

# Dust – Climate Interactions

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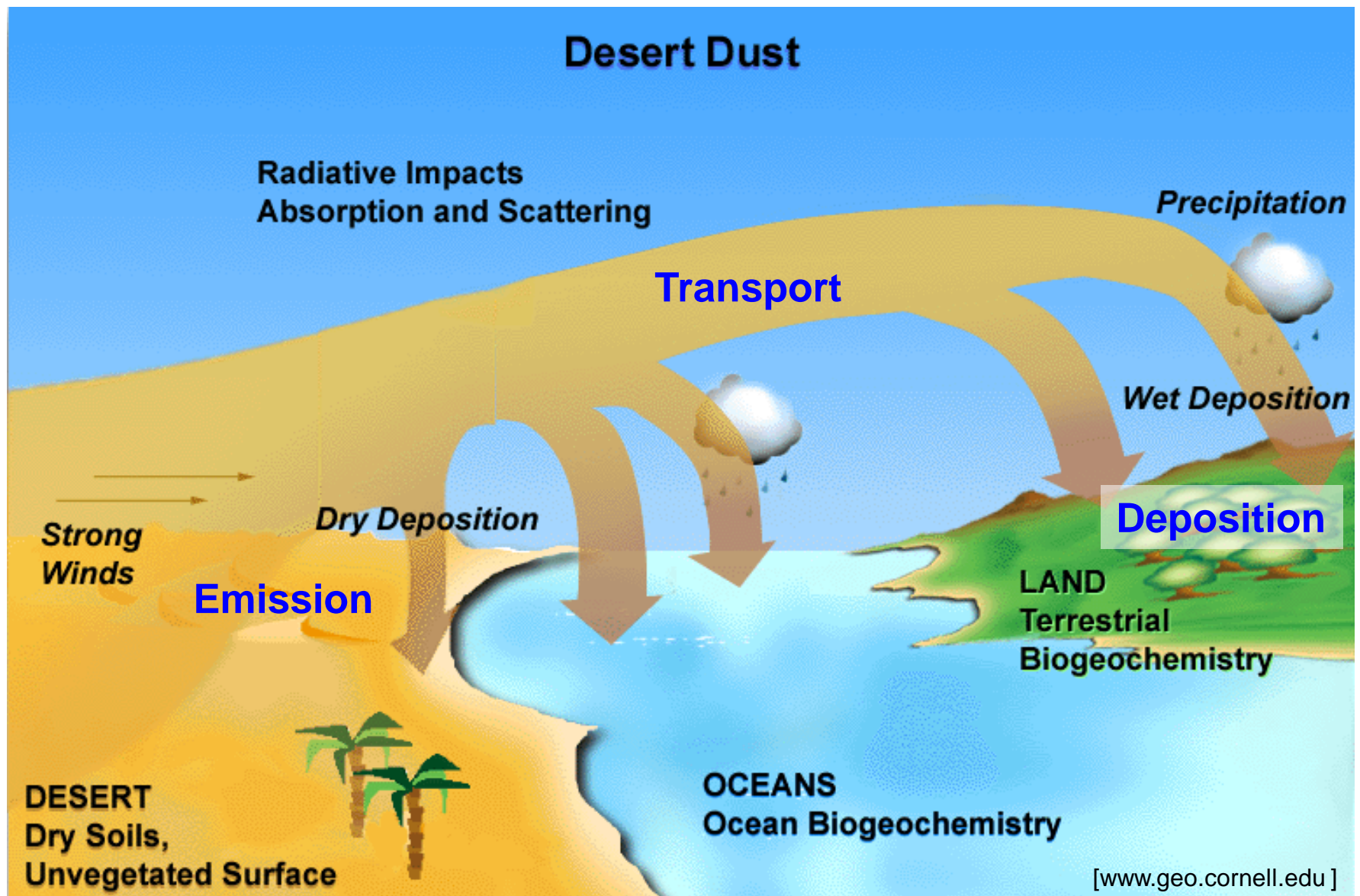
- Direct and indirect climate forcing
- Regional impacts on temperature and hydrological cycle
- Dust as micro-nutrient fertilises marine and terrestrial ecosystems
- Neutralisation of 'acid rain', atmospheric chemistry
- Transport medium for bacteria, fungi, and pesticides
  - 'Coral bleaching'
  - Human health
- Economy
  - Reduced visibility (aviation, ground transport, solar energy, ...)
  - Limited reliability of electronic devices

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# Atmospheric Dust Cycle



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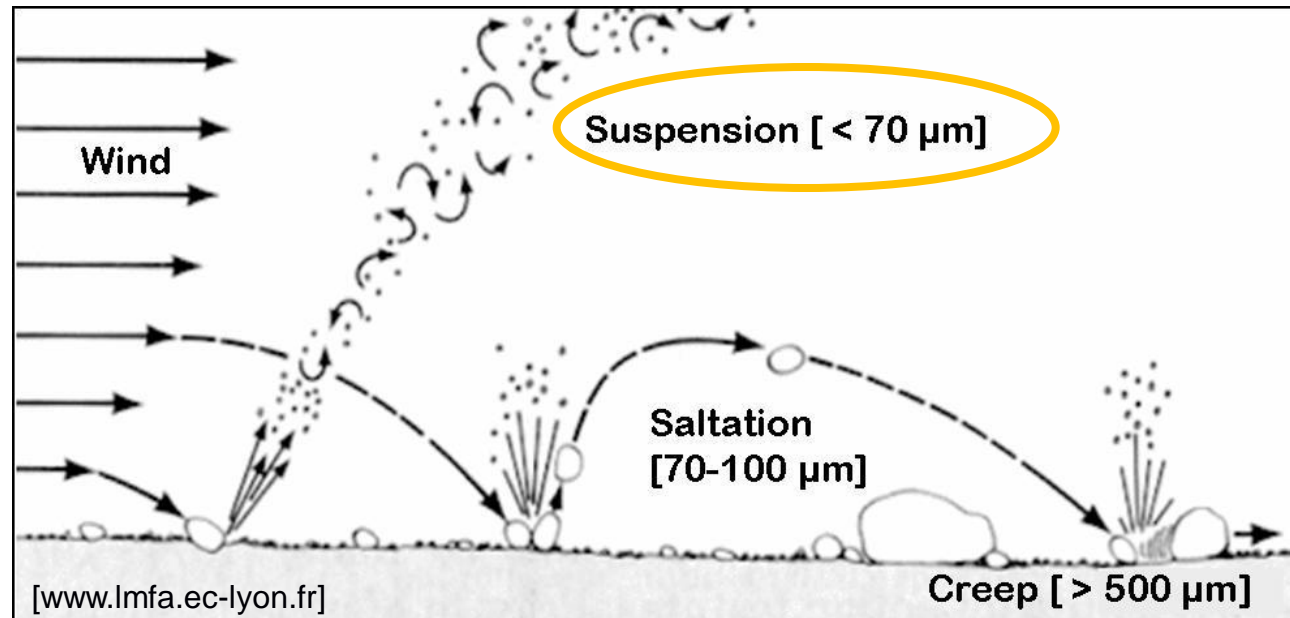
# Dust – Climate Interactions



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Dust in suspension,  
Mauritania

Dust Emission

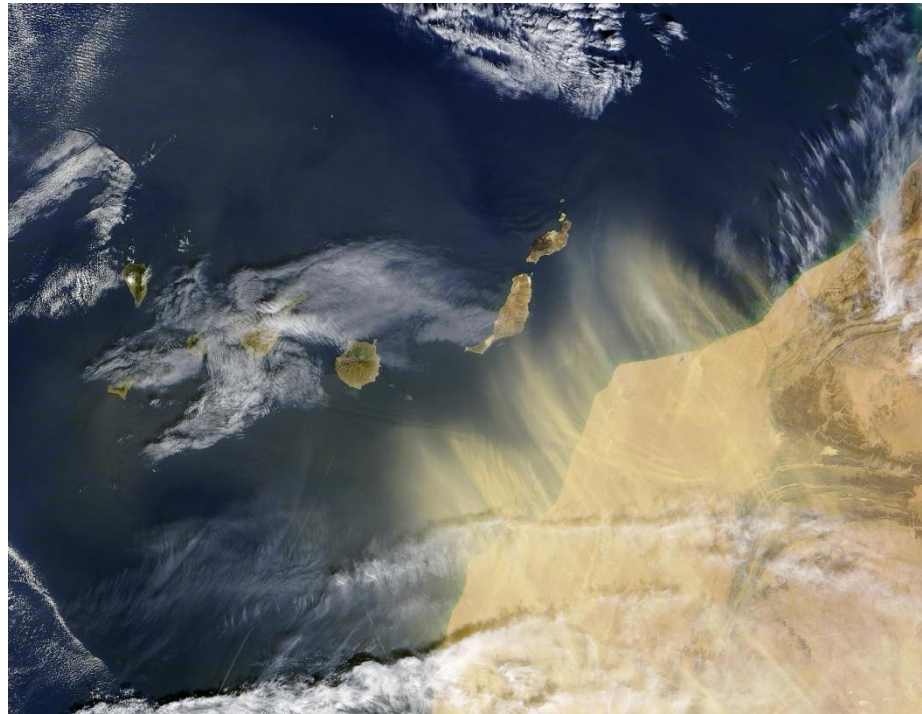


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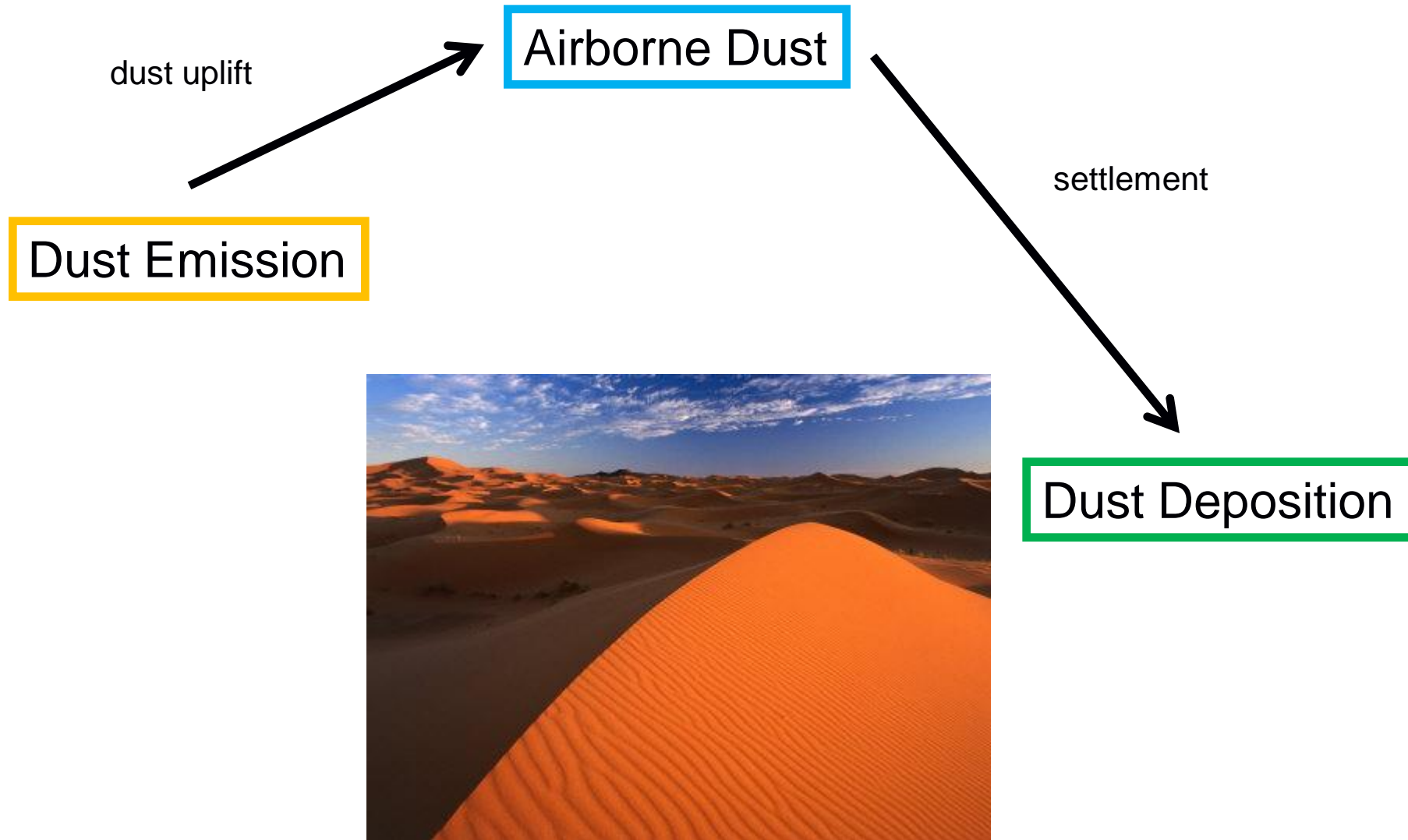
dust uplift

