Stochastic simulation as an alternative (or supplement) to decadal predictions

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Outline

- Motivation
- General modeling strategy
- Two realizations
- Summary

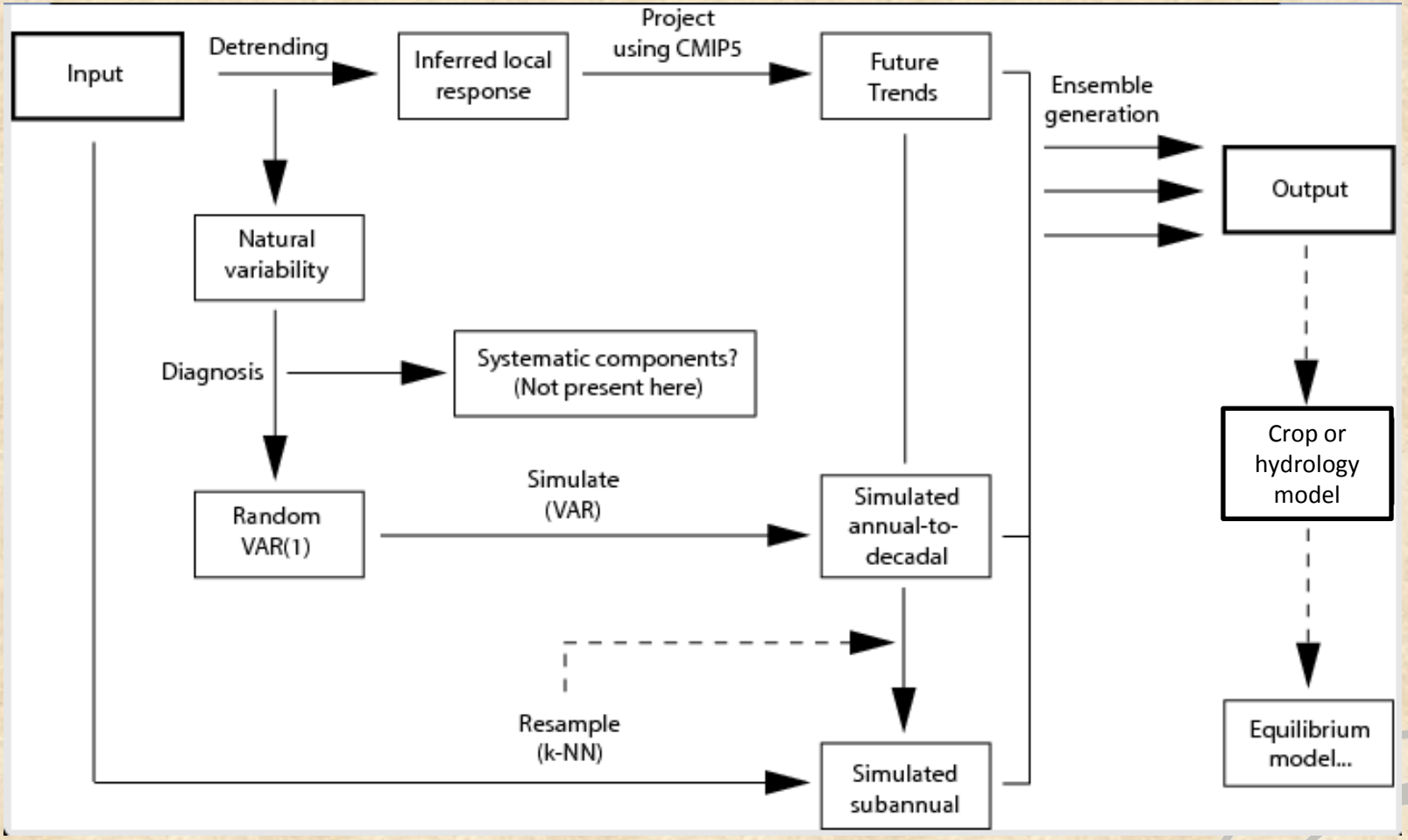
Achievable decadal forecast skill still to be determined

- Information sought beyond verifiable decadal forecast horizons, over land and at fine spatial and temporal scales.
- Data desired that is suitable for driving application (crop, hydrology…) models.
- How, then, to “inform the risk management space?”

General strategies for stochastic simulation

- Combine, or “layer” information
  - From different sources
    - GCMs: Large-scale, forced response
    - Observations: Character of local variability
    - Ongoing research: Refine GCM information…
  - On differing time scales
    - Climate change: Centennial (more or less)
    - Interannual-to-decadal
    - Subannual (monthly or daily)
    - Possible interactions…

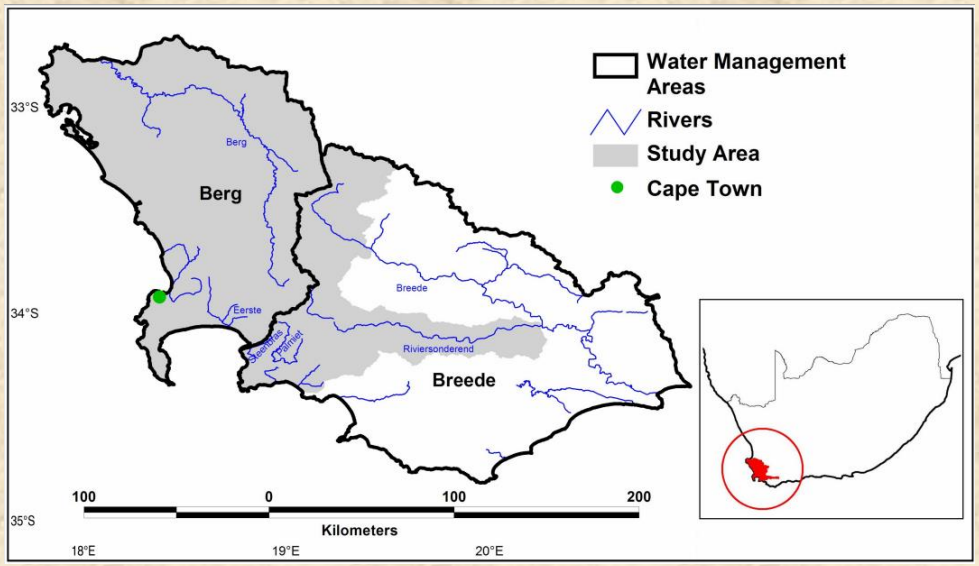
Common simulation framework, different realizations



