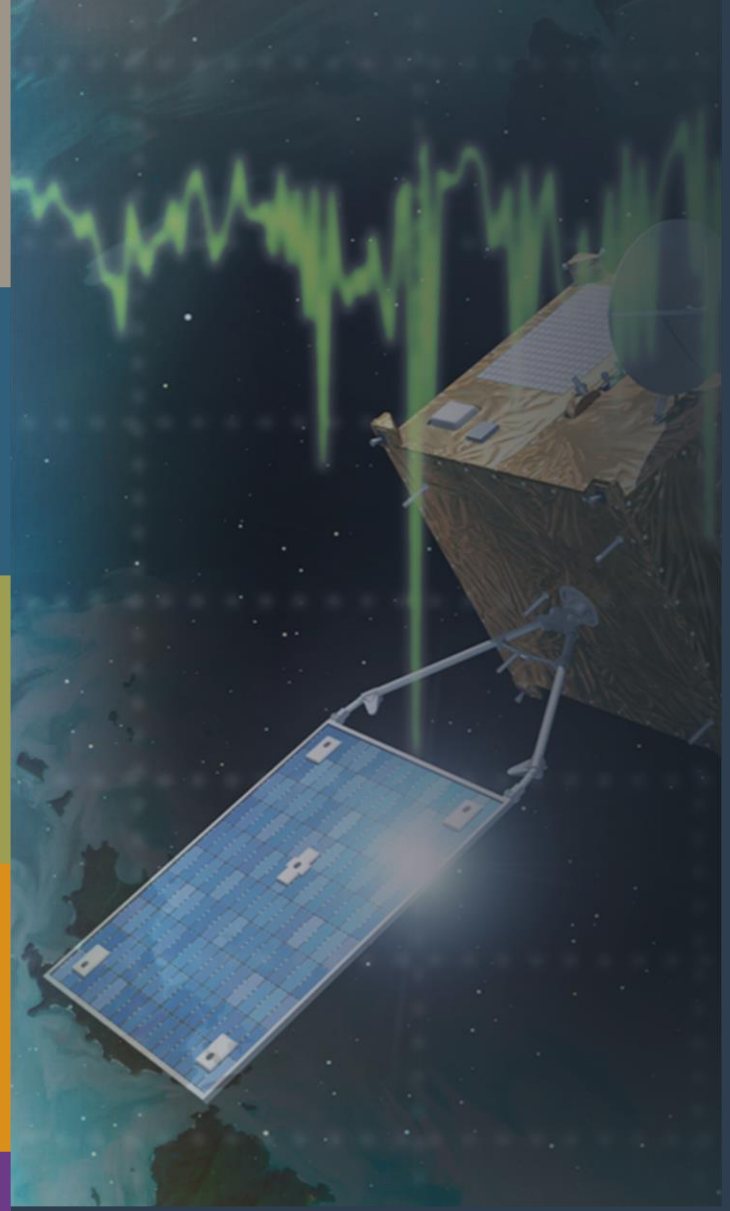
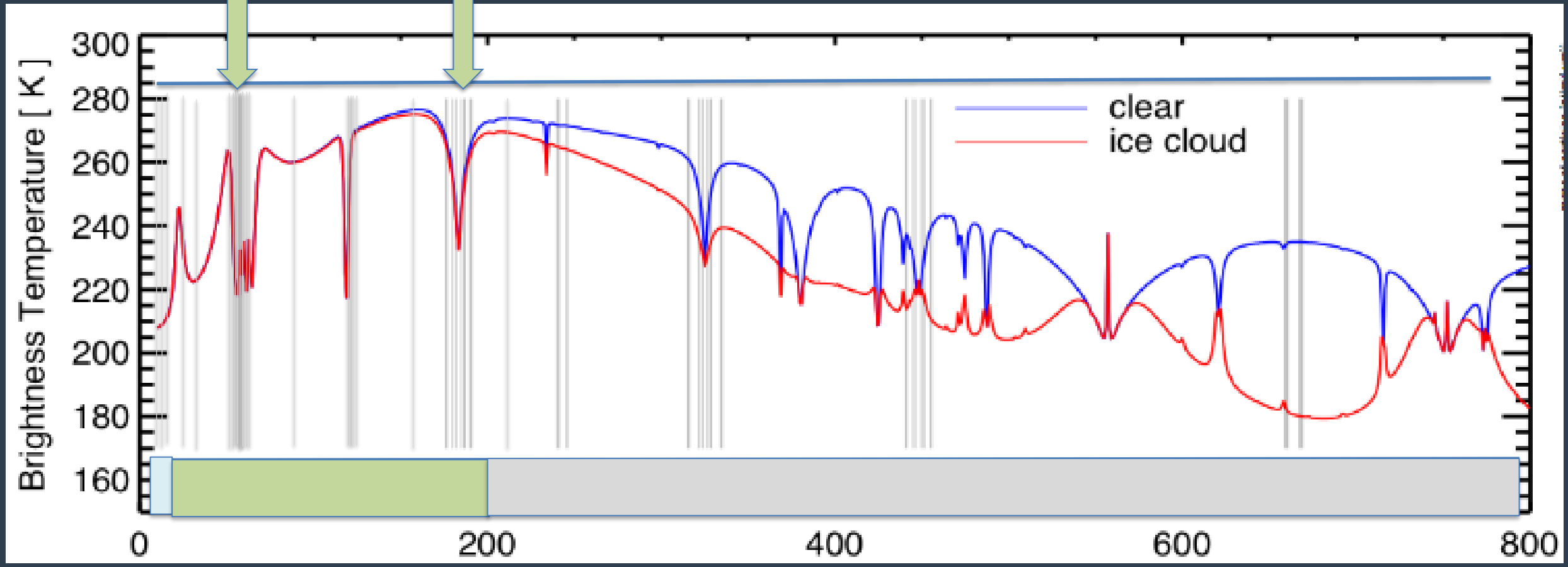


