Biogenic aerosols and their interactions with climate

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1. **OVERVIEW OF BIOGENIC AEROSOL**
   - **Definition and categories**
   - **Why important?**

2. **FORMATION OF SECONDARY BIOGENIC AEROSOLS AND EFFECT OF CLIMATE CHANGE**
   - **Precursor emission and transport**
   - **Chemical reaction and formation of BSOA, and role of anthrop. Emissions**

3. **EFFECT OF BIOGENIC AEROSOL ON CLIMATE**

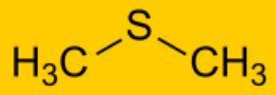
1 OVERVIEW OF BIOGENIC AEROSOL

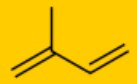
- **Definition and categories**
- **Why important?**

BIOGENIC AEROSOL

Aerosols whose matters are from biogenic sources, usually plants or microbe.

- **Primary biogenic aerosol** ⟶ Coarse particle
  - **Tiny parts from plants or animals**
  - **Leaf abrasions, dead microbe**
  - **Bacteria, pollen, virus => health effect**
  - **Can serve as CCN , IN (Andraud, 2011)**
- **Secondary biogenic aerosol** ⟶ Fine particle
  - **Condensational formation from oxidation of gaseous precursor emitted by biosphere**
  - ***Ocean: Plankton ➔ DMS ➔ sulfate***
  - ***Terrestrial: Forest ➔ isoprene ➔ polymer ➔SOA***
  - **Health effect?**
  - **Direct and indirect effect**





BIOGENIC AEROSOL: WHY IMPORTANT?

- Important portion of aerosols, especially in summer of biologically active areas. (Goldstein and Galbally, 2007; Hallquist et al, 2009)

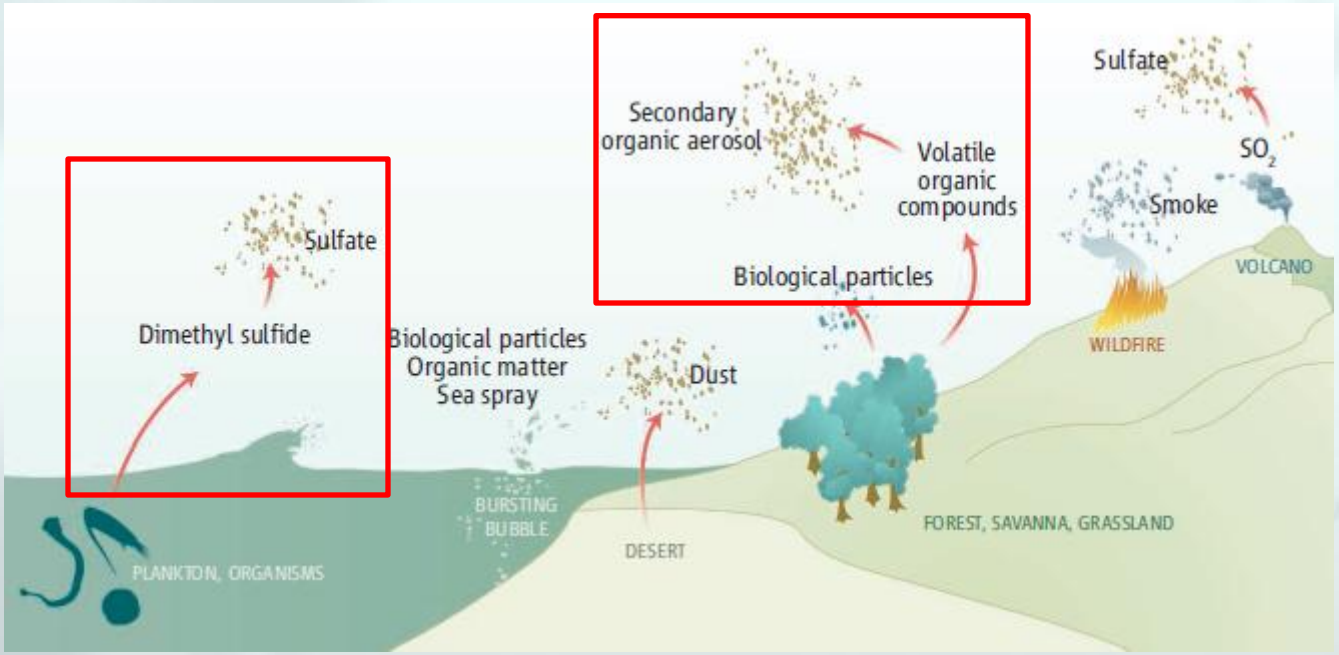
Table 1. Flux estimates (TgC/yr) for the different sources of organic aerosol based on the latest top-down approach. S1 and S2 represent two plausible scenarios, based on global constraints. See text for more details and a description of terms and abbreviations.

