WMO OMM

World Meteorological Organization
Organisation météorologique mondiale
Organización Meteorológica Mundial
Всемирная метеорологическая организация
المنظمة العالمية للأرصاد الجوية
世界气象组织

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7 تشرين الأول/ أكتوبر 2024

عدد المرفقات: 1 (بالإنكليزية فقط)

الموضوع: الطبعة الأوليَّة لعام 2024 من *المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقيين* (البرنامج الفضائي - 12)

الإجراءات المطلوبة: (1) استعراض المبادئ التوجيهية وعنوانها المنقح *"المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقية والمتخصصين في مجالات التطبيق ذات الصلة"*، وإرسال تعقيباتكم إلى أمانة المنظمة في موعد أقصاه **15 كانون الأول/ ديسمبر 2024**

(2) ترشيح ممثليكم لحضور الجلسات الإعلامية التي ستُعقَد عبر الإنترنت يومي **5 و6 تشرين الثاني/ نوفمبر 2024**، وستُعرض فيها الطبعة الأولية لعام 2024 من هذه المبادئ التوجيهية

تحية طيبة وبعد،

يسرُّني إبلاغكم أن المختبر الافتراضي للتعليم والتدريب في مجال الأرصاد الجوية الساتلية (VLab)، الذي أنشأه فريق تنسيق سواتل الأرصاد الجوية (CGMS) والمنظمة العالمية للأرصاد الجوية، قد وضع *المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقية والمتخصصين في مجالات التطبيق ذات الصلة* لمساعدة مراكز التدريب على تحديد أهداف تعليمية ملائمة للعناصر المتعلقة بالسواتل في الدورات التدريبية التي تقدمها هذه المراكز. والمستخدمون الرئيسيون لهذه المبادئ التوجيهية هم مراكز التدريب والمُدرِّبون الذين يقدمون دورات تدريبية تدعم الأرصاد الجوية التطبيقية ومجالات التطبيق ذات الصلة.

وتناولت الطبعة الأولى من *المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقيين* (البرنامج الفضائي - 12) - التي نُشِرت في عام 2017 ونُقِّحت في عام 2018 - المهارات المرتبطة بالأرصاد الجوية التطبيقية. وتُحدِّث طبعة عام 2024 هذه المبادئ التوجيهية لأخصائيي الأرصاد الجوية التطبيقية، وتضيف مبادئ توجيهية للمتخصصين في تقديم خدمات المناخ والأرصاد الجوية الزراعية. وأُضيف القسمان الأخيران بناءً على طلب من أعضاء المختبر الافتراضي.

وتهدف المبادئ التوجيهية إلى دعم تنفيذ أُطُر الكفاءات في المنظمة (*خلاصة وافية لأُطُر الكفاءات في المنظمة* (مطبوع المنظمة رقم 1209)). وتقدم هذه الطبعة من المبادئ التوجيهية إرشادات بشأن المهارات اللازمة من أجل الاستفادة الفعَّالة من الصور والنواتج المستخرجة من سواتل الأرصاد الجوية والسواتل البيئية. ويمكن تحديث هذه الطبعة مستقبلاً لمواكبة التطورات العلمية أو توضيح التعديلات في تقنيات تفسير البيانات المستمدة من هذه السواتل.

إلى: الممثلين الدائمين لأعضاء المنظمة

صورة إلى: المستشارين الهيدرولوجيين
رؤساء الاتحادات الإقليمية ونوابهم
رئيس لجنة الرصد والبنية التحتية ونظم المعلومات (INFCOM) ونائبه (نوابه)
أعضاء المختبر الافتراضي وشركائه

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وفي هذا السياق، سأكون ممتنة لو تكرمتم بدراسة نص الطبعة الأوليَّة لعام 2024 من *"المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقية والمتخصصين في مجالات التطبيق ذات الصلة"* (الواردة بالمرفق)، وإرسال تعليقاتكم أو اقتراحاتكم إلى أمانة المنظمة، عناية السيدة Zoya Andreeva (zandreeva@wmo.int)، في أقرب وقت ممكن، في موعد أقصاه **15 كانون الأول/ ديسمبر 2024**. وستُؤخذ تعقيباتكم القيِّمة بعين الاعتبار في الصياغة النهائية للطبعة الأوليَّة لعام 2024، التي ستُرسل لاحقاً إلى أعضاء لجنة الرصد والبنية التحتية ونظم المعلومات (INFCOM) للموافقة عليها بالمراسلة. وسيُترجَم هذا المطبوع بعد ذلك إلى جميع لغات الأمم المتحدة.

