The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1934-9

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Examples of regional climate modelling activities over Africa.

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Rondebosch
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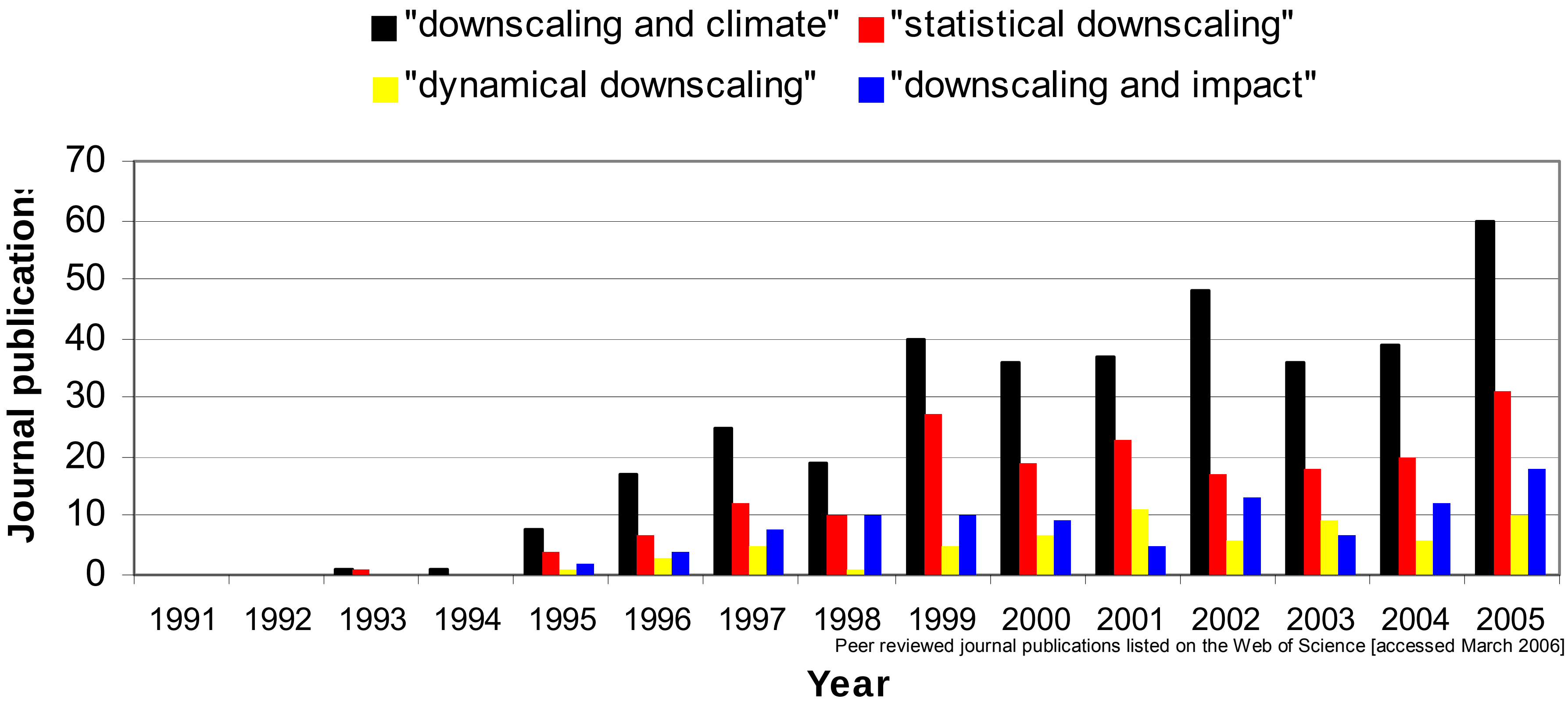
SOUTH AFRICA

RCM Climate modeling over (southern) Africa

Climate change, context, objectives

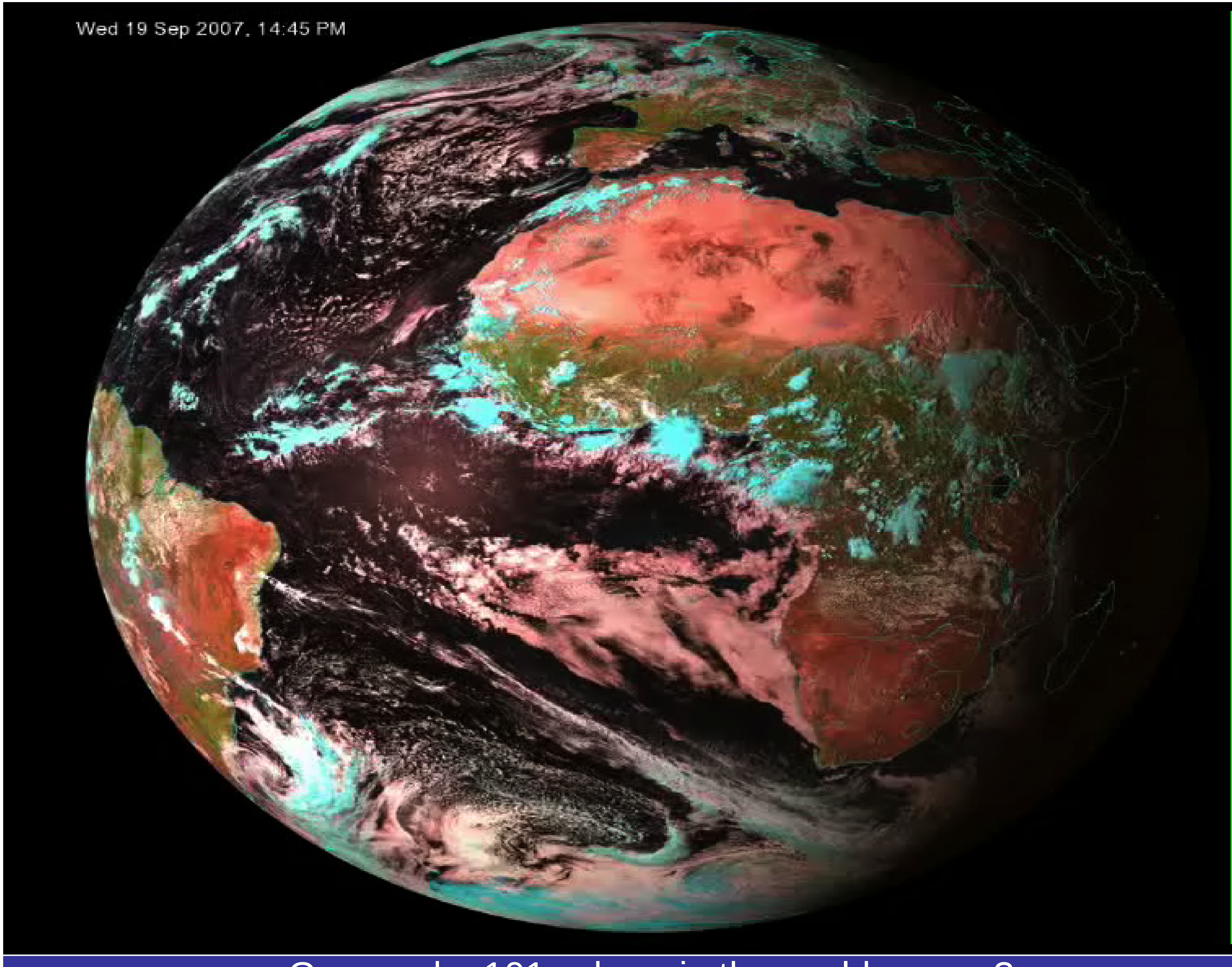
Bruce Hewitson, Francois Englebrecht, Neil McKellar, Igor Oliveira

Talk #1 of three leading to discussion time



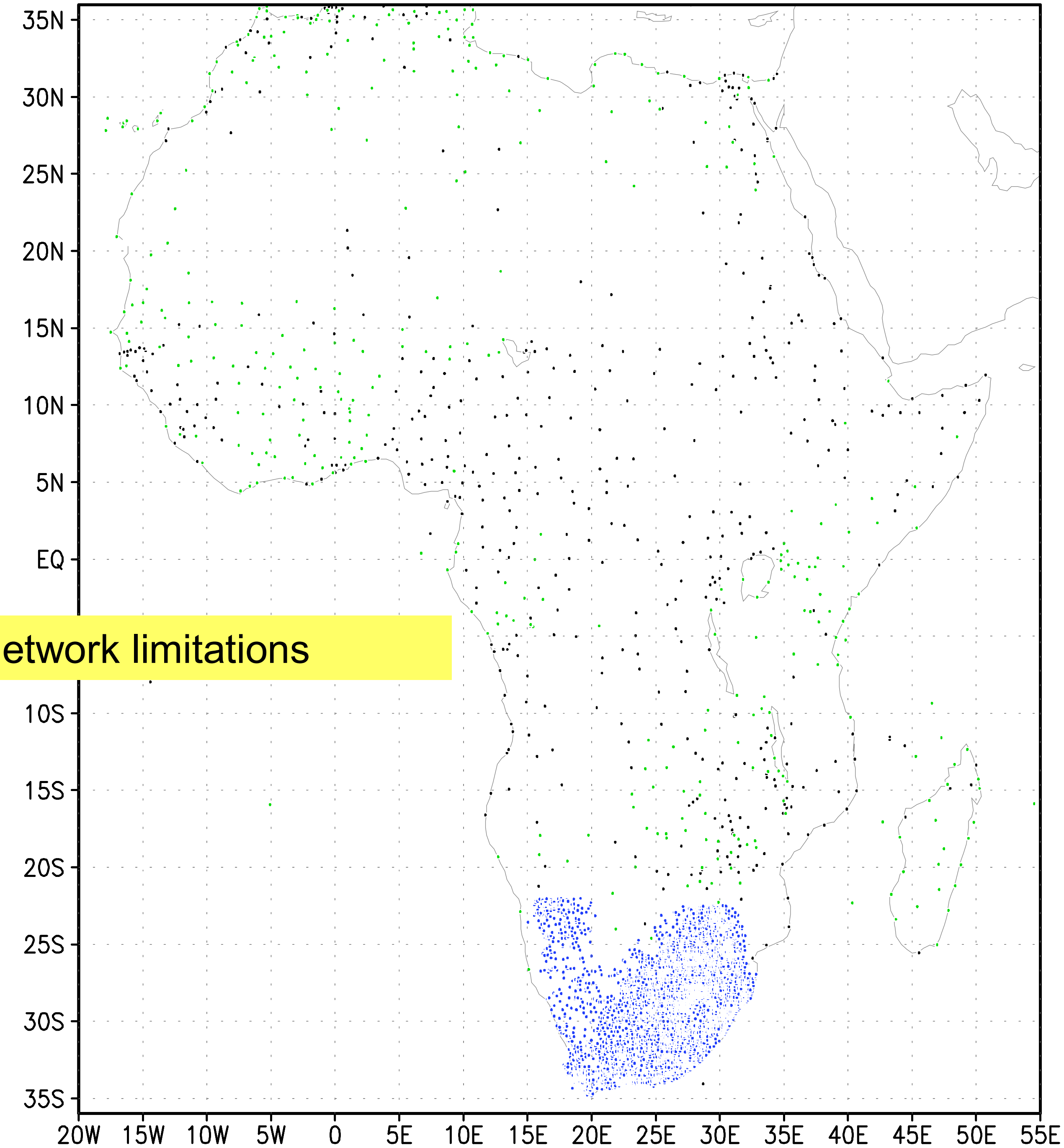
Peer reviewed journal publications listed on the Web of Science [accessed March 2006]

1. Comments on context and the $50 000 challenge
2. The best IPCC has to offer
3. RCM attempts to downscale
4. Other approaches
5. Circulation issues
6. Processes: land surface
7. Other modeling
8. Dissemination and communication
9. New initiatives



movie

Geography 101: where in the world are we?



Station network limitations

CSAG

The context of modeling in Africa:

a) Poorly understood processes; high degree of variability; teleconnections of variable stability

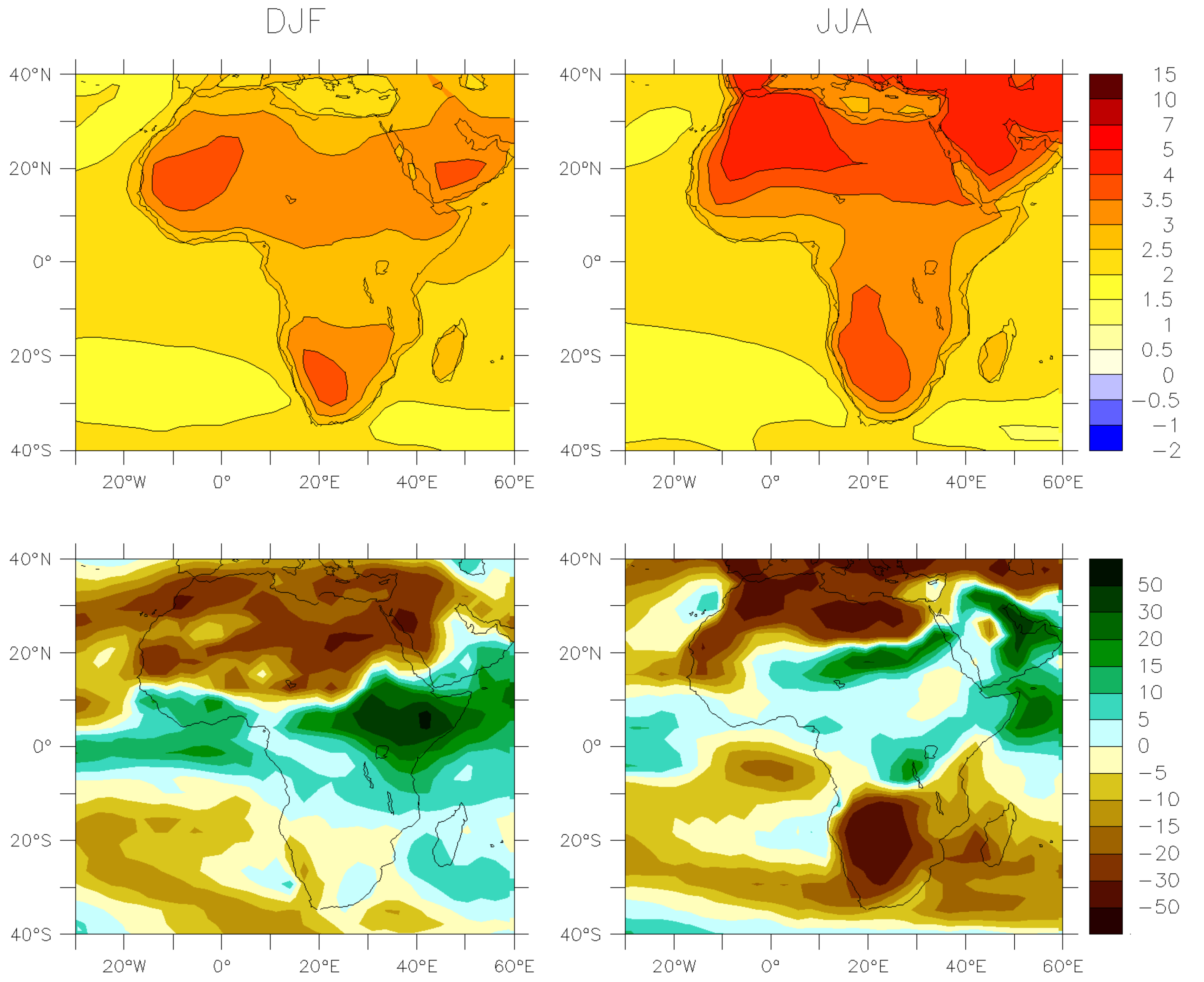
b) In-continent funding heavily focused on research results of tangible societal value

c) Small community of researchers; often playing to the tune of international agendas

d) The $50 000 challenge: Given
   - 2 years
   - $50 000
   - One PI and one PhD
   - A 4-CPU PC cluster
   - Erratic electricity
   - A multi-demanding work environment

