DACCIWA

Dynamics-aerosol-chemistry-cloud interactions in West Africa

The influence of Low-Level Clouds over Southern West Africa in the Regional Monsoon System as simulated by ICON in NWP mode

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DACCIWA



www.dacciwa.eu

DACCIWA (Dynamics-Aerosol-Chemistry-Cloud Interactions in West Africa) studies the impact of the vast increase in anthropogenic emissions in West Africa on the local weather and climate

project partners in Germany, France, UK, Switzerland, Ghana and Nigeria

project is funded by the European Union 7th Framework Program with approx. €9 M

Project overview: Knippertz et al., BAMS (2015)

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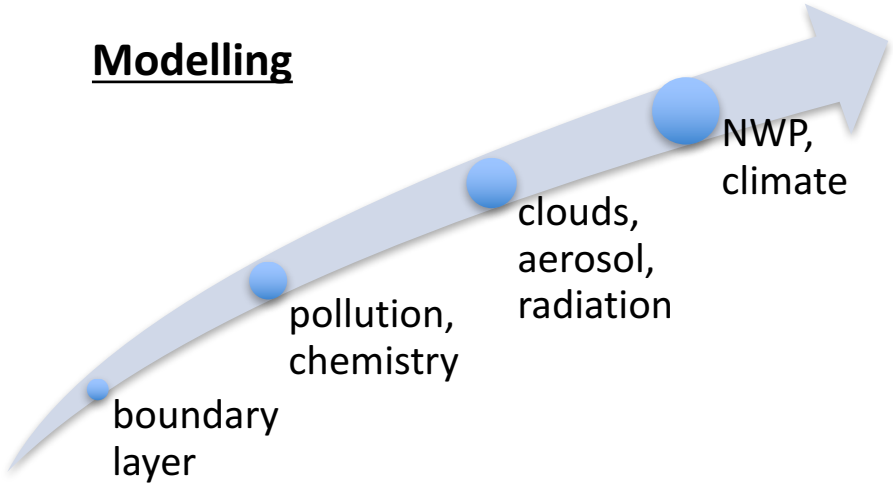
Modelling



Campaign (Ghana, Togo, Benin) 06/07 2016

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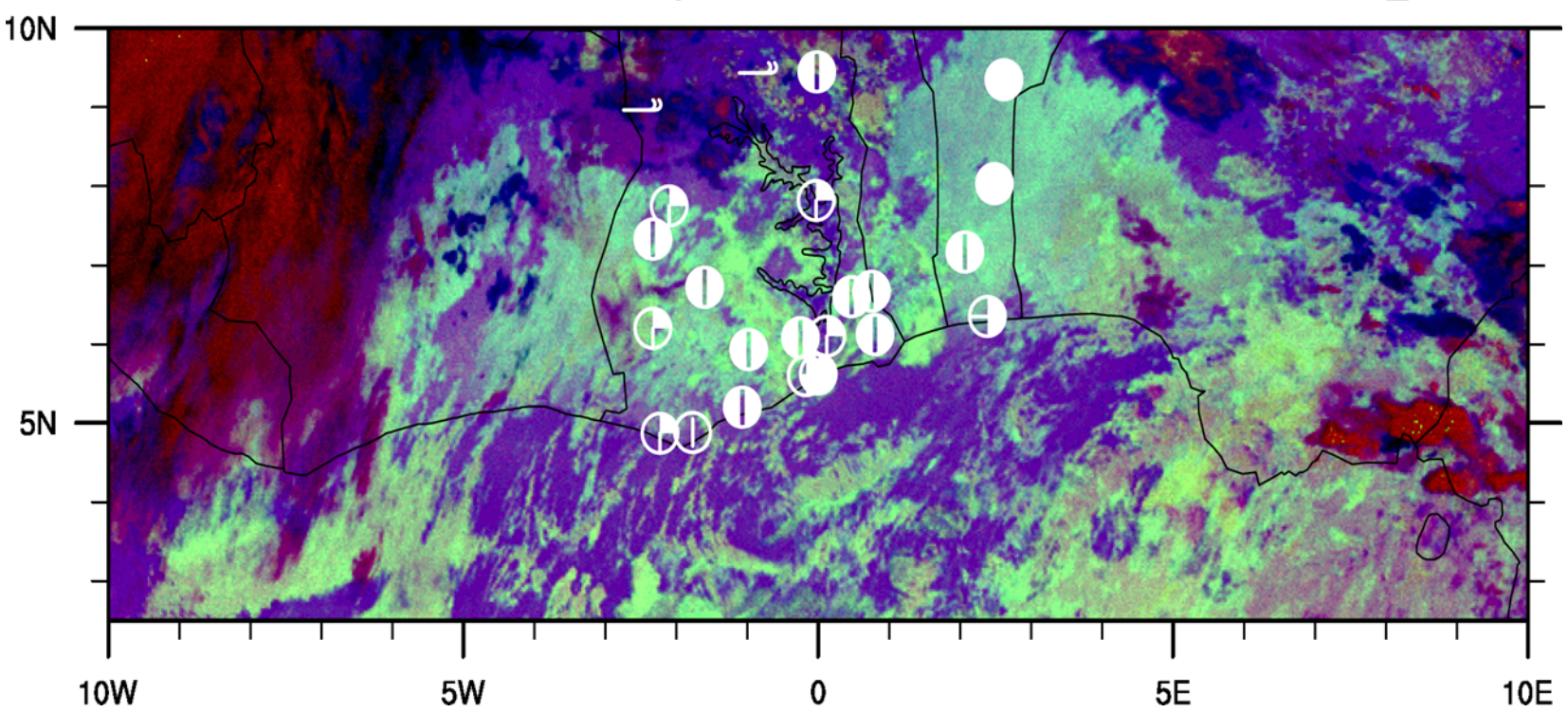
- **3 ground sites**
- **3 aircrafts**
- **Radiosonde campaign**
- **Urban sites**

Low level clouds in southern W.-Africa - observations

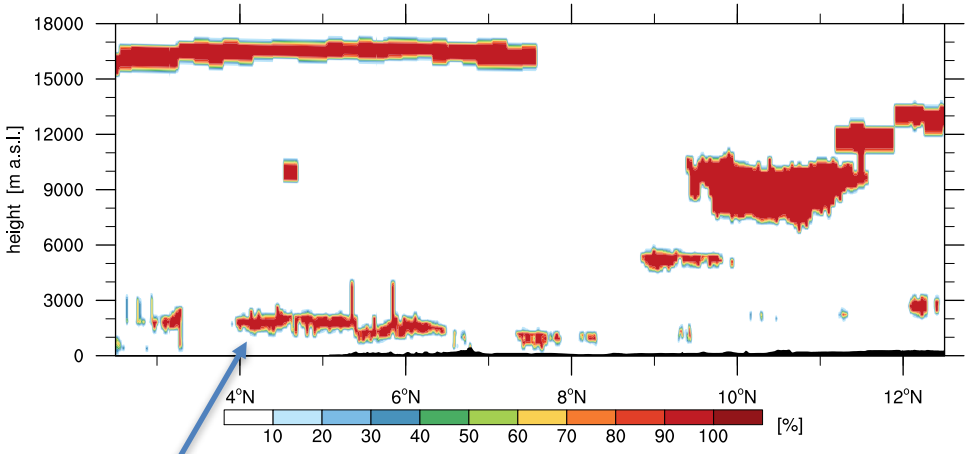
MSG RGB Composite & SYNOP low cloud observations at 03 UTC 20 August 2006



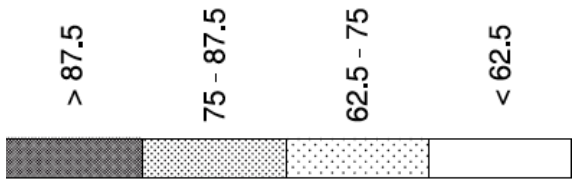
Low-level clouds develop frequently at night, height about 300 m, formation connected to stabilisation through radiative cooling and the nocturnal low level jet

van der Linden et al. (2015, JGR)

