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The impact of deforestation in the Congo Basin rainforest on the regional climate.

T. Akkermans, N. Van Lipzig

COSMO/CLM User Seminar, 5-8/03/2013, Offenbach/Main

DEPARTMENT OF **EARTH AND ENVIRONMENTAL SCIENCES**
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Carbo Africa

KATHOLIEKE UNIVERSITEIT
LEUVEN

1. Research Objective

1. OBJECTIVES

- **Overall objectives:**
  - Quantify the impact of realistic deforestation scenario on future regional climate → this presentation
  - Compare this with the impact of future increased greenhouse gases → ongoing work

2. Model Evaluation

- But first we have check the model's performance, hence..

2. MODEL EVALUATION

2. Model Evaluation

- Model setup
  - **COSMO-CLM²** (Davin et al.,2011)
    - COSMO4.0, *coupled to..*
    - Community Land Model 3.5
  - 210x180 grid cells
  - 35 vertical levels (~CORDEX-Afr.)
  - 1989-2009 and 2040-2060
- Evaluation in sub-domains
  - Surface field averages
    - AFRC (Tropical Africa),
    - HTRN (Humid Tropics North),
    - EQTR (Equatorial region),
    - HTRS (Humid Tropics South).
  - Zonal mean:
    - CRSS (Cross Section north-south)

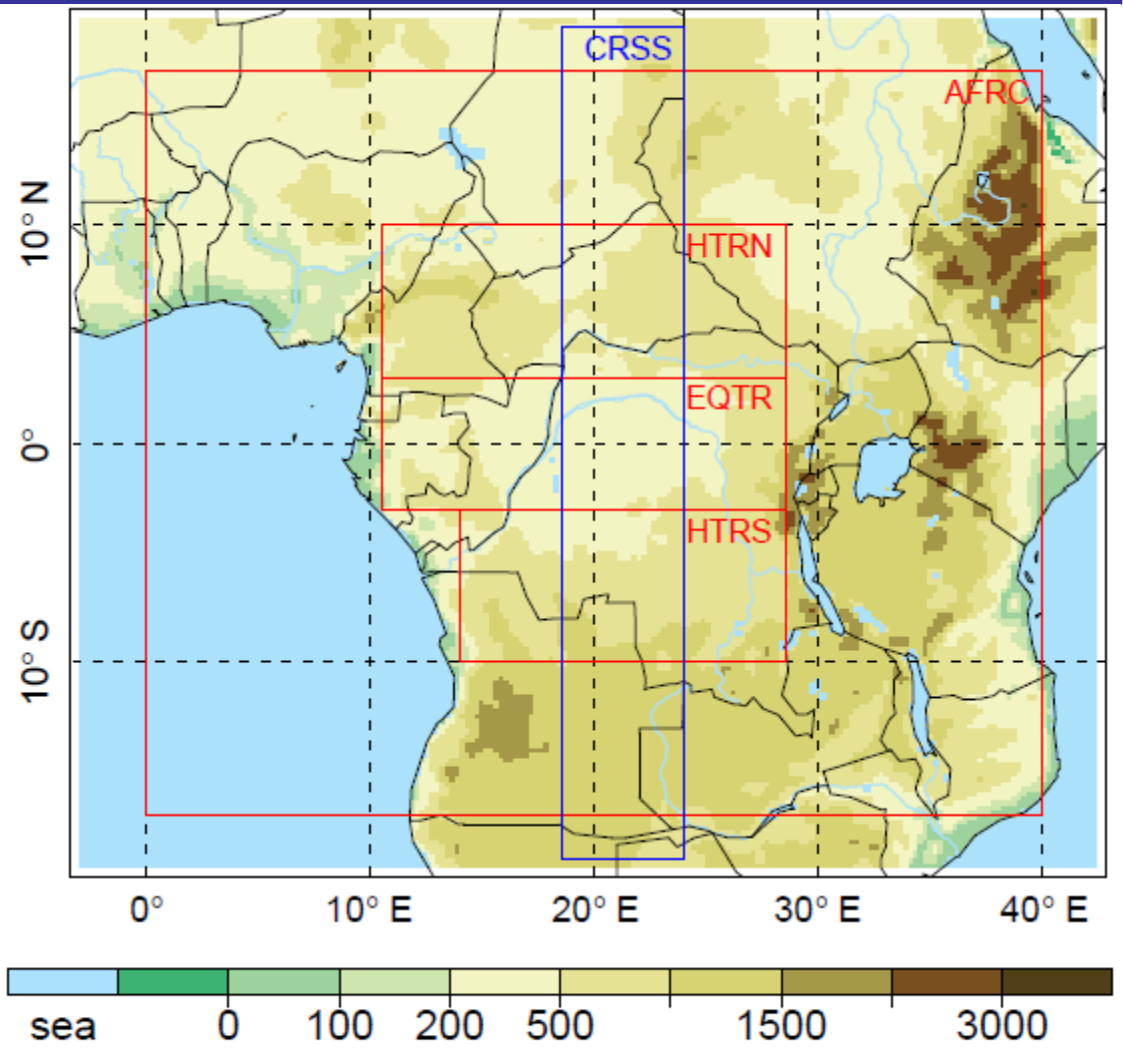
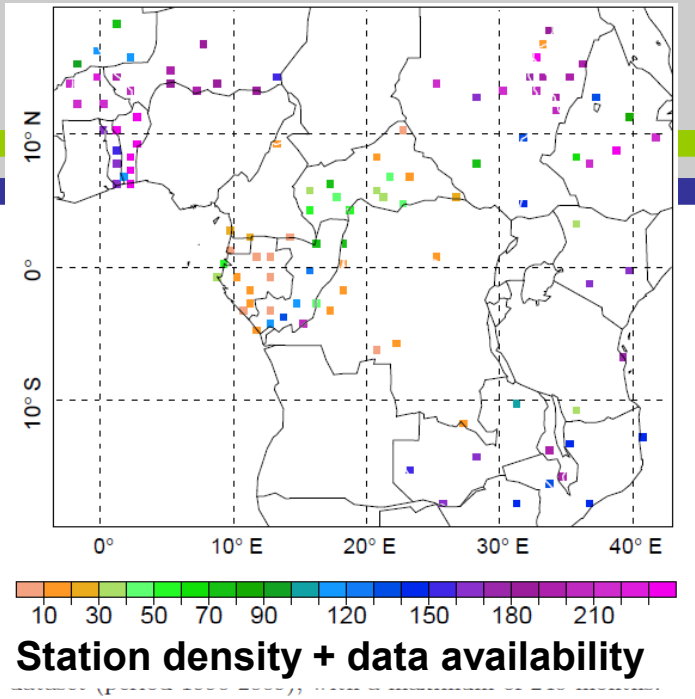


Fig. 1 Model domain used in this study with corresponding topography and regions of interest: AFRC (Tropical Africa), EQTR (Equatorial Tropics), HTRN (Humid Tropics, North) and HTRS (Humid Tropica, South). CRSS is a special region of interest for which zonal-averaged atmospheric cross sections are made.

2. Model Evaluation

- **Monthly mean 2m-temperature (K):** 1990-2009.
- Problem in Central Africa: CRU station density + data gaps



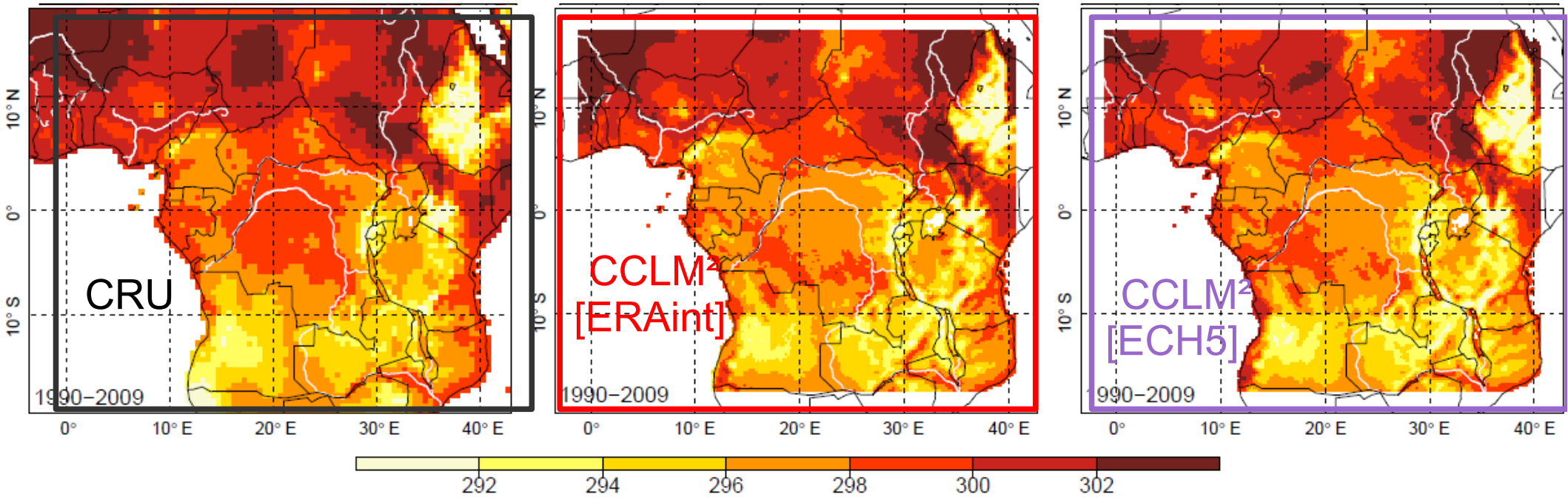
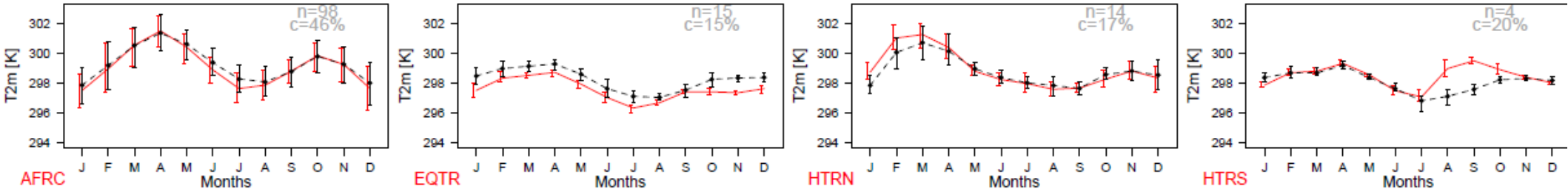


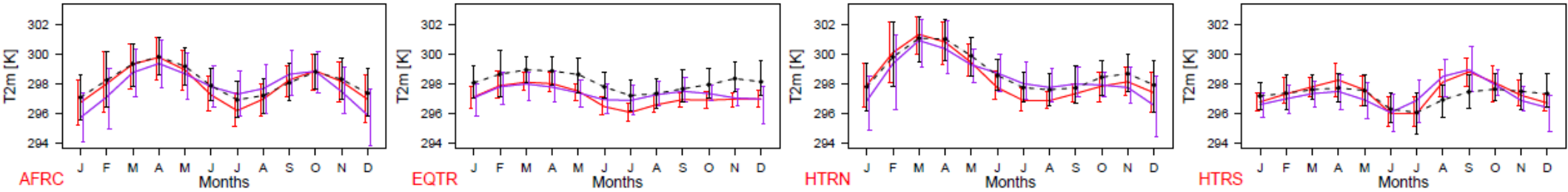
Fig. 5 Mean 2m-temperature [K] during 1990-2009. (left) CRU observations; (center) *PRR* simulation; (right) *PGR* simulation.

