CLOUD PHYSICS BASED PRECIPITATION PRODUCTS FOR WEATHER AND CLIMATE APPLICATIONS

Rob Roebeling

Thanks to:
Marie Doutriaux-Boucher, Jan Fokke Meirink, and Erwin Wolters

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Content


Motivation

Role of precipitation in water balance

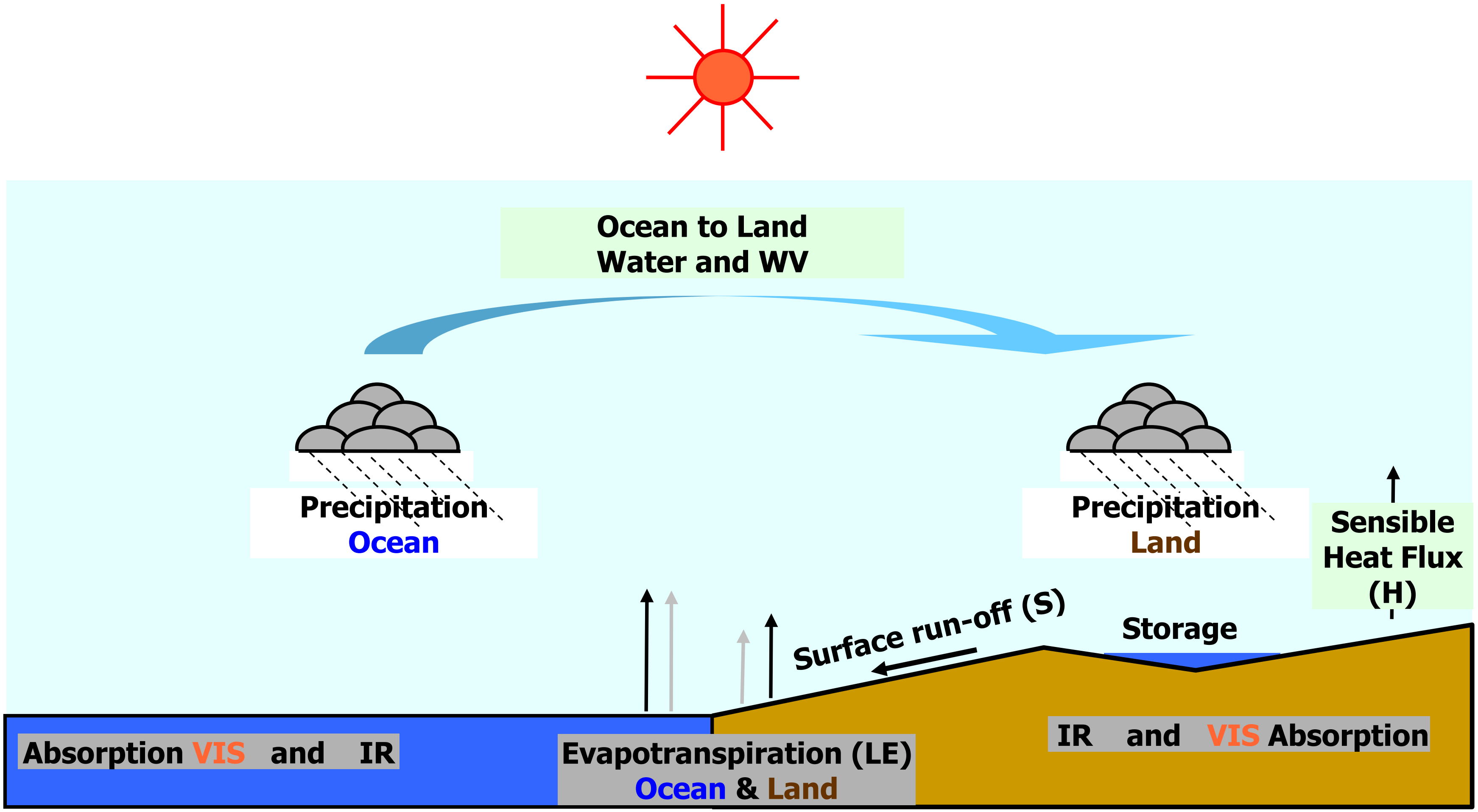


Figure: *Schematic representation of the role of clouds and precipitation in the water balance*

Basics of Cloud Physical Properties Retrievals

Cloud Physical Properties Retrieval (1/3)

Introduction

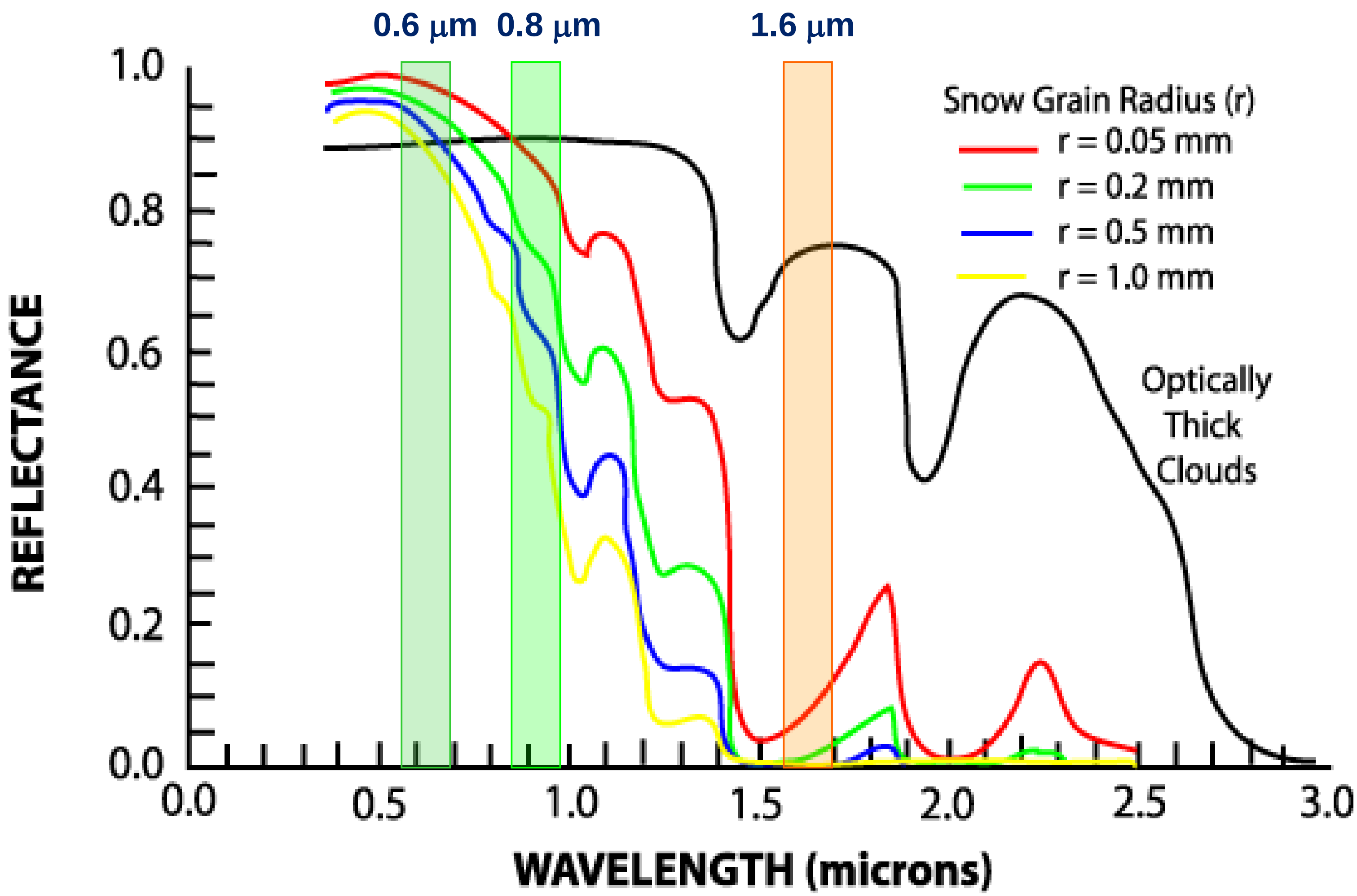
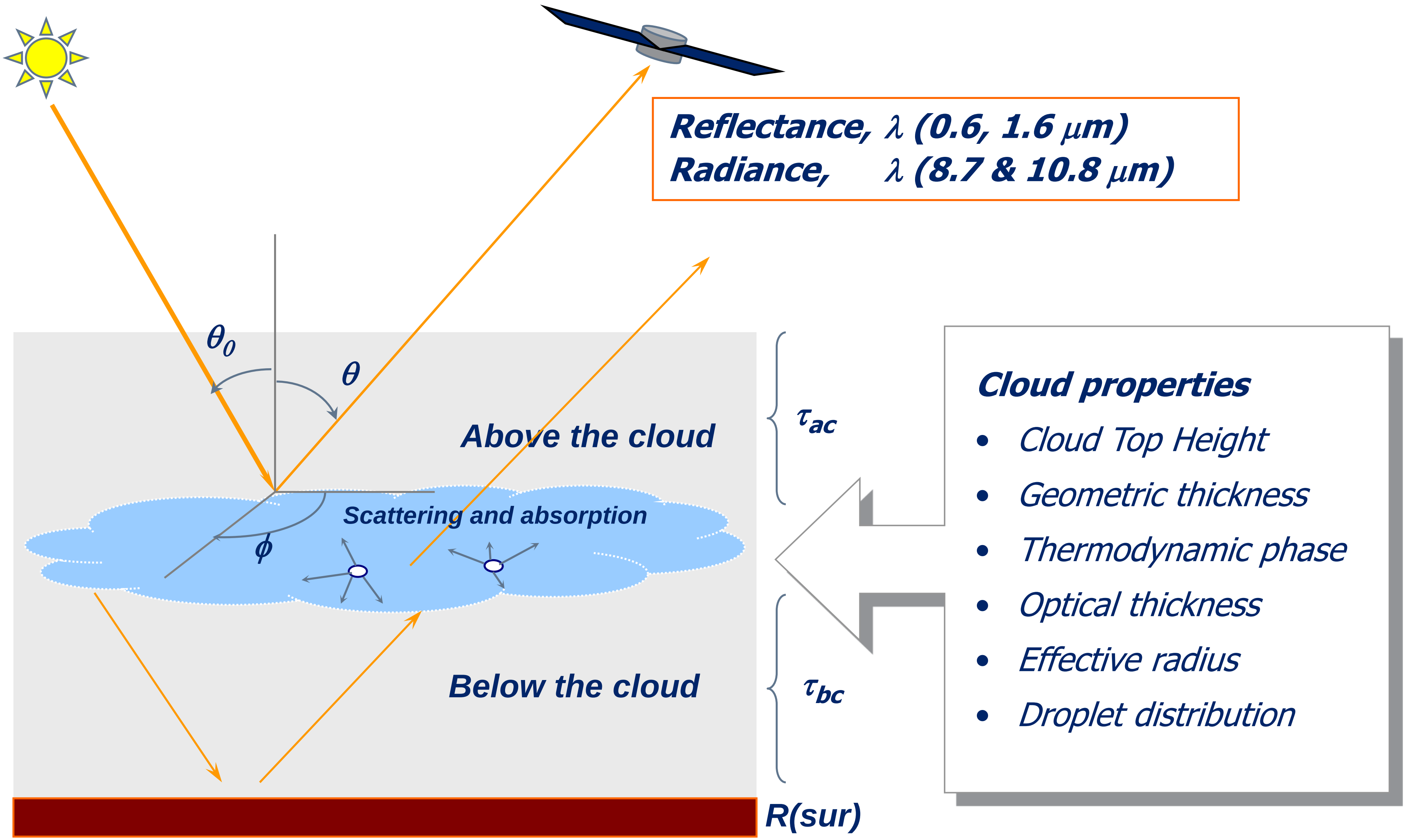


