Observing warm rain events over southern West Africa using CM-SAF cloud products

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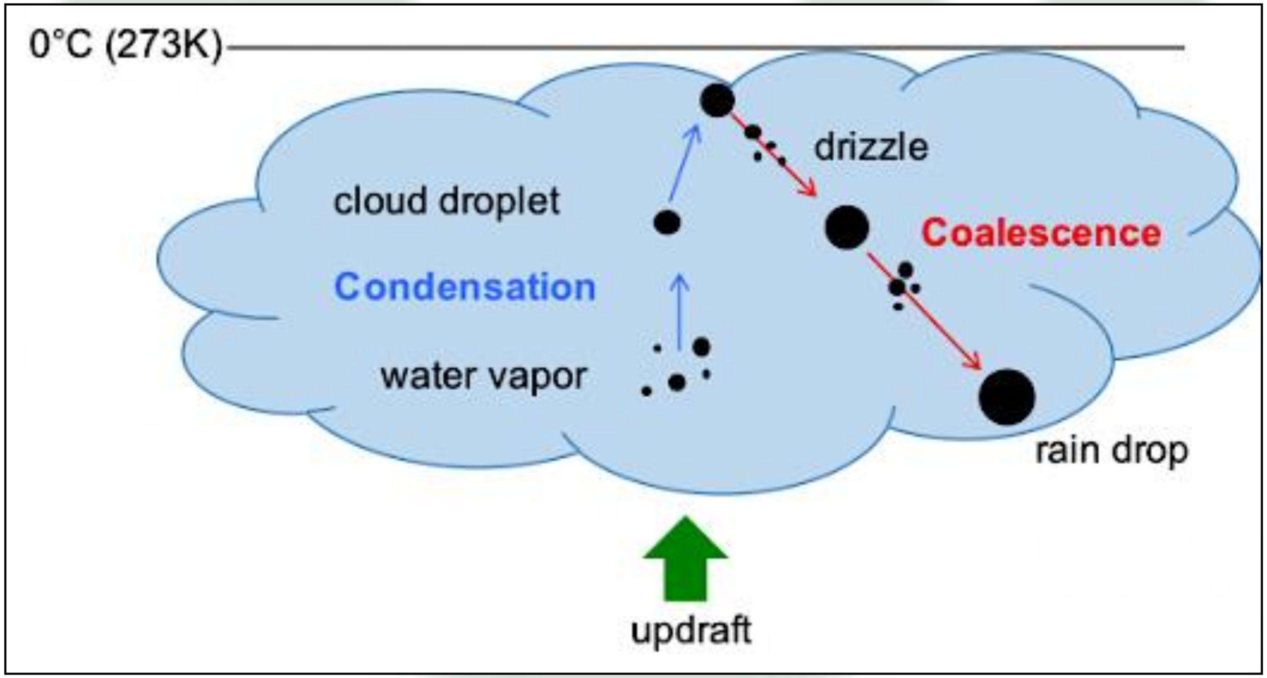
Warm rain

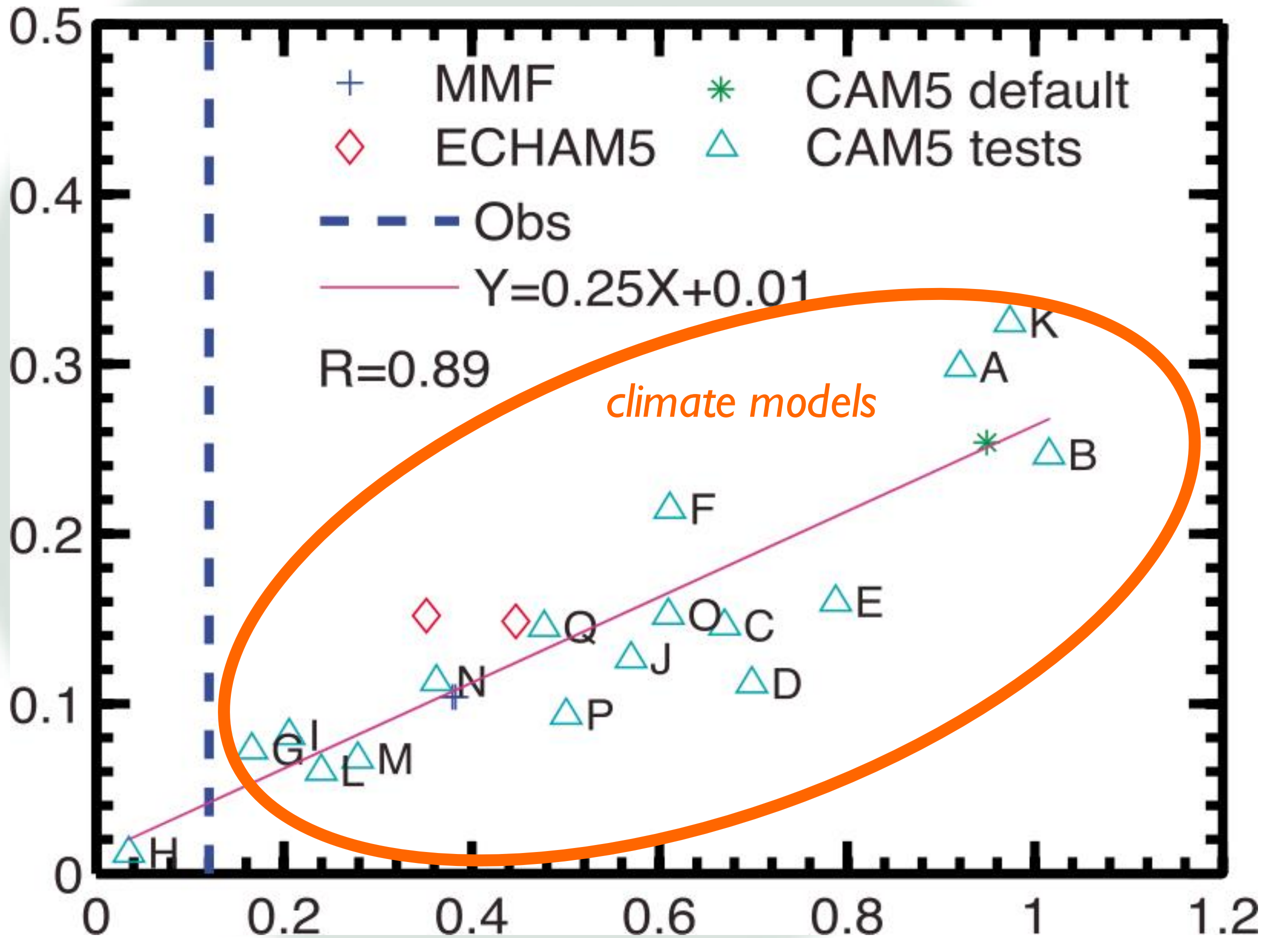
"Rain formed from a cloud having temperatures at all levels above 0°C, and resulting from the droplet coalescence process."

– *AMS glossary of meteorology*



Source: GEWEX Process Evaluation Studies (PROES)

