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FORTH C·STACC Center for the Study of Air Quality & Climate Change

Atmospheric particulate matter and its impacts on climate, public health and ecosystems

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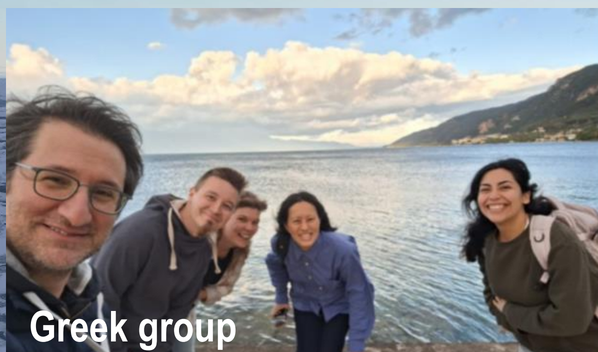
ENV 167 Presentation, December 2, 2024

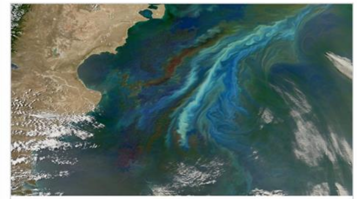
LAPI – Athanasios (Thanos) Nenes

Laboratory of atmospheric processes and their impacts



http://lapi.epfl.ch

http://cstacc.iceht.forth.gr



Biogeochemical Cycles

Aerosol – Cloud – Climate Interactions

Air Quality and Health

Aerosol Chemistry and Impacts

iMIRACLI

Clean Cloud

FORCeS

GREEN FJORD

ReCLEAN

LIPIC Air

erc European Research Council Established by the European Commission

EASVOLEE

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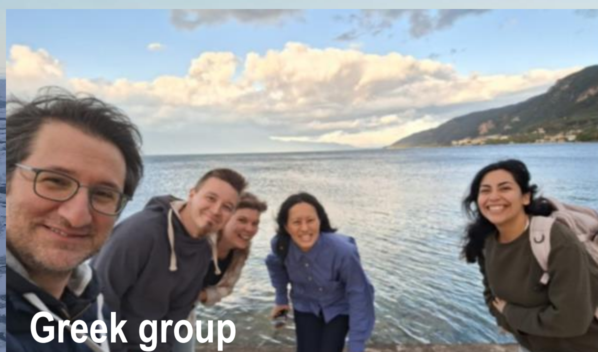
LAPI – Athanasios (Thanos) Nenes

Laboratory of atmospheric processes and their impacts



http://lapi.epfl.ch

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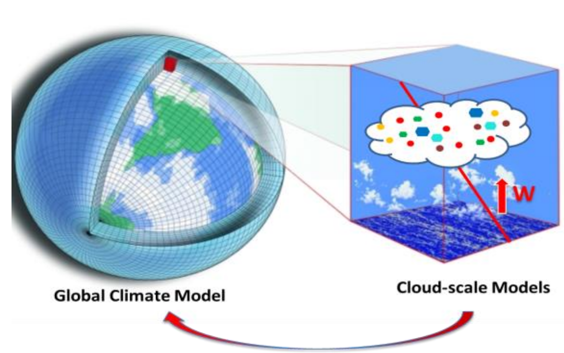
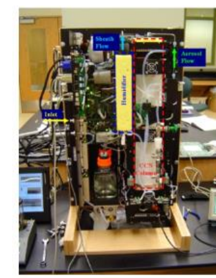
Field and Laboratory Observations

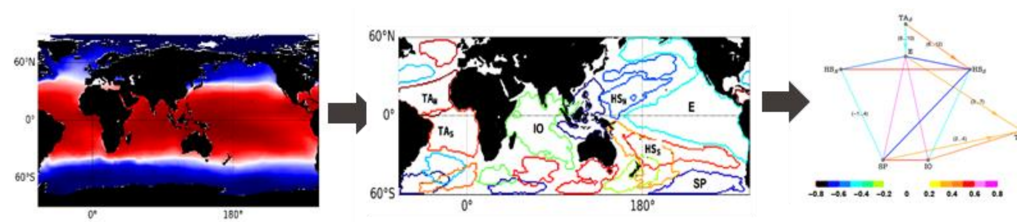
Modeling



Instrumentation

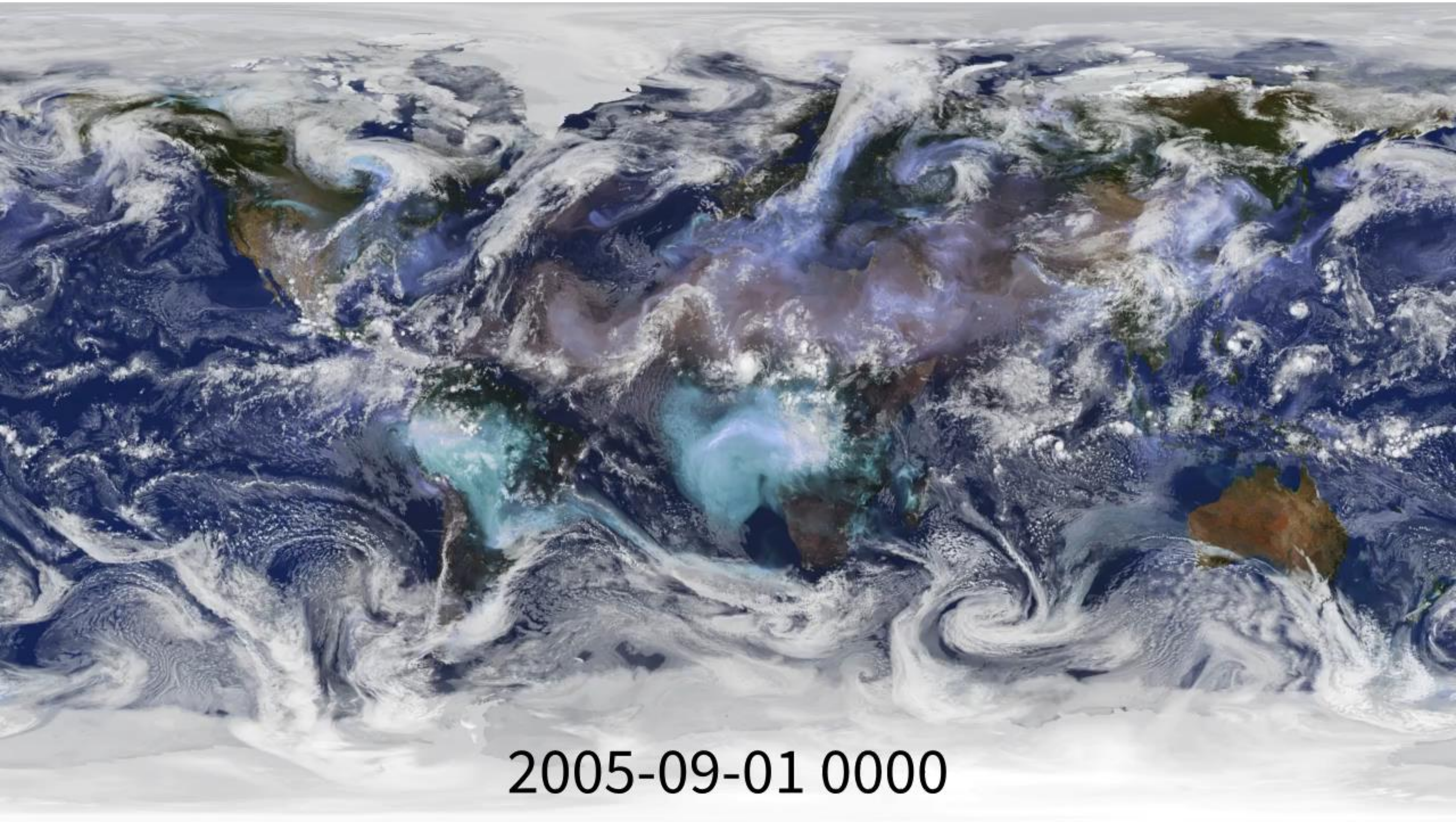


Cloud Condensation Nuclei Counter, US Patent 7,656,510

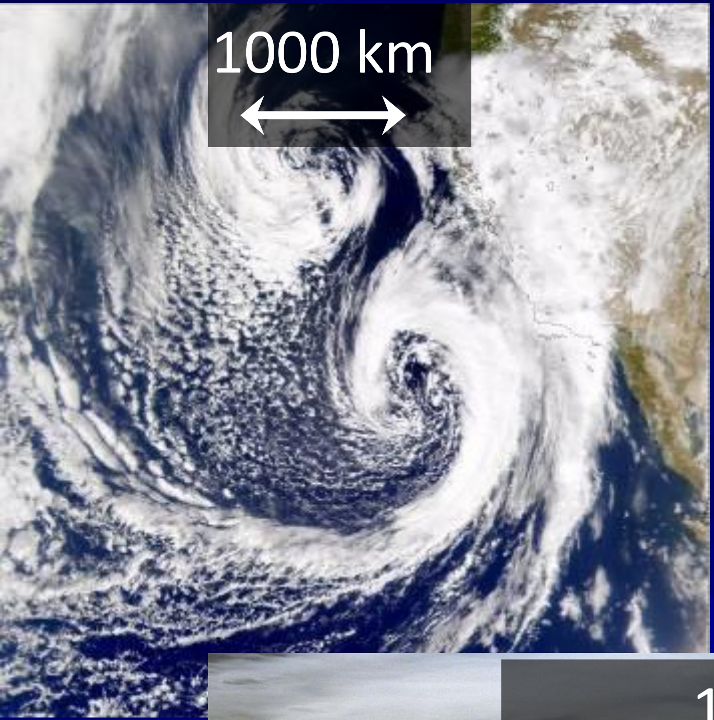


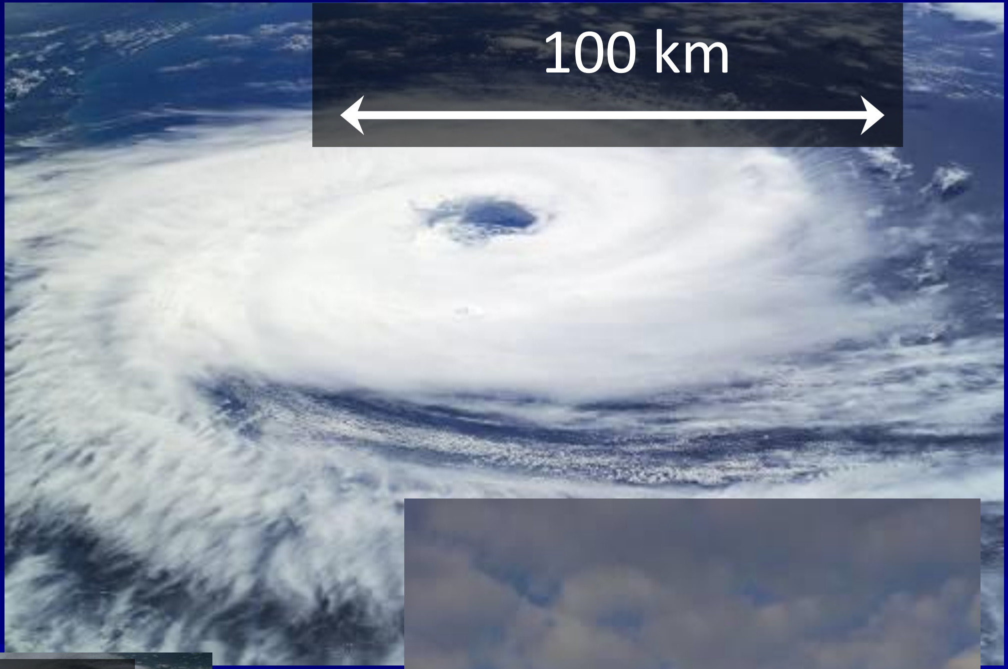
Data science

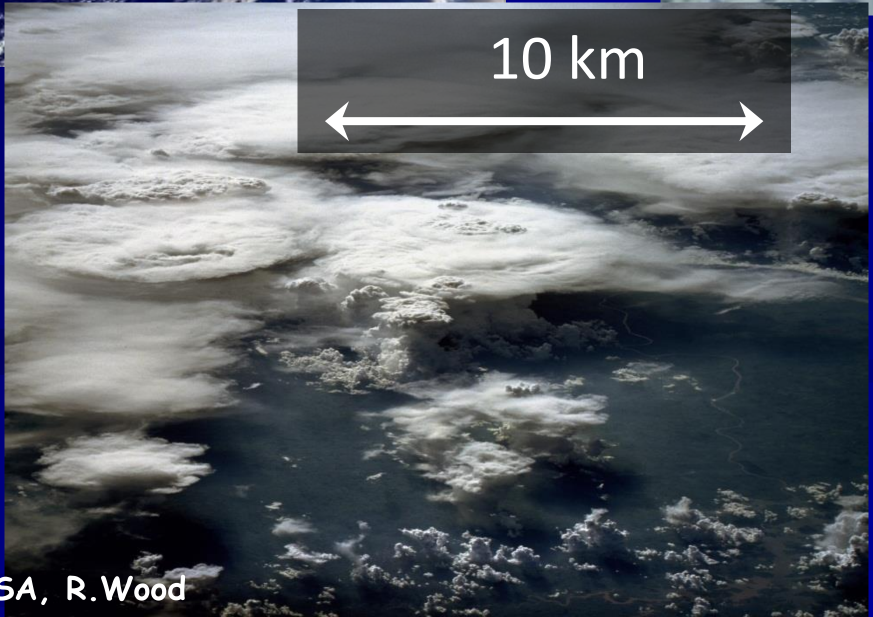
Clouds are everywhere and at all scales…



Clouds are everywhere and at all scales…







Photos: NASA, R.Wood

Clouds have an important radiative impact.

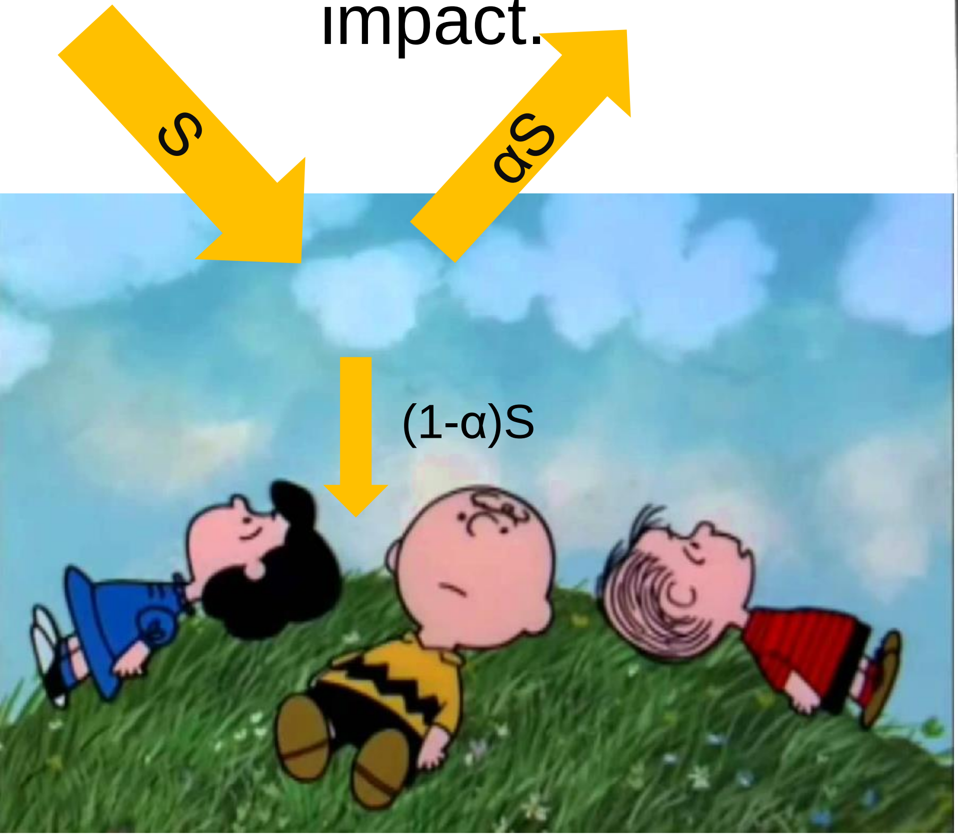


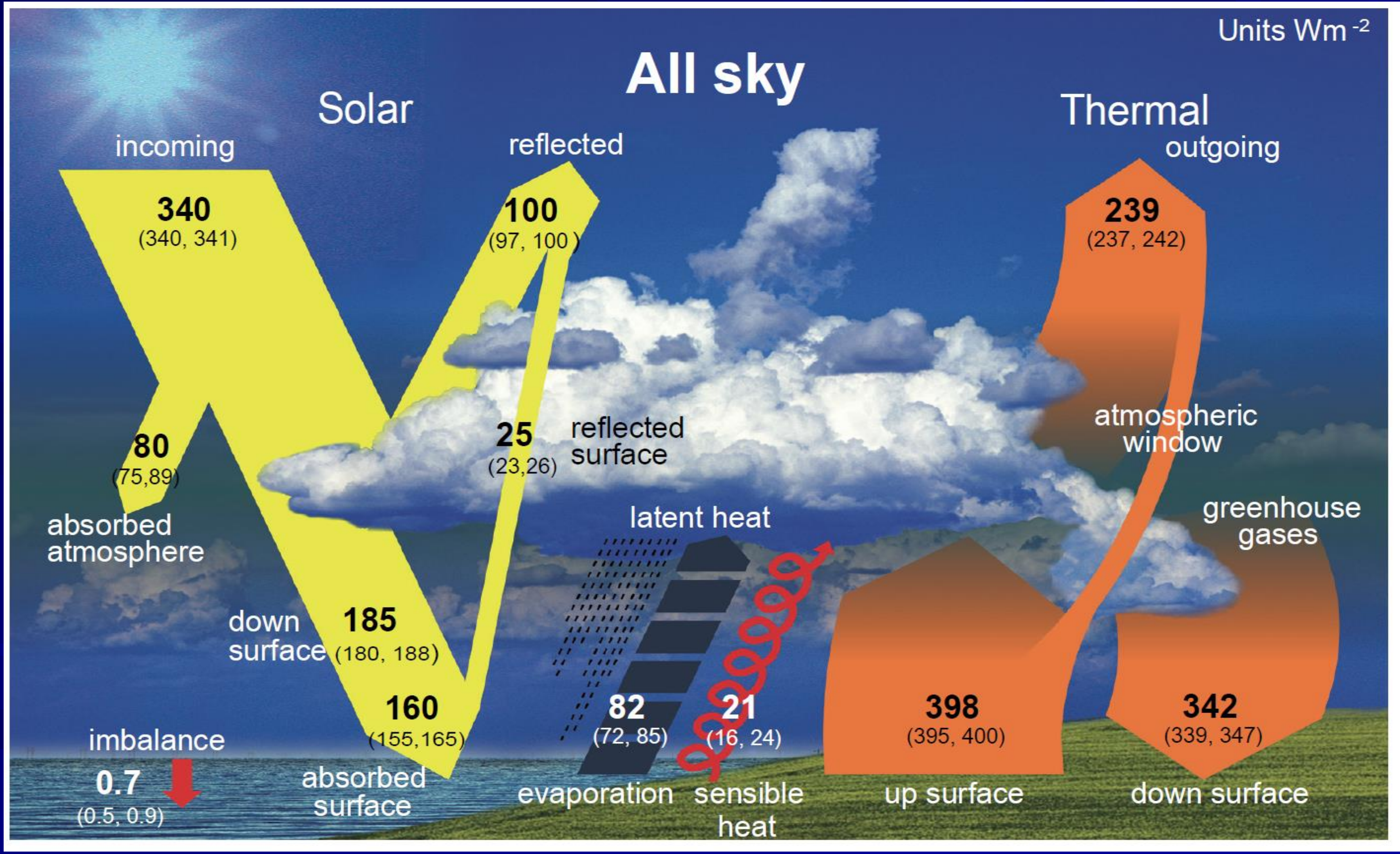
Photo from Wynn Bullock

Clouds also have an important hydrological impact.

Both critically important for regional and global climate

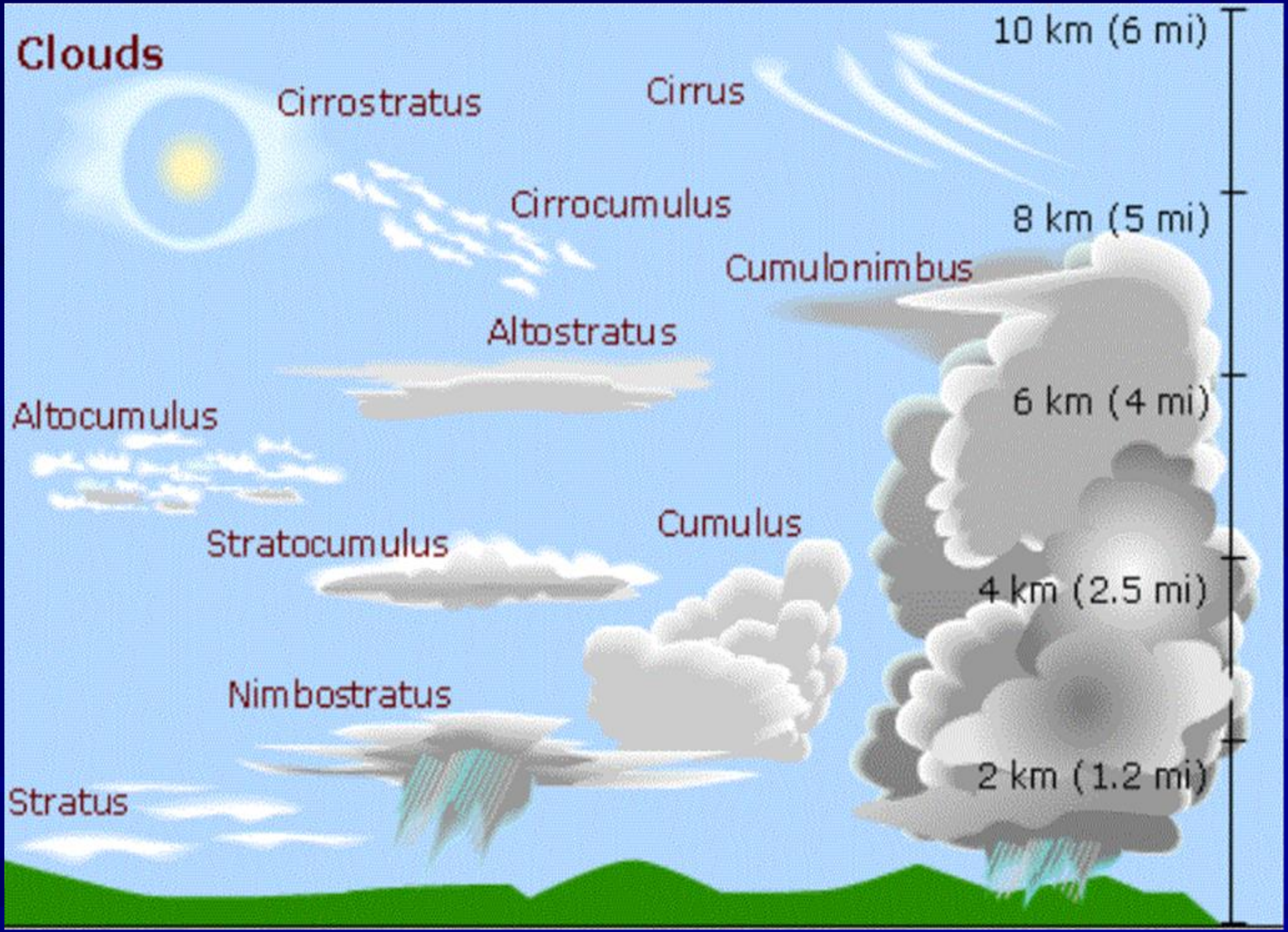
Courtesy: S.Sullivan

Clouds play a central role in the climate system



Based on J.T. Houghton: "The science of climate change"

Cloud impacts vary alot



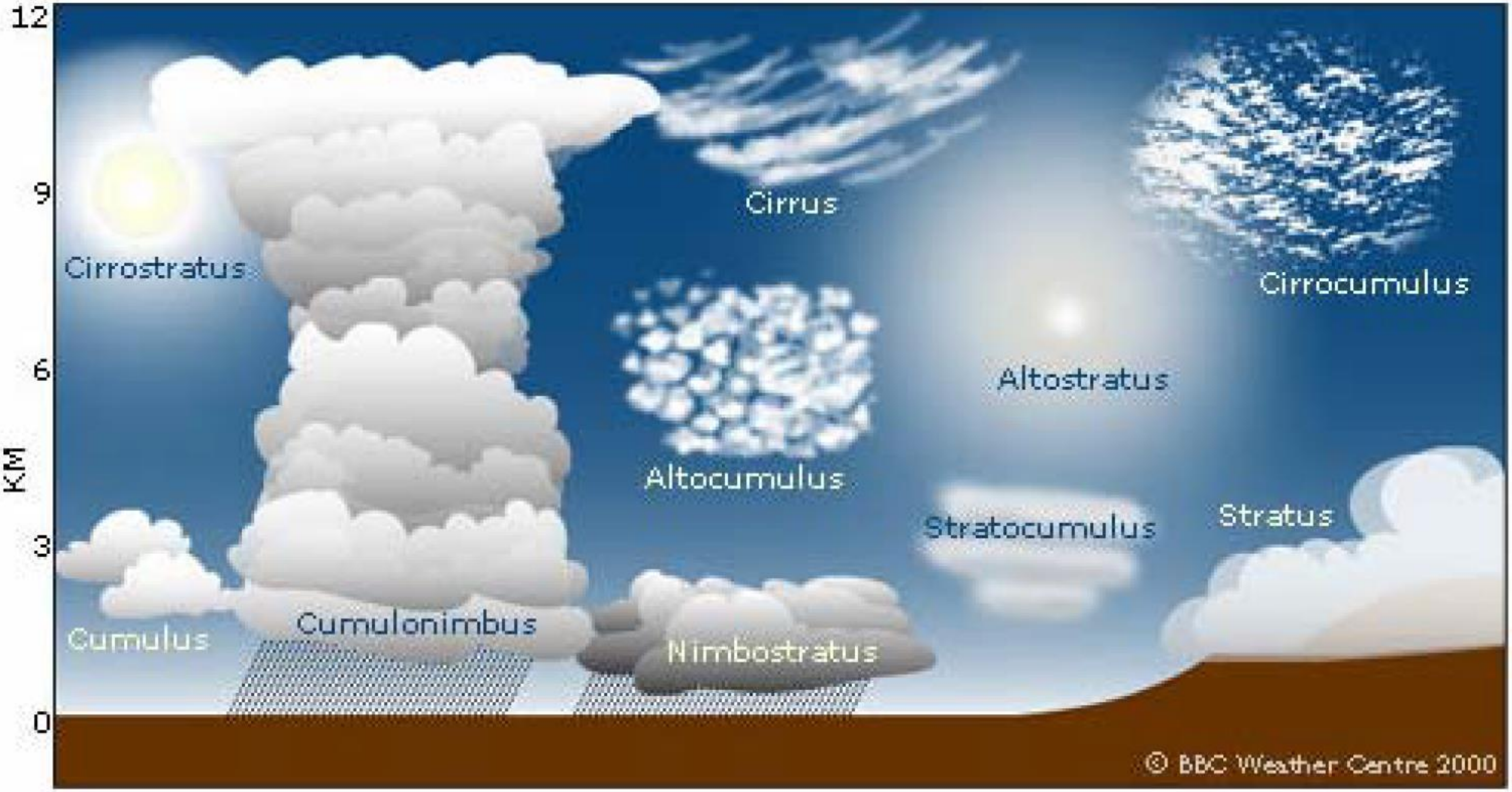
High clouds (ice crystals): ***warm*** **climate**

Mid-level: Warm/cool

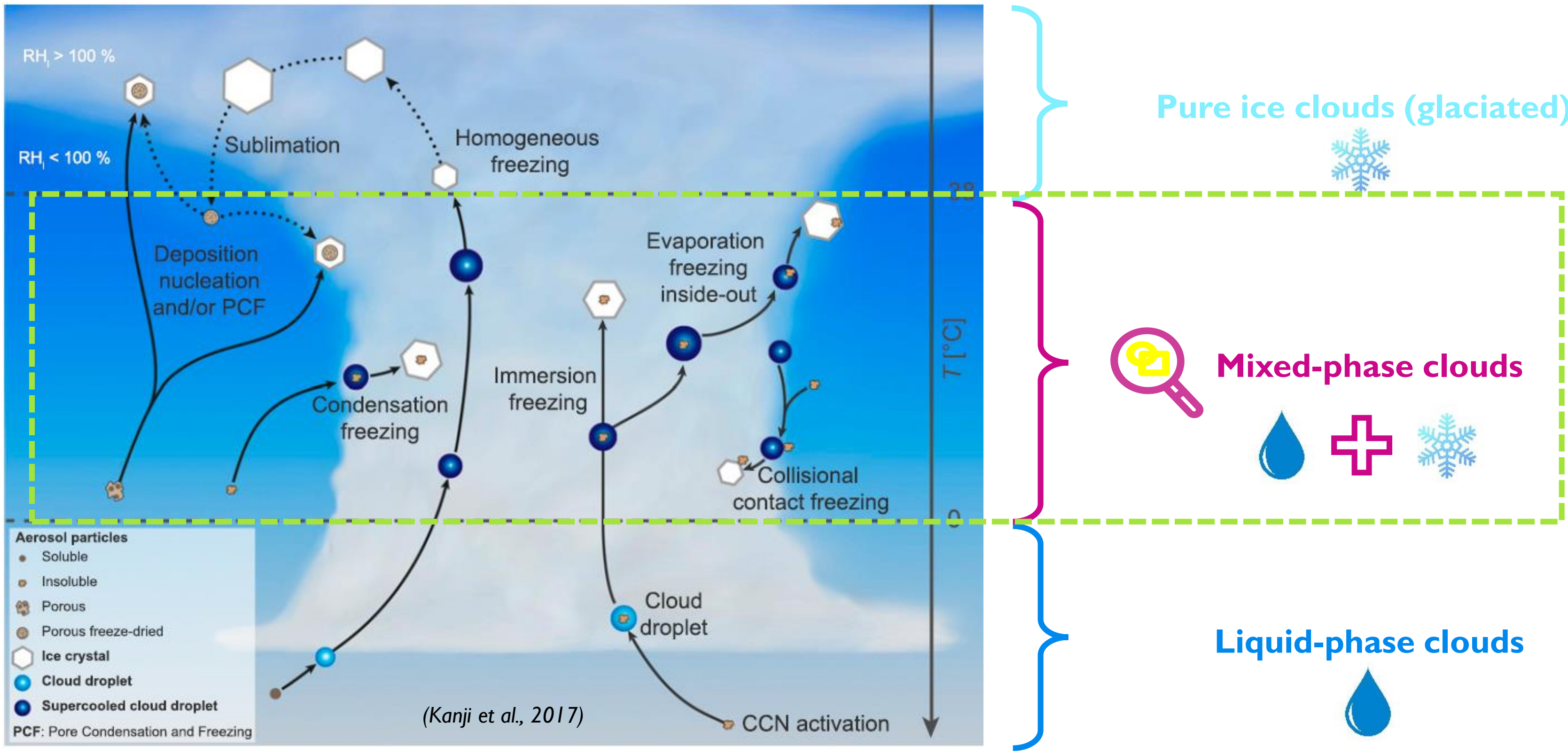
Low clouds (liquid drops): ***cool*** **climate**

http://www.ucar.edu/news

Common Cloud Names, Shapes, and Altitudes:

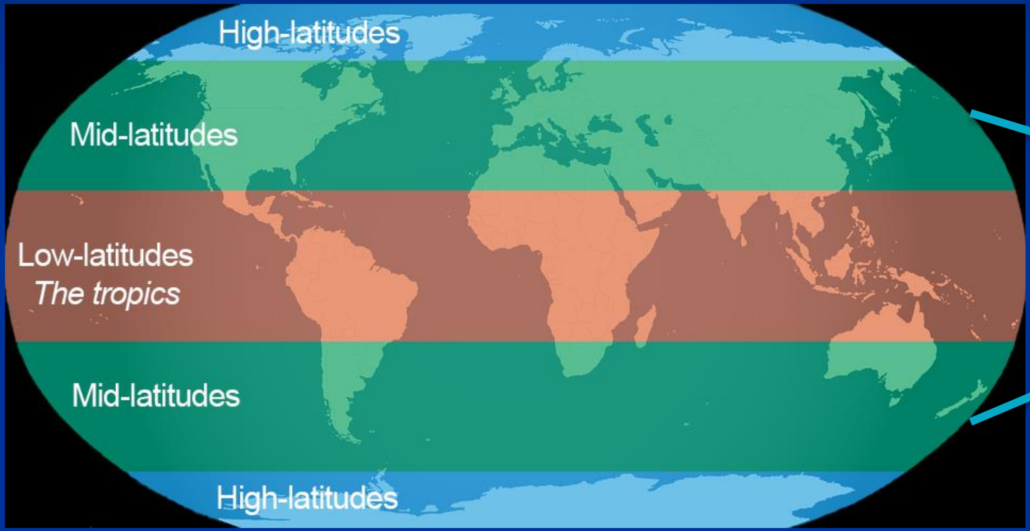


Clouds types in the atmosphere



Atmospheric Particles ("aerosol") are the seeds for cloud formation
Aerosol/Cloud/Climate interactions are a major source of uncertainty in climate projections

Liquid+ice ("mixed-phase") clouds Are very important for climate

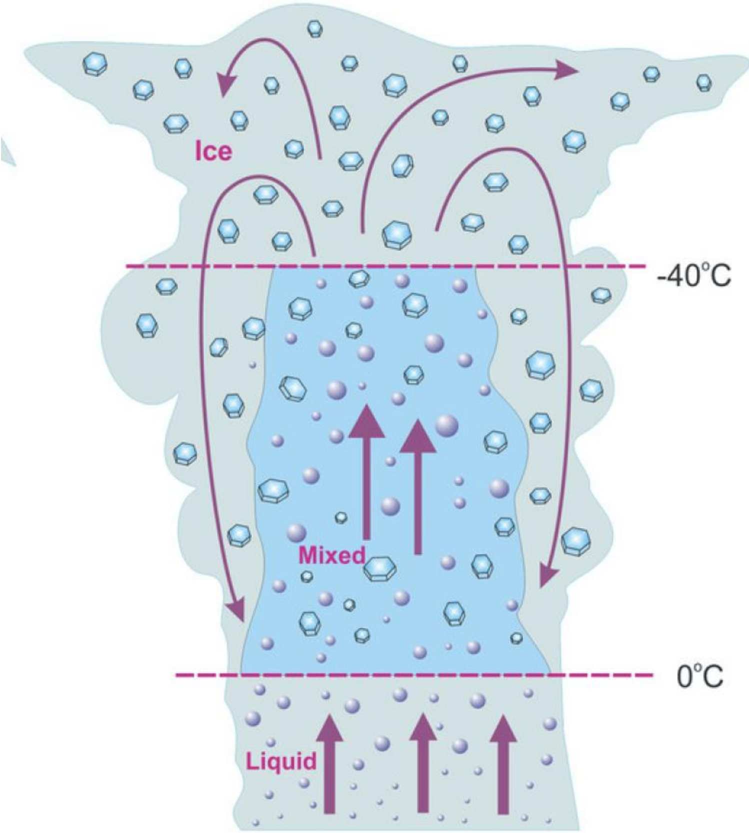


30-50% of precipitation occurs from the ice phase

Field and Heymsfield, 2015
Mülmenstädt et al. 2015

"...much of what is rain, when it arrives at the surface of the Earth, might have been snow, when it began its descent . . ."

