What is driving the change in vegetation productivity in northern Eurasia?

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1. Introduction

- Physiological response of plants to *[Morison & Morecroft, (2008)]:*
  - Temperature – optimum effect (bell shaped curve)
  - Water – affects hydraulics & chemistry
  - CO_2 – fertilization effect
  - Sunlight (cloudiness) – direct effect on photosynthesis
  - Fire – remove old growth / facilitate new growth
- Increasing seasonal cycle amplitude of atmospheric CO_2 concentration *[Myneni et al., 1997; Graven et al., 2013]*
- Most existing studies compare role of temperature and moisture in controlling vegetation productivity. Lack of consensus about dominant factor shows the uncertainty *[Nemani et al., 2003; Yi et al., 2013; Parida & Buermann, 2014]:*
  - Increasing temperature – dominant stimulatory role
  - Decreasing or lack of sustained increase in moisture – inhibitory role

2. Questions -> Hypothesis

- What are the main environmental factors driving vegetation changes in northern Eurasia?
  - Based on existing studies our hypothesis is that Temperature would be dominant in the colder north while Precipitation in the warmer and dryer south.
- How are the drivers affecting vegetation productivity? We hypothesize that:
  - Since the peak of productivity is in summer, the environmental factors should have the maximum impact in summer.
  - Temperature changes would lead to increasing productivity in the colder and wetter north and a decreasing productivity in the dryer and warmer south.
  - Precipitation would increase while cloudiness an fires would decrease productivity in a majority of the study area.

3. Data used

- Satellite derived GPP: GIMMS3g (Global Inventory Modeling & Mapping Studies) & VIP (Vegetation Index & Phenology).
- Flux tower GPP: The Free Fair-Use dataset from www.fluxdata.org
- Modeled GPP: LPJ-GUESS (Lund-Potsdam-Jena General Ecosystem Simulator) sensitivity runs.
- Temperature & Precipitation: Univ. of Delaware & CRU (Climatic Research Unit)
- Atmospheric concentration of CO_2: NOAA ESRL (National Oceanic and Atmospheric Administration – Earth System Research Laboratory)
- Cloudiness: CRU climatology
- Fire: GFED (Global Fire Emissions Database)

4. Accuracy of the model generated GPP data

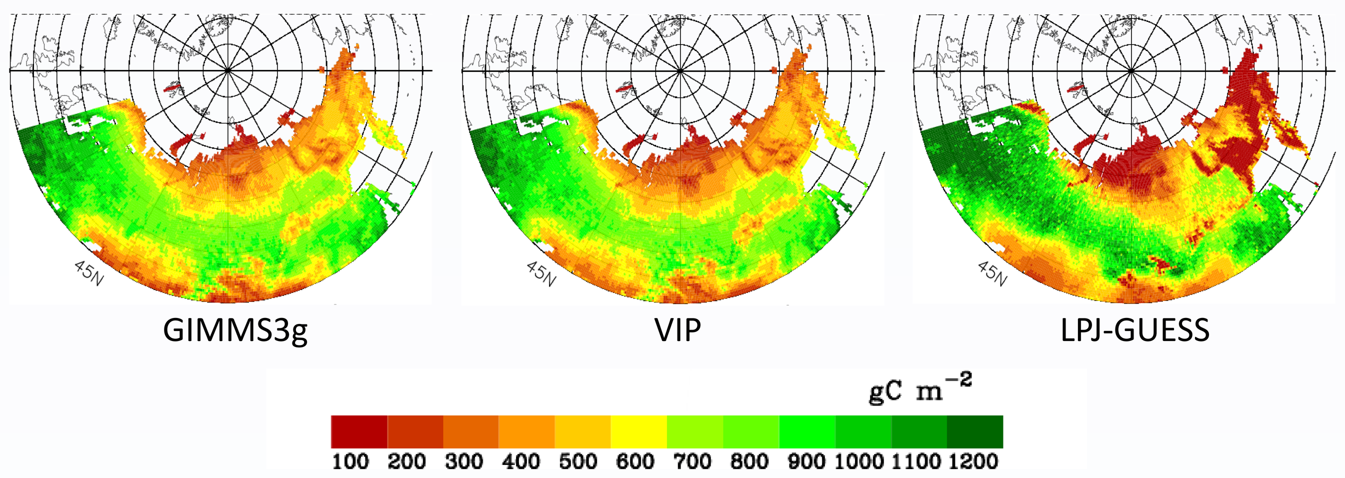
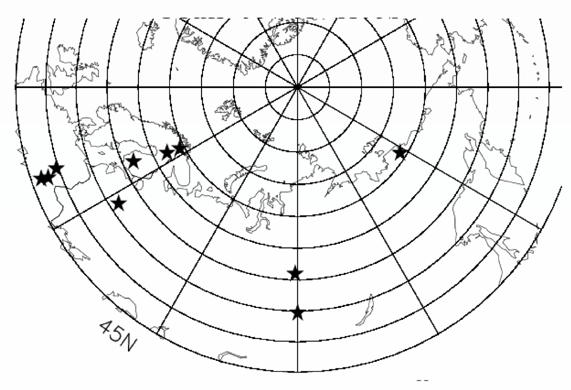