2. Model Evaluation

- ***Therefore: do field-averaged evaluation in two ways:***
  - Only on CRU pixels containing ground stations, and only using valid monthly means (ignoring data gaps in both model and CRU observations):



  - On the entire CRU gridded dataset*:*



Legend: ***---*** *observations,* ***---*** *CCLM²[ERAint],* ***---*** *CCLM²[ECHAM5]*

Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

2. Model Evaluation

- **Precipitation (mm/month): 1990(1998)-2009.TRMM observations (satellite+gauges)**

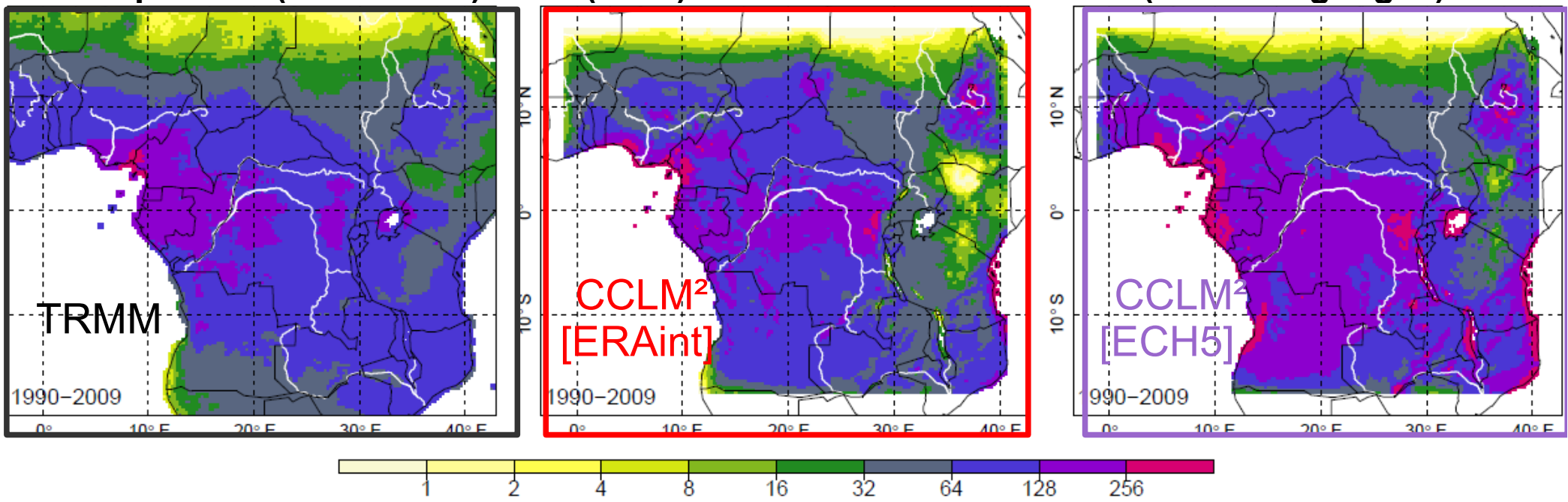
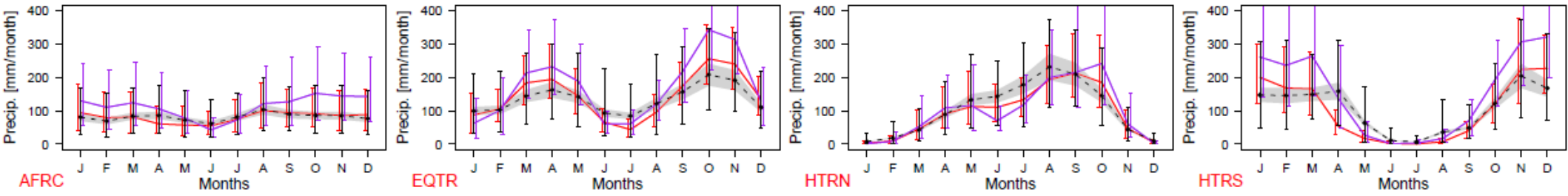


Fig. 7 Mean precipitation [mm/month] during 1998-2009 for observations and 1990-2009 for simulations. (left) TRMM observations; (center) *PRR* simulation; (right) *PGR* simulation.



Legend: --- observations, --- CCLM²[ERAint], --- CCLM²[ECHAM5]

Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

2. Model Evaluation

- Also evaluated: Column Precipitable Water, Cloud cover, Energy budget components (surface and TOA), Latent and Sensible heat fluxes.
- **Generally good agreement** of model and observations within the uncertainty range. Annual cycle mostly well represented

3. Quantifying deforestation impact

Now we now the model has a satisfying performance, we can investigate..

3. DEFORESTATION IMPACT

3. Quantifying deforestation impact

- **Community Land Model**: tile-based vegetation
  - 17 ”Plant Functional Types” (PFT's)
  - Can co-exist within a single grid cell
  - 1 of these is Evergreen Tropical Forest
- **Deforestation scenario for 2050**
  - Spatial distribution based on Zhang et al. (2006)
  - Certain % forest removal in each pixel
  - Replace removed portion with a realistic combination of successional vegetation:
    - Bare soil
    - Crops
    - Grass
    - Fallow trees

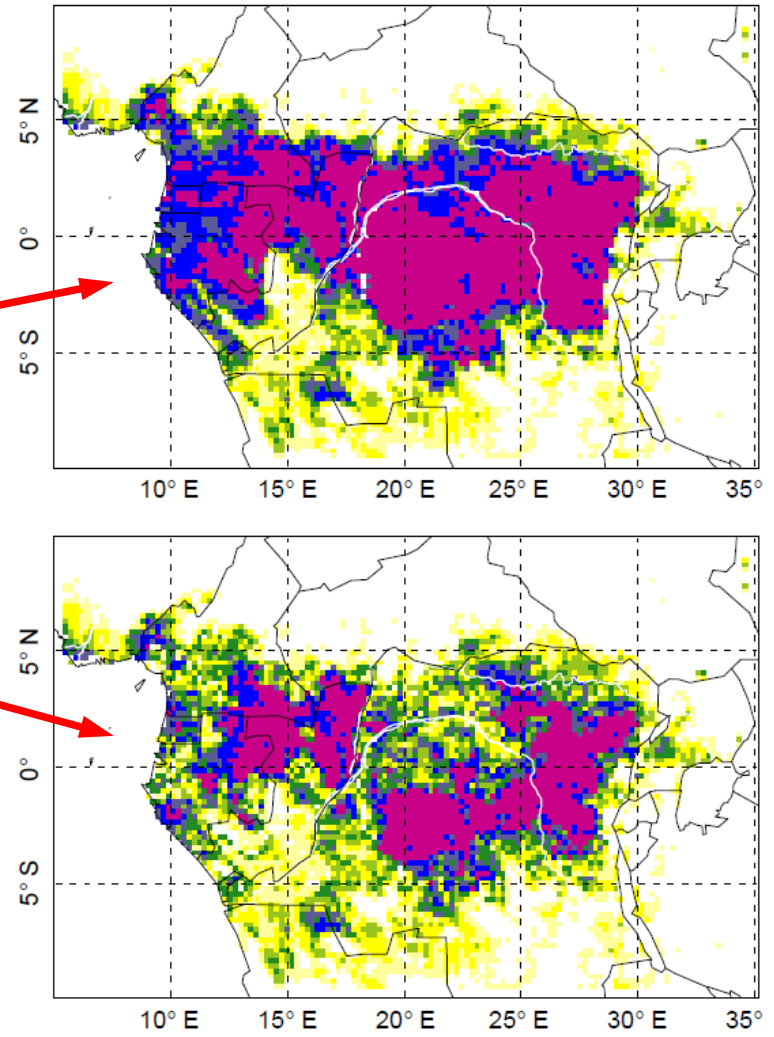


Fig. 2 (top) Evergreen tropical forest in COSMO-CLM² (% PFT Broadleaved Evergreen Forest per grid cell) in the reference simulations; (centre) after implementation of deforestation scenario. Four grid cells which are used for additional analyses are indicated by a small orange rectangle; (bottom) histogram of deforestation amounts for all grid cells affected by the deforestation scenario.

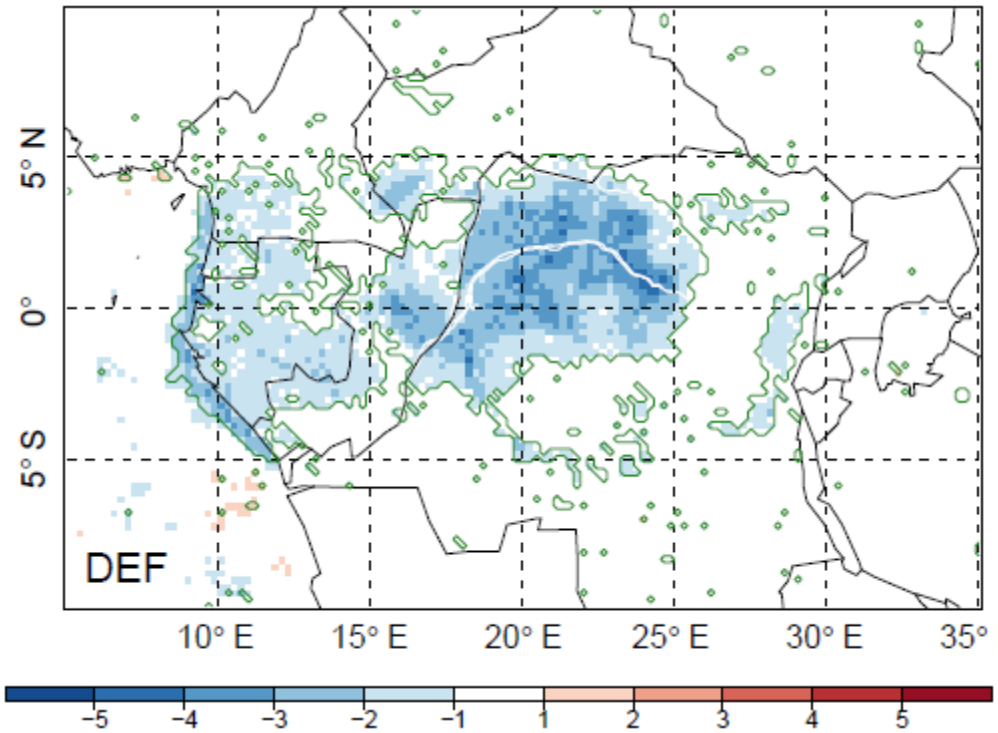
Zhang Q, Justice CO, Jiang M, Brunner J, Wilkie DS. 2006. A GIS-based assessment on the vulnerability and future extent of the tropical forests of the Congo Basin. Environmental monitoring and assessment 114: 107?21. DOI: 10.1007/s10661-006-2015-3.

3. Quantifying deforestation impact

Direct impact on energy balance components:

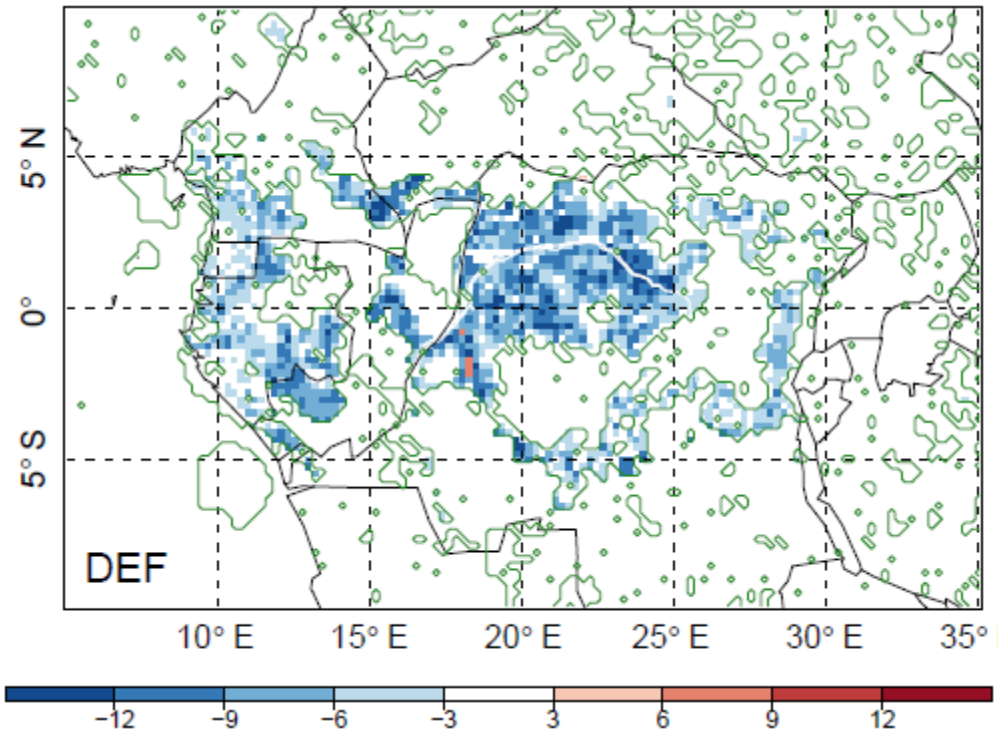
SW*net* + LW*net* = LE + H + G

SW*net* decreases (higher albedo)