Meteorological Applications of TeraHertz Spectrum

Stephen English
Deputy Director Research
ECMWF

Spectrum Policy Forum meeting 20 April 2022

ECMWF



L, C, X bands
Earth surface and precipitation

K, Ka, V, W, G bands
Atmospheric temperature and humidity all-weather

Sub-millimetre bands
Ice cloud, stratosphere, trace gases
(on EPS Second Generation from mid-2020s)

Passive bands used in meteorology and climate above 85 GHz

Bands above 85 GHz of importance to operational weather prediction, climate monitoring and disaster risk reduction		
Frequency GHz	*Instruments*	*Information content*
86-92	AMSR-2 AMSU-A ATMS SSMIS MWHS-2 MWRI MTVZA-GY MWS	Precipitation
100-102 109.5-111.8 114.25-116 116-122.25	TROPICS MWHS-2 MWI TEMPEST	Temperature profile, cloud
148.5-151.5 155.5-158.5 164-167	ATMS GMI MWHS-2 MTVZA-GY AMSU-B MHS MWS+I TEMPEST	Precipitation, water vapour
174.8-182.0 182.0-185.0 185.0-190.0 190.0-191.8	AMSU-B ATMS SSMIS MWHS-2 SAPHIR GMI TROPICS MTVZA-GY MWS+I,ICI	Water vapour
200-209 226-231.5	TROPICS MWS	Ice cloud
239.2-247.2	ICI	Ice cloud
314.15-336.15	ICI	Ice cloud
439.3-456.7	ICI	Ice cloud
659.8-668.2	ICI	Ice cloud

JAXA (Japan) CMA (China) NASA/NOAA/DOD (USA)
ESA/EUMETSAT/CNES/UK (Europe) Roscosmos (Russia) ISRO (India)