وتيسيراً لعملية الاستعراض التي تُجريها مرافقكم الوطنية للأرصاد الجوية والهيدرولوجيا (NMHS)، أودُّ إبلاغكم أنه من المقرر عقد جلستين إعلاميتين عبر الإنترنت في يومي **5 و6 تشرين الثاني/ نوفمبر 2024**. وتهدف هاتان الجلستان إلى عرض المطبوع المُنقَّح باسم *"المبادئ التوجيهية بشأن المهارات والمعارف الساتلية اللازمة لأخصائيي الأرصاد الجوية التطبيقية والمتخصصين في مجالات التطبيق ذات الصلة"*، والتحدث باستفاضة عن تطبيق هذه المبادئ التوجيهية من خلال تدريب العاملين في المرافق الوطنية للأرصاد الجوية والهيدرولوجيا عليها.

وفي هذا الصدد، أودُّ دعوة المُمثِّلين المعنيين بمرافقكم الوطنية إلى المشاركة في الجلستين الإعلاميتين وفقاً للجدول الزمني التالي:

الجلسة	**التاريخ**	**الوقت (بالتوقيت العالمي المنسق)**
النصف الشرقي من الكرة الأرضية	5 تشرين الثاني/ نوفمبر 2024	04:00-03:00
النصف الغربي من الكرة الأرضية	6 تشرين الثاني/ نوفمبر 2024	15:00-14:00

ويُرجى التسجيل لحضور هاتين الجلستين عبر هذا الرابط: https://forms.office.com/e/hnkxFyphY4.

وأغتنم هذه الفرصة لأعرب لكم ولمرافقكم الوطنية عن تقديري لإسهاماتكم المستمرة في أنشطة المنظمة.

وتفضلوا بقبول فائق الاحترام،

البروفيسورة سيليستى ساولو
الأمينة العامة

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Guidelines on Satellite Skills for Operational Meteorologists and Specialists in Related Application Areas

Contents

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The WMO–Coordination Group for Meteorological Satellites Virtual Laboratory for Education and Training in Satellite Meteorology Management Group (VLMG) initiated the enabling skills presented in this publication in consultation with the CALMet community in 2013. WMO published the first version of these guidelines in 2017, and updated this publication in 2018 and 2024.

VLMG Co-Chair, Bernadette Connell (Cooperative Institute for Research in the Atmosphere, United States of America), led the work in 2024.

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INTRODUCTION

These guidelines comprise three main sections and describe the enabling skills[1] that support WMO Competency Frameworks (*Compendium of WMO Competency Frameworks* (WMO-No. 1209)) related to the use of satellite data by operational meteorologists[2] and specialists in the provision of climate and agrometeorological services.

The aim of the guidelines is to support implementation of the WMO Competency Frameworks. The first version of the guidelines (published in 2017 and revised in 2018) covered the skills associated with operational meteorology (*Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (WMO SP-12)). This 2024 version updates the guidelines for operational meteorologists and also adds guidelines for specialists in the provision of climate and agrometeorological services. See the Appendix for a detailed explanation of the changes and additions.

The guidelines were developed by the WMO–Coordination Group for Meteorological Satellites Virtual Laboratory for Education and Training in Satellite Meteorology (VLab), to help training centres develop appropriate learning objectives for the satellite-related elements of their courses. The main users of the guidelines are the training centres and trainers who implement courses to support operational meteorology and related application areas.

This publication provides guidance on the skills necessary to effectively utilize the imagery and products retrieved from various environmental satellites. It can be updated in the future to follow scientific advancements or to reflect adaptations in interpretation techniques.

How to use these guidelines

In this publication, enabling skills are defined as the identification, interpretation and application of satellite data required of operational meteorologists and specialists of climate and agrometeorological services. The order of acquiring the skills does not necessarily follow the structure presented in these guidelines, and can be adapted to training organization approaches.

Trainers and training managers who want to align their materials to the WMO competencies may use these guidelines to develop appropriate learning objectives for the satellite-related elements of their courses. This publication should be used in conjunction with the qualifications found in the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I, and the WMO Competency Frameworks.

Operational meteorologists and specialists of climate and agrometeorological services can use these guidelines to assess their own levels of skills in using satellite data.

This publication covers a wide range of satellite skills. Depending on the job requirements, an individual may use only a subset of these. The background knowledge and skills, and the

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[1] As the skills support the competencies, they have been designated "enabling skills" rather than "competencies".

[2] Although no reference is made to "operational meteorologist" in the WMO Convention, for the purpose of this publication, "operational meteorologist" refers to a person who performs the duties of analysis, diagnosis, prognosis and forecasting of the weather.

performance components that support this Skills Framework should be customized by each organization, its service requirements and available satellite data.

Basic knowledge

It is assumed users of these guidelines have basic knowledge in satellite remote sensing and understand the following:

(a) Satellites include geostationary and low-Earth orbit satellites with passive and active sensing;

(b) Systems, features and phenomena of interest will be dependent on the required forecasting tasks and geographic area of responsibility;

(c) Imagery includes single and multiple channels and combinations of channels, including RGB (red/green/blue) composites, as well as derived products;

(d) Satellite data interpretation is not undertaken in isolation but occurs within the context of all other observations, guidance and situational awareness;

(e) Access, selection, display and manipulation of satellite data;

(f) Characteristics, limitations and possible errors in the satellite data.