Airborne Dust

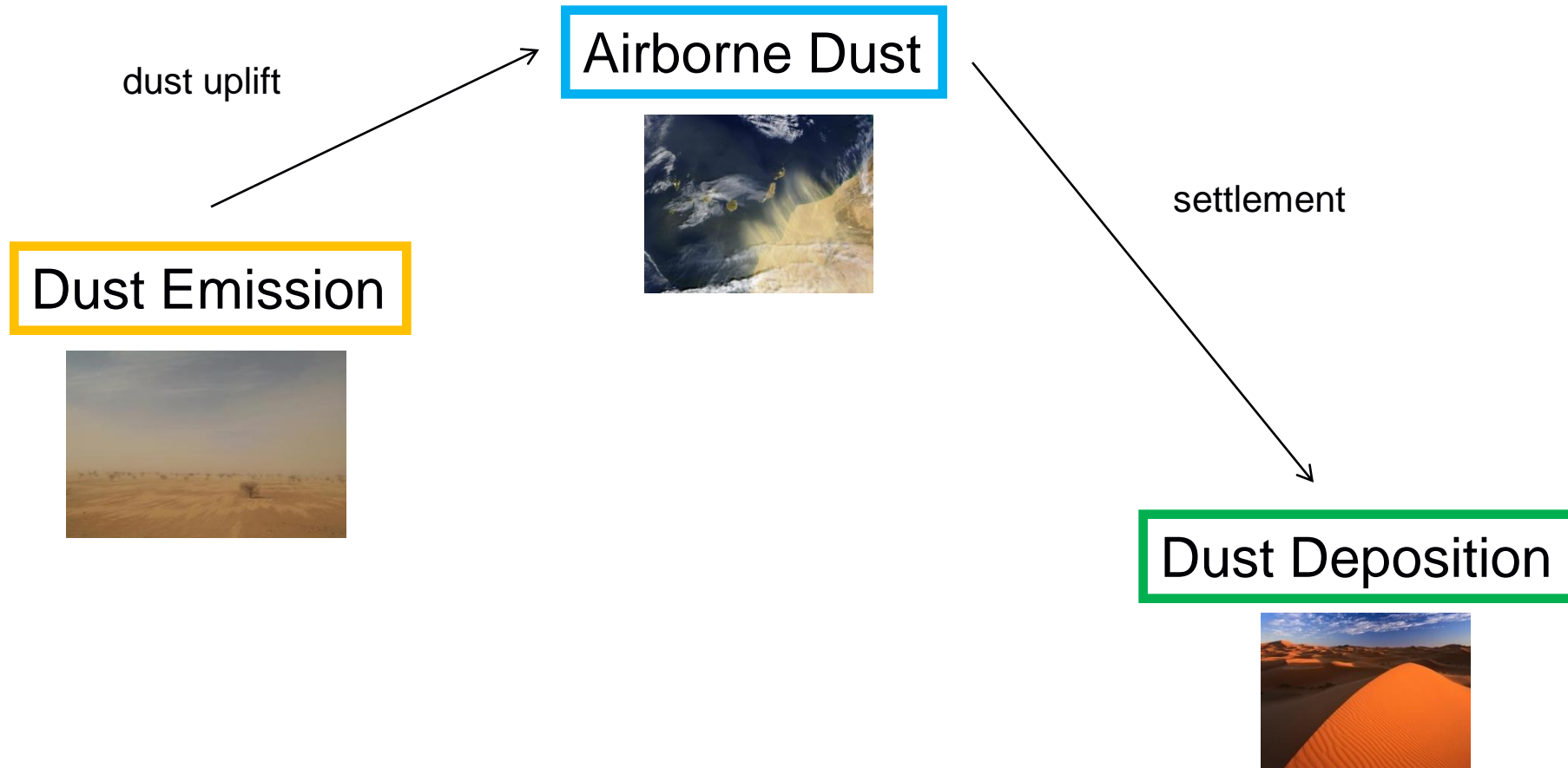
Dust Emission



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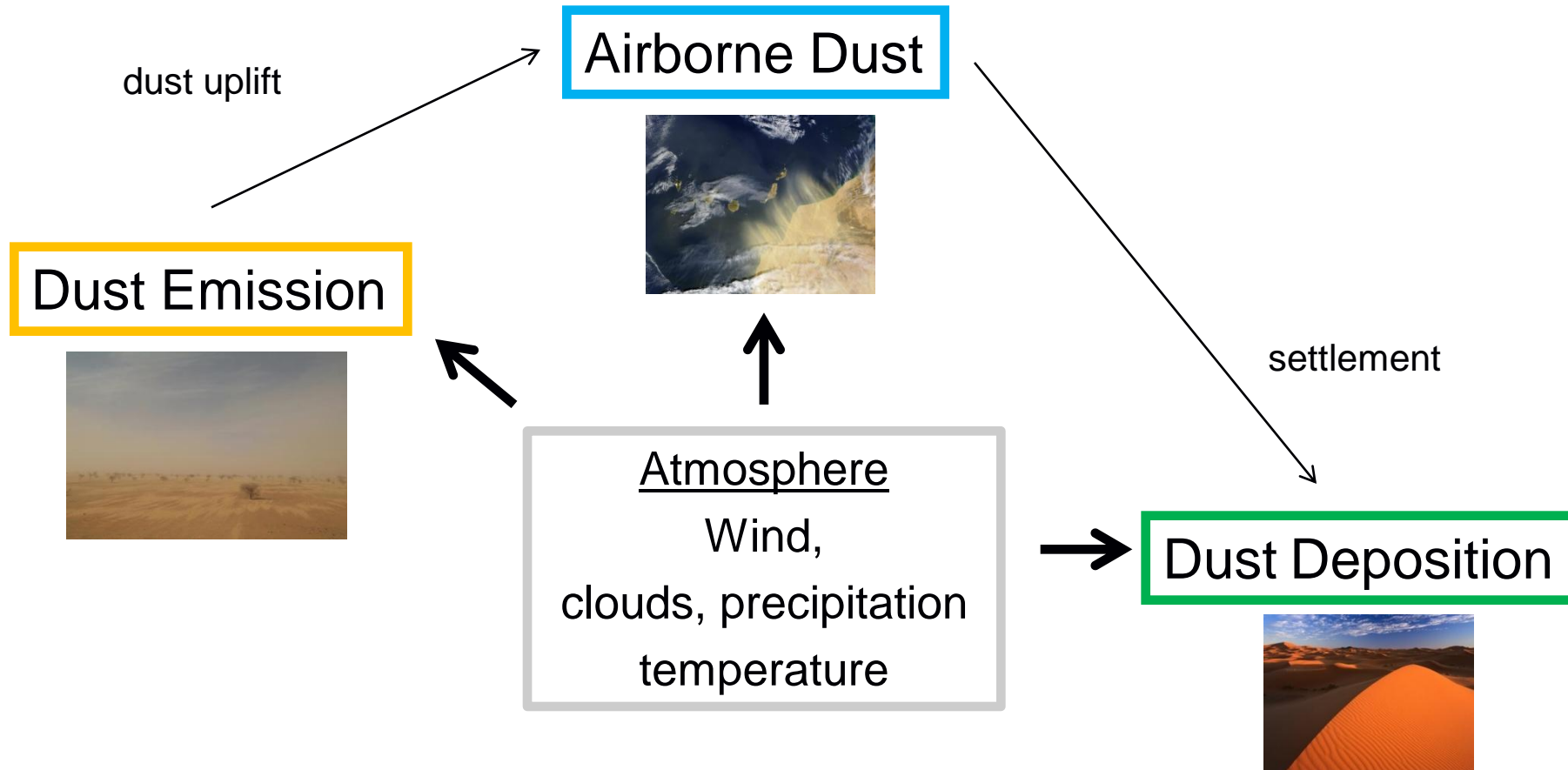


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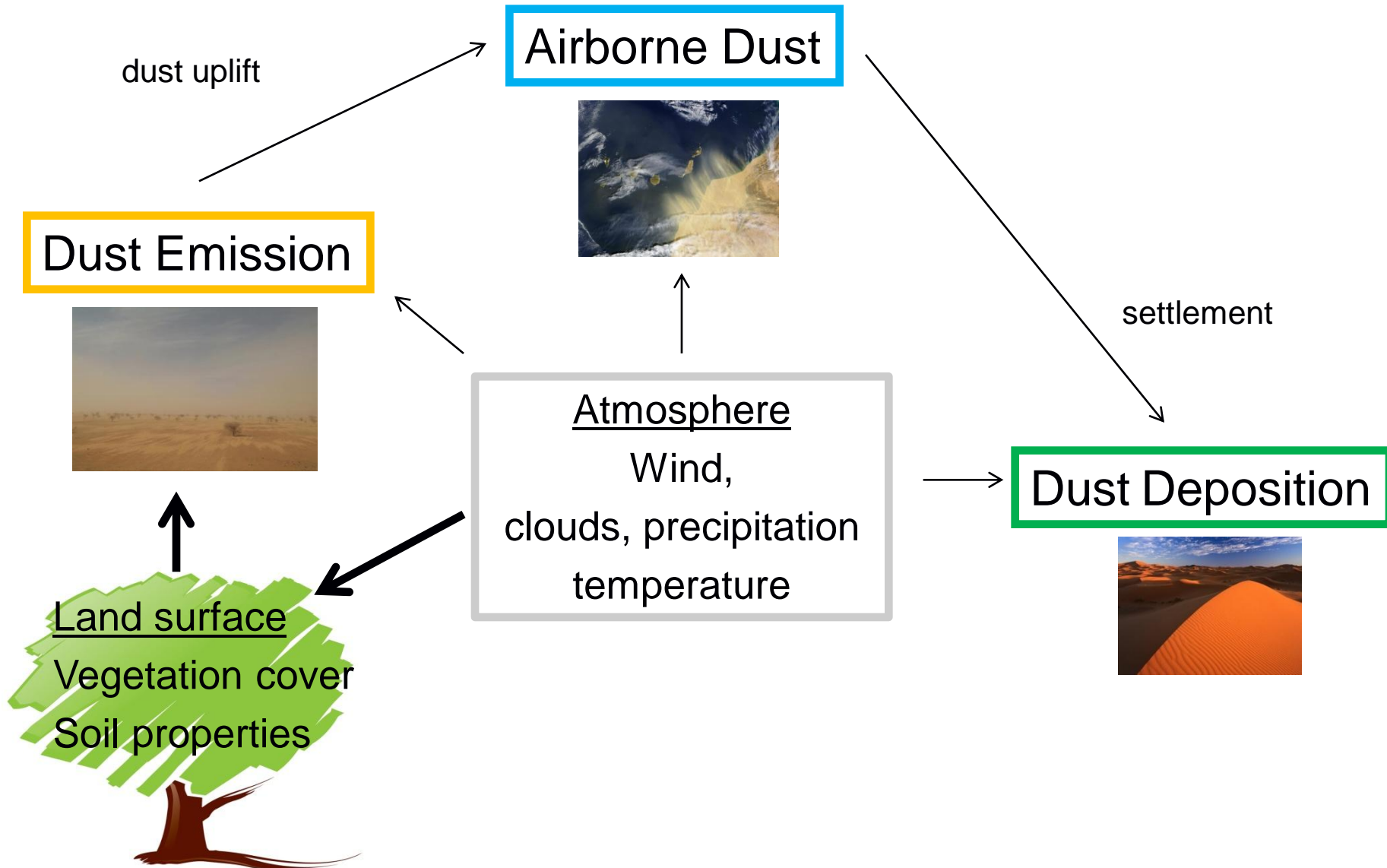




