Daily rainfall detection and estimation over land using microwave surface emissivities

C. Birman, F. Karbou
and J.-F. Mahfouf

4th Workshop on Remote Sensing and Modeling of Surface Properties

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Introduction

Overview of existing rainfall products

- Several precipitation products are available over France: raingauges, ANTILOPE reanalysis (raingauges + radars), AROME NWP model forecasts…
- But the surface networks of radars and raingauges are sparse over the globe
- Rainfall retrieval from satellite is the only mean to provide a global coverage.
- Several rainfall detection and estimation exist:
  - Visible/infra-red (onboard geostationary satellites) and/or microwave (passive and active): CMORPH, TRMM…
  - Microwave observations are the most suitable, but they are only available on board polar orbiting satellites → poor temporal sampling
  - Rainfall retrievals over ocean: emission from liquid hydrometeors enhances the low background radiances (emissivty close to 0.5) at the top of the atmopshere at frequencies below 35 GHz.
  - Over land: rainfall retrievals are achieved through the scattering signal produced at frequencies above 35 GHz that decreases the radiances at the top of the atmopshere.

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Introduction

Rainfall retrieval over land using microwave emissivities

- The emissivity at 89 Ghz are used to:
  - Detect rainfall occurrence
  - Estimate a daily amount of precipitation
- Original method developed specifically over land surfaces
- Use of surface properties in the microwave region instead of top of the atmosphere radiances
- Emissivities derived at 89 GHz from AMSU-A, -B and SSMI/S sensors are used to (1) detect rainfall events and (2) retrieve daily rainfall rates over France
  - Independant data are available to calibrate and validate the method
  - The method is applied over France but could be applied over other regions

Data and models

Microwave data

The radiative transfer equation is inverted to compute the emissivity from Tbs, for window channels between 19 and 150 GHz from AMSU-A, -B and SSMI/S → best sensitivity to precipitation at 89 GHz (91 GHz for SSMI/S).

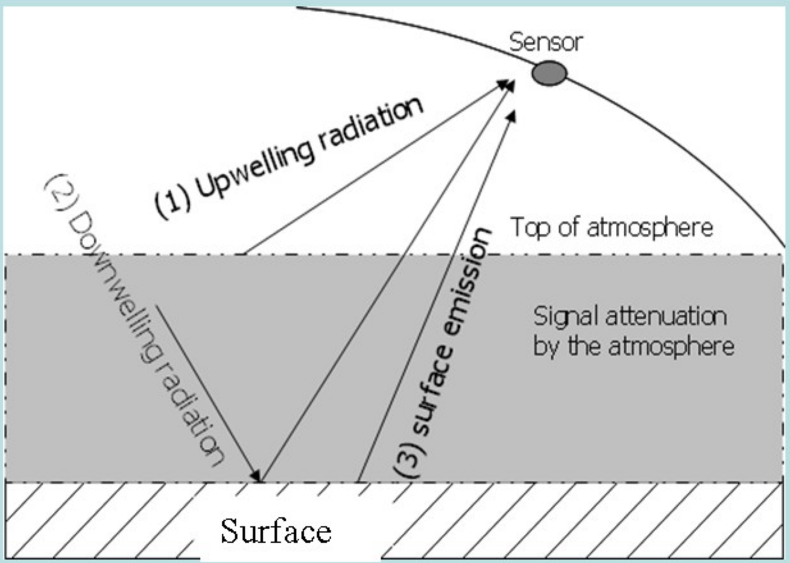

Schéma simplifié de la mesure satellite (plusieurs hypothèses simplificatrices)

Extraction of surface contribution in the measured Tbs:
inversion of radiative transfer equation

Radiative transfer model + auxiliary data:
T / q profiles and Ts (NWP model)

↓

$$\epsilon(p,\nu) = \frac{T(p,\nu) - T(\nu,\uparrow) - T(\nu,\downarrow) \times \tau}{\tau \times (Ts - T(\nu,\downarrow))}$$

Precipitation data

Antilope reanalysis (combination of radar and raingauges): Used to derive an emissivity_to_rainfall empirical function

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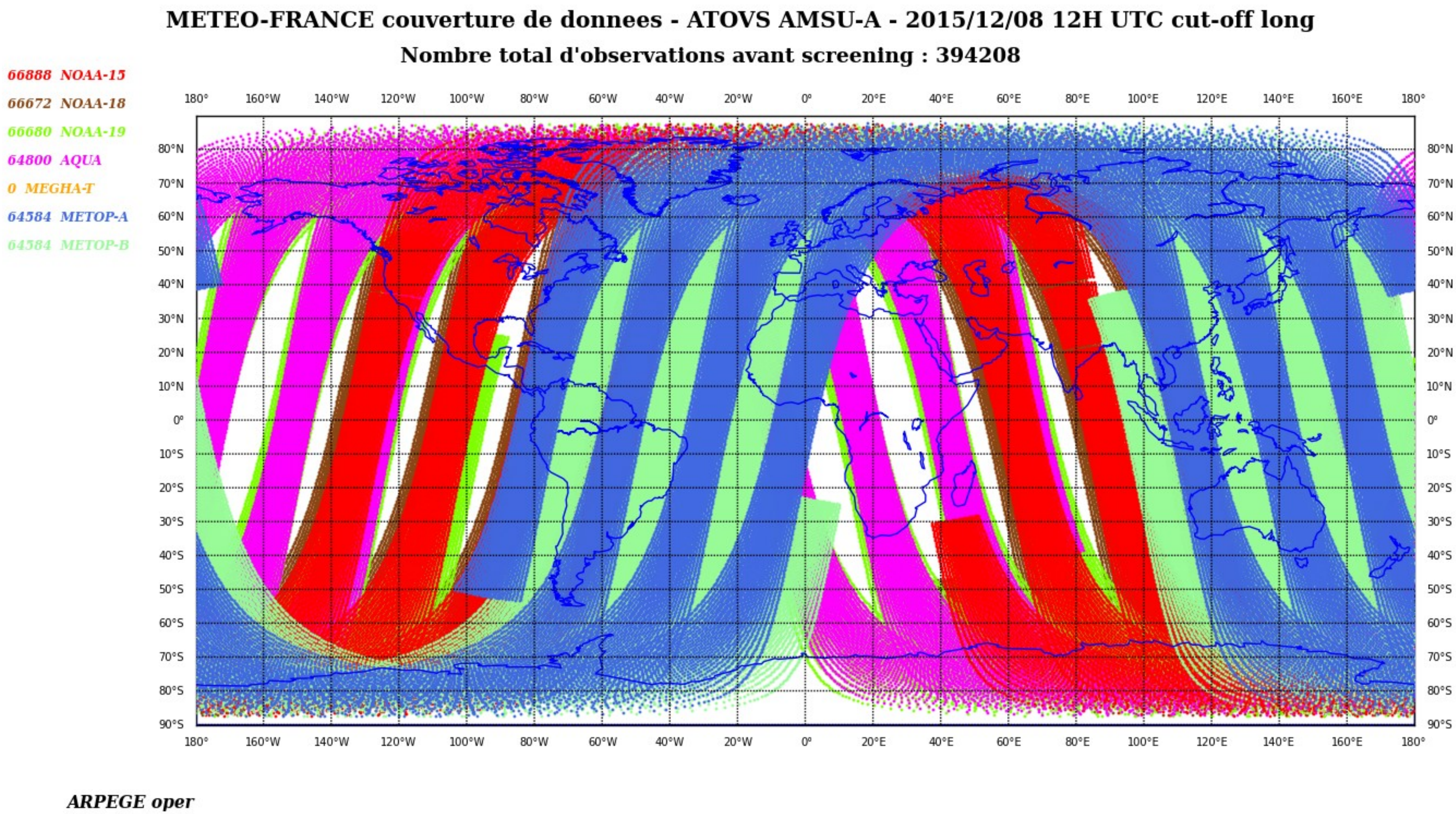
Data and models

