An Overview of the Vertical Structure of the Atmospheric Boundary Layer in the Central Arctic during MOSAiC

MOSAiC International Arctic Drift Expedition

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Research Questions

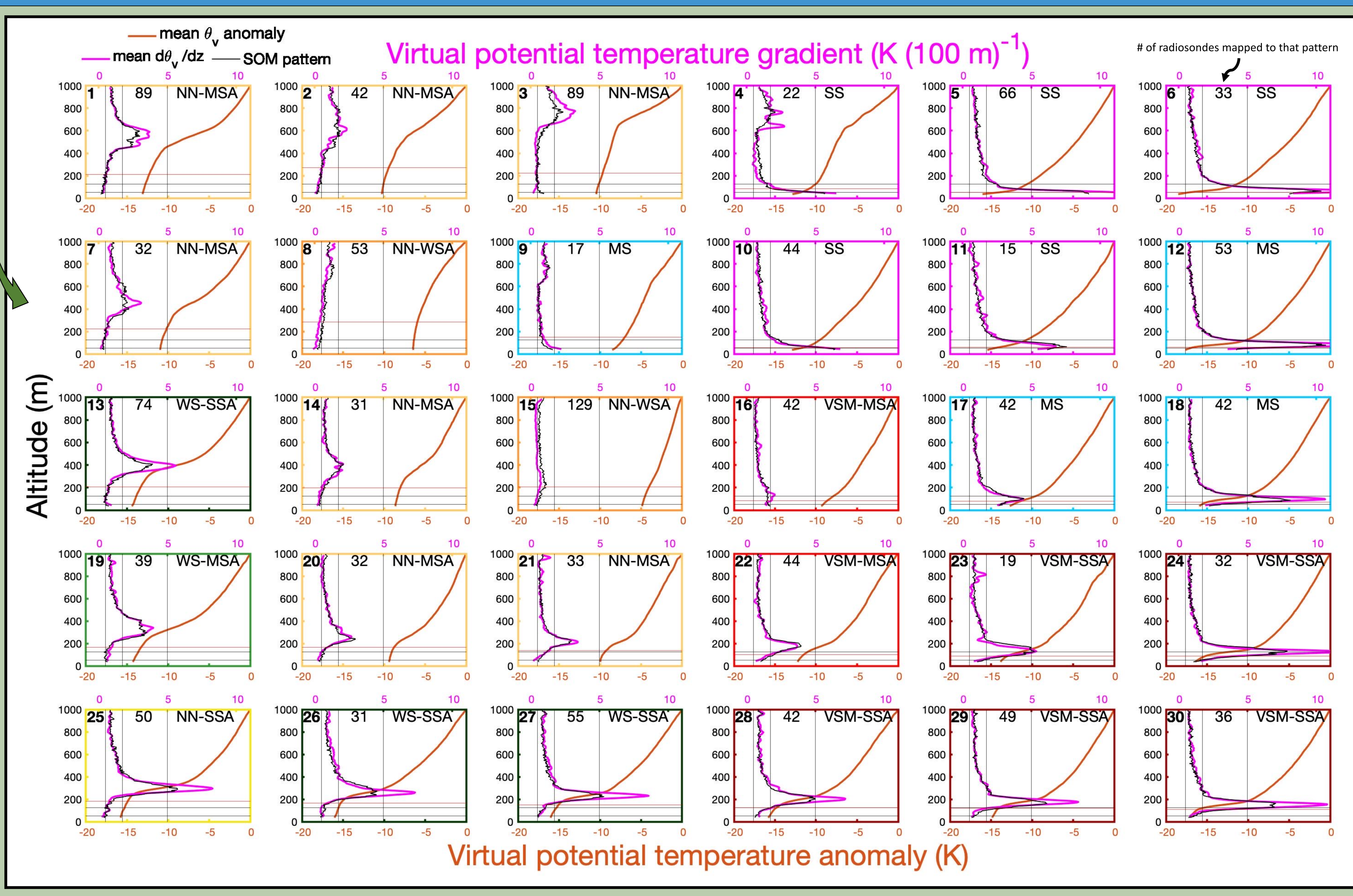
1. What are the atmospheric boundary layer (ABL) structures and stability regimes present in the central Arctic, and their relative frequencies?
2. What are the relationships between ABL stability and other relevant atmospheric features, including low-level jets (LLJs), temperature inversions (TIs) and atmospheric moisture?