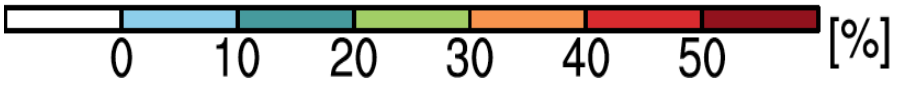
Satellite observations



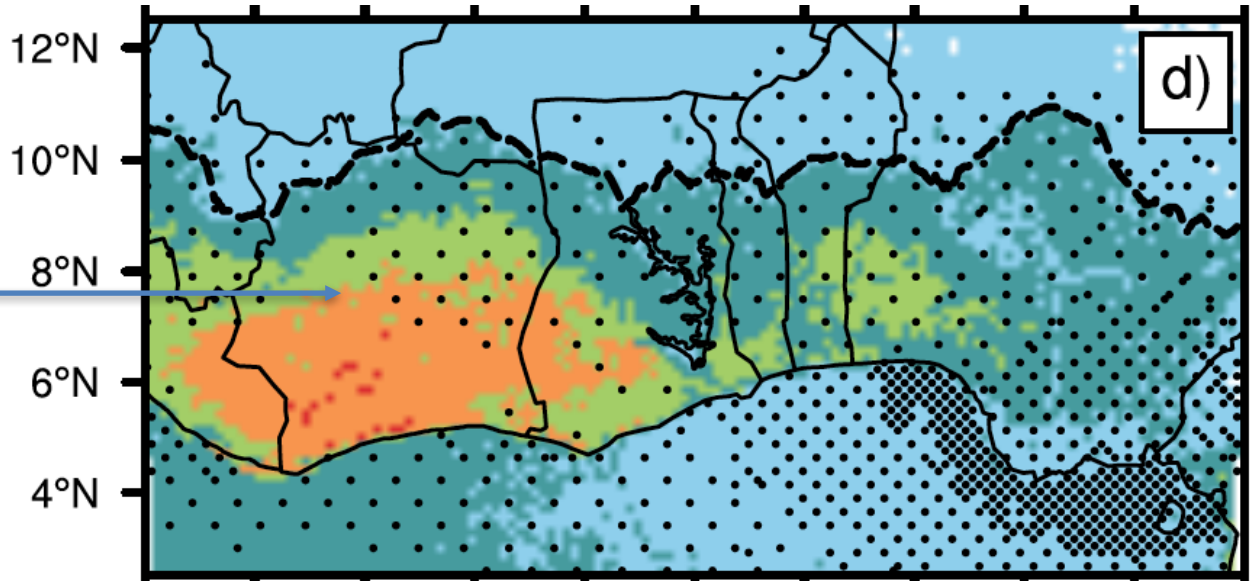
GEOPROF



Percentage of higher level clouds



Low level clouds often obscured by higher level cloudiness
-> impact on statistical measures



van der Linden et al. (2015, JGR)

Bad representation in climate models

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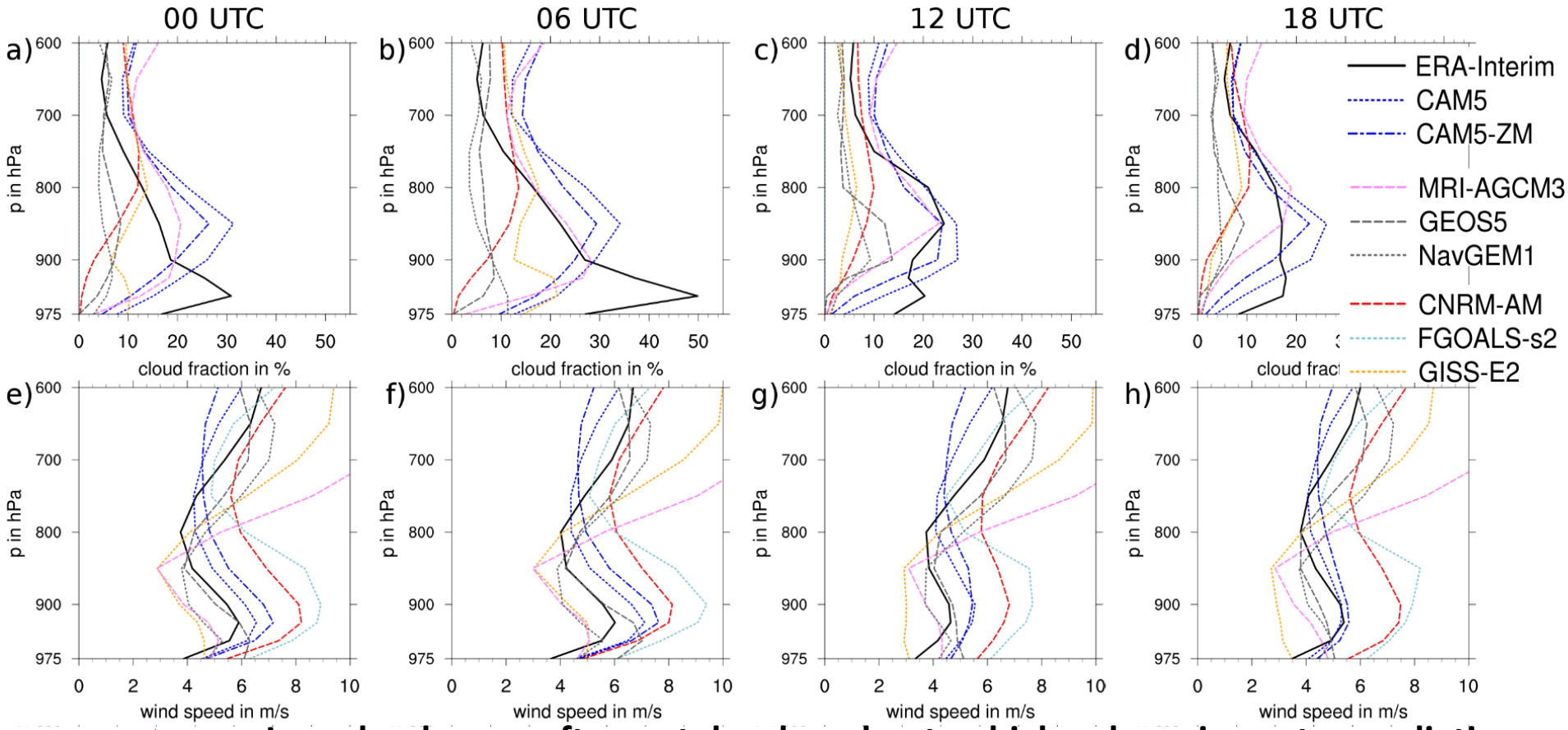
Diurnal cycle of cloud and wind profiles from Year Of Tropical Convection modelling effort, 1991-2009 average + ERA-interim to compare:

