Mean Albedo Model of the Earth: Estimation and Validation from the GRACE Mission Satellites.

M.A. Sammuneh[1], F. Deleflie[1], R. Biancale[2], L. Sagnières[3,1], D. Coulot[4,1], A. Pollet[4], J. Mahenc[5,1]

[1] Institut de Mécanique Céleste et de Calcul des Éphémérides
Observatoire de Paris- PSL / GRGS
[2] GFZ German Research Centre for Geosciences,Postdam, Germany
[3] Department of Mechanical Engineering, McGill University, Montreal, Quebec H3A0C3, Canada
[4] IGN LASTIG LAREG, IGN, ENSG, Univ. Univ Paris Diderot, Sorbonne Paris Cité,F-75013 Paris, France,
[5] Ecole Nationale de la Météorologie (ENM), F-31100, Toulouse, France

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Outline

1. Motivations for a new mean albedo model
2. Data sets and existing models
   - Stephens 1980
   - Model derived from ECMWF grids (available @ GRGS)
   - Model derived from CERES grids, publicly available
3. Tests on GRACE Satellites
   - Radial calculation strategy
   - Comparison with CNES/GRGS GRACE orbits and with accelerometer data
4. Conclusions and prospects

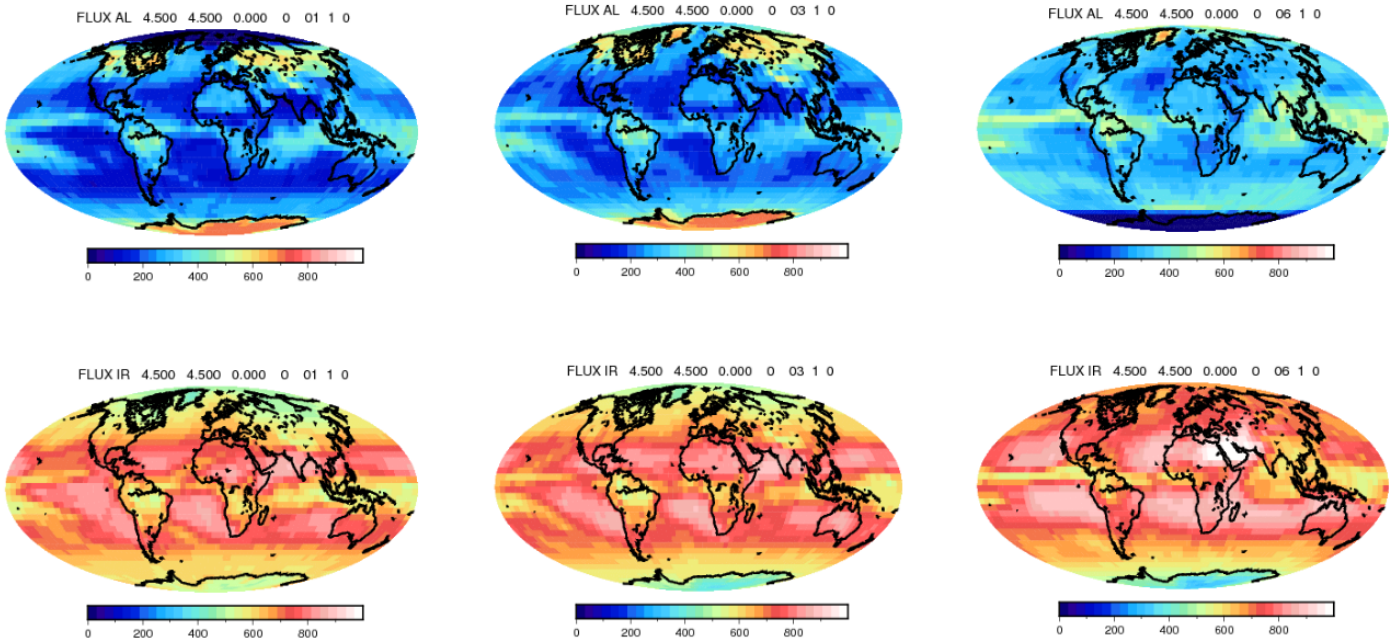
1. Motivations for a new mean Albedo Model

- Earth environment applications
  - Earth radiation budget (mean value and time evolution of the mean Earth albedo)
  - Variations at different time and spatial scales
- Current model (Stephens, 1980) is outdated and deduced from a limited number of observations
- (Long term) comparison between data sets
  - How different are the mean values (over time and space)?
  - What are the differences between mean and daily models?
- Operational products provided by Analysis Centers
  - Precise orbit determination and related products
  - How much accuracy is lost when using a mean model?
  - Mean model can be used even when datasets unavailable

2. Albedo Models

STEPHENS Albedo Grid Model

- Worldwide Presentation Scale of Albedo
- Annual and seasonal averaged Earth atmosphere radiation budgets
- Satellite observations available in late 1979
- Data were accumulated from samples from 3 to 5 months, between the years 1964 to 1977



2. Albedo Models

European Centre for Medium-Range Weather Forecasts (ECMWF)

- Observations covering 16 years (2000-2016)
- Provides estimates of albedo in 3 wavebands
visible 0.3-0.7 μm, Shortwave infrared 0.7-3 μm :Total 0.3-3 μm
- Derived primarily from estimates of surface directional spectral reflectance from 3 streams of European satellite sensor data

Clouds and the Earths Radiant Energy System (CERES)

- Observations obtained from multiple spacecraft over the last two decades.
- Temporal evolution of monthly-averaged fluxes.
- Composed of 1°x1° grids.

