Earth Exploration-Satellite Service (EESS) - Passive Spaceborne Remote Sensing

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What is a passive sensor?

RR 1.183 - *passive sensor:* A measuring instrument in the *earth exploration-satellite service* or in the *space research service* by means of which information is obtained by reception of *radio waves* of natural origin.

- *Passive sensors* measure the electromagnetic energy emitted and scattered by the Earth and the constituents of its atmosphere.
- *Spaceborne passive microwave sensors* provide the ability to obtain **all-weather, day and night, global** observations of the Earth and its atmosphere.

Passive sensor operations

- All matter emits, absorbs and scatters electromagnetic energy.
- Passive sensors are ***radiometers*** which are low noise receivers patterned after radio astronomy instruments.
- Power measured by passive sensors is function of surface composition, physical temperature, surface roughness, and other physical characteristics.

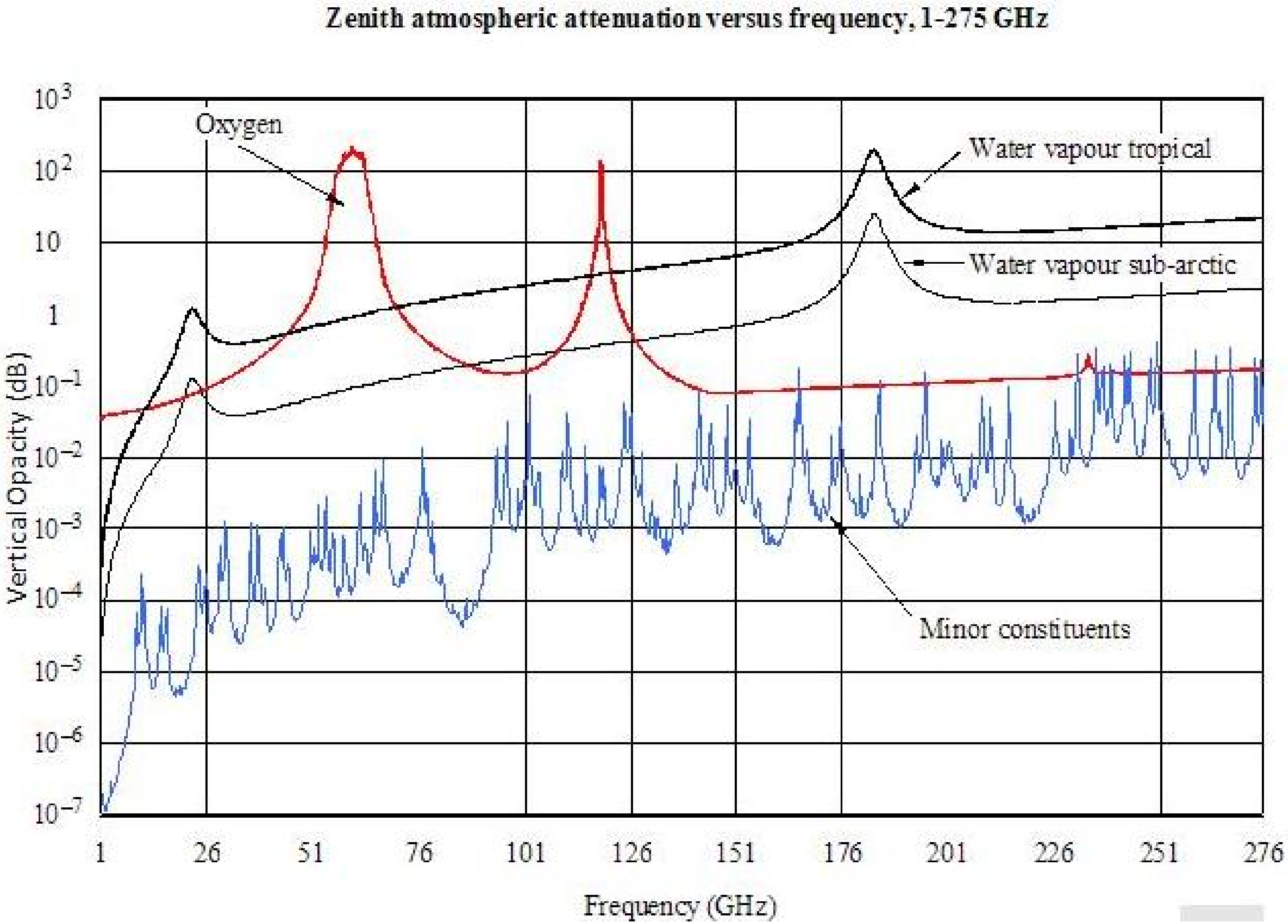
Types of passive microwave sensors

- Imaging sensors
  - Many environmental data products are produced using multivariable algorithms to retrieve a set of geophysical parameters simultaneously from calibrated multi-channel microwave radiometric imagery
- Atmospheric sounding sensors
  - Atmospheric sounding is a measurement of vertical distribution of physical properties of a column of the atmosphere such as pressure, temperature, wind speed, wind direction, liquid water content, ozone concentration, pollution, and other properties
- Microwave limb sounding sensors
  - Limb sounders observe the atmosphere in directions tangential to the atmospheric layers and are used to study low to upper atmosphere regions where the intense photochemistry activities may have a heavy impact on the Earth's climate

Passive sensor data products (Part 1)

- Measured radiation
  - Occurs naturally
  - Very low power levels
  - Contain essential information on the physical processes
- Radiation peaks indicate presence of specific chemicals
- Absence of radiation from certain frequencies indicates the absorption by atmospheric gases
- Strength or absence of signals at particular frequencies is used to determine whether specific gases are present and, if so, in what quantity and at what locations.

