

# Radiocommunications and climate change

2020 edition





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*“Climate change is the defining issue of our time – and we are at a defining moment. We face a direct existential threat. Climate change is moving faster than we are – and its speed has provoked a sonic boom SOS across our world. We know what is happening to our planet. We know what we need to do. And we even know how to do it. Enormous benefits await humankind if we can rise to the climate challenge. A great many of these benefits are economic. Every day we fail to act is a day that we step a little closer towards a fate that none of us wants -- a fate that will resonate through generations in the damage done to humankind and life on earth. Our fate is in our hands. The world is counting on all of us to rise to the challenge before it’s too late.”*

*Antonio Guterres  
UN Secretary-General*

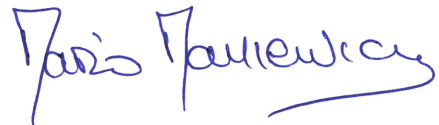
*“A digital revolution is sweeping across the world, driven by the emergence of frontier technologies ranging from artificial intelligence to the Internet of Things and 5G. Whether we are dealing with rising sea levels, biodiversity loss, water shortages, air quality or food security, these technologies hold great potential for addressing the root causes and already devastating effects of the climate crisis.”*

*Houlin Zhao  
ITU Secretary-General*

# Foreword

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Climate change and growing exploitation of the Earth's natural resources is leading to a range of environmental problems that require international action. If humanity is going to respond effectively, many of the solutions will be informed by global monitoring of the environment, including the use of space assets. As accurate weather predictions need to start from the best possible estimate of the current state of the atmosphere, it is crucial that meteorologists have real-time, accurate global observations about what is happening in the Earth's atmosphere over land and oceans. And for this, they rely on space sensing. Satellite data is today an indispensable input for weather prediction models and forecast systems used to produce safety warnings and other information in support of public and private decision-making.



*Mario Maniewicz,  
Director,  
ITU's Radiocommunication Bureau*

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Timely warning of natural and environmental disasters, accurate climate prediction and a detailed understanding, conservation and efficient management of scarce resources such as biomass, biosphere, mineral resources, water and energy are essential requirements for sustainable economic development. Information about climate, climate change, weather, precipitation, pollution or disasters is a critically important everyday issue for the global community. Monitoring activities provide this information, which is required for the daily weather forecast and prediction, for studies on climate change, for the protection of the environment, for economic development (transport, energy, agriculture, building construction, urban development, deployment of utilities, agriculture, security) and for safety of life and property. Earth observations are also used to obtain pertinent data regarding natural resources, this being particularly crucial for developing countries. It is important not to forget that this information is either based on measurements or gathered, provided and distributed by radiocommunication systems. Radio systems are fundamental to monitoring the climate and helping countries to mitigate and adapt to the effects of climate change and in addressing its major challenges.

The ITU Radiocommunication Sector (ITU-R) plays a vital role in worldwide development of radiocommunication systems, dealing with all relevant appropriate technical, operational and regulatory aspects. The ITU has assigned three main strategic goals to the ITU-R, in particular:

- to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum and satellite orbits by all radiocommunication services. This is the role of ITU World Radiocommunication Conferences, which meet every three to four years and where ITU Member States decide to update the Radio Regulations, the international treaty that contains the regulatory provisions to be followed in using radio frequency spectrum;
- to ensure interference-free operations of radiocommunication systems, including space systems. This is the role of ITU Member States, by applying the procedures of the Radio Regulations, which are administered by the ITU Radiocommunication Bureau;
- to establish Recommendations, Reports and Handbooks to assure the necessary performance and quality in operating radiocommunication systems. This is the role of ITU-R Study Groups.

ITU-R provides life blood for development of any radiocommunication system and its work is paramount to the successful operation of any radio application. During his visit to ITU headquarters (June 2007), the United Nations Secretary-General, Mr. Ban Ki-moon remarked that "ITU is one of the most important stakeholders in terms of climate change".



# 1

## Radiocommunications systems and applications in support of understanding, assessing and mitigating the effects of climate change

Monitoring the environment by means of satellite or terrestrial radio systems is essential in comprehending the enormous forces that make Earth a living world but may also threaten life. The geological features are clearly visible from space; even the ocean topography measured with centimetre accuracy mimics the relief of the ocean floor, revealing trenches and volcanic ranges. Gathered data helps us to understand the dynamics of our atmosphere, its interaction with the ocean and land masses and thus are essential in building the prediction models that are used every day in forecasting weather. Long-term effects on climate can only be understood by relying on outer-space active or passive sensors measuring the wave height, the water temperature, the salinity, the ozone concentration - all kinds of data that capture the behaviour of our environment. Table 1 specifies the different types of radio applications used by Earth observation systems.

**TABLE 1 : Types of Earth observation systems**

Passive applications		Satellite remote passive sensors
		Ground-based passive sensors
Active applications	Ground-based radars	Weather radars, wind profiler radars and oceanographic radars
	Meteorological aids	Radiosondes
	Earth to space data transmission bands	Earth exploration and meteorological satellites
	Space to Earth data transmission bands	Earth exploration and meteorological satellites
	Space based radars	Satellite remote active sensors, (altimeters, scatterometers, synthetic aperture radars, precipitation radars and cloud profile radars)

The European Union Radio Spectrum Policy Group (RSPG), in its Report and Opinion on “a Coordinated EU Spectrum Approach for Scientific Use of Radio Spectrum” (25 October 2006) concluded, in particular, that:

**“Most of this societal value is incommensurable in financial terms, as they relate to preventing large losses of lives or threats to socio-political stability and security. However, scientific use of spectrum also has a direct impact in many economic areas, and in producing economic spin-offs in technology and economic developments in energy, transportation, agriculture, communications, medicine, etc.”**

The long-term economic impact of information from remote sensing satellites is substantial, in both the production of food and other agriculture products, and the operation of businesses and industries that are dependent on both local weather and long-term climate stability. Civil aviation, shipping and land transportation draw direct benefits and savings from the timely preparation for adverse weather conditions.

## Satellite observations of the Earth's atmosphere and surface

Satellites provide the most cost-efficient, if not the only, way to monitor the environment of the entire Earth – land, sea, and air. Unique capabilities of satellites include observing wide-areas non-intrusively and uniformly (by using the same instrument) with the ability to rapidly target any point on Earth, including remote and inhospitable places, and to continue with a series of observations over a long period of time. Through these capabilities, the Earth Exploration Satellite Service brings many benefits to society in the non-profit and commercial sectors.

Satellites are the best means of providing a snapshot of the present state of our planet from a single, unified perspective. No single-instrument spacecraft can provide a complete picture; however, the current fleet of spacecraft, operating in concert and sharing their data, gives us the best assessment of global conditions available.

These data serve two purposes:

- to provide a baseline for observing and measuring climate change and its effects upon the planet; and
- to provide scientifically sound input to climate models.

Climate science has advanced spectacularly through satellite observations. The radiometer flown on Explorer 7 from 1959 to 1961 made possible the direct measurement of the energy entering and leaving Earth. This mission and follow-on missions enabled scientists to measure Earth's energy balance with much greater confidence compared to earlier indirect estimates and resulted in improved climate models. As radiometers improved, these measurements achieved the precision, spatial resolution and global coverage necessary to observe directly the perturbations in Earth's global energy budget associated with short-term events such as major volcanic eruptions. These radiometers directly measure the equator-to-pole heat transport by the climate system, the greenhouse effect of atmospheric trace gases, and the effect of clouds on the energy budget of Earth. These observations have advanced our understanding of the climate system and improved climate models.

*Spaceborne sensing (passive and active)* of the Earth's surface and atmosphere plays an essential and increasingly important role in operational and research meteorology, in particular for mitigating the impact of weather and climate-related disasters, and in understanding, monitoring and predicting climate change and its impact.

The impressive progress made in recent years in weather and climate analysis and forecasts, including warnings for dangerous weather phenomena (heavy rain, storms, cyclones) that affect all populations and economies is, to a great extent, attributable to spaceborne observations and their assimilation in numerical models.

*Spaceborne passive sensing* for meteorological applications is performed in bands allocated by the ITU to the Earth exploration-satellite (passive) and meteorological satellite services. Passive sensing requires the measurement of naturally occurring radiations, usually of very low power levels, which contain essential information on the physical process under investigation. Spaceborne passive sensing of the Earth's surface and atmosphere is of increasing importance in operational and research meteorology. It contributes also to the understanding, monitoring and prediction of climate change and its impact. Meteorological systems are also used to monitor changes in climate and the environment. Mankind is faced with a variety of environmental

phenomena which require careful investigation and analysis. Meteorological systems gather long-term measurement data in support of studies on changes in climate and environment.

Since the level of the observed emissions is very low, amounting virtually to thermal noise, atmospheric attenuation can have a huge impact on them, particularly on account of radio-wave energy absorption in oxygen and water vapour in the atmosphere, as can emissions from the Earth's atmosphere itself. In these circumstances, selecting the right frequencies for passive sensors is critical to achieving the required measurement quality, since far from all frequencies are suitable for observations. Thus, for example, measurements at frequencies around 1.4 GHz provide the most accurate information on salinity, the 6 GHz band is most suitable for measuring sea temperature, 24 GHz for water vapour and above 36 GHz for water clouds. It thus becomes clear that, in practice, shared use of frequencies of active services with passive sensors is impossible. In these circumstances, the Radio Regulations identify a series of frequency bands in which emissions are forbidden. These include the frequency bands 1 400-1 427 MHz, 2 690-2 700 MHz, 10.68-10.7 GHz, 15.35-15.4 GHz, 23.6-24 GHz, 31.3-31.5 GHz, 31.5-31.8 GHz, 48.94-49.04 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz, 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz and 250-252 GHz.

