Spatial and Temporal Characteristics of Satellite-derived Clear-sky Atmospheric Temperature Inversion Strength in Arctic cold season, 1980-1996

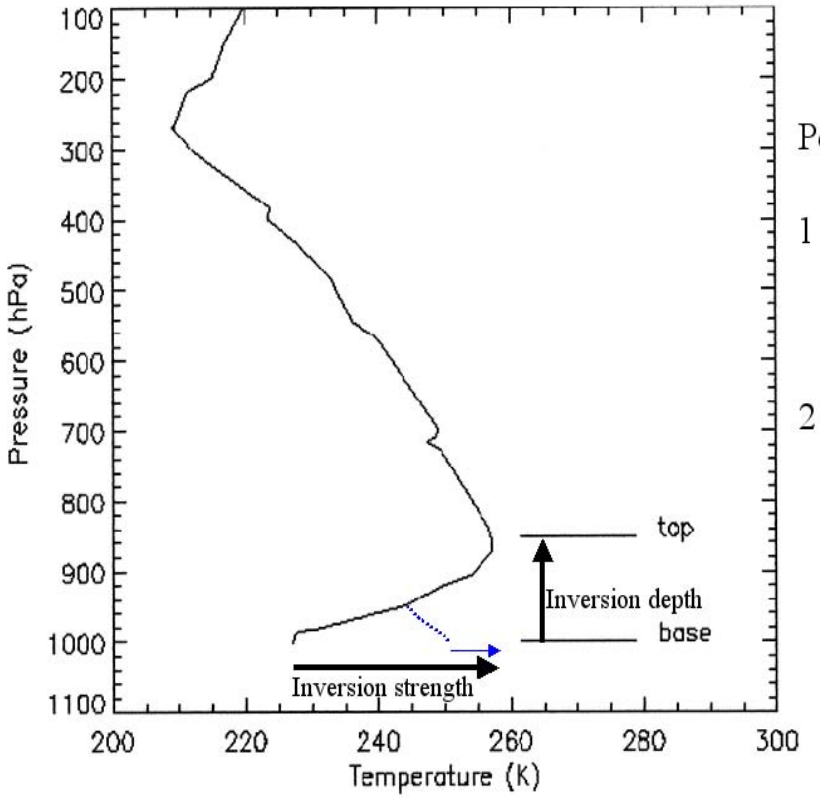
Yinghui Liu[1], Jeffrey R. Key[2], Axel Schweiger[3], Jennifer Francis[4]

[1]CIMSS, AOS, University of Wisconsin-Madison
[2]Office of Research and Applications, NOAA/NESDIS
[3]Polar Science Center, University of Washington, Seattle, Washington
[4]Rutgers University, NewBrunswick, New Jersey

Outline

- What is temperature inversion
- Motivation and goal
- Data
- Theoretical basis and method
- Results
- Summary

What is temperature inversion?



Temperature profile measured at Verhojansk, Russia, 1200 UTC 3 Dec 2001. Temperature inversion top and base are indicated.

Polar Inversion Classification:

1 Surface Invesions
- a. Radiation invesions
- b.Melting inversions

2 Lifted Inversions
- a. Horizontal advection inversion
- b.Subsidence inversion

Motivation and Goal

Understanding polar temperature inversions is important:

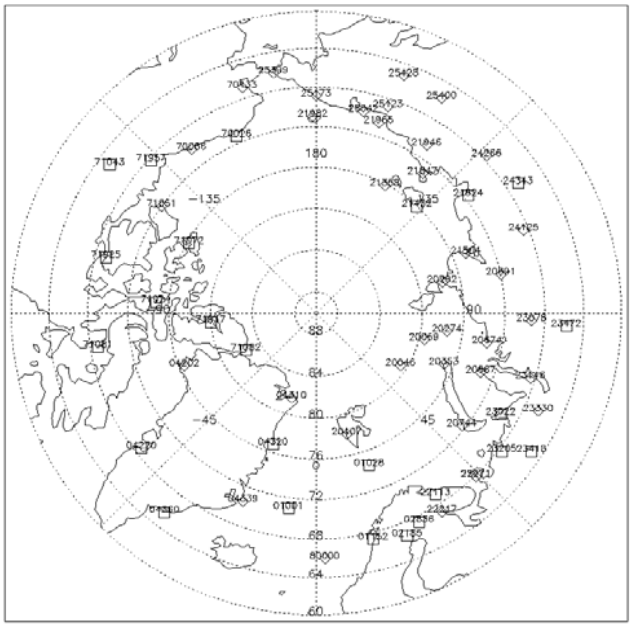
1. Inversions cover large areas in polar region, and are persistent all year

2. Temperature inversions affect heat and moisture fluxes, pollution gases and aerosol transport, surface wind velocity and lead formation; the inversion characteristics is needed to simulate the movement of sea ice

3. Arctic is a key region to understand the current and to predict the future climate change; the decreasing trend of inversion strength is expected, but not found in the conventional data from 1950-1990.

4. Conventional observation can not cover the whole Polar Regions, and with low temporal resolution. Satellite provides a way to retrieve the inversions with high spatial and temporal resolution, which makes the study of inversion change study possible.

