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Contribution of uneven warming to the observed wind stilling in North China for 1961-2016

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Global warming vs. Wind stilling

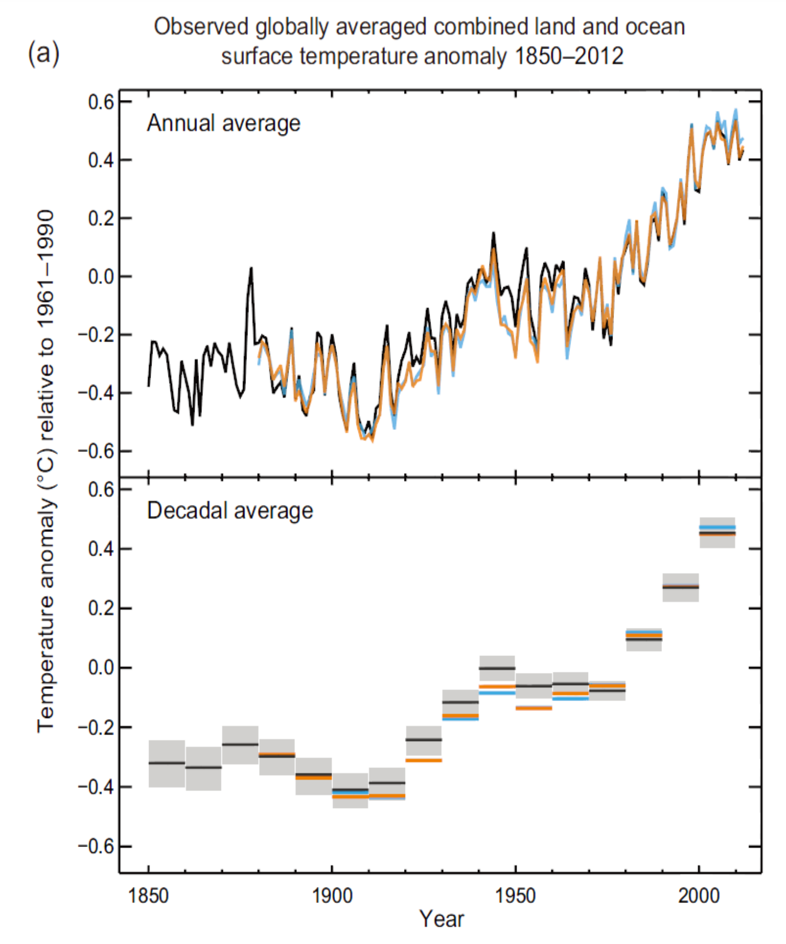


Figure 1. Global average near-surface air temperature anomaly over land and ocean for 1850-2012. IPCC, 2013

- **Global average air temperature increased since 1850,** particularly in the last fifty year (+0.12 °C decade^{-1}).
- **Wind stilling occurred in most terrestrial stations** (−0.140 m s^{-1} decade^{-1}) for the last few decades, especially in mid-latitude regions.

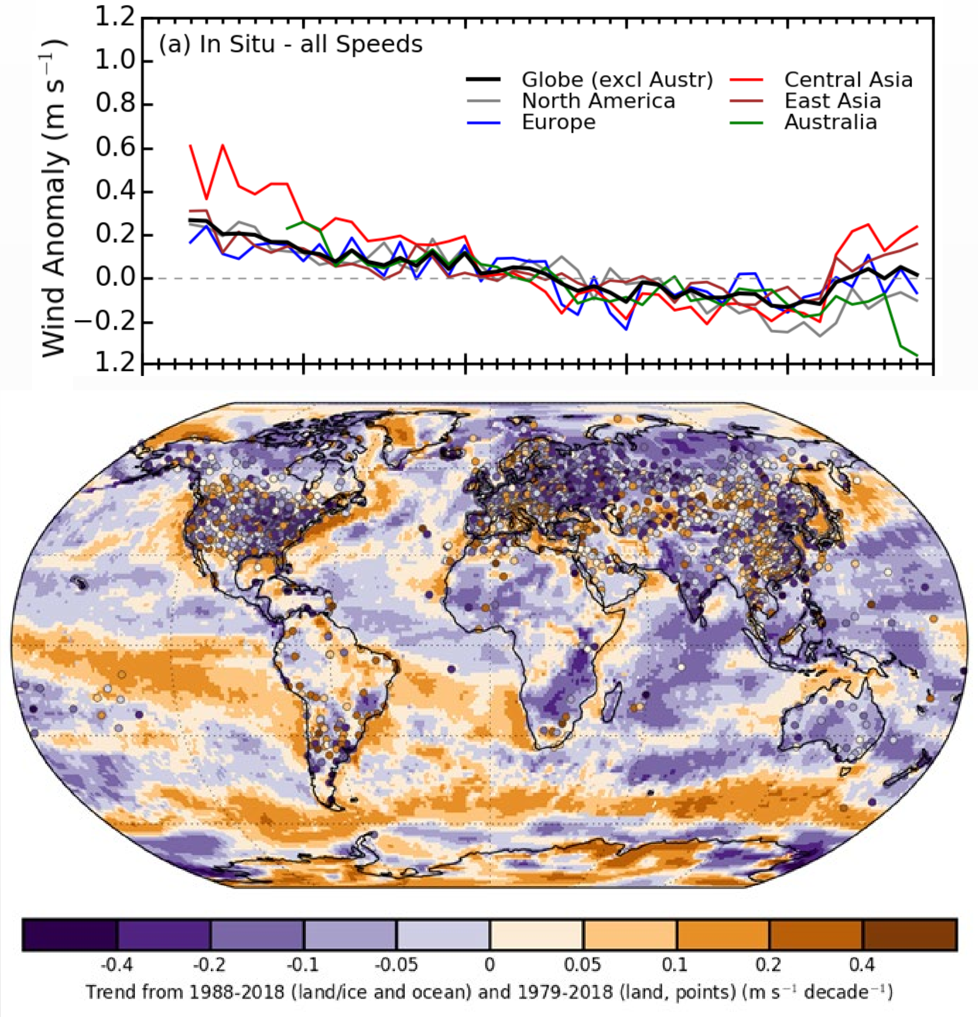


Figure 2. Global and regional land surface wind speed anomaly (m s^{-1}; relative to 1981–2010) using HadISD3. Global wind speed trends (in m s^{-1} dec^{-1}) Azorin-Molina *et al.*, 2019.

