Guidelines on Satellite Skills and Knowledge for Operational Meteorologists

2018 edition

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

SP-12

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EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at http://public.wmo.int/en/resources/meteoterm.

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Chair, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 81 17
Email: publications@wmo.int

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EXECUTIVE SUMMARY

This document describes the enabling skills that support WMO Competency Frameworks related to the use of satellite data by operational meteorologists.[1] The skills are as follows:

1. Identify surface features;

2. Identify cloud types and their characteristics;

3. Identify and interpret broadscale, synoptic and mesoscale systems;

4. Identify and interpret atmospheric phenomena;

5. Interpret derived fields and derived products;

6. Identify and interpret oceanic and water features and systems;

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

The primary focus of this document is on meteorological forecasting. More specific in-depth usage of satellite data in specialized areas, such as oceanography, hydrology, climatology and agrometeorology, is not currently considered.

The satellite skills were developed by the WMO–Coordination Group for Meteorological Satellites (CGMS) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab), to help training centres to develop appropriate learning objectives for the satellite-related elements of their courses. The WMO–CGMS VLab is a global network of specialized training centres and meteorological satellite operators working together to improve the utilization of data and products from meteorological and environmental satellites.

This document provides guidance on the skills and knowledge necessary to effectively utilize the imagery and products produced by many environmental satellites used by the operational meteorologist in the forecasting process.

BACKGROUND

The application of satellite data and these enabling skills supports the various existing WMO Competency Frameworks and those under development. These require the operational meteorologists to:

(a) Analyse and monitor continually the evolving meteorological and/or hydrological situation;

(b) Forecast meteorological and hydrological phenomena and parameters;

(c) Effectively communicate the information to the users.

As these skills support the competencies, they have been designated as enabling skills rather than as competencies.

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1 Although no reference is made to "operational meteorologist" in the Convention of the World Meteorological Organization, for the purpose of this document "operational meteorologist" refers to one who performs the duties of analysis, diagnosis, prognosis and forecasting of the weather.

HOW TO USE THIS DOCUMENT

This document defines enabling skills as the interpretation, identification and application of satellite skills required of an operational meteorologist. It does not specify how or the order in which satellite meteorology should be taught.

Trainers and training managers who want to align their courses to the competencies may use this document to develop appropriate learning objectives for the satellite-related elements of their courses. This document 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) and the definitions of WMO competencies.

Operational meteorologists can use the present document to assess their own level of skill, for example, novice, advanced or expert, with respect to the application of satellite data.

This document covers a wide range of possible skills and knowledge requirements. An individual may need only a subset of these, depending on the job requirements. The performance and knowledge requirements that support these skills should be customized for each organization, its service requirements and available satellite data.

BASIC KNOWLEDGE

It is assumed that the user of this document has basic knowledge in satellite remote-sensing and understands the following:

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

(b) Imagery includes single and multiple channels and combinations of channels, including RGB (red/green/blue) displays and derived products;

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

(d) Systems, features and phenomena of interest will be dependent on the required forecasting tasks and location;

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

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

SKILL 1: IDENTIFY SURFACE FEATURES

Description

Identify geographical features, surface characteristics and conditions.

Performance components

1.1 Identify terrain and geographical features.

1.1.1 Discriminate between land and water (oceans, seas, lakes, rivers, 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, different vegetation types and clear areas, sand and desert.

1.2.1 Identify vegetation-free areas and vegetation types. Identify different types of desert surface, for example, sand and desert pavement.

1.2.2 Identify areas of recent burning.

1.2.3 Identify hotspots (fires, volcanic activity, etc.).

1.2.4 Identify areas of recent volcanic ash cover.

1.2.5 Identify areas of flooding.

1.2.6 Identify areas of drought.

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.

1.3.3 Identify sea ice.

Skills, techniques and knowledge requirements

To be contextualized depending on the local circumstances:

1.a Application of Infrared (including water vapour (WV)), visible and microwave channels.

1.b Application of multi-channel RGB imagery and products.

1.c Application of products and derived products (lighting, LEO flood and moisture products, land, etc.), particularly for longer-term monitoring such as drought.

1.d Background interpretation of satellite images (scale, texture, colour, shadow, etc.).