Data

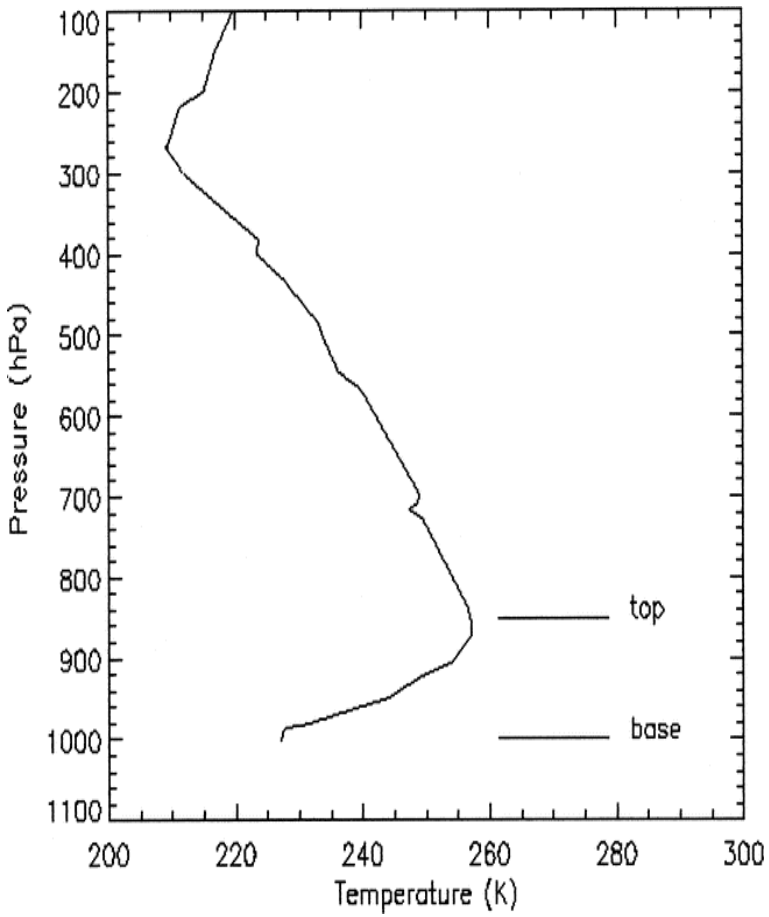


Radiosonde data from 1980 to 1996 from 61 stations in Arctic

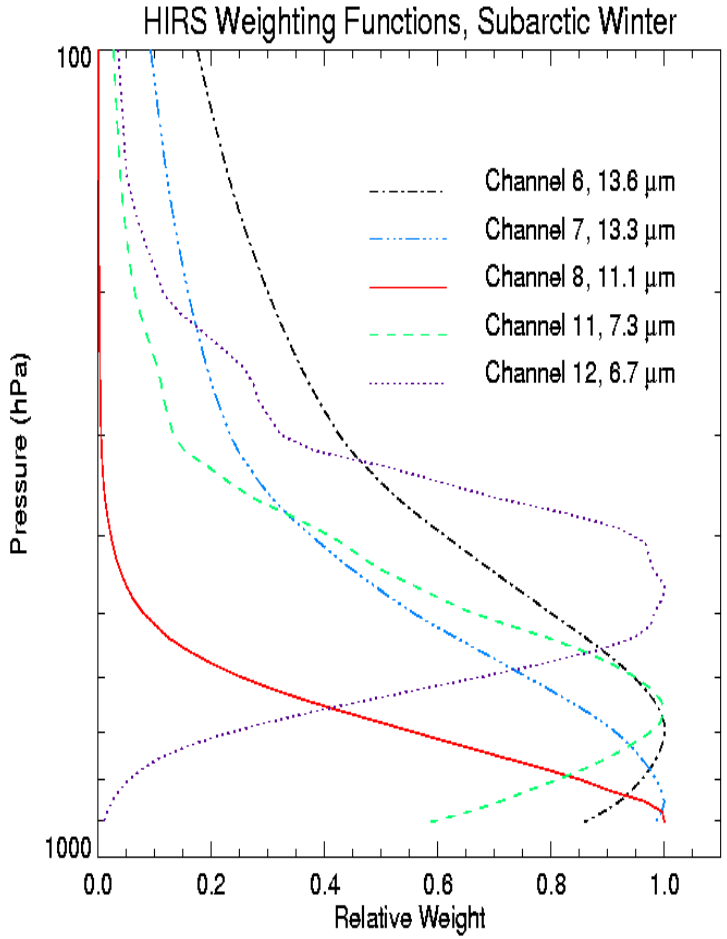
- The satellite-derived, surface skin temperature, temperature profile with spatial resolution of 100 km x 100 km at 13 pressure levels (10, 30, 50, 70, 100, 300, 400, 500, 600, 700, 850, 900, 1000 hPa) from TOVS Polar Pathfinder (Path-P) dataset. The inversion strength from this profile is called profile inversion strength.

TIROS-N Operational Vertical Sounder (TOVS) brightness temperatures (BT) at 7.3 μm and 11 μm from 1980 to 1996. NOAA-6 (1979-1982), NOAA-7 (1983-1984), NOAA-9 (1985-1986), NOAA-10(1987-1991), NOAA-11(1992-1994), NOAA-12(1995-1996), data are used.

Theoretical basis and method

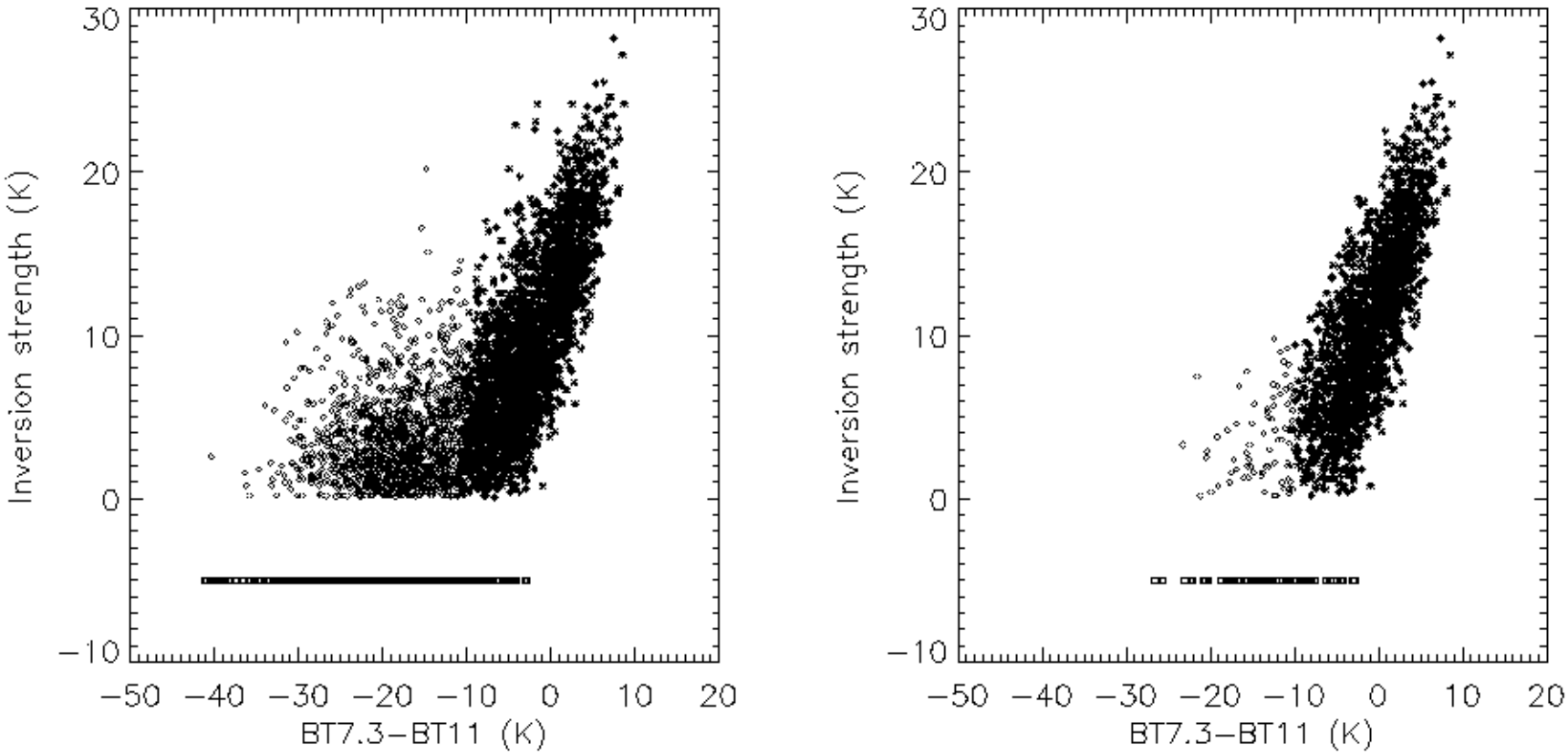


Temperature profile measured at Verhojansk, Russia, 1200 UTC 3 Dec 2001. Temperature inversion top and base are indicated.



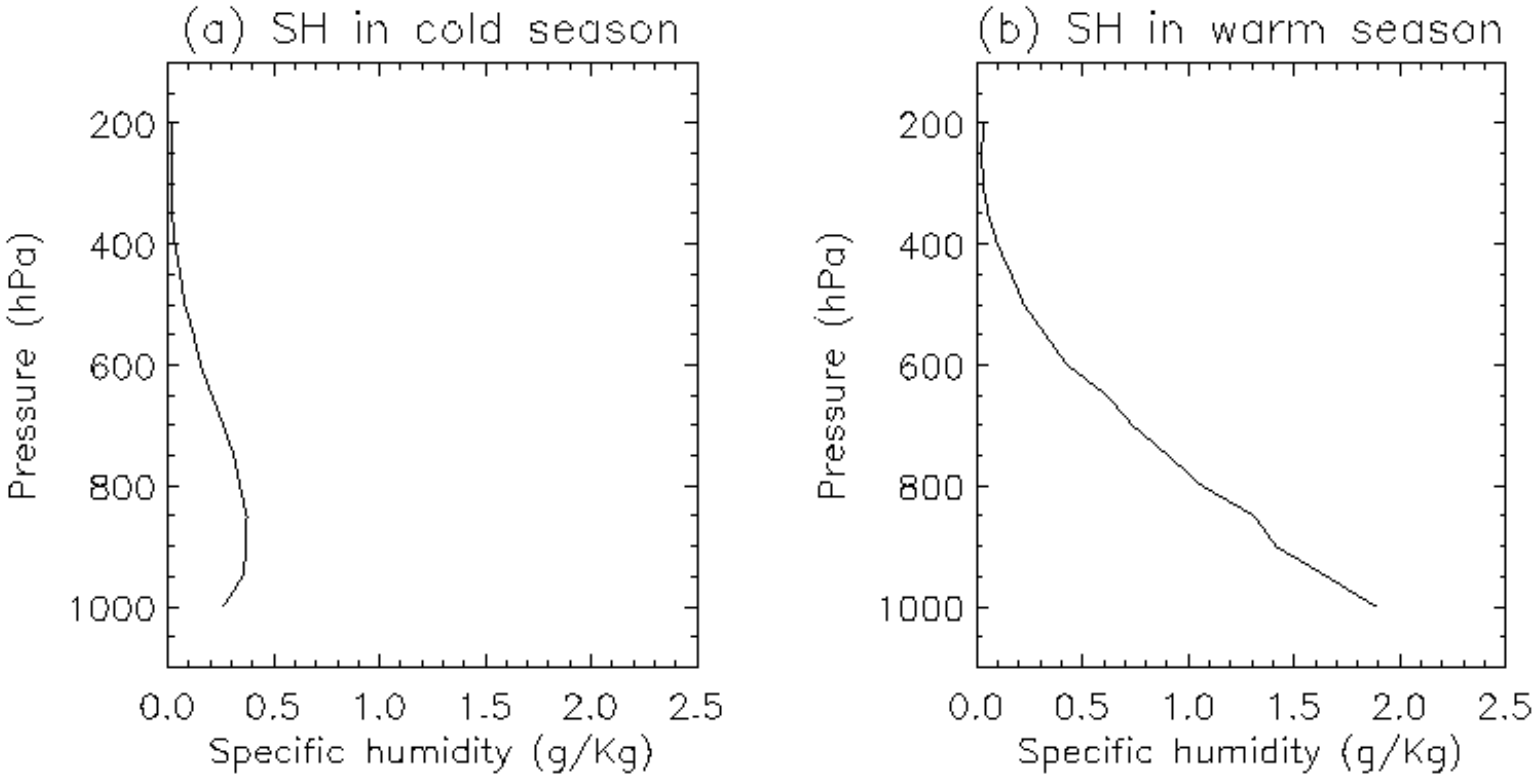
Weighting function for 6.7 µm, 7.3 µm, 11 µm, 13.3 µm, and 13.6 µm channels using a subarctic winter standard atmosphere profile.

