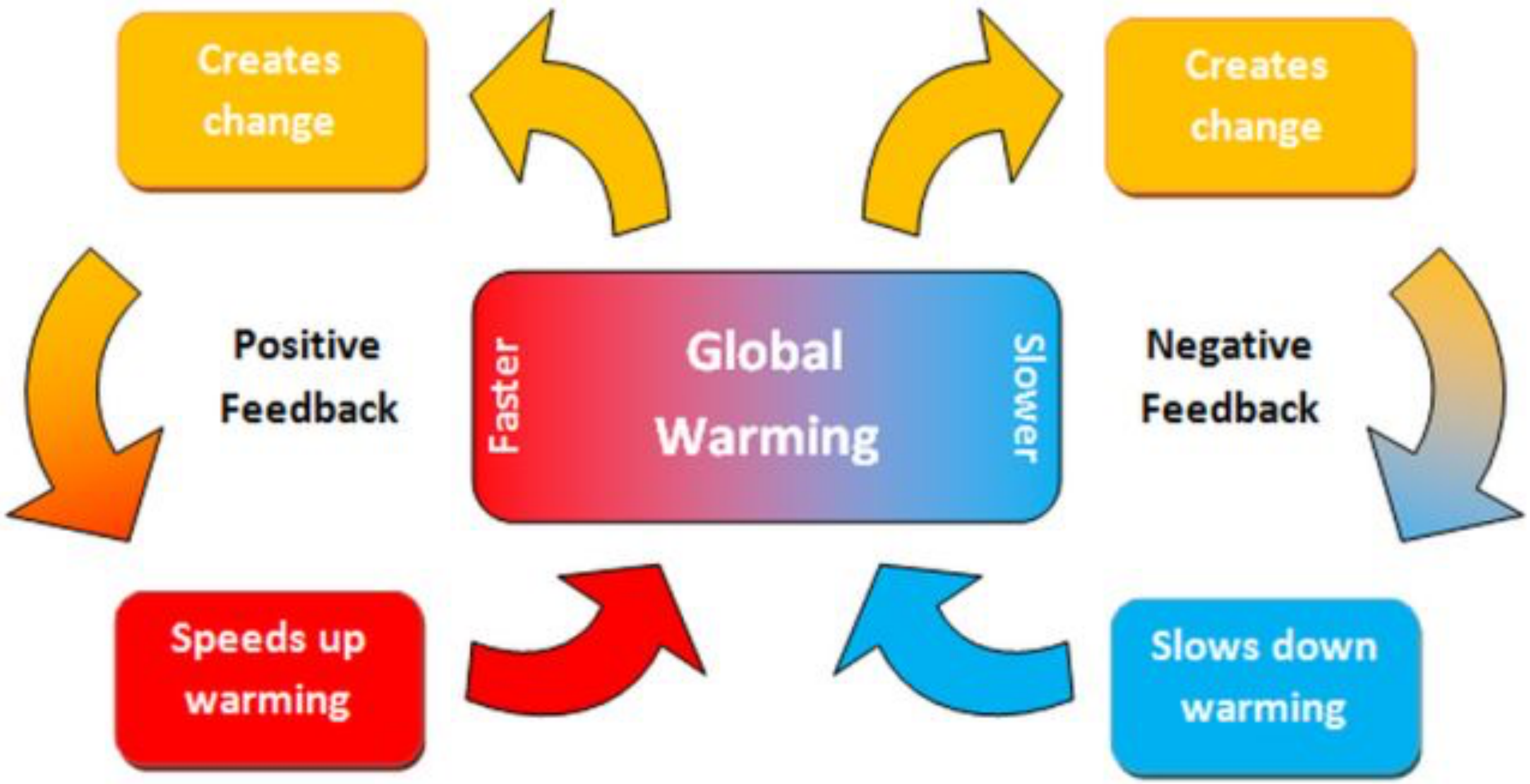
Introduction to the Biosphere-Atmosphere system

Lecture Autumn 2025

Part VIII

Steffen M. Noe

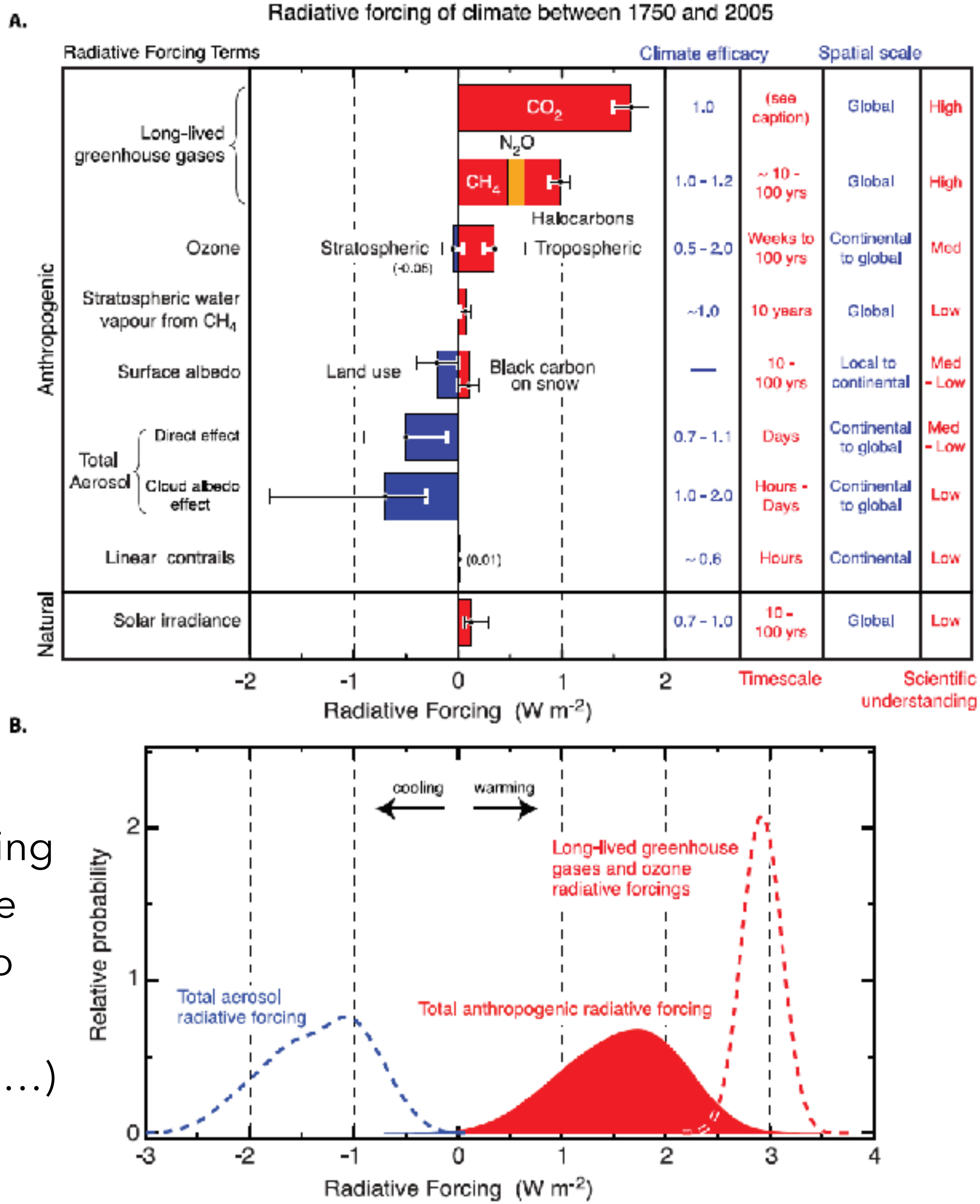
Climate relevant feedbacks can be positive or negative



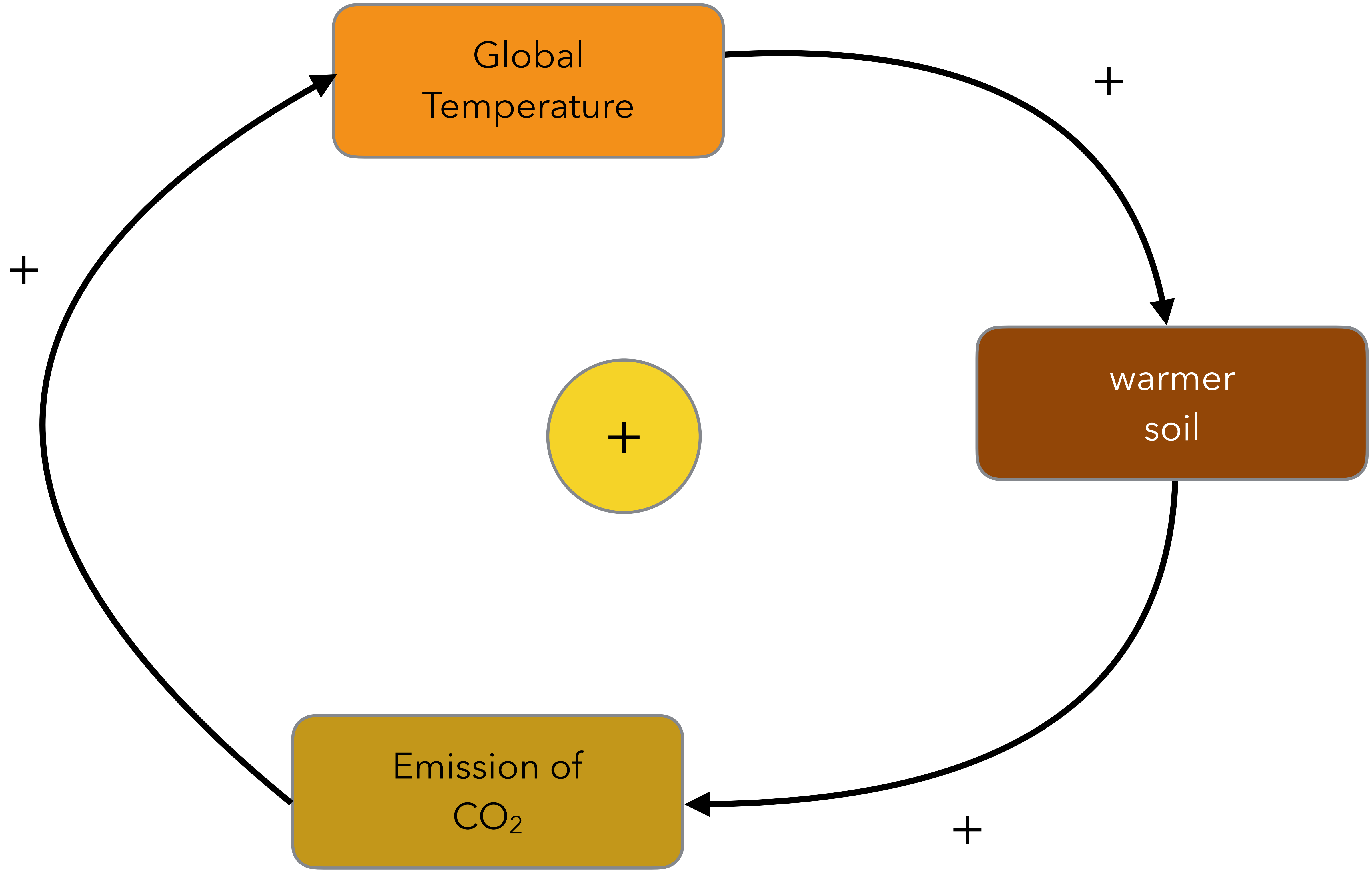
Positive and negative effects

Ozone and surface albedo can act in two directions. Cooling or warming!

