GROUP ON EARTH OBSERVATIONS

INTERGOVERNMENTAL PANEL ON climate change

GEOSS support for IPCC assessments

A workshop on the data needs of the climate impacts, adaptation and vulnerability research community, 1 – 4 February 2011

SUMMARY AND RECOMMENDATIONS

I) Objective

The objective of the GEOSS-IPCC workshop was to provide guidance on how to improve the delivery of multi-disciplinary data and data products to researchers studying climate change impacts, adaptation and vulnerability via the Global Earth Observation System of Systems (GEOSS).

This objective was inspired by the recognition that the scientific literature and research that underlies the assessments of the Intergovernmental Panel on Climate Change (IPCC) could benefit enormously from improved and sustained Earth observations. Because the issues of climate change and climate impacts, adaptation and vulnerability are multi-disciplinary, researchers need access to a wide array of observation data and information products in addition to published scientific literature. As GEOSS addresses nine societal benefit areas (SBAs) and their interlinkages, it has the potential to provide this research community with better access to a broad range of relevant information.

To ensure that GEOSS evolves in a manner that benefits this key user group, the workshop focussed on identifying and understanding their needs. The recommendations summarized below are presented as possible guidance and incentives to the governments and organizations that contribute to GEOSS.

II) Organization

The workshop was organized by the IPCC and the Group on Earth Observations (GEO) with the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP) and the International Geosphere-Biosphere Programme (IGBP). IPCC Working Group II Co-Chair Christopher Field and GEO Secretariat Director José Achache served as co-chairs. Some 60 participants from the earth observation and climate research communities attended during the three days.

Representing an important Earth observation user community, the IPCC advised on participants and presenters who could describe the needs of climate researchers, including quality, quantity, format and timeliness of data and information. While the IPCC itself does not conduct research, its assessment reports benefit from the high quality of published research. Its Fifth Assessment Report (AR5) will be published in 2013-2014 based primarily on the peer-reviewed literature available by cut-off dates specific to each of the three working groups in 2012 and 2013. The IPCC Plenary approved the planned IPCC-GEOSS workshop at its 31st session in October 2009.

Representing both the providers and users of Earth observations and data, GEO consists of 86 governments, the European Commission and 61 international organizations – among them the fundamentally important networks of GCOS, IGBP and WCRP. GEO identified participants and presenters who could respond to the user needs presented at the workshop by identifying opportunities for improving the collection and dissemination of relevant data and information via GEOSS. The GEO Executive Committee recognized the value of the planned workshop.

The workshop sought to build on the results of the 2007 Sydney (Australia) Workshop on "Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the Fourth Assessment Report"; the 2009 Hawaii (USA) Joint IPCC-WCRP-IGBP Workshop on "New Science Directions and Activities Relevant to the IPCC AR5"; and other relevant workshops.

The three-day workshop consisted of five sessions:

1) Data users and data providers – chaired by Christopher Field and José Achache
2) Managing data to support the assessment process – Robert Chen, CIESIN
3) Water resources – Taikan Oki (U. of Tokyo) and Stuart Minchin (CSIRO, Australia)
4) Land cover and land use – Steve Running (U. of Montana) and Thelma Krug (INPE, Brazil)
5) Extreme events and disasters – Xuebin Zhang (Environment Canada)

A drafting group of around 12 session chairs and participants met on the fourth day to outline the present summary. The resulting draft text was circulated by email to all participants before being finalized by the workshop co-chairs. While some of the recommendations could have an impact on the Fifth Assessment Report that is currently underway, many focus on the longer term needs of both the research and assessment communities.

III) Recommendations

Recommendation 1: Promote the development of new observation systems and databases based on past and future gap analyses

A structured and comprehensive appraisal of the data required by the literature underlying the IPCC Working Group II chapters of the current assessment report (AR5) could be used to identify and prioritize the observation and information systems that will likely be needed to support future, post-AR5, assessments on vulnerabilities, impacts and adaptation. The excellent gap analyses already completed or planned by GCOS, IGBP and others provide a strong basis for this work. The effort now underway in the GEO community to develop a comprehensive GEOSS gap analysis strategy should further contribute.