Theoretical basis and method



Relationship between inversion strength and $BT_{7.3}$-BT_{11} for (a) all seasons, and (b) for cold season. The square represents the cases without temperature inversion. The diamond represents the case with $BT_{7.3}$-BT_{11} less than –10 K. The star represents the case with $BT_{7.3}$-BT_{11} larger than –10 K.

Theoretical basis and method



The composite Specific Humidity (SH) profiles for (a) cold season, and (b) in warm season.

Theoretical basis and method

The inversion strength and depth can be retrieved using Brightness temperatures at different channels.

$$INVST = a_0 + a_1 * BT_{11} + a_2 * (BT_{7.3} - BT_{11}) + a_3 * (BT_{7.3} - BT_{11})^2$$

This inversion strength is called 2-channel inversion strength.

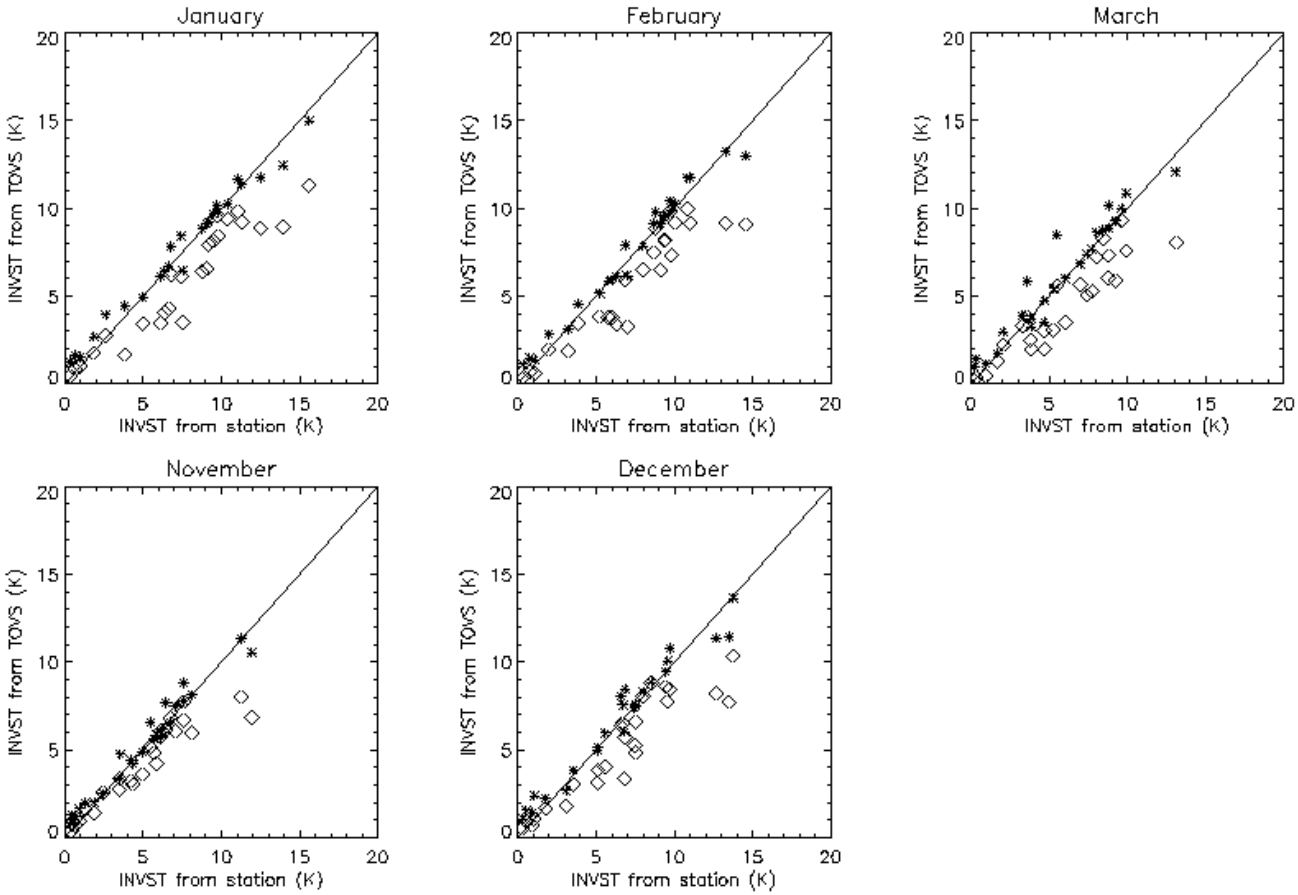
Advantage:

Temperature inversion strength and depth can be derived using simple statistical equations.

Disadvantage:

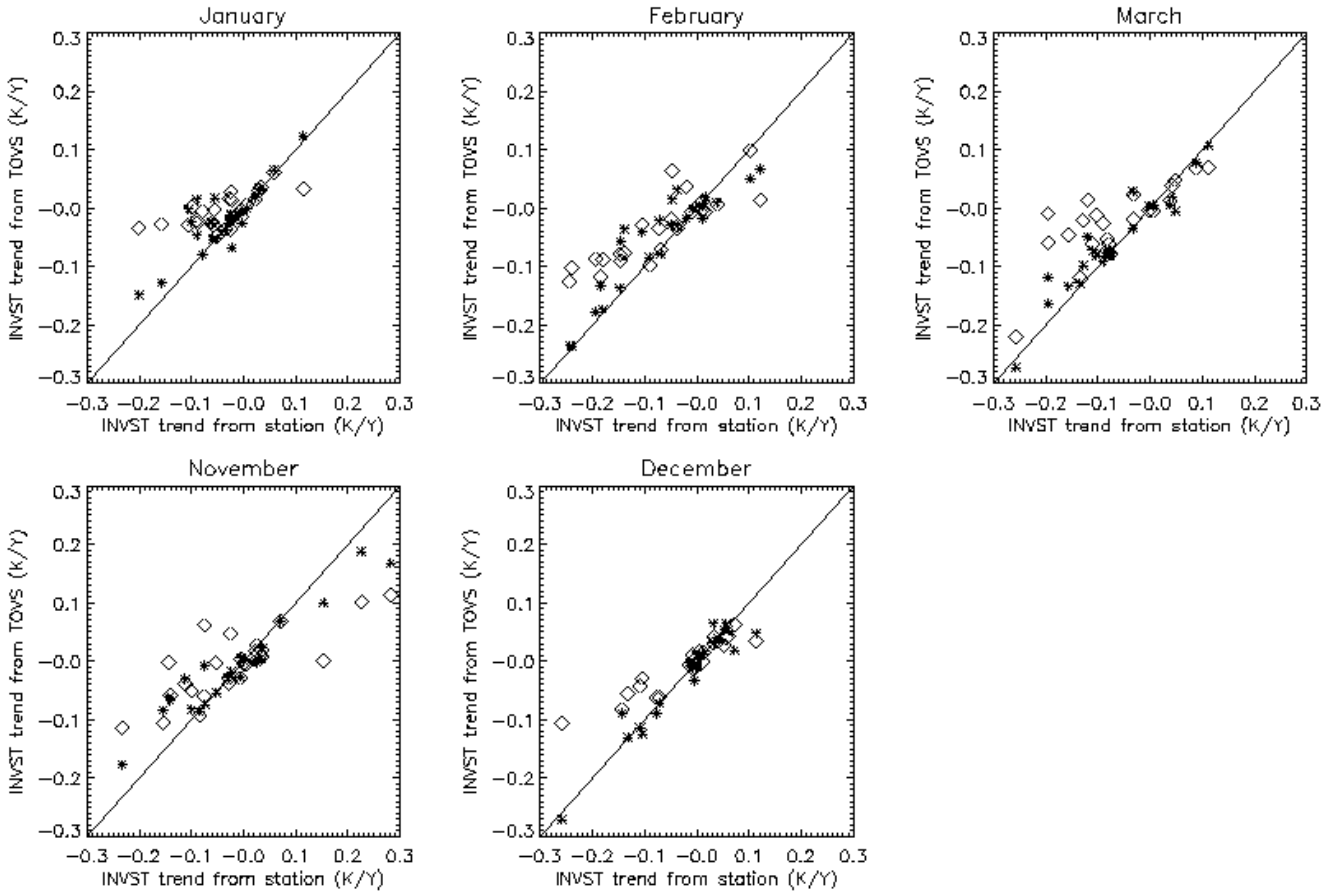
Only for clear sky and cold season.

