The Megha-Tropiques Mission

October 20\textsuperscript{th}, 2009 0000Z courtesy www.satmos.meteo.fr

Rémy Roca (LMD) and the French MT science team
The Megha-Tropiques mission
Outline of the talk

• Mission & Objectives
  – Payload
  – Orbit

• Activities on ERB in the MT team
  – Flux Algorithm development
  – Clear sky greenhouse effect and WV using CERES
  – GEO activity

• Cal/val plan

• Conclusions
  – IAO
The Megha-Tropiques mission
Overview

Indo-french mission realized by
The Indian Space Research Organisation and the
Centre National d’Etudes Spatiales

Dedicated to the
Water and energy cycle in the Tropics

Low inclination on the equator (20°);
865 km height

High repetetivity of the measurements

Launch foreseen in spring 2010
Expected duration: instruments 3 yr Plateform 5 yr fuel/operation
The Megha-Tropiques mission
Scientific objectives

Atmospheric energy budget in the intertropical zone and at system scale (radiation, latent heat, …)

Life cycle of Mesoscale Convective Complexes in the Tropics (over Oceans and Continents)

Monitoring and assimilation for Cyclones, Monsoons, Mesoscale Convective Systems forecasting. NRT capability.

Contribution to climate monitoring:

- Radiative budget (complementary to CERES)
- Precipitation (enhanced sampling in the tropics)
- Water vapour (enhanced sampling in the tropics)
The Megha-Tropiques mission
Payloads (1/2)

• ScaRaB: broad band instrument for inferring longwave and shortwave outgoing fluxes at the top of the atmosphere

• ScaRaB-3 on MT

• Cross track scanning
• 40 km resolution at nadir

<table>
<thead>
<tr>
<th>Channel</th>
<th>Description</th>
<th>Spectral Interval</th>
<th>Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VIS (visible)</td>
<td>0.55 – 0.65 μm</td>
<td>Interferential</td>
</tr>
<tr>
<td>2</td>
<td>SW (or solar)</td>
<td>0.2 – 4 μm</td>
<td>Silice filter</td>
</tr>
<tr>
<td>3</td>
<td>T (total)</td>
<td>0.2 – 100 μm</td>
<td>No filter</td>
</tr>
<tr>
<td>4</td>
<td>IR (Infrared)</td>
<td>10.5 – 12.5 μm</td>
<td>Interferential</td>
</tr>
</tbody>
</table>
The Megha-Tropiques mission

Payloads (2/2)

**SAPHIR**: microwave sounder for water vapour sounding: 6 channels in the WV absorption band at 183.31 GHz. (cross track, 10 km)

**MADRAS**: microwave imager for precipitation: channels at 18, 23, 37, 89 and 157 GHz, H and V polarisations. (conical swath, <10 km to 40 km)

**GPS RO**: water vapor profile …

**GEOSTATIONARY DATA**

- Cloud mask for the MW algo
- Quicklook for interpreting MT data
- Basic inputs for MCS tracking algorithm
- Basic inputs for Level 4 rainfall (radiation) products
The Megha-Tropiques mission

Orbit (2/2)

Half day

1 orbit

SCARAB sampling over 20°F-20°N
Min 4 per day
Max 6 per day

Mean number of overpasses per day

Latitude

Rémy Roca et al, MT Overview, Fort Collins, CO, November 2009
Life cycle of Mesoscale Convective Systems
Compositing with MT

Date: 16/07/2002
Heure: 00:30
The Megha-Tropiques mission
Earth radiation budget measurement summary

Across scales:
from the tropical belt down to the MCS scale

Combination of the payloads:
WV sounding (SAPHIR) and OLR (Scarab) to study the greenhouse effect

Latent heat (MADRAS) and CRF (Scarab) to study the relative role of these two components of the atmospheric heating

Cloud information (GEO) and WV in the low levels (MADRAS) and TOA RB (ScaRaB) to constrain surface radiation budget estimates
ERB activities in the MT Team

Products developpements
Chomette, Raberanto, et al

ERB products Day 1
L3 regional monthly mean average TOA fluxes (SW+LW)
Mean accuracy of 5 Wm\(^{-2}\) (~20 Wm\(^{-2}\) for instantaneous fluxes)
Radiance to flux conversion with ADM (12 scene types)

Scarab ERBE Like algorithm (SEL)

L2 Instantaneous TOA fluxes (SW+LW)
Accuracy of 10 Wm\(^{-2}\) for instantaneous fluxes
CERES ADMs are considered as reference

<table>
<thead>
<tr>
<th></th>
<th>Estimated regional (1°) instantaneous SW TOA flux error (W.m(^{-2})) – All sky</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANN</td>
<td>10.8</td>
</tr>
<tr>
<td>ERBE-like</td>
<td>24.4</td>
</tr>
</tbody>
</table>

