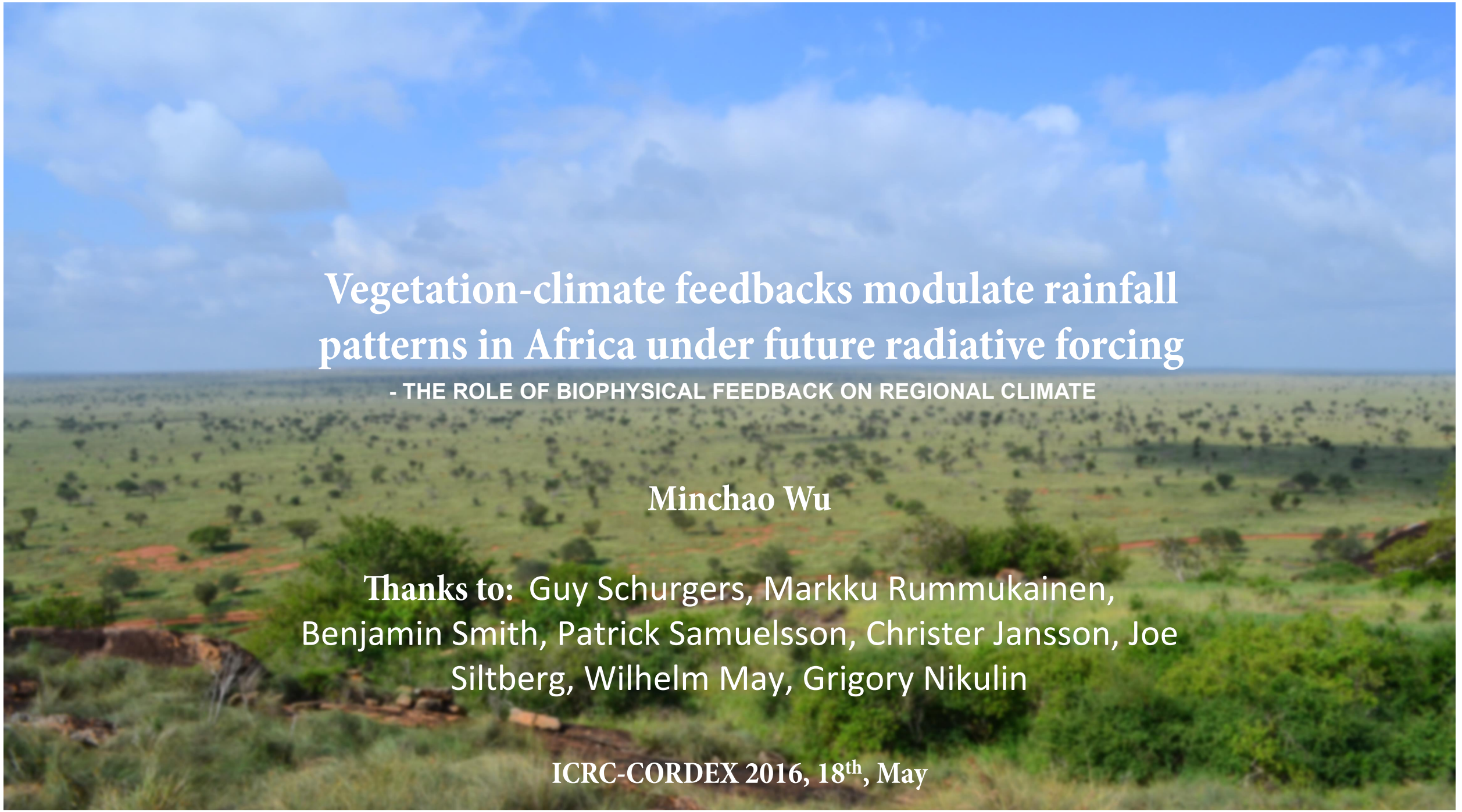


Vegetation-climate feedbacks modulate rainfall patterns in Africa under future radiative forcing

- THE ROLE OF BIOPHYSICAL FEEDBACK ON REGIONAL CLIMATE

Minchao Wu

Thanks to: Guy Schurgers, Markku Rummukainen, Benjamin Smith, Patrick Samuelsson, Christer Jansson, Joe Siltberg, Wilhelm May, Grigory Nikulin

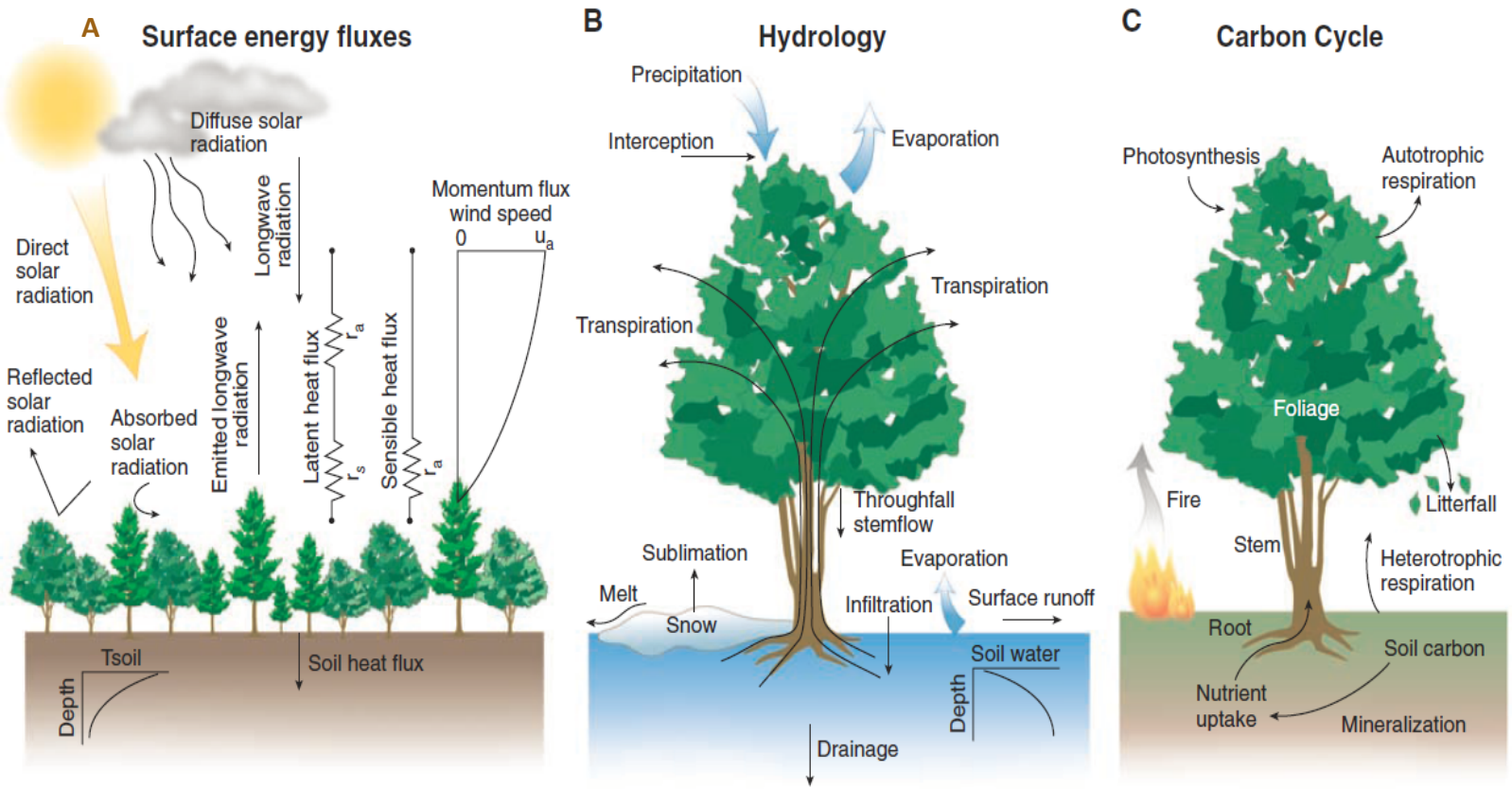
ICRC-CORDEX 2016, 18th, May

Outline

- Introduction
  - Vegetation feedback
  - Object of this study
  - CORDEX-Africa as a case study
- Methods
  - RCA-GUESS: a Coupled Vegetation-Climate regional ESM
- Results
  - Influences on land surface properties
  - Influences on atmospheric dynamics
- Conclusions

