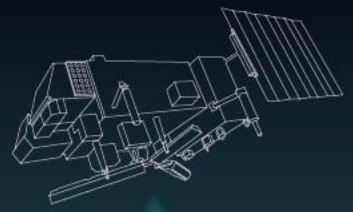

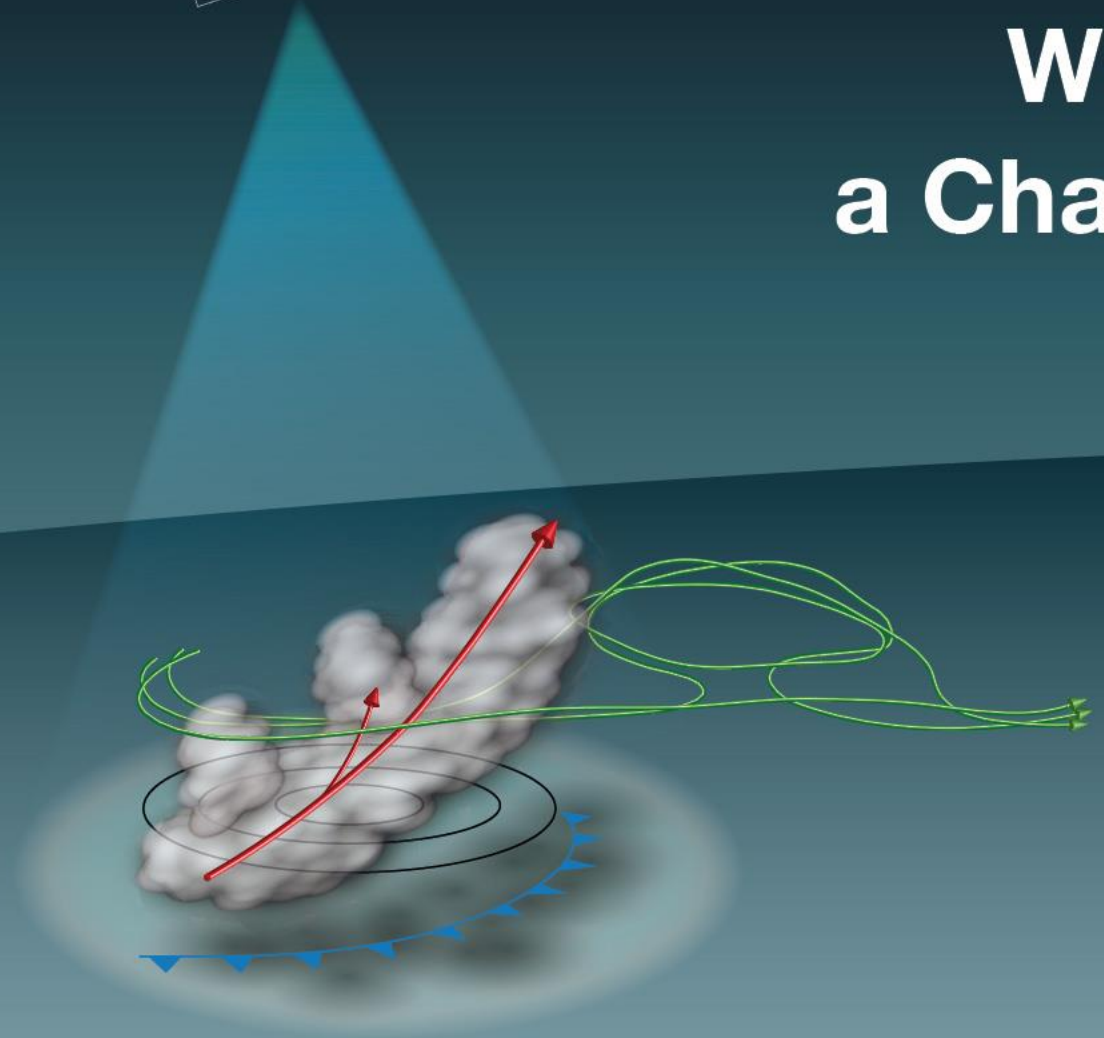

Virtual Workshop:
Warm Conveyor Belts – a Challenge to Forecasting

10–12 March 2020

#WCBWS

ECMWF

What information can current observations provide about Warm Conveyor Belts?

Stephen English

ECMWF

Stephen.English@ecmwf.int

With thanks to Alan Geer, Marta Janiskova, Tony McNally (ECMWF), Estel Cardellach (IEEC), Bill Blackwell (MIT) and EUMETRAIN training website for use of their material

ECMWF

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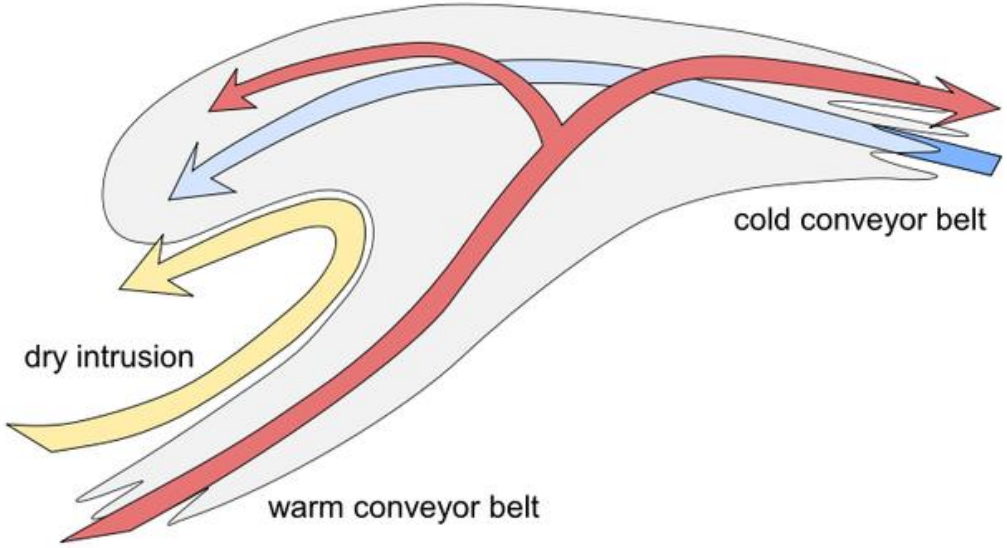
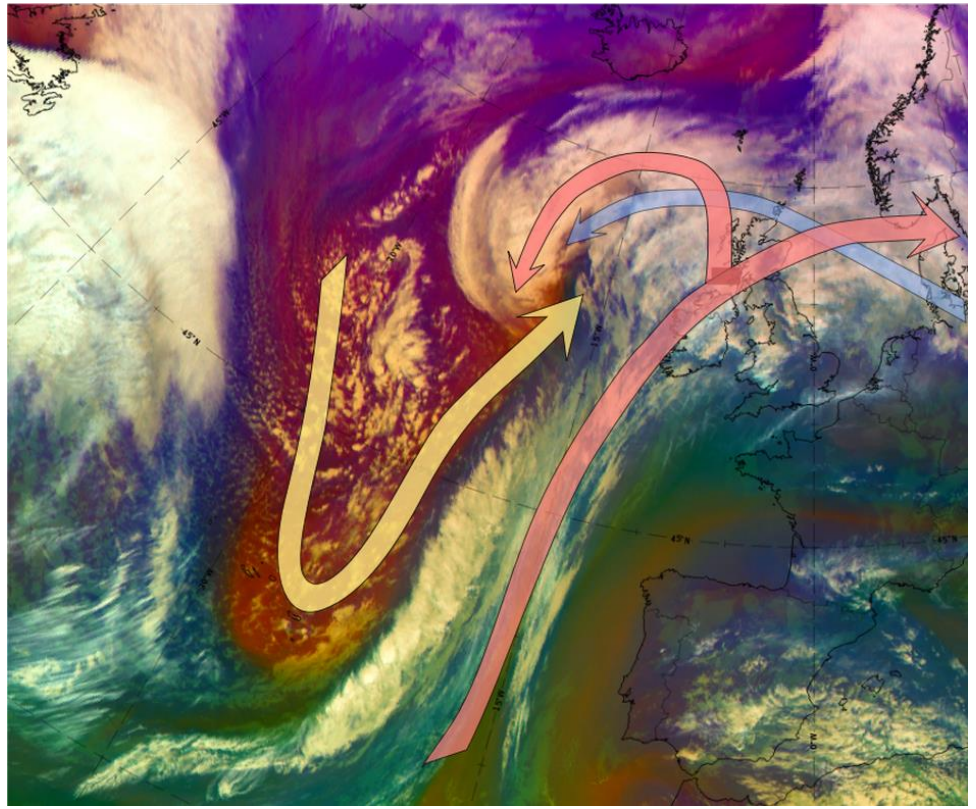
Warm Conveyor Belts

Characteristics of warm conveyor belts (WCBs) (*Schäfler et al 2011):*

- Elongated cloud bands with spiral and hook features;
- Intense latent heating;
- Surface precipitation;
- Association and interaction with cold conveyor belt.





