Meteorological Data Sources

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https://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi

1.3 Integrated Climate Data Center

The CliSAP-Integrated Climate Data Center (ICDC) allows easy access to climate relevant data from in-situ measurements and satellite remote sensing. These data are important to determine the status and the changes in the climate system. Additionally some relevant re-analysis data are included, which are modeled on the basis of observational data.

1.3.1 Coverage, spatial and temporal resolution

- Period: 07/2006 to 02/2011
- Temporal resolution: Monthly
- Coverage and spatial resolution:
  - Global
  - Spatial resolution: 2° x 2°, cartesian grid
  - Geographic longitude: -180°E to 180°E
  - Geographic latitude: -90°E to 90°E
  - Dimension: 180 columns x 90 rows for total ("total") cloud cover, and coverage of high ("high"), middle ("mid") and low level ("low") clouds; 180 columns x 90 rows x 40 levels for product "profile"
  - Altitude: variable for "total", "high", "mid", and "low"; every 480 m for "profile"
- Format: NetCDF

1.3.2 Solar Irradiance

CM-SAF (see below).

1.3.3 Cloud Cover

This data set is only available for a restricted user group. Contact.

This data set is based on observations of two vertically profiling satellite sensors: a radar (CloudSat) and a lidar (CALIPSO-CALIOP). The CloudSat radar operates at a frequency of 94 GHz (wavelength: about 2 mm). The CALIPSO lidar operates with three channels: two at 532 nm which perpendicular to each other polarization and one at 1064 nm.

1.4 NCDC-NOAA

NOAA's National Climatic Data Center (NCDC) maintains the world's largest climate data archive and provides climatological services and data to every sector of the United States economy and to users worldwide. Records in the archive range from paleoclimatic data to centuries-old journals to data less than an hour old. The Center's mission is to preserve these data and make them available to the public, business, industry, government, and researchers.

1.4.1 Satellite data

The National Oceanic and Atmospheric Administration (NOAA) manages a constellation of geostationary and polar-orbiting meteorological spacecrafts. These satellites are distributed among three operational programs: the Suomi NPOESS Preparatory Project (NPP), the Geostationary Operational Environmental Satellite Program (GOES), and the Polar Operational Environmental Satellite Program (POES). The Defense Meteorological Satellite Program (DMSP) satellites are operated by the U.S. Department of Defense and the data are archived and distributed by NOAA's National Climatic Data Center (NCDC) under the Shared Processing Program.

- The International Satellite Cloud Climatology Project (ISCCP) provides global cloud information at many resolutions (32 to 280km) and time scales (3 hourly to monthly) derived from geostationary and polar orbiting satellite instruments. Global; varying resolution 1983–2009
- Climate Data Record Program Gridded Satellite (GridSat) from ISCCP B1 Infrared (IR) window channel brightness temperatures. Data have been calibrated and remapped to gridded netCDF. 70N-70S; 8km 3 hourly; 1981-2009

1.5 CALIPSO

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite provides new insight into the role that clouds and atmospheric aerosols (airborne particles) play in regulating Earth's weather, climate, and air quality.

CALIPSO combines an active lidar instrument with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols over the globe. CALIPSO was launched on April 28, 2006 with the cloud profiling radar system on the CloudSat satellite.

CALIPSO and CloudSat are highly complementary and together provide new, never-before-seen 3-D perspectives of how clouds and aerosols form, evolve, and affect weather and climate. CALIPSO and CloudSat fly in formation with three other satellites in the A-train constellation to enable an even greater understanding of our climate system from the broad array of sensors on these other spacecraft.

1.5.1 Data products

Extracted from Document No: PC-SCI-503.

Lidar Level 1 data values consist of geolocated profiles of calibrated lidar return signals. Level 1 IIR and WFC data consist of calibrated radiances.

There are three types of Lidar Level 2 products: layer products (cloud and aerosol), profile products (backscatter and extinction) and a vertical feature mask (cloud and aerosol locations and type). IIR Level 2 products are provided based on the IIR Swath (all pixels across swath) and IIR Track (coincident with lidar footprints). The Lidar Level 2 cloud layer products are produced at three horizontal resolutions: 1/3 km, 1 km, and 5 km. The Lidar Level 2 aerosol layer products are produced at a 5 km horizontal resolution. The cloud and aerosol layer data products are written in Hierarchical Data Format (HDF).

Lidar Level 3 products contain monthly-averaged parameters that are mapped onto a uniform spatial grid.

The highest quality data products generated by the DMS are referred to as Standard data products. These products have a 2-4 day latency to incorporate the global meteorological and other reference products.

The CALIPSO project has also developed several special products such as an Expedited Level 1.5 near-real time product released to operational forecast centers and a Lidar Level 3 Aerosol data product. The Expedited Level 1.5 data set is a merged product using the Lidar Level 1 data, Level 2

Aerosol profiles and Level 2 Vertical Feature Mask information. It provides continuous, calibrated and geo-located profiles of cloud-cleared data. The Lidar Level 3 Aerosol data product is a monthly-averaged data set derived using Lidar Level 2 products and maps aerosol parameters onto a uniform space and time grid and employs various filtering options.

Data can be freely ordered from NASA ASDC.

1.5.2 CloudSat

CloudSat is a satellite mission designed to measure the vertical structure of clouds from space. The radar data produces detailed images of cloud structures which will contribute to a better understanding of clouds and climate. Please peruse this website to find out more about the CloudSat mission and the Data Processing Center.

1.5.3 Products:

CloudSat data products are made available in HDF-EOS format and are created with HDF-EOS 2.5 based on HDF 4.1r2. Data is available after registration from the CloudSat Data Processing Center.