	Best estimate	Low limit	High limit	S1	S2	Modern OC	Fossil OC	HOA	OOA
OC Top-down estimate	150	60	240						
Primary anthropogenic	5	2	8	2	5		5	5	
Primary biomass burning	11	5	18	8	15	11		6	5
Oxidized low volatility anthropogenic	5	1	10	10	5		5		5
Oxidized low volatilty biomass burning	14	1	26	20	15	14			14
Secondary anthropogenic	10	3	17	10	15		10		10
Secondary biomass burning	17	0	34	20	20	17			17
BSOC	88	0	180	10	150	88			88
Sum	150			80	225	130 (87%)	20 (13%)	11 (7%)	139 (93%)

BIOGENIC AEROSOL: WHY IMPORTANT?

NATURAL vs. ANTHROPOGENIC:

Biogenic aerosol is an important part of naturally formed aerosols



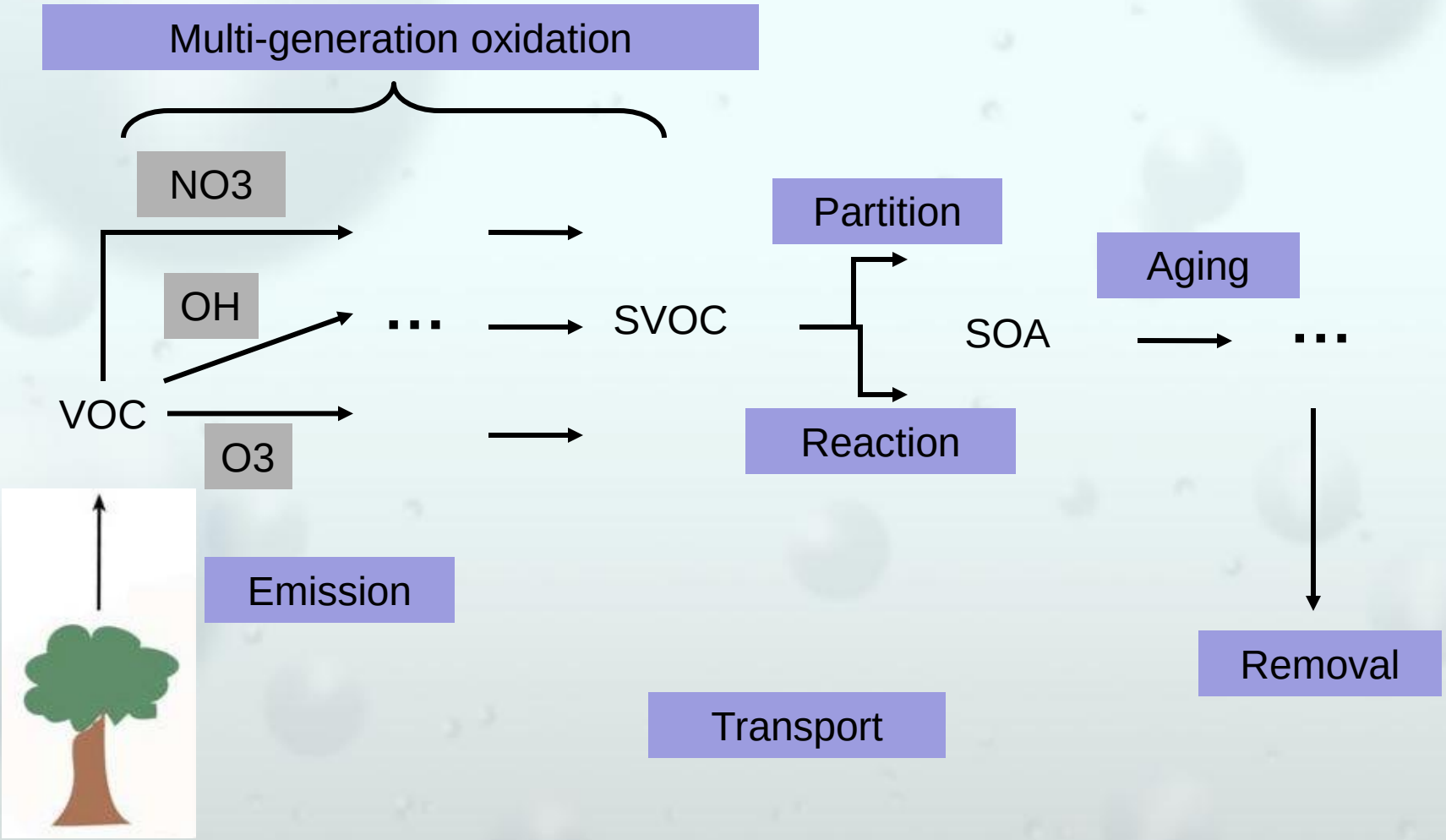
(Andreae, 2007)