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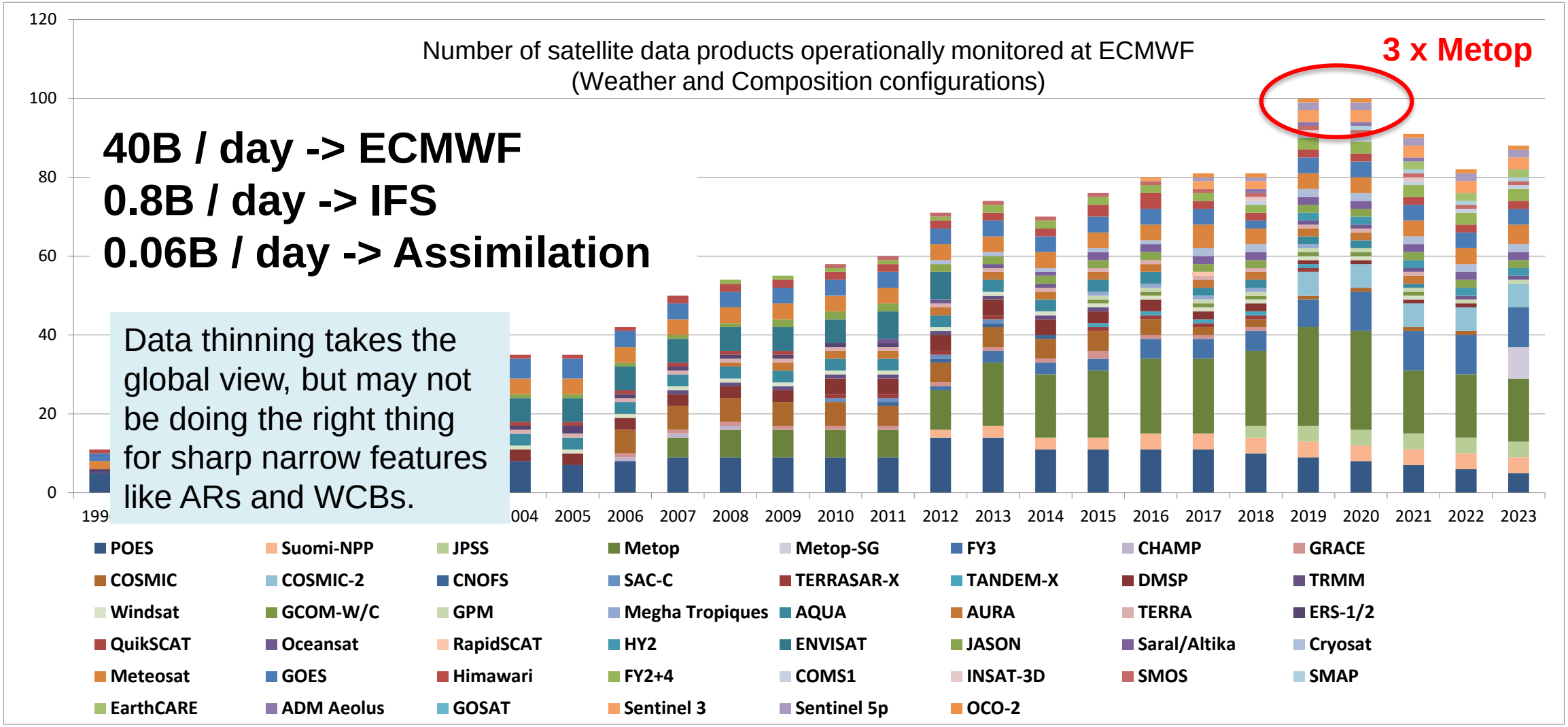
* *Schäfler, A. & Dörnbrack, A. & Wernli, H. & Kiemle, C. & Rahm, S. (2011). Airborne lidar observations in the inflow region of a warm conveyor belt. QJRMS. 137. 1257-1272. 10.1002/qj.827.*

Workshop goals: observations

Numerical weather prediction assimilates a wealth of observations

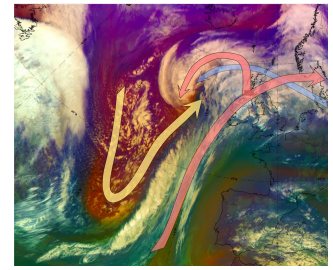
- What are the key observations which currently constrain WCBs?
- How well do they could constrain the relevant scales and parameters?
- Do WCBs strengthen the case for additional observations in future?
- Can we learn from intensive campaigns like NAWDEX and AR?

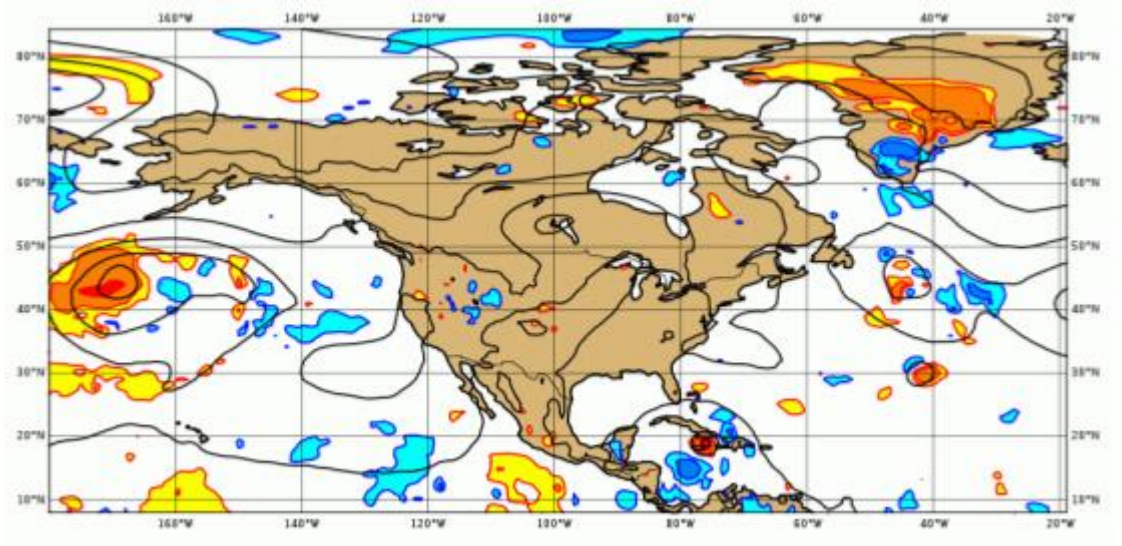
Numerical weather prediction assimilates a wealth of observations



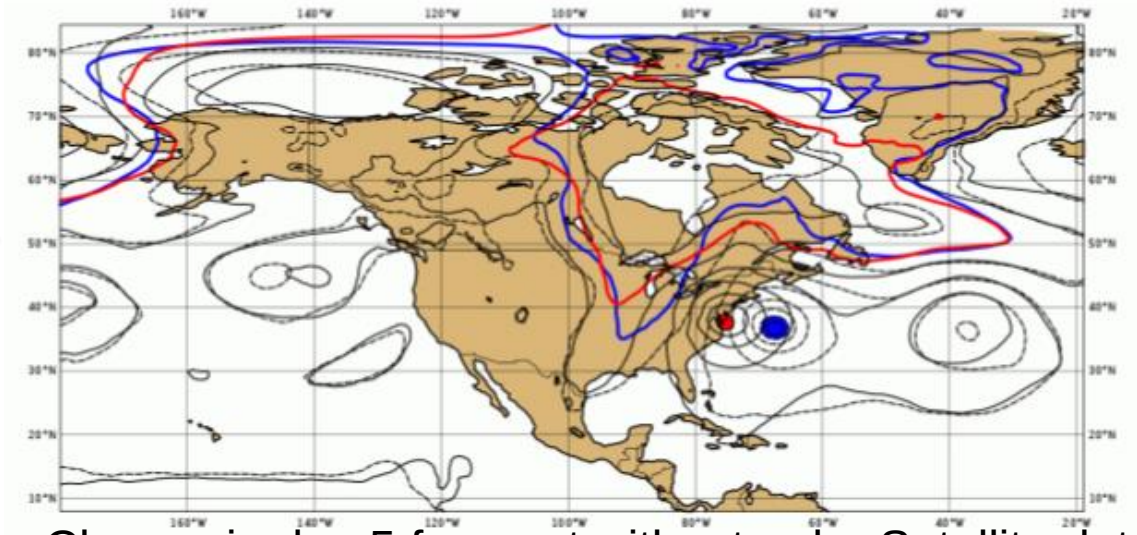
What are the key observations which currently constrain WCBs?

