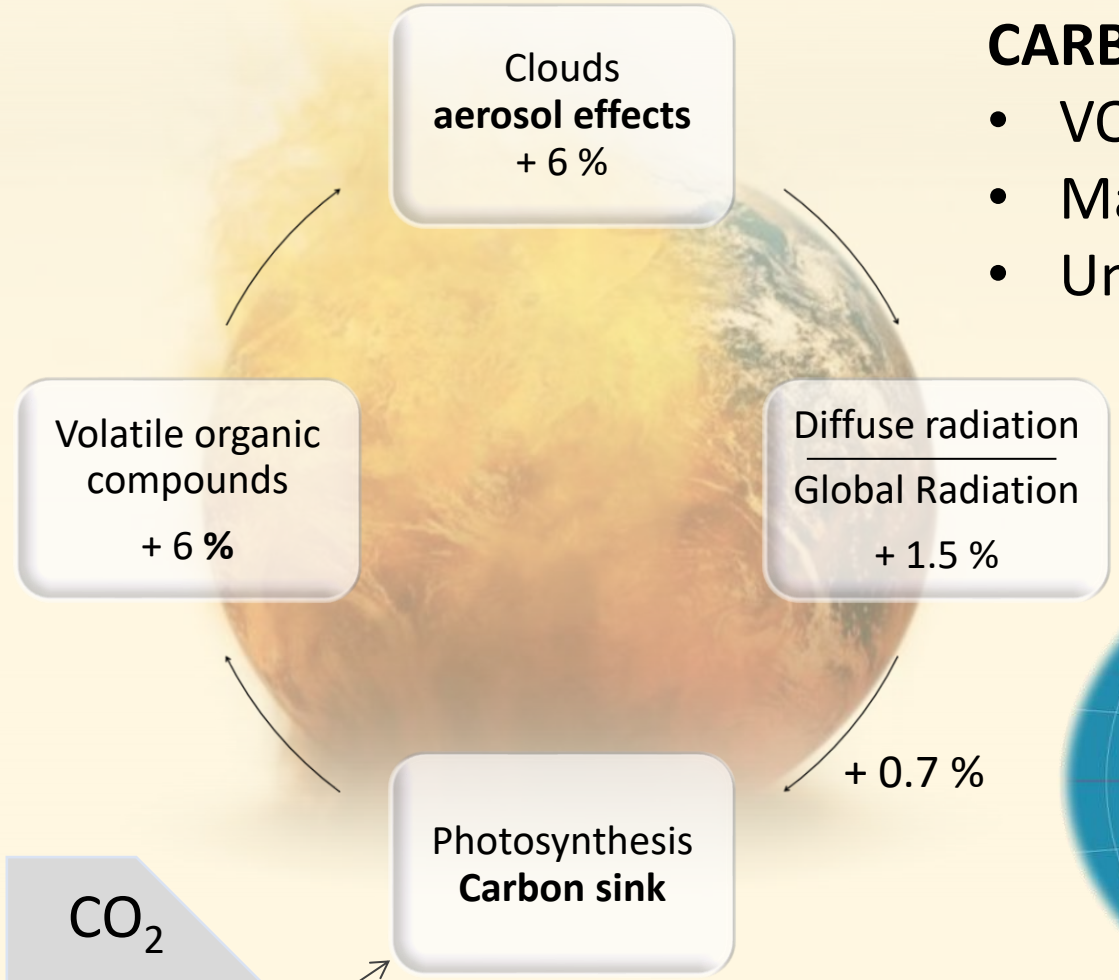
CarbonSink+ i.e. the total climate effect

- Agriculture and forestry
  - Carbon sink (photosynthesis)
  - VOC (volatile organic carbon production) as a side product of photosynthesis
  - VOCs makes aerosol particles, which makes cloud droplets and further precipitation
  - Albedo effect
  - Soil and animals emit ammonia and amines, which helps aerosol production
  - This kind of biogenic aerosols are good for climate

  - Taking CarbonSink+ into account: agriculture much more positive in climate point of view than typically thought
    - Improving 10-80%
    - The same for forests

THE POTENTIAL OF SMEAR CONCEPT: GLOBAL COMPREHENSIVE FEEDBACK ANALYSIS



CARBON SINK PLUS

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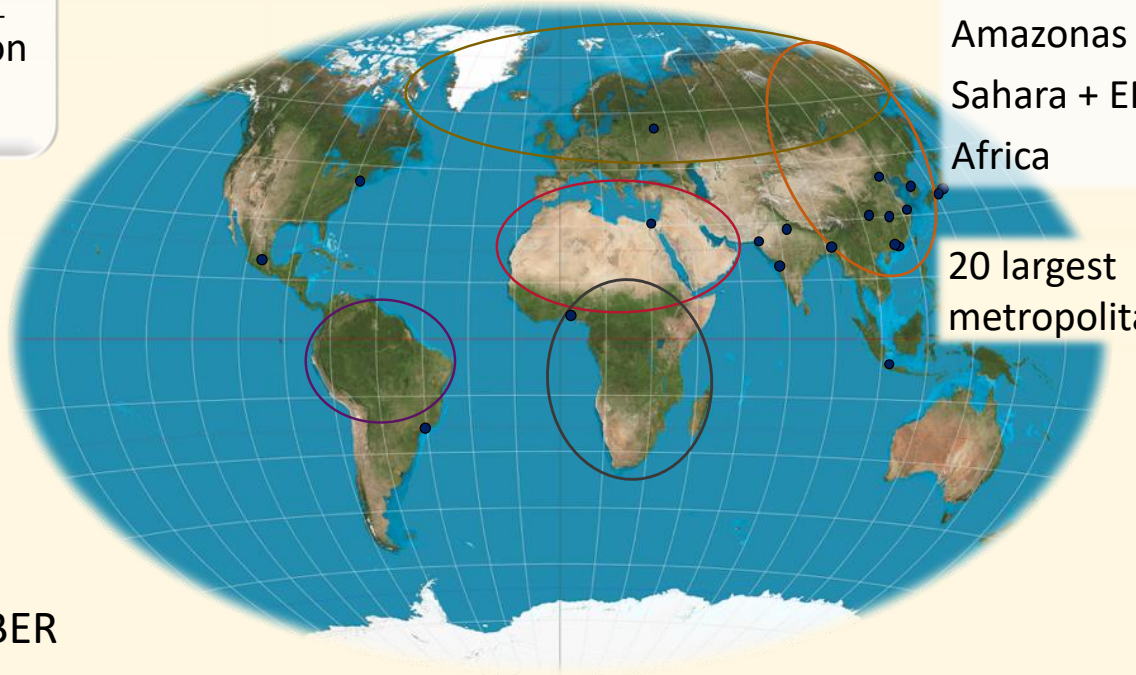
- Max 1.8 x carbon sink (Hyytiälä / SMEAR II results)
- Uncertainties

  => observations / models



Kulmala et al., 2014,2020 BER

Agriculture, food chain and Climate

- Emssions
- Several items postive to climate not considered
  - CarbonSink+
  - Aerosol formation
    - Amines (animals, soil)
    - Ammonia (animals, soil)
    - Organics
- We need integrative approach
- We need CARBO+ (HIILI+)

