Climatology, Variability and Change In Arctic Surface-Based Inversions

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Key Points

- Little prior study of large-scale planetary boundary layer climatology
- Arctic surface-based inversions (SBI) are common, especially in autumn and winter
- SBI characteristics are sensitive to vertical resolution
- 2 climate models and ERA-Interim simulate radiosonde-observed seasonal and spatial SBI patterns, but with biases
- Detecting multi-decadal SBI trends is challenging

Motivation and Context

- Planetary boundary layer controls many climate processes
- Little evaluation of PBL representation in climate models
- Overall aim – characterize global PBL climatology
  - **Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis.**

    Seidel, D. J., C. O. Ao, and K. Li, JGR (2010)
  - **Climatological characteristics of Arctic and Antarctic surface-based inversions.**
    Zhang, Y., D. J. Seidel, J.-C. Golaz, C. Deser, R. A. Tomas, J. Climate (2011)
  - **Challenges in estimating trends in Arctic surface-based inversions from radiosonde data.**
    Zhang, Y., and D. J. Seidel, GRL (2011)
  - **Climatological variations in planetary boundary layer mixing heights over the continental United States and Europe.**

    Seidel, D. J., Y. Zhang, A. Beljaars, J.-C. Golaz, A. Jacobson, B. Medeiros, S. Park, submitted to JGR

Complex planetary boundary layer structures

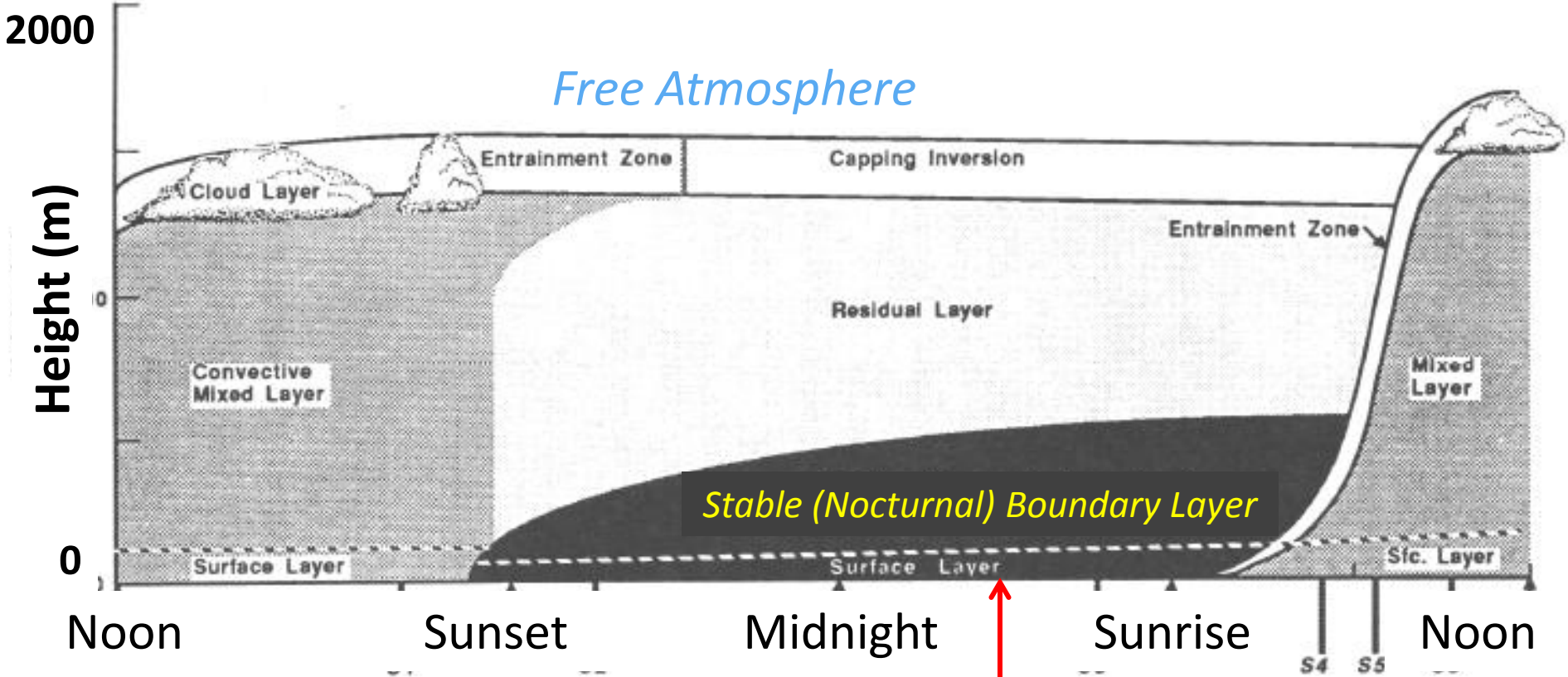


Figure from Stull (1988)

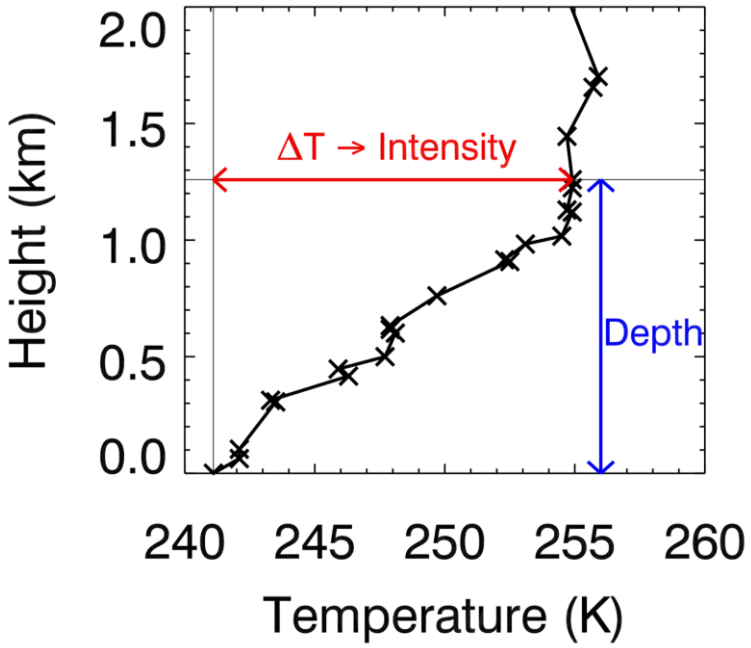
Surface-Based Inversion (SBI)

