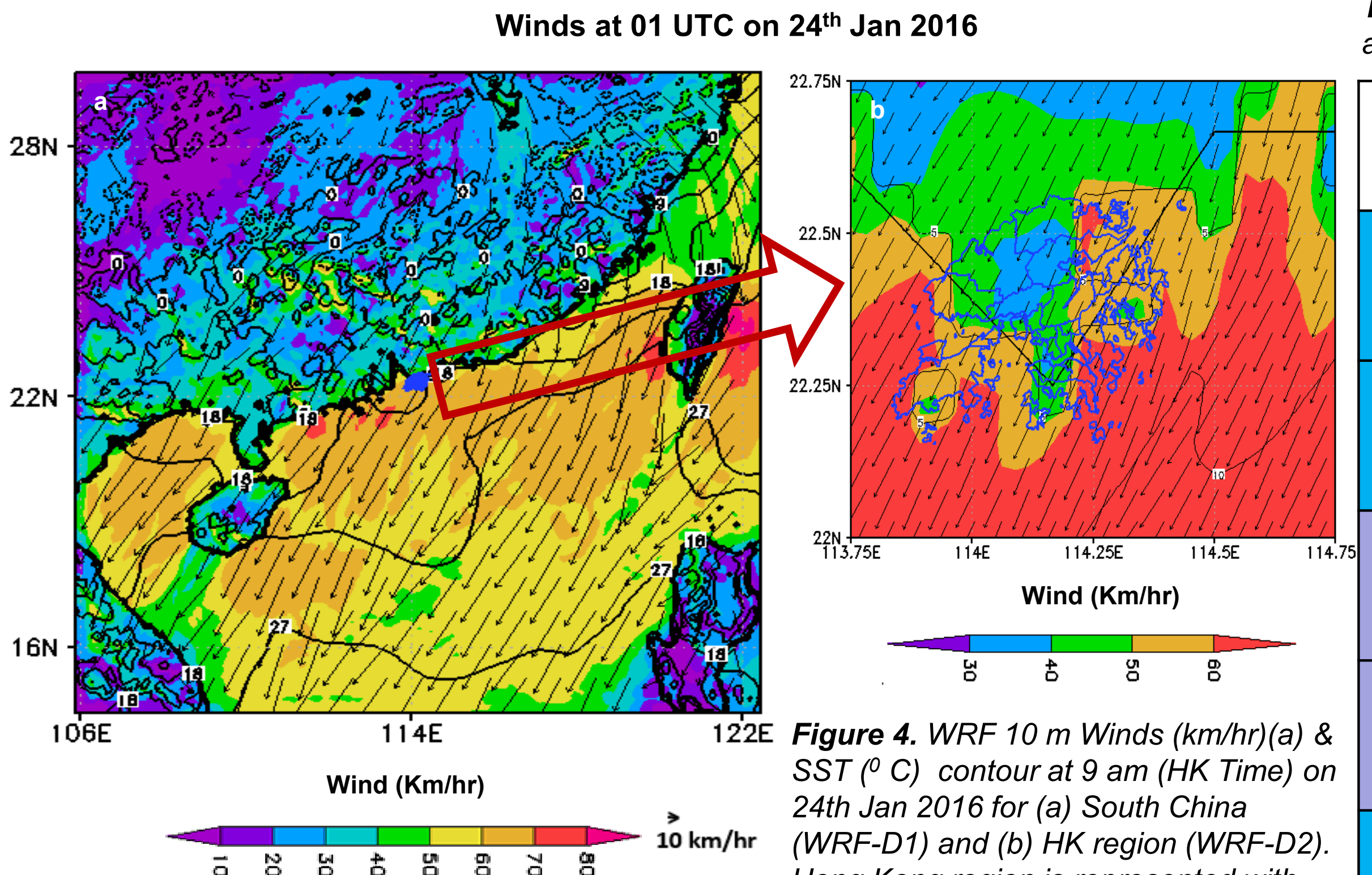
Winds at 01 UTC on 24th Jan 2016

Figure 4. *WRF 10 m Winds (km/hr)(a) & SST (^{0} C) contour at 9 am (HK Time) on 24th Jan 2016 for (a) South China (WRF-D1) and (b) HK region (WRF-D2). Hong Kong region is represented with blue shade in (a) and (b).*

Table 1. *PG between SH and SCS, and between SH and LPS for CSs (blue cells) and non-CSs (violet cells).*

(Non-) CS Event	Date	PG (Pa/km): SH and SCS	PG (Pa/km): SH and LPS
Jan 2016	23 06 UTC	1.165	1.616
	23 12 UTC	1.228	1.503
	23 18 UTC	1.514	1.462
Dec 2009	14 06 UTC	0.874	1.669
	14 12 UTC	0.902	1.657
	14 18 UTC	0.947	1.626
Dec 2009	17 12 UTC	0.887	2.295
	17 18 UTC	0.984	2.286
	18 00 UTC	0.897	2.213
Jan 2008	13 12 UTC	1.024	2.040
	13 18 UTC	1.008	2.475
	14 00 UTC	0.942	2.650
Feb 2008	4 06 UTC	0.669	1.650
	4 12 UTC	0.721	1.565
	4 18 UTC	0.829	1.561

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Zhao et al. 2018. Impact of Climate Change on Siberian High and Wintertime Air Pollution in China in Past Two Decades. Earth's Future, 6, 118–133.