Requirements of operational Numerical Weather Prediction

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Acknowledgements:
Clément Albergel
Magdalena Alonso-Balmaseda
Gianpaolo Balsamo
John Eyre
Stephen English
Joaquin Muñoz-Sabater
Patricia de Rosnay, and others

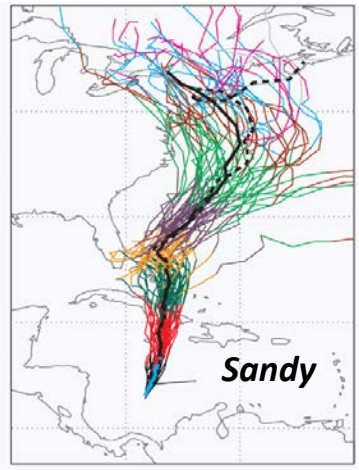
NWP challenges for the next decade

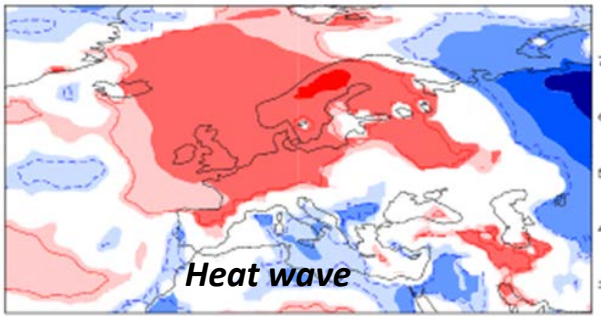
Enhanced predictive skill in key areas:

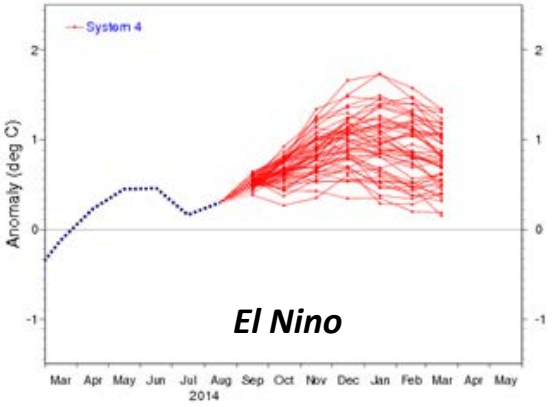
High-impact weather
(medium range, d3-d10)

Weather regimes
(monthly range, d10-d45)

Large-scale anomalies
(seasonal range, d45-365)

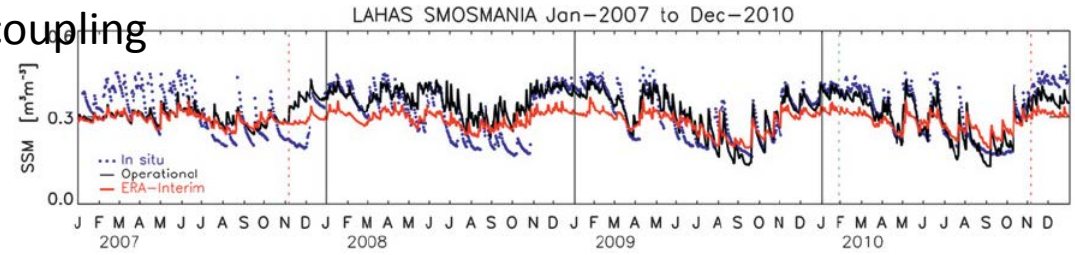






Enhanced climate monitoring capabilities:

- Land – atmosphere coupling
- Ocean – sea-ice – atmosphere coupling



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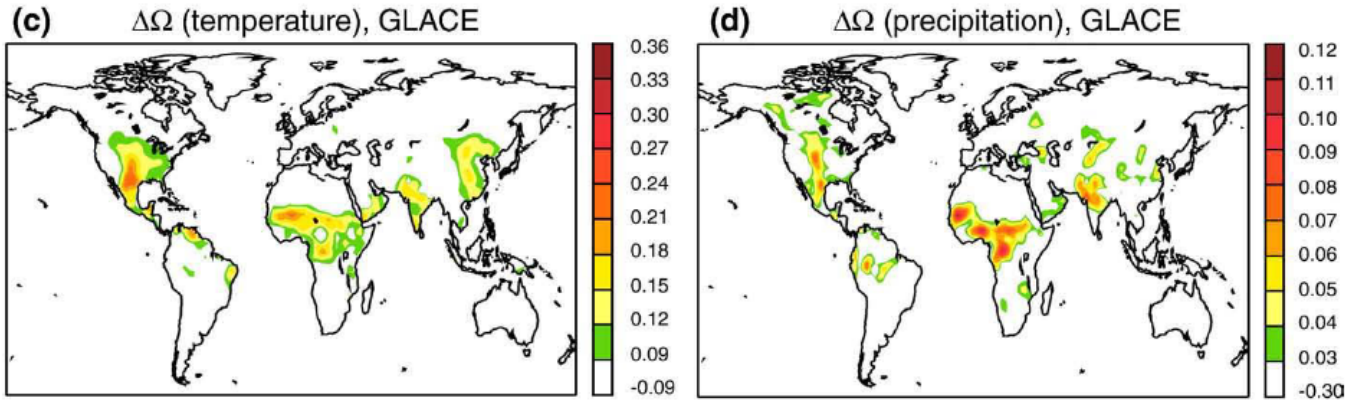
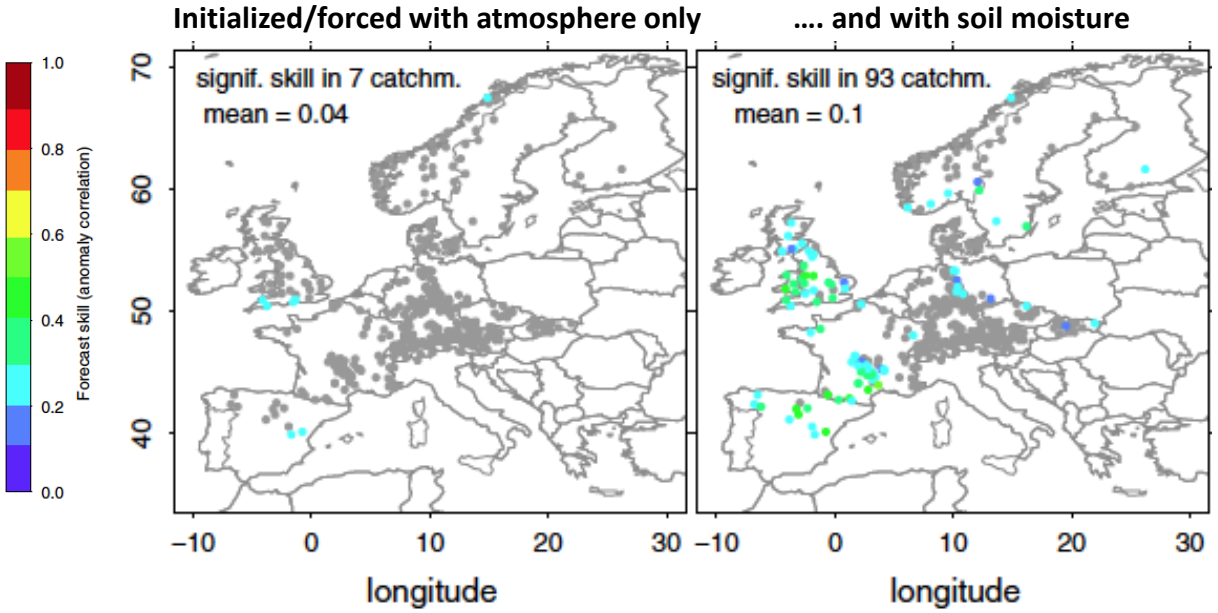
Link climate change - weather: Soil moisture



