Karlsruhe Institute of Technology

DACCIWA

# Evaluation of cloud processes over West Africa in climate models

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Workshop on
“Application of Satellite Climate Data Records in Numerical Modeling”
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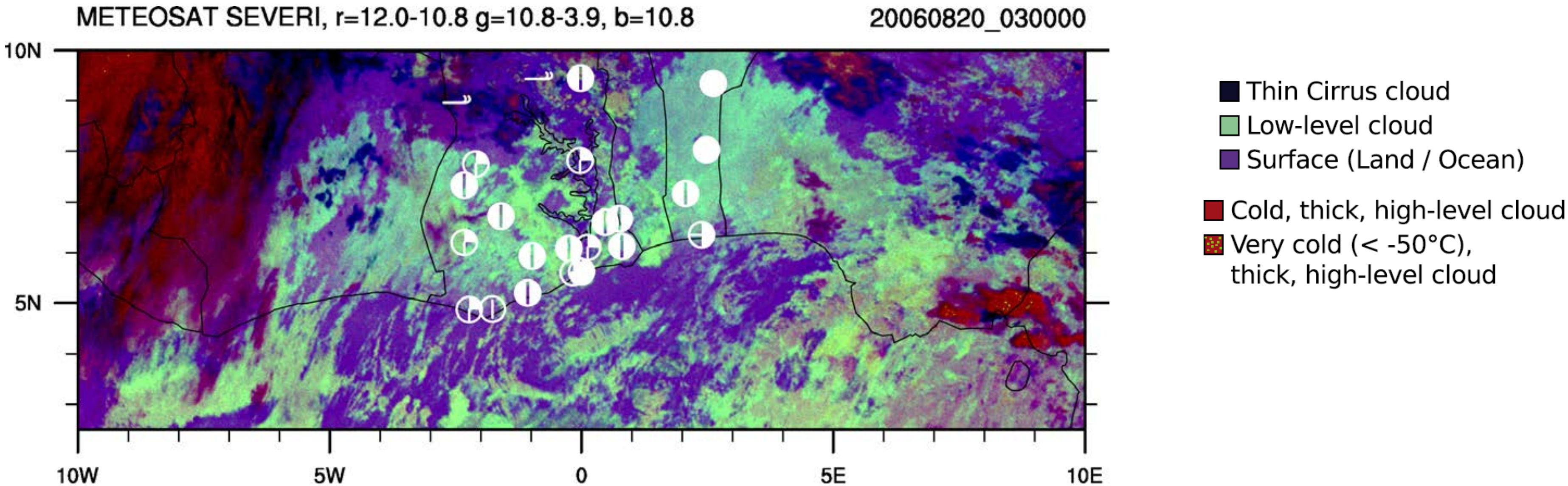
# Outline

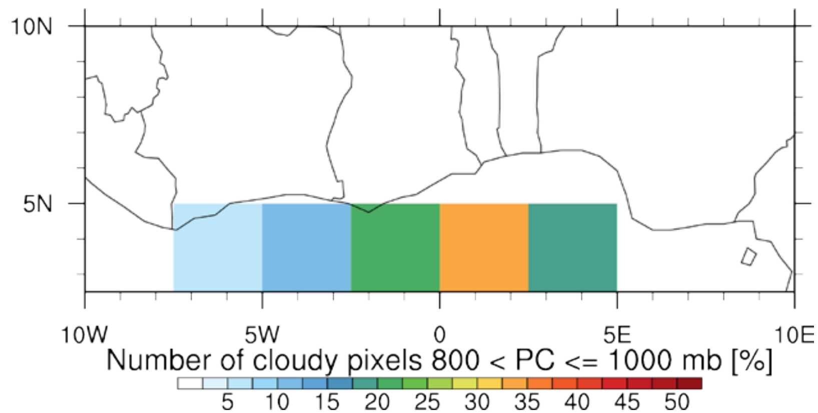
1. Why were low clouds in southern West Africa a neglected phenomenon?
2. Climatological relevance
3. Impacts on surface radiation
4. Comparison of in-situ solar irradiance with CM SAF SARAH and CLARA data sets
5. Low clouds and night-time low-level (NLLJ) jet in GASS-YOTC models
6. Summary