Impacts of wind speed changes

- **Wind speed changes have key impacts on environment and society**, e.g., dust storm , air pollution diffussion and wind farm, among many others.

DUST STORMS

WINTER HAZE IN BEIJING

LONG-TERM WIND POWER GENERATION

Figure 3. Socioeconomic and environmental impacts of wind speed.

Study area: North China

- Including Mongolian Plateau, Loess Plateau and northern China Plain.
- Within an overall continental climate, varies from humid in the east to arid and semi-arid in the west, and mainly controlled by westerly winds.
- Land cover varies between forest, grassland and barren land with sparse vegetation.

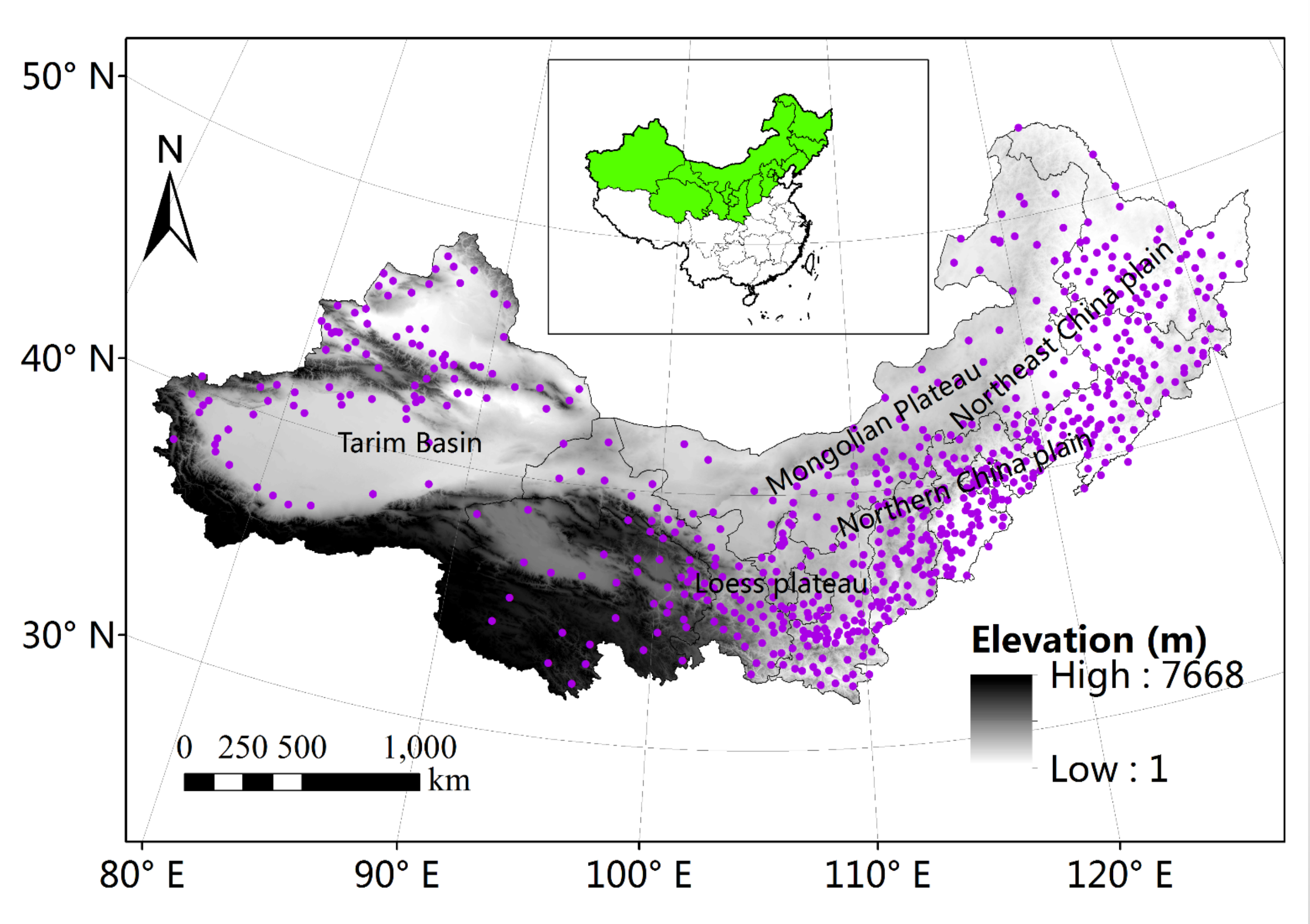
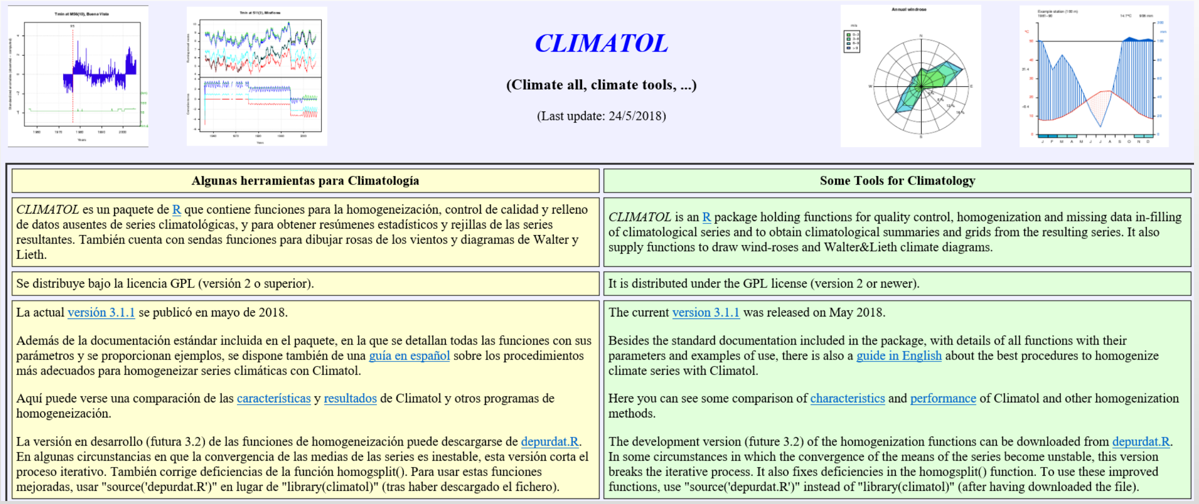


Figure 4. Terrain map and distribution of 690 weather stations in North China.