- 1B-CPR-FL: Radar Backscatter Profiles (First-Look)
- 1B-CPR: Radar Backscatter Profiles
- 2B-GEOPROF: Cloud Geometrical Profile
- 2B-CLDCLASS: Cloud Classification
- 2B-CWC-RO: Cloud Water Content (Radar-only) (includes liquid and ice)
- 2B-TAU: Cloud Optical Depth
- 2B-CWC-RVOD: Cloud Water Content (Radar-Visible Optical Depth) (includes liquid and ice)
- 2B-FLXHR: Fluxes and Heating Rates
- 2B-GEOPROF-LIDAR: Radar-Lidar Cloud Geometrical Profile
- 2B-CLDCLASS-LIDAR: Radar-Lidar Cloud Classification

1.6 EUMETSAT

EUMETSAT operates a fleet of meteorological satellites, and their related ground systems, to deliver reliable and cost-efficient data, images and products. These, in turn, service requirements for weather and climate monitoring — primarily of national meteorological services in the Member- and Cooperating States.

There are several data products available:

1.6.1 Atmosphere

- Atmospheric Motion Vectors

Atmospheric Motion Vectors at all heights below the tropopause, derived from 5 channels (Visual 0.8, Water Vapour 6.2, Water Vapour 7.3, Infrared 10.8 and the High Resolution Visual channel), all combined into one product. Vectors are derived by tracking the motion of clouds and other atmospheric constituents as water vapour patterns. The initial resolution is a 24 pixels grid (HRV 12 high res. pixels), but as the algorithm tries to adjust the position to the point of the maximum contrast (typically cloud edges), the end resolution varies. The height assignment of the AMVs is calculated using the Cross-Correlation Contribution (CCC) function to determine the pixels that contribute the most to the vectors. An AMV product contains between 30 000 and 50 000 vectors depending of the time of the day, and uses SEVERI image data from Meteosat-8 and onwards (24 per day).

- Clear Sky Radiances

The Clear-Sky Radiances (CSR) product is a subset of the information derived during the Scenes Analysis processing. The product provides the radiances for a subset of the MSG channels averaged over all pixels within a processing segment which have been identified as clear, except for channel WV6.2 where the CSR is also derived for areas containing low-level clouds. The final CSR product is BUFR encoded at every third quarter of the hour (e.g 00:45, 01:45 ...) and distributed to the users via EUMETCAST and GTS. It is also stored in the EUMETSAT Data Centre. Applications and Users: Numerical weather prediction

- Cloud Analysis

Identification of cloud layers with cloud type and coverage, height and temperature. Applications and Users: Weather forecasting, numerical weather prediction, climate research and monitoring. (24 per day)

- Optimal Cloud Analysis

The basic premise of the scheme is that best quality products are derived when all the information in the measurements is used, properly accounting for errors in the measurements and supporting data, and making use of physical radiative transfer calculations. In the current configuration, the 0.6, 0.8, 1.6, 10.8 and 12 µm channels are employed to estimate cloud optical depth, phase and cloud particle size and pressure on a pixel-by-pixel basis. This will soon be extended to include the 3.9, 8.7 and 13 µm channels and pixel fractional cloud cover. Coded as a prototype system by RAL in 2001, the 'Optimal Cloud Analysis' scheme is now under development at EUMETSAT with the aim to provide potential 'Day-2' products from the MSG SEVIRI instrument.

- IASI

The main objective of the Infrared Atmospheric Sounding Interferometer (IASI) is to provide high resolution atmospheric emission spectra to derive temperature and humidity profiles with high spectral and vertical resolution and accuracy. Additionally it is used for the determination of trace gases, as well as land and sea surface temperature, emissivity and cloud properties. The Cloud Parameters (CLP) product contains fractional cloud cover, cloud top pressure and temperature and cloud phase, retrieved from the IASI sounder measurements. The spatial sampling is ca. 25 km at nadir.

- Cloud Motion Winds

This product is a high-quality subset of the ELW product. The winds are derived for all three spectral channels (VIS in half resolution) as for the ELW Product. However, the CMW product only includes the best wind for each segment determined from the QI value. There are other limitations, specified in the dissemination limit table. A typical product will contain up to 750 winds per channel. The product is distributed for the synoptic hours of 00, 06, 12 and 18 UTC in SATOB code. (16 per day)

1.6.2 Land

- Land Surface Temperature

Land Surface Temperature (LST) is the radiative skin temperature over land. LST plays an important role in the physics of land surface as it is involved in the processes of energy and water exchange with the atmosphere.

LST is useful for the scientific community, namely for those dealing with meteorological and climate models. Accurate values of LST are also of special interest in a wide range of areas related to land surface processes, including meteorology, hydrology, agrometeorology, climatology and environmental studies.

- ASCAT Winds and Soil Moisture at 12.5 km Swath Grid

This ASCAT Multi-parameter product contains surface wind vectors over ocean and soil moisture index over land. Additionally, the backscatter values involved in the retrieval of the geophysical parameters above are also included, as well as several quality flags to facilitate the use of the data. For NWP users this product is provided in BUFR format. The netCDF version of this product contains Winds ONLY.

- Advanced Very High Resolution Radiometer

The Advanced Very High Resolution Radiometer (AVHRR) operates at 5 different channels simultaneously in the visible and infrared bands, with wavelengths specified in the instrument channels description. Channel 3 switches between 3a and 3b for daytime and nighttime. As a high-resolution imager (about 1.1 km near nadir) its main purpose is to provide cloud and surface information such as cloud coverage, cloud top temperature, surface temperature over land and sea, and vegetation or snow/ice. In addition, AVHRR products serve as input for the level 2 processing of IASI and ATOVS. (15 per day, ~1Gb)

1.7 CM SAF

1.7.1 Description

The Satellite Application Facility on Climate Monitoring (CM SAF) is a joint venture of the Royal Netherlands Meteorological Institute, the Swedish Meteorological and Hydrological Institute, the Royal Meteorological Institute of Belgium, the Finnish Meteorological Institute, the Deutscher Wetterdienst, Meteoswiss, the UK MetOffice, with the collaboration of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The CM SAF was funded in 1992 to retrieve, archive, and distribute climate data to be used for climate monitoring and climate analysis. The spatial resolution of the different products ranges from 15 to 90 km^2.