Climate positive (Ilmastohyvis)

- Agricultural land forms aerosol particles
- Aerosol particles forms cloud condensation nuclei and furthermore cloud droplets and clouds
  - Without aerosol particles we do not have rain
  - When we take into account all climate effects the total effect is bigger than carbon sink only
- More observations needed from different ecosystems (files, forests etc.), landuse and animals
  - Then we can develop relevant models and find out the real total climate effect

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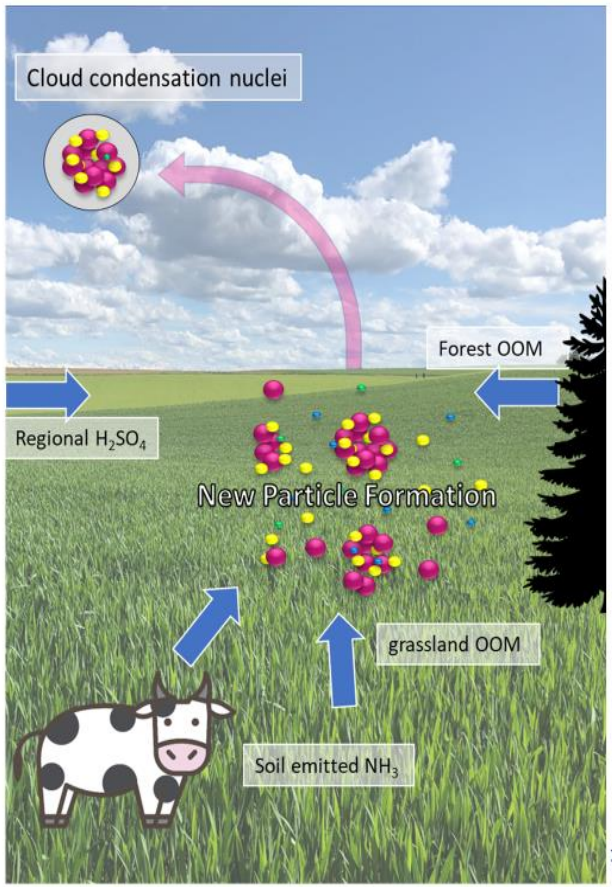
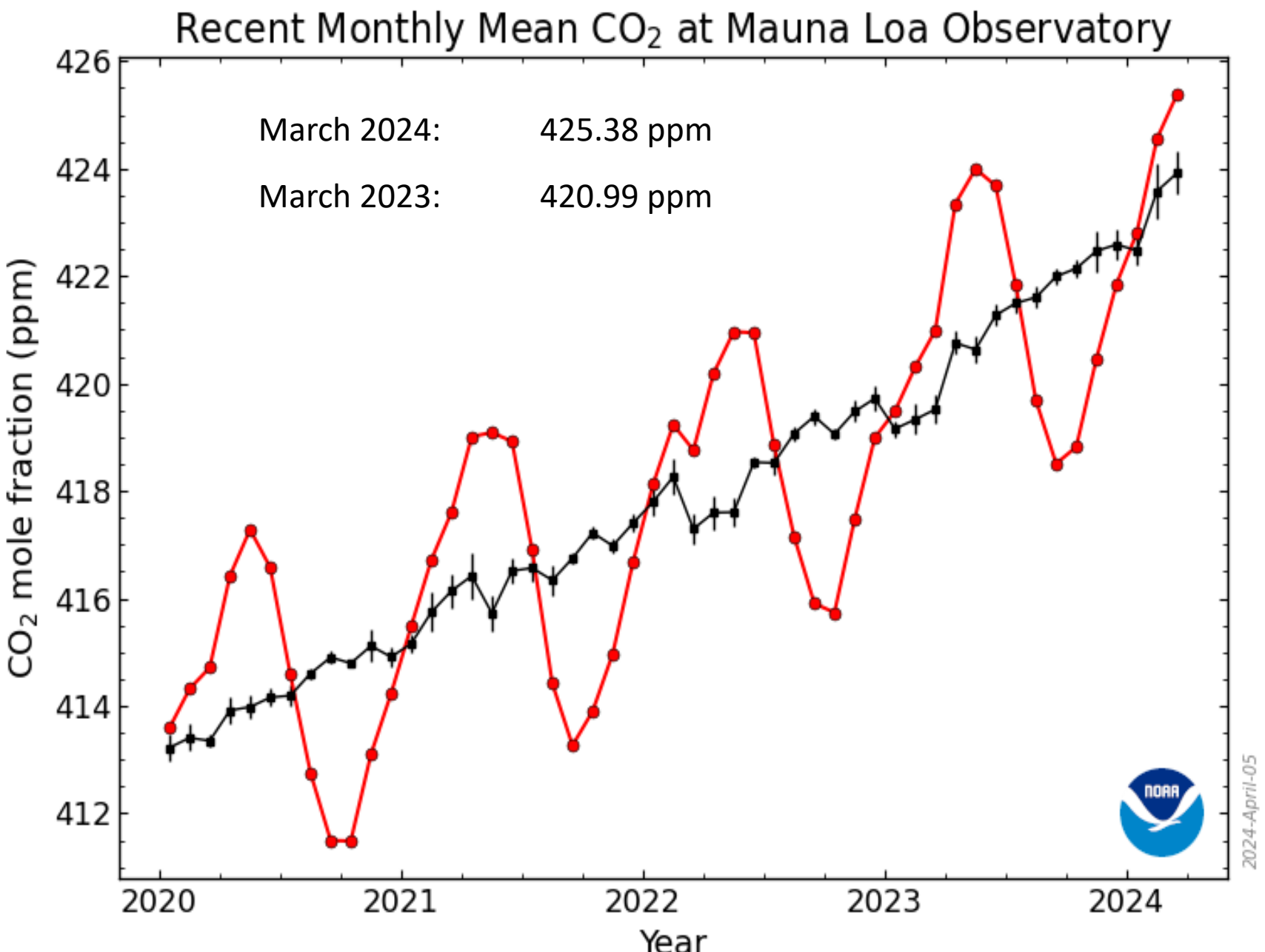


Ilmastohyvis: Hiili+

Markku Kulmala et al.

