Exploiting sub-millimetre microwave frequencies to improve weather forecasts at ECMWF

EUMETSAT Fellows Day, 2nd March 2026

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ECMWF

Overview

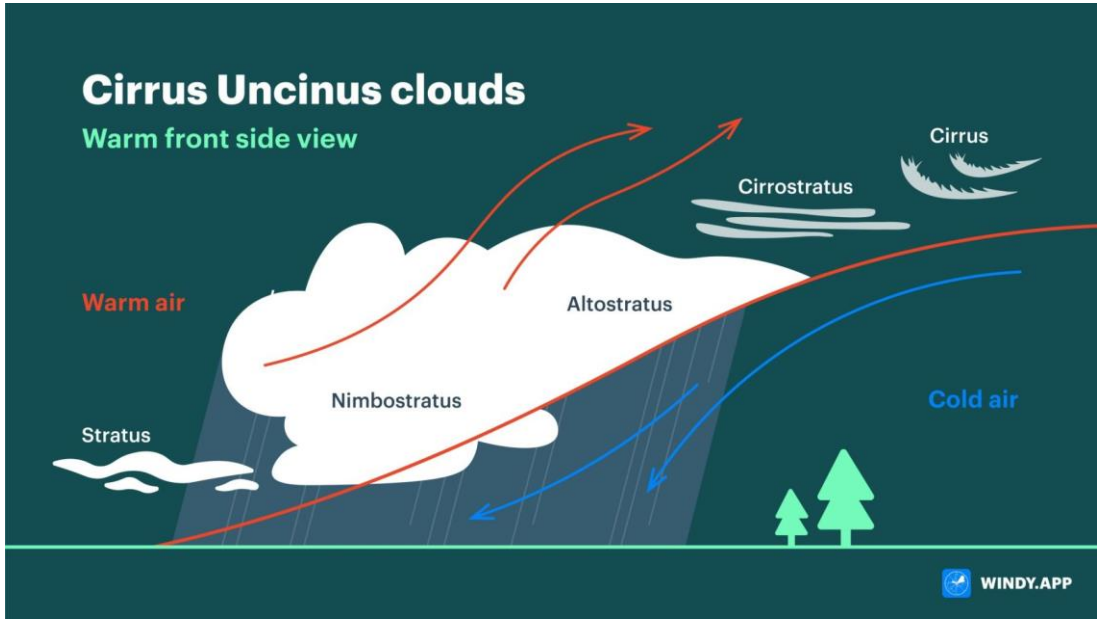
The importance of cloud ice in forecasting