Before answering, recall its not always local obs that matter for medium range prediction
e.g. Storm Sandy forecast study from McNally, Bonavita and Thepaut, 2019 ECMWF TM696





Change in Analysis without polar satellite data

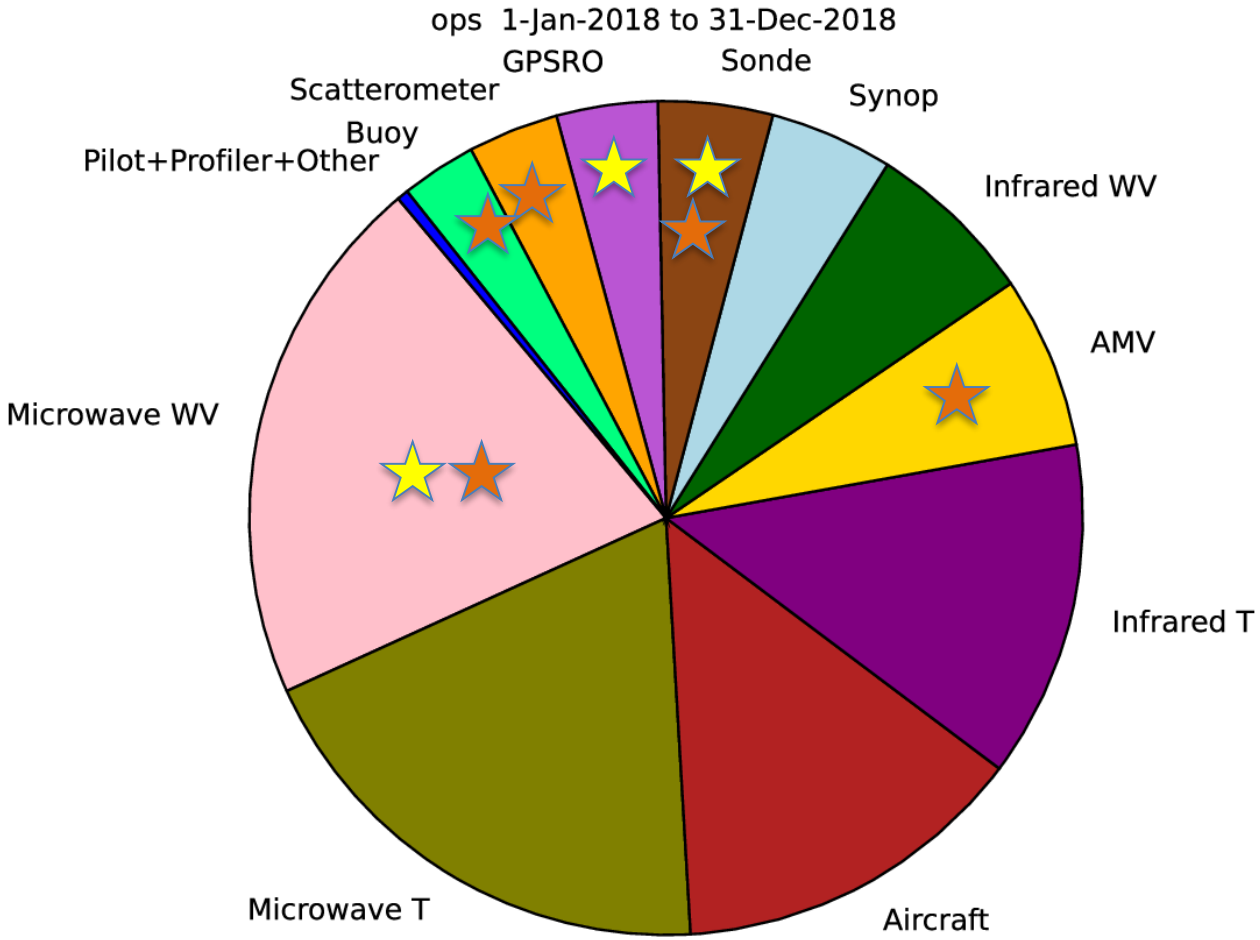


Change in day-5 forecast without polar Satellite data

Non-local observations are critical for forecasts beyond 1-2 days ahead

Thanks to Tony McNally for these figures

What are the key observations which currently constrain WCBs?



Global picture (pre-Aeolus)

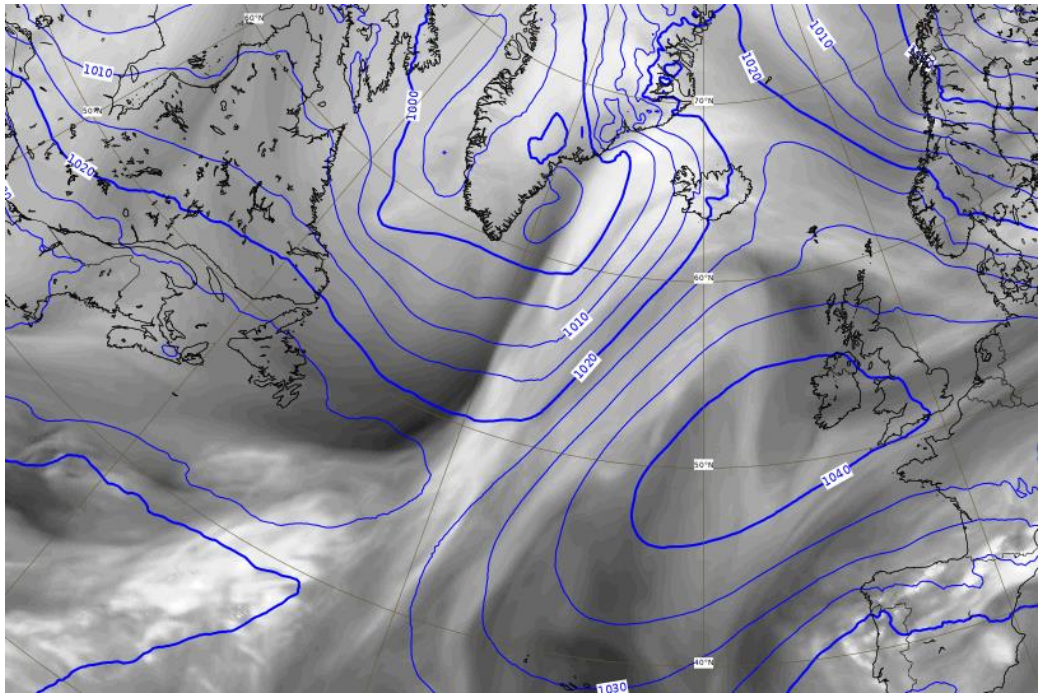
For local impact in WCBs, what is likely to be different?

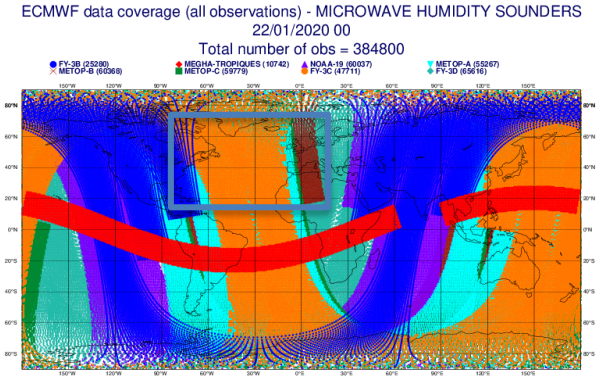
Observations providing low level water vapour information in cloudy areas?

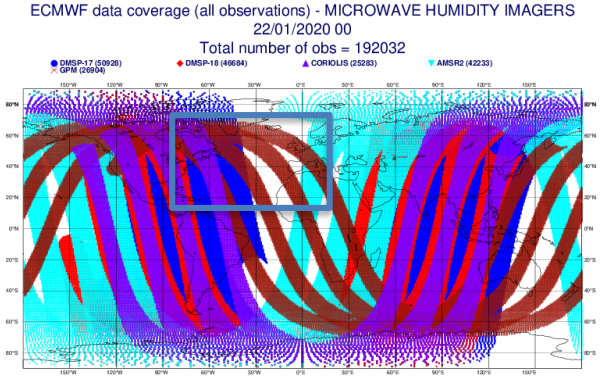
Observations providing dynamical information?

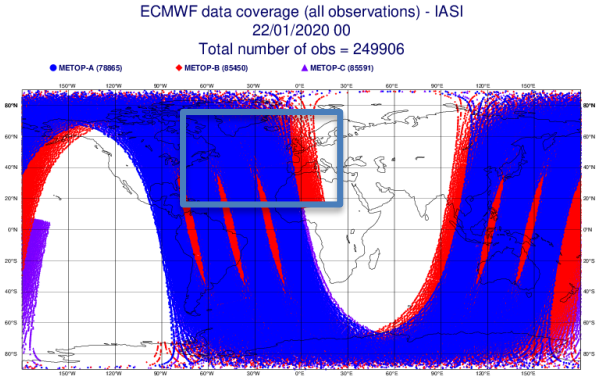
Thanks to Alan Geer for this figure

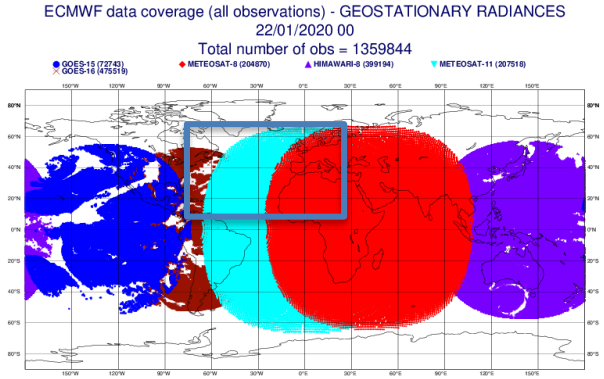
How well do they could constrain the relevant scales and parameters?