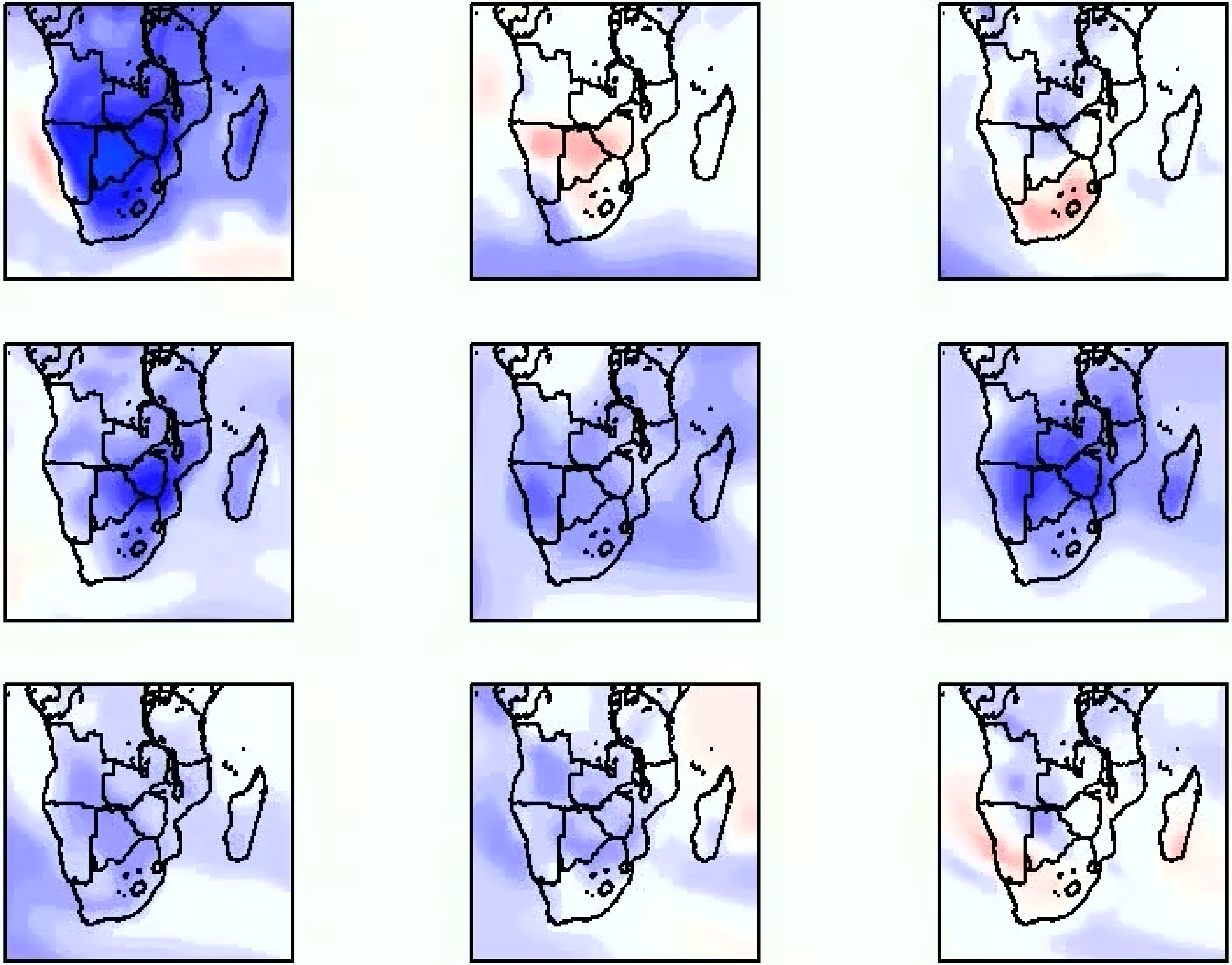
Design a RCM experiment that at the end of the day a policy person in government can publicly defend as:

"THIS is the societal value of the $50 000 research"

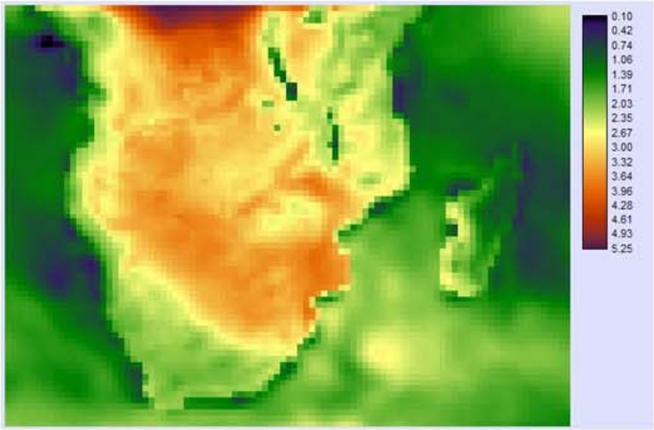


Rainfall(%)/Temperature changes by end of 21st Century

2002

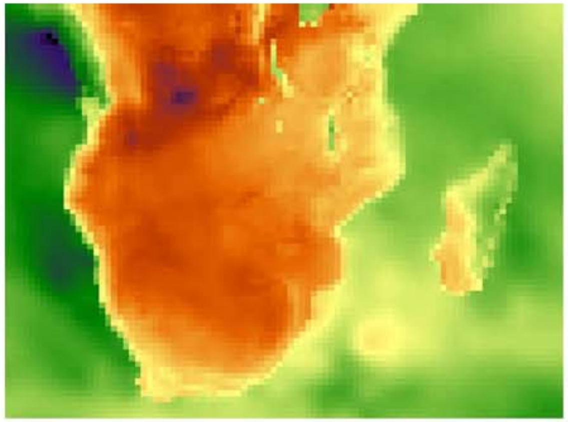


Climate Change: RCM downscaling future T anomaly



AUG

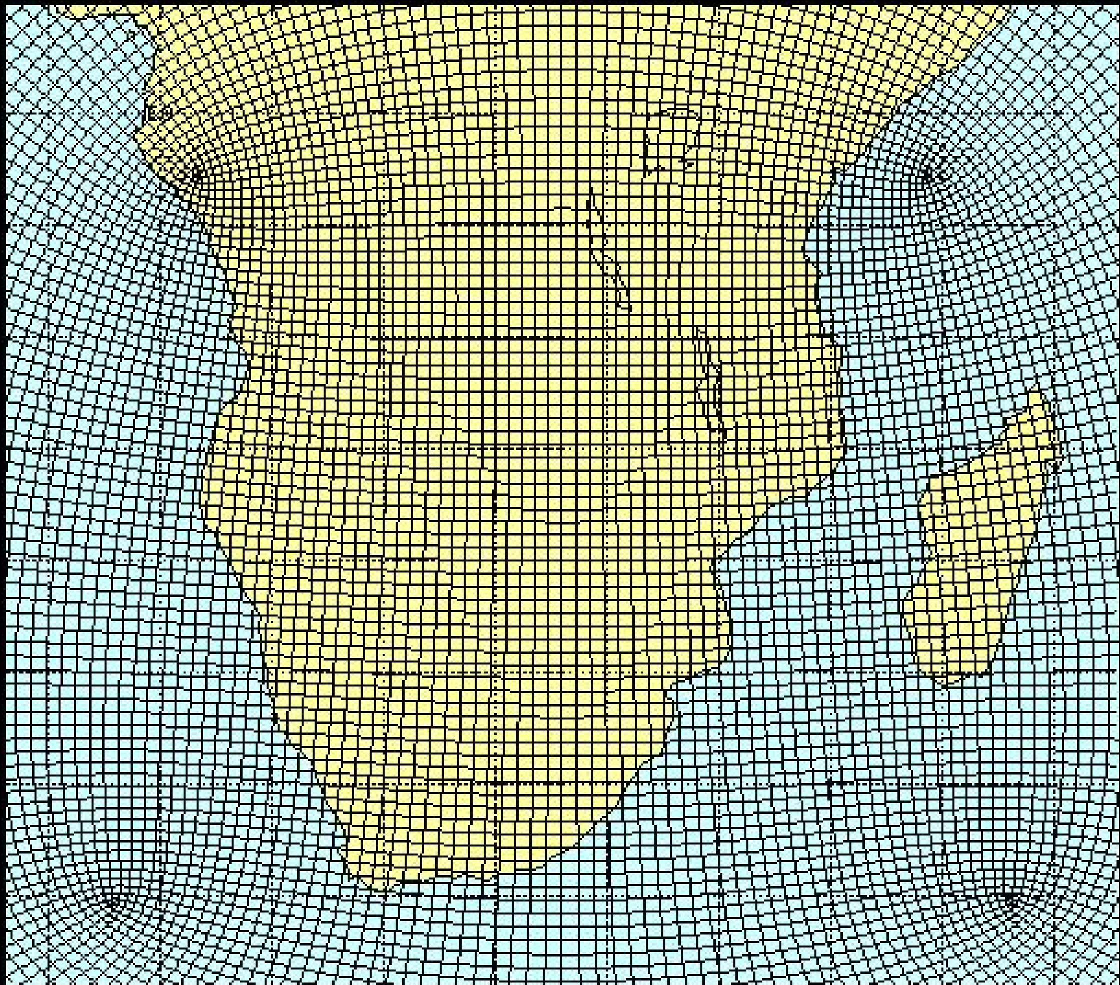
Two RCMs



AUG

“Single model climate change projections are useless” (Giorgi, 2008)

Conformal Cubic Atmospheric Model over southern Africa (F. Englebrecht)



CCAM developed by J.L. McGregor, CSIRO

Horizontal res approximately 60 km over southern Africa, decreases gradually to about 400 km

Simulations of Climate Change with the fully coupled CSIRO Mk 3 AOGCM

1961-2100

1961-2000: Forced with observed Greenhouse Gas Concentrations

2001-2100: Forced with predicted Greenhouse Gas Concentrations corresponding to the A2 SRES Scenario

High-resolution simulations of Climate Change with the Conformal-Cubic Atmospheric Model

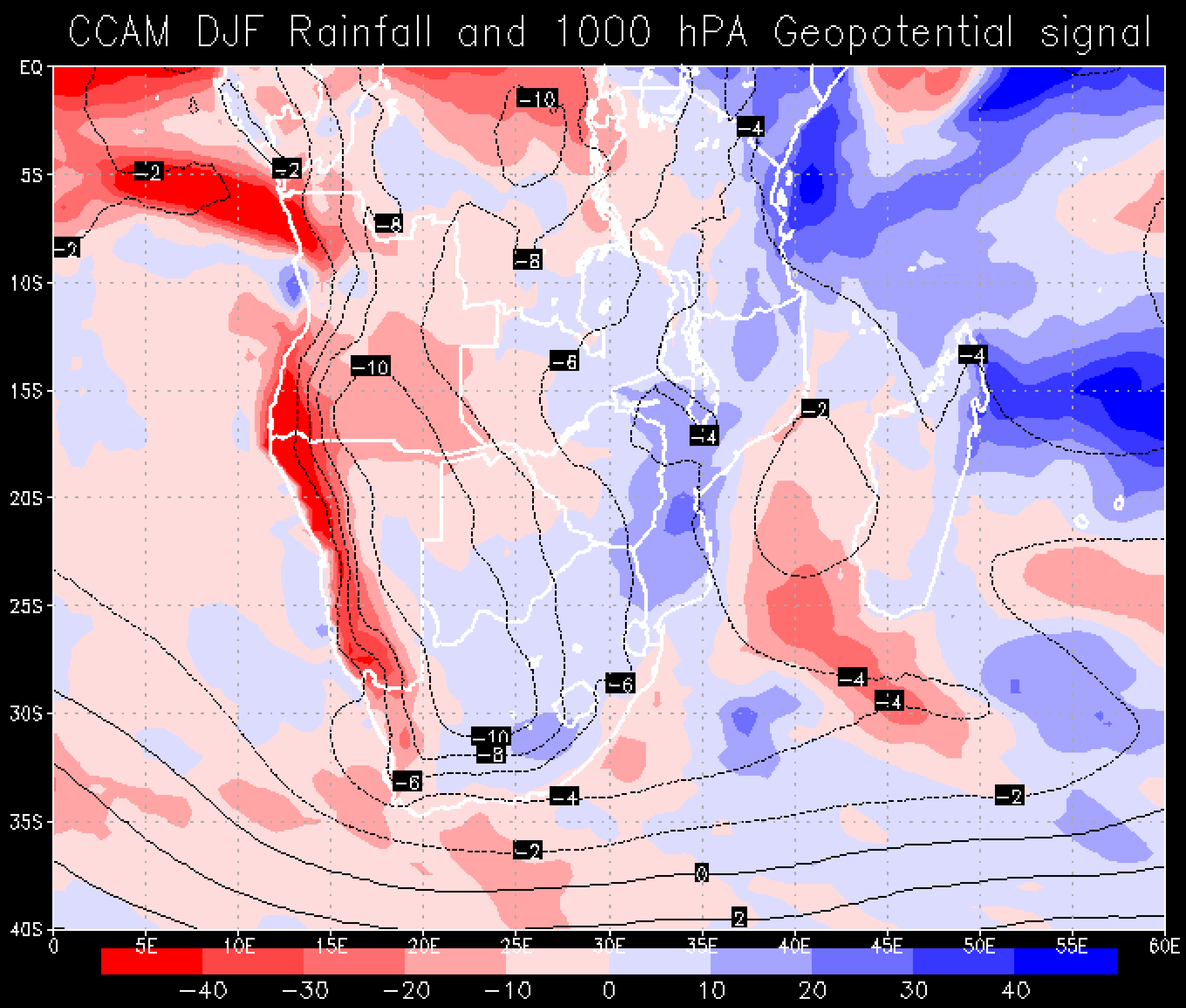
1975-2005

Forced with SSTs from the coupled run and observed Greenhouse Gas Concentrations

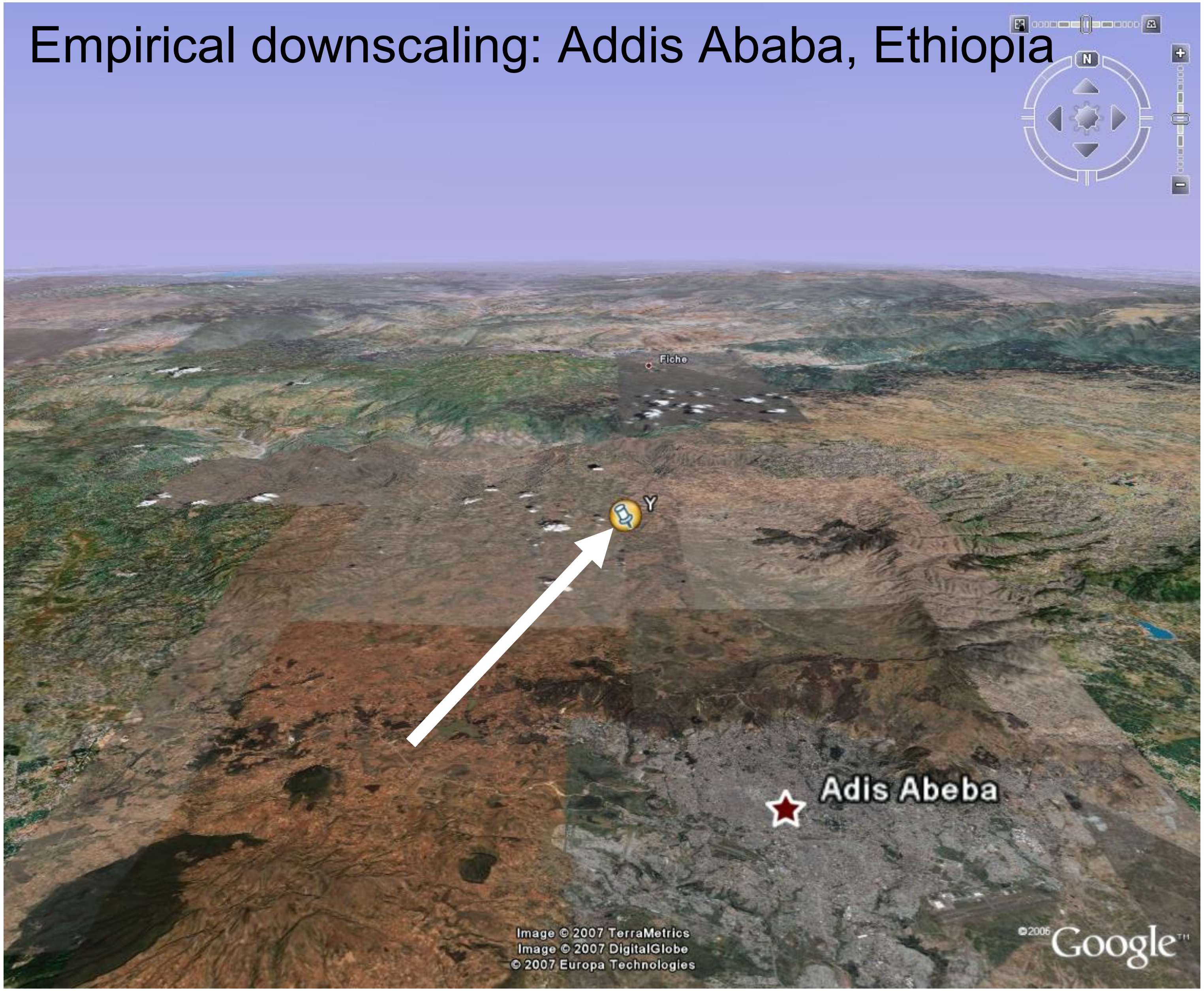
2070-2100

Forced with simulated SSTs from the coupled run and predicted Greenhouse Gas Concentrations corresponding to the A2 SRES Scenario

Change in DJF rainfall (%)