# Nocturnal monsoon stratus: long unrecognized

MSG RGB Composite & SYNOP low cloud observations at 03 UTC 20 August 2006




ISCCP D1 low-level cloud cover 03 UTC 20 August 2006

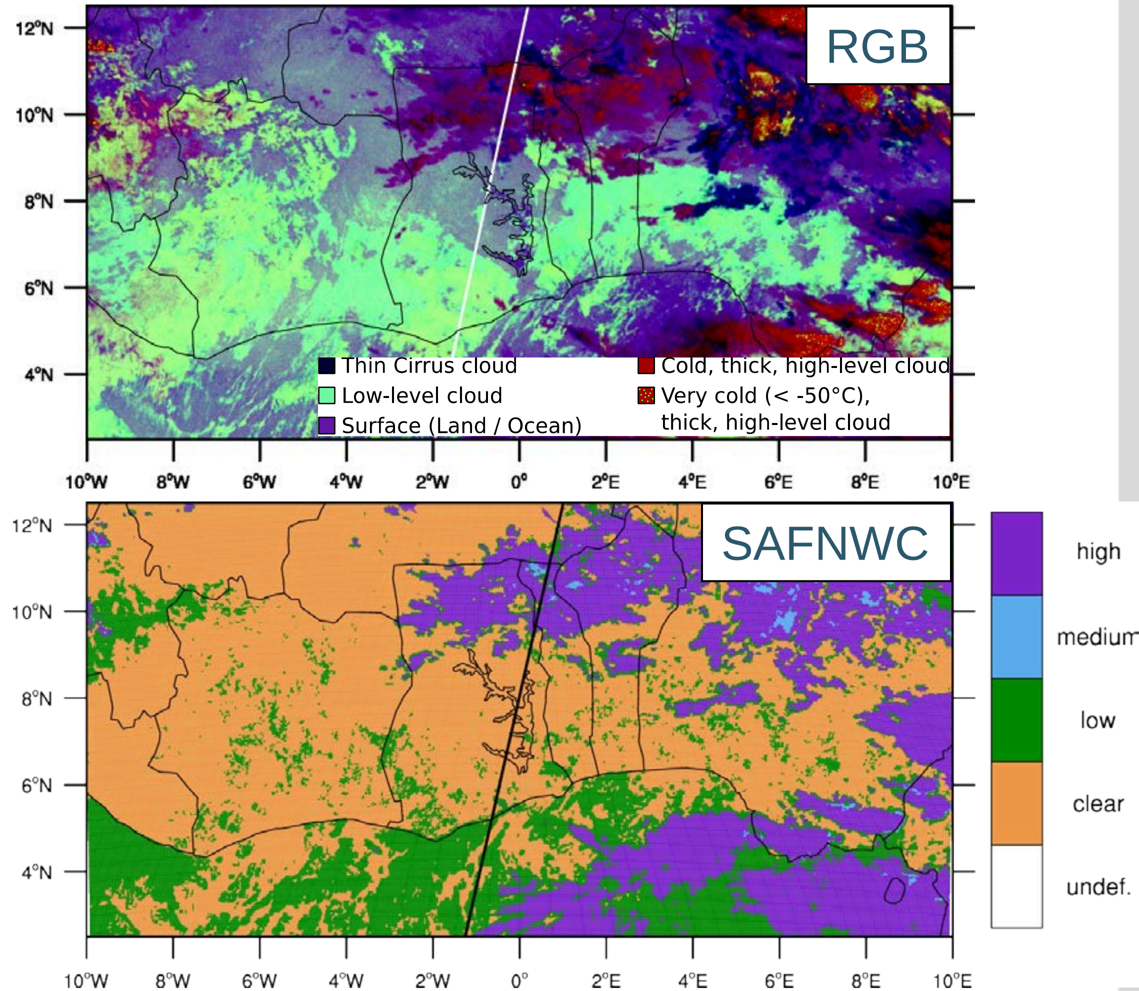



ISCCP does not see the nocturnal stratus clouds over the continent at all

# Nocturnal monsoon stratus: long unrecognized

19 Aug. 2007 0130 UTC

MSG SEVIRI RGB composite vs. NWC SAF* cloud type classification at night

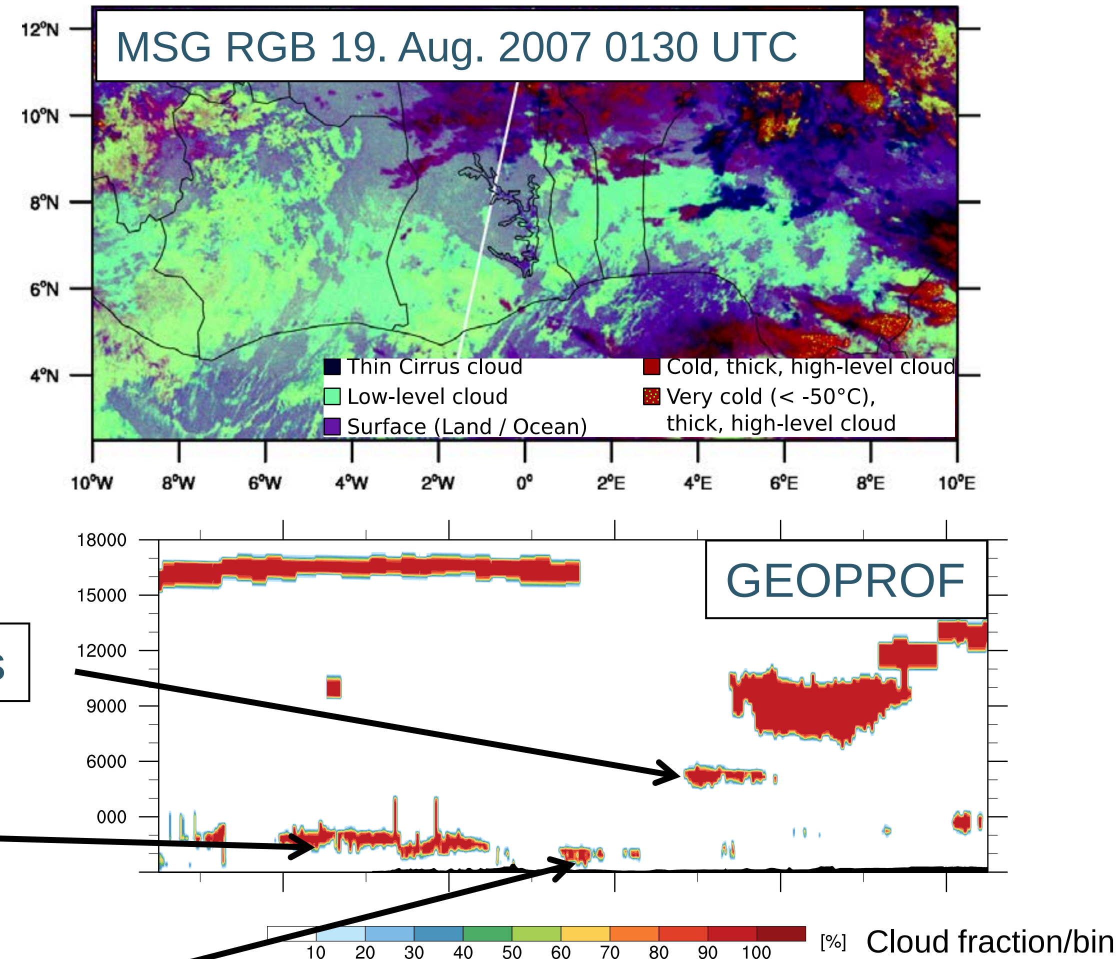



- A very similar cloud classification algorithm is currently used in CLAAS (from CM SAF, likely calibrated SEVIRI data used)

van der Linden et al. (2015, JGR)

# Misrepresentation of low clouds in satellite products

Low clouds are often concealed by mid- and upper-level clouds



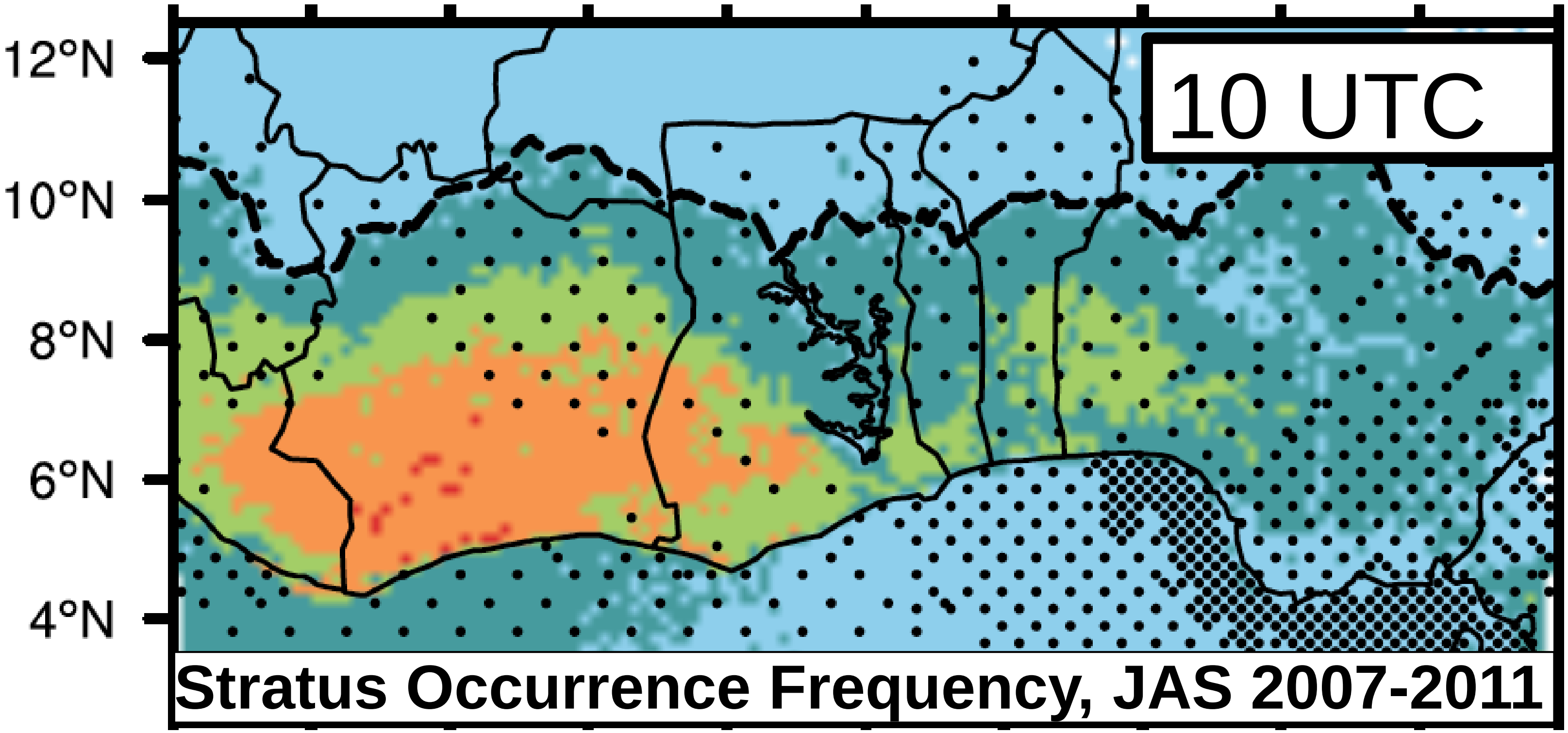

Mid-level clouds

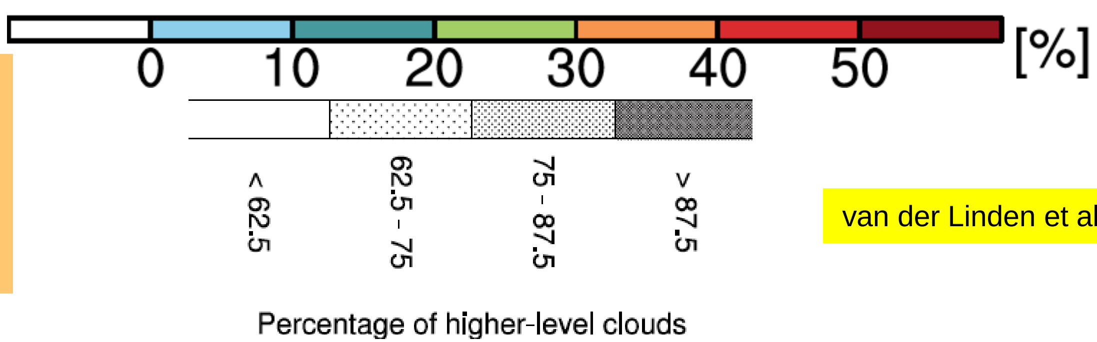
Low clouds below high clouds

Low clouds close to the ground

van der Linden et al. (2015, JGR)

