Progress Towards Key Documents CEOS Response to GCOS IP

Mitchell D. Goldberg
CEOS Climate SBA Coordinator
NOAA/NESDIS

CEOS Task

- **WP4200: CEOS Coordinated Response to new GCOS-IP Due: September 2012**

GCOS IP 2010

- The 2010 edition of the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (IP-10) replaces a similarly titled Plan (IP-04) which was published in 2004.* ***Its purpose is to provide an updated set of Actions required to implement and maintain a comprehensive global observing system for climate that will address the commitments of the Parties under Articles 4 and 5 of the UNFCCC and support their needs for climate observations in fulfilment of the objectives of the Convention.***

- *This revised Plan updates the Actions in the IP-04, taking account of recent progress in science and technology, the increased focus on adaptation, enhanced efforts to optimize mitigation measures, and the need for improved prediction and projection of climate change. It focuses on the timeframe 2010-2015*

Example of the GCOS Actions related to upper air

ECV – Upper-air Temperature

Specific microwave radiance data from satellites (Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit A (AMSU-A)) have become key elements of the historical climate record and need to be continued into the future to sustain a long-term record. For climate applications, the satellite systems must be operated in adherence with the GCMPs. Failure of an on-board AMSU-A (or equivalent) instrument should be regarded as a strong driver to launch a new satellite in the series. The new high-resolution infrared sounders such as the Atmospheric Infrared Sounder (AIRS), the IASI (Infrared Atmospheric Sounding Interferometer) and the future CrIS (Cross-Track Infrared Sounder) improve the vertical resolution of satellite-derived temperature soundings, which should significantly improve the monitoring of temperature change. Atmospheric temperature sounding data play an important role, along with radiosonde and aircraft data in reanalyses of temperature and other upper-air variables. Radiosonde temperatures form an important climate data record in their own right, albeit requiring careful homogenisation to account for instrumental and real-time processing changes. Aircraft temperatures are also prone to biases for which adjustments need to be developed by reanalysis centres.

Action A20 *[A19 IP-04]*

Action: Ensure the continued derivation of MSU-like radiance data, and establish FCDRs from the high-resolution IR sounders, following the GCMPs.
Who: Space agencies.
Time-Frame: Continuing.
Performance Indicator: Quality and quantity of data; availability of data and products.
Annual Cost Implications: 1-10M US$ (for generation of datasets, assuming missions, including overlap and launch-on-failure policies, are funded for other operational purposes) (Mainly by Annex-I Parties).

GPS radio occultation (RO) measurements provide high vertical resolution profiles of atmospheric refractive index that relate directly to temperatures above about 6 km altitude (where water vapour effects are small). They provide benchmark observations that can be used to "calibrate" the other types of temperature measurement, and supplement the GRUAN in this regard. RO instruments are flown on multiple low Earth orbiting satellites. The COSMIC (Constellation Observing System for

59

Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)

Meteorology, Ionosphere and Climate) fleet of satellites provides real-time data and the GNSS Receiver for Atmospheric Sounding (GRAS) instrument is the first of a series of operational RO instruments. Real-time use of the data has been established and a positive impact on Numerical Weather Prediction (NWP) has been demonstrated. Climate applications are being developed by providing consistent time series of bending angles and refractivity profiles. The introduction of other GNSS offers opportunities for further improvement in coverage of RO data.

Action A21 *[A20 IP-04]*

Action: Ensure the continuity of the constellation of GNSS RO satellites.
Who: Space agencies.
Time-Frame: Ongoing; replacement for current COSMIC constellation needs to be approved urgently to avoid or minimise a data gap.
Performance Indicator: Volume of data available and percentage of data exchanged.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

GCOS Satellite Supplement

- ..provides supplemental detail to the 2010 Update of the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (GCOS-138, August 2010, hereafter called the 'GCOS Implementation Plan' or 'IP-10') related to the generation of global climate products derived from measurements made from satellites

News

Update of the Satellite Supplement – now open for public review

High-level requirements on the accuracy, stability and resolution of satellite-based datasets and derived products in support of the GCOS ECVs were defined in 2006 and documented in the "Satellite Supplement" (GCOS-107) to the 2004 GCOS Implementation Plan.

An 2011 Update of the Satellite Supplement is currently underway. The draft document is now opened for public review from 9 May to 1 July 2011: Draft Document

3.1.3. ECV Upper-Air Temperature

Data on upper-air temperatures are of key importance for detection and attribution of tropospheric and stratospheric climate change. Temperatures measured by high-quality radiosondes are used as a reference for satellite-derived temperatures to characterise their errors and to assist in correction of biases. Upper-air temperatures are crucial for distinguishing the various possible causes of climate change and for the validation of climate models, and they can potentially be used for improved understanding of long-term variability in atmospheric circulation.

Top-of-atmosphere microwave radiances (e.g., from the Microwave Sounding Unit (MSU) and Advanced Microwave Sounding Unit A (AMSU-A)) have become key elements of the historical climate time series, and their measurement needs to be continued into the future to sustain a long-term record. The MSU time series have been used for nearly two decades to estimate temperature trends. They are being continued with data from AMSU-A and other microwave sounders. These time series can be interpreted as deep layer mean temperatures derived from linear combinations of microwave sounder brightness temperatures. Layer-mean temperatures in the middle to upper stratosphere are inferred from the Stratospheric Sounding Unit, SSU (1979-2006) and AMSU-A (1998 to present). Layer-mean temperatures in the mesosphere can potentially be derived from the Special Sensor Microwave Imager SSMI/S (2004 to present). The new advanced infrared sounders, such as the Atmospheric Infrared Sounder (AIRS), the Infrared Atmospheric Sounding Interferometer (IASI), and the future Cross-Track Infrared Sounder (CrIS) improve the vertical resolution and stability of satellite-derived temperature soundings.

GPS radio occultation (RO) measurements of bending angle relate directly to temperatures above about 6km altitude (where water vapour effects are small). They provide benchmark observations that can be used to "calibrate" the other types of temperature measurement. GPS-RO instruments are flown on multiple low Earth orbiting satellites. The COSMIC (Constellation Observing System for Meteorology, Ionosphere, and Climate) fleet of satellites provides real-time data, and the GNSS Receiver for Atmospheric Sounding (GRAS) instrument is the first of a series of operational GPS-RO instruments. Real-time use of the data has been established and a positive impact on Numerical Weather Prediction (NWP) has been demonstrated. Provision of a consistent time series of bending angles is developing for climate applications. The introduction of other GPS constellations (e.g., Galileo) offers opportunities for further improvements in coverage. Recent research has shown that the GPS-RO technique provides information about both the temperature and water vapour profile in the middle to lower troposphere.

Atmospheric temperature sounding data, along with radiosonde, GPS-RO, and aircraft data also play an important role in reanalyses of temperature and other upper-air variables. High spectral resolution infrared radiances as proposed for the reference-type CLARREO mission can be used as anchor points for reanalyses, calibration of other infrared radiometers, and validation of climate models.

Detailed global-scale analyses of temperature are best obtained from reanalyses for many applications, although retrievals of temperature profiles continue to be used in climate research. In either case, FCDRs

Product A.3.1 Upper-air temperature retrievals

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Tropospheric temperature profile	25km	1km	4h	0.5K	0.05K
Stratospheric temperature profile	100km	2km	4h	0.5K	0.05K

In addition to the temperature records derived from profile retrieval or reanalysis combining different observations (satellites, *in situ*), it is necessary to provide independent satellite-based analyses of temperature for validating variability and trends. These analyses are usually undertaken with an understanding of the regions of the atmosphere where satellites can provide the most accurate measurements (e.g., MSU-equivalent radiances, GPS-RO analyses).