*Space-borne active sensing* for meteorological and climatological processes is performed in particular by altimeters for ocean and ice studies, by scatterometers for sea surface winds, or by rain and cloud radars. It provides important information on the state of the ocean and land surfaces and atmospheric phenomena. Earth Exploration-Satellite Service (EESS) satellites support long-term climate modelling by providing truly global input data. While satellite observations are short-term on a climatological time scale, they nonetheless provide many essential climate variables, some of which are largely dependent upon satellite observations while others are supported and enhanced by satellite observations. Computer models derive the most likely scenarios for the development of changes in the climate. Thus, these passive and active sensing measurements are essential background information to develop climate scenarios needed for the development of national and global policies concerning global climate change.

The underlying operating principle of EESS active systems resides in the satellite illuminating the object or surface to be studied and capturing the reflected signal, which can be processed and used as a source of information for analysing various characteristics or phenomena. Active sensors present certain advantages by comparison with passive sensors, in that they display unique sensitivity to several fluctuating land/sea/atmosphere parameters (e.g. vegetation humidity and cloud height). Furthermore, with active sensing it is possible, for example, to penetrate through the surface and vegetation, operate in any weather and at any time, achieve high spatial resolution, enhance measurement quality by varying the illumination angle, and operate in a wide spectral range without any dependence on emissions from narrowband phenomena. Since the wanted signal traverses the atmosphere twice, attenuating and scattering, choosing the optimum band is very important when planning EESS systems. The list of frequency bands allocated in accordance with the Radio Regulations to EESS (active) and the required frequency band depending on the type of radar are shown in Table 2.



**TABLE 2 : Frequency bands allocated to EESS (active) and required bandwidth depending on type of radar**

Frequency band allocated under RR Article 5	Required bandwidth				
	Scatterometer	Altimeter	SAR	Precipitation radar	Cloud profiling radar
432-438 MHz			6 MHz		
1 215-1 300 MHz	5-500 kHz		20-85 MHz		
3 100-3 300 MHz		200 MHz	20-200 MHz		
5 250-5 570 MHz	5-500 kHz	320 MHz	20-320 MHz		
8 550-8 650 MHz	5-500 kHz	100 MHz	20-100 MHz		
9 300-9 900 MHz	5-500 kHz	300 MHz	20-600 MHz		
13.25-13.75 GHz	5-500 kHz	500 MHz		0.6-14 MHz	
17.2-17.3 GHz	5-500 kHz			0.6-14 MHz	
24.05-24.25 GHz				0.6-14 MHz	
35.5-36 GHz	5-500 kHz	500 MHz		0.6-14 MHz	
78-79 GHz					0.3-10 MHz
94-94.1 GHz					0.3-10 MHz
133.5-134 GHz					0.3-10 MHz
237.9-238 GHz					0.3-10 MHz

Weather monitoring and prediction is the most operationally advanced discipline in the field of Earth observation. For decades, satellite observations have been providing key data leading to improved weather forecasts. These range for tracking cloud motions to providing the temperature and humidity profiles being fed into more and more accurate computer-based weather forecast models. The impact of improved weather forecasts ranges across many human endeavours such as agriculture, transportation, water management, public health, construction, tourism/recreation, energy, and others. EESS satellites support long-term climate modelling by providing truly global input data. While satellite observations are short-term on a climatological time scale, they still provide many essential climate variables, some of which are largely dependent upon satellite observations while others are supported or enhanced by satellite observations (see Table 3). In addition, EESS satellites also serve to monitor global effects of climatic changes as they occur. Such effects include the long-term monitoring of sea level and glacial ice and changes in the growing season.

**TABLE 3: Essential climate variables supplied by satellites**

	Atmospheric variables	Oceanic variables	Terrestrial variables
<b>D</b> <b>e</b> <b>p</b> <b>e</b> <b>n</b> <b>d</b> <b>e</b> <b>n</b> <b>t</b>	Surface precipitation	Sea surface temperature	Lake levels
	Upper air Earth radiation budget	Sea level	Snow cover
	Upper air temperature	Sea state	Glaciers and ice caps
	Upper air wind speed and direction	Sea ice	Albedo
	Upper air water vapour	Ocean colour (biology)	Land cover (including vegetation type)
	Upper air cloud properties	Sub-surface salinity	Soil moisture
	Carbon dioxide		Leaf area index
	Ozone		Biomass
	Aerosol properties		Fire disturbance
			Fraction of absorbed photosynthetically active radiation
<b>S</b> <b>u</b> <b>p</b> <b>o</b> <b>r</b> <b>t</b> <b>e</b> <b>d</b>	Surface air temperature	Surface salinity	River discharge
	Surface air pressure	Surface currents	Water use
	Surface radiation budget	Surface CO <sub>2</sub> partial pressure	Ground water
	Surface wind speed and direction	Sub-surface temperature	Permafrost/seasonally-frozen ground
	Surface water vapour	Sub-surface currents	
	Methane	Sub-surface nutrients	
	Other long-lived greenhouse gases	Sub-surface carbon	
		Sub-surface ocean tracers	
	Sub-surface phytoplankton		

## Ice shields

One of the central questions in climate change and cryosphere (ice-region) research is how the warming climate will affect the ice sheets. It is important since the amount of continental ice and melt water entering the ocean strongly contributes to the change in sea level. Prior to the advent of satellites, polar data was restricted to data locally gathered during hospitable seasons. The use of satellite-borne radio instrumentation has proven particularly useful in polar regions as such regions have extended periods of darkness during winter, when observations in the visible spectrum are precluded. The synthetic view from satellites, particularly from satellites equipped with radio sensors, has increased polar data coverage by multiple orders of magnitude, and access is no longer restricted by seasons.

Before satellites, Antarctica's and Greenland's ice sheet mass balance was assumed to be controlled by the difference between ice melting and accumulation rates, and the rate of ice discharge into the ocean was assumed to be constant. Satellite radar images revealed that:

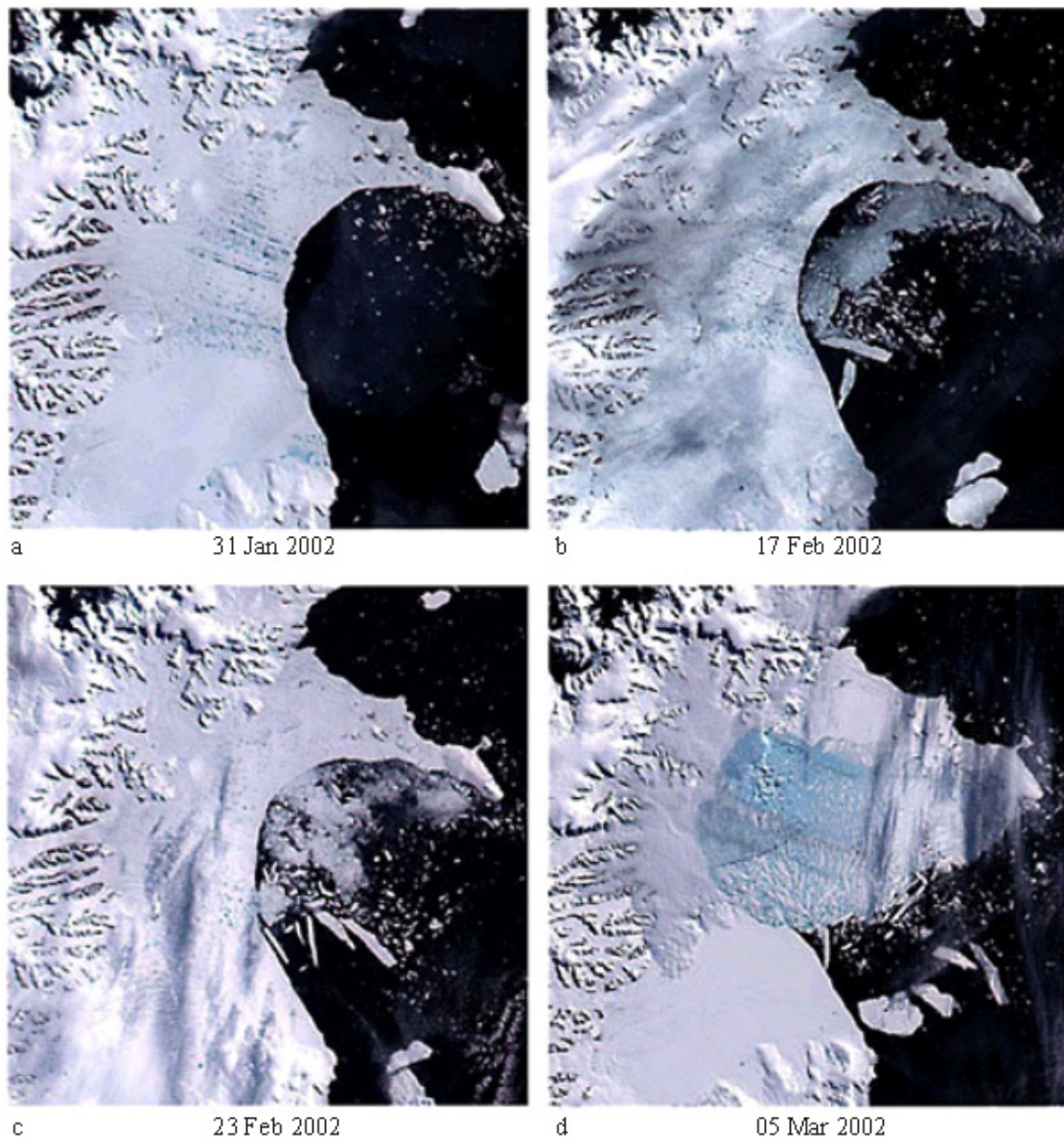
- the velocity of ice sheet flow is highly variable;
- there exist complex networks of ice streams;
- the velocity of ice stream flow toward the sea has increased measurably in response to climate change.