Areas of strong coupling between soil moisture and temperature or rainfall correspond to **transitional** climate zones (Seneviratne et al. 2010)



Monthly predictive skill (here temperature) needs accurate soil moisture initialization (Orth and Seneviratne 2014)

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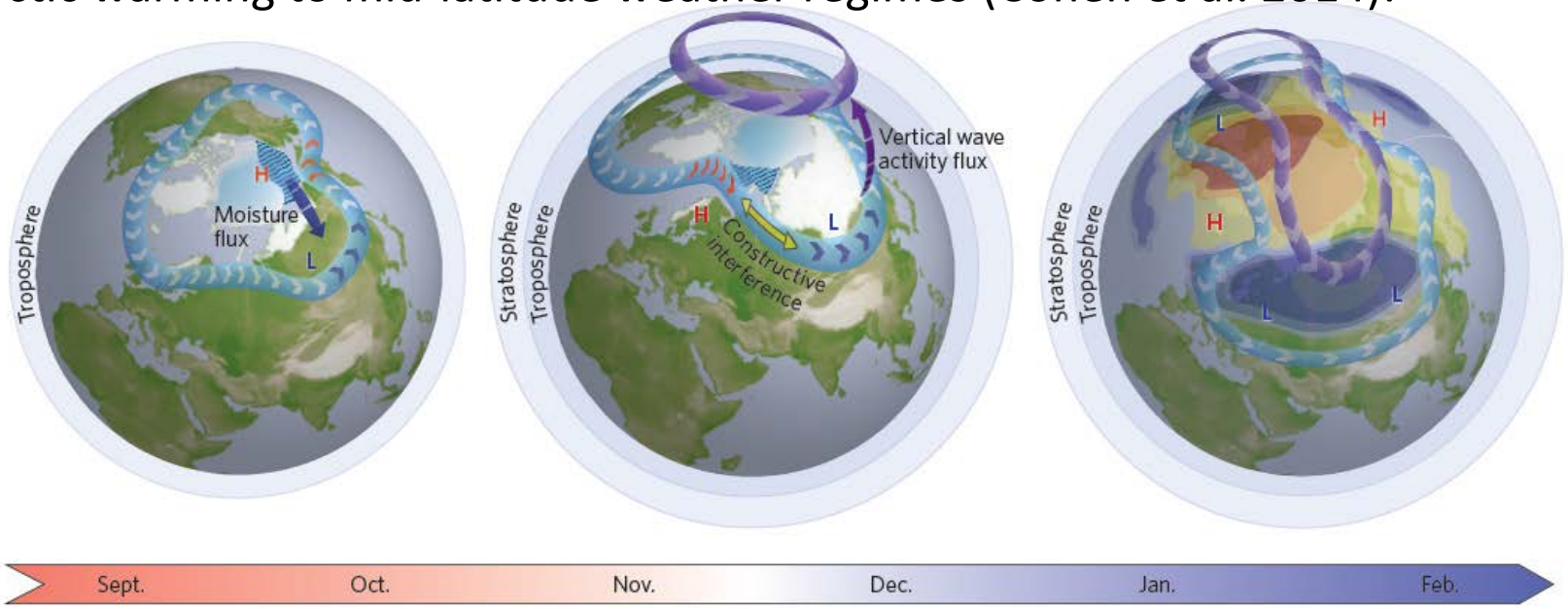
Link climate change - weather: Sea-ice and snow

Conceptual model of cryosphere (Arctic sea-ice and Eurasian snow) linking Arctic warming to mid-latitude weather regimes (Cohen et al. 2014):



Arctic sea-ice loss causes enhanced vertical transport, southward shift of jet with enhanced snowfall downstream, strengthened Arctic dipole, enhanced upward Rossby wave activity, weakened polar vortices, more stable longitudinal forcings

➔ Needs representation in global models and accurate/continuous observation (thin ice regime important as heat fluxes strongly affected)

