

WMO-BIPM workshop on

Measurement Challenges
for Global Observation Systems
for Climate Change Monitoring
Traceability, Stability and Uncertainty

30 March – 1 April 2010
WMO Headquarters
Geneva, Switzerland



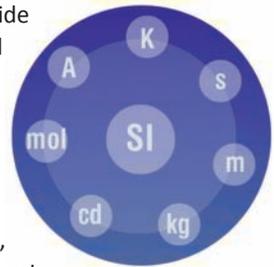
Andrew Wallard

*Director of the International
Bureau of Weights and
Measures*

Changes in the world's climate and the influence of human activity on our planet are of key concern. Increasingly, world leaders are faced with important decisions on environmental matters, which often have vast economic implications, and they wish to rely on the most accurate scientific observations of the state of the global environment. This need for scientific observations of ever increasing accuracy and complexity is placing stringent demands on the accuracy of global observing systems and on the traceability of measurement results to internationally agreed units of measurement and standards. Furthermore, the need to accurately interpret small changes in long-term environmental data series requires measurement standards with well-characterized uncertainties and well-monitored and maintained stabilities.

Recognizing this need, the World Meteorological Organization (WMO) and the International Bureau of Weights and Measures (BIPM) are jointly hosting this international workshop. The workshop will gather scientists from the Earth observing systems and the metrology communities to discuss ways in which they can collaborate so as to deliver ever more accurate and reliable observations of the Earth's climate.

Requirements for high-quality observational data and their worldwide compatibility were a governing principle when the International Meteorological Organization (IMO) was established in 1873. They also have been the foundations for the technical references in collecting and exchanging worldwide meteorological and climate observations since the establishment of WMO, the IMO successor, in 1950. Since that time, standardization responsibilities of the WMO Commission for Instruments and Methods of Observations, including defining technical standards, conducting instrument intercomparisons, testing and calibration and implementing quality control procedures, have been significantly expanded to cope with the fast development of measuring technology, in order that the traceability of measurements to the International System of Units (SI) could be guaranteed. Today, many of the challenges faced by climate science are indeed measurement challenges, for example, assessing the trends in concentrations of greenhouse gases and their regional sources and sinks, assessing the radiative impacts of these gases, and assessing the resulting changes in surface and atmospheric temperature.



Assessing climate change will depend crucially on the uncertainties associated with these measurements and the robustness of climate data and their compliance with the internationally agreed climate monitoring principles of the Global Climate Observing System. Measurement uncertainties can only be determined, and hence minimized, if proper consideration is given to the metrological traceability of the measurement results to stated standards. National Metrology Institutes have traditionally provided primary measurement standards to underpin a wide range of physical and chemical measurements.

These standards often require many years of research and development to realize and are subject to constant refinement. The International Bureau of Weights and Measures, which is mandated to provide the basis for a single, coherent system of measurements throughout the world, traceable to the SI, organizes and facilitates the international comparison of these standards in order to ensure international consistency.

Stringent requirements for the stability of primary measurement standards remain a key objective for WMO in order to meet data quality objectives. For example, the activities of Central Calibration Laboratories and World Calibration Centres within the WMO Global Atmosphere Watch Programme, or the World Radiation Centre within the WMO World Weather Watch Programme, have been important components of the quality assurance programme for key atmospheric and environmental measurements. These



Michel Jarraud
*Secretary General of the
World Meteorological
Organization*

activities have been the recent focus of increased collaboration between the meteorology and measurement science communities to ensure, within the framework of the WMO Integrated Global Observing System, the development of standards and the delivery of highly accurate data for atmospheric and climate monitoring in support of the implementation of the Global Framework for Climate Services, which was established by the World Climate Conference-3, held in Geneva from 31 August to 4 September 2009.



The concept of metrological traceability is achieving a higher profile in the planning of climate monitoring systems, but much work remains to be done to ensure that future climate science is based on the most robust metrology currently achievable across all measurement classes.

The present workshop brings together the relevant communities to debate and review the status of applied meteorology, with respect to metrological traceability, in eight specific theme areas. The goal will be to identify key measurement issues in climate science, Earth observation and numerical weather prediction models where there is a requirement to develop or improve underpinning metrology, and explore the ways in which the metrology and Earth observation communities can work together to reduce uncertainties and thus ensure the accuracy and comparability of climate science measurements both now and in the future. The workshop has been convened to strengthen the links between our communities and identify activities that will act as examples for the future development of measurement science in the field of Earth observation.

