EARTH 270 – DISASTERS AND NATURAL HAZARDS (v. 2018)

Kensennuma City, Miyagi Prefecture , Japan, March 2011

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UNIVERSITY OF WATERLOO

NATURAL HAZARDS OF CONCERN IN EARTH 270 (v. 2018)

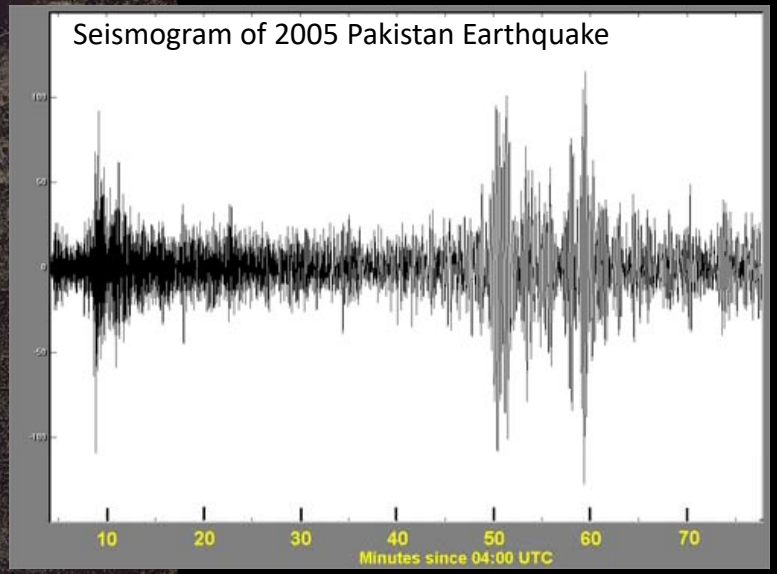
HAZARD GROUP	HAZARD TYPE
GEOHAZARDS	**EARTHQUAKES** **TSUNAMI** **VOLCANOES** **LANDSLIDES** SURFACE COLLAPSE
ATMOSPHERIC HAZARDS	**HURRICANES (TROPICAL CYCLONES, TYPHOONS)** **TORNADOES** DROUGHT HEAT WAVE WILDFIRE
HYDROLOGIC HAZARDS	**GLACIER HAZARDS** **FLOODS (RIVER AND COASTAL)**
ULTIMATE HAZARDS	**ASTEROID IMPACTS (ARMAGEDDON)** **SOLAR FLARES (SPACE WEATHER)**

MANY HAZARDS DEVELOP MULTIPLE THREATS (e.g. Earthquake-triggered landslides; Earthquake-triggered tsunami; Floods caused by Hurricane heavy rainfall; Storm surges caused by Hurricanes). SOME HAZARDS ARE HYBRID HAZARDS (e.g., tsunamis, landslides, flooding)

OVERVIEW OF NATURAL HAZARDS

Eruption of Eyjafjallajokull, Iceland, April, 2010

1. EARTHQUAKES



- Energy released during shear failure of earth's crust causes sudden violent motion of earth surface (seismic shaking)

- Magnitude Scale based on energy released (e.g., Richter Scale)

- Intensity of shaking (Mercalli Scale)

Balakot, Pakistan, 2005 (M7.6); 86,000 deaths in Pakistan Earthquake

MAY 2008 EAST SICHUAN EARTHQUAKE (M7.9), CHINA

- 5.36 M buildings collapsed (88,000 deaths)
- Earthquake triggered many thousands of landslides
- Some formed landslide dams and formed extensive lakes which threatened communities downstream

2009 L'AQUILA EARTHQUAKE, ITALY (M ~ 6.3 ; 4,000 BUILDINGS COLLAPSED; 295 DEATHS)

Duomo San Massimo, L`Aquila – Built in 13th Century; destroyed by earthquake in 1703; Rebuilt in 18 and 19th Centuries; damaged in 2009.

Central Italy Earthquake (M6.2; depth = 4 km; August 24. 2016) – 299 deaths (Damage in Amatrice)

Central Italy Earthquake (M6.2; depth = 4 km; August 24. 2016) – 299 deaths
Damage in Amatrice

1995 Kobe Earthquake, Japan

THE MILLION DEATH QUAKE

THE SCIENCE OF PREDICTING EARTH'S DEADLIEST NATURAL DISASTER

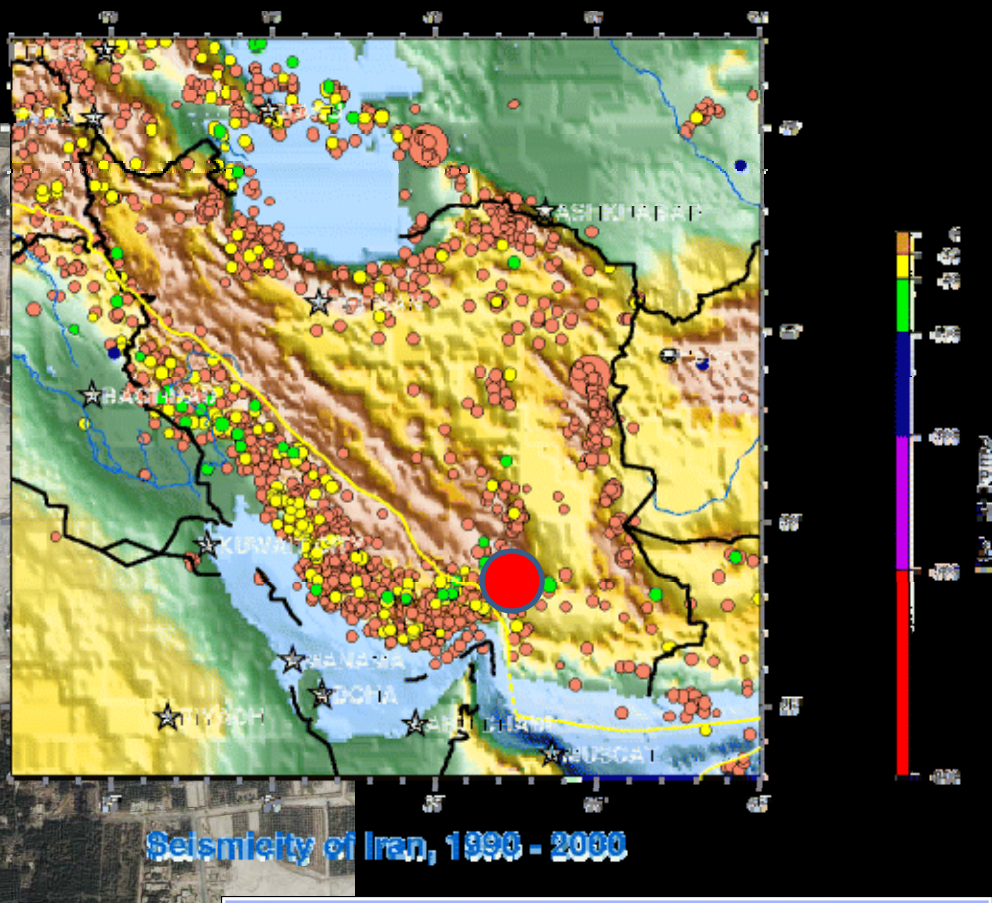
ROGER MUSSON

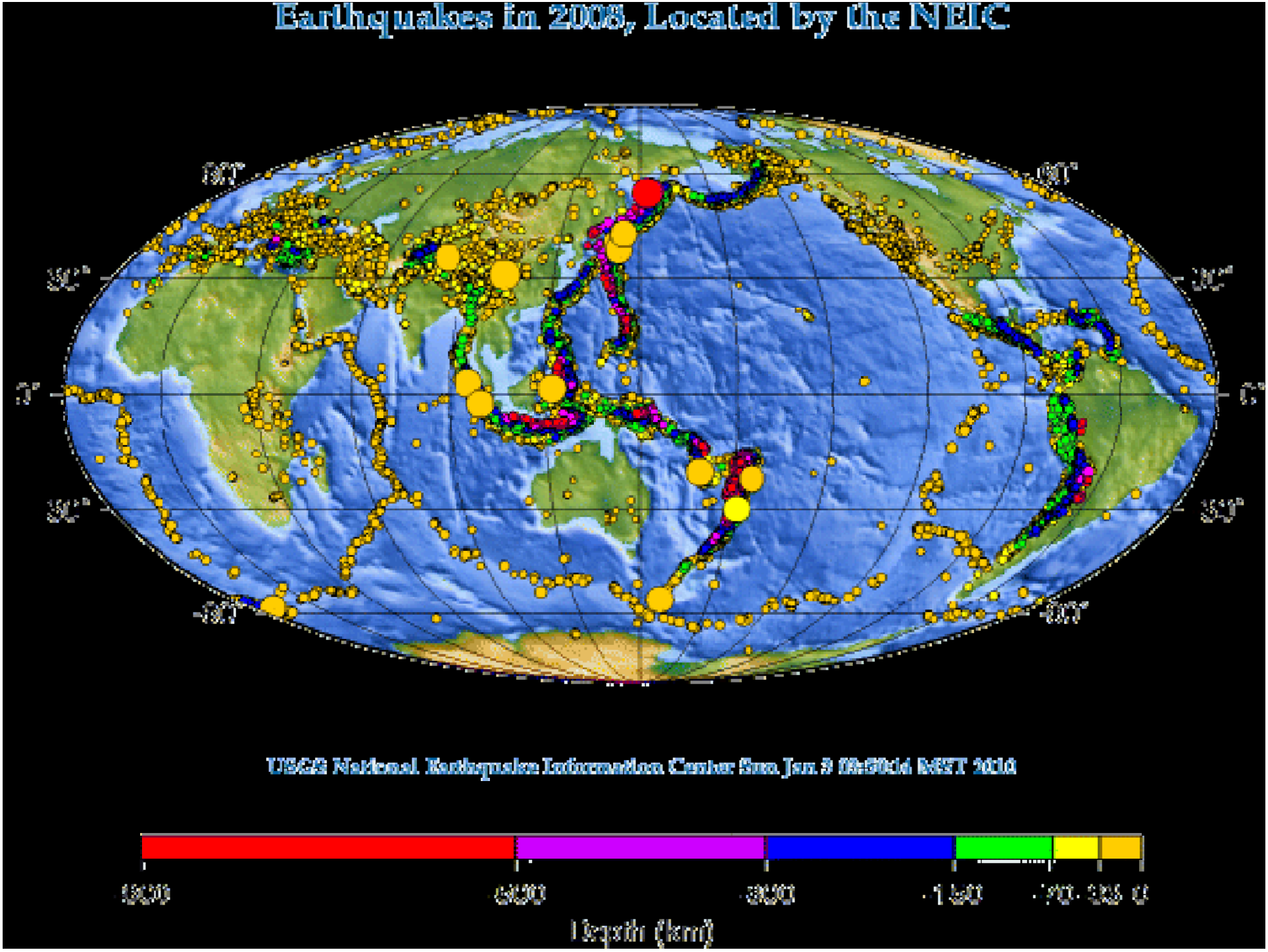
10

EARTHQUAKES DON'T KILL PEOPLE, BUILDINGS DO

THE EIGHTEENTH-CENTURY HISTORIAN EDWARD GIBBON IS famous chiefly for his monumental *History of the Decline and Fall of the Roman Empire,* which appeared in six volumes between 1776 and 1788. His stock still stands high among professional historians today, and students are sometimes warned, should they believe they have an original idea, to check that Gibbon did not think of it first.

2003 BAM EARTHQUAKE, IRAN (M6.6) – Over 30,000 deaths




Earthquakes in 2008, Located by the NEIC
USGS National Earthquake Information Center Sun Jun 8 09:50:04 MST 2008
Depth (km)

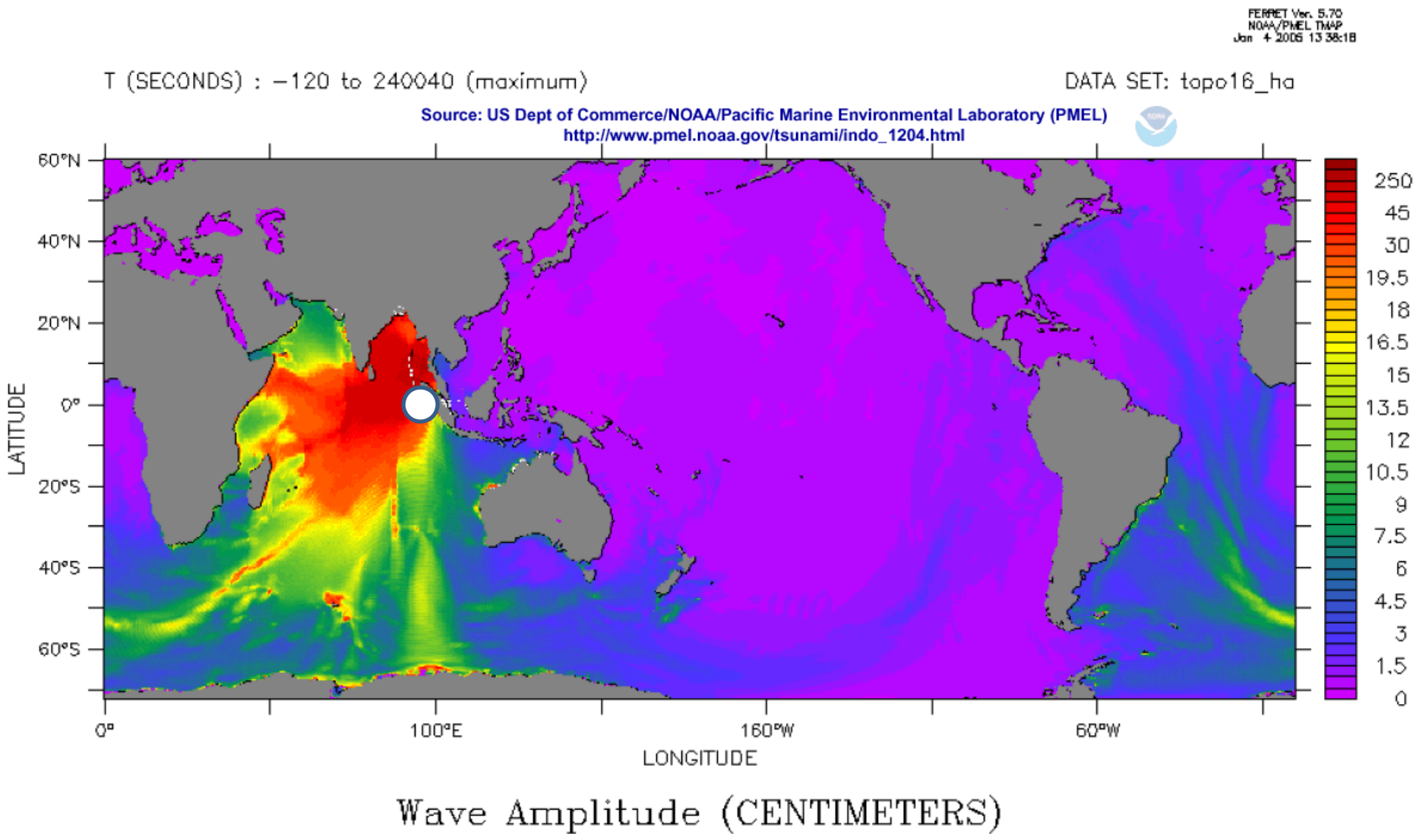
SECONDARY EFFECTS 1 - LIQUEFACTION

Foundation failure in silts and sands due to liquefaction in 1964 Niigata Earthquake (M7.5), Japan

