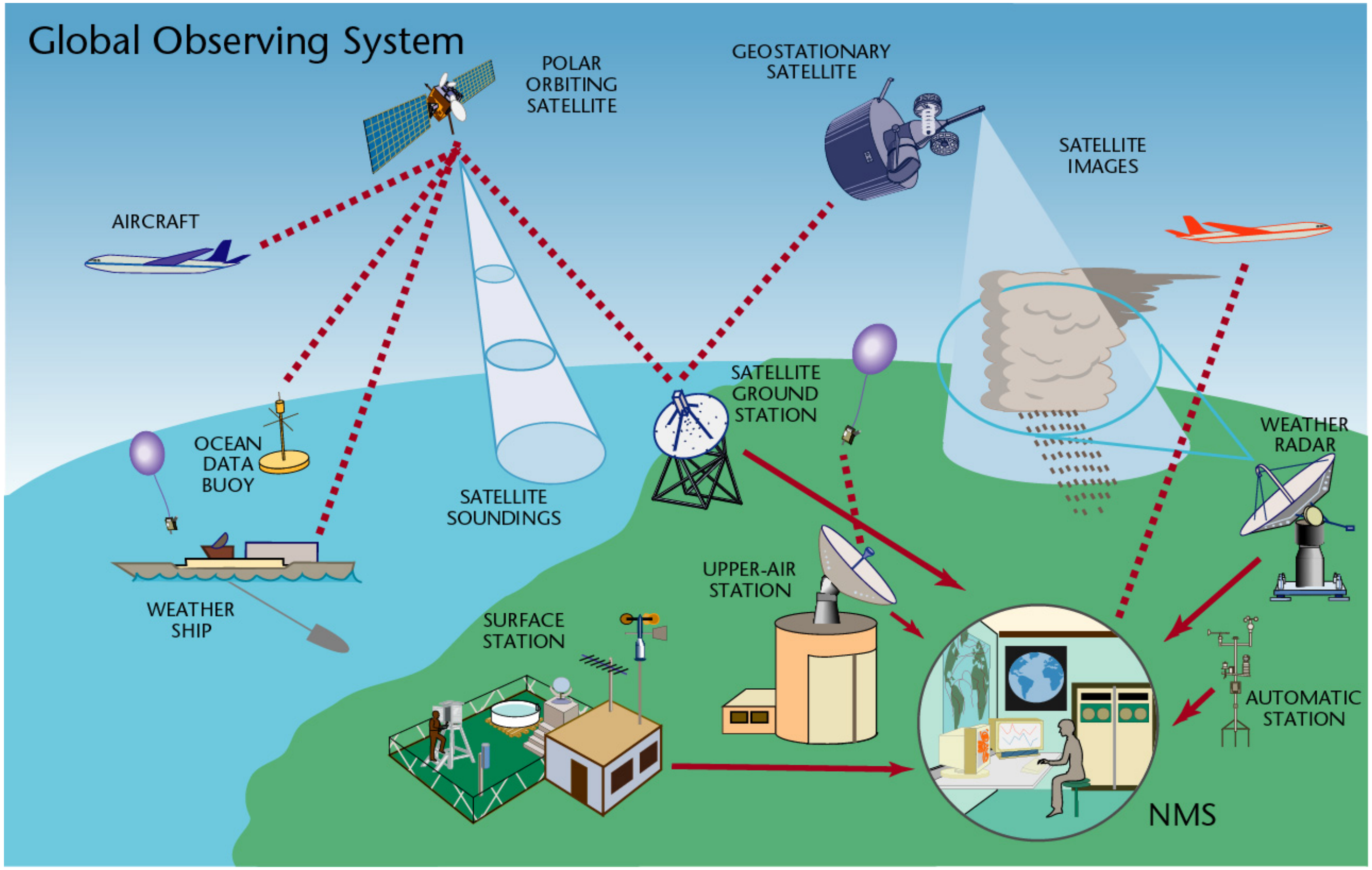
How will the future observational system develop?

a journey from ground to space

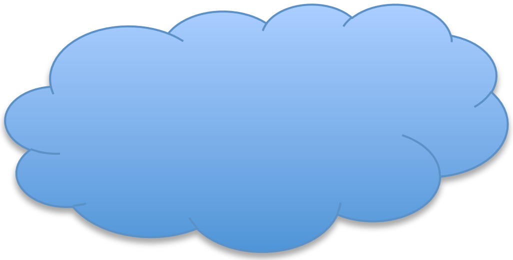


Global Observing System (GOS) co-ordinated by the World Meteorological Organization (WMO)

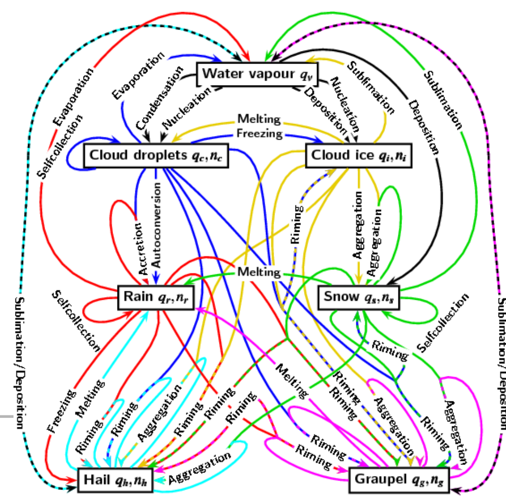
Susanne Crewell, University of Cologne

Universität zu Köln

From simple clouds



to „Seamless Prediction of the Earth System: From minutes to months“



WMO, G Brunet, S Jones, PM Ruti Eds., [WMO-No. 1156](), (ISBN 978-92-63-11156-2), Geneva.

Why observations?

- **Prerequisite for seamless prediction of the Earth system**
  - nowcasting
  - initializing NWP models, producing reanalysis
  - understanding processes
    evaluating individual components (e.g. parameterizations)
  - evaluating predictions
- **Monitoring of the status of the planet**
- **Improvement of environmental planning**

International coordination also across disciplines is necessary
Observing Systems Capability Analysis and Review Tool (OSCAR)
http://www.wmo-sat.info/oscar/