Validation – monthly mean



Comparison of monthly mean Inversion Strength (INVST) from weather stations, and from TOVS data in November, and December, January, February, and March over 1980-1996. The star symbols represent the results from the 2-channel statistical method. The diamond symbols represent the results from the TOVS retrieved temperature profiles.

Validation - trend



Comparison of Inversion Strength (INVST) trends from weather stations and from TOVS data in November, and December, January, February, and March over 1980-1996. The star symbols represent the results from the 2-channel statistical method. The diamond symbols represent the results from the TOVS retrieved temperature profiles.

Results

- Monthly mean 2-channel inversion strength and trend during 1980 to 1996; Monthly mean profile inversion strength and trend during 1980 to 1996; and comparisons between these two.

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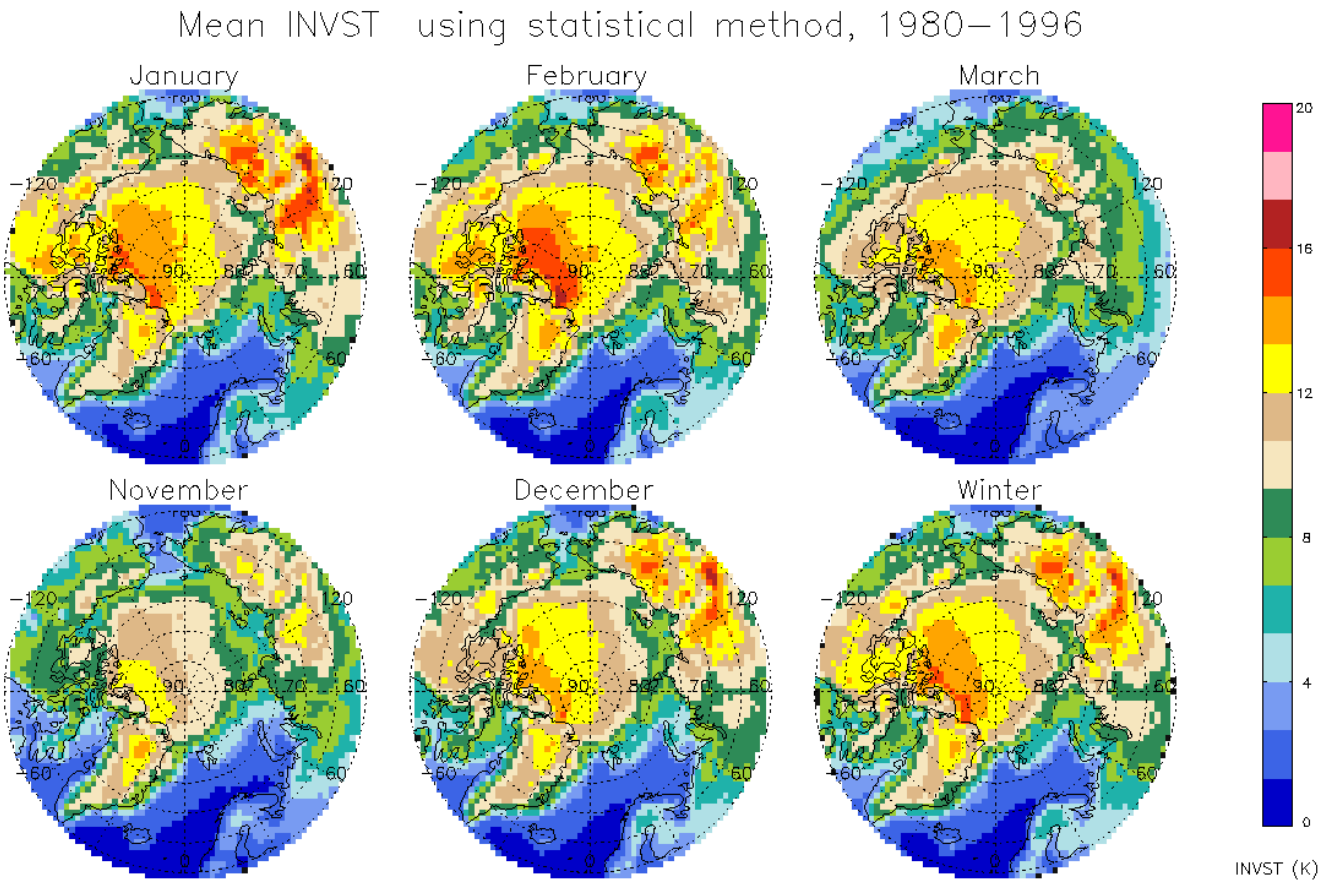
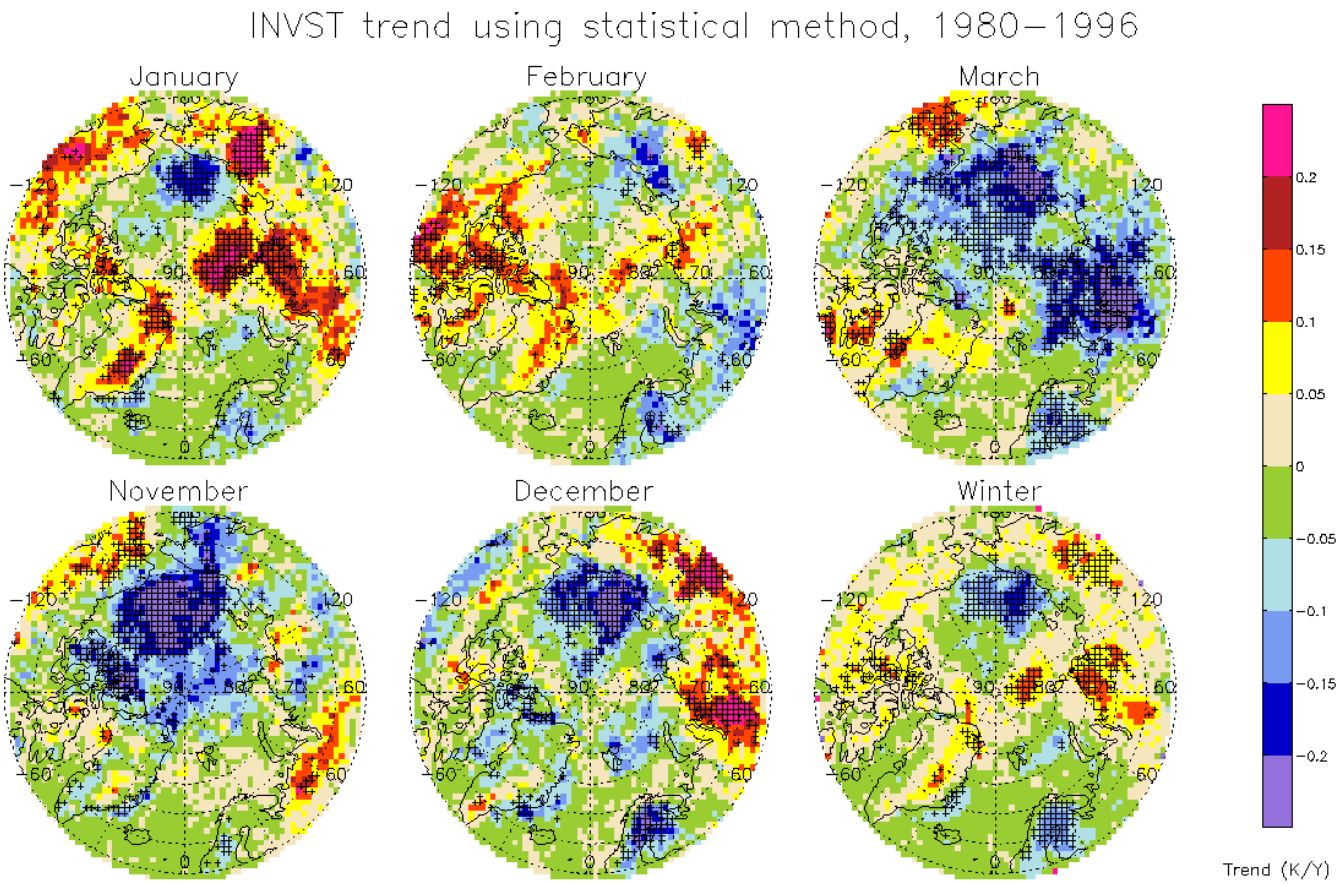
- The relationship between inversion strength trend and surface temperature trend from 1980 to 1996; relationship between inversion strength monthly mean anomalies and AO monthly mean anomalies.

