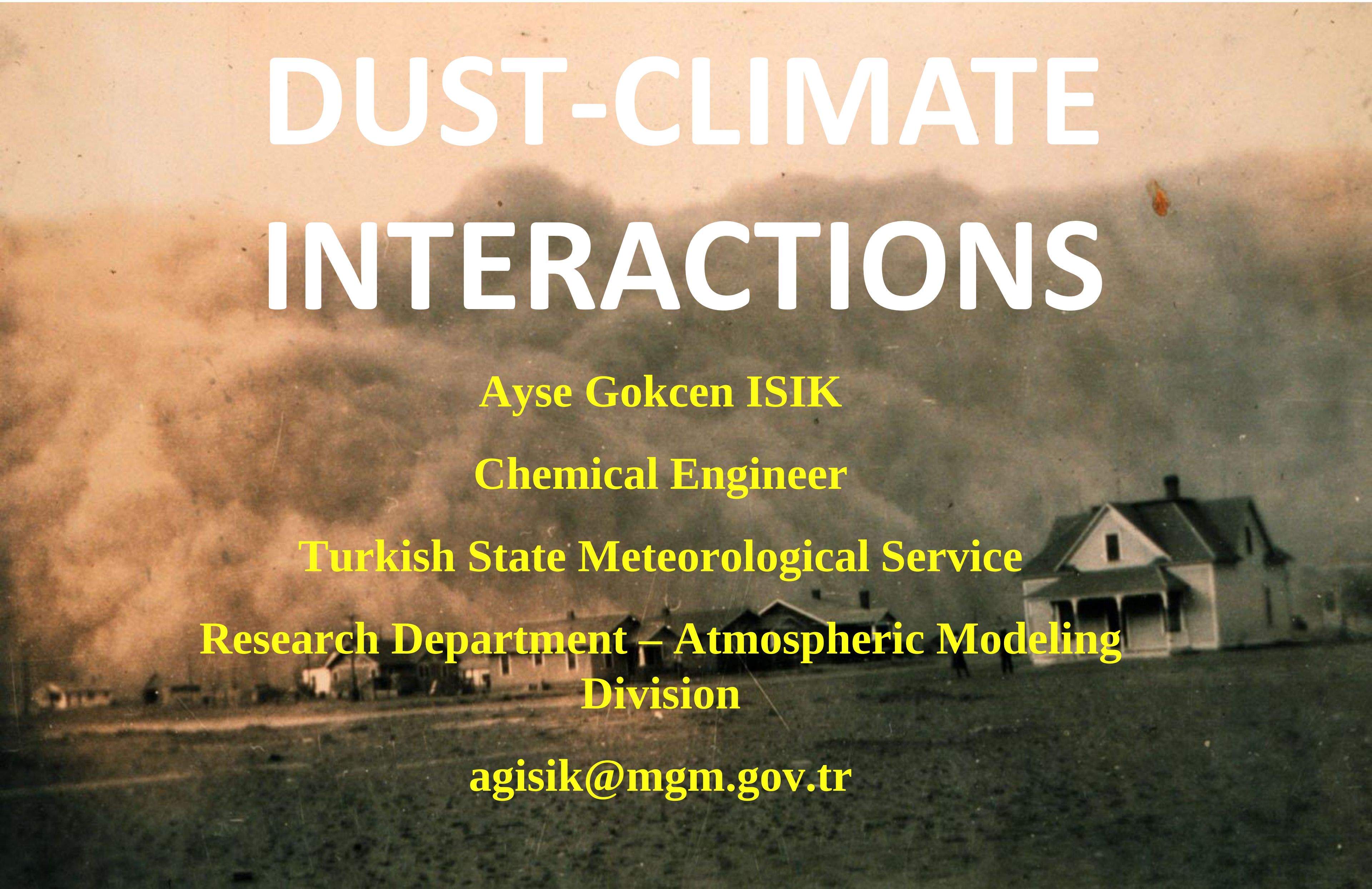

DUST-CLIMATE INTERACTIONS

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"Dust is one of the missing jigsaw pieces in climate research"


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Orman ve Su İşleri
Bakanlığı

METEOROLOJİ

Dust Impacts

- Direct and indirect climate forcing
- Regional impacts on temperature and hydrological cycle
- Dust as micro-nutrient
  - Fertilizes marine and terrestrial ecosystems
- Neutralization 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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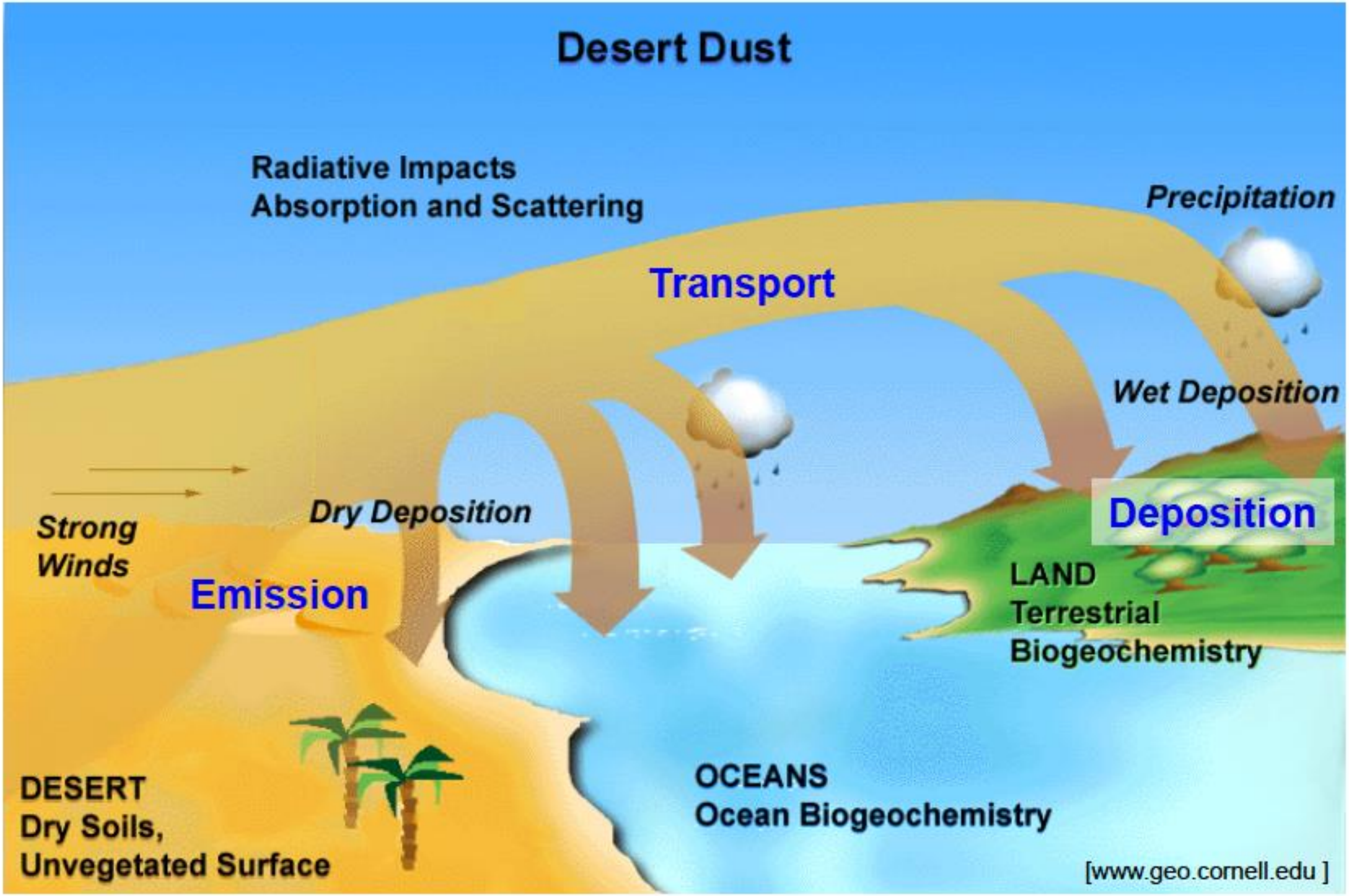
Bakanlığı

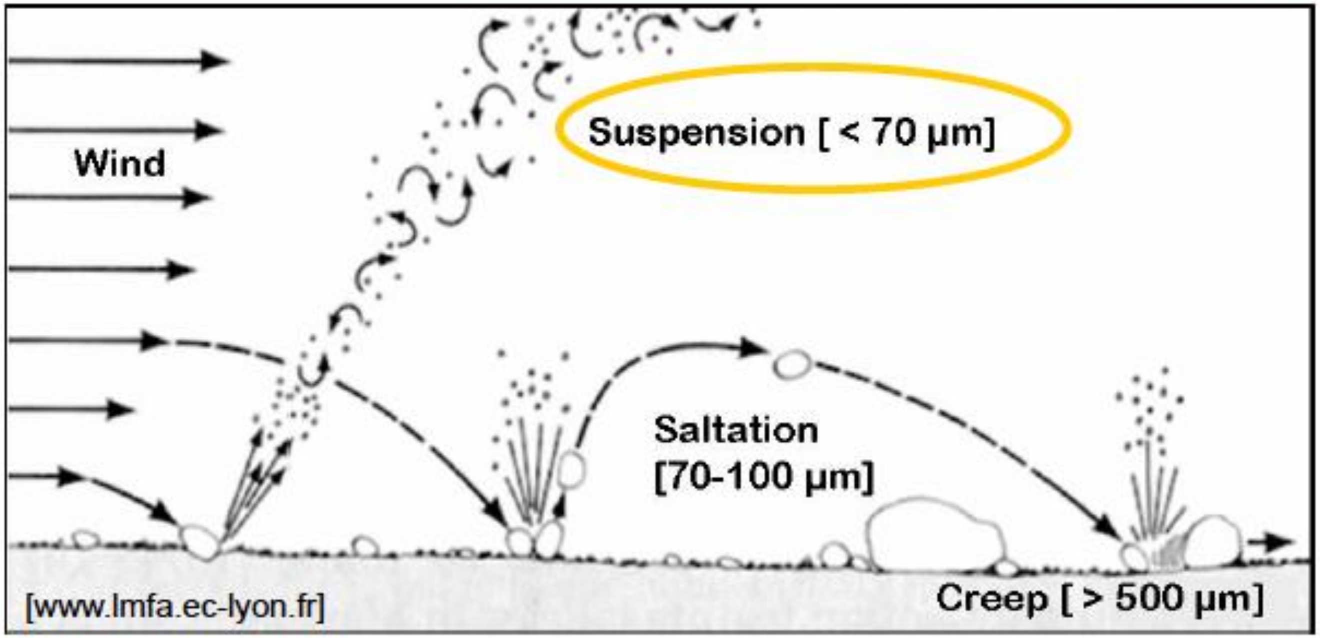
METEOROLOJİ

Atmospheric Dust Cycle



Dust in suspension, Mauritania

Dust Emission



Dust moves through several processes:

- By **saltation**(bouncing)

where small particles move forward through a series of jumps or skips, like a game of leap-frog.