Homogenization of wind speed data

- **Station relocations**, **anemometer changes** and **anemometer aging** produced artificial shifts on wind speed series.
- The **R package Climatol** was applied to quality control and homogenizing the 690 raw wind speed series for 1961-2016.



CLIMATOL

(Climate all, climate tools, ...)

(Last update: 24/5/2018)

Algunas herramientas para Climatología	Some Tools for Climatology
CLIMATOL es un paquete de R que contiene funciones para la homogeneización, control de calidad y relleno de datos ausentes de series climatológicas, y para obtener resúmenes estadísticos y rejillas de las series resultantes. También cuenta con sendas funciones para dibujar rosas de los vientos y diagramas de Walter y Lieth.	*CLIMATOL* is an R package holding functions for quality control, homogenization and missing data in-filling of climatological series and to obtain climatological summaries and grids from the resulting series. It also supply functions to draw wind-roses and Walter&Lieth climate diagrams.
Se distribuye bajo la licencia GPL (versión 2 o superior).	It is distributed under the GPL license (version 2 or newer).
La actual versión 3.1.1 se publicó en mayo de 2018. Además de la documentación estándar incluida en el paquete, en la que se detallan todas las funciones con sus parámetros y se proporcionan ejemplos, se dispone también de una guía en español sobre los procedimientos más adecuados para homogeneizar series climáticas con Climatol. Aquí puede verse una comparación de las características y resultados de Climatol y otros programas de homogeneización. La versión en desarrollo (futura 3.2) de las funciones de homogeneización puede descargarse de depurdat.R. En algunas circunstancias en que la convergencia de las medias de las series es inestable, esta versión corta el proceso iterativo. También corrige deficiencias de la función homogsplit(). Para usar estas funciones mejoradas, usar "source('depurdat.R')" en lugar de "library(climatol)" (tras haber descargado el fichero).	The current version 3.1.1 was released on May 2018. Besides the standard documentation included in the package, with details of all functions with their parameters and examples of use, there is also a guide in English about the best procedures to homogenize climate series with Climatol. Here you can see some comparison of characteristics and performance of Climatol and other homogenization methods. The development version (future 3.2) of the homogenization functions can be downloaded from depurdat.R. In some circumstances in which the convergence of the means of the series become unstable, this version breaks the iterative process. It also fixes deficiencies in the homogsplit() function. To use these improved functions, use "source('depurdat.R')" instead of "library(climatol)" (after having downloaded the file).

Figure 5. Climatol package. (http://www.climatol.eu/)

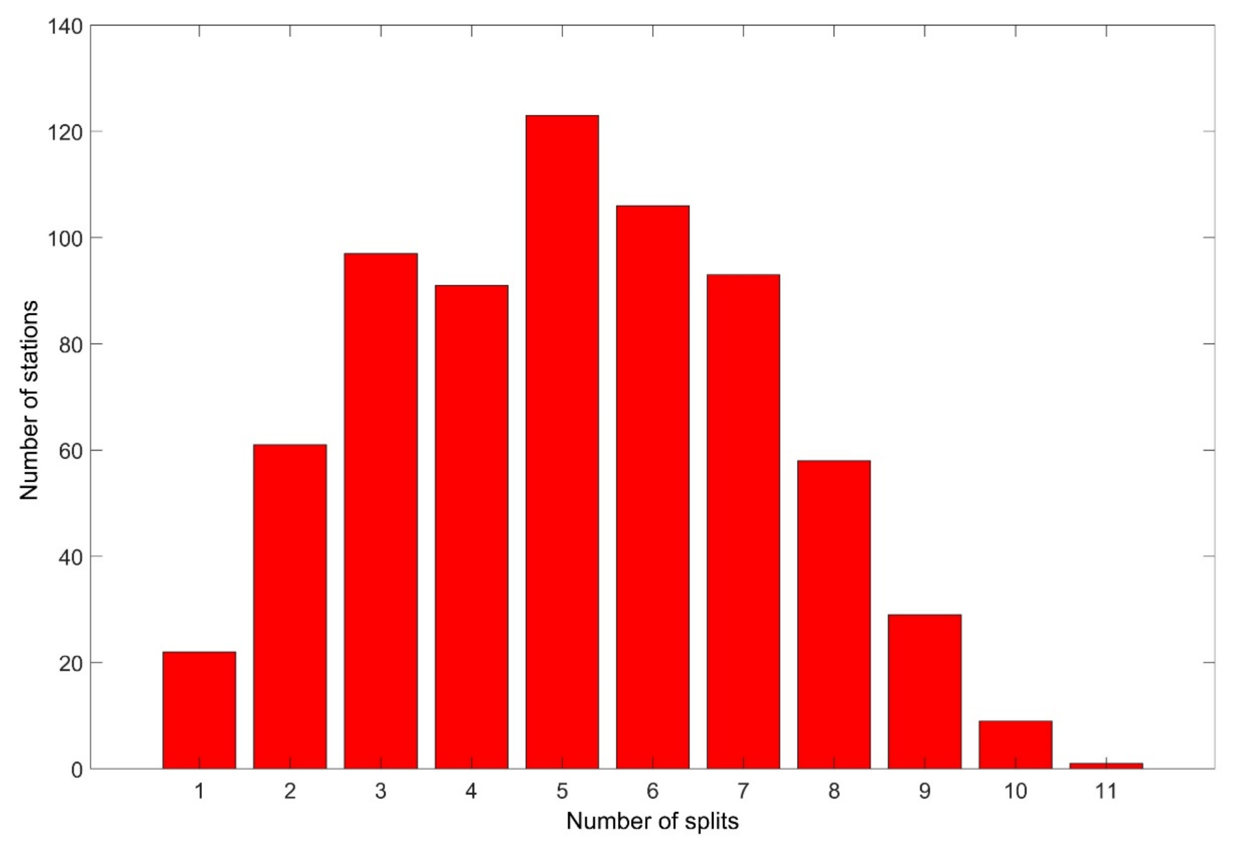


Figure 6. Histogram of the number of break points detected for all stations.

Observed wind stilling

- Mean wind speed displayed a **significant declining trend** annually and seasonally. The **highest negative trend** was found **in spring**.

- Mean wind speed was relative **stable in the 1960s**, then experienced **a rapidly downward trend 1970s onward**.

