Extending TOA radiation back to 1978 using wide field-of-view data

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16 September 2010

Outline

Aim of this work

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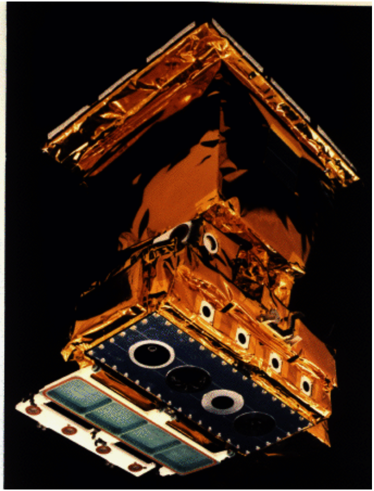
Long time series of the total radiation emitted by the Earth, for the purpose of climate studies

- Total radiation (SW+LW) measured by wide field-of-view radiometer, W m^{-2}
  - Operated much longer than scanner
  - SW filter suffers from ageing
- Monthly averages
- Coverage in time and space: +81° to -81° latitude, November 1978 to September 1999 (nearly 21 years)
- Disadvantages: cannot study cloud forcing, TOA albedo; low spatial resolution
- Compared to former work: want to use more recent models and processing techniques

The wide field-of-view radiometer

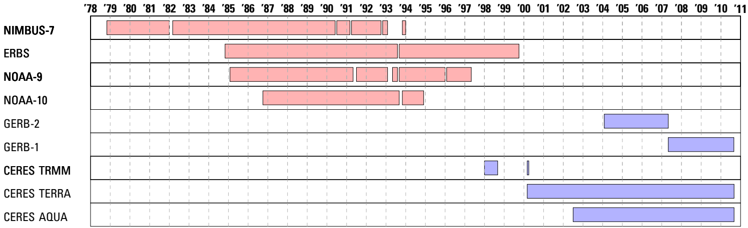


Source: http://mynasadata.larc.nasa.gov/images/erbenonscanner.gif

Nonscanner on board ERBS

- 2 wide field-of-view radiometers:
  - one radiometer for SW: 0.2 to 5 μm
  - one radiometer for TW: all wavelengths
- 2 medium field-of-view radiometers

Data sources



- Three sun-synchronous satellites with an inclination ≈ 99°: NIMBUS-7 (11 am), NOAA-9 (2.30 pm), NOAA-10 (7.30 pm)
- One precessing satellite: ERBS (inclination ≈ 57°)
- Instantaneous (4-second) measurements from SEFDT and MWDT datasets

Outline

Assumptions & limitations

- We assume the spectral response of the total wave (TW) measurement is sufficiently flat
- No intercalibration of different satellites (except common reference altitude)
- For the moment: albedo independent of solar zenith angle

Obtaining the monthly average flux

Starting from instantaneous measurements from the WFOV radiometer:

- Conversion of datafiles from native format to NETCDF
- Processing the raw measurements
- Binning in 5°× 5° bins
- Regression of the diurnal model on the data
- Numerical integration of the monthly average diurnal model from 0 to 24 hours
- Checks on the quality of the regression and final output

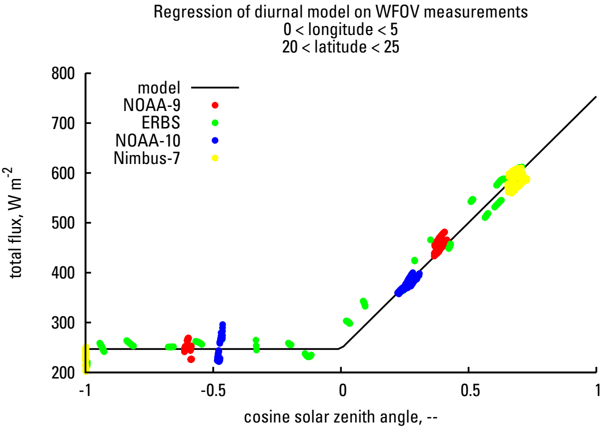
Elimination of direct sunlight

- Not using solar zenith angle: seems to throw away good measurements without taking into account solar eclipse by Earth disc
- But using geometric technique
  - Takes into account angle between spacecraft, Earth and sun
  - Takes into account solar eclipse by Earth (ellipsoid shape with GRS80 parameters)

Regression of the diurnal model

Model equation and example (Sahara region)

$$F(t) = \begin{cases} p_0 + p_1 \cos z(t) & \text{if } \cos z > 0 \\ p_0 & \text{otherwise} \end{cases}$$



Regression of the diurnal model

Why a diurnal model in terms of solar zenith angle?