CERES Instrument Temporal Coverage

Spacecraft	Instrument(s)	Launch Date	Start Date	End Date
TRMM	PFM	11/27/1997	12/27/1997	05/29/2001
Terra	FM1 & FM2	12/18/1999	02/25/2000	Still in operation
Aqua	FM3 & FM4	05/04/2002	06/19/2002	Still in operation
S-NPP	FM5	10/28/2011	01/27/2012	Still in operation

2. Albedo Models

New GRGS Mean Models from ECMWF and CERES datasets

- Based on data from 2000 to 2016
- Output is values formed by a series of monthly grids
- Sampled 4.5°x4.5° grids in latitude and longitude
- Format is consistent with use as input into GINS orbit determination software

Table: Globally- and time-averaged values

GRIDS	Albedo	Infrared
Stephens	0.307	0.699
ECMWF	0.369	0.713
CERES	0.292	0.705

2. Albedo Models

Comparison of the three models

- Differences visible in monthly grids
- Stephens vs. ECMWF vs. CERES

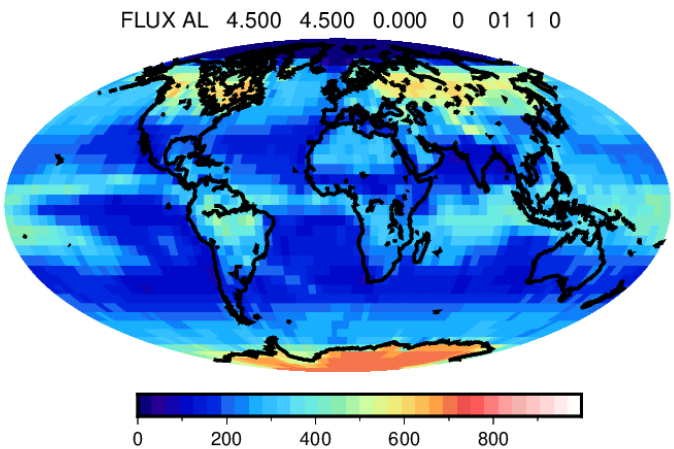


Figure 1: Stephens January Grid

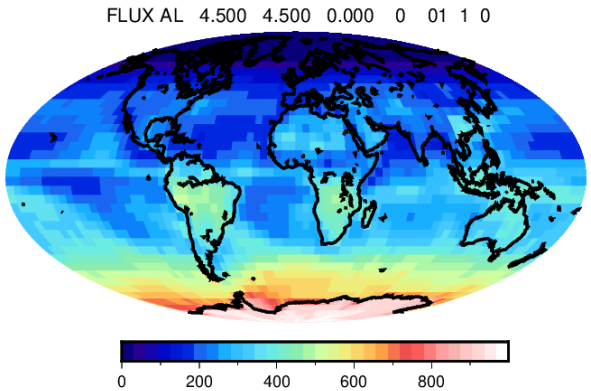


Figure 2: Av. CERES January Grid

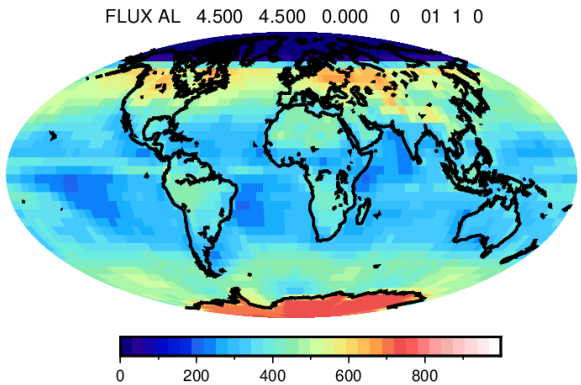
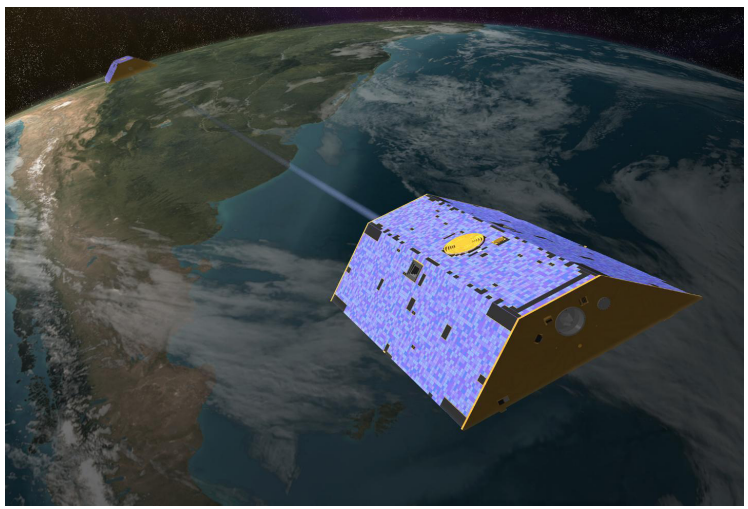


