Climatology, Variability and Change in Polar Planetary Boundary Layers

Dian Seidel[1], Yehui (Ally) Zhang[1], Clara Deser[2], Chris Golaz[3], Bob Tomas[1]

[1]NOA A Air Resources Lab, Silver Spring, Maryland [2]NCAR Climate and Global Dynamics Division. Boulder, Colorado [3]NOAA Geophysical Fluid Dynamics Lab, Princeton, New Jersey

Goals

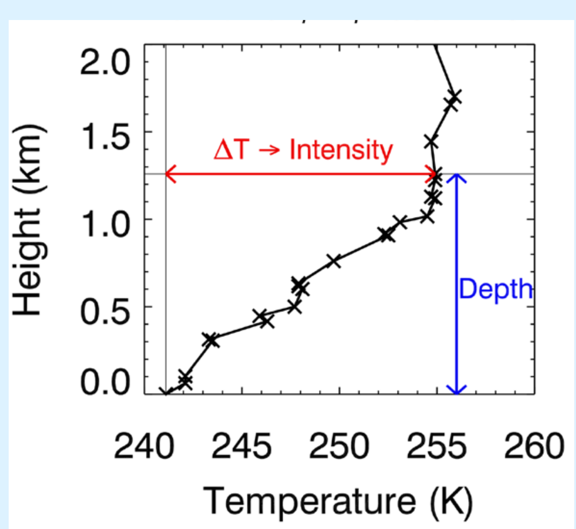
- Understand the climatology and variability of the polar planetary boundary layer (PBL) and its relation to other aspects of polar climate
- Focus on surface-based inversions (SBI), a common feature of the wintertime polar PBL
- Evaluate suitability of available datasets for studies of PBL climatology and trends
- Quantify uncertainty in climatological statistics
- Evaluate the simulation of SBIs in climate models
- Analyze long-term SBI trends

Data

Type	Name	Period	Horizontal Resolution	Vertical Resolution (# levels p≤500 hPa)
Radiosonde	Integrated Global Radiosonde Archive	1990-2009	113 Arctic 19 Antarctic stations	10-30
Climate Models	GFDL AM3	1990-2007	2˚lat × 2.5˚lon	15
	NCAR CAM3		~ 1.4˚ lat & lon	8
Reanalysis	ERA-Interim	1990-2009	1.5˚lat & lon	16

- Radiosonde, model simulations, and reanalysis data all processed identically
- Monthly, seasonal, annual climatological statistics computed from individual profiles
- Separate analyses for 0000 and 1200 UTC
- 20-yr anomaly time series. All data tested for possible inhomogeneities.

Surface-Based Inversions (SBIs)



SBIs are a relatively simple type of PBL structure, common in polar regions.

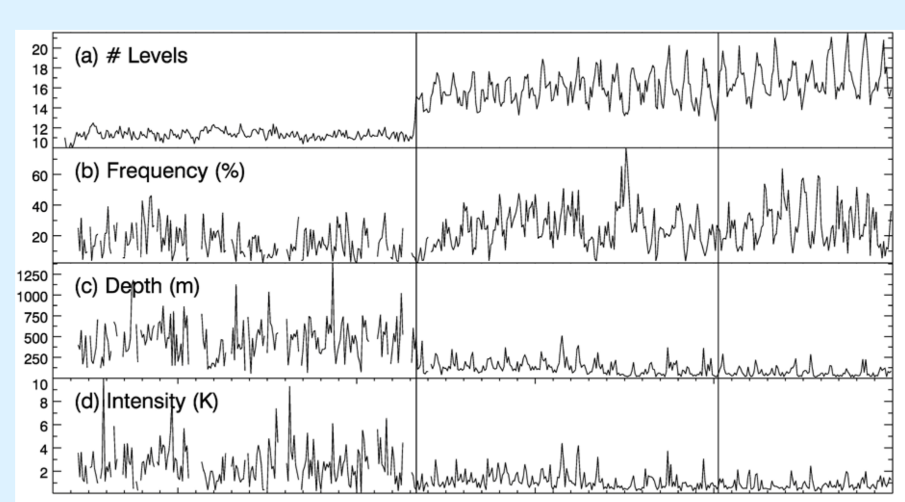
SBI climatology is described with three parameters:

- Frequency of occurrence
- Depth (distance from surface to SBI top)
- Intensity (temperature difference: SBI top minus surface)

Left: SBI in radiosounding at Alert, Canada (82°N, 62°W) 1200 UTC 14 February 2009

Inhomogeneity of Radiosonde Observations

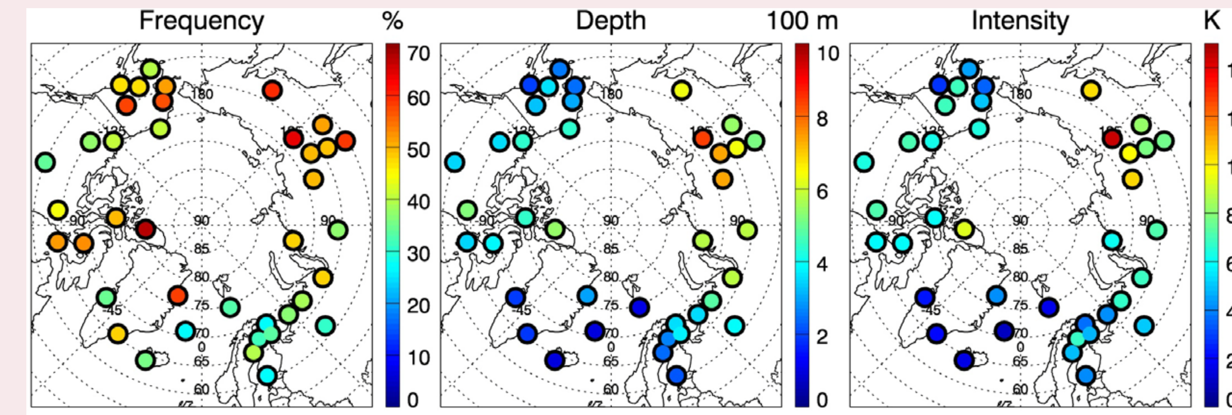
Changes in observational methods, particularly those affecting radiosonde vertical resolution, introduce artificial changes in representations of SBIs.



Right: Increases in the number of data levels affects estimates of monthly mean climatological SBI properties at Jan Mayen, Norway (71°N, 9°W).

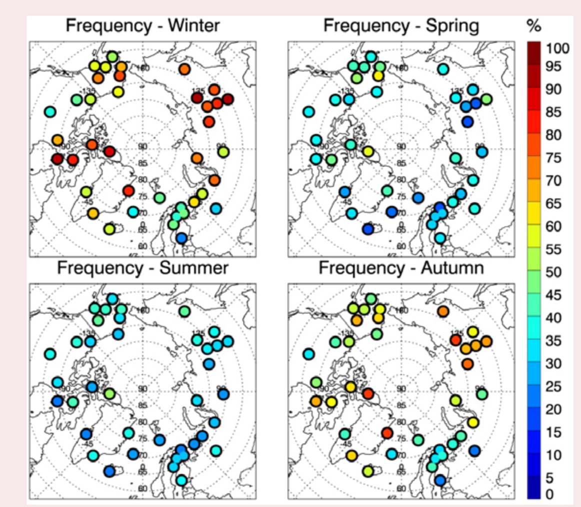
SBI intensity and depth data are very sensitive to this problem.
Frequency of SBI occurrence is more robust.
Only 39 of 113 Arctic (and 6 of 19 Antarctic) stations have homogeneous records for 1990-2009.

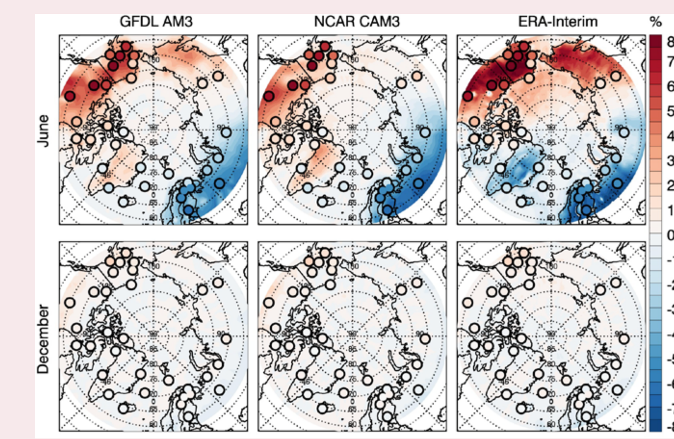
Arctic Surface-Based Inversion Climatology



