Philipps Universität Marburg

Causes and Consequences of Sand & Dust Storms (SDS) – Experiences from Central Asia and Other Regions

Christian Opp[1],

[1]Faculty of Geography, University of Marburg, Germany

NaDiMa Dialogue #3 Droughts, Sand & Dust Storms: Challenges and Management

September 23, 2020

Outline

1. Basics of SDS (Research History)
   Causes / Prerequisites and Origin of SDS

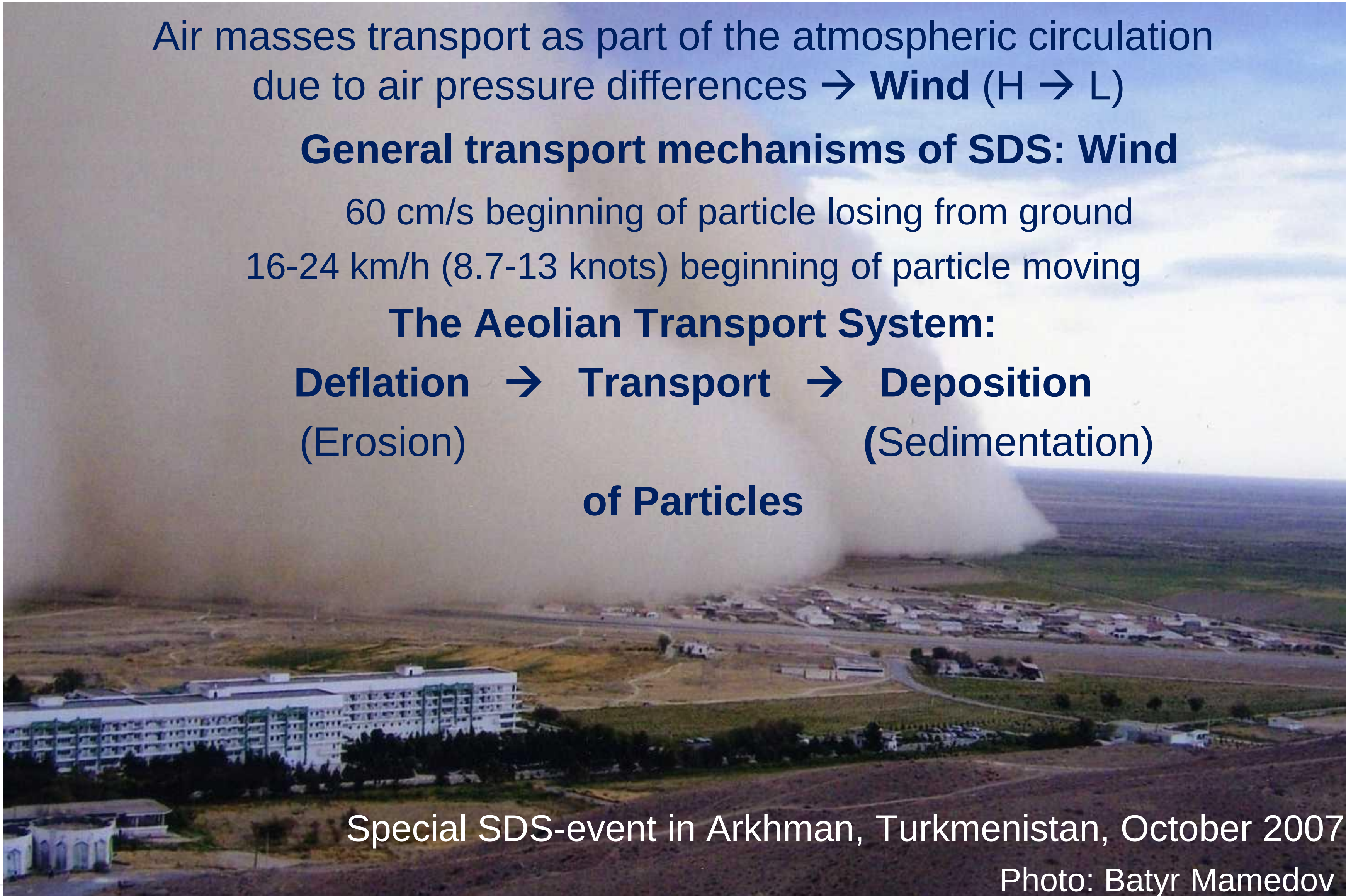
With Examples from Central Asia (Kazakhstan, Uzbekistan, Turkmenistan), Australia, Germany China, and other regions

2. Different Effects of SDS

3. Economic Impacts of SDS

4. Consequences for Mitigation and Hazard Reduction

Causes / Prerequisites of SDS in the Atmosphere: Wind



Air masses transport as part of the atmospheric circulation due to air pressure differences → **Wind** (H → L)

General transport mechanisms of SDS: Wind

60 cm/s beginning of particle losing from ground

16-24 km/h (8.7-13 knots) beginning of particle moving

The Aeolian Transport System:

Deflation → Transport → Deposition

(Erosion) (Sedimentation)

of Particles

Special SDS-event in Arkhman, Turkmenistan, October 2007

Photo: Batyr Mamedov

Causes / Prerequisites of SDS: <u>Lose Particles on the Surface</u>

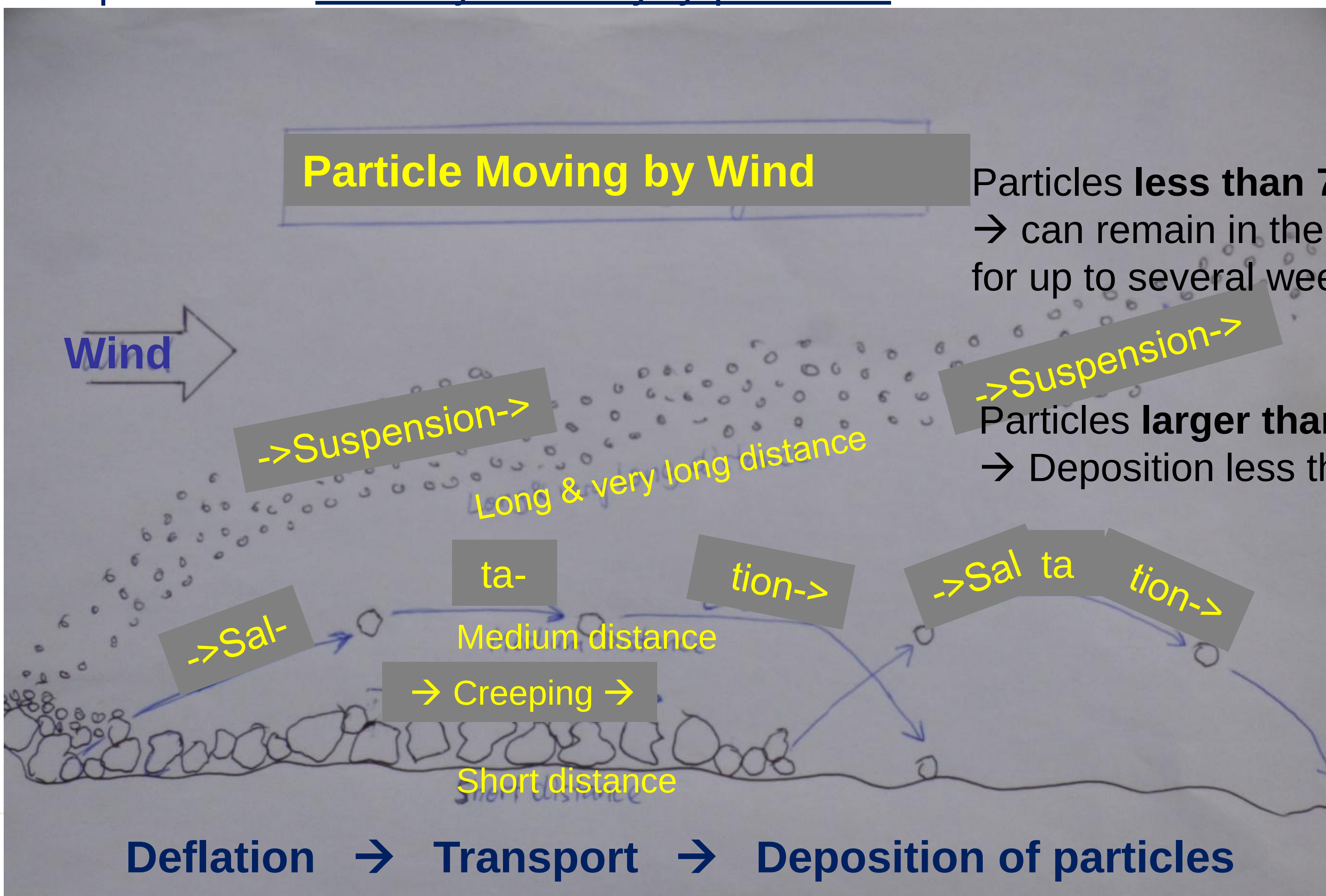
The difference: **Sand** Transport or/and **Dust** Transport

Short distance sand transport by wind

Creeping and saltation of coarse, mostly sandy particles

Long distance dust transport by wind (atmospheric circulation)

Suspension of fine silty and clayey particles in the air



Particles **less than 70µm**
→ can remain in the atmosphere for up to several weeks

Particles **larger than 70µm**
→ Deposition less than one day

Causes / Prerequisites of SDS on the Soil Surface

Soil surfaces can be **sources (areas of deflation = wind erosion)** and **sinks (areas of deposition = sedimentation)** of SDS

in dependence on their location and disposition

Source areas: soil surface features (disposition of the surface to the wind)

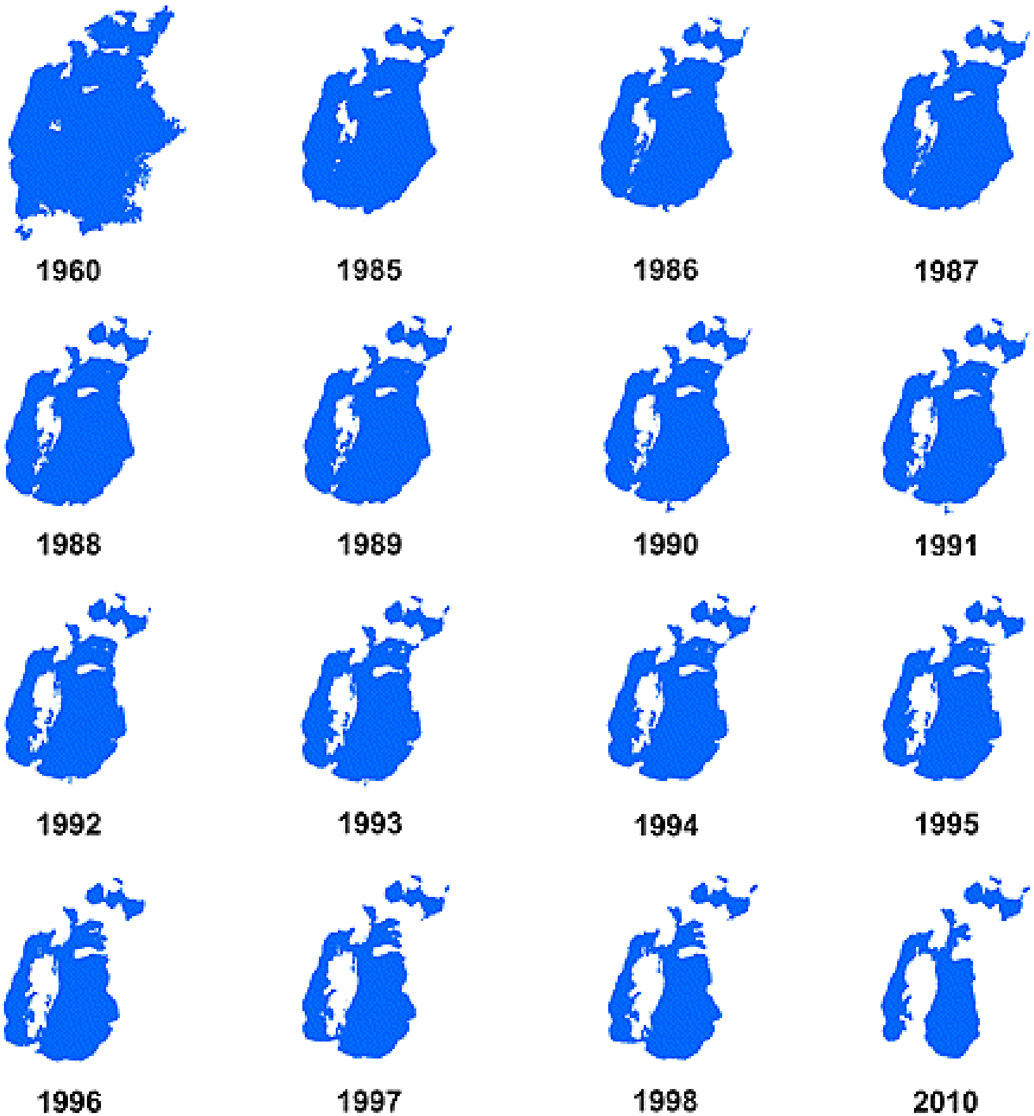
- autochthonous (on-site) and allochthonous (from off-site) weathered, **lose particles** (clay, silt, sand), which are able to be transported by wind

