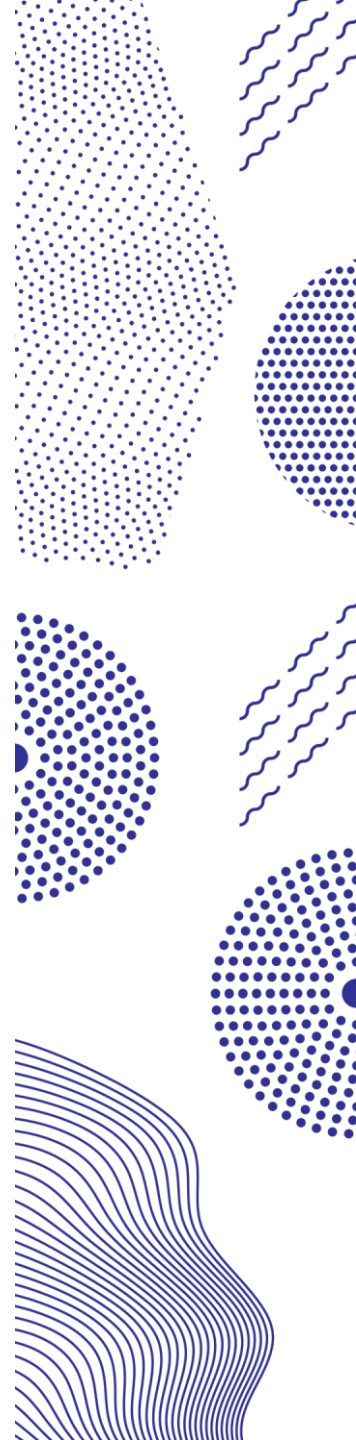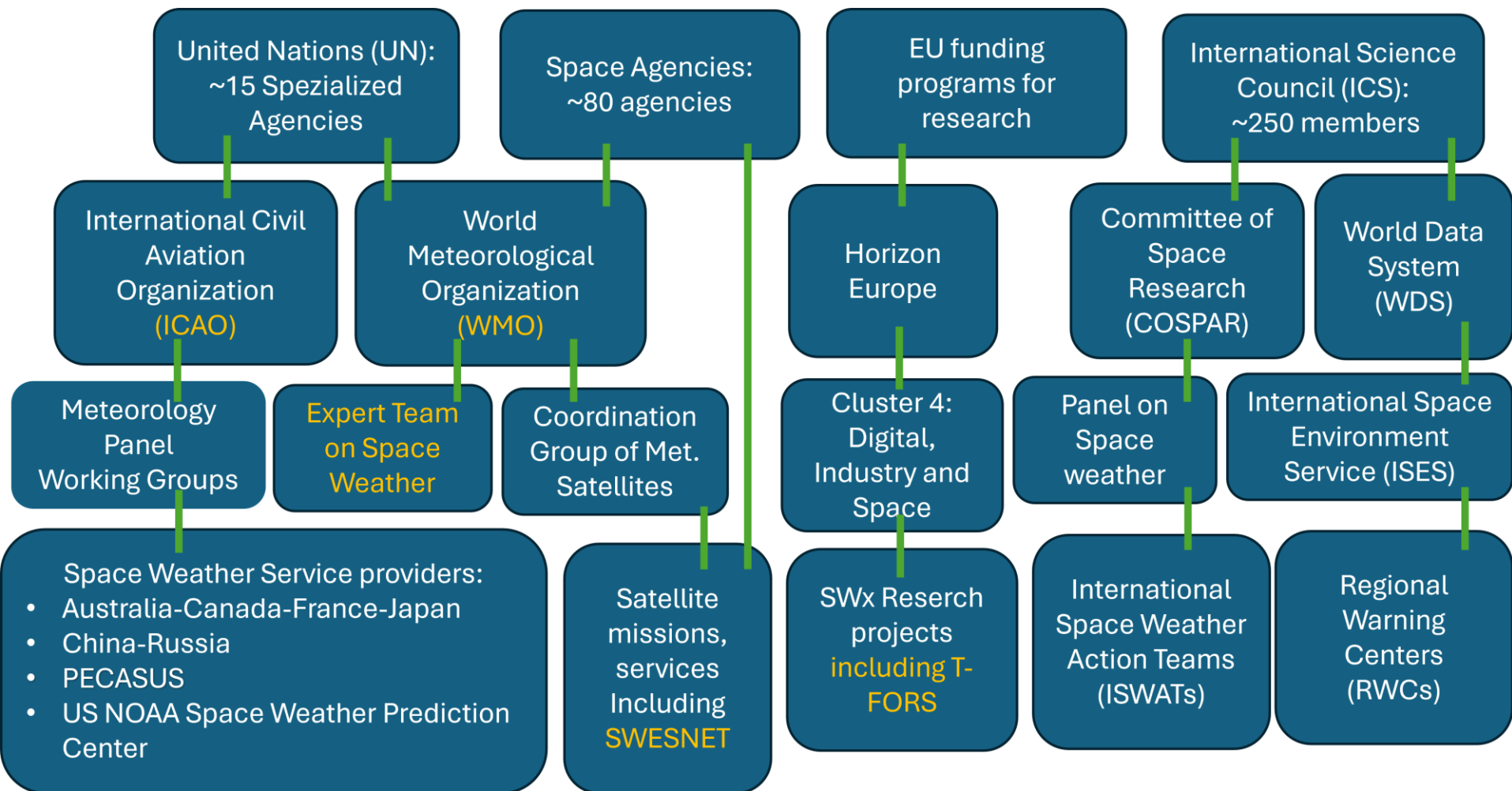# T-FORS prototype services