LUND
UNIVERSITY

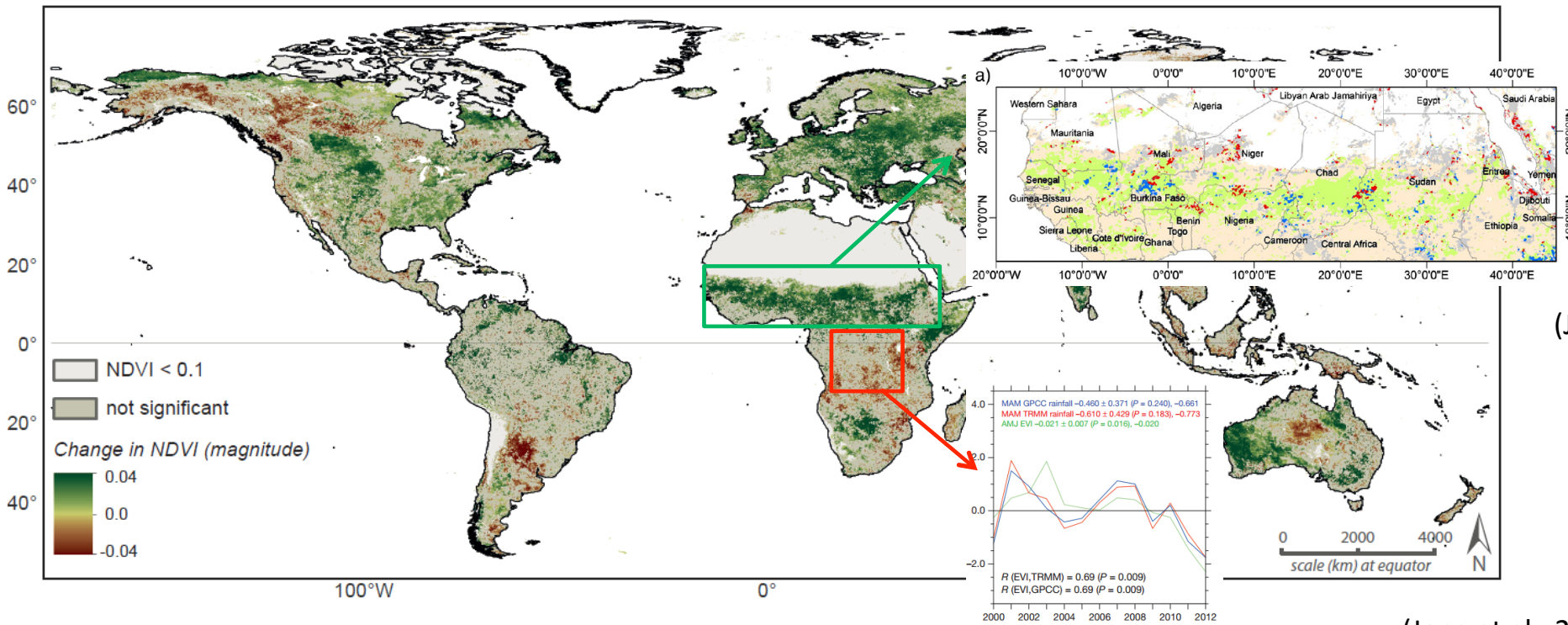
Vegetation feedback



- Influence climate via land-atmosphere interaction (Bonan et al. 2008)
  - Biophysical feedback: albedo feedback, hydrological feedback (ET)
  - Biogeochemical feedback: carbon cycle

LUND UNIVERSITY

Emerging vegetation changes in the past few decades



(Jamali et al., 2014)

(Jong et al., 2013)

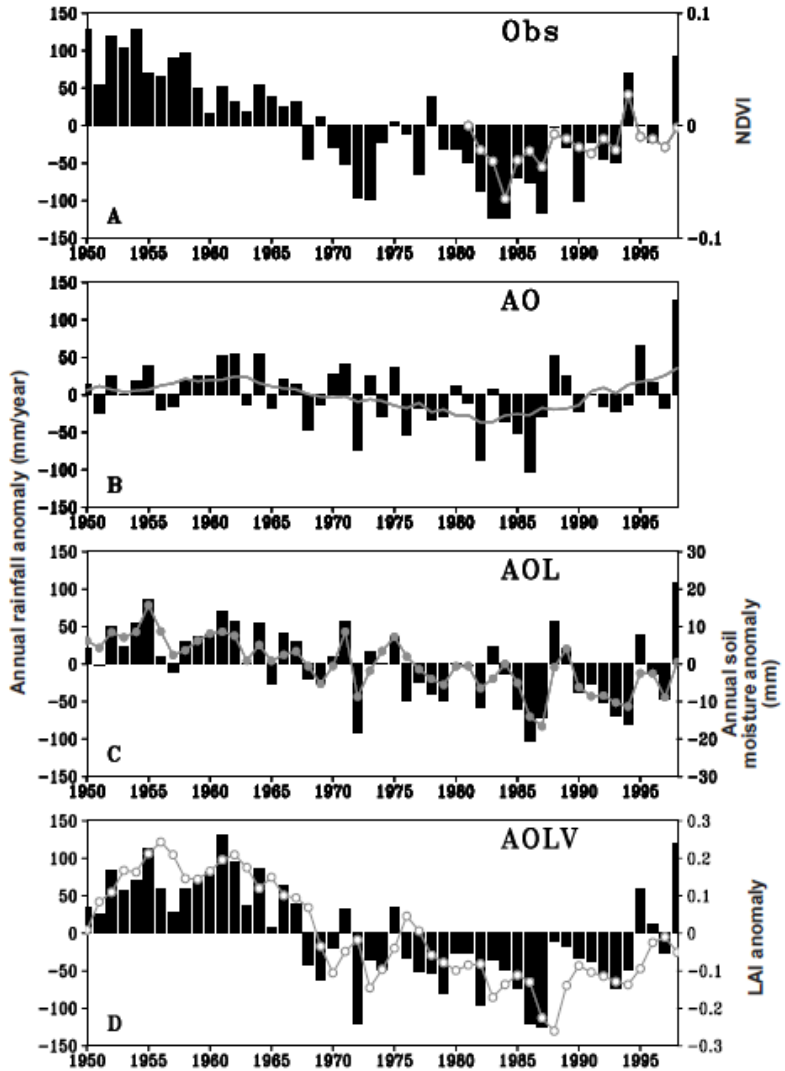
(Zhou et al., 2014)

- Global land surface in the recent decades has changed significantly
- Changes in vegetation: net primary productivity, vegetation structure

