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European Space Agency

Does Increasing Temperature Increase Carbonaceous Aerosol Direct Radiative Effect over Forests?

The Living Planet Fellowship

Tero Mielonen, A. Hienola, T. Kühn, J. Merikanto, A. Lipponen, T. Bergman, H. Korhonen, P. Kolmonen, L. Sogacheva, D. Ghent, A. Arola, G. de Leeuw, H. Kokkola,

Today's menu

- **Background**

- **Overview of the project**
  - Does **I**ncreasing **T**emperature **I**ncrease **C**arbonaceous **A**erosol Direct Radiative Effect over Boreal Forests?

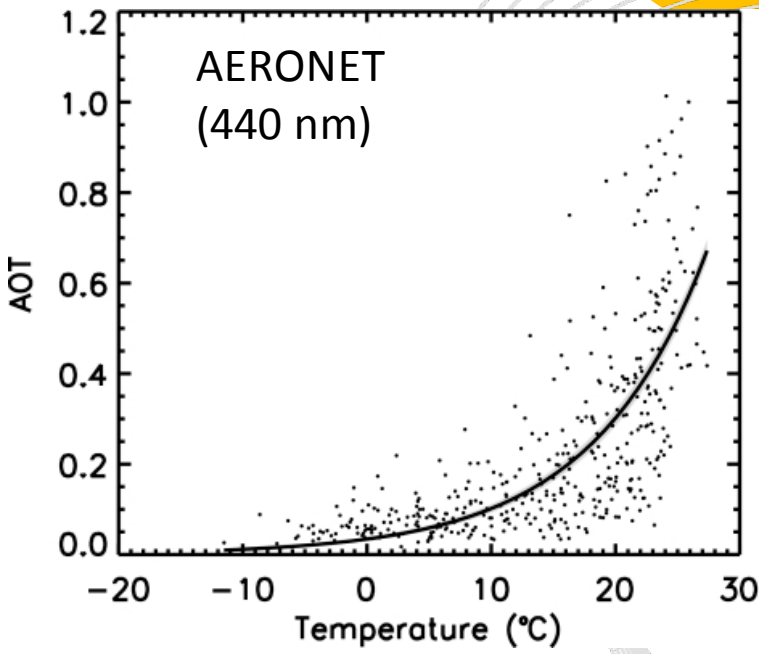
- **Results**
  - Southeastern US
  - Boreal forests in Russia
  - Future predictions

Background

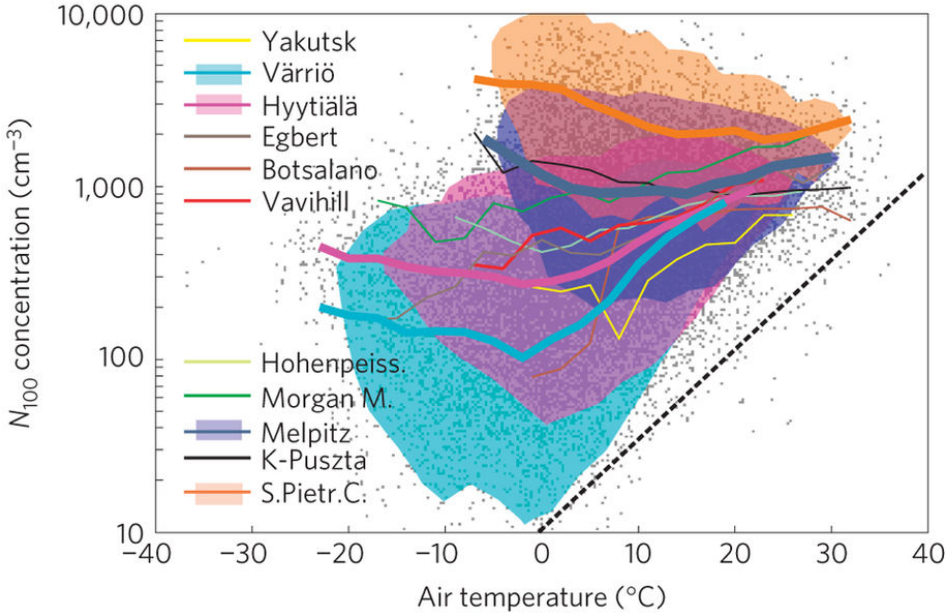
- Studies have shown that the amount of aerosols increase as temperature increase
- Aerosol cooling effects are strengthened by rising biogenic organic vapour (BVOC) emissions in response to warming

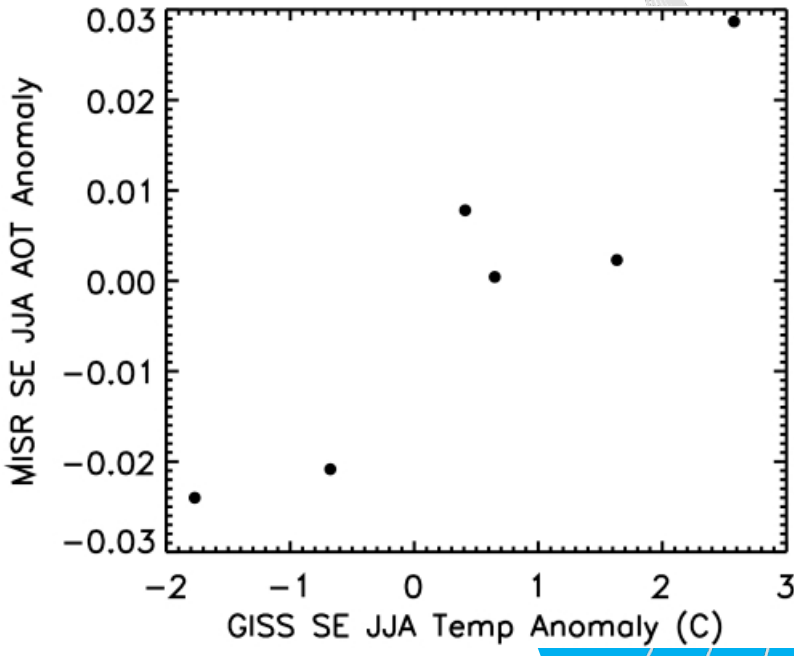
→ regional negative climate feedbacks in a warming climate

Goldstein et al., PNAS, 2009.