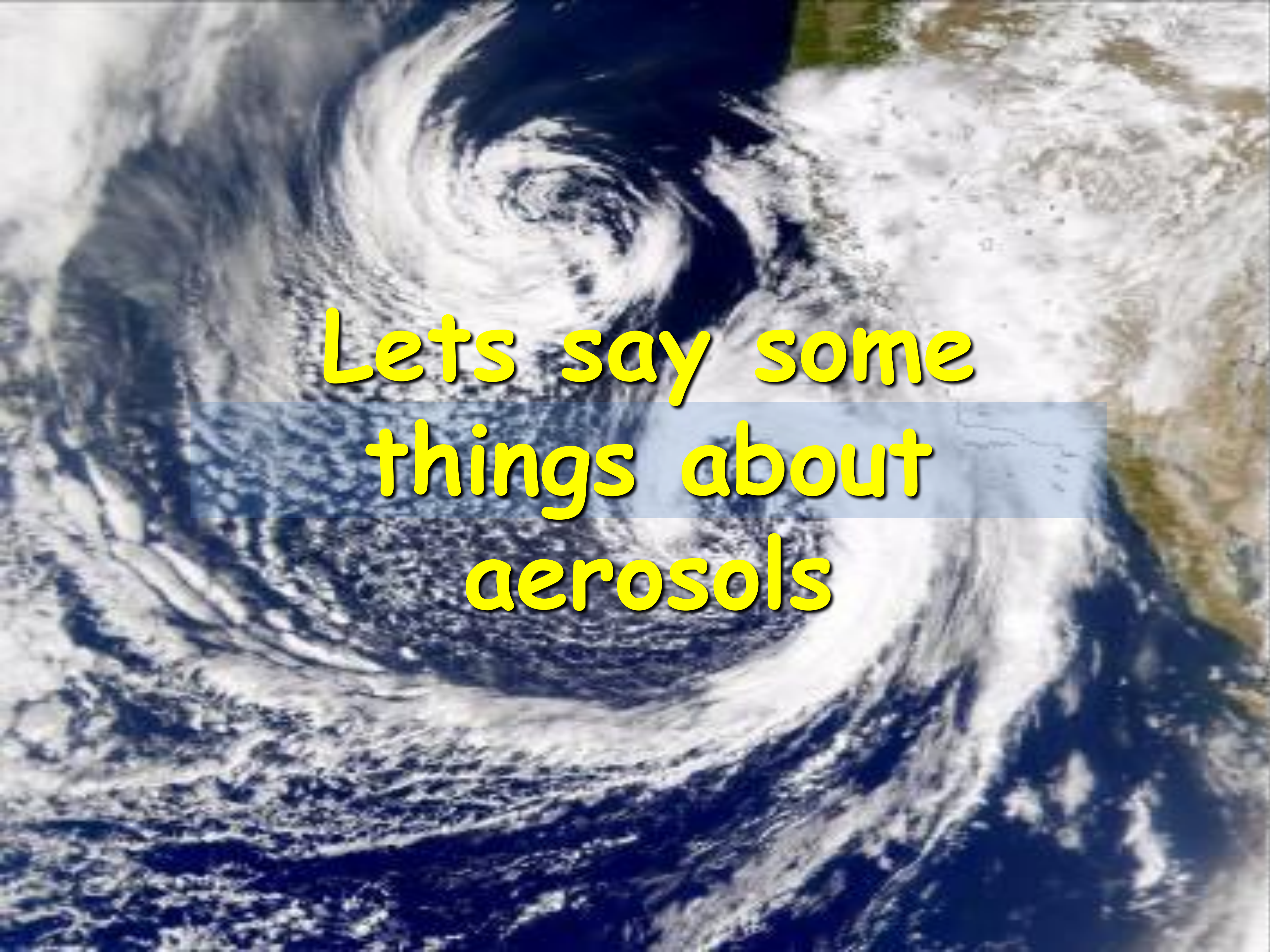
Mixed-Phase clouds are important for extremes and control precipitation on a regional and global scale



Precipitation at mid- and high-latitudes mostly generated from the mixed- and ice- cloud phase

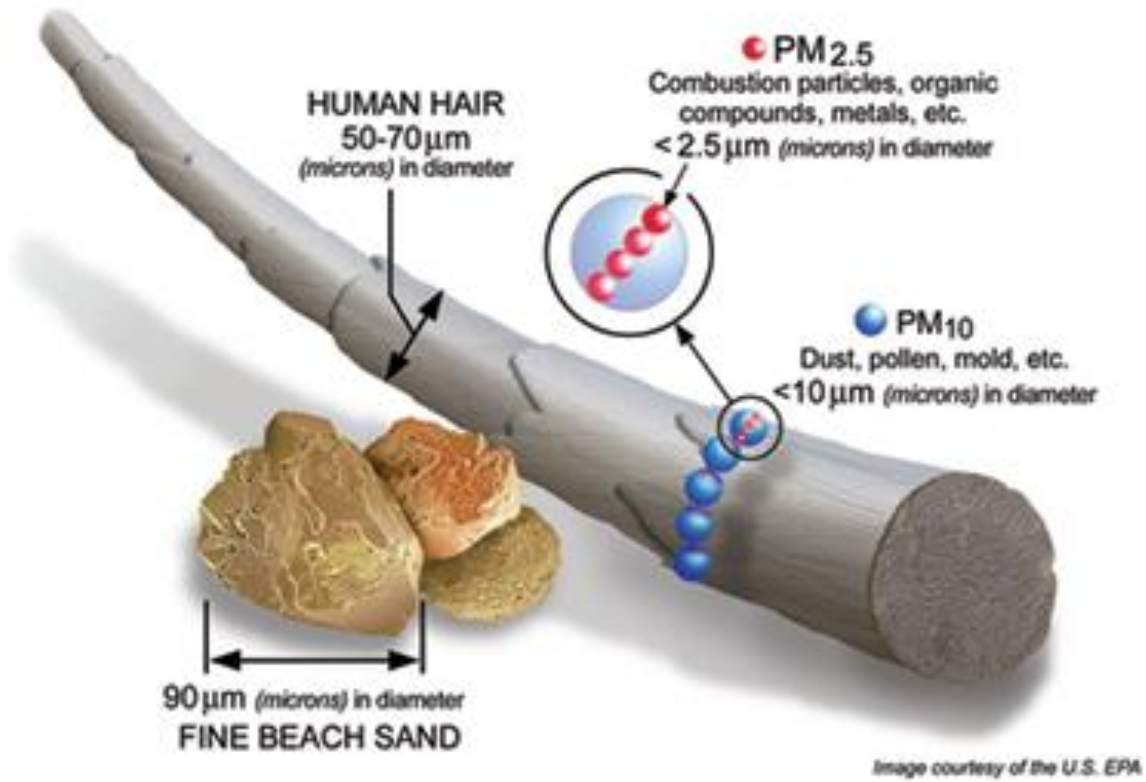
Mulmenstadt et al . 2015

Precipitation extremes have huge impacts on economy and society at large.



Lets say some things about aerosols

Aerosol sizes and "names"



Origins of Aerosol

Primary emissions

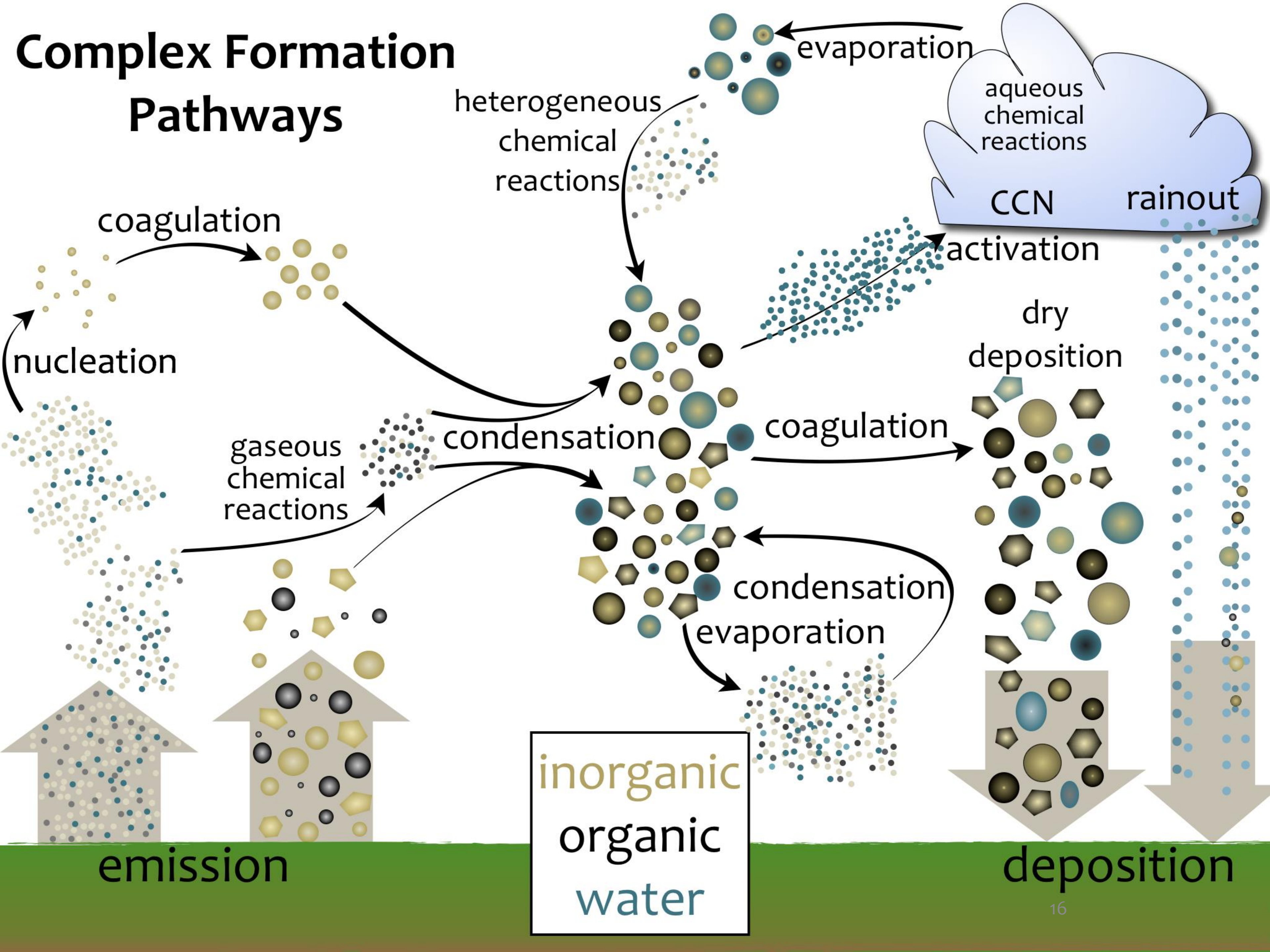
Automobiles, industry, domestic, vegetation, forest fires, seasalt, ...

Secondary compounds

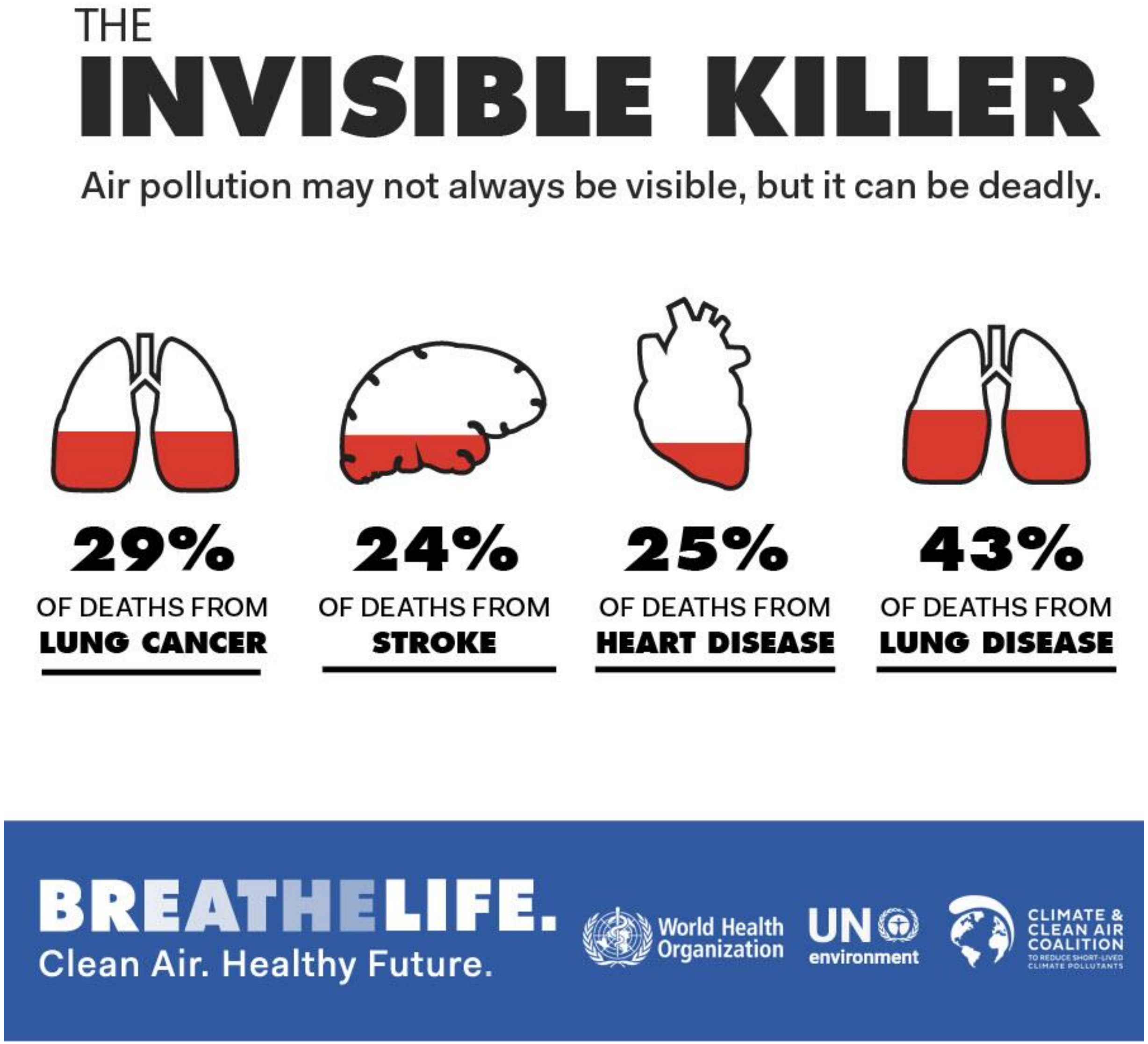
Oxidation of precursors (by O_3, H_2O_2, OH, NO_3, etc.) generates organic compounds.

Reaction of volatile bases (NH_3) with acids, dust and seasalt form $(NH_4)_2SO_4$, NH_4NO_3 and many other salts.

Complex Formation Pathways

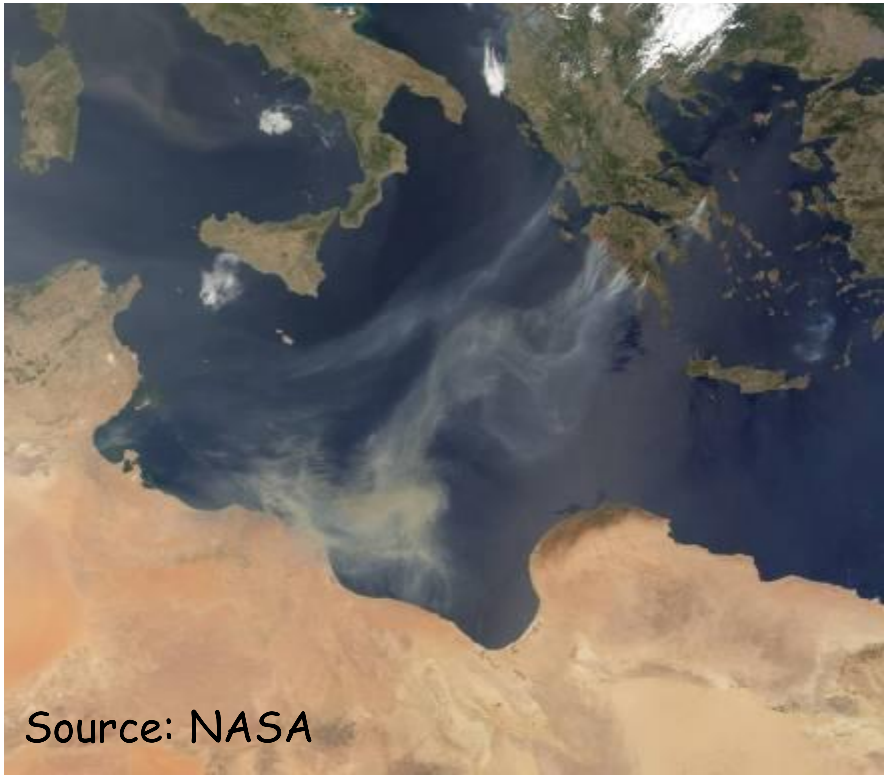


Why do we care about aerosols?
They can kill you



- **The WHO estimates that 4.2 million people die prematurely every year due to ambient (outdoor) air pollution.**
- **Pollutants with the strongest evidence for public health concern, include particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).**

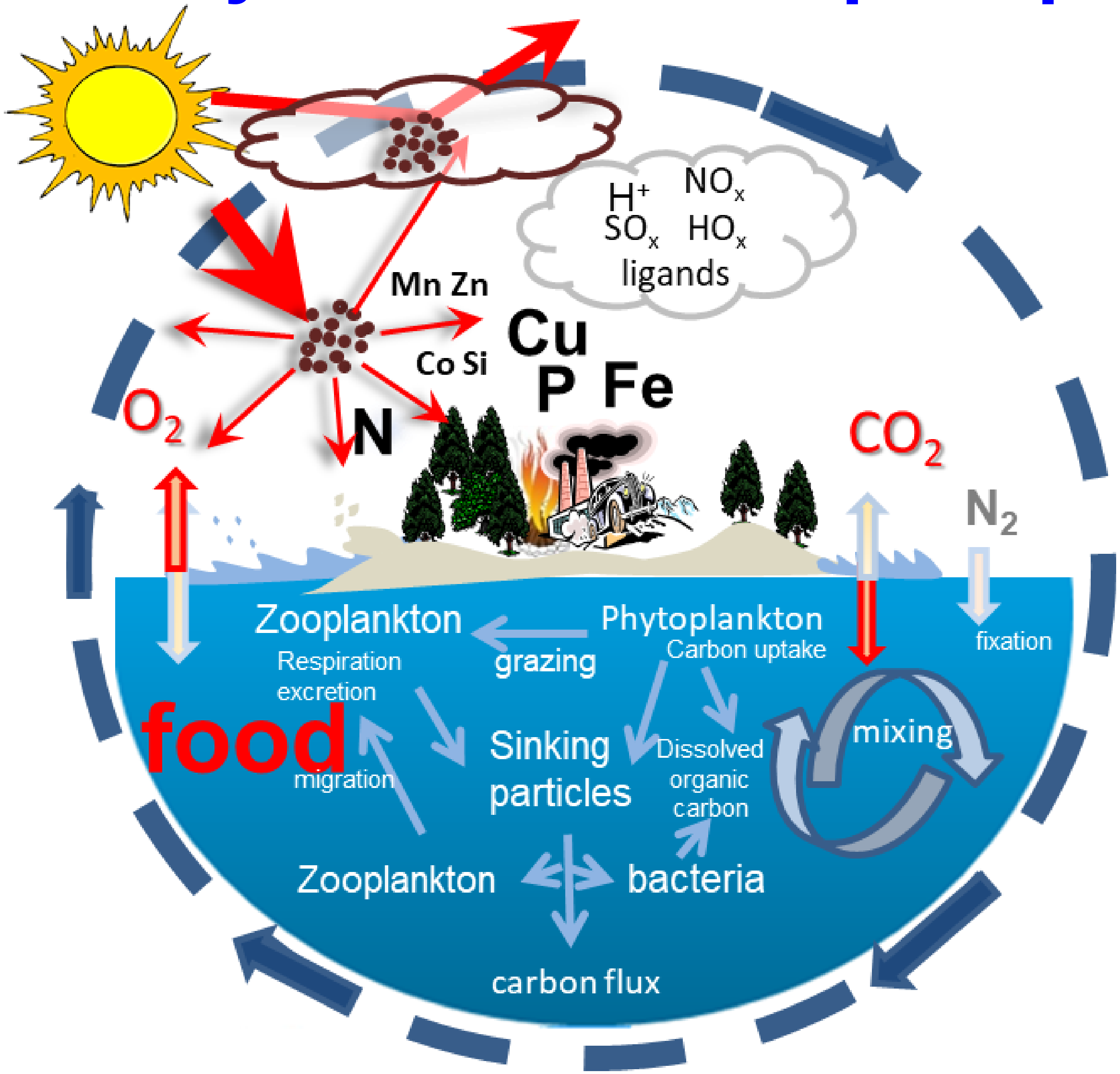
Why do we care about aerosols?
They reflect/absorb sunlight & affect climate



Dust and smoke over
East Mediterranean
(cooling + heating)

Soot from Kuwaiti
oil fires
(heating effect)

Why do we care about aerosols?
They affect clouds, precipitation & climate



Atmosphere is a major corridor for transporting nutrients between land and ocean.

Anthropogenic emissions perturb nutrient fluxes *considerably*.

Large but very uncertain impacts on ecosystems, food, climate


Now let's switch
to clouds and
aerosols again!

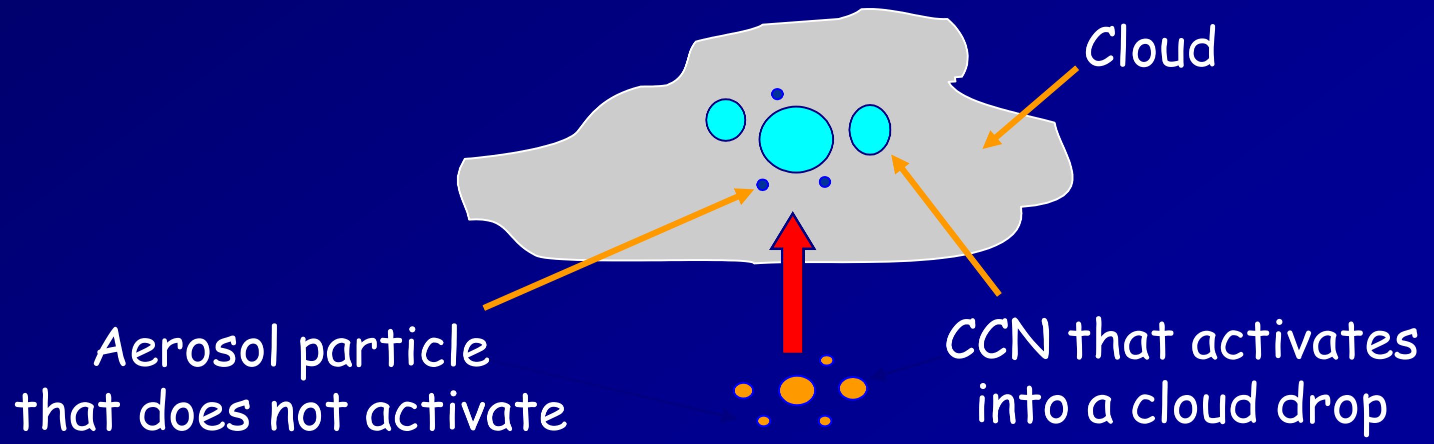
How do (liquid water) clouds form?

Clouds form in regions of the atmosphere where there is too much water vapor (it is "supersaturated").

This happens when air is cooled (primarily through expansion in updraft regions and radiative cooling).

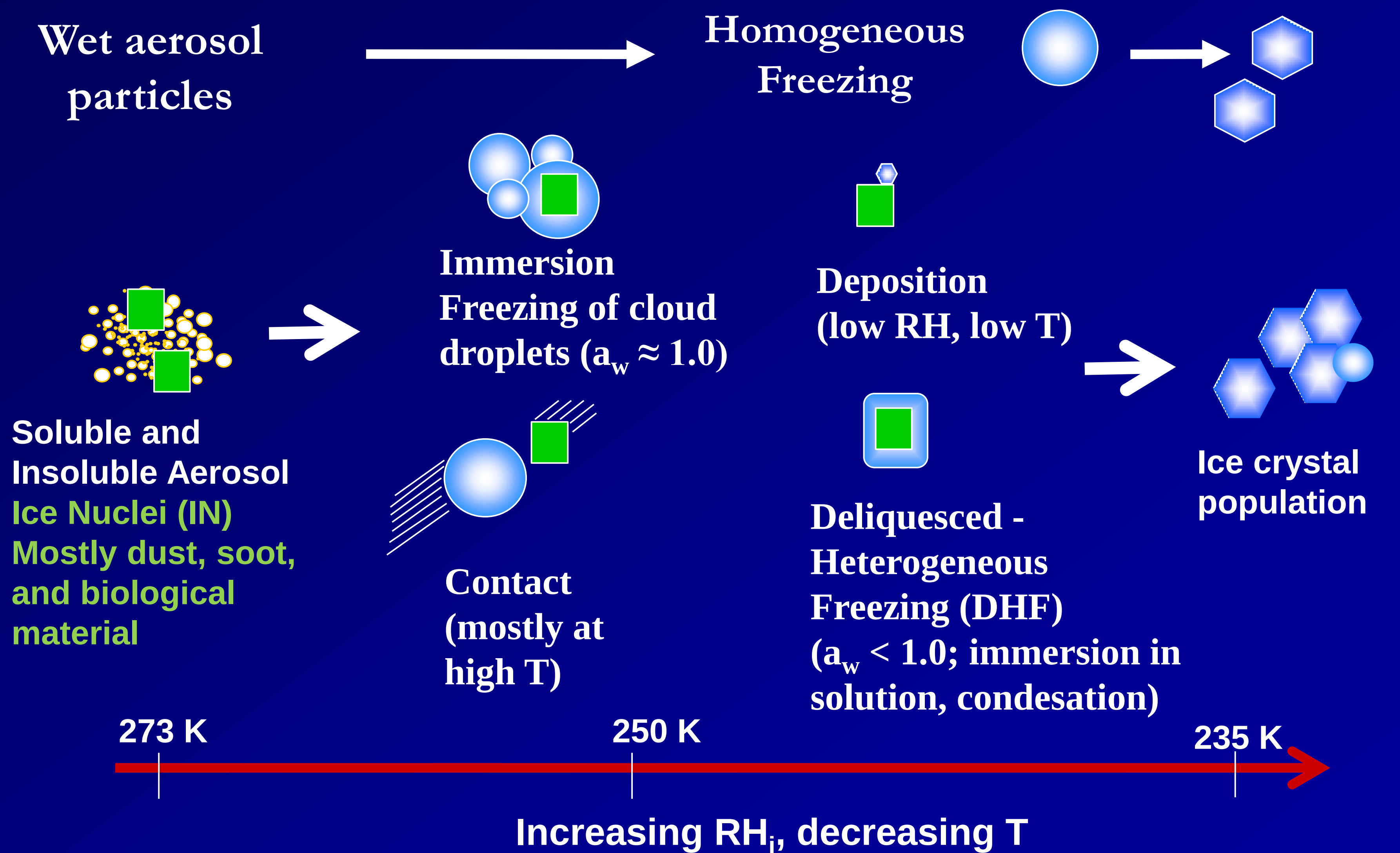
Cloud droplets nucleate on pre-existing particles found in the atmosphere (aerosols) with ~ 0.1μm diameter.

Aerosols that can become droplets are called cloud condensation nuclei (CCN).



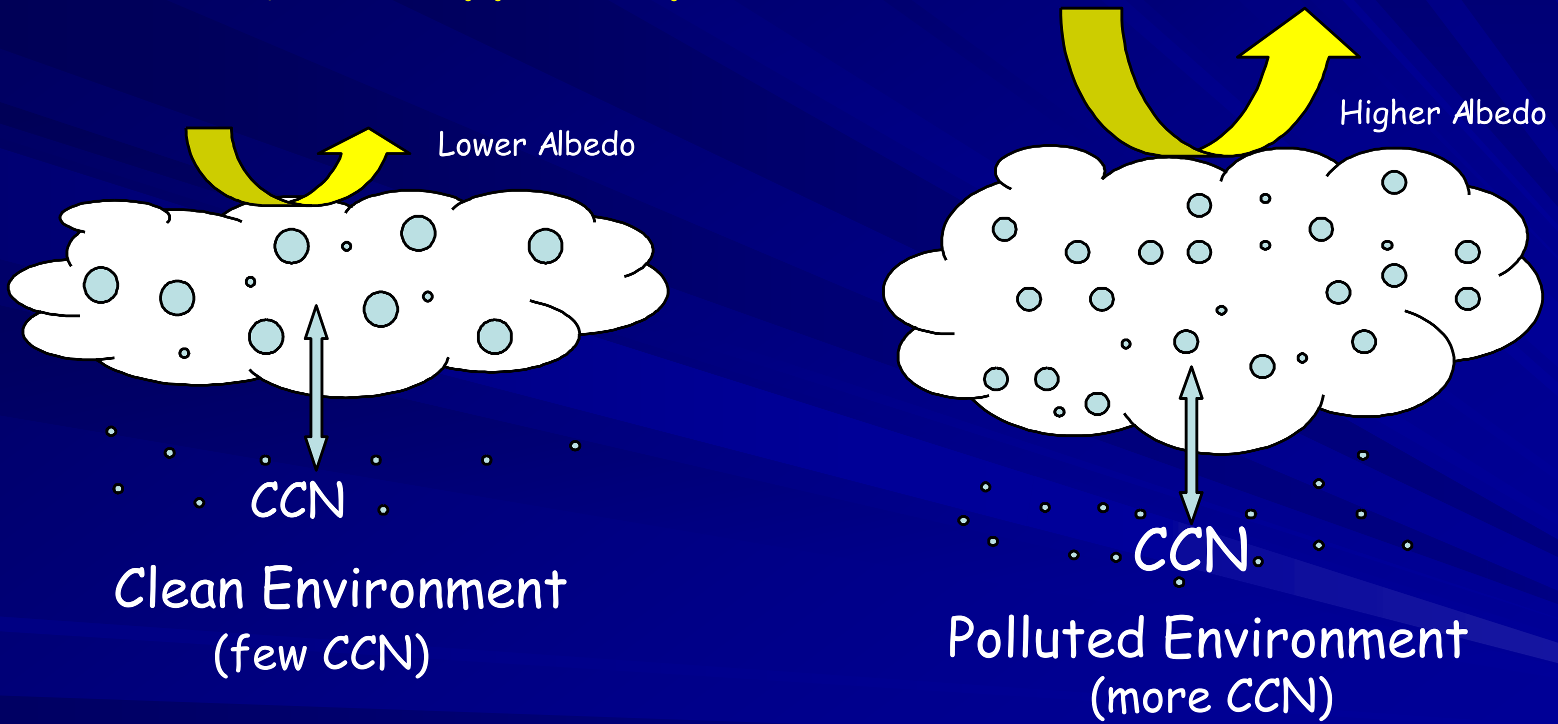
Ice formation mechanisms

Multiple mechanisms for ice formation can be active.



Increases in aerosol affects warm clouds

You make clouds that are "whiter", precipitate less (persist longer) and potentially cover larger areas of the globe. This is thought to yield a net cooling on climate and is termed as the "**indirect climatic effect of aerosols**".

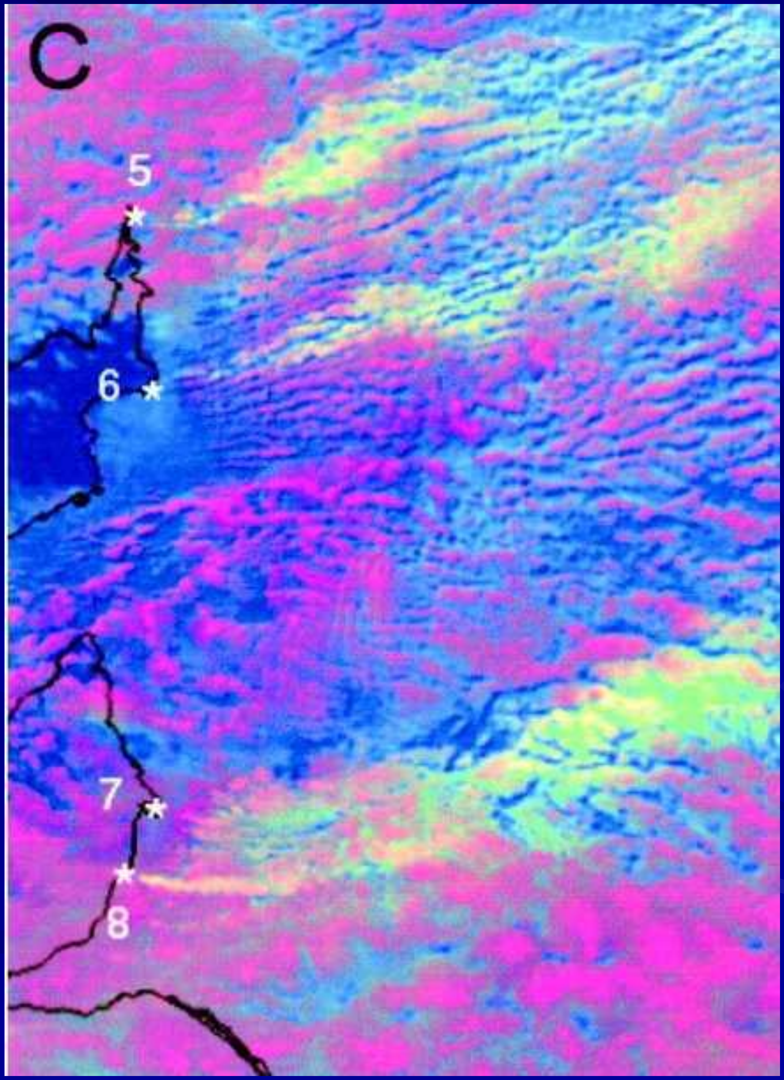


Increasing particles tends to cool climate (potentially alot).

Quantitative assessments done with climate models.

Observational evidence of indirect effect

Satellite observations of clouds off W. Australia.



Red: Clouds with low reflectivity.