	Trend	*p*-value
Annual	-0.103	**
Winter (DJF)	-0.109	**
Spring (MAM)	-0.137	**
Summer (JJA)	-0.078	**
Autumn (SON)	-0.086	**

Table 1. Annual and seasonal mean wind speed trends ($m\ s^{-1}\ dec^{-1}$) across North China for 1961-2016. Trends are shown, with significant defined as $p<0.05$ (**).

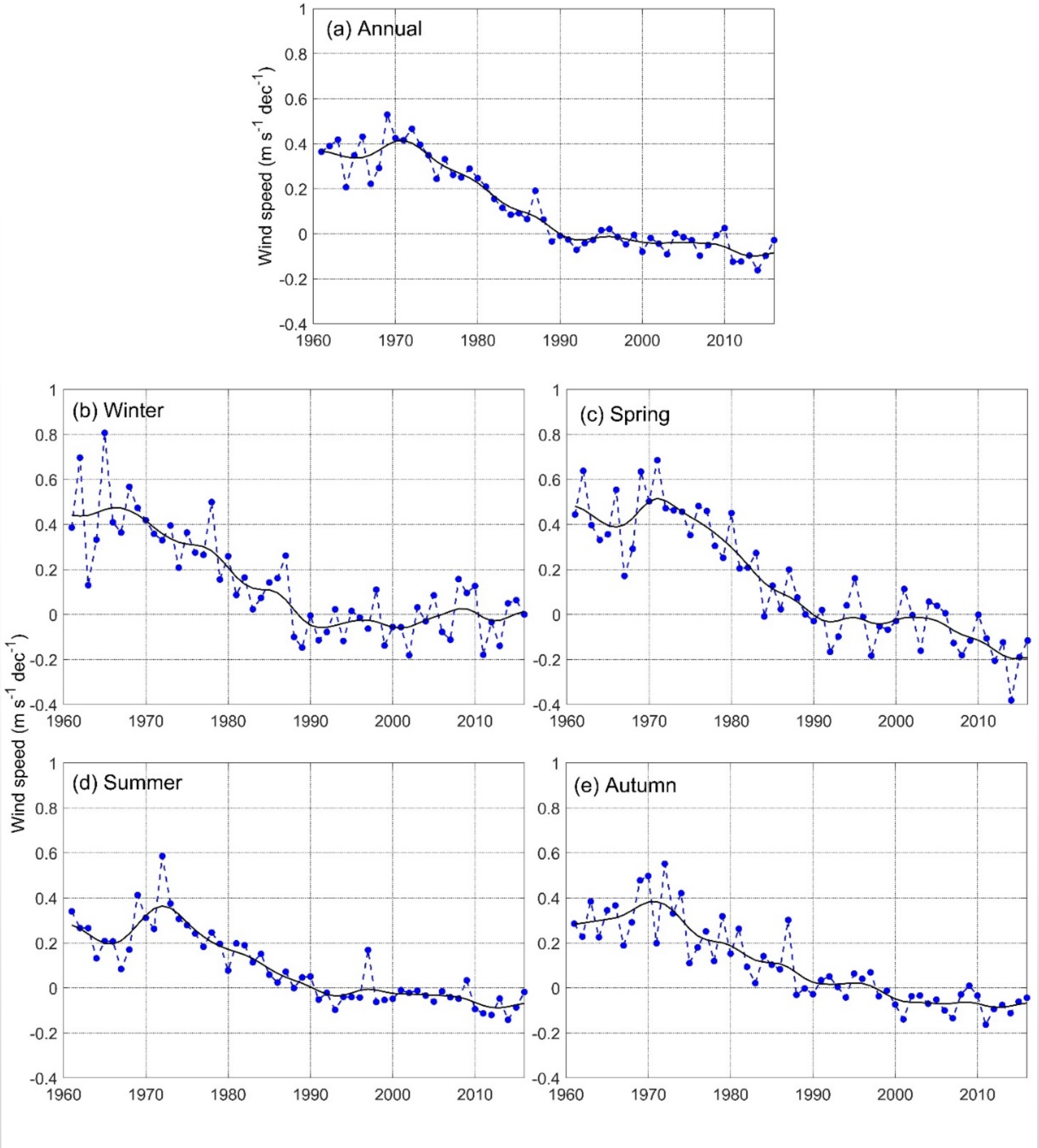


Figure 7. Annual and seasonal mean wind speed anomaly series over North China for 1961-2016. Series are expressed as anomaly (1981-2010 mean)

Spatial distribution of wind speed trends

- Annually, mean wind speed showed a **widespread downward trend.**

- Seasonally, **the same widespread negative pattern dominated**; except for some few stations showing **positive trends in west part** of North China.

