5. CONSISTENT OBSERVATIONS ACROSS THE EARTH SYSTEM CYCLES

The Earth's energy, water and biogeochemical cycles play a fundamental role in the Earth's climate. Indeed, current climate change is driven by the interaction of the gaseous phases of the carbon and nitrogen cycles and radiative properties of the atmosphere. GCOS has traditionally focused more on state variables of the system and less on fluxes. The original ECVs in previous implementation plans were designed largely on the basis of individual usefulness and maturity; in recent years, much use has been made of climate records based on ECVs to close budgets of energy, carbon and water and to study changes in growth rates of atmospheric concentrations or interaction among land, ocean and atmosphere in a more integrated way. This new perspective on the importance of the Earth cycles in the selection of ECVs allows us to identify gaps and where ECVs contribute to fundamental understanding of the cycle. Closing the cycles will allow improved forecasts of the impacts of climate change. In particular, closing the Earth's energy balance and the carbon and water cycles through observations is still an outstanding scientific issue that requires high-quality climate records of key ECVs. If key pools or state variables are missing, these budgets cannot be closed. Importantly, closing the budget of a cycle requires attention to the exchange fluxes between the domains of atmosphere, land, ocean and ice.

The fluxes in the water and energy cycles are linked through the latent heat flux exchange between ocean and atmosphere and land and atmosphere. In this Implementation Plan, latent and sensible heat fluxes over the ocean are a new ECV with actions on similar fluxes over land to demonstrate the feasibility of their observation on a global scale.

For carbon fluxes, exchanges between the ocean and atmosphere need to be estimated, as well as those between land and atmosphere, and between land and ocean through transport of organic material by rivers. The inclusion of a new ECV on anthropogenic fluxes of GHGs provides the key driver of changes in the carbon cycle. These fluxes are mainly from fossil-fuel combustion, cement production and land use and land-use change. Also significant are the fire disturbance, soil carbon, land use and above-ground biomass ECVs.

This Plan presents four targets for overall closing of the cycles and budgets based on observations. GCOS realizes that these targets may not be met immediately; indeed, they may take a decade or more to achieve, but they provide an assessment of how good the overall observations should be and should lead to improvements in individual ECV observations. These targets will eventually be met by achieving the individual ECV requirements.

The targets for the carbon cycle are given in Box 4. Below-ground biomass is not yet an ECV; it is currently estimated from above-ground biomass, following IPCC methods. It needs to be identified as a separate term and may become an ECV at some stage if suitable, large-scale monitoring methods can be identified. Another missing flux is the land-sea flux of carbon that is not currently observed globally and is not well understood. A joint action by TOPC and OOPC may be needed to consider this need.

Accumulation of carbon dioxide and other greenhouse gases in the atmosphere, such as methane, is monitored by the atmospheric composition ECVs and in the oceans as part of the carbonate system. Anthropogenic GHG fluxes is a new ECV in this new Implementation Plan.

Box 4: Closing the carbon budget

Targets	Quantify fluxes of carbon-related greenhouse gases to +/- 10% on annual timescales 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
Who	Operators of GCOS-related systems, including data centres
Time frame	Ongoing
Performance indicator	Regular assessment of uncertainties in estimated fluxes and inventories

To close the water cycle, the principal requirement is the turbulent flux of latent heat (evaporation) from ocean and land to the atmosphere. Precipitation over the oceans is also poorly understood. Though fluxes from land are more difficult to observe on a global basis, given their heterogeneity, the current set of ECVs, including precipitation, river discharge, water vapour, sea level, soil moisture and groundwater, should be sufficient to close the global water cycle. Accurate measures of these ECV are, however, needed (Box 5).

Box 5: Closing the global water cycle

Targets	Close water cycle globally within 5% on annual timescales
Who	Operators of GCOS-related systems, including data centres
Time frame	Ongoing
Performance indicator	Regular assessment of the uncertainties in estimated turbulent flux of latent heat

The main impact of GHGs on the Earth's system is a reduction in energy exiting the top of the atmosphere and increased energy storage in the Earth system, mainly in the oceans. The ability of observations to close the energy budget of the Earth is, therefore, important. Over recent years, the budget imbalance has amounted to 0.5-1 Wm-2 globally. Improving quantification of ocean heat content, land surface temperature, latent and sensible heat fluxes from ocean and land to the atmosphere should reduce the budget imbalance (Box 6).

Box 6: Closing the global energy balance

Targets	Balance energy budget to within 0.1 Wm^{-2} on annual timescales
Who	Operators of GCOS-related systems, including data centres
Time frame	Ongoing
Performance indicator	Regular assessment of imbalance in estimated global energy budget

Climate change affects the biosphere of the planet by, for example, changing oxygen, water and nutrient supplies. An overarching aim is to quantify change in environmental conditions that directly influence the biosphere (Box 7). Climate impacts significantly affect a wide range of factors in the biosphere, such as:

(a) Increasing areas with oceanic oxygen concentration low enough to seriously affect animal survival and movement;

(b) Changes in the supply of nutrients from the interior ocean or the land to the surface layer, where the nutrients are available for primary production;

(c) Temperature changes leading to a redistribution of biomes and ecosystem niches, which will affect the opportunity of plant and animal species to survive; for example, the displacement of isotherms towards higher altitudes in mountain environments, forcing living organisms to move to higher altitudes or become extinct;

(d) Climatic changes leading to disappearance of specific ecosystems, such as forests, grasslands, permafrost and mangroves and the consequent loss of habitat and biodiversity. Climate changes are leading to expanding geographical ranges of pests and diseases.

Box 7: Explain changing conditions of the biosphere

Targets	Measured ECVs that are accurate enough to explain changes of the biosphere (for example, species composition, biodiversity, etc.)
Who	Operators of GCOS-related systems, including data centres
Time frame	Ongoing
Performance indicator	Regular assessment of the uncertainty of estimates of changing conditions as listed above