INAR / ACCC

University of Helsinki



Annual Monthly Max

May 2018: 411.44 ppm

May 2019: 414.86 ppm

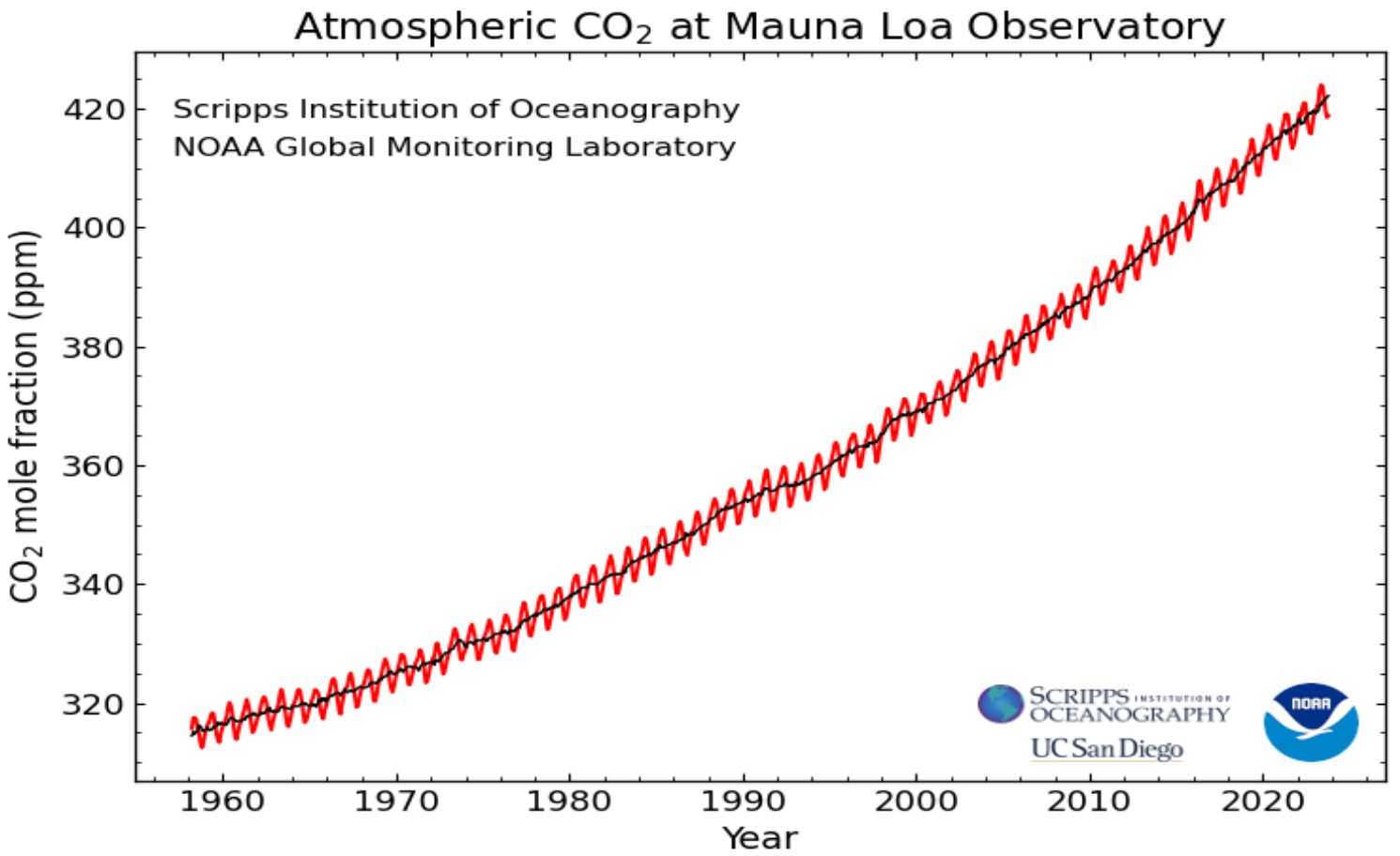
May 2020: 417.31 ppm

May 2021: 419.31 ppm

May 2022: 420.99 ppm

May 2023: 424.00 ppm

Should be in 20 years: Emissions – Sinks < 0



Päästöjen vähentäminen

Nielujen kasvattaminen

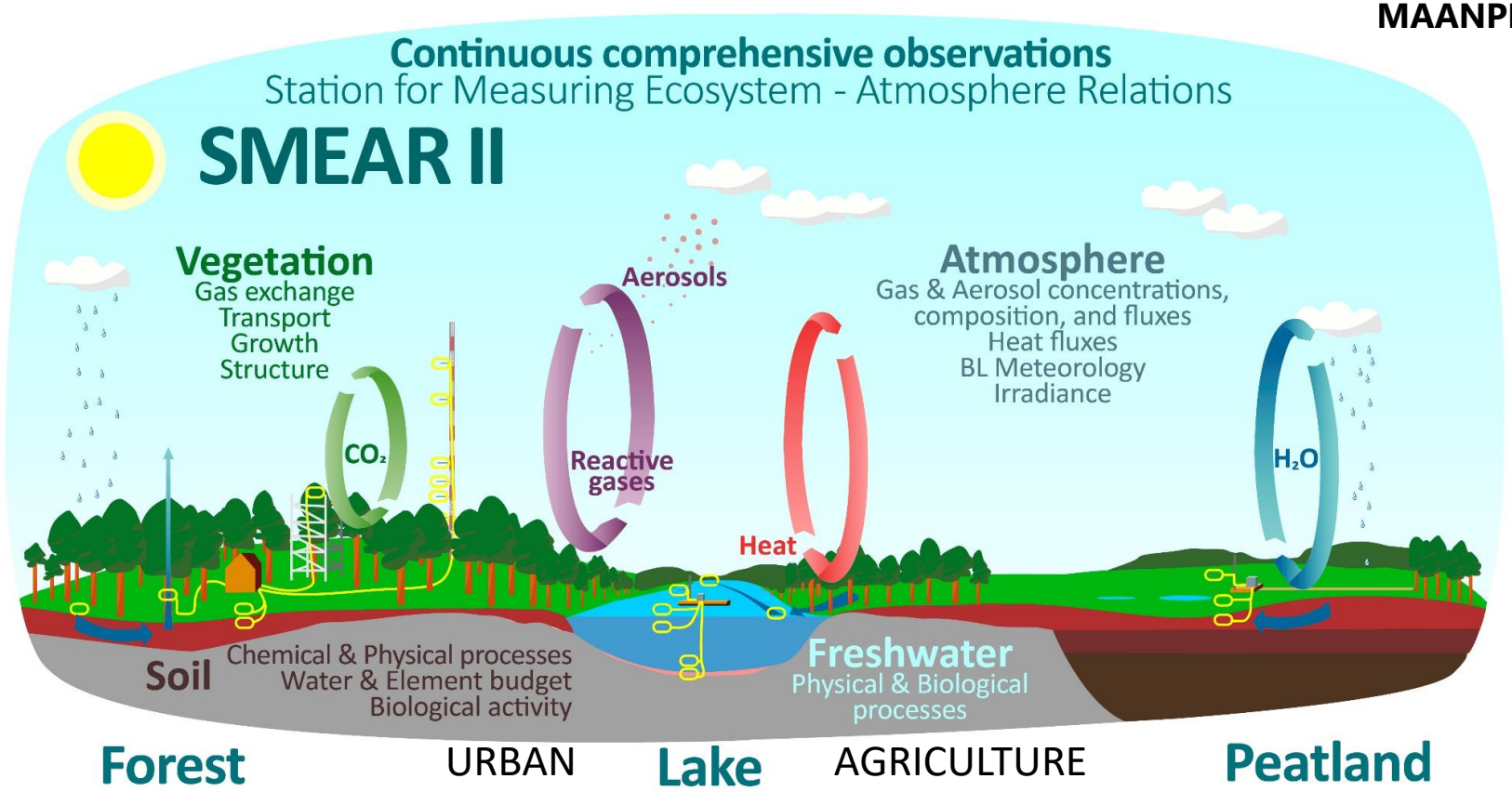
Jos Globaalit nielut
kasvavat 2% vuodessa
Ja päästöt vähenevät 2% vuodessa
Menee 23 vuotta
Ennenkuin pitoisuudet alkavat
Laskemaan

Tarvitaanko SRM:ää?