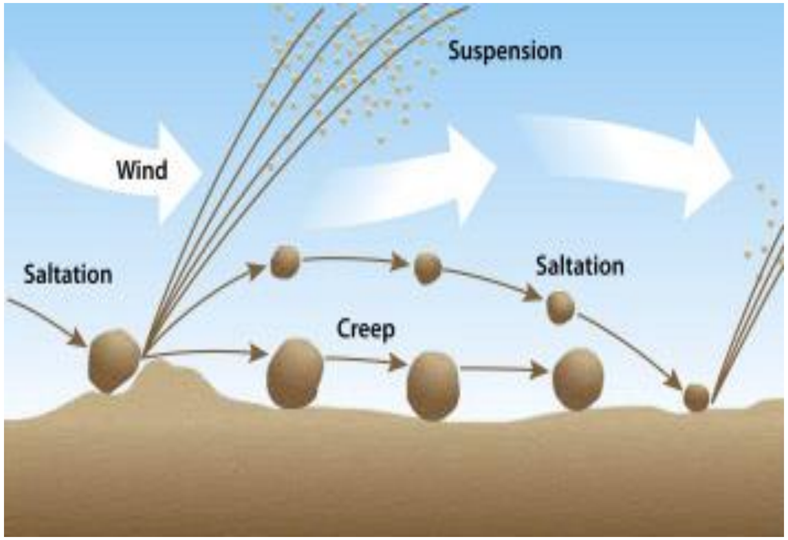
- By **creep**(rolling)

where sediment moves along the ground by rolling and sliding. Large particles and/or light winds favor creep.

- By **suspension**

where sediment materials are lifted into the air and held aloft by winds.

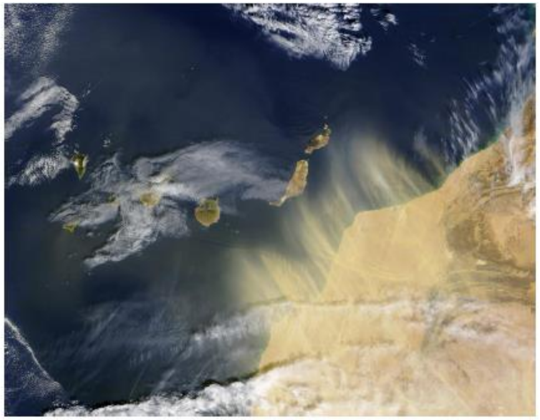
- Wind erosion begins with particle creep of large particles. Soon, saltation of sand particles begins.
- The latter two processes are integral to the formation of dust storms since they loft dust into the air.