White: Clouds that reflect alot.

Blue: Clear sky.

Rosenfeld et al., Science

Observational evidence of indirect effect

Air pollution can affect cloud properties

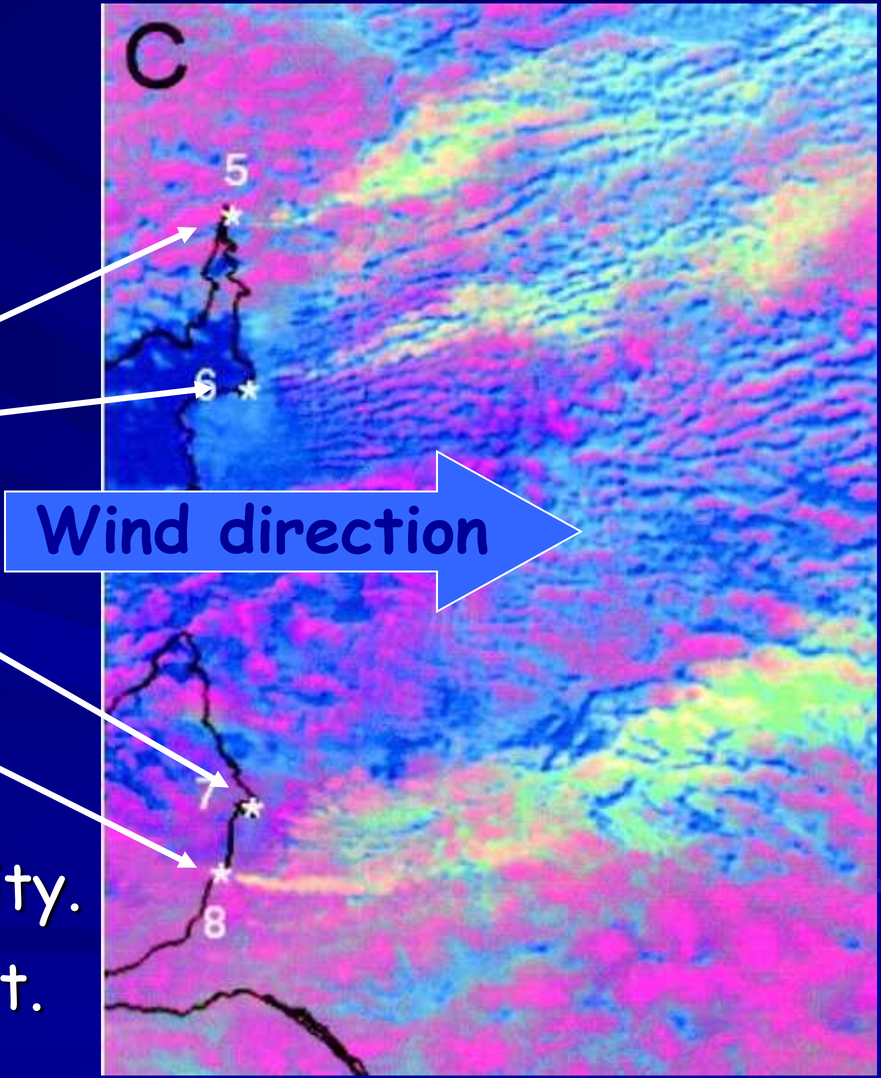
Satellite observations of clouds off W. Australia.

Power plant

Lead smelter

Port

Oil refineries



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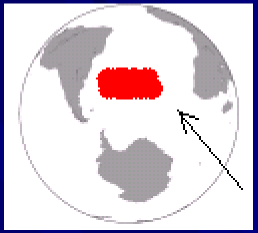
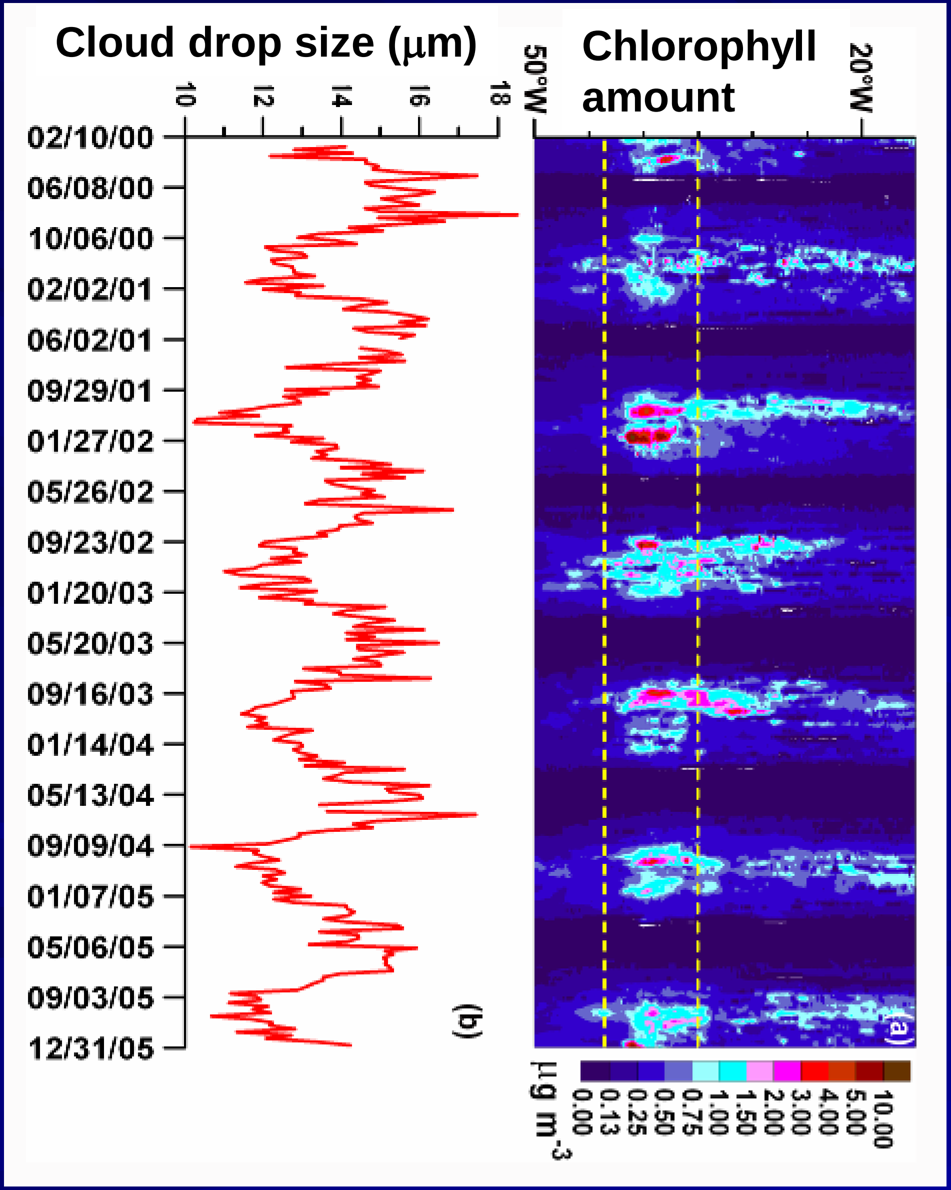
Rosenfeld et al., Science

Phytoplankton affect clouds too…

Location: East of Patagonia (South America)





Meskhidze and Nenes, Science, 2006

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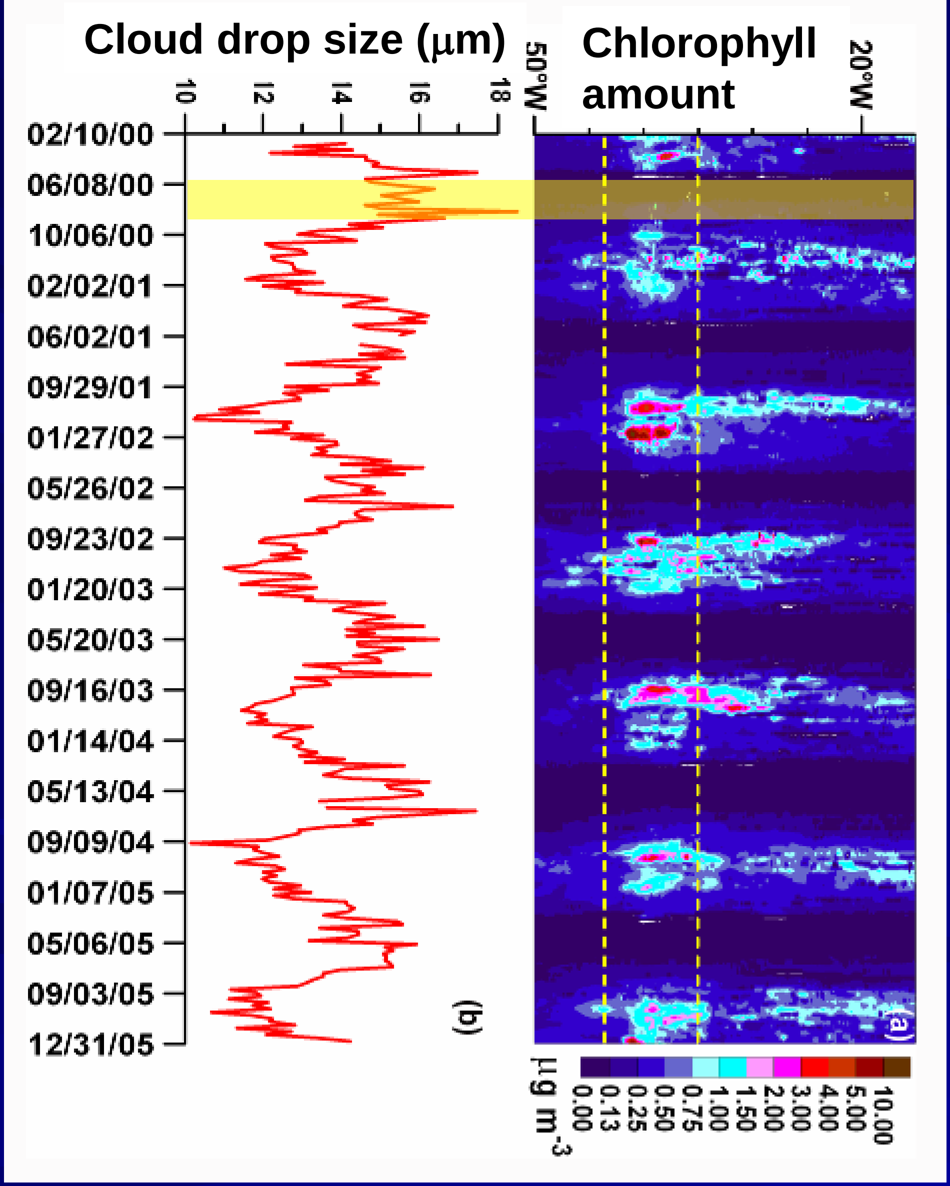

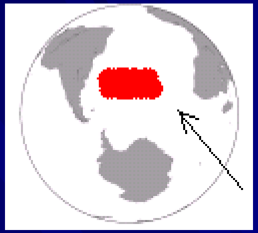

Low chlorophyll period, clouds have large drops (not very reflective)

Meskhidze and Nenes, Science, 2006

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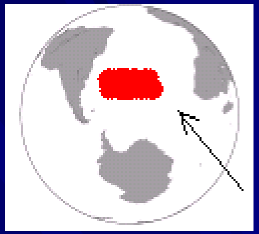

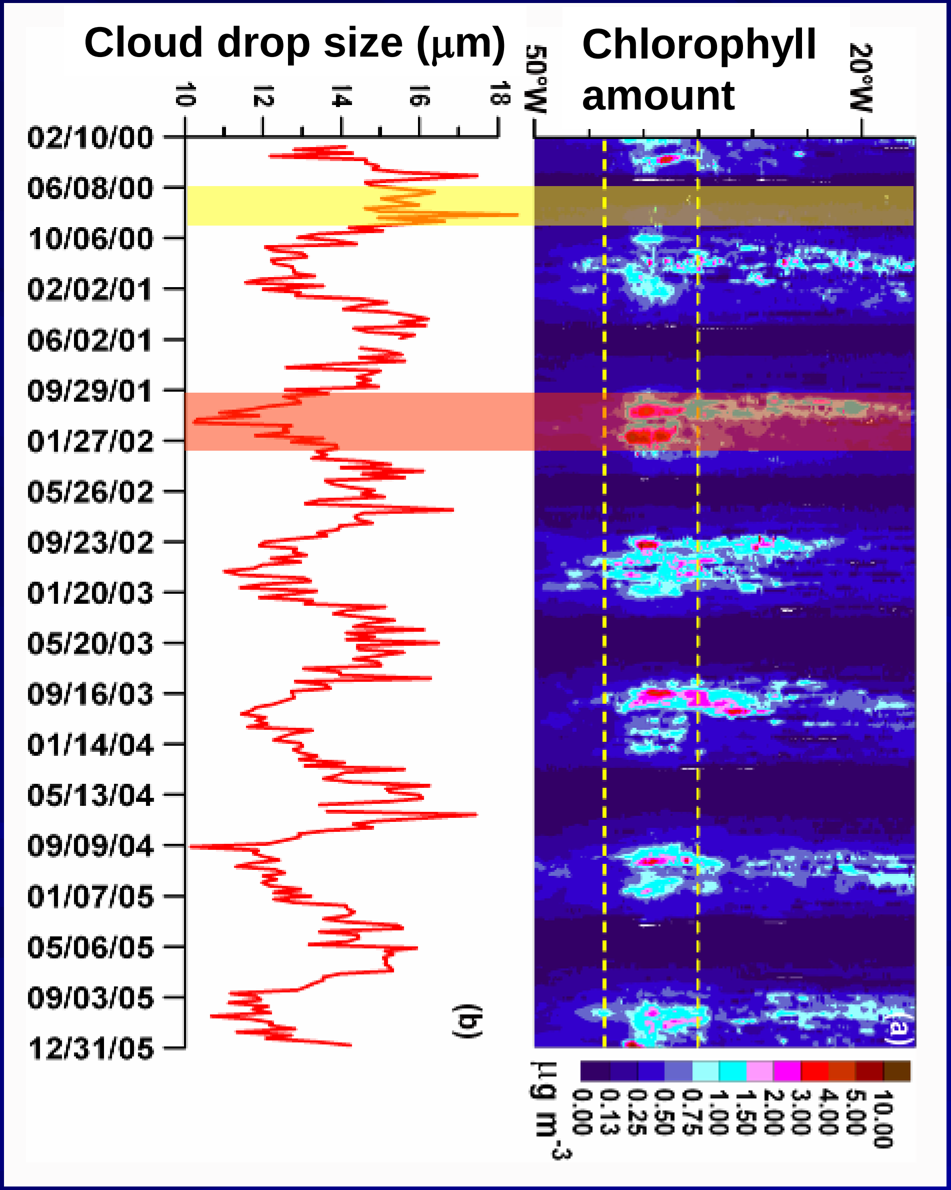

Low chlorophyll period, clouds have large drops (not very reflective)

High Chlorophyll period, Clouds have small drops (very reflective)

Meskhidze and Nenes, Science, 2006

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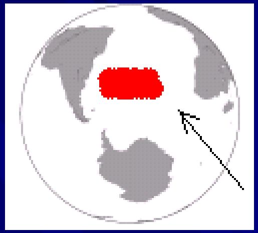
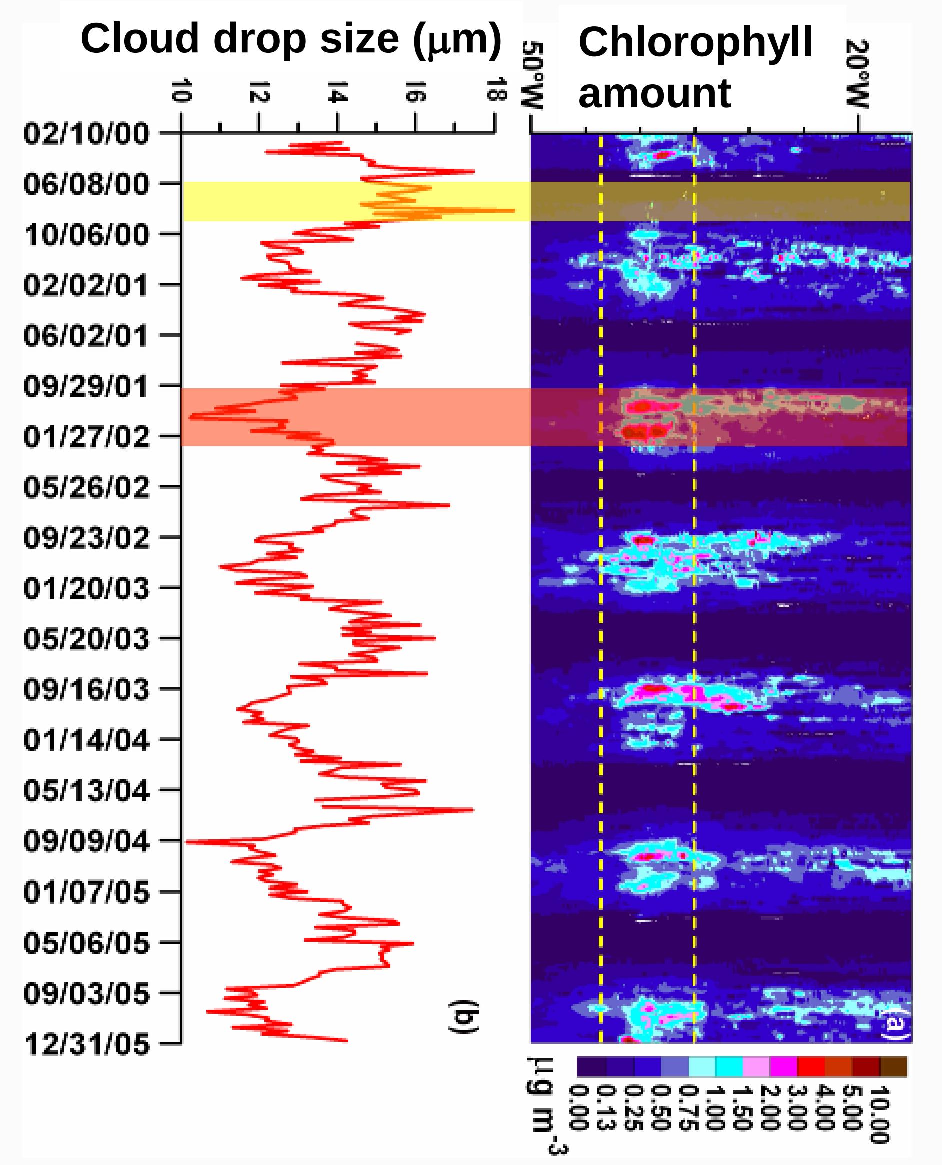




Low chlorophyll period, clouds have large drops (not very reflective)

High Chlorophyll period, Clouds have small drops (very reflective)

Phytoplankton emissions increase particle loads, and strongly impact clouds.

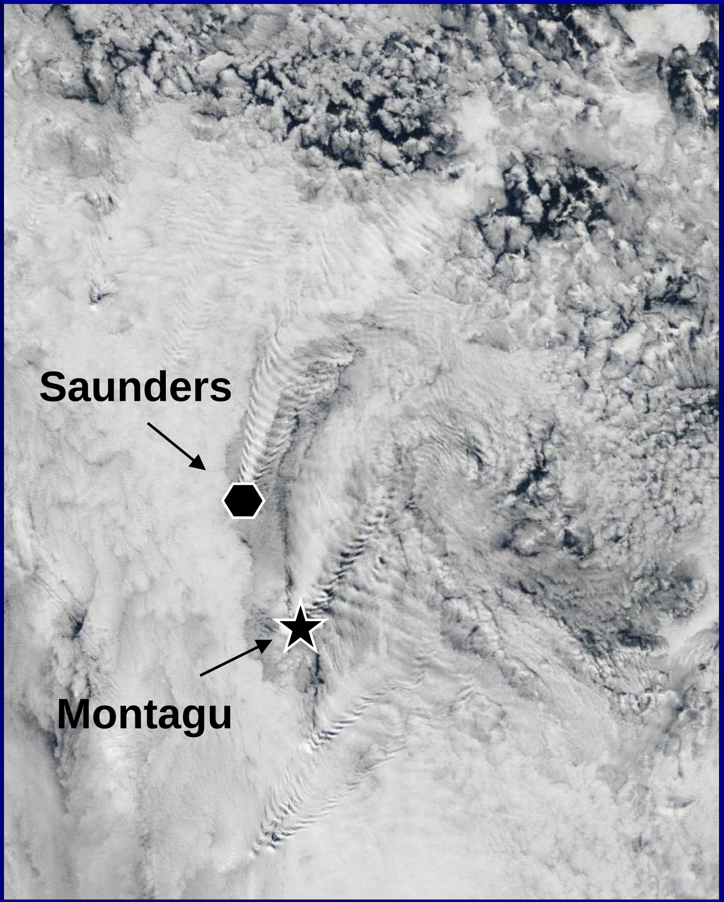
Biology-cloud interactions affect radiation in the region.

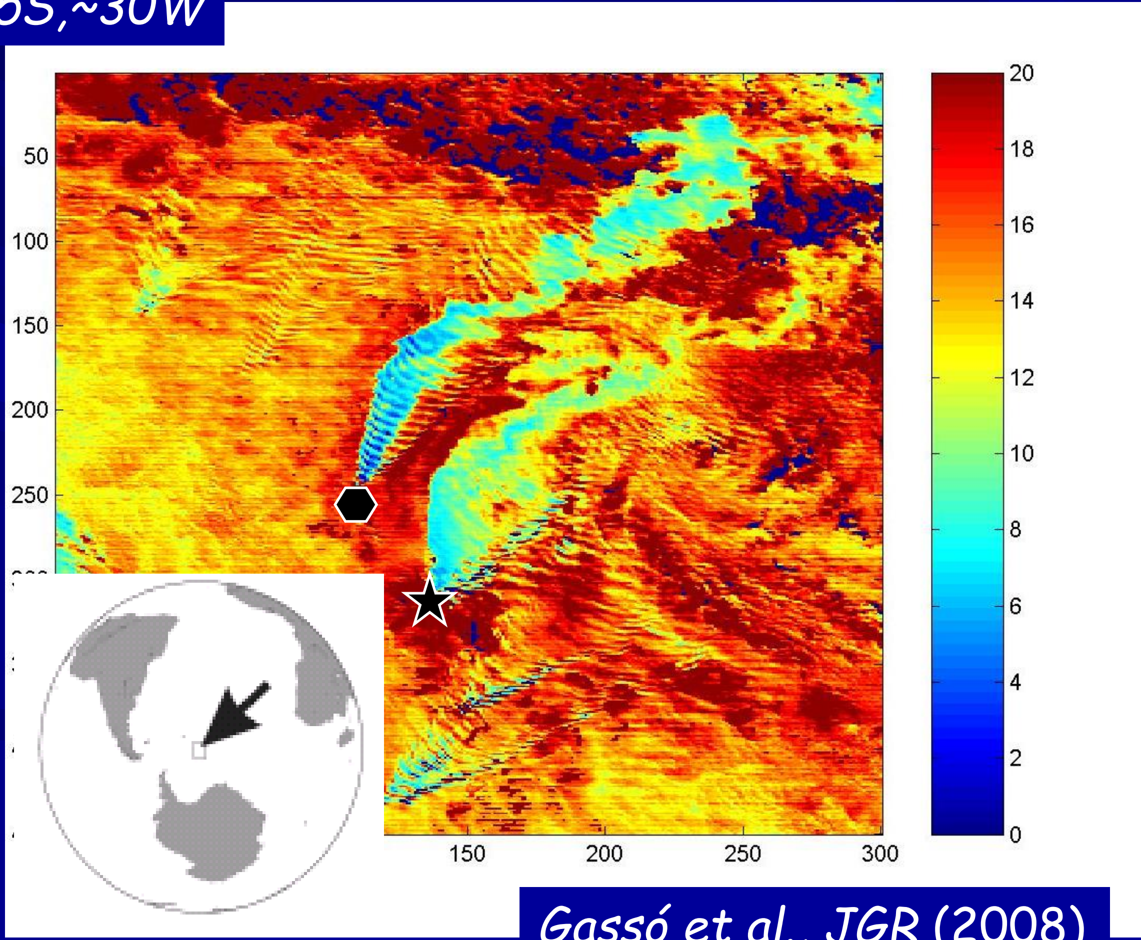
Meskhidze and Nenes, Science, 2006

So do volcanoes (even when "sleeping") …

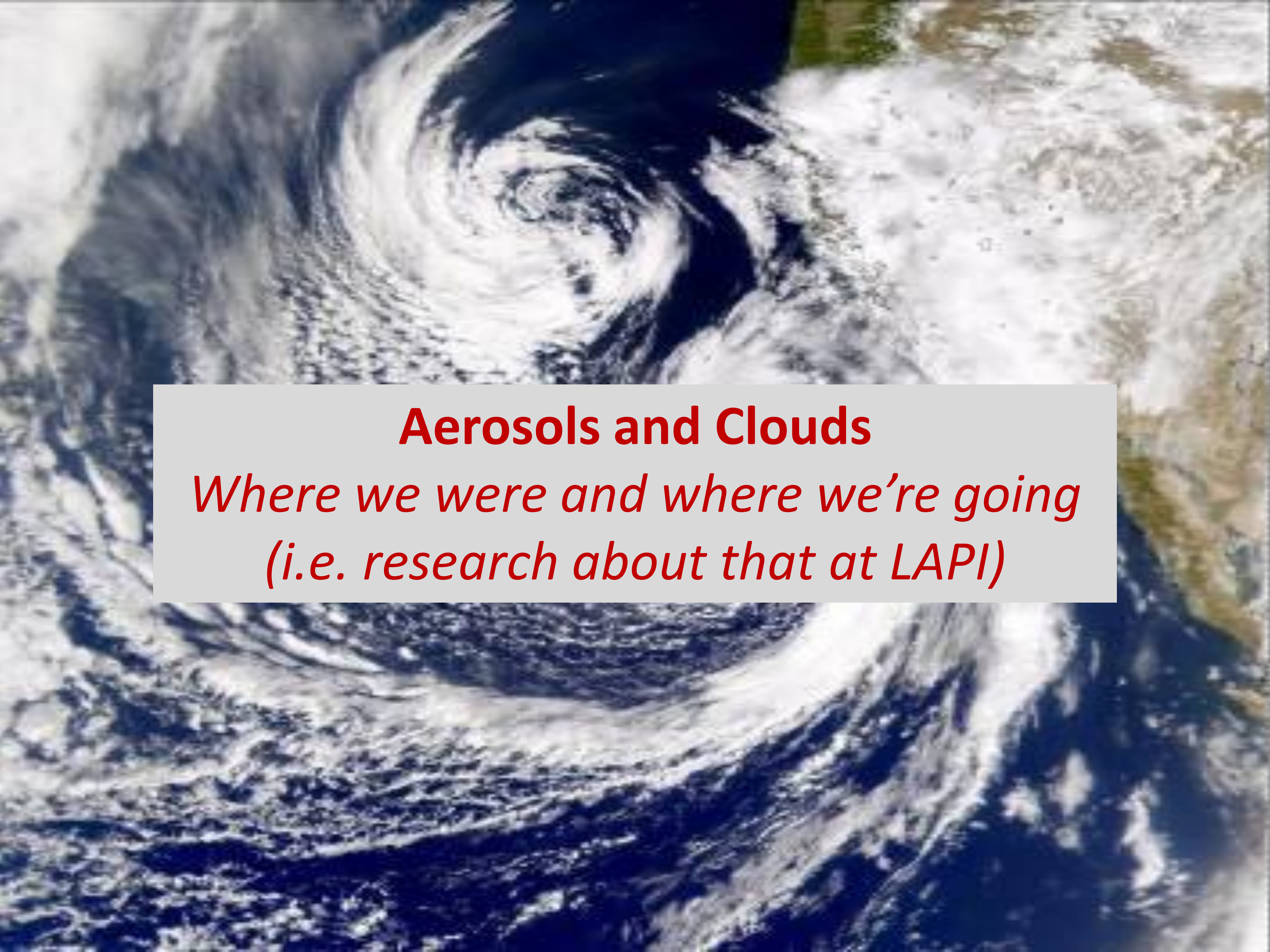
Volcanoes continuously emit SO_2 which becomes sulfate aerosol. The aerosol can substantially increase CCN in volcanic plumes. Clouds in the plume are much more reflective than outside.

Location: Sandwich Islands , ~55S,~30W





Gassó et al., JGR (2008)

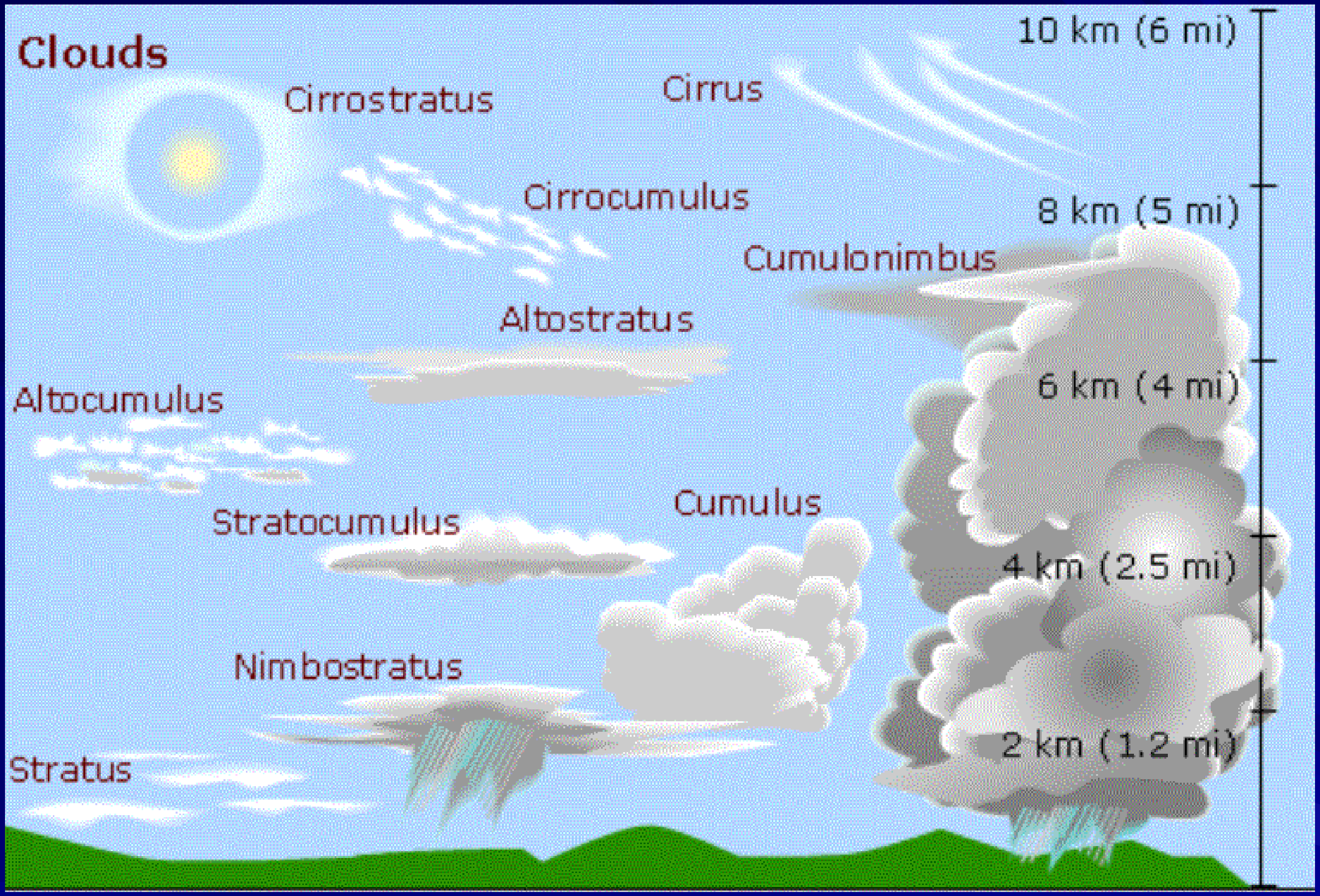


Aerosols and Clouds

Where we were and where we're going

(i.e. research about that at LAPI)

Cloud types and phase



High clouds (ice crystals): ***warm*** **climate**

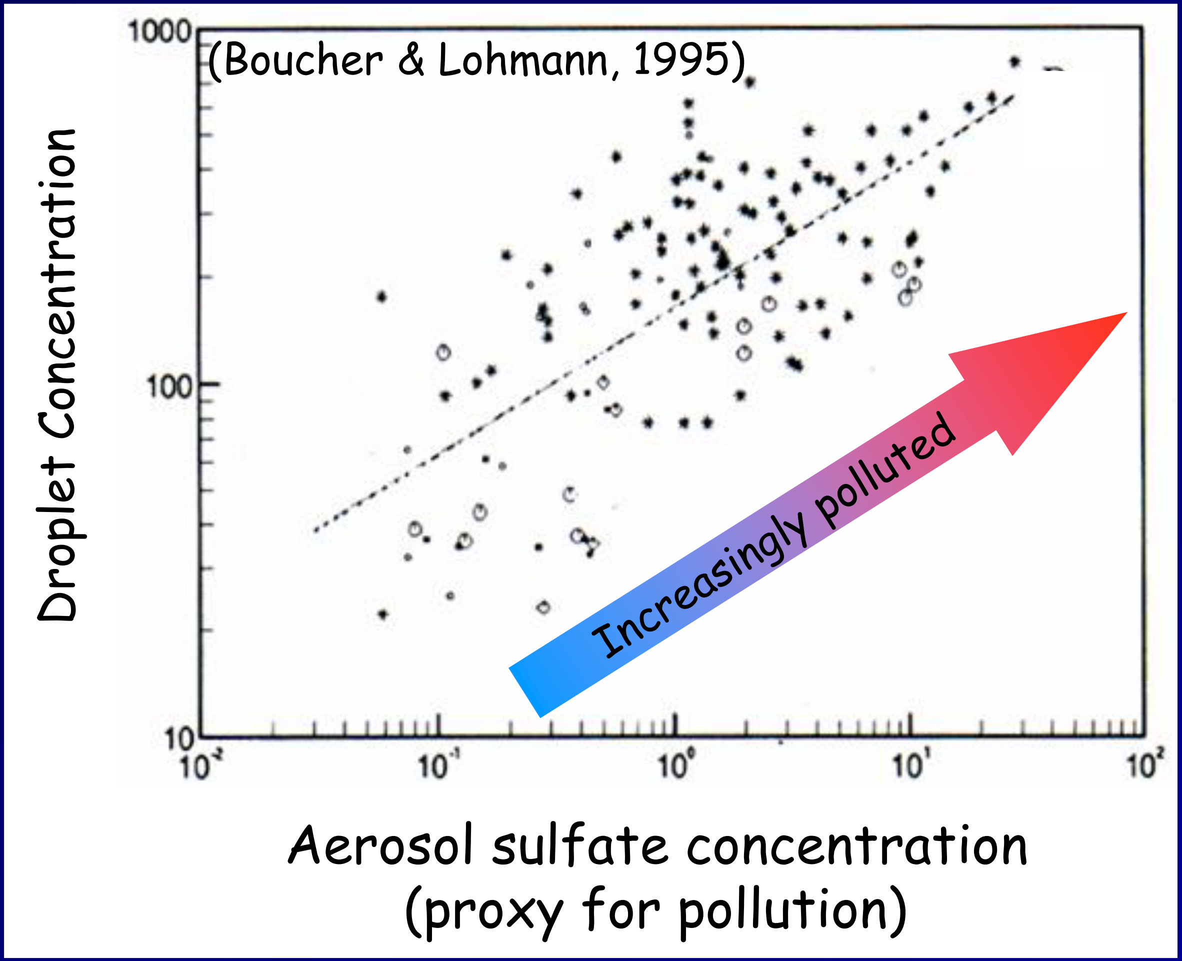
Mid-level: Warm/cool

Low clouds (liquid drops): ***cool*** **climate**

Cloud drops/crystals are not created directly from the vapor phase but form upon **airborne particulate matter (aerosol particles)**

http://www.ucar.edu/news

Aerosol-cloud interaction relationships: Major source of climate prediction uncertainty



Empirical approaches used….

