

Chapter 2

Sources of Remote Sensing Data for Precision Irrigation

Satellite Data

Satellite observation provides information of a large area with spatial resolution from under a meter up to 50 km and temporal resolution from 5 min up to a few days. Satellites measure radiances over various parts of the spectra of electromagnetic radiation. The data is subsequently processed to derive geophysical parameters for the observed area and delivered in this more informative form as satellite observation products. High resolution products are more suitable for irrigation [1], especially in cases where the land parcels are small. The satellite data of interest for the precision irrigation is mostly data relevant to the water cycle, hydrology and meteorology and provided by missions aimed at gathering such data.

Operational Readily Available Satellite Missions for Precision Irrigation

Currently operational satellites relevant to the problems of precision irrigation and water management include a myriad of missions run by a number of US and European agencies. We provide an overview of these missions as an integral part of the subsequent discussion of different satellite products derived from data acquired by these missions, which are directly used for precision irrigation.

The National Aeronautics and Space Administration (NASA) and United States Geological Survey (USGS) missions within the Landsat satellite series are part of a program that is the longest running enterprise for acquisition of satellite imagery of Earth. The Landsat-7 satellite with the Enhanced Thematic Mapper Plus (ETM+) was launched with the 15 April 1999 and is operational, but has experienced a malfunction that caused the loss of 22 % of the entire scene since 2003. The ETM+ is an eight-band, multispectral scanning radiometer, providing imagery with wide-ranging applications in agriculture.

Another NASA mission, Earth Observing System (EOS), includes two satellites: Terra (EOS AM) and Aqua (EOS PM). Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard these satellites. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1–2 days, acquiring data in 36 spectral bands, or groups of wavelengths. These data is aimed at improving our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

In addition to MODIS, the EOS satellites have a number of other instruments of interest:

- Aqua, launched on May 4, 2002, has different instruments such as the Atmospheric Infra-red Sounder (AIRS), the Advanced Microwave Sounding Unit-A (AMSU-A) and the Cloud and the Earth's Radiant Energy System (CERES).
- Terra, launched on December 18, 1999, sports the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), CERES and the Multi-angle Imaging Spectroradiometer (MISR).

AIRS and AMSU-A are aimed at deriving temperature and humidity in the lower parts of the atmosphere, while CERES is aimed at cloud monitoring, ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. MISR is designed to measure the intensity of solar radiation reflected by the Earth system (planetary surface and atmosphere) in various directions and spectral bands.

In addition to NASA's missions, the US National Oceanic and Atmospheric Administration (NOAA) operates a series of polar-orbiting environmental satellites:

- NOAA-15 to NOAA-17 satellites (the last launched on June 24, 2002) represent a series of NOAA satellites, which carry the Advanced TIROS Operational Vertical Sounder (ATOVS), an instrument that combines High Resolution Infrared Radiation Sounder Version 3 (HIRS/3), AMSU-A and AMSU-B. In addition to ATOVS these satellites carry the Advanced Very High Resolution Radiometer (AVHRR).
- The NOAA-18 and NOAA-19, launched on May 20, 2005 and February 4, 2009 are equipped with new instruments, including the Microwave Humidity Sounder (MHS), developed by EUMETSAT, which replaced AMSU-B as part of the ATOVS on NOAA-18 and the European MetOp satellites. NOAA-19 is part of the Polar Operational Environmental Satellite (POES) system, consisting of two satellites, together with the European organization for the Exploitation of Meteorological Satellites (EUMETSAT) METOP. The system consists of a morning and afternoon satellite, in order to ensure that every part of the Earth is observed at least twice every 12 h.

Currently the ATOVS is generating products from the NOAA-15, 16, 18 and METOP-A satellites. This instrument package provides information on

temperature and humidity profiles, total ozone, clouds and radiation on a global scale. The AVHRR is also a radiation-detection imager that can be used for remotely determining cloud cover and the surface temperature.