Product A.3.2 Temperature of deep atmospheric layers

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
layers	100km	5km	averages	0.2K	0.02K

Benefits

- Monitoring and detection of temperature trends and variability in the troposphere and stratosphere at global and regional scales
- Validation of climate model predictions
- Input to reanalyses
- Linkage with trends in surface air temperature

Currently achievable performance

- MSU trends in the troposphere show differences between different data products but are generally in closer agreement with trends from newly homogenised radiosonde data than with trends computed earlier from radiosondes
- GPS-RO accuracy within 0.1 K and has exceptional stability, and already meets the target in the upper troposphere and lower stratosphere

Requirements for satellite instruments and satellite datasets

FCDRs of passive microwave and IR-based satellite data for use in reanalysis, for example:

- Ongoing provision of advanced IR sounder capability, such as AIRS, IASI, and CrIS
- Homogenized consistent reprocessing of TOVS / ATOVS data record
- Use of other available stable sensors in orbit for determination of absolute biases and intercalibration of operational satellites

FCDRs of past and future data records from passive microwave and IR sounding and GNSS radio occultation, for example through:

- Passive microwave and IR sounding from at least two satellites in low Earth orbit using instruments with spectral and scanning characteristics to provide global coverage and continuity with the past record
- A long-term constellation of GPS-RO measurements to continue the limited record established by past and present missions
- SSU FCDR for middle and upper stratospheric layer mean temperatures from 1979-2006

Calibration, validation and data archiving needs

- Differences in trends estimated from MSU/AMSU radiances point to the need for improved adjustments for effects of instrumental and orbital drifts and inter-satellite differences
- Use of GPS-RO to validate absolute accuracy of MSU/AMSU mean temperatures
- Development of SI-traceable standards for absolute calibration of microwave instruments
- Intercalibrated HIRS using high quality AIRS and IASI and, in the future, using SI traceable measurements
- Support for GRUAN and other ground-based observations for validation of future satellite data records
- Use of GSICS bias-correction coefficients and bias-adjustment information from reanalysis for operational sounders (e.g., MSU, AMSU, HIRS, SSU)
- Use of NWP to monitor sudden changes in measurement biases

Adequacy/inadequacy of current holdings

- Some uncertainty remains in MSU/AMSU-based temperature trends, despite progress in reconciliation with other estimates
- Accuracy is generally adequate for interannual climate variability
- Work has started to put together GPS-RO data as a climate data record

Immediate action, partnerships, and international coordination

- Extend current microwave FCDRs with new sensors (e.g., ATMS, FY-3, SSMIS)
- Assess the accuracy of SSMIS for upper stratosphere/lower mesosphere temperature trends
- Ensure continuation of GPS-RO for reference temperature measurements (e.g., COSMIC-2)
- Construct an FCDR of bending angles from GPS-RO data
- Continue intercomparisons of advanced IR sounders, imagers, and, later CLARREO if possible to assess and monitor accuracy and stability of high spectral infrared radiance data.
- Produce FCDRs of HIRS radiances back to 1979 and VTPR back to 1972
- Use GRUAN to provide reference temperatures
- Coordination by SPARC, AOPC WGARO, ITWG, IROWG, GEWEX Radiation Panel and GSICS for calibration.

Link to GCOS Implementation Plan

[IP-10 Action A20] Ensure the continued derivation of MSU-like radiance data and establish FCDRs from the high-resolution IR sounders in accordance with the GCMPs
[IP-10 Action A21] Ensure the continuity of the constellation of GNSS RO satellites

Other applications

- GPS-RO has potential for monitoring height of inversion layers (i.e., the tropopause and boundary layer)

GCOS satellite supplement provides

- Products, Target Requirements, Benefits
- Rationale
- Currently Achievable Performance
- Requirements for satellite instruments and data
- Calibration, Validation and Archiving Needs
- Adequacy and Inadequacy of Current Holdings
- Immediate Actions, Partnerships and International Coordination.

CEOS Response:

- Reinforces the needs called out by the GCOS Satellite Supplement
  - Provides more detail on the deliverables, coordination, activities and who will lead the effort.
  - Calls out agency activities
  - Calls out international coordination
- Can include additional activities not called out by GCOS but may be considered important by CEOS.
- Provides to CEOS, what can be achieved with current funding and additional funding

CEOS
Committee on Earth Observation Satellites

Approach (1/2)

- **47 Actions to respond to.**
- **Identified domain leads (atmosphere, ocean, terrestrial)**
  - Goldberg – Atmosphere
  - Dowell – Ocean
  - Dwyer – Terrestrial
- **Coordinate with CEOS working groups, CEOS virtual constellations, and Climate related external groups (e.g. SCOPE-CM, GSICS, WCRP, CGMS), and experts to develop plans responding to the GCOS IP10 actions via templates**
- **We expect that the new CEOS response will help agencies to plan their Climate Data programs and vice versa**

Approach (2/2)

- Identify Subject Matter Experts(~3) for each GCOS-IP action to develop response via common template
- Identify existing coordination groups (eg. GOFC-GOLD for fire) for vetting the response
- Use input from the GCOS satellite supplement
- WGC to review and provide input to templates
  - Key activities should intersect agency climate programs
- Use templates to develop the report
- Report will be reviewed by Working Group on Climate
- Finalize report by September 2012

Status since Plenary/SIT

- Supported the update of the GCOS Satellite Supplement
- Briefed GCOS AOPC, Feedback on 2 templates

- Received 7 draft templates of 15 for Atmosphere
  - A11, A19, A21, A26, A29, A32, A34
- Received 3 draft templates of 9 from Ocean
  - O7, O10, O15
- Received 3 of 21 from Terrestrial
  - T16, T29, T39

- Leveling exercise underway (complete by June 15),

  Actual completion was August 30

- Goal to have 70% November, 100% in February

Outcome of the Level Exercise

- My initial survey, was that a few were very good, and a few was an echo of the GCOS supplement.
- Enlisted the System Engineering expertise of the SEO to review all the completed templates and to recommend a modified template so there would be no confusion.
- We found T39 to be the best, and T39 was converted to the new template and now we are ready to complete the other actions.

CEOS Climate Action Template - Describing activities for 2011 - 2015

GCOS Action T39

Action: Develop set of active fire and FRP products from the global suite of operational geostationary satellites.

Who: Through operators of geostationary systems, via CGMS, GSICS, and GOFC-GOLD.

Time-Frame: Continuous.

Performance Indicator: Availability of products.

Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

- **CEOS Action XX:**
- **Lead CEOS Agency :**
- **Contributing agencies:**
- **Team Leaders:** CEOS agency member, co-lead
- **Members:**
- **International Coordination Bodies:**
- **Description of the Deliverable(s):**
- **Significance of the Deliverable(s):**
- **Accuracy requirements**
  - Target: Planned: Threshold:
- **Stability requirements**
  - Target: Planned: Threshold:
- **Horizontal resolution requirements**
  - Target: Planned: Threshold:
- **Vertical resolution requirements**
  - Target: Planned: Threshold:
- **Data Requirements**
  - Continuity of key data sets
  - New datasets potentially improving product over next 5 years
  - Key datasets for validation
- **Science Requirements**
  - Calibration/Intercalibration
  - Intercomparisons
  -
- **Key activities and time frames to meet deliverables (2011 – 2015).**
  -
  -
  -
- **What can be achieved with current funding?**
  -
  -
  -
- **What additional funding is recommended?**
  -
  -
  -

Supporting Material from GCOS-IP

ECV – Fire Disturbance

Fire disturbance on Earth is characterised by large spatial and temporal variations on multiple time scales (diurnally, seasonally and inter-annually). By consuming vegetation and emitting aerosols and trace gases, fires have a large influence on the storage and flux of carbon in the biosphere and atmosphere, can cause long-term changes in land cover, and affect land-atmosphere fluxes of energy and water.

In general, fires are expected to become more severe under a warmer climate, depending on changes in precipitation. At the same time, some ecosystems, particularly in the Tropics and boreal zones, are becoming subject to increasing fire due to growing population, economic, and land-use pressures. The amount of burned biomass in ecosystems can vary by an order of magnitude, especially between wet and dry years, and these strong year-to-year variations may influence the interannual change seen in the global atmospheric CO_2 growth rate.

Informed policy- and decision-making clearly requires timely and accurate quantification of fire activity and its impacts nationally, regionally, and globally. Burned area, active fire detection, and Fire Radiative Power datasets together form the Fire Disturbance ECV, and the separate products can be combined to generate improved information, e.g., mapping of fire affected areas to the fullest extent, including the

Template: The CEOS Response to the GCOS Implementation Plan & Satellite Supplement (Describing 2011-2015 CEOS Activities)

Throughout the completion of this template, please bear in mind the GCOS IP/SS content associated with this action in its entirety. These templates will compile to form a comprehensive, coordinated CEOS response to addressing the satellite Earth observation needs discussed thoroughly in the GCOS Implementation Plan and Satellite Supplement (IP/SS).