The clear articulation of the gaps in observation and information systems and the opportunities for addressing them should inspire more structured and prioritized efforts by governments to fill spatial, temporal or measurement gaps in time for future assessments. Gaps can also be addressed through the ongoing efforts to populate the GEOSS Common Infrastructure (GCI) and Data CORE (Data Collection of Open Resources for Everyone).

All past and future gap assessments could be published in the peer-reviewed literature as review papers that could potentially be cited in IPCC assessment reports. These reports could then serve as valuable tools for encouraging efforts to fill gaps.

Actions: Invite IGBP, GCOS, the GEO Monitoring and Evaluation Working Group and the GEO Executive Committee to advocate for and guide new investments in observations and data based on all past and planned gap assessments. Invite workshop participants and other experts to consider contributing review papers to peer-reviewed journals on gaps and how to address them.

Recommendation 2: Align the GEO Work Plan with the observation and information requirements of the researchers whose findings will be assessed by the IPCC

Several GEO Tasks are assembling information relevant to the variables mentioned in the three planned AR5 Working Group I chapters on observations of the atmosphere and surface, the ocean, and the cryosphere; these observations will likely be addressed by future assessment reports as well. The GEO Tasks also aim to facilitate wider access to such observations. The relevant information includes, among other variables, climate data and data products, measures of climate forcing on terrestrial environments, and measures of climate impacts (such as drought and runoff) on terrestrial ecosystems.

Actions: Cross-reference relevant GEO Tasks and activities with the "observations" chapters of the Fifth Assessment Report, anticipating that the findings of these chapters will remain relevant to future assessments. Ensure that the data needs of climate impacts, adaptation and vulnerability researchers are reflected in the updated GEO Work Plan for 2012-2015.

Recommendation 3: Strengthen current efforts to develop useful indicators and metrics of the continuity, quality, usability, transparency and provenance of contributed GEOSS components

The IPCC generally focuses on journal-based literature in its assessments. However, given the paucity of literature on many aspects of climate impacts, adaptation and vulnerability, it could be useful to directly assess datasets that provide clear information (e.g. changes in land cover). For this to be possible, however, some equivalent of peer review for large and dynamic datasets, databases, and data products and tools would be required.

By supporting existing initiatives by GCOS, WCRP and others, and publishing useful indicators and metrics, the GEO community can assist scientists in making informed choices about the data that they access through the GEOSS Common Infrastructure (GCI). The proposed GEO Continuity Indicators and GEO "Label", for example, could provide a range of metrics for communicating the objective quality, subjective usability and usefulness, and transparency, continuity and provenance of GEOSS components. This in turn could provide a potentially important added value to scientists and thus better literature for the IPCC to assess. The ability to access quality metrics and peer assessments of Earth observation datasets or components would provide some level of confidence in the usability of the data in the climate change research that is assessed by IPCC. The ability to differentiate a low-quality dataset from a high-quality one should become an important functionality of GEOSS. It should be noted that the developers of such indicators face many challenges, and that broad-based expert reviews are essential.

Actions: The GEO community should consider prioritizing and accelerating its work on developing indicators and metrics through the GEO Work Plan. Funding should be sought for conducting assessments of the strengths and weaknesses of important datasets.

Recommendation 4: Identify and pursue opportunities to improve data sharing in support of the climate change community

Building on the GEOSS Data Sharing Principles, Implementation Guidelines, and Action Plan, GEO should work with the climate change research community and with the providers of data to improve data sharing in critical areas. This is especially urgent in light of the need for increased transparency and traceability in the IPCC assessment reports. GEO provides both an institutional and technical framework to support full and open access to key climate-related datasets, especially for research and education, and to facilitate improved data reanalysis, documentation, quality control, use of international standards, and climate diagnostics and prediction. GEO should explore opportunities to make the new GEOSS Data CORE (Data Collection of Open Resources for Everyone) a key platform for accessing critical global climate and climate-related datasets contributed by the GEO and climate research communities.

