Detecting solar dimming in observed river flow

Nic Gedney (UK Met Office)

(Gedney, Huntingford, Weedon, Boucher & Cox, Nat. Geosci. 2014)

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- Potential drivers of changes in river flow
- Experimental setup
- Model evaluation
- Modelled responses to drivers
- Analysis and attribution
- Conclusions

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Potential drivers of river flow changes

Runoff~Precip-Evap-Δstore

Climate: Precip, SW & LW radiation, cloud cover

Aerosols:

clear-sky radiation (total & diffuse frac), cloud props & extent

Land use (water and energy availability)

CO_2 effect on vegetation: water user efficiency, growth

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Exptal Setup

JULES forced ***Off-line*** with WATCH forcing data over the Northern Hemisphere at 2^{o} resolution.

WATCH forcing (Weedon et al, 2011) :

resolution: 0.5^{o}; 1901-2001

monthly mean obs:

CRU TS2.1, precip (GPCCv4) + gauge correction

ERA40 –sub-monthly variability

Aerosol effect of downward SW (HadGEM2-ES)

Fully transient “ALL” run: meteorology, land use, atmos CO2 & aerosols varying throughout 20th Century

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20th Century Simulations

- "Climate-Only": climate varying in 20th Century
  (Fixed: aerosol, CO2, land cover)
- "Clim-Landuse": climate + land use varying
- "Clim-CO2": climate + CO2 varying
- "Clim-Aerosol": climate + aerosols varying

⇒ The effect of:

$X_{CLIMATE}$="Climate-only"

$X_{LANDUSE}$="Climate-Landuse" - "Climate-Only"

X_{CO2} "stomatal effect" ="Clim-CO2" - "Climate-Only"

$X_{AEROSOL}$ "radiative effects" ="Clim-Aerosol" - "Climate-Only"

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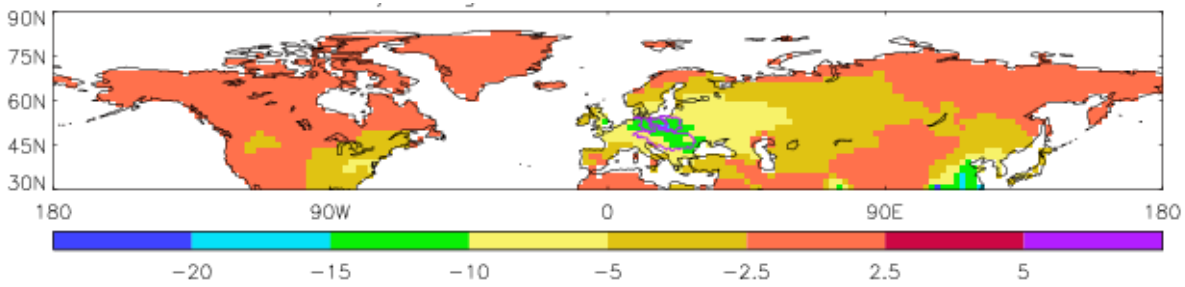
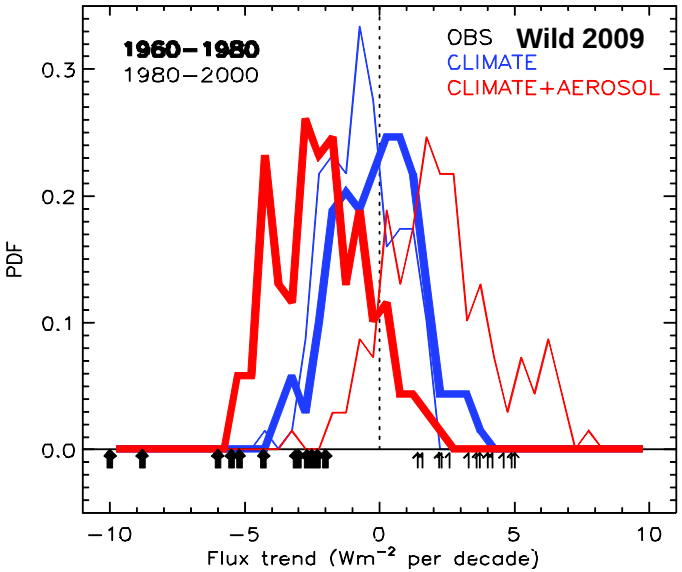
Solar Dimming Evaluation

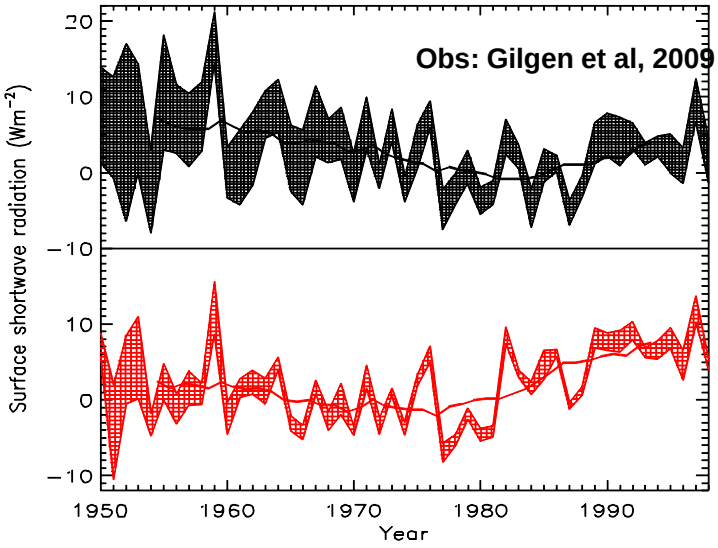
Change in total surface SW (Wm^{-2}) due to AEROSOL [1975-84]-1900's



Trends in European SW



Temporal anomalies: annual European SW



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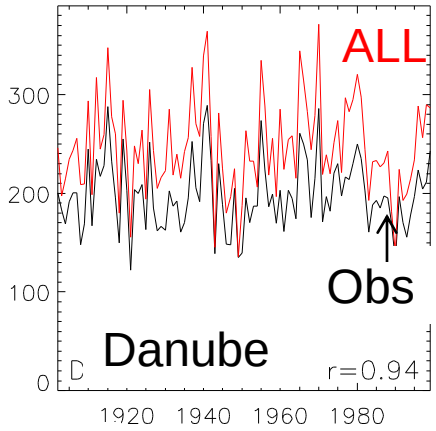
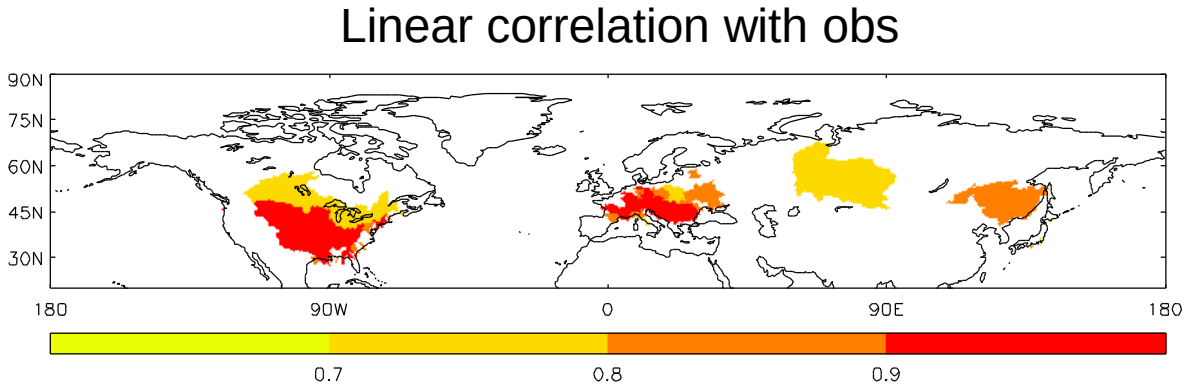
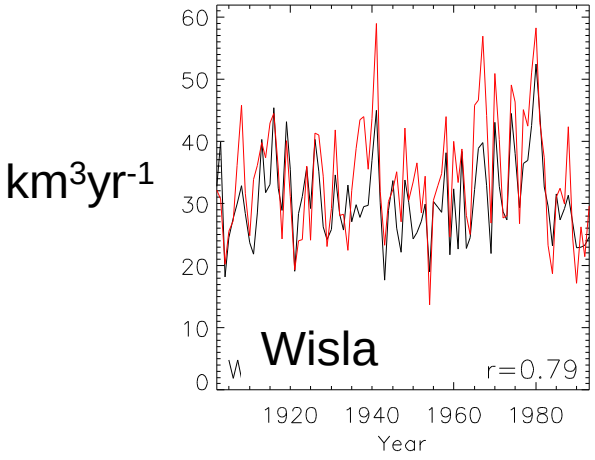
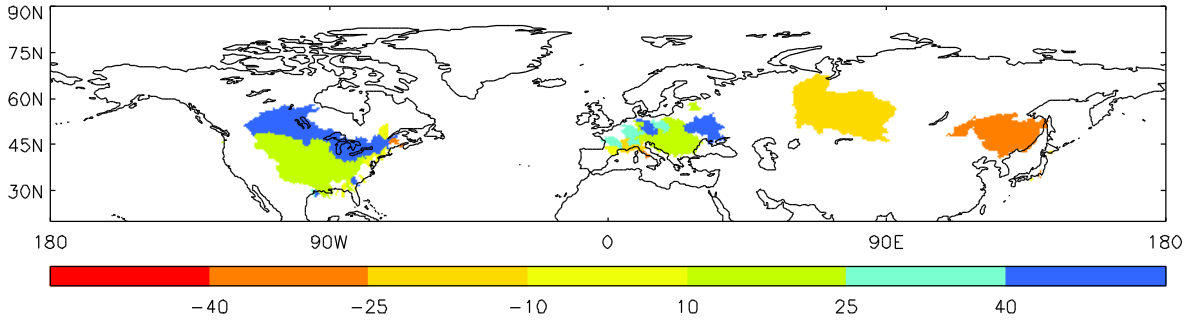
Annual river flow evaluation against obs (Dai et al, 2009)