Microwave data



Observations from ASMU-A instrument (up to 6 instruments), on December 08, 2015

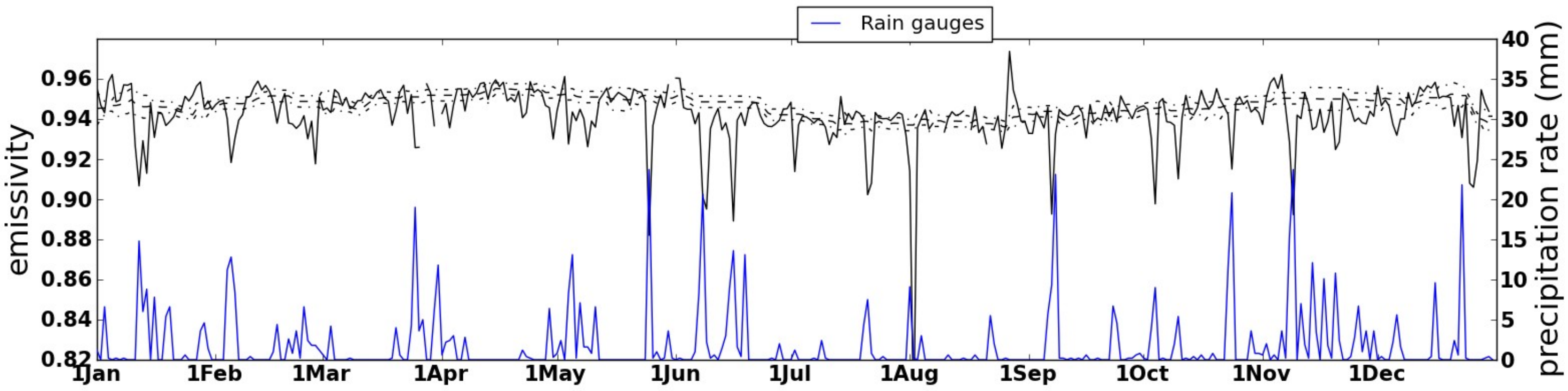
EMIRR algorithm (Emissivity Rainfall Retrieval)

Rainfall event detection using emissivities

- Rainfall detection: based on the daily variability of emissivity with respect to a dry soil reference.

- Negative correlation between rainfall occurrence and emissivity: the emissivity drops when rainfall occurs and increases gradually to its normal value when soil dries.

- Dry soil reference: using a dynamical atlas for dry soil emissivity: Computed over a 2-week sliding window using clear sky emissivities



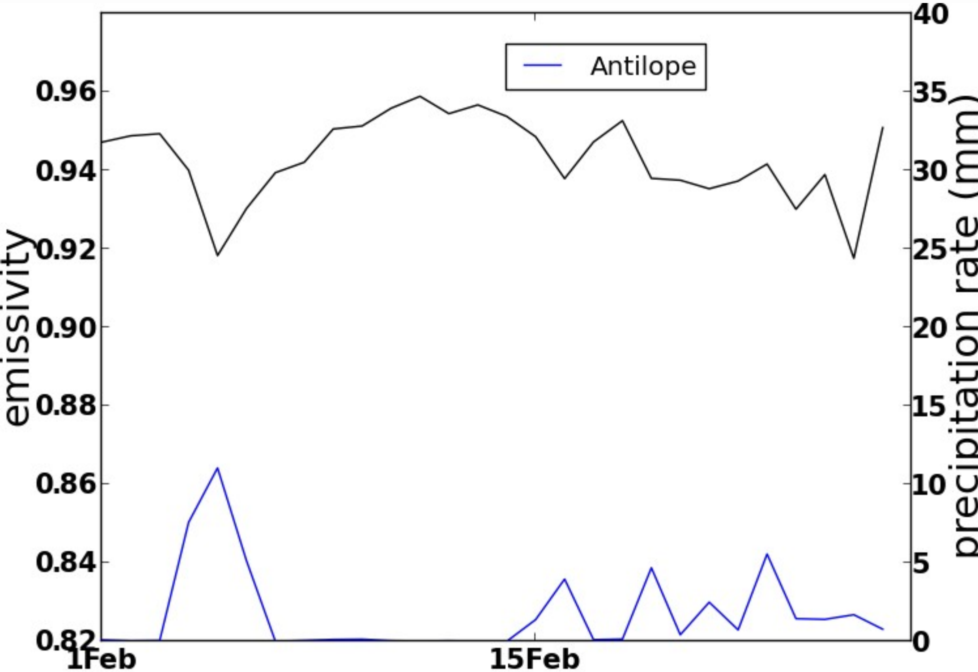
Time series of observed rainfall from Antilope (blue), 89 GHz emissivity (black line) and of its dry soil value (black dashed line) over the year 2010 near Agen

EMIRR algorithm (Emissivity Rainfall Retrieval)