One indication of climate change/global warming is the retreat, rather than advance, of ice sheet flows (both glaciers and sea ice). The study of glacier regimes worldwide reveals widespread retreat since the late 1970s, with a marked acceleration since the late 1980s. Remote sensing is used to document changes in glacier extent (the size of the glacier) and the position of the equilibrium line (the elevation on the glacier where winter accumulation is balanced by summer melt). Since 1972, satellites have provided optical imagery of glacier extent. Synthetic Aperture Radars (SAR) are now used to study zones of glacial snow accumulation and ice melt to determine climate forcing, and laser altimetry is used as well to measure change in glacier elevation.

Because glaciers respond to past and current climatic changes, a complete global glacier inventory is being developed to track the current extent as well as the rates of change of the world's glaciers. The "Global Land Ice Measurements from Space" project is using data from the ASTER and the Landsat Enhanced Thematic Mapper to inventory about 160 000 glaciers worldwide. These measurements and the resulting trend analyses are important indicators of climate change and exemplify the value and importance of long-term data sets for understanding the complex climate system.

Ice sheets can be easily monitored by spaceborne instrumentation, both active and passive. The breakups of major ice sheets (e.g. the Larsen B Ice Shelf) in the Antarctic have been observed from space. These breakups, if not attributed to global warming, have been accelerated by it. The collapse of the Larsen B Ice Shelf in Antarctica in 2002 - captured only because of frequent coverage by satellite imagery - dramatically illustrated the dynamics of ice sheets on astonishingly short timescales (Fig. 1). These revelations carry weighty implications: the rapid transfer of ice from the continental ice sheets to the sea could result in a significant rise of sea level.

FIGURE 1 : The collapse of the Larsen B Ice Shelf in Western Antarctica. 2 000 km<sup>2</sup>, of ice shelf disintegrated in just two months



RS.1333-01

Source: *Earth Observations from Space: the First 50 Years of Scientific Achievements*, p. 3, 2008, downloadable from URL: <http://www.nap.edu/catalog/11991.html>.

Understanding changes to ice sheets, sea ice, ice caps, and glaciers is important for understanding global climate change and predicting its effects. In particular, “shrinking ice sheets” and their contribution to sea-level rise were identified as the third most significant “Breakthrough of the Year” for 2006 according to **Science** magazine. Given the projected climate change and associated sea-level rise, having global satellite polar coverage available in the future will serve crucial societal needs unmet by any other observing system.

## Oceans

The oceans cover about 71% of the globe's surface and play a key role in the climate system in several respects. They are also an excellent indicator of climate change. For example, measuring sea levels reveals vital clues about global warming.

Changes in weather, climate and environment pose serious challenges to mankind. Meeting these challenges requires further improvements in weather forecasting, especially for mid- to long-term predictions. If there is a clearer picture of what is going to happen in the next days, the next months - or even in the coming season - people and industries can prepare themselves much better for unstable weather patterns. Meeting these challenges also implies a better understanding of global climatic factors that cause such phenomena such as El Niño and La Niña in the Pacific Ocean, dangerous hurricanes and typhoons, and especially rising sea levels.

A key to understanding the forces behind changing weather patterns can only be found by mapping variations in ocean surface conditions worldwide and by using the collected data to develop and run powerful models of ocean behaviour. By combining oceanic and atmospheric models, we can provide the required accurate forecasts on both a short- and long-term basis. The coupling of oceanic and atmospheric models is needed to fully take into account the mesoscale (medium distance) dynamics of the oceans. This coupling of oceanic and atmospheric models becomes important for weather forecasting beyond two weeks. The oceans are also an important part of the process of climate change, and a rise in sea levels all over the world is widely recognized potentially as one of the most devastating consequences of global warming.

### Sea surface temperature and mean sea level rise

An important contribution to climate science was made by the long-term record of sea surface temperature (SST). SST is now also measured by passive microwave instruments. SST is one of the most important indicators of global climate change and a vital parameter for climate modelling.

The SST record exposed the role of the oceans in regional and global climate variability and revealed important details about ocean currents. More than 80% of the total heating of the Earth system is stored in the ocean, and ocean currents redistribute this heat across the globe. Trend analysis of the SST record helped improve the understanding of the important climate-atmosphere feedbacks in the tropics that are also responsible for El Niño-Southern oscillation (ENSO) events in the Pacific Ocean. Advances in understanding the ENSO, led by satellite observations of sea surface winds, sea surface heights, and sea surface temperatures, have had a profound impact on regional climate and weather predictions. Furthermore, the intensity of hurricanes has been linked to sea surface temperatures. Consequently, the understanding of both sea surface temperatures and hurricanes has benefited from studies using data from satellites.

In addition, SST is central in coupling the ocean with the atmosphere and is a controlling factor in the heat and vapour exchange between the two. Trend analysis of SST provided evidence for global warming and the important climate-atmosphere feedback in the tropics that is also responsible for ENSO events. These SST observations, combined with *in situ* vertical temperature measurements of the ocean to a depth of 3 000 m, provided evidence to detect anthropogenic global warming in the ocean.

Understanding the increase in SST and anthropogenic heat input to the surface ocean also has important ramifications for quantifying and predicting sea level rise. Mean sea level rise could

be a sign of global warming. Monitoring this level is an application of altimetry, and one of the main issues in Environmental sciences of the 21st century.

It is quite difficult to separate the natural variability of the climate from the effects of global warming. Measurements of the mean sea levels have been derived for 15 years from satellite observations. These observations have been consistent and have produced an accurate time series of satellite observations. However, such a period of time is short. In addition to that, it is necessary to indicate that human induced perturbation is added to the natural climate variability. Therefore, climate change signals can be detected only if they are greater than the background natural variability. Detecting global climate change is much more demanding than monitoring regional impacts. Part of the observed rise in sea level is due to increased water temperature. However, mean rise in sea level is only part of the story. The rise in the level of the oceans is far from being uniform. In certain ocean regions the sea level has risen (by up to 20 mm a year in some places), while in other regions it has fallen an equivalent amount. One major concern is that rising sea levels may inundate coastal regions throughout the world and may completely submerge low islands. While this effect is expected to be significant over a relatively large timescale (decades to centuries), topography derived from satellite observations can aid by identifying those areas which are vulnerable.

Sea-surface temperature measurements not only revealed important information about ocean circulations (e.g. the Gulf Stream), but also advanced climate research by providing detailed information on the heat input into the ocean. Observations of ocean colour combined with SST measurements led to new discoveries about the physical-biological coupling in the ocean, with important implications for the ocean's role in the carbon cycle.

Satellite observations afford the only means of estimating and monitoring the role of ocean biomass as a sink for carbon. In particular, the fundamental question of whether the biological carbon uptake is changing in response to climate change can only be addressed with satellite measurements. It requires not only ocean colour measurements (phytoplankton biomass and productivity) but also coincident space-based observations of the physical ocean environment (circulation and mixing), land-ocean exchanges (through rivers and tidal wetlands), and other factors such as winds, tides, and solar energy input to the upper ocean. Observing linkages between the physical and chemical environment and the biology of the ocean is a significant achievement of observations from space.



## Soil moisture and ocean salinity

Evaporation, infiltration, and recharge of the groundwater usually occur through the unsaturated vadose zone, which extends from the top of the ground surface to the underground water table. The root zone of the vegetation, wherein vegetation takes-up water, is within the vadose zone and is the interface between the vegetation and the hydrological system. The amount of water available in the vegetation controls plant transpiration and photosynthesis and thus CO<sub>2</sub> sequestration. The amount of water in the vadose zone is also directly linked to the ability of the soil to produce drainage after rainfall. The soil-vegetation-atmosphere transfer (SVAT) schemes used in meteorology and hydrology are designed to describe the basic evaporation processes at the surface and the partitioning of water between vegetation transpiration, drainage, surface runoff, and soil moisture content. A realistic initial value of the amount of water in the vadose zone must be provided to SVAT models.