We wish you all a fascinating and successful three days in Geneva, and thank you for your support and commitment.

Michel Jarraud & Andrew Wallard

Workshop Objectives

- A. Identify key measurement issues in climate science, Numerical Weather Prediction model (NWP) and Earth observation where there is a requirement for improved underpinning metrology.
- B. Foster closer links and develop dialogue between the metrology and the Earth observation systems communities.

Workshop Programme

Tuesday, 30 March 2010		Wednesday, 31	
8:30	Registration and coffee	8:30	Sessions
9:00	Plenary	10:00	
10:15	Coffee	10:30	Sessions
10:45	Plenary	12:00	
12:15	Lunch	14:00	Sessions
14:15	Introduction to sessions	14:30	Discussi
15:55	Coffee	15:30	
16:25	Introduction to sessions	16:00	Sessions
18:30	Reception {WMO cafeteria}	18:00	

- C. Drive agenda setting and road mapping within National Metrology Institutes (NMIs) and ensure that measurement science is developed to meet the needs of climate science, NWP and Earth observation community needs.
- D. Inform the Earth observation systems community about the capabilities and plans of the NMIs.

March 2010	Thursday, 1 April 2010	
A, B1, C, and D	8:30	Sessions F, G, H, and B2
Coffee	10:00	Discussions F, G, H, and B2
A, B1, C, and D	11:00	Coffee
Lunch	11:30	Reports from sessions
A, B1, C, and D	12:30	Lunch
ons A, B1, C, and D	14:30	Reports from sessions
Coffee	15:30	Coffee
F, G, H, and B2	16:00	Prioritization of activities
Closure	17:00	Closure

Plenary

Chair: Wenjian ZHANG (WMO) & Andrew Wallard (BIPM)

Rapporteur: Luis Mussio, BIPM



9:00 Welcome
Michel Jarraud, *Secretary General, WMO*

9:15 WMO global observing systems for climate monitoring
Wenjian ZHANG, *Director of the Observing and Information Systems Department, WMO*



9:45 Metrology for long-term measurement data
Ernst O. Göbel, *President, PTB {DE} and President, CIPM*

10:15 Coffee

10:45 Climate change and its impact
Jean-Pascal van Ypersele, *Vice-chair, IPCC*



11:15 The importance of metrological traceability for climate change assessment
James G. Anderson, *Philip S. Weld Professor of Atmospheric Chemistry, Harvard College {US}*

11:45 *To be announced*

Introduction to sessions

Chair: Robert Wielgosz (BIPM) & Bertrand Calpini (MeteoSwiss)

Rapporteur: Luis Mussio, BIPM

- 14:15 A:** Climate trends from satellite sounding data
Fuzhong Weng, NOAA NESDIS {US}
- 14:40 B1:** Stable time series for key GHGs and other trace species
Robert Wielgosz, BIPM
- 15:05 C:** Radiation and Earth energy balance
Werner Schmutz & Eugene Rozanov, PMOD/WRC
- 15:30 D:** Earth surface (land and water) temperature
Pascal Lecomte, ESA
- 15:55** Coffee
- 16:25** Aerosol composition and radiative properties
Urs Baltensperger, Paul Scherrer Institut {CH}
- 16:50 F:** Microwave imagery data in climate and NWP
Karen St. Germain, ESA
- 17:15 G:** Surface properties: albedo, land cover and ocean colour
Nigel Fox, NPL {UK}
- 17:40 H:** Ocean salinity
Klaus-Dieter Sommer, PTB {DE}
- 18:05 B2:** Remote sensing of atmospheric composition and traceability issues in spectroscopic data
James Whetstone, NIST {US}

Tuesday, 30 March 2010

Room: Salle A

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A. Climate trends from satellite sounding d

Microwave Sounding (MWS) data from the Microwave Sounding Unit / Advanced Microwave Sounding Unit (MSU/AMSU) instruments form one of a small number of key datasets used to assess global trends in atmospheric temperatures since 1979, and thereby provide an important test of climate model predictions. Complex inter-sensor biases have so far hampered efforts to determine temperature trends with sufficient certainty to test models. MWS data is also extremely important in NWP data assimilation, where the high accuracy of forecast temperature fields places very stringent requirements on the quality of measured radiances. Microwave data from operational platforms will continue to be used to determine temperature trends and current agency plans foresee a constellation of operational MWS instruments until 2030 at least. In the future temperature-sounding data will be provided by a new generation of microwave temperature-sounding instruments carried on platforms launched by the U.S., European, Chinese, Japanese and Russian agencies. Improved traceability for pre-launch testing and calibration is one important aspect of a wider effort to improve the consistency of the satellite data record.