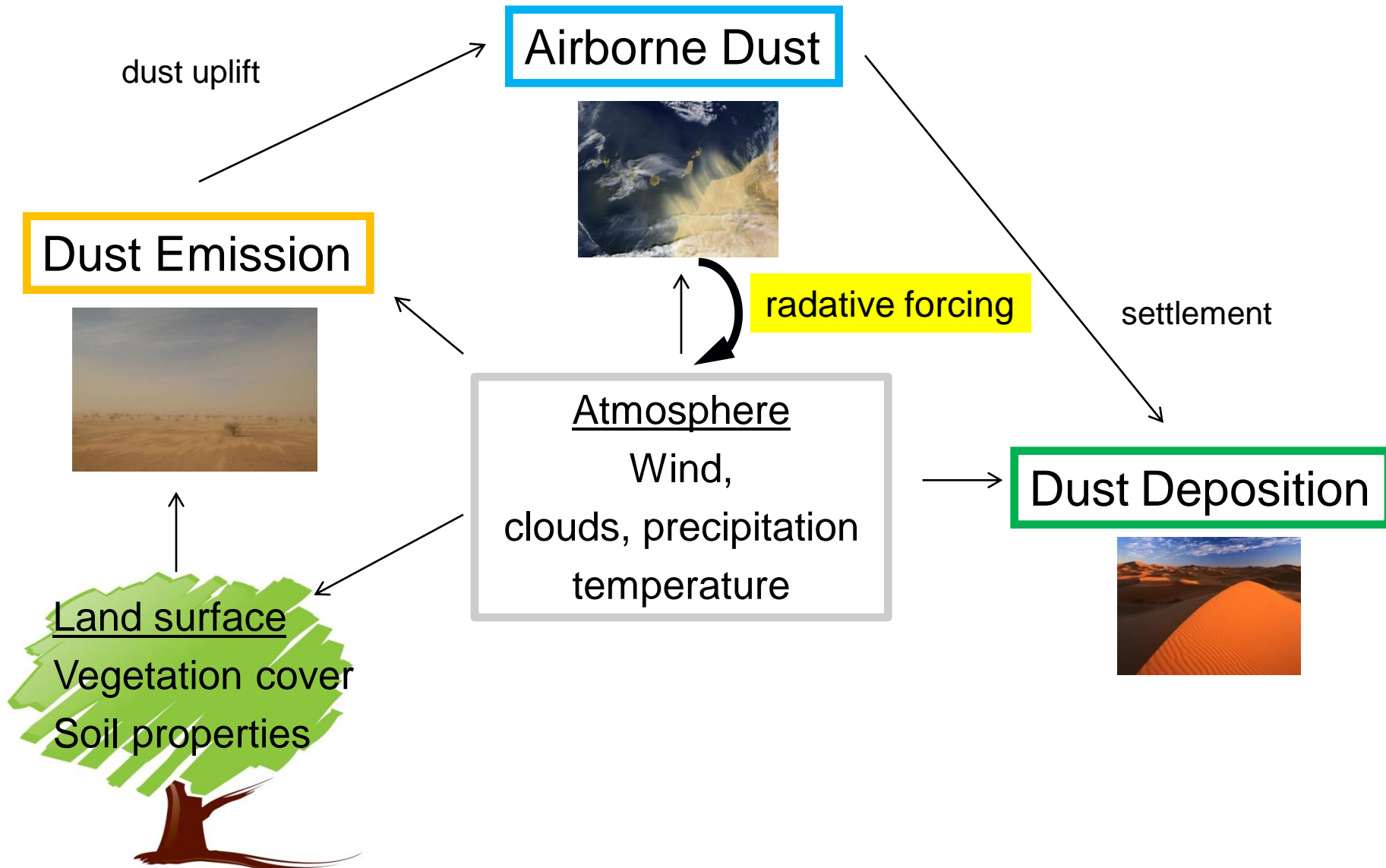
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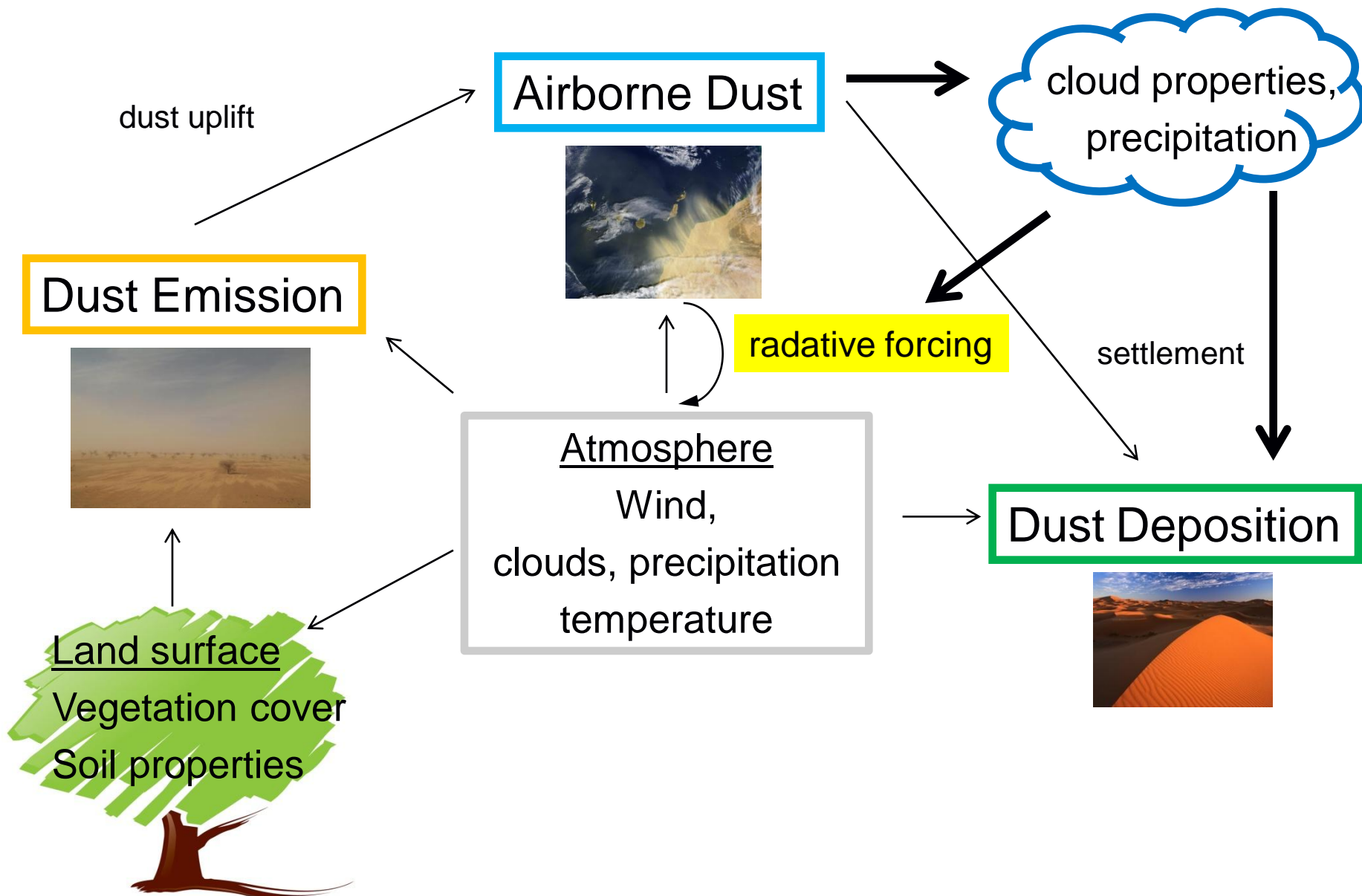
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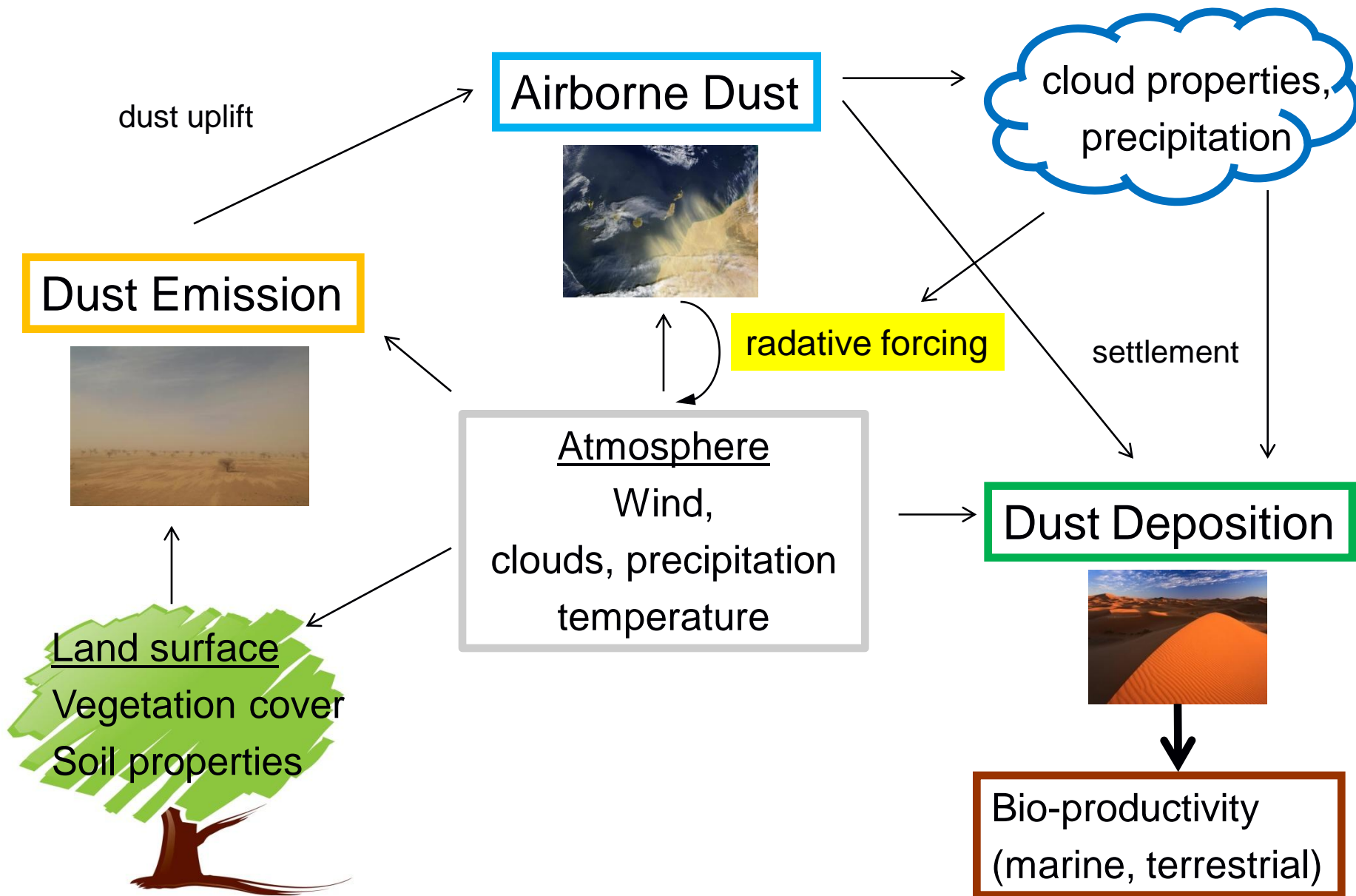
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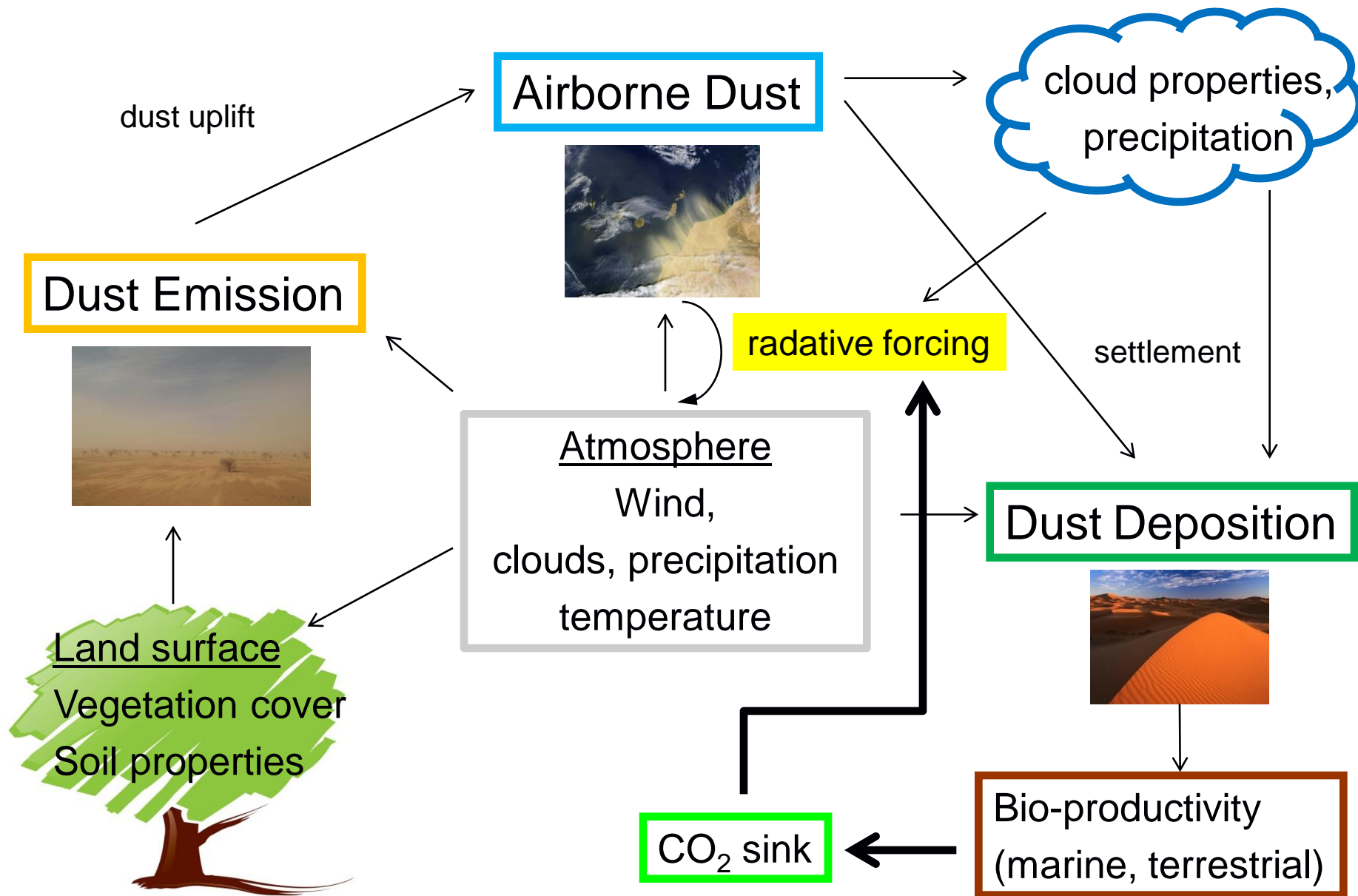