compared with WMO aspirations on space weather service
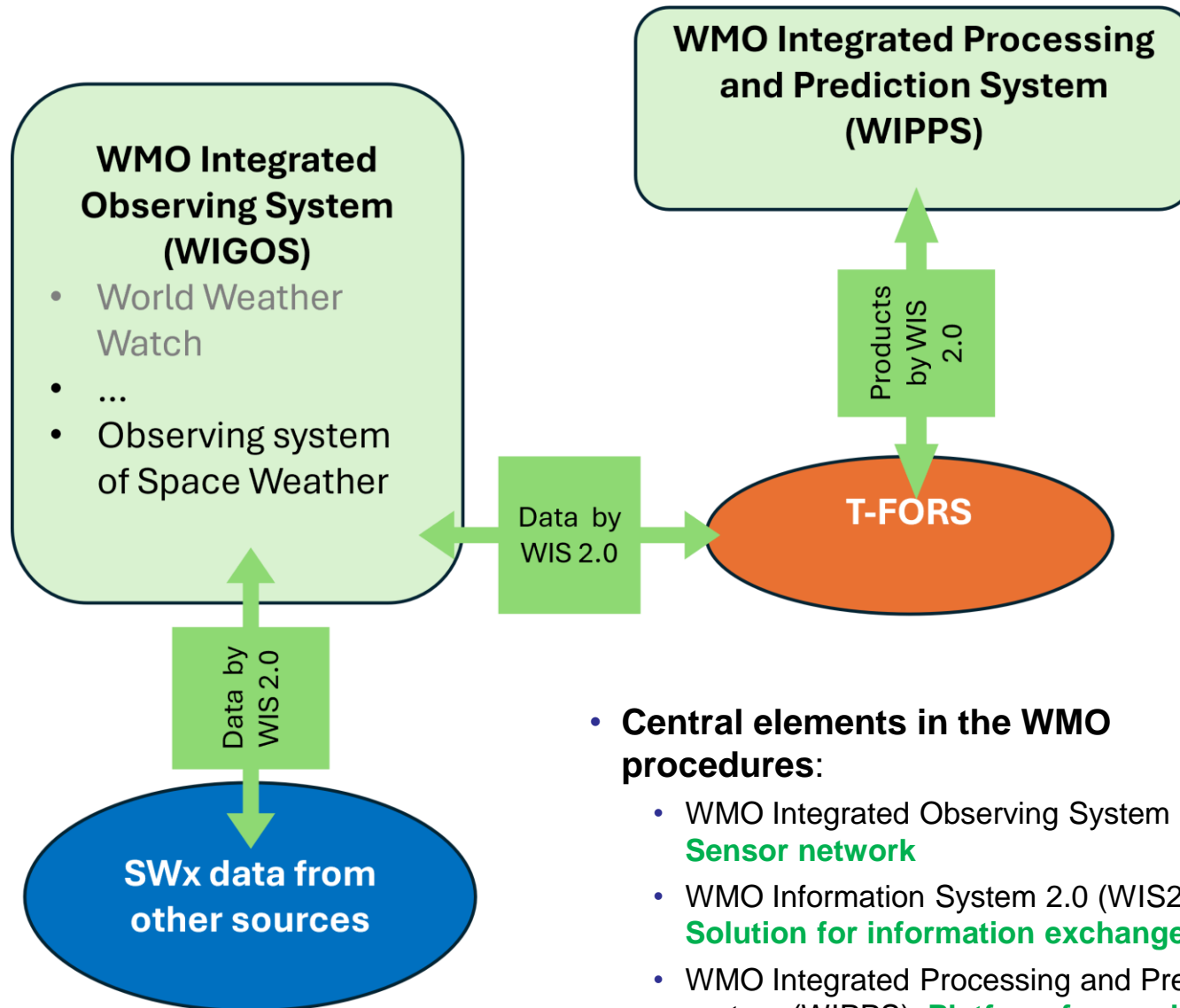
Kirsti Kauristie

