Status of the BBR LW Radiance to Flux Baseline conversion algorithm

A. Velazquez Blazquez, N. Clerbaux, A. Ipe, E. Baudrez, I. Decoster, S. Nevens, S. Dewitte (RMIB)

Royal Meteorological Institute of Belgium (RMIB)
Vrije Universiteit Brussel(VUB)

Earth Radiation Budget Workshop 2012
GFDL, Princeton, NJ. 22 - 25 October 2012

Outline

The EarthCARE mission

- Objectives: Enable advances in climate modeling by simultaneous observation of aerosol and cloud properties and the radiation and hydrological cycle parameters.
- Space segment:
  - Backscatter Lidar (ATLID) - ESA High-spectral resolution and depolarisation
  - Cloud Profiling Radar (CPR) - JAXA/NICT -36 dBZ sensitivity, 500 m vertical range, Doppler
  - Multi-Spectral Imager (MSI) - ESA 7 channels, 150 km swath, 500 m pixel
  - Broadband Radiometer (BBR) - ESA 2 channels, 3 views (nadir, fore and aft)
- Orbit: Polar Sun-synchronous, DN 14:00
- Height: 393 km Lifetime: 2(+1) years
- Repeat cycle: 25 days (9 days for cal/val orbit)
- Flux retrieved from BBR measurements will be used to constrain the derivations of vertical profiles of Earth radiation budget components within the atmosphere. Required accuracy: $10 Wm^{-2}$

BBR Configuration

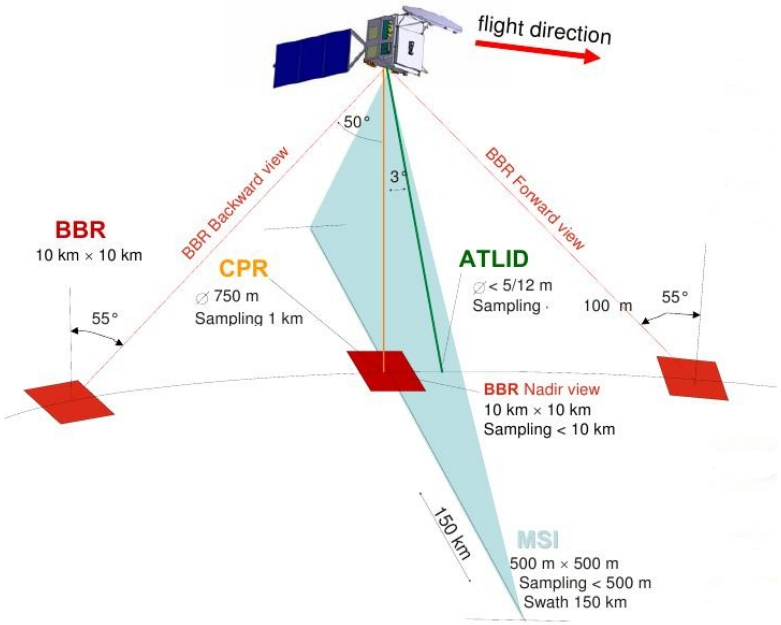
- Along track sampling: 3 telescopes (nadir 0°, fore +55°, aft -55°)
- Two spectral channels:

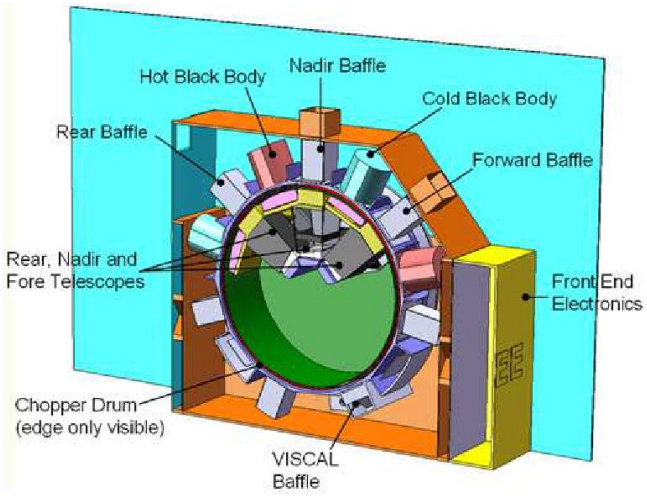
  SW (0.2 - 4 μ m)
  TOT (0.2 - 50 μ m)

- Radiometric accuracy:

  SW 2.5 $\mathrm{Wm^{-2}sr^{-1}}$
  LW 1.5 $\mathrm{Wm^{-2}sr^{-1}}$

- Pixel:
  - 10 x 10 km for the 3 telescopes
  - 0.1 pixel co-registration





Flux conversion algorithms

Two different algorithms will be developed:

1. Baseline Flux Retrieval Algorithm ⇒ to obtain flux accuracies consistent with those of current ERB missions (GERB, CERES, ScaRaB)
   - Flux estimate for a single view
   - Weighting of the views
   - Estimation of the reference level
2. Advanced Flux Retrieval Algorithm ⇒ to fullfill EC accuracy requirements

Angular Distribution Models

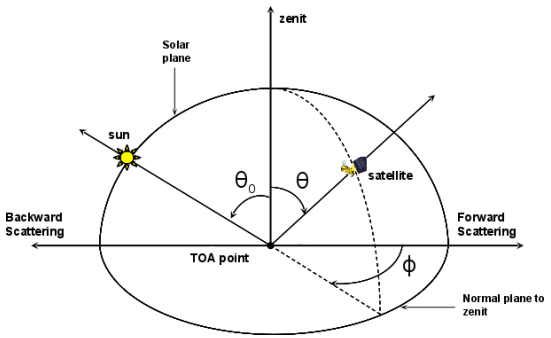
- Broadband radiometers such as GERB, CERES and BBR measure solar $L(\theta_0, \theta, \phi)$ and thermal radiances $L(\theta, \phi)$ $[Wm^{-2}sr^{-1}]$ at the TOA. To estimate the LW flux:

$$F = \int_{\theta=0}^{\frac{\pi}{2}} \int_{\phi=0}^{2\pi} L(\theta, \phi) cos(\theta) sin(\theta) d\theta d\phi$$

- Isotropic radiance field $\Rightarrow F = \pi \cdot L$
- Anisotropic radiance field $\Rightarrow$ Flux is estimated from the directional radiances measured by the BB radiometers.