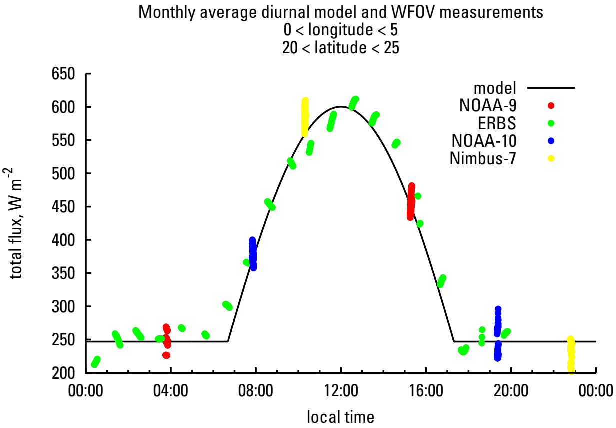
- Solar zenith angle at noon varies considerably, depending on season and latitude
- Corollary: even measurements at fixed local time lead to a range of zenith angles, which is better for the regression
- Regression of a linear two-parameter model is the obvious approach when only heliosynchronous data with two measurements per day are available
- Can estimate baseline (night-time) flux without night-time measurements

Disadvantage:

- Limited range of the independent variable at high latitudes

Numerical integration of the diurnal model

Example (Sahara region)



Checks on the quality of the regression

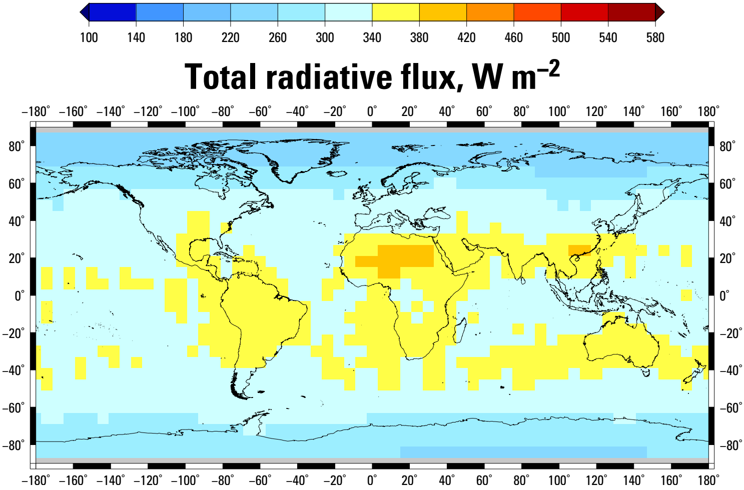
Values can be rejected for several reasons

1. An error occured during fitting (e.g., too many iterations in Levenberg-Marquardt)
2. Regression as a whole is not significant
3. Regression is useless according to the Box criterion (explains less than the error)
4. Null hypothesis cannot be rejected for at least one of the parameters
5. At least one parameter is nonphysical (e.g., negative night-time flux)
6. Numerical integration cannot be performed for numerical reasons
7. Resulting average flux is nonphysical (i.e., negative)