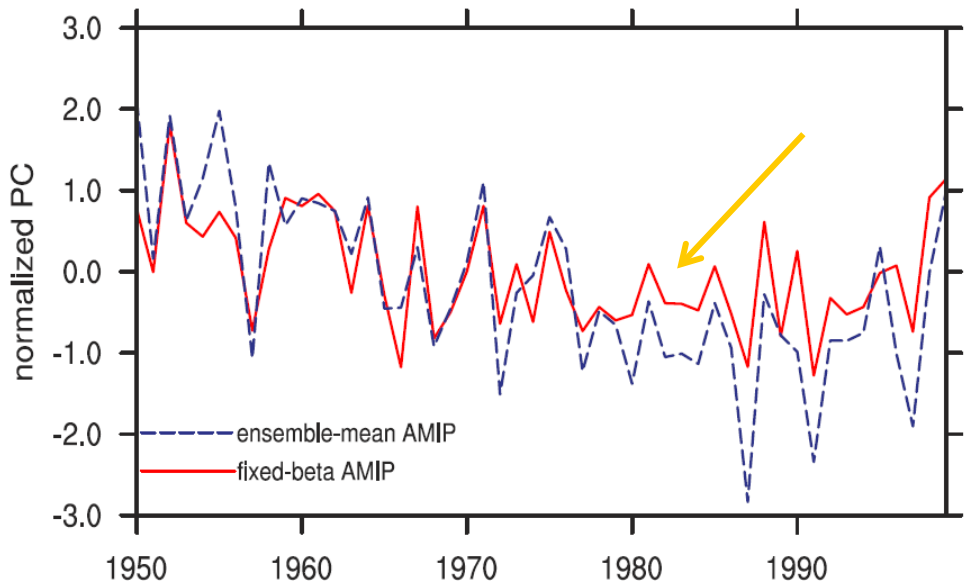
LUND UNIVERSITY

Importance of vegetation feedback in the past few decades

Precipitation variability is reproduced



Zeng et al., 1999



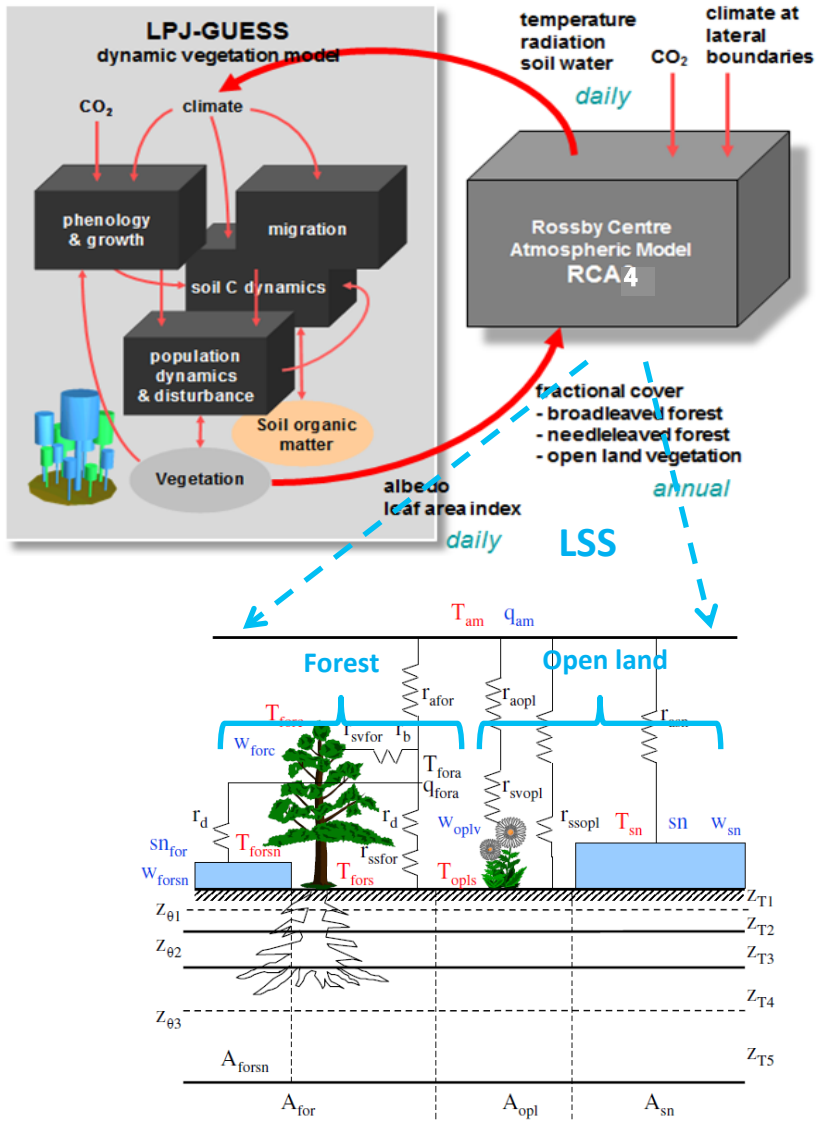
- Circulation changes over Africa:
  - **SSTs, land-ocean contrast:** (Giannini et al., 2003): disable land-atmosphere interaction reduce internal variability of rainfall over land.

LUND UNIVERSITY

What is the role of vegetation feedback in future climate projection?

- How does the climate change in future?
- How does the vegetation change in future?
- What are the interactions between them, and how?

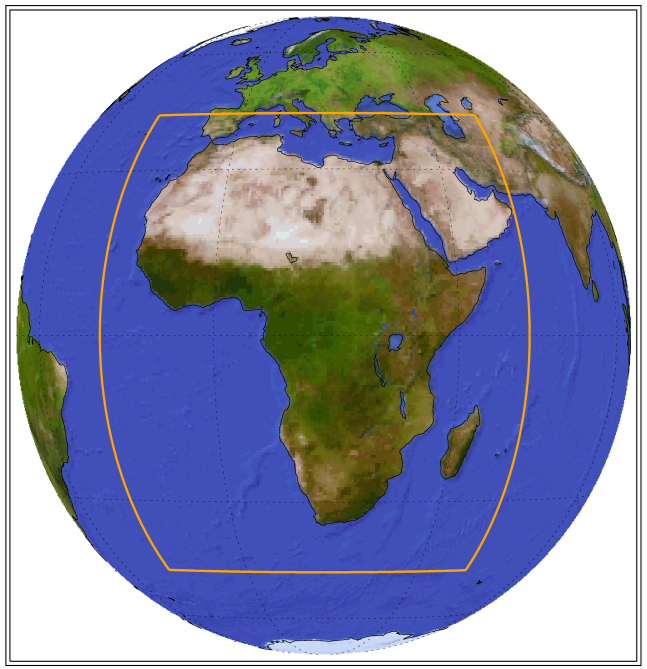
A Regional ESM - RCA-GUESS : Coupled Vegetation-Climate



- Regional climate model: RCA4 (*Kjellström et al.*, 2005; *Samuelsson et al.*, 2011):
  - *Atmosperic processes*
  - *Low boundary conditions (e.g. Surface temp.)*
- DVM: LPJ-GUESS (Smith et al., 2001) as a vegetation dyamics component:
  - *PFTs*
  - *Carbon assimulation, respiratioin, allometric growth, tree height etc.*
  - *Resources competiton*
  - *Stochastic bioclimatic disturbance (by patches), etc*
- Land surface scheme (LSS, samuelsson et al., 2006, Smith et al., 2011):
  - *Vegetated area (forest, crop), bare soil lake, river, etc.*
  - *Tile approach: high vegetated tile and low vegetated tile*

LUND UNIVERSITY

Experimental design



- RCA-GUESS over the CORDEX-Africa:
  - *Big enough to capture possible remote effect*
- 0.44° resolution:
  - *Small enough to consider land surface heterogeneity*
- Boundary conditions: CanESM2:
  - *Reproduce African climatology well*
  - *Well-validated SSTs*
- Future climate scenario: RCP8.5
- Vegetation cover and population structure from 8 plant functional types (PFTs) in LPJ-GUESS were grouped in to evergreen and deciduous forest and herb then feedback to RCA.