Paasonen et al., Nature Geoscience, 2013.





Objectives of the ITICA project

- investigate the causes of the positive correlation between AOD and LST and quantify their radiative effects

  - over the Southeastern US (Goldstein et al. 2009)
  - over boreal regions (Paasonen et al. 2013)

- estimate the significance of the negative feedback caused by a warming-induced increase in the aerosol direct radiative effect

Satellite products used in the project

(2005-2011, Level 3)

- AATSR Land surface temperature (LST): 200 GB (1.4 million files!)
- AATSR Aerosol Optical Depth (AOD): 10 GB
- AIRS Carbon Monoxide (CO): 1.4 TB
- OMI Nitrogen Dioxide (NO2): 30 GB
- MODIS Land cover types (IGBP): 12 GB
- MODIS Thermal Anomalies (FRP): ~ 100 MB

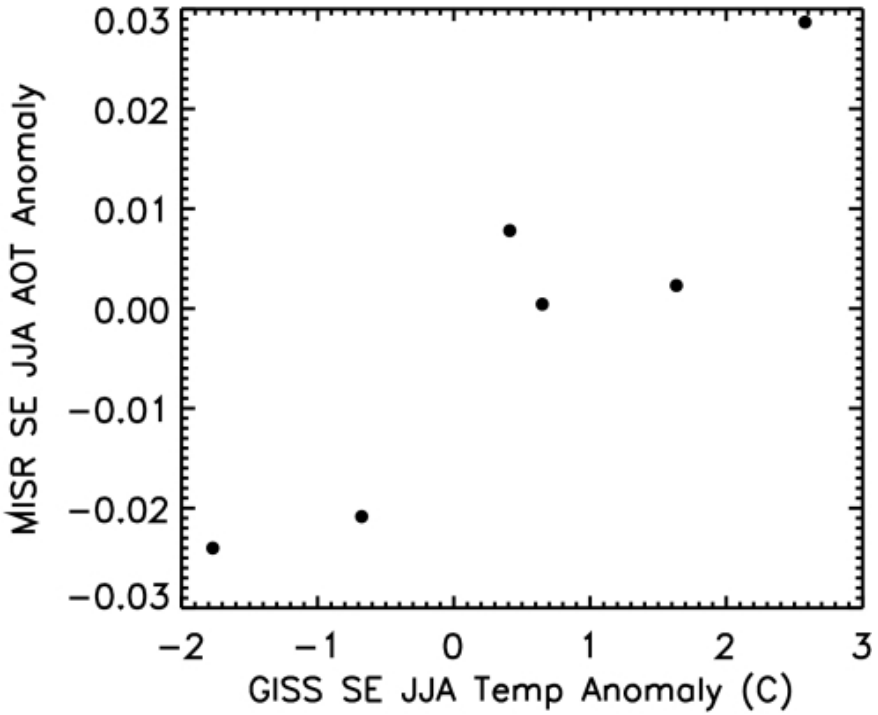
Products mainly collocated to a daily, 1x1 degree grid

Model simulations done in the project

- Four simulations with ECHAM6.1-HAM2.2-SALSA (about 3 TB each!)
  - CONTROL (2002-2010)
  - noBB: without biomass burning emissions
  - noBIOSOA: without biogenic SOA formation
  - noAQSOA: without SOA formed in aqueous phase

- Future simulations (RCP8.5)
  - CONTROL (2045-2055)
  - noBIOSOA

Results:
Southeastern US



Goldstein et al. (2009)
Years 2000-2005

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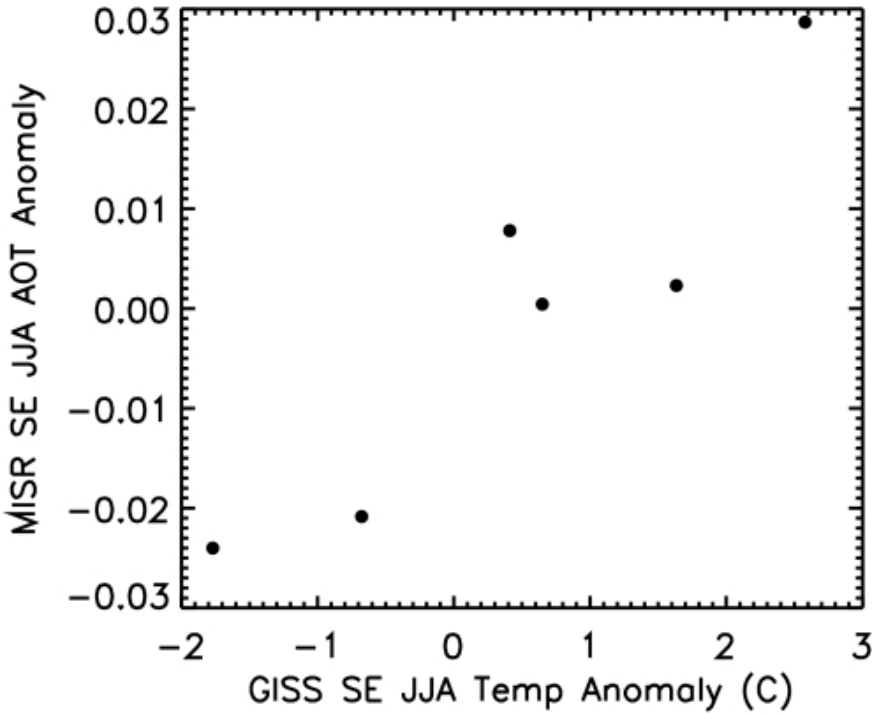

