# Downscaling large-scale climate variability using a regional climate model: the case of ENSO over Southern Africa

Benjamin Pohl*, Damien Boulard, Julien Crétat, Nicolas Vigaud*
* Centre de Recherches de Climatologie, UMR Biogéosciences, CNRS / université de Bourgogne, Dijon, FRANCE
benjamin.pohl@u-bourgogne.fr

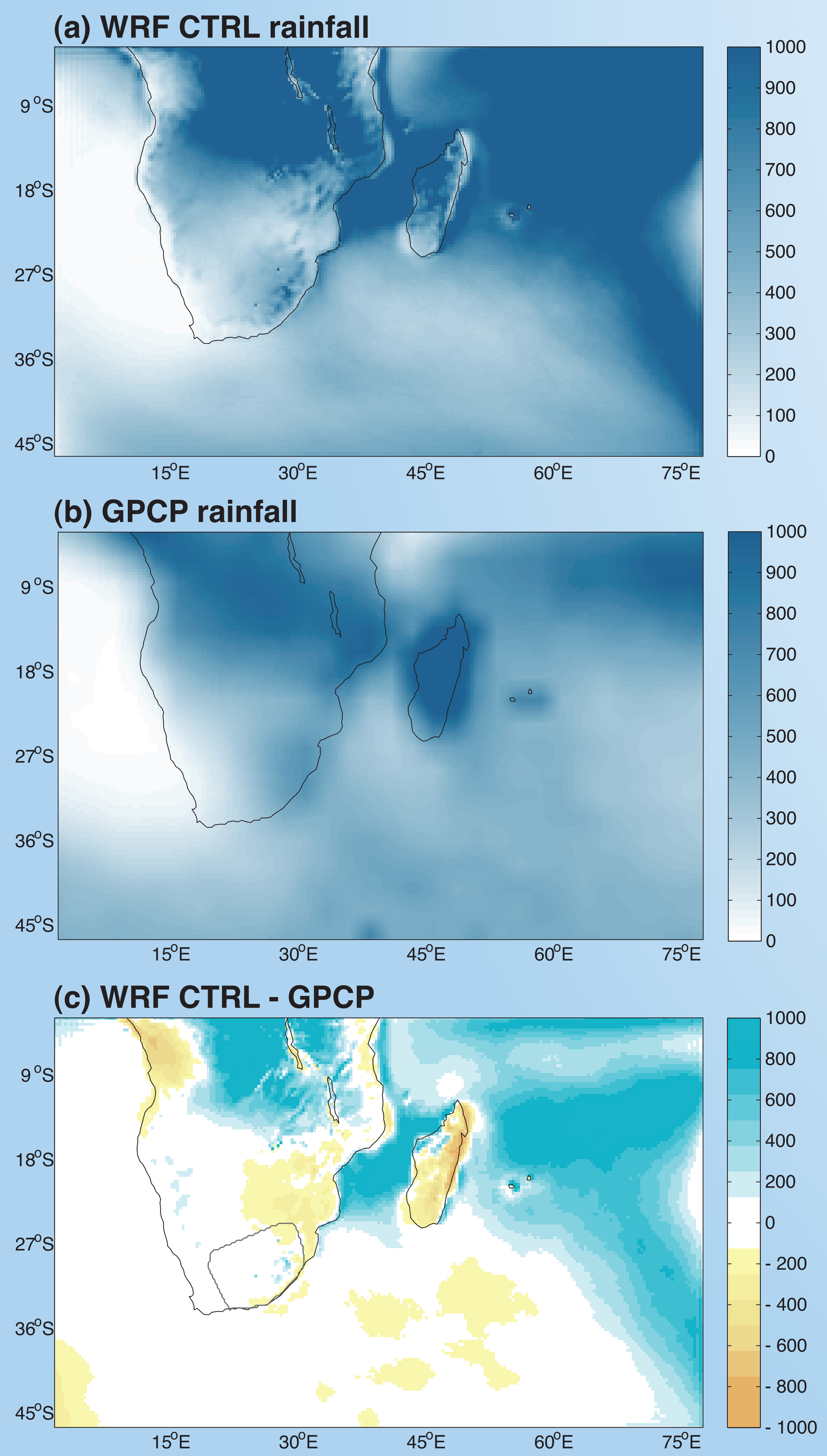
## PROBLEMATICS

- Assess the capability of a current state-of-the-art RCM in simulating regional effects of ENSO over Southern Africa
- Document to which forcing (SST or atmosphere) simulated anomalies respond
- Understand the causes of the model deficiencies