! **Never that simple: interaction between biogenic precursors and anthropogenic emissions can enhance the aerosol yields**

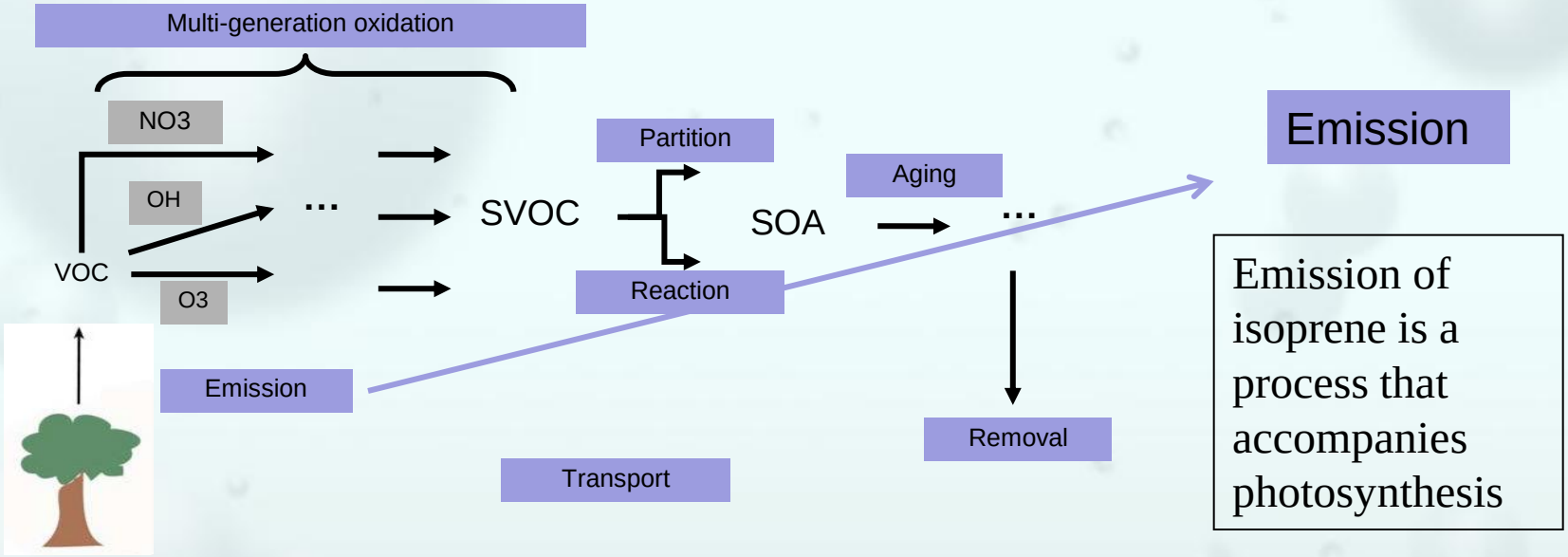
2 FORMATION OF SECONDARY BIOGENIC AEROSOLS AND EFFECT OF CLIMATE CHANGE

- Precursor emission and transport
- Chemical reaction, condensation and formation of BSOA
- Interaction with anthrop. emissions

BSOA PROCESSES



BSOA PROCESSES



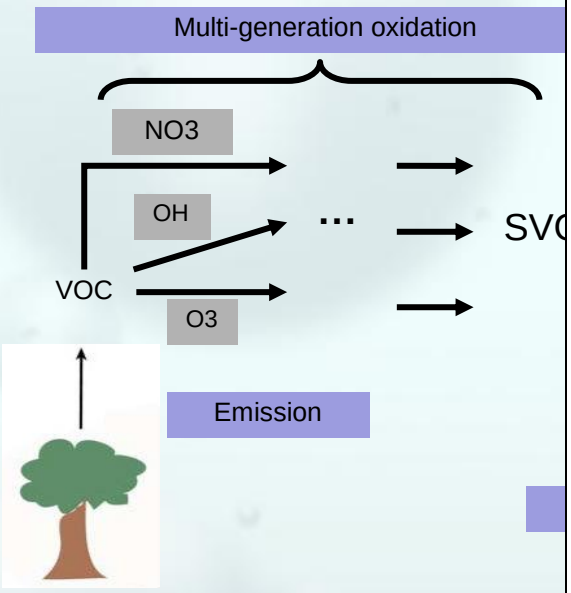
Emission of isoprene is a process that accompanies photosynthesis

Effecting factors:
1)Vegetation type, coverage, leaf area index and leaf physiology;
2)Canopy environment: solar radiation, temperature, humidity (soil moisture), chemical composition, wind, etc.

