Requirements of operational Numerical Weather Prediction

Peter Bauer
European Centre for Medium-range Weather Forecasts, ECMWF

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
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)
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)
High-impact weather: Wind speed

- 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
... one thing about Reanalyses

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

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
... and another about Reanalyses

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

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
<table>
<thead>
<tr>
<th>Product</th>
<th>How observed?</th>
<th>Status?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moisture</td>
<td>• ASCAT (surface)</td>
<td>• Assimilation experiments well underway</td>
</tr>
<tr>
<td></td>
<td>• Synop (2m in situ temperature and humidity for root zone)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assimilation experiments well underway</td>
<td></td>
</tr>
<tr>
<td>Sea ice thickness</td>
<td>• Only a few <em>in situ</em> measurements.</td>
<td>• Assimilation techniques very early stage</td>
</tr>
<tr>
<td>(for sea ice &lt; 50cm)</td>
<td>• Cryosat for thicker sea ice.</td>
<td>• Regional systems</td>
</tr>
<tr>
<td>Snow depth</td>
<td>• Synop + other <em>in situ</em></td>
<td>• Assimilation techniques developing</td>
</tr>
<tr>
<td></td>
<td>• Other microwave snow water equivalent</td>
<td>• MW interpretation difficult</td>
</tr>
<tr>
<td>Marine wind speed</td>
<td>• At high wind speeds ship and buoy only</td>
<td>• Fairly easy – established techniques e.g. Scat, SSM/I and emerging techniques</td>
</tr>
<tr>
<td>(0-100+ kts)</td>
<td>• Well observed &lt; 50kt by scatterometer, altimeter and passive microwave</td>
<td></td>
</tr>
<tr>
<td>Salinity</td>
<td>• ARGOS</td>
<td>• Low sensitivity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ocean (re)analysis</td>
</tr>
</tbody>
</table>

*Only one really close to operational use*
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.
Derived requirements: WMO Procedure

WMO Rolling Review of Requirements:

- User requirements for observations
- Gap Analyses (Statements of Guidance)
- Implementation Plan
- Long-term Vision for global observing systems
- Programmes of Members and Agencies
- Observing capabilities

Derived requirements: WMO Procedure
# User requirements: threshold, breakthrough, goal

## Soil moisture (only for surface soil moisture!)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Horizontal res. (km)</th>
<th>Uncertainty (m³/m³)</th>
<th>Temporal res. (h)</th>
<th>Timeliness (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global NWP</td>
<td>5 / 15 / 100</td>
<td>.02 / .04 / .08</td>
<td>3 / 24 / 120</td>
<td>3 / 24 / 120</td>
</tr>
<tr>
<td>Hydrology</td>
<td>0.01 / 0.3 / 250</td>
<td>.01 / .02 / .05</td>
<td>24 / 36 / 72</td>
<td>24 / 120 / 3000</td>
</tr>
<tr>
<td>GCOS</td>
<td>50 / 60 / 100</td>
<td>.005 / .007 / .01</td>
<td>168 / 268 / 720</td>
<td>1y / 1y / 2y</td>
</tr>
</tbody>
</table>

## Ocean salinity (only for sea-surface salinity!)

<table>
<thead>
<tr>
<th>Applications</th>
<th>Horizontal res. (km)</th>
<th>Uncertainty (psu)</th>
<th>Temporal res. (h)</th>
<th>Timeliness (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global NWP</td>
<td>5 / 100 / 250</td>
<td>0.1 / 0.2 / 0.3</td>
<td>24h / 30d / 60d</td>
<td>3d / 24d / 120d</td>
</tr>
<tr>
<td>GCOS</td>
<td>100 / 200 / 500</td>
<td>0.05 / 0.1 / 0.3</td>
<td>7d / 11d / 30d</td>
<td>10d / 15d / 30d</td>
</tr>
</tbody>
</table>
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