Fig 1. Annual mean Gross Primary Productivity (GPP) averaged over a 6 year period (2005 – 2010). GIMMS3g and VIP datasets are satellite data driven model estimates. LPJ-GUESS data simulated by the process based model.



	GIMMS3g	VIP	Mean
Annual	0.36	0.29	0.33
Spring	0.64	0.57	0.61
Summer	0.46	0.40	0.44
Fall	0.13	0.27	0.21

Fig 2 & Table 1. Validation of the GIMMS3g and VIP GPP datasets using data from 10 publicly available flux towers. Map (left) shows the distribution of the flux towers. Table (right) shows the Nash-Sutcliffe efficiency values, which indicates how well the plot of observed versus simulated data fits the 1:1 line. Values range from –Inf to 1. The closer to 1, the more accurate the model is.

5. Trend & seasonality of satellite derived GPP

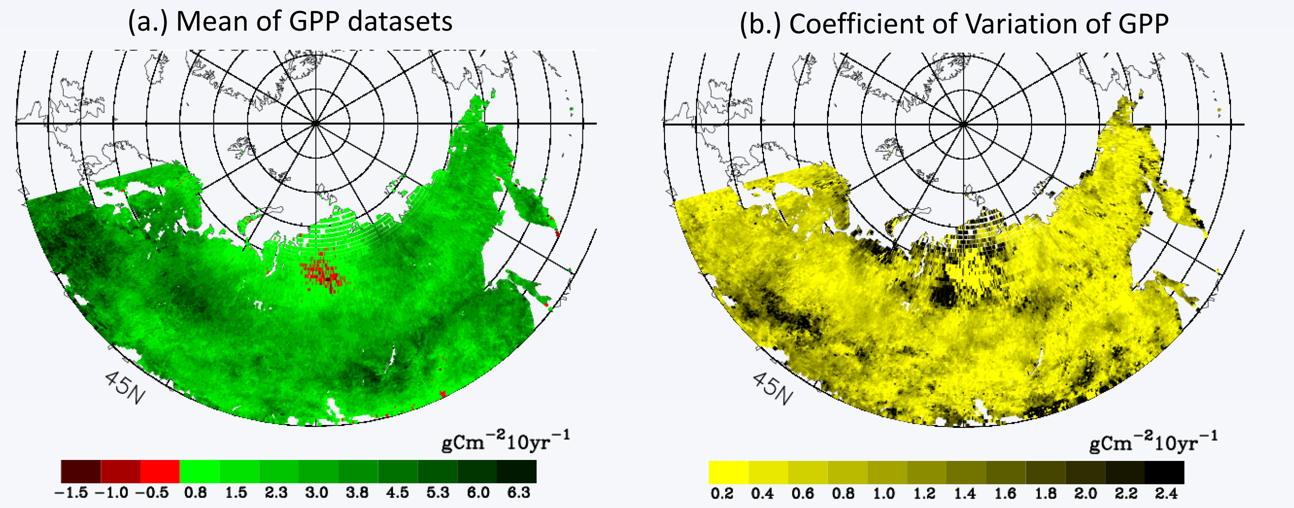


Fig 3. Trend map of the annual values of the satellite derived GPP datasets (1982 – 2008). (a.) Mean trend of the two datasets. (b.) Spatial uncertainty (coefficient of variation).