Dust Cycle

dust uplift

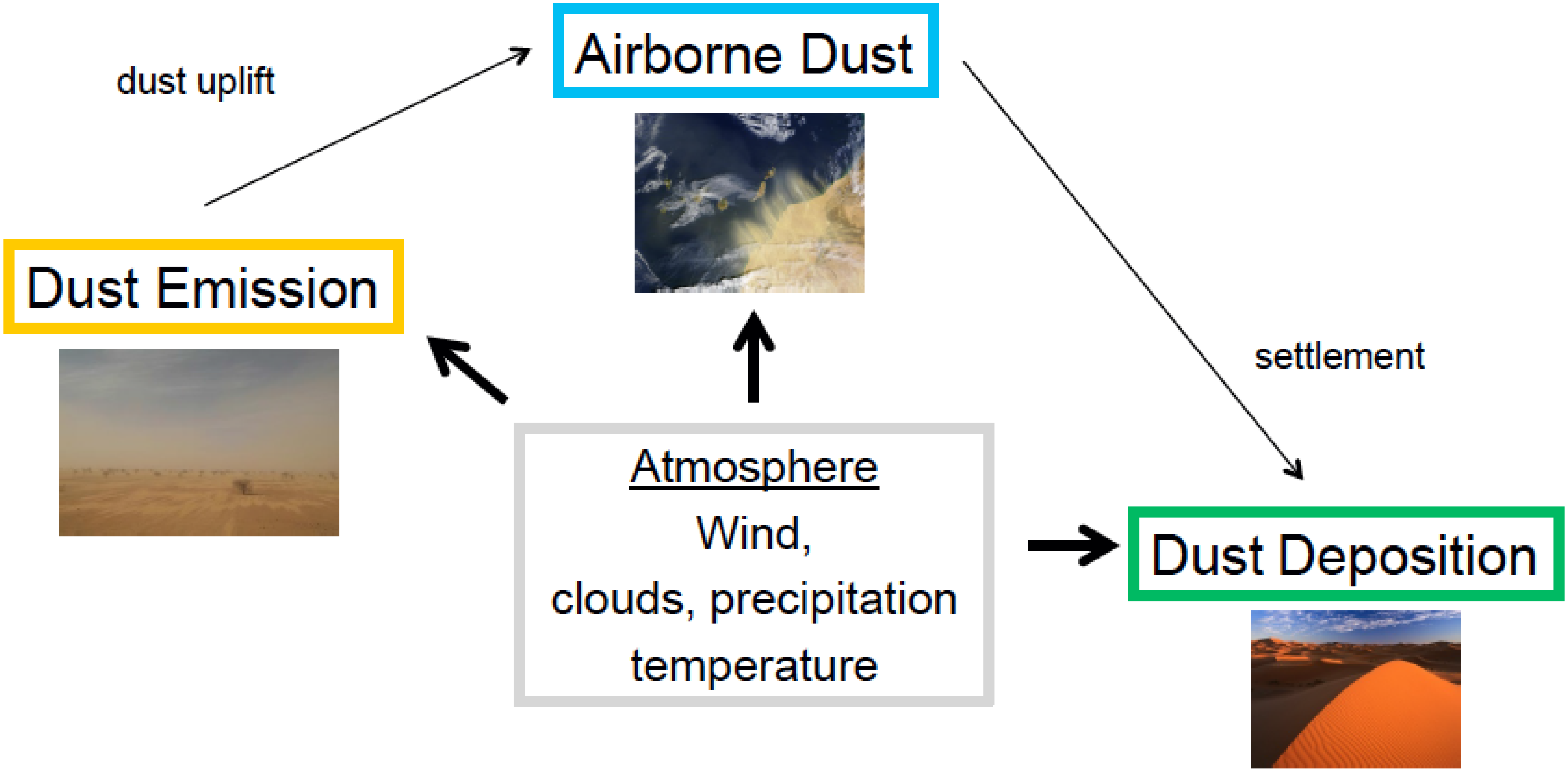
Airborne Dust



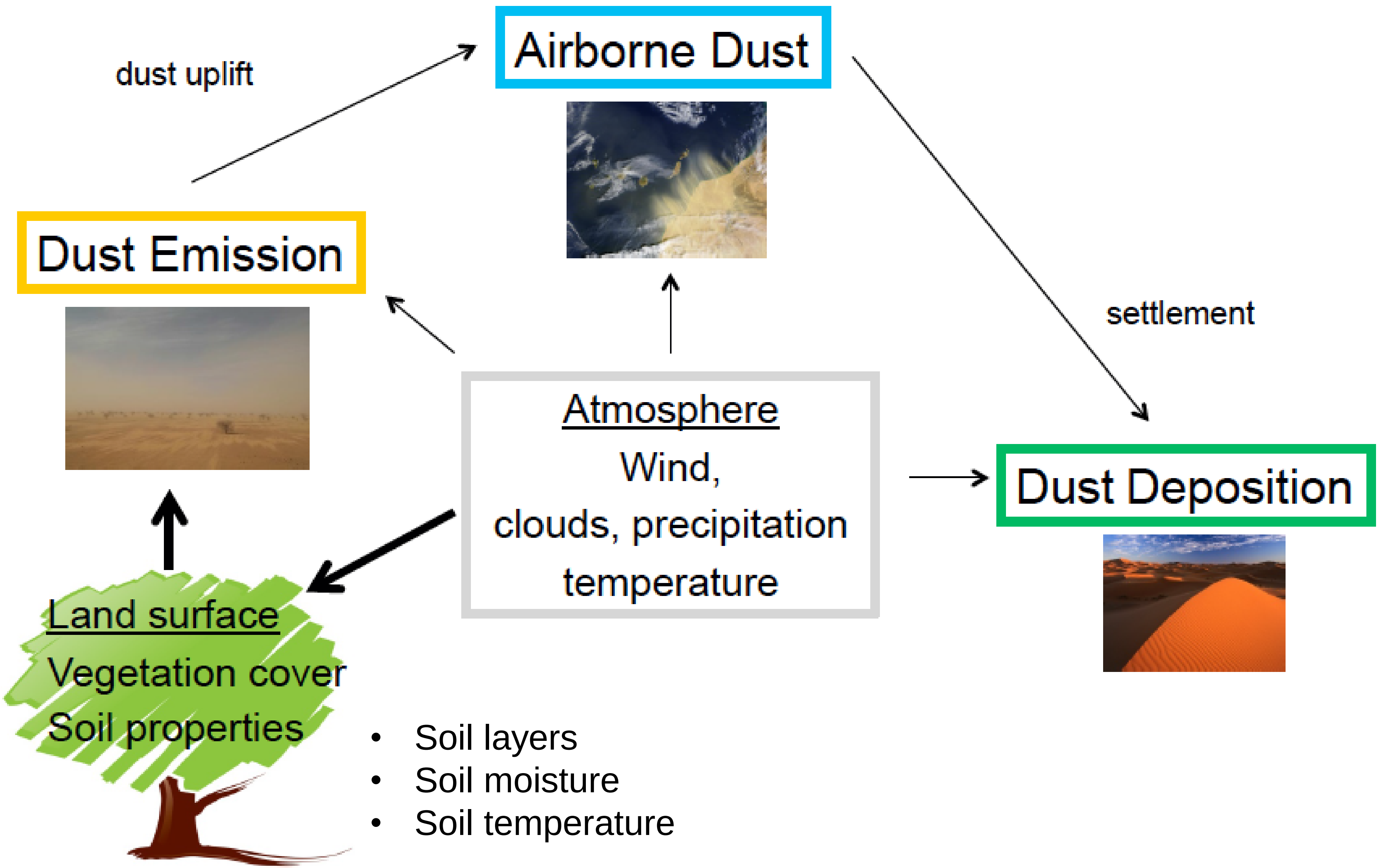
settlement

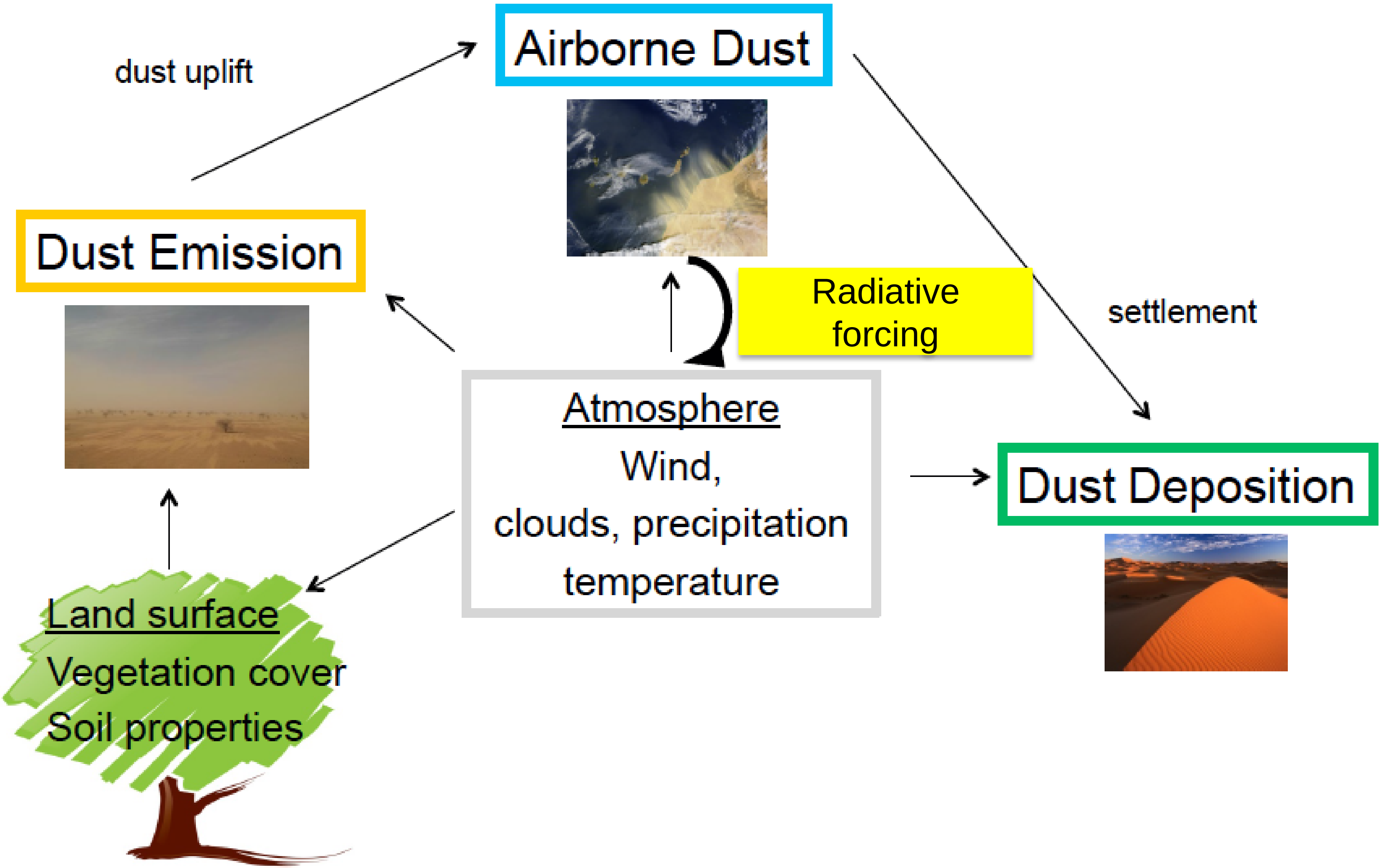
Dust Emission

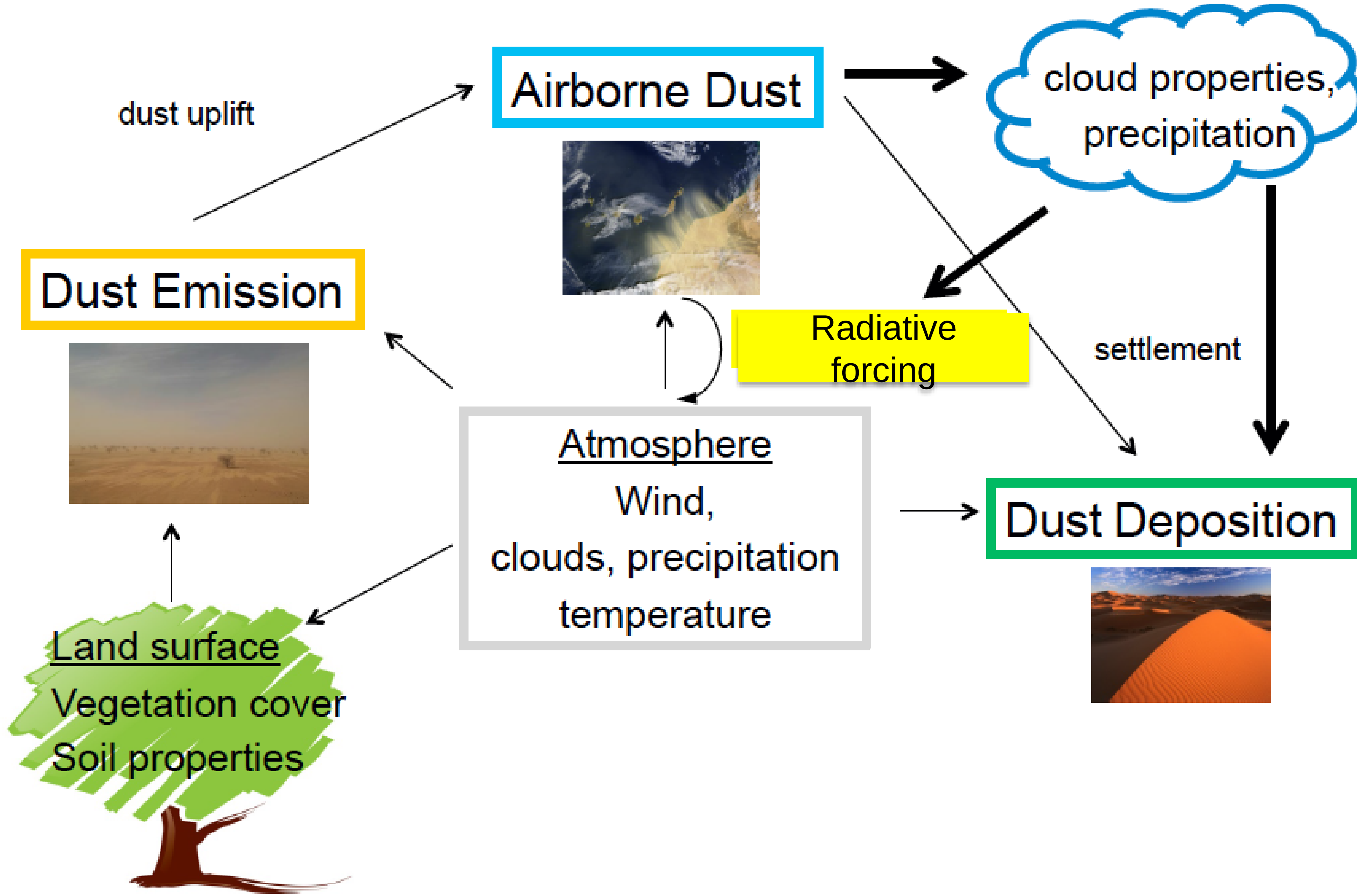
Dust Cycle



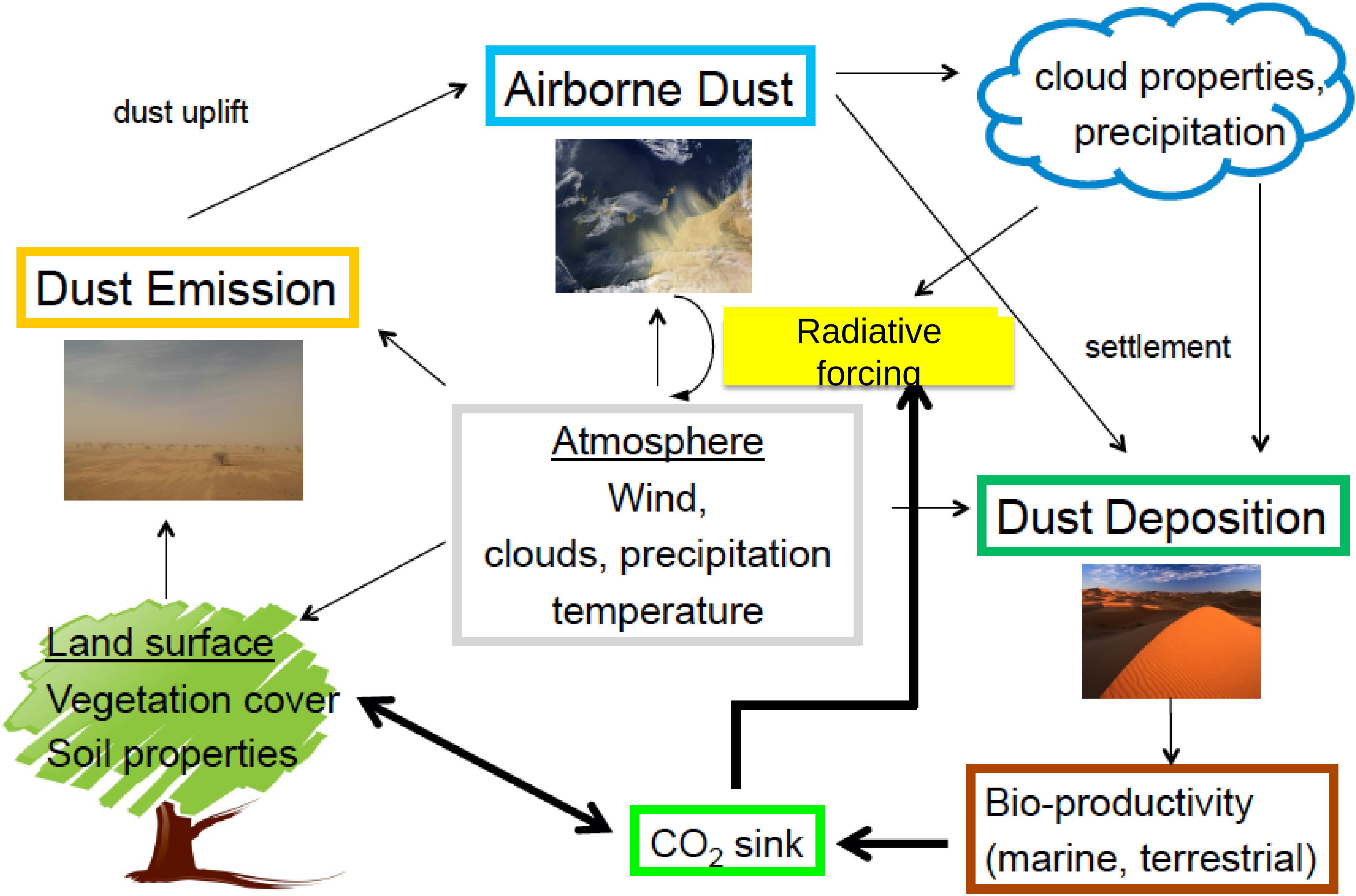
Most natural aerosol sources are controlled by climatic parameters like wind, moisture and temperature.