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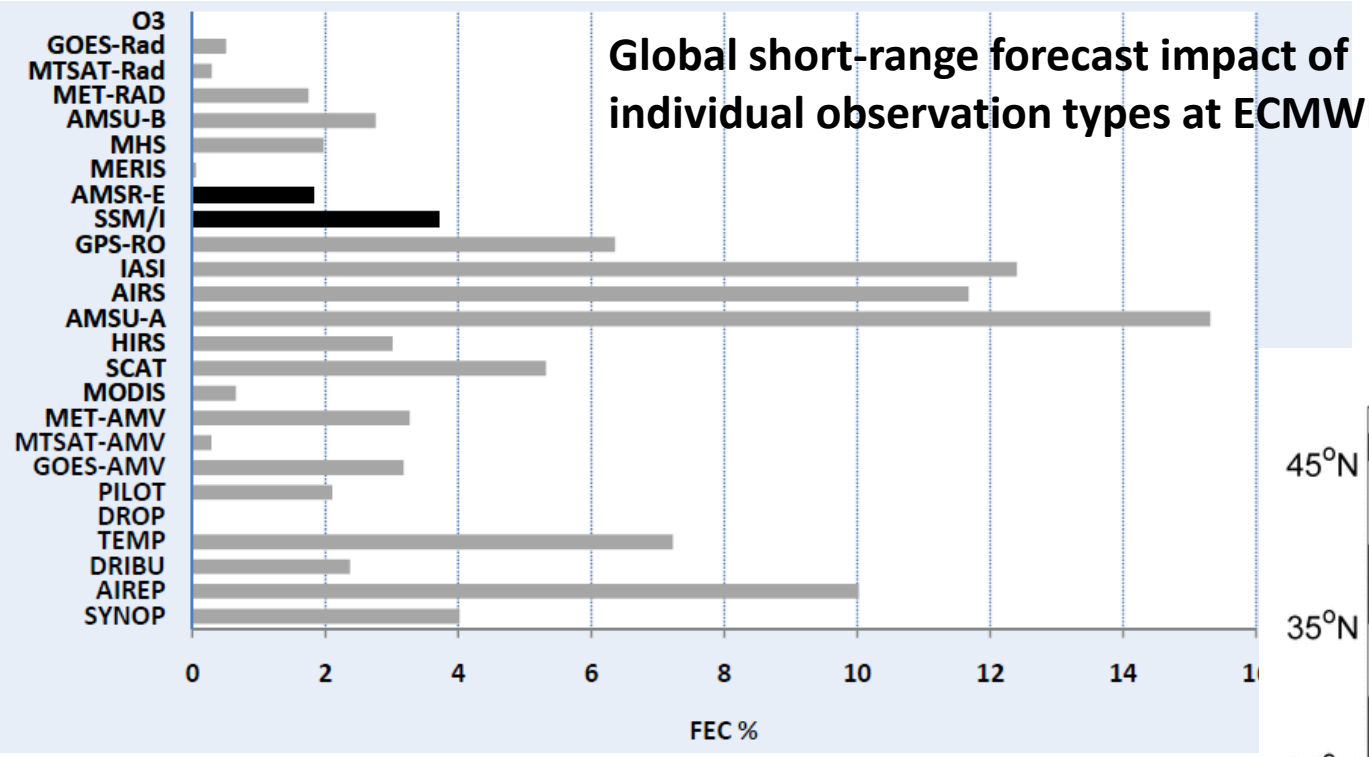
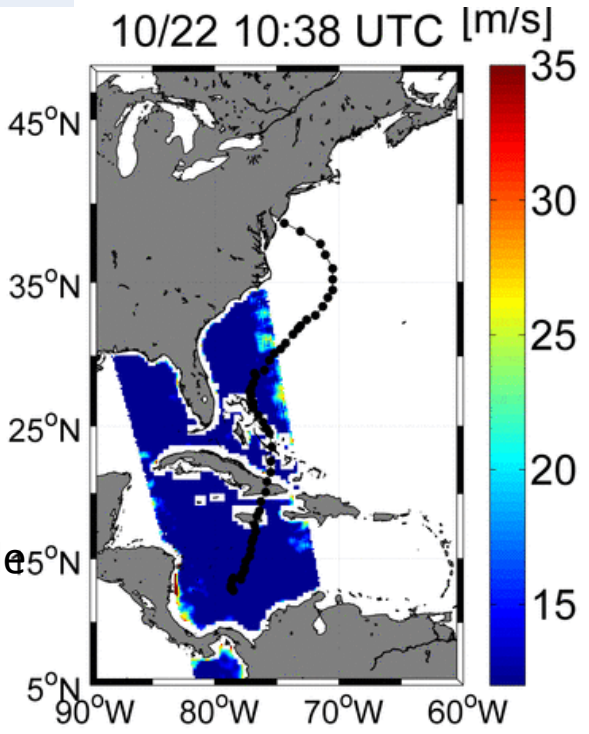
High-impact weather: Wind speed