Figure 3: Av. ECMWF January Grid

3. Tests on Low Satellite Orbits

GRACE Satellites

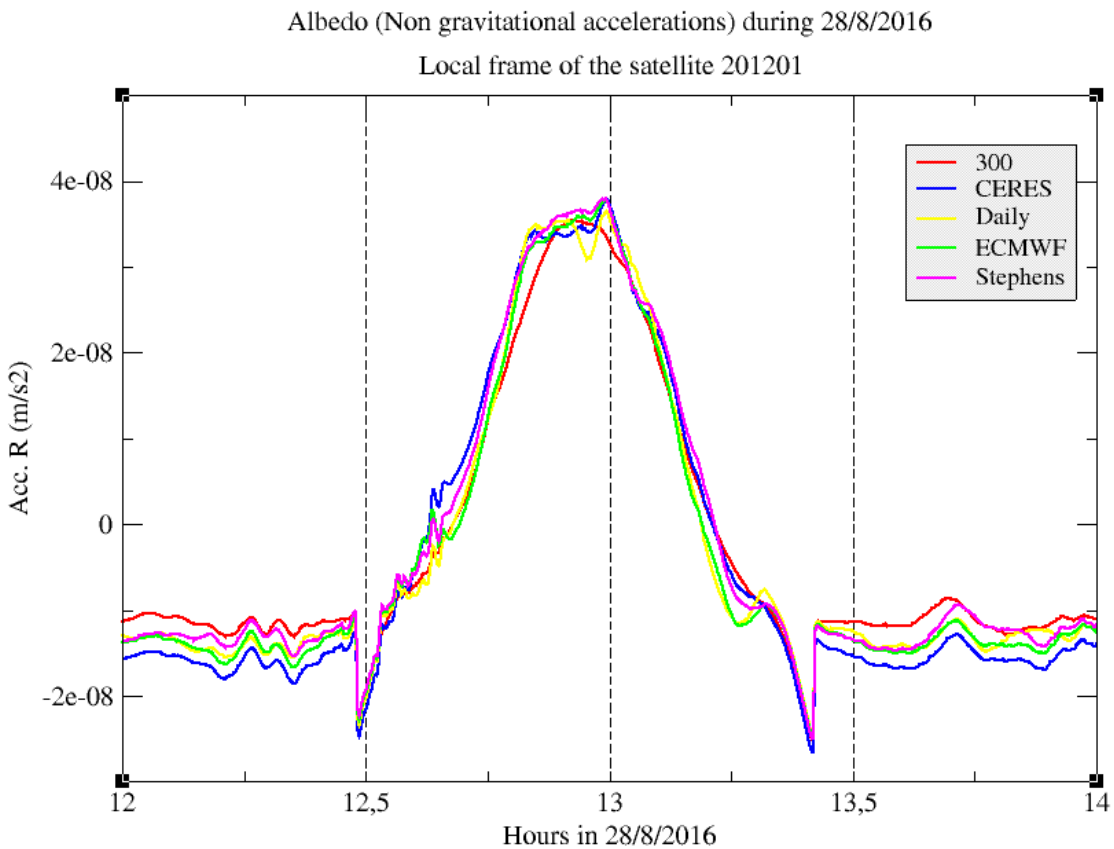
- GRACE are low orbiting satellites (around 400 km).
- Low satellites are more sensitive to albedo (and also to atmospheric drag).
- For GRACE, non-gravitational forces can be monitored by accelerometer data seen as references.



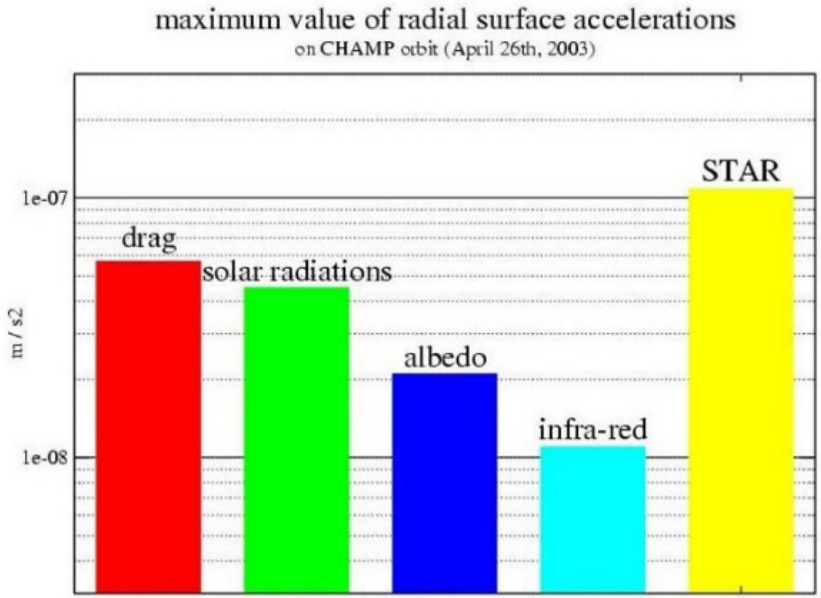
3. Tests on Low Satellite Orbits

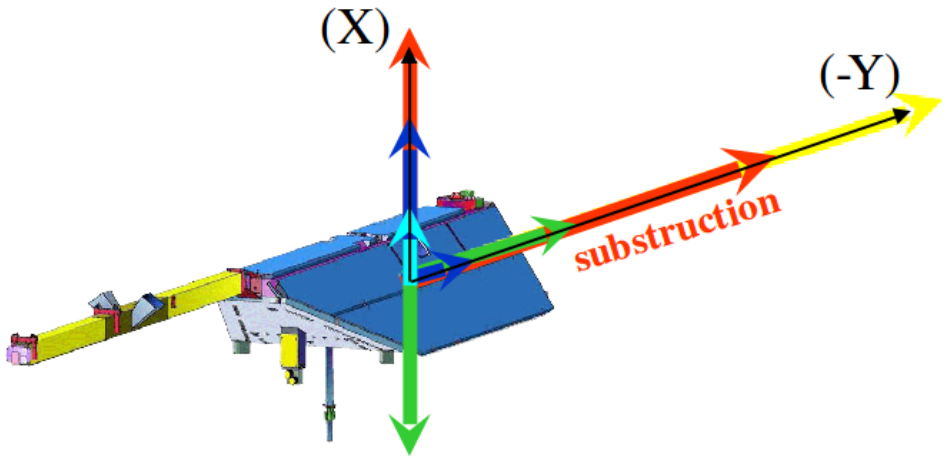
Albedo models behavior

- By modifying the albedo model changes in acceleration can be analyzed
- Most important in the radial direction



Radial calculation strategy (RCS)