Anisotropic Factor (AF):

$$R(\theta, \phi) = \frac{\pi L(\theta, \phi)}{F}$$



Theoretical spectral model

Methodology: Operational procedure used in the LW GERB flux estimation (Clerbaux, 2003) applied to each of the BBR views.

- LW TOA Fluxes are obtained through theoretical second order regressions on the 3 MSI thermal channels or BT differences, using a large database of LibRadtran 1.4 + SBDART (clear sky) radiance and flux simulations.
  NB radiances are obtained by spectral convolution with the spectral response curve of the corresponding NB channel:

$$L_{nb}(\theta) = \int_0^{\inf} L(\theta, \lambda) S(\lambda) d(\lambda)$$

  Note: SEVIRI 8.7, 10.8 and 12 μm spectral responses are used as MSI spectral responses are not yet provided.

- Anisotropic Factors (AF, $R(\theta, \phi)$) are estimated from theoretical simulated thermal radiances and fluxes.

$$R(\theta, \phi) = \frac{\pi L(\theta, \phi)}{F}$$

RT-based geophysical datasets

SITS LibRadtran database improved for warm scenes (270)

- 12096 thermal (LW) simulations, 540 are clear sky
- Outputs at: 18 VZA: 0° to 85°, step 5°
- ASTER surface emission
- OPAC aerosol definition
- Standard atmospheric profiles + wv scaled
- Cloud properties from Yang parametrization
- Fine spectral resolution
- LW sim: 2.5 to 100 μm (762 λ) + extended up to 500 μm
  - 2.5 to 14 μm, step of 0.05 μm
  - 14.1 to 50 μm, step of 0.1 μm
  - 55 to 100 μm, step of 0.5 μm
- Surface Temperature from profile + ΔT

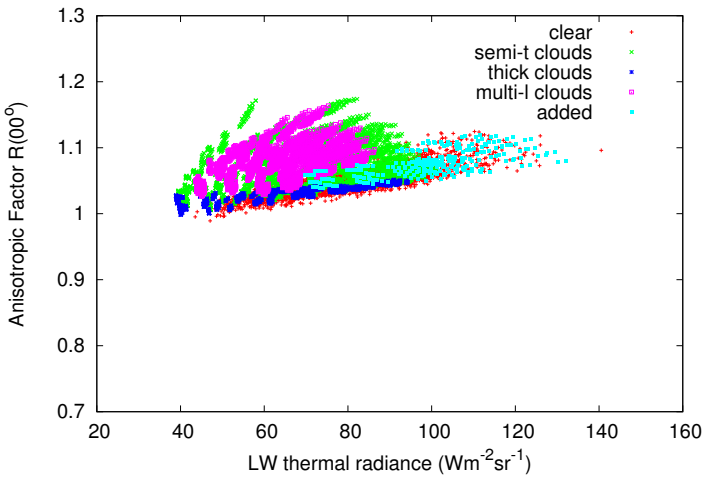
SBDART database

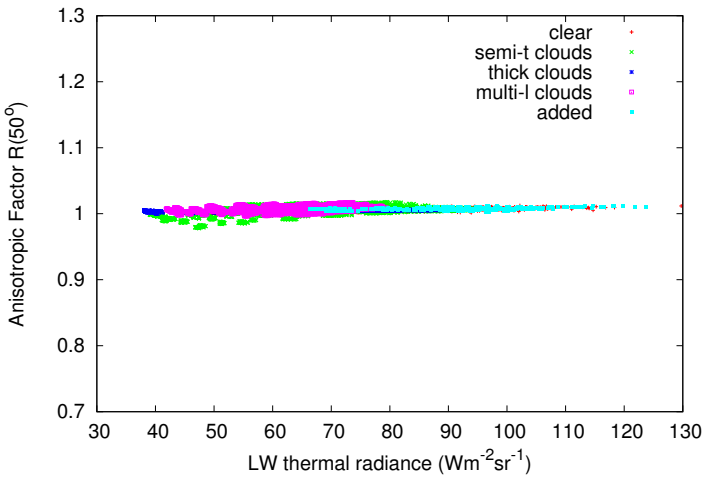
- 4622 thermal (LW) simulations, only used clear sky ones (2311)
- Outputs at: 18 VZA: 0° to 85°, step 5°
- Atmospheric profiles from TIGR-3 database
- Fine spectral resolution
- LW sim: 2.5 to 100 μm (431 λ) + extended up to 500 μm
- Emissivity generated randomly between 0.85 and 1
- Surface Temperature generated randomly with values close to the lowest in the atmospheric profile