[Courtesy: Ifremer]

- Near surface wind speed crucial for NWP, also constrains surface pressure, may be *the* most important single observable
- Good coverage with passive microwave and scatterometers, except:
  - at very low wind speeds
  - at very high wind speeds

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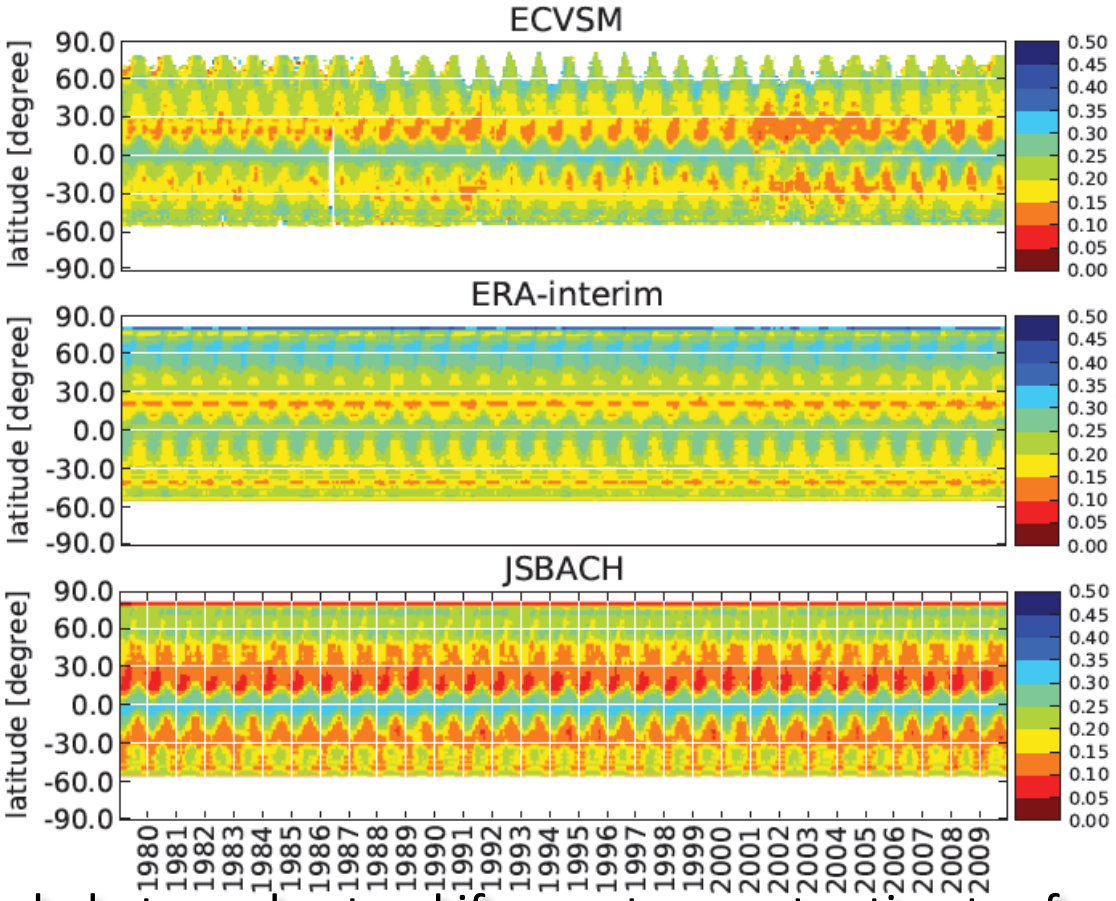
… one thing about Reanalyses