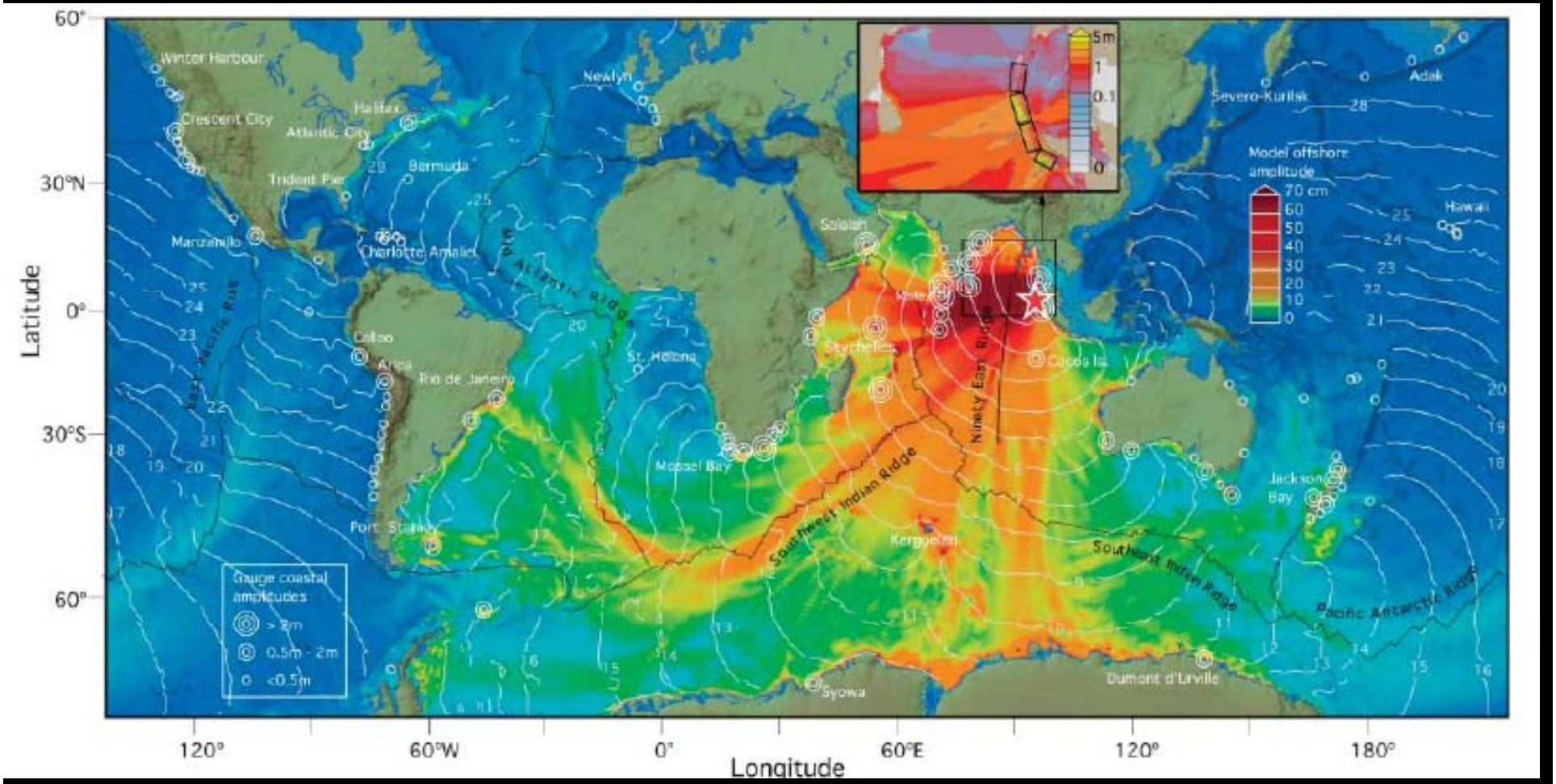
SECONDARY EFFECTS 2 – LANDSLIDES

2001 Las Colinas landslide, El Salvador (ca. 600 deaths) triggered by January 2001 earthquake (M7.7) – very high impact; very small landslide

SECONDARY EFFECTS 3 -TSUNAMI

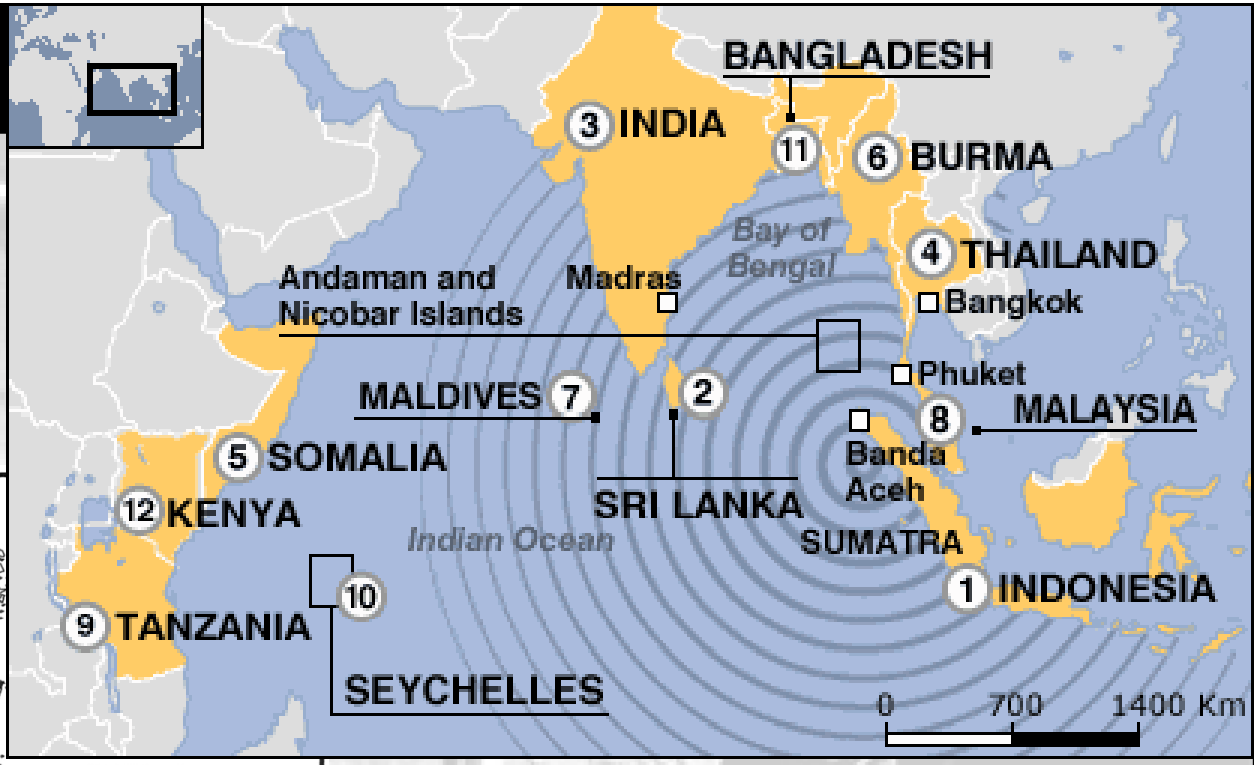


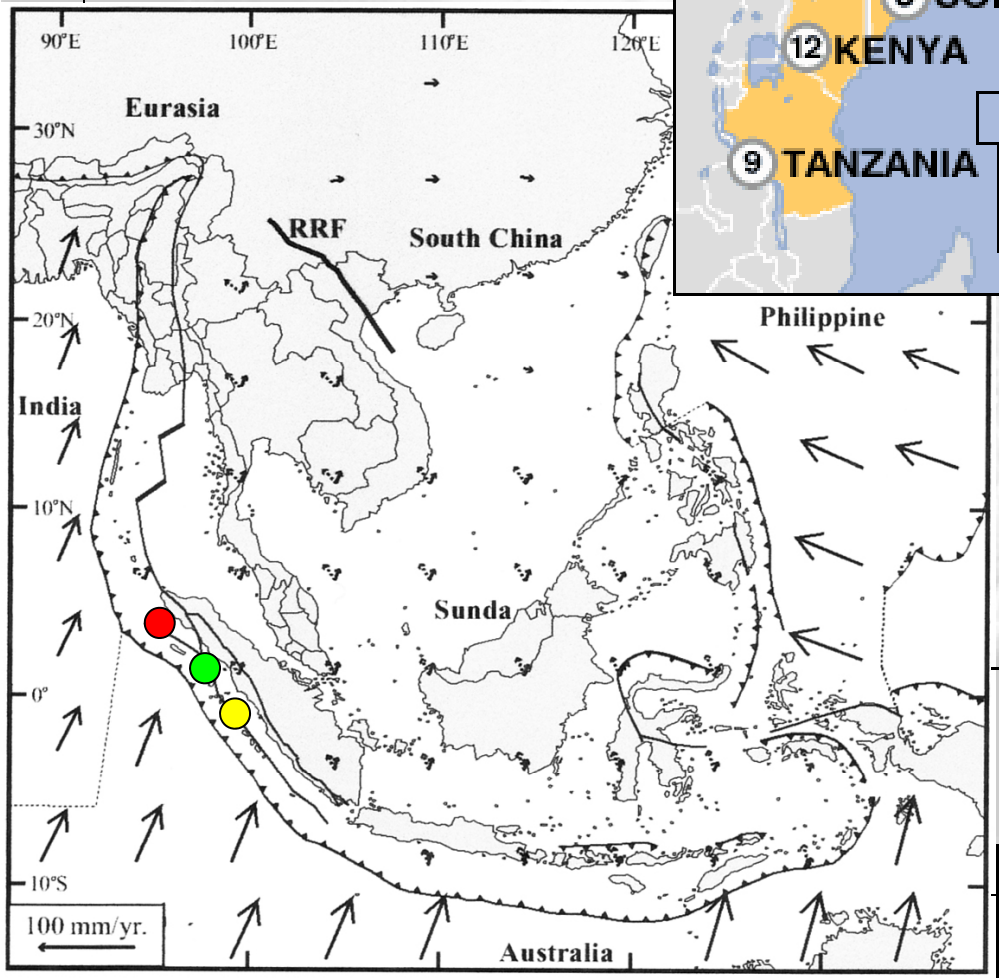
2. TSUNAMI



a) Earthquake displacement of sea floor b) Submarine landslide c) Sub-aerial landslide

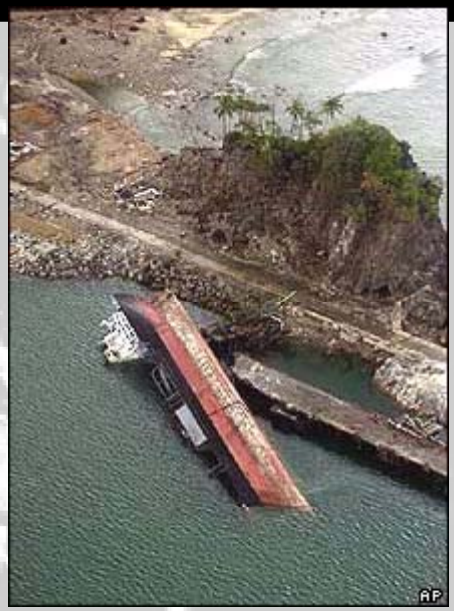
2004 M9.1 SUMATRA EARTHQUAKE (red dot) AND TSUNAMI





PREVIOUS GREAT MEGATHRUST EARTHQUAKES IN 1797, 1833 (yellow dot) and 1861 (green dot) ALONG SUNDA TRENCH SUBDUCTION ZONE – all generated tsunamis

DAMAGE IN 2004 TSUNAMI



245,000 deaths

(AP PHOTO)

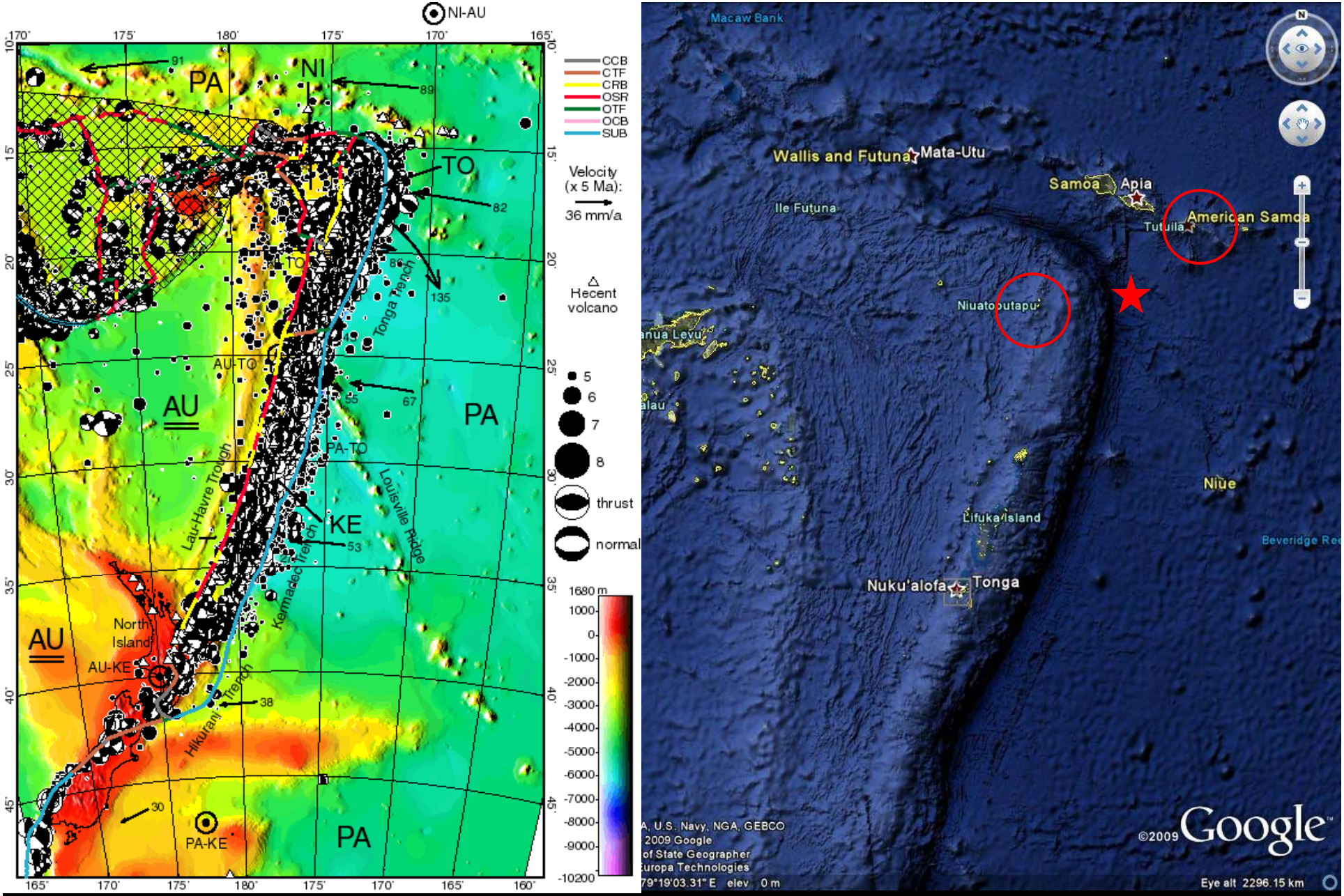
DAMAGE IN 2004 TSUNAMI

Quickbird image of tsunami damage in Banda Aceh, Indonesia – December 28, 2004

Village on the coast of Sumatra

DigitalGlobe satellite image shows M8.1 earthquake-triggered tsunami waves crashing over American Samoa's Tafuna International Airport, September 29, 2009; 115 deaths in region (max wave height 4.11 m)