Actions*:* Encourage the GEO Data Sharing Task Force and the relevant GEO Communities of Practice to identify and pursue opportunities to address climate data sharing needs, including through the Data Sharing Action Plan and the GEOSS Data CORE. Develop a communications effort to support this work. Invite the World Climate Research Programme (WCRP), the IPCC's Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) and the Data Distribution Centre (DDC) to identify key data sources or networks where data sharing principles or procedures could be implemented or improved by the climate change research and assessment communities. Initiate discussions about developing a data sharing approach for climate impacts, adaptation and vulnerability data consistent and/or coordinated with the GEOSS Data Sharing Principles and associated implementation efforts. Develop case examples to demonstrate success stories of data sharing in the field of climate impacts, vulnerabilities and adaptation research.

Recommendation 5: Consider inviting the IPCC Data Distribution Center to contribute to, and be accessible via, GEOSS

The IPCC Data Distribution Centre (DDC) can provide rapid access to new climate model experiments needed by climate researchers, for example through the Program for Climate Model Diagnosis and Intercomparison (PCMDI) archive portal. It also serves as a long-term home for some of the key datasets used in past assessments and reports, including socioeconomic scenario data, climate observations, and environmental and socioeconomic baseline data. Operated by the British Atmospheric Data Center (BADC), the Deutsches Klimarechenzentrum (DKRZ), and the Center for International Earth Science Information Network (CIESIN) at Columbia University, and under the oversight of the IPCC's Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA), the DDC represents a valuable data resource that could benefit the broad GEOSS user community and all GEO societal benefit areas. However, the list of available IPCC datasets is not complete, and funding for the DDC can be problematic. GEO could help the DDC to address these issues and to reach out more effectively to the climate assessment community, especially in developing countries. Making DDC data and services available via GEOSS would facilitate the ability of users to access and integrate climate modelling and observation data as well as other relevant IPCC datasets.

<u>Actions</u>: Invite and assist TGICA and DDC managers to register data and services in GEOSS. Address associated technical and institutional issues at future meetings of the TGICA. Invite GEO Committees and Communities of Practice to review and identify opportunities for facilitating this effort and promoting new value-added services based on DDC data holdings. Coordinate efforts with relevant GEO Members and Participating Organizations, including the International Council for Science (ICSU) World Data System.

Recommendation 6: Strengthen the critical role of GCOS in setting requirements for the climate observing component of GEOSS

Given the diversity of activities and investments in the climate arena, it is essential to ensure that they are well coordinated, fully aligned and mutually supportive. A useful step forward would be to identify aspects of the GEO climate societal benefit area that have not yet been addressed by GCOS and take actions to strengthen them. To promote clarity, a brochure could be produced describing the respective roles of GCOS and GEOSS.

<u>Actions</u>: Request the GEO and GCOS Secretariats to work together on messaging and on producing a joint brochure on climate observations.

Recommendation 7: Provide technical advice to GCOS on how to improve the value of the Essential Climate Variables (ECVs)

The Essential Climate Variables are well-designed and well-specified core variables for the measurement of climate change. They are also valuable for the broader purpose of measuring climate change impacts and for other societal benefit areas, such as biodiversity, ecosystems and agriculture. However, because the ECVs were based on observations that were considered feasible and could be produced via well-established methods, they do not include a number of important variables for which methods and networks are still evolving. Consequently, the temporal and spatial scales and methodologies proposed for some ECVs may not be sufficient for certain uses, implying a gap that should be filled. In particular, the measurement of vulnerabilities and impacts may require a broader set of variables than the predominantly biophysical ECVs. For example, in the longer term defining practical sets of Essential Human Variables (EHVs) for measuring the human response to climate change, as well as sets of Essential Environmental Variables (EEVs), might be beneficial. Such Variables could properly address the typical scales at which the observed processes take place and facilitate integration across disciplines and scales.

Some examples of specific technical proposals include:

- Merge the current ECVs defined as plant biomass and soil carbon into a single ECV of net primary production (NPP). Eight of the ECVs relate directly to land and vegetation. The vegetation biomass and soil carbon ECVs, however, are not yet mature and do not have established algorithms and global datasets. These two ECVs could be combined into one and titled "annual aboveground net primary production", or NPP. The justification for this is that work on developing global NPP datasets has been ongoing for at least a decade, and many analyses have been published, including a number of prominent papers in Science and Nature. Additionally, the US National Aeronautics and Space Administration (NASA) is producing a standard global 1 km dataset produced from the MODIS sensor. In contrast, there are not yet any global datasets of spatially explicit plant biomass or soil carbon.