Objectives

- Review the use of the MWS data in climate, reanalysis and NWP and the associated measurement uncertainty requirements for these applications.
- Review agency plans for MWS instruments and current practice in pre-launch characterization.
- Review current approaches to define and reduce measurement uncertainties in measured radiances.
- Establish best practice for future missions.
- Specify requirements for improved underpinning metrology, to provide a focus for national and international metrology programmes.
- Foster improved international collaboration between users, agencies, instrument teams and the metrology community, in order to reduce risk for future missions.

Background: Microwave sounding unit lower troposphere and lower stratosphere 1979-2009 temperature trend (°C/decade) and 12 months running mean global temperature time series with respect to 1979-1998.

Source: <http://www.remss.com/data/msu/data>

Chair: Fuzhong Weng, NOAA NESDIS {US}
Rapporteur: Roger Saunders, Met Office, Exeter {UK}

- 8:30** Climate trends from microwave sounding data:
Lessons learned – a post-launch perspective
Carl Mears, Remote Sensing Systems (RSS) {US}
- 9:00** Reanalysis, climate trends and an evaluation of the satellite
sounding data record
Dick Dee, Reanalysis Section, ECMWF {UK}
- 9:30** Improved atmospheric sounding with ATMS
Bill Blackwell, MIT Lincoln Laboratories {US}
- 10:00** Coffee
- 10:30** Pre-launch testing, characterization and on-orbit
performance of the FY-3 microwave sensors
Jun Yang, CMA / CMSC {CN}
- 11:00** Microwave sounding and imaging requirements
for the future EUMETSAT Polar System
Peter Schlüssel, EUMETSAT
- 11:30** A review of microwave metrology at NIST in support
of satellite sounding missions
David Walker, NIST {US}
- 12:00** Lunch
- 14:00** Towards standard pre-launch and post-launch calibration/
validation of microwave sensors
Xiaolong Dong, NMRESL/CSSAR/CAS {CN}
- 14:30** Latest progress on the microwave sounder's metrology
technologies by BIRMM of China
Chen Yunmei, BIRMM {CN}
- 15:00** Topic Discussion

B. Stable time series for key greenhouse ga

Extended time series of the concentration of carbon dioxide and methane in the atmosphere have played a seminal role in the identification of the causes of global climate change. They also provide a basis for monitoring and planning future mitigation strategies. These time series depend on the use of stable standards, with demonstrated comparability among measurement sites, to achieve the validity and stability required for them to be used to identify trends and distributions in atmospheric concentration.

