WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

The WMO Integrated Global Observing System; Introduction and Overview

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World Meteorological Organization
Organisation météorologique mondiale

Outline

- Introduction to WIGOS
- Activities of the Pre-operational Phase (2016-2019)
- The WMO Rolling Review of Requirements and OSCAR
- WIGOS Technical tools; OSCAR/Surface and the WIGOS Data Quality Monitoring System (WDQMS)
- GBON, the Global Basic Observing Network
- Summary and Conclusions

What is the WMO Integrated Global Observing System (WIGOS)?

- WMO foundational activity addressing all observing needs of the weather, climate, water and environmental services of its Members
- A framework for integrating all WMO observing systems and WMO contributions to co-sponsored observing systems under a common regulatory and management framework in order to improve effectiveness and efficiency
- WIGOS is not replacing or taking over existing observing systems, which will continue to be owned and operated by a diverse array of organizations and programmes, national as well as international.

WIGOS homepage

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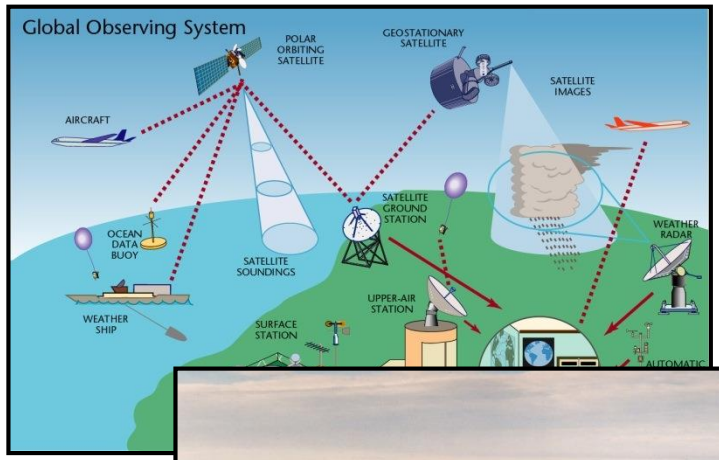
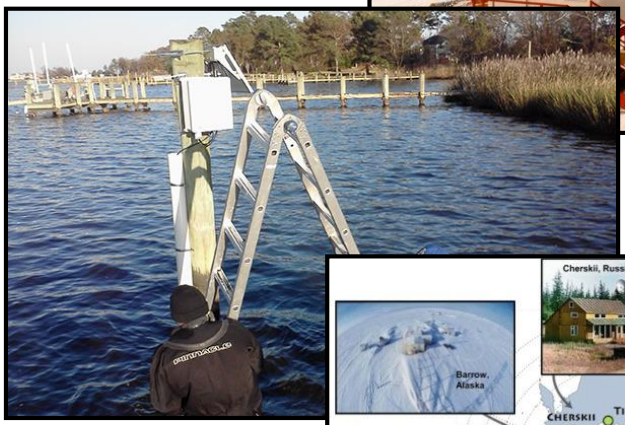
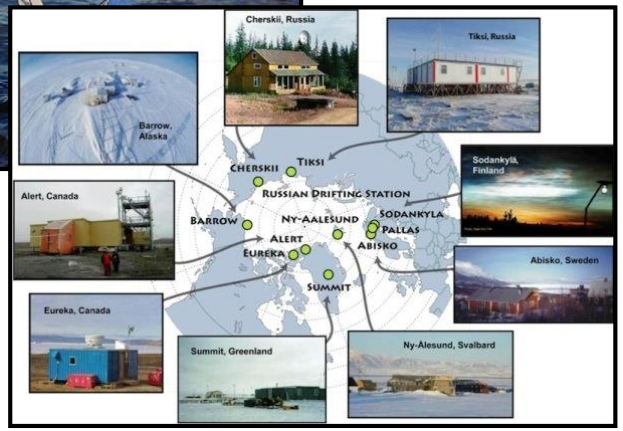
WIGOS Component Systems

- Global Observing System (WWW/**GOS**)
- Observing component of Global Atmospheric Watch (**GAW**)
- WMO Hydrological Observations (including **WHOS**)
- Observing component of Global Cryosphere Watch (**GCW**)







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Why do we need WIGOS?

- **I. NMHS mandate typically broader now than when the World Weather Watch and the GOS were created, including e.g.**
  - Climate monitoring, climate change, mitigation
  - Air quality, atmospheric composition from urban to planetary scales
  - Oceans
  - Cryosphere
  - Water resources
- **II. Technical and scientific advances:**
  - Observing technology
  - Telecommunications
  - Numerical modeling and data assimilation
  - Increased user demand to access and use observations in decision making

Why do we need WIGOS?

- **III. Economic realities**
  - Budgetary pressure on many NMHS, in spite of expanding mandates and increasing demand for services
  - Efficiency by exploiting synergies
    - Integration of observing networks across disciplines (e.g. weather and climate)
    - Integration across organizational boundaries, e.g. between different national ministries/departments operating observing systems
    - Integration across technological boundaries, e.g. between surface- and space-based systems

What do we mean by Integration?