Data

Type	Name	Period	Horizontal Resolution	Vertical Resolution (# levels <500 mb)
Radiosonde	IGRA*	1990-2009	113 Arctic stations [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

* NOAA/NCDC Integrated Global Radiosonde Archive (Durre and Yin, 2008)

Surface-Based Inversions (SBI)

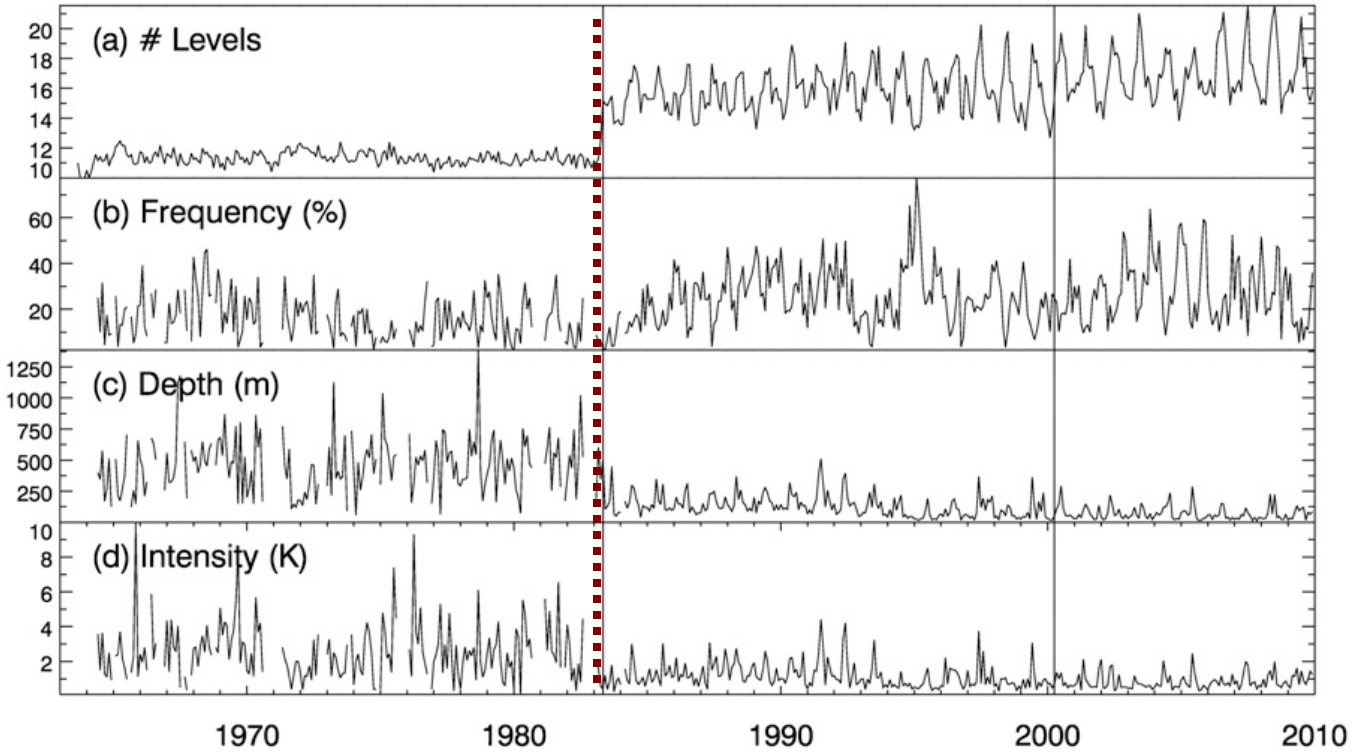


- We computed 3 SBI parameters:
  - Frequency → f
  - Depth → Δz
  - Intensity → ΔT
- We examined:
  - Seasonal Variations (focus on winter)
  - Spatial Variations (focus on Arctic)
  - (Differences Between 12 and 00 UTC)
  - Obs/Model Differences
  - Possibility of Detecting Trends

