Intraseasonal Variation of Visibility in Hong Kong

Wen Zhou, Richard Li and Eric Chow

Guy Carpenter Asia-Pacific Climate Impact Center

School of Energy and Environment , City University of Hong Kong

Visibility & Air Pollution

- Visibility data were used to estimate $PM_{2.5}$ levels (McDonnell et al., 2000), the relationship between visibility and air particles (Malm et al., 1994； Kim et al., 2011)
- Daily reduced visibility is defined as visibility below 8 km along with relative humidity < 95% (Chang & Koo, 1986; Leung & Lam, 2008). The number of days in which visibility was less than 8 km rose to 102 in 2004 (HKO)

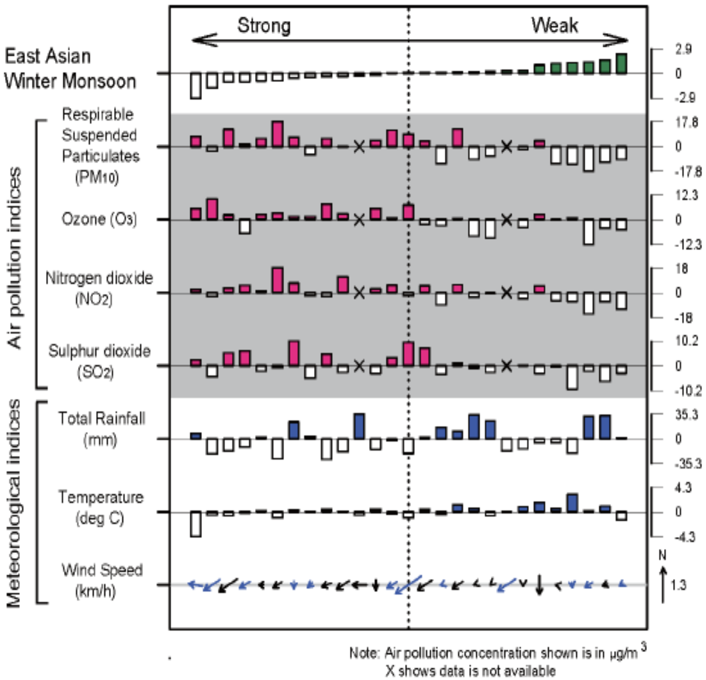
Table 2. Correlation between air pollution indices and visibility during 2001–2007.

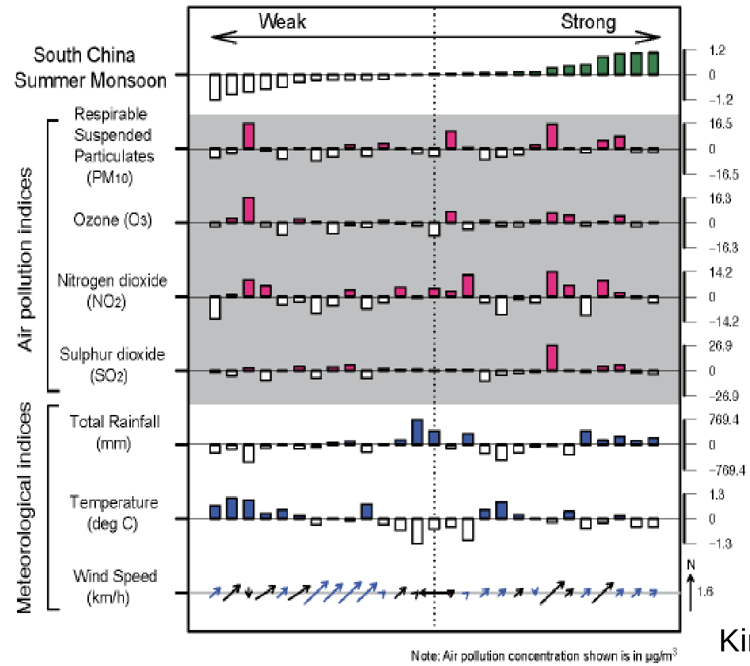
No	Station Name	PM_{10}	O_3	NO_2	SO_2
1	Central/Western	**−0.81**	**−0.41**	**−0.84**	−0.03
2	Eastern	**−0.80**	**−0.35**	**−0.82**	0.01
3	Kwai Chung	**−0.74**	**−0.53**	**−0.61**	**0.35**
4	Kwun Tong	**−0.77**	**−0.58**	**−0.68**	**0.22**
5	Sha Tin	**−0.79**	**−0.44**	**−0.83**	0.13
6	Sham Shui Po	**−0.70**	**−0.64**	**−0.59**	**0.22**
7	Tai Po	**−0.72**	**−0.44**	**−0.48**	0.00
8	Tap Mun	**−0.74**	**−0.60**	**−0.42**	**−0.30**
9	Tsuen Wan	**−0.76**	**−0.43**	**−0.78**	0.04
10	Tung Chung	**−0.72**	−0.17	**−0.75**	**−0.52**
11	Yuen Long	**−0.71**	**−0.27**	**−0.72**	**−0.29**
12	Causeway Bay	**−0.67**	NA	**−0.74**	−0.20
13	Central	**−0.74**	NA	**−0.73**	−0.19
14	Mong Kok	**−0.76**	NA	**−0.75**	−0.09

* Correlation estimates shown in boldface is statistically significant at the 5% level.

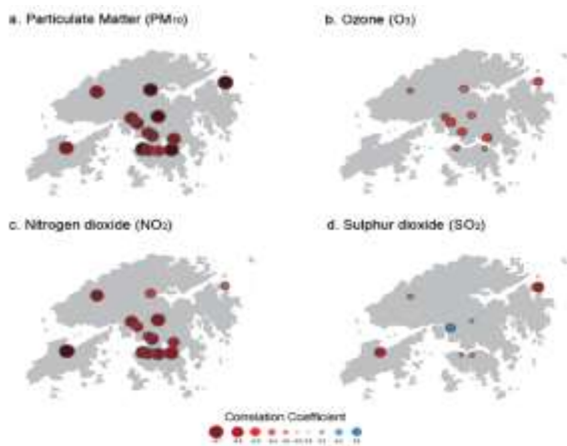
Kim et al, 2011

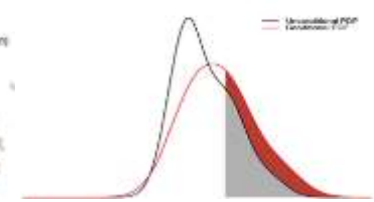
Variability and Risk analysis of HK air quality & Monsoon and ENSO