Atmospheric attenuation below 275 GHz

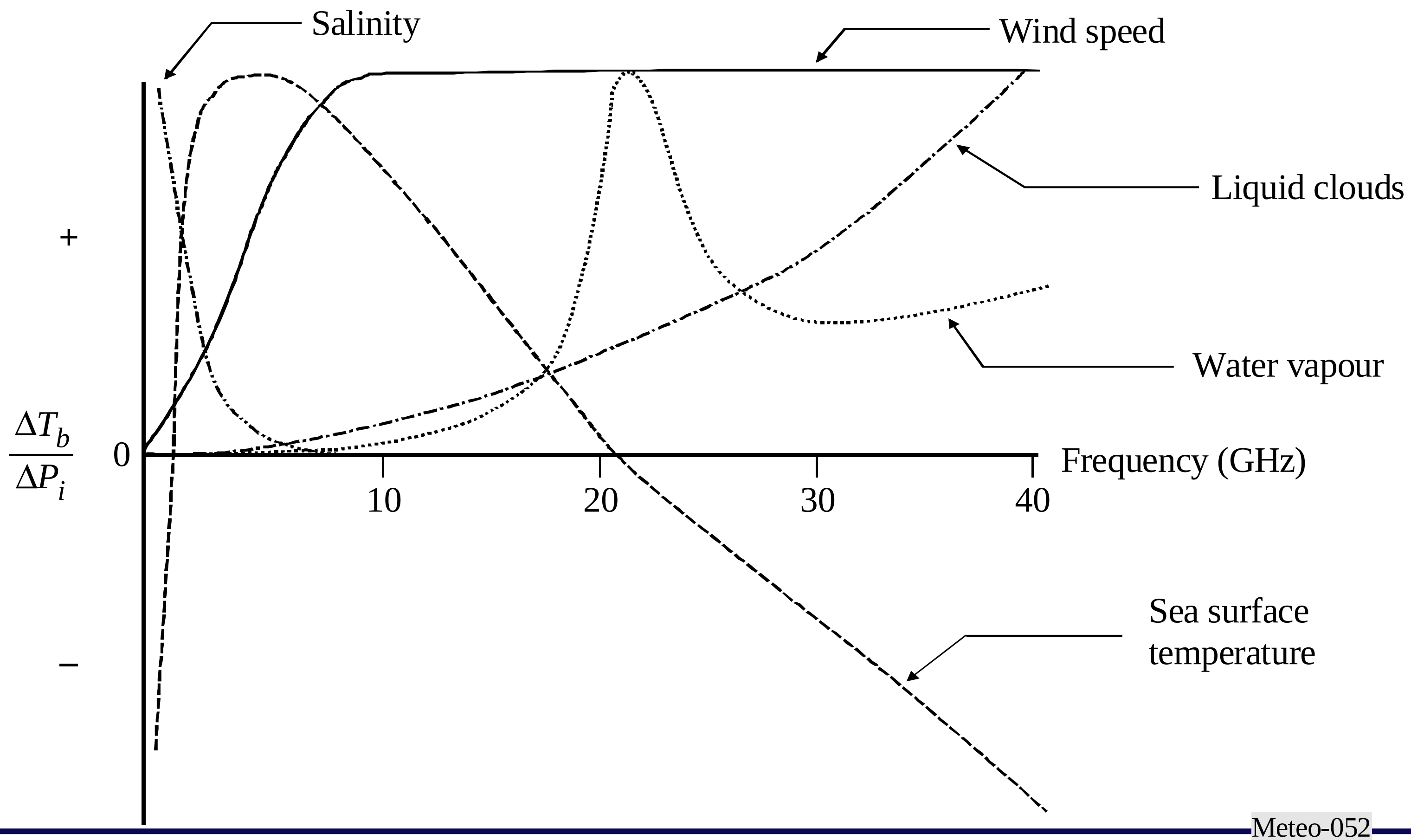


Passive sensor data products (Part 2)

- Environmental information is obtained through passive sensor measurements
  - Frequency bands determined by fixed physical properties (molecular resonance)
  - Frequencies do not change
  - Information cannot be duplicated in other frequency bands
- Signal strength at a given frequency may depend on several variables
  - Use of several frequencies necessary to match the multiple unknowns
  - Use of multiple frequencies is primary technique used to measure various characteristics of the atmosphere and surface of the Earth

Multiple frequencies used over oceans

Sensitivity of brightness temperature to geophysical parameters over ocean surface