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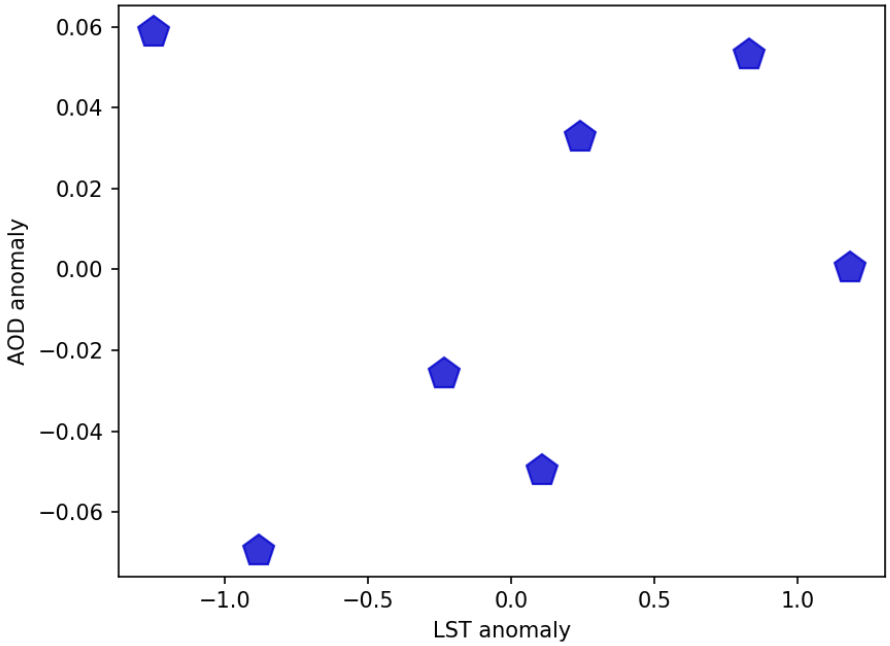
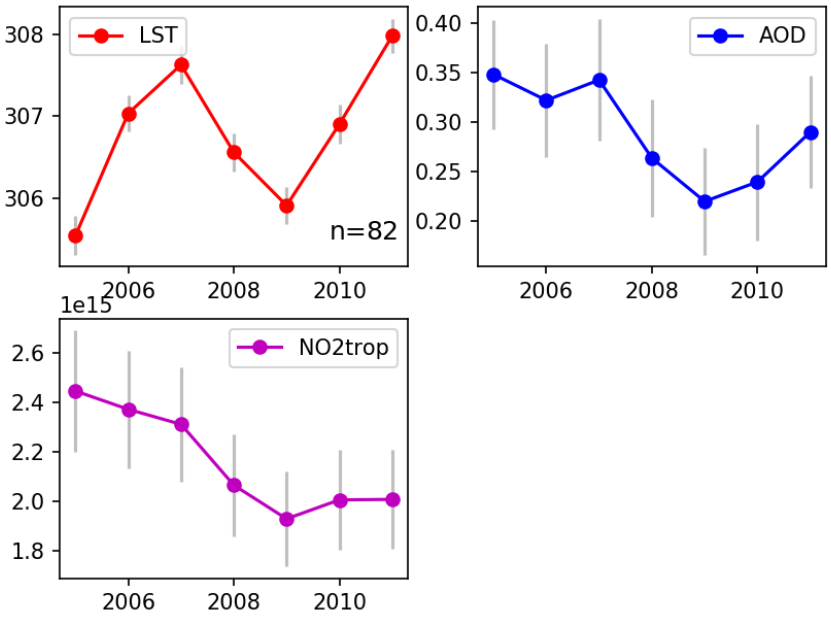


AATSR data (JJA)
Years 2005-2011

Results:
Comparison of summers in the southeastern US



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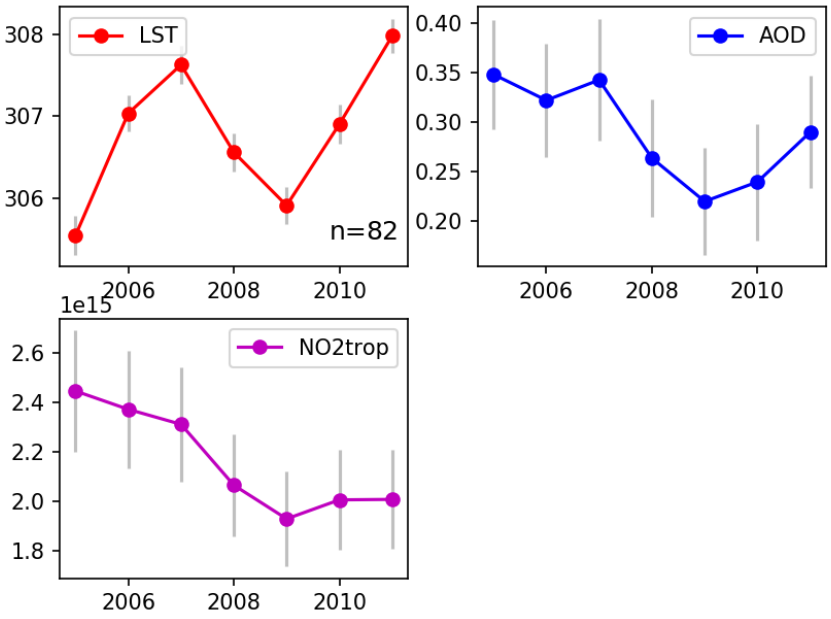