HYYTIÄLÄ: SMEAR II-station (boreal forest, country side)

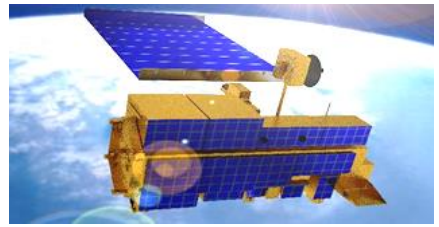
Methods / Tutkimusmenetelmät

- Kattavien maanpintamittausten, kaukomittausten ja monitasoisten mallien yhdistäminen



MAANPINTAMITTAUKSET

SATELLIITTIDATA

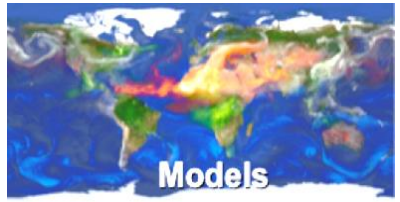


NYKYTILA

Mallien lähtötila

Erilaisen datan yhdistäminen

Konteksti



Täydentää kokonaiskuvaa

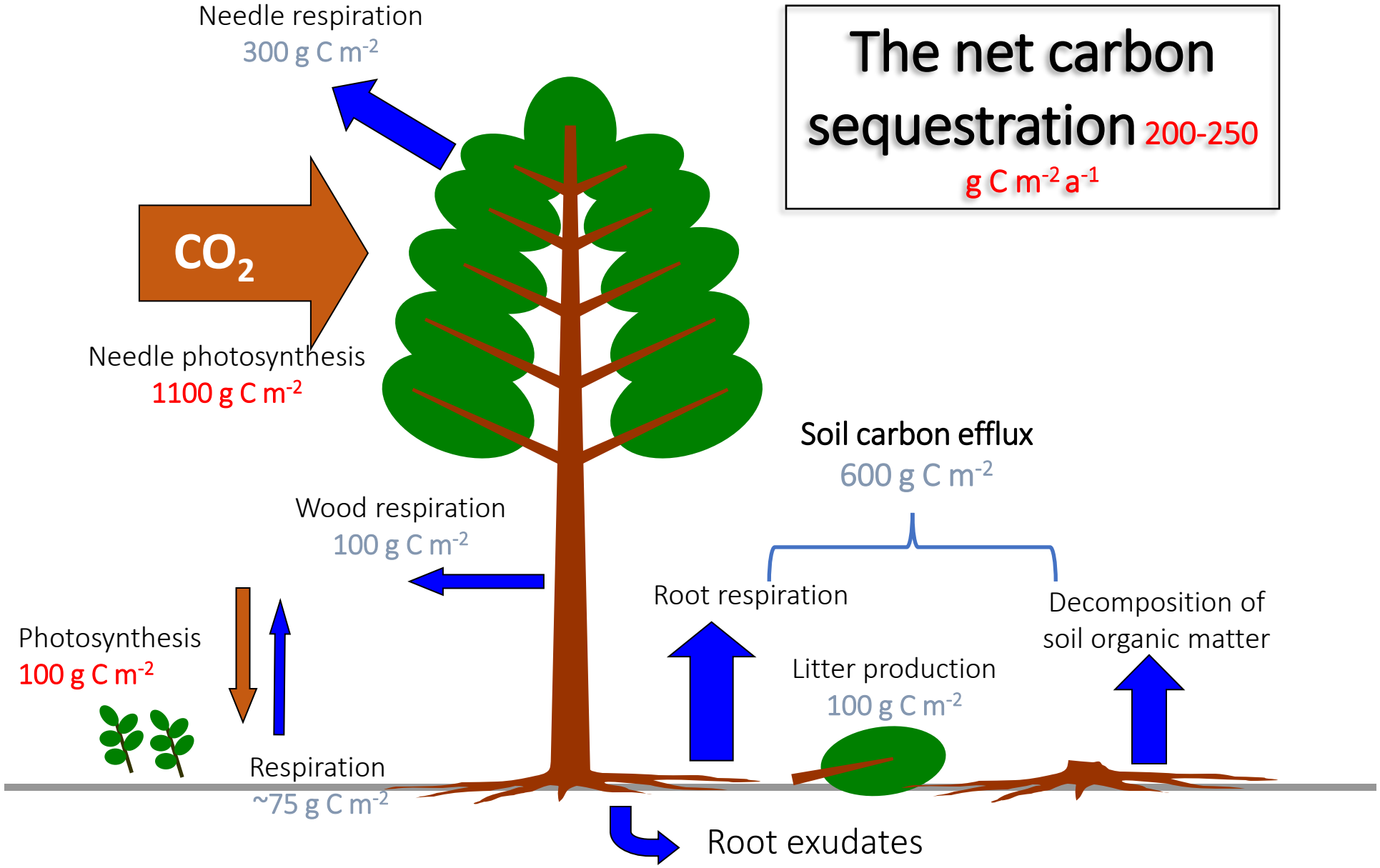
Ennustaa tulevaa

MONITASOISET MALLIT

ACCC

CARBON: partitioning

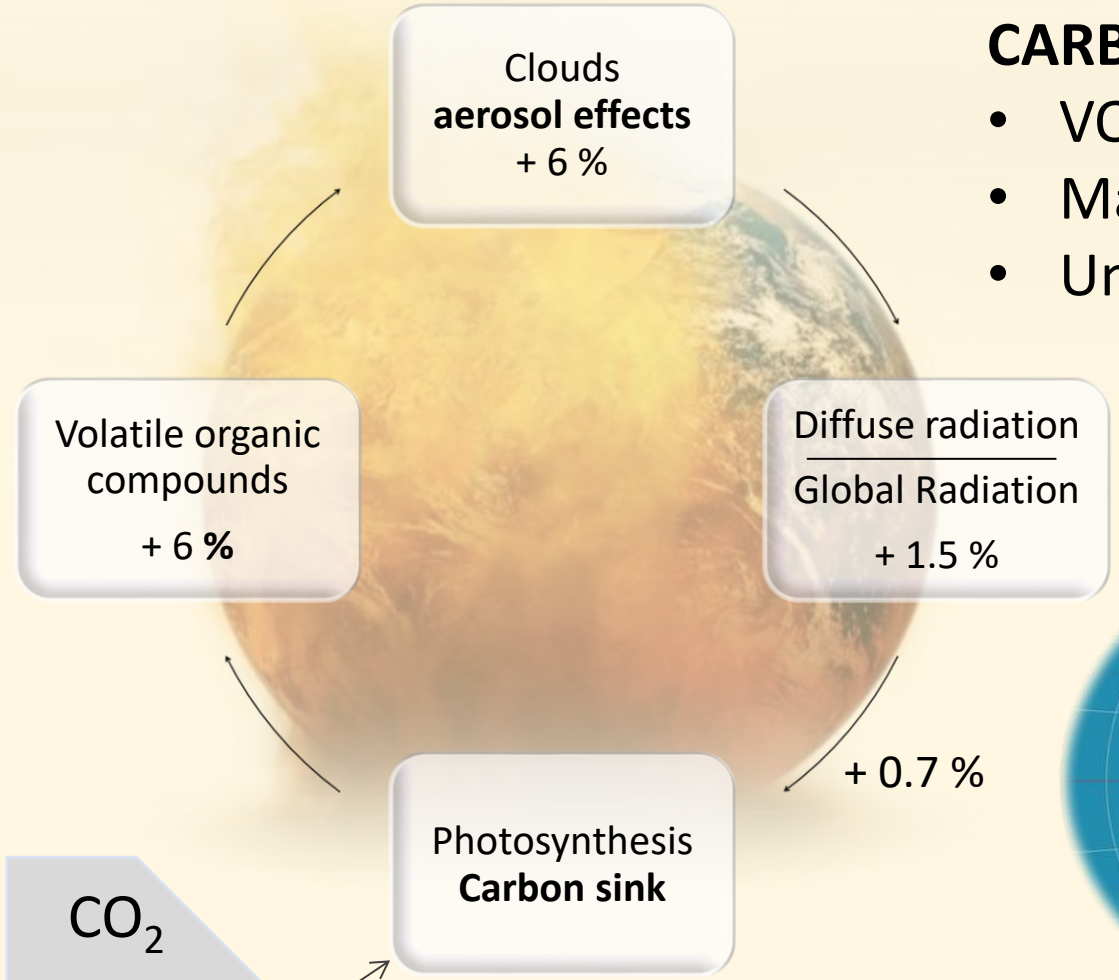
Processes



The net carbon sequestration 200-250 g C m^{-2} a^{-1}

Courtesy: Pasi Kolari

THE POTENTIAL OF SMEAR CONCEPT: GLOBAL COMPREHENSIVE FEEDBACK ANALYSIS



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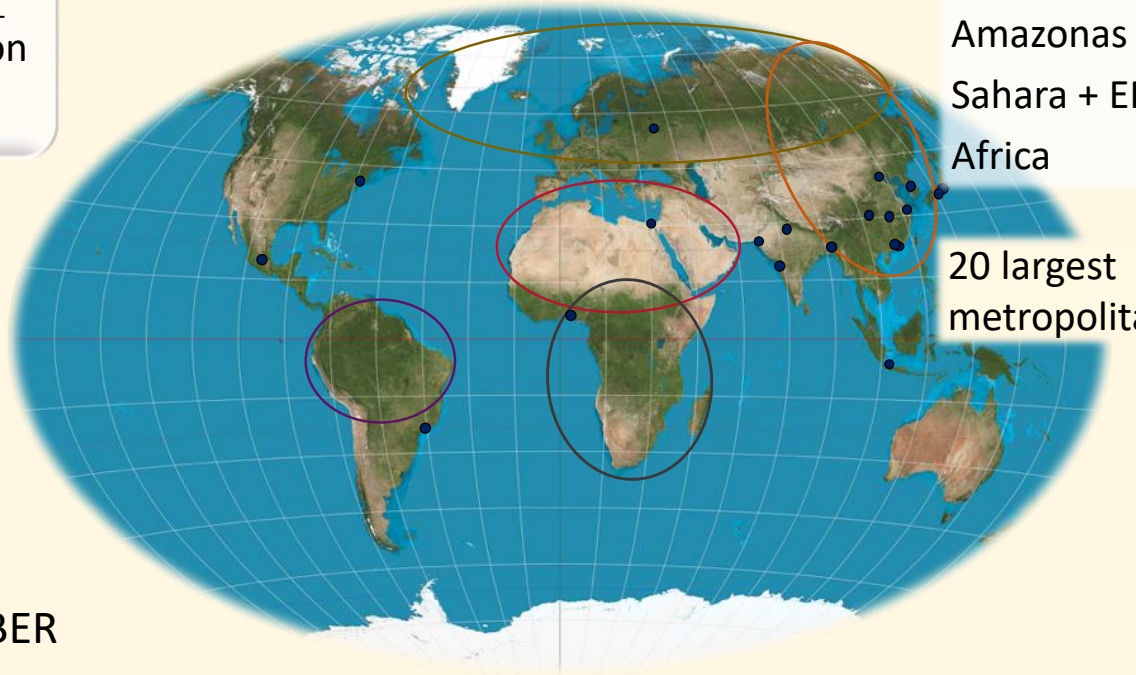


Kulmala et al., 2014,2020 BER