Decreases by 3-4W/m²

LE decreases more (less ET and lower aer.resistance)



Decreases by 9-12W/m²

Green lines: significant at the 1% level

Changes not significant at 20% level are not shown

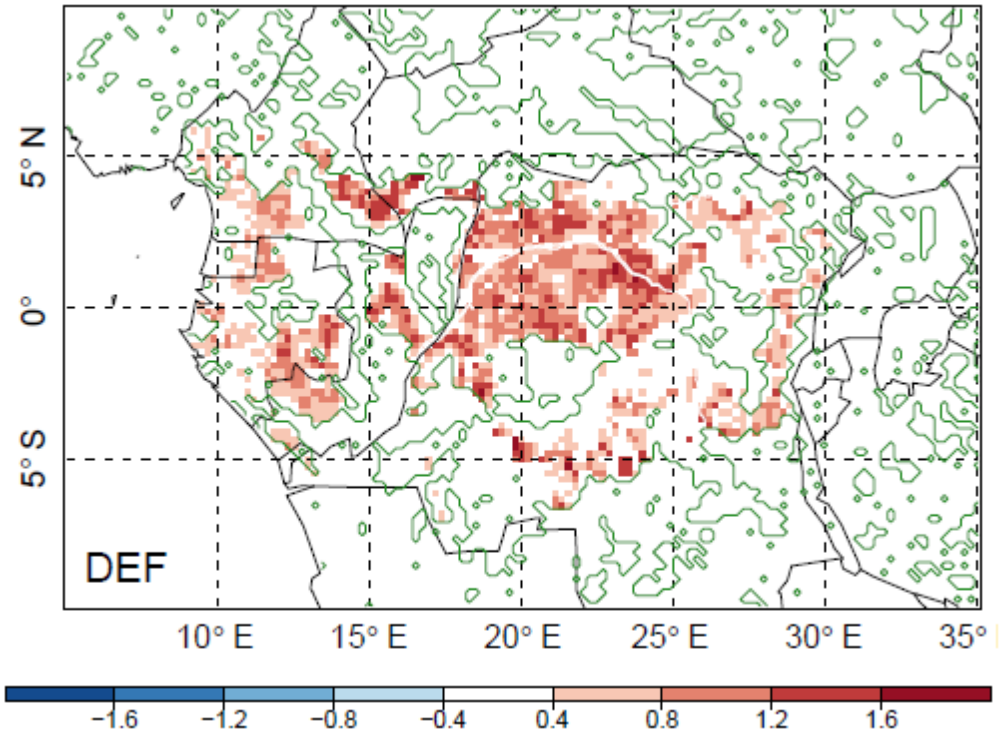
3. Quantifying deforestation impact

SW*net* + LW*net* > **LE** + H + G

Result: energy excess at earth's surface !

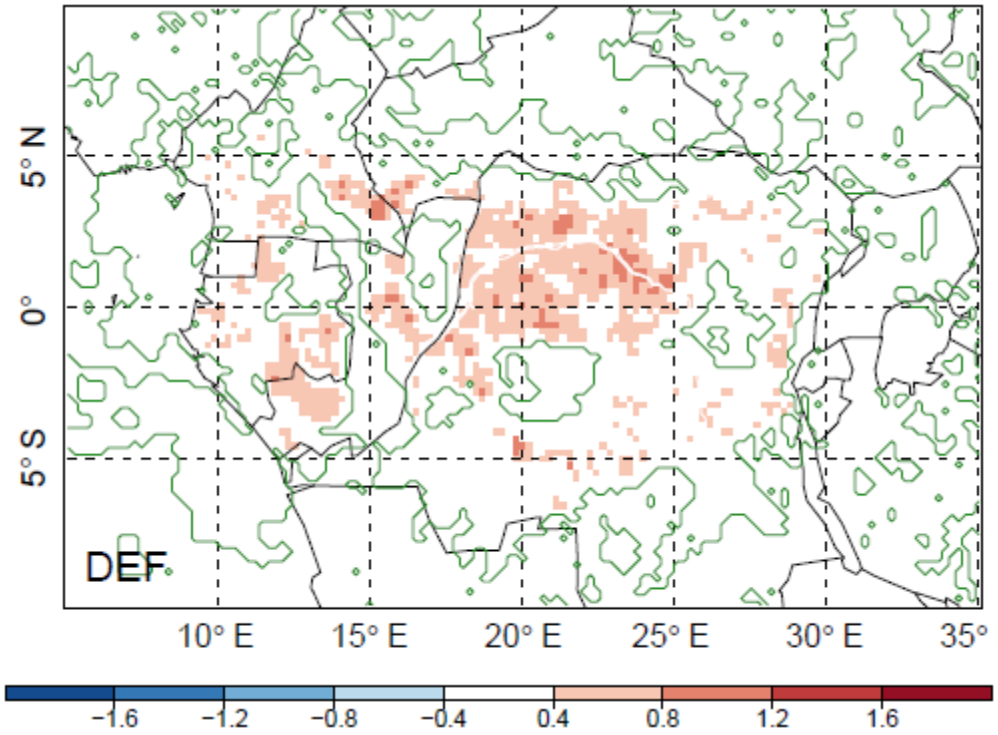
= dT/dt = increase of skin temperature (skin= ground+leaves)

Ground Temp. increases



Decreases by +/- 1K

2m-Temp. Increases as a result



Decreases by +/- 0.5K

Green lines: significant at the 1% level

Changes not significant at 20% level are not shown

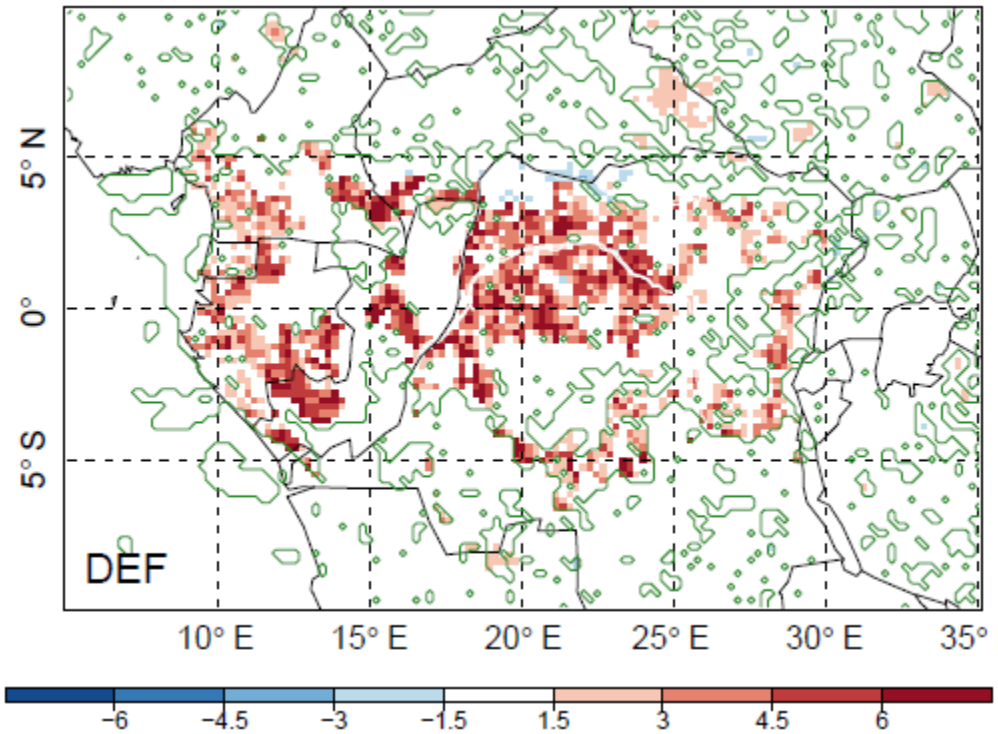
3. Quantifying deforestation impact

But energy balance always restores the equilibrium (achieve balance closure):

- Increased **LW*out***, hence decreased **LW*net***
- Increased **H**

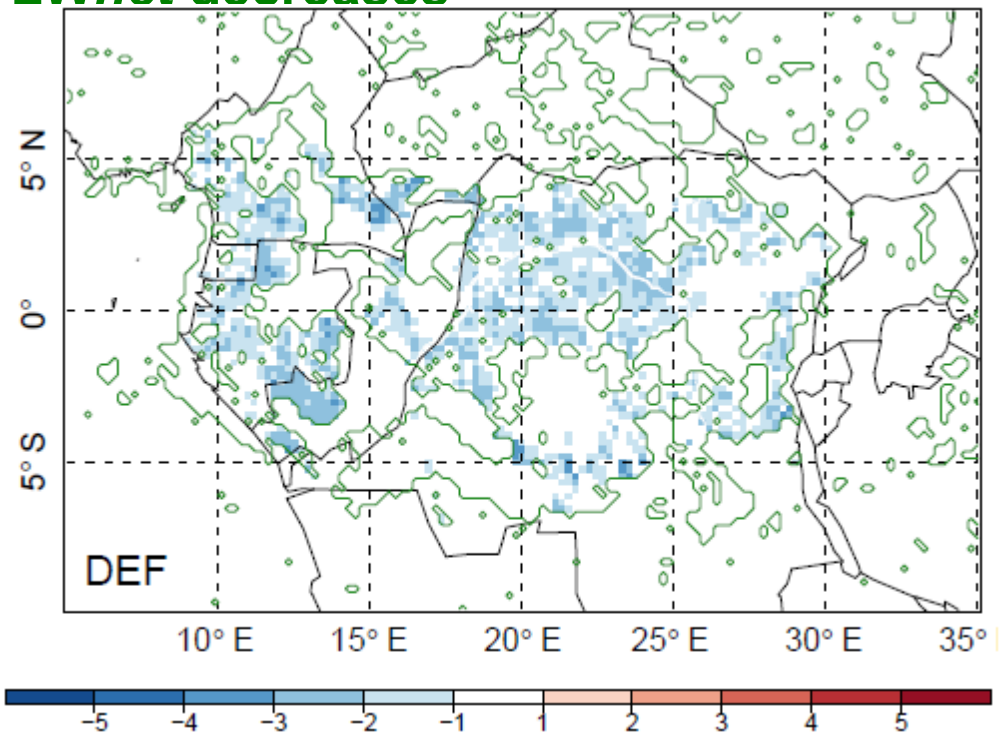
SWnet + LWnet = LE + H + G

Sensible heat flux increases



Increases as a result of increased ground temperature and in order to achieve balance closure

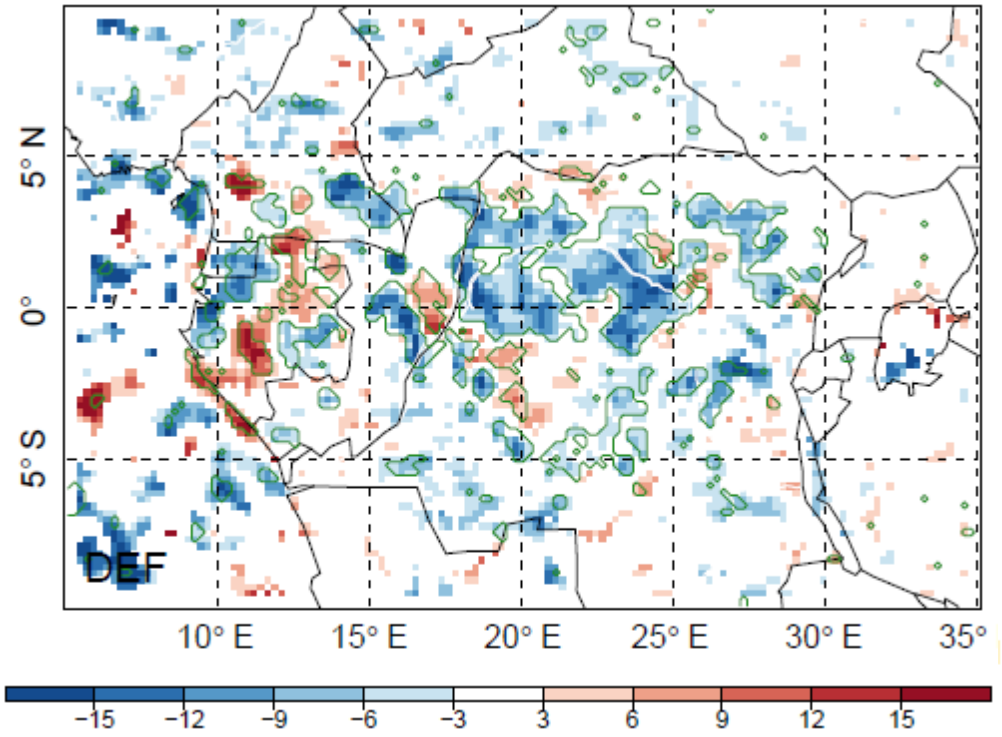
LW*net* decreases



Decreases as a result of increased ground temperature and in order to achieve balance closure