Greene et al., Water Resourc. Res, 2012

A Tale of Two Regions

Western Cape; Southeast South America (SESA)



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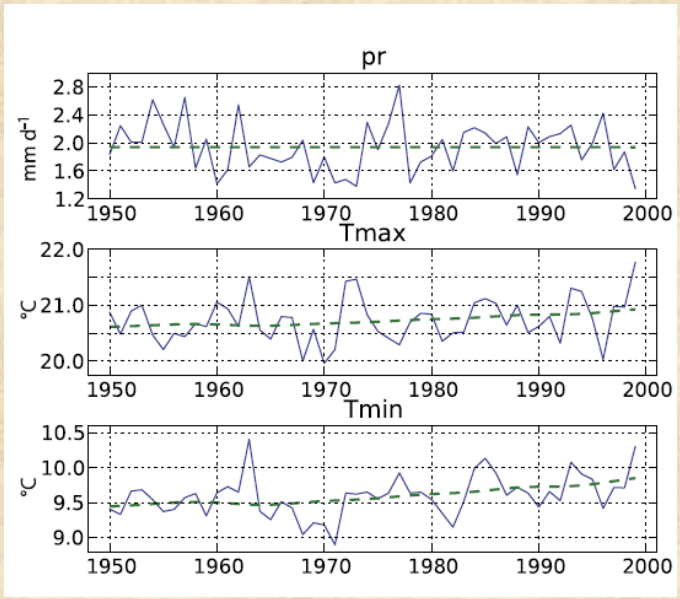
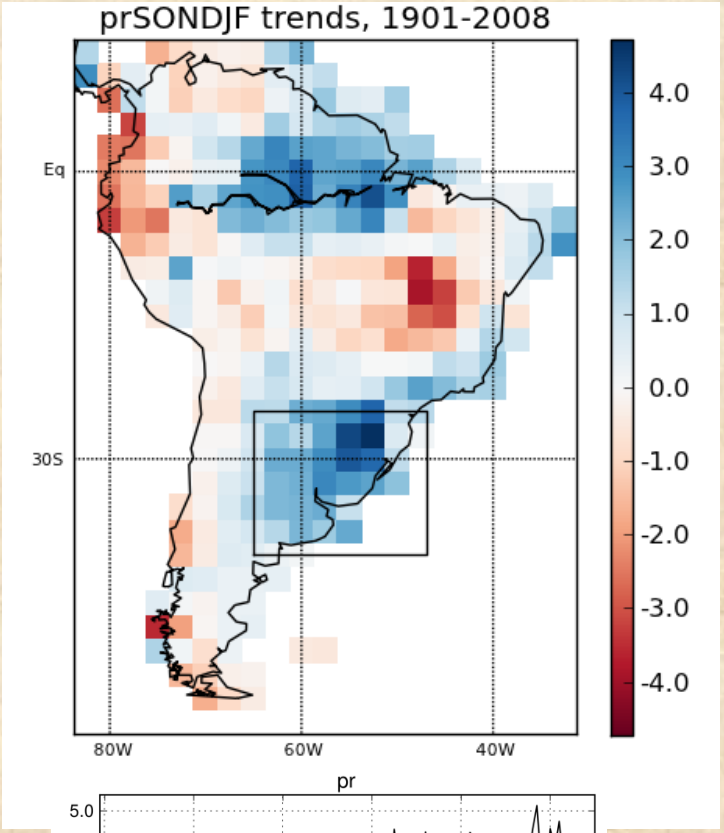
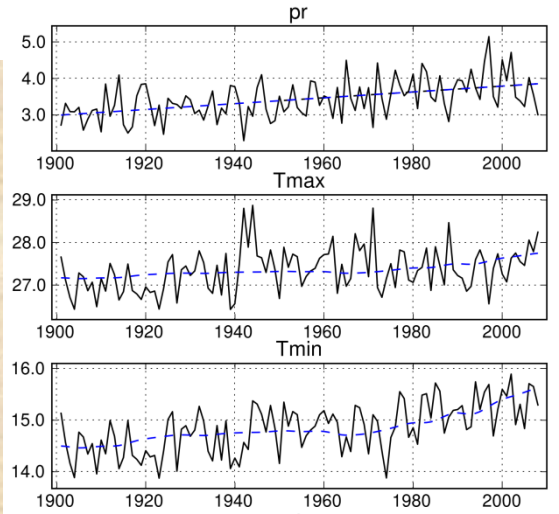