1. SATELLITE SKILLS FOR OPERATIONAL METEOROLOGISTS

This section describes the enabling skills that support the WMO Competency Frameworks related to the use of satellite data by operational meteorologists. The skills are as follows:

1. Identify surface features.
2. Identify cloud types and their characteristics.
3. Identify and interpret broad-scale, synoptic and mesoscale systems.
4. Identify and interpret atmospheric phenomena.
5. Identify and interpret oceanic and water features and fields.
6. Compare satellite data with numerical weather prediction (NWP) outputs.

METEOROLOGY SKILL 1: IDENTIFY SURFACE FEATURES

Description

Identify geographical features, surface characteristics and conditions to provide context for interpreting meteorological conditions.

Performance components

1.1 Identify terrain and geographical features:

1.1.1 Discriminate between land and water (oceans, seas, lakes, wetlands, rivers and inlets).

1.1.2 Distinguish mountainous from low-lying regions.

1.1.3 Differentiate natural versus human-modified areas.

1.2 Identify surface characteristics and conditions, including dry/wet and vegetated/clear areas:

1.2.1 Identify and monitor land cover (vegetated (forested, grassland or mixed), vegetation-free (bare rock, bare soil or sand) and urban areas).

1.2.2 Identify areas of recent burning.

1.2.3 Identify hotspots (fires, volcanic activity and so forth).

1.2.4 Identify areas of recent volcanic ash cover.

1.2.5 Identify areas of flooding.

1.2.6 Identify areas of drought (indicate favoured source areas for dust storms).

1.2.7 Identify areas of human-induced land degradation/modification and water pollution.

1.3 Identify snow/ice cover and analyse its extent:

1.3.1 Discriminate between cloud and snow.

1.3.2 Identify frozen rivers and lakes; identify ice jam on rivers and lakes.

1.3.3 Identify sea ice and ice floes.

Background knowledge and skills

1.a Use remote-sensing principles to interpret infrared (including water vapour), visible and microwave data to distinguish surface features.

1.b Select the appropriate multichannel RGB imagery to interpret surface features.

1.c Select the appropriate derived products to monitor drought, flooded areas and fires.

1.d Interpret the surface feature of interest within the context of the surrounding features, the scale of the image, the time of day, the season, the texture and colour of the feature, animation and other aspects.

1.e Combine satellite data with other remotely sensed data (for example, from drones and aircraft) and other data products to better interpret and evaluate land surface types and conditions.

METEOROLOGY SKILL 2: IDENTIFY CLOUD TYPES AND THEIR CHARACTERISTICS

Description

Identify cloud types and features, including cloud top height and temperature, thickness and microphysics. These will be used to determine the current and developing meteorological conditions.

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Performance components

2.1 Identify stratiform, cumuliform and cirriform cloud regions and individual cloud types and their characteristics.

2.2 Identify cumulonimbus clouds and their stage of evolution.

2.3 Identify fog and discriminate between fog and low cloud.

2.4 Identify contrails and ship trails.

2.5 Assess cloud top heights based on brightness temperatures, surface observations and sounding data (observed, satellite-derived and numerical models).

2.6 Identify clouds made of water droplets, ice particles or a mixture.

2.7 Discriminate between clouds with small or large cloud particle sizes.

Background knowledge and skills

2.a Interpret satellite data characteristics (texture, albedo, brightness temperature, cloud microphysics, synoptic and mesoscale patterns and so forth) to identify cloud types and their characteristics (thick, thin, multilayered, top height, developing, decaying and so forth).

2.b Apply RGB products, microphysical parameters and derived products to identify clouds composed of different phases and clouds with small or large particle sizes.

2.c Identify and interpret the cloud feature of interest within the context of the surrounding features, the scale of the image, the time of day, the season, the texture and colour of the feature, animation and other aspects.

METEOROLOGY SKILL 3: IDENTIFY AND INTERPRET BROAD-SCALE, SYNOPTIC AND MESOSCALE SYSTEMS

Description

Identify, locate and interpret broad-scale, synoptic and mesoscale atmospheric systems, their characteristics, strength and stage of evolution, and deduce atmospheric dynamic and thermodynamic properties.

Performance components

For each system, select an appropriate conceptual model to characterize the system, and its orientation, strength and stage of evolution, including precursor signatures. Recognize departures from climatological or idealized models and that some features relate to more than one category.

A full analysis or prediction involves using all types of available data and guidance, and is a higher-level task. Satellite interpretation contributes to this higher-level task.