Maatalous, elintarviketju ja Ilmasto

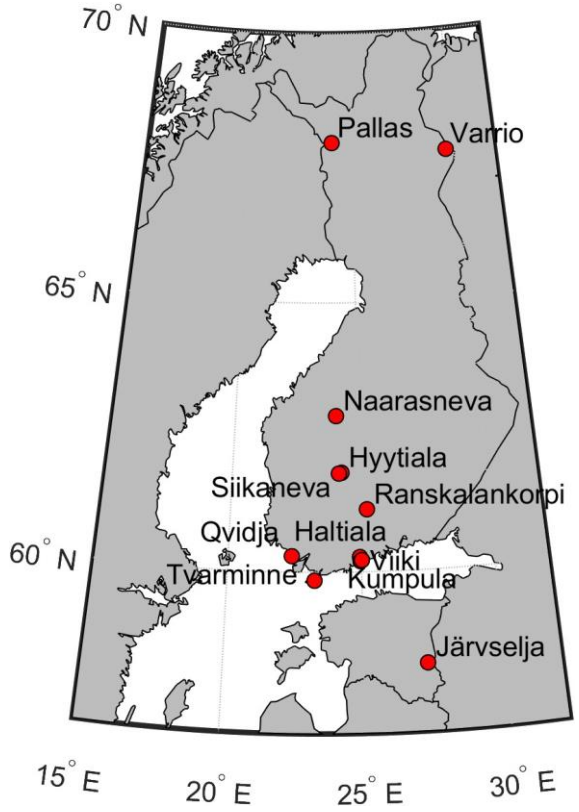
- Päästöt
- Monet ilmaston kannalta positiiviset asiat eivät mukana
  - Hiilinielu plus
  - Hiukkasmuodostus
    - Amiinit (eläimet, maaperä)
    - Ammoniakki (eläimet, maaperä)
    - Orgaaniset aineet
- Tarvitaan kokonaisvaltainen, integroiva lähestyminen
- Tarvitaan CARBO+ (HIILI+)

Ilmastohyvis

- Maatalousmaa tuottaa hiukkasia
- Nämä hiukkaset muodostavat pilvipisaroiden tiivistysmiytimiä ja sittemmin pilvipisaroita ja pilviä
  - Ilman hiukkasia ei ole sadetta
  - Hiukaset ja pilvet hidastavat ilmastonmuutosta
- Kun otetaan huomioon kaikki ilmastovaikutukset, kokonaisvaikutus huomattavasti suurempi kuin pelkkä hiilinielu
- Tarvitaan lisää mittauksia erilaisilta pelloilta ja eläimistä
  - Siten saadaan tehtyä relevanteja malleja ja tietää todellinen ilmastovaikutus

