Fourth DBCP Capacity Building Workshop for the North Pacific Ocean and Its Marginal Seas (NPOMS-4)

(Busan, Republic of Korea, 2-4 November 2015)

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

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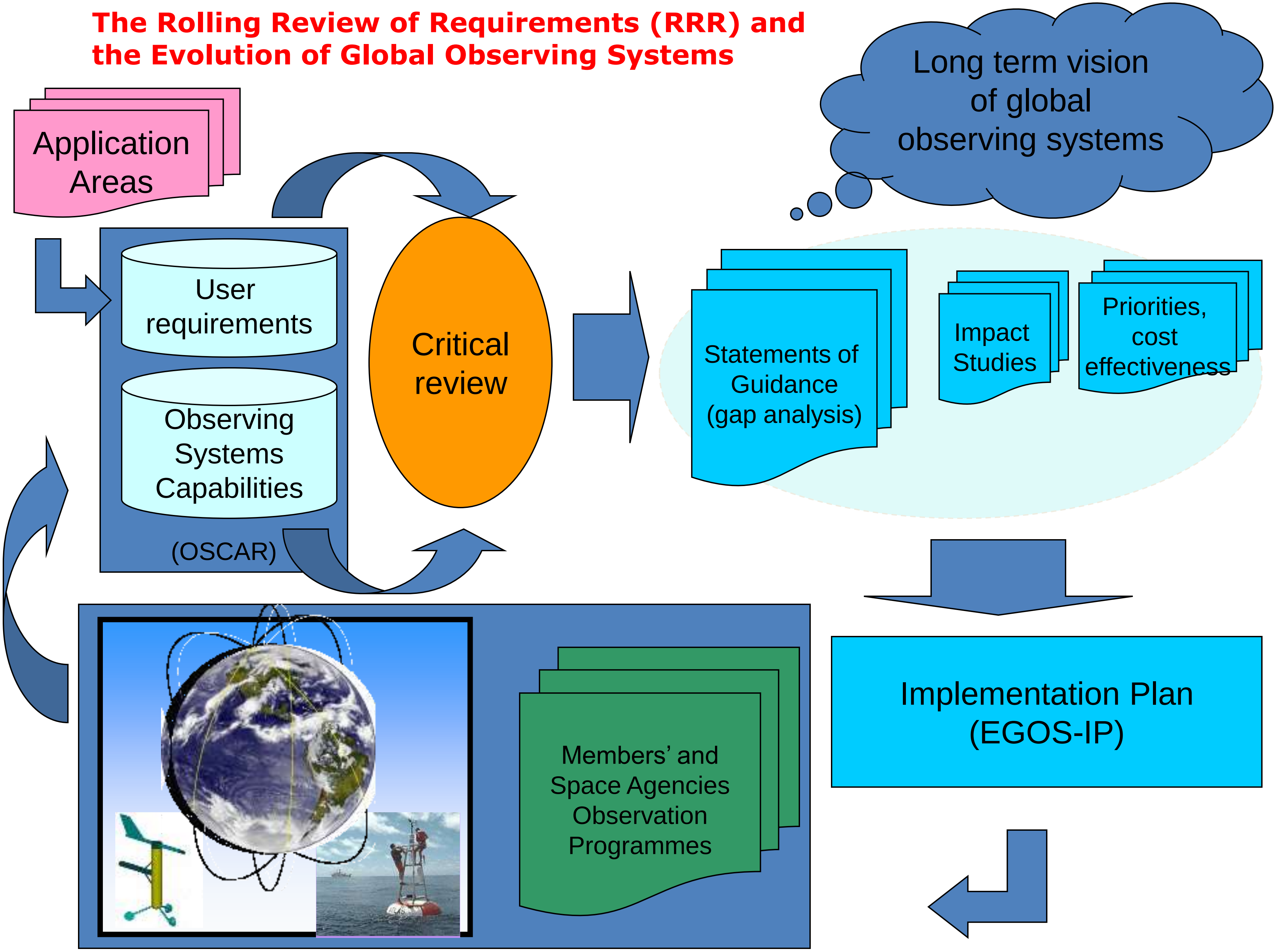
Requirements for Sea Level Pressure

