ECMWF and the Copernicus Ecosystem

Welcome. In this video, we explore the significance of weather forecasting and climatic condition monitoring within the context of satellite systems and ECMWF, the European Centre for Medium-Range Weather Forecasts. The global need for accurate weather predictions is growing, driven by climate change, agricultural dependencies, and disaster preparedness. Understanding the systems that deliver these forecasts has therefore become crucial for many industries, including agriculture, urban planning, and emergency response. ECMWF produces some of the world's most accurate weather models and represents a pivotal component of climate research and weather prediction. Its medium-range forecasts are among the most reliable global predictions available. Its strength lies not only in short-term forecasting, but also in its ability to model the atmosphere and the climate system with a medium-term horizon, helping meteorologists understand weather patterns and phenomena over longer timeframes.

This capability is built on a global numerical weather prediction model that uses vast amounts of data from satellites, weather stations, and radiosondes, which are balloon-borne instruments, to simulate atmospheric conditions. These data sources provide real-time observations of temperature, humidity, wind speed, cloud cover, and precipitation, all feeding into ECMWF's models. The system produces global weather forecasts for up to fifteen days ahead.

Satellite Data in ECMWF Weather Forecasting

Satellite data plays a vital role in ECMWF's predictions. Satellites from the Copernicus Programme, including Sentinel-1, Sentinel-2, and Sentinel-3, provide comprehensive data about the Earth's surface, oceans, and atmosphere. They allow global observation of climatic conditions by tracking key variables such as sea surface temperature, snow cover, airborne pollutants, and vegetation conditions. All of these are essential inputs for climate modelling and the monitoring of long-term climatic trends. Sentinel-1 helps monitor surface deformations and flooding, and its observations are also useful for analysing geophysical phenomena and potential risks related to seismic activity. Sentinel-2 offers high-resolution multispectral imagery to track vegetation health, soil moisture, and land use.

Sentinel-3 provides thermal and oceanographic data, supporting a better understanding of sea temperature and the effects of thermal radiation on the Earth's climate. Integrating data from all these satellites with ECMWF's models greatly improves the accuracy of weather forecasts and climate projections. For day-to-day forecasting, ECMWF models use data gathered by both polar-orbiting and geostationary satellites. Polar-orbiting satellites, such as those in the MetOp series, orbit the Earth at different latitudes and capture high-resolution measurements across the entire planet. Geostationary satellites, such as MSG and Himawari, continuously observe the same area of the Earth, enabling real-time monitoring of weather systems like hurricanes, storm fronts, and cloud formations.

The combination of both types is crucial. Polar-orbiting satellites provide global atmospheric measurements at higher resolution, while geostationary satellites deliver real-time information on rapidly changing weather systems. Together, they ensure both global coverage and high temporal resolution. For long-term climate monitoring, ECMWF uses satellite data to assess climatic trends over time. Sea surface temperature, or SST, is a major climatic variable for studying ocean circulation and its influence on weather patterns. By incorporating satellite observations of SST into climate models, ECMWF can better predict large-scale weather phenomena like El Niño or La Niña, which significantly affect global rainfall and temperature distributions.

Weather Variables in the EagleArca Platform

The Weather service available on the EagleArca platform provides daily updates on a wide range of atmospheric variables. These measurements are crucial for understanding both immediate and longer-term environmental factors, affecting everything from urban planning to agriculture. The following sections describe each variable category and its significance.

Precipitation, Soil and Runoff

Rain, measured in millimetres, indicates the amount of precipitation that has fallen over a specific period. It is an essential metric for understanding weather patterns, drought conditions, and irrigation needs. Total Precipitation extends this measurement to include all types of precipitation, such as rain, snow, hail, and sleet. This provides a more comprehensive view of how weather interacts with the environment, especially in areas prone to mixed precipitation types.