Historic development

Historically observations come from

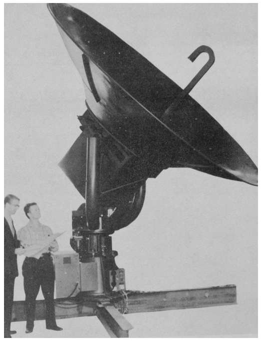
- synoptic stations
- radio soundings

declining

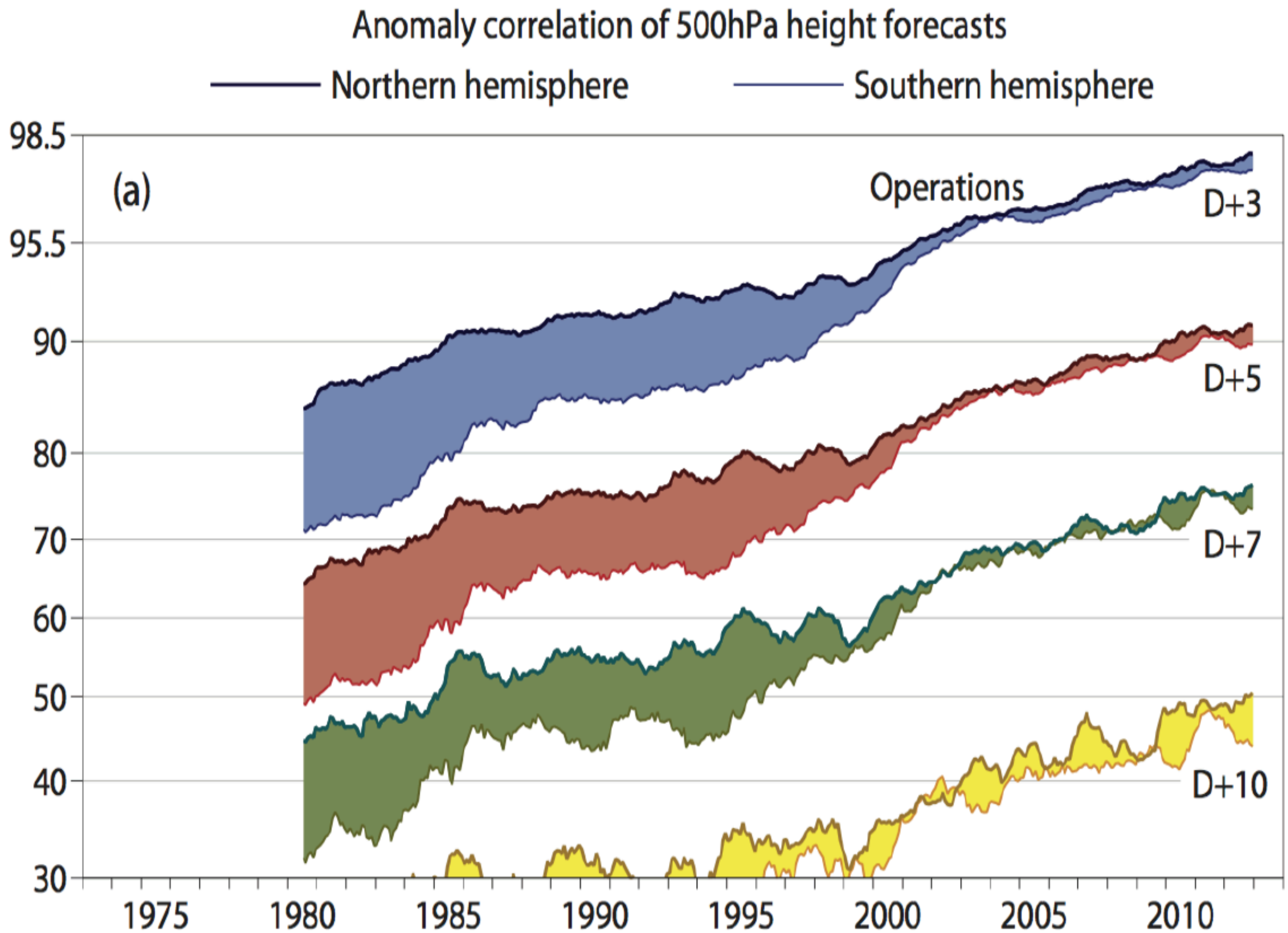
- operational meteorological satellites hmmh

The last fifty years have seen great progress in the availability of innovative observations of many geophysical variables on different spatio-temporal scales

- routine aircraft observations
- weather radar networks
- Global Navigation Satellite System
- lightning detector,
- ceilometers and other evolving instruments,



How important are observations?



What data are used most?

What data are most (least) available for data assimilation?

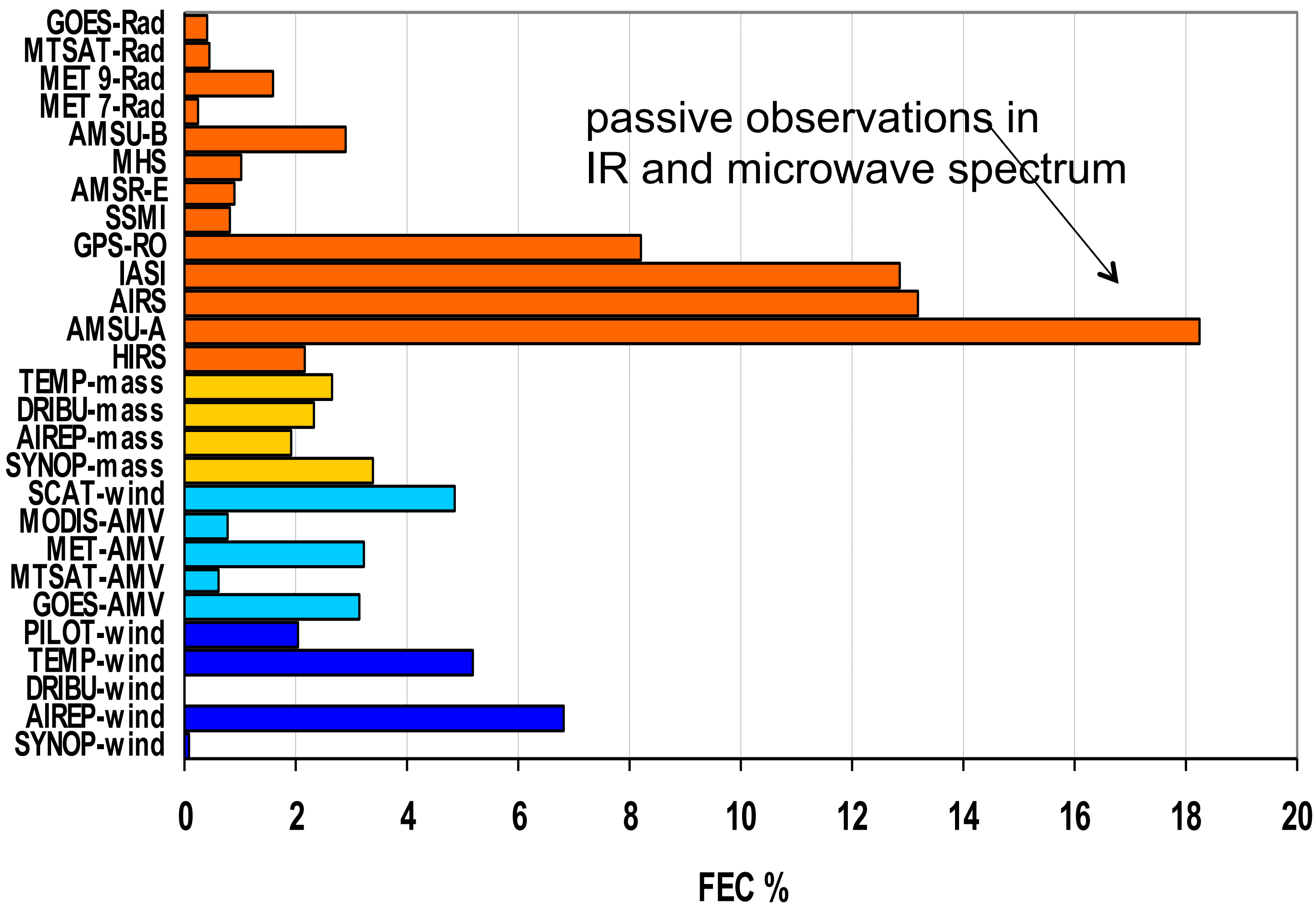
What data source is used with the highest (lowest) percentage?