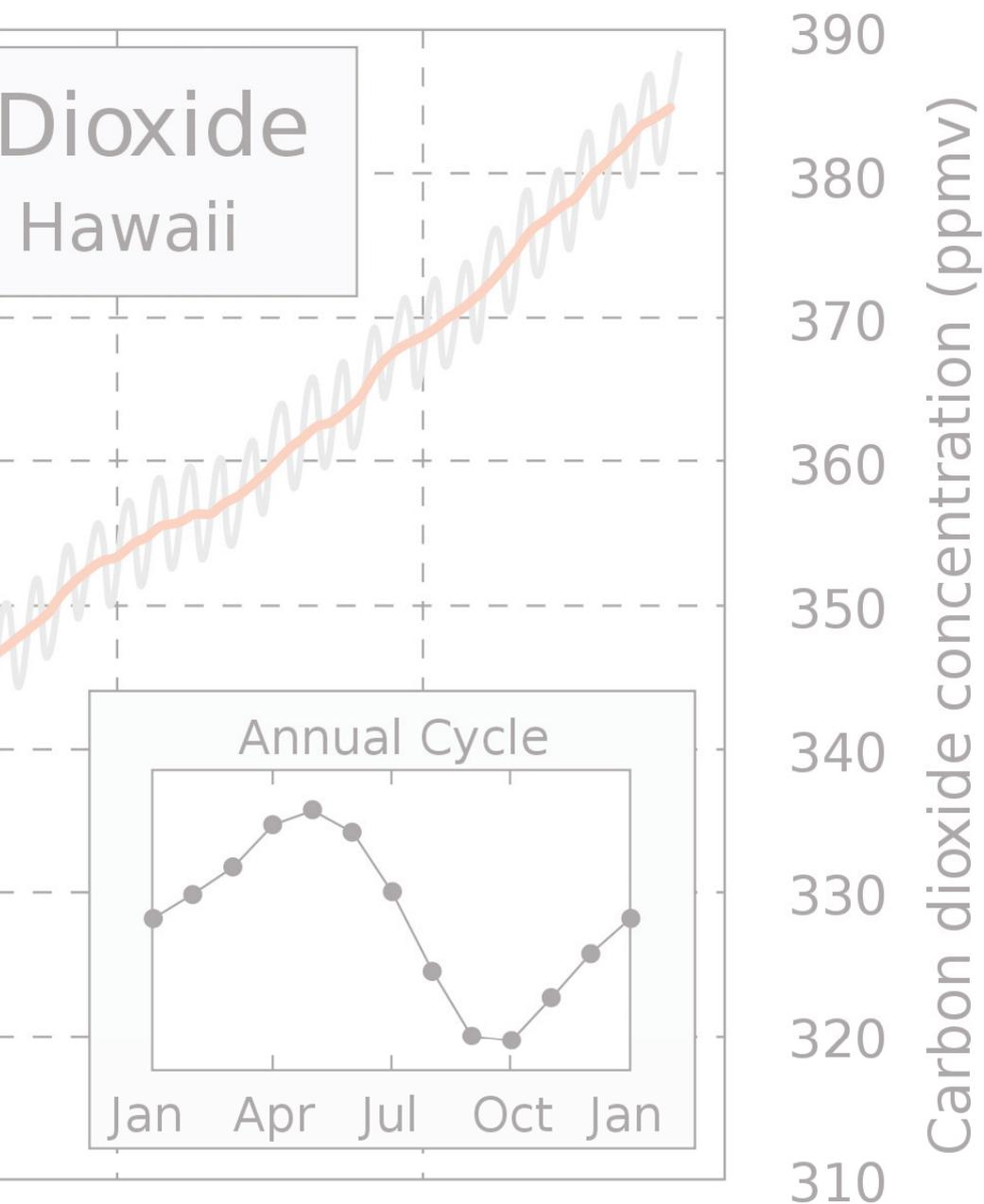
In addition, observations of other species including ozone and volatile organic compounds (VOCs) are now being coordinated by the WMO Global Atmosphere Watch (GAW) programme. The central calibration laboratory function for these species is provided by the BIPM/CCQM. This collaboration between the metrology and climatology communities is effective and provides a model for interactions in other fields.

Future challenges in the area will include the development of standards for new analytes such as the oxides of nitrogen, oxygen and selected monoterpenes as well as facilitating the expansion of global networks to increasingly remote locations whilst maintaining the accuracy of the measurement standards used.

Objectives

- To summarize the state of the art and consider what level of trend detection is achievable based on current measurements and the present availability of standards.
- To identify priorities for new analytes and improvements to the accuracy of measurements of existing analytes.
- To explore the relationship between measurements referred to “SI-traceable” measurement standards and those referred to measurement “scales”.
- To review the use (or “assimilation”) of “SI-traceable” data into atmospheric chemical models and the consequences on the accuracy and quality of the results.
- To discuss the relationship between measurement data of atmospheric composition taken at one or a few points to the results of column- or range-resolved measured data.

ses and other trace species



Background: History of atmospheric CO₂ concentrations measured at Mauna Loa, Hawaii. This curve is known as the Keeling curve.