3.1 Identify and locate the following broad-scale systems and features:

3.1.1 Intertropical convergence zones, monsoon and trade wind regimes.

3.1.2 Westerly regimes with embedded cyclones and anticyclones.

3.1.3 Polar and tropical easterlies and systems.

3.1.4 Broad-scale waves.

3.1.5 Zonal, meridional flows, mobile and blocking systems.

3.1.6 Upper- and low-level circulations.

3.1.7 Low-level moisture boundaries.

3.2 Identify and locate the following synoptic-scale systems and features:

3.2.1 Anticyclones.

3.2.2 Cyclones, tropical cyclones and lows, extratropical and polar lows, at upper and lower levels.

3.2.3 Jet streams, convergence and frontal zones, conveyor belts and dry slots.

3.2.4 Troughs, ridges and cols, deformation axes and waves.

3.2.5 Cloud regions – stratiform, stratocumulus, cumulus (cold outbreaks and trade cumulus), cloud bands, cloud streets and cloud shields.

3.2.6 Cold pools and thermal shear.

3.3 Identify and locate the following mesoscale systems and features:

3.3.1 Local thermal and topographic circulations, including land and sea breezes, katabatic and anabatic winds, foehn winds, mountain waves, banner clouds, island and peninsula effects (including Kármán vortices and V-shaped wave clouds), heat lows and troughs, and lake effect snow.

3.3.2 Convective environments and areas of instability, convective initiation, inhibition and the breakdown of inhibition.

3.3.3 Convective cells and cloud systems (including pulse convection, multicells, supercells, squall lines, mesoscale convective complexes and systems) and associated mesoscale features, including outflow boundaries and storm-top features.

3.3.4 Convergence lines (mesoscale boundaries and interactions, dry lines and cloud streets).

3.3.5 Low-level jets.

3.3.6 Gravity waves and bores.

Background knowledge and skills

3.a Compare satellite imagery, RGB products, and derived temperature, moisture and wind fields with conceptual models to identify atmospheric systems in various stages of evolution.

3.b Utilize the Dvorak and other techniques to deduce tropical system development, intensity and decay.

3.c Utilize satellite lightning products to track convective system evolution and identify intensity changes.

METEOROLOGY SKILL 4: IDENTIFY AND INTERPRET ATMOSPHERIC PHENOMENA

Description

Identify and interpret atmospheric phenomena, their characteristics and stages of evolution to improve the meteorological forecast.

Performance components

For each phenomenon, locate, identify and determine its characteristics and, when appropriate, its stage of evolution.

A full analysis or prediction involves all available data and guidance and is a higher-level task. Thus, the satellite interpretation task, together with other data processing and analysis, contributes to a higher-level task.

4.1 Identify and locate the following:

4.1.1 Dust storms and sandstorms, and plumes and areas of raised dust.

4.1.2 Fires and smoke.

4.1.3 Moisture features, precipitation types and amounts.

4.1.4 Volcanic ash particulates, sulfur dioxide (SO_2) and other chemical emissions.

4.1.5 Aerosol and particulate pollution.

4.1.6 Features indicating regions of clear air turbulence.

4.1.7 Features indicating regions conducive to icing.

Background knowledge and skills

Use satellite imagery and products to:

4.a Discriminate between blowing dust/sand, cloud and smoke under conditions of day and night, and over land and water.

4.b Detect fires, their intensity and probable movement.

4.c Distinguish areas of varying moisture content as well as precipitation type and amount (for example, convective, stratiform and deep versus shallow precipitation).

4.d Identify and analyse volcanic emissions to determine the areal extent, height, thickness and temporal evolution of the ash cloud, SO_2 and other constituents.

4.e Identify pollutants and atmospheric constituents.

4.f Identify ozone-rich regions in the middle and upper atmosphere.

4.g Identify clear air turbulence signatures.

METEOROLOGY SKILL 5: IDENTIFY AND INTERPRET OCEANIC AND WATER FEATURES AND FIELDS

Description

Identify and interpret oceanic and water features and fields relevant to meteorological forecasting. Oceanographers would require more extensive skills that are not covered here.

Performance components

5.1 Interpret sea-surface temperature fields and their characteristic broad-scale and mesoscale patterns.

5.2 Interpret sea-surface wind data.

5.3 Identify and interpret sea-state data and relate these to wave height and swell.

5.4 Identify and interpret oil slicks and their evolution.

5.5 Identify and interpret pollution and algal blooms.

5.6 Identify and interpret areas of sun glint and dark zones.

5.7 Identify and interpret sea ice, its extent, movement and characteristics (for example, young and old sea ice, sea ice undergoing ablation and containing melt ponds).

5.8 Identify and interpret ocean currents and eddies and regions of ocean upwelling using sea-surface temperature, wind, wave and sea-surface height.

Background knowledge and skills

5.a Recognize sea-surface temperature limitations resulting from cloud cover, diurnal variations of skin surface water temperature and influence of deeper water temperatures.