Observing warm rain important for understanding cloud-aerosol interactions

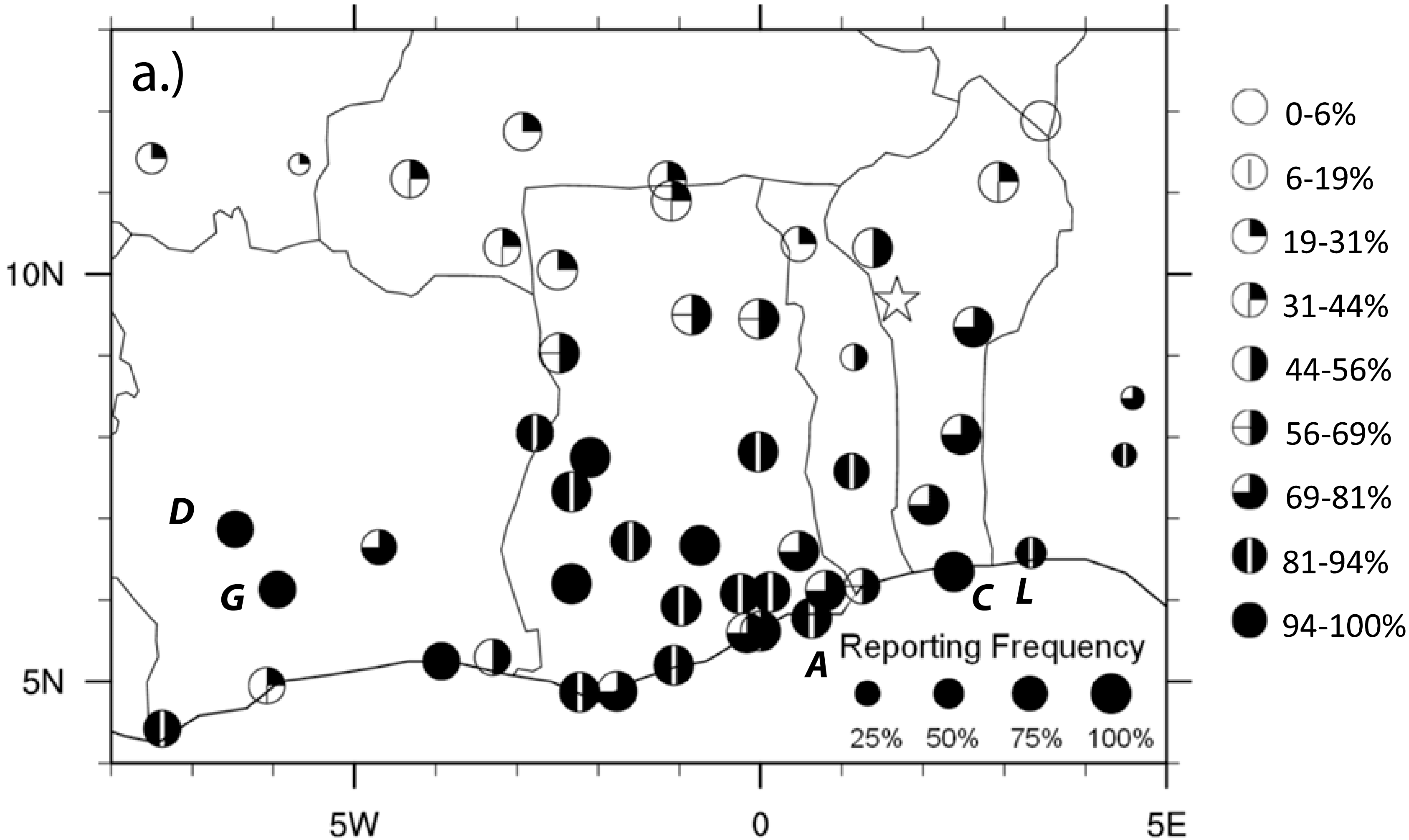


d ln(LWP)/
d ln(CCN)

S_{pop}
(Susceptibility of probability of precipitation)

Wang et al. (GRL, 2012)

Warm clouds are frequently observed



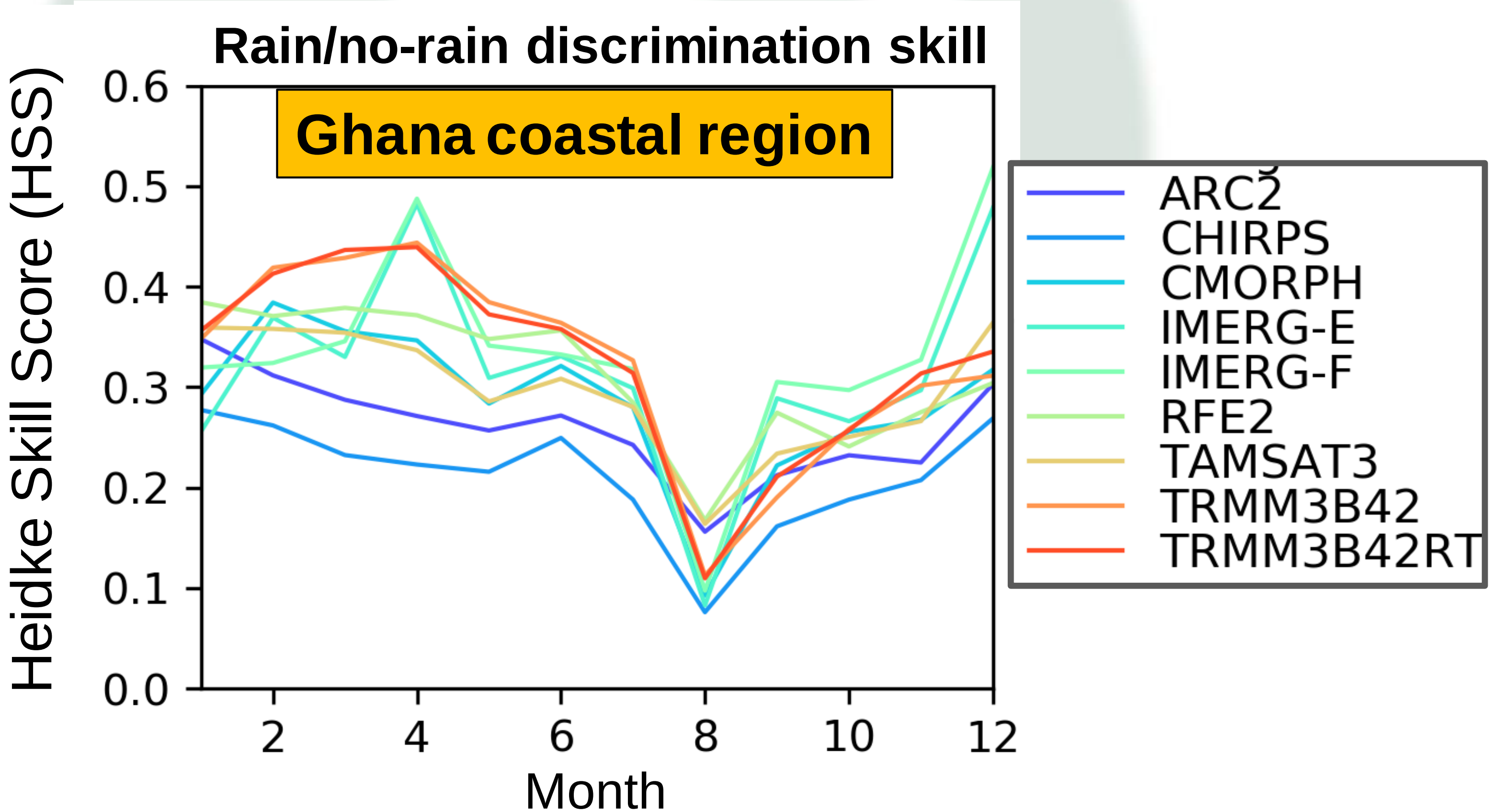
Frequency (%) of stratus and stratocumulus at 6 UTC, Jun–Oct 2006

Schrage and Fink (MWR, 2011)

Difficult to observe warm rain

- Satellite rainfall retrievals heavily rely on cold cloud signatures from passive microwave and thermal infrared retrievals
- Many satellite rainfall datasets therefore miss warm rain events

Skill relative to random chance



Detecting warm rain from shortwave cloud property retrievals

Chiu et al. (ACP, 2014)

Can skillfully detect raining warm clouds combining *cloud optical depth* τ and *cloud effective radius* r_e

$$r_e^* = \frac{E}{\tau}$$

$r_e > r_e^*$ warm rain

$r_e \leq r_e^*$ no rain

r_e^* (μm): critical effective radius for precipitation
E (μm): empirically optimised coefficient

Assumes a sufficient amount of liquid water and sufficiently large droplet size required for precipitation

AIM
Apply this method to CM-SAF shortwave cloud property retrievals from SEVIRI to detect warm rain

Method adapted from Nauss and Kokhanovsky (ACP, 2006)

Satellite data

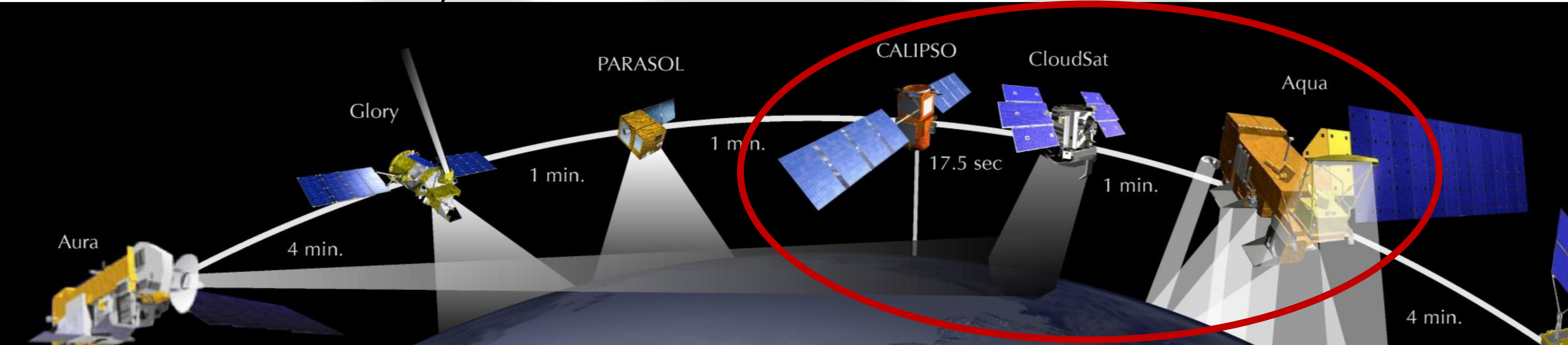
Geostationary: CM-SAF Cloud Physical Properties (CPP) dataset using SEVIRI edition 2 (2004–2015) ***Benas et al. (ESSD, 2017)***

- Cloud phase, cloud optical depth and effective radius (0.6µm & 1.6 µm)
- **High spatial (~3km, pan-Africa) and temporal (15min) coverage**

Calibration and evaluation data

LEO *A*-train satellite retrievals (2006–2010), 2 overpasses per day

1. *CloudSat*: 94 GHz Cloud Profiling Radar (CPR), 2C-PRECIP-COLUMN to **detect the occurrence of warm rain** (~1.5 km horiz. res., ~250m vert. res.)
2. DARDAR-MASK product, combines CPR and CALIOP (lidar on CALIPSO) to **determine cloud phase**
3. *Aqua MODIS Collection 6*: cloud phase, optical depth, effective radius (1km horizontal res.)