Results – 2-channel monthly mean



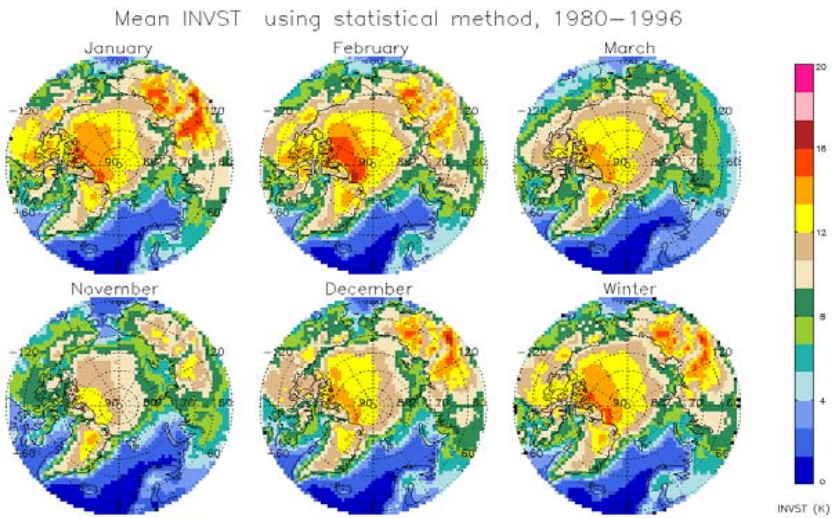
Monthly mean clear-sky inversion strength (K) in January, February, March, November, December, and winter (DJF) over 1980-1996 using 2-channel statistical method.

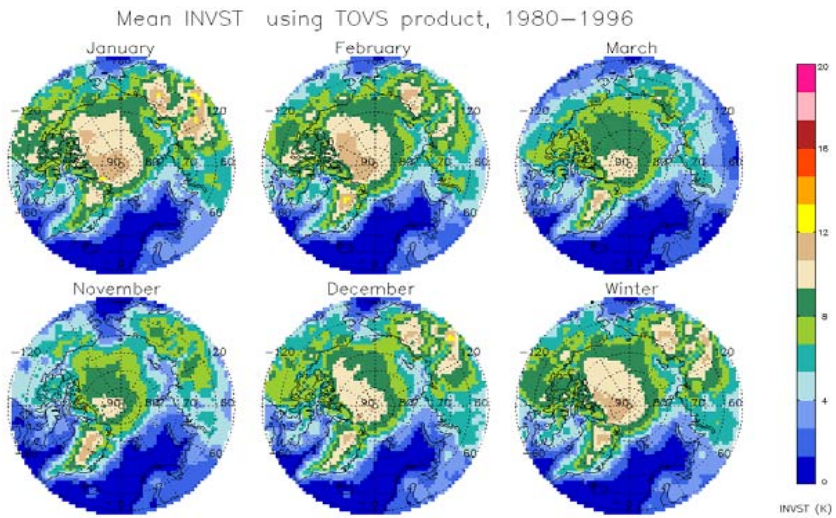
Results – 2-channel trend

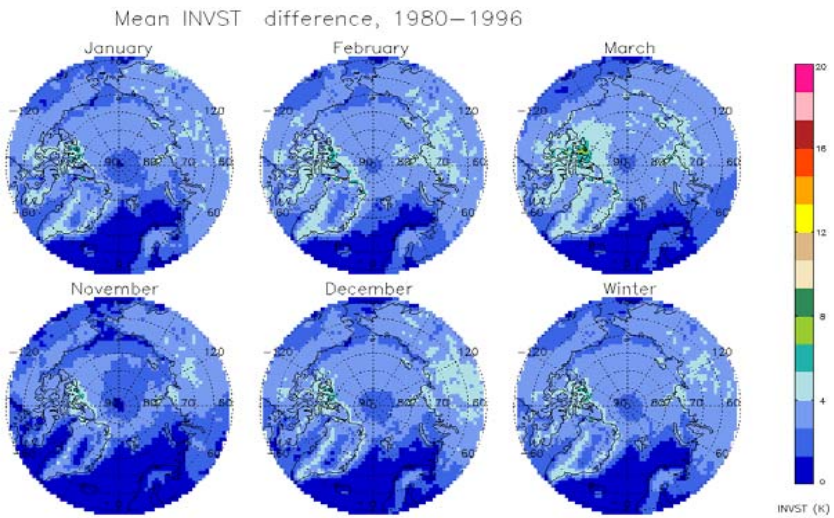


Monthly trend of clear-sky inversion strength (K/Year) in January, February, March, November, December, and winter (DJF) over 1980-1996 using 2-channel statistical method. The trend with confidence level larger than 90% based on F test is labeled with +.