5.b Recognize sea-surface wind limitations, including wind direction ambiguities, wind speed inaccuracies and rain effects.

5.c Recognize sea-state measurement limitations and errors based on active microwave sensors and synthetic aperture radar.

5.d Use microwave sensors, synthetic aperture radar, multispectral imagery and derived products to detect oil slicks, algae and sea ice.

5.e Understand the relationship between sun glint, dark zones, and windy and calm ocean surface conditions.

5.f Distinguish between sun glint and cloud characteristics using satellite imagery, products and animations.

METEOROLOGY SKILL 6: COMPARE SATELLITE DATA WITH NUMERICAL WEATHER PREDICTION (NWP) OUTPUTS

Description

Satellite measurements are one of many inputs to NWP models. They are used to improve operational weather forecasts by comparing the current atmospheric state with NWP model output. This is accomplished by identifying the differences in location and magnitude of specific weather features identified in NWP outputs and the current satellite imagery. Finally, NWP outputs should be validated and adjusted for the improvement of operational forecasts.

Performance components

6.1 Evaluate basic NWP output fields against satellite data.

6.2 Identify and assess various weather features by integrating satellite, NWP products and other observation data.

6.3 Use satellite data to quantify NWP limitations.

6.4 Use NWP information to enhance understanding of the features shown in the satellite data.

6.5 Use satellite data and products in conjunction with NWP at different stages of the analysis and forecast processes.

Background knowledge and skills

6.a Maintain a basic understanding of atmospheric dynamics.

6.b Maintain a basic understanding of NWP outputs and their limitations.

6.c Understand the dynamic relationship between satellite data and NWP outputs for diagnosing weather systems and related atmospheric circulations to improve operational forecasts.

2. SATELLITE SKILLS FOR PROVISION OF CLIMATE SERVICES

This section describes the enabling skills for using satellite data that support existing WMO Competency Frameworks on the provision of climate services (listed in the *Compendium of WMO Competency Frameworks* (WMO-No. 1209)), and should be used in parallel with *WMO Guidelines on the Creation of Climate Normals* (WMO-No. 1203).

It is assumed that creating climate data records (CDRs) based on satellite measurements is beyond the capacities of most National Climate Services. Satellite-based CDRs are created and supplied by satellite data providers and other relevant organizations. There may be different satellite-based CDRs available for the same variable. These may come from different providers, be derived from different satellite instruments, combine different satellite instruments and be retrieved using different methods. A complete description of the creation of satellite-based CDRs is complex and far beyond the scope of these guidelines.

In this section, CDR refers to long-term record of satellite data, stable and homogeneous over time. It is assumed all satellite measurements used in the creation of a CDR are calibrated, the algorithms and auxiliary data used in the retrieval of geophysical variables are documented for the entire data record, and uncertainty information is included.

The enabling skills to work with satellite-based CDRs are as follows:

1. Choose a suitable satellite product for the climate task.

2. Integrate satellite-based climate data records (CDRs) with data from other sources.

3. Compute climate-related statistics using satellite-derived climate products.

4. Use satellite-based climate data records (CDRs), including climate-related indices, for climate monitoring.

It is assumed that people working with CDRs have the general data manipulation skills required for the tasks, such as: reading different format files, extracting the relevant fields from the data files and choosing a suitable software tool or programming language. Such data manipulation skills are not explained in this publication.

CLIMATOLOGY SKILL 1: CHOOSE A SUITABLE SATELLITE PRODUCT FOR THE CLIMATE TASK

Description

Sources for satellite-based CDRs are available from different satellite operators globally. Currently, the terminology associated with the data from such sources is not consistent. To work with these data, it is necessary to know where to search for satellite-based CDRs that are suitable for the task. Well-maintained satellite-based CDRs come with a description of the data characteristics in the form of a product user manual or product guide, as well as a comprehensive description of the algorithms applied to generate CDRs in the form of an algorithm theoretical basis document. It is important for users of satellite-based CDRs to understand these descriptions and judge if a product is suitable for the task.

Performance components

1.1 Determine which satellite products are available for various climate applications and tasks and access the datasets.
1.2 Evaluate the strengths and limitations, including the uncertainty in the measurements of satellite products for various climate applications and tasks.
1.3 Monitor satellite product updates and changes in relation to climate applications and tasks.

Background knowledge and skills

1.a Know the main sources and databases of available CDRs, including their latest updates, and how to access these data records.

1.b Find relevant information about CDRs. Be aware of potentially different terminology, spatial and temporal coverage and resolution, uncertainty and other characteristics.

1.c Recognize uncertainties in satellite-based CDRs to properly use these data records for a specific application. Uncertainty information should be included in the data files or in the product documentation (for example, the product user manual or similar).