SKILL 2: IDENTIFY CLOUD TYPES AND THEIR CHARACTERISTICS

Description

Identify cloud types and features including height and temperature of tops, thickness and microphysics.

Performance components

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

2.2 Identify cumulonimbus clouds, their intensity, organization and stage of development.

2.3 Identify fog and discriminate between fog and low cloud.

2.4 Identify contrails and ship trails.

2.5 Deduce 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 particles.

Skills, techniques and knowledge requirements

2.a Distinguish cloud types and characteristics (thick, thin, multilayered, top height, developing, decaying) based on texture, albedo, brightness temperature, and synoptic and mesoscale context.

2.b Interpret brightness temperatures and deduce cloud thickness.

2.c Use RGB products to identify fog and night microphysics, shadows on visible imagery and animation to identify valley fogs as well as meteorological situational awareness and surface and aircraft observations.

2.d Use RGB products and/or microphysical parameters to identify clouds composed of different phases and clouds with small or large cloud particles.

2.e Utilize derived products.

2.f Interpret the background of satellite image properties (scale, texture, colour, shadow, etc.).

SKILL 3: IDENTIFY AND INTERPRET BROADSCALE, SYNOPTIC AND MESOSCALE SYSTEMS

Description

Identify, locate and interpret broadscale, synoptic and mesoscale atmospheric systems, their characteristics, strength and stage of evolution, and deduce atmospheric dynamical and thermodynamical properties.

Performance components

For each system, select and apply conceptual models to locate and identify the system, its orientation, strength and stage of evolution, including precursor signatures, taking into account departures from climatological or idealized models. (Categories are not exclusive and some features relate to more than one category.)

Note that a full analysis or prediction involves all available data and guidance and is a higher-order competency. Thus, the satellite interpretation task is not an end in itself but, in conjunction with other data, contributes to this higher-level task.

3.1 Identify and locate the following broadscale 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 Broadscale 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, dry slots.

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

3.2.5 Cloud regions – stratiform, stratocumulus, cumulus (cold outbreaks, 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, cloud streets).

3.3.5 Low-level jets.

3.3.6 Gravity waves and bores.

Skills, techniques and knowledge requirements

3.a Use Infrared, water vapour and visible (including high-resolution visible channel) and detailed conceptual models to identify atmospheric systems.

3.b Utilize the Dvorak tropical cyclone enhancement and techniques to deduce tropical cyclone intensity.

3.c Use RGB products (airmass RGB, microphysics RGB, etc.) to identify atmospheric systems and use for operational forecasting.

SKILL 4: IDENTIFY AND INTERPRET ATMOSPHERIC PHENOMENA

Description

Identify and interpret atmospheric phenomena, their characteristics, strength and stage of evolution.

Performance components

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

Note that a full analysis or prediction involves all available data and guidance and is a higher-order competency. Thus, the satellite interpretation task is not an end in itself but, in conjunction with other data, contributes to this higher-level task.

4.1 Identify and locate the following:

4.1.1 Dust 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, sulphur dioxide (SO_2) and other chemical emissions.

4.1.5 Aerosol and particulate pollution.

4.1.6 Features indicating regions of clear air turbulence.

Skills, techniques and knowledge requirements

4.a Discriminate between dust/sand, cloud and smoke; day and night, over land (particularly desert surfaces) and water, using single, multi-channel and RGB imagery.

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

4.c Distinguish precipitation type and amount (convective, stratiform and deep versus shallow precipitation) using satellite channels including microwave channel data.

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 using single, multi-channel and RGB imagery.

4.e Correctly identify pollutants and atmospheric constituents (SO_2, nitrogen dioxide (NO_2), etc.) in RGB composites or products.

4.f Use the appropriate RGB to identify ozone-rich regions in the middle and upper atmosphere.

4.g Identify clear air turbulence (CAT) signatures using single channel (including water vapour channels), multi-channel, RGB composites and synthetic satellite imagery.

SKILL 5: INTERPRET DERIVED FIELDS AND DERIVED PRODUCTS

Description

Advanced interpretation of fields and parameters from product analysis across all the other skills.