1.7.2 Products

The CM SAF provides two categories of data: operational products and climate data. The operational products are built on data that is validated with on-ground stations and then is provided in near real time to develop variability studies in diurnal and seasonal time scales. However, climate data are long-term data series to assess inter-annual variability.

The Operational Products are divided in four classes:

- Clouds
  - Fractional cloud cover
  - Cloud optical depth
  - Cloud phase
  - Cloud top height
  - Cloud top pressure
  - Cloud top temperature
  - Cloud type
  - Cloud water path
- Surface radiation
  - Surface albedo
  - Surface downward longwave radiation
  - Surface incoming direct radiation
  - Surface incoming shortwave radiation
  - Surface net longwave radiation
  - Surface net shortwave radiation
  - Surface outgoing longwave radiation
  - Surface radiation budget
- Radiation fluxes at the top of the atmosphere
  - Emitted thermal radiative flux at top of atmosphere
  - Incoming solar radiative flux at top of atmosphere
  - Reflected solar radiative flux at top of atmosphere
- Water vapour and temperature products

- Water vapour, temperature and rel. humidity at 5 layers
- Temperature and specific humidity at 6 pressure levels
- Vertically integrated water vapour

These products are available at daily and monthly temporal resolutions. Some of the equivalent climate data sets are available with hourly temporal resolutions.

The data provision is free of charge from the Web User Interface.

1.8 LSA SAF

Land Surface Analysis Satellite Applications Facility

The main purpose of the Land SAF is to increase the benefits from MSG and EPS data related to land, land-atmosphere interactions and biophysical applications, namely by developing techniques, products and algorithms that will allow a more effective use of data from the two planned EUMETSAT satellites. Although directly designed to improve the observation of meteorological systems, the spectral characteristics, time resolution and global coverage offered by MSG and EPS allow for their use in a broad spectrum of other applications, namely within the scope of land biophysical applications.

Activities to be performed within the framework of the Land SAF shall involve the development of products that are especially relevant in the following fields of application:

- Weather forecasting and climate modelling, which require detailed information on the nature and properties of land. Highest Land SAF priority should be towards the meteorological community and, within that community, NWP has been already identified as the one that has the greatest potential of fully exploit the products;
- Environmental management and land use, which require information on land cover type and land cover changes (e.g. provided by biophysical parameters or thermal characteristics);
- Natural hazards management, which requires frequent observations of terrestrial surfaces in both the solar and thermal bands;
- Climatological applications and climate change detection.

1.9 MODIS

1.9.1 Description

The Moderate-resolution Imaging Spectroradiometer (MODIS) is a payload scientific instrument launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km). Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. Three on-board calibrators (a solar diffuser combined with a solar diffuser stability monitor, a spectral radiometric calibration assembly, and a black body) provide in-flight calibration.

1.9.2 Products

There are six Level-2 (Orbital Swath) MODIS Atmosphere products collected from two platforms: the Terra platform and the Aqua platform. Each product is assigned an 8-character Earth Science Data Type (ESDT) name, given below, which is used in cataloging and archiving the datasets. The Level-2 MODIS Atmosphere products are:

- The Aerosol Product monitors aerosol type, aerosol optical thickness, particle size distribution, aerosol mass concentration, optical properites, and radiative forcing. The ESDT names are MOD04_{L2} (Terra) and MYD04_{L2} (Aqua).

- The Water Vapor Product monitors atmospheric water vapor and precipitable water. The ESDT names are MOD05_{L2} (Terra) and MYD05_{L2} (Aqua).

- The Cloud Product monitors the physical and radiative properties of clouds including cloud particle phase (ice vs. water, clouds vs. snow), effective cloud particle radius, cloud optical thickness, cloud shadow effects, cloud top temperature, cloud top height, effective emissivity, cloud phase (ice vs. water, opaque vs. non-opaque), and cloud fraction under both daytime and nighttime conditions. The ESDT names are MOD06_{L2} (Terra) and MYD06_{L2} (Aqua).

- The Atmosphere Profile Product monitors profiles of atmospheric temperature and moisture, atmospheric stability, and total ozone burden. The ESDT names are $MOD07_{L2}$ (Terra) and $MYD07_{L2}$ (Aqua).
- The Cloud Mask Product indicates whether a given instrument field of view (FOV) of the Earth's surface is unobstructed by clouds or affected by cloud shadows. The cloud mask also provides additional information about the FOV including the presence of: cirrus clouds, ice/snow, and sunglint contamination. Finally flags denoting day/night and land/water are included. The ESDT names are $MOD35_{L2}$ (Terra) and $MYD35_{L2}$ (Aqua).
- The post-launch Joint Atmosphere Product contains a spectrum of key parameters gleaned from the complete set of standard at-launch Level 2 products: Aerosol, Water Vapor, Cloud, Profile, and Cloud Mask. The Joint Atmosphere product was designed to be small enough to minimize data transfer and storage requirements, yet robust enough to be useful to a significant number of MODIS data users. Scientific data sets (SDS's) contained within the Joint Atmosphere product cover a full set of high-interest parameters produced by the MODIS Atmosphere group, and are stored at 5-km and 10-km (at nadir) spatial resolutions. The ESDT names are MODATML2 (Terra) and MYDATML2 (Aqua).

MODIS Data is distributed free of charge through the Level 1 and Atmosphere Archive and Distribution System (LAADS). MODIS Data is stored in Heirarchical Data Format (HDF).