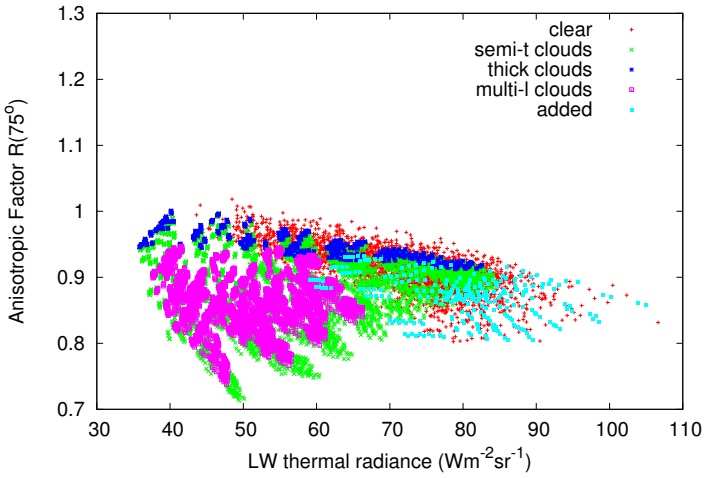
Anisotropic Factors

A. Velazquez,
N.Clerbaux et al.

LibRadtran SITS DB + clear sky SBDART DB + improved SITS warm scenes







Anisotropy Models

Anisotropy Models:

Second order regression models from multiple narrow-band simulated radiances and Brightness Temperatures have been analyzed.

1. $R = f(L_{8.7\mu m}, L_{10.8\mu m}, L_{12.0\mu m})$ all scene types (discarded)
2. $R = f(BT_{10.8}, BT_{8.7} - BT_{10.8}, BT_{12.0} - BT_{10.8})$ all scene types
3. $R's = f(BT_{10.8}, BT_{8.7} - BT_{10.8}, BT_{12.0} - BT_{10.8})$ in bins of 20 $Wm^{-2}sr^{-1}$
4. $R = f(BT_{10.8}, BT_{12.0} - BT_{10.8})$ 2 BT to avoid surface emissivity issues (binned)
5. $R = f(BT_{10.8}, BT_{12.0} - BT_{10.8})$ 2 BT + improved DB (binned)

Validation strategy

- **Validation database**

  In order to test the models for the radiance to flux conversion, a validation database of collocated BBR-like and CERES SSF-Ed2B FM1, FM2, FM3, FM4 data for March and September 2004 has been built.

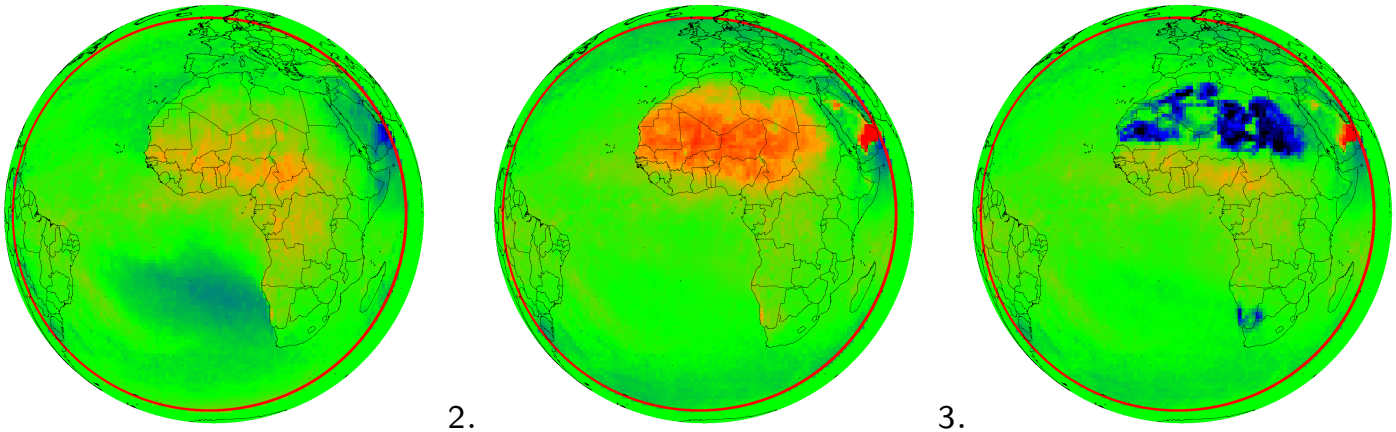
  - $\approx$ 240 millions of CERES and SEVIRI pairs over the SEVIRI disk
  - BBR BB radiances obtained from the conversion from NB SEVIRI radiances to GERB BB radiances using known coef for GERB.
  - angular model for the BBR applied to BBR BB radiances to obtain BBR flux.

- **Apply theoretical ADM's to CERES night time data**

  Similar ADM's developed using MODIS 11.03 and 12.02 channels are applied to CERES night time BB radiances and then compared with CERES Fluxes