The Defense Meteorological Satellite Program (DMSP) collects and disseminates cloud cover and precipitation data acquired using a set of polar orbiting satellites. DMSP-F15, launched on December 12, 1999, carries the Special Sensor Microwave Imager (SSM/I), the Special Sensor Microwave Temperature Sounder (SSM/T-1) and the Special Sensor Microwave Water Vapour Sounder (SSM/T-2). DMSP-F15 is still operational. Subsequent missions (DMSP-F16, DMSP-F17 and DMSP-F18) are equipped with the Special Sensor Microwave Imager/Sounder (SSMIS) which replaces and improves upon the two previously used instruments. The SSMIS is able to estimate atmospheric temperature, moisture, and surface parameters from data collected at frequencies ranging from 19 to 183 GHz. All satellites are operational at the time of writing.

Suomi National Polar-orbiting Partnership, formerly known as the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project assures a bridge between the EOS satellites and the forthcoming series of Joint Polar Satellite System (JPSS) satellites. The JPSS satellites, previously called the NPOESS are developed jointly by NASA for the NOAA. The system currently consists of a single satellite. It is equipped with several instruments relevant to irrigation. The Advanced Technology Microwave Sounder (ATMS) is a passive microwave radiometer with 22 channels dedicated to the measure of temperature and moisture profiles for weather prediction. The Cross-track Infrared Sounder (CrIS), which is a Michelson interferometer, intended for atmospheric temperature and moisture observations. The Visible Infrared Imaging Radiometer Suite (VIIRS) provide imagery of clouds under sunlit conditions in a dozen bands, and also provides coverage in a number of infrared bands for night and day cloud imaging applications. It collects visible and infrared views of Earth's dynamic and surface processes. In addition VIIRS measures atmospheric and oceanic properties, including cloud and sea-surface temperature. The Clouds and the Earth's Radiant Energy System (CERES) is a 3-channels radiometer measuring reflected solar radiation, emitted terrestrial radiation, and total radiation to monitor the Earth's total thermal radiation budget. The first satellite was launched on October 28, 2011.

The satellite missions of European organization for the Exploitation of Meteorological Satellites (EUMETSAT) of interest to the subject of this book are:

- The spin-stabilized Meteosat Second Generation (MSG) that images the full earth every 15 min and consists of a series of four geostationary meteorological satellites, which are designed to operate consecutively. This platform is equipped with the Spinning Enhanced Visible and Infrared Imager (SEVIRI) that provides imagery with a 3 km resolution at nadir and in 12 spectral bands [2]. The instrument provides data about the temperatures of clouds, land and sea surfaces, as well as allowing for the analysis of the characteristics of atmospheric air masses. The last in the series, Meteosat-10 (MSG-3) was successfully launched, on July 5th, 2012.

- The EUMETSAT Polar System (EPS) is the polar orbiting operational meteorological satellite system for the morning orbit, consisting of Meteorological-Operational (METOP) satellites, the first of which was successfully launched on October 19, 2006. The sensors on-board METOP are the Advanced Very High Resolution Radiometer (AVHRR), the Advanced Scatterometer (ASCAT), the Infrared Atmospheric Sounding Interferometer (IASI), the Advanced Microwave Sounding Unit A1 and A2 (AMSU-A), the Microwave Humidity Sounder (MHS) and the Global Navigation Satellite System Receiver for Atmospheric Sounding (GRAS). AVHRR is a visible/infrared imaging radiometer using 6 channels for global measurement of cloud cover, sea surface temperature, ice, snow and vegetation cover and characteristics. ASCAT is a real-aperture radar in C-band using vertically polarized antennas for global sea surface wind vector measurement. The main objective of IASI is to derive temperature and humidity profiles with high vertical resolution and accuracy. HIRS is an atmospheric sounder using 19 infrared channels (3.8–15 μm) and one visible channel to designed to provide temperature and humidity profiles, surface temperature, cloud parameters and total ozone. MHS is a self-calibrating, cross-track scanning, five-channel microwave, full-power radiometer operating in the 89–190 GHz range, designed to provide information on atmospheric water vapor. The GRAS sensor uses the radio-occultation technique to retrieve temperature and humidity profiles.