Percentage error in long-term mean

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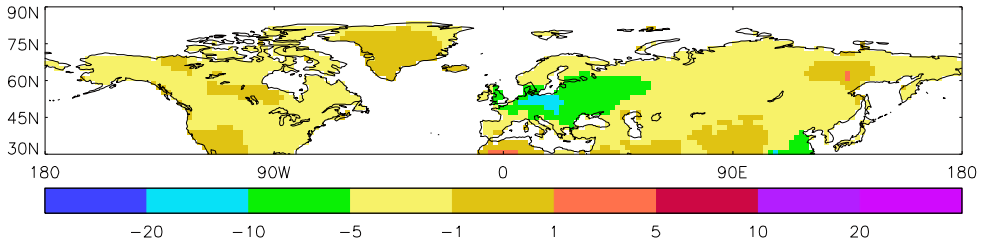
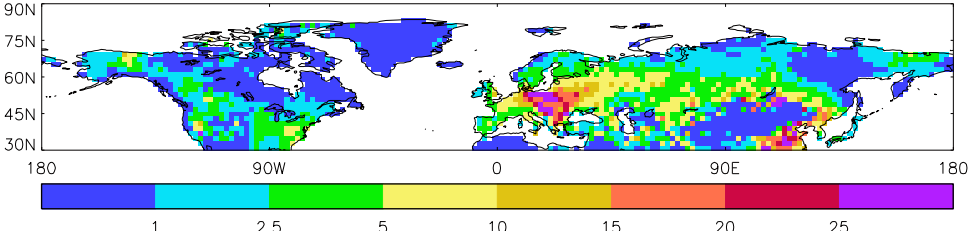
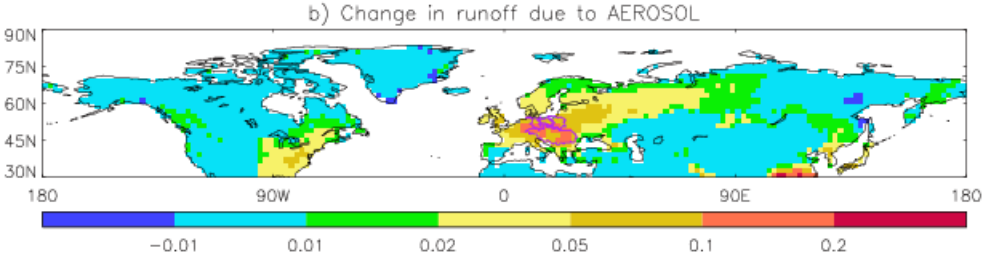
% dSW (AEROSOL):



% dRO AEROSOL:

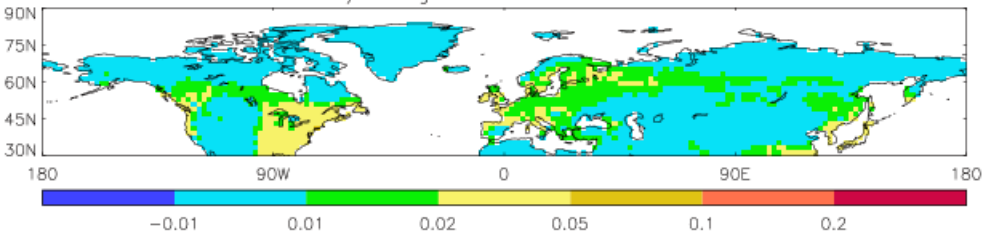


dRO (kg/m2/day) AEROSOL:

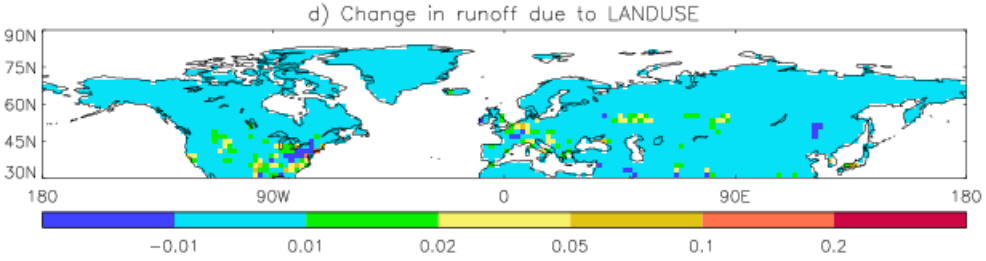


Modelled changes between:
1900s & [1975-1984]

dRO CO2:



dRO LANDUSE:



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Analysing which factors are driving changes in river flow

Ordinary least-square regressions on annual mean basin flow anomaly responses:

$$X^{obs} = \sum \beta_i X_i^{mod}$$

$$X^{obs} = \beta_{CLIMATE} X_{CLIMATE} + \beta_{LANDUSE} X_{LANDUSE} + \beta_{CO2} X_{CO2} + \beta_{AEROSOL} X_{AEROSOL}$$

Concatonate all (normalised and weighted) basin data together to maximise spatial & temporal differences.

No basins with significant permafrost & irrigation

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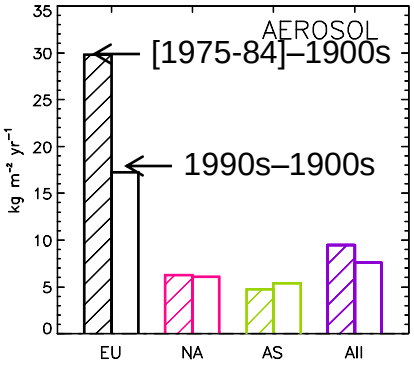
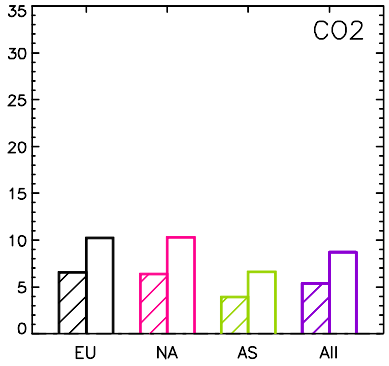
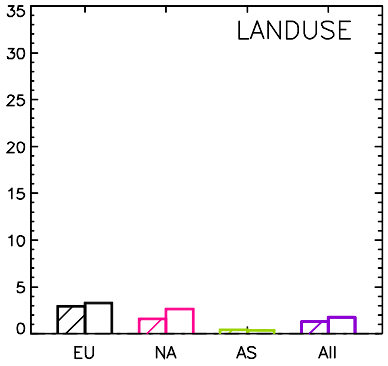
Modelled 20th century regional runoff changes