Example: Alert, Canada (82N, 62W)
1200 UTC 14 February 2009

Embedded non-inversion layers < 100 m allowed

Sounding Resolution Affects SBI Characteristics



1983 Changes In Average Values

11 → 16 levels

16 → 25 %

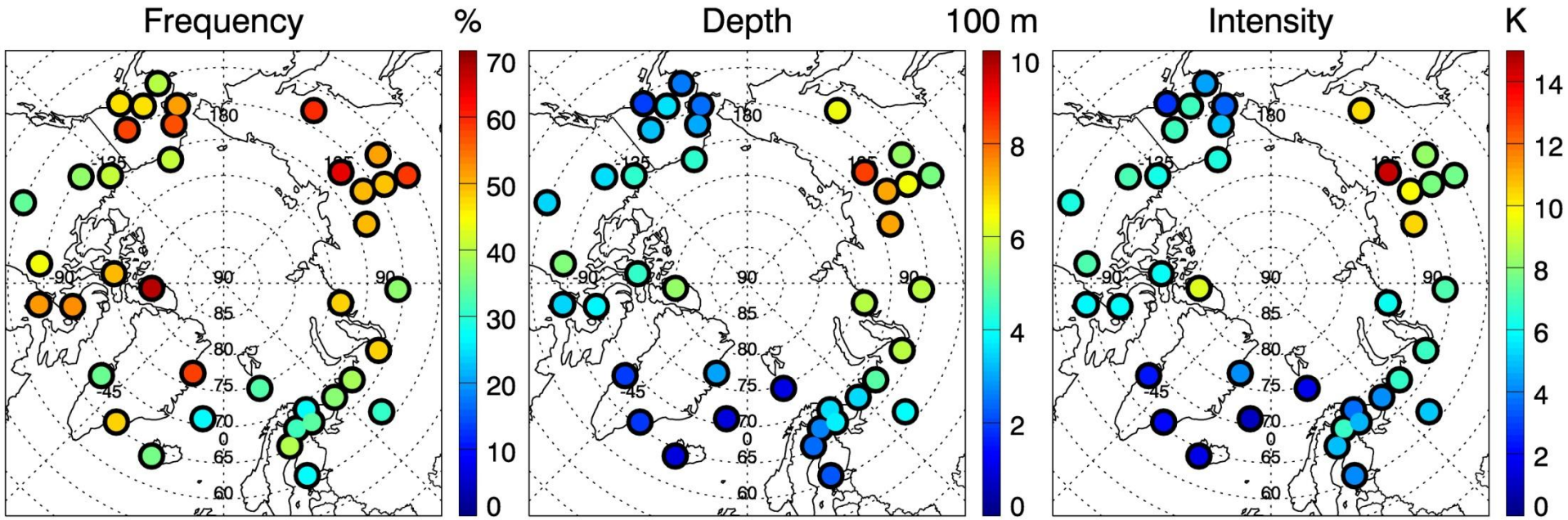
456 → 131 m

2.5 → 1.2 K

SBI characteristics at Jan Mayen, Norway (71N, 9W), 1963-2009

1983 increase in vertical resolution of soundings

1990-2009 Arctic SBI Climatology
From Radiosondes



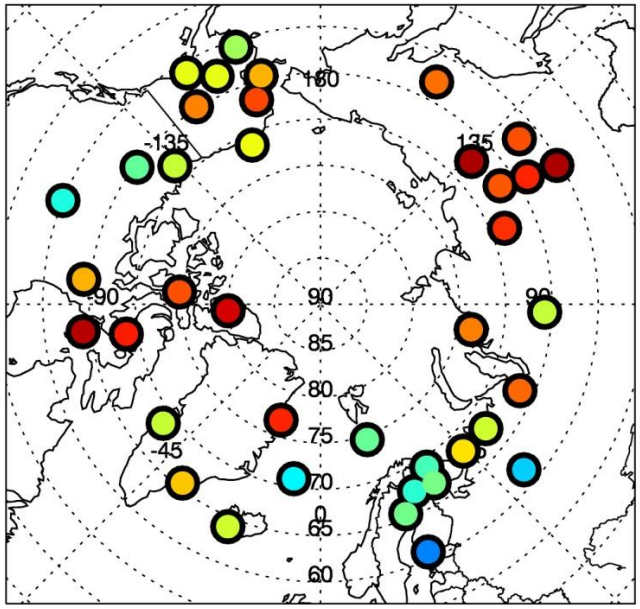
46%

356 m