Source: http://commons.wikimedia.org/wiki/File:Mauna_Loa_Carbon_Dioxide-en.svg

B1. Stable time series for key GHGs and other trace species

Chair: Robert Wielgosz, BIPM
Rapporteur: Martin Milton, NPL {UK}

- 8:30** Greenhouse gas observations in the GAW programme
Oksana Tarasova, WMO/GAW
- 9:00** Ensuring traceability and comparability of measurements for greenhouse gas monitoring
Jim Butler, NOAA {US}
- 9:30** The World Calibration Centre for VOCs
Rainer Steinbrecher, FZK-KIT {DE}
- 10:00** Coffee
- 10:30** Supporting traceable global measurements through international comparison exercises
Martin Milton, NPL {UK}
- 11:00** Calibrating measurements of long-lived atmospheric trace gases: The dominant importance of precision over accuracy and the role of defined calibration scales
Ray Weiss, Scripps Institution of Oceanography {US}
- 11:30** Trend analysis for greenhouse and reactive gases
Brigitte Buchmann, EMPA
- 12:00** Lunch
- 14:00** Ozone cross-sections and primary standards
Joële Viallon, BIPM
- 14:30** Topic Discussion

Wednesday, 31 March 2010

B2. Remote sensing of atmospheric composition and traceability issues in spectroscopic data

Chair: James Whetstone, NIST {US}

Rapporteur: Robert Wielgosz, BIPM

- 16:00** Relating point measurements of atmospheric composition to integrated-path and range-resolved measurements
Bertrand Calpini, METEOSWISS {CH}
- 16:30** Satellite measurements of tropospheric species from GOSAT
Tatsuya Yokota, NIES {JP}
- 17:00** Reference standards for space-based remote sensing of carbon dioxide and greenhouse gases
Charles Miller, JPL, NASA {US}
- 17:30** Integration of column CO₂ measurements into the existing *in situ* network for greenhouse gases
Thorsten Warneke, University of Bremen {DE}
- 18:00** Closure, second day
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- 8:30** Global observations of greenhouse gases using SCIAMACHY
John Burrows, Bremen {DE}
- 9:00** Comparison of spectroscopic measurements of water vapour
Volker Ebert, PTB {DE}
- 9:30** Linking remote measurements of GHG concentrations to the SI through intrinsic molecular properties
Joe Hodges, NIST {US}
- 10:00** Satellite observations of greenhouse gases
Peter Bernath, University of York {UK}
- 10:30** Topic Discussion

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Room: Salle A

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C. Radiation and Earth energy balance

The temperature of the Earth responds to changes in the radiative energy balance maintained between the incoming solar radiation and the outgoing reflected solar radiation and emitted thermal radiation. Accurate total and spectral space and surface measurements of these radiation components at various spatial and temporal scales are critical for understanding the long-term trends in the Earth's climate. Moreover, these measurements must be tied to the SI to ensure their comparability independent of time, locale, or sensor. The measurement problem is extremely challenging since the accuracy required is commensurate with the state of the art for spectral radiance and irradiance measurements performed in environmentally controlled laboratories at National Metrology Institutes. The present session will review the current state of the art in Earth radiation measurements and efforts to improve their accuracy and strengthen their tie to the SI.

Issues

- Current state of the art in the measurement of total solar irradiance and key challenges for the future.
- Quantitative requirements and potential solutions for long-term climate benchmark measurements of the Earth's energy balance.
- Terrestrial radiation networks: Climate need and traceability.
- Climate sensitivity to solar variability (total and spectrally resolved): uncertainty drivers.
- The Earth's energy balance: The current record.
- Metrological challenges and specific uncertainty specifications.
- Barriers to international collaboration.

Background: Solar radiation spectrum for direct light at both the top of the Earth's atmosphere and at sea level.

Source: http://www.globalwarmingart.com/wiki/File:Solar_Spectrum.png

Chair: Werner Schmutz, PMOD/WRC

Rapporteur: Dave Young, NASA {US}

8:30 Climate benchmark missions: CLARREO

Bruce Wielicki, NASA {US}

9:00 Total solar irradiance: Challenges for the future

Werner Schmutz, PMOD/WRC

9:30 Solar spectral irradiance: Current understanding and challenges for the future

Jerry Harder, University of Colorado {US}

10:00 Coffee

10:30 TSI radiometer facility to improve calibrations of total solar irradiance instruments

Greg Kopp, University of Colorado {US}

11:00 The history and the future of the WRR

Wolfgang Finsterle (PMOD/WRC) & Rainer Winkler (NPL {UK})

11:30 Climate sensitivity to solar variability

Joanna Haigh, Imperial College {UK}

12:00 Lunch

14:00 Radiation networks of the WMO: traceability and meeting the needs of climate

Bruce Forgan, Bureau of Meteorology {AU}

14:30 Global dimming/brightening and its metrological challenges

Atsumu Ohmura, ETH {CH}

15:00 Topic Discussion

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Room: C2

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D. Earth surface (land and water) temperature

The change in temperature of the Earth's surface, particularly the Oceans but of increasing importance, Land, is a key indicator of climate change, as well as providing data for operational meteorological services. Remote sensing from space of infrared spectral radiance provides (through Planck's law) global temperature data sets. The sea surface temperature community is well coordinated and is particularly advanced in terms of metrology and traceability. Driven by the need to detect subtle changes, of < 0.01 K over decades, they provide good examples of best practice. However, the uncertainties are still highly challenging and there are issues about reliably linking current sensors to future ones with large variations between measurements based at different sites.