20-Yr Climatological Means

Median Station Values:
Frequency: 46%
Depth: 356 m
Intensity: 6.1 K





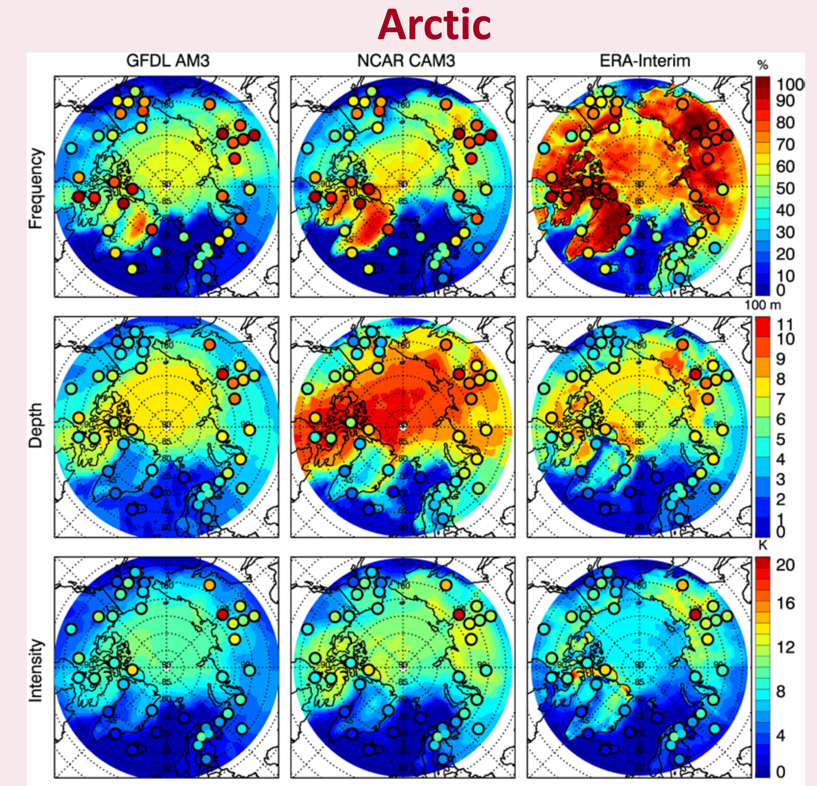
Seasonal Variations: SBIs are more frequent in winter and autumn.

"Diurnal" Variations:
Maps show 1200 minus 0000 UTC SBI frequency difference. In Arctic summer, but not in winter, diurnal changes in solar elevations angles influence SBI formation.
Climate models and ERA-Interim capture this variability.

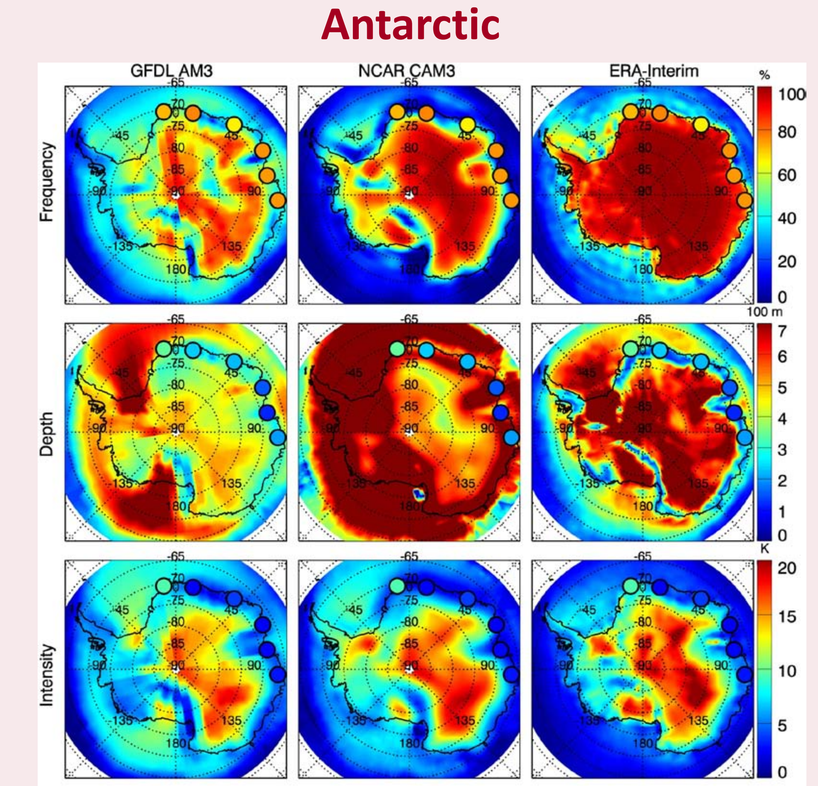
Comparison of Observations with 2 Climate Model Simulations and ERA-Interim Reanalysis