LUND UNIVERSITY

Experimental design

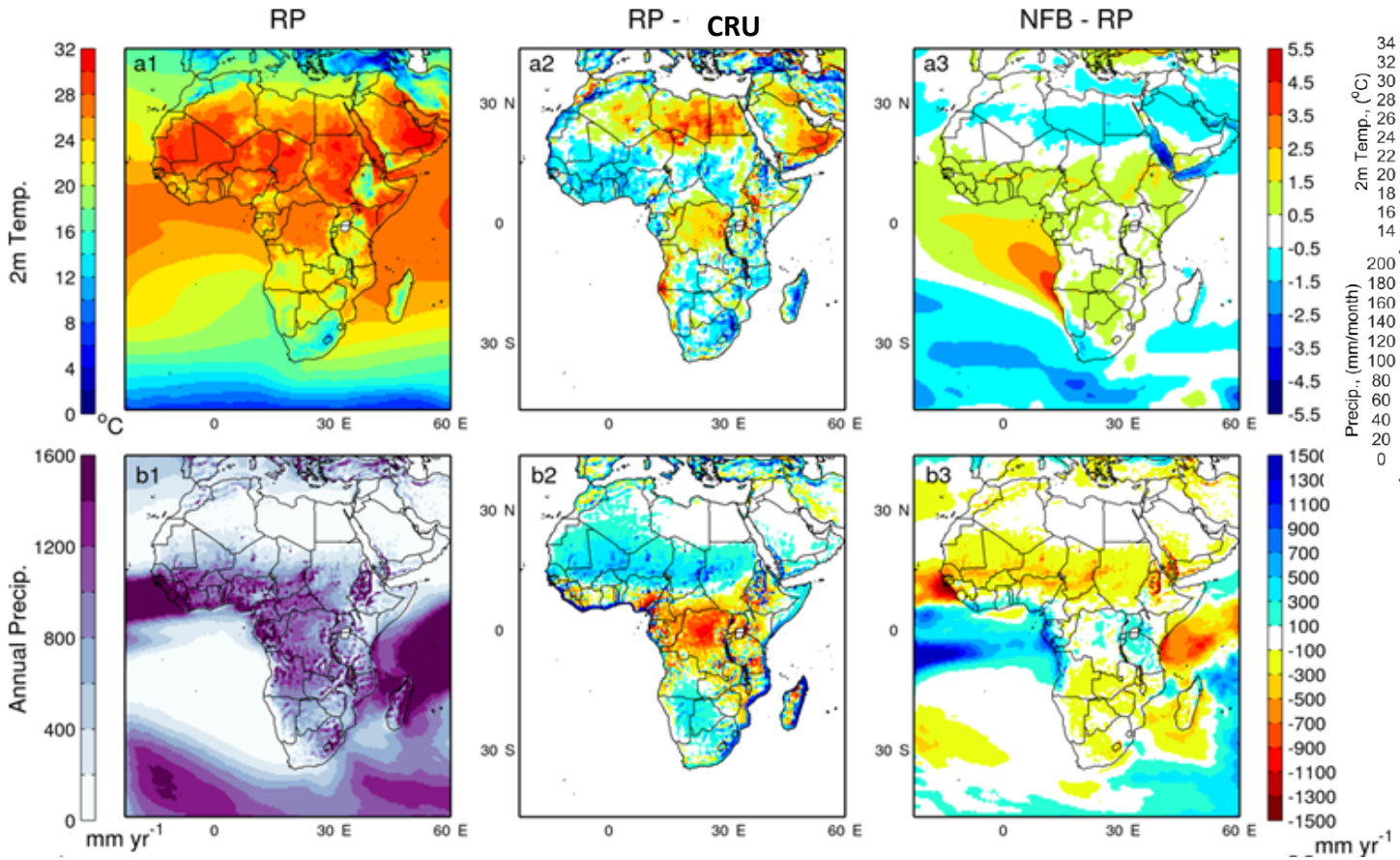
	Runs	Vegetation Feedbacks	Radiative forcing[a]	CO_2 forcing[b] for vegetation sub-model	Simulated period	Boundary condition
evaluation	RP	Dynamic	Historical	Historical	1979-2011	ERA-Interim
feedback	FB	Dynamic	Transient under RCP8.5	Transient under RCP8.5	1961-2100	CanESM2
feedback	NFB	Prescribed vegetation simulated from 1961 to 1990	Transient under RCP8.5	Transient under RCP8.5	1991-2100	CanESM2
Physiology effect (CO_2)	FB_CC	Dynamic	Transient under RCP8.5	Historical until 2005 and constant afterward	1991-2100	CanESM2

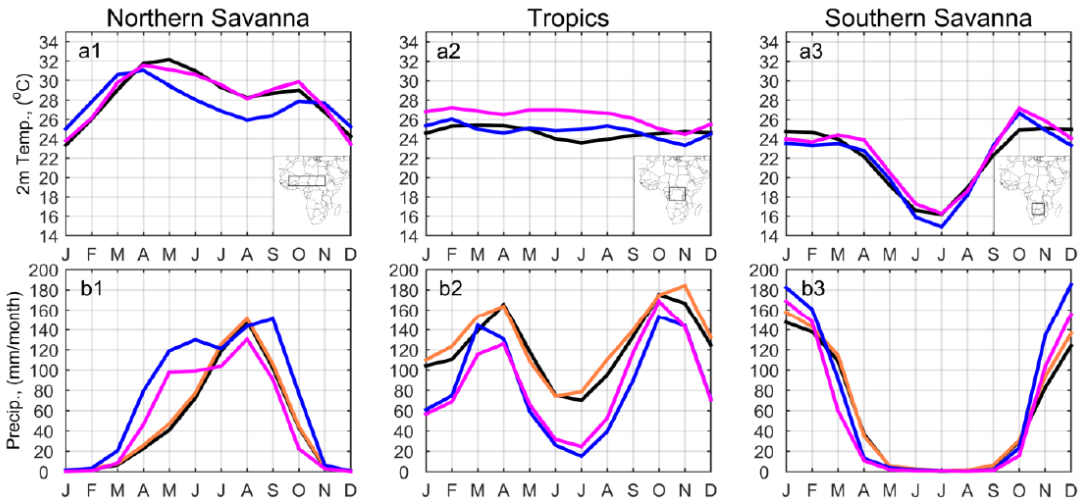
Notes: a, using equivalent atmospheric CO_2 concentration; b, using actual atmospheric CO_2 concentration.