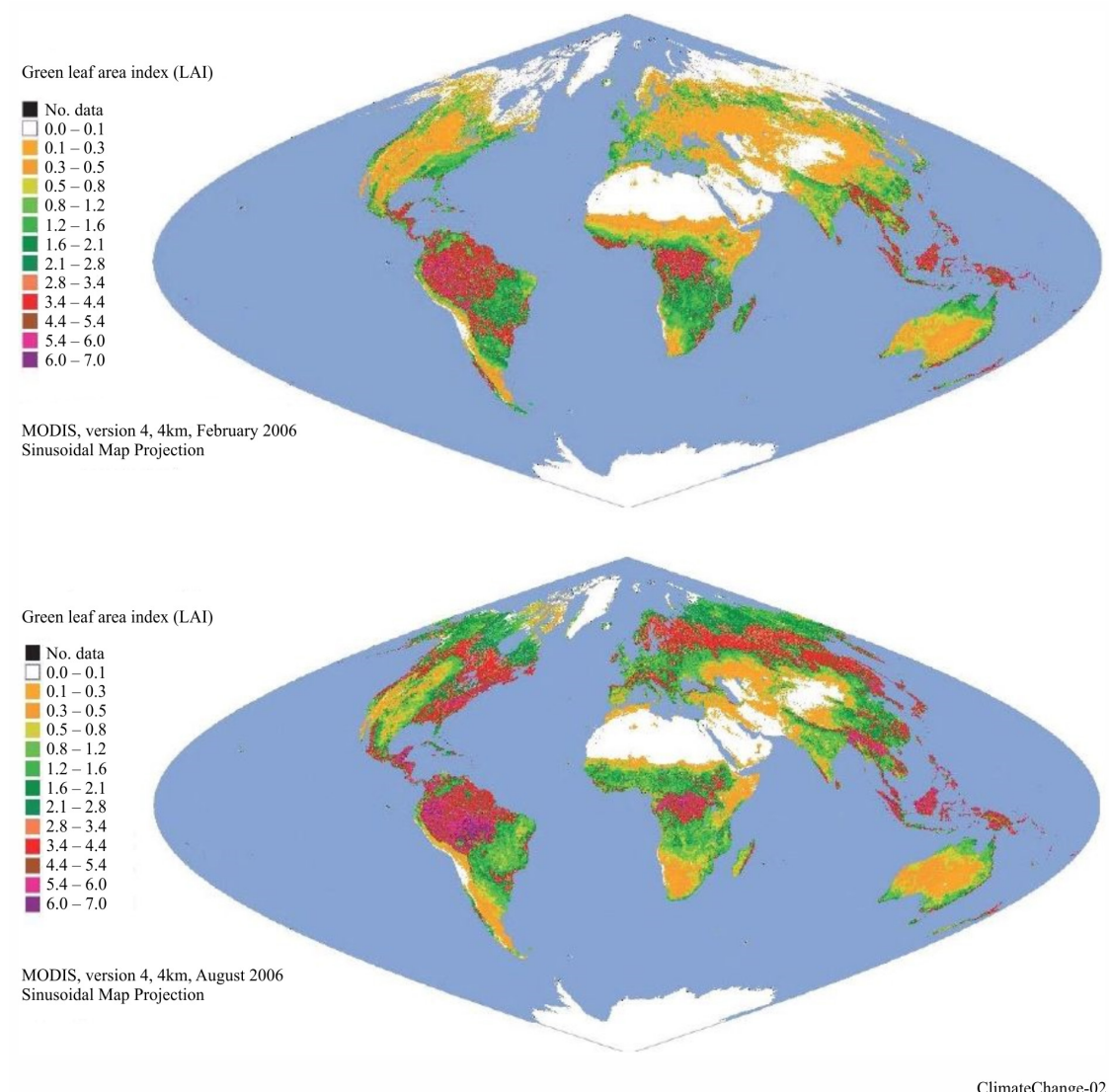
When dealing with bare soil or sparsely covered vegetation, evaporation rate and runoff can be calculated from the surface soil moisture time series. As for vegetation covered surfaces, the amount of water in the vegetation (vegetation optical depth) has to be accounted for. The vegetation optical depth itself may be a very useful product to monitor the vegetation dynamics.

Knowledge of the distribution of salt (salinity) in the global ocean and its annual and inter-annual variability are crucial in understanding the role of the ocean in the climate system. Salinity is fundamental in determining ocean density and hence the thermohaline circulation. Ocean salinity is also linked to the oceanic carbon cycle, as it plays a part in establishing the chemical equilibrium, which in turn regulates the CO<sub>2</sub> uptake and release. Therefore, the assimilation of sea surface salinity measurements into global ocean bio-geo-chemical models should improve estimates of the absorption of CO<sub>2</sub> by the oceans.

## The biosphere

Satellite monitoring of the dynamics of Earth's vegetation is essential to understanding global ecosystem functioning and response to climate variability and climate change. This observation (Fig. 2) has become more precise by its extension to a biophysical measurement.

**FIGURE 2 : Green Leaf Indices from MODIS showing seasonal changes in vegetation**

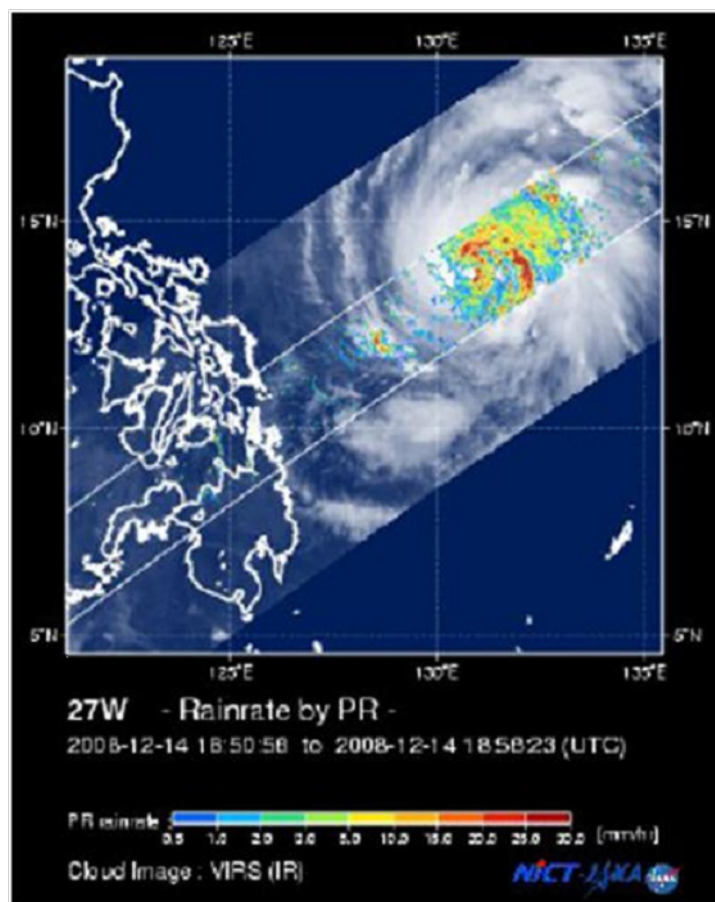


## Meteorological radars

Meteorological radars are used to sense the conditions of the atmosphere for routine forecasting, severe weather detection, wind and precipitation detection, precipitation estimates, detection of aircraft icing conditions and avoidance of severe weather for navigation. Meteorological radars transmit horizontally polarized pulses which measure the horizontal dimension of a cloud (cloud water and cloud ice) and precipitation (snow, ice pellets, hail and rain particles).

Polarimetric radars, also called dual-polarization radars, transmit pulses in both horizontal and vertical polarizations. These radars provide significant improvements in rainfall estimation, precipitation classification, data quality and weather hazard detection over non-polarimetric systems. An example of measurements made by radar is shown in Fig. 3.

FIGURE 3 : Rain rate distribution of a typhoon



EESS4-13

The Radio Regulations contain three specific references to meteorological radars in the Table of Frequency Allocations. The three references are contained in footnotes associated with the bands 2 700-2 900 MHz, 5 600-5 650 MHz and 9 300-9 500 MHz.

### Wind profiler radars

The development of weather forecasting presently requires frequent, closely spaced and high-quality wind data with improved accuracy from near-the-Earth's surface to high in the atmosphere. Wind data based principally on balloon borne instruments, satellite measurements and automated aircraft reporting systems are insufficient to satisfy the needs of the increasingly high-resolution atmospheric computer models as well as those on man-machine interactive forecasting systems. Without substantial increases in high resolution wind data, the capacity of these new models and interactive systems being deployed later this decade to improve weather forecasts and severe weather warnings will be greatly limited.

Planetary numerical models of the atmosphere which produce three- to ten-day forecasts require upper air data from extensive areas of the globe. Especially in remote areas, wind profiler radars operating unattended may offer a means of obtaining essential high-altitude data for these models from data sparse areas. Numerical models for forecasts from 3 to 48 h covering a continent or smaller area require data from a large vertical extent of the atmosphere,

typically from 200 m to 18 km, with vertical resolution of approximately 250 m depending on the application. The time resolution presently needed is for hourly data.

For very short-term weather forecasting, air pollution monitoring, wind field analyses and forecasts of toxic plume trajectories resulting from chemical or nuclear incidents, severe weather warnings for aviation, meteorological observations, airport operations, and public protection, meteorologists need wind information with a very high temporal and spatial resolution, mainly in the lower atmosphere. The requirements are for continuous data acquisition, between the ground and 5 km, with a desirable resolution sometimes as low as 30 m. Measurements will usually be made in populated areas.

Wind profiler radars also play an important role in experimental atmospheric research. Their ability to measure wind with a high temporal and spatial resolution makes them very well suited for the experimental verification of models, for boundary layer research and for the investigation of processes that are important for understanding the atmosphere, including climate evolution.

At present, meteorological organizations use balloon borne systems to measure profiles of wind, temperature, and humidity from the ground to high in the atmosphere. While current wind profiler radars do not operationally measure all of these parameters, they do have several advantages in comparison to the balloon-based systems in meeting the above-mentioned requirements:

- they sample winds nearly continuously;
- the winds are measured almost directly above the site;
- the vertical air velocity can be measured;
- they provide the temporal and spatial density soundings needed to compute derived fields in a much more timely manner;
- the cost per observation is lower;
- they operate unattended in nearly all weather conditions.

In addition, it has been demonstrated that wind profiler radars can be adapted to measure temperature profiles when they are used in conjunction with a radio-acoustic sounding system. This opens the possibility to obtain denser and higher quality temperature profiles compared to present measurement techniques such as balloon tracking. No other measurement technique will present comparable advantages in the near future, including satellite borne sensors.

Global harmonization of wind profiler radar operational frequencies and identification of spectrum by a world radiocommunication conference is most important. This will enable cost-effective development and exploitation of wind profiler radars. In practice, systems are built for three frequency bands, i.e. around 50 MHz, 400 MHz, and 1 000 MHz.