GCOS Action T39 [IP-04 NONE]

Action: Develop set of active fire and FRP products from the global suite of operational geostationary satellites.
Who: Through operators of geostationary systems, via CGMS, GSICS, and GOFC-GOLD
Time-Frame: Continuous
Performance Indicator: Availability of products
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties)

CEOS Agencies:

- Leads:
- Contributors:

Team:

- Leads:
- Members:

International Coordination Bodies:

-

Relevant existing CEOS actions:

-

CEOS Deliverable(s) as related to this GCOS Action –

Please list all current and planned CEOS activities, outcomes, and deliverables that address the needs identified in the GCOS IP/SS for this action. Describe each one, including a brief recap of the significance of the deliverables' role in climate observations (it is not necessary to restate the content of the GCOS IP/SS). Elaborate or add any relevant content as necessary. Please also discuss the needs that CEOS is not currently planning to address, but that CEOS agrees are important. Include satellites/instruments, products/programs, coordination, etc., making sure to fully address the content of GCOS IP/SS sections such as "Requirements for satellite instruments and satellite datasets" and "Immediate action, partnerships, and international coordination", etc.

- Specific Deliverable #1:
- Specific Deliverable #2
- Specific Deliverable #3

Accuracy –

List the current, planned, and future accuracy capabilities, if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, and any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Stability –

List the current, planned, and future stability capabilities, if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, and any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Horizontal resolution –

List horizontal resolution capabilities (current, planned, future), if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Vertical resolution –

List vertical resolution capabilities (current, planned, future), if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Data & Science Requirements –

Discuss and respond to the data/science requirements mentioned in the GCOS IP/SS as related to this GCOS action and the relevant CEOS deliverables. What does CEOS need in terms of data and science help, in order to accomplish these deliverables? Why are they needed and who can help?

- For deliverable 1
- For deliverable 2
- For deliverable 3

Planned activities/time frames to meet deliverables (2011 – 2015) –

Include resources/websites where a reader might find more information on these activities, if possible.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Are the above activities sufficient to accomplish the GCOS action? If not, what is missing? What additional activities in support of this GCOS action can be accomplished with additional funding? Discuss.

- For deliverable 1
- For deliverable 2
- For deliverable 3

Template: The CEOS Response to the GCOS Implementation Plan & Satellite Supplement (Describing 2011-2015 CEOS Activities)

Throughout the completion of this template, please bear in mind the GCOS IP/SS content associated with this action in its entirety. These templates will compile to form a comprehensive, coordinated CEOS response to addressing the satellite Earth observation needs discussed thoroughly in the GCOS Implementation Plan and Satellite Supplement (IP/SS).

GCOS Action T39 [IP-04 NONE]

Action: Develop set of active fire and FRP products from the global suite of operational geostationary satellites. **Who:** Through operators of geostationary systems, via CGMS, GSICS, and GOFC-GOLD **Time-Frame:** Continuous **Performance Indicator:** Availability of products **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties)

CEOS Agencies:

- Leads: NOAA
- Contributors: EUMETSAT

Team:

- Leads: Ivan Csiszar (NOAA NESDIS), Hans-Joachim Lutz (EUMETSAT), Prins (UW-Madison CIMSS – consultant)
- Members: Christopher Schmidt (UW-Madison, CIMSS), Martin Wooster (Kings College, London), Wilfrid Schroeder (UMd/ESSIC)

International Coordination Bodies:

- GOFC-GOLD Fire Implementation Team
- Coordination Group for Meteorological Satellites (CGMS)
- Global Space-based Inter-Satellite Calibration System (GSICS)
- CEOS WGCV LPV

Relevant existing CEOS actions:

- No currently active relevant CEOS actions

CEOS Deliverable(s) as related to this GCOS Action –

Please list all current and planned CEOS activities, outcomes, and deliverables that address the needs identified in the GCOS IP/SS for this action. Describe each one, including a brief recap of the significance of the deliverables' role in climate observations (it is not necessary to restate the content of the GCOS IP/SS). Elaborate or add any relevant content as necessary. Please also discuss the needs that CEOS is not currently planning to address, but that CEOS agrees are important. Include satellites/instruments, products/programs, coordination, etc., making sure to fully address the content of GCOS IP/SS sections such as "Requirements for satellite instruments and satellite datasets" and "Immediate action, partnerships, and international coordination", etc.

- Specific Deliverable #1:

The deliverable is standardized long-term active fire and Fire Radiative Power (FRP, Watts or J/s) products from the global suite of operational geostationary satellites.

The active fire product provides information on the location of pixels containing fire activity and associated metadata. Detailed metadata is crucial for the proper interpretation of active fire products especially given the significant differences in the fire monitoring capabilities of the global geostationary satellite systems. Metadata should include specifics such as: an indication of the fire pixel confidence level; satellite and processing coverage regions; algorithm block-out zones associated with viewing geometry, solar reflection contamination, and specific biomes; data and algorithm anomalies and limitations; instrument saturation; an opaque cloud mask; atmospheric attenuation information; and geo-location characterization uncertainties.

Fire Radiative Power (Watts or J/s) is the time derivative of the fire radiative energy, which is proportional to the biomass consumed by the fire. Multiple FRP observations can in principle provide estimates of total fire emissions (CO_2, PM 2.5, etc.) through estimating time-integrated Fire Radiated Energy (FRE).

Fire is a global phenomenon with large variability in both time and space. It is an important ecosystem disturbance factor and contributes to atmospheric emissions on multiple time scales. Active fires have a strong diurnal component and geostationary monitoring is essential for providing a more complete view of regional, diurnal, seasonal, and interannual variability in fire activity. Detection of active fires is also required by some burned area product algorithms. Active fire information can serve as part of the validation process for burned area products and diurnal information on emissions is vital for modeling applications. In recent years modelers have shown interest in utilizing fire radiative energy/power to characterize emissions. One may assert that the total FRE of a fire is directly related to mass consumed by the heat of combustion, which can then be related to PM 2.5, CO_2 and other emissions.

Due to the disparity and inadequacy in regional and national fire reporting protocols, satellite remote sensing represents the most suitable and cost effective method for consistent, long-term regional and global scale monitoring. Over the past 10 years the use of geostationary satellites for both diurnal fire detection and characterization has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change research, emissions monitoring, aerosol and trace gas transport modeling, air quality, and land-use and land-cover change detection. Current (GOES-E/-W/-South America, Met-8/-9, MTSAT-1R/-2, FY-2C/2D) and future (Indian INSAT-3D, Russian GOMS Elektro L MSU-GS, Korean COMS) operational geostationary platforms will enable nearly global geostationary fire monitoring with significant improvements in capabilities over the next 5-7 years (e.g. GOES-R, MTG).

The development of the Global Geostationary Fire Monitoring Network is coordinated through the Global Observation of Forest and Landcover Dynamics (GOFC-GOLD) Fire Mapping and Monitoring Implementation Team (IT). The GOFC-GOLD Fire IT is organizing a meeting on October 18-19 in Stresa, Italy, where the status of the network will be discussed. A separate workshop hosted by NOAA/NESDIS is planned for Spring 2012.

- Specific Deliverable #2
- Specific Deliverable #3

Accuracy –

Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, and any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1

The accuracy of current and future global geostationary active fire and FRP products is dependent on a variety of factors including spatial resolution, viewing conditions (e.g. viewing angle, cloud coverage, solar contamination, etc.), calibration, noise levels and saturation levels in the 3.9 and 11 µm bands at higher temperatures, and multi-spectral data pre-processing chains.

Although active fire products and FRP from the current global geostationary sensors are limited by the relatively coarse resolution (4-5 km at sub-satellites point) in the 3.9 and 11 µm bands, this will improve over the next five years. The requirements for next generation geostationary sensors, such as the GOES-R Advanced Baseline Imager (2 km resolution) include a detection rate of 50% for fires emitting more than 75 MW within a fire temperature range of 500 to 1200 K and a mapping accuracy of 1 km (at sub-satellite point). Estimates of sub-pixel fire radiative power are required to be within 50% of truth.