- Redefine the fire disturbance ECV as land-cover change and disturbance. The fire disturbance ECV would be more valuable if redefined as "land-cover change and disturbance". Disturbances have other causes besides fire, notably hurricanes, large insect epidemics, and land clearance. All such disturbances are quantified as changes in land-cover, itself an ECV. Global consistent disturbance detection is still a subject of research that has produced a handful of one-off research products in the literature. The NASA MODIS global fire-detection datasets are the most mature and straightforward, but while the other types of disturbances are currently less clearly identified, they may soon be addressed by new GEO 30m land-cover/land-cover-change products. Among specialists, land-cover change is the most fundamental metric, and the causes of change require an additional analysis.

- Conduct an intercomparison of LAI and FAPAR. Leaf Area Index (LAI) and the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) are, respectively, structural and radiometric measures of plant canopies. LAI and FAPAR have been derived from earlier Normalized Difference Vegetation Index (NDVI) algorithms but are specific and verifiable biophysical variables, in contrast to abstract and dimensionless indices such as NDVI. There are now a small number of global datasets derived from common, although not identical, algorithms, and from different sensors, mostly SeaWifs, MERIS and MODIS. There are also several 10-30 year long global time-series datasets at resolutions of 1 km to 8 km that are progressively being used by the wider earth science community. Moreover, next-generation sensors such as Sentinel 3 and VIIRS are planning to ensure the continuity of these critical datasets. These datasets are at a stage of maturity and wide interest where a formal intercomparison and validation is essential to using them with confidence. The Land Production Validation (LPV) subgroup of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV) has developed a voluntary international committee to attempt this intercomparison for FAPAR/LAI, but the participants do not have financial support. This activity should be made a high priority and could be accomplished in a year.

- Define Land Surface Temperature as an ECV. Radiometric land-surface temperatures (LST) from satellite sensors such as MODIS and AATSR provide a valuable look at temperatures across the earth's land surface. Satellite-derived LST represents an aerial average, unlike the point measurements of air temperature from ground stations. Satellite surface-temperature measurements from thermal infrared data can be combined with those from microwave data to provide an all-weather product. Thermal-infrared surface-temperature measurements are, like many other ECVs derived from optical data, only available under clear sky conditions. Unlike air temperatures, surface temperatures are highly controlled by surface albedo, wetness and wind and vegetation cover and therefore respond strongly to climate change. Satellite surface-temperature records extend back to the early 1980s, which will enable a 20- to 30-year ECV to be developed. In order to derive surface temperature from satellite data, the emissivity of the surface, which provides additional information on land cover and land-cover/land-use change, must be obtained. Satellite-derived LST is widely used for evaluating vegetation cover change and disturbance, drought stress, and land-energy balance heterogeneity beyond station towers.

- Consider the implementation of Human, Environmental and other kinds of Essential Variables. While Essential Climate Variables are perfectly designed to address observations on the time and spatial scales of climate change, human- and environment-related changes may need to be assessed at different scales. Because impacts, adaptation and vulnerability tend to require local and regional scale assessment, Essential Human Variables (EHVs) and Essential Environmental Variables (EEVs) should be designed at these scales. A set of well defined EHVs would also allow the definition of land cover and land use to include "land management".

Actions: Request GCOS to consider the above technical recommendations during the course of its regular review process and encourage interested experts to engage directly on this issue.

Recommendation 8: Promote high-resolution data for, and analyses of, changing climate extremes

The main way that people experience climate change is through changes in extremes because much of the time, even with a changed climate, the weather and climate are the same as before. However, it has been very difficult to determine just how extremes are changing owing to the limited availability of the required data. Significant improvement is needed in the ability of scientists to 1) document what changes are occurring; 2) provide various statistics on the extremes (such as certain percentile levels); 3) understand the relationships with other fields and thus why they are occurring and changing; and 4) validate the performance of models that can then be used with greater confidence to make predictions.

