# Capabilities of the EUMETSAT Polar System Second Generation Ice Cloud Imager

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## Introduction

The Ice Cloud Imager (ICI) will be launched in 2022 aboard the second of the EUMETSAT Polar System Second Generation satellites (METOP-SG B), with its primary objectives of supporting climate monitoring of ice cloud properties and validating and improving these properties in numerical weather prediction (NWP) models (www.eumetsat.int/website/home/Satellites/FutureSatellites/EUMETSATPolarSystemSecondGeneration/ICI/index.html). It will yield direct, sensitive measurements of ice clouds and complement heritage observing systems by providing a fundamentally new source of data compared to past missions.

This study examines the ability of the ICI to measure upper tropospheric ice clouds as compared to sensors on legacy satellite missions. This information will be used to identify which Environmental Data Records (EDRs) should be produced by NESDIS (including product requirements), determine what changes are needed to the STAR enterprise algorithms in order to create NOAA-unique EDRs, and, finally, to develop approaches for user engagement and exploitation of ICI data within the end user community.

Our initial product development efforts will largely involve pre-mission radiative transfer modeling activities to understand the information content and ICI channel sensitivities to cloud ice content, ice water path, ice habit and effective ice particle size. Radiative transfer calculations will initially be based on RTTOV (the Community Radiative Transfer Model, unfortunately, does not currently cover the submillimeter wavelength range) for a unique sub-km global NWP simulation by the Non-hydrostatic Icosahedral Atmospheric Model (NICAM). Analyses based on these synthetic data will provide information on how the ICI can complement NOAA enterprise cloud products generated from METOP-SG A visible/infrared and microwave data and help to establish requirements for the NESDIS ICI products.

## Methods

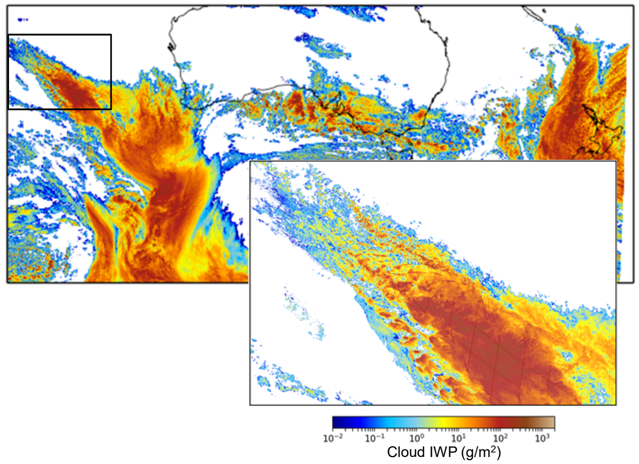
### Instrument characteristics

- The ICI is a 13-channel conical-scanning submillimeter-wave imaging radiometer with instrument specifications given in the table below.[1]
- The Microwave Humidity Sounder (MHS) is the heritage sensor used in obtaining water vapor profiles and cloud ice properties. It is a 5-channel cross-track-scanning millimeter-wave radiometer with frequencies at 89 GHz (0.22K), 157 GHz (0.34K), 183.311±1 GHz (0.51 K), 183.311±3 GHz (0.40 K), and 190.311 GHz (0.46 K), where NeDT is in parentheses. Footprint size is about 15.9 km at nadir and 50 x 27 km at the swath edge.[2]

| Channel | Center freq (GHz) | Bandwidth (MHz) | NeDT cold (K) | NeDT warm (K) | Footprint (km) | Zenith Angle (deg) | Application |
|---|---|---|---|---|---|---|---|
| 1 | 183.31±7 | 2x2000 | 0.42 | 0.53 | 15.10 | 53.85 | Water vapor profile and snowfall |
| 2 | 183.31±4 | 2x1500 | 0.48 | 0.61 | 15.02 | 53.85 | |
| 3 | 183.31±2 | 2X1500 | 0.48 | 0.61 | 15.01 | 53.85 | |
| 4H | 243.2±2.5 | 2x3000 | 0.42 | 0.50 | 14.84 | 51.86 | Cloud ice and cirrus |
| 4V | 243.2±2.5 | 2x3000 | 0.43 | 0.52 | 14.47 | 51.86 | |
| 5 | 325.15±9.5 | 2x3000 | 0.84 | 0.94 | 14.85 | 53.91 | Cloud ice effective radius |
| 6 | 325.15±3.5 | 2x2400 | 0.94 | 1.05 | 14.91 | 53.91 | |
| 7 | 325.15±1.5 | 2x1600 | 1.15 | 1.29 | 14.90 | 53.91 | |
| 8 | 448±7.2 | 2x3000 | 0.94 | 1.04 | 14.38 | 53.92 | Cloud ice water path and cirrus |
| 9 | 448±3 | 2x2000 | 1.16 | 1.29 | 14.39 | 53.92 | |
| 10 | 448±1.4 | 2x1200 | 1.52 | 1.69 | 14.23 | 53.92 | |
| 11H | 664±4.2 | 2x5000 | 0.89 | 0.96 | 14.80 | 51.77 | |
| 11V | 664±4.2 | 2x5000 | 0.89 | 0.96 | 14.75 | 51.80 | |