The European Space Agency (ESA) main earth observation mission—the Environmental Satellite (ENVISAT), ended on May 9, 2012. It is supposed to be replaced by the new Sentinel satellites, to be launched during 2013. At the time of writing the only operational ESA mission of interest is the Soil Moisture Ocean Salinity (SMOS) Earth Explorer mission dedicated in particular to the measurement of soil moisture for hydrology applications. SMOS mission uses the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) sensor and was launched on November 2, 2009.

The French space agency, the Centre National d'Etudes Spatiales (CNES) developed and runs the Satellite Pour l'Observation de la Terre (SPOT) satellite series, which provides a very-high resolution earth observation data, appropriate for irrigation and agriculture applications. The two operational satellites in this mission are SPOT-4 and SPOT-5. SPOT-4 is equipped with the High Resolution Visible and Infra-red (HRVIR) and VEGETATION sensors. SPOT-5, launched on May 4, 2002, is equipped with High Resolution Geometric (HRG), High-Resolution Stereoscopic (HRS) and VEGETATION sensors. HRVIR and HRG are 5-band multispectral imaging sensors. The aim of the VEGETATION instrument is to provide accurate measurements of the main characteristics of the Earth's plant cover. Practically daily global coverage and a resolution of 1 km make this sensor an ideal tool for observing long-term regional and global environmental changes. HRS provides a 3D representation of the area.

Satellite Based Products for Irrigation

In this section, we provide an overview of different products that can be obtained from various readily accessible sources. The products are discussed in terms of geophysical parameters that are available within specific products, since some of them are derived from a multi-sensor approach and differ significantly in the source data obtained from the sensors.

The lowest level data acquired by the sensors is referred to as the level-1 data. The geophysical parameters are derived from the level-1 satellite data and delivered as level-2, level-3 or level-4 satellite products. A level-2 product consists of derived geophysical variables that maintain the same resolution and location as level-1 source data. The level-3 product corresponds to gridded variables in derived spatial and/or temporal resolutions. The level-4 data consists of model output or results of analyses of lower-level data.

While most of the products are distributed directly from the mission management agencies, the EUMETSAT disseminates satellite data and products both directly and through the Satellite Application Facility (SAF) network dedicated to specialized development and processing centres. Some SAFs are relevant for irrigation:

- SAF on Land Surface Analysis (LSA) develops, process and disseminates products based on MSG and MetOp data dedicated in particular to surface radiation budget and surface water balance [3].
- SAF Ocean and Sea Ice Satellite (OSI) process and disseminates products for a comprehensive information on the ocean-atmosphere interface [4].
- SAF on Support to Operational Hydrology and Water Management (H-SAF) develops process and delivers products based on microwave and infrared satellite measurements. H-SAF focuses on precipitation, soil moisture and snow cover products [5].

Surface Radiation Budget Parameters

Radiation data can be used to calculate the solar energy at ground surface, which is crucial for the estimation evapotranspiration. Such data comes in different flavors: surface temperature, Down-welling Surface Longwave Flux (DSLW), Down-welling Surface Shortwave Flux (DSSL), Downward Longwave Irradiance (DLI) and Solar Surface Irradiance (SSI).

Surface Temperature

The LSA SAF Land Surface Temperature (LST) product is estimated from MSG/SEVIRI data. It provides the LST field over Europe every 15 min. The product is

operational and its resolution, determined by the SEVIRI instrument spatial resolution, is 3×3 km.

A surface temperature product is also generated from AVHRR/METOP data and provides LST over Europe every 12-h. The product is pre-operational and at the AVHRR spatial resolution of 1×1 km at nadir. The target accuracy of the product is 2 K and it is generated only in cloud free areas. In addition to temperature information, the delivered data provides quality information and uncertainty.

The surface temperature is also derived from MODIS/Aqua and Terra data. The product is operational at the spatial resolution of 5×5 km and provides 4 observations per day.

An LST product is to be soon derived from VIIRS/NPP data. The spatial resolution will be increased to 750 m, with two measurements per day.