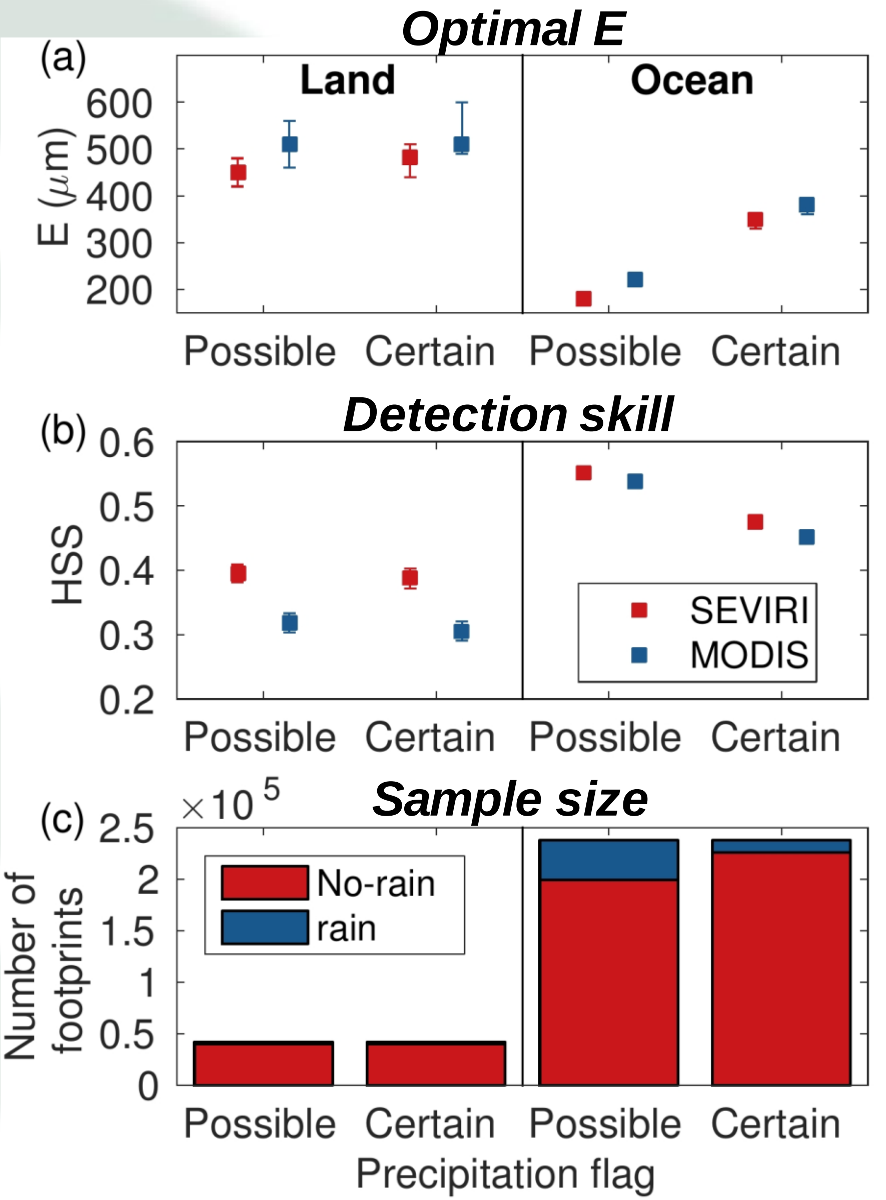
Developing warm rain detection for SEVIRI

1. Collocate *SEVIRI* cloud retrievals with daytime overpasses from *A-Train* sensors, June–September, 2007–2010

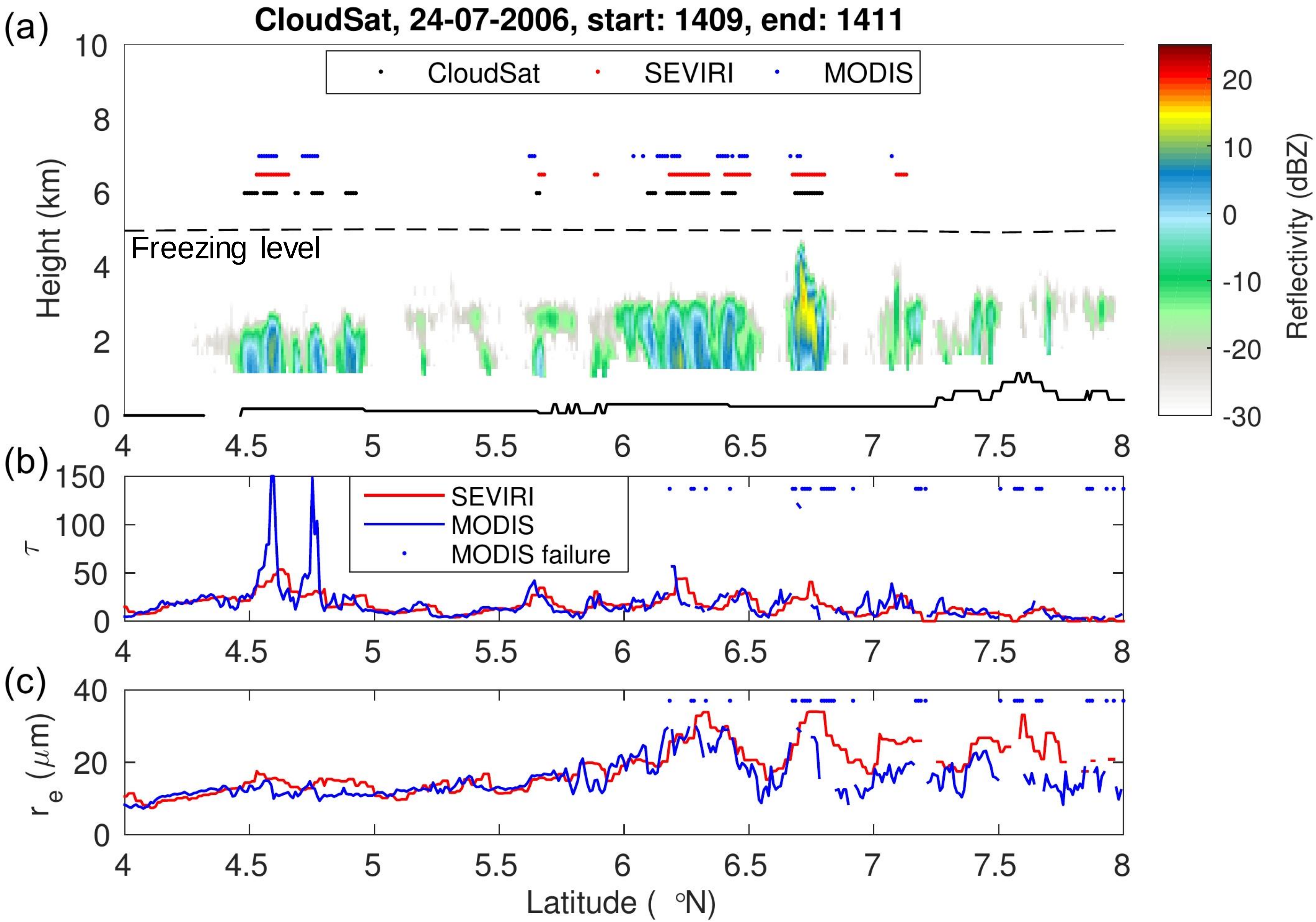
2. Select warm clouds:
   - Liquid water phase in SEVIRI and MODIS
   - Single liquid water cloud layer and no overlying higher-level cloud in DARDAR-MASK

