

High Impact Weather Research Section

Cloud Physics Research Program

Overview

BACKGROUND

In order to deliver on mandate, which includes scientific research on the monitoring and prediction of weather and climate conditions for Canadians, the research conducted in HIWR is defined as belonging to one or more of the following four research programs:

- Radar
- Aircraft
- Nowcasting/High-Impact Weather
- Cloud Physics

The Cloud Physics (CP) program serves to improve the measurements of clouds, precipitation and radiation, both from in situ and remote sensing observations, the physical understanding of cloud processes, and the representation of clouds and cloud processes in numerical models, including those used in ECCC operational prediction systems. Within MRD and the department at large, the CP program provides a direct link between HIWR and the NWP and climate modeling activities as well as a path for the other three HIWR research programs to contribute indirectly.

This document provides a brief overview of the HIWR's CP research program, with mention of a few current projects that are part of the program.

MAIN THEMES

The following are the main themes of the CP program, to which the various specific on-going projects, from short-term to long-term, belong.

1. Measurements of clouds/precipitation/radiation using specialized instruments

This theme pertains to improving our capacity to measure cloud properties and precipitation as well as to explore and develop better ways to apply such measurements to the evaluation of clouds, precipitation, and radiation in NWP models, both for standard verification and to examine and understand strengths and weakness of the model.

This includes the following:

- improvements of measurement techniques and data processing
- use of dual-polarization radar to evaluate NWP model clouds/precipitation
- use of satellite observations to examine model clouds/precipitation/radiation
- use of research aircraft observations to evaluate model cloud microphysics and to validate radar retrievals
- use of in situ or specialized remote sensing ground-based microphysical observations to evaluate model clouds/precipitation
- use of instrument simulators (for ground-based radar and satellite observations) to examine model clouds/precipitation

2. Advancing the understanding of fundamental cloud physics

As NWP models go to higher resolution, it becomes increasingly important to represent detailed in-cloud microphysical processes. In contrast to most subgrid-scale processes in atmospheric models, whose representation by physical parameterization schemes is necessary almost entirely due to lack of resolution (and computational resources), the scientific community lacks a complete understanding of the fundamental physics for many in-cloud processes. These processes impact precipitation and radiation in clouds, thus the lack of complete understanding is an obstacle to our capacity to represent them, and/or their effects, in atmospheric models. Therefore, in addition to contributing to fundamental scientific knowledge, this theme ultimately serves to improve numerical models (theme 3).

Some examples of specific current topics include research on:

- secondary ice production
- ice crystal growth/decay rates (and change in particle shape)
- formation of freezing drizzle and freezing rain conditions
- representation of mixed-phase clouds
- 3D cloud effects on radiative transfer
- Radiative transfer in optically thin ice clouds

3. Improvement to the representation of radiation and grid-scale clouds in numerical models

A premise behind this theme is that regardless of the extent to which AI-based models become used for operational NWP, traditional dynamical/physical models will always play key roles in NWP, though these roles may shift from providing direct numerical guidance for weather forecasting towards training AI-based modeling systems and/or individual model components. Therefore, the capacity to parameterize physical processes related to clouds in dynamical models will always be relevant in ECCC; in fact, it will become increasingly important as NWP systems move to higher resolution, either to provide direct numerical guidance or to train AI-based systems. HIWR scientists (as well as those in other sections in MRD) have specialized expertise in the parameterization of radiative transfer and grid-scale cloud microphysics, as well as expert knowledge in the themes 1 and 2, which support theme 3.

Specific topics include the following:

- improvement of the 3D radiative transfer
- Monte Carlo radiative transfer code
- improvement and continued development of the P3 microphysics scheme
- improved links to the microphysics scheme with prognostic aerosols
- development of prediction capabilities for contrail cirrus clouds