Airborne Dust
dust uplift
Dust Emission
settlement
Atmosphere
Wind,
clouds, precipitation
temperature
Dust Deposition
Land surface
Vegetation cover
Soil properties
• Soil layers
• Soil moisture
• Soil temperature


Airborne Dust
dust uplift
Dust Emission
Radiative forcing
settlement
Atmosphere
Wind,
clouds, precipitation
temperature
Dust Deposition
Land surface
Vegetation cover
Soil properties



Airborne Dust
cloud properties,
precipitation
dust uplift
Dust Emission
Radiative
forcing
settlement
Atmosphere
Wind,
clouds, precipitation
temperature
Dust Deposition
Land surface
Vegetation cover
Soil properties

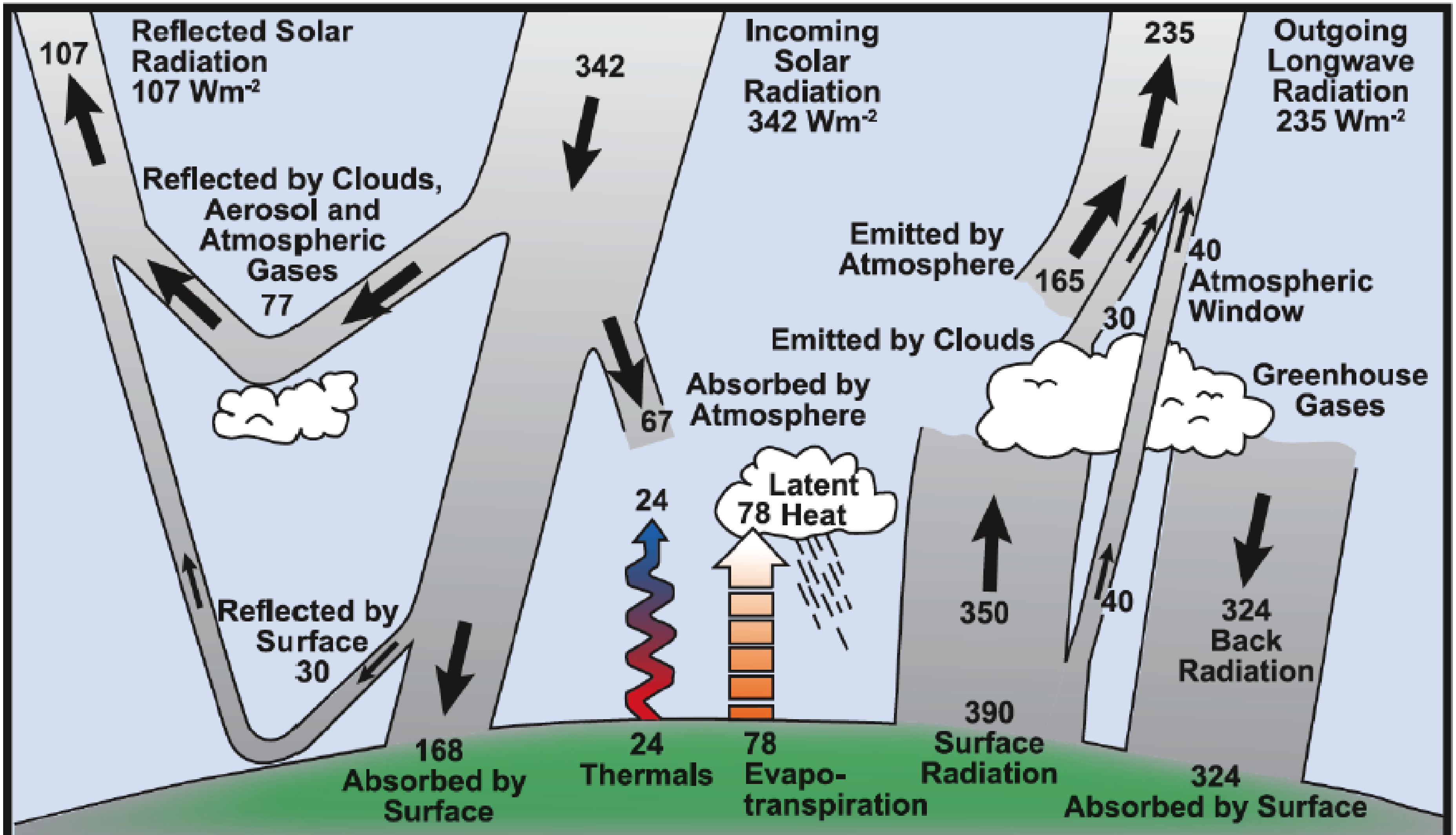


dust uplift
Airborne Dust
cloud properties,
precipitation
Dust Emission
Radiative forcing
settlement
Atmosphere
Wind,
clouds, precipitation
temperature
Dust Deposition
Land surface
Vegetation cover
Soil properties
CO_2 sink
Bio-productivity
(marine, terrestrial)

To understand the role of dust in climate change:

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

Energy Balance



IPCC report, 2007

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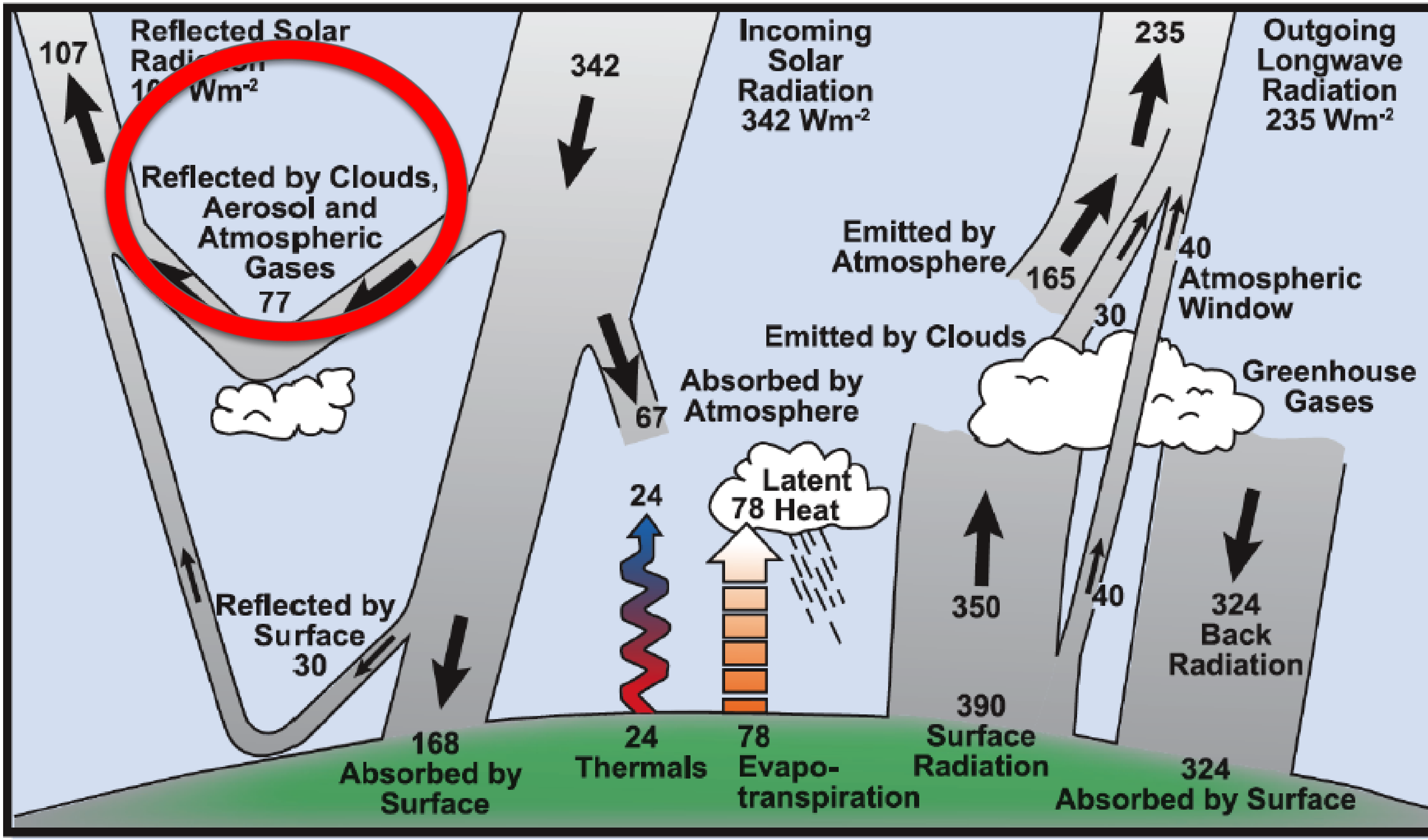
METEOROLOJİ

Energy Balance



IPCC report, 2007

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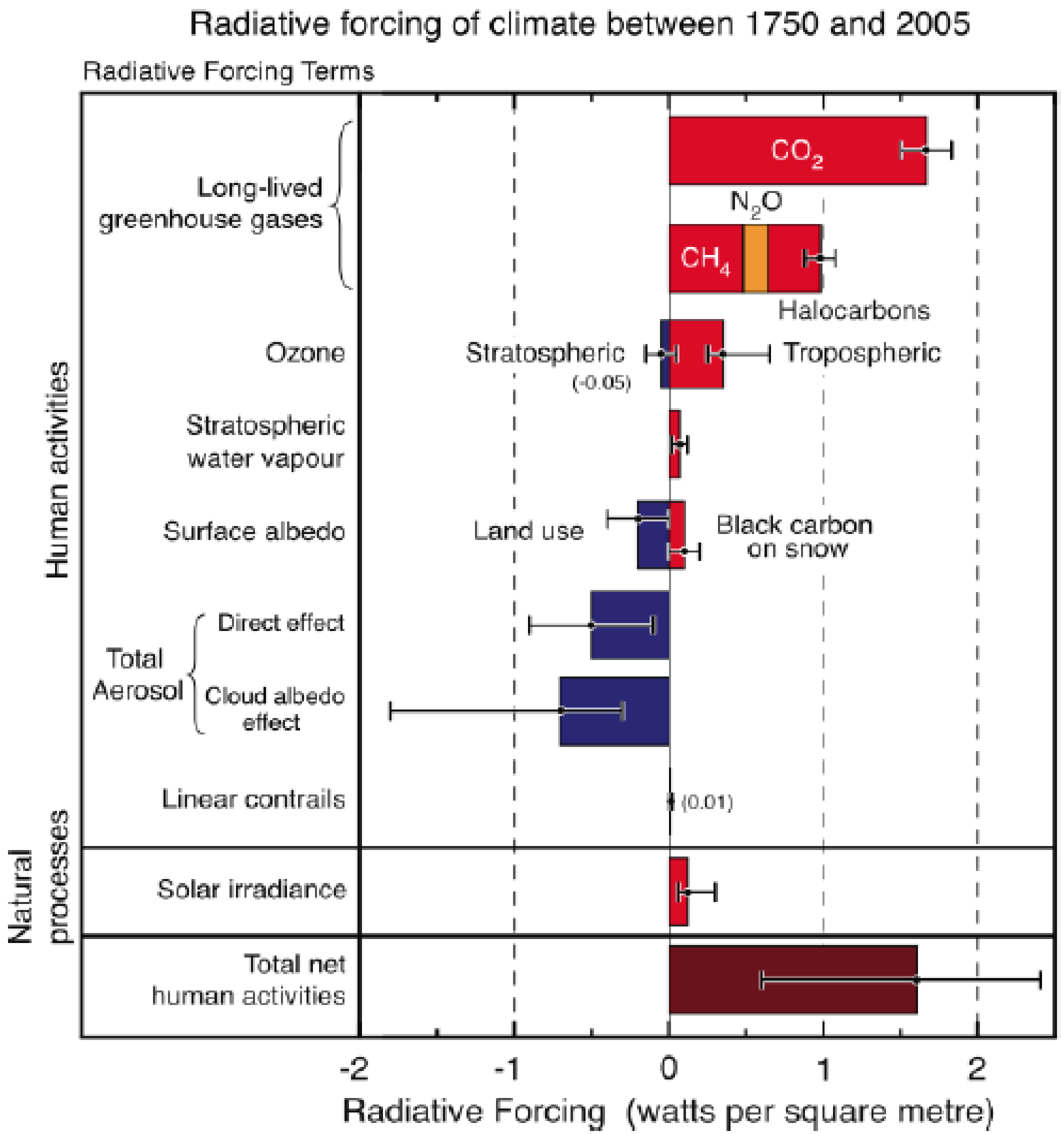
Radiative Forcing