Further detailed analysis is needed to determine omission and commission errors and the accuracy of the FRP retrievals against the requirements listed in the Satellite Supplement. This work needs to be done in coordination with CEOS WGCV LPV and GOFC-GOLD Fire. The 5% error of commission is potentially achievable on a global basis after algorithm improvements to eliminate false alarms over previously burned areas whose size is comparable to the satellite pixel. The 30% error of omission (on a per fire basis, compared to 30m spatial resolution detections) is unlikely to be achieved to the pixel size and the large number of small fires below the corresponding detection limit.

- For deliverable 2
- For deliverable 3

Stability –

List the current, planned, and future stability capabilities, if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, and any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1

Sensors used for fire detection and characterization need to be consistently and systematically calibrated at the high end of the dynamic range. Sensor saturation levels need to be well known and stable over time and sensor behavior at and beyond saturation needs to be properly characterized; sensor artifacts need to be minimized or eliminated. The monitoring of sensor behavior needs to be coordinated by GSICS.

- For deliverable 2
- For deliverable 3

Horizontal resolution –

above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1

Horizontal resolutions of next generation global geostationary fire products and FRP are on the order of 2 km (at sub-satellite point). Therefore neither the active fire detection nor the FRP product meets or is expected to meet the 1km horizontal resolution requirement listed in the GCOS Satellite Supplement.

- For deliverable 2
- For deliverable 3

Vertical resolution –

List vertical resolution capabilities (current, planned, future), if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1

This is not applicable, since global geostationary active fire and FRP are land surface products.

- For deliverable 2
- For deliverable 3

Temporal resolution –

List temporal resolution capabilities (current, planned, future), if applicable, specific to each of the deliverables mentioned above. Discuss how they differ from that requested in the GCOS IP/SS, why, how to get closer, any planned/potential CEOS activities addressing the discrepancies.

- For deliverable 1

For temporal resolution, the requirement is 6 hrs for active fire detection, which will be exceeded by the 15-30min frequency of observations. For FRP, a separate 1-hr requirement is listed, which is likely to be met even if ~50% of the observations are obscured by cloud cover.

Data & Science Requirements –

Discuss and respond to the data/science requirements mentioned in the GCOS IP/SS as related to this GCOS action and the relevant CEOS deliverables. What does CEOS need in terms of data and science help, in order to accomplish these deliverables? Why are they needed and who can help?

- For deliverable 1

A global geostationary fire monitoring network is technically feasible but must be supported by operational agencies to sustain the activity and produce standardized long-term data records and derived active fire products and FRP of known accuracy. This requires commitment from operational agencies for ongoing support of global geostationary fire monitoring through appropriate sensor design and application and subsequent ongoing characterization and consistent validation programs. A major constraint with some of the current operational geostationary sensors is low saturation in the 3.9 µm fire channel which severely hinders the ability to detect and characterize fires during peak solar heating when many anthropogenic fires occur.

The development community, implementation teams, and operational fire product producers require the following information/data:

- near real-time access (< 5 minutes) to well calibrated and navigated full spatial resolution

- detailed information on data pre-processing chains
- indication of saturation of pre-aggregated detector samples in both the 3.9 and 11 µm bands
- calibration of the 3.9 and 11 µm bands at higher temperatures
- noise characterization at higher temperatures
- band-to-band co-registration information
- information regarding point spread functions.

Specifically, there is a need for minimum and ideally no smoothing or filtering of information within the 3.9 µm band, and for detailed characterization of its behavior beyond 300K and up to the saturation point. It is imperative that agencies provide detailed information on how observations in this channel are pre-processed and converted to level 1 radiance imagery from which fire products will be derived.

- New datasets potentially improving product over next 5 years

The recent launch of the Korean COMS and Russian GOMS Electro-L MSU-GS platforms and the expected launch of INSAT-3D in 2011 will enable nearly global fire monitoring with unprecedented coverage of fire in Eastern Europe and Asia. These systems are somewhat similar to the current GOES and Meteosat series in terms of fire monitoring capabilities and limitations. We expect to see significant improvements with the next generation GOES-R Advanced Baseline Imager (ABI, launch in 2015) and Meteosat Third Generation (MTG, launch in 2017). Both of these missions have a fire monitoring requirement and will include improved spatial resolution (2 km) and 400-450K saturation in the 3.9 µm band with enhanced diurnal temporal monitoring.

In order to ensure that future geostationary sensors provide continuity from current products and are capable of enhanced active fire detection and characterization, the fire monitoring community should be involved in evaluating specifications for next generation operational geostationary satellites and provide feedback to operational agencies on issues relating to data access and pre-processing chains, saturation in the middle and long-wave IR window bands, characterization of sensor behavior at high temperatures, navigation, band-to-band co-registration, PSF implications, and cal/val.

- Key datasets for validation

The international fire community has been working with the CEOS WGCV LPV in an effort to standardize the validation of satellite fire products, specifically identifying the three-stage CEOS Hierarchy of Validation as a good approach. Although various fire databases exist on the regional and national level, they must be used cautiously due to inconsistencies in reporting protocols and other discrepancies. The CEOS/WGCV/LPV subgroup is working to establish a network of sites for long term validation of fire products. These sites must meet specific selection criteria to ensure consistency, completeness, and accuracy in reporting.

To date geostationary active fire and FRP product validation studies have been limited in scope due to the lack of adequate ground truth and limited funding and resources for aircraft validation studies in various biomes and under different viewing conditions. Routine operational cal/val 30 m Landsat7 ETM+, Terra ASTER, Landsat Data Continuity Mission OLI) and should be automated (to the extent possible). Ideally, high spatial resolution instruments capable of detecting the radiative power of a fire without the influence of sensor saturation should be employed. This could involve over-flights of fires by airborne systems, for example, NASA Ames (UAV), data from USFS over-flights, and dedicated over-flights by fire-dedicated airborne systems (e.g. AMS, FIREMAPPER). This effort should be done in cooperation with the CEOS WGCV LPV.

- **Science Requirements**
  - Calibration/Intercalibration

For sub-pixel fire characterization fire algorithms require well-calibrated data from the cold (for background and weak fire pixel signal assessment) to very hot brightness temperatures (for strong fire pixel signal assessment). If calibration and noise (NEdT) on the hot end for the 3.9 and 11 µm bands are not well characterized, FRP will be suspect on the hot end. Current and planned missions typically offer adequate calibration and noise information at lower temperatures (<330K) but do not adequately address calibration and NEdT on the hot end (>375K). The fidelity of global geostationary fire products can only be maintained with ongoing calibration of the 3.9 and 11 µm bands at higher temperatures and characterization of noise levels at higher temperatures.

Characterization of sensor behavior beyond saturation is also needed. Experience with current and previous satellite sensors has demonstrated spurious sensor output when the incoming radiance exceeds the sensors' saturation level. The spurious behavior is a consequence of the folding of the output count value, resulting in either a physically interpretable (but incorrect) value below the saturation value, or in a near-zero value. In some cases saturated pixels can result in a "stuck bit" effect that results in a false elongation of a fire signature along a scan line. This was observed on the GOES-8 instrument and has also been documented in Met-8/-9 SEVIRI imagery in Europe and South America.

- Intercomparisons

The global suite of operational geostationary sensors are similar yet present diverse and unique fire monitoring capabilities and limitations. In order to develop consistent merged or fused global geostationary active fire and FRP products, it is necessary to characterize and understand the differences between the sensors and their respective products. This will require intercomparison studies with each other, higher resolution instruments (MODIS, ASTER, Landsat, airborne systems), and ground truth.

- Additional Sensor and Data Issues

Additional work must be done to address the impact of pre-processing protocols on fire detection and characterization. This includes smoothing that occurs as a result of georectification procedures and the methodology used to aggregate and flag saturated sub-pixel detectors. Other issues that must be investigated include sensor specific band-to-band co-registration and PSF implications for active fire detection and characterization of FRP.

- For deliverable 2
- For deliverable 3

Planned activities/time frames to meet deliverables (2011 – 2015) –

Include resources/websites where a reader might find more information on these activities, if possible.