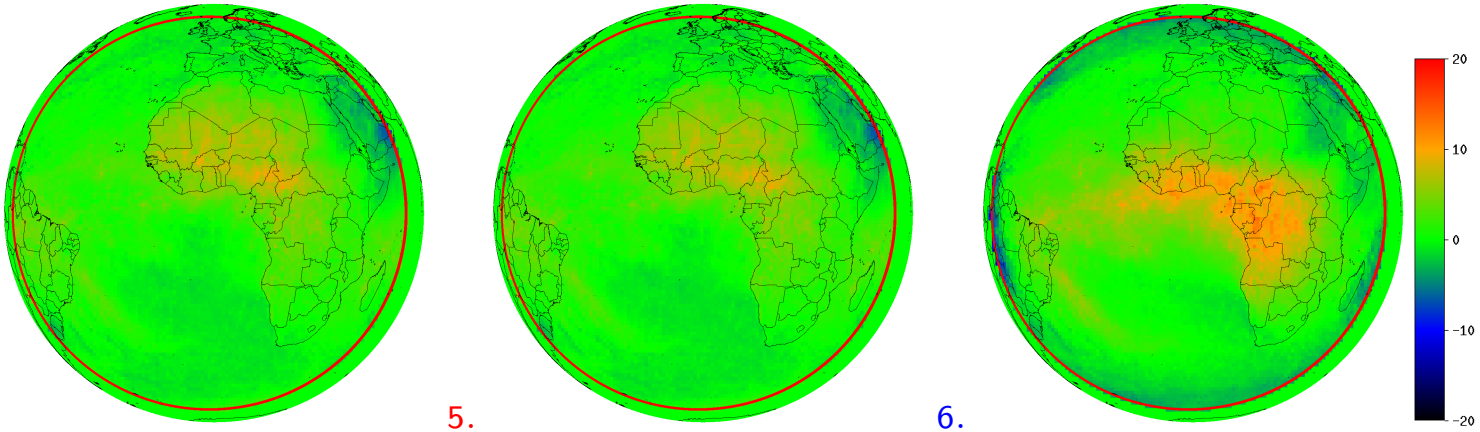
Validation strategy

Comparisons of GERB-like / BBR-like data with collocated CERES - March 2004



1. 2. 3.

(1) $F_{BBR-like} - F_{CERES}$ for LibRadTran + SBDART CS 3-inputs model
(2) $F_{BBR-like} - F_{CERES}$ for LibRadTran + 2*SBDART CS 3-inputs model BT diff
(3) $F_{BBR-like} - F_{CERES}$ for LibRadTran + SBDART CS 3-inputs model BT, $20 Wm^{-2} sr^{-1}$ bins



4. 5. 6.

(4) $F_{BBR-like} - F_{CERES}$ for LibRadTran + SBDART CS 2-inputs model BT
(5) $F_{BBR-like} - F_{CERES}$ for LibRadTran + SBDART CS 2-inputs model BT improved DB
(6) $F_{BBR-like} - F_{CERES}$ GERB Ed-01 for SBDART 4-inputs L-model

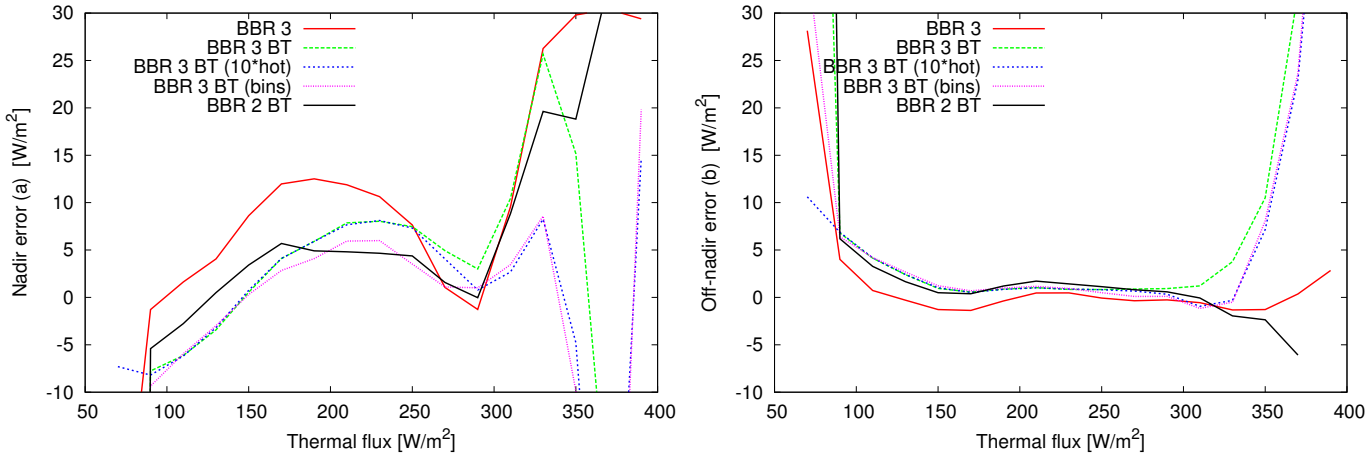
Validation strategy

Residual angular dependency

Differences between CERES and BBR-like data are analyzed as a function of the VZA as:

$$F_{BBR} - F_{CERES} = a(F_{BBR})\frac{52.5 - \theta_{BBR}}{52.5} + b(F_{BBR})$$