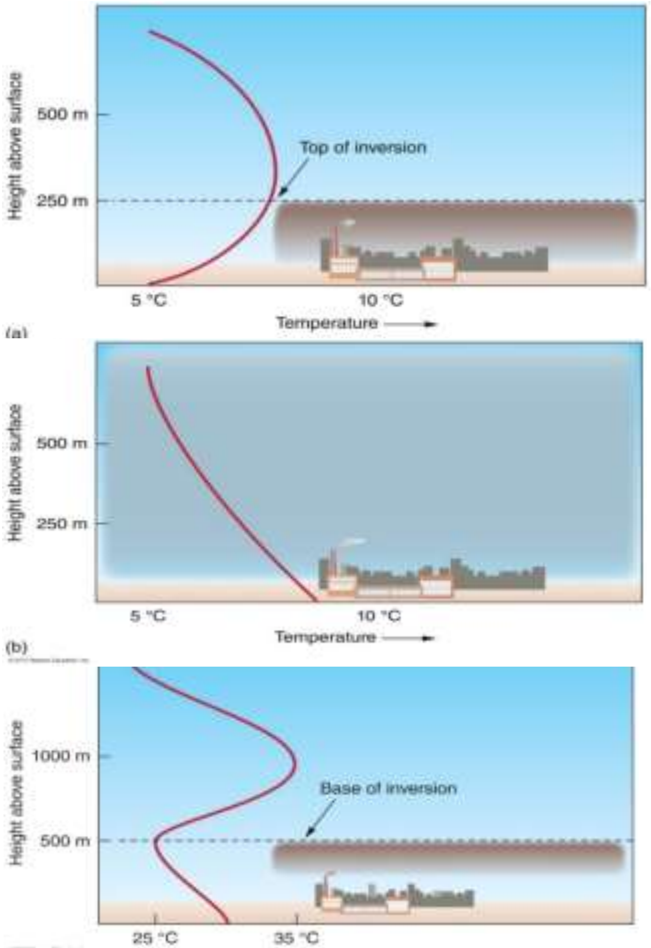
Kim et al, 2011

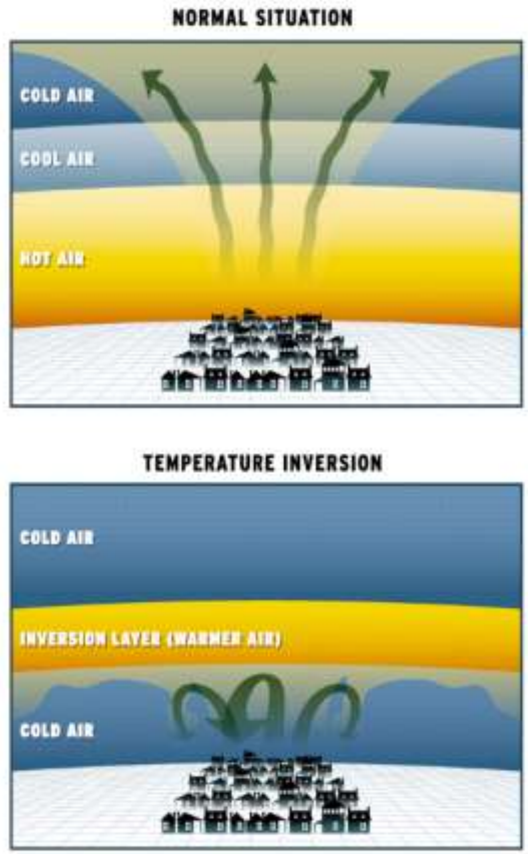


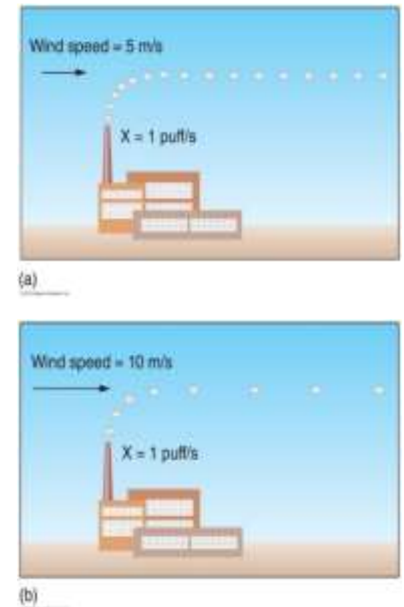


$$\text{API Risk} = \frac{P[(API \geqslant API_{100}|SM)]}{P(API \geqslant API_{100})}$$

Atmospheric Conditions and Air Pollution





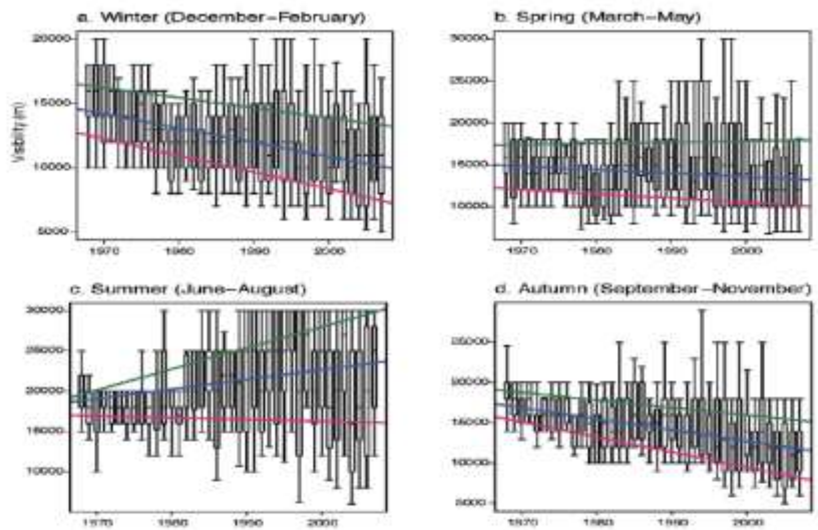


➤To further investigate the intraseasonal variation of visibility and the associated modulating factors in order to reveal the influence of atmospheric conditions.

Datasets

- Daily meteorological data from NCEP-NCAR reanalysis: relative humidity (RH), specific humidity (q), omega, geopotential height (GPH), zonal wind (u), meridional wind (v), and temperature (temp)
- Hourly visibility data during 2000–2007 from the HKO
- API from EPD