Some key differences

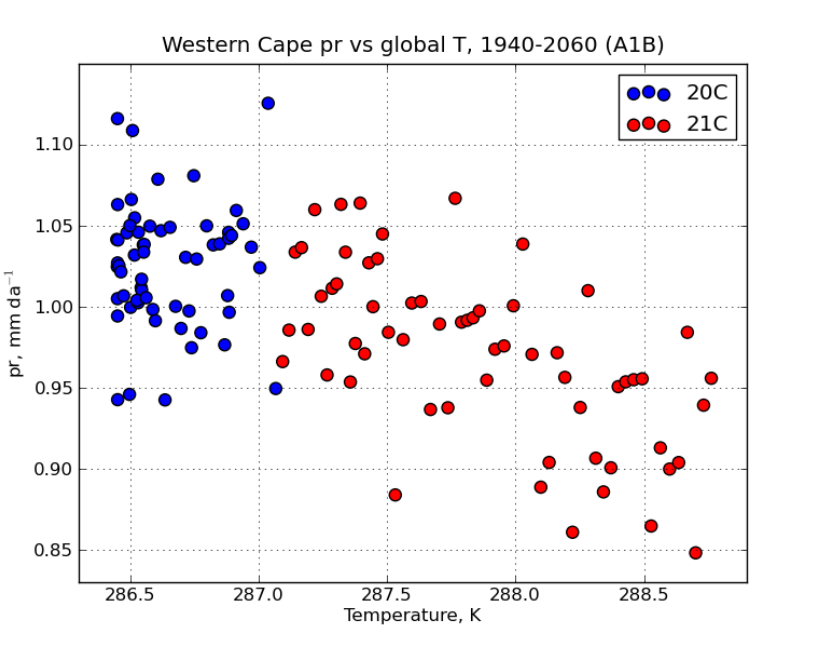
Western Cape

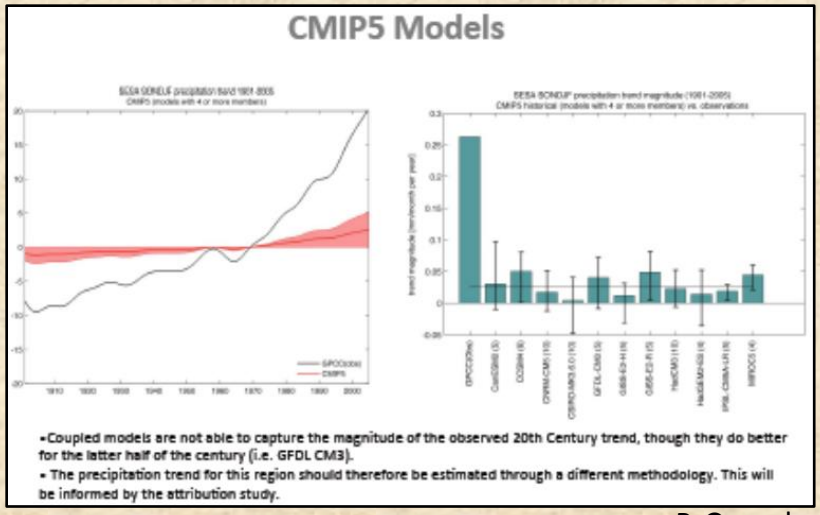
- Smaller spatial extent
- Observational data are station-level
- Daily time resolution
- 20C precipitation trend is effectively null
- 21C trend is toward drying, with good model consensus

SESA

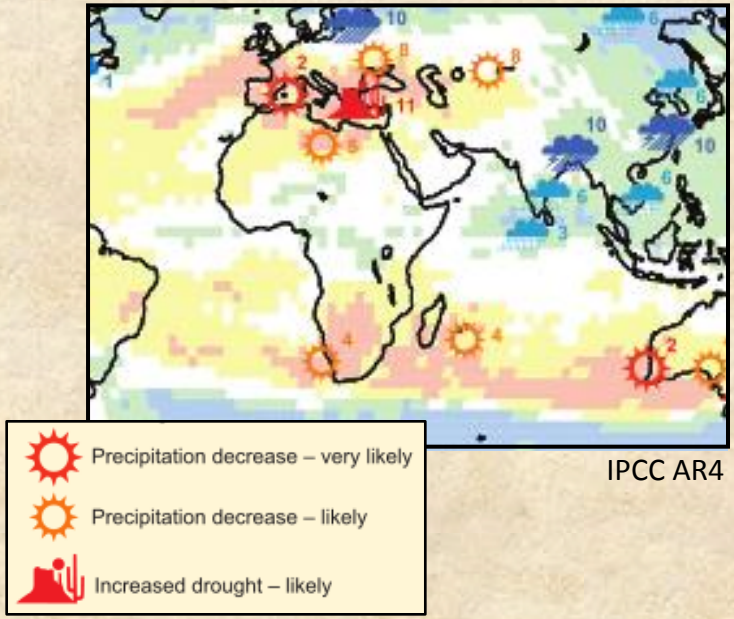
- Larger extent (30x)
- Observational data are gridded
- Monthly resolution
- 20C precipitation trend is markedly upward
- Difficult to infer 21C trend from GCMs