Emission inventory: 1) satellite observation. 2) laboratory. 3) in situ observation. 4) modeling: MEGAN (models of emissions of gases and aerosols from nature)

(Guenther,2006)

BSOA PROCESSES



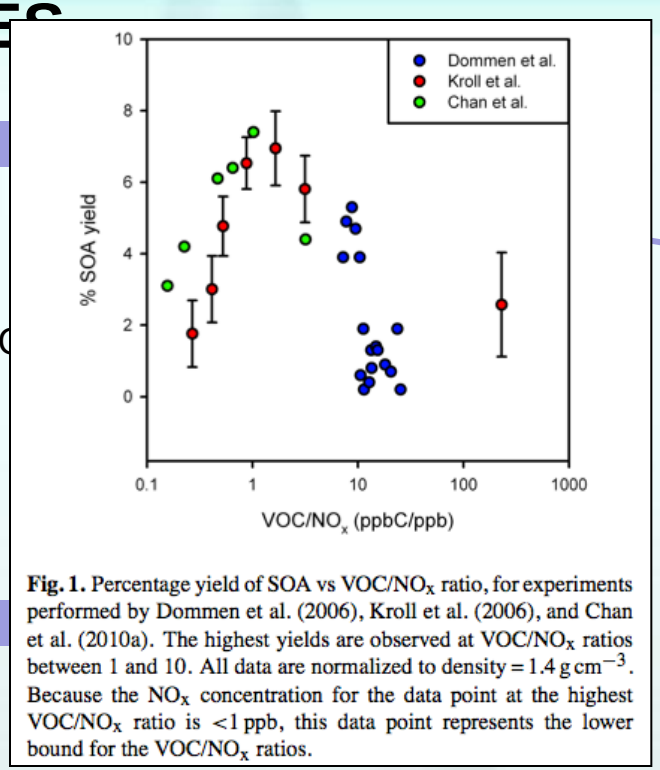


Fig. 1. Percentage yield of SOA vs VOC/NO_x ratio, for experiments performed by Dommen et al. (2006), Kroll et al. (2006), and Chan et al. (2010a). The highest yields are observed at VOC/NO_x ratios between 1 and 10. All data are normalized to density = 1.4 g cm^{-3}. Because the NO_x concentration for the data point at the highest VOC/NO_x ratio is <1 ppb, this data point represents the lower bound for the VOC/NO_x ratios.

