ICOS | INTEGRATED CARBON OBSERVATION SYSTEM

An analysis of the GCOS 2016 Implementation Plan from ICOS perspective

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Part 1: Essential Climate Variables

- The design of ICOS is directly responding to the ECVs in all three domains;
- ICOS has an integrated data life cycle, well established data access through the ICOS Carbon Portal and an open data policy;
- Being a Research Infrastructure, ICOS is inheriting long-term sustainability;
- Becoming operational, ICOS aims to provide stronger support towards GCOS within a global coalition of Research Infrastructures.

Atmosphere composition ECVs

ICOS atmosphere stations with CO_2 and CH_4 measurements are ‚contributing network' in GAW

- ✓ **Action A33: Maintain WMO GAW CO_2 and CH4 monitoring networks**

ATMOSPHERIC DOMAIN – COMPOSITION ECV	
Carbon dioxide	
Contributing networks	Status
WMO GAW Global Atmospheric CO_2 Monitoring Network (major contribution to the GCOS comprehensive network for CO_2) consisting of: WMO GAW continuous surface monitoring network	Operational; partial network; operational data management
WMO GAW surface flask sampling network	Operational; partial network; operational data management.
Airborne sampling (Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL), In-service Aircraft for a Global Observing System (IAGOS, former Civil Aircraft for the Regular Investigation of the At- mosphere Based on an Instrument Container (CARIBIC), Measurement of Ozone and Water Vapour on Airbus In-service Aircraft (MOZAIC), NOAA, JMA), AirCore	Limited operational aircraft vertical profiling initiated
WMO GAW TCCON, Network for the Detection of Atmospheric Composition Change (NDACC), (ground-based Fourier Transform Infrared Spectrometry (FTIR)	Operational, partial network
Contributing satellite data	Status
VIS, short-wave infrared imagery (SWIR)and high-resolution IR GOSAT-2 and OCO-2	
Methane, other long-lived greenhous	
Contributing networks	
WMO GAW Global Atmospheric CH_4 Monitoring Network (major contribution to the GCOS comprehensive network for CH_4) consisting of: GAW continuous surface monitoring network	Operational; partial network; operational data management.
GAW surface flask sampling network	Operational; partial network; operational data management
Advanced Global Atmospheric Gases Experiment (AGAGE), System for observation of halogenated GHG in Europe and University of California at Irvine, USA	Operational; partial network; operational data management
Airborne sampling (CONTRAIL, IAGOS (former CARIBIC, MOZAIC), NOAA, JMA)	Limited operational aircraft vertical profiling initiated.
NDACC, TCCON	Operational; partial network; operational data management
Contributing satellite data	Status
IR, UV, SWIR nadir sounders GOSAT-2	Satellite measurements on CH_4 are maturing and are part of operational satellites. SWIR retrievals are available from SCIAMACHY and GOSAT, soon to be complemented by Sentinel 5p Tropospheric Monitoring Instrument (ESA/EU) (TROPOMI) and follow-on Sentinel 5 instruments. IR data from AIRS, CrIS and IASI
IR and microwave limb sounders	MLS, performs N_2O measurements in the stratosphere as well as of the other GHGs (ACE-FTS, SMR). Uncertain continuity of profiling limb sounders

