

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



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# 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: Lose Particles on the Surface

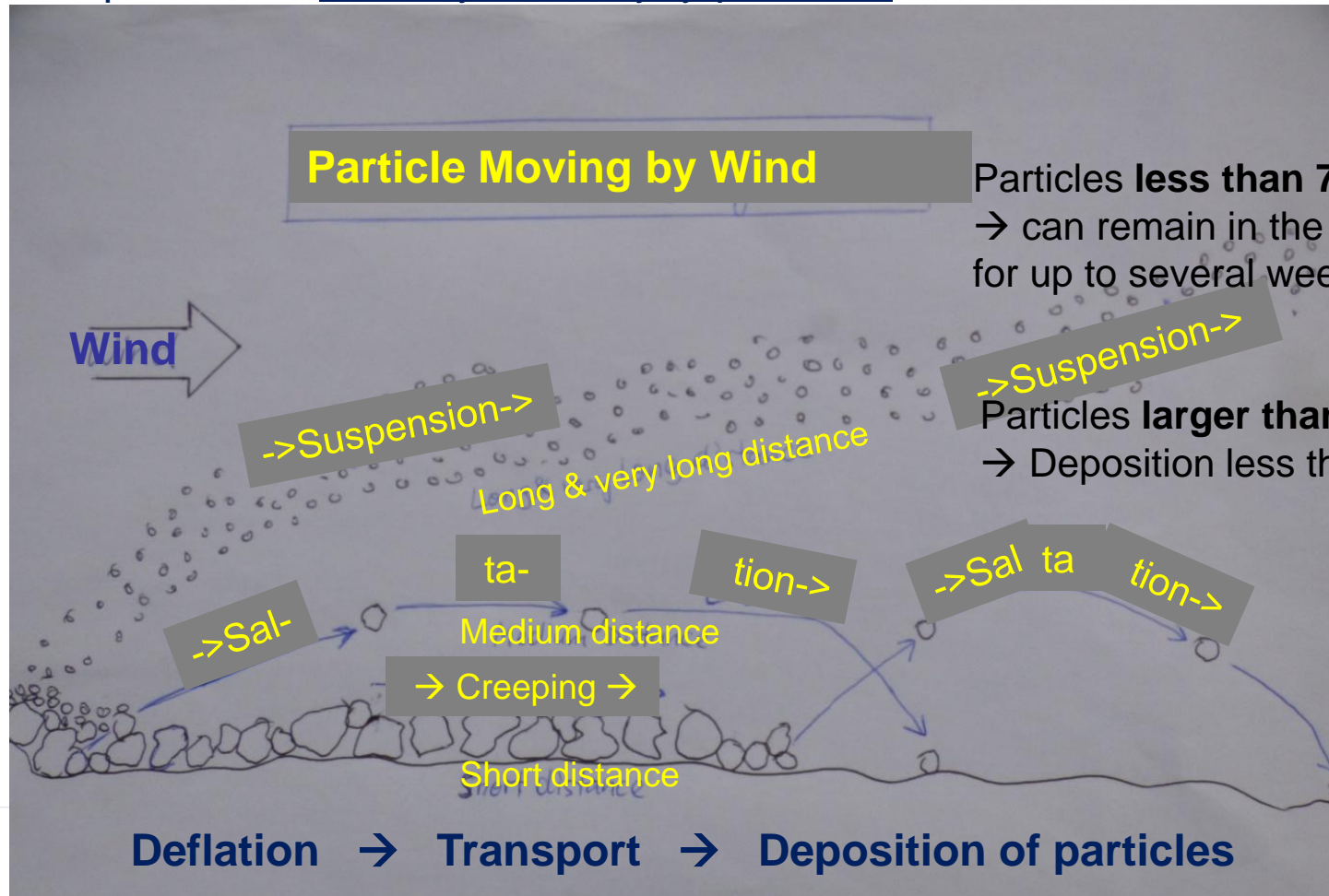
The difference: **Sand** Transport or/and **Dust** Transport

**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



## 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

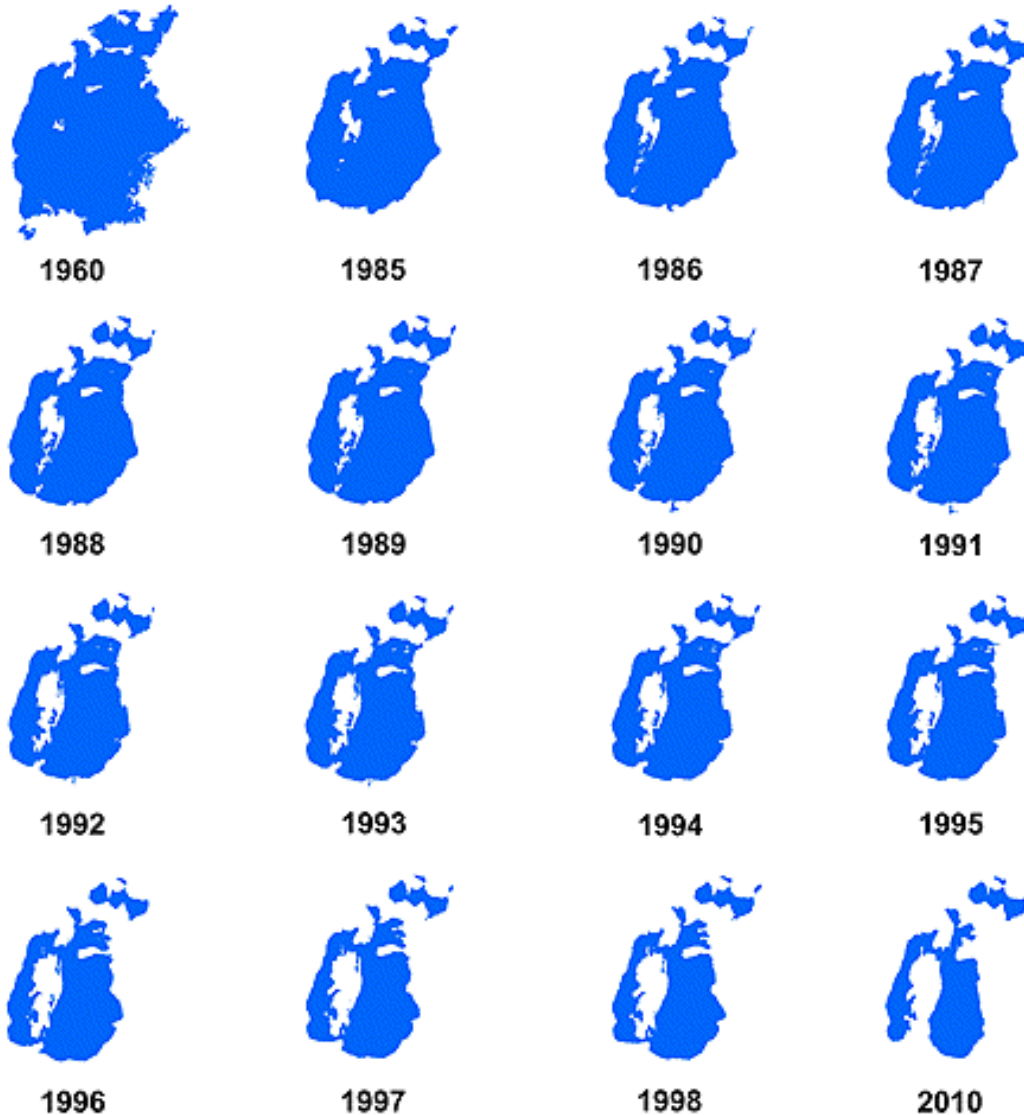
The following surface features support the deflation process:

- (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 Dried Lake Surfaces

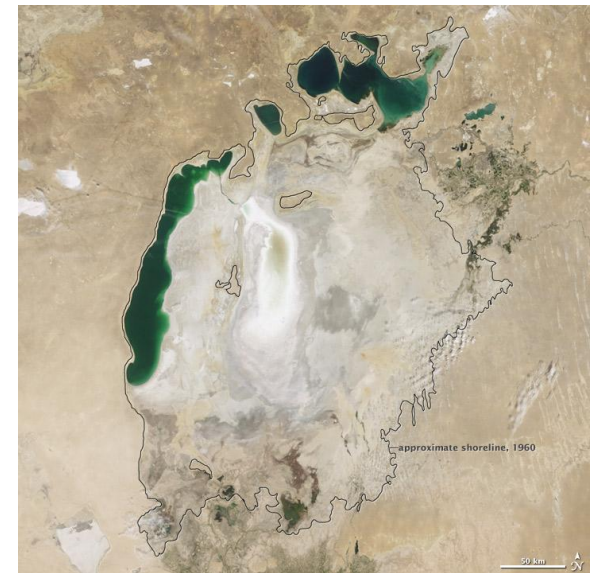
„Disappearing“ of the Aral Sea



Ressler (1999)



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



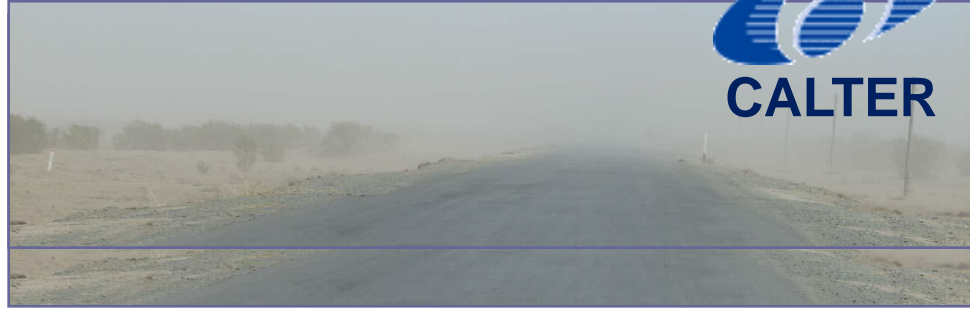
September 2009  
from a sink to a  
source of salts

<http://visibleearth.nasa.gov/data>

# 1. Basics of SDS 2. Effects of SDS 3. Economic Impacts 4. Consequences Causes / Prerequisites of SDS on Dried Lake Surfaces