The following surface features support the deflation process:

- (large) wind-open areas (e.g. coasts, lakes, treeless areas, open pit mines)
- drought / dryness (very low soil moisture) of the upper soil or sediment layer
- low degree of coverage by biological crusts
- low degree of coverage by vegetation
- loosening of the soil structure of agricultural used land by tillage or trampling

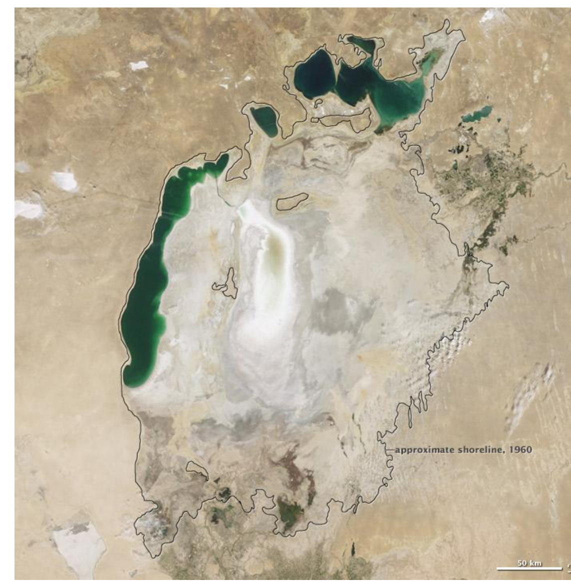
Source Areas of SDS on Dryed Lake Surfaces

„Disappearing“ of the Aral Sea



Ressl (1999)

from Aral Sea (sink area) to Aral Kum (source area)



September 2009

from a sink to a source of salts

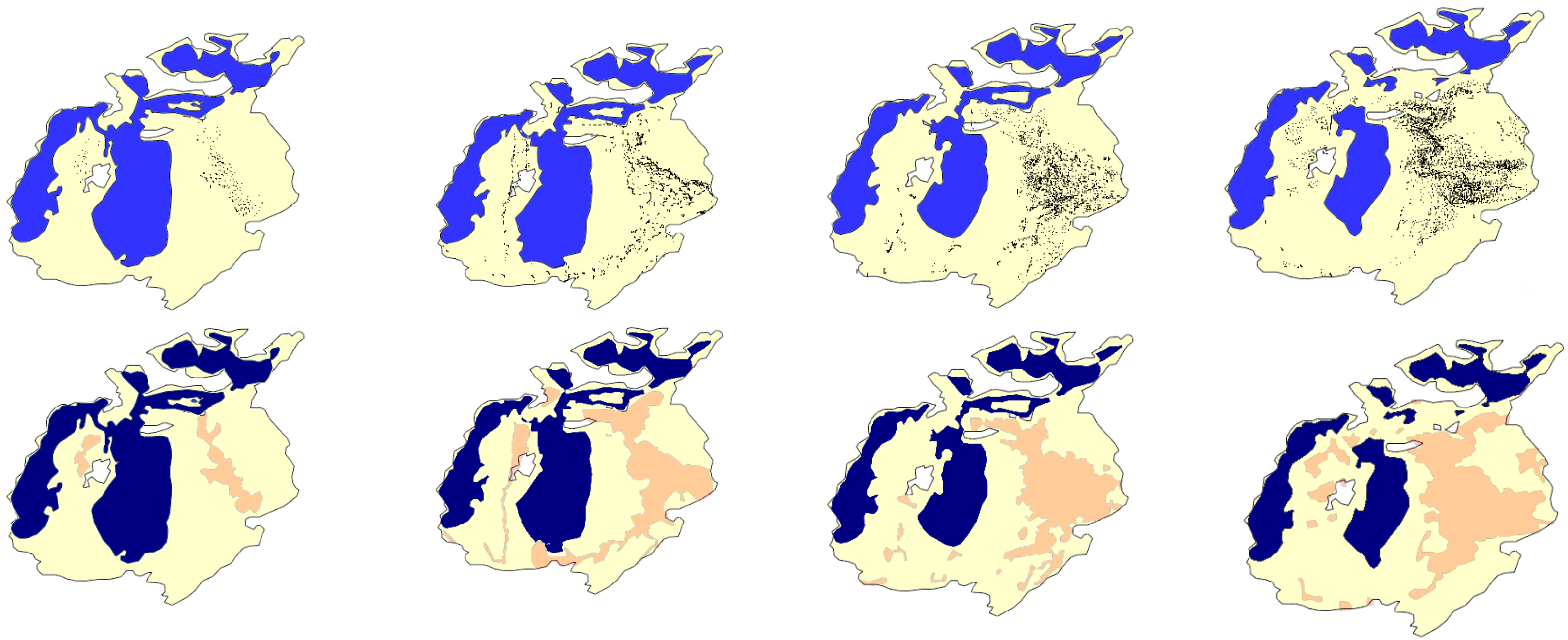
http://visibleearth.nasa.gov/data

Causes / Prerequisites of SDS on Dryed Lake Surfaces

CALTER

CALTER

Detection of Dust Storms (above) and Deflation Areas (below)
Around the Aral Sea



2005 2006 2007 2008

after Batirbaeva & Vitkovskaya (2008)

Origin of Dust in the Atmosphere

Natural origin: (90%)

Low precipitation areas

Wind (blown soil) erosion areas

Volcanic ashes

Dry lake and river bed sediments

Glacial and periglacial sediments

Forest and grassland fires

Marine terraces

Sea spray

Human activity: (10%)

