Desert Storms and their ability to move microorganisms and toxins around the globe

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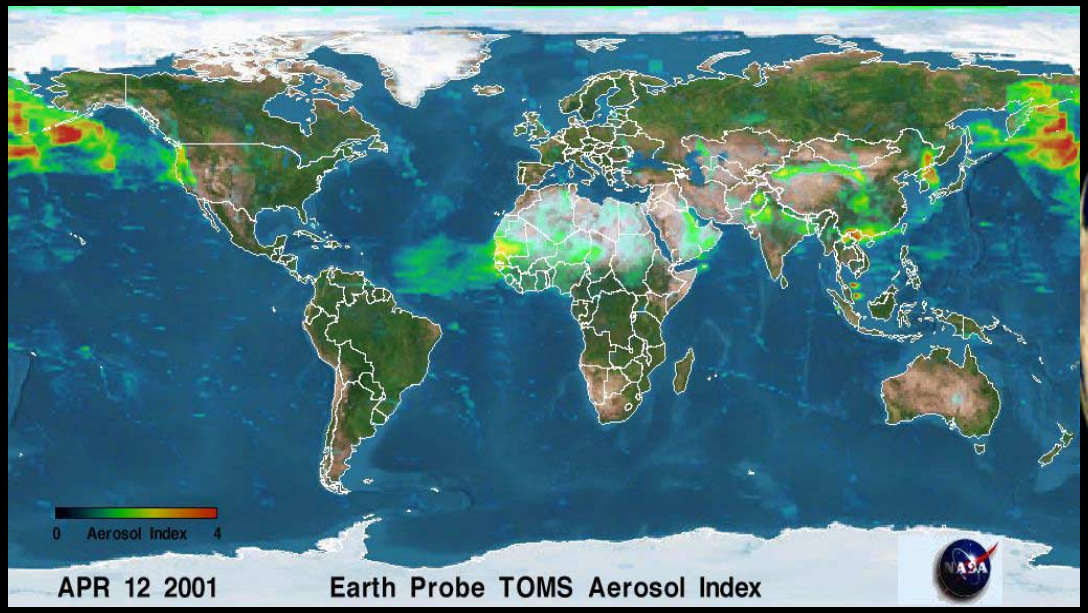
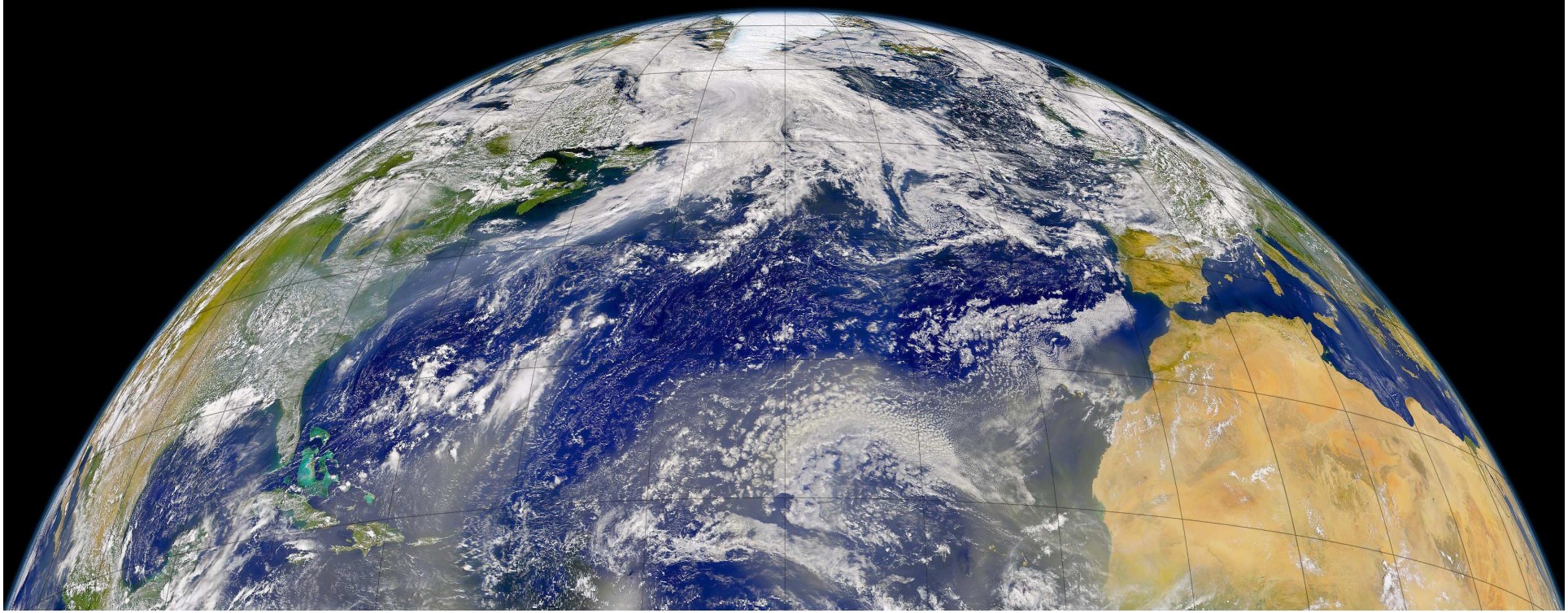
Asian Dust Storm – April 2001



Animation – NASA.JSC

African desert dust forms an atmospheric bridge between Africa and the Caribbean

SeaWiFS image, August 8, 2001. Image provided by the SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE



Atmospheric dust - Human and ecosystem health

- **Dust as a trigger for harmful algae blooms**
  - **Death of marine organisms**
  - **Human illness – respiratory stress, skin rash, paralysis and memory loss from consumption of contaminated seafood**
- **Dust as a carrier of toxins**
  - **pesticides, herbicides, hydrocarbons, metals, industrial emissions…**
  - **implications – direct (*exposure = death/acute illness*) or indirect (*exposure = immune suppression*)**
- **Dust as a carrier of microorganisms**
  - **Pathogenic = disease outbreaks**
  - **Non–pathogenic = ecological change**
- *Respiratory stress from inhalation of soil particles*

El Nino conditions = no rain….no runoff…….dust event moved through area on 23 October 2002

CRIMSON TIDE - Algae a taste of this summer's blooming drought

The Daily Telegraph , 05-11-2002 , Ed: 1 - State , Pg: 003 , 550 words , LOCAL
THE NSW coast is turning bright red, in what experts claim is an unprecedented rise in algal blooms. As a consequence, an eerie fluorescent green glow is beginning to appear at night in waters around Sydney Harbour. Yesterday the crimson tide had eng...

Photo courtesy of Dr. Tony Ladson, Civil Engineering, Monash University, Clayton, Victoria, Australia

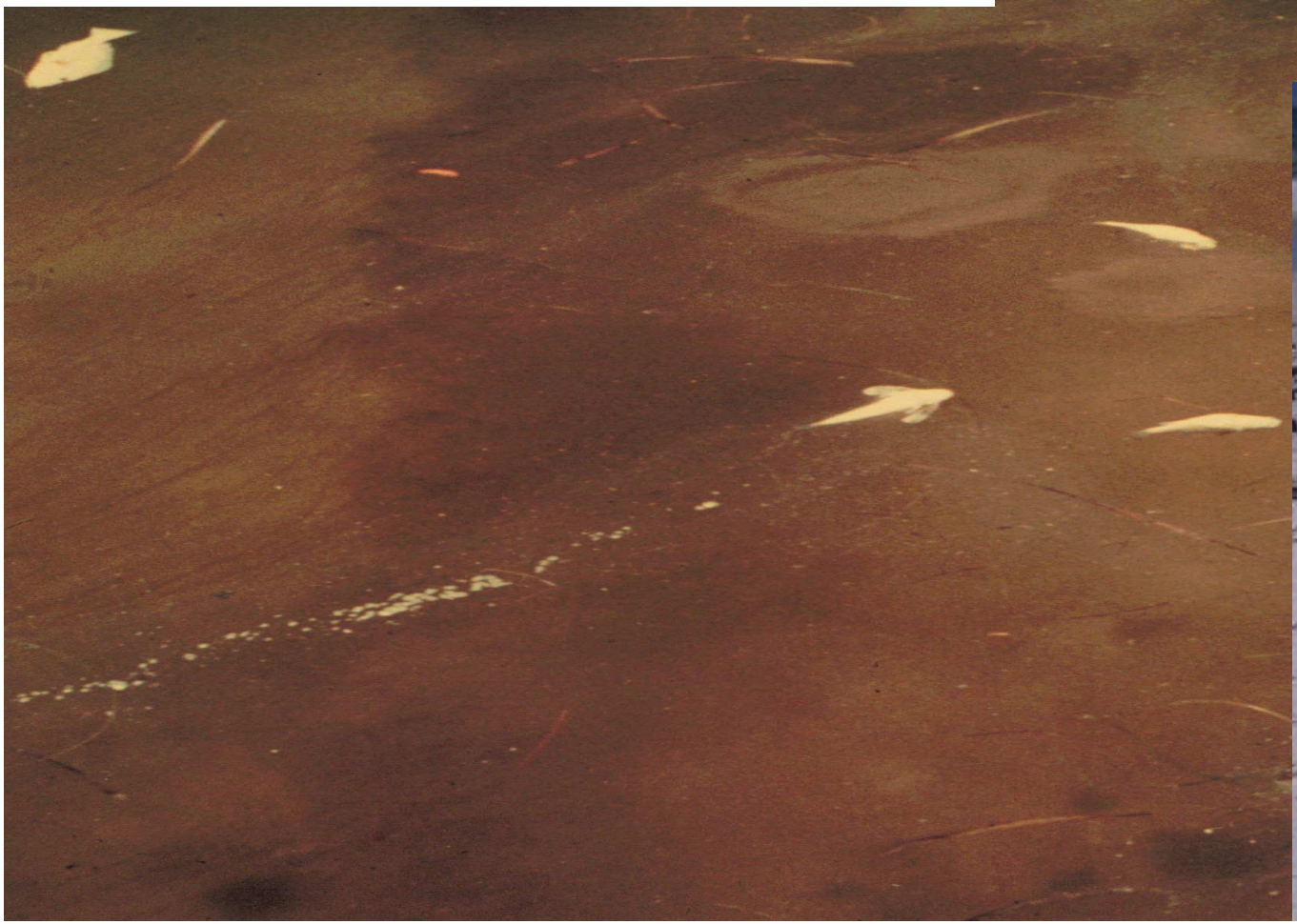
Terra – MODIS, Image 22385, http://visibleearth.nasa.gov