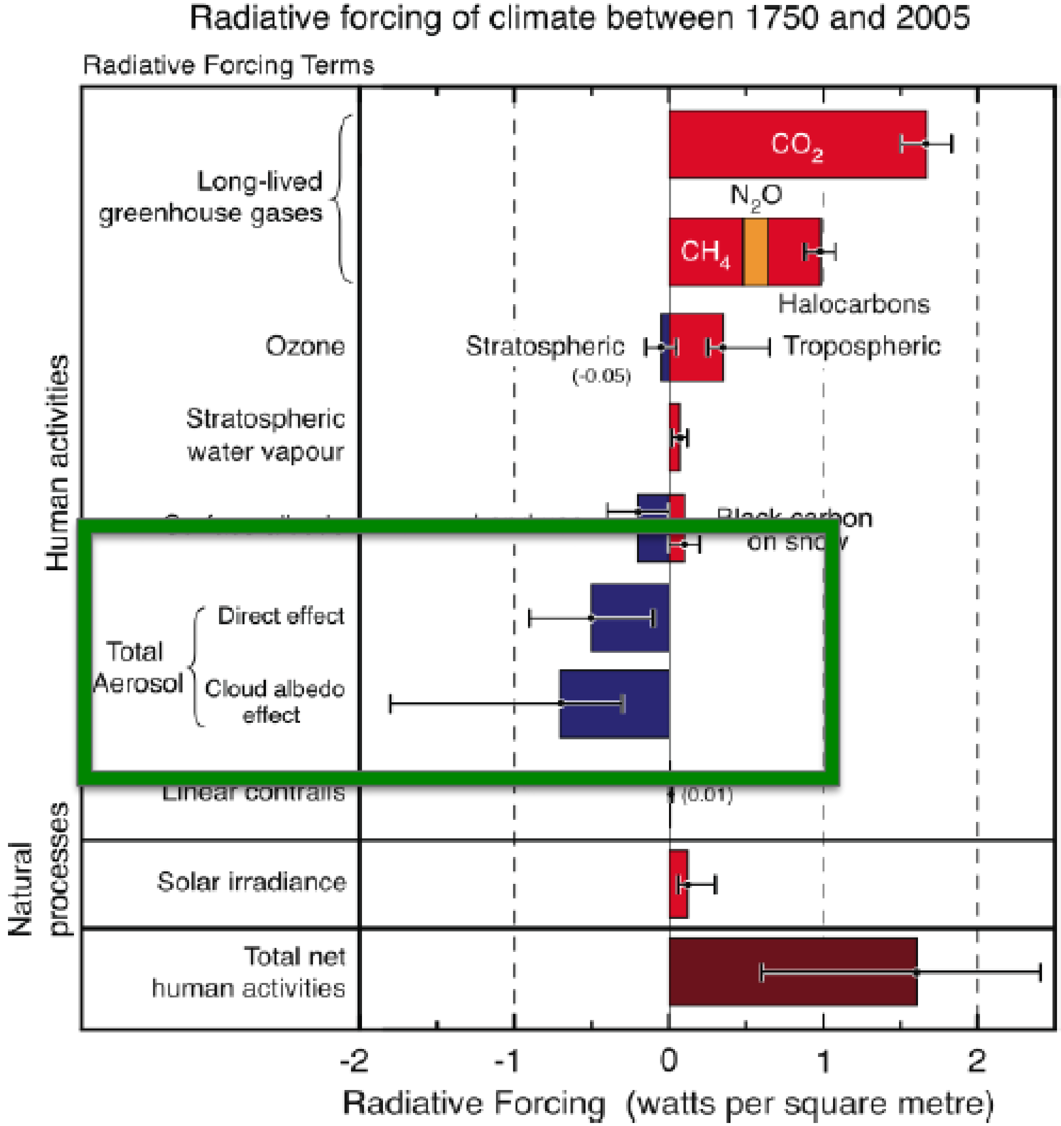
METEOROLOJİ



- ‘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

IPCC report, 2007

Radiative Forcing



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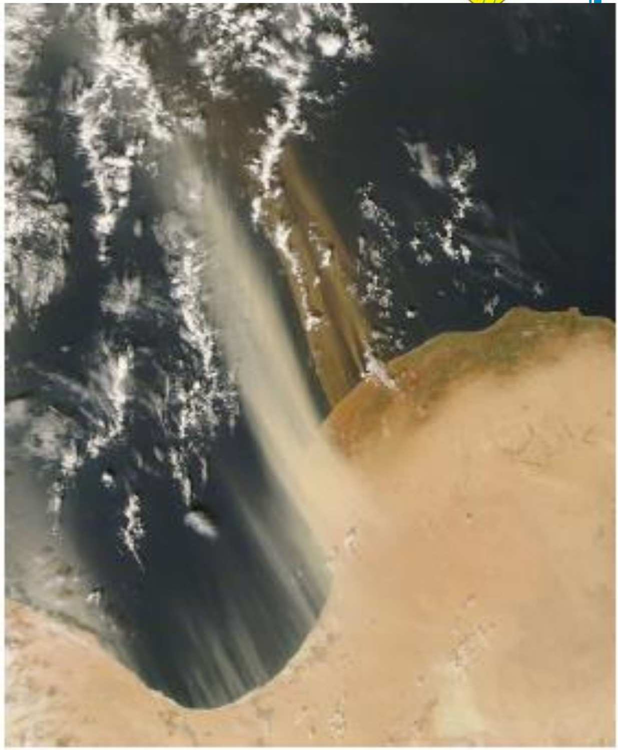
IPCC report, 2007

Dust Radiative Forcing

- 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** !

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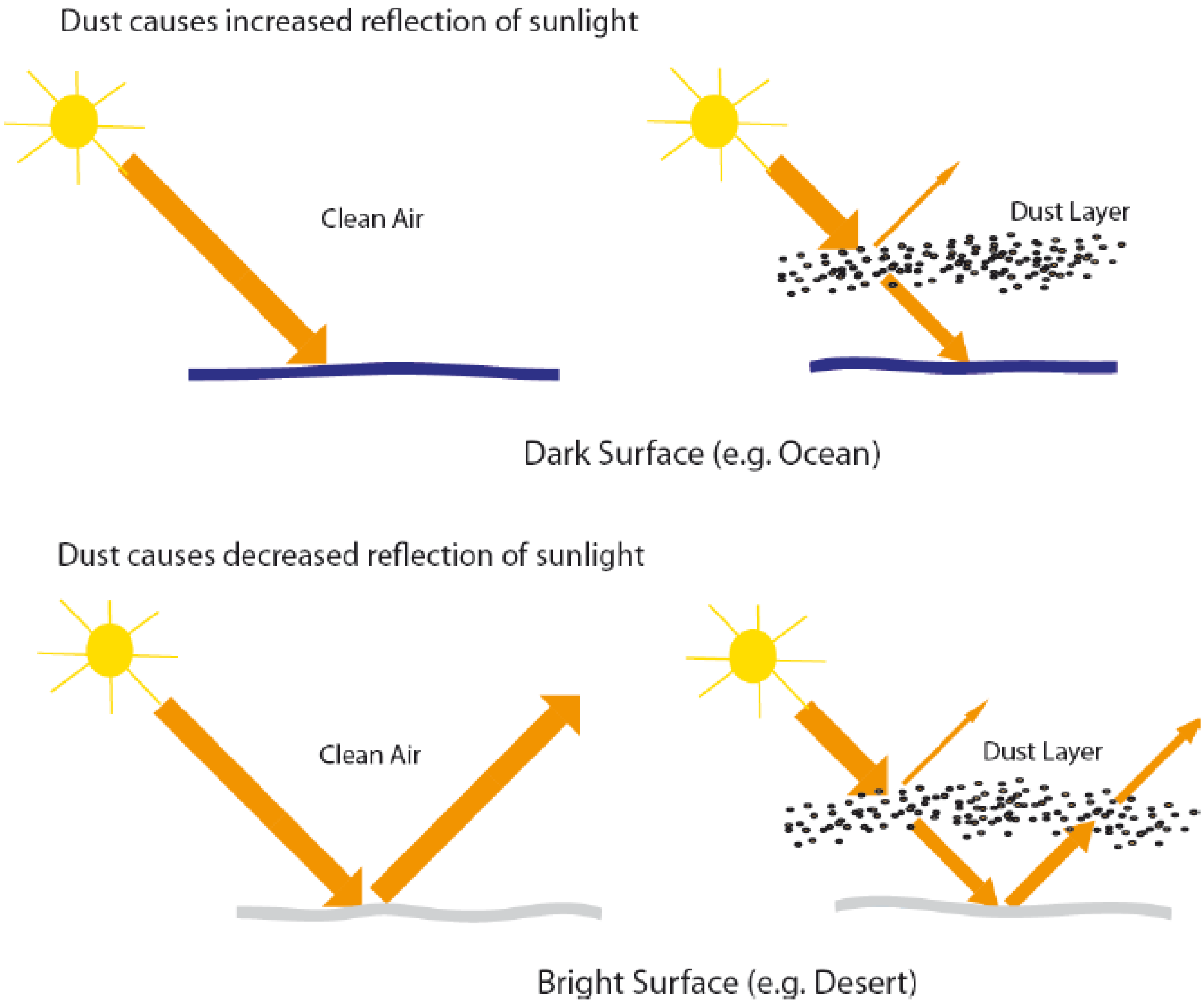
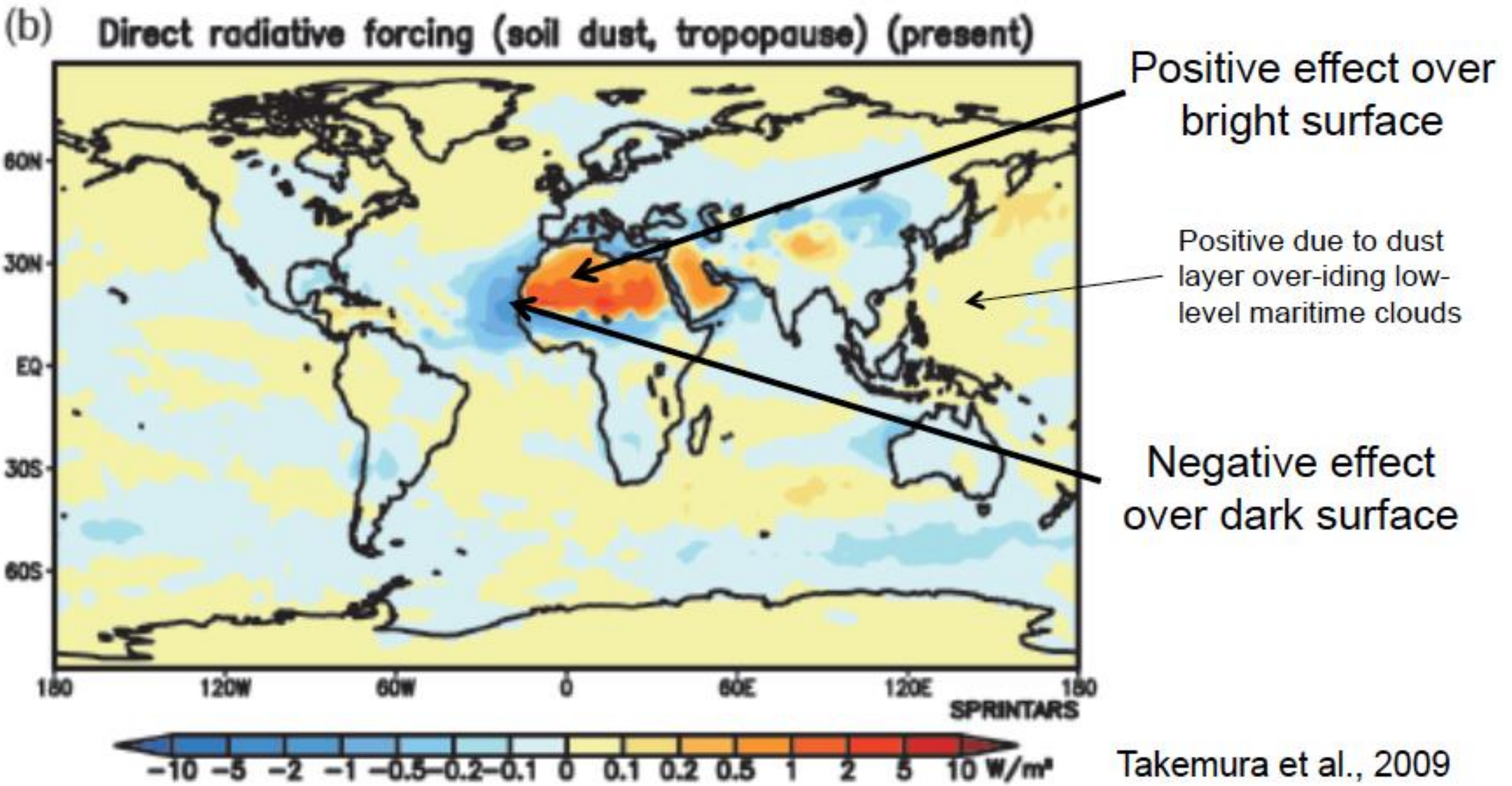
Direct Radiative Forcing