Air Core

Discussion about TCCON integration ongoing

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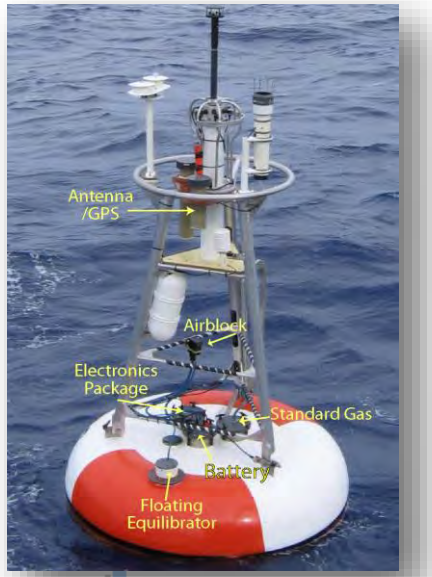
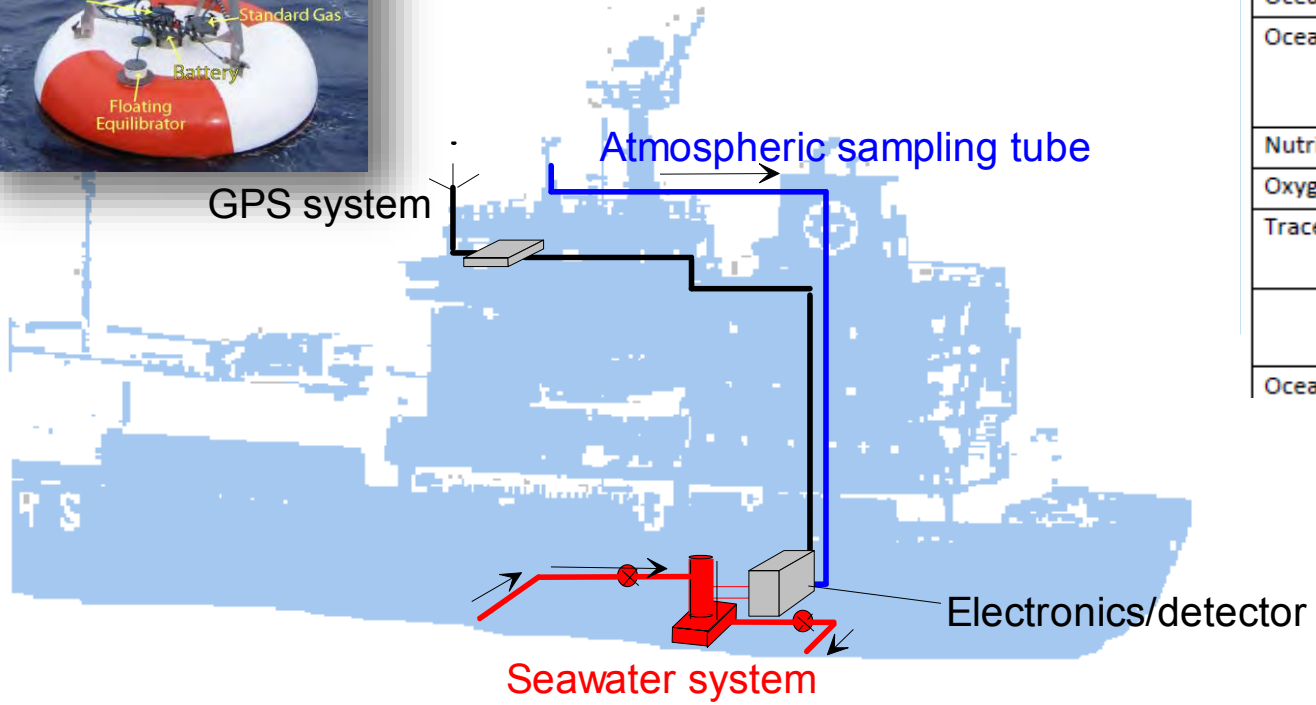
Ocean biogeochemistry



Fixed stations

Voluntary Observing Ships



Biogeochemistry Panel

GCOS • GOOS • WCRP

SOCONET • SURFACE OCEAN CO_2 OBSERVING NETWORK •

OOPC Ocean Observations Panel for Climate

	Biogeochemical	
Carbon dioxide partial pressure (surface)	Inorganic carbon	Reframed to accurately reflect current observing requirements to characterize the carbonate system; depending on the platform, a choice of ideally at least 2 variables of dissolved inorganic carbon, total alkalinity, CO2 partial pressure (pCO2) or pH to be observed
Carbon dioxide partial pressure (subsurface)		
Ocean acidity (surface)		
Ocean acidity (subsurface)		
Nutrients	Nutrients	Includes: nitrate, phosphate, silicate.
Oxygen	Oxygen	
Tracers	Transient tracers	Includes: sulphur hexafluoride (SF6), CFCs, C-14, tritium, helium-3.
	Nitrous oxide	A new ECV to reflect the ocean's role for nitrogen dioxide cycling
Ocean colour	Ocean colour	