Issues

- The issues associated with establishing long-term base measurements of surface temperature (Land/Ocean) at climate level uncertainties.
- Next generation of satellite sensors for surface temperature measurements and their pre-/post-launch traceability.
- *In situ* measurements and their traceability: buoys, ships
- Establishing an internationally acceptable operational SST product
- Metrological barriers to achieving quality climate data
- Reliability and issues with historical temperature records

Background: Comparison of global average surface temperature record (by Jones and Moberg) with microwave sounder (MSU) satellite data of lower atmospheric temperatures by Christy et al. (UAH) and Schabel et al. (RSS).

Source: http://www.globalwarmingart.com/wiki/File:Satellite_Temperatures.png

Chair: Pascal Lecomte, ESA

Rapporteur: Jerry Fraser, NIST {US}

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- 8:30** GHRSSST as a model for deriving climate data from operational sources
Peter Minnett, RSMAS, University of Miami {US}
- 9:00** Extending benchmark measurements of traceable SST measurements: SLSTR (Sentinel 3)
Dave Smith, RAL
- 9:30** Global and local measurements of SST: harmonization and traceability
Christopher Merchant, University of Edinburgh {UK}
- 10:00** Coffee
- 10:30** *In situ* temperature measurements
Etienne Charpentier, WMO
- 11:00** Establishing quality climate data: traceability needs and issues
David Llewellyn-Jones, University of Leicester {UK}
- 11:30** Validating post-launch instrumentation: CEOS comparison of brightness temperature instrumentation
Theo Theocharous, NPL {UK}
- 12:00** Lunch
- 14:00** Establishing climate surface temperature quality data: Traceability needs and issues
Dick Reynolds, NCDC, NOAA {US}
- 14:30** Topic Discussion

Wednesday, 31 March 2010

Room: TBA

F. Microwave imagery data in climate and N

Microwave imagers (MWI) in polar orbit, operating in the range 6 GHz to 183 GHz, provide information on a range of atmospheric variables, including water vapour, cloud liquid water, precipitation, ocean surface winds, sea ice and sea surface temperature. Data from operational satellite missions have been used for climate research and NWP for more than 10 years. The use of this data for climate trend analysis is well established. Cal/Val programmes, as well as increasingly sophisticated use of the data in NWP assimilation systems, have highlighted a number of instrument calibration problems with several previous imager missions. As with microwave sounders, improved traceability for pre-launch testing and calibration is one important aspect of a wider effort to improve the consistency of the satellite data record. Agencies in the US, Europe, Japan, India, China and Russia have plans to launch imager missions over the next 10 years.

Aims

- Review the current use of the data in NWP and climate research and review the measurement uncertainty requirements associated with these applications.
- Review instrument calibration issues uncovered to date and on-orbit radiometric performance of current imaging missions.
- Review current practice in pre-launch characterization and in microwave metrology.
- Establish best practice for future missions.
- Specify requirements for improved underpinning metrology in order to provide a focus for national and international metrology programmes.
- Foster improved international collaboration between users, agencies, instrument teams and the metrology community, in order to reduce risk for future missions.

Background: Total precipitable water data from an Advanced Microwave Sounding Unit (AMSU).