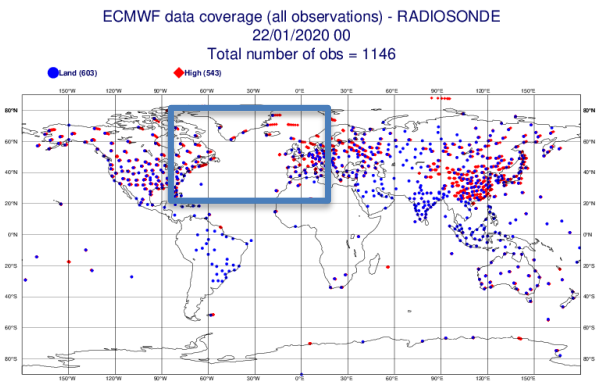


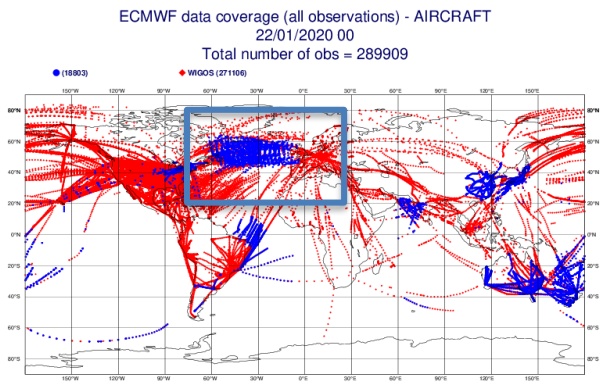




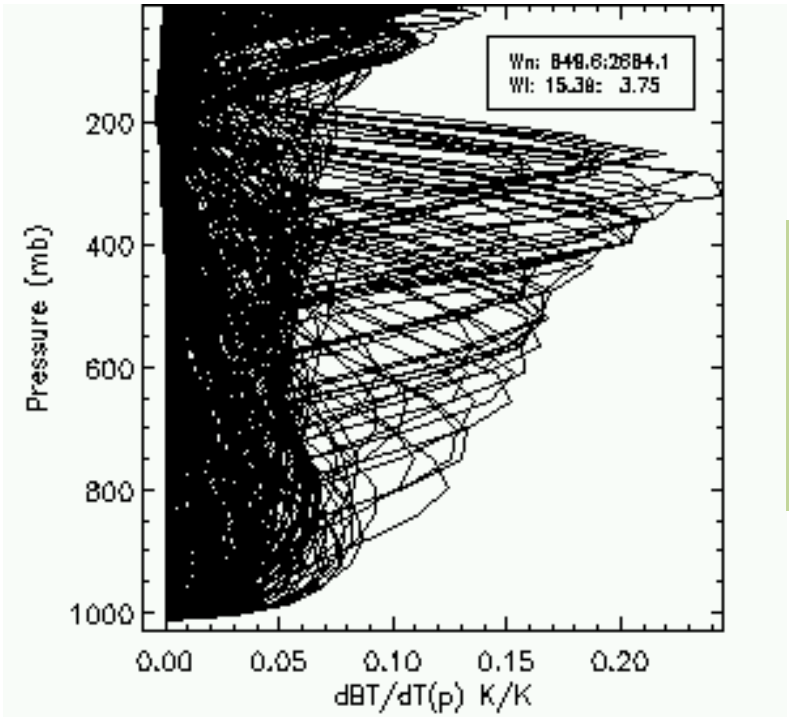




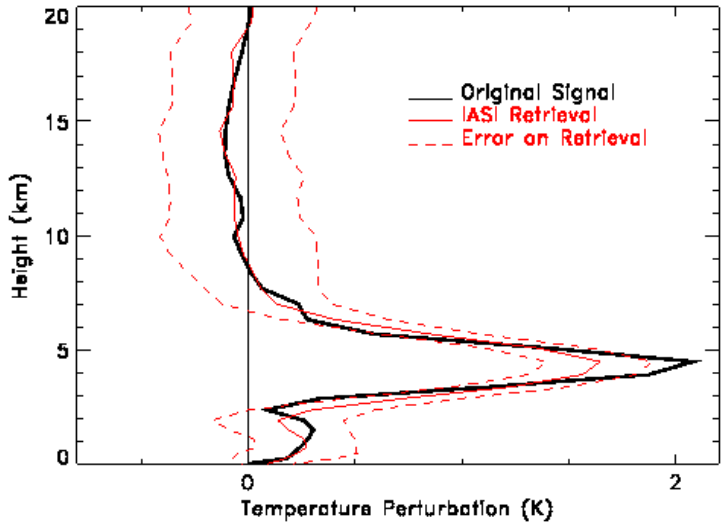


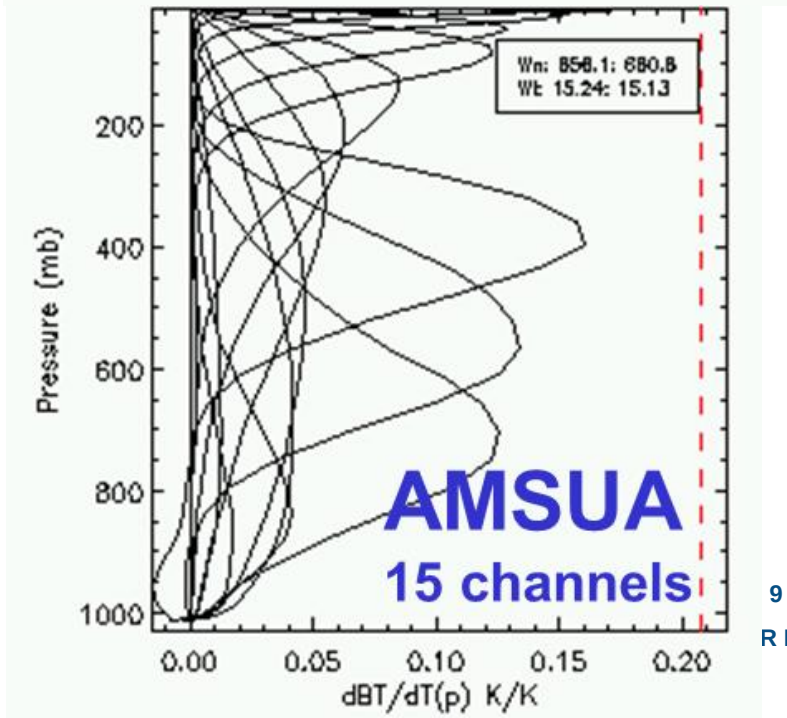


- **This implies plentiful observations, at least for this case.**
- **But how well do they meet requirements?**