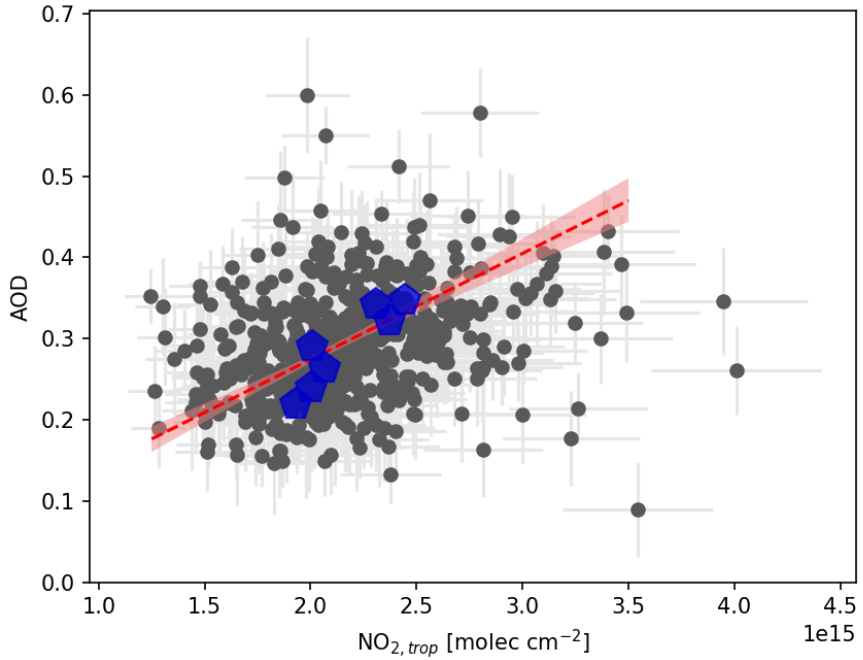

Results:
Calculation of “non-anthro” AOD

- anthropogenic contribution was estimated with a linear fit between the summertime AOD and tropospheric NO_2 columns ($AOD=1.31e^{-16}NO_{2,trop}+0.013$)
- with this relationship the anthropogenic AOD was estimated from the observed tropospheric NO_2 values
- the “non-anthro” AOD was estimated by subtracting the anthropogenic AOD from the total AOD

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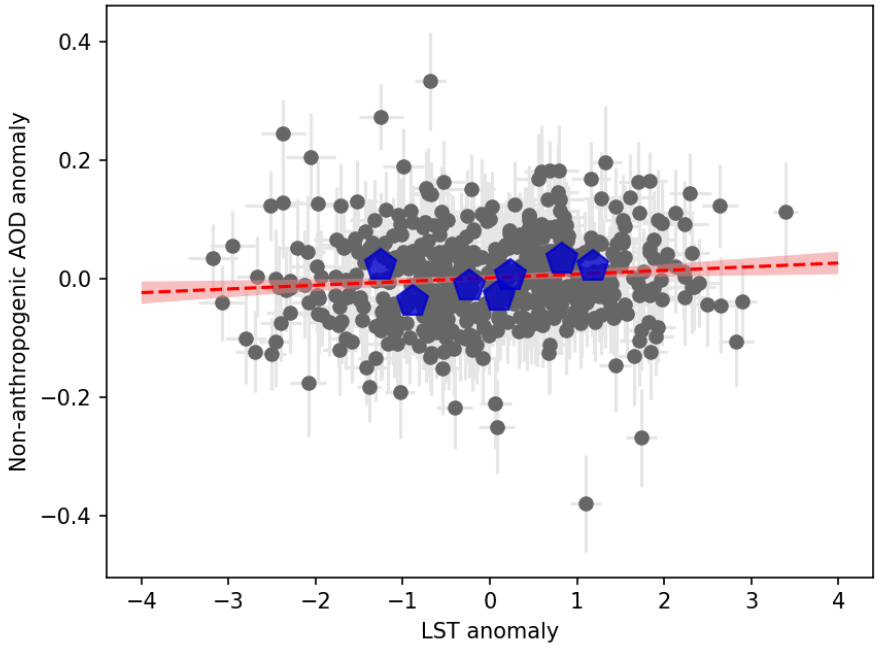

$AOD_{NA,ano}=0.006*LST_{ano}$ - 0.001

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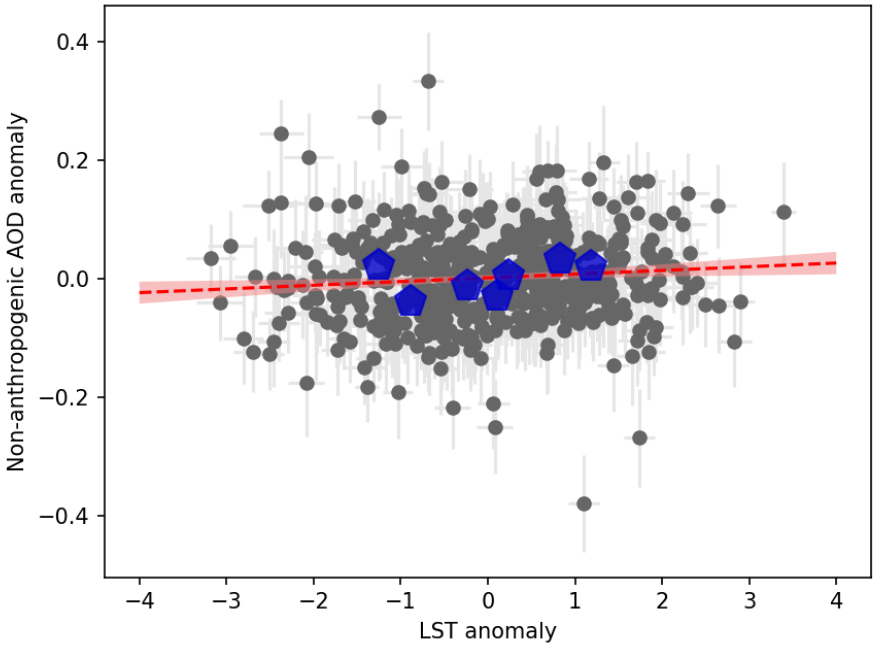
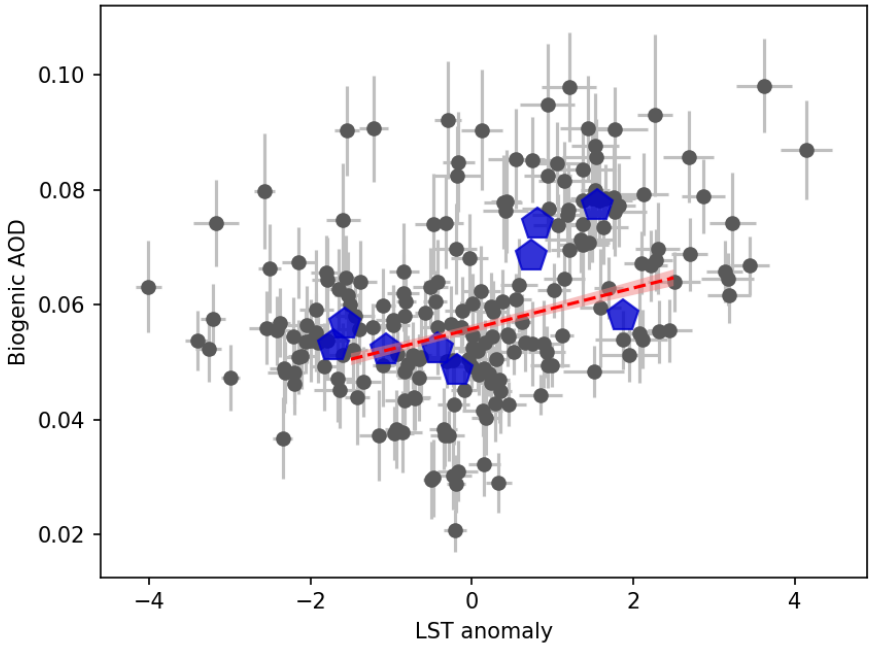
Model comparison