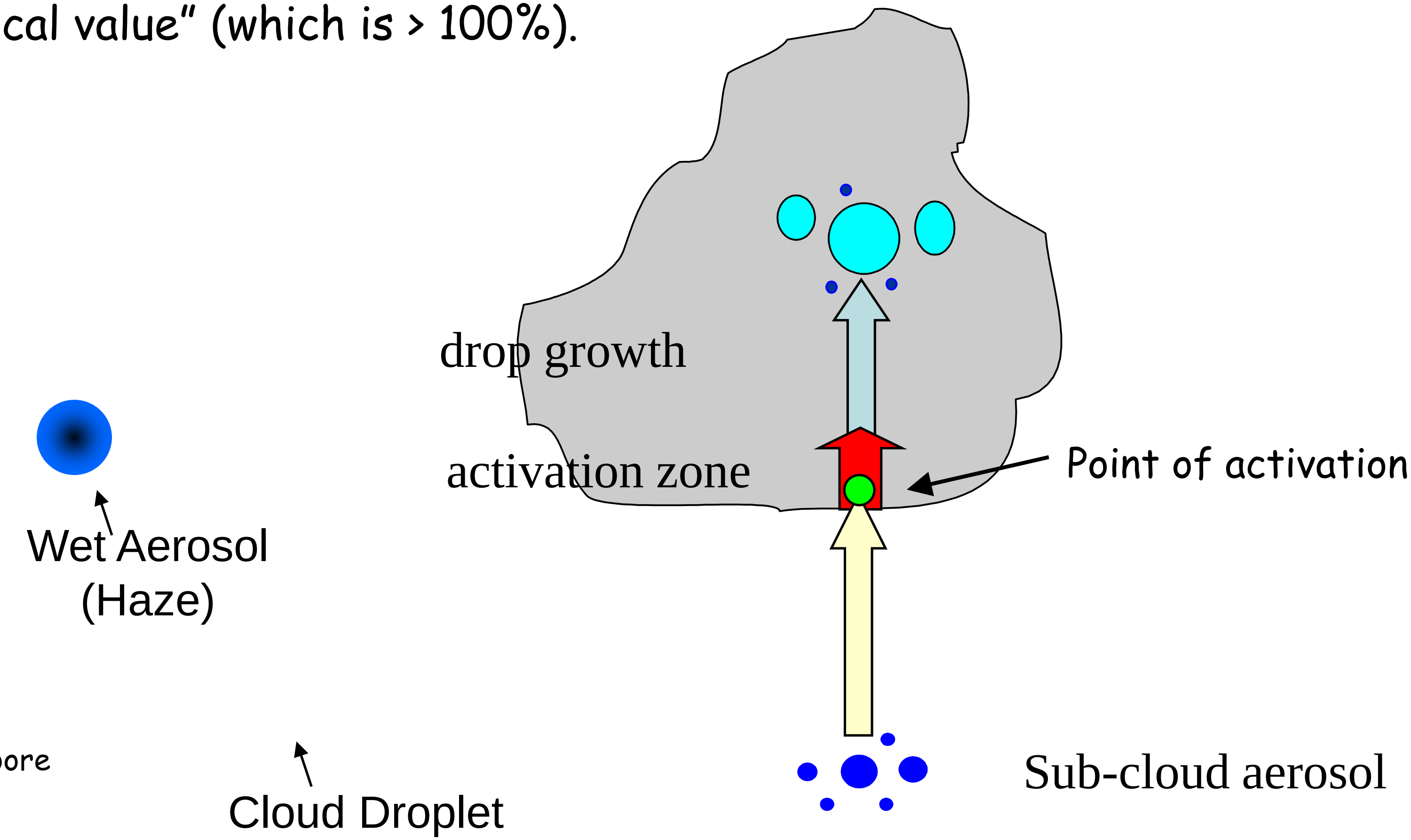
Large uncertainty by not accounting for:

- Meteorology
- Cloud microphysics
- Composition
- …

For ice clouds, crystal numbers were simply prescribed ("tuned") to match satellite data

"Mechanistic parameterization" provide the physical links required.

- To act as a CCN, each particle requires exposure to relative humidity above a "critical value" (which is > 100%).



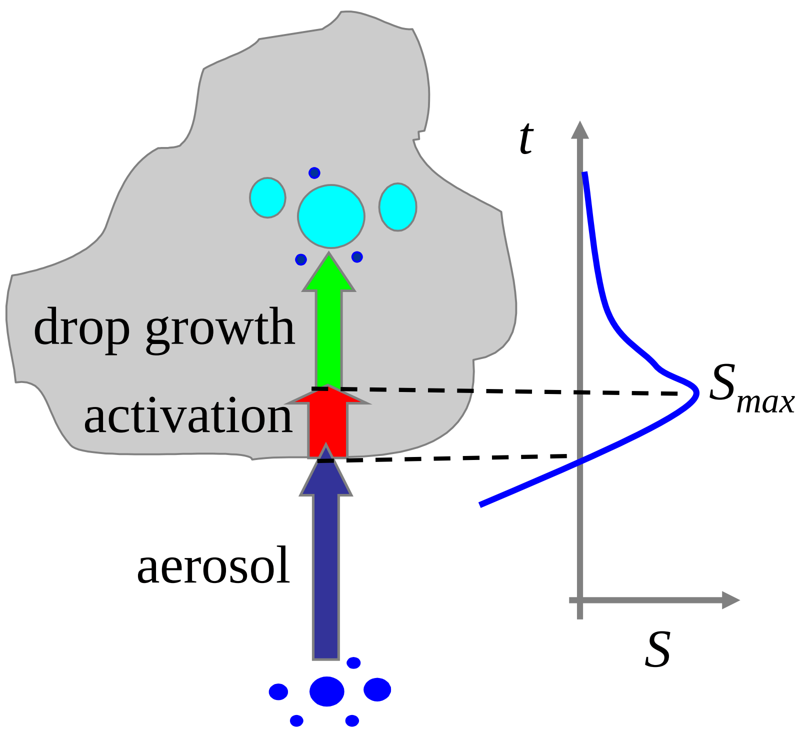
courtesy: R.Moore

- For all this to work, you need to know the composition and size of each particle to get the CCN concentrations "right".

"Mechanistic parameterization" provide the physical links required.

Algorithm for calculating N_d (Mechanistic parameterization):

1. Calculate s_{max} (approach-dependent)
2. N_d is equal to the CCN with $s_c < s_{max}$



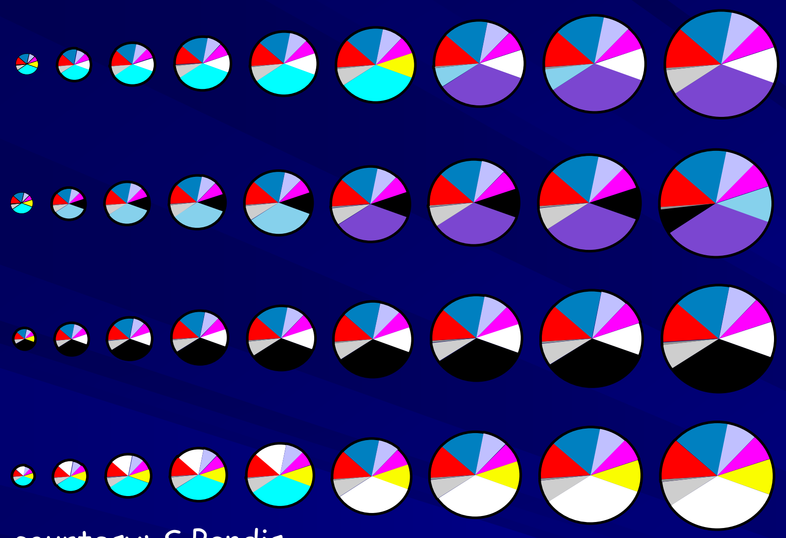
Mechanistic Parameterizations: Twomey (1959); Abdul-Razzak et al., (1998); Nenes and Seinfeld, (2003); Fountoukis and Nenes, (2005); Kumar et al. (2009), Morales and Nenes (2014), and others.

Input: P,T, vertical wind, particle size distribution,composition.

Output: Cloud properties (droplet number, size distribution).

We have also done the same for ice (cirrus) clouds (Barahona et al., 2008, 2009ab) and doing it for mixed-phase clouds & secondary ice (Sotiropoulou et al., 2020, 2021; Georgakaki et al., in prep

Aerosol Problem: Complexity



courtesy: S.Pandis

An integrated "soup" of

- Inorganics, organics (1000's)
- Particles can have uniform composition with size…
- … or not
- Can vary vastly with space and time (esp. near sources)

Organic species are a headache

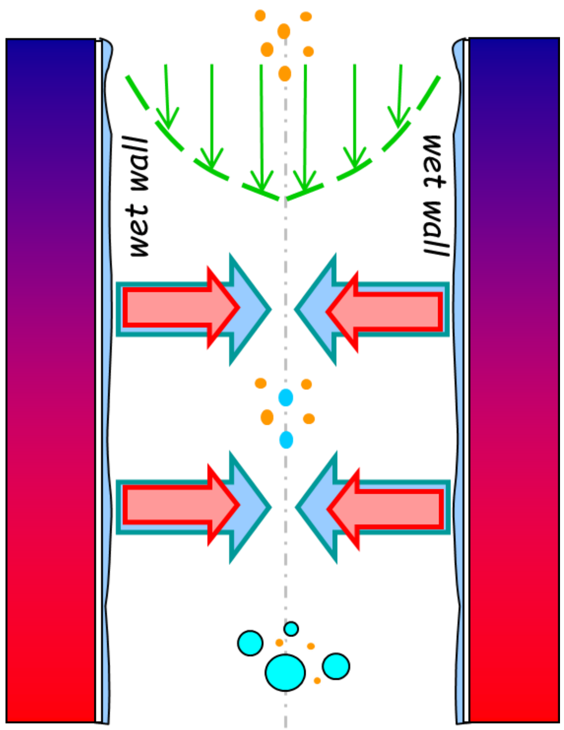
- They can facilitate cloud formation by acting as surfactants and adding solute (hygroscopicity)
- Oily films can form and delay cloud growth kinetics

In-situ data to study the aerosol-CCN link:

Usage of CCN activity measurements to "constrain" the above "chemical effects" on cloud droplet formation.

Continuous-Flow Streamwise Thermal Gradient Chamber

CFSTGC… aka "DMT CCN Counter"



- Metal cylinder with wetted walls
- Streamwise Temperature Gradient
- Water diffuses faster than heat
- Supersaturation, S, generated at the centerline = *f* (Flowrate, Pressure, and Temp. Gradient)

Roberts and Nenes (2005), US Patent 7,656,510

Lance et al., (2006), Lathem and Nenes (2011), Raatikainen et al. (2012)

Interesting story on how all this happened…

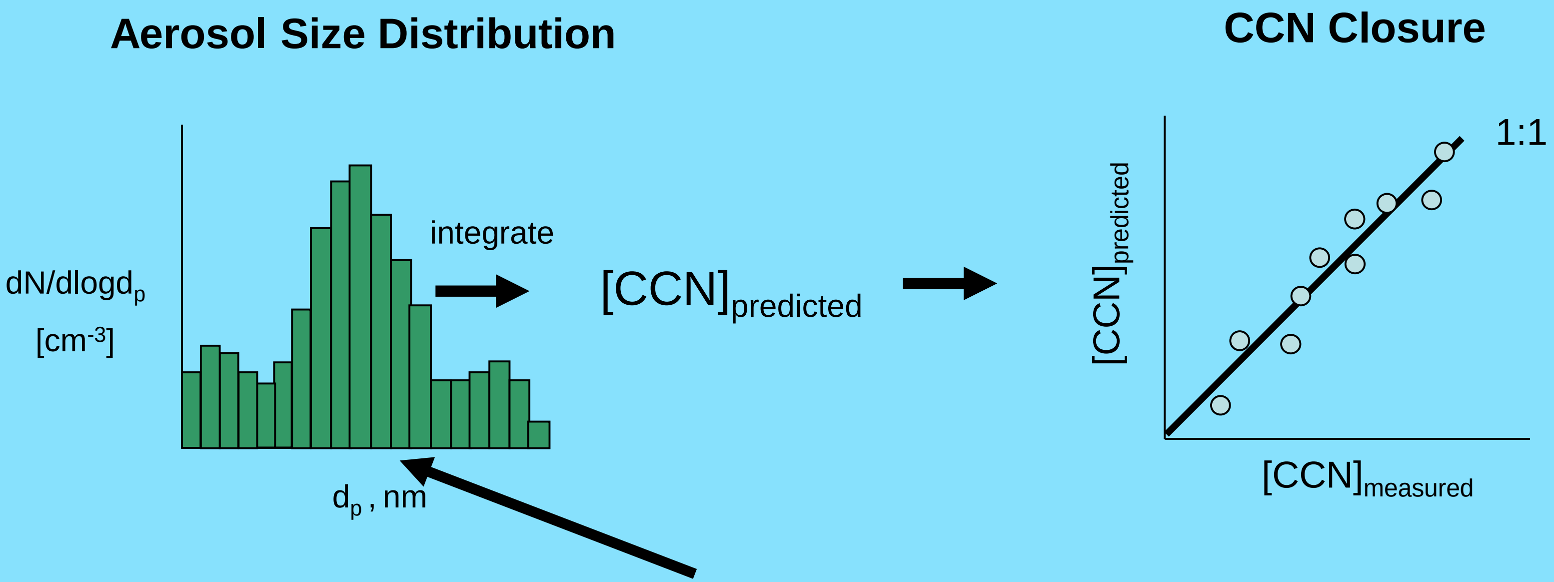
Development phases of cloud chamber

scale = 1 m

1st version 2nd version Commercial ver. Mini-instruments

Testing CCN activation theory: CCN "Closure" studies

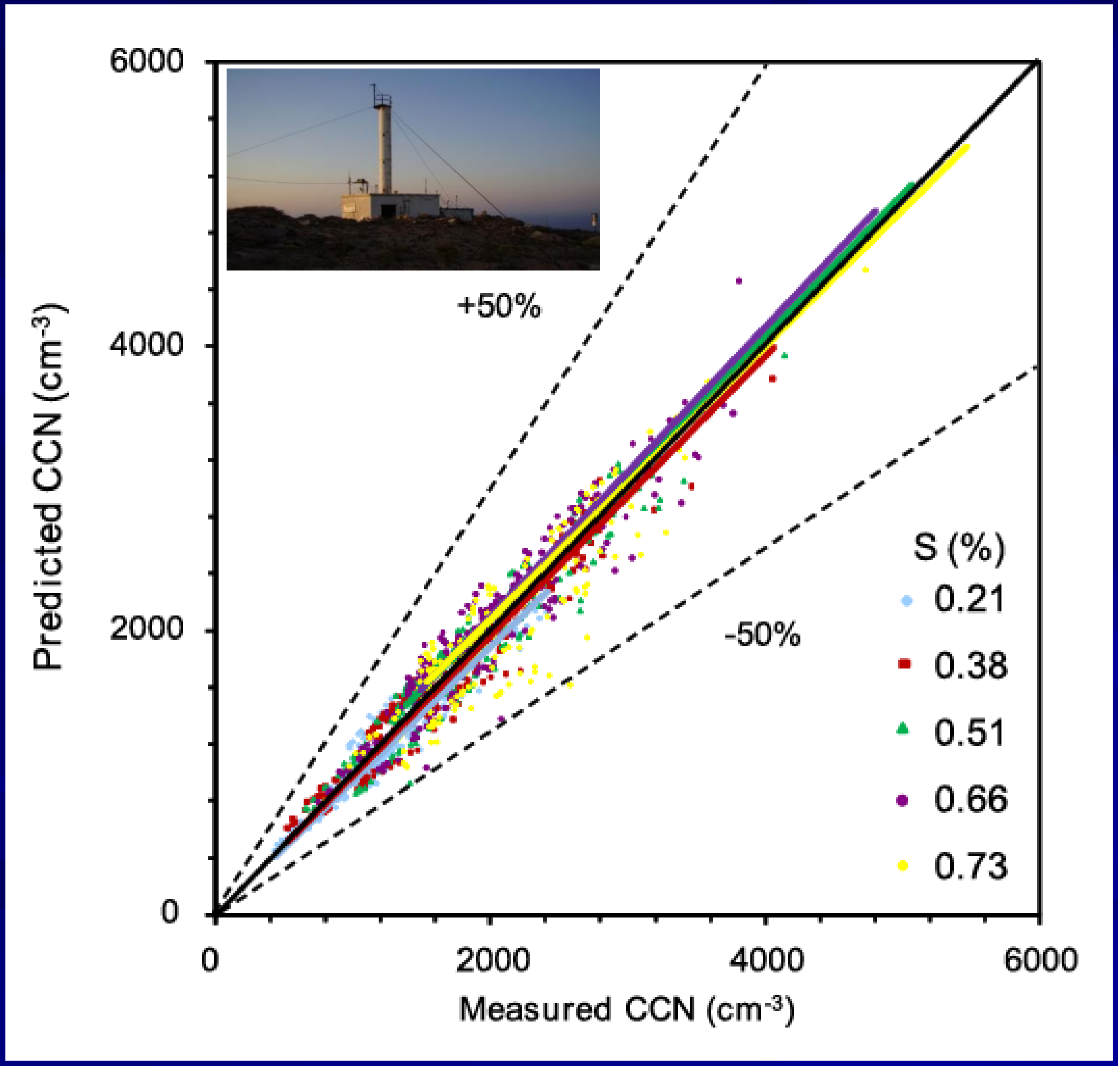
Compare measurements of CCN to predictions using theory and a simple description of molar volume for organics



Use theory to determine the **size** of particles above which they can act as CCN based on instrument supersaturation.

This size then can determine the "bulk" composition of particles using the concept of *hygroscopicity*.

Example: Finokalia Aerosol Measurement Campaigns (Crete, Greece)



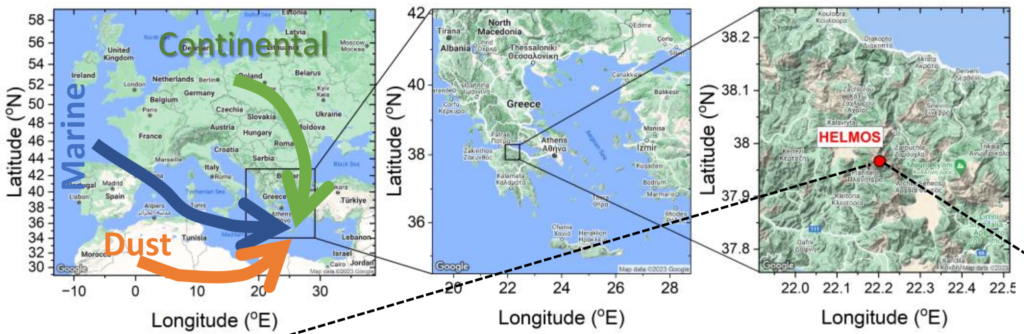
2% overprediction (on average).

CCN/Droplet prediction theory *really* works.

Simple treatment of organic aerosol hygroscopicity *really* works too.

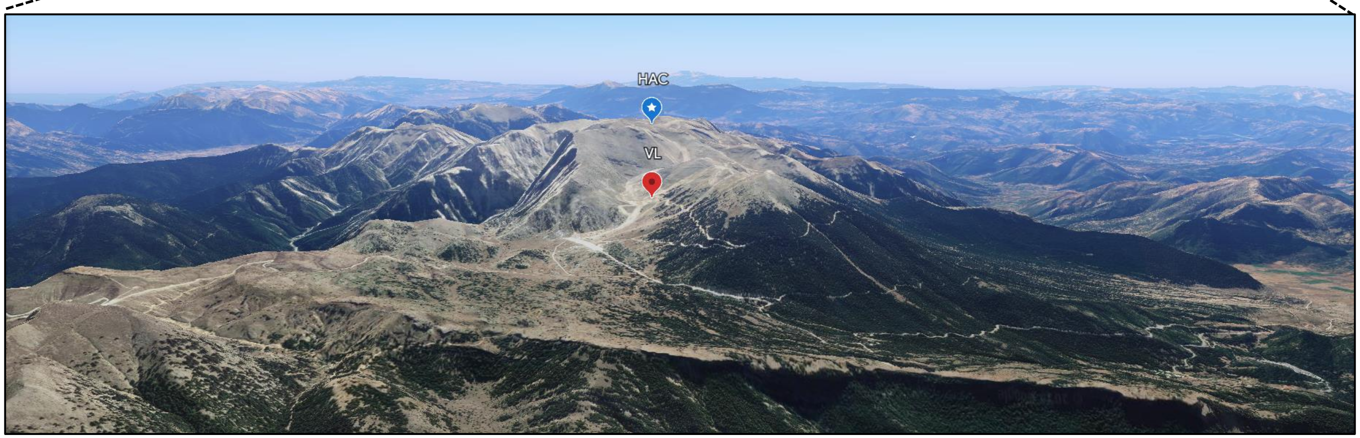
(Bougiatioti et al., ACP, 2009; 2012 and many other studies)

Mt. Helmos: Where mythology, aerosols & clouds meet



Some facts:

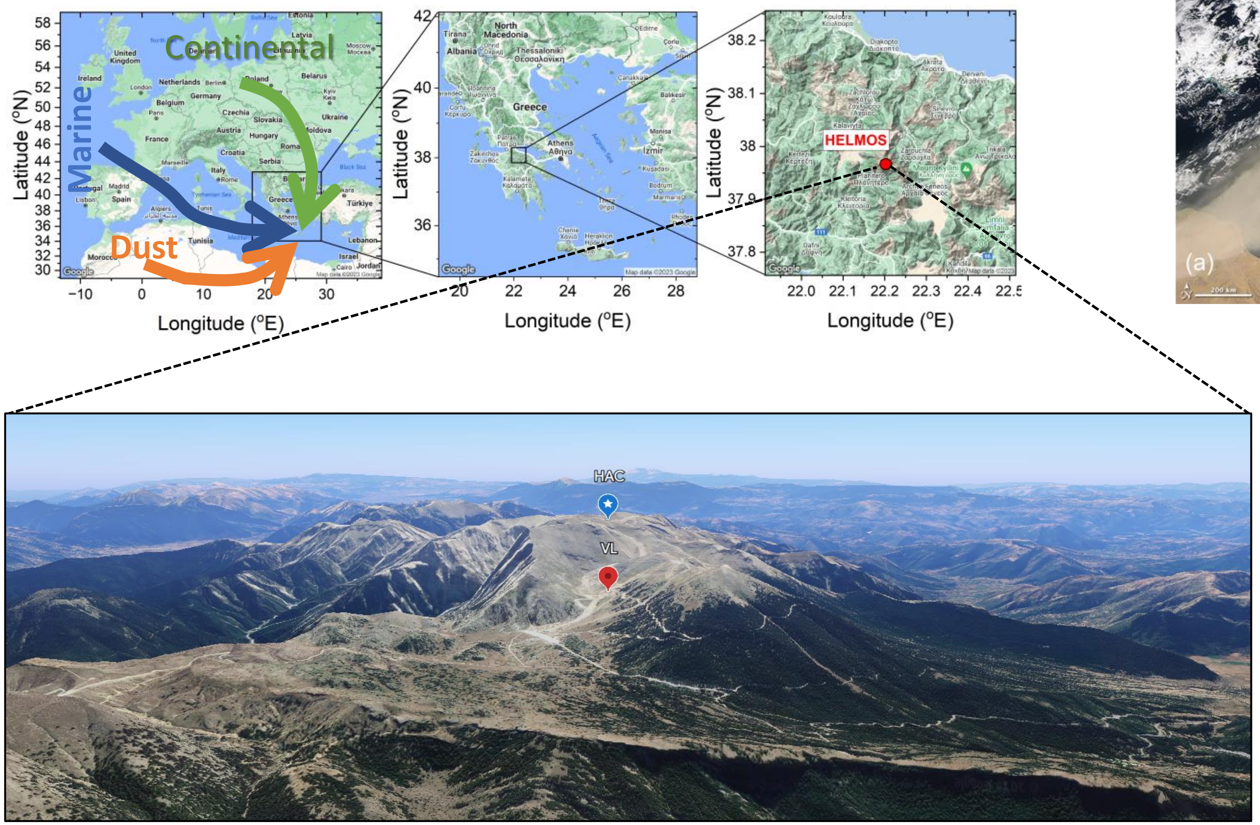
- River Styx near $(HAC)^2$ – back entrance to Hades
- Hermes was born there and had a home there too.
- Achilles was bathed by the fairy Thetis there and… almost became immortal.

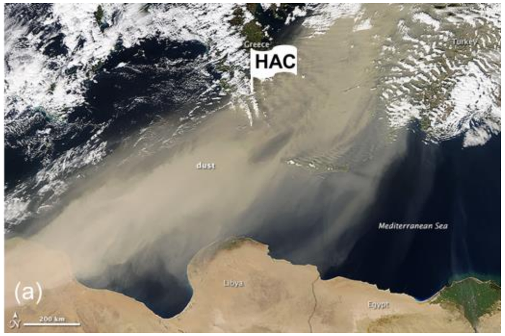


Modern history:

- Played significant role in Greek War of Independence, serving as hideout for guerrilla fighters

Mt. Helmos: Where mythology, aerosols & clouds meet



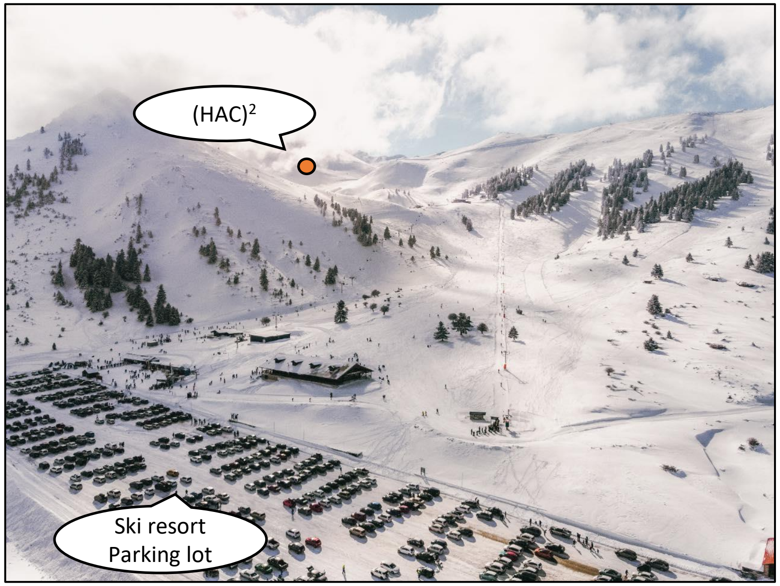


Dust transportation over Peloponnese (Feb 1, 2015)

Wildfire smoke over Peloponnese (Aug 8, 2021)

Images: Google Earth; NASA (https://earthobservatory.nasa.gov)

CHOPIN: Cleancloud Helmos OrograPhic sIte experimeNt



Some facts:

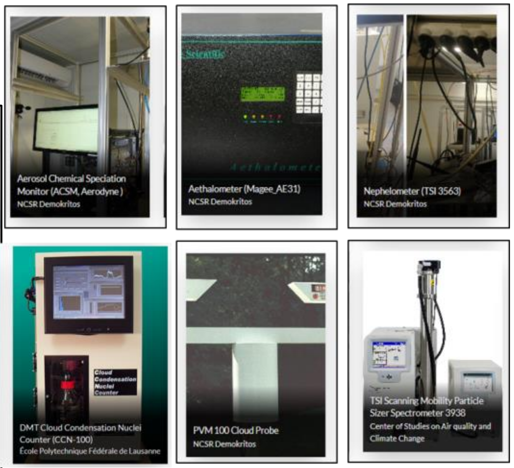
- *Period*: Oct.2024 – Jan 2025 (and later for some instruments)
- *Coordination*: NCSR Demokritos (K.Eleftheriadis) with scientific coordination from FORTH (A.Nenes) and EPFL/NTUA (A.Papayannis)

AARHUS UNIVERSITY · FORTH C-STACC Center for the Study of Air Quality & Climate Change · TROPOS Leibniz Institute for Tropospheric Research · Stockholm University · Finnish Meteorological Institute · KIT Karlsruher Institut für Technologie · °CICERO · The Cyprus Institute Research·Technology·Innovation · EPFL

Key goals of the experiment:

1. Understand processes and drivers of cloud formation (build upon CALISHTO).
2. Evaluate, improve and develop remote sensing algorithms for aerosols and clouds

CHOPIN instruments (not complete list… a lot more in place)



Cloudwater collector

Drones

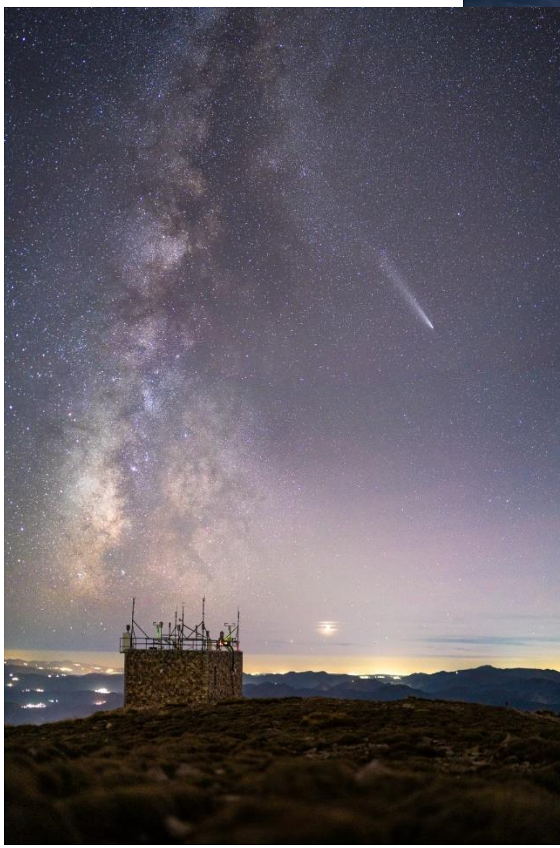
We invite the whole community to participate!