Burning of fossil fuels

Alteration of surface cover

Industrial sites

Slashed and burned agricultural areas

Overgrazed grassland

Open pit mines

Main dust producing areas

Low sparse grasslands

Baren deserts

Sand Deserts

Semi-Deserts

Polar and alpine Deserts

Salt Playas, Sabkhas

Sparse dunes and ridges NASA.gov

Other Sources of Dust in the Atmosphere

Volcanic ashes

Topsoil erosion

Biomass burning

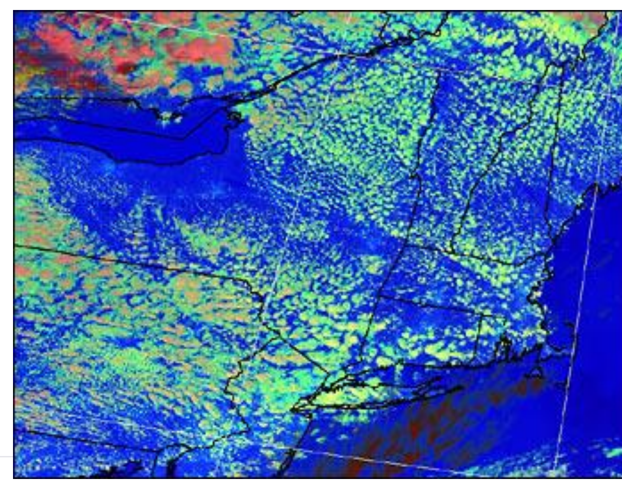

near Eagle, Alaska

August 8, 2005

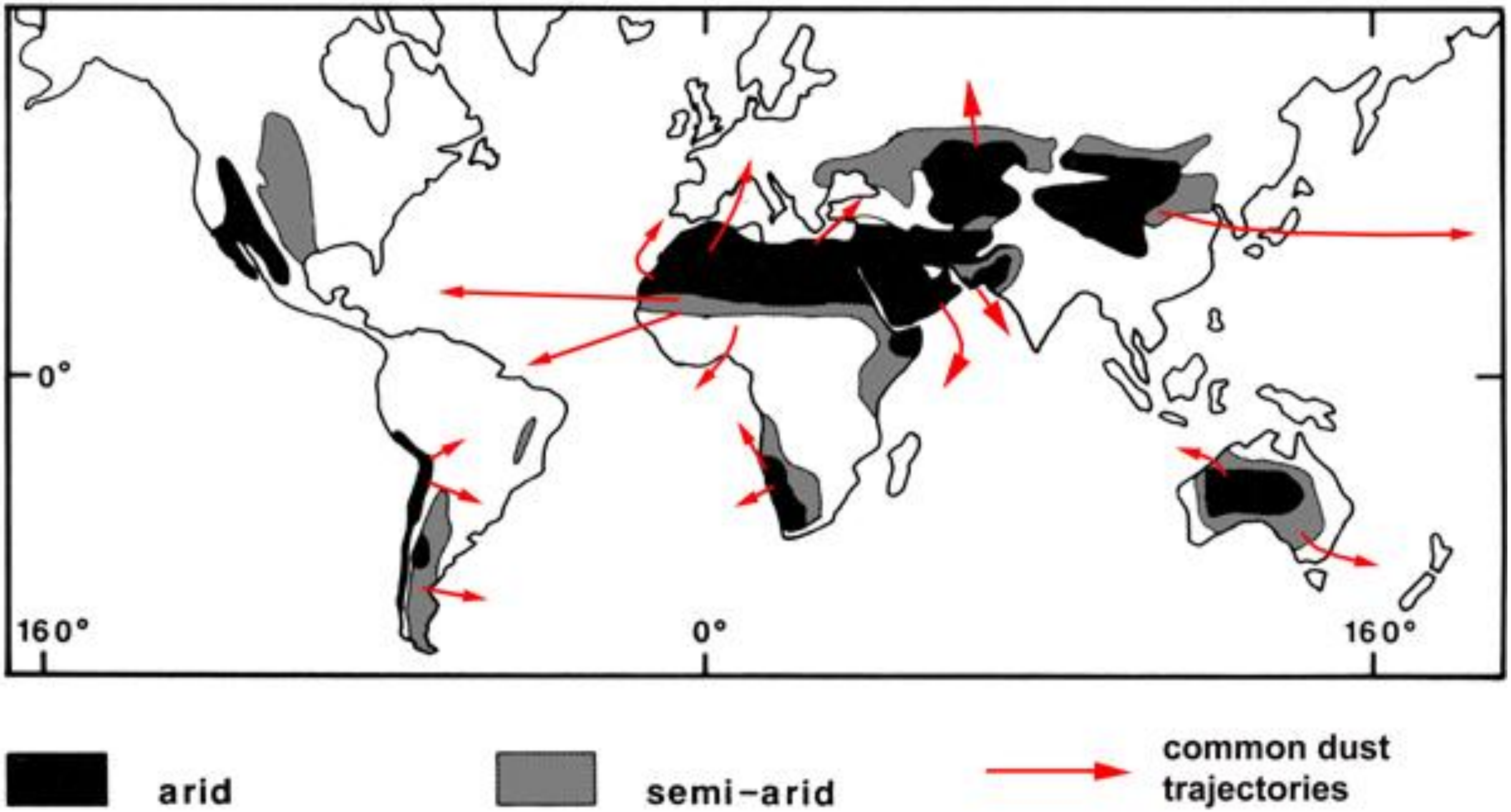

Liechfield NP, Australia

September 8, 2019

Industrial emissions



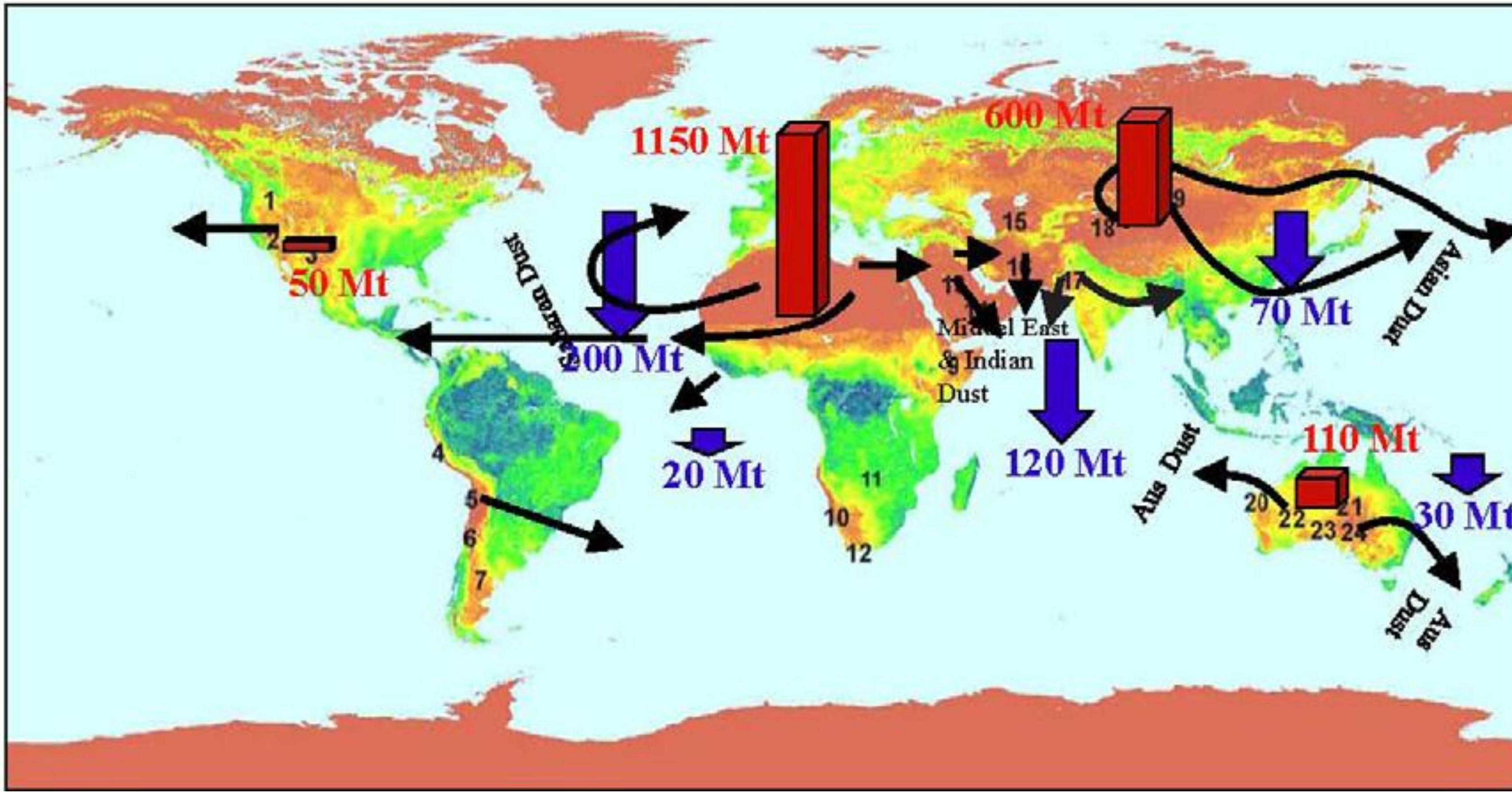
Global Dust Source Areas and Transport Trajectories



http://nasa.earthobservatory.gov/

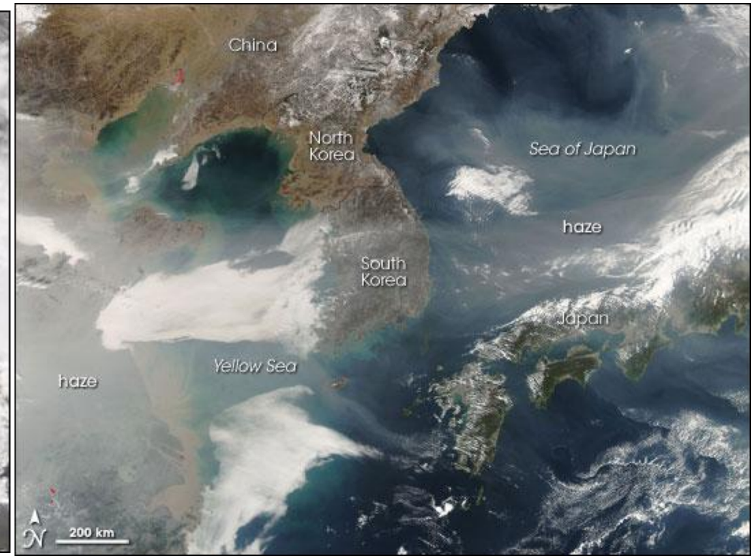
Major dust source areas particulary located along the northern and southern tropics (Tropic of Cancer and Tropic of Capricorn)

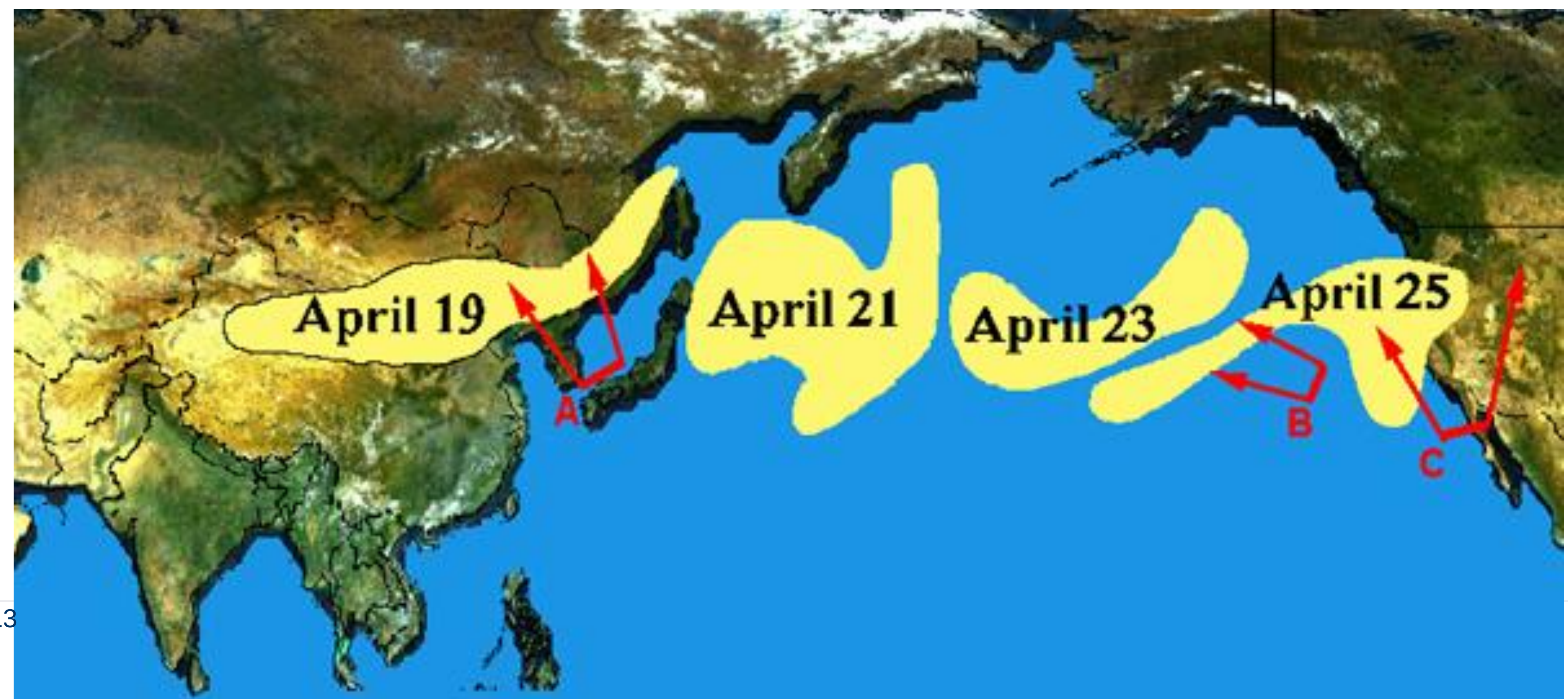
World's Major Deserts, Dust Emissions, Dust transport Routes, and Dust Depositions



Shao et al. (2011), p. 188

Trans-Pacific Asian Dust Transport, April 2006

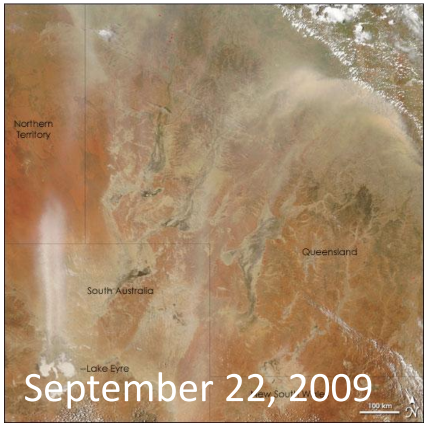




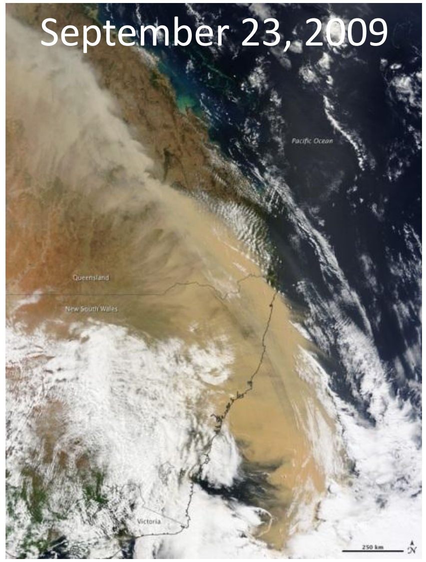
http://nasa.earthobservatory.gov

SDS – September 2009 East-Australia

Sydney
September 23, 2009



September 22, 2009



September 23, 2009

Sydney
September 23, 2009

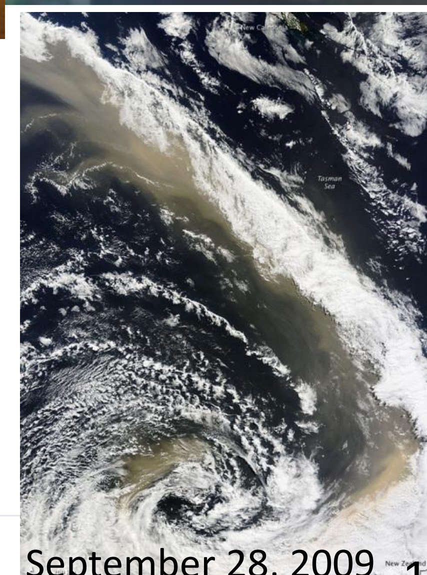
Photo : Janet Kavanagh

Sydney
September 23, 2009

September 24, 2009

September 26, 2009

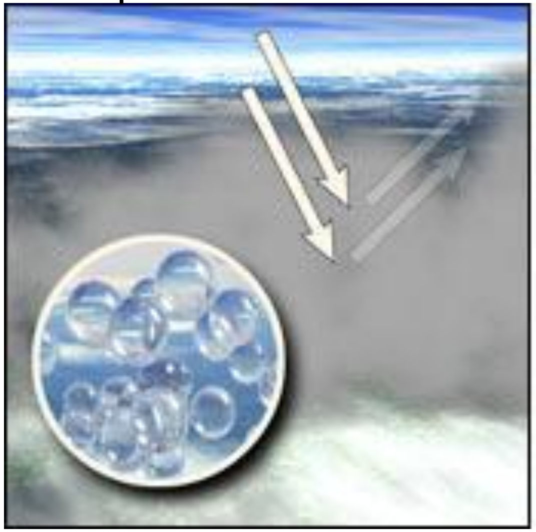
September 27, 2009



September 28, 2009

http://earthobservatory.nasa.gov

Effects of Dust (and Sand) Storms in the Atmosphere



Yearly 2,000 Mt dust emissions → atmosphere

Deposition 75% on land, 25% on ocean (Shao 2011)