It is important to characterize and quantify complex and highly variable processes



ECV

Reanalysis

Free-running Model

[Roux et al. 2013]

Reanalyses can help to understand if we get correct estimates for the right reasons:

- Need long time series of well calibrated (reprocessed) datasets
- Complementarity of observing systems and models is crucial

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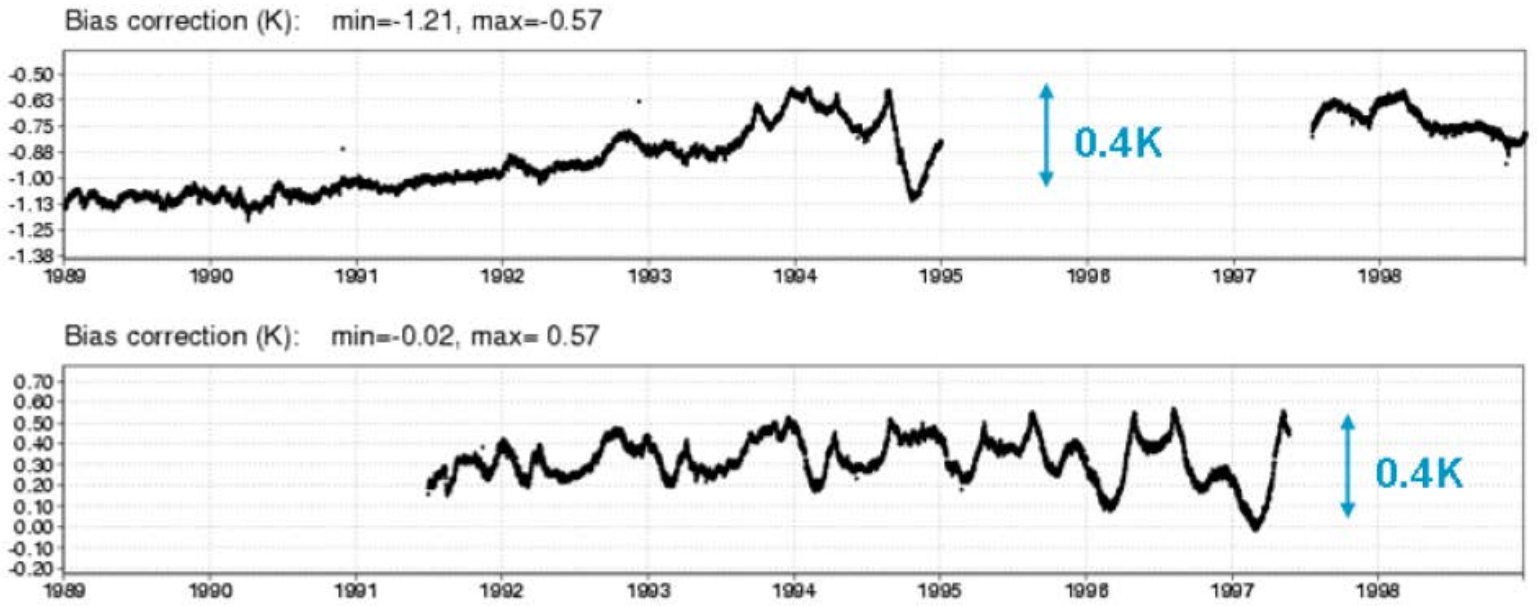
… and another about Reanalyses