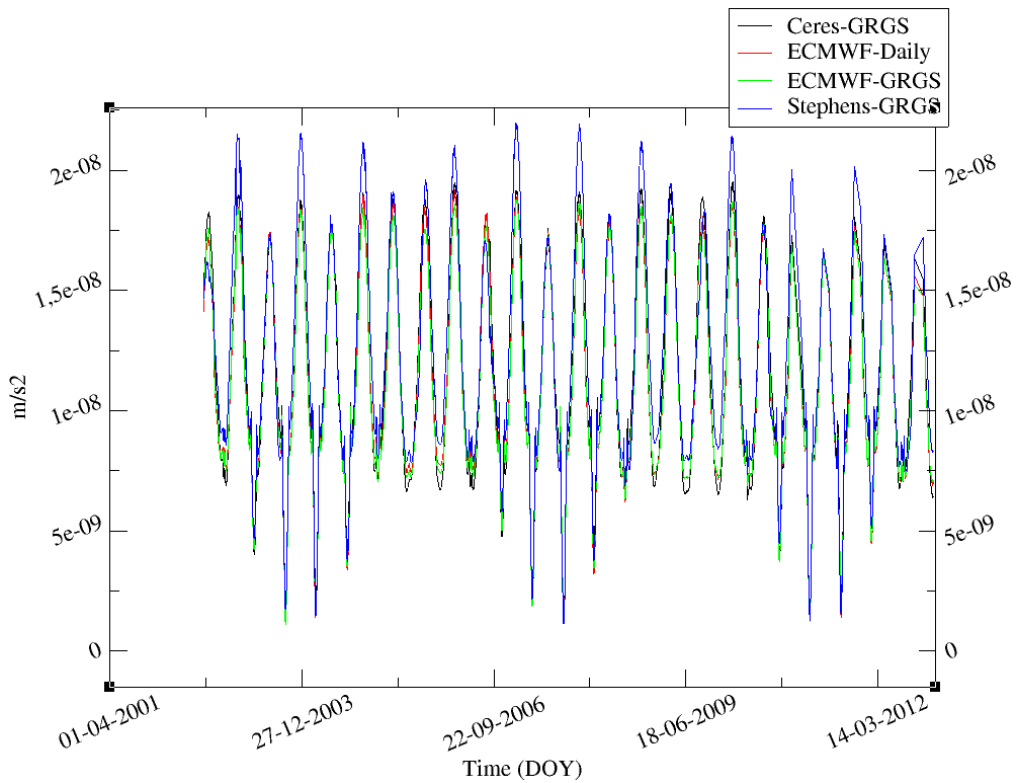


$$R_X = \frac{C_L}{C_D} * [(B + F.R_Y^{STAR}) - \frac{1}{m}(F_Y^{SUN}) + F_Y^{albedo} + F_Y^{IR})] + \frac{1}{m}\left(F_X^{SUN} + F_X^{albedo} + F_X^{IR}\right) \quad (1)$$

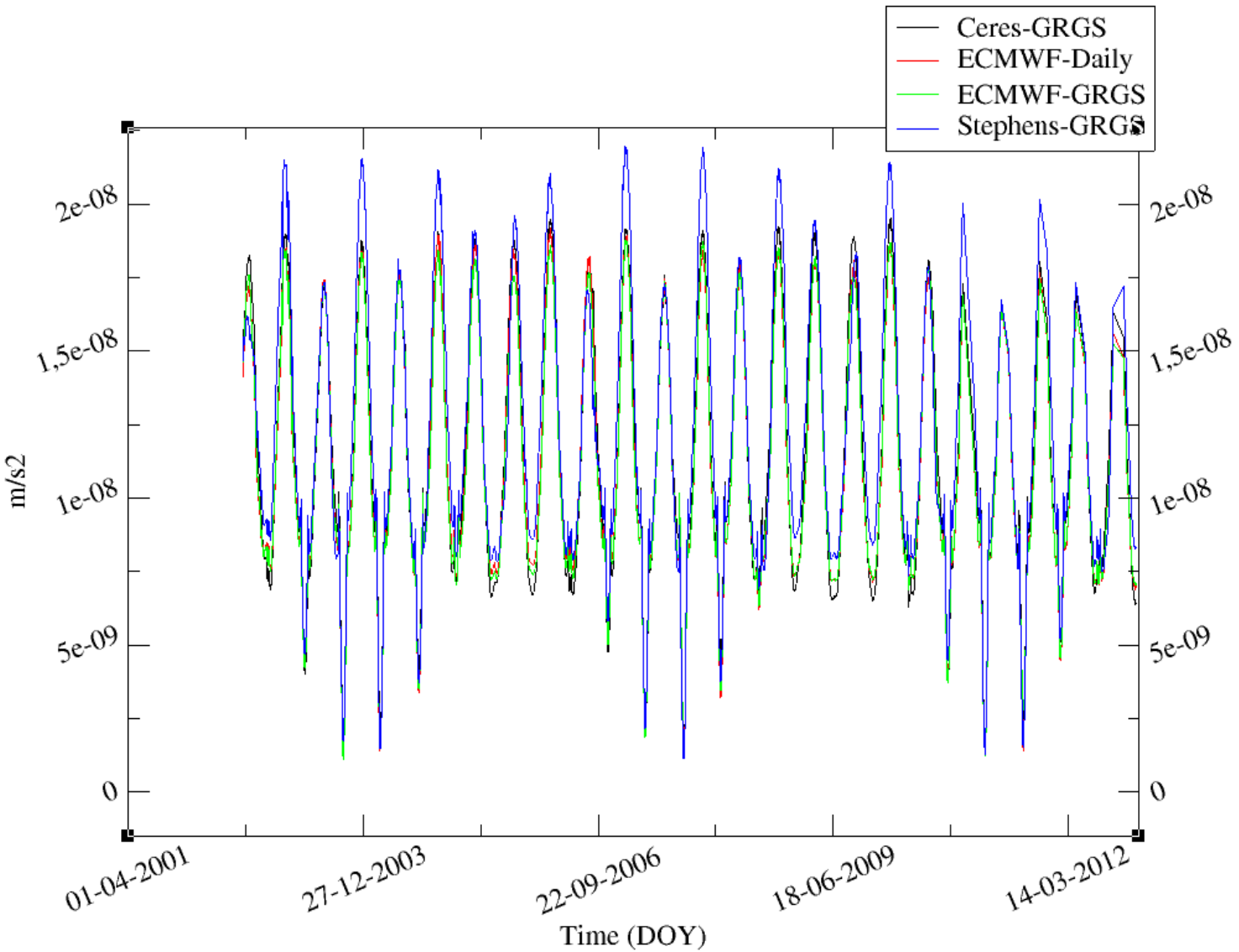
Radial calculation strategy (RCS) results