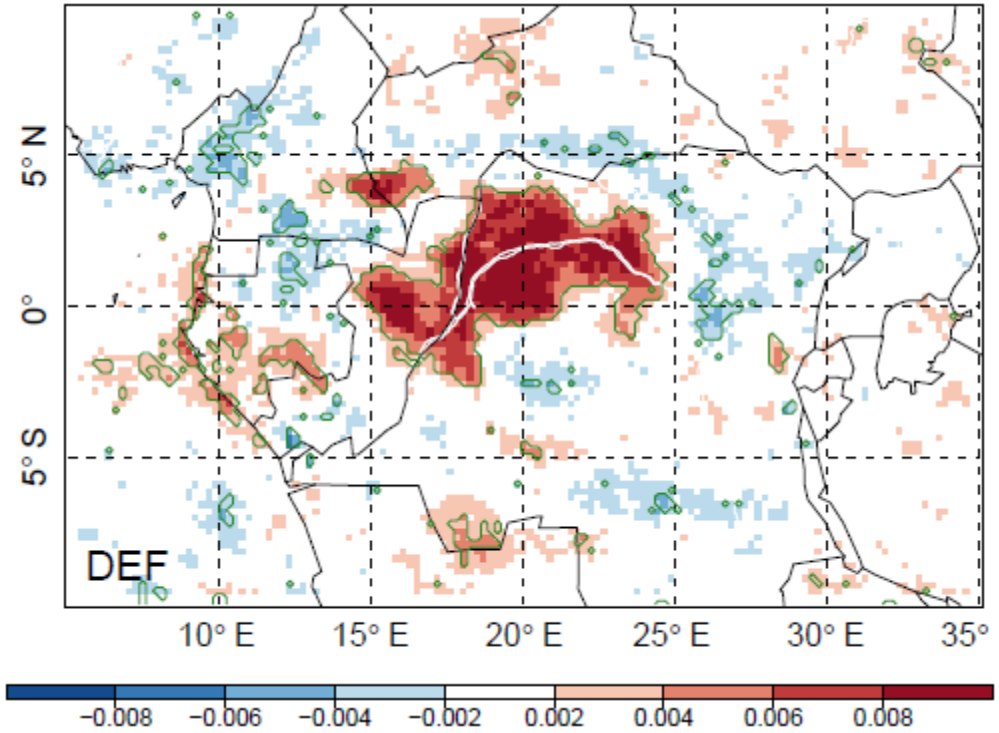
3. Quantifying deforestation impact

Precipitation (difference)
[%]



Generally decreases in deforested region.

Cloud cover (difference)
[-]



Generally increases in deforested region

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3. Quantifying deforestation impact

- Deforestation impact: vertical cross section of atmosphere (south-north):
- **Temperature (K) during 2041-2060: stronger signal in DJF and JJA**

Green lines: significant at the 1% level
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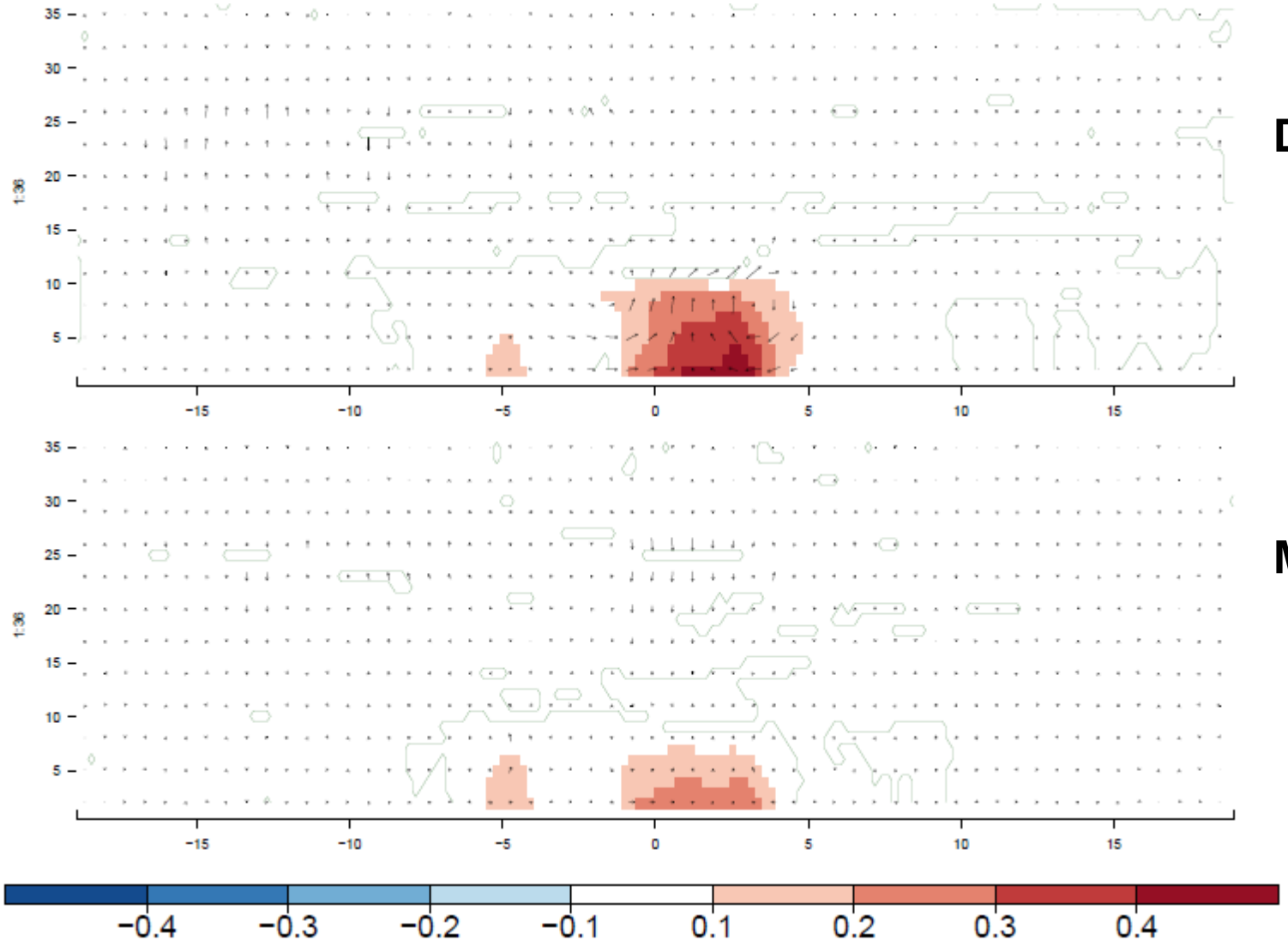

3. Quantifying deforestation impact

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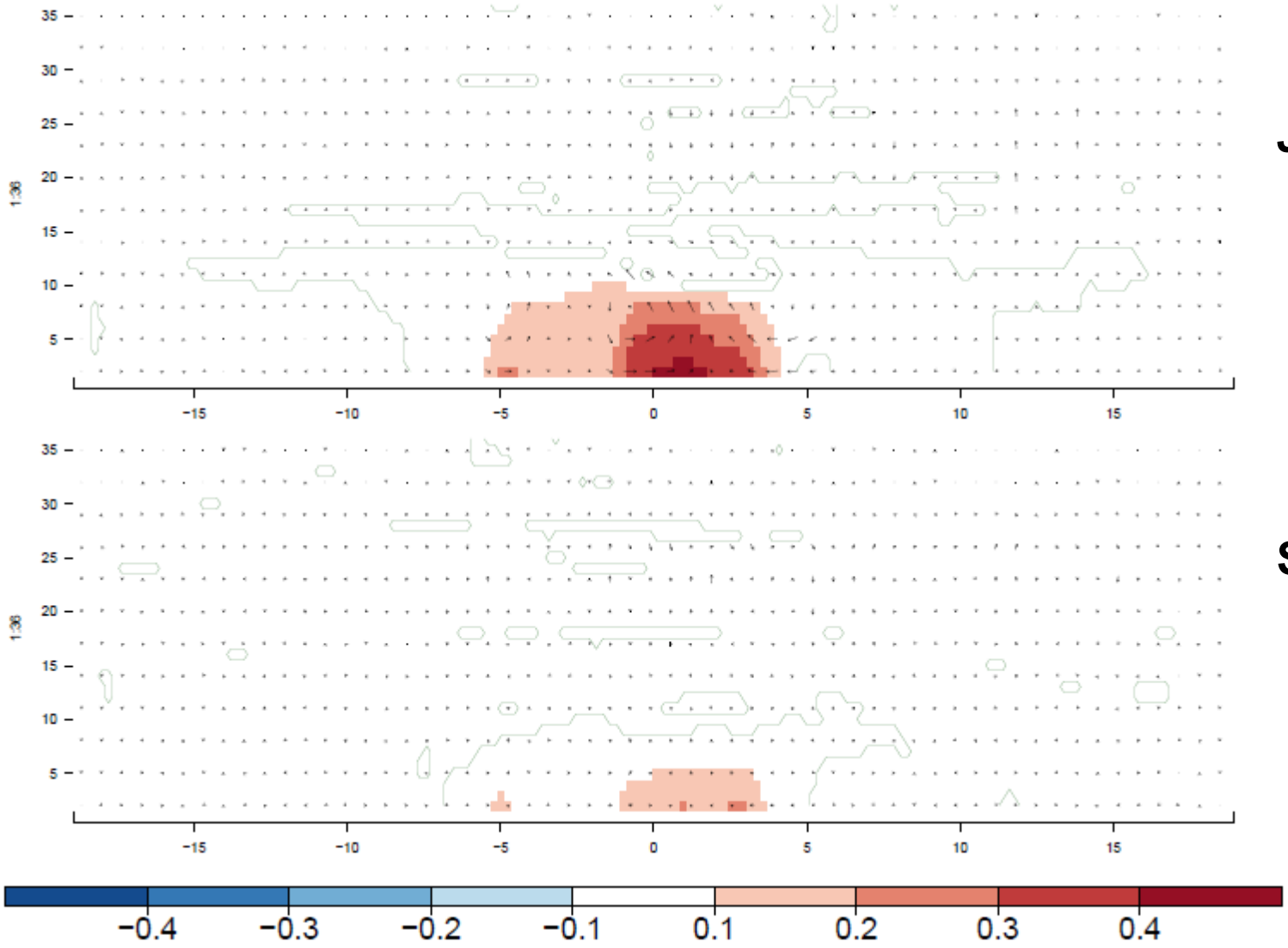
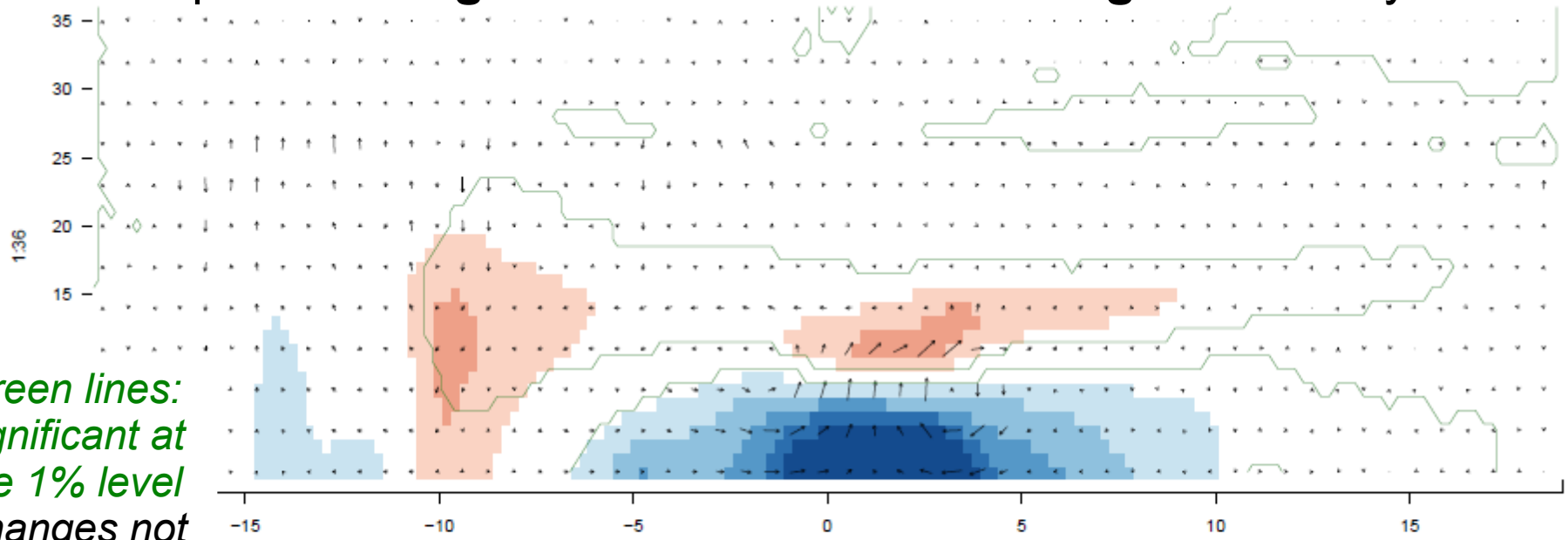