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Terrestrial

	Name	Quantities measured	Measurements	Appicable standards	Sources of Data
HYDROLOGICAL	River discharge	Mean daily discharge data from all major river basins draining into the world's oceans are required. Measured parameters are: River discharge (m^3/day) Water level (m) Flow velocity (m/s) Cross-section (m^2)	Satellite microwave altimeters National In situ observations according to WMO standards. GTN-R	ISO/TC 113: WMO (2010) WMO (2008a) WMO (2009)	GTN-R data centre: Global Runoff Data Centre Satellite data centre: Hydroweb at LEGOS/CNES
	Groundwater	Groundwater volume change (m^3/month) Groundwater level (m): Groundwater recharge (m^3/s): Groundwater discharge (m^3/s): Wellhead level (m): Water quality	Gravity measurements have been used to estimate changes of groundwater at a very coarse scale globally (about that of the largest aquifers). Satellite gravity missions need to be operationalized. National In situ observations	ISO/TC 147/SC 6 N 120, ISO 5667-18:2001 Part I8	Data centre: International Ground Water Resources Assessment Centre (IGRAC)
	Lakes	Lake water level (cm) Water extent (m^2) Lake surface water temperature (C^o) Lake ice cover (m^2) Lake ice thickness (m) Lake colour (Lake water leaving reflectance)	Satellite microwave altimeters for lake level Multi-spectral optical and thermal sensors for water extent, water temperature, water colour and ice cover SAR for water extent and ice cover National In situ observations according to WMO standards. Global Terrestrial Network- Lakes (GTN-L)	WMO (2006) WMO (2008(a))	Data centre: HYDROLARE Satellite data centre: Hydroweb Copernicus Global Land Service / CEOS, ESA CCI, GloboLakes
	Soil moisture	Surface soil moisture content (m^3/m^3) Freeze/thaw status (yes/no) Surface inundation (m^2) Vegetation optical depth (dimensionless)	Microwave radiometers, scatterometers and synthetic aperture radars in 1–10 GHz range (L, C and X-band), complemented by medium-resolution optical and thermal sensors	WMO (2008(b))	ESA CCI Soil Moisture Copernicus Climate Change Service
		Root-zone soil moisture content (m^3/m^3)	International Soil Moisture Network (ISMN) as part of GTN-H		

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Terrestrial

Tower based at all sites

Tower based at all sites

Flux data for model calibration

Annual courses at all sites

BIOSPHERE	Albedo	Bidirectional reflectance factors (BRF), Reflectance anisotropy (bidirectional reflectance distribution function (BRDF) model parameters), bidirectional hemispherical reflectance under isotropic illumination or white-sky albedo (BHRiso), directional hemispherical reflectance or black-sky albedo (DHR) and bidirectional hemipherical reflectance or blue-sky albedo (BHR) for modelling and adaptation	Daily to monthly measurements of both black-sky and white-sky albedo in spectral bands and visible, near-infrared, and shortwave broadband Use of operational geostationary satellites (SCOPE-3M Project) and moderate resolution optical polar orbiters (SCOPE-CM-02, MODIS, MISR, VIIRS, AVHRR, Metop, MERIS, Sentinel-3, SPOT-VGT, PROBA-V) In situ data for calibration/validation, Baseline Surface Radiation Network (BSRN) – augmented with International Fluxnet station data and Aeronet optical depth data CEOS/WGCV/LPV; NASA-Modland Atmospheric radiation measurement sites		Copernicus Climate Change Service, Copernicus Global Land Service, NASA/LPDAAC, EUMETSAT CM SAF, EUMETSAT LSA SAF
	FAPAR	Fraction of incoming solar radiation at the top of the vegetation canopy that contributes to photosynthesis.	In situ data for calibration/validation No designated baseline network exists. CEOS WGCV;FLUXNET; TERN,EnviroNet NEON,ICOS		Copernicus Climate Change Service, Copernicus Global Land Service, NASA/LPDAAC, EUMETSAT CM SAF, EUMETSAT LSA SAF
	LAI	One half of the total leaf area per unit ground area	Optical, multi-spectral and multi-angular observations No designated baseline network exists. CEOS WGCV; FLUXNET; Long-term infrastructural networks, e.g. TERN, NEON, ICOS		Copernicus Climate Change Service, Copernicus Global Land Service, NASA/LPDAAC, EUMETSAT CM SAF, EUMETSAT LSA SAF
	Land-surface temperature	Land-surface skin temperature	Thermal infrared data data, Copernicus Global Land Service, NASA/LPDAAC, EUMETSAT LSA SAF		
	Land cover (including vegetation type)	Land cover classes	Column measurements: 300-m resolution satellite imagery 10–30 m resolution satellite imagery European Copernicus program and Landsat continuity mission National maps No designated reference network	No agreed standards but see GLCN (2014), GOFC-GOLD (2015a), and LCCS/LCML	ESA LC-CCI, NGCC.