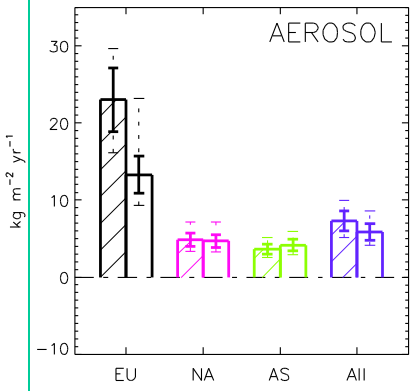


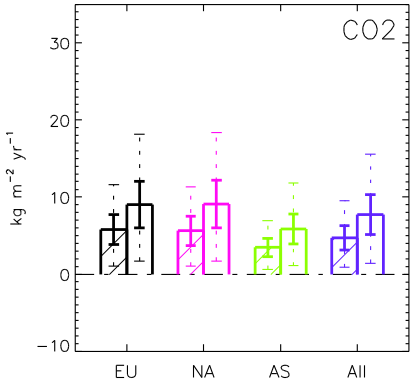


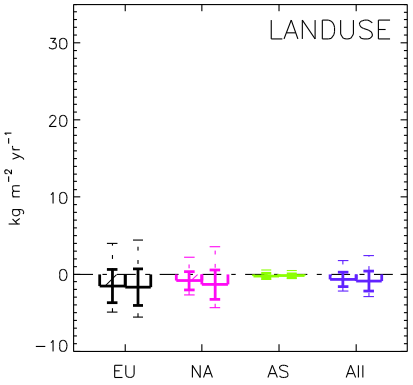


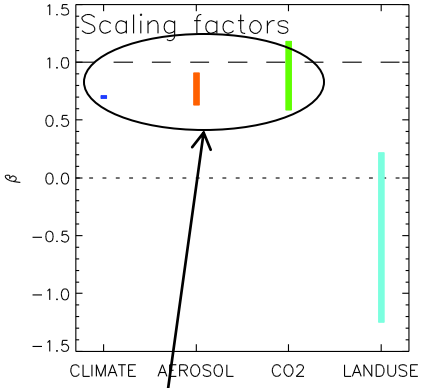
Modelled

Attributed









5 to 95% β ranges

Detected signals

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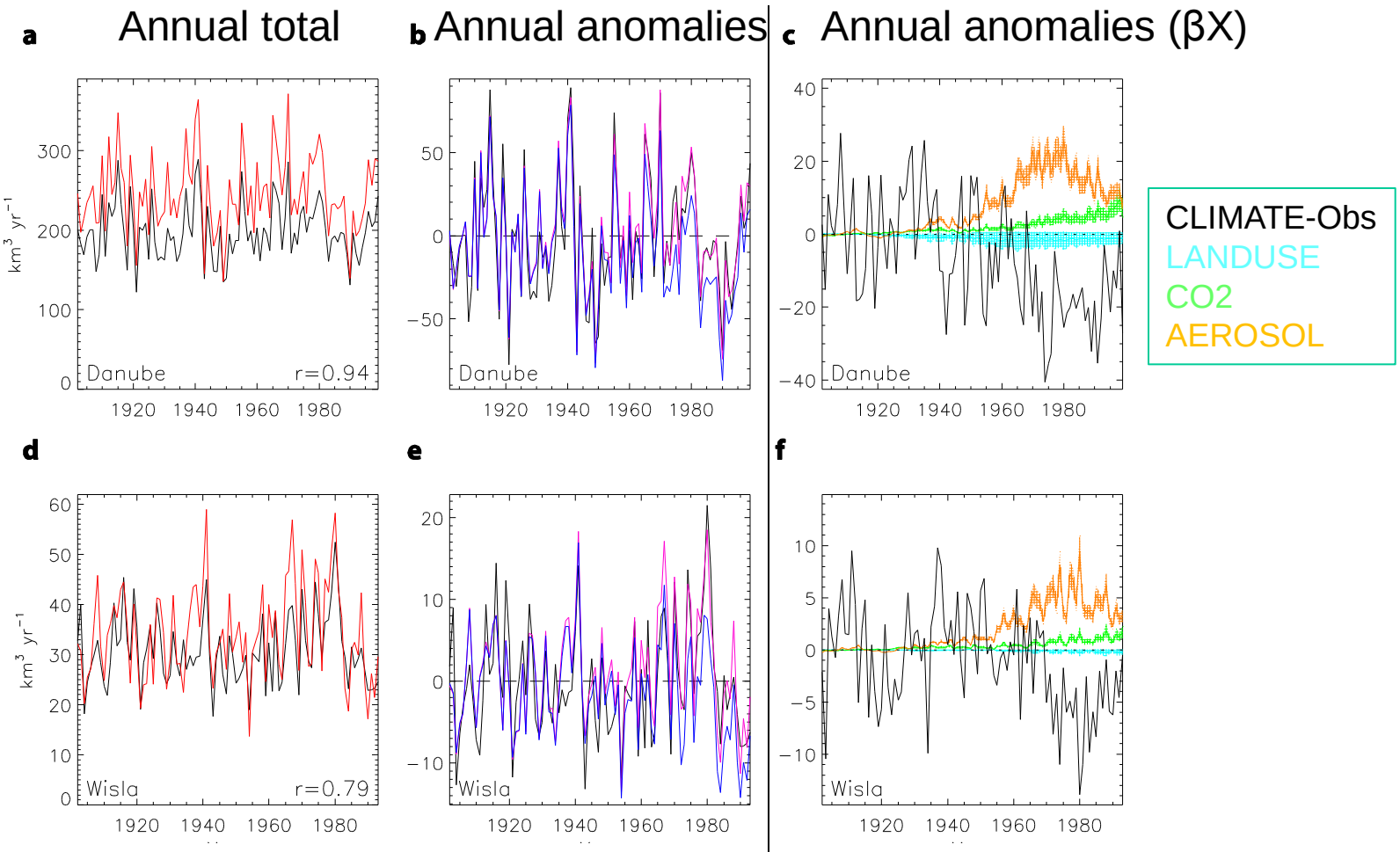
Annual mean river flow for Danube and Wisla

Obs
All
CLIMATE
Fit



CLIMATE-Obs
LANDUSE
CO2
AEROSOL

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Regression analysis also applied to individual basins:

Also detect aerosol dimming at the 5% significance level over individual basins

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Conclusions

- Meteorology cannot explain obs river flow alone
- Detect aerosols (solar dimming/brightening) in observed river flow:
  - Northern extra-tropical region
  - Individual basins inc.: Danube, Wisla, Elbe & Oder
- Central Europe: solar dimming increased river flow ~10-25% ~1980
- Anthropogenic aerosols impact significantly on land hydrology and water resources

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Conclusions contd

- Technique enables detection of aerosols on sfc hydrology:
  - Observed off-line forcing
  - Good aerosol depiction
  - Basin scale– appropriate for scale of aerosol concs
  - Use of multiple basin, long obs river flow time series

- Also able to detect stomatal closure effect in line with previous analysis.

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Future Work

- Aerosol effect over other regions.
- Indirect effects of aerosols on cloud cover and rainfall
- Application to other influences e.g:
  - Deforestation
  - Irrigation

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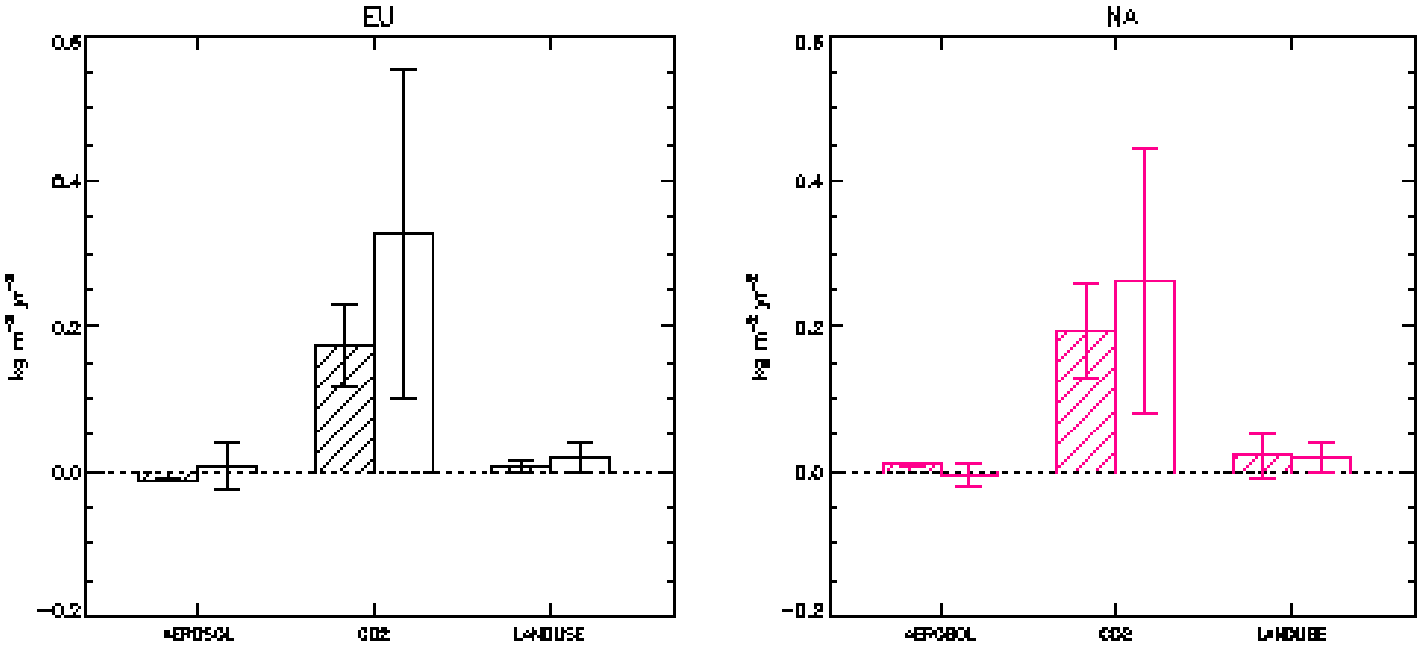
Comparison of attributed 1960-1995 runoff trends with Gedney et al 2006.

Regional averages are calculated only from basins used here (hashed) and, for entire continent in Gedney et al 2006 (clear).