Empirical downscaling: Addis Ababa, Ethiopia

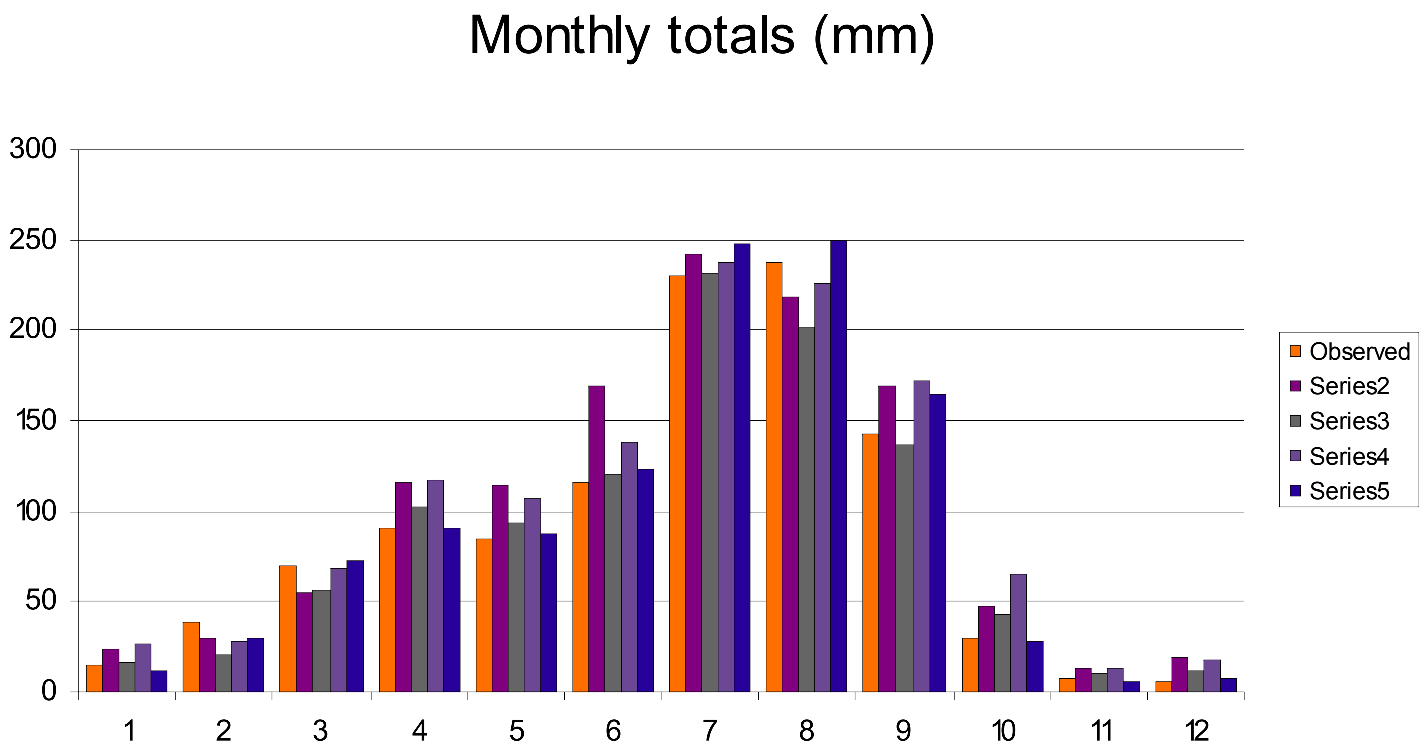


NCEP predictors, daily precipitation, Addis Ababa

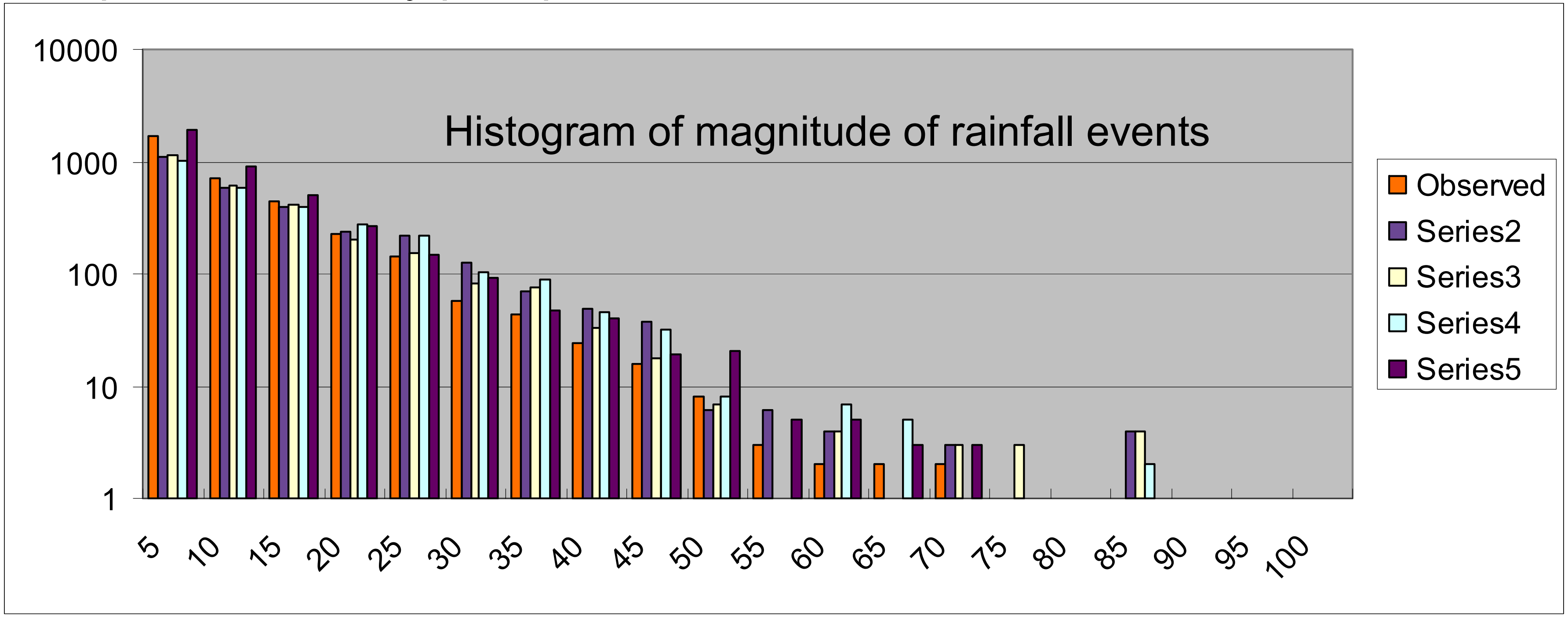
Continental environment, convective rainfall systems, tropical location.

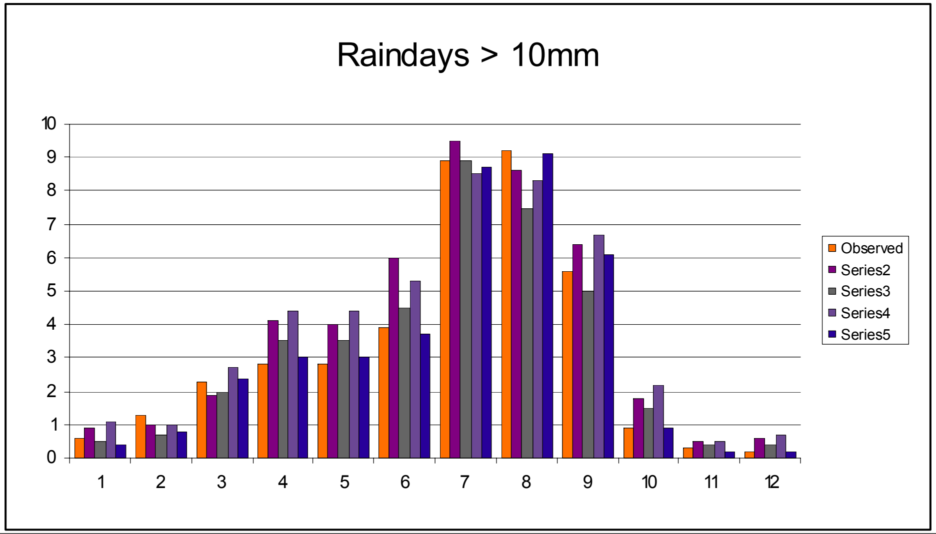
Method A: three downscalings with different predictor sets
Method B: one downscaling, different predictor set to Method A

Predictors include parameters reflecting lower and mid troposphere circulation and humidity

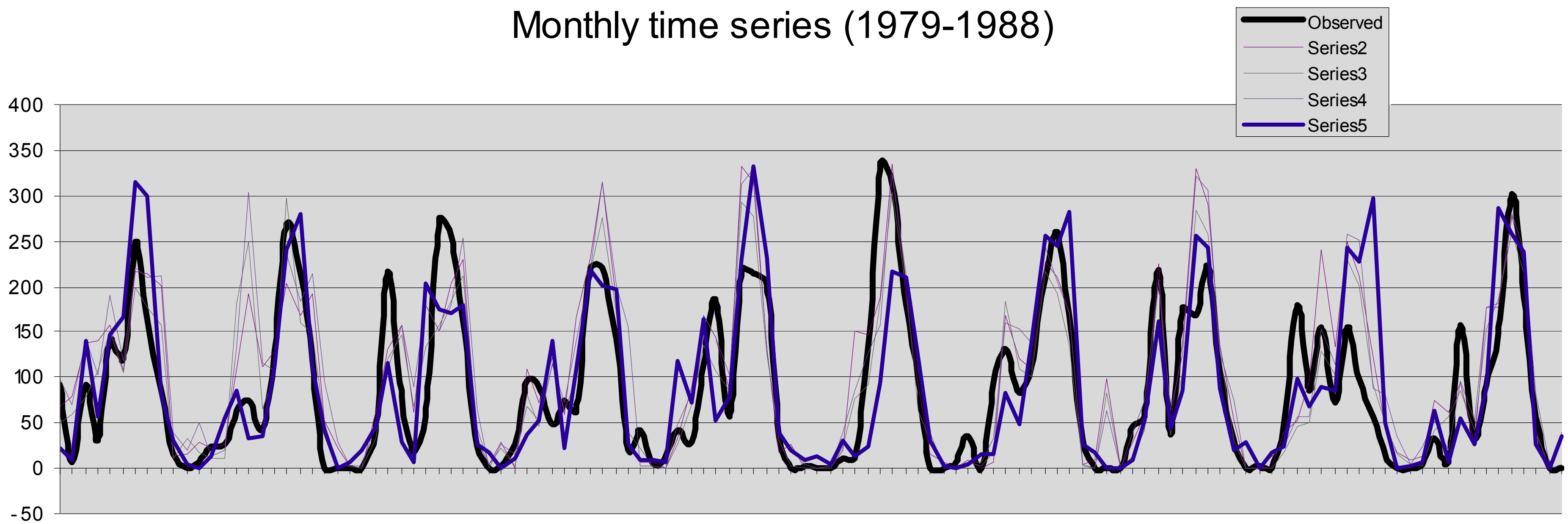


NCEP predictors, daily precipitation, Addis Ababa





NCEP predictors, daily precipitation, Addis Ababa



Overall a credible representation of local climate in terms of both low frequency and high frequency response to the daily atmospheric predictors

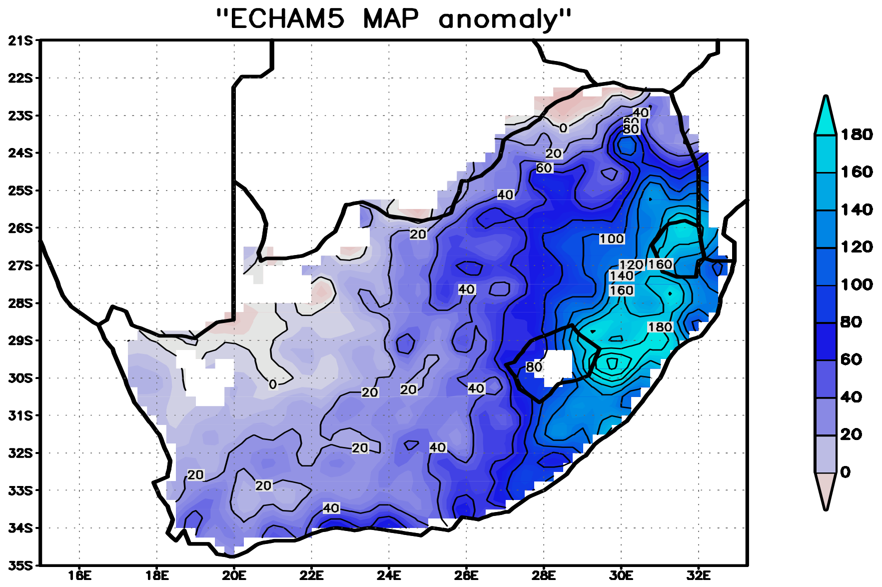
One method over-predicts the frequency of low magnitude rain events → not a major impact on totals, but relevant to, for example, soil moisture and landscape hydrology

Other method over predicts frequency of high magnitude events marginally → gives too high totals in some months

No systematic evidence of one set of predictors outperforming another

Creation of envelope of scenarios

Note: sub-annual projected changes can be very different to mean annual change
Good consensus between downscaled models on broad patter of change



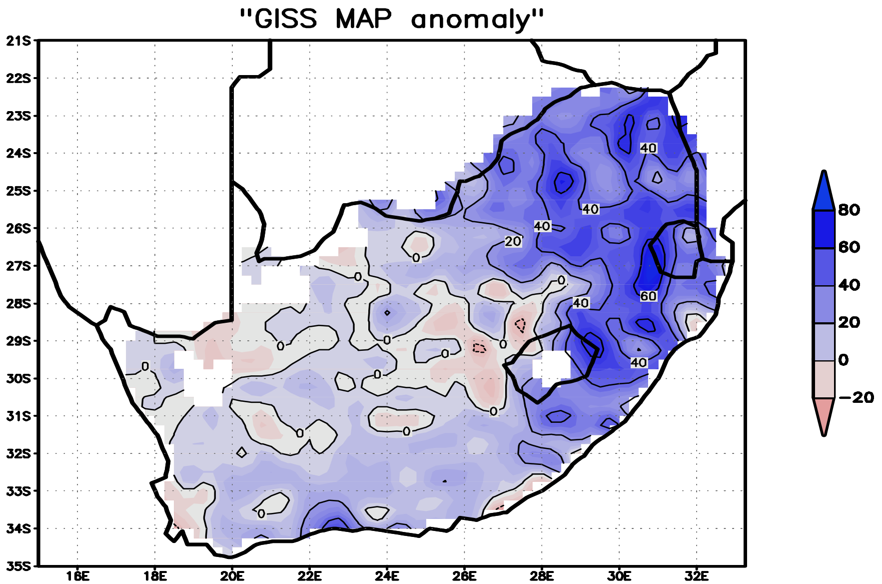
No one model is "correct", no one timeline into the future is "right"

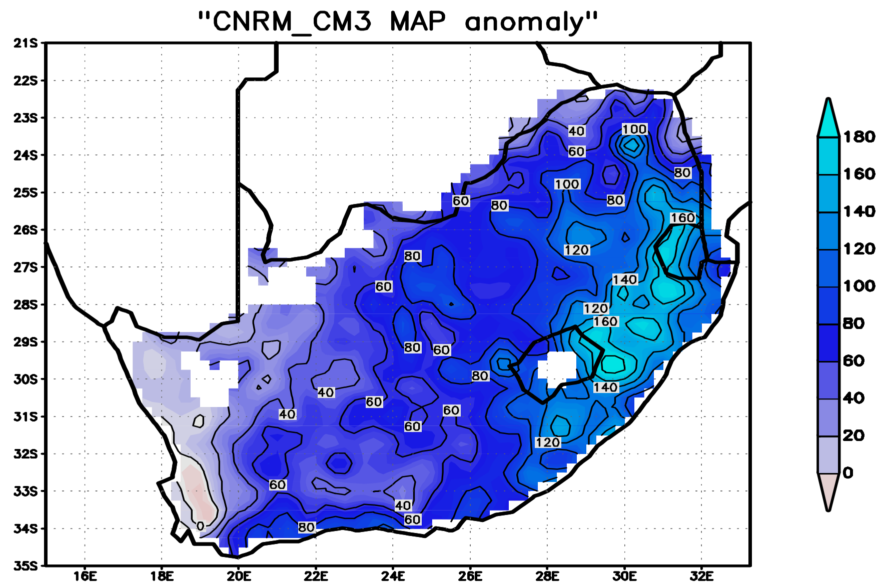
The models provide a realm of possibility, and give some idea of probability