Terrestrial

Tree height and circumference

Ground lidar in test mode

Repeated stock take

Annual carbon balances

BIOSPHERE	Above-ground biomass	Above-ground living biomass (excludes roots, litter and dead wood) Forest above-ground biomass (AGB) is sometimes derived using the subsidiary variable forest height.	The growing stock volume (related to biomass by wood density) of boreal and temperate forests has been estimated from long time series of C-band SAR data (ESA Envisat) with relative accuracy of 20-30% at 0.5° resolution. L-band SAR data can be used to estimate forest biomass up to about 100 t ha-1, but the JAXA PALSAR-2 is the only L-band SAR currently in orbit. Tropical biomass maps have been derived from forest height measurements made with the IceSAT lidar which failed in 2009. Three missions dedicated to measuring forest structure and biomass are planned to be in orbit by 2021; the ESA BIOMASS P-band SAR; the NASA Global Environmental Dynamics Investigation vegetation lidar on the International Space Station; and the NASA-ISRO NISAR L-band radar. The Argentine SAOCOM 1-A Airborne lidar can provide biomass maps at distr No designated baseline network exists. The FAO's Forest Resource Assessments provide national statistics but not spatially explicit map-type data on forest biomass.	GOFC-GOLD (2015a) GOFC-GOLD (2015b) GFOI (2013) IPCC (2006)	No global data centre for either forest or non-forest biomass.
	Soil carbon	Fraction of carbon in soil	No satellite sensors. National in situ data. No designated global network major geographical gaps Harmonized World Soil Database (HWSD) National soil carbon surveys New, high-resolution soil data are available - SoilGrids250m product[65] New soil profile data for the world, once shared by the data providers, can be included in WoSIS[66], thereby providing a growing source of input for SoilGrids products and other applications.	GFOI (2013) IPCC (2006)	

Real ground truthing?

