Sub-mm cloud satellite projects

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Overview

- Climatology of Ice Water Path (IWP)
- Sub-mm wave cloud measurement principle
- Satellite mission proposal history
- Aircraft instruments
- Kiruna SAT group plans
- Summary

Missing in this talk:

Missions for rain measurement, particularly TRMM

Active missions, CLOUDSAT, CALIPSO, EarthCARE

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IWP models and data

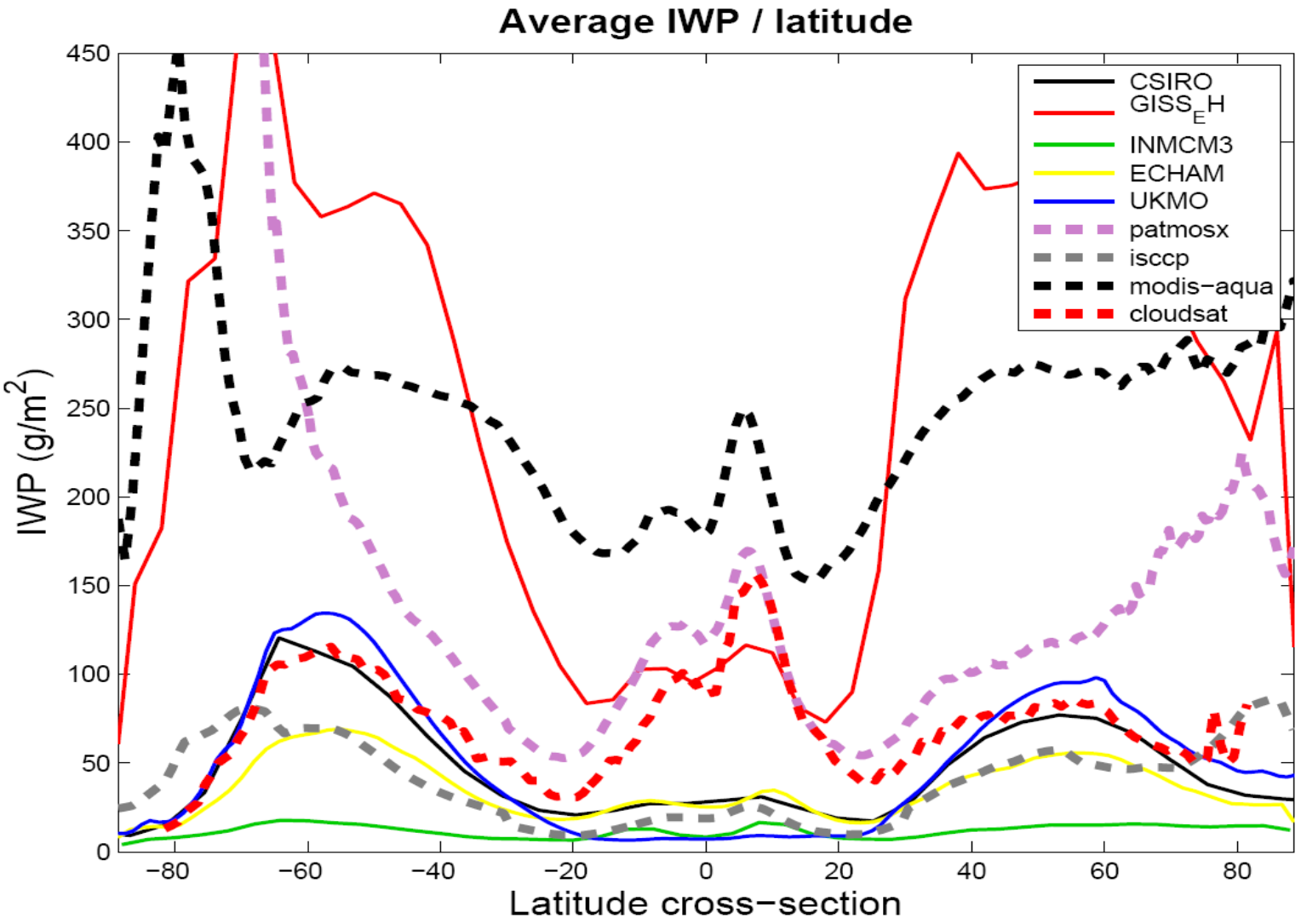
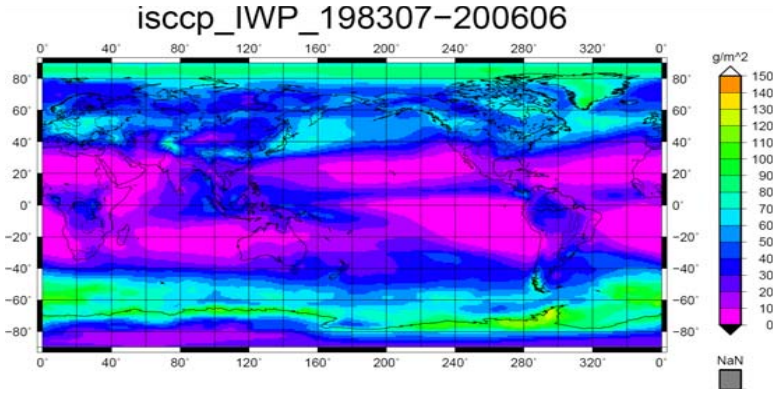
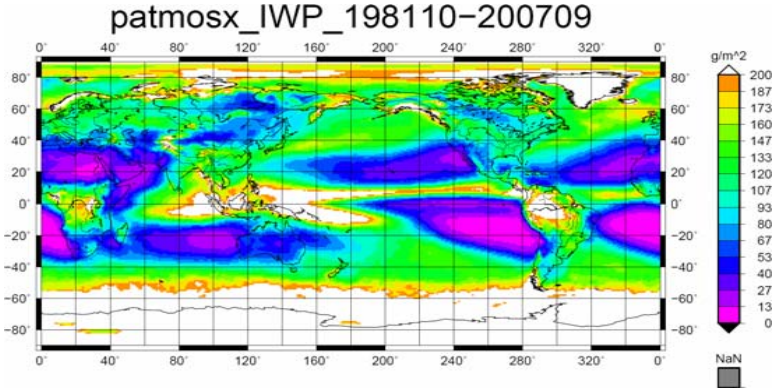


Figure: Salomon Eliasson

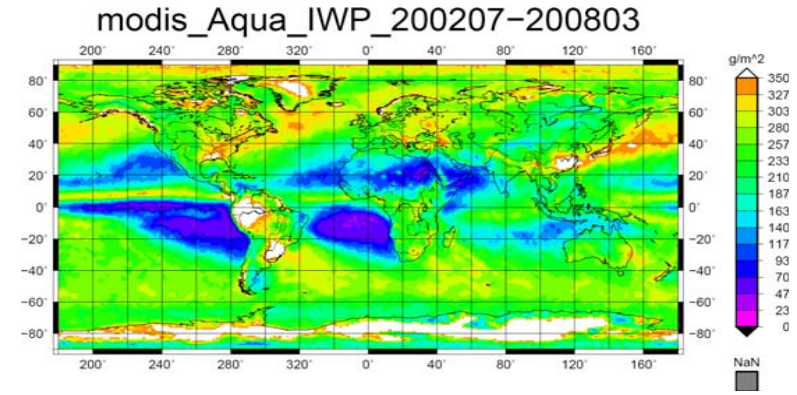
Subset of satellite IWP products using different retrieval techniques



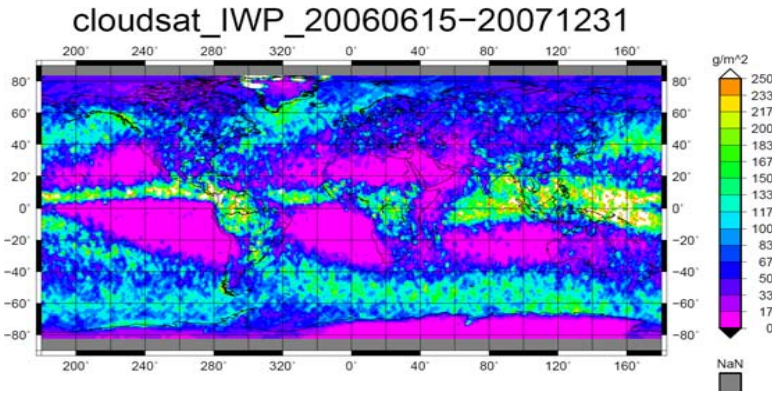
Retrieved using 1 vis & 1 IR channel. Primarily from geostationary satellites. Note: low IWP values.