3. Quantifying deforestation impact

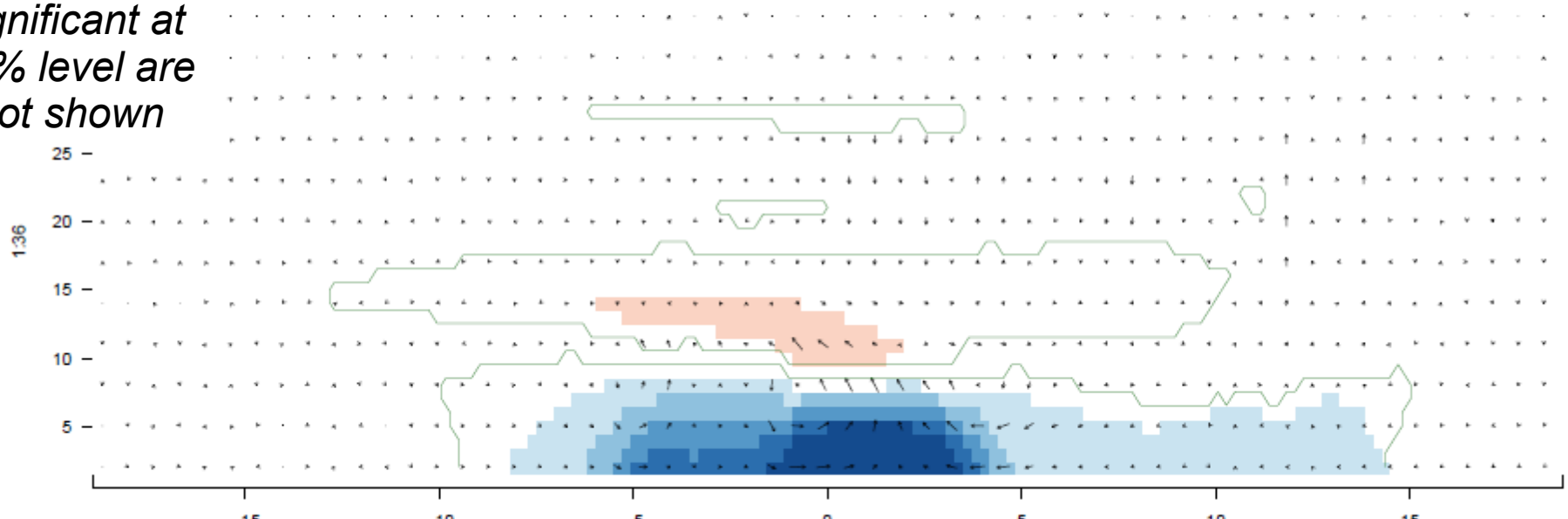
- Development of **regional heat low** and **convergence** in ”dry” season:



DJF

Green lines: significant at the 1% level

Changes not significant at 20% level are not shown



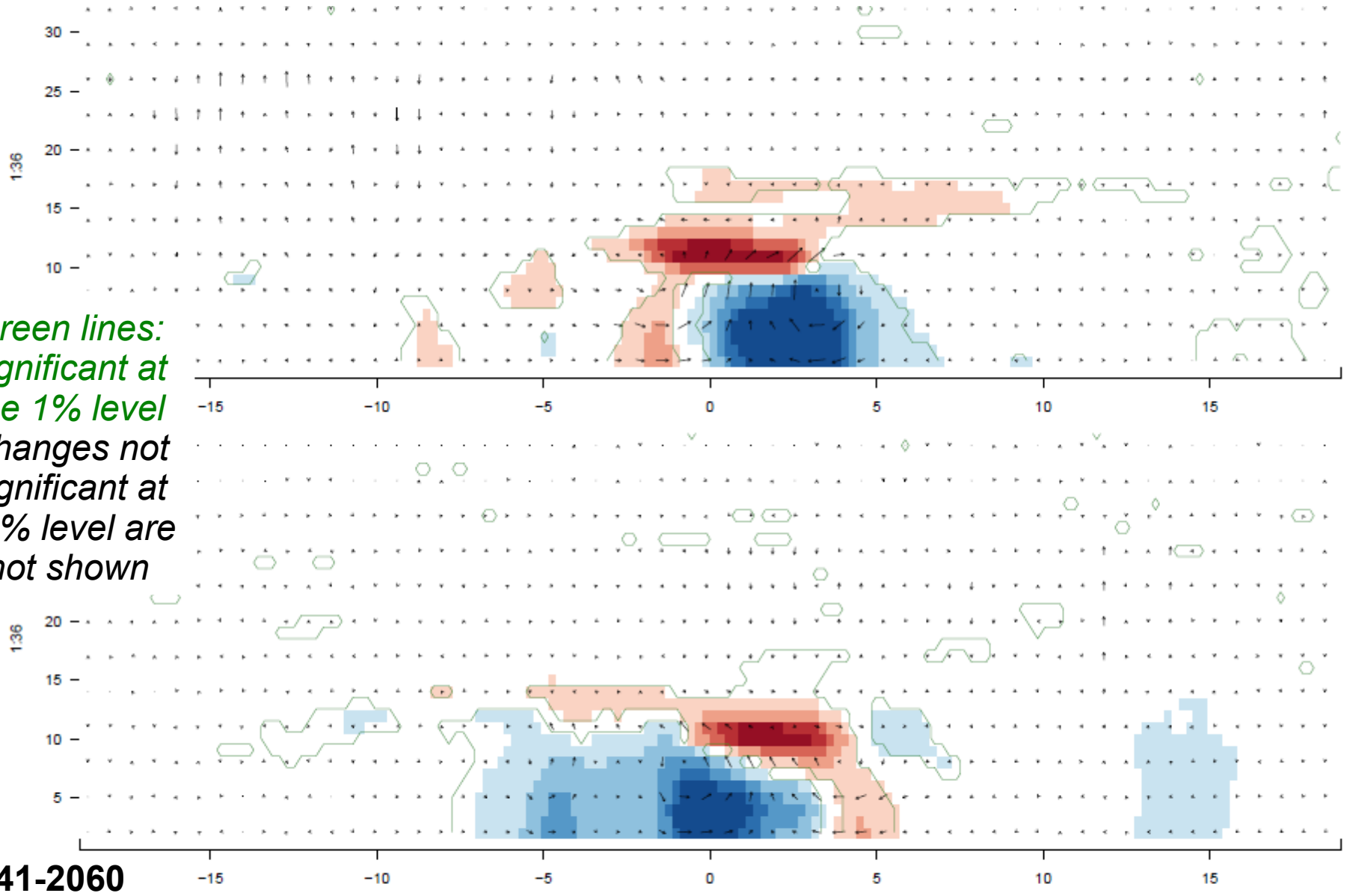
JJA

2041-2060

Scale in Pascal or mbar

3. Quantifying deforestation impact

Hence advection of humidity also changes, depending on origin of air..