• a correlation between dust events and harmful algal blooms.

> •*Walsh and Steidinger. 2001. Saharan dust and Florida red tides: The cyanophyte connection. Journal of Geophysical Research - Oceans. 106(C6):11,597-11,612*
>
> •*Lenes et al. 2001. Iron fertilization and the Trichodesmium response on the West Florida shelf. Limnology and Oceanography. 46(6):1261-1277*

• an increase in biomass in the North Pacific following a Gobi dust event.

> •*Bishop et al 2002. Robotic Observations of Dust Strom Enhancement of Carbon Biomass in the North Pacific. Science. 289:817-821*



Toxins and Dust

- Pesticides - in airborne dust near the Aral Sea, phosalone (*highly toxic to aquatic vertebrates, invertebrates and crustaceans*) concentrations were as high as 126mg/kg. ***O'hara et al. 2000. Lancet.***

• DDT residue found in children's blood and human breast milk in the vicinity of the Aral Sea. ***Jensen et al. 1997. Science of the Total Environment*** and ***Hooper et al. 1997. Environmental Health Perspectives*** **respectively.**

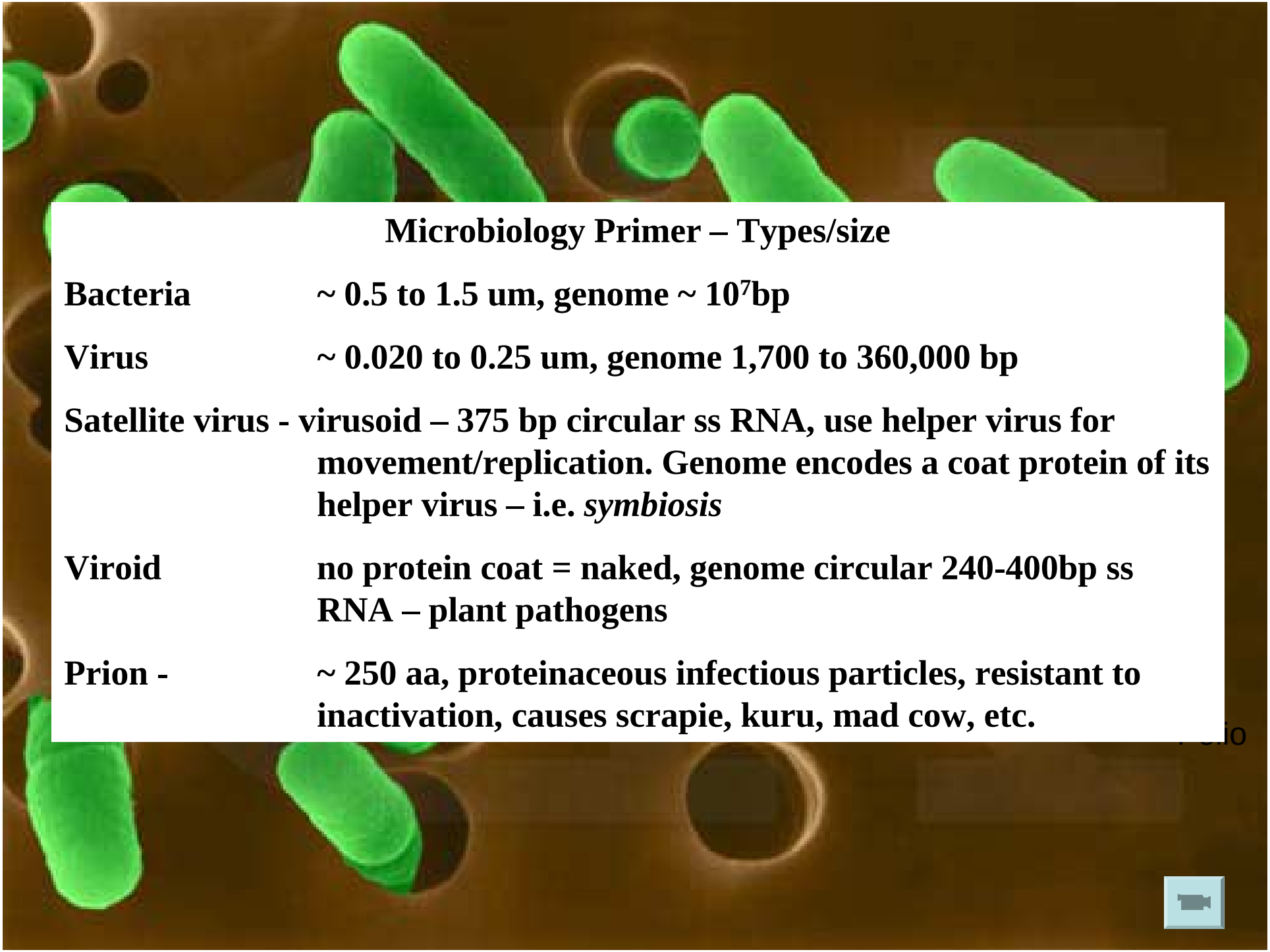
• DDT residue found in Arctic mammals (aquatic and terrestrial), crustaceans and human populations. Suspected atmospheric transport of pesticides from Europe and and Asia. ***Cleemann et al. 2000. Science of the Total Environment*** and ***Dewailley et al. 2000 Environmental Health Perspectives*** **respectively.**

• Certain pesticides and herbicides were only found in atmospheric samples during African dust events along Israel's coastal plain (5-pentyl and 5- heptyl-2(3H)-furanone, degradation products of trifluraline or profluraline and degradation products of pyridyltetrazole-containing herbicides). ***Falkovich et al. 2004. Journal of Geophysical Research***

• **USGS preliminary data** – same group of pesticides found in Mali, Africa and the USVI during African dust events. USVI concentrations are lower

• Radioisotopes – elevated levels of Cesium – 137 (Chernobyl origin) occurred in a Saharan desert dust colored rain event in Greece. ***Papastefanou et al. 2000. Journal of Environmental Radioactivity.***

• Metals, industrial waste, hydrocarbons etc…….



Microbiology Primer – Types/size

Bacteria ~ 0.5 to 1.5 um, genome ~ 10^7bp

Virus ~ 0.020 to 0.25 um, genome 1,700 to 360,000 bp

Satellite virus - virusoid – 375 bp circular ss RNA, use helper virus for movement/replication. Genome encodes a coat protein of its helper virus – i.e. *symbiosis*

Viroid no protein coat = naked, genome circular 240-400bp ss RNA – plant pathogens

Prion - ~ 250 aa, proteinaceous infectious particles, resistant to inactivation, causes scrapie, kuru, mad cow, etc.