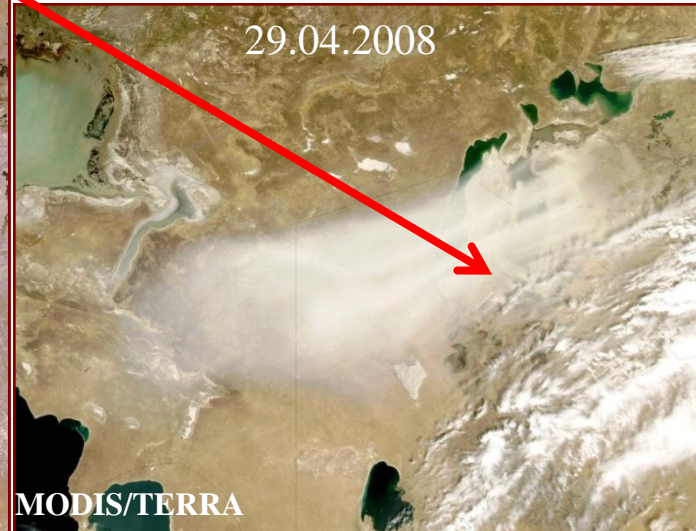
29th April 2008, near Muynyak



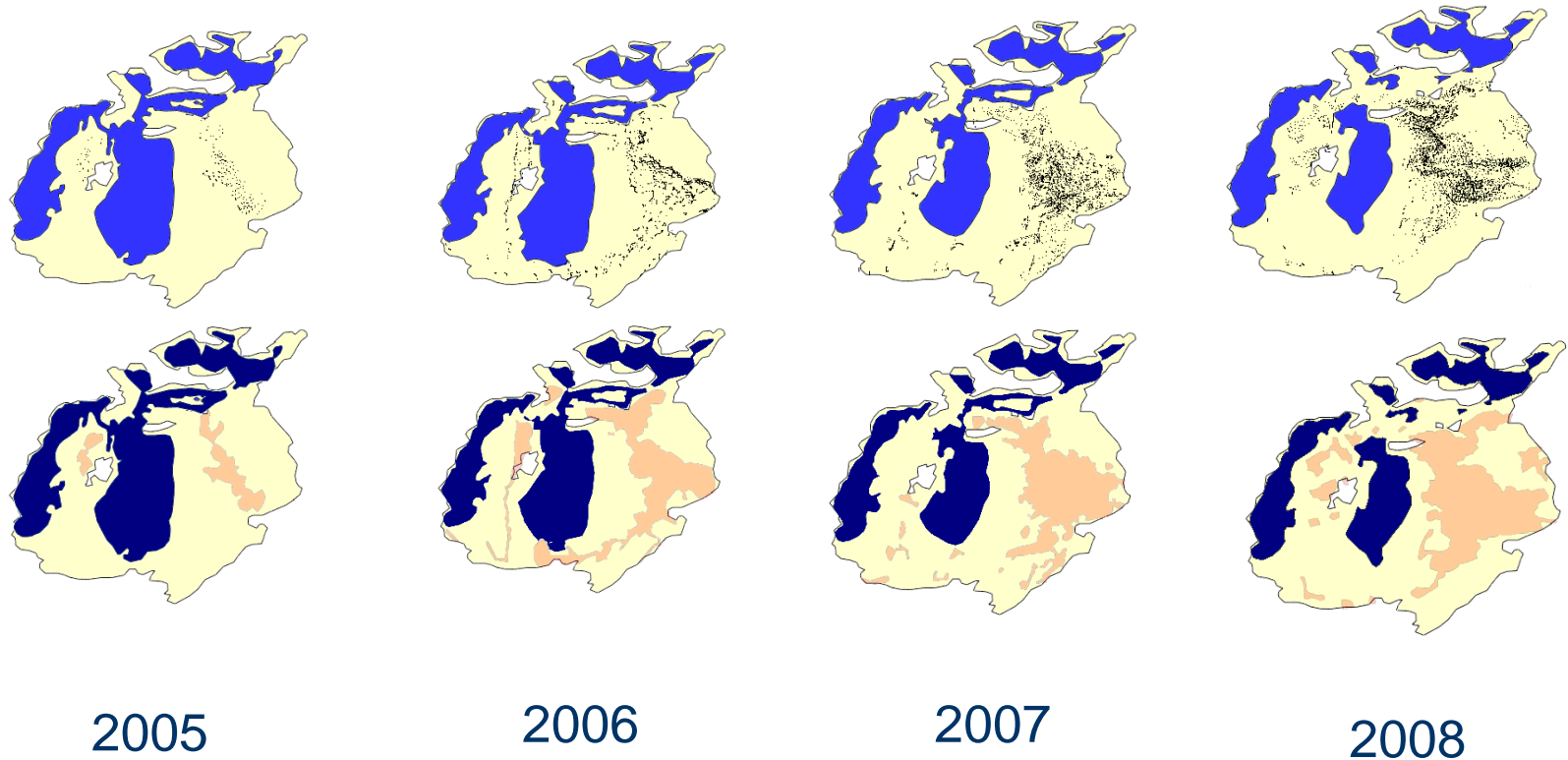
01.04.2008

10.04.2008

29.04.2008



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



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

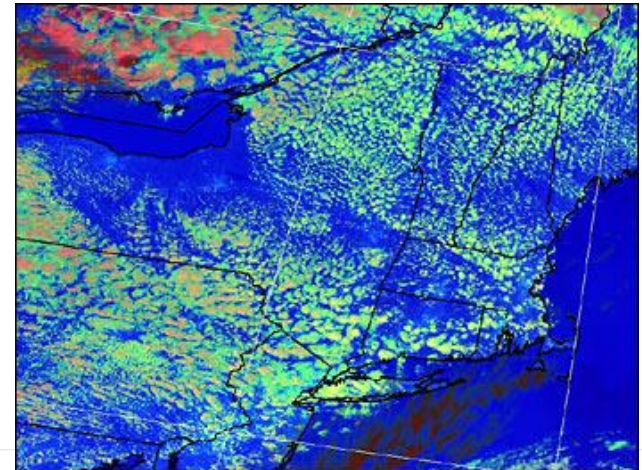


Liechfield NP, Australia

August 8, 2005

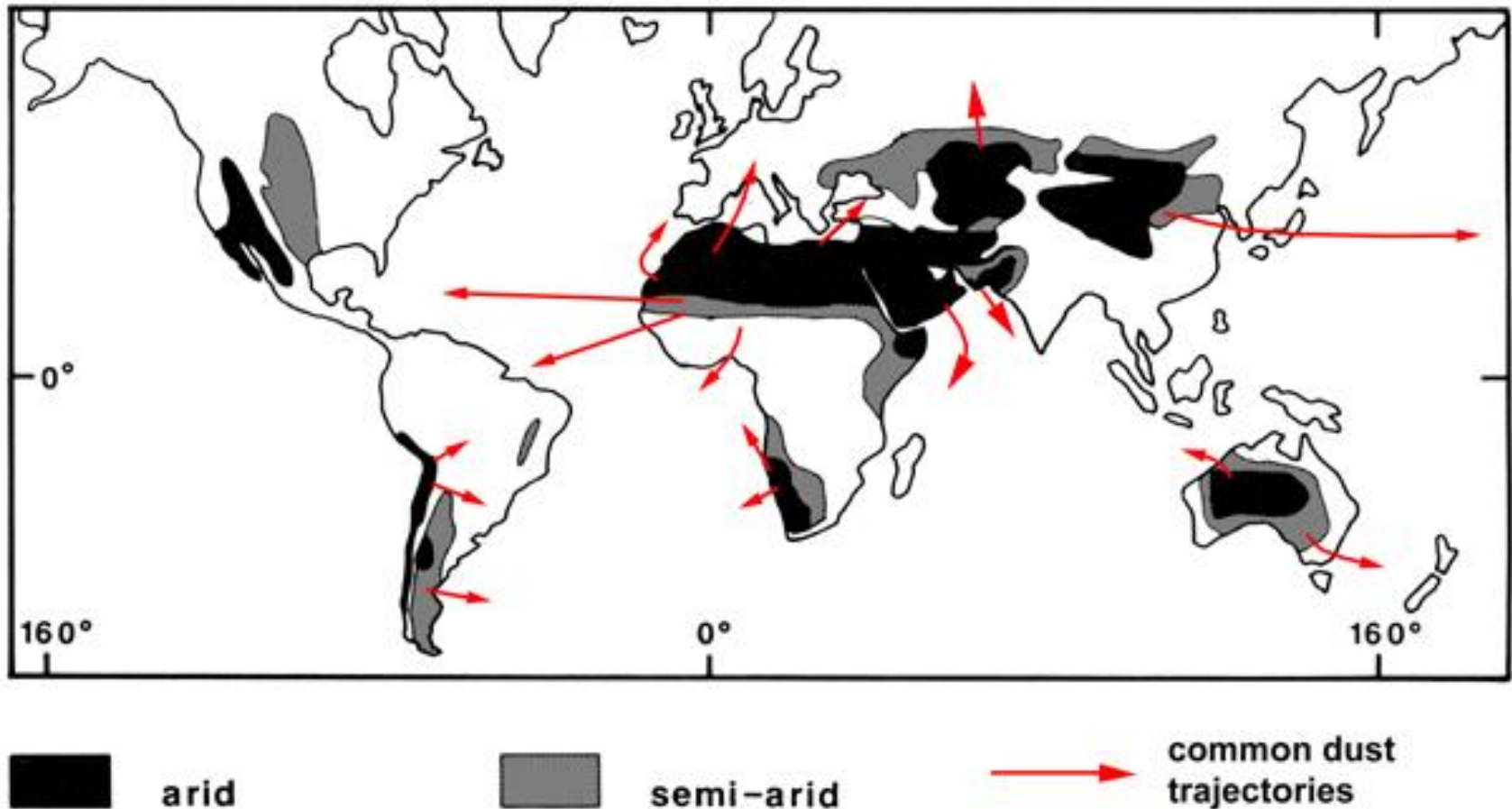
September 8, 2019