It is important to distinguish variability of Earth system from observational quality



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NWP usage of SMOS 'observables'

Product	How observed?	Status?
Soil moisture	• ASCAT (surface) • [illegible] root zone)	• [illegible] periments well
Sea ice thickness (for sea ice < 50cm)	• Only a few *in situ* measurements. • Cryosat for thicker sea ice.	• Assimilation techniques very early stage • Regional systems
Snow depth	• Synop + other *in situ* • Other microwave snow water equivalent	• Assimilation techniques developing • MW interpretation difficult
Marine wind speed (0-100+ kts)	• At high wind speeds ship and buoy only • Well observed < 50kt by scatterometer, altimeter and passive microwave	• Fairly easy – established techniques e.g. Scat, SSM/I and emerging techniques (lidar)
Salinity	• ARGOS	• Low sensitivity • Ocean (re)analysis

Only one really close to operational use

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Derived requirements: WMO Activities

WMO Rolling Review of Requirements process (RRR)

- Global NWP, High-resolution NWP, Seasonal and Inter-Annual Forecasting, Nowcasting and Very Short Range Forecasting, Aeronautical Meteorology, Atmospheric Chemistry, Ocean Applications, Agricultural Meteorology , Hydrology, Climate Monitoring, Climate Applications, Space Weather
- Geophysical parameter, technology free – not instrument oriented

WMO Vision for the Global Observing System in 2025

- General themes and issues, Response to user needs, Integration, Expansion, Automation, Consistency and homogeneity, Space-based component, Surface-based component, System-specific trends and issues
  - 6 geostationary, 3 polar orbiting planes
  - Scatterometers, low-frequency radiometers
- Comparison with space agency plans

WMO Implementation Plan for the Evolution of Global Observing Systems

- responds to vision, provides guidance, prepares roadmap, assigns roles
- **Action: Study the benefits brought by satellite demonstration missions like SMOS (missions based on low-frequency microwave radiometers) on atmospheric, hydrological and oceanic models, in a quasi operational context, and decide if a similar operational mission can be designed.**