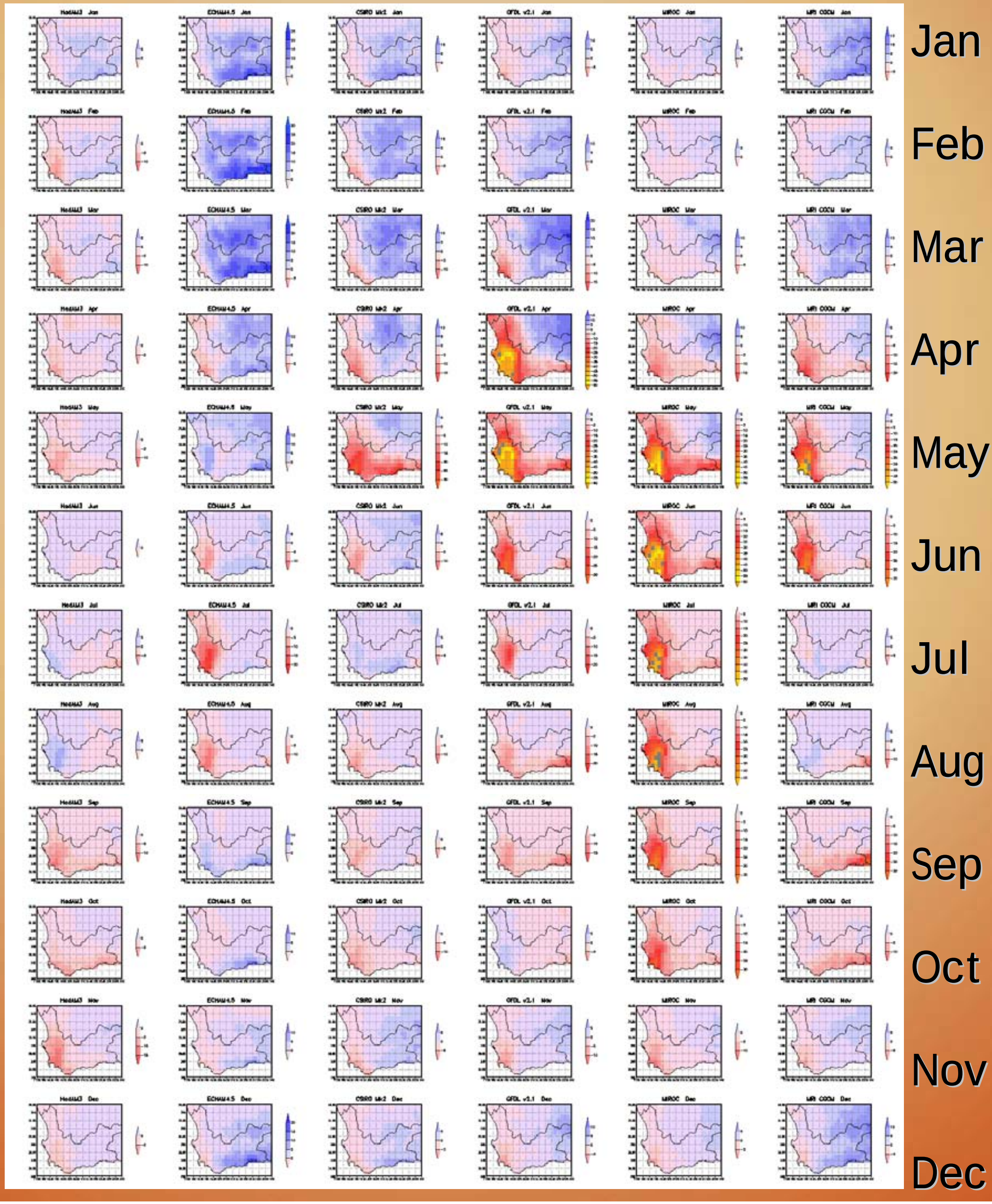
→ The envelope also helps identify what is <u>less</u> likely to happen

GrADS: COLA/IGES

2008-01-15-15:38







The Western Cape:

Projected changes in rainfall pattern and magnitude

Monthly Total

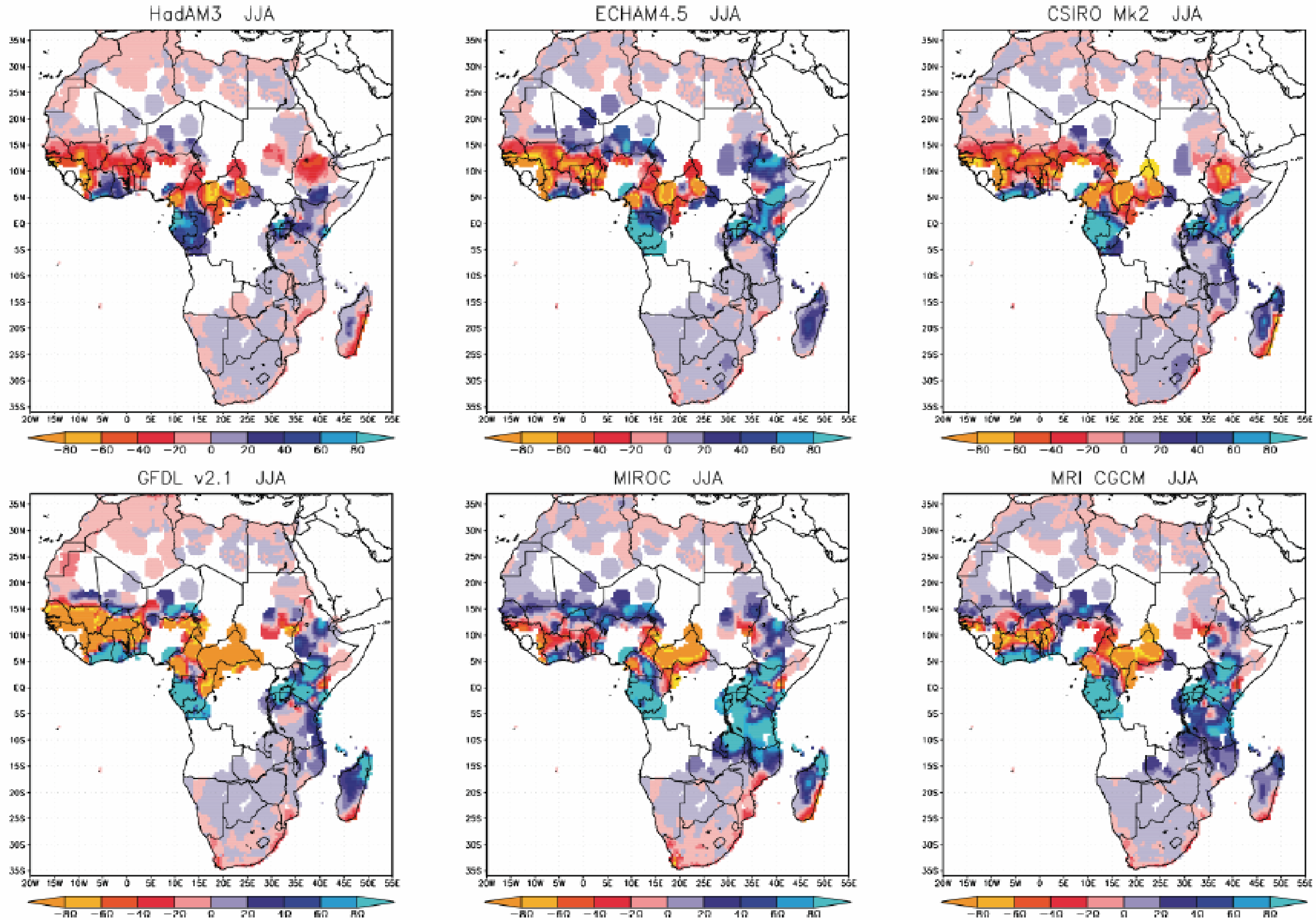
Downscaling to a 0.1° precipitation grid:

6 GCMs

SRES A2 forcing

Future – Control anomaly

Statistically downscaled precipitation change



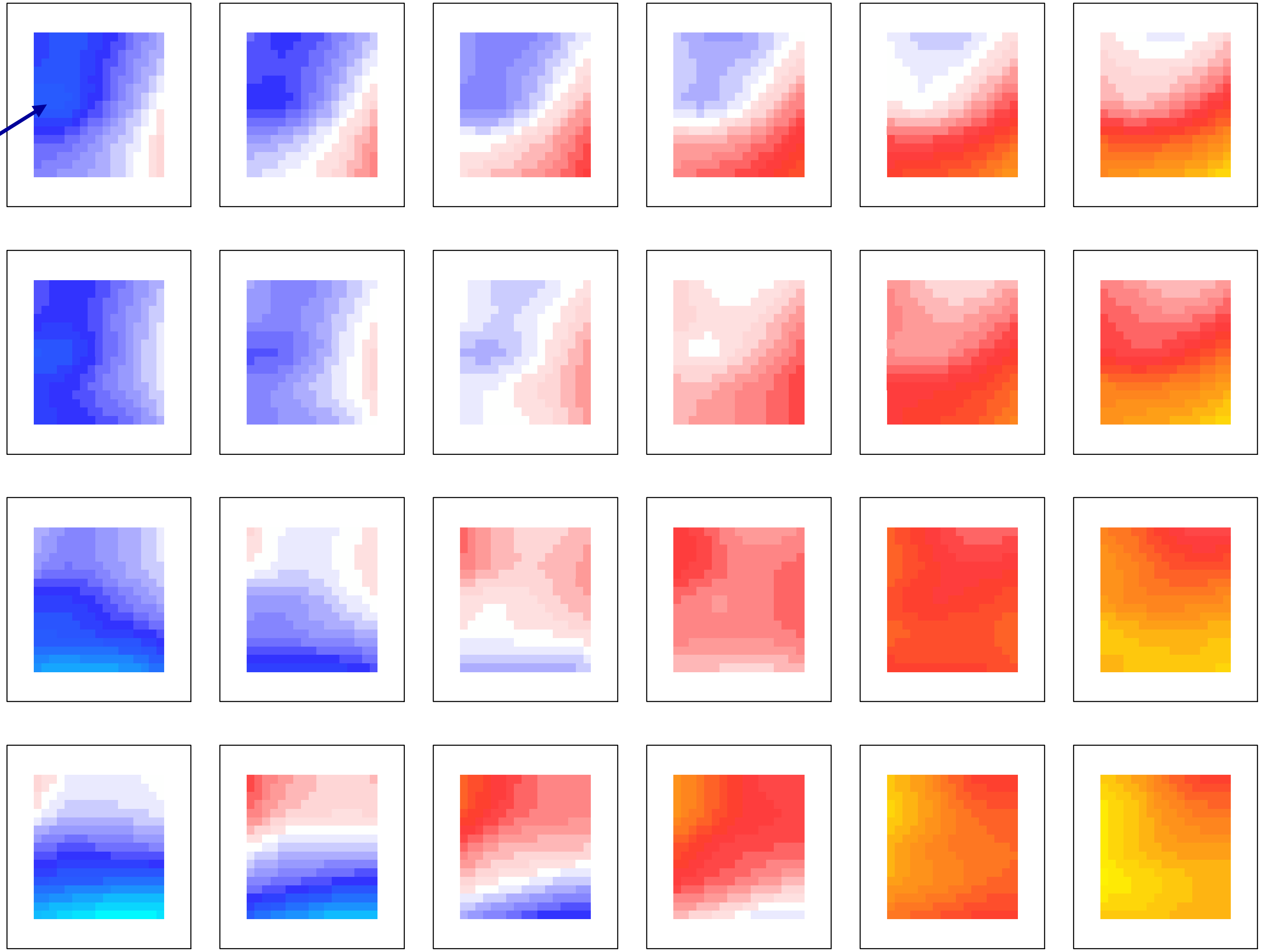
Ar4, Ch 11

Circulation change (as opposed to grid cell change)

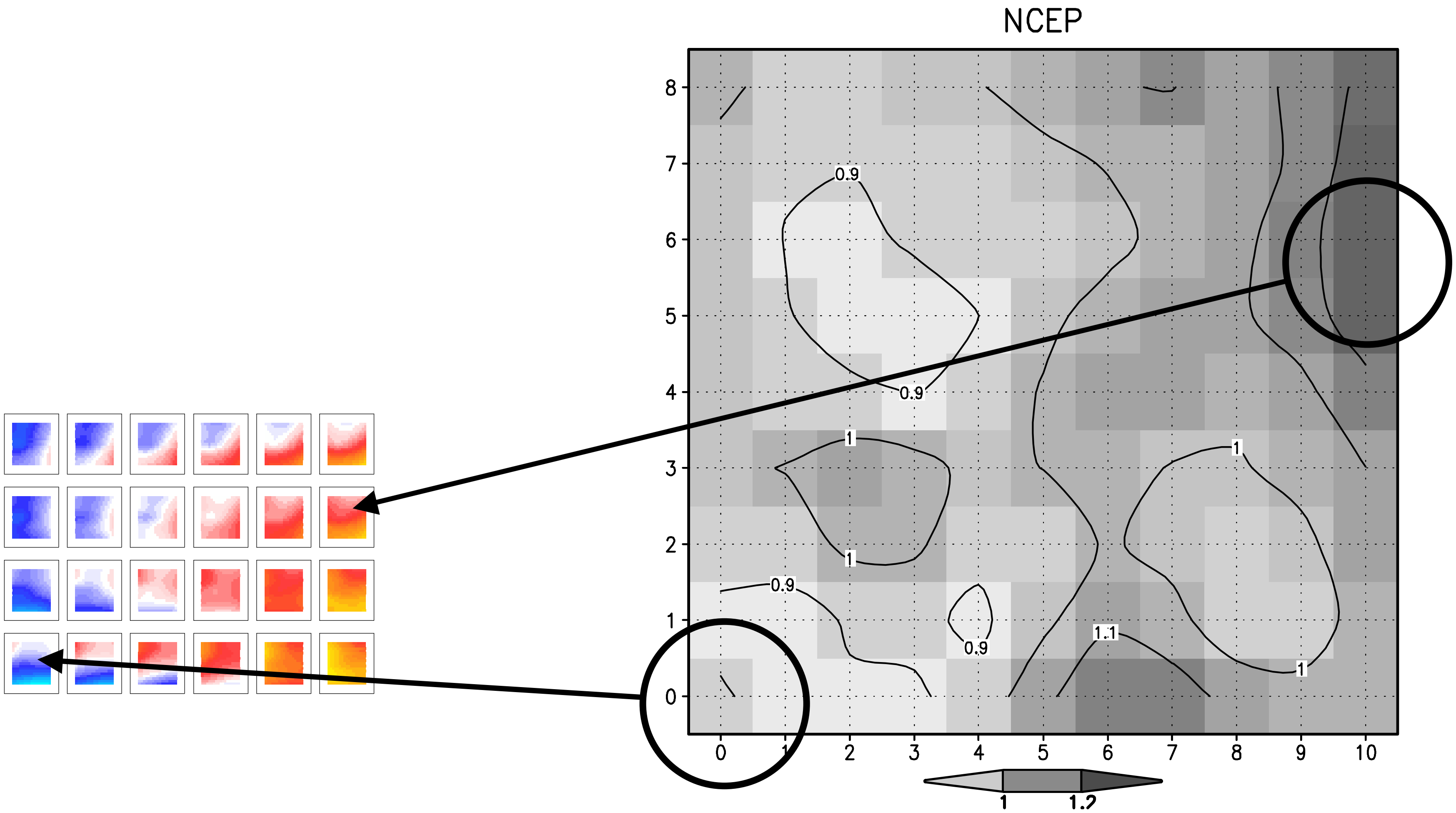
Example: 15° by 15° window over Cape Town, surface, mid troposphere u, v, q, t daily fields using Self Organizing Maps (SOM).