Note: runoff trends due to aerosol over this time period are relatively small because the dimming circa 1960 and 1994 are similar



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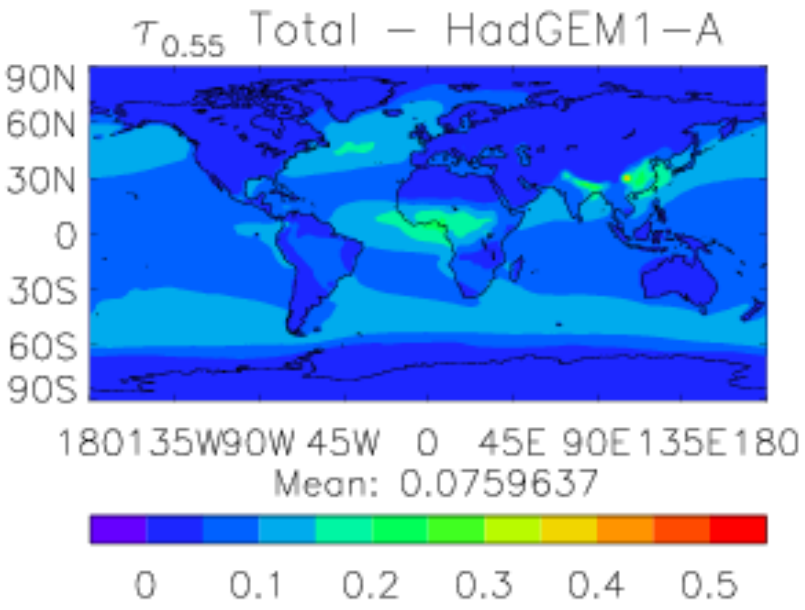
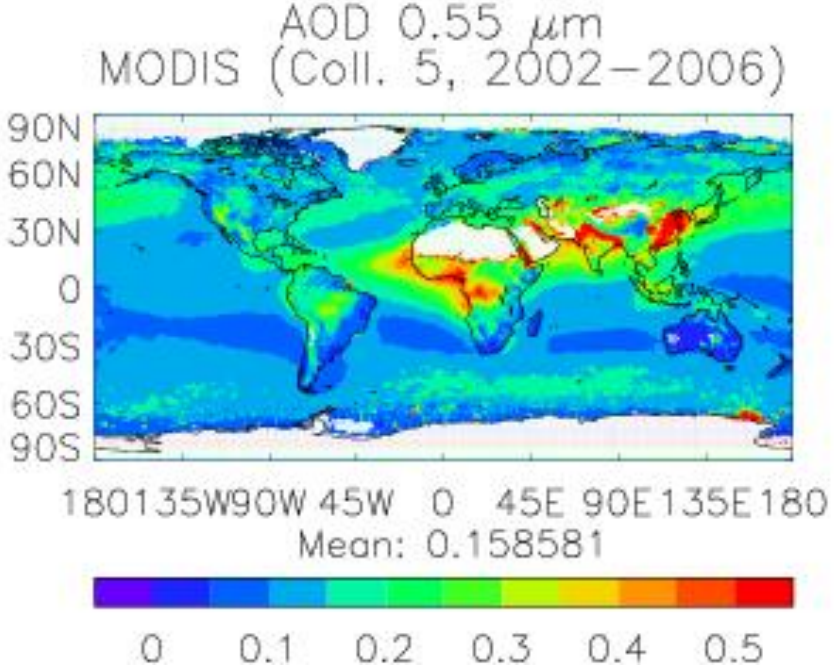
Aerosol optical depth in HadGEM1





Present-day total aerosol optical depth is small compared to ground-based and satellite retrievals

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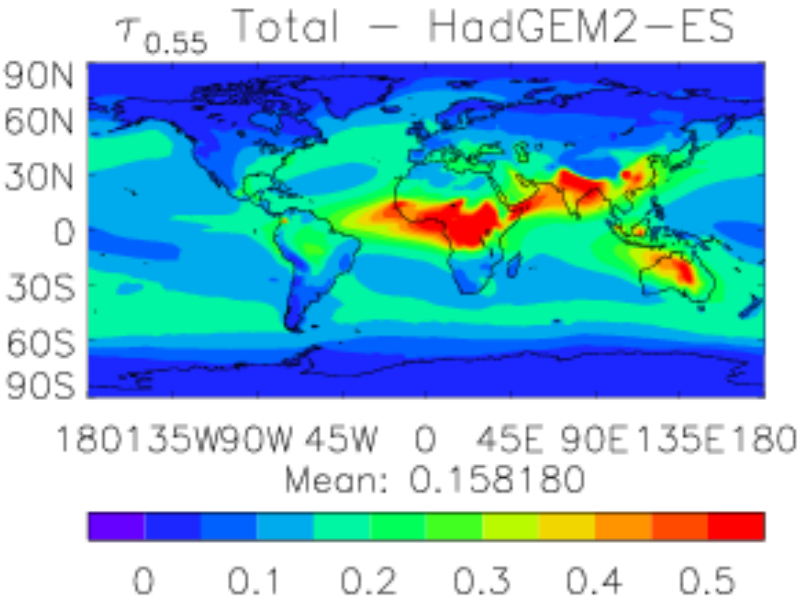
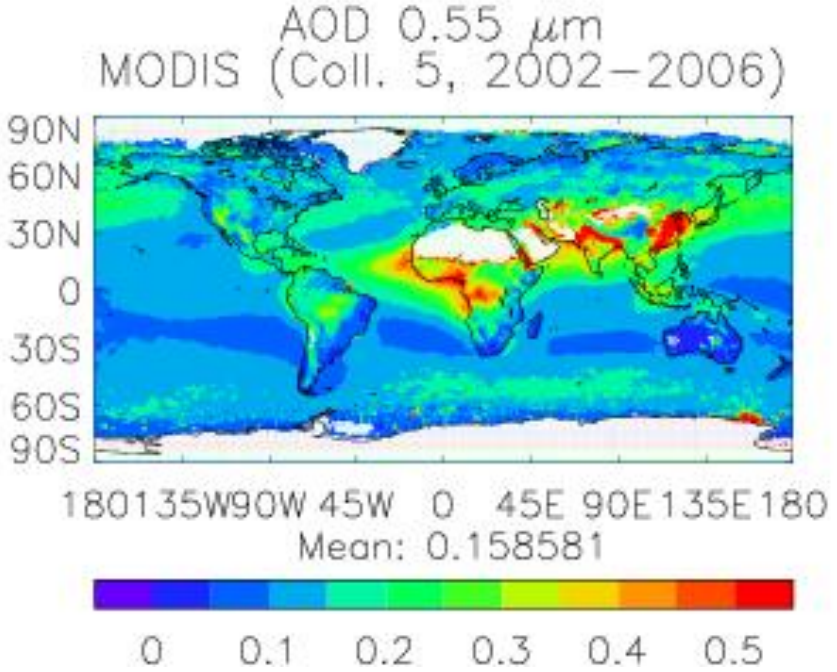
Aerosol optical depth in HadGEM2-ES





Improvements yield a much better comparison against observed total aerosol optical depth

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Modelled changes Between:
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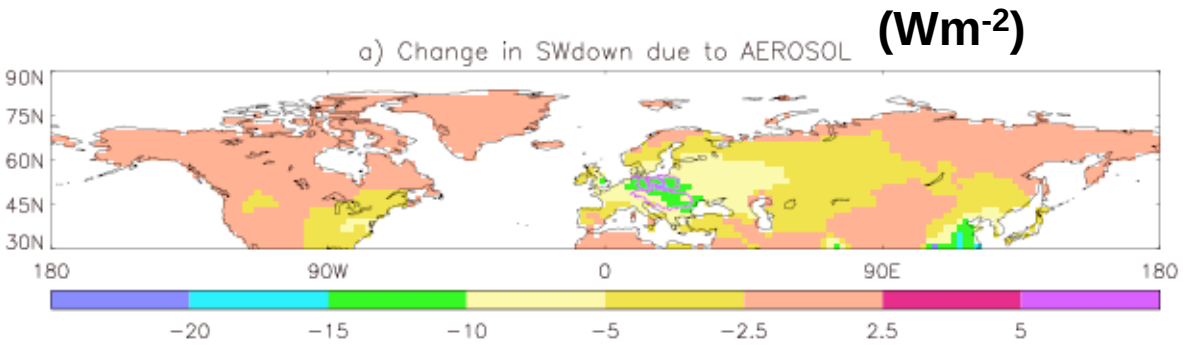