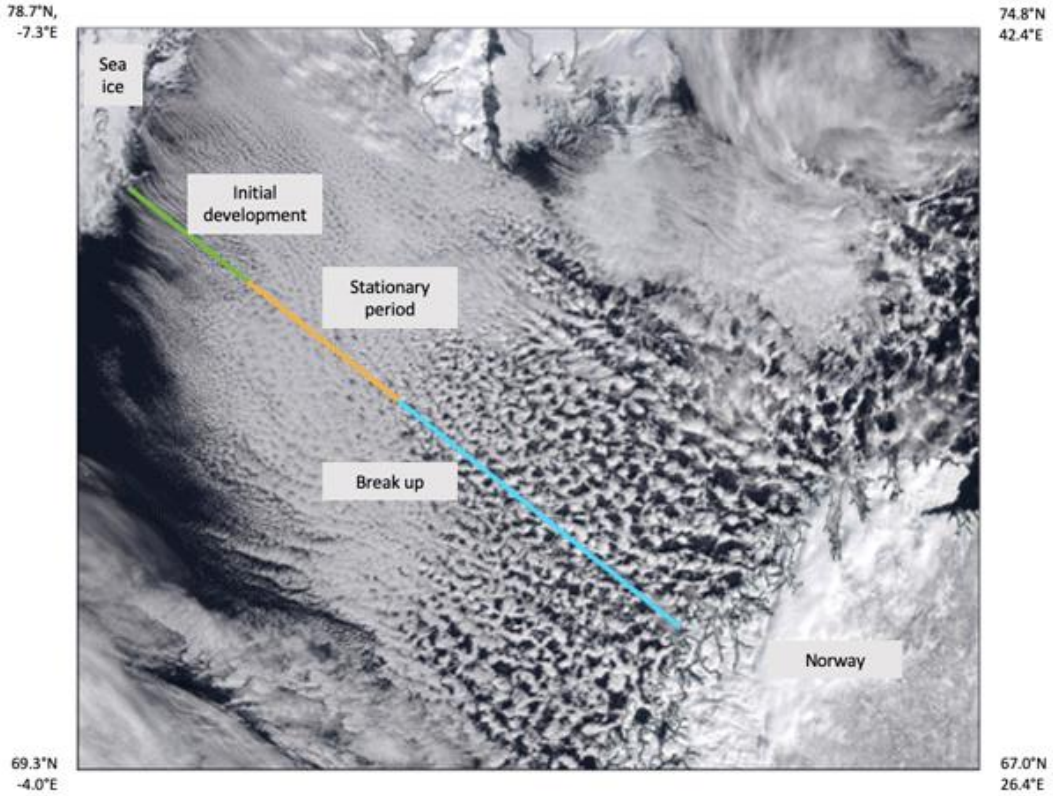
Assimilating sub-millimetre frequencies

Plans for the next year

The importance of ice clouds in forecasting

1. Signaling changing weather

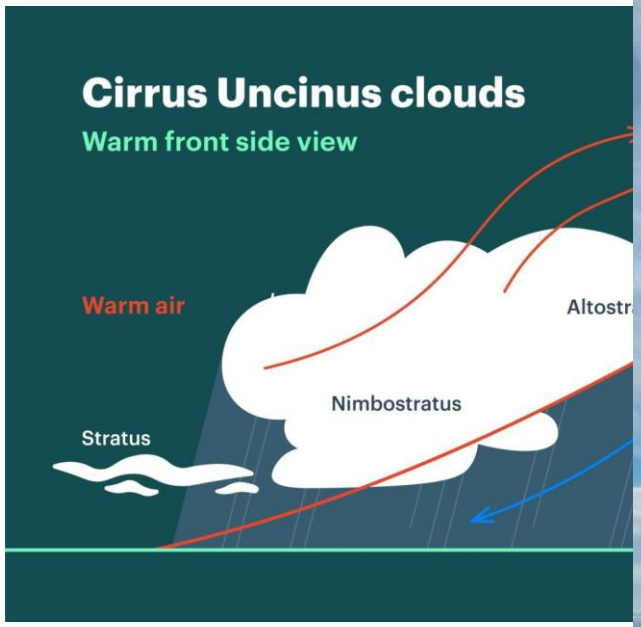


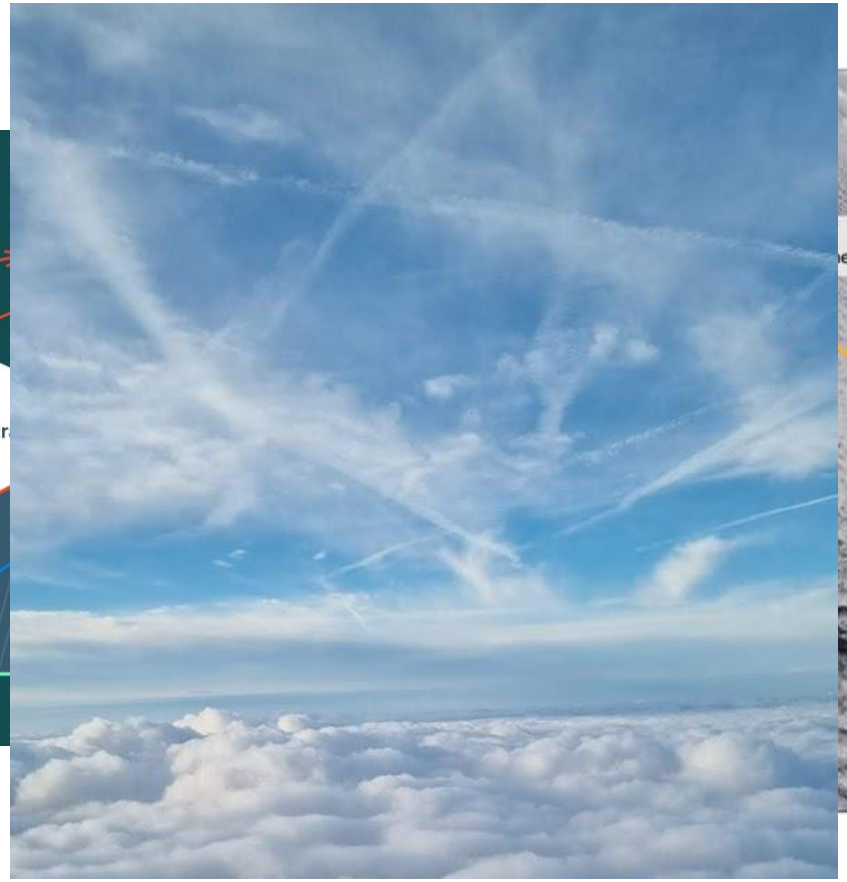


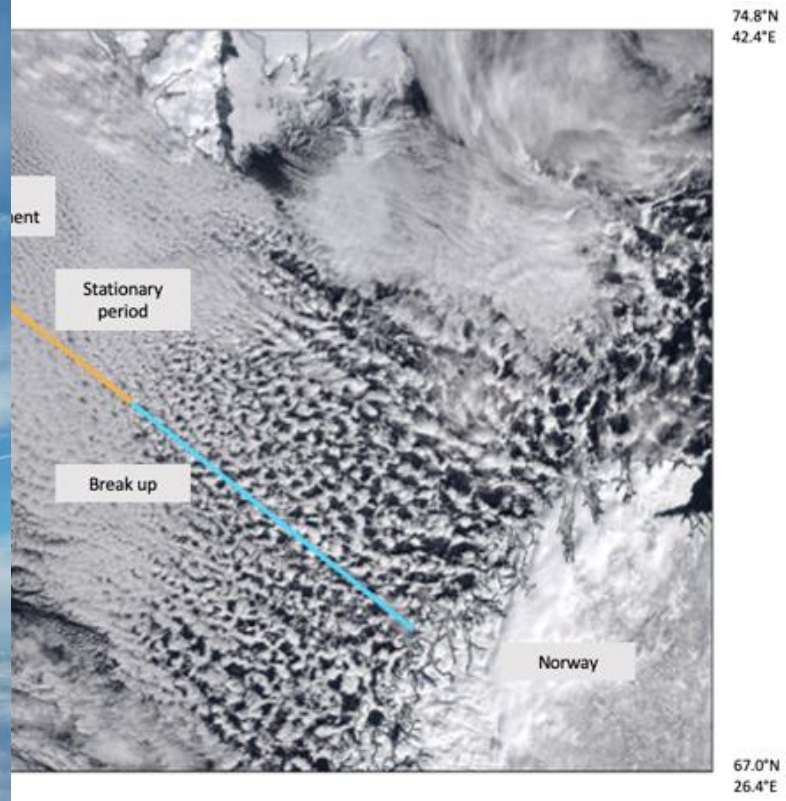
Murray-Watson et al. 2023

The importance of ice clouds in forecasting

1. Signaling changing weather