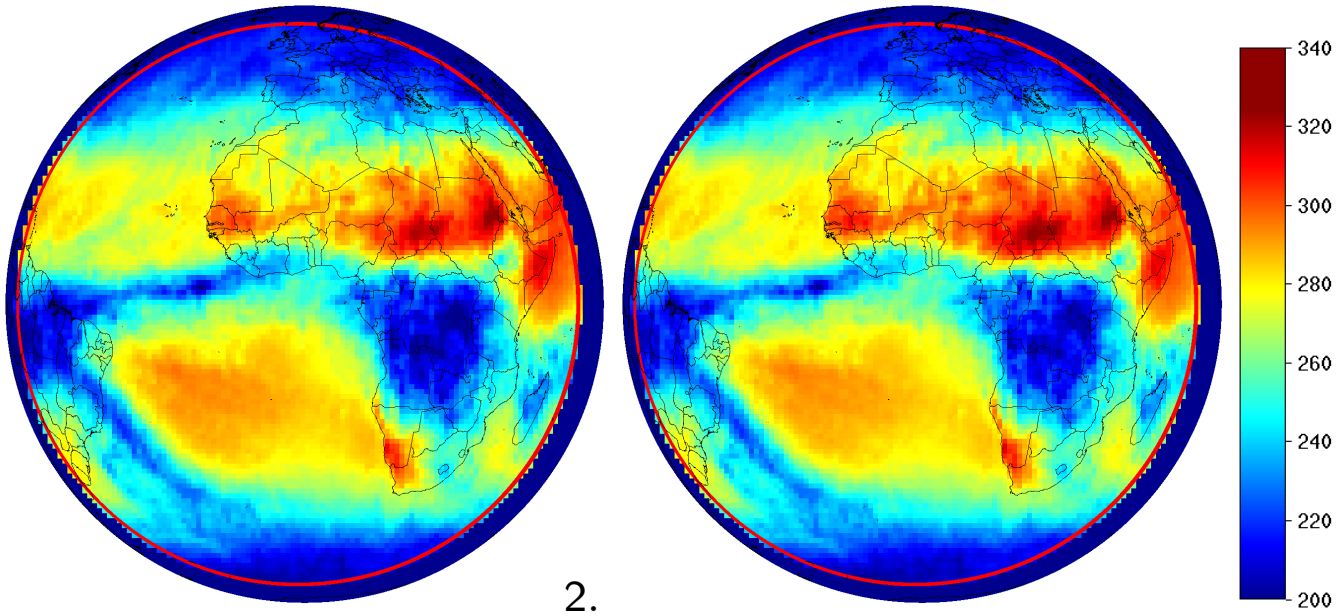
In which $a(F_{BBR})$ and $b(F_{BBR})$ are estimated over 20 Wm^{-2} bins of F_{BBR}.



a and b factors close to 0 indicate that the angular modelling is performing well. All models perform well up to 280 Wm^2.

Validation strategy

1. 2.

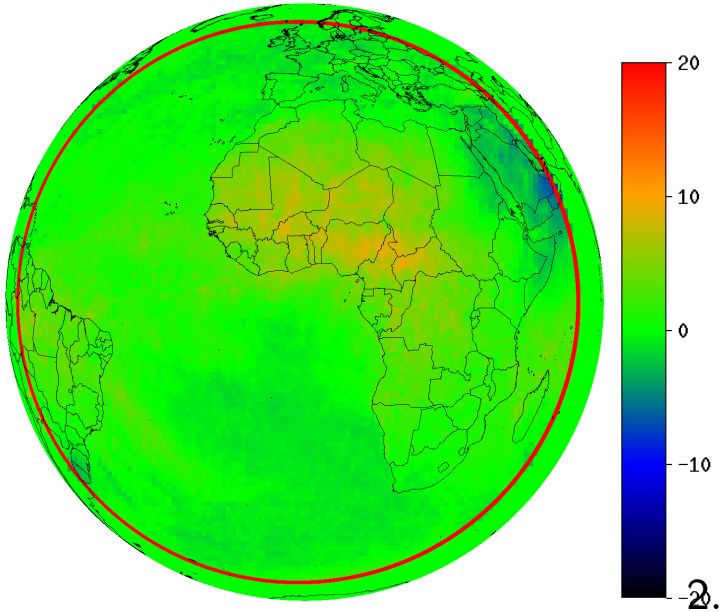


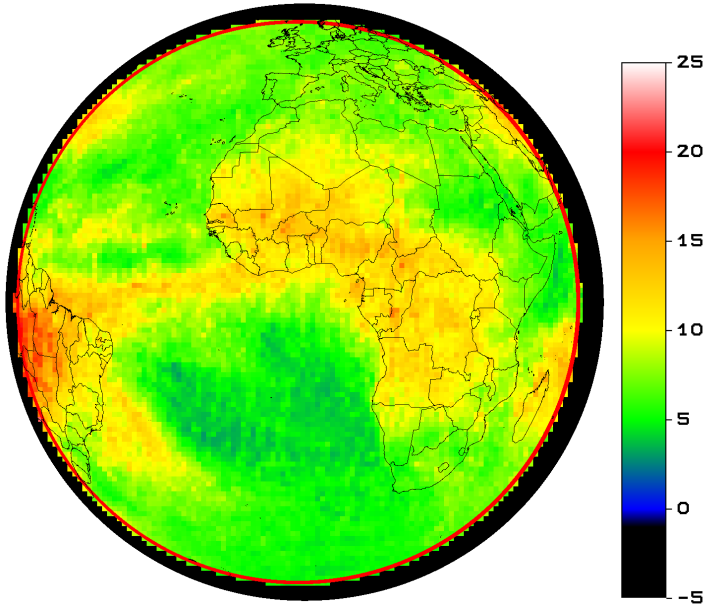
(1) Mean CERES Flux March 2004
(2) Mean BBR Flux March 2004

$F_{BBR-like}$ vs $F_{CERES}(Wm^{-2})$

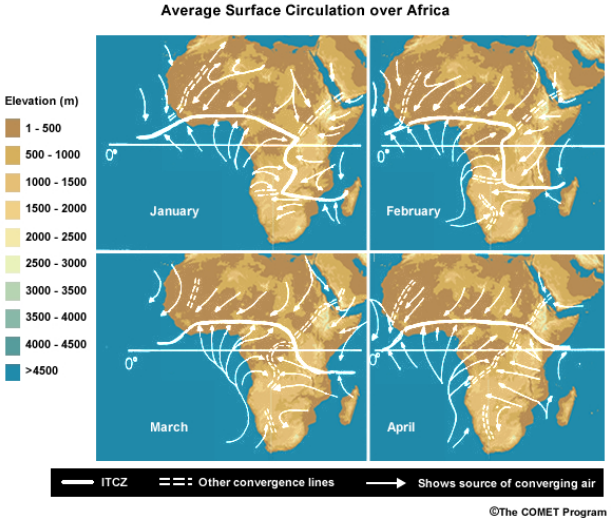
N=10^7	GERB 4 Ed-1 (SBDART)	BBR 3	BBR 3 BT	BBR 3 bins 20 W m^{-2}	BBR 2 BT	BBR 2 BT Improved DB
VZA < 60	7.8	7.7	8.5	8.5	7.2	7.2
VZA < 5	7.9	7.0	5.8	5.6	6.1	6.1
50<VZA<55	7.6	7.6	7.7	7.7	7.7	7.7

Validation strategy

1. 