Results – monthly mean comparison

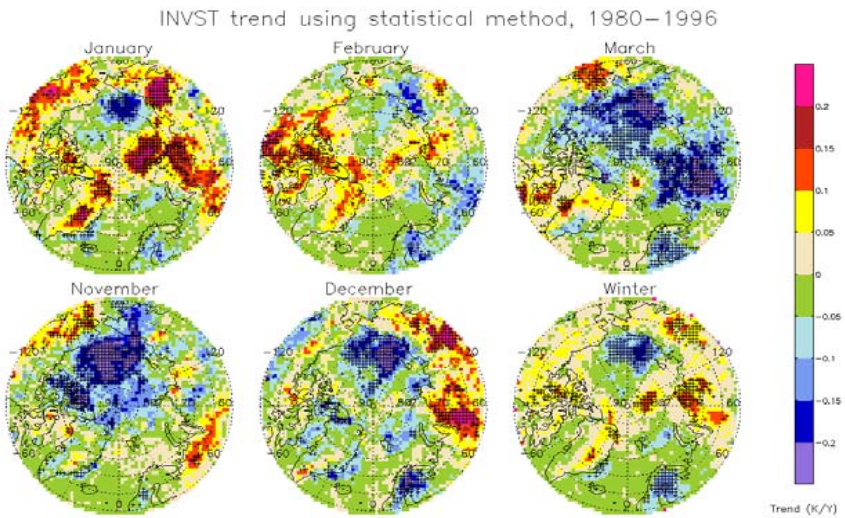


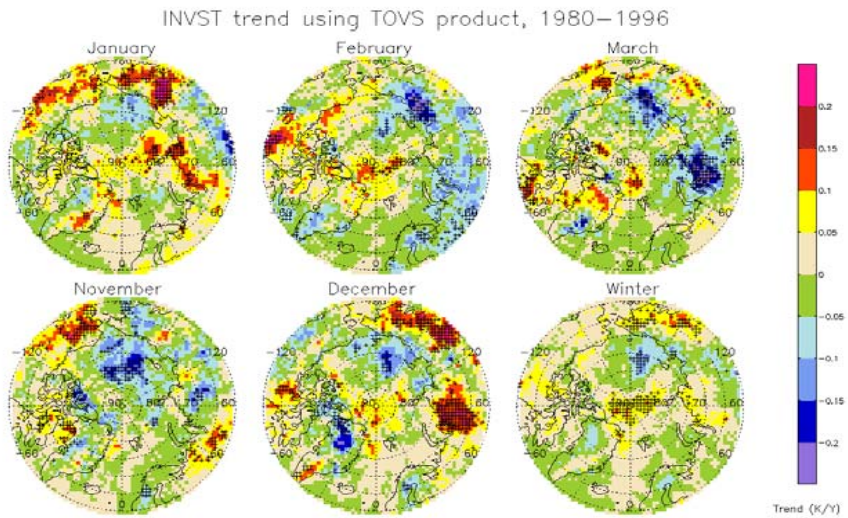


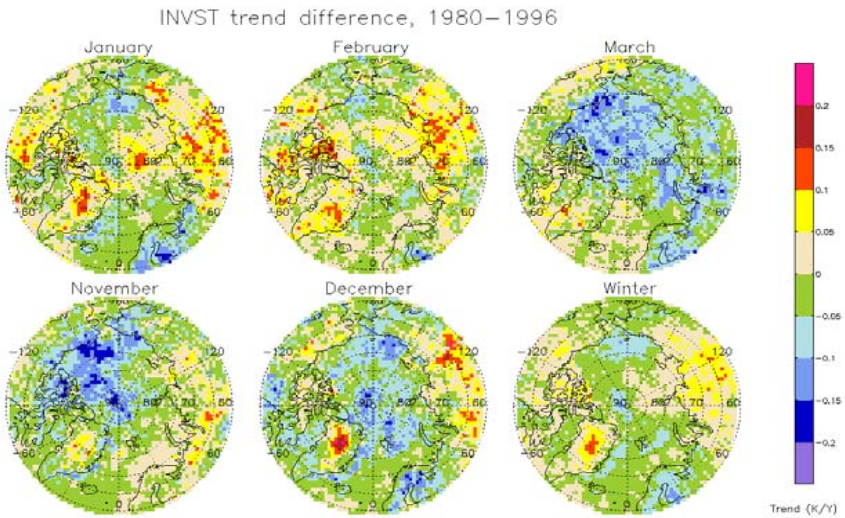


Both 2-channel and profile monthly mean inversion strengths have similar spatial distribution, but the latter has smaller magnitude

Results – trend comparison

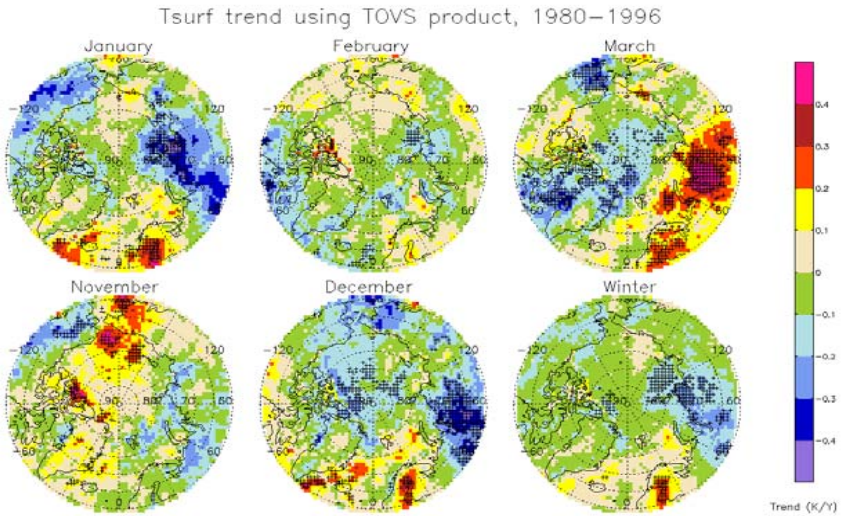


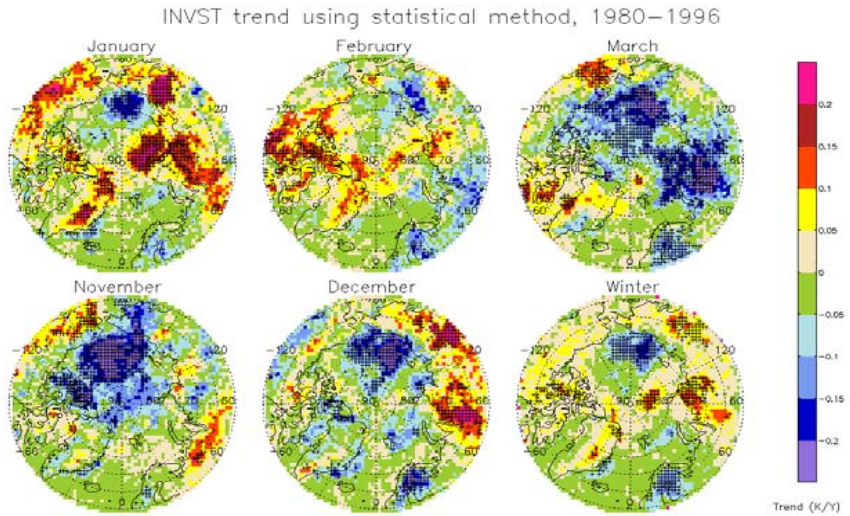




Both 2-channel and profile inversion strength trends have similar spatial distribution, but the latter has smaller magnitude and lower confidence level