Most analysis of climate change has addressed monthly mean values of temperature, rainfall and other variables. Increasingly over the past decade, attention has focused on accessing and analyzing daily data. A number of studies have resulted from regional workshops organized jointly by the World Meteorological Organization Commission for Climatology (CCl) and the World Climate Research Programme (WCRP) project on Climate Variability and Predictability (CLIVAR) Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI). Scientists from various countries brought their data to these workshops to be analyzed by freely available software and with guidance from experts. Support for this and similar activities should be continued.

Moreover, the impacts of extremes can differ enormously depending on the time of day and how long they occur, so that daily mean data are simply not sufficient. The call for hourly observations is clear in the GCOS second adequacy assessment report and has been reinforced many times. A major problem seems to be not that the data do not exist, but rather that countries will not make them available or will only make them available with a charge. To overcome these objections, some new approaches are needed that result in a clear quid pro quo: if countries make their data available, then they should benefit from the findings (in fact, making data available often inspires further research, which in turn can enrich the development of national adaptation strategies). One way to ensure this would be to place the data into a special archive that is freely and openly accessible provided the users guarantee that all results using the data are made available through an associated web site. Agencies may also call for special statistical analyses of the data, with the results published and disseminated, and the knowledge fed into adaptation strategies. Thus scientists whose models have been validated with the data and then used to make projections should be encouraged to make the predictions available.

Actions: Through the GEO Work Plan, engage active contributors in this field and seek to develop an enhanced initiative to acquire, recover, access and analyze hourly mean observations and sub-daily values of many variables.

Recommendation 9: Coordinate global land-water balance calculations from interested research teams and intercompare the results

The policy relevance of the changing water balance on land-surface degradation is huge. The most accurate measure of the changing hydration or desertification of the land surface is achieved by computing an integrated surface-water balance. This is simply a mass balance of precipitation inputs and evapotranspiration and runoff outputs, preferably computed from daily data. There is appreciable evidence that many parts of the planet's land surface are experiencing a reduction in land-water balance despite increasing precipitation because rising atmospheric temperatures are increasing evaporative demand. Changes in the character of precipitation, notably greater intensity and reduced frequency, can lead to longer dry spells and a higher percentage of runoff, even if the amount of precipitation remains the same. These trends are contributing to aridification in these landscapes. However few groups assemble consistent datasets of the inputs of precipitation, temperature, humidity and runoff. One approach to these problems is to compile composite indices.

Actions: The GEO community should lead and coordinate an effort to improve datasets relevant to making global land-water balance calculations and support the development of composite indices.

Recommendation 10: Develop data infrastructures and promote networking for sharing data, information and knowledge on water resources and climate impacts

It is still difficult for planners to incorporate the global projections generated by scientists into effective strategies for adapting to changes in water resources and the water cycle. While the IPCC's Fourth Assessment Report clearly documented the qualitative changes in extreme hydro-climatic events at global scale, it could not address quantitative changes at regional and river-basin scales. Owing to the large uncertainties in model projections of future climate impacts on regional and local hydrology, these projections are more difficult to use directly for adapting infrastructure design.

Obtaining better quality local and regional projections will, among other things, require improving flood-simulation and other impact models. The resolution of global climate models (GCMs), their representation of cloud microphysics and topography, and their ability to simulate high-intensity precipitation events all need to be improved. Coordinated and intensive field campaigns could be launched to improve the coupling of atmospheric and land-surface processes, including their heterogeneity and bio-geochemical cycles.

Major efforts are underway to initialize climate models and make predictions of the climate for up to about three decades ahead, a timeframe for which the current state of the climate system clearly matters. This work should provide some additional regional information, although it is very much in the beginning stages. However, it must also be recognized that some aspects of the climate are more predictable than others. Variables related to temperature, including the water-holding capacity of the atmosphere, can be more robustly predicted than those that depend on dynamics and the infinite variety of weather systems. Hence, projections of increases in the intensity of heavy rains and longer dry spells as well as of shorter snow seasons are likely to be more predictable than projections of changes in the amount of precipitation.

Meanwhile, uncertainties need to be better quantified. The collection, archiving and analysis of historical instrument records, with particular emphasis on identifying and extending relatively complete, long-term hydrologic datasets, would help to improve the performance of models at basin scale. Metrics to evaluate the skill of global and regional climate models (GCMs and RCMs) need to be developed and improved. The use of analysis based on multi-model and multi-projection ensembles should be increased. The sources of uncertainty in the statistical inference of risks of hydrologic extremes need to be better understood; a specific challenge is to develop robust alternatives to currently used frequency analysis methods based on the stationarity assumption.