Expectations (and putative climatic controls) differ…

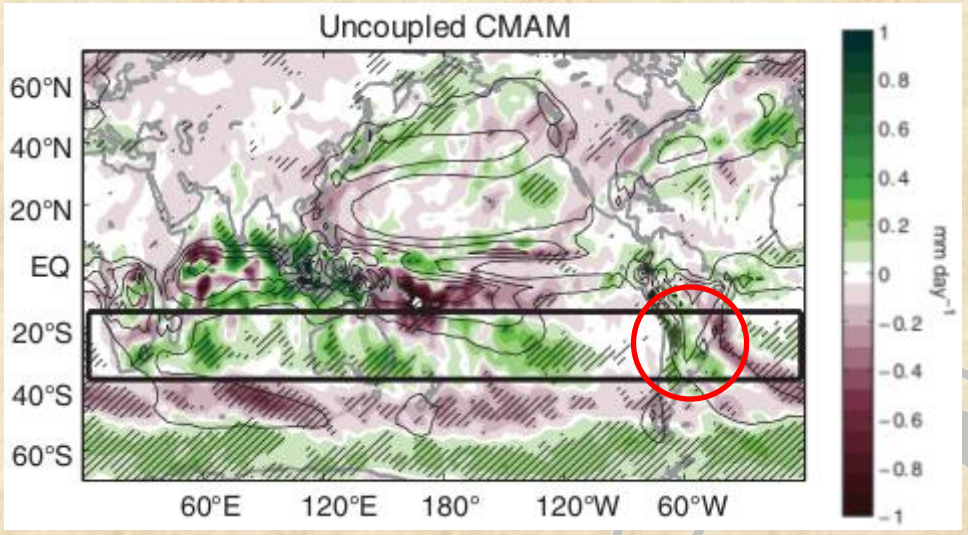




P. Gonzalez



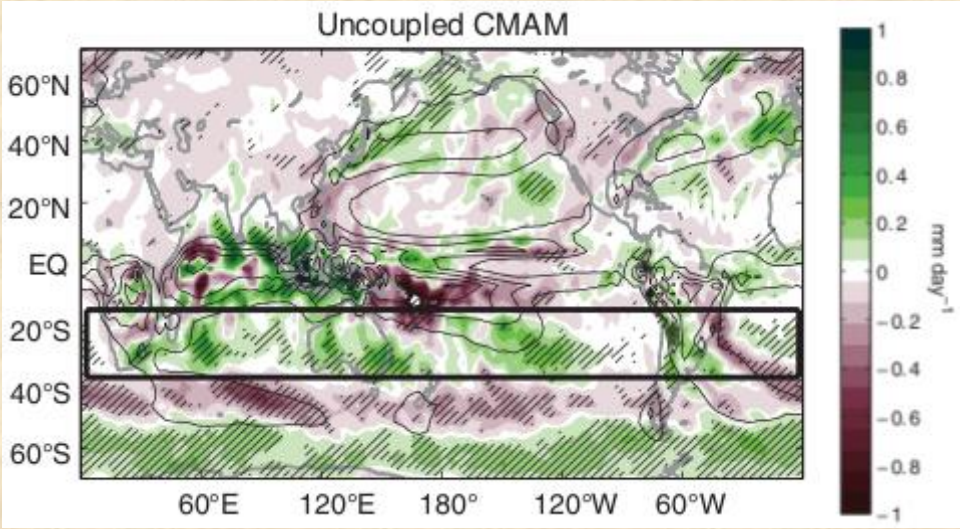
IPCC AR4

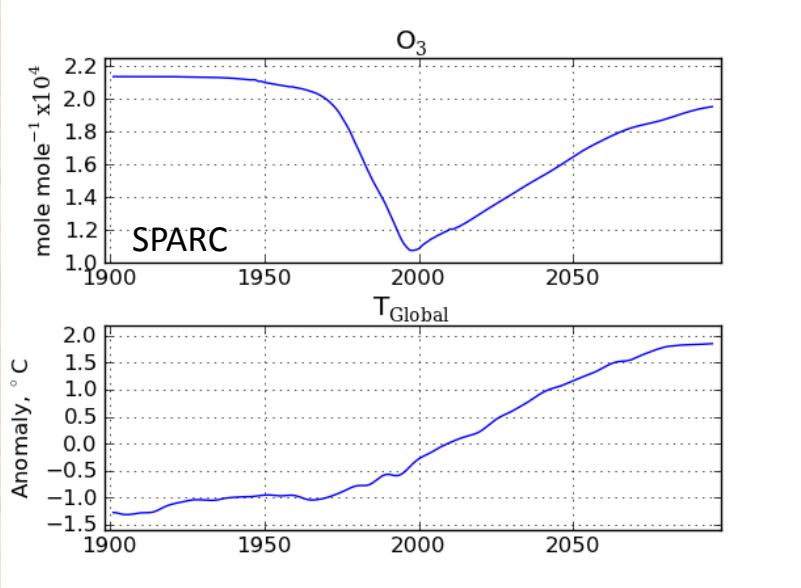


Kang et al., 2011

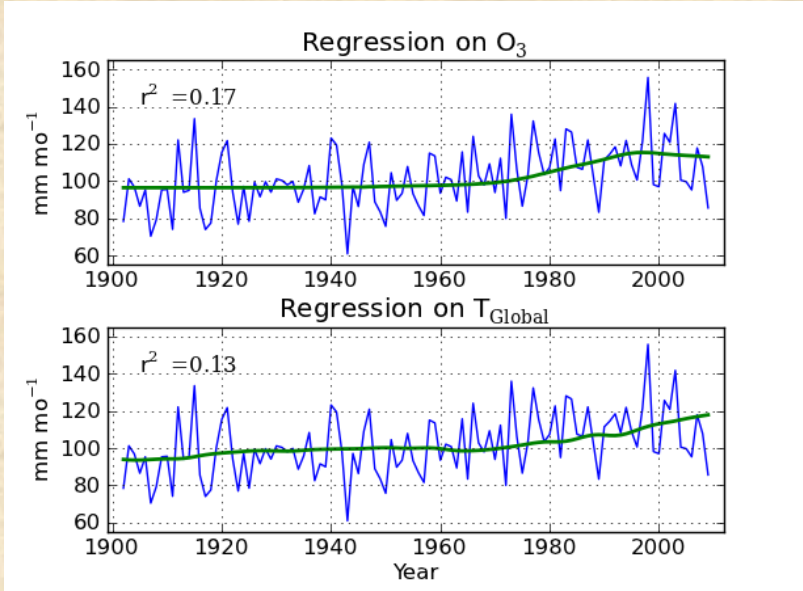
The SESA case in a bit more detail

- Ozone depletion is hypothesized to have moistened the southern hemisphere subtropics (right).
- Increasing GHG believed to have had a similar effect in SESA.
- As ozone recovers these influences will be *opposed.*



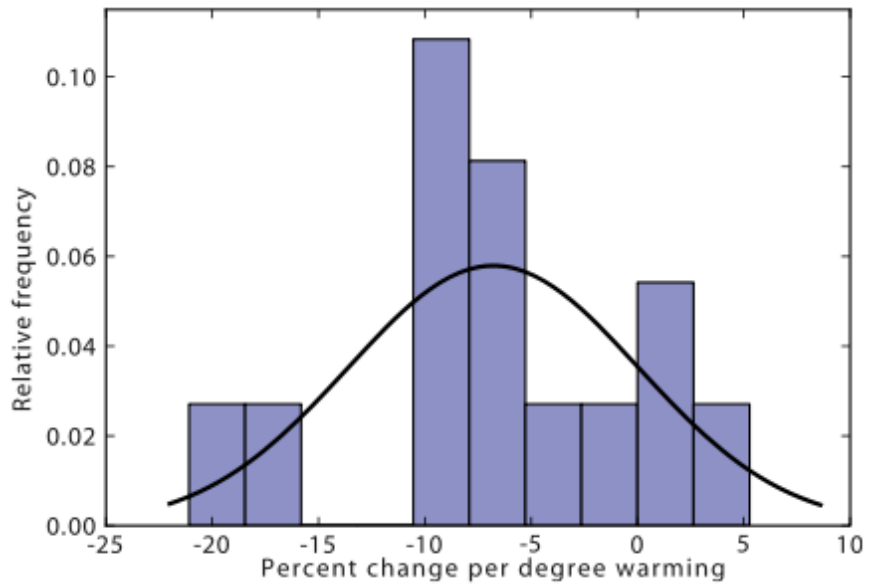


Top: Integrated O_3 concentration, 100-300 hpa, 70-90S, zonal mean, SON. Bottom: Multimodel mean, global annual mean T.

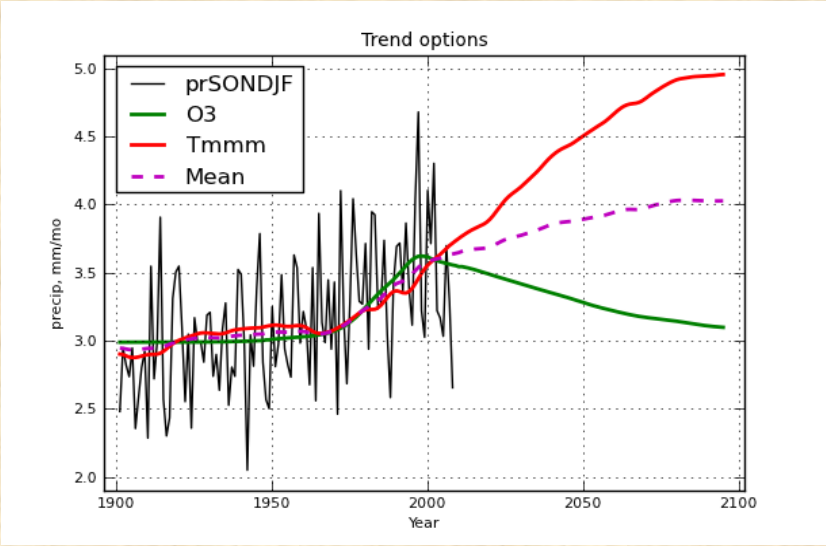


Fitted values for the two curves at left, regressed on the 20C observational precipitation record for SESA.