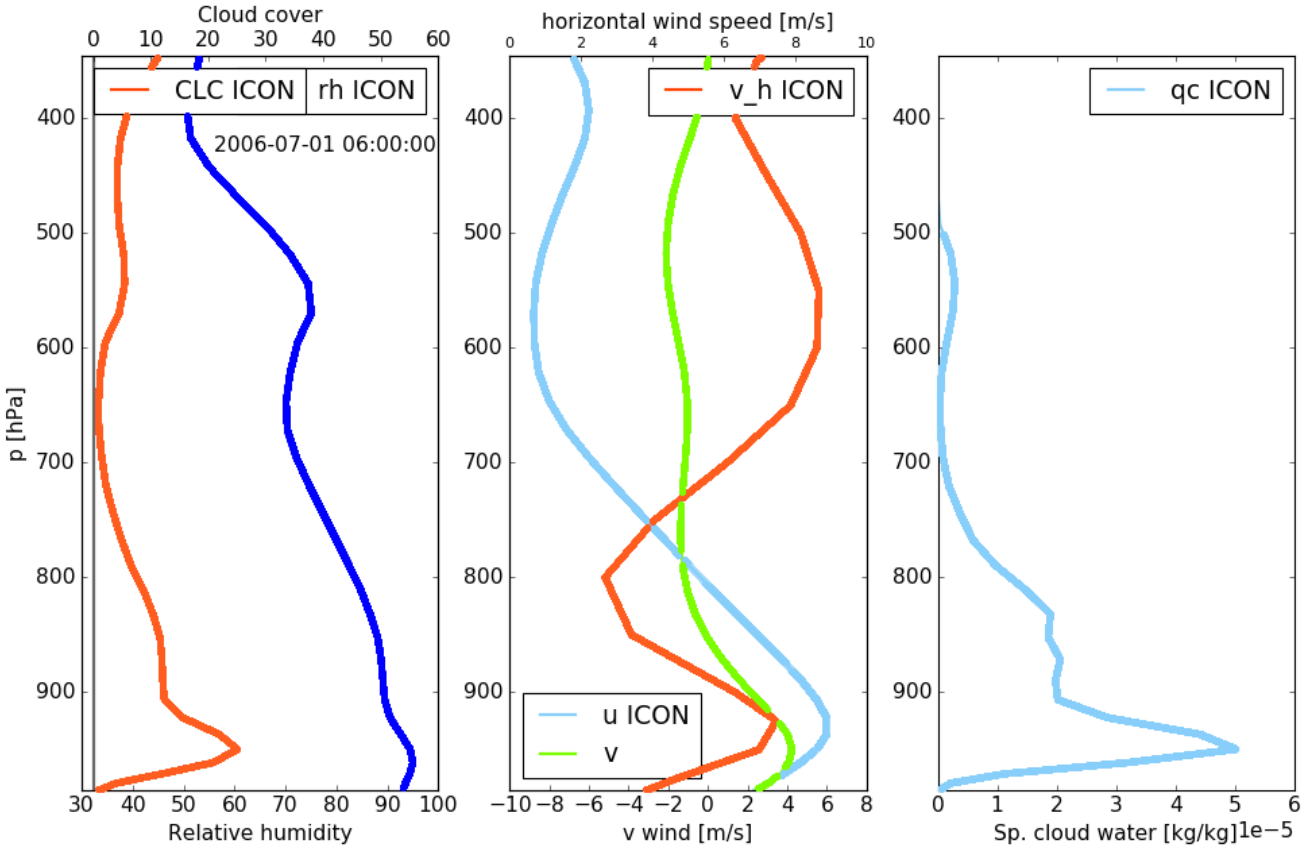


Low cloud cover often not developed or too high -> large impact on radiation, nocturnal LLJ too strong Hannak et al. 2017

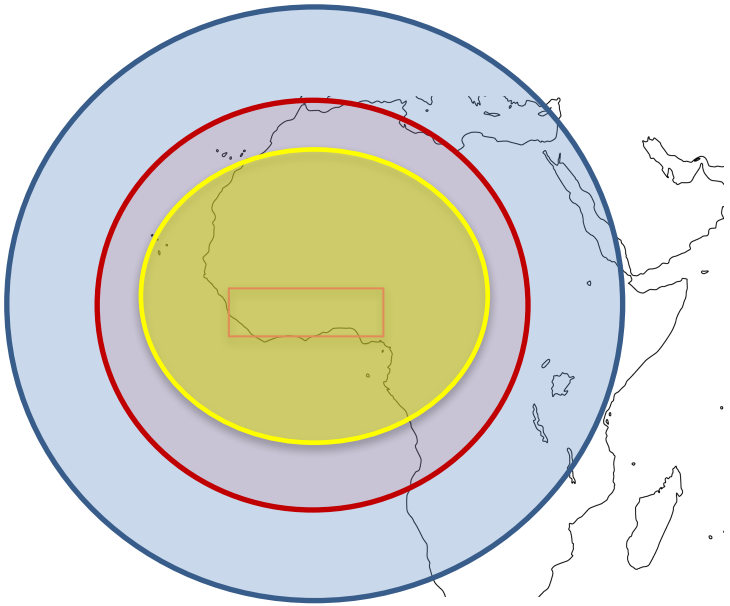
ICON: Sensitivity test possible?

- NWP model ➜ physics packages, initialisation
- Higher horizontal resolution (14 km vs 50 km)
- Has low clouds? Yes!
- NLLJ not too pronounced

➜ suitable as bench-mark



Make clouds transparent



- **multiply cloud liquid water below 750 hPa with constant factor prior to ever call of radiation scheme (in DACCIWA box)**
- Jul 2006
- 5-day simulation started every 4 days
- Output hourly
- Initialised with ERA Interim reanalysis
- 7 sets in total, τ ranging from 0.1 – 10* τ_{orig}
- For 2 nd round only τ =0.1 and 1.0 * τ_{orig}
- 91 level