3. Warm rain/no-rain occurrence from CloudSat using near-surface (~1km) reflectivity
   - "*rain certain*" > 5 dBZ
   - "rain possible" > –5 dBZ

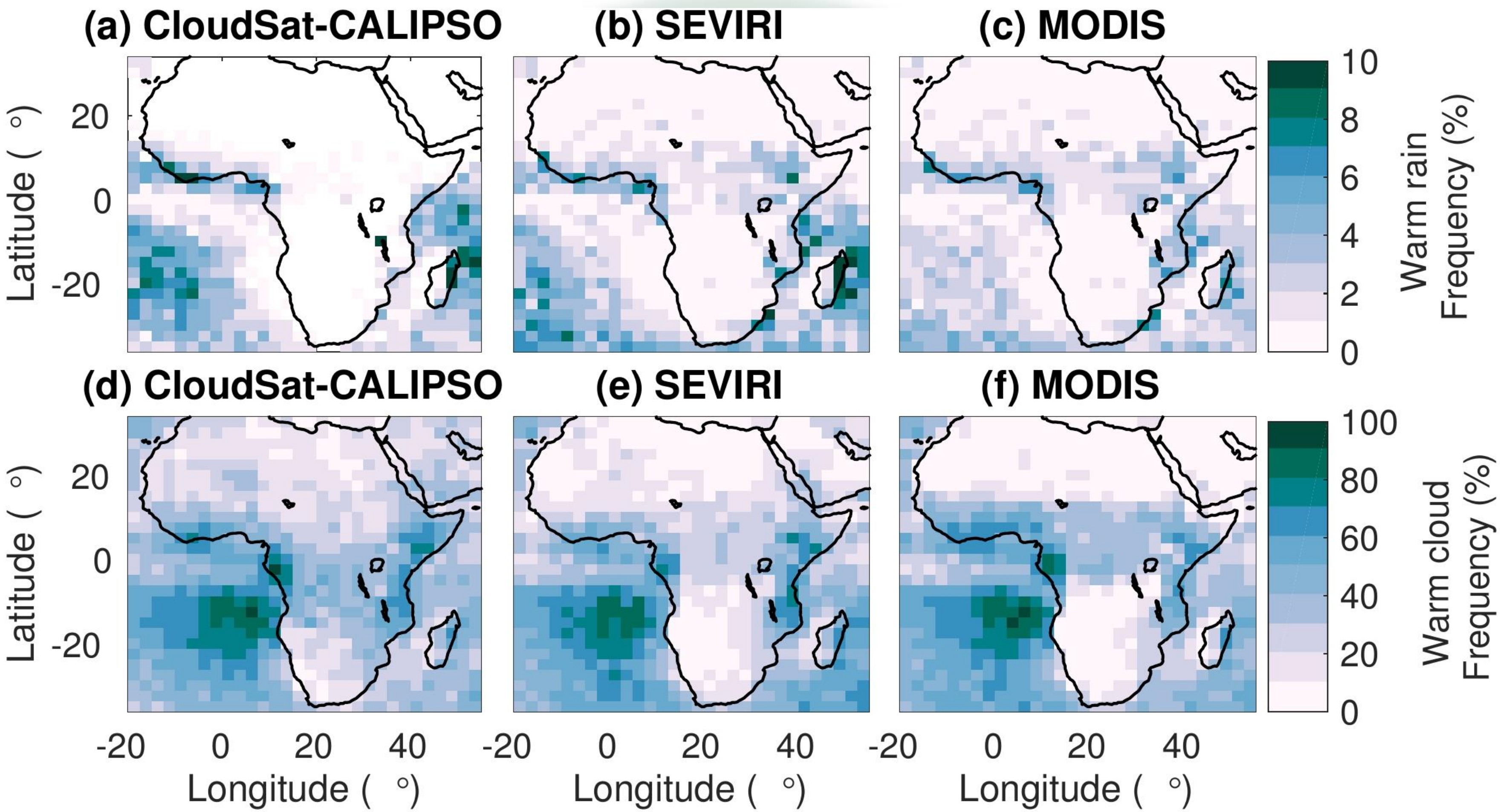
4. Compare rainfall detection skill varying coefficient *E* until an optimal value found where detection skill is maximised



An example over southern West Africa



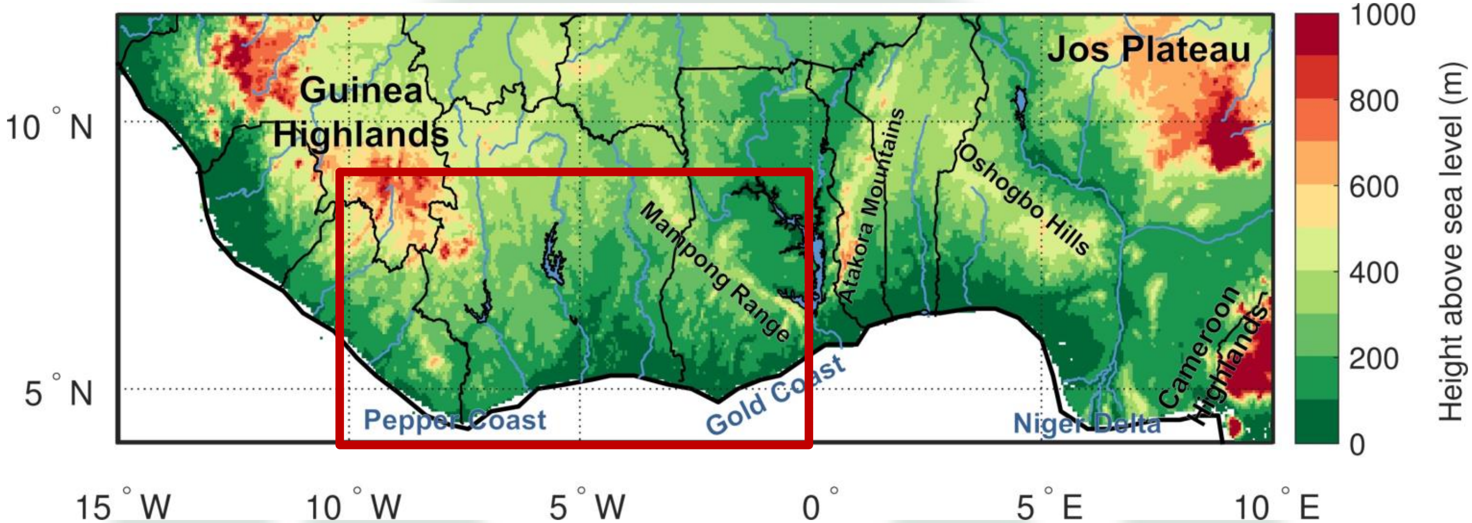
Comparison between active and passive retrievals