LUND UNIVERSITY

RESULTS

Present-day climate



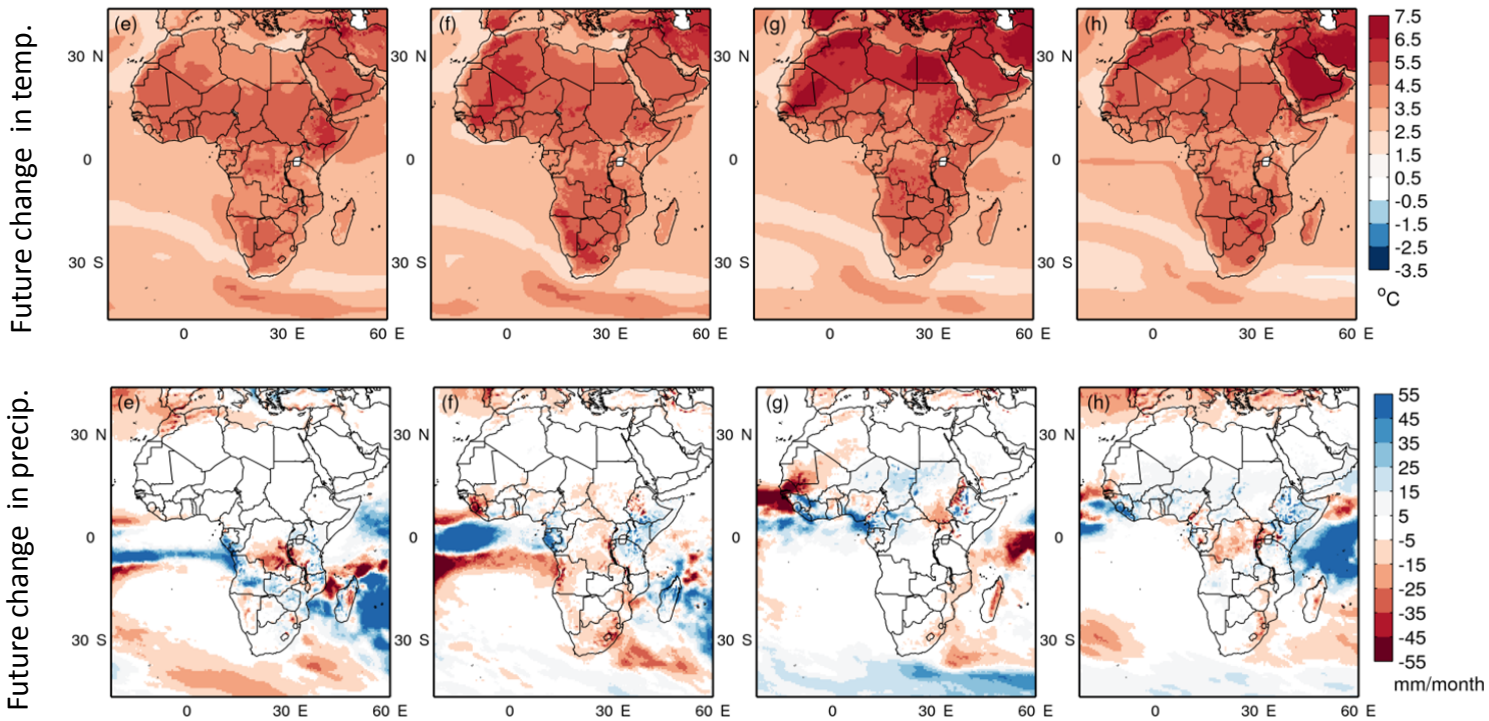


able to capture the main climatological features:

spatial pattern, seasonality.

LUND UNIVERSITY

Future climate changes

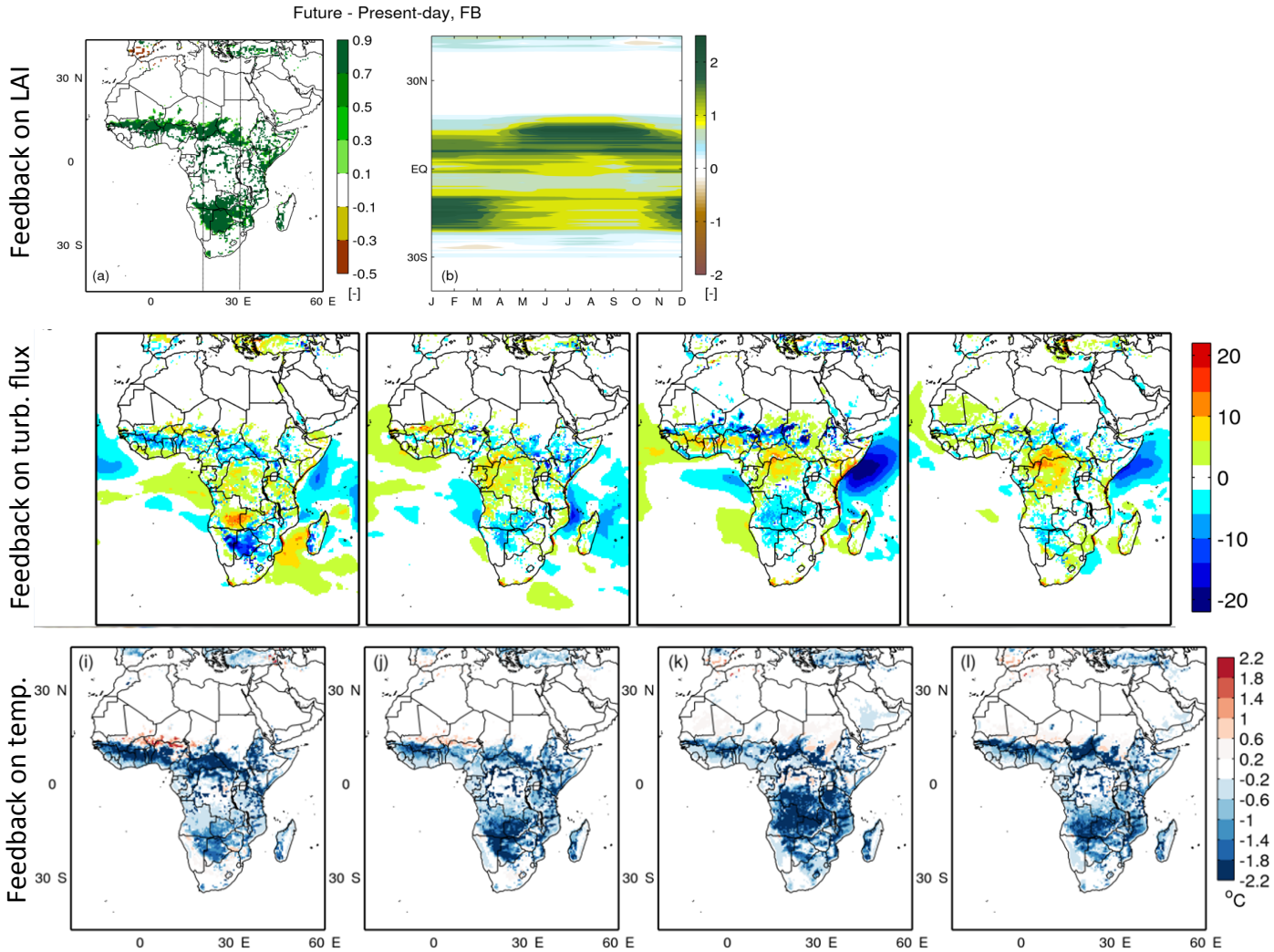


- Temperature
  - *+2-6°C in general*
  - *Warming of Land is larger than ocean*
- Precip.:
  - *Main changes happen in Monsoon area*
  - *Change over land following ITCZ*