Gravitational and Non gravitational forces

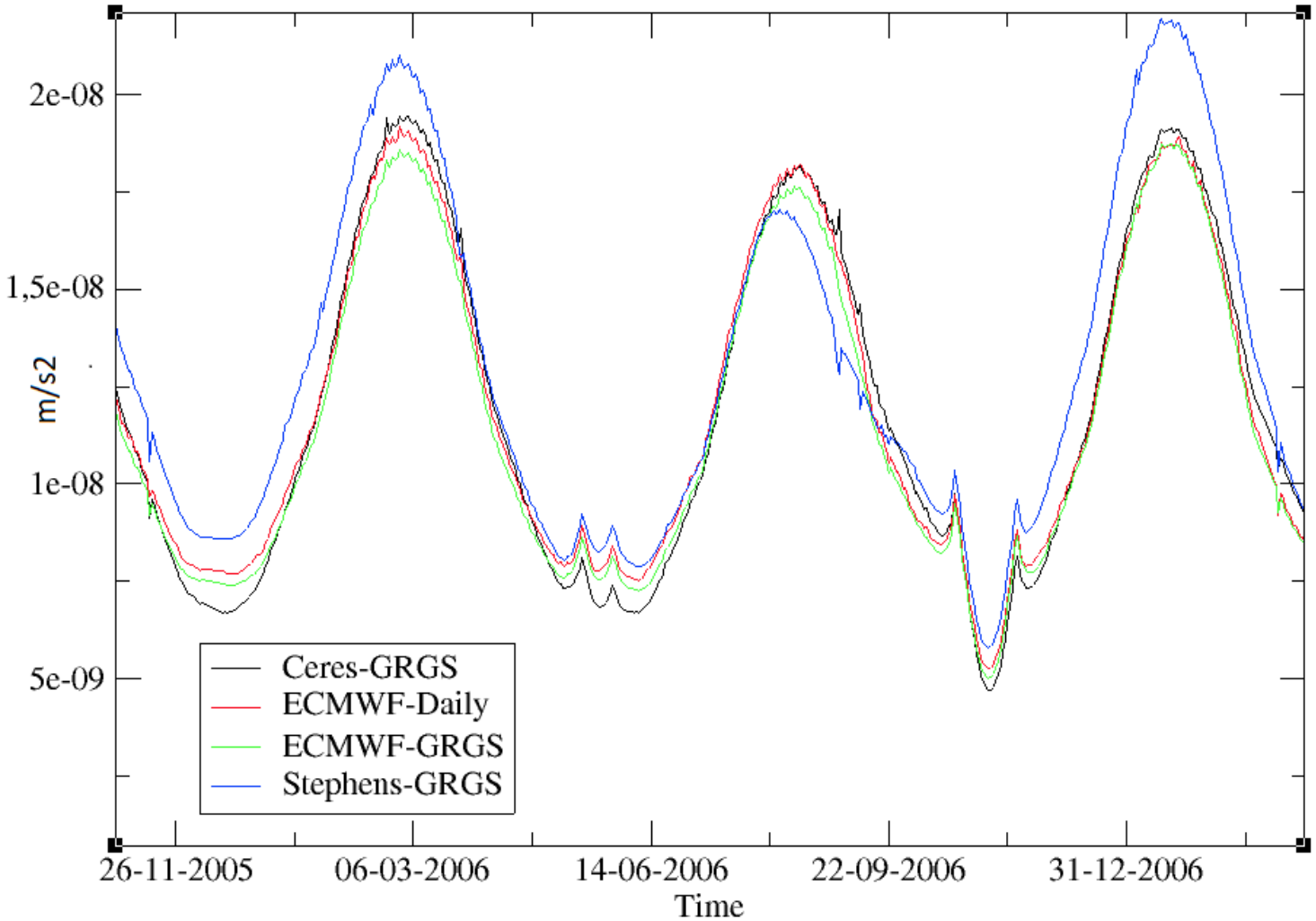
Ten years daily radial Standard deviation of the differences between GRACE surface accelerations (using albedo models of RCS) and GRACE accelerometer data RL04 orbits based on GPS and accelerometer data