## EXPERIMENTAL SETUP

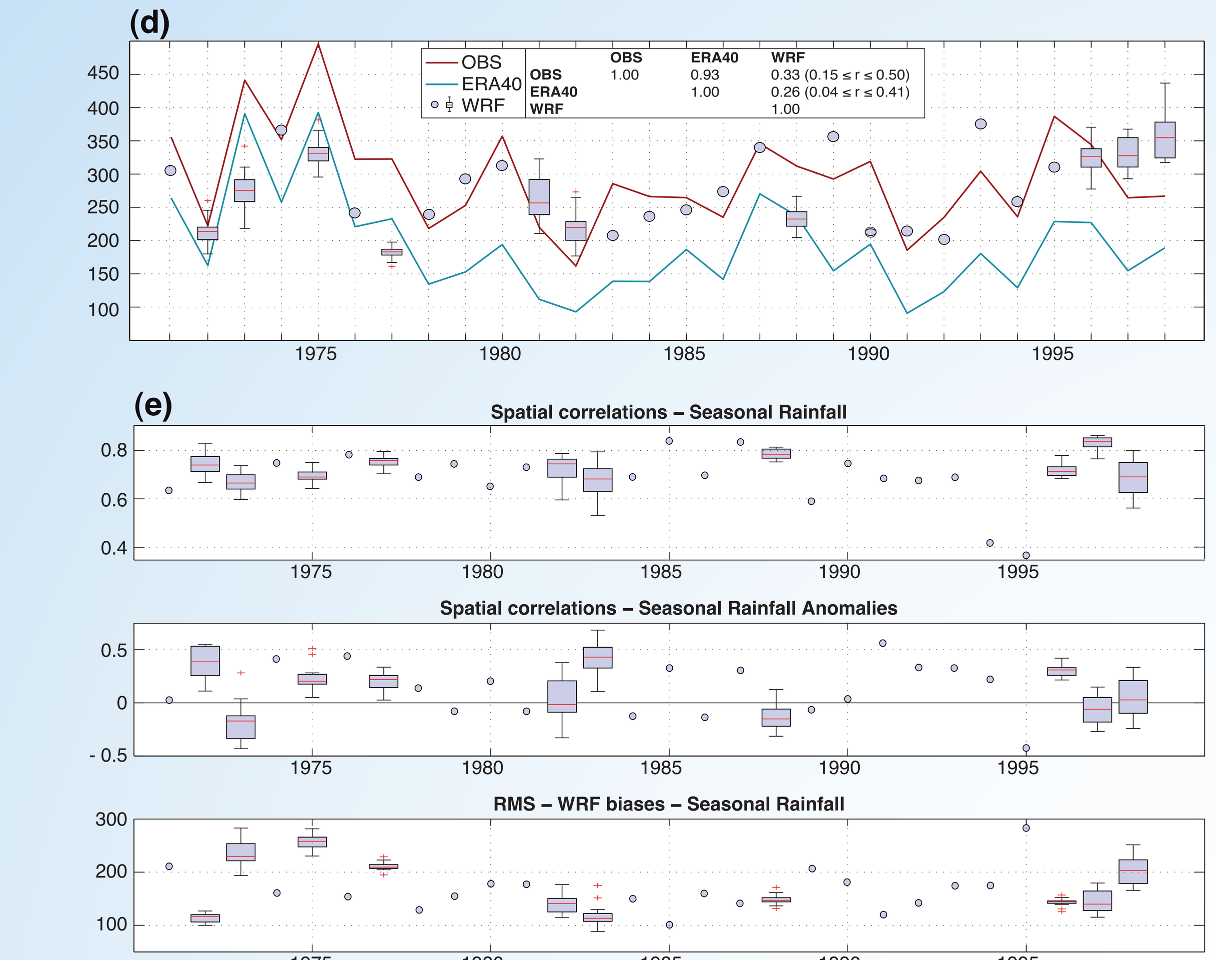
- **WRF/ARW v3.2.1**, 35km horizontal resolution, 28 levels, domain [1.5°S-48.5°S, 0.5°E-79.5°E]
- **Seasonal simulations:** Nov. to March 1971-72 to 2000-01, after one-month spin-up (Oct.)
- **Forcings:** ERA40, 1.5° resolution, every 6h, ERA40 montly SST (interpolated daily)
- **Physics:** Grell-Dévényi convection, Yonsei Univ. PBL, Morrison microphysics, Dudhia SW and RRTM LW radiation, NOAH LSM and Monin-Obukhov surface
- **Additional experiments:** OML exp. using a simple ocean mixed-layer model / SST_CLIM driven by observed atmosphere and climatological SST / ATM_CLIM driven by climatological atmosphere and observed SST
- **15-member simulations** for 10 years