- 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



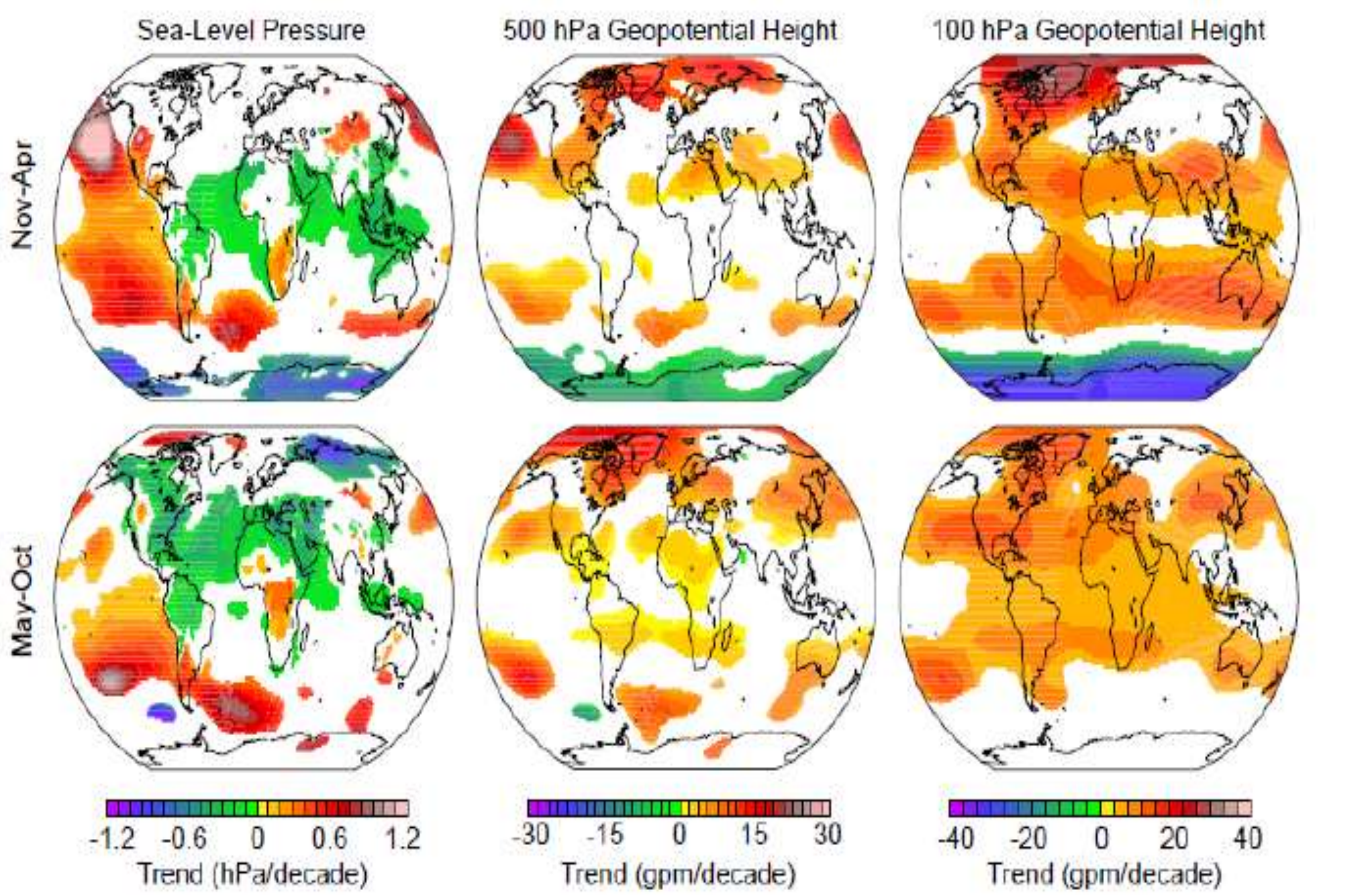
Requirements for climate monitoring (GCOS)

- 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 flet 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 phenomenons 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.wmo-sat.info/oscar/variables/view/10