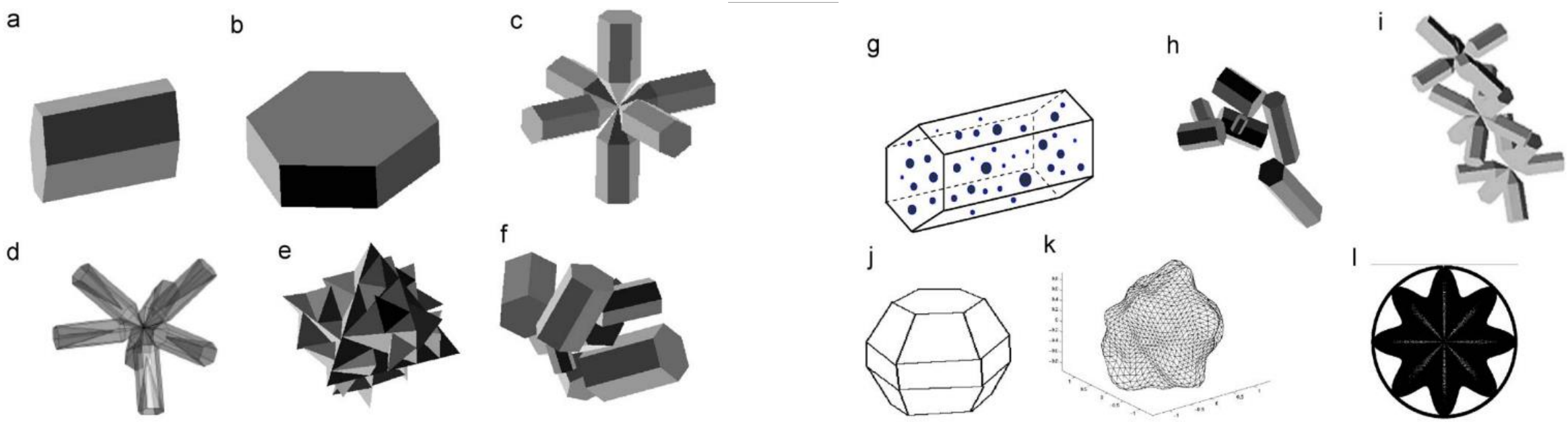




Murray-Watson et al. 2023

The importance of ice clouds in forecasting

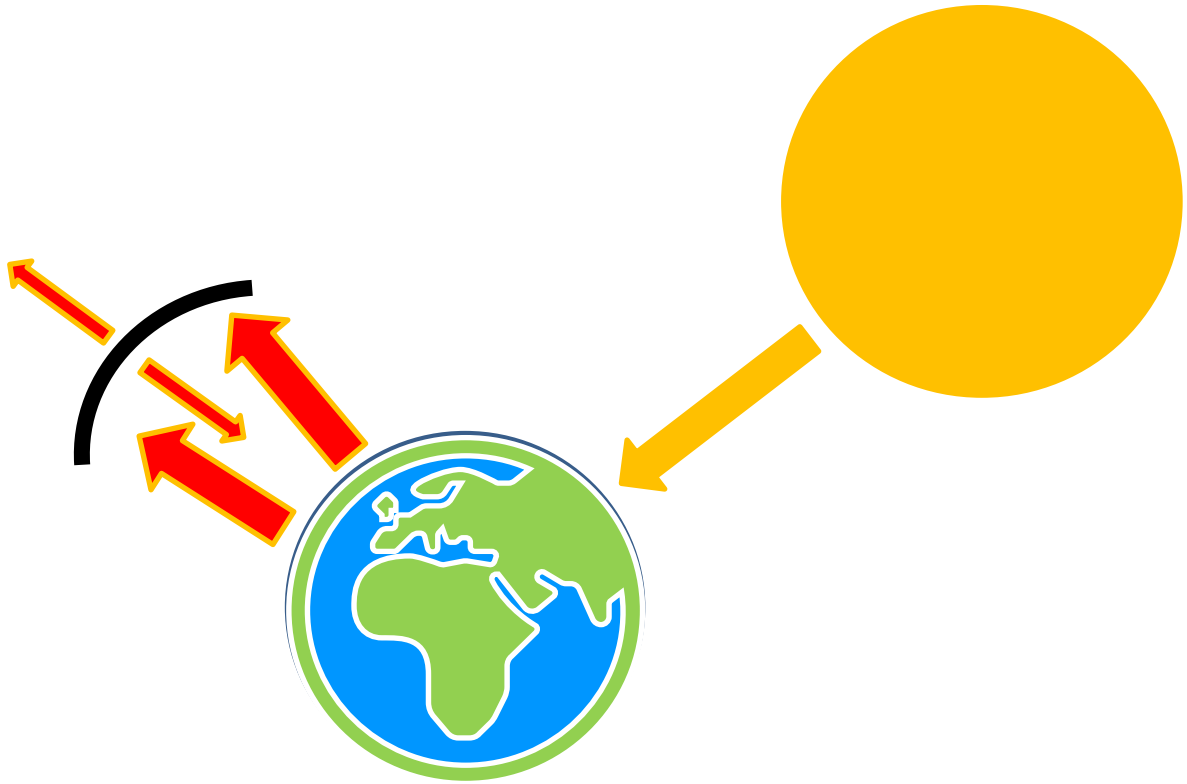
2. Crystals are crystals!



Baran et al 2009

The importance of ice clouds in forecasting

3. A changing climate

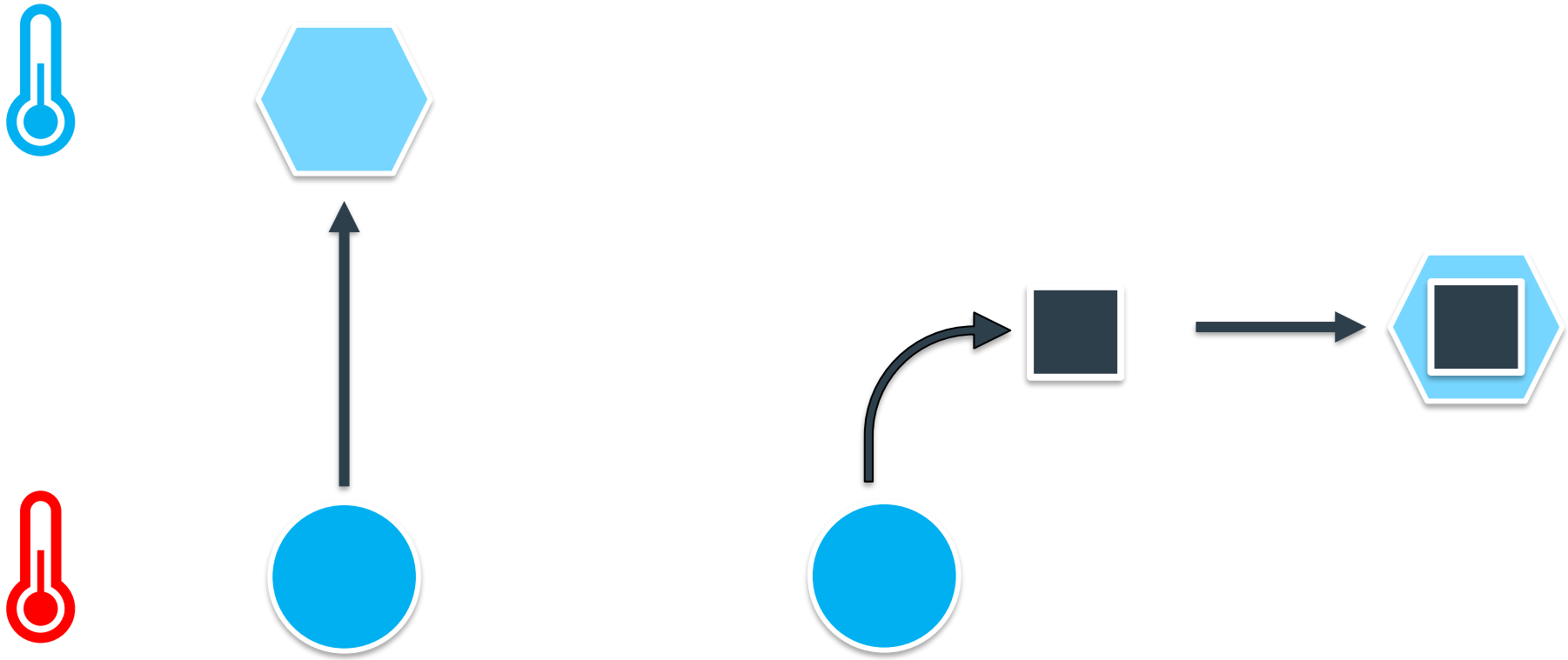


The complexities of ice clouds

Ice clouds form through two mechanisms:

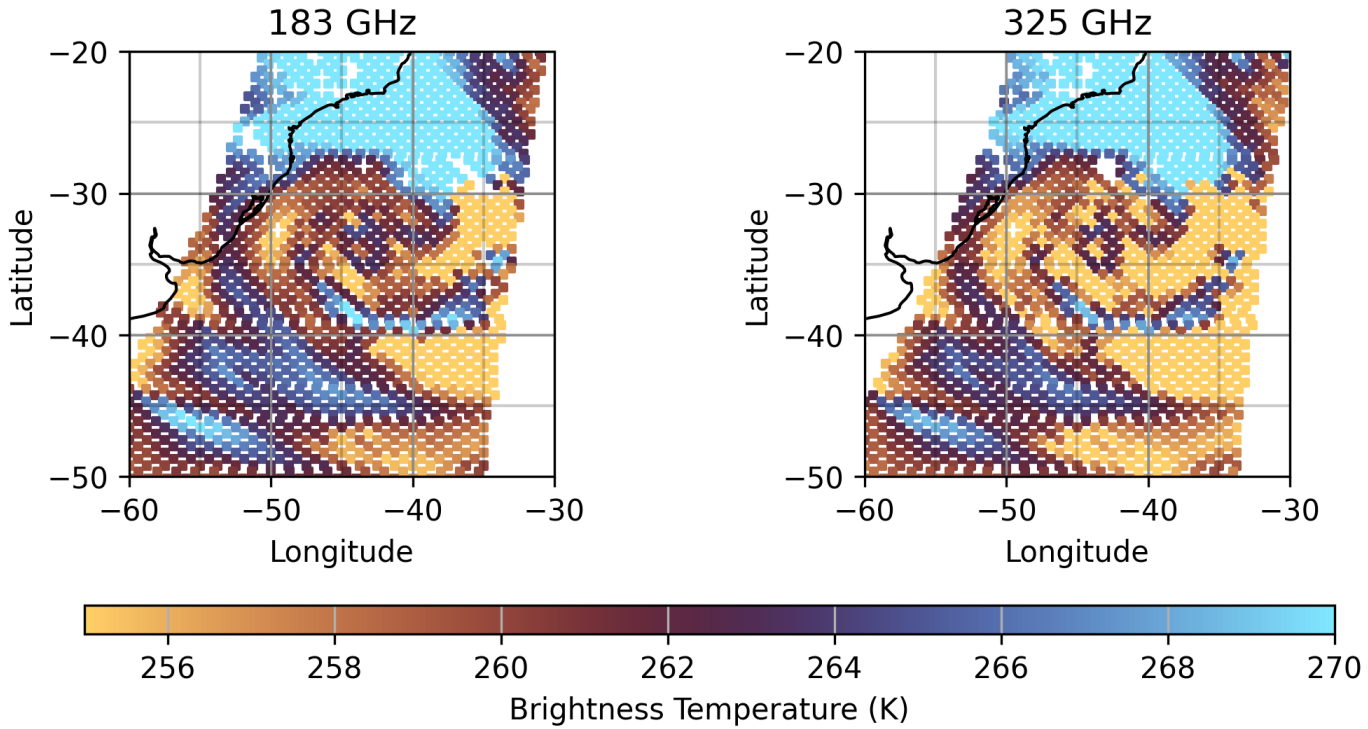
Homogeneous Freezing

Heterogeneous Nucleation



Where can we improve?

Exploiting sub-millimetre frequencies (>300 GHz) for ice clouds



Extinction of radiation is dominated by scattering for ice and snow at these wavelengths

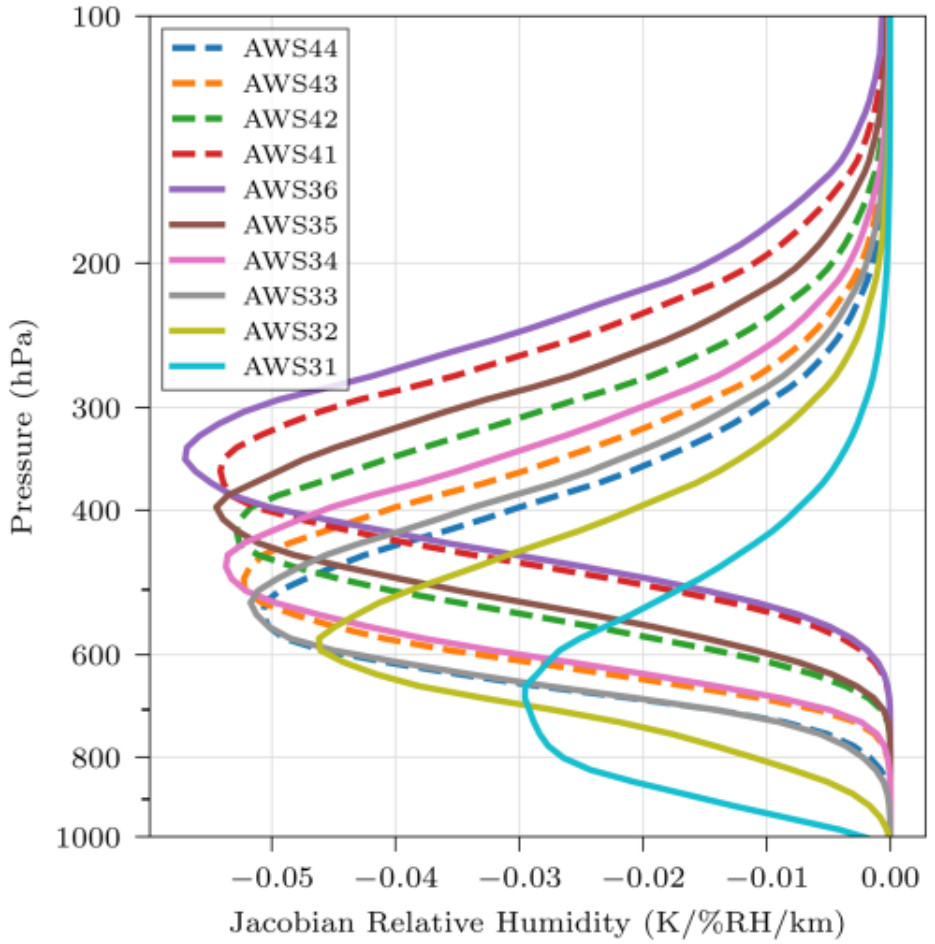
Arctic Weather Satellite (AWS) Microwave Radiometer

- Launched in August 2024 and assimilated (all-sky) at ECMWF since July 2025 (first to do so!)
- Improve Arctic and global weather forecasts
- Polar orbiting satellite holding a cross-track scanning microwave radiometer (developed in three years)
- Four horns:
  - 50 GHz (CH1-8)
  - 89 GHz (CH9)
  - 183 GHz (CH11-15)
  - 325 GHz (CH16-19)

AWS: Humidity and Ice Cloud Sensitivity

- The (solid line) 183 GHz and (dashed line) 325 GHz channels have a similar clear-sky sensitivity to humidity.