Methods

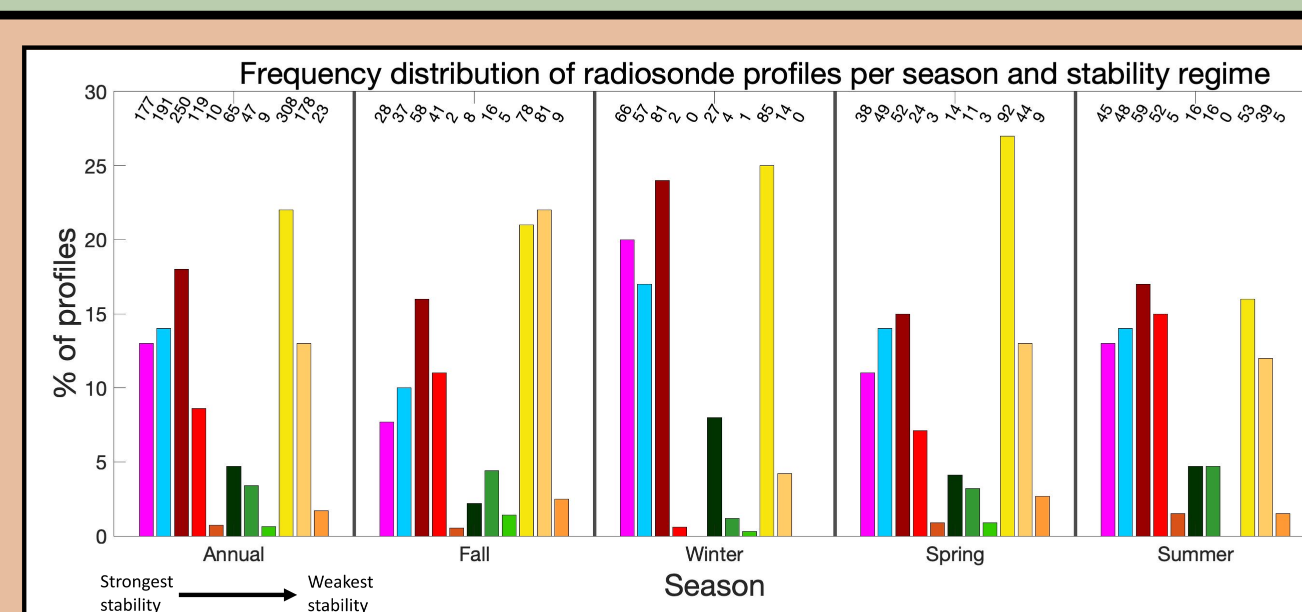
SOM analysis: A self-organizing map (SOM) analysis is conducted with the radiosonde profiles to objectively identify the range of lower atmospheric virtual potential temperature structures which occur in the central Arctic, and their relative frequencies during the MOSAiC year.

Stability regime analysis: Radiosonde profiles are grouped by stability regime, based on near-surface stability (below 50 m) and stability above the ABL (up to 1 km), to determine the statistics on various atmospheric characteristics as a function of stability regime.

Results



- The SOM patterns (left) reveal that the near-surface stability of the Arctic atmosphere spans from strongly stable to near-neutral, and stability between the ABL and 1 km spans from strongly to weakly stable.
- The most frequent SOM pattern is pattern number 15.
- Observations in Fall (Sep – Nov) dominate patterns in the center and left of the grid (patterns 2, 8, 15, 20, and 22).
- Observations in Winter (Dec – Feb) dominate patterns in the far right and bottom of the grid (patterns 5, 6, 12, 18, and 23 to 30).
- Observations in Spring (Mar – May) are well distributed throughout the grid.
- Observations in Summer (Jun – Aug) dominate two patterns the upper right of the grid (patterns 4 and 17).