# How extensive is the monsoon stratus?

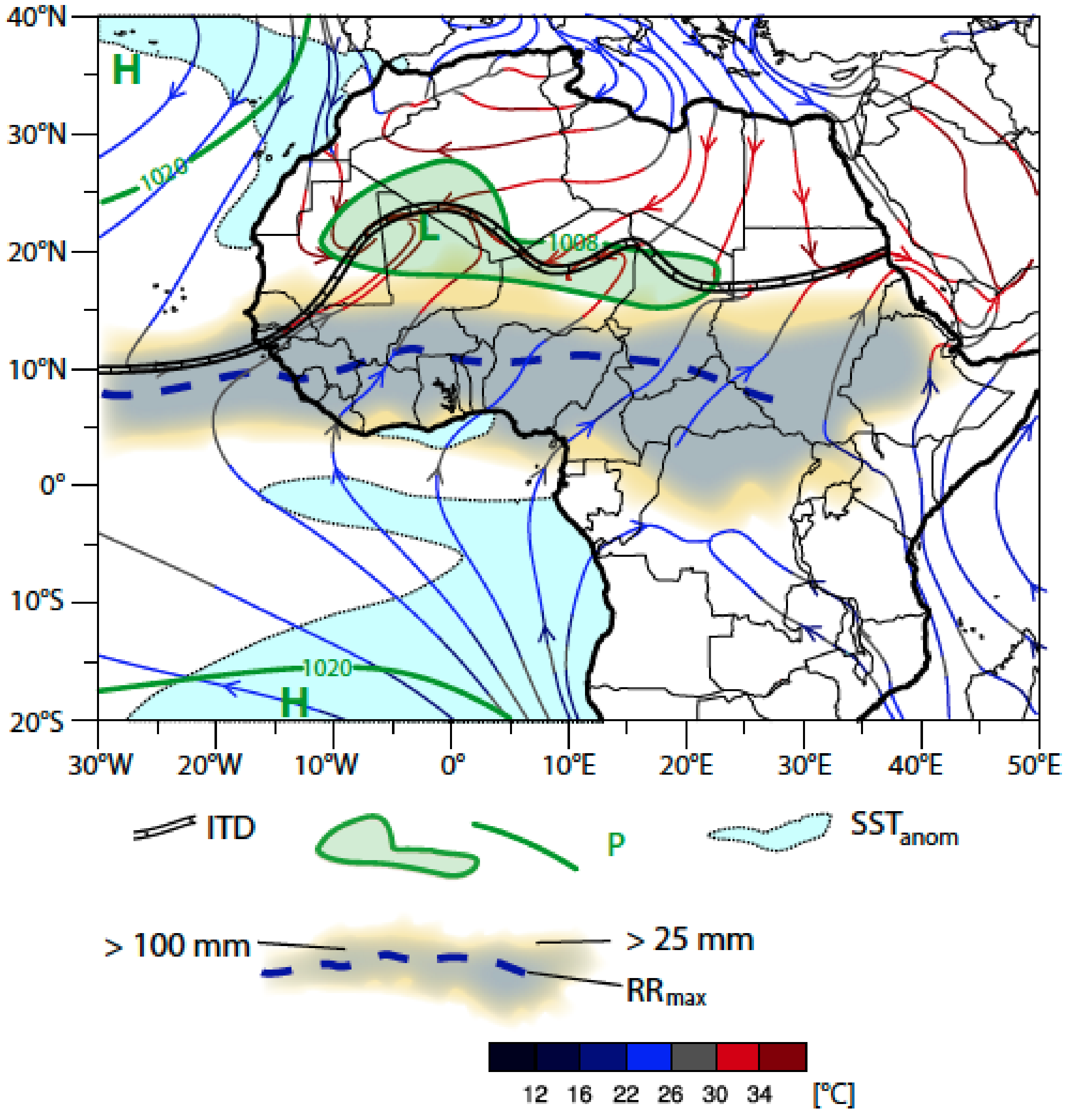



based on NWC SAF at daytime – then “ok”

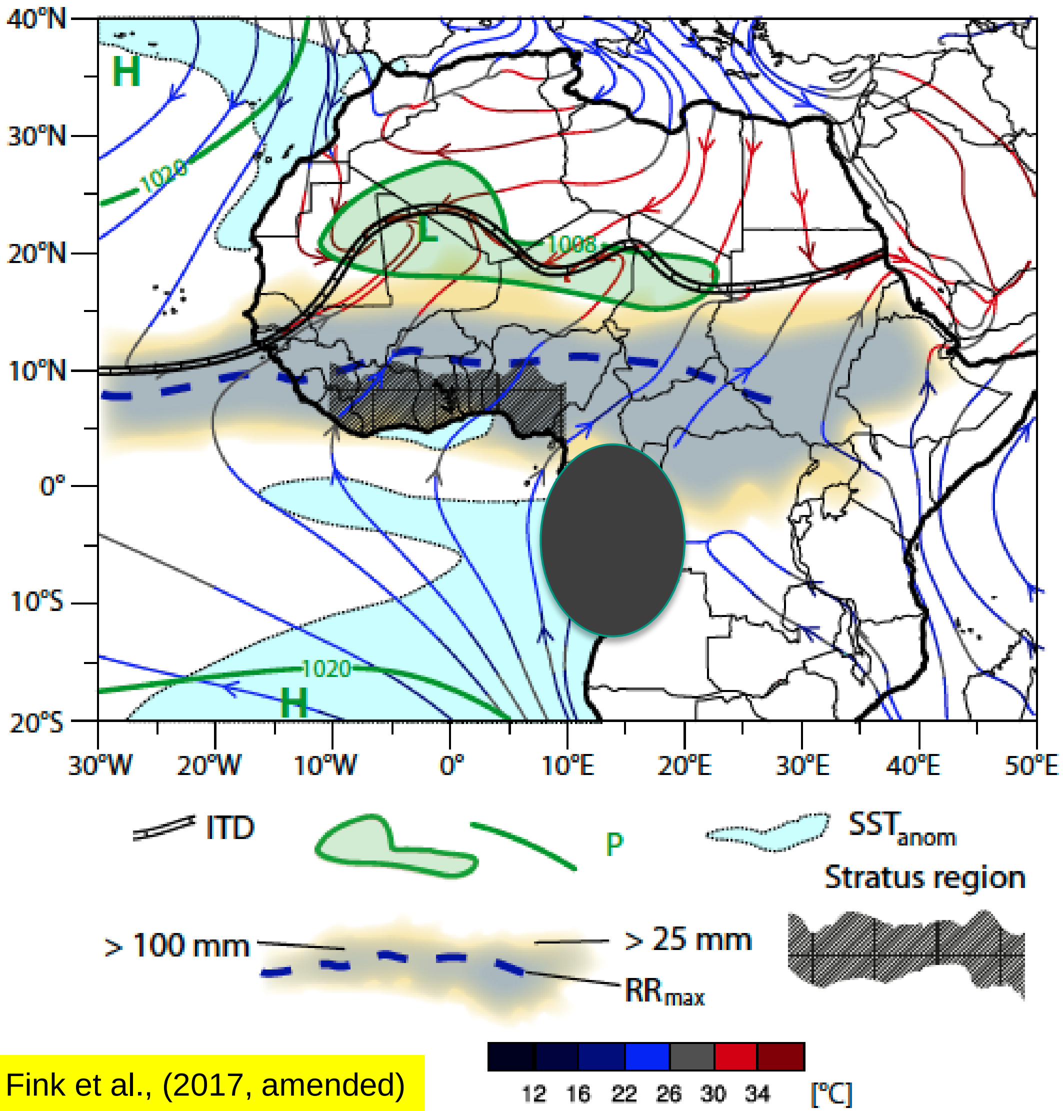
van der Linden et al. (2015, JGR)

# How extensive is the monsoon stratus?




Fink et al. (2017, amended)

# How extensive is the monsoon stratus?




Fink et al., (2017, amended)

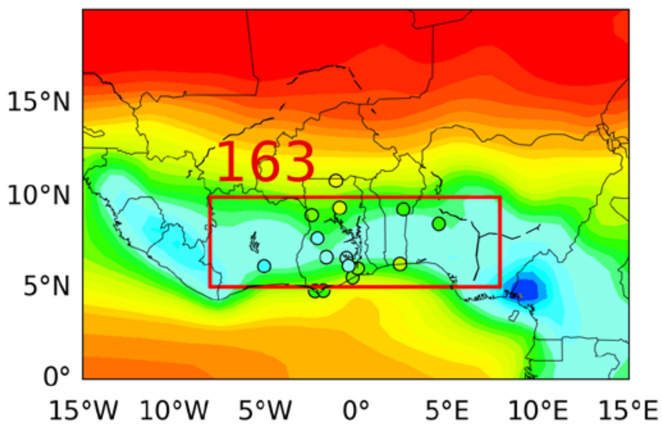
Southern West Africa:

- 800,000 km² at 09-10 LT
- Is observed throughout the year, though less frequent and extensive in the winter dry season

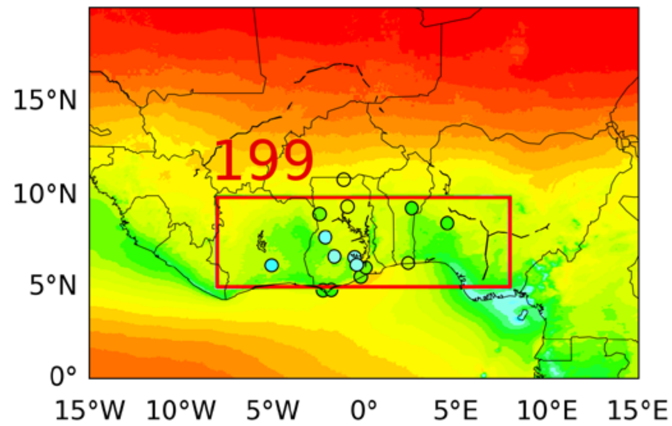
Large stratus area in southern Hemi-sphere ("ellipsoid")