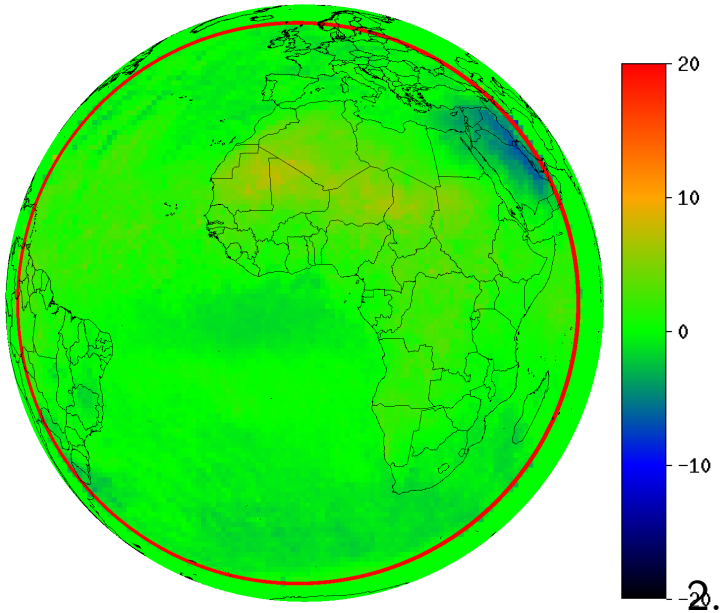
2. 

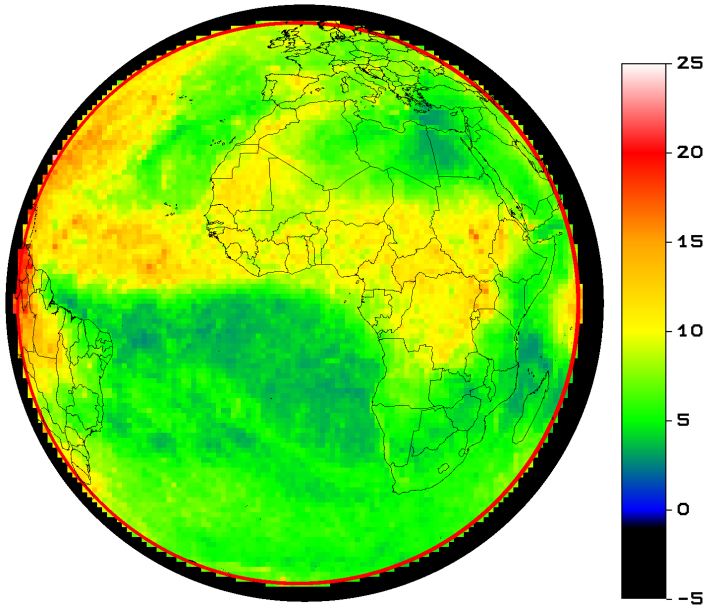
(1) Mean BBR - CERES Flux March 2004
(2) Std dev BBR - CERES Flux March 2004



Validation strategy

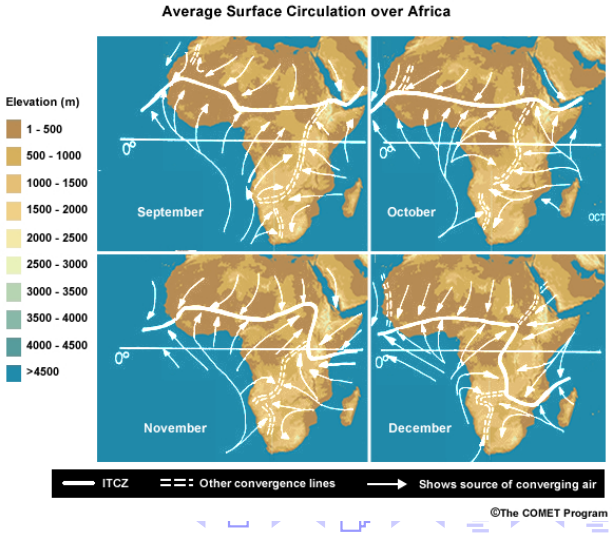
A. Velazquez,
N.Clerbaux et al.

1. 

2. 

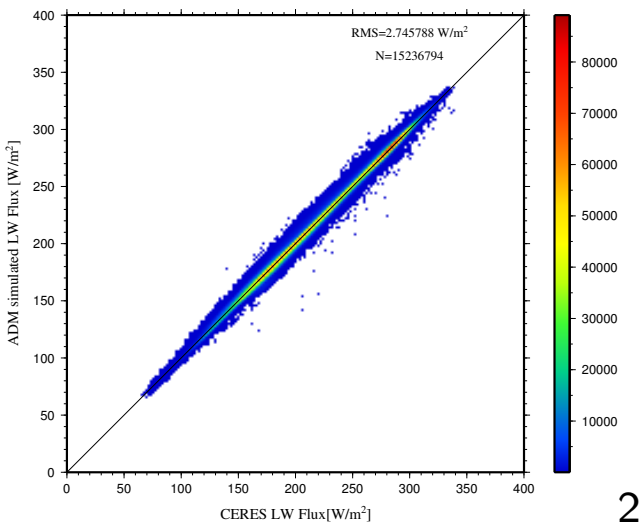
(1) Mean BBR - CERES Flux Sep 2004
(2) Std dev BBR - CERES Flux Sep 2004