Finnish Meteorological Institute

Space weather networking from Top to Bottom

United Nations (UN): ~15 Spezialized Agencies

Space Agencies: ~80 agencies

EU funding programs for research

International Science Council (ICS): ~250 members

International Civil Aviation Organization (ICAO)

World Meteorological Organization (WMO)

Horizon Europe

Committee of Space Research (COSPAR)

World Data System (WDS)

Meteorology Panel Working Groups

Expert Team on Space Weather

Coordination Group of Met. Satellites

Cluster 4: Digital, Industry and Space

Panel on Space weather

International Space Environment Service (ISES)

Space Weather Service providers:
- Australia-Canada-France-Japan
- China-Russia
- PECASUS
- US NOAA Space Weather Prediction Center

Satellite missions, services Including SWESNET

SWx Reserch projects including T-FORS

International Space Weather Action Teams (ISWATs)

Regional Warning Centers (RWCs)

How T-FORS could be integrated with WMO?

WMO Integrated Processing and Prediction System (WIPPS)

WMO Integrated Observing System (WIGOS)
- World Weather Watch
- ...
- Observing system of Space Weather

Data by WIS 2.0

Products by WIS 2.0

T-FORS

Data by WIS 2.0

SWx data from other sources

- **Central elements in the WMO procedures**:
  - WMO Integrated Observing System (WIGOS): **Sensor network**
  - WMO Information System 2.0 (WIS2.0): **Solution for information exchange**
  - WMO Integrated Processing and Predictions system (WIPPS): **Platform for products**

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Why this is a tempting idea?