PATMOS-x: Retrieved from 2 Vis, I near-IR & 2 IR channels from polar-orbiting satellites.



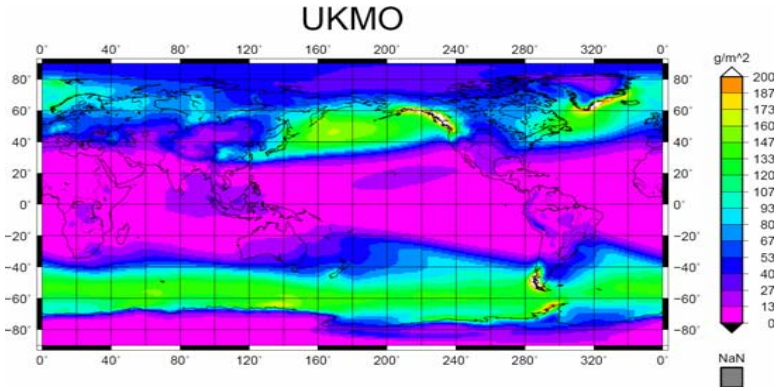
Retrieved from as many as
36 spectral channels from VIS to IR on polar orbiting satellites (here: Aqua)



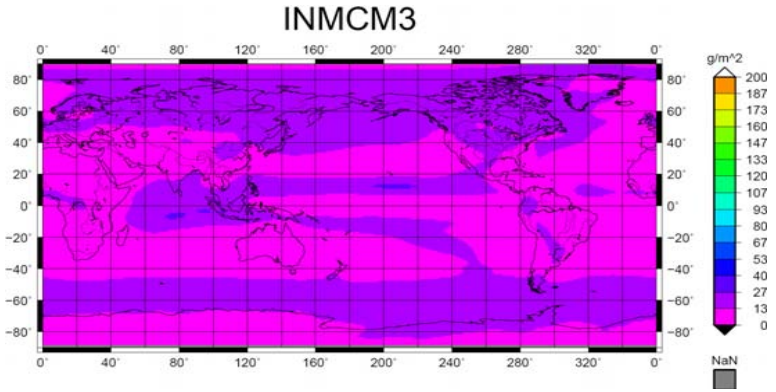
Retrieved from satellite- borne cloud-radar and IR measurements in polar orbit.

Figures: Salomon Eliasson

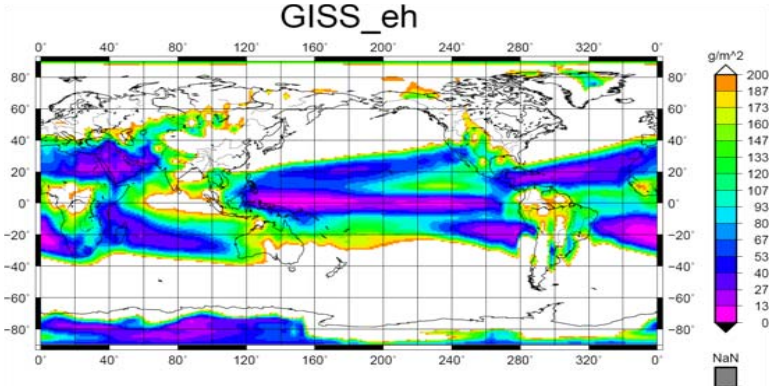
Sample GCMs used in IPCC Ar4



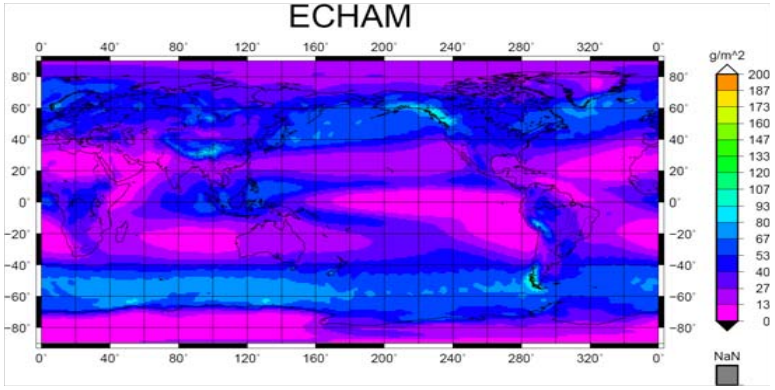
UKMO: In general larger IWP values than most GCMs but lower than IWP data from satellite. Weak ITCZ and TWP.



INMCM3: Strange IWP distribution in the tropical pacific. Very low IWP values compared to satellite data.



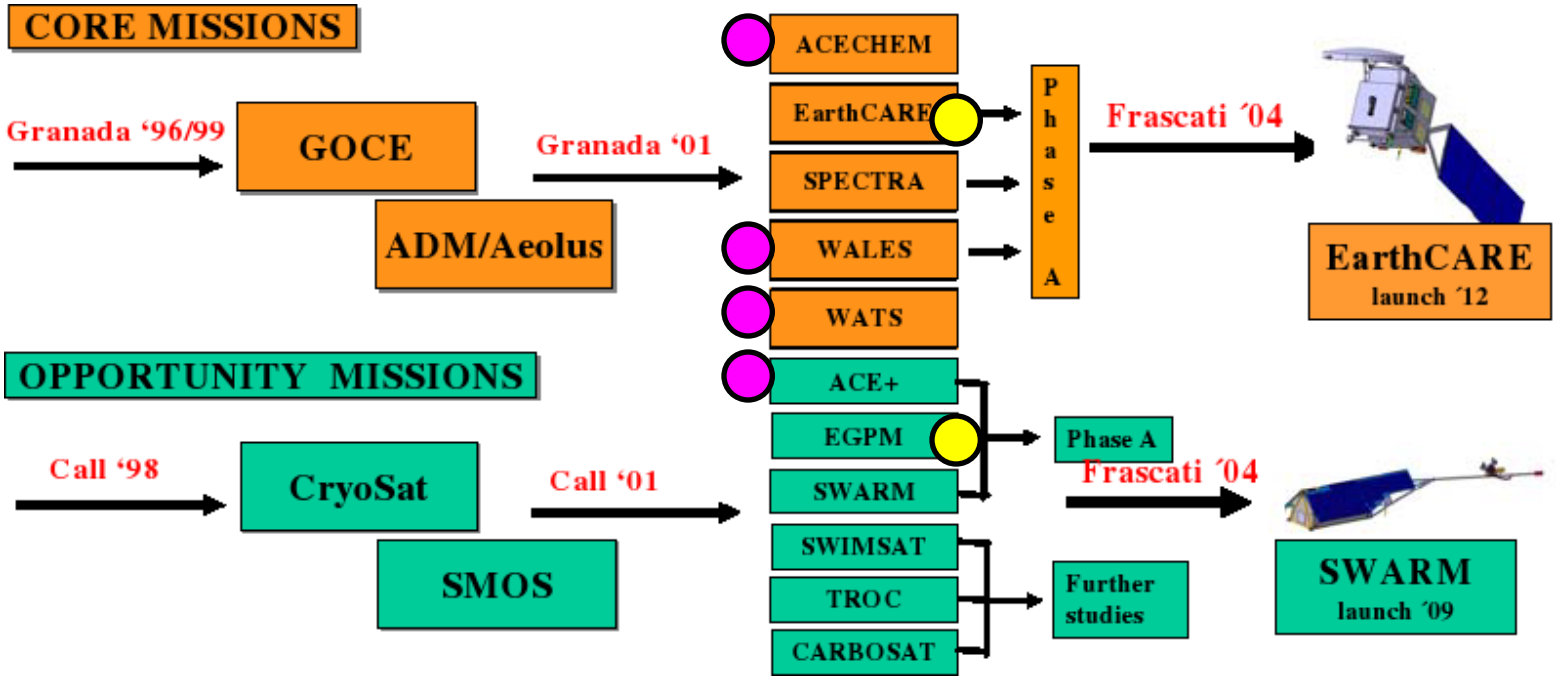
GISS_eh: Coarse spatial resolution with the largest IWP values. Very strong local maximum east of the Himalayas. Very dry Pacific equator