LUND UNIVERSITY

Vegetation feedback

Results: vegetation feedback effects



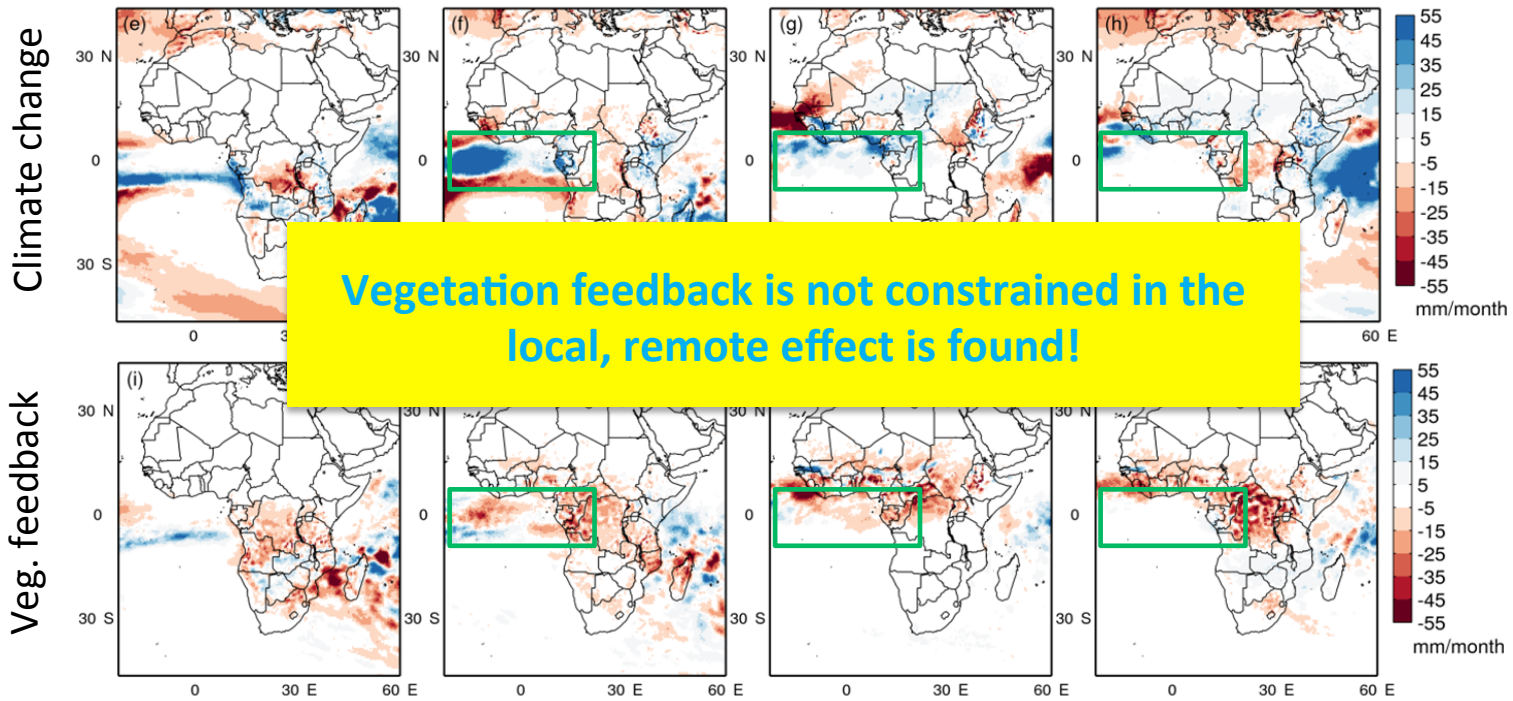
- *Forest extension : driven by "CO_2 fertilization", mainly happen in semi-arid area.*

Identified local effects:

- *Transpiration(+) -> shift in surface energy balance (EF+) -> cooling effect*
- *Warming effect, mainly for winter, arid area <- albedo (-) & radiation absorption (+)*

LUND UNIVERSITY

Results: remote effects – land-ocean contrast

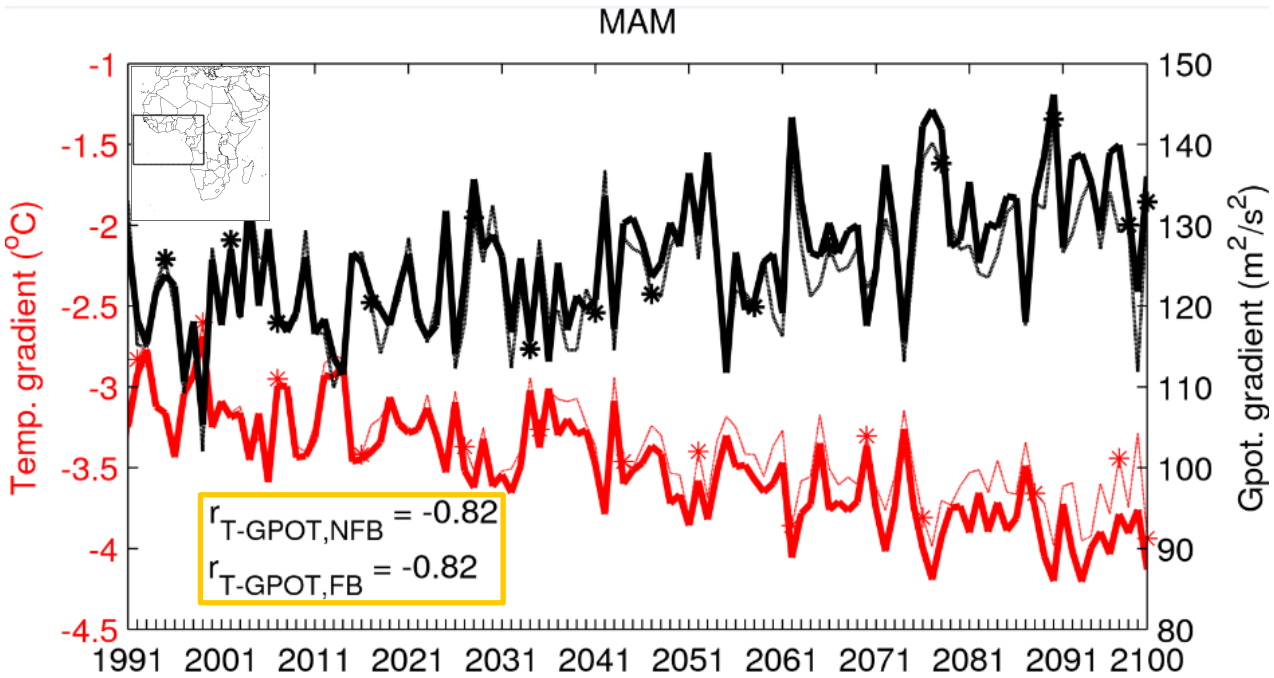


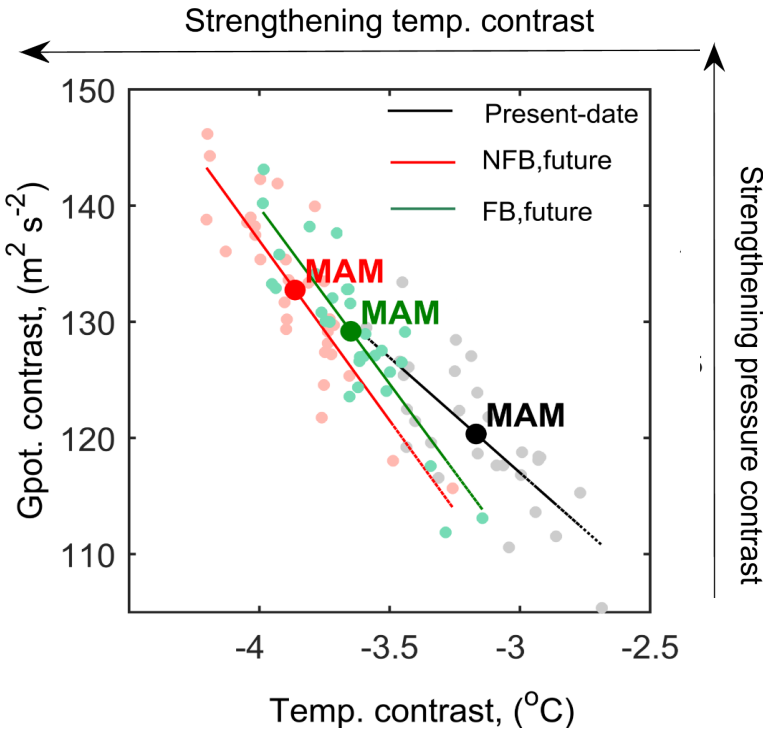
Vegetation feedback is not constrained in the local, remote effect is found!

