Guidelines on Satellite Skills and Knowledge for Operational Meteorologists

2017 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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SUMMARY

This document describes the underpinning skills that support the WMO competencies that relate to the use of satellite data by operational meteorologists. The skills are:

(a) Identification of surface features;

(b) Identification of cloud types and their characteristics;

(c) Identification and interpretation of broad-scale, synoptic and mesoscale systems;

(d) Identification and interpretation of atmospheric phenomena;

(e) Interpretation of derived fields and derived products;

(f) Identification and interpretation of oceanic features and systems.

Meteorologists in different locations or performing different job tasks will have access to different satellites with their particular characteristics and to various display and manipulation systems and tools. They will also be dealing with a variety of local meteorological systems and phenomena.

The focus of this document is on meteorological forecasting. Other uses of satellite data, for example, research, oceanography, hydrology, climatology and other specialist areas will be considered separately in other documents.

The skills definition was developed by the WMO–Coordination Group for Meteorological Satellites (CGMS) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) to make it quicker and easier for training centres to develop learning objectives that relate to the WMO competencies.

HOW TO USE THIS DOCUMENT

This document specifies the satellite interpretation skills required of a meteorological forecaster. It does not specify how satellite meteorology should be taught or the order in which it should be taught. This will vary according to many different circumstances, including the particular job tasks required; whether it is taught as part of a short course, a full initial course or independent learning; and whether it is a separate subject, integrated with other data sources and theory as part of a meteorological systems approach, or a combination by initially teaching background satellite theory followed by an integrated systems approach.

BACKGROUND

The interpretation of satellite imagery is not an end in itself but an element of the competent forecaster's toolbox.

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. The WMO competencies for operational meteorologists and hydrologists and the qualifications for meteorologists and meteorological technicians provide a basis for the VLab training that targets operational meteorologists.

The application of satellite data and satellite skills and knowledge supports the WMO competencies for operational meteorology and hydrology. These require the competent meteorologists to “Analyse and monitor continually the evolving meteorological and/or hydrological situation”, “Forecast meteorological and hydrological phenomena and parameters” and effectively communicate the information to the users (Resolution 4 (Cg-17) – Report of the extraordinary session (2014) of the Commission for Basic Systems relevant to technical regulations concerning public weather services competencies).

As these skills support the high-level competencies, this document designates the satellite interpretation requirements as contributing or enabling skills rather than as competencies in their own right.

Trainers who want their courses to be aligned to the qualifications and competencies can use this document to more quickly develop appropriate learning objectives for the satellite-related elements of their courses. This document should, of course, be used in conjunction with the qualification and WMO competency definitions.[1]

Operational meteorologists can use the present document to calibrate the breadth and depth of the underlying knowledge and skills with respect to the application of satellite data.

The performance requirements that support these skills and knowledge will be based on the particular context of the organization, its service requirements and available satellite data. This document covers the full range of possible skills and knowledge requirements. Any individual will require only a subset of these, according to their job requirements.

In addition to the general competencies of a meteorological forecaster, the following conditions, background skills and knowledge will apply.

GENERAL CONDITIONS

(a) Imagery includes still and animated (looped) imagery of single and multiple channels and combinations of channels, including "red–green–blue" (RGB) displays, derived quantitative products (processed satellite data blended with numerical weather prediction data) and synthetic satellite imagery from numerical model predictions;

(b) Satellites include geosynchronous and polar orbiting satellites with passive and active sensing;

(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.

ACCESS, SELECTION, DISPLAY AND MANIPULATION OF SATELLITE DATA

The forecaster will be able to:

(a) Access data from geostationary and polar orbiting satellites;

(b) Select the most appropriate channels, combinations of channels and products for the task at hand;

(c) Display and manipulate the imagery as individual or combined channels, singly or with animation;

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1 Refer to the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I – Meteorology, http://library.wmo.int/pmb_ged/wmo_1083_en.pdf; and http://www.wmo.int/pages/prog/dra/etrp/competencies.php, respectively.