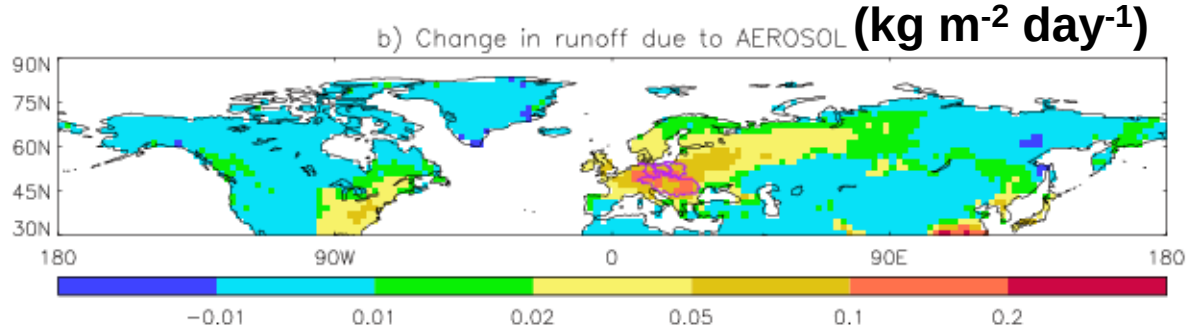

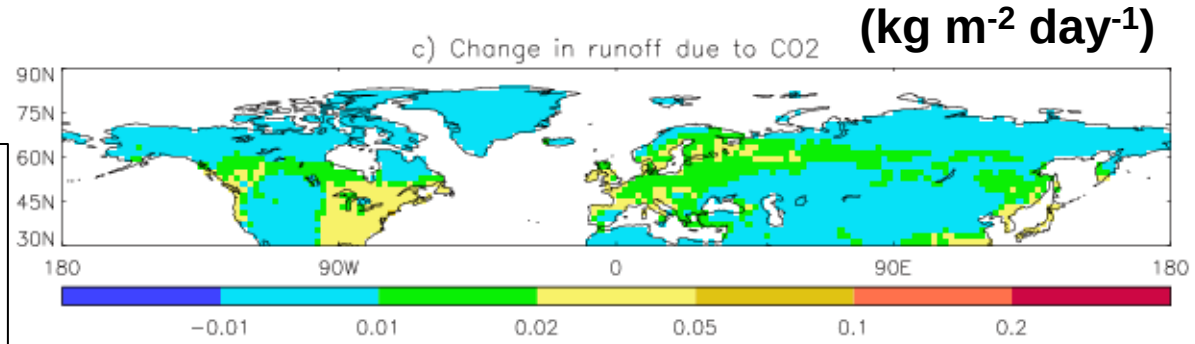

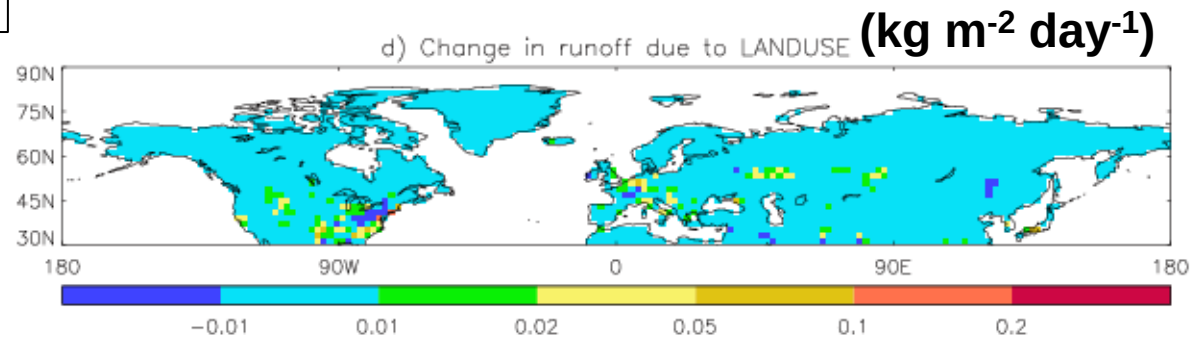

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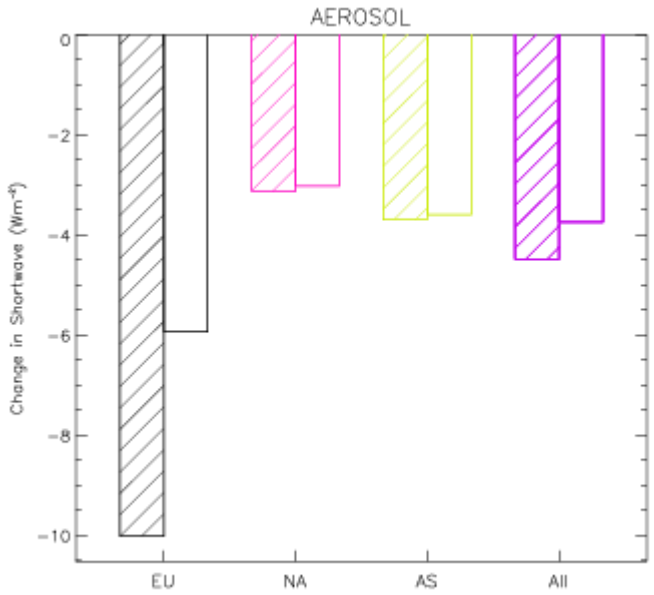

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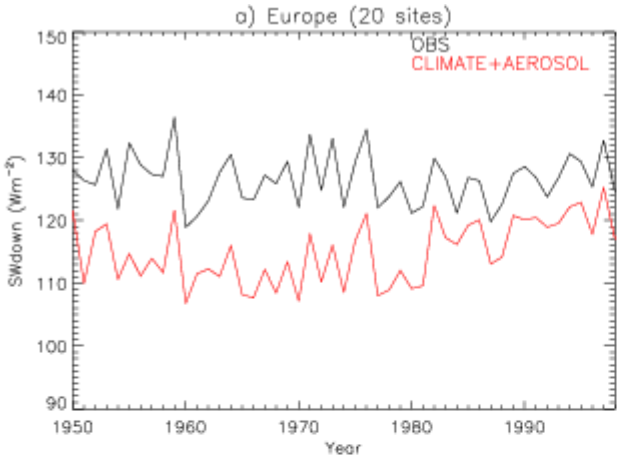

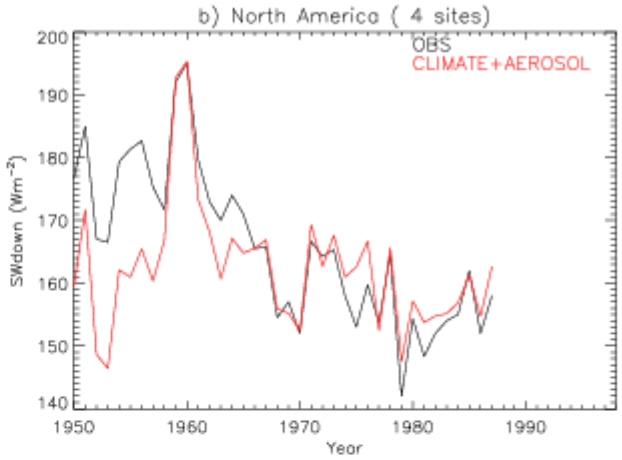

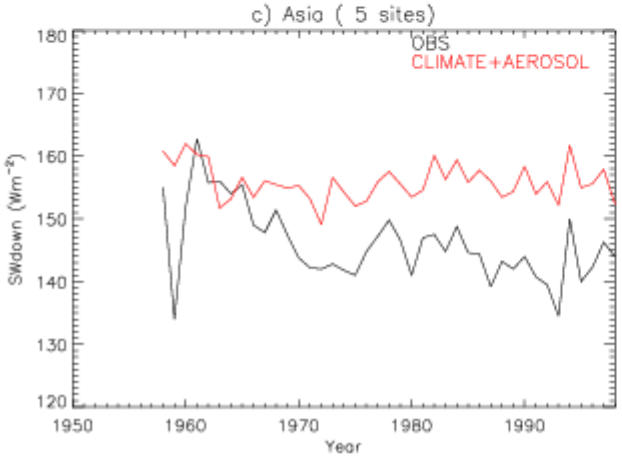

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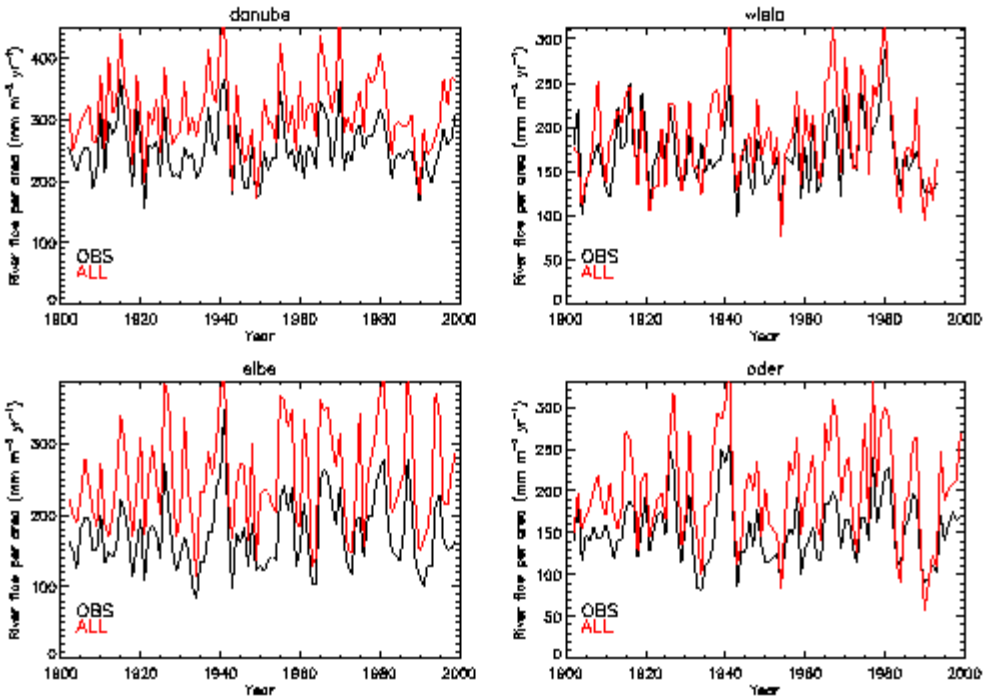