Oxidation

- Multi-pathway
- Multi-generation
- Anthropogenic influences

Major oxidant: OH, O3, NO3

1.NO3: nighttime with NO3 (21% global SOA burden, Hoyle et al. (2007))

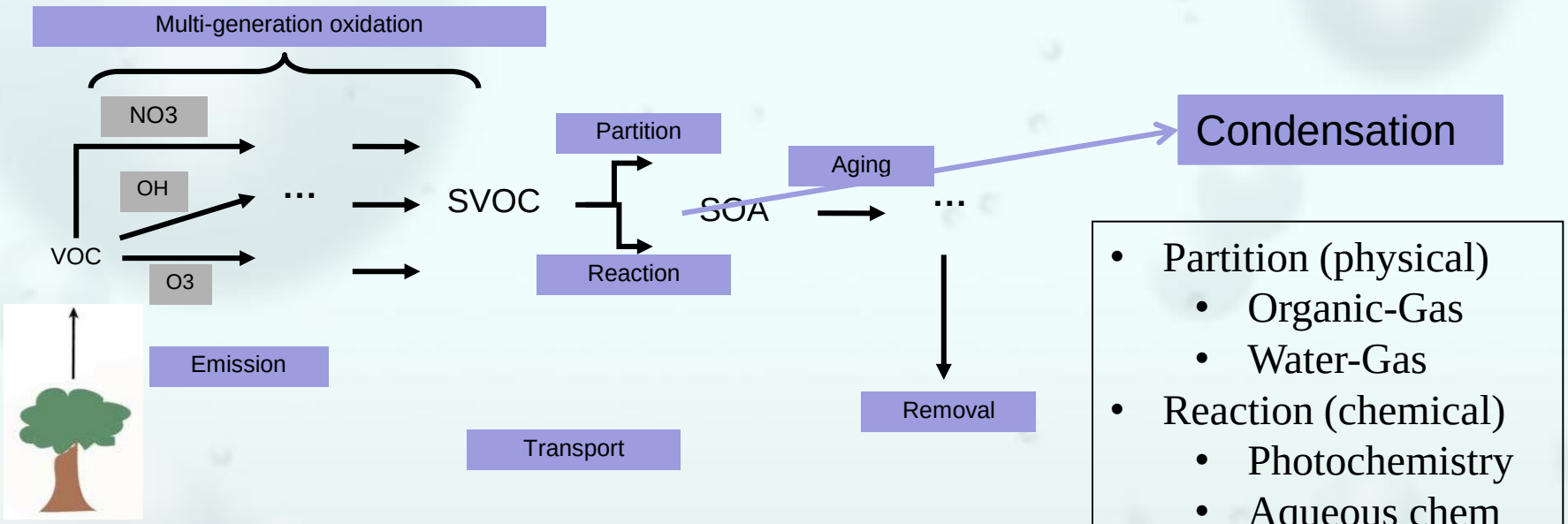
2.O3 and OH: **a)** Anthropogenic may alter conc of O3 and OH; **b)** NOx interferes with pathway. Competition between RO2+HO2 and RO2+NO. (**VOC/NOx**)

3.Different effect on different species. (e.g. monoterpene and sequiterpene)

4.New findings: RO2+NO2->MPAN (Chan,2010). (**NO2/NOx**)

Hoyle et al. (2011)

BSOA PROCESSES



- Partition (physical)
  - Organic-Gas
  - Water-Gas
- Reaction (chemical)
  - Photochemistry
  - Aqueous chem