Modeling of trend and its uncertainty



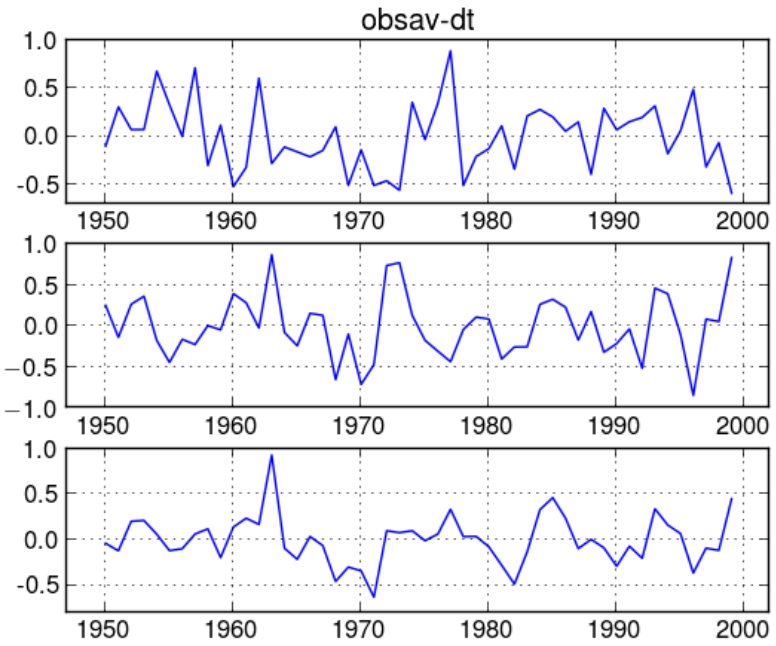
PDF of GCM regional precipitation trends for the Western Cape region, expressed as percent change per degree global temperature increase. Mean is -6.7% per degree global temperature increase.



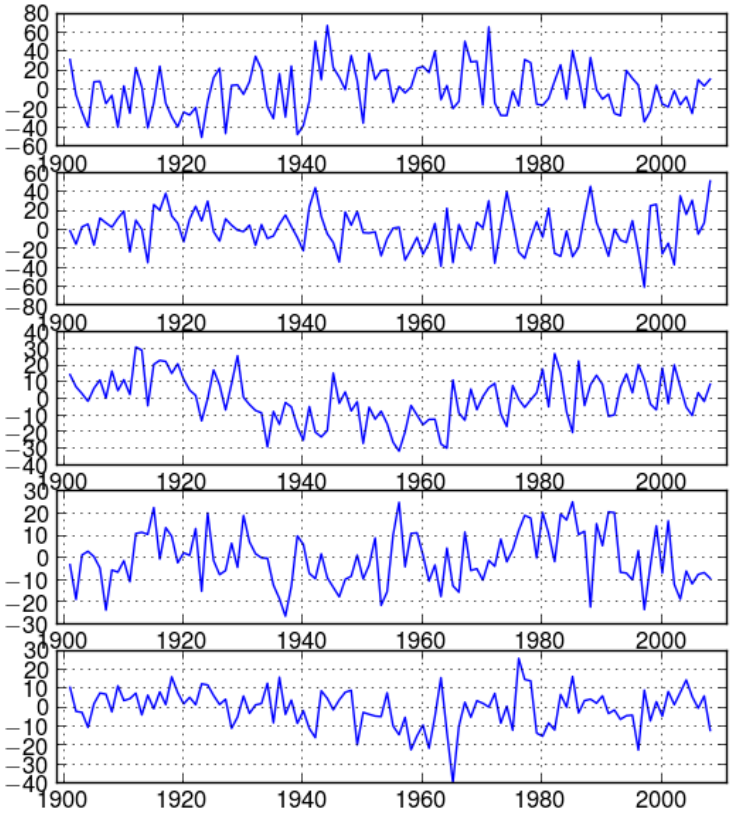
Projected trends for SONDJF precipitation in SESA, based on two forcing assumptions. Red: Global temperature is controlling, Green: (South Polar) stratospheric ozone is controlling. Dashed line shows the mean.