Outline

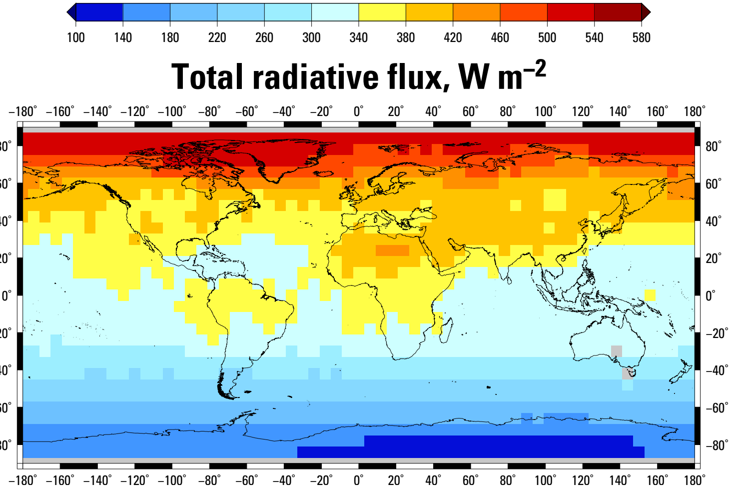
Total radiation, W m^{-2}

March 1979



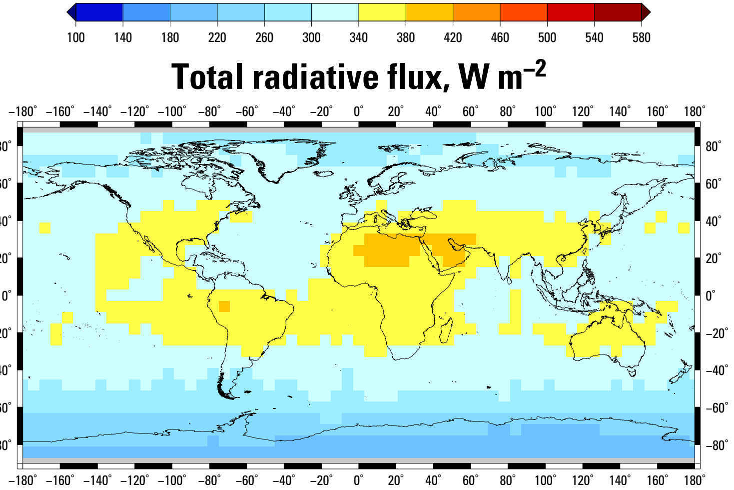
Total radiation, W m^{-2}

June 1979



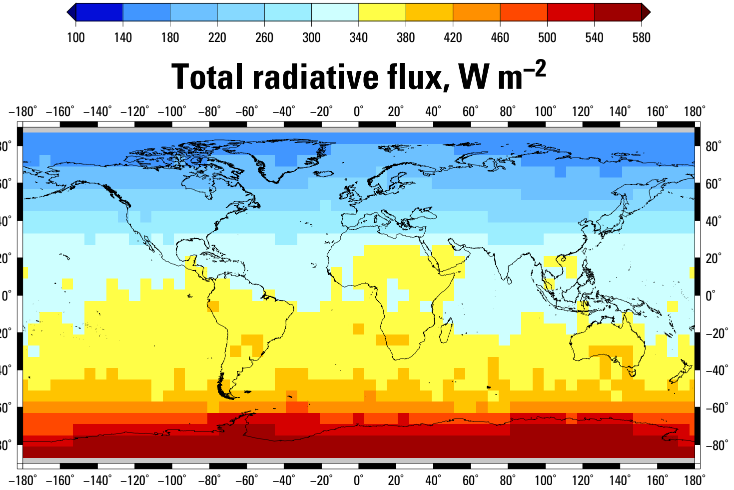
Total radiation, W m^{-2}

September 1979



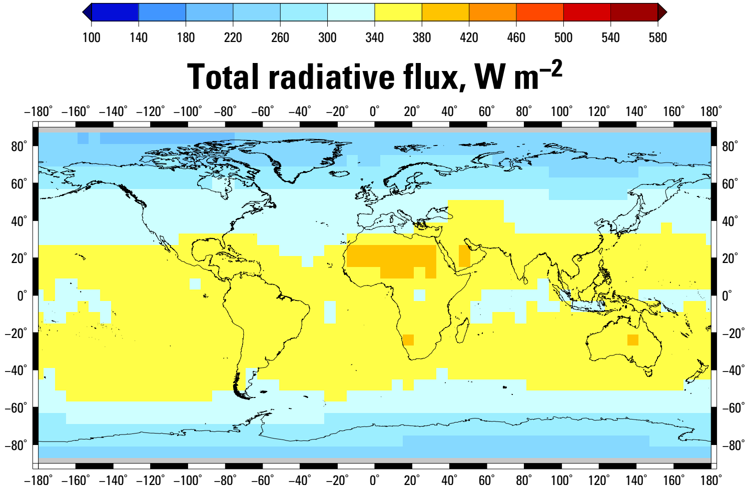
Total radiation, $W\ m^{-2}$

December 1979