2 types of experiments

1 st:	
Global grid:	53 km
1.Nest:	26 km
2.Nest:	13 km

2 nd:
Add 3rd nest with 6.5 km, explicit convection

Nests are centred at 0°/0°

Results: surface temperature

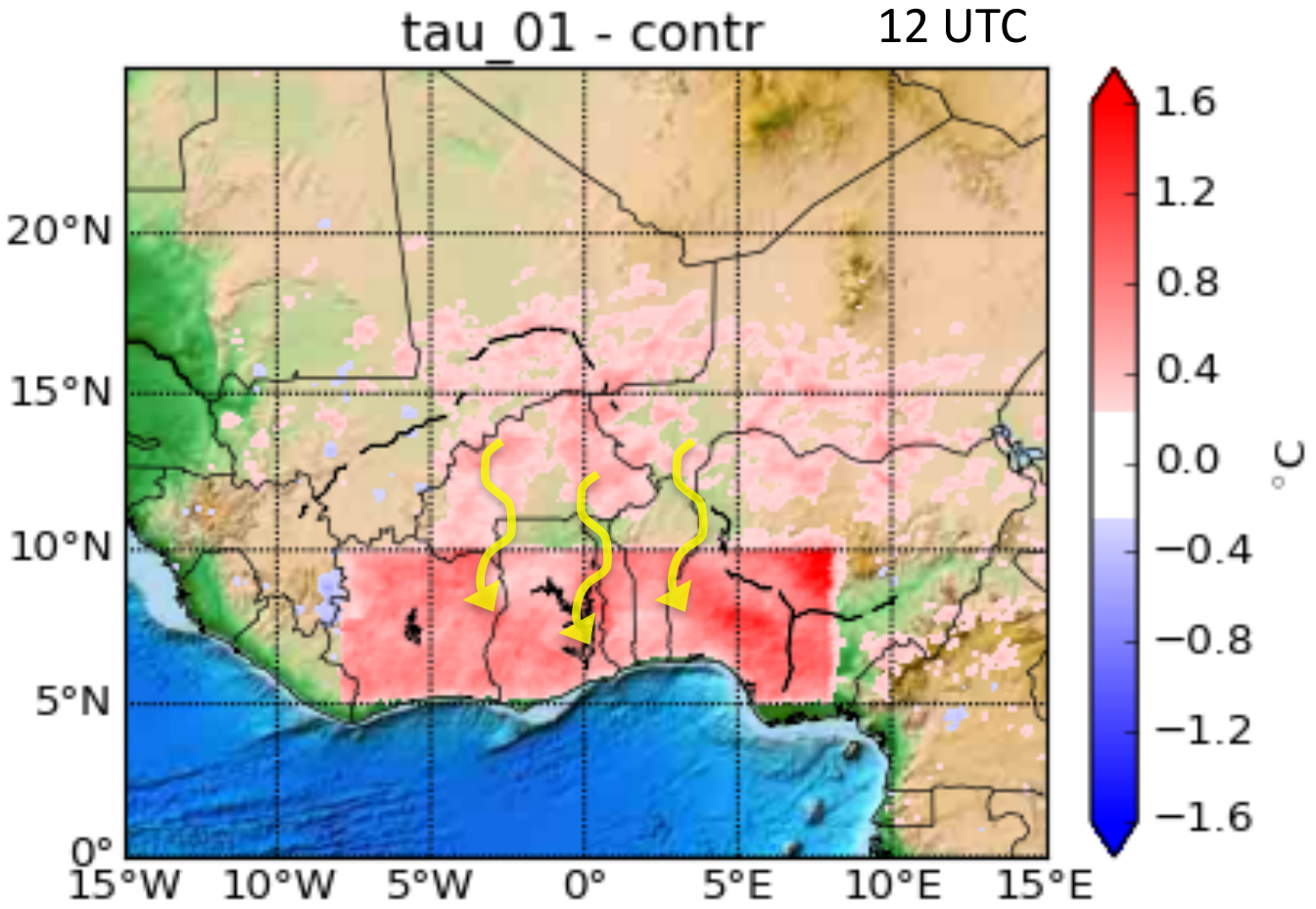
Average diurnal cycle from Jul 2006

DACCIWA region:

Clouds more transparent ($tau_t = 0.1*tau_o$)

Results:
Increased solar insolation

-> $T_{surflayer}$ increases



Convection + turbulence! Influence in one module translates into others

Tendency of relative humidity

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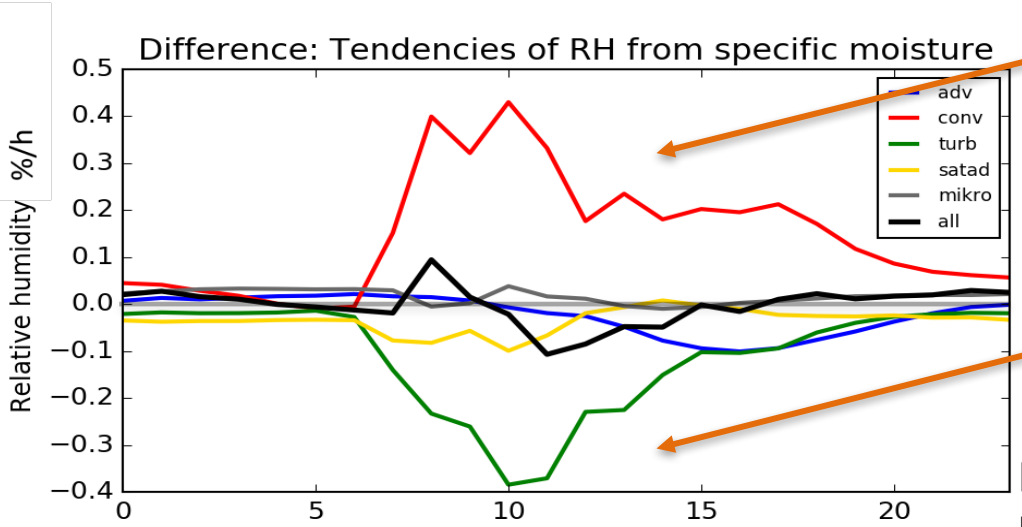
Contributions of atmospheric processes to rh, average diurnal cycle

Difference exp. – contr.

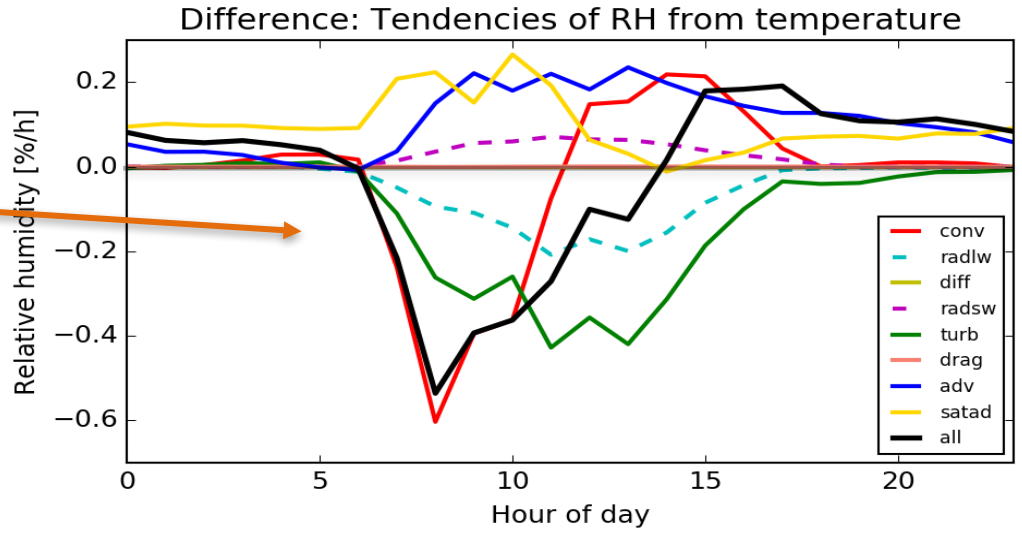
$$\frac{\partial RH}{\partial t} = a \cdot \frac{\partial q_s}{\partial t} - b \cdot \frac{\partial T}{\partial t}$$



Convection

Turbulence

Both affected by low clouds (in model)

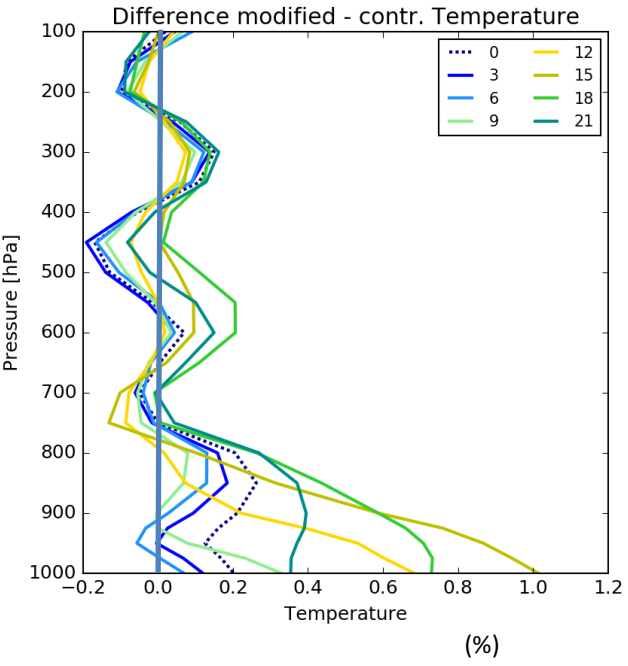


Longwave radiation
less influence
-> modification translates into other physics modules

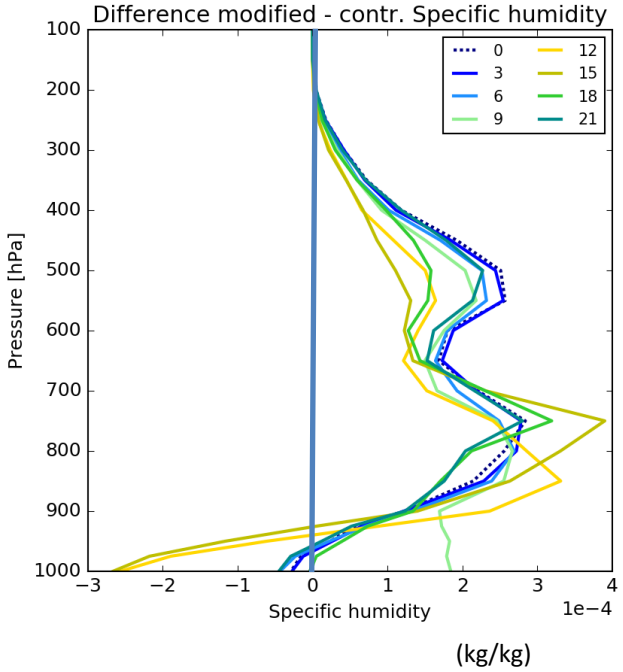
Thermodynamics

- **Specific moisture, winds, and cloud cover (cloud water content) -> precipitation**