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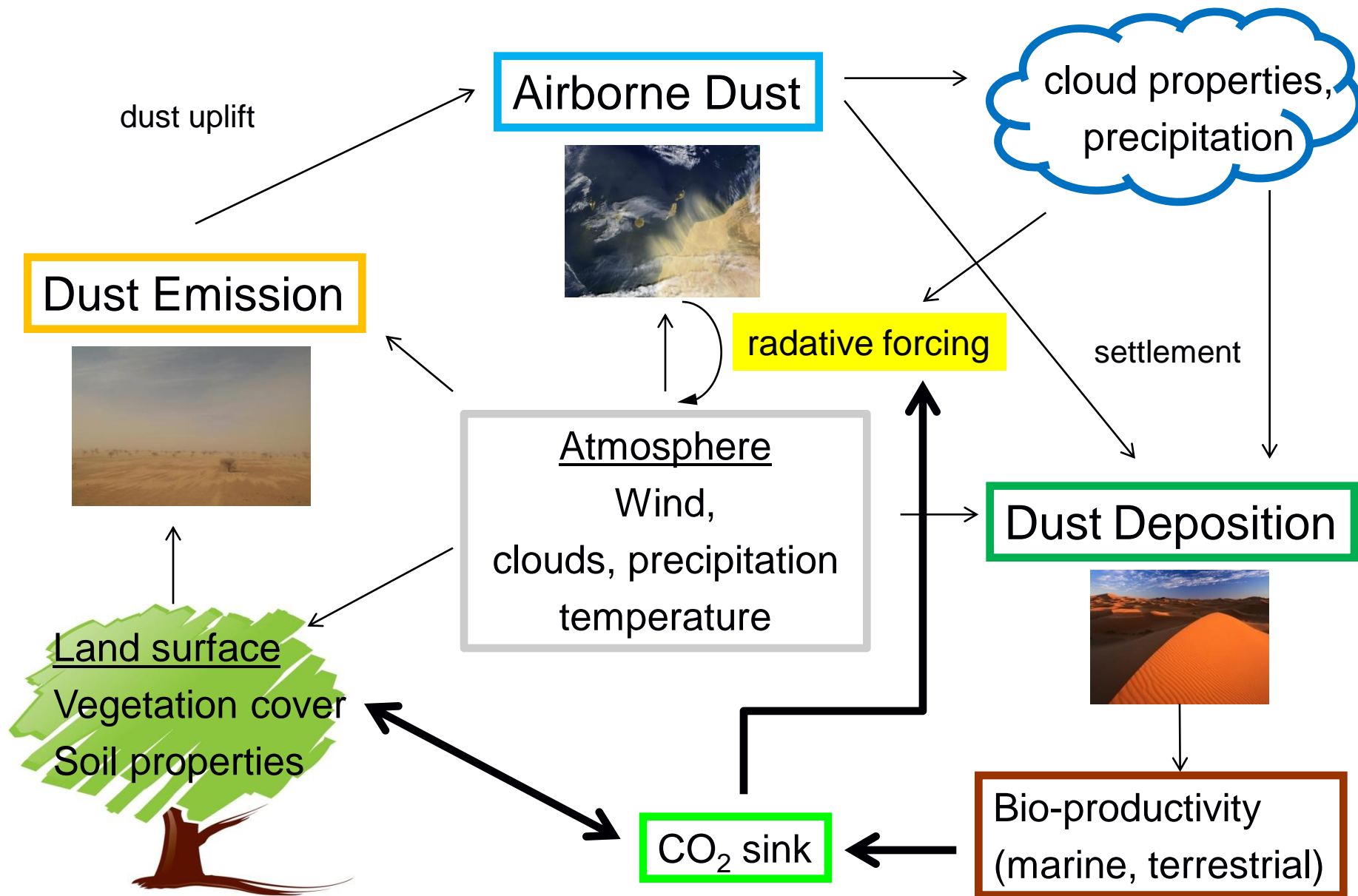




# Dust – Climate Interactions



# Dust – Climate Interactions



# Towards understanding the Role of Dust in Climate Change



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- Describe the amounts and geographic distribution of mineral dust fluxes (models/remote sensing).
- Quantify the direct radiative forcing effects of a realistic dust field and the resulting impacts on climate.
- Assess the impact of increased dust input on marine productivity.

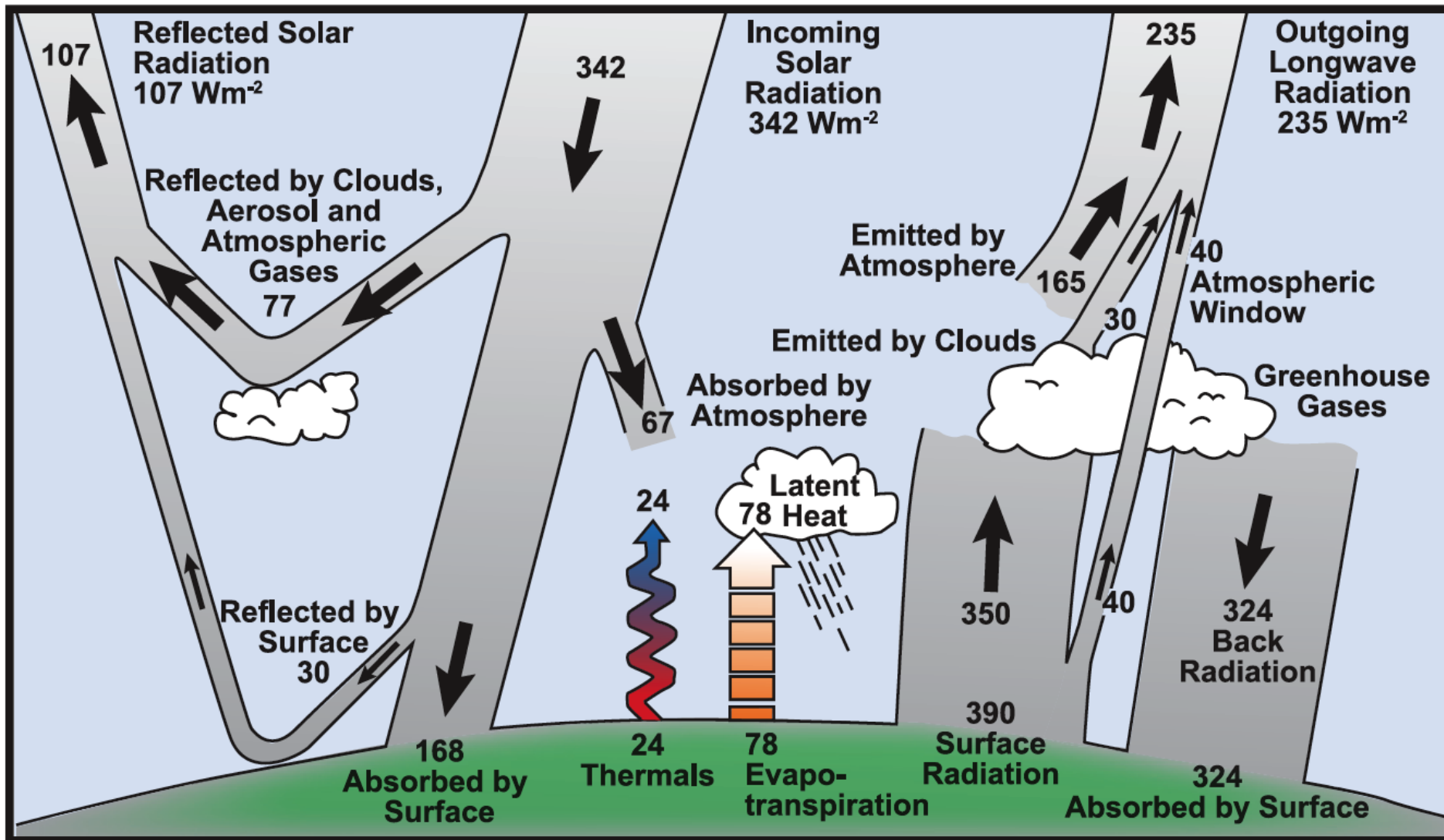
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# Energy Balance



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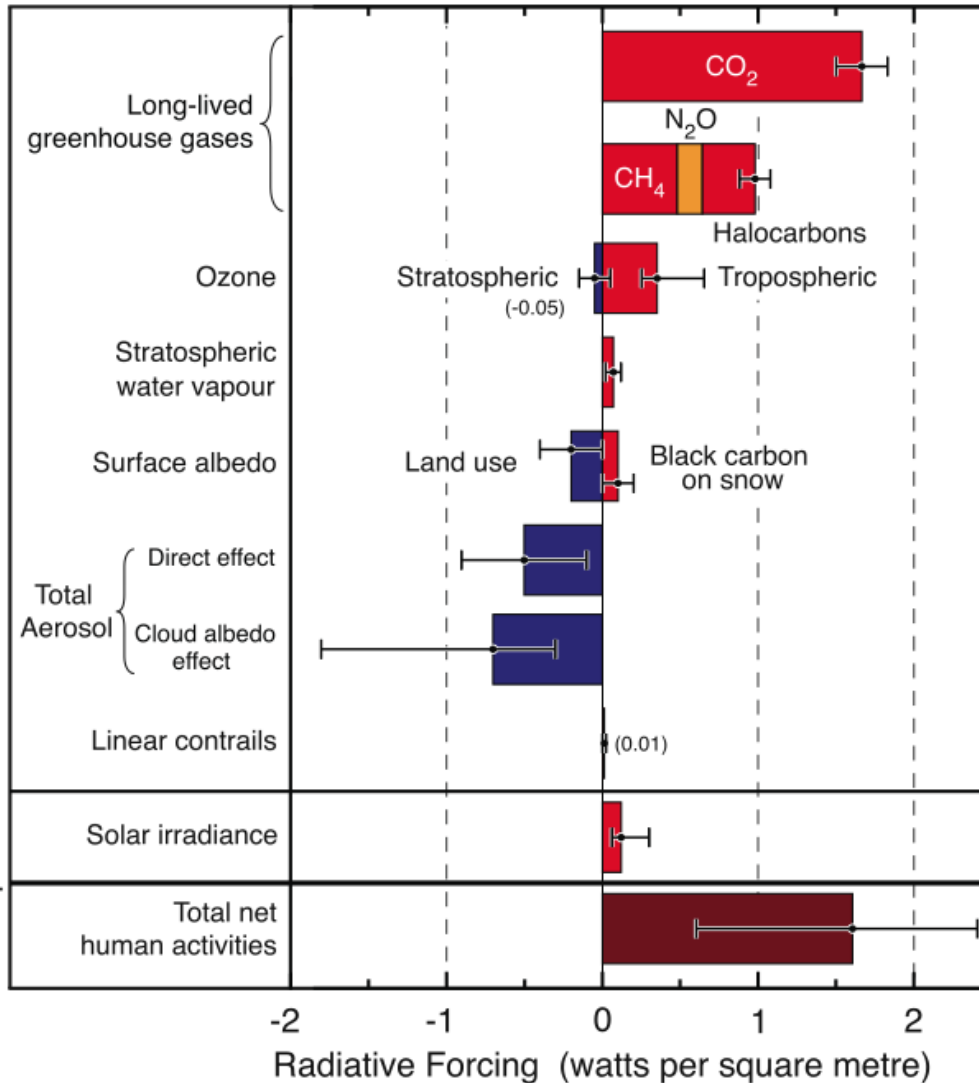