## Industrial emissions



1. Basics of SDS 2. Effects of SDS 3. Economic Impacts 4. Consequences

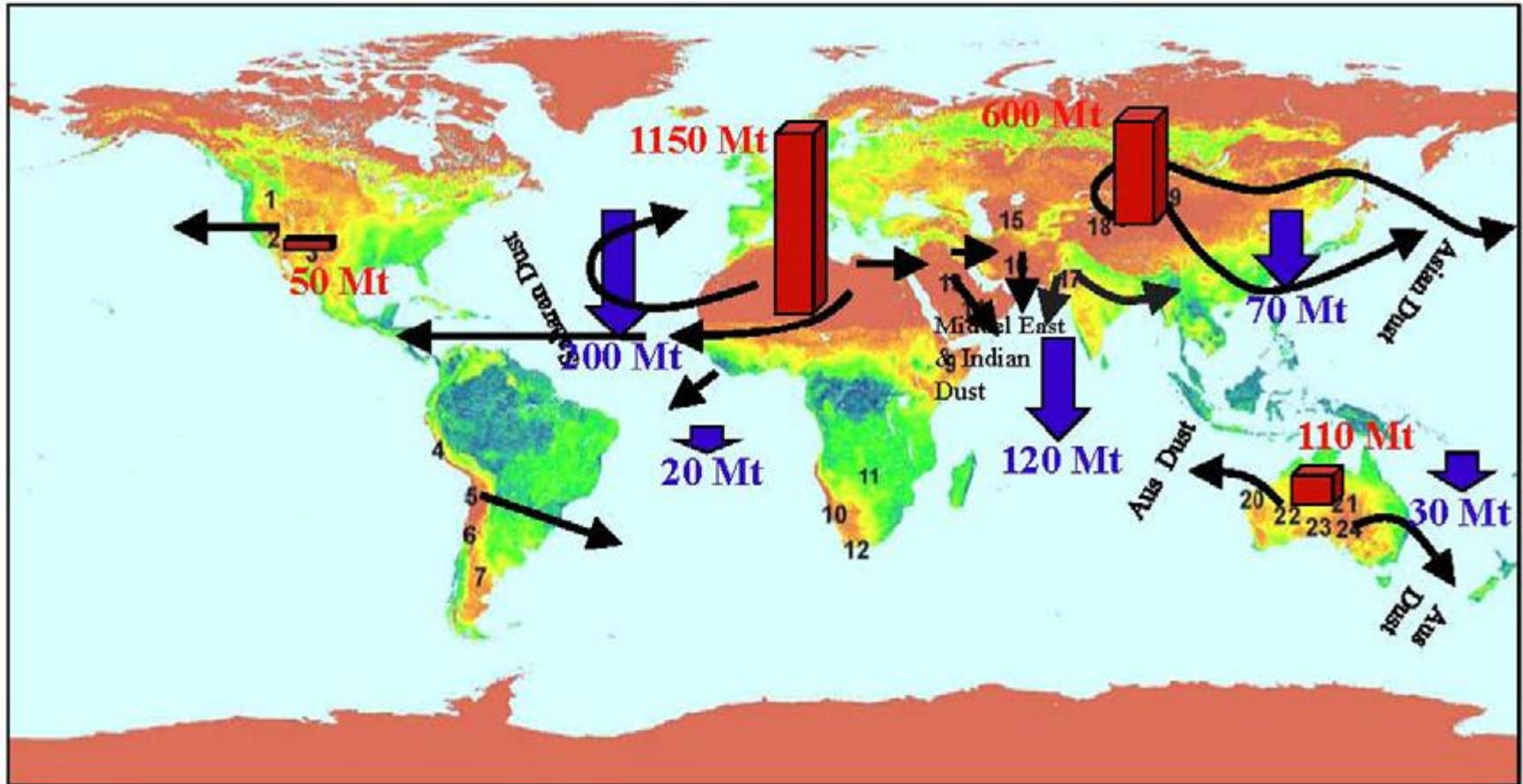
# Global Dust Source Areas and Transport Trajectories



<http://nasa.earthobservatory.gov/>

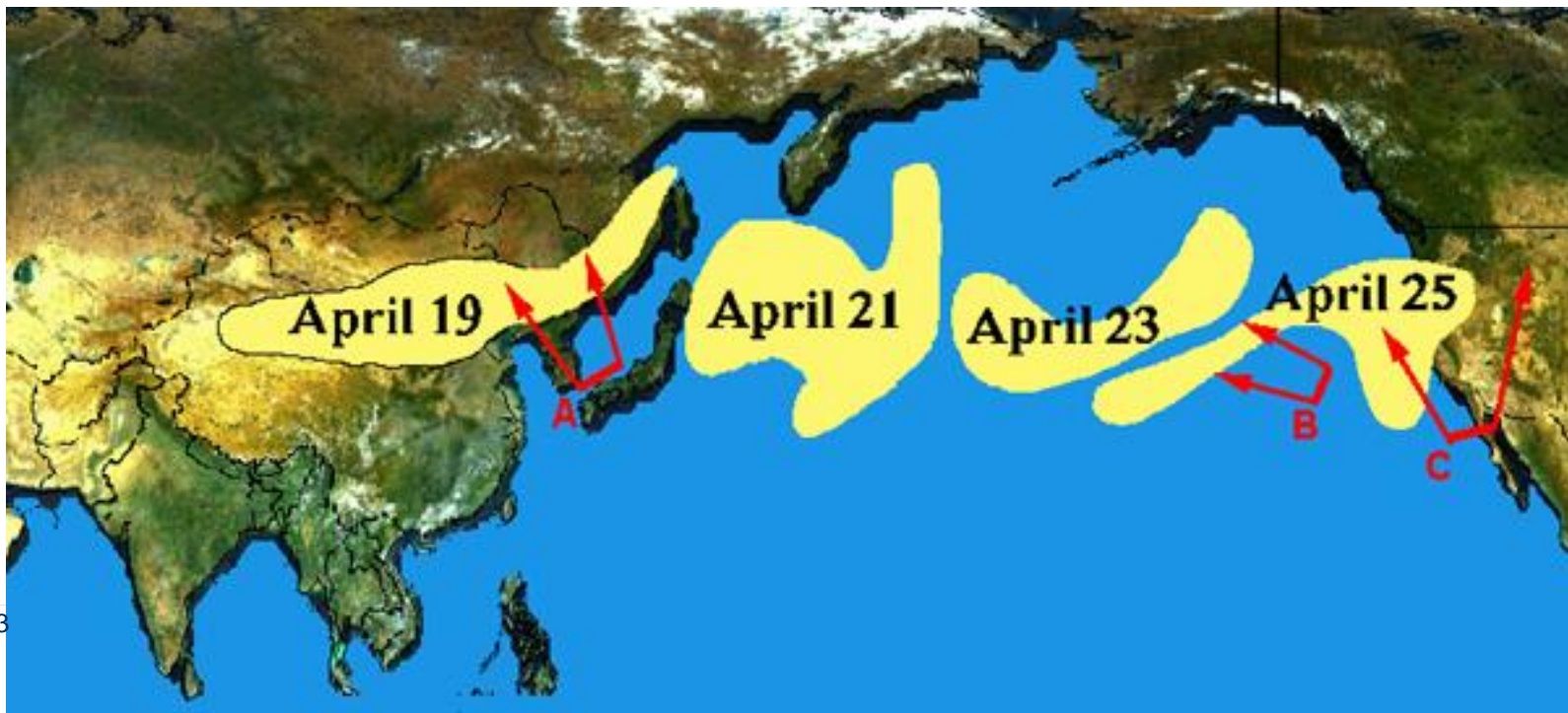
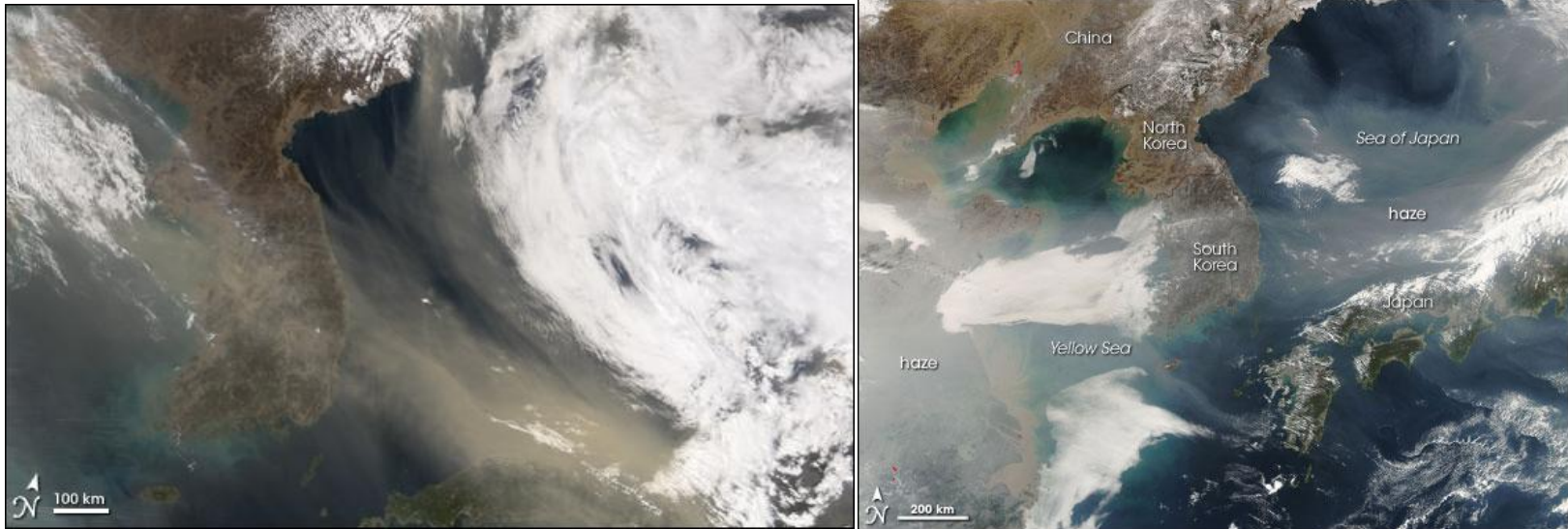
Major dust source areas particularly located along the northern and southern tropics (Tropic of Cancer and Tropic of Capricorn)