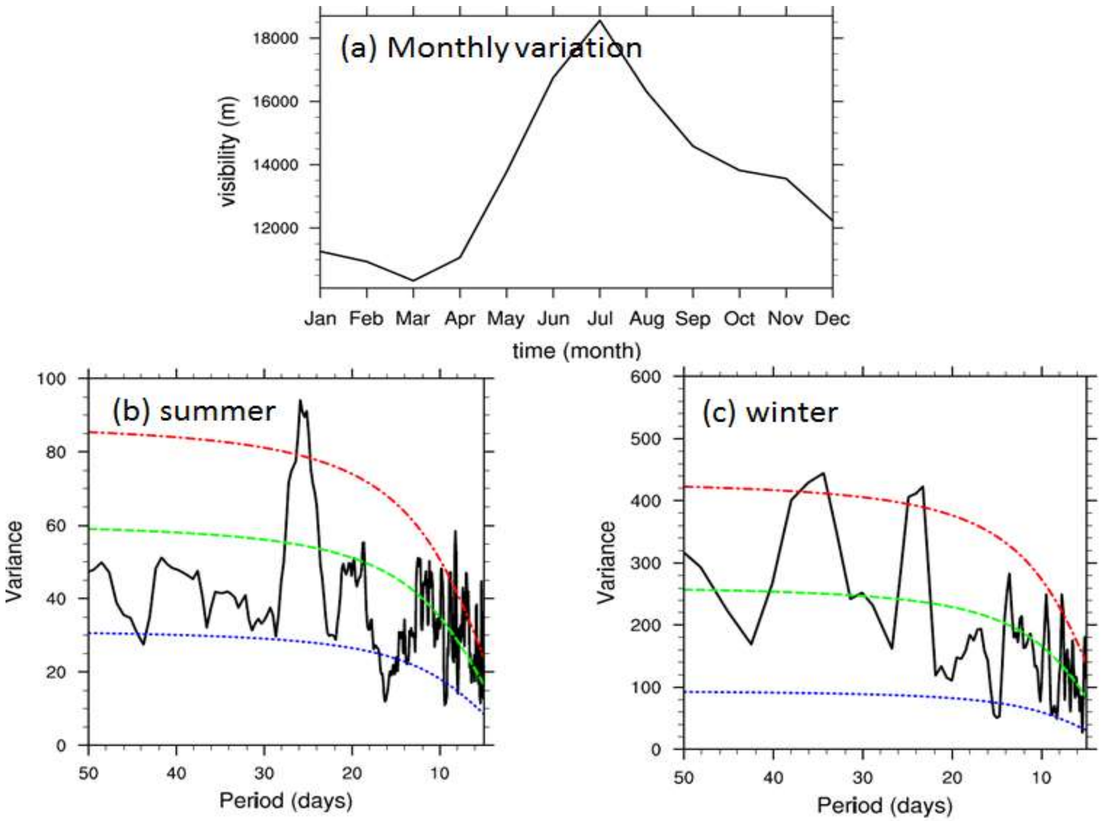
API	Air Pollution Level	Health Implications
0 to 25	Low	Not expected
26 to 50	Medium	Not expected for the general population
51 to 100	High	Acute health effects are not expected but chronic effects may be observed if you are exposed to such levels persistently for a long time.
101 to 200	Very High	People with existing heart or respiratory illnesses may notice mild aggravation of their health conditions. Generally healthy individuals may also notice some discomfort.
201 to 500	Severe	People with existing heart or respiratory illnesses may experience significant aggravation of their symptoms. There may also be widespread symptoms in the healthy population (e.g. eye irritation, wheezing, coughing, phlegm and sore throats).



Average and 90th percentile of daily reduced visibility hours during summer and winter

Number of hours of reduced visibility per day	Summer (JAS)	Winter (JFM)
Average	1.59	6.48
90th percentile	7	17

Temporal Variation of Visibility in Hong Kong

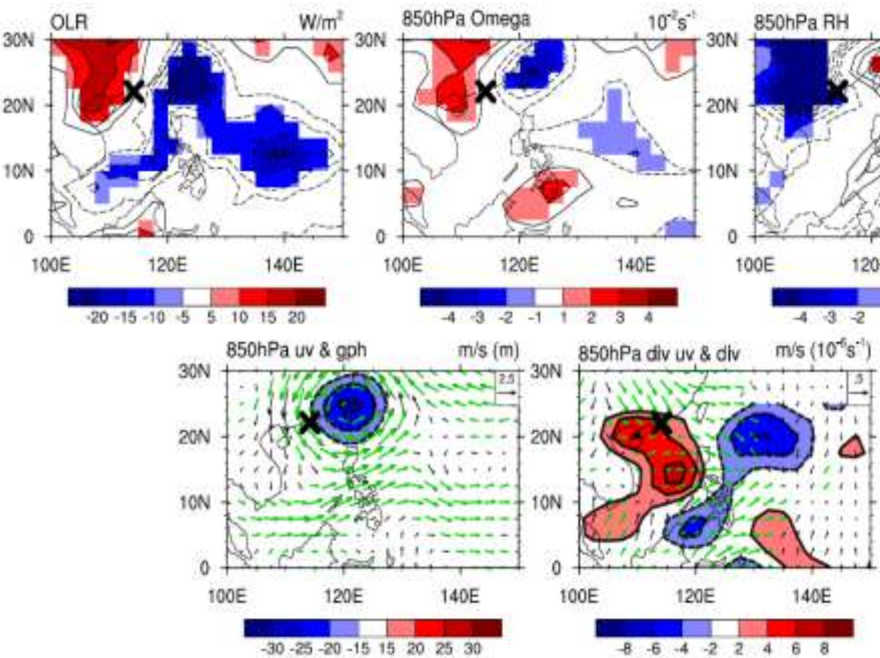


- Clear seasonal variation with better (poor) visibility being observed in summer (winter)
- Dominant peaks on 3–10 days & 20–30 days (summer) and 20–40 days (winter)

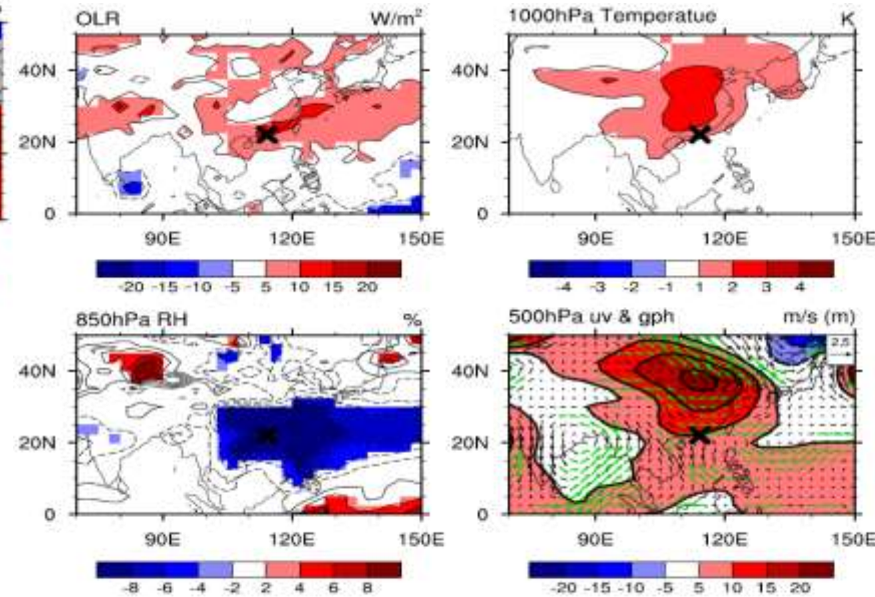
Power spectrum of daily reduced visibility hours in Hong Kong

