COMBLE

Cold-air Outbreak in the Marine Boundary Layer Experiment

Principal investigator

Bart Geerts

gleerts@uwyo.edu

University of Wyoming

Other contact

Michael Tjernström (michaelt@misu.su.se)

Areas of contribution

Polar atmospheric processes

Modelling and forecasting

Education

Observations

Outreach

Summary

COMBLE (Cold-air Outbreak in the Marine Boundary Layer Experiment) aims to increase the understanding of cold-air outbreaks (CAOs). When cold Arctic air flows from the ice out over the warmer water, strong boundary-layer convection and wind shear interact to form mixed-phase clouds with a highly fetch-dependent structure, first organized in “streets” evolving into cells as the boundary layer deepens. Surface heat fluxes are typically very large, and the cloud and boundary-layer circulation effectively transfers heat into an originally stratified environment. CAOs are also an important factor for the formation of Polar Lows. While often appearing striking in satellite imagery, CAO processes are poorly documented due to their hostile environment. Occurrence and downstream development are not well represented in weather and climate models.
The field campaign will be launched in the 2019-2020 timeframe; the main observation period will be in winter: Jan-Apr 2020. COMBLE is built around the ARM Mobile Facility (AMF), observations at Ny-Ålesund and from MOSAiC, tied together by research aircraft. The observation strategy includes a far downstream site (AMF) at the northern Norway coast, a midstream site (ARM instruments plus mobile cloud radar) on Bear Island, and nearstream observations at Ny-Ålesund; upstream observations will come from MOSAiC. Research aircraft will provide in-situ observations and map the spatial development and link the fixed location sites. All fixed sites will provide both surface-based remote sensing of the lower troposphere and in-situ observations such as surface fluxes and radiosoundings. COMBLE modelling will cover scales from the local using LES, regional scales using mesoscale models and the global scale using GCMs.

**Description**

COMBLE (Cold-air Outbreak in the Marine Boundary Layer Experiment) aims to increase the understanding of so-called cold-air outbreaks (CAOs). These appear when cold Arctic air with strong winds flows from the sea ice southward out over the warmer water, and strong boundary-layer convection (BLC) and wind shear interact to form mixed-phase clouds with a highly fetch-dependent structure. Near the source, the clouds are organized in rolls or “cloud streets”, due to coherent circulations within or near the top of the well-mixed boundary layer, but gradually evolving into cells as the boundary layer deepens. This transitioning involves a complex interaction between many processes such as the surface fluxes, boundary-layer mixing and cloud-related processes including cloud-aerosol interaction, radiative processes, and precipitation. Surface heat fluxes are typically very large, and the cloud and boundary-layer circulation effectively transfers heat into an originally stratified environment. CAOs also provide a favorable environment for the formation of Polar Lows; an intense form of cyclones appearing over high-latitude oceans. While often appearing striking in satellite imagery, CAO processes are poorly documented due to their hostile environment. Occurrence and downstream development are not represented well in weather and climate models, mainly because the processes important for CAOs are not well resolved by these models. Both CAOs and Polar Lows represent a type of severe weather condition that is difficult to forecast with a large impact on many human activities.

COMBLE spans a large international consortium with members from about 20 institutes in US, UK, Germany, Norway and Sweden, and consists of both a field component and modeling. Specifically, COMBLE aims to:

* describe and quantify the fetch-dependent mesoscale organization and the vertical structure of COAs, including vertical profiles of vertical velocity and turbulence in convection, cloud liquid water and ice mass concentrations, cloud particle sizes, phases and shapes, and fluxes of surface heat, moisture, and radiation;
* examine the impact of varying aerosol conditions in the upstream Arctic boundary layer, as well as marine aerosol sources and anthropogenic pollution, on the CAO clouds and on ice initiation and snow growth processes in a range of wind and temperature regimes;
* evaluate ground-based remote sensing observations performed with the ARM mobile facility with accompanying aircraft measurements, and broaden the ARM point observations of CAO to the regional scale using those airborne measurements, as detailed below;
* and provide integrated data sets of dynamical, thermodynamical, and microphysical characteristics of CAO boundary layer to enable constraining high-resolution numerical simulations, developing process-level understanding of BLC, and, subsequently, evaluating and improving representations of shallow convection in cold-air outbreaks in weather and climate.