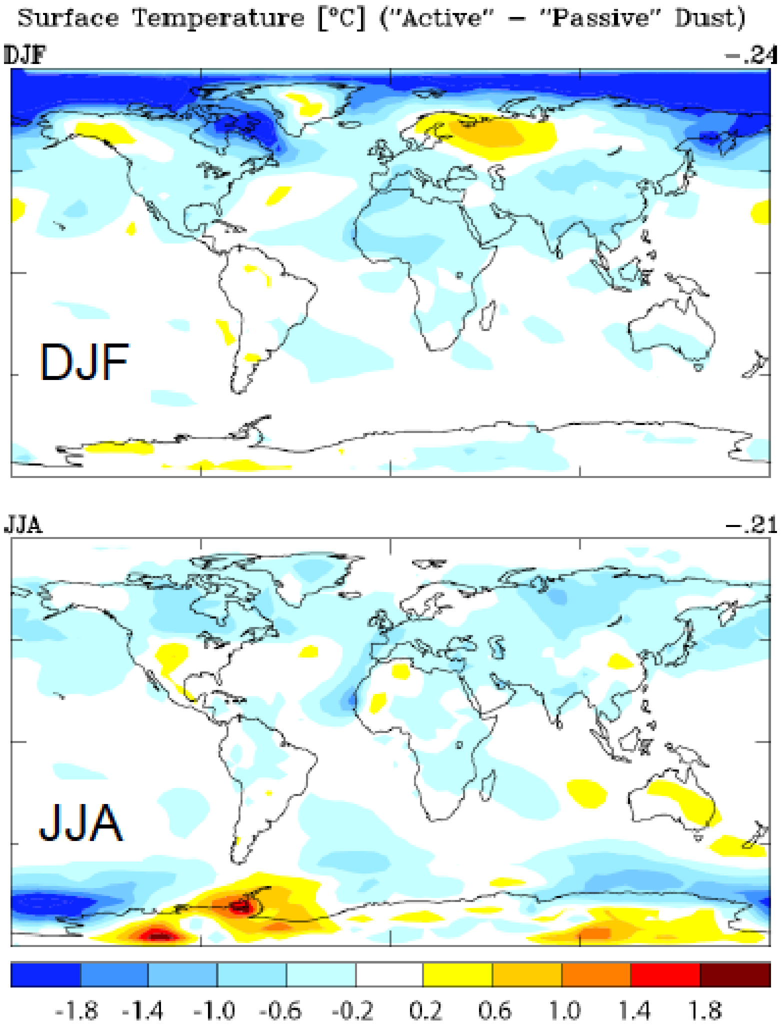
Dust Radiative Forcing



Takemura et al., 2009

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

Direct Radiative Forcing

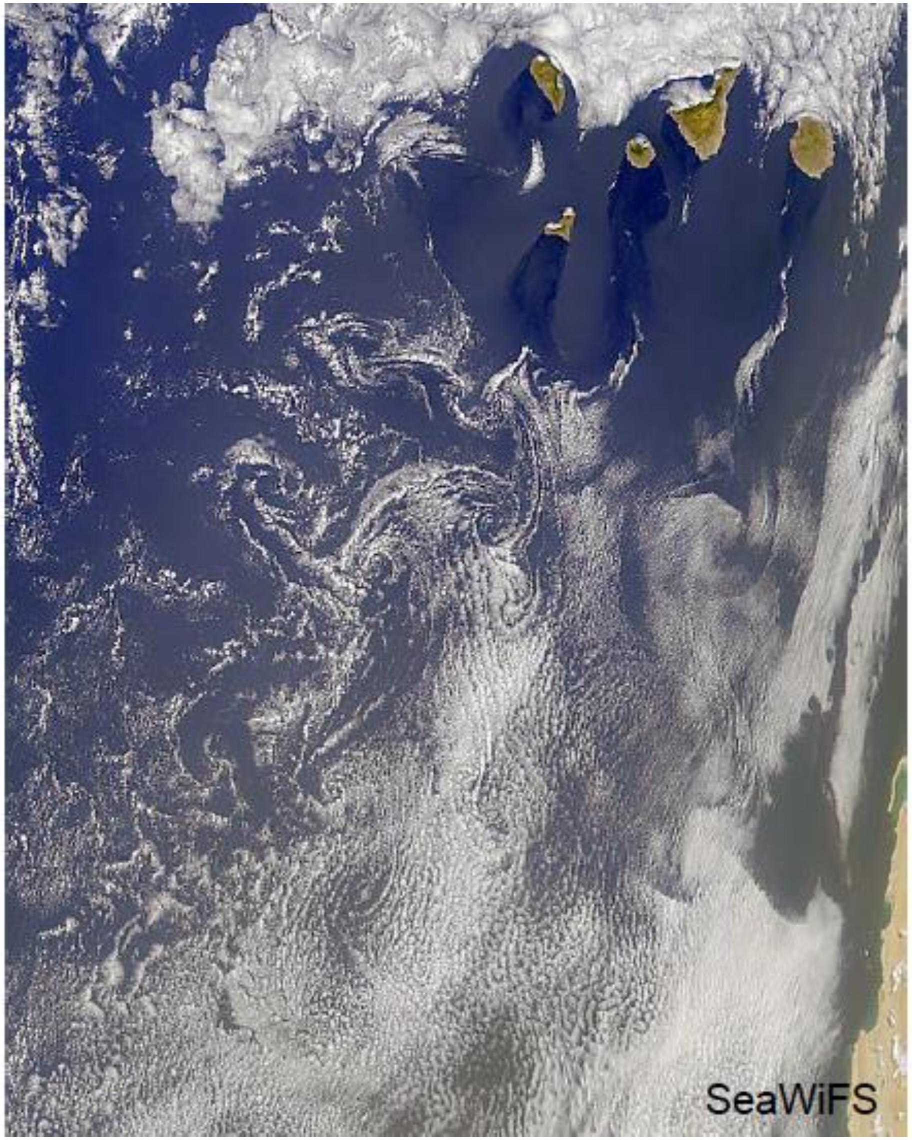


GISS model simulation, I. Tegen

- 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

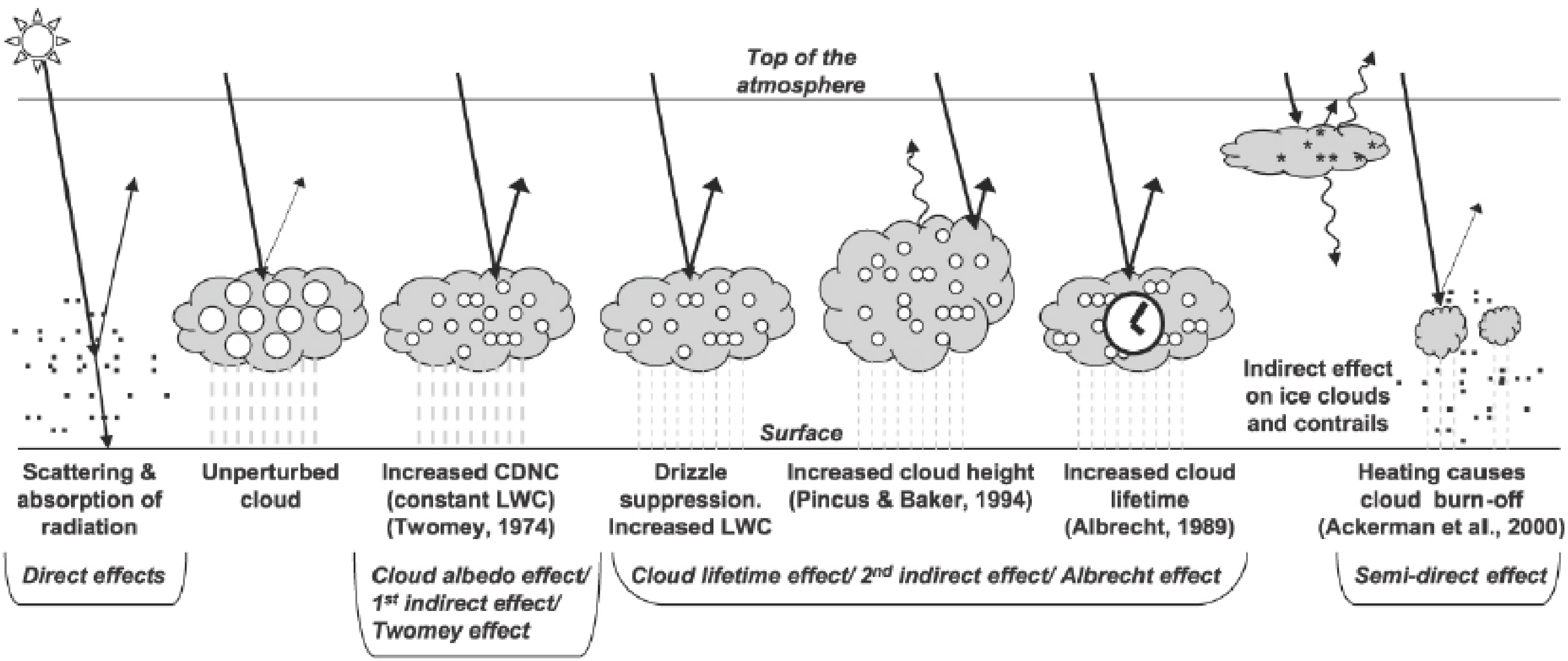
Indirect Dust Effect

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



Aerosol – Cloud Interactions

Indirect effect: aerosol-cloud effect

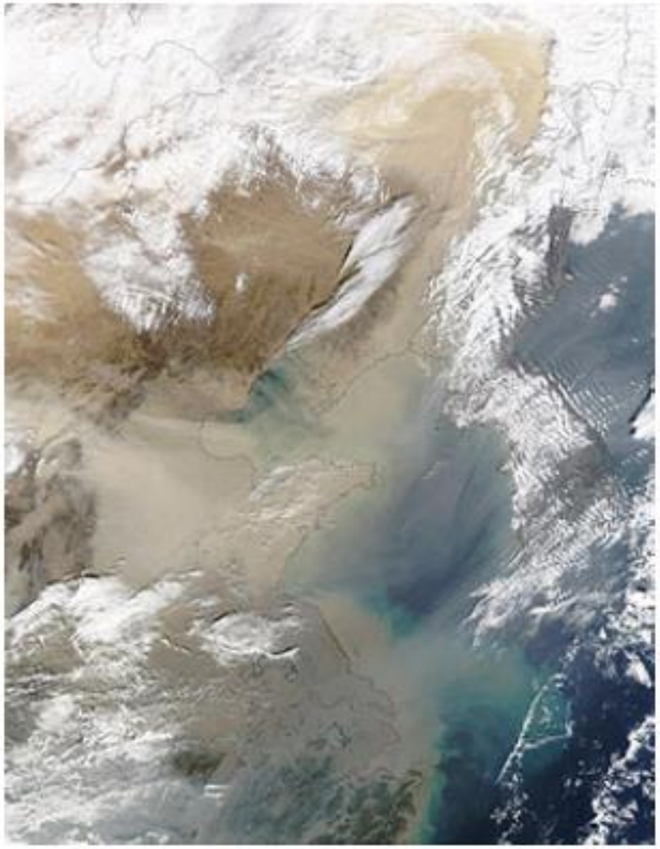