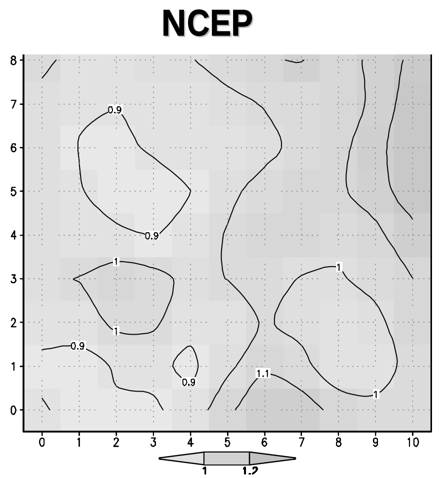
(Aside: for those interested see Reusch et al., 2005: EOF/PCA versus SOMs, *Polar Geography)*

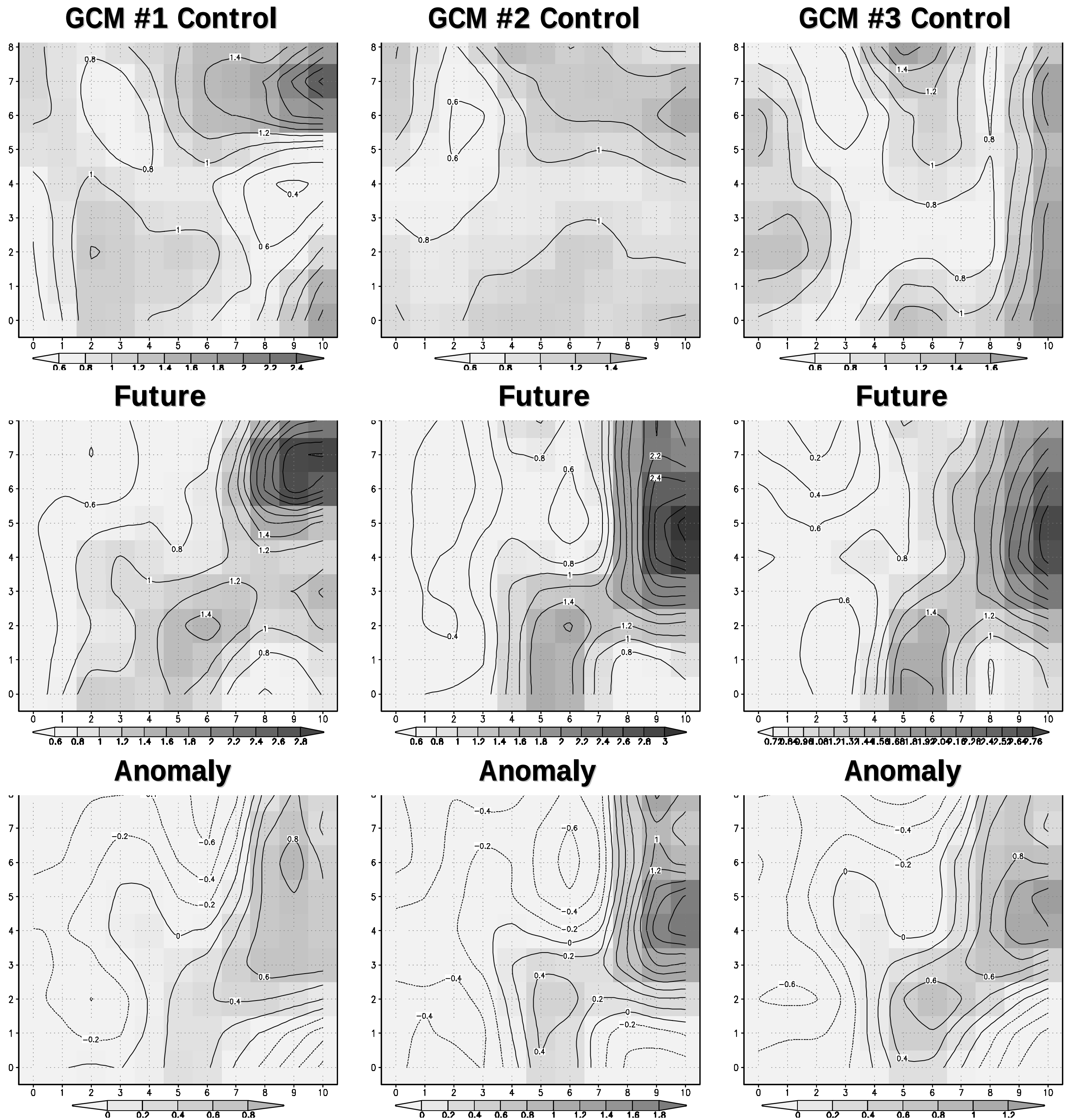
Archetype of daily synoptic multivariate state



Frequency of synoptic occurrence







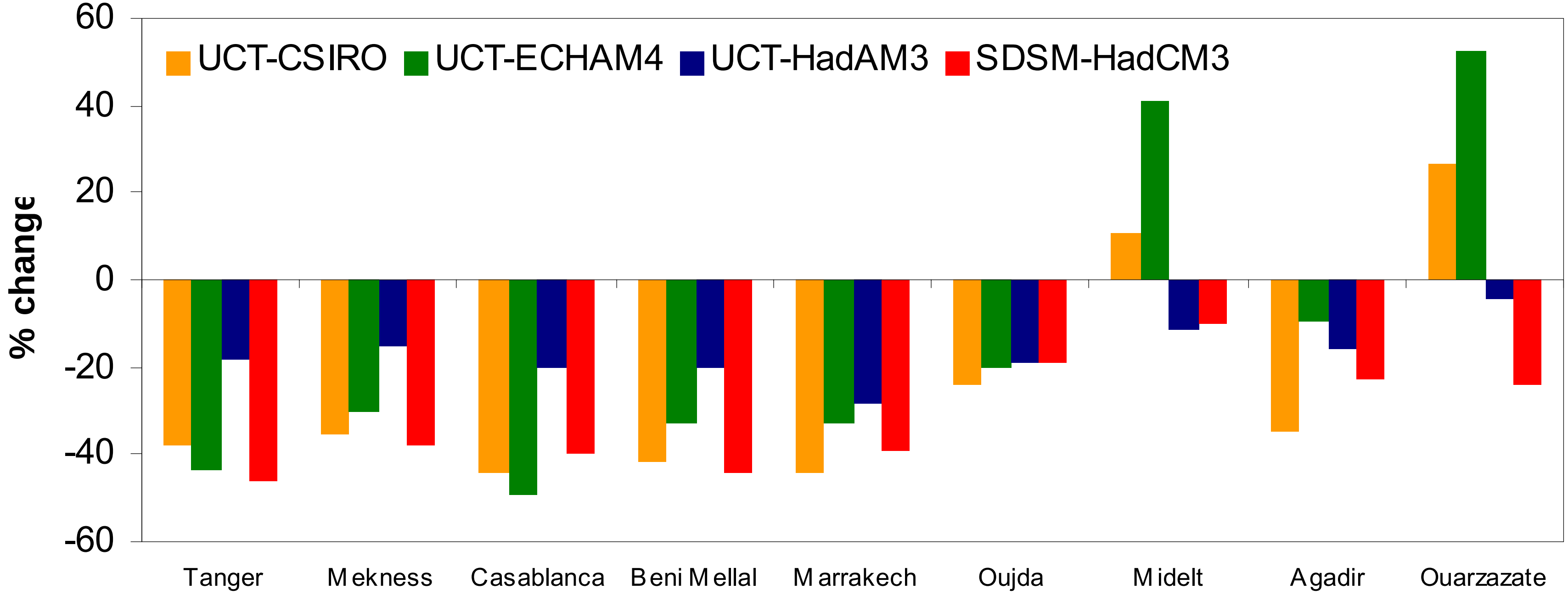
Commonality change in frequency of synoptic modes

Self Organizing Map using an 11 by 9 array of atmospheric states based on daily u, v, q, T at surface and 700hPa

Climate change and the common circulation deltas?

On the assumption that the GCMs are simplified representations of reality, and proportionally sensitive to the real world anthropogenic forcing;

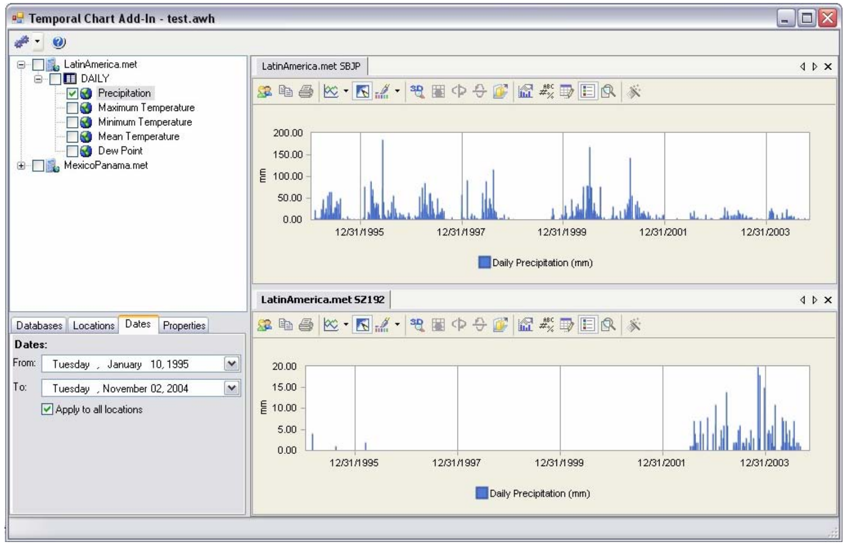
Given empirical downscaling propagates signal and error of the large scale atmospheric response; and evidence that **circulation-delta** is largely consistent across GCMs

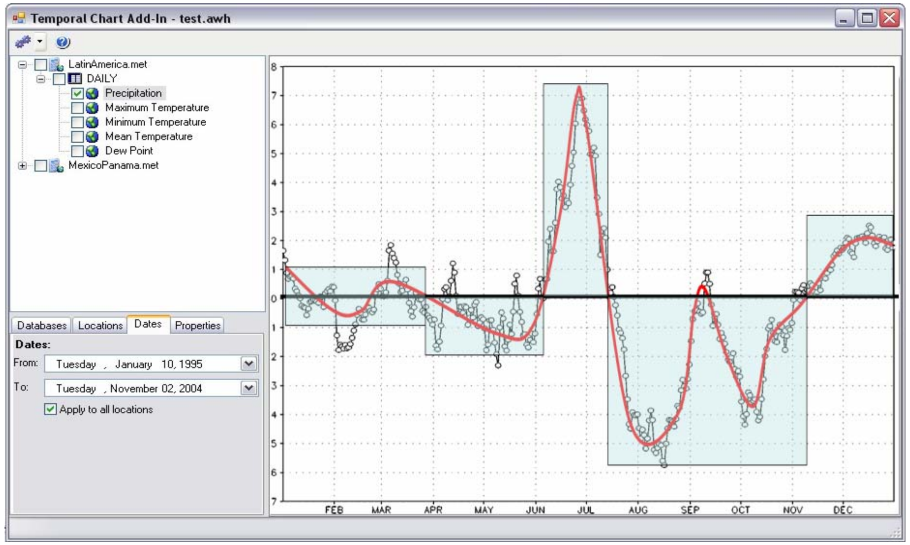


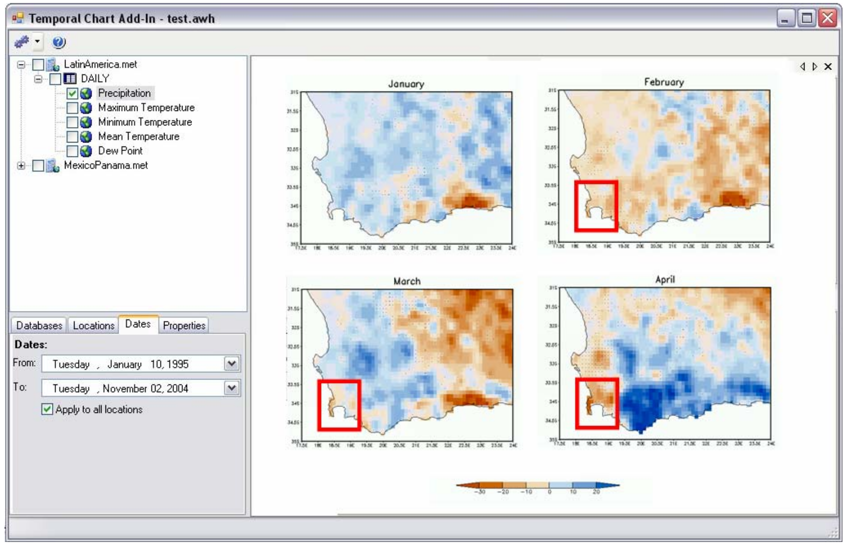
Downscaled annual precipitation scenarios for sites in Morocco by the 2080s under SRES A2 emissions. Source: World Bank (2007)

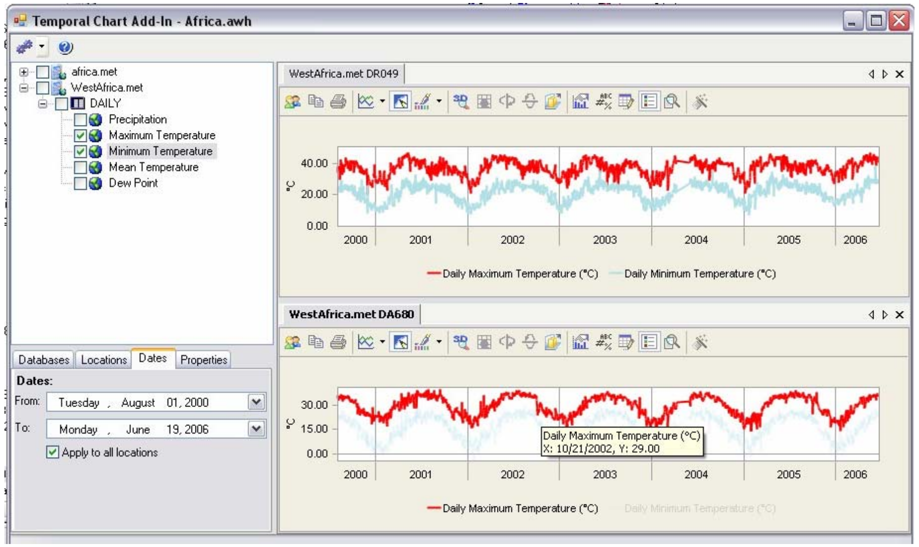
Climate Change Exploration (CCE)

www.weAdapt.org









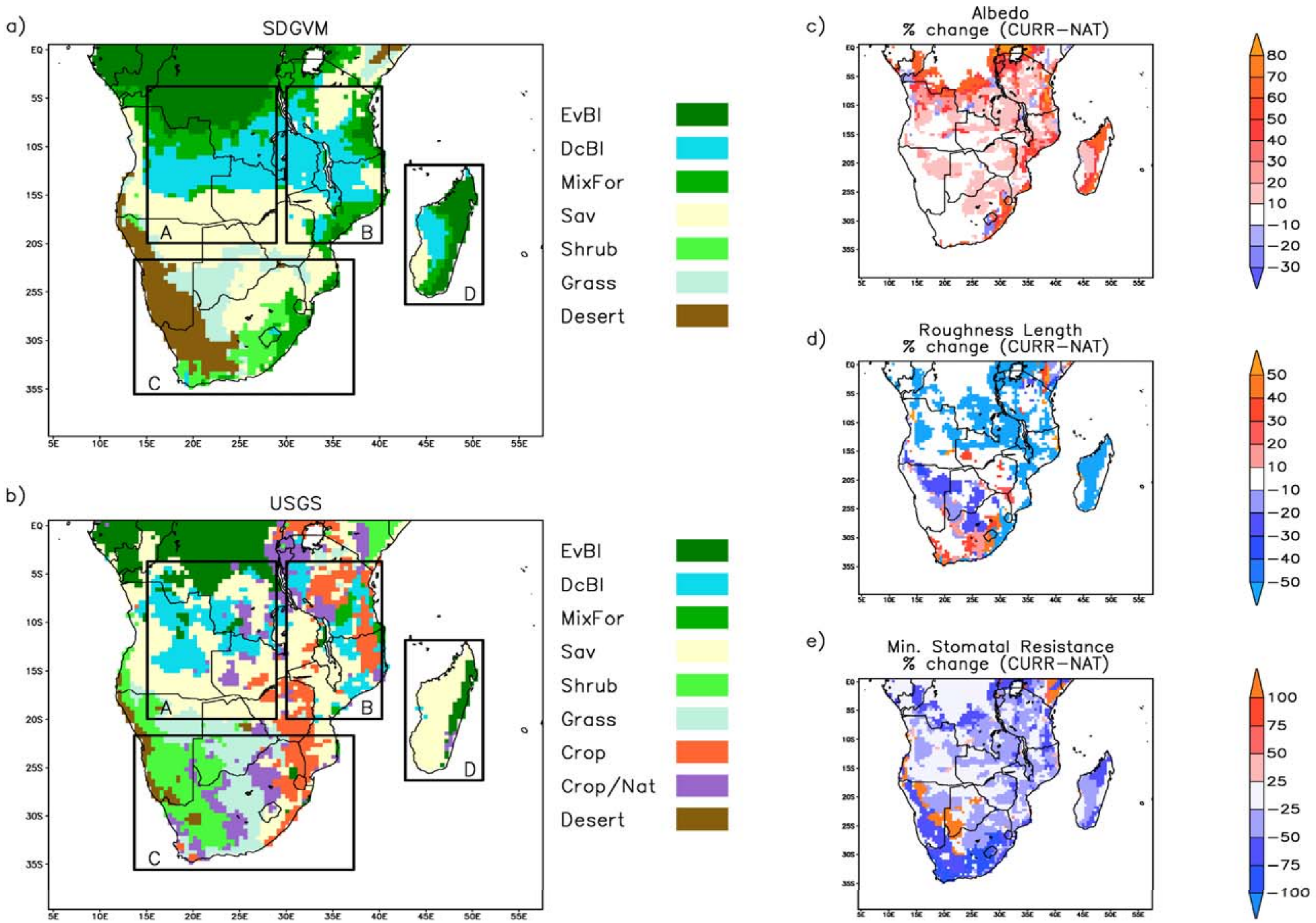
Exploring regional process with RCMs to inform climate change understanding
N. MacKellar

- Simulate potential climatic impacts of idealised vegetation change in southern Africa (potential natural to present day map).
- Evaluate the importance of synoptic forcing in modulating atmospheric response to land-surface change.
- Identify potential mechanisms through which vegetation properties may affect summer rainfall in the region.