Runoff, also measured in millimetres, indicates the amount of water that flows over the land surface and can potentially contribute to flooding. This variable is particularly useful for managing urban drainage systems and agricultural irrigation, and for assessing the risk of soil erosion. Soil moisture and soil temperature, labelled in the platform as soil_moist and soil_tempe, provide real-time data on soil conditions. They are key for monitoring irrigation needs, predicting drought conditions, and managing crop health. Finally, snowfall and snow depth are also provided, completing the picture of precipitation and its accumulation on the surface.

Temperature and Humidity

Temperature, measured in degrees Celsius, provides a snapshot of the thermal state of the atmosphere. Surface temperature indicates the temperature of the land surface specifically. It is important in both urban heat island studies and agriculture, where it helps assess crop development, frost risks, and heat stress. Relative humidity, expressed as a percentage, refers to the amount of moisture in the air relative to the maximum the air can hold at a given temperature. It is a key determinant of perceived comfort and directly influences the rate of evapotranspiration in crops, which makes it essential for managing water resources in agriculture.

The dew point, in degrees Celsius, is the temperature at which air becomes saturated with moisture and water vapour begins to condense. It is important for predicting fog formation and frost. In agriculture, dew point data provides early warnings about frost risks that are critical for protecting crops. Apparent temperature, also in degrees Celsius, represents the temperature as perceived by the human body. It accounts for both air temperature and humidity, and is especially relevant in urban heat island studies, where dense building structures and fewer green spaces can lead to higher perceived temperatures.

Pressure and Wind

The platform provides two pressure readings. Mean sea-level pressure, labelled in the platform as pressure_m, is expressed in hectopascals and corrected for altitude. It helps interpret large-scale weather systems: low-pressure systems are associated with storms and bad weather, while high-pressure systems correspond to clear skies and stable conditions. Surface atmospheric pressure, labelled as surface_pr, determines local weather conditions and wind patterns.

Wind speed and wind direction, labelled in the platform as wind_speed and wind_direction, are crucial for understanding weather systems and air quality. Wind affects the distribution of pollutants, moisture, and heat, particularly in urban areas and agricultural regions where airflow influences irrigation, pesticide application, and heat accumulation. Wind data also helps predict the movement of weather fronts and storm systems, and is important for industries such as aviation, shipping, and renewable energy, specifically wind power.

Cloud Cover and Atmospheric Instability

Cloud cover, expressed as a percentage, indicates how much of the sky is covered by clouds and directly affects solar radiation, temperature, and precipitation. It is also useful for predicting weather changes, such as the development of storms or the transition to clear sky conditions. The platform provides cloud fraction values broken down by altitude, labelled as cloud_co_1, cloud_co_2, and cloud_co_3, representing low, middle, and high-level clouds respectively. This layered view provides a deeper understanding of atmospheric conditions at different altitudes, supporting weather forecasting and climate modelling.

CAPE, measured in joules per kilogram, stands for Convective Available Potential Energy and is a measure of atmospheric instability. It quantifies the potential energy in the atmosphere that can fuel storm development. The higher the CAPE value, the greater the likelihood of severe weather events such as thunderstorms, hail, and tornadoes.

Atmospheric Column Variables

Total column water vapour measures the total amount of water vapour integrated vertically through the atmosphere above a given location. Water vapour is the primary greenhouse gas and plays a central role in the Earth's water cycle, influencing precipitation patterns, cloud formation, and energy transfer. Total column ozone is crucial for understanding both the health of the stratospheric ozone layer and the presence of ground-level ozone, which is a significant air pollutant.

Applications in Agriculture

Weather forecasting and climate data are vital for the agriculture sector. With Sentinel-2 data, farmers can monitor vegetation health using vegetation indices like NDVI and EVI, derived from satellite reflectance in the red and near-infrared bands. These indices provide early warnings about crop health. They help farmers decide when to irrigate, how to manage pest pressure, and how to optimise water use across the growing season. Temperature forecasting is equally critical, especially when linked with frost prediction or heat stress. Sentinel-3 land surface temperature data allows agricultural decision-makers to anticipate temperature anomalies that could harm crops, offering more time for preparation and mitigation.

