10. Satellite weather and climate monitoring

Meteorology was the first scientific discipline to use space capabilities in the 1960s, and today satellites provide observations of the state of the atmosphere and ocean surface for the preparation of weather analyses, forecasts, advisories and warnings, for climate monitoring and environmental activities. Three quarters of the data used in numerical weather prediction models depend on satellite measurements (e.g. in France, satellites provide 93% of data used in Météo-France's Arpège model). Three main types of satellites provide data: two families of weather satellites and selected environmental satellites.

Weather satellites are operated by agencies in China, France, India, Japan, Korea, the Russian Federation, the United States and Eumetsat for Europe, with international co-ordination by the World Meteorological Organisation (WMO). Some 18 geostationary weather satellites are positioned above the earth's equator, forming a ring located at around 36 000 km (Table 10.1). Their positioning – i.e. American satellites over the West Atlantic, European satellites over the East Atlantic, European and Indian satellites over the Indian Ocean – allows global coverage thanks to international co-operation in weather data exchanges. They share this congested geostationary orbit with more than 300 commercial telecommunications satellites. They are complemented by 17 polar-orbiting weather satellites circling the earth at a much lower altitude (around 850 km) in sun-synchronous orbit, which allows them to revisit a given spot on earth every day at the same hour, making 7 to 16 orbits per day (i.e. "morning" or "afternoon" satellite). The United States, Europe, China and the Russian Federation are so far the only ones operating these essential polar-orbiting satellites, which allow a closer monitoring of the earth's atmosphere (Table 10.2).

In addition to these dedicated weather satellites, around 160 environmental satellite missions in low-earth orbit are currently measuring selected climate parameters (they include both R&D and earth observation satellites, see *9. Satellite earth observation*). Around 30% of these are bilateral or multilateral missions, with different countries providing key instruments on-board satellites (see Figure 1.2). The United States, the European Space Agency and France have established the most joint operations for environmental satellite missions (e.g. NASA is co-operating with Japan's Aerospace Exploration Agency on the Tropical Rainfall Measuring Mission (TRMM); ESA and NASA cooperate on the Solar and Heliospheric Observatory (SOHO), while the French CNES is co-operating with India on the Megha-Tropiques mission to study the water cycle). Paradoxically, although there have never been so many weather and environmental satellites in orbit, funding issues in several OECD countries threaten the sustainability of the provision of essential long-term data series on climate.

Methodological notes

Based on data from the World Meteorological Organisation's database *Observing Systems Capability Analysis and Review* (OSCAR) database, which includes meteorological and environmental satellites.

Sources

Eumetsat, *www.eumetsat.int/*.

National Oceanic and Atmospheric Administration (NOAA), *www.noaa.gov/satellites.html*.

World Meteorological organisation (WMO) Space Programme, *www.wmo.int/pages/prog/sat/index_en.php*.

Notes

10.1 et 10.2 :

1. As of June 2014, some instruments are malfunctioning ("Warning" mode).
2. The satellite is about to become operational ("commissioning" mode)

Note: For the US Defense Meteorological Satellite Program (DMSP) satellites, the US Department of Defense (DoD) is responsible for development and operations, while NOAA provides linkage with the civilian meteorological community.

Information on data for Israel: *http://dx.doi.org/10.1787/888932315602*.

10.1. Current geostationary weather satellites

Actors: / Satellites' orbital position:	East Pacific	West Atlantic	East Atlantic	Indian Ocean	West Major Pacific
United States (NOAA)	1 sat. (GOES-15)	2 sats (GOES-13, GOES-14[2])			
Europe (Eumetsat)			3 sats (Meteosat-9, -10 and -11[2])	1 sat. (Meteosat-7)	
India (Indian Space Research Organisation)				4 sats (INSAT-3C, Kalpana-1, INSAT-3D, INSAT-3A)	
Russian Federation (RosHydroMet)				1 sat. (Electro-L N1[1])	
China (China Meteorological Admin.)				2 sats (Feng-Yun-2D, FY-2E)	1 sat. (FY-2F[2])
Korea (Korea Meteo. Administration)					1 sat. (COMS-1)
Japan (Japan Meteorological Agency)					2 sats (Himawari-6 and -7)

Source: Adapted from WMO, *Oscar Database, 2014.*

10.2. Current polar orbiting weather satellites (in sun-synchronous orbit)

	Early Morning Orbit	Morning Orbit	Afternoon Orbit
United States	4 satellites (US Defense Meteo. Satellite Program DMSP-F13[1], DMSP-F16, DMSP-F17, DMSP-F19[2], DoD)	1 sat. (DMSP-F18, DoD)	6 sats (Suomi-NPP (NASA), DMSP-F14[1] and DMSP-F15[1] (DoD), NOAA-15[1], NOAA-18 and NOAA-19 (NOAA))
Europe	-	2 sats (Metop-A and Metop-B, Eumetsat)	-
Russian Federation	-	1 sat. (Meteor-M N1[1], RosHydroMet)	-
China		2 sats (FY-3C and FY-3A[1], CMA)	1 sat.(FY-3B, CMA)

Source: Adapted from WMO, *Oscar Database, 2014.*

Satellites' unique contributions to weather and climate

Since the launch of the first successful weather satellite, TIROS-1, by NASA in 1960, weather satellites are making a major contribution to weather forecasting and climate monitoring. They provide atmospheric measurements: the level of aerosols and greenhouse cases in the atmosphere, monitor the ozone layer, energy capture; atmospheric humidity, temperature (typically by aid of infrared and microwave sounders) and atmospheric winds; as well as measuring cloud cover density, identifying the cloud types and studying cloud particle properties; monitoring of volcanic ash plumes and other particles entering the atmosphere. In addition come other land- and sea-related aspects of climate monitoring, such as land cover (snow/ice, fires) and ocean monitoring (sea level, salinity, currents). Polar-orbiting satellite data feed into Numerical Weather Projection models (NPW), which forecasters use for forecasts 10-12 days in advance. Geostationary satellites provide the images used to identify current weather patterns and carry out shorter-term forecasts. GPS radio occultation is a relatively new technique (first applied in 1995) for performing atmospheric measurements. The technique involves a low-earth orbit satellite receiving a signal from a GPS satellite. The signal has to pass through the atmosphere and gets refracted along the way. The magnitude of the refraction depends on the temperature and water vapour concentration in the atmosphere. Satellite missions have brought on major scientific breakthroughs particularly in climate observation (e.g. satellite detection of long-term damage to the ozone layer leading to the passage of the Montreal Protocol in 1987; and detection and monitoring of the dramatic changes in the extent of Arctic sea-ice coverage). Satellite data are also increasingly used for epidemiology, which combines medical parameters, weather conditions, entomology and general land use information to detect possible tipping points in disease occurrences in many parts of the world (e.g. dengue fever, malaria).

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