## MEAN CLIMATE




- Realistic simulated rainfall geography over Africa *(a)*
- Wet biases *(c)* over Indian Ocean, Mozambique Channel and tropical Africa (too strong ITCZ)
- Weak biases over Southern Africa

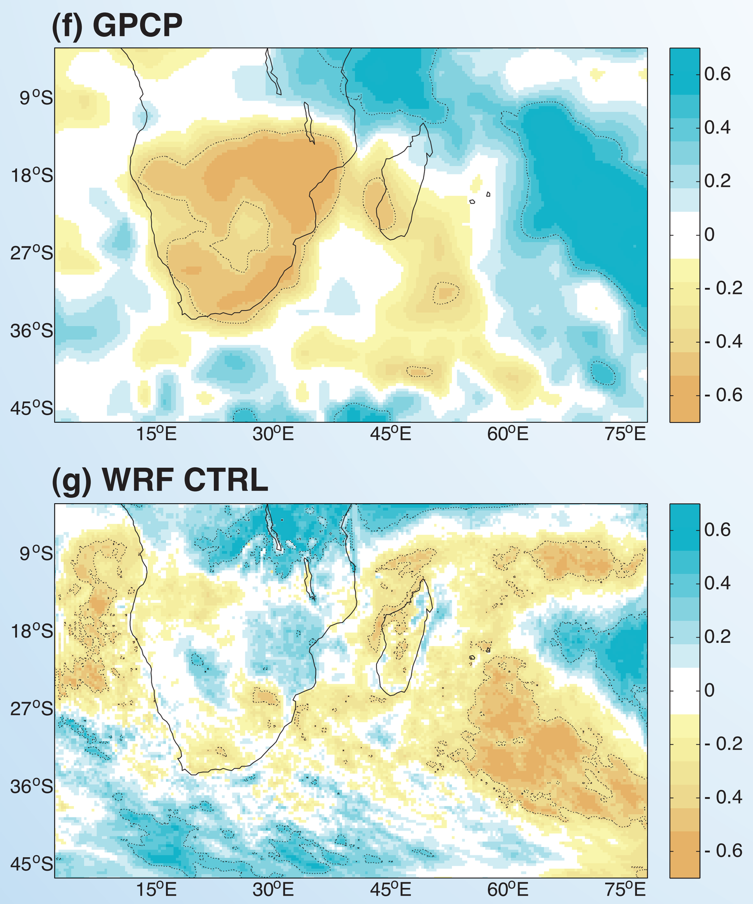
## RAINFALL INTERANNUAL VARIABILITY




*(d) Observed and simulated rainfall in regional index contoured in Fig. (c); box-and-whisker plots show the results of ensemble simulations; (e) Spatial correlations of seasonal mean rainfall and seasonal anomalies, and RMS errors of simulated biases.*

- Weak co-variability between observation and simulations + strong internal variability: large uncertainties in 30-year correlations (0.15 ≤ r ≤ 0.50)
- Strong (weak) spatial correlations with seasonal mean rainfall (anomalies): simulated interannual variability perfectible
- **Implication of ENSO ??**