1.10 PVGIS

PVGIS (Photovoltaic Geographical Information System) is a research, demonstration and policy-support instrument for geographical assessment of the solar energy resource in the context of integrated management of distributed energy generation.

- Computation of clear-sky global irradiation on a horizontal surface
- Sky obstruction by local terrain features (hills or mountains) calculated from the digital elevation model.
- Interpolation of the clear-sky index and computation of global irradiation on a horizontal surface.

Results available at `http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php`

1.11 OpenWeatherMap

The OpenWeatherMap service provides open current weather and forecast that is available on our web-site for everybody and by API for developers. Ideology of our service is inspired by OpenStreetMap and Wikipedia that make information free and available for everybody. OpenWeatherMap provides wide range of weather data including current weather,forecast, precipitations, wind, clouds, data from weather stations, lots of maps, analytics and many others. We have own model of weather calculation that involves global meteorological broadcast data, own WRF calculation for regions and real-time data from more than 40,000 weather stations.

1.11.1 API

You need an API key.

- Current Weather data: `http://openweathermap.org/current`
- Historical data: `http://openweathermap.org/history`
- Weather stations: `http://openweathermap.org/api_station`

1.11.2 Pricing

`http://openweathermap.org/price`

1.12 INPE (Brasil)

1.13 ADRASE - CIEMAT

Radiación solar media mensual, resolución aproximada de 5x5 km.

- Media mensual y anual más probable durante un periodo de largo plazo (imágenes de satélite, modelo aproximadamente Heliosat)
- Variabilidad esperada de los valores diarios mensuales: (series largas de datos de estaciones de AEMET y extrapolación espacial con IDW)

Disponible en `http://adrase.es`

2 Weather Forecast

2.1 NCDC-NOAA

Data is available through the NOAA National Operational Model Archive & Distribution System (NOMADS). There is a Thredds server.

2.1.1 Global Data Assimilation System

The Global Data Assimilation System (GDAS) is the system used by the Global Forecast System (GFS) model to place observations into a gridded model space for the purpose of starting, or initializing, weather forecasts with observed data. GDAS adds the following types of observations to a gridded, 3-D, model space: surface observations, balloon data, wind profiler data, aircraft reports, buoy observations, radar observations, and satellite observations. GDAS data are available through NOMADS as both input observations to GDAS and gridded output fields from GDAS. Gridded GDAS output data can be used to start the GFS model. Due to the diverse nature of the assimilated data types, input data are available in a variety of data formats, primarily Binary Universal Form for the Representation of meteorological data (BUFR) and Institute of Electrical and Electronics Engineers (IEEE) binary.

2.1.2 Global Forecast System (GFS)

The Global Forecast System (GFS) is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 18 miles (28 kilometers) between grid points, which is used by the operational forecasters who predict weather out to 16 days in the future. Horizontal resolution drops to 44 miles (70 kilometers) between grid point for forecasts between one week and two weeks. The GFS model is a coupled model, composed of four separate models (an atmosphere model, an ocean model, a land/soil model, and a sea ice model), which work together to provide an accurate picture of weather conditions.

2.1.3 Global Ensemble Forecast System (GEFS)

The Global Ensemble Forecast System (GEFS) is a weather forecast model made up of 21 separate forecasts, or ensemble members. The National Centers for Environmental Prediction (NCEP) started the GEFS to address the nature of uncertainty in weather observations, which are used to initialize weather forecast models. The proverbial butterfly flapping her wings can have a cascading effect leading to wind gusts thousands of miles away. This extreme example illustrates that tiny, unnoticeable differences between reality and what is actually measured can, over time, lead to noticeable differences between what a weather model forecast predicts and reality itself. The GEFS attempts to quantify the amount of uncertainty in a forecast by generating an ensemble of multiple forecasts, each minutely different, or perturbed, from the original observations. With global coverage, GEFS is produced four times a day with weather forecasts going out to 16 days. Gridded data are available through NOMADS. NOMADS also contributes GEFS ensemble data to the THORPEX Interactive Grand Global Ensemble (TIGGE) by calculating a dozen WMO-required variables and passing to the National Center for Atmospheric Research (NCAR) for permanent archive.

NOMADS also provides an additional tool, the NOMADS Ensemble Probability Tool, which allows a user to query the multiple forecast ensemble to determine the probability that a set of conditions will occur at a given location using all of the GEFS ensemble members in near real-time.

Many other forecast products are available at the GEFS homepage.

2.1.4 North American Model (NAM)

NAM is a regional weather forecast model covering North America down to a horizontal resolution of 12km. Dozens of weather parameters are available from the NAM grids, from temperature and precipitation to lightning and turbulent kinetic energy.

2.1.5 Rapid Refresh (RAP)

RAP is a regional weather forecast model of North America, with separate subgrids (with different horizontal resolutions) within the overall North America domain. RAP forecasts are generated every hour with forecast lengths going out 18 hours.

2.1.6 Rapid Update Cycle (RUC)

RUC is a regional weather forecast model of the Continental United States (CONUS) with forecast lengths going out 12 hours. RUC data are no longer produced operationally by the National Centers for Environmental Prediction (NCEP).

2.2 WRF

2.2.1 Description

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers.

The effort to develop WRF has been a collaborative partnership, principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides operational forecasting a model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community.

2.2.2 Institutions

This system is used by several institutions:

- NCAR ARW: 20 km CONUS: 72 h fcst from 00 Z initialization, and 48 h fcst from 12 Z initialization from 40 km Eta, mass coordinate. 36/12 km CONUS/Central US two-way nested run: 48 h fcst from 00 Z initialization, initialization from 40 km Eta grib data, mass coordinates
- NCEP/EMC: WRF-NMM at 12 km horizontal resolution out to 84 hours, 4 times a day; HiRes Window runs from WRF-NMM (5.2 km) and WRF-ARW (5.8 km).