# 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>

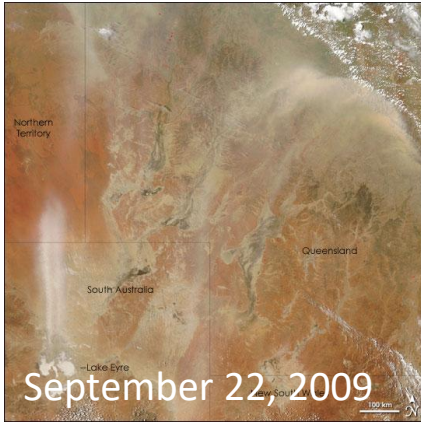
# SDS – September 2009 East-Australia



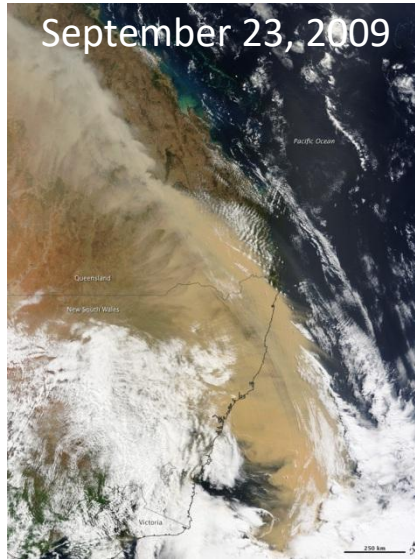
Sydney  
September 23, 2009



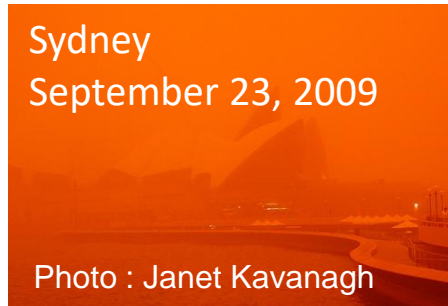
Sydney  
September 23, 2009



September 22, 2009



September 23, 2009



Sydney  
September 23, 2009

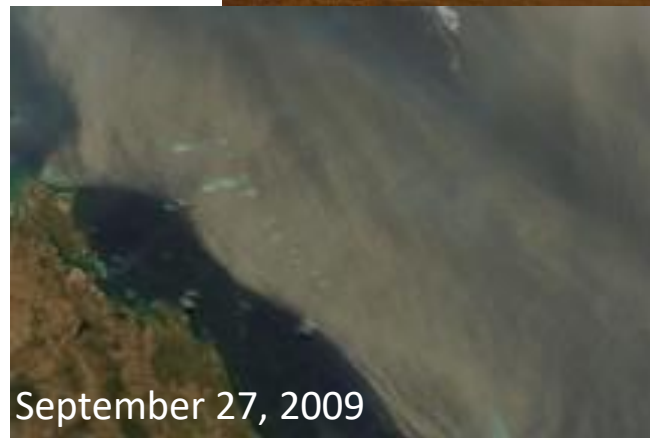
Photo : Janet Kavanagh



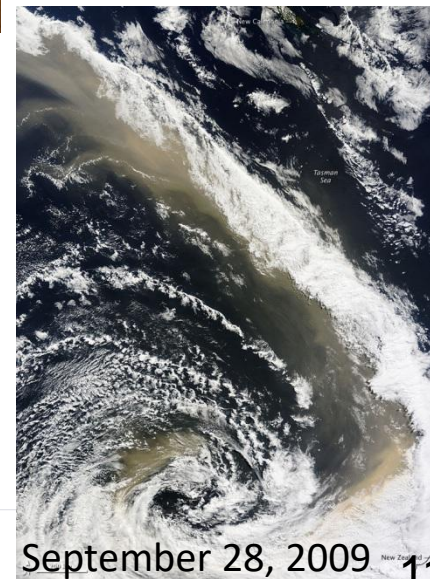
September 24, 2009



September 26, 2009



September 27, 2009



September 28, 2009

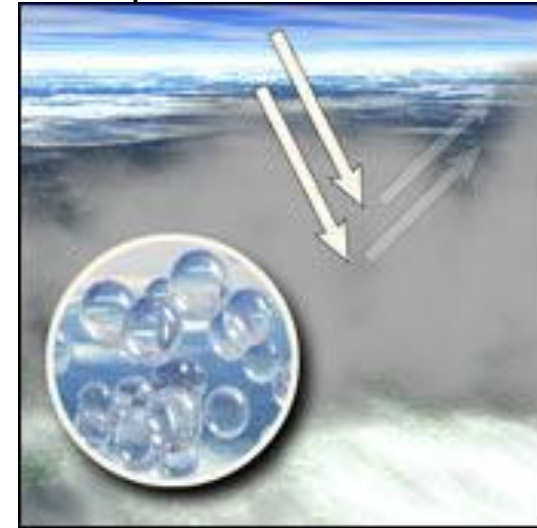
# Effects of Dust (and Sand) Storms in the Atmosphere

Yearly 2,000 Mt dust emissions → atmosphere

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

## Changes on Climate, Atmosphere,

- 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

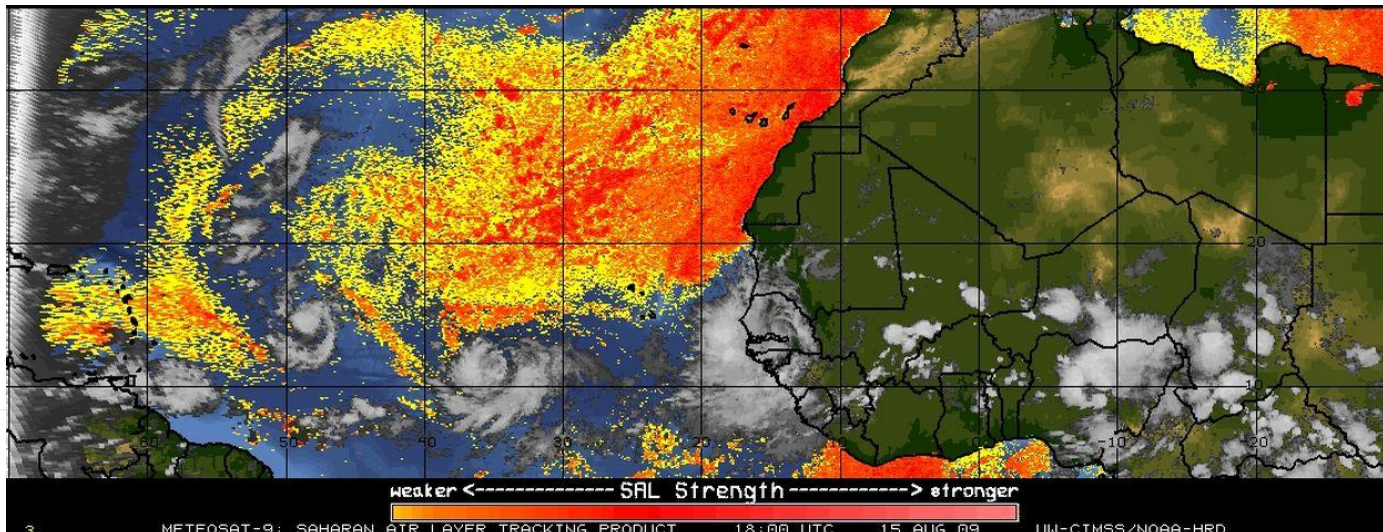
## Dust – Atmosphere – Ocean - Interaction



- Cooling the ocean surface temperature
- Fertilizing (c.f. iron) the ocean
- Changing the CO<sub>2</sub> storage of the ocean and the CO<sub>2</sub> 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

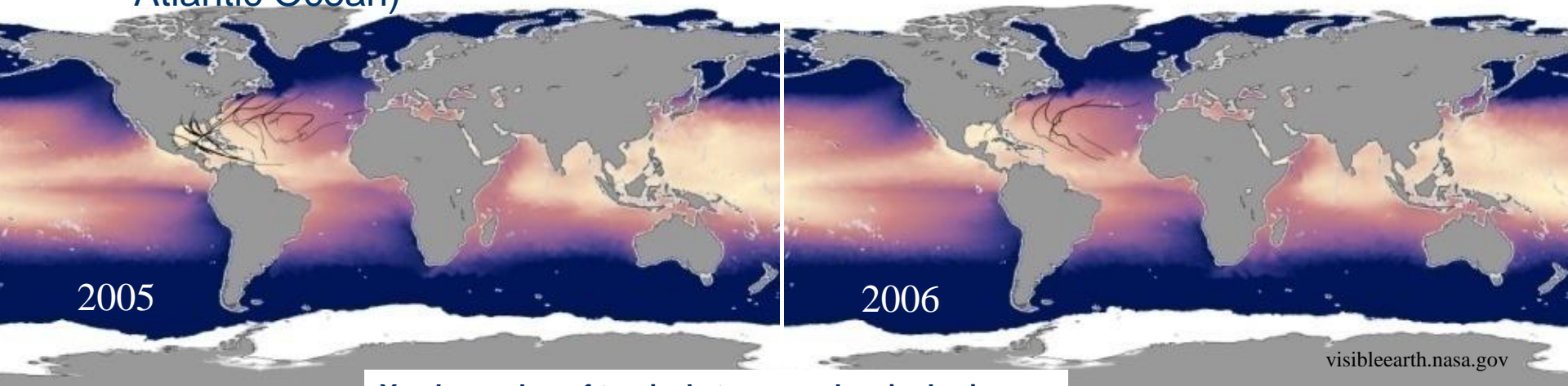
source:  
NOAA 2009



# Effects of Dust Transport through the Atmosphere

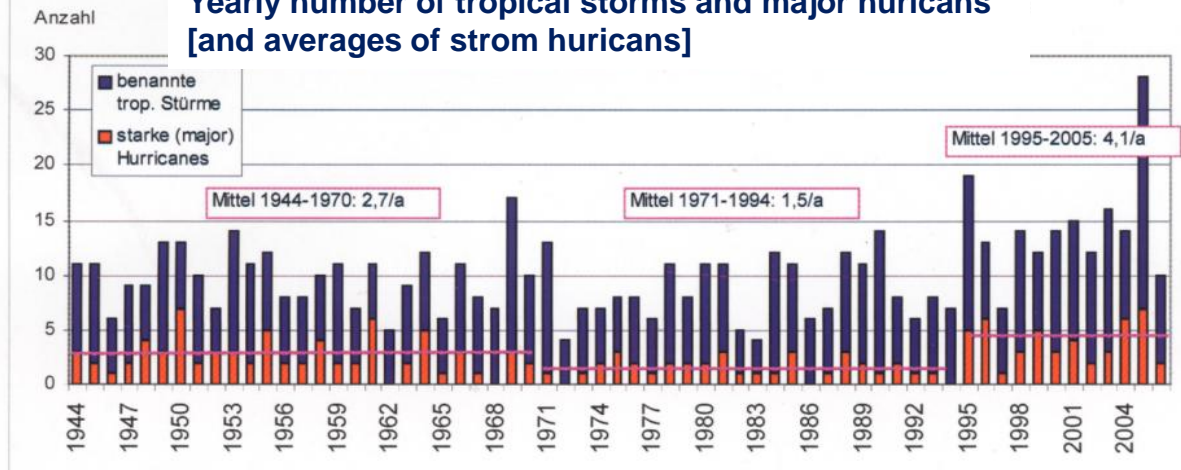
## → Ocean - Atmosphere - Interaction

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



visibleearth.nasa.gov

**Yearly number of tropical storms and major hurricanes  
[and averages of storm hurricanes]**



Europ. Meteorological  
Calendar 2008

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

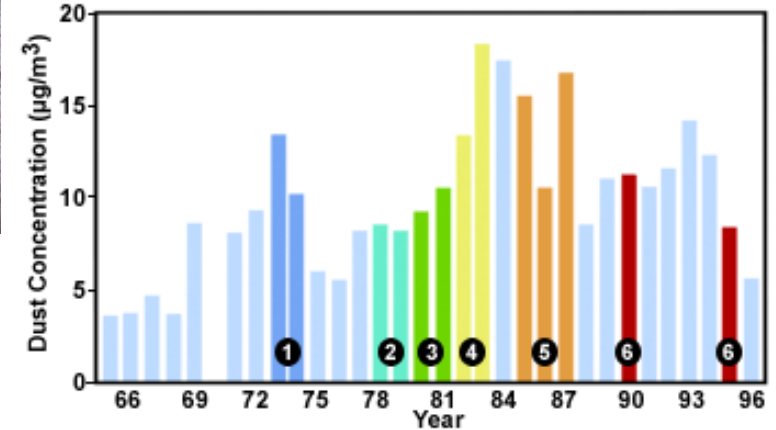
# Effects of Dust Deposition in Latin America