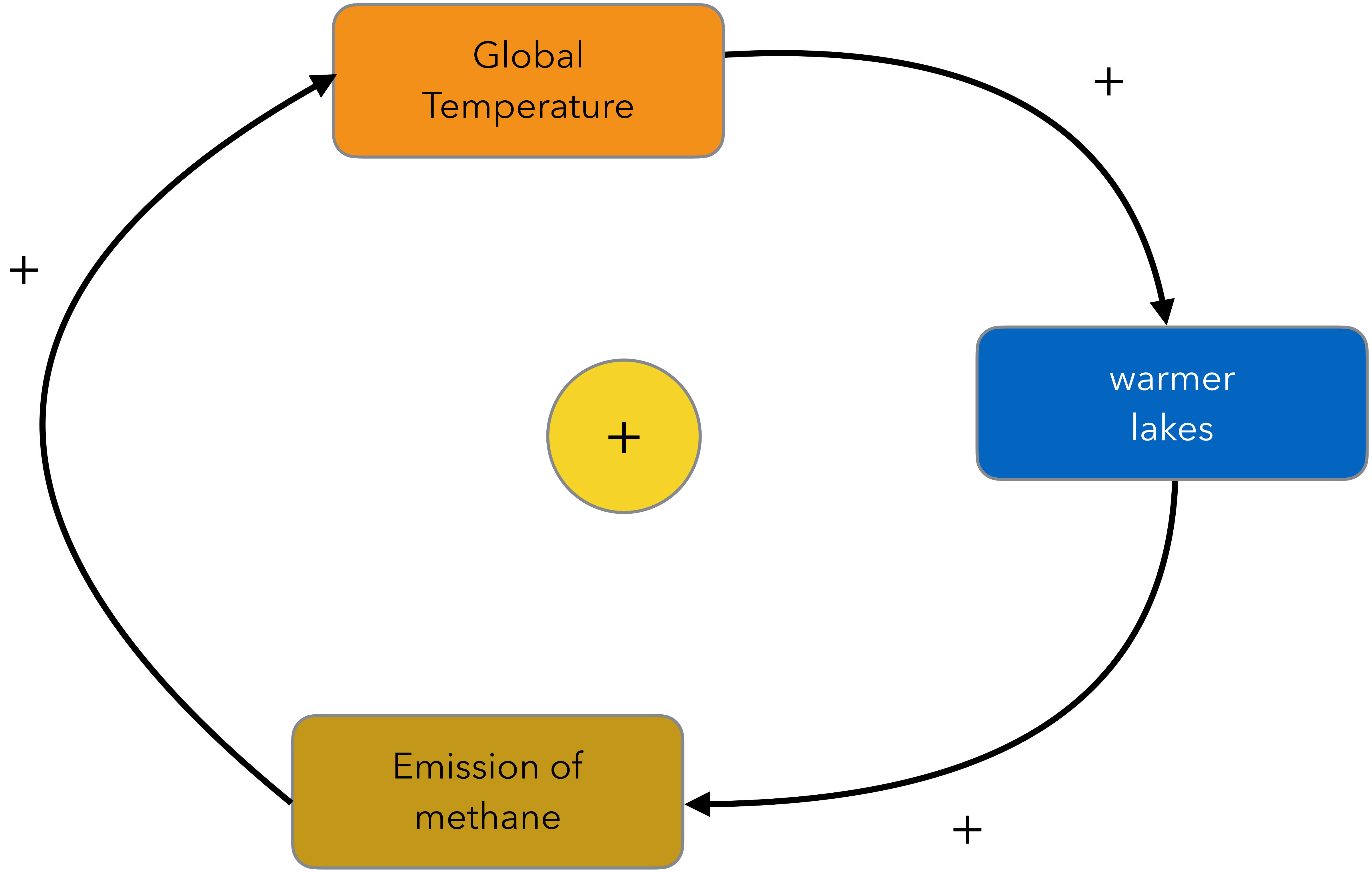
The concept of radiative forcing relates the capacity to change Earth's energy balance due to change in "forcing" agents. (greenhouse gases, aerosols,…)



Carbon dioxide - climate feedback

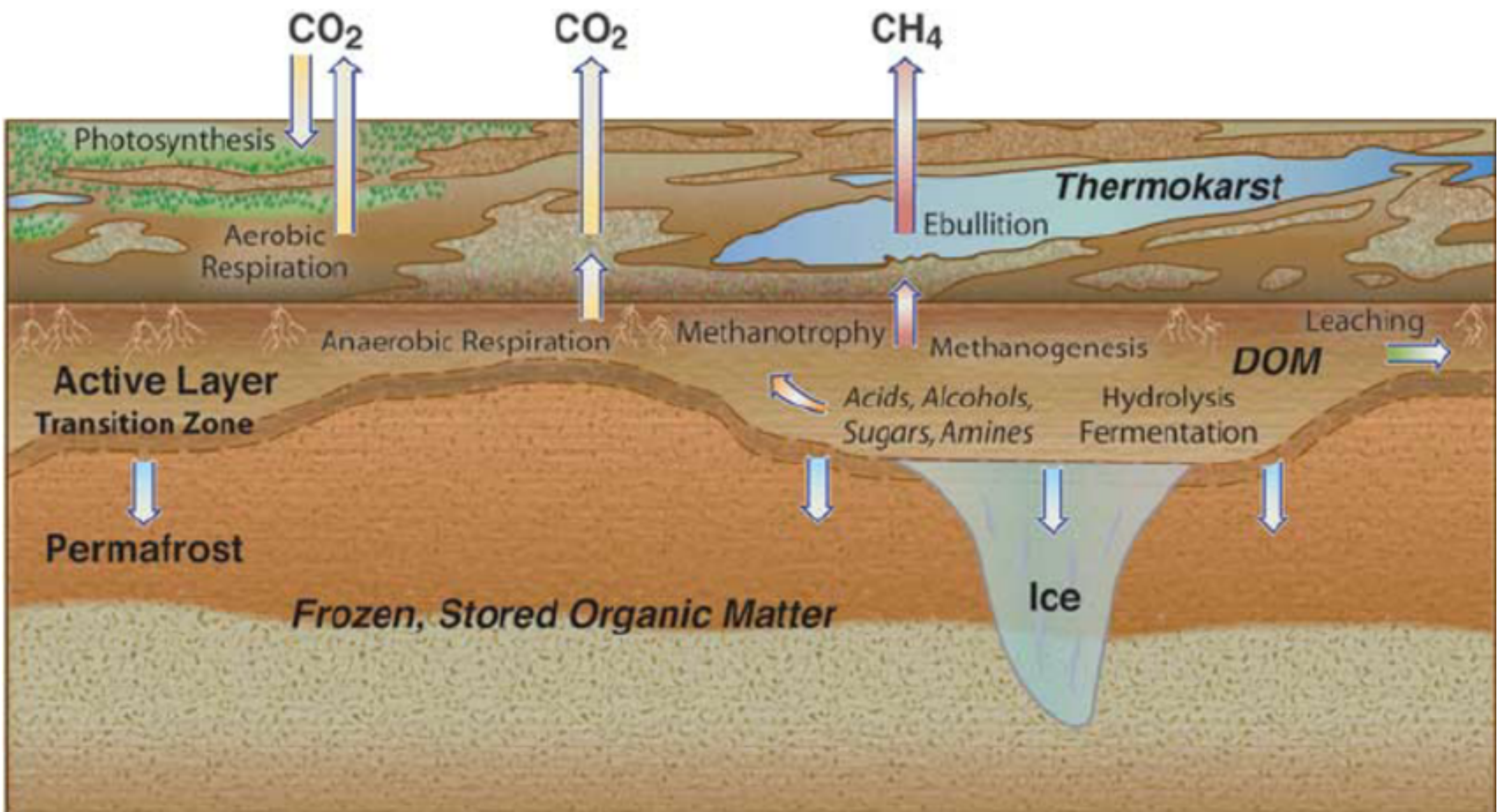


Methane - climate feedback



Carbon release is the major forcing driver

Water vapor “follows” the temperature rise and accelerates the warming process further.



Atmospheric CO_2: Principal Control Knob Governing Earth's Temperature

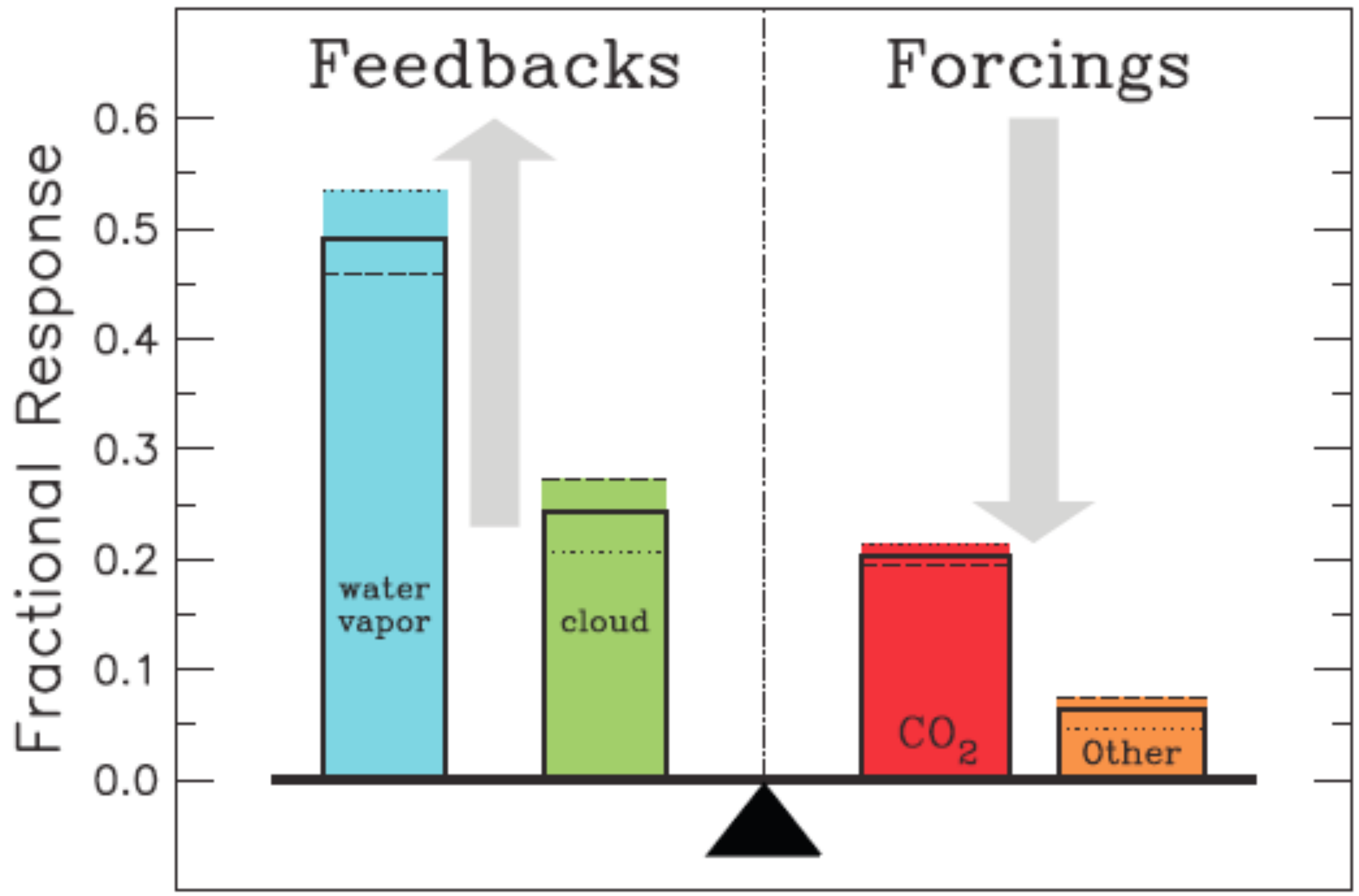
Andrew A. Lacis,* Gavin A. Schmidt, David Rind, Reto A. Ruedy