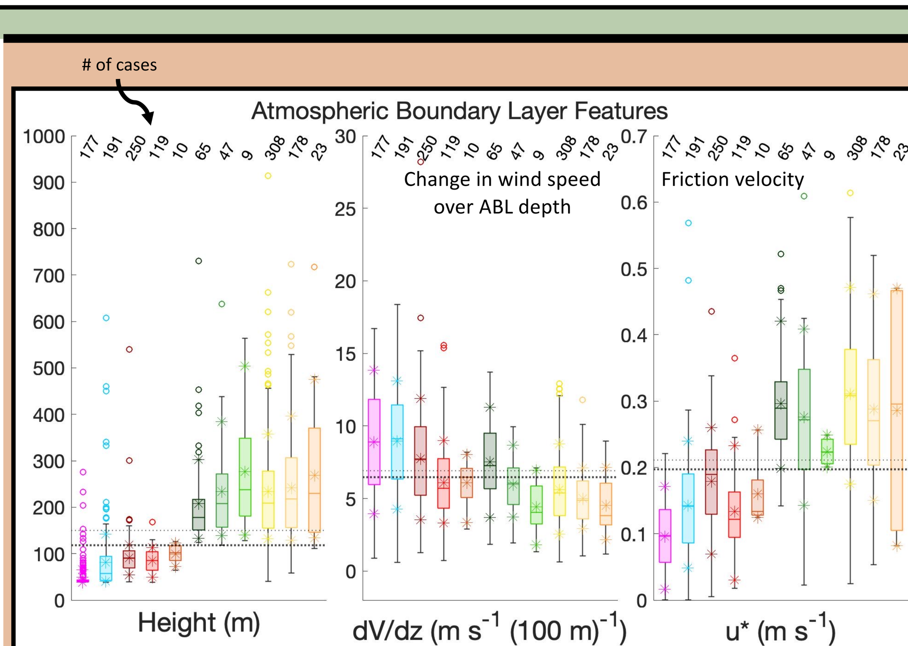


- The regimes which occur with the highest frequency are SS and MS, as well as VSM and NN with strong stability aloft.
- The weakly stable regimes are relatively infrequent.

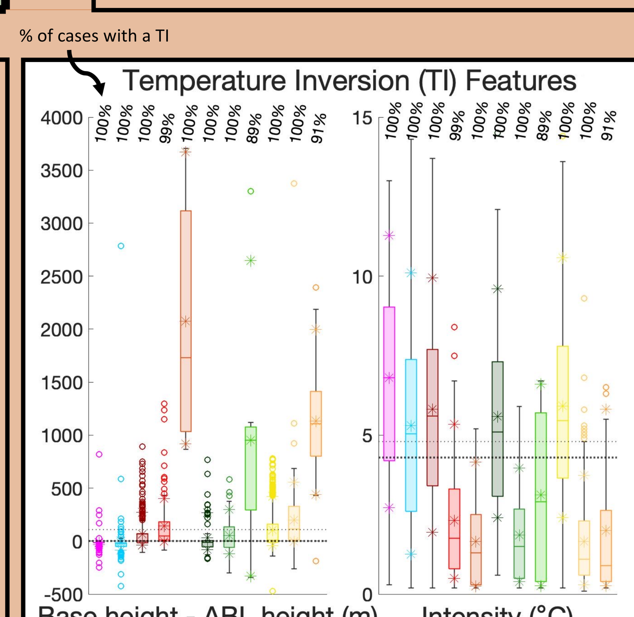
Legend for all figures:

Stability Regime	Abbreviation
Strongly Stable	SS
Moderately Stable	MS
Very Shallow Mixed – Strongly Stable Aloft	VSM-SSA
Very Shallow Mixed – Moderately Stable Aloft	VSM-MSA
Very Shallow Mixed – Weakly Stable Aloft	VSM-WSA
Weakly Stable – Strongly Stable Aloft	WS-SSA
Weakly Stable – Moderately Stable Aloft	WS-MSA
Weakly Stable	WS
Near-Neutral – Strongly Stable Aloft	NN-SSA
Near-Neutral – Moderately Stable Aloft	NN-MSA
Near-Neutral – Weakly Stable Aloft	NN-WSA