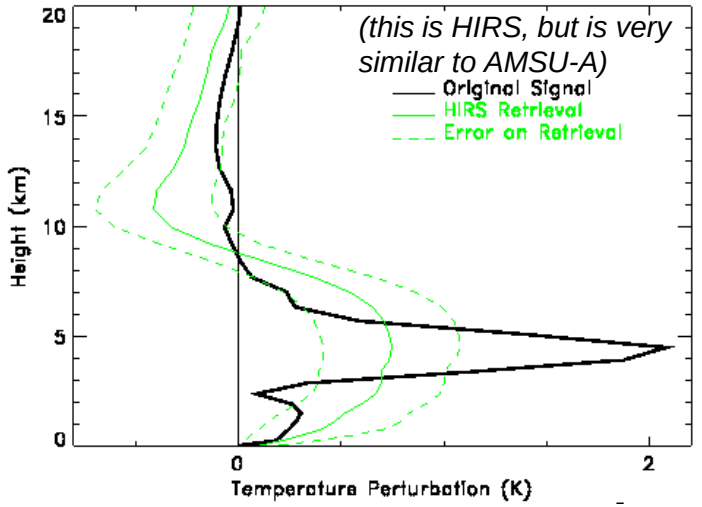


IR: e.g. 8461 channels
Horizontal 4-12 km
Vert 1-2 km





MW: e.g. 15 channels
Horizontal 17-50 km
Vertical 3-5 km

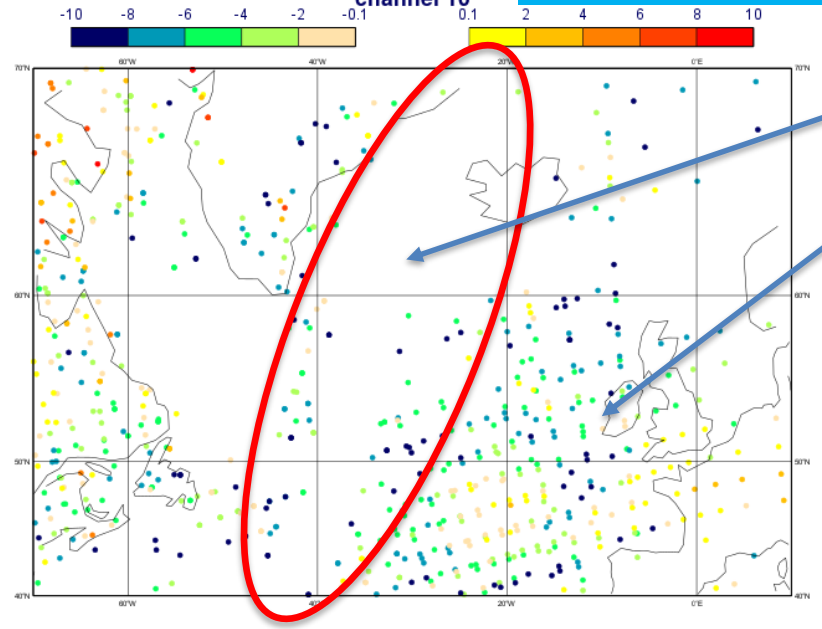


Thanks to Tony McNally for these figures

B too dry

HIRS FG departure channel 10

B too moist

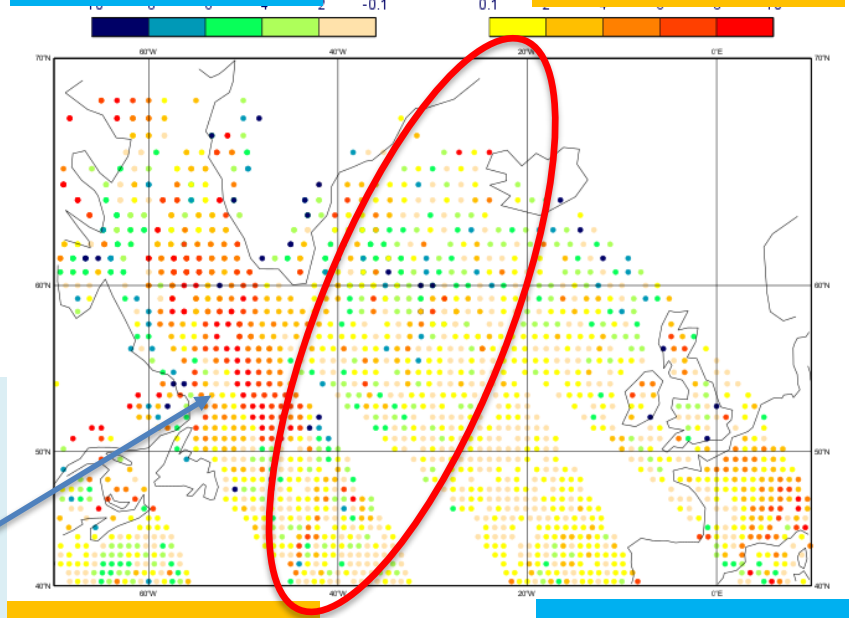


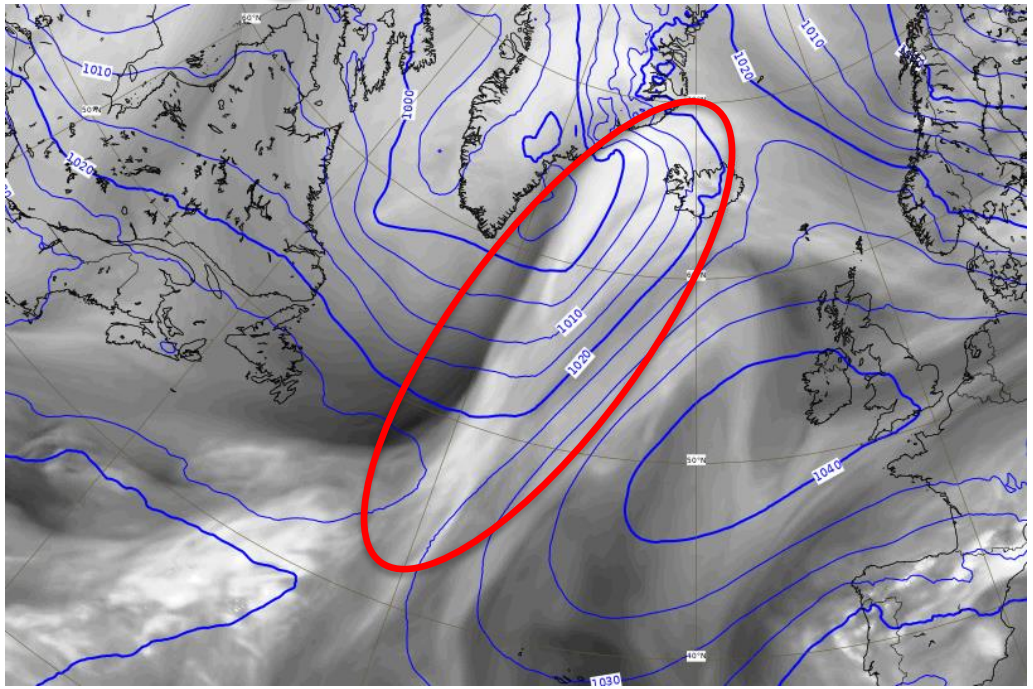
IR humidity: No data in WCB itself. Data in WCB feeder airstream (Helen Dacre talk yesterday) and dry intrusion.

B too moist

GMI FG departure channel 5

B too dry





MW humidity
MW imagers e.g. GMI (24 GHz) give low level humidity but also liquid cloud has impact

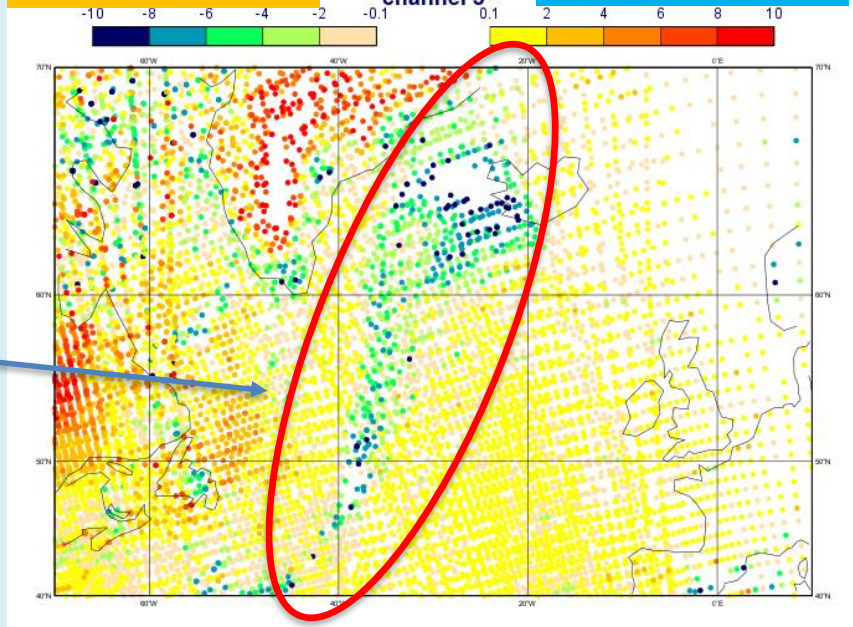
Sounders e.g. MHS (183 GHz) low to mid troposphere:

-ve O-B at 183 GHz could be water vapour or ice cloud

B too dry

MHS FG departure channel 5

B too moist



Do WCBs strengthen the case for additional observations in future?

- Current observations:
  - Microwave: coarse resolution, needs sophisticated “all-sky radiance” approach (Alan Geer talk);
  - Infrared: cloud problem, and currently poor temporal resolution (but MTG-IRS, FY-4A-GIIRS ….);
  - Radio occultation: horizontal resolution issue, but genuinely all-weather (plus new ideas, see later);
  - In situ (e.g. dropsondes) – ok in field campaigns, but expensive as an operational system.

- Can we enhance IR and VIS impact through all-sky assimilation ?

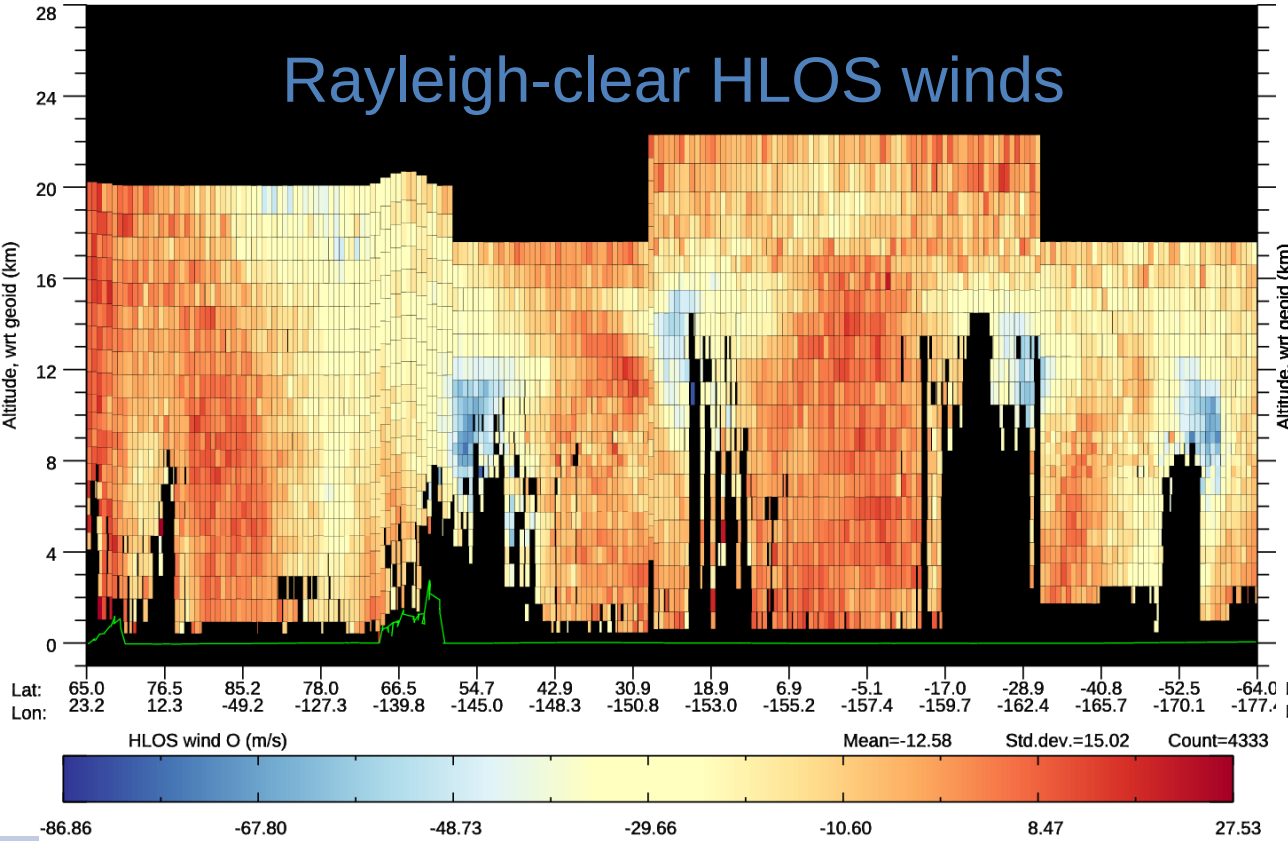
- Only active sensing (Radar, Lidar, new GNSS concept) can provide higher vertical resolution:
  - Studies e.g. *Schäfler et al. 2011* show value of lidar wind and humidity to study WCBs
  - Successful demonstration of wind lidar, cloud radar, cloud lidar assimilation at ECMWF