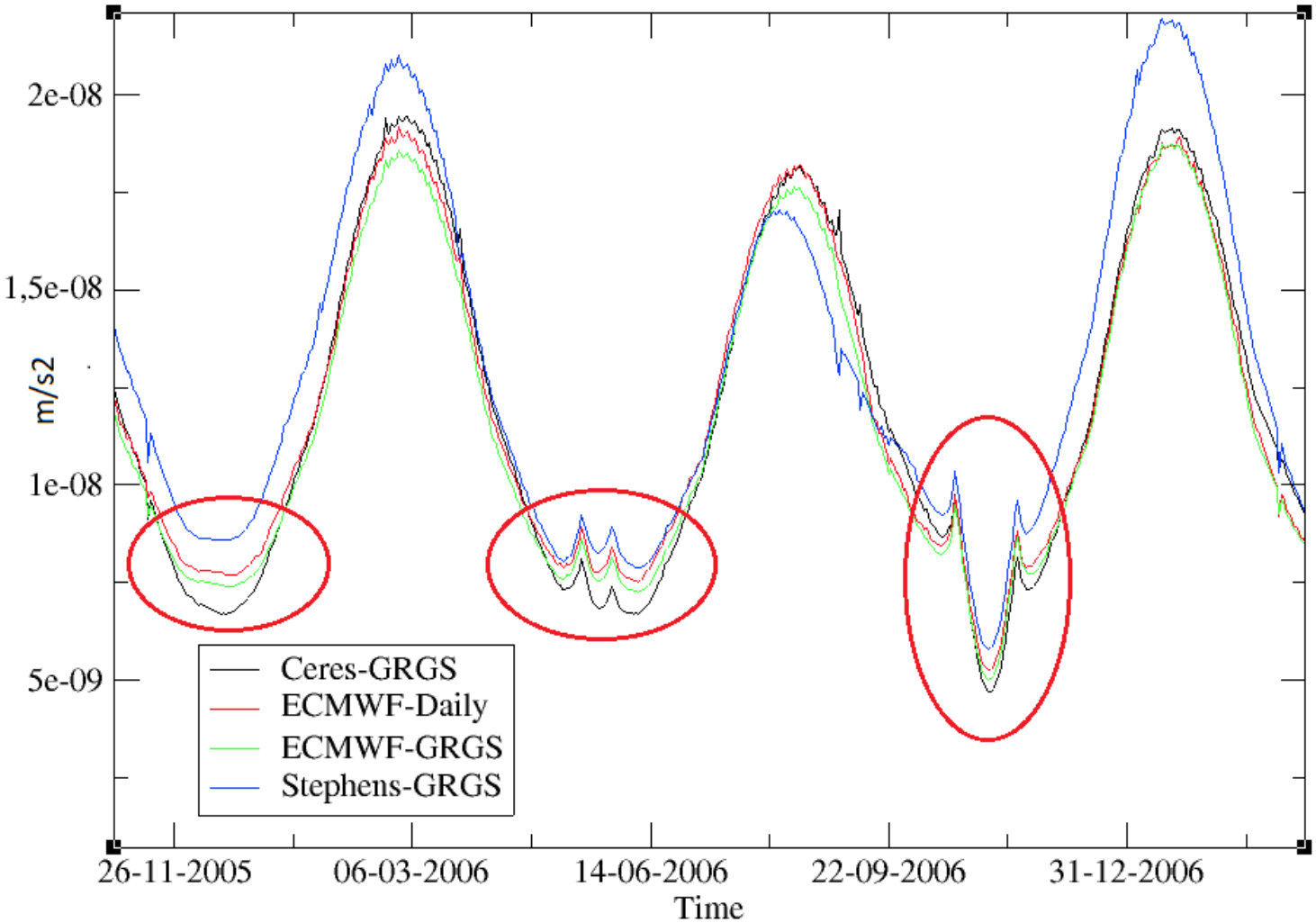
Albedo models behavior



Albedo models behavior



Albedo models behavior



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