# Radiative Forcing

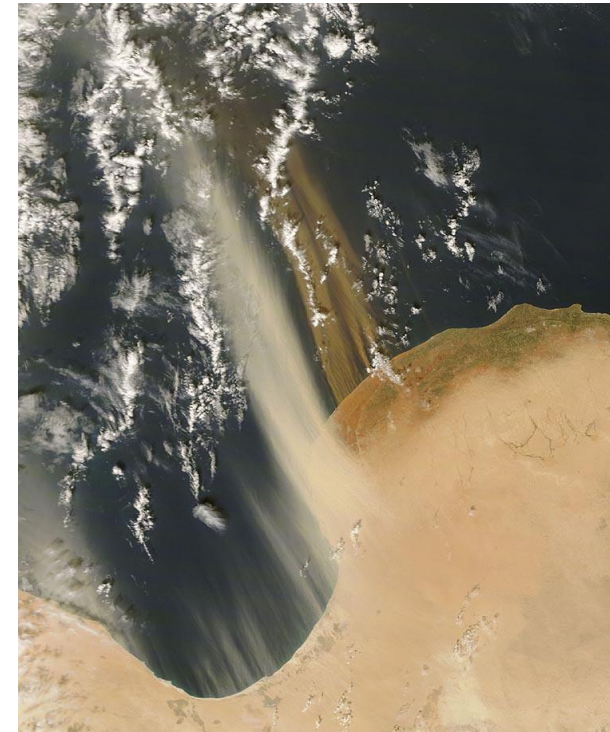
Radiative forcing of climate between 1750 and 2005

Radiative Forcing Terms



- ‘Greenhouse gases’ as carbon dioxide warm the atmosphere by efficiently absorbing thermal infrared radiation emitted by the Earth’s surface
- Backscattering of incoming sunlight by aerosol particles partly offsets this warming
- Soil dust aerosol is a major part of the atmospheric aerosol load

- Extinction efficiency
  - ⇒ Light absorption and scattering per particle
- Single scattering albedo
  - ⇒ Ratio of light scattering to light extinction
- Asymmetry parameter
  - ⇒ Fraction of forward scattered light



Parameters depend on **particle size**, **mineralogical composition**, and **particle shape** !

# Direct Radiative Forcing



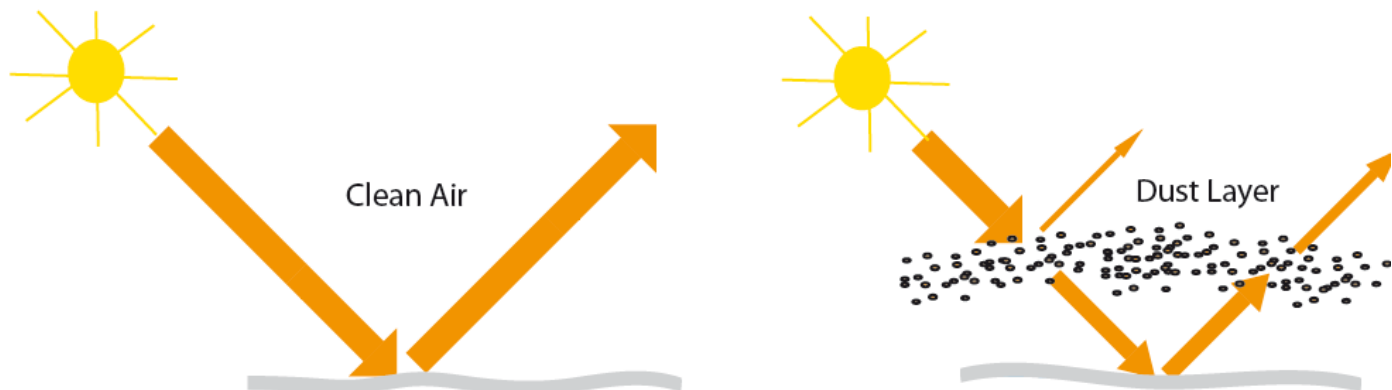
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Dust causes increased reflection of sunlight



Dark Surface (e.g. Ocean)

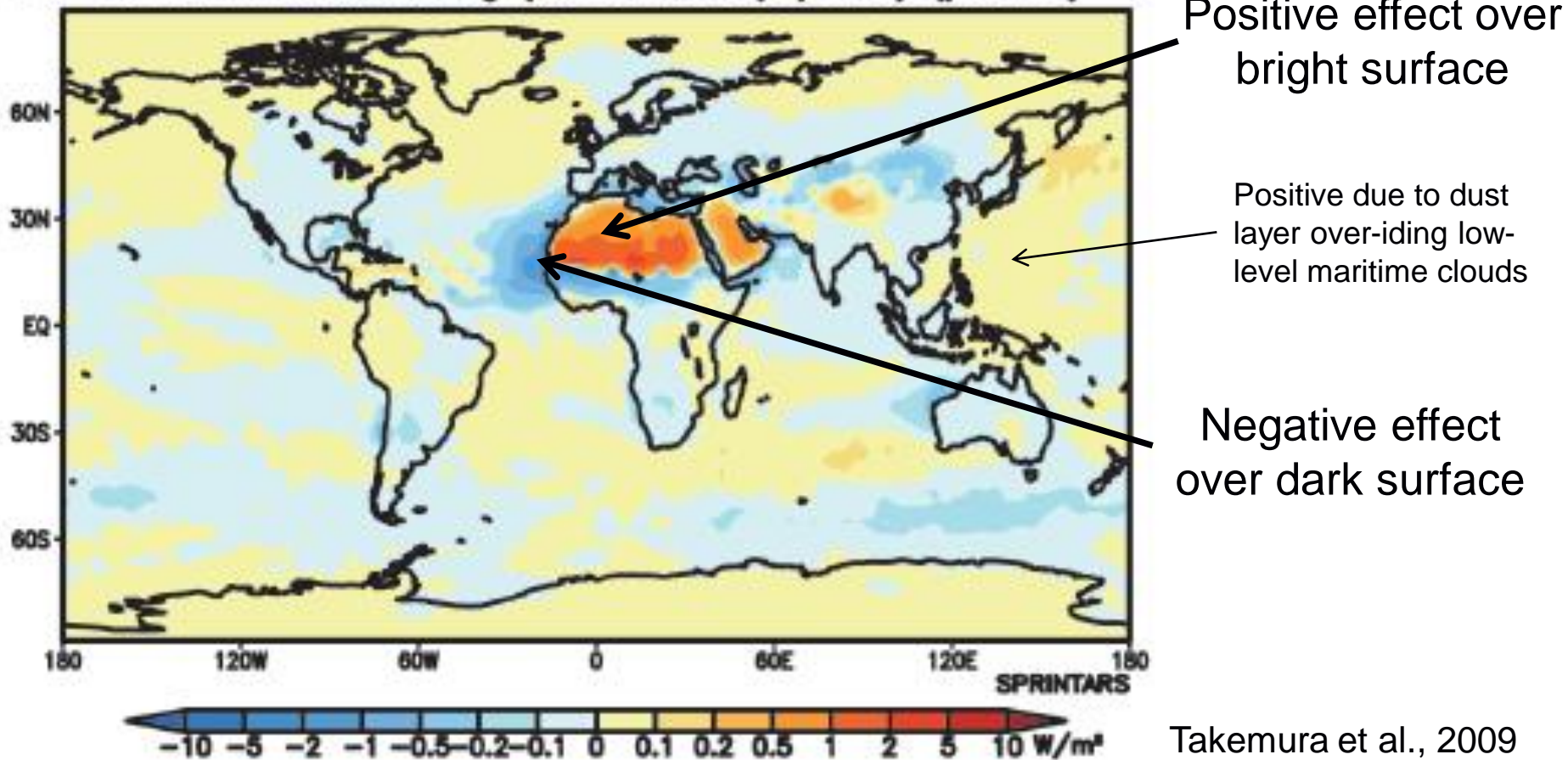
Dust causes decreased reflection of sunlight



Bright Surface (e.g. Desert)

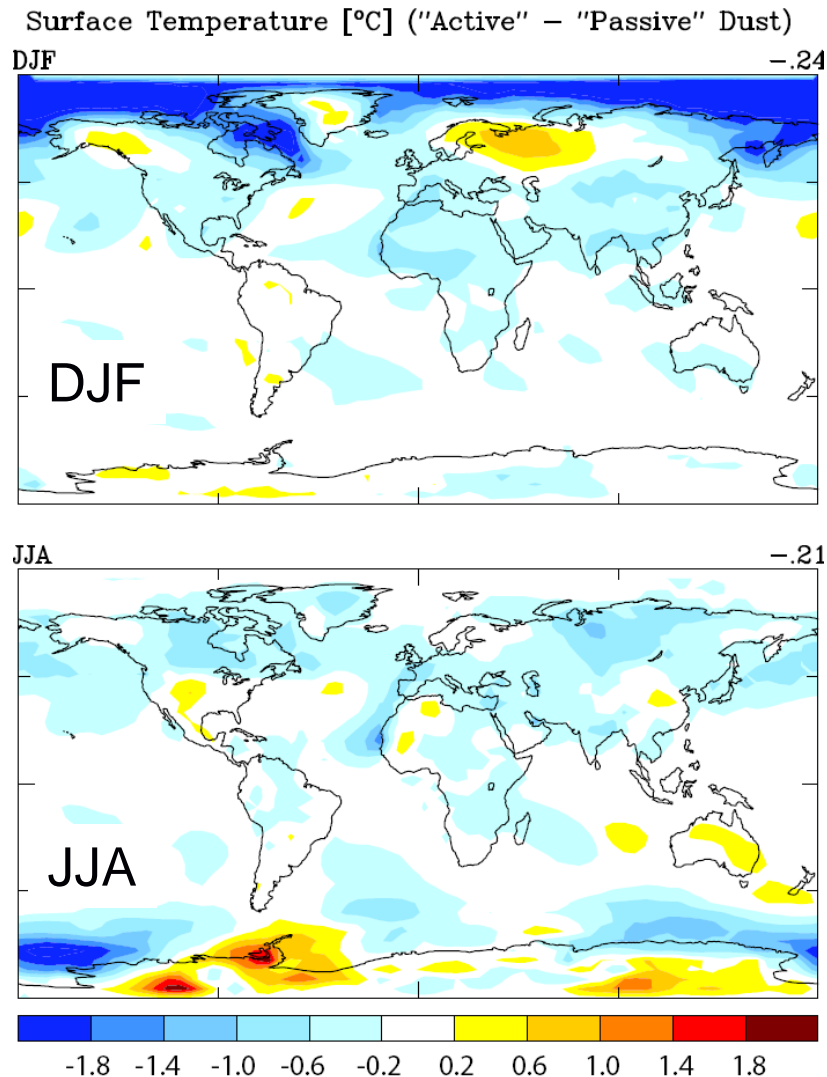
# Direct Radiative Forcing

(b) Direct radiative forcing (soil dust, tropopause) (present)



**Direct radiative forcing:** difference in radiative budget between including and excluding dust aerosol within the same simulation

# Direct Radiative Forcing



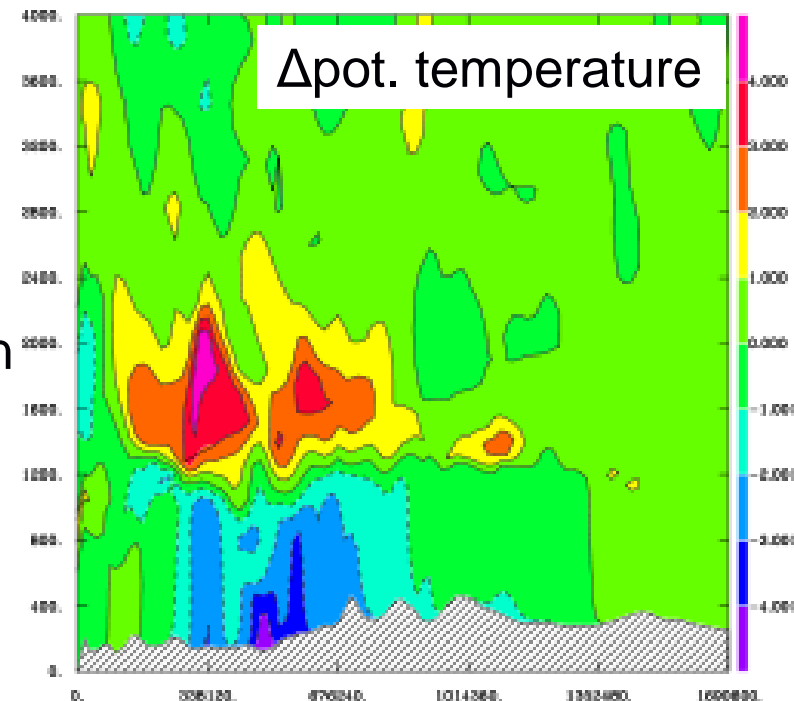
GISS model simulation, I. Tegen

- Change in temperature due to dust
- Negative feedback
  - reduced surface winds
  - enhanced atmospheric stability
  - reduced dust emission
- Replicates dust radiative forcing patterns
- Indicates complex interactions