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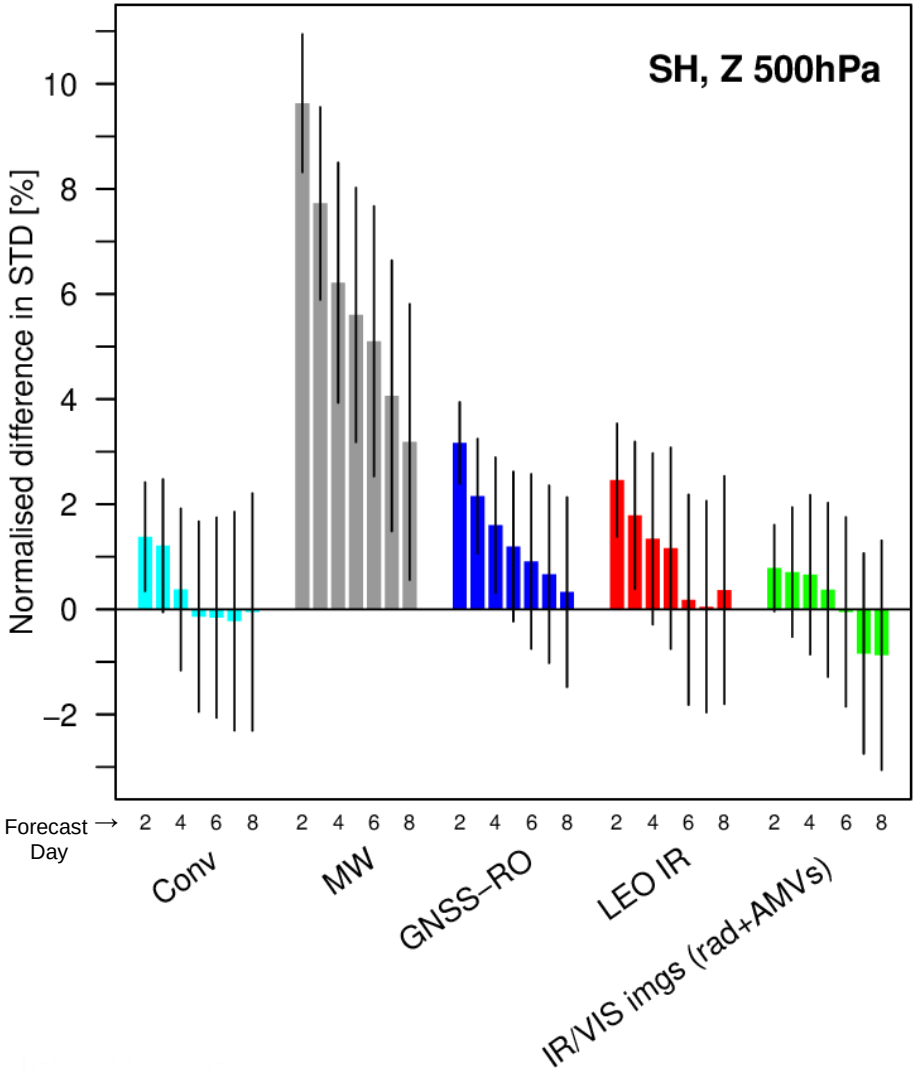
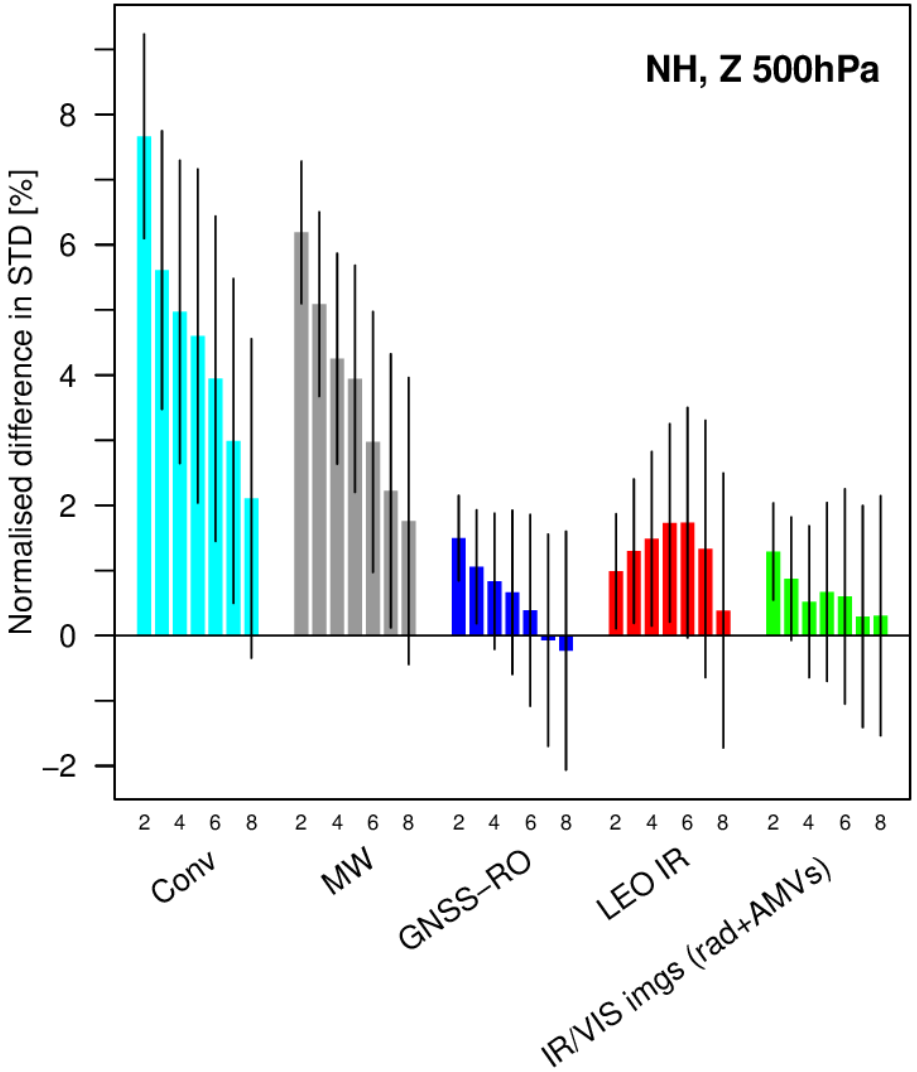
Active bands used / planned in meteorology and climate