Data assimilated by MetOffice on one day

# Obs	Source	Percent
1.300	TEMP radiosonde	95
830	PILOT (wind)	21
18.000	windprofiler	17
370.000	aircraft	25
80.000	SYNOP	20
30.000	ships and buoys	70
>3.000.000	satellite surface winds	5
>1.000.000	atm. motion vectors	10
>6.000.000	satellite radiances	15
3.000	radio occultation	80
450.000	GNSS IWV	< 1

The value of observations

Contribution of individual observing systems to reduction of 24 h forecast error averaged over period September to December 2008.

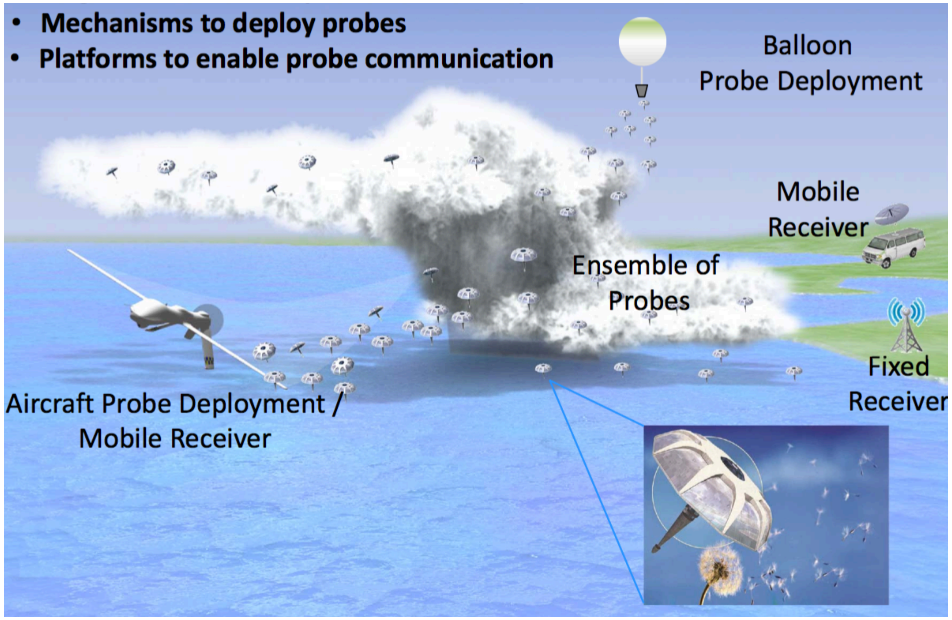


Peter Bauer
Promet,
ECMWF

In situ measurements

Sensor miniaturization and integration

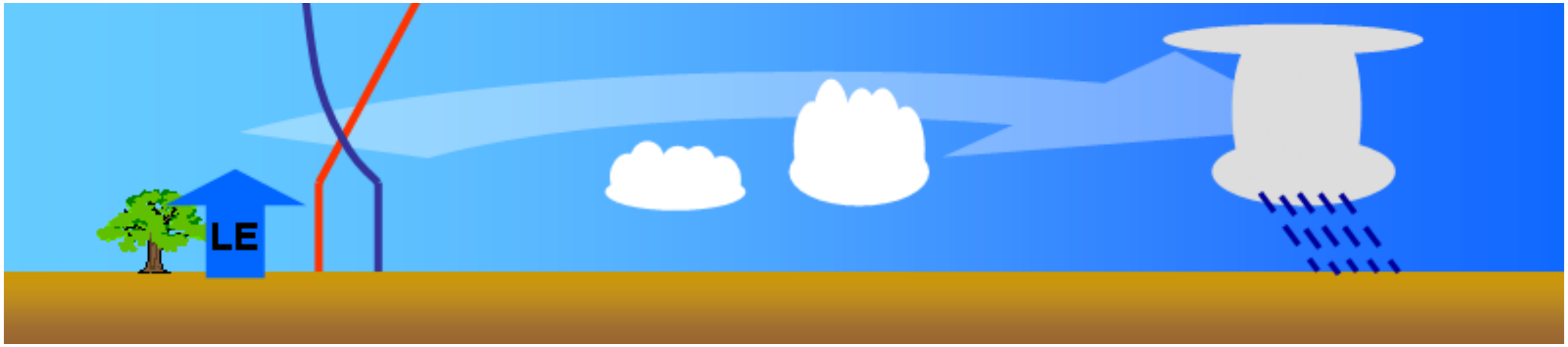
crowd sourcing sites and utilising mobile phone technology.
by 2016 0.5-1 one billion smartphones and tablets will have the capacity to measure pressure as well as parameters such as position, humidity, and temperature (Mass and Madaus, 2014).



biodegradable electronic components can be deployed in a wireless network to capture the 3D structure

Surface and in situ

Focus on land-surface interaction
ABL is difficult to capture from satellites and in-situ sensors



Splittered community (hydrology, agriculture..)
Land surface interaction on slower time scales but higher resolution, e.g. pore size distribution, hydrolic conductivity..)

International Soil Moisture Network (Dorigo et al. 2013).

- Multipath GPS for snow moisture and snow depth
- Cosmic rays measurments for soilmoisture

on the way to remote sensing

Drones

Global Hawk

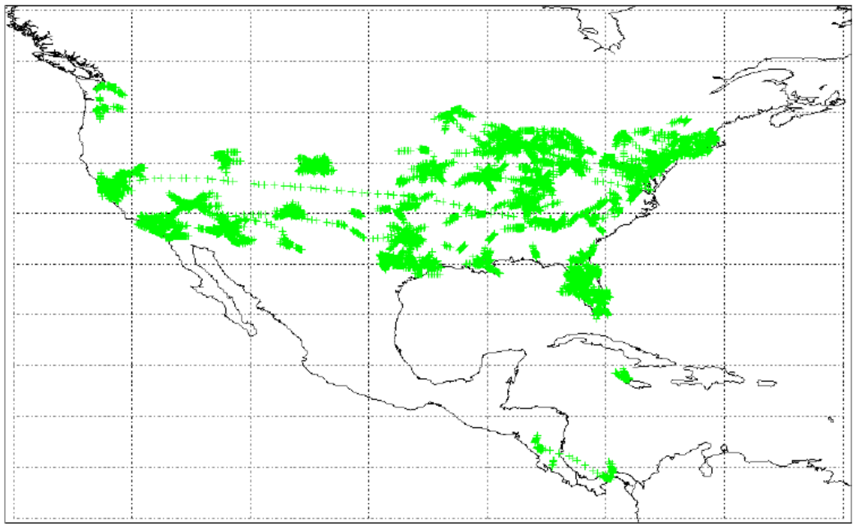
Braun et al., 2013

Airborne observations

Operational aircraft observations of temperature and wind

relatively few with high quality humidity

1 July 2014 AMDAR q availability 700 - 350 hPa



In-service aircraft for Global Observation System (IAGOS, www.iagos.org/)