Winter Climatological SBI Frequency, Depth and Intensity

Arctic



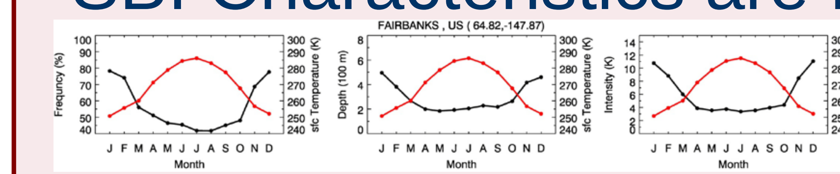
Antarctic



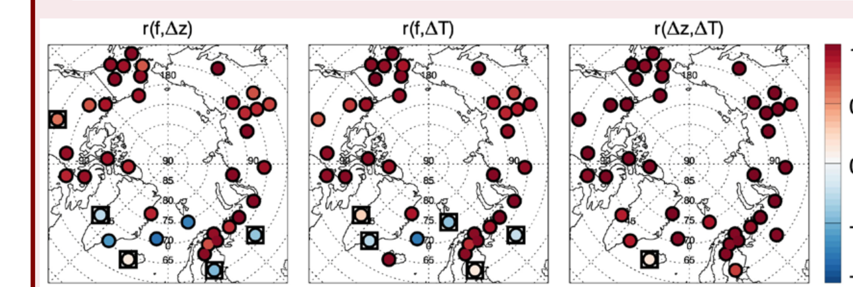
- Climate models capture basic spatial patterns of observations, including seasonal variations (not shown), but underestimate SBI frequency.
- GFDL model, with lower vertical resolution, simulates lower SBI depths than NCAR model.
- The reanalysis more accurately reproduces observations.
- No radiosonde data over Arctic ocean.

- Large differences among models and reanalysis.
- Large simulated gradients between Antarctic continent and Southern Ocean.
- Few Antarctic radiosonde stations, and all are along the coast, so evaluation of simulations is very uncertain.

SBI Characteristics are Positively Correlated

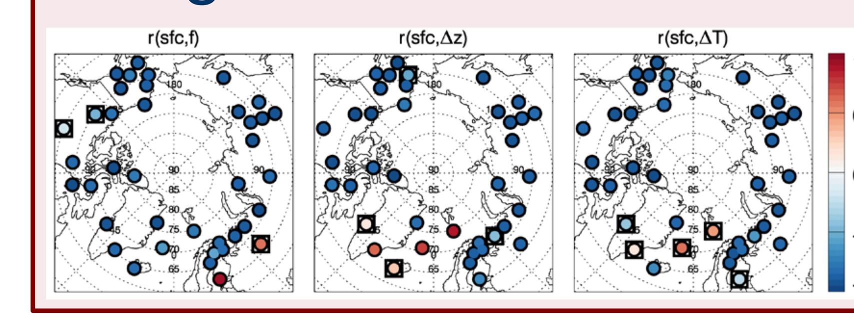


Similar Seasonal Variations of SBI Frequency, Depth, and Intensity



Top: Seasonal cycles at Fairbanks, Alaska.
Bottom: Correlation of mean monthly values at all Arctic stations. Interannual anomalies (not shown) are also positively correlated.