Achieving these improvements will require physical and institutional infrastructures for inter-operability, data standards and methods for quality control and validation, and protocols for institutional collaboration. The availability of historical observation data to support the calibration and validation of model-generated climate projections and to support local and regional impact assessments needs to be increased. Knowledge bases of local-level data, information and best practices for directed action need to be developed and shared. Scientists should be encouraged to present their findings in language understandable by decision-makers, planners and other non-scientists; at the same time, decision-makers and other non-specialists should be encouraged to increase their scientific literacy with respect to climate change. The enhanced networking of educational institutes, especially the higher education sector, is vital for sharing research and data related to climate change and its impacts.

Progress in research depends on improving data availability, enhancing monitoring endeavours worldwide, addressing the challenges posed by projected climate change to freshwater resources, and reversing the shrinkage of observation networks. Broadening access to available observation data is a prerequisite to improving understanding of the ongoing changes. Relatively short hydrometric records can underplay the full extent of natural variability and confound detection studies, while long-term river flow reconstruction can place recent trends and extremes in a broader context. Data on water use, water quality, and sediment transport are even less readily available. Land-use change and the human use of water also make it more difficult to distinguish the changes associated with climate from those caused by other sources (see Recommendation 11).

Actions: GEO should proactively encourage the holders of water data to share their data via GEOSS. Through its revised Work Plan and water Tasks, GEO should initiate a coordinated field campaign on the validation of hydrological models.

Recommendation 11: Differentiate human and climate impacts on water resources by developing baselines and indicators

Quantifying climate change impacts on water resources requires assessing the changes in water systems on a river-basin scale. In addition, the impacts due to climate change and those due to direct human interventions (such as water works) need to be differentiated. This will make it possible to quantify the variability of, and changes in, the various components of the water cycle, including precipitation, evaporation, soil moisture, surface water storage, and groundwater storage, as well as permafrost and snow and ice storage. When analyzed together with primary climate variables such as temperature and wind speed, the changes can then be attributed to different forcing factors.

Long-term in-situ hydrometeorological measurements from reference sites will be essential for detecting trends and validating earth observation data and model simulations. Stream gauge stations need to be maintained and extended for consistent long-data records. Water-use data need to be generated from both earth observation data and water-management information; the latter would be very difficult to collect, however, due to the sensitivity of the information, in particular for cross-border basins.

A better approach could be to analyse data from pristine basins that have experienced minimum human impact in order to develop a baseline and indicators for climate change impacts. A metadata catalogue of pristine basins has been developed by the Global Runoff Data Center (GRDC).

Actions: Craft a strategy for developing a baseline and indicators using pristine basins. Encourage experts from the GEO Water Community of Practice to generate a review paper providing specific recommendations. Encourage space agencies, as part of their broader reviews of the robustness of remote sensing products, to develop dedicated studies on the provision of satellite observations in data-scarce environments, which are critical for quantifying climatic impacts. The GEO community should coordinate and promote data sharing needed to quantify uncertainties in satellite observations against in-situ reference observations data. Build the capacity of the users of models to understand the models' limitations and to correctly interpret their results. Encourage researchers to take concerted actions to aggregate and analyze climatic impacts in data-scarce environments and reanalyze existing studies in detail, separating those based on observation data with uncertainty certification from those studies that are less rigorous.

Recommendation 12: Conduct a formal intercomparison and accuracy assessment of the half dozen or so most prominent land-cover datasets and revisit optimum land-cover classification logic

Land-cover is a critical ECV and foundational variable that is used as an input for most other analyses of surface meteorology, hydrology and ecology and for quantifying change. Global land-cover datasets, usually at 1 km, have been developed over the last decade, but often cannot be directly compared for consistency due to differences in classification logic. Comparisons are most commonly made using high-resolution, multi-date land-cover maps from Landsat, ASTER or SPOT over small, well ground-measured test areas.