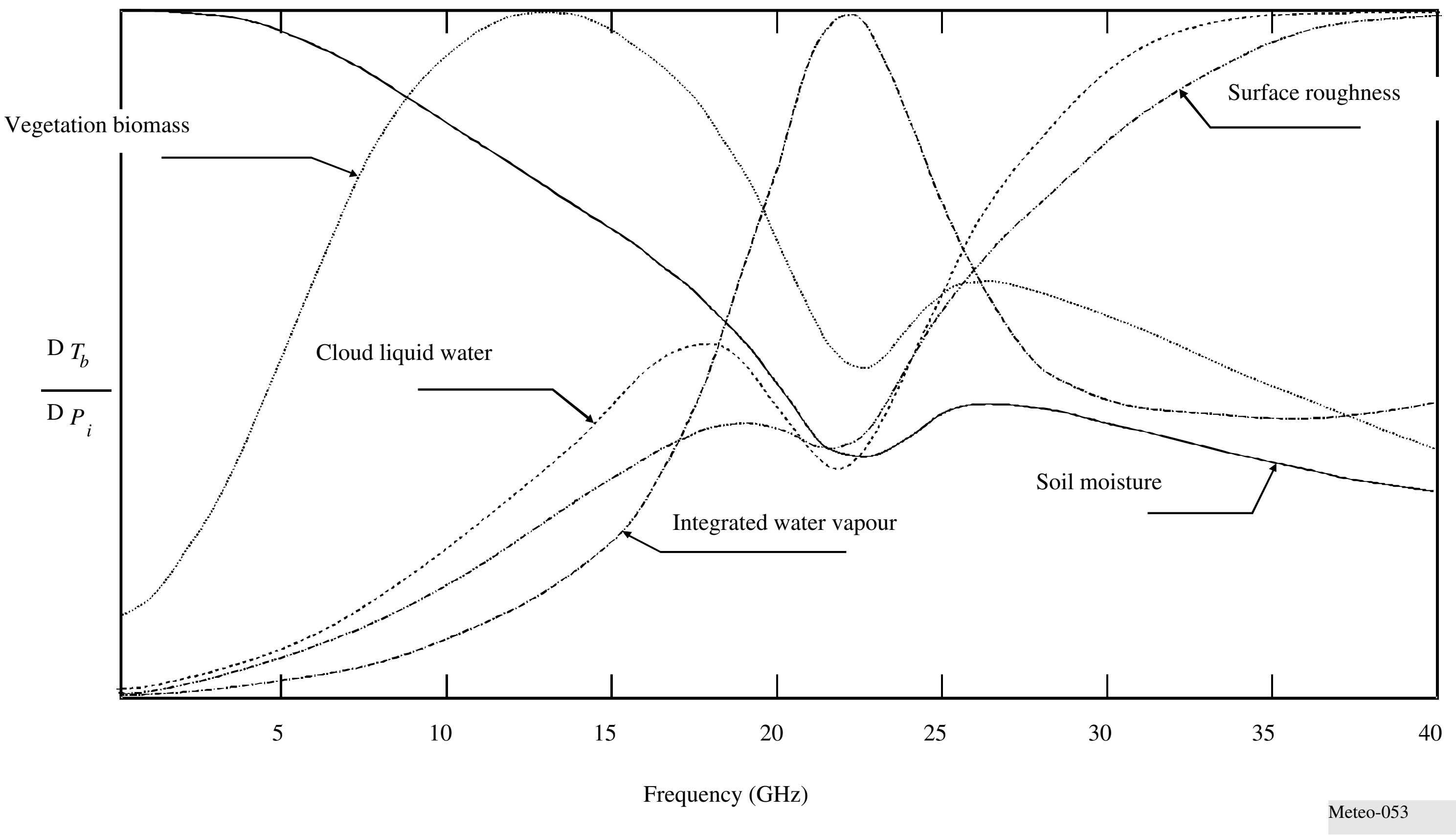


Multiple frequencies used over oceans

- Measurements at around 1.4 GHz give are best for ocean salinity
- Measurements around 6 GHz offer the best sensitivity to sea surface temperature
- The 17-19 GHz region, where the signature of sea surface temperature and atmospheric water vapour is the smallest, is optimum for ocean surface emissivity.
- Total content of water vapour is best measured around 24 GHz, while liquid clouds are obtained via measurements around 36 GHz.
- Five frequencies (around 6 GHz, 10 GHz, 18 GHz, 24 GHz and 36 GHz) are necessary for determining the dominant parameters.

Multiple frequencies used over land

Sensitivity of brightness temperature to geophysical parameters over land surfaces



Multiple frequencies used over land

- A frequency around 1.4 GHz is needed to measure soil moisture.
- Measurements in the 5 GHz to 10 GHz range are needed to estimate vegetation biomass once the soil moisture contribution is known.
- Two frequencies are needed around the water vapour absorption peak (typically 18-19 GHz and 23-24 GHz) to assess the atmospheric contribution.
- A frequency around 37 GHz is needed in combination with these frequencies to derive all of the above.

EESS (passive) allocations in exclusive passive bands (RR No. 5.340)

1400-1427 MHz	50.2-50.4 GHz	164-167 GHz
2690-2700 MHz	52.6-54.25 GHz	182-185 GHz
10.68-10.7 GHz	86-92 GHz	190-191.8 GHz
15.35-15.4 GHz	100-102 GHz	200-209 GHz
23.6-24 GHz	109.5-111.8 GHz	226-231.5 GHz
31.3-31.5 GHz	114.25-116 GHz	250-252 GHz
31.5-31.8 GHz*	148.5-151.5 GHz	

* in Region 2 only

EESS (passive) allocations shared with active services

10.6-10.68 GHz	54.25-59.3 GHz
18.6-18.8 GHz	116-122.25 GHz
21.2-21.4 GHz	155.5-158.5 GHz
22.21-22.5 GHz	174.8-182 GHz
31.5-31.8 GHz*	185-190 GHz
36-37 GHz	235-238 GHz