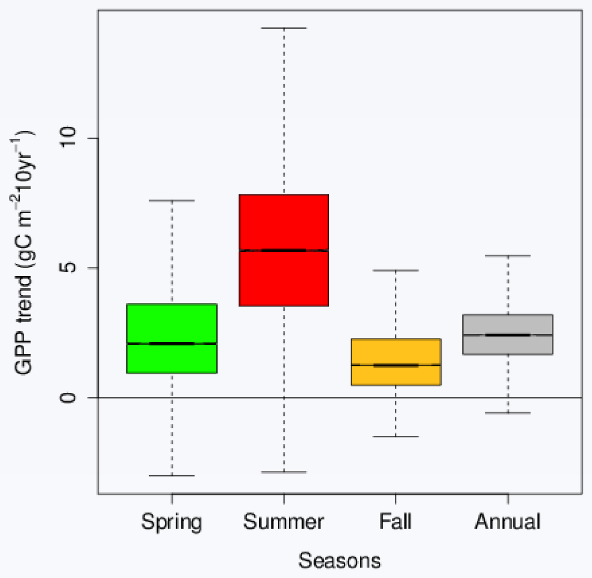


Fig 4. Distributions of seasonal GPP trends for satellite derived GPP (mean to 2 databases). GPP trends are predominantly above zero. For a majority of the region, the GPP trends are highest for summer.

6. Trend of environmental drivers

	Pos. trend (% of area)	Neg. trend (% of area)	Trend 10yrs^{-1} (regional mean)	Coefficient of Variation
Temperature	0.6%	0.1%	0.45 °C	0.4
Precipitation	17.1%	9.3%	0.4 mm month^{-1}	5.9
Cloudiness	6.0%	14.4%	-0.2% of pixel	4.8
Burnt Area	0.7%	0.3%	-0.9 hectares	20.6

Table 2. Trend statistics for environmental drivers. The 1st and 2nd columns list the fraction of the region demonstrating significant (95%) positive trends and negative trends respectively. The 3rd column is the regional mean trend of the drivers per decade. The 4th column is the coefficient of variation.

7. What influences GPP the most and when?

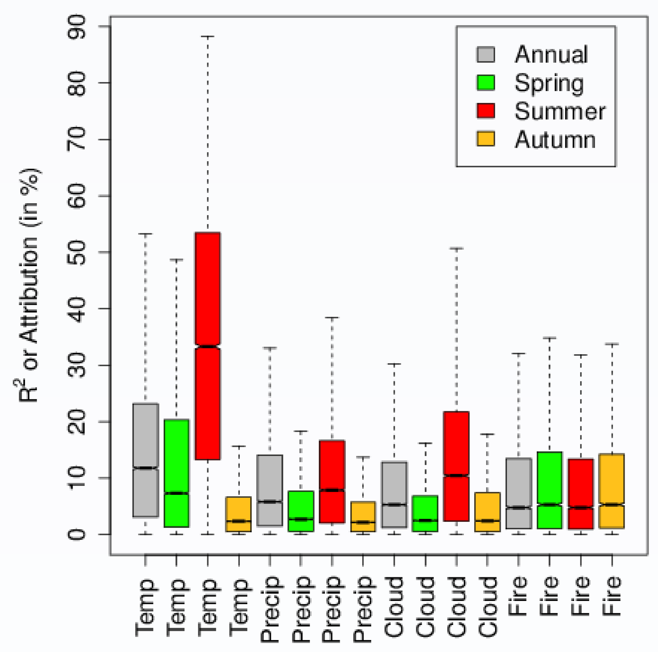


Fig 5. R^2 or the relative contribution of each environmental driver to the inter-annual variability in satellite derived GPP (both de-trended).

8. Correlation among the individual environmental drivers

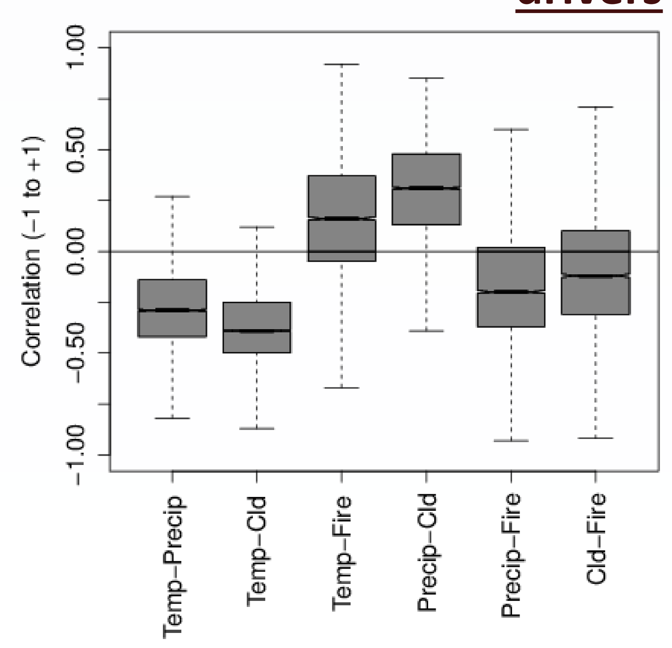


Fig 6. Distributions for correlation between each de-trended environmental driver.