<u>Changes on Climate, Atmosphere,</u>

- Energy balance of the Earth
- Heating the atmosphere (increase of solar energy adsorbed in the atmosphere, around 50%)
- Cooling of the Earth surface (3x more than the warming effect of greenhouse gases)
- Clouds occurrence, clouds thickness and rainfall pattern (→ *partly higher, partly lower amount of rainfall*) → Water cycle, carbon cycle,
- Visibility

→ Air transport, esp. jet plains

→ Health problems

Effects of Dust Transport through the Atmosphere

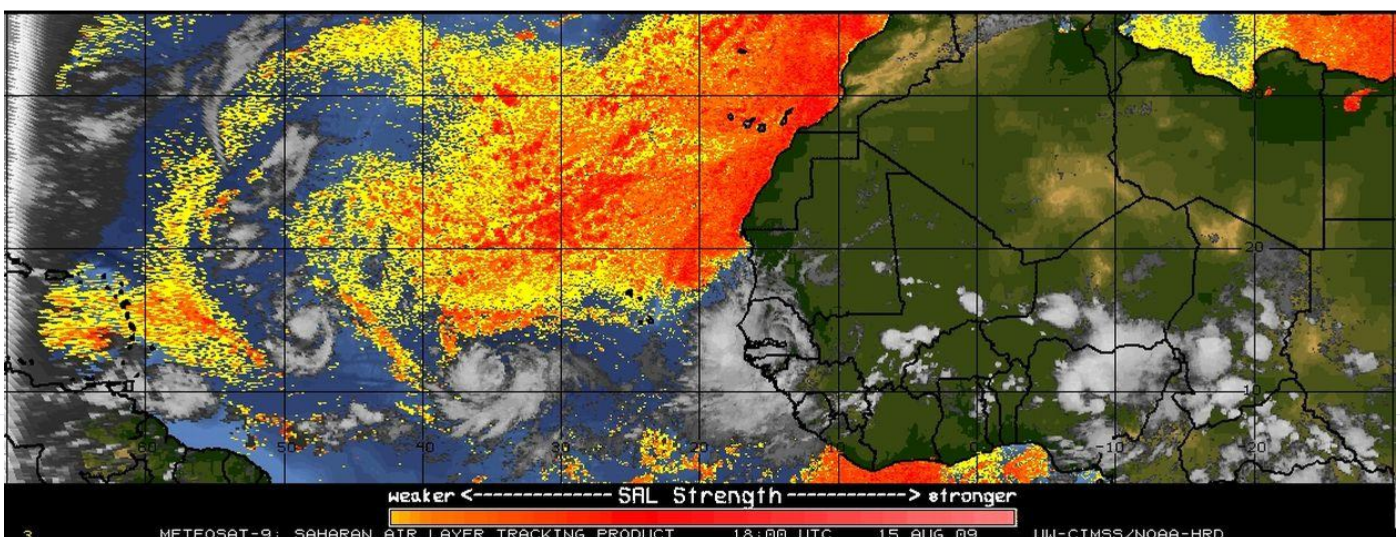
Dust – Atmosphere – Ocean - Interaction

Trans-Atlantic Saharian Dust Transport

- Cooling the ocean surface temperature
- Fertilizing (c.f. iron) the ocean
- Changing the CO_2 storage of the ocean and the CO_2 exchange with the atmosphere

Example: Trans-Atlantic or Saharan Air (Dust) Layer causes with underflowing cooler air masses a stable temperature inversion

source: NASA. earthobservatory.gov



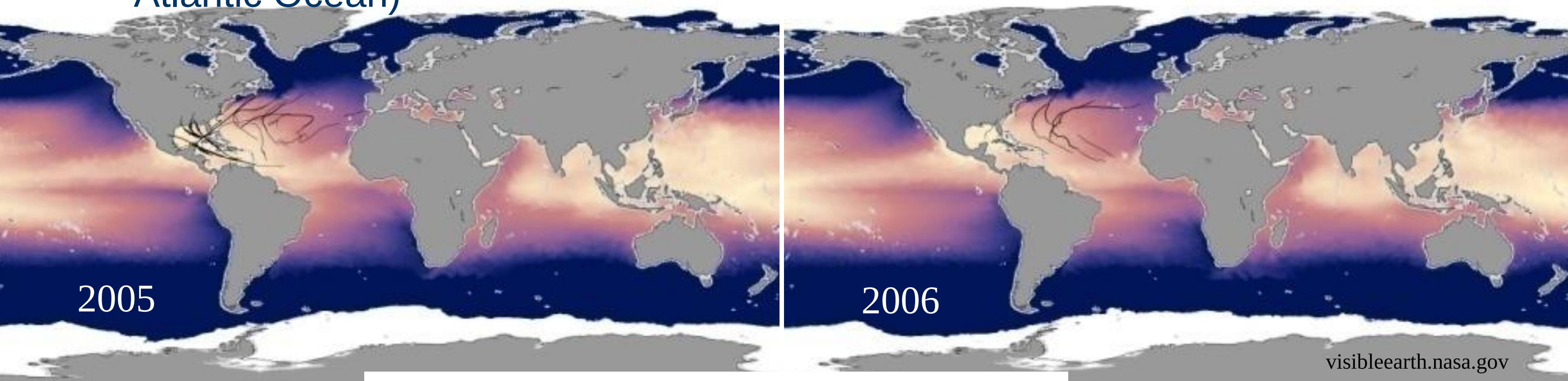
Aerosol-Index above Atlantic Ocean

source: NOAA 2009

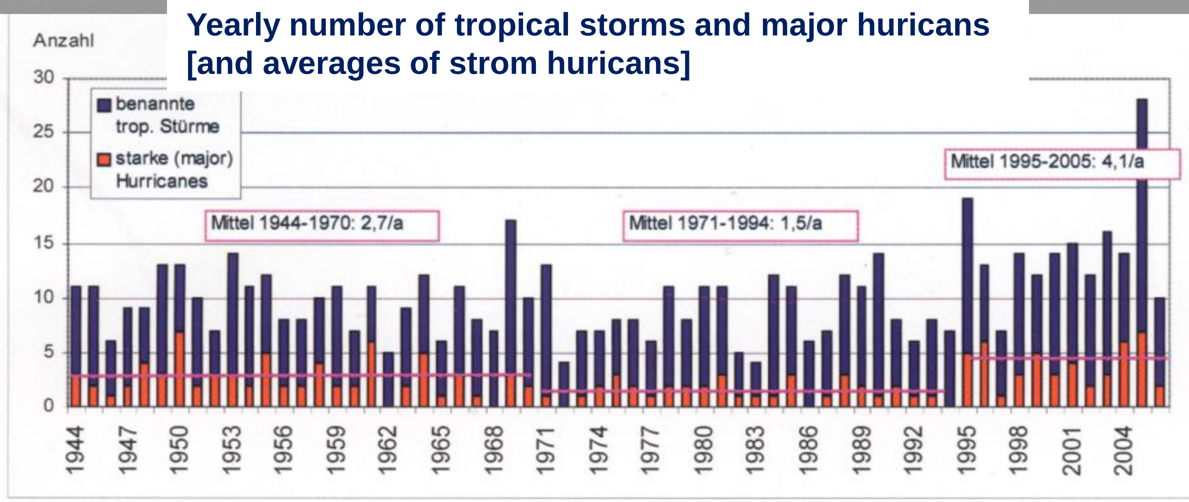
Effects of Dust Transport through the Atmosphere

→ Ocean - Atmosphere - Interaction

- promote (c.f. 2005, 2008, 2017, less dusty years) or
- prevent (2006, more dusty year) hurricane origin (on water surface of the Atlantic Ocean)



Yearly number of tropical storms and major huricans [and averages of strom huricans]



Anzahl der atlantischen Hurrikane ab Stufe 3 (s. Abb. 1) seit 1944

Europ. Meteorological Calendar 2008

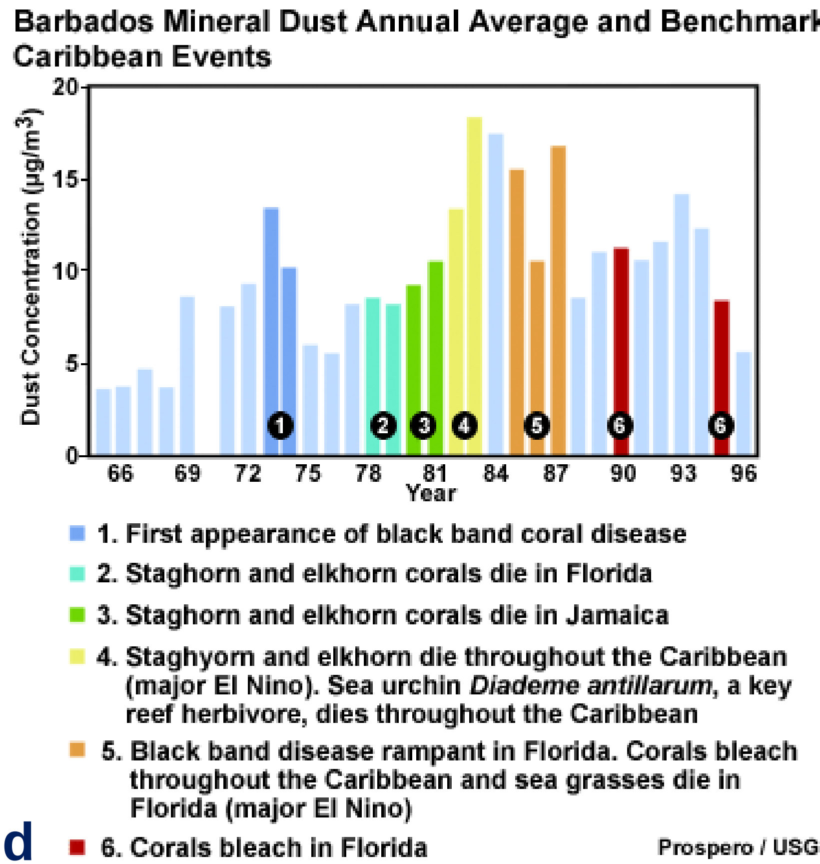
Effects of Dust Deposition in Latin America

→ Degradation of marine ecosystems in the ocean

- Bleeching and decline of coral reefs
- mass mortalities of other marine species