## REGIONAL ENSO EFFECTS




| CTRL | OML | SST_CLIM | ATM_CLIM | OBS | ERA40 | MEI | (h) |
|---|---|---|---|---|---|---|---|
| - | 0.79 | 0.68 | 0.24 | 0.33 0.31 | 0.26 | -0.16 | CTRL |
| | - | 0.79 | 0.20 | 0.35 0.33 | 0.26 | -0.17 | OML |
| | | - | -0.22 | 0.24 0.39 | 0.17 | 0.06 | SST_CLIM |
| | | | - | 0.51 0.16 | 0.45 | -0.60 | ATM_CLIM |
| | | | | - | 0.93 | -0.69 | OBS |
| | | | | | - | -0.66 | ERA40 |
| | | | | | | - | MEI |

*(f) 30-year correlations between GPCP estimates and the Multivariate ENSO Index. 95% significant values are contoured.(g) As (f) for WRF-simulated rainfall. (h) Correlation matrix between simulated rainfall (exps. CTRL, OML, SST_CLIM, ATM_CLIM) in regional index contoured in Fig. (c), rain-gauge records, ERA40 rainfall and the Multivariate ENSO Index. 95% significant values are in color.*

- Observation *(f)*: meridional convective dipole, with dry (wet) conditions over Southern Africa (Equatorial East Africa) during El Niño years
- Simulations *(g)*: no ENSO effects over Southern Africa, sign errors over most parts of the South-West Indian Ocean

**Model sensitivity experiments:**

- Weak dependency to the model physics (not shown)
- Not due to biased OA heat exchanges: exp. OML very similar to CTRL
- Only exp. ATM_CLIM capable to reproduce regional ENSO effects over Southern Africa — exp. SST_CLIM reproduces none of the observed interannual variability
- **Role of regional SST in Southern African climate ?**
- **Reproducibility / Robustness of these results ?**

## 1982-83 CASE STUDY

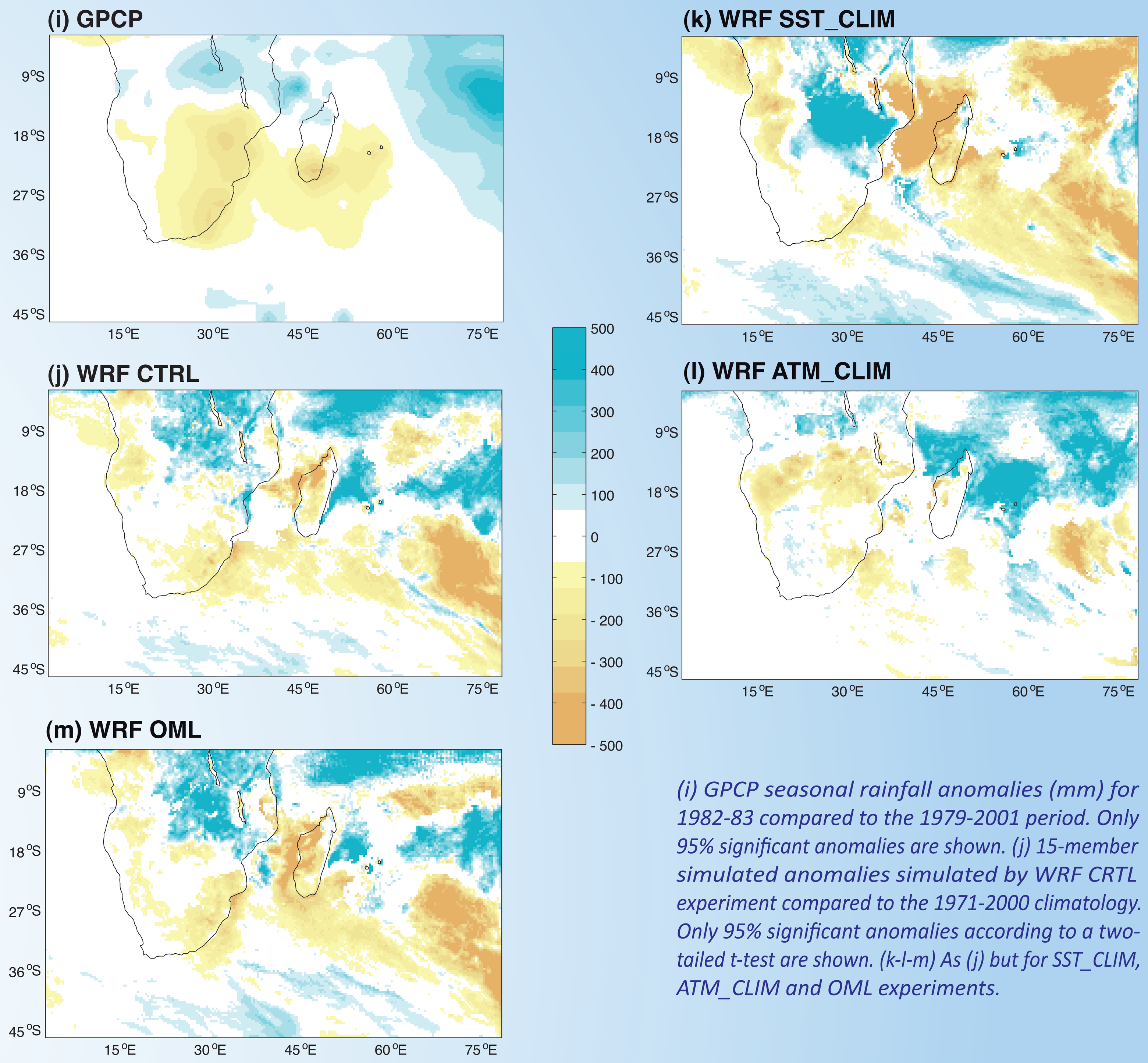
**15-member ensemble anomalies to consider the model internal variability and assess the reproducibility of the simulated climate**