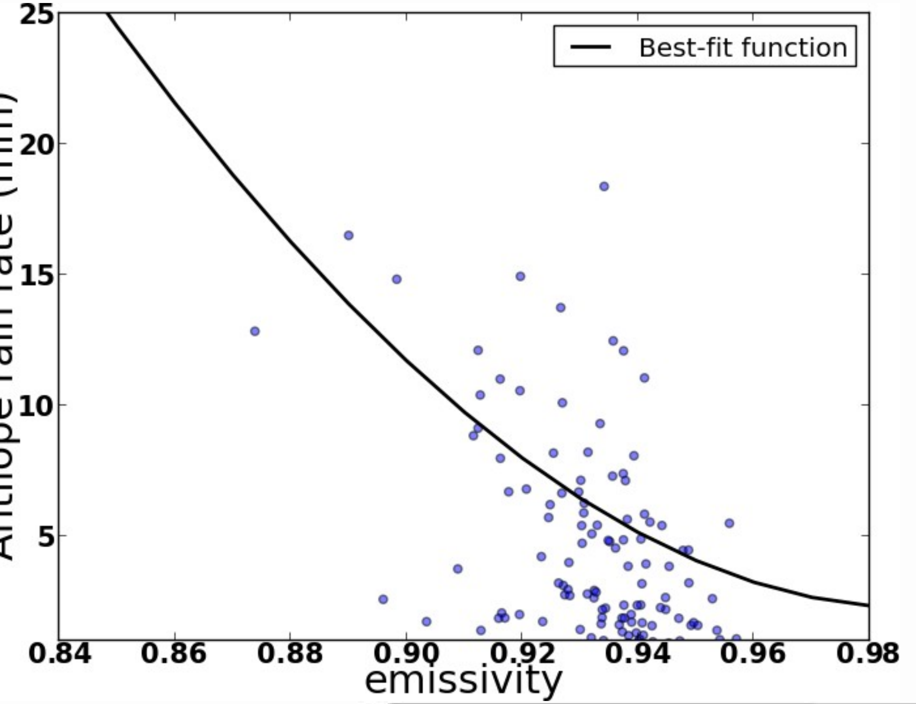
In case of rainfall event, 24h rainfall rate is estimated from emissivities

- One fit function adjusted over France

Time series of the emissivity at 89 GHz (black) and rainfall (blue) during February 2010 near Agen