Down-Welling Surface Longwave Flux (DSLW)

The LSA SAF product is estimated from MSG/SEVIRI data and provides land surface radiation budget fields over Europe every 30 min or daily since 2005. The product is operational and at the SEVIRI spatial resolution 3×3 km at the sub-satellite point. A similar product is also generated by using AVHRR/METOP data, and provides DSLW over Europe every 12-h. This product is pre-operational and at the AVHRR spatial resolution of 1×1 km at nadir. Both products have a target accuracy of 5–10 %. They are generated only in cloud-free areas and delivered with quality information and uncertainty.

Down-Welling Surface Shortwave Flux (DSSF)

This LSA SAF product is estimated from MSG/SEVIRI data. It provides land surface radiation budget fields over Europe every 30 min or daily. The product is operational and at the SEVIRI spatial resolution of 3×3 km at sub-satellite point. The target accuracy is 5–10 %. It is generated only in cloud-free areas and delivered with quality information and uncertainty.

Downward Longwave Irradiance (DLI)

The OSI SAF DLI is derived from Meteosat data. The product is delivered for cloud-free areas over sea and lands in a 0.05° regular grid from 60W-60E to 60S-60N. The product is operational and is disseminated hourly and daily.

Solar Surface Irradiance (SSI)

The OSI SAF SSI is derived from Meteosat data. The product is the instantaneous field of SSI calculated over sea and land in a 0.05 degree regular grid from 60W-60E to 60S-60N. The product is operational and is disseminated hourly and daily.

The main products relevant to the surface radiative budget are listed in Table 2.1 in terms of horizontal, temporal resolution, data availability delay, condition of observation (see). Table 2.2 outlines the terms of use, shortcomings and advantages.

Surface Water Balance Parameters

Snow Cover

The snow cover information is important for the snowmelt and runoff calculation.

The snow cover LSA SAF product is estimated from MSG/SEVIRI and ASCAT/METOP data. It provides snow cover information over Europe daily (for the previous 24-h). The product is operational and distributed at the spatial resolution of 3×3 km at the sub-satellite point. The target accuracy is greater than 75 % hit rate in forest areas, greater than 90 % hit rate in other regions and the false alarms rate less than 3 %. The product is generated only in cloud-free areas and delivered with quality information and uncertainty.

The National Snow and Ice Data Center (NSIDC) derives snow-related information from MODIS data. The snow cover product suite is composed of products covering a range of spatial and temporal resolutions, from 500 m to 0.05 degrees, and from swath to daily, 8-day and monthly. The level 3 MODIS Aqua and Terra snow cover is a global product at the spatial resolution of 500 m gridded in a sinusoidal map projection [6, 7]. The level 2 MODIS Aqua and Terra snow cover is a 5 min swath product at the spatial resolution of 500 m [8, 9]. The product is processed daily and contains quality flags. The overall absolute accuracy of the products is about 93 %, varying by land cover and snow conditions.

Table 2.1 Main products for the surface radiative budget

Product	Horizontal resolution	Temporal resolution	Data availability delay	Condition of observation
LST SEVIRI	3 km	15 min	NRT	Cloud-free/land
LST AVHRR/MetOp	1 km	2 per day	NRT	Cloud-free/land
LST MODIS Terra/Aqua	5 km	4 per day	NRT	Cloud-free/land
DSLFI SEVIRI	3 km	30 min	NRT	Cloud-free/land
DSSF SEVIRI	3 km	30 min	NRT	Cloud-free/land
DLI SEVIRI	0.05 deg	1 h	NRT	Cloud-free
SSI SEVIRI	0.05 deg	1 h	NRT	Cloud-free

Table 2.2 Licensing, advantages and shortcomings of main products for the surface radiative budget

Product	Terms of use	Shortcomings	Advantages
LST SEVIRI	License	Horizontal resolution over Europe	Temporal resolution
LST AVHRR/MetOp	License	Temporal resolution pre-operational	Horizontal resolution
LST MODIS Terra/Aqua	Free of charge	Temporal resolution	Horizontal resolution
DSLIF SEVIRI	License	Horizontal resolution over Europe	Temporal resolution
DSSF SEVIRI	License	Horizontal resolution over Europe	Temporal resolution
DLI SEVIRI	License		Temporal resolution
SSI SEVIRI	License		Temporal resolution