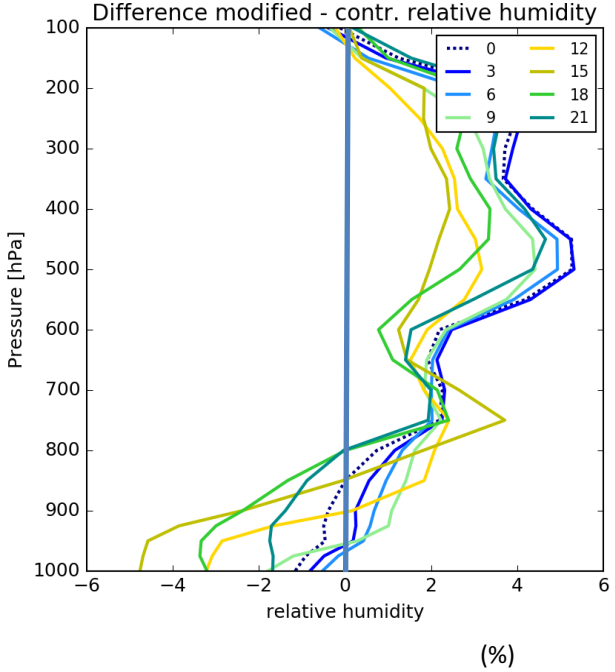
Heating of surface and cloud layers (more humidity + latent heat release)



Moistening at 800 hPa, later drying near surface -> transport q upwards

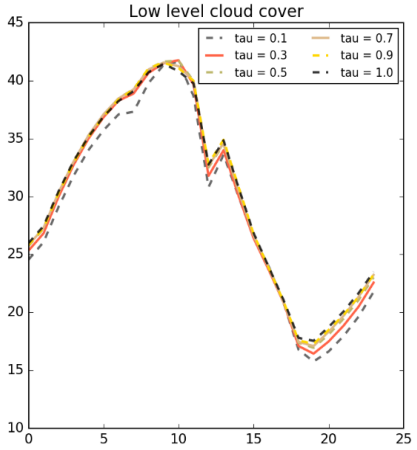


Reduced rh close to surface but increase above, (very low at night) -> clouds??