Ample physical evidence shows that carbon dioxide (CO_2) is the single most important climate-relevant greenhouse gas in Earth's atmosphere. This is because CO_2, like ozone, N_2O, CH_4, and chlorofluorocarbons, does not condense and precipitate from the atmosphere at current climate temperatures, whereas water vapor can and does. Noncondensing greenhouse gases, which account for 25% of the total terrestrial greenhouse effect, thus serve to provide the stable temperature structure that sustains the current levels of atmospheric water vapor and clouds via feedback processes that account for the remaining 75% of the greenhouse effect. Without the radiative forcing supplied by CO_2 and the other noncondensing greenhouse gases, the terrestrial greenhouse would collapse, plunging the global climate into an icebound Earth state.

15 OCTOBER 2010 VOL 330 **SCIENCE** www.sciencemag.org

…and the role of water vapour

Fig. 1. Attribution of the contributions of individual atmospheric components to the total terrestrial greenhouse effect, separated into feedback and forcing categories. Horizontal dotted and dashed lines depict the fractional response for single-addition and single-subtraction of individual gases to an empty or full-component reference atmosphere, respectively. Horizontal solid black lines are the scaled averages of the dashed- and dotted-line fractional response results. The sum of the fractional responses adds up to the total greenhouse effect. The reference atmosphere is for conditions in 1980.



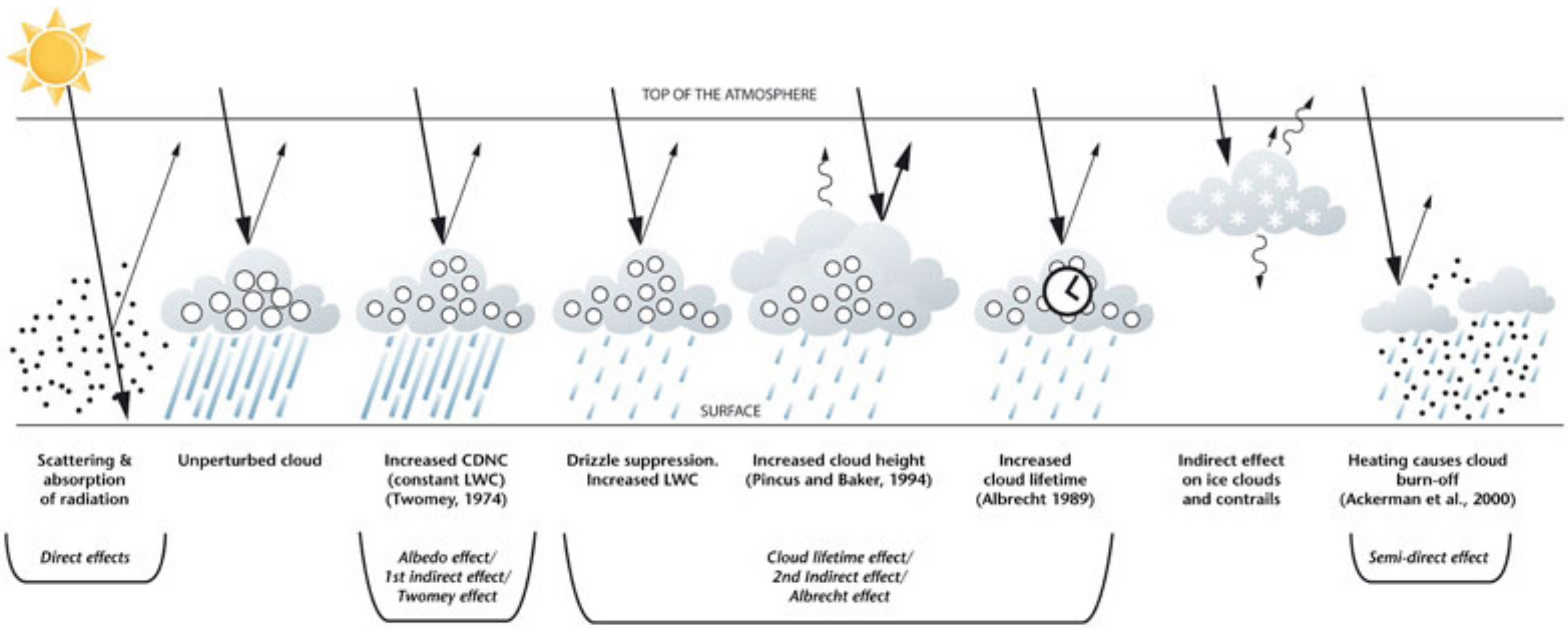
in short:

If the forcing changes the feedback follows!

Andrew A. Lacis *et al.*
Science 15 October 2010:
vol. 330 no. 6002 pp. 356-359
DOI: 10.1126/science.1190653

