ECMWF Feature article

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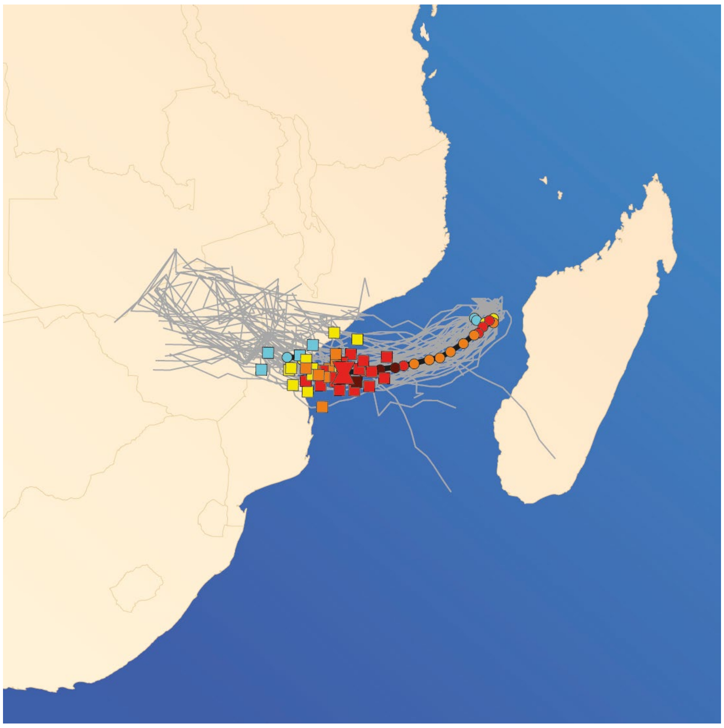
VIEWPOINT

Why we need to protect weather prediction from radio frequency interference



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Why we need to protect weather prediction from radio frequency interference

Stephen English

Numerical weather prediction (NWP) relies on observations from Earth observation satellites, radiosondes, aircraft, radar and other observing systems as inputs. In turn, these observing systems rely on the allocation of radio frequency bands both for directly observing the atmosphere and the planet and for exchanging observations through telecommunication networks. These allocations are defined in international agreements and regularly updated at an event called the World Radiocommunication Conference (WRC) in the light of new requirements. The next WRC, WRC-19, takes place this coming November. The World Meteorological Organization (WMO), with strong support from space agencies such as EUMETSAT and ESA, as well as EUMETFREQ (a EUMETNET programme), coordinates the response of the international meteorological community and represents the community at WRC-19. Their goal is to ensure that frequencies used operationally at centres like ECMWF continue to be allocated to this application area, without interference from new users. This process is increasingly challenging as many new application areas are emerging that require frequency bands, for example the next-generation mobile phone data service, 5G. In the WRC, the demands of different application areas need to be weighed up, taking into account economic and societal benefits.

A proactive approach

For the meteorological case to be fairly heard, the spectrum managers who make decisions on radio-frequency allocations need the best and most up-to-date information on the value of the bands to meteorology, in terms that can be compared to other application areas. This enables them to try to ensure continued allocation of the required frequencies to the Earth Exploration-Satellite Service (EESS), as well as protecting these frequencies from out-of-band emissions from neighbouring frequency bands. Therefore, ECMWF has been proactive in providing information and coordinating inputs from the wider meteorological community to support the WMO and the space agencies. In particular, ECMWF organised a workshop on radio frequency interference in September 2018, which was attended by representatives of many major NWP centres (*https://www.ecmwf.int/en/learning/workshops/radio-frequency-interference-rfi-workshop*). Following this, ECMWF wrote an article for the International Telecommunication Union (ITU) News Magazine, which gained prominence at the ITU headquarters. This stimulated further interest, and ECMWF has been engaging with the media to ensure a broad understanding of the meteorological use of radio frequencies, for example by contributing to an article published by *Nature News* entitled ‘Global 5G wireless networks threaten weather forecasts’ (*www.nature.com/articles/d41586-019-01305-4*).

ITU News Magazine article. An article by Stephen English on the issue of radio frequency interference was published in the *ITU News Magazine* 01/2019 and advertised at the ITU headquarters.

The value of passive microwave sensing

Many satellite observations for NWP use passive sensing techniques in radio frequency bands. Such passive measurements are made by very sensitive instruments that measure the very low-power microwave radiances naturally emitted from the atmosphere and the Earth’s surface. These passive

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techniques are the most vulnerable to interference from new users of radio frequencies generating electromagnetic emissions for their own purposes. Passive sensing makes it possible to gain information on the current state of the Earth system by exploiting the absorption characteristics of the atmosphere. There are absorption peaks due to the molecular resonance of atmospheric gases, including water vapour. There is also absorption and scattering by clouds and precipitation, which increase with frequency, and a slow increase in absorption by water vapour with increasing frequency. How efficiently the Earth's surface emits and reflects microwave radiation also changes slowly with increasing frequency.