IPCC report, 2007

Dust Effect on Marine Ecosystem

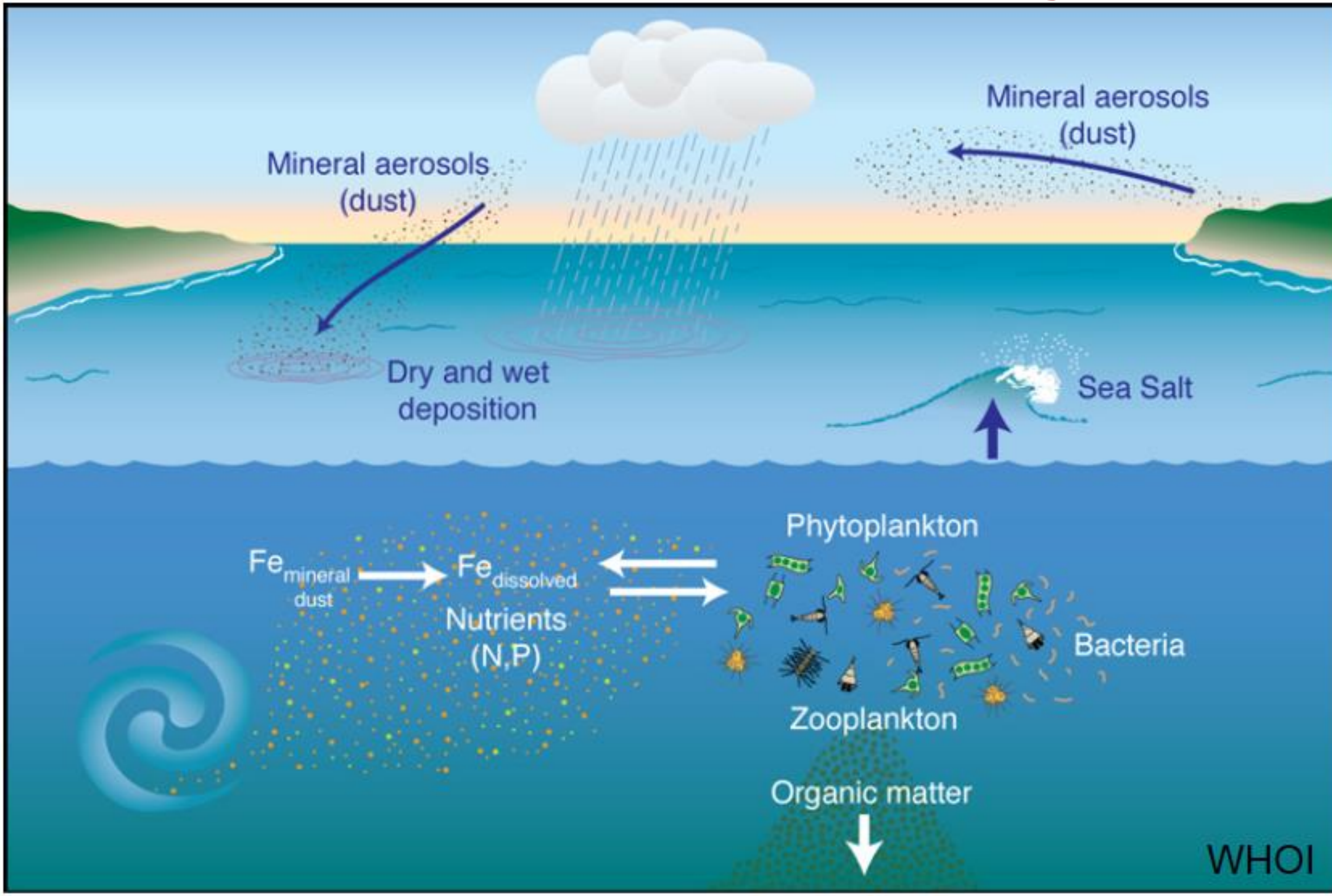
"Iron Hypothesis"

- 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 live 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 Co_2 uptake



NASA

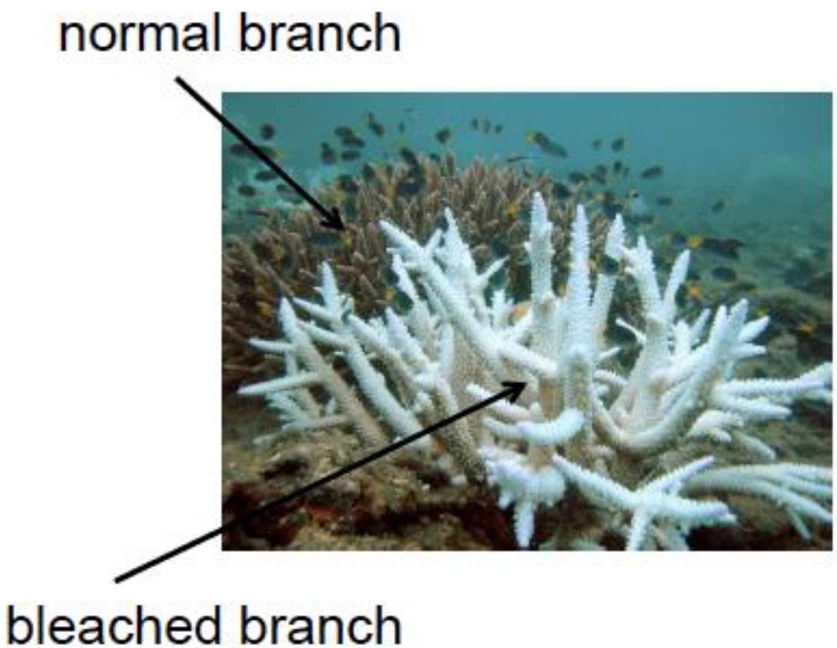
Dust Effect on Marine Ecosystem

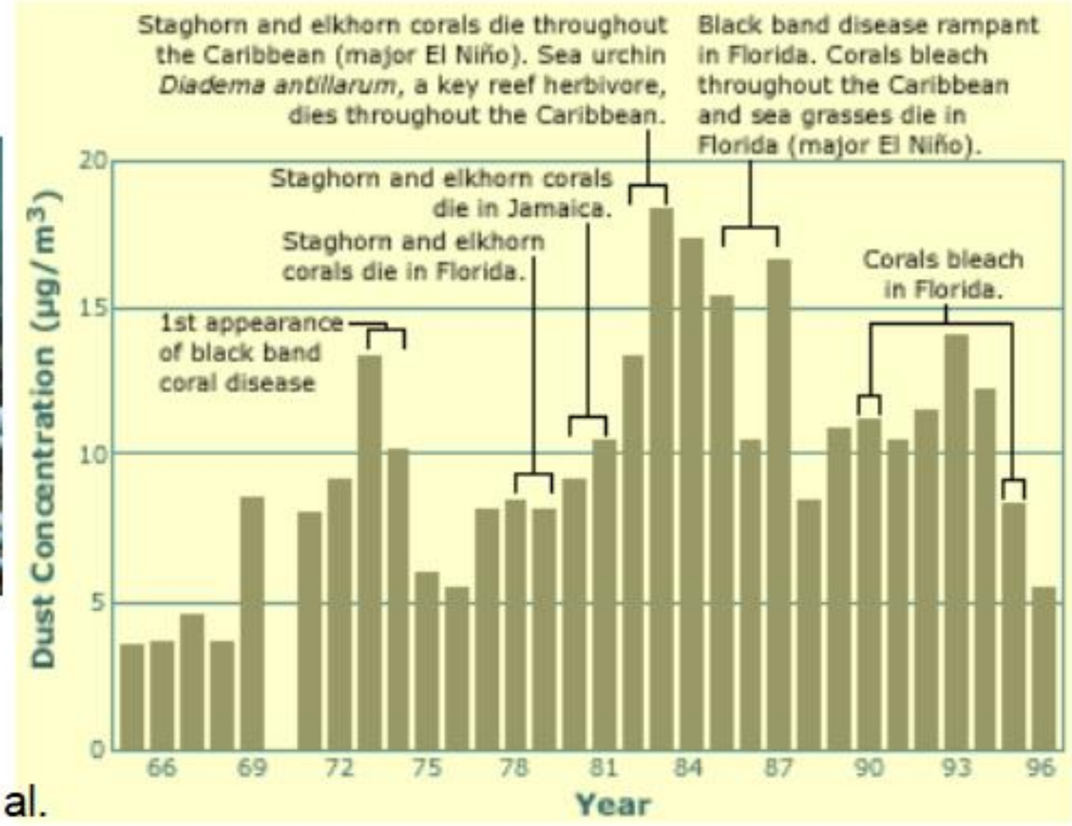


Coral Bleaching

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

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





http://earthobservatory.nasa.gov, Shinn et al.