Circulation Features associate with Visibility Impairment

Summer



Winter

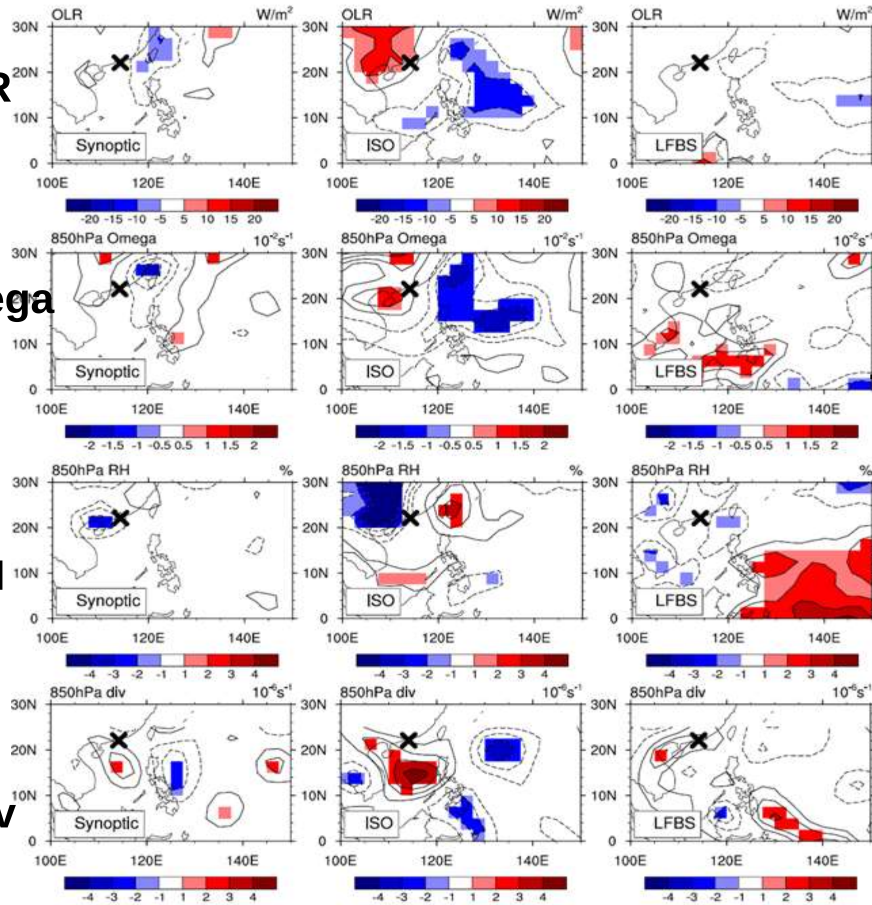


Zhou et al, 2016

- Suppressed convection
- Reduced moisture
- Northeasterlies

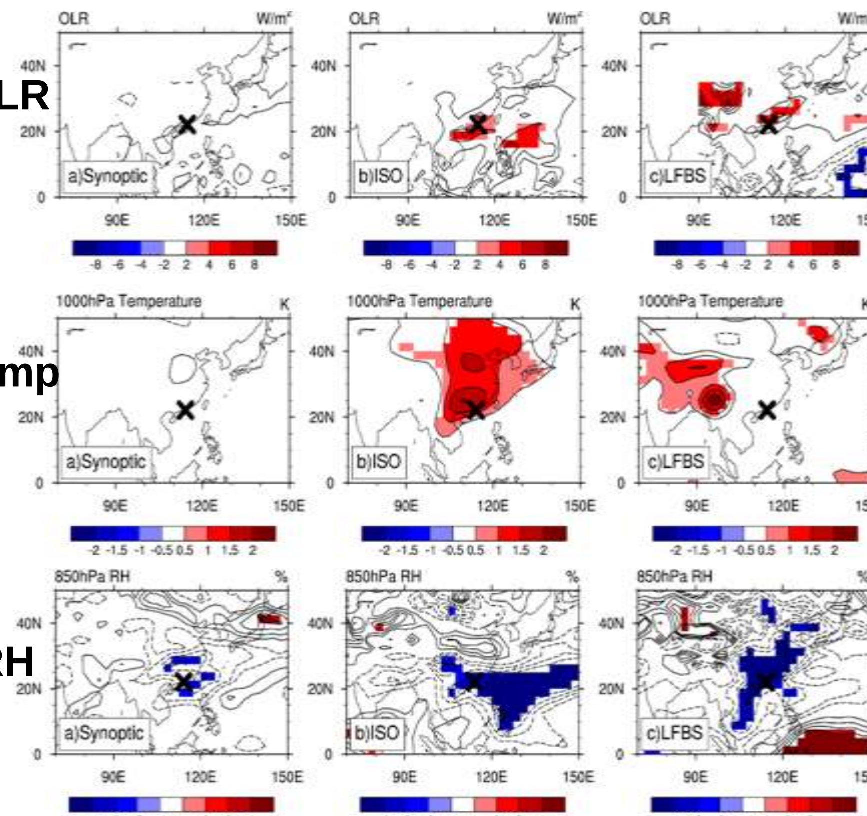
Multiscale control of visibility impairment in Hong Kong & synoptic, intraseasonal, and low-frequency background

Summer



3-10 days **10-90 days** **>90 days**

Winter



3-10 days **10-90 days** **>90 days**

Synoptic, intraseasonal, and LFBS components and the overall anomalies of different environmental variables in Hong Kong

Summer

Circulation anomalies (averaged over 20–25°N; 110–115°E)	Synoptic component	Intraseasonal component	LFBS component	Total
OLR (W/m^2)	1.71 (17%)	**8.11 (79%)**	0.14 (1%)	10.24
850 hPa omega	**0.35 (31%)**	**0.81 (71%)**	0.11 (10%)	1.14
850 hPa relative humidity (%)	**-1.49 (33%)**	-**2.51 (56%)**	-0.47 (11%)	-4.47
850 hPa divergence ($10^{-5}s^{-1}$)	0.48 (16%)	**1.54 (52%)**	0.96 (32%)	2.99