### Oceanographic Radars

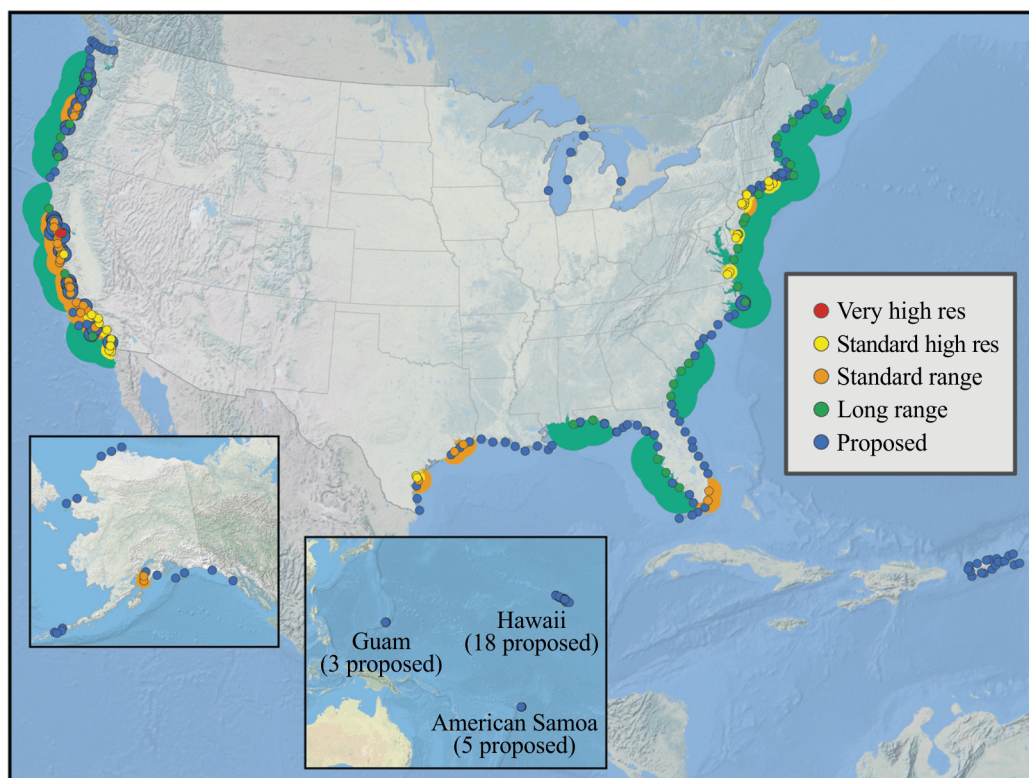
A significant percentage of the world's population lives within 50 miles of the coastline. This heightens the need for accurate, reliable and detailed measurements of coastal environmental variables. Just as the winds in the atmosphere provide information about where and when weather systems occur, ocean currents determine the movement of oceanic events. These two dynamic flows are also used to determine where pollutants, man-made or natural, will travel. Presently, ocean current measurements are not as readily available as wind measurements.

Because of this, there is an increasing interest in the ability to accurately measure the currents and waves in coastal waters. The global oceanography community is planning for the implementation of coastal sea surface monitoring radar networks. The benefits to society for improved measurement of coastal currents and sea state include a better understanding of issues like coastal pollution, fisheries management, search and rescue, beach erosion, maritime navigation, and sediment transport. Coastal radar measurements of the sea surface provide support to meteorological operations through the collection of sea state and dominant ocean wave data.

In addition, oceanographic radar technology has applications in global maritime domain awareness by allowing the long-range sensing of surface vessels. This will benefit the global safety and security of shipping and ports. The need for additional data to mitigate the effects of disasters, including tsunamis, to understand climate change, and to ensure safe maritime travel has led to the consideration of operational use of oceanographic radar networks on a global basis.

As of 2009, 143 oceanographic radars spread unevenly throughout the United States of America coastal regions (this total includes radars that are not currently operating on a regular basis). Nearly all the oceanographic radar systems in the United States of America are owned and operated by university research departments. Existing and proposed oceanographic radar sites for the United States of America, the Pacific Islands and the Caribbean Regions are shown in Fig. 4.

**FIGURE 4 : Existing and proposed oceanographic radar sites for the United States of America, the Pacific Islands and the Caribbean Regions**

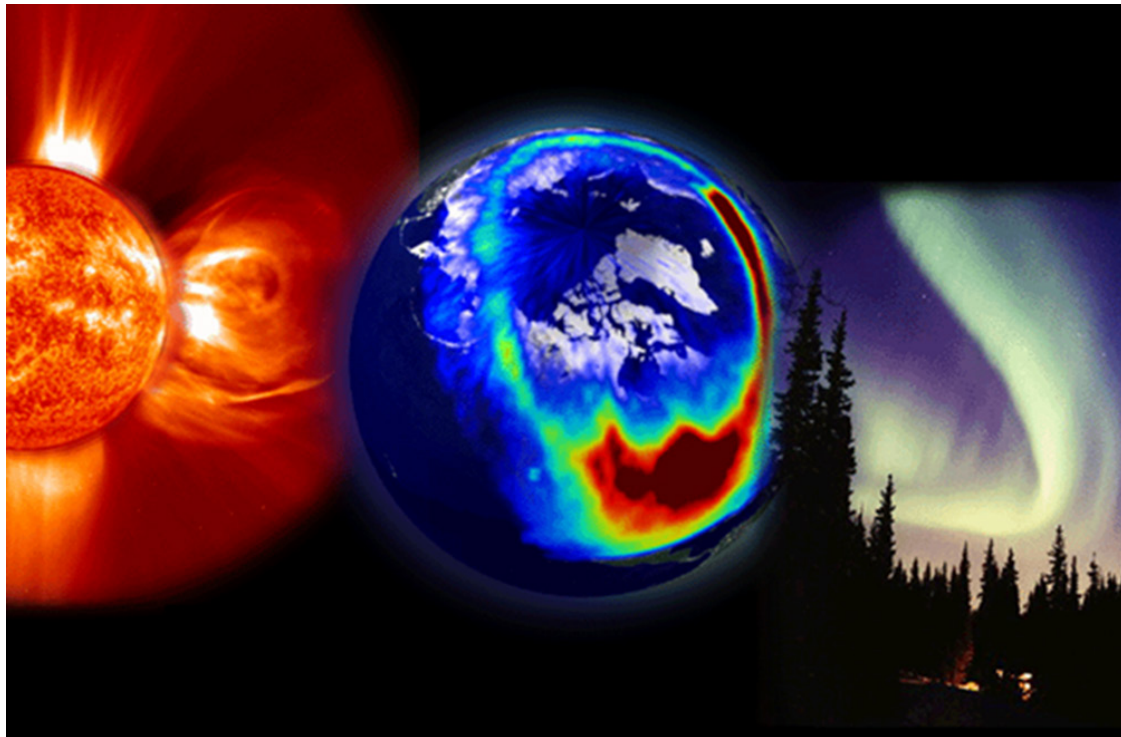




## Solar radio monitoring

Our growing appreciation of our susceptibility to the Sun's behaviour has led to the development of a new discipline called "space weather". Space weather, like its more familiar counterpart closer to the ground, is the study of the changing conditions in the region of space near the Earth. However, instead of studying wind and rain, space weather scientists measure electromagnetic radiation and the behaviour of solar plasma (Fig. 5).

**FIGURE 5 : Solar activity seen from a satellite and from the ground**



Source: SOHO

On long and intermediate timescales, the consequences of solar variability upon climate are ranked with the effects of terrestrial volcanism and the summation of all human activity. More important on shorter timescales is the role of space weather in disrupting our technical infrastructure in space, in the air and on the ground.

Solar radio monitoring is a specialized branch of radio astronomy. It plays an active role in space weather services and research, and facilitates - through the monitoring of solar activity - space weather forecasting and the generation of timely alerts of solar eruptive events that can impact the Earth and human activities.

A longer-term consideration, but still a major natural hazard to be considered, is the possibility of giant solar flares. These seem to occur randomly. None have occurred since the appearance of our modern, technologically dependent society, with its extreme reliance on power and communication infrastructure. The impact of one of these events would be severe and could have major worldwide disrupting consequences that should be better assessed, as such an extreme situation is unprecedented.

This major new global technological risk cannot be controlled, which highlights the crucial role played by early-warning systems that rely on continuous monitoring of the Sun to mitigate



its effects. Ground-based solar radio telescopes are one of such early-warning systems. The objectives of solar radio monitoring are:

- to better understand solar-driven changes in the climate and other environmental parameters that have scientific, economic or humanitarian impacts;
- to understand and forecast space weather phenomena that affect our communications, transportation or other infrastructure, and activities such as agriculture and fisheries.

It is common in addressing many environmental and terrestrial issues to assume that the Sun is simply a constant energy source. In fact, the Sun produces a complex and ever-changing mixture of particles and electromagnetic waves, modulated by the general level of solar magnetic activity. Measurement of solar radio emission will remain an important part of the monitoring of the driving force disturbing our environment. This emission has no discernible direct effect on our environment or technologies, apart from the rare occasions when the solar radio emission is strong enough to degrade radio systems, which has happened on several occasions. Radio observations provide excellent stethoscopes on facets of solar behaviour that can have dramatic effects on our environment and activities on Earth, in the atmosphere and in space. The impact of solar activity on our environment, activities and infrastructure is manifold.

### Meteorological aids

Meteorological aids systems are mainly used for *in situ* upper air measurements of meteorological variables (pressure, temperature, relative humidity, wind speed and direction) in the atmosphere up to an altitude of 36 km. The measurements are vital to national weather forecasting capability (and hence severe weather warning services for the public involving protection of life and property). The meteorological aids and associated tracking systems provide simultaneous measurements of the vertical structure of temperature, relative humidity and wind speed and direction over the full height range required. The variation of these meteorological variables in the vertical contains the majority of the critical information for weather forecasting. The MetAids systems are the only meteorological observing systems able to regularly provide the vertical resolution that meteorologists need for all four variables. Identification of the heights where sudden changes in a variable occur is vital. Thus, continuity of reliable measurements is essential throughout the trip of the radiosonde.

The MetAids observations are produced by radiosondes carried by ascending balloons launched from land stations or ships, dropsondes deployed from aircraft and carried by a parachute, and rocketsondes lifted into the atmosphere by rocket and descend under a parachute during data collection (see example at Fig. 6). Radiosonde observations are carried out routinely by almost all countries, two to four times a day. The observation data are then circulated immediately to all other countries within a few hours via the World Meteorological Organization (WMO) Global Telecommunications System (GTS). The observing systems and data dissemination are all organized under the framework of the World Weather Watch Programme of WMO.