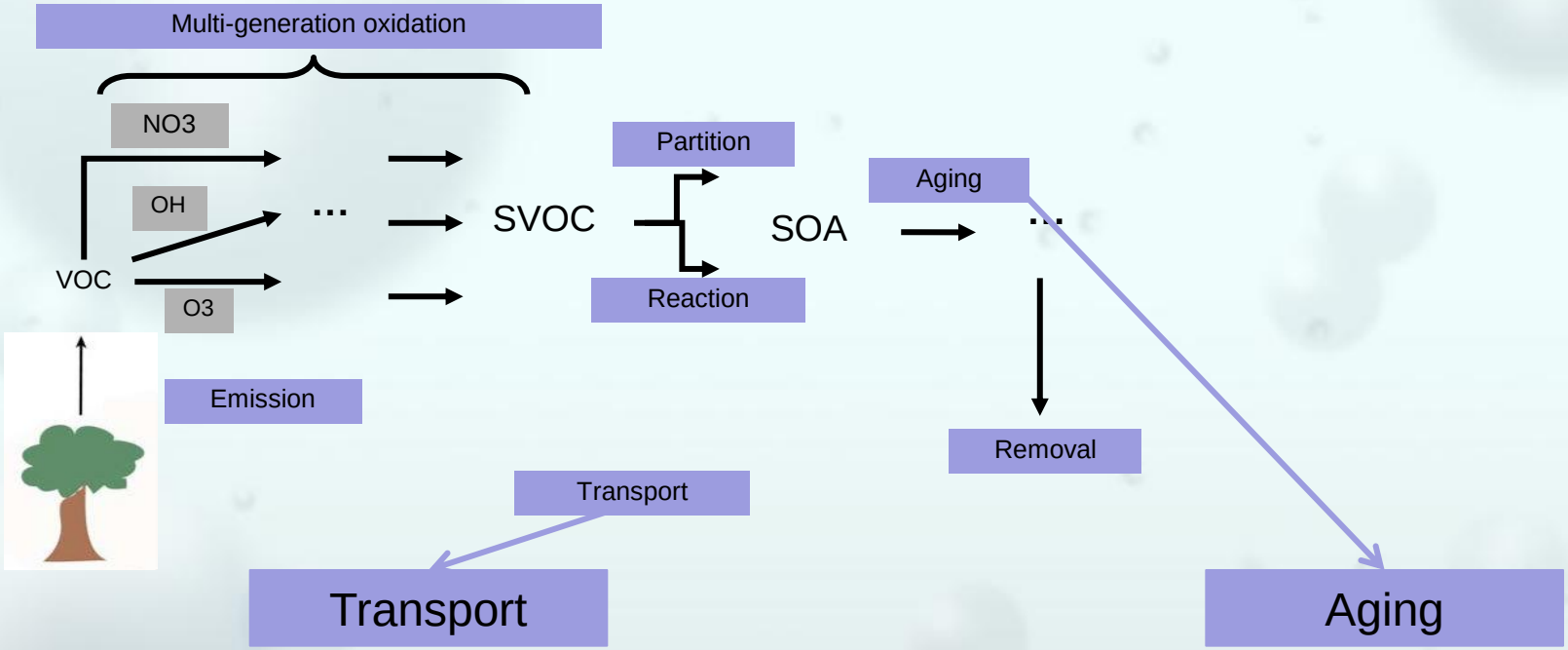
For BSOA, most SVOC condenses onto the surface of pre-existing aerosols.

- Composition and surface property of pre-existing aerosols
- Acidity of aerosols
- Mixture pattern: internal & external
- Polarity of SVOC molecules

Anthropogenic influence: sulfur aerosol is most important "seeds" over land.

Hoyle et al. (2011)

BSOA PROCESSES



Usually in above-canopy layer.
Pose problems for ground measurements.