“Natural” variability: Interannual to decadal scale

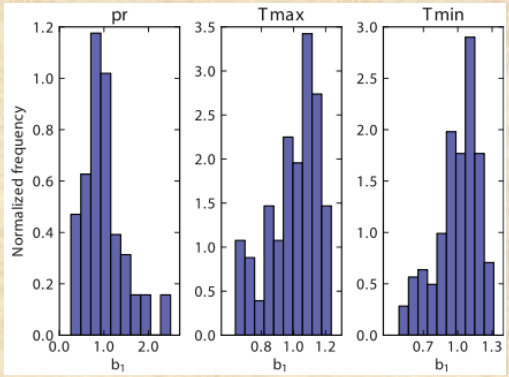
Western Cape: Regional mean series



SESA: Principal components

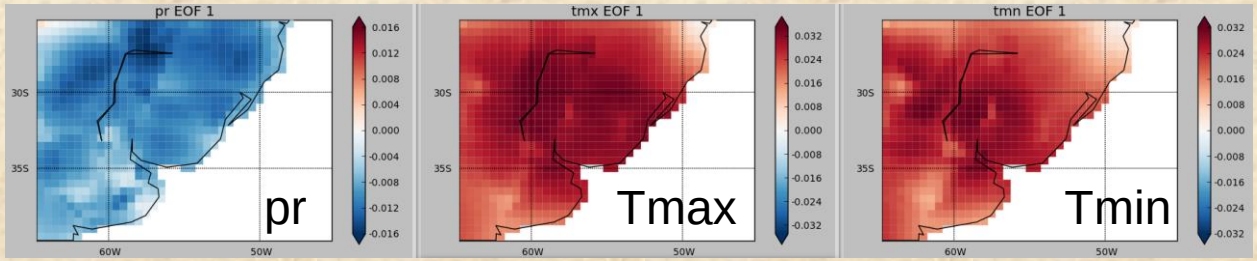


Evidence of coherent behavior…

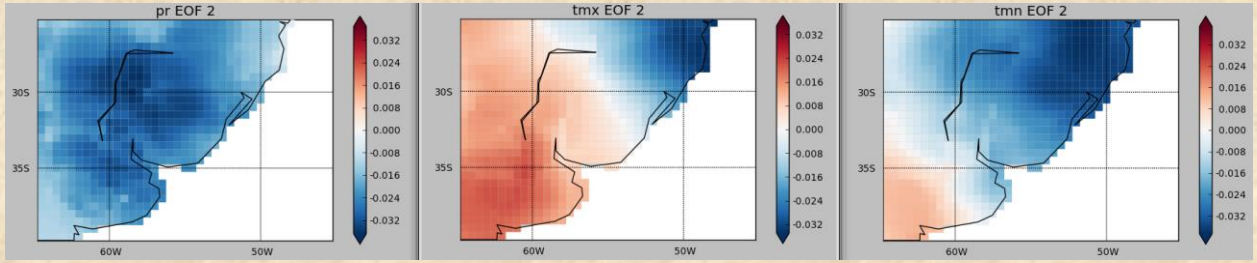


Require a model that conserves (a) Serial autocorrelation and (b) intervariable correlations, lag correlations: VAR.

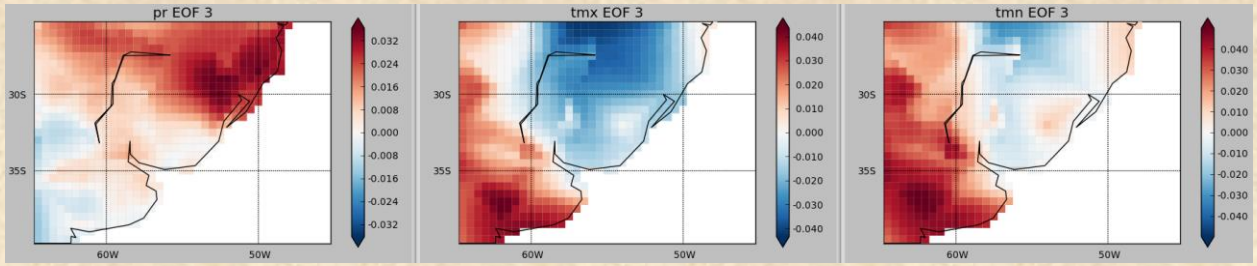
For SESA, spatial coherence is achieved by PCA