ECHAM5: Relatively good agreement with ISCCP (except Pacific Ocean)

Figures: Salomon Eliasson

ESA Earth Explorers



(Adapted from R. Münzenmayer, EADS Astrium GmbH)

Humidity

Clouds

last call

CIWSIR

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Existing Satellite Observations

- **Cloud emission** (IR radiometry):
  Retrieval of ice water path (IWP) and size (D) only for thin (semitransparent) ice clouds
  (ATSR-2, HIRS, Meteosat, ...)
- **Solar reflectance** (UV/Vis):
  Retrieval of D and gross habit classification for particles near cloud top
  (POLDER, Meteosat, ...)
- **Cloud transmission** (mm-wave):
  Retrieval of IWP only for thick (deep convective) ice clouds
  (AMSU-B, SSM-T2, ...)

mm/sub-mm ice remote sensing idea

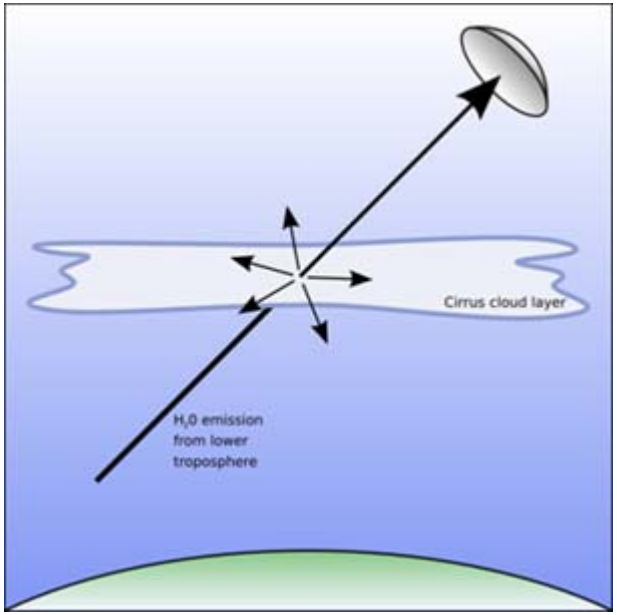


Figure: Oliver Lemke

Buehler, S. A., C. Jimenez, K. F. Evans, P. Eriksson, B. Rydberg, A. J. Heymsfield, C. Stubenrauch, U. Lohmann, C. Emde, V. O. John, T. R. Sreerekha and C. P. Davis (2007), **A concept for a satellite mission to measure cloud ice water path and ice particle size**, *Q. J. R. Meteorol. Soc.*, *133*(S2), 109–128, doi:10.1002/qj.143.

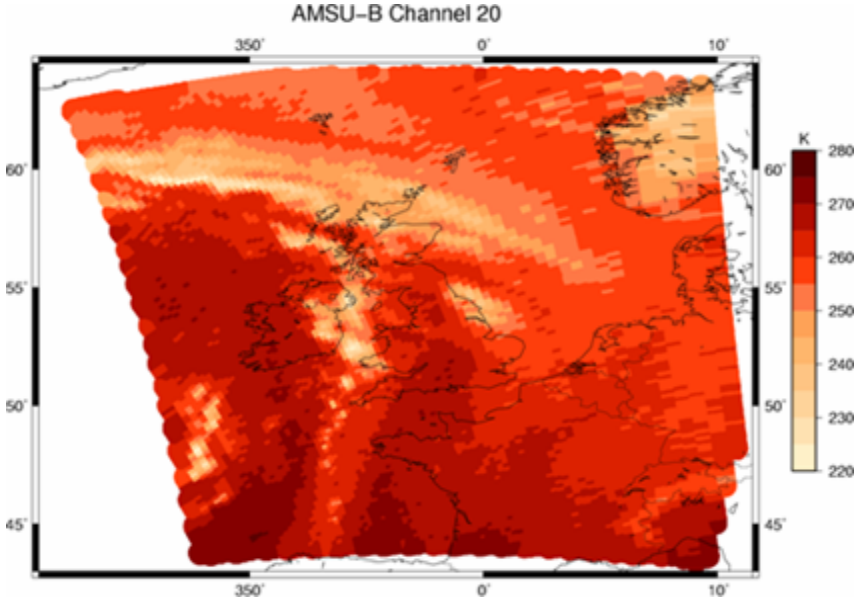
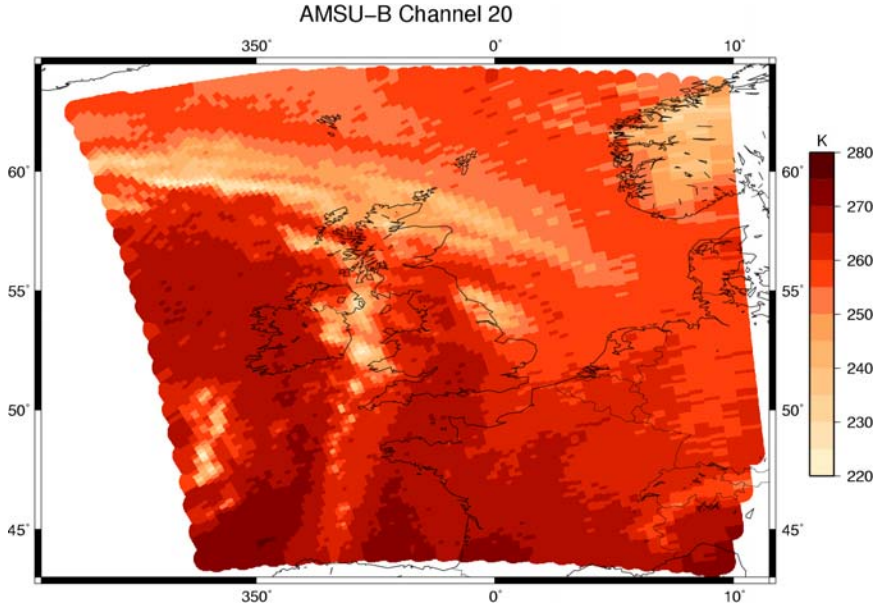
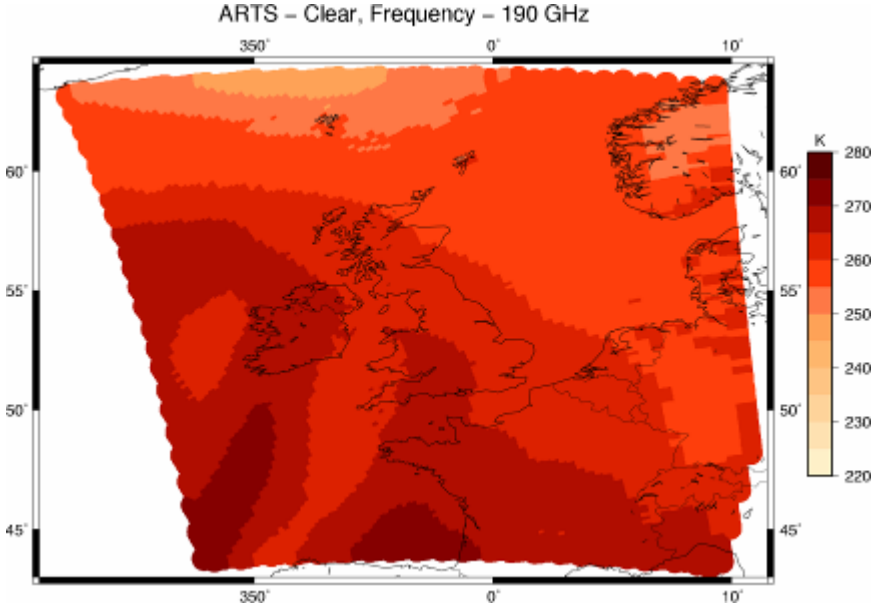
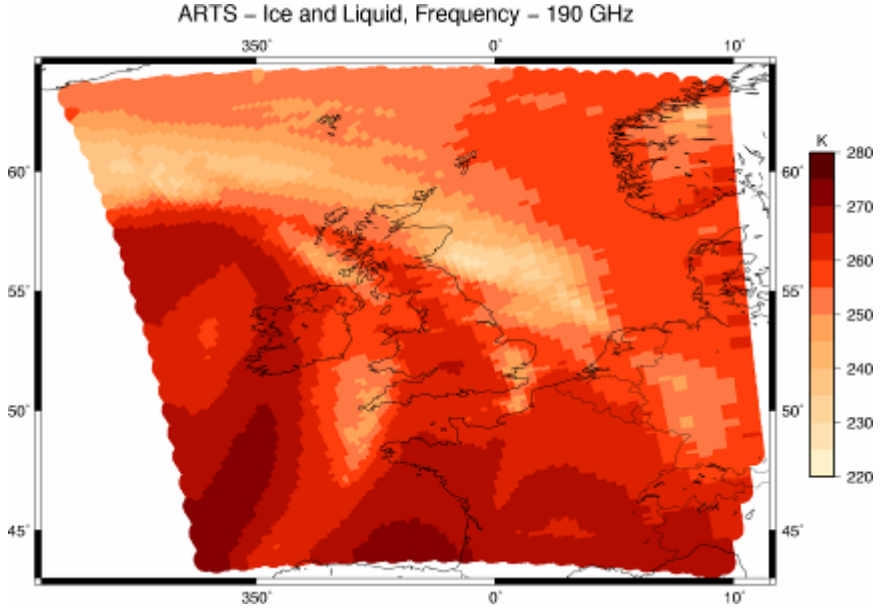