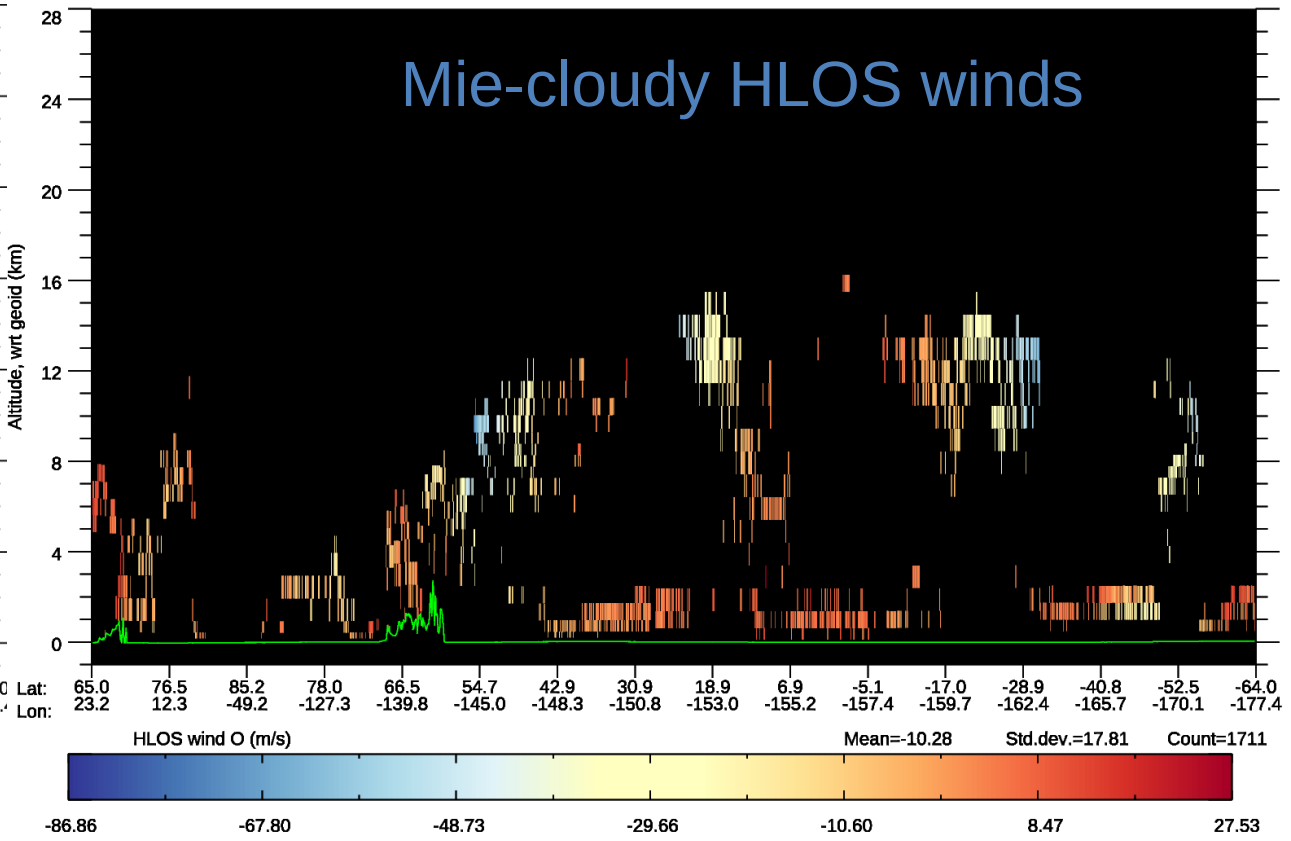
New observations: Aeolus

(Rennie and Isaksen, cloud + precip workshop, ECMWF, Feb 2020)

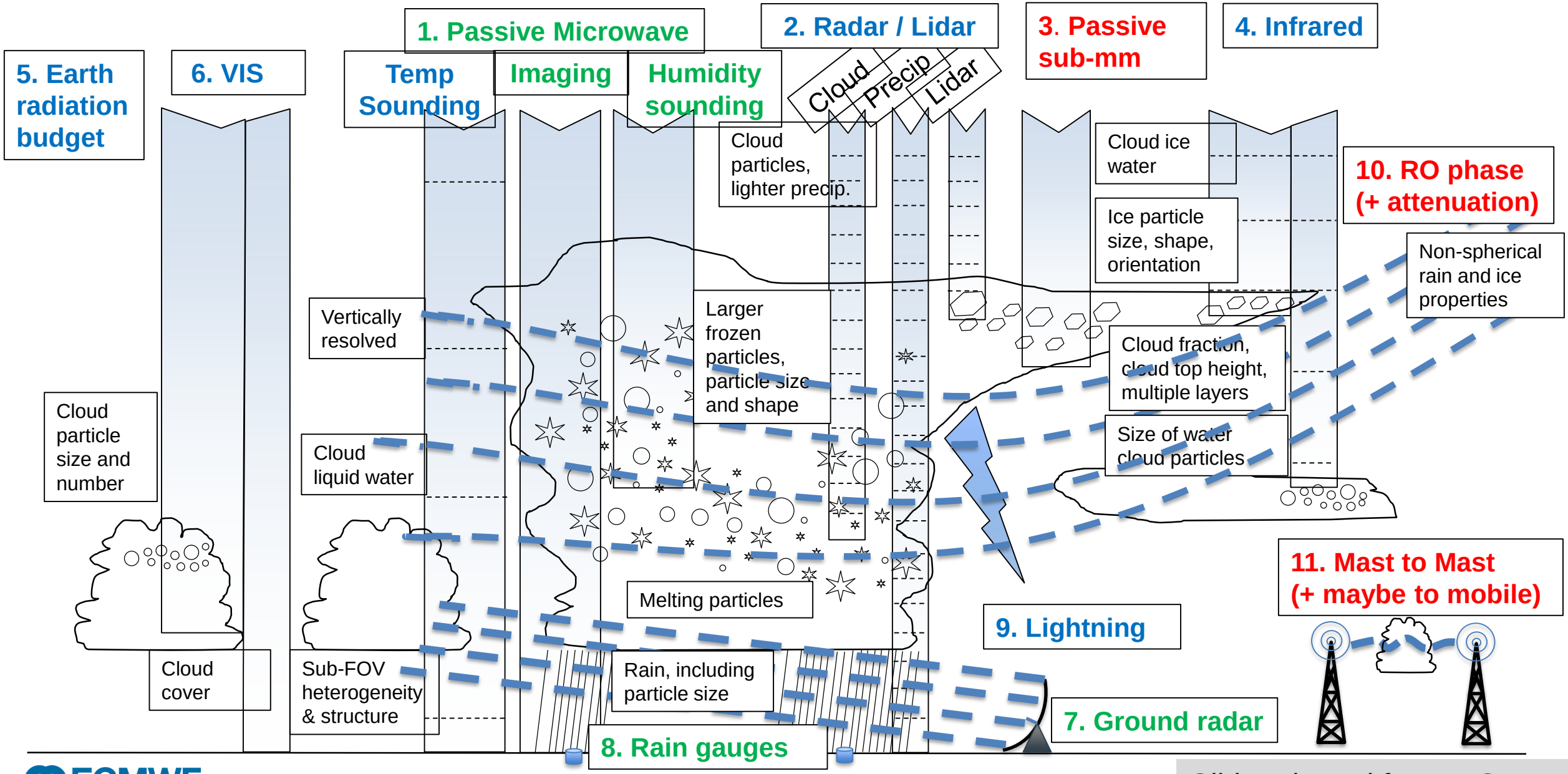
Thanks to Mike Rennie for these figures

- Aeolus has been operating for over 1.5 years
- Used operationally at ECMWF since January 2020
- Significant positive impact: several papers talk of value of wind lidar for WCBs (+ Schäfler talk yesterday)
- Mie winds (error ~ 3.5 m/s) provide wind information in cloudy areas