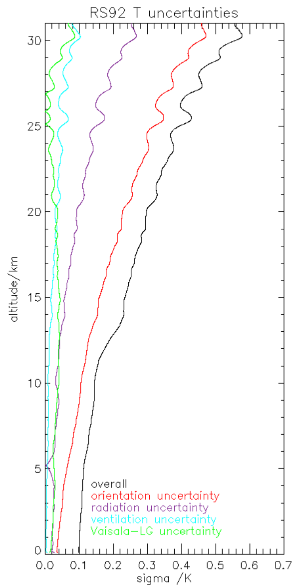
European Research Infrastructure with high-tech instruments for regular in-situ measurements of atmospheric chemical species (O_3, CO, CO_2, NO_y, NO_x, H_2O)

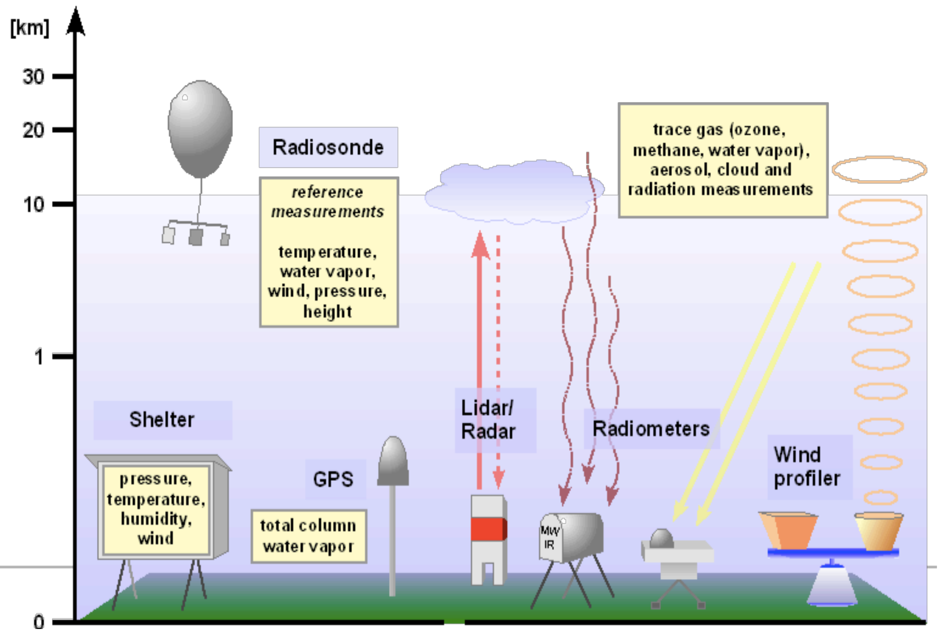
Installation of the new IAGOS equipment for atmospheric measurements aboard an Airbus A340 of Lufthansa

Future reference observations

GCOS Reference Upper-Air Network (GRUAN)
Uncertainty, Redundancy and Consistency

GCOS Cascade of upper-air networks





Ground-based remote sensing networks

Opportunities

- can respond to new technologies on a much shorter time scale
- advances in automation, miniaturization and communication allow to reduce personnel cost
- observations of convective processes with high temporal and spatial resolution

Challenges

- various degrees of maturity
- automatic quality control
- exploitation for NWP

CWINDE Wind profiler network

Ground-based networks

- Each group to choose one network,
  e.g. microwave radiometer, ceilometer...
- What products can your instrument network deliver?
- What are the advantages compared to other instruments?
- Who would be your users?
- Which density should your network have?
- How much would a funding agency need to spend to install/operate such a network?

The judges will decide!

Other networks

- **Ceilometer networks**
  aerosol backscatter profiles, visibility, cloud base height, boundary layer monitoring
- **Doppler wind lidar**
  vertical profiles of wind vector, variance profiles, mixing layer height
- **Radar wind profilers** (assimilated)
  vertical wind profile
- **Microwave radiometers**
  temperature profiles, humidity, liquid water path
- **Infrared spectrometers**
  temperature and humidity profiles, tin cloud and aerosol properties
- **Water vapour lidar**, i.e. Raman and differential absorption lidar (DIAL)
- **Weather radars**
  precipitation, Doppler velocity, hydrometeor typing
  (Phased array radar - electronic scanning)
- **Lightning networks**

Microwave Radiometer Intercomparison 2001

Crewell, S., et al., 2004: The BALTEX Bridge Campaign: An integrated approach for a better understanding of clouds. *Bull. Amer. Meteor. Soc.*, 85(10), 1565-1584, doi: 10.1175/BAMS-85-10-1565.

TOPROF WG MWR

1. **Establish protocols for providing QC MWR data (+ uncertainties)**
   - Review protocols for calibration, scanning, and maintenance
   - Collect already available calibration documents via MWRnet and compile to one document
   - Put together Calibration Procedure Document (CPD)

2. **Coordinate the data processing chain (e.g. harmonised network)**
   - Common data format and data life cycle
   - Establish a common forward model & advanced retrieval method
   - Continue ground-based RTTOV development (MO)
   - Develop standardized 1DVAR retrieval