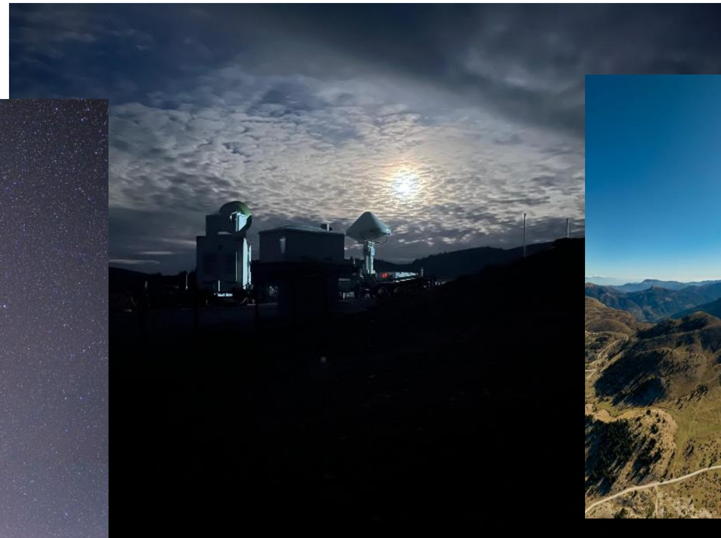
Moments from CHOPIN

Moments from CHOPIN

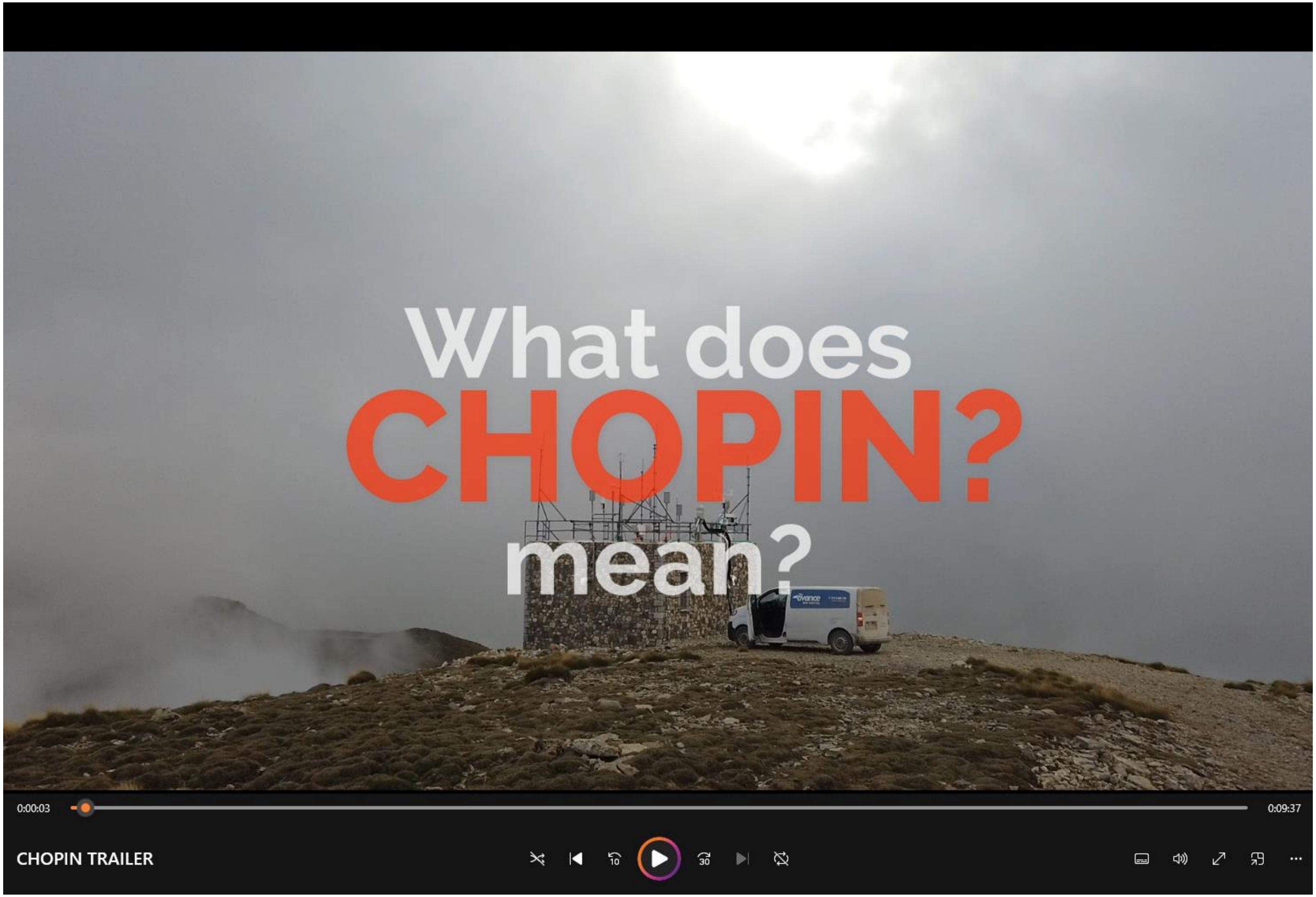
Moments from CHOPIN

Moments from CHOPIN

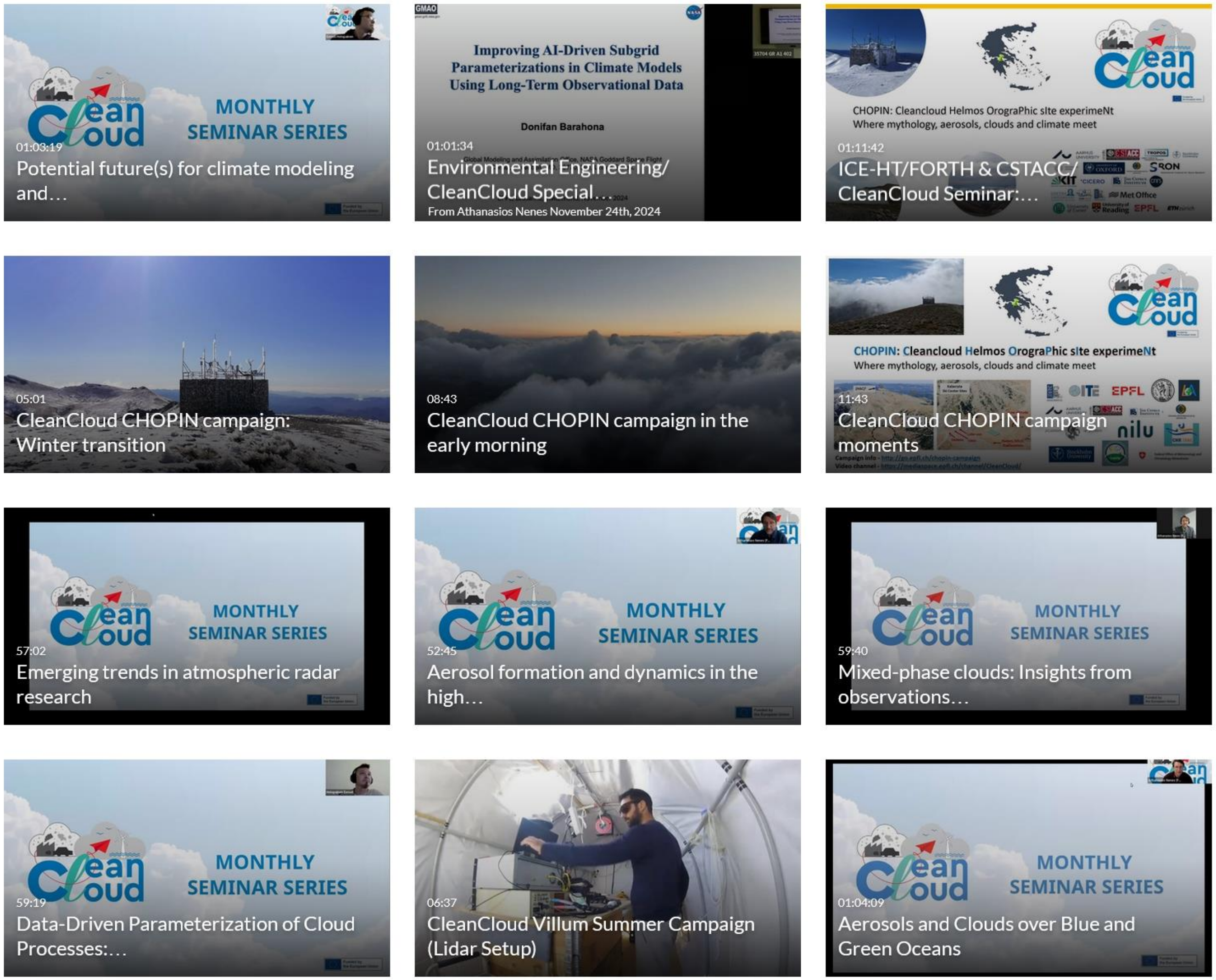




Let's watch CHOPIN science and researchers in action!



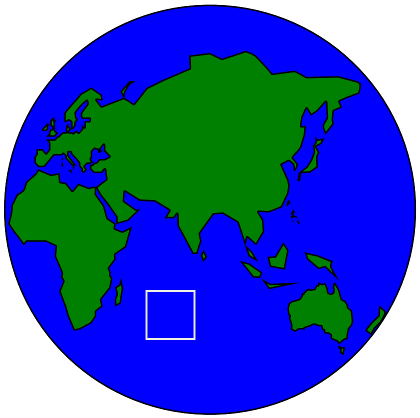
Lets take a break to stretch our legs … but keep the nice visuals going on!



https://mediaspace.epfl.ch/channel/CleanCloud/70678

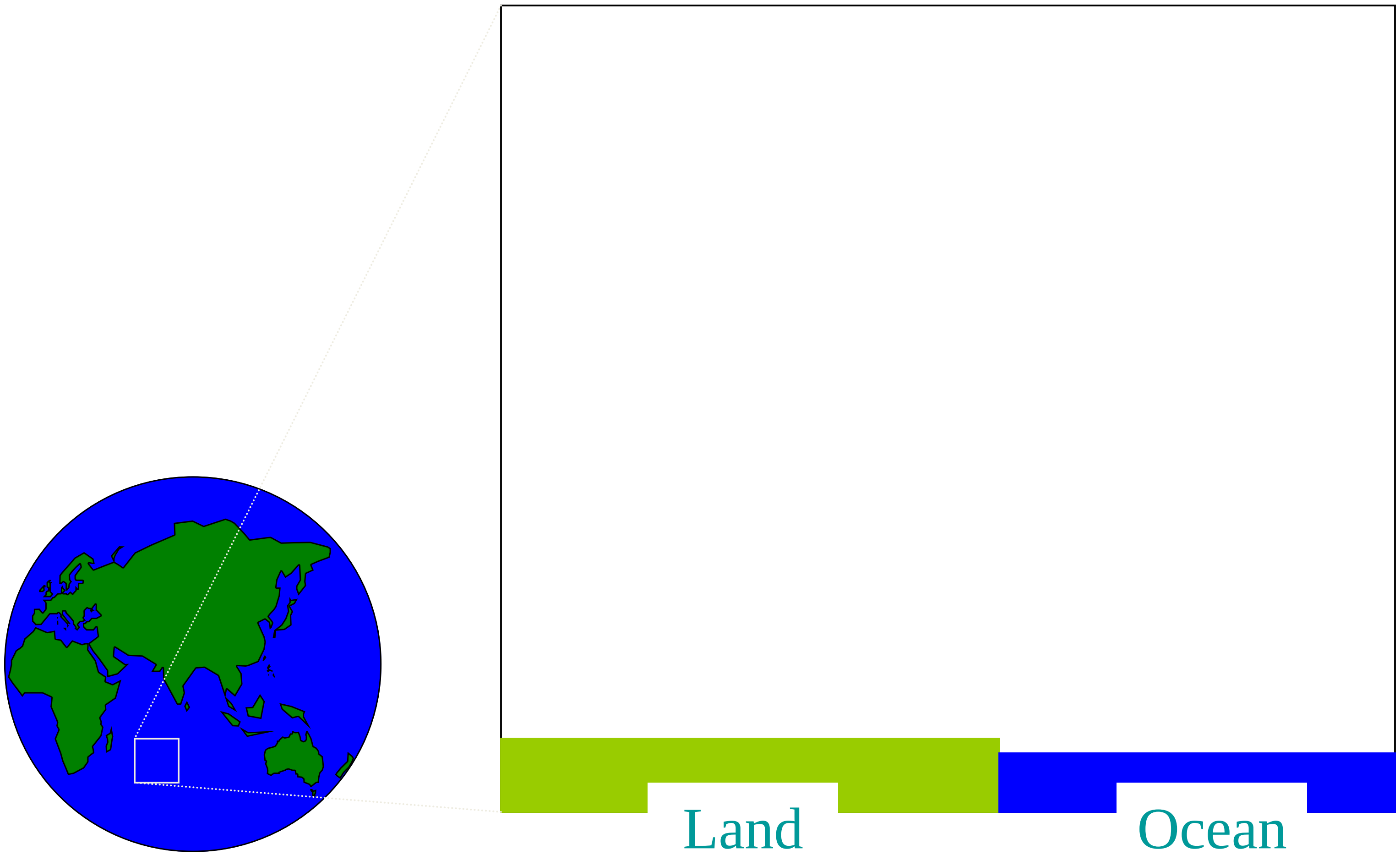
Global Climate Models: Tools of understanding

- Divide the Earth into small parts ("grid cells").
- Write equations describing
    - Conservation of Energy, Water, chemical constituents
    - Evolution of aerosol size distribution
    - Interactions of land/ocean with atmosphere
    - … etc.
- Prescribe initial conditions (e.g., climatology).
- Integrate the equations (numerically) over time.



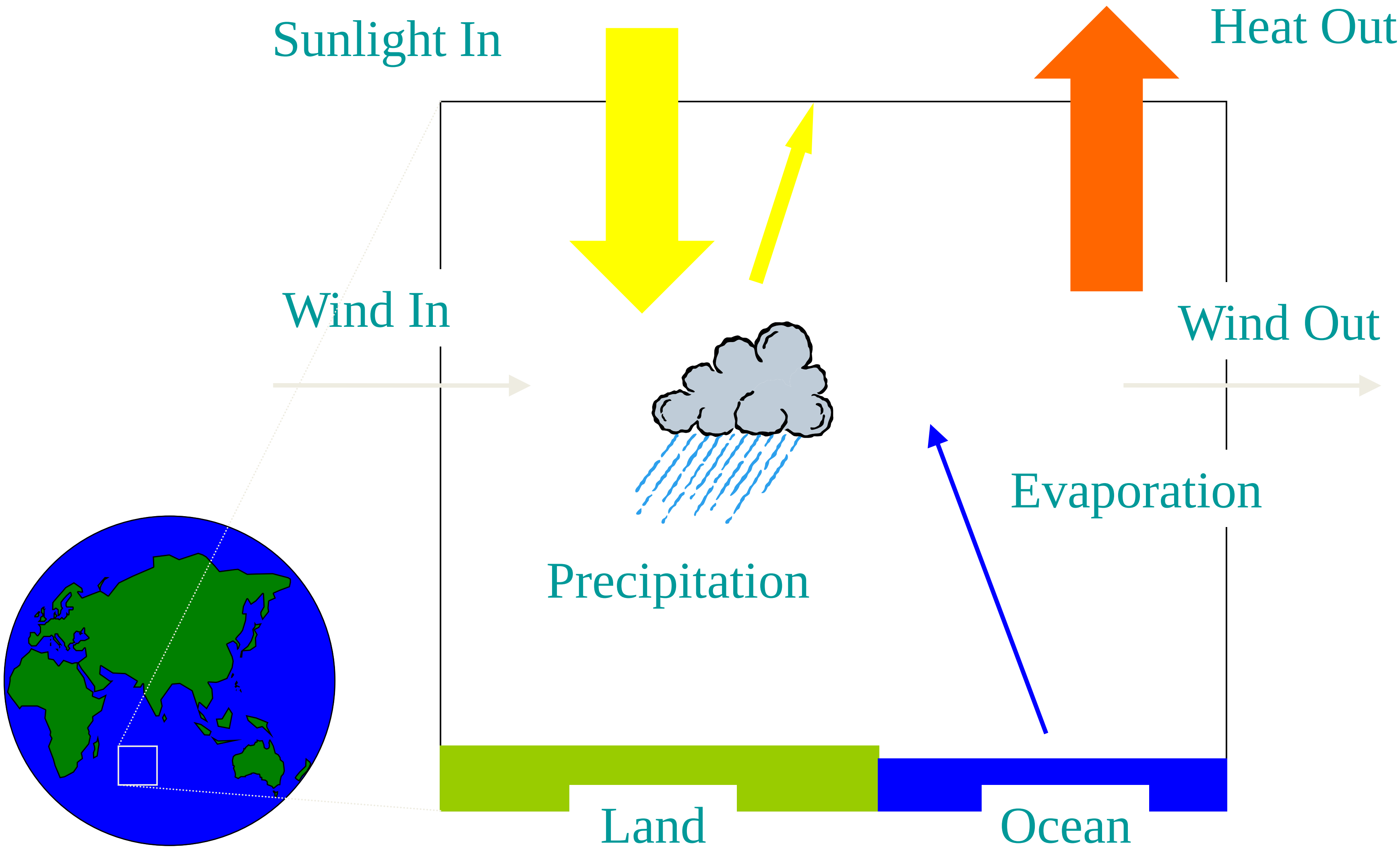
How Computer Climate Models Work

Example: conservation of energy in the atmosphere



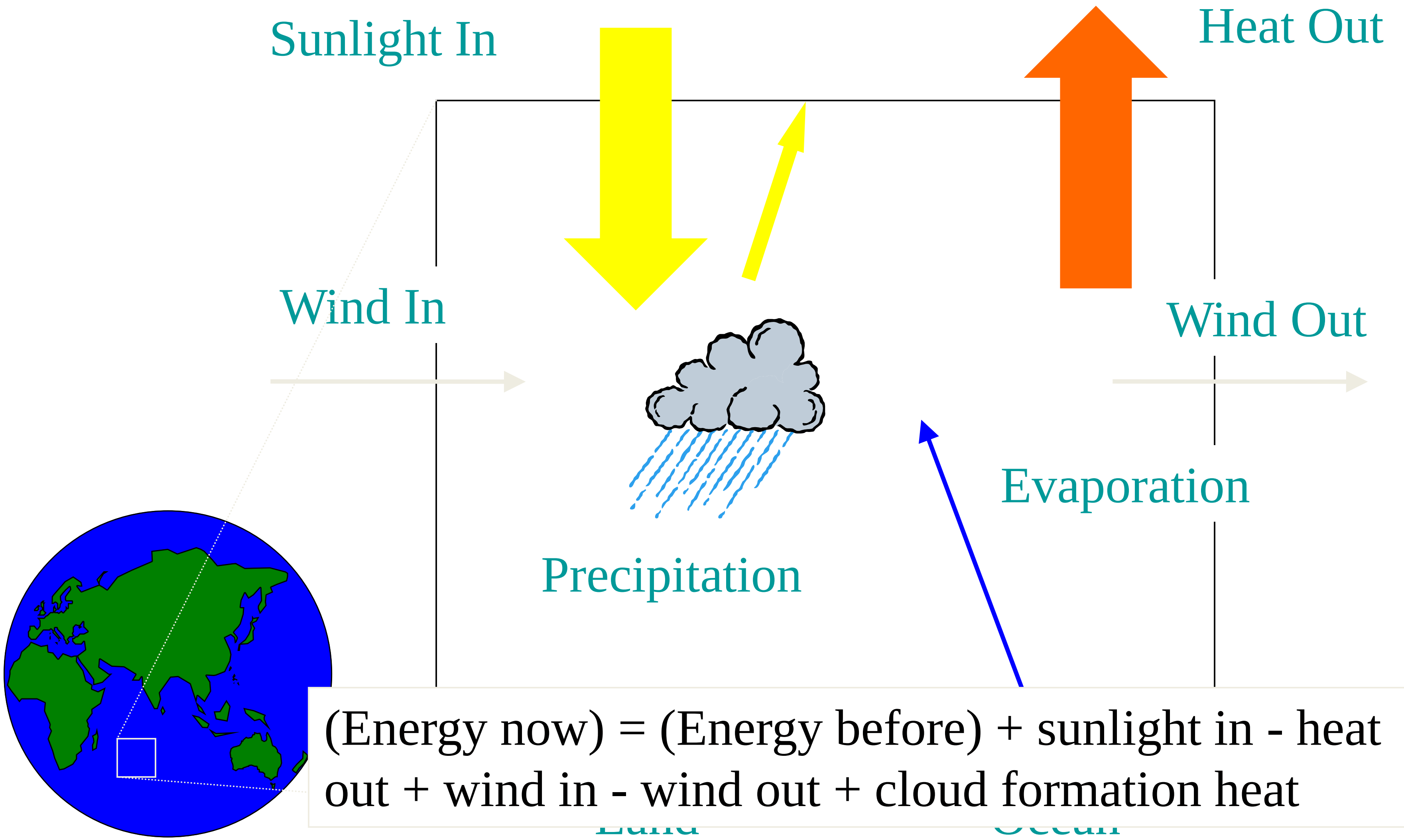
How Computer Climate Models Work

Example: conservation of energy in the atmosphere

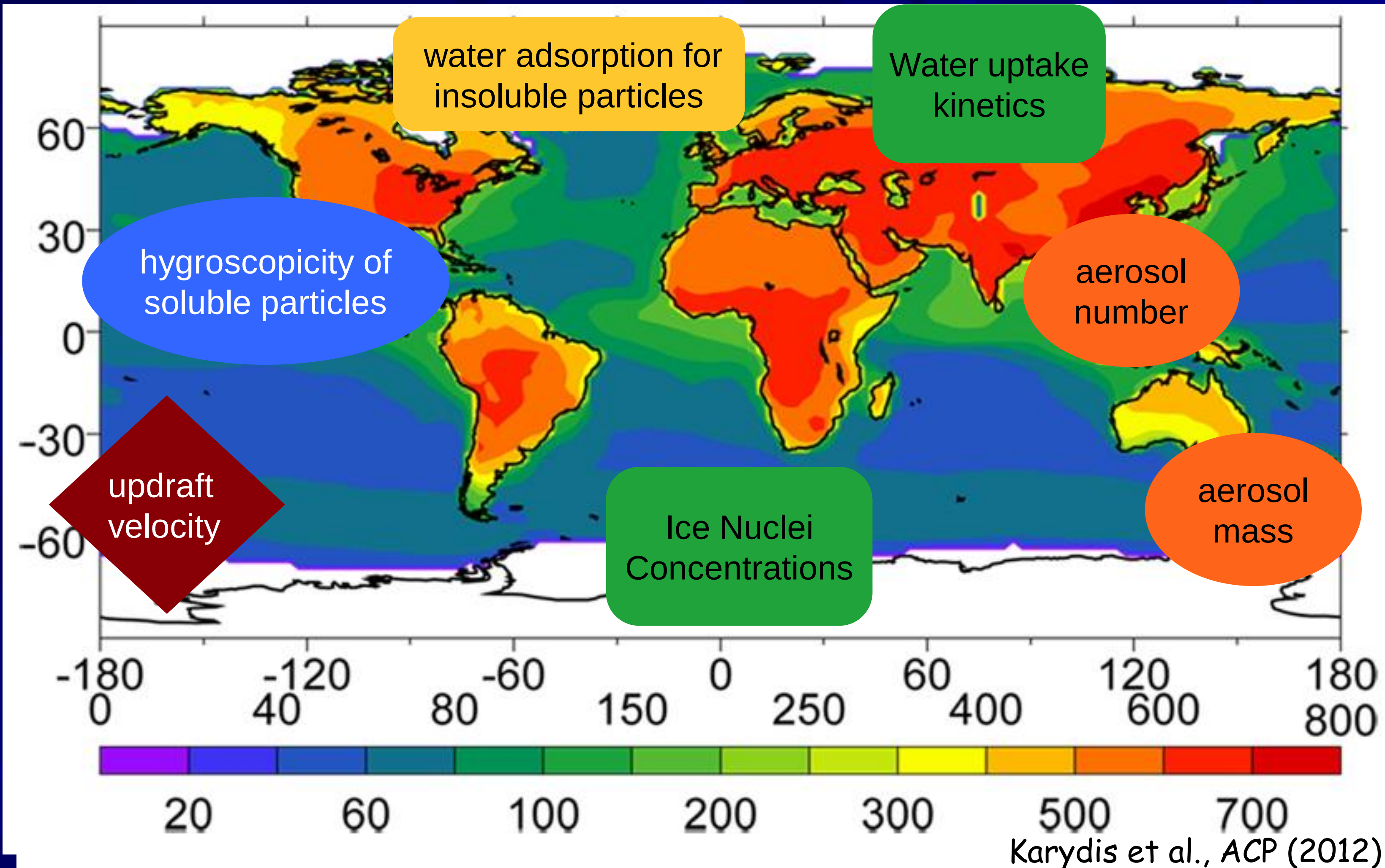


How Computer Climate Models Work

Example: conservation of energy in the atmosphere

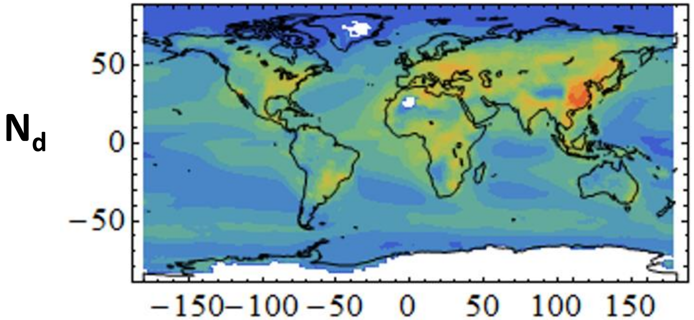


(Energy now) = (Energy before) + sunlight in - heat out + wind in - wind out + cloud formation heat

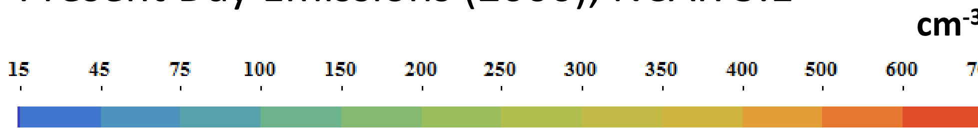


How important is each parameter? What causes most variability? What needs to be best understood?

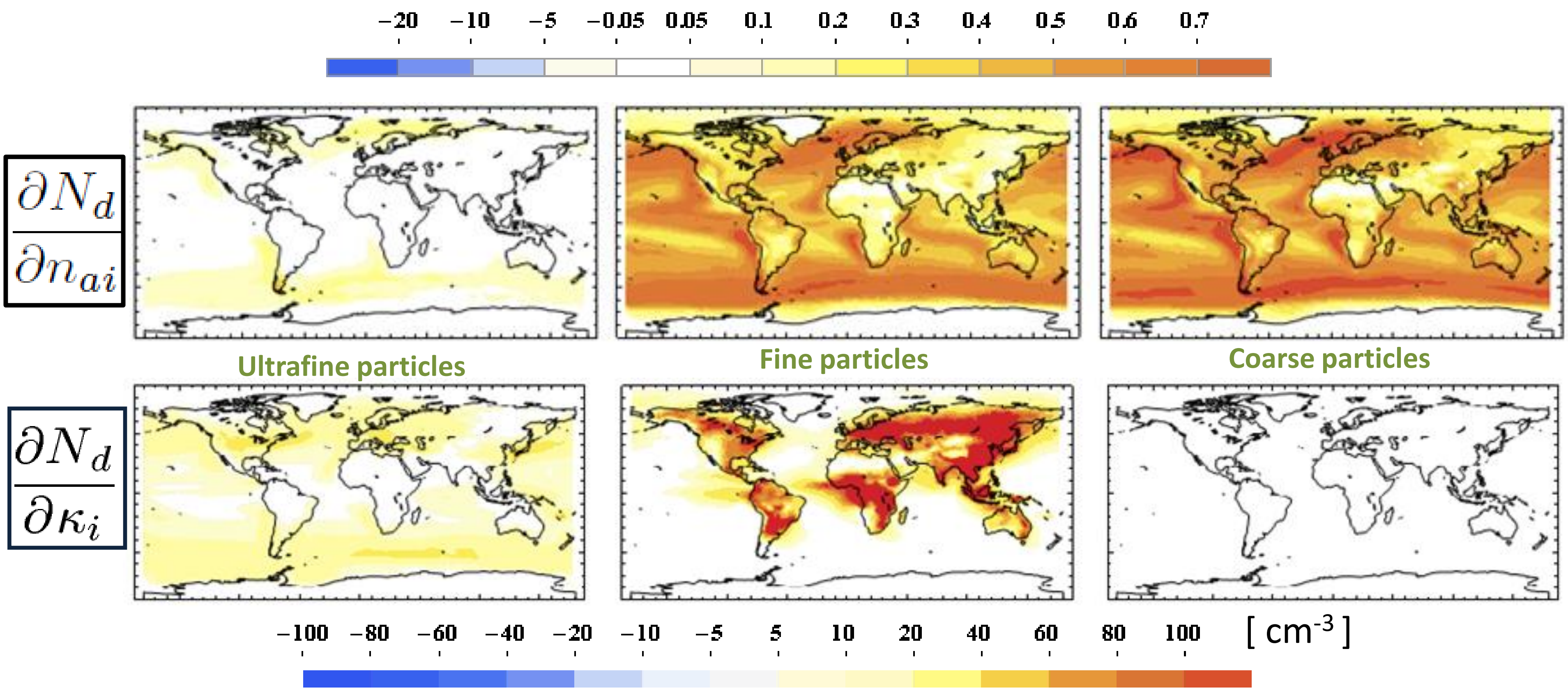
Our group contributes to climate models



Present Day Emissions (2000), NCAR 5.1



Morales and Nenes, ACP (2014)

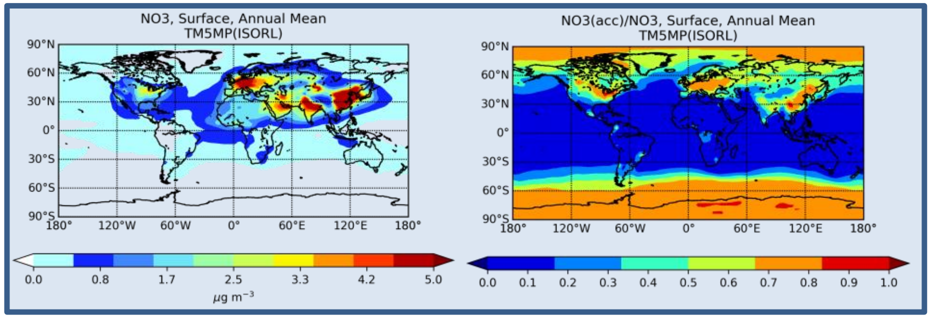


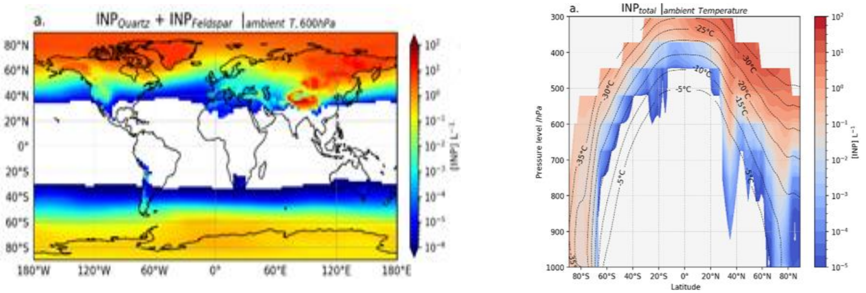
Climate Modeling: EC-Earth Consortium Member and contributor to many global and regional climate models

CSTACC contributions to EC-Earth include (blue means contributions to future IPCC runs)

- - aerosol representation :
  - coarse mode nitrate and the thermodynamic module isorropia lite
  - Brown carbon (BrC), the absorbing component of organic aerosol
  - K-feldspar & quartz dust minerals with ice nucleating properties (INP)
  - Marine organics and terrestrial bioaerosols with ice nucleating properties
- - liquid, ice and mixed-phase clouds (their representation and interaction with aerosols
- - nutrient representation and their atmospheric deposition

CSTACC modules for aerosol (ISORROPIA) and clouds widely used in other global climate models (NorESM, CESM, GFDL, NASA GEOS, ECHAM-HAM, HadGCM, ICON) & regional climate models (WRF/Polar-WRF)



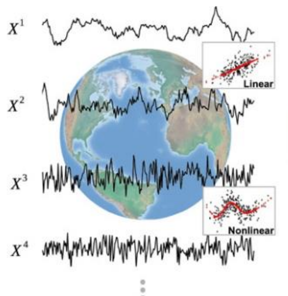


Chatziparaschos et al., to be submitted to ACPD, 2022

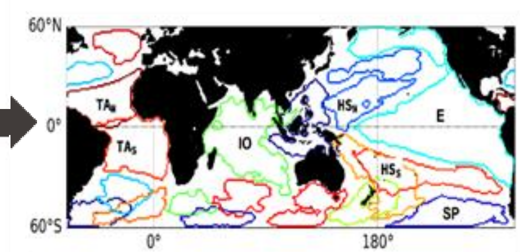
Center for the Study of Air Quality & Climate Change

Data mining & Knowledge Discovery to Constrain Climate Sensitivity

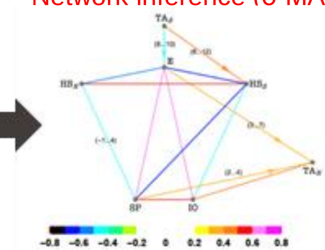
Take climate model output



Dimensionality reduction (δ-MAPS)



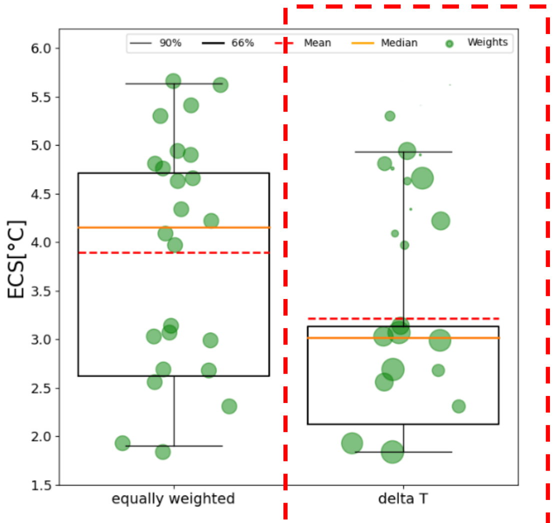
Network inference (δ-MAPS)



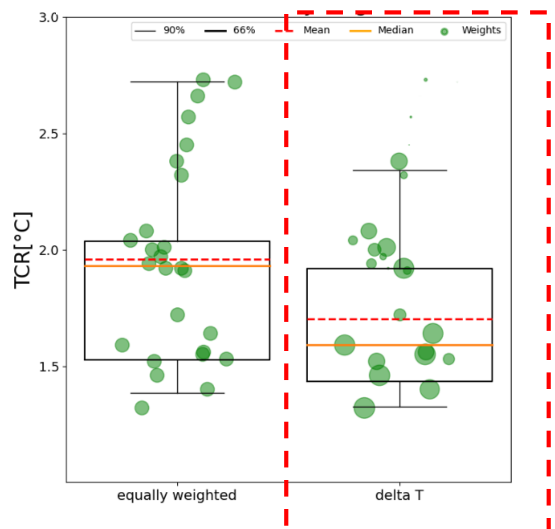
Observations and reanalysis

1. HadISST
2. COBEv2

Equilibrium Climate Sensitivity



Transient Climate Sensitivity



Application of Network Analysis (δ-MAPS) to climate model simulations reduces the uncertainty range of future projections.

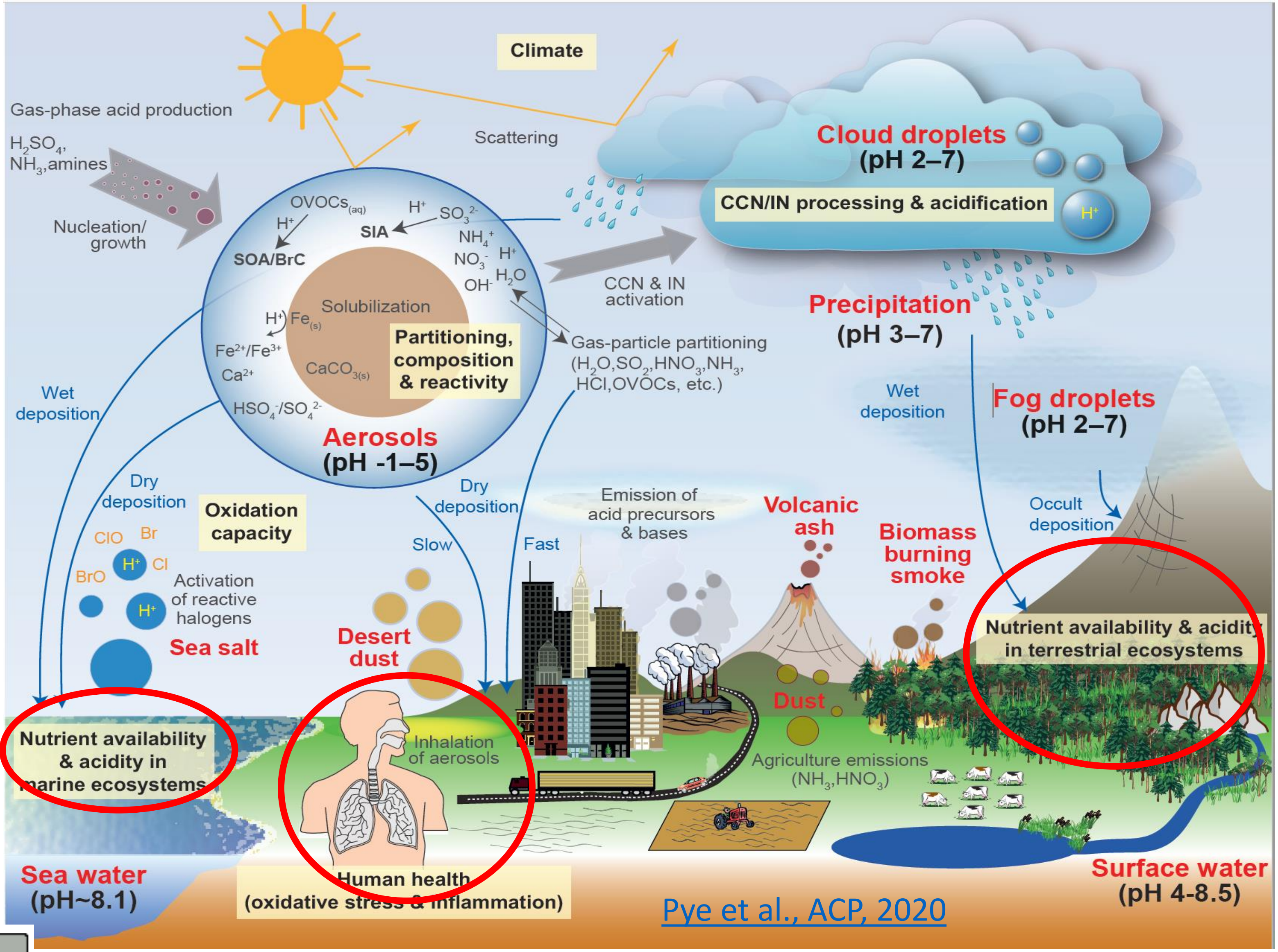
We developed a “robust” emergent constraint the climate community needs.