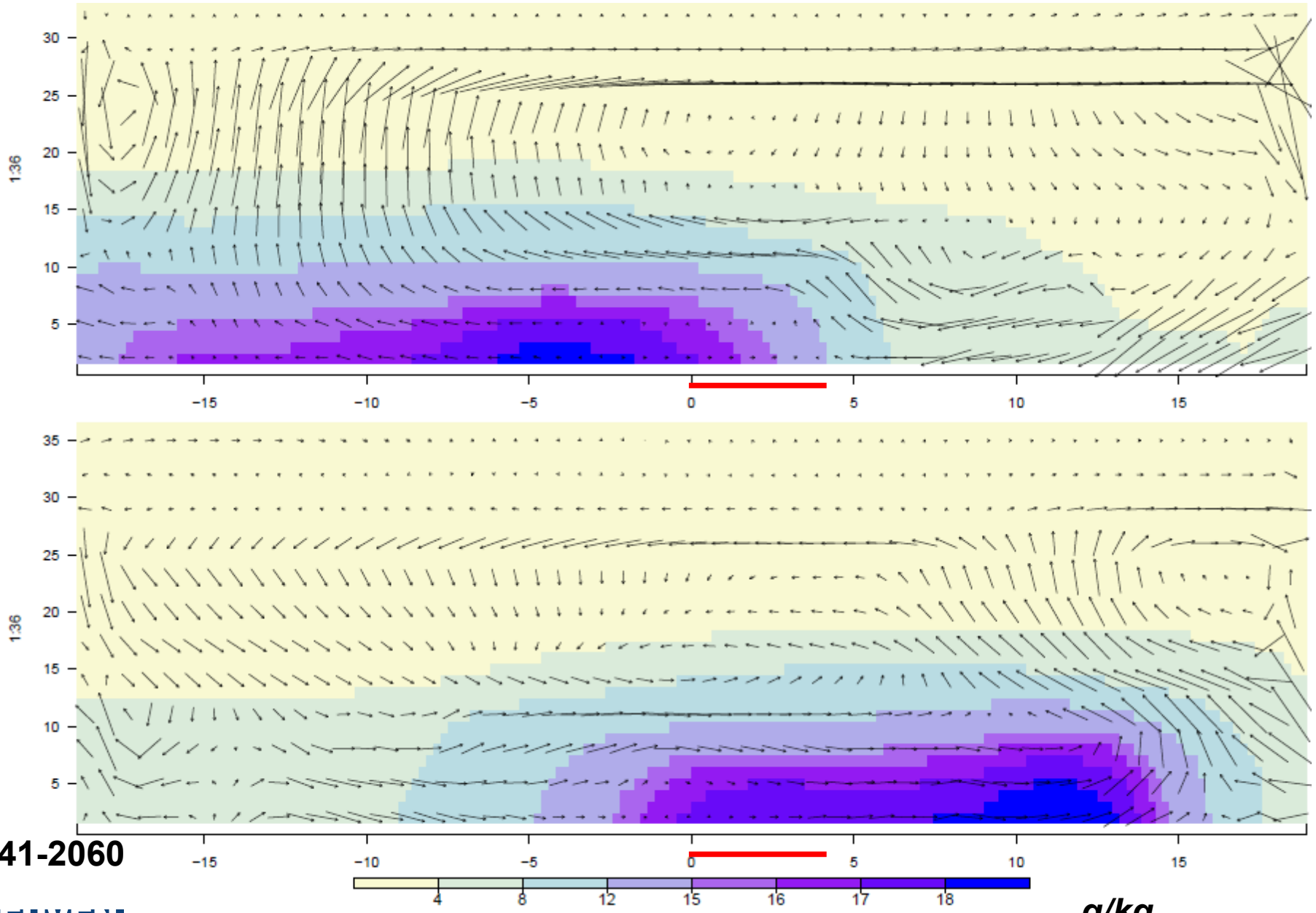


Green lines: significant at the 1% level

Changes not significant at 20% level are not shown

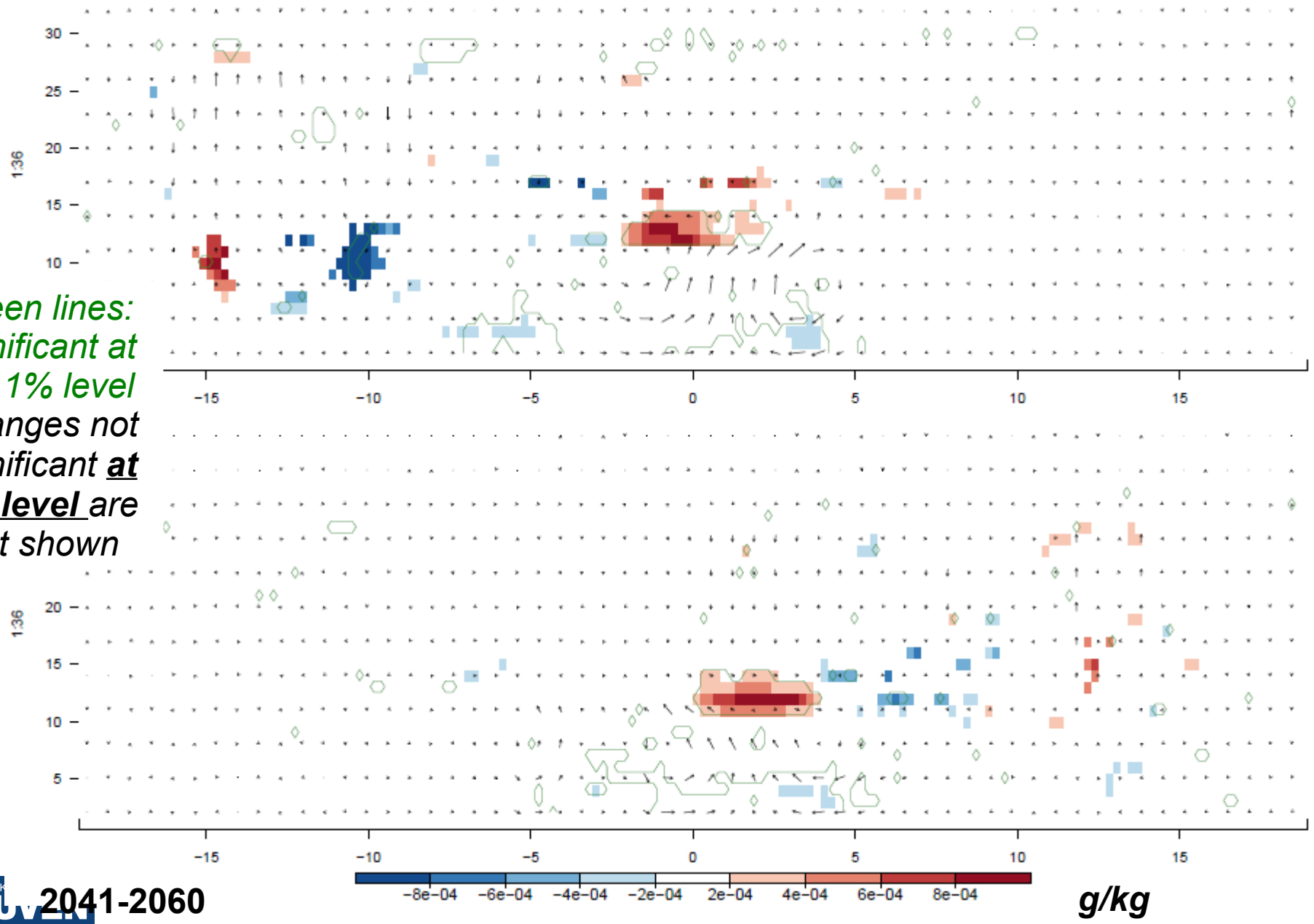
3. Quantifying deforestation impact

Climatology (2041-2060) of specific humidity (colours) and wind (arrows):



3. Quantifying deforestation impact

Cloud water (liquid+ice):



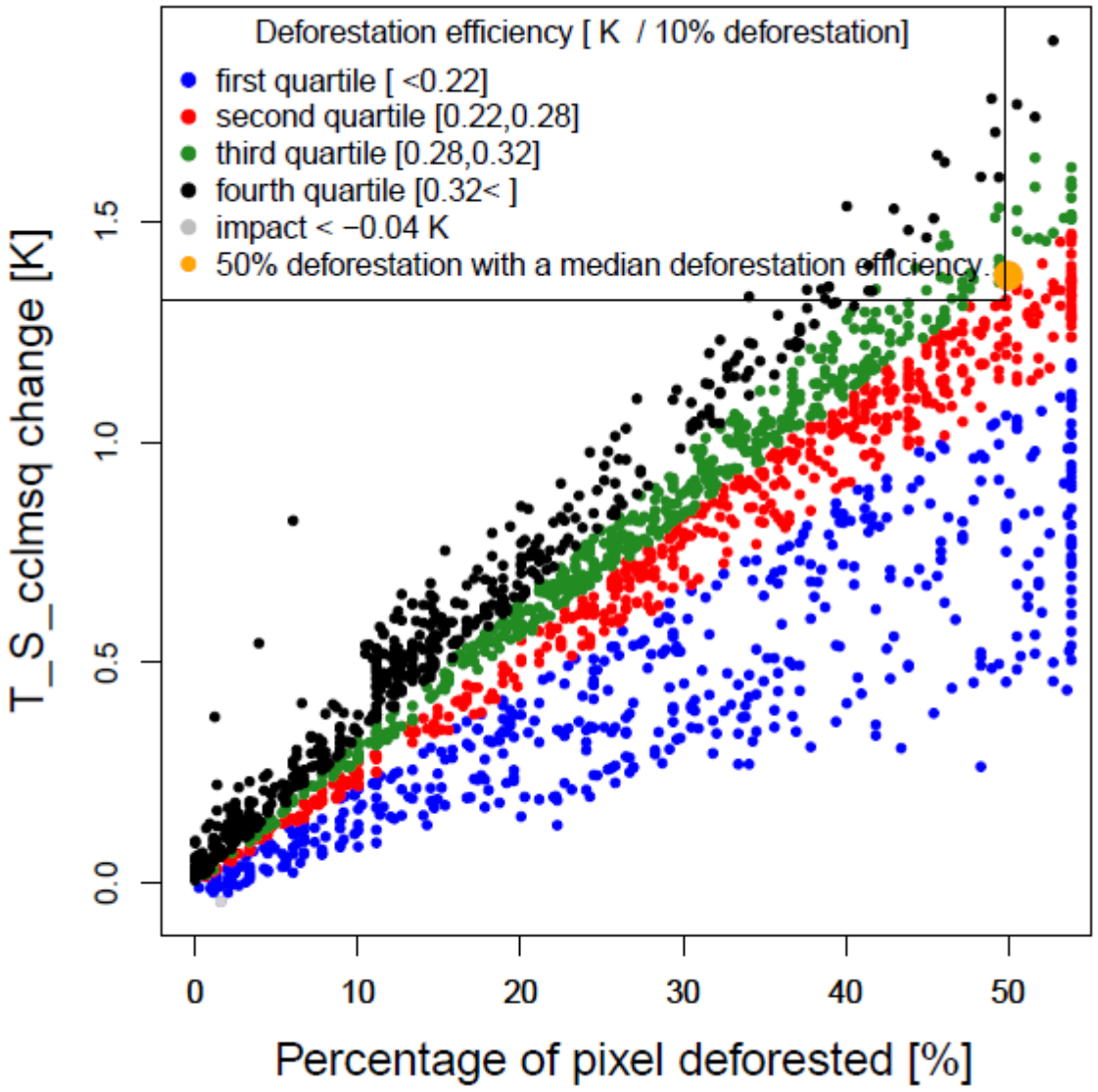
Green lines: significant at the 1% level

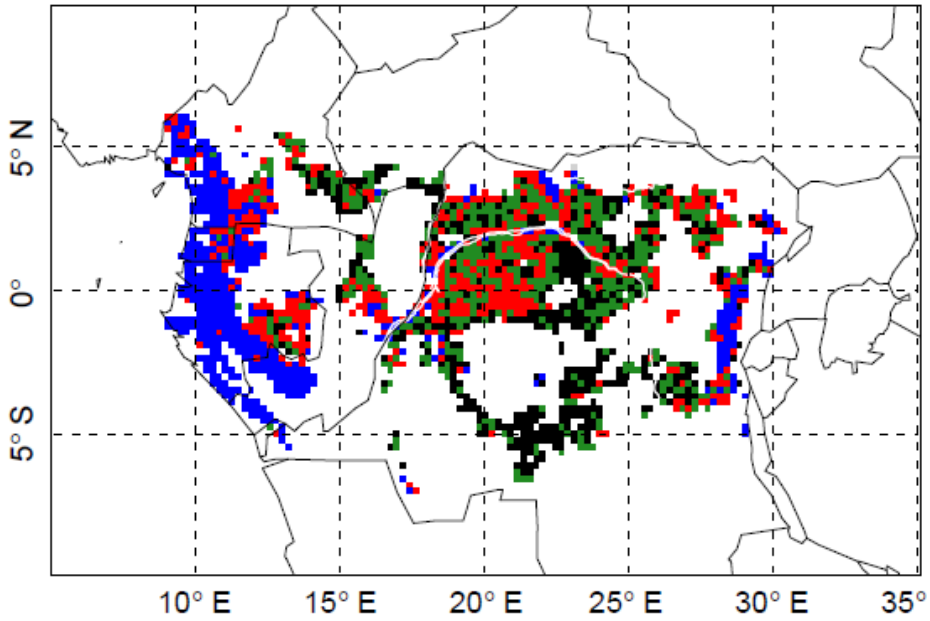
*Changes not significant **at 5% level** are not shown*

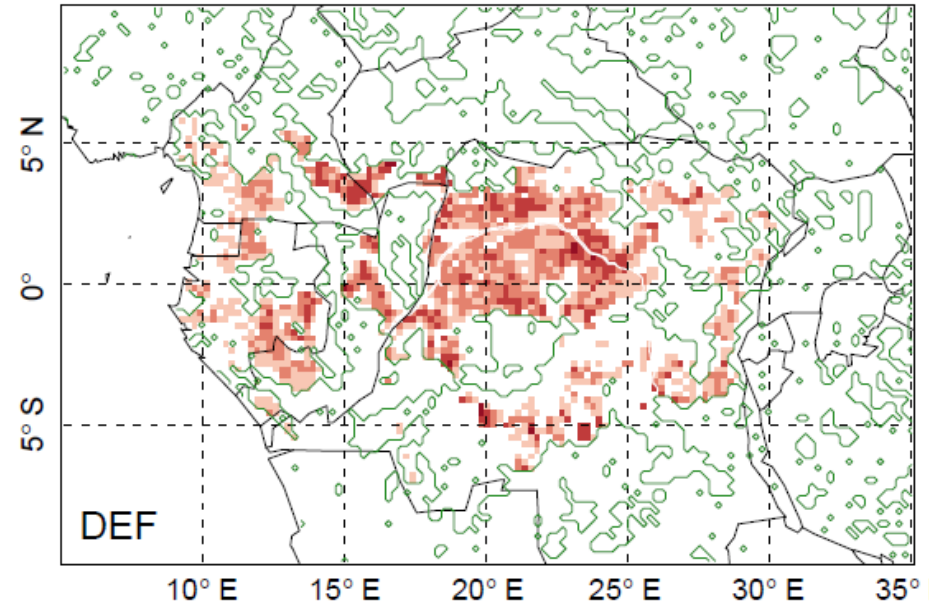
2041-2060

3. Quantifying deforestation impact

- ”Deforestation Efficiency”







4. CONCLUSIONS & FUTURE WORK

4. Conclusions and future work

- COSMO-CLM² **performs generally well** over the model domain and sub-domains
- When using ECHAM5 lateral boundary conditions, an **overestimation of monsoon precipitation** is persistent.
- On average, ground **temperature increases** by 0.8-1.2K, and 2m-temperature by 0.6-0.8K
- **Cloud cover increase** is small (1%) but significant and can be explained by the heat low development.
- **Precipitation decrease** (9-12%) is significant but still has to be investigated.
- TO DO:
  - looking to stability parameters e.g. CAPE and Potential temperature to explain precipitation change.
  - Compare with impact of increased greenhouse gases;

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Vielen dank!