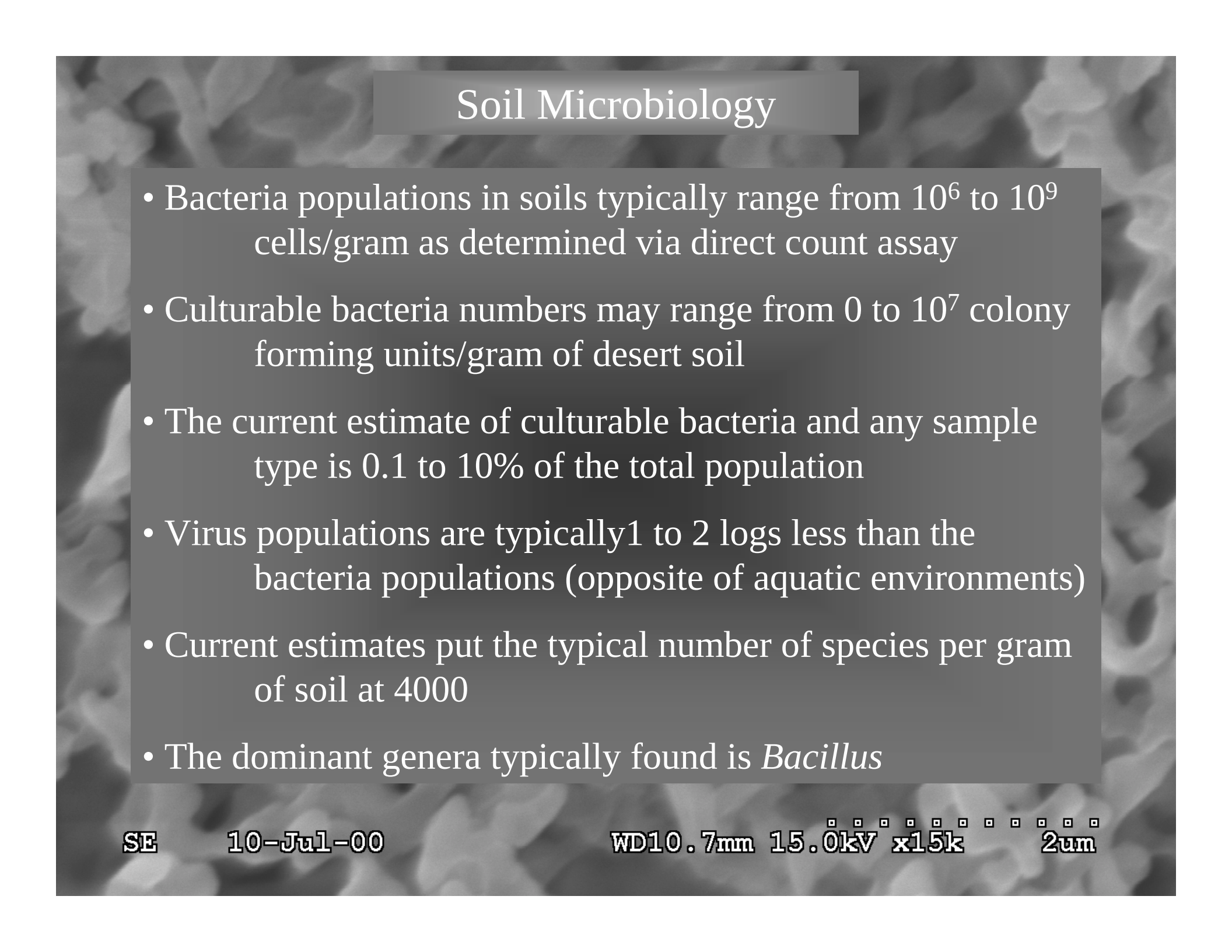
Table 1. Human airborne pathogens

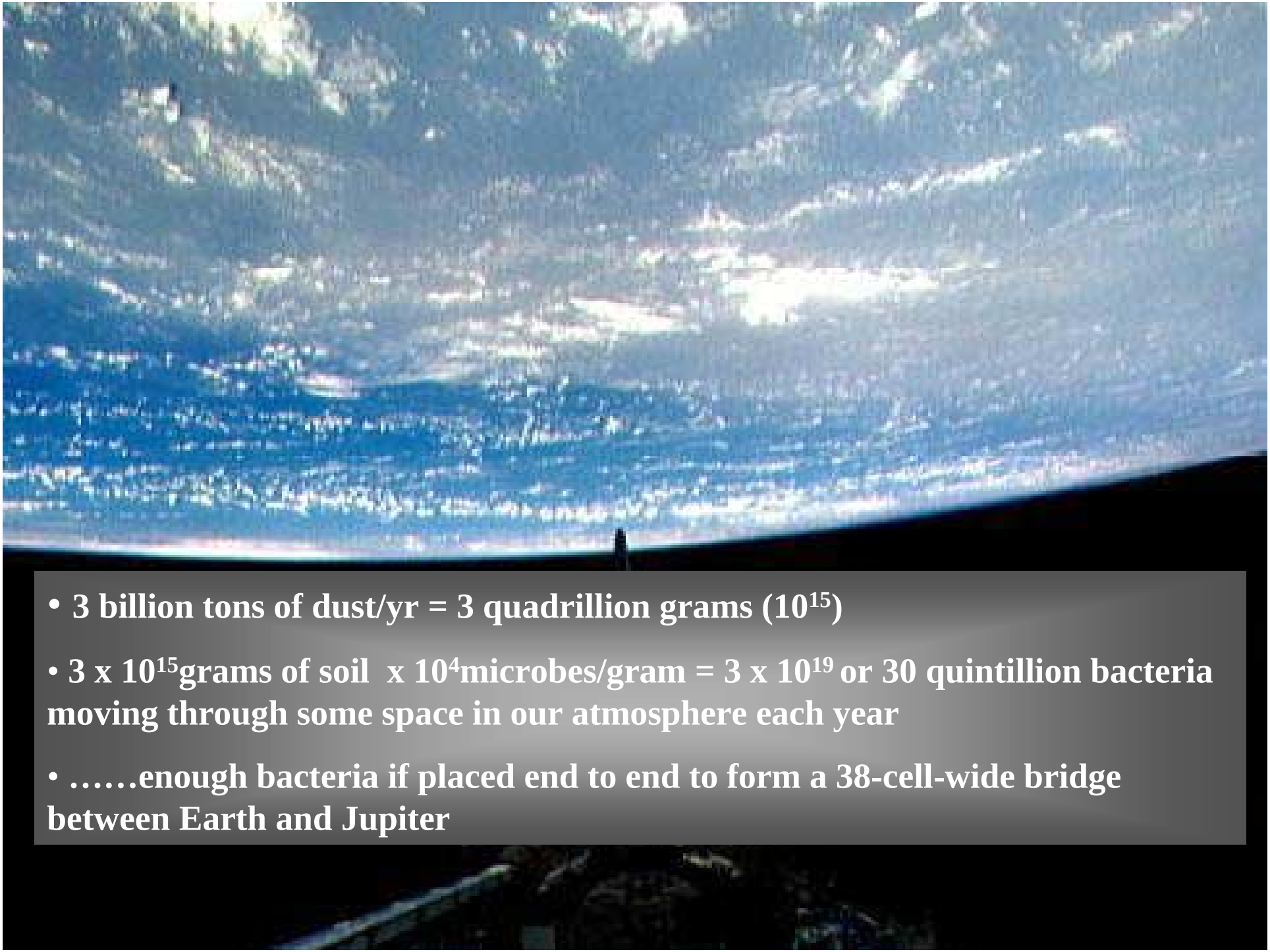
Agent	Disease
Bacteria	
Yersinia pestis	the 'Black Plague' which killed off ¼ of Europe's population in the 14th century
Bacillus anthracis	Anthrax
Mycobacterium tuberculosis	Tuberculosis
Legionella pneumophila	Legionnaires' Disease
Bordetella pertussis	Whooping Cough
Corynebacterium diphtheriae	Diphtheria
Chlamydia psittaci	Psittacosis
Haemophilus influenza *Streptococcus pneumonia* *Neisseria meningitidis*	Bacterial flu, bacterial meningitis
Fungi	
Cryptococcus neoformans	Cryptococcosis
Aspergillus sp.	Aspergillosis
Coccidioides immitis	Coccidiomycosis – desert dust storms
Histoplasma capsulatum	Histoplasmosis
Blastomyces dermatitidis	Blastomycosis
Virus	
Rhinoviruses	The 'common cold'
Influenza viruses	Viral flu
Herpes virus -3	Chicken pox
Hantavirus	Hantavirus pulmonary syndrome – dust cont. w/mice urine/feces
Poxvirus - Variola virus	Smallpox

What of other or unknown pathogenic microorganisms?
Is there a limit to range (airborne survival)?

Soil Microbiology

- Bacteria populations in soils typically range from 10^6 to 10^9 cells/gram as determined via direct count assay
- Culturable bacteria numbers may range from 0 to 10^7 colony forming units/gram of desert soil
- The current estimate of culturable bacteria and any sample type is 0.1 to 10% of the total population
- Virus populations are typically1 to 2 logs less than the bacteria populations (opposite of aquatic environments)
- Current estimates put the typical number of species per gram of soil at 4000
- The dominant genera typically found is *Bacillus*





- **3 billion tons of dust/yr = 3 quadrillion grams (10^{15})**
- **3 x 10^{15}grams of soil x 10^{4}microbes/gram = 3 x 10^{19} or 30 quintillion bacteria moving through some space in our atmosphere each year**
- **……enough bacteria if placed end to end to form a 38-cell-wide bridge between Earth and Jupiter**

Microbiology Research Sites

+ NASA High Altitude Samples ~20,000m

	Dust (CFU/m^3)	No Dust (CFU/m^3)	Ratio - Dust/No Dust
Mali - Bacteria	6460	636	10.2
Mali - Fungi	195	63	3.1
Mali - Total	6655	699	9.5
N. Caribbean - Bacteria	72	5	14.4
N. Caribbean - Fungi	32	7	4.6
N. Caribbean - Total	104	12	8.7
Turkey - Bacteria	4	1	4
Turkey - Fungi	52	18	2.9
Turkey - Total	56	19	3
Mali/N. Caribbean	**Ratio**	**% Inactivation**	
Bacteria	89.7	99	
Fungi	6.1	86	
Total	64	98	