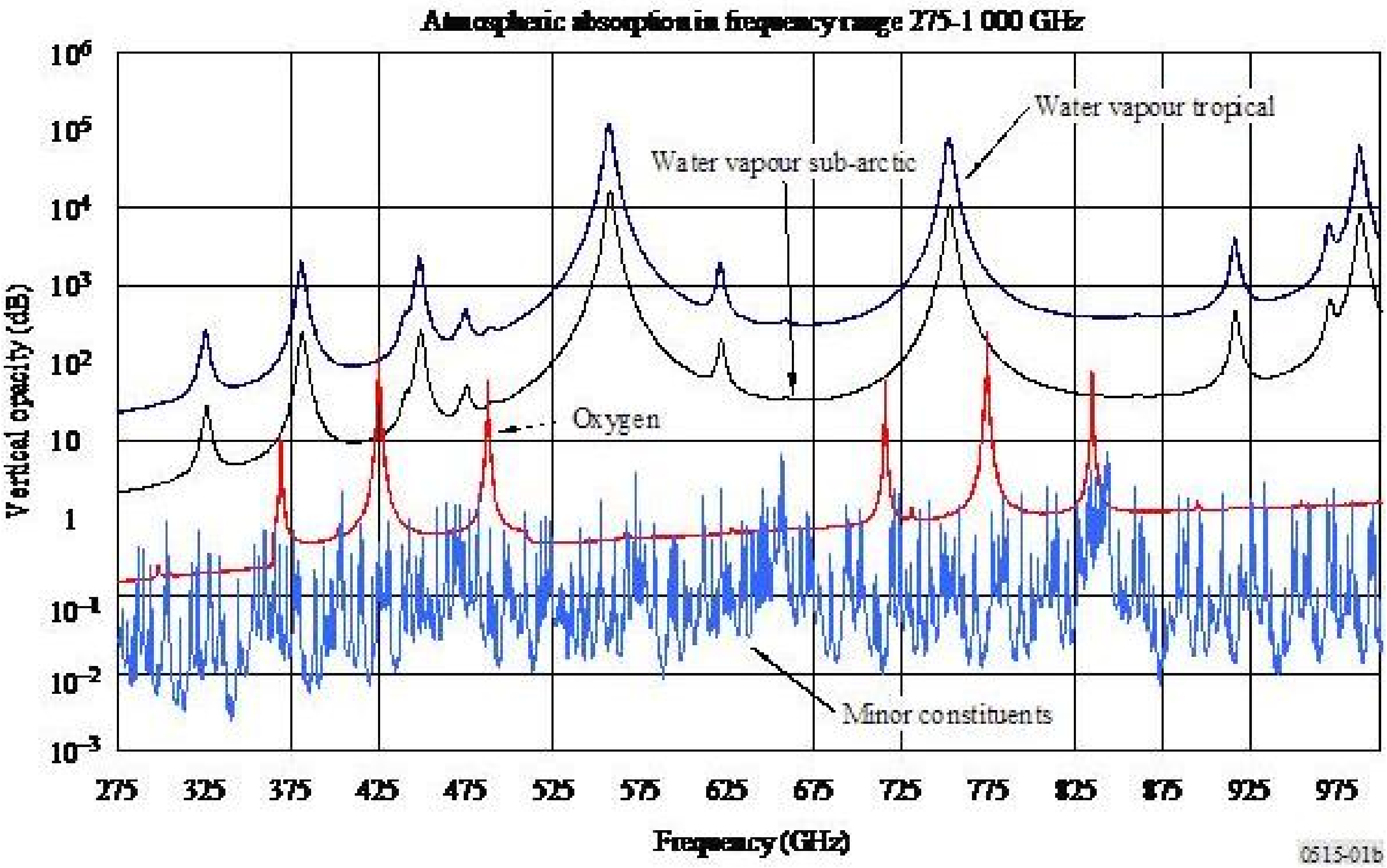
* in Regions 1 & 3 only

EESS (passive) bands allocated on a secondary basis or not allocated

1370-1400 MHz
2640-2690 MHz
4200-4400 MHz
4950-4990 MHz
6425-7250 MHz*
15.2-15.35 GHz

* this band is not allocated to the EESS (passive) but it is used subject to RR No. **5.458**