## → Degradation of marine ecosystems in the ocean

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



Barbados Mineral Dust Annual Average and Benchmark Caribbean Events



- 1. First appearance of black band coral disease
- 2. Staghorn and elkhorn corals die in Florida
- 3. Staghorn and elkhorn corals die in Jamaica
- 4. Staghorn and elkhorn die throughout the Caribbean (major El Nino). Sea urchin *Diademe antillarum*, a key reef herbivore, dies throughout the Caribbean
- 5. Black band disease rampant in Florida. Corals bleach throughout the Caribbean and sea grasses die in Florida (major El Nino)
- 6. Corals bleach in Florida

Prospero / USGS

## → 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

Chara Sands, Russia



Kyzyl Kum, Uzbekistan



Germany's biggest Inland Dune, in Gommern



Taklamakan, Xinjiang, China



# 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

## → Degradation of land ecosystem

### 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



Moving sands, Kyzyl Kum Desert, Uzbekistan



near Aralsk, Kazakhstan



near Urgench, Uzbekistan



Taklamakan, Xinjiang, China

# 1. Basics of SDS 2. Effects of SDS 3. Economic Impacts 4. Consequences

## Dust Storm South of Rostock, (Germany) Autobahn A19

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

HINTERGRUND SPEZIELL

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

#### Bund: Agrarindustrie schuld an Sandsturm

Rostock (dpa) Über die Entstehung des Sandsturms, der den Massenunfall auslöste, hat ein Streit entbrannt. Der Bund für Umwelt und Naturschutz Deutschland (BUND) gab der Agrarindustrie eine Mitschuld. Durch die überhöhte Verschleißrate der Bodenstruktur haben die Böden immer weniger Humusgehalt, sie degradieren", sagte der Bund-Agrarexperte im Neuland, Burkhard Boloff. Im abere Kraum trockne durch die keine Verwendung von Kunstdüngern aus und je geringer der Humusgehalt bei den landwirtschaftlichen Böden, desto schneller Spiel habe der Wind. Eine wesentliche Rolle bei solchen Sandstürmen spielen nach Auffassung des Bund auch die riesigen Felder. Die Wind-Fesseln sei auf den großen Feldern viel größer als bei beispielsweise in Schwäbisch-Hallau, wo die Felder vergleichsweise eine durchschnittliche Größe haben.



Bild des Grauens: Feuerwehrmänner dämmen am letzten LKW der Massenkarawalle einen Schwbrand ein.

## Zwischen Trauma und

### Nach der Katastrophe: Seelsorger kümmern sich um Verletzte und Helfer

Kavelstorf. Sie waren auf dem Weg in ihre sonntägliche Ostsee-Wochenende oder wollten nach einer arbeitsreichen Woche einfach nur nach Hause. Doch kurz vor dem Ziel brach am Freitag ein dunkle Wolke aus Sand und Staub den Tod. Acht Menschen starben, 130 wurden verletzt. Der Unfall auf der A 19 bei Rostock ist die schlimmste Massenkarawalle der vergangenen 20 Jahre. Jetzt werden die Ursachen ermittelt, die Staatsanwaltschaft ermittelt.

Von Kai Lachmann

Das letzte Wrack liegt neben der Autobahn inmitten verlorener Güterwagen. Der LKW ist nur noch ein rausgerissenes Häuflein Schrott. Lärmschutzwand trotz von Metallgestänge auf den schweren, matschigen Boden. Der Brandgeruch hat sich verzogen. Im Graben neben dem Staatsweidewald überreste der Katastrophe verstreut. Scherben, Plastikflaschen, zerstückelte Arbeitshandschuhe, Verpackungen von Müllbindern. Auf der anderen Seite haare sich Fernsehensammler. Reporter berichten live von der A 19.

Die ausgebrannten Wracks wurden längst abtransportiert. Das Feuer entzündete sich an einem Hinterrad, dass die Metallteile aufglühten und in einzelne Stellen tiefe Löcher hinterlassen hat. „Da muss sich der Tank oder der Motor eines Wagens befinden haben“, vermutet Manfred Röhler vom Landeskriminalamt. Röhler ist Leiter des Ermittlungsteams für den Unfall. Er ist ein Mann, der für ein Bild steht. Am Tag danach koordiniert der 57-jährige die Reparaturen der Autobahn. Auf rund 100 Meter Länge muss die Strecke erneuert werden.

Der Sturm hat sich gelegt. Es ist bereits windstill. Nur noch selten weht Gallaubstach vom verengten Acker herüber. Drehbühnen-Lärm setzt ein. Mit einer Füllschicht von langem Strohstreu, die obere Schicht der Fahrschienen Richtung



Abschau von Normalität: Straßenschilder ansehen gestern den verschütteten Berg ab, damit die A 19 schnell wieder freigegeben werden kann.



raume Zeit bewogen werden“, sagt Hübner. „Es gibt nur einen Fortschritt: 500 Meter von



in der Sandwolke, wie blind.“



sonntag freigegeben. Ein in Richtung Normalität deutet wird an dieser Stelle pro Stunde progressiv werden sehen. „Aber was“ sagt Thomas Hübner, Leiter der Autobahnmeisterei Kavelstorf. „Aber was“ sagt Thomas Hübner, Leiter der Autobahnmeisterei Kavelstorf. „Aber was“ sagt Thomas Hübner, Leiter der Autobahnmeisterei Kavelstorf.

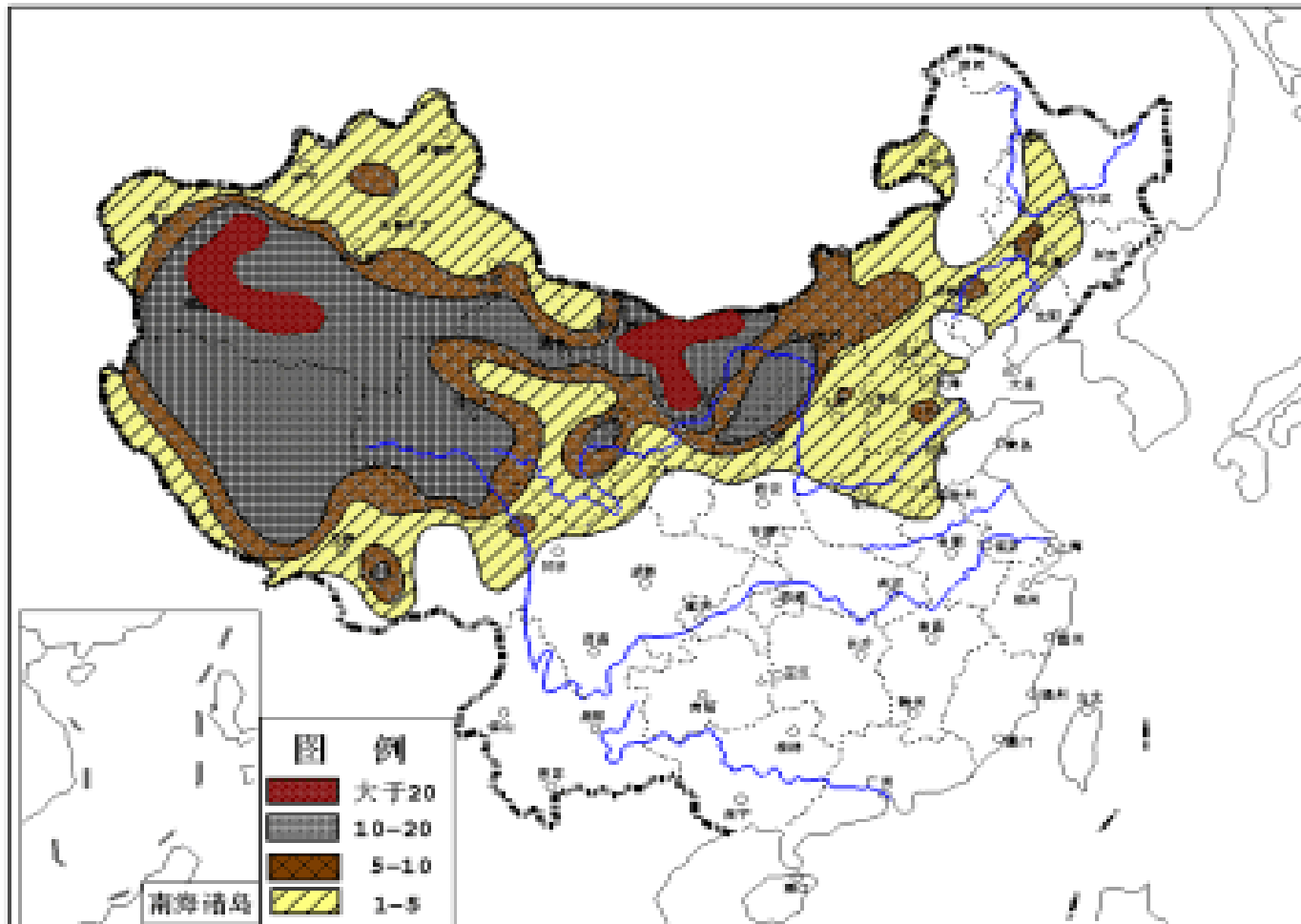
#### STICHWORT

#### Sandstürme

Sandstürme kennt man vor allem aus der Wüste, aber auch in Nordostdeutschland sind sie keine Selbstenheit. Voraussetzungen dafür sind lange anhaltende Hochdrucklagen und trockene, kalte Fronten. Dann kann der Sturm größere Mengen Sand und Geröll aus den Feldern in die Luft heben – der Sandsturm ist da. Schon mehrfach haben solche Stürme den Verkehr behindert, allerdings noch nie mit so katastrophalen Folgen wie am Freitag auf der A 19.