- Most bands used in global weather studies are PASSIVE – measuring variations in what for other applications is the noise floor, which varies with changes in the atmosphere and earth's surface
- However, some are ACTIVE e.g. radar, altimeter, scatterometer
  - 238 GHz on NASA's SMICES ice cloud radar
  - 94 GHz on NASA's CloudSat radar since 2006, ESA/JAXA EarthCARE from 2023
  - 36 GHz Preciptiation radar on GPM since 2014; Radar Altimeter – CNES SARAL/ALTIKA
  - 13 GHz Precipitation radar on GPM since 2014; Radar Altimeter – NASA SEASAT since 1978; Scatterometer on QuikSCAT, OCEANSAT since 1999
  - 5 GHz Synthetic Aperture Radar and Scatterometer – ERS/ENVISAT/Sentinel since 1991; China's HY since 2011
  - Also ground based radar at S-band (~3 GHz), C-band (~6 GHz), x-band (~10 GHz), Ka-band (~30 GHz)

Forecast impact, day 2-8: 500 hPa geopotential

Verified against operational analyses, 3 periods combined





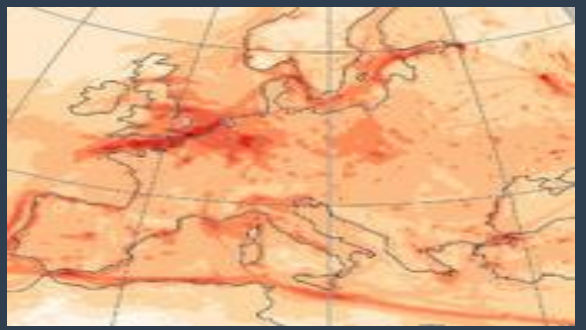
From Niels Bormann, ECMWF

Key areas benefiting from Numerical Weather Prediction

Public weather advice

Public snow, flood & fire

Hurricane & tornado



Air quality

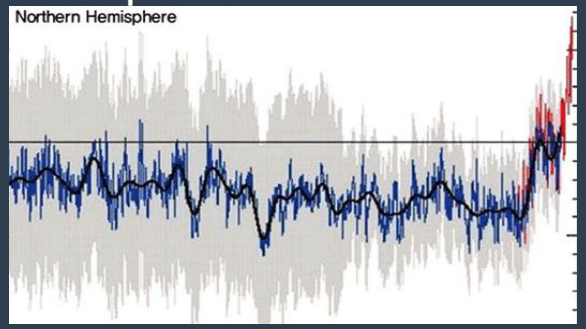
Warnings, public safety, protection of life and property