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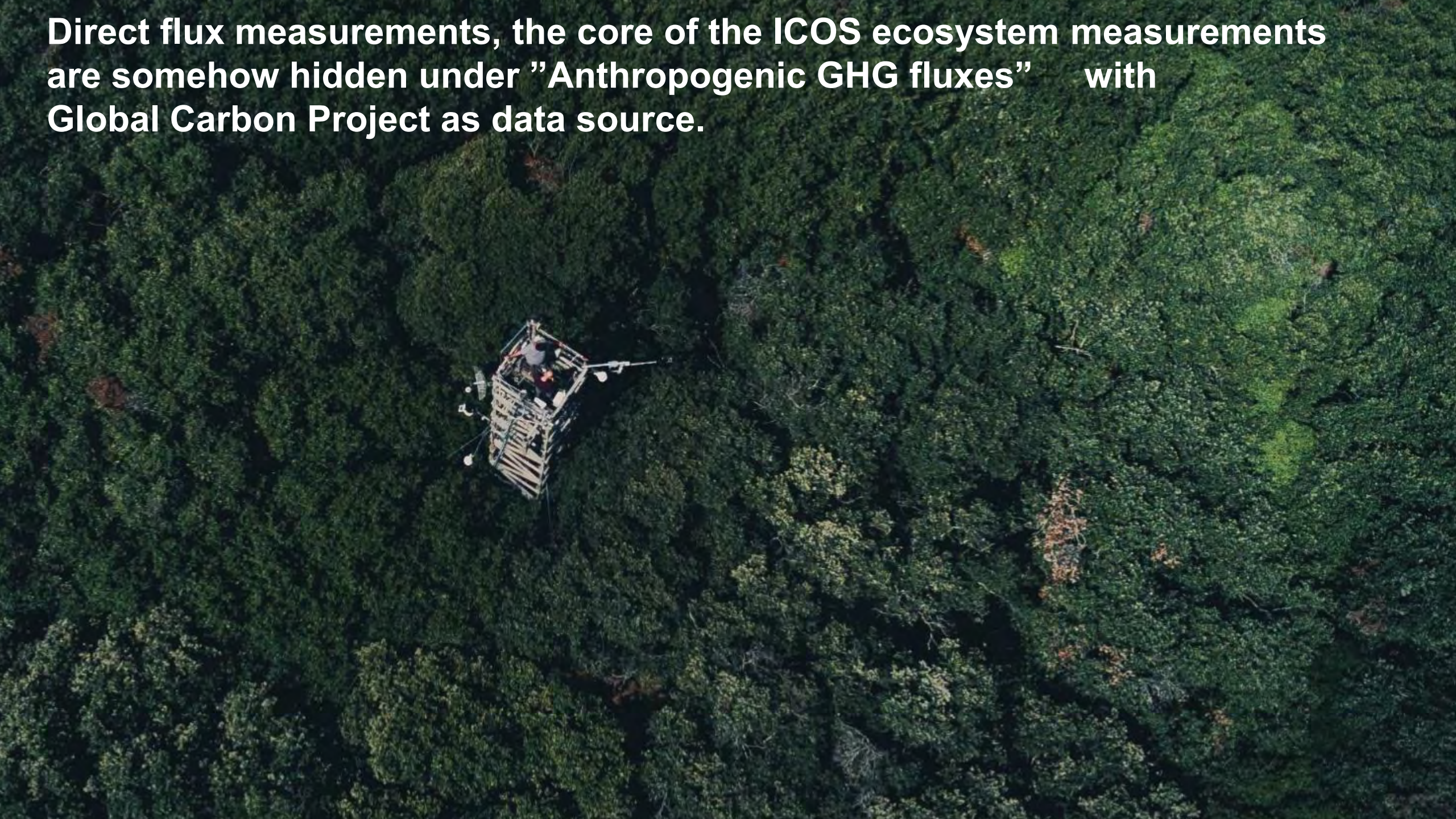
HUMAN DIMENSION	Anthropogenic water use	Water used by humans for drinking water, reservoir storage and agricultural or industrial purposes	None Areas of irrigated land can be estimated from land-use information; other information from census data No network, but a single georeferenced database (AQUASTAT) for irrigation exists based on national data reported to FAO. Several datasets are available to be merged into one single dataset indicating water use and availability		AQUASTAT UN Water http://www.unwater.org/statistics/en/
	Anthropogenic greenhouse gas fluxes	Emissions from fossil-fuel use, industry, agriculture and waste sectors	Estimated from fuel and activity statistics CDIAC, BP, IEA for global estimates, national reporting to UNFCCC	IPCC (2006) IPCC (2013) GFOI (2014)	National reporting to UNFCCC CDIAC Global Carbon Project
		Emissions/removals by land-use sectors	Estimated by IPCC methods using statistics and satellite observations of changes in land cover (see ECV land cover and above ground biomass) National reporting to UNFCCC		
		Emissions/removals by "land sink"	Improved knowledge on afforestation, reforestation and forest growth rates Direct measurements of fluxes such as FluxNet		Global Carbon Project
		Estimated fluxes by inversions of observed atmospheric composition	Observations of atmospheric composition, in situ and satellite; modelling of atmospheric transport and processes in a data-assimilation scheme GAW, IG3IS, GEOCarbon, ICOS, CEOS Carbon Observations Strategy, Copernicus C3S/CAMS, Global Carbon Project		Global Carbon Project

Direct flux measurements, the core of the ICOS ecosystem measurements are somehow hidden under ”Anthropogenic GHG fluxes” with Global Carbon Project as data source.