Influences on the tropical convergence
and
parts of monsoon area

LUND UNIVERSITY

Results: remote effects – land-ocean contrast

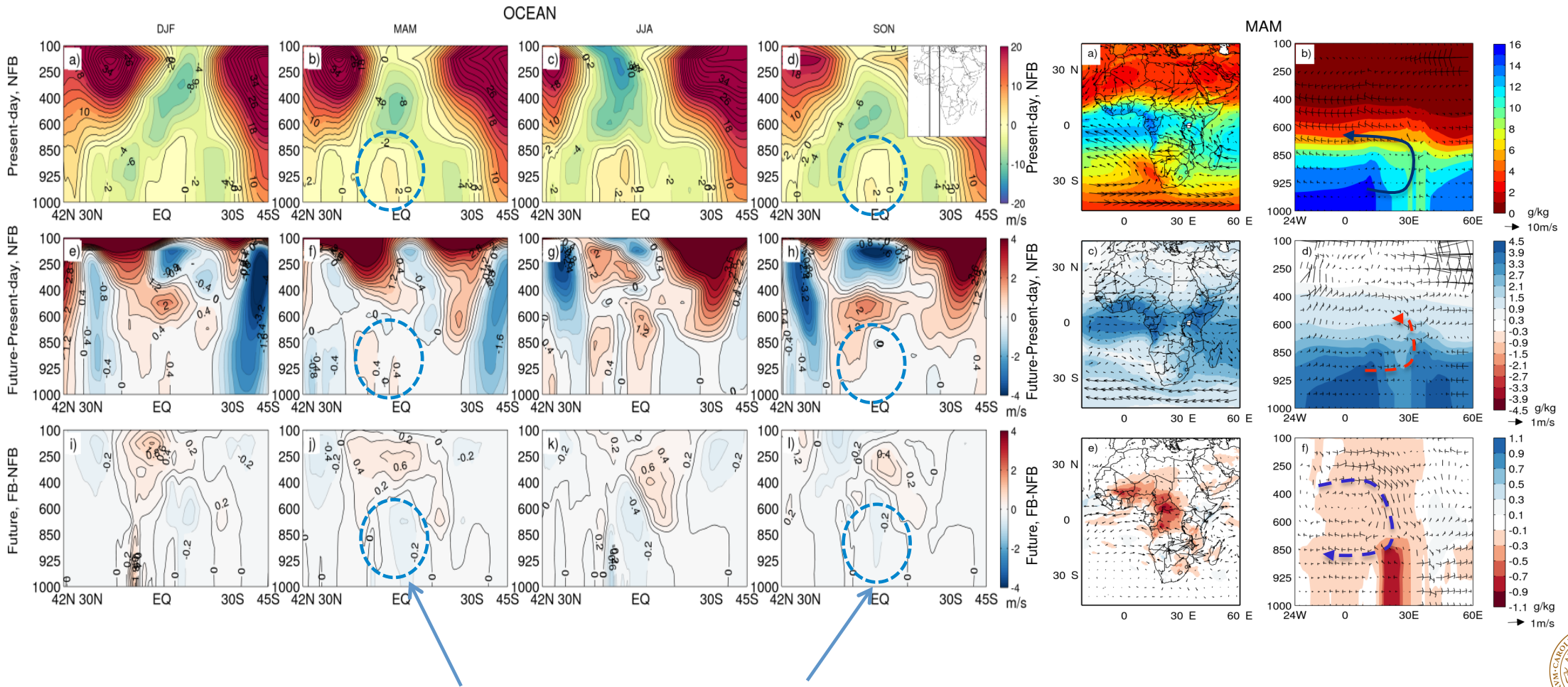




Land-ocean temp. contrast and pressure contrast are highly correlated

LUND UNIVERSITY

Results: remote effects – circulation



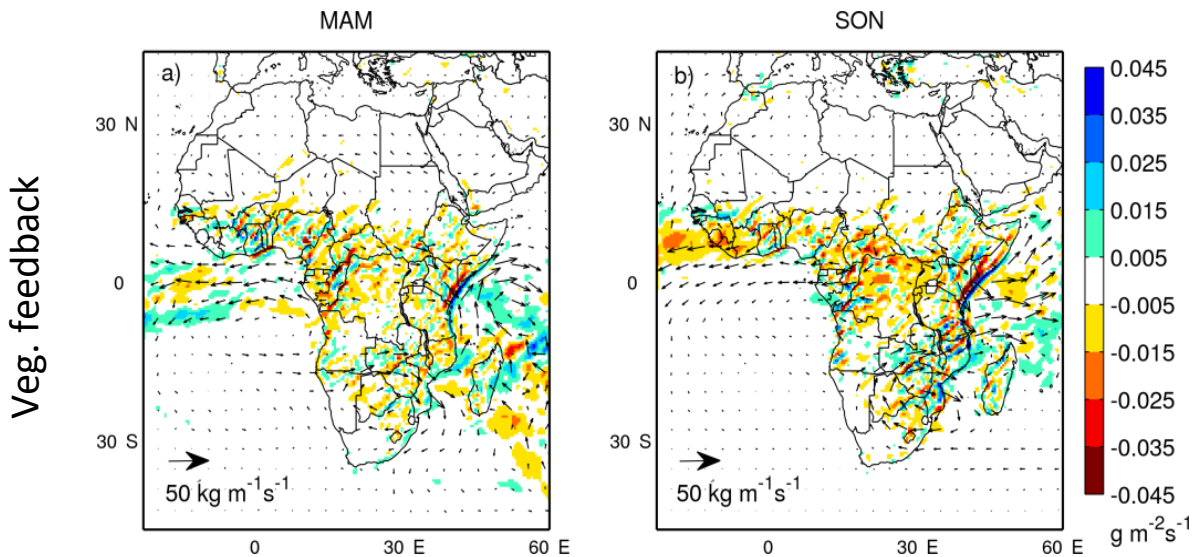
Changes in westerlies wind speed

LUND UNIVERSITY

Results: remote effects – moisture flux

Given the changes in circulation, and according to Law of conservation of mass: the lost water must have some place to go.

Where have they been to?



Water over Land (-)