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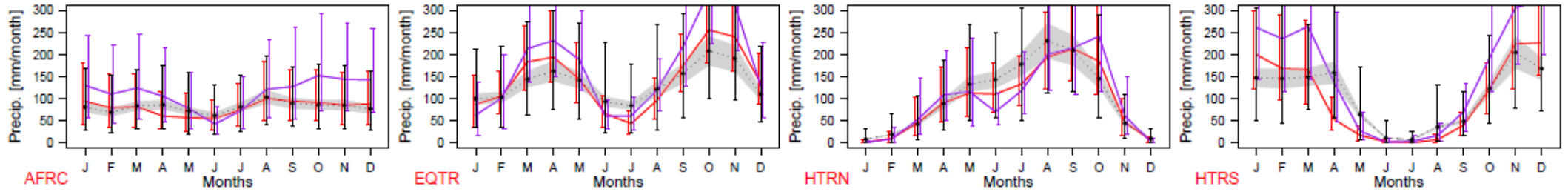
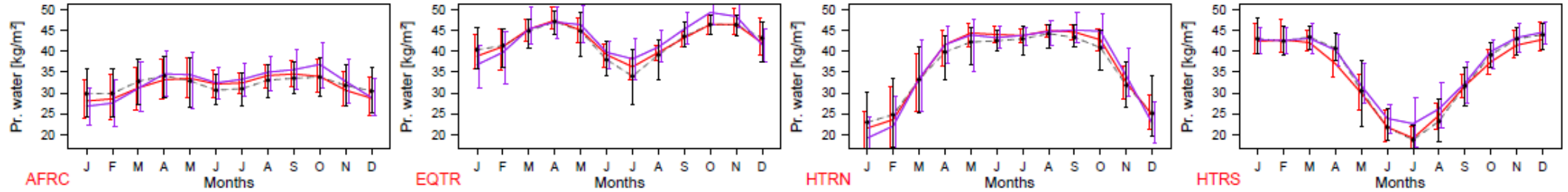
2. Model Evaluation

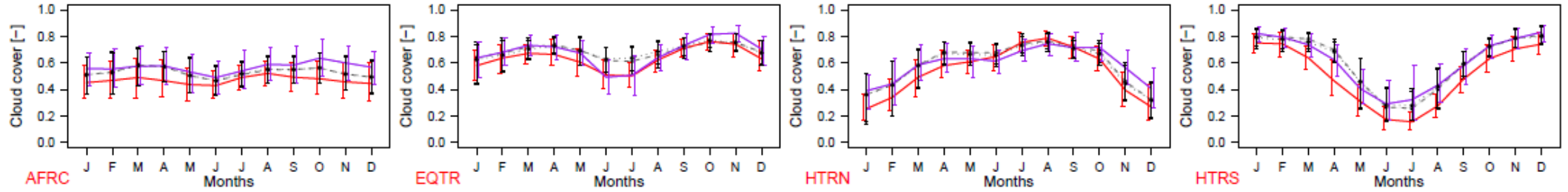
- Precipitation (mm/month): 1998-2009, observations: TRMM:



- Precipitable water (kg/m²): 1990-2007, observations: GEWEX-SRB:



- Cloud Cover (-): 1990-2007, observations: GEWEX-SRB:

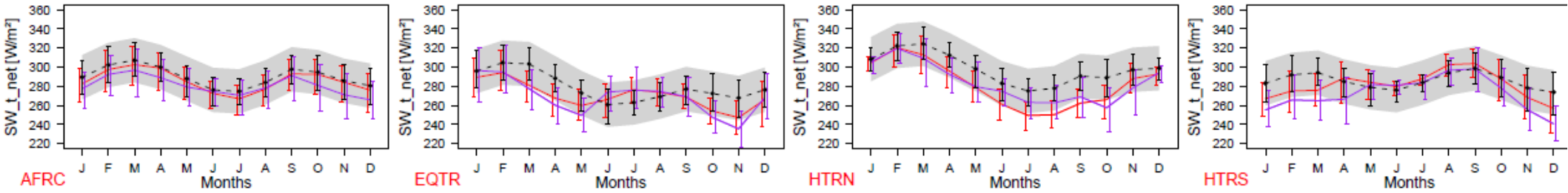


Legend: **---** observations, **---** CCLM²[ERAint], **---** CCLM²[ECHAM5]

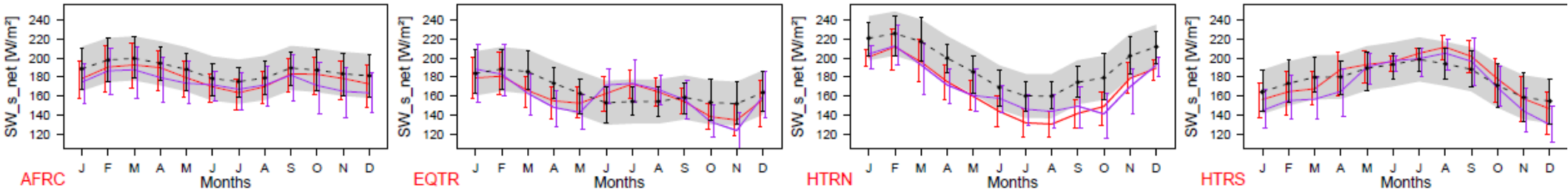
Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

2. Model Evaluation

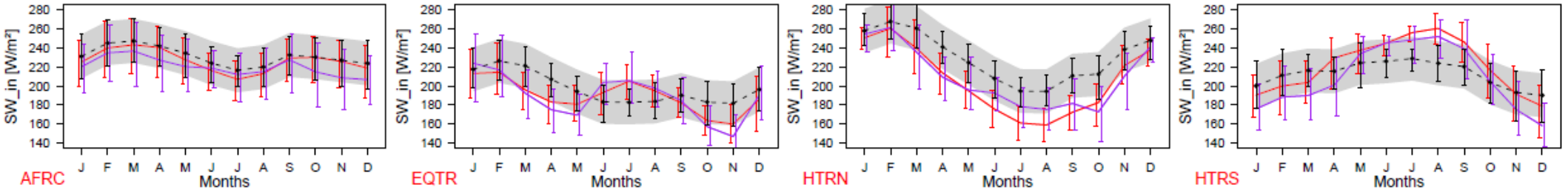
- SW TOA net radiation (W/m²): 1990-2007, observations: GEWEX-SRB:



- SW SFC net radiation (W/m²): 1990-2007, observations: GEWEX-SRB:



- SW SFC incoming radiation (W/m²): 1990-2007, observations: GEWEX-SRB:



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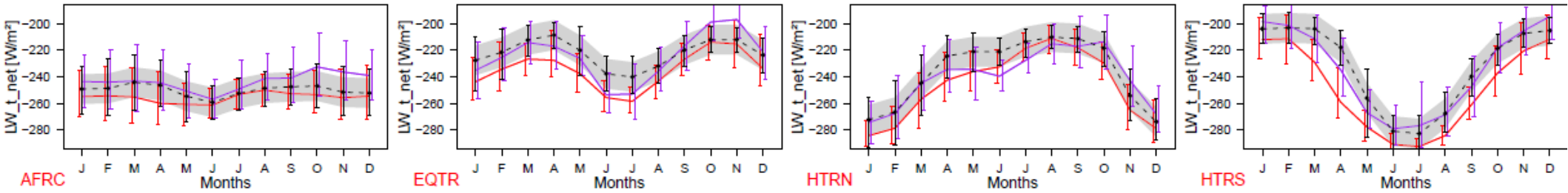
Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

2. Model Evaluation

- LW TOA net radiation (W/m²): 1990-2007, observations: GEWEX-SRB:



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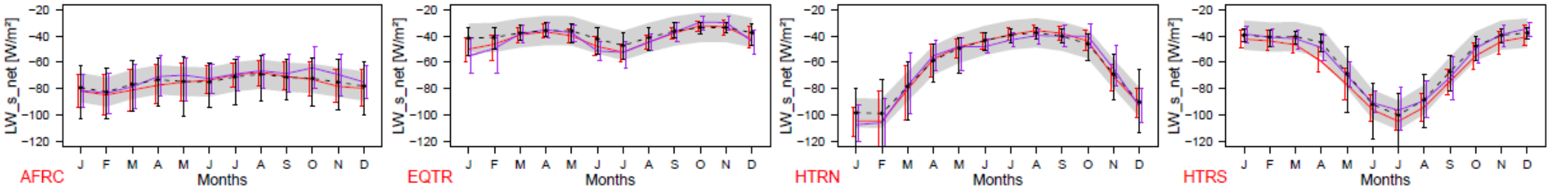

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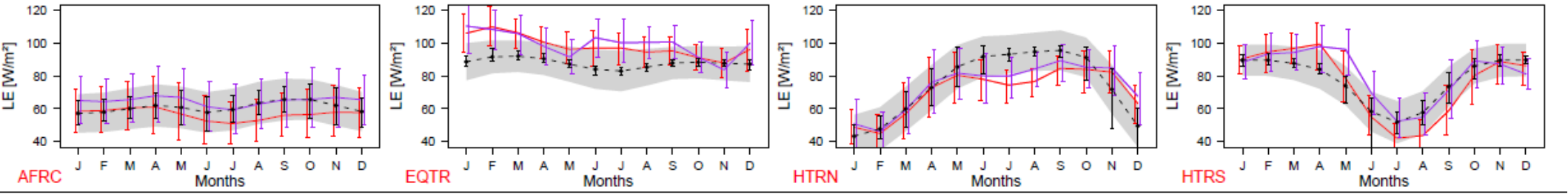

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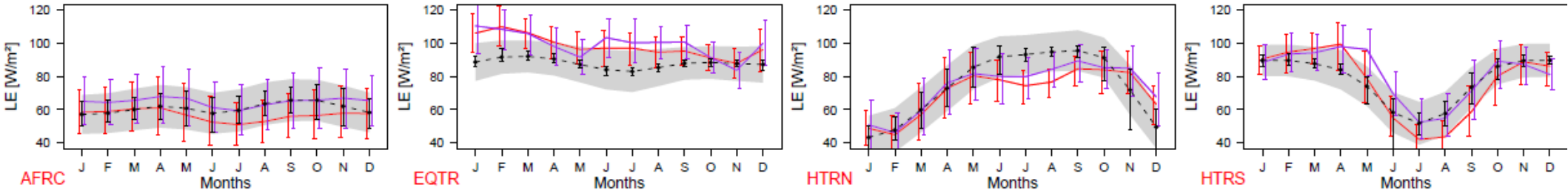
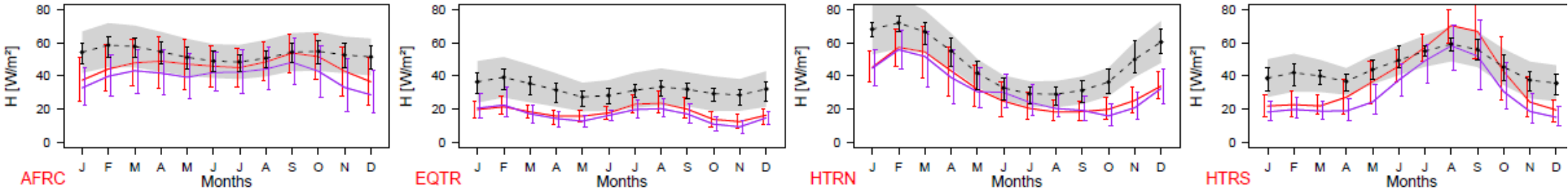
Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

2. Model Evaluation

- Latent heat flux (W/m²): 1990-2009, *"observations"*: FLUXNET-MTE (Jung.):



- Sensible heat flux (W/m²): 1990-2009, *"observations"*: FLUXNET-MTE (Jung):



Jung et al., 2009, Towards global empirical upscaling of FLUXNET eddy covariance observations: validation of a model tree ensemble approach using a biosphere model, Biogeosciences, 6, 2001–2013.