Scarab Artificial Neural Network algorithm (SANN)

ERB products Day 2
L2/L3 surface radiation budget
ERB activities in the MT Team
Products developpements

(SANN Broadband – CERES) SW Flux (W.m\(^{-2}\)) ; 08/29/1998
Mean = -0.10 ± 14.93
(SEL ➔ ± 18.57)

**With Broad bands**
50% error reduction with respect to SEL (except for ocean/glint scenes where it’s worse)

**With Narrow bands**
40% error reduction with respect to SANN broadband ➔ Essentially due to improvements for ocean/glint scenes

(SANN Narrowband – CERES) SW Flux (W.m\(^{-2}\)) ; 03/20/1998 Mean = -1.15 ± 9.60

Problem for convective cloud at the swath edge
Ocean Glint errors

Rémy Roca et al, MT Overview, Fort Collins, CO, November 2009
ERB activities in the MT Team

Clear sky greenhouse effect activities
Guzman, Picon et al

- CERES AQUA
- HSB

Building a Collocated database
RS (nite)+CERES

Building HSB WV retrieval +CERES

Radiosondes +CRM

Preliminary results

bias (RS – CERES) = 6.65 (W/m²)
linear fit: y = 0.857x + 37.118
RMS = 10.92 (W/m²)
R² = 0.82

Jul, Aug, Sep 2002, 61 points (red)
Jan 2003, 13 points (blue)
ERB activities in the MT Team

GEO cloud activities

Sèze et al

SAF NWC cloud classification is streaming

GOES-E 1500GMT 3 channels
GOES-W 2100GMT 3 channels

SEVIRI 1200GMT 5 channels

MTSAT 0300GMT 4 channels
ERB activities in the MT Team

GEO cloud activities  cloud top pressure over land

Sèze et al

GLAS >0.02
GLAS >0.2
SEVIRI

Distributions normalized by the number of sample in the distribution.

Rémy Roca et al, MT Overview, Fort Collins, CO, November 2009
The CAL/VAL Plan

- Radiometric quality check before and after launch
  - spectral characterization
  - gain determination
  - DCC method to validate SW radiances

- Vicarious calibration (indirect methods)
  - With terrestrial targets with known reflectance (desert, thick clouds)

- Internal consistency checks
  - Independence of TOA fluxes on the viewing geometry
  - comparison with historical data

- Comparison with other ERB instruments
  - CERES
  - GERB
Validation using CERES one example

Example with CERES (2 days), ±5 mn, no viewing angular conditions

Megha-Tropiques

Altitude = 865.5 km
Inclinaison = 20.00 °
Période = 101.93 min * Révol./j.=14.13

0 km <-> 2292 km - Superposition (pt interm.) avec Aqua
Phasage = [14; -1; 7] 97

>>> Durée représentée : 2880.0 min = 2.00 jours

*** [+/ 1106 km] Megha-Tropiques [+/ 1801 km] Aqua
International Announcement of Opportunity (IAO)

Proposals evaluated by a Joint Indo-French committee

It should be noted that this AO does not fund the 'projects', but only ensures that the selected Principal Investigators (PI) are provided with Relevant data sets at no cost.

- Development of retrieval algorithms and Cal/Val experiments
- Basic research on the physics of the Tropical Climate
- Synergistic studies using multi-sensor/multi-satellite data to understand convective processes
- Techniques development for assimilation of MT radiances or derived geophysical parameters in numerical models

Opening of the call: **November 2009 end**

http://www.cnes.fr
http://www.isro.in
http://meghatropiques.ipsl.polytechnique.fr
Thank you for your attention

http://megha-tropiques.ipsl.polytechnique.fr
• Back up slides
ScaRaB Artificial Neural Network

ANN learning with TRMM data (10 km spatial resolution at nadir) (orbit near to MT orbit – 35° inclination compared to 20°)

Learning data set
CERES Rad. + Flux

Data stratification

Training stage of the ANN
FFEB

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bins #</th>
<th>Bin width</th>
</tr>
</thead>
<tbody>
<tr>
<td>VZA</td>
<td>7</td>
<td>10°</td>
</tr>
<tr>
<td>SZA</td>
<td>9</td>
<td>10°</td>
</tr>
<tr>
<td>RAZ</td>
<td>9</td>
<td>20°</td>
</tr>
<tr>
<td>LWR</td>
<td>15</td>
<td>10 W.m^{-2}sr^{-1}</td>
</tr>
<tr>
<td>SWR</td>
<td>30</td>
<td>10 W.m^{-2}sr^{-1}</td>
</tr>
</tbody>
</table>