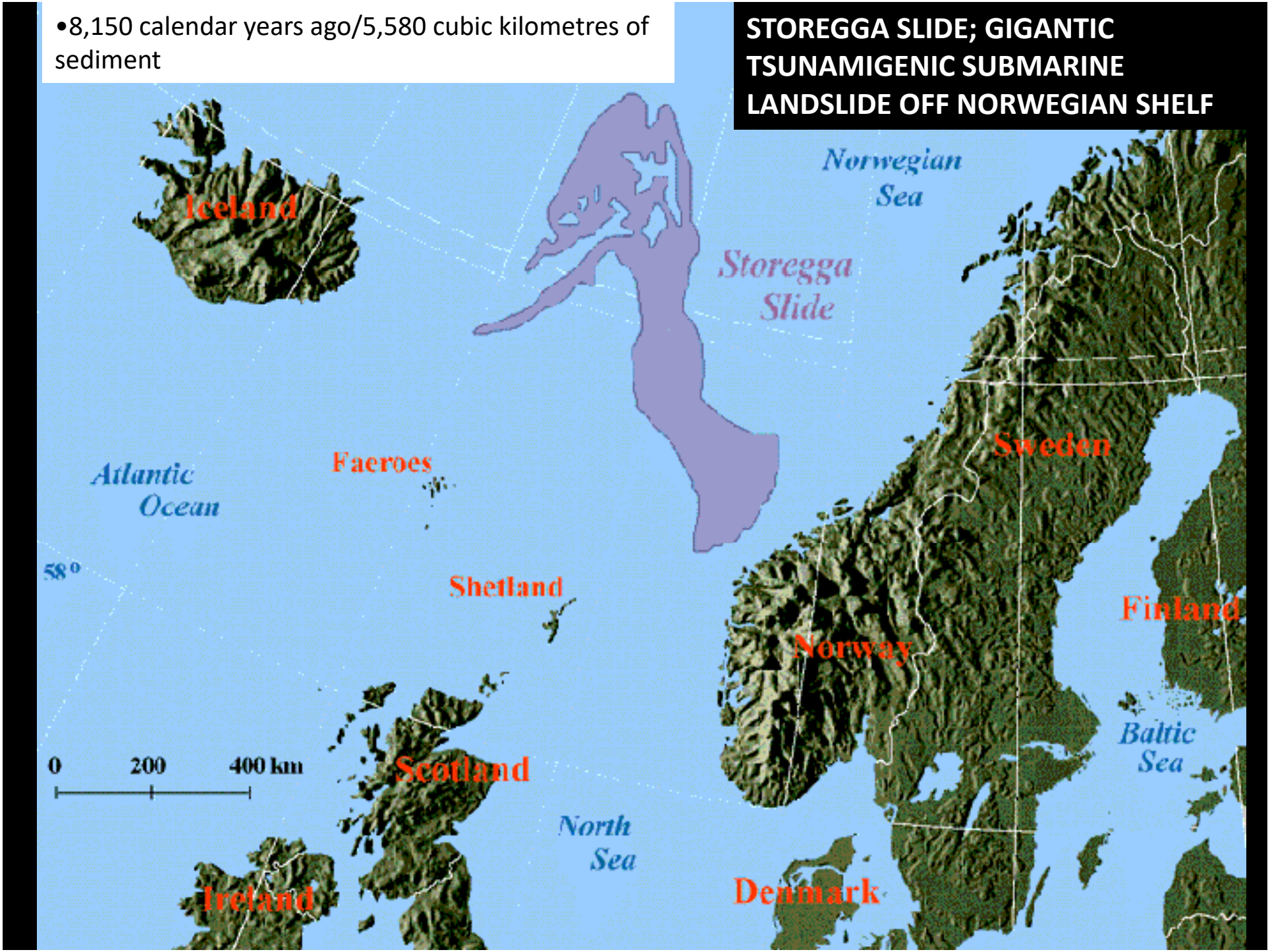
Devastation on coast of Niutoputapu, Tonga – September 2009

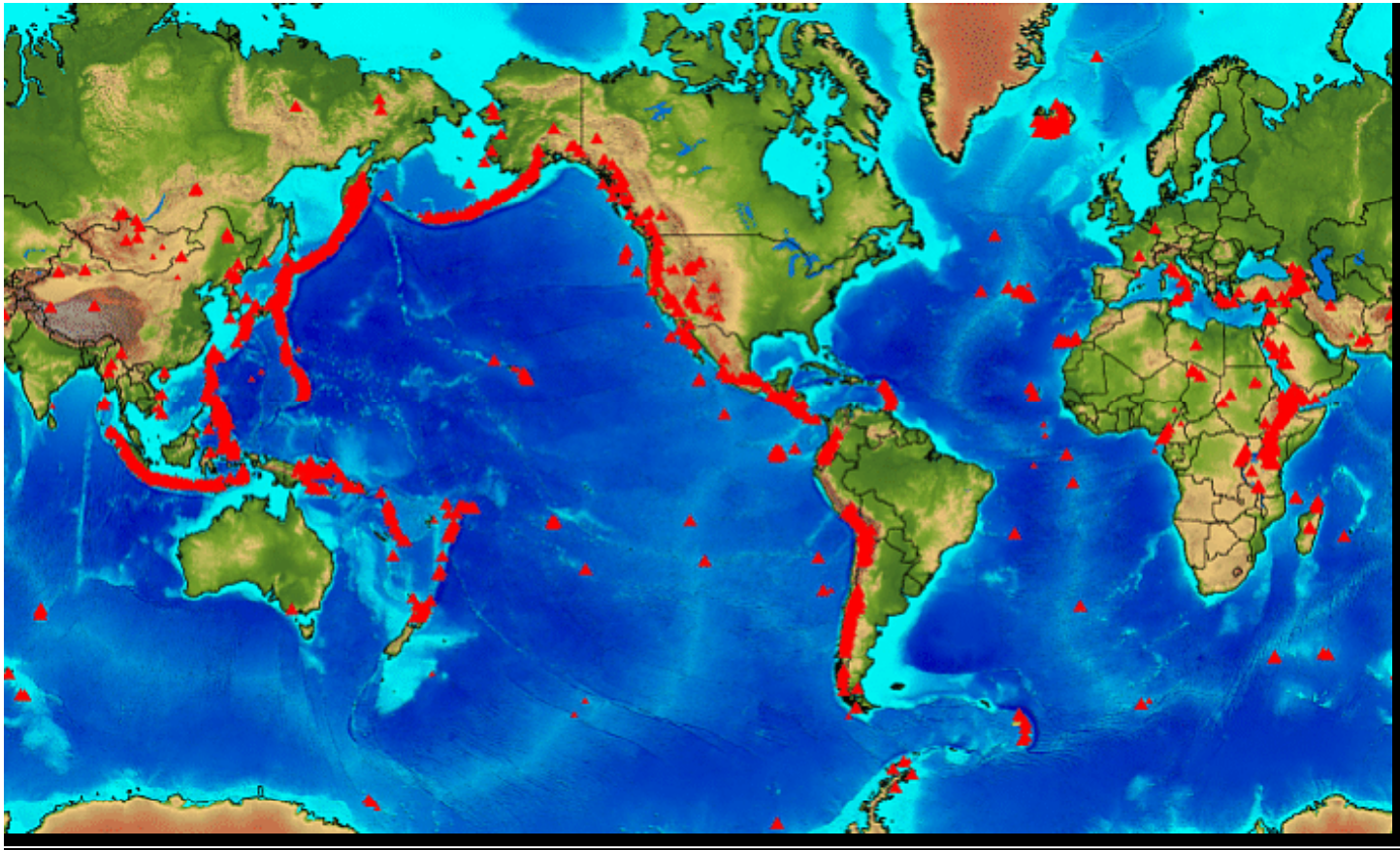


HISTORICAL SEISMICITY (1964-1998) OF TONGA TRENCH (WHITE TRIANGLES =VOLCANOES) AND EPICENTRE OF TSUNAMIGENIC 2009 SAMOA EARTHQUAKE (RED STAR), SOUTHWEST PACIFIC

•8,150 calendar years ago/5,580 cubic kilometres of sediment

STOREGGA SLIDE; GIGANTIC TSUNAMIGENIC SUBMARINE LANDSLIDE OFF NORWEGIAN SHELF



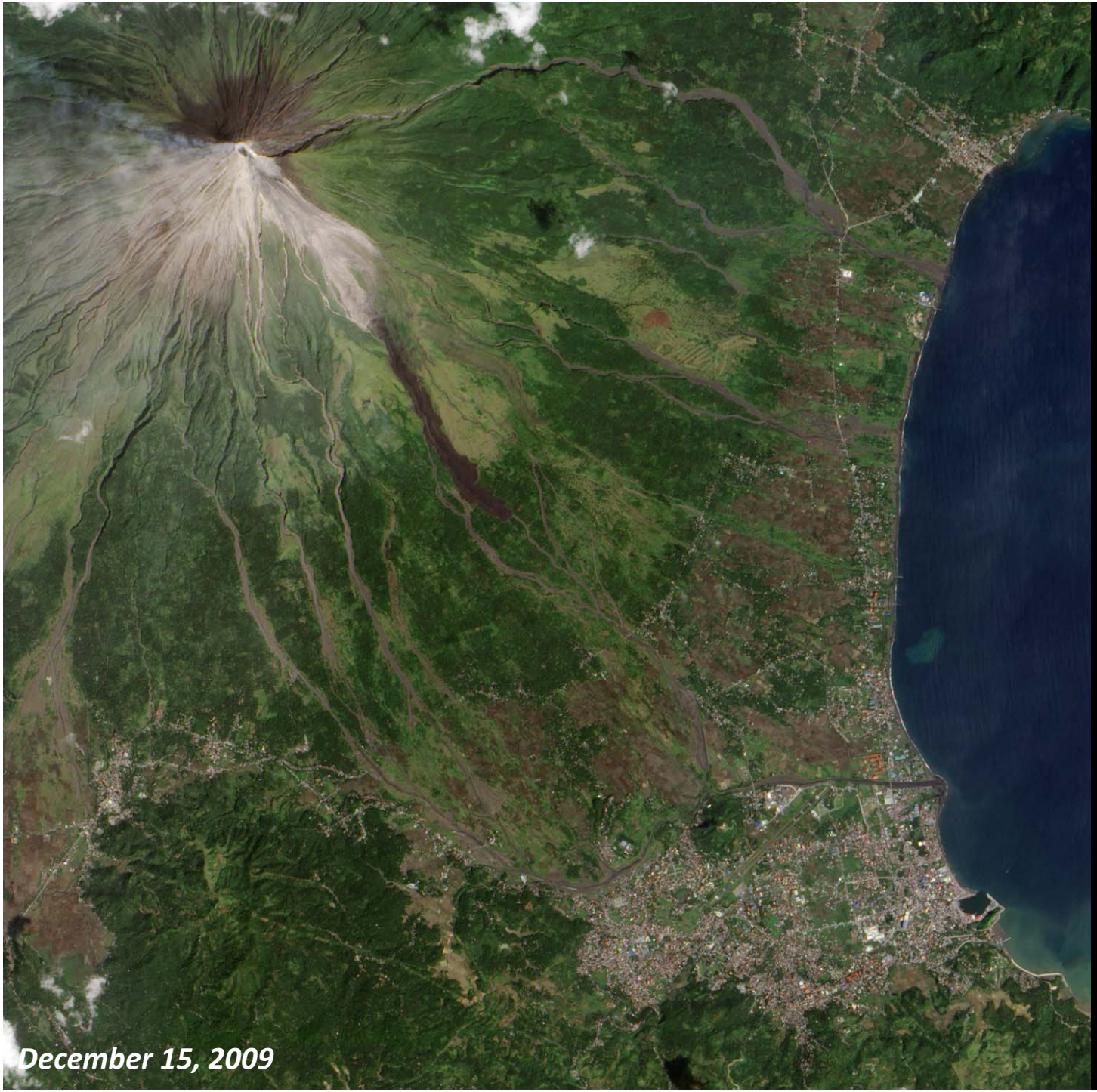


3. VOLCANOES

- Eruptive hazards (lava and pyroclastic flows, airborne ash, ashfall, volcanic mudflows)
- Post-eruptive rainfall-induced volcanic mudflows
- Large-scale flank collapse
- Many volcanoes near population centres

Mayon volcano, Philippines

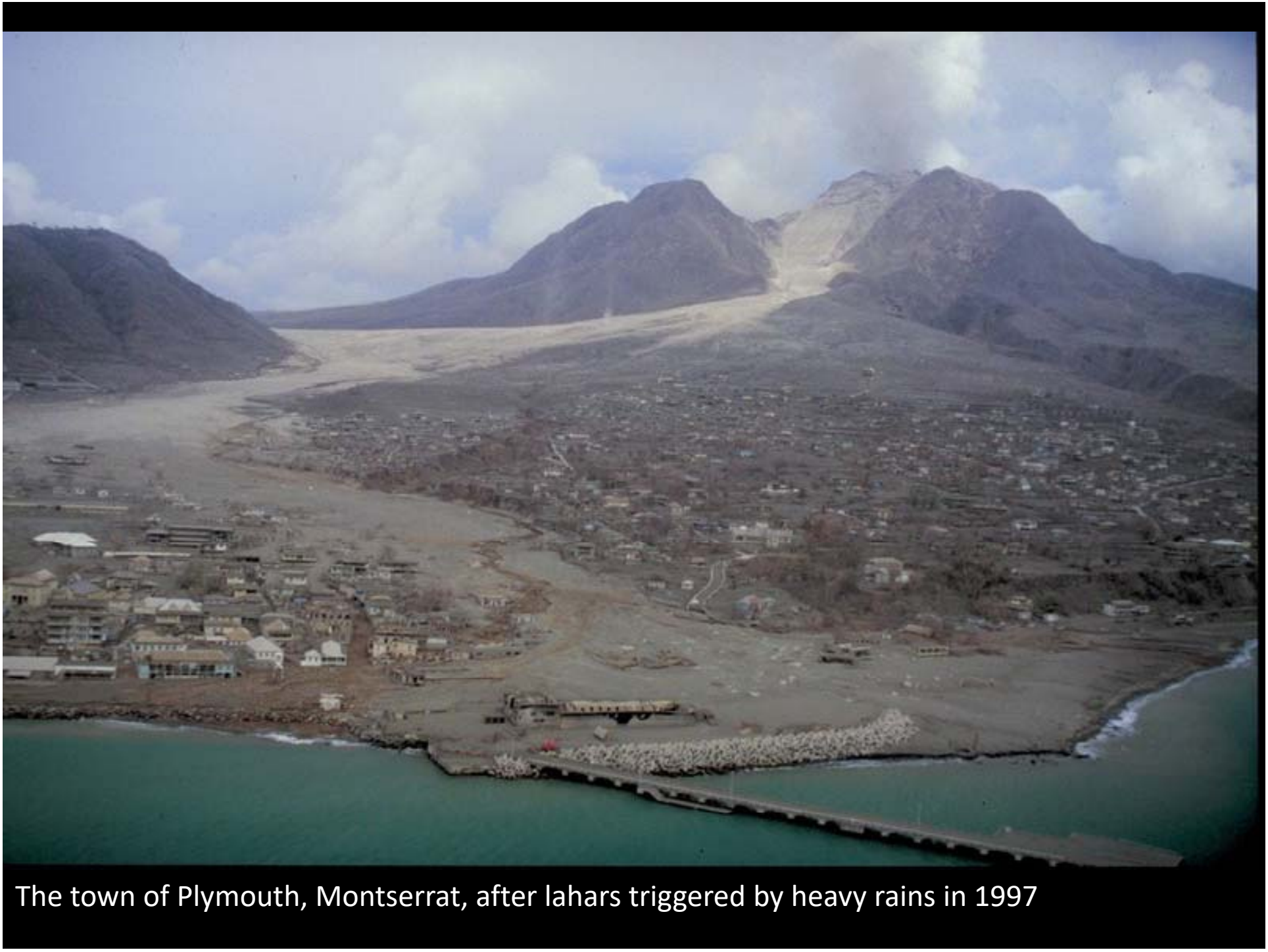
Eruption of Mayon Volcano, Philippines, 1984 (USGS)



December 15, 2009

Mayon Volcano, on the Philippine island of Luzon, continued its activity on December 28, 2009. Described as showing an “intense level of unrest” by the Philippine Institute of Volcanology and Seismology, Mayon exhibited 7 ash explosions, dozens of earthquakes related to the movement of magma beneath the volcano, over 100 rock falls from the summit, and 3 active lava flows. The Philippine government is enforcing evacuations in a danger zone extending 7 kilometers north and 8 kilometers south of the summit.

