An update on the barometer drifter, a cost effective technology for providing sea level pressure observations, and addressing multiple requirements

Etienne Charpentier (WMO Secretariat)
John Eyre (UK Metoffice)
Luca Centurioni (SIO, USA)
Sid Boukabara (NOAA, USA)
Requirements for Sea Level Pressure

• An Essential Climate Variable (ECV), which cannot be observed adequately from space
• Addressing multiple requirements
  ✓ Climate monitoring (GCOS)
  ✓ Climate services
  ✓ Numerical Weather Prediction
  ✓ Ocean applications (e.g. marine services)
  ✓ ...
The Rolling Review of Requirements (RRR) and the Evolution of Global Observing Systems

Application Areas

User requirements
Observing Systems Capabilities

Critical review

Impact Studies
Statements of Guidance (gap analysis)
Priorities, cost effectiveness

Long term vision of global observing systems

Implementation Plan (EGOS-IP)

Members’ and Space Agencies Observation Programmes

Application Areas

User requirements
Observing Systems Capabilities

Critical review

Impact Studies
Statements of Guidance (gap analysis)
Priorities, cost effectiveness

Implementation Plan (EGOS-IP)

Members’ and Space Agencies Observation Programmes
Requirements for climate monitoring (GCOS)

- Requirements detailed in GCOS-IP 2010 update (GCOS No. 184)
  - SLP is an Essential Climate Variable (ECV) to characterize the atmosphere at the land and ocean surface
  - Action A6: include SLP measurement on drifters
  - Action O8: drifter array to be sustained with 1250 units with SST & SLP measurements ...
Requirements for climate monitoring (GCOS)

- SLP pressure observations allow description of the geostrophic, barotropic global atmospheric circulation, which accounts for the largest part of the atmospheric circulation.
- Climate changes are felt through:
  - Changes in ocean (T, velocity, sea level - 1hPa ≈ 1cm)
  - Changes in atmosphere (AT, circulation)
- Changes in atmospheric circulation also impact waves, wind regimes (monsoon), hydro cycles.
- SLP used by scientists for:
  - Computation of trends
  - Climate model diagnostic
  - Constructing climate indices
Trends in sea level pressure, 500hPa & 100 hPa geopotential height in November to April, and May to October over last 30 years from ERA.
Requirements for Ocean Applications

• Statement of Guidance for Ocean (SoG) Applications
  – Sea Level measurements should be accompanied with SLP & wind observations
  – SLP needed to detect & monitor atmospheric phenomena over the ocean (tropical cyclones) that significantly constrain shipping
  – Isolated SLP measurements can play an important role in synoptic forecasting especially when they differ from model outputs
  – SLP measurements are sparse, particularly in tropical regions
### Requirements for SLP (OSCAR Database)

http://www.wmosat.info/oscar/variables/view/10

#### Requirements defined for Air pressure (at surface) (10)

This table 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.

