The Arctic Atmospheric Boundary Layer Structure and Its Interactions with the Free Troposphere and Surface

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ASR Atmospheric System Research

Objectives of This Recently Funded Work

Overall objective: evaluate, develop, and understand the Arctic Inversion Dual-Mixed Layer paradigm, its substructures, and a few key processes. Specific objectives include:

1) Evaluate and further develop the AI/dual mixing layer paradigm for cloudy and clear-sky states by comparing the basic MOSAIC AI characteristics with previous studies; exploring the modulation of the AI seasonal and synoptic variability; understanding where and how the LLJ fits into this structural paradigm; determining if the paradigm holds true for clear skies with just the removal of the CML; determining if there is a seasonal variability for the dual mixed-layer concept; exploring the generality of the concept of distinct SML and CML for cloudy states; and addressing how larger-scale forcings and cloud depth/type impact the concept.

2) Identify the forcing and characteristics of the dual mixed-layer coupling process by exploring the relative impacts of synoptic forcing, cloud-top height, and microphysical forcing/radiational cooling for modulating the penetration depth of the CML and coupling with the SML.

3) Identify the roles of low-level jets in the AI paradigm, especially for vertical mixing by identifying their locations and temporal occurrence relative to other AI structures, characterizing their associated turbulence structure, and quantifying their mixing contribution and efficiency

4) Characterize the turbulent structures and their relationships with mixing layers, cloudy-sky coupling modes, and the clear-sky structural paradigm. This will include characterizing the vertical structure of turbulent mixing, exploring the characteristic length scales of turbulent eddies forced by different mechanisms, and exploring the eddy length-scale implications for the efficiency of vertical mixing and transport.

References

Persson, P.O.G., and T. Vihma, 2017: The Atmosphere Over Sea Ice. Chapter 6 in *Sea Ice*, 3rd Edition. Edited by David N. Thomas, Wiley-Blackwell, London. 652 pp., 160-196 ISBN: 9781118778388

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Arctic Inversion Dual-Mixed Layer Structural Paradigm

Key structural features

Arctic Inversion (AI) – General, large-scale inversion that forms over Arctic, ice/snow-covered regions. AI top is interface with the free troposphere. Structural features occur within the AI as air moves over ice/snow. Separation of AI from ABL is the unique aspect of this paradigm.

Atmospheric boundary layer (ABL) – the locally-formed atmosphere-surface boundary layer. It may be stable or consist of a temperature inversion, or a surface-forced surface mixed layer (SML).

Cloud mixed layer (CML) – upside-down convection driven by cloud-top radiative cooling of clouds within the AI. It forms a mixed layer totally independent of surface characteristics, and may couple with ABL.

Low-level jets (LLJs) – synoptically or inertially forced local wind maxima occurring under either clear or cloudy conditions. LLJs may force local vertical mixing