MALI
Taoudenni
Bidon 5
ALGERIE
AZAOUAD
Tessalit
Araoune
Mabrouk
Kidal
Tabankort
MAURITANIE
TOMBOUCTOU
Bourem
TENERE
LAC FAGUIBINE
NIGER
GOUNDAM
Mt. IN RHABE
NIAFOUNKE
GAO
Ménaka
Ansongo
RÉSERVE TEMPORAIRE DE FAUNE D'ANSONGO-MENAKA
SAHEL
NIORO
Nara
PARC NATIONAL DE LA BOUCLE DE BAOULE
MOPTI
FALAISES DE BANDIAGARA
NIGER
KAYES
FORÊT DE BADINN-KO
Ké-Macina
TILLABERI
BANDIAGARA
BAFOULABE
RÉSERVE DE FINA
SÉGOU
SAN
BURKINA FASO
NIGER
KITA
KOUTIALA
OUAGADOUGOU
BAMAKO
GUINEE
BOUGOUNI
SIKASSO
BOBO DIOULASSO
SIGUIRI
Mt. MINA
GHANA
TOGO
BENIN
NIGERIA
COTE D'IVOIRE

USGS

Bamako, Mali, West Africa

Viable Counts From Mali Filters

Date	Sample Conditions	Liters of air filter	Total Bacteria/Filter	Total Fungi/ Filter
Feb 3, 2001	Dust	151	2368	20
Mar 2, 2001	Dust	76	556	22
Mar 29, 2001	Dust	71	396	6
Mar 30, 2001	Dust	81	194	30
Apr 5, 2001	Dust	81	108	8
Dec 13, 2001	Non-dust	80	86	10
Mar 1, 2002	Non-dust	81	16	0

USGS

Mali Bacterial Pathogens Detected

10% are animal pathogens

5% are plant pathogens

27% are opportunistic human pathogens

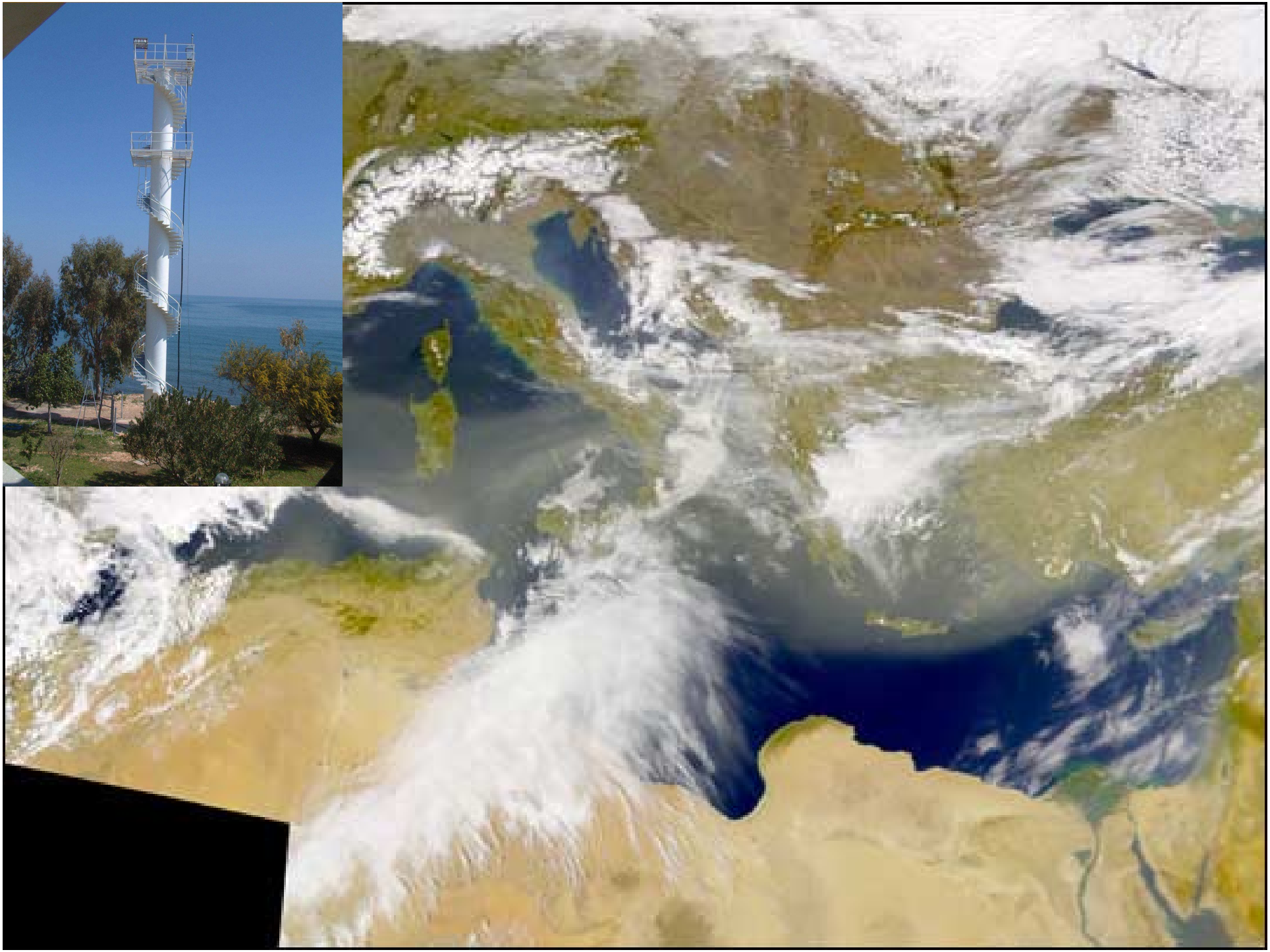
Examples:

Staphylococcus xylosis--cause of septicemia in loggerhead turtles in the Canary Islands

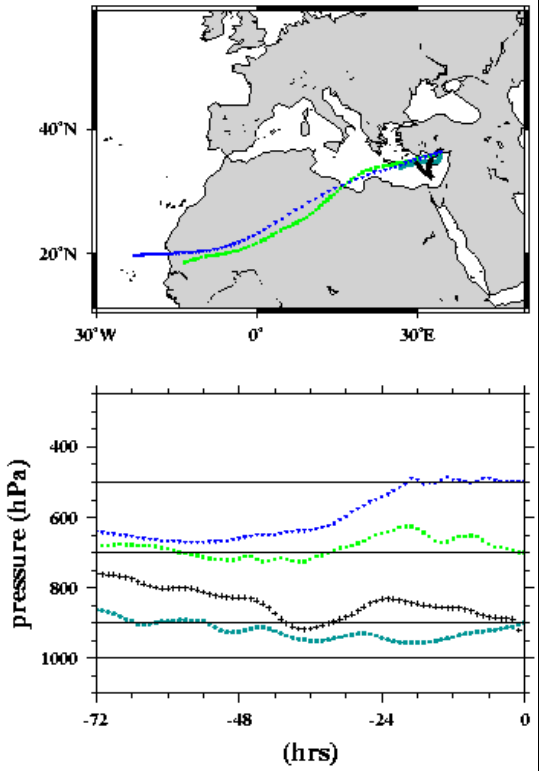
Bacillus pumilus--cause of 'bacterial blotch' on peaches