Transport

Energy

Agriculture

Tourism



Climate change Monitor

Public health and famine

Business and commerce

Defence

ECMWF

The EESS bands are a system

- 1.4 and 6.8 GHz bands give surface information (land, snow, ocean, sea ice)
- 10.7 GHz gives precipitation (rain, snow) information
- 18.8, 24 and 31 GHz bands give cloud liquid information
- 50-60 GHz gives 3D temperature information
- 175-192 GHz gives 3D humidity information
- 89, 150 (or 157, 166 GHz) and 229 (or 209) GHz cloud ice information
- Higher frequencies give very detailed cloud information (ice particle size, type, orientation) which is very important for climate models

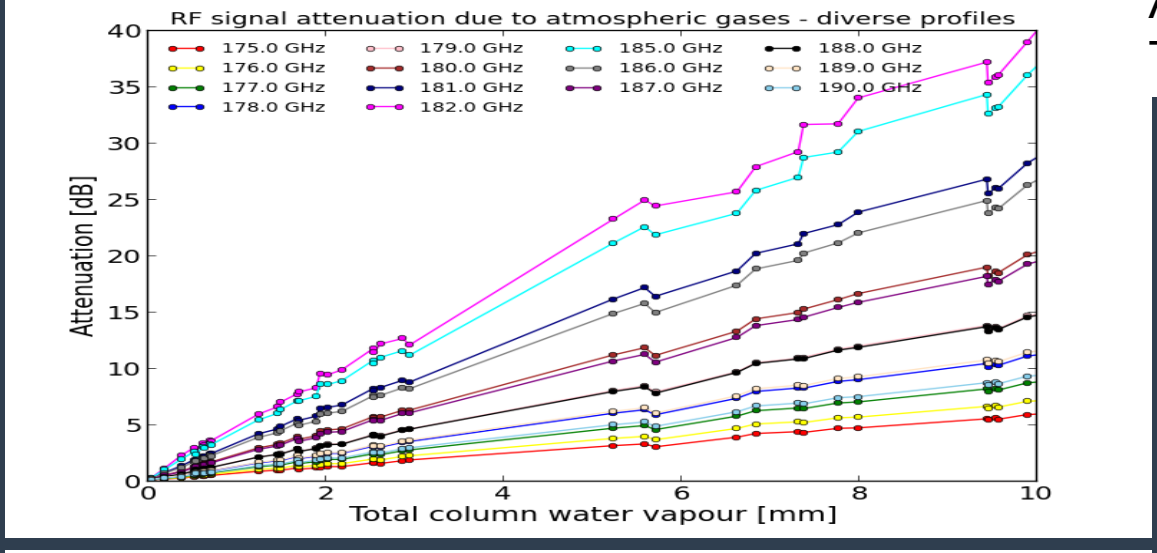
Loss of one band impacts the use of the others