- T-FORS has conducted R&D on standards which are relevant for WMO
  - Data policy (FAIR, Research Data Alliance)
  - Metadata model (SPASE)
  - Standards for observations quality
- Particularly the topic of MSTIDs is linked with other disciplines of WMO interests (atmospheric gravity waves)
- With additional development T-FORS products have relevance in global scales
  - Tsunamis and tropical cyclones
  - Civil aviation
- T-FORS products use data from a representative set of key instruments → A good pilot case observing requirements
  - Solar wind data, F10.7
  - Ionosondes and magnetometers

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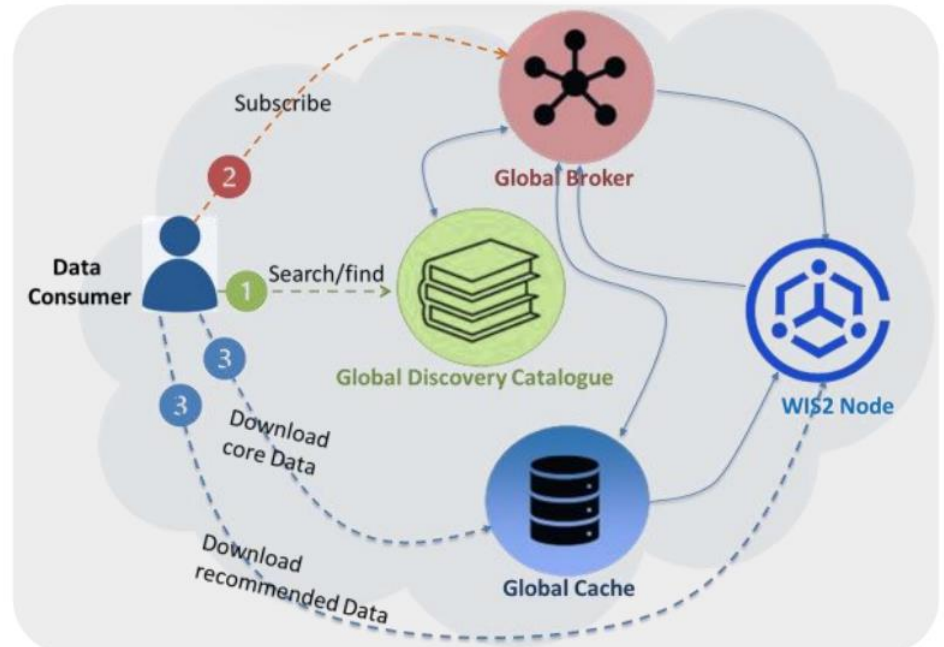
But what are the challenges?

- The work for SWx concrete integration into WMO is still at its very beginning
  - First tests on WIS2.0 for ionosonde data sharing are under work
  - SWx Observing system is mentioned in the WIGOS Manual, but exact description of the system and its sensors is still missing

- Data Policy issues
  - FAIR principles designed primarily for research
  - WMO has policies for operational services
    - Core data shall be open for all
    - Recommended data can be restricted but only partly supported by WIS2.0

- Lack of motivation
  - SWx community has already several nice platforms for sharing their products and services
  - Who pays for the extra work to become WMO compliant?

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Why WIS2.0 for Space Weather?

- Enables one unified machinery for dissemination of
    - Satellite data
    - Ground-based data
    - Products, forecasts
- Facilitates inter-comparisons and verification
- Notifications about NRT data availability for automated fetching
- Cache memory support for *core data* available
- First experiments of dissemination of *recommended data* can be conducted in the WIS2inbox Free and Open Source Software (has been tested between INPE and FMI)

Harvesting WIS2.0 with its all benefits will require adaptation on both sides – space weather and WMO.

OSCAR & User requirements

- WIPPS development shall be based on Rolling Review Requirements which specify the user needs of the application area.

- T-FORS user requirements
  - TID nowcasts, warnings, and retrospective analyses
  - Time resolution 5 min, space resolution ~50 km, intensity with four severity levels
  - Latencies 15 min, 1 hour, 2 hours
  - What are the requirements for input observables?