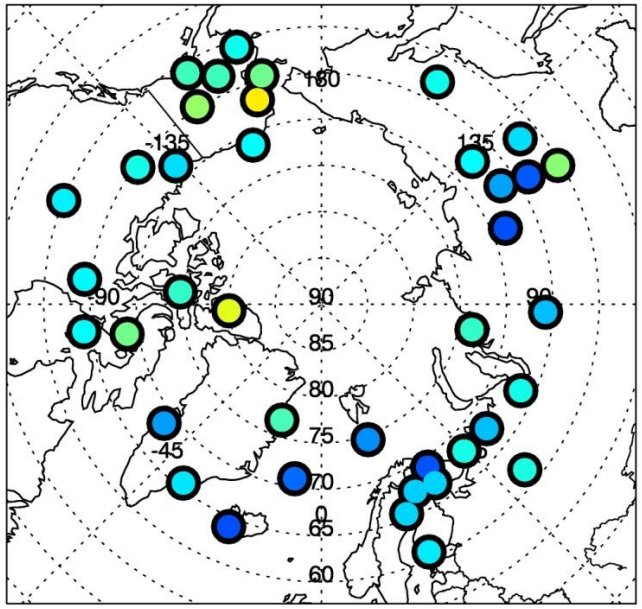
6.1 K

Median Values

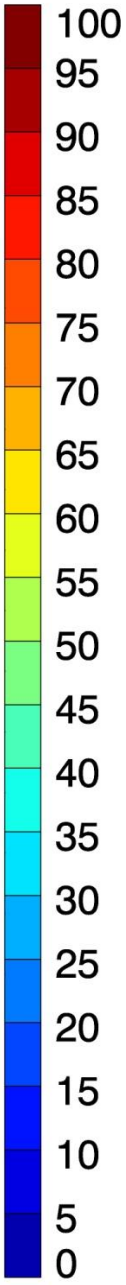
Frequency - Winter



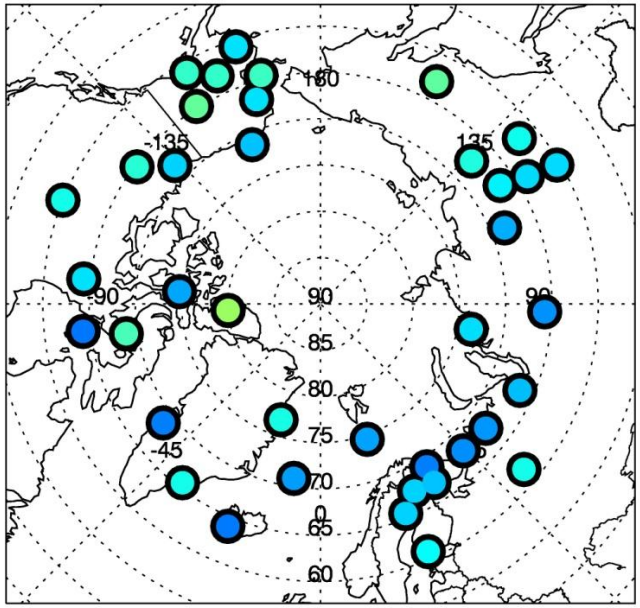
Frequency - Spring



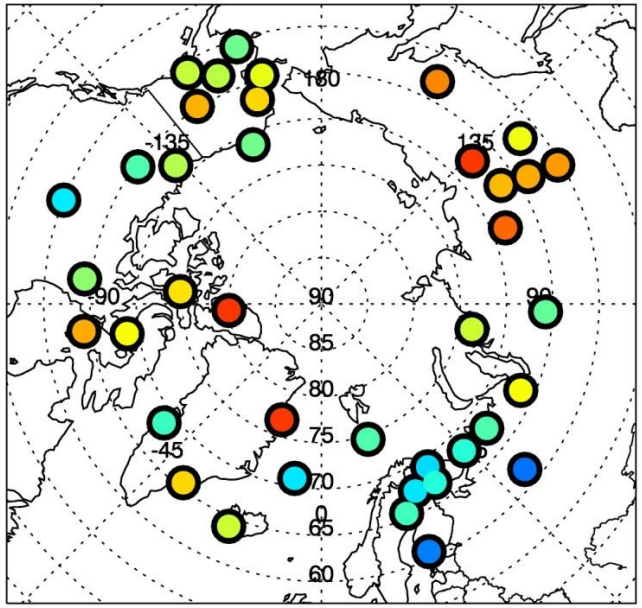
%



Frequency - Summer

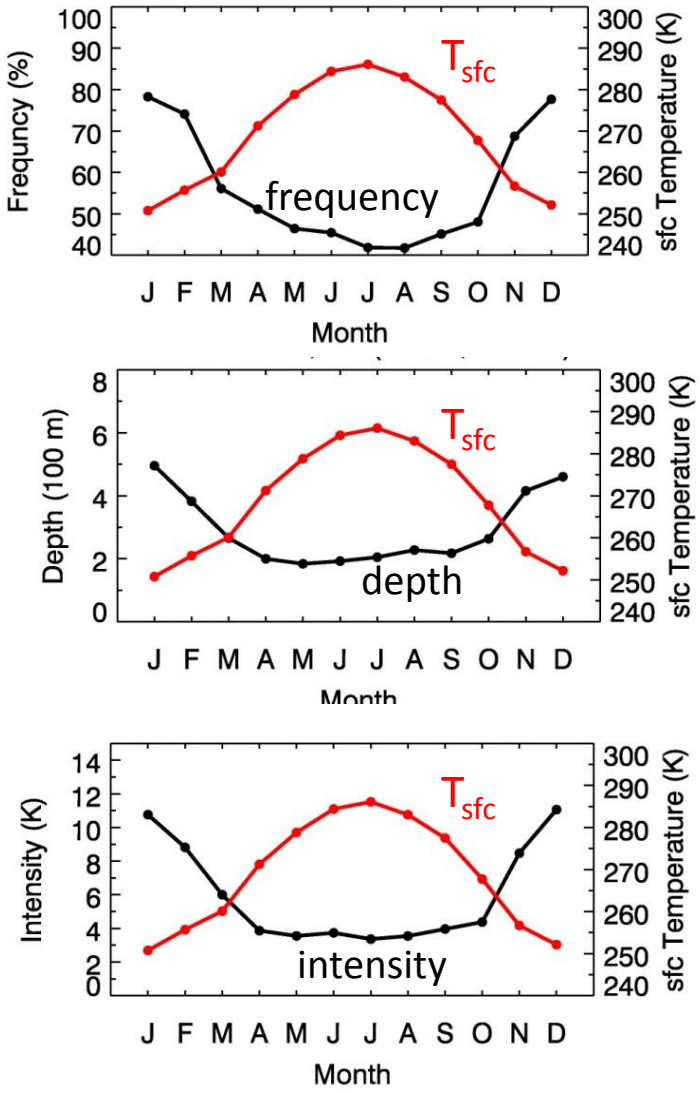


Frequency - Autumn



Arctic SBIs common in winter and autumn

SBI Annual Cycle Relations



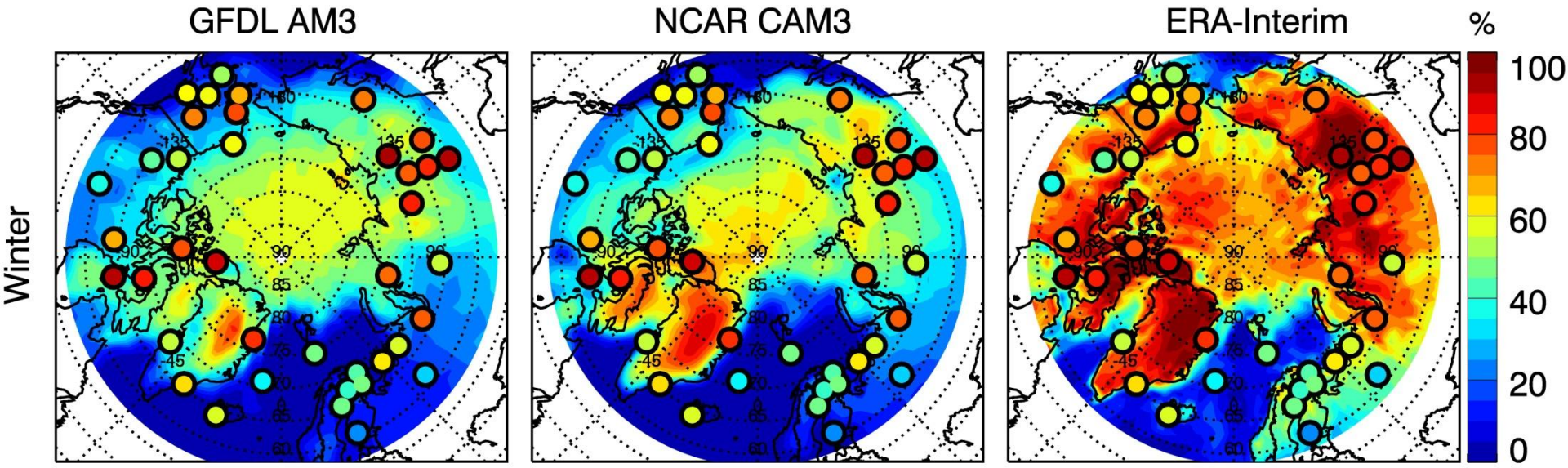
Fairbanks, Alaska

(Most Arctic stations show similar annual cycles)