- Observation *(i)*: very dry conditions over Southern Africa and the South-West Indian Ocean, moderate wet anomalies over tropical Africa
- WRF CTRL exp. *(j)*: biased over the Indian Ocean, realistic over Africa (but wet / dry anomalies over / under-estimated)
- WRF OML exp. *(m)*: similar to CTRL exp., indicating no destructive effects between surface and lateral forcings

**To which forcing do these anomalies respond?**

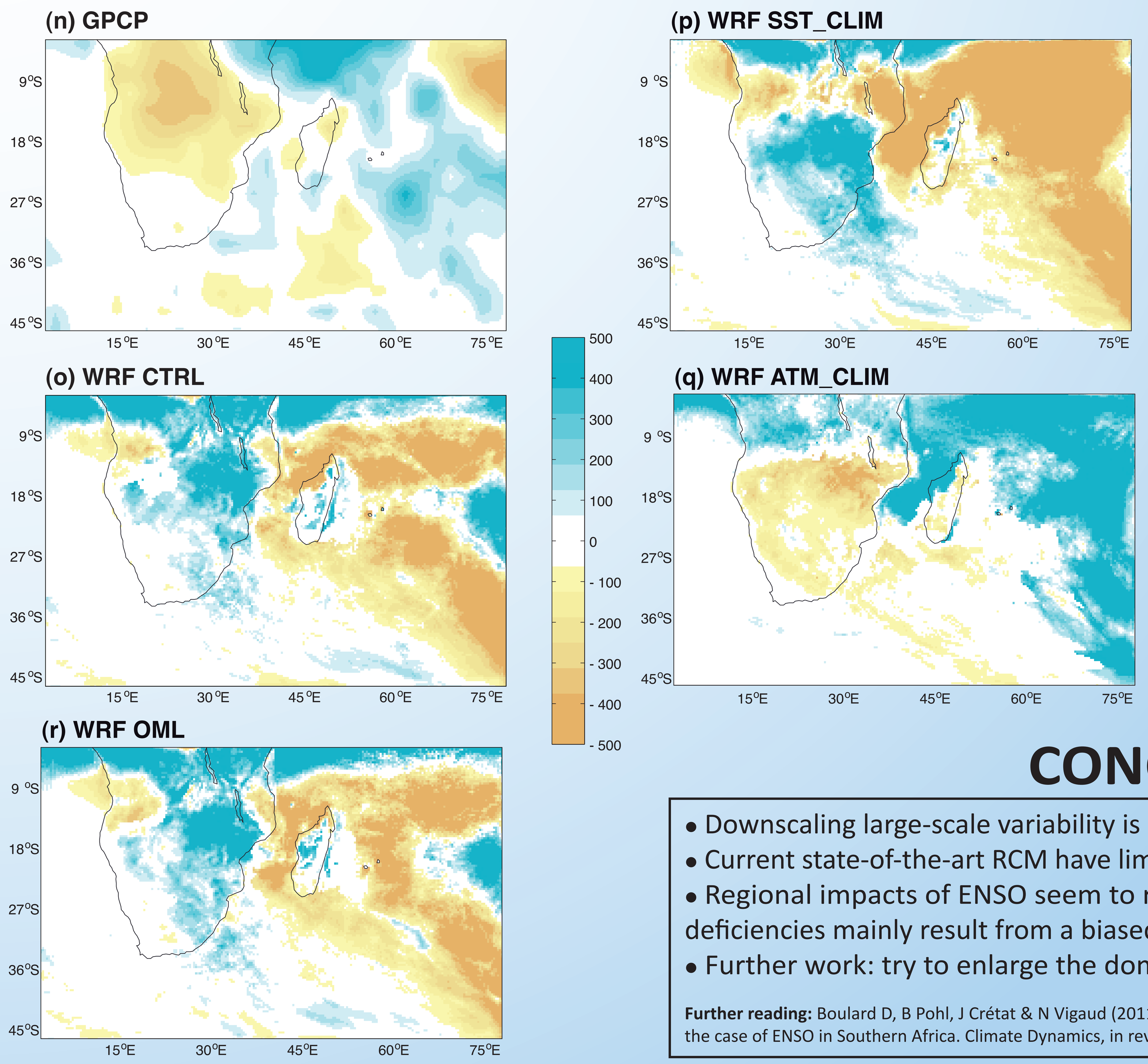
- WRF SST_CLIM exp. *(k)*: strong reversed-sign anomalies over tropical Southern Africa and the Indian Ocean; no clear anomalies over South Africa. The lateral atmospheric forcing seems to account for most oceanic biases of CTRL exp.
- WRF ATM_CLIM exp. *(l)*: anomalies of correct sign over the whole domain, but of too weak amplitude and spatial coherence

- **Confirms the significant influence of regional SST anomalies**
- **Both realistic atmosphere and SST are needed to reproduce rainfall anomalies over South Africa**




*(i) GPCP seasonal rainfall anomalies (mm) for 1982-83 compared to the 1979-2001 period. Only 95% significant anomalies are shown. (j) 15-member simulated anomalies simulated by WRF CRTL experiment compared to the 1971-2000 climatology. Only 95% significant anomalies according to a two-tailed t-test are shown. (k-l-m) As (j) but for SST_CLIM, ATM_CLIM and OML experiments.*