TÄHÄN MENNESSÄ MITATTU

Site	Organization	Ecosystem	Time period for EC	Time period NAIS
Hyytiala (SMEAR Ⅱ)	UH	Forests	2001-2022	2013.05-2022
Varrio (SMEAR Ⅰ)	UH	Forests	2012-2022	2017.08-2022
Siikaneva1 (SMEAR Ⅱ)	UH	Wetlands	2005-2022	2019.01-2022
Kumpula (SMEAR Ⅲ)	UH	Urban	2004-2022	2016.04-2022
Haltiala (SMEAR Agr)	UH	Cropland	2021-2022	2021.06-2022
Naarasneva (SMEAR Agr)	UH	Peatlands	2021-2022	2021.10-2022
Viikki (SMEAR Agr)	UH	Grassland	2021-2022	2022.06-2022
Tvarminne	UH	Costal	2022-2022	2022.06-2022
Järvselja (Smear Estonia)	Esto Uni of Life Science	Forests	2015-2022	2015.08-2022
Qvidja	UH/FMI	Grassland	2018-2022	2018.11-2022
Ränskälänkorpi	UH/FMI	Forests	2019-2022	2020.06-2022
Pallas	FMI	Tundra	2003-2022	2008.05-2022



In progress: Ke et al.: More ecosystems …; Peräkylä et al.: Albedo/Radiatrion balance – forest petaland comaprison Ezhova/Laanti et al. ….

Study sites (so far)

Haltiala (Agricultural)

Viikki & Qvidja (Agricultural)

Siikaneva (Peatland)

Kumpula (Urban)

Tvarminne (Coastal)

Hyytiälä, Järvelja, Värriö & Ränskälänkorpi (Forest)

Mittaukset (uudet)

- Mitataan HIILI+ niiltä pelloilta, joissa jo Eddy Coavariance mittaukset käynnissä.
  - CO2 vuot, perusmeteorologia
  - Mahdollisuuksien mukaan myös N2O vuot, Metaanivuot
- Potentiaaliset paikat LUKEn 6 peltoa, SMEAR Agri Viikki, Puutarha-alue Helsinki, Qwidja
- Aerosolimuodostuksen ilmastovaikutukset
  - Mitataan CIC instrumentilla (Cluster Ion Counter)
- Navetat, muut eläisuojat

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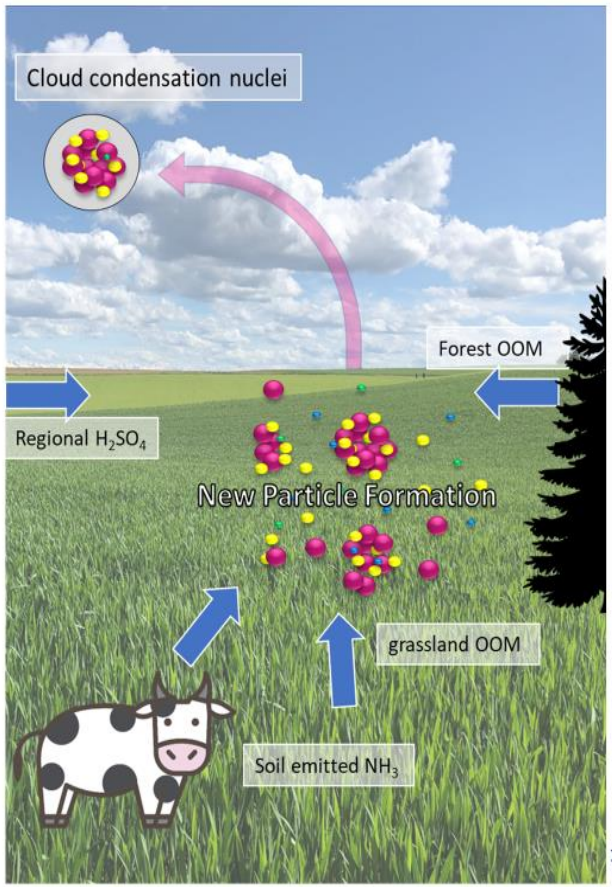

Environmental Science: Atmospheres

ROYAL SOCIETY OF CHEMISTRY

PAPER

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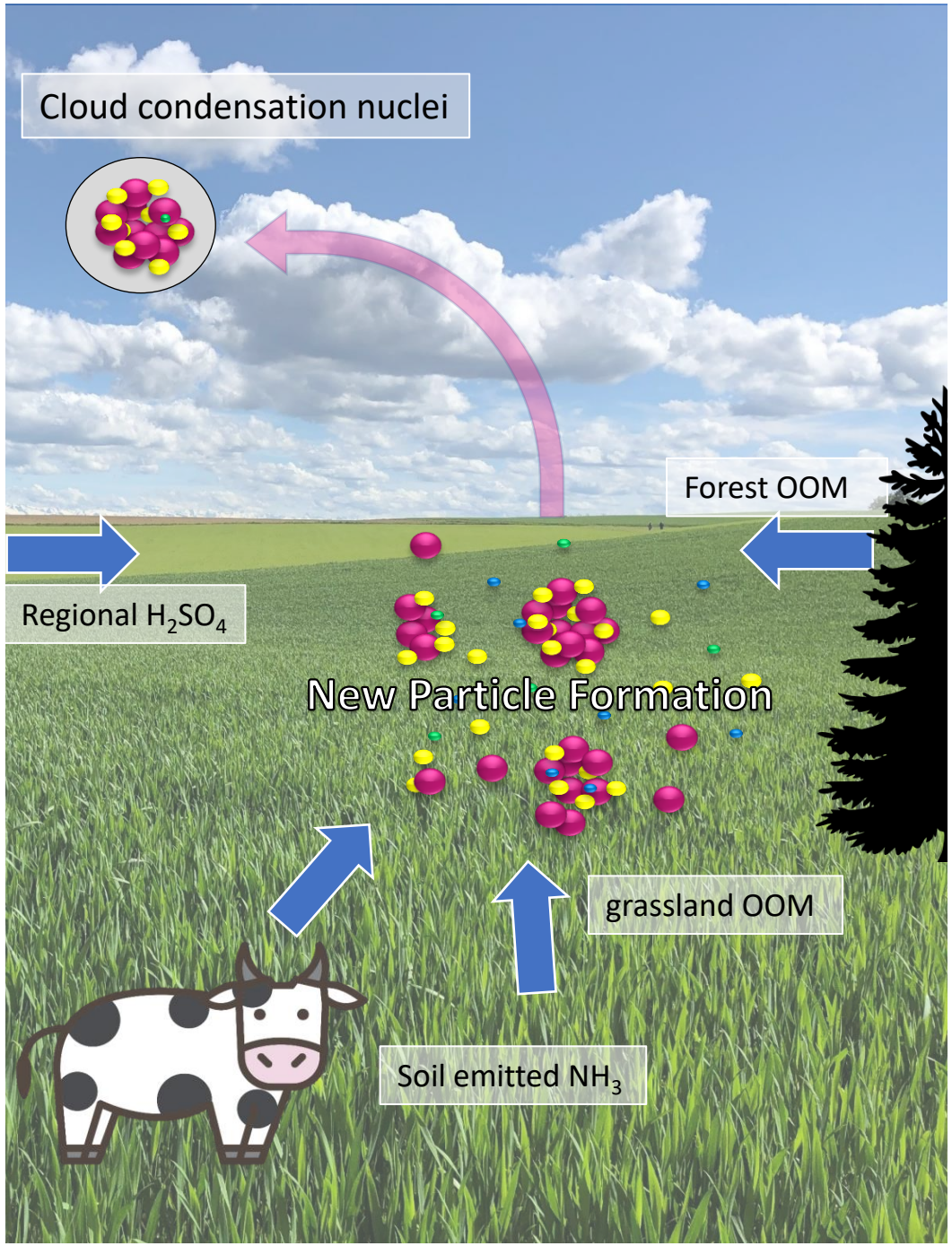
Cite this: *Environ. Sci.: Atmos.*, 2023, **3**, 1195