For individual cases:

- Reduction in surface temperature much stronger
  - Up to 12°C for March 2006 case [Tulet et al., 2007, Cavazos et al., 2009, Mallet et al., 2009]
  - “Disturbed” diurnal cycle for surface temperature
- Enhanced atmospheric stability
  - “Dust layer as second heat source”
  - Negative feedback on dust emission



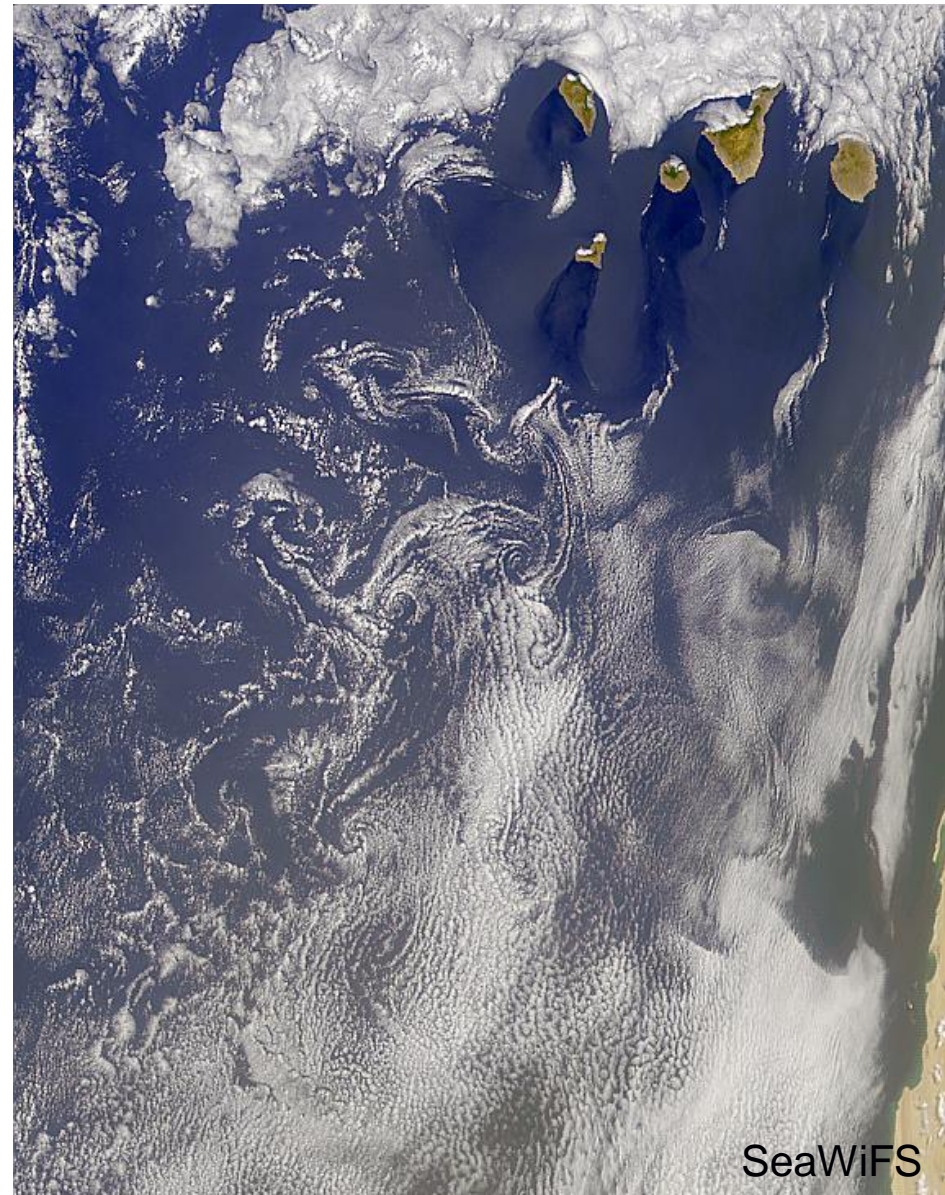
Tulet et al., 2008

# Indirect Dust Effect

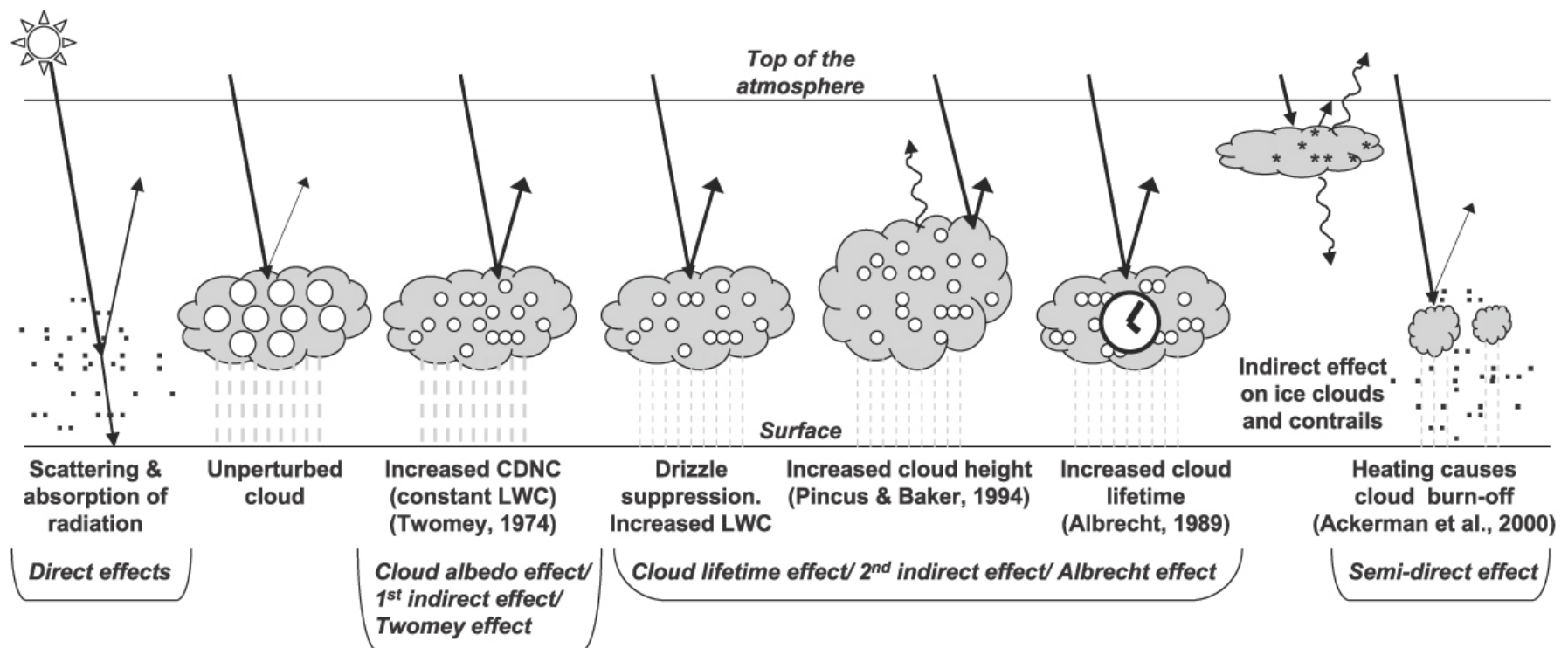


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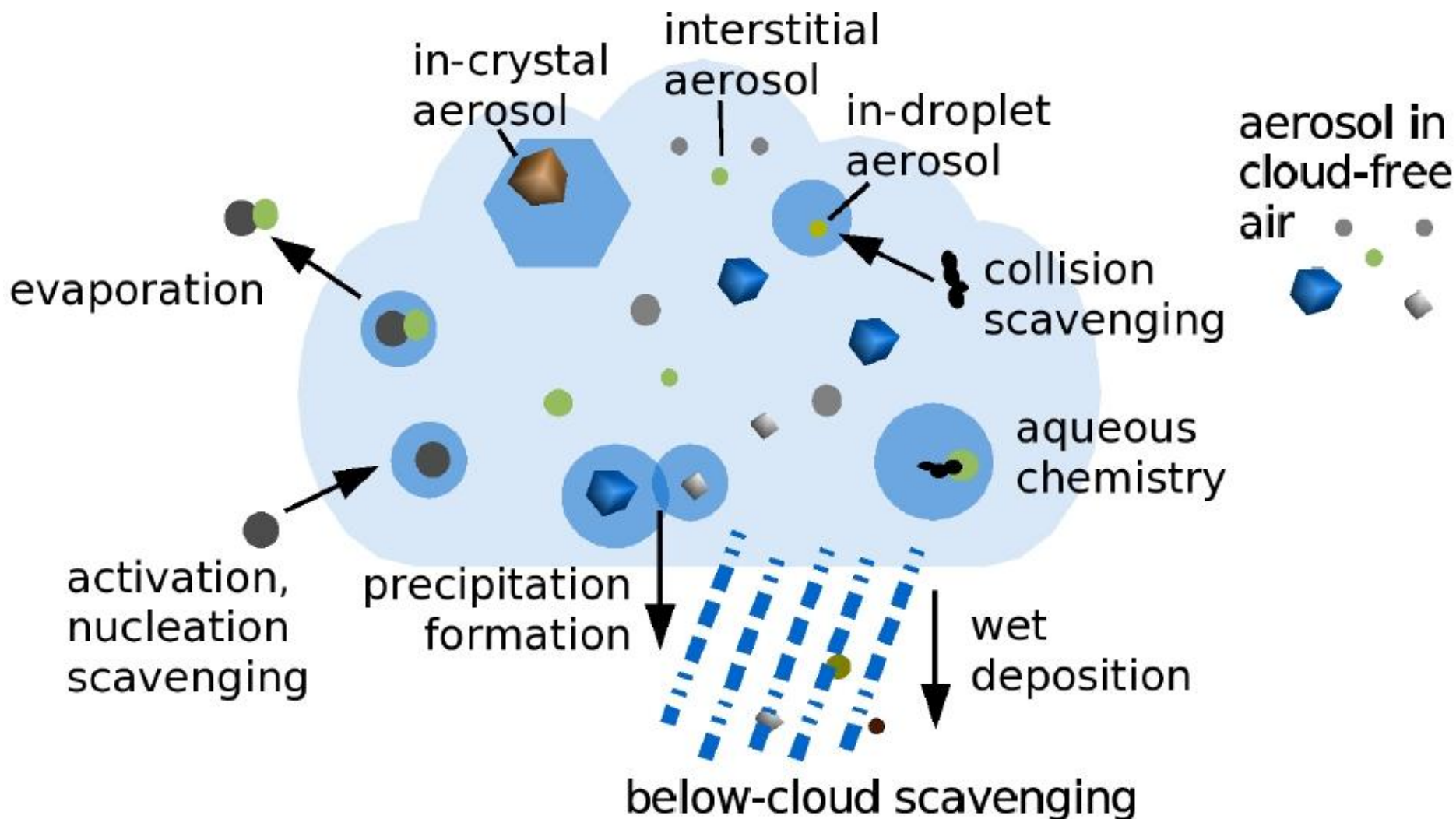
Dust, and aerosol particles at all, can interact with clouds – modify their properties and ultimately their radiative effect