## 1997-98 CASE STUDY




*(n-r) As (i-m) but for 1997-98 anomalies.*

- Observation *(n)*: dry (weak) anomalies over Angola and Zambia (South Africa): **regional ENSO impacts on Southern Africa are not linear**
- WRF CTRL and WRF OML *(o,r)*: sign errors over the Indian Ocean and Africa: **no skill in simulating 1997-98 ENSO effects**
- WRF SST_CLIM *(p)*: the 1997-98 atmosphere forcing causes the strong biases in WRF CTRL exp.
- WRF ATM_CLIM *(q)*: the 1997-98 SST forcing favors anomalies of correct sign, but of too weak amplitude over Africa

- **Biases due to lateral (atmospheric) forcings**
- **Convincing response to surface (SST) forcings**

## CONCLUSIONS

- Downscaling large-scale variability is not a straightforward exercise
- Current state-of-the-art RCM have limited skill in simulating ENSO influence over Africa
- Regional impacts of ENSO seem to result from both surface and atmosphere: WRF deficiencies mainly result from a biased response of the regional atmosphere
- Further work: try to enlarge the domain to include Pacific SST as an explicit forcing?

**Further reading:** Boulard D, B Pohl, J Crétat & N Vigaud (2011) Downscaling large-scale climate variability using a regional climate model: the case of ENSO in Southern Africa. Climate Dynamics, in revision