Cloud and aerosol effects

Aerosol effect is mixing with albedo



Met Office

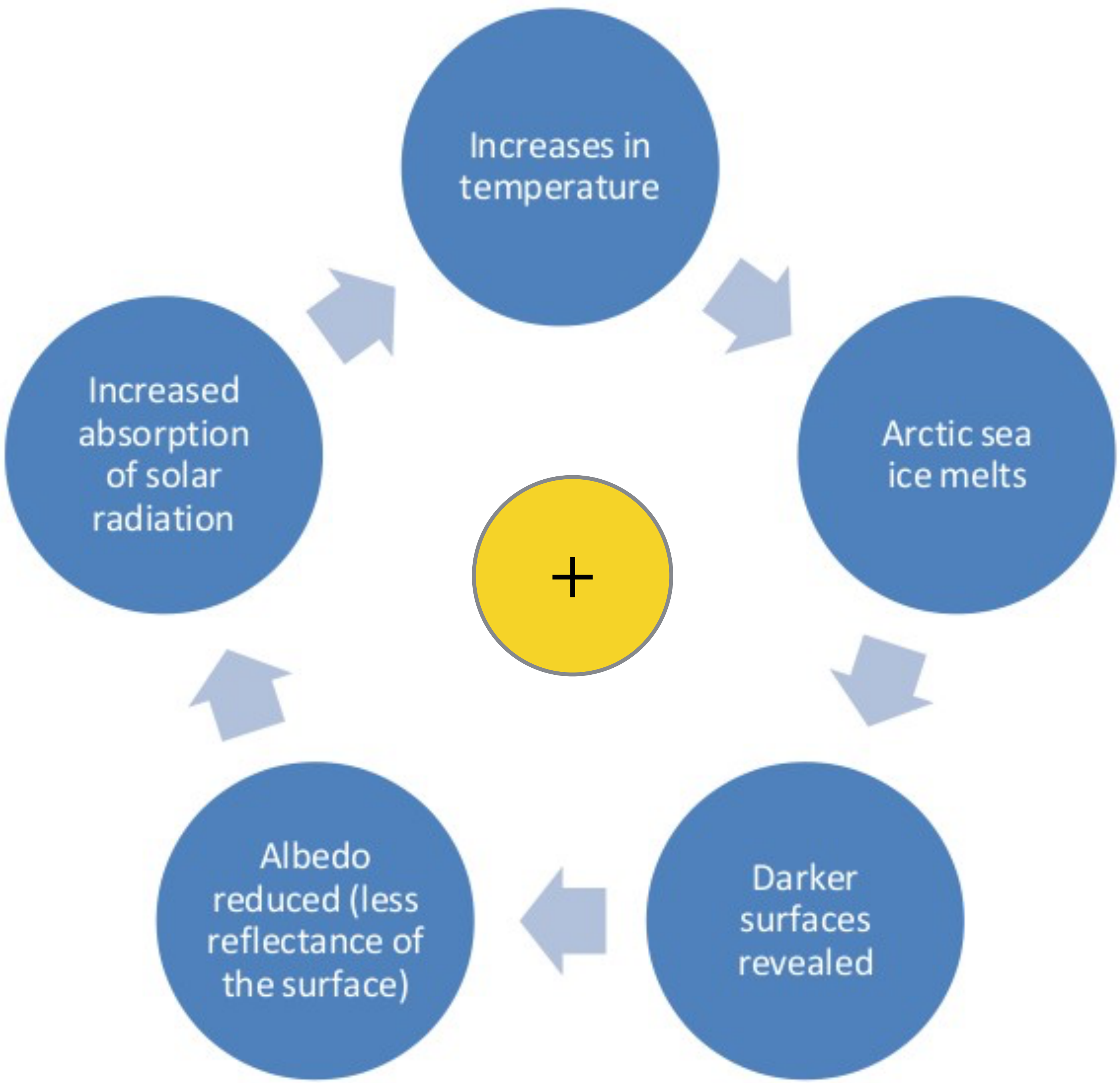
Smog (aerosols) in China

17 May 2016

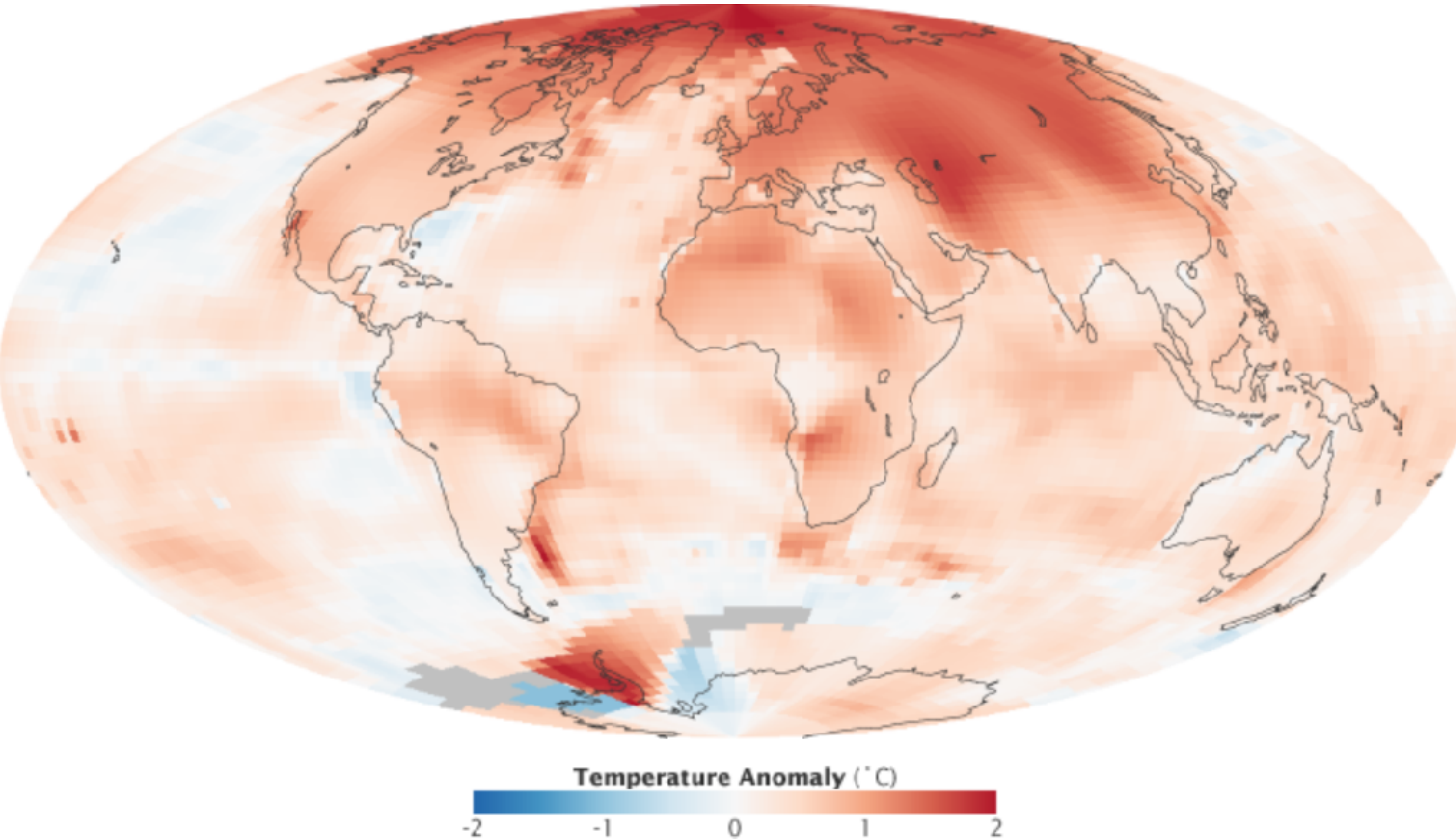
20 May 2016

Sea ice albedo

Sea ice - albedo feedback

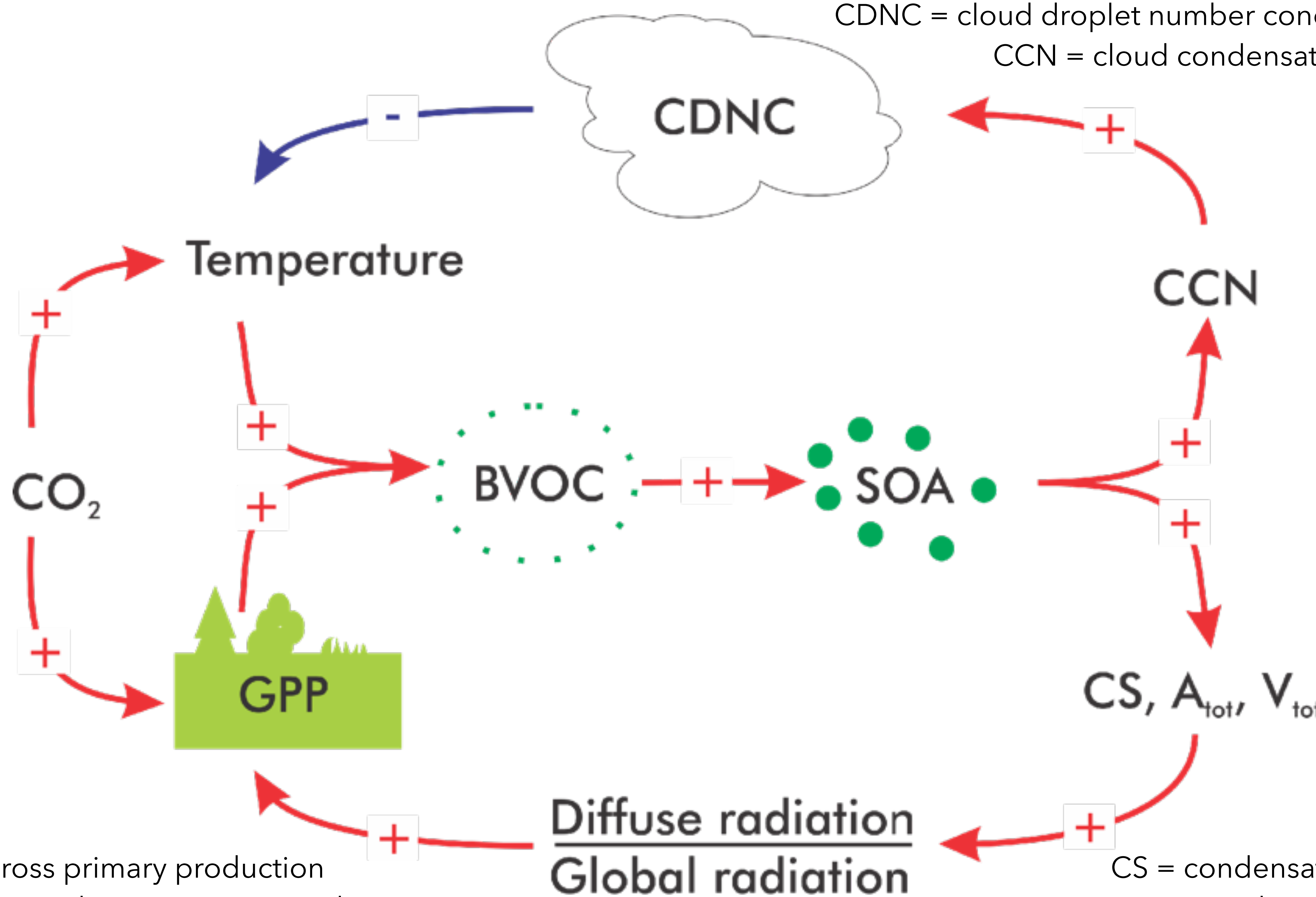


Sea ice albedo change is linked to the Arctic amplification



Climate - Cloud - Forest feedbacks driven by CO2

CDNC = cloud droplet number concentration
CCN = cloud condensation nuclei



GPP = gross primary production
SOA = secondary organic aerosol
BVOC = biogenic volatile organic compound

CS = condensation sink
A = aerosol surface
V = aerosol volume

Forest maintained feedbacks

Direct effect of aerosols on solar radiation and gross primary production in boreal and hemiboreal forests

Ekaterina Ezhova[1], Ilona Ylivinkka[1], Joel Kuusk[2], Kaupo Komsaare[3], Marko Vana[3], Alisa Krasnova[4], Steffen Noe[4], Mikhail Arshinov[5], Boris Belan[5], Sung-Bin Park[6], Jošt Valentin Lavric[6], Martin Heimann[1,6], Tuukka Petäjä[1], Timo Vesala[1,7], Ivan Mammarella[1], Pasi Kolari[1], Jaana Bäck[7], Ullar Rannik[1], Veli-Matti Kerminen[1], and Markku Kulmala[1]

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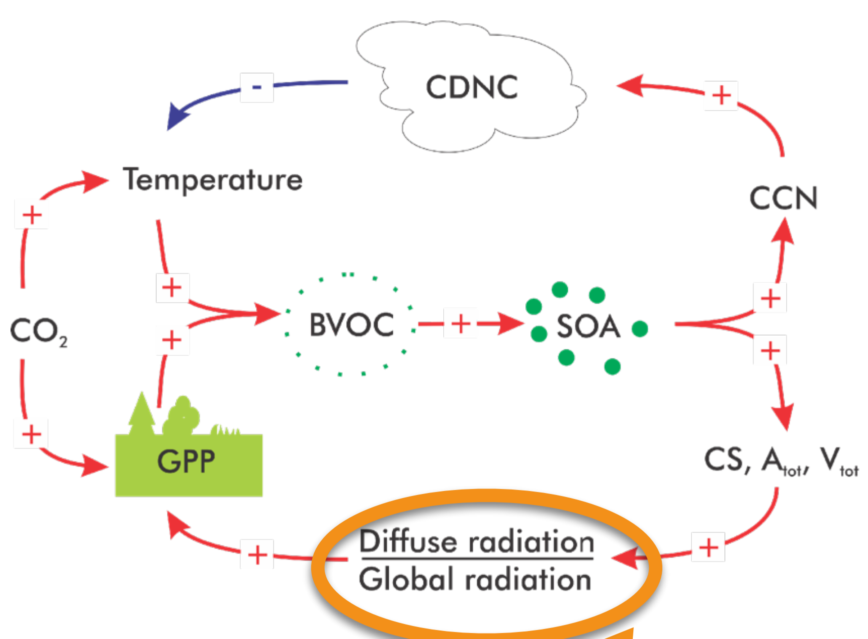
Review status

This discussion paper is a preprint. A revision of the manuscript is under review for the journal Atmospheric Chemistry and Physics (ACP).



