Towards cross-ECV activities in the new GCOS Implementation plan—what are the questions?

Han Dolman and the GCOS/WMO secretariat
1. GCOS – The way we work
2. GCOS ECV and Climate cycles
3. Adaptation
4. What role can you play?
The goal of the GCOS is to provide comprehensive information on the total climate system involving the multi-disciplinary range of physical, chemical and biological properties and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes.

The GCOS is intended to meet the needs of:

- Climate system monitoring, climate change detection and monitoring the impacts of and response to climate change, especially in terrestrial ecosystems and mean sea-level;
- Data for application to national economic development;
- Research toward improved understanding, modelling and prediction of the climate system

- The first step is for GCOS to identify what needs to be observed and to define requirements of these observations
- This lead to the **Essential Climate Variables: ECV**
- GCOS reviews the performance of observations of ECV and reports to WMO, UNFCCC and others
- GCOS provides advice and support

*Extract from GCOS MoU 1998*
• Supporting and promoting climate observations
  – Atmospheric Observations, WMO:
    • ECV requirements feed into WMO requirements (OSCAR), System monitoring (WDQMS), network development/ improvement (GBON), Data Exchange
    • GCOS Networks: GSN GUAN and GRUAN
  – Ocean Observations, (IOC and WMO): works with GOOS on ECV requirements feeding into observational networks and WMO (OSCAR)
  – Terrestrial Observations: working with a wide range of bodies covering
    • Global Terrestrial Networks (Hydrology, Glaciers, Permafrost...);
    • Land Use and fires GOFC-GOLD
    • GHG fluxes and anthropogenic water use

• Reporting
  – UNFCCC (Status Report, Implementation Plan, regular reporting to UNFCCC on climate observations
  – WMO and IOC on user needs
  – GCOS Sponsors

• Regional Plans/Information (Regional workshops)

• GCOS Cooperation Mechanism: Direct support to countries (NMHS) e.g. on radiosondes, communications
1. STATUS OF THE GCOS ESSENTIAL CLIMATE VARIABLES (Adequacy of the Observing System and Data Stewardship)

2. STATUS OF THE OBSERVING NETWORKS
   2.1 Satellite Observations
   2.2 GCOS Networks
   2.3 Ocean Networks
   2.4 Terrestrial Networks

3. STATUS OF THE IMPLEMENTATION OF ACTIONS FROM THE 2016 IMPLEMENTATION PLAN

4. OBSERVATIONS OF AND FOR ADAPTATION, AND EXTREMES

5. OBSERVATIONS OF THE EARTH SYSTEM CLIMATE CYCLES

6. CONCLUSIONS

### Adequacy of the Observational System

<table>
<thead>
<tr>
<th>ECV</th>
<th>Adequacy of the Observational System Assessment</th>
<th>Availability and Stewardship Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Discharge</td>
<td>In-situ observations with gaps and highly variable Satellite data: measure water elevations, no direct measurement of discharge. Global monitoring but weak temporal resolution depending on the satellite orbit cycle (several days). The use of constellations (with 10 satellites or more) could improve the temporal resolution.</td>
<td>In-situ data quality and availability dependents on national hydrological service Satellite data: all freely available, long-term monitoring foreseen with the Copernicus program, QA/QC but dependant on in-situ data, and adequate metadata. Water elevation accuracy less precise than in situ (few decimetres accuracy).</td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>Meeting requirements in semi-arid regions and crop lands, issues still in dense vegetation, organic soils, and regions of strong topography</td>
<td>Most datasets are open access, including doi and validation reports and many are produced operationally</td>
</tr>
<tr>
<td>Glaciers</td>
<td>Very limited glaciers have in-situ observations. Satellite data is globally covered but has too low spatial resolution to extract useful data with sufficient time resolution.</td>
<td>In-situ data and remote sensing data is collected and published by prevailing networks with high quality and efficacy. Users can access and use most data easily.</td>
</tr>
<tr>
<td>Ice Sheet and Ice Shelves</td>
<td>Great achievements cover vast and ca. inaccessible area.</td>
<td>Data product efforts were done, and information was compiled, and dissimilation have been progressing.</td>
</tr>
</tbody>
</table>
ECV and the Earth’s Climate cycles
Essential Climate Variables (ECV)

- are physical, chemical or biological variables that critically contribute to the characterization of Earth’s climate.
- are not of stand-alone variables; they are part of a wider concept.
- are founded on climate science and observational capability and infrastructure.