Ricard et al., in prep

Aerosols, Acidity and Impacts

An exploding area of research

The Acidity of Atmospheric Particles



Pye et al., ACP, 2020

Emissions & partitioning affect aerosol acidity

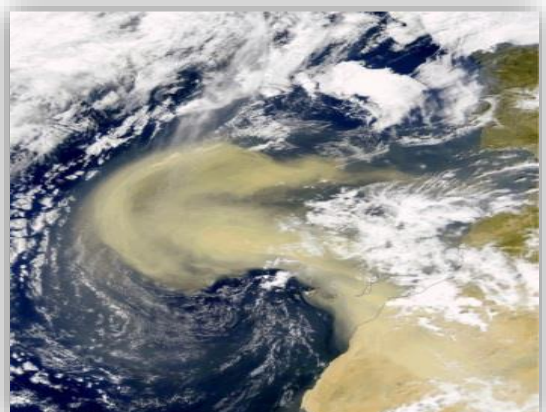
Acidic  → SO_2(g), NOx(g), VOCs — *Oxidation* → H_2SO_4(p), HNO_3(p), Org acids (p)

Basic  → NH_3(g) + Mineral dust, sea salt (Na, K, Ca, Mg, etc.)

Formation of aerosol species and amount **depends on particle pH**

pH varies a lot over space, time and particle size!

Fine Mode (D_p < 1 µm)



Mainly in coarse mode (D_p > 1 µm)

adapted from: H.Guo

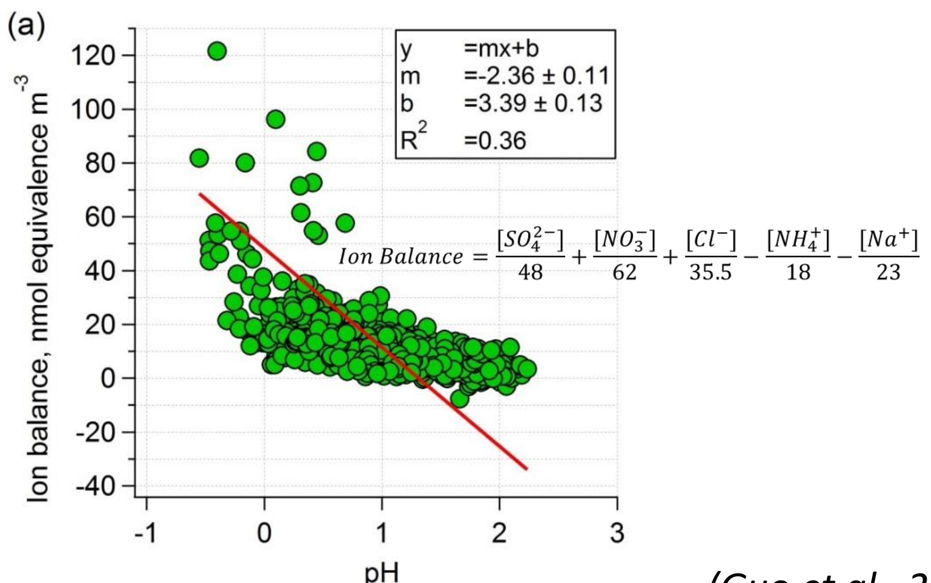
Measuring aerosol pH: The problem

- No direct measurement of pH is available for single particles *in-situ*.
- Emerging offline methods – but a long way to go before they are widely used.
- "pH proxies" (ion balance, molar ratios), **do not strongly correlate with pH**

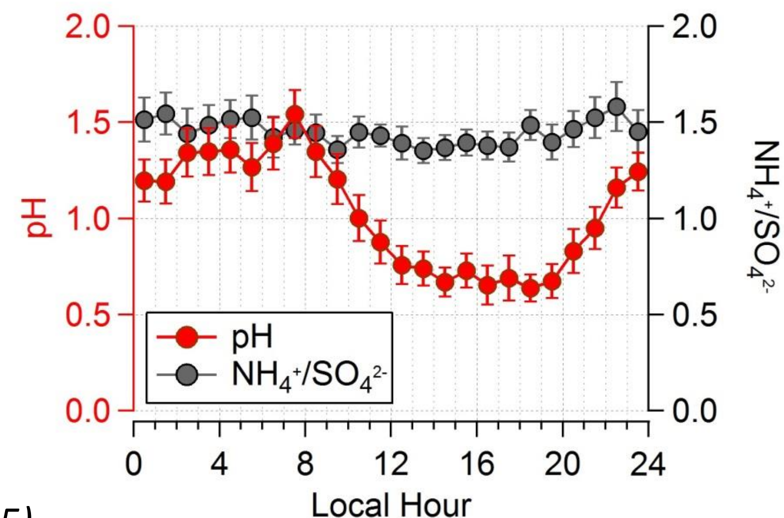
$$pH = -\log_{10}[H^+] = -\log_{10}\frac{1000H^+_{air}}{LWC} \qquad H^+_{air}, LWC\ units\colon\ \mu g\ m^{-3}\ air$$

- Current gold standard: Measurements + Thermodynamic modeling

Ion balance:



NH_4^+/SO_4^{2-} Molar ratio:



(Guo et al., 2015)

Determining aerosol pH: The “heart” of it

ISORROPIA-II calculates:

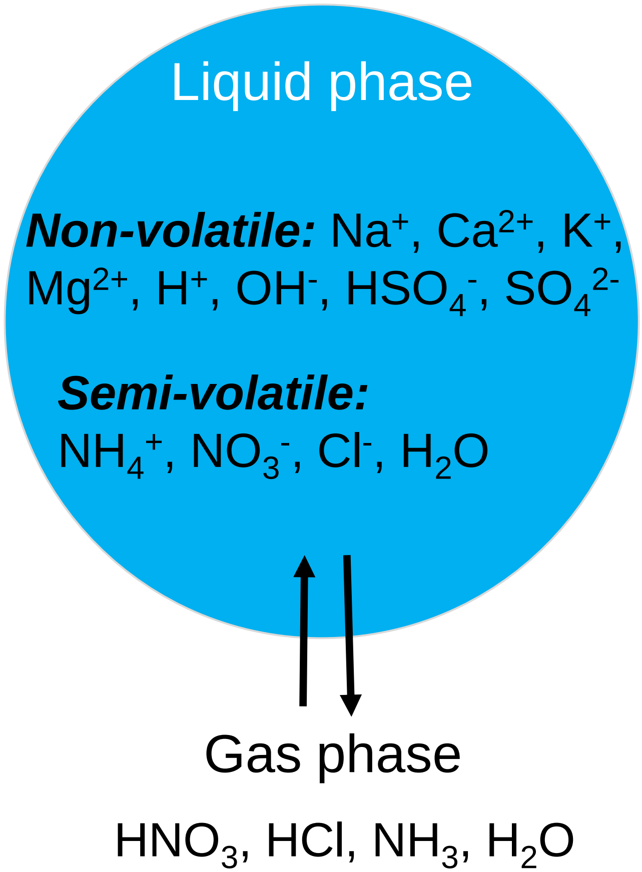
the composition and phase state of an NH_4^+-SO_4^{2-}-NO_3^--Cl^--Na^+-Ca^{2+}-K^+-Mg^{2+}-water inorganic aerosol in equilibrium with gases

Assumptions:

- “metastable” aerosol & no phase separation (a single aqueous phase)
- $PM_{2.5}$ in equilibrium with gas

Forward mode:

calculates equilibrium partitioning given total concentration of species (gas + particle)



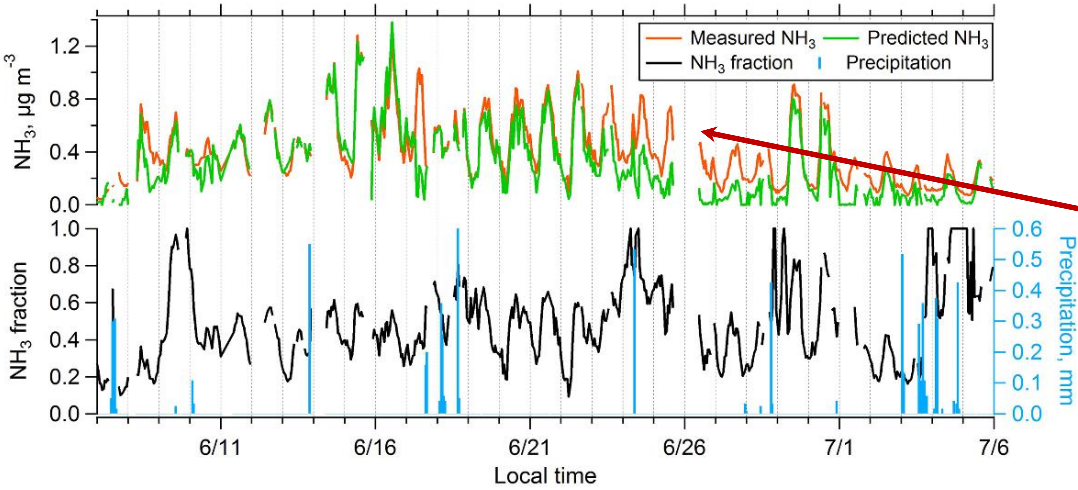
http://isorropia.epfl.ch

Input: Total nitrate (HNO_3+NO_3^-) → Output: HNO_3, NO_3^-

Input: Total ammonium (NH_3+NH_4^+) → Output: NH_3, NH_4^+

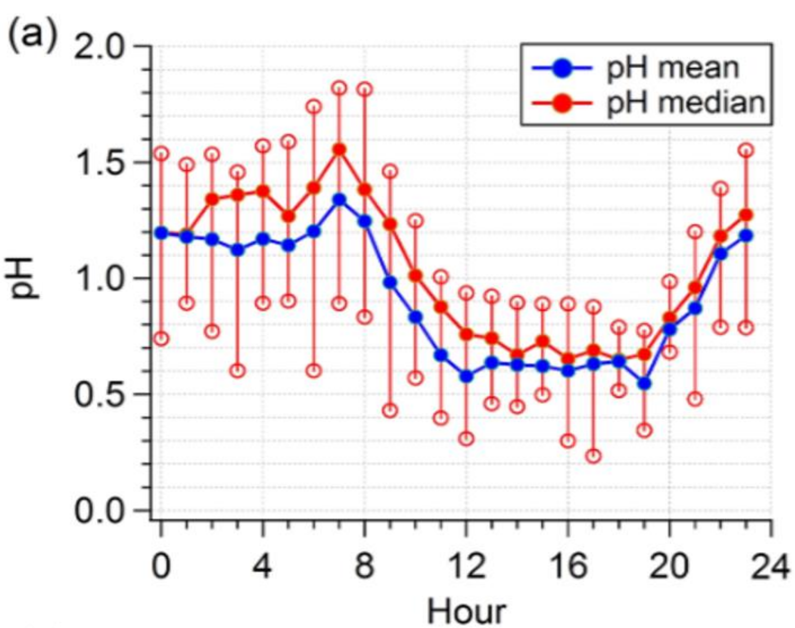
pH constrained by NH_3-NH_4^+ partitioning

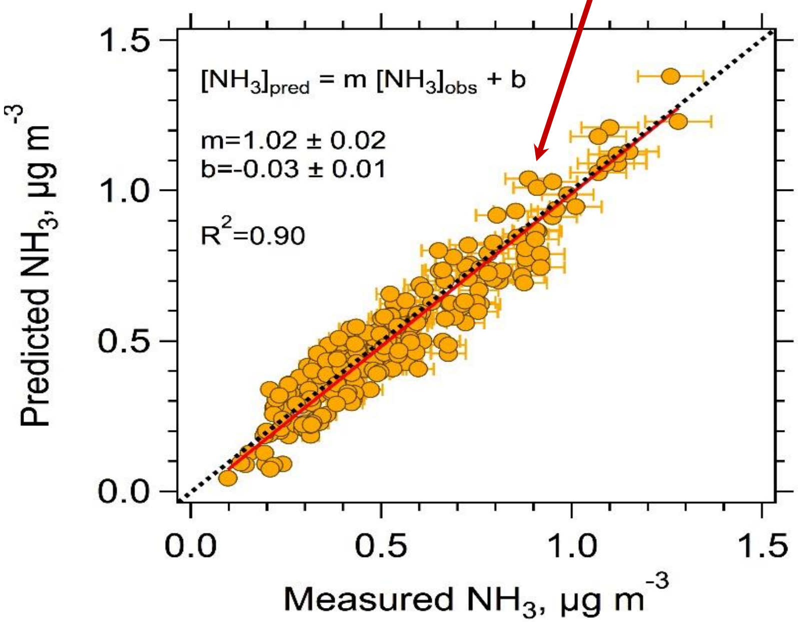
SOAS: *(Southern Oxidant Aerosol Study)* 6/7, 2013 Centreville, AL (CTR)



Guo et al., ACP, 2015.

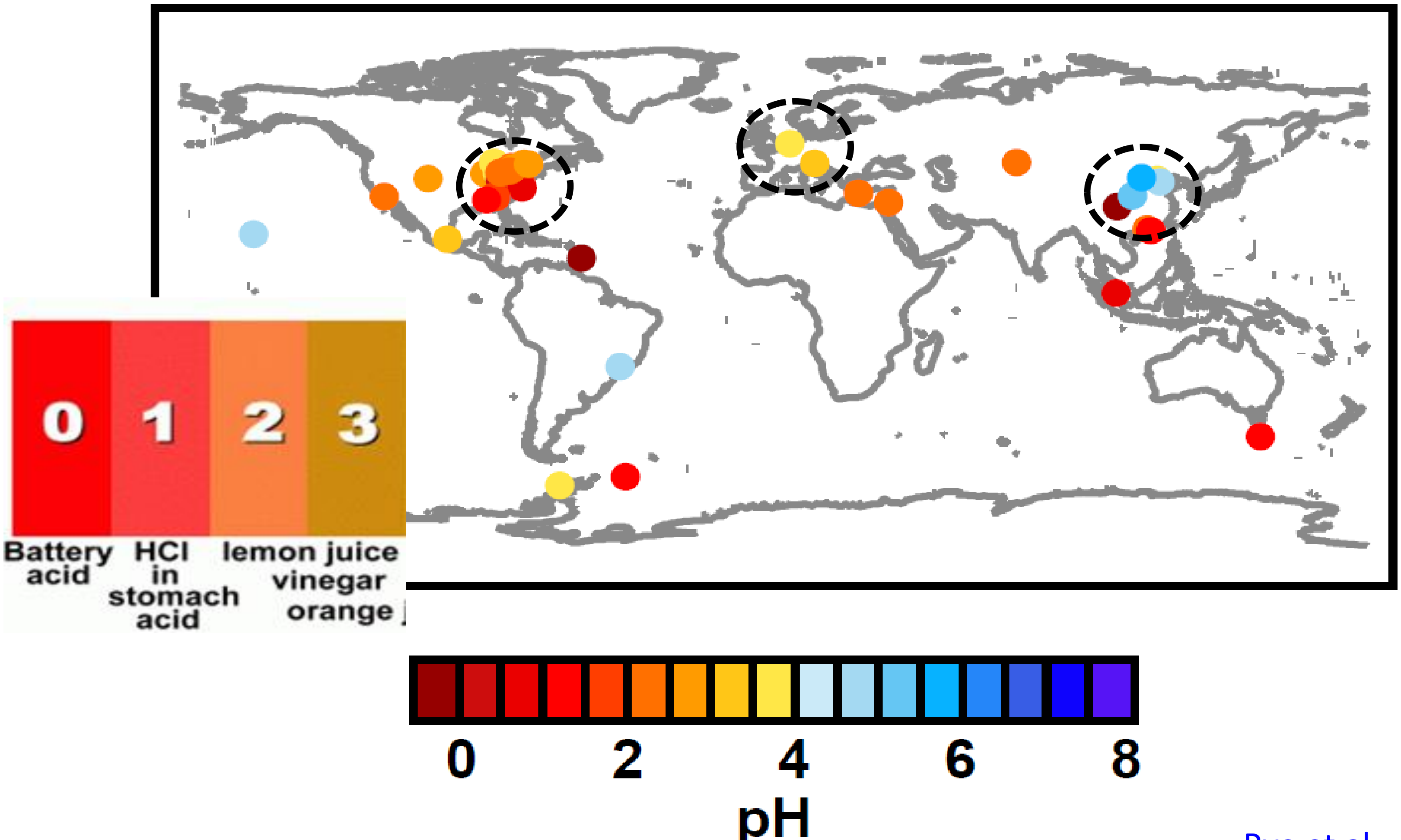
Comparison of <u>predicted vs. observed</u> gas-phase NH_3.





Acidic aerosol is everywhere

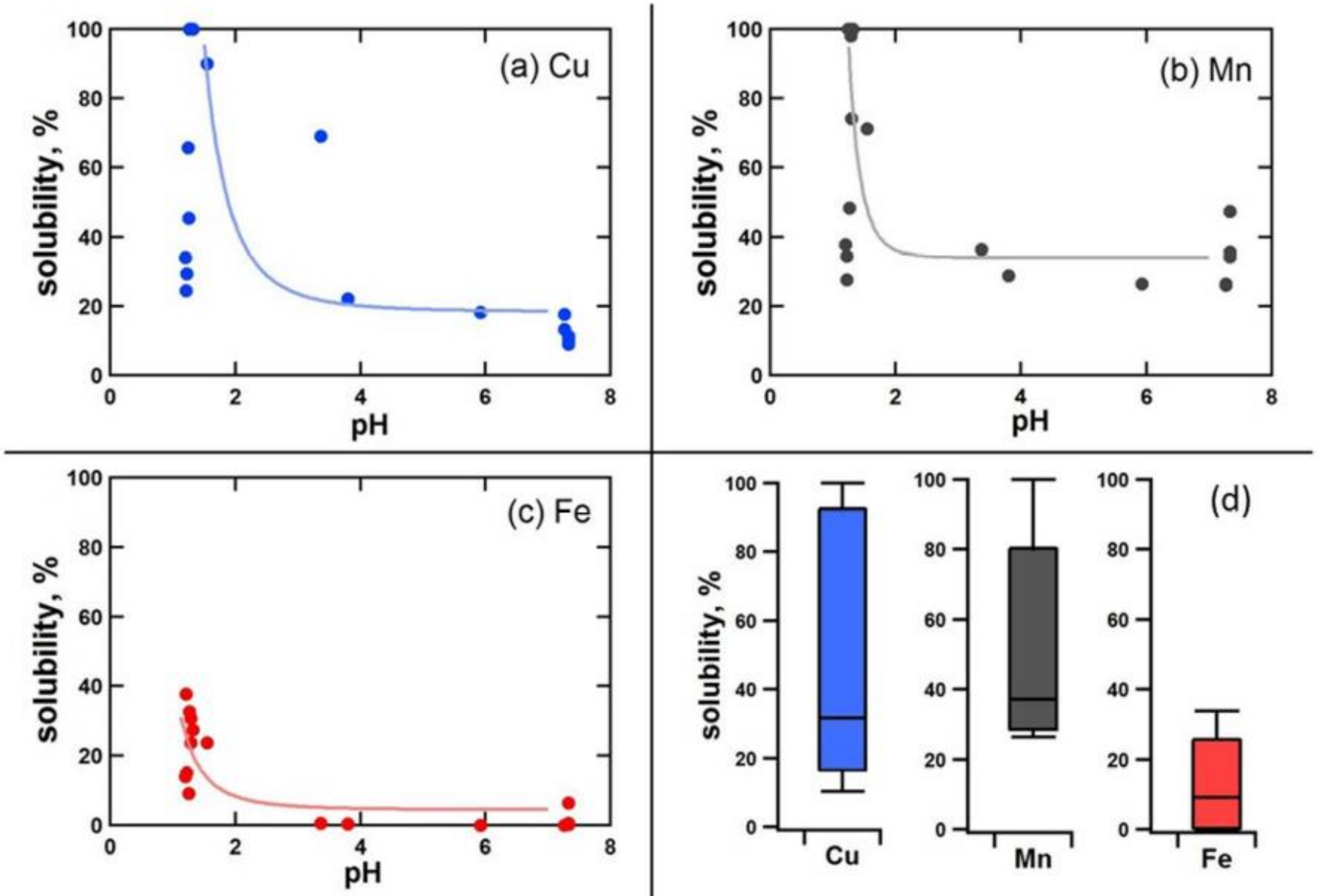
pH varies **alot**



Pye et al., ACP, 2020

Health impacts: Acidity dissolves metals

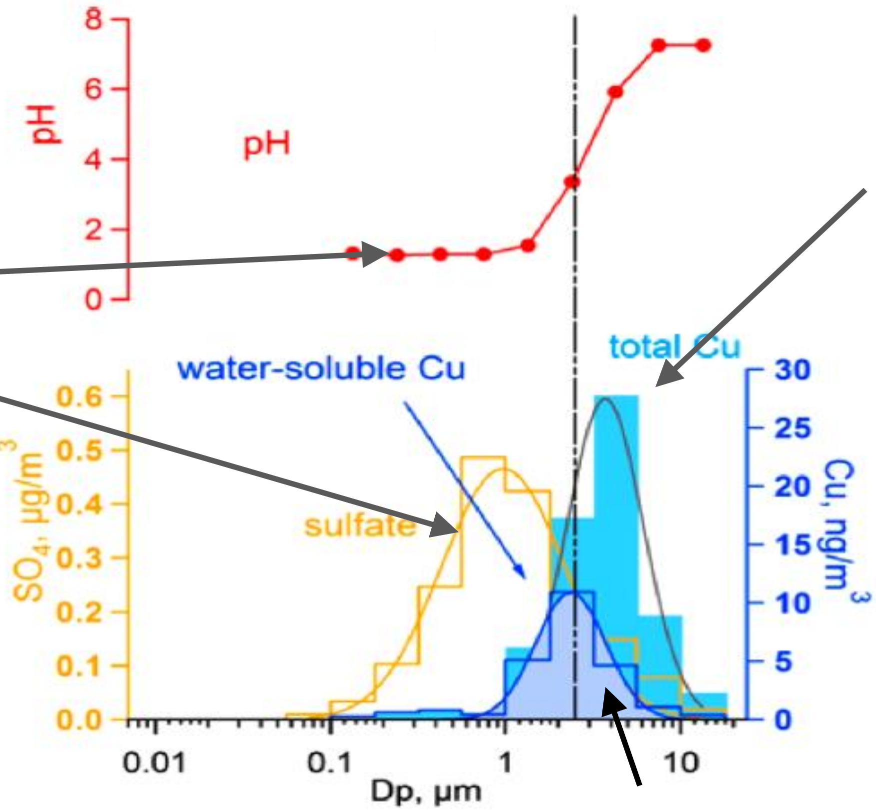
- pH is profound for determining PM2.5 levels.
- Important driver of toxicity – and can explain the association of sulfate, soluble metals etc. with adverse health outcomes.



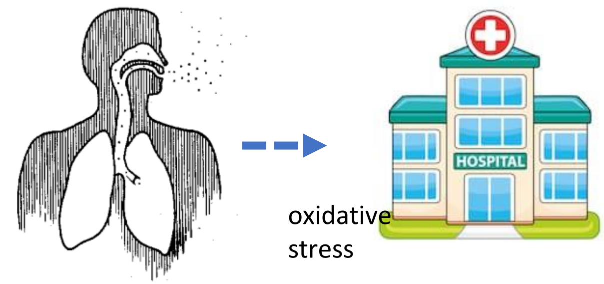
Fang et al. *ES&T* 2017

Health impacts: Acidity dissolves metals

Acidic PM_1 due to presence of sulfate and few NVCs.



Emitted insoluble metals in coarse mode.

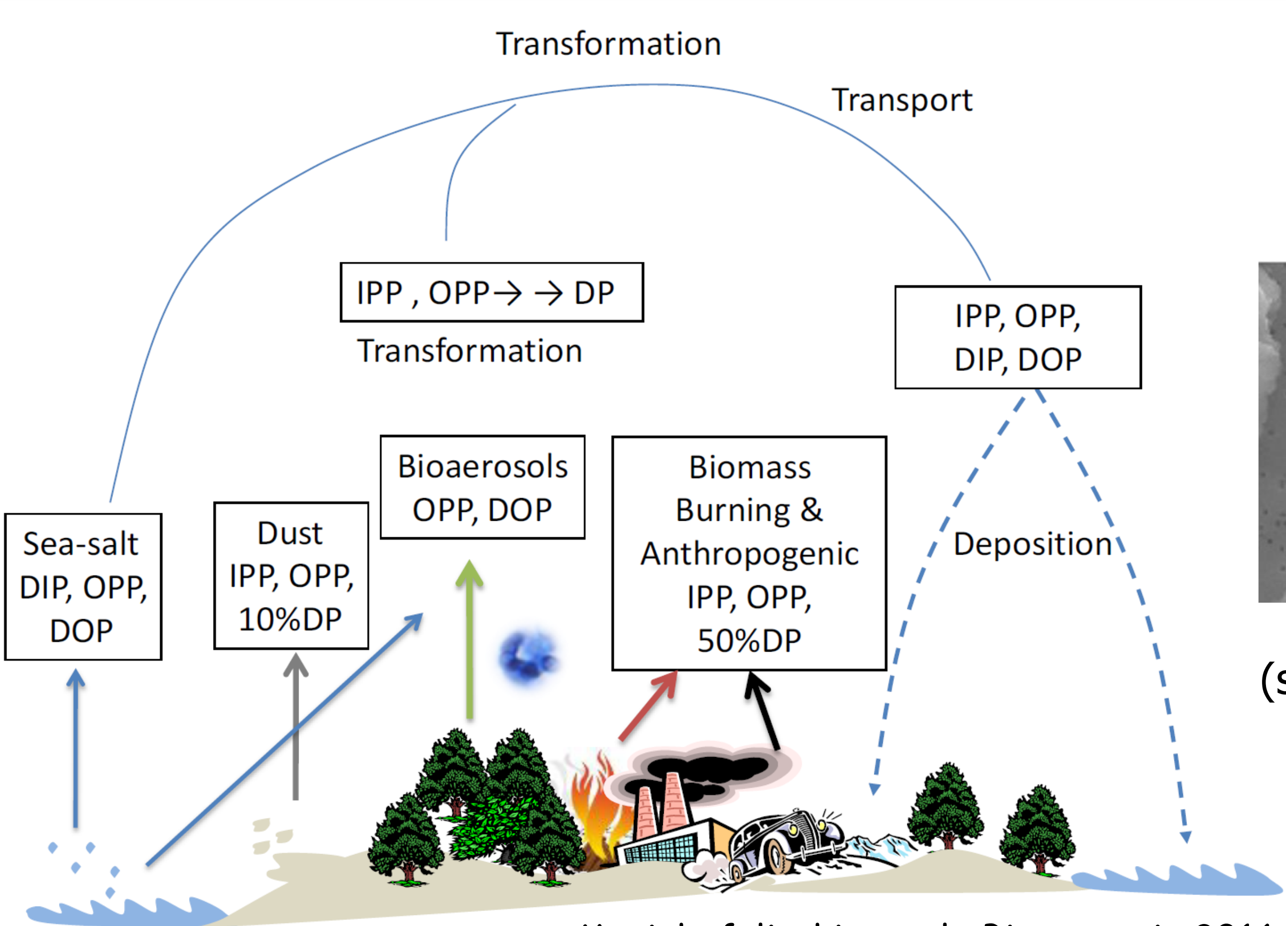


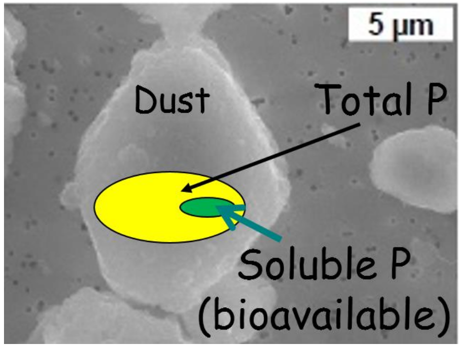
Fang et al. *ES&T* 2017
Dallenbach et al., Nature, 2020

Cu becomes soluble by acid dissociation.

- Soluble metals appear where acidity is strong (pH low)
- Toxicity related to inhalation of soluble metals
- ***Mechanism explaining why PM 2.5 sulfate in the environment is associated with toxicity***

Particle pH affects global nutrient cycles





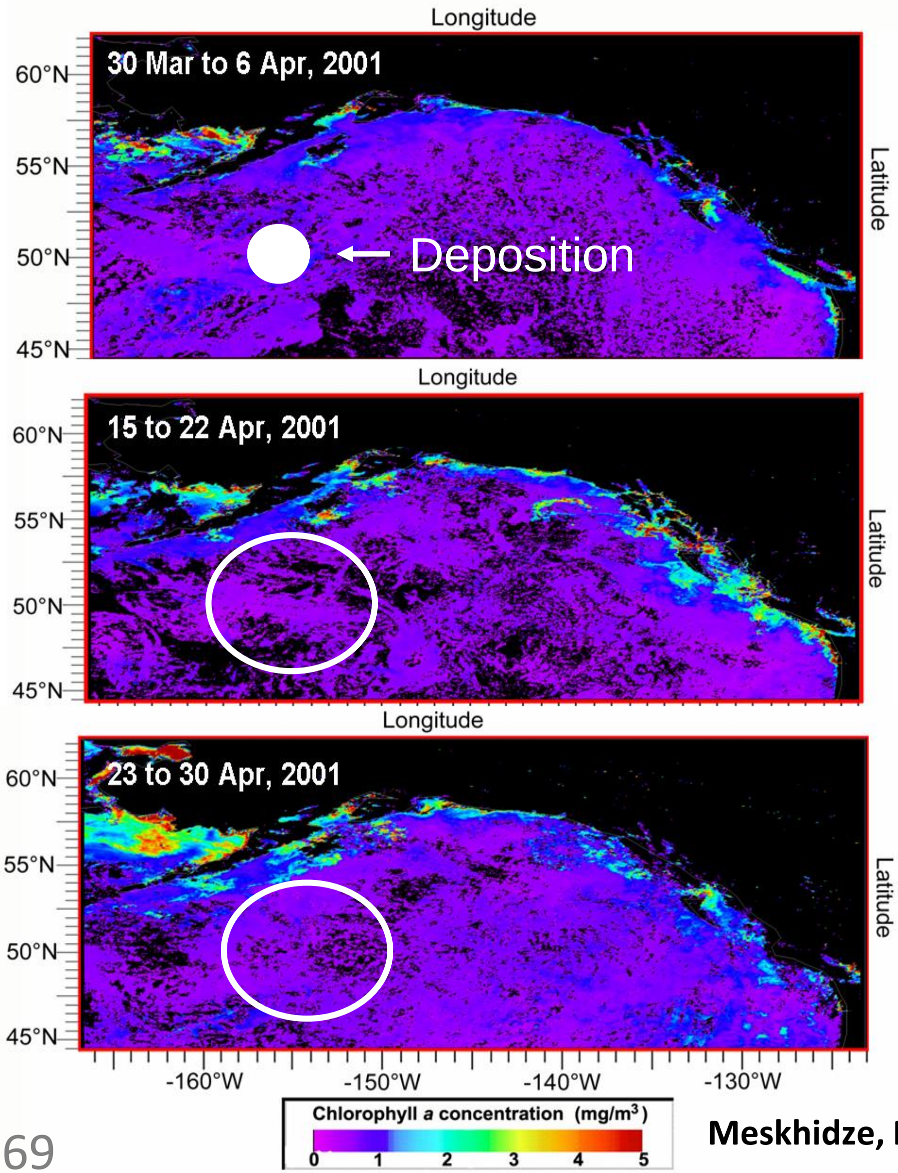
(same applies to Fe, Cu)

Myriokefalitakis et al., Biogoeosci., 2016

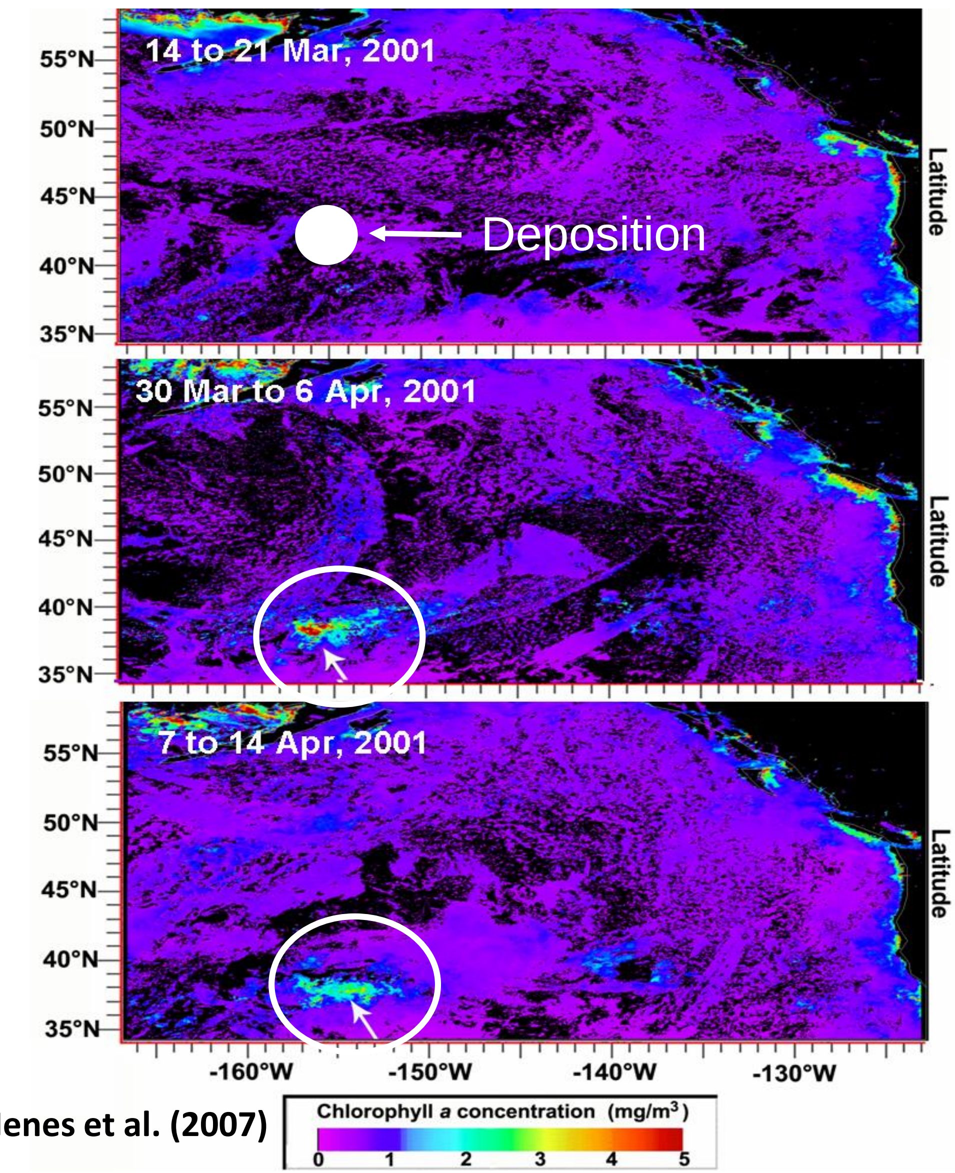
- Mineral dust is a prime source of P, Fe, Cu to the (offshore) ocean.
- Interaction of Dust with pollution affects their soluble (bioavailable) fraction.
- Aging largely occurs by acidification/dissolution of metal-containing minerals.