<table>
<thead>
<tr>
<th>ID</th>
<th>Variable</th>
<th>Layer</th>
<th>App Area</th>
<th>Uncertainty</th>
<th>Stability/decade</th>
<th>Hor Res</th>
<th>Ver Res</th>
<th>Obs Cycle</th>
<th>Timeiness</th>
<th>Coverage</th>
<th>Conf Level</th>
<th>Val Date</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Global NWP</td>
<td>0.5 hPa</td>
<td></td>
<td>15 km</td>
<td>100 km</td>
<td>60 min</td>
<td>6 min</td>
<td>6 min</td>
<td>firm</td>
<td>2000-02-10</td>
<td>John Eyre</td>
</tr>
<tr>
<td>251</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Global NWP</td>
<td>0.5 hPa</td>
<td></td>
<td>15 km</td>
<td>100 km</td>
<td>60 min</td>
<td>6 min</td>
<td>6 min</td>
<td>firm</td>
<td>2000-02-10</td>
<td>John Eyre</td>
</tr>
<tr>
<td>335</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>High Res NWP</td>
<td>0.5 hPa</td>
<td></td>
<td>1 km</td>
<td>5 km</td>
<td>30 min</td>
<td>15 min</td>
<td>15 min</td>
<td>firm</td>
<td>2010-02-01</td>
<td>T Montimerie</td>
</tr>
<tr>
<td>336</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>High Res NWP</td>
<td>0.5 hPa</td>
<td></td>
<td>1 km</td>
<td>5 km</td>
<td>30 min</td>
<td>15 min</td>
<td>15 min</td>
<td>firm</td>
<td>2010-02-01</td>
<td>T Montimerie</td>
</tr>
<tr>
<td>417</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Marine biology</td>
<td>10 hPa</td>
<td></td>
<td>50 km</td>
<td>75 km</td>
<td>24 h</td>
<td>3h</td>
<td>3h</td>
<td>firm</td>
<td>2003-10-20</td>
<td>GOOS JFO</td>
</tr>
<tr>
<td>487</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Ocean Applications</td>
<td>0.5 hPa</td>
<td></td>
<td>10 km</td>
<td>25 km</td>
<td>30 min</td>
<td>30 min</td>
<td>30 min</td>
<td>firm</td>
<td>2011-03-07</td>
<td>Ali Mafimbo (JCOMM)</td>
</tr>
<tr>
<td>488</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Ocean Applications</td>
<td>1 hPa</td>
<td></td>
<td>1 km</td>
<td>10 km</td>
<td>60 min</td>
<td>3h</td>
<td>3h</td>
<td>firm</td>
<td>2011-03-07</td>
<td>Ali Mafimbo (JCOMM)</td>
</tr>
<tr>
<td>57</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Climate-AOPC</td>
<td>0.5 hPa</td>
<td></td>
<td>200 km</td>
<td>300 km</td>
<td>3 h</td>
<td>3h</td>
<td>3h</td>
<td>reasonable</td>
<td>2007-07-19</td>
<td>AOPC</td>
</tr>
<tr>
<td>58</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Climate-AOPC</td>
<td>0.5 hPa</td>
<td></td>
<td>200 km</td>
<td>300 km</td>
<td>3 h</td>
<td>3h</td>
<td>3h</td>
<td>reasonable</td>
<td>2007-07-19</td>
<td>AOPC</td>
</tr>
<tr>
<td>721</td>
<td>Air pressure (at surface)</td>
<td>Near Surface</td>
<td>Aeronautical Meteorology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>firm</td>
<td>2013-12-05</td>
<td>J van der Meulen</td>
</tr>
</tbody>
</table>
Requirements for Numerical Weather Prediction (GNWP)

- Goal: 15km, Breakthrough: 100km, Threshold: 500 km
- Statement of Guidance for GNWP states that
  “Over ocean, ships and buoys provide observations of good frequency, where accuracy is good for surface pressure. However, coverage is marginal or absent over some areas in the tropics and the Arctic“
- 5th WMO workshop on the impact of observing systems on NWP (Sedona, May 2012)
  ✓ SLP from drifters is having substantial impact on NWP: “The influence of buoy surface pressure observations is particularly large on a per-observation basis and their OSE impact extends from the surface throughout the troposphere in mid-latitudes“
Requirements for Numerical Weather Prediction (GNWP)

- ECMWF 2012 study to quantify the interaction between terrestrial and space-based observing systems on NWP skill
  - OSE used to test for VOS & drifter data in particular, with focus on the North Atlantic
    - Impact of SLP from drifters on forecast performance is large, especially in the lower atmosphere (it is more expressed over the Southern Hemisphere)
    - Additional buoy data introduced at the North-Atlantic area within the E-SURFMAR program prove to locally improve surface pressure forecast scores but this impact is moderate and it lasts up to 24-72h
    - The impact of the additional buoy data can be clearly seen in extreme weather events
    - Surface pressure from drifters has higher impact on per observation basis than any other type of observation, incl. satellite (e.g. 5 times higher than for synoptic stations)
Forecast Error (FEC) distribution for observing systems (24H forecast)
(top: summed up; bottom: normalized per observation)

ECMWF 2012 study
DBCP Pilot Project on the Impact of SLP from drifters on NWP

- 2-year project initiated by DBCP-28 (2012)
- Lead by Luca Centurioni (SIO, USA).
- Impact study conducted in 2014 with ECMWF for
  - Observing System Experiment (OSE) on the analysis of cyclogenesis episodes with and without concurrent SLP drifter data
  - Quantification of the impact by using the Degree of freedom for Signal (DFS) and the Forecast Error Reduction (FEC) diagnostic tools for the same cyclogenesis episodes
Average sea level pressure analyses differences, in Pascal, between the control and denial experiments.
Normalized differences of mean sea level pressure root mean-squared errors between the control and denial experiment for November-December 2010. Red (blue) colors indicate degradations (improvements) in the denial experiment. Forecast ranges: 12h, 24h, 48h, 72h, 96h and 120h
Conclusion of DBCP Pilot Project on the Impact of SLP from drifters on NWP