Method

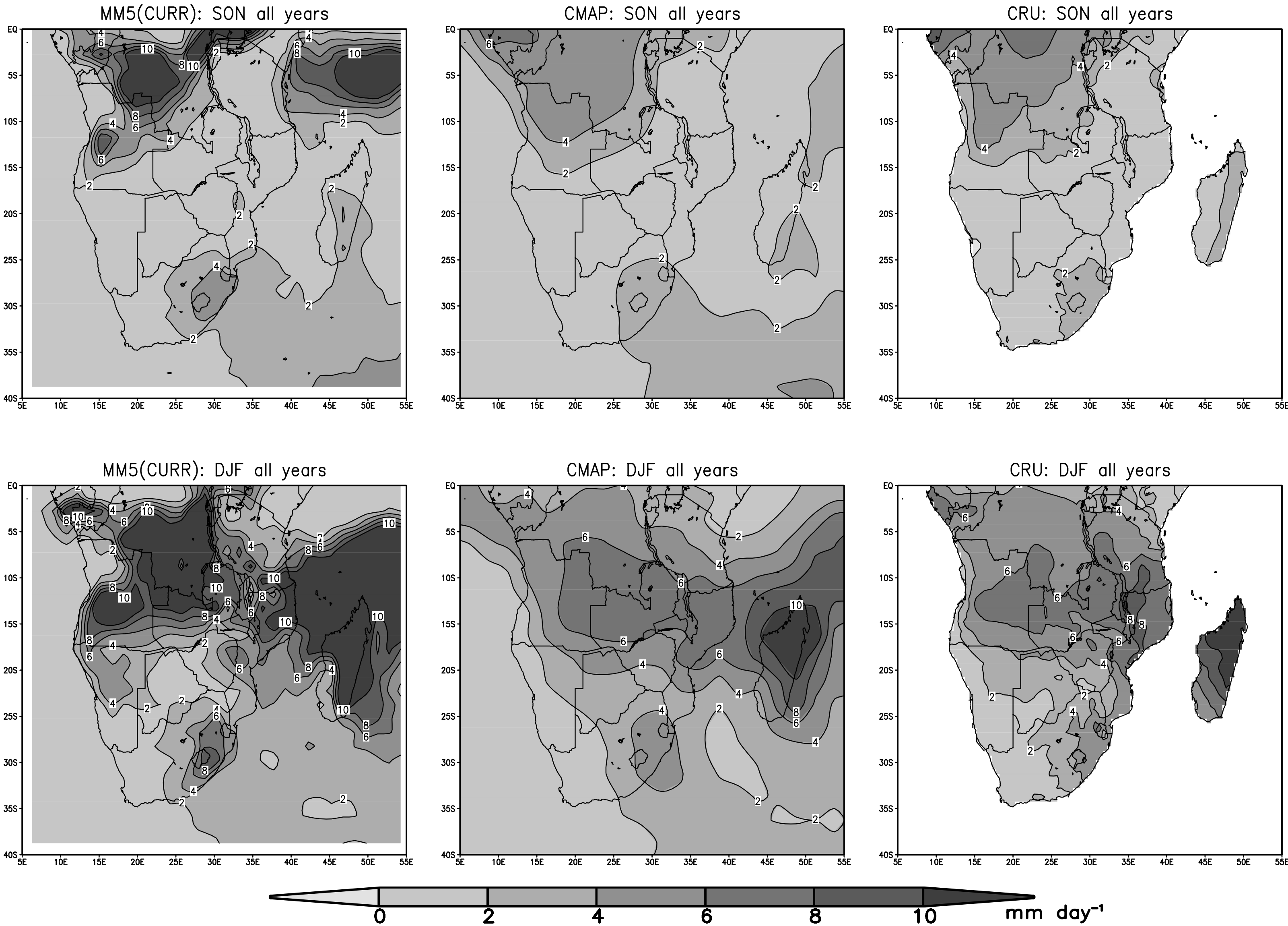
- Vegetation maps:
  - Potential natural: spatial distribution of PFTs simulated by Sheffield Dynamic Global Vegetation Model
  - Present day: USGS classification
- Climate model:
  - MM5
  - 50 km resolution over sub-equatorial Africa; 23 sigma levels
  - NOAH land surface; Betts-Miller convective precip; MRF PBL
  - NCEP initial and boundary conditions
  - 3 time periods:
    - 1 Aug – 28 Feb 1988-89, 1991-92, 1995-96

Vegetation maps: a) Potential natural (SDGVM) and b) present day (USGS), with associated differences in c) albedo, d) roughness length and e) minimum stomatal resistance (USGS minus SDGVM).



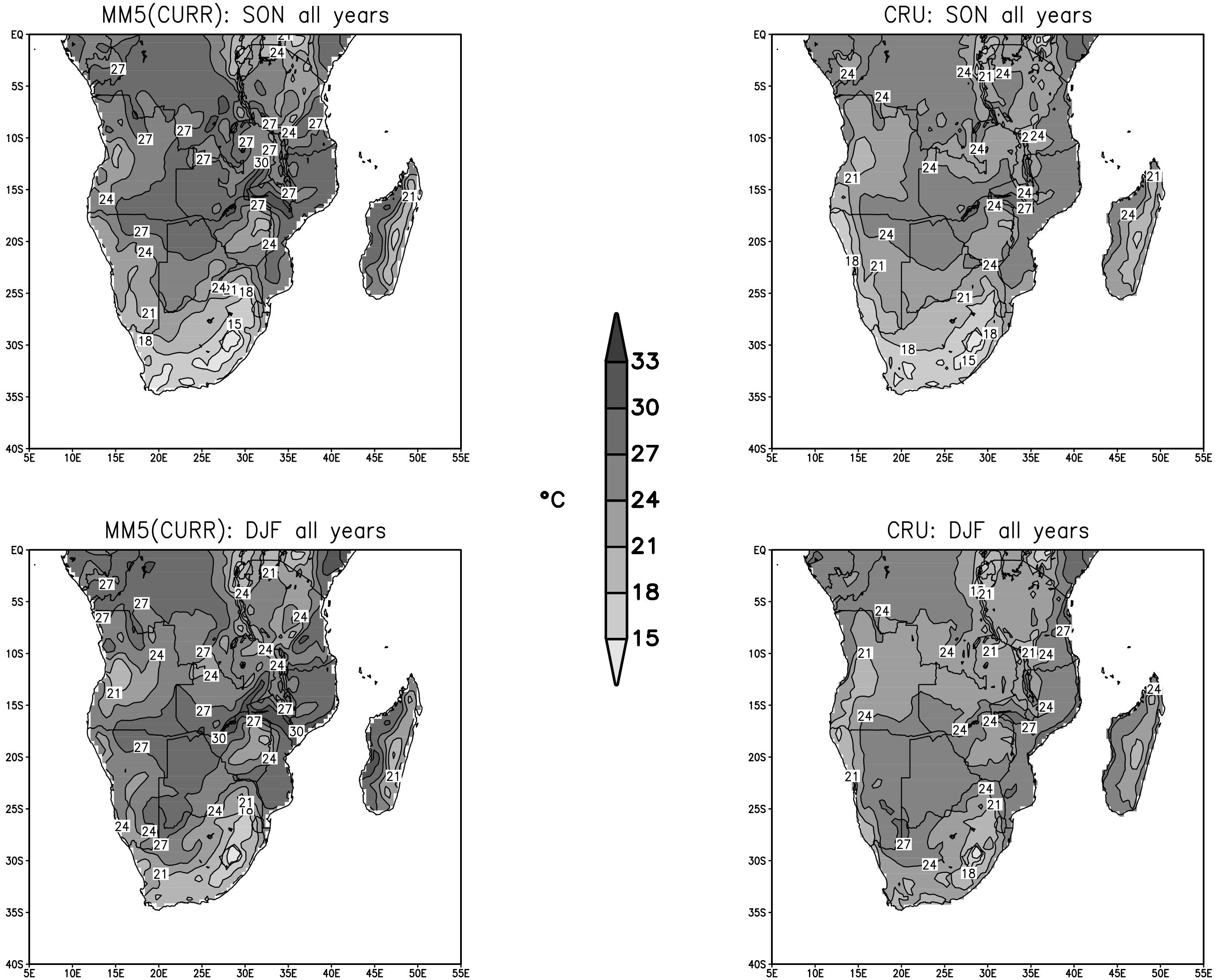
MM5 simulated precipitation (left column) - mean SON (top) and DJF (bottom) for all 3 periods compared to CMAP (centre column) and CRU (right).

* Note high precip bias in MM5 – amplitude of diurnal cycle overestimated by Betts-Miller scheme.

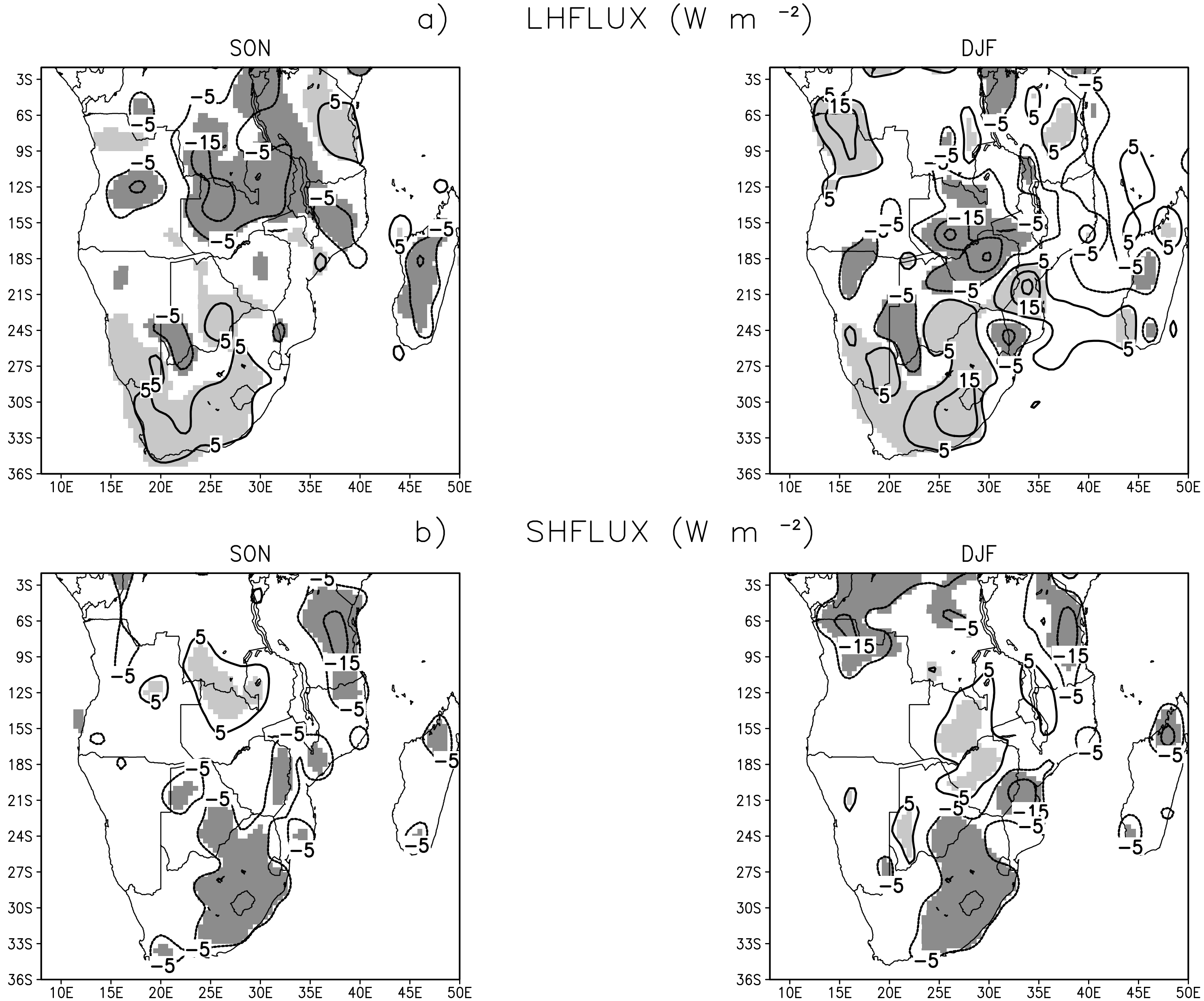


MM5 simulated 2m temperature (left) - mean SON (top) and DJF (bottom) for all 3 periods compared to CRU (right).

* Generally positive bias in MM5 most likely due to excessive incident shortwave radiation at the surface.

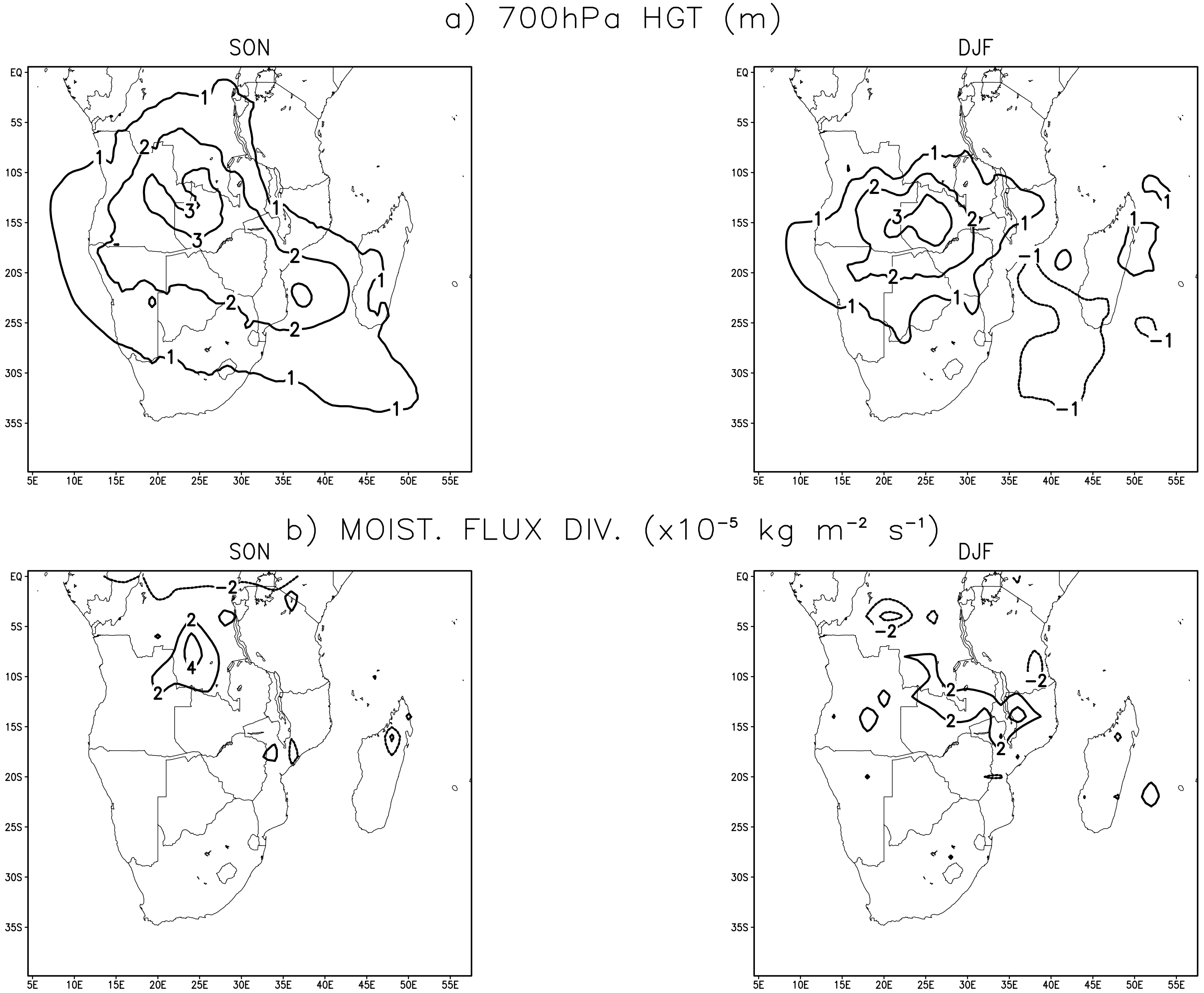


Mixed response in latent and sensible heat fluxes.