3. **Engage NWP DA community (requirements, tools)**

Ground-based remote sensing networks

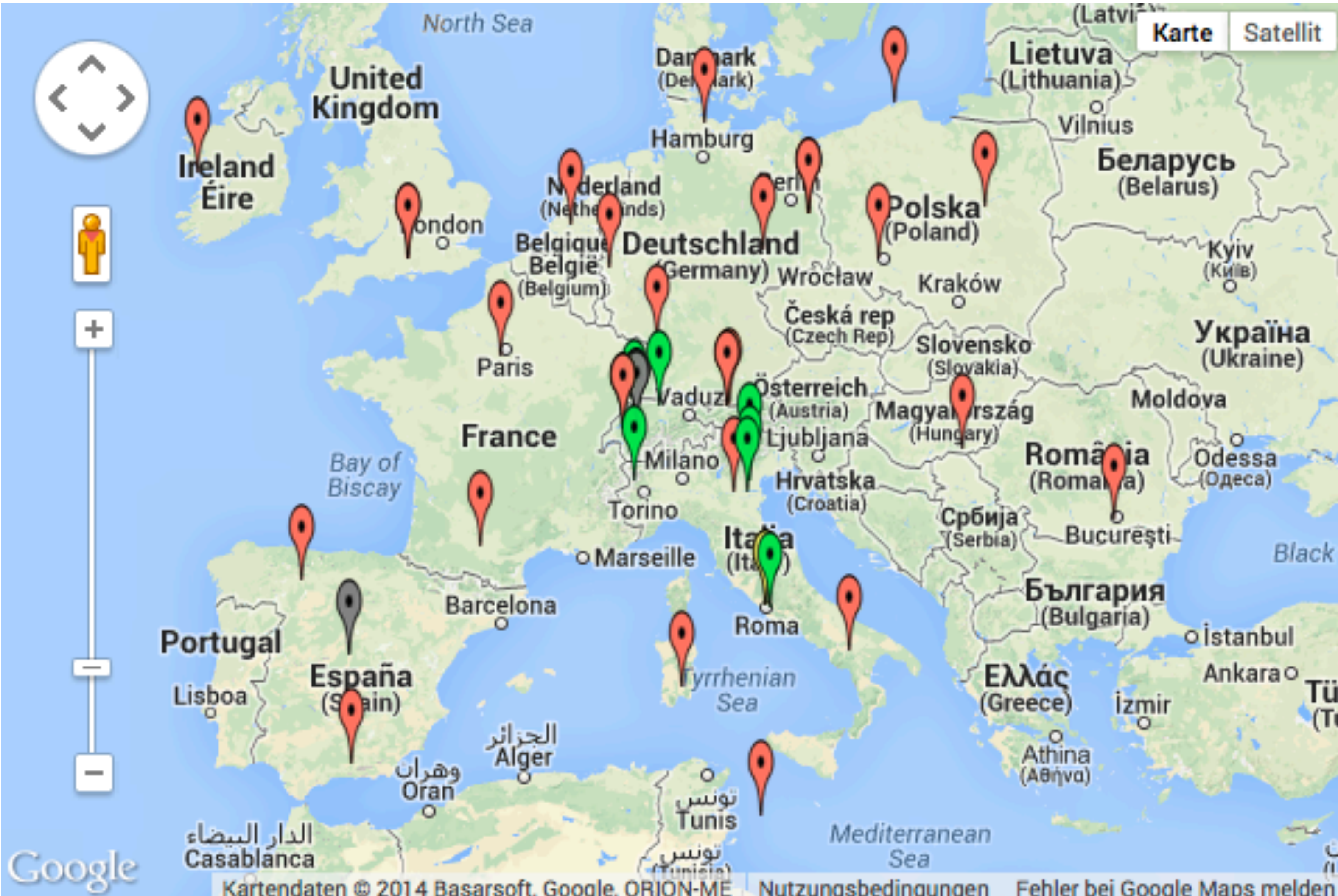
MWRNET - International Network of Ground-based Microwave Radiometers

(c)

Figure 3. Maps of exemplary ground-based networks a) CWINDE network; b) European lidar and ceilometer network; and c) MWRnet from COST EG-CLIMET final report