### Cloud simulation

- The NICAM global simulation was initialized at 00 UTC 22 August 2012 with 3.5 km horizontal resolution and 94 vertical levels. Following a 3-day spin-up, the simulation was continued with 870 m resolution.[3]
- Our case study uses the 870 m resolution data at 00:30 UTC 26 August 2012.
- Microphysics parameterization is a modification of the Lin method[4] for five hydrometeor species (cloud liquid, cloud ice, rain, snow, graupel).[5]

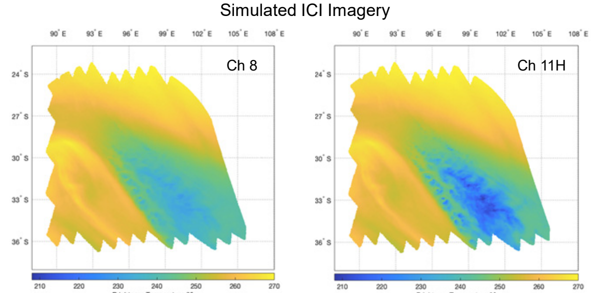



### Simulated MHS and ICI data

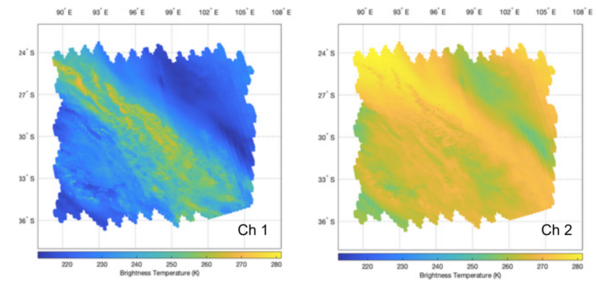
- RTTOV-SCATT v12.3 was used to compute both clear sky and all-sky sensor radiances from NICAM 870 m data; limitations include increased errors for strong scattering and unaccounted for sources of polarization generated by ice particles.
- High-resolution synthetic radiance data were collocated with conical-scanning AMSR-E geolocation data (used as a proxy for the ICI) assuming a footprint size of 14.8 km (3dB) and Gaussian spatial smoothing. A similar collocation method was used for the MHS but based on actual MHS geolocation data.

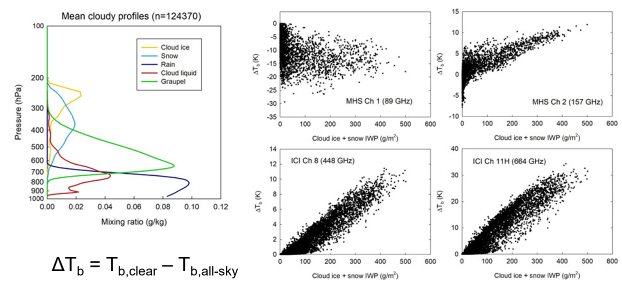
## Results

Simulated ICI Imagery




Simulated MHS Imagery




$$\Delta T_b = T_{b,clear} - T_{b,all\text{-}sky}$$

- ICI brightness temperature depression ($\Delta T_b$) at 448/664 GHz shows a linear relationship to ice water path (IWP), where the signal is dominated by significant snow in the upper troposphere (see left figure above).
- MHS window channels show no relationship at 89 GHz but a reasonable relationship exists at 157 GHz for larger IWPs that may also result from graupel.

## Conclusions

- Early results based on synthetic radiances for a high-resolution model simulation demonstrate the high sensitivity of the ICI to upper tropospheric ice as a complement to the ice precipitation sensitivity of the MHS.
- Next steps are to explore other radiative transfer models that account for polarization effects and include scattering properties for different ice particle habits, as well as extend the analysis to different regions and cloud types.

### References

[1]Bergadà et al., 2016, 14[th] Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, Espoo, Finland.
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[3]Satoh et al., 2014, Progress in Earth and Planetary Science, 1:18.
[4]Lin et al., 1983, Journal of Applied Meteorology, 22, 1065-1092.
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