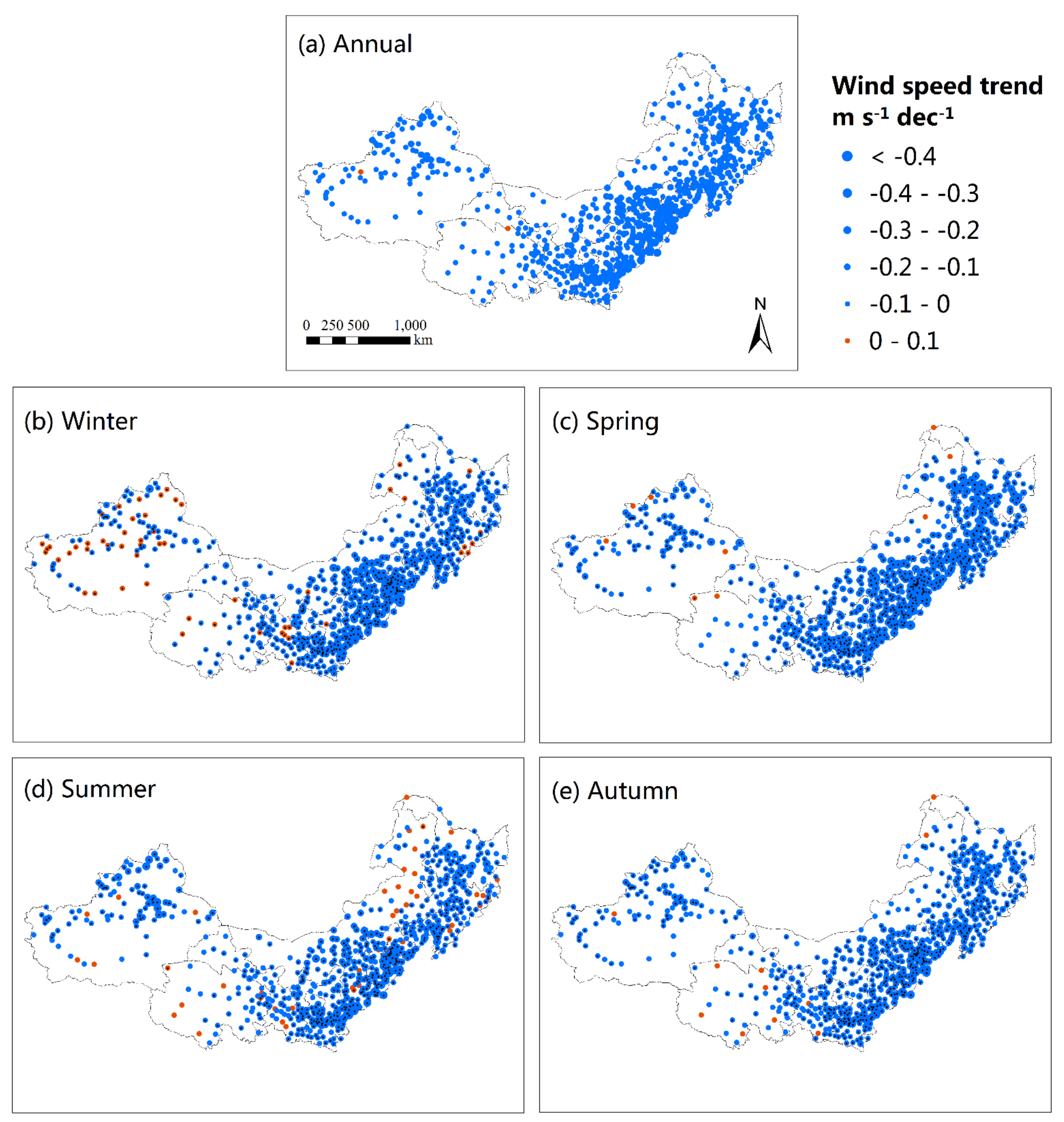
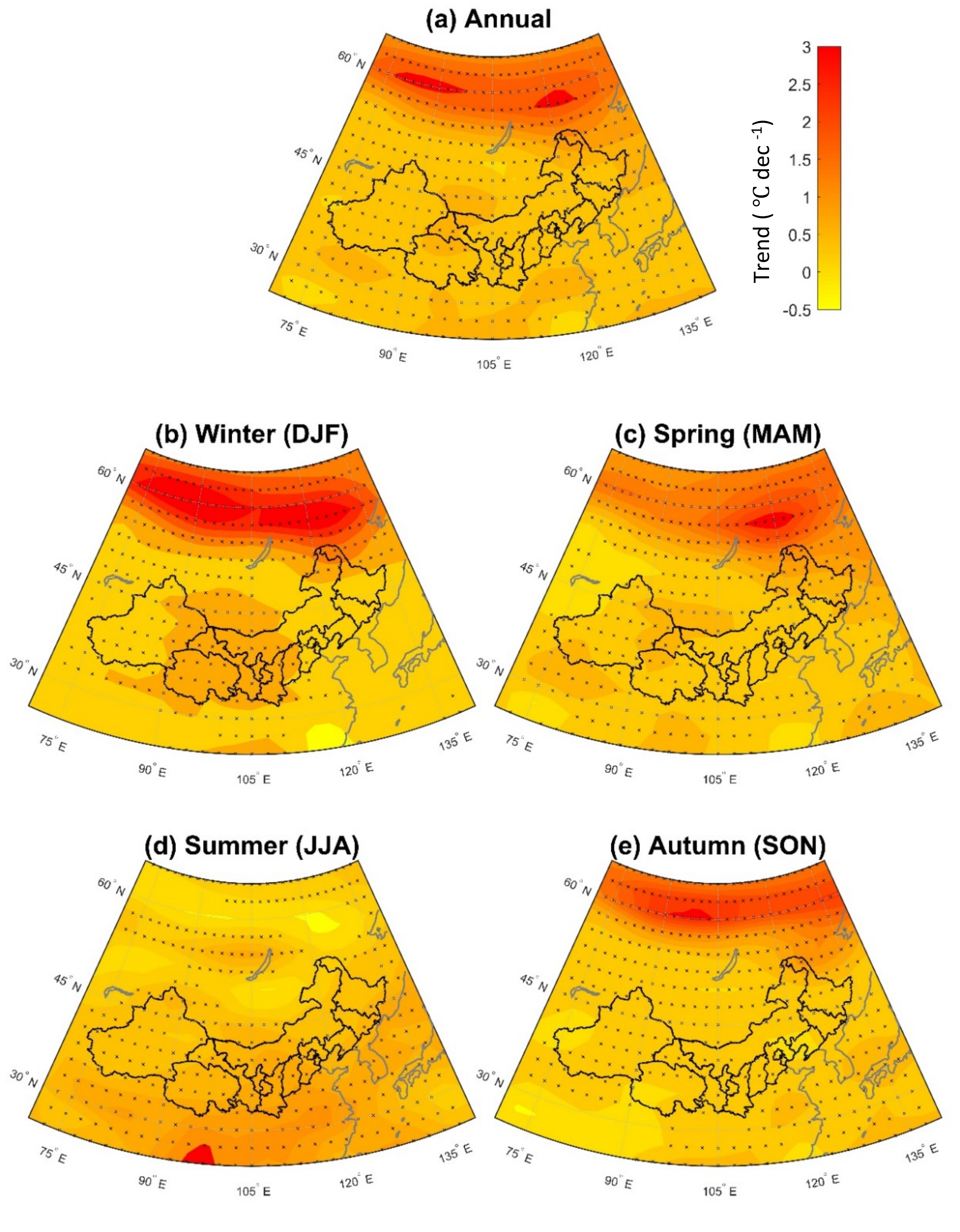


Figure 8. Spatial distribution of the sign and magnitude of annual-seasonal wind speed trends (black dots in the circle show significant at $p<0.05$)