Key messages

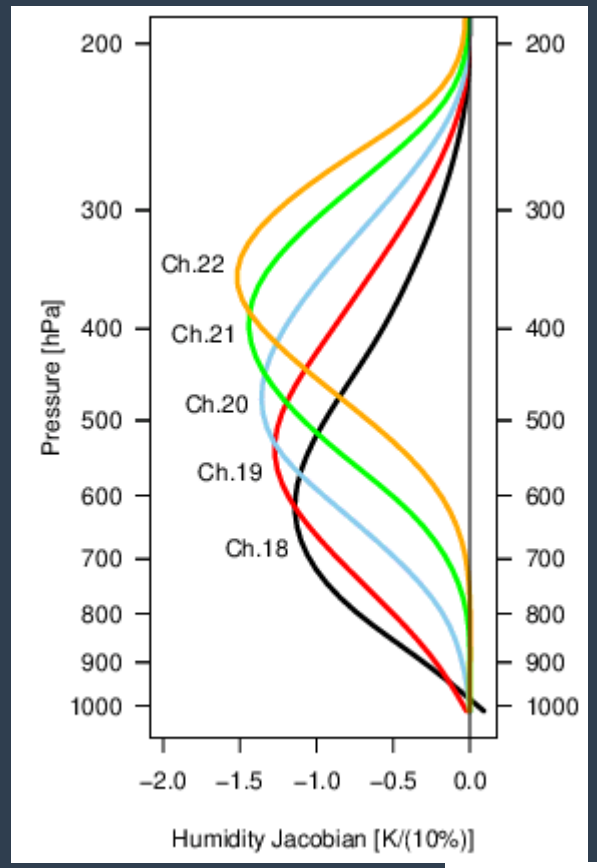
- Need to communicate to governments / decision makers on the high socioeconomic benefit of the sounding bands, notably at 50-60 and 175-191 GHz;
- Main direct impact comes from the sounding bands 50 to 60 GHz (temperature) and 175-191 GHz (water) but we need the “window” and “surface” bands to correctly interpret the sounding bands;
- 90% of the 100-1000 GHz range is of no interest to meteorology and climate – but the bands that are of interest (87-91, 115-124, 164-168, 175-192, 228-230, 239-247, 314-336, 439-456, 658-671 GHz) are critically important

Backup slides

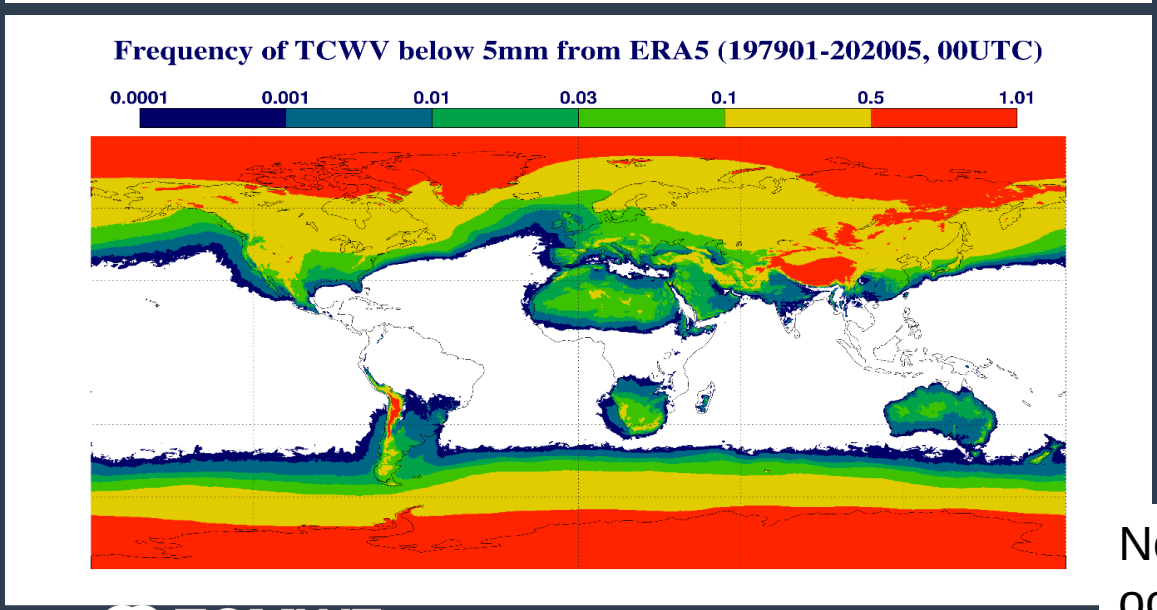
Sensitivity of attenuation to 3D variations in water vapour