(d) Apply enhancements to imagery;

(e) Access and display derived data.

CHARACTERISTICS, LIMITATIONS AND POSSIBLE ERRORS IN THE SATELLITE DATA

The forecaster will take into account factors affecting data quality and characteristics, including:

(a) Satellite resolution (time, horizontal, vertical) and channel;

(b) Position of the satellite subpoint – resolution, parallax errors;

(c) Time of scan for different parts of the image and latency of delivery;

(d) Satellite sensitivities, precision, accuracy and wavelength characteristics;

(e) Variations due to sun angle.

Skill 1: Identify surface features

Description

Identify geographical features, surface characteristics and conditions.

Performance components

(a) Identify terrain and geographical features:

- (i) Discriminate between land and water (oceans, seas, lakes, rivers and inlets);
- (ii) Distinguish mountainous from low-lying regions;
- (iii) Differentiate natural versus human-modified areas;

(b) Identify surface characteristics and conditions, including dry and wet, different vegetation types and clear areas, sand and desert:

- (i) Identify vegetation-free areas and vegetation types; identify different types of desert surface, for example, sand and desert pavement;
- (ii) Identify areas of recent burning;
- (iii) Identify hotspots (for example, fires or volcanic activity);
- (iv) Identify areas of recent volcanic ash cover;
- (v) Identify areas of flooding;

(c) Identify snow and ice cover and analyse the extent:

- (i) Discriminate between cloud and snow;
- (ii) Identify frozen rivers and lakes.

Skills, techniques and knowledge requirements

(a) Infrared and visible channels;

(b) Multichannel RGB products (natural colour RGB, day microphysics RGB, microphysics RGB, snow RGB, dust RGB);[2]

(c) Derived products (for example, from the Satellite Application Facility on Land Surface Analysis).

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

(a) Identify stratiform, cumuliform and cirriform cloud regions and individual cloud types and their characteristics;

(b) Identify cumulonimbus clouds, their intensity, organization and stage of development;

(c) Identify fogs and discriminate between fog and low cloud;

(d) Identify contrails and ship trails;

(e) Deduce cloud top heights based on brightness temperatures, surface observations and sounding data (observed, satellite-derived and numerical models);

(f) Identify clouds made of water droplets, ice particles or a mixture;

(g) Discriminate between clouds with small or large cloud particles.

Skills, techniques and knowledge requirements

(a) Cloud types and characteristics (thick, thin, multilayered, developing and decaying) based on texture, brightness, brightness temperature, and synoptic and mesoscale context;

(b) Brightness temperatures, contamination from higher levels;

(c) Fog and night microphysics RGB products, shadows on visible imagery and animation to identify valley fogs, as well as meteorological situational awareness and surface and aircraft observations;

(d) RGB products and/or microphysical parameters to identify clouds composed of different phases and clouds with small or large cloud particles;

(e) Infrared, water vapour and visible imagery (including high-resolution visible channel).

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2 Recommended WMO standards for RGB products are provided in http://www.wmo.int/pages/prog/sat/documents/RGB-WS-2012_FinalReport.pdf.

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 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 and 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.

(a) Broad-scale systems and features:

- (i) Intertropical convergence zones, monsoon and trade wind regimes;
- (ii) Westerly regimes with embedded cyclones and anticyclones;
- (iii) Polar easterlies and systems;
- (iv) Broad-scale waves;
- (v) Zonal, meridional flows, mobile and blocking systems;
- (vi) Upper and low-level circulations;

(b) Synoptic-scale systems and features:

- (i) Anticyclones;
- (ii) Cyclones, tropical cyclones and lows, subtropical, mid-latitude and polar lows, at upper and lower levels;
- (iii) Jet streams, convergence and frontal zones, conveyor belts, dry slots;
- (iv) Troughs, ridges and cols, deformation axes, waves;
- (v) Cloud regions – stratiform, stratocumulus, cumulus (cold outbreaks, trade cumulus), cloud bands and cloud shields;
- (vi) Cold pools and thermal shear;

(c) Mesoscale systems and features:

- (i) 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;
- (ii) 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;

(iii) Convergence lines (mesoscale boundaries and interactions, dry lines, cloud streets);

(iv) Low-level jets;

(v) Gravity waves and bores.

