Sensitivity of global ecosystems to climate anomalies in observations and models

Diego Miralles

Contributions from: Matthias Demuzere, Christina Papagiannopoulou, Willem Waegeman, Stijn Decubber, Niko Verhoest, Wouter Dorigo
To provide new evidence of how hydro-climatic extremes have changed over the satellite era

To show the extent to which ESMs reproduce these extreme events

Climate models predict an aggravation of droughts, extreme precipitation events and heatwaves as we progress into the future.

However, the recent Intergovernmental Panel of Climate Change (IPCC) AR5 report remains inconclusive on this matter, revealing large discrepancies in the model projections of these extremes. These uncertainties obstruct the adequate long-term management and societal adaptation.

Objectives

1. To provide new evidence of how hydro-climatic extremes have changed over the satellite era

2. To provide new insights into past changes in vegetation and their sensitivity to climatic extremes

3. To show the extent to which ESMs reproduce these extremes
① Mostly satellite-based:
   - Land and near-surface air temperature (7 datasets)
   - Incoming short/long radiation (2 datasets)
   - Precipitation (8 datasets)
   - Snow water equivalent (1 dataset)

② Construction of 'higher-level features':
   - De-trended seasonal anomalies
   - Lagged variables
   - Past cumulative variables
   - Extreme indices, etc.

3,884 climatic variables (monthly, 1° x 1°)

De-trended seasonal anomalies of vegetation 'observations': NDVI, VOD, EVI, LAI, SIF
1. Mostly satellite-based:
   - Land and near-surface air temperature (7 datasets)
   - Incoming short/long radiation (2 datasets)
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2. Construction of 'higher-level features':
   - De-trended seasonal anomalies
   - Lagged variables
   - Past cumulative variables
   - Extreme indices, etc.

1. Nonlinear Granger-causality framework
   - Baseline prediction model based on past vegetation
   - Full random forest model based on a past vegetation plus the whole input data-cube

De-trended seasonal anomalies of vegetation 'observations': NDVI, VOD, EVI, LAL, SIF
A non-linear Granger-causality framework to investigate climate–vegetation dynamics

Christina Papagiannopoulou¹, Diego G. Miralles²,³, Stijn Decubber¹, Matthias Demuzere², Niko E. C. Verhoest², Wouter A. Dorigo¹, and Willem Waegeman¹

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Explained vegetation variance → Granger causality
Potential to isolate the effect of:

1. Particular climatic variables
2. Past time lags & cumulative periods

Main controls over vegetation

Environmental Research Letters
Vegetation anomalies caused by antecedent precipitation in most of the world
Christina Papagiannopoulou¹, Diego G. Miralles², Wouter Dorigo³, Niko Verhoest⁴, Mathieu Depoorter⁵, Willem Waegeman⁶

61% of world's vegetated land primarily limited by water
Radiation and temperature yield immediate anomalies. Their effects dissipate shortly, contrary to water.
✓ Previously reported range: [20–45]% | Ours: 61%

1. Quantify non-linear impacts of climate on vegetation, including extremes, lagged and cumulative responses

2. Way to disentangle the co-linearity between radiation/temperature and precipitation

Papagianopoulou et al. (2017, ERL)

Nemani et al. (2003, Science)

Wu et al. (2015, GCB)

Seddon et al. (2016, Nature)
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② Way to disentangle the co-linearity between radiation/temperature and precipitation

Papagiannopoulou et al. (2017, ERL)

Nemani et al. (2003, Science)

Wu et al. (2015, GCB)

Change in soil moisture drought  
IPCC AR4 (2007)

Seddon et al. (2016, Nature)
To provide new evidence of how hydro-climatic extremes have changed over the satellite era.

To provide new insights into past changes in vegetation and their sensitivity to climatic extremes.

Climate models predict an aggravation of droughts, extreme precipitation events and heatwaves as we progress into the future.

However, the recent Intergovernmental Panel of Climate Change (IPCC) AR5-report remains inconclusive on this matter, revealing large discrepancies in the model projections of these extremes. These uncertainties obstruct the adequate long-term management and societal adaptation.
### Model Land Model Reference
- **BCC-CSM1** BCC-AVIM1.0 *Wu et al. (2013)*
- **BNU-ESM** CoLM + BNU-DGVM  
- **CanESM2** CLASS2.7 + CTEM1  
- **GFDL-ESM2M** LM3  
- **INM-CM4** Simple model  
- **MIROC-ESM** MATSIRO + SEIB-DGVM

### Land Resolution
- **DGVM**
    - **Y**: Yes
    - **N**: No
- **Reference**
    - *Wu et al. (2013)*
    - *http://esg.bnu.edu.cn*
    - *Arora et al. (2011)*
    - *Dunne et al. (2013)*
    - *Voldin et al. (2010)*
    - *Watanabe et al. (2011)*

### Selected variables (available daily, except target variable LAI)

<table>
<thead>
<tr>
<th>Name</th>
<th>Long name</th>
<th>Unit</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>tas</td>
<td>Near-Surface Air Temperature</td>
<td>K</td>
<td></td>
</tr>
<tr>
<td>pr</td>
<td>Precipitation</td>
<td>kg/m² s</td>
<td></td>
</tr>
<tr>
<td>snw</td>
<td>Surface snow amount</td>
<td>kg/m²</td>
<td>Introduced as a proxy for snow water equivalent. I’ll probably remove this one</td>
</tr>
<tr>
<td>mrsos</td>
<td>Moisture in Upper Portion (10 cm) of Soil Column</td>
<td>kg/m²</td>
<td></td>
</tr>
<tr>
<td>rsds</td>
<td>Surface Downwelling Shortwave Radiation</td>
<td>W/m²</td>
<td>Only used to derive Net Radiation</td>
</tr>
<tr>
<td>rlds</td>
<td>Surface Downwelling Longwave Radiation</td>
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<td>rlus</td>
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Multi-dimensional data-cube to study biosphere–climate sensitivity

Non-linear G-causality framework based on random forests

Observational results confirm interactions are highly non-linear

Most continental land is driven by water availability