Observed uneven warming



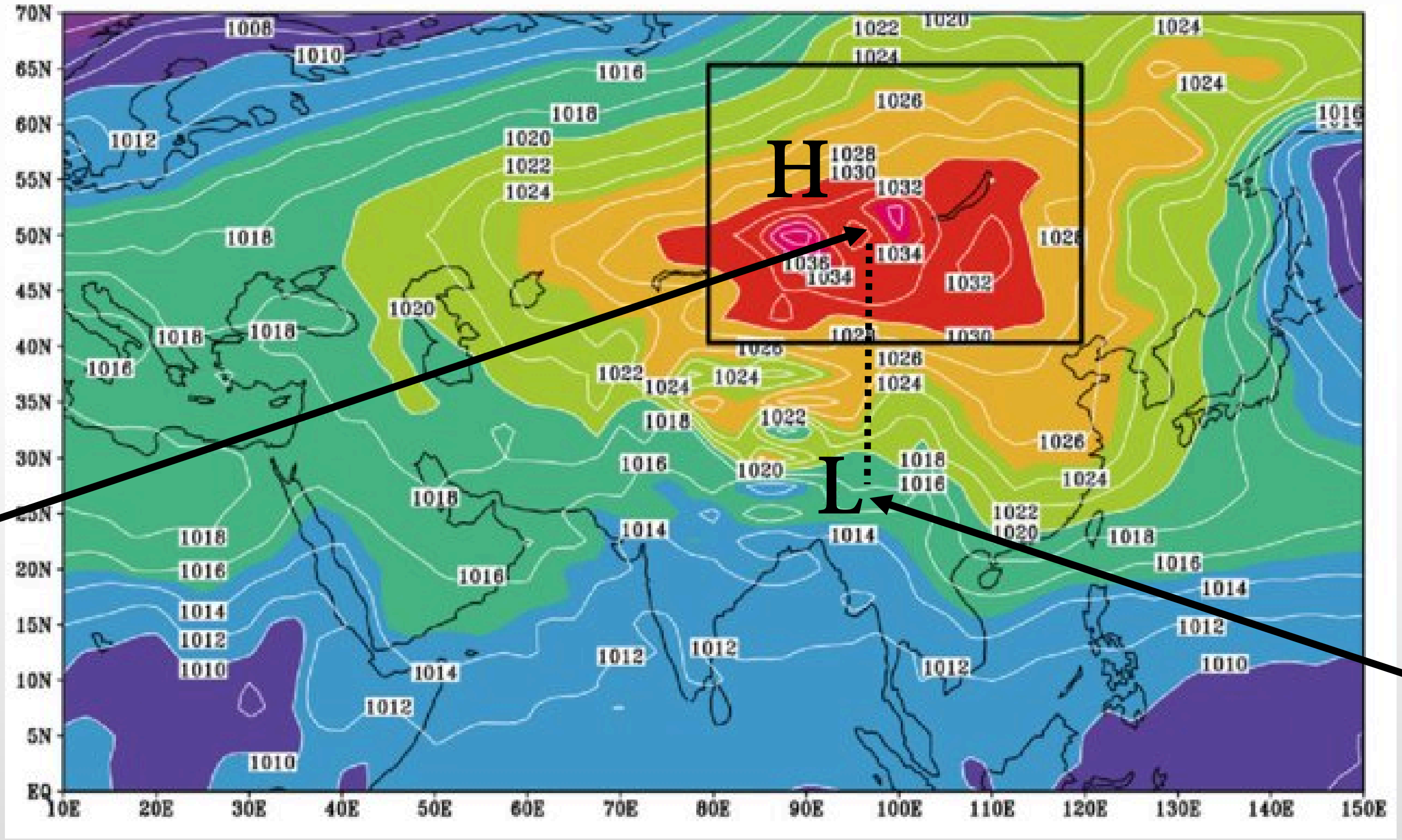
- An **uneven warming** was observed, with **air temperature increasing more quickly at high latitudes than at middle latitudes,** except for **summer.**

Figure 9. Annual and seasonal air temperature trends (in °C dec^{-1}) over North China and surroundings for 1961-2016 (black 'x' indicates significant trends at p<0.05). NCEP/NCAR reanalysis.

Sea level pressure over North China and surroundings

H

High pressure in high latitudes, i.e., **Siberian high pressure, mongolian high pressure.**



L

Low pressure in **mid- latitudes**, including North China.

Figure 10. Mean sea level pressure (SLP) climatology over North China and surroundings. Hasanean *et al.*, 2013

What are the changes in air pressure and pressure gradient?

- Annually, the air pressure in **high latitudes** was **decreasing quickly** than in **mid-latitudes**, which means a reduced **pressure gradient**.

- Seasonally, **similar spatial patterns** were detected in **winter and spring**, while an **increasing air pressure** in **mid-latitudes** was found in **summer and autumn**, those all show a **weakening of air pressure gradient** .