The EagleArca platform's daily updates on rainfall, humidity, and soil conditions allow farmers to continuously assess drought and flood risks and plan for pest management. The data also supports protection of crops from frost, heat stress, and other weather-related damage. The platform enables tracking of seasonal weather patterns as they evolve, supporting adjustments for climate-related risks and the optimisation of water resources across the growing season.

Applications in Urban Environments

In urban environments, weather forecasting and climate models are essential for managing heat islands. The Urban Heat Island effect occurs when built-up areas experience significantly higher temperatures than surrounding rural areas, primarily due to impervious surfaces such as roads and buildings that absorb heat. By combining ECMWF weather forecasts with Sentinel-3 land surface temperature data, cities can identify areas subject to heat accumulation and implement cooling strategies, such as increasing urban green spaces or using reflective materials on roads. The platform also supports the analysis of how green spaces, rooftops, pavement, and urban structures influence local microclimates, helping planners design more resilient environments and reduce heat-related health risks for urban populations.

ECMWF's data also supports air quality management and infrastructure planning in cities. By incorporating aerosol and pollutant data from Sentinel-5P and other Copernicus missions, urban planners can assess pollution sources, track NO2 levels, and evaluate strategies to reduce emissions and improve air quality. Rainfall and runoff data further support the planning of urban drainage systems, helping cities manage flood risk and prevent waterlogging in built-up areas.

Disaster Management and Climate Research

Real-time weather data plays a key role in disaster management. During events such as floods, heatwaves, or wildfires, the EagleArca platform can be used to track temperature fluctuations, precipitation intensity, and wind direction, providing crucial information for emergency responders. The ability to view these changes in real time enables faster decision-making and better resource allocation during critical situations.

For climate research, the long-term availability of historical weather data through EagleArca allows scientists to observe changes in climatic conditions over time, track seasonal patterns, and model future environmental changes. This data, combined with datasets such as Sentinel-1 for monitoring land subsidence or Sentinel-2 for tracking vegetation health, contributes to a comprehensive understanding of how climate change is impacting specific regions.

Visualization in EagleArca: The Weather Service

The Weather service on EagleArca provides real-time weather data refreshed daily, offering a comprehensive view of atmospheric conditions across large spatial areas. The data is sourced from advanced satellite systems and atmospheric monitoring instruments, ensuring high accuracy and global coverage. Within the platform, weather variables are visualized through the 2D view, providing an intuitive, map-based interface where users can observe the spatial distribution of atmospheric parameters. By zooming in on different geographic areas, users can track specific trends in detail, from precipitation patterns to temperature anomalies and wind dynamics. This view also helps urban planners identify where heat is accumulating and understand how elements such as green spaces, rooftops, pavement, and urban structures influence local microclimates.

The daily refresh of data ensures that users are always working with the most current atmospheric measurements, without the delays of manual reporting or outdated weather stations. This continuous update cycle improves the accuracy of forecasts, enables more reliable weather alerts, and better prepares users for extreme events such as heavy rainfall, windstorms, heatwaves, floods, and wildfires. Alongside real-time updates, EagleArca archives historical weather data, allowing users to access and analyze atmospheric conditions over extended time periods.

This makes it possible to track seasonal patterns, observe multi-year climate trends, and evaluate how specific weather events have evolved across a region. Combined with daily updates, the Weather service becomes a complete decision-support environment, whether for managing irrigation in agriculture, monitoring heat accumulation in cities, or coordinating responses to extreme weather events.

ECMWF and Copernicus: An Integrated Framework

ECMWF's weather and climate models are central to improving weather forecasts and understanding atmospheric conditions on both global and regional scales. The integration of satellite data from Copernicus missions like Sentinel-1, Sentinel-2, and Sentinel-3 with ECMWF's predictive capabilities provides an essential toolset for addressing a wide range of environmental challenges. From agriculture to urban planning and disaster preparedness, this integrated approach enhances our ability to make data-driven decisions that improve resilience to climate extremes and support sustainable development. As satellite systems and predictive modelling continue to improve, the combination of ECMWF's meteorological capabilities and Copernicus satellite data will play an increasingly important role in shaping the future of climate resilience and environmental management globally.