SBI characteristics are positively correlated

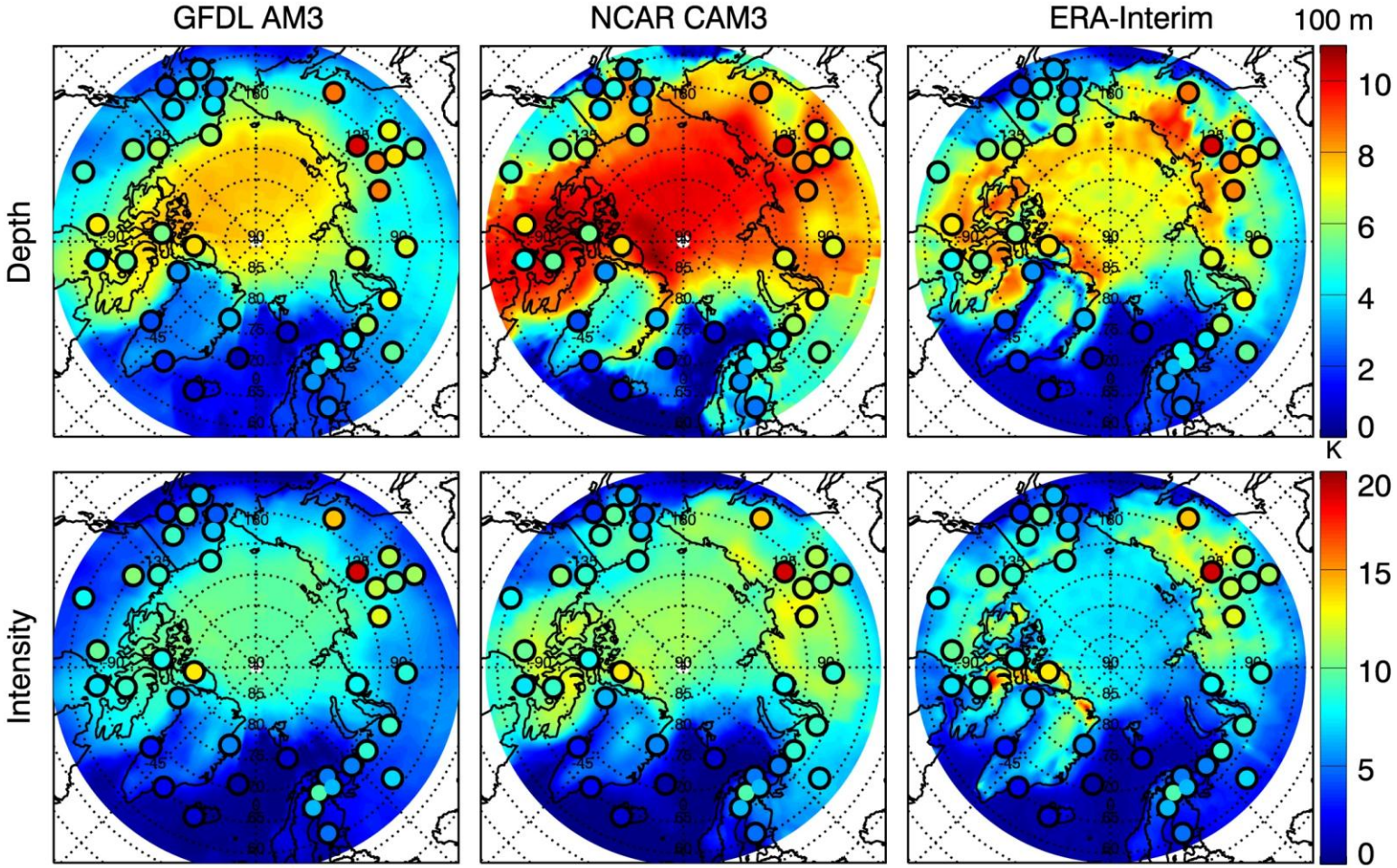
Negatively correlated with surface temperature

Obs/Model Comparisons: SBI Frequency in Winter



- Similar spatial distributions (and seasonal patterns)
- ERA-Interim agrees well with (assimilated) observations
- Climate models underestimate SBI frequency
- ERA-Interim shows higher Arctic Ocean SBI frequency than climate models

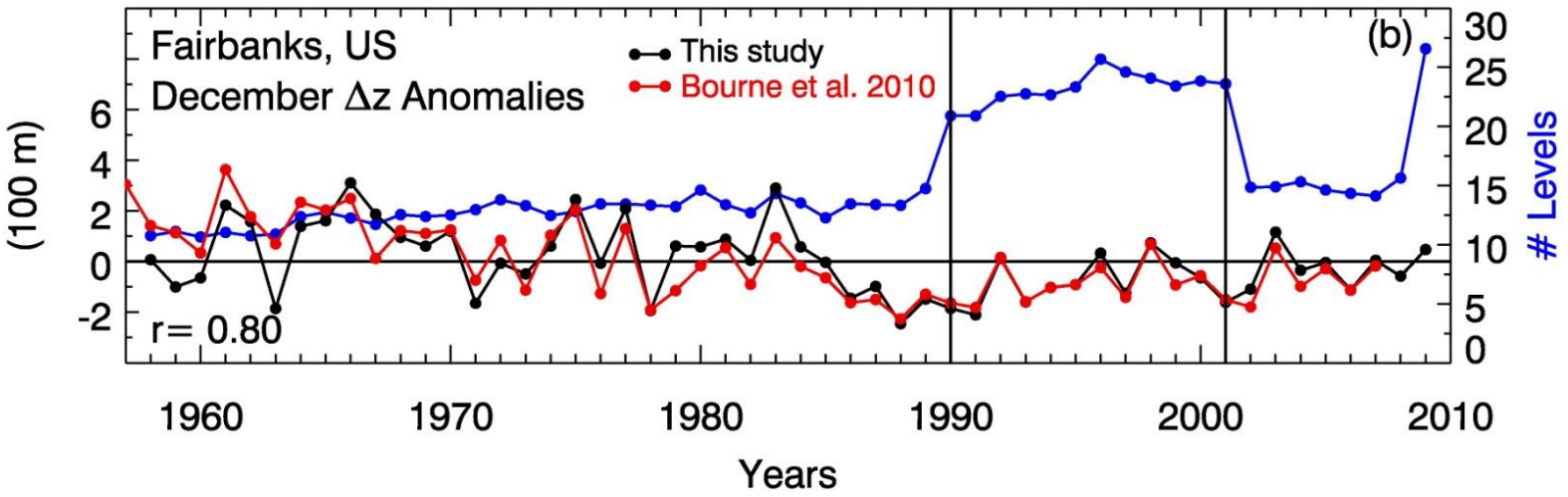
Winter Arctic SBI Depth and Intensity



- Model and reanalysis spatial patterns match observations.
- NCAR SBIs are deeper, perhaps due to lower vertical resolution.