Evapotranspiration

The LSA SAF EV product is estimated from MSG/SEVIRI data. It provides the evapotranspiration field over Europe, either every 30 min or daily. The product is in its pre-operational phase and distributed at the SEVIRI spatial resolution of 3×3 km at sub-satellite point. The Evapotranspiration (EV) field quantifies the water vapour flux from the ground surface (soil and canopy). The target accuracy is 25 % if evapotranspiration is greater than 0.4 mm/h and 0.1 mm/h otherwise.

The EV field is calculated based on the reference evapotranspiration, which is the evapotranspiration from the grass reference surface as defined by the Food and Agriculture Organization (FAO). A coefficient is applied for each crop get the final EV data.

The level 4 EV is also derived from MODIS/Aqua and Terra data. The product is operational at the spatial resolution of 1×1 km and provides 2 observations per day in cloud-free areas. The product is disseminated with quality flags and standard deviation data.

Soil Moisture

EUMETSAT calculates the level 2 surface soil moisture index product by using ASCAT data. The product is operational and disseminated in near real time. The soil moisture index represents the degree of saturation of first layers of the soil (<5 cm) and is given in %, ranging from 0 (dry) to 100 (wet). The nominal spatial resolution is 50×50 km or 25×25 km on double swath of 550 km with a gap in between of about 700 km. A global coverage is achieved over Europe in 1.5 days. Root mean square error of 25 km resolution soil moisture index is about $0.03\text{--}0.07 \text{ m}^3$ of water per m^3 of the soil, depending on the soil type.

The H-SAF small-scale surface soil moisture by radar scatterometer is based on the METOP/ASCAT data. The 25 km soil moisture product is disaggregated and

Table 2.3 Main products for the surface water balance

Product	Horizontal resolution	Temporal resolution	Data availability delay	Condition of observation
Snow cover MSG+MetOp	3 km	Daily	NRT	Cloud-free
Snow cover MODIS Terra/Aqua	500 m	2 daily	NRT	Cloud-free
EV SEVIRI	3 km	30 min/daily	NRT	Cloud-free
EV MODIS Terra/Aqua	1 km	2 per day	NRT	Cloud-free
Soil moisture index ASCAT	25 km	Full coverage over Europe in 36 h	NRT	Land
Soil moisture index ASCAT+ASAR	1 km	36 h	NRT	Land

re-sampled at 1 km to satisfy hydrological requirements, using the ENVISAT ASAR data. Therefore, the spatial resolution of the product is at least 25 km and at best 1 km. The temporal resolution is 1.5 days over Europe with several gaps of coverage. The product is pre-operational, but is able to satisfy the majority of applicable requirements and is considered by the relevant steering group suitable for distribution to users, and delivered in near real time via EUMETCast and off-line via the EUMETSAT Data Centre.

The main products available for the surface water balance are listed in Table 2.3, in terms of horizontal, temporal resolution, data availability delay and conditions of observation. Table 2.4 provides the overview of the terms of use, shortcomings and advantages.

Table 2.4 Licensing, advantages and shortcomings of main products for the surface water balance

Product	Terms of use	Shortcomings	Advantages
Snow cover MSG+MetOp	License	Accuracy in forestry area/Horizontal resolution over Europe	
Snow cover MODIS Terra/Aqua	Free of charge		Horizontal resolution
EV SEVIRI	License	Horizontal resolution over Europe pre-operational	Temporal resolution
EV MODIS Terra/Aqua	Free of charge	Temporal resolution	Horizontal resolution
Soil moisture index ASCAT	License	Temporal resolution Spatial resolution	
Soil moisture index ASCAT+ASAR	License	Temporal resolution—pre-operational	Horizontal resolution

Wind-Related Products

EUMETSAT wind-related products are derived from both MSG/SEVIRI data, by tracking the motion of cloud fields and humidity patterns, and METOP ASCAT measurements. With the MSG/SEVIRI data, the height below the tropopause is determined based on infrared temperature measurements and converted into pressure levels, using the European Centre for Medium-Range Weather Forecast (ECMWF) forecasts. The Atmospheric Motion Vectors relevant to precision irrigation applications are described in the remainder of this section.