- Assimilating the 325 GHz channels (+183 GHz) should give us extra information about cloud ice.



Eriksson, et al. 2025

Precursor for EUMETSAT Polar System-Sterna (EPS-Sterna)

- The EPS-Sterna constellation contains (initially) six AWS-like satellites in sun-synchronous polar orbits.
- Provides unprecedented global and temporal coverage
  - Revisit time < 3 hours
- Expected to significantly improve NWP models
- Launch date (expected): 2029

OHB

Instruments onboard Metop-SG satellites

Microwave Sounder (MWS)

- Total power radiometer on board Metop-SG A
- Extends to 229 GHz
- Work begun at ECMWF to assimilate these observations

Ice Cloud Imager (ICI)

- Conical scanning radiometer on board Metop-SG B
- Extends further into the sub-millimetre range

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Assimilating sub-millimetre frequencies

What is the long-term impact?

How are these frequencies affecting the forecasts?

What is the long-term impact?

Run Observing System Experiments during the NH Summer:

Experiment 1: AWS 50 + 183 GHz

Experiment 2: AWS 50 + 183 + 325 GHz

What is the long-term impact?

Run Observing System Experiments during the NH Summer:

Experiment 1: AWS 50 + 183 GHz

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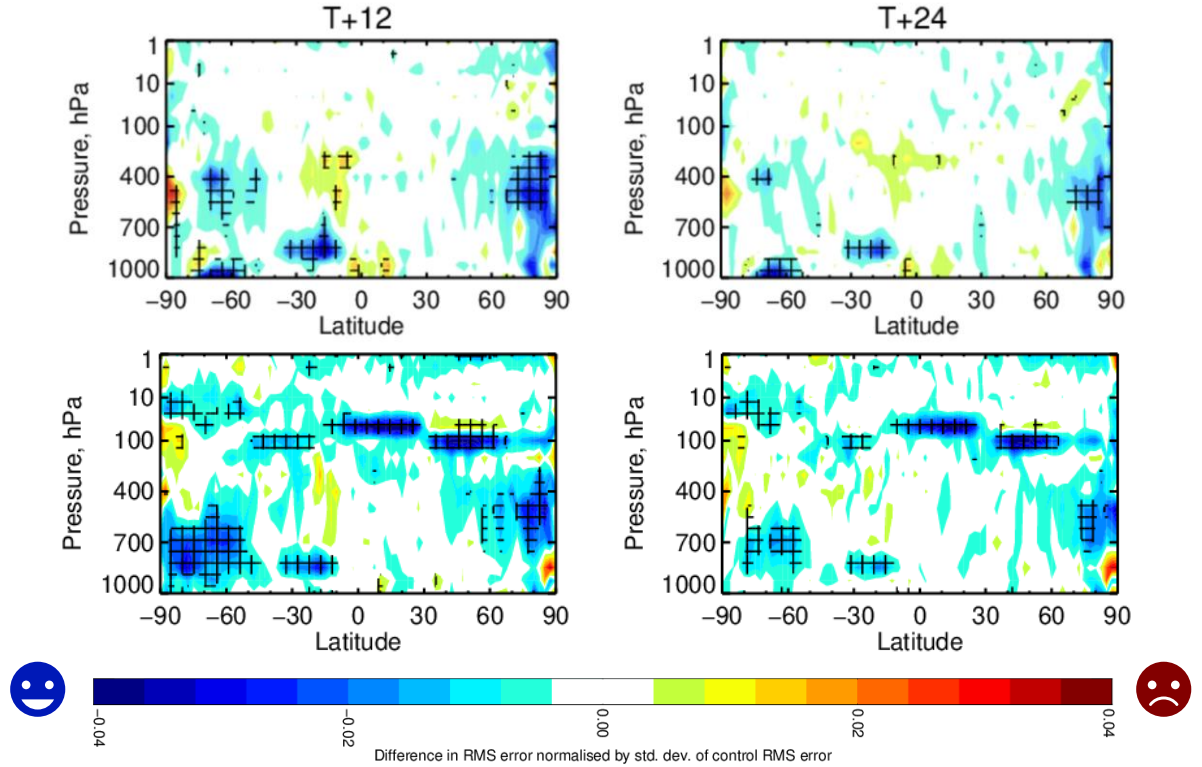
Forecast scores for (top) temperature and (bottom) humidity.

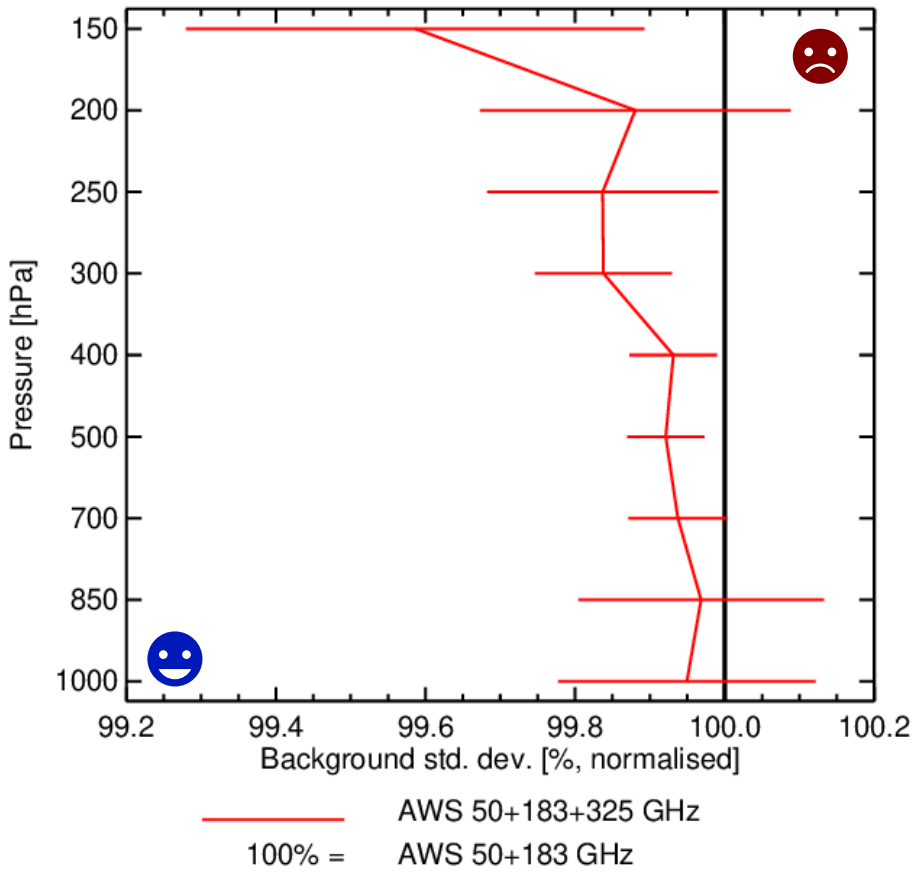
1. Clear improvements at higher latitudes
2. Improvements to the humidity at higher altitudes