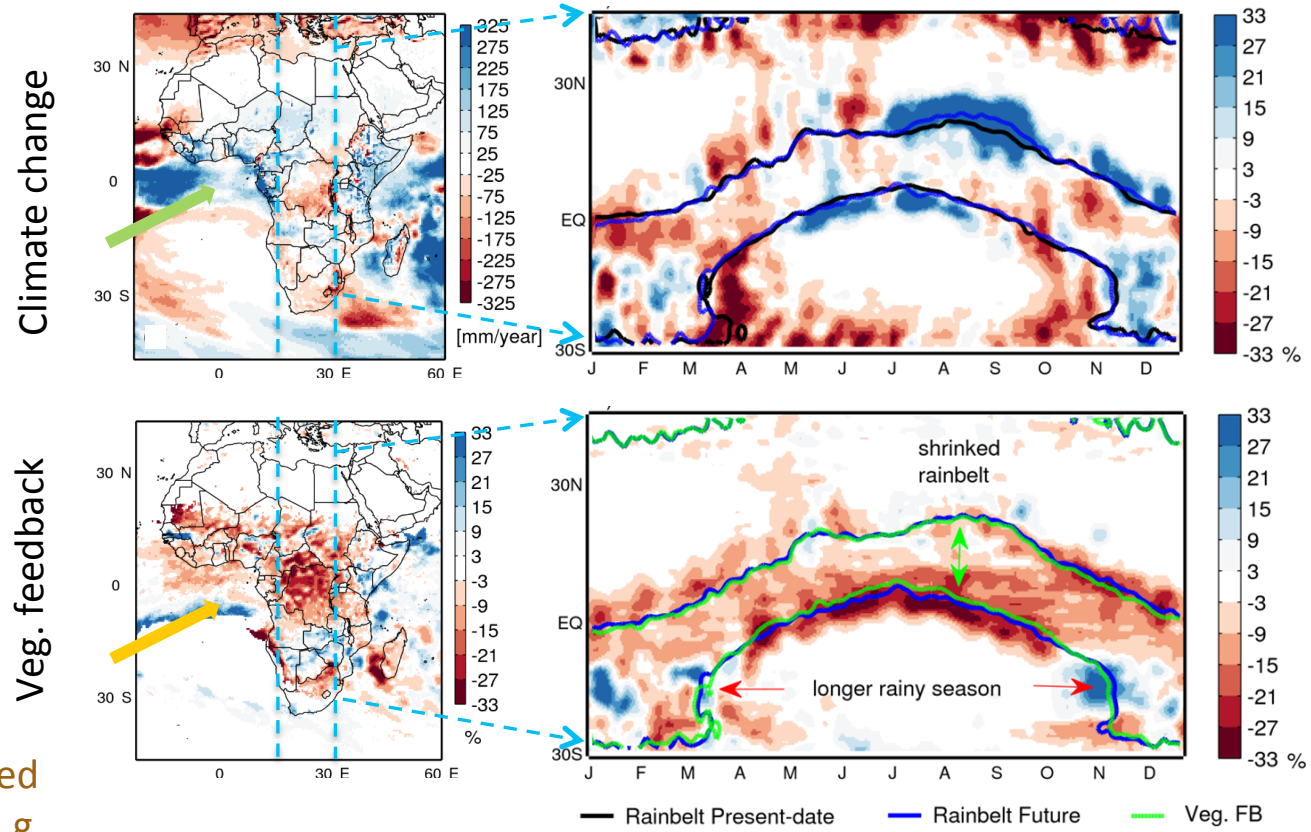
Water over Ocean (+)

LUND UNIVERSITY

Results: remote effects – rainbelt

Strengthened circulation

- Land ocean contrast
- boundary layer lapse rate
- surface energy balance
- etc.



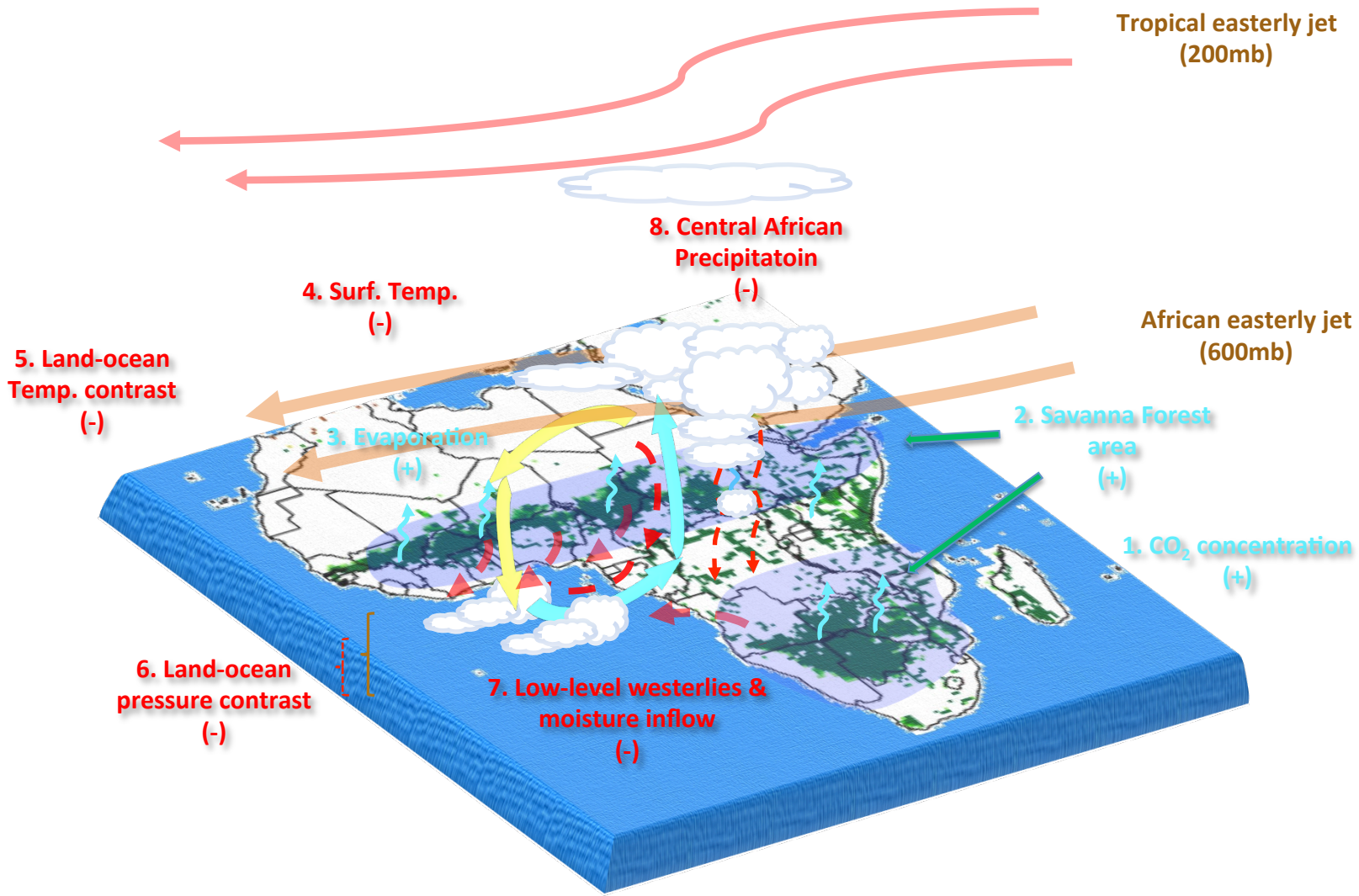
Weakened inflow, e.g. Walker cell

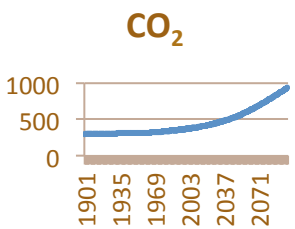
Extension of rainbelt

- Shrinkage of rainbelt, via decrease in rainfall intensity, but ITF retains
- Longer rainy season for some regions (local effects)

LUND UNIVERSITY

To summarize





LUND UNIVERSITY

Main messages:

- This is the first study of vegetation feedback on climate over CORDEX-Africa domain.
- Vegetation feedback can play an important role in future climate projection
- Bacuase vegetation changes is an important feature for future land surface.
- Biophysical feedback is not merely constrained to be local, remote effects are also possible, its importance depends on regions.
- Size of simulation domain should be appropriate to capture the remote effects.
- The importance of land-ocean contrast to moisture inflow to land, and to its hydrological cycle
- Alterntative understanding: changes in land-ocean contrast is not necessary driven by ocean (e.g. SSTs), but also can be from changes over land.

LUND UNIVERSITY

Thanks for listening!