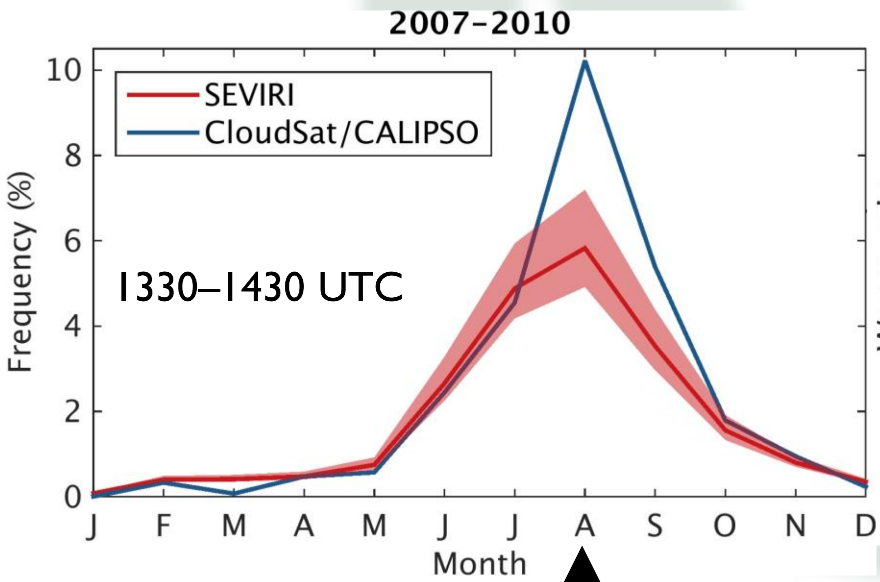


Binned at 2.5º, JJAS 2007-2010

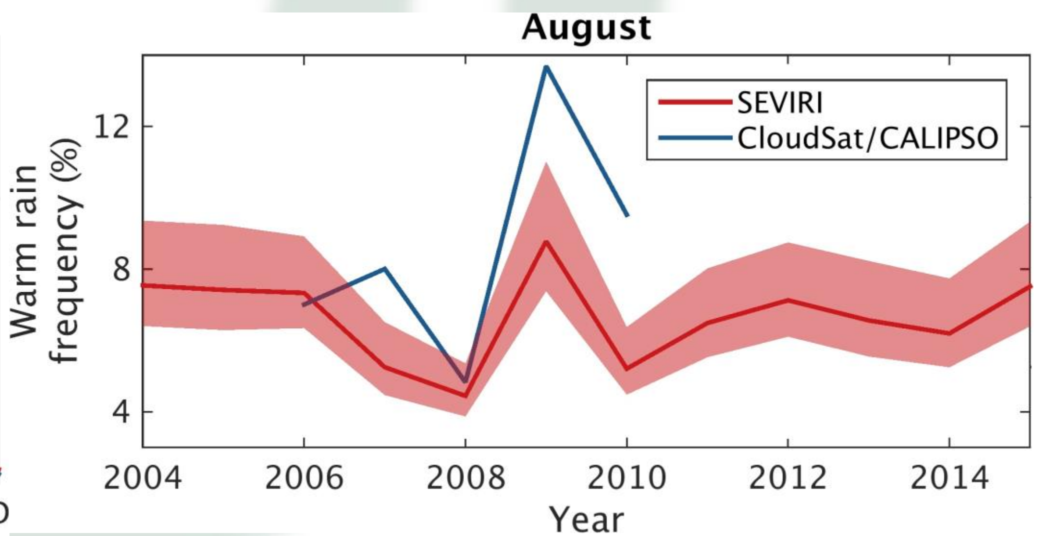
- For 28% of MODIS warm clouds the cloud optical depth and effective radius not retrieved and therefore no warm rain retrieval

Southern West Africa: Seasonal cycle and interannual variability



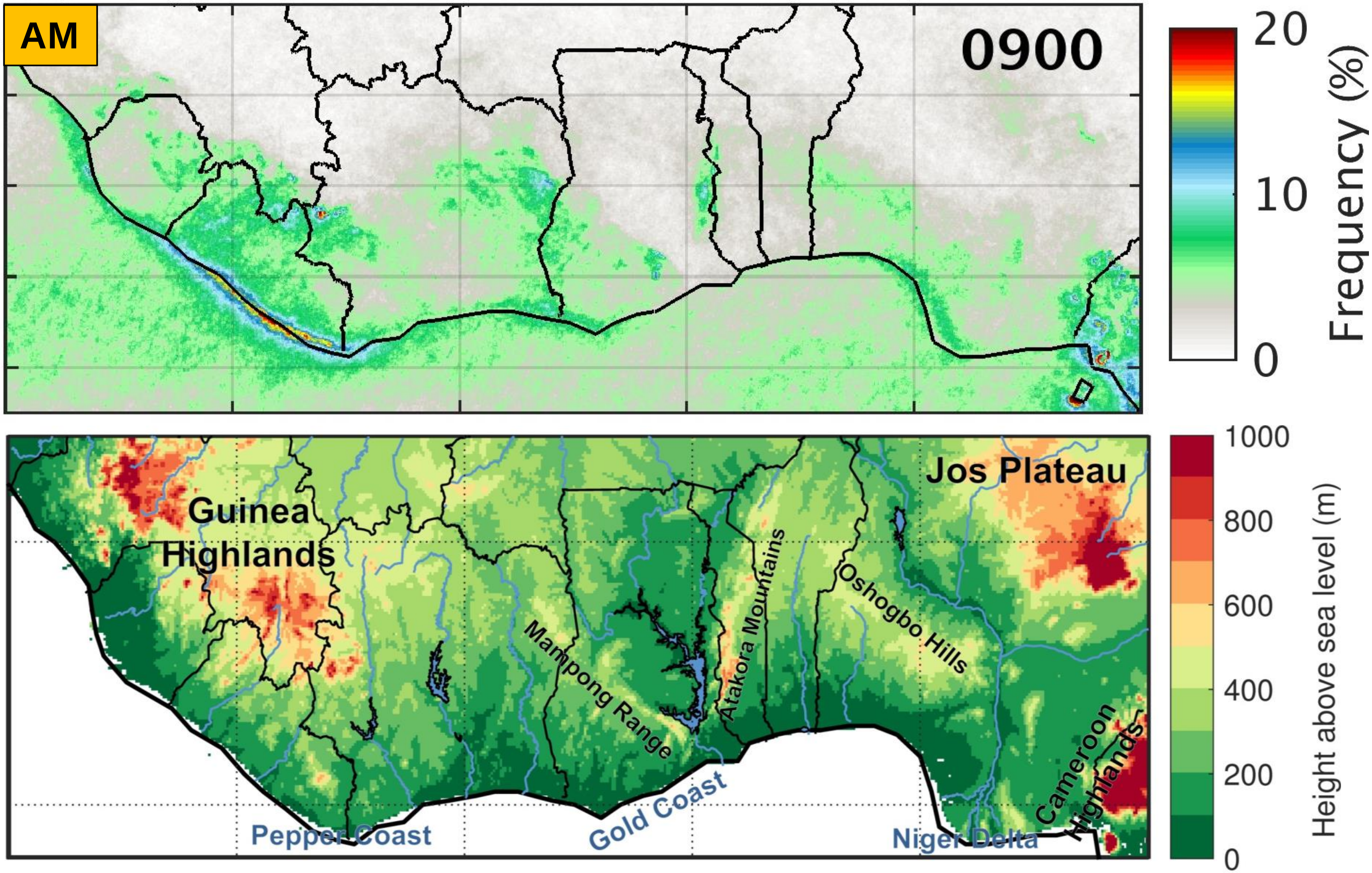


"Little dry season"