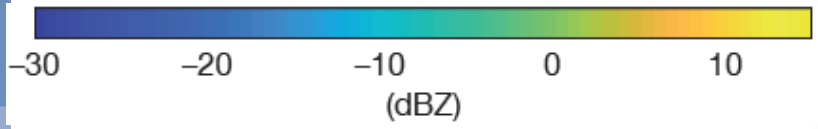
Cloud and precipitation sensitive satellite observations: now and near future

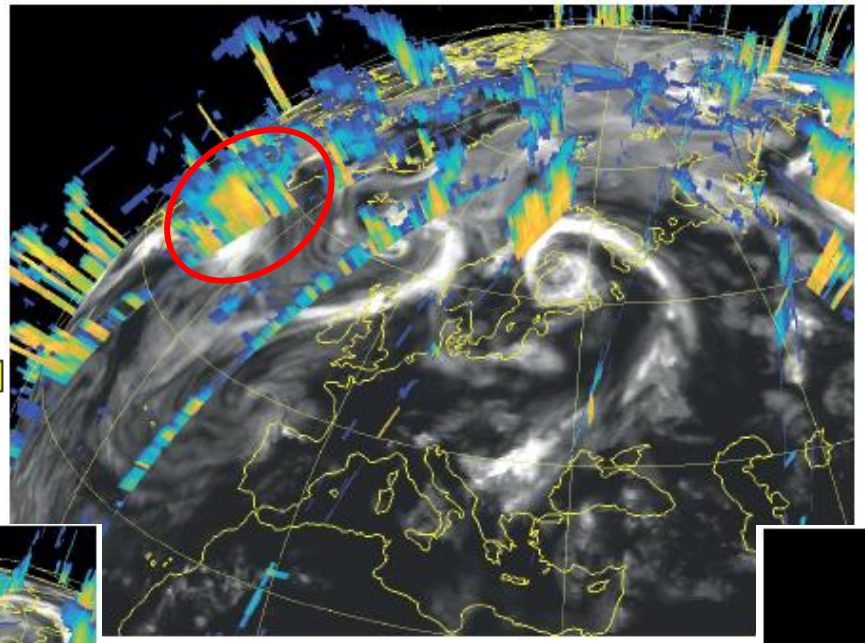


Slide adapted from A Geer

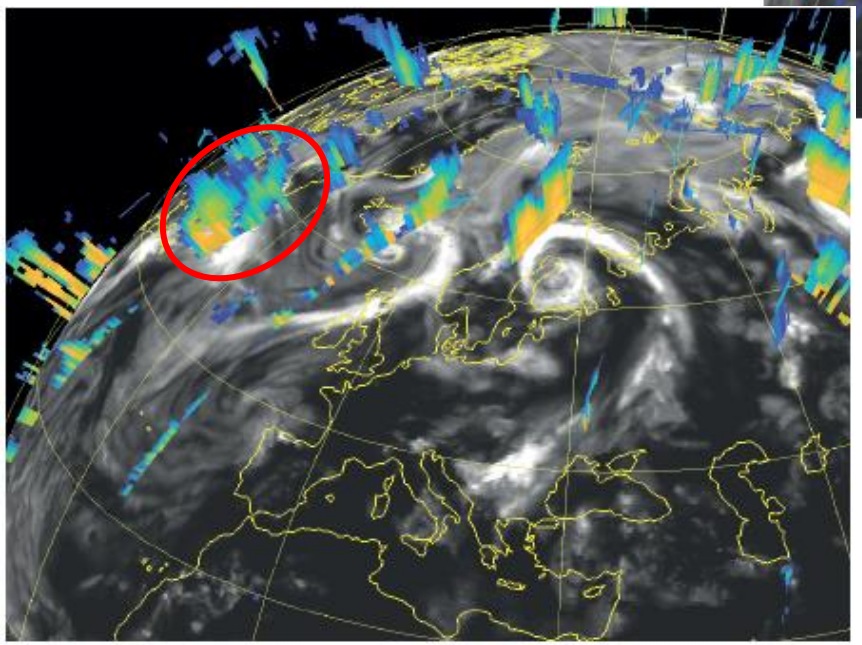
New observations: EarthCARE (Janiskova and Fielding cloud + precip workshop, ECMWF, Feb 2020)

Experiments assimilating Cloudsat radar reflectivity (94 GHz) and CALIPSO lidar backscatter (532 nm).



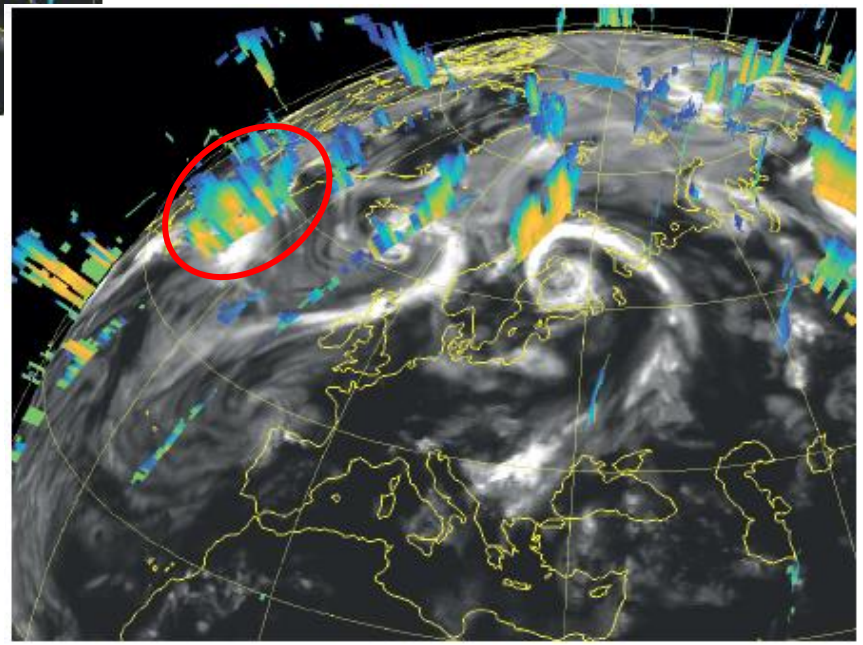


CloudSat radar



First guess (FG)

Analysis (AN)



Positive impact on headline NWP scores (research only).

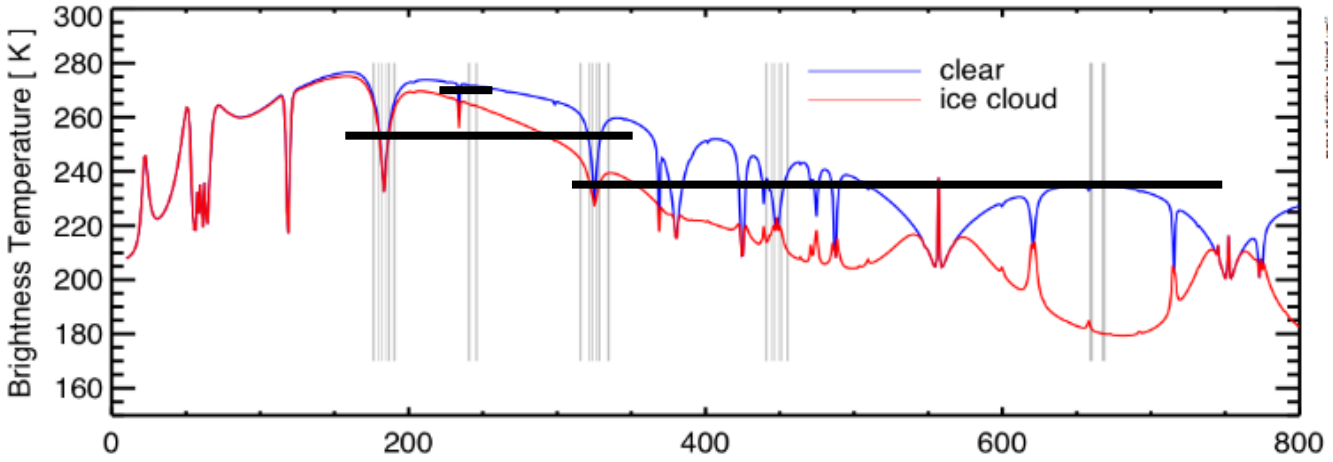
Illingworth talk to follow.

Situation: 20070731 21:00 UTC – 20070801 09:00 UTC

Thanks to Marta Janiskova and Mark Fielding for these figures

Future Observations: EPS-SG: Ice Cloud Imager - ICI

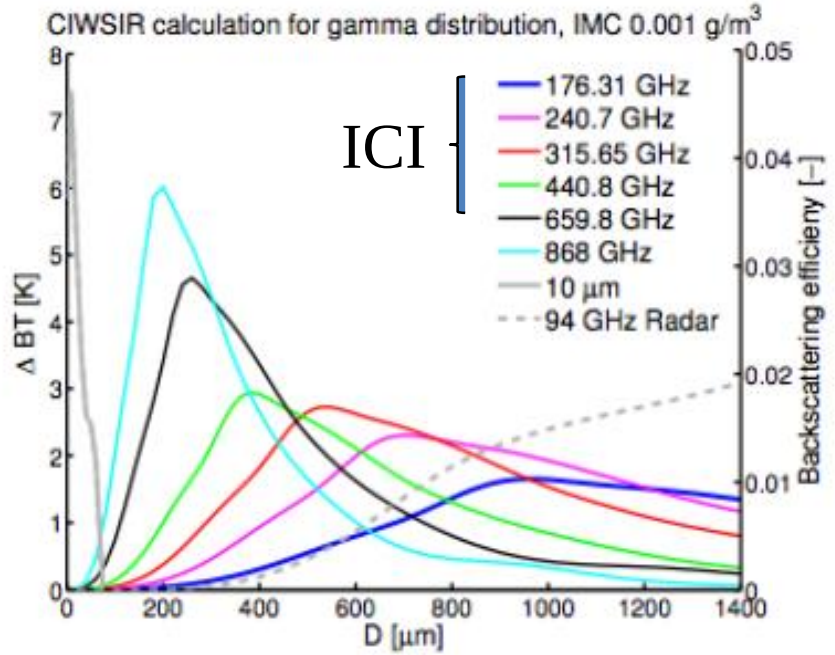
Thanks to IceCloud proposal (Buehler et al.) for these figures



Ice water path

+

Some information on particles (size, shape, orientation….)