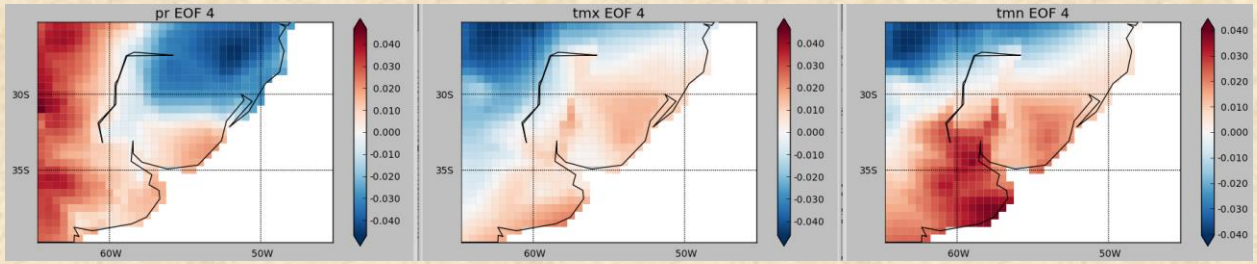
28% of variance



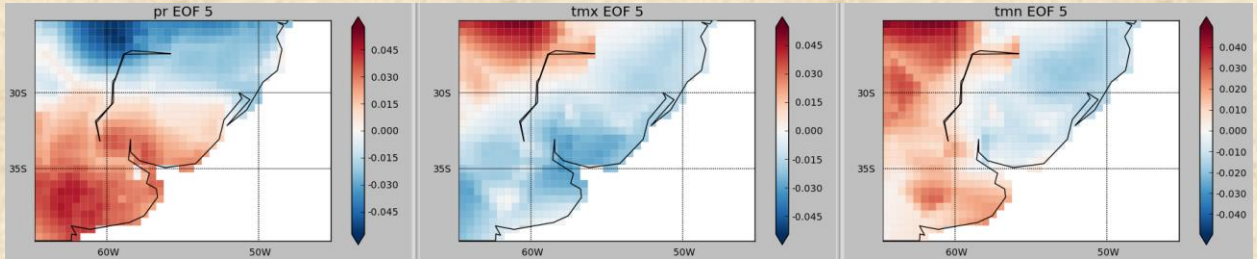
19%



9%



7%

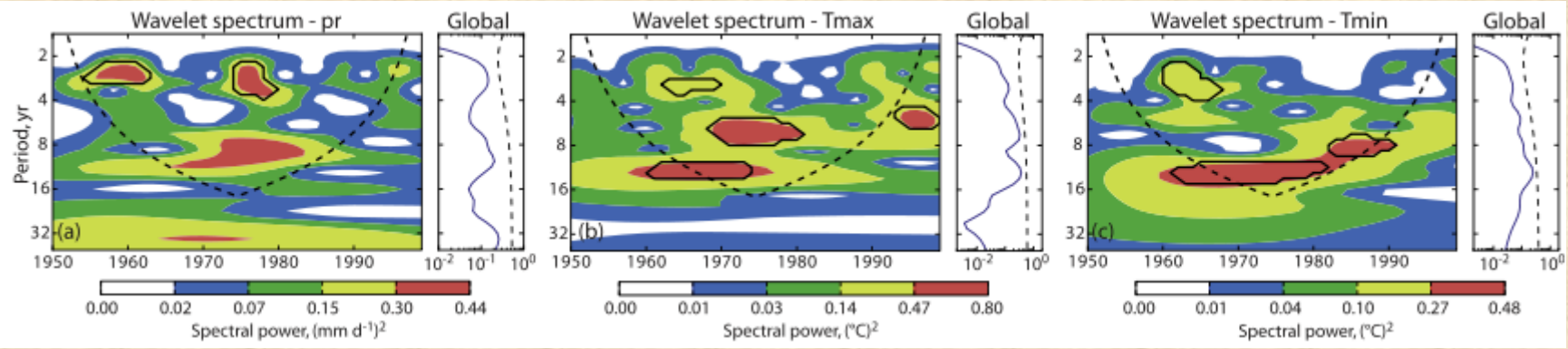


4%

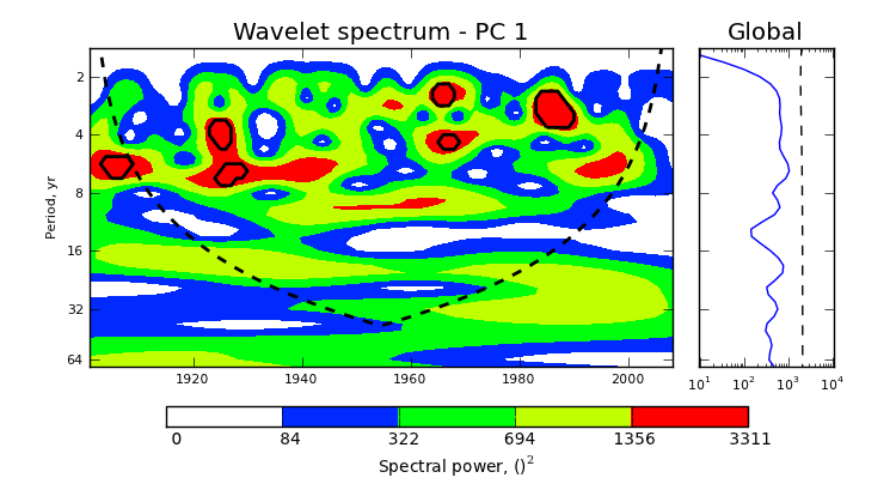
- First 5 EOFs explain ~70% of variance, similar to regression-based estimates.
- Large-scale patterns dominate.
- Robust features: Anticorrelation of pr, T (esp Tmax), positive correlation of Tmax, Tmin.
- Five PCs simulated using a reduced state-space model, based on VAR(1).

Spectral analysis suggests VAR(1) model structure

Western Cape

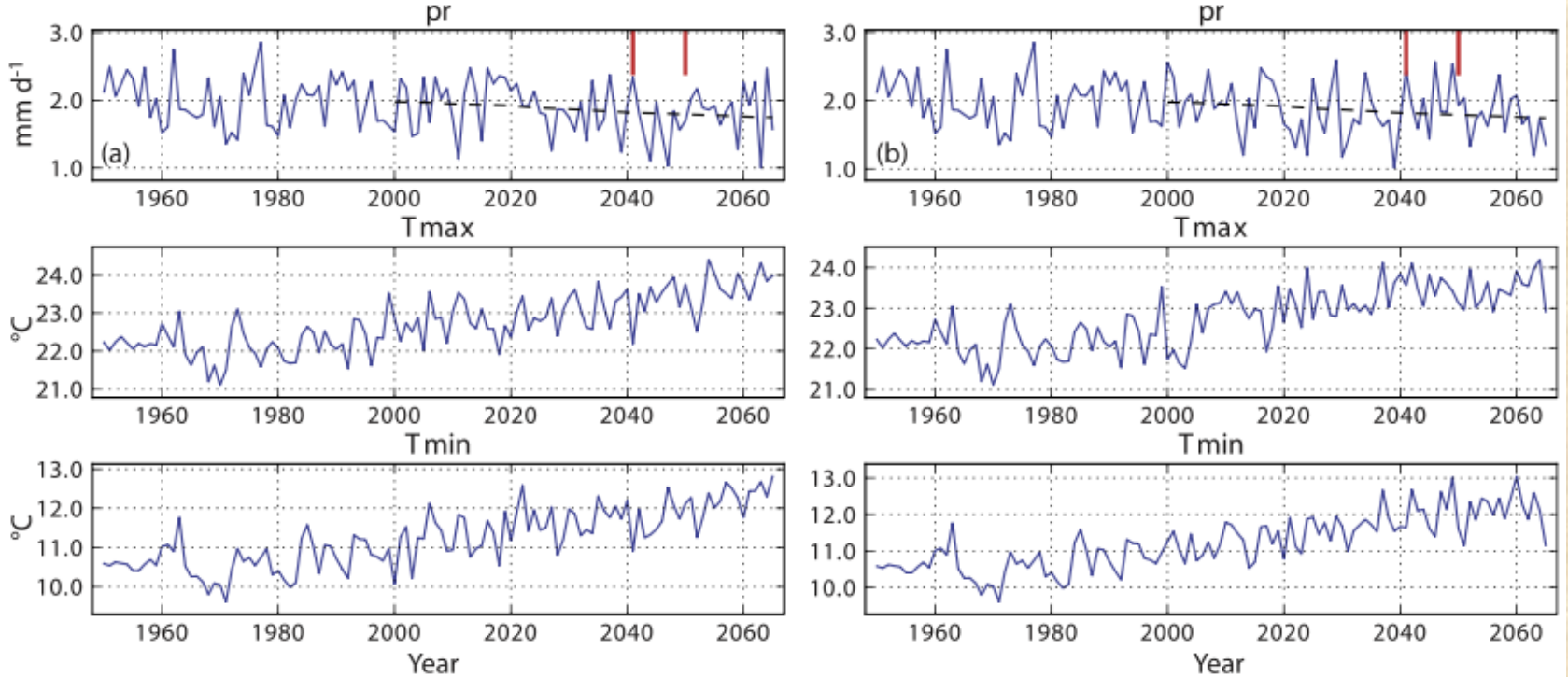


SESA (PC 1 shown)



VAR(1): Vector Autoregressive of order 1; not structurally different than “LIM”