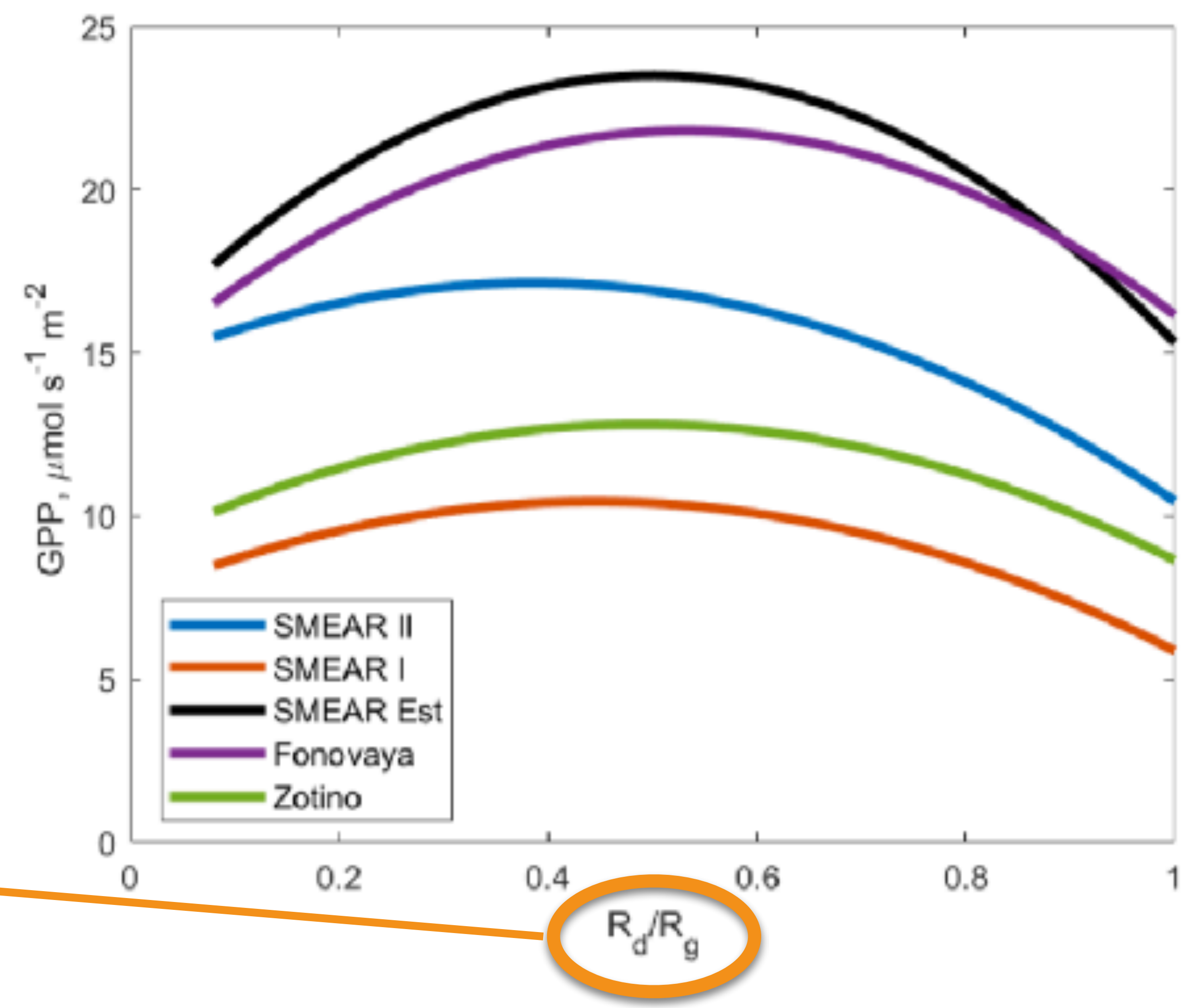


Figure 8. Estimated GPP dependences on R_d/R_g for all the sites (obtained as GPP = LUE · PAR using the coefficients for PAR and LUE dependences on R_d/R_g reported in Table 4).

Forest maintained feedbacks new insights

BOREAL ENVIRONMENT RESEARCH 25: 145–159 © 2020
ISSN 1797-2469 (online) Helsinki 12 November 2020

CarbonSink+ — Accounting for multiple climate feedbacks from forests

Markku Kulmala[1)*], Ekaterina Ezhova[1)], Tuomo Kalliokoski[1)2)], Steffen Noe[3)], Timo Vesala[1)], Annalea Lohila[1)4)], Jari Liski[4)], Risto Makkonen[1)4)], Jaana Bäck[2)], Tuukka Petäjä[1)] and Veli-Matti Kerminen[1)]

We have now accounted also for the albedo effects!

More forest - darker surface - warmer
More forest - more clouds - cooler

Both processes have the highest effect in summer!

More CO2 - higher GPP - more CO2 uptake!

We need to know more how to balance the system!

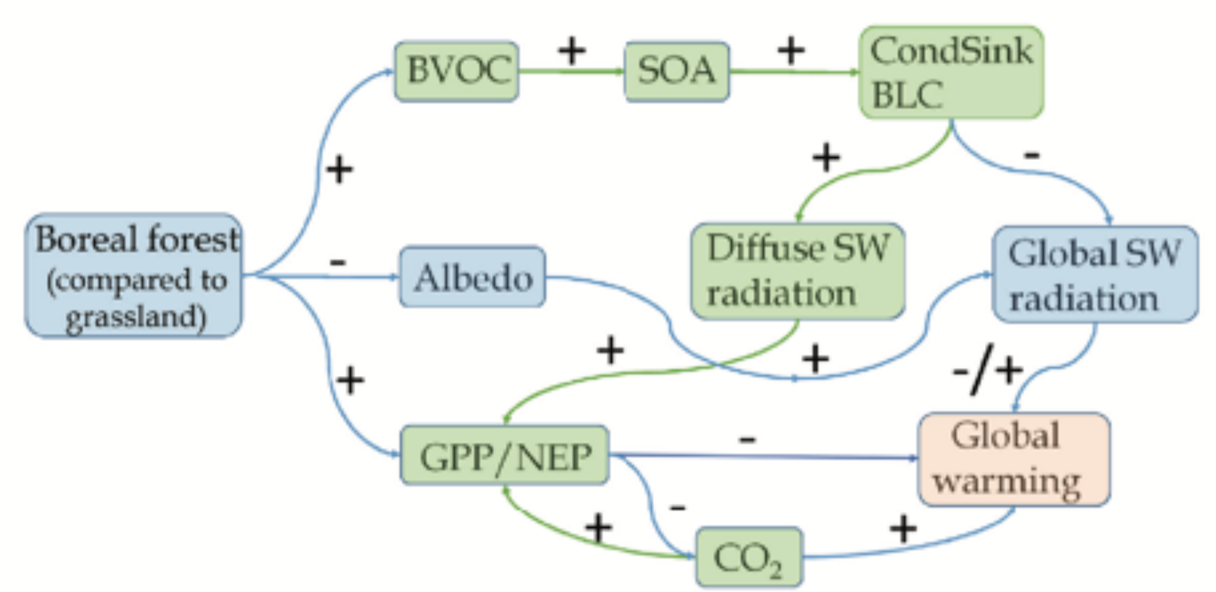
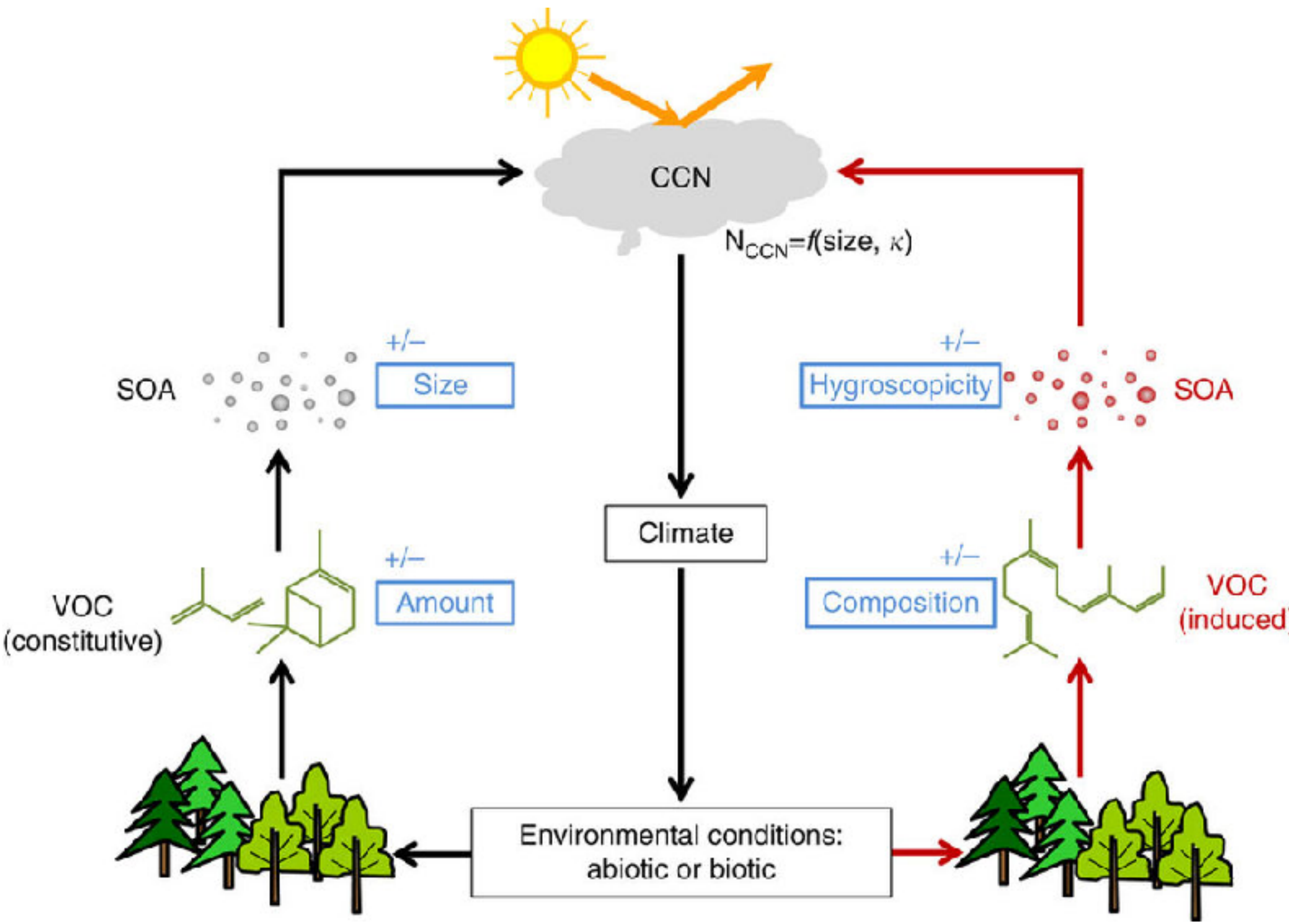