The field campaign will be launched in the 2019-2020 timeframe. This is late in YOPP but fits well with the recently added YOPP winter SOP in 2020, due to MOASiC. Due to logistical considerations, many instruments must be deployed in late summer of 2019, but the Special Observing Period (SOP) will focus on winter, when
CAOs are most frequent; Jan-Apr 2020. The COMBLE observation program is built around several instrument sites. The ARM Mobile Facility (AMF) will be deployed far downstream from the ice edge, at the coast of northern Norway; most likely at Andenes, that has the necessary infrastructure and a wide sector with open-water fetch. The midstream site will be Bear Island; this is an ideal site but due its remote location and lack of a harbor, a sub-set of mobile ARM instruments will be located here; surface-based remote sensing instruments, including a mobile cloud radar. Bear Island has an operational weather station operated by the Norwegian Met Service with operational radiosoundings; COMBLE will increase the number of soundings per day during the SOP. Closer to the ice edge COMBLE will benefit from partner institutions with already existing observations at Ny-Ålesund on Svalbard, and for upstream conditions COMBLE will rely on MOSAiC; at this time the drifting icebreaker Polarstern should be in the ice north of Svalbard. All fixed sites will provide both advanced surface-based remote sensing of the lower troposphere and in-situ observations such as surface fluxes and radiosoundings and will be tied together with research aircraft; the NCAR C-130 from the USA, and Polar-5 and HALO aircrafts from Germany. Satellite information will also be used.

COMBLE will also provide modeling on all relevant scales, from the local scale using LES and/or cloud-resolving models, over the regional scale using mesoscale models for numerical weather prediction and on to the global scale using GCMs. To capture the explicit interactions among processes at the surface, boundary layer processes and cloud processes including aerosol, precipitation and radiation that are associated with cold-air outbreaks, small-scale cloud resolving and large-eddy simulation (LES) models will be based directly on in-situ and remote sensing observations. Regional scale numerical weather prediction (NWP) models will be used to implement and test improved physics representation derived from the small-scale model simulations. Improved forecasting capability of the NWP models will be evaluated for the spatial and temporal evolution of the boundary layer, the cloud morphology and phase partition, and the precipitation associated with CAO. Finally, GCMs will be implemented to access the mass and energy exchanges between the surface and the atmosphere associated with CAO (GCMs) based on the improved understanding of CAOs from both observations and model physics; GCMs will also be used to create present and future climatologies of CAOs.

**Timeline**

2018-01-01 - 2021-12-31

**Regional emphasis**

Northern hemisphere: Yes

Southern hemisphere: No

**Further specification**

Northern North-Atlantic, from Northern Norway to the ice edge.
Key project deliverables

This is a science-driven project, motivated by a need for increased understanding. Hence the main deliverables are science papers, model improvements and an extensive dataset for further model development and model evaluations and testing.

Data management

The field program rests heavily on DoE ARM and NCAR facilities, that have pen databases for all data that is collected. Other participants also have open data requirements from their national funding agencies. All data will be openly available to the public, but likely at different actual locations.

Is data provided to WMO Global Telecommunication System

Yes

Real-time provision

Operational-type observations, such a synop observations from the different sites, radiosoundings and drop sondes will be distributed to the GTS in real time.

Other information

Funding is being sought during 2017. US funding comes primarily from NSF and DoE ARM, UK funding from NERC, German funding is already avialble through the AC3 project, and Swedish and Norwegian funding is sought from national funding agencies.

With several funding agencies in different countries involved, no single time for the funding is possible; the date above is an average guess. ARM has already approved a pre-proposal for the AMF; full proposals to ARM and NSF are being drafted now. Other countries than US have other time lines.

Timelines

<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date</th>
<th>End date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern North-Atlantic</td>
<td>70-90 North</td>
<td>15 West to 30 East</td>
<td>2019-08-01</td>
<td>2020-06-01</td>
<td>Field activity; total time, note SOP 2020-01-01 through 2020-03-31</td>
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</tbody>
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