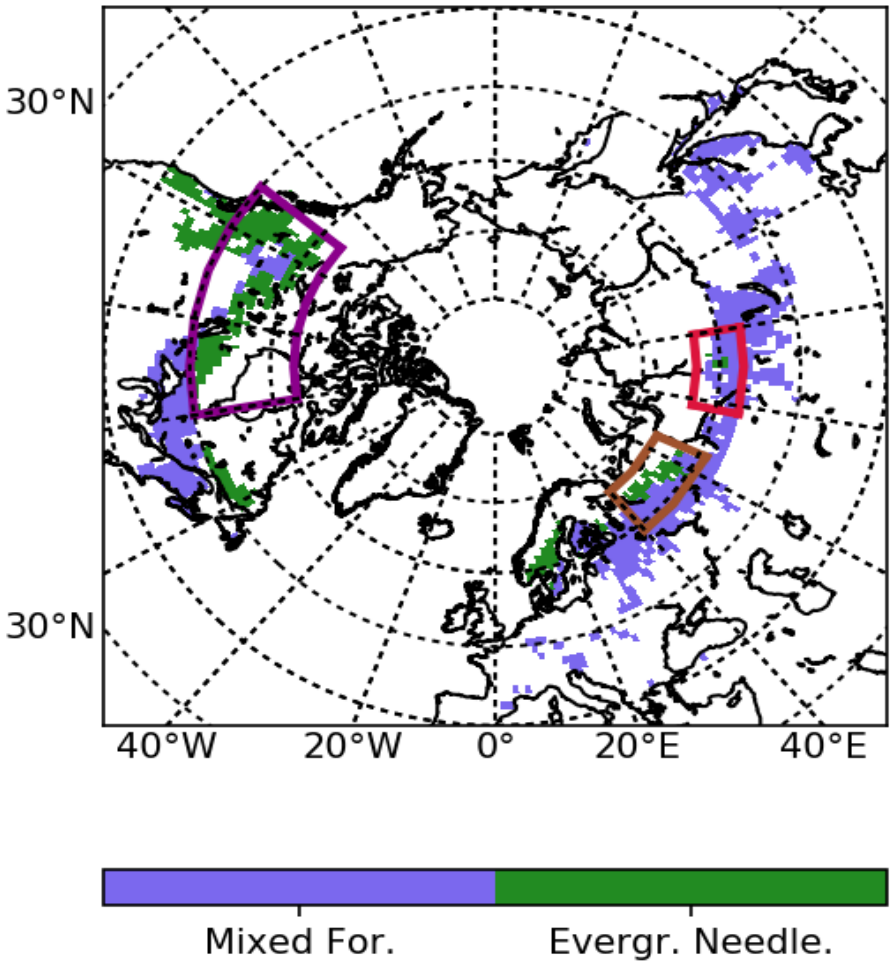


$AOD_{NA,ano}=0.006*LST_{ano} - 0.001$

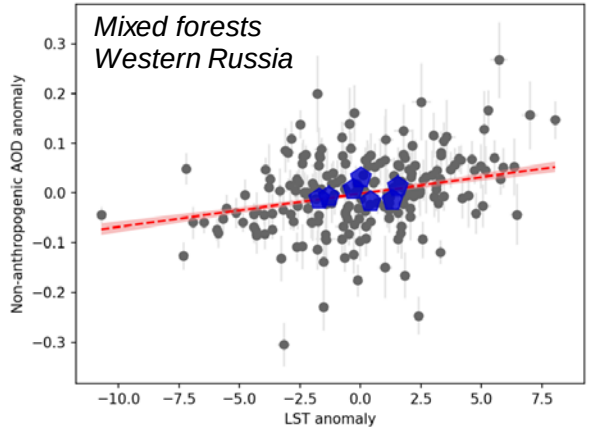
$AOD_{bio}=0.004*LST_{ano} + 0.056$

Mielonen et al., *Atmosphere*, in review.