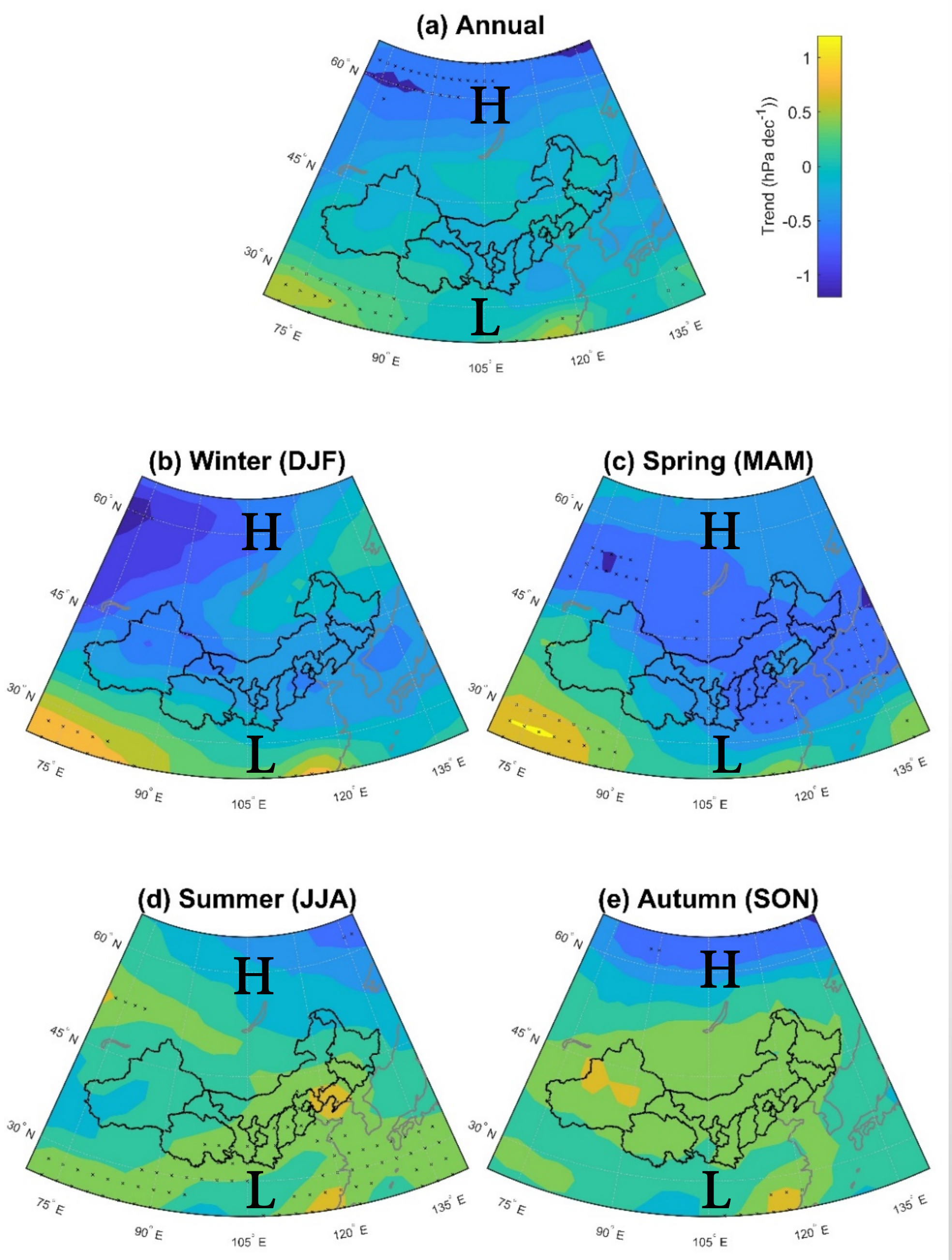


Figure 11. Annual and seasonal surface air pressure (hPa dec^{-1}) over North China and surroundings for 1961-2016 (black 'x' indicates significant trends at $p<0.05$). NCEP/NCAR

The mechanism of uneven warming to wind stilling

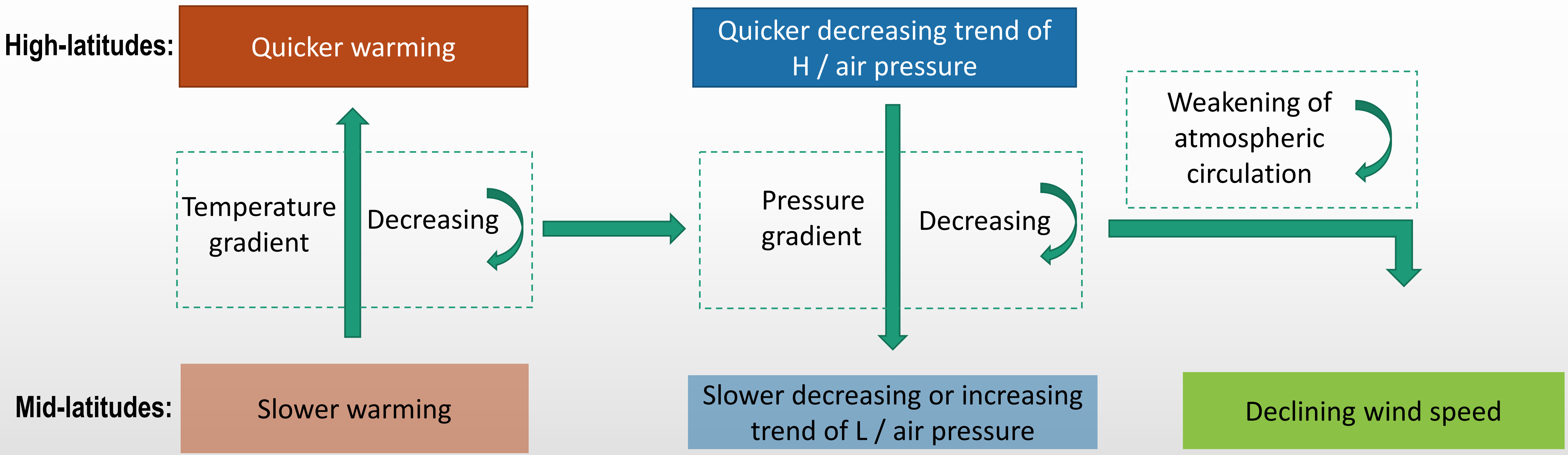
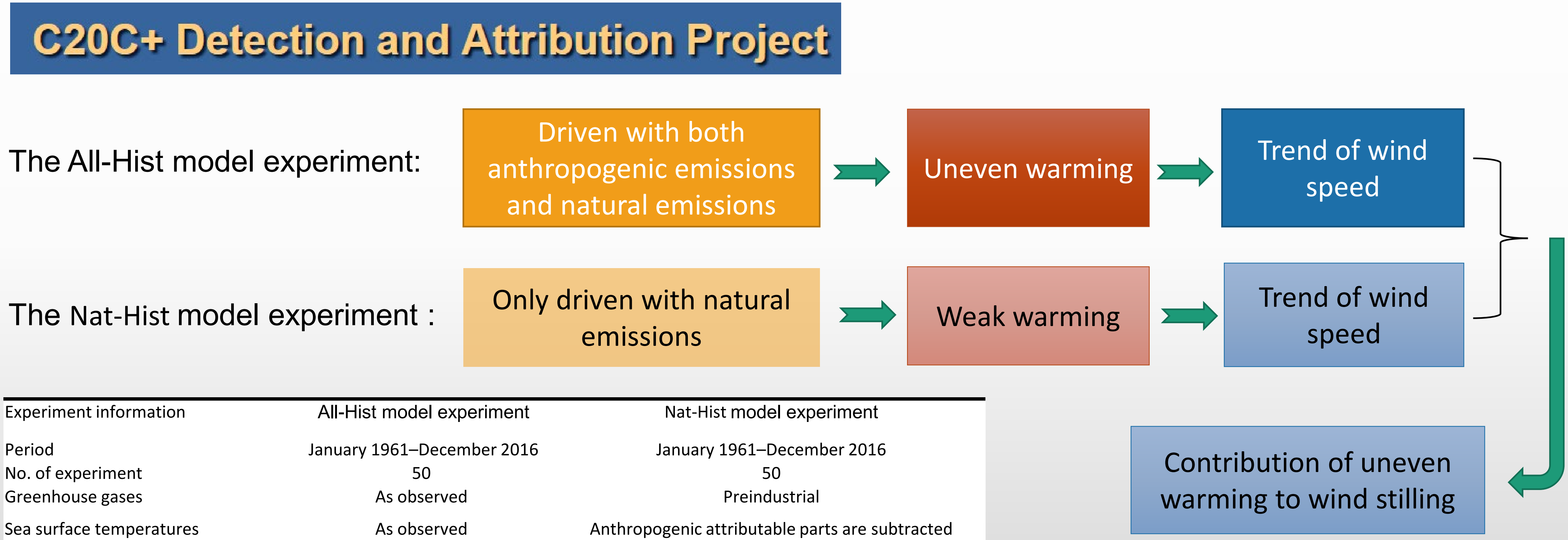