- For deliverable 1
- NOAA NESDIS operations currently provides Wildfire Automated Biomass Burning Algorithm (WF_ABBA) active fire locations and FRP in various formats for GOES-E/-W, Meteosat-9, and MTSAT-1. WF_ABBA fire masks and metadata have not yet been released as part of the NESDIS operational fire product, although they are available from UW-Madison CIMSS. The time frame for operational release is currently unknown.
- EUMETSAT is implementing a global geostationary fire product.
- Provided the data are accessible in near real-time and well-calibrated/navigated, the WF_ABBA will be adapted to COMS, GOMS Elektro L MSU-GS over the next 2 years. Funding is being sought for the operational implementation of the extended product by NOAA/NESDIS.
- UW-Madison CIMSS has delivered the initial GOES-R ABI fire algorithm and will continue to evaluate and update the algorithm
- GOFC-GOLD Fire is planning a thematic workshop in Spring 2012, hosted by NOAA/NESDIS.

- For deliverable 2
- For deliverable 3

Are the above activities sufficient to accomplish the GCOS action? If not, what is missing? What additional activities in support of this GCOS action can be accomplished with additional funding? Discuss.

- For deliverable 1
- Additional funding is needed to complete the adaptation of the WF_ABBA to Korean COMS and INSAT-3D and to adapt to GOMS Elektro L MSU-GS. Funding is also needed to transfer to NESDIS operations.
- Funding is needed to develop and implement routine cal/val activities. This will require timely access to ground truth data and higher resolution satellite data (Landsat, ASTER, etc.).
- In order to create consistent fused global geostationary active fire and FRP products, funding is needed to perform intercomparison studies.

  Funding is needed to develop and implement consistent fused global geostationary fire products.
- For deliverable 2
- For deliverable 3

Supporting Material from GCOS-IP: ECV – Fire Disturbance

Fire disturbance on Earth is characterised by large spatial and temporal variations on multiple time scales (diurnally, seasonally and inter-annually). By consuming vegetation and emitting aerosols and trace gases, fires have a large influence on the storage and flux of carbon in the biosphere and atmosphere, can cause long-term changes in land cover, and affect land-atmosphere fluxes of energy and water.

In general, fires are expected to become more severe under a warmer climate, depending on changes in precipitation. At the same time, some ecosystems, particularly in the Tropics and boreal zones, are becoming subject to increasing fire due to growing population, economic, and land-use pressures. The amount of burned biomass in ecosystems can vary by an order of magnitude, especially between wet and dry years, and these strong year-to-year variations may influence the interannual change seen in the global atmospheric CO_2 growth rate. Informed policy- and decision-making clearly requires timely and accurate quantification of fire activity and its impacts nationally, regionally, and globally. Burned area, active fire detection, and Fire Radiative Power datasets together form the Fire Disturbance ECV, and the separate products can be combined to generate improved information, e.g., mapping of fire affected areas to the fullest extent, including the timing of burning of each affected grid-cell. Estimates of total dry matter fuel consumption (and thus carbon emission) can be calculated from these products. By applying species-specific emissions factors, emission totals for the various trace gases and aerosols can then be calculated.

Fires are typically patchy and heterogeneous. Measurements of global burnt area are therefore required at a spatial resolution of 250 m (minimum resolution of 500 m) from optical remote sensing, ideally on a weekly basis, and, if possible with day of burn information. Detection of actively burning fires and measurement of Fire Radiative Power (FRP) is often adequately done at lower spatial resolutions (1 km), but the sensor must have mid- and thermal-infrared spectral channels with a wide dynamic range to avoid sensor saturation. Active fires should be detected from Low Earth Orbit satellites multiple times per day, with one of the measurements being located near the peak of the daily fire cycle, and their FRP should be calculated. Some geostationary satellites allow active fire and FRP data generation at coarser spatial resolutions as rapidly as every 15 minutes to provide the best sampling of the fire diurnal cycle that may be required for certain applications (e.g., for temporal integration of FRP data to estimate total carbon emissions; and to link to atmospheric chemistry models/observations).

The various space-based products require validation and inter-comparison. Validation of medium- and coarse-resolution fire products involves field observations and the use of high-resolution imagery, in collaboration with local fire management organizations and the research community. The CEOS WGCV, working with the GOFC-GOLD, is establishing internationally-agreed validation protocols that should be applied to all datasets before their release. A fully stratified sampling scheme (designated CEOS level 3) that adequately represents the nature of fire activity over the globe is needed. The validation protocol for burned area products, based on multi-temporal higher resolution reference imagery, is mature and has been documented. The active fire validation protocol requires simultaneous high resolution airborne or satellite imagery, which is not readily available except for the single-platform Terra MODIS/ASTER configuration. Therefore, an effective active fire and FRP validation protocol is still under development.

Summary

- CEOS has a significant task to respond to the latest GCOS IP
- Excellent opportunity to engage the community to work together in response to the GCOS-IP
- Completed the leveling of the completed draft templates (CEOS GCOS IP action plans) and provided feedback
- Achieve critical mass - minimum 70 % of templates completed by Plenary
  - Significant all-day side meeting at CEOS plenary to review, with domain leads, VCs, Working Groups, etc.

CEOS Response to GCOS Satellite Supplement

Subject: [Fwd: CEOS LPV Albedo comments - GCOS 107]
From: Mitch Goldberg
Date: 7/11/11 8:41 AM
To: Carolin Richter, GCOSJPO, CEOS SIT Secretariat, Stover, Shelley K. (LARC-E302)[STARSS II Affiliate], Jerome Lafeuille, Barbara Ryan, Killough, Brian D. (LARC-D2)

Dear Carolin,

Hope all is well with you and the GCOS family. In addition to the comments you received from the CEOS Land Product Validation subgroup of the CEOS cal/val working group, attached are comments from GSICS and the CEOS System Engineering Office (SEO). The GSICS comments focused on the definition of accuracy.

Feel free to contact us for additional information. Shelly organized the comments from the SEO.

Best regards,
Mitch

Subject: CEOS LPV Albedo comments - GCOS 107
From: Gabriela Schaepman-Strub <gabriela.schaepman@ieu.uzh.ch>
Date: Thu, 30 Jun 2011 14:28:13 +0200
To: crichter@wmo.int
CC: Mitch.Goldberg@noaa.gov, sbojinski@wmo.int, "Nightingale, Joanne M. (GSFC-614.5)[SIGMA SPACE CORPORATION]" <joanne.m.nightingale@nasa.gov>, schaaf@bu.edu, gcosjpo@wmo.int, gcos@meteoschweiz.ch, marie-claire@greeningconsulting.co.uk, 'Gregory L Stensaas' <stensaas@usgs.gov>, dwyer@usgs.gov

Dear Caroline,

We herewith would like to provide our response to the open review process of GCOS 107 (satellite supplement) due on 1st July, regarding the Terrestrial Albedo ECV.

On behalf of the surface radiation focus area of CEOS LPV we are investing considerable time and efforts to consolidate specifications and accuracy information of operational satellite-inferred albedo products, to coordinate international intercomparison and validation (with in situ data networks such as BSRN) efforts, and advise and support the validation of new satellite products (e.g. GlobAlbedo, Geoland 2).

Given our role and experience we would like to make the following comments and recommendations:

1. We appreciate the efforts thus far to update the GCOS satellite supplement 2006 and fully support the general recommendations for extensive validation, intercomparison and reprocessing of long term records of albedo given its crucial role in the surface energy budget.
Furthermore we strongly advocate support for in situ networks such as BSRN. However, in our perspective, the albedo part of the satellite implementation plan (version currently open for review) still does not reflect the current and future needs or targets of the international climate user community. We therefore have added a number of suggested changes to the document in track changes (attached).

2. The suggestions (particularly with respect to the need for spectral measurements and more realistic temporal and spatial targets) are CRUCIAL to guarantee that the targeted albedo products and quality information will be available for climate modeling and for monitoring the albedo changes relevant to climate forcing.

3. Given the role of CEOS LPV in coordinating intercomparison and validation, the time investment in providing comments to the previous and current satellite supplement, as well as the importance of changes needed from our perspective we hope that there will be another opportunity to review the revised version before it is officially released.

4. We are open for any discussion on specifications or intercomparison and validation requirements, please just get in contact with us if required.