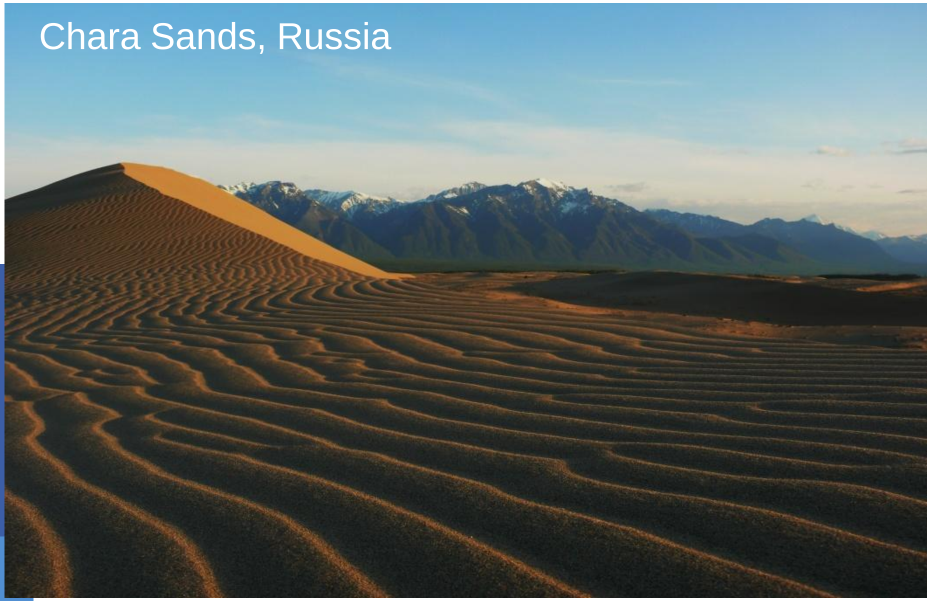


→Fertilizing tropical rainforests on land

of the Caribbean and South America

Effects of Sand and Dust Transport on Land

Aeolian landforms (e.g. dunes) as sinks and sources of sand and dust



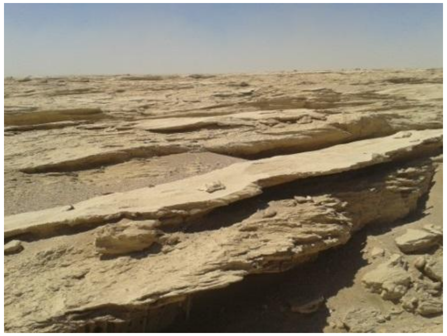
Effects of Sand and Dust Transport on Land

→ **Degradation of land ecosystems**

a) **at SDS source areas by wind erosion**

- deflation of surface layers
- exposition of subsoil layers, in some cases: salty pans, e.g. of salt depressions

Yardangs in Xinjiang



Salt pans in Uzbekistan

Effects of Sand and Dust Transport on Land

→ <u>Degradation of land ecosystem</u>

b) at DSS deposition areas

- Overlaying of the surface layer (burying of topsoils, traffic lanes)
- Deformations on vegetation (leave and stomata)
- Disturbance / change of geochemical balance
- Damping up of rivers, contamination of drinking water


near Aralsk, Kazakhstan


Moving sands, Kyzyl Kum Desert, Uzbekistan


near Urgench, Uzbekistan

Dry river bed of Amu Darya


Taklamakan, Xinjiang, China

Dust Storm South of Rostock, (Germany) Autobahn A19

April 8th 2011; 8 people died, 41 people injured, 150 cars damaged


Seite 6 HINTERGRUND SPEZI

+++ Der Massenunfall auf der A 19 bei Rostock +++ Der Mass

Bund: Agrarindustrie schuld an Sandsturm

Bild des Grauens: Feuerwehrmänner dämmen am letzten LKW der Massenkarambolage einen Schwelbrand ein.

Zwischen Trauma und

Nach der Katastrophe: Seelsorger kümmern sich um Verletzte und Helf

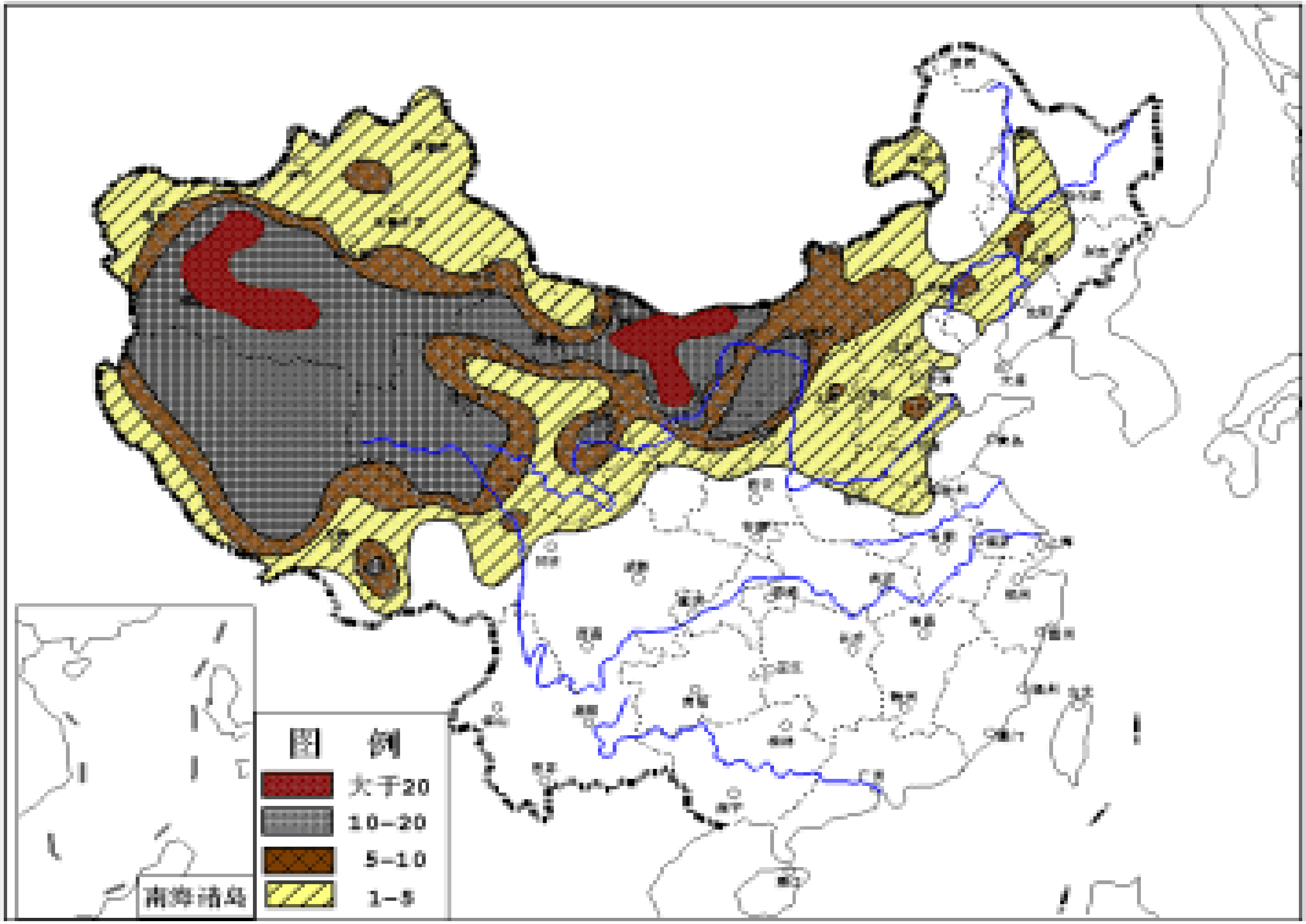
Einzelnes Auto löst Flammenmeer aus

STICHWORT

Sandstürme

Anschein von Normalität: Straßenbauer arbeiten gestern den versch... Belag ab, damit die A 19 schnell wieder freigegeben werden kann.

Days of Dust Storms per Year in China



Source: Zhang (2006)

In past 50 years of the 20th century, the number of annual dust storm days was decreasing; but since 1997, however, there is an increasing trend.

Sand and Dust Storm Damages in the Train Urumqi-Beijing

April 12, 2006 Source: Zhang (2006)

T70次列车在新疆遭沙尘暴左侧窗玻璃全毁(图)

http://www.sina.com.cn 2006年04月12日01:22 兰州晨报

大家将卧铺上的棉被和床单拿下来遮挡损坏的车窗

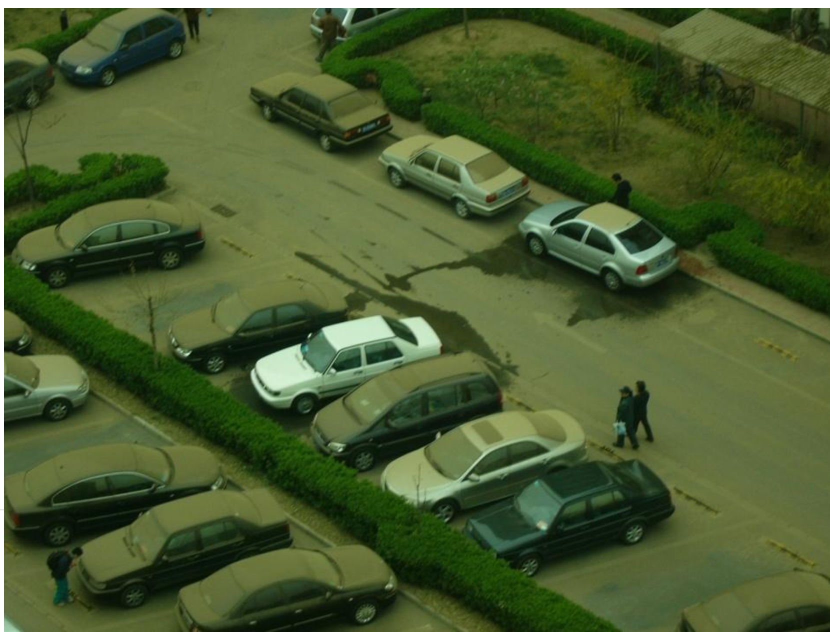
Dust Storm Effects in Beijing, April 17, 2006

Source: Zhang (2006)

Dust Storm Effects in Beijing, April 17, 2006

Source: Zhang (2006)

Dust Storm Effects in Beijing, April 17, 2006



Source: Zhang (2006)

Effects of Sand and Salty Dust Storms on Human Health

Increasing illness of respiratory tracts, inflammation of the eyes, and other organs


Salt crusts on the street

Study area	Rayon Kazalinsk		Rayon Zhanakorgan	
Quantity of tested children	2030	100%	1979	100%
Quantity of diseases, including	229	11.3%	239	11.9%
Acute pneumonia	145	**63.0%**	153	**65.1%**
Chronic bronchitis	63	**27.5%**	68	**29.4%**
Chronic pneumonia	21	**9.5%**	13	**5.5%**

Increase of cancer illness in Kharakalpakstan, Republic Uzbekistan (number/1,000 persons/year)

year	number of cancer
1980	4,5
1981	5,8
1982	7,1
1983	7,2
1984	7,1
1985	7,4
1986	8,7
1987	9,5
1988	7,5
1989	9,9
1990	7,8

Source: State Medical Institute, Almaty, M.M. Baizanov, V.A. Dasiev, G. Muratbaeva

Economic Impacts of Sand and Dust Storms

Immediate term	Long-term
Immediate human health problems (e.g., respiratory problems) and mortality	Cumulative human health problems (e.g., bronchitis,cardiovascular disorders)
Annual and perennial crop damage	Soil erosion and reduced soil quality
Livestock mortility	Soil pollution through deposition of toxic biological substances (fungi, bacteria), heavy metals, or salts
Infrastructural damage (e.g., buildings, electricity and telephone structures, power facilities, solar farms,machinery, greenhouses)	Disruption of global climate regulation (through feedbacks involving global warming, ocean productivity and CO_2 production, precipitation changes, global ice volume, sea level, hydrological cycle, and vegetation cover)
Costs of clearing sand and dust from infrastructure (e.g.,roads, airports, dams, irrigation canals, flood control structures, ditches, power facilities)	
Interruption of transport (air, road, rail) and communications; air and road traffic accidents	

(Source: UNEP, WMO UNCCD 2016: Global Assessment of Sand and Dust Storms); summarized from Goudie and Middleton (2006)

Economic Impacts of Sand and Dust Storms

Costs of removal of blown sand from Infrastucture in the Middle East
(Source: UNEP, WMO UNCCD 2016: Global Assessment of Sand and Dust Storms)

Area	Reference	Year	Costs (USD) per cubic meter
Kuwait	Al-Dousari et all. (in press)	1993	1.8
Kuwait	Al-Dousari et all. (in press)	2013	5.33
Hafouf, Saudi Arabia	Alghamdi & Al Kahdami 2005	2004	0.5
Sistan, Iran	Pahlavanrami et al. 2012	2000	2.0
Sistan, Iran	Pahlavanrami et al. 2012	2004	0.5