The radiosonde network provides the primary global source of real-time *in situ* measurements. WMO Regulations (Manual on the Global Data-Processing System (GDPS)) require that radiosonde measurements ought to be made and circulated to all GDPS centres worldwide at national, regional, and global levels for numerical weather prediction. The observation stations are required, worldwide, at a horizontal spacing of less than or equal to 250 km, during the first decade of the twenty-first century, with a frequency of observation of from one to four times per day. However, the numerical weather prediction models for small scale meteorological

phenomena (e.g. thunderstorm, local winds, tornadoes) and environmental emergencies actually require local upper air observations every one to three hours at a horizontal resolution from 50 to 100 km. Observations are to be provided from a variety of observing systems, chosen according to the needs of national administrations, including MetAids measurements, wind profiler radar measurements or satellite measurements.

**FIGURE 6 : Launch of a radiosonde**



Source: R.P Leck, Earth Resource Technologies Inc.

The radiosonde observations are essential to maintain stability in the WMO Global Observing System (GOS). Remotely sensed measurements from satellites do not have the vertical resolution available from radiosondes. Successful derivation of vertical temperature structure from these satellite measurements usually requires a computation initialized either directly from radiosonde statistics or from the numerical weather forecast itself. In the latter case, the radiosonde measurements ensure that the vertical structure in these forecasts remains accurate and stable with time. In addition, the radiosonde measurements are used to calibrate satellite observations by a variety of techniques. Radiosonde observations are thus seen to remain absolutely necessary for meteorological operations for the foreseeable future.

Large worldwide changes have occurred in atmospheric temperature and ozone in the last 20 years, with many of the largest changes taking place at heights between 12 and 30 km above the surface of the Earth. The changes are large enough to cause concern about safety of future public health. Routine daily radiosonde observations to heights above 30 km identify the distribution in the vertical of the changes that occur and hence allow the causes of the changes to be evaluated. Ozonesonde measurements to similar heights determine the vertical distribution of the ozone depletion that now appears to be occurring in both Southern and Northern Hemisphere winter and spring. Many countries fly ozonesondes at least three times per week during these seasons to monitor developments.

Other MetAids systems may be deployed independently of the main civilian meteorological organization by national research institutes and other users. Specific investigations will include environmental pollution, hydrology, radioactivity in the free atmosphere, significant weather phenomena (e.g. winter storms, hurricanes, thunderstorms, etc.) and investigation of a range of physical and chemical properties of the atmosphere. This use is not decreasing with time, since with modern automation it is now much easier to successfully operate mobile systems and shipboard systems without highly skilled operators and a large amount of supporting equipment. MetAids operations have to accommodate these users, and this expands the radio-frequency spectrum required for MetAids operations. This is particularly critical when launch sites of these other users are within 150 km of the meteorological organization launch sites.

The radiosonde networks are implemented and operated by national meteorological services in compliance with recommended practices and procedures internationally agreed upon by WMO. The current number of radiosonde stations reporting regularly is about 900. About 800 000 radiosondes are routinely launched in a year in association with the WMO network and it is estimated that about another 400 000 radiosondes are used for defence use and specialized applications.

*Dropsondes* are meteorological sensor packages that are carried aloft on aircraft and dropped beneath a parachute to profile the atmosphere. They are deployed from altitudes ranging from 3 000 to 21 400 m and tracked to the Earth's surface. While they can be used over landmasses, they are typically used over ocean areas where operation of a radiosonde site is not possible. Dropsondes are used extensively for monitoring conditions within tropical storms, hurricanes and typhoons since the aircraft can drop them at key points as the aircraft traverses the storm. Dropsondes transmit sensor data to a receiver on board the aircraft. An aircraft deploying dropsondes may track and receive data from as many as eight dropsondes simultaneously requiring the use of a multi-channel receiver system. This permits the aircraft to fly a pattern through a storm, releasing dropsondes and to collect data from key points within the storm. Dropsondes use GPS and their location information is combined and transmitted with the measured pressure, temperature, and humidity data in order to calculate and forecast wind speed.

Dropsondes dropped from an aircraft pass through the atmosphere very quickly as they descend beneath the parachute. Data loss for even a brief period of time can lead to large portions of missing data for significant parts of the atmosphere. While all data during the descent is critical, many applications place additional emphasis on the last data point before the dropsonde reaches the surface. The last data point represents the conditions on the surface, which are critical for forecasting applications.

Dropsondes allow profiling of the atmosphere within large storms while they are still far from land. The data is critical to monitoring the strength of the storm and predicting the future strength and track.

Dropsondes have also been used worldwide for meteorological and climatological research over oceans and over land. Dropsondes allow rapid deployment of a high density of sensor packages in areas where deployment of radiosonde stations is not possible. Their use also allows rapid reconfiguration of the network in response to changing conditions, something ground based radiosonde stations cannot quickly respond to.

*Rocketsondes* are used by space agencies and other users that have data requirements that cannot be met with use of radiosondes or dropsondes. Rocketsonde systems, like dropsondes,

collect atmospheric data as they descend through the atmosphere. Rather than being dropped from aircraft like dropsondes, rocketsondes are lifted quickly into the atmosphere on a small solid fuel rocket and data is collected as the rocketsonde falls back to earth under a parachute.

Rocketsondes are deployed for atmospheric measurements by a small solid fuel rocket. Both low altitude and high altitude rocketsonde systems are used. Use of rocketsondes is not extensive, though they are critical when only their unique data performance will satisfy data requirements.

The low-altitude version is used to very quickly deploy a measurement package to a height of approximately 1 000 m so the boundary layer conditions can be measured. In this version, the sensor package is ejected from the rocket body at apogee.

The high-altitude version is used to deploy atmospheric measurement packages to altitudes (above 32 km) that cannot be reached with balloon borne radiosondes. After launch, the rocket motor quickly burns out at a low altitude (~2 000 m) and separates from a dart that carries the rocketsonde payload to apogee (73 to 125 km). At apogee, the rocketsonde payload is ejected from the dart and descends through the atmosphere below a parachute. In addition to transmission of meteorological data from the rocketsonde, the parachute is constructed of aluminized Mylar to enable radar skin tracking for atmospheric winds measurement. The time period from deployment at apogee to termination of data collection at 14 km is typically 100 min. The radar skin tracking is performed in a radiodetermination band rather than in a frequency band allocated to MetAids.

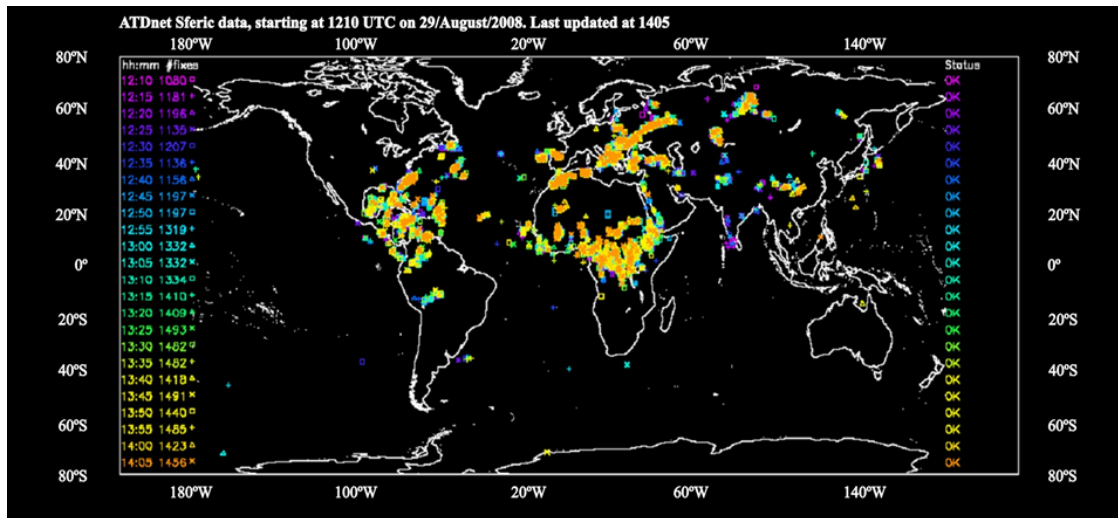
MetAids *long-range lightning detection* has been performed since 1939, originally with a very manpower-intensive system measuring the direction from which signals were received, but since 1987 detection has been carried out with an automated system using the time differences of signals received to derive strike locations.

This system utilizes a network of “detector” out-stations to monitor spectral emissions of cloud to ground lightning strikes. Sky waves, reflected off the ionosphere, propagate for very large distances with relatively little attenuation and are preceded by a ground wave at shorter ranges. Thus, it is possible to receive the emissions from the cloud to ground strokes at thousands of kilometres from the stroke location. A distributed network of ground-based sensors can locate the origin of the lightning stroke, using the time differences between the arrivals of the lightning emission at the individual sensor sites.

At June 2010, the network comprised eleven sensors distributed across Europe from Iceland to Cyprus, operating in collaboration with Finland, France, Germany, Iceland, Ireland, Portugal and Switzerland. The further sensor has been placed in La Reunion (in the Indian Ocean to the east of Madagascar) to evaluate improvements in location for Africa, but this is not yet processed as part of the operational system. In the immediate future new sensors are to be installed in Croatia, at some sites in Africa, South America, the Middle East and in western Asia, and in the long term there should be opportunities to extend the system to provide global coverage.

The typical output from the system is illustrated in Fig. 7, where the lightning locations have been detected at a time of year when there are few thunderstorms in Europe, with intense activity in Central Africa, the Caribbean and parts of South America.