- NOAA/GSD: 15 hr North American WRF runs, 13 km, hourly initialization, Gridpoint Statistical Interpolation (GSI) data assimilation; 15 hr CONUS WRF runs, 3 km, hourly initialization from RUC native-level coordinate.
- NOAA/NSSL: WRF-ARW, 4km, sub-CONUS, 36 h forecast
- National Observatory of Athens: 24km: 72h forecast from 00 Z and 12 Z initialization (European region)
- AFWA: Real time WRF forecast over North America (password required): 48 h, 00 Z
- University of Illinois: Real time WRF forecast: 25 km (midwest region), 36 h, 00 Z initialization, mass coordinate
- Millersville Univ, PA: 25 km Eastern US (east of Rockies): 36 h, mass coordinate
- University of Utah, UT: 12.5 km Western US (west of Rockies): 48 h, mass coordinate

2.2.3 Meteogalicia

- Results from a WRF model freely available at the Thredds server
- Model WRF runs twice a day initialized at 00UTC (96 hours) and 12UTC (84 hours).
- Three nested domains configured for 36km, 12km and 4km resolution.
- Spatial data:
  - 2D: WRF_{2D}/catalog.html
  - 3D: $\text{WRF/catalog}_{\text{grib}}$.html
- Time series:

var=swflx&point=true&latitude=42.13393&longitude=-1.652131

2.2.4 BSC

El Barcelona Supercomputing Center usa este modelo para realizar short-term forecasting of solar irradiance. Se ha realizado una tesis doctoral con el título "Sistema de pronóstico de radiación solar a corto plazo a partir de un modelo meteorológico y técnicas de post-proceso para España".

2.2.5 UPM

El Grupo de Modelos y Software para el Medio Ambiente de la Facultad de Informática de la UPM publica resultados gráficos de la versión 3.6 de este modelo.

2.3 MM5

The PSU/NCAR mesoscale model is a limited-area, nonhydrostatic or hydrostatic (Version 2 only), terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulation. It has been developed at Penn State and NCAR as a community mesoscale model and is continuously being improved by contributions from users at several universities and government laboratories.

The last major MM5 release (3.7) was December 2004, with the last bug fix release in October 2006. Email support has been discontinued, and online documentation and tutorials have been frozen.[1]

The Weather Research and Forecasting model (WRF) was designed as the successor to MM5 and includes all capabilities available within the MM5

2.3.1 Description

The Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) is the latest in a series that developed from a mesoscale model used by Anthes at Penn State in the early 70's that was later documented by Anthes and Warner (1978). Since that time, it has undergone many changes designed to broaden its usage. These include (i) a multiple-nest capability, (ii) nonhydrostatic dynamics, which allows the model to be used at a few-kilometer scale, (iii) multitasking capability on shared- and distributed-memory machines, (iv) a four-dimensional data-assimilation capability, and (v) more physics options.

The model (known as MM5) is supported by several auxiliary programs, which are referred to collectively as the MM5 modeling system.

Terrestrial and isobaric meteorological data are horizontally interpolated (programs TERRAIN and REGRID) from a latitude-longitude mesh to a variable high-resolution domain on either a Mercator, Lambert conformal, or polar stereographic projection. Since the interpolation does not provide mesoscale detail, the interpolated data may be enhanced (program RAWINS or little$_{\mathrm{r}}$) with observations from the standard network of surface and rawinsonde stations using either a successive-scan Cressman technique or mul-

[1] DEFINITION NOT FOUND.

tiquadric scheme. Program INTERPF performs the vertical interpolation from pressure levels to the sigma coordinate system of MM5. Sigma surfaces near the ground closely follow the terrain, and the higher-level sigma surfaces tend to approximate isobaric surfaces. Since the vertical and horizontal resolution and domain size are variable, the modeling package programs employ parameterized dimensions requiring a variable amount of core memory. Some peripheral storage devices are also used.

Since MM5 is a regional model, it requires an initial condition as well as lateral boundary condition to run. To produce lateral boundary condition for a model run, one needs gridded data to cover the entire time period that the model is integrated.

2.4 ECMWF

The European Centre for Medium-Range Weather Forecasts (ECMWF, the Centre) is an intergovernmental organisation supported by 34 States, based in Reading, west of London, in the United Kingdom.

ECMWF produces a suite of operational forecasts for various lead times:

- Medium-range forecast: comprises the high-resolution and the ensemble forecasts of weather, at the space and time-scales represented by the relevant model, up to 10 and 15 days ahead, respectively, and the associated uncertainty.
- Extended-range (monthly) forecast: comprises ensembles of individual forecasts and post-processed products of average conditions (e.g. weekly averages) up to 1 month ahead, and the associated uncertainty.
- Long-range forecast: comprises ensembles of individual forecasts and post-processed products of average conditions (e.g. monthly averages) up to 13 months ahead, and the associated uncertainty.

In addition re-forecasts are calculated operationally using the current system configuration but applied to the weather over past decades.

Depending on the products `different tariffs` may apply. Specific data sets are available free of charge from the data server, subject to terms and conditions.

2.5 AEMET

Dentro de las actividades de I+D+i de AEMET se encuadran los modelos numéricos HIRLAM y HARMONIE, la predicción probabilítica y la predic-

ción inmediata. AEMET ofrece los resultados dentro de su cartera de servicios según una lista de tarifas. Según se recoge en esta lista "el suministro de prestaciones a los organismos de investigación, oficialmente reconocidos como tales, en la realización de proyectos de investigación no lucrativos debe ser realizada, por quien esté debidamente autorizado, en el modelo establecido por el Instituto Nacional de Meteorología para este fin."

2.5.1 Hirlam

Hirlam es un modelo hidrostático de puntos de rejilla con una dinámica semilagrangiana, en el que son parametrizados los procesos radiativos y los que suceden a escala sub-rejilla (turbulencia, nubes y condensación, convección, intercambios de agua y energía con la superficie...).