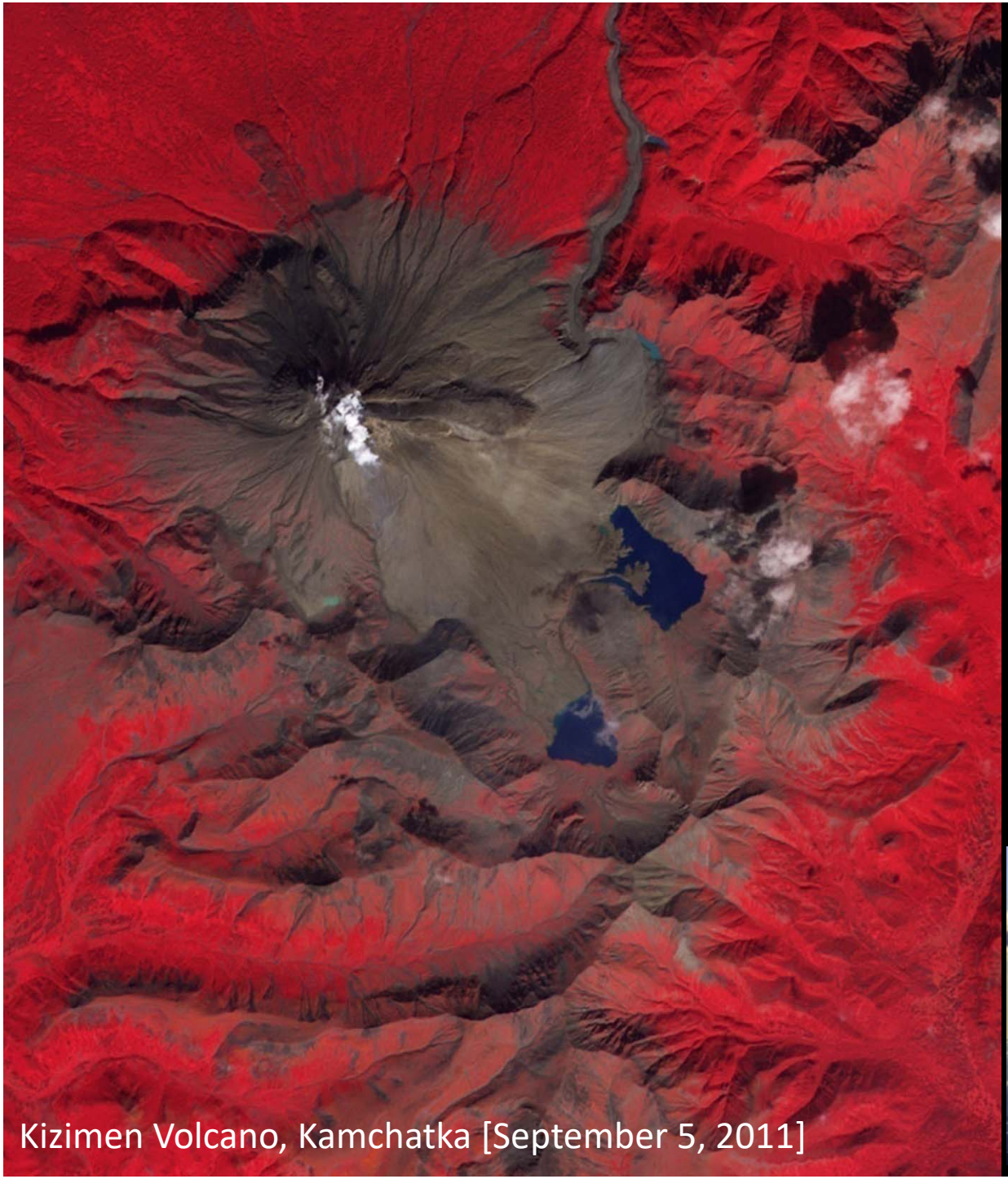

Montserrat – October 2009



The town of Plymouth, Montserrat, after lahars triggered by heavy rains in 1997

ERUPTION OF MOUNT SINABUNG, SUMATRA, INDONESIA [November 14, 2013]

Eruption February 2014

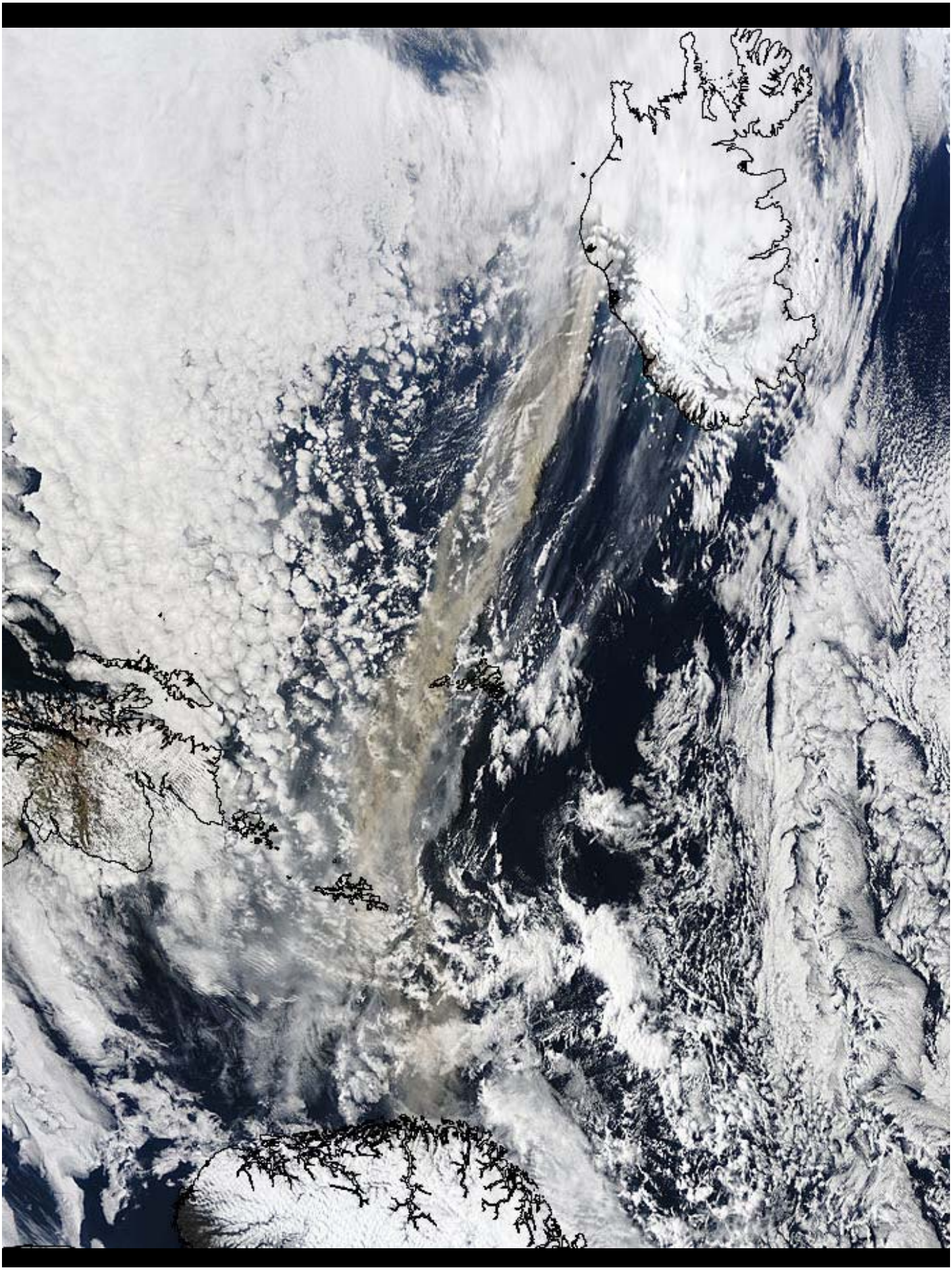


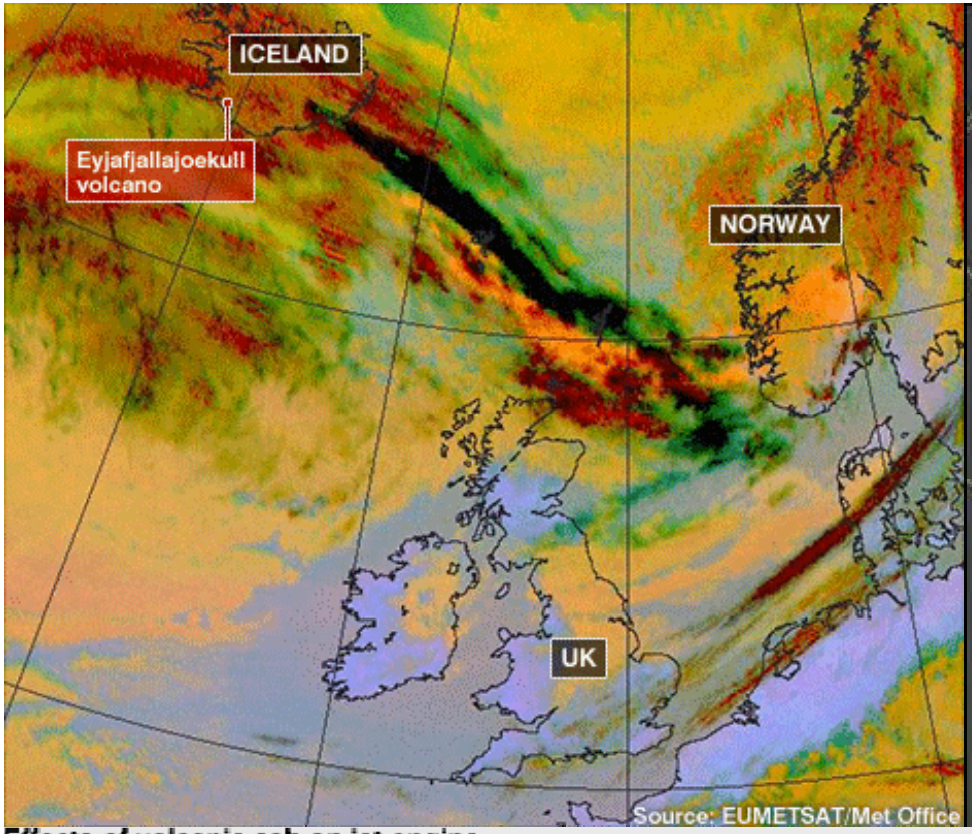
Kizimen Volcano, Kamchatka [September 5, 2011]

VOLCANOES ERUPTING IN 2011 INCLUDE;

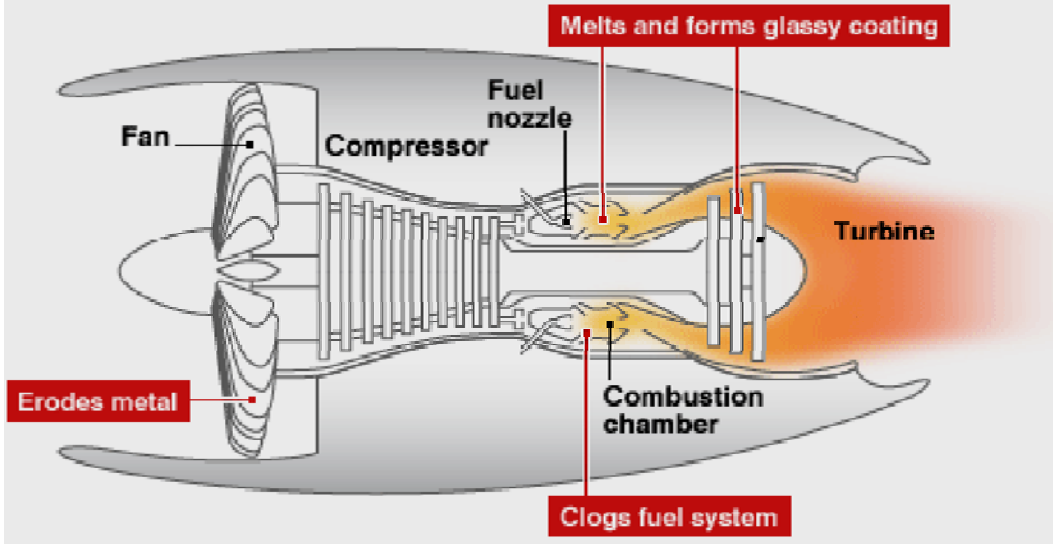
- Etna (Italy)
- Tungutahua (Ecuador)
- Grimsvotn (Iceland)
- Nabro (Eritrea)
- Puyehe-Cordon (Chile)
- Soputan (Indonesia)
- Krakatoa (Indonesia)
- Shiveluch (Russia)
- Cerro Hudson (Chile)
- Zubair Islands (Red Sea)
- Kizimen (Russia)
- Shinmoe-Dake (Japan)

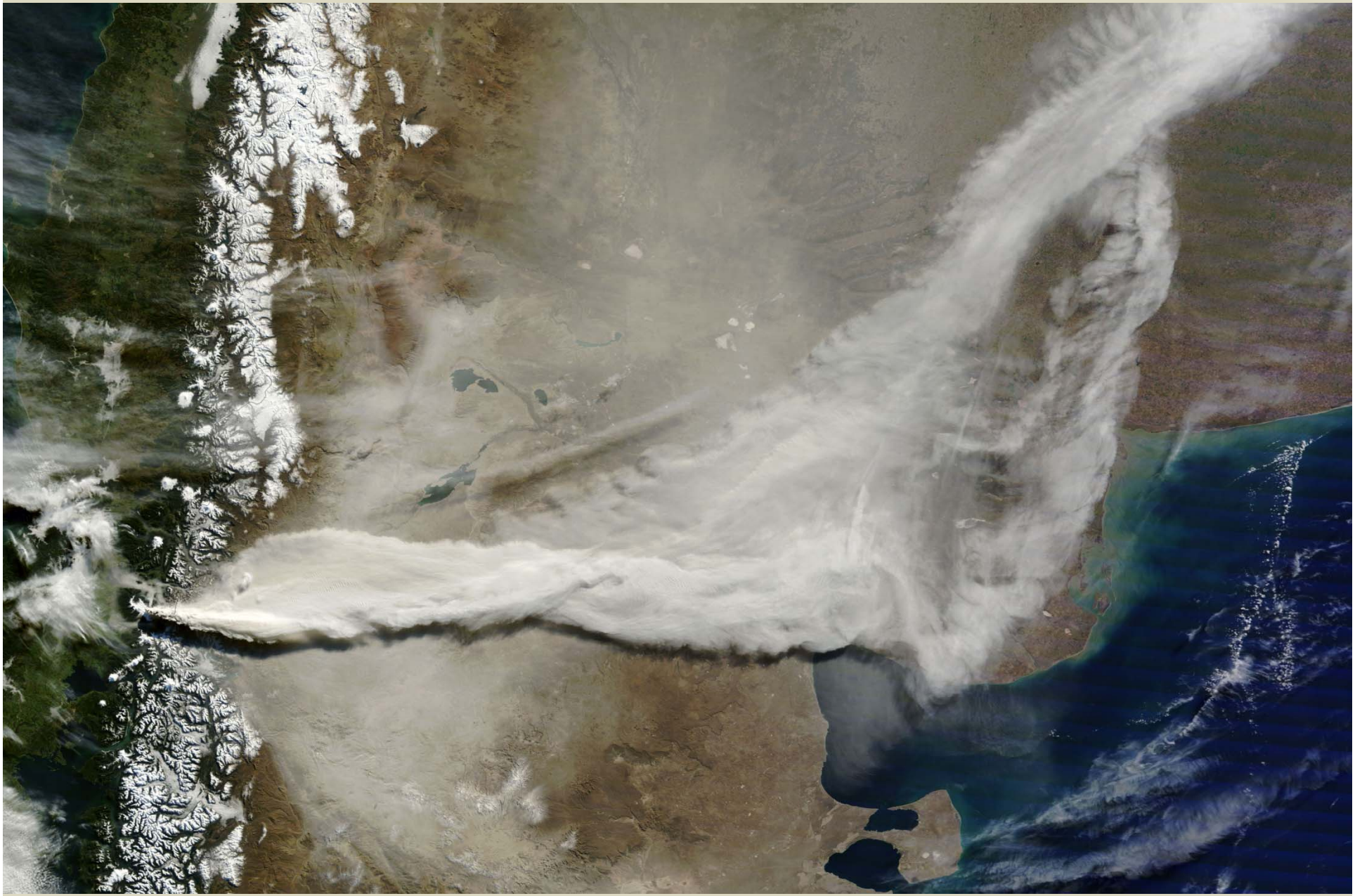
EYJAFJALLAJOKULL GLACIER ERUPTION, ICELAND, APRIL 2010