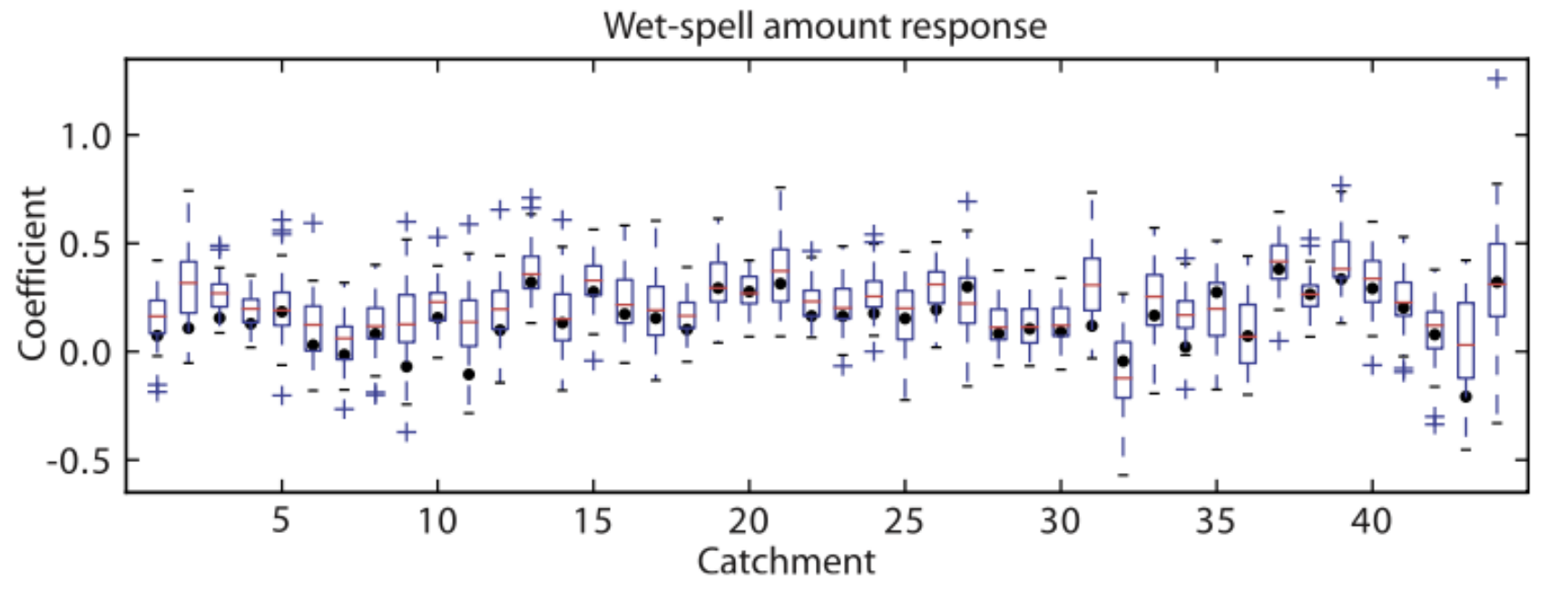
Simulation and downscaling



- Left: Excursion during 2041-2050 lies at the fifth percentile for decadal means, and is superimposed on the multimodel mean trend plus a small station-level trend offset.
- Right: A 95th-percentile excursion is superimposed on the same trend.
- Plots show simulated annual means for a particular station. Full time resolution is daily.
- Shift in interannual variance not supported by IPCC models, thus not incorporated.
- K-NN block resampling scheme preserves spatial covariation at the daily time step.
- Probabilities for excursions exceeding given levels can be computed.
- Daily-resolved output to drive crop, hydrology, economic models for impact assessment.

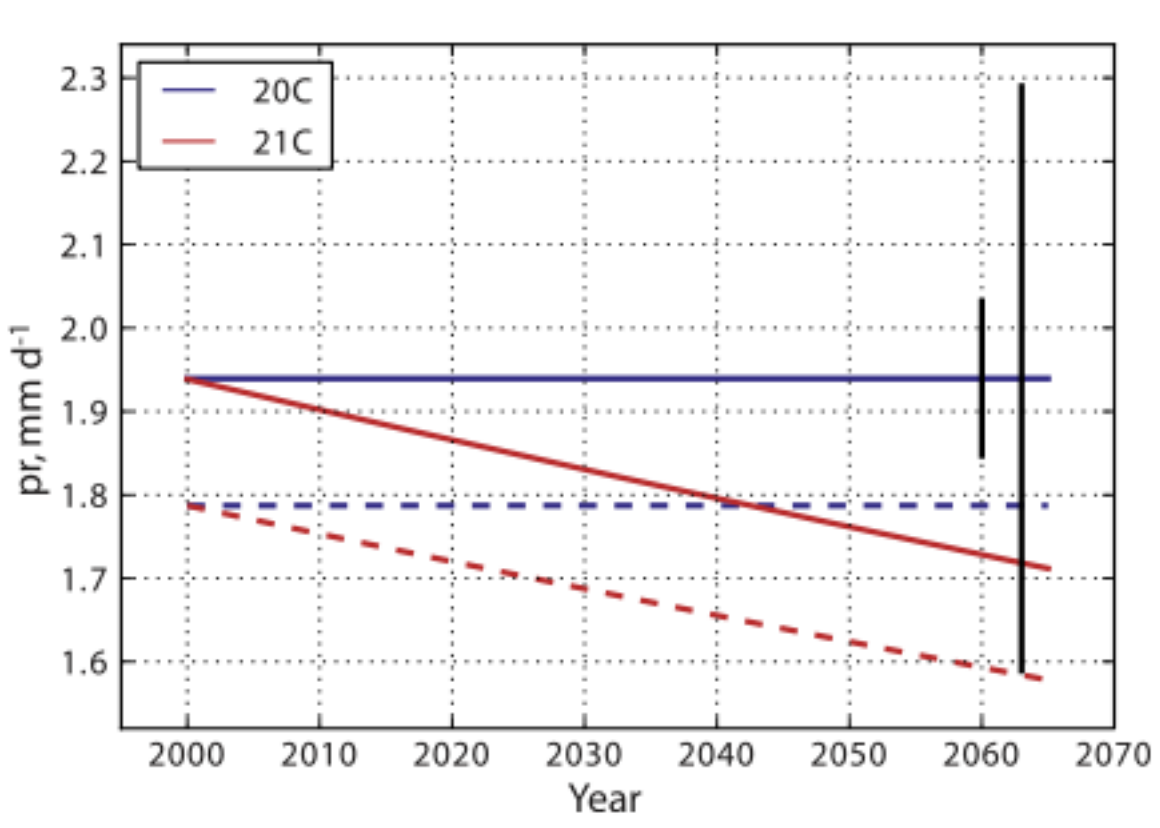
Validation: Subannual statistics…

Downscaling from seasonal mean values performed by k-NN resampling



Western Cape: Dependence of 3-day wet spell amounts on annual mean precipitation, shown for 44 independent stations. Ensemble size is 50.

Balance of trend, variability



Western Cape, regional mean precipitation, multimodel mean trend: By 2040 annual mean pr has declined to the value of the fifth percentile for 10-year means. This decrease must be viewed in the context of significant interannual variability (longer vertical black line, far right). Significance is context-dependent.

Summary

- “Layered” information from a variety of sources.
- Forced, natural variability modeled independently, but cross-scale interaction is considered.
- Seasonal-to-decadal scale: VAR(1) model, fitted to data or PCs.
- Downscaling to monthly/daily using k-NN.
- Utility: Drive agricultural, hydrologic or other applications models that require spatiotemporally disaggregated inputs.

Thank You!