Performance components

Interpret fields and parameters in order to integrate them with other data, observations and guidance (including NWP outputs) as input to analysis and diagnosis.

5.1 Correctly interpret and appropriately integrate:

- 5.1.1 Surface temperatures.
- 5.1.2 Vertical temperature and moisture profiles.
- 5.1.3 Atmospheric winds.
- 5.1.4 Cloud type, cloud top temperature.
- 5.1.5 Total and liquid precipitable water.
- 5.1.6 Vegetation and fire danger indices, soil moisture.

Skills, techniques and knowledge requirements

5.a Recognize the strengths and weaknesses of single channel, multi-channel, RGB products and satellite-derived products/fields and how they complement other meteorological information.

5.b Describe the impacts of satellite observations on Numerical Weather Prediction (NWP) outputs. This will include the use of water vapour (WV) synthetic imagery mapped against potential vorticity (PV) fields from the NWP products.

SKILL 6: IDENTIFY AND INTERPRET OCEANIC AND WATER FEATURES AND SYSTEMS

Description

Identify and interpret oceanic features and systems relevant to meteorological forecasting. Note that oceanographers would require more extensive skills that are not covered here.

Performance components

6.1 Interpret sea-surface temperature fields and their characteristic broadscale, synoptic and mesoscale patterns.

6.2 Interpret sea-surface wind data.

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

6.4 Identify and interpret oil slicks and their evolution.

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

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

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

6.8 Identify and interpret ocean currents and eddies and regions of ocean upwelling.

Skills, techniques and knowledge requirements

Recognize and/or utilize the following:

6.a Sea-surface temperature limitations, including cloud cover, skin temperature, deeper temperatures.

6.b Sea-surface wind limitations, including wind direction ambiguities, wind speed inaccuracies, rain effects.

6.c Sea-state measurement limitations and errors based on active microwave sensors and aperture radar.

6.d Sea-ice detection methods using microwave sensors, synthetic aperture radar and multispectral infrared imagery, RGBs and derived products.

6.e Relationship between sun glint, dark zones and ocean surface (windy or calm) conditions.

6.f Multispectral infrared imagery and products to distinguish between sun glint and cloud characteristics.

SKILL 7: COMPARE SATELLITE DATA WITH NUMERICAL WEATHER PREDICTION (NWP) OUTPUTS

Description

Identify variations (or differences) between meteorological phenomena as they appear in satellite imagery (for example, WV imagery) and NWP model outputs (for example, PV, synthetic WV imagery) to assess and validate NWP outputs for the improvement of operational weather forecasting.

Performance components

For the assessment of NWP model outputs, apply meteorological concepts to the interpretation of satellite imagery, for example, compare the WV imagery with NWP outputs (for example, PV fields and synthetic WV imagery) and identify the differences in location and magnitude of NWP from the satellite imagery. Finally, validate and adjust NWP outputs for the improvement of operational forecasts.

Note that new multi-channel satellites with high temporal and spatial resolution can be used as ground truth because it represents real-time atmospheric flows. Thus the contribution of satellite data to the adjustment of NWP outputs will be the highest level task based on all the dynamical concepts and observation data.

7.1 Evaluate basic NWP output fields using satellite data and model output.

7.2 Identify and assess various weather features by integrating satellite and NWP products.

7.3 Deduce when and how to use satellite imagery to address NWP limitations.

7.4 Use NWP information to enhance the understanding of the features shown in the satellite images.

7.5 Use satellite data in conjunction with NWP at different stages of the analysis and forecast process.

Skills, techniques and knowledge requirements

7.a Have a basic understanding of the atmospheric dynamics.

7.b Have a basic understanding of NWP outputs and their limitations.

7.c Understand the dynamical relationship between satellite imagery and NWP outputs for diagnosing synoptic-scale atmospheric circulation systems.

7.d Utilize the high-resolution satellite imagery in conjunction with NWP model output to better diagnose meteorological phenomena and improve operational forecasts.

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For more information, please contact:

World Meteorological Organization

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Communication and Public Affairs Office

Tel.: +41 (0) 22 730 83 14/15 – Fax: +41 (0) 22 730 80 27

Email: cpa@wmo.int

public.wmo.int

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