High Resolution Visible Winds (HRV)

The High Resolution Visible Winds product is calculated using a high resolution segment matrix with a 16×16 pixels segment size (about 48 km at the equator). The product is operational and generated every 1.5 h during daytime.

High Resolution Water Vapour Winds

The High Resolution Water Vapour Winds (HWW) product produces images that are divided into sub-areas of 16×16 pixels, i.e. the same resolution as the HRV product. Only the segments where a cloud has been detected are processed. The HWW is operational and generated every 1.5 h.

Ocean Surface Winds

Winds over ocean are important to quantify the ocean-atmosphere exchanges and may be of use to irrigation professionals.

The SAF OSI ASCAT 25 km wind product uses the METOP/ASCAT level 1b data at the spatial resolution of 25 km with 12.5 km cell spacing. The product gives the wind speed and direction above the ocean surface (10 m). The product is generated in near real-time, it is operational, it is disseminated every 12-h through the EUMETCast system. The product provides the wind speed in m/s from 0 to 50 m/s, but it is known to be less reliable for wind speeds in excess of 25 m/s. The product's accuracy is characterized by a wind component Root Mean Square Error (RMSE) smaller than 2 m/s and a bias of less than 0.5 m/s in wind speed.

The SAF OSI ASCAT costal wind products also use the METOP/ASCAT level 1b data at the spatial resolution of 12.5 km. The cell spacing is the same as the 25 km product but more wind data are available closer to the coast. The product gives the wind speed and direction above the ocean surface (10 m). The product is pre-operational, it is disseminated every 12-h. The product has the same characteristics as ASCAT 25 km winds product.

Table 2.5 Main wind-related products

Product	Horizontal resolution	Temporal resolution	Data availability delay	Condition of observation
HRV	48 km	1.5 h	NRT	Cloudy area daytime
HWW	48 km	1.5 h	NRT	Cloudy area
ASCAT	25 km	12 h	NRT	Ocean
ASCAT Costal	12.5 km	12 h	NRT	Ocean coast

The main wind products are listed in see Table 2.5 in terms of horizontal, temporal resolution, data availability delay, condition of observation. Table 2.6 provides the terms of use, shortcomings and advantages.

Precipitation Products

The EUMETSAT Multi-Sensor Precipitation Estimate (MPE) product is derived from MSG and SSMI/I and SSMIS instruments on DMSP satellites. The product is delivered at MSG full pixel resolution in near real-time; it consists of the rain rate in mm/h. The product is disseminated every 15 min at the GRIB2 format. The product contains two quality indicators (standard deviation and correlation coefficient) calculated on 5×5 degrees of latitude and longitude box. They are based on comparison of rain rate calculated with Meteosat 8/9 IR channels and SSM/I water vapor channels. The quality indicators are used to identify region where precipitations can be used with confidence. This product is more accurate in case of convective precipitation than in frontal or orographic rainfall. This product accuracy is good for tropical and subtropical regions and it can be used with limitations at higher latitudes.

The H-SAF precipitation rate at ground is derived form Geostationary Earth Orbiting InfraRed (IR) (MSG/SEVIRI), supported by Low Earth Orbiting microwave (DMSP/SSMIS, MetOp/MHS/AMSU-A and NOAA/MHS/AMS-A). The product is delivered at the MSG IR pixel size (average over Europe is about 8 km) over the H-SAF area limited to latitude 25–67.5 North and to longitude—25 West 45East. The accuracy is better than 10 mm/h in 80 % of the cases. This product is

Table 2.6 Licensing, advantages and shortcomings of the main wind products

Product	Terms of use	Shortcomings	Advantages
HRV	License	Horizontal resolution and sampling and only daytime	Vertical profile of wind
HWW	License	Horizontal resolution and sampling	Vertical profile of wind
ASCAT	License	Temporal resolution	
ASCAT costal	License	Temporal resolution	Winds in coastal area

not applicable for low rate (more suitable for convective precipitation). The product is pre-operational and delivered in near real-time every 15 via EUMET-Cast and EUMETSAT Data Centre.