August mean = 6.7%, S.D. = 1.2%

High-resolution 12-yr climatology from SEVIRI



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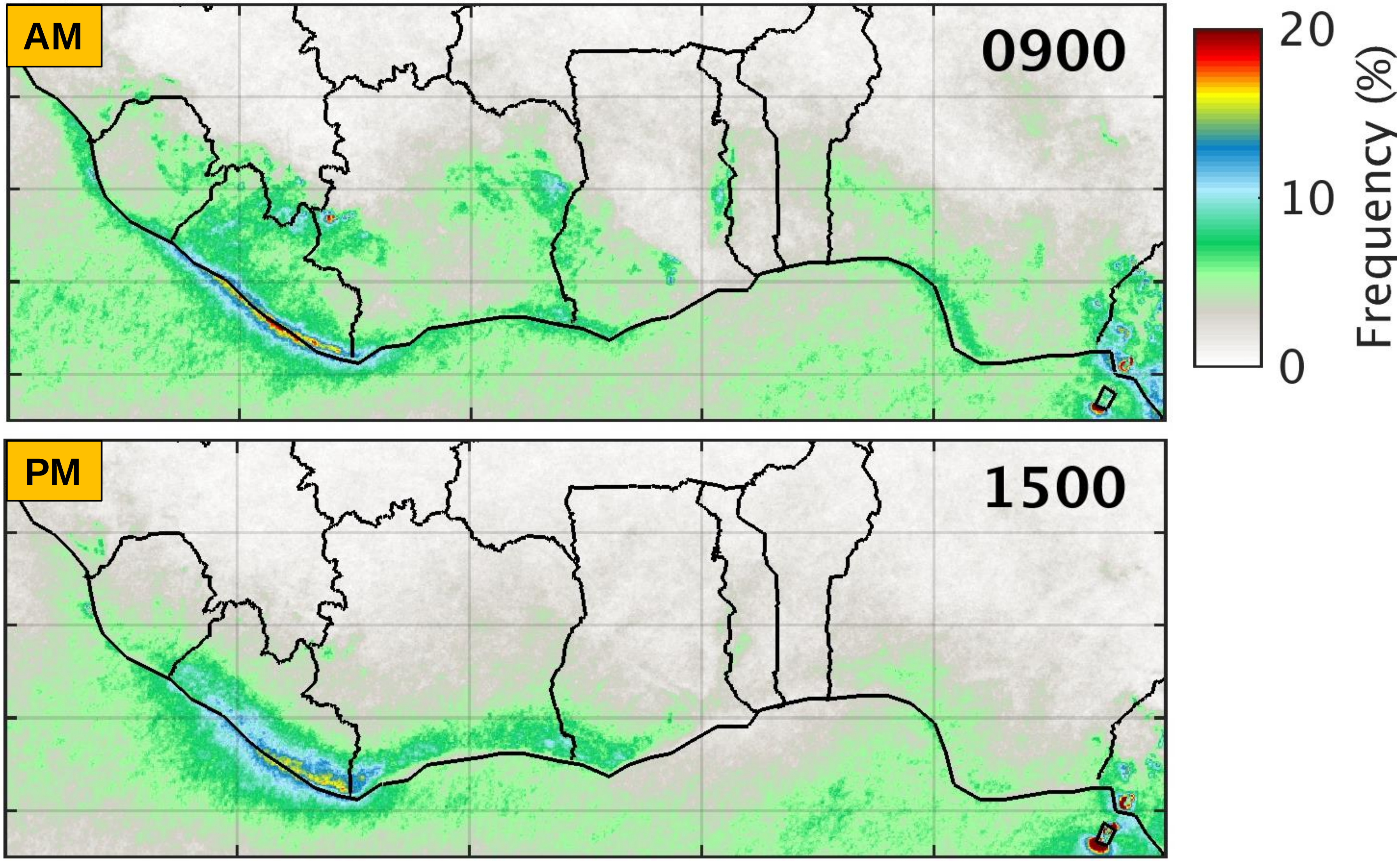
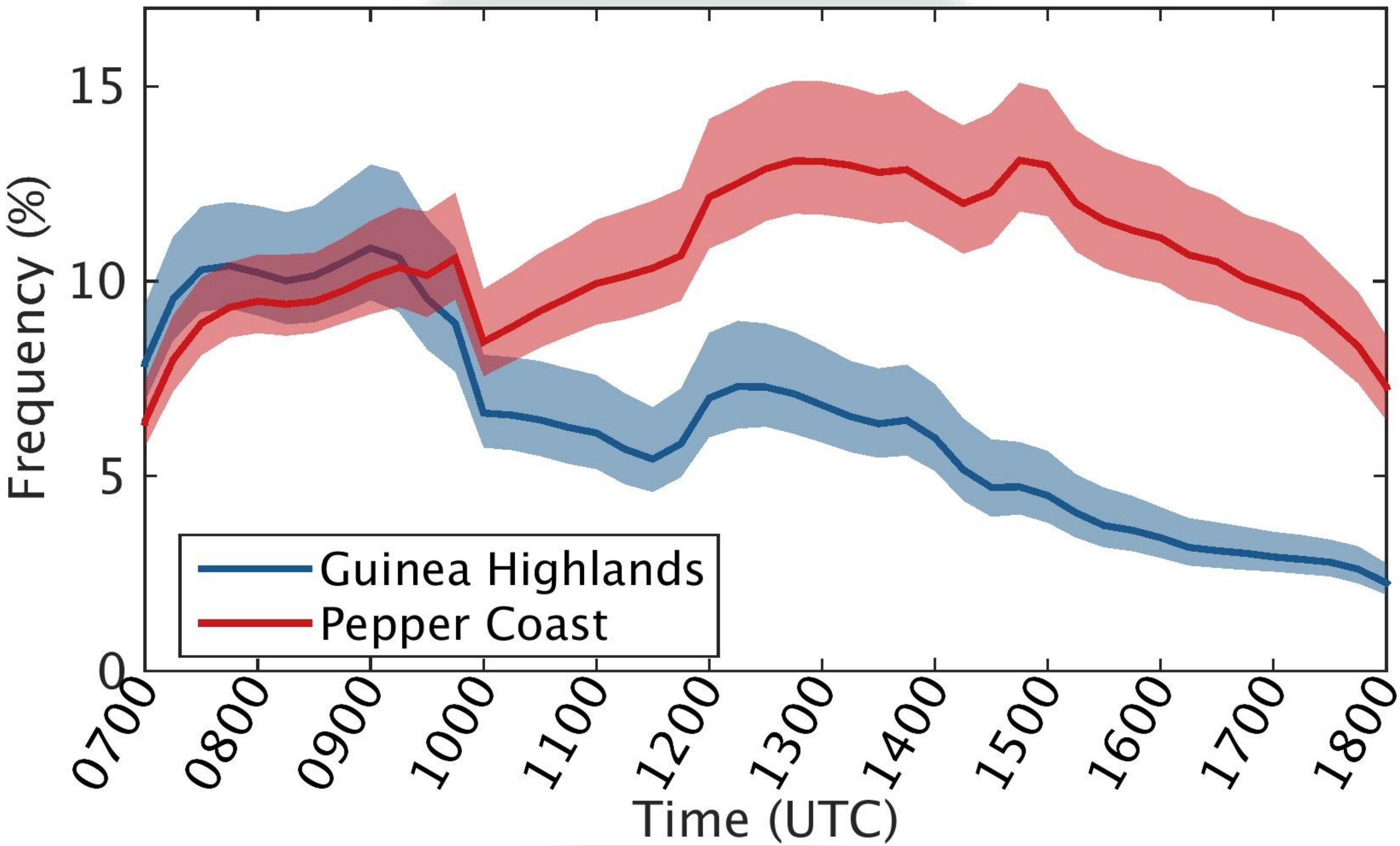
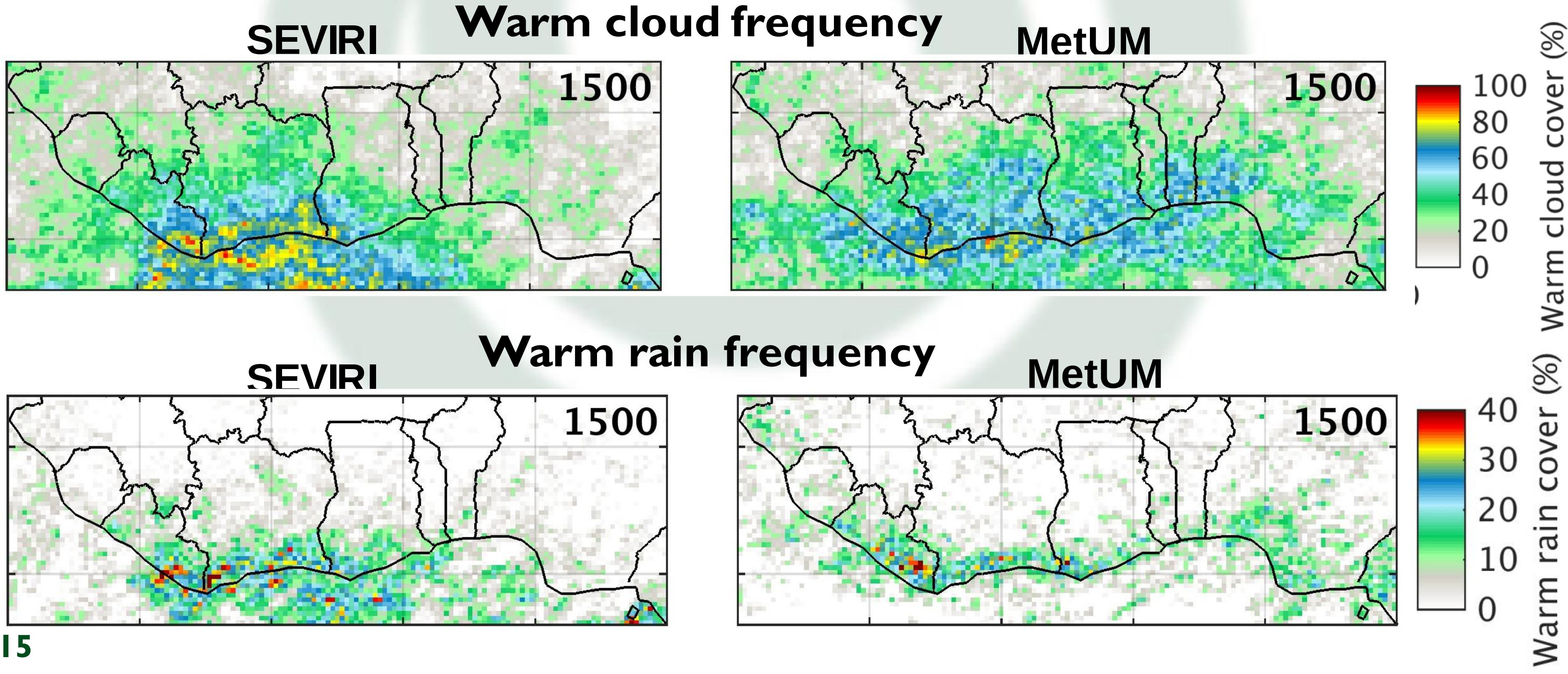


Diurnal (daytime!) cycle



Application to model evaluation

- Met Office Unified Model (version 7.1) simulations at 4 km resolution, 8 days: 27 July - 3 August 2006 *(Cascade simulations described in Pearson et al., QJRMS 2013)*
- Explicit convection, nested in a 12 km simulation with parameterised convection, initialised and updated with boundary conditions derived from ECMWF analysis.
- Low-level cloud = difference between the areal cloud fraction at the surface and at the freezing level > 0.5
- Warm rain event if > 3 mm d^{-1}



Summary

- Observing warm rain important for understanding cloud-aerosol interactions, evaluating model processes, and improving satellite rainfall retrievals
- Used *A-Train* sensors to develop and evaluate a method to detect the occurrence of warm rain using geostationary daytime cloud property retrievals from SEVIRI
- Warm rain is most frequent over southern West Africa in August, over coastal and highland regions
- Model simulations capture some of the spatial pattern and magnitude of warm rain frequency along the coast but underestimated over the Gulf of Guinea

Further opportunities & challenges

- Study warm rain variability in other regions
- Evaluate cloud-aerosol interactions
- Retrievals during night-time and warm rain amounts

Thank you!