Figure: Sreerekha T.R.


AMSU–B Channel 20
350°
0°
10°
60°
55°
50°
45°
K
280
270
260
250
240
230
220


ARTS – Clear, Frequency – 190 GHz
350°
0°
10°
60°
55°
50°
45°
K
280
270
260
250
240
230
220


ARTS – Ice and Liquid, Frequency – 190 GHz
350°
0°
10°
60°
55°
50°
45°
K
280
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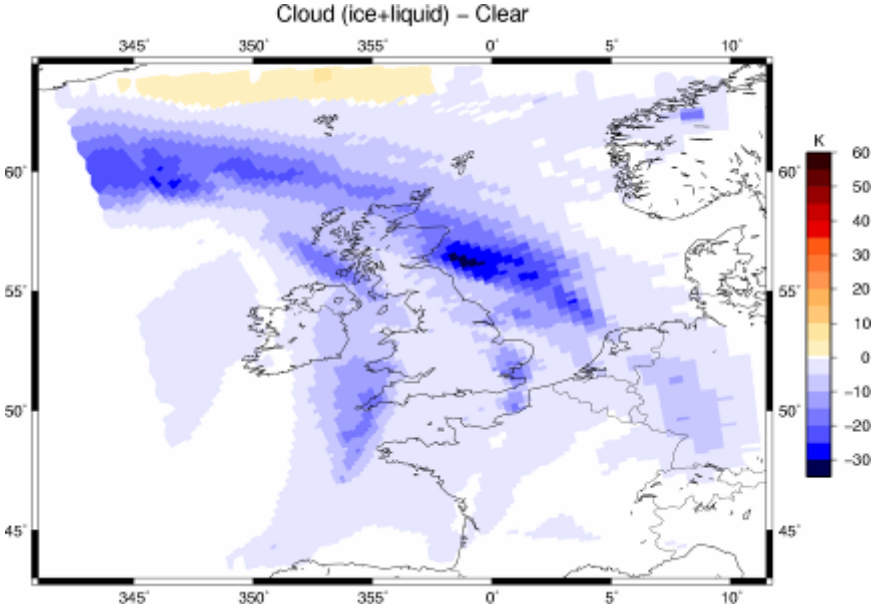
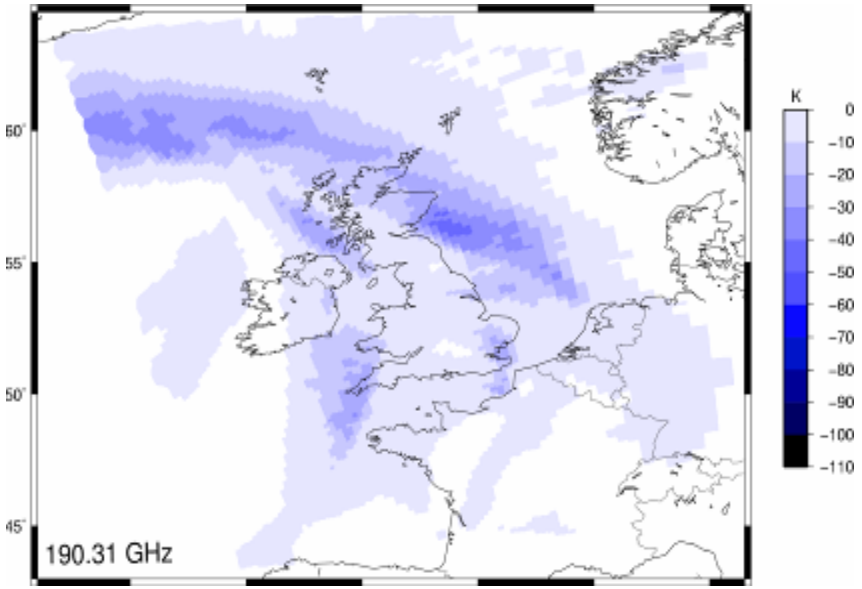
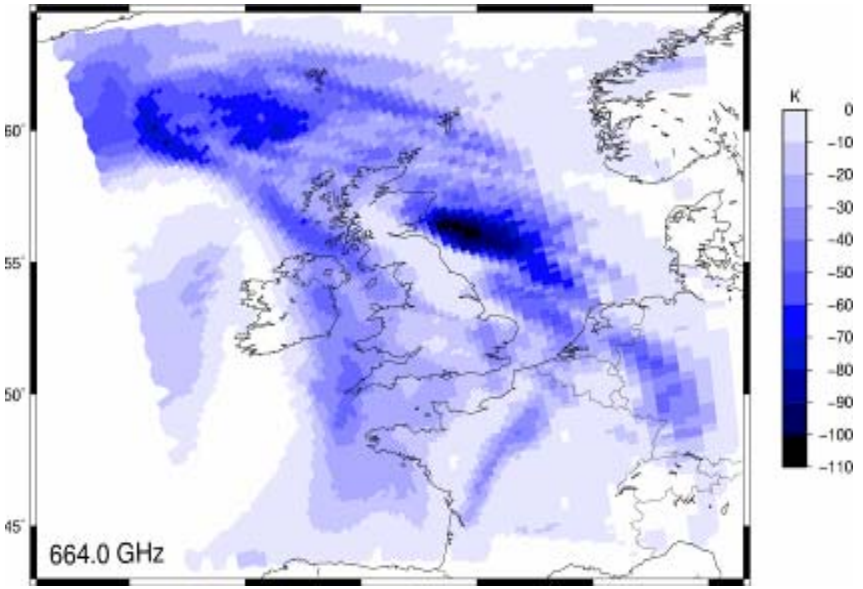
240
230
220


Cloud (ice+liquid) – Clear
345°
350°
355°
0°
5°
10°
60°
55°
50°
45°
K
60
50
40
30
20
10
0
-10
-20
-30





(ARTS Simulation: Sreerekha T.R.)