El estado inicial atmosférico, o análisis, se obtiene corrigiendo una primera estimación (basada en una predicción a corto plazo reciente), mediante la asimilación de observaciones convencionales (procedentes de estaciones de superficie en tierra, barcos y boyas, radiosondeos y aviones), así como los datos brutos medidos por los instrumentos a bordo de los satélites meteorológicos, mediante un método variacional tri o tetradimensional (3DVAR o 4DVAR). Los campos iniciales de superficie y suelo (temperatura del agua del mar, espesor y cobertura de nieve, humedad y temperaturas del suelo y subsuelo...) se describen gracias a un sistema de análisis objetivo que utiliza diferentes tipos de observaciones.

La cadena HIRLAM se ejecuta 4 veces al día en AEMET en 3 dominios distintos: un área euroatlántica con 16km de resolución horizontal y dos centradas en la Península Ibérica y Canarias de 5km de resolución. El número de niveles en la vertical es de 40. Los campos previstos del modelo global del Centro Europeo de Predicción a Plazo Medio (CEPPM) se reciben 4 veces al día y se utilizan como forzamientos en los contornos del dominio de integración y para mejorar la descripción de la componente de larga escala del análisis. Las observaciones utilizadas para determinar el estado inicial atmosférico se reciben regularmente gracias al sistema mundial de telecomunicaciones establecido por la Organización Meteorológica Mundial.

En HIRLAM-AEMET 0.16° según el nivel seleccionado se puede acceder a los siguientes parámetros:

- Superficie: presión, precipitación, viento, nubosidad y temperatura
- 850 hPa y 500 hPa: temperatura y geopotencial
- 300 hPa: viento y geopotencial

En HIRLAM-AEMET 0.05° se puede seleccionar por C. Autónomas los parámetros de superficie: temperatura, viento y precipitación.

En la pestaña CEPPM se puede seleccionar entre los parámetros de presión en superficie y geopotencial de 500 hPa para tres zonas del planeta: Atlántico Norte, Hemisferio Norte y Hemisferio Sur.

Alcances: los tres primeros días, a intervalos de 6 horas, para HIRLAM-AEMET 0.16°, y los tres días siguientes, a intervalos de 24 horas, del modelo CEPPM. Para HIRLAM-AEMET 0.05° día y medio, a intervalos de 3 horas.

2.5.2 Harmonie

Cuando se avanza hacia resoluciones de unos pocos kilómetros, los efectos no hidrostáticos deben estar representados en los modelos meteorológicos y algunos fenómenos que en resoluciones inferiores deben ser parametrizados comienzan a ser descritos explícitamente. En el año 2006, los Consorcios europeos de PNT HIRLAM y ALADIN acordaron comenzar una cooperación para el desarrollo de sistemas de muy alta resolución basados en modelos no hidrostáticos.

El sistema HARMONIE, que se está desarrollando en HIRLAM, es el resultado de esta colaboración y ha sido diseñado de forma flexible, pudiendo ser utilizado en diferentes escalas espaciales: desde la sinóptica hasta resoluciones inferiores a 1km. Además del modelo de predicción, consta de un sistema de asimilación de datos para la inicialización del estado atmosférico y de un módulo de análisis de superficie. Tiene implementados diferentes conjuntos de parametrizaciones físicas que resultan apropiados para cada escala espacial. El núcleo de la dinámica no hidrostática aprovecha los desarrollos obtenidos por el grupo ALADIN. Las librerías de código se comparten entre el CEPPM, los Consorcios HIRLAM y ALADIN y el Servicio Meteorológico francés.

El modelo HARMONIE en modo no hidrostático incluye 6 variables de pronóstico para los procesos húmedos: vapor de agua, agua líquida, cristales de hielo, lluvia, nieve y nieve granulada o granizo. Esta versión del modelo se ejecuta diariamente en modo experimental en AEMET sobre un área que cubre la península Ibérica y Baleares a 2,5km de resolución horizontal y 65 niveles en la vertical.

2.5.3 SAF de Nowcasting

El SAF de Nowcasting (NWC SAF), pertenece a la Red de Centros de Aplicaciones Satelitales (Satellite Application Facilities, SAF) que la organización

europea para la explotación de los satélites meteorológicos, EUMETSAT, tiene distribuidos por Europa, como parte del segmento terrestre. Su objetivo es proporcionar servicios operativos que optimicen el uso de datos de satélite para la predicción inmediata y a muy corto plazo.

El NWC SAF está desarrollado por un Consorcio integrado los Servicos Meteorológicos Nacionales de Francia, Suecia, Austria y España, siendo liderado por AEMET. El proyecto fue firmado en diciembre de 1996 entre EUMETSAT y el entonces Instituto Nacional de Meteorología, comenzando la fase de desarrollo en febrero de 1997. Para conseguir su objetivo, el SAF de Nowcasting es el responsable del desarrollo y mantenimiento de aplicaciones software, así como de dar apoyo a los usuarios en el uso tanto del software como de los productos finales. El NWC SAF está considerado Centro de Excelencia para el Nowcasting en EUMETSAT.

Los productos desarrollados son aplicables a los satélites meteorológicos geostacionarios MSG (Meteosat Second Generation) y de órbita polar PPS (Tiros-NOAA y EPS-Metop). AEMET es responsable de los productos MSG en aire claro, el de estimación de precipitación convectiva y el de vientos en alta resolución.

Para plazos inferiores a 6 horas (1-3-6 horas), junto a los modelos deterministas (CEPPM, HIRLAM y HARMONIE), la incorporación del resto de herramientas (productos del NWC SAF, aplicaciones operativas de nowcasting, observaciones de satélite, radar y estaciones meteorológicas automáticas...), ha permitido ensayar predicciones experimentales cuantitativas de las áreas (alrededor de un punto) donde se esperaba precipitación intensa con probabilidad del 60-80%, así como la cantidad de precipitación esperada, hora de inicio de la precipitación/convección (+/- 30 minutos) y predicción del desplazamiento de los sistemas nubosos responsables de la lluvia fuerte o convección severa.

