CGMS-XXX
WMO WP-20
Prepared by WMO
Agenda item: II/4

RADIANCE SATELLITE PRODUCTS

(Submitted by WMO)

Summary and purpose of document

To inform CGMS Members of the status of the utilization of satellite data by the World Climate Research Programme

ACTION PROPOSED

(1) CGMS Members to note the status of the utility of satellite data by WCRP and comments as appropriate
(2) CGMS Members to consider the addition of new global products for climate research
(3) CGMS Members to consider GEWEX recommendations as contained in Section 5.

DISCUSSION

Radiance Products for Climate Research

1. Summary

1.1 WCRP is a major user of CGMS satellite data for most research areas covered by its research Programme. A working group has recently been formed to update and provide a synthesis of the needs of the climate scientific community with respect to Earth observation satellite data and products. Its mandate is twofold:

- To specify the WCRP areas where the issue of the scientific exploitation of satellite data is the most crucial, and provide guidelines on the kind of support which could be solicited from space agencies;

- To prepare a Statement of Guidance for submission to space agencies covering the following items: how satellite missions under development fulfil WCRP scientific requirements; which of the new missions under consideration but not yet decided are particularly relevant to climate research objectives; and, remaining gaps in earth observation systems.

1.2 As a first contribution to this task, the enclosed report has been prepared by Dr William Rossow, NASA GISS, on behalf of the GEWEX (Global Energy and Water Experiment) committee in charge of coordinating global data sets for climate research.

1.3 Recommendations expressed in part five of this report are submitted to CGMS Working Group II for discussion and action in coordination with WCRP research groups. A special effort is also recommended for the development of two new global products, surface skin temperature and upper-tropospheric humidity.

1.4 A summary report from the WCRP working group mentioned above should be available for submission to the next Consultative Meeting on high-level policy on satellite matters which will take place at WMO at the beginning of next year.

2. GEWEX Perspective on Use of Operational Satellites for Climate Research

2.1 The climate is forced by absorption of solar radiation, mostly at the surface, with a strong diurnal and seasonal cycle. The main transfer of energy is by evaporation of water from the surface, latent heating of the atmosphere by precipitation and re-radiation from the atmosphere to space. All of these processes involve and are strongly modulated by clouds. Since atmospheric processes rapidly integrate local forcing differences and couple local responses into a global response, diagnosis of climate variations must be done globally but at space-time-scales characteristic of the weather and the forcing variations. Note that the same argument leads to a requirement for global information for long-range weather forecasting. Moreover, since a climate change may appear as a change in the distribution of cloud-radiation-precipitation magnitudes, rather than a change in their mean, time-resolved observations are needed to diagnose climate changes. Thus, the GRP perspective on the use of operational satellite observations focuses on analysis of the space-time variations of atmospheric and surface properties, with special attention to clouds, radiation and precipitation.

2.2 The only practical way to obtain the needed long-term, global observations of the state of the climate system and its variations at weather scales is to use the international constellation of operational weather satellites; but for these satellites to useful for this purpose requires that they be part of and operated as a globally complete and uniform constellation that provides a common core set of measurements over a long time period. Note that in the first 30 years of operation, the weather satellite constellation has added exactly one new common wavelength to the two that it started with! With relatively little effort (cooperation), the number of common wavelengths could now be five and soon many more. To integrate the constellation's measurements, all radiances must be calibrated and CROSS-CALIBRATED, both between satellites in a particular series and among all satellites in operation. The radiance data must be archived in similar formats to be analyzed as a single dataset to produce merged global data products. Achieving these objectives would make a significant contribution even if no further instrument improvements were made.

2.3 There is a strong urge to reduce the pixel (field-of-view) size for operational satellite imagery below 1 km, based on claims of improved results, even though this design puts a huge strain on data handling resources and generally precludes any research use or climate analysis of the data. The large data volumes also encourage/require development of analysis procedures that take empirical short cuts that usually degrade data quality much more than supposedly gained from the pixel size reduction. These claims are, in fact, physically inconsistent or incorrect. At solar wavelengths, pixels smaller than about a few kilometres are not radiatively independent (this problem is worse at thermal infrared wavelengths), so that observed radiance variations cannot be assigned uniquely (linearly) on a one-to-one basis to a location. Current analyses of such high resolution data never take proper account of this characteristic. Accurate retrievals of physical quantities from radiance measurements require 3-D radiative transfer codes at spatial scales less than about 3 km, so unless such codes are to be used, retrieval accuracy is degraded, not improved, by reducing pixel sizes below about 3 km. Finally, although the instrument angular response may be well characterized, over-sampling pixels is usually a waste of resources because the necessary de-convolution of the radiance measurements is never performed. The argument for such measurements from a weather forecasting perspective is flawed since the forecast value of atmospheric measurements at scales at or smaller than a few kilometres is nil because the motions at these scales are not predictable (put another way, since this is the scale of convective instability, the memory of the system is rapidly lost). So, while high spatial resolution measurements may be needed to integrate properly over non-linear relationships, which can usually be achieved by sub-sampling high-resolution measurements, the information cannot be used directly (linearly) in atmospheric models at such small scales.