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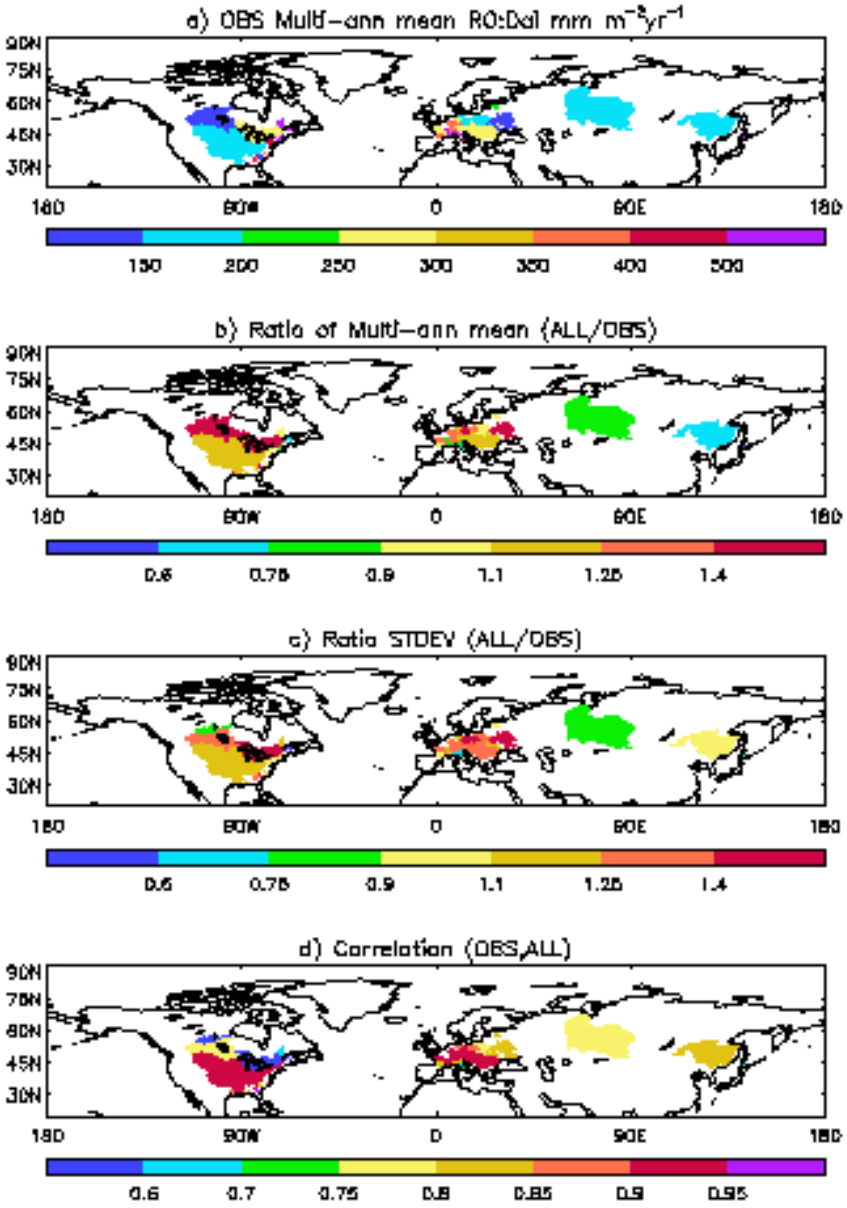

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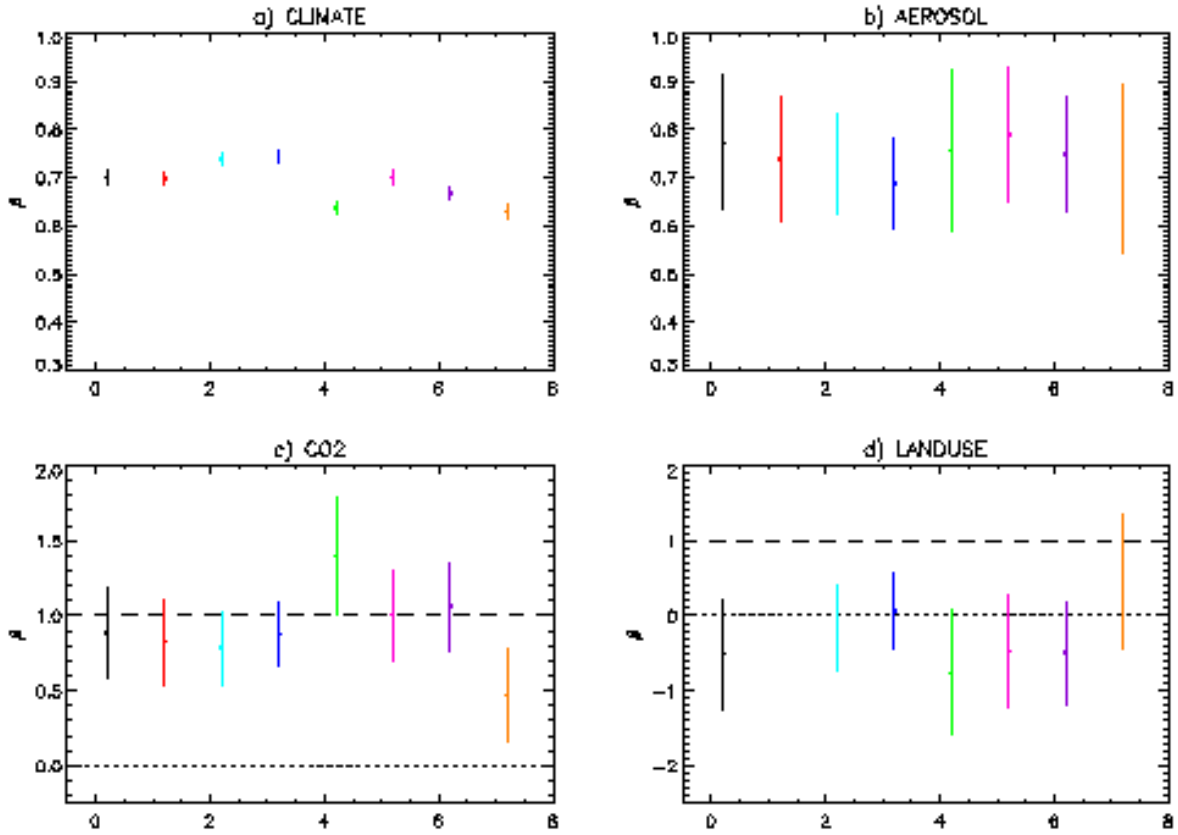

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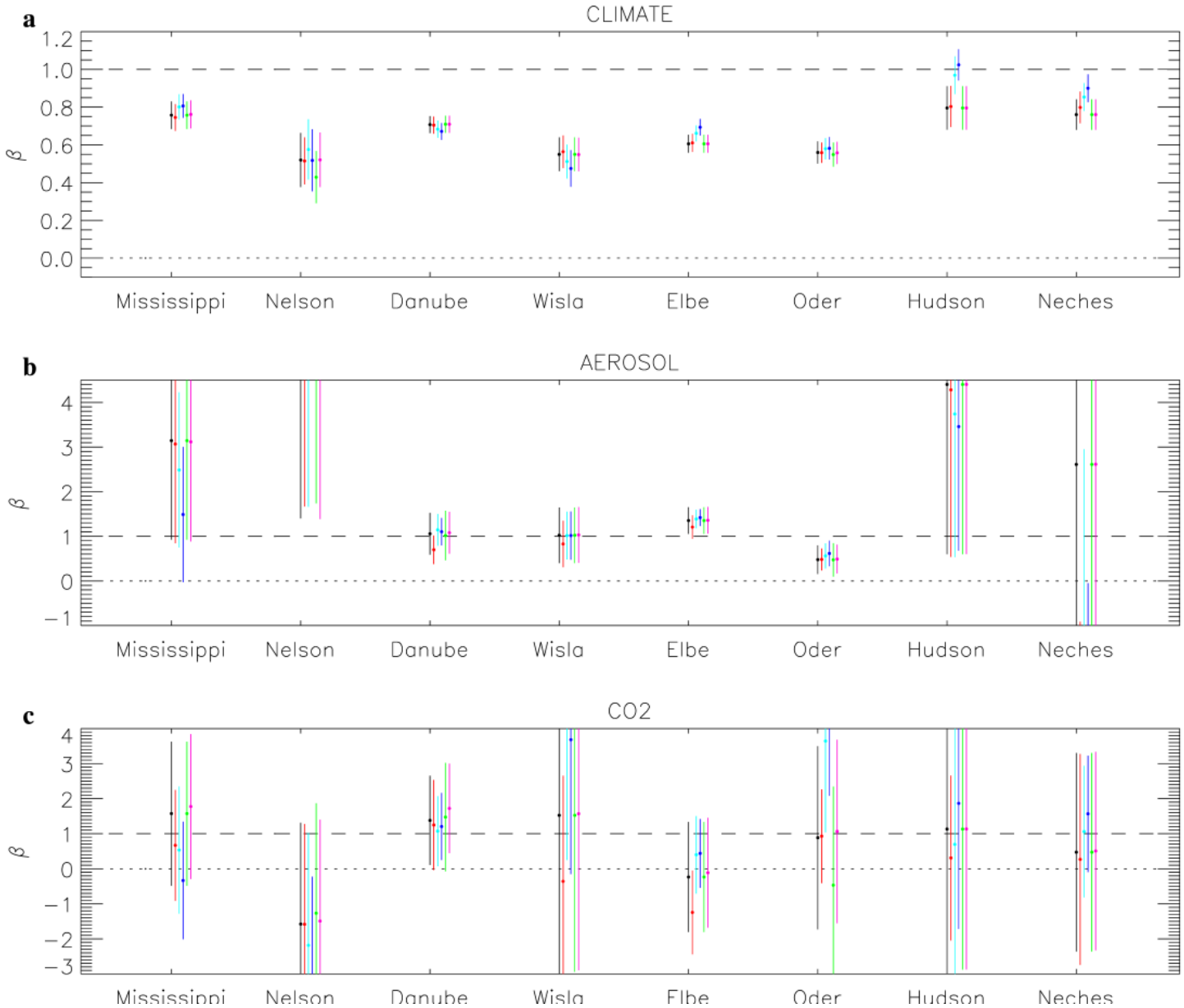