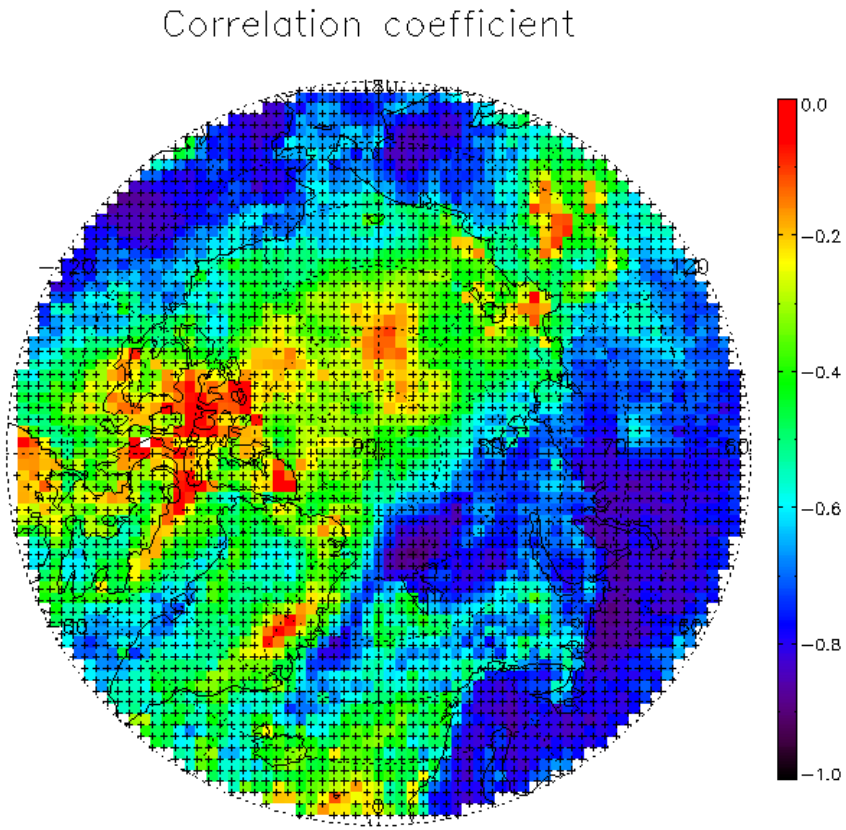
Results – discussion





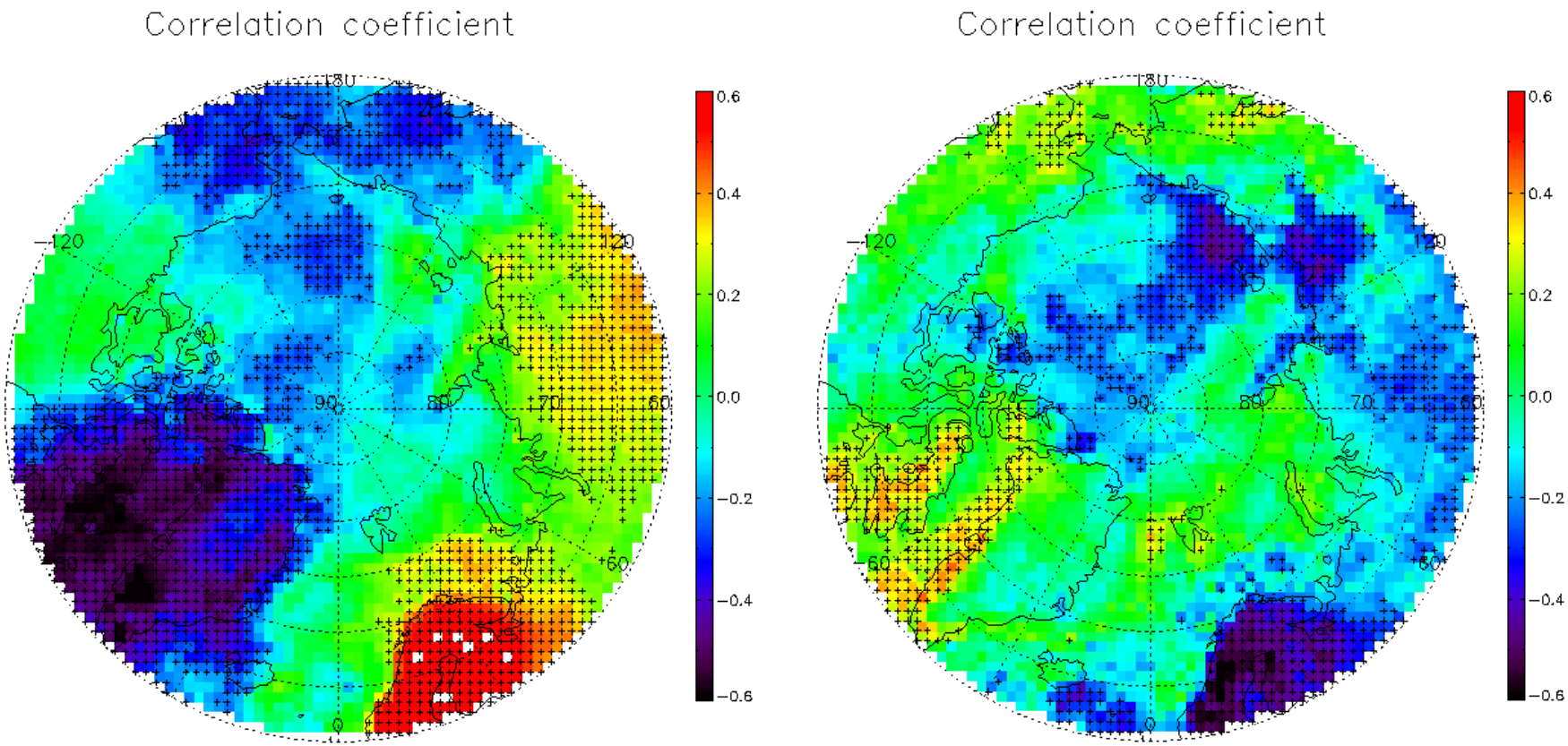
The comparison of the inversion strength trend and the surface skin temperature trend.

Results – discussion



Correlation coefficient between the monthly mean surface skin temperature anomalies and monthly mean 2-channel statistical inversion strength anomalies during 1980 to 1996. The correlation coefficient with confidence level larger than 95% based on F test is labeled with +.

Results – discussion



Correlation coefficient between the monthly AO index anomalies and the monthly mean surface skin temperature anomalies (left), and between the monthly AO index anomalies and monthly mean 2-channel statistical inversion strength anomalies (right) during 1980 to 1996. The correlation coefficient with confidence level larger than 95% based on F test is labeled with +.

Summary

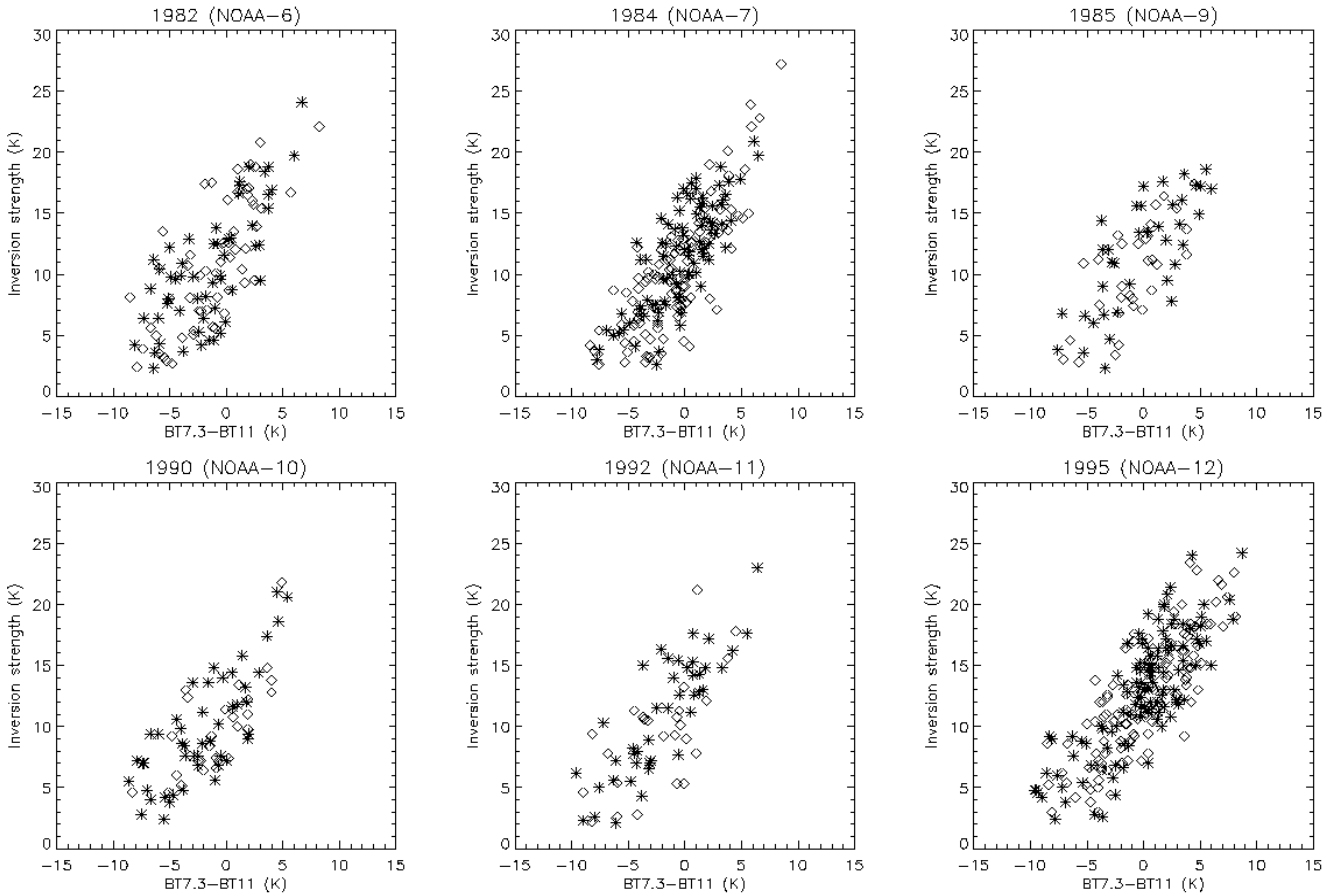
- Inversion strength can be retrieved using a simple statistical equation in Arctic in cold season.

- Both 2-channel and profile monthly mean inversion strength has similar spatial distributions, but the latter has smaller magnitude. Both 2-channel and profile inversion strength trends have similar spatial distribution, but the latter has smaller magnitude and lower confidence level.

- . In the cold season, there is significant decreasing trend of inversion strength over Chukchi Sea, part of Beaufort Sea and Laptev Sea. There is increasing trend in winter season over Alaska Region, over Northeastern Russia and North Canada, over North Central Russia.