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Satellite mission proposals history

1995: Sub-mm observations of cloud ice first time suggested

(Evans and Stephens, J. Atmos. Sci, 1995)

1999: EU project CLOUDS

(lead by Bizzarry, sub-mm component lead by Miao/Künzi)

2002: First explorer mission proposals to ESA

GOMAS (Bizzarri et al.)

CIWSIR (Künzi et al.)

2005: Mission proposal to NASA

SIRICE (Ackerman et al.)

2005: Second explorer mission proposals to ESA

GOMAS (Bizzarri et al.)

CIWSIR (Buehler et al.)

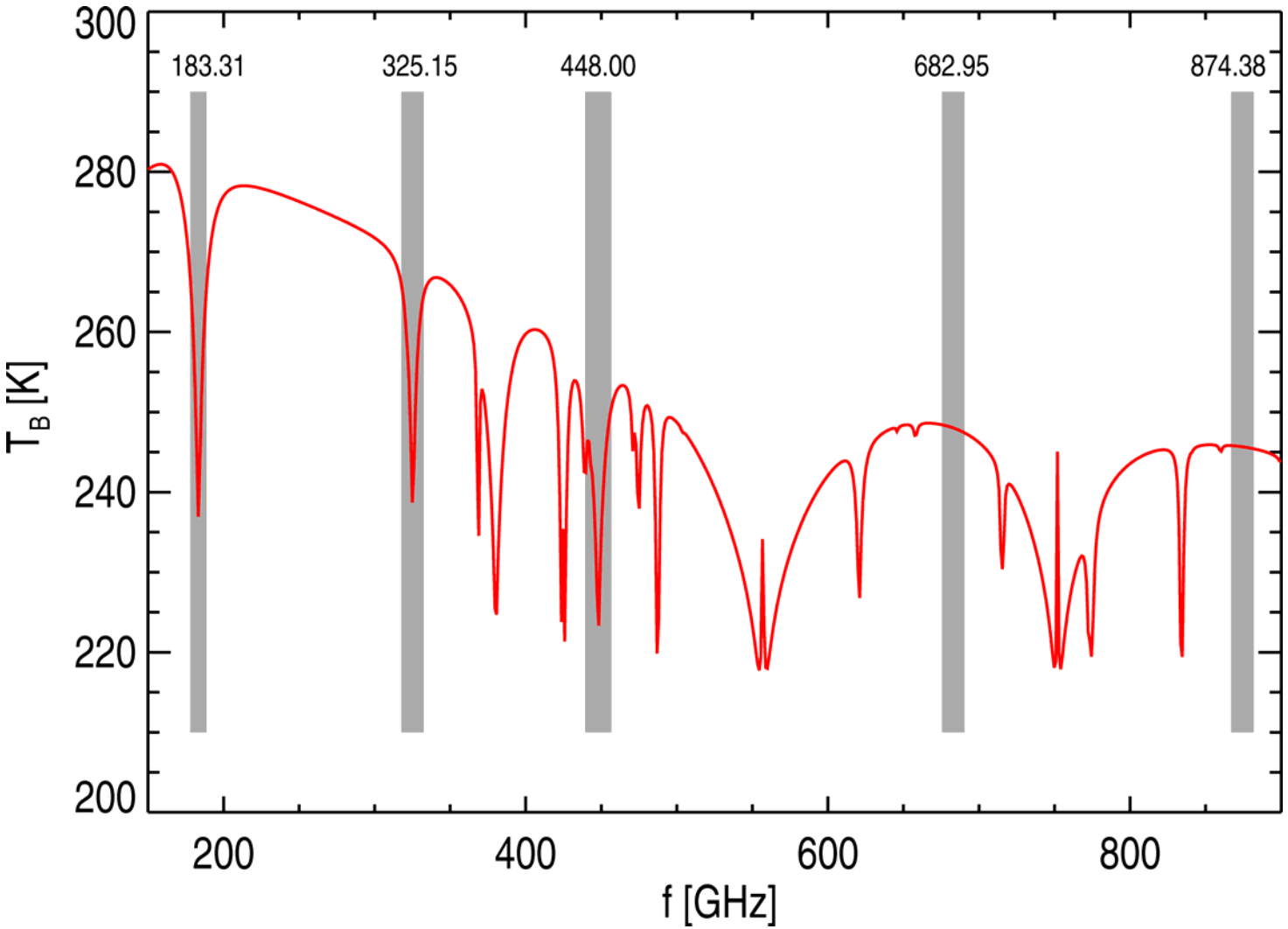
2006/2007: ESA study

'Establishment of Mission and Instrument Requirements to Observe Cirrus Clouds at Sub-Millimetre Wavelengths' (Jarret et al.)