With best regards,

Crystal Schaaf and Gabriela Schaepman-Strub

Leads of the surface radiation focus area of CEOS LPV http://lpvs.gsfc.nasa.gov/srad_background.html

Accuracy:
Closeness of the agreement between the result of a measurement (single or averaged product values) and a true (reference) value of the measurand.

Product accuracy is determined by total uncertainty of the product (often determined by the root-mean square), which generally has a random and a systematic component. Total uncertainty can be influenced by factors such as spatial/temporal sampling, biases introduced by the retrieval method, biases introduced by interpolation methods, calibration errors, geo-location errors, and instrument noise. Total uncertainty can vary over space and time.

Recommend replacing with:

Uncertainty:

The uncertainty of the product often determined by the root-mean square has a random and a systematic component. Total uncertainty can be influenced by factors such as spatial/temporal sampling, biases introduced by the retrieval method, biases introduced by interpolation methods, calibration errors, geo-location errors, and instrument noise. Total uncertainty can vary over space and time. For products representing large spatial and temporal domains, the random component can approach zero, leaving the systematic component as the dominant source of the uncertainty.

(Total: 48)

Action C8 *[IP-04 C10]*

Action: Ensure continuity and over-lap of key satellite sensors; recording and archiving of all satellite metadata; maintaining appropriate data formats for all archived data; providing data service systems that ensure accessibility; undertaking reprocessing of all data relevant to climate for inclusion in integrated climate analyses and reanalyses, undertaking sustained generation of satellite-based ECV products.
Who: Space agencies and satellite data reprocessing centres.
Time-Frame: Continuing, of high priority.
Performance Indicator: Continuity and consistency of data records.
Annual Cost Implications: Covered in the domains.

Action C21

Action: Implement modern distributed data services, drawing on the experiences of the WIS as it develops, with emphasis on building capacity in developing countries and countries with economies in transition, both to enable these countries to benefit from the large volumes of data available world-wide and to enable these countries to more readily provide their data to the rest of the world.
Who: Parties' national services and space agencies for implementation in general, and Parties through their support of multinational and bilateral technical cooperation programmes, and the GCOS Cooperation Mechanism.
Time-Frame: Continuing, with particular focus on the 2011-2014 time period.
Performance Indicator: Volumes of data transmitted and received by countries and agencies.
Annual Cost Implications: 30-100M US$ (90% in non-Annex-I Parties).

Action A8

Action: Ensure continuity of satellite precipitation products.
Who: Space agencies.
Time-Frame: Continuous.
Performance Indicator: Long-term homogeneous satellite-based global precipitation products.
Annual Cost Implications: 10-30M US$ (for generation of climate products, assuming missions funded for other operational purposes) (Mainly by Annex-I Parties).

Action A11[20] *[IP-04 A11]*

Action: Ensure continuous generation of wind-related products from AM and PM satellite scatterometers or equivalent observations.
Who: Space agencies.
Time-Frame: Continuous.
Performance Indicator: Long-term satellite observations of surface winds every six hours.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Action A19

Action: Implement and evaluate a satellite climate calibration mission, e.g., CLARREO.
Who: Space agencies (e.g., NOAA, NASA, etc).
Time-Frame: Ongoing.
Performance Indicator: Improved quality of satellite radiance data for climate monitoring.
Annual Cost Implications: 100-300M US$ (Mainly by Annex-I Parties).

Action A20 *[A19 IP-04]*

Action: Ensure the continued derivation of MSU-like radiance data, and establish FCDRs from the high-resolution IR sounders, following the GCMPs.
Who: Space agencies.
Time-Frame: Continuing.
Performance Indicator: Quality and quantity of data; availability of data and products.
Annual Cost Implications: 1-10M US$ (for generation of datasets, assuming missions, including overlap and launch-on-failure policies, are funded for other operational purposes) (Mainly by Annex-I Parties).

Action A21 *[A20 IP-04]*

Action: Ensure the continuity of the constellation of GNSS RO satellites.
Who: Space agencies.
Time-Frame: Ongoing; replacement for current COSMIC constellation needs to be approved urgently to avoid or minimise a data gap.
Performance Indicator: Volume of data available and percentage of data exchanged.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

Action A23 *[IP-04 A22]*

Action: Continue the climate data record of visible and infrared radiances, e.g., from the International Satellite Cloud Climatology Project, and include additional data streams as they become available; pursue reprocessing as a continuous activity taking into account lessons learnt from preceding research.
Who: Space agencies, for processing.
Time-Frame: Continuous.
Performance Indicator: Long-term availability of global homogeneous data at high frequency.
Annual Cost Implications: 10-30M US$ (for generation of datasets and products) (Mainly by Annex-I Parties).

Action A24 *[IP-04 A23]*

Action: Research to improve observations of the three-dimensional spatial and temporal distribution of cloud properties.
Who: Parties' national research and space agencies, in cooperation with the WCRP.
Time-Frame: Continuous.
Performance Indicator: New cloud products.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

Action A25 *[IP-04 A24]*

Action: Ensure continuation of Earth Radiation Budget observations, with at least one dedicated satellite mission operating at any one time.
Who: Space agencies.
Time-Frame: Ongoing.
Performance Indicator: Long-term data availability at archives.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

Action A26

Action: Establish long-term limb-scanning satellite measurement of profiles of water vapour, ozone and other important species from the UT/LS up to 50 km.
Who: Space agencies, in conjunction with WMO GAW.
Time-Frame: Ongoing, with urgency in initial planning to minimize data gap.
Performance Indicator: Continuity of UT/LS and upper stratospheric data records.
Annual Cost Implications: 100-300M US$ (including mission costs) (Mainly by Annex-I Parties).

Action A27

Action: Establish a network of ground stations (MAXDOAS, lidar, FTIR) capable of validating satellite remote sensing of the troposphere.
Who: Space agencies, working with existing networks and environmental protection agencies.
Time-Frame: Urgent.
Performance Indicator: Availability of comprehensive validation reports and near real-time monitoring based on the data from the network.
Annual Cost Implications: 10-30M US$ (30% in non-Annex-I Parties).

Action A28 *[IP-04 A27]*

Action: Maintain and enhance the WMO GAW Global Atmospheric CO_2 and CH_4 Monitoring Networks as major contributions to the GCOS Comprehensive Networks for CO_2 and CH_4.
Who: Parties' national services, research agencies, and space agencies, under the guidance of WMO GAW and its Scientific Advisory Group for Greenhouse Gases, in cooperation with the AOPC.
Time-Frame: Ongoing.
Performance Indicator: Dataflow to archive and analyses centres.
Annual Cost Implications: 10-30M US$ (50% in non-Annex-I Parties).

Action A29

Action: Assess the value of the data provided by current space-based measurements of CO_2 and CH_4, and develop and implement proposals for follow-on missions accordingly.
Who: Parties' research institutions and space agencies.
Time-Frame: Urgent, to minimise data gap following GOSAT.
Performance Indicator: Assessment and proposal documents; approval of consequent missions.
Annual Cost Implications: 1-10M US$ initially, increasing with implementation (10% in non-Annex-I Parties).

Action A32

Action: Continue production of satellite ozone data records (column, tropospheric ozone and ozone profiles) suitable for studies of interannual variability and trend analysis. Reconcile residual differences between ozone datasets produced by different satellite systems.
Who: Space agencies.
Time-Frame: Ongoing.
Performance Indicator: Statistics on availability and quality of data.
Annual Cost Implications: 10-30M US$ (Mainly by Annex-I Parties).

Action A33 *[IP-04 A31]*

Action: Develop and implement a coordinated strategy to monitor and analyse the distribution of aerosols and aerosol properties. The strategy should address the definition of a GCOS baseline network or networks for *in situ* measurements, assess the needs and capabilities for operational and research satellite missions for the next two decades, and propose arrangements for coordinated mission planning.
Who: Parties' national services, research agencies and space agencies, with guidance from AOPC and in cooperation with WMO GAW and AERONET.
Time-Frame: Ongoing, with definition of baseline *in situ* components and satellite strategy by 2011.
Performance Indicator: Designation of GCOS baseline network(s). Strategy document, followed by implementation of strategy.
Annual Cost Implications: 10-30M US$ (20% in non-Annex-I Parties).