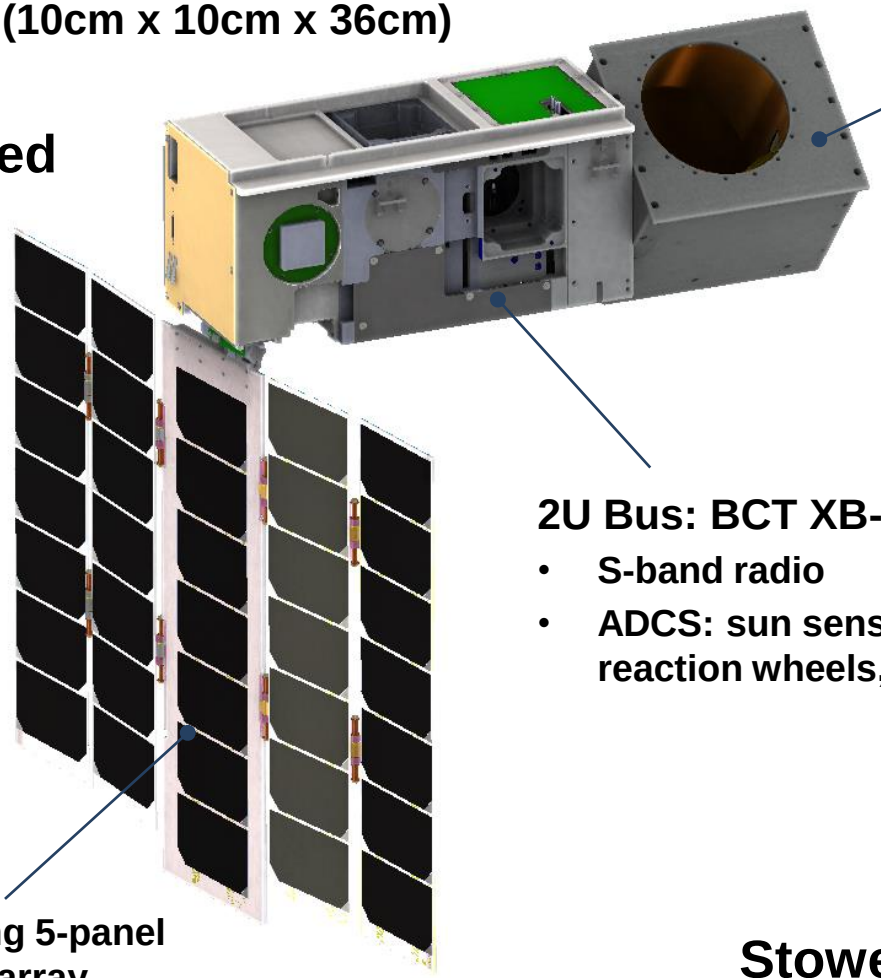
ECMWF

Future Observations: Small MW satellite constellations, e.g. TROPICS

TROPICS CubeSat Overview

3U CubeSat
(10cm x 10cm x 36cm)

Deployed



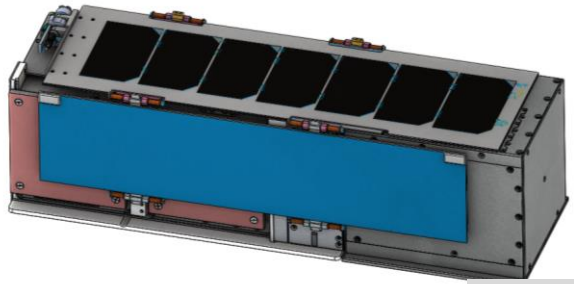
Articulating 5-panel solar array

1U Payload
- Rotating microwave radiometer
- Scanner assembly
- 83 mm aperture
- Noise-diode / sky calibration

Ultra-compact W / F / G radiometer
- W band 92 GHz
- F band 7 ch (114-119 GHz)
- G band 4 ch (183±1, 3, 7), 204 GHz

2U Bus: BCT XB-1
- S-band radio
- ADCS: sun sensor(s), star-camera, reaction wheels, torque rods

Stowed

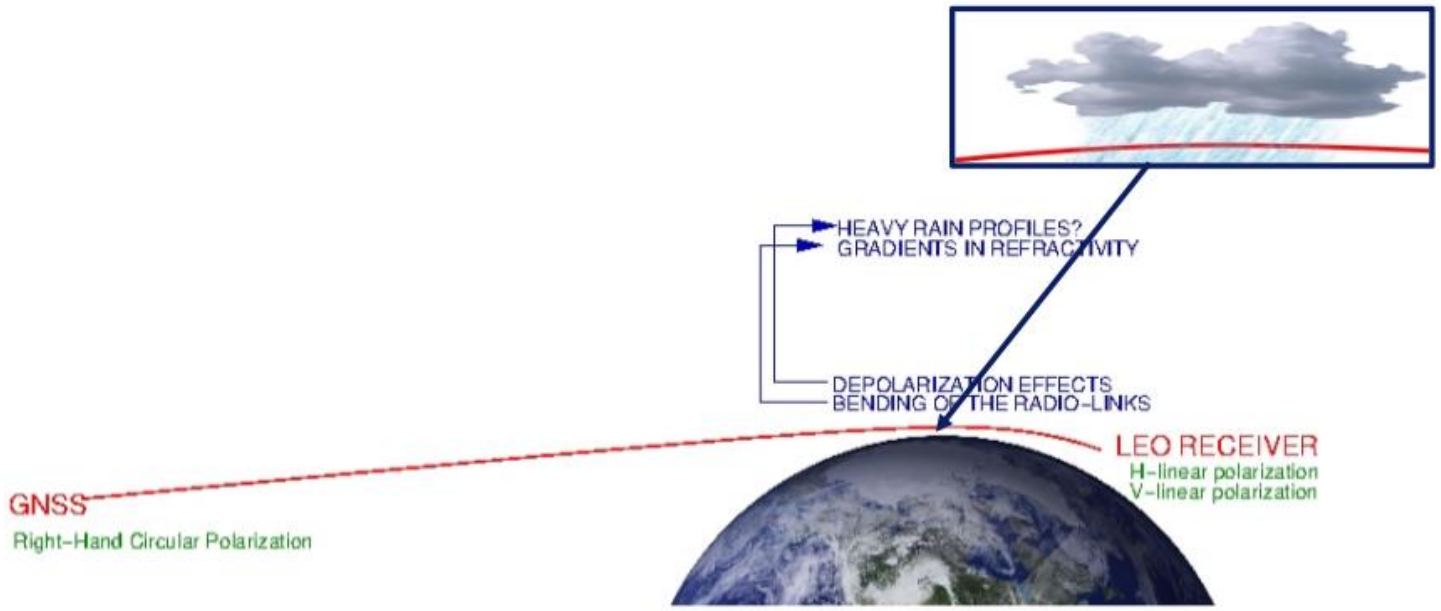


Thanks to Bill Blackwell (MIT) for this slide

GNSS Phase

GNSS-PRO:

Institute of Space Sciences CSIC IEEC



'NEW' GNSS-PRO PRODUCTS:

VERTICAL PROFILES OF THERMODYNAMIC VARIABLES (typically temperature, pressure, water vapor)

+ **VERTICAL PROFILES OF INTENSE RAIN**

The Radio Occultation and Heavy Precipitation aboard PAZ experiment (ROHP-PAZ)

https://paz.ice.csic.es

Demonstrating sensitivity to rain and frozen hydrometeors.

Thanks to Estel Cardellach (ICE, CSIC, IEEC) for this slide

Summary

What do we have?

- Wind and dynamics: Aeolus; from radiances: all-sky feature tracking, AMVs; in situ (when available);
- Humidity; all-sky MW for large scale total moisture in cloudy areas, IR from Geo (MTG-IRS, FY4-GIIRS) for moisture flux but only in cloud-free conditions or need big step forward in all-sky IR;
- Keep in mind non-local observations are critical to medium range forecasting of events.

Gaps?

- We lack vertical resolution esp. below cloud top: Radar and lidar e.g. EarthCARE may help, and also polarimetric GNSS?;
- Wind lidar follow-on is important, Aeolus won't last long.

Field Campaigns?

- WIGOS good for DA, but insufficient for process studies, so obvious role there;
- For operational DA, campaigns should aim to teach us how to use the existing WIGOS better.