Atmospheric Weather Parameters

Temperature, Humidity and Surface Temperature

The EUMETSAT IASI level 2 Atmospheric Water Vapour and Surface Skin Temperature (TWT) product is derived from IASI level1c, AMSU-A and MHS data. The product provides vertical profiles of temperature and humidity on 90 pressure levels, and surface skin temperature. The sampling is about 25 km at nadir. The quality of the vertical profiles is strongly related to the cloud properties available in the IASI CLP product. The accuracy of the product is 1 K for the temperature profile in the troposphere and 10 % for the relative humidity profile. The product is operational and disseminated in near real-time on GTS (The World Meteorological Organisation's Global Telecommunication System) or EUMET-cast with a timeliness of 3 h. Moreover the product is delivered through the EUMETSAT DATA Centre in HDF5 format with a timeliness of 8–9 h. the product is delivered twice per day.

The temperature and humidity profiles are derived from MODIS/Aqua and Terra data. The product provides vertical profiles on 20 pressure levels. The product is operational at the spatial resolution of 5×5 km and it provides 4 observations per day in cloud-free areas.

Surface Pressure

The Surface Pressure (SP) is derived from MODIS/Aqua and Terra data. The product is operational at the spatial resolution of 5×5 km and it provides 4 observations per day. The product is disseminated in HDF format.

The main atmospheric weather products are listed below (see Tables 2.7 and 2.8) in terms of horizontal, vertical, temporal resolution, data availability delay, condition of observation, terms of use, shortcomings and advantages.

Biogeophysical Measurements

These products are used to depict the spatial and temporal change of the vegetation cover. They are useful to initiate and update the land use variable of atmospheric models.

Table 2.7 Main atmospheric weather parameters

Product	Horizontal Resolution	Vertical resolution	Temporal resolution	Data availability delay	Condition of observation
IASI TW	12 km	90 levels	2 per day	NRT	Cloud-free
MODIS TW	5 km	12 levels	4 per day	NRT	Cloud-free
IASI skin temperature	12 km	NA	2 per day	NRT	Cloud-free
MODIS SP	5 km	NA	4 per day	NRT	Cloud-free

Table 2.8 Licensing, advantages and shortcomings of main atmospheric weather parameters

Parameter	Terms of use	Shortcomings	Advantages
IASI TW	License	Horizontal and temporal resolution	Vertical resolution
MODIS TW	Free	Temporal and vertical resolution	Horizontal resolution
IASI skin temperature	License	Horizontal and Temporal resolution	Vertical resolution
MODIS SP	Free	Temporal and vertical resolution	Horizontal resolution

Fraction of Vegetation Cover (FVC)

FVC gives the partition between soil and vegetation. This LSA SAF product is estimated from MSG/SEVIRI data. It provides vegetation cover information over Europe daily or every 10 days. The product is operational and at the SEVIRI spatial resolution 3×3 km at nadir. The product is disseminated with a target accuracy of 0.1 achieved in 75 % of land pixels. The products is generated only in cloud free and snow free areas and delivered with quality information and uncertainty. The quality of the product is bad for the large view zenith angles especially in the north of Europe.

Leaf Area Index (LAI)

The LAI is the surface of leaves per surface of ground, it measures the surface involved in radiation absorption and in vegetation atmosphere exchanges. The LAI is a key parameter for the evapotranspiration estimation. This LSA SAF product is estimated from MSG/SEVIRI data and it is processed over Europe with a characteristic time scale of 5 days and generated daily or every 10 days. The product is operational and with the spatial resolution 3×3 km at nadir. The product is disseminated with a target accuracy of 0.6 achieved in 70 % of land pixels. The products is generated only in cloud free and snow free areas and delivered with quality information and uncertainty. The quality of the product is bad for the large view zenith angles especially in the north of Europe.