Paper entitled “A Global Ocean Observing System for Measuring Sea Level Atmospheric Pressure: Effects and Impacts on Numerical Weather Prediction” was submitted to BAMS by Luca Centurioni (SIO), Andras Horanji (ECMWF), Carla Cardinali (ECMWF), Etienne Charpentier (WMO) and Richard Rick Lumpkin (AOML)

Recommendations:
- Quantity and distribution of drifters measuring SLP should be preserved as much as possible in order to avoid any analysis and forecast degradations
- Drifter array should be extended to the tropical region as well and the impact of the data should be quantified with regional FSO studies
Available technologies for measuring SLP

• Space observations
  ✓ Reliable HR wind observations are made
  ✓ SLP gradient can be derived from SVW from satellites
  ✓ However, it is not possible to anchor adequately the surface pressure field with satellite data alone

• Voluntary Observing Ships (VOS)
  • Providing good (≈ 1 hPa for AWS, ≈ 1.3 hPa for manual) and cost-effective SLP observations
  • Less ships but more observations thanks to AWS
  • Most of observations made in the Northern Hemisphere
VOS observations
Available technologies for measuring SLP (moored buoys)

• Coastal buoys
• Tropical moored buoys
• Coverage limited in coastal regions to the mid-latitudes of Northern Hemisphere, and the tropical ocean
• Providing good SLP observations ($\approx 0.8 \text{ hPa}$)
Available technologies for measuring SLP (Drifters)

- Lagrangian drifters used (SVP) for surface velocity & SST (1250 units maintained operational by DBCP)
- SVPB has barometer installed on SVP drifter and provide good SLP observations (≈ 0.9 hPa)
- Both reliable technology (nominal 18 month lifetime)
- Provide high temporal resolution data (1h)
- Only source of SLP data in huge parts of the global ocean
- Cost-effective technology
- Upgrade scheme allows synergies, cooperation, and sharing of resources
- Drifter limitations
  - Changing position so only make sense in networks with coordinated deployment strategies
  - Limited life-time & no refurbishment (re-seeding needed)
  - Limited timeliness if using Argos (excellent timeliness with Iridium)
The SVPB Lagrangian drifter

Air Pressure Port

Sea Surface Temperature Sensor

Drogue

15 m

7.60 m

0.61 m

DETAIL A
Buoy observations
Cost effectiveness of SLP from drifters

- Typical hardware cost of USD 3,000 for SVPB
- Satcom cost up to USD 1,500/yr if using Argos
- Satcom cost cheaper if using Iridium
- Barometer upgrade: USD 1,500 (no additional costs for deployment, Satcom, etc.)
- USD 6,000,000 to operate drifter network (1250 units, incl. 50% SVPBs)
  - Cost of barometers is 10% of that total cost
  - Cost per SLP observation = USD 0.11 (for hourly observations)
Drifter limitations ...

- They are drifting & their positions depend on currents, sea state, wind (EEZ not an issue for surface drifters)
  ⇒ Need a network approach with concerted deployment strategy
- Limited life-time (18 months) and not refurbished (seen as consumables)
  ⇒ Re-seeding needed
- Timeliness can be large if using Argos
  ⇒ Other systems such as Iridium offer better and good performances
Importance of collaboration between oceanographers and meteorologists with regard to SVPB deployments

• Effective cooperation has been put in place with drifters for
  ✓ Oceanography
    • Surface velocity means
    • Sea Surface Temperature (SST)
  ✓ Meteorology
    • Sea Level Pressure
✓ Shared and standard technology used
  ✓ Oceanographers add barometers on drifters & share data in real-tie on GTS
  ✓ Meteorologists use Lagrangian drifters with drogue & submit data to Global Drifter Assembly Centre.
Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)

• A result of the RRR process taking into account gap analyses for all WMO Application Areas, cost-effectiveness of observing systems, and the priorities of the Organization

• A key document providing Members with clear and focused guidelines and recommended actions in order to stimulate cost-effective evolution of the observing systems to address in an integrated way the requirements of WMO programmes and co-sponsored programmes

• Available on WMO website in 4 languages (link here)

• DBCP related actions in EGOS-IP

  Action G52: Support DBCP in its mission (1250 drifters, 400 MBs) for SST, surface velocity, air T & wind

  Action G53: Install barometer on all newly deployed drifting buoys