N=10^7	BBR 2 BT March 04	BBR 2 BT Sept 04
VZA < 60	7.2	6.7
VZA < 5	6.1	4.1
50 < VZA < 55	7.7	7.2

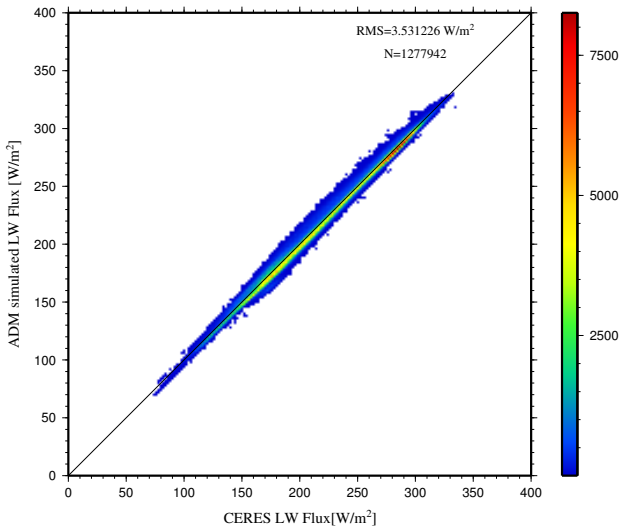


Validation strategy

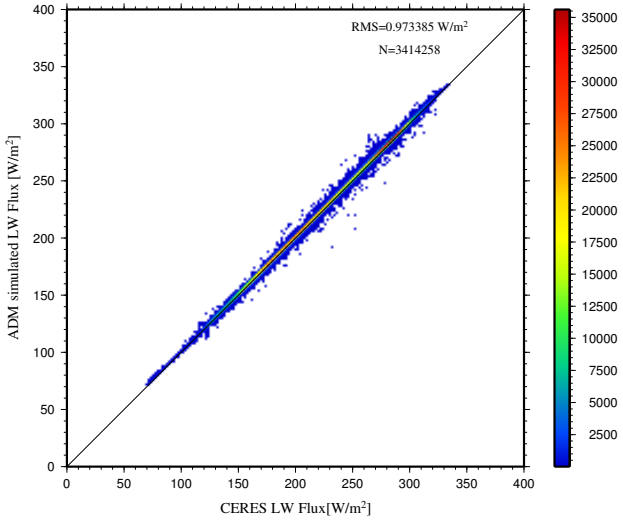
Theoretical ADM's applied to CERES SSF Ed-3A night time data



1.



2.



3.

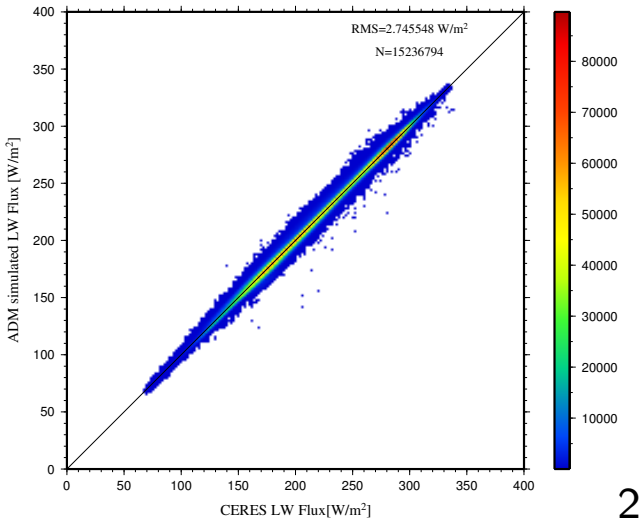
(1) All viewing zenith angles. $RMS = 2.75 Wm^{-2}$

(2) Nadir ($\theta < 5$). $RMS = 3.56 Wm^{-2}$

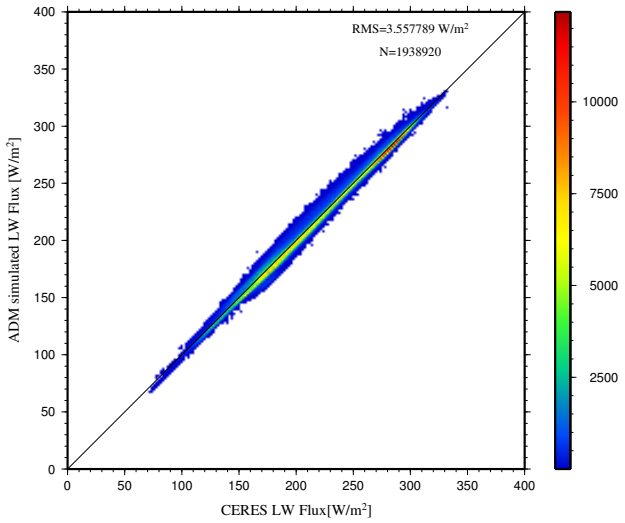
(3) Off-nadir ($50 < \theta < 55$). $RMS = 0.98 Wm^{-2}$