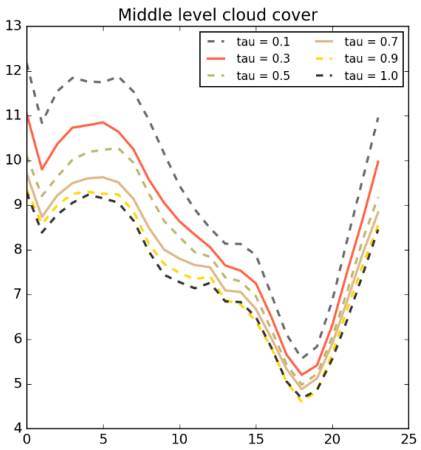


Cloud cover diurnal cycle

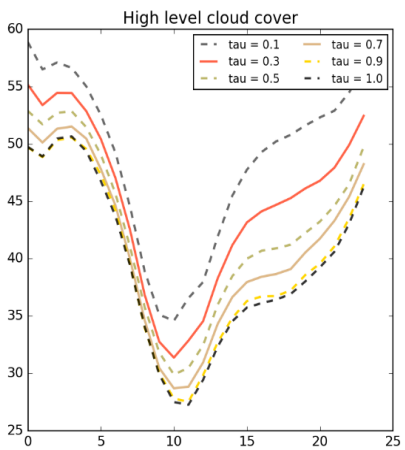
1000 – 700 hPa



650 – 450 hPa

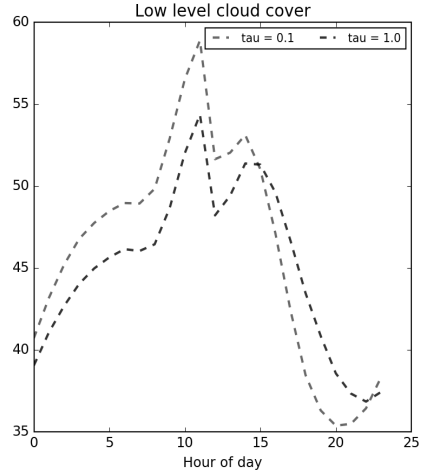


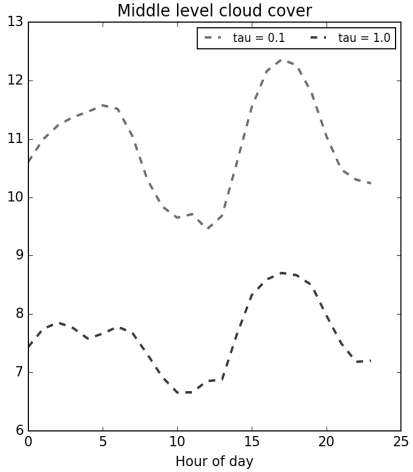
400 - 100 hPa

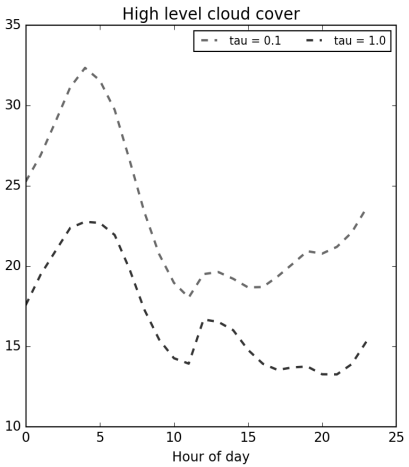


Layers chosen from average state for July 2006

14 km nest



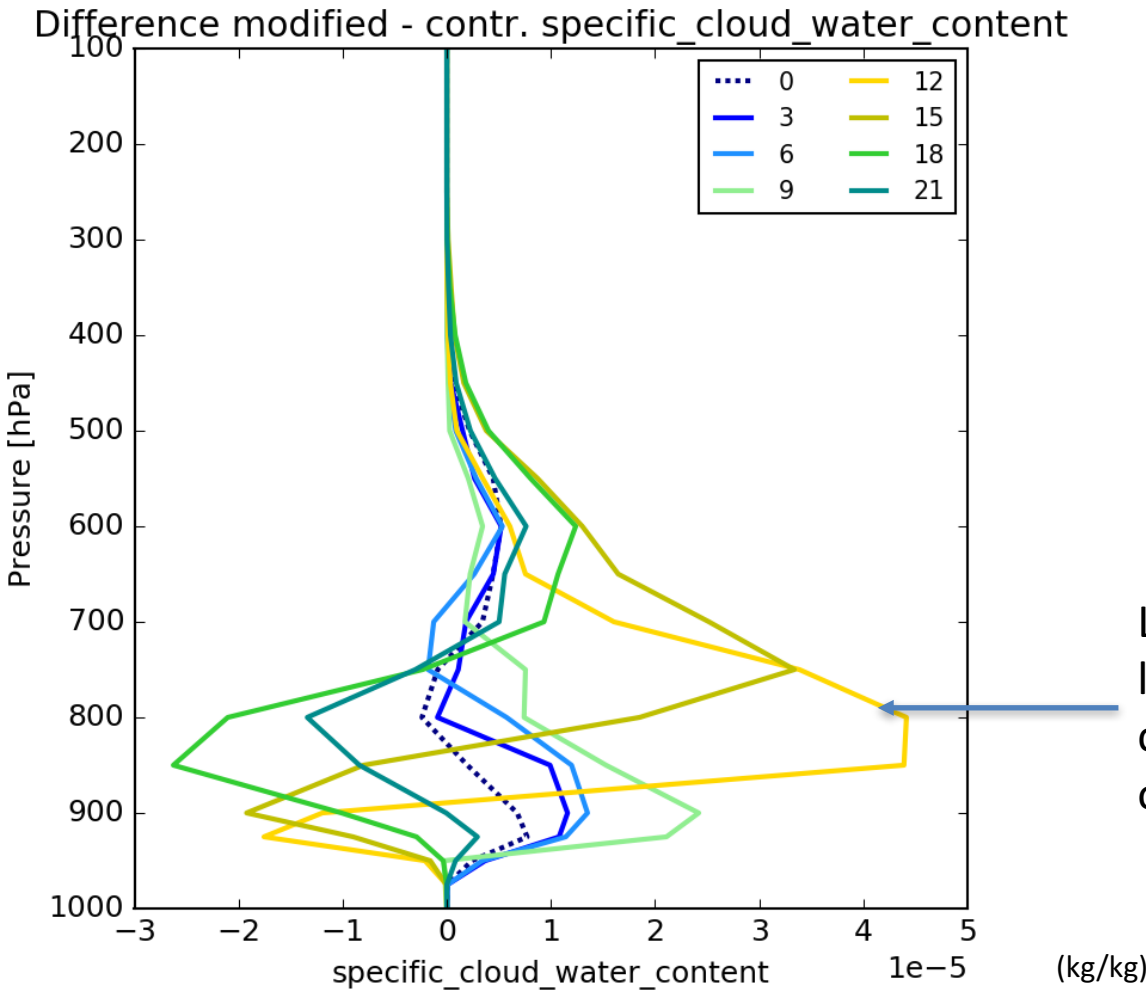




6.5 km nest

Effect on high cloud cover stronger than on lowest levels, Increase of cloudiness with decreasing optical thickness of low level clouds

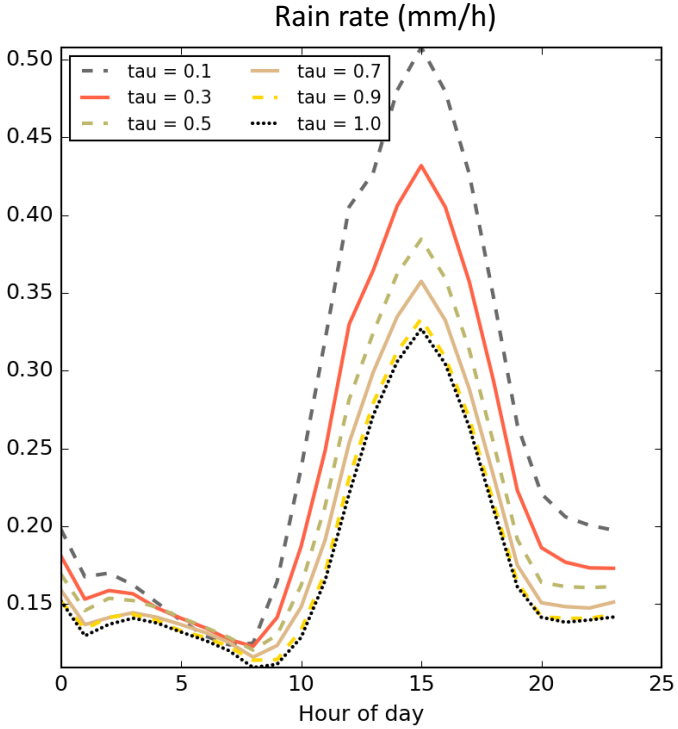
Cloud cover diurnal cycle



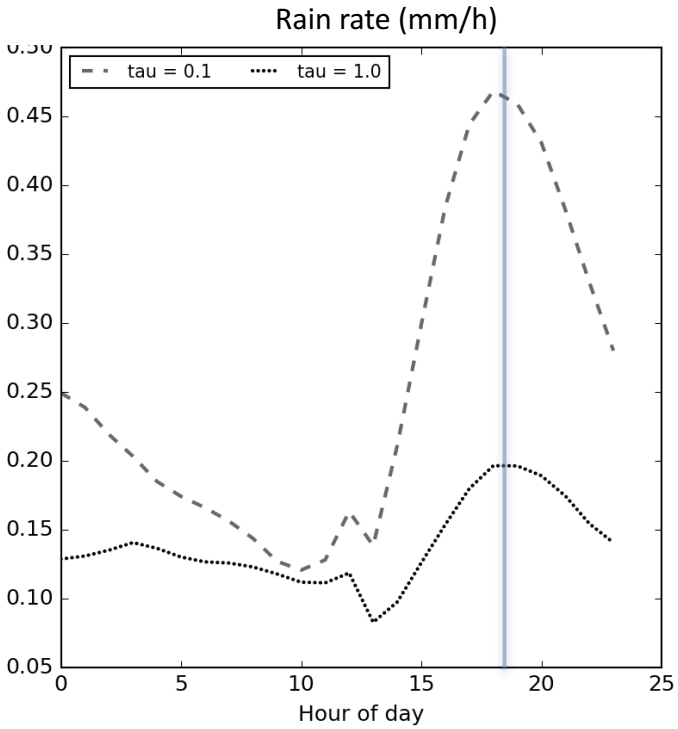
Lifting of cloud layer compared to original run