Am 8. April 2003 berichtete die Polizei in Mecklenburg-Vorpommern von Straßensperren auf gleich mehreren Straßen. Auch in Teilen Brandenburg kam es damals zu diesem Phänomen. Folge waren Unfälle mit Beschädigung. Am 11. April 1997 trug ein Sturm mit mehr als 90 Stundenkilometern große Mengen Erde von Acker in Mecklenburg-Vorpommern ab. Eine Lawastöße zwischen Genthain und Lohme war wegen bis zu 50 Zentimeter hoher Gallaubstach für Stunden unpassierbar. In den Sandböden betrug die Sicht teils nur zwei Meter. da

## Days of Dust Storms per Year in China



Source: Zhang (2006)

In past 50 years of the 20<sup>th</sup> 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)

70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



# Dust Storm Effects in Beijing, April 17, 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	Percentage	Quantity	Percentage
Quantity of tested children	2030	100%	1979	100%
Quantity of diseases, including	229	11.3%	239	11.9%
<b>Acute pneumonia</b>	145	<b>63.0%</b>	153	<b>65.1%</b>
<b>Chronic bronchitis</b>	63	<b>27.5%</b>	68	<b>29.4%</b>
<b>Chronic pneumonia</b>	21	<b>9.5%</b>	13	<b>5.5%</b>

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

# 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 mortality	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 <sub>2</sub> 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 Infrastructure 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 al. (in press)	1993	1.8
Kuwait	Al-Dousari et al. (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  
→ **Management** → increasing sorption and stabilisation of soil surfaces

Plantations in Khorezm

- increasing coverage of vegetation
- Sand and dust catcher



Sand catcher in Turmenistan

- Prevention of deflation
- Dune stabilization



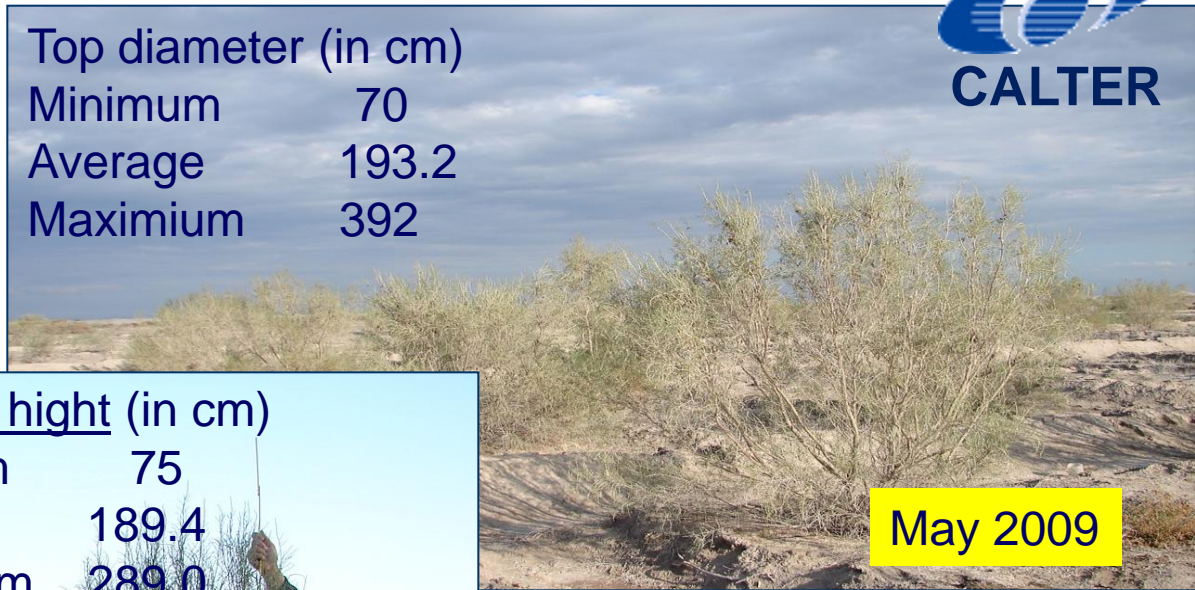
# Plantations on the Dry Lake Bed of the Aral Sea



## *Haloxylon aphyllum*- Plantation with irrigation near Muinak (Uzbekistan)

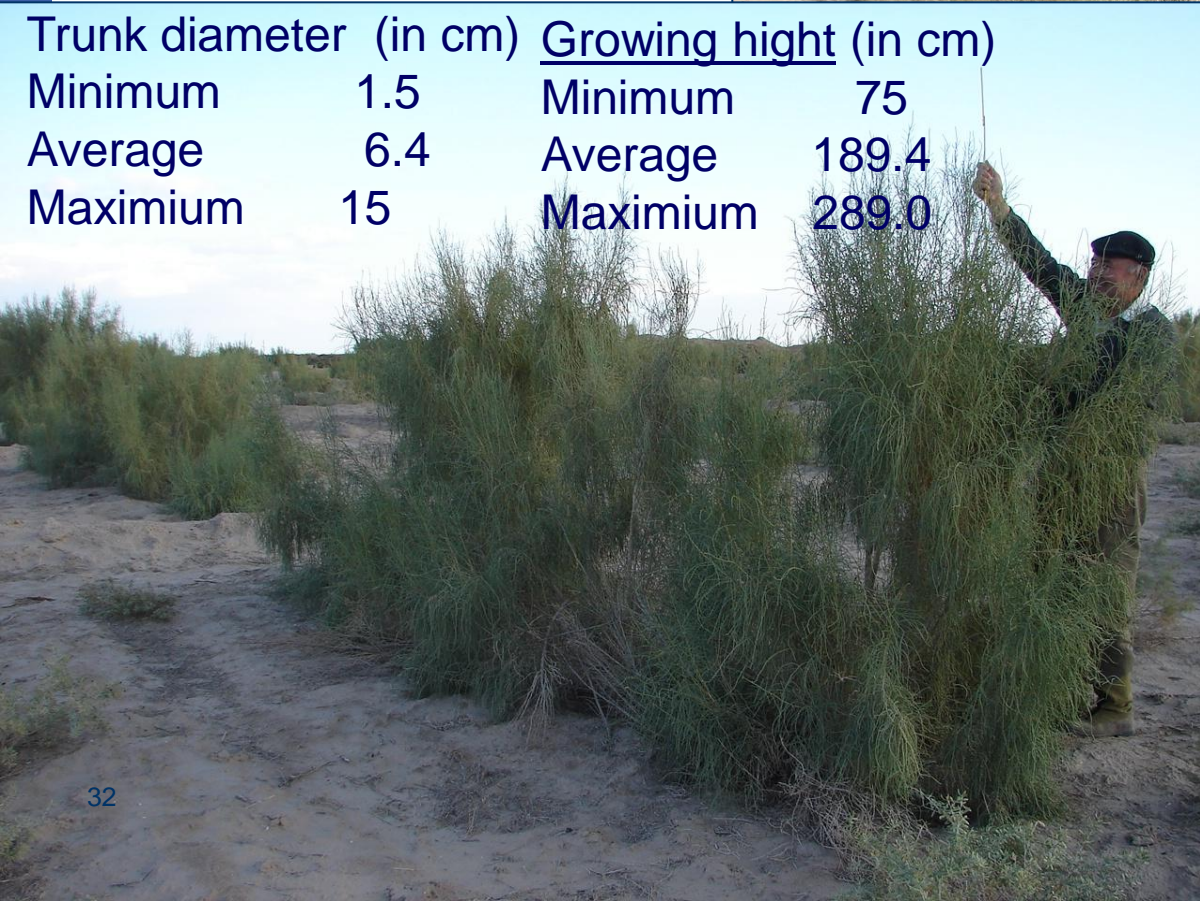
source: Treshkin & Kuzmina (2009)

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



May 2009

Trunk diameter (in cm)		<u>Growing height</u> (in cm)	
Minimum	1.5	Minimum	75
Average	6.4	Average	189.4
Maximum	15	Maximum	289.0





# Plantations on the Dry Lake Bed of the Aral Sea



## *Haloxylon aphyllum* Plantation without Irrigation

### Near Muinak (Uzbekistan)

source: Treshkin & Kuzmina (2009)

