Introduction to the geostationary Earth radiation budget experiment and data

By Dr. Dominique Crommelynck, 2003.

Introduction

On august 28th 2002 the Meteosat Second Generation (MSG) satellite has been launched with the geostationary Earth radiation budget (GERB) on board together with the SEVIRI telescope.

GERB is the result of a consortium collaboration between the United Kingdom (NERC, RAL, IC), Italy (ASI), Belgium (OSTC, IRMB) and the support of ESA (ESTEC) that started the feasibility and phase A study for an announcement of opportunity (AO) instrument to be placed on MSG1 of EUMETSAT.

A GERB science team (GIST) led by the Principal Investigator Prof. Dr. John Harries has been set up with potential European users as well as colleagues of the Langley Research Centre (LARC) of the National Aeronautic and Space Administration (NASA). GERB is an instrument that measures the total emitted and solar reflected radiances over the Earth area seen by MSG with a nominal resolution at nadir of 50 km and a temporal sampling of 5 minutes.

The objective of this short paper is to highlight the what, how and why of the project in view to trigger the interest of Russian scientists involved in atmospheric physics, meteorology and climatology.

It is an introduction to well documented web sites of the Rutherford Appleton Laboratories (RAL); the Royal Meteorological Institute (RMIB) http://gerb.oma.be/; and the Imperial College (IC) http://www.sp.ph.ic.ac.uk/gerb/index.html GERB groups.

For what will the GERB observations be useful?

For climate monitoring

What can be done with the GERB observations of the top of the atmosphere (TOA) total flux derived from the measured total irradiance (solar reflected plus infrared emitted radiation) ?

With the knowledge of the total solar irradiance normalised at 1 AU, also called solar constant, it can be used to calculate the net flux at the TOA. If the net flux is integrated over the whole Earth it provides information about the heating up or cooling down of it. Without observations it is assumed that the mean Earth flux is zero.

If the Earth could be surrounded by GERB-like observations the global climate could be effectively monitored continuously.

For atmospheric physics and meteorology research

Because the GERB observations overcome the famous sampling problem due to the high spatiotemporal variability of the atmosphere, it is possible together with the knowledge of the Earth surface energy budget and the atmospheric latent heat sources to evaluate the energy content of the atmosphere, driving source of the atmospheric general circulation. This is reflected from the primitive energy budget equation integrated over appropriate volumes and time intervals.

How does the GERB instrument work?

The observation platform

Up to now the Earth radiation budget (ERB) terms have only been observed with polar satellites able to see one location on Earth only two times a day with a twelve hour time interval. During some short periods several ERB satellites have been available simultaneously (NOAA- 9, NOAA-10, ERBS and actually TRRM, AQUA and TERRA) providing six observations a day of the same place. See the Earth Observation (EOS) program with the Cloud and the Earth's Radiant Energy System (CERES) home page: http://asd-www.larc.nasa.gov/ceres/.

This is however still insufficient to monitor the atmosphere without additional objective modelisation. Therefore the European ERB observations program got to be installed on the European meteorological satellite (EUMETSAT) geostationary satellite. Although this does not cover the whole Earth it will for the first time open the road to the radiation terms of the energy budget equation with well-sampled data.

The instrument

What is required are the radiation fluxes at the TOA, as this can of course not be observed from a satellite at that level, one is obliged to measure radiances instead and to calculate the fluxes by using the information provided by the SEVIRI imager to identify the required bidirectional reflection function or angular dependency model (ADM).

In addition, as the geostationary EUMETSAT satellites are not attitude stabilised like those of NOAA, but as they are spinning stabilised, the resulting situation is highly challenging and constrains very much the design of the instrument that is continuously exposed to 18 G.

The detector is an array of 256 pixels coated with an absorbing black paint (pixel size view at nadir is 44.6*39.3 km; NS*EW). It is exposed during 40 msec to a given vertical portion of the Earth telescope image “frozen” on the array with a vertical mirror counter rotating at the same speed as the MSG rotation. After each satellite rotation the next image portion is observed, the whole Earth disk of 256 samples plus some measurements of the surrounding space are obtained in 2.5 minutes.

The next 2.5 minutes a quartz mirror allows only solar radiation to reach the same sensor array. During each rotation of the satellite, the counter rotating mirror allows the telescope (a three mirror anastigmatic system) to see successively the Earth, a diffusing cavity surface open to solar radiation, and a black body infrared calibration source.