Yearly off-site costs associated with wind erosion in New Mexico in the mid 1980s: 466 Million US$
On-site site costs associated with wind erosion in New Mexico in the mid 1980s: 10 Million US$
Source: Huszar & Piper 1986
Iran: 1 Billion US$, Iraq: 1.4 Billion US$, USA: 9.6 Billion US$, Beijing 665 Million US$ /per year
Between 11-56 Million AUS$ off-site costs, mostly for health impacts (William & Young 1999)

Consequences for Mitigation and Hazard Reduction

The following surface features support the deflation process:

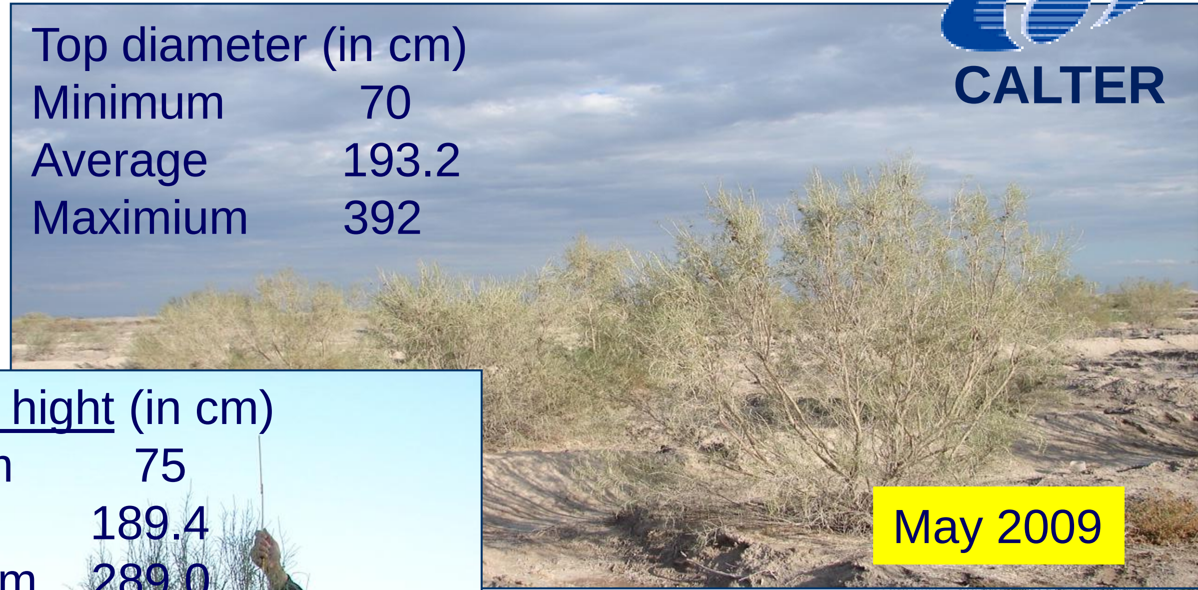
- (large) wind-open areas (e.g. coasts, lakes, treeless areas, open pit mines)
- dryness (very low soil moisture) of the upper soil or sediment layer
- low degree of coverage by biological crusts
- low degree of coverage by vegetation → Management → high degree of coverage
- loosening of the soil structure of agricultural used land by tillage or trampling

→ Manangement → increasing sorption and stabilisation of soil surfaces

Plantations on the Dry Lake Bed of the Aral Sea

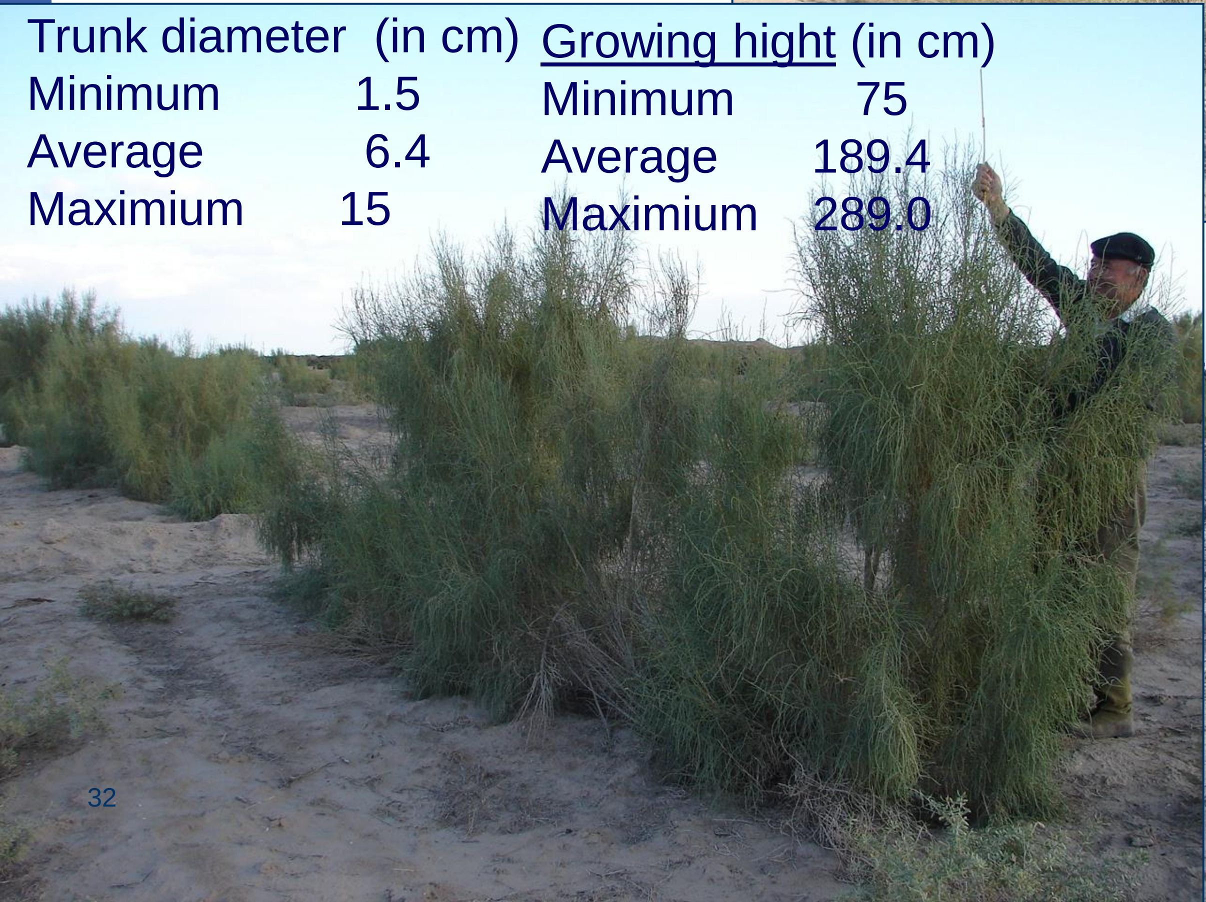
CALTER

***Haloxylon aphyllum*-**
Plantation with irrigation near Muinak (Uzbekistan)
source: Treshkin & Kuzmina (2009)



Top diameter (in cm)	
Minimum	70
Average	193.2
Maximium	392

May 2009



Trunk diameter (in cm)	
Minimum	1.5
Average	6.4
Maximium	15

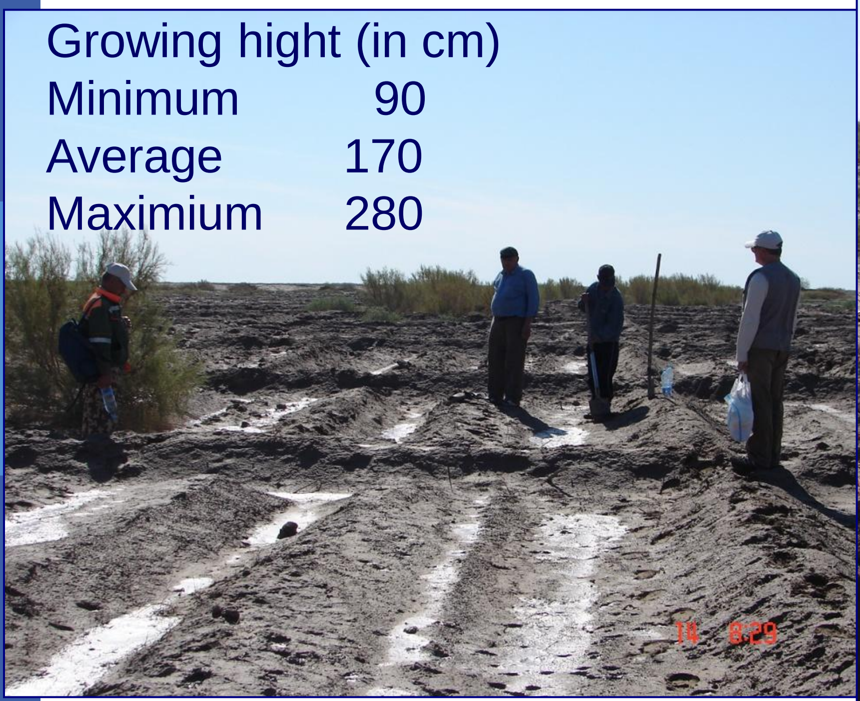
<u>Growing hight</u> (in cm)	
Minimum	75
Average	189.4
Maximium	289.0

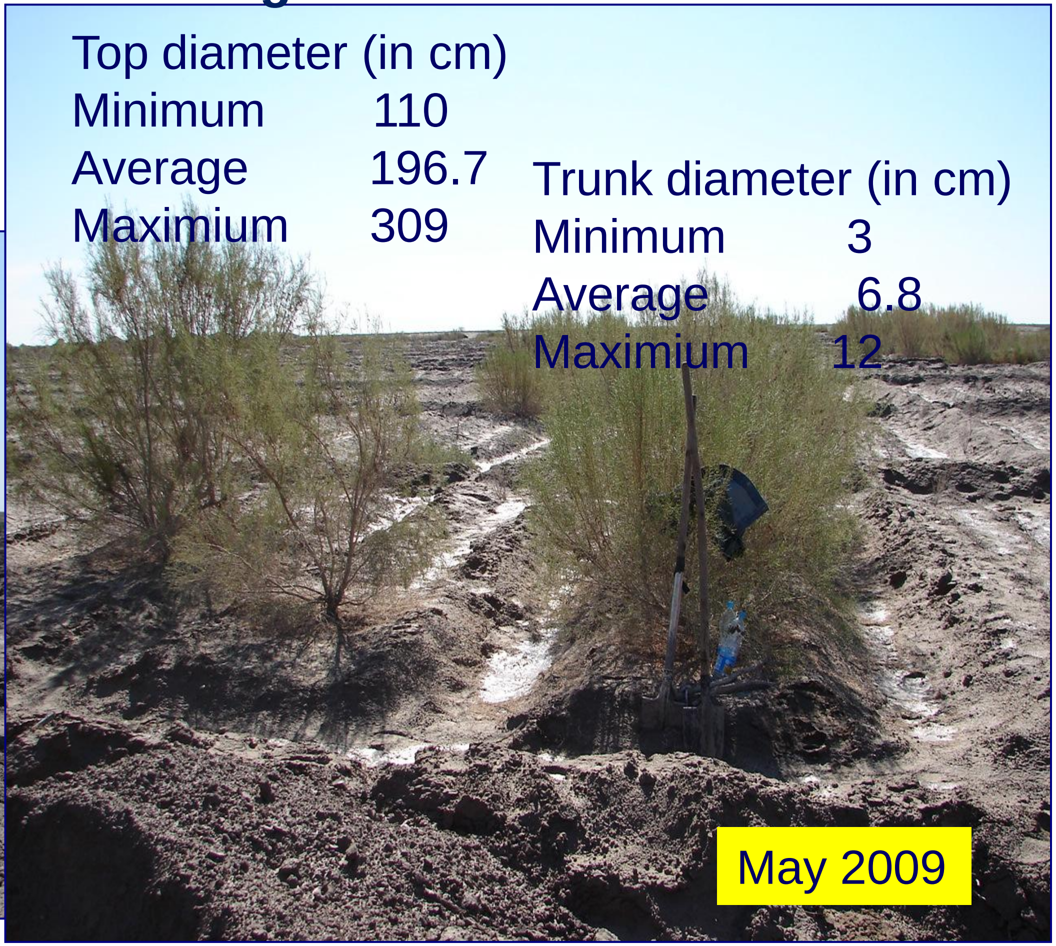
Plantations on the Dry Lake Bed of the Aral Sea