- The requirements for observations can be specified in the WMO Observing Systems Capability Analysis and Review (OSCAR). Examples of relevant parameters under discussions:
  - Ionosonde parameters
  - WMO collaborates with CGMS for long term plans to ensure availability of solar wind parameters

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Example: Form for foF2

Measured quantity: Highest frequency which reflects back from the ionosphere
Physical variable: Maximun electron density in the ionosphere

Please click on the help icon for a explanation of the values required.

Uncertainty Goal	**Uncertainty Breakthrough**	**Uncertainty Threshold**	**Uncertainty Priority ***
0.05 MHz	0.1 MHz	0.2 MHz	1.0
Stability Goal	**Stability Breakthrough**	**Stability Threshold**	**Stability Priority ***
0.05 MHz	0.1 MHz	0.2 MHz	1.0
Hr Goal	**Hr Breakthrough**	**Hr Threshold**	**Hr Priority ***
100 km	200 km	500 km	0.8
Vr Goal	**Vr Breakthrough**	**Vr Threshold**	**Vr Priority ***
			0.5
Layer/s Quality Goal	**Layer/s Quality Breakthrough**	**Layer/s Quality Threshold**	**Layer/s Quality Priority ***
			0.5
Oc Goal	**Oc Breakthrough**	**Oc Threshold**	**Oc Priority ***
5 minutes	15 minutes	60 minutes	0.8
Timeliness Goal	**Timeliness Breakthrough**	**Timeliness Threshold**	**Timeliness Priority ***
1 minutes	10 minutes	60 minutes	0.8
Coverage Quality Goal	**Coverage Quality Breakthrough**	**Coverage Quality Threshold**	**Coverage Quality Priority ***
			0.5

??

Difficulties to fill these fields with proposed information: populated areas/land areas/Globally

WMO OMM

WIGOS Metadata standard & SPASE Data, Origination, and Infra Resources

/1/ observed variable

Specifies the basic characteristics of the observed variable and resulting datasets. It includes an element describing spatial representativeness of the observations as well as the biogeophysical compartment.

+ observed variable – measurand [1]**
+ measurement unit [0..1]** (mandatory for measured variables)
+ temporal extent [1]
+ spatial extent [1]
+ representativeness of observation [0..1]**

/2/ purpose of observation

Specifies the main application area(s) of the observation and the observing programme(s) and networks an observation is affiliated to.

+ application area(s) [0..1]**
+ programme/network affiliation [1]**

/3/ station/platform

Specifies the observing facility, including fixed station, moving equipment or remote-sensing platform, at which an observation is made.

+ region of origin of data [0..1] (a)**
+ territory of origin of data [0..1] (a)**
+ station/platform name [1]
+ station/platform type [1]**
+ station/platform unique identifier [1]
+ geospatial location [1]**
+ data communication method [0..1]**
+ station operating status [1]**
+ station/platform cluster [0..1]**

(a) mandatory for fixed land-based stations

/10/ contact

Specifies where information about an observation or dataset can be obtained.

contact (nominated focal point) [1]**

/9/ ownership and data policy

Specifies who is responsible for the observation and owns it.

+ supervising organization [1]
+ data policy/use constraints [1]**

/4/ environment

Describes the geographical environment within which the observation is made. It also provides an unstructured element for additional meta-information that is considered relevant for adequate use of the observations and that is not captured anywhere else in the standard.

+ surface cover [0..1]** (a)
+ surface cover classification scheme [0..1]** (a)
+ topography or bathymetry [0..1]** (a)
+ events at observing facility [0..1]**
+ site information [0..1]**
+ surface roughness [0..1]**
+ climate zone [0..1]**

(a) mandatory for surface-based observations

WIGOS Metadata Standard v1.02

+ /1/ observed variable
+ /2/ purpose of observation
+ /3/ station/platform
+ /4/ environment
+ /5/ instruments and methods of observation
+ /6/ sampling
+ /7/ data processing and reporting
+ /8/ data quality
+ /9/ ownership and data policy
+ /10/ contact

/8/ data quality

Specifies the data quality and traceability of the observation.