In global-scale analysis, disturbance measures are detected by land-cover change using various algorithms and satellite or ground-based inputs. Disturbance generates huge pulses of policy-relevant carbon fluxes and is a core component of REDD+ (Reducing Emissions from Deforestation and forest Degradation – Plus) analysis. Other data sources, such as census data and forestry statistics, can further support assessments of changes in land cover and land use.

Actions: Include a formal assessment of land-cover datasets activity in the GEO Work Plan and invite other contributors. Invite the GEO community to recommend improvements.

Recommendation 13: Develop and host globally consistent 30m databases on annual land-cover and forest cover after intercomparing the current commonly used datasets

The REDD+ policy goal of reducing carbon emissions from forest practices is laudable, given the current emission rate of 1-1.5Pg/yr. However, the methodologies to actually develop individual national reporting are well beyond the capacity of most countries and would lead to fundamentally uncomparable datasets. A more scientifically valid approach would be to separate REDD+ implementation into (1) a set of standardized, consistent global datasets available to all countries and (2) a compatible recommended methodology that countries could then follow to merge these global datasets, assemble their national databases and compute their final greenhouse gas (GHG) emissions. It should not be expected that all countries will be able to develop accurate and comparable GHG estimates by relying on ground data only: there are nearly infinite methodological and sampling differences, and many countries have no organized carbon-relevant datasets at all.

Fortunately, the United States and China have each started work on producing the first full global 30m land-cover maps, which could help to meet the first requirements above. When available, these new datasets should be tested against the current regional 30m land-cover datasets in a formalized validation procedure. Large or location-critical land-cover changes then need to be interpreted using land-use evaluation and by assessing the economic or policy motivation of landowners. Land degradation is a slower and more long-term type of land-cover change that is sometimes not detected by more episodic disturbance analysis. In some cases a vulnerability assessment of the socioeconomic consequences of land-cover changes is an important final step.

The standard global datasets should include an annual accurate land-cover and forest cover dataset, first at the current state-of-the-art of 0.8-1.0 km, and then improving to 30m resolution when the new global 30m datasets that the two countries are developing are complete. An intercomparison of the commonly used global land-cover datasets should precede this step. Next, a global annual land-cover change detection dataset should be produced with a consistent methodology. Third, a reference database of annual plant production can be provided globally from existing satellite-driven datasets. In the future a reference computed carbon-dioxide balance, or Net Ecosystem Exchange, dataset could be developed from a number of global carbon models as a reference dataset for countries to start their carbon calculations. The countries could then add flux-tower data, forest-inventory data, land-ownership and land-use information and other ground datasets to revise or correct the globally generated initial carbon estimate.

Actions: Encourage IGBP and others to include the intercomparison of current land-cover databases as a research priority. Identify agencies or organizations willing and able to develop and host globally consistent datasets. Address this issue as well via the GEO Forest Carbon Tracking Task and the GEO Global Forest Observation Initiative (GFOI).

Recommendation 14: Strengthen efforts to generate higher resolution and more frequent datasets for urban areas, transitional zones (ecotones) and other complex or rapidly changing areas

The new global 30m datasets being developed by the United States and China should be complemented by higher resolution datasets for certain kinds of area. Urban areas, in particular, with their dense populations, diverse and rapidly changing land uses, and high vulnerability to climate impacts, need to be mapped at higher resolution. However, developing accurate and up-to-date land-cover, land-use and land-use change maps for urban centers, particularly those undergoing rapid expansion, can pose major challenges. Maintaining up-to-date land-use and land-cover information is both costly and time-consuming using traditional field and aerial photography methods; remote sensing technology, however, can increasingly provide an efficient and less-expensive way for mapping cities.

Other areas of the globe, such as coastal areas with their complex natural and socioeconomic processes, protected areas with their high level of vulnerability to human action and climate impacts, and degraded areas that may be difficult to interpret at low resolution, may also benefit from higher resolution or more frequent coverage. The resulting datasets could be presented as value added products.

Actions: Identify agencies or organizations willing and able to lead an effort to address urban land-cover and land-use-change mapping. Address this need through the global mapping activities in the GEO Work Plan. The GEO Secretariat should attempt to engage UN Habitat in the GEO Work Plan. High-resolution datasets for other types of areas can also be addressed through the appropriate Tasks.