CALTER

Haloxylon aphyllum Plantation without Irrigation
Near Muinak (Uzbekistan)

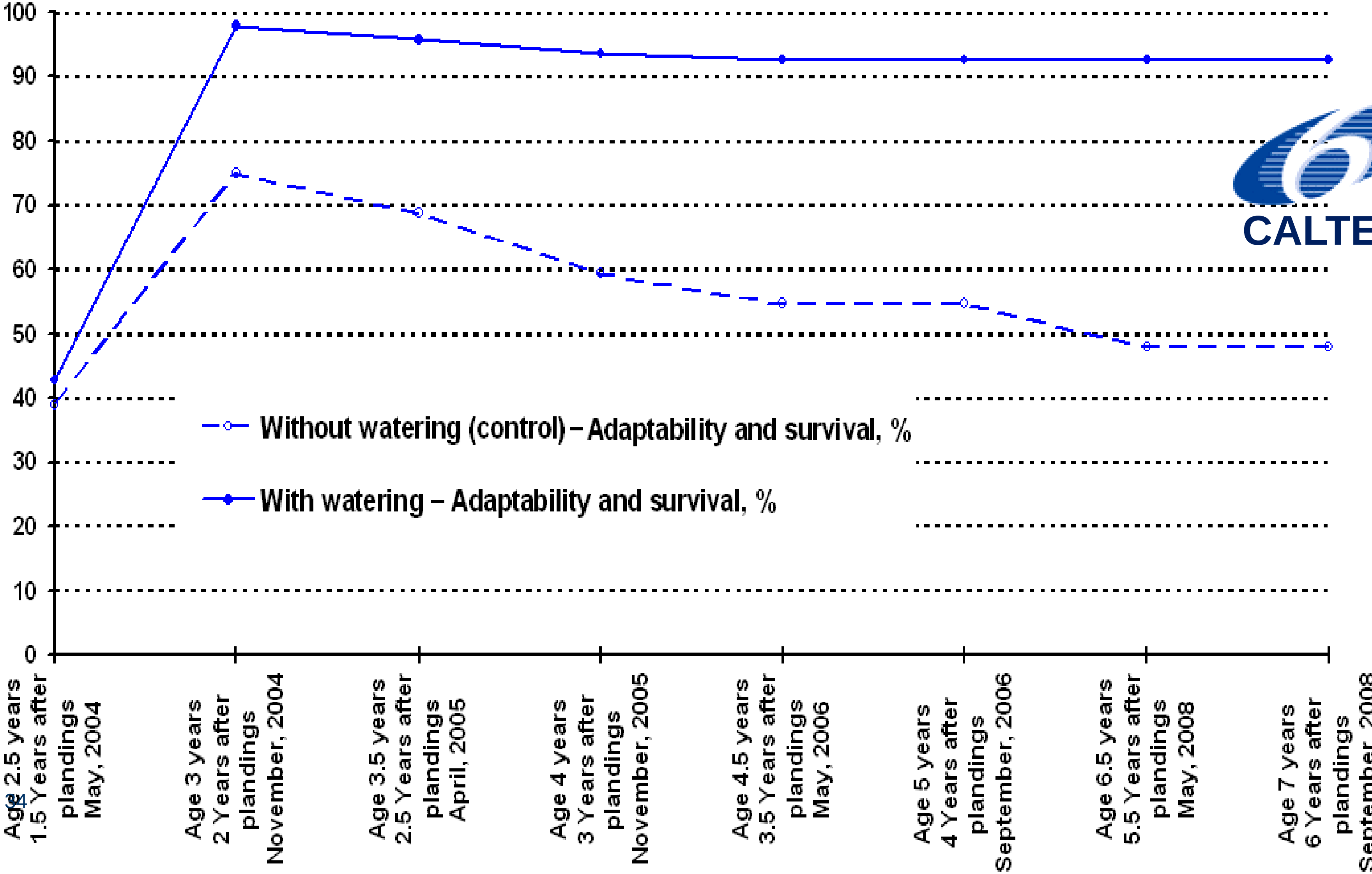
source: Treshkin & Kuzmina (2009)





Adaption and Survival (%) of Saxaul (*Haloxylon aphyllum)* on Solonchaks of the Dryed Aral Sea Bottom

source: Treshkin & Kuzmina (2009)

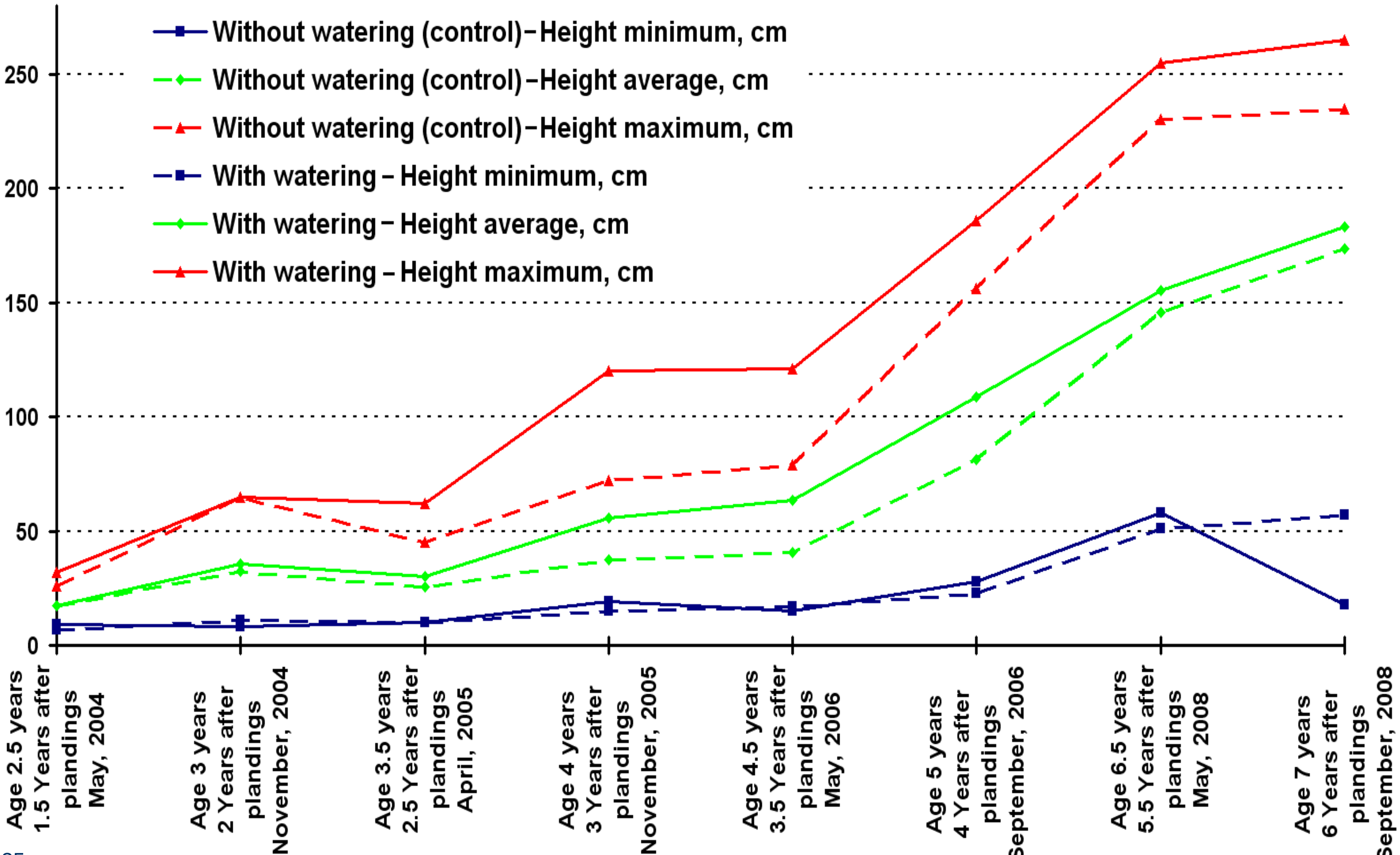


CALTER

Growing hight of Saxaul- (*Haloxylon aphyllum*) Plants on Solonchaks of the dryed Aral Sea Bottom

CALTER

source: Treshkin & Kuzmina (2009)