Figure 7 : Example of two hour's lightning detection output



The data provided by the lightning system is used by meteorological organizations worldwide and contributes towards safety of life, both in terms of forecasting for public safety and safety in forecasting aviation operations, especially over the oceans and large areas of land where national lightning detection systems do not exist. As well as the dangers of the lightning strike itself, thunderstorms can result in intense precipitation with consequent flooding, severe icing, wind shear, turbulence, and gusting winds.

## Mobile systems

There is a growing need to provide wireless access media that can link sensors and actuators associated with humans or widely dispersed objects to core networks in order to support an increasing number of service applications. Mobile wireless access systems are in demand for a variety of services such as environmental monitoring; stolen goods tracing; monitoring of gas, water, and electricity use for reducing environmental loads; social security, health care, etc.

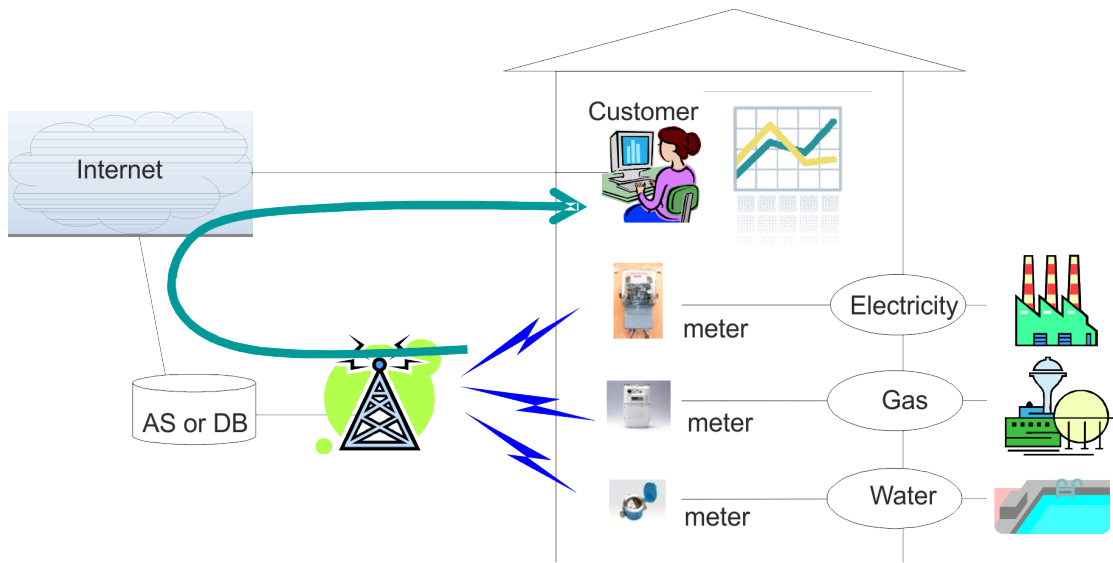
The mobile wireless access system is a large cell-based public network that can provide telecommunications to various objects including machine-to-machine services with wide area coverage. A large cell-based wireless access system with a cell radius of several kilometres is especially practical in supporting rural and non-residential areas as well as urban or residential areas owing to its simple and cost-effective deployment. Available service categories and service examples are following:

- remote meter reading of utilities such as water, gas and electricity: this application also allows homeowners to visualize the energy consumption of each home for environmental assessment (see Fig. 8);
- meteorological observation: air temperature and humidity measurement, precipitation measurement, water level measurements of rivers and the sea, CO<sub>2</sub> concentration measurement;
- environmental observation and protection: environmental pollution observation, including air, water and soil, industrial waste investigation, monitoring in the chemical industry, ecosystem investigation;
- disaster prevention and avoidance measures: earthquake observation (e.g. seismic sensing), flood monitoring, debris flow observation;
- intelligent transportation and traffic management systems: minimize transportation distances and fuel consumption;

- M-Government, M-medicine, M-business and M-commerce - the adoption of mobile technologies to support and enhance government and business performance and foster a more connected society. Focus is placed on the needs of the public sector and of the end-users, be these citizens or businesses, to ensure that technology is exploited to reorganise the way people work and to meet the needs of citizens through improved service delivery and empowering citizens to connect to a wide range of information and services, e.g. legal information, health, education, finance, employment, transportation and public safety. This contributes to energy and natural resource conservation and energy efficiency by:
  - helping to limit duplication of effort and resources, by sharing data and resources, by automating repetitive tasks and by centralizing tasks and services in central and/or distributed processors: data centres, common applications servers, etc.;
  - increasing the efficiency in the use of existing and/or common resources, with particular concern about computational and human resources;
  - decreasing the use of paper and contributing to recycling;
  - decreasing wait times and queuing;
  - limiting travel and cutting on GHG emissions;
  - reducing commuting and pollution;
  
- Intelligent building systems: environmental control systems are emerging as tools that can allow remote management of human dwellings and facilities including buildings and construction sites. Intelligent building systems (IBS) integrate mobile systems in their design and operation in order to manage comfort, security and costs. Using wireless systems as well as networked devices and intelligent algorithms is the technological foundation for a "smart building". This consists of a combination of networked devices such as intelligent thermostats, presence sensors, lighting sensors and controls, heating ventilating and air conditioning systems, security, fire, vibration, strain and moisture sensors, elevator and escalator control systems, and other building systems communicating over a "single broadband infrastructure". These technologies could save more than 30 per cent of the energy costs of existing buildings and over 70 per cent for new buildings while allowing these new buildings to become net electric energy suppliers to the electric power grid. A good example is remote control of office air conditioning. This application allows control operators to collect environmental information such as temperature and humidity throughout office rooms or the whole building, and helps optimize energy use by controlling distributed air conditioners (see Fig. 9).

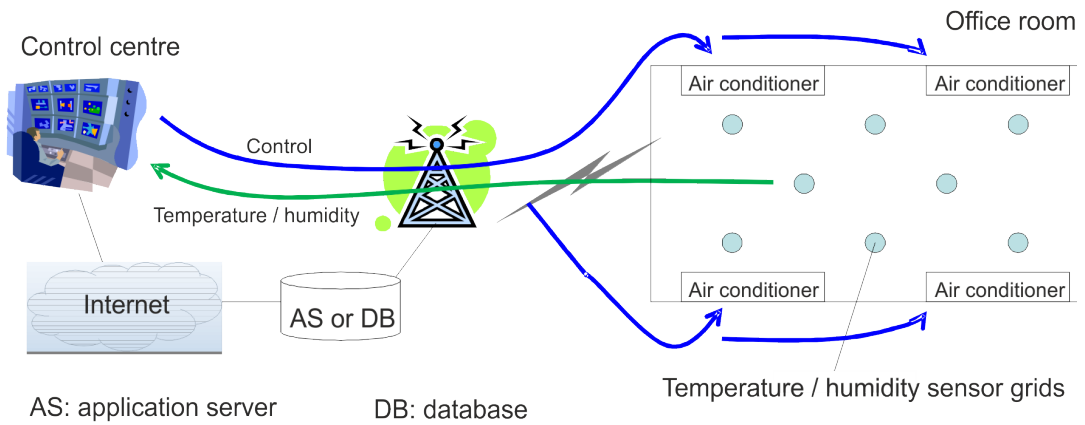


FIGURE 8 : Visualization of home energy consumption



ClimateChange-08

FIGURE 9: Remote control of office air conditioning



AS: application server

DB: database

ClimateChange-09

# 2

## ITU-R Study Group activities

ITU-R Study Groups are established and assigned study Questions to prepare draft Recommendations. All ITU-R Recommendations are developed by radiocommunication world experts from all countries, thereby enjoying a high reputation and worldwide implementation, getting therefore the status of international standards in their domain of application.

Studies focus on the following:

- efficient management and use of the spectrum/orbit resource by space and terrestrial services;
- characteristics and performance of radio systems;
- operation of radio stations;
- radiocommunication aspects of distress and safety matters.

Furthermore, ITU-R Study Groups carry out preparatory studies for World and Regional Radiocommunication Conferences (WRCs, RRCs). Study Groups accomplish their work in cooperation with other international radiocommunication organizations. More than 1 500 specialists, representing ITU Member States and Sector and Associate Members throughout the world, currently participate in the work of ITU-R Study Groups. At present, there are six Study Groups specializing in the following areas:

SG 1 - Spectrum management

SG 3 - Radiowave propagation

SG 4 - Satellite services

SG 5 - Terrestrial services

SG 6 - Broadcasting service

SG 7 - Science services

Concerning climate change in particular, the work of ITU-R Study Groups are currently focusing on:

- management of radiocommunications in disaster prediction, detection, mitigation and relief;
- support of disaster prediction, detection, mitigation or relief radiocommunication systems. Details are presented in Table 4;
- calling on ITU-R Study Groups to develop Recommendations, Reports or Handbooks on:
  - best practices in place to reduce energy consumption within ICT systems, equipment or applications operating in a radiocommunication service;
  - use of radio systems or applications which can support reduction of energy consumption in non-radiocommunication sectors;
  - effective systems for monitoring the environment and monitoring and predicting climate change, and ensuring reliable operation of such systems.