I. Integrated network design, e.g. across national borders:

- Radar and lightning detection networks
- Radiosonde networks designed together with those of neighboring countries

II. Integration across disciplines: Multi-purpose networks

- No separate networks for application areas that rely on measurements of the same variables, e.g. weather and climate

III. Integration across organizational boundaries:

- Take advantage of other organizations outside the NMHS that operated observing systems; partner with them where possible

What do we mean by Integration? (II)

IV. Integration across technological boundaries; space- and surface-based observing system as one

- Space: excellent spatial and temporal coverage
- Ground-based: fine-scaled structure, in situ validation and can provide measurements not possible from space

V. Integration across different levels of performance; concept of tiered networks can include e.g.:

- Crowd-sourced data, IoT observations (massive amounts of data, poor or unknown quality)
- Standard networks; routine, operational quality data
- Reference data; traceable to SI standards (sparse, high quality)

VI. Operate networks as an integrated system;

- Common data formats, common display systems;
- All data available at common access points;

The WIGOS Pre-Operational Phase (2016-2019) decided by Cg-17 in 2015

- Increased emphasis on regional and national activities
- Five main priority areas:

I. WIGOS Regulatory Material, supplemented with necessary guidance material

II. WIGOS Information Resource, including the Observing Systems Capabilities analysis and Review tool (OSCAR), especially OSCAR/Surface

III. WIGOS Data Quality Monitoring System (WDQMS)

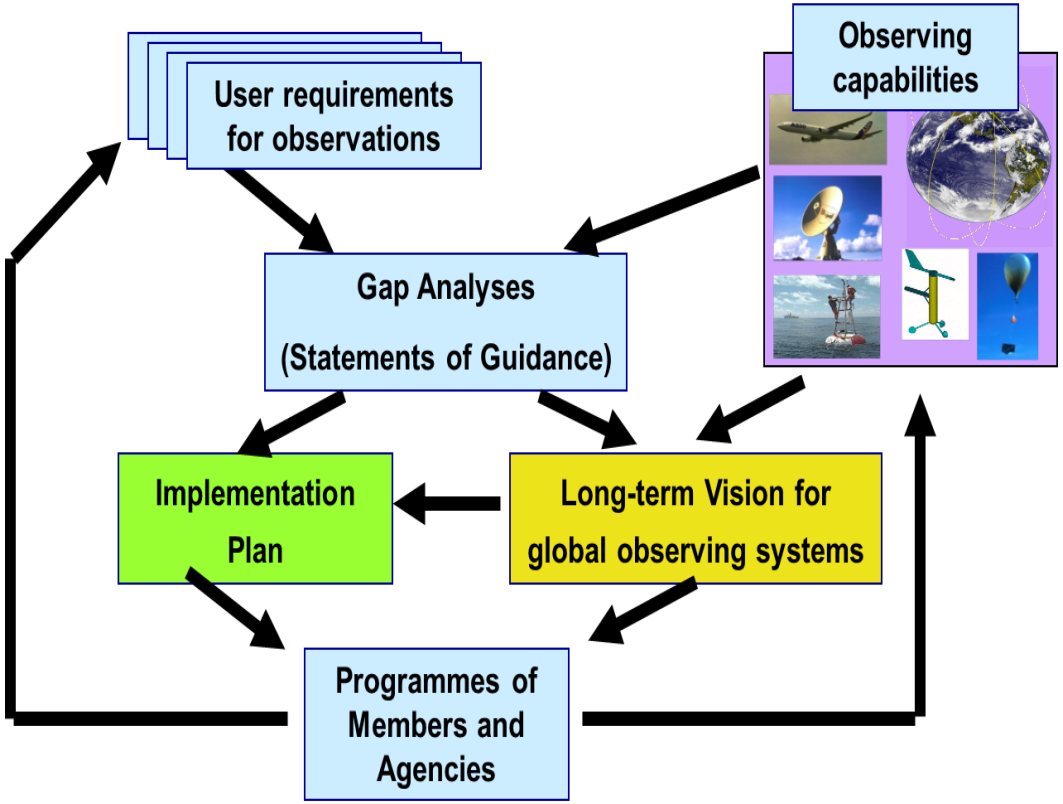
IV. Regional Structure; *Regional WIGOS Centers*

V. National WIGOS Implementation, coordination and governance mechanisms

Rolling Review of Requirements (RRR)

- WMO Congress: All WMO and WMO co-sponsored observing systems shall use the RRR to design networks, plan evolution and assess performance.