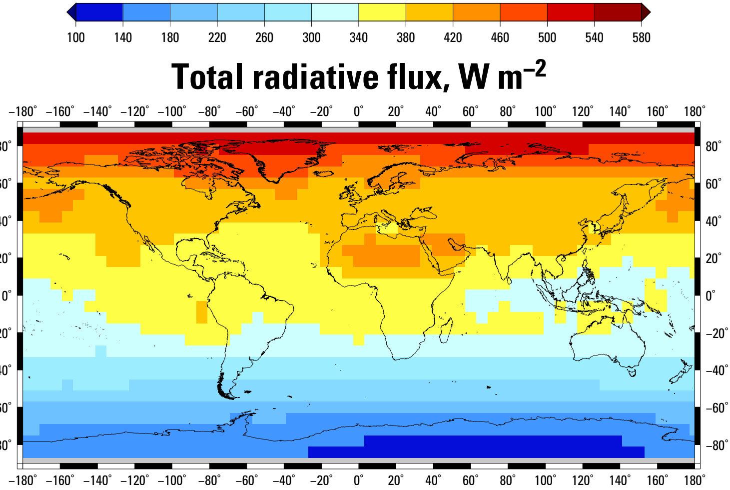
Total radiation, W m^{-2}

March 1987



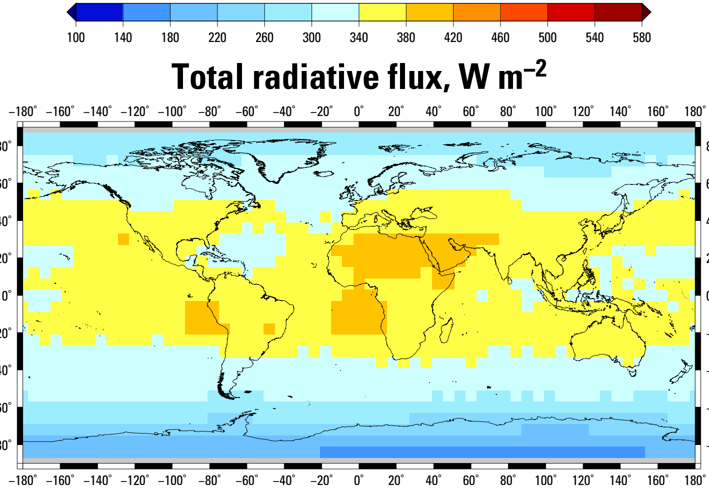
Total radiation, W m^{-2}

June 1987



Total radiation, $W\ m^{-2}$

September 1987



Total radiation, W m^{-2}

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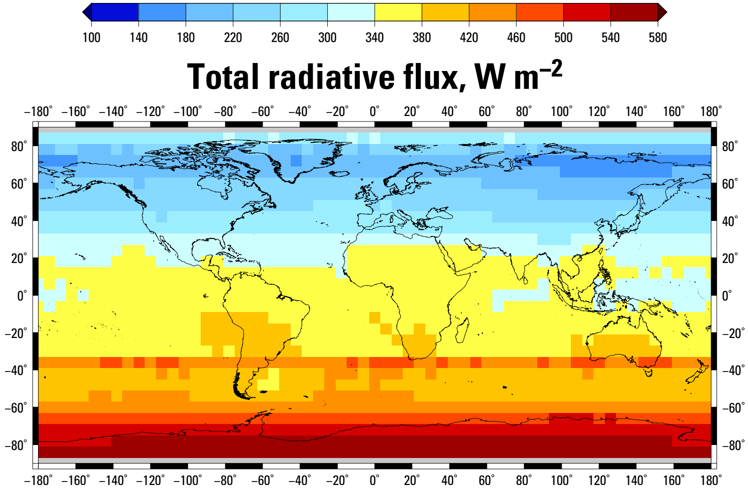
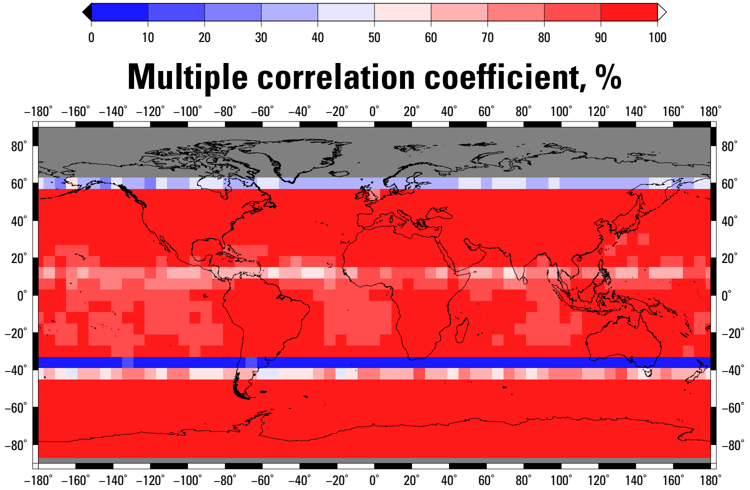