Winter

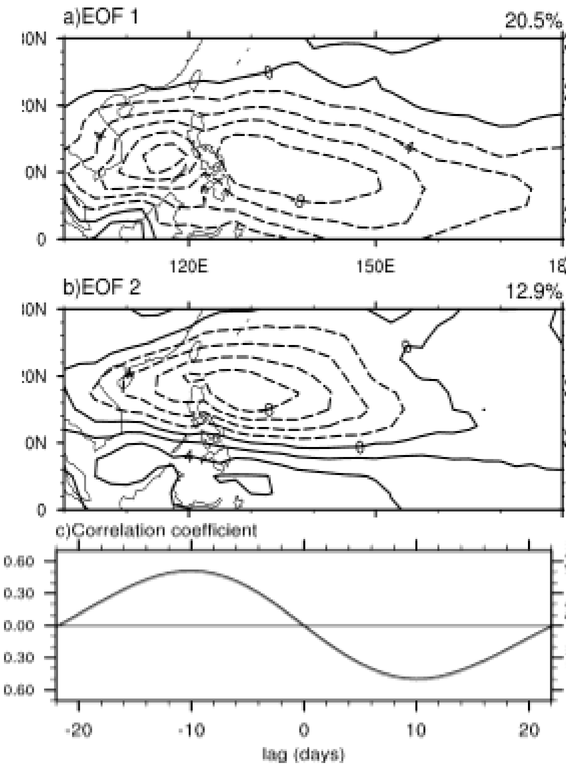
Circulation anomalies (averaged over 20–25°N; 110–115°E)	Synoptic component	Intraseasonal component	LFBS component	Total
OLR (W/m^2)	1.47 (16%)	**3.79 (41%)**	**3.79 (41%)**	9.30
1000 hPa temperature (K)	0.038 (2%)	**1.43 (92%)**	**0.094 (6%)**	1.56
850 hPa relative humidity (%)	-2.27 (22%)	**-4.69 (45%)**	**-3.38 (32%)**	-10.52

Intraseasonal Oscillation: MJO modulation

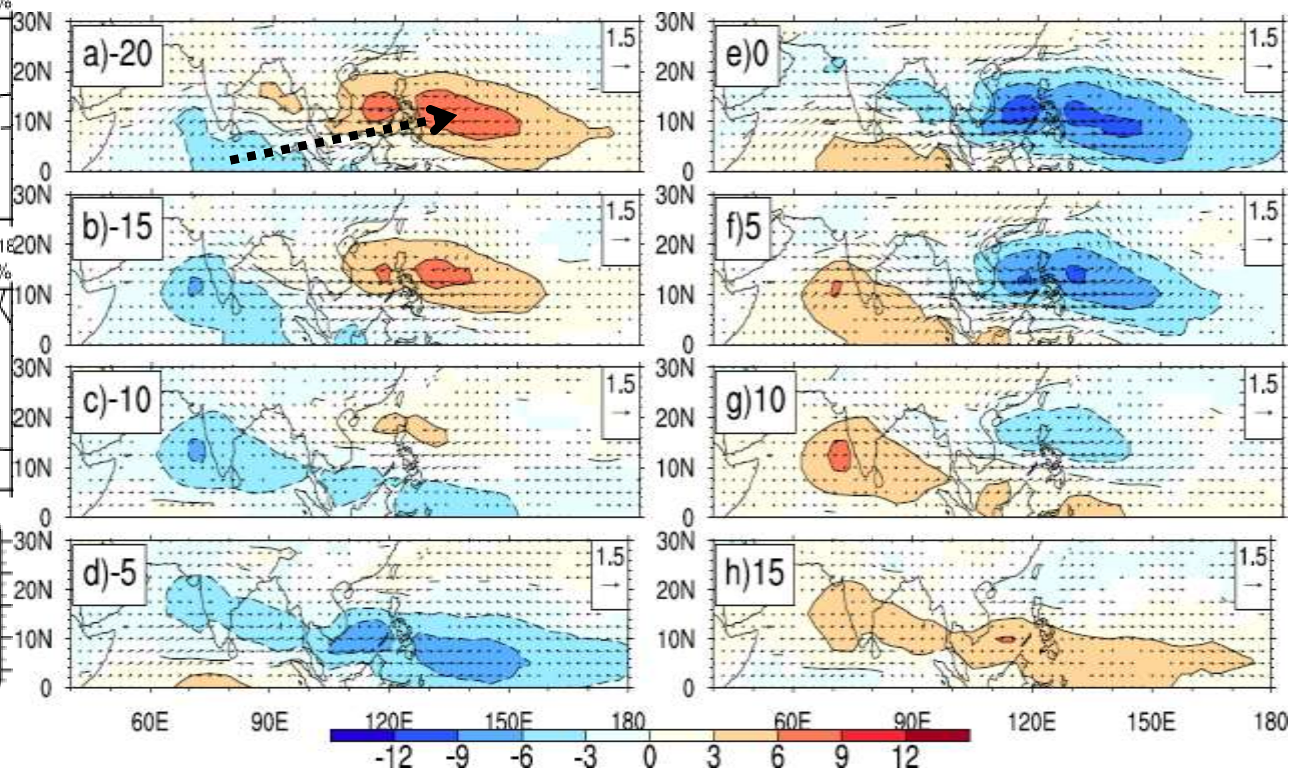
The 30–60-day Madden-Julian Oscillation (MJO) exhibit typical origin, spatial scale and propagation characteristics

$$\textbf{Phase}_{MJO} = \tan^{-1}[PC2_{MJO} / PC1_{MJO}]$$
$$\textbf{Amplitude}_{MJO} = [PC1_{MJO}^2 + PC2_{MJO}^2]^{1/2}$$

Dominant mode of MJO modulation



Lagged regression of the 30–60-day filtered OLR anomalies and 850 hPa wind against $PC1_{MJO}$



Changes in local visibility and API for different MJO phases

Summer

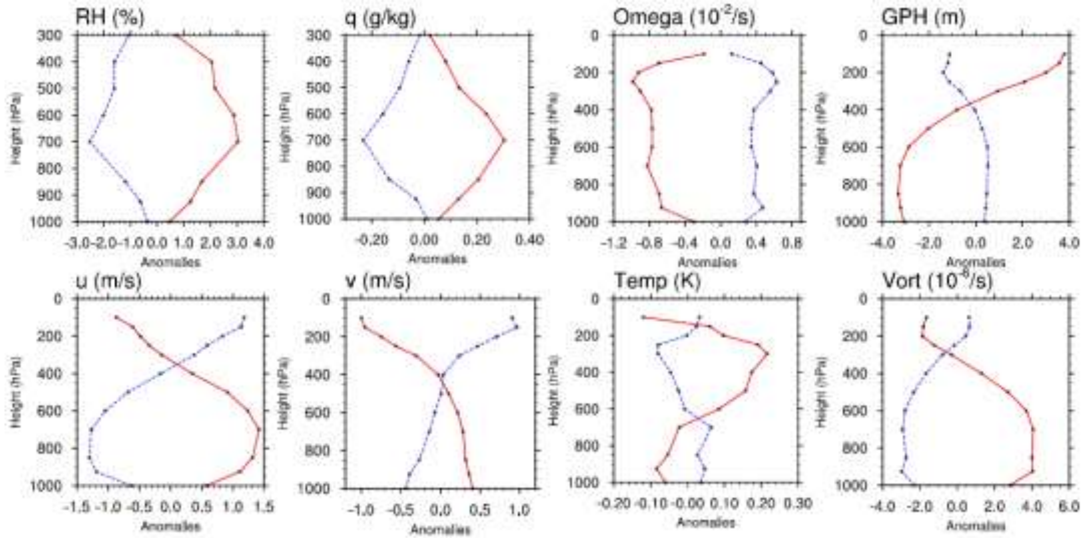
MJO	No of hours of reduced visibility per day	No of hours of API > 100 per day (Central)	No of hours of API > 100 per day (Mongkok)	No of hours of API > 100 per day (Causeway Bay)
Phase 1+2	2.13	1.26	1.37	0.37
Phase 3+4	0.87	0.28	0.16	0
Phase 5+6	0.85	0.90	0.79	0.30
Phase 7+8	2.38	1.48	1.41	0.81
Climatology	1.59	0.97	0.91	0.36