- The RRR is the process used by WMO to collect, vet and record user requirements **for all WMO application areas** and match them against observational capabilities



Rolling Review of Requirements

WIGOS Information Resource (OSCAR)

- The RRR is supported by three key databases of **OSCAR**, the *Observation Systems Capabilities and Review* tool :
  - **OSCAR/Requirements**, in which "technology free" requirements are provided for each application area, expressed in units of geophysical variables (260 in total currently);
  - **OSCAR/Space,** listing the capabilities of all satellite sensors, whether historical, operational or planned
  - **OSCAR/Surface,** list surface-based capabilities; developed by MeteoSwiss for WMO, operational since May 2016

OSCAR homepage

OSCAR/Requirements

- The following requirements are listed for each of the (currently 14 application) areas and for all relevant geophysical variables:
  - Spatial (horizontal and vertical) and temporal resolution, uncertainty, data latency, required coverage area, source, and level of confidence
- Each requirement is expressed in terms of three separate values:
  - Threshold (observations not useful unless this is met)
  - Break-through (optimum cost-benefit ratio)
  - Goal (exceeding this provides no additional benefit)
- OSCAR/Requirements information content is assembled by CBS and other WMO Inter-Program Expert Teams and Task Teams and is informed by the broader scientific community, e.g. via WMO Impact Workshops

OSCAR

Observing Systems Capability Analysis and Review Tool

Variable: Wind (horizontal)

Definition

Full name	Wind (horizontal)		
Definition	3D field of the horizontal vector component (2D) of the 3D wind vector. The acuracy is meant as vector error, i.e. the module of the vector difference between the observed vector and the true vector.		
Measuring Units	$m.s^{-1}$	**Uncertainty Units**	$m.s^{-1}$
Horizontal Res Units	km	**Vertical Res Units**	km
Stability Units	$m.s^{-1}$ (Stability /decade)		

Comment:	
Last modified:	

Classification

- **Domain:** Atmosphere
  - **Sub-domain:** Basic atmospheric
    - **Variable:** Wind (horizontal)
      - **Measured in Layers:**
        - HS&M
        - LS
        - HT
        - LT
        - LoThermo
        - HiThermo
- **Cross-cutting themes:**
- **Used in Application Areas:**
  - Aeronautical Meteorology
  - Climate-AOPC
  - Climate Modelling
  - Research
  - Global NWP
  - High Res NWP
  - Nowcasting / VSRF
  - Ocean Applications
  - SPARC
  - Space Weather

Requirements defined for *Wind (horizontal)* (25)

This tables shows all related requirements. For more operations/filtering, please consult the full list of Requirements

Note: In reading the values, goal is marked blue, breakthrough green and threshold orange

Id	Variable	Layer	App	Uncertainty	Stability	Hor	Ver	Obs	Timeliness	Coverage	Conf	Val	Source

			Area		/ decade	Res	Res	Cyc			Level	Date	
119	Wind (horizontal)	HS&M	Climate-AOPC	2 $m.s^{-1}$ 3 $m.s^{-1}$ 7 $m.s^{-1}$		100 km 200 km 500 km		3 h 4 h 6 h	3 h 6 h 12 h	Global	firm	2007-07-19	AOPC
120	Wind (horizontal)	HT	Climate-AOPC	2 $m.s^{-1}$ 3 $m.s^{-1}$ 5 $m.s^{-1}$		100 km 200 km 500 km		3 h 4 h 6 h	3 h 6 h 12 h	Global	firm	2007-07-19	AOPC
121	Wind (horizontal)	LS	Climate-AOPC	2 $m.s^{-1}$ 3 $m.s^{-1}$ 5 $m.s^{-1}$		100 km 200 km 500 km	0.5 km 0.65 km 1 km	3 h 4 h 6 h	3 h 6 h 12 h	Global	firm	2007-07-19	AOPC
122	Wind (horizontal)	LT	Climate-AOPC	2 $m.s^{-1}$ 3 $m.s^{-1}$ 5 $m.s^{-1}$		100 km 200 km 500 km		3 h 4 h 6 h	3 h 6 h 12 h	Global	firm	2007-07-19	AOPC
22	Wind (horizontal)	HT	Aeronautical Meteorology	2 $m.s^{-1}$ 2.7 $m.s^{-1}$ 5 $m.s^{-1}$		50 km 63 km 100 km	0.15 km 0.238 km 0.6 km	5 min 6 min 10 min	60 min 84 min 3 h	Global	firm	2000-06-23	ET ODRRGO
23	Wind (horizontal)	LS LT	Aeronautical Meteorology	2 $m.s^{-1}$ 3 $m.s^{-1}$ 5 $m.s^{-1}$		50 km 70 km 100 km	0.15 km 0.3 km 0.6 km	5 min 7 min 10 min	60 min 90 min 3 h	Global	firm	2000-06-23	ET ODRRGO
239	Wind (horizontal)	HS&M	Climate Modelling Research	3 $m.s^{-1}$ 4 $m.s^{-1}$ 5 $m.s^{-1}$		50 km 100 km 500 km	2 km 3 km 5 km	3 h 6 h 12 h	30 d 45 d 60 d	Global	reasonable	1998-10-29	WCRP
240	Wind (horizontal)	LS HT LT	Climate Modelling Research	1 $m.s^{-1}$ 2 $m.s^{-1}$ 4 $m.s^{-1}$		10 km 50 km 250 km	0.2 km 1 km 3 km	60 min 3 h 6 h	30 d 45 d 60 d	Global	reasonable	2012-12-01	WCRP
310	Wind (horizontal)	HS&M	Global NWP	1 $m.s^{-1}$ 5 $m.s^{-1}$ 10 $m.s^{-1}$		50 km 100 km 500 km	1 km 2 km 3 km	60 min 6 h 12 h	6 min 30 min 6 h	Global	firm	2009-02-10	John Eyre
311	Wind (horizontal)	HT	Global NWP	1 $m.s^{-1}$ 3 $m.s^{-1}$ 8 $m.s^{-1}$		15 km 100 km 500 km	0.5 km 1 km 3 km	60 min 6 h 12 h	6 min 30 min 6 h	Global	firm	2009-02-10	John Eyre
312	Wind (horizontal)	LS	Global NWP	1 $m.s^{-1}$ 3 $m.s^{-1}$		15 km 100 km	0.5 km 1 km	60 min 6 h	6 min 30 min	Global	firm	2009-02-10	John Eyre