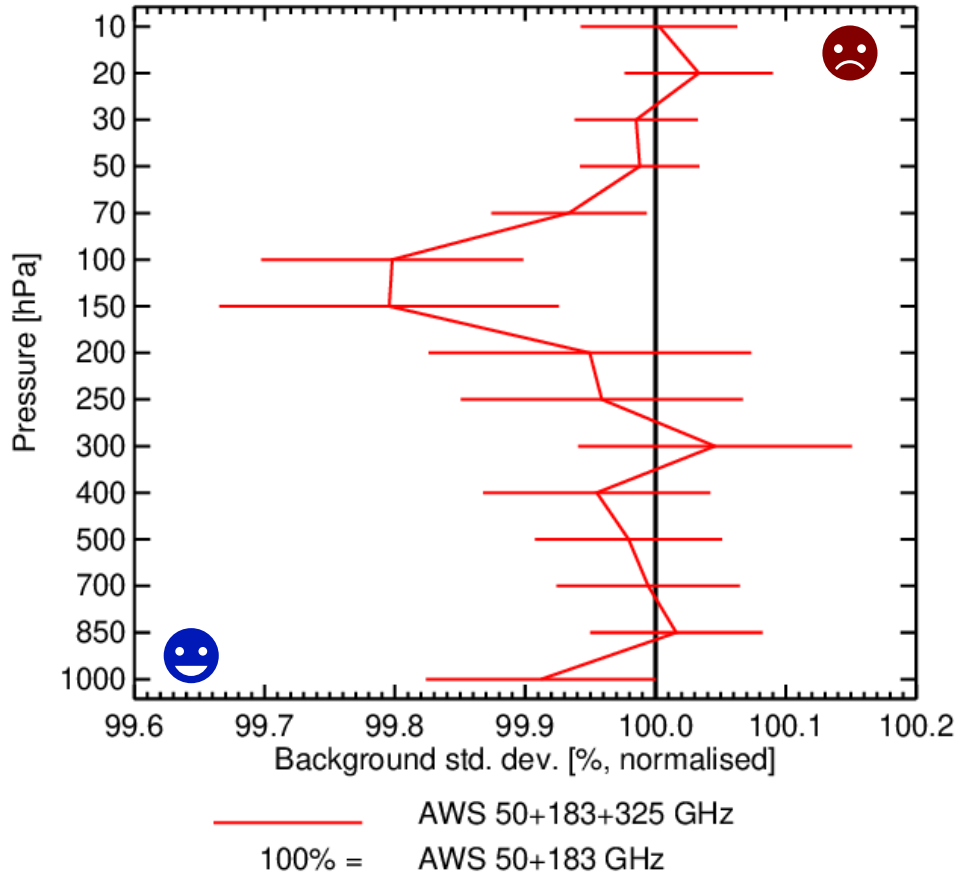
What is the long-term impact?