Action A34

Action: Ensure continuity of products based on space-based measurement of the precursors (NO_2, SO_2, HCHO and CO in particular) of ozone and aerosols and derive consistent emission databases, seeking to improve temporal and spatial resolution.
Who: Space agencies, in collaboration with national environmental agencies and meteorological services.
Time-Frame: Requirement has to be taken into account now in mission planning, to avoid a gap in the 2020 timeframe.
Performance Indicator: Availability of the necessary measurements, appropriate plans for future missions, and derived emission data bases.
Annual Cost Implications: 10-30M US$ (10% in non-Annex-I Parties).

Action: Ensure coordination of contributions to CEOS Virtual Constellations for each ocean surface ECV, in relation to *in situ* ocean observing systems.
Who: Space agencies, in consultation with CEOS Virtual Constellation teams, JCOMM, and GCOS.
Time-Frame: Continuous.
Performance Indicators: Annually updated charts on adequacy of commitments to space-based ocean observing system from CEOS.
Annual Cost Implications: <1M US$ (Mainly by Annex-I Parties and implementation cost covered in Actions below).

Action O7 *[IP-04 O9]*

Action: Continue the provision of best possible SST fields based on a continuous coverage-mix of polar orbiting IR and geostationary IR measurements, combined with passive microwave coverage, and appropriate linkage with the comprehensive *in situ* networks noted in O8.
Who: Space agencies, coordinated through CEOS, CGMS, and WMO Space Programme.
Time-Frame: Continuing.
Performance Indicator: Agreement of plans for maintaining a CEOS Virtual Constellation for SST.
Annual Cost Implications: 1-10M US$ (for generation of datasets) (Mainly by Annex-I Parties).

Action O10 *[IP-04 O12]*

Action: Ensure continuous coverage from one higher-precision, medium-inclination altimeter and two medium-precision, higher-inclination altimeters.
Who: Space agencies, with coordination through the CEOS Constellation for Ocean Surface Topography, CGMS, and the WMO Space Programme.
Time-Frame: Continuous.
Performance Indicator: Satellites operating, and provision of data to analysis centres.
Annual Cost Implications: 30-100M US$ (Mainly by Annex-I Parties).

Action O12 *[IP-04 O16]*

Action: Research programmes should investigate the feasibility of utilizing satellite data to help resolve global fields of SSS.
Who: Space agencies, in collaboration with the ocean research community.
Time-Frame: Feasibility studies complete by 2014.
Performance Indicator: Reports in literature and to OOPC.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Action O15 *[IP-04 O18]*

Action: Implement continuity of ocean colour radiance datasets through the plan for an Ocean Colour Radiometry Virtual Constellation.
Who: CEOS space agencies, in consultation with IOCCG and GEO.
Time-Frame: Implement plan as accepted by CEOS agencies in 2009.
Performance Indicator: Global coverage with consistent sensors operating according to the GCMPs; flow of data into agreed archives.
Annual Cost Implications: 30-100M US$ (10% in non-Annex-I Parties).

Action O19 *[IP-04 O23]*

Action: Ensure sustained satellite-based (microwave, SAR, visible and IR) sea-ice products.
Who: Parties' national services, research programmes and space agencies, coordinated through the WMO Space Programme and Global Cryosphere Watch, CGMS, and CEOS; National services for *in situ* systems, coordinated through WCRP CliC and JCOMM.
Time-Frame: Continuing.
Performance Indicator: Sea-ice data in International Data Centres.
Annual Cost Implications: 1-10M US$ (Mainly by Annex-I Parties).

Action O20 *[IP-04 O21]*

Action: Document the status of global sea-ice analysis and reanalysis product uncertainty (via a quantitative summary comparison of sea-ice products) and to prepare a plan to improve the products. **Who:** Parties' national agencies, supported by WCRP CliC and JCOMM Expert Team on Sea Ice (ETSI). **Time-Frame:** By end of 2011. **Performance Indicators:** Peer-reviewed articles on state of sea-ice analysis uncertainty; Publication of internationally-agreed strategy to reduce uncertainty. **Annual Cost Implications:** <1M US$ (Mainly Annex-I Parties).

Action O28 *[IP-04 O29]*

Action: Develop projects designed to assemble the *in situ* and satellite data into a composite reference reanalysis dataset, and to sustain projects to assimilate the data into models in ocean reanalysis projects. **Who:** Parties' national ocean research programmes and space supported by WCRP. **Time-Frame:** Continuous. **Performance Indicator:** Project for data assembly launched, availability and scientific use of ocean reanalysis products. **Annual Cost Implications:** 1-10M US$ (10% in non-Annex-I Parties).

Action O41 *[IP-04 O3]*

Action: Promote and facilitate research and development (new improved technologies in particular), in support of the global ocean observing system for climate. **Who:** Parties' national ocean research programmes and space agencies, in cooperation with GOOS, GCOS, and WCRP. **Time-Frame:** Continuing. **Performance Indicator:** More cost-effective and efficient methods and networks; strong research efforts related to the observing system; number of additional ECVs feasible for sustained observation; improved utility of ocean climate products. **Annual Cost Implications:** 30-100M US$ (10% in non-Annex-I Parties).

Action T5

Action: Develop an experimental evaporation product from existing networks and satellite observations.
Who: Parties, national services, research groups through GTN-H, IGWCO, TOPC, GEWEX Land Flux Panel and WCRP CliC.
Time frame: 2013-2015.
Performance indicator: Availability of a validated global satellite product of total evaporation.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

Action T8 *[IP-04 T6]*

Action: Submit weekly/monthly lake level/area data to the International Data Centre; submit weekly/monthly altimeter-derived lake levels by space agencies to HYDROLARE.
Who: National Hydrological Services through WMO CHy, and other institutions and agencies providing and holding data; space agencies; HYDROLARE.
Time-Frame: 90% coverage of available data from GTN-L by 2012.
Performance Indicator: Completeness of database.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

Action T10 *[IP-04 T8]*

Action: Submit weekly surface and sub-surface water temperature, date of freeze-up and date of break-up of lakes in GTN-L to HYDROLARE.
Who: National Hydrological Services and other institutions and agencies holding and providing data; space agencies.
Time-frame: Continuous.
Performance Indicator: Completeness of database
Annual Cost Implications: <1M US$ (40% in non-Annex-I Parties).

Action T13

Action: Develop a record of validated globally-gridded near-surface soil moisture from satellites.
Who: Parties' national services and research programmes, through GEWEX and TOPC in collaboration with space agencies.
Time frame: 2014.
Performance indicator Availability of globally validated soil moisture products from the early satellites until now.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

Action T14

Action: Develop Global Terrestrial Network for Soil Moisture (GTN-SM).
Who: Parties' national services and research programmes, through IGWCO, GEWEX and TOPC in collaboration with space agencies.
Time frame: 2014.
Performance indicator: Fully functional GTN-SM with a set of *in situ* observations (possibly co-located with reference network, cf. T3), with standard measurement protocol and data quality and archiving procedures.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

Action T16 *[IP-04 T11]*

Action: Obtain integrated analyses of snow cover over both hemispheres. **Who:** Space agencies and research agencies in cooperation with WMO GCW and CliC, with advice from TOPC, AOPC and IACS **Time-Frame:** Continuous. **Performance Indicator:** Availability of snow-cover products for both hemispheres. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties).

Action T20 *[IP-04 T14]*

Action: Ensure continuity of laser, altimetry, and gravity satellite missions adequate to monitor ice masses over decadal timeframes. **Who:** Space agencies, in cooperation with WCRP CliC and TOPC. **Time-Frame:** New sensors to be launched: 10-30 years. **Performance Indicator:** Appropriate follow-on missions agreed. **Annual Cost Implications:** 30-100M US$ (Mainly by Annex-I Parties).

Action T23 *[IP-04 T17]*

Action: Implement operational mapping of seasonal soil freeze/thaw through an international initiative for monitoring seasonally-frozen ground in non-permafrost regions. **Who:** Parties, space agencies, national services, and NSIDC, with guidance from International Permafrost Association, the IGOS Cryosphere Theme team, and WMO GCW. **Time-Frame:** Complete by 2013. **Performance Indicator:** Number and quality of mapping products published. **Annual Cost Implications:** 1-10M US$ (10% in non-Annex-I Parties).