OSCAR/Space

- Repository of metadata about *all satellite sensors (past, present and future) relevant to WMO Programs and Application Areas*
  - Instrument type, measurement technique, high-level characteristics (mass, power, data rate)
  - Programmatic information, e.g. agency, measurement program, operating period, heritage, etc.
  - Orbit, coverage, repeat frequency, resolution
  - ***Capabilities, expressed in terms of geophysical variables that can be derived from the measurements provided by the sensor, listed in order of decreasing fidelity***
- OSCAR/Space 2.0 released in June 2016
  - Objective, rule-based assessment of capabilities

Unique to OSCAR/Space

OSCAR

Observing Systems Capability Analysis and Revi

Home | Observation Requirements | Space-based Capabili

Overview | Programmes | Satellites | Instruments | Frequencies | Ag

Instrument: AIRS

Instrument details

Acronym	AIRS			
Full name	Atmospheric Infra-Red Sounder			
Purpose	Temperature/humidity sounding, ozone pro green-house gases			
Short description	Grating spectrometer, 2378 channels, reso supporting channels in VIS/NIR [see detail below]			
Background	New development			
Scanning Technique	Cross-track: 90 samples scanned, swath 1 one 13.5-km line each 2.67 s			
Resolution	13.5 km IFOV for the spectrometer; 2.3 km channels			
Coverage / Cycle	Global coverage once/day			
Mass	177 kg	Power	220 W	Data

Providing Agency	NASA
Instrument Maturity	Flown on an R&D satell
Utilization Period:	2002-09-01 to ≥2016
Last update:	2012-09-05

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Variable	Relevance for measuring this variable	Operational limitations	Explanation
Cloud top height	1 - primary	Discontinuous coverage.	MWIR and TIR spectrometry in window and water vapour band (for emissivity) to estimate cloud top height from its temperature
Cloud top temperature	1 - primary	Discontinuous coverage.	TIR spectrometry in window and water vapour band (for emissivity)
Sea surface temperature	1 - primary	Cloud sensitive.	MWIR and TIR spectrometry (inclusive of several narrow-bandwidth windows and absorption bands for atmospheric corrections)
Atmospheric temperature	2 - very high	Cloud sensitive.	MWIR spectrometry in the CO2 4.3 micrometer band; TIR in the CO2 15 micrometer band
Cloud cover	2 - very high	Discontinuous coverage.	MWIR and TIR spectrometry
Land surface temperature	2 - very high	Cloud sensitive. Coarse spatial resolution.	MWIR and TIR spectrometry (inclusive of several narrow-bandwidth windows and absorption bands for atmospheric corrections)
Specific humidity	2 - very high	Cloud sensitive.	TIR spectrometry in the water vapour band around 6.3 micrometers
Integrated Water Vapour (IWV)	2 - very high	Cloud sensitive.	TIR spectrometry in the bands around 6.3 and above 11 micrometers
Upward long-wave irradiance at	2 - very high	Spectral interpolation needed	MWIR and TIR spectrometry in the windows regions around 3.7 and 11 micrometers, and in water vapour and CO2 bands around 4.3, 6.3 and

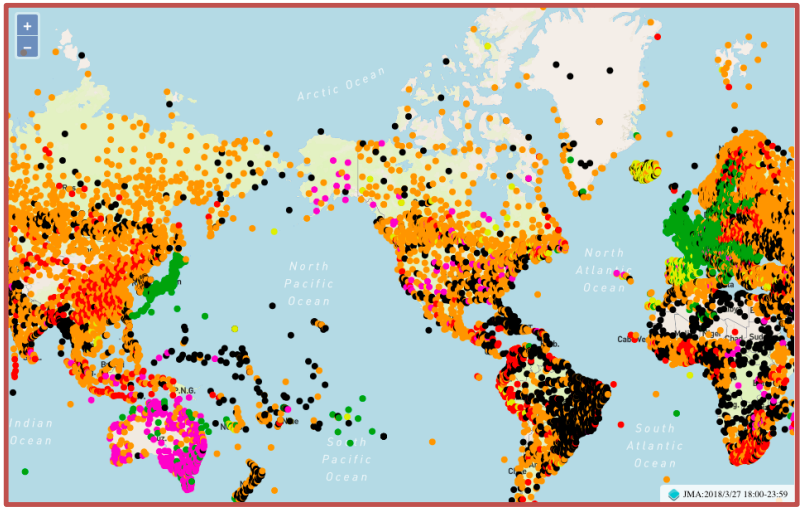
Showing 1 to 30 of 33 entries

OSCAR/Surface

("What is WIGOS?"; more in tomorrow's presentation)

