**FROM ICE TO ATMOSPHERE: SIMULATING BOUNDARY LAYER EVOLUTION IN ARCTIC COLD-AIR OUTBREAKS WITH CLASS MODEL**

**Introduction**

Understanding the dynamic processes within the marine boundary layer, especially during Arctic cold-air outbreaks, is pivotal for advancing our knowledge of polar meteorology and improving climate models. This study, drawing inspiration from the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) campaign, utilizes the CLASS model to simulate the evolution of air masses from the Arctic ice edge. By integrating observed data for surface heat and latent heat fluxes from the COMBLE field campaign into the CLASS model, this report aims to elucidate the transformation of boundary layer characteristics, providing a detailed examination of how variations in surface fluxes influence cloud formation and boundary layer development in polar regions.

**OBJECTIVES**

This study, utilizing the CLASS model, aims to replicate the complex dynamics of the marine boundary layer observed during Arctic cold-air outbreaks as detailed in the COMBLE campaign. It seeks to analyze how variations in surface and latent heat fluxes influence key boundary layer properties like height, temperature, and humidity. A pivotal aspect involves exploring how these flux variations impact cloud formation within the boundary layer, enhancing our understanding of polar cloud systems. Additionally, the study aims to validate the CLASS model's simulations against empirical observations, ensuring accuracy in representing boundary layer phenomena. Ultimately, the goal is to integrate these insights into broader climate modeling, refining predictions of polar meteorological events.

**DATA ACQUISITION**

The data utilized in this boundary layer study was sourced from the Eddy Correlation Flux Measurement System (30ECOR) of the ARM Mobile Facility during the COMBLE campaign in 2019-2020. Focused on the Arctic marine boundary layer, COMBLE, led by the University of Wyoming and funded by the DOE, aimed to understand the transformations of atmospheric air masses during cold-air outbreaks, a phenomenon influencing the boundary layer dynamics over high-latitude oceans.

The primary observational site was near Andenes, Norway, close to the Arctic Ocean ice edge, while a secondary site was on Bear Island. These locations, chosen for their proximity to key atmospheric features, provided comprehensive data over six months, crucial for understanding boundary layer processes. Instruments at these sites captured a range of atmospheric parameters, essential for boundary layer analysis, including wind, temperature, atmospheric structure, and cloud properties, along with aerosol data focusing on ice-nucleating particles, critical for cloud formation in the boundary layer.

The campaign’s extensive dataset, especially measurements of surface heat and latent heat fluxes, was instrumental in this study. By extracting 'maximum' and 'mean' values of these fluxes from the COMBLE data, we applied them as fixed inputs in the CLASS model. This approach allows us to simulate and analyze the boundary layer's response to different flux intensities, offering insights into the impact of surface flux variations on the boundary layer characteristics such as height, temperature, humidity, and cloud formation processes. Thus, the integration of COMBLE data is pivotal in advancing our understanding of the complex dynamics within the Arctic marine boundary layer.

**MODEL IMPLEMENTATION**

In this study, the CLASS (Chemistry Land-surface Atmosphere Soil Slab) model was employed to simulate the intricate evolution of the marine boundary layer during Arctic cold-air outbreaks. The CLASS model, renowned for its comprehensive integration of land, atmospheric, and chemical interactions, offers an advanced platform for studying the atmospheric boundary layer and its complex interactions with air chemistry and land surfaces. Its temporal resolution is a key feature, although it does not provide horizontal or vertical resolution.

We focused on the Lagrangian evolution of air parcels moving from the ice edge for up to 24 hours, aiming to follow these parcels from the Arctic ice edge southward. This approach is pivotal in understanding the atmospheric transformations that occur in this region. Within the CLASS model, several tabs facilitate detailed settings: Basic, Wind, Rad/Geo, Surface, Species, Reactions, and Adv.surf. For this simulation, the Basic, Wind, Rad/Geo, and Surface tabs were primarily utilized.

In the Basic tab, the initial mixed-layer potential temperature and specific humidity were set at 258 K and 1 g/kg-1, respectively, reflecting the cold and dry conditions at the ice edge. A Lagrangian framework was assumed, with no advection. Surface sensible and latent heat fluxes, crucial for this study, were derived from the ECOR data, with maximum and mean values implemented as surface kinematic heat and moisture fluxes. The maximum values were 0.5703 Kms-1 (sensible) and 0.0005 gkg-1 ms-1 (latent), and the mean values were 0.2016 Kms-1 (sensible) and 0.0001 gkg-1 ms-1 (latent).

For the Wind tab, we activated the Coriolis parameter (set at 0.0001379 s-1) and included the shear effect on entrainment, keeping other parameters at their default settings. The Rad/Geo tab was configured with a latitude of 75.25 degrees North and longitude of 10.32 degrees East, corresponding to the 73rd day of the year (March 13th). Radiation was disabled, and shallow cumulus settings were adjusted as needed for simulations with or without clouds.

In the Surface tab, the mode was switched from land to sea, aligning with our focus on oceanic conditions, with other settings left as default.

Through this carefully calibrated simulation, we were able to generate data on boundary layer height, potential temperature, specific humidity, u-wind, v-wind, cloud-core fraction, total cloud fraction, and mass flux. These parameters were observed both with and without cloud cover, providing insights into how each variable behaves from the edge of the ice to over 24 hours as it makes landfall.