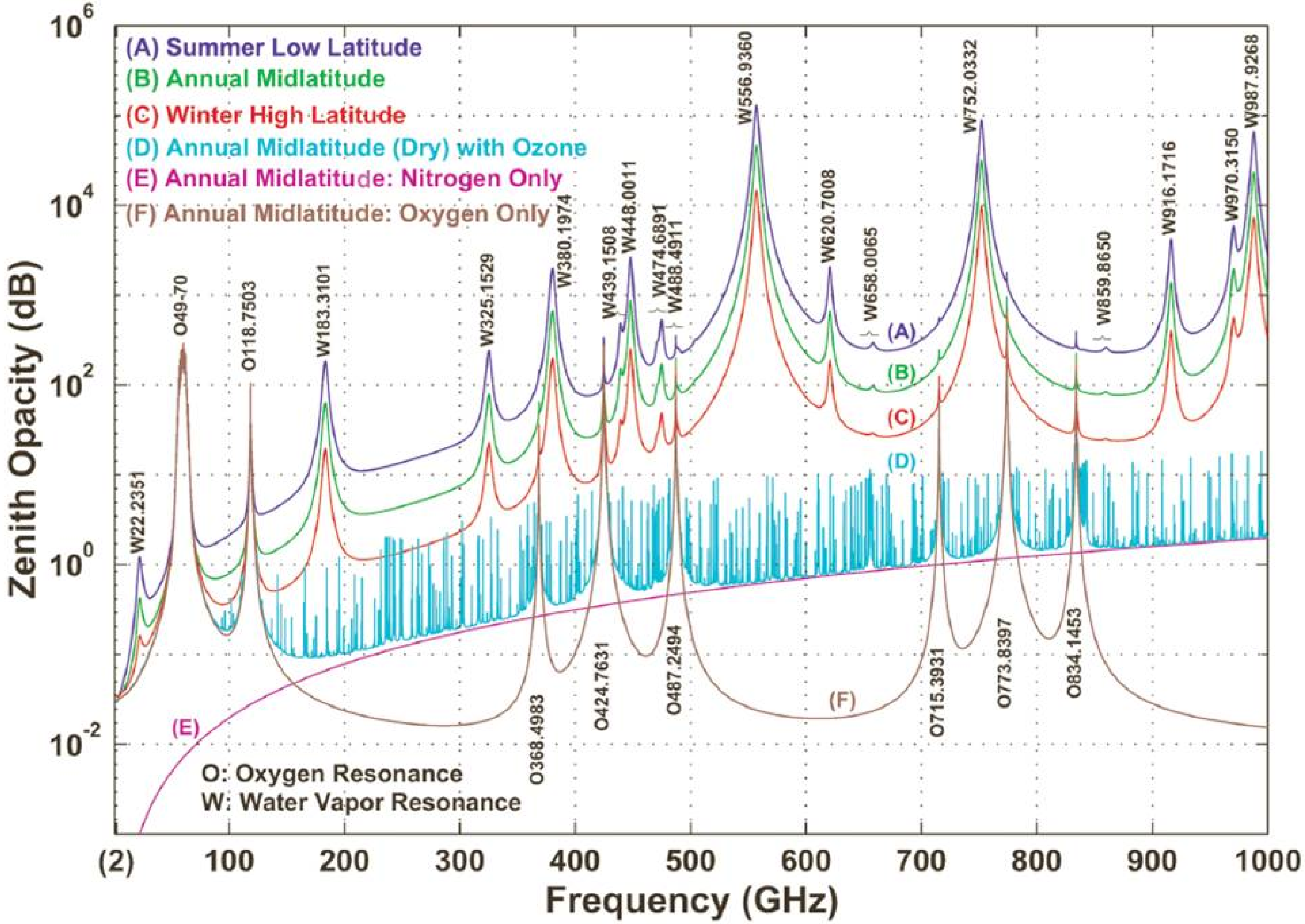
Atmospheric attenuation above 275 GHz



EESS (passive) use above 275 GHz

- Current Bands in RR No. 5.565:
  - Earth exploration-satellite service (passive): 275-277 GHz, 294-306 GHz, 316-334 GHz, 342-349 GHz, 363-365 GHz, 371-389 GHz, 416-434 GHz, 442-444 GHz, 496-506 GHz, 546-568 GHz, 624-629 GHz, 634-654 GHz, 659-661 GHz, 684-692 GHz, 730-732 GHz, 851-853 GHz and 951-956 GHz
- WRC-12 Agenda Item 1.6 (Resolution 950) considers revising the passive bands given in footnote 5.565
- Studies within the ITU-R are attempting to define frequency bands of interest to passive services in the 275 – 3 000 GHz range.

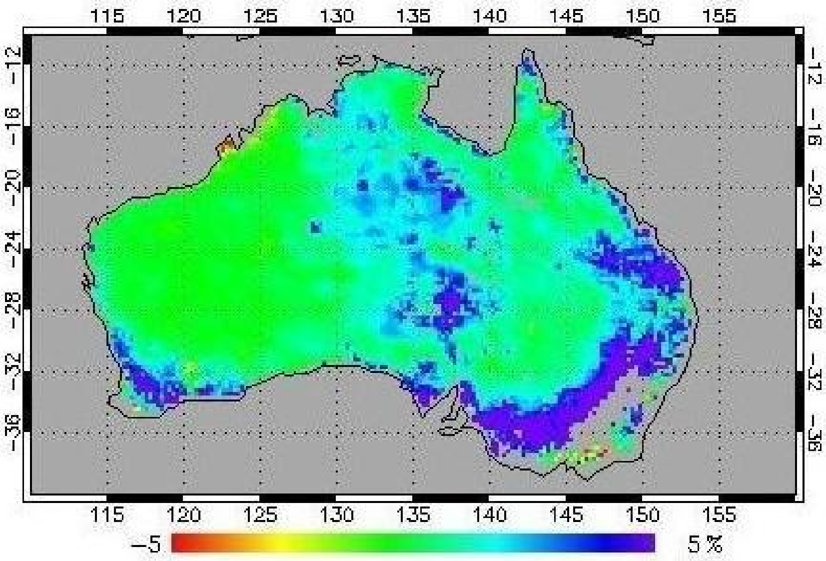
EESS (passive) use above 275 GHz



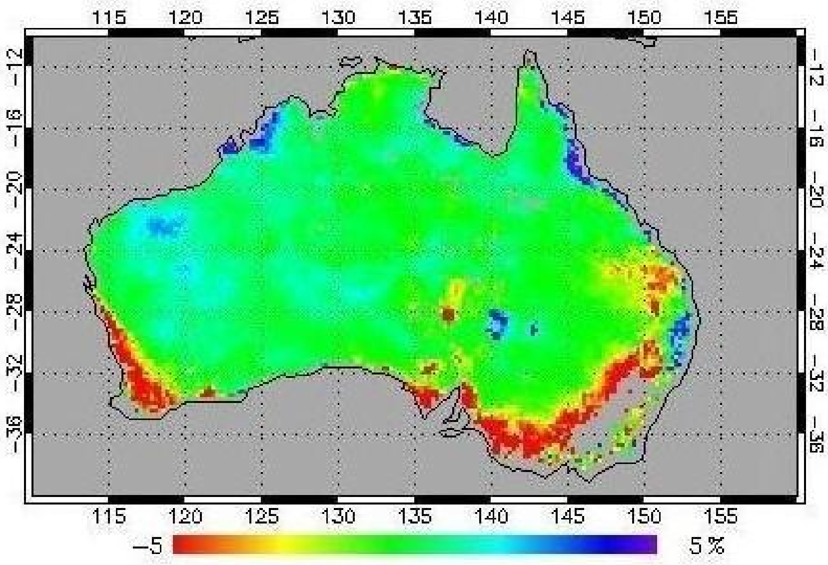
Passive Microwave Remote Sensing

Some Examples

Soil moisture measurements (AMSR-E)