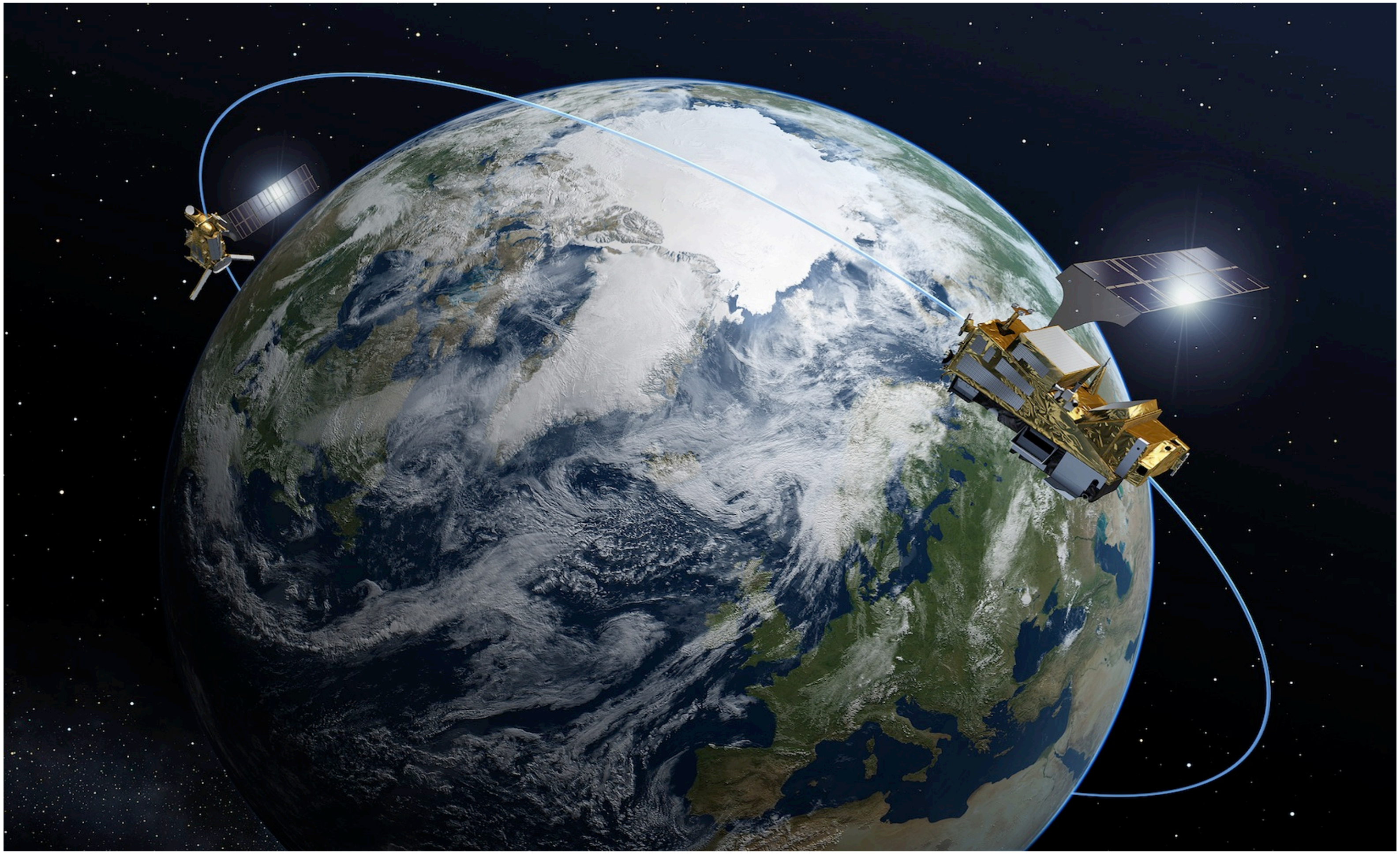
http://cetemps.aquila.infn.it/mwrnet/

Microwave radiometer network

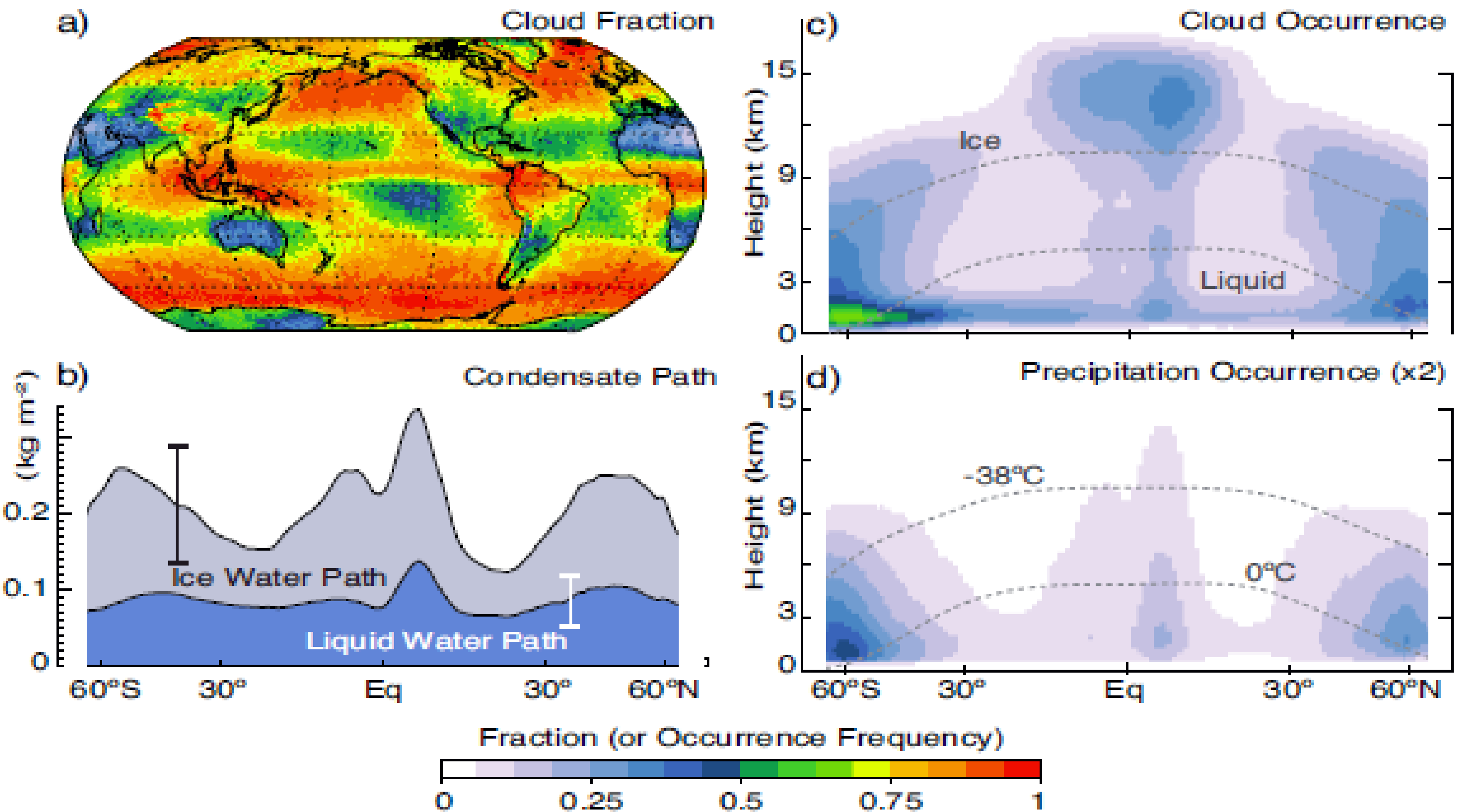


The long way into the sky

Example: ICI on MetOP



Global distribution of clouds



Boucher et al., 2013 (IPCC Report, Chapter 7: Clouds and Aerosols)

Satellite missions - identifying the need

- European Organisation for the Exploitation of Meteorological Satellites (Eumetsat) operates the **Eumetsat Polar System (EPS)** in morning orbit.
- The first MetOP series will come to an end in the 2020 time frame.
- Follow up series (MetOp - Second Generation) should also respond to climate monitoring and consider evolution of applications
- Position Paper 2006
  Cloud, Precipitation and Large Scale Land Surface Imaging (CPL)
  „Obs. Requirements for Meteorology, Hydrology, and Climate“

User Needs (NWP)

Priority 1 cloud parameter

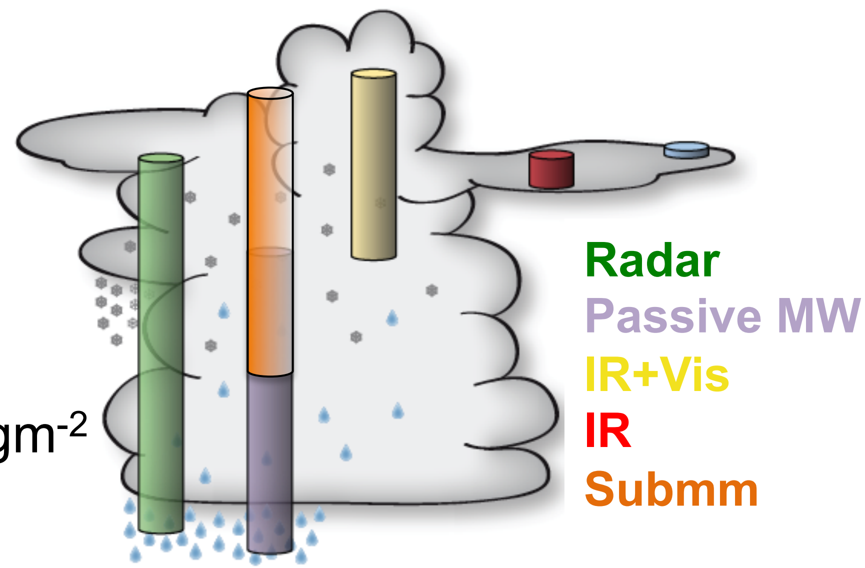
- Cloud ice profile (**IWC**)

Priority 1 precipitation parameter

- Precipitation profile (liquid and **solid**)
- Precipitation rate at surface (liquid and **solid**)
- Precipitation detection (liquid and **solid**)

How to measure ice clouds?