- Implementation layer of the *WIGOS Metadata Standard*: **Modern, electronic, searchable inventory of metadata for all observing stations/platforms under WIGOS**
  - OSCAR/Surface will replace *WMO Pub. 9, Volume A*, but will also include information from similar inventories for other (non-GOS) components of WIGOS
  - Developed jointly by WMO and MeteoSwiss, with the Swiss government providing the major part of the funding
  - Operational since May 2016
  - Education and training Members in populating, editing and using OSCAR/Surface is a major priority for 2016-2019 financial period

WIGOS Data Quality Monitoring System (WDQMS; more in tomorrow's presentation)



- Real-time monitoring of performance (data availability and data quality) of all WIGOS components, searchable by region, country, station type, period, etc.;
- Delayed mode monitoring of data quality as measured against reference sources of information to be included for other observations;
- Incident management component for mitigation of performance issues;
- **The WDQMS describes how well WIGOS is functioning**
- **Pilot project, NWP-based monitoring; ECMWF, NCEP, DWD, JMA;**
- **NWP Pilot has led directly to GBON development (next slides).**

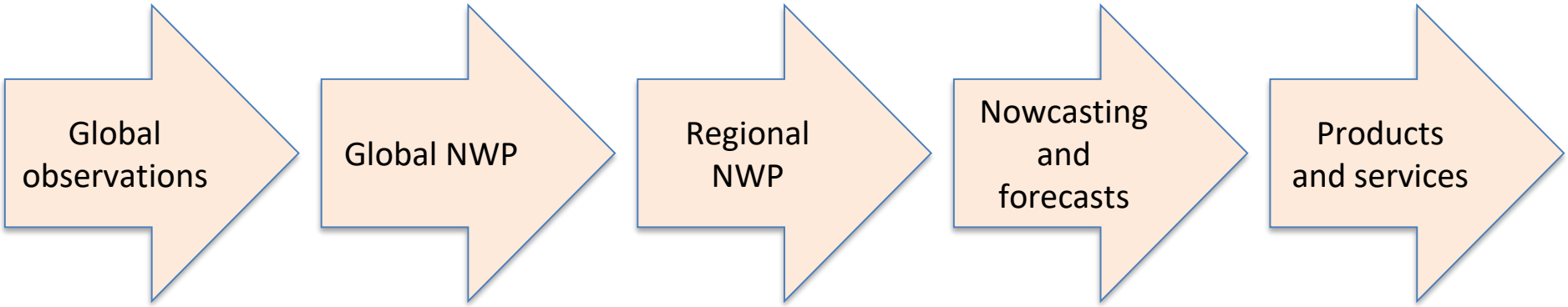
WMO Application Areas listed in the RRR (January 2017)

1. **Global numerical weather prediction**
2. High-resolution numerical weather prediction
3. Nowcasting and very short range forecasting
4. Seasonal and inter-annual forecasting
5. Aeronautical meteorology
6. Forecasting atmospheric composition
7. Monitoring atmospheric composition
8. Atmospheric composition for urban applications
9. Ocean applications
10. Agricultural meteorology
11. Hydrology
12. Climate monitoring *(currently under revision by GCOS and WCRP)*
13. Climate applications *(currently under revision by GCOS and WCRP)*
14. Space weather

Why focus on application area 1: Global NWP?

- Global Numerical Weather Prediction is a foundational activity for nearly all weather and climate applications
- Global NWP is a pre-requisite for all higher resolution NWP and related quantitative methods used for nowcasting and short-range prediction, also for hurricanes
  - Global NWP shares many of its requirements with high resolution NWP, except the latter are even more stringent
- Global NWP requires global observational data and is as such fully dependent on international data exchanged coordinated by WMO

Importance of Global Numerical Weather Prediction (NWP) for all WMO Members



Without **local observations**, both global, regional and mesoscale NWP guidance will be poor;