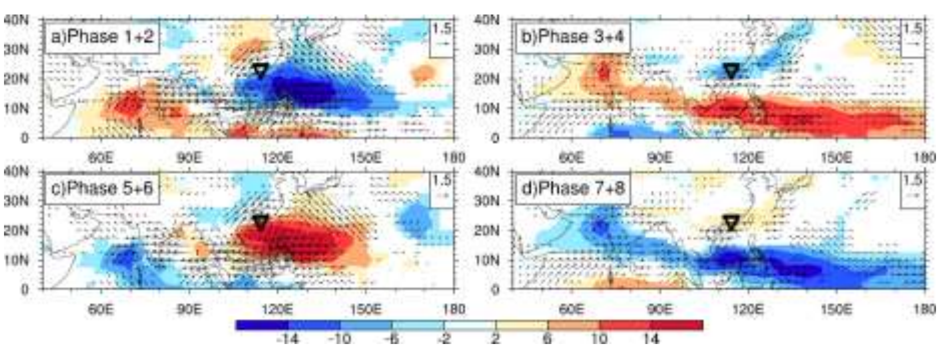
Winter

MJO	No of hours of reduced visibility per day	No of hours of API > 100 per day (Central)	No of hours of API > 100 per day (Mongkok)	No of hours of API > 100 per day (Causeway Bay)
Phase 1+2	6.25	2.95	2.53	1.99
Phase 3+4	7.23	2.08	0.92	1.06
Phase 5+6	6.55	0.35	0.21	0.35
Phase 7+8	6.66	1.83	0.79	1.28
Climatology	6.48	1.84	1.13	1.19

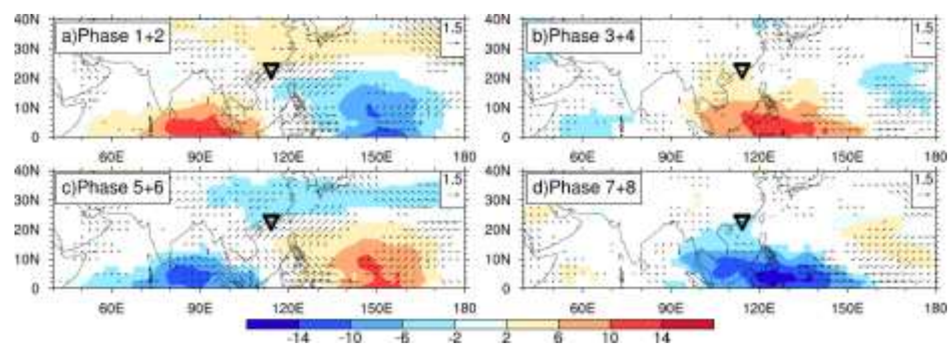
MJO modulation in summer

Vertical profiles of 30–60-day filtered anomalies of relative humidity (RH), specific humidity (q), omega, geopotential height (GPH), zonal wind (u), meridional wind (v), temperature (temp), and relative vorticity (Vort) for **MJO** **phase 3+4 (red lines)** and **phase 7+8 (blue lines)** **in summer**