Validation strategy

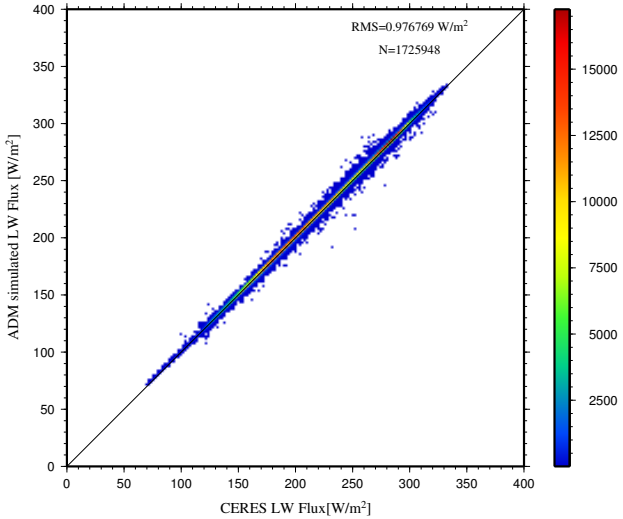
Theoretical ADM's applied to CERES SSF Ed-2B night time data



1.



2.



3.

(1) All viewing zenith angles
(2) Nadir ($\theta < 5$)
(3) Off-nadir ($50 < \theta < 55$)

Best weighting of the nadir view

Plane parallel scenes

$$F = \frac{\pi L_{fore}(\theta,\phi)}{2R(\theta,\phi)} + \frac{\pi L_{aft}(\theta,\phi)}{2R(\theta,\phi)}$$

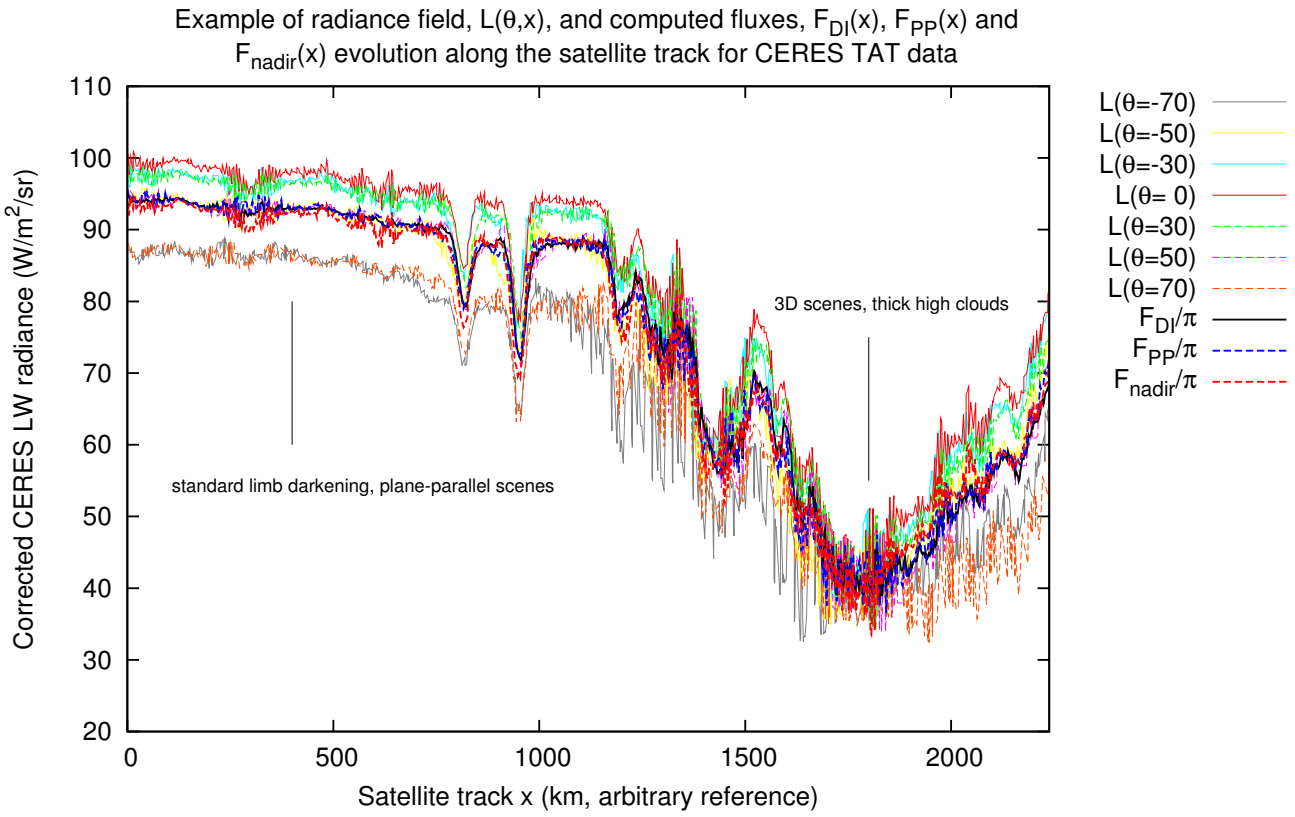
Proposal:

$$F = \frac{1-\alpha}{2}\frac{\pi L_{fore}}{R_{fore}} + \frac{1-\alpha}{2}\frac{\pi L_{aft}}{R_{aft}} + \alpha\frac{\pi L_{rad}}{R_{rad}}$$

- α close to 0 for all scenes with standard limb-darkening curves
- α close to $1/3$ for complex $3D$ scenes (verified on CERES Ed 2B TAT data)

Best weighting of the nadir view. Verification

α will be estimated based on the variability of the MSI 10.8 μm channel radiance within the BBR footprint.
The method will be validated on CERES TAT with α estimated from MODIS band 31 and LW flux coming from direct integration of the LW radiance field



Future work

- Cirrus correction
- Define Flux reference level for the collocation of the views to avoid parallax