Fit function between emissivity and rainfall

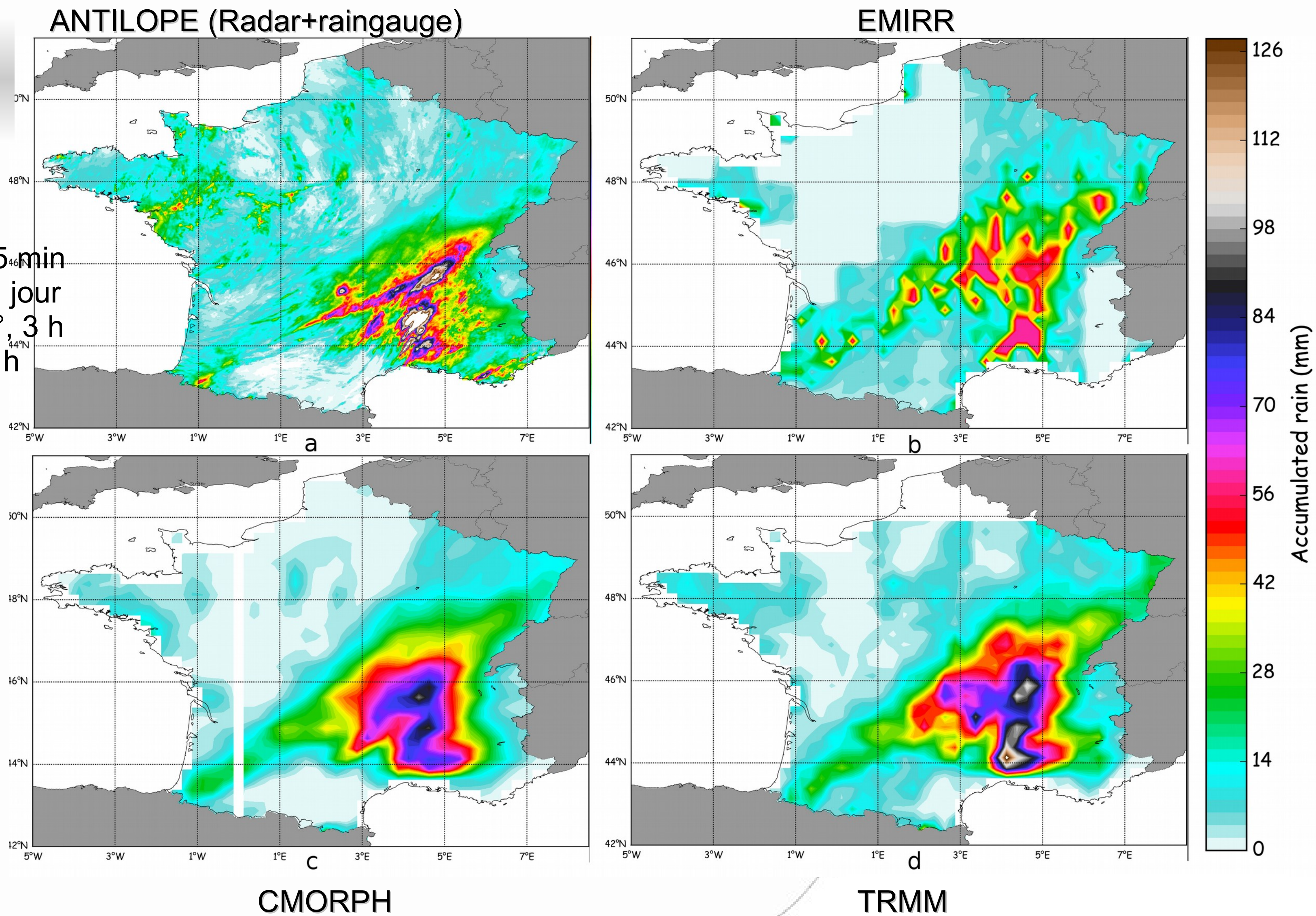


Evaluation of results

Results: comparsison against other satellite products

Case study: September 7, 2010

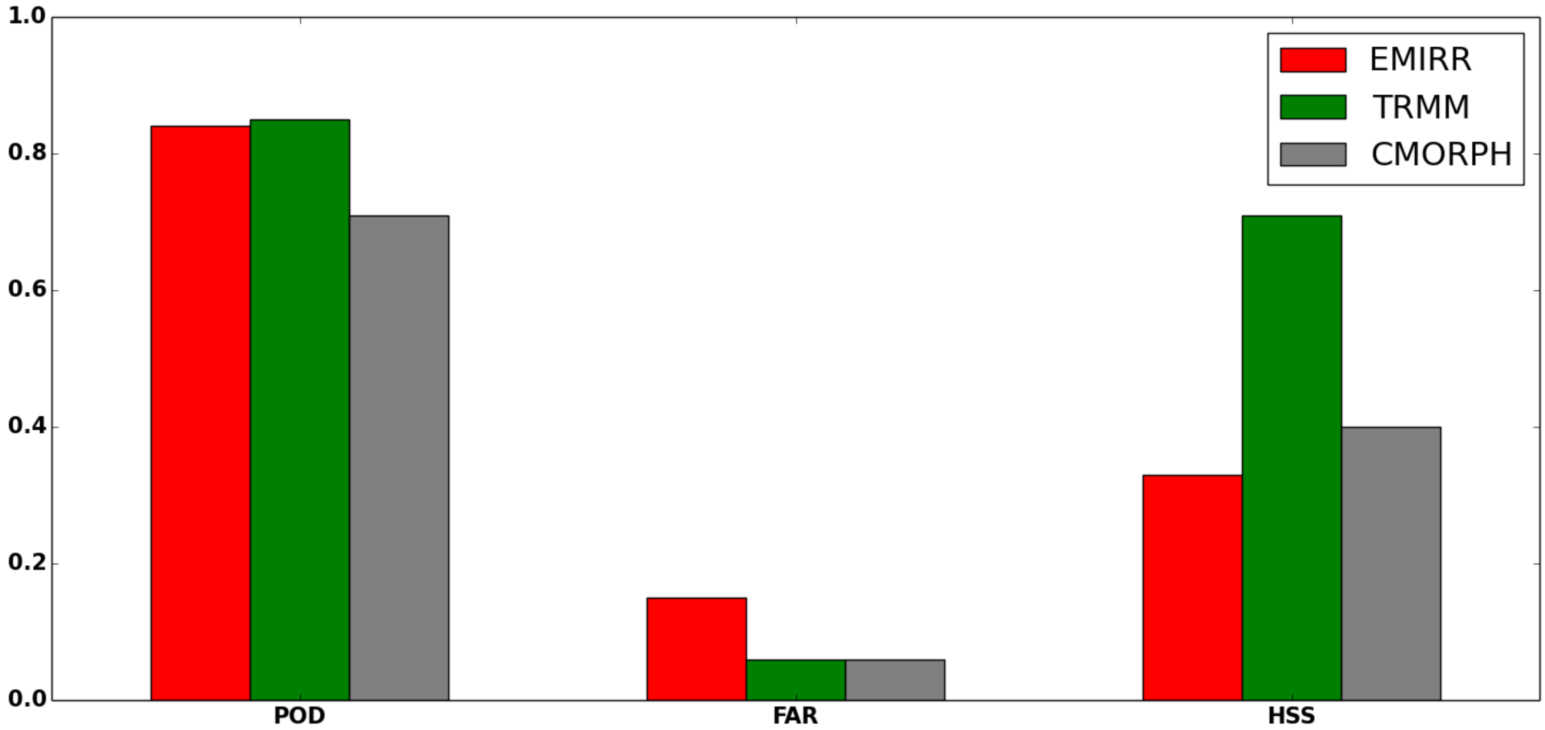
Antilope : 1 km, 5 min
EMIRR : 0,25°, 1 jour
CMORPH : 0,25°, 3 h
TRMM : 0,25°, 3 h



Evaluation of results