Summer



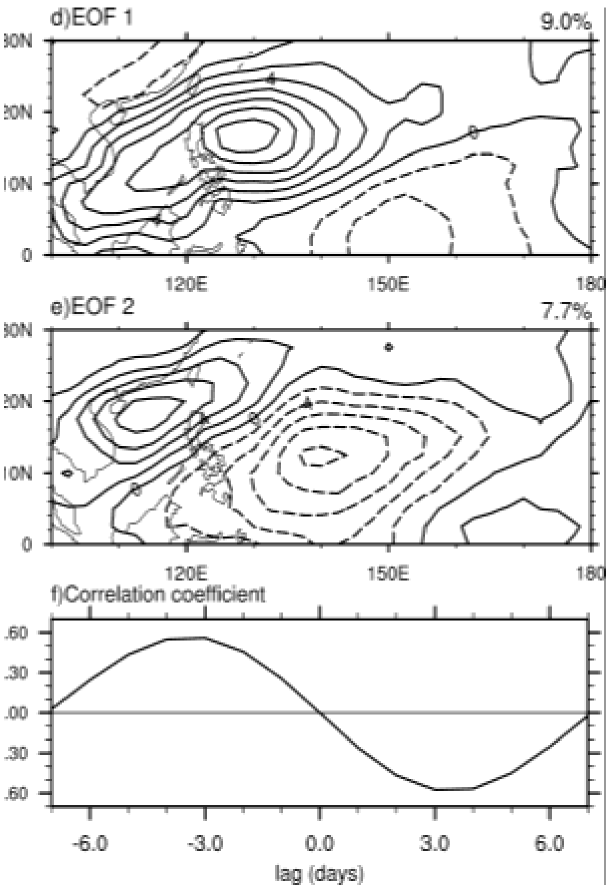
Winter

Intraseasonal Oscillation: QBWO (10-20-day) modulation

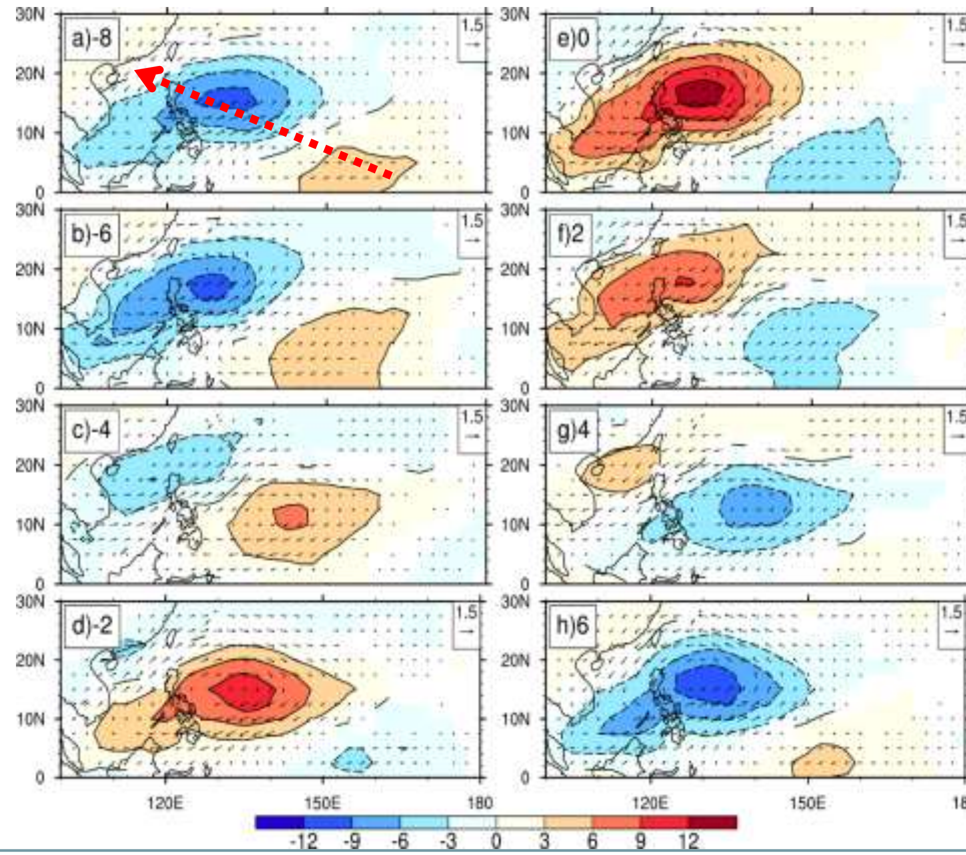
$$Phase_{QBWO} = \tan^{-1} [PC2_{QBWO} / PC1_{QBWO}]$$

$$Amplitude_{QBWO} = [PC1_{QBWO}{}^{2} + PC2_{QBWO}{}^{2}]^{1/2}$$

Dominant mode of QBWO modulation



Lagged regression of the 10–20-day filtered OLR anomalies and 850 hPa wind against $PC1_{QBWO}$



Changes in local visibility and API for different QBWO phases

QBWO	No of hours of reduced visibility per day	No of hours of API > 100 per day (Central)	No of hours of API > 100 per day (Mongkok)	No of hours of API > 100 per day (Causeway Bay)
Phase 1+2	**0.16**	**0**	**0**	**0**
Phase 3+4	**0.97**	0.82	0.73	0.60
Phase 5+6	**2.44**	**1.76**	**1.38**	**1.05**
Phase 7+8	1.82	0.90	0.58	0.32
Climatology	1.59	0.97	0.91	0.36

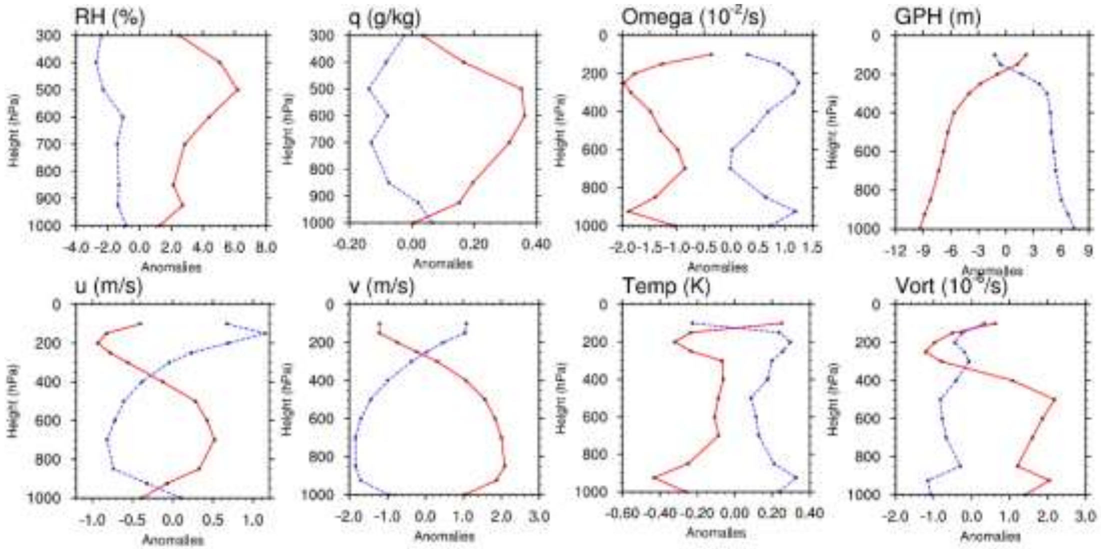
Summer

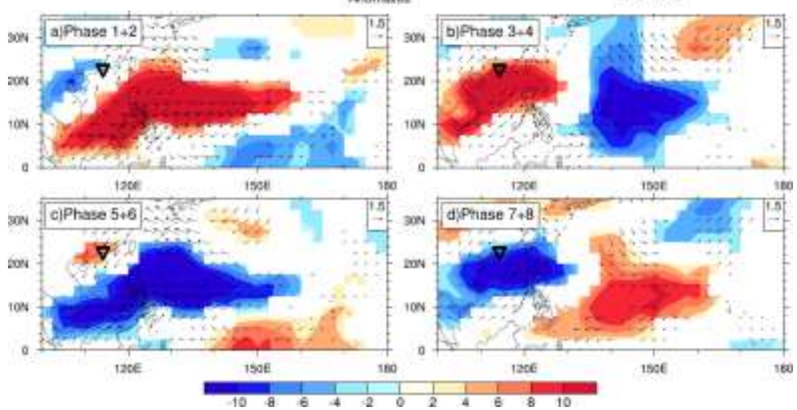
QBWO	No of hours of reduced visibility per day	No of hours of API > 100 per day (Central)	No of hours of API > 100 per day (Mongkok)	No of hours of API > 100 per day (Causeway Bay)
Phase 1+2	5.07	2.02	1.28	1.48
Phase 3+4	6.58	**3.16**	**2.14**	**2.56**
Phase 5+6	5.95	1.11	0.45	1.06
Phase 7+8	6.26	1.08	**0.16**	0.75
Climatology	6.48	1.79	0.98	1.43

Winter

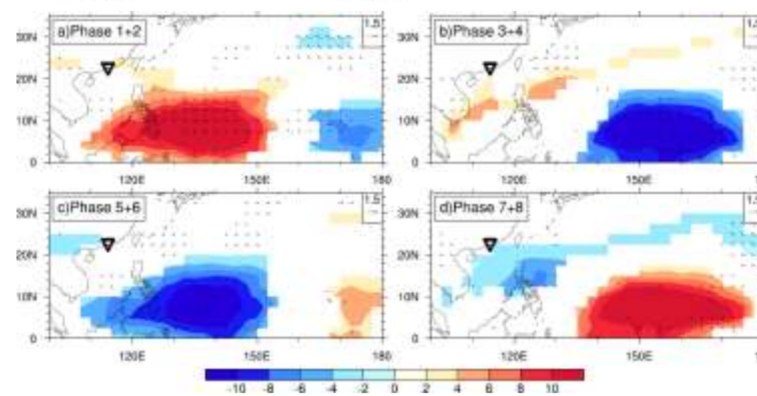
QBWO modulation in summer

Vertical profiles of 10–30-day filtered anomalies of relative humidity (RH), specific humidity (q), omega, geopotential height (GPH), zonal wind (u), meridional wind (v), temperature (temp), and relative vorticity (Vort) for **QBWO phase 1+2 (red lines)** and **phase 5+6 (blue lines) in summer**