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

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 Area	Uncertainty	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness	Coverage	Conf Level	Val Date	Source
250	Air pressure (at surface)	Near Surface	Global NWP	0.5 hPa 1 hPa 1 hPa		15 km 100 km 500 km		60 min 6 h 12 h	6 min 30 min 6 h	Global land	firm	2009-02-10	John Eyre
251	Air pressure (at surface)	Near Surface	Global NWP	0.5 hPa 1 hPa 1 hPa		15 km 100 km 500 km		60 min 6 h 12 h	6 min 30 min 6 h	Global ocean	firm	2009-02-10	John Eyre
335	Air pressure (at surface)	Near Surface	High Res NWP	0.5 hPa 0.6 hPa 1 hPa		1 km 5 km 20 km		30 min 60 min 3 h	15 min 30 min 2 h	Global land	firm	2010-02-01	T Montmerle
336	Air pressure (at surface)	Near Surface	High Res NWP	0.5 hPa 0.6 hPa 1 hPa		1 km 5 km 20 km		30 min 60 min 6 h	15 min 30 min 2 h	Global ocean	firm	2010-02-01	T Montmerle
417	Air pressure (at surface)	Near Surface	Marine biology	10 hPa 12 hPa 15 hPa		50 km 75 km 100 km		24 h 36 h 2 d	3 h 4 h 7 h	Global ocean	firm	2003-10-20	GOOS JPO
487	Air pressure (at surface)	Near Surface	Ocean Applications	0.5 hPa 1 hPa 1 hPa		10 km 25 km 100 km		30 min 2 h 12 h	30 min 60 min 2 h	Global ocean	firm	2011-03-07	Ali Mafimbo (JCOMM)
488	Air pressure (at surface)	Near Surface	Ocean Applications	1 hPa 5 hPa 10 hPa		1 km 10 km 25 km		60 min 3 h 6 h	3 h 6 h 12 h	Global ocean	firm	2011-03-07	Ali Mafimbo (JCOMM)
67	Air pressure (at surface)	Near Surface	Climate-AOPC	0.5 hPa 0.65 hPa 1 hPa		200 km 300 km 500 km		3 h 6 h 24 h	3 h 6 h 12 h	Global land	reasonable	2007-07-19	AOPC
68	Air pressure (at surface)	Near Surface	Climate-AOPC	0.5 hPa 0.65 hPa 1 hPa		200 km 300 km 500 km		3 h 6 h 24 h	3 h 6 h 12 h	Global ocean	reasonable	2007-07-19	AOPC
721	Air pressure (at surface)	Near Surface	Aeronautical Meteorology							Point	firm	2013-12-05	J van der Meulen

Requirements for Numerical Weather Prediction (GNWP)

- Goal: 15km, Breakthrough: 100km, Threshold: 500 km
- Statement of Guidance for GNWP states that

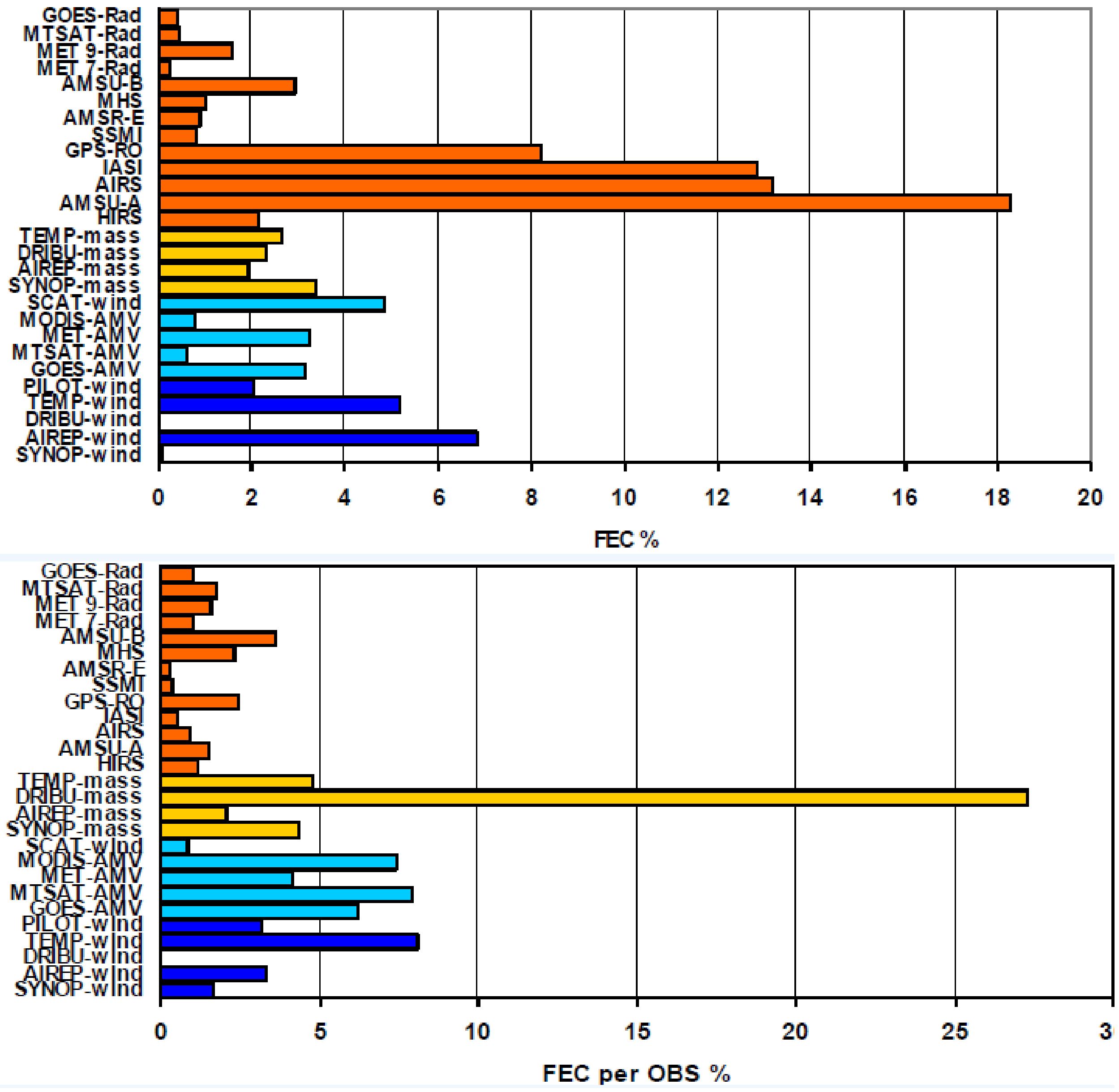
  " Over ocean, ships and buoys provide observations of good frequency, where accuracy is good for surface pressure. However, coverage is marginal or absent over some areas in the tropics and the Arctic "
- 5th WMO workshop on the impact of observing systems on NWP (Sedona, May 2012)
  - ✓ SLP from drifters 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)