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More info:

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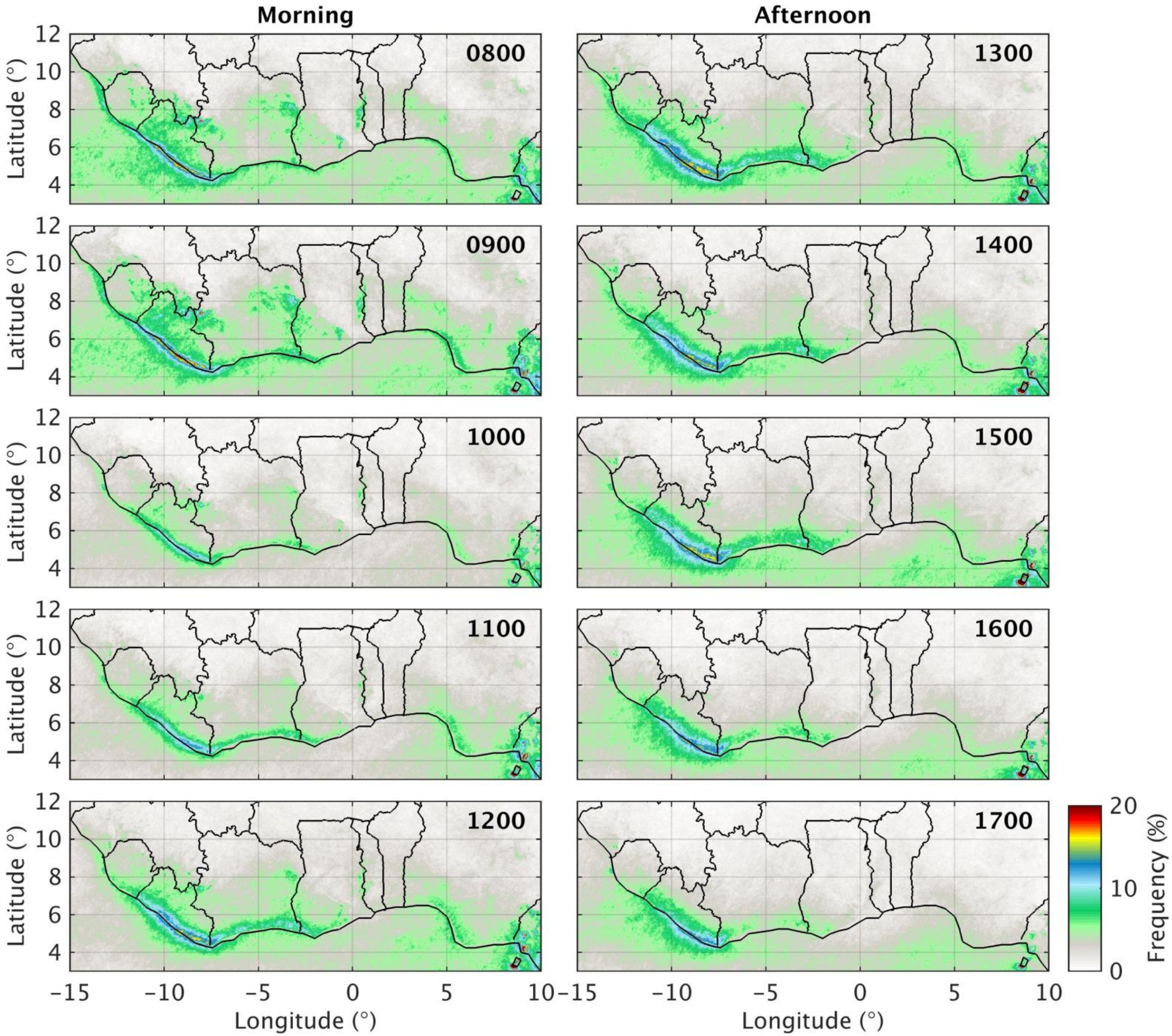
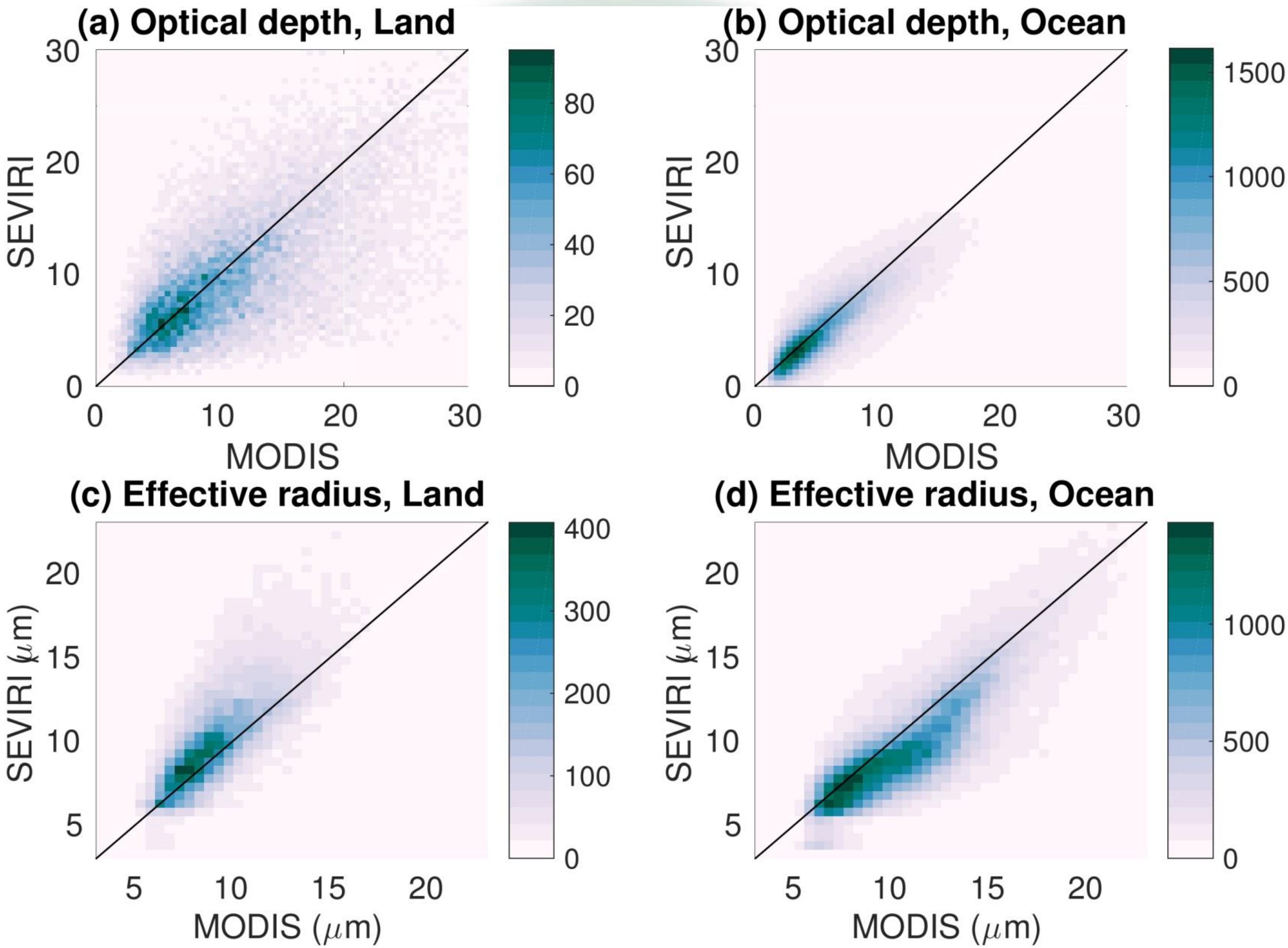