Summer



Winter

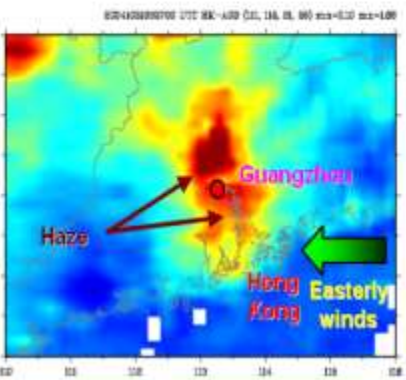
Summary

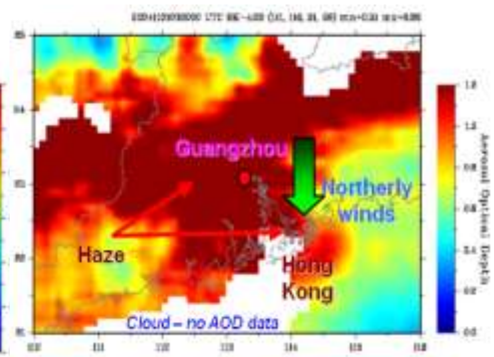
- The two dominant modes of the ISO (MJO & QBWO) both contribute significantly to visibility variation in Hong Kong by modulating the associated atmospheric circulations

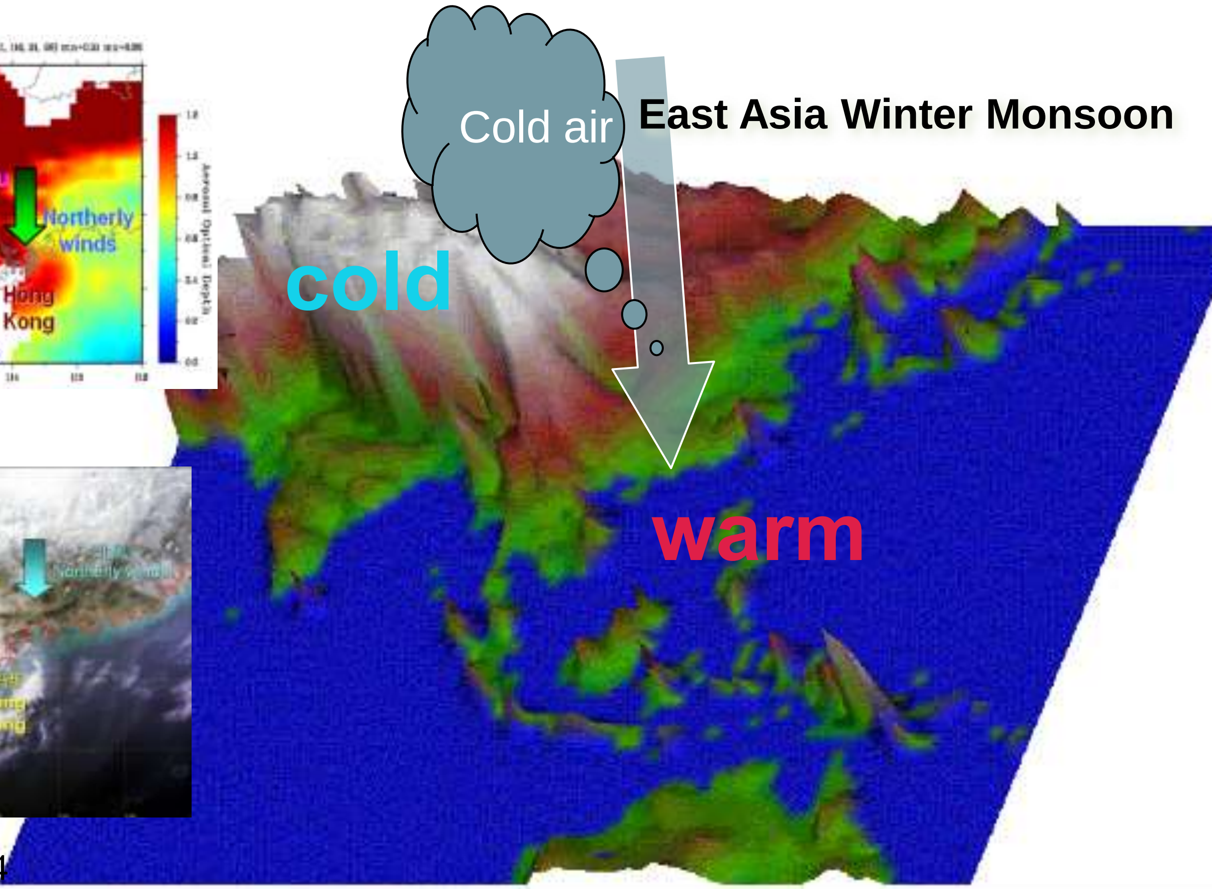
- In summer, local visibility and air quality are found to be significantly affected by the MJO and QBWO through modulating the associated atmospheric circulations

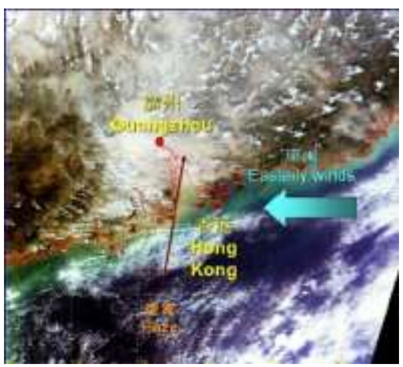
- In winter, the modulation effects appear to be weaker due to the southward shift of the MJO-related and QBWO-related convection.

Discussion: Cold air brings more pollutants to Hong Kong

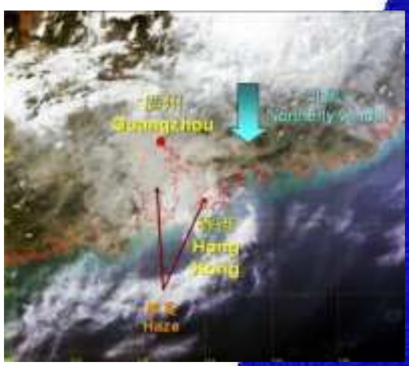








31 Oct 2004



1 Nov 2004

- The passage of a cold front can transport regional pollutants from the north, causing deterioration in local visibility in winter (Wang et al. 2003)
- The midlatitude intraseasonal signals might be the key factor in visibility modulation in winter

Thank You!