Strongest stability → Weakest stability



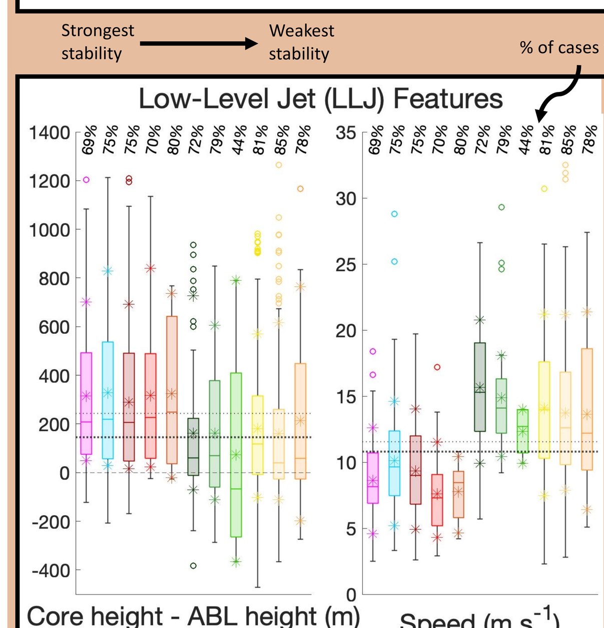
- ABL height increases with decreasing stability.
- ABL dV/dz is highest for SS and MS, as the wind above the ABL is decoupled from the surface due to the strong stratification.
- Greater mechanical mixing (u*) likely contributes to weaker stability regimes.



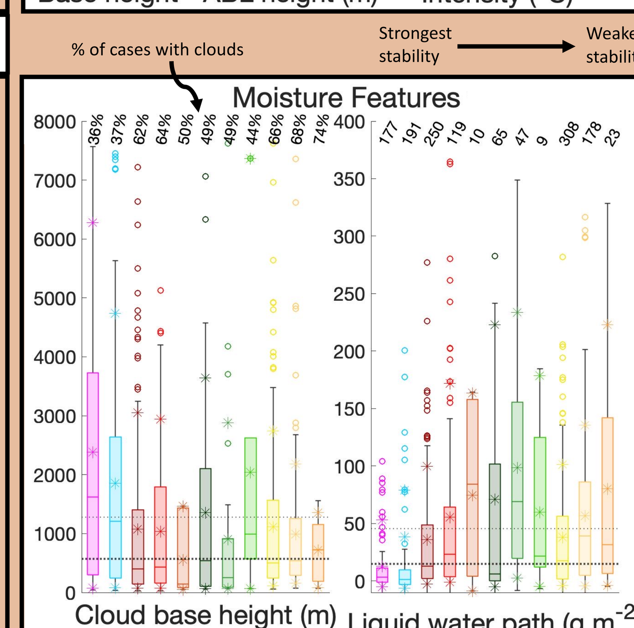
- A TI was observed in 99.7% of profiles, the only regimes without a TI being those with weak stability aloft.
- TI base height is below ABL height for SS, MS, and WS-SSA and above ABL height for all other regimes. The –WSA regimes have TI base a large distance above the ABL.
- TI intensity decreases with decreasing stability with the –SSA regimes having the greatest TI intensity.

Strongest stability → Weakest stability

Mean
Median



- An LLJ was observed in 76% of profiles with similar frequency by stability regime and season.
- The LLJ core is higher above ABL height for the stronger stability regimes, consistent with inertial oscillations, and closer to ABL height for the weaker stability regimes, consistent with baroclinicity.
- LLJ speed increases with decreasing stability, with a step increase between VSM and WS.



- Clouds were observed within 30 min before 64% of radiosondes. Low clouds (cloud base height ≤ 2 km) were observed within 30 min before 50% of radiosondes.
- Higher cloud base height contributes to stronger stability, and lower cloud base height contributes to VSM and NN.
- Strong stability occurs when liquid water path is low, and liquid water path increases with decreasing stability.

Conclusions

- The central Arctic atmosphere is inclined to be stable somewhere in the lowest 1 km, but the height of this stable layer can become elevated, separated from the surface by a near-neutral or weakly stratified layer, when turbulence is generated.
- Weaker stability is associated with a deeper ABL, greater u*, faster LLJ, higher TI base, weaker TI intensity, lower cloud base height, and elevated moisture levels.
- When the atmosphere above the ABL is very stable, there must be higher amounts of turbulence to mix out the near-surface layer, than if there is weaker stability aloft.

Acknowledgements

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