**TABLE 4 : The scope of ongoing studies within ITU-R relating to climate change**

Activities	Major tasks	Radiocommunication services involved	ITU-R Study Group
Monitoring the environment	Satellite observations of the Earth's atmosphere and surface The acquisition, processing, analysis and distribution of data from remote sensing satellites	Earth exploration-satellite service	SG 7
		Meteorological satellite service	
		Space operation service	
	Solar radio monitoring	Radioastronomy Space research service	SG 7
	Ground observation of atmosphere characteristic	Meteorological aids service	SG 7
		Radionavigation service Radiolocation service	SG 5
Mobile service		SG 5	
Other applications	Construction optimisation Traffic optimisation Energy savings Planting decisions Irrigation planning	Earth exploration-satellite service	SG7
		Mobile	SG 5

# 3

## Results of recent World Radiocommunication Conferences



### World Radiocommunication Conference 2019 (WRC-19)

WRC-19 established conditions to protect the existing services from receiving harmful interference from future IMT mobile and base stations. Of great importance was the need and priority given to protecting sensitive science services in adjacent bands, particularly the Earth exploration-satellite service (EESS) passive band where measurements are made that are then used in weather prediction models. Harmful interference into this band could impact these measurements and make weather prediction increasingly less accurate. Concerning operations of EESS (passive) in the 23.6-24 GHz, WRC-19 adopted Resolution 750 (Rev. WRC-19) on Compatibility between the Earth exploration-satellite service (passive) and relevant active services, to be implemented in two steps:

- A limit of  $-33/-29$  dBW/200 MHz applies for base/mobile stations brought into use before 1 September 2027.
- A limit of  $-39/-35$  dBW/200 MHz will apply for base/mobile stations brought into use after 1 September 2027.

The World Radiocommunication Conference (WRC-19) also adopted:

- Resolution 646 (Rev.WRC-19) – Public protection and disaster relief
- Resolution 647 (Rev.WRC-19) – Radiocommunication aspects, including spectrum-management guidelines, for early warning, disaster prediction, detection, mitigation and relief operations relating to emergencies and disasters
- Resolution 657 (Rev.WRC-19) – Protection of radio spectrum-reliant space weather sensors used for global prediction and warnings

Radiocommunication Assembly 2019 (RA-19) adopted a number of Resolutions asking ITU-R to conduct appropriate studies, in particular:

- Resolution ITU-R 55-3 – ITU studies of disaster prediction, detection, mitigation and relief
- Resolution ITU-R 60-2 – Reduction of energy consumption for environmental protection and mitigating climate change by use of ICT/radiocommunication technologies and systems
- Resolution ITU-R 61-2 – ITU-R’s contribution in implementing the outcomes of the World Summit on the Information Society and the 2030 Agenda for Sustainable Development

Download WRC-19 Final Acts here: (<https://www.itu.int/pub/R-ACT-WRC.14-2019/en>)

## World Radiocommunication Conference 2015 (WRC-15)

WRC-15 agreed to new allocations in the 7-8 GHz frequency range needed to uplink large amounts of data for operations plans and dynamic spacecraft software modifications that will eventually lead to simplified on-board architecture and operational concepts for future missions of earth-exploration satellite services (EESS).

Allocations of spectrum in the 9-10 GHz frequency range will lead to the development of modern broadband sensing technologies and space-borne radars on active sensing EESS. Scientific and geo-information applications will provide high quality measurements in all weather conditions with enhanced applications for disaster relief and humanitarian aid, land use and large-area coastal surveillance.

## Previous World Radiocommunication Conferences

Decisions taken at the World Radiocommunication Conferences 2007 and 2012 reinforced ITU’s mandate in the area of sustainability, climate change and emergency communications, and secured the availability of spectrum and satellite orbit for the operation of radio systems intended for monitoring the environment and assessing and predicting climate change, as follows:

### - **Meteorological-satellite service gets more spectrum**

Additional spectrum for the meteorological-satellite service was allocated. Existed allocation to the meteorological satellite service (MetSat) was extended to the bands 7.85-7.9 GHz and 18.3-18.4 GHz. This will enable future MetSat systems to perform measurements and observations of meteorological and climate parameters with much higher resolution, hence to better understand and predict weather and climate change.

### - Satellite remote passive sensing development and protection

Conferences updated spectrum use aimed at the future of Earth observation applications with the development of passive sensors on-board meteorological and environmental satellites to monitor water vapour and oxygen spectral lines, which are needed for ice

cloud and precipitation measurements and for storm monitoring and climate studies. Mandatory and recommended emission limits were adopted for active services in order to protect passive services.

- **Oceanographic radars get support**

Global spectrum requirements for oceanic radars to mitigate the effects of disasters, including tsunamis, to understand climate change, and to ensure safer maritime travel was considered. To this end, a number of frequency allocations to the radiolocation service between 4 MHz and 42.5 MHz were made. The relevant protection levels for interference caused by oceanographic radars were adopted. These radars operate using ground-waves that propagate over the sea to measure coastal sea surface conditions in support of environmental, oceanographic, meteorological, climatological, maritime and disaster mitigation operations and for the surveillance of coastal pollution, fisheries management, search and rescue, beach erosion, and maritime navigation.

- **More spectrum for active sensing**

Extension of the EESS active sensing allocation around 9500-9900 MHz was agreed, providing a required contiguous 500 MHz band available for such things as synthetic aperture radar (SAR) mapping of the Earth's surface topology.

- **Development of lightning detection system is protected**

WRC-12 adopted new regulatory and technical provisions to protect automated systems that are used to detect and predict lightning strikes. The data provided by such systems are used by meteorological organizations worldwide. In particular, the data are valuable in forecasting for aviation, especially over the oceans and the large areas of land where national lightning detection systems do not exist.

A number of Resolutions were approved, reflecting specific concerns of Member States regarding the use of radiocommunications for mitigation of negative effects of climate change, natural and man-made disasters, for example:

- urge the ITU-R study groups to accelerate their work, particularly in the areas of disaster prediction, detection, mitigation and relief; address the broader category of public protection and disaster relief, and encourage administrations to consider identifying frequency bands or ranges or parts thereof when undertaking their national planning for the purposes of achieving regionally harmonized frequency bands or ranges for advanced public protection and disaster relief solutions;
- continue the development of new technologies such as International Mobile Telecommunications (IMT) and intelligent transport systems (ITS) to support or supplement advanced public protection and disaster relief applications;
- highlight the importance of using effective measures to predict, detect, alert, and otherwise mitigate the effects of natural disasters through the coordinated and effective use of radio-frequency spectrum. National spectrum planning for emergency and disaster relief should take into account the need for cooperation and bilateral consultation with other concerned administrations. This can be facilitated by spectrum harmonization, as well as agreed spectrum management guidelines for disaster relief and emergency planning. Identifying frequency availability within individual administrations – within which equipment could operate – may ease interoperability and interworking. It is clearly important to have frequencies available for use in the very early stages of humanitarian assistance for disaster relief;
- continue to assist Member States with their emergency communication preparedness activities by maintaining the database of frequencies available today for use in emergency situations;

- highlight the importance of collecting and exchanging Earth observation data in order to maintain and improve the accuracy of weather forecasts, which contribute to the protection of life and preservation of property throughout the world.



# 4

## Conclusions

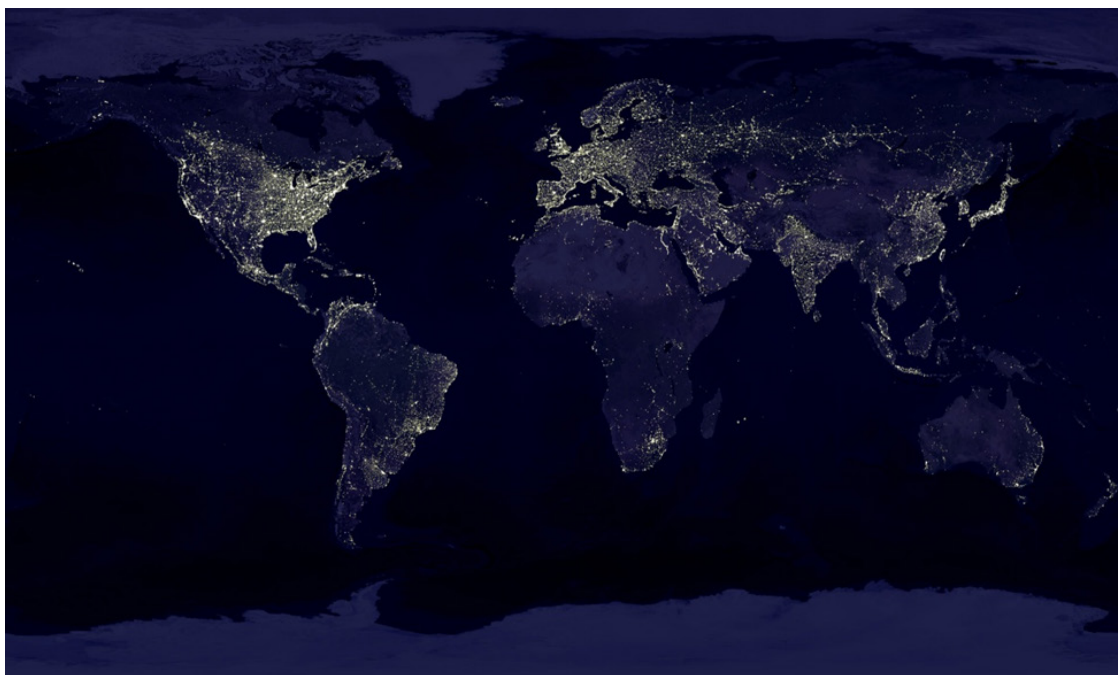
The impact of human activities on the environment - and on climate change in particular - are issues of growing concern confronting life on Earth. Radiocommunications offer a number of opportunities to advance global environmental research, planning and action. These include monitoring and protecting the environment as well as mitigating of and adapting to climate change.

This report shows that ICTs can help to significantly reduce greenhouse gas (GHG) emissions while increasing energy efficiency and reducing the use of natural resources. This is achieved through the use of radio-based technology for travel replacement, recycling and reduced energy consumption. The report also looks extensively at the use of ICTs in many different aspects of work on the environment, including environmental observation, analysis, planning, management and protection, mitigation, and capacity building.

### Illustrations : Conceptual architecture of the Global Earth Observing System of Systems (GEOSS)



### Visible night lights on the Earth









International  
Telecommunication  
Union  
Place des Nations  
CH-1211 Geneva 20  
Switzerland

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