# Large impact on solar incoming radiation

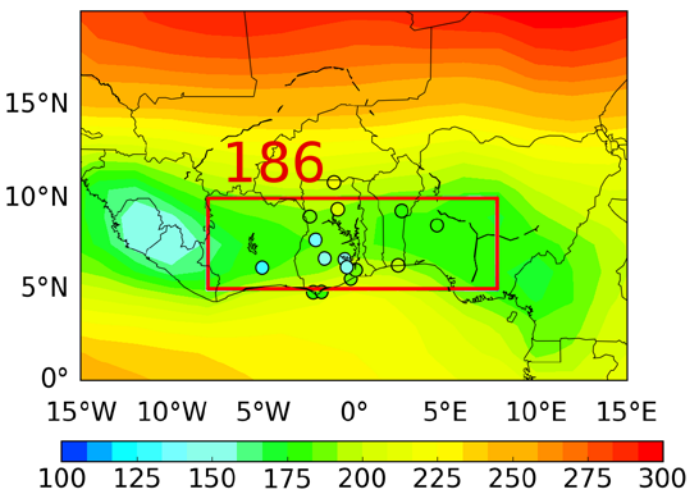
ERA-Interim, JAS 1991-2010




CM SAF SARAH JAS 1983-2008



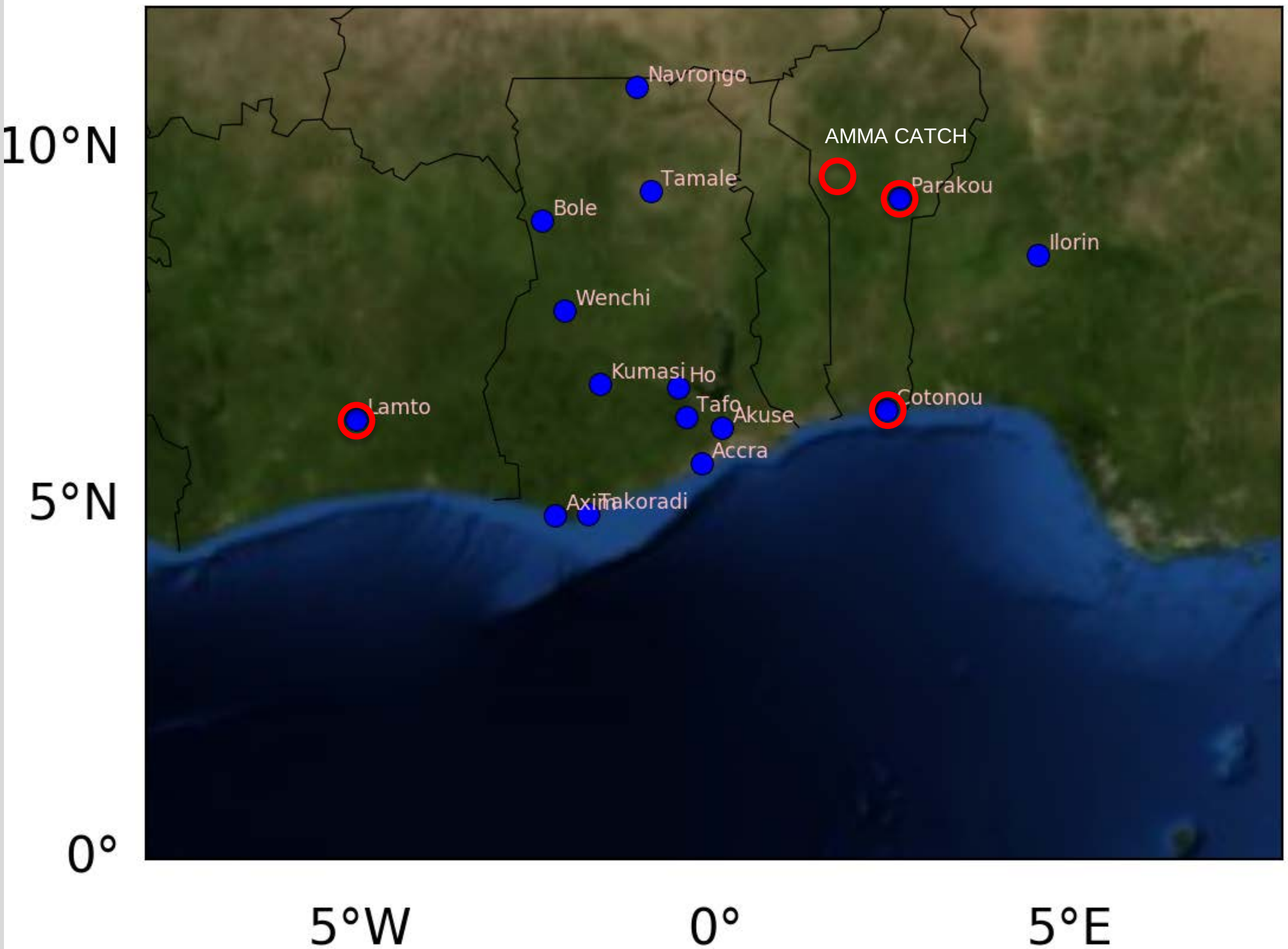

GASS YOTC model mean, JAS 1991-2010




Hannak et al. (2016, JCLIM)

- Large discrepancies among gridded products in stratus region
- Station data show much lower values than CM SAF SARAH-V2

# Does “ground” truth in solar irradiance exist?



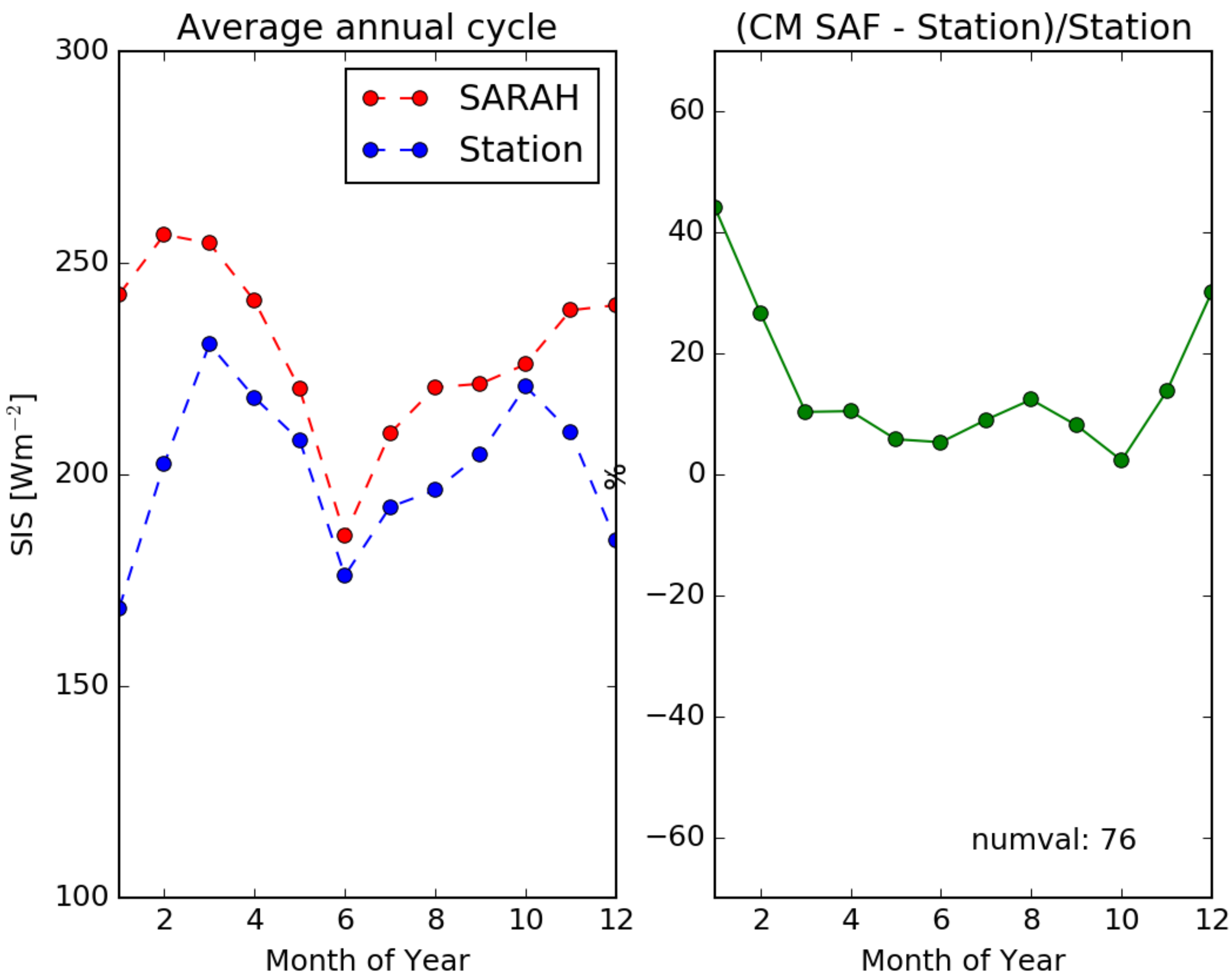

Time-series vary between 1954 and 2016, average length: 14 years

Temporal stability: good, (with exceptions)