Ecosystems respond to increased nutrient deposition

Dust deposition event & weak acidity

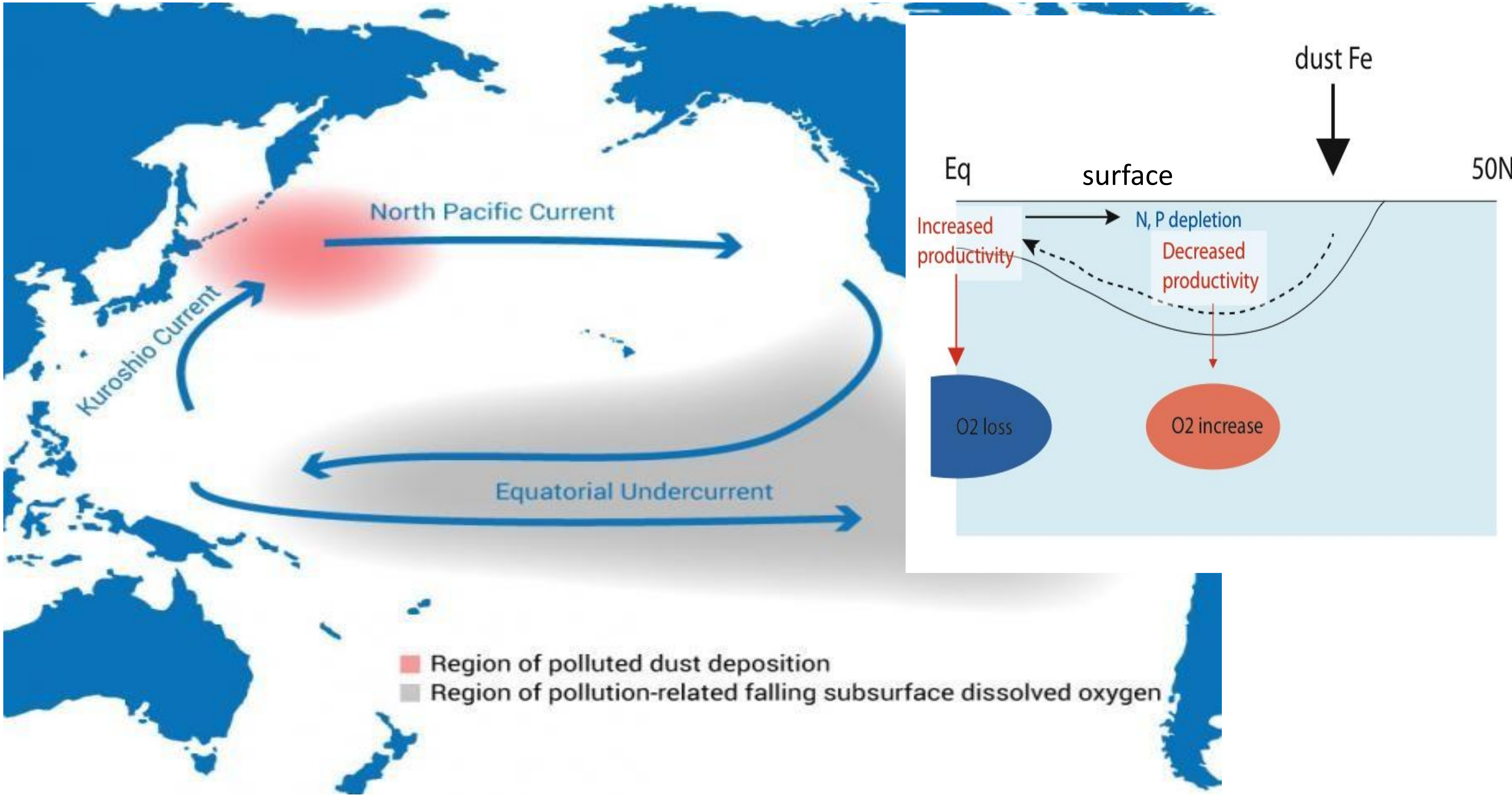


Dust deposition event & strong acidity



Meskhidze, Nenes et al. (2007)

Fe deposition can profoundly impacts productivity and ocean O_2 levels – far from deposition region.

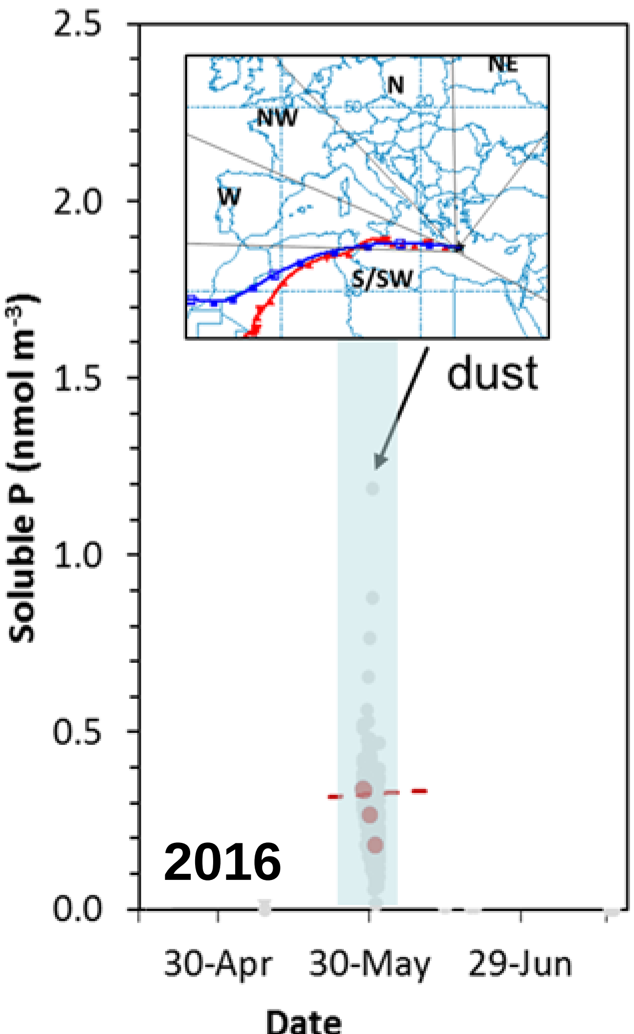


Acceleration of oxygen decline in the tropical Pacific over the past decades by aerosol pollutants

T. Ito[1*], A. Nenes[1,2,3,4], M. S. Johnson[5], N. Meskhidze[6] and C. Deutsch[7]

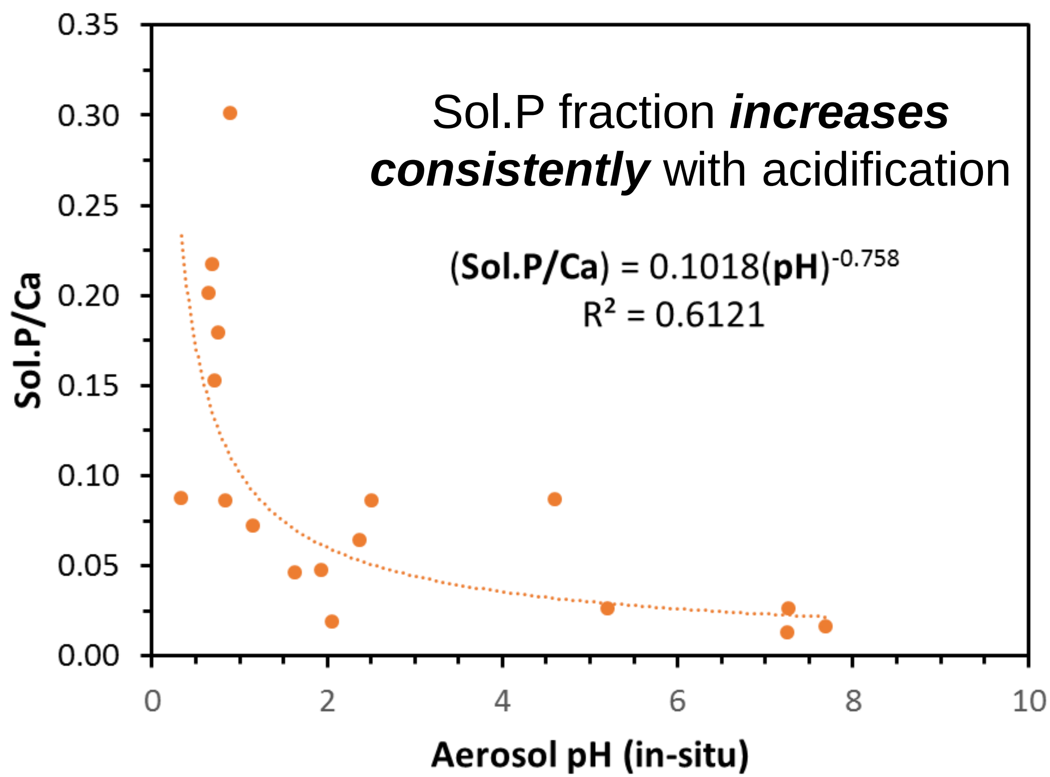
16 MAY 2016 | DOI: 10.1038/NGEO2717

Acidification solubilizes dust P: evidence from E.Mediterranean data.



Focus on dust events:

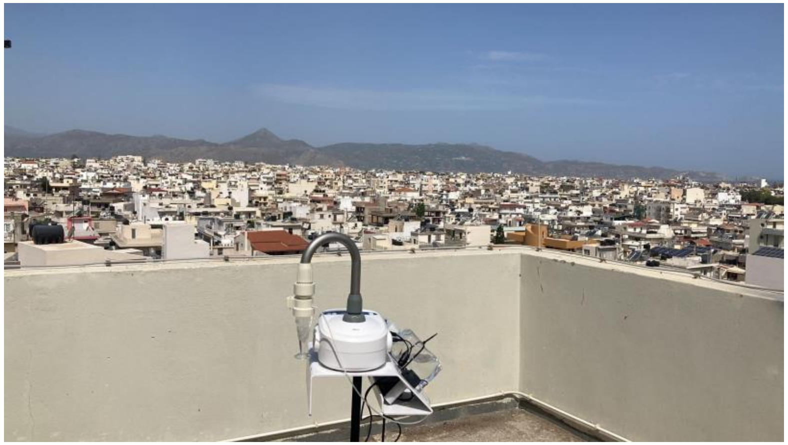
- ISORROPIA (Fountoukis and Nenes, 2007) to obtain aerosol pH for in-situ (fine mode) aerosol
- Express P/Ca vs.aerosol pH (as Nenes et al. 2011)



Violaki et al., *in review* (2021)

Fertilization of E.Mediterranean ecosystems from dust (AQUACOSM-plus).

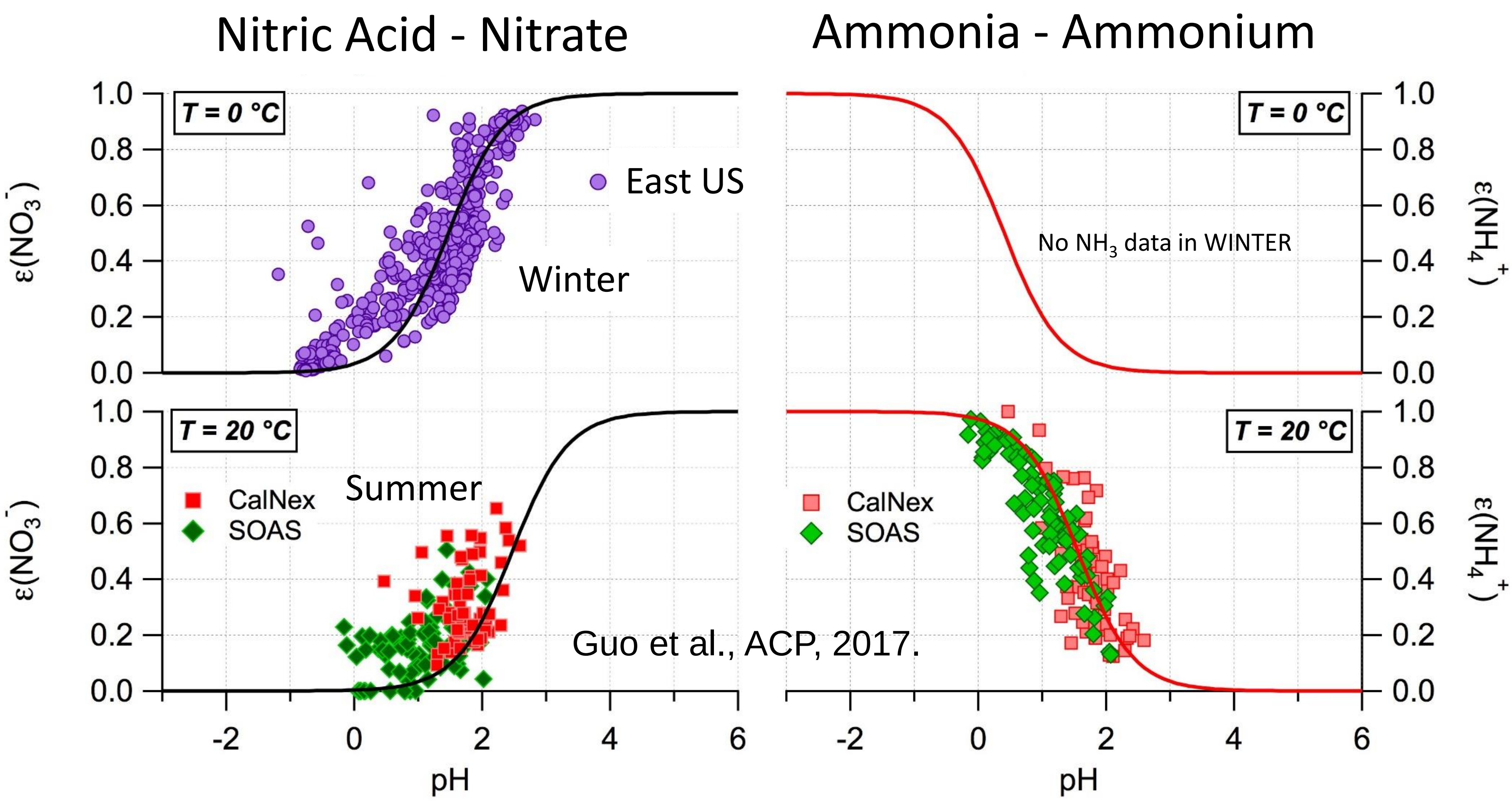
- May-June 2022
- Understand impacts of pollution/bioaerosol/dust deposition on marine ecosystems.
- Collection of aerosol from different sources, and deposit them to seawater collected from the E.Mediterranean



Fertilization of E.Mediterranean ecosystems from dust (AQUACOSM-plus).

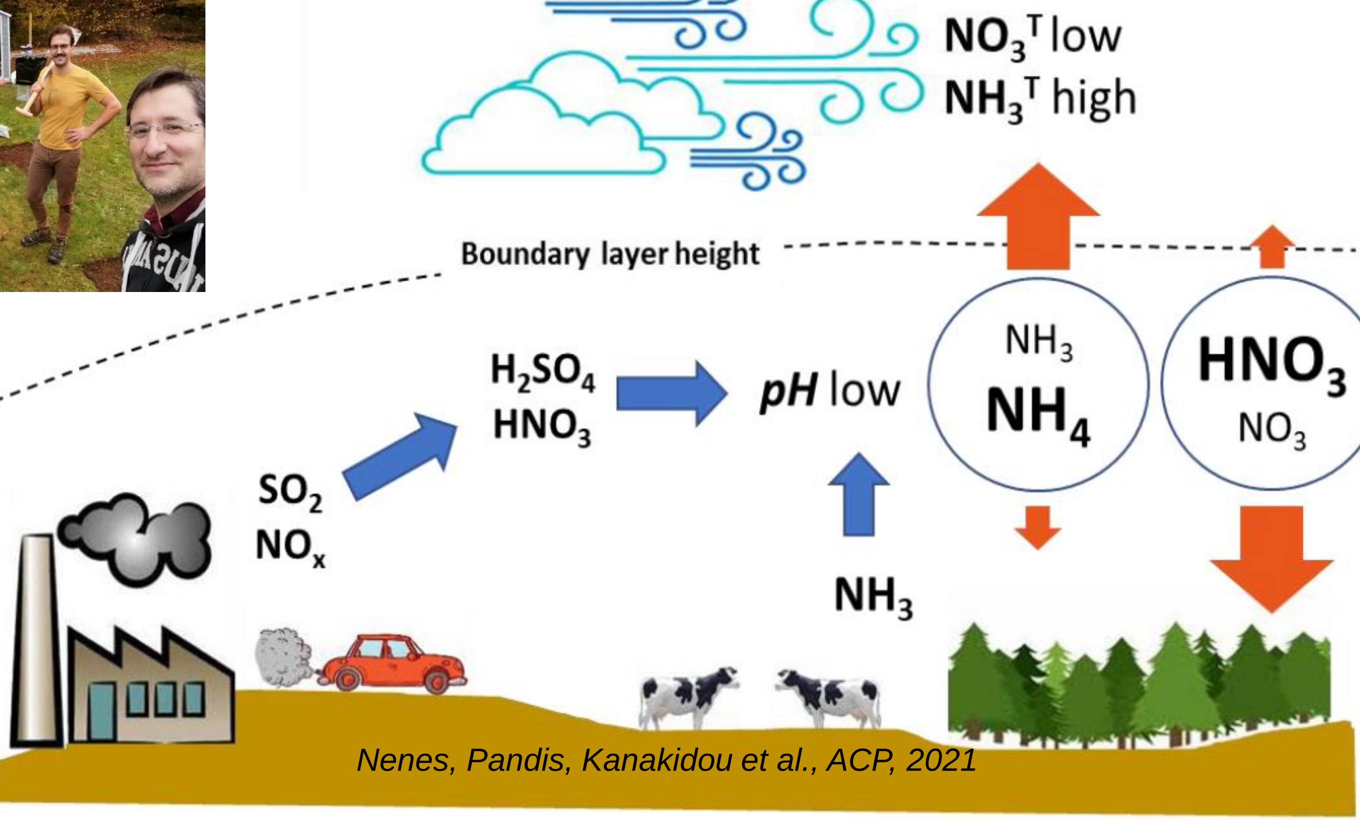
Characterization of aerosol generated from perturbed ecosystems for understanding impacts on clouds.

pH and observed partitioning of nitrate and ammonium follow "S - curves"



Consistency between predicted and observed partitioning of both species affirms that predicted *acidity levels with models are reasonable*.

Because of its effect on partitioning, acidity impacts even dry nitrogen deposition – impacting ecosystems



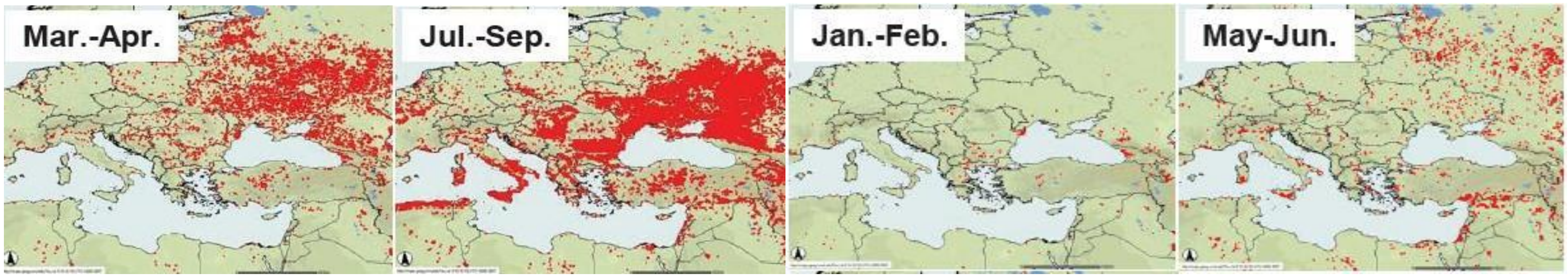
Nenes, Pandis, Kanakidou et al., ACP, 2021

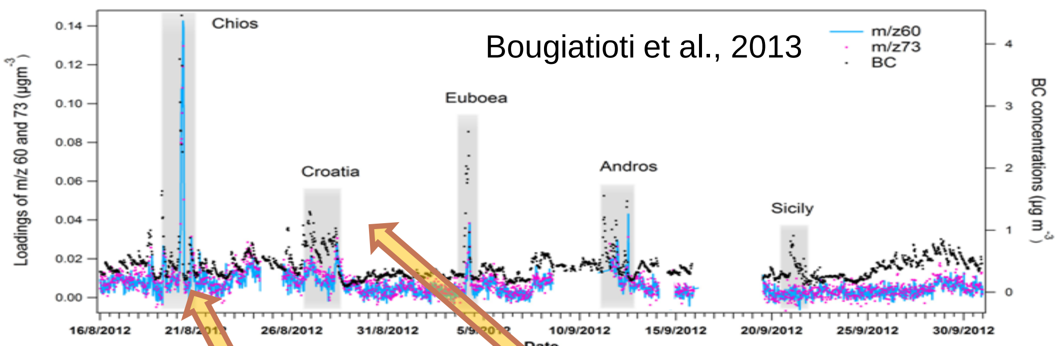
We are now exploring how these deposition pattern changes affect plant growth (ReCLEAN joint initiative lead by our lab)

Other current exciting areas of research

Biomass Burning: a major aerosol source of great influence for our region

BB smoke is always present in the Eastern Mediterranean.

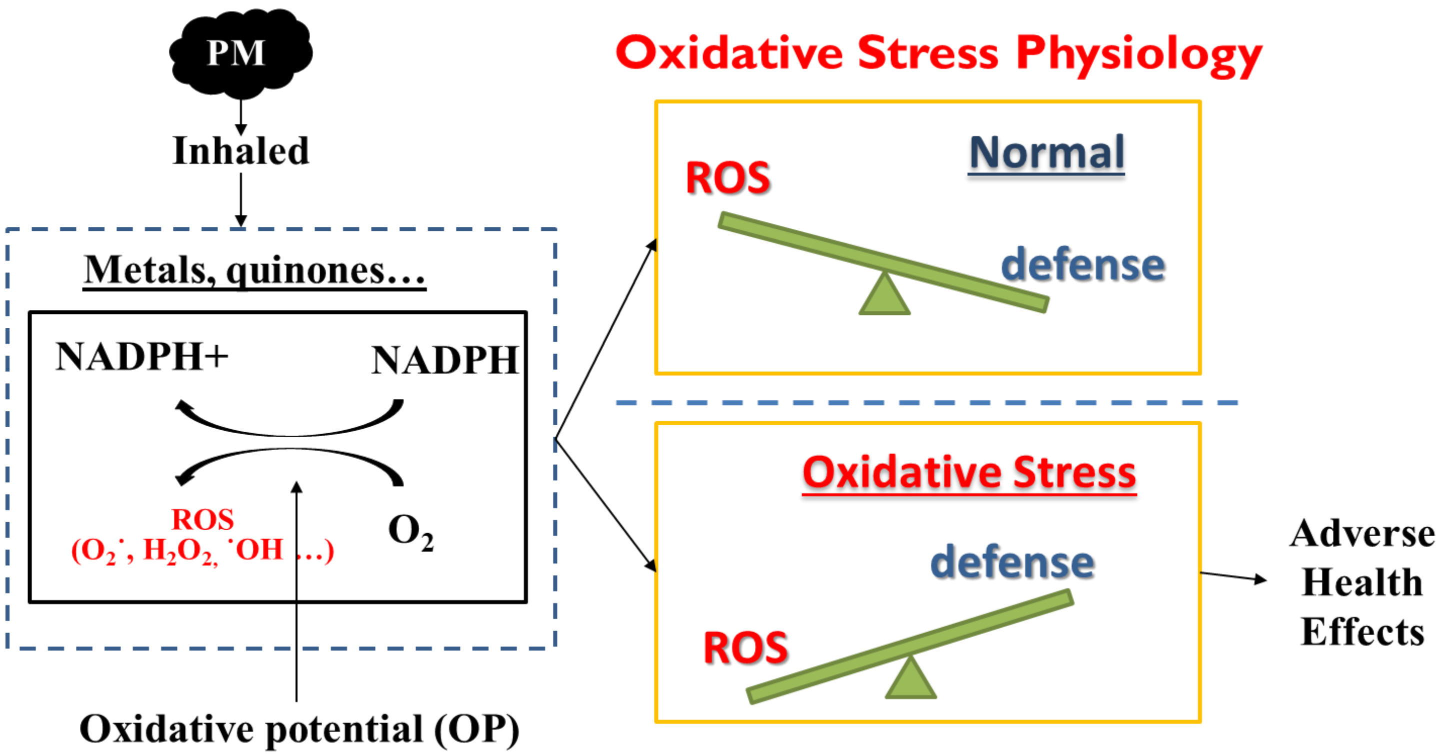




BB influence "phases":

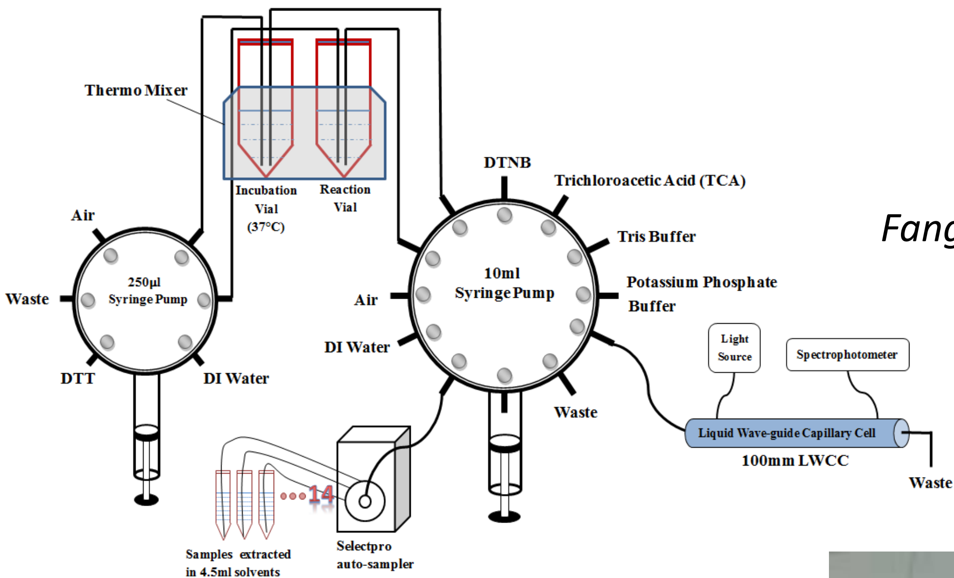
- *Summer/early fall*: wildfire smoke from isolated events that age 0 - 3 days before reaching Greece
- *Winter/early spring:* Fresh BB from domestic burning in urban areas (Athens, Ioannina, etc.).
- Both constitute unique "natural settings" for studying BB aerosol over a range of ages.

Biomass Burning: Health impacts

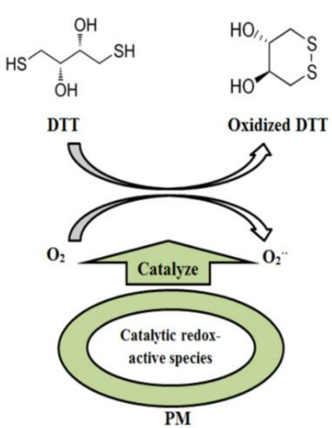


DTT assay	AA assay
chemical surrogate to biological antioxidant	physiological antioxidant in lung lining fluid
$DTT + O_2 + H^+ \xrightarrow[\text{pH=7.4, T=37°C}]{\text{PM}} DTT_{ox} + H_2O_2$ [Cho et al., 2005]	$AA + 2\,O_2 \xrightarrow[\text{pH=7.4, T=37°C}]{\text{PM}} AA_{ox} + 2\,O_2^{\cdot}$ [Ayres et al., 2008]

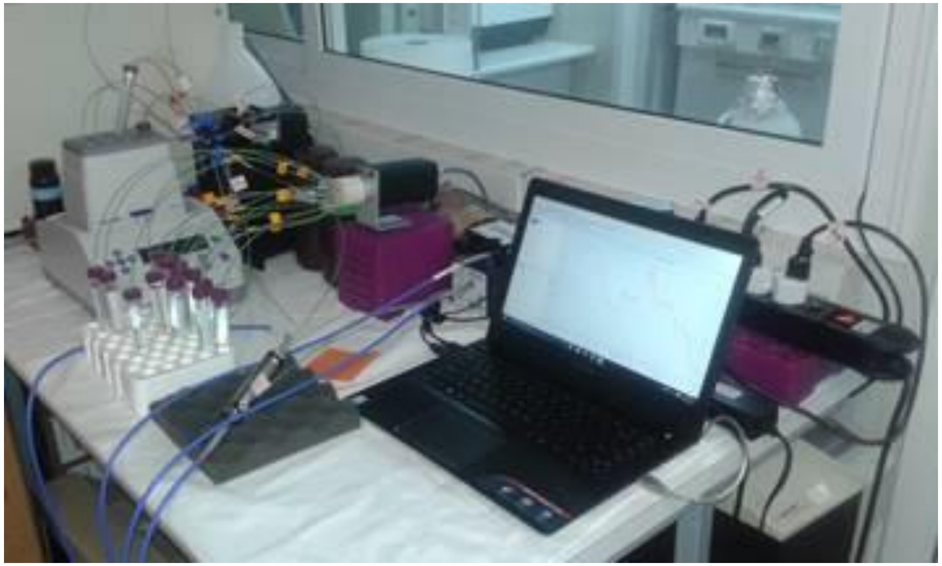
Dithiothreitol (DTT) Assay – An abiotic assay of Oxidative Potential



Fang et al. Atmos. Meas. Tech., 2014

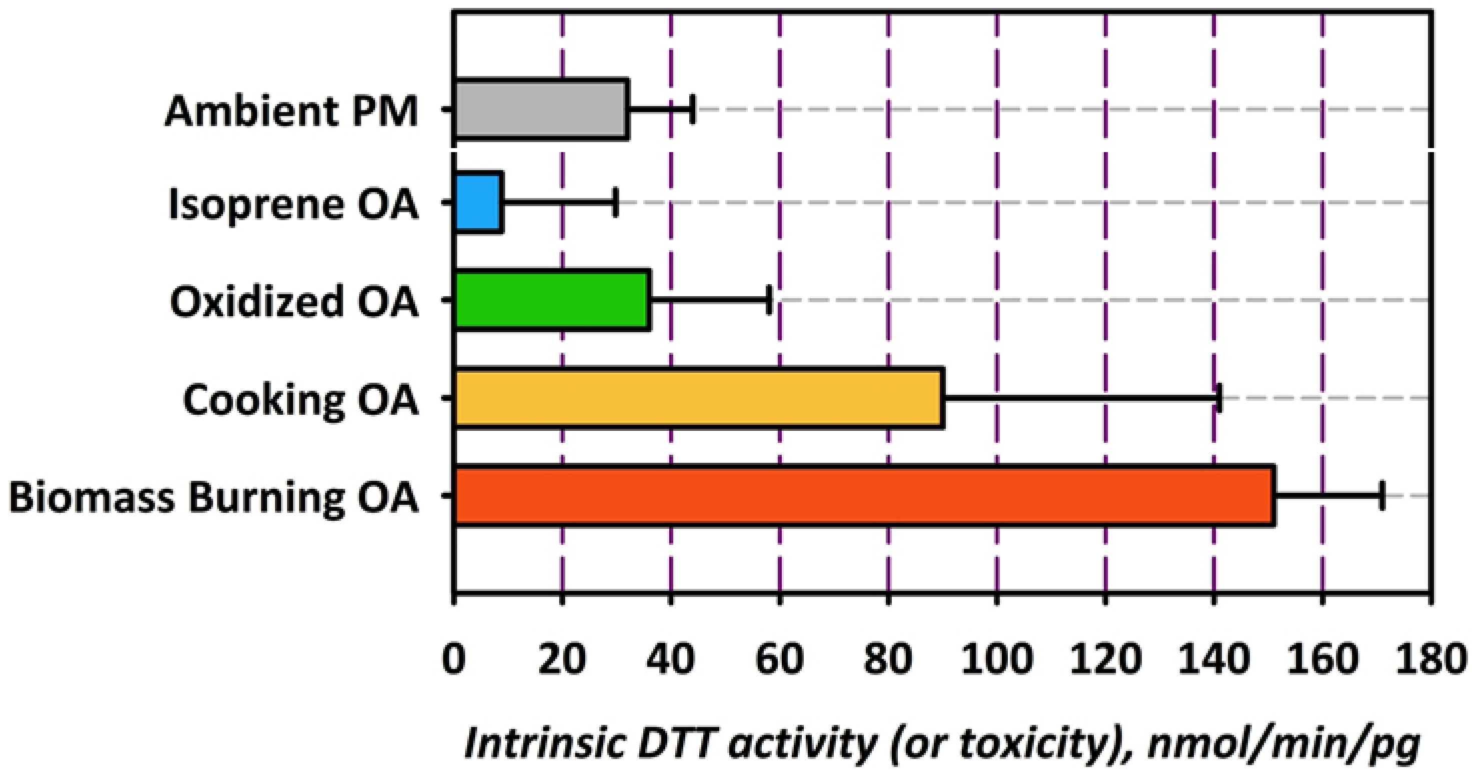


DTT Assay at CSTACC-FORTH, Greece



Intrinsic Potential of OAs to generate ROS

Verma et al., (2017).