## Indirect effect: aerosol-cloud effect

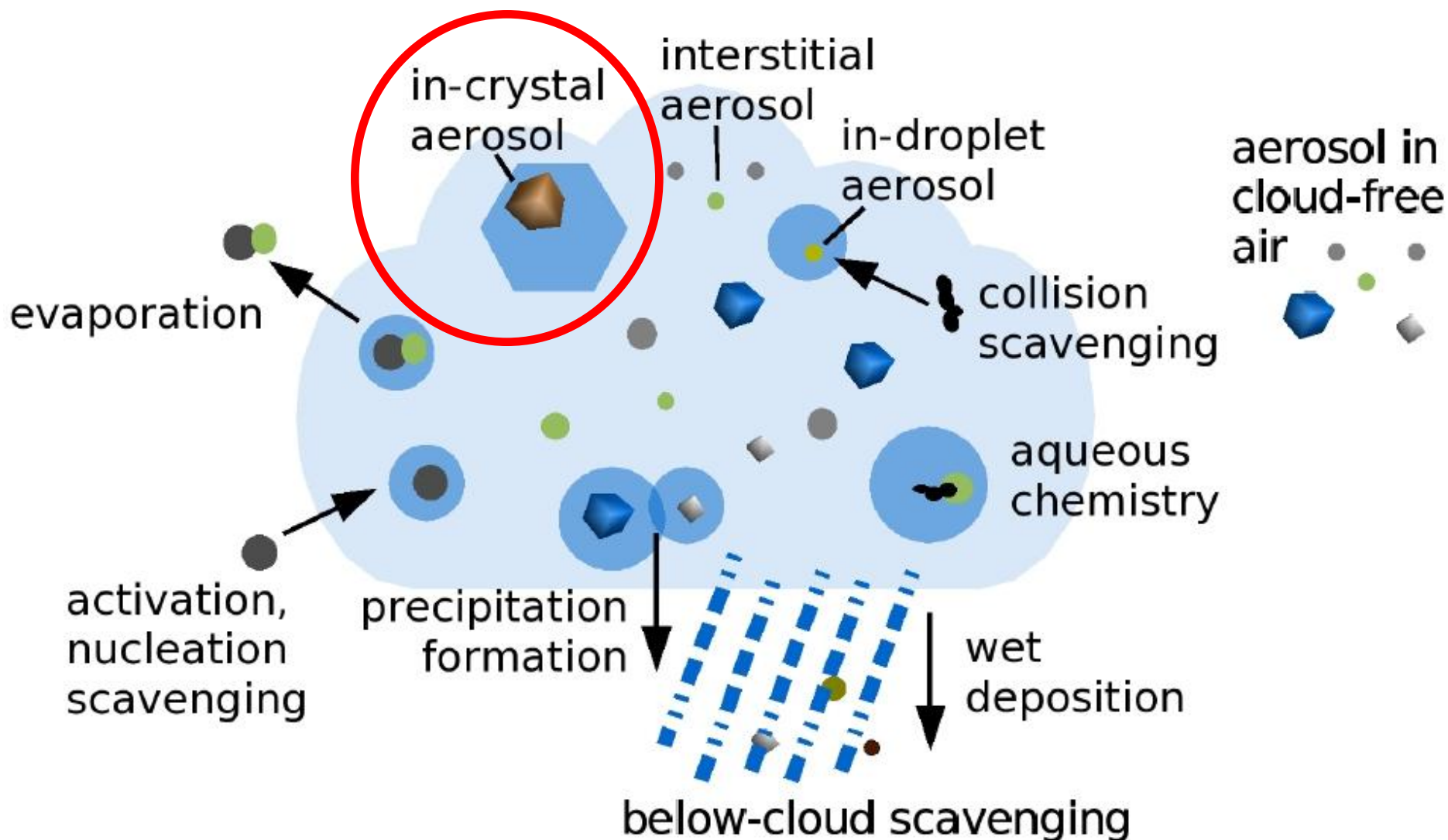


# Aerosol – Cloud Interactions



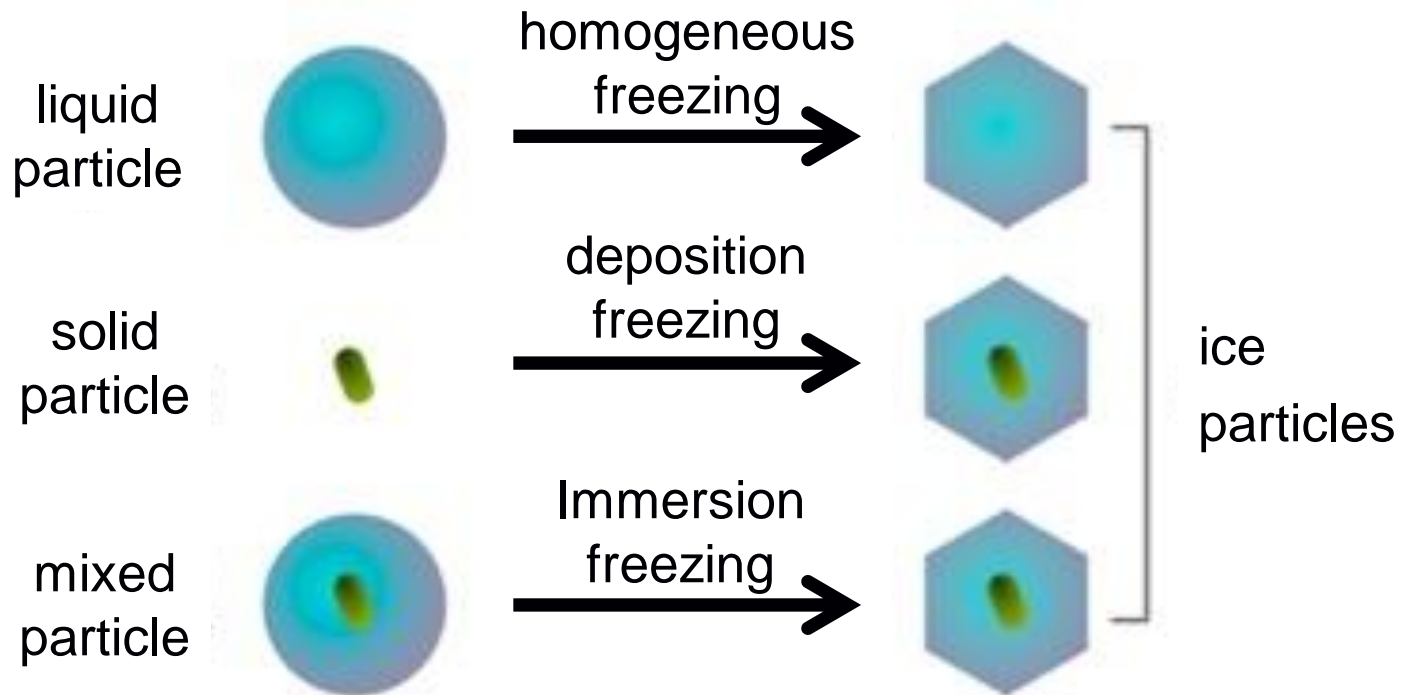


# Aerosol – Cloud Interactions



# Dust triggering Droplet Freezing

- Droplet freezing at  $-38^{\circ}\text{C} < T < 0^{\circ}\text{C}$
- Main mechanism:



- Importance of indirect dust-cloud effect is still unclear!



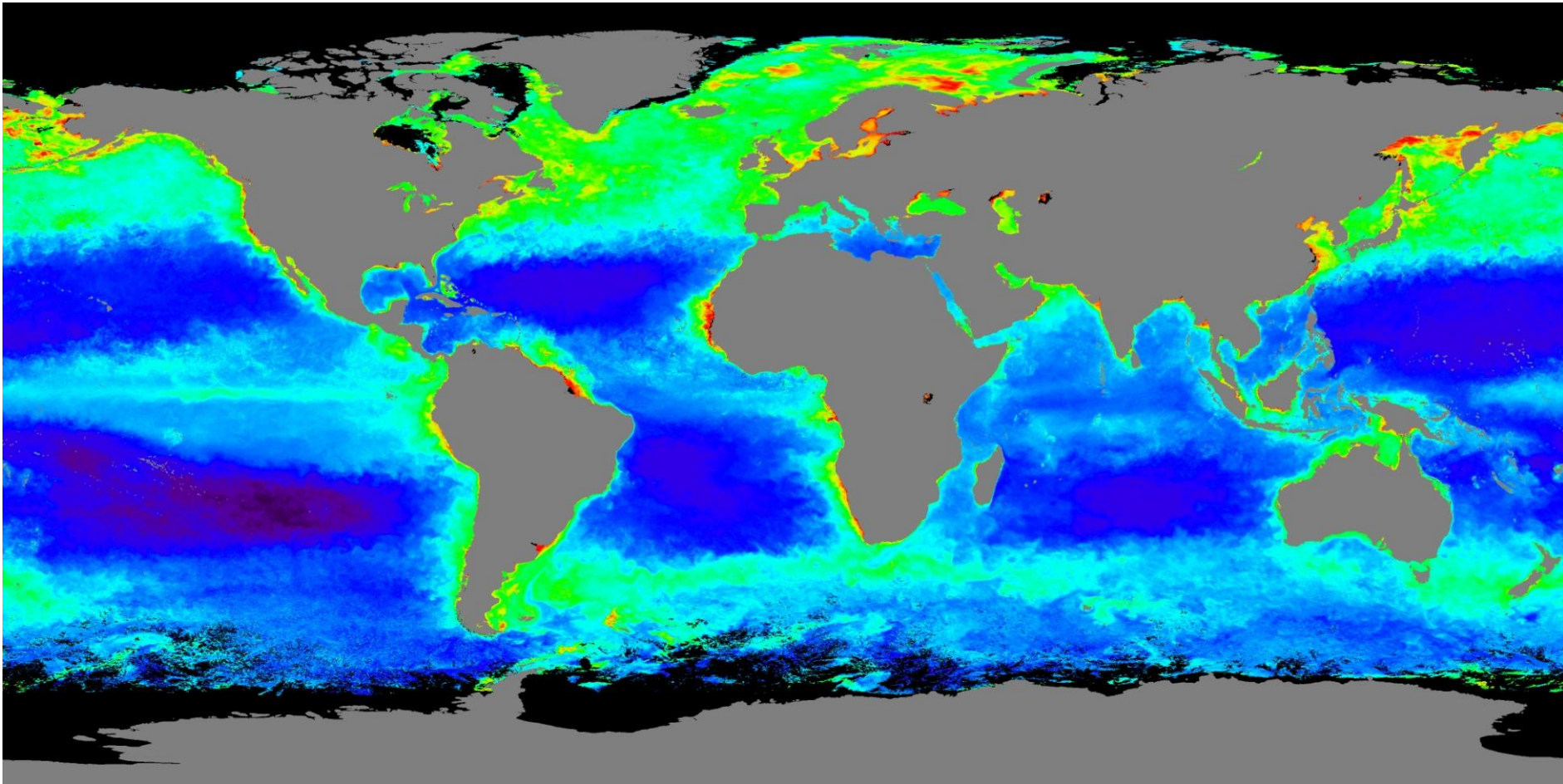
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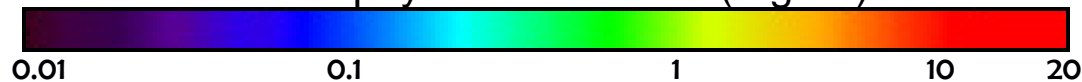
# Marine Bio-Productivity: Chlorophyll



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chlorophyll concentration ( $\text{mg}/\text{m}^3$ )

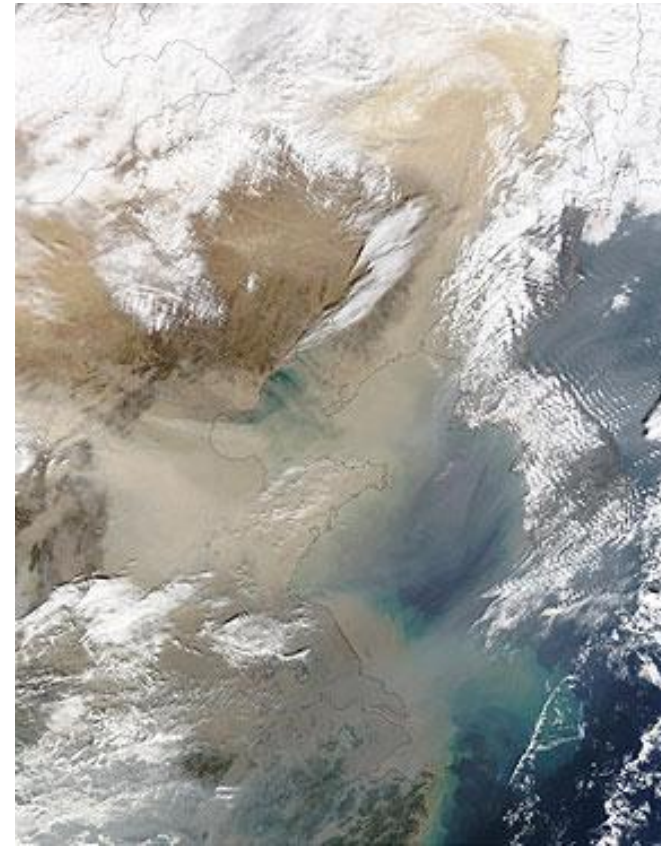


<http://earthobservatory.nasa.gov>

# Dust Effect on Marine Ecosystem

## “Iron Hypothesis”

- Even at high levels of nutrients (e.g. Nitrate, phosphate) certain ocean areas show less bio-productivity, i.e. Phytoplankton growth [Martin et al., 1988]
- Iron can be a controlling factor for marine life in high-nutrient low chlorophyll (HNLC) regions
- Iron contained in desert dust blown over ocean regions can contribute to iron supply in such regions, increasing bio-productivity and ultimately  $\text{CO}_2$  uptake