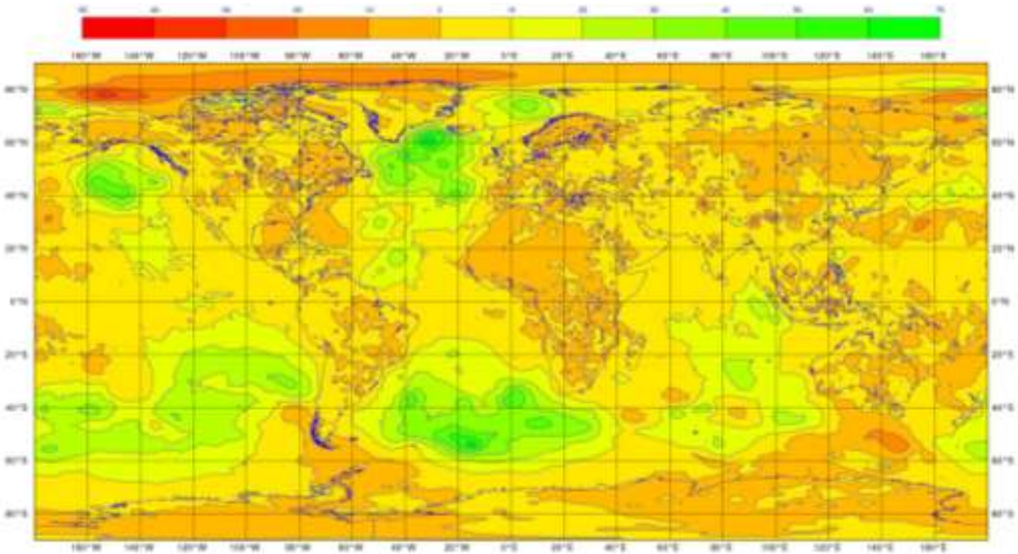
ECMWF 2012 study



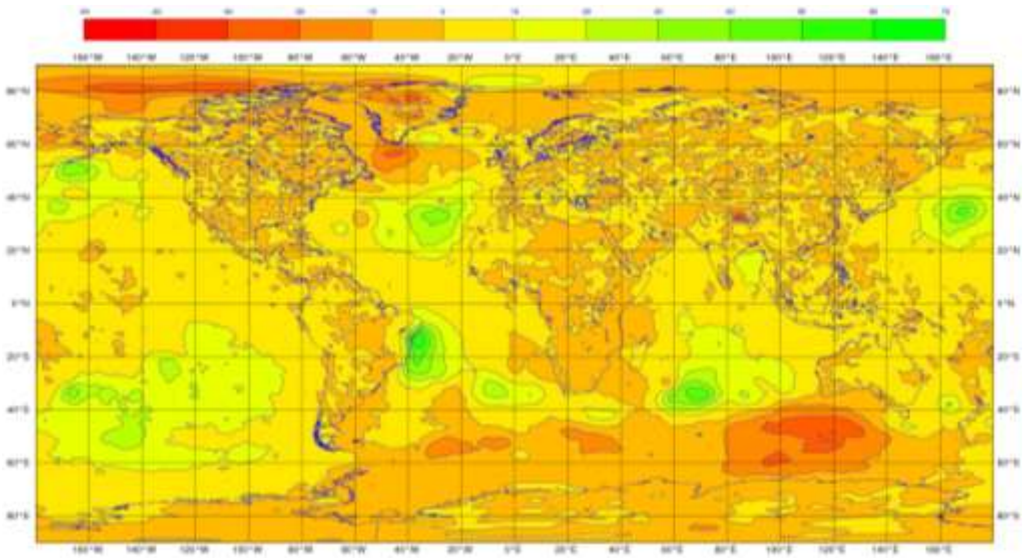
DBCP Pilot Project on the Impact of SLP from drifters on NWP

- 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 cyclogenesys episodes

Average sea level pressure analyses differences, in Pascal, between the control and denial experiments

