Climate change and Environment: needs and challenges to be addressed by the CCM

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Agreement between the World Meteorological Organization and the International Committee for Weights and Measures

Text approved by the CIPM on 10 October 2001

Article I

1. The World Meteorological Organization (WMO), referred hereinafter as "the Organization", and the International Committee for Weights and Measures, referred hereinafter as "the Committee", agree that with a view to facilitating the implementation of their objectives, set respectively in the Convention of WMO and in the Metre Convention, they will act in close cooperation with each other and consult each other regularly in regard to matters of common interest.

2. The Committee recognizes the responsibilities of the Organization in the field of meteorology, hydrology and other related geophysical sciences as set forth in the Convention of the Organization and recognizes in the Agreement between the United Nations and the Organization and in particular that the Organization has a mandate to ensure that data obtained in the course of its work is standardized, accurate and reliable.

3. The Organization recognizes the responsibilities of the Committee as set forth in the Metre Convention and in particular the recommendation of the Member States set out in Resolution 4 of the 21st General Conference of Weights and Measures (1995) related to the need to use SI units in studies of Earth resources, the environment, human well being and related issues.

4. Accordingly, the Organization and the Committee will consult together to ensure that data, related in particular to measurements of state and composition of atmosphere and water resources, coming from the programmes organized under the auspices of the Organization are properly based on units traceable to the SI through the procedures of the Mutual Recognition Arrangement for National Measurement Standards drawn up by the Committee and those of the Technical Regulations of the Organization.

Article II

Reciprocal representation

1. Representatives of the Committee shall be invited to attend sessions of bodies of the Organization and to participate without vote in the deliberations of these bodies and, where appropriate of its committees or commissions with respect to items on the agenda in which the Committee has an interest.

2. Representatives of the Organization shall be invited to attend the General Conference of Weights and Measures and to participate without vote in the deliberations of that body with respect to items on the agenda in which the Organization has an interest.

3. Appropriate arrangements shall be made by agreement from time to time for reciprocal representation of the Organization and the Committee at other meetings convened under their respective auspices which consider matters in which the other organization has an interest.

Article III

Traceability to SI

Measurement Challenges for Global Observation Systems for Climate Change Monitoring

Traceability, Stability and Uncertainty

30 March – 2 April 2010

WMO Headquarters

Geneva, Switzerland
CIPM Strategy 2030+

CIPM identified the Climate change and Environment as one of the five “Metrology Grand Challenges”

CIPM recognized Metrology is critical to ensuring the monitoring of the global climate and broader environment,

The mitigation policies and their implementation are based on firm evidence.
Recommendation 6 (WMO-CIMO-17), 2018

Improvement of traceability in measurement and calibration results in NMHS

The traceability of measurement and calibration results is key to ensuring confidence in:
- measurement data,
- their quality and
- their suitability for use in specific application areas: the assessment of climate variability and change

Recommendation 11 (WMO-CIMO-17), 2018

CIMO encouraged the cooperation between WMO and BIPM

WMO-INFCOM-2-decision 7, 2022

The Commission for Observation, Infrastructure and Information Systems decides:

1. To intensify activities on the assessment of uncertainty evaluations;

2. To harmonize the definitions and terminology related to the term "uncertainty" across technical publications overseen by the Commission to ensure their use is correct, consistent and understood when used among WMO communities;
European Metrology Network on Climate and Ocean Observations
Launched in 2019

Aim: Building partnerships between metrology and the climate & ocean observation communities to enhance metrological best practice across Europe and beyond.

Members: NMI, Dis and Affiliated partners

Stakeholders needs report

Strategy Research Agenda

- In situ sensors
- Networks
- Satellite Sensors

ECVs
EOVs

https://www.euramet.org/climate-and-ocean-observation
GCOS expert panels maintain definitions of Essential Climate Variables (ECVs) which are required to systematically observe Earth`s changing climate. GCOS currently specifies 55 ECVs.