Fate of anthropogenic CO_2 emissions (2006-2015)

34.1 $GtCO_2$/yr

91%

9%

3.5 $GtCO_2$/yr

Sources = Sinks

16.4 $GtCO_2$/yr

44%

31%

11.6 $GtCO_2$/yr

26%

9.7 $GtCO_2$/yr

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

Global GPP

440 $GtCO_2/yr$

Global Resp

440 $GtCO_2/yr$

Anthropogenic CO_2 emissions

37,6 $GtCO_2/yr$

31%

11.6 $GtCO_2/yr$

26%

9.7 $GtCO_2/yr$

Fossil fuels CO_2 emissions

34.1 $GtCO_2/yr$

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Terrestrial

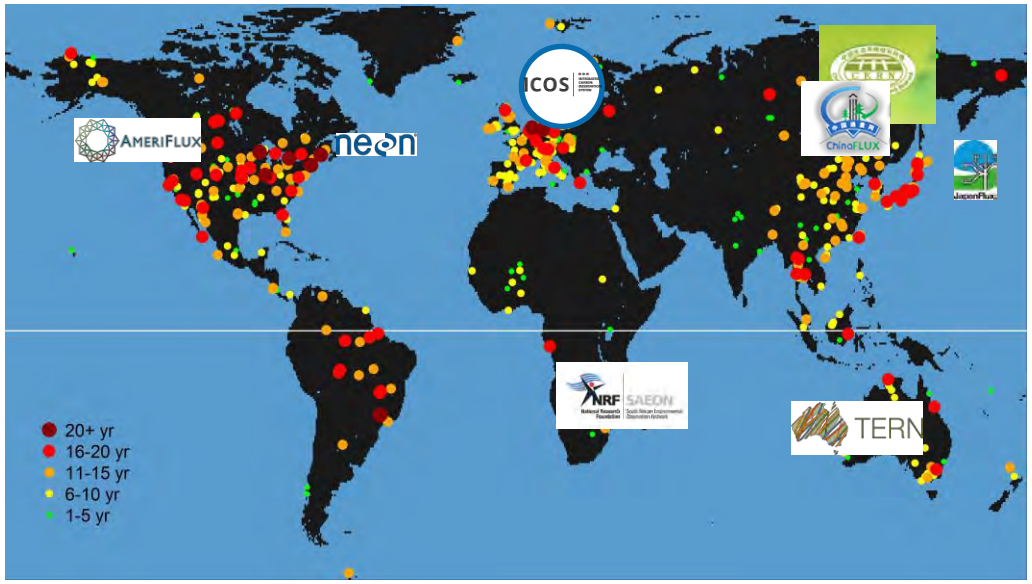
Suggestion

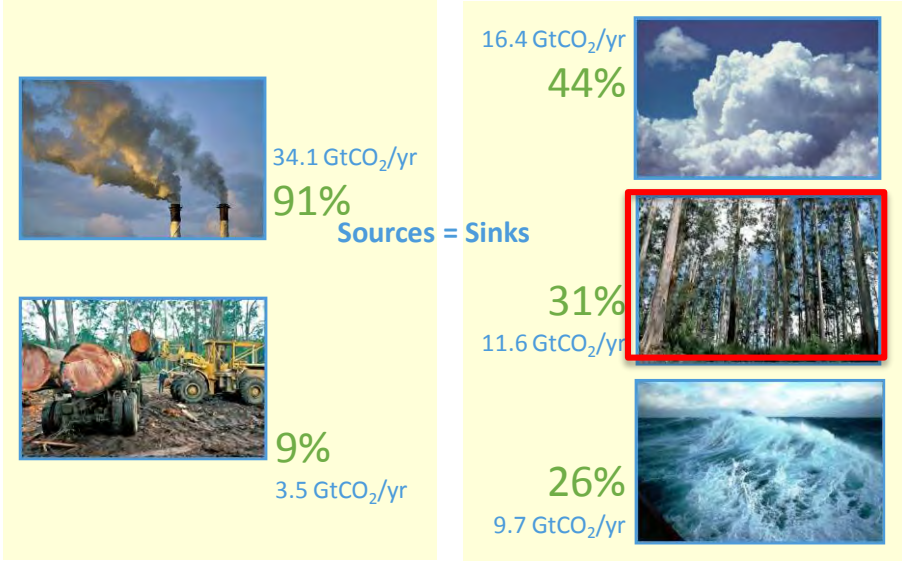
There should be a ECV „Terrestrial CO_2 fluxes“ as stand-alone Biosphere ECV (not as a sub-category of Anthropogenic greenhouse gas fluxes in the human dimension)