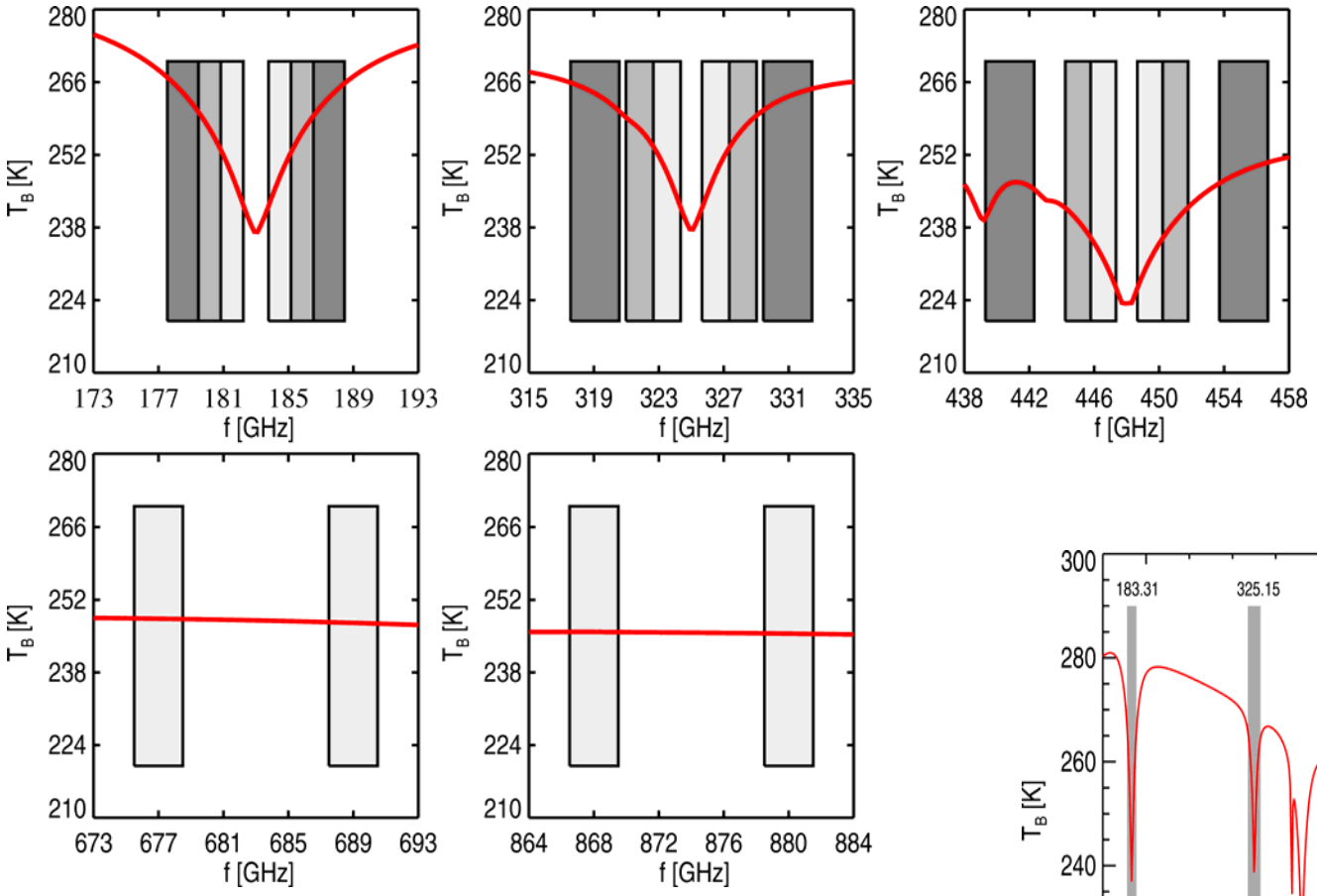
2007-now: Parallel ESA studies

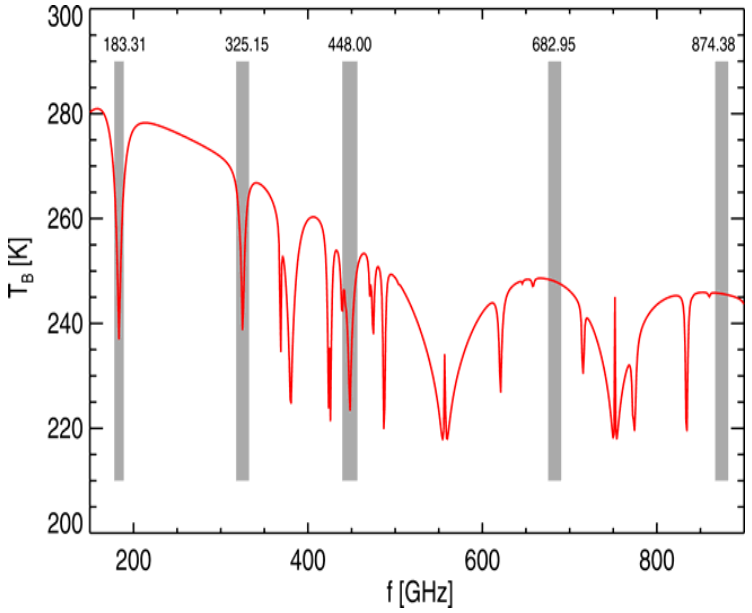
Study of a Sub-millimetre Wave Airborne Demonstrator for Observations of Precipitation and Ice Clouds

First CIWSIR proposal



(All Figures in this section: Kuenzi et al., CIWSIR Mission Proposal, 2002)