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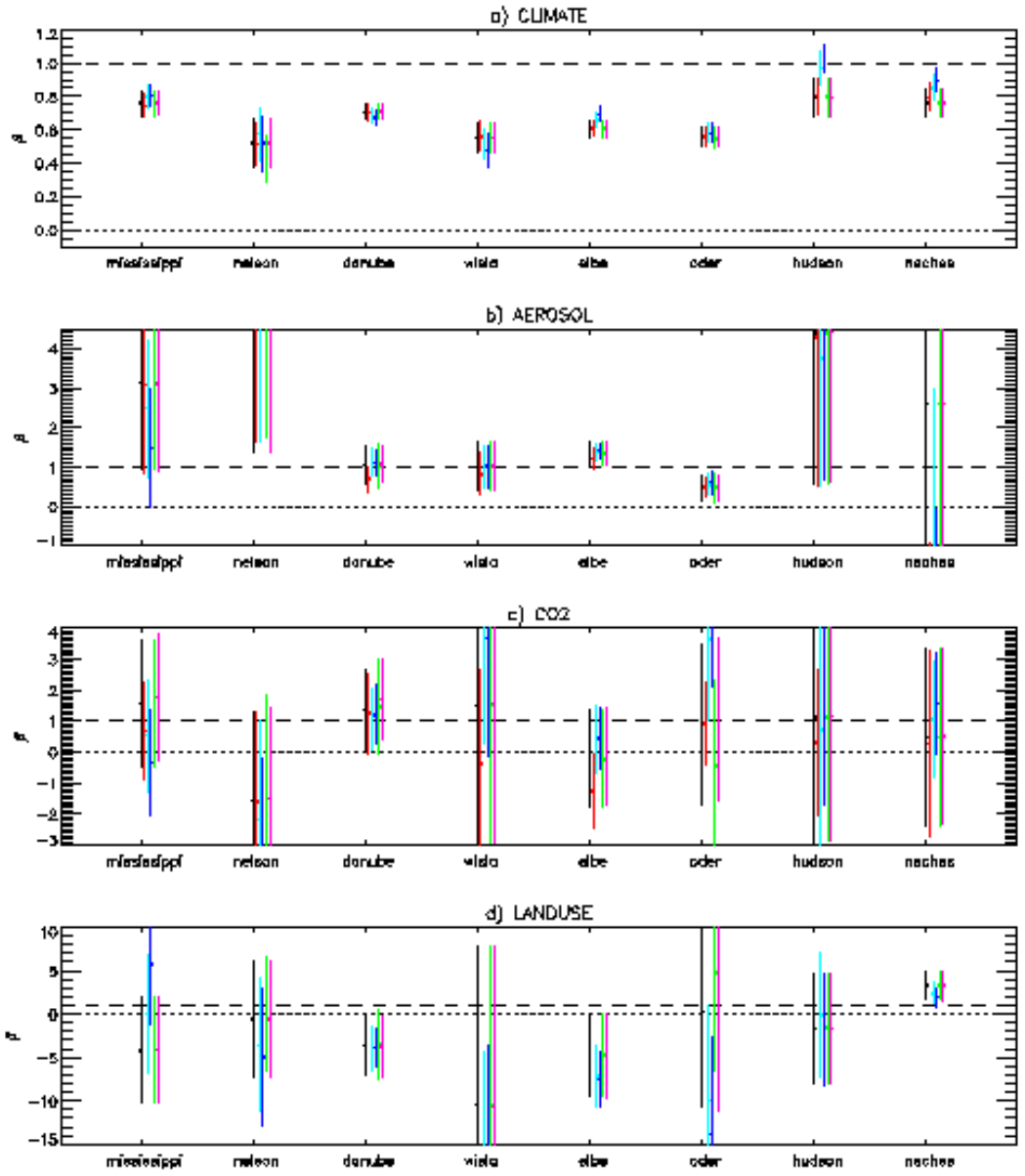

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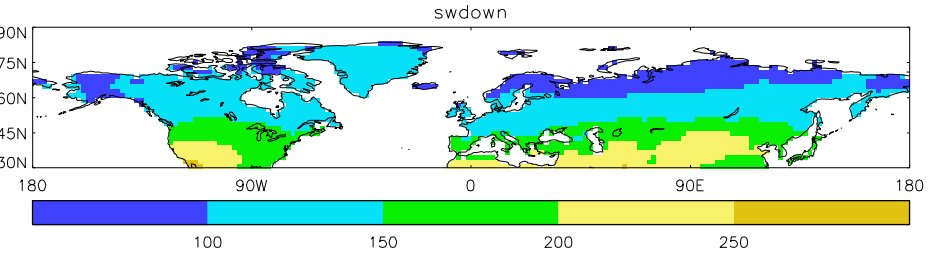
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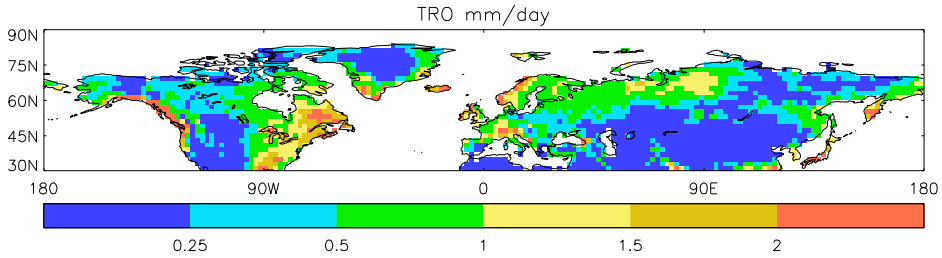
TRO mm/day
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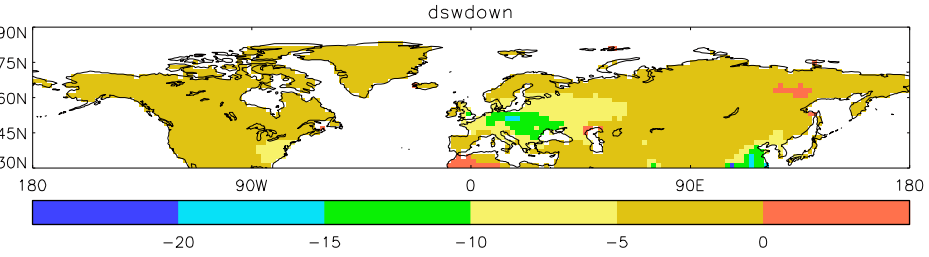
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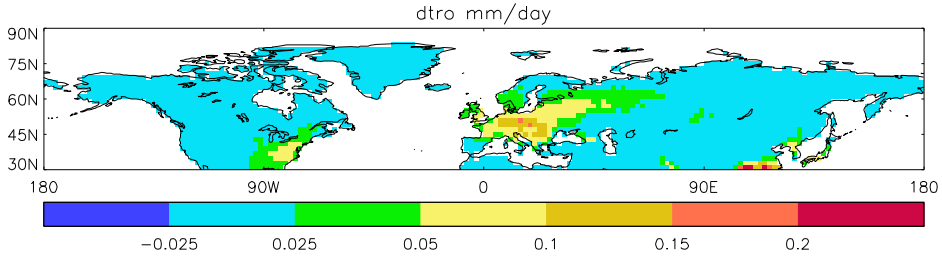
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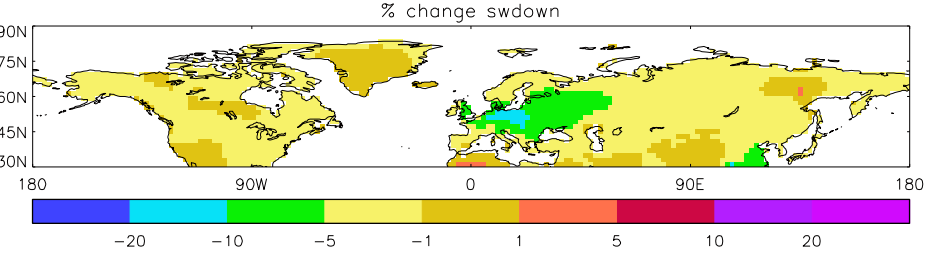
% change swdown
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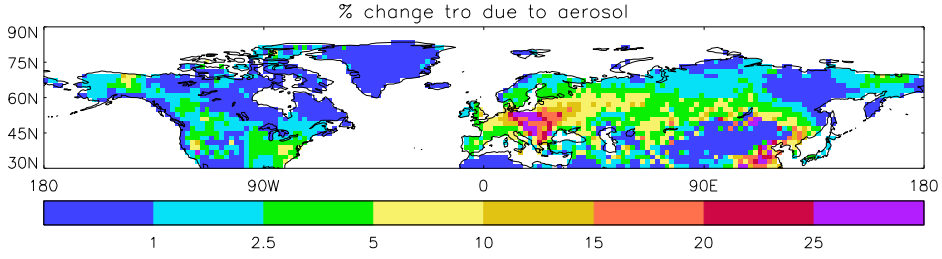
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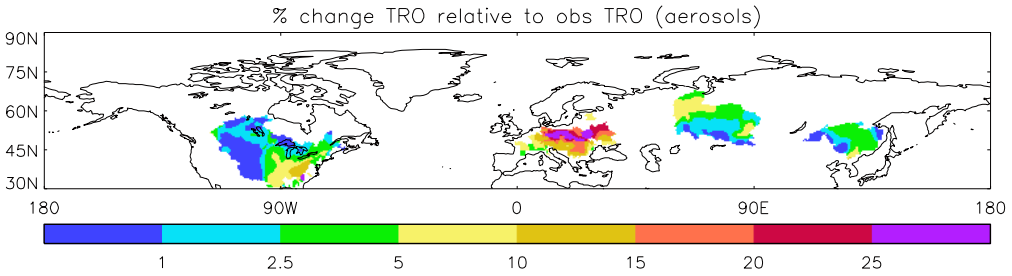