The synergistic role of sulfuric acid, ammonia and organics in particle formation over an agricultural land†

Lubna Dada, *[ab] Magdalena Okuljar,‡[a] Jiali Shen,‡[a] Miska Olin,[c] Yusheng Wu,[a] Laura Heimsch,[d] Ilkka Herlin,[e] Saara Kankaanrinta,[e] Markus Lampimäki,[a] Joni Kalliokoski,[c] Rima Baalbaki,[a] Annalea Lohila,[d] Tuukka Petäjä,[a] Miikka Dal Maso,[c] Jonathan Duplissy,[af] Veli-Matti Kerminen[a] and Markku Kulmala *[a]

Agriculture provides people with food, but poses environmental challenges. *Via* comprehensive observations on an agricultural land at Qvidja in Southern Finland, we were able to show that soil-emitted compounds (mainly ammonia and amines), together with available sulfuric acid, form new aerosol particles which then grow to climate-relevant sizes by the condensation of extremely low volatile organic compounds originating from a side production of photosynthesis (compounds emitted by ground and surrounding vegetation). We found that intensive local clustering events, with particle formation rates at 3 nm about 5–10 times higher than typical rates in boreal forest environments, occur



The big picture

Within an agricultural land, **soil-emitted compounds**, together with available **sulfuric acid**, form **new aerosol particles**, which then grow to climate-relevant sizes by the condensation of **extremely low volatile organic compounds** originating from a side production of photosynthesis.

We find that agricultural land areas are more than **10 times more efficient** in producing growing aerosol particles than the adjacent boreal forest environment, and hence are expected to be several times more efficient in eventually producing cloud condensation nuclei which could change the recognition of agricultural lands as solely global warming contributors.

BOREAL ENVIRONMENT RESEARCH 29: 1–16 © 2024
ISSN 1797-2469 (online) Helsinki 5 January 2024
Editor in charge of this article: Antti Arola

A novel concept for assessing the potential of different boreal ecosystems to mitigate climate change (CarbonSink+ Potential)

Markku Kulmala* 1,2,3 , Piaopiao Ke 1 , Anna Lintunen 1,4 , Otso Peräkylä1 ,
Aleksi Lohtander 1 , Santeri Tuovinen 1 , Janne Lampilahti 1 , Pasi Kolari 1 ,
Pauliina Schiestl-Aalto 1,4 , Tom Kokkonen 1 , Tuomo Nieminen 1,5 , Lubna Dada 1,6 , Ilona Ylivinkka 1 , Tuukka Petäjä 1,3 , Jaana Bäck 4 , Annalea Lohila 1,7 , Laura Heimsch 6 , Ekaterina Ezhova 1 and Veli-Matti Kerminen 1

1) Institute for Atmospheric and Earth System Research
2) Aerosol and Haze Laboratory, Beijing Advanced Innovation Center for Soft Matter Sciences and Engineering, Beijing University of Chemical Technology (BUCT), Beijing, China
3) Joint International Research Laboratory of Atmospheric and Earth System Sciences, School of Atmospheric Sciences, Nanjing University, Nanjing, China
4) Institute for Atmospheric and Earth System Research (INAR) / Forest Sciences,Faculty of Agriculture and Forestry, University of Helsinki, Finland
5) Department of Physics, Faculty of Science, University of Helsinki, Finland
6) Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, 5232 Villigen, Switzerland
7) Finnish Meteorological Institute, Finland

*(corresponding author’s e-mail: markku.kulmala@helsinki.fi)

PAIKALLINEN JA GLOBAALI MERKITYS

- ILMASTO, RUUAN TUOTANTO, VEDEN RIITTÄVYYS KUULUVAT YHTEEN
- YHTIÖIDEN JA MAATILOJEN ILMASTOVAIKUTUS
- KANNATTAA TIETÄÄ (MITATA JA MALLITTAA) MYÖS NE VAIKUYTUKSET JOTKA OVAT ILMASTO KANNALTA POSITIIVISIA ELI AEROSOLIHIUKASTEN TUOTTO

Scope of Global Grand Challenges

Global warming

Climate change

Earthquakes

Volcanoes

Air quality

Energy

Fresh water

Epidemic diseases

Ocean acidification

Biodiversity loss

Deforestation

Chemicalisation

Food supplies

Demography / Population / Urbanization

We have a natural greenhouse effect.

- Without it the mean surface T ca - 18 °C
- Now ca 14 °C

→ ***Climate is changing – but how?***

DISCIPLINES

Natural Sciences

Social Sciences

Medicine

Technology etc

PEEX / IEAS

Science Diplomacy / TWAS

WMO/GAW

Global SMEAR

ICOS, ACTRIS, eLTER

From ideas to implementation!