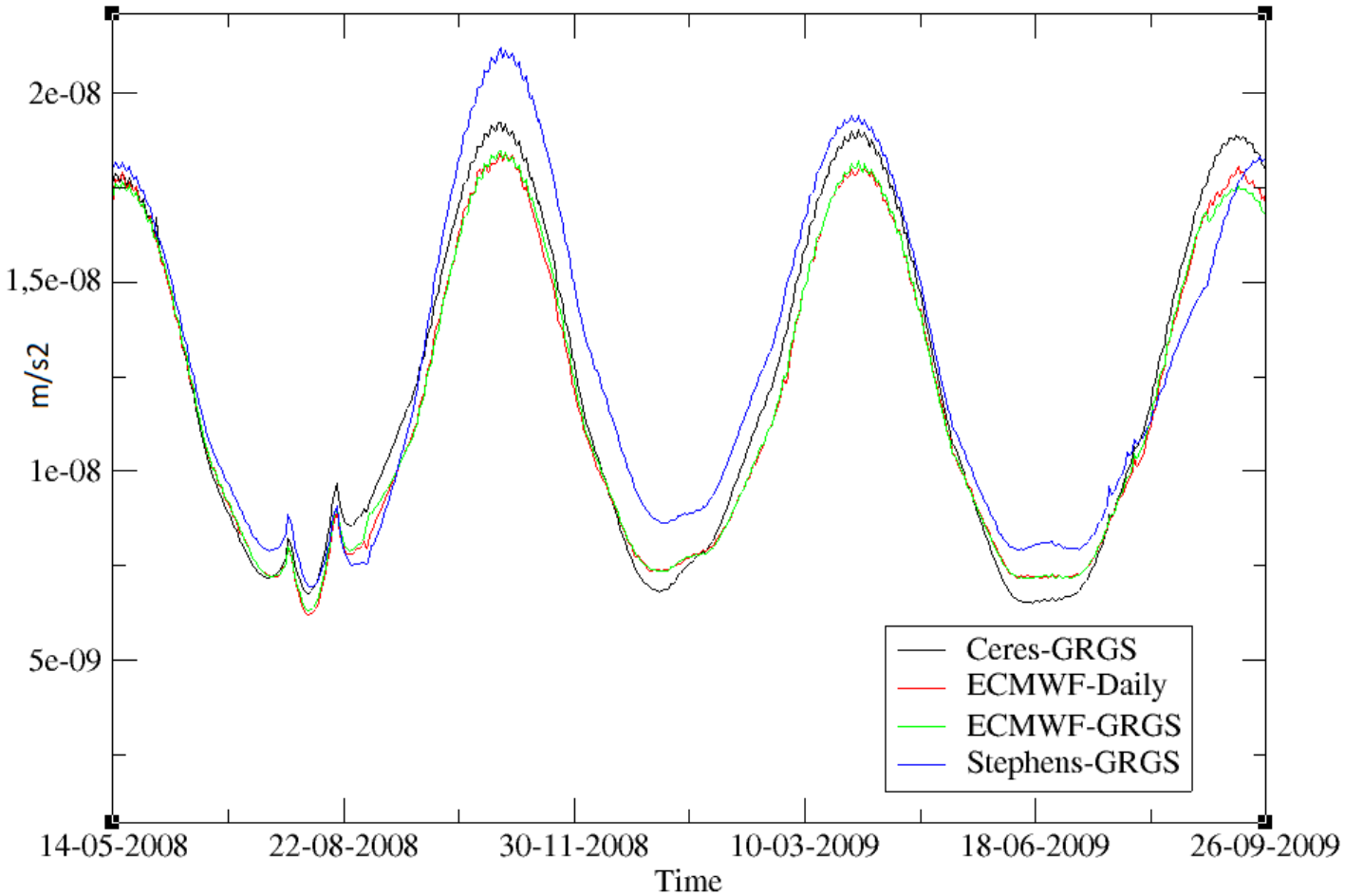
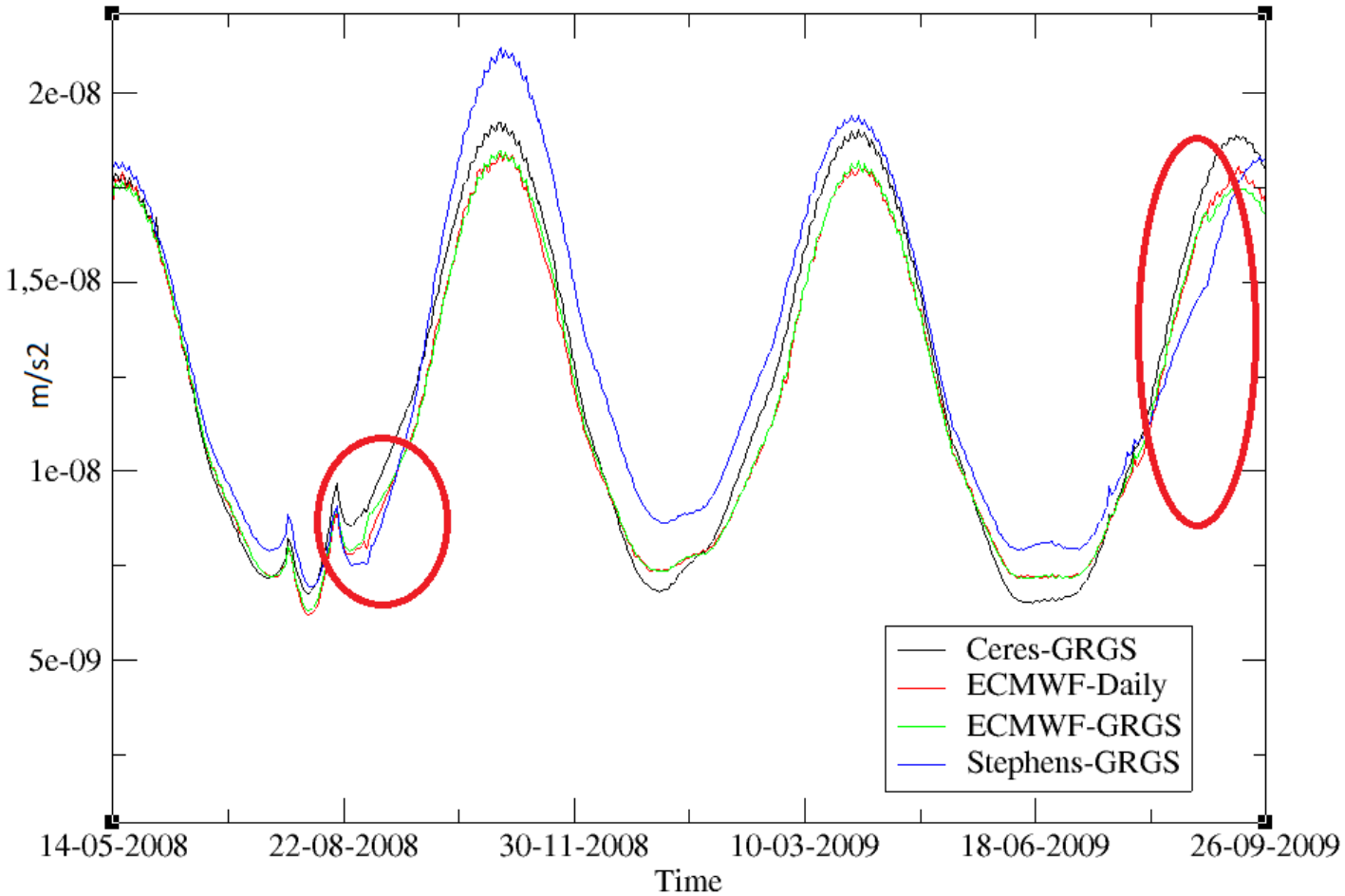
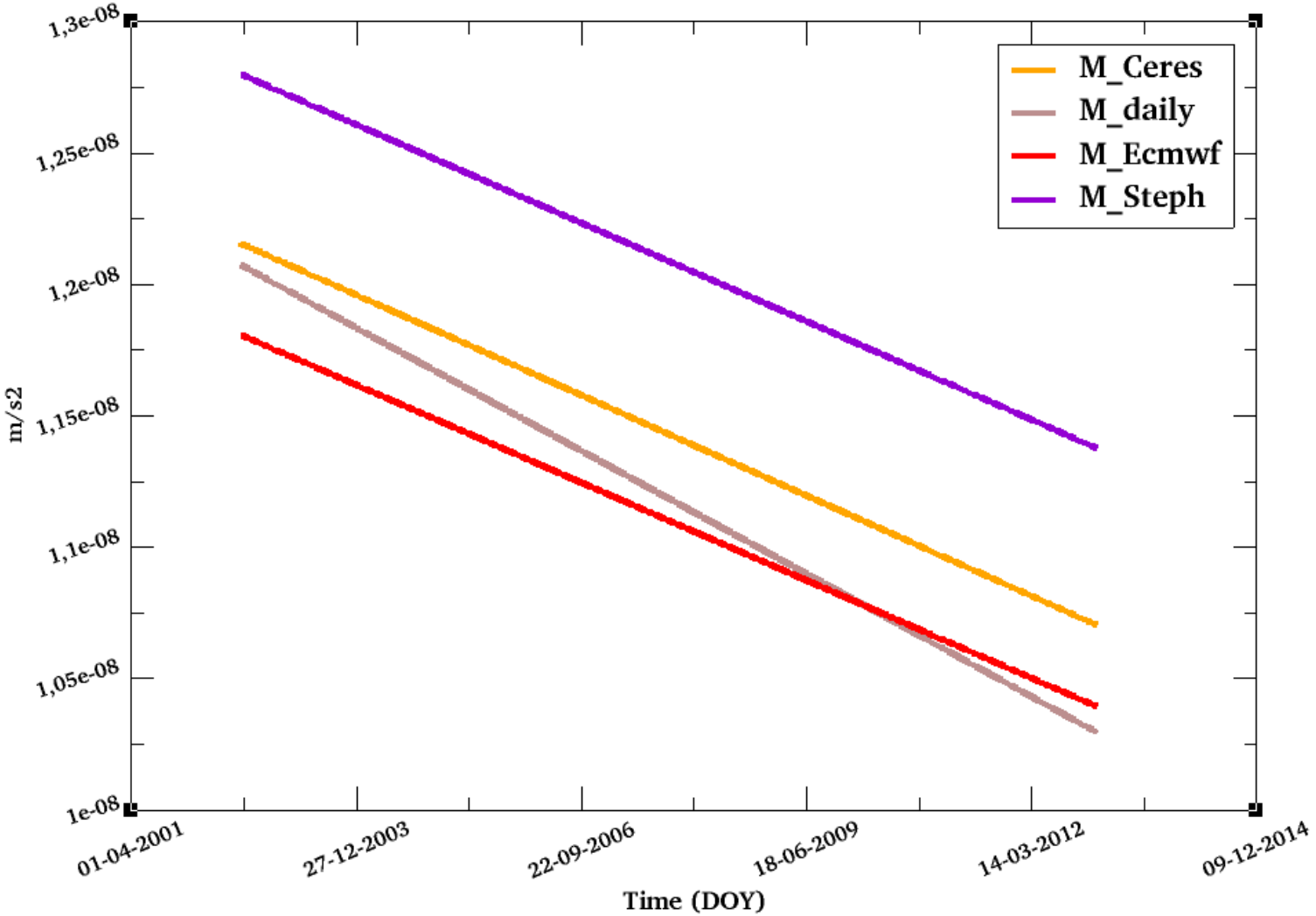