Fig. *Example spectra of snow surfaces, an ice-cloud and a water-cloud. The color blocks indicate the positions (and spectral width) of the SEVIRI Visible and Near-Infrared channels*

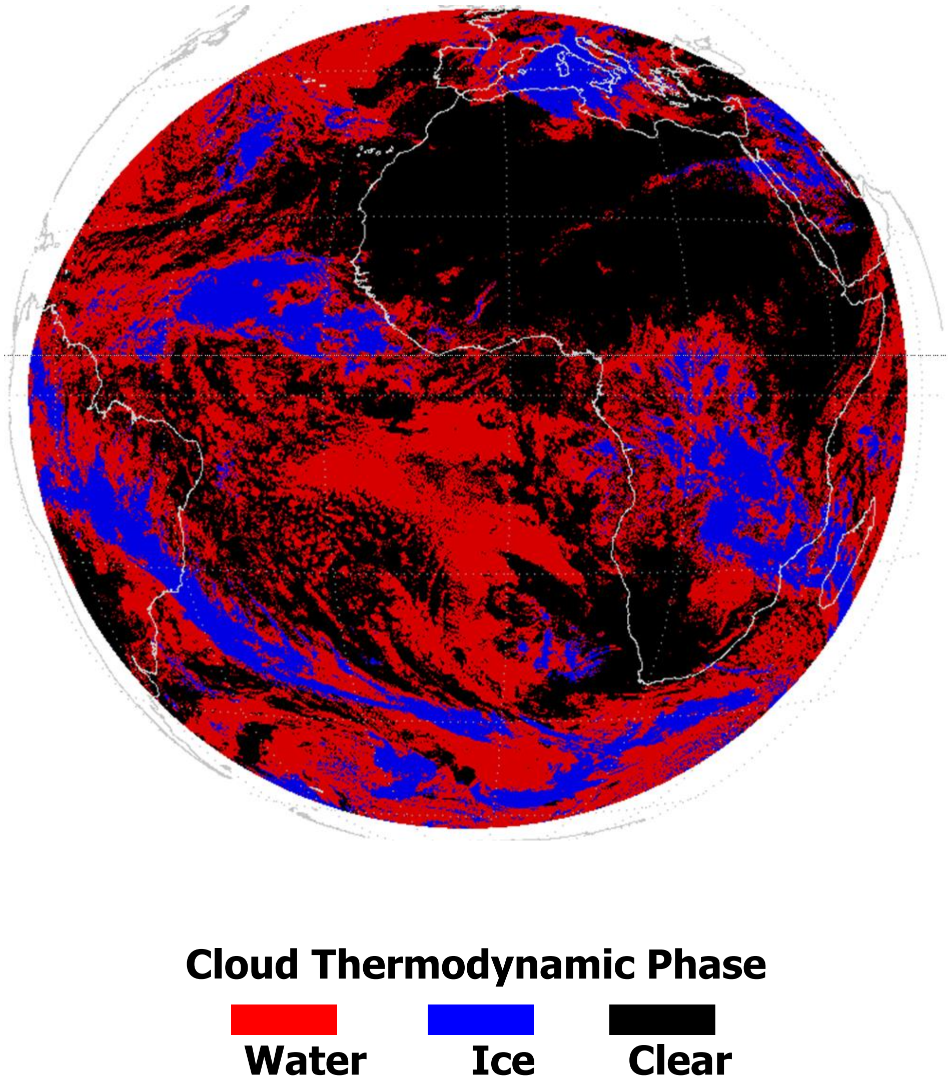
Cloud Physical Properties Retrieval (2/3)

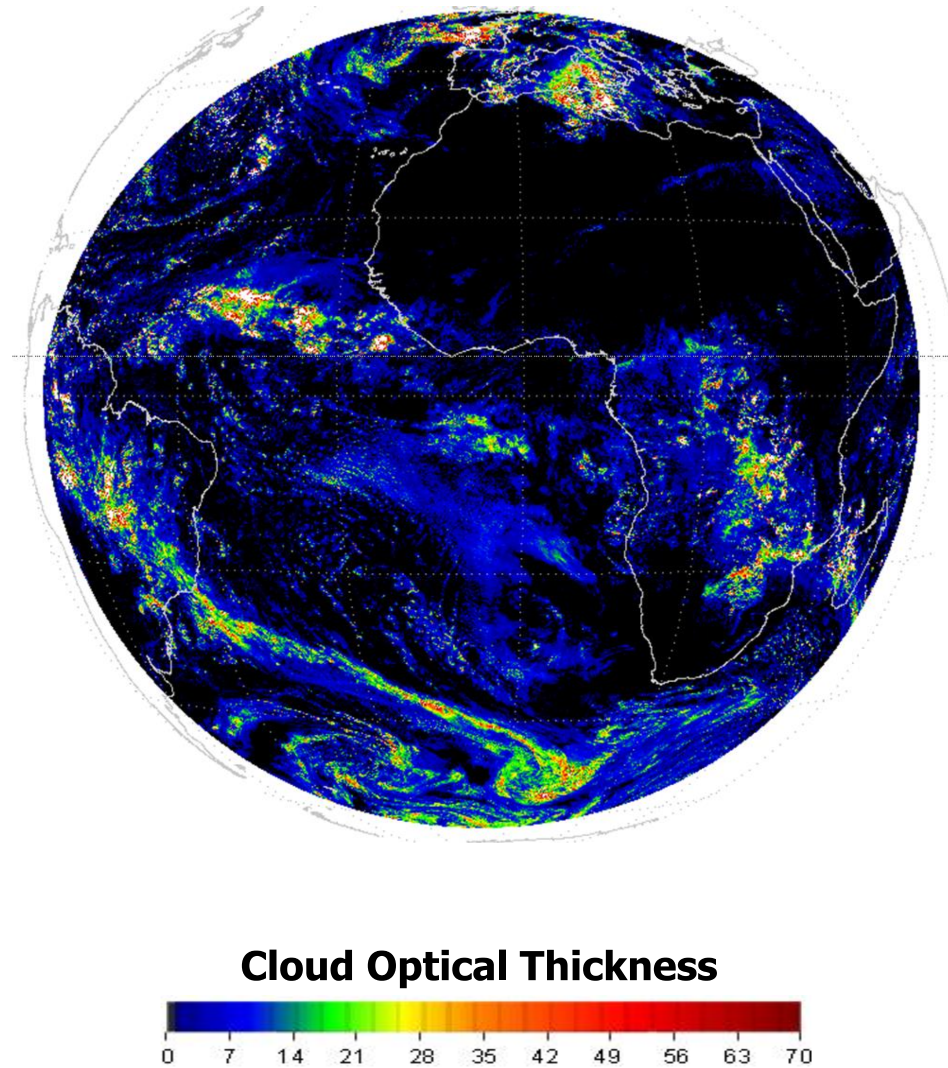
Principle

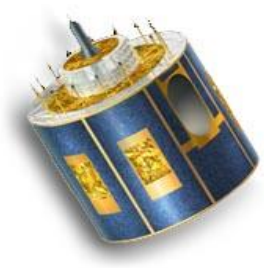


Cloud Physical Properties Retrieval (3/3)

Examples

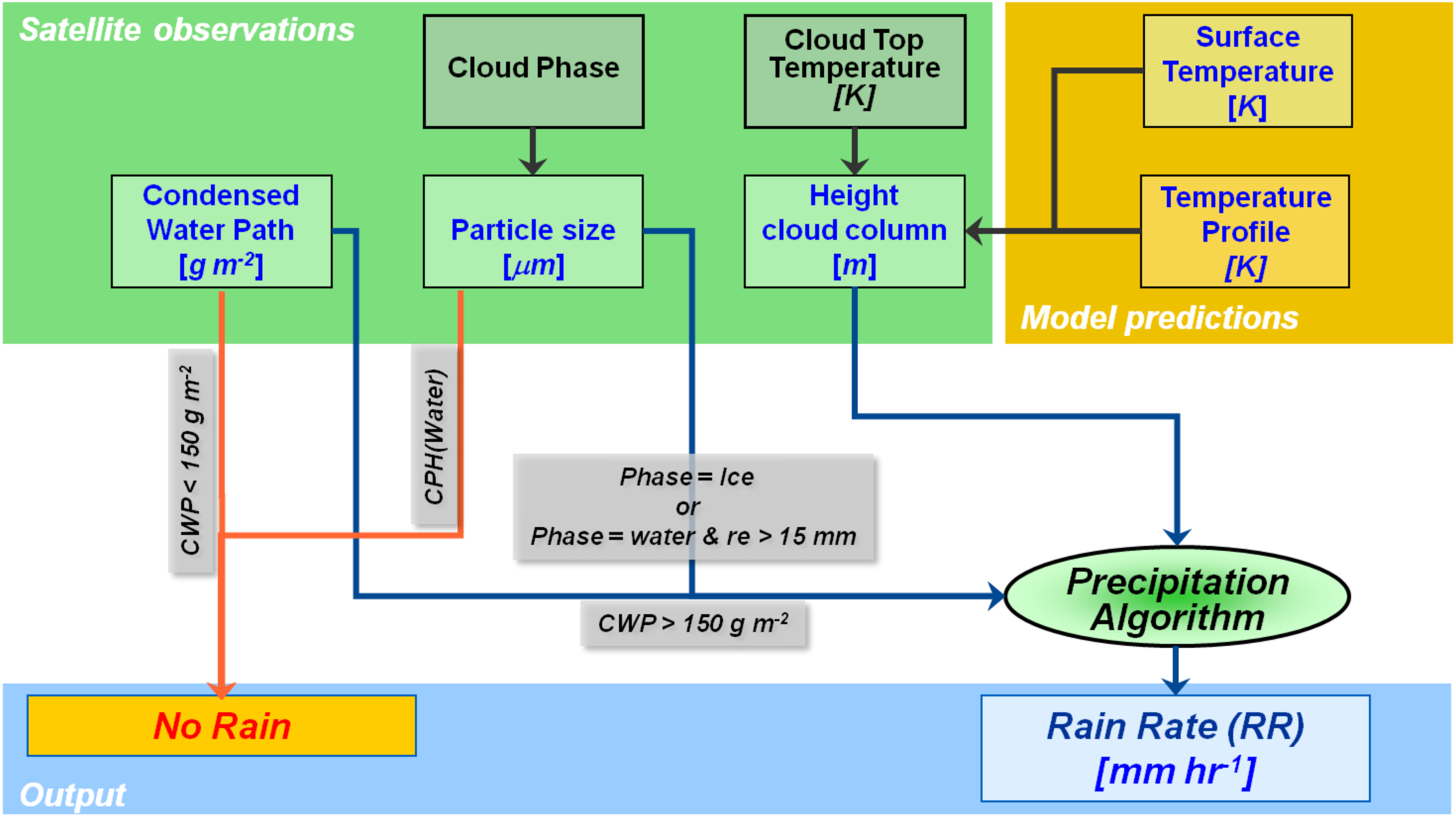






Basics of Cloud Physics based Precipitation retrieval

Cloud Physics based Precipitation Retrieval (1/3)



Cloud Physics based Precipitation Retrieval (2/3)

Step 1: Calculate height of rain column (H)

$$H = \frac{(CTT_{max} - CTT_{pix})}{6.5} + \Delta H$$

Step 2: Calculate maximum rain rate (R_{max})

$$R_{max} = \left[\frac{H}{C1}\right]^{1.6} + \Delta R$$

Step 2: Calculate cloud physics rain rate (R_{cpp})

$$R_{cpp} = \frac{C2}{H}\left[\frac{\mathrm{CWP} - \Delta\mathrm{CWP}}{\Delta\mathrm{CWP}}\right]^{1.6}$$