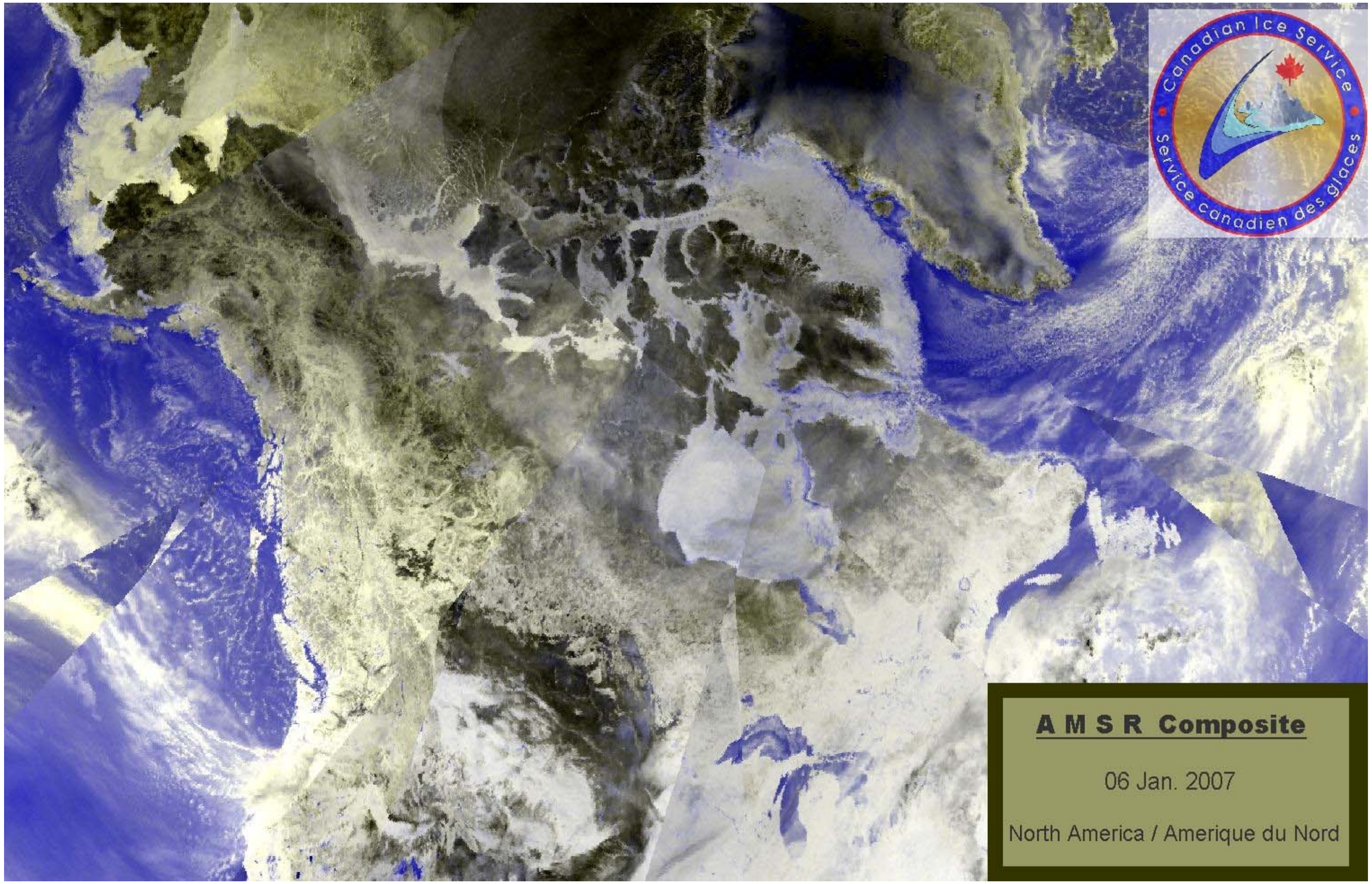


Soil Moisture in 2005

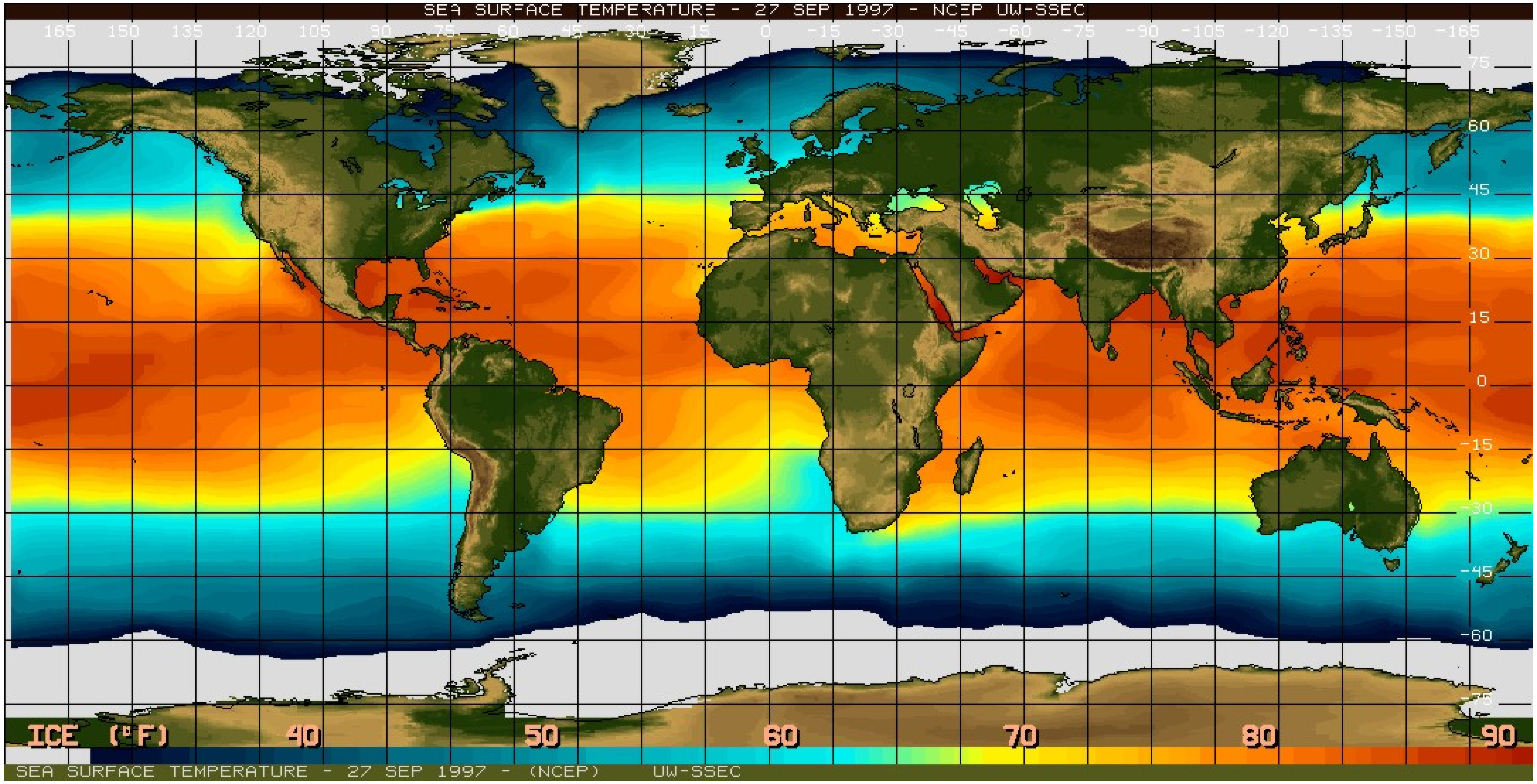