ECV datasets provide the empirical evidence

- to understand and predict the evolution of climate,
- to guide mitigation and adaptation measures,
- to assess risks
- to enable attribution of climatic events to underlying causes,
- to underpin climate services.

SOURCE: Bojinski, S. et al., 2014
## 2016 Essential Climate Variables (ECVs)

<table>
<thead>
<tr>
<th>Atmospheric</th>
<th>Oceanic</th>
<th>Terrestrial</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface</strong></td>
<td><strong>Physical</strong></td>
<td><strong>Hydrology</strong></td>
</tr>
<tr>
<td>Precipitation, Surface pressure, Surface radiation budget, Surface wind speed and direction, Surface temperature, Surface water vapour</td>
<td>Ocean surface heat flux, Sea ice, Sea level, Sea state, Sea surface Salinity, Sea surface temperature Subsurface currents, Subsurface salinity, Subsurface temperature</td>
<td>Groundwater, Lakes, River discharge, Soil moisture</td>
</tr>
<tr>
<td><strong>Upper-air</strong></td>
<td><strong>Biogeochemical</strong></td>
<td><strong>Cryosphere</strong></td>
</tr>
<tr>
<td>Earth radiation budget, Lightning, Upper-air temperature, Upper air water vapor, Upper-air wind speed and direction</td>
<td>Inorganic carbon, Nitrous oxide, Nutrients, Ocean colour, Oxygen, Transient tracers</td>
<td>Glaciers, Ice sheets and ice shelves, Permafrost, Snow</td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td><strong>Biological/ecosystems</strong></td>
<td><strong>Biosphere:</strong></td>
</tr>
<tr>
<td>Aerosols properties, Carbon dioxide, Methane and other greenhouse gases, Cloud properties, Ozone, Aerosol and ozone precursors</td>
<td>Marine habitat properties, Plankton</td>
<td>Above-ground biomass, Albedo, Fire, Fraction of absorbed photosynthetically active radiation, Land cover, Land surface temperature, Latent and sensible heat fluxes, Leaf area index, Soil carbon</td>
</tr>
<tr>
<td><strong>Human use of natural resources:</strong></td>
<td></td>
<td>Anthropogenic greenhouse gas fluxes, Anthropogenic water use</td>
</tr>
</tbody>
</table>

*SOURCE: GCOS Implementation Plan 2016*
<table>
<thead>
<tr>
<th>Item</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECV</td>
<td>Name of ECV</td>
</tr>
<tr>
<td>Products</td>
<td>Sub-variables needed (e.g. lake area, temperature and colour)</td>
</tr>
<tr>
<td>Frequency</td>
<td>e.g. hourly, annual, etc.</td>
</tr>
<tr>
<td>Resolution</td>
<td>Horizontal and vertical</td>
</tr>
<tr>
<td>Required measurement uncertainty</td>
<td>Follow international definitions</td>
</tr>
<tr>
<td>Stability</td>
<td>Vital for climate change</td>
</tr>
<tr>
<td>Standards/References</td>
<td>Where they exist</td>
</tr>
</tbody>
</table>

**2022**

**Requirements**

<table>
<thead>
<tr>
<th>Item</th>
<th>SI Unit</th>
<th>Metric</th>
<th>Value</th>
<th>Derivation and Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Resolution</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Vertical Resolution</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Temporal Resolution</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Timeliness</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Required Measurement Uncertainty</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>G</td>
<td>B</td>
<td>T</td>
<td></td>
</tr>
</tbody>
</table>