1.d Have a basic understanding of the retrieval principles of climate variables and the production of CDRs and how that relates to the application of the data.

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CLIMATOLOGY SKILL 2: INTEGRATE SATELLITE-BASED CLIMATE DATA RECORDS (CDRS) WITH DATA FROM OTHER SOURCES

Description

For many climatological tasks, it is important to integrate data from different sources. The sources include reanalysis models, in situ measurements and satellite-based measurements.

Performance components

2.1 Integrate satellite-based climate products with other sources of information in a scientifically and technically sound manner.

2.2 Work with geospatial data: assess if the data are on an appropriate grid for the related climate application and task. It is important to understand that changing the geographical projection or grid and re-sampling the data can have an adverse impact on the results and interpretation.

Background knowledge and skills

2.a Be aware of data dependencies. Some satellite-based climate products use in situ measurements or a reanalysis model as auxiliary data during the retrieval process. Some reanalyses assimilate satellite-based climate products. This results in satellite products that are not completely independent.

2.b Be aware of temporal and spatial resolution as well as sampling issues. Look for the information in the product documentation.

2.c Be familiar with different projections, grids and spatial re-sampling techniques and know manipulating these may negatively affect the data.

2.d Use geospatial visualization and analysis tools (for example, geographic information system (GIS) technology) to integrate data from different measurement sources to produce spatial climate information.

CLIMATOLOGY SKILL 3: COMPUTE CLIMATE-RELATED STATISTICS USING SATELLITE-DERIVED CLIMATE PRODUCTS

Description

Use satellite-based climate variables to calculate climate-related statistics.

Performance components

3.1 Compute satellite-based climate statistics such as normals (reference values), averages and other statistical information as needed.

3.2 Compute various satellite-based sector-oriented climate products to meet the needs of different end users.

Background knowledge and skills

3.a Be familiar with CDRs available from providers.

3.b Understand (from CDR documentation) the assumptions, strengths and limitations of the underlying satellite retrieval, as well as the effects these have on statistics.

3.c Be proficient in applying statistical methods, especially for spatial time series and extreme value analysis.

3.d Be proficient in processing satellite data to ensure accuracy and reliability of climate statistics.

3.e Be familiar with different quality control procedures to filter and ensure accuracy of satellite-derived climate statistics.

3.f Understand the methodologies used to compute climate-related statistics.

CLIMATOLOGY SKILL 4: USE SATELLITE-BASED CLIMATE DATA RECORDS (CDRS), INCLUDING CLIMATE-RELATED INDICES, FOR CLIMATE MONITORING

Description

Leveraging satellite-based CDRs and derived indices from data providers for comprehensive climate monitoring provides crucial insights to support informed policymaking and decision-making.

Performance components

4.1 Integrate diverse satellite-based CDRs and indices into a cohesive monitoring framework.

4.2 Use global and regional climate indices to monitor climate, climate forecasts and future projections.

4.3 Create spatial maps and visualizations to convey complex climate monitoring information derived from satellite data in a clear and accessible manner.

Background knowledge and skills

4.a Use statistical methods to validate and interpret computed climate indices.

4.b Use time series analysis to track climate changes over specific periods of time using satellite-derived data.

4.c Apply change detection methods to identify sudden or gradual shifts in satellite-derived climate variables.

4.d Use geospatial visualization and analysis tools (for example, GIS technology) to produce user-specific climate information.

3. SATELLITE SKILLS FOR PROVISION OF AGROMETEOROLOGICAL SERVICES

This section describes the enabling skills for using satellite data that support the existing guidelines for curricula in agricultural meteorology (*Guidelines for the Education and Training* *of Personnel in Meteorology and Operational Hydrology* (WMO-No. 258), Volume I, Supplement No. 2).

It is assumed that the creation of agrometeorological products based on satellite measurements is beyond the capacities of most National Meteorological and Hydrological Services. Satellite-based agrometeorological products are created and supplied by satellite data providers and other relevant organizations, with agrometeorologists primarily obtaining and analysing these products.

The skills enabling specialists in the provision of agrometeorological services to work with satellite-based agrometeorological data are as follows:

1. Choose a suitable satellite product for the agrometeorological task.

2. Integrate satellite-based agrometeorological data with data from other sources.

3. Monitor land and vegetation type and condition using satellite-derived products and indices.

4. Monitor meteorological parameters in relation to agrometeorological hazards.

AGROMETEOROLOGY SKILL 1: CHOOSE A SUITABLE SATELLITE PRODUCT FOR THE AGROMETEOROLOGICAL TASK

Description

Identify and access various satellite products that can be used for agrometeorological purposes.

Performance components

1.1 Determine which satellite products are available for various agrometeorological applications and tasks and access the datasets.

1.2 Evaluate the strengths and limitations, including the uncertainty in measuring various satellite products for various agrometeorological applications and tasks.