Effects of volcanic ash on jet engine

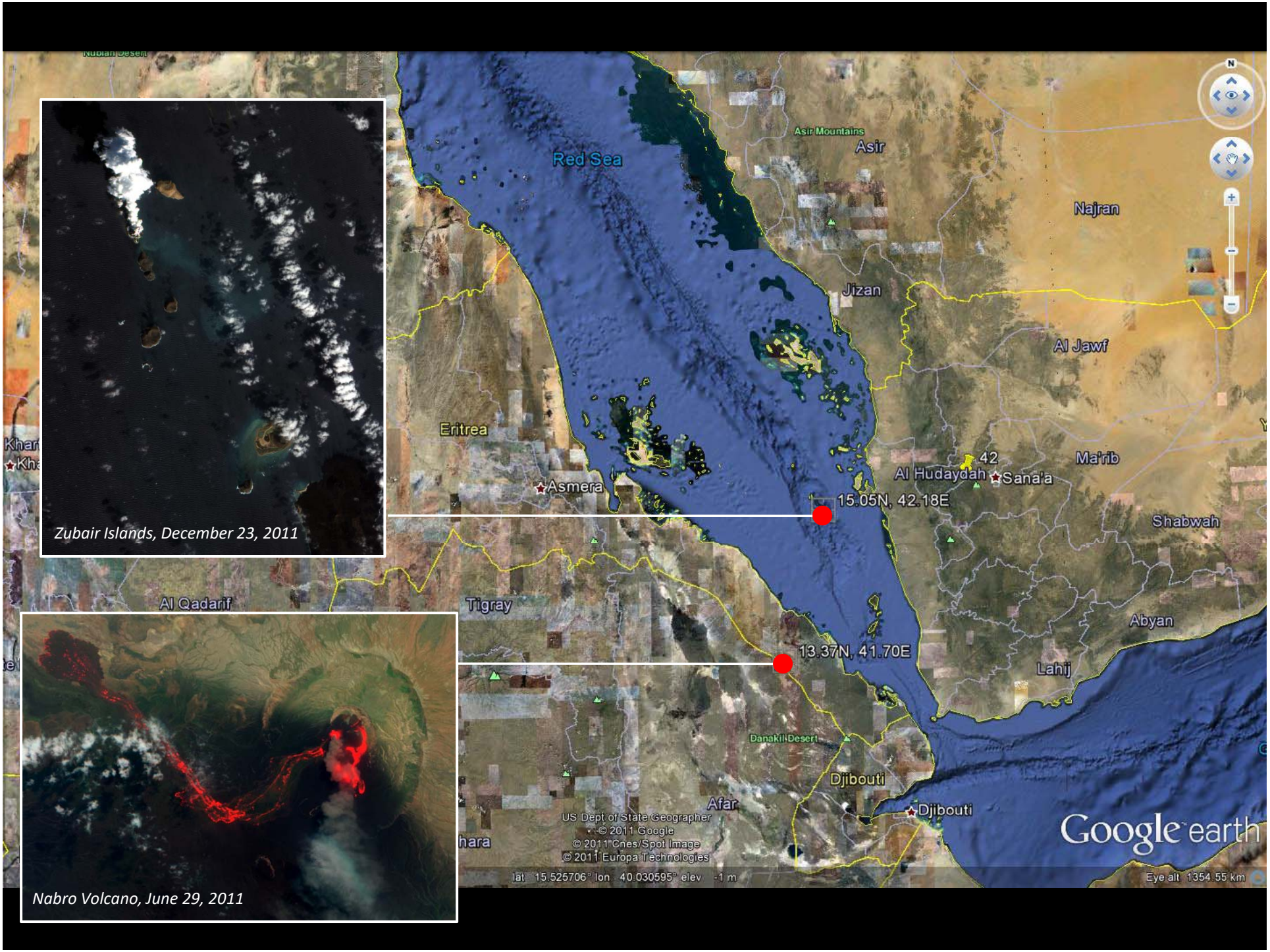




ONGOING ERUPTION OF PUYEHE-CORDÓN CAULLE VOLCANO, CHILE [June 13, 2011]

ONGOING ERUPTION OF PUYEHE-CORDÓN CAULLE VOLCANO, CHILE [June, 2011]

Air traffic disrupted in Australia, NZ, Chile and Argentina (June 2011)


Zubair Islands, December 23, 2011
Nabro Volcano, June 29, 2011
Red Sea
Asir Mountains
Asir
Najran
Jizan
Al Jawf
Eritrea
Asmera
Al Hudaydah
Sana'a
Ma'rib
15.05N, 42.18E
Shabwah
Al Qadarif
Tigray
13.37N, 41.70E
Abyan
Lahij
Danakil Desert
Djibouti
Afar
Djibouti
US Dept of State Geographer
© 2011 Google
© 2011 Cnes/Spot Image
© 2011 Europa Technologies
lat 15.525706° lon 40.030595° elev -1 m
Eye alt 1354.55 km
Google earth

4. LANDSLIDES

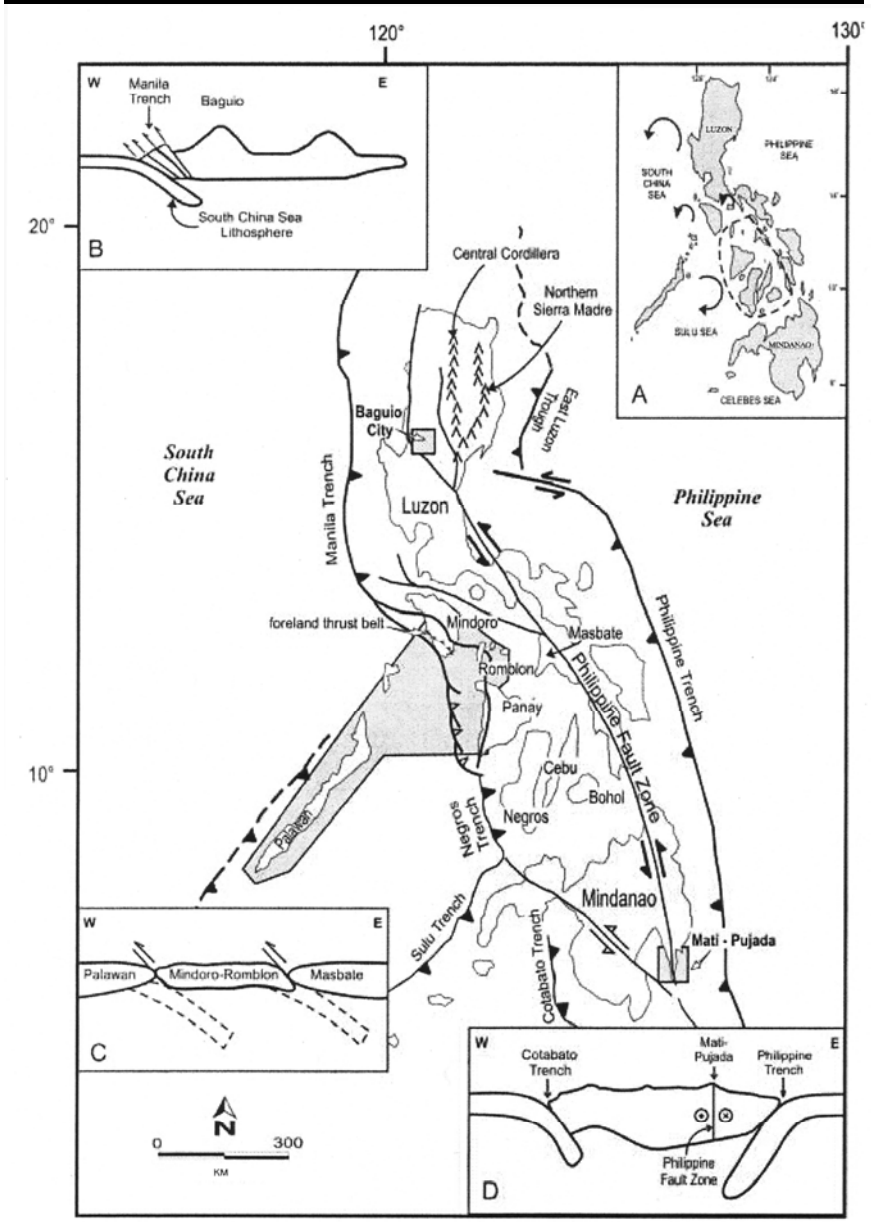
1903 Frank Slide, Alberta ; Canada's top landslide disaster (75 deaths)

- Catastrophic mass movement of earth materials (soil, rock – also including artificial materials) downslope
- Catastrophic mass movements travel at 5 m/s or greater
- Some average velocities of disastrous landslides exceed 50 m/s
- Landslides may show multiple modes of movement due to transformation of initial mechanism

ANATOMY OF A LANDSLIDE DISASTER – THE 2006 GUINSAUGON LANDSLIDE, PHILIPPINES

2006 landslide on Leyte Island, Philippines (1100 deaths)

2006 landslide on Leyte Island, Philippines (1100 deaths)


120°
130°
20°
10°
W
E
Manila Trench
Baguio
South China Sea Lithosphere
B
Central Cordillera
Northern Sierra Madre
East Luzon Trough
Baguio City
South China Sea
Philippine Sea
Manila Trench
Luzon
foreland thrust belt
Mindoro
Masbate
Romblon
Panay
Philippine Fault Zone
Philippine Trench
Cebu
Bohol
Negros
Negros Trench
Palawan
Sulu Trench
Mindanao
Mati - Pujada
Cotabato Trench
LUZON
PHILIPPINE SEA
SOUTH CHINA SEA
SULU SEA
MINDANAO
CELEBES SEA
A
Palawan
Mindoro-Romblon
Masbate
C
Cotabato Trench
Mati-Pujada
Philippine Trench
Philippine Fault Zone
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0
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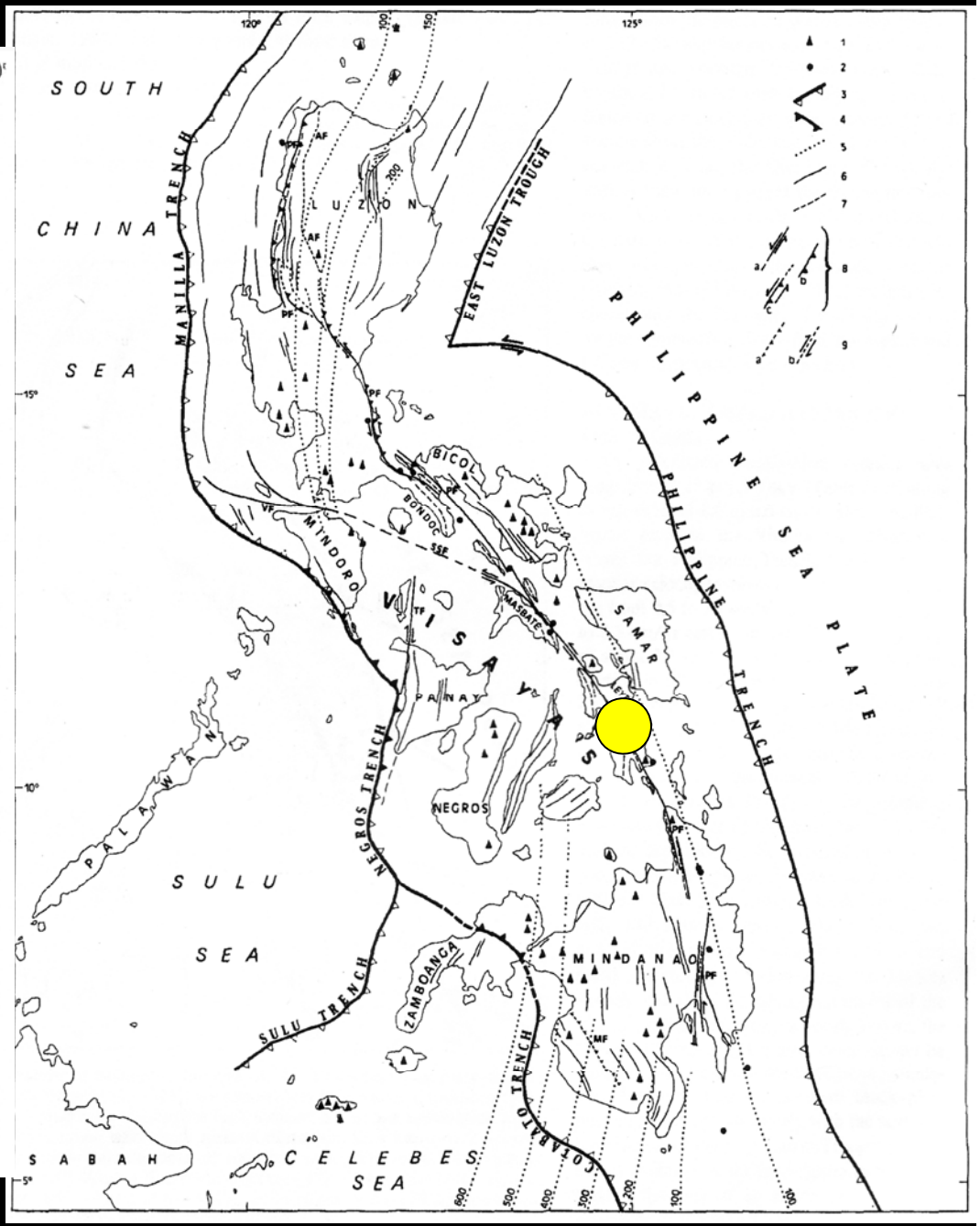
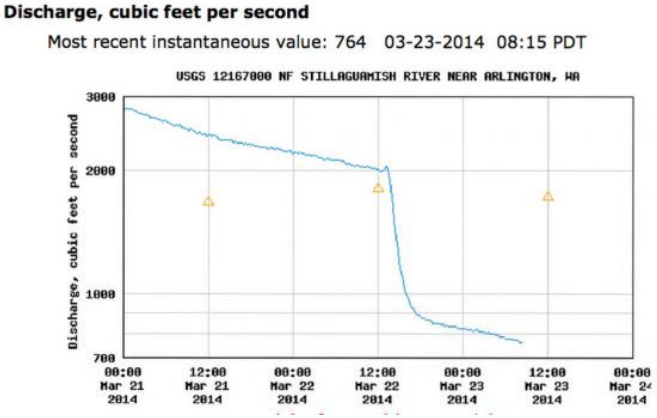
KM


SOUTH
CHINA
SEA
MANILA TRENCH
EAST LUZON TROUGH
PHILIPPINE SEA PLATE
PHILIPPINE SEA
LUZON
BICOL
BONDOC
MINDORO
MASBATE
VISAYAS
PANAY
SAMAR
NEGROS
PALAWAN
SULU
SEA
NEGROS TRENCH
SULU TRENCH
ZAMBOANGA
MINDANAO
COTABATO TRENCH
SABAH
CELEBES
SEA
120°
125°
15°
10°
5°


03.12.2006 12:10


03.12.2006 17:15

OSO LANDSLIDE, WASHINGTON STATE, USA : MARCH 22, 2014



OSO LANDSLIDE, WASHINGTON STATE, USA

MARCH 22, 2014 – 44 deaths

SUNKOSHI LANDSLIDE, NEPAL (August 2, 2014) : 5.5Mm^3 / 156 deaths /debris blocked Sunkoshi River/ impacted Sunkoshi hydropower station.