Influence on precipitation

14 km



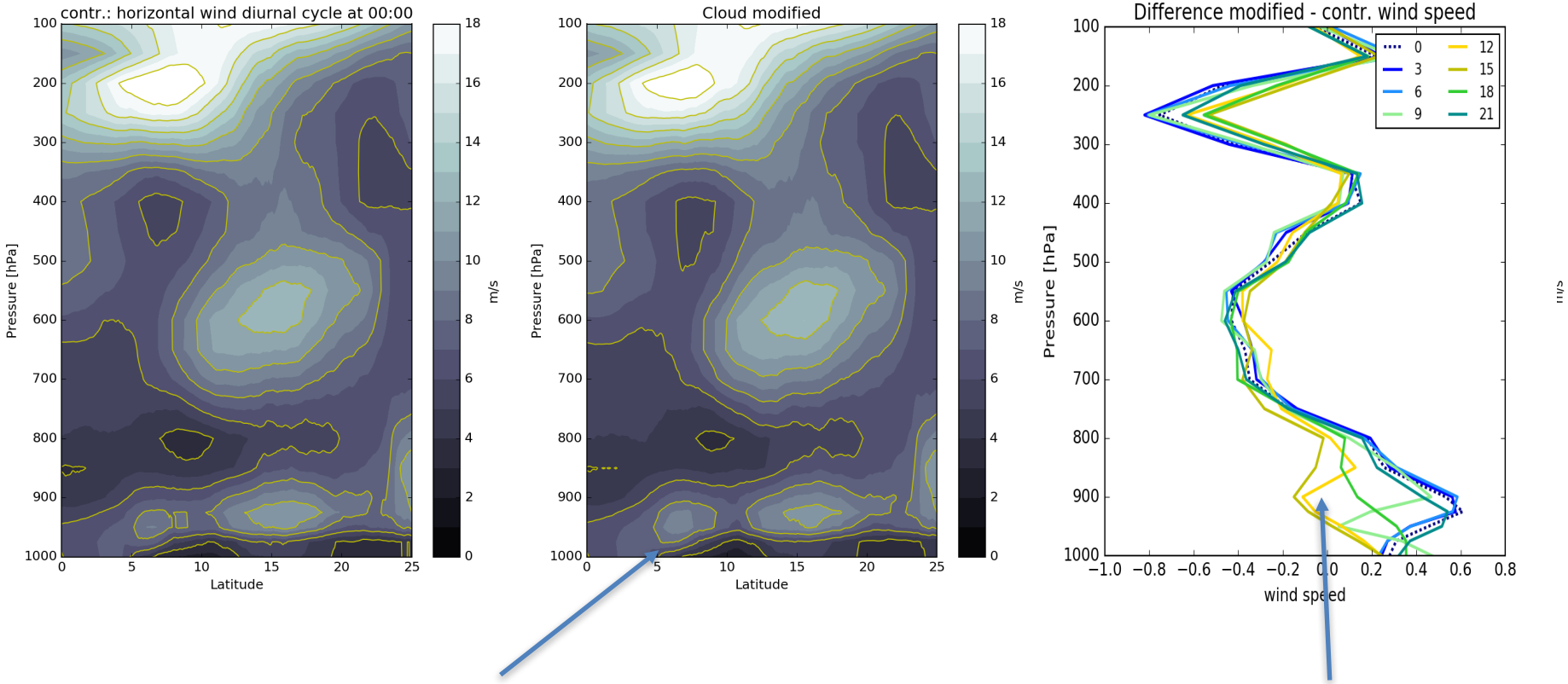
6.5 km



- Smaller tau -> more precipitation in all experiments
- Convection-permitting: peak later in the early evening, difference between control and tau=0.1 bigger than in 14 km run

Horizontal wind speed

Average diurnal cycle, July 2006

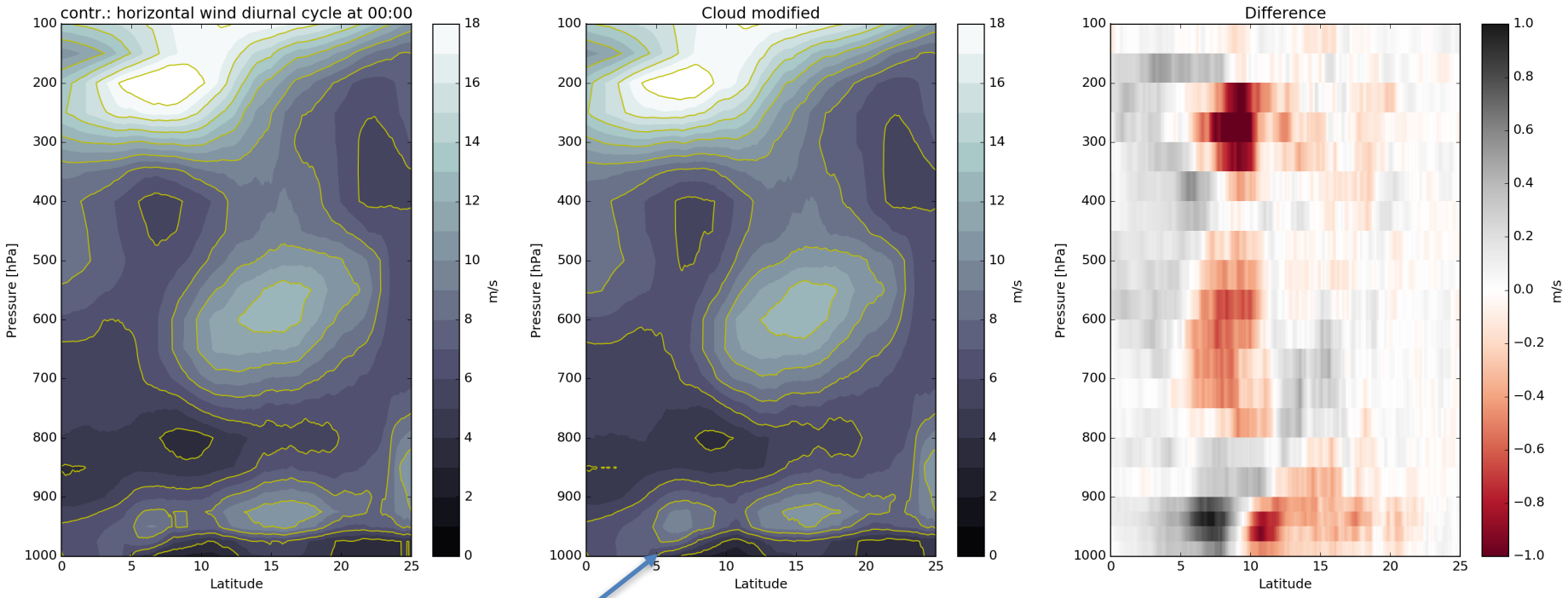


Intensification of nocturnal low level jet

Reduced wind speed in the afternoon

Horizontal wind speed

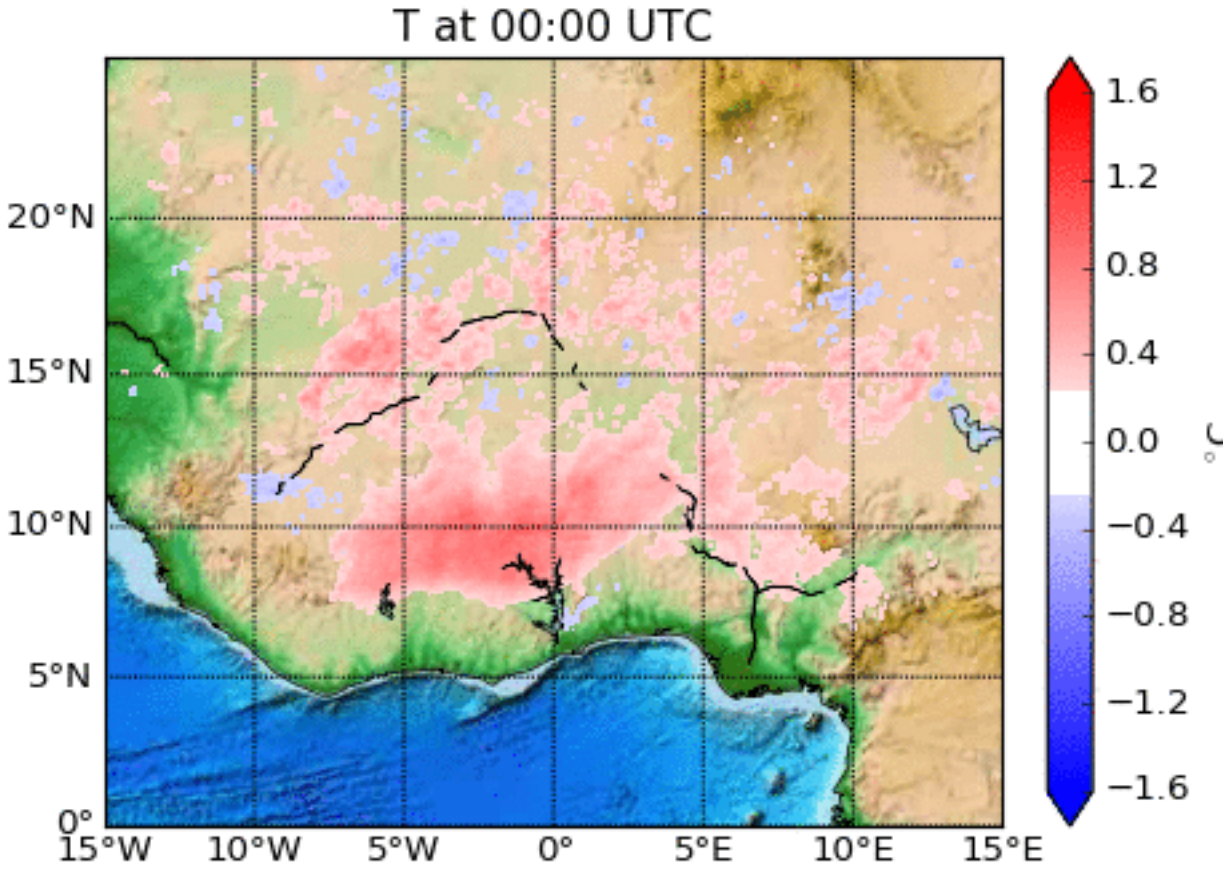
Average diurnal cycle, July 2006



Intensification of
nocturnal low level jet

Effects downstream
of DACCIWA box!