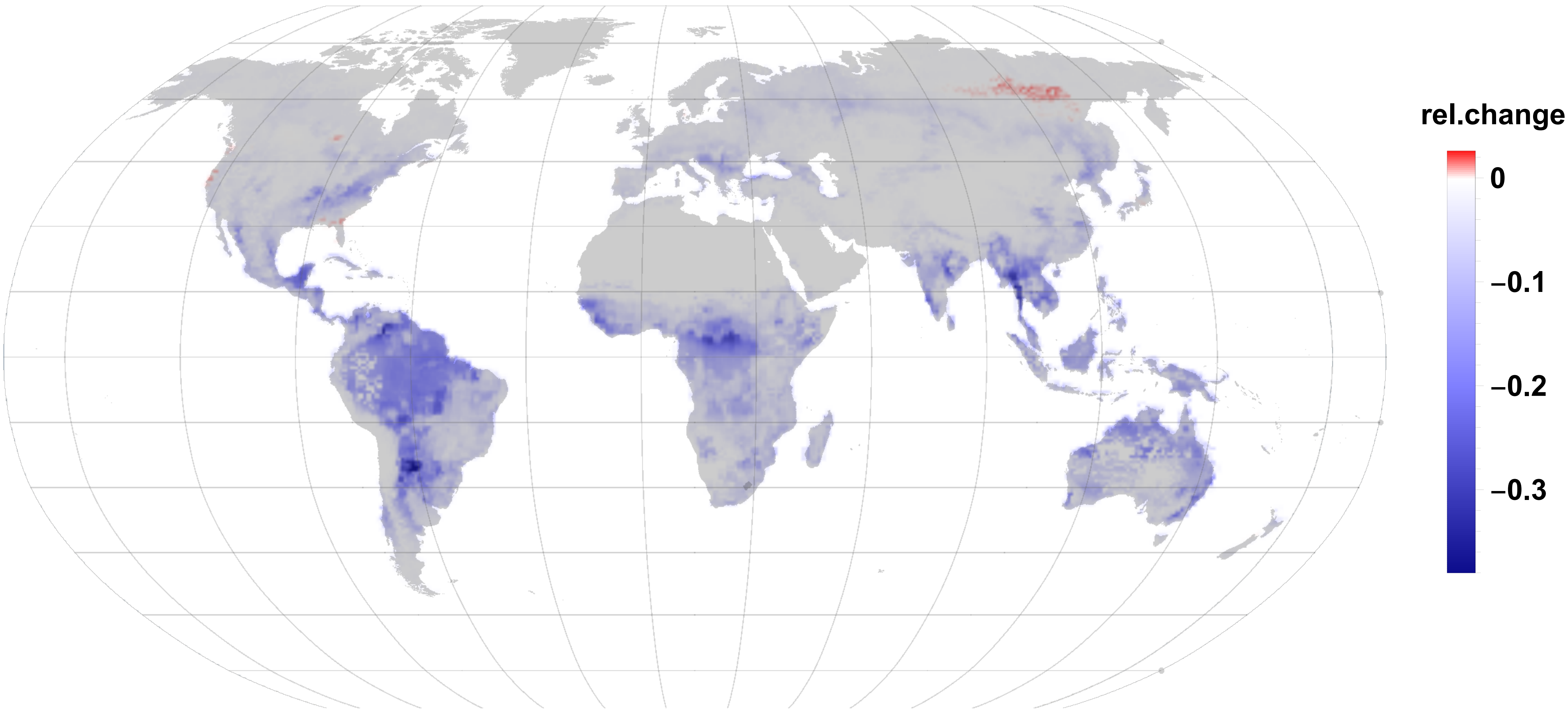
Fig 2. Schematic of the boreal forest effect on warming illustrating CarbonSink+ concept. GPP refers to the gross primary production, NEP to net ecosystem production, BVOC to biogenic volatile organic compounds, SOA to secondary organic aerosol, CondSink to condensation sink, BLC to boundary layer clouds, SW to shortwave radiation. Plus (minus) means a positive (negative) response between the two quantities linked by an arrow. Green arrows correspond to enhancing interactions in CarbonSink+.

Different feedbacks for constitutive and induced BVOC emissions



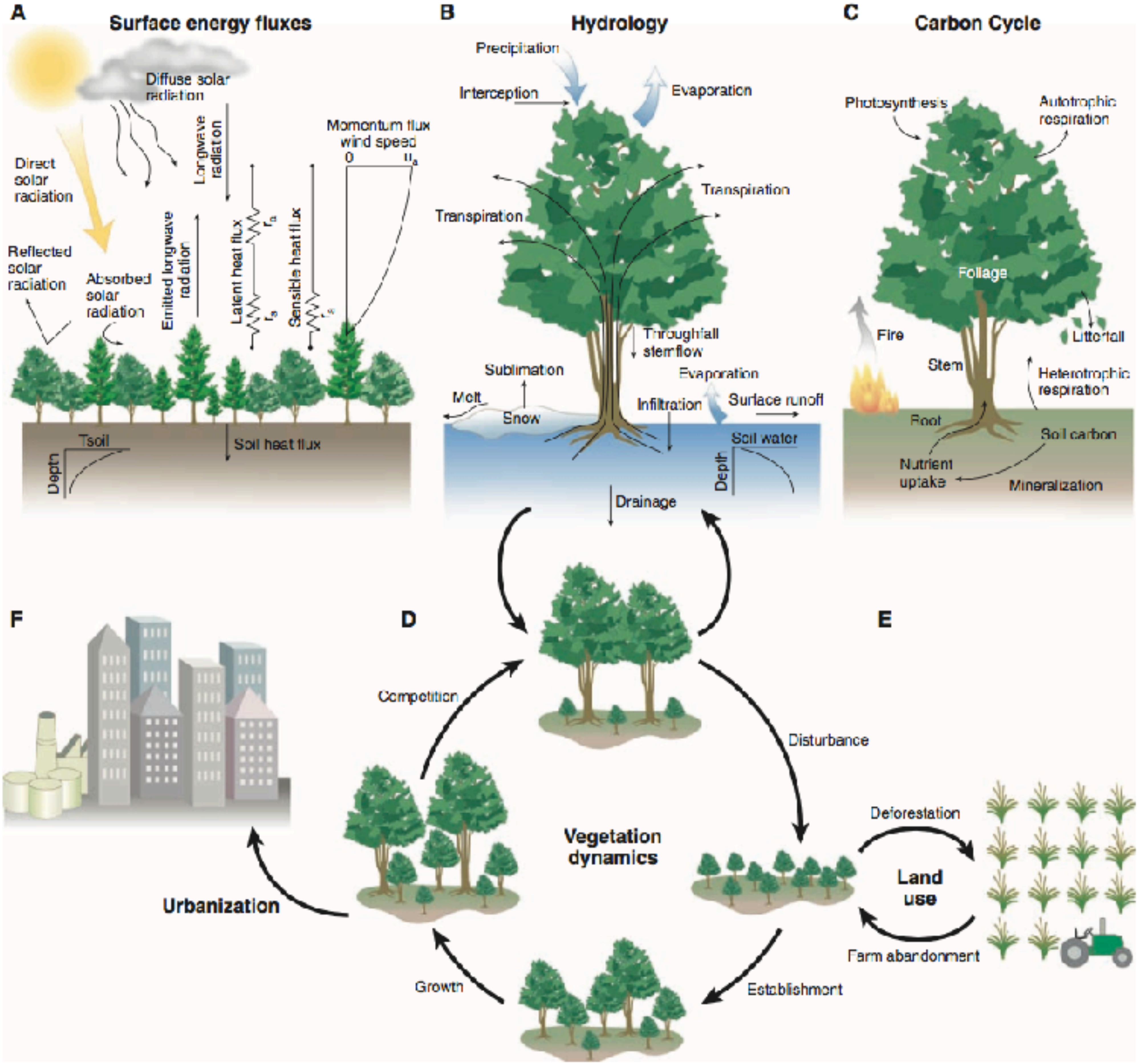
Example for modeled insect induced monoterpene emissions

Scenario: An insect that damages broad-leafed tree species.

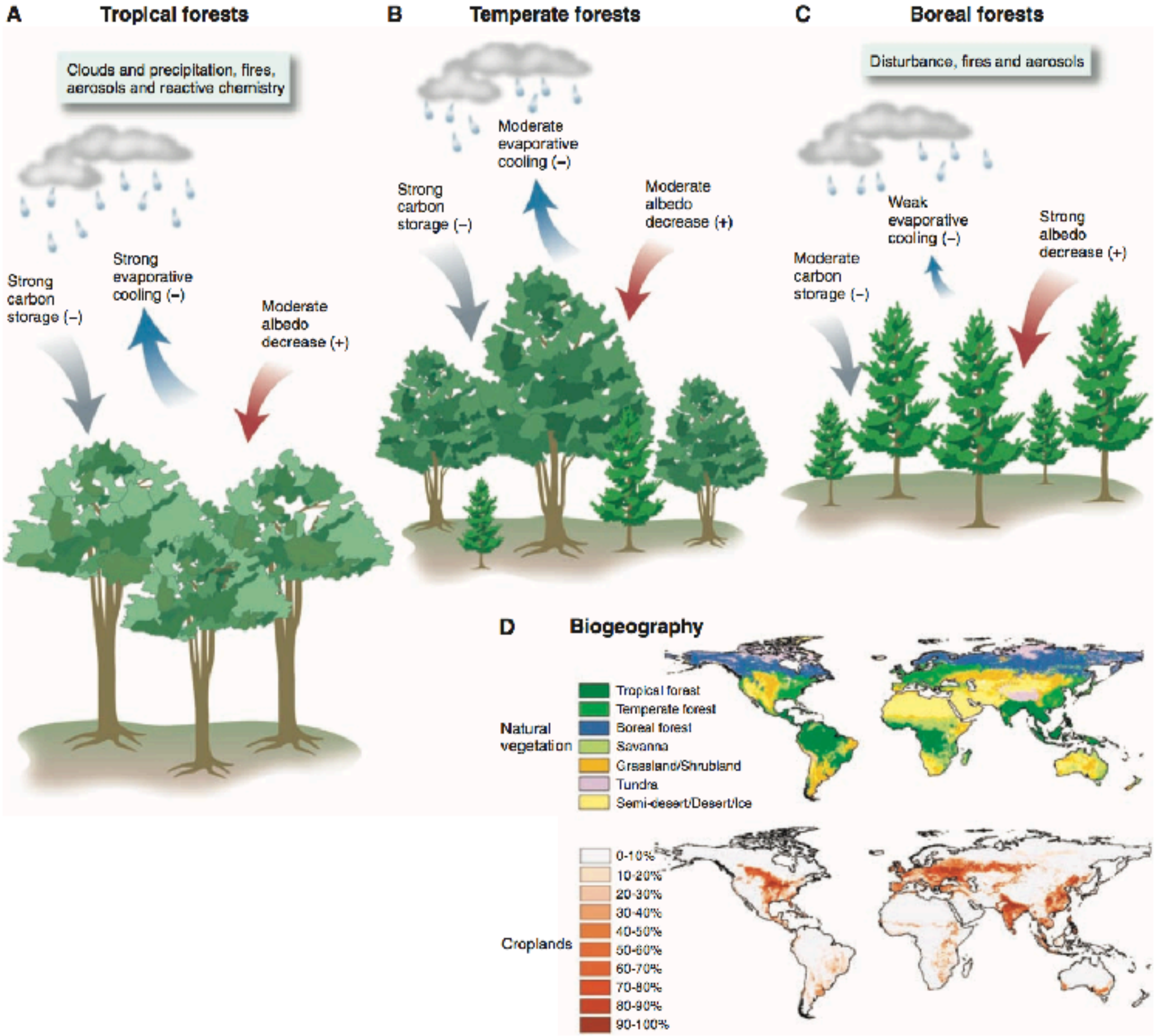


Noe S.M., Niinemets Ü. 2020: Impact of gall-forming insects on global BVOC emissions and climate: A perspective. Frontiers in Forests and Global Change 3:9