Gordonia terrae--cause of infection in immunocompromised patients

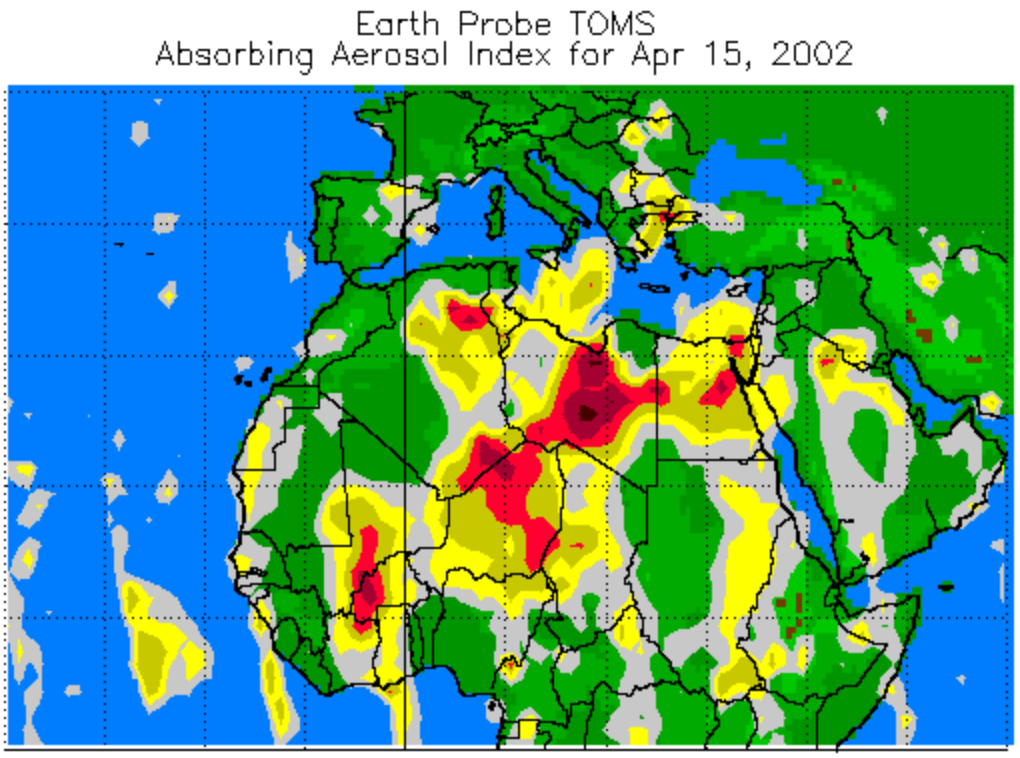
USGS

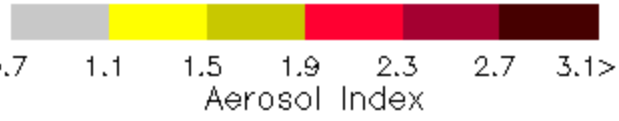


24	4/14/02	9:00/20	0	4
25	4/14/02	14:54/20	0	2
Blank5	4/14/02	15:16/20	0	0
26	4/15/02	8:27/20	5	38
27	4/15/02	13:42/20	3	35
28	4/15/02	17:33/20	6	121
29	4/16/02a	15:03/40 (filte	1	33
29	4/16/02b	15:03/40 (filte	0	34
Blank6	4/16/02	15:47/20	0	0

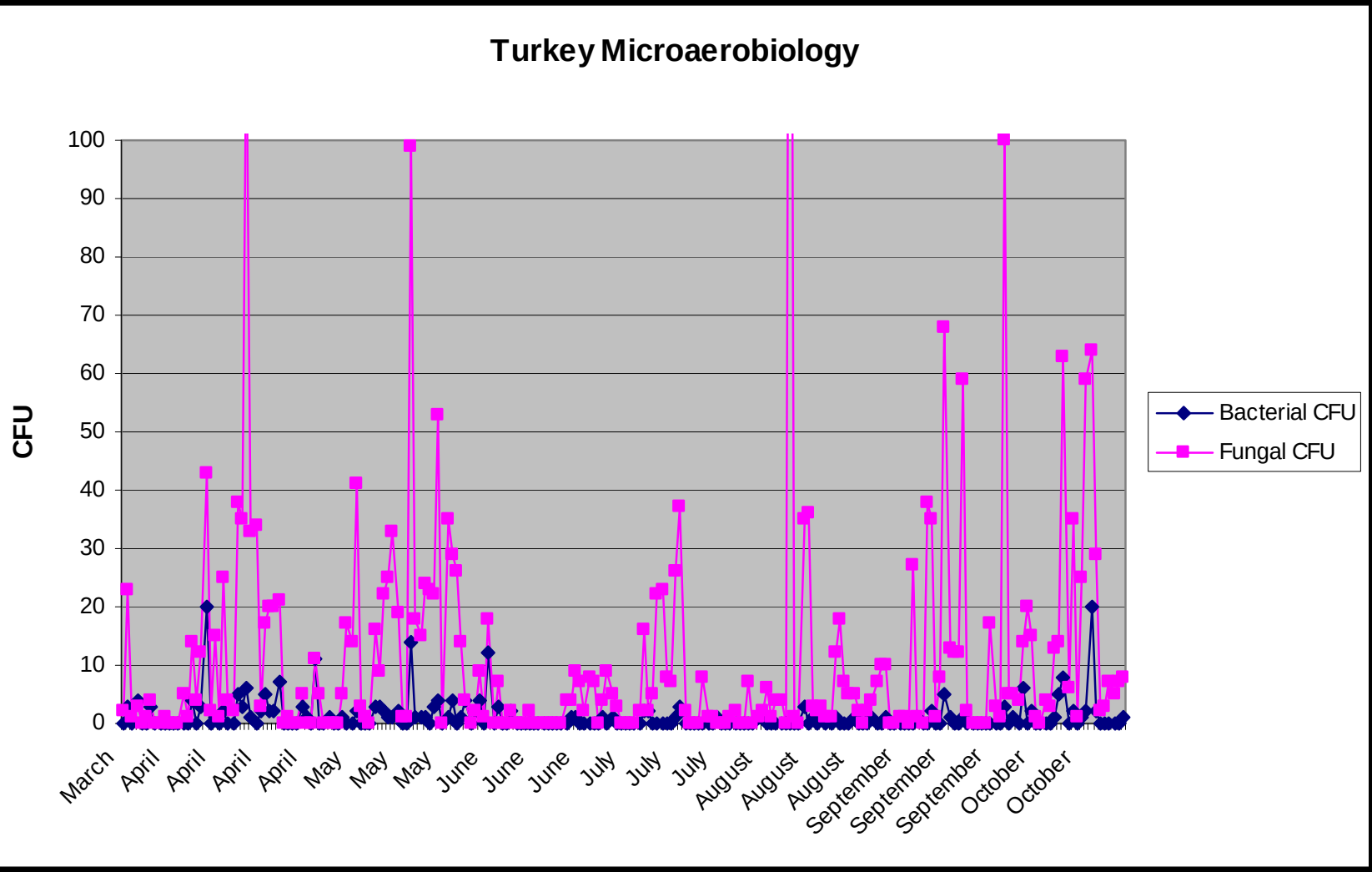


Model – European Center for Medium-Range Weather Forecasts. http://www.ecmwf.int/