Explore the impact on forecasted winds through the Observed-Background stats

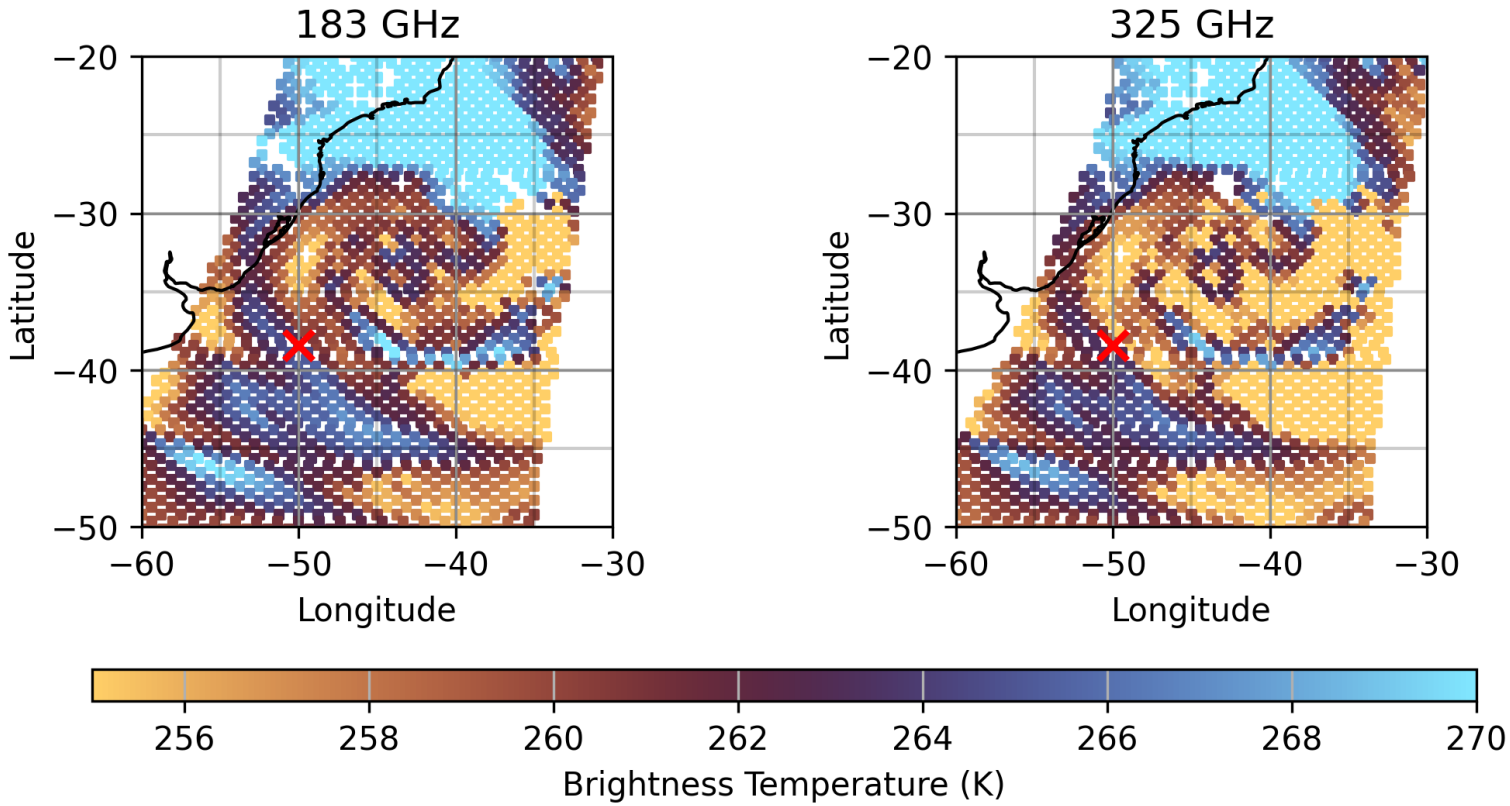
AMVs in the Northern Hemisphere



Winds across the Globe

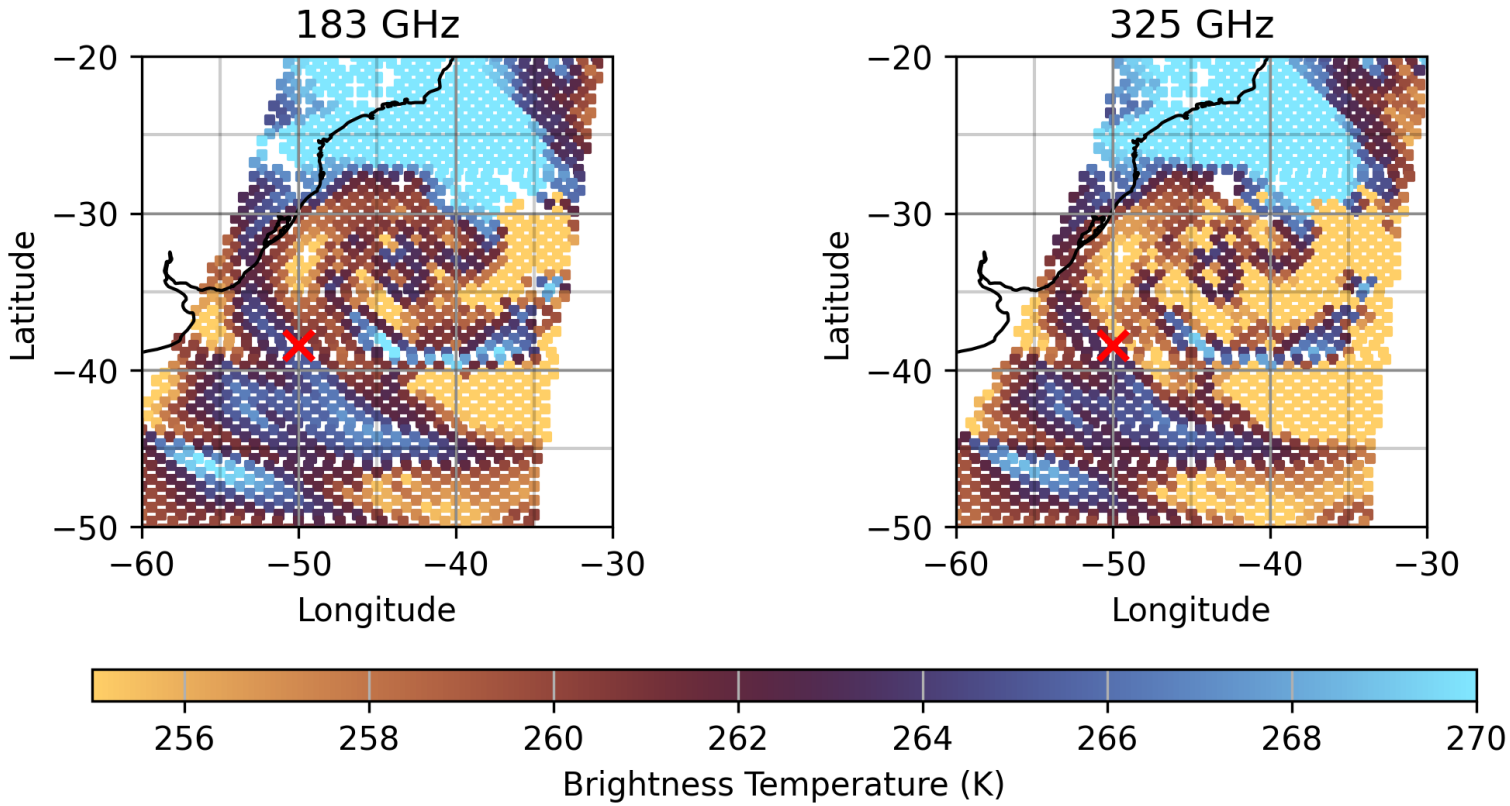


How are these frequencies affecting the forecasts?



How does a single AWS observation affect the assimilation?

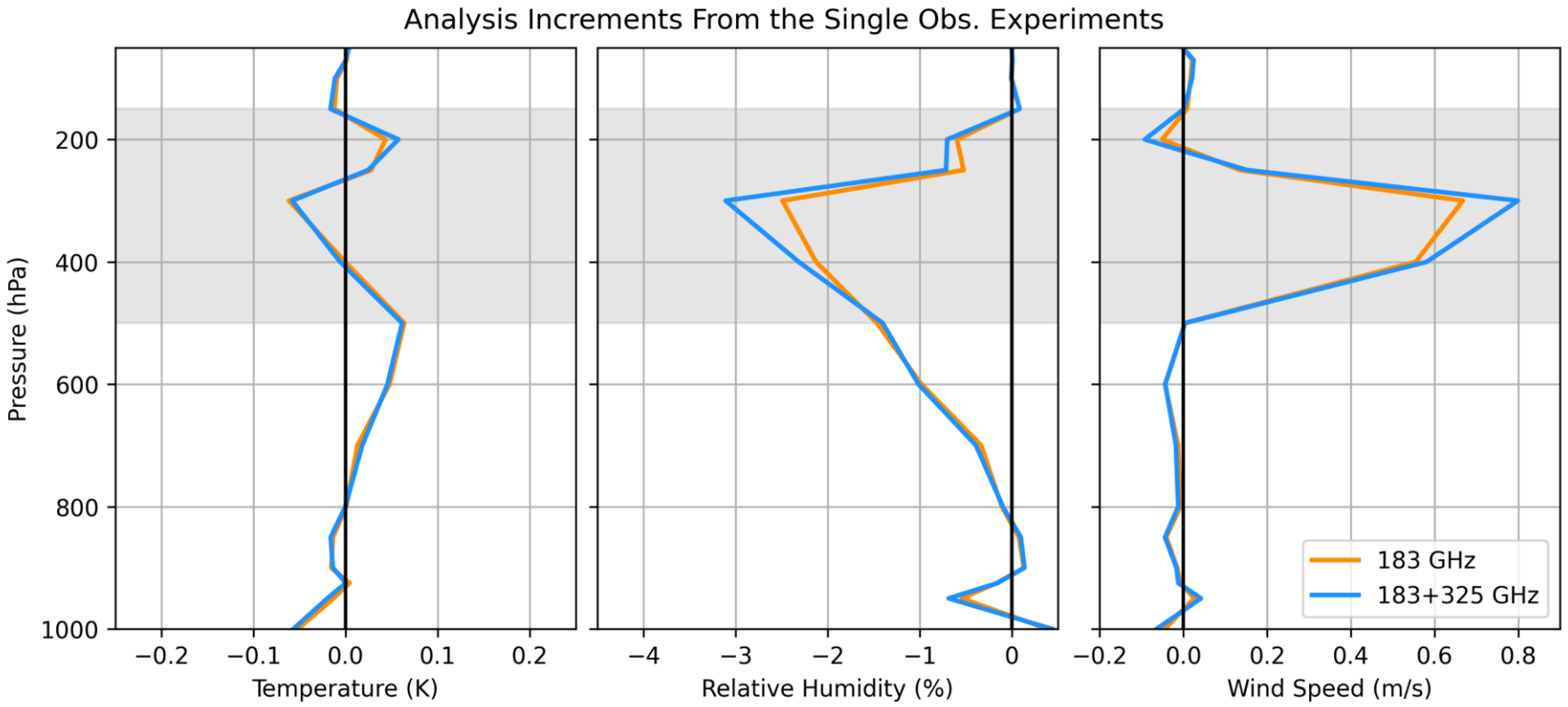
How are these frequencies affecting the forecasts?