+ uncertainty of measurement [0..1] (b)
+ procedure used to estimate uncertainty [0..1]** (a)
+ quality flag [0..1]** (c)
+ quality flagging system [0..1]** (a)
+ traceability [1]** (a)

(a) mandatory whenever (b) or (c) are reported, respectively

/7/ data processing and reporting

Specifies how raw data are transferred into the observed variable and reported.

+ data-processing methods and algorithms [0..1]
+ processing/analysis centre [0..1]
+ temporal reporting period [1]**
+ spatial reporting interval [0..1] (a)
+ software/processor and version [0..1]
+ level of data [0..1]**
+ data format [0..1]**
+ version of data format [0..1]
+ aggregation period [1]**
+ reference time [0..1]**
+ reference datum [0..1] (b)
+ numerical resolution [0..1]
+ timeliness (of reporting) [1]
+ schedule of international exchange [1]

(a) mandatory for remote-sensing and mobile stations; (b) mandatory for stations/platforms that report a derived quantity that depends on a local datum.

/6/ sampling

Specifies how sampling and/or analysis are used to derive the reported observation or how a specimen was collected.

+ sampling procedures [0..1]
+ sample treatment [0..1]
+ sampling strategy [0..1]**
+ sampling time period [0..1]
+ spatial sampling resolution [0..1]
+ temporal sampling interval [0..1]
+ diurnal base time [0..1]
+ schedule of observation [1]

/5/ instruments and methods of observation

Specifies the method of observation and describes characteristics of the instrument(s) used to make the observation. If multiple instruments are used to generate it, then this category should be repeated.

+ source of observation [1]**
+ measurement/observing method [1]**
+ instrument specifications [0..1] (a)
+ instrument operating status [0..1]**
+ vertical distance of sensor [0..1] (a) (b)
+ configuration of instrumentation [0..1] (a) (c)
+ instrument control schedule [0..1] (a)
+ instrument control result [0..1]** (a)
+ instrument model and serial number [0..1] (a)
+ instrument routine maintenance [0..1] (a)
+ maintenance party [0..1]
+ geospatial location [0..1] (a) (d)
+ maintenance activity [0..1]
+ status of observation [0..1]**
+ exposure of instruments [0..1]** (a)

(a) mandatory for instrumental observations; (b) mandatory if proximity of ref. surface impacts on observation; (c) mandatory if prescribed by best practice; (d) mandatory if different from station/platform

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About WIPPS (Processing and Prediction) for registered users

WIPPS Web Portal

WIPPS Dashboard

WIPPS Newsletter

Forecast Verification

Data Quality Monitoring

Summary of centers/networks and activity with filtering functionality Links to products

Information about products and their users

Information about upgradings

Reports by Lead Centers who verify forecasts against observations

Reports by Lead Centers who conduct long term data quality monitoring

Comments from the view point of T-FORS

Products maintained as federated services (c.f. SWESNET). TIDs in the context of meteorological phenomena (e.g. tropical cyclones)

A way to follow the users of T-FORS services

Larger reader community for the T-FORS upgradings

Besides forecasts in time also quality of global products should be monitored (performance in regions with sparse or no observations)
Any volunteers for a Lead Center?

E.g. INTERMAGNET/SuperMAG could serve here as a pilot Lead Center for magnetic observatory data.

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Conclusions

- **T-FORS would be a good pilot for WMO collaboration**
  - Preparatory work for standards has partly been done already
  - Relevant products for WMO Early Warnings for All –initiative (Key Action Area: Enhancing Capacity to detect Hazards, including tsunamis, tropical cyclones…)
- **Jump to the "WMO world" will not be easy but doable with additional resources for**
  - Adaptation to the WMO standards and regulations
  - Expanding the scope from Europe to other parts of Globe

Photo: Wikipedia (Avantouinti)

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