**Data sources**:

- World Radiation Data Centre (WRDC)
- The Global Energy Balance Archive (GEBA)
- Lamto Geophysical Observatory
- Karslruhe Institute of Technology
- AMMA CATCH
- (2 stations, not used yet)

# Cotonou: coastal station, few stratus

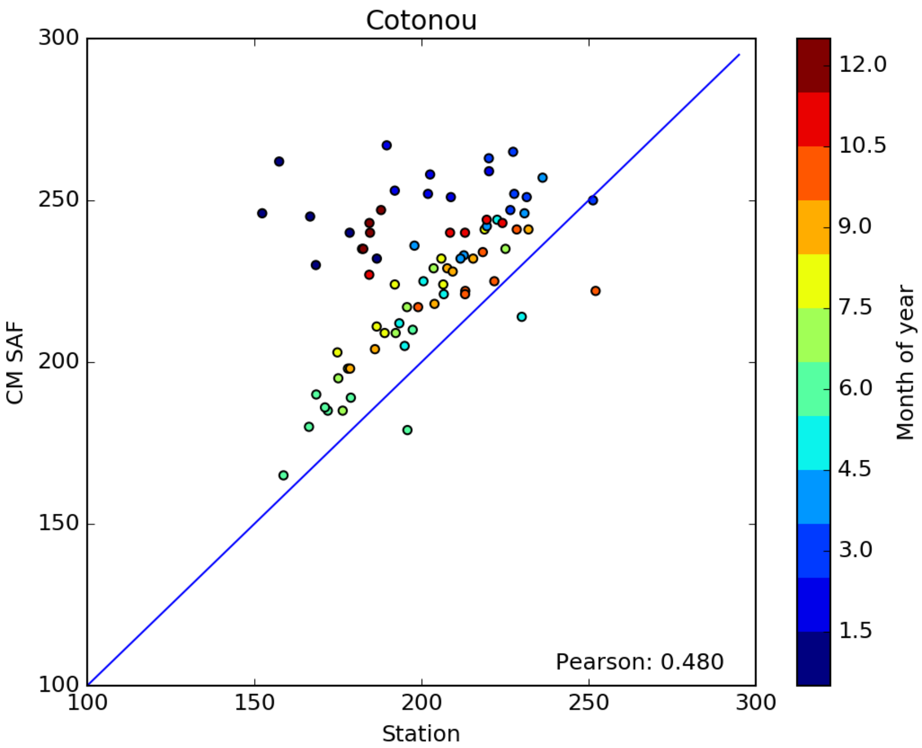



Strongest deviations in winter

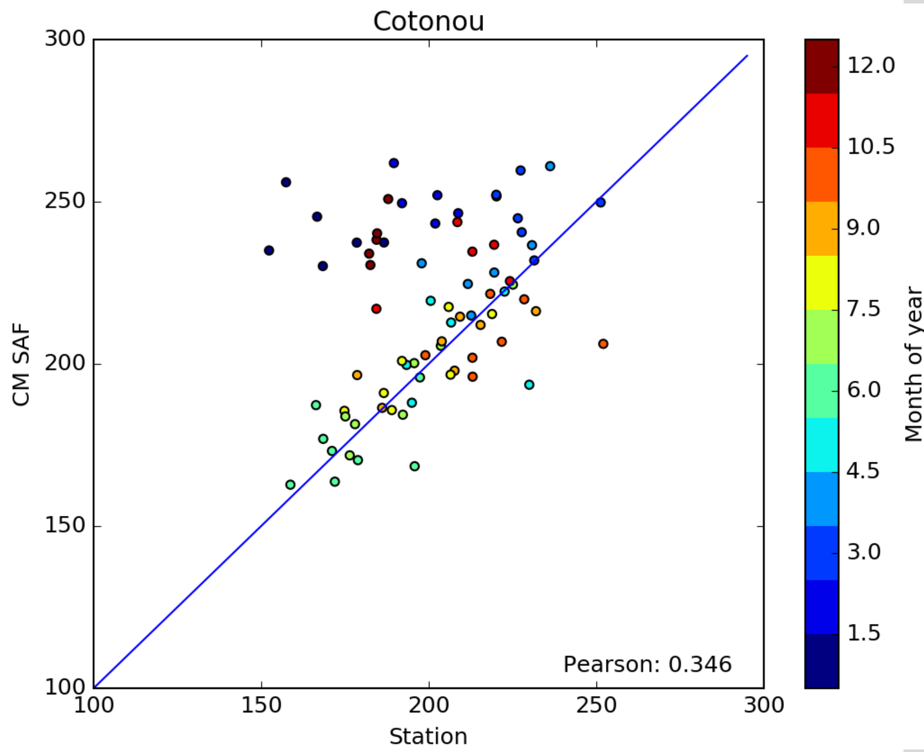
Period: 2001-2008

# Cotonou: coastal station, few stratus in summer

SARAH-V2

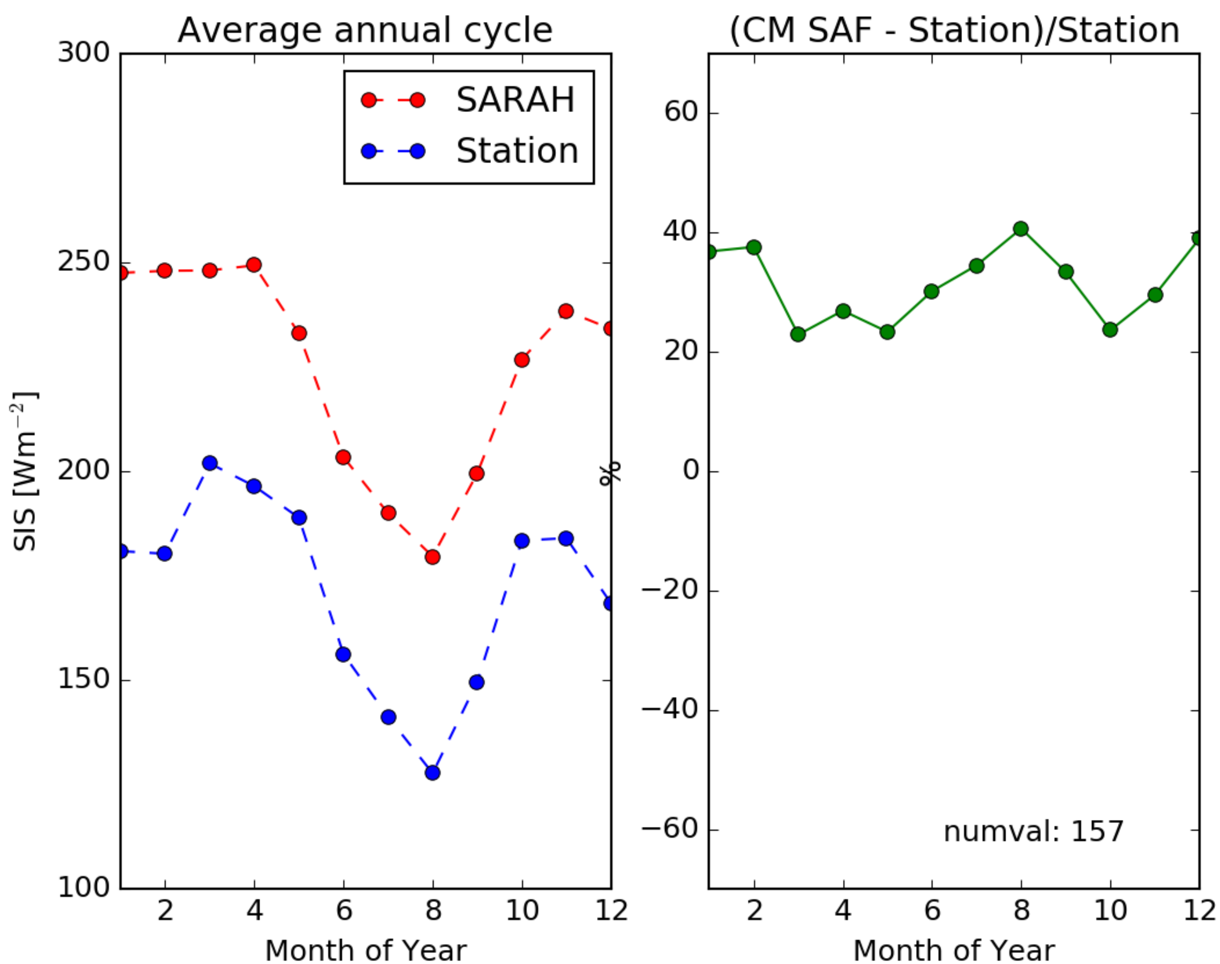



CLARA-V2




Strongest deviations in winter -> problems with dust and biomass burning aerosols