Background information/explanation for each value mandatory

In order to make the process transparent and allow for discussions

Have 3 values: “threshold”, “breakthrough” and “goal”
• GCOS aims for these important parts of the climate system to be completely measured
• GCOS has set long-term targets for monitoring all 4
• One ECV can belong to several cycles
• ECV must be consistent within a cycle and between cycles
• ECV are also measured for other purposes – avoid duplication
• Papers on each cycle under preparation, results will feed into the Status Report
• e.g for the carbon cycle, not just fluxes but ocean and terrestrial carbon measurements should be consistent – operating across these domains GCOS can provide guidance
The Earth’s climate cycles

• Assess the status of consistently assessing the variability of the carbon, hydrological and energy cycles at various spatial and temporal scales,

• Assess the relevant land, atmosphere, and ocean storages and the fluxes between them, including anthropogenic fluxes and stores,

• Identify gaps in existing observation systems and in consistency and attribute their origin,

• Conclude with formulating guidelines for future Earth cycle observation strategies.
Climate impacts significantly affect a wide range of factors in the biosphere, such as:

- Temperature changes leading to a redistribution of biomes and ecosystem niches, which will change conditions of specific ecosystems such as forests, grasslands, wetlands, etc.
- Changes in ocean productivity and the global nutrient budget will change the availability of nutrients for primary production at different latitudes.
- Changes in surface temperature and regional precipitation patterns may change geographical ranges of specific species.

Operators of GCOS-related systems, including data centres.

### Box 4: Closing the carbon budget

<table>
<thead>
<tr>
<th>Targets</th>
<th>Quantify fluxes of carbon-related greenhouse gases to +/- 10% on annual timescales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantify changes in carbon stocks to +/- 10% on decadal timescales in the ocean and on land, and to +/- 2.5 % in the atmosphere on annual timescales</td>
</tr>
</tbody>
</table>

Operators of GCOS-related systems, including data centres.

### Box 5: Closing the global water cycle

| Time frame | Close water cycle globally within 5% on annual timescales |

Operators of GCOS-related systems, including data centres.

### Box 6: Closing the global energy balance

| Time frame | Balance energy budget to within 0.1 Wm$^{-2}$ on annual timescales |

Operators of GCOS-related systems, including data centres.

### Box 7: Explain changing conditions of the biosphere

| Time frame | Ongoing |

Operators of GCOS-related systems, including data centres.

| Performance indicator | Performance indicator |

Regular assessment of the uncertainty of estimates of changing conditions as listed above.
Heat stored in the Earth system: where does the energy go?

**EARTH ENERGY IMBALANCE:**

1. $0.47 \pm 0.1 \ (0.87 \pm 0.12) \ W/m^2$
2. Required CO$_2$ reduction: $-57 \pm 8 \ ppm$

**Total Heat Gain:**

- **Ocean:** 89% (90%)
  - 0-700 m: 52% (59%)
  - 700-2000 m: 28% (31%)
  - >2000 m: 9% (10%)

- **Land:** 6% (5%)
- **Cryosphere:** 4% (3%)


Just published on Monday 7/9/20
This is not a GCOS paper per sé.

Another paper Crisp, Tanhua, Dolman et al is in preparation.
Earth System cycles and budgets

• There are fundamentally two way to compile budgets and determine imbalances:
  – Look at the (time difference of) stocks
  – Look at the fluxes
• These two ideally should match (e.g. the Earth’s Energy Imbalance)
• GCOS works with WCRP to make these two approaches match by improving the data quality and identifying gaps, and specifying ECV requirements.
The challenge of providing adaptation climate data

• “GCOS should establish a specific activity to understand the needs of adaptation and how to develop their observational requirements. This will require the direct involvement of adaptation experts rather than rely solely on the observation experts traditionally associated with the GCOS Science panels, including those with financial, implementation and policy responsibilities for successful adaptation to climate change. “

• “The ability to understand and estimate risks, both current and how they change in the future, will be vital to support adaptation planning and increase the resilience of societies to climate changes. GCOS should consider the world-wide and regional observations that support or monitor adaptation, but not the detailed local observational needs, in line with its remit as a global observing system.”
• Most ECVs are conceived for long term climate monitoring purposes
• For adaptation, we need generally high spatial and temporal resolution
• The science panels are reviewing the current requirements with this view in mind: i.e. are they useful for adaptation purposes?
ECVs and Adaptation

For each ECV we are checking the relevance for extremes and adaptation.

