Amplified summer warming in Europe-West Asia and Northeast Asia after the mid-1990s

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Keeling curve: CO2 increasing

Latest CO$_2$ reading
November 09, 2015
400.14 ppm

Carbon dioxide concentration at Mauna Loa Observatory

Full Record ending November 9, 2015
Global warming, Regional warming
EXTREME HEAT EVENTS WILL BECOME MORE SEVERE

INCREASE IN AVERAGE TEMPERATURE

When average temperatures increase, the average temperature of “hot weather” and “record hot weather” will become even hotter.\(^\text{16}\)

From CDC
Casualties increasing dramatically

(World Meteorological Organization 2013)
DEATHS IN THE UNITED STATES ATTRIBUTED TO WEATHER CONDITIONS, 2000–2009

- Cold: 5%
- Heat: 24%
- Hurricane: 23%
- Flood: 13%
- Tornado: 11%
- Wind: 9%
- Lightning: 8%
- Winter Storm: 7%

 Hurricane Katrina, August 2005

From CDC, USA

Centers for Disease Control and Prevention
Communicable Disease Center
One of the most severe extreme heat events in recent U.S. history occurred in July 1995 in Chicago. During this event, the extended increase in daily maximum temperatures (black line) as compared to the average for 1990-2000 (blue line) had an estimated result of more than 650 deaths.³
Although warming brings great challenges, there may be some benefits from it.
Northeast China: Important Base of Grain Production

1/5 of total production in China
Cultivated land area increases greatly in Northeast China

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>2010</th>
<th>%</th>
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<tbody>
<tr>
<td>Cultivated area</td>
<td>1623</td>
<td>2149</td>
<td>32.4%</td>
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(unit: hm², hectare)
Why the cultivated area increasing in Northeast China:

• China needs more crop product
• China’s policy
• More high-tech used
• … …
Northeast Asia experienced an extraordinary warming trend

Possible reason for more cultivated area in Northeast China

Zhu et al. (2012) GRL
Became warmer particularly since middle 1990s

Both maximum and minimum temperature increases

Summer becomes longer
~ 15 days

Summer day: Tmax > 25°C
Tropical Night: Tmin > 25°C
Temperature increase since mid-1990s, particularly over Europe and Northeast Asia

(Sutton and Dong, 2012; Stainforth et al., 2013; Chen and Lu, 2014; Dong et al., 2016; Dong et al., 2017)

P1: 1964-1996
P2: 1997-2016
Possible mechanism for regional warming

• Polar amplification: temperature increases more quickly in high latitudes of the northern hemisphere (Screen and Simmonds 2010, 32 Pithan and Mauritsen 2014, Xie et al 2015).

• Land warming greater than ocean warming (Sutton et al 2007, Dong et al 2009, Boer 2011, Joshi et al 2013).

• Drier land warming greater than wetter land warming (Zhou et al 2015, 2016).

Possible mechanism for regional warming

- Polar amplification: temperature increases more quickly in high latitudes of the northern hemisphere.
- Land warming greater than ocean warming
- Drier land warming greater than wetter land warming
Natural process

- High pressure
  - Down flow
  - Less cloud
  - More solar radiation

High temperature
The regional feature of Eurasian warming is similar to the temperature anomalies associated with the Silk Road Pattern.

Black bold lines represent the areas of Silk Road Pattern-related temperature.
A teleconnection along the jet (Sato and Takahashi, 2006; Yasui and Watanabe, 2010)

Silk Road Pattern (Lu et al. 2002)

Circumglobal Teleconnection (Ding and Wang, 2005)

EOF–V200 (Sato and Takahashi, 2006; Yasui and Watanabe, 2010)

Silk Road Pattern (Enomoto et al., 2003)
Summer Asian Jet

200-hPa zonal wind

Upper-tropospheric jet

U200: 20-40 m/s
Theory of jet waveguide

Wavelength is determined by basic flows

\[ K_s \approx 6, \quad \text{wavelength is } \sim 60 \text{ degrees} \]

\[
K_s = \left( \frac{a \beta M}{\bar{v}} \right)^{1/2}
\]

\[
= \left\{ \left[ 2 \Omega - \left( \frac{1}{\cos \phi} \frac{\partial}{\partial \phi} \right)^2 (\cos^2 \phi \bar{v}) \right] / \bar{v} \right\}^{1/2} \cos \phi
\]

(Hoskins and Ambrizzi, 1993)
SRP affects the northern hemisphere climate

- **Surface air temperatures** (Enomoto 2004; Wakabayashi and Kawamura 2004; Ding and Wang 2005; Sato and Takahashi 2006; Ding et al. 2011; Zhang and Jin 2016)

- **Rainfall** (Lu et al. 2002; Tao and Wei 2006; Huang et al. 2011; Chen and Huang 2012; Ding et al. 2013; Saeed et al. 2014; Su and Lu 2014; Zhang and Jin 2016)

- ......

![Map](Chen and Huang 2012)
Silk Road Pattern (SRPI)

Normalized PC1 of the V200-EOF within (20°-60°N, 0°-150°E)

SRPI > 0, a positive phase SRP
SRPI shows a strong decadal change, explaining 29.6% of total variance.
After removing SRP, the warming tends to be uniform.
AMO concurs with the decadal change in SRP

Silk Road Pattern

AMO

AMO concurs with the decadal change in SRP
AMO: Atlantic Multidecadal Oscillation

From Sutton et al. Science 2005
Fig. 7. Regressions of surface temperature onto the standardized AMO index: (a–d) CRU (for land temperature) and HadISST (for SST); (e–h) GISS. Black dots indicate statistical significance at the >95% confidence level, based on the t-test. Units: °C.
AMO concurs with the decadal change in SRP
We hypothesize that the AMO can affect circulations over Europe and then modulate the decadal change in SRP.

Watanabe 2004; Goswami et al. 2006
Summary

- The summer warming is amplified after the mid-1990s over Europe-West Asia and Northeast Asia.
- AMO induces this warming pattern by modulating the Silk Road Pattern—a dominant teleconnection pattern over the Eurasian continent in summer.
- The SRP exhibits a strong decadal variability, explaining about 30% of the total variance.