Quality of the regression

December 1987



Quality of the regression

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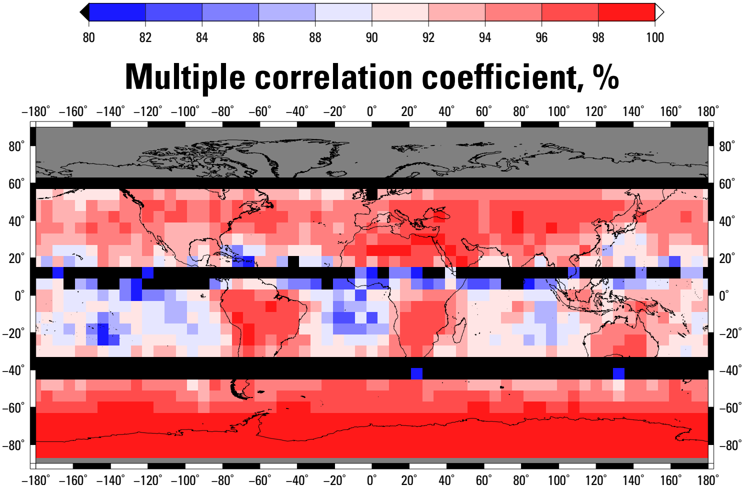
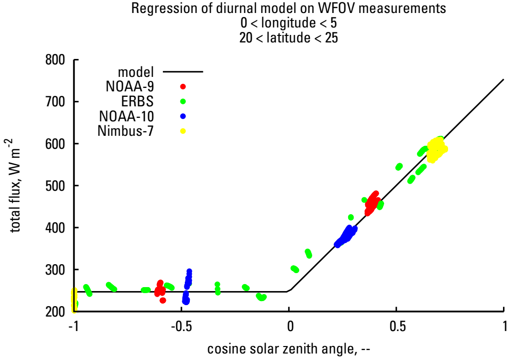
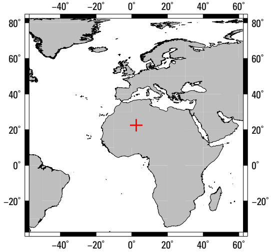