Pictures of the instrument can be seen at the gallery of the RAL GERB home page.

The operations

The sensor array is provided with build in amplifiers and response time adjustment for each pixel. The two sequences of total and solar earth disk measurements are repeated three times to provide the nominal 15 minutes GERB image synchronised with the SEVIRI image. The black body can be brought at different temperatures and the data from the diffusing cavity are used at appropriate solar incidence angles to correct the optical system for aging.

The corrections and operation imperfections

Although the vertical sensor array is blackened every pixel has not the same sensitivity and absorption coefficient, in addition the spectral reflectivity of the telescope is not uniform as is the absorption of the quartz window and the directional reflectivity of the counter rotating mirror. These instrumental imperfections, also susceptible to aging need to be corrected on the basis of the ground determined characterisations combined with the two on board calibration sources.

This justifies in the data the existence of the terms “filtered” and “unfiltered”.

The timing of the GERB image acquisition is based on the “start of line” pulse provided by the MSG spacecraft. Although it should be stable it is altered by some periodical and random noise, therefore a correction is required to guarantee the correct geolocation of the GERB image pixels. It is easy to understand also that at some times the Sun must be prevented to enter the instrument and that at some limited times of the day stray light can contaminate the accuracy of GERB data that are then flagged.

The data treatment and management

The data from GERB is received by EUMETSAT and transmitted to RAL where the different mentioned corrections are applied to provide the nominal total and solar filtered radiances expressed in Wm-2sr-1 units The radiances are transmitted to the RMIB where they are converted to TOA nominal unfiltered fluxes expressed in Wm-2 (instrumental spectral effects are removed and appropriate ADM’s applied).

Next when the geolocation error will be removed, the nominal nadir resolution of 50 km will be improved to a resolution of about 10 km.

The detailed processing is described at http://gerb.oma.be/. The results obtained by the RMIB are sent back to the RAL GSSPS for climate archiving, while quasi real time data are made accessible in about less than 40 minutes after their observation and kept accessible during one month.

Applications for GERB data

A wealth of applications will issue from GERB data. Radiation budget variability studies will lead to radiation budget climatology over the regions covered by MSG; it will include seasonal clear-sky fluxes variability necessary to derive the cloud radiative forcing. It will also lead to studies of cross effects and feedbacks between the Earth surface radiation and energy budgets, the temperature and water vapour temporal and spatial variability of the atmosphere. In relation with meteorology and climate numerical modelisation have already been compared to GERB observations with striking results. See: http://www.nerc-essc.ac.uk/~rpa.

Study and research intentions of the GIST members are summarised in the table "Users and their primary interests in GERB data" of Science Application found at the RAL GERB home page.

The objective of the RMIB to make the near real time data easily accessible aims to trigger collaborations over Europe and the countries covered by MSG.

How to obtain the GERB data

An on-line catalogue of available long time archive can be found in the Gerb Ground Segment Processing System (GGSPS) web page. The access is however restricted to GIST members.

Near real time level 2.0 (radiances and fluxes) can be obtained within less than 4 hours of their observation from the RMIB on line short-term service (ROLLS). Access to the ftp site requires registration and password, it can be obtained from gerb@oma.be. The products are described in the RMIB GERB home page. A sample of animations and images of reflected and emitted radiances and fluxes, as well as cloud cover, amount, and phase are displayed for 12:00 UTC in the "News" part of the same home page.

Conclusion

In 1958 and 1962 Prof. Dr. Jacques Van Mieghem director of the RMIB illustrated the necessity to perform Earth radiation budget observations at synoptic scale respectively in its papers "Radiation Data Needed in Dynamical Meteorology" and "Pour une exploration synoptique du champ du rayonnement dans l'atmosphère", both published in Archiv für Meteorologie, Geophysik und Bioklimatologie.

In 1968 he set up a small team directed by Dr. D. Crommelynck to realise its goal. Due to the ambitious subject and the limited logistics of Belgium, focus was put on the easiest part of the task: the monitoring of the solar constant and its variability. Collaboration first with LARC and later with ESA led many years later to set up the RAL, IC, RMIB consortium as well as the GIST that finally gave life to the dream over the European Earth hemisphere. In the future we hope that the results obtained with GERB will trigger other space agencies to follow and enclose the Earth globally into a huge virtual space calorimeter.

Note: References are embedded in the different mentioned home pages.

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