3. Status of GEWEX global satellite projects and datasets

3.1 Within GEWEX, space and time sampled versions of all the operational satellite imaging radiance data are used by several projects to produce global data products. The International Satellite Cloud Climatology Project (ISCCP) produces cloud products that currently cover 1981-2001. The Global Aerosol Climatology Project (GACP) produces a global aerosol product that covers the same period. The Global Precipitation Climatology Project (GPCP) produces a global precipitation product that covers the period from 1979 to 2001. In producing the cloud products, ISCCP also uses the operational sounder temperature-humidity profile products. The ISCCP and temperature-humidity data are then used, together with other datasets, to determine the surface (and top-of-atmosphere) radiative fluxes by the Surface Radiation Budget project (SRB), currently covering the period from 1983 to 1995. The GPCP product is produced by combining weather satellite infrared measurements with operational microwave imager measurements.

3.2 Currently, the operational agencies produce three relevant products that can also be used for climate studies, if their uniformity of processing method and calibration were sufficient (which is not currently the case with one exception): atmospheric temperature-humidity profiles, cloud-tracked and vapor-tracked winds and (bulk) SST (there is one experimental aerosol product and some experimental upper tropospheric humidity products). Only the SST product has a process to anchor long-term, satellite-to-satellite calibration and is re-processed with a uniform analysis method.

3.3 As part of the ISCCP processing, a global surface skin temperature dataset is produced from infrared radiance measurements. This product is biased, however, because it is limited to clear conditions; however, current research results suggest that a combined infrared-microwave analysis could provide an un-biased surface skin temperature. Likewise, the experimental upper tropospheric humidity products are biased to clear conditions (quality is also limited by crude cloud-clearing procedures); but recent research results suggest that a combined infrared-microwave analysis could remove this limitation and provide an improved cirrus cloud product as well.

3.4 All of the GEWEX data products and the research products discussed above are or can be produced using data from operational satellites that come under the purview of CGMS, yet after 20 years:

ISCCP still provides the ONLY systematic calibration and cross-calibration of the radiances from the weather satellite constellation over its whole operational period
NONE of the GEWEX data products has been made operational.

4. Exploitation of the new operational satellites

4.1 Since the new operational satellite instruments have introduced very few new spectral channels that are common to the global constellation, the main near-term value of these data for climate studies is in their use for research of two kinds: development of new analyses that refine our interpretation of the older, longer data records and development of new and/or advanced data products that increase the information available about the climate. Some especially important research issues that can be addressed now by the new operational instruments are: (1) systematic, very high time (and space) resolution observations of the dynamical evolution of convective cloud systems, especially if measurements of their microphysical and macrophysical characteristics were merged with equivalent resolution measurements from precipitation radar networks to cover a large (> 1000 km) domain, (2) high time resolution sounder observations connected with the development of convective systems, and (3) higher-time resolution observations of land surface temperature variations that reflect the effects of moisture and vegetation on land-atmosphere exchanges.

4.2 With some additional research to mature the analysis procedures, two new global products could be produced from current operational satellite measurements.

4.3 Surface skin temperature: In addition to the current bulk SST products produced from the polar orbiting weather satellites, it would be straightforward to add surface (skin) temperatures (clear-sky) from infrared radiance measurements that resolve diurnal variations over both oceans and land. Such a product is already produced by ISCCP but needs some refinement. Further research is needed to combine the infrared radiances with operational microwave measurements to provide all-weather results (the diurnal sampling from microwave instruments will be much better in the future than it has been to date). Development of this measurement capability would also improve microwave sounder analyses by providing better characterization of the land surface in the microwave. When the skin temperature data are combined with surface air temperature measurements from surface weather stations and surface radiative fluxes, their diurnal variations can provide an estimate of surface latent plus sensible heat fluxes that are indicative of surface moisture over land areas. These results would also provide indirect indications of atmospheric boundary layer changes that relate to the transfer of energy and water from the surface to the troposphere. The combined infrared-microwave product could be extended back to 1987.

4.4 Upper-tropospheric humidity: Since 1996, all of the geostationary satellites make measurements sensitive to upper tropospheric water vapour, so it would also be straightforward to add an upper-tropospheric humidity product (clear sky). Some experimental products are being produced but they need to be made globally uniform. The upper tropospheric humidity may well exhibit a diurnal variation associated with deep convection. Research is needed to combine the infrared measurements with microwave humidity results into a single all-weather upper tropospheric water vapour and cirrus product. Since cloud detection governs the accuracy of any infrared measurement, the analysis of these data should be consistent with the cloud products.

5. GEWEX Recommendations to CGMS Members

(1) Continue and expand to all operational instruments the routine production of reduced-volume (sampled) versions of all radiance datasets that can be used for long-term climate analyses.

(2) Take steps to make radiance calibration, calibration monitoring and satellite-to-satellite cross-calibration of the whole operational constellation a part of the operational satellite system.

(3) Participate in and support activities to compare old and new data products from weather satellites as a step towards implementation of the production of long-term and globally uniform products.

(4) Make specific plans to achieve a more rapid convergence of operational satellite measurements to a expanded common core set.