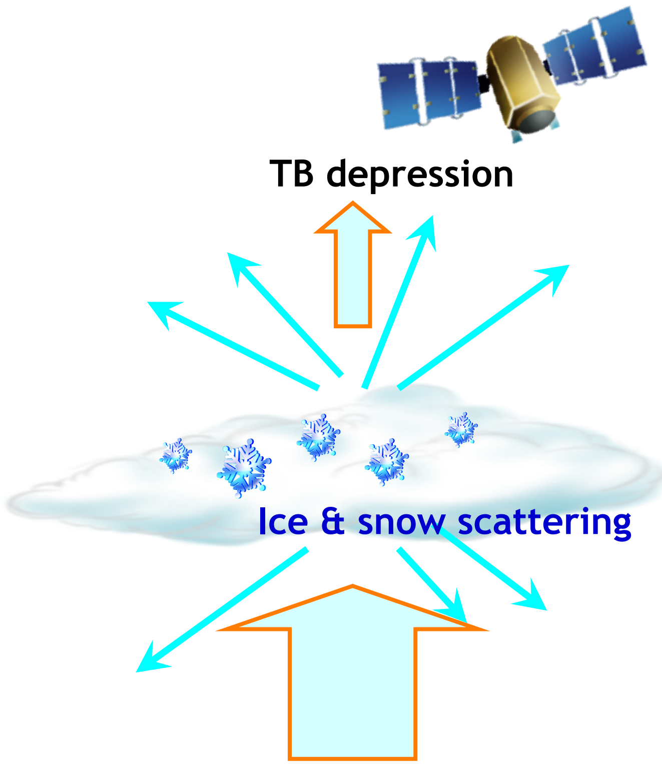
- **Active microwaves** (CloudSat CPR)
  - → poor spatial coverage
- **Passive microwaves**
  - → only sense precipitating ice
- **VIS / IR techniques**
  - → only sense ice water path < 100 gm^{-2}
- **Lidars**
  - → only sense optical depths < 3

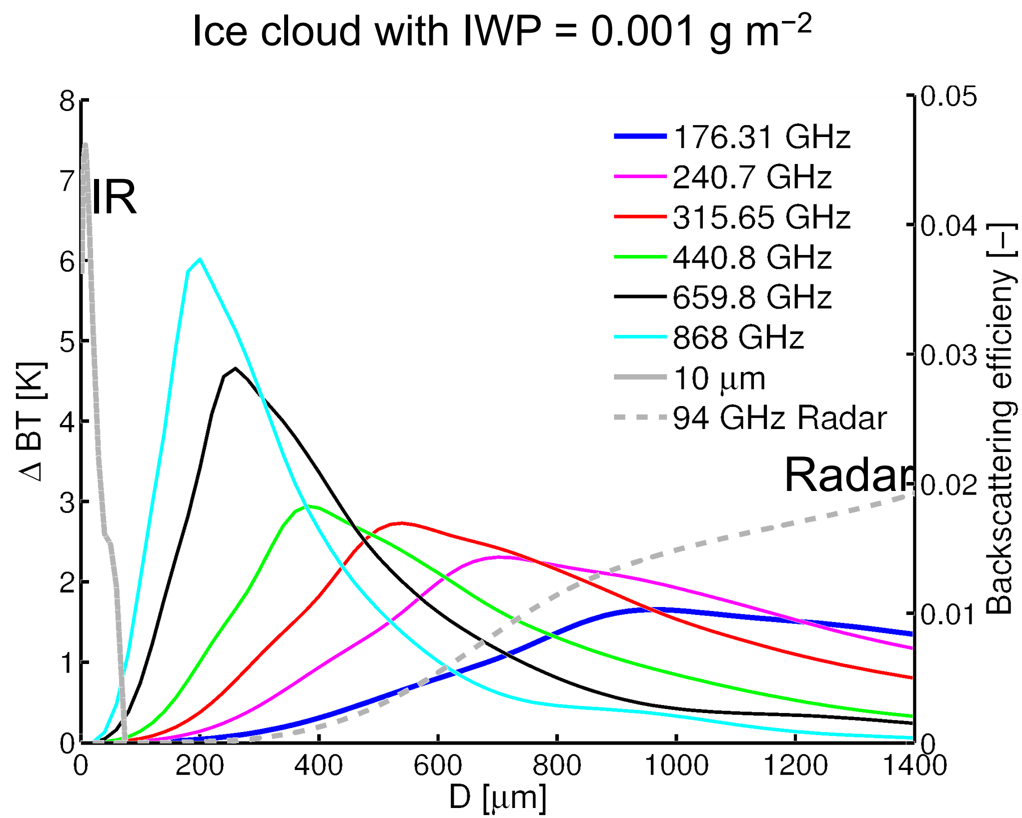


Adapted from
Eliasson et al., 2011

- **Submm channels**
  - → sense different altitudes of cloud depending on wavelength
  - → estimate ice mass and mean ice particle size

Submillimeter principle

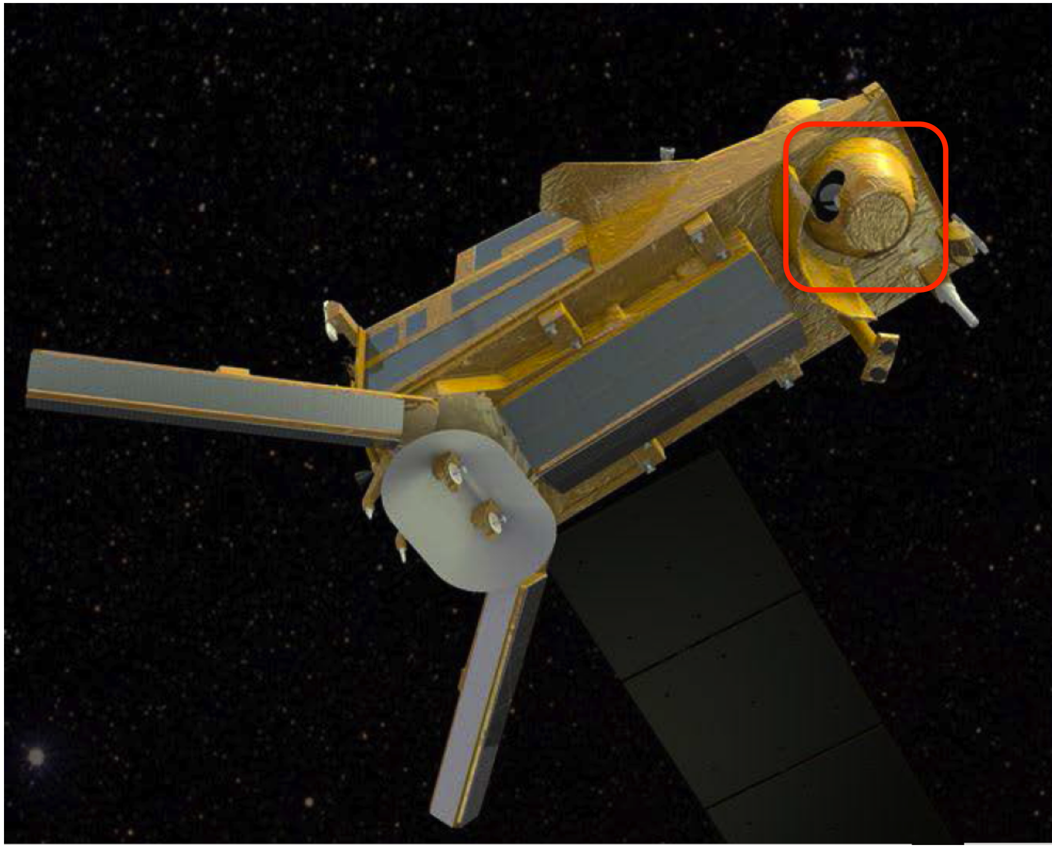




Buehler et al., 2007

Submm waves sense different particle sizes and fill gap between IR and radar

- Eumetsat User Consultation Meeting held in 2011.
- MetOp-SG will consist of two satellites.
- Sat-B is the "microwave" satellite.
- ICI is one of the instru-ments embarked on Sat-B.
- ICI is a completely new instrument with no heritage from any space borne precursors.