1.3 Select the appropriate vegetation index/indices for different vegetation types and at different stages of development.

1.4 Monitor for satellite product updates and changes in relation to agrometeorological applications and tasks.

Background knowledge and skills

1.a Know which parameters can be derived from satellite data for the agrometeorological task.

1.b Know the main sources and databases of satellite information for the agrometeorological task, including its latest updates, and how to access the datasets.

1.c Maintain a basic understanding of the retrieval principles of the products used, such as land surface temperature, soil moisture, vegetation indices, precipitation and evapotranspiration.

1.d Maintain a sound understanding of the potential limitations of satellite observations and products, including quality flags, for the agrometeorological task.

AGROMETEOROLOGY SKILL 2: INTEGRATE SATELLITE-BASED AGROMETEOROLOGICAL DATA WITH DATA FROM OTHER SOURCES

Description

Integrate, analyse and visualize satellite-based agrometeorological data and indices with in situ measurements, models and data from other sources. This allows putting the data in context, enhancing understanding and tailoring information for agricultural monitoring purposes.

Performance components

2.1 Integrate satellite-based agrometeorological products with other data sources (for example, land-use maps or surface-based measurements) in a scientifically and technically robust manner.

2.2 Work with geospatial data: assess if the data are on a grid appropriate for the related agrometeorological application and task and understand that changing the geographical projection or grid and re-sampling the data can have an adverse impact on the results and interpretation.

Background knowledge and skills

2.a Know what data (for example, NWP and in situ) are used to create the various satellite products of interest and understand how this may affect the quality of satellite products.

2.b Be familiar with different projections, grids and spatial re-sampling techniques, and know manipulating these may negatively affect the data.

2.c Be aware of temporal and spatial resolution as well as sampling issues. Look for this information in the provider’s product documentation.

2.d Maintain a basic understanding of ground truthing and satellite data verification methods, including integration with station data.

2.e Use geospatial visualization and analysis tools (for example, GIS technology) for mapping, analysing and communicating agrometeorological information.

AGROMETEOROLOGY SKILL 3: MONITOR LAND AND VEGETATION TYPE AND CONDITION USING SATELLITE-DERIVED PRODUCTS AND INDICES

Description

Identify land and vegetation type and assess and monitor growth and condition using various satellite-derived products and indices.

Performance components

3.1 Monitor land and vegetation type and extent using satellite-derived products and indices.

3.2 Monitor land and vegetation conditions using satellite products and images.

3.3 Monitor vegetation growth for purposes of agricultural yield prediction and food security monitoring.
3.4 Monitor relevant meteorological parameters (soil moisture, land surface temperature, precipitation, evapotranspiration and so forth).
3.5 Compare vegetation indices and meteorological parameters with climatological records to identify conditions of potential elevated stress to vegetation.

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Background knowledge and skills

3.a Interpret satellite images to identify land surface and vegetation characteristics and conditions.

3.b Understand the relationship between weather conditions and vegetation status, and their impacts on satellite vegetation indices (immediate versus delayed).

3.c Understand the advantages and limitations of using satellite vegetation indices for monitoring vegetation.

3.d Use time series of vegetation indices and satellite-derived meteorological parameters to detect anomalies.

AGROMETEOROLOGY SKILL 4: MONITOR METEOROLOGICAL PARAMETERS IN RELATION TO AGROMETEOROLOGICAL HAZARDS

Description

Use satellite-derived indices and products to monitor the duration and extent of agrometeorological hazards. Such hazards include drought, excessive precipitation, fires, frost, and abnormal and extreme temperatures.

Performance components

4.1 Identify drought impact.
4.2 Monitor frost and freezing conditions.
4.3 Monitor soil moisture in relation to agricultural and hydrological hazards, particularly droughts and floods.
4.4 Monitor abnormal and extreme temperatures in relation to agrometeorological hazards.
4.5 Monitor real-time fire conditions and occurrence.
4.6 Monitor for pest and disease impacts on vegetation.

Background knowledge and skills

4.a Maintain foundational knowledge on droughts and other agrometeorological hazards: types, causes, mechanisms of formation and evolution, indicators and impacts on vegetation.

4.b Maintain an understanding of the relationship between satellite-derived vegetation indices and the impacts of agrometeorological hazards, particularly droughts.

4.c Apply change detection methods to identify sudden or gradual shifts in satellite-derived vegetation indices.

4.d Recognize that the impact of a developing hazard may not immediately show on a vegetation index, and a hazard may be more appropriately identified by meteorological parameters.

APPENDIX. REVISION HISTORY OF THE GUIDELINES

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This appendix provides further details on the changes and additions made to the guidelines first published in 2017, revised in 2018 and updated in 2024.