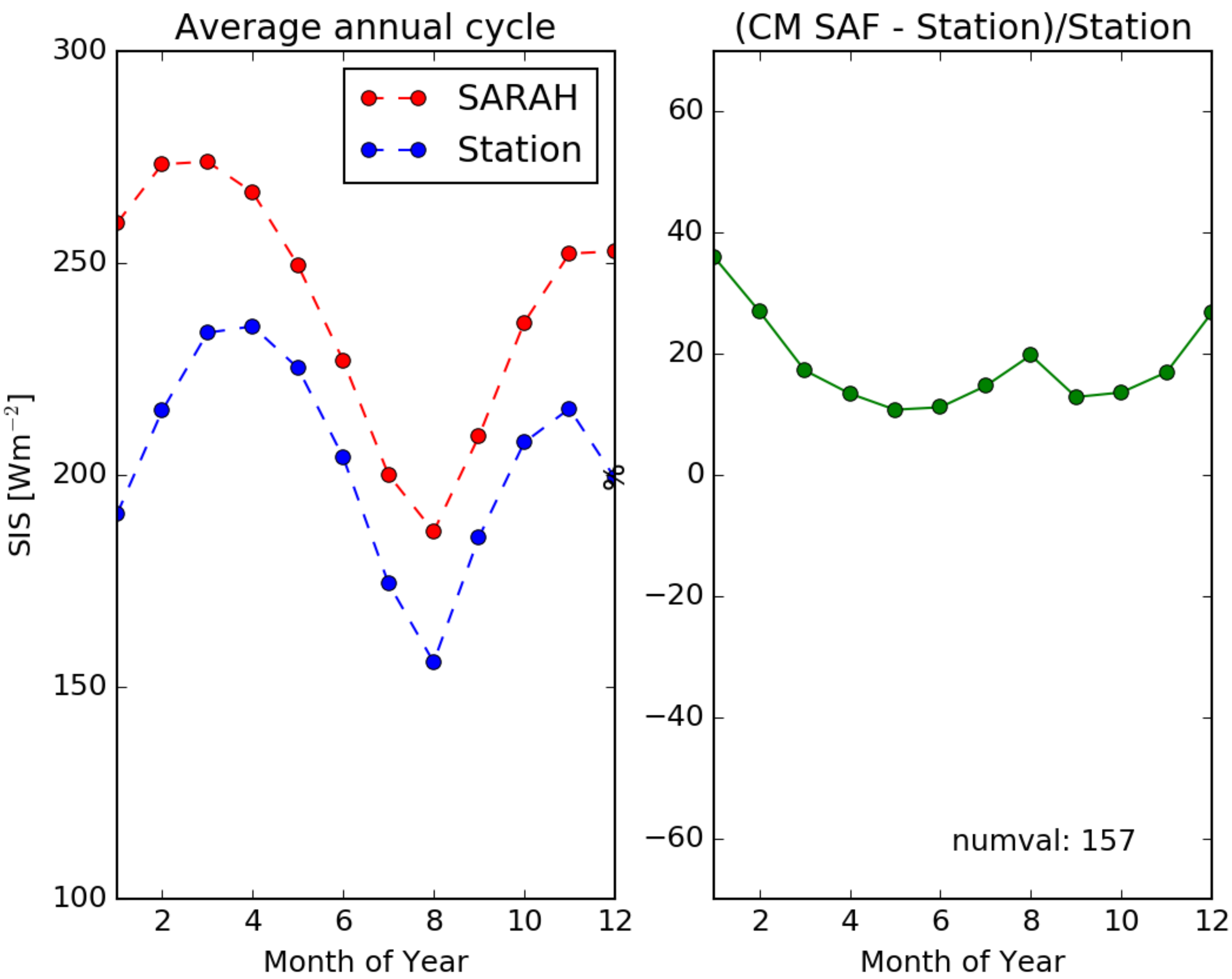
# Lamto: near coast, lots of stratus in summer




Large deviations in summer and winter, somewhat better in pre- and post-monsoon season

Period: 2001-2014

# Parakou: inland, lots of aerosols in winter




Generally high deviations, but here mainly in winter (dry season)

Period: 2001-2015

# Likely reasons for biases in CM-SAF products

**Summer:**

Extensive cloudiness spoil the search for the minimum counts

**Winter:**

Hypothesis is Aerosol, likely hygroscopically grown soot

**Method for CM SAF's SARAH**

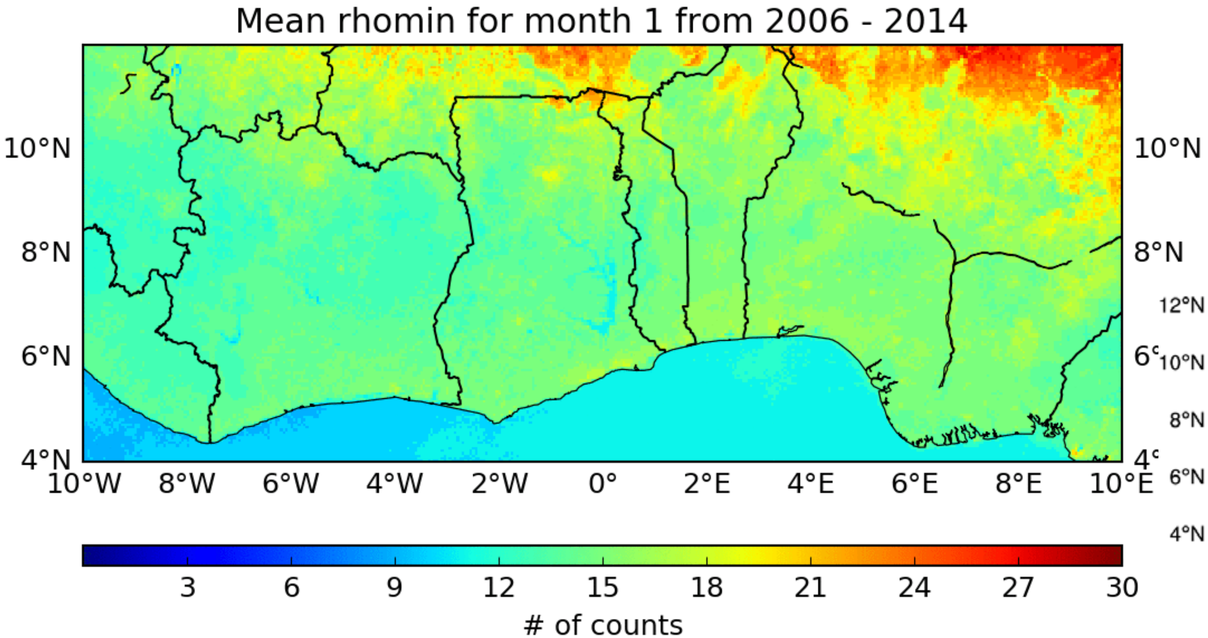
Use counts of visible channels of MVIRI and SEVIRI, find minimum counts per month and pixel + maximal possible counts on whole disc, determine cloud index *n* via:

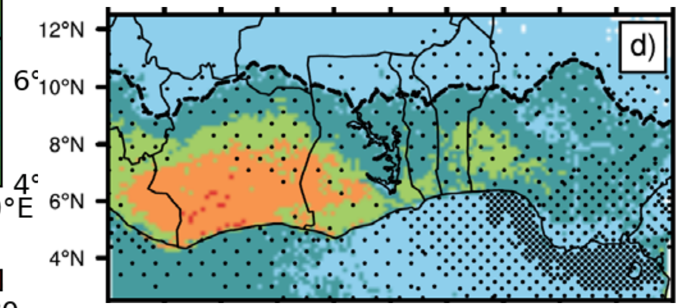
$$n = \frac{\rho - \rho_{min}}{\rho_{max} - \rho_{min}}$$

Clear-sky solar radiation via look-up table with aerosol climatology, solar radiation for all skies with cloud index