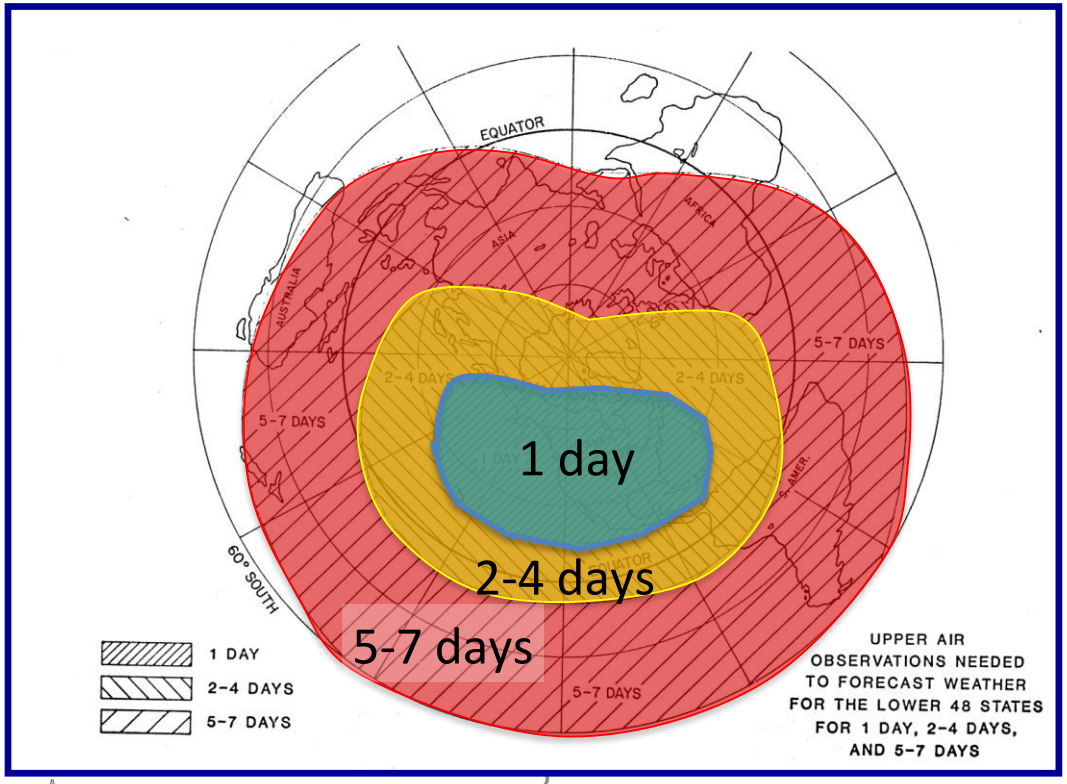
- Leading in turn to poor basis for weather and climate services at all forecast ranges;

- This issue affects all WMO Members, but it is particularly serious in the tropics

Why is it important to have observations everywhere?

Global Numerical Weather Prediction (NWP):

- is a **foundational capability** for weather forecasting climate reanalysis
- needs observations **everywhere** for accurate predictions **anywhere**



Weather prediction beyond the 3-4 day range essentially requires observations from the whole world;

WMO is the only organization with the mechanisms to provide these observations.

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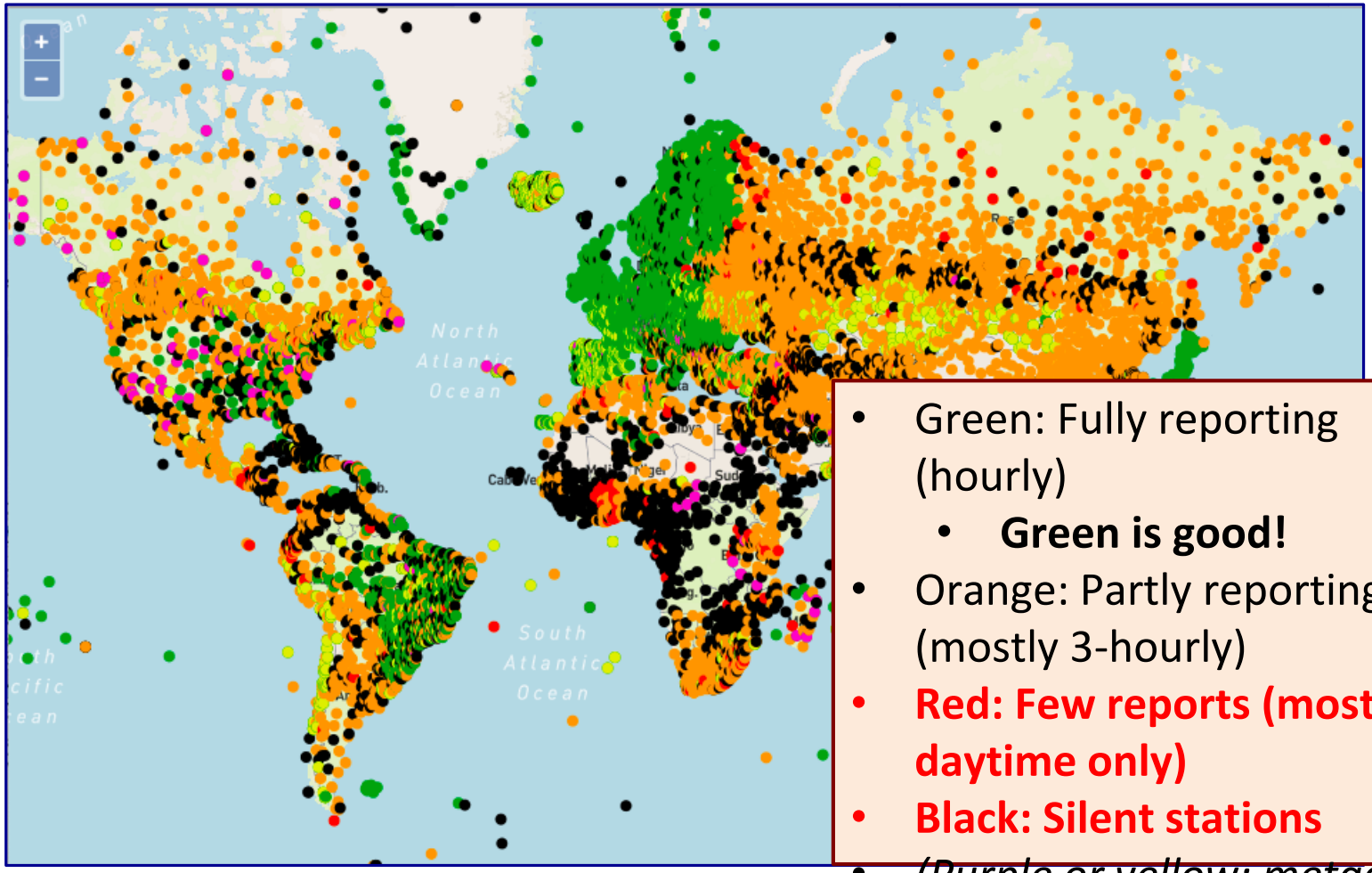
Where are we currently missing observations?

