TICFIRE

Thin Ice Clouds in Far IR Experiment for Microphysics and Atmospheric Water Cycle in the Arctic

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Areas of contribution
User-aspects and verification
Polar atmospheric processes
Modelling and forecasting
Polar-lower latitude linkages
Education
Observations
Data assimilation

Summary
Optically Thin Ice Clouds (TIC) processes are still poorly represented in data assimilation and in atmospheric models. It is now recognized that anthropogenic aerosol can alter cloud microphysics and precipitation. In addition to the needs of filling a gap in cloud observation at high latitudes, these clouds, sensitive to aerosols via
ice nucleation, can significantly modulate the amount of far infrared radiation escaping the Earth, and consequently the temperatures in the upper and the mid troposphere. Since their signature in the far infrared is also very sensitive to their microphysical properties (crystals size and shape) and optical depth, these quantities can be retrieved from ground-based and satellite observations. Theoretical calculations and measurements demonstrate that the far infrared spectrum of the atmosphere could provide valuable information for weather forecast data assimilation and climate simulations, about its water vapour content, the microphysical characteristics of ice clouds and common light precipitation, especially in dry and cold regions. In this context, the Thin Ice Clouds in the Far InfraRed Experiment (TICFIRE) tech demo satellite mission was proposed to the Canadian Space Agency and is currently under review. In view of YOPP, with the Canadian Space Agency and in collaboration with NETCARE, PAHA and AVATAR, we have initiated new measurements in the mid and far IR range (8-50 µm) to advance our knowledge of the water cycle in the high Arctic with the deployment of the Far IR Radiometer (FIRR). The FIRR is meant to be a breadboard for the future TICFIRE satellite instrument and for new ground-based measurements with potential applications to Canadian Arctic stations for improving monitoring and weather prediction in polar regions.

Description

Currently, one of the most sought-after measurements in cloud and radiation research is far-infrared radiation. Actually, our monitoring of the solar and IR spectrum is well covered by many satellites, with the notable exception of the spectrally resolved far IR (16 to 100 µm) range, so critical for the atmospheric energy balance responsible for weather and climate processes. Current climate and forecasting models lack an adequate dataset in the far IR for their verification. The same spectral range where cooling is strong is also of interest for satellites, ground, and aircraft-based measurements, for this is where the variation of spectral transmittance (or the Jacobian) is most effective at altering the tropospheric energy budget at low water vapor concentration in cold climates when the rotation band weakens, opening the so-called "dirty window". For clear-sky conditions, more than half of the outgoing thermal energy comes from the far-IR spectral region. To add to the problem, a prime concern with observing and modelling climatic change, especially in polar regions, is the great uncertainty of cloud microphysics on far-IR radiative transfer. This is most crucial for very cold atmospheres where far-IR emission is dominant, especially during the cold polar nights.

Actually, no significant far IR monitoring is done from space and E-AERI (limited to wavelength below ~25 µm) at ground stations are few and far between. Given this situation, it is recognized that new radiometric instruments that measure far-IR radiation are in need of and are being developed (e.g., the TICFIRE mission proposed by Blanchet et al., 2009). While spectrometers and interferometers have spectral resolutions in the range of 0.1 cm-1 to 1 cm-1 (e.g., AERI and FIRST), their slow response, often in limb-mode, is ill-suited for climate and weather purposes that require viewing of clouds on a nadir-centred wide swath at horizontal resolutions of ~10 km. An alternative that we have proposed, based on microbolometer radiometer technology, operates at low spectral resolution in the mid- and far-IR ranges (8 µm to 50 µm). Targeted applications include cloud microphysics, radiative transfer, vertical profiling of thin ice clouds and water vapor concentration for analyses of climatic processes and weather forecasting. The rational for far IR campaign with suitable instruments may be summarized by the following statements:

• The lack of a dedicated campaign on polar thin ice clouds (TIC) during the Arctic polar night (October – April) is an important gap in our knowledge of the physical processes involved in their development, limiting their parameterization in atmospheric prediction models;
• We have no in-situ confirmation of the predicted climatic effect of acid coated IFN on ice nucleation and TIC microphysical properties;
• The new FIRR instrument specially designed for monitoring TIC properties requires in situ verification and
validation before operational applications (ground or space-based).

Theoretical calculations demonstrate that the far infrared spectrum of the atmosphere could provide valuable information for weather forecast data assimilation, about its water vapor content, the microphysical characteristics of ice clouds and common light precipitation, especially in dry and cold regions. In this context, the Thin Ice Clouds in the Far InfraRed Experiment (TICFIRE) tech demo satellite mission was proposed to the Canadian Space Agency and is currently under review. To prove the relevance and feasibility of such a mission, the Far InfraRed Radiometer (FIRR) was developed as a prototype of the satellite instrument. As Eureka is an ideal site to test the FIRR, the latter was installed at the CANDAC-ØPAL site in October 2015 to measure downward longwave radiation throughout the winter-spring 2015-2016. We are planning to extend these measurements through the YOPP period with a second instrument proposed by Environment and Climate Change Canada (ECCC) at the Iqaluit super-site. The FIRR takes measurements in 9 spectral bands ranging from 8 to 50 \( \mu \text{m} \), particularly covering the under-explored far infrared part of the spectrum. Operating the FIRR at Eureka and Iqaluit serves four objectives:

1) Validating FIRR measurements against the reference provided by the Extended range Atmospheric Emission Radiometric Interferometer (E-AERI) installed nearby, and against radiative transfer calculations based on temperature, pressure and relative humidity profiles from other instruments at the sites.

2) Highlighting the sensitivity of FIRR measurements to ice clouds, in support of the TICFIRE mission and assessment of weather prediction improvement through data assimilation algorithms and best estimation methods.

3) Developing retrieval algorithms for water vapor and ice cloud properties, and comparing them to independent retrievals available from the other instruments installed at the same sites.

4) Evaluating the contribution of polar clouds on the energy cycle and weather systems development at the regional scale and global scales.

Timeline


User relevant aspects

Close collaboration with Environment and Climate Change Canada (ECCC) and the Canadian Space Agency (CSA)

Provider relevant aspects

Sharing instruments and support at the Arctic sites of Iqaluit (ECCC) and Eureka (CANDAC-PAHA and ECCC).
Regional emphasis

Northern hemisphere: Yes
Southern hemisphere: No

Key project deliverables

1) Spectral (broadly resolved) far IR measurements in conjunction with a suite of other instruments at the sites.
2) Assessment of the strength of polar thin ice clouds (TIC) as a function of properties in the energy balance and generation of synoptic storms at high latitudes.
3) Contribution to improving radiometric instrument suitable for polar conditions
4) Contribution to data assimilation of clouds and water profiles in weather forecasting systems especially during cold seasons.

Data management

Locally at the UQAM site with a dedicated system

Is data provided to WMO Global Telecommunication System

Yes

Real-time provision

Limited to near real time radiance data

Other information

Currently phasing out initial funding from FAST program at CSA and extended to the end of March 2018.