Action T24 *[IP-04 T19]*

Action: Obtain, archive and make available *in situ* calibration/validation measurements and co-located albedo products from all space agencies generating such products; promote benchmarking activities to assess the quality and reliability of albedo products. **Who:** Space agencies in cooperation with CEOS WGCV. **Time-Frame:** Full benchmarking/intercomparison by 2012. **Performance Indicator:** Publication of inter-comparison/validation reports. **Annual Cost Implications:** 1-10M US$ (20% in non-Annex-I Parties).

Action T25 *[IP-04 T21]*

Action: Implement globally coordinated and linked data processing to retrieve land surface albedo from a range of sensors on a daily and global basis using both archived and current Earth Observation systems. **Who:** Space agencies, through the CGMS and WMO Space Programme. **Time-Frame:** Reprocess archived data by 2012, then generate continuously. **Performance Indicator:** Completeness of archive. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties)

Action T27 *[IP-04 T26]*

Action: Generate annual products documenting global land-cover characteristics and dynamics at resolutions between 250 m and 1 km, according to internationally-agreed standards and accompanied by statistical descriptions of their accuracy.
Who: Parties' national services, research institutes and space agencies in collaboration with GLCN and GOFC-GOLD research partners and the GEO Forest Carbon Tracking task team.
Time-Frame: By 2011, then continuously.
Performance Indicator: Dataset availability.
Annual Cost Implications: 1-10M US$ (20% in non-Annex-I Parties).

Action T28 *[IP-04 T27]*

Action: Generate maps documenting global land cover based on continuous 10-30 m land surface imager radiances every 5 years, according to internationally-agreed standards and accompanied by statistical descriptions of their accuracy.
Who: Space agencies, in cooperation with GCOS, GTOS, GOFC-GOLD, GLCN, and other members of CEOS.
Time-Frame: First by 2012, then continuously.
Performance Indicator: Availability of operational plans, funding mechanisms, eventually maps.
Annual Cost Implications: 10-30M US$ (20% in non-Annex-I Parties).

Action T29 *[IP-04 T29]*[51]

Action: Establish a calibration/validation network of *in situ* reference sites for FAPAR and LAI and conduct systematic, comprehensive evaluation campaigns to understand and resolve differences between the products and increase their accuracy.
Who: Parties' national and regional research centres, in cooperation with space agencies coordinated by CEOS WGCV, GCOS and GTOS.
Time-Frame: Network operational by 2012.
Performance Indicator: Data available to analysis centres.
Annual Cost Implications: 1-10M US$ (40% in non-Annex-I Parties).

Action T30 *[IP-04 T30]*

Action: Evaluate the various LAI satellite products and benchmark them against *in situ* measurements to arrive at an agreed operational product.
Who: Parties' national and regional research centres, in cooperation with space agencies and CEOS WGCV, GCOS/TOPC, and GTOS.
Time-Frame: Benchmark by 2012.
Performance Indicator: Agreement on operational product.
Annual Cost Implications: 1-10M US$ (10% in non-Annex-I Parties).

Action T31 *[IP-04 T28]*

Action: Operationalize the generation of FAPAR and LAI products as gridded global products at spatial resolution of 2 km or better over time periods as long as possible.
Who: Space agencies, coordinated through CEOS WGCV, with advice from GCOS and GTOS.
Time-Frame: 2012.
Performance Indicator: One or more countries or operational data providers accept the charge of generating, maintaining, and distributing global FAPAR products.
Annual Cost Implications: 10-30M US$ (10% in non-Annex-I Parties).

Action T32

Action: Develop demonstration datasets of above ground biomass across all biomes. **Who:** Parties, space agencies, national institutes, research organizations, FAO in association with GTOS, TOPC, and the GOFC-GOLD Biomass Working Group. **Time frame:** 2012. **Performance Indicator:** Availability of global gridded estimates of above ground biomass and associated carbon content. **Annual Cost Implications:** 1-10M US$ (20% in non-Annex-I Parties).

Action T34

Action: Develop globally gridded estimates of terrestrial carbon flux from *in situ* observations and satellite products and assimilation/inversions models. **Who:** Reanalysis centres and research organisations, in association with national institutes, space agencies, and FAO/GTOS (TCO and TOPC). **Time Frame:** 2014-2019. **Performance indicator:** Availability of data assimilation systems and global time series of maps of various terrestrial components of carbon exchange (e.g., GPP, NEP, and NBP). **Annual Cost Implications:** 10-30M US$ (Mainly by Annex-I Parties).

Action T35 *[IP-04 T32]*

Action: Reanalyse the historical fire disturbance satellite data (1982 to present). **Who:** Space agencies, working with research groups coordinated by GOFC-GOLD. **Time-Frame:** By 2012. **Performance Indicator:** Establishment of a consistent dataset, including the globally available 1 km AVHRR data record. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties).

Action T36 *[IP-04 T33]*

Action: Continue generation of consistent burnt area, active fire, and FRP products from low orbit satellites, including version intercomparisons to allow un-biased, long-term record development. **Who:** Space agencies, in collaboration with GOFC-GOLD. **Time-Frame:** Continuous. **Performance Indicator:** Availability of data. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties).

Action T37 *[IP-04 T34]*

Action: Develop and apply validation protocol to fire disturbance data. **Who:** Space agencies and research organizations. **Time-Frame:** By 2012. **Performance Indicator:** Publication of accuracy statistics. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties

Action T39

Action: Develop set of active fire and FRP products from the global suite of operational geostationary satellites. **Who:** Through operators of geostationary systems, via CGMS, GSICS, and GOFC-GOLD. **Time-Frame:** Continuous. **Performance Indicator:** Availability of products. **Annual Cost Implications:** 1-10M US$ (Mainly by Annex-I Parties).

	A	D	H	I
1	**Action Number**	**Action Text**	**Action Development Teams**	**Community Feedback Groups**
4	A8	Ensure continuity of satellite precipitation products.	Steve Neeck	Precip Constellation, CGMS IPWG, GPM X-Cal WG
5	A11	Ensure continuous operation of AM and PM satellite scatterometer or equivalent observations.	Stan Wilson	OSVW constellation
6	A19	Implement and evaluate a satellite climate calibration mission, e.g., CLARREO.	Dave Young, Nigel Fox	CLARREO and TRUTHs Teams
7	A20	Ensure the continued derivation of MSU-like radiance data, and establish FCDRs from the high-resolution IR sounders, following the GCMPs.	Cheng-Zhi Zou (NOAA) Carl Mears, Denis Blumstein (CNES)	NOAA MSU/AMSU CDR Team, EUMETSAT, IASI/AIRS/CriS Team, GSICS
8	A21	Ensure the continuity of the constellation of GNSS RO satellites.	Dave Ector, Axel Von Engeln	CGMS International Radio Occultation Working Group (IROWG)
9	A23	Continue the climate data record of visible and infrared radiances, e.g., from the International Satellite Cloud Climatology Project, and include additional data streams as they become available; pursue reprocessing as a continuous activity taking into account lessons learnt from preceding research.	Ken Knapp, Bill Rossow	GEWEX
10	A24	Research to improve observations of the three-dimensional spatial and temporal distribution of cloud properties.		GEWEX
11	A25	Ensure continuation of Earth Radiation Budget observations, with at least one dedicated satellite mission operating at any one time.	John Bates (NOAA), Bruce Wielicki (NASA)	NASA Langley, GEWEX
12	A26	Establish long-term limb-scanning satellite measurement of profiles of water vapour, ozone and other important species from the UT/LS up to 50 km.	Larry Flynn (NOAA), John Burrows (Bremen)	ACC, ……
13	A27	Establish a network of ground stations (MAXDOAS, lidar, FTIR) capable of validating satellite remote sensing of the troposphere.	CEOS WGCV ACSG (Bojan Bojkov?), Jay Herman (NASA)	
14	A28	Maintain and enhance the WMO GAW Global Atmospheric CO2 and CH4 Monitoring Networks as major contributions to the GCOS Comprehensive Networks for CO2 and CH4.		CEOS Carbon Task Force
15	A29	Assess the value of the data provided by current space-based measurements of CO2 and CH4, and develop and implement proposals for follow-on missions accordingly.	Moriyama (JAXA), Wickland(NASA)	CEOS Carbon Task Force