Results: comparison against other satellite products

Median scores for detection of accumulated precipitation over five days (threshold 1mm) with respect to ANTILOPE over the year 2010

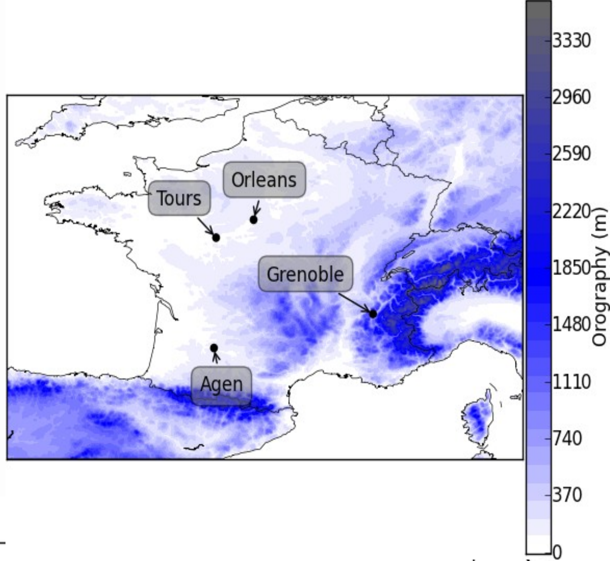


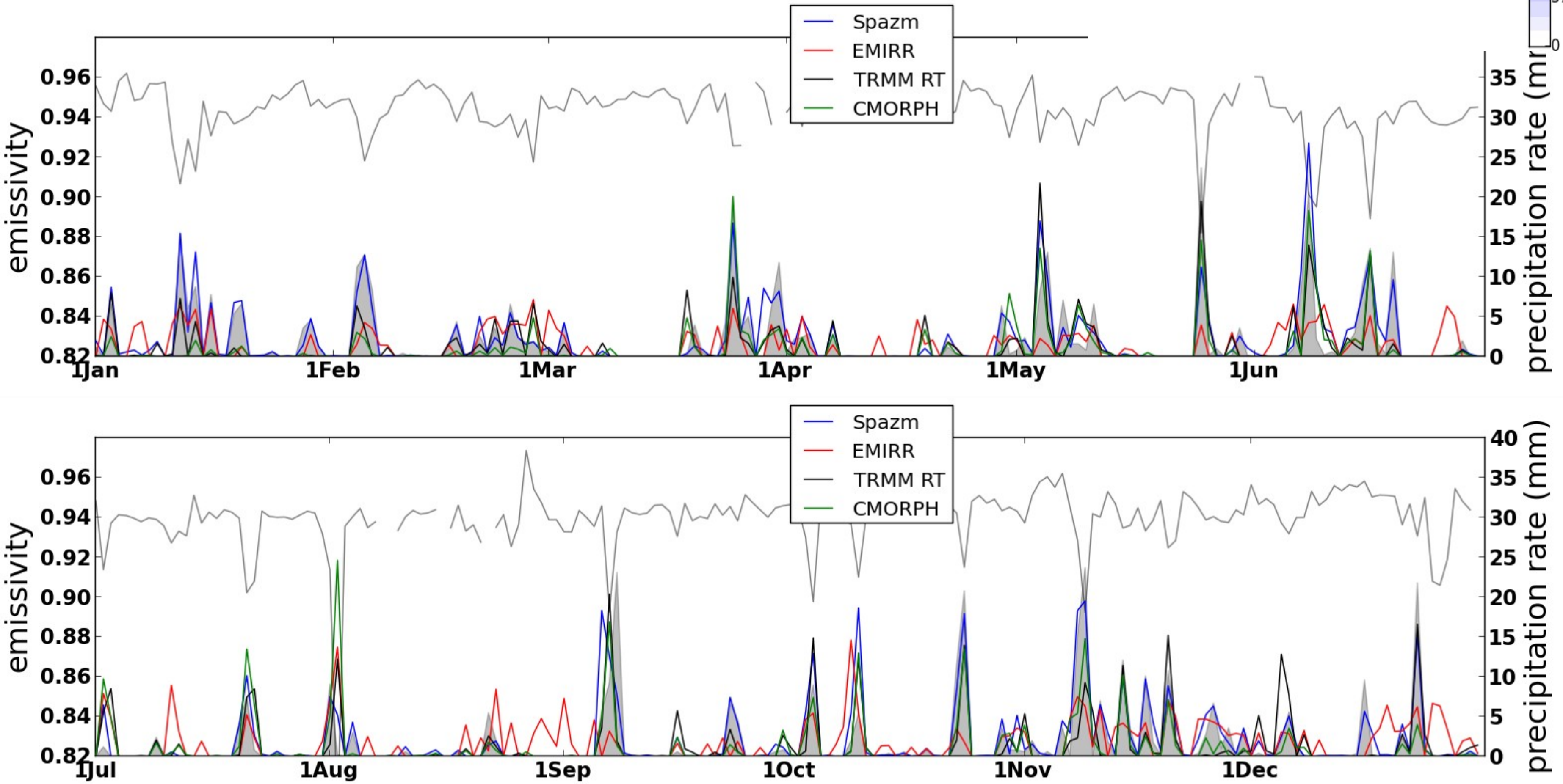
POD : Probability of Detection
FAR : False Alarm Ratio
HSS : Heidke Skill Score

Evaluation of results

Results: (2) Comparison with other satellites products

Time series of daily precipitations observed by rain gauges (grey) and retrieved by various products available over France (EMIRR, Spazm (Gottardi et al., 2012), CMORPH et TRMM-RT), near Agen

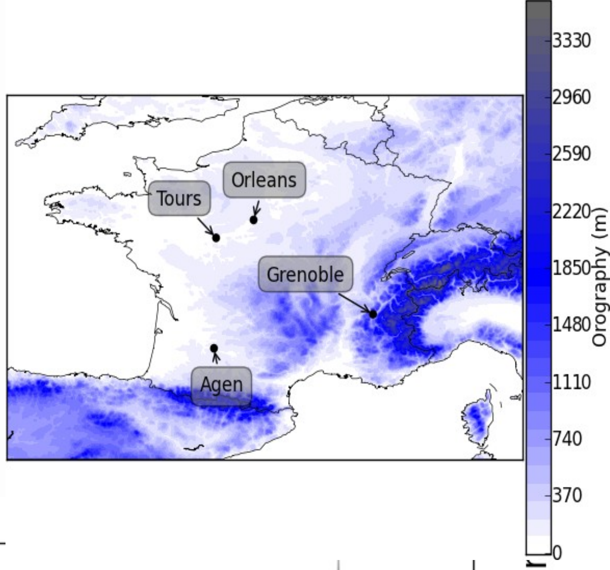


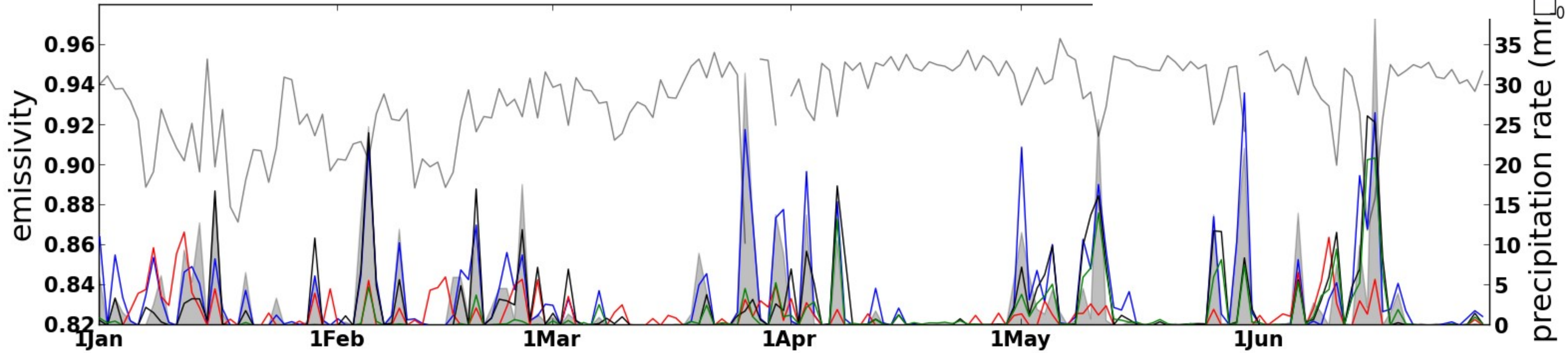


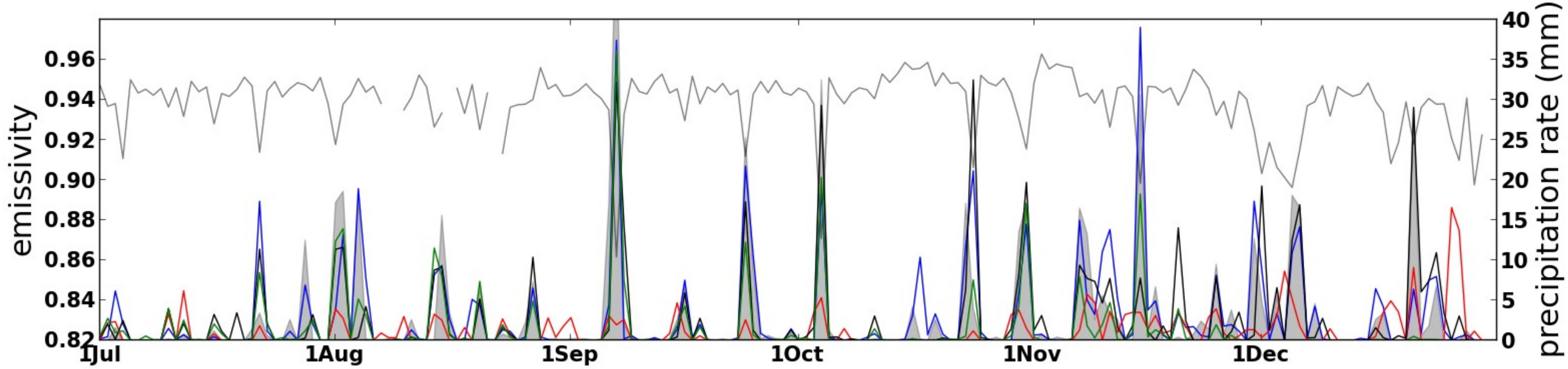
Evaluation of results

Results: (2) Comparison with other satellites products

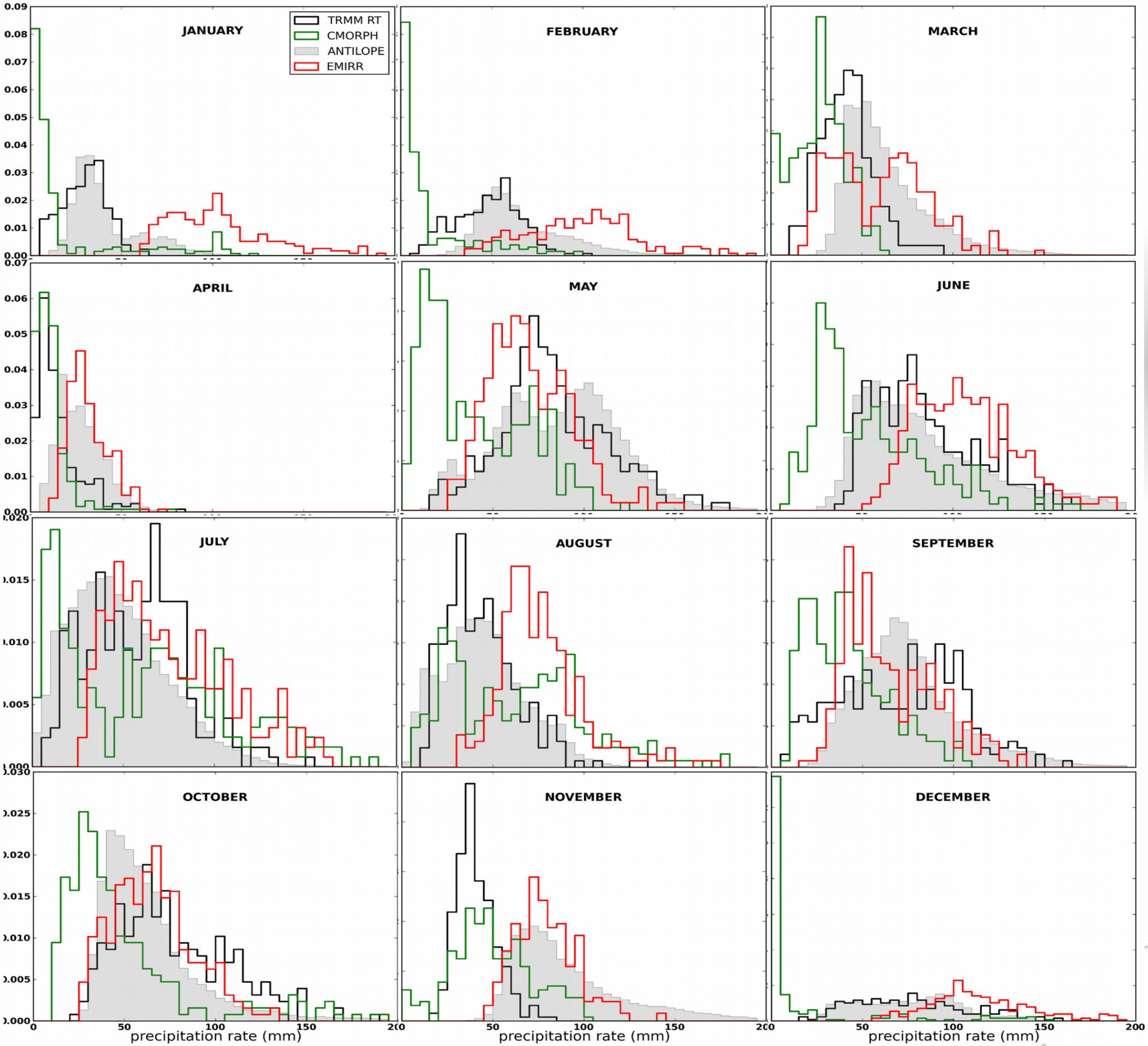
Time series of daily precipitations observed by rain gauges (grey) and retrieved by various products available over France (EMIRR, Spazm (Gottardi et al., 2012), CMORPH et TRMM-RT), near Grenoble







Evaluation of results



Histograms of monthly precipitation accumulations over the year 2010 over a large area (1°W-5°E, 44°N*48°N), with TRMM, CMORPH, EMIRR and ANTILOPE products.

Conclusion

Concluding remarks

- Encouraging results giving the relative simplicity of the algorithm
- Satisfactory results for rainfall events detection: good POD but some false alarms
- The algorithm under-estimates large rainfall amounts and over-estimates lower amounts: an appropriate bias correction procedure is necessary (based on rain gauges)
- Limitation over mountainous areas due to solid precipitation and snow on the ground
- A more sophisticated statistical method (neural network or variationnal method) could improve rainfall rates retrievals, incorporating a priori information (e.g. from high resolution Numerical Weather Prediction models).
- The algorithm can be applied to other regions of the world: development of a dynamical dry soil emissivity atlas as a function of soil type, emissivty-to-rainfall function depending on soil type

Birman, C., F. Karbou, J-F. Mahfouf, Daily rainfall detection and estimation over land using microwave surface emissivities, J. Appl. Meteor. Clim., 54.4 (2015): 880-895.

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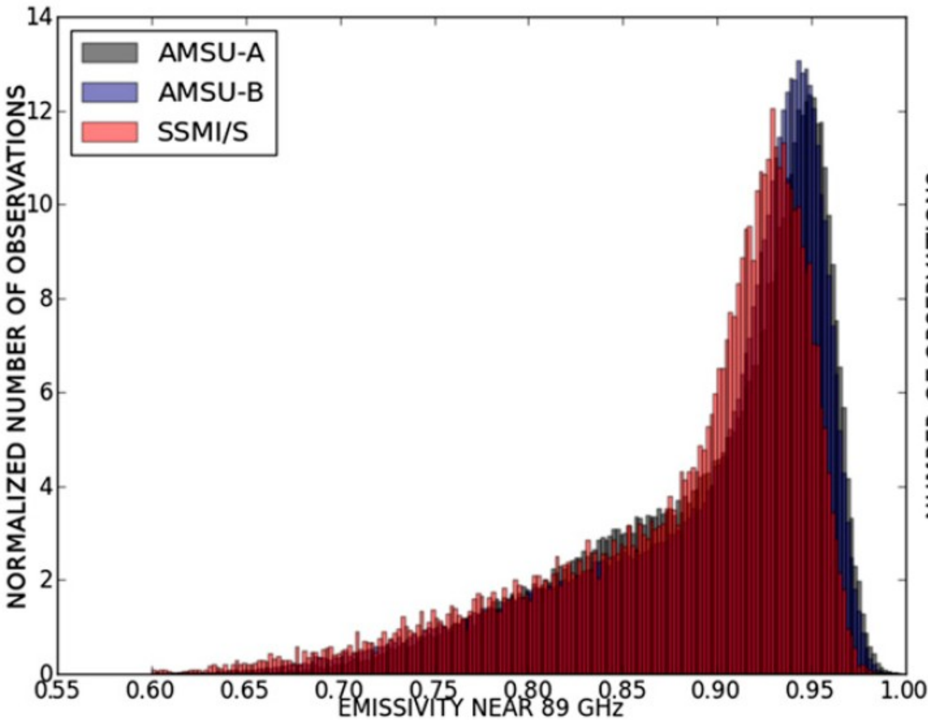
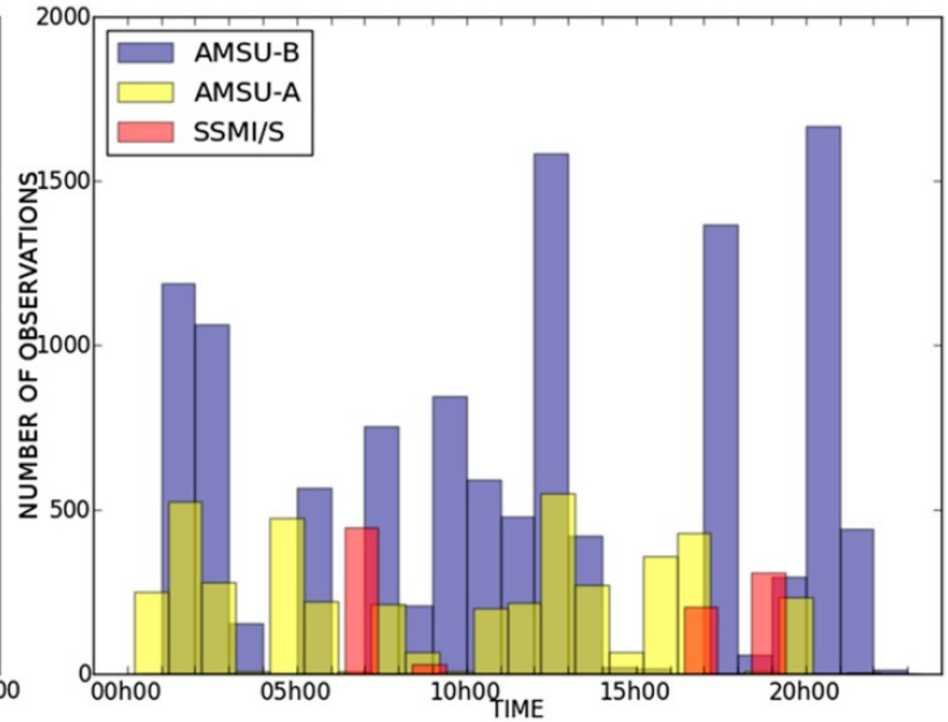
Questions?

Data and models

Microwave data

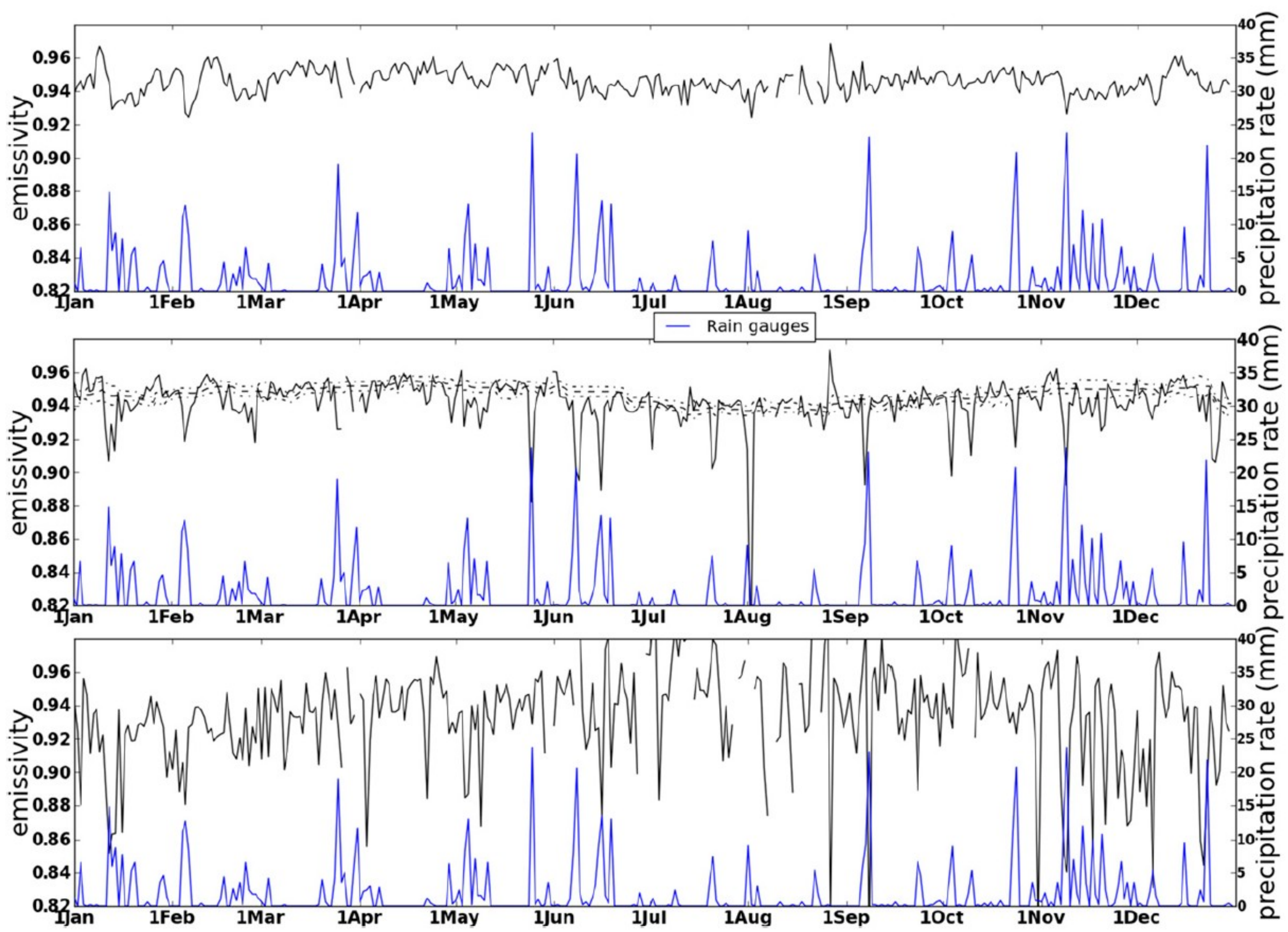
- Sampling of diurnal cycle





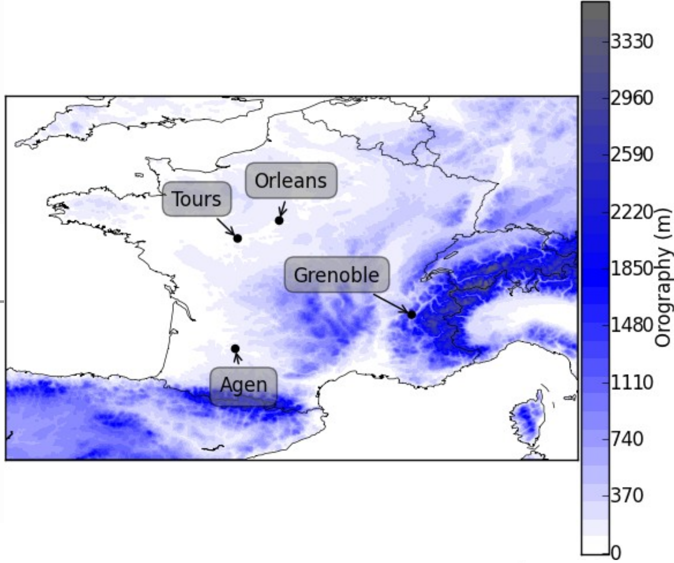
Left : Normalised histogram of emissivities at 89 GHz from AMSU-A and -B instruments and at 91 GHz from SSMI/S instrument, over the month of February 2010
Right : Daily distribution of observations at 89 GHz from AMSU-A, -B instruments and at 89 GHz from SSMI/S instrument on February 3, 2010

Data and model



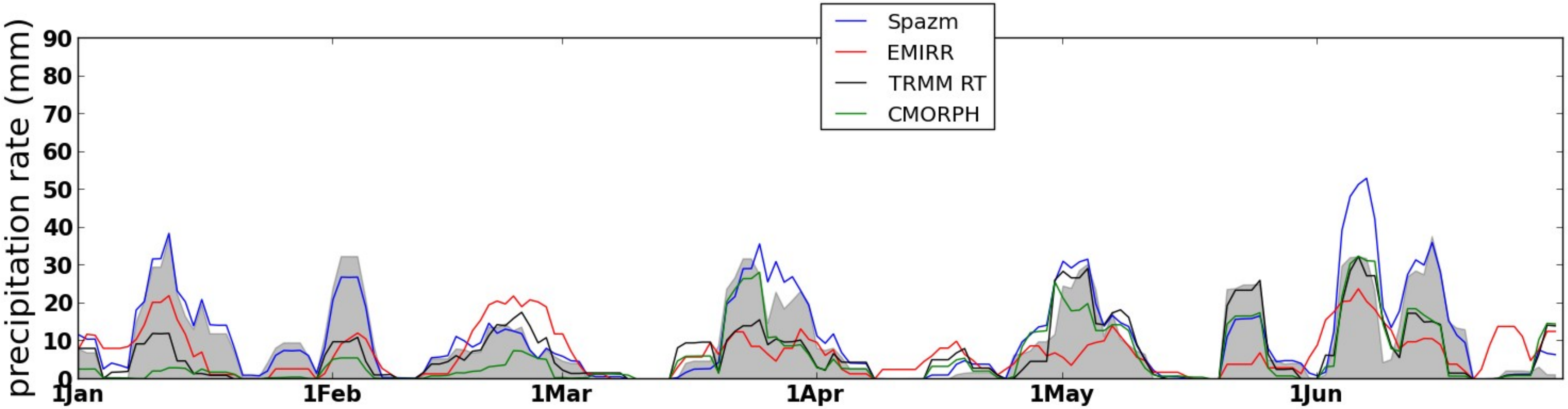
Time series of daily rainfall rate (blue) and daily emissivities (black) at 31 GHz from AMSU-A (top), 89 GHz from AMSU-B (middle) and 150 GHz from AMSU-B (bottom) over the year 2010 near Agen.

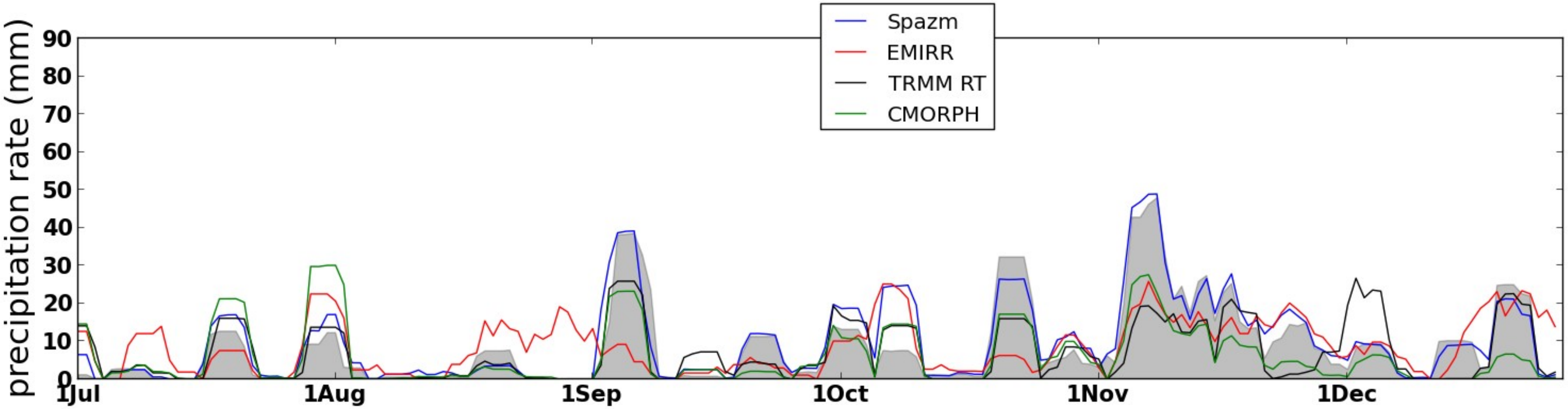
Evaluation of results (3/3)



Results: comparison against rain gauges

Agen





Estimation des précipitations journalières sur la France par radiométrie micro-onde

Résultats : (2) Comparaison à d'autres produits satellitaires

Séries temporelles des précipitations analysées par les pluviomètres (gris) et restituées par les différents produits disponibles sur la France (EMIRR, Spazm (Gottardi et al., 2012), CMORPH et TRMM-RT), près d'Agen