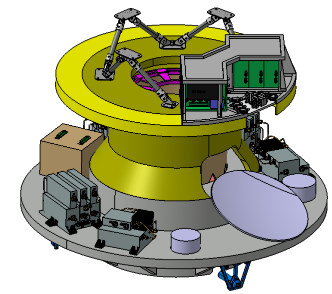
ICI Accommodation on Sat-B

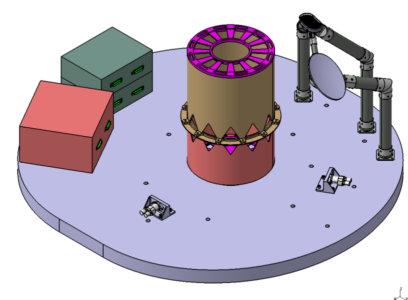
Launch scheduled for December 2022

ICI Characteristics

ICI Prime: Casa Espacio

Channel Name	Frequency (GHz)	Bandw. (MHz)	Simplified Utilization
ICI-1	183.31±7.0	2×2000	Water vapor profile and snowfall
ICI-2	183.31±3.4	2×1500	
ICI-3	183.31±2.0	2×1500	
ICI-4	243.20±2.5	2×3000	Quasi window, cloud ice retrieval, cirrus clouds
ICI-5	325.15±9.5	2×3000	Cloud ice effective radius
ICI-6	325.15±3.5	2×2400	
ICI-7	325.15±1.5	2×1600	
ICI-8	448.00±7.2	2×3000	Cloud ice water path and cirrus
ICI-9	448.00±3.0	2×2000	
ICI-10	448.00±1.4	2×1200	
ICI-11	664.00±4.2	2×5000	Cirrus clouds, cloud ice water path





Courtesy of Airbus Defence and Space

Gaps: Polar regions

International Arctic Systems for Observing the Atmosphered with a limited number of 10 observation sites distributed over the Arctic, the Arctic Monitoring and Assessment Programme (http://www.amap.no)

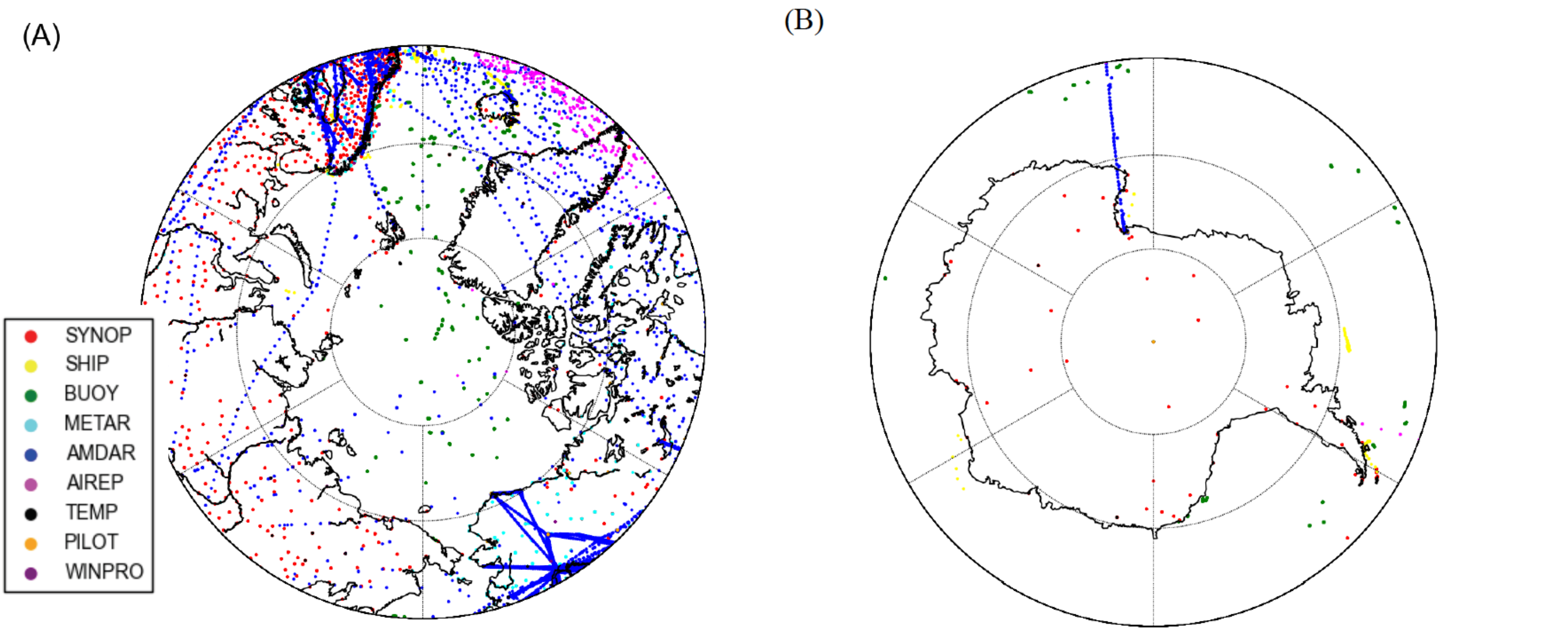


Figure 2. Observations received over the Arctic (A) and Antarctic (B) at the Met Office (UK) in a 24 hr period from 21Z 09/02/15 to 21Z 10/02/15

Air quality

Objective

- understanding of the changes in reactive gases, aerosol and greenhouse gases
- validation of chemistry-climate models

- **Global Atmosphere Watch (GAW) programme of WMO**
  GAW World Data Centres (see http://gaw.empa.ch/gawsis/)
  work toward near-real-time data

- **GALION (GAW Aerosol Lidar Observation Network)**
  network of networks (existing systems at established stations)
  GAW Report No. 178

- **Network for the Detection of Atmospheric Composition Change (NDACC,** http://www.ndsc.ncep.noaa.gov**)**
  > 70 high-quality, remote-sensing research stations
  physical and chemical state of the stratosphere and upper troposphere
  emphasis on the long-term evolution of the ozone layer

Future observations

Challenges

- provide high-resolution observations networks for convective-scale NWP
- atmospheric conditions under cloudy conditions
- more comprehensive involvement of hydrology, air quality,...

Opportunities

- synergetic use of different ground-based remote sensing systems
- exploitation of new satellite platforms and sensors
- integrating new sources of data such as from crowd sourcing

Threats

- satellite instruments fail and are not replaced
- surface networks over land and ocean decline