Trends in Arctic SBIs

- Previous studies report inconsistent results for limited regions (Bradley et al. 1993, Walden et al. 1996, Kahl et al. 1996, Bourne et al. 2010)
- Most ignore data homogeneity, so trends are suspect



- Of 113 stations, we judged 19 homogeneous for 1990-2009

Key Points

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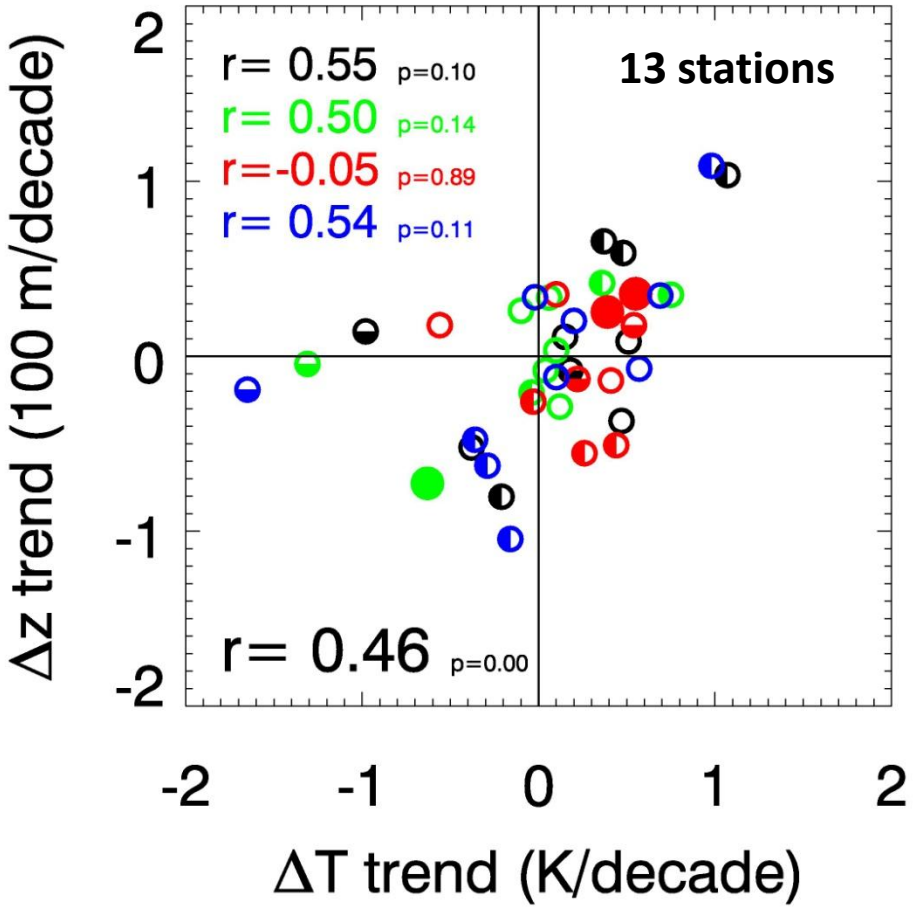
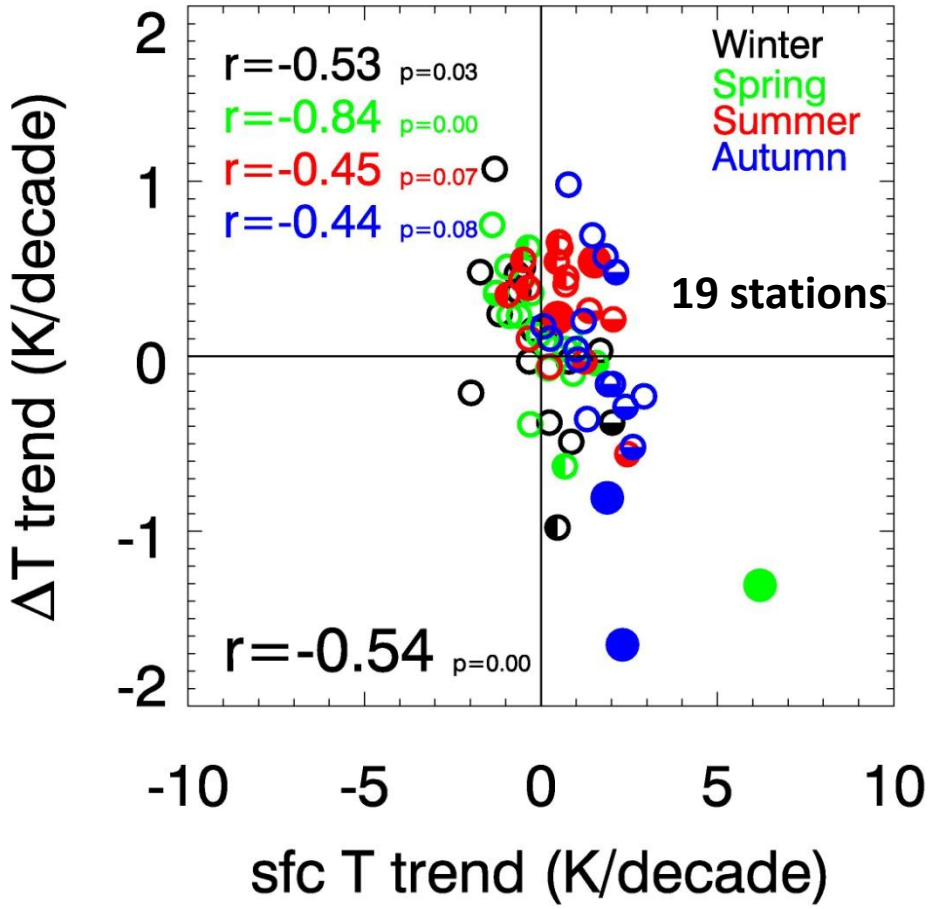
Thank you!