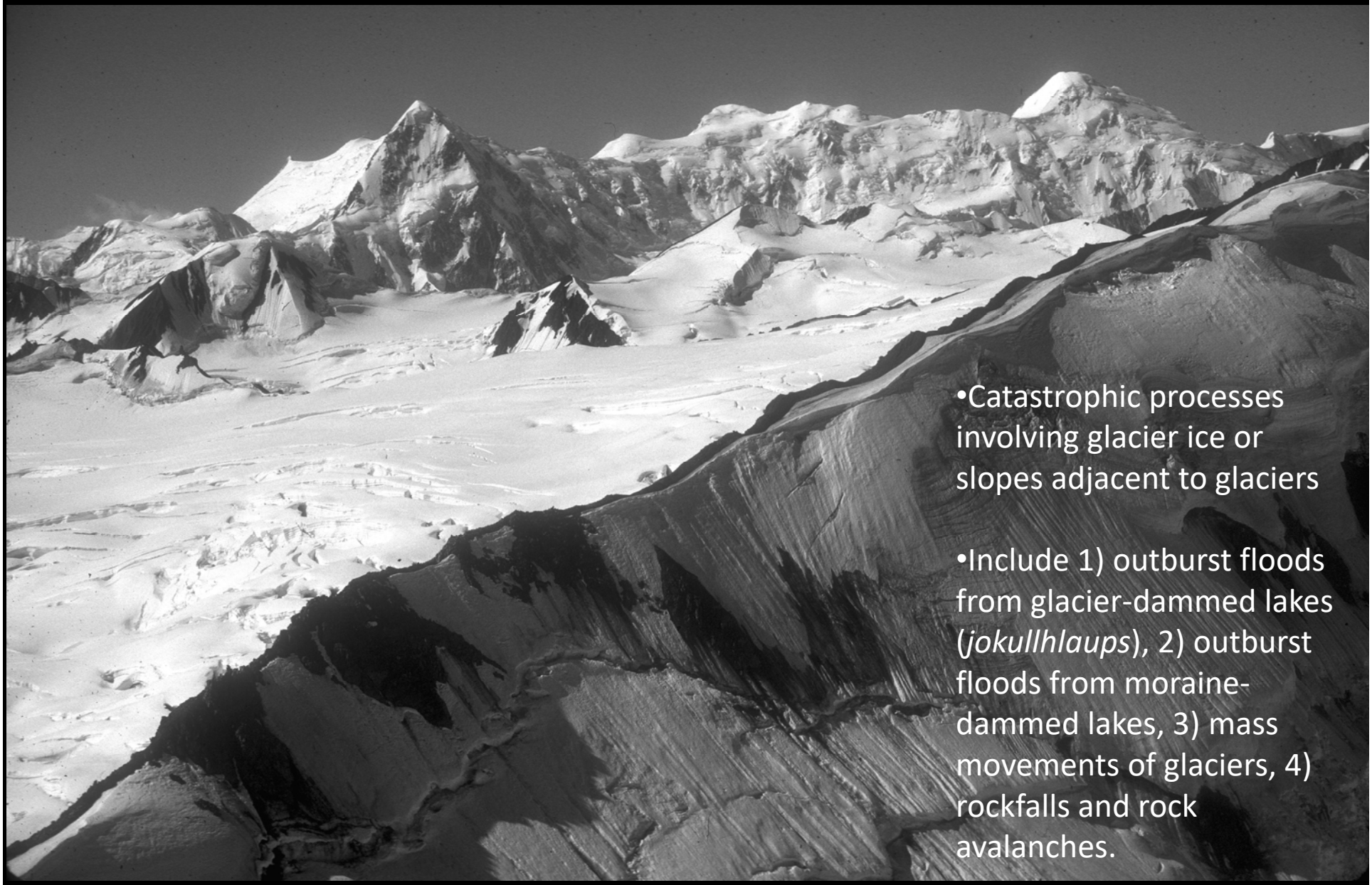
AB BAREK LANDSLIDE, BADAKHSHAN PROVINCE, NE AFGHANISTAN (May 2, 2014)

SECONDARY EFFECTS OF LANDSLIDES

1908 landslide and displacement wave at Notre-Dame-de-la-Salette, Lièvre River, Québec

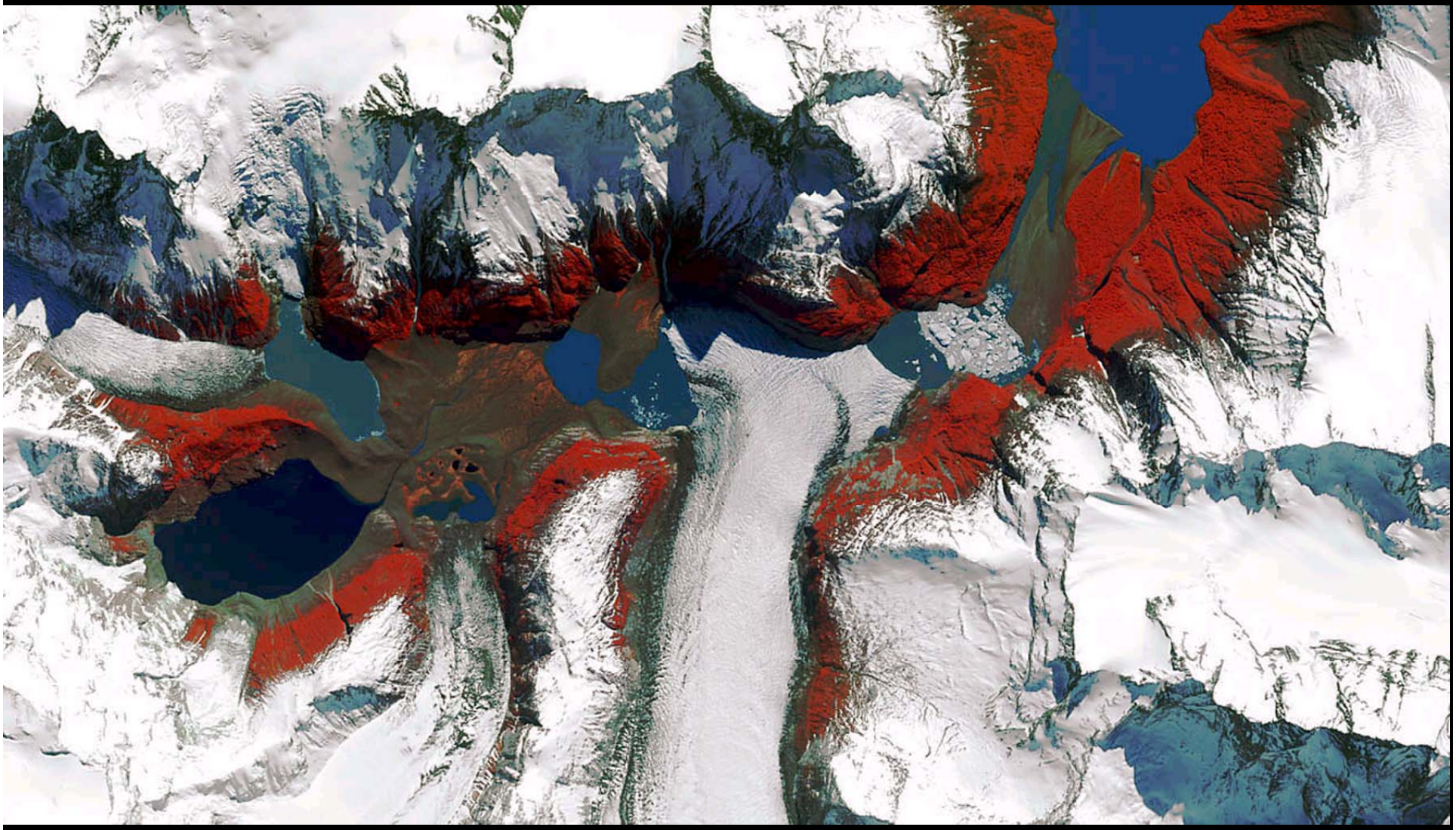
1903 Leda Clay landslide and landslide dam at Poupore, Lièvre River, Québec

5. GLACIER HAZARDS



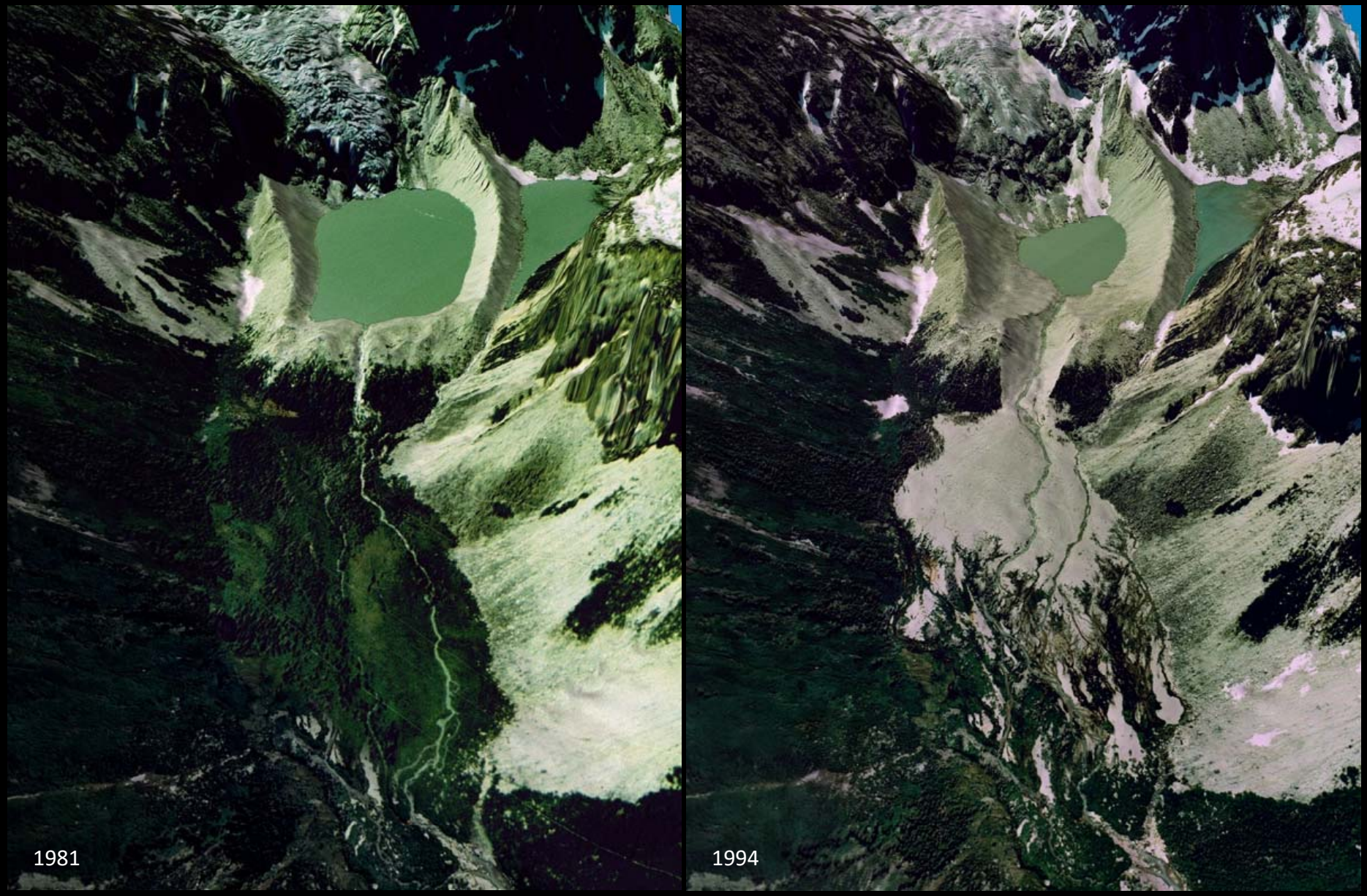
- Catastrophic processes involving glacier ice or slopes adjacent to glaciers

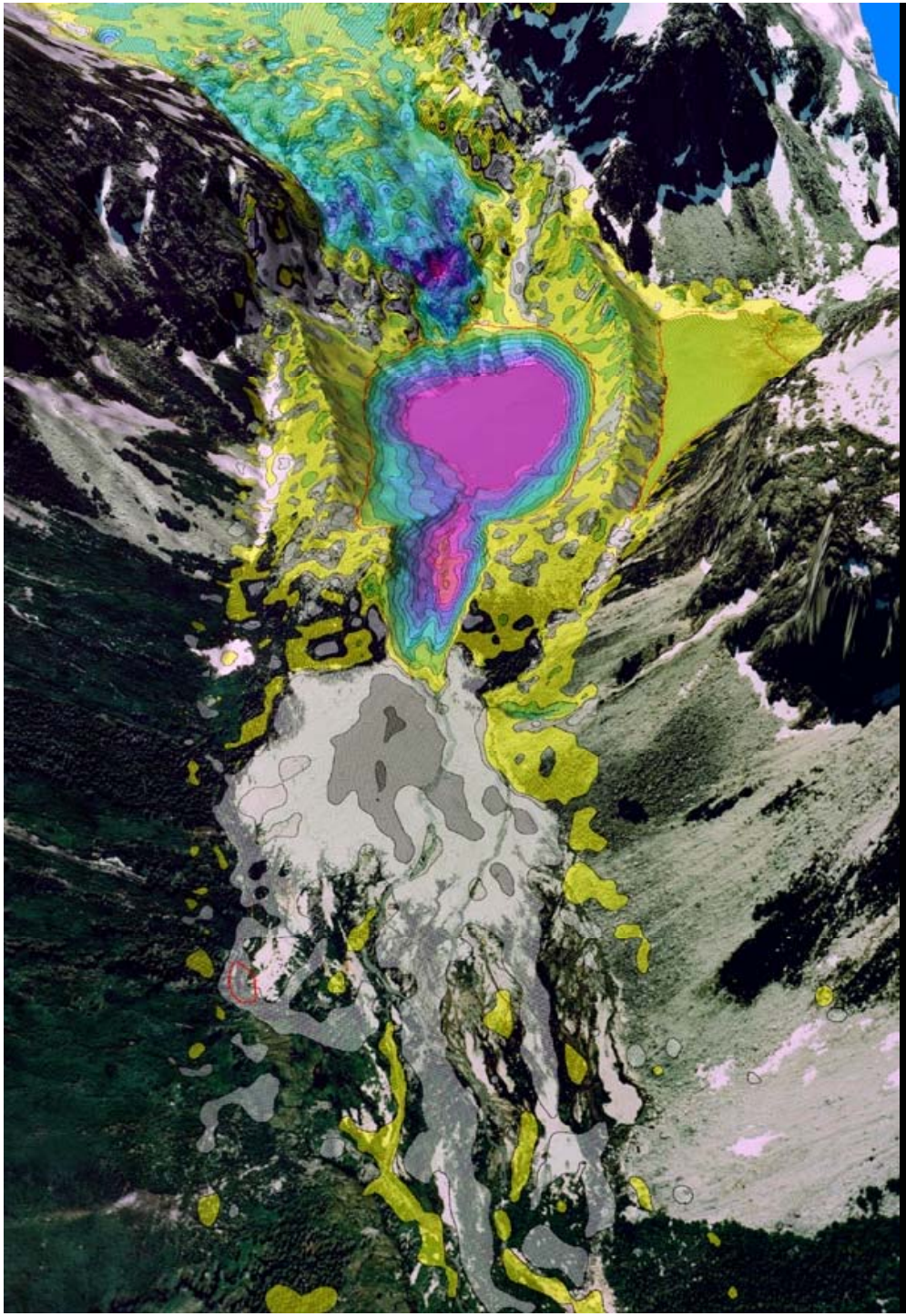
- Include 1) outburst floods from glacier-dammed lakes (*jokullhlaups*), 2) outburst floods from moraine-dammed lakes, 3) mass movements of glaciers, 4) rockfalls and rock avalanches.