Step 3: Assign rain rate

If $R_{cpp} < R_{max}$ --> $R = R_{cpp}$

If $R_{cpp} > R_{max}$ --> $R = R_{max}$

Where

ΔH	: Offset height rain column	[km]
ΔR	: Offset rain rate	[mm hr^{-1}]
ΔCWP	: Offset Condensed Water Path	[g m^{-2}]
C1	: Constant	[hr]

Where

CTT_{pix}	: Cloud Top Temperature pixel	[K]
CTT_{max}	: Cloud Top Temperature maximum	[K]
CWP	: Condensed Water Path	[g m^{-2}]
C2	: Constant	[km^2 hr^{-1}]

Roebeling and Holleman (2009), JAMC

Cloud Physics based Precipitation Retrieval (3/3)

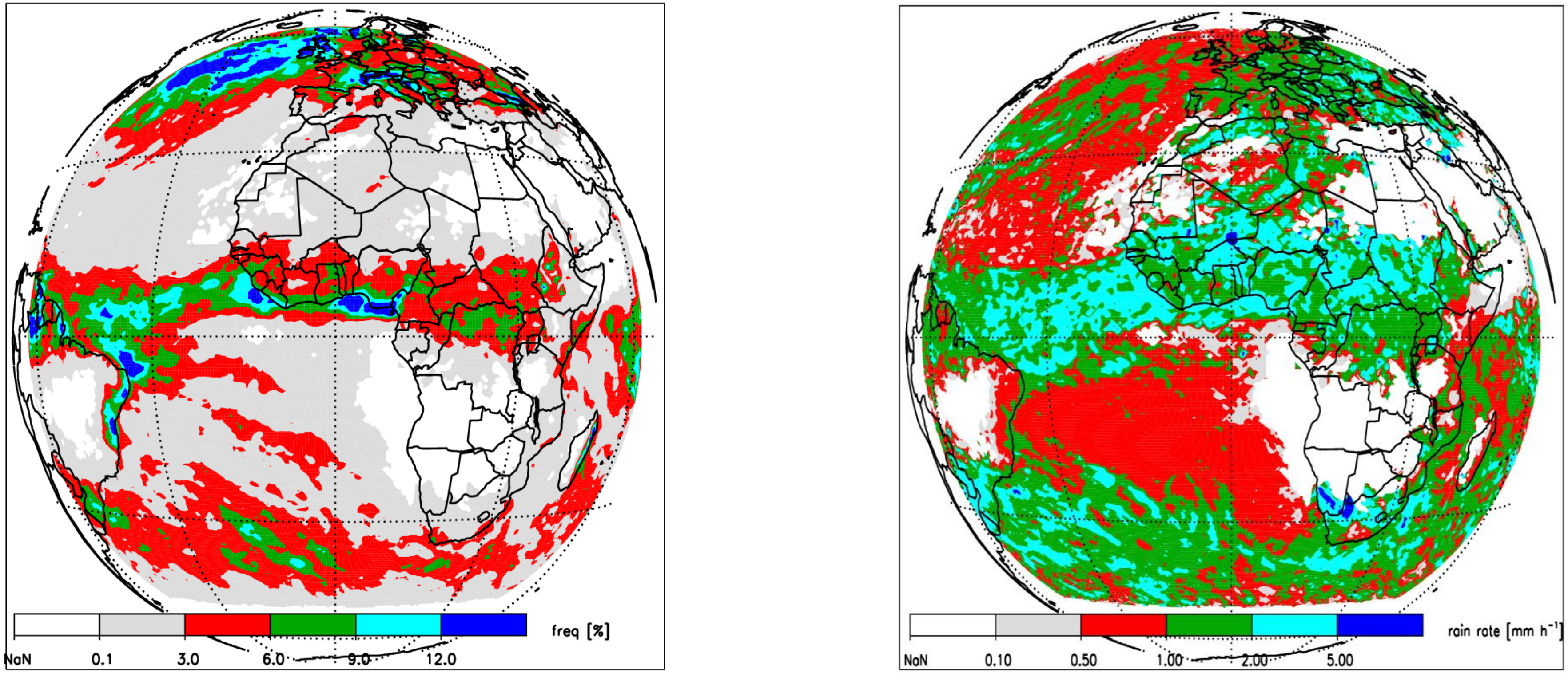


Fig. *Example of monthly precipitation occurrence (left) and precipitation intensity (right) for July 2008*

Validation

How to validate satellite retrievals?

Validation activities

- Comparison against ground-based observations;
- Comparison against retrievals of other providers;
- Comparison against other instruments
  (e.g. GPM, Weather Radar)

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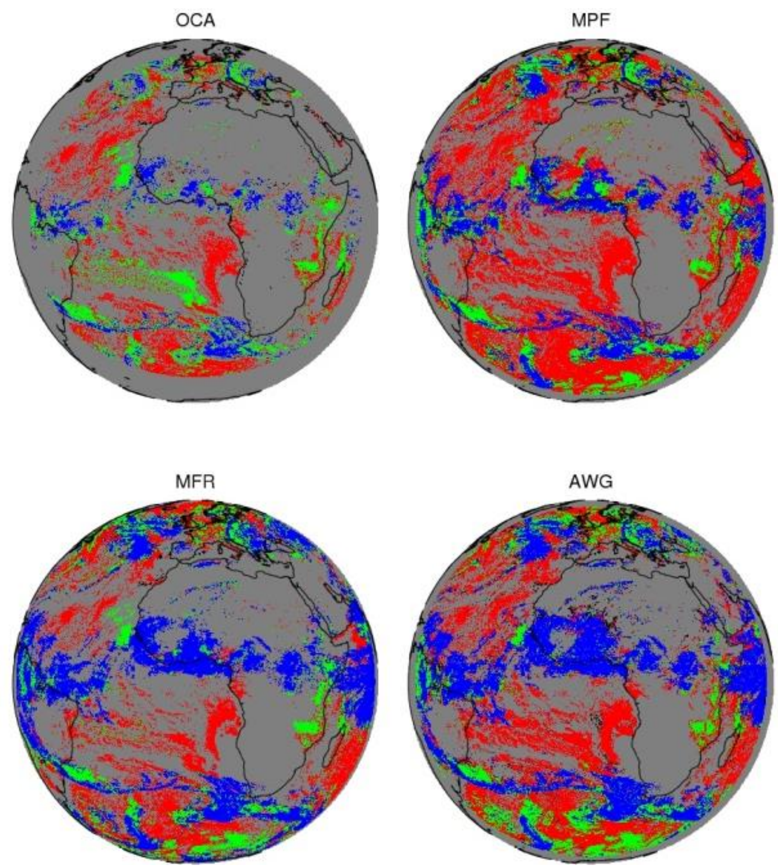

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How to validate satellite retrievals?

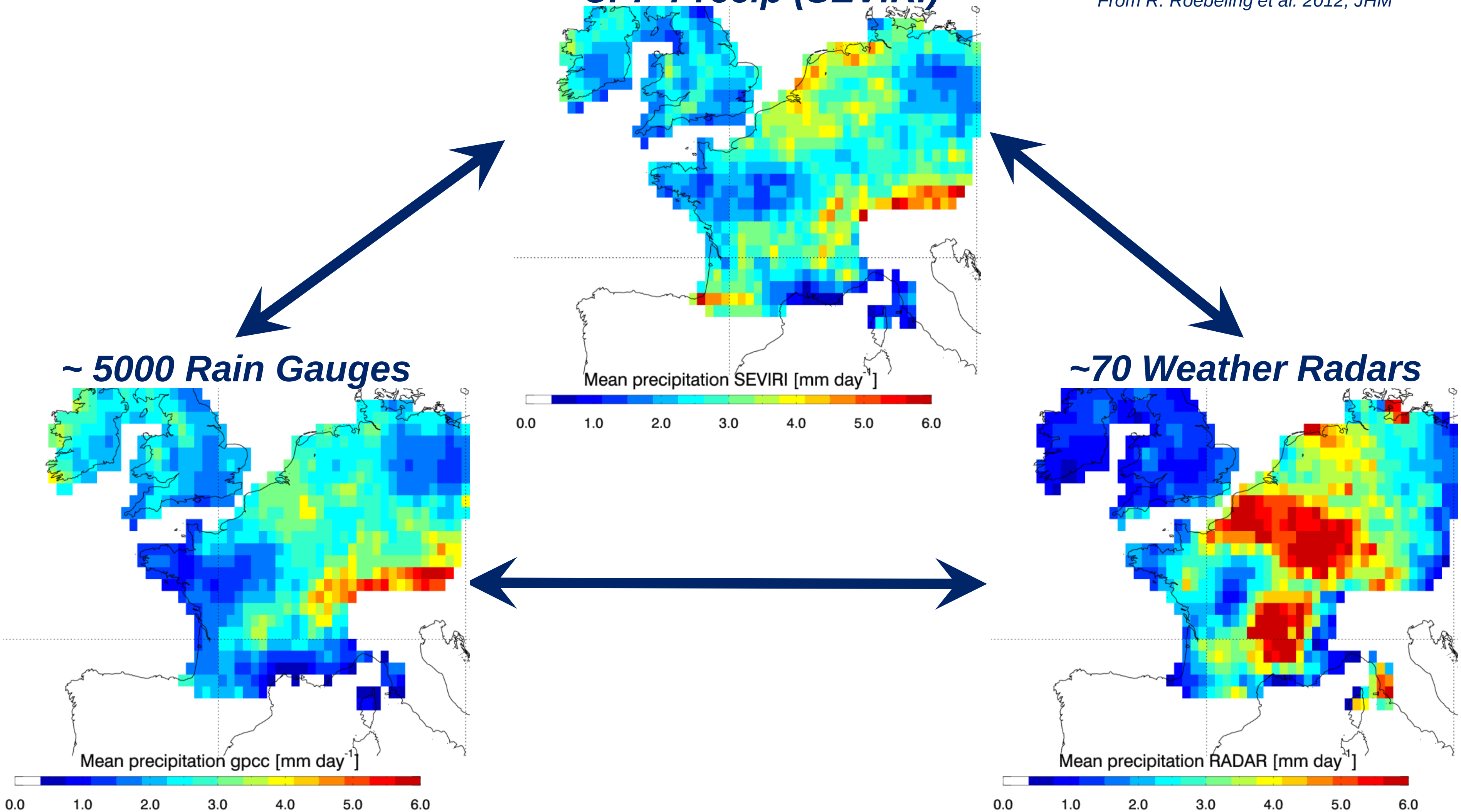
Validation activities

- Comparison against ground-based observations;
- Comparison against retrievals of other providers;
- Comparison against other instruments *(e.g. GPM, Weather Radar)*

Triple Collocation
Introduction

Mean daily precipitation during May-August 2006
From R. Roebeling et al. 2012, JHM

CPP-Precip (SEVIRI)



Triple Collocation
Spatial Triple Errors

Instr	*Mean*	*Max*	*Std*	*Err*	*RMSE*	*Correl*
			2005			
GPCC	2.22	6.82	0.91	0.47	2.39	1.00
ECA	1.88	6.33	0.81	0.16	2.39	0.93
RADAR	2.70	24.89	1.71	6.01	2.39	0.18
SEVIRI	2.71	6.74	0.88	0.75	2.39	0.86
			2006			
GPCC	2.39	6.43	0.88	0.59	2.55	1.00
ECA	2.07	5.92	0.79	0.66	2.55	0.94
RADAR	2.92	16.76	1.69	2.26	2.55	0.39
SEVIRI	2.61	6.23	0.82	0.47	2.55	0.80
			2007			
GPCC	3.35	7.84	0.94	0.48	3.49	1.00
ECA	2.99	7.22	0.82	0.52	3.49	0.92
RADAR	3.57	12.34	1.78	3.23	3.49	0.29
SEVIRI	2.72	8.83	0.91	0.61	3.49	0.79