1990-2009 Seasonal Trends at a Few Stations



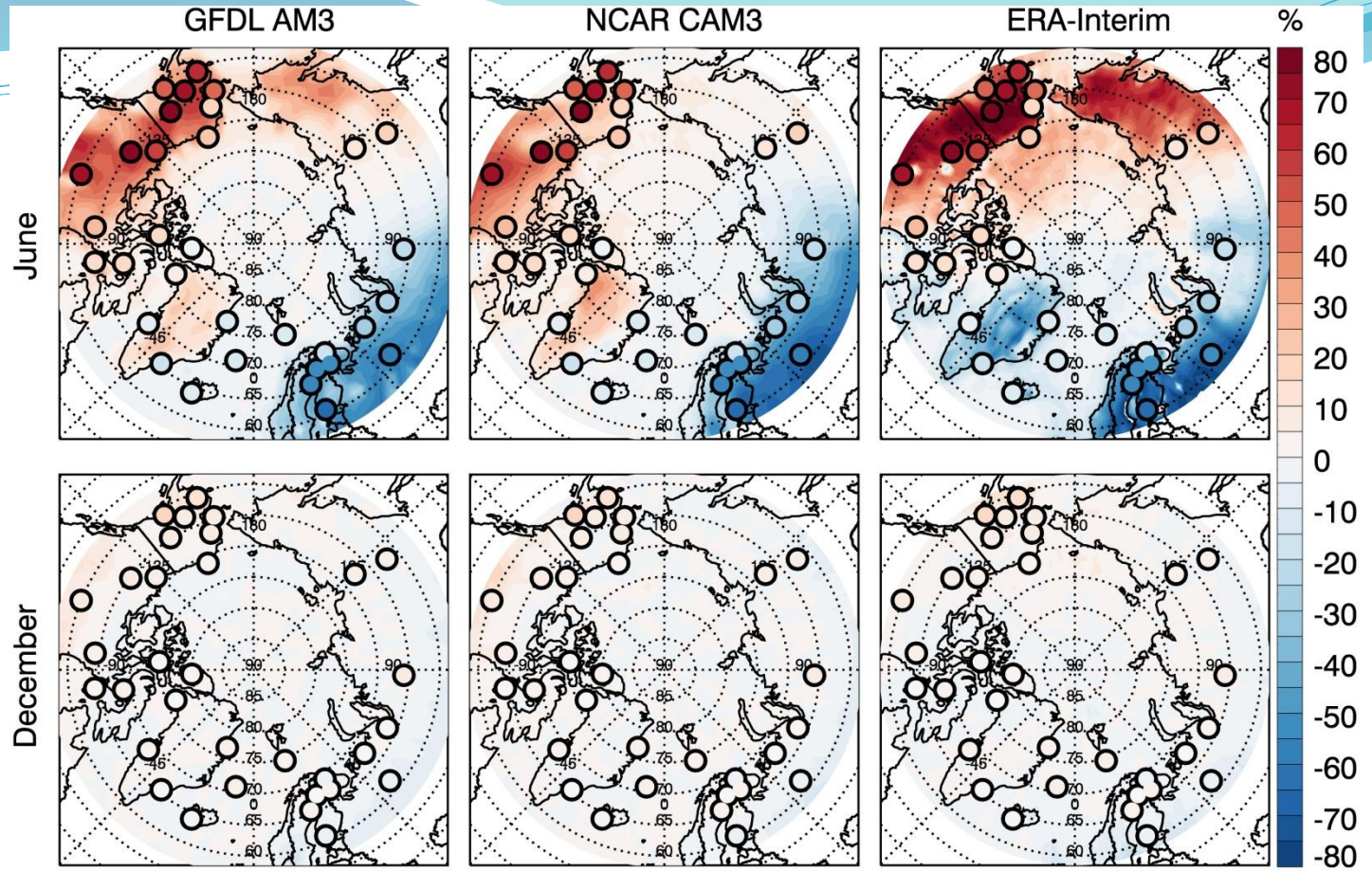


SBI intensity trend is positively related with SBI depth trend, but negatively related with the surface temperature trend