Continue oxidation and reaction
CCN/seed
OC/EC ratio
Highly conjugated compounds
➔<u>weakly absorption</u>

(Bones, 2010)

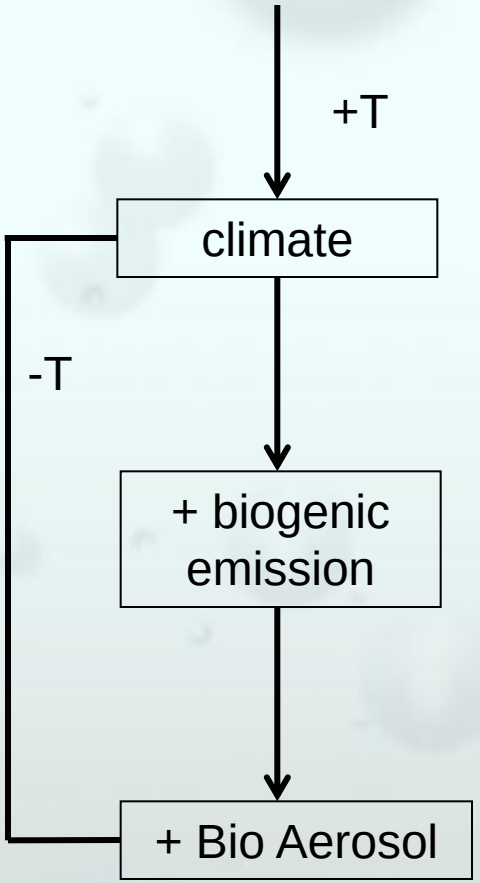
3 EFFECTS OF BIOGENIC AEROSOLS ON CLIMATE

- Direct radiative cooling
- Indirect influence on cloud formation

BIOGENIC AEROSOLS: EFFECTS ON CLIMATE

- Possibly important negative feedback
- Can be very important in a regional scale. E.g. Amazonia, south-east US
- **Direct effect**: concentration (spatial and temporal distribution), size and composition. **-3.9W/m2: S.E. US** (Goldstein, 2009)
- **Semi-direct effect**: absorptive aerosol (Bones, 2010)
- **Indirect effect (**Twomey effect): concentration, water solubility, composition, mixture property, if CCN
- Cloud sensitive to aerosol number when background low (Andreae, 2007)

- Predictions from different models vary a lot due to inability to predict SOA. Current models underestimate formation of SOA



Summary of existing questions

SOA mechanism

1. Model underestimate SOA, indicating missing sources or mechanism
2. Model underestimate OH in biogenically active areas, indicating unknown mechanisms
3. Assess aerosol levels without human interference, and how anthropogenic sources interacts with natural precursors to produce BSOA

Climate interaction

4. Distinguish the contribution of natural and anthropogenic aerosol, and on this basis, evaluate aerosol climate effect
5. How terrestrial and oceanic ecosystem respond to climate change? How this will affect BSOA source strength?

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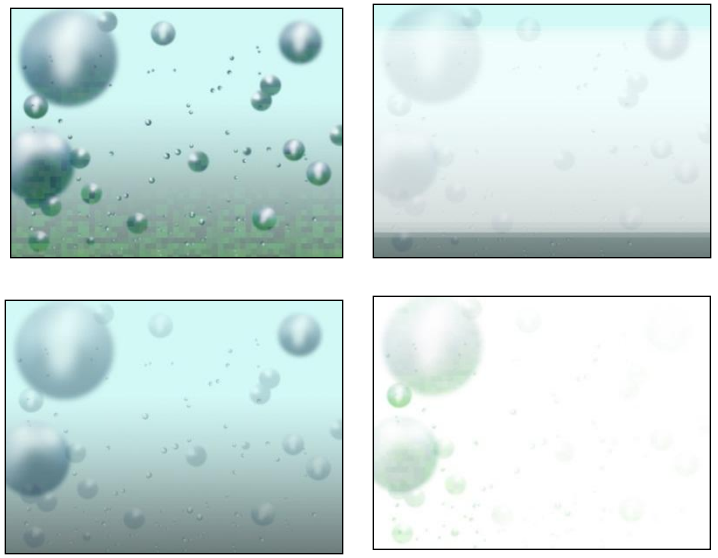

Thank you!