(surface-based; satellite data can help, but cannot do the job alone)



- Green: Fully reporting (hourly)
  - **Green is good!**
- Orange: Partly reporting (mostly 3-hourly)
- **Red: Few reports (mostly daytime only)**
- **Black: Silent stations**
- *(Purple or yellow: metadata problems)*

Surface pressure obs available to global NWP Centres on 17 February 2019, 18Z

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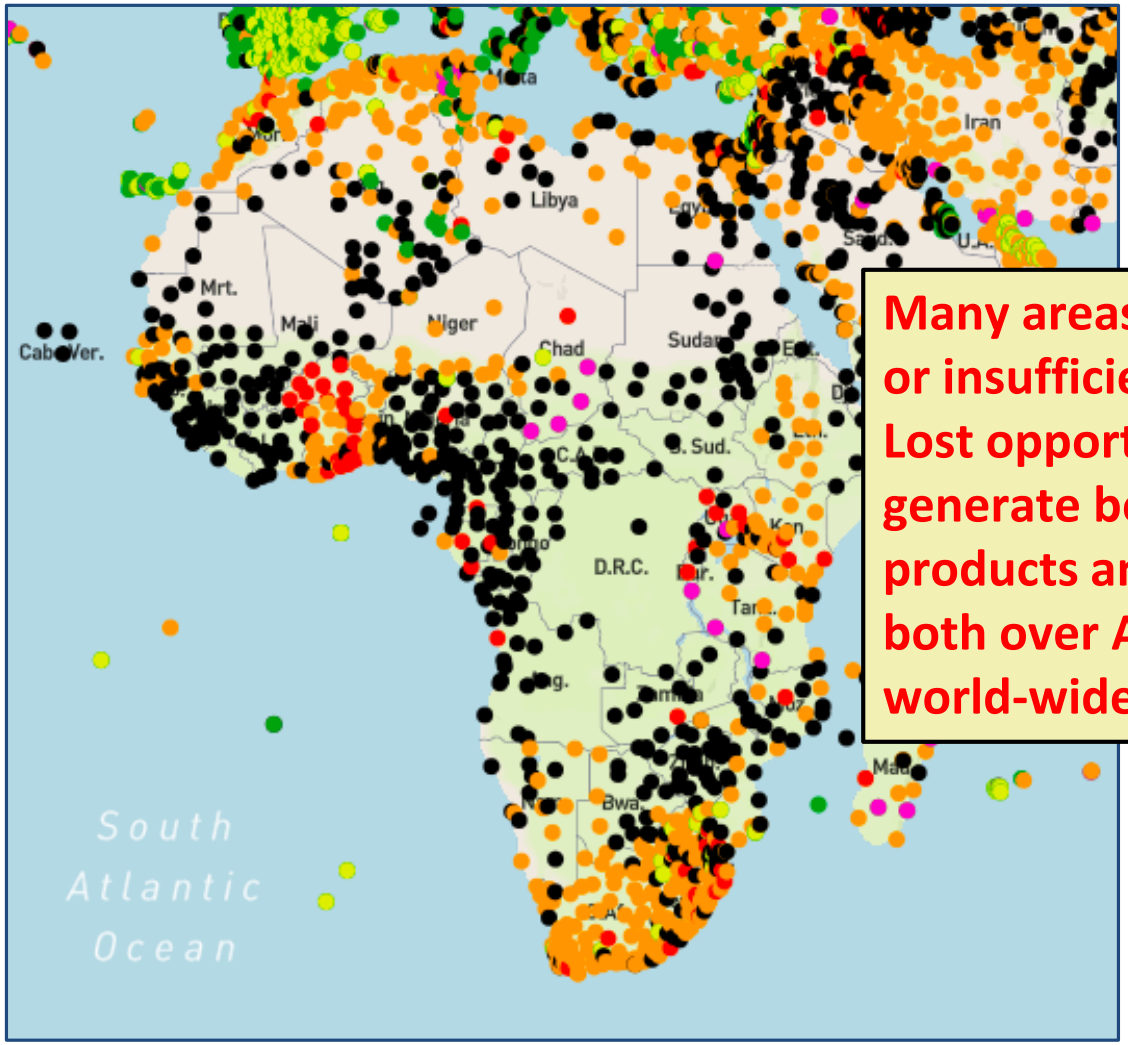
Missing surface observations over Africa