The level 4 LAI is derived from MODIS/Aqua and Terra data. The product is operational at the spatial resolution of 1×1 km and it provides 2 observations per day in cloud-free areas. The characteristic time scale of the product is 8 days.

Table 2.9 Main biogeophysical parameters

Product	Horizontal resolution	Temporal resolution	Data availability delay	Condition of observation
LSA FVC	3 km	Daily	NRT	Cloud-free snow-free
LSA LAI	3 km	Daily (5 days)	NRT	Cloud-free snow-free
MODIS LAI	1 km	2 per day (8 days)	NRT	Cloud-free snow-free
LSA FPAR	3 km	Daily (5 days)	NRT	Cloud-free snow-free
MODIS FPAR	1 km	2 per day (8 days)	NRT	Cloud-free snow-free

The product is disseminated with quality flags and standard deviation. The accuracy is 0.5 LAI units RMSE globally.

Fraction of Absorbed Photosynthetic Active Radiation

Fraction of Absorbed Photosynthetic Active Radiation (FAPAR) is the PAR absorbed by the green part of the vegetation of the canopy. It is an essential parameter for the calculation of the photosynthesis and water exchange between the vegetation and the lower part of the boundary layer. This LSA SAF product is estimated from MSG/SEVIRI data and it is processed over Europe with a characteristic time scale of 5 days and generated daily or every 10 days. The product is operational and at the SEVIRI spatial resolution 3×3 km at nadir. The product is disseminated with a target accuracy of 0.1 achieved in 70 % of land pixels. The products is generated only in cloud free and snow free areas and delivered with quality information and uncertainty. The quality of the product is bad for the large view zenith angles especially in the north of Europe.

The level 4 FPAR is derived from MODIS/Aqua and Terra data. The product is operational at the spatial resolution of 1×1 km and it provides 2 observations per day in cloud-free areas. The characteristic time scale of the product is 8 days. The product is disseminated with quality flags and standard deviation. The accuracy is 0.12 FPAR units RMSE globally.

The main biogeophysical parameters are listed below (see Table 2.9) in terms of horizontal, temporal resolution, data availability delay, condition of observation, terms of use, shortcomings and advantages (Table 2.10).

Table 2.10 Licensing, advantages and shortcomings of main biogeophysical parameters

Product	Terms of use	Shortcomings	Advantages
LSA FVC	License	Horizontal resolution	
LSA LAI	License	Horizontal resolution	
MODIS LAI	Free		Horizontal resolution
LSA FPAR	License	Horizontal resolution	
MODIS FPAR	Free		Horizontal resolution

Data Accessibility

All MODIS level 1 and Atmosphere data products are available to the public (at no charge) through the Level 1 and Atmosphere Archive and Distribution System (LAADS).

Selected MODIS level 4 land data are available at Land Processes Distributed Active Archive Center (LP DAAC) Data Pool. Data are downloadable via direct FTP access and at no cost to the user. The operational data are not included in this Data Pool.

The NASA's Earth Observing System Data and Information System (EOSDIS) provides access to near-real time products from the MODIS and AIRS instruments in less than 2.5 h from observation by using the Land and Atmosphere Near-real time Capability for EOS (LANCE). Data are freely available after self-registration.

The MODIS snow cover data are available from the NSIDC Data Poolweb server or by subscription for automated requests.

All data including near real-time METEOSAT, MetOp data and products delivered via EUMETCast, Direct Dissemination and FTP over the internet require a registration on the Earth Observation Portal (EO Portal). The EO Portal allows users to access and manage their subscriptions to data, products and services provided by EUMETSAT. EUMETCast is EUMETSAT's primary dissemination mechanism for the near real-time delivery of satellite data and products generated by the EUMETSAT Application Ground Segment and SAFs.

For the delivery of products, the EUMETSAT Data Policy applies. Data are subject to a set of licensing terms and conditions. The type of licence required will depend upon the *Data Usage* and the set of data you wish to receive. These conditions may involve the payment of fees. Council may waive such fees on a case by case basis for specific applications.

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