Soil Moisture in 2006

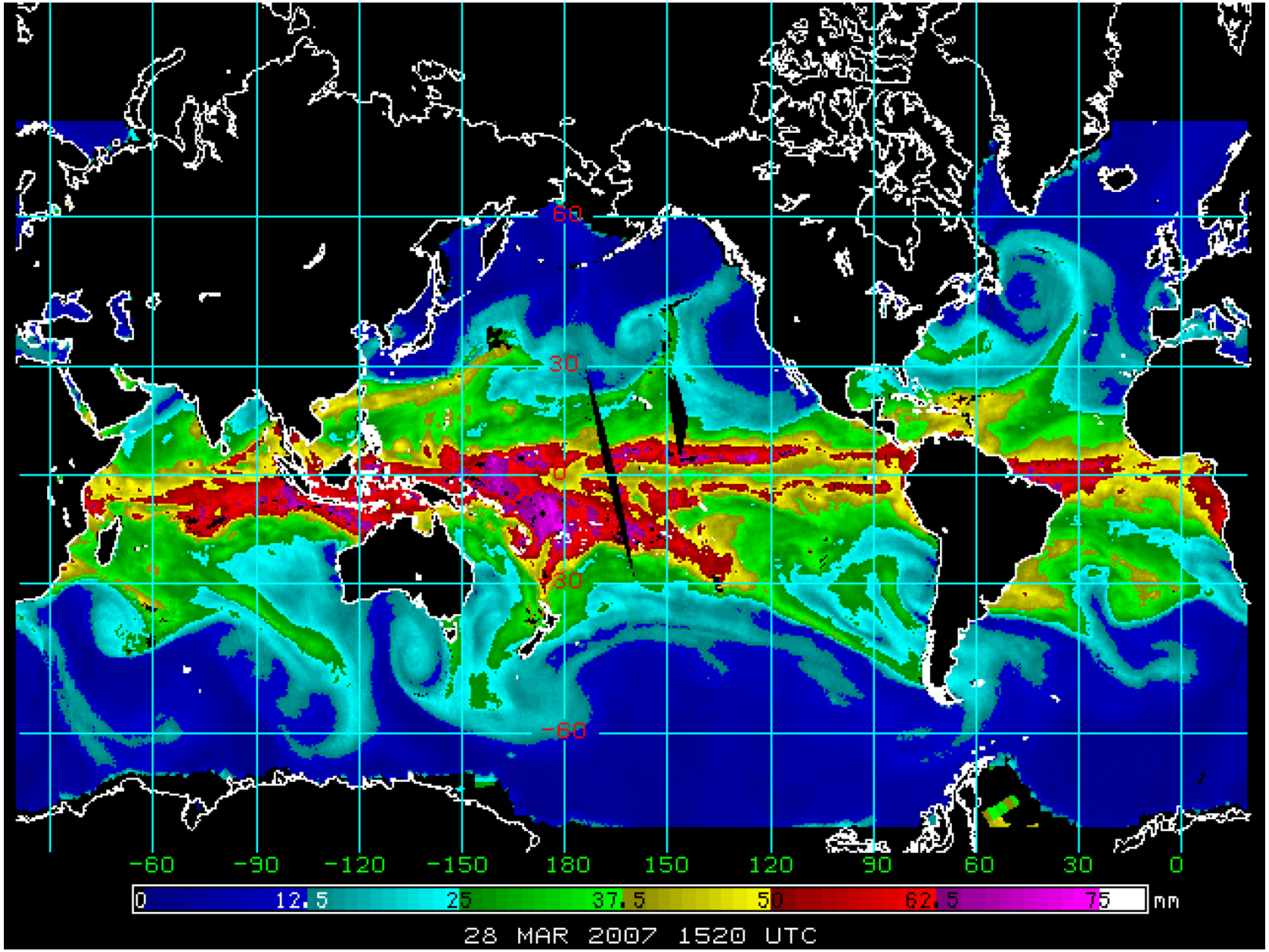
Sea ice over North America – 2007 (AMSR data)