# Likely reasons for biases in CM-SAF products

## Rho min annual cycle

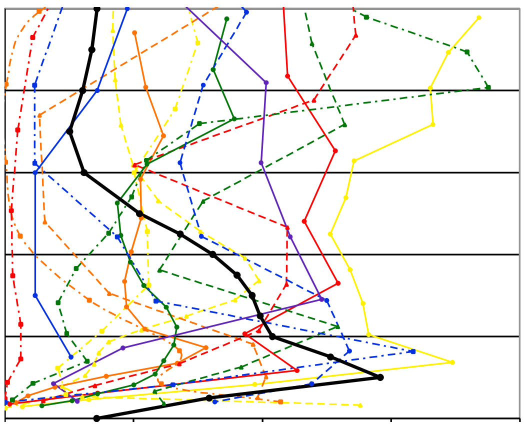


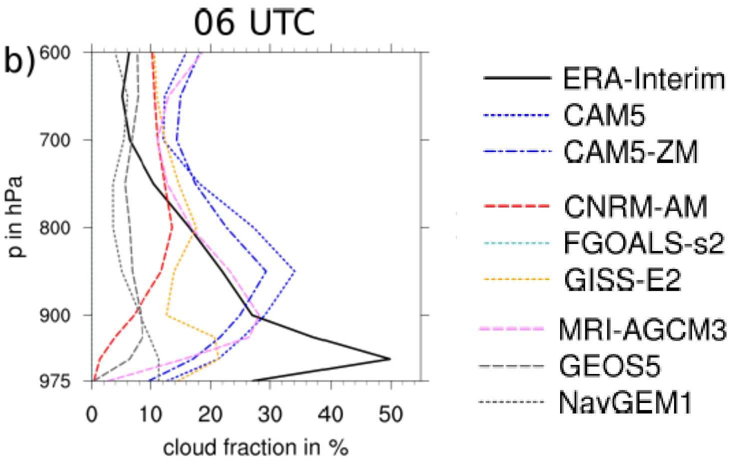

Rho_min (approx. Albedo) changes too much in summer
-> simple suggestion: suggest reprocessing with rho_min from April

# Low clouds & NLLJ in global models

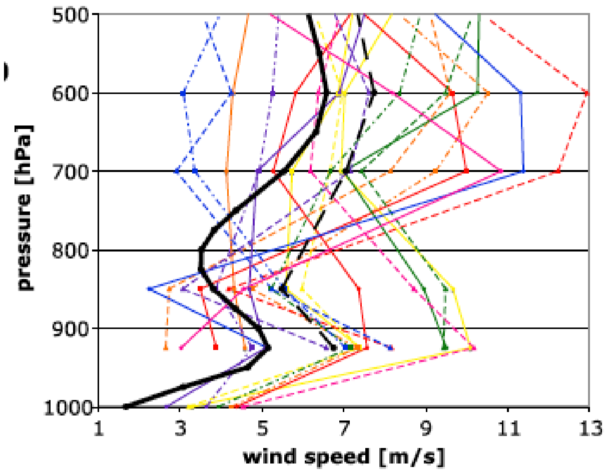
## CMIP3 vs. ERA-I cloud cover



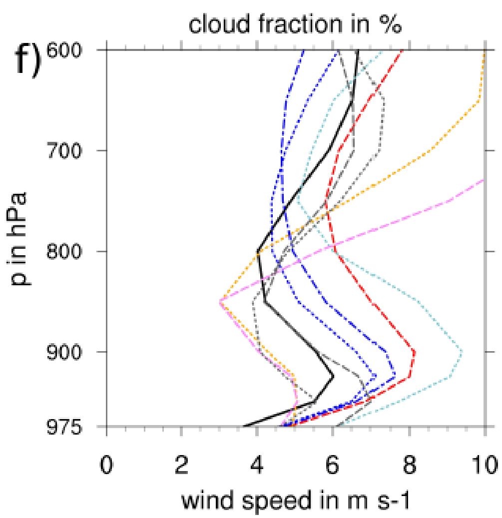
## YOTC-CMIP5 vs. ERA-I cloud cover @ 06 UTC




## CMIP3 vs. ERA-I NLLJ




## YOTC-CMIP5 vs. ERA-I NLLJ @ 06 UTC




Knippertz et al. (2011, JGR)

Hannak et al. (2016, JCLIM).

# Summary

- Problems with stratus detection in CM SAF CLAAS product at night
  -> we still rely on SYNOP eye observation for long-term climatologies
- Difficulties in CM SAF SARAH and CLARA for summer and winter
- Summer: Problems with cloud mask/albedo
- Winter: Problems with swollen aerosol

-> Difficulties in validation of NWP and climate models that show large biases in West Africa

# Backup Slides

- GEBA:

  Gilgen, H. and A. Ohmura, 1999: The Global Energy Balance Archive (GEBA).

  Bull.Am.Met.Soc., 80,831-850.

- WRDC:

  http://wrdc.mgo.rssi.ru/wwwrootnew/publ/WRDC issue 2015 1.pdf

# References

- GEBA:

Gilgen, H. and A. Ohmura, 1999: The Global Energy Balance Archive (GEBA).

Bull.Am.Met.Soc., 80,831-850.

- WRDC:

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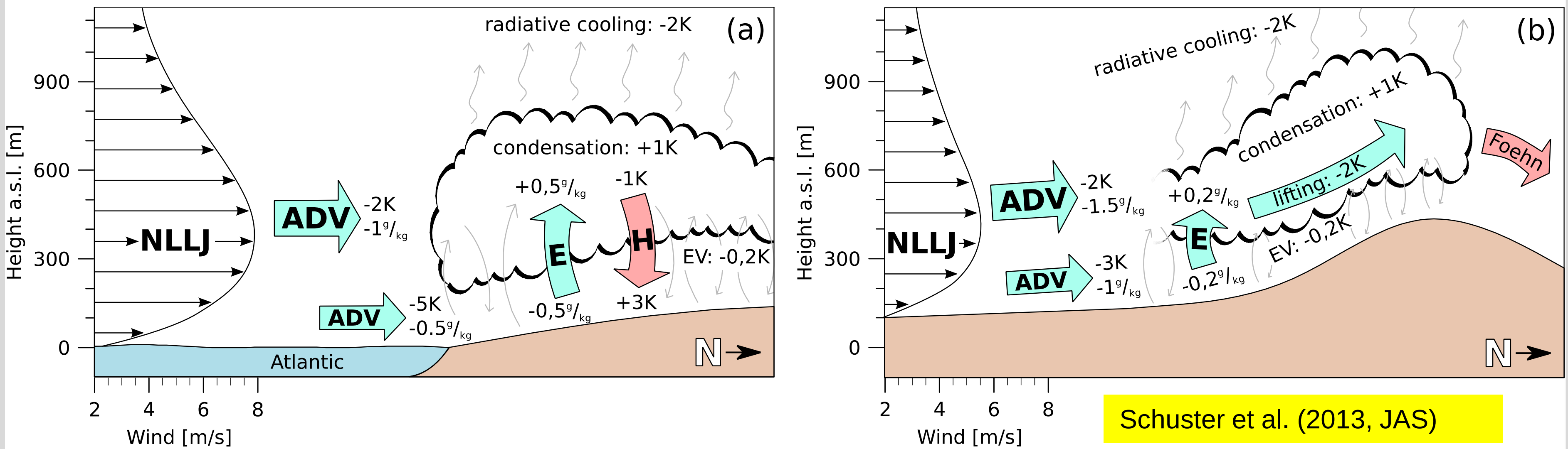
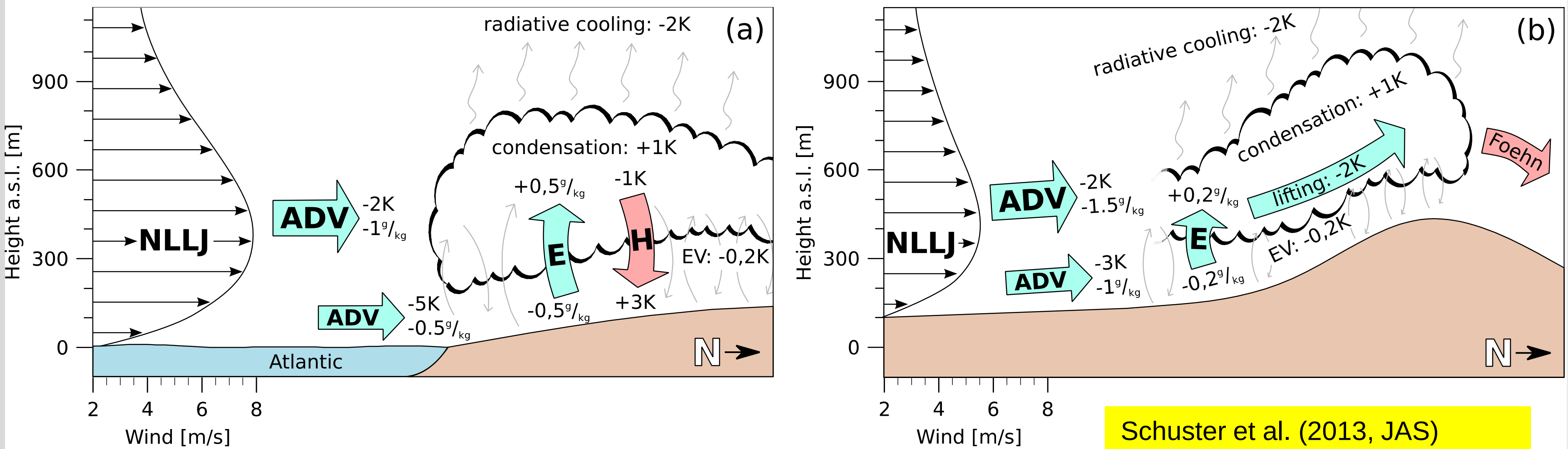
# How are ultra-low clouds related to the NLLJ?