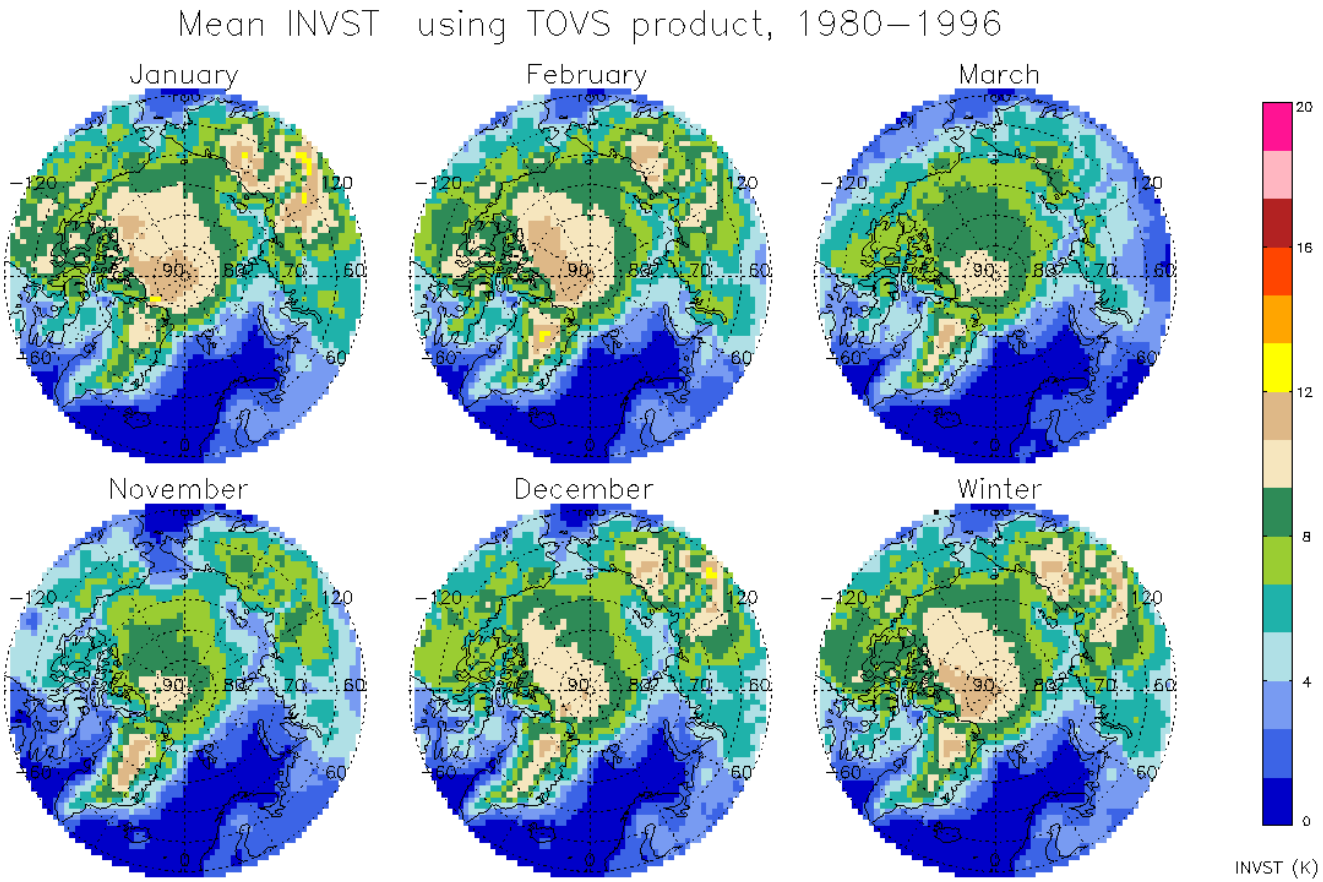
- Inversion strength trend is closely related to surface temperature trend, and also is related to AO trend.

Data & Theoretical basis and method



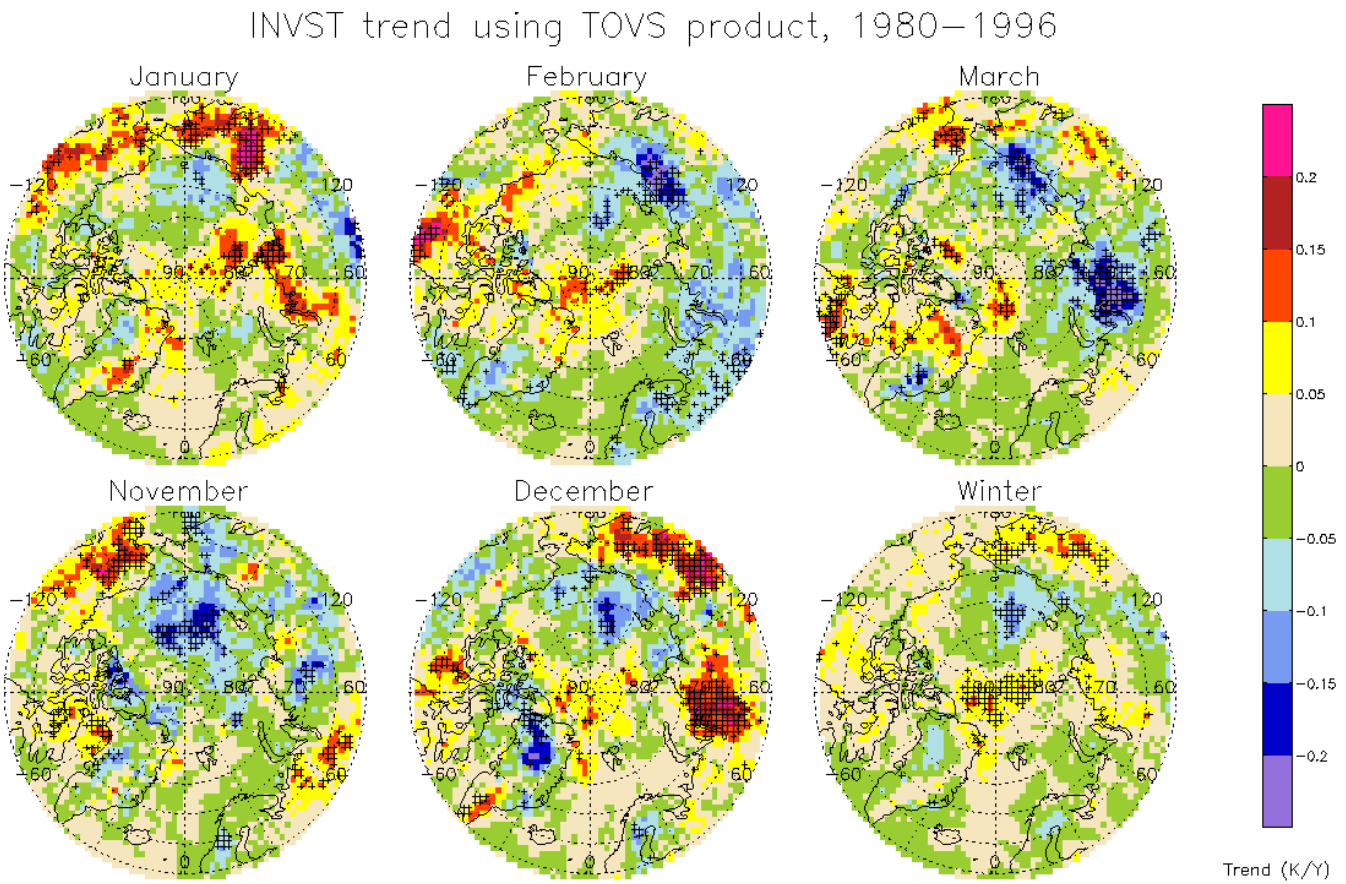
Relationship between inversion strength and $BT_{7.3}$-BT_{11} for different years and NOAA satellites.

Results – profile monthly mean



Monthly mean clear-sky inversion strength (K) in January, February, November, December, March, and winter (DJF) over 1980-1996 from TOVS retrieved temperature profiles.

Results – profile trend



Monthly trend of clear-sky inversion strength (K/Year) in January, February, November, December, March, and winter (DJF) over 1980-1996 from TOVS retrieved temperature profiles. The trend with confidence level larger than 90% based on F test is labeled with +.

Inversion strength climatology
Liu, Key, Schweiger, and Francis May 26, 2005