Results:
Boreal regions



Results:
Western and Eastern Russia



$AOD_{NA,ano}=0.007*LST_{ano}$ - 0.001

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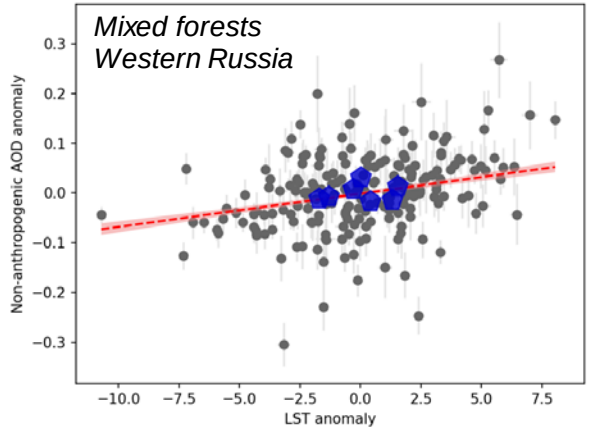

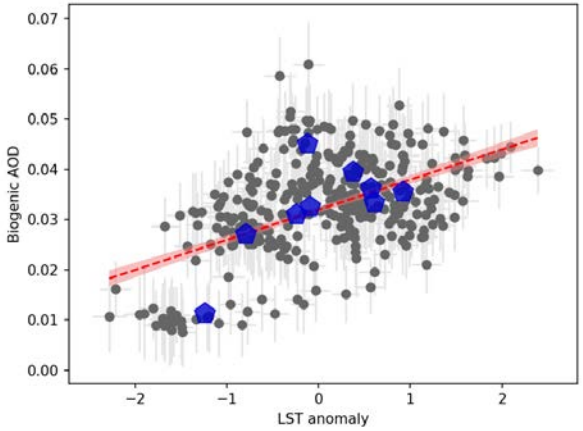

$AOD_{NA,ano}=0.007*LST_{ano} - 0.001$

$AOD_{bio}=0.006*LST_{ano} + 0.032$

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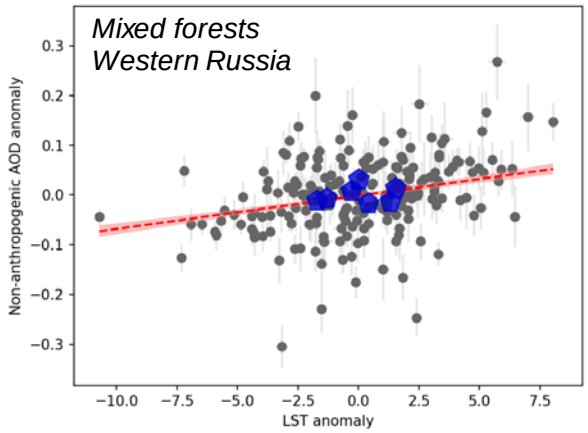

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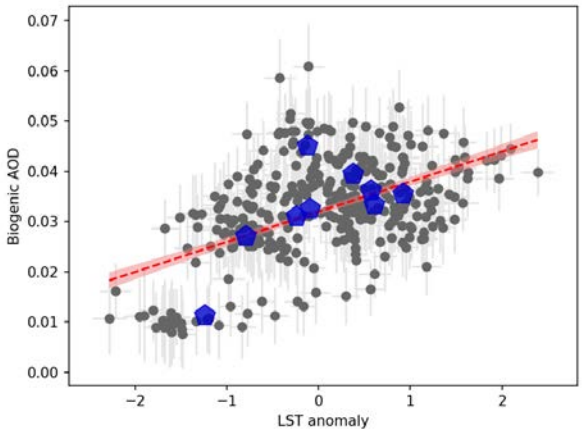
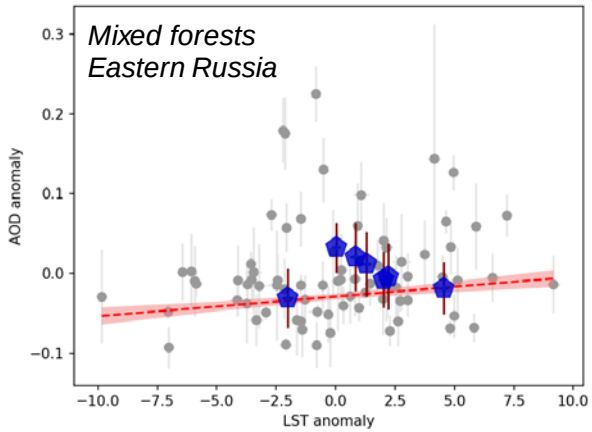


$AOD_{bio}=0.006*LST_{ano} + 0.032$



$AOD_{ano}=0.0025*LST_{ano} - 0.003$

Results:
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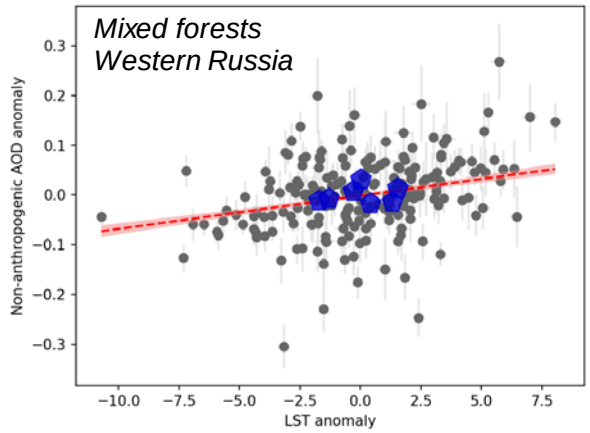

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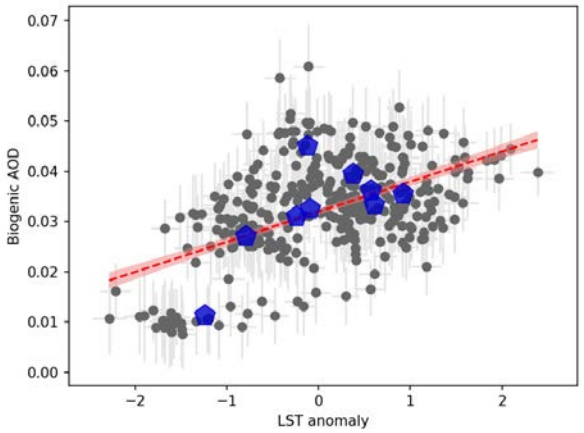