Glacier-retreat since the end of the Little Ice Age, ca. A.D. 1900

Effect of 1983 outburst from moraine-dammed lake in the Nostetuko River basin, British Columbia





NOSTETUKO LAKE OUTBURST SUMMARY

Date: July 19, 1983

Outburst Volume: 6.5 M m^3

Breach Loss Volume: 1.6 M m^3

Max. Discharge: ca. 10,000 m^3/s

Max. Wave Run-Up: 11.7 m

Wave Velocity:15 m/s

Drawdown: 38 m

Cause: glacier avalanche

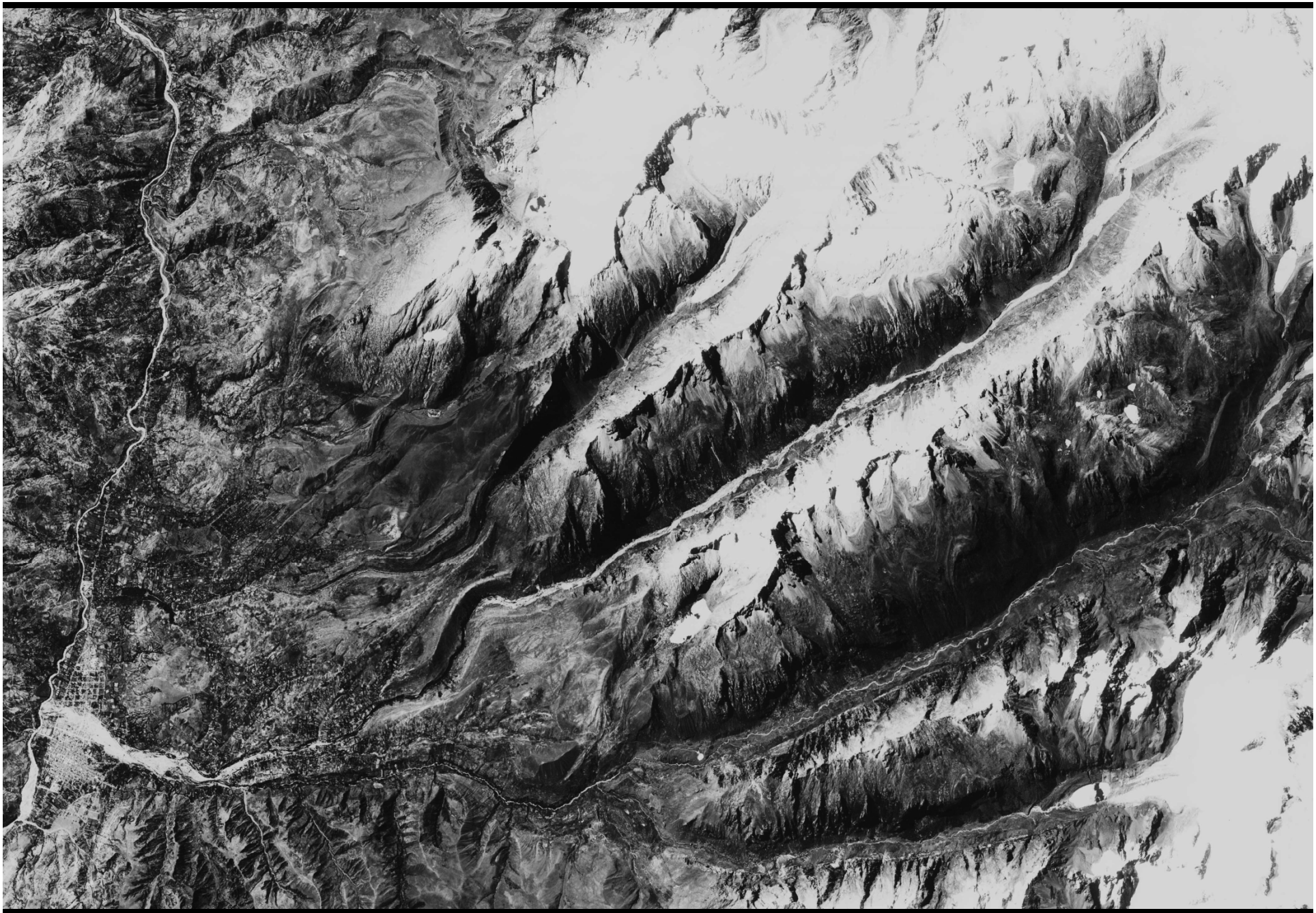
Volume of Glacier Avalanche: ca. 1.5 M m^3

Laguna Llaca, Cordillera Blanca, Peru [April 2011]

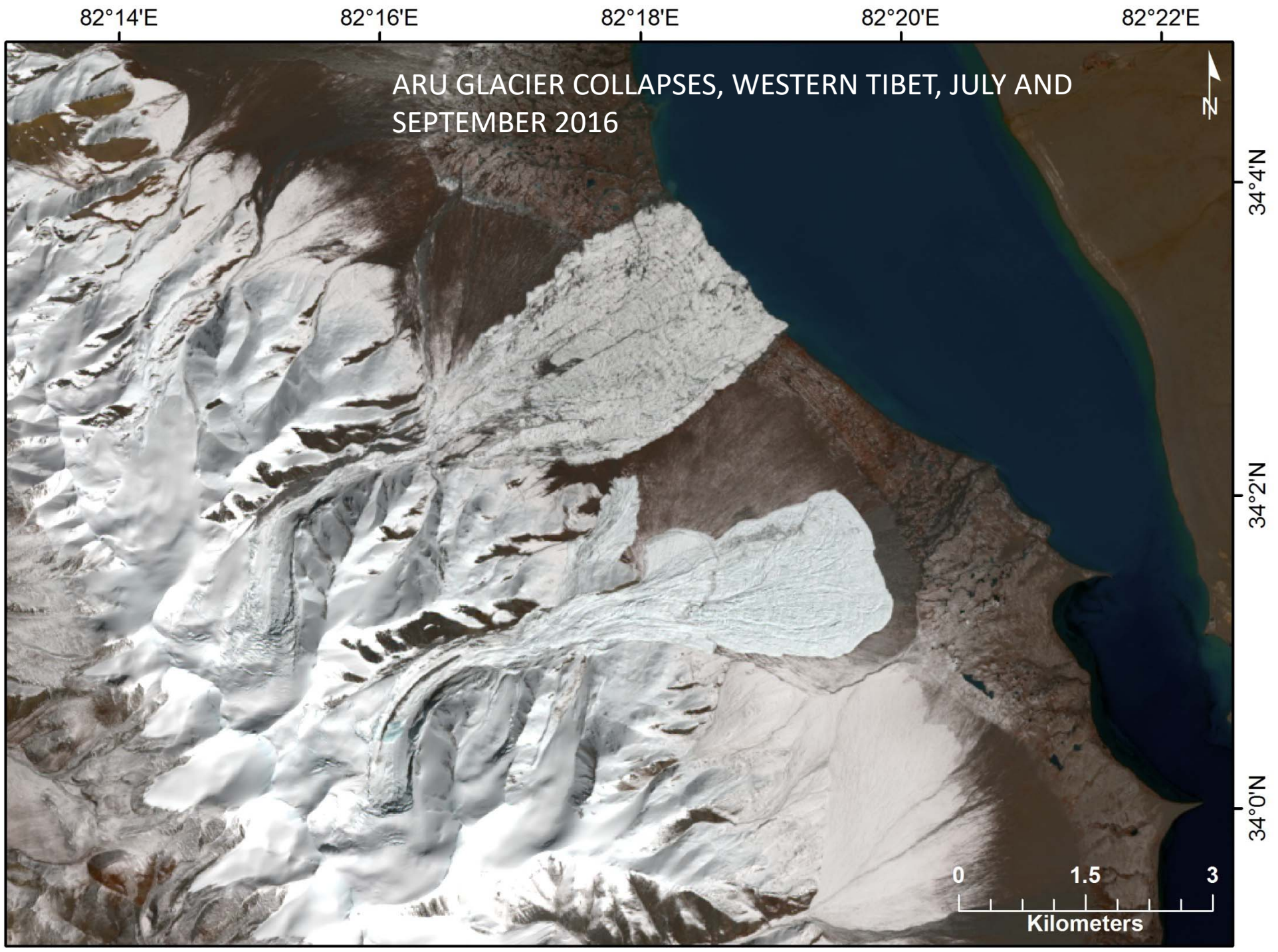
1941 LAGUNA COHUP OUTBURST, CORDILLERA BLANCA, PERUVIAN ANDES

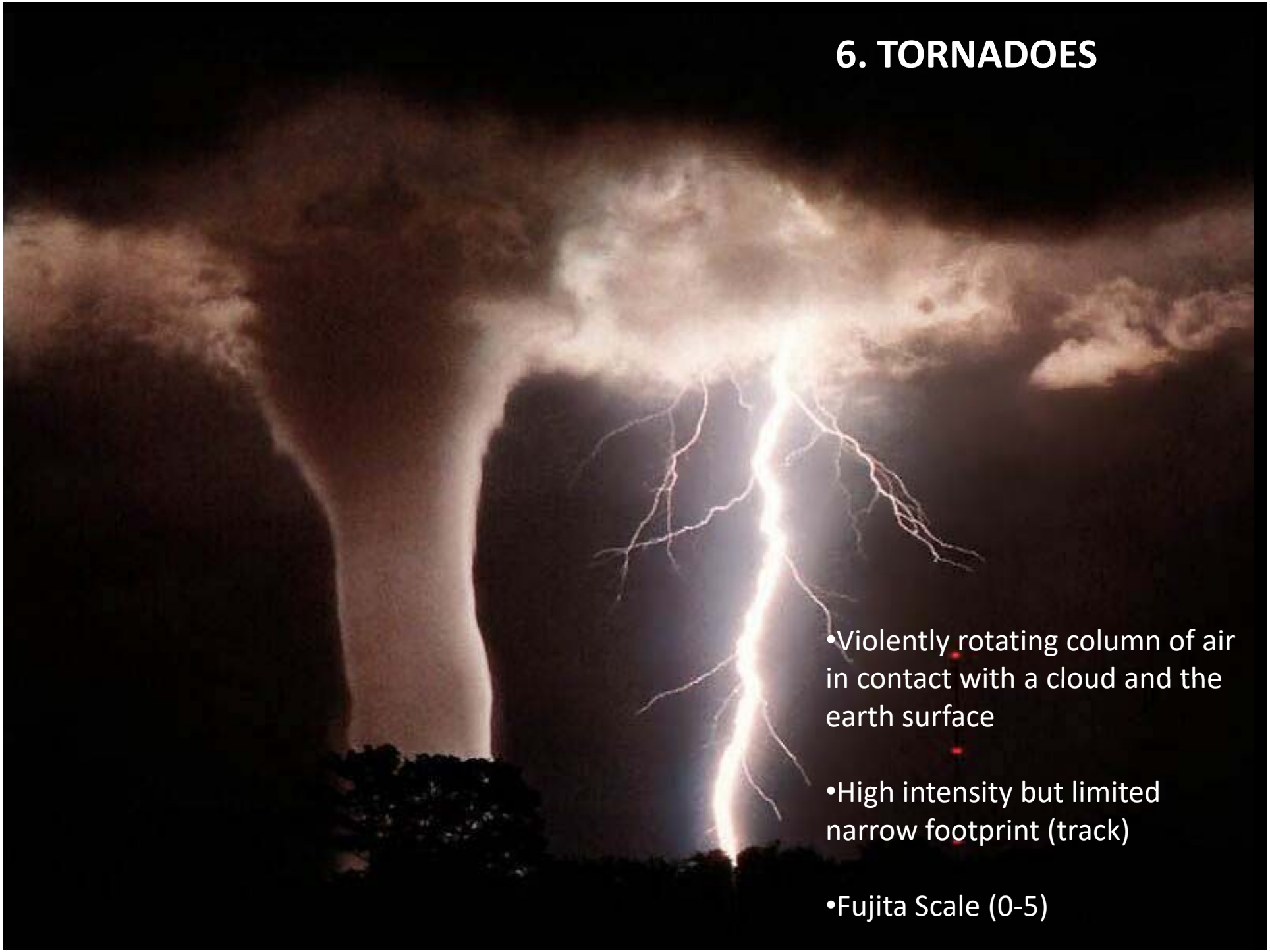
48. Die am 13. XII. 1941 ausgebrochene Laguna Cohup, die einen Teil der Stadt Huaras wegriß (7. IX. 1947).

51. Die von der Sturzflut der Laguna Cohup teilweise zerstörte Stadt Huaras. Flugbild von Westen (24. VI. 1947).



Corona spy satellite image 1962


82°14'E
82°16'E
82°18'E
82°20'E
82°22'E
ARU GLACIER COLLAPSES, WESTERN TIBET, JULY AND SEPTEMBER 2016
N
34°4'N
34°2'N
34°0'N
0
1.5
3
Kilometers



6. TORNADOES

•Violently rotating column of air in contact with a cloud and the earth surface

•High intensity but limited narrow footprint (track)

•Fujita Scale (0-5)

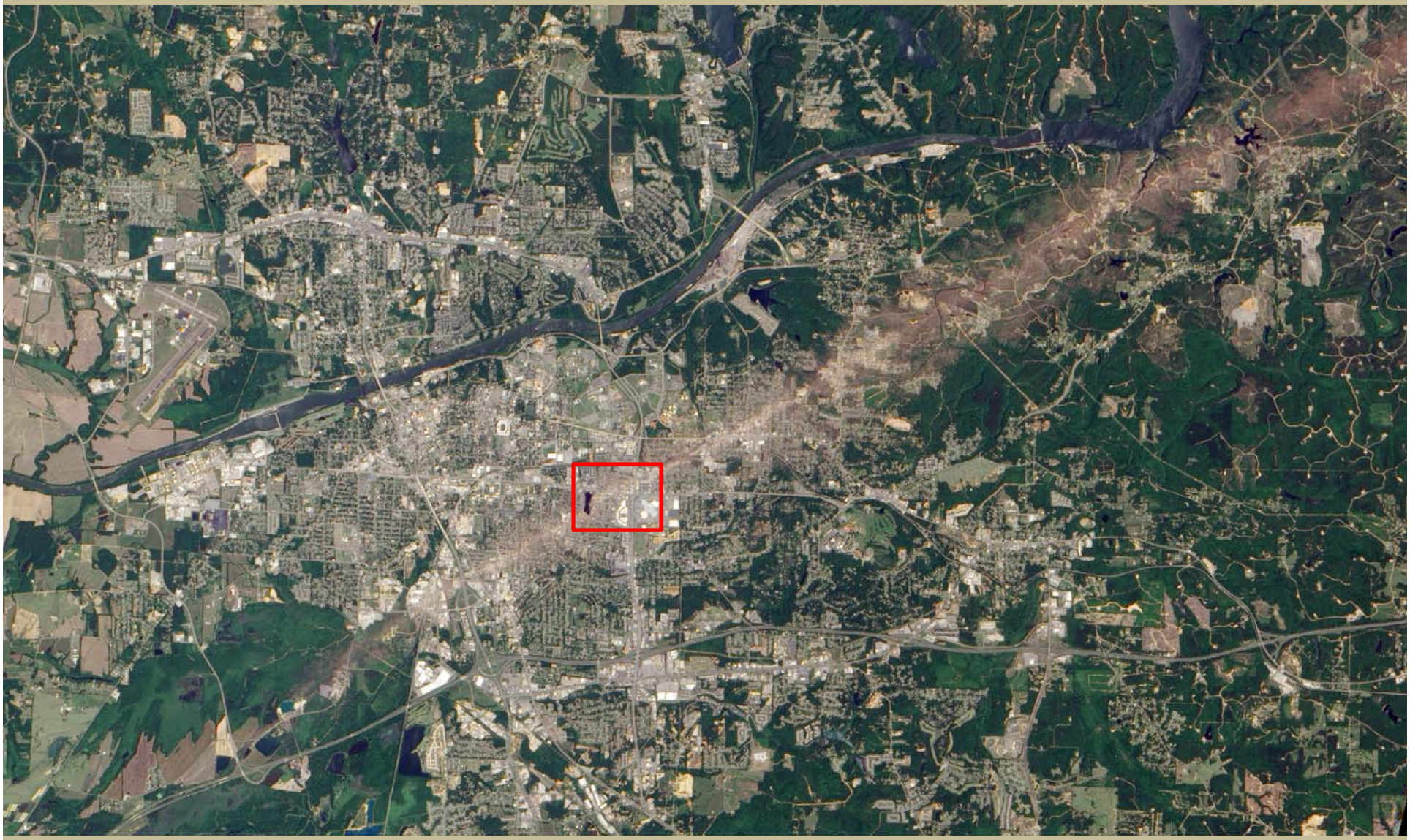
Track speed in tornadoes exceeds about 25 m/s
Rotating wind speeds in a tornado exceed 125 m/s

Pine Lake, 2000

Regina, 1912

Canada's deadliest tornadoes (*source: Environment Canada*)		
Regina, Sask.	Jun. 30, 1912	28 dead, hundreds injured
Edmonton, Alta.	Jul. 31, 1987	27 dead, hundreds injured
Windsor, Ont.	Jun. 17, 1946	17 dead, hundreds injured
Pine Lake, Alta.	Jul. 14, 2000	12 dead, 140 injured
Windsor, Ont.	Apr. 3, 1974	9 dead, 30 injured
Valleyfield, Que.	Aug. 16, 1888	9 dead 14 injured
Barrie, Ont.	May 31, 1985	8 dead, 155 injured
Sudbury, Ont.	Aug. 20, 1970	6 dead, 200 injured
St-Rose, Que.	Jun. 14, 1892	6 dead, 6 injured
Buctouche, N.B.	Aug. 6, 1879	5 dead, 10 injured