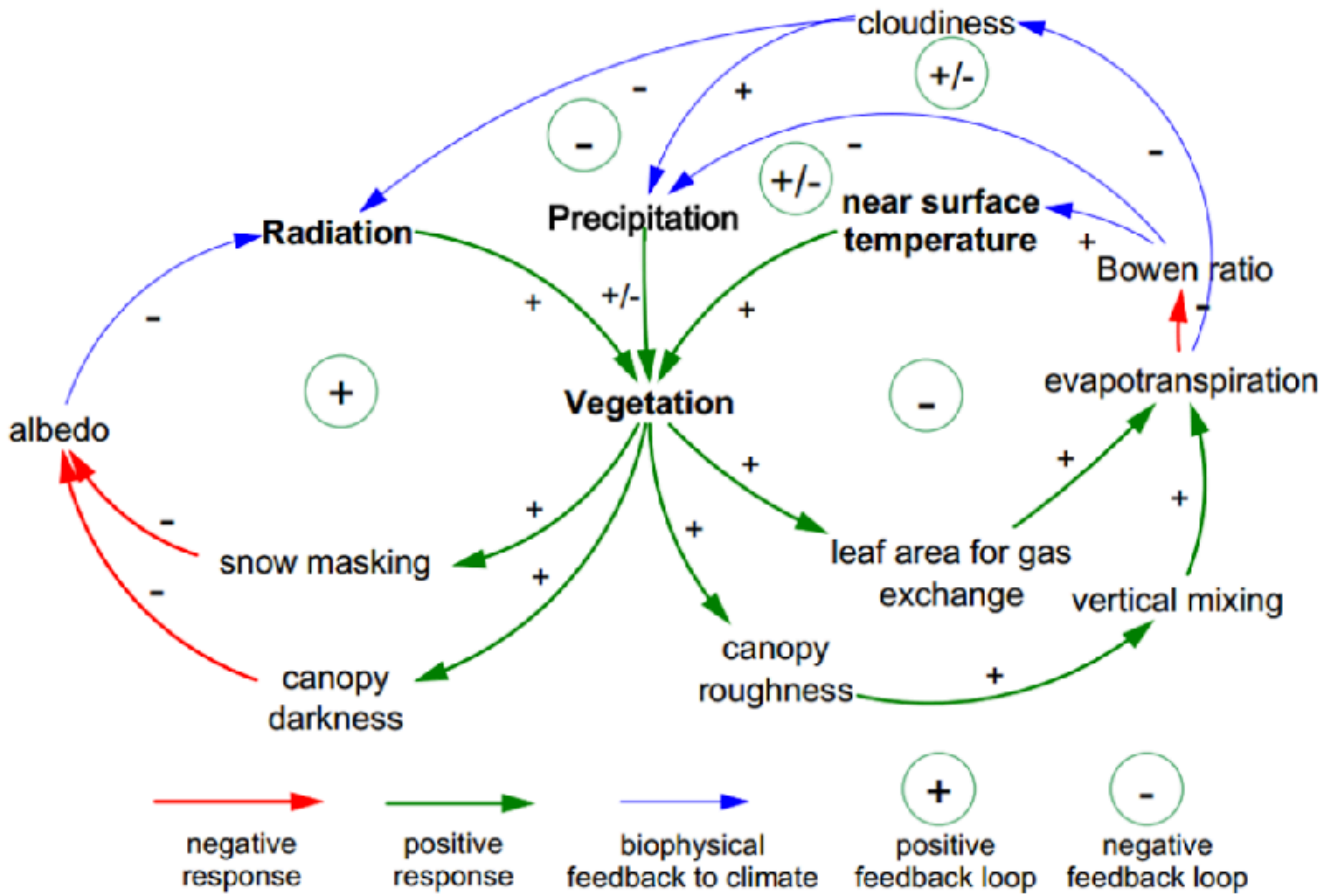
Forests in Flux



Forests in Flux



Multiple feedback/feedforward loops



Understanding feedbacks in land-atmosphere-ocean-society system

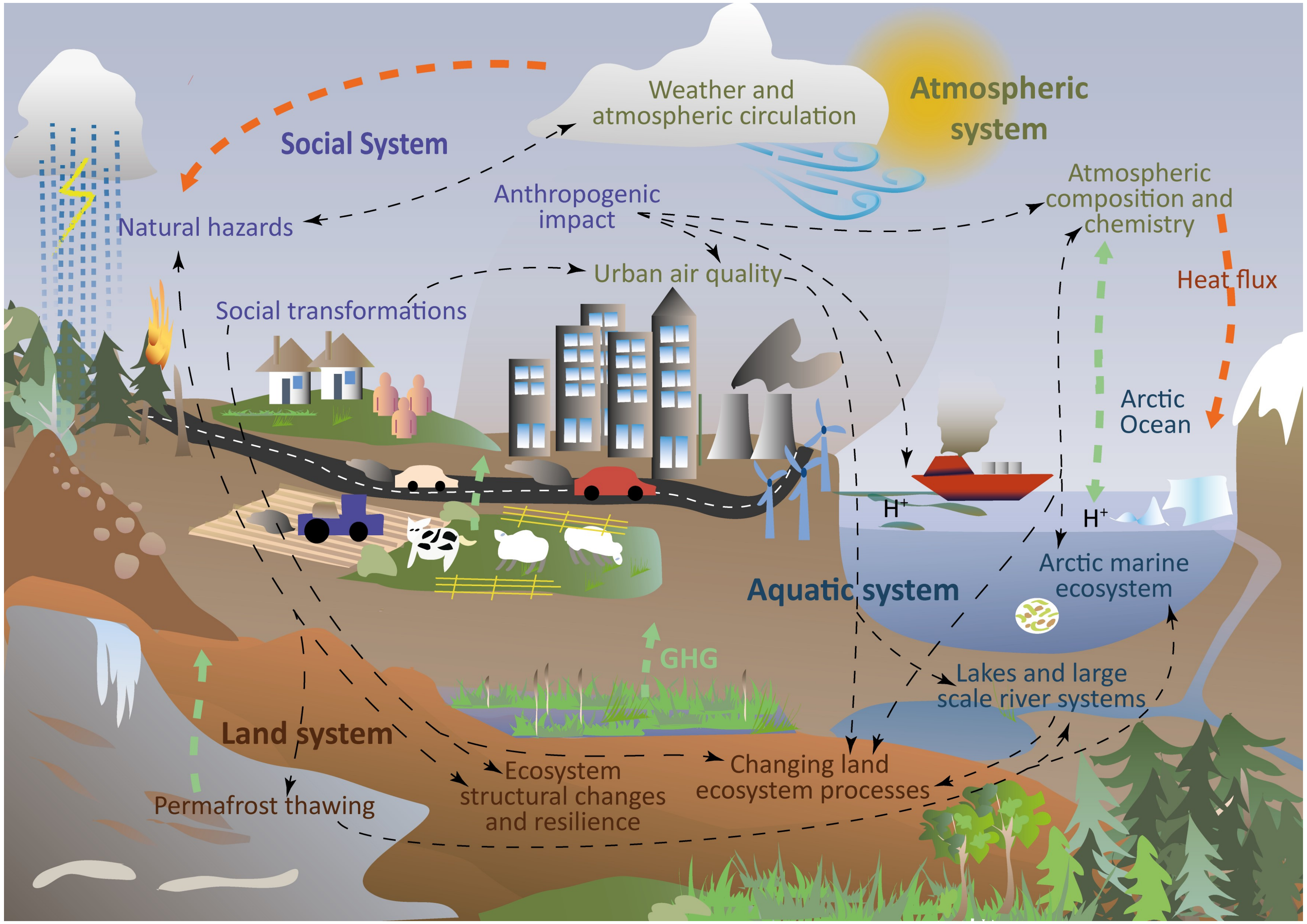


Figure 1. The thematic research areas relevant to the Northern Eurasian land system include land topic 1 “changing ecosystem processes”, land topic 2 “ecosystem structural changes and resilience” and land topic 3 “risk areas of permafrost thawing”. For the atmospheric system they are atmosphere topic 1 “atmospheric composition and chemistry”, atmosphere topic 2 “Urban air quality”, are atmosphere topic 3, “atmospheric circulation and weather”, for the aquatic system they are aquatic topic 1 “Arctic Ocean in the climate system”, aquatic topic 2 “maritime ecosystems”, aquatic topic 3 “Lakes and large river systems”, and for the social system they are society topic 1 “natural resources and anthropogenic activities”, society topic 2 “natural hazards” and society topic 3 “social transformations”.

Feedbacks need to include human activity

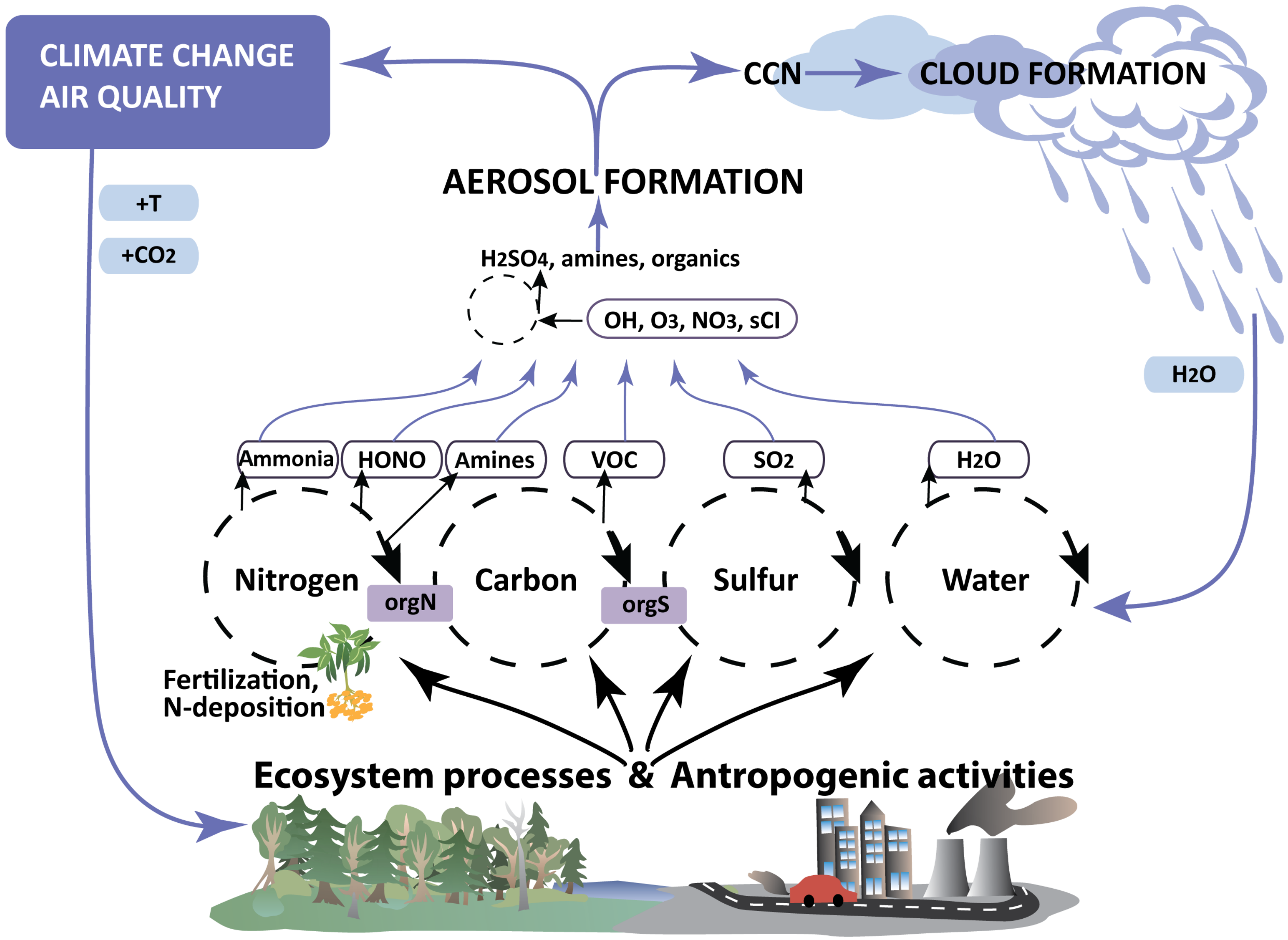


Figure 4. In urban and industrialized regions, the process understanding of biogeochemical cycles includes anthropogenic sources, such as industry and fertilizers, as essential parts of the biogeochemical cycles.