Many areas of missing or insufficient data: Lost opportunities to generate better products and services both over Africa and world-wide

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What is WMO doing about this problem?

- With the aim of improving the exchange of observational data for global NWP, EC-70 (June 2018) requested:
  - CBS to *develop an overarching design for the **Global Basic Observing Network (GBON)** that meets threshold requirements for Global Numerical Weather Prediction and Global Climate Monitoring (Analysis) according to WMO Rolling Review of Requirements*
  - *The Inter-Commission Coordination Group on WIGOS to develop relevant provisions of the Manual on WIGOS regarding the implementation of the GBON and propose them to Cg-18 in 2019*

- ***By WMO standards, this is an extremely rapid development schedule***
- ***Testament to the EC view of the importance of this issue!***

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Draft GBON provisions: Surface Observations
(to be submitted to Cg-18 for approval)

- 3.2.2.4 Members **shall** operate a set of surface land observing stations/platforms that observe atmospheric pressure, air temperature, humidity, horizontal wind, precipitation and snow depth, located such that the GBON has a **horizontal resolution of 500 kilometres or higher** for all of these variables, with an **hourly frequency**.

- 3.2.2.5 Members **should** make available additional surface land observations of atmospheric pressure, air temperature, humidity, horizontal wind, precipitation and snow depth that enable GBON to have a **horizontal resolution of 100 kilometres or higher** for all of these variables, with an **hourly frequency**.

Draft GBON provisions: Upper air observations
(to be submitted to Cg-18 for approval)

- 3.2.2.7 Members **shall** operate a set of upper air stations over land that observe temperature, humidity and horizontal wind profiles, with a vertical resolution of 100 m or higher, **twice a day** or better, up to a level of 30 hPa or higher, located such that GBON has a **horizontal resolution of 500 kilometres or higher** for these observations.

- 3.2.2.8 Members **should** operate a subset of the selected GBON upper air observing stations that observe temperature, humidity and horizontal wind profiles up to 10 hPa or higher, at least once per day, located such that, where geographical constraints allow, GBON has a **horizontal resolution of 1000 kilometres or higher**, for these observations.

4.1 What are the benefits of GBON to WMO Members?

- **Better global coverage, leading to better global NWP output; direct benefits, as well as indirect benefits, thanks to better boundary conditions for regional/mesoscale NWP;**
- Observations are valuable, but single observations have little value in and of themselves;
  - **International data exchange is massive global multiplier on investment in observations;**
  - Like a jigsaw puzzle, the full benefits of a global observing system can be realized only if all (or nearly all) the pieces are made available.

What is the requirement for individual WMO Members?

- Four categories of implementation (examples):
  1. **Members already complying with the GBON provisions** (e.g. Japan, Western Europe) – *no further action is needed;*
  2. **Members where GBON-compliant observations are made, but not currently exchanged**, (e.g. USA, China) - *new data exchange practices must be adopted;*
  3. **Members with insufficient national resources,** (e.g. parts of Africa, Caribbean, South Pacific); *use GBON to help steer internationally funded development projects toward integrated observing systems set up for international data exchange;*
  4. **Areas where GBON requirements are not met due to geographic constraints;** (e.g. Indian Ocean, North Pacific) – *opportunities for new technologies, satellite remote sensing.*

Summary and Conclusions

- WIGOS Pre-operational Phase 70% completed; main technical systems implemented/under implementation;
- All three OSCAR databases are now operational;
- OSCAR/Surface has replaced WMO Pub. 9, Vol. A as the official WMO station catalog;
- WDQMS already providing powerful diagnostics of the workings of WIGOS/WIS and the compliance of WMO Members with WMO regulatory and guidance material;
  - Room for very substantial improvement!
  - This is a limiting factor in the quality of monitoring, forecast and warning products;
  - GBON development is a direct result of WDQMS!