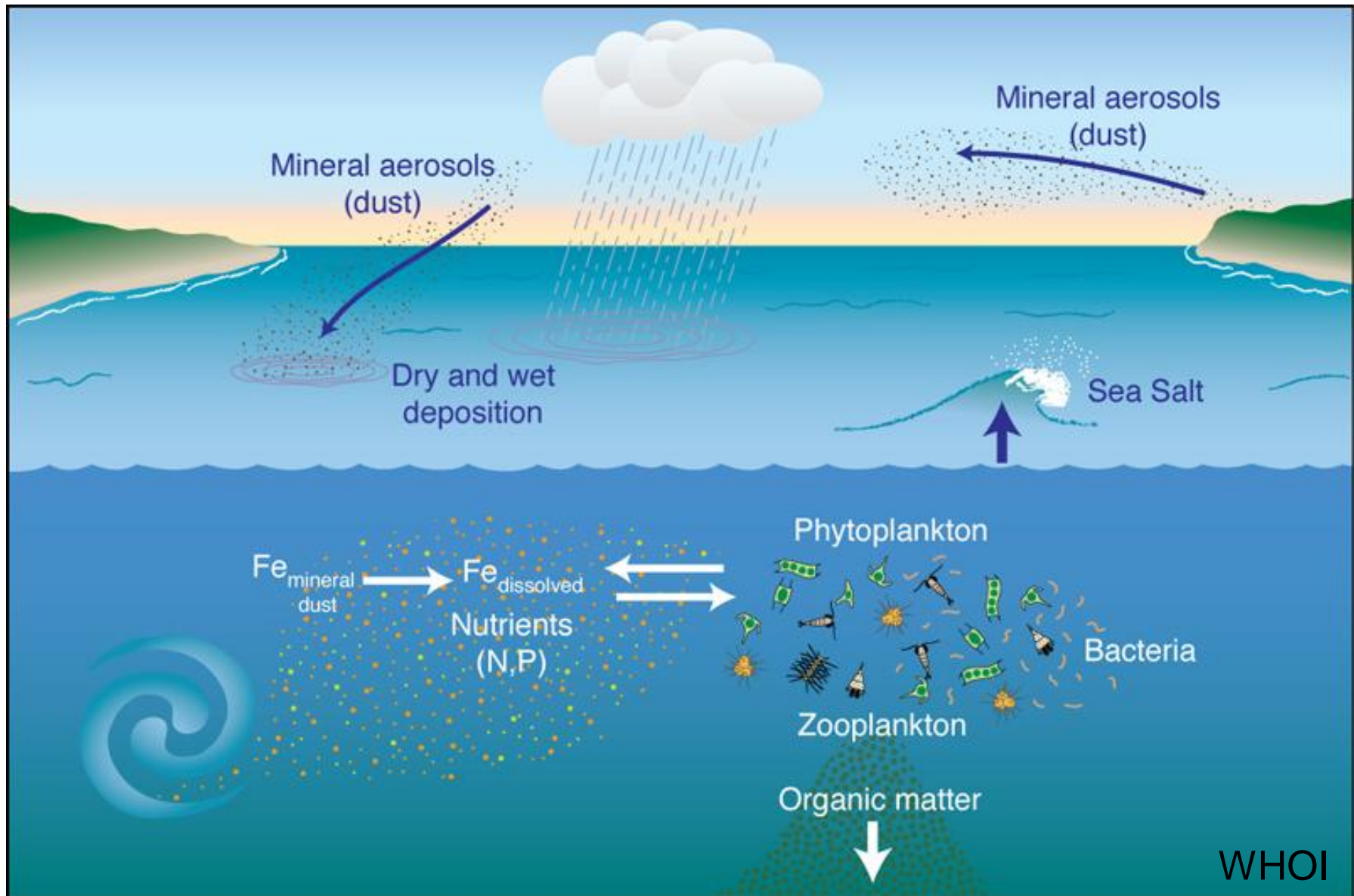
NASA



# Dust Effect on Marine Ecosystem



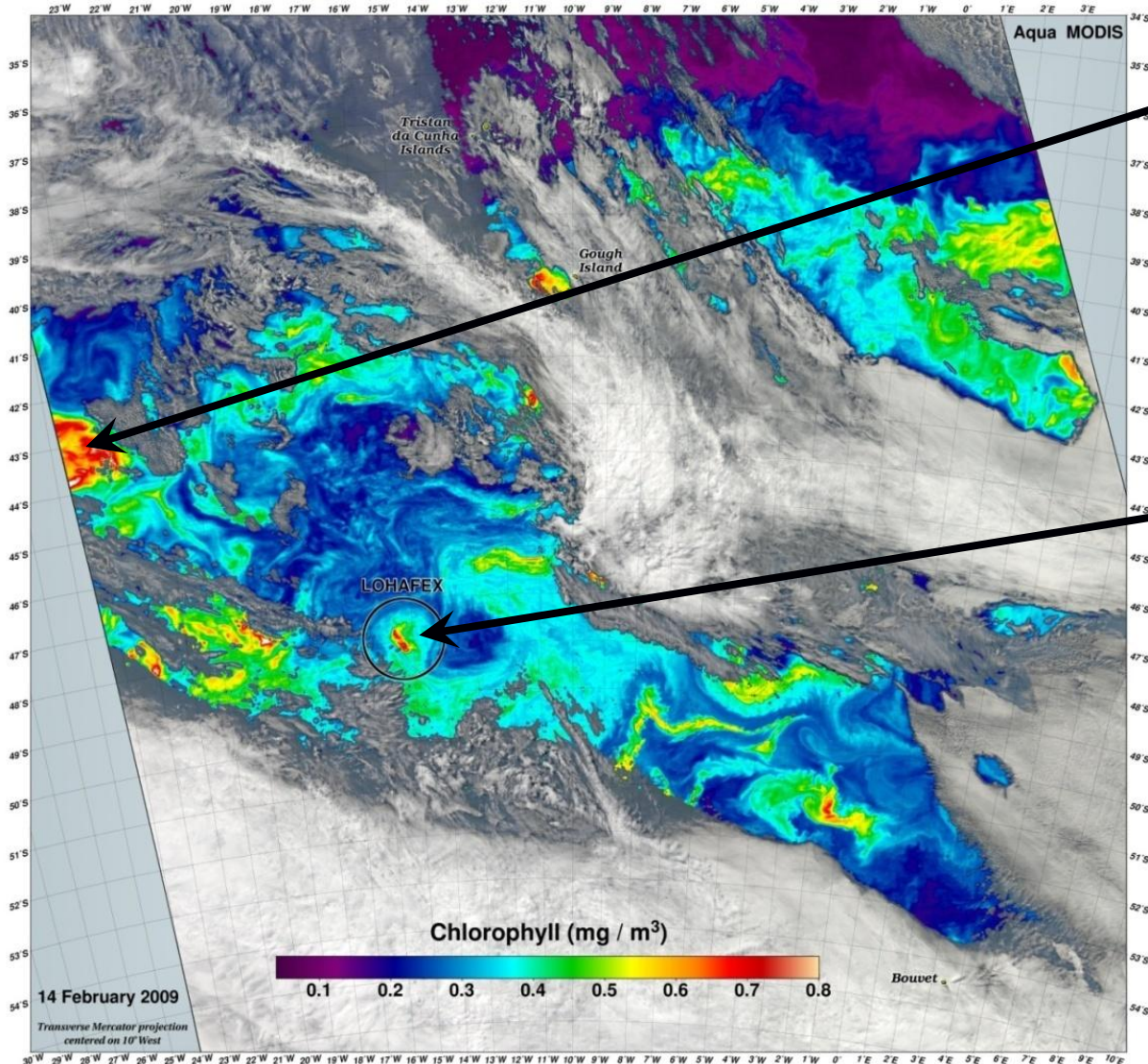
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# Marine Ecology: Iron Fertilization Experiment



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Natural plankton  
bloom

Plankton bloom after  
artificial addition of  
iron (LOHAFEX  
experiment)

# Coral Bleaching

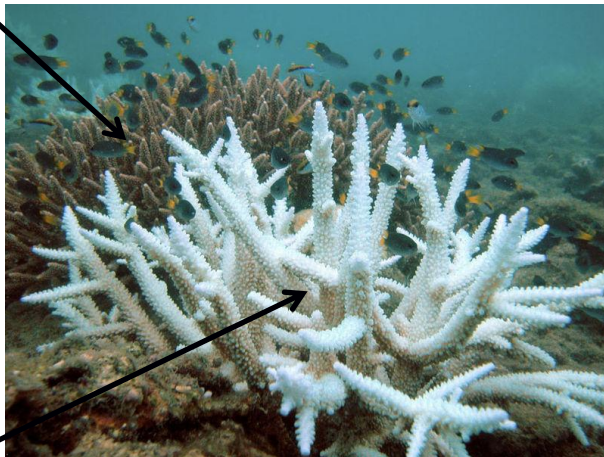


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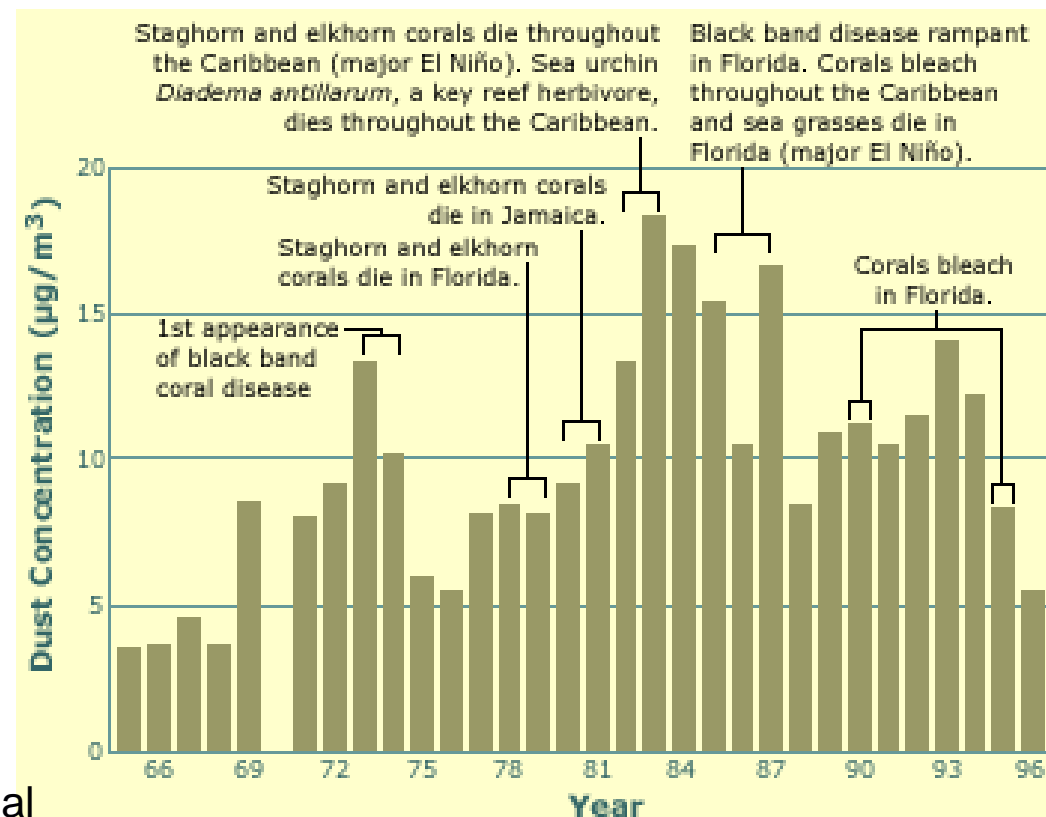
Coral Bleaching: "loss of intracellular endosymbionts due to expulsion or loss of algal population" [wikipedia]

- Related to pathogens transported on dust [Shinn et al., 2000]

normal branch



bleached branch





- Distribution of airborne dust particles depends on atmospheric parameters, such as surface winds, vertical mixing, precipitation, vegetation cover
- Dust, however, impacts on climate in various ways
  - **Direct radiative forcing** by dust leading to surface cooling is its best understood climate effect
  - **Indirect dust effects** on cloud properties or the marine ecosystem are suspected to be important, but remain unquantified so far.