Experiment 1: 183 GHz only

Experiment 2: 183 + 325 GHz

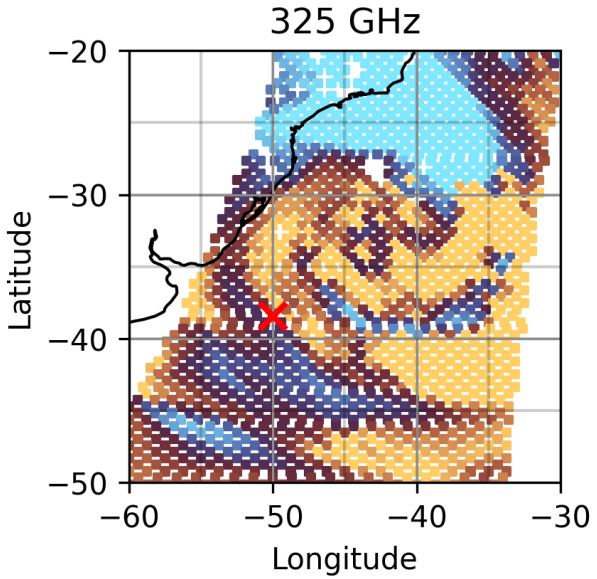
How are these frequencies affecting the forecasts?

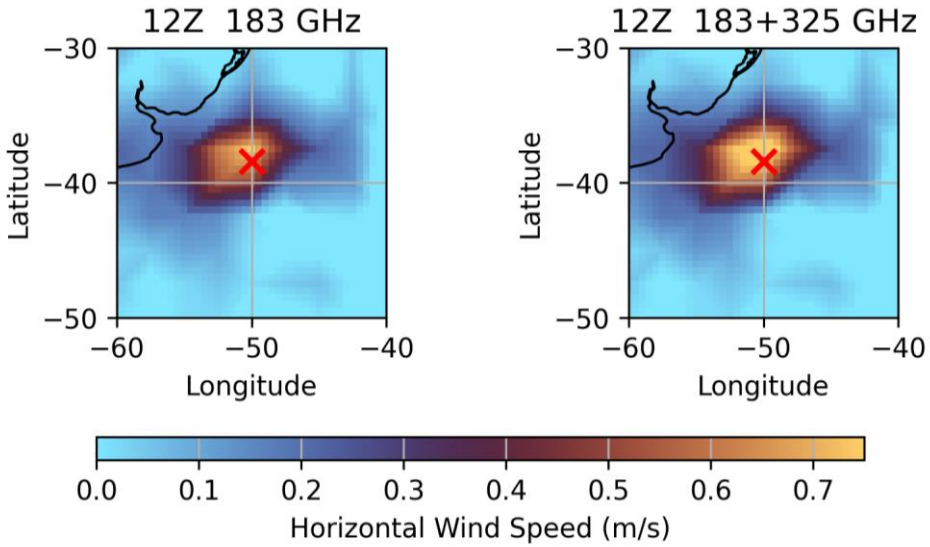


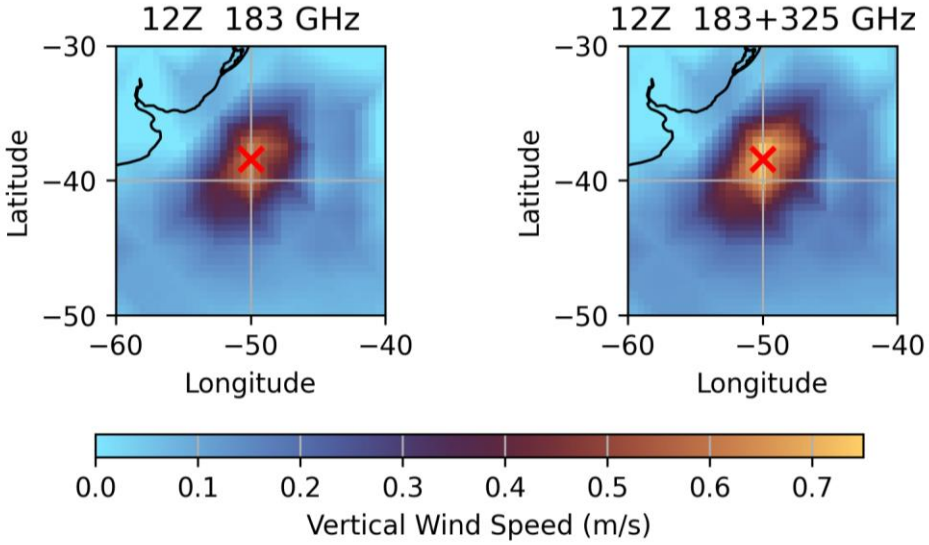
Including the 325 GHz channels strengthen the analysis increments

How are these frequencies affecting the forecasts?

- ~10% increase in both horizontal and vertical wind speeds
- Pushing the cloud further away in the right direction







Plans for the next year

Further exploiting the sub-millimetre range

Revision of the all-sky observation error models

Expand the use of surface-sensitive channels