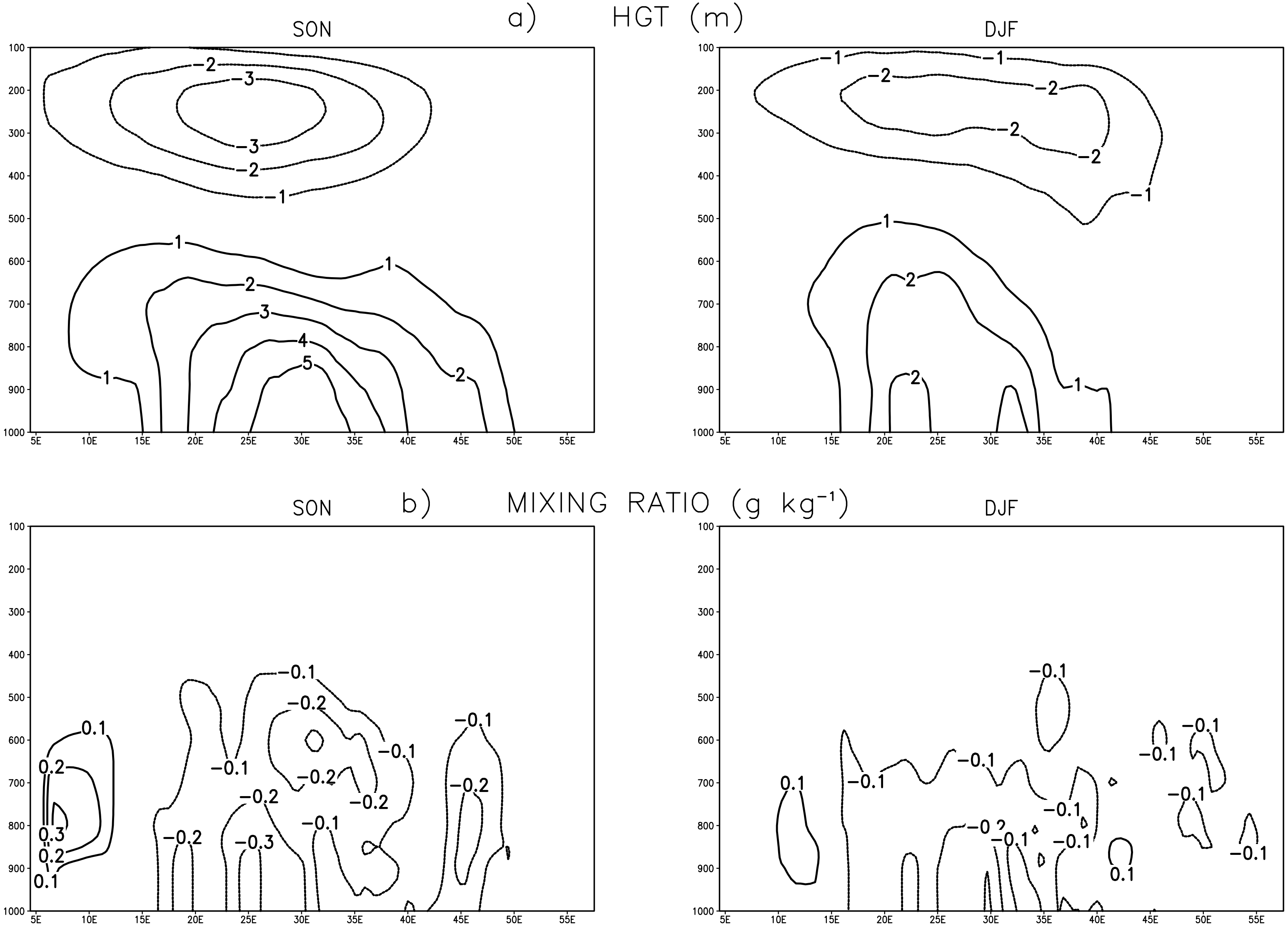
MM5 simulated latent (a) and sensible (b) heat fluxes – mean SON and DJF difference (present day minus potential natural vegetation). Shading indicates significance at 95% level.

Extensive increases in lower tropospheric geopotential height and consequent increases in moisture flux divergence over continent.



MM5 simulated 700 hPa geopotential heaight (a) and vertically integrated moisture flux divergence (b) – mean SON and DJF difference (present day minus potential natural vegetation).

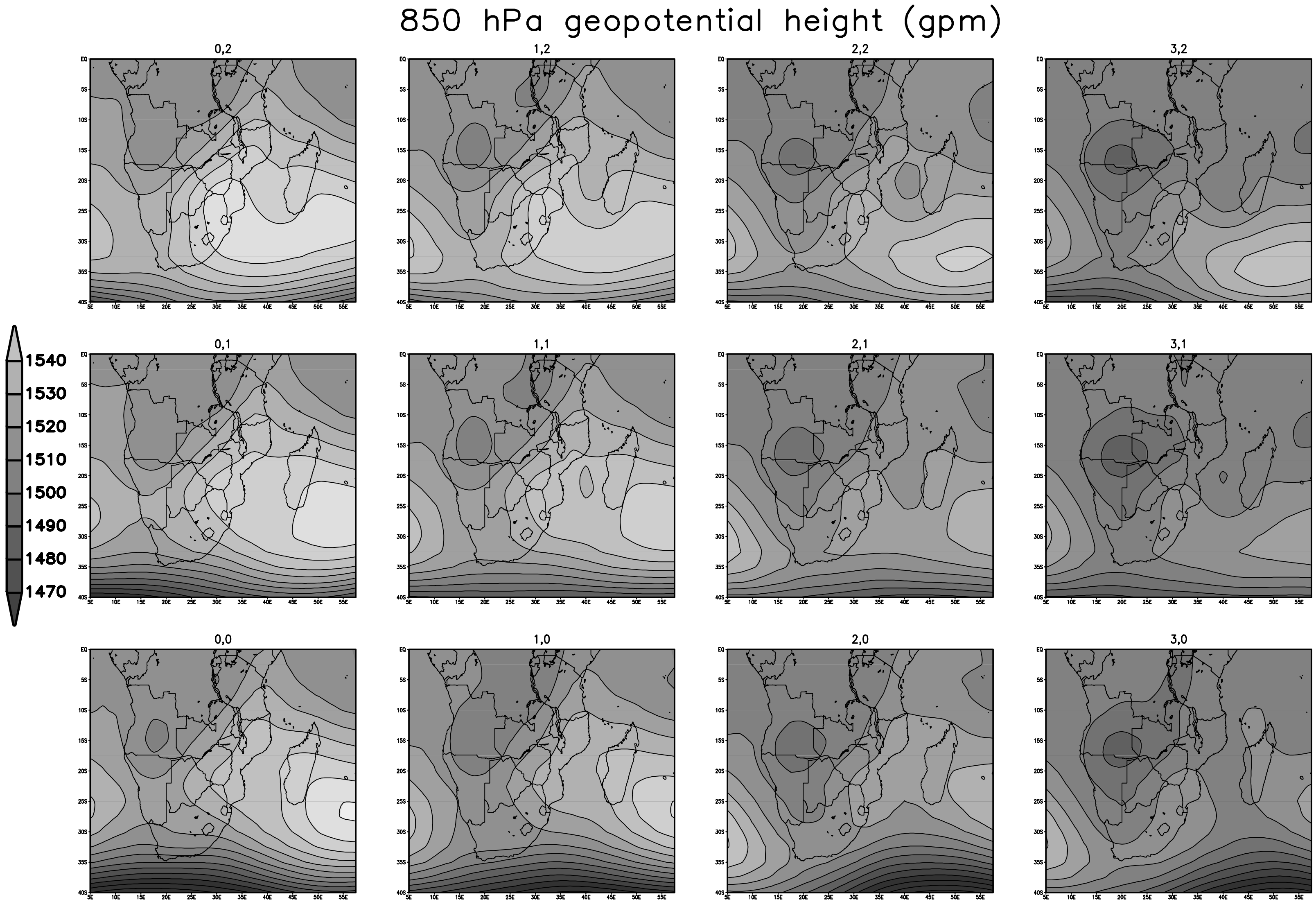
Geopotential height and atmospheric moisture differences extend to 500 hPa level. Response is strongest in SON.



Vertical transects meridionally averaged from 10-25 °S of a) Geopotential height and b) water vapour mixing ratio– mean SON and DJF difference (present day minus potential natural vegetation).

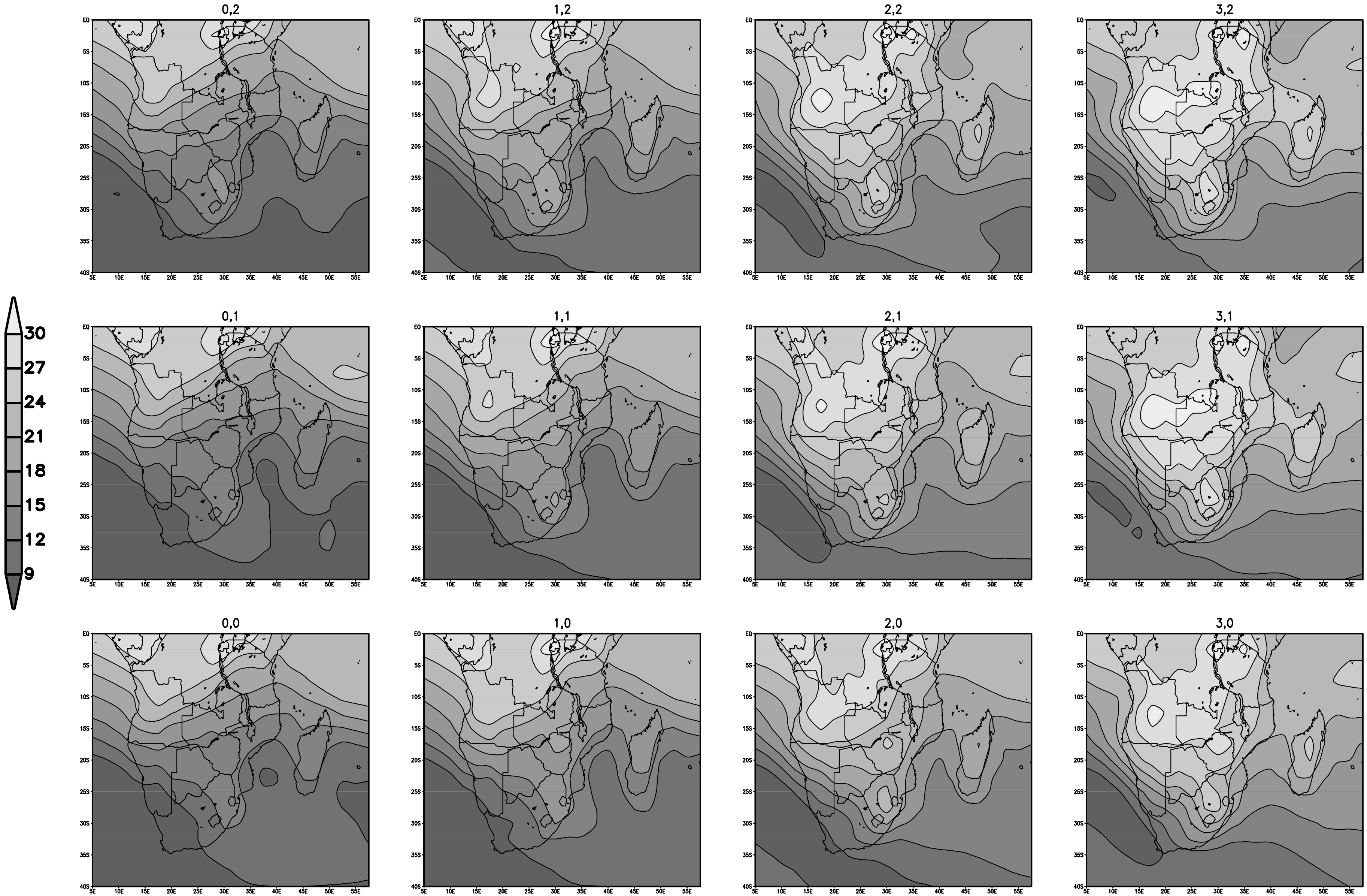
Synoptics: archetypal patterns in NCEP boundary conditions as identified by the SOM. Conditions typical of late winter/spring occur on the left of the array; summer-type patterns toward the right.

This slide: 850 hPa geopot. height; following slide: precipitable water.

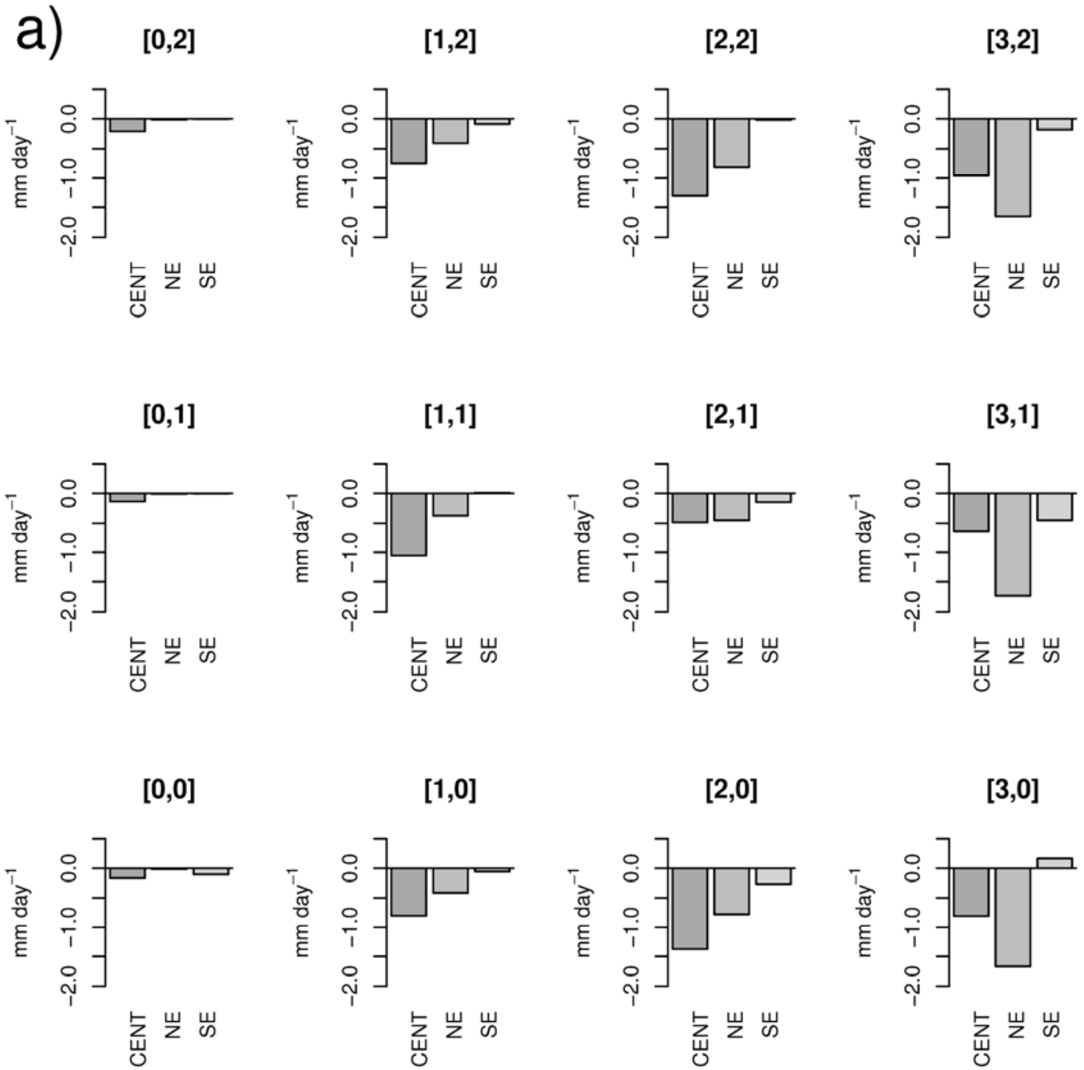


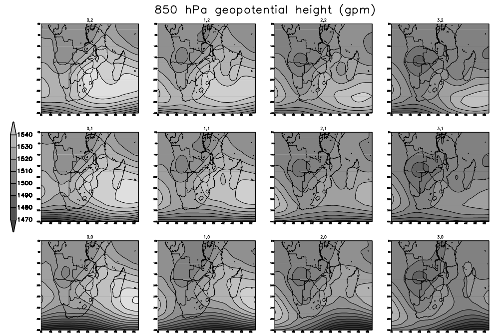
Synoptics cont…

Precipitable water: 850hPa -> 500hPa (mm)

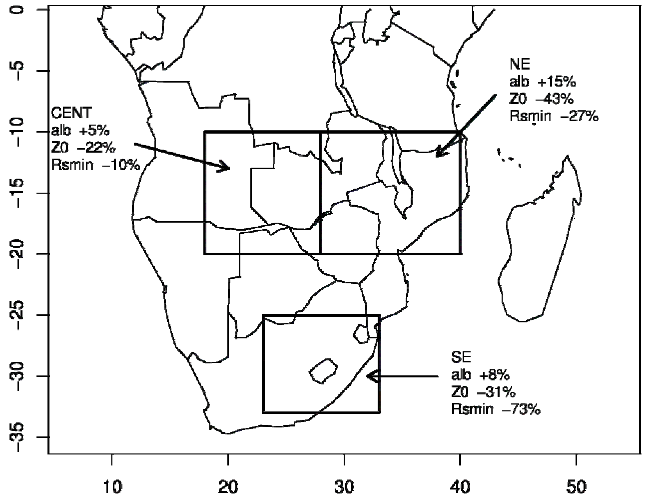


Precipitation response strongest in CENT and NE for nodes closer to the right-hand side of the SOM, but SE shows little change for all nodes.