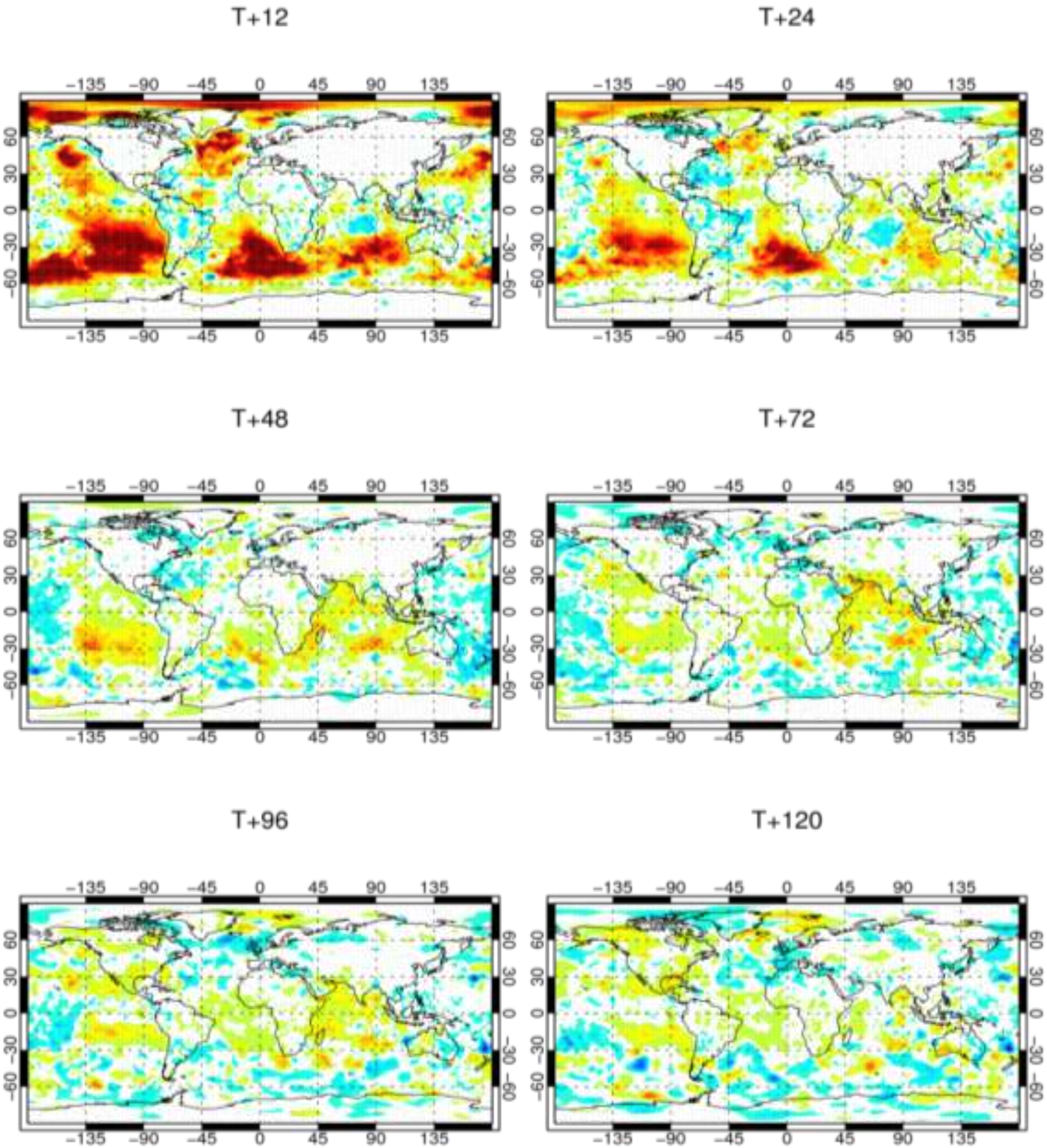


November-December 2010



July-August 2012