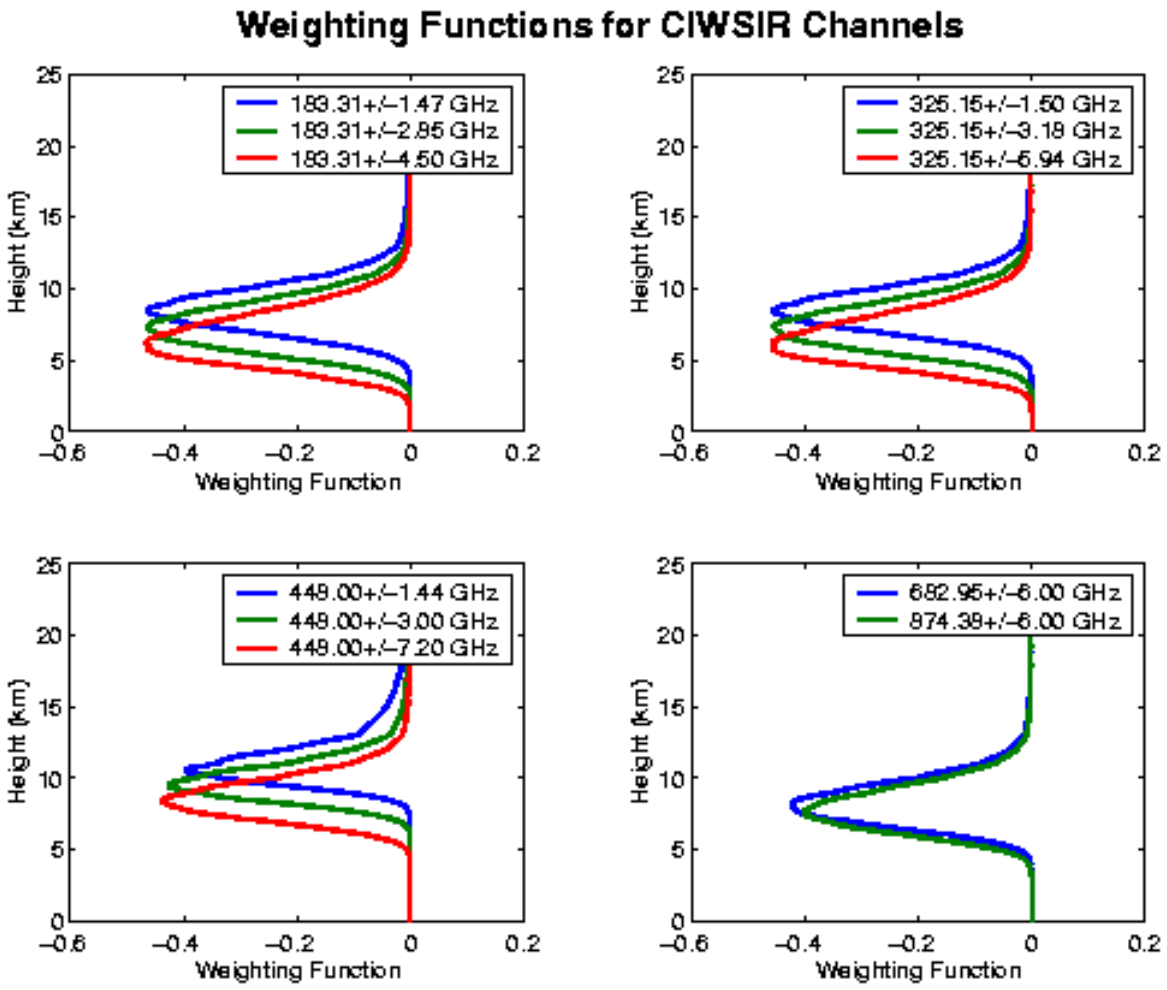




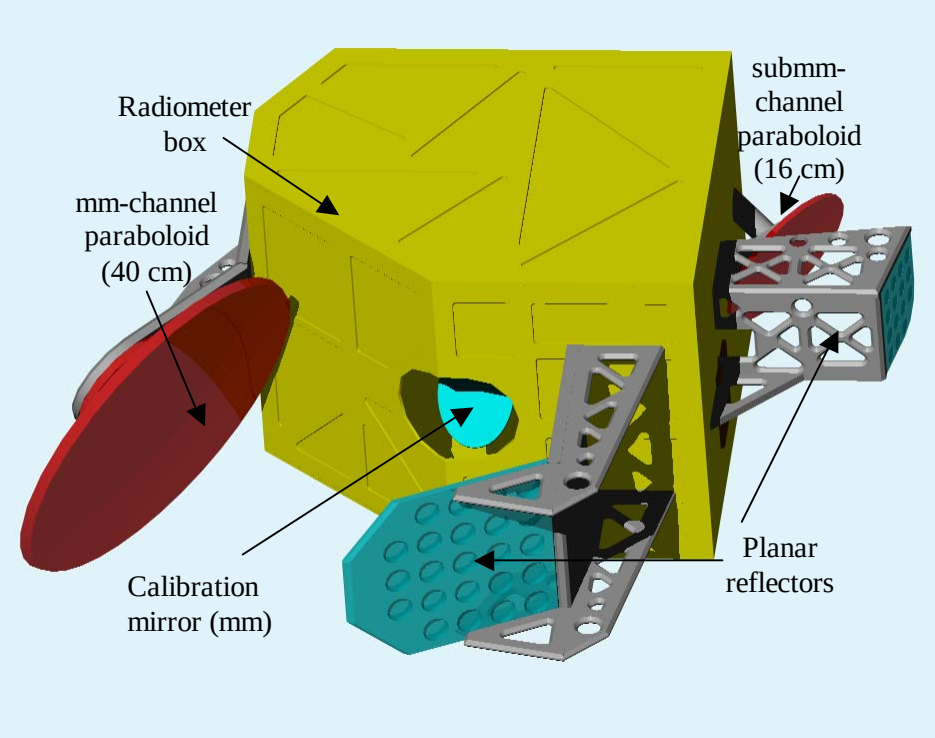
- 11 channels.
- Rough channel positions already similar to current proposal.
- Highest two channels polarized.

Channel selection philosophy

- Wide spread in frequency.
- Jacobian matching accross bands (no longer done in current proposal).
- Avoid strong O_3 lines.



Instrument concept

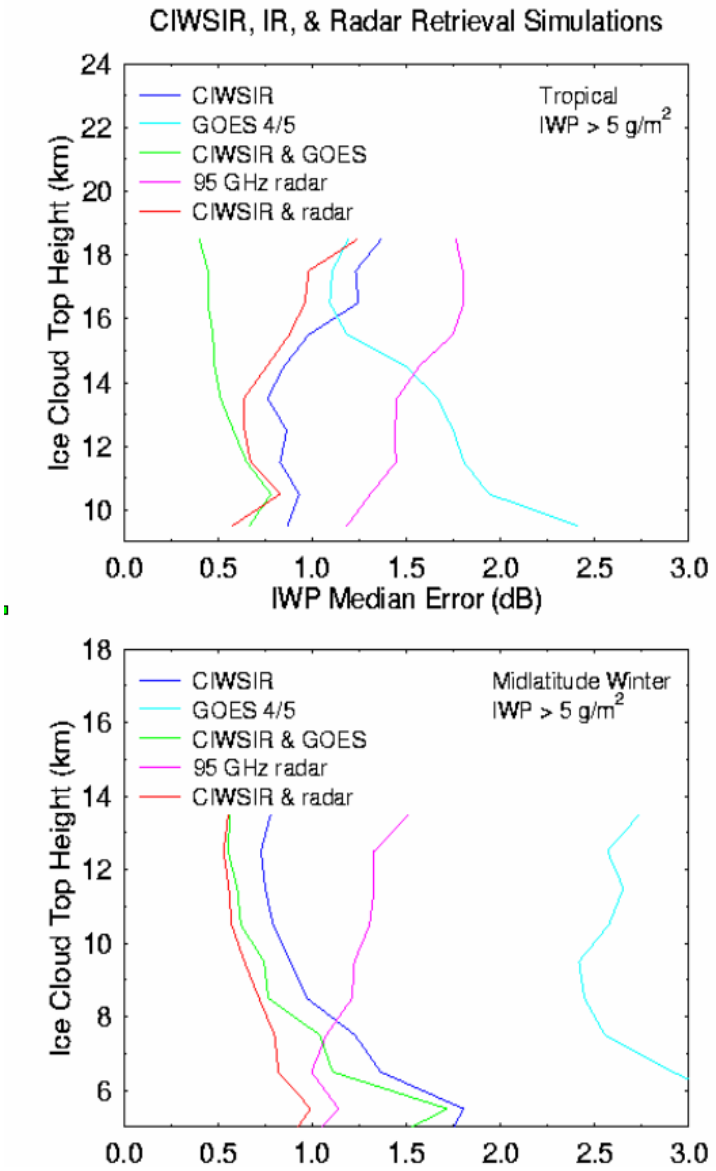


- Conical scanner with 2 main reflectors.

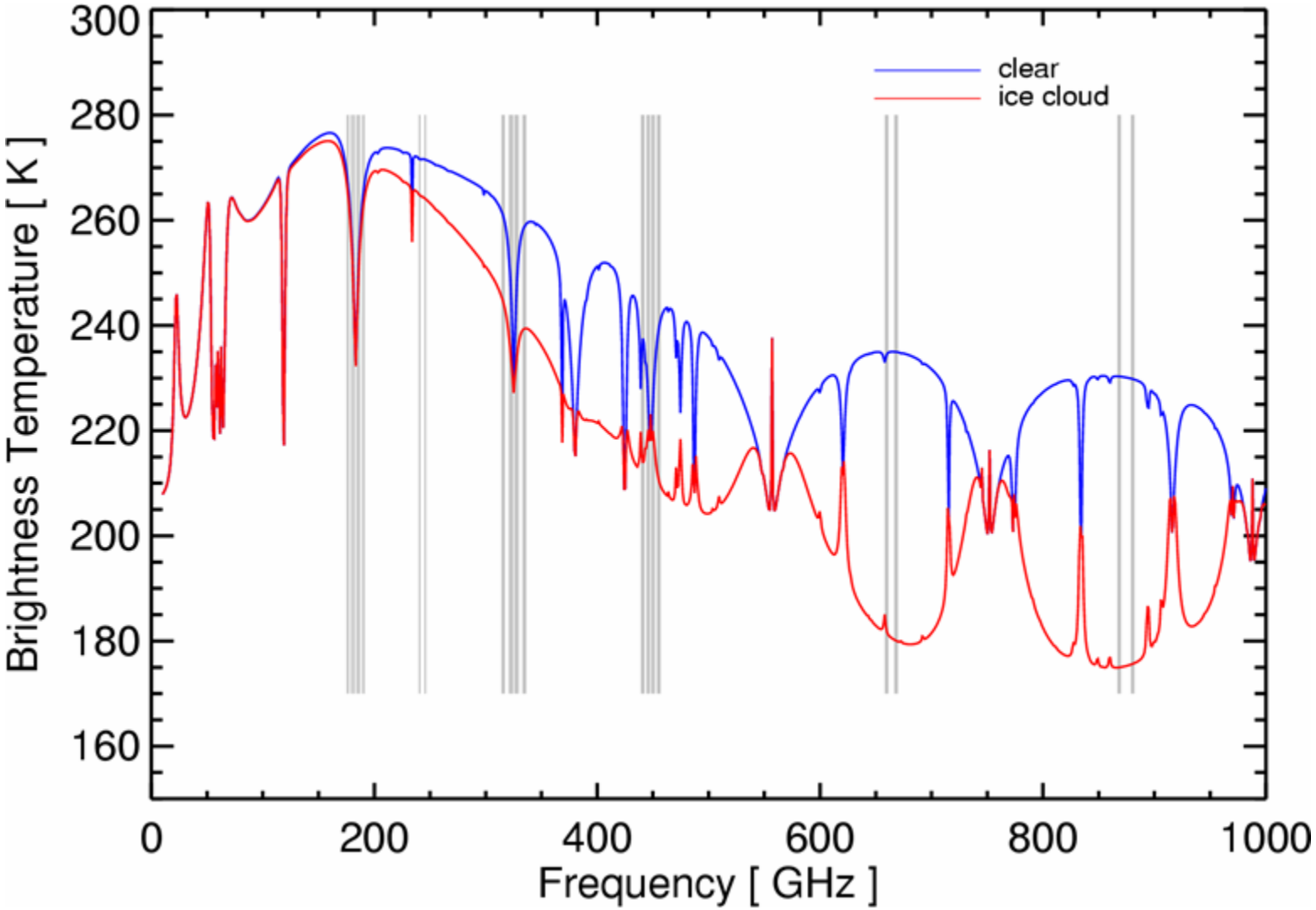
„Historical“ retrieval simulations

- IWC retrieval performance study (Evans 2002) :
- CIWSIR best single sensor
- Improvements by adding
  - 94 GHz Radar
  - 2 IR channels (10.2-11.2, 11.5-12.5μm), e.g. on METOP, NOAA, AQUA,...