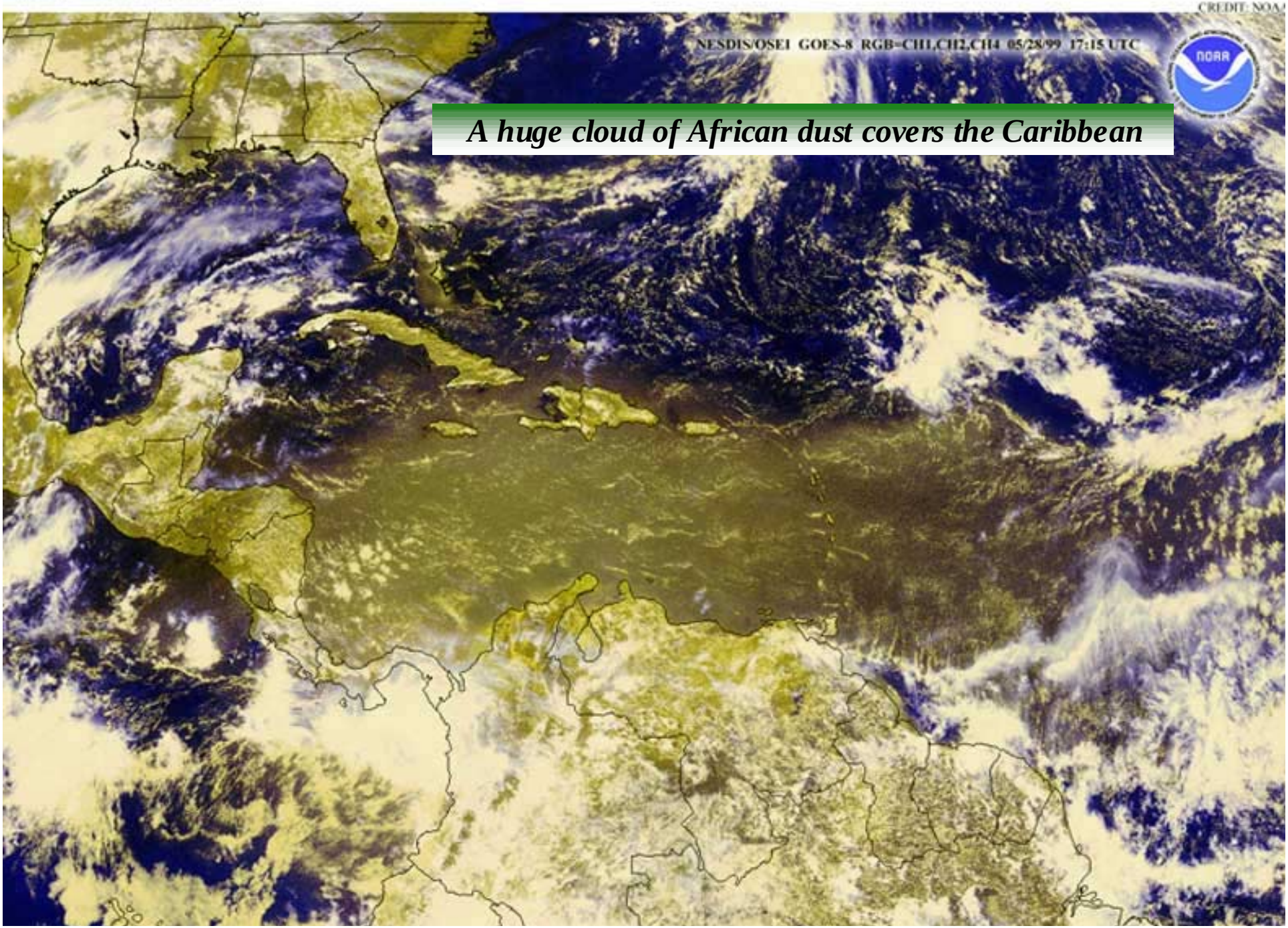
Goddard Space Flight Center



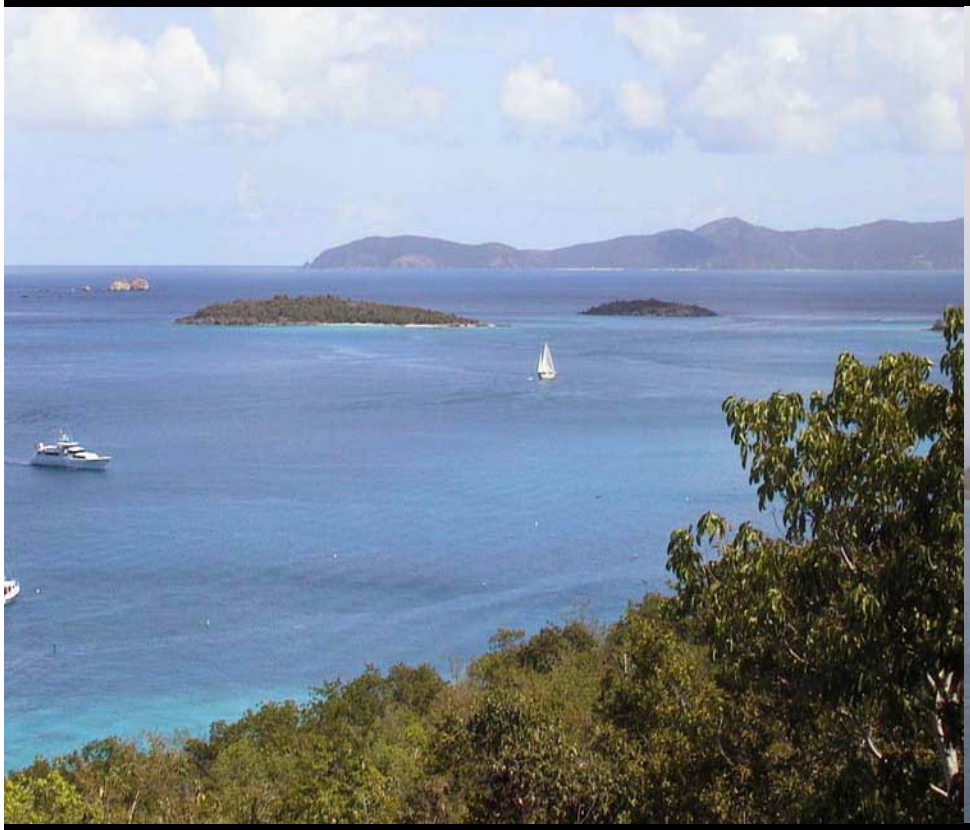
- **Turkish atmospheric samples dominated by fungi**
- **March - October of 2002, collected 249 bacteria and 2601 fungi**
- **Dominant fungi are species of *Cladosporium* and *Alternaria* (potent human allergen)**

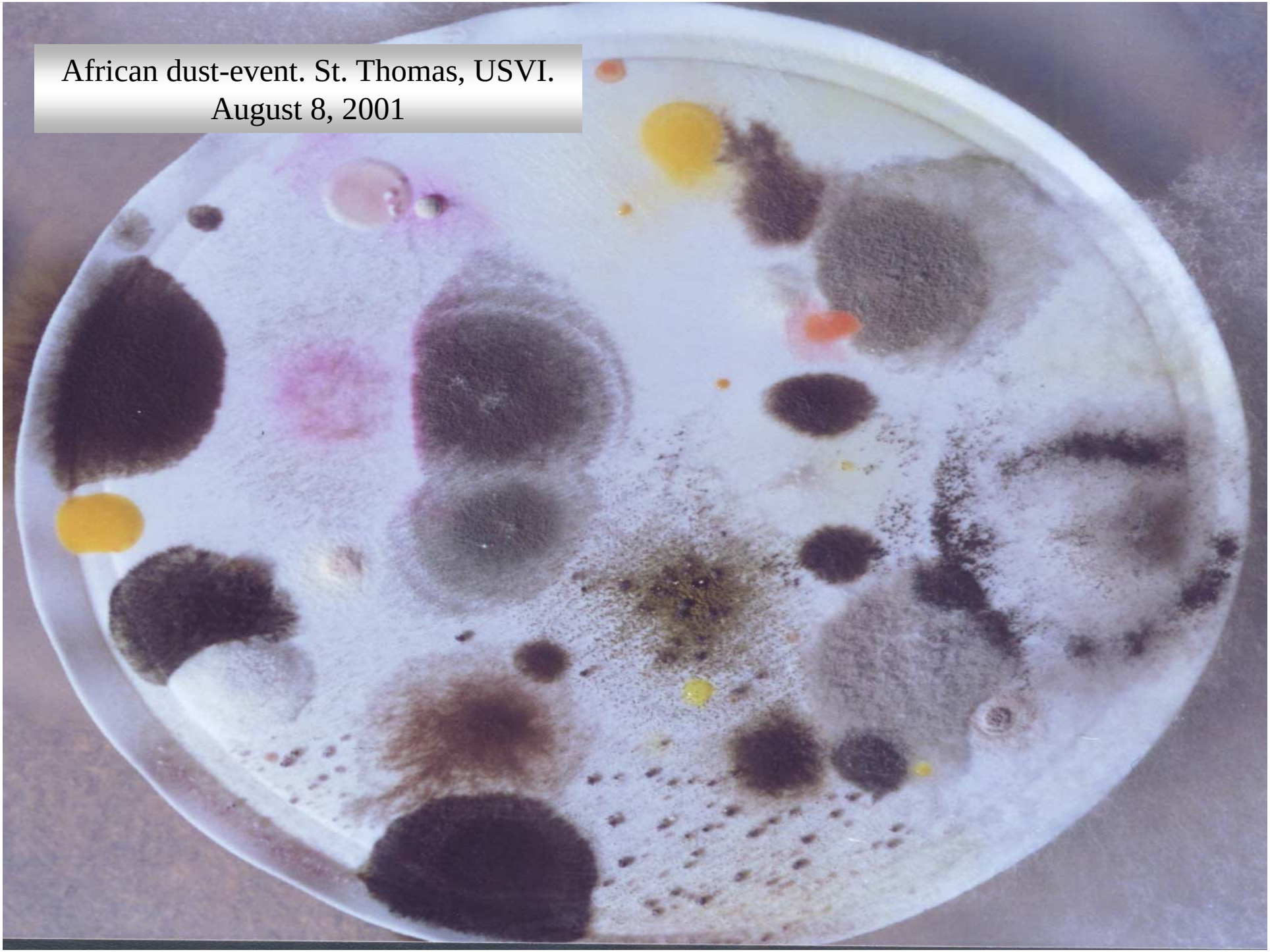
Airborne dust (brown haze) over the Caribbean Sea. This dust originated in the Sahara Desert of western Africa where it was lifted and carried off the coast by strong winds.