- **Highest Toxicity for BBOA (and Cooking OA)**
- Very low toxicity for Isoprene Organic Aerosol (from trees)
- **How do these toxicities evolve as BB ages?**

ERC CoG PyroTRACH: identify smoke particles and their impacts from emission to deposition

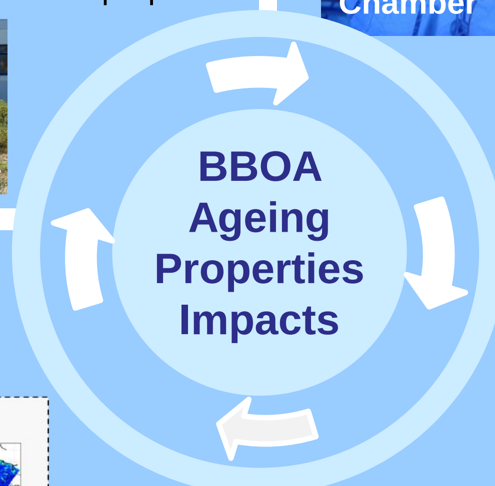
In-situ sampling & Processing

- Highly populated urban area with fresh BB emissions.
- Remote site exposed to BB plumes 0-3 days old.
- Age *in-situ* BB aerosol in portable environ.chamber
- Characterize aerosol properties

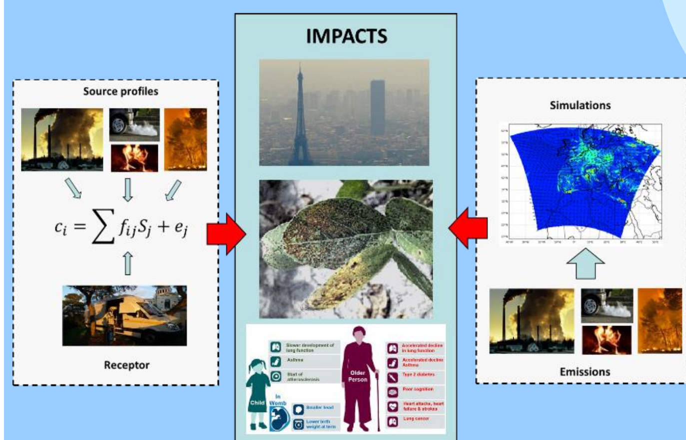
Lab Generation & Processing

- Generate fresh smoke from a variety of BB types.
- Age aerosol in the ICE-HT/FORTH environmental chamber for characteristic oxidation pathways and atmospheric conditions.
- Characterize aerosol properties

- Lab data used for unraveling ambient data.
- Focus on decay of ROS/BrC and stability of chemical markers.



Impacts & Implications



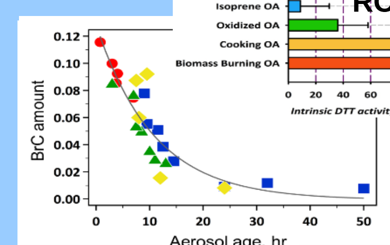
Attribution & Lifecycle

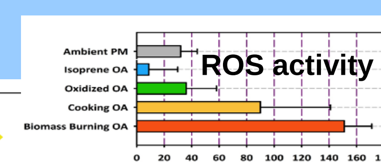
Impacts on
- Climate
- Air quality

Parameterization

- Determine optical parameters for BrC.
- Intrinsic ROS activity for each BBOA type
- Volatility distributions for BrC, ROS.
- Factor analysis for BBOA contribution to OA.

ROS/BrC





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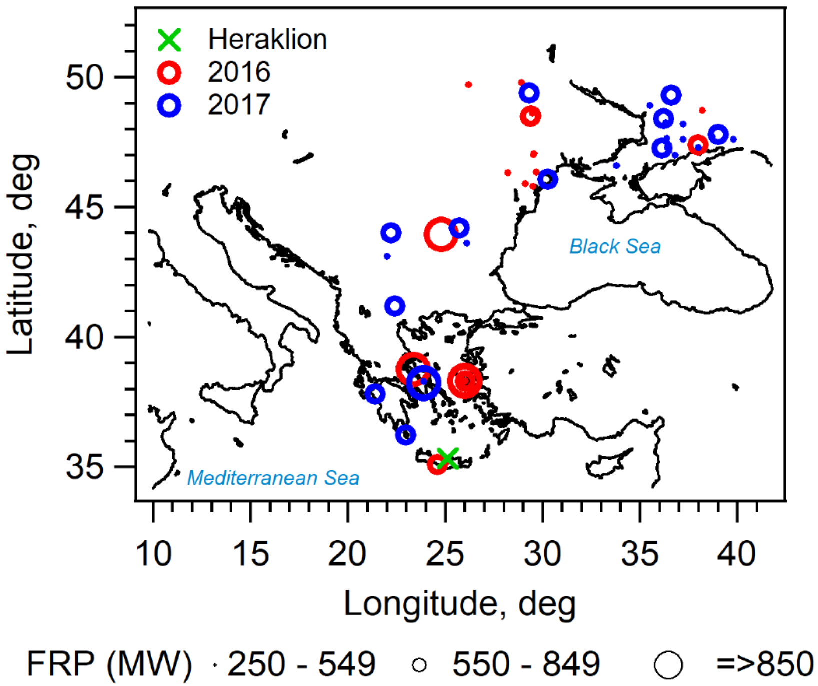
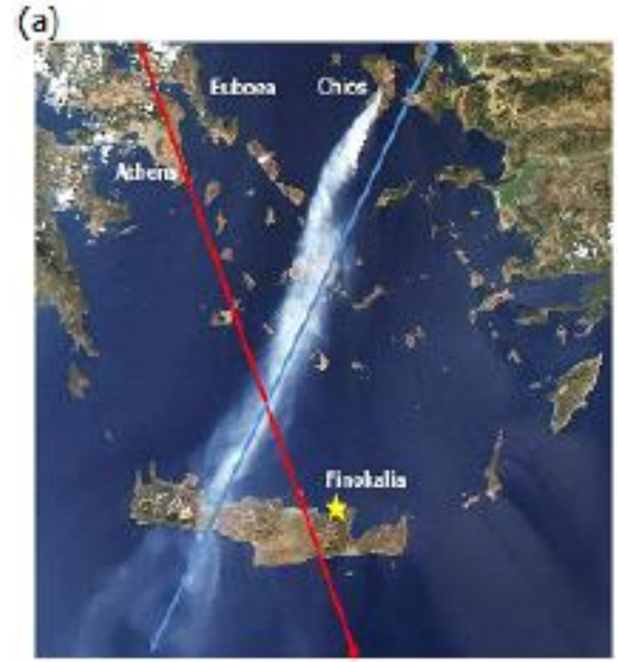


Fig.1: Locations and sizes of relevant fire events in 2016 (red) and 2017 (blue), as detected by MODIS.



Apply now to ambient samples:

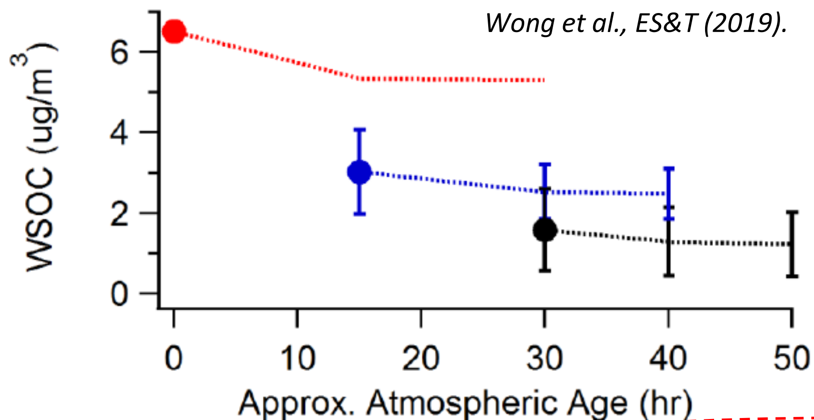
Filters collected at E. Mediterranean site (Finoka
Crete) with BB influence

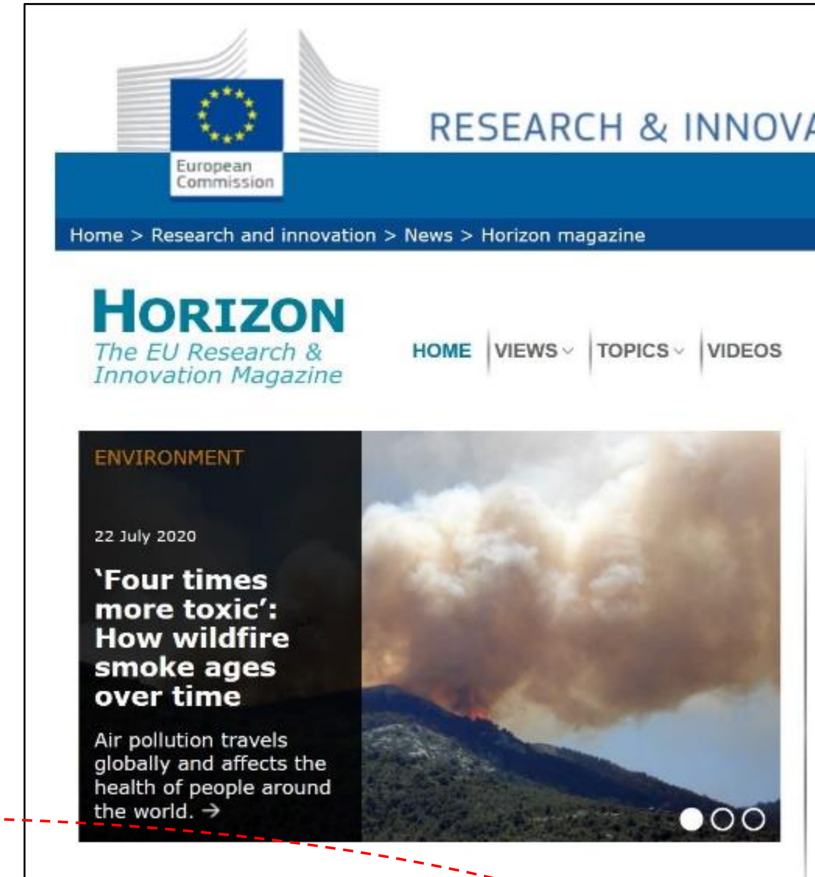
Further UVA Light Exposure for Crete Filters (15 and 30 hours)

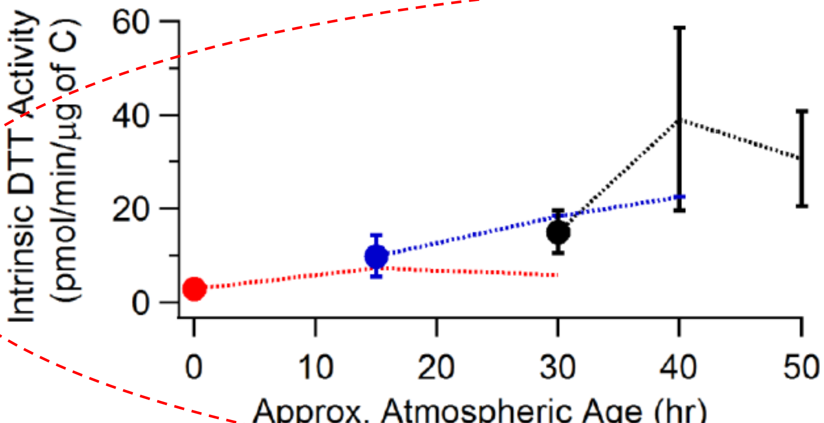
("Fresh", "Intermediate", and "More Aged" Samples – just WS components)

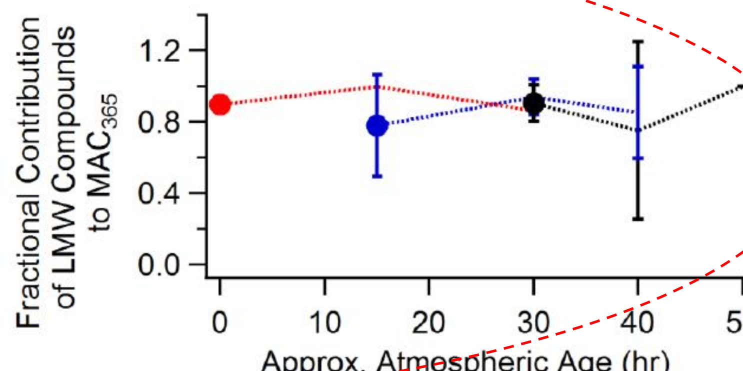
Analysis: WSOC, WS-DTT, Bulk and Size Separated BrC

Wong et al., ES&T (2019).









As smoke ages: It becomes more TOXIC and LESS Brown overall. The large molecules however REMAIN.

BB smoke transforms very quicky at nighttime (in urban centers)

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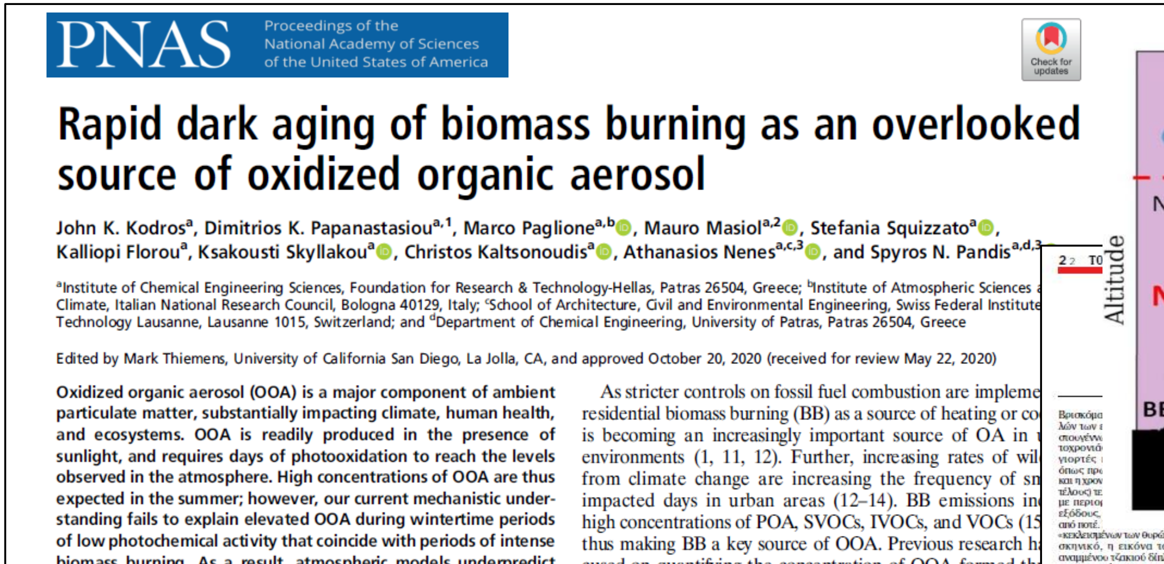

PNAS Proceedings of the National Academy of Sciences of the United States of America

Check for updates

Rapid dark aging of biomass burning as an overlooked source of oxidized organic aerosol

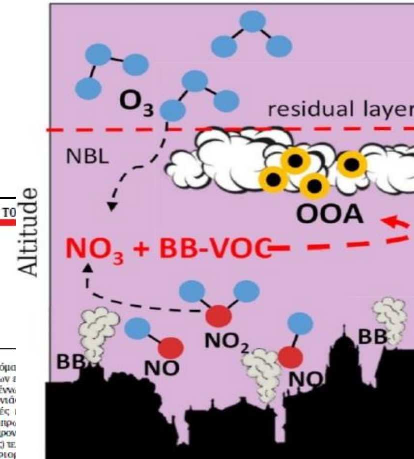
John K. Kodros[a], Dimitrios K. Papanastasiou[a,1], Marco Paglione[a,b], Mauro Masiol[a,2], Stefania Squizzato[a], Kalliopi Florou[a], Ksakousti Skyllakou[a], Christos Kaltsonoudis[a], Athanasios Nenes[a,c,3], and Spyros N. Pandis[a,d,3]

[a]Institute of Chemical Engineering Sciences, Foundation for Research & Technology-Hellas, Patras 26504, Greece; [b]Institute of Atmospheric Sciences a… Climate, Italian National Research Council, Bologna 40129, Italy; [c]School of Architecture, Civil and Environmental Engineering, Swiss Federal Institute… Technology Lausanne, Lausanne 1015, Switzerland; and [d]Department of Chemical Engineering, University of Patras, Patras 26504, Greece

Edited by Mark Thiemens, University of California San Diego, La Jolla, CA, and approved October 20, 2020 (received for review May 22, 2020)

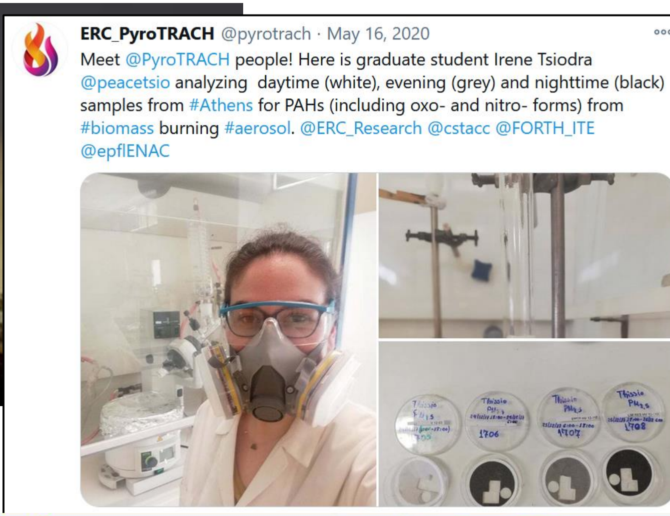
Oxidized organic aerosol (OOA) is a major component of ambient particulate matter, substantially impacting climate, human health, and ecosystems. OOA is readily produced in the presence of sunlight, and requires days of photooxidation to reach the levels observed in the atmosphere. High concentrations of OOA are thus expected in the summer; however, our current mechanistic understanding fails to explain elevated OOA during wintertime periods of low photochemical activity that coincide with periods of intense biomass burning. As a result, atmospheric models underpredict

As stricter controls on fossil fuel combustion are impleme… residential biomass burning (BB) as a source of heating or co… is becoming an increasingly important source of OA in … environments (1, 11, 12). Further, increasing rates of wil… from climate change are increasing the frequency of sm… impacted days in urban areas (12–14). BB emissions in… high concentrations of POA, SVOCs, IVOCs, and VOCs (15… thus making BB a key source of OOA. Previous research h…



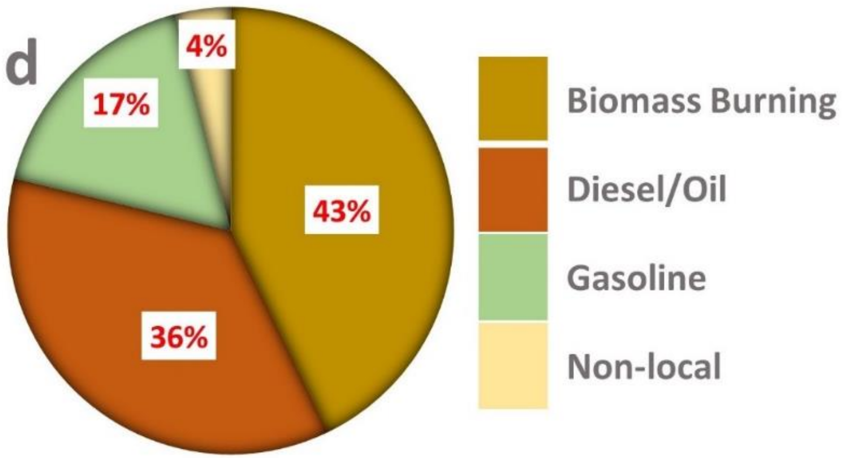
- New chemistry rapidly changes BB smoke at night (surprise).
- Inclusion in models explains large biases.
- *Important impacts* on the BB toxicity as it ages.
- Reshapes our understanding on how BB evolves over time, especially in urban centers and populated regions.

PAHs from BB during wintertime biomass burning episodes


ERC_PyroTRACH @pyrotrach · May 16, 2020

Meet @PyroTRACH people! Here is graduate student Irene Tsiodra @peacetsio analyzing daytime (white), evening (grey) and nighttime (black) samples from #Athens for PAHs (including oxo- and nitro- forms) from #biomass burning #aerosol. @ERC_Research @cstacc @FORTH_ITE @epflENAC

estimated annual carcinogen exposure for Athens

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Air pollution

This article is more than 5 months old

Wood burners cause nearly half of urban air pollution cancer risk – study

Exclusive: Wood smoke is a more important carcinogen than vehicle fumes, finds Athens analysis

Damian Carrington
Environment editor
@dpcarrington
Fri 17 Dec 2021 07.00 GMT

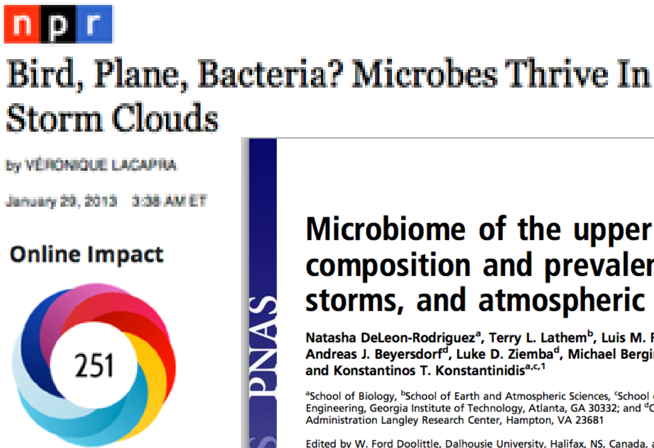
Scientists warn that as well as polluting the air outside, wood burners triple the level of harmful pollution inside homes. Photograph: Parmorama/Alamy

Wintertime exposure dominates annual exposure to carcinogens (PAHs). BB is > 50% responsible

Tsiodra, I., Grivas, G., Tavernaraki, K., Bougiatioti, A., Apostolaki, M., Paraskevopoulou, D., Gogou, A., Parinos, C., Oikonomou, K., Tsagkaraki, M., Zarmpas, P., Nenes, A., and Mihalopoulos, N.: Annual exposure to PAHs in urban environments linked to wintertime wood-burning episodes, Atmos. Chem. Phys., 2021.

Other current exciting areas of research

Bioaerosol research: Quantifying airborne microbes, their interactions and impacts



npr

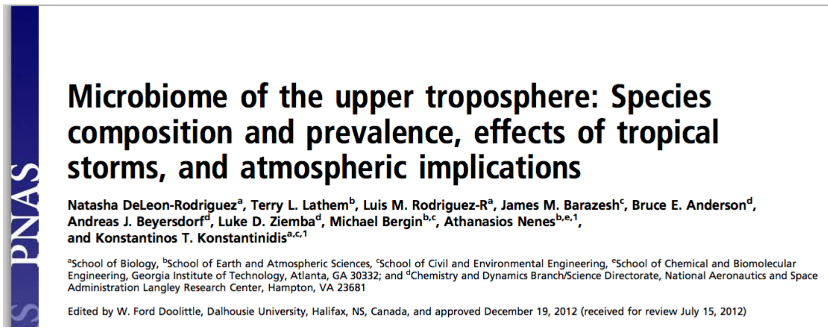
Bird, Plane, Bacteria? Microbes Thrive In Storm Clouds

by VÉRONIQUE LACAPRA

January 29, 2013 3:38 AM ET

Online Impact

251



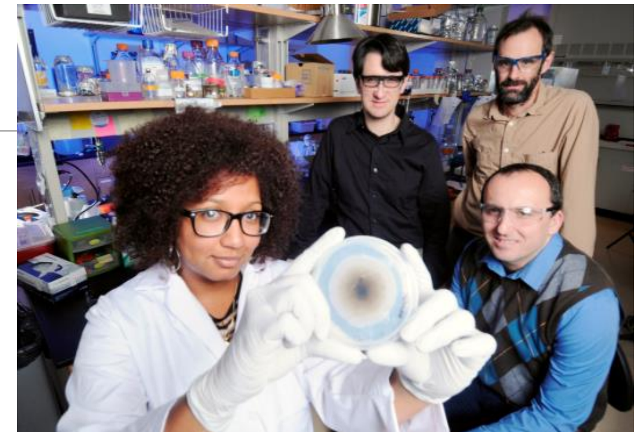
PNAS

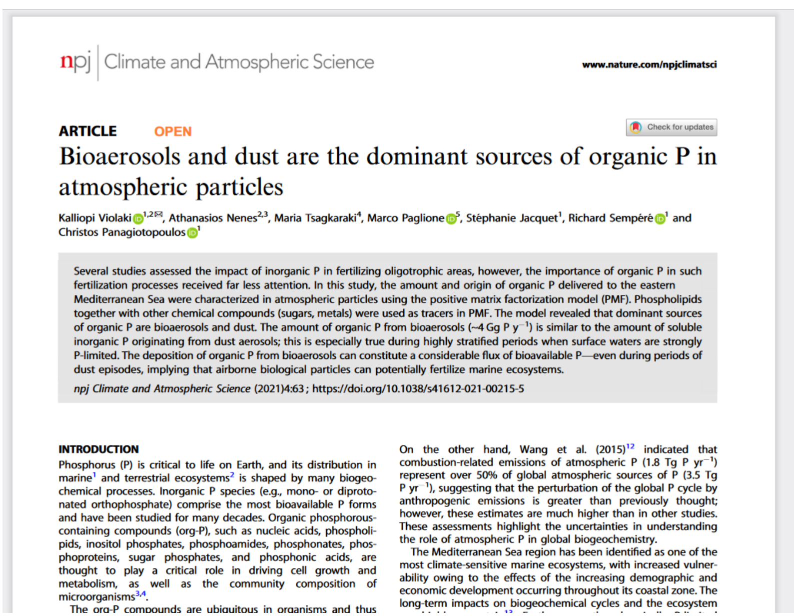
Microbiome of the upper troposphere: Species composition and prevalence, effects of tropical storms, and atmospheric implications

Natasha DeLeon-Rodriguez[a], Terry L. Lathem[b], Luis M. Rodriguez-R[a], James M. Barazesh[c], Bruce E. Anderson[d], Andreas J. Beyersdorf[d], Luke D. Ziemba[d], Michael Bergin[b,c], Athanasios Nenes[b,e,1], and Konstantinos T. Konstantinidis[a,c,1]

[a]School of Biology, [b]School of Earth and Atmospheric Sciences, [c]School of Civil and Environmental Engineering, [e]School of Chemical and Biomolecular Engineering, Georgia Institute of Technology, Atlanta, GA 30332; and [d]Chemistry and Dynamics Branch/Science Directorate, National Aeronautics and Space Administration Langley Research Center, Hampton, VA 23681

Edited by W. Ford Doolittle, Dalhousie University, Halifax, NS, Canada, and approved December 19, 2012 (received for review July 15, 2012)





npj | Climate and Atmospheric Science www.nature.com/npjclimatsci

ARTICLE OPEN

Check for updates

Bioaerosols and dust are the dominant sources of organic P in atmospheric particles

Kalliopi Violaki[1,2✉], Athanasios Nenes[2,3], Maria Tsagkaraki[4], Marco Paglione[5], Stéphanie Jacquet[1], Richard Sempéré[1] and Christos Panagiotopoulos[1]

Several studies assessed the impact of inorganic P in fertilizing oligotrophic areas, however, the importance of organic P in such fertilization processes received far less attention. In this study, the amount and origin of organic P delivered to the eastern Mediterranean Sea were characterized in atmospheric particles using the positive matrix factorization model (PMF). Phospholipids together with other chemical compounds (sugars, metals) were used as tracers in PMF. The model revealed that dominant sources of organic P are bioaerosols and dust. The amount of organic P from bioaerosols (~4 Gg P y^{-1}) is similar to the amount of soluble inorganic P originating from dust aerosols; this is especially true during highly stratified periods when surface waters are strongly P-limited. The deposition of organic P from bioaerosols can constitute a considerable flux of bioavailable P—even during periods of dust episodes, implying that airborne biological particles can potentially fertilize marine ecosystems.

npj Climate and Atmospheric Science (2021)4:63 ; https://doi.org/10.1038/s41612-021-00215-5

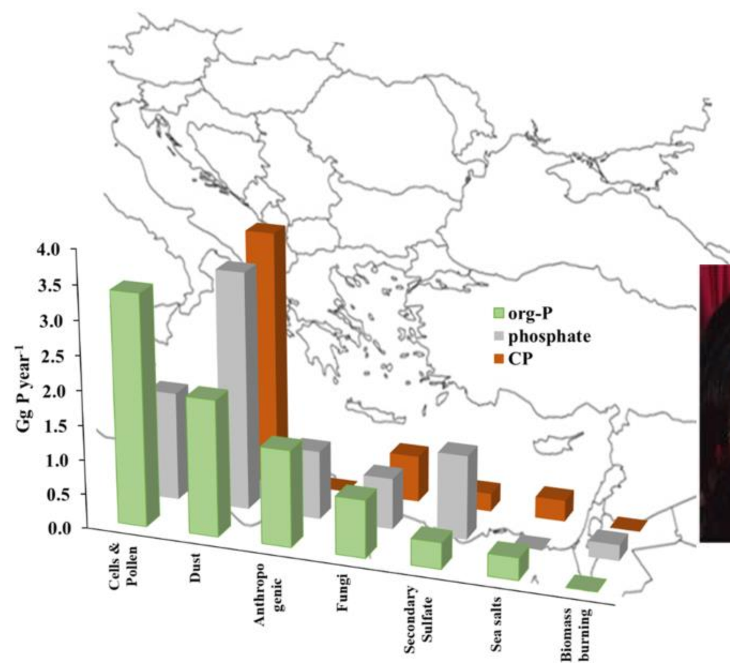
INTRODUCTION

Phosphorus (P) is critical to life on Earth, and its distribution in marine[1] and terrestrial ecosystems[2] is shaped by many biogeochemical processes. Inorganic P species (e.g., mono- or diprotonated orthophosphate) comprise the most bioavailable P forms and have been studied for many decades. Organic phosphorous-containing compounds (org-P), such as nucleic acids, phospholipids, inositol phosphates, phosphoamides, phosphonates, phosphoproteins, sugar phosphates, and phosphonic acids, are thought to play a critical role in driving cell growth and metabolism, as well as the community composition of microorganisms[3,4].

The org-P compounds are ubiquitous in organisms and thus

On the other hand, Wang et al. (2015)[12] indicated that combustion-related emissions of atmospheric P (1.8 Tg P yr^{-1}) represent over 50% of global atmospheric sources of P (3.5 Tg P yr^{-1}), suggesting that the perturbation of the global P cycle by anthropogenic emissions is greater than previously thought; however, these estimates are much higher than in other studies. These assessments highlight the uncertainties in understanding the role of atmospheric P in global biogeochemistry.

The Mediterranean Sea region has been identified as one of the most climate-sensitive marine ecosystems, with increased vulnerability owing to the effects of the increasing demographic and economic development occurring throughout its coastal zone. The long-term impacts on biogeochemical cycles and the ecosystem

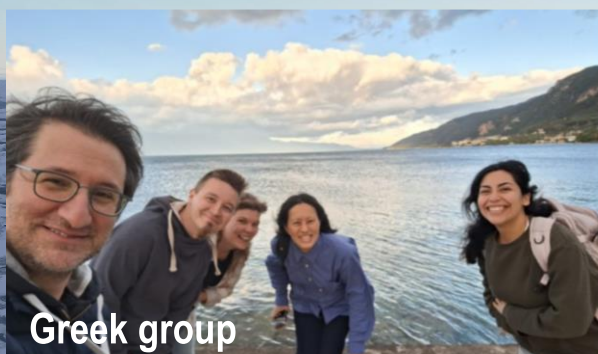


EPFL

FORTH C·STACC Center for the Study of Air Quality & Climate Change

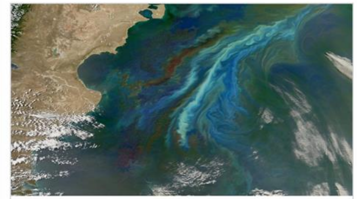
LAPI – Athanasios (Thanos) Nenes

Laboratory of atmospheric processes and their impacts



http://lapi.epfl.ch

http://cstacc.iceht.forth.gr



Biogeochemical Cycles

Aerosol – Cloud – Climate Interactions

Air Quality and Health

Aerosol Chemistry and Impacts

iMIRACLI

CleanCloud

FORCeS

ReCLEAN

GREEN FJORD

PIPC Air

erc European Research Council Established by the European Commission

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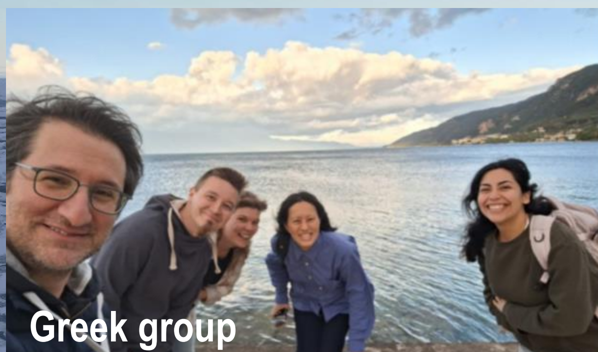

http://lapi.epfl.ch

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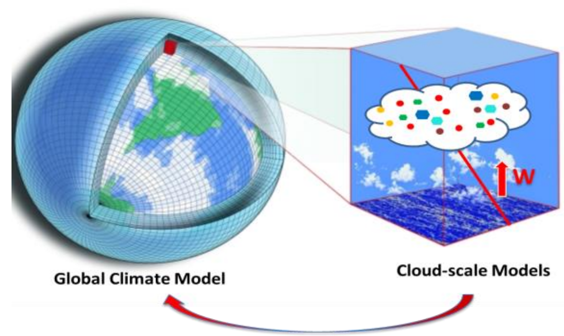
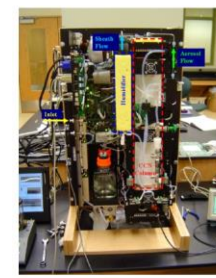
Field and Laboratory Observations

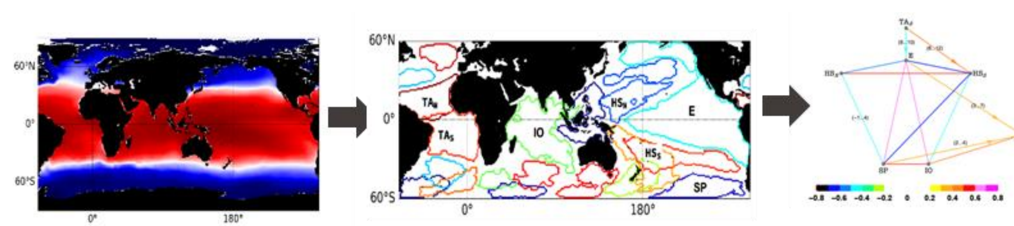
Modeling



Instrumentation



Cloud Condensation Nuclei Counter, US Patent 7,656,510



Data science

Thank you!!

For more information, please visit
http://lapi.epfl.ch - @LAPI_epfl
And don't forget to visit the LAPI video channel at http://mediaspace.epfl.ch !