Detecting solar dimming in observed river flow
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(Gedney, Huntingford, Weedon, Boucher & Cox, Nat. Geosci. 2014)
• Potential drivers of changes in river flow
• Experimental setup
• Model evaluation
• Modelled responses to drivers
• Analysis and attribution
• Conclusions
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
Exptal Setup

JULES forced Off-line with WATCH forcing data over the Northern Hemisphere at 2° resolution.

WATCH forcing (Weedon et al, 2011):

- resolution: 0.5°; 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
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:

- CLIMATE=“Climate-only”
- LANDUSE=“Climate-Landuse” - “Climate-Only”
- CO2 “stomatal effect” =“Clim-CO2” - “Climate-Only”
- AEROSOL “radiative effects“ =“Clim-Aerosol” - “Climate-Only”
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

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

Danube

Wisla

Linear correlation with obs

Percentage error in long-term mean
Modelled changes between: 1900s & [1975-1984]

- % dSW (AEROSOL):
- % dRO AEROSOL:
- dRO (kg/m²/day) AEROSOL:
- dRO CO2:
- dRO LANDUSE:
Analysing which factors are driving changes in river flow

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

\[ X_{\text{obs}} = \sum \beta_i X_{\text{mod}} \]

\[ X_{\text{obs}} = \beta_{\text{CLIMATE}} X_{\text{CLIMATE}} + \beta_{\text{LANDUSE}} X_{\text{LANDUSE}} + \beta_{\text{CO2}} X_{\text{CO2}} + \beta_{\text{AEROSOL}} X_{\text{AEROSOL}} \]

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

No basins with significant permafrost & irrigation.
Modelled 20th century regional runoff changes

Modelled

Attributed

5 to 95% β ranges

Detected signals
Annual mean river flow for Danube and Wisla

- **a** Annual total
- **b** Annual anomalies
- **c** Annual anomalies \((βX)\)

**Obs All**

**CLIMATE**

- Fit

**LANDUSE**

- CO2
- AEROSOL
Regression analysis also applied to individual basins:

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

• Aerosol effect over other regions.

• Indirect effects of aerosols on cloud cover and rainfall

• Application to other influences e.g:
  • Deforestation
  • Irrigation

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.
Aerosol optical depth in HadGEM1

Present-day total aerosol optical depth is small compared to ground-based and satellite retrievals
Aerosol optical depth in HadGEM2-ES

Improvements yield a much better comparison against observed total aerosol optical depth
Modelled changes
Between: 1900s & [1975-1984]
Also detect aerosol dimming at the 5% significance level over individual basins.
Modelled changes between: 1900s & [1975-1984]
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