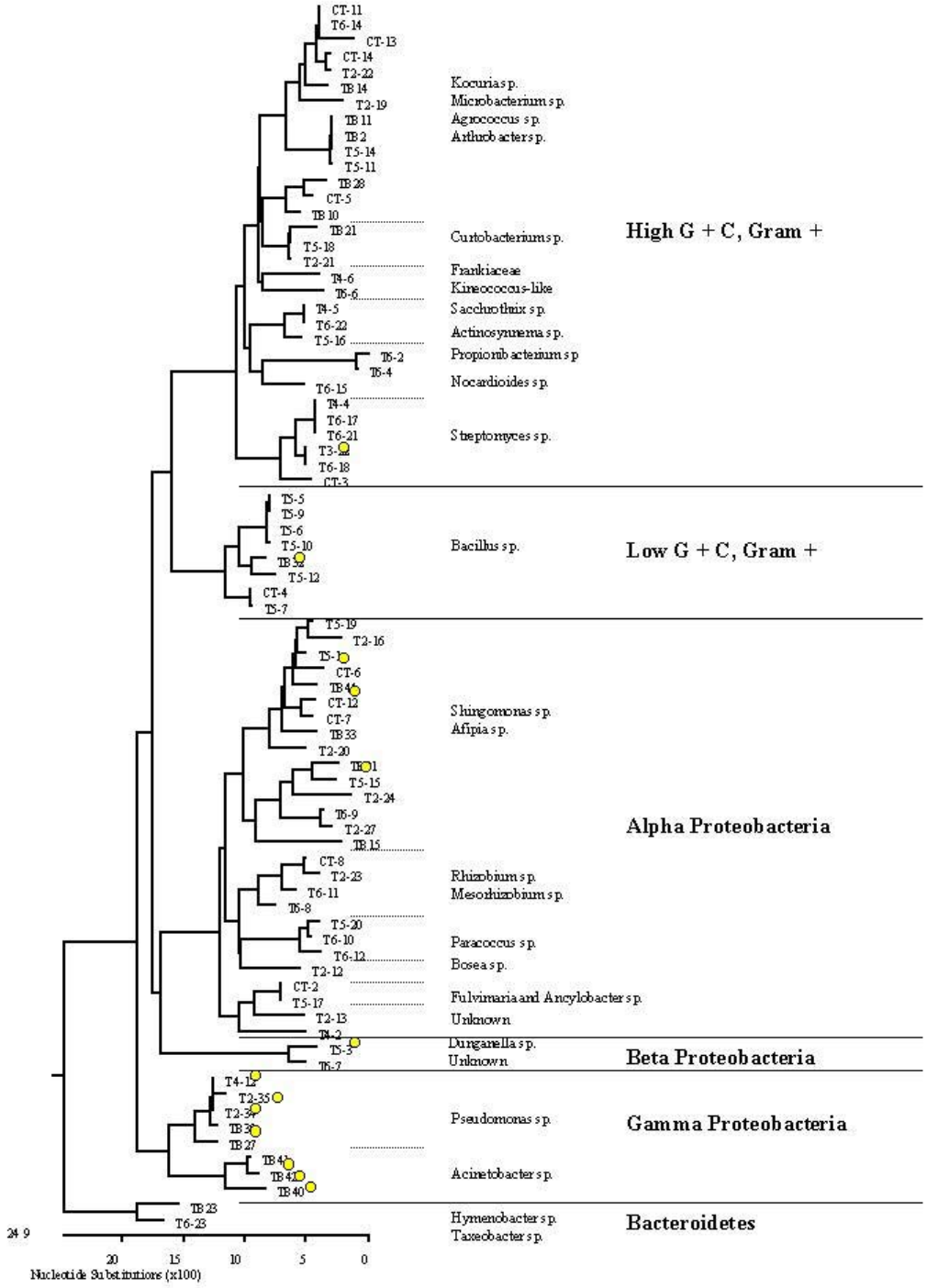
CREDIT: NOAA



A huge cloud of African dust covers the Caribbean



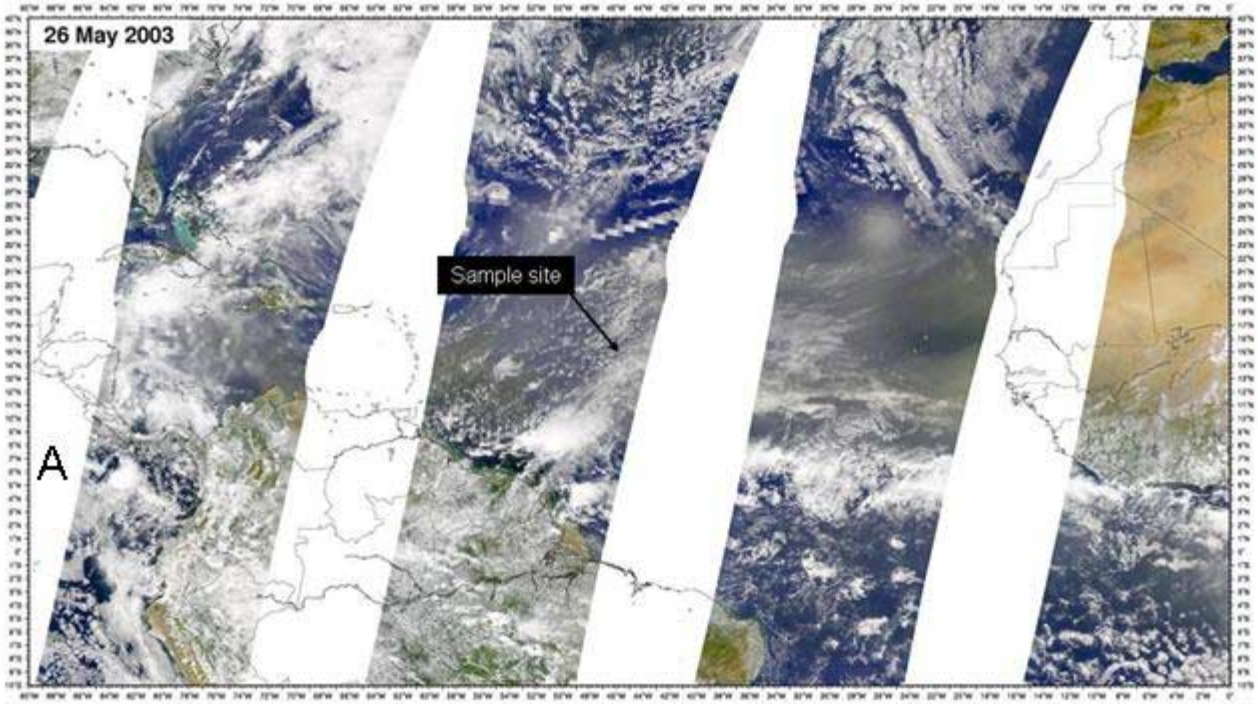

African dust-event. St. Thomas, USVI.
August 8, 2001

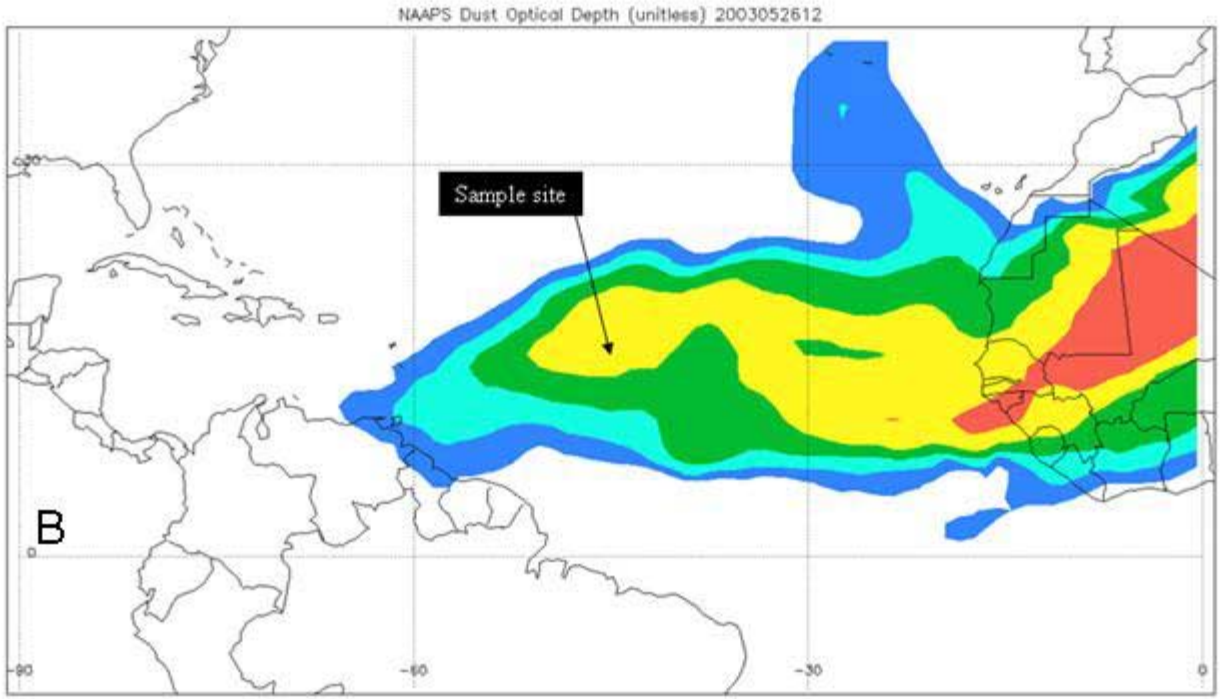


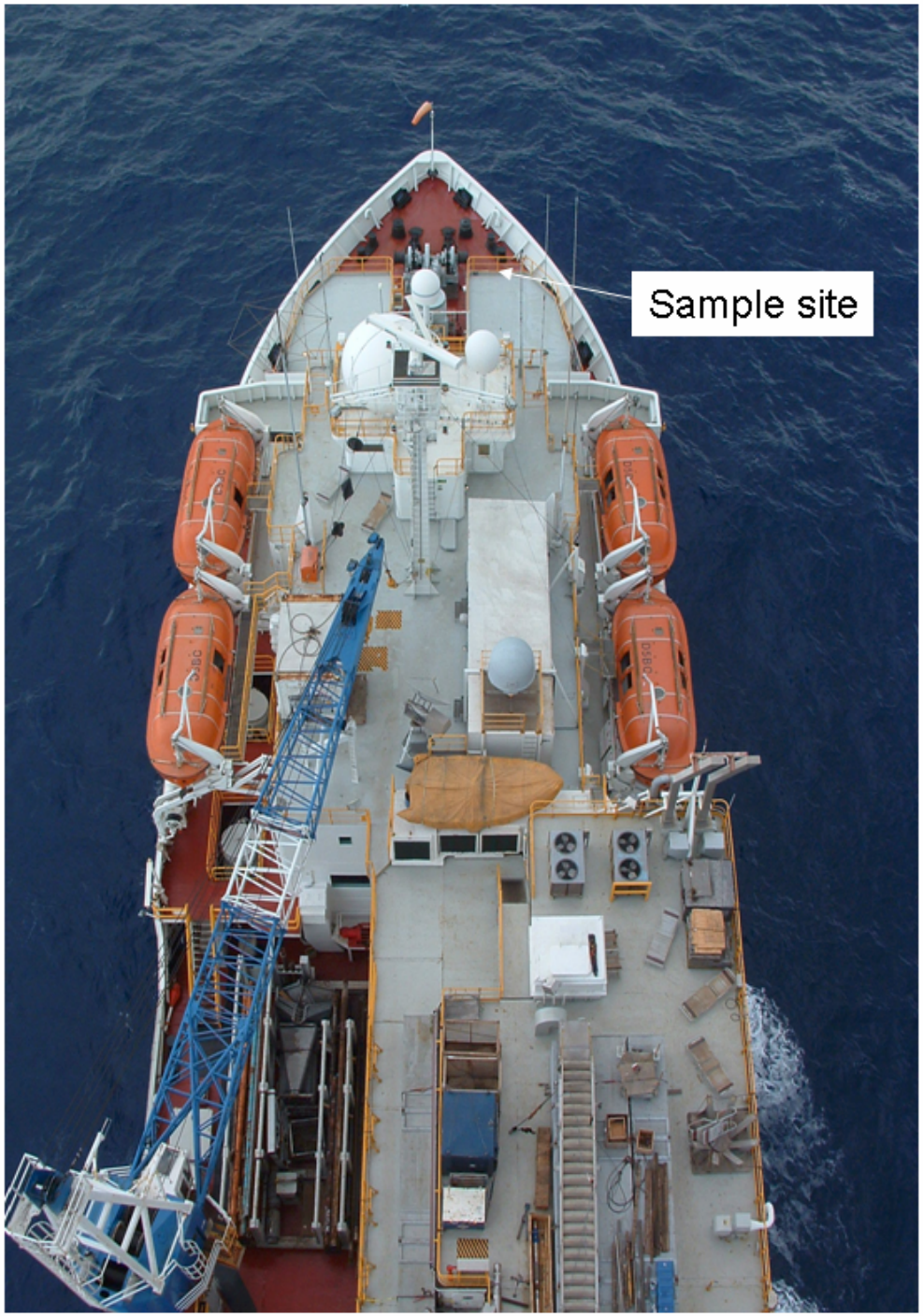
~ 10% of Caribbean African dust isolates are known human opportunistic pathogens

~20% of Caribbean African dust isolates are known plant or animal pathogens

ODP Leg 209
May – June 2003

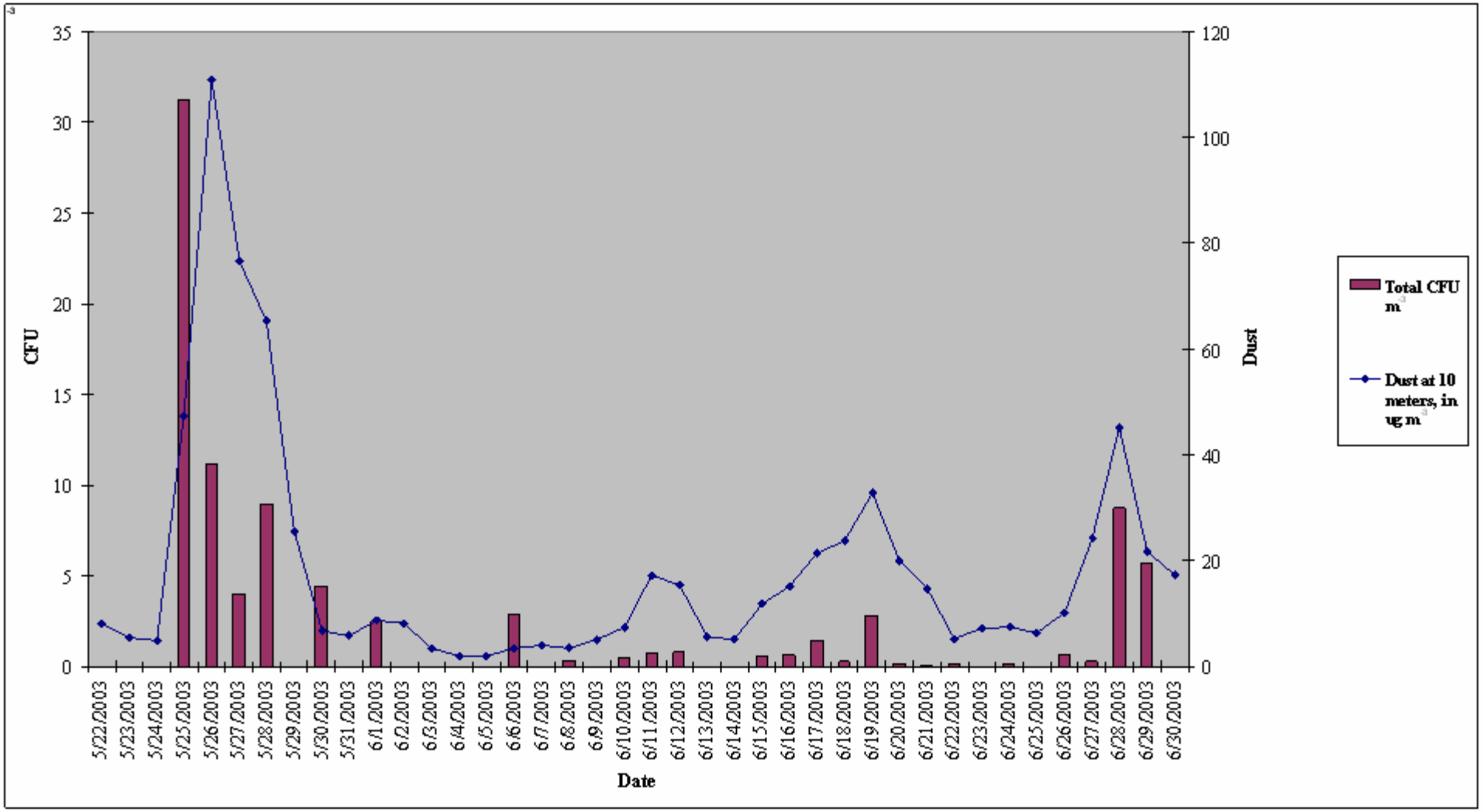





Sample site

ODP Leg 209 – a statistically significant correlation between airborne microorganisms and the NAAPS model dust deposition values.

Tropical mid-Atlantic ridge, May – June 03



Tropical Mid-Atlantic Ridge Aerobiology (May-June 2003)

- 28 bacteria and 72 fungi isolated
- Bacteria - 2/4 *Bacillus aminovorans* and *Kocuria rosea* (human catheter related bacteremia) 100% DNA homology to two Mali isolates. The remaining 2 *B.aminovorans* and a *Bacillus* sp. isolate also closely identified to Mali isolates.
- Bacteria - *3 Gordonia terra* isolates = human pathogen (sepsis, brain abscess) and this species also isolated in Mali
- Fungi - *Massaria platani* (Florida sycamore canker pathogen) and *Alternaria dauci* (Florida carrot pathogen) also isolated
- Most dominant fungal isolate *Lojkania enalia* (10 CFU) – two of five commercially available strains (ATCC) were isolated in Liberia, Africa