In the new IP this may have consequences for the requirements.

<table>
<thead>
<tr>
<th>ECV</th>
<th>Extremes</th>
<th>Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed and direction (surface)</td>
<td>Essential</td>
<td>Essential</td>
</tr>
<tr>
<td>Temperature (surface)</td>
<td>Essential. Land Surface Air Temperatures are used to infer many of the ETCCDI extreme indices. Extremes of heat and cold have large-scale implications for human health, thermal comfort, agriculture, ecosystem services etc. Emerging SST requirement for monitoring of marine heat waves</td>
<td>Essential. Knowledge of present temperature variations is key to effective adaptation decision making.</td>
</tr>
<tr>
<td>Pressure (surface)</td>
<td>Sea-level pressure datasets are widely used for the study of tropical and extra-tropical storms. SLP measurements are also used for assessments of long-term changes in storminess and wind speeds since the 19th century.</td>
<td>Essential, particularly for circulation indices and the numbers of tropical and mid-latitude storms.</td>
</tr>
<tr>
<td>Water vapour (surface)</td>
<td>Essential as contribution to heat stress index. Used in some drought indicators.</td>
<td>Essential as a key contributor to heat stress indices</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Extreme events can be captured regionally on a local to global scale by combining observing systems like radar adjusted to in situ measurements. In situ measurements provide direct estimates at many locations.</td>
<td>Precipitation is a key variable in adaptation decision making. Lack of or too much precipitation leads to some of the most widespread and costly impacts to which we must adapt. Longer term precipitation records are key to understand natural variability and the range of possible future conditions. Data rescue and long-term analysis are key.</td>
</tr>
<tr>
<td>Surface Radiation Budget</td>
<td>Extremes in surface radiation can be captured, with better capture at continuously monitored in-situ sites.</td>
<td>Limited applicability</td>
</tr>
<tr>
<td>Upper-air temperature</td>
<td>Limited applicability</td>
<td>Limited applicability</td>
</tr>
</tbody>
</table>
ECV and the CCIs

What can you do?
Update of the GCOS IP: input from status report and climate observations conference

Timeline: *Published by October 2022*

- A shorter document than earlier Implementation Plans
- Integrative actions
  - Consider benefits of synthesis and consideration of activities across ECVs
- Actionable actions
  - Things that are actionable by GCOS / GCOS sponsors
- Important actions
  - Select what is critical
- **Update of requirements**

**Process for Updating Requirements**

- Two public reviews
- Greater involvement of stakeholders
- More detailed information and definitions required
- More specific consideration of different users (e.g. adaptation and extremes)
This conference follows on from the first climate observations conference, Global Climate Observation: The Road to The Future held on 2–4 March 2016 in Amsterdam.

**AIM:** assess how well the current global climate observing system supports current and near-term user needs for climate information. In particular the meeting will examine how well observations of the global Earth cycles (the global energy balance, global water and carbon cycles, and explaining changing conditions of the biosphere) support users’ needs for climate data.

The outputs will provide inputs into the **next GCOS implementation plan** which will make recommendations to meteorological networks, major observing systems and satellite agencies and will be presented to the UNFCCC in 2022 as a contribution towards the UNFCCC’s Global Stocktake.

Opportunity for experts dealing with climate observations and other key stakeholders to review and give input to and feedback on the production of the Implementation Plan.

Invitation for papers and posters in the autumn 2020.
• Review of ECV requirements: March 2020

• Input to GCOS Status Report: August 2020
  • Satellite observations
  • Status of the implementation of satellite related actions from the GCOS IP 2016

• Review of GCOS Status Report: January-March 2021

• Input in Climate Observations Conference: October 2021

• Review of GCOS Implementation Plan: January-March 2022
  (includes 2nd review of ECV requirements)