Albedo models behavior



GRACE results



Conclusions and prospects

1. (Stephens, 1980) stills provides good results, once tested on recent orbits
2. Even if slight, some improvements with these new versions of the models presented here
3. geographic correlation of the error to be investigated (in terms of Sun and satellites directions)
4. no significant changes over the last 15 years of the mean albedo detected from artificial satellite perturbations
5. to be continued by increasing the number of tested arcs to get more realistic statistics
6. The developed averaged models provide an acceptable substitute to the non-averaged ones

In memoriam...

Richard BIANCALE 1957-2019

Thank you for your attention

Back-up slides

2. Albedo Models

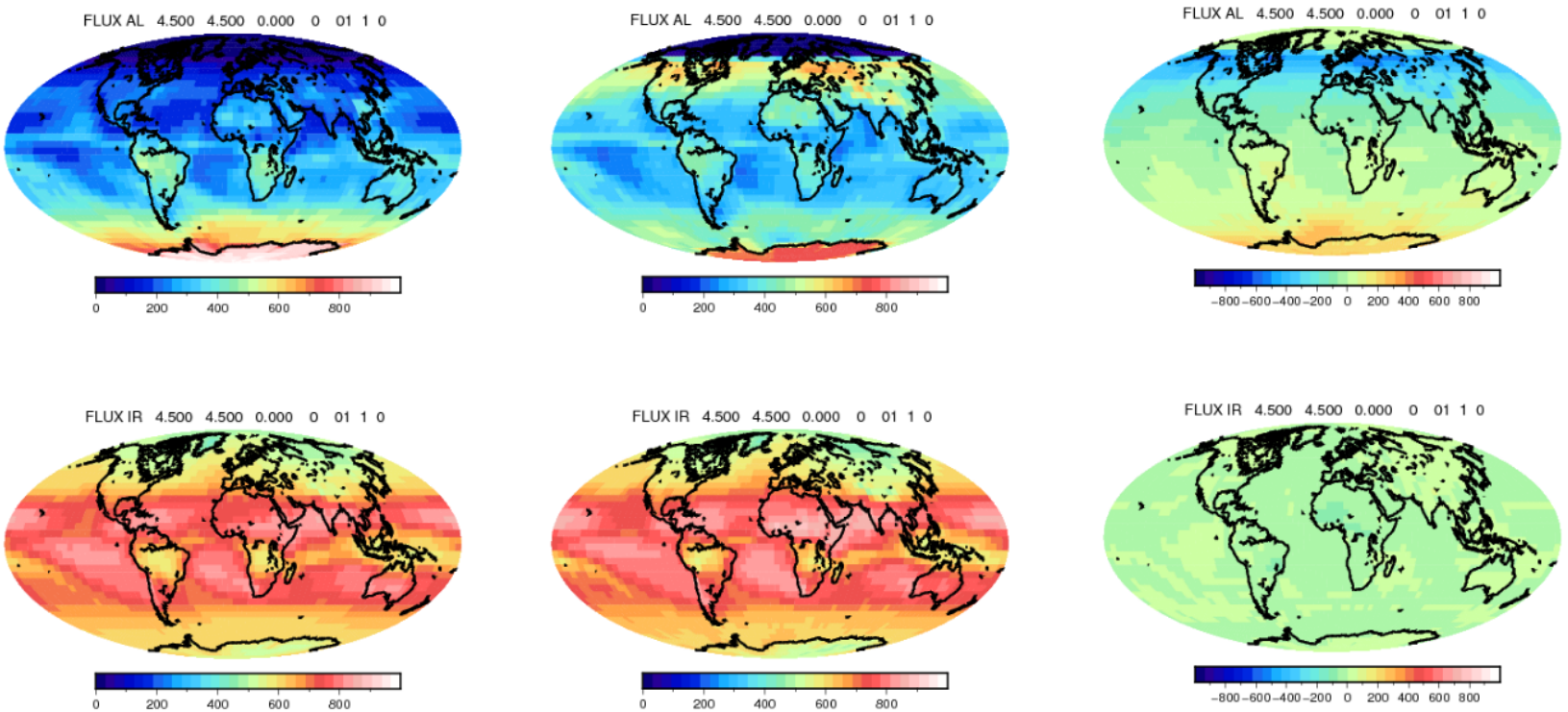


Figure: Albedo (top) and Infrared (bottom) values for CERES (left), ECMWF (middle) and their differences (right) over the Earth for January. Roughly speaking, the differences are structured in four zones, with a location depending upon the seasons.

Radial calculation strategy (RCS) results

Gravitational and Non gravitational forces

- External perturbations and output orbits are determined using the orbit determination software GINS.