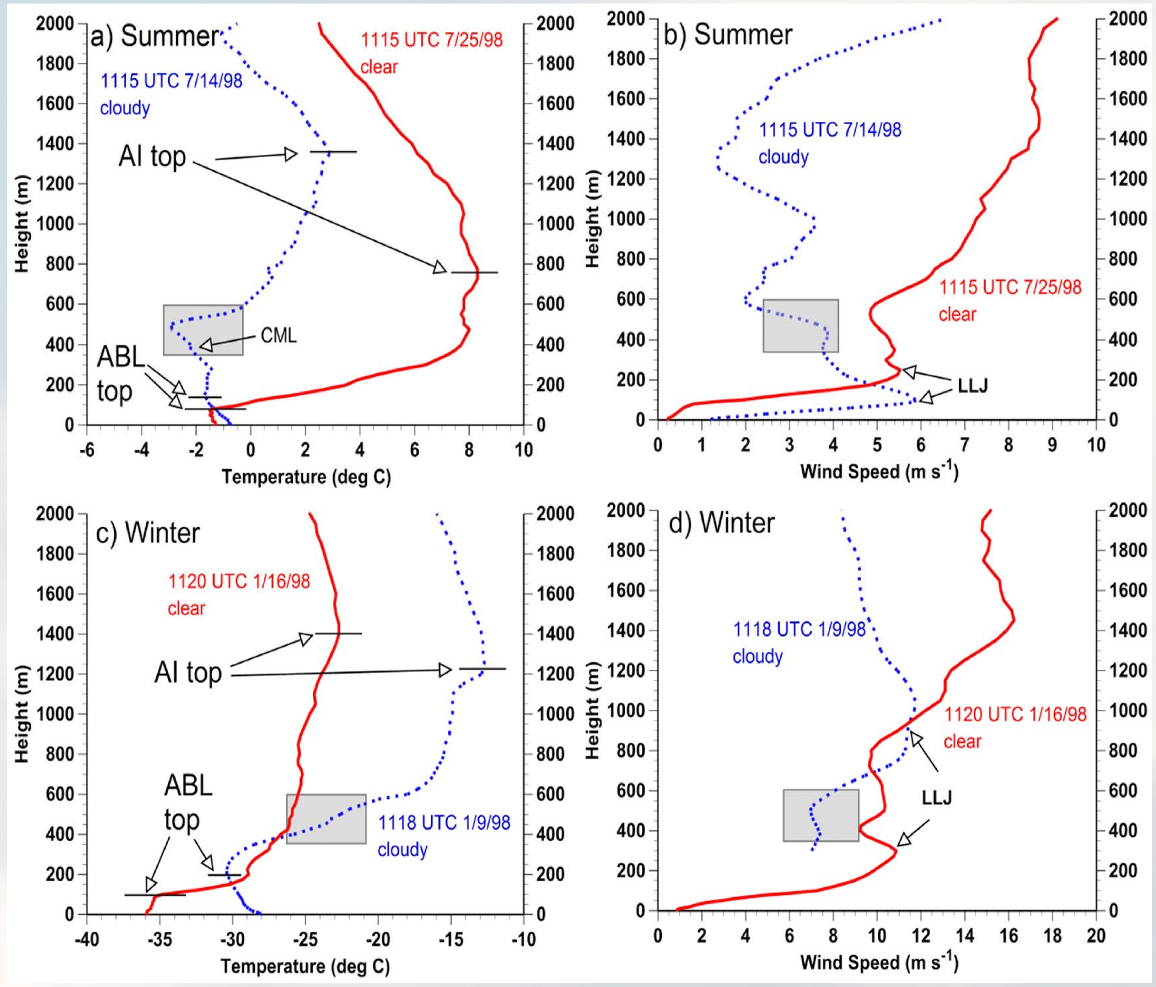


***Figure 1:** Sample temperature and wind profiles in the lowest 2 km at the SHEBA site for a), b) summer and c), d) winter for clear (solid) and cloudy (dotted) conditions. The shaded grey region represents the observed clouds for the respective soundings. The Arctic inversion tops (AI), the atmospheric boundary layer tops (ABL), the cloud mixed layer (CML), and the low-level jets (LLJ) are given for each profile. (from Persson and Vihma 2017)*