1. Products
    - Cloud products
    - Precipitating clouds
    - Cconvective rainfall rate
    - High resolution
    - Air mass analysis

    ...
2. Nowcasting SAF User Policy

All current National Meteorological Services within the EUMETSAT Member States and Co-operating States and those who in a future shall become EUMETSAT Member States or Co-operating States, will be automatically considered potential users.

Any other Organisation may apply to become a user through the Leading Entity (emailing to NWC SAF Manager mafernandeza@aemet.es and asanchezp@aemet.es). Decision will be taken by the Nowcasting SAF according to the EUMETSAT Data Policy affecting the Nowcasting SAF and will be communicated to the intended user accordingly.

2.5.4 Sistemas de Predicción por Conjuntos para la predicción probabilística

Para generar predicciones a medio plazo, entre 3 y 5 días, AEMET postprocesa y utiliza las salidas del Sistema global de Predicción por Conjuntos (Ensemble Prediction System, EPS), del Centro Europeo de Predicción a Plazo Medio (CEPPM), basado en perturbaciones del estado inicial atmosférico y de las contribuciones de las parametrizaciones físicas del modelo. Para la predicción probabilística en el corto plazo, hasta 48 horas, AEMET es pionera en el desarrollo y ejecución experimental a escala diaria de un Sistema de Predicción por Conjuntos, SREPS, de mayor resolución (25km) y con 25 miembros, basado en la integración de 5 modelos numéricos en área limitada diferentes forzados con las predicciones de 5 modelos globales distintos. Con ello se pretende muestrear las incertidumbres procedentes de los errores de los modelos, las condiciones iniciales y las condiciones de contorno.

2.5.5 Desarrollo de técnicas avanzadas de verificación

La verificación de las predicciones de los modelos meteorológicos frente a observaciones forma parte de las cadenas operativas de predicción numérica del tiempo ejecutadas en AEMET, tanto deterministas como las basadas en predicción por conjuntos. Con SREPS, AEMET diseñó, desarrolló y puso en funcionamiento un sistema completo de postproceso de las salidas de sus miembros, así como de verificación de las predicciones probabilísticas generadas, que ha sido posteriormente implementado en el sistema GLAMEPS de HIRLAM.

2.5.6 Métodos de adaptación estadística a las salidas de los modelos numéricos

A pesar del aumento significativo de su resolución y complejidad, los modelos numéricos meteorológicos son representaciones simplificadas de los procesos atmosféricos. Cuando se requieren predicciones cuantitativas de variables tales como lluvia, temperaturas extremas, etc. a nivel muy local, todavía se hace necesario aplicar a sus salidas métodos de adaptación estadística. AEMET viene trabajando en el desarrollo y puesta en funcionamiento de diferentes métodos de adaptación estadística de las salidas directas de los modelos desde hace más de dos décadas.

2.5.7 Herramientas para la identificación objetiva de estructuras convectivas

Una gran cantidad de los casos de lluvias intensas y vientos fuertes que ocurren muy frecuentemente en España son producidos por fenómenos convectivos, que en ocasiones llevan también asociados granizo de gran tamaño e incluso tornados. A lo largo de la última década, AEMET ha venido desarrollando nuevas aplicaciones para analizar y caracterizar de forma objetiva en 2 y 3 dimensiones las estructuras convectivas. El procedimiento desarrollado integra diferentes fuentes de datos: radar, rayos, satélite y salidas de modelos numéricos. También incluye un módulo específico para estimar la probabilidad de granizo, así como la extrapolación de las esctructuras convectivas. Las herramientas han sido desarrolladas en el entorno del sistema McIDAS y generan avisos gráficos a los predictores sobre la ocurrencia de este tipo de fenómenos. Estos productos son de gran ayuda para la labor de vigilancia y predicción inmediata llevada a cabo por los predictores, tanto en los avisos de índole general como en la predicción para sectores de usuarios específicos, como el aeronáutico.

2.6 forecast.io

2.6.1 Data sources

Forecast.io is backed by a wide range of data sources, which are aggregated together statistically to provide the most accurate forecast possible for a given location:

- Dark Sky's own hyperlocal precipitation forecasting system (id darksky), backed by radar data from the following systems:

  - The USA NOAA's NEXRAD system (USA).
  - The UK Met Office's NIMROD system (UK, Ireland).
  - (More coming soon.)
- The USA NOAA's LAMP system (USA, id lamp).
- The UK Met Office's Datapoint API (UK, id datapoint).
- The Norwegian Meteorological Institute's meteorological forecast API (global, id metno).
- The USA NOAA's Global Forecast System (global, id gfs).
- The USA NOAA's Integrated Surface Database (global, id isd).
- The USA NOAA's Public Alert system (USA, id nwspa).
- The UK Met Office's Severe Weather Warning system (UK, id metwarn).
- Environment Canada's Canadian Meteorological Center ensemble model (global, id cmc).
- The US Navy's Fleet Numerical Meteorology and Oceanography Ensemble Forecast System (global, id fnmoc).
- The USA NOAA and Environment Canada's North American Ensemble Forecast System (global, id naefs).
- The USA NOAA's North American Mesoscale Model (North America, id nam).
- The USA NOAA's Rapid Refresh Model (North America, id rap).
- The Norwegian Meteorological Institute's GRIB file forecast for Central Europe (Europe, id metno_{ce}).
- The Norwegian Meteorological Institute's GRIB file forecast for Northern Europe (Europe, id metno_{ne}).
- Worldwide METAR weather reports (global, id metar).
- The USA NOAA/NCEP's Short-Range Ensemble Forecast (North America, id sref).