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Dust-Climate Modeling

METEOROLOJİ

African dust was evaluated with 23 state-of-the-art global climate models used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

- found that all models fail to reproduce basic aspects of dust emission and transport over the second half of the 20th century.

- The models systematically underestimate dust emission, transport, and optical depth, and year-to-year changes in these properties

(Evan et al 2015)

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Summary

- 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.

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Future Work

- laboratory experiments of mineral dust optical properties
- modeling analyses of mineral dust optical properties

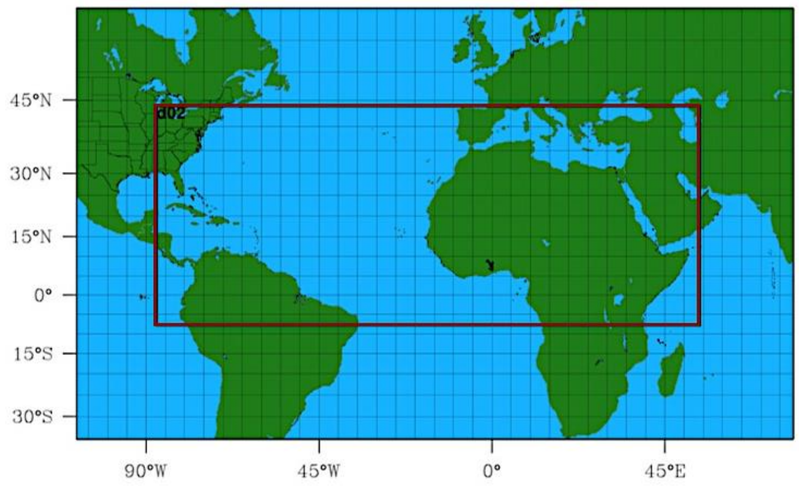
  >>>significantly improve our understanding of the impact of mineral dust aerosol on global climate

- chemistry

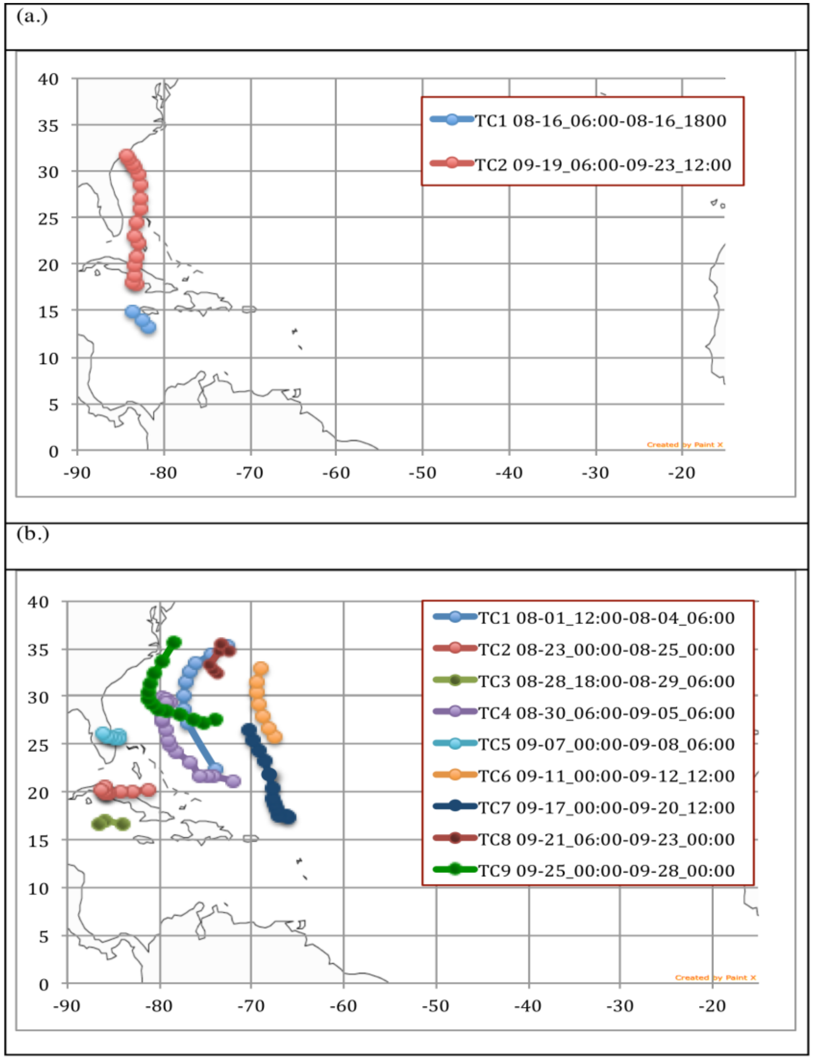
  >>>the impact that chemistry has on cloud formation including the cloud condensation and ice nuclei activity of mineral dust aerosol.

Numerical Experiment - WRF

- The 2007 hurricane season was chosen for the study because of its normal activity.
- For WRF dust simulations, the model integrates from June 25 to October 1
- Two domains with two-way interaction are configured.
- The model spatial resolutions are 36 km and 12 km for domain 1 and 2, respectively.
- Two numerical experiments are conducted. The dust short-wave radiation interaction is activated in one simulation (called ON) and is deactived on the other (called OFF).



Hurricane Tracking Results over Atlantic



Hurricane tracks for the (a) OFF and (b) ON experiment .

Starting and ending times of each storm (Month-Day-Time) are also provided.

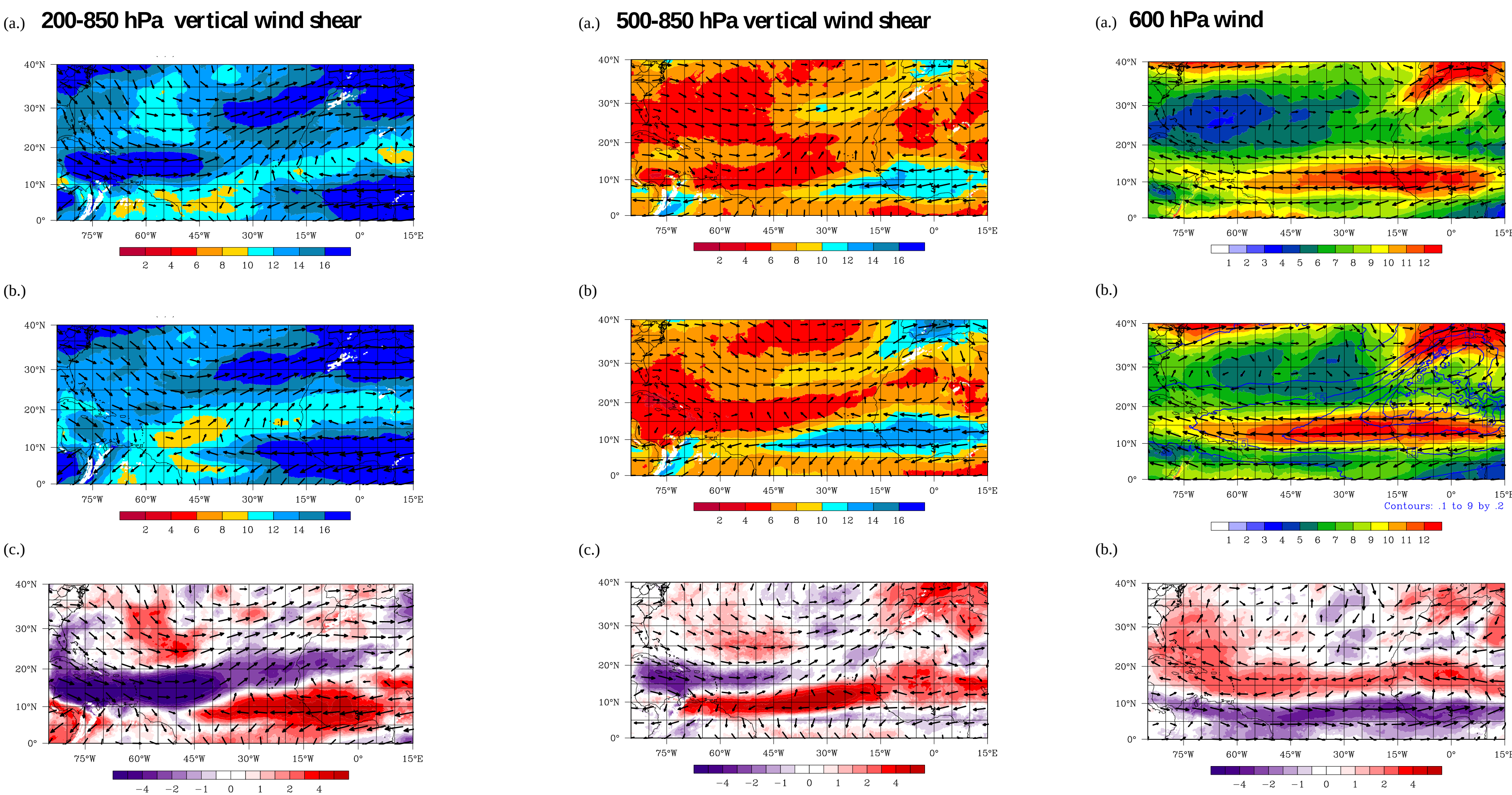
Results

	ON		OFF	
	200-850 hPa Shear (m/s)	500-850 hPa Shear (m/s)	200-850 hPa Shear (m/s)	500-850 hPa Shear (m/s)
July	12.19	6.93	13.16	5.65
August	10.85	6.67	13.61	6.10
September	12.22	5.26	19.48	6.58
Average	11.75	6.29	15.42	6.11

Monthly and three month average shear values from July to September for both ON and OFF experiment over MDR

- 9 TCs formed in the ON experiment, while only 2 TCs formed in the OFF experiment through July to September.
- The results show that for a normal year the dust-radiation interaction reduces vertical wind shear over West Atlantic and thus increases the TC development over region, which is more comparable to observations.

Results



Three month average values (July-September 2007) with AOD contours and wind shear vectors from(a) OFF, (b) ON, and (c) difference of two experiments (ON-OFF).


Thank you
☺
QUESTIONS
???
A massive sandstorm blowing off the northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand. The massive nature of this particular storm was first seen in this SeaWiFS image acquired on Saturday, 26 February 2000 when it reached over 1000 miles into the Atlantic. These storms and the rising warm air can lift dust 15,000 feet or so above the African deserts and then out across the Atlantic, many times reaching as far as the Caribbean where they often require the local weather services to issue air pollution alerts as was recently the case in San Juan, Puerto Rico. Recent studies by the U.S.G.S.(http://catbert.er.usgs.gov/african_dust/) have linked the decline of the coral reefs in the Caribbean to the increasing frequency and intensity of Saharan Dust events. Additionally, other studies suggest that Sahalian Dust may play a role in determining the frequency and intensity of hurricanes formed in the eastern Atlantic Ocean (http://www.thirdworld.org/role.html)
Provided by the SeaWiFS Project, NASA/GSFC and ORBIMAGE