Skills, techniques and knowledge requirements

(a) Detailed conceptual models of each atmospheric system;

(b) Dvorak tropical cyclone enhancement and techniques for tropical cyclone intensity;

(c) RGB products (for example, airmass RGB, microphysics RGB);

(d) Infrared, water vapour and visible imagery (including high resolution visible channel).

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.

Phenomena include:

(a) Dust and sand storms, and plumes and areas of raised dust;

(b) Fires and smoke;

(c) Precipitation types and amounts;

(d) Volcanic ash particulates and chemical emissions;

(e) Aerosol and particulate pollution;

(f) Features indicating regions of clear-air turbulence.

Skills, techniques and knowledge requirements

(a) Dust and sand storms:

(i) Conditions – detect dust over land and water, night and day;

(ii) Discriminate between dust, cloud, smoke and desert surfaces;

(iii) Dust RGB products;

(b) Fires and smoke:

Locate fires and their movements;

(c) Pollution:

Pollutants include SO_2, NO_2, and the like;

(d) Volcanic ash – identify and analyse in particular:

(i) Volcanic emissions including ash, $SO_{2;}$

(ii) Determine the areal extent of the ash cloud, its height and its temporal evolution;

(iii) Volcanic ash RGB;

(e) Precipitation:

Precipitation type (convective, stratiform and deep versus shallow precipitation) using satellite channels including microwave channel data;

(f) Other aerosols:

Use the airmass RGB to identify ozone-rich regions in the middle and upper atmosphere;

(g) Clear-air turbulence:

Identify clear air turbulence signatures using water vapour channels and synthetic satellite imagery.

Skill 5: Interpret derived fields and derived products

Description

Interpret fields and parameters, and compare and contrast them with information from other observational data.

Performance components

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

Derived fields include:

(a) Surface temperatures;

(b) Vertical temperature and moisture profiles;

(c) Atmospheric winds;

(d) Cloud type and cloud top temperature;

(e) Total and liquid precipitable water;

(f) Vegetation and fire danger indices, and soil moisture.

Skills, techniques and knowledge requirements

(a) Strengths and weaknesses of satellite-derived products/fields;

(b) Image interpretation – both single channel, RGB products and derived products;

(c) Satellite data in combination with derived products;

(d) Knowledge of other sources of observational data, for example, surface-based observations, radiosonde data, and radar products.

Skill 6: Identify and interpret oceanic features and systems

Description

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

Performance components

(a) Interpret sea-surface temperature fields and their characteristic broad scale, synoptic and mesoscale patterns;

(b) Interpret near-surface wind data;

(c) Identify and interpret sea-state data and relate these to wave height and swell;

(d) Identify and interpret oil slicks and their evolution;

(e) Identify and interpret areas of sun glint and dark zones;

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

(g) Identify and interpret ocean currents and eddies and regions of ocean upwelling.

Skills, techniques and knowledge requirements

(a) Sea-surface temperature limitations, including cloud cover, skin temperature and deeper temperatures;

(b) Sea-surface wind detection (scatterometer), including wind direction ambiguities, wind speed inaccuracies and rain effects;

(c) Sea-state measurement limitations and errors based on active microwave sensors and aperture radar. Sea-ice detection methods using microwave sensors, synthetic aperture radar and multispectral radiometers. MODIS sea-ice algorithm;

(d) Relationship between sun glint, dark zones and ocean surface conditions;

(e) Sun glint and high cloud characteristics;

(f) Sea ice and cloud characteristics.

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