Below 10 GHz, the atmosphere is almost completely transparent, even in the presence of clouds. These low frequencies directly sense the planet's surface, providing information on sea-surface temperature (SST), soil moisture, sea ice coverage and snow. At 18 GHz, the dielectric properties of sea water are such that emission has a low sensitivity to SST, so the surface emission is primarily sensitive to the sea state and small waves. At 22–24 GHz, there is a weak water absorption line, and by measuring close to this spectral line we gain information on total column water vapour. At 31 GHz, information on the liquid water content of clouds is obtained. There is a strong oxygen absorption band at 50–60 GHz. This is a remarkable spectral feature, enabling us to gain information on the 3D structure of atmospheric temperature with little impact from clouds, especially ice clouds, and water vapour. Above 60 GHz the most important spectral feature of interest is the water vapour line at 183 GHz, which provides information on the 3D structure of water vapour. Frequencies above 200 GHz can provide very detailed information about trace gases and ice clouds. All these spectral features arise from the laws of physics and are therefore determined by nature. They are a unique asset which cannot be substituted by other measurements. Each of these bands thus provides information essential to modern state-of-the-art weather prediction. Furthermore, there are strong interdependencies between bands: to extract the information from one band it is usually important to have two or three other bands available, for example to know the impact of clouds on a temperature sounding.

Assessments of the impact of weather observations have found that microwave observations are presently the most important satellite observing system for global NWP, typically contributing around 30–40% of the overall improvement in forecast skill arising from the use of observations. It has also been demonstrated that without microwave observations there would be a major loss of resilience to changes in the WMO Integrated Global Observing System (WIGOS): the skill of forecasts would vary more from day to day and month to month as the number of observations available fluctuates (e.g. due to satellite failures and new satellite launches). When microwave observations are not present, the degradation from any loss of hyperspectral infrared observations is several times larger than when microwave observations are present.

The WMO Integrated Global Observing System (WIGOS). Satellite observations, including those that use passive sensing techniques in radio frequency bands, are a crucial part of the WMO Integrated Global Observing System (WIGOS) used to support numerical weather prediction. (Source: WMO)

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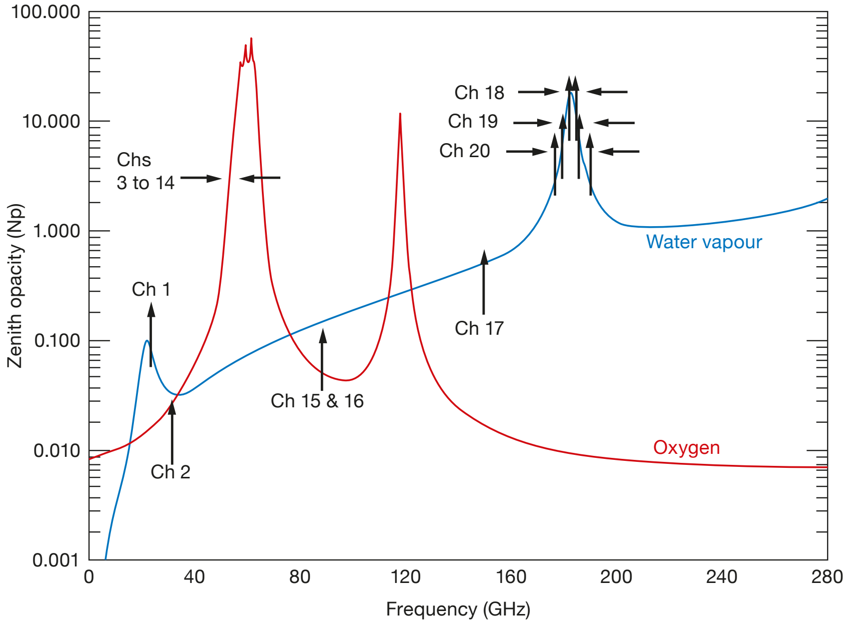
The use of radio frequencies in meteorology is not limited to these passive microwave observations. Systems such as weather radar also suffer from radio frequency interference. Radiosondes rely on a specific allocation for tracking and telecommunication. Command and download of data from all satellites needs specific frequency allocations. All these allocations are every bit as important as the passive allocations.



Atmospheric opacity in the frequency range 0–280 GHz. The chart shows frequencies used by the channels of the Advanced Microwave Sounding Unit (AMSU-A, channels 1-15, AMSU-B channels 16-20), one of the most important instruments used in NWP. It has been continuously operated since 1998 on a series of operational satellites run by NOAA and EUMETSAT. Today there are also a range of new-generation instruments that measure microwave radiances, such as China's MWTS-2 and MWHS-2, Russia's MTVZA-GY and the USA's ATMS, amongst many others. (Source: S. J. English et al., 1994, *Q.J.R. Meteorol. Soc.*, doi:10.1002/qj.49712051706.)

Why we need to act

NWP users are already seeing evidence of radio frequency interference in the L (~1.4 GHz), C (~6.9 GHz), X (~10.7 GHz) and K (~18.7 GHz) frequency bands, notably on the European SMOS instrument and the Japanese AMSR2 instrument. Loss of these and other bands would have a negative impact on national weather warning systems as well as our ability to monitor climate change through the Copernicus Climate Change Service (C3S), implemented by ECMWF on behalf of the EU. New applications (e.g. 5G) outside the field of meteorology are interested in higher frequencies, e.g. in bands adjacent to 24 GHz and 50 GHz, which are crucial for obtaining accurate estimates of water vapour and temperature in the analysis, from which the forecast is then run. Although the radio regulations prohibit all emissions in the passive allocations at 24 and 50 GHz, we also have to ensure protection is in place to limit the level of out-of-band emissions from active systems operating in neighbouring bands (e.g. emissions from the 5G band between 24.25 GHz and 27.5 GHz affecting the passive band 23.6–24.0 GHz).

In a world hungry for the use of radio frequencies in new applications, meteorological centres such as ECMWF need to be clear about the value of our use of such frequencies. The next key event is the World Radiocommunication Conference in November 2019. ECMWF's high level of activity this year reflects the fact that there are many questions for that meeting that will decide the future viability of many bands used for operational weather forecasting. ECMWF will continue to support the WMO and space agencies in this important activity.

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