Observational Examples

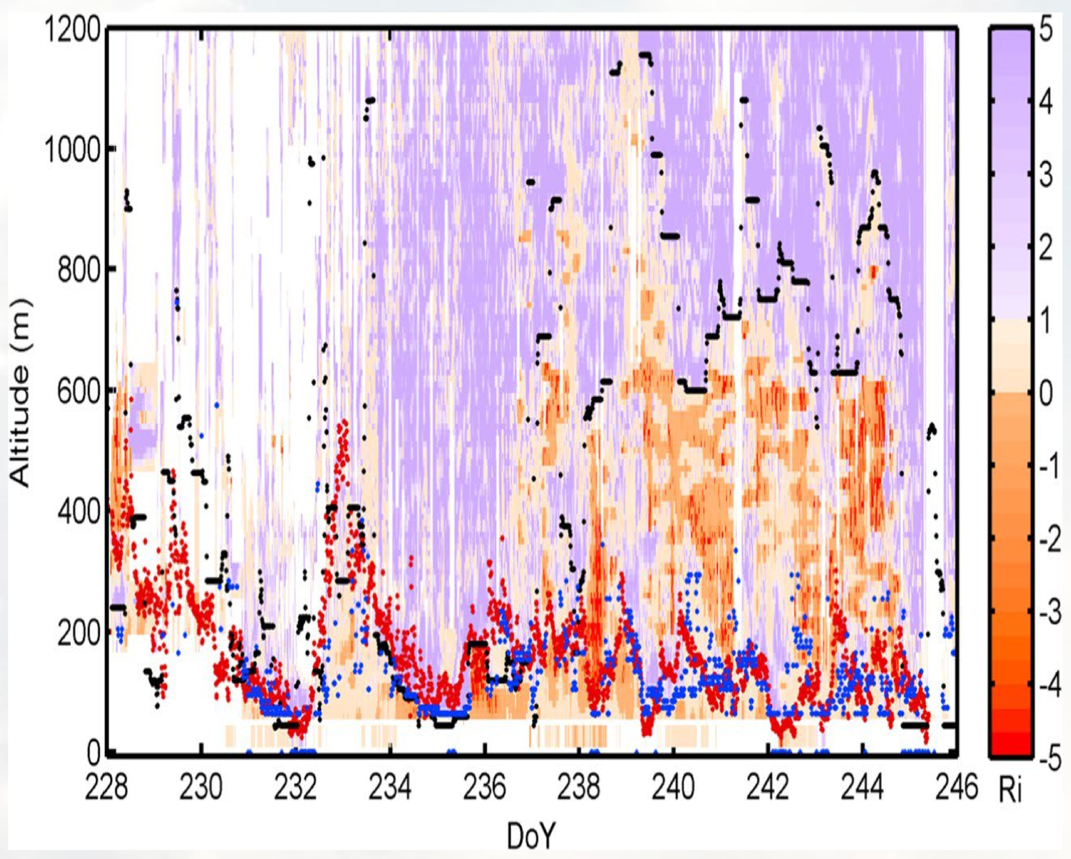


Fig 2: Time-height cross section of Richardson number. Data below 35 m derived from the mast profiles. Also included are the SML depth from the analytical formula HCN =1.36 u(fN)_1/2 (red dots), SML depths from an analysis of Ri (HRi; blue dots), and observed top of the CML (zi; black dots). The color scale is broken at Ri = 0 and Ri = 1 to make distinct the regimes of turbulent convection, stratified nonturbulent flow, and stable but turbulent (or potentially turbulent) flow. (from Brooks et al 2017)*