Essential Ocean Variables
To be able to deliver ocean forecasts and early warnings, climate projections and assessments and protect ocean health and its benefits, it is vital to measure Essential Ocean Variables (EOVs). 33 EOVs

<table>
<thead>
<tr>
<th>Physical</th>
<th>Biochemistry</th>
<th>Biology and Ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea state</td>
<td>Oxygen</td>
<td>Phytoplankton biomass and diversity</td>
</tr>
<tr>
<td>Ocean surface stress</td>
<td>Nutrients</td>
<td>Zooplankton biomass and diversity</td>
</tr>
<tr>
<td>Sea ice</td>
<td>Inorganic carbon</td>
<td>Fish abundance and distribution</td>
</tr>
<tr>
<td>Sea surface temperature</td>
<td>Transient tracers</td>
<td>Marine turtles, birds, mammals abundance and distribution</td>
</tr>
<tr>
<td>Subsurface temperature</td>
<td>Particulate matter</td>
<td>Hard coral cover and composition</td>
</tr>
<tr>
<td>Surface currents</td>
<td>Nitrate oxides</td>
<td>Seagrass cover and composition</td>
</tr>
<tr>
<td>Subsurface currents</td>
<td>Stable carbon isotopes</td>
<td>Macroalgal canopy cover and composition</td>
</tr>
<tr>
<td>Sea surface salinity</td>
<td>Dissolved organic carbon</td>
<td>Mangrove cover and composition</td>
</tr>
<tr>
<td>Ocean surface heat flux</td>
<td></td>
<td>Microbial biomass and diversity (&quot;emerging&quot;)</td>
</tr>
<tr>
<td>Ocean bottom pressure</td>
<td></td>
<td>Invertebrate abundance and distribution (&quot;emerging&quot;)</td>
</tr>
</tbody>
</table>

Cross-disciplinary (including human impact)

| Ocean colour | Marine debris ("emerging") | Ocean sound |

Essential Climate Variables

<table>
<thead>
<tr>
<th>Surface</th>
<th>Hydrosphere</th>
<th>Cryosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Groundwater</td>
<td>Glaciers</td>
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<tr>
<td>Pressure</td>
<td>Lakes</td>
<td>Ice sheets and ice shelves</td>
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<tr>
<td>Radiation budget</td>
<td>River discharge</td>
<td>Permafrost</td>
</tr>
<tr>
<td>Temperature</td>
<td>Terrestrial water storage</td>
<td>Snow</td>
</tr>
<tr>
<td>Water vapour</td>
<td></td>
<td></td>
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<tr>
<td>Wind speed and direction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upper-air</th>
<th>Land</th>
<th>Biosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth radiation budget</td>
<td>Groundcover</td>
<td>Above-ground biomass</td>
</tr>
<tr>
<td>Lightning</td>
<td></td>
<td>Albedo</td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td>Evaporation from land</td>
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<tr>
<td>Water vapour</td>
<td></td>
<td>Frazil</td>
</tr>
<tr>
<td>Wind speed and direction</td>
<td></td>
<td>Fraction of absorbed photosynthetically active radiation (FPAR)</td>
</tr>
<tr>
<td>Clouds</td>
<td></td>
<td>Land cover</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Atmospheric Composition</th>
<th>Ocean</th>
<th>Biogeochemistry</th>
<th>Biological/ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosols</td>
<td>Ocean surface heat flux</td>
<td>Inorganic carbon</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide, methane and other greenhouse gases</td>
<td>Nitrous oxide</td>
<td>Marine habitats</td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>Ocean currents</td>
<td>Nutrients</td>
<td></td>
</tr>
<tr>
<td>Precursors for aerosols and ozone</td>
<td>Oxygen</td>
<td>plankton</td>
<td></td>
</tr>
</tbody>
</table>

Essential Ocean Variables

- Ocean surface heat flux
- Sea ice
- Sea surface salinity
- Sea surface temperature
- Surface currents
- Subsurface currents
- Seagrass
- Macroalgal canopy
- Mangrove cover
- Microbial biomass
- Invertebrate abundance

Anthropogenic Greenhouse gas fluxes
Anthropogenic water use
Surface pressure:

- Actual pressure + Pressure trend (pressure change + pressure characteristic).

The pressure change is the net difference between pressure readings for a specified interval of time.

The pressure characteristic is an indication of how the pressure has changed during that period of time, for example, decreasing then increasing, or increasing and then increasing more rapidly.

Pressure fields are a pillar for the predictions of the state of the atmosphere.

- barometer itself,
- The exposure also requires special attention: wind, radiation, temperature, pressure shocks and vibrations
- WIND: A draught-free environment is needed. Static Pressure Heads for minimizing wind influence. It ‘filters out’ the effect of dynamic pressure,
- Differences in the way in which the barometer is operated during calibration compared with its operational use.
- Field inspections should be performed in low gradient weather conditions with stable atmospheric pressure and low wind speeds.

Upper-Air pressure:

Radiosonde –

Very large dynamic range (3, 1 000) hPa, with a resolution of 0.1 hPa over most of the range and a resolution of 0.01 hPa for pressures less than 100 hPa.