9. How does GPP correlate with the environmental drivers?

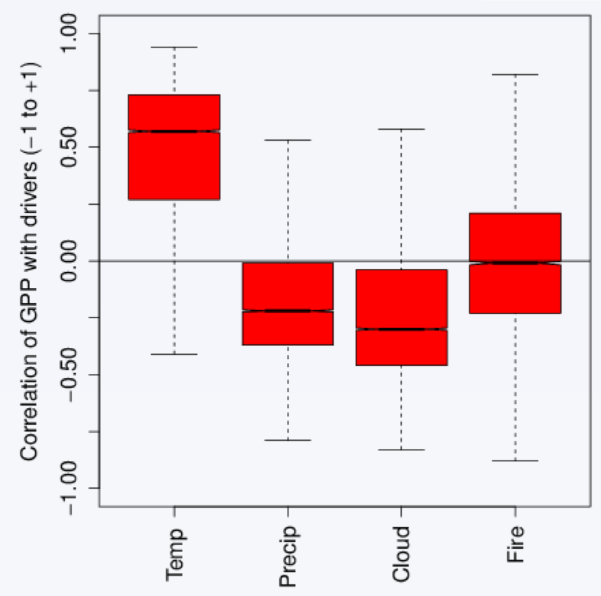


Fig 7. Distribution for correlation between de-trended satellite derived GPP and summer values of each de-trended environmental driver.