Attenuation as a function of TCWV close to 183 GHz



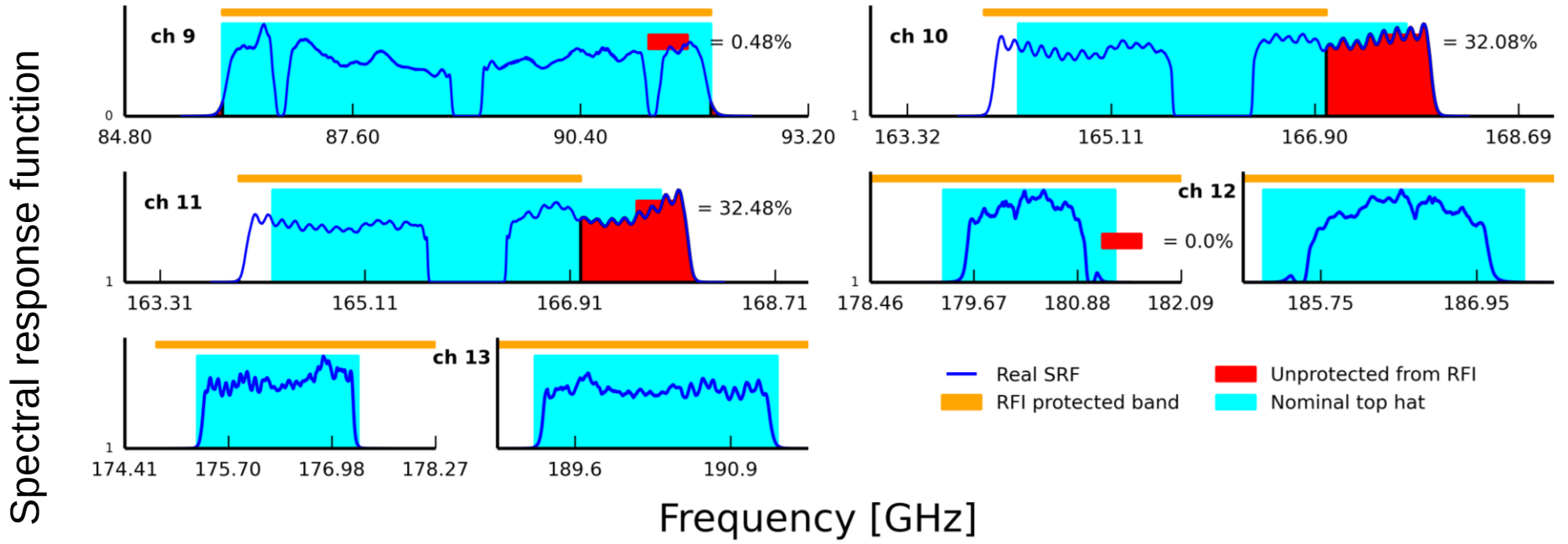
Weighting functions



Normalised frequency of occurrence (1=100%) of TCWV < 5mm in ERA5

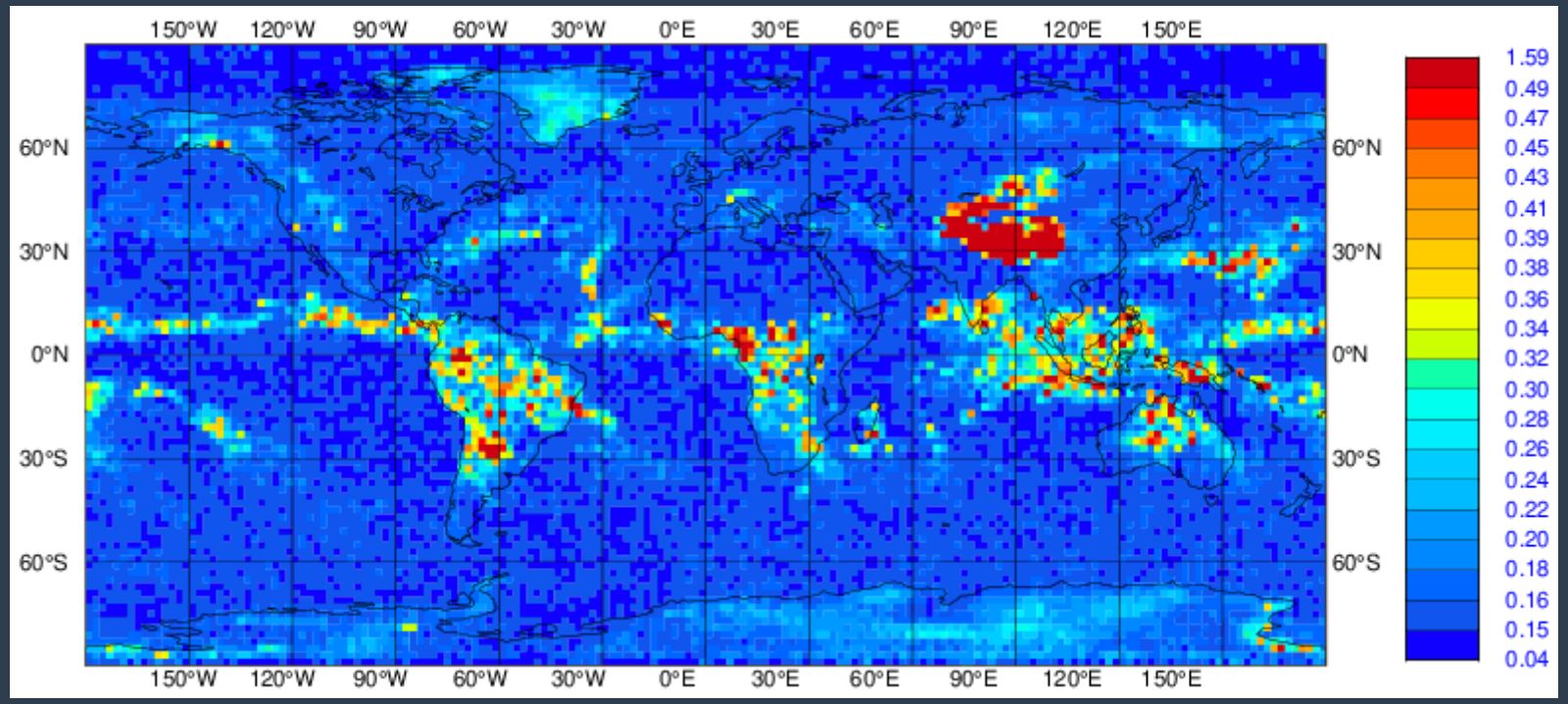
Spectral Response Functions

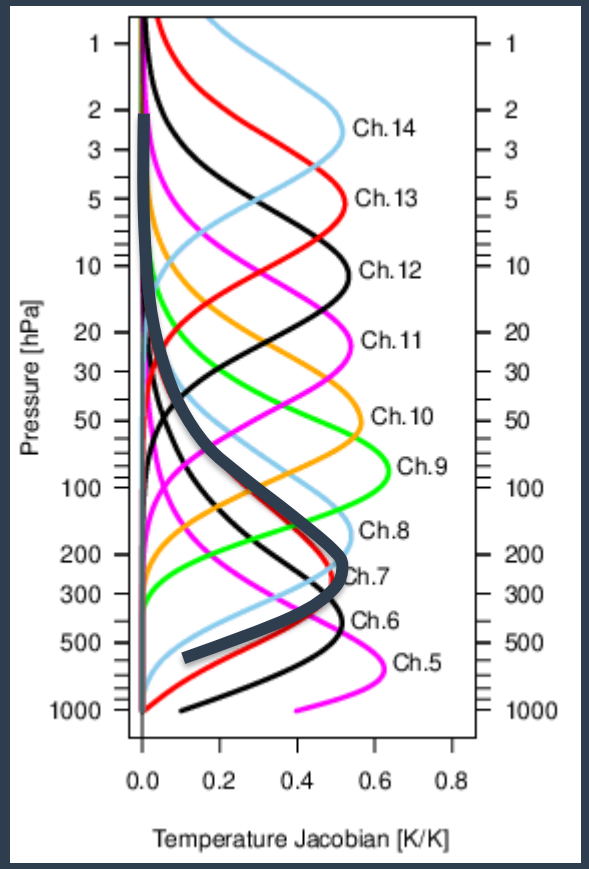
Until recently instrument spectral response functions rarely published: now it is a requirement to avoid measuring outside protected bands e.g. GMI from NASA below



From Emma Turner, Met Office

Sounding bands are affected by cloud and surface – we need other bands to account for this correctly.





Note: we measure thermal radiation so express everything as a temperature – brightness temperature. Hard for user communities like ours to interpret limits expressed in dB/MHz.

Monitoring system run by Mohamed Dahoui, ECMWF