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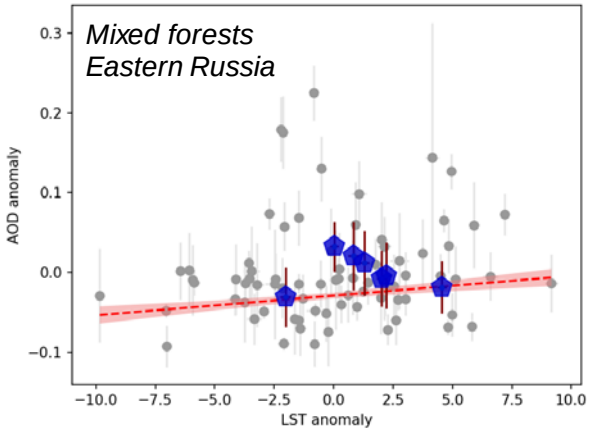
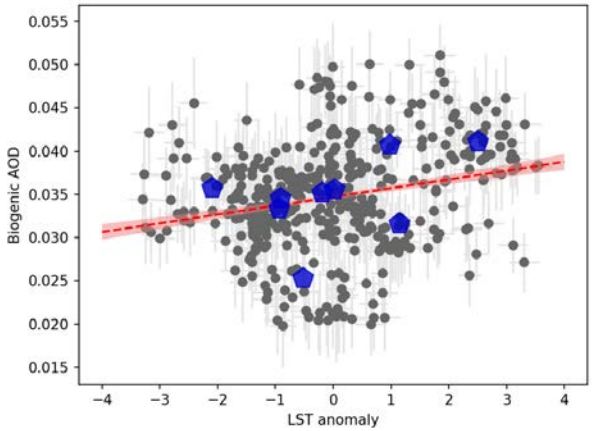


$AOD_{ano}=0.0025*LST_{ano} - 0.003$



$AOD_{bio}=0.0012*LST_{ano} + 0.035$

Direct radiative effect (DRE) calculations

$$DRE = S_{rad}\phi AOD(1-C_c)T_{atm}^2(1-R_s)^2\left(2R_s\frac{1-\varpi}{(1-R_s)^2}-\beta\varpi\right)$$

Updated version of the equation from Haywood and Shine (1995)

S_{rad} = incident solar radiation (461 W/m^2) at the top of the atmosphere
ϕ = mean daytime value of the secant of the solar zenith angle (1.33)
C_c = fractional cloud amount (0.0 for clear-sky and 0.6 for all-sky)
T_{atm} = aerosol free atmospheric transmission (0.76)
R_s = surface reflectance (0.15)
ω = single scattering albedo (0.972)
β = up-scatter fraction (0.21)
AOD = change in AOD per Kelvin

Results:
Direct radiative effects

Region	**DRE_{obs}** [$W/m^2/K$]	**DRE_{sim}** [$W/m^2/K$]
SE US	-0.31±0.22	-0.34±0.02
Canada	-0.21±0.36	-0.138±0.002
Eastern Russia	-0.15±0.07	-0.17±0.01
Western Russia, ENF	-0.29±0.03	-0.25±0.01
Western Russia, MF	-0.41±0.07	

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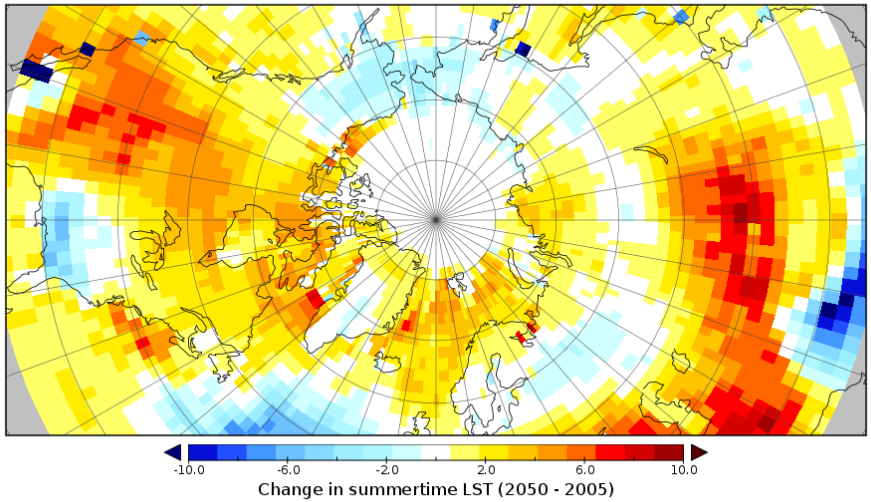
→ Observations and simulations produce corresponding results
→ All regions exhibit negative climate feedbacks!

Results: Future



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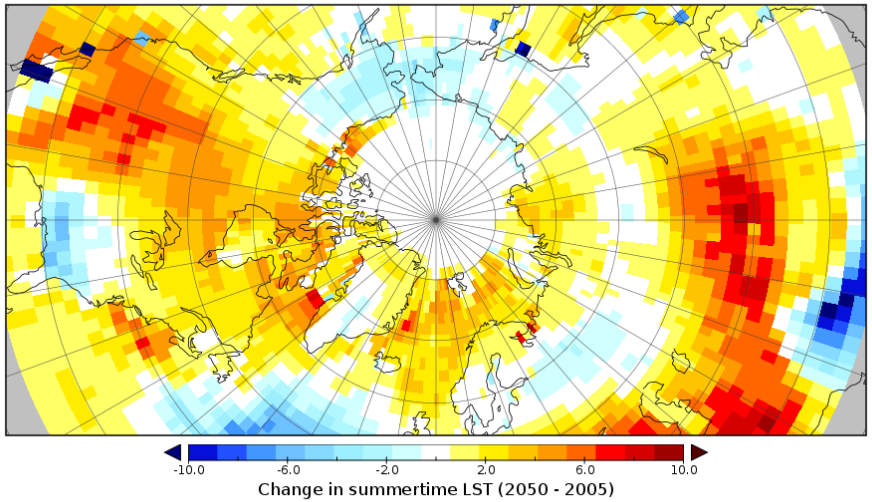