Schuster et al. (2013, JAS)

- Processes that favour stratus formation
  - Upward flux of latent heat and downward flux of sensible heat – promoted the shear underneath the NLLJ
  - Cold air advection from the ocean and/or cooling by forced lifting at the windward side of orography.

# How are ultra-low clouds related to the NLLJ?




Schuster et al. (2013, JAS)

- Processes that suppress stratus formation
  - High stability inhibits shear-driven turbulence, the critical Richardson number is not reached.
  - Clouds at the lee sides of small mountain ranges are dissipated by Foehn effects.
  - Advection of drier air from the south.

# The „stratus“ problem

- Stratus formation appears to be a subtle balance between “stratogenetic” and “stratolytic” processes

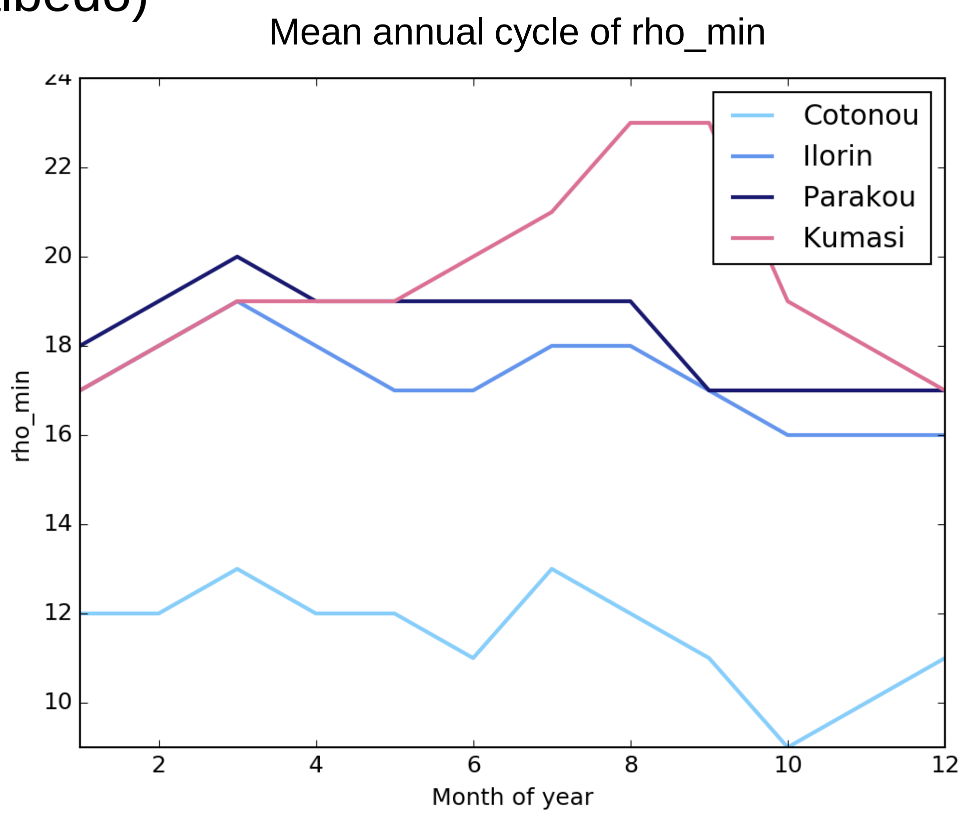
- Processes involved in morning extension/thickening and late mid-day dispersion of stratus not clear yet

-> More surface and PBL observations needed

-> will be carried out in June-July 2016 by DACCIWA

# Likely reasons for biases in CM-SAF products

Quite likely a problem in finding the minimal count per month $\rho_{min}$ (corresponding to ground albedo)




Minimal count will be too high
-> overall data range not big enough

$$n = \frac{\rho - \rho_{min}}{\rho_{max} - \rho_{min}}$$

Effective cloud index *n* becomes smaller with growing $\rho_{min}$

-> too much radiation

# Winter

Assumption: atmosphere hazy from aerosol particles grown by water uptake, difficult for sensor

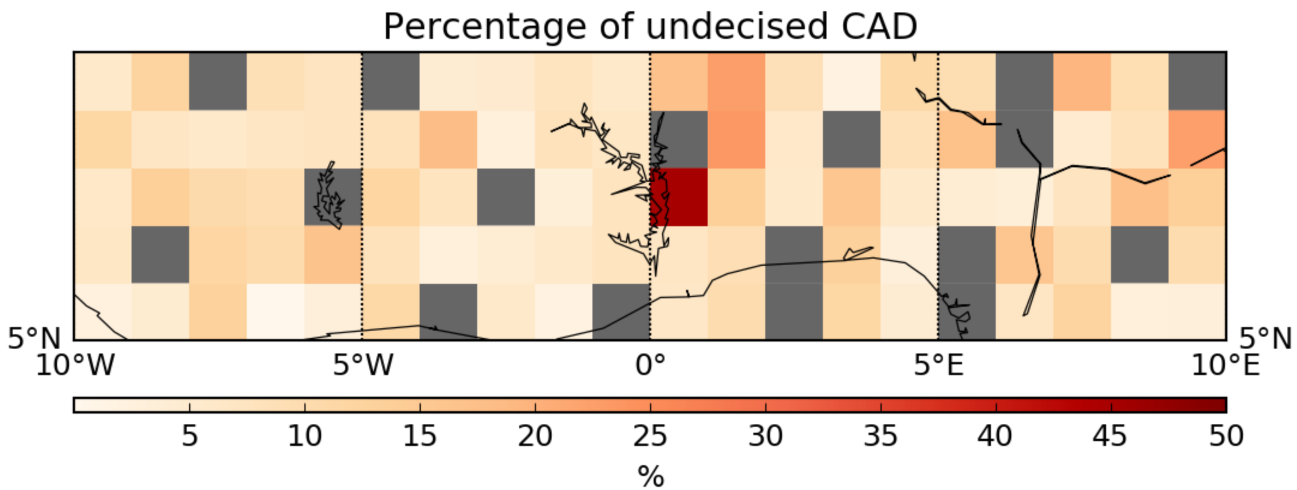
Idea to corroborate the assumption:

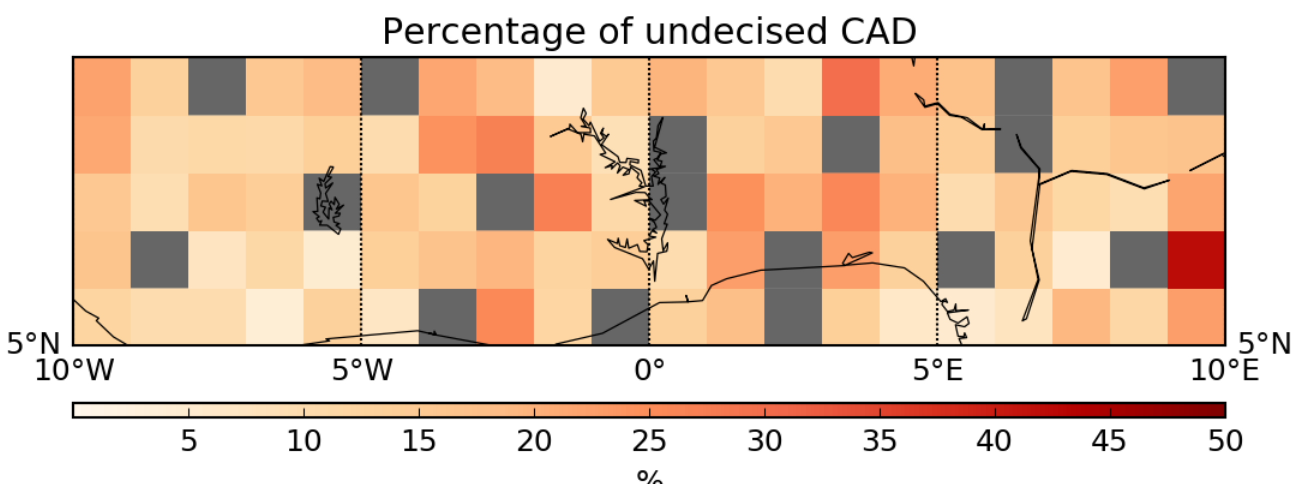
Look into CALIOP data (level 2 lidar profiles), where aerosol and clouds are retrieved with one algorithm, the cloud-aerosol discrimination (CAD) score gives a measure of certainty whether that pixel is really a cloud, aerosol or something in between

The latter is interesting for us, “in between range” is likely Aerosol coated with water

# CALIOP

Summer:




Neither aerosol, nor cloud (this experiment): |CAD| ≤ 70

Aerosol:
CAD = -100

Cloud:
CAD = 100

J,J,A 2010 and
N,D,J 2010-2011

# Summary

- Station data of 15 stations in southern West Africa used for inter model comparison
- Difficulties in CM SAF data (mainly SARAH) for summer and winter, transition times show better agreement
- Two mechanisms proposed: summer: minimal count (surface) cannot be determined due to persistent cloud contamination; winter: swollen Aerosol -> to haze, difficult regime for sat.
- CALIOP test somewhat corroborates the winter assumption