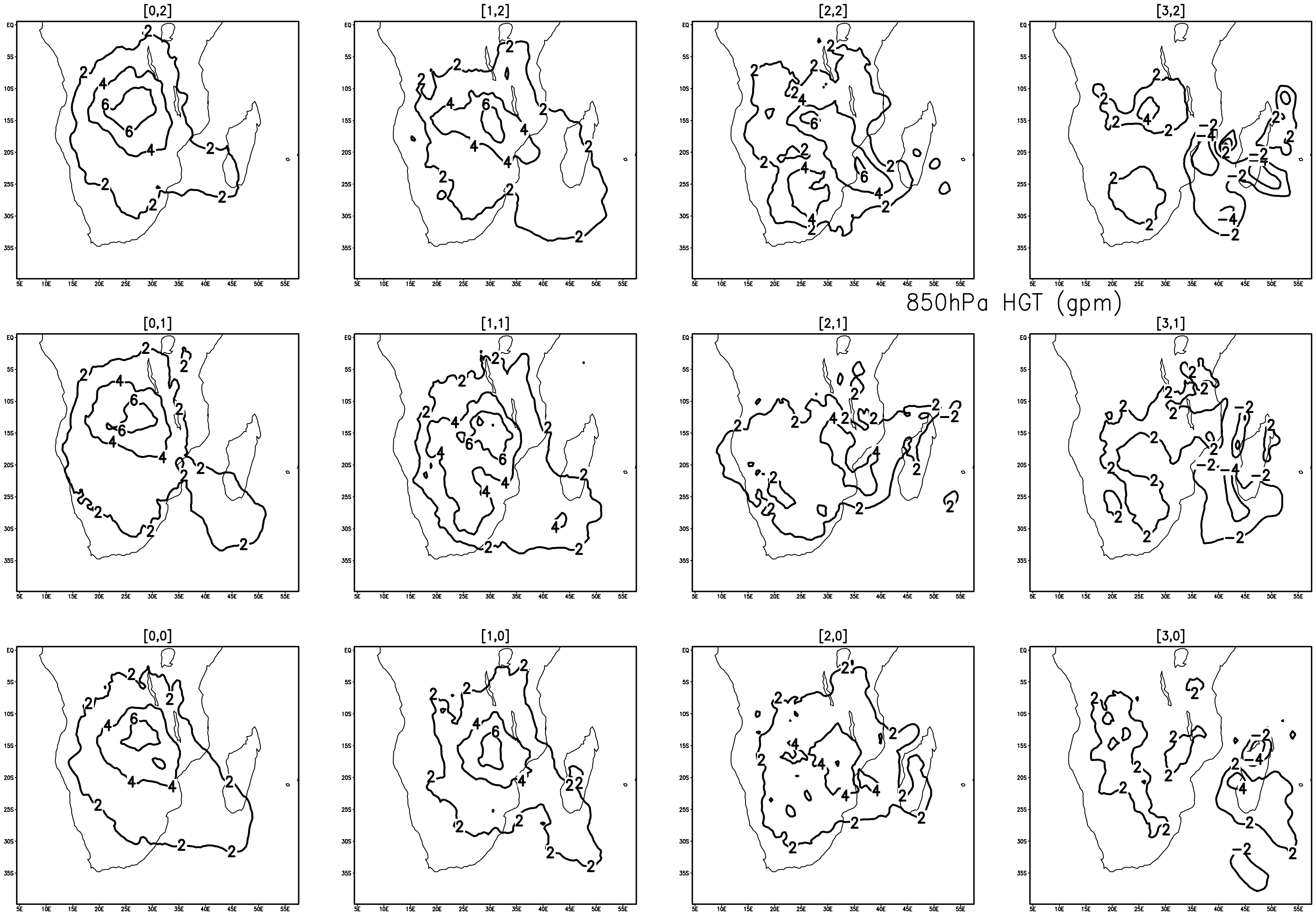




MM5 simulated regional precipitation differences (present day minus potential natural vegetation) averaged for each SOM node.



850 hPa height response strongest for nodes closer to the left-hand side of the SOM (ie. late winter/spring).



MM5 simulated 850 hPa geopot. height differences (present day minus potential natural vegetation) averaged for each SOM node.

Land surface change conclusions

- Changing vegetation map in MM5 from potential natural to present day conditions results in:
  - surface cooling through increased albedo;
  - subsidence in lower troposphere due to surface cooling;
  - reduced moisture flux convergence due to increased subsidence;
  - surface cooling mitigated by reduced rainfall.
- Synoptic evaluation:
  - conditions typical of late winter/spring show strongest temperature and geopot. height response;
  - summer-type conditions show strongest rainfall response.

Land surface change conclusions cont…

- Implications?
  - altered albedo in spring can potentially impact summer rainfall onset through altered circulation:
    - Implications for land surface feedback under climate change
    - Suggests seasonal forecasts may improve by incorporating observed albedo?

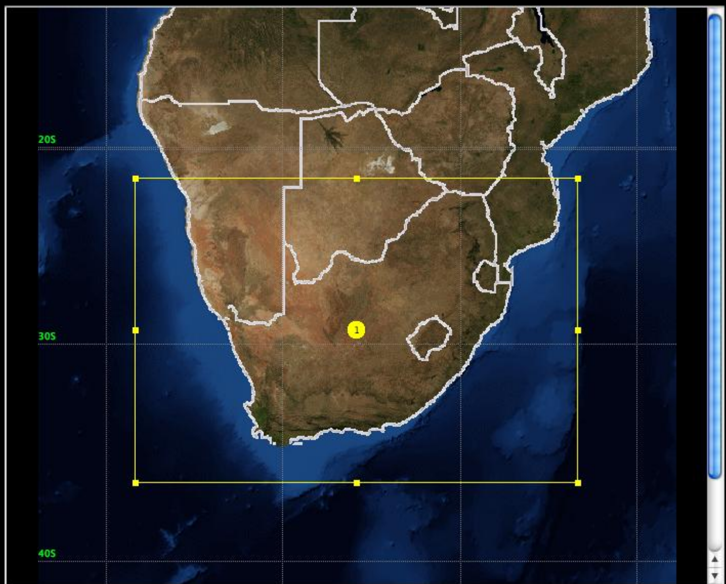
Africa doing perturbed physics??

- Using the WRF model to explore perturbations in:
  - Land Surface Model : 4 parameters
  - Radiation Schemes : 2 parameters
  - Microphysics : 2 parameters
  - Convection : 7 to 10 parameters
  - Boundary Layer : 2 parameters

The ‘problem’

- Assuming 3 possible values for each parameter:
- Total = 524880 simulations

Example



- 80 x 50 points, ΔT= 180 *s*
- 1 10 day simulation = 6 hours
- All simulations = you do the math …..

(Dual AMD 1,7Ghz machine)

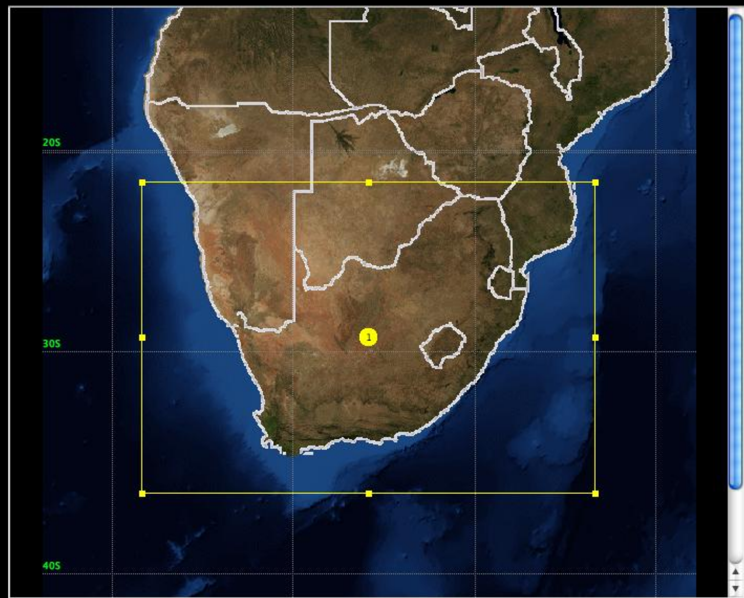
One ‘solution’

- World Community Grid
  - Grid Computation solution provided by IBM®
  - User donated idle CPU time from home computers
  - 5th Super Computer of the world
  - +700k Devices registered
  - +110k years of CPU time
  - Since 2004, hosting health sciences project (Dengue Drugs, Muscular Dystrophy,Cancer, AIDS etc)
  - First Climate-related project
  - WRF “boinced” with help from IBM

AfricanClimate@Home Phase 1

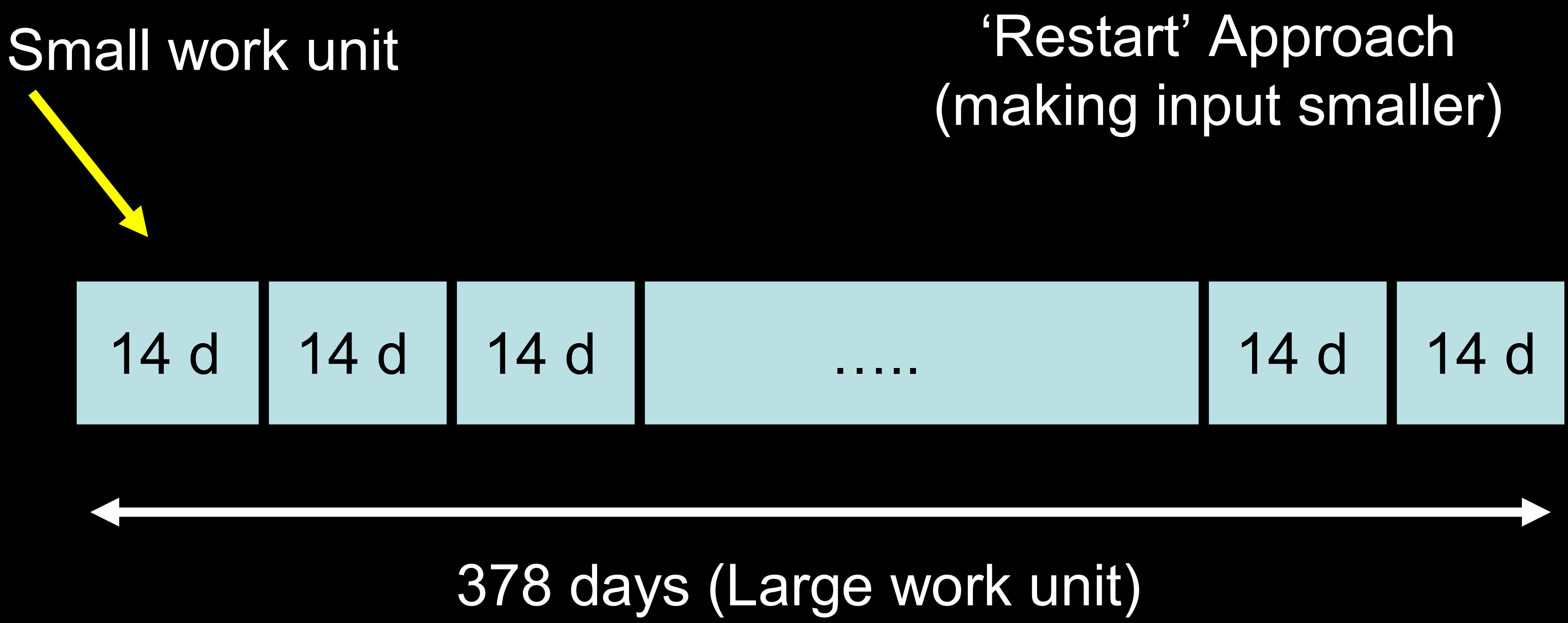
- Just the 4 parameters from the Land Surface Model being analyzed ($3^4+1=82$ simulations)
  - LAI, Stom Res, Wilting Point, Porosity
- Domain over South Africa
- 1-year simulation
- Simplified output

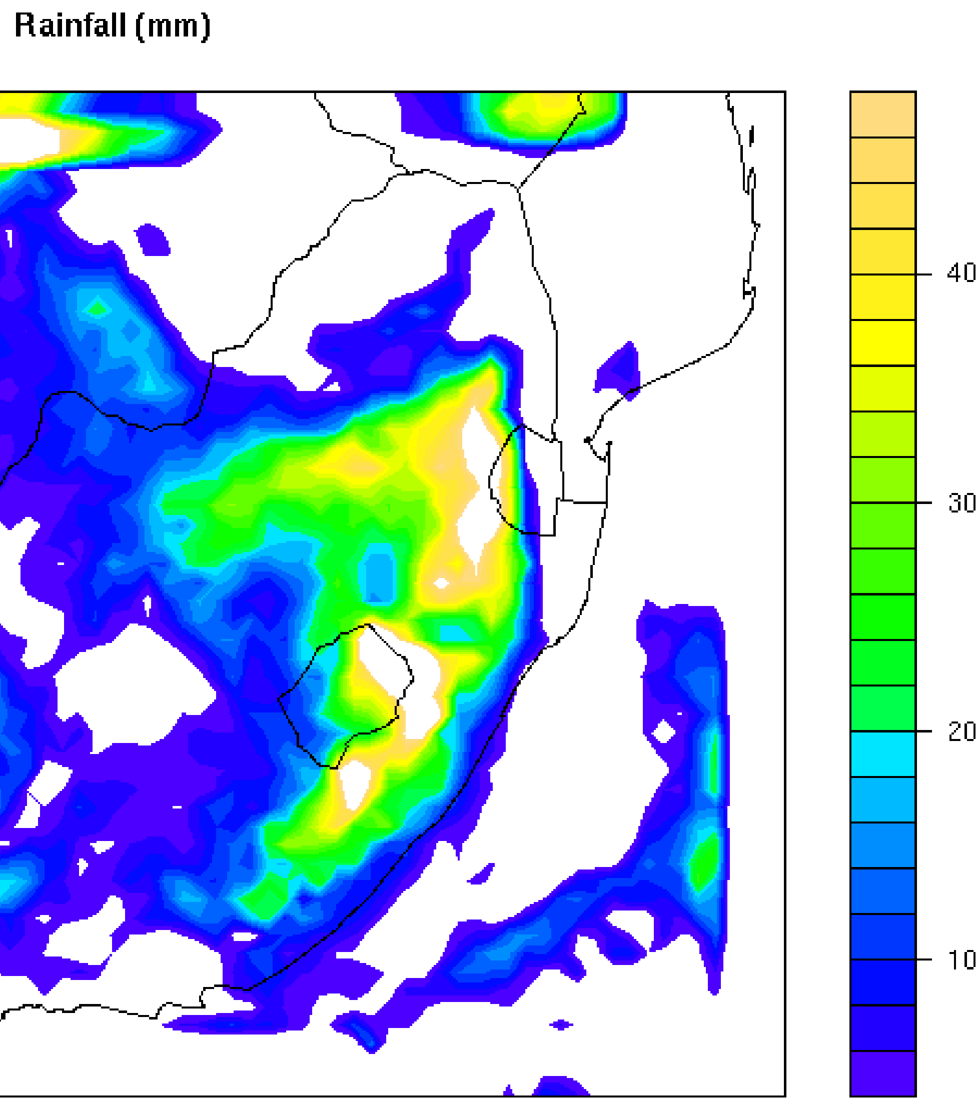
AfricanClimate@Home



AfricanClimate@Home Phase 1

- Main issue for implementations:
  - Large input and output files (Large Download and Upload time)




Rainfall (mm)
40
30
20
10

Current Status

- Phase 1 launched 03.Sep.2007 at University of Cape Town
- Windows and Linux versions running on the BOINC agent
- Mac Intel Version to be released shortly
- 95% of the first 14-day period already finished in 1st 3 weeks

Phase 2 Plan:

- Include other WRF schemes
  - Convection, PBL, Microphysics & Radiation
- Full-Africa domain(s)
- Multi-Year simulation
  - Need to implement data compression

Other developments:

→ New Microsoft funded project: Partnership with Hadley Centre, Oxford University, Washington State University
- Perturbed physics ensembles with HadRM running under MSWindows!!!
- Experiment design still underway
- Initial runs in-house, extension through "ClimatePrediction.net"-type dissemination

→ RCM and Climate change e-learning developments

→ Computing not the primary limit; rather it's people

→ Question of: with limited resources, what are / should be the priorities of the Africa climate modeling community

→ For seasonal forecasting activities, aerosols, soil moisture, etc, hear from next speaker.


Cape Argus 150
Weather fury hits Cape
Fierce winds and rain batter province
Say
Rasool: what the report says
Fears over huge city arms theft
Give the Gift of Good Taste
Smith shaped our history, says DA
Picardi REBEL
ALL WE EVER TALK ABOUT IS THE WEATHER.