- 25% of fungi isolated are known pathogens of some organism (i.e., plant or animal, 4 CFU of *Neotestudina rosatii* – human pathogen - mycetoma)

African dust over St. Petersburg, Florida, July 25-28, 2005

Atmospheric particle concentration

July 15, 2005 (clear/normal conditions) = 3,000/Liter

July 25, 2005 (dust conditions) = 30,000/Liter

Conclusions

- **Dust storms have been directly implicated in long range dispersion of toxic compounds**
- **Bacteria, fungi and viruses are transported globally in clouds of desert dust**
- **This emerging field of research may play a significant role in human and environmental health issues**

Microorganism	Infectious dose
Campylobacter jejuni	500-800 cells
Shigella sp.	~100 cells
Yersinia sp. (Y.pe4,000stis)	10^6 to 10^9 cells (1 cell)
Neisseria meningitis	Unknown
Bacillus anthracis	5 cells – mouse, 3,000 cells – monkey, 10^6 cells rat, 4,000 – 8,000 primate. Human estimates 8,000 – 50K, 50, 1-3 cells????
Influenza virus	2 – 790 pfu
Astroviruses	< 100
Rotavirus	< 100
Rhinovirus	1-30 virus particles
Hantavirus	Unknown
Smallpox virus	Unknown
Hepatitis A virus	10-100 virus particles
Coccidioides immitis	<10 arthroconidia - mice……..WW II, in California's San Joaquin Valley, 8-25% rate of new infections among military personnel per year
Histoplasma capsulatum	10 spores – mice
Aspergillus sp.	Unknown

Above dose levels are for the average healthy human and are not infectious doses for the old, young, or the immunocompromised