2024

This edition replaces the 2018 publication of the *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (WMO SP-12). It now comprises three main sections that describe the enabling skills for: (1) operational meteorologists (legacy), (2) specialists in the provision of climate services (new) and (3) specialists in the provision of agrometeorological services (new). The latter two sections have been added at the request of VLab members.

Updates to section 1. Satellite skills for operational meteorologists

"Skill 5: Interpret derived fields and derived products" has been removed as it was felt this was incorporated in the remaining skills. When the satellite skills were first drafted over 10 years ago, single and multi-image combination products were commonly used. With new satellites and a tremendous growth in multichannel, multisensor and multiobservation products, there is no longer a need to have this as a separate skill. The remaining skills have been renumbered as:

1. Identify surface features.
2. Identify cloud types and their characteristics.
3. Identify and interpret broad-scale, synoptic and mesoscale systems.
4. Identify and interpret atmospheric phenomena.
5. Identify and interpret oceanic and water features and fields.
6. Compare satellite data with numerical weather prediction (NWP) outputs.

Performance components have been added as follows:

1.2.7 Identify areas of human-induced land degradation/modification and water pollution.

4.1.7 Features indicating regions conducive to icing.

Several skill descriptions have been rewritten to enhance clarity and include additional aspects. The "Skills, techniques and knowledge requirements" sections have been renamed as "Background knowledge and skills" to better reflect their purpose. In a few background sections, components have been combined.

Trainers are encouraged to include satellite skills and performance components with course or workshop descriptions and on certificates provided for the course or workshop. To minimize effort in renumbering and relabelling the satellite skills addressed by training materials that use older editions of SP-12, it is recommended to add the edition date to past and new materials and a link to the SP-12 publication in the WMO e-Library. This is especially important in reference to the renumbered, deleted and new skills and performance components. Although it will not be possible to adjust certificates that have already been issued, existing web pages should be updated. It is recommended to include the top skill regularly and for special topic training, include performance components as appropriate.

Example text referencing top skills and targeted performance components from the 2018 edition

This training supported the following satellite skills and performance components listed in the *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (2018 edition):

Skill 2: Identify cloud types and their characteristics.
Skill 3.2.3: Jet streams, convergence and frontal zones, conveyor belts, dry slots.
Skill 5: Interpret derived fields and derived products.
Skill 6: Identify and interpret oceanic and water features and fields.

Example text referencing top skills and targeted performance components from the 2024 edition

This training supported the following satellite skills and performance components listed in the *Guidelines on Satellite Skills for Operational Meteorologists and Specialists in Related Application Areas* (2024 edition):

Meteorology Skill 2.1: Identify stratiform, cumuliform and cirriform cloud regions and individual cloud types and their characteristics.
Meteorology Skill 6.5: Use satellite data and products in conjunction with NWP at different stages of the analysis and forecast processes.
Climatology Skill 1: Choose a suitable satellite product for the climate task.
Climatology Skill 4.2: Use global and regional climate indices to monitor climate, climate forecasts and future projections.

2018

The 2017 version of the *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (WMO SP-12) was revised in 2018. It was included under section 1 in the *Compendium of WMO Competency Frameworks* (WMO-No. 1209), published in 2019. To have a consistent reference structure, the skills were organized under a number system instead of the previous number / letter / roman number structure. This allows easy referencing of skills when used in course descriptions and on certificates.

Additions to this version included Skill 7 and other performance components listed below, as well as updates to various "Skills, techniques and knowledge requirements" sections:

Skill 7: Compare satellite data with numerical weather prediction (NWP) outputs.

Performance components:

1.2.6 Identify areas of drought.

1.3.3 Identify sea ice.

3.1.7 Low-level moisture boundaries.

3.3.2 Convective environments and areas of instability, convective initiation, inhibition and the breakdown of inhibition.

6.5 Identify and interpret pollution (including runoff and algal blooms).

2017

The *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* were first published as WMO SP-12. They included six skills:

1. Identify surface features.

2. Identify cloud types and their characteristics.

3. Identify and interpret broad-scale, synoptic and mesoscale systems.

4. Identify and interpret atmospheric phenomena.

5. Interpret derived fields and derived products.

6. Identify and interpret oceanic features and systems.

REFERENCES

World Meteorological Organization (WMO). *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology* (WMO-No. 258), Volume I, Supplement No. 2. Geneva, 2009.

World Meteorological Organization (WMO). *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (WMO SP-12). Geneva, 2017.

World Meteorological Organization (WMO). *WMO Guidelines on the Creation of Climate Normals* (WMO-No. 1203). Geneva, 2017.

World Meteorological Organization (WMO). *Guidelines on Satellite Skills and Knowledge for Operational Meteorologists* (WMO SP-12). Geneva, 2018.

World Meteorological Organization (WMO). *Compendium of WMO Competency Frameworks* (WMO-No. 1209). Geneva, 2019.

World Meteorological Organization (WMO). *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I – Meteorology. Geneva, 2023.