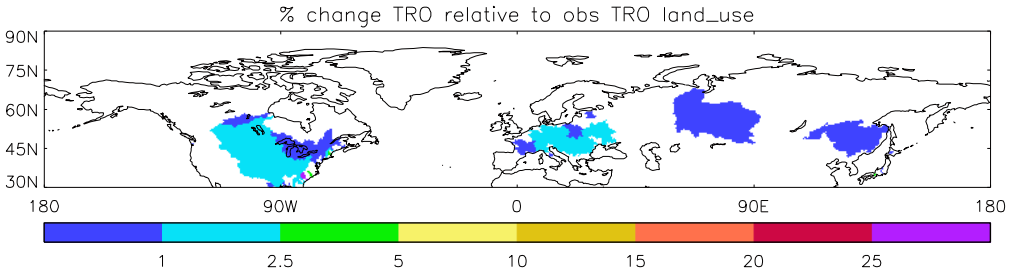

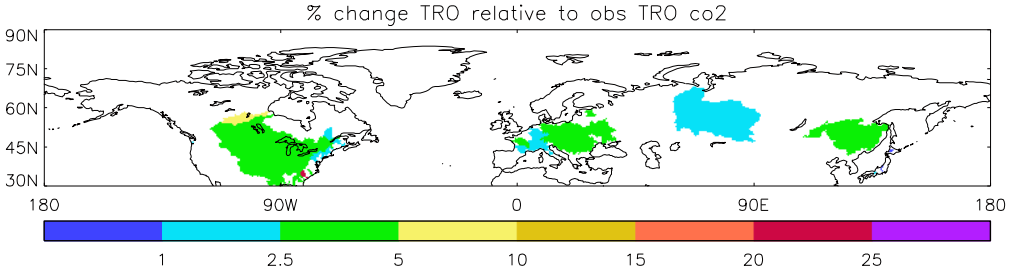

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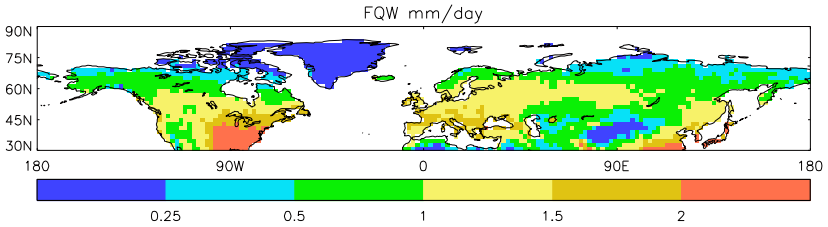

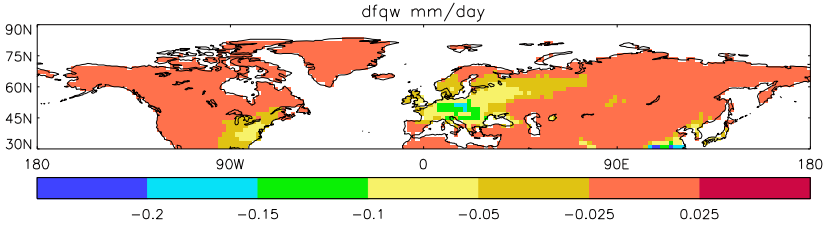

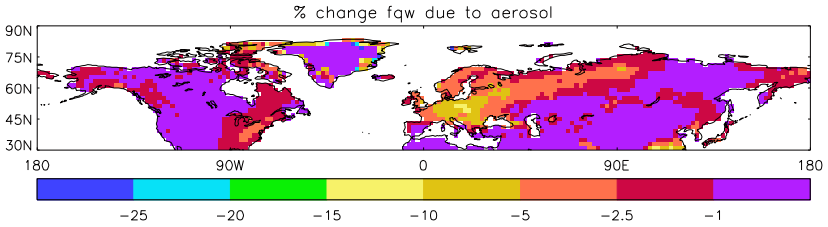

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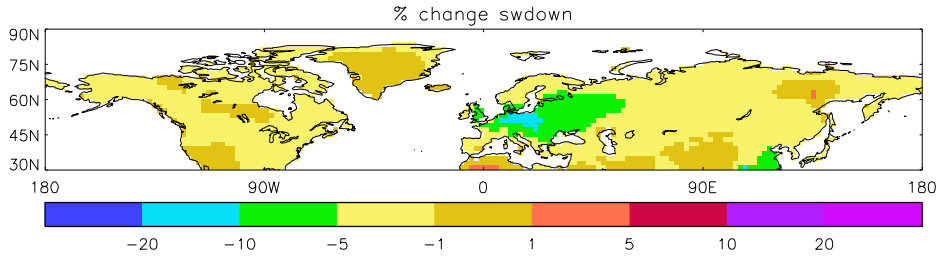
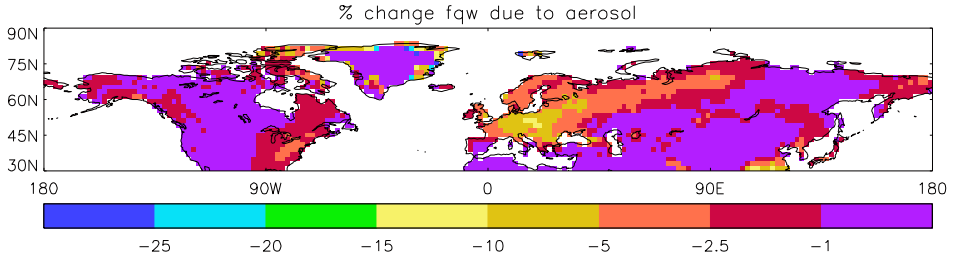
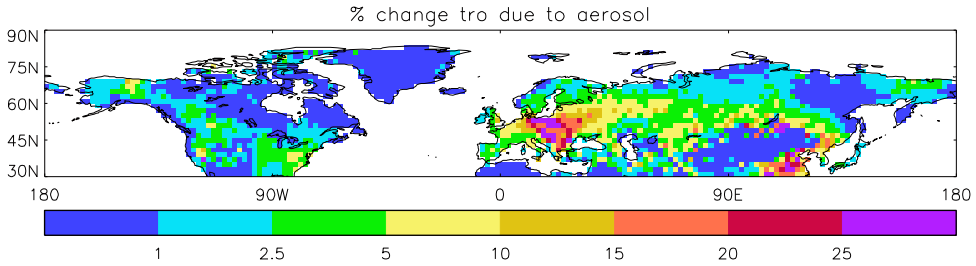
Modelled changes between: 1900s & [1975-1984]







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Refinements to Gedney et al, 2006 setup

No inter-basin infilling of river flow measurements

Basin average river flow data

Longer time series

Improved aerosol representation

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