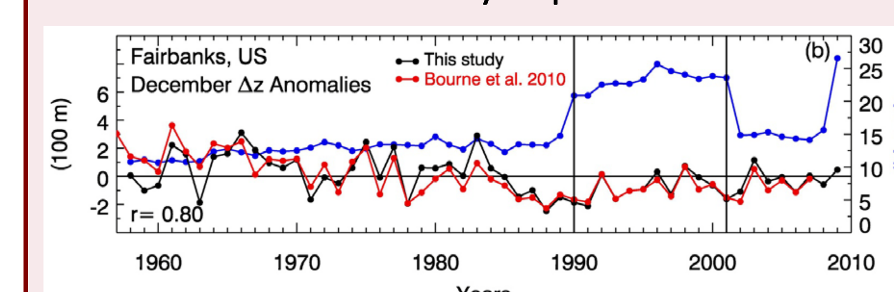
Negative Correlations with Surface Temperature



Lower surface temperature in winter is associated with more frequent, more intense, and deeper SBIs.
Interannual variations show similar (but weaker) negative correlations.

Trends in Arctic SBIs

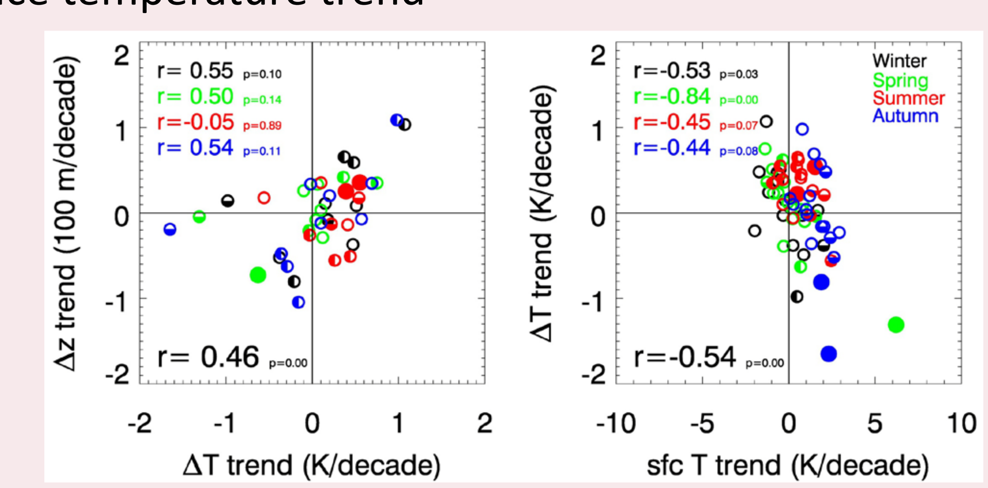
Radiosonde data inhomogeneity severely limits the value of the archive for SBI trend estimates. Previously reported trends Arctic SBI trends are likely to be erroneous.



Left: Bourne et al. (Atmos. Res. 2010) reported decrease in SBI depth, but it was likely due to the 1990 increase in sounding vertical resolution.

Seasonal 1990-2009 SBI trends at Arctic stations with homogeneous records show:

- Few clear patterns
- SBI depth increases at Alaskan stations, decreases in Canada and Europe
- SBI frequency increases in Greenland over the decade 2000-2009
- SBI intensity trend is positively correlated with depth trend, negatively correlated with the surface temperature trend



Publications

Zhang, Y., D.J. Seidel, J.-C. Golaz, C. Deser, and R.A. Thomas, 2011: **Climatological Characteristics of Arctic and Antarctic surface-based inversions** *J. Climate*, 2011,doi: 10.1175/2011JCLI4004.1.

Zhang, Y., and D.J. Seidel, 2011: **Challenges in estimating trends in Arctic surface-based inversions from radiosonde data**, *Geophys. Res. Lett.*, 38, doi:10.1029/2011GL048728.

Presented at World Climate Research Program ~ Open Science Conference
24-28 October 2011 Denver, Colorado