ACCC

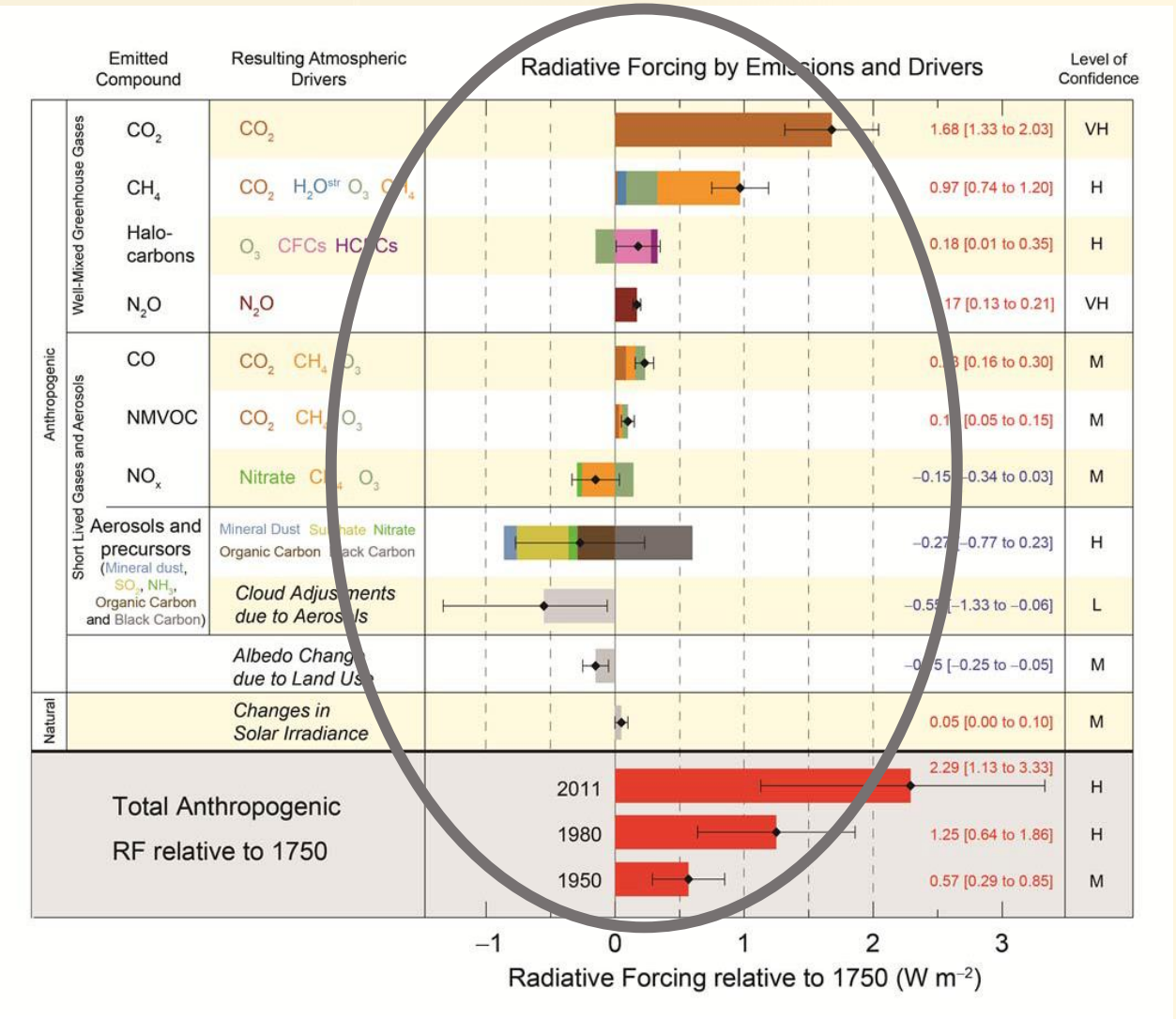
INTEGRATED APPROACH:
THE GLOBAL EARTH OBSERVATORY / GLOBAL SMEAR

Current observations (see IPCC 2013) are fragmented:

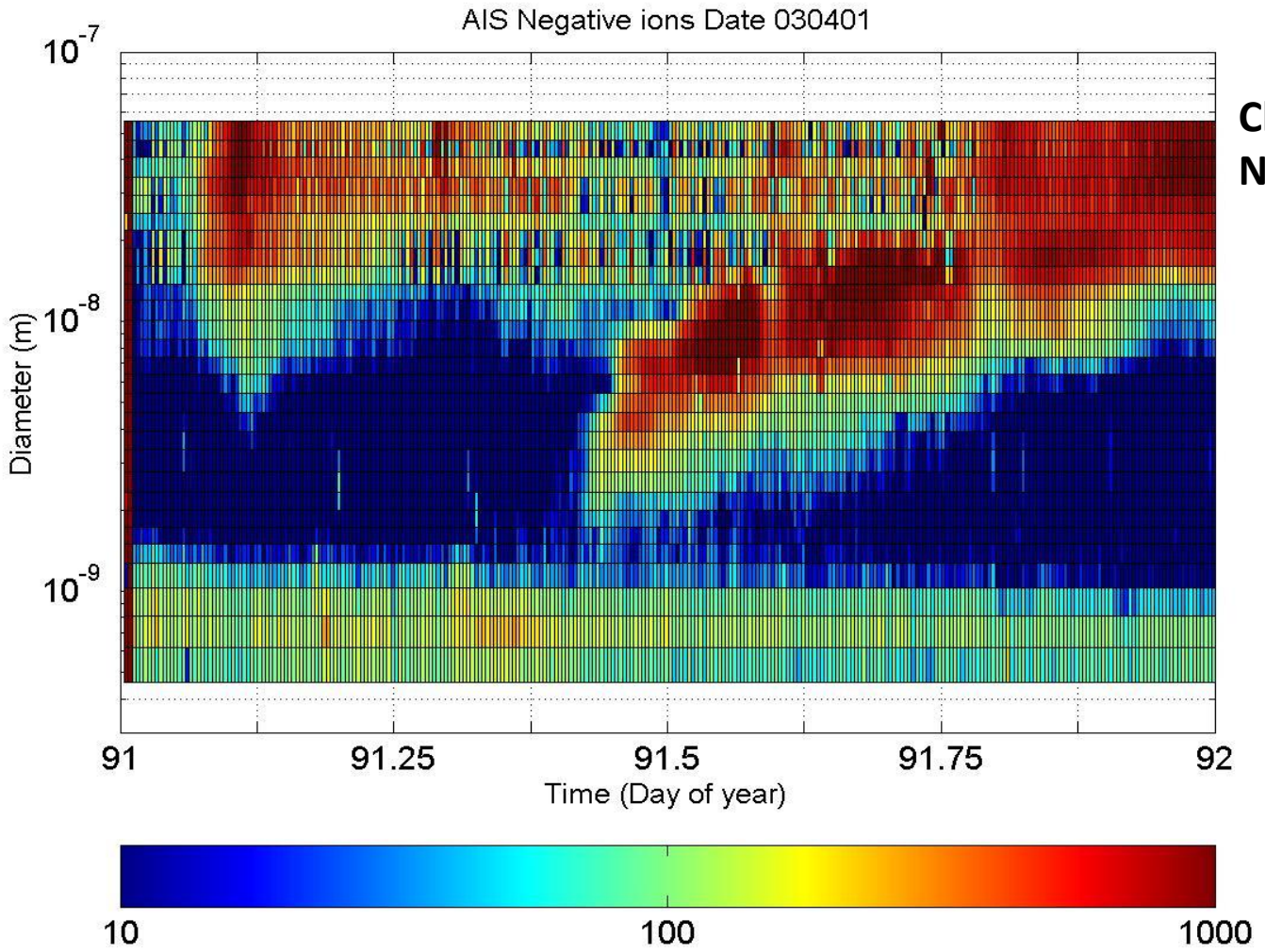
1) Greenhouse gases
2) Aerosols
3) Air quality
4) Ecosystems
5) Climate
6) …

Future aspiration: **Integrated approach**

- **To understand feedbacks**
- **To reduce uncertainties**
- **To mitigate and adapt effectively**



SMEAR SCIENCE RESULTS:
Observation of Nucleation Burst in Finland



Cloud Condensation Nuclei

Aerosol particles

Cluster Ions

Kulmala et al., 2004, ACP [25]
Kulmala et al., 2007, Science

Ongoing work

- Compare different locations and sites
- Photosynthesis (GPP)
- Aerosol impacts: negative ions (2 - 2.3nm)
  - Best size to compare carbons sink and CarbonSink+
- Both have positive cooling effect on the climate.

- **Is there a relation between GPP and Negative ions?**
- **How do different sites or ecosystems compare to each other?**