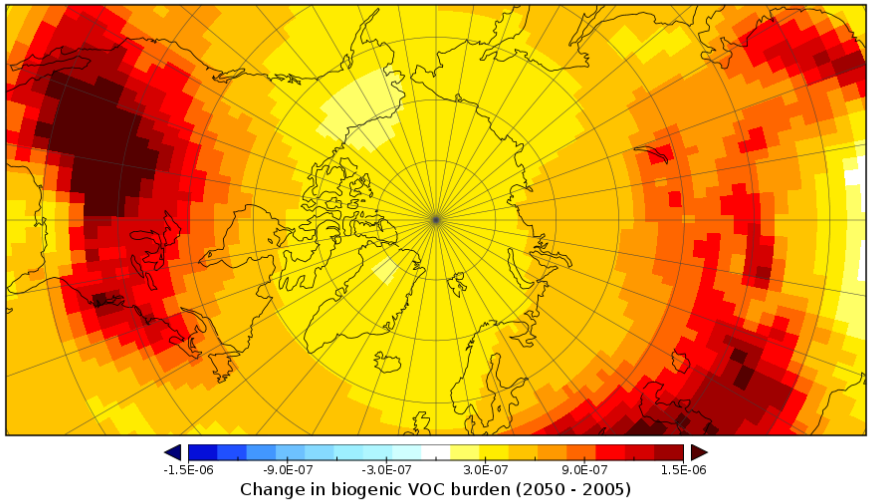

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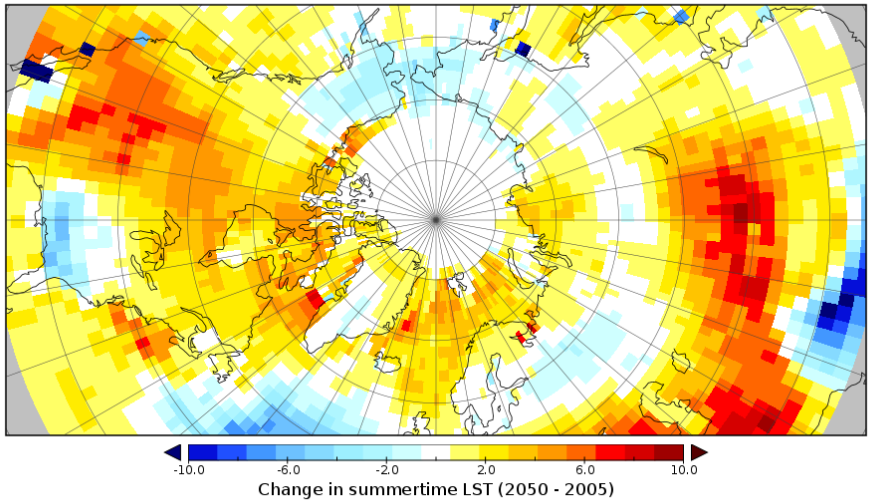

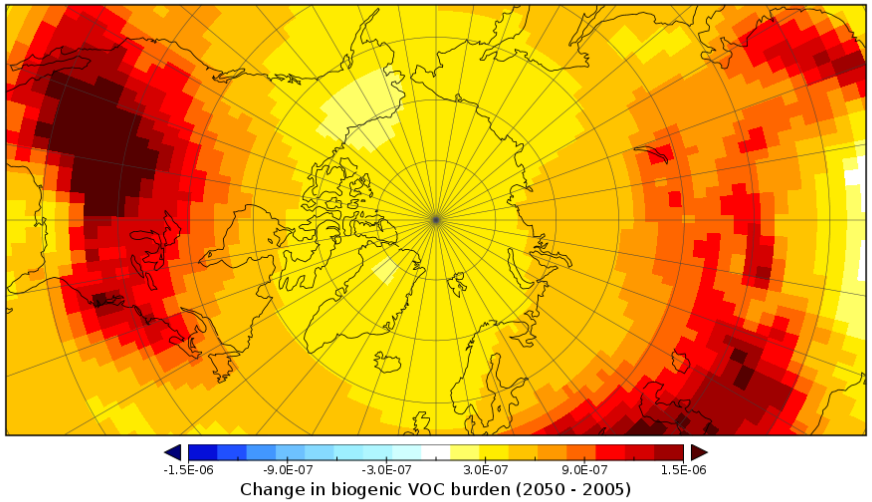

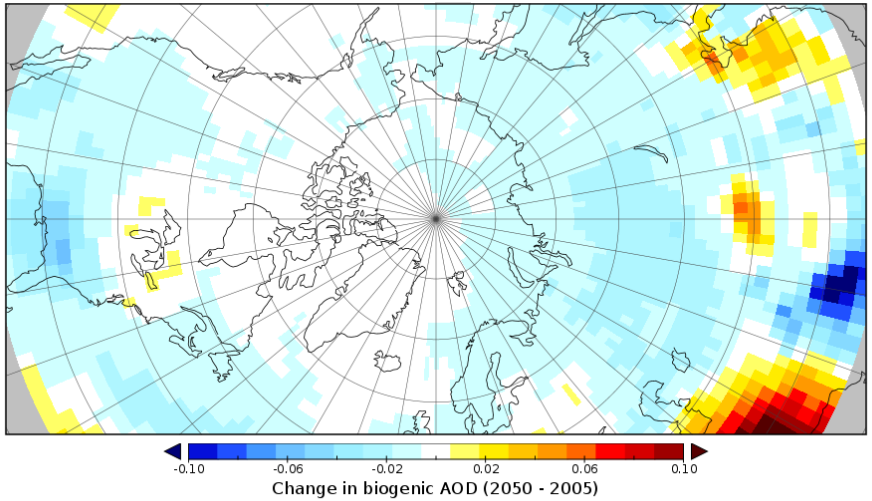

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- The temperature dependence of biogenic AOD is stronger in the presence of anthropogenic aerosols

- The temperature dependent biogenic AOD has significant radiative effects in the present day climate but the significance decreases in the future, thus biogenic aerosols do not appear to produce a strong negative climate feedback.

Thank you!

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