- Legend: **---** observations, **---** CCLM²[ERAint], **---** CCLM²[ECHAM5]

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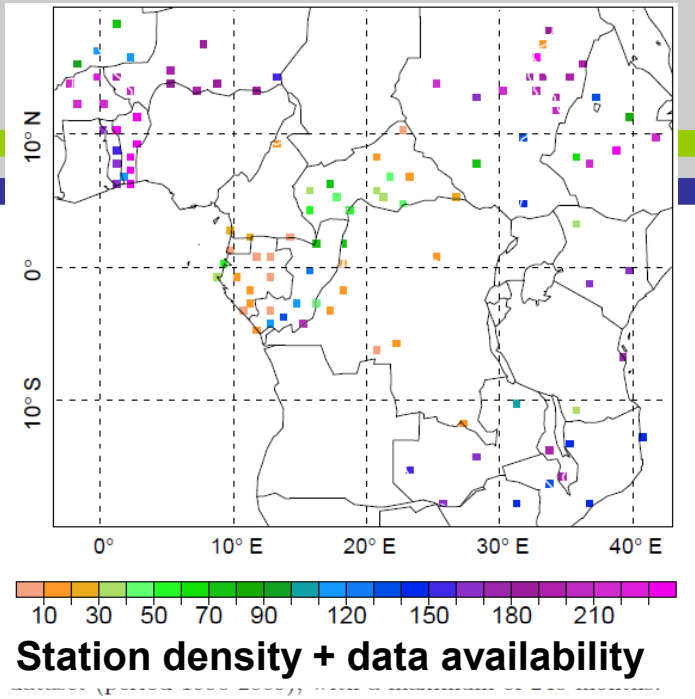
2. Model Evaluation

- Monthly mean temperature (K): 1990-2009.
- Problem in Central Africa: CRU station density + data gaps



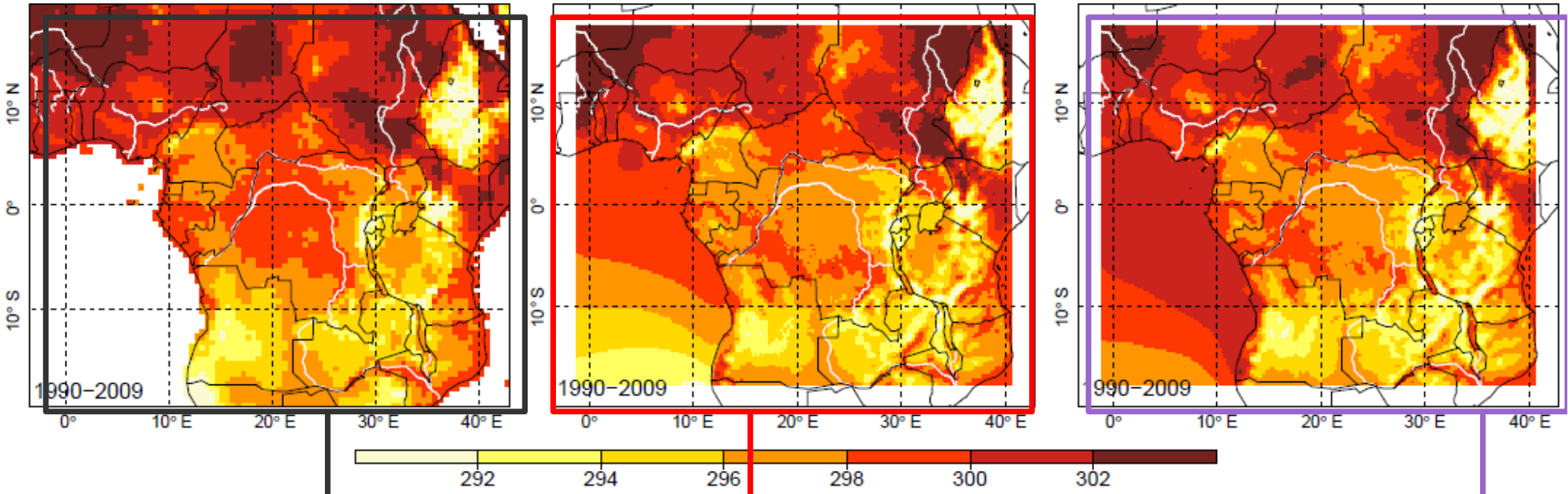


Fig. 5 Mean 2m-temperature [K] during 1990-2009. (left) CRU observations; (center) *PRR* simulation; (right) *PGR* simulation.

CRU

CCLM²[ERAint]

CCLM²[ECHAM5]

2. Model Evaluation

- **Precipitation (mm/month): 1990-2009(2007).TRMM observations (satellite+gauges)**

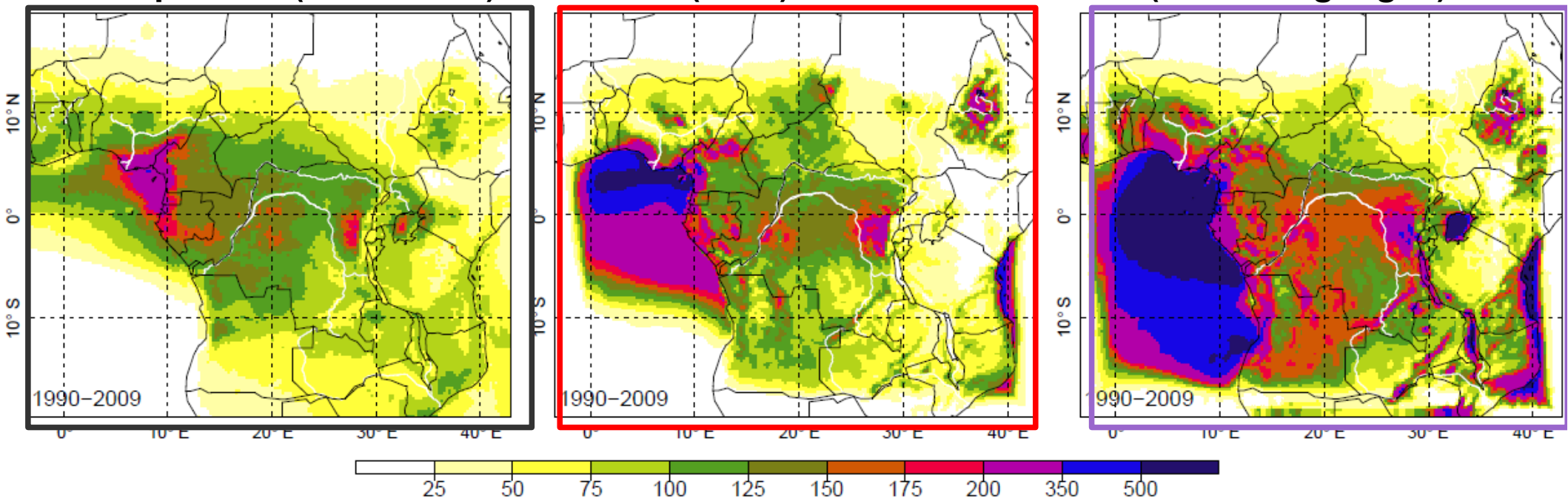
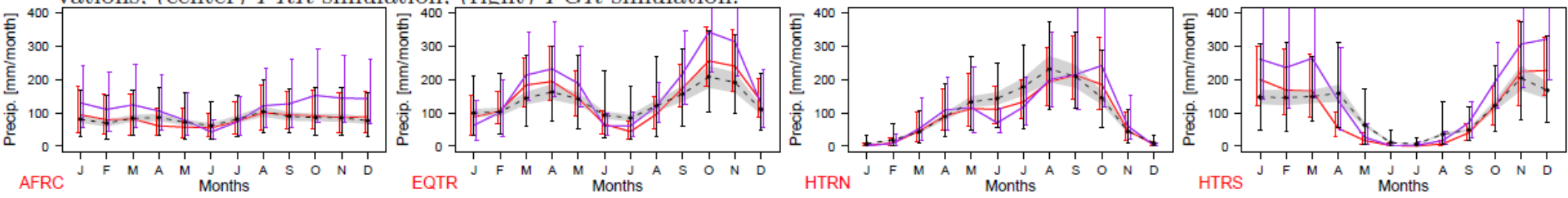


Fig. 7 Mean precipitation [mm/month] during 1998-2009 for observations and 1990-2009 for simulations. (left) TRMM observations; (center) *PRR* simulation; (right) *PGR* simulation.

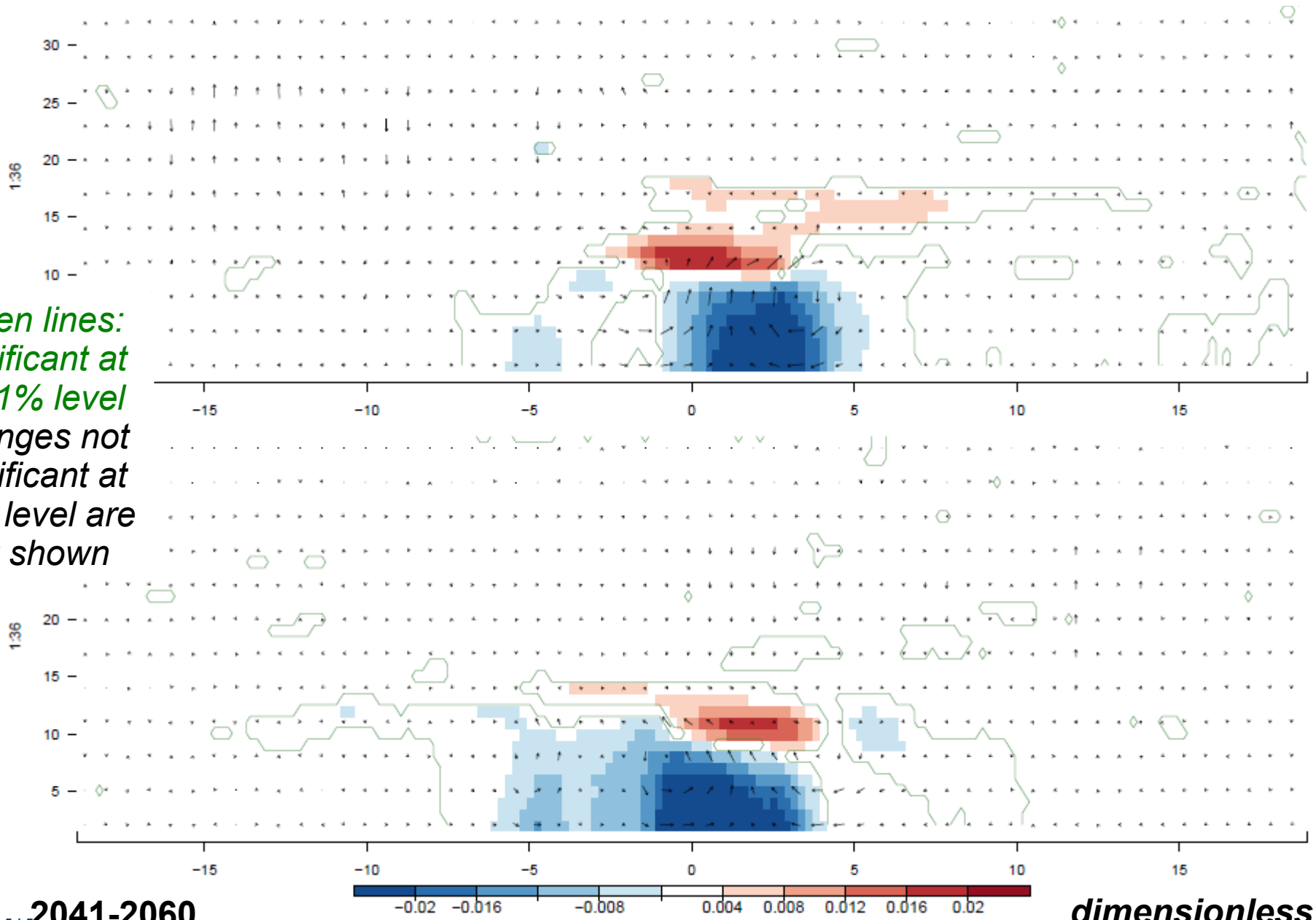


Legend: --- observations, --- CCLM²[ERAint], --- CCLM²[ECHAM5]

Multi-year average annual cycle of **monthly mean** (horizontal lines), **max** and **min** (vertical bars), and observation uncertainty (**grey zone**)

3. Quantifying deforestation impact

Relative humidity (dimensionless):



Green lines: significant at the 1% level

Changes not significant at 20% level are not shown

2041-2060

dimensionless