Source: <http://amsu.cira.colostate.edu/TPW.gif>

Chair:	Karen St. Germain, NPOESS IPO {US}
Rapporteur:	William Bell, ECMWF {UK}
16:00	Trends in total precipitable water from microwave imagery data <i>Graeme L. Stephens, Colorado State University {US}</i>
16:30	Microwave imagery data in NWP <i>William Bell, ECMWF {UK}</i>
17:00	NPOESS Microwave Imager/Sounder (MIS) sensor development <i>David B. Kunkee, The Aerospace Corporation {US}</i>
17:30	Lessons learned from AMSR and plans for GCOM-W <i>Haruhisa Shimoda, EORC, JAXA {JP}</i>
18:00	Closure, second day
8:30	Pre-launch testing, calibration and on-orbit performance of the METEOR-M N 1 microwave imager/sounder <i>A. B. Uspensky & I. V. Cherny, State Research Center on Space Hydrometeorology "Planeta" {RF}</i>
9:00	Calibration issues of microwave imagers <i>Shannon Brown, JPL {US}</i>
9:30	A plan for developments of climate data records from special sensor microwave imager (SSM/I) and sounder (SSMIS) <i>Fuzhong Weng, NOAA, NESDIS</i>
10:00	Topic Discussion

G. Surface properties: albedo, land cover and

Knowledge of the reflective properties of the Earth's surface is critical to understanding the Earth's radiation budget and also for modelling of precipitation. Land cover classification and its change with time, together with Ocean chlorophyll, through spectrally resolved measurements of solar reflected radiation (and in the future fluorescence) allow studies of the carbon cycle. Accurate spectral reflectance measurement of the Earth is also an essential measurement to enable its signature to be removed from space based aerosol measurements. However, in this theme the more fundamental issue relates to how the atmosphere modifies the propagation of radiation through it. Thus correction for this effect is one of the dominant sources of uncertainty in establishing a traceable link between the radiance/reflectance measured at the top of the atmosphere and that leaving the surface. Uncertainties of $< 1\%$ and in some cases ($\sim 0.2\%$) are now being requested by the climate science community. Future NWP and GCM models will endeavour to incorporate land-cover information as the spatial grids reduce in scale. Similar measurements (although with lower accuracy requirements) provide operational information on pollution, disaster monitoring, agriculture and mineral prospecting, which, although not directly climate variables, are of critical importance in the wider context. In addition to normal instrument calibration, measurement issues for this community include atmospheric correction issues, angular effects and spatial resolution.

Aims

- Critical uncertainty drivers and key sensor characteristics for pre-/post-launch calibration of satellite sensors.
- Post-launch calibration and validation activities and their traceability needs for the future.
- Traceability requirements for pre-flight sensor calibration
- Equating TOA radiances/reflectances to true surface variables at all spatial scales.
- The establishment of operational, global data sets and sensor-to-sensor interoperability
- Specification of metrological uncertainties originating from understanding and monitoring impact of the carbon cycle.

Background: CERES-Aqua 2003-2004 mean annual total sky albedo. Total sky albedo is the fraction of the incoming solar radiation that is reflected back into space by regions of the Earth including cloudy days.

Source: <http://daac.gsfc.nasa.gov/giovanni/>

d ocean colour

Chair: Nigel Fox, NPL {UK}

Rapporteur: Carol Johnson, NIST {US}

16:00 Metrology considerations for the next generation of satellite sensors

Bruce Guenther, NOAA {US}

16:30 Advances in traceability for pre-flight calibration

Carol Johnson, NIST {US}

17:00 Post-launch calibration and validation needs for ocean colour sensors

Giuseppe Zibordi, JRC {IT}

17:30 Measurement uncertainties of surface albedo and need for traceability

Jan-Peter Mueller, MSSL {UK}

18:00 Closure, second day

8:30 Improving field spectroradiometric measurements for optical land surface imager calibration and product generation

Michael Schaepman, University of Zurich {CH}

9:00 The oceans, the carbon cycle and the establishment of a climate data record

Sean Bailey, NASA {US}

9:30 Remote sensing of the Earth: propagation through, and correction for, the atmosphere

Menghua Wang, NOAA {US}

10:00 Topic discussion

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Room: C2

H. Ocean salinity

The global circulation of seawater, which is driven by density fluctuations, has a large impact on the climate. Salinity, a measure for dissolved material in water, is, in addition to pressure and temperature, used to calculate the density of seawater. Salinity, linked to the overall water cycle including the ocean-atmosphere interaction, constitutes one of the key climate variables. Salinity is an important input quantity in oceanographic models.

The Practical Salinity Scale, PSS-78, and the International Equation of State of Seawater (EOS-80), which expresses the density of seawater as a function of practical salinity, temperature and pressure, have served the oceanographic community for thirty years.

However, practical salinity defined in terms of relative conductivity measurements is not traceable to SI units.