Recommendation 15: Improve the integration of in-situ, low-altitude, airborne and satellite observations in order to benefit from the diverse scales that they provide

Regional scale assessments, in particular, can profit from the more comprehensive integration of observations at various temporal, spectral and spatial scales. However, efforts to integrate the in-situ measurements, low-altitude observations (e.g. from balloons), and airborne and spaceborne observations that provide complementary scales are not well advanced. In particular, such integration will make it possible to better assess regional scale feedback mechanisms, particularly at the surface-atmosphere interface.

Actions: Include observations from airborne instruments, which are too often overlooked, when integrating in-situ and satellite observations. Implement a specific GEO task on scaling issues to support more complete observational approaches.

Recommendation 16: Strengthen support for human dimensions data

Given the end-to-end nature of climate issues, from economic and social drivers of climate change to diverse impacts on environmental and human systems, GEO should take the lead in providing integrated access to, and support of, data and information on the human dimensions of climate change through GEOSS. In particular, the GEO community should work to fill in gaps in data on human vulnerability, adaptation, and the socioeconomic aspects of climate change drivers and impacts. For example, data on issues such as water demand, urbanization, agriculture, transportation networks, disaster impacts and vulnerability, protected and degraded areas, and coastal zones are hard to access and integrate. Such improved human dimensions data are essential for all societal benefit areas. The new topics being addressed in the next IPCC Working Group II assessment report, such as human security and livelihood and poverty, also highlight the increasing importance of understanding the complex interactions between climate and society, especially with regard to sustainable development and human security.

Actions*:* Invite relevant GEO Task teams to lead the development and documentation of specific human dimensions datasets and services. Encourage GEO Communities of Practice to identify key needs and opportunities. Invite IPCC Working Group II authors and the IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) to identify key human dimensions data gaps and needs for IPCC assessments that GEO could consider addressing in its 2012-2015 Work Plan. Identify funding needs and priorities.

Recommendation 17: Conduct an assessment of IPCC capacity-building needs

A capacity building assessment could consider the data needs of each chapter in the Working Group II contribution to the Fifth Assessment Report as a way of preparing for post-AR5 assessments. It could also explore the feasibility and broader relevance to the research community of, among others, the following products and actions:

- A web-based handbook on how to assess impacts and vulnerability (including a dashboard of indicators and related steps with regard to locally-derived and globally-derived data);
- a mechanism (perhaps web-based) to make access to existing data and assessment findings easier;
- guidelines on developing quick-start manuals that could accompany each available dataset to promote proper use;
- strengthen funding and capacity for digitalizing existing data collected in the field in many countries in order to secure these data and facilitate their use;
- invite potential partners to develop regional networks allowing for appropriate capacity building and financing needs for existing national efforts that may be suffering from budget cuts;
- a project involving major funding partners to ensure that existing data sources are made freely available to the research community, possibly by employing incentives such as covering training costs for freely available data;
- leverage the IPCC assessment process and its network of experts to facilitate global capacity building, e.g. a platform for freely sharing data among all IPCC authors and their colleagues, including basic training material (a handbook on how to use it, quick-start manuals, and a user-generated log on how it has been used), or facilitating the availability of IPCC experts to deliver technical briefs to other experts on issues related to existing sources of data (traditional tools and techniques for collecting local data, digitalization, etc.), and new sources of data (or new on-the-ground observation techniques, tools and technologies such as use of mobile phones, etc.); and
- provide training to IPCC authors on the potential and use of new data as they become available, on the nature of the assessment process and on the need to publish as many as possible of their key results in the journal-based literature.

Activities: Encourage the IPCC, in partnership with appropriate bodies such as UNEP, WMO and GEO, to undertake a capacity-building assessment of IPCC needs.

Recommendation 18: Adopt modern visualization and communication tools to communicate the science of climate impacts, vulnerability and adaptation

The GEO community across its nine societal benefit areas is exposed regularly to innovative communication tools, initiatives and visualizations that could prove valuable in communicating the science of climate change. Both the earth observation and climate research communities could benefit by improving how they communicate key scientific issues to stakeholders and the public.

Actions: As an initial step, the GEO Secretariat could host on the GEO web site a small collection of links videos and visualization products which might be valuable for the IPCC and the broader GEO community.

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ANNEX I

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