June
Polar Day →

Differences:
SBI $f_{12z} - f_{00z}$

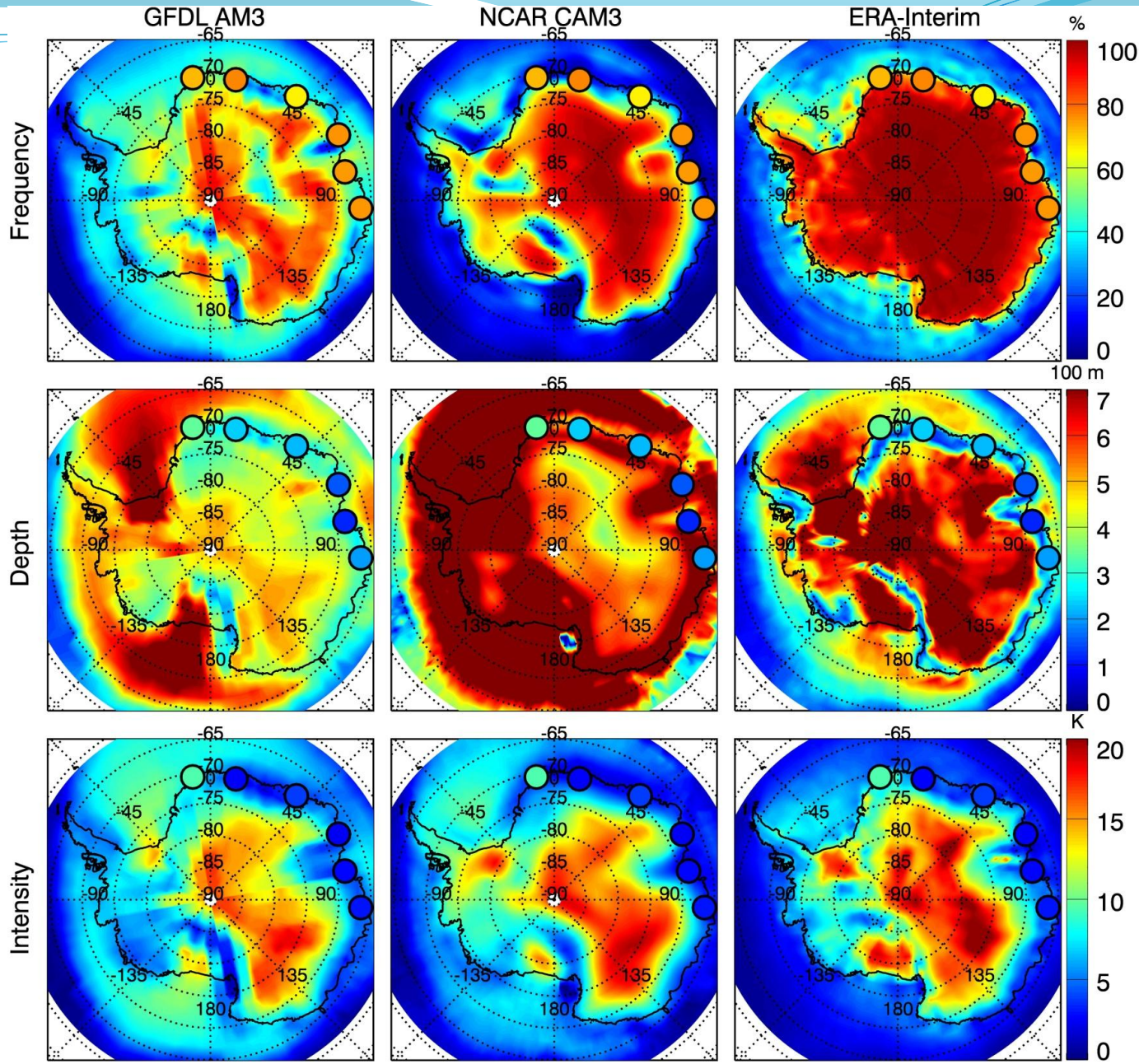
December →
Polar Night



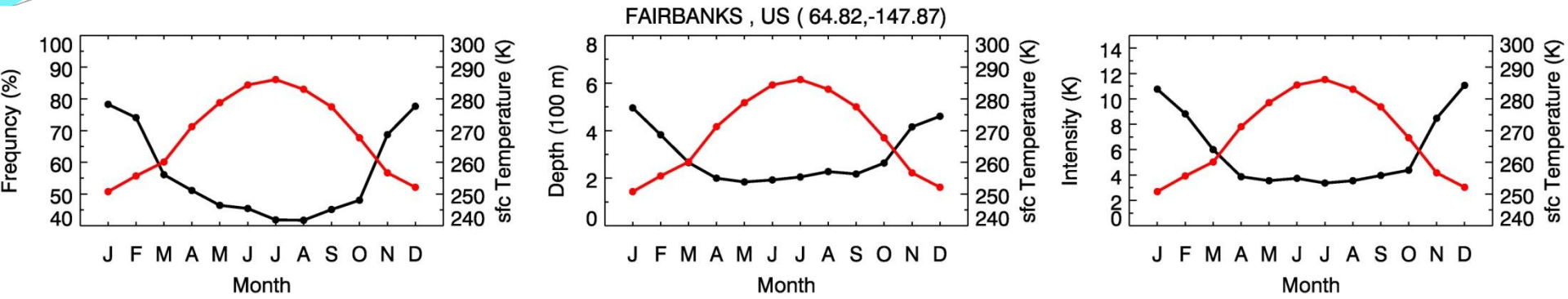
- SBI frequency in December shows near-zero differences
- In Arctic summer (day), solar elevations angles are higher at 0000 UTC near the International Dateline, and solar heating reduces the tendency for SBI formation

Winter **Antarctic** SBI climatology

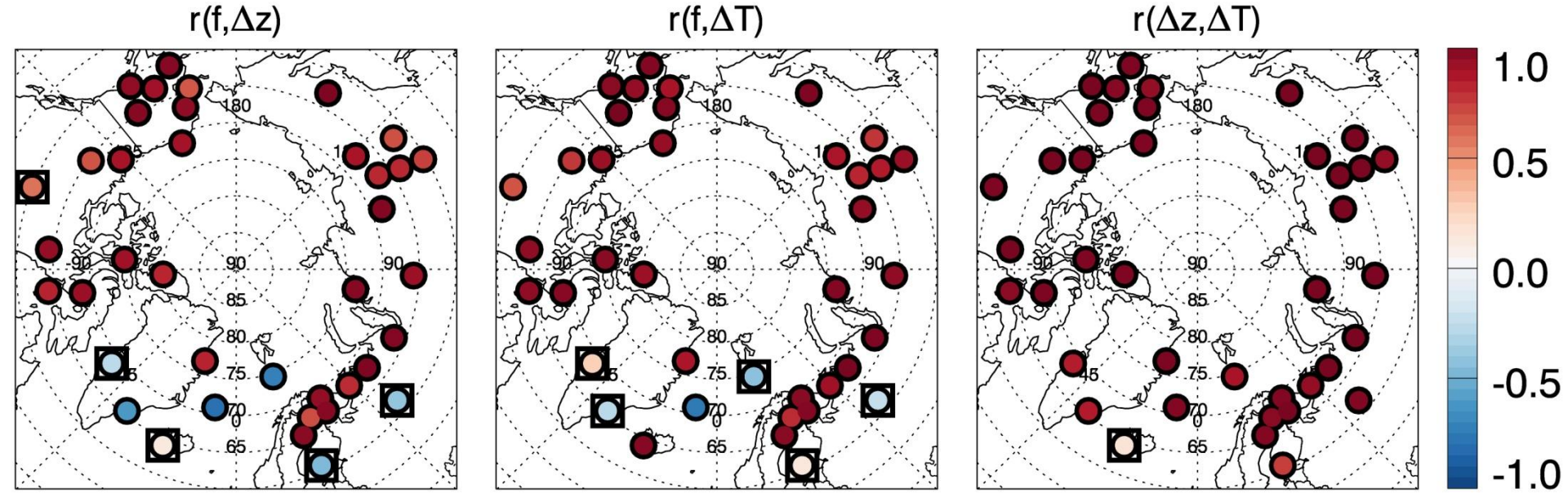
- Only coastal radiosonde stations
- Big land/sea contrast in models
- Simulations of Antarctic more disparate than Arctic



SBI Annual Cycle Relations



SBI characteristics are positively correlated.



SBI characteristics are negatively correlated with surface temperature.