These instruments work under extremely wide range of meteorological conditions:

- (-95, 50) °C
- (1%, 100%) for relative humidity
- heavy rain, in the vicinity of thunderstorms, and in severe icing conditions.

Today, many modern radiosonde systems use GPS navigation signals to locate the position of the radiosonde and have excluded the use of a pressure sensor. But still direct measurements of pressure in the troposphere present advantage for some proposes.
Wind speed and direction: Surface
- weather monitoring and forecasting,
- for wind-load climatology,
- for probability of wind damage
- estimation of wind energy,
- as part of the estimation of surface fluxes: evaporation for air pollution dispersion and agricultural applications.

Usual wind instruments: wind vane and cup or propeller anemometer
New ones. Sonic anemometers: Work to be done on Calibration and uncertainty measurements

The most difficult aspect of wind measurement is the exposure of the anemometer (10 m above the ground and without obstacles around.

WMO/CIMO Siting classification (distance to obstacles). Uncertainties associated to influence of the obstacles
-Urban Climate ??? Uncertainties in urban wind???

In Upper-Air:
Wind is fundamental for understanding and predicting the behaviour of the atmosphere
- vertical wind
- horizontal wind
- Instruments working under extreme meteorological conditions
**Precipitation**

**Precipitation**: is linear depth. Determined by volumetric (volume/area) or by weight measurements (mass/area).

**Rainfall intensity** is linear depth per hour, usually in millimetres per hour (mm h⁻¹).

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**Catching Instruments**

The weight of the catch is measured, in particular for solid precipitation.

**Non-Catching Instruments**

Based on detection of the drops:
- drop size distribution
- velocity of the drops

**Reference instruments**
- rain
- snow

**European Incipit Project**

Traceability chain?
Standard?
Calibration uncertainties?

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**WMO Spice Project**: Solid precipitation

In addition to traceability in the laboratory, the understanding of each **measurement uncertainty components** is needed.

- **Catching uncertainty**: the ability of the instrument to collect the exact amount of water according to the definition of precipitation at the ground: wetting, evaporation, splashing, freezing and **wind**.

- **Quantification uncertainty** are related to the ability of the instrument to sense correctly the amount of water collected by the instrument.

- **Other uncertainties**: for example sensitivity to exposure: WMO **Siting classification** + Urban climate.

Laboratory and field intercomparisons on rainfall intensity gauges is a powerful tool.
Ocean
- Ocean Surface Stress: \( \text{N/m}^2 \)
- Ocean Surface and Subsurface Salinity
- Ocean Surface and Subsurface Currents
- Sea State
- Sea Surface Height
- Ocean bottom pressure (OBP)

Cryosphere
- Ice Sheets and Ice Shelves
- Snow
- Glaciers
- Permafrost

- All these four domains include different variables that characterize them
- Limits between ice and snow??
Metrology for Climate Action Workshop 2022

Hosted by the BIPM and WMO
26-30 September 2022

Participation
The workshop is open to experts and stakeholders active in the fields of climate science, observations, modelling, GHG mitigation and measurement and measurement science willing to contribute to the development of recommendations on key technical challenge areas for metrology in these fields.

Interest in participation can be registered below, including topics that the participant wishes to contribute to, as well as suggestions of
**Measurement Quality Classification Scheme** (system)

- Measurement system & calibration (Annex 1A)
- Instrument(s) coupling
- Maintenance & verification
- Environment effects

**Siting Classification Scheme** (measurement exposure)

- Class 1
- Class 2
- Class 3
- Class 4
- Class 5

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**Required**

- User requirements
  - OSCAR
  - Goal
  - Breakthrough
  - Threshold
  - Other sources

**Actual components**

**Actual total**

= Overall measurement uncertainty
Why is Metrology important?:

It provides:
- Robust comparability of the measurements taken in different places and at different times
- Detection of Climate trends in reduced time
- Understanding atmospheric/oceanic/cryosphere processes

Final goal: Establishment of powerful and fit for purpose policies for the mitigation and adaptation to climate change

How is Metrology useful?

- Contribution to the homogeneous definition of some Climate Variables
- Defining traceability chains
- Establishment of fit for purpose procedures for:
  - 1. Calibration
  - 2. Maintenance
  - 2. Measurement
  - 3. Evaluation of influence parameters
  - 4. Uncertainty budgets
  - 5. Laboratory instruments comparisons
  - 6. Field instruments comparisons under real conditions of use
  - 7. Defining the needed metadata associated to each measurement

Interdisciplinary teams
Thank you

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