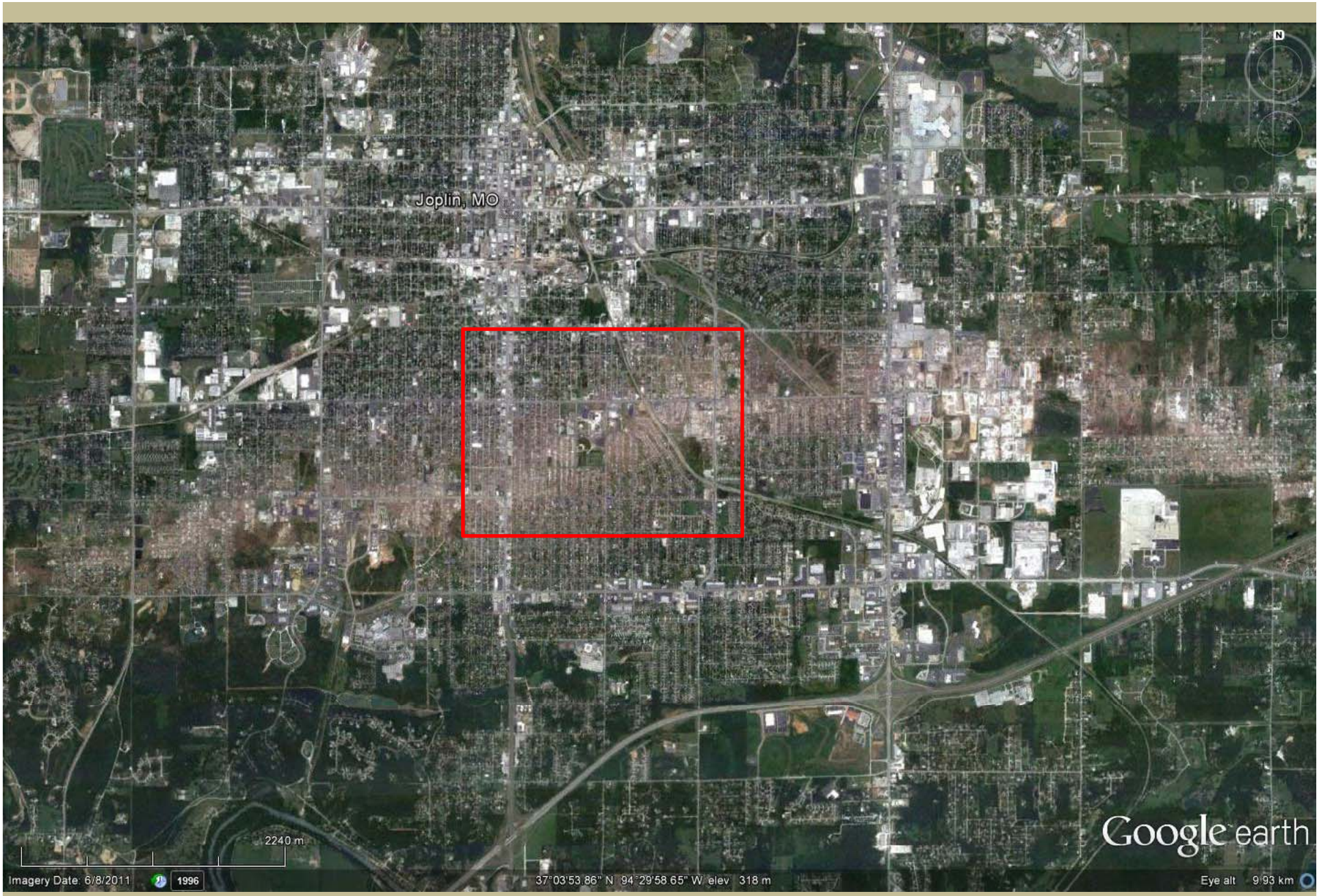
MANY DEADLY TORNADOES IN USA IN 2011



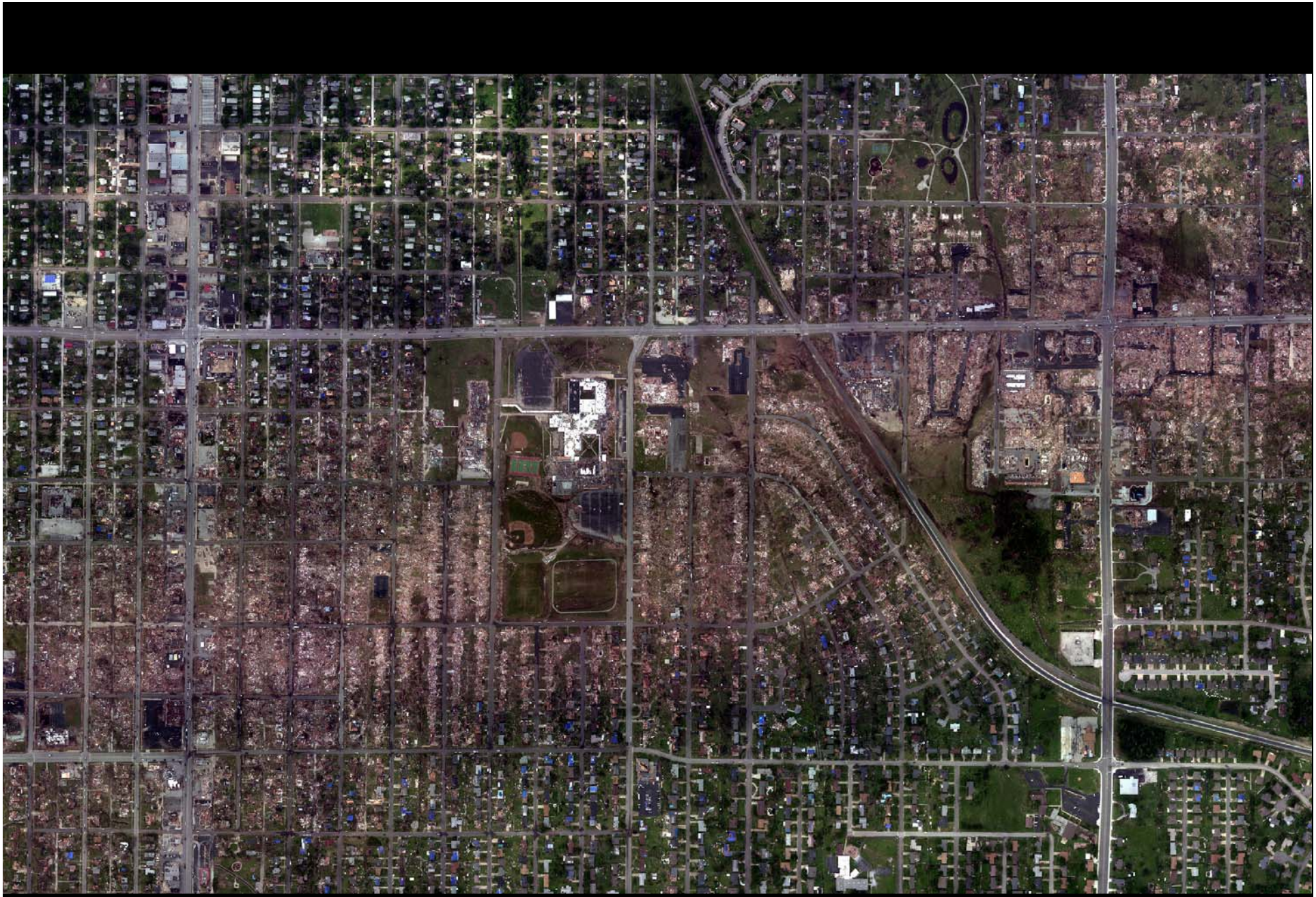
TORNADO TRACK, TUSCALOOSA, ALABAMA [27 April, 2011]

TUSCALOOSA TORNADO, ALABAMA, 27 April, 2011

TORNADO TRACK, TUSCALOOSA, ALABAMA [27 April, 2011]



EF-5 TORNADO TRACK, JOPLIN, MISSOURI, MAY 22, 2011 (157 deaths and over 1,000 injuries: $6.7 B USD insured damage)



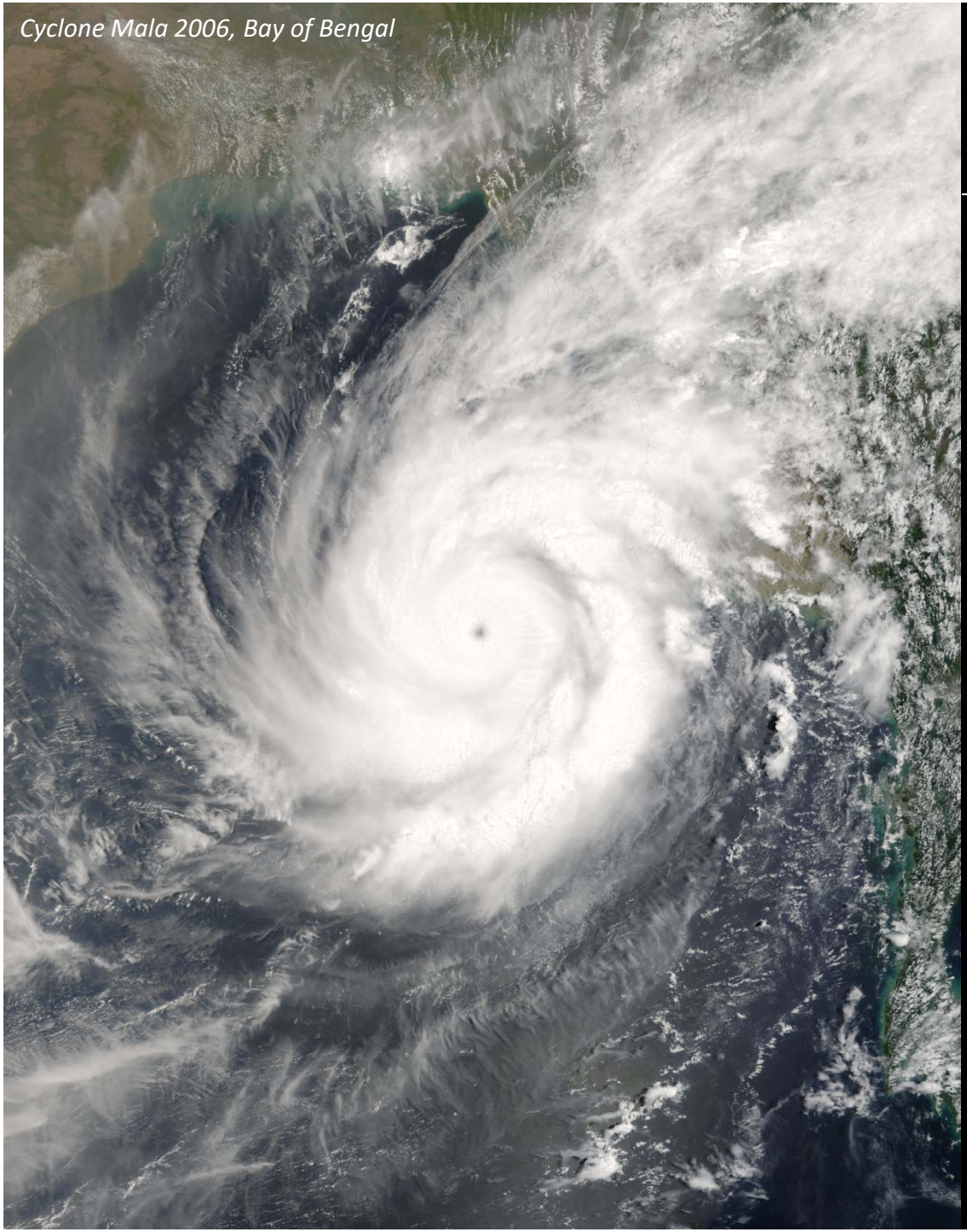
Large scale aerial photograph of Joplin, Missouri (May 24, 2011)

Goderich Tornado (F3) August 23, 2011

COLIN MCCONNELL/TORONTO STAR

The force of the storm shredded mature trees in Goderich's main square, above. The smell of gas downtown was so strong after the tornado that locals said they could almost taste it.

$5M for tornado-torn Goderich



Cyclone Mala 2006, Bay of Bengal

7. HURRICANES AND COASTAL IMPACTS

- **Hurricanes** are tropical atmospheric disturbances with maximum sustained wind speeds of 33 m/s or greater (also known as **Tropical Cyclones** and **Typhoons**)

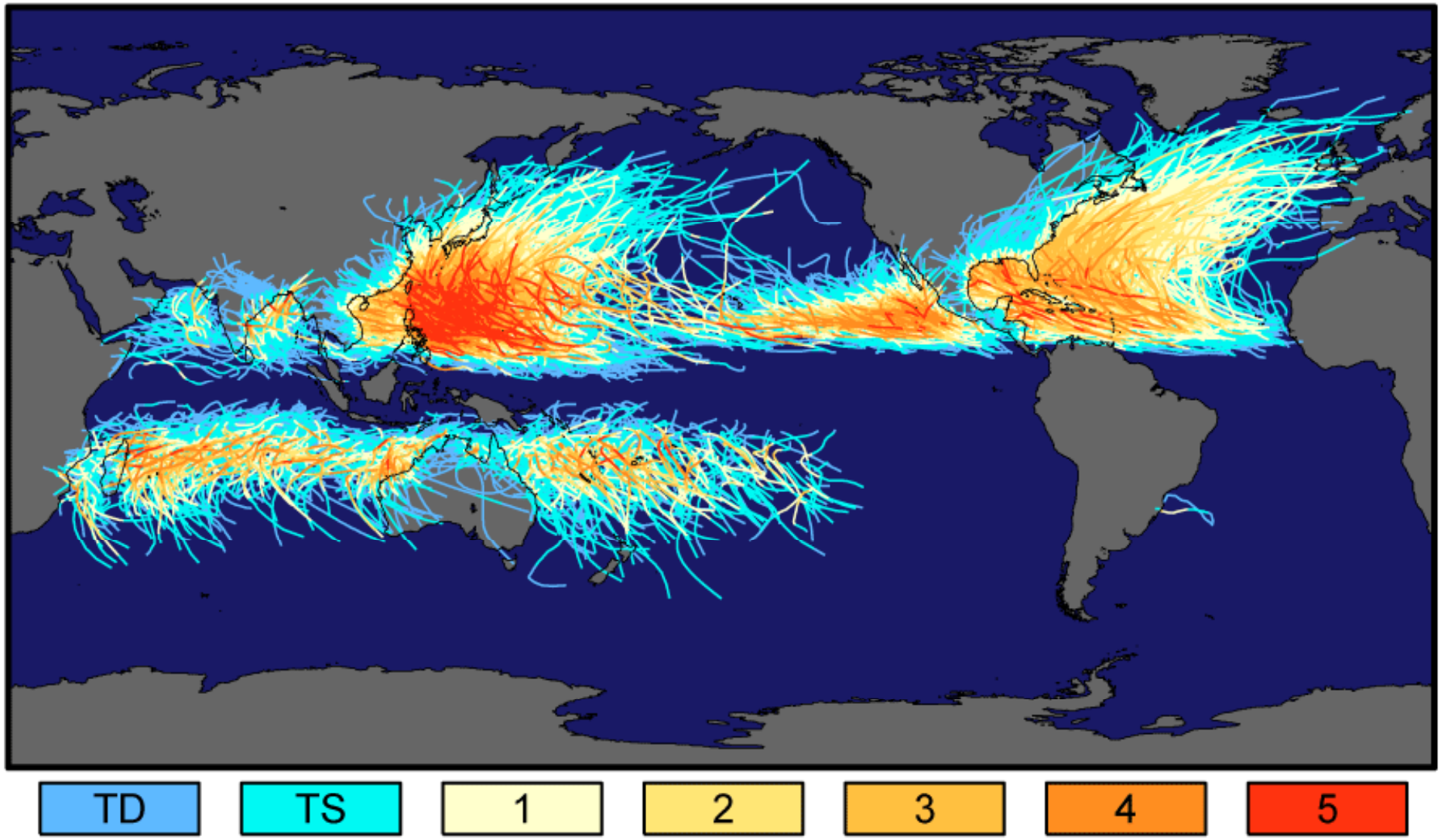
- Intensity a function of sea temperature

- Intensity Scale is the Saffir-Simpson Scale (1-5)