Comparison between SEVIRI and MODIS retrievals



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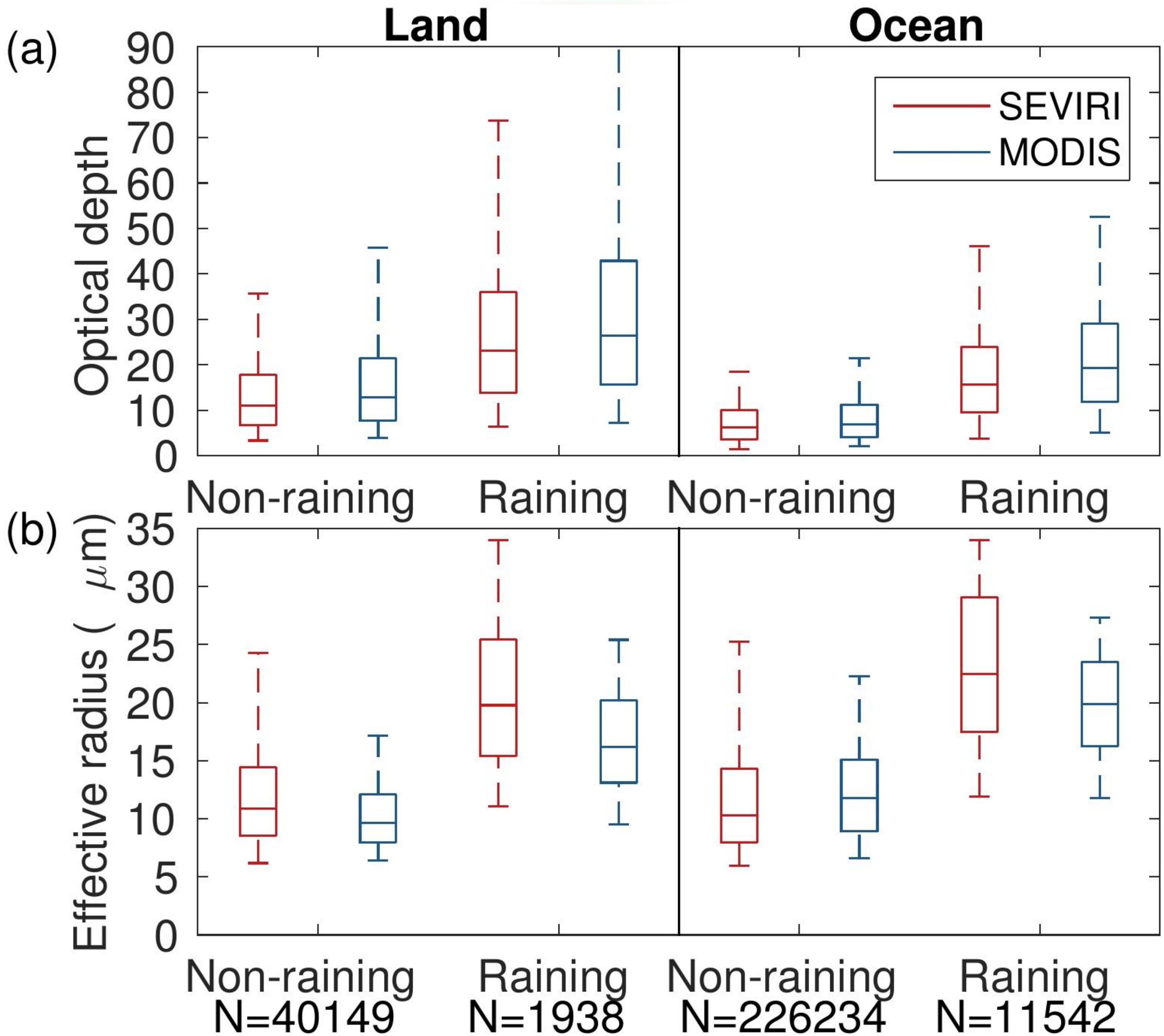
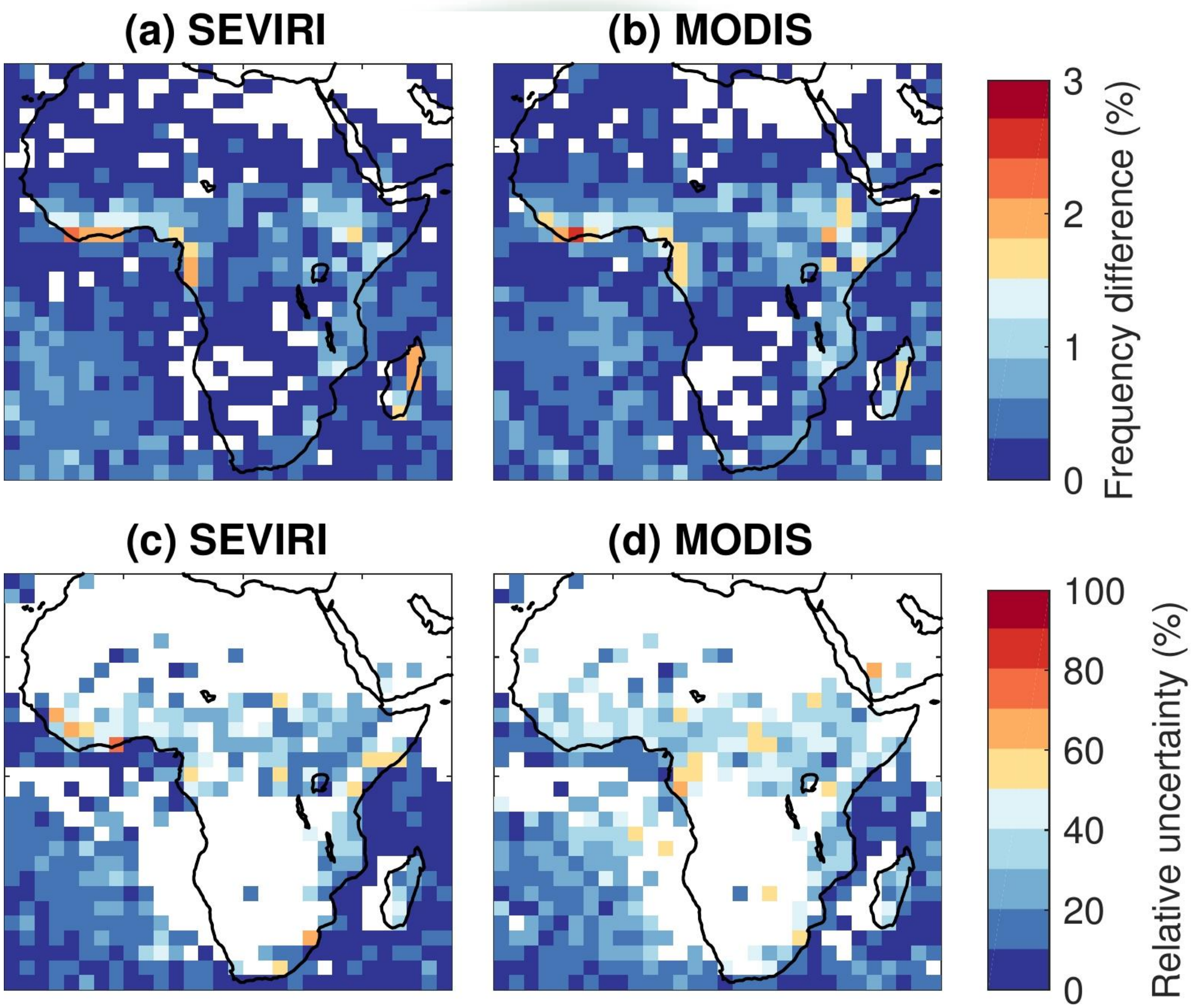


Uncertainty in frequency due to variation in coefficient *E*



The frequency difference in (a) and (b) is the difference between warm rain frequencies derived from the 5th and 95th percentiles of E for “rain certain”. The relative uncertainty (%) in (c) and (d) is the frequency difference in (a) and (b), divided by the warm rain frequencies from optimal *E*

Optimal parameters

TABLE 2 A summary of the median and the range for the optimized coefficient *E* and Heidke Skill Score (HSS), derived from SEVIRI and MODIS retrievals over land and ocean during June–September 2007–2010. The range represents the 90% confidence intervals computed from bootstrap resampling of the dataset 1,000 times. These values are provided for warm rain delineation using the "rain possible" and "rain certain" precipitation flags, defined by radar reflectivity thresholds as listed, from CloudSat 2C-PRECIP-COLUMN products

	SEVIRI				MODIS			
	Coefficient *E* (μm)		HSS		Coefficient *E* (μm)		HSS	
	Median	Range	Median	Range	Median	Range	Median	Range
Land								
Rain certain (reflectivity >5 dBZ)	480	440–510	0.39	0.37–0.40	510	490–600	0.31	0.29–0.32
Rain possible (reflectivity >−5 dBZ)	450	420–480	0.40	0.38–0.41	510	460–560	0.32	0.30–0.33
Ocean								
Rain certain (reflectivity >0 dBZ)	350	330–350	0.47	0.47–0.48	380	360–390	0.45	0.45–0.46
Rain possible (reflectivity > −15 dBZ)	200	190–200	0.55	0.55–0.55	230	220–240	0.54	0.53–0.54

Application to model evaluation