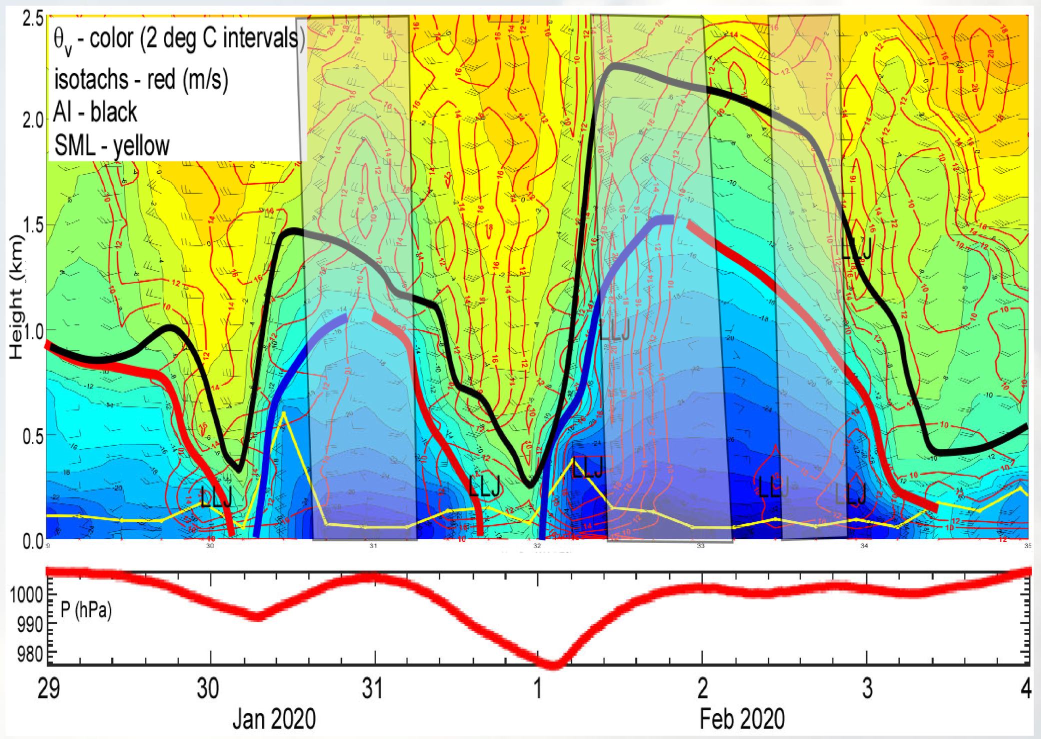
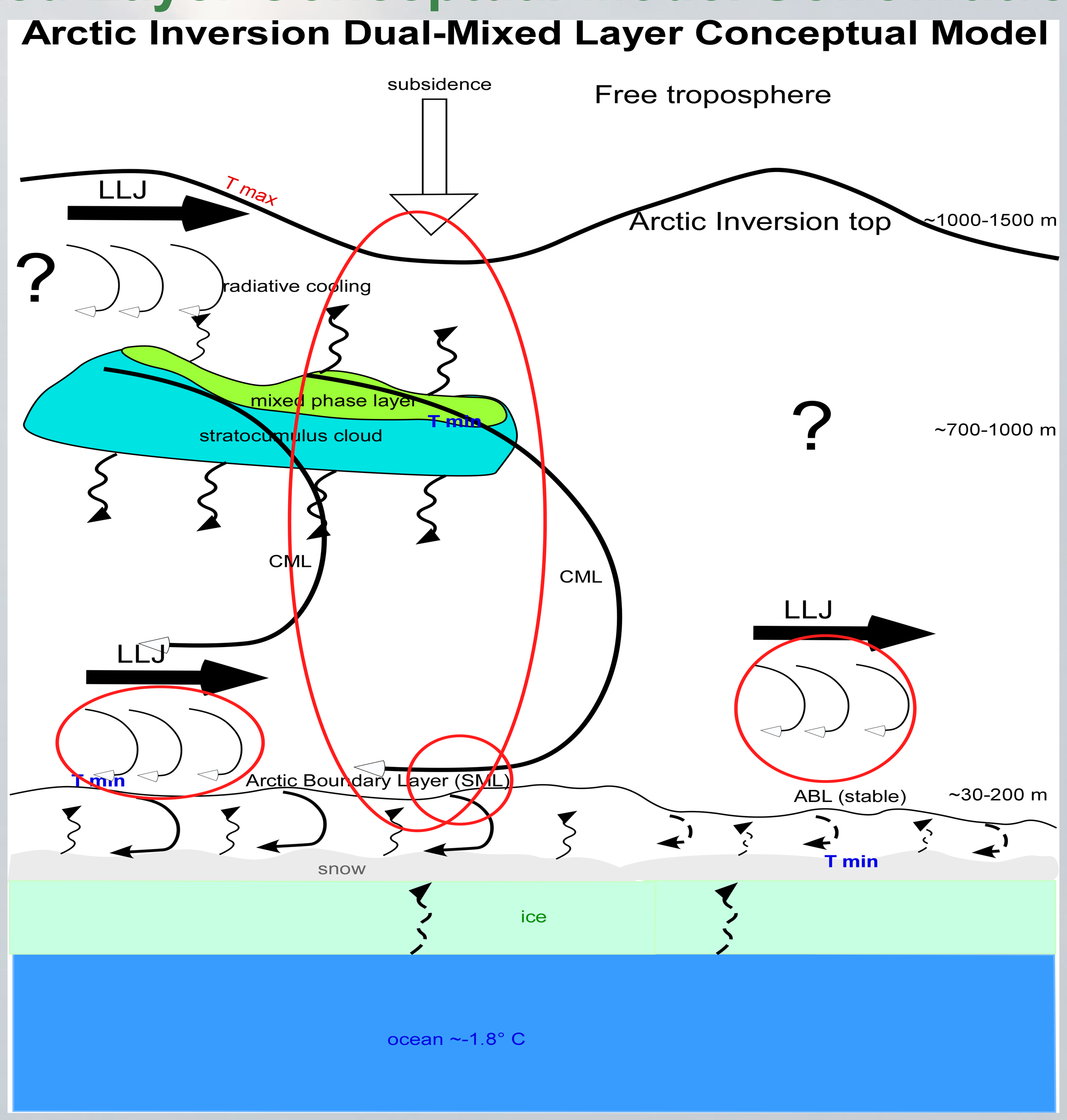


Fig. 3: Temporal evolution of AI top (heavy black line) and SML (yellow line) for a synoptically active period during MOSAiC. Several LLJs also occur within AI above SML height. Background fields are virtual potential temperature (color; 2° C intervals), isotachs (red; m/s), and wind barbs from 6-h soundings. The red and blue heavy lines show shallow warm fronts and cold fronts, respectively, the AI top is defined by the temperature maximum, and the SML is defined by the base of a positive θ_v gradient. Sounding data below 50 m height is unreliable and is not used, so the minimum SML depth is 50 m.. Clear periods are marked by the grey shading. The bottom panel shows the MSL pressure measured on the Polarstern.

Arctic Inversion Dual-Mixed Layer Conceptual Model Schematic

Fig. 4: Schematic showing key structural features of the hypothesized conceptual model. The left side shows cloudy conditions and the right side clear-sky conditions



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