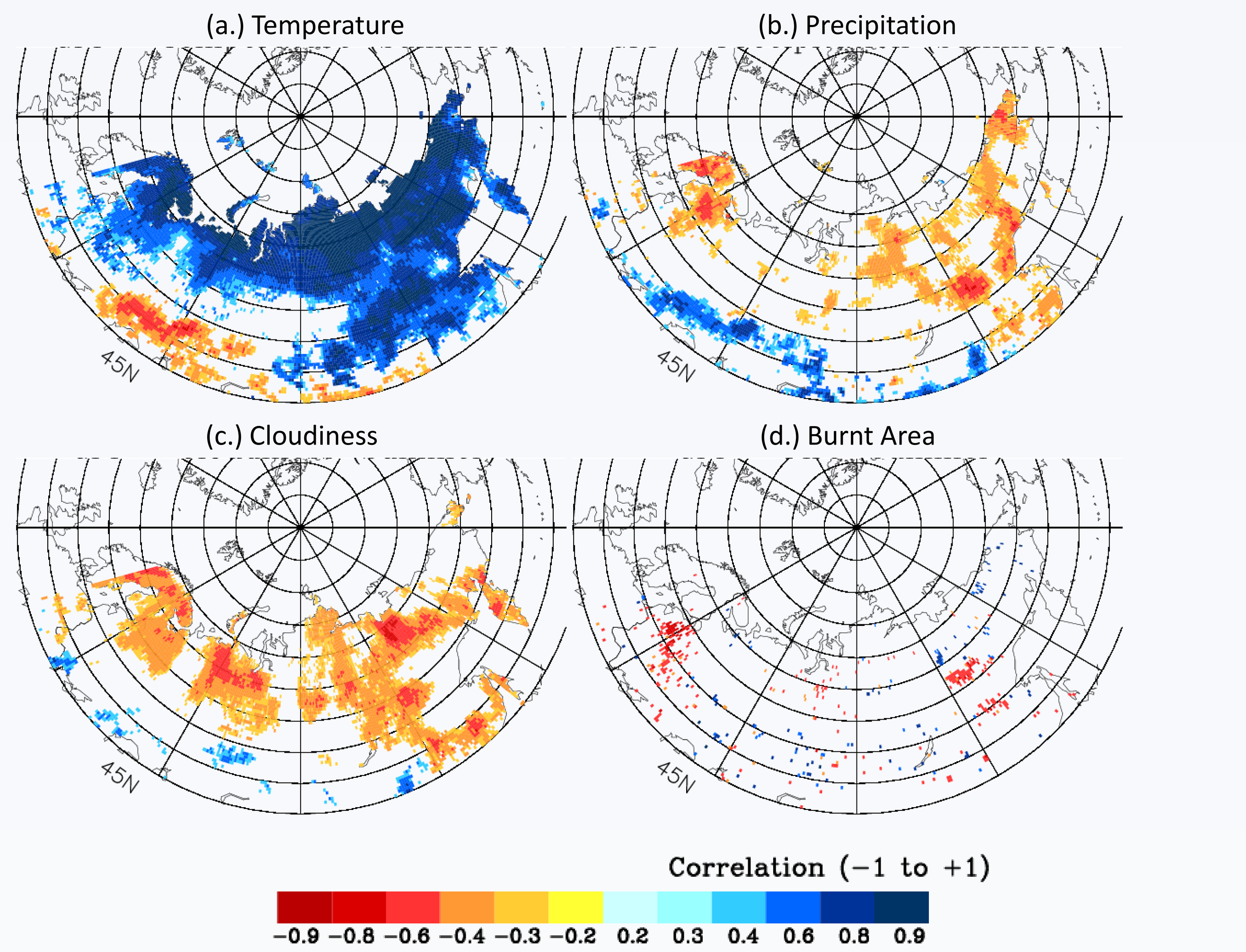


Fig 8. Maps showing area characterized by statistically significant (95%) correlation between de-trended values of annual satellite derived GPP and summer values of each environmental driver. Sub-figures show the correlation between GPP and (a) Temperature, (b) Precipitation, (c) Cloud cover and (d) Burnt area.

10. Assessing impacts of environmental drivers using process based model sensitivity simulations

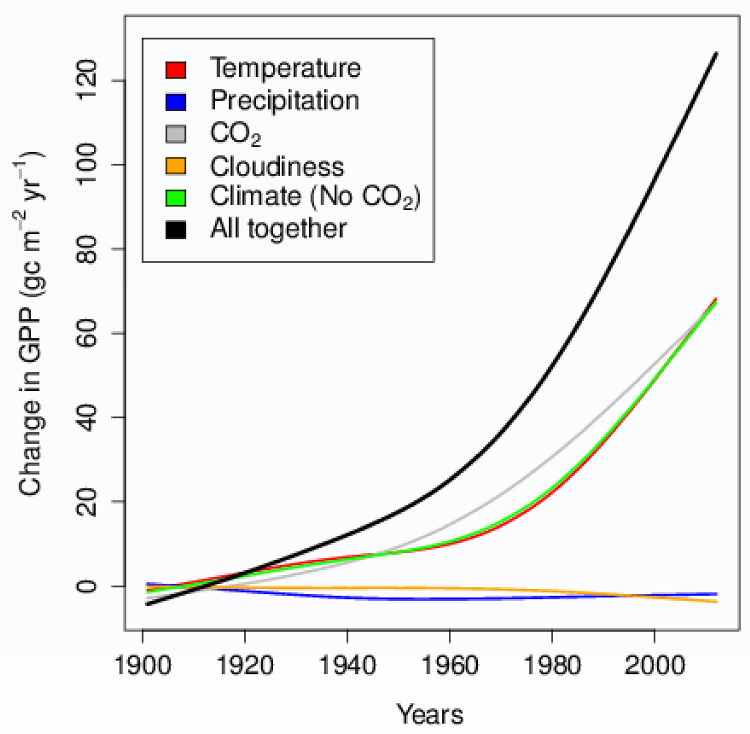


Fig 9 (Preliminary results). Demonstration of the effect of individual environmental drivers on GPP, i.e. process of photosynthesis by performing sensitivity runs with process based model LPJ-GUESS. To assess the impact of individual driver, simulations were carried out with one or a group of environmental drivers being kept constant and then subtracting the values of the resulting run from the control run.

11. Conclusions

- The trend in GPP is predominantly positive.
- Most of the increase in GPP is observed in summer, the peak of the growing season.
- Air temperature is the most dominant factor influencing temporal changes in vegetation with the highest impact being observed in summer. Except the relatively drier areas in the south-western part of the region, temperature has resulted in increasing productivity in most of northern Eurasia. This has also been reflected in the sensitivity study by LPJ-GUESS.
- Precipitation and Cloudiness has demonstrated a predominantly negative correlation with GPP in the north and positive in small areas in the south of the region. This has not however been reflected by LPJ-GUESS.
- Atmospheric CO_2 concentration, has been found to increase GPP by the study with LPJ-GUESS. This effect could not be assessed using spatially explicit statistical methods because of the nature of the CO_2 data.