In 2009 the Intergovernmental Oceanographic Commission (IOC) endorsed the new Thermodynamic Equation of Seawater 2010 (TEOS-10), from which accurate algorithms for calculating density of seawater, and many other thermodynamic properties (i.e. heat content), are available. Oceanographers now have consistent and accurate formulations to quantify the transport of heat in the ocean and the exchange of heat between the ocean and atmosphere. Part of the new thermodynamic treatment of seawater involves adopting absolute salinity. In contrast to practical salinity, absolute salinity is expressed in SI units and incorporates the small spatial variations of the composition of seawater in the global ocean. Absolute salinity is also appropriate for the calculation of freshwater fluxes and for calculations involving the exchange of freshwater with the atmosphere and with ice.

The algorithm that calculates absolute salinity from knowledge of the practical salinity and the spatial location should however be refined on the basis of more SI-traceable ocean measurements.

This session will address the observations and monitoring requirements that are necessary to ensure traceable salinity data for future climate studies.

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Background: Annual mean sea surface salinity from the World Ocean Atlas 2005. Salinity in practical salinity units (PSU).

22 **Source:** http://en.wikipedia.org/wiki/File:WOA05_sea-surf_SAL_AYool.png

Chair: Klaus-Dieter Sommer, PTB {DE}

Rapporteur: Petra Spitzer, PTB {DE}

16:00 TEOS-10: International Thermodynamic Equation of Seawater 2010

Rainer Feistel, Institut für Ostseeforschung {DE}

16:30 Salinity calibration standards adopted in the International Argo Programme

Birgit Klein, BSH {DE}

17:00 Sea-salt composition and oceanographic salinity scales

Rainer Feistel, Institut für Ostseeforschung {DE}

17:30 Global climate and ocean observing systems, opportunities and challenges

Martin Visbeck, Leibniz-Institut für Meereswissenschaften IFM-GEOMAR {DE}

18:00 Closure, second day

8:30 The sea surface salinity observation system

Thierry Delcroix, IRD {FR}

9:00 Traceable salinity measurements

Petra Spitzer, PTB {DE}

9:30 Role of the oceans in global cycles of carbon and nutrients

Chen-Tung Arthur Chen, Institute of Marine Geology and Chemistry, National Sun Yat-Sen University {TW} and Chair of the International Geosphere Biosphere Programme

10:00 Topic Discussion

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Room: TBA

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Reports from Sessions & Prioritization of activities

Chair: Robert Wielgosz (BIPM) & Bertrand Calpini (MeteoSwiss)

Rapporteur: Luis Mussio, BIPM

- 11:30** A: Climate trends from satellite sounding data
Fuzhong Weng, NOAA NESDIS {US}
- 11:45** B: Stable time series for key GHGs and other trace species
Matrin Milton, NLP {UK}
- 12:00** C: Radiation and Earth energy balance
Werner Schmutz, PMOD/WRC
- 12:15** D: Earth surface (land and water) temperature
Pascal Lecomte, ESA
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- 14:45** G: Surface properties: albedo, land cover and ocean colour
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- 15:00** H: Ocean salinity
Klaus-Dieter Sommer, PTB {DE}
- 15:15** B2. Remote sensing of atmospheric composition and traceability issues in spectroscopic data
James Whetstone, NIST {US}
- 15:30** Coffee
- 16:00** Prioritization of activities
Bill Bell, ECMWF {UK}
- 17:00** Closure

Thursday, 1 April 2010

Room: Salle A

Steering Committee

Omar Baddour {co-coordinator of the workshop}	WMO
William Bell	ECMWF
James Butler	AREP, GAW and GCOS
Bertrand Calpini {co-chair of the Steering Committee}	WMO, CIMO
Bruce Sumner	HMEI
Pedro Espina {co-coordinator of the workshop}	NIST
Werner Schmutz	WRC
Nigel Fox	NPL
Gerald Fraser	GSICS
Martin Milton	NPL
Petra Spitzer	PTB
Andrew Wallard {co-chair of the workshop}	BIPM
Fuzhong Weng	NOAA
James Whetstone	NIST
Robert Wielgosz {co-chair of the Steering Committee}	BIPM
Wenjia ZHANG {co-chair of the workshop}	WMO

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Notes

A large rectangular area with a light yellow background and a blue border, containing 20 horizontal dotted lines for writing notes.

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