#### Growing height (in cm)

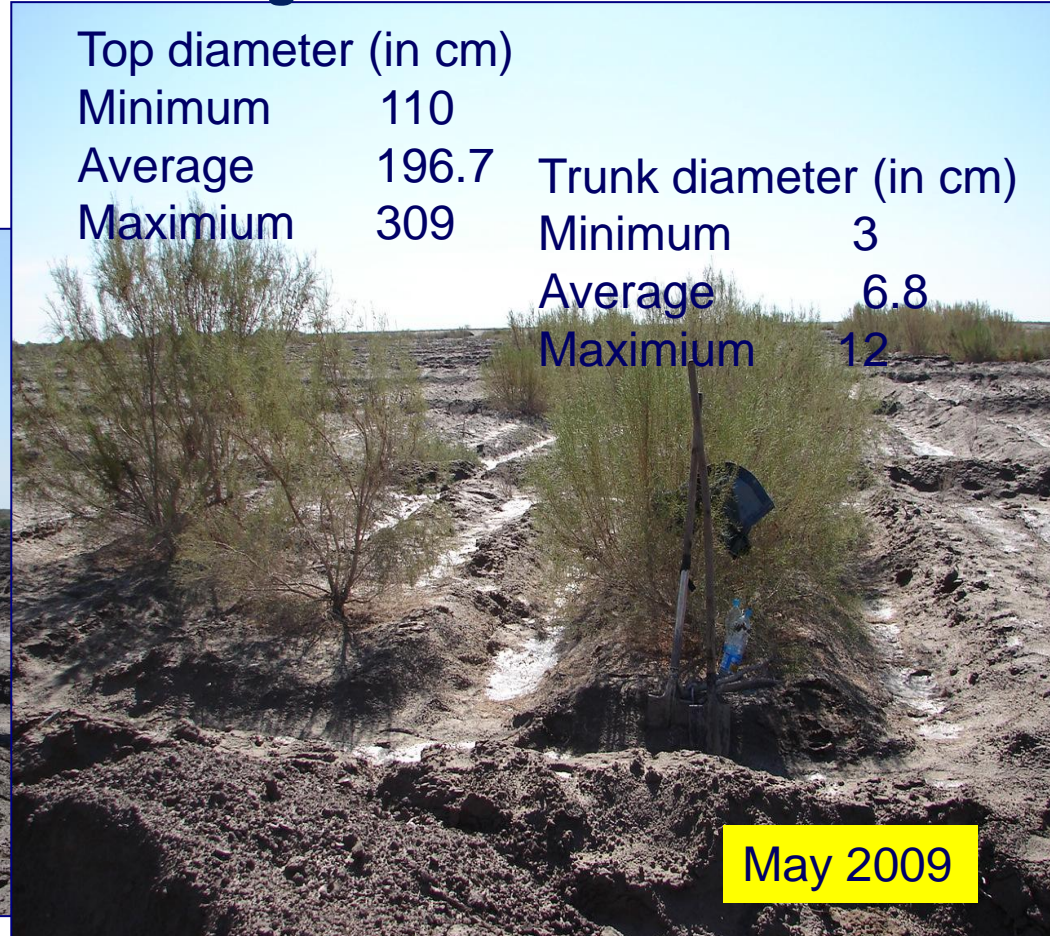
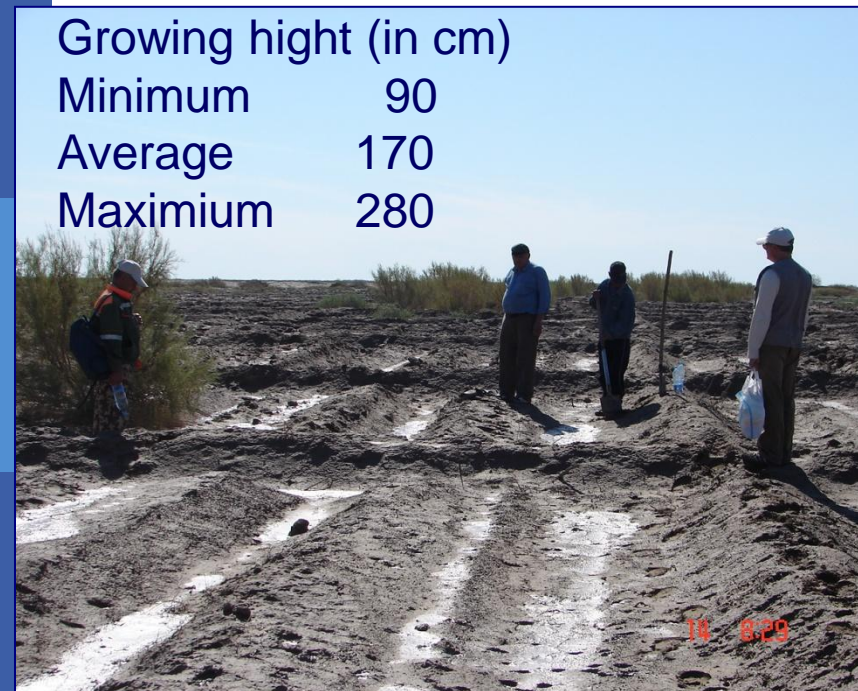
Minimum	90
Average	170
Maximum	280

#### Top diameter (in cm)

Minimum	110
Average	196.7
Maximum	309

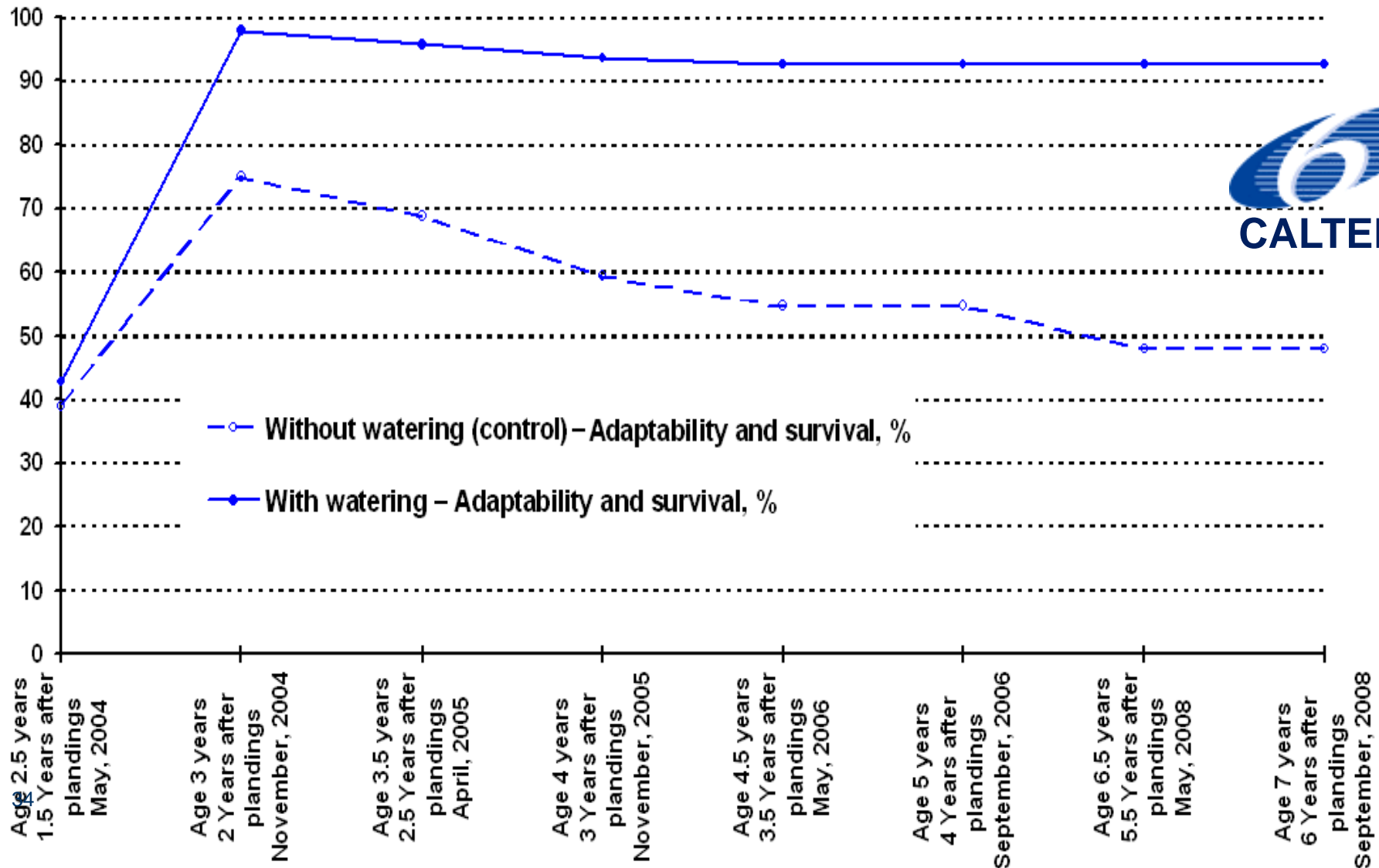
#### Trunk diameter (in cm)

Minimum	3
Average	6.8
Maximum	12



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

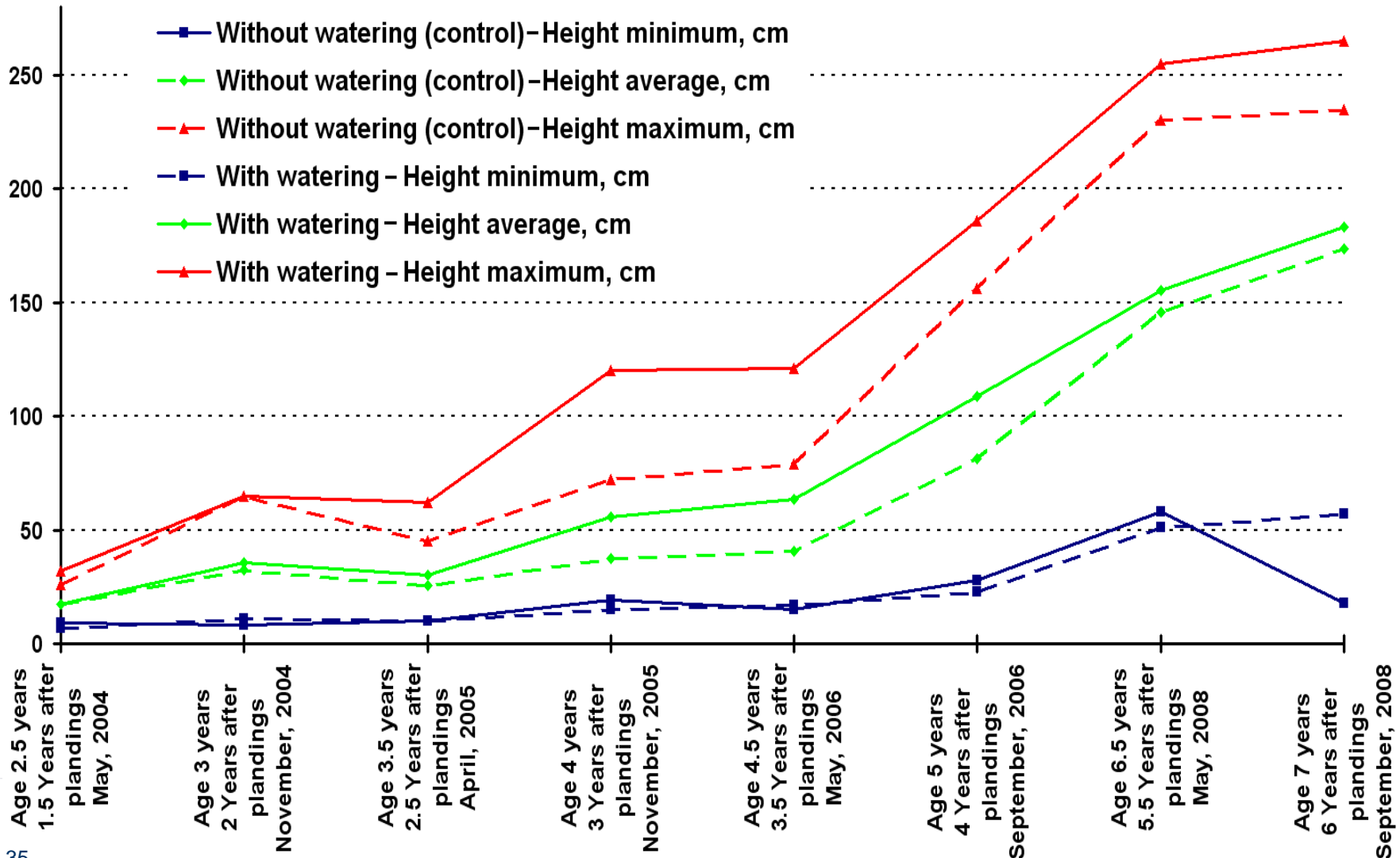
source: Treshkin & Kuzmina (2009)