Exemple : one SW case

Stratification goal : reduce the size of the learning data set by keeping its statistical representation.
7x9x9x15x30 = 255150 bins

6 scene types
no-glint ocean, glint, medium-high and low medium, tree-shrub, dark and bright desert

SANN
ScaRaB L2 algorithm

Validation data set
CERES radiances

Obtaining fluxes and compare them with CERES fluxes for validation
### ScaRaB Artificial Neural Network (SANN) LW results

<table>
<thead>
<tr>
<th>Leaning data</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP 68 days 01/98 – 08/98</td>
<td>VZA, PW, LLw, Lsw</td>
</tr>
<tr>
<td>XT 16 days 07/98 – 08/98</td>
<td>VZA, Lir, Llw, Lsw</td>
</tr>
<tr>
<td>XT 16 days 07/98 – 08/98</td>
<td>VZA, PsAbs, Lir</td>
</tr>
<tr>
<td>XT 16 days 07/98 – 08/98</td>
<td>VZA, PsAbs</td>
</tr>
</tbody>
</table>

For each bin, the standard deviation of the ADM~0.01 (corresponding to 2.4 Wm-2 for a global LW means of 240 Wm-2) which marks the intrinsic accuracy of the model.

*compared to the intrinsic model error 2.4 Wm\(^{-2}\)*

<table>
<thead>
<tr>
<th>Version</th>
<th>Error Wm(^{-2})</th>
<th>Rms error reduction Wm(^{-2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERBE</td>
<td>+2.94 ± 3.15*</td>
<td>4.30</td>
</tr>
<tr>
<td>ANNa</td>
<td>-0.60 ± 2.89*</td>
<td>2.95 (30%)</td>
</tr>
<tr>
<td>ANNc</td>
<td>-1.20 ± 2.99*</td>
<td>3.22 (25%)</td>
</tr>
</tbody>
</table>
ScaRaB validation, one example

ScaRaB/MT & GERB/MSG

- MT Launch: 2010, life-time 3 years
- GERB: continuous program (GERB 3 and 4 until 2015... and more)
- Common spatial coverage (30°N-30°S → MT limits 50°W-50°E → MSG limits)
- Similar footprints: ~40 km
**ScaRaB validation, one example**

**Possible ScaRaB/GERB Comparisons**

- **Radiances** comparisons of simultaneous co-located and co-angular observations
  - **SW radiances**
    - Co-angular \((\theta_{\text{zenith}} \pm 5^\circ \ \& \ \theta_{\text{azimuth}} \pm 10^\circ)\)
    - Simultaneous \((\Delta T \pm 7.5 \text{ mn})\)
  - **LW radiances**
    - Same as SW without the \(\theta_{\text{azimuth}}\) constraint

- More comparisons!
  - Fluxes of simultaneous co-located observations
  - Monthly means fluxes of the common tropical area
ScaRaB validation, one example

ScaRaB/GERB Simultaneous SW co-location

Megha-Tropiques
>>> Durée représentée : 720.0 min = 0.50 jour
Inclinaison = 20.00 °
Altitude = 855.5 km
Période = 101.93 min * révol./j. = 14.13
θ zenith ± 5°
θ azimuth ± 10°

Trace des fauchées orthogonales (mode XT)
** Domi-fauchée : 48.9° [ 2.0 ] - Au sol : 1108.2 km [ 0.10 min ]

Projection : Mercator
CP : 0.0 ° ; 0.0 ° / GZ : 12.0 ° N ; 0.0 °
Propriété : Conforme
Noeud asc. : 0.00 ° [12:00 TSM]
TSM (local)
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
heures

© T.:Cylindrique - Grille : 10°
 Aspect : Direct > zoom : 6.00
$\xi_\omega$
MC * LMD
$\alpha_{\lambda\alpha}$, November
ScaRaB validation, one example

For 7 days (SW) - $\theta_{\text{zenith}} \pm 5^\circ$ - $\theta_{\text{azimuth}} \pm 10^\circ$

Megha-Tropiques

Altitude = 865.5 km  
a = 7243.678 km
Inclinaison = 20.00 °
Période = 101.93 min  * Révol./j. = 14.13

>>> Durée représentée : 7.00 jours

Trace des fauchées orthogonales (mode XT)

** Demi-fauchée : 48.9° [2.0] - Au sol : 1108.2 km [0.10 min]

[TSM (local)]

00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 heures

Validation

Projection : Mercator  
Centre Project. : 0.0 ° ; 0.0 °  
Noeud asc. : 0.00 °

Propriété : Conforme  
Aspect : Direct > zoom : 3.00

© T.:Cylindrique - Grille : 10°

MC * LMD

$\Xi_{\text{nov}}$

$\Lambda_\text{nov}$

November
ScaRaB validation, one example

For 7 days (SW) - $\theta_{\text{zenith}} \pm 10^\circ$ - $\theta_{\text{azimuth}} \pm 20^\circ$ :