- The USA NOAA/NCEP's Real-Time Mesoscale Analysis model (North America, id rtma).
- The USA NOAA/ESRL's Meteorological Assimilation Data Ingest System (global, id madis).

2.6.2 API

The Forecast API lets you query for most locations on the globe, and returns:

- Current conditions
- Minute-by-minute forecasts out to 1 hour (where available)
- Hour-by-hour forecasts out to 48 hours
- Day-by-day forecasts out to 7 days

2.6.3 Pricing policy

You can use the API in both commercial and non-commercial applications.

- The first thousand API calls you make every day are free, period.
- Every API call after that costs $1 per 10,000 (that is, 0.01¢).
- Credit us with a "Powered by Forecast" badge that links to `http://forecast.io/` wherever you display data from the API.

2.7 OpenWeatherMap

The OpenWeatherMap service provides open current weather and forecast that is available on our web-site for everybody and by API for developers. Ideology of our service is inspired by OpenStreetMap and Wikipedia that make information free and available for everybody. OpenWeatherMap provides wide range of weather data including current weather,forecast, precipitations, wind, clouds, data from weather stations, lots of maps, analytics and many others. We have own model of weather calculation that involves global meteorological broadcast data, own WRF calculation for regions and real-time data from more than 40,000 weather stations.

2.7.1 API

Our API can provide you with weather forecast for any location on the Earth. The flexible algorithm of weather calculation let us get weather data not only for cities but for any geographic coordinates. It is important for megapolices, for example, where weather is different on opposit city edges. You can get forecast data every 3 hours or daily. The 3 hours forecast is calculating for 5 days. Daily forecast is calculating for 14 days. All weather data can be obtained in JSON or XML format.

2.7.2 Pricing

http://openweathermap.org/price

3 Reanalysis

Reanalysis is a scientific method for developing a comprehensive record of how weather and climate are changing over time. In it, observations and a numerical model that simulates one or more aspects of the Earth system are combined objectively to generate a synthesized estimate of the state of the system. A reanalysis typically extends over several decades or longer, and covers the entire globe from the Earth's surface to well above the stratosphere. Reanalysis products are used extensively in climate research and services, including for monitoring and comparing current climate conditions with those of the past, identifying the causes of climate variations and change, and preparing climate predictions. Information derived from reanalyses is also being used increasingly in commercial and business applications in sectors such as energy, agriculture, water resources, and insurance.

3.1 NCDC-NOAA

3.1.1 Climate Forecast System Reanalysis and Reforecast (CFSRR)

The Climate Forecast System (CFS) is a model representing the global interaction between the Earth's oceans, land, and atmosphere. Produced by several dozen scientists under guidance from the National Centers for Environmental Prediction (NCEP), this model offers hourly data with a horizontal resolution down to one-half a degree (approximately 56km) around the Earth for many variables. CFS uses the latest scientific approaches for

taking-in, or assimilating, observations from many data sources: surface observations, upper air balloon observations, aircraft observations, and satellite observations. The Climate Forecast System Reanalysis (CFSR) is an effort to generate a uniform, continuous, and best-estimate record of the state of the ocean-atmosphere for use in climate monitoring and diagnostics. The method keeps the model's software constant and runs the model retrospectively, from 1979 through the present. In addition to the reanalyses efforts, the CFS model was also used to generate a Reforecast of past weather forecasts. These reforecasts help us better understand the model's ability to produce accurate weather forecasts.

3.1.2 Reanalysis-1 / Reanalysis-2

The National Centers for Environmental Prediction (NCEP) is involved with two global reanalysis projects in joint ventures with other organizations. The first is the NCEP/NCAR Reanalysis (Reanalysis-1), a global reanalysis of atmospheric data spanning 1948 to present. It was created in cooperation with the National Center for Atmospheric Research (NCAR). The second project is the NCEP/DOE Reanalysis (Reanalysis-2) project, a global reanalysis of atmospheric data spanning 1979 to present. It was created in cooperation with the Department of Energy (DOE). Many data sources went into the generation of both reanalyses: surface observations, upper-air balloon observations, aircraft observations, and satellite observations. Data from both reanalyses are available as a global set of gridded weather data at a 2.5 degree by 2.5 degree horizontal resolution. The main difference between these two global reanalysis projects is the starting date of their period of records. The year 1979 was chosen as a beginning date with Reanalysis-2 as it coincides with the date of modern satellite weather ingest. Reanalysis-1 begins in the year 1948, and the data input pattern, better known as data assimilation, changes over the course of this reanalysis, making it an inconsistent (though still scientifically valid) reanalysis record due to there being no satellite ingest in the early part of the Reanalysis-1 dataset.

3.2 ENSEMBLES

ENSEMBLES is an EU-funded Integrated Project that intends to develop an ensemble prediction system for climate change based on the principal state-of-the-art, high resolution, global and regional Earth System models developed in Europe, validated against quality controlled, high resolution gridded datasets for Europe, to produce for the first time, an objective prob-

abilistic estimate of uncertainty in future climate at the seasonal to decadal and longer timescales.

This ensemble prediction system will be used to quantify and reduce the uncertainty in the representation of physical, chemical, biological and human-related feedbacks in the Earth System (including water resource, land use, and air quality issues, and carbon cycle feedbacks).

Data is available free of charge. There is a Thredds server.

3.3 reanalyses.org

Using a collaborative Wiki framework, the goal of reanalyses.org is to facilitate comparison between reanalysis and observational datasets. Evaluative content provided by reanalysis developers, observationalists, and users; and links to detailed data descriptions, data access methods, analysis and plotting tools, and dataset references are available. Discussions of the recovery of observations to improve reanalyses is also a focus. The wiki framework encourages scientific discussion between members of reanalyses.org and other reanalysis users.