PEEX - a project to understand impact of climate change in northern Eurasia

Atmos. Chem. Phys., 16, 14421–14461, 2016
www.atmos-chem-phys.net/16/14421/2016/
doi:10.5194/acp-16-14421-2016

Atmospheric Chemistry and Physics
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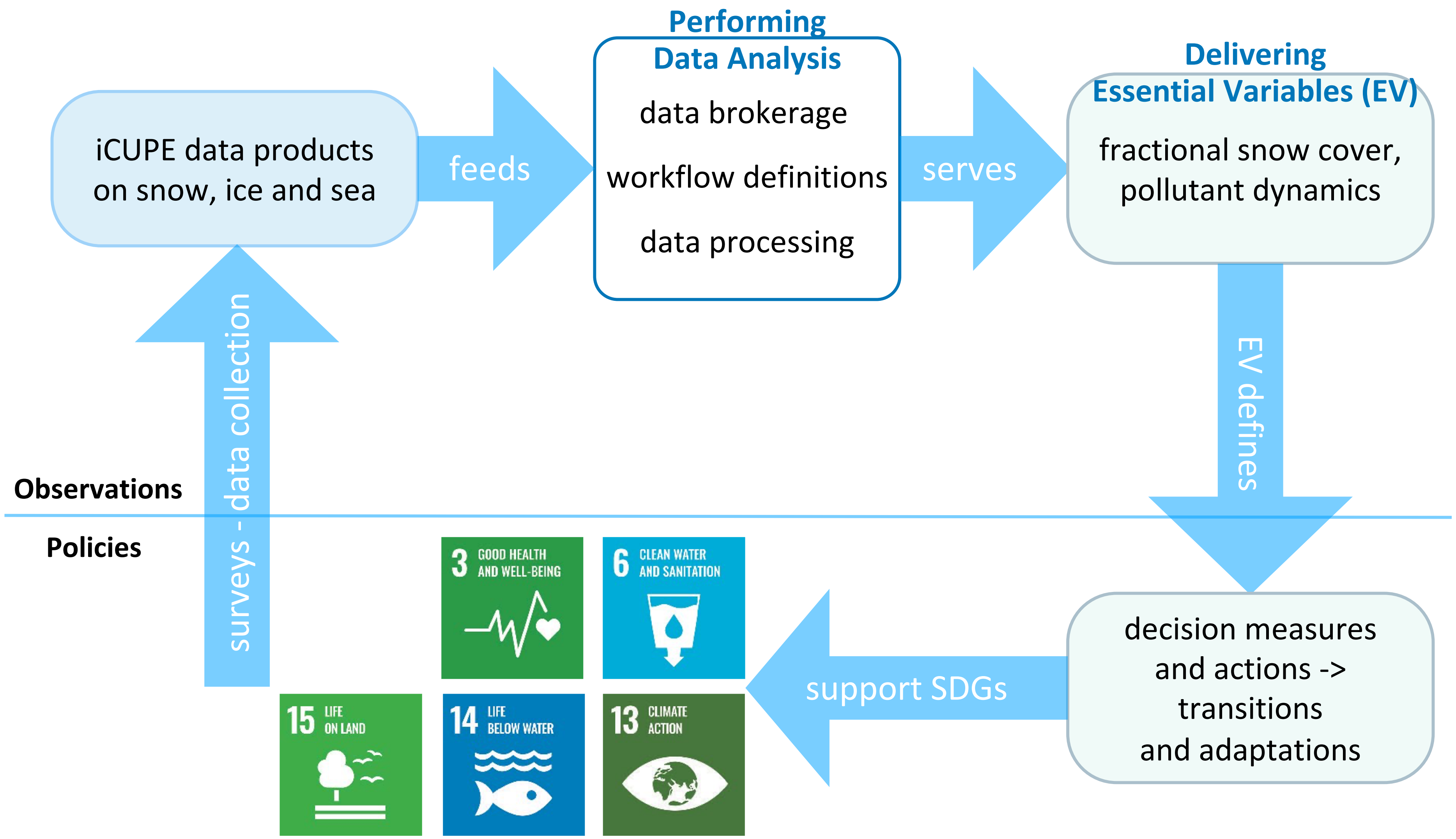
Pan Eurasian Experiment
PEEX

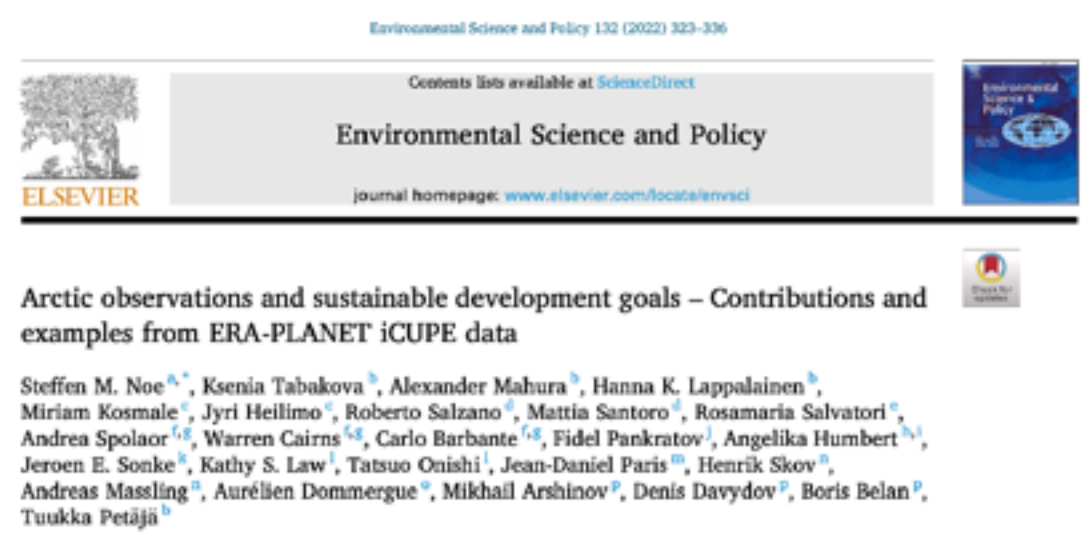
Pan-Eurasian Experiment (PEEX): towards a holistic understanding of the feedbacks and interactions in the land–atmosphere–ocean–society continuum in the northern Eurasian region

Hanna K. Lappalainen[1,2,36], Veli-Matti Kerminen[1], Tuukka Petäjä[1,36], Theo Kurten[3], Aleksander Baklanov[4,5], Anatoly Shvidenko[6], Jaana Bäck[7], Timo Vihma[2], Pavel Alekseychik[1], Meinrat O. Andreae[8], Stephen R. Arnold[9], Mikhail Arshinov[10], Eija Asmi[2], Boris Belan[10], Leonid Bobylev[11], Sergey Chalov[12], Yafang Cheng[8], Natalia Chubarova[12], Gerrit de Leeuw[1,2], Aijun Ding[13], Sergey Dobrolyubov[12], Sergei Dubtsov[14], Egor Dyukarev[15], Nikolai Elansky[16], Kostas Eleftheriadis[17], Igor Esau[18], Nikolay Filatov[19], Mikhail Flint[20], Congbin Fu[13], Olga Glezer[21], Aleksander Gliko[22], Martin Heimann[23], Albert A. M. Holtslag[24], Urmas Hõrrak[25], Juha Janhunen[26], Sirkku Juhola[27], Leena Järvi[1], Heikki Järvinen[1], Anna Kanukhina[28], Pavel Konstantinov[12], Vladimir Kotlyakov[29], Antti-Jussi Kieloaho[1], Alexander S. Komarov[30], Joni Kujansuu[1], Ilmo Kukkonen[31], Ella-Maria Duplissy[1], Ari Laaksonen[2], Tuomas Laurila[2], Heikki Lihavainen[2], Alexander Lisitzin[20], Alexsander Mahura[5], Alexander Makshtas[32], Evgeny Mareev[33], Stephany Mazon[1], Dmitry Matishov[34,†], Vladimir Melnikov[35,36], Eugene Mikhailov[37], Dmitri Moisseev[1], Robert Nigmatulin[20], Steffen M. Noe[38], Anne Ojala[7], Mari Pihlatie[1], Olga Popovicheva[39], Jukka Pumpanen[40], Tatjana Regerand[19], Irina Repina[16], Aleksei Shcherbinin[27], Vladimir Shevchenko[20], Mikko Sipilä[1], Andrey Skorokhod[16], Dominick V. Spracklen[9], Hang Su[8], Dmitry A. Subetto[19], Junying Sun[41], Arkady Y. Terzhevik[19], Yuri Timofeyev[37], Yuliya Troitskaya[33], Veli-Pekka Tynkkynen[42], Viacheslav I. Kharuk[43], Nina Zaytseva[22], Jiahua Zhang[44], Yrjö Viisanen[2], Timo Vesala[1], Pertti Hari[7], Hans Christen Hansson[45], Gennady G. Matvienko[10], Nikolai S. Kasimov[12], Huadong Guo[44], Valery Bondur[46], Sergej Zilitinkevich[1,2,12,33], and Markku Kulmala[1,36]

Climate-society feedback



An example of environmental monitoring, data provision to society, and feedback on climate action via UN Sustainable Development Goals.



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Arctic observations and sustainable development goals – Contributions and examples from ERA-PLANET iCUPE data

Steffen M. Noe, Ksenia Tabakova, Alexander Mahura, Hanna K. Lappalainen, Miriam Kosmale, Jyri Heilimo, Roberto Salzano, Mattia Santoro, Rosamaria Salvatori, Andrea Spolaor, Warren Cairns, Carlo Barbante, Fidel Pankratov, Angelika Humbert, Jeroen E. Sonke, Kathy S. Law, Tatsuo Onishi, Jean-Daniel Paris, Henrik Skov, Andreas Massling, Aurélien Dommergue, Mikhail Arshinov, Denis Davydov, Boris Belan, Tuukka Petäjä