Megha-Tropiques

Trace - Géom/Géosta [ Zén: 10 / Azi: 20 ] - avec : METEOSAT

>>> Durée représentée : 7.00 jours

Inclinaison = 20.00 °

Période = 101.93 min * Révol./j.-14.13

Altitude = 865.5 km

a = 7243.678 km

** Demi-tauchée : 48.9° [ 2.0 ] - Au sol : 1 108.2 km [ 0.10 min ]

Projection : Mercator

Centre Project. : 0.0 ° ; 0.0 °

Nœud asc. : 0.00 °

MC * LMD

Atlas
ScaRaB validation, one example

For 1 day (LW) - $\theta_{\text{zenith}} \pm 5^\circ$ - $\theta_{\text{azimuth}}$ no constraint

Megha-Tropiques
Trace - GéoM/Géosta [ Zén: 5 / Azi:180 ] - avec : METEOSAT
Altitude = 865.5 km
Inclinaison = 20.00 °

Durée représentée : 1440.0 min = 1.00 jour
Période = 101.93 min * Révol./j = 14.13

Trace des fauchées orthogonales (mode XT)

** Demi-fauchée : 49.9° [ 2.0 ] - Au sol : 1103.2 km [ 0.50 min ]

Projection : Mercator
Centre Project. : 0.0 ° ; 0.0 °
Nœud asc. : 0.00 °

MC ★ LMD

Iξλων

MT Overview, Fort Collins, CO, November 2009
### Average SW flux errors (bias±standard deviation) in [Wm-2] of the ANN ADM (ANN-BB-RAP in green; ANN-BB-XT in blue & ANN-NB-XT in yellow).

<table>
<thead>
<tr>
<th>Scene type</th>
<th>all</th>
<th>all but ocean/glint</th>
<th>ocean/glint</th>
<th>ocean/no glint</th>
<th>LMTS/land</th>
<th>MHTS/land</th>
<th>bright desert</th>
<th>dark desert</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANN-BB-RAP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1st period)</td>
<td>-4.68 ±15.08</td>
<td>-3.05 ±9.57</td>
<td>-11.24 ±24.35</td>
<td>-4.28 ±9.19</td>
<td>-0.32 ±10.29</td>
<td>-0.47 ±9.96</td>
<td>-1.50 ±6.49</td>
<td>-0.29 ±9.76</td>
</tr>
<tr>
<td>(2nd period)</td>
<td>-3.06 ±13.58</td>
<td>-1.90 ±8.85</td>
<td>-8.30 ±23.02</td>
<td>-2.91 ±8.33</td>
<td>0.89 ±10.23</td>
<td>0.27 ±9.39</td>
<td>-0.50 ±5.96</td>
<td>-0.28 ±9.14</td>
</tr>
<tr>
<td><strong>ANN-BB-XT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1st period)</td>
<td>-1.42 ±10.62</td>
<td>-1.28 ±8.12</td>
<td>-2.02 ±16.64</td>
<td>-1.08 ±7.71</td>
<td>-0.53 ±9.04</td>
<td>-0.98 ±8.78</td>
<td>0.77 ±6.06</td>
<td>0.04 ±8.91</td>
</tr>
<tr>
<td>(2nd period)</td>
<td>-0.39 ±9.30</td>
<td>-0.16 ±7.22</td>
<td>-1.42 ±14.72</td>
<td>-0.23 ±6.93</td>
<td>0.08 ±8.54</td>
<td>-0.14 ±7.82</td>
<td>-0.24 ±4.83</td>
<td>-0.24 ±7.15</td>
</tr>
<tr>
<td><strong>ANN-NB-XT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1st period)</td>
<td>-1.15 ±9.39</td>
<td>-1.10 ±7.48</td>
<td>-1.40 ±14.33</td>
<td>-1.61 ±6.51</td>
<td>-0.36 ±9.14</td>
<td>-0.77 ±10.13</td>
<td>1.57 ±6.37</td>
<td>1.05 ±8.02</td>
</tr>
<tr>
<td>(2nd period)</td>
<td>-0.24 ±8.29</td>
<td>+0.01 ±6.78</td>
<td>-1.52 ±12.39</td>
<td>-0.05 ±6.06</td>
<td>+0.07 ±8.33</td>
<td>-0.13 ±9.05</td>
<td>+0.06 ±5.06</td>
<td>+0.27 ±6.88</td>
</tr>
</tbody>
</table>

**Learning period ➔ 2nd period  -  Validation period ➔ 1st period**