Increasing Sorption and Stabilisation of Soil Surfaces

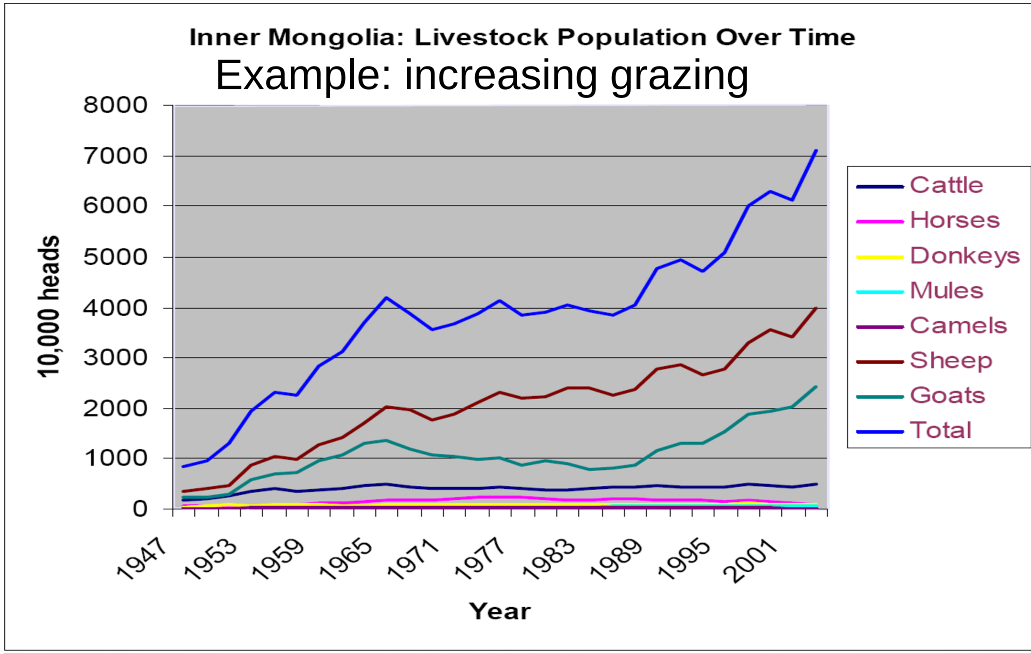

Dune stabilization by sand catcher

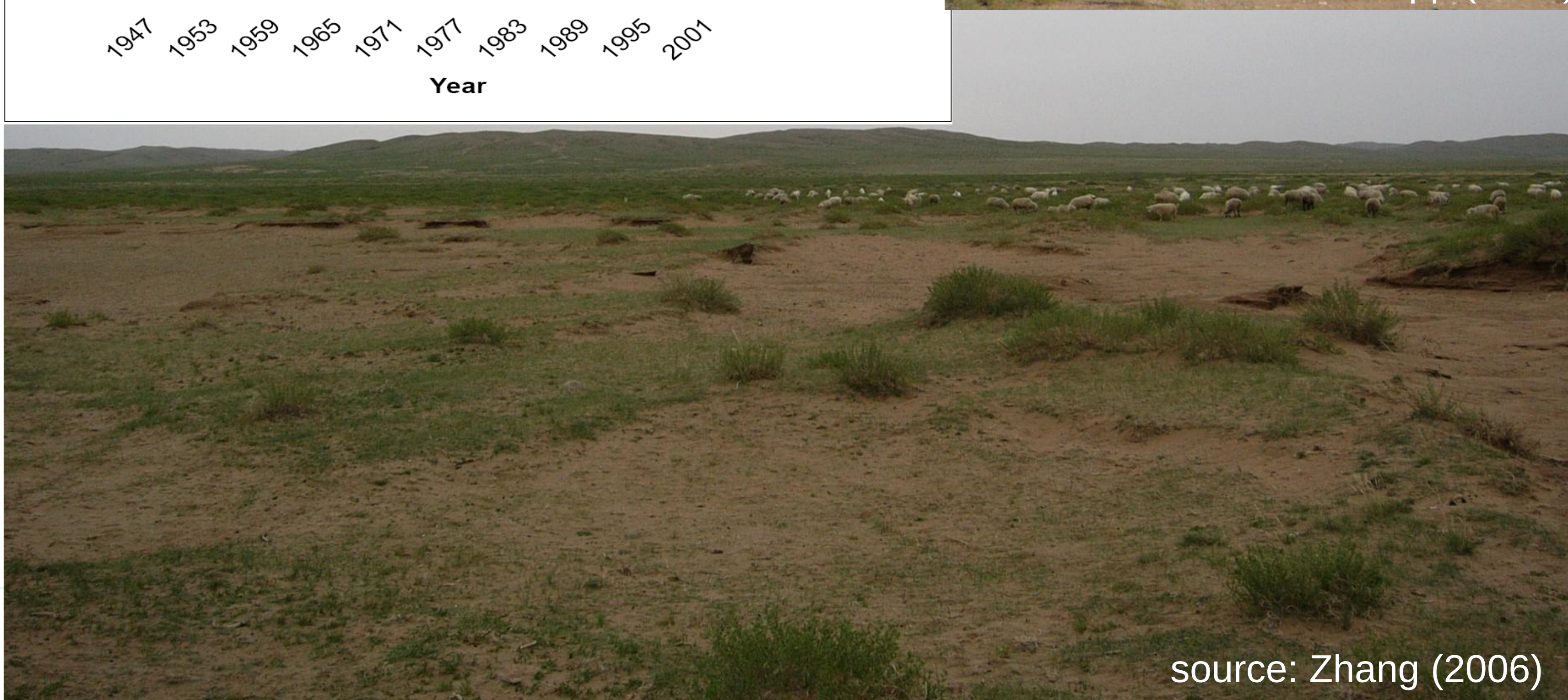

Plant cover revitalization by watering


Dune stabilization by oil mulching


Plantation of biological barriers

Decreasing Number and Frequency of Grazing Animals





TAKE HOME MEASSAGE

- It is necessary to distinguish between short-distance, near-surface sand storms (consisting predominately of sand) and long-distance via the atmosphere dust storms (consisting predominately of silt and clay)

- Barren ground and sites with low coverage by vegetation (dunes, soil surfaces, dry lake and river beds) are the main source areas of SDS

- The aeolian (by wind) transport system consists of deflation (at the source area), transport, and deposition (at the sink area)

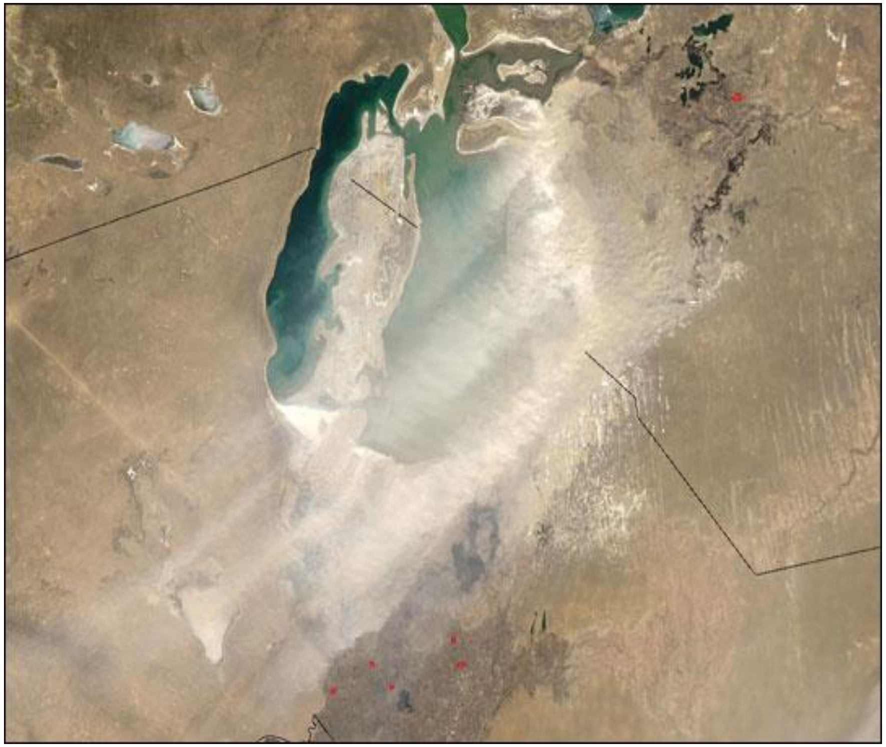
- Sand transport is forming deflation relief (like yardangs) at the source areas, and dunes at the deposition areas; some sink areas can also become sources of SDS

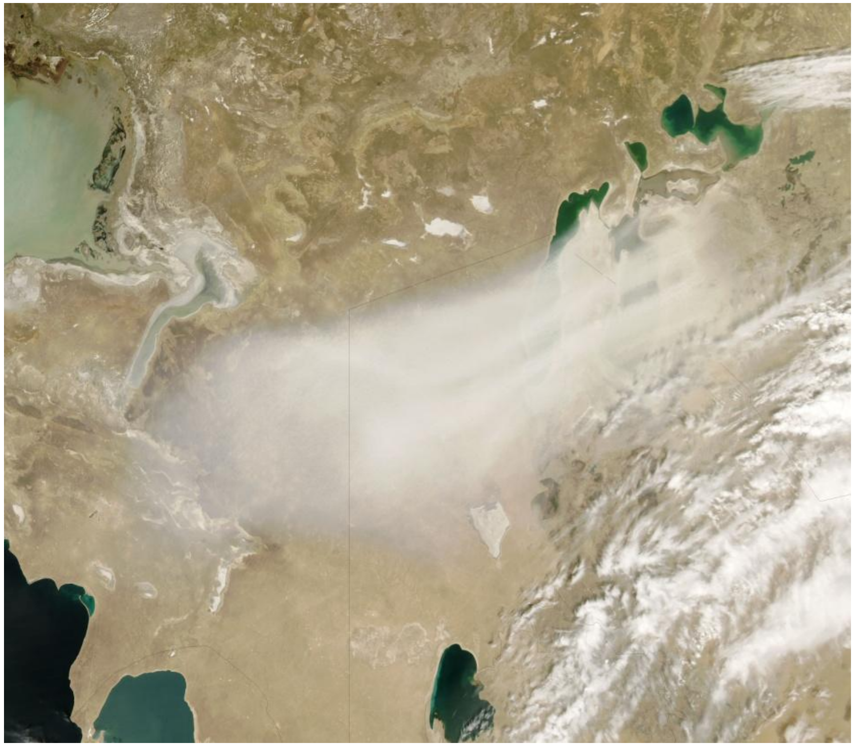
- Dust transport via the atmoshere modulates the radiation, the ocean surface temperature, the the climate and the snow and ice

- SDS and its depositions do have mostly harmful effects on infrastructure, plants, animals and human health (respiratory tracts, inflammation of the eyes, and others)

- For prevention and reduction of the negative effects of SDS it is necessary to increase the coverage of barren ground by vegetation or by water (in case of dry lake and river beds)
- In case of SDS people should use face masks!

Danke! ,
Thank you for your attention!
سپاسگزارم





L = 100…150 km

L = 800 km

http://nasa.earthobservatory.gov/

Marburg Research Setup in Central Asia

Aralkum
1 - Muynak
2 - Jaslyk
3 - Aralskoe more
4 - Kazalinsk

Kyzylkum
5 - Kyzylorda
6 - Nurata
7 - Bukhara
8 - Buzubay
9 - Beruniy

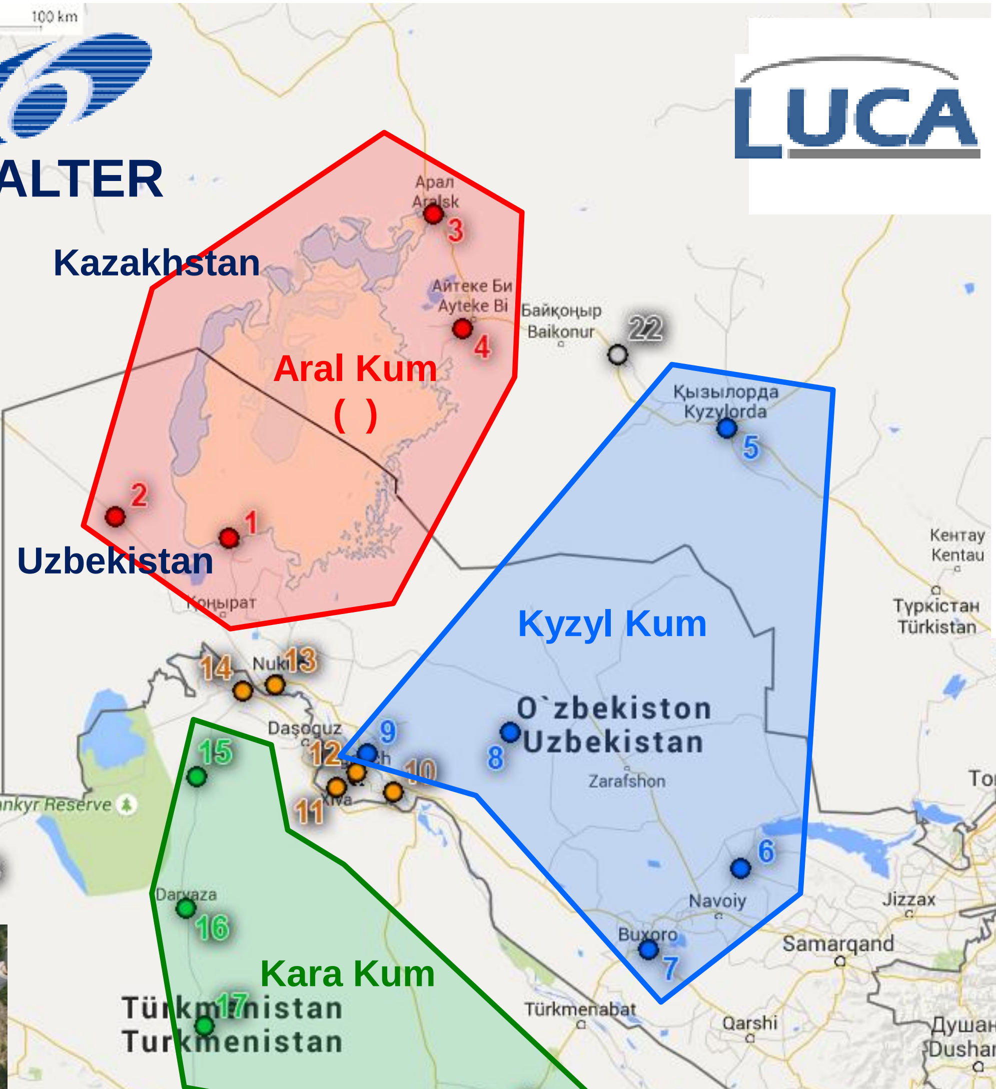
Khorezm
10 - Yangibazar
11 - Khiva
12 - Urgench
13 - Takhiatash
14 - Kunya-Urgench

Karakum
15 - Shasenem
16 - Darvaza
17 - Bokurdak
18 - Repetek

other
19 - Termez
20 - Ferghana
21 - Tashkent
22 - Dzhusaly
23 - Chagyl

CALTER

LUCA



23 Meteorological Stations
- Monthly dust deposition samples;
- 40 dust storm samples;
- Monthly meteo. data (Temp., Precip., Wind);
- Operated between 2003 and 2012;

- Soil samples (*) in 3 depths from the Aralkum and 13 stations

- 674 dust samples (369 g; avg. 0.55 g)
- 456 meteo. data sets (430x Temp. & Precip.; 214x Wind)
- Complete overlap: 151 data sets

Base map: google maps