Downstream of DACCIWA box

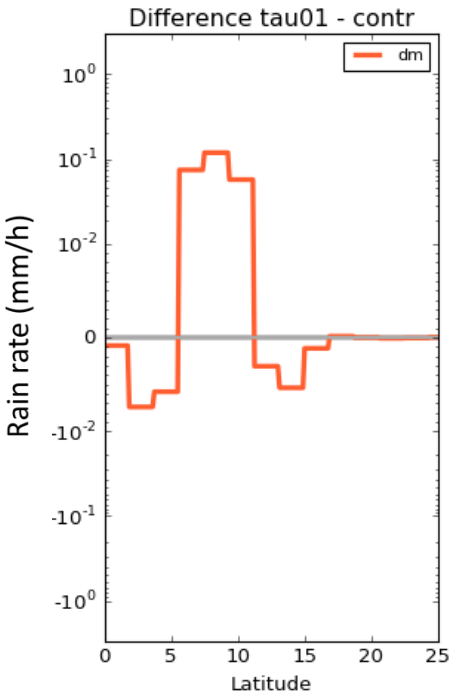


Signal propagates northwards at night, leaves initial box

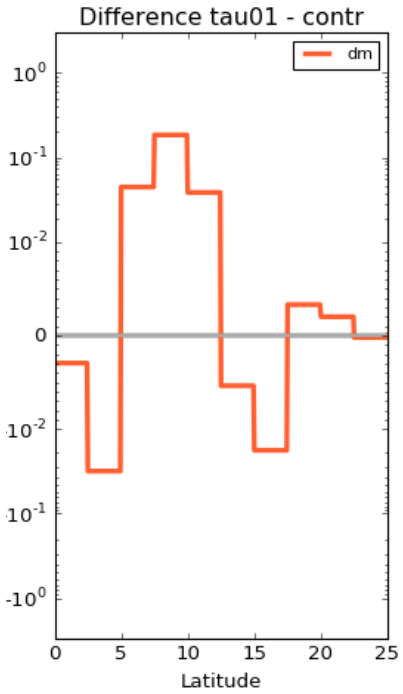
Precipitation outside of DACCIWA box

Precipitation monthly mean, zonal average

14 km



6.5 km



Net loss and net gain of precipitation for transparent clouds outside of DACCIWA region

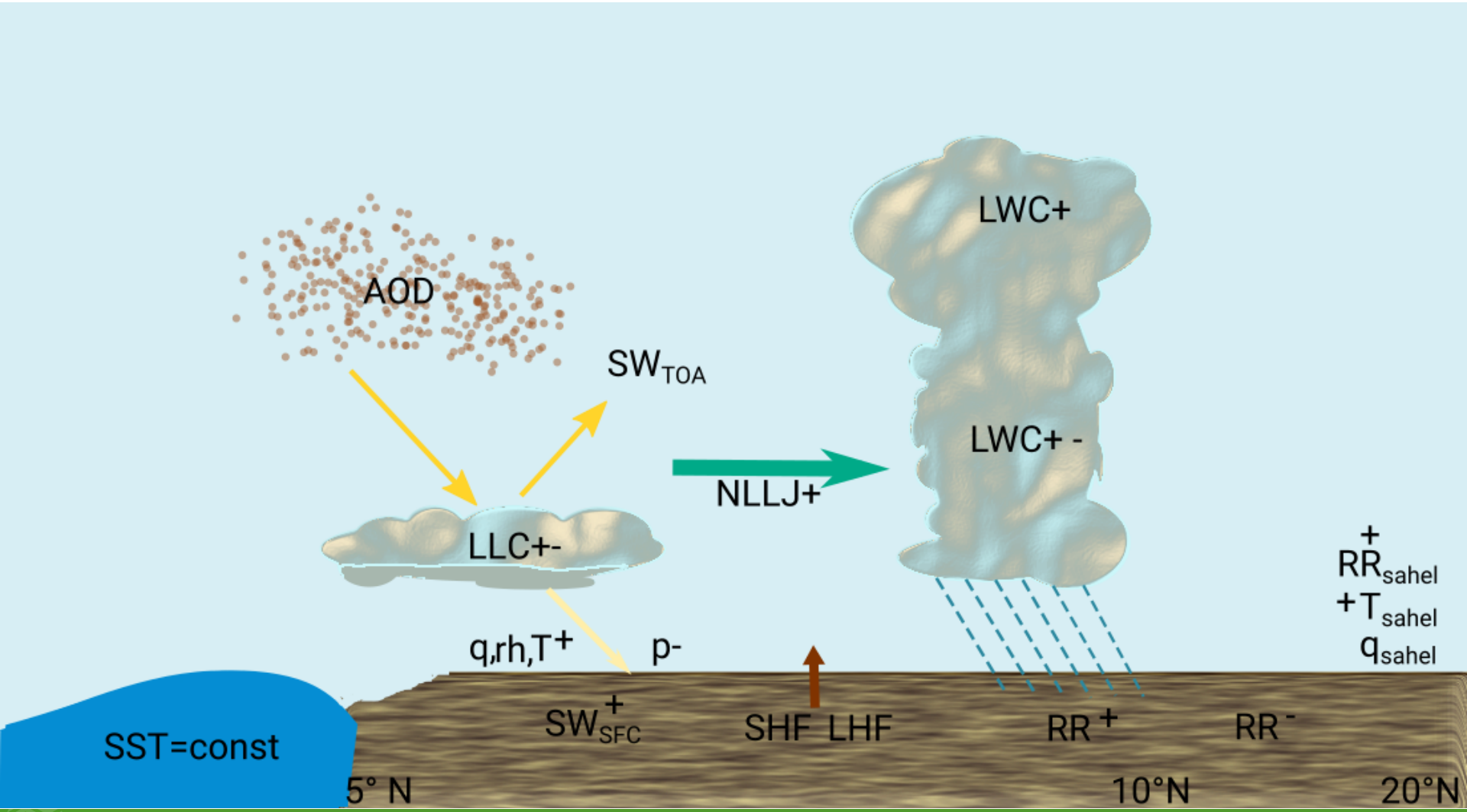
Conclusions

DACCIWA region: Transparent clouds: more shortwave rad. -> higher T after sunrise, enhanced turbulence and convection -> enhanced cloudiness + precip., nocturnal LLJ intensifies, decrease of wind speed in boundary layer in the afternoon but more wind at coast

Downstream: Influence of experiment reaches out of DACCIWA box, T, p, specific moisture and precipitation signals travel northwards at night, slightly stronger gradient of equivalent potential temperature leads to enhanced monsoon flow for transparent clouds

Explicit convection: corroborate effects, but:
differences in intensity and timing of effects, diurnal formation of cc differs strongly in explicit runs, particularly true for low level clouds
Net effect on precipitation outside of DACCIWA region

Thank you!


AOD
SW$_{TOA}$
LWC+
LWC+ -
NLLJ+
LLC+-
q,rh,T^{+}
p-
SW$^{+}_{SFC}$
SHF LHF
RR^{+}
RR^{-}
$^{+}$RR$_{sahel}$
+T$_{sahel}$
q$_{sahel}$
SST=const
5° N
10°N
20°N