# Growing height of Saxaul- (*Haloxylon aphyllum*) Plants on Solonchaks of the dried Aral Sea Bottom



source: Treshkin & Kuzmina (2009)



# Increasing Sorption and Stabilisation of Soil Surfaces

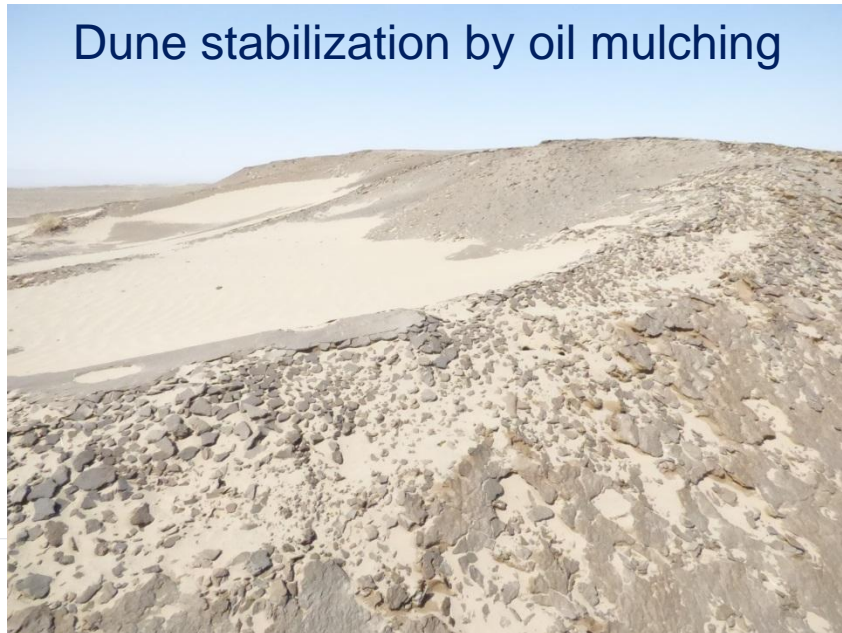
Dune stabilization by sand catcher



Plant cover revitalization by watering



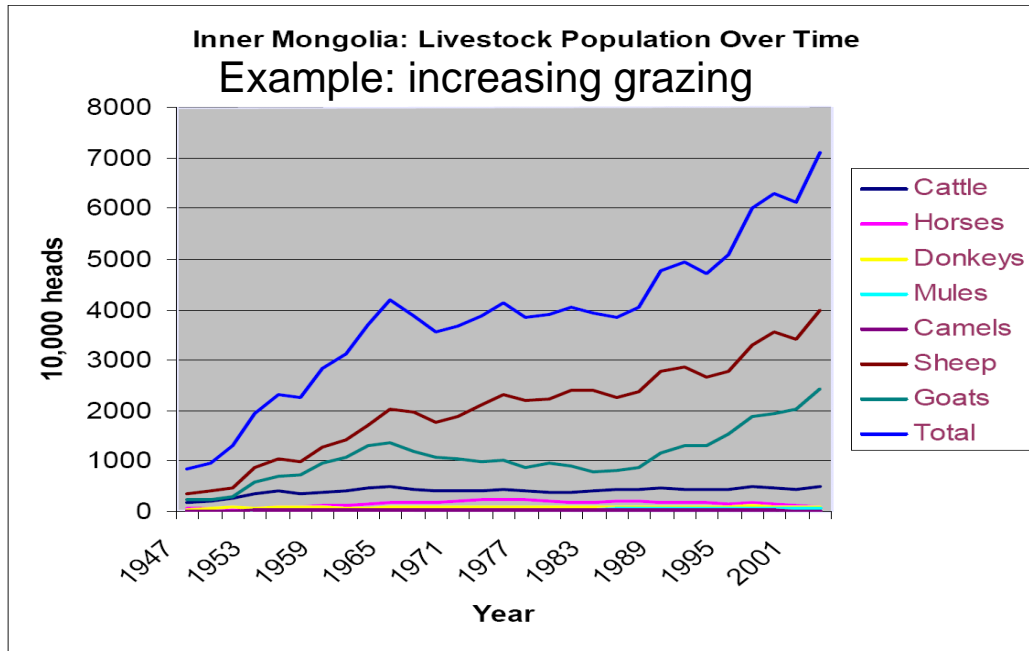
Dune stabilization by oil mulching



Plantation of biological barriers



# Decreasing Number and Frequency of Grazing Animals



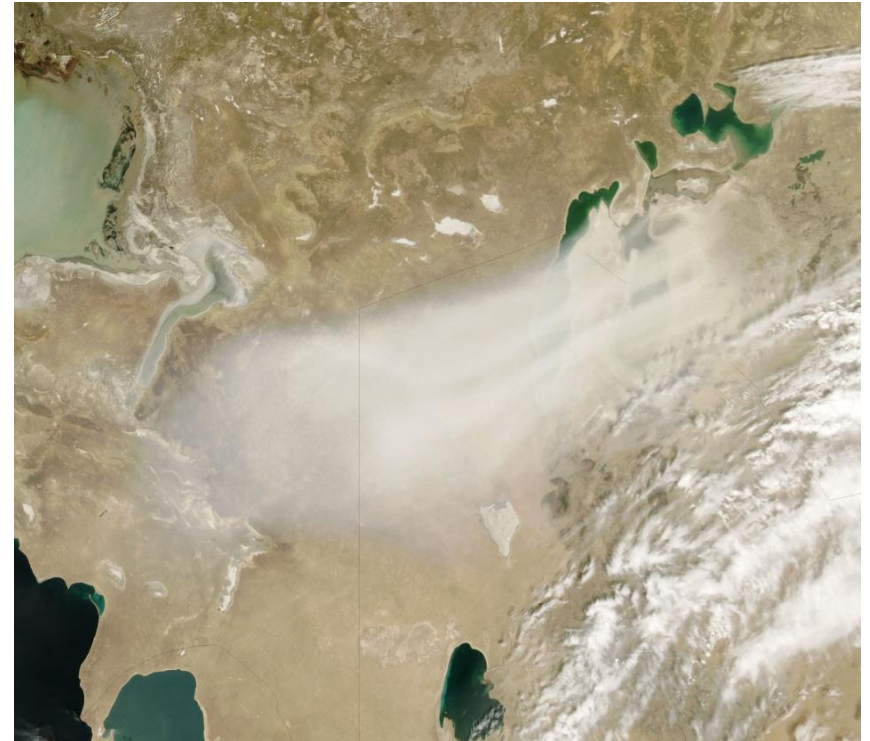
# TAKE HOME MESSAGE

- 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 atmosphere 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



$L = 100 \dots 150 \text{ km}$



$L = 800 \text{ km}$

<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

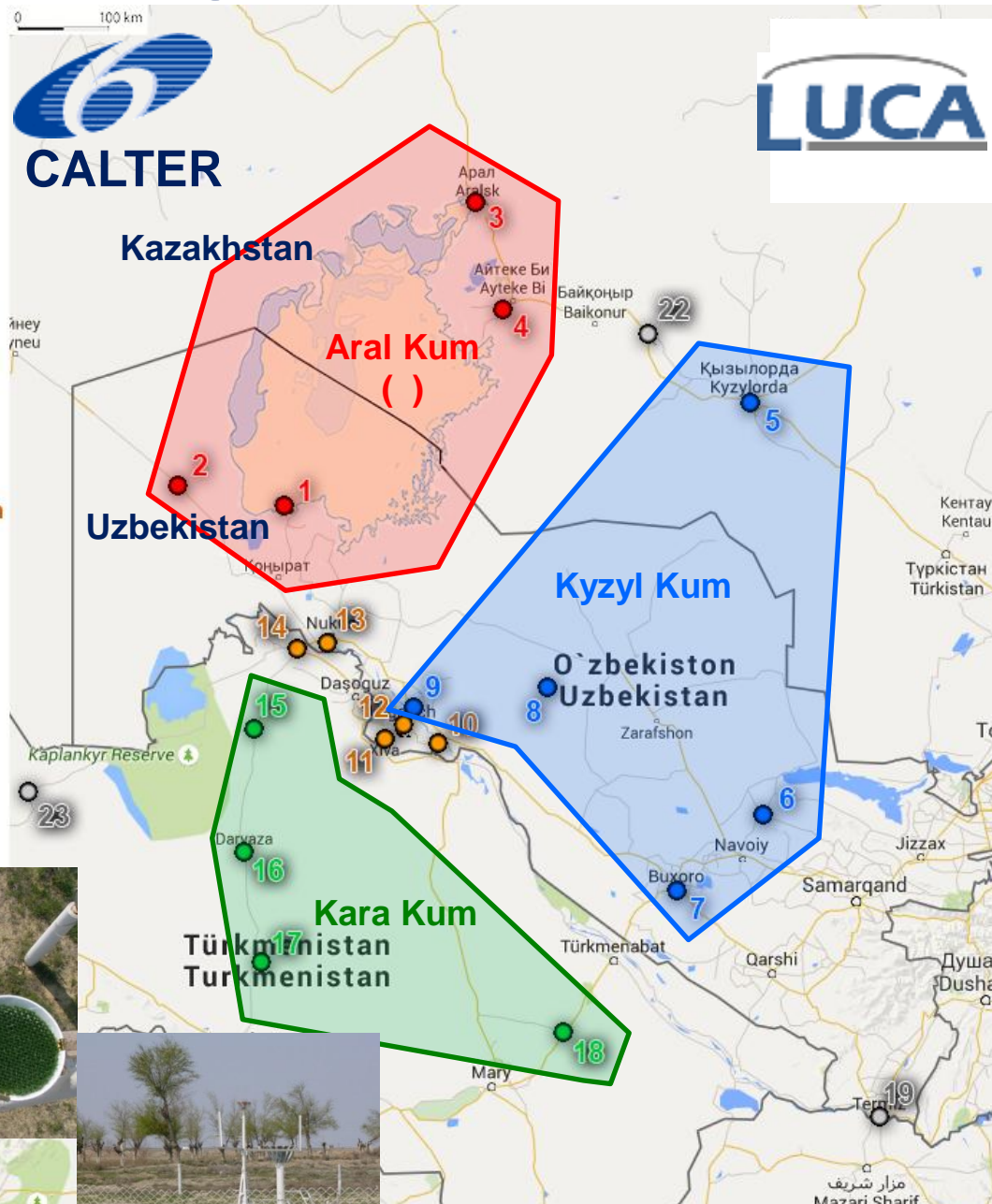
- 10 - Yangibazar
- 11 - Khiva
- 12 - Urgench
- 13 - Takhiatash
- 14 - Kunya-Urgench

## Karakum

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

## other

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



## 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