Rationale

Land sink is mainly a natural (biospheric) process that is very vulnerable to climate change and human land management..

Standardized observations conducted by large and sustainable research infrastructures and who also support the integration within fluxnet.





Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

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Global Climate Indicators

Headline Indicators

Temperature and Energy	Atmospheric Composition	Ocean and Water	Cryosphere
Surface Temperature	Atmospheric CO_2	Ocean Acidification	Glacier Mass Balance
Ocean Heat	Where are ecosystems and the biosphere?	Sea Level	Arctic and Antarctic Sea Ice Extent

Global Climate Indicators

	Temperature and Energy	Atmospheric Composition	Ocean and Water	Cryosphere	Terrestial Ecosystems
Headline Indicators	Surface Temperature	Atmospheric CO_2	Ocean Acidification	Glacier Mass Balance	General ecosystem change
	Ocean Heat	Other atmospheric GHG	Sea Level	Arctic and Antarctic Sea Ice Extent	GHG fluxes

Two quotes

”There is no overall coordination of terrestrial observations: the Global Terrestrial Observing System (GTOS) aimed to do this but is no longer operational. GTOS was set up to provide overall coordination of terrestrial observations, including identifying users' needs, defining observational requirements and coordinating observations across different themes, e.g. climate change, biodiversity loss, preserving ecosystems, agriculture and water. The need for cooperation continues, …”

GCOS The global observing system for climate: implementation needs, WMO 2016

”A systems approach is vital when responding to the impacts of climate change. Ecosystem-based approaches can tackle mitigation and adaptation and provide co-benefits for sustainable development.”

UNFCCC Summary report on the tenth meeting of the research dialogue Bonn, Germany, 3 May 2018 Note by the Chair of the SBSTA

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Part 2: Actions
A quick note about data

- ✓**Action G15: Open data policies**
- ✓**Action G16: Metadata**
- ✓**Action G17: Support to national data centres**

  ICOS Carbon Portal is a data centre for 12 countries
- ✓ **Action G18: Long-term accessibility of data**
- ✓ **Action G19: Data access and discoverability**
- ✓ **Action G20: Use of digital object identifiers for data records**

Part 2: Actions

Action T1:	Improve coordination of terrestrial observations
Action	Establish mechanism to coordinate terrestrial observations: this will be particularly important for climate change impacts and adaptation where local information will be critical and will not be provided through GCOS directly. It includes biodiversity and natural resources information and could also incorporate socio-economic components (e.g. health) so as to become fine-tuned with post-2015 frameworks. This would be based on discussions with stakeholders and could include a formal framework or regular meetings to exchange ideas and coordinate observational requirements.
Benefit	Efficient observing systems with minimal duplication, delivering consistent and comparable data to a range of different users
Time frame	2017: Hold workshops to discuss way forward 2019: Mechanism in place.
Who	All involved in terrestrial observations. Initially TOPC, GEO, ICSU, GOFC-GOLD, FluxNet, NEON
Performance indicator	Presence of active mechanism
Annual cost	US$ 100 000–1 million

NEON is only one regional Research Infrastructure

What is the specific role expected from GEO?

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Part 3: What to be done where by whom and when?

Global coalition of stable Research Infrastructures could improve GCOS particularly in the terrestrial ecosystem domain and work towards a GTOS successor.

Leading global organisation could be GEO.

In this context, ICOS supports the further development of FLUXNET as a main data source for a new ECV on „terrestrial CO_2 fluxes“

THANK YOU FOR YOUR ATTENTION!

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