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)

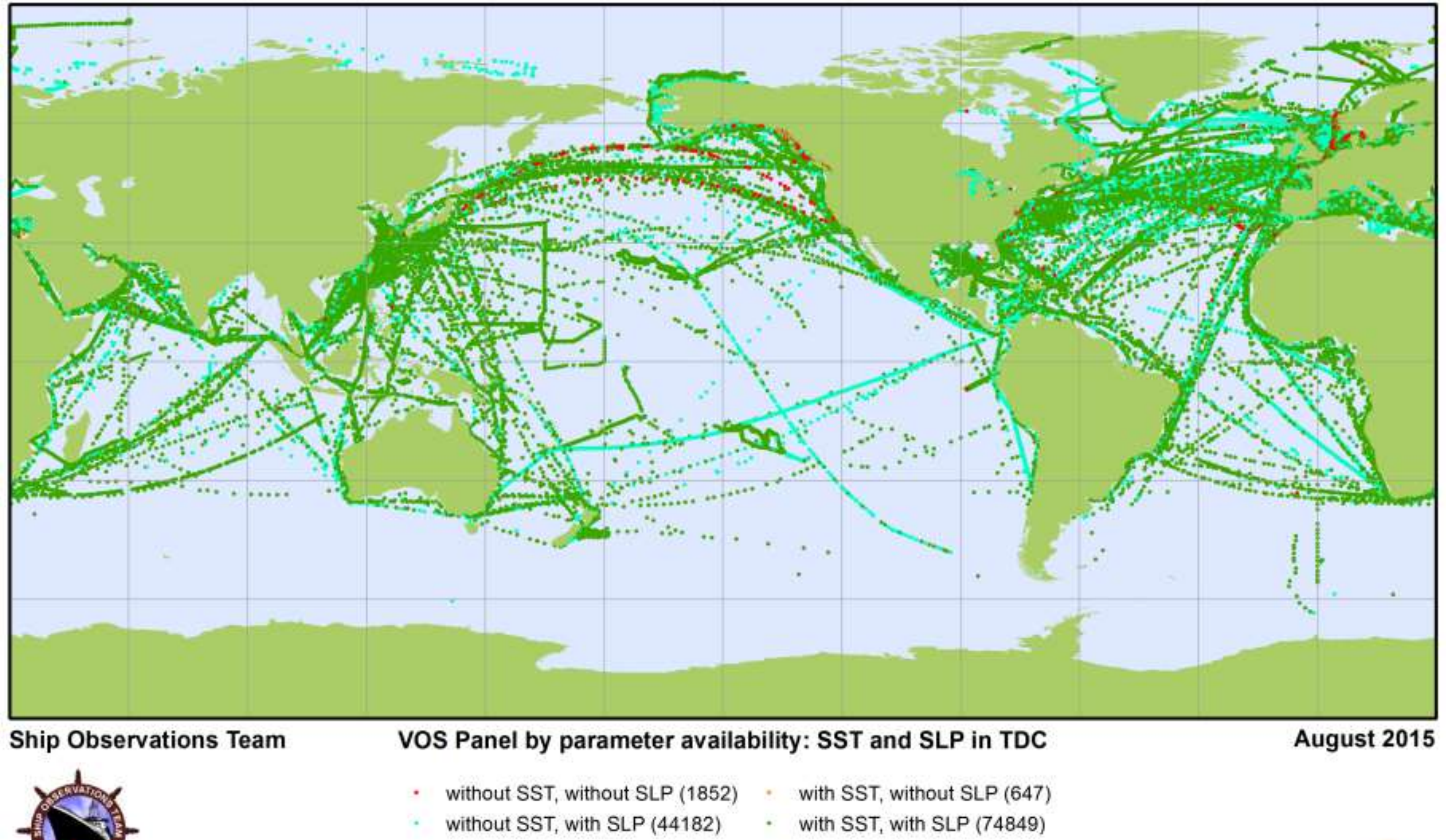
Recommendations:

- ✓ 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

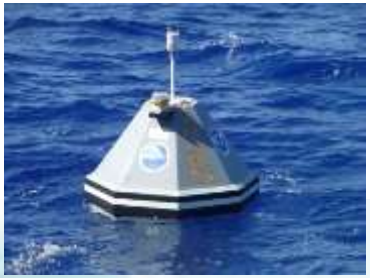
- Space observations
  - ✓ Reliable HR wind observations are made
  - ✓ SLP gradient can be derived from SVW from satellites
  - ✓ However, it is not possible to anchor adequately the surface pressure field with satellite data alone
- Voluntary Observing Ships (VOS)
  - Providing good (≈ 1 hPa for AWS, ≈ 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

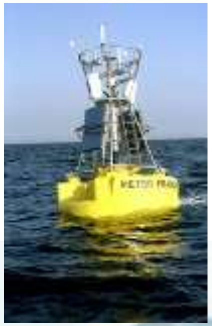
VOS observations



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 (≈ 0.8 hPa)

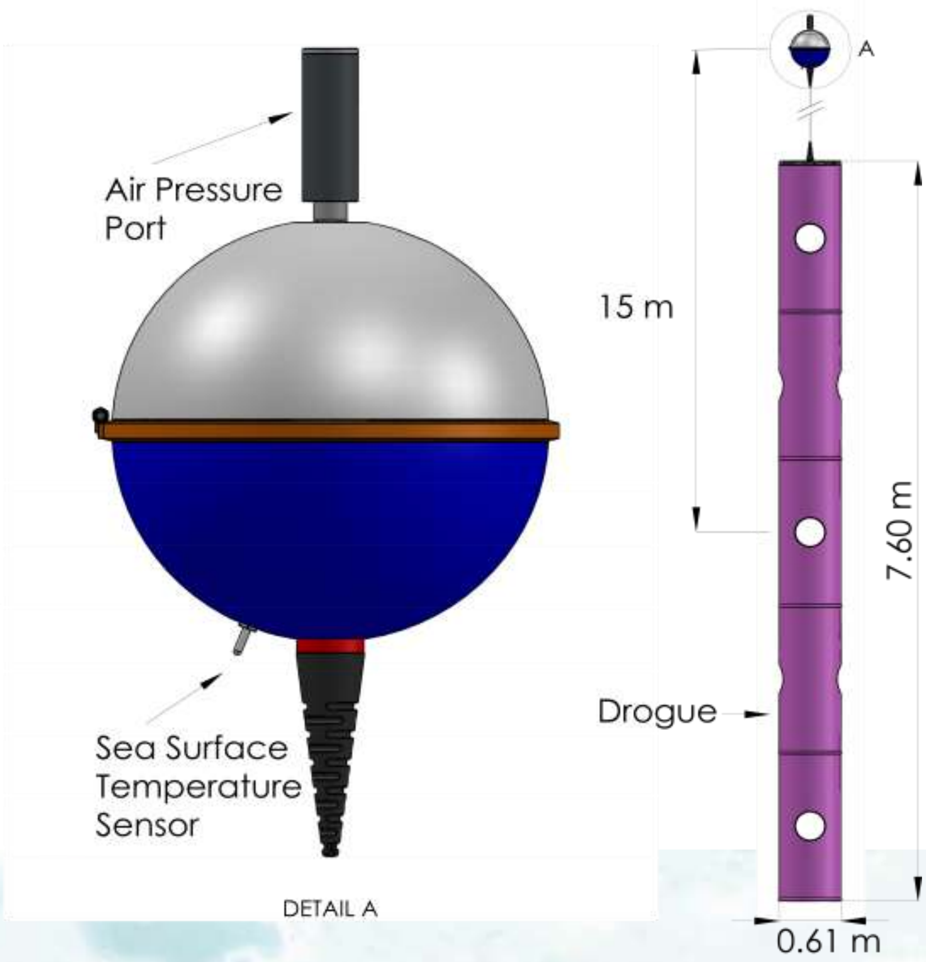




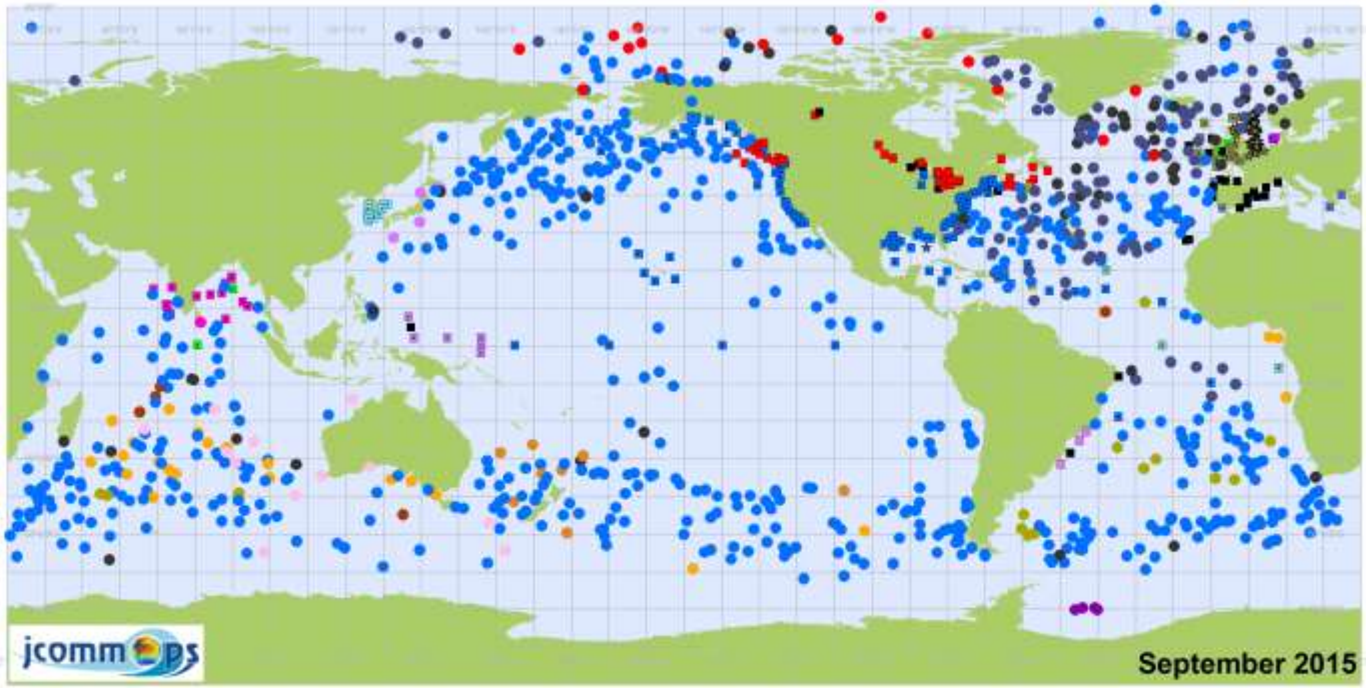
Available technologies for measuring SLP (Drifters)

- 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



Buoy observations



Barometer Drifting Buoys (872)

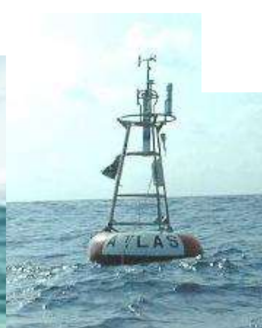
- AUSTRALIA (12)
- CANADA (16)
- EUROPE (110)
- FRANCE (25)
- GERMANY (4)
- INDIA (1)
- JAPAN (4)
- NEW ZEALAND (8)
- UK (18)
- USA (614)
- USA/FRANCE (5)
- UNKNOWN (55)

Barometer Moored Buoys (260)

- BRAZIL (4)
- UK-FR (1)
- BRAZIL/FRANCE/USA (3)
- CANADA (38)
- FRANCE (1)
- GERMANY (3)
- GREECE (2)
- INDIA (17)
- IRELAND (2)
- JAPAN (6)
- SOUTH KOREA (11)
- SPAIN (2)
- UK (12)
- USA (123)
- USA/INDIA (2)
- UNKNOWN (33)

Barometer Fixed Platforms (90)

- UK (86)
- USA (4)



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**