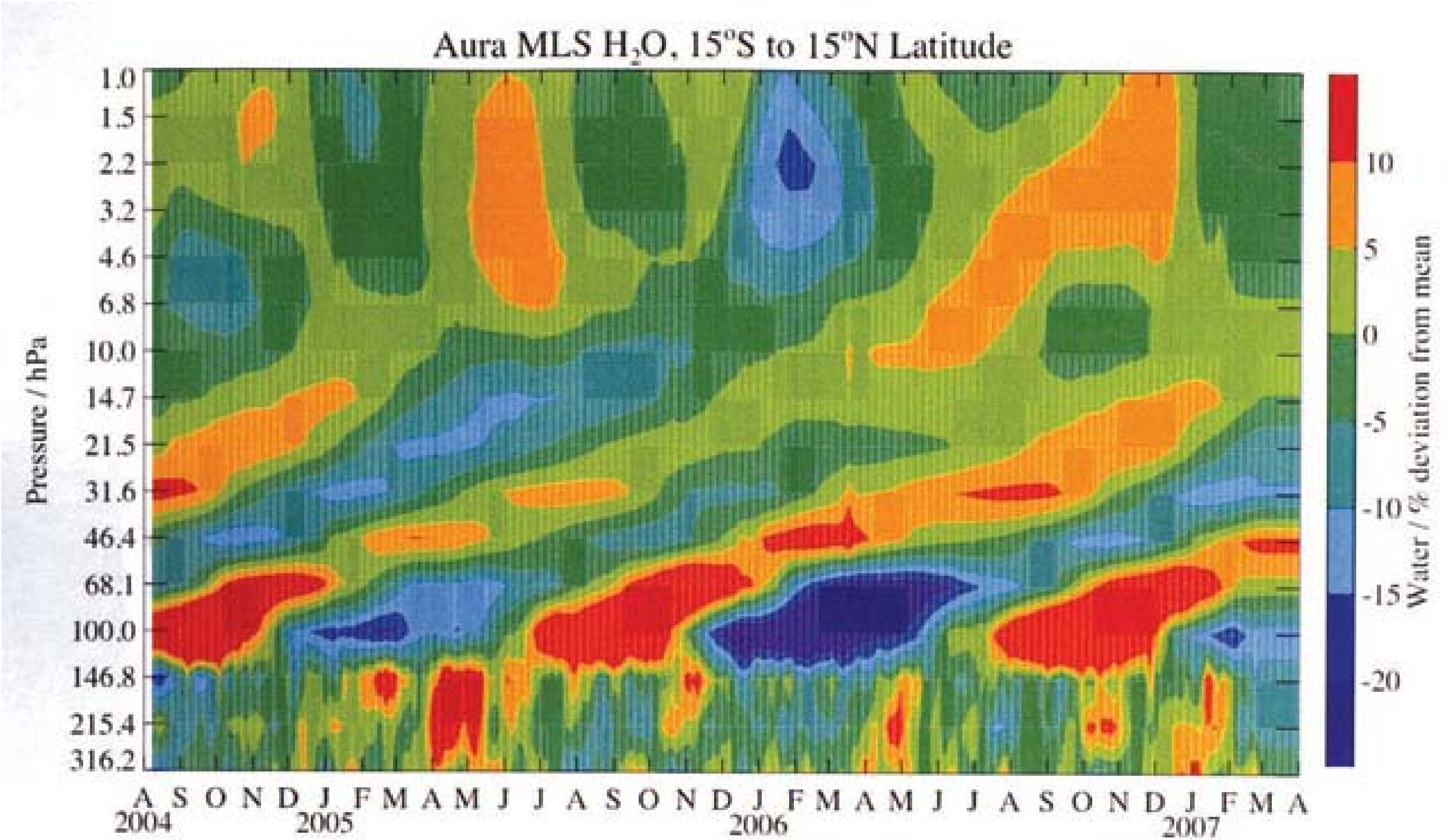
Sea surface temperature measurements



Vertically integrated water content of the atmosphere (kg/sq m)



Atmospheric water vapour measured by microwave limb sounding instrument



ITU-R Recommendations governing passive microwave sensing

- **RS.515**: Frequency bands and bandwidths used for satellite passive sensing
- **RS.1028:** Performance criteria for satellite passive remote sensing
- **RS.1029:** Interference criteria for satellite passive remote sensing
- **RS.1813:** Reference antenna pattern for passive sensors operating in the Earth exploration-satellite service (passive) to be used in compatibility analyses in the frequency range 1.4-100 GHz
- **RS.[PASSIVE_CHARS]:** Technical and operational characteristics of EESS (passive) systems using allocations between 1.4 and 275 GHz (PENDING)

Conclusions

- Passive microwave sensors are particularly sensitive to accumulated radiation from a multitude of emitters on the ground, both from in-band and out-of-band.
- While a single terrestrial emitter may not radiate enough power to cause harm, a large number of these emitters can still be harmful through the aggregation of their signals.
- Perhaps the biggest threat to passive sensing operations is interference that is undetected corrupting data that is then mistaken for valid data leading to flawed conclusions.