Triple Collocation
Temporal Triple Errors

Rain Gauge (E-OBS) | **CPP-Precip (SEVIRI)** | **EU Weather Radars**

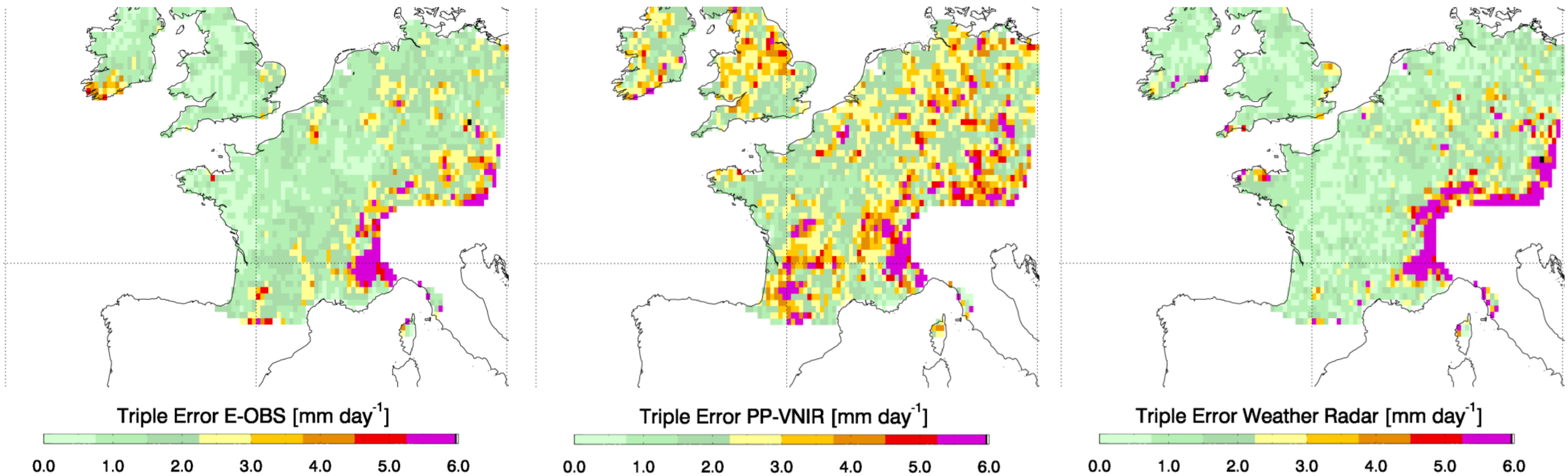


Fig: *Temporal Triple Errors for Weather Radars, CPP-Precip and E-OBS based on 10-day variations during May-August 2006, 2006, and 2007*

E-OBS: Gridded preciptation dataset from KNMI

R. Roebeling et al. 2012, JHM

Triple Collocation
Temporal Cross Correlations

Rain Gauge (E-OBS) **CPP-Precip (SEVIRI)** **EU Weather Radars**

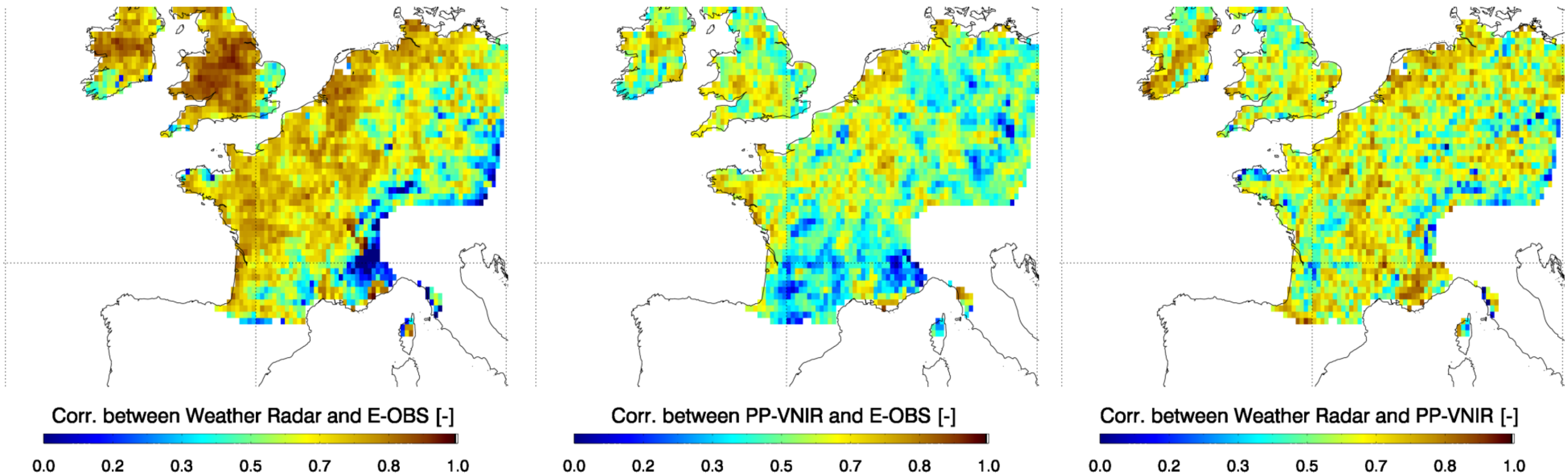


Fig: *Correlations between Weather Radars, CPP-Precip and E-OBS based on 10-day variations during May-August 2006, 2006, and 2007*