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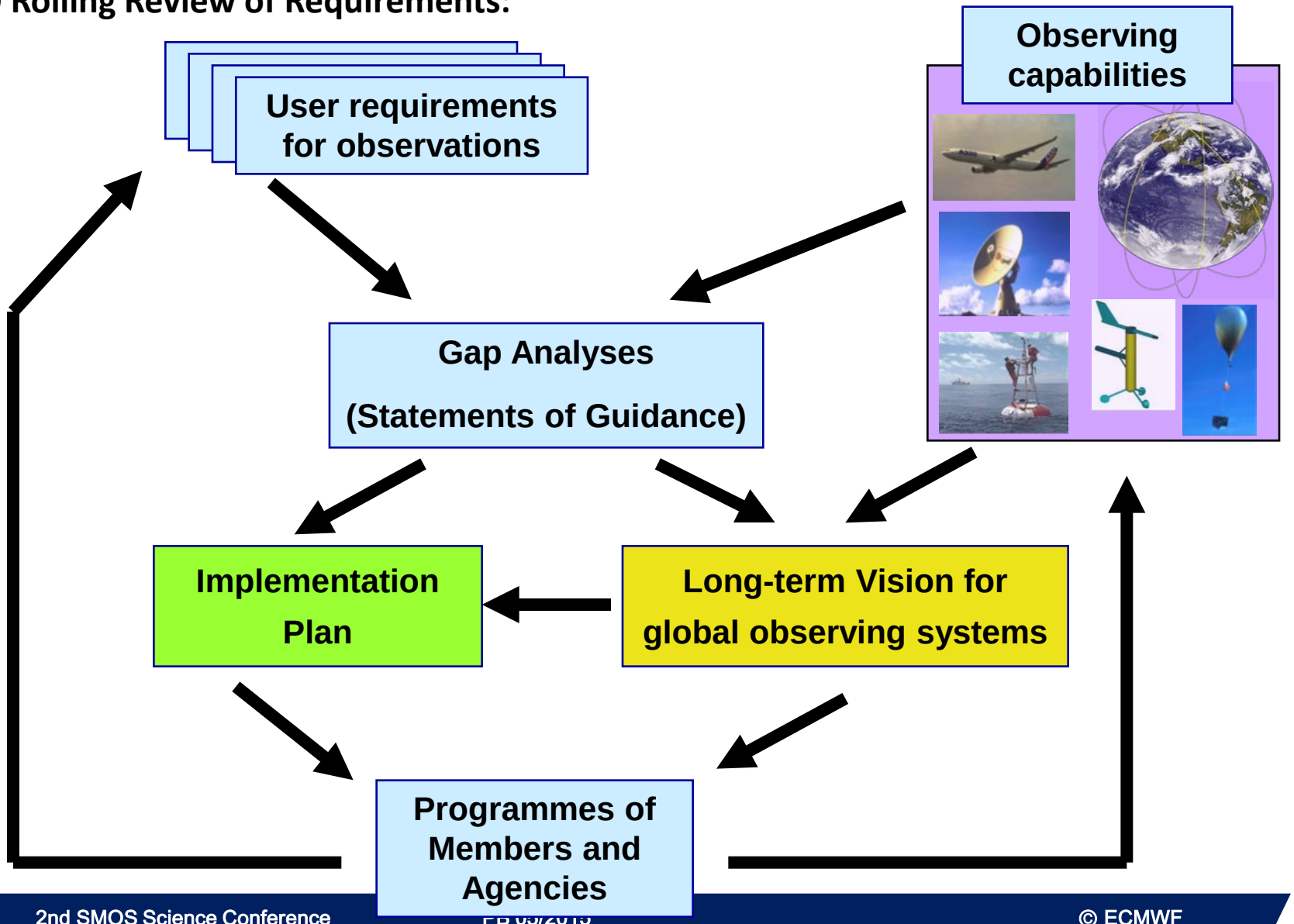
Derived requirements: WMO Procedure

WMO Rolling Review of Requirements:



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User requirements: threshold, breakthrough, goal

Soil moisture (only for surface soil moisture!)

Applications	Horizontal res. (km)	Uncertainty (m^3/m^3)	Temporal res. (h)	Timeliness (h)
Global NWP	5 / 15 / 100	.02 / .04 / .08	**3 / 24 / 120**	**3 / 24 / 120**
Hydrology	**0.01 / 0.3 / 250**	.01 / .02 / .05	24 / 36 / 72	24 / 120 / 3000
GCOS	50 / 60 / 100	**.005 / .007/ .01**	168 / 268 / 720	1y / 1y / 2y

Ocean salinity (only for sea-surface salinity!)

Applications	Horizontal res. (km)	Uncertainty (psu)	Temporal res. (h)	Timeliness (h)
Global NWP	**5 / 100 / 250**	0.1 / 0.2 / 0.3	**24h / 30d / 60d**	**3d / 24d / 120d**
GCOS	100 / 200 / 500	**0.05 / 0.1 / 0.3**	7d / 11d / 30d	10d / 15d / 30d

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Conclusions

WMO (collective user community) perspective:

- For microwave observations in L-band, space agencies' plans currently do **not** provide an adequate response to the "WMO Vision for 2025".
- Problem is worse for salinity than for soil moisture, because of plans for continuity of scatterometers but none for salinity.
- Towards new "WMO Vision for 2040":
  - if Vision 2025 is implemented, which user requirements still unfulfilled?
  - which technologies will be mature in 2040?

Operational NWP user perspective (like ECMWF):

- All of the above, and
- Procedures need responding to emerging application areas (sea-ice, snow, extreme winds)
- In many cases, data assimilation system bottleneck for operational use
- More 'technical' requirements like timeliness, early access, reprocessing capability often decide about usage in NWP regardless of everything else

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