➞ **Need for simultaneous IR measurements already recognized.**

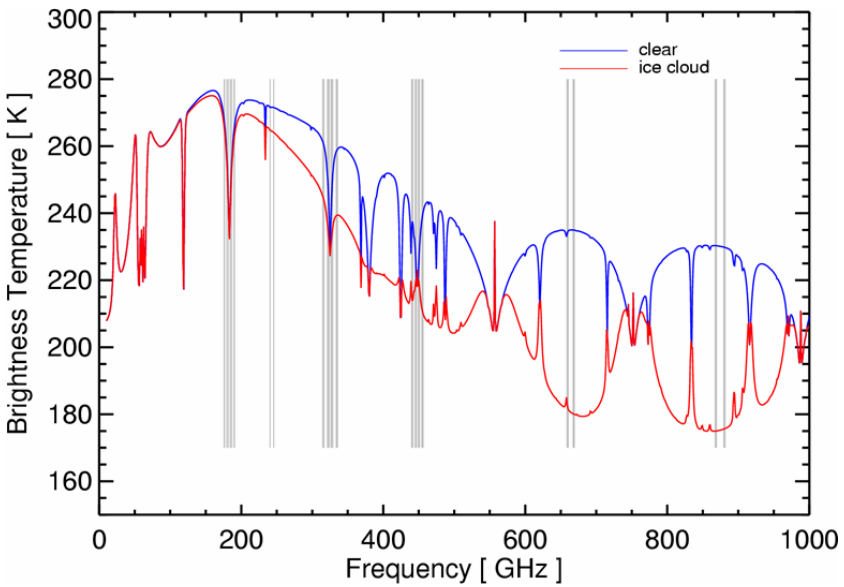


Second CIWSIR proposal



(Buehler et al., CIWSIR Mission Proposal, 2005, figure by Viju O. John)

Second CIWSIR proposal



- No more Jacobian matching, since simulations showed better performance without.
- Added window channel at 243 GHz.
- Still two very high frequency channels at 664 and 874 GHz.
- Still polarization for highest two channels

- 874 was later suggested to be dropped.
- Polarization signal later was shown stronger in lower frequency channels by simulations. (Probably due to multiple scattering and saturation effects.)
- Hard to accurately assess expected polarization signal, since strongly dependent on ice particle properties.

The CIWSIR Instrument after ESA optimization study

- 5 frequency bands: 183 – 664 GHz
- All channels singly polarised (45°)
- Horizontal resolution: 15km; 7.5km for 664 GHz
- Single antenna aperture for all channels

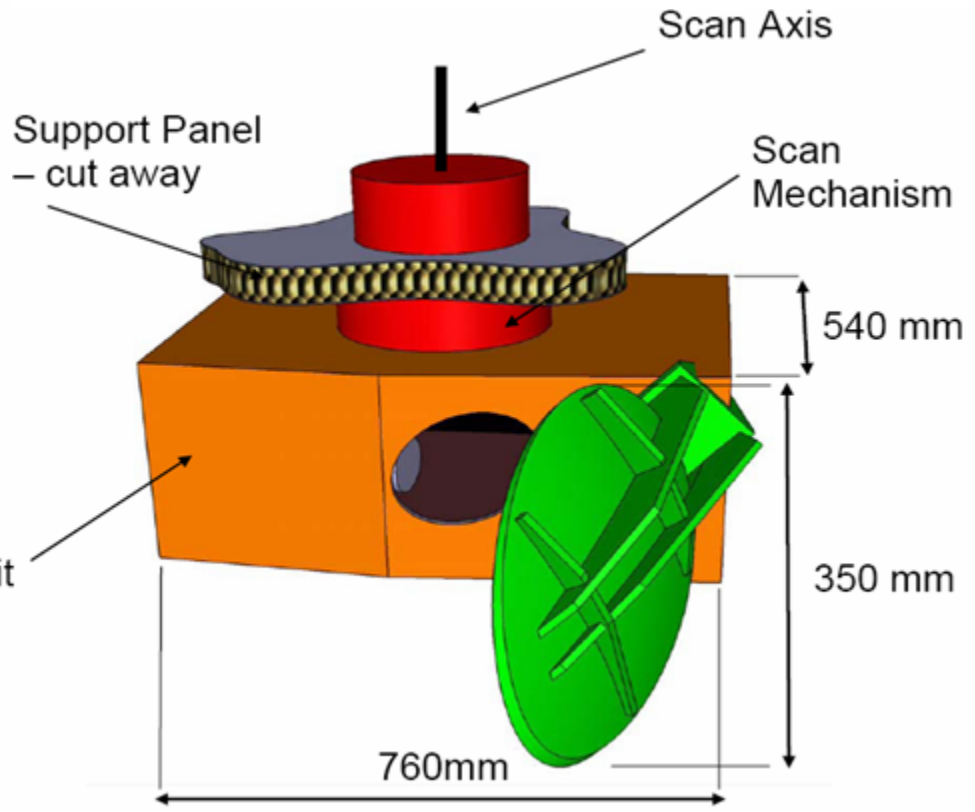


Figure: Sula Systems

- Goal: Ice water path and effective ice particle size with 15 km horizontal resolution and 25% accuracy.

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Airborne sub-mm sensors (mostly as of 2005)

Name	Located	PI	Channels	Platform / max height
CoSSIR	GSFC	J. Wang	183 (3x) 380 (4x) 487 (3x) V+H 640	ER-2 / 21 km
CoSSIR (2007)	GSFC	J. Wang	183 (3x) 380 (4x) 640 V+H	ER-2 / 21 km
PSR/S	NOAA/ETL	A. Gasiewski	183 (7x) 325 (3x) 340 380 (5x) 425 (5x) 500	P-3 / 9km DC-8 / 12 km ER-2 / 21 km WB-57 / 20 km Geophysica / 21 km
?	Met Office	C. Lee	?	FAAM

+ ESA activities!

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Kiruna SAT group plans

- Recently little active work on cloud ice remote sensing, due to limited personnel
- New persons expected:
  - Two new PhD students (Iran, India)
  - Assistant professor (in-situ ice particle measurements, USA)
  - Second assistant professor (ice remote sensing, USA?)
- Want to get more active again in this area
- Concentrate on AMSU/HIRS IWP retrieval
- Collaborations very welcome
  - Ongoing collaborations
    - Patrick/Bengt (Chalmers), Frank (Univ. of Colorado), Cory Davis (Metservice New Zealand): Training data
    - Carlos/Catherine (Obs. Paris): NN retrieval
  - Possible collaborations in RT area?
  - Want to contribute to Met Office instrument (if successful in applying for Swedish funding)

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- Sub-mm measurement promising for IWP and effective particle size measurements
- Also natural extension of existing mm observational capabilities (AMSU-B / MHS)
- Need to demonstrate end-to-end performance with existing mm data and **aircraft instruments**
- Need for accurate, fast, and user friendly RT models
- Kiruna SAT group is looking for collaboration in
  - RT
  - Retrieval
  - Aircraft data