Figure 12. Diagram representing the role of uneven warming in the observed wind stilling in North China.

Discussion

1. Quantifying the contribution of uneven warming to wind stilling



Experiment information	All-Hist model experiment	Nat-Hist model experiment
Period	January 1961–December 2016	January 1961–December 2016
No. of experiment	50	50
Greenhouse gases	As observed	Preindustrial
Sea surface temperatures	As observed	Anthropogenic attributable parts are subtracted
Sea ice	As observed	Anthropogenic attributable parts are subtracted
Tropospheric aerosols	As observed	Preindustrial
Volcanic aerosols	As observed	As observed
Solar irradiance	As observed	As observed
Land cover	As observed	As observed
Stratospheric zone	As observed	Preindustrial

Table 2. The detail of All-hist and Nat-Hist model experiment in the C20C+ Detection and Attribution Project.

Discussion

2. Other drivers of wind stilling

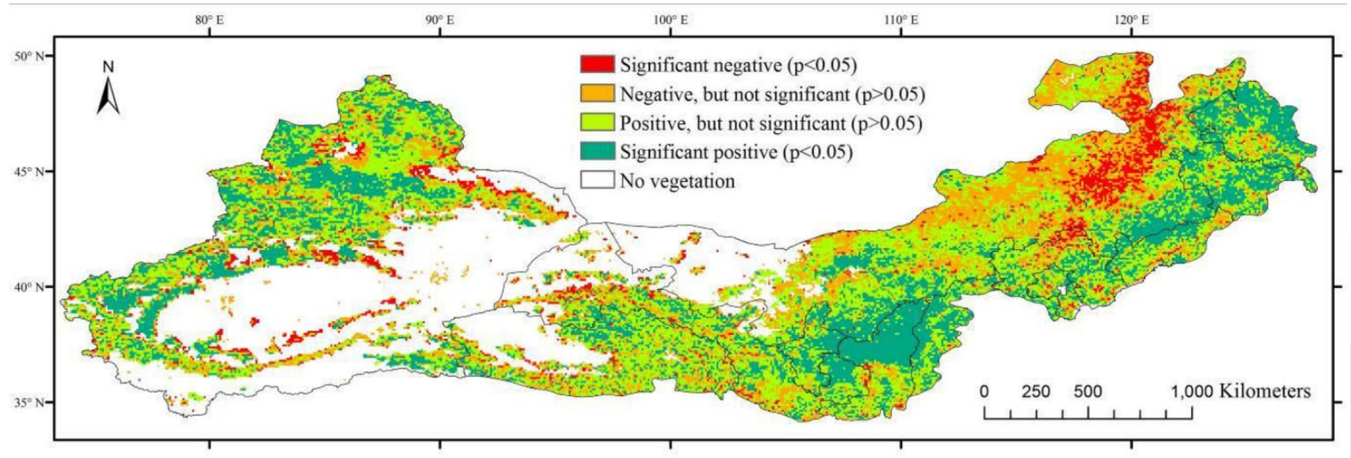


Figure 13. Increased vegetation in North China. **He *et al.*, 2015**

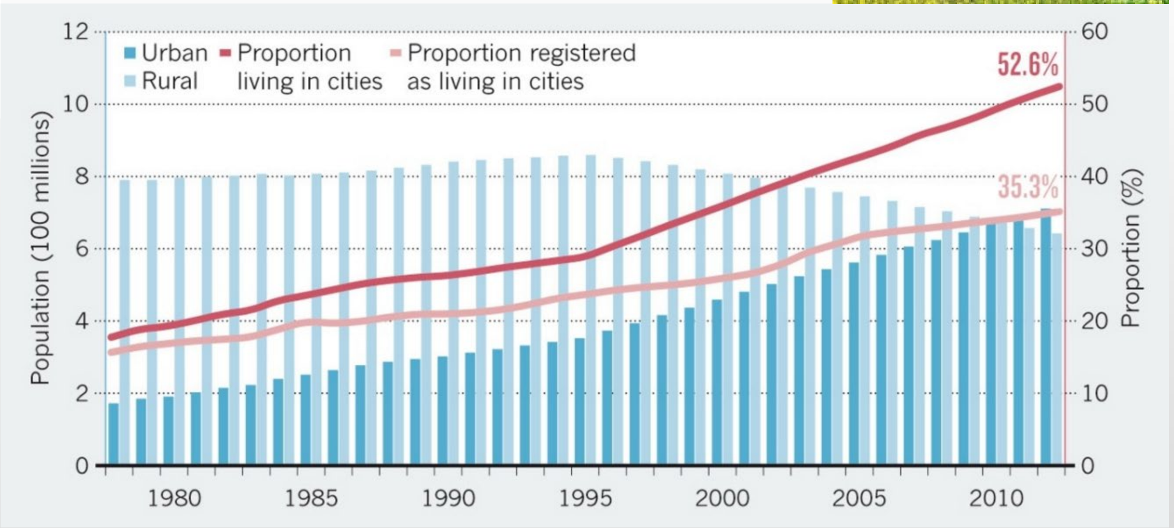


Figure 14. Rapid urbanization in China during last few decades. Bai *et al.*, 2015

Conclusion

1. Significant declining trend of mean wind speed was observed in North China for 1961-2016.
2. An uneven warming was detected, which indicated a decrease in air temperature gradient between high-latitudes and mid-latitudes.
3. The declining of air temperature gradient weakened the air pressure gradient, which can partly explain the observed wind stilling in North China.

Thank you!

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