An example of a good regression

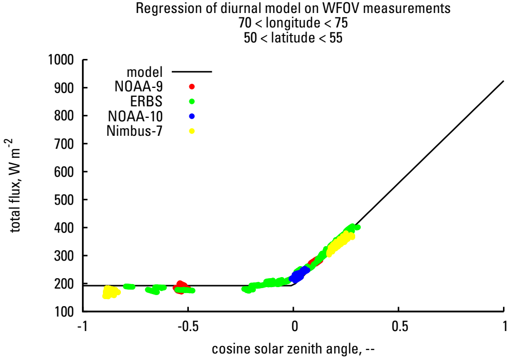
$R^2 = 0.98$

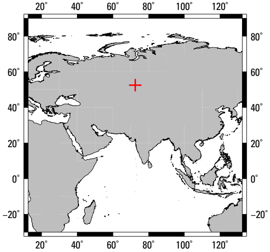




Partially sunlit at sunrise/sunset transition

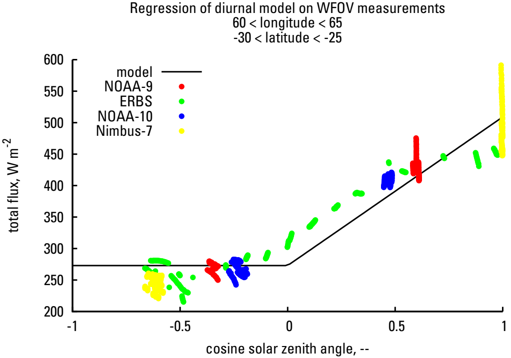
$R^2 = 0.96$

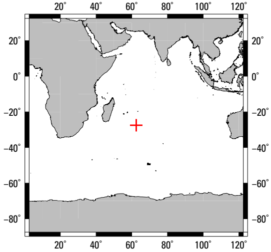




Zenith angle dependence over ocean surface

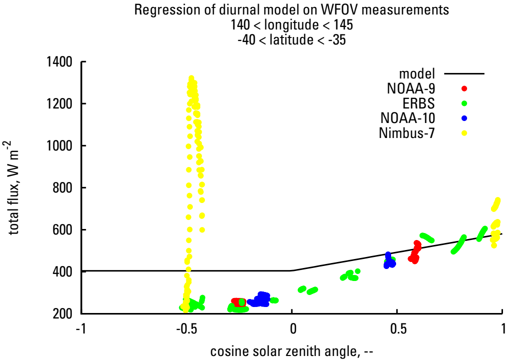
$R^2 = 0.91$

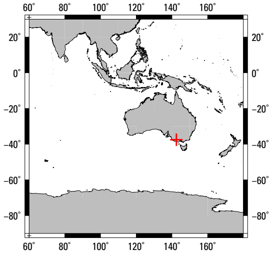




A very poor regression

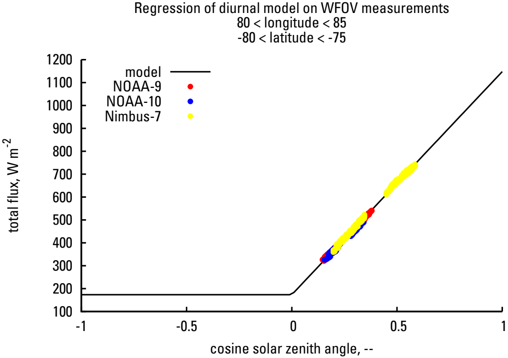
$R^2 = 0.05$ with NIMBUS-7 data, $R^2 = 0.96$ without

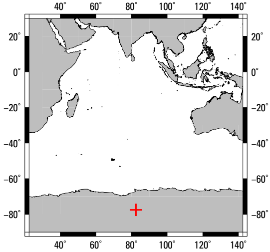




Estimate intercept with daytime measurements only

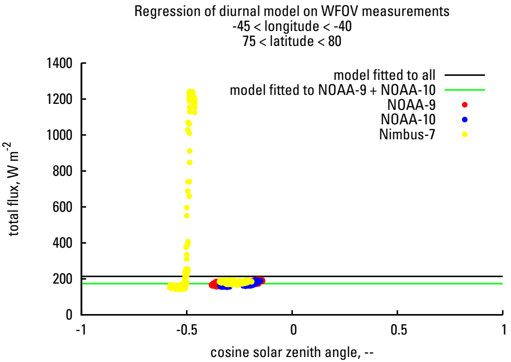
$R^2 = 0.99$

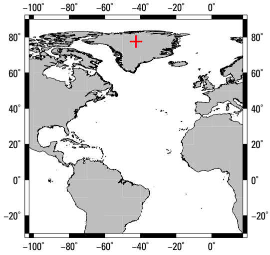




Modified diurnal model during polar winter

$s^2 = 37705$ with NIMBUS-7 data, $s^2 = 91$ without





Conclusions

- Revived the old NIMBUS-7 and less older ERBE data
- WFOV measurements do contain usable spatial information
- Made TOA radiation maps over nearly 21 years (November 1978 – September 1999) and nearly the entire globe, sometimes with scarce data
- Problems remain: stray light? diurnal models inappropriate?

Future work

- Incorporate more recent measurements (GERB, CERES)
- Better filtering of the data
- Improve diurnal models
- Applications: e.g. volcanic eruptions (El Chichón 1982, Pinatubo 1991)

Acknowledgements

- Dr. George L. Smith
- Dr. Takmeng Wong
- Michelle, Kathleen and staff of NASA Langley User and Data Services
- GERB team at RMIB, and in particular Nicolas & Steven
- RMIB