E-OBS: Gridded preciptation dataset from KNMI

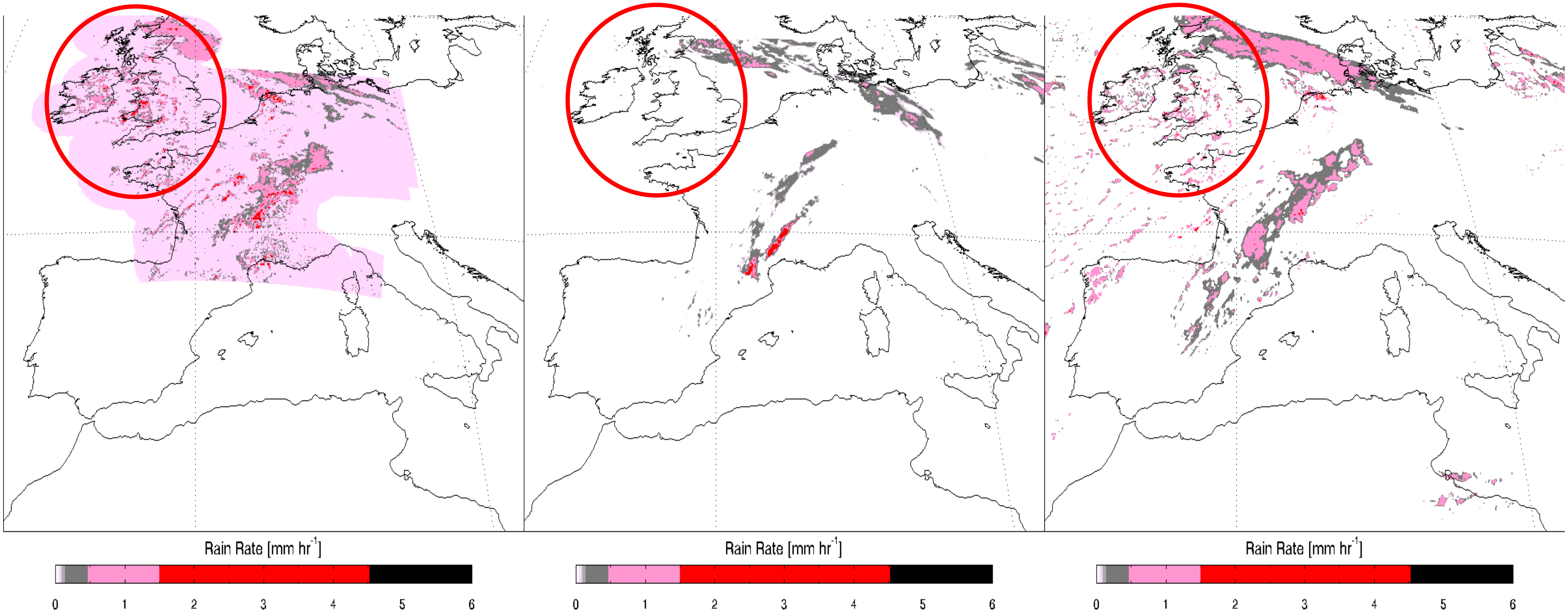
R. Roebeling et al. 2012, JHM

Weather Applications

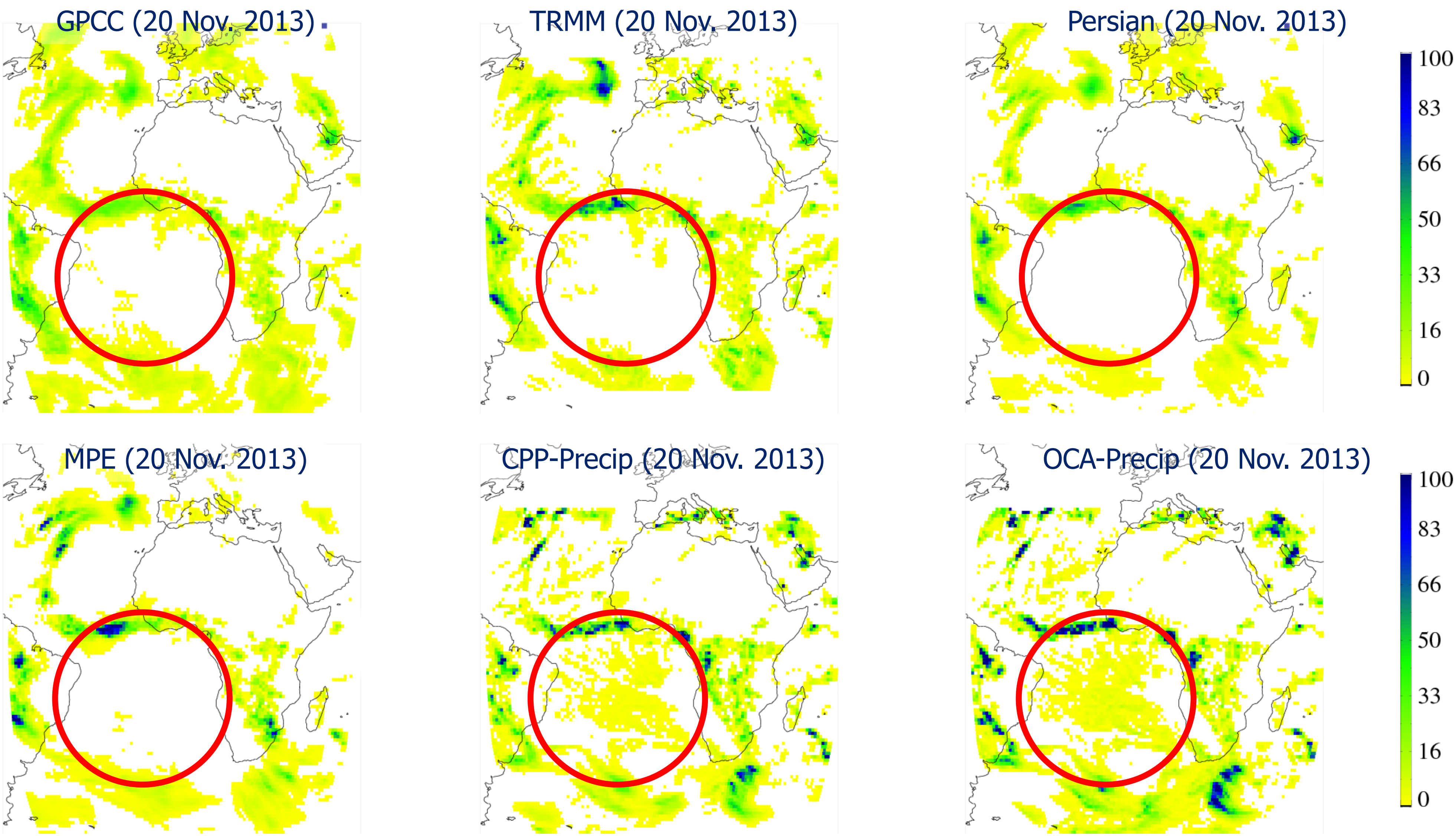
Shallow Convective Precipitation

Diurnal cycle 1 July 2007

Weather Radar ***EUMETSAT-MPE (SEVIRI)*** ***CPP-Precip (SEVIRI)***



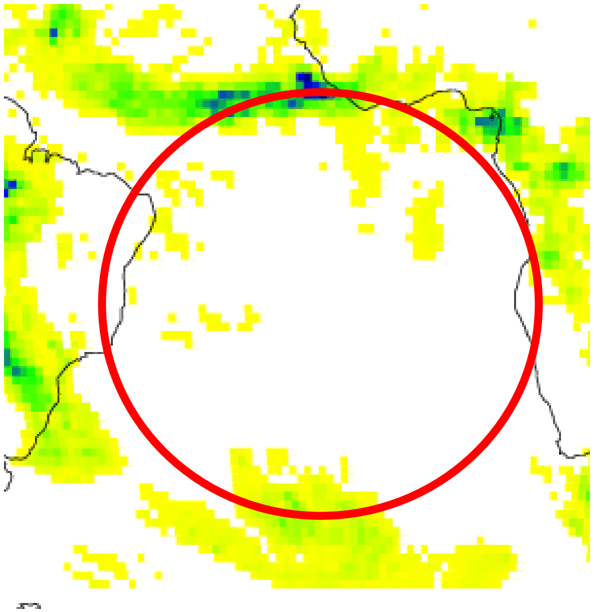
Trade Cumulus Precipitation



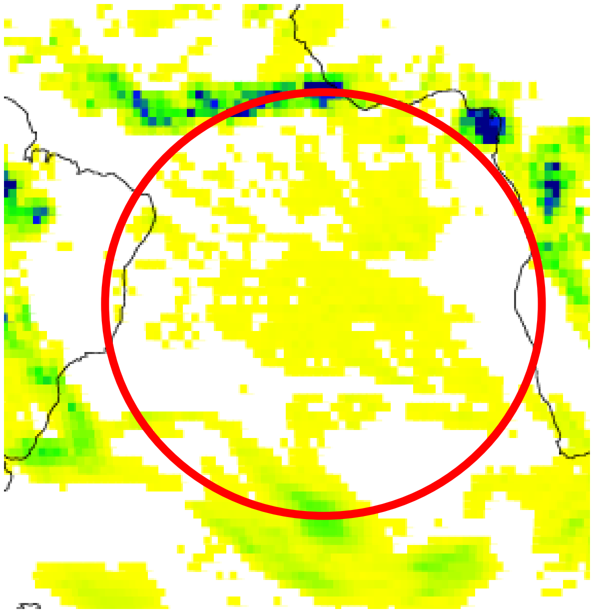
Trade Cumulus Precipitation

Daily mean precipitation - 20 November 2013

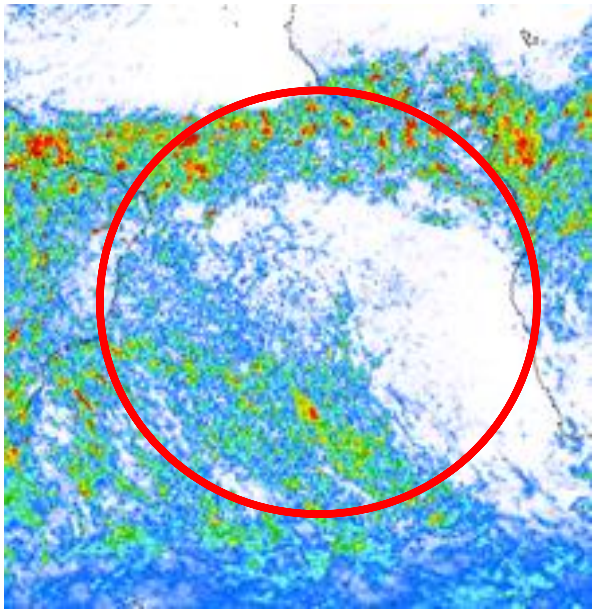
TRMM



CPP-Precip (SEVIRI)



GPM (Example)

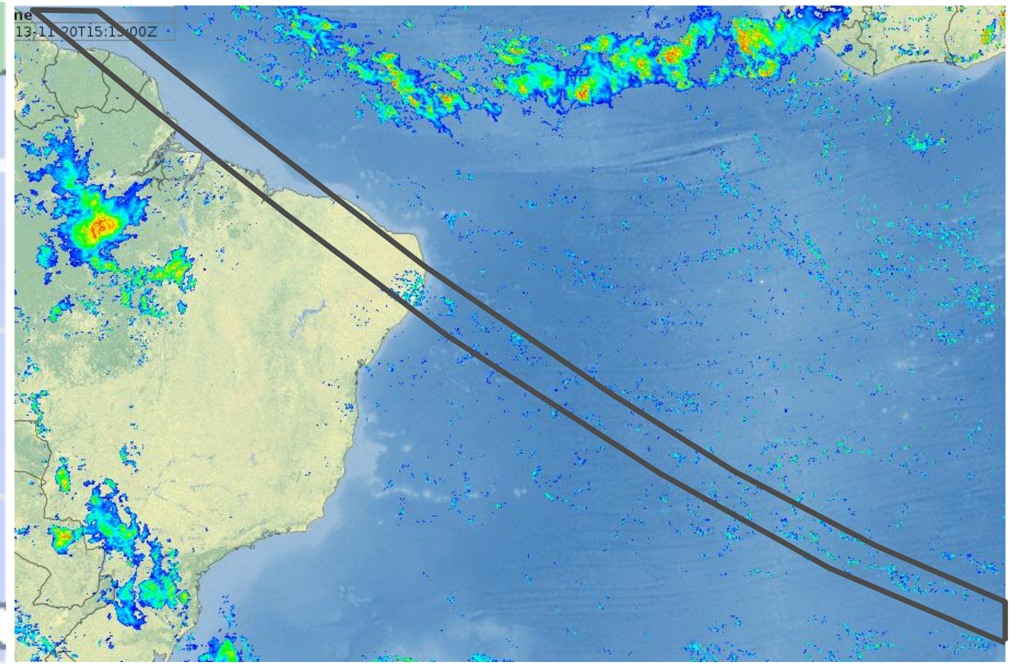


Passive Microwave and Passive Infra-red instruments have difficulties to detect the occurrence and retrieve rain rates of shallow (warm) rain systems.

Trade Cumulus Precipitation

Quick look
GPM
20 November 2013

Quick look
CPP-Precip (SEVIRI)
20 November 2013



CPP-Precip (SEVIRI) has sufficient spatial resolution and sensitivity to detect shallow (warm) rain systems.

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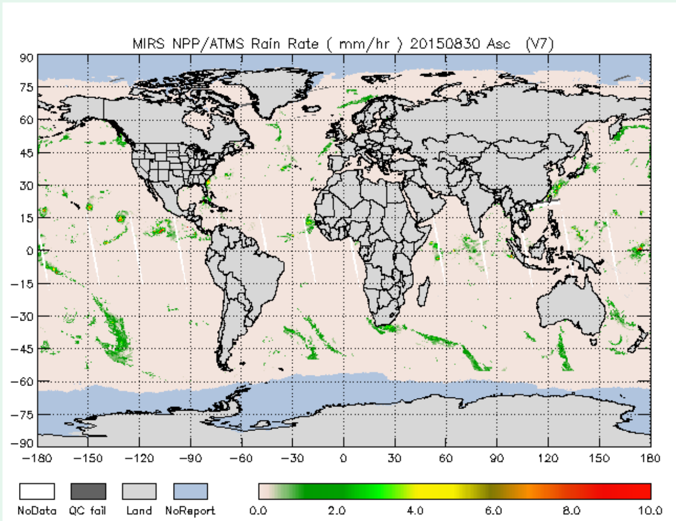
VIIRS Night time retrievals

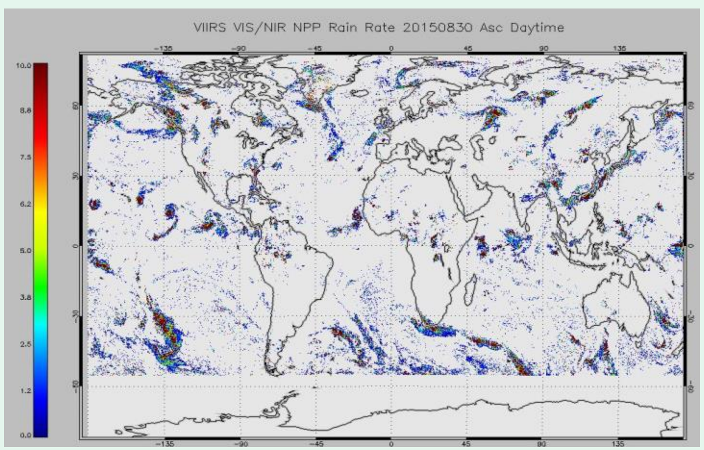
Courtesy: A. Walther (CIMSS)

Day time Rain Rate

ATMS/MIRS rain rate

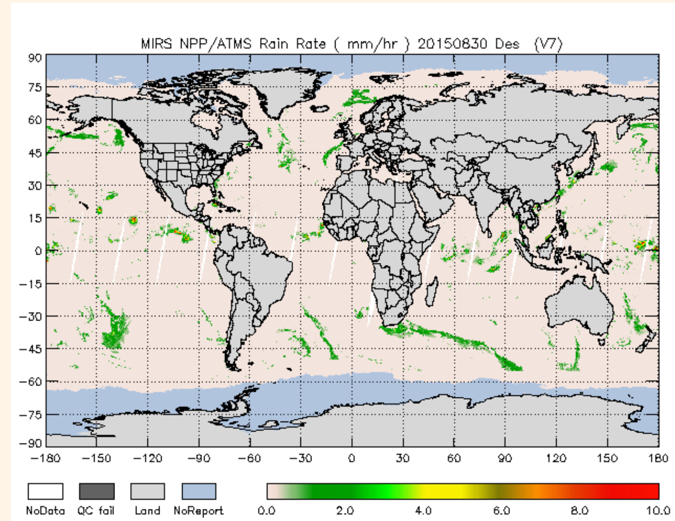


VIIRS VIS/NIR method

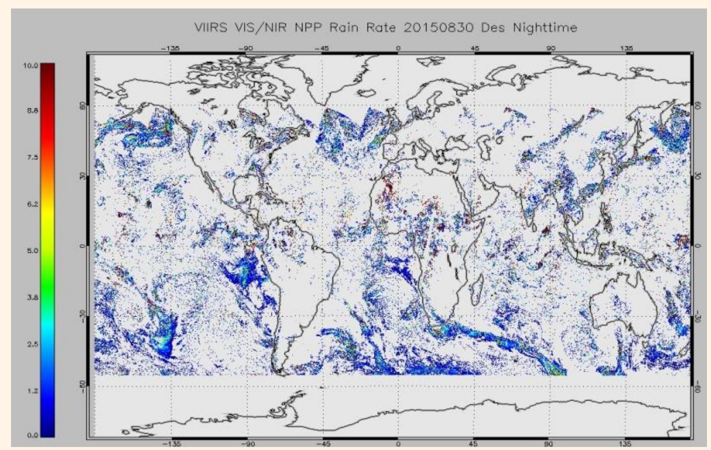


Night time Rain Rate

ATMS/MIRS rain rate



VIIRS VIS/NIR method



VIIRS Night time retrievals

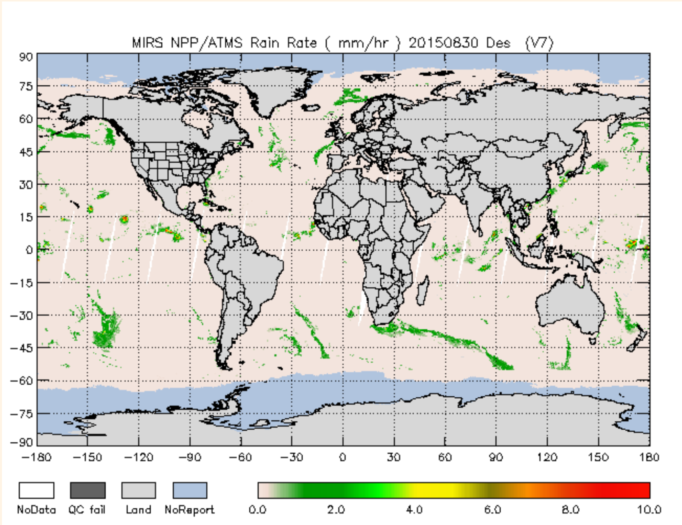
Courtesy: A. Walther (CIMSS)

- **Preliminary results reveal that the night-time visible and near-infrared channels on the VIIRS instrument, based on Moonlight, may be used to detect (and retrieve) rain;**

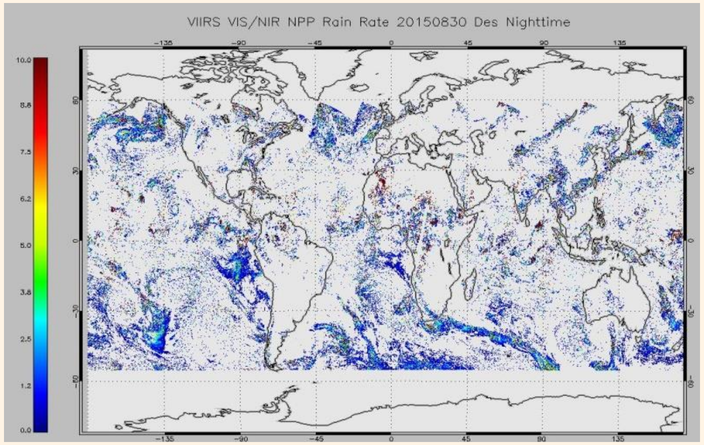
- **Further works is ongoing at CIMMS to refine the VIS/NIR night-time retrievals.**

Night time Rain Rate

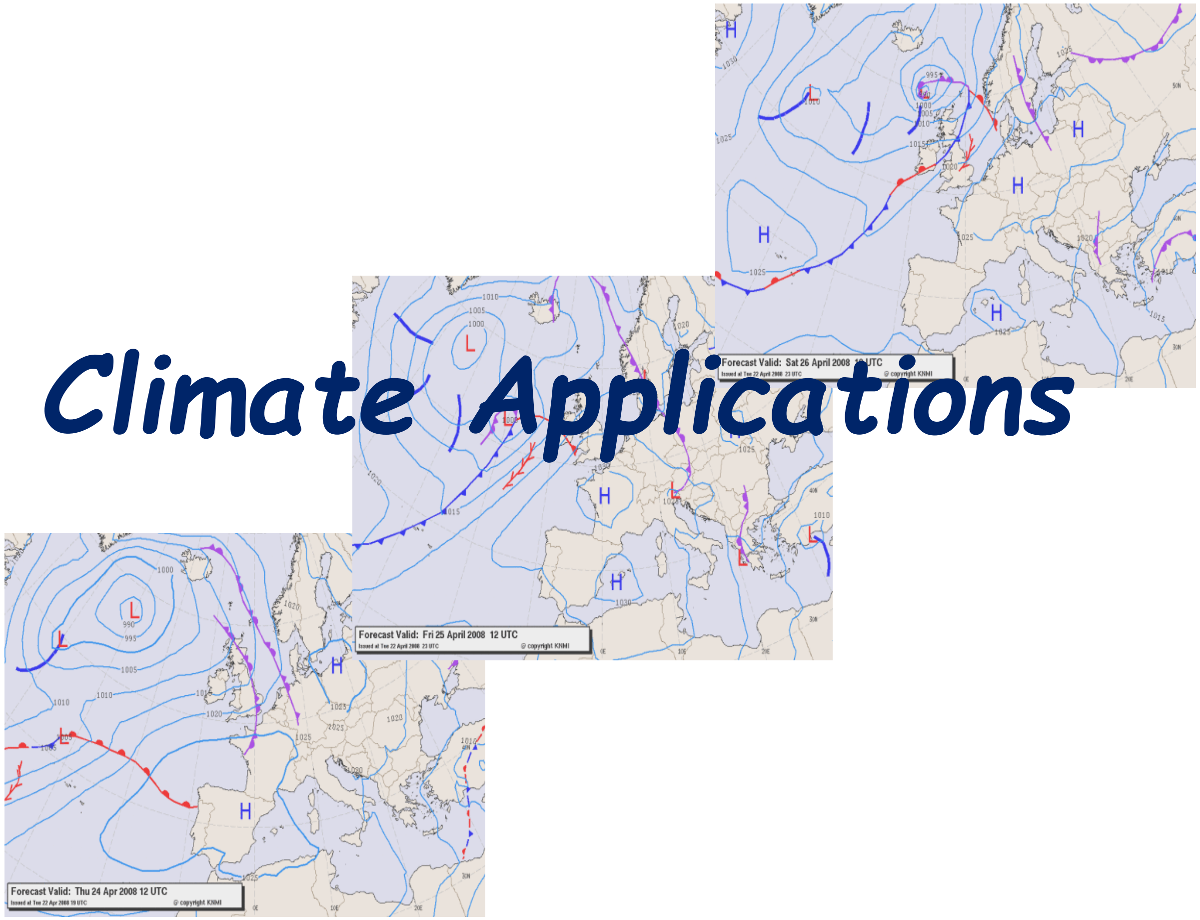
ATMS/MIRS rain rate



VIIRS VIS/NIR method



Climate Applications



Model Evaluation
Precipitation parameterization

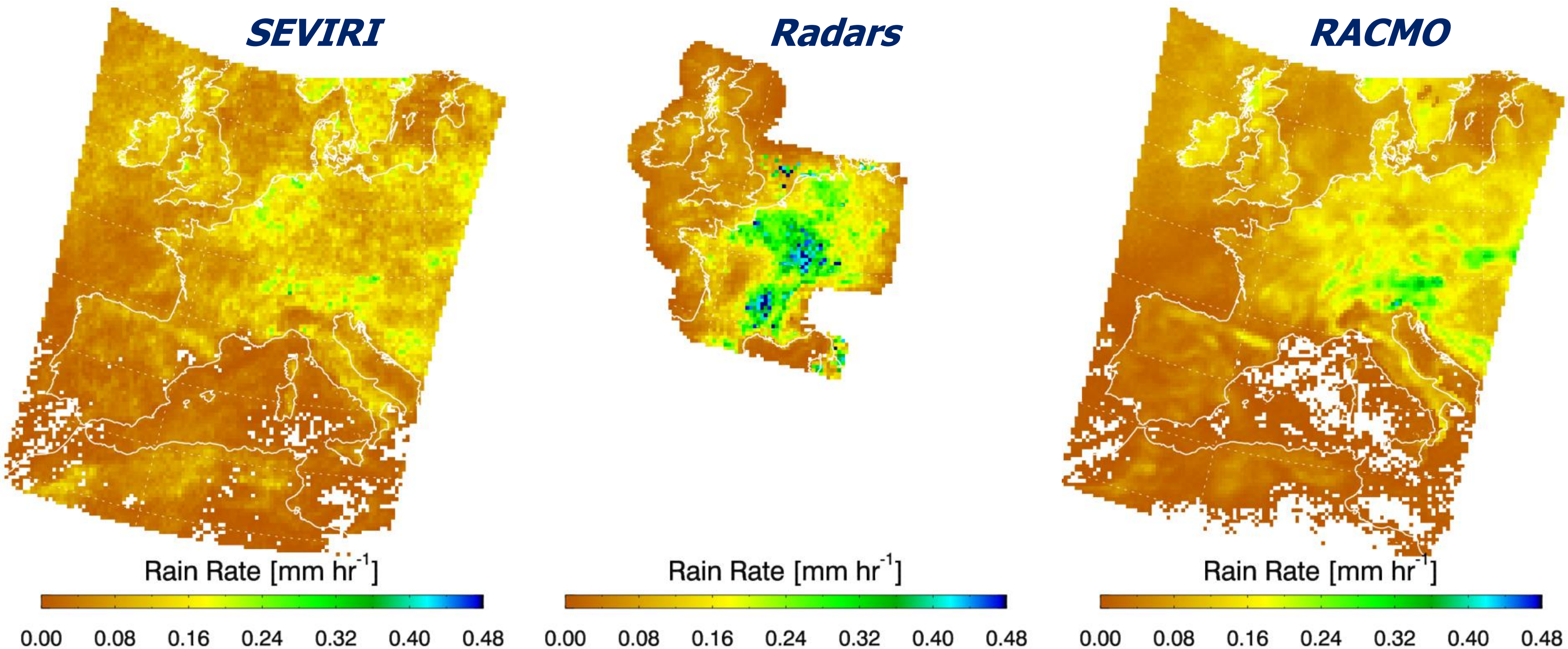


Fig: *SEVIRI, Weather Radars, and RACMO mean rain rate during May – Sept 2006*

Model Evaluation
Precipitation parameterization

Ocean
May-Sept 2006

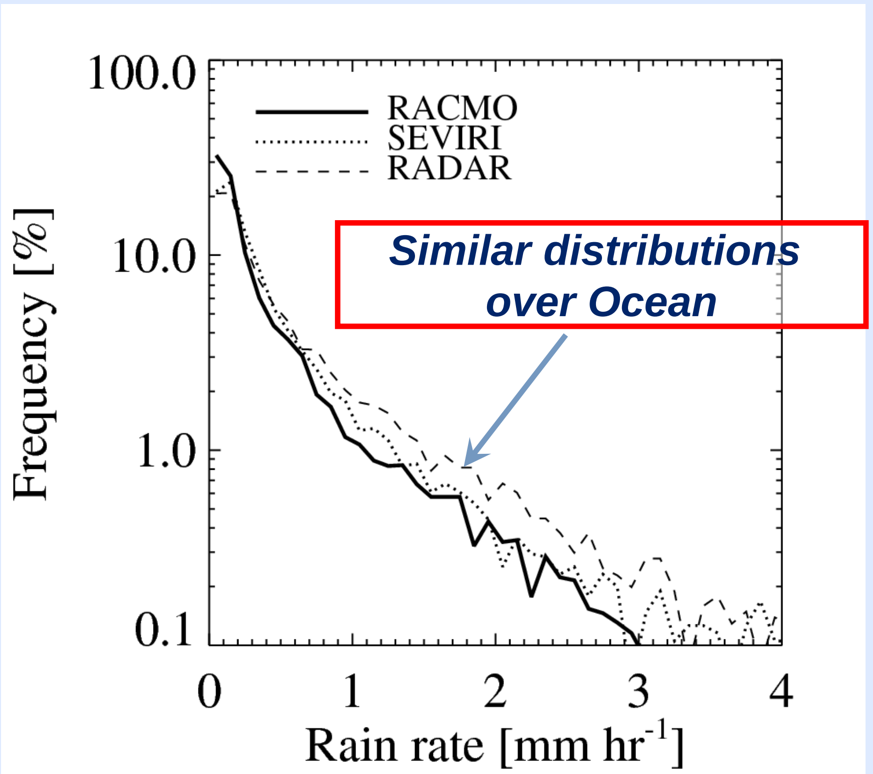
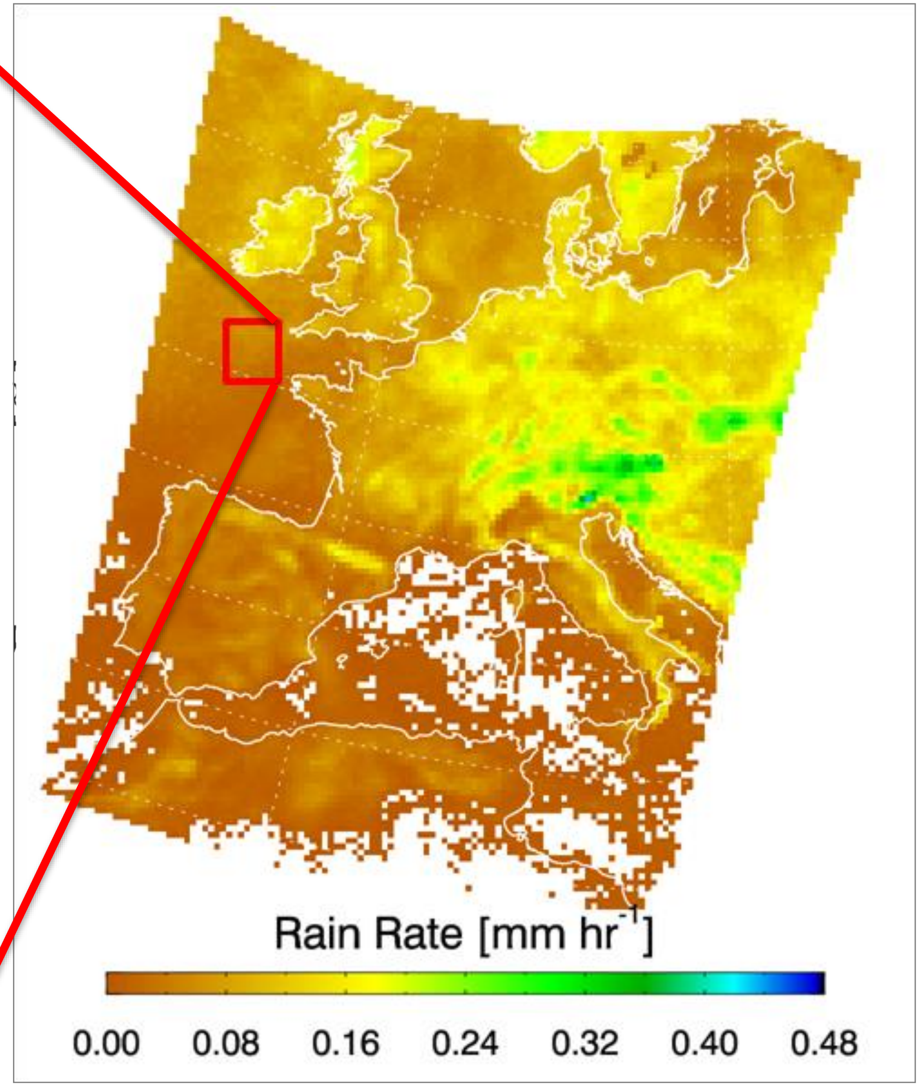
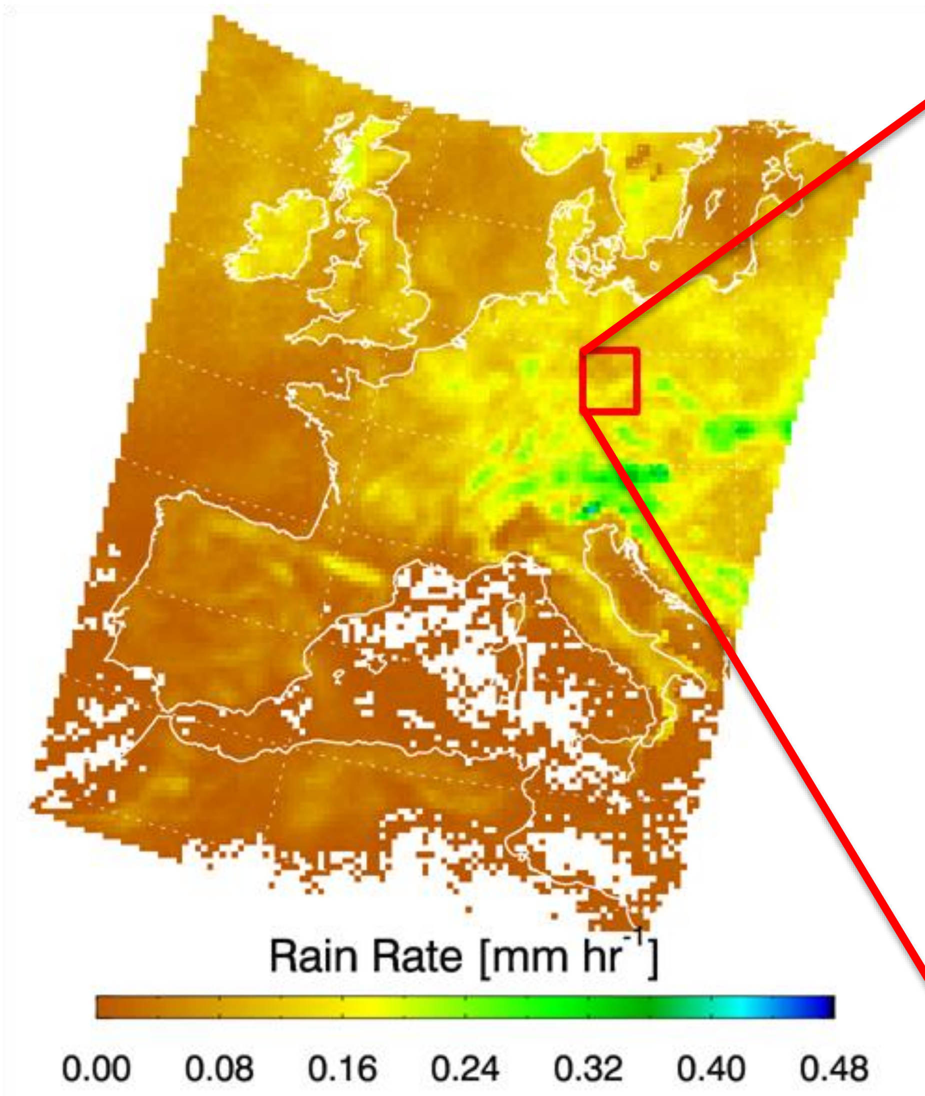


***Fig:** Frequency distributions of RACMO, Weather Radars and SEVIRI Rain Rate*



Model Evaluation
Precipitation parameterization



Continental Europe
May – Sept. 2006

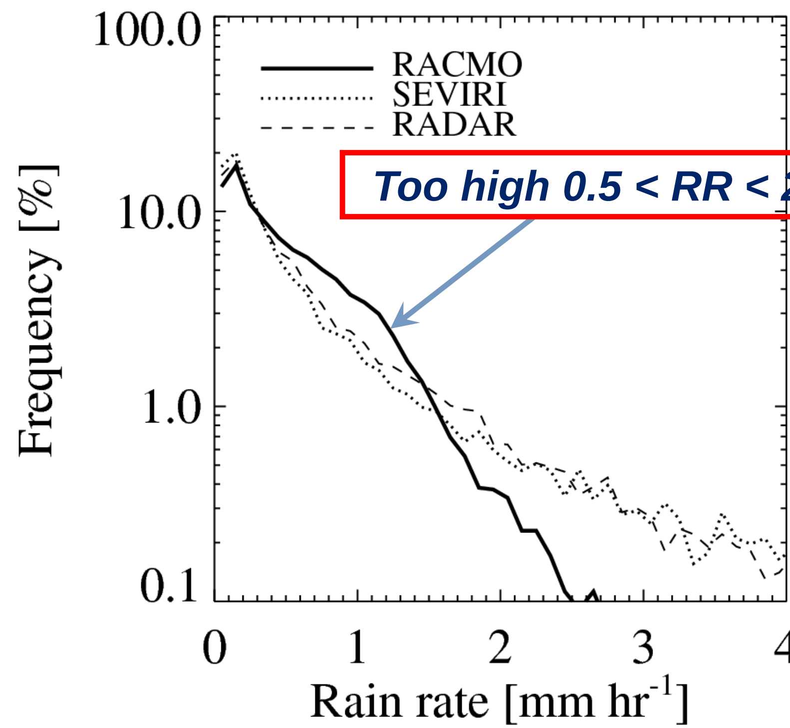


Fig: *Frequency distributions of RACMO, Weather Radars and SEVIRI Rain Rate*

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Model Evaluation
Precipitation parameterization

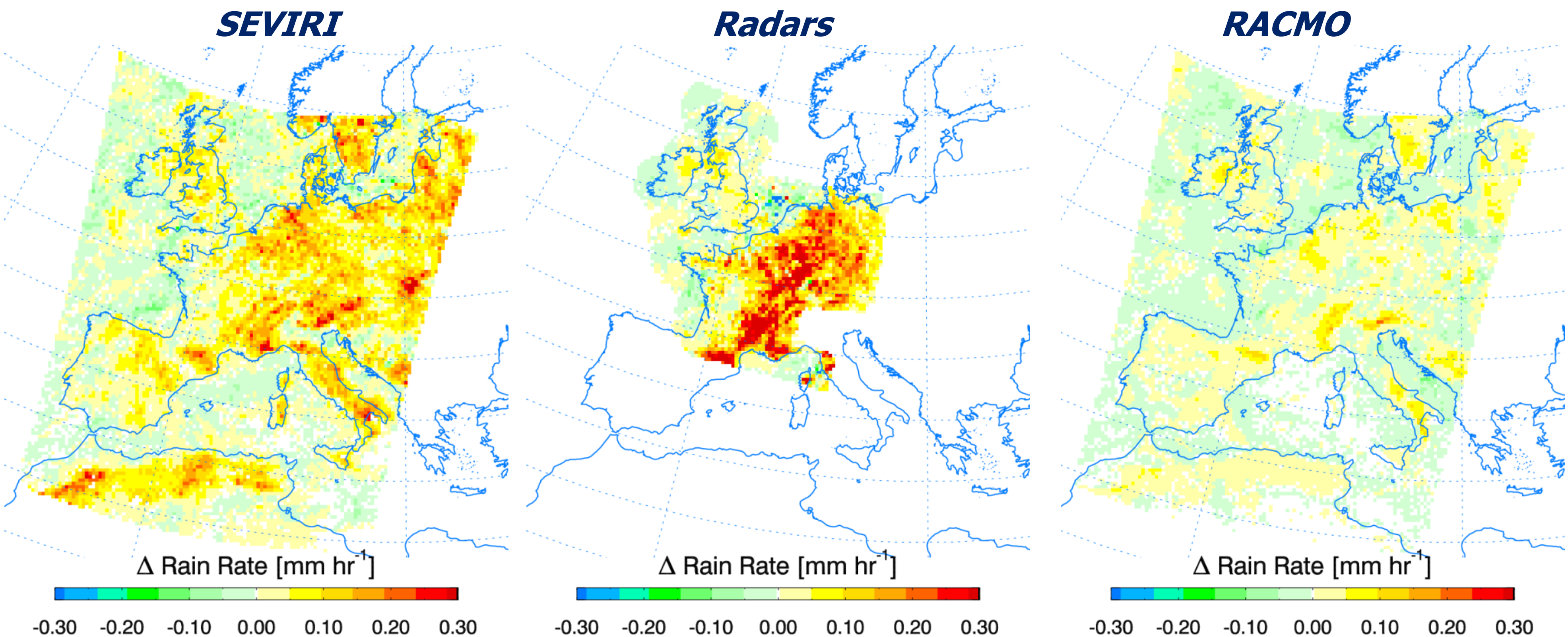
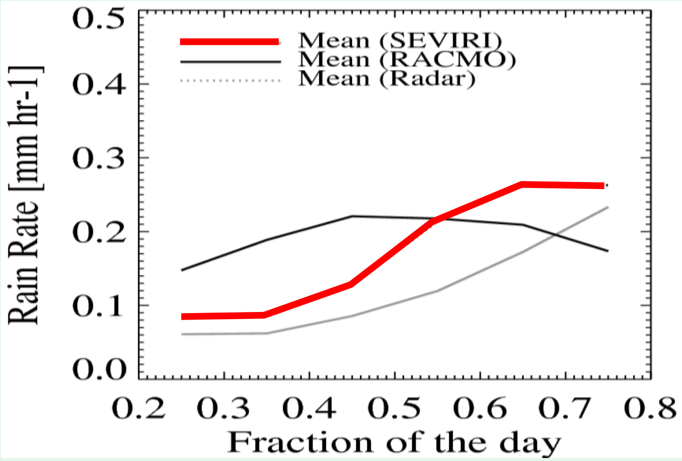


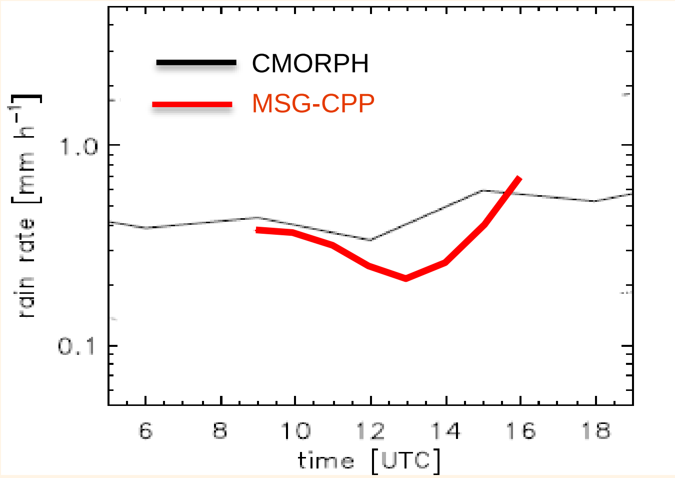
***Fig:* Noon (12-16hr) - Morning (8-12 hr)** *rain rate differences for SEVIRI, Weather Radars and RACMO during May – Sept 2006*

Model Evaluation
Diurnal Cycles

EUROPE



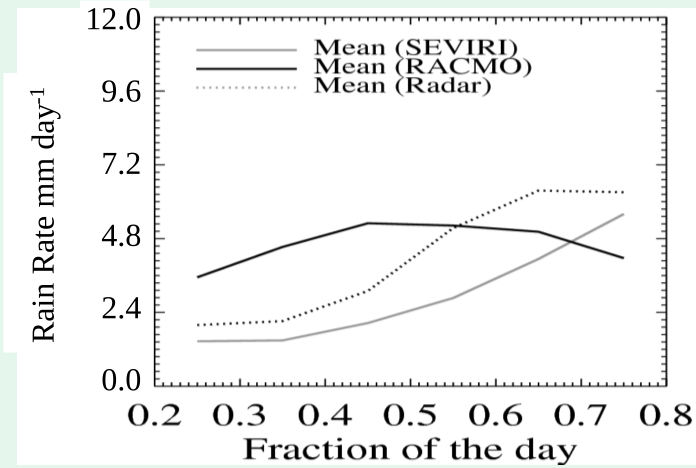
AFRICA

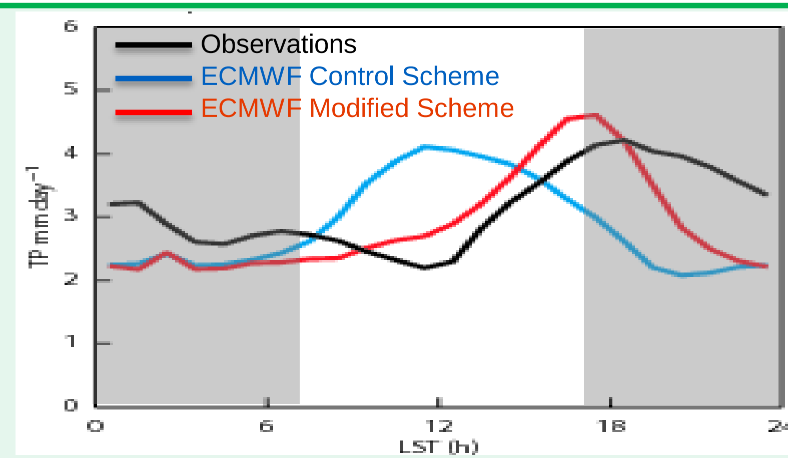


Wolters et al., 2011, HESS

Model Evaluation
Diurnal Cycles

EUROPE





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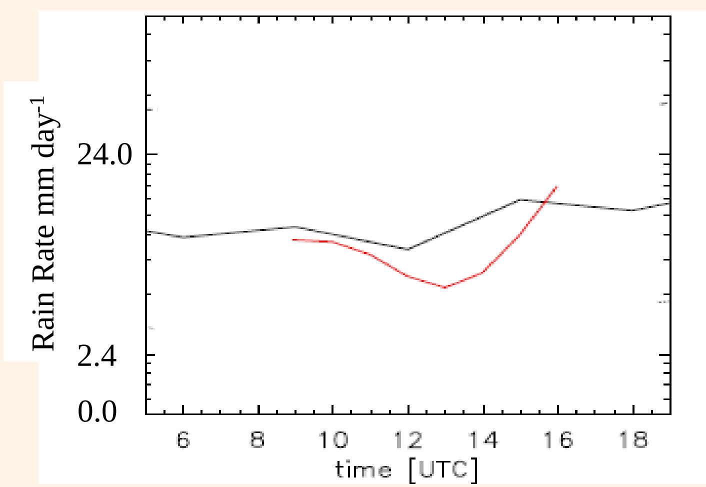

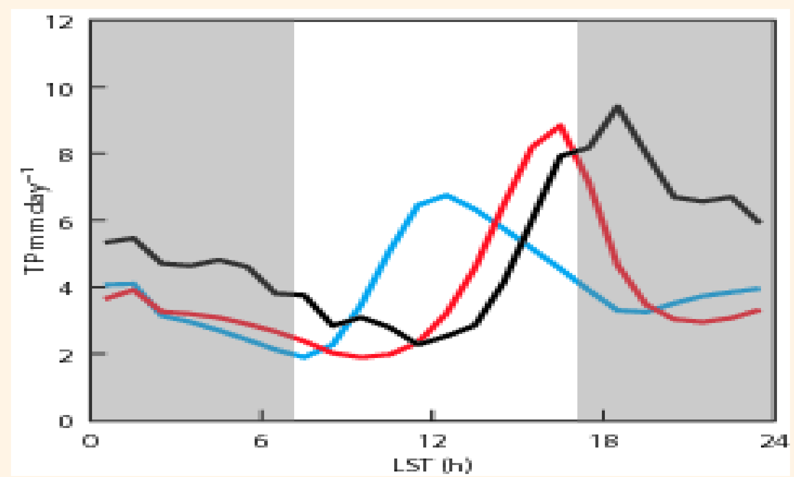

Wolters et al., 2011, HESS

Courtesy Prof. Erland Källén, ECMWF

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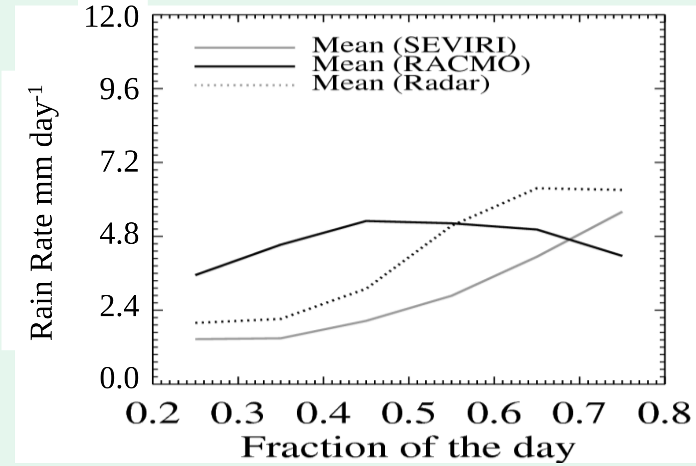
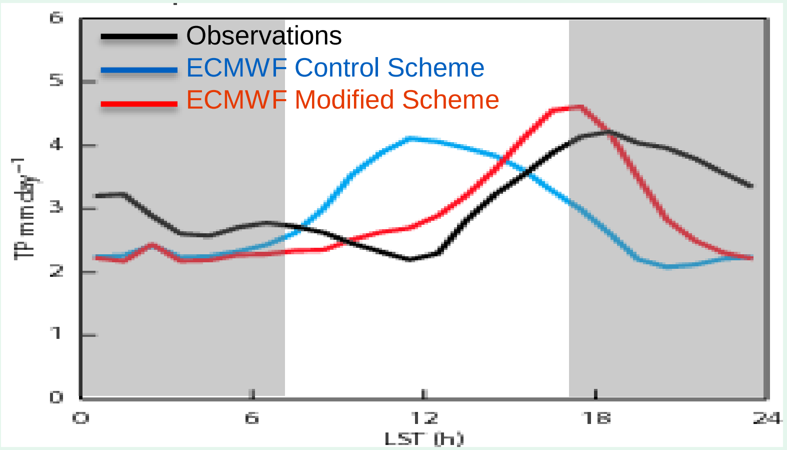
Model Evaluation
Diurnal Cycles

EUROPE





- **CPP-Precip (SEVIRI) allows for sampling the diurnal cycle of rain rate during daylight hours;**
- **Rain Rate diurnal cycles from CPP-Precip (SEVIRI) match in shape and magnitude with observed diurnal cycles of rain rate;**
- **Rain Rate diurnal cycles from CPP-Precip (SEVIRI) could help to improve model parameterizations of rain rate**

Wolters et al., 2011, HESS

Courtesy Prof. Erland Källén, ECMWF

References

References and Data Availability

References

- Roebeling R.A. and I. Holleman, 2009: SEVIRI rainfall retrieval and validation using weather radar observations, J. Geophys. Res., 114, D21202, doi:10.1029/2009JD012102.
- Wolters, E.L.A., B.J.J.M. van den Hurk en R.A. Roebeling, 2011, Evaluation of rainfall retrievals from SEVIRI reflectances over West Africa using TRMM-PR and CMORPH, *HESS*, 2011, 15, 437-451, doi:10.5194/hess-15-437-2011.
- Roebeling, R. A., E.L.A. Wolters, J.F. Meirink and H. Leijnse, 2012: Triple collocation of precipitation retrievals from SEVIRI with gridded rain gauge data and weather radar observations over Europe, J. of Hydro. Met., 13, 1552–1566, doi: http://dx.doi.org/10.1175/JHM-D-11-089.1
- Maidment, R., Grimes, D., Tarnavsky, E., Allan, R. P., Stringer, M., Hewison, T., Roebeling, R., Black, E., 2014: The 30-year TAMSAT African Rainfall Climatology And Time-series (TARCAT) Dataset, J. Geophys. Res., 119,, 10619-10644, doi:10.1002/2014JD021927

Data Quick looks and Downloads:

- **Near real-time viewer (15 min data)** -> http://msgcpp.knmi.nl/
- **Download near real-time data (15 min data)** -> ftp://msgcpp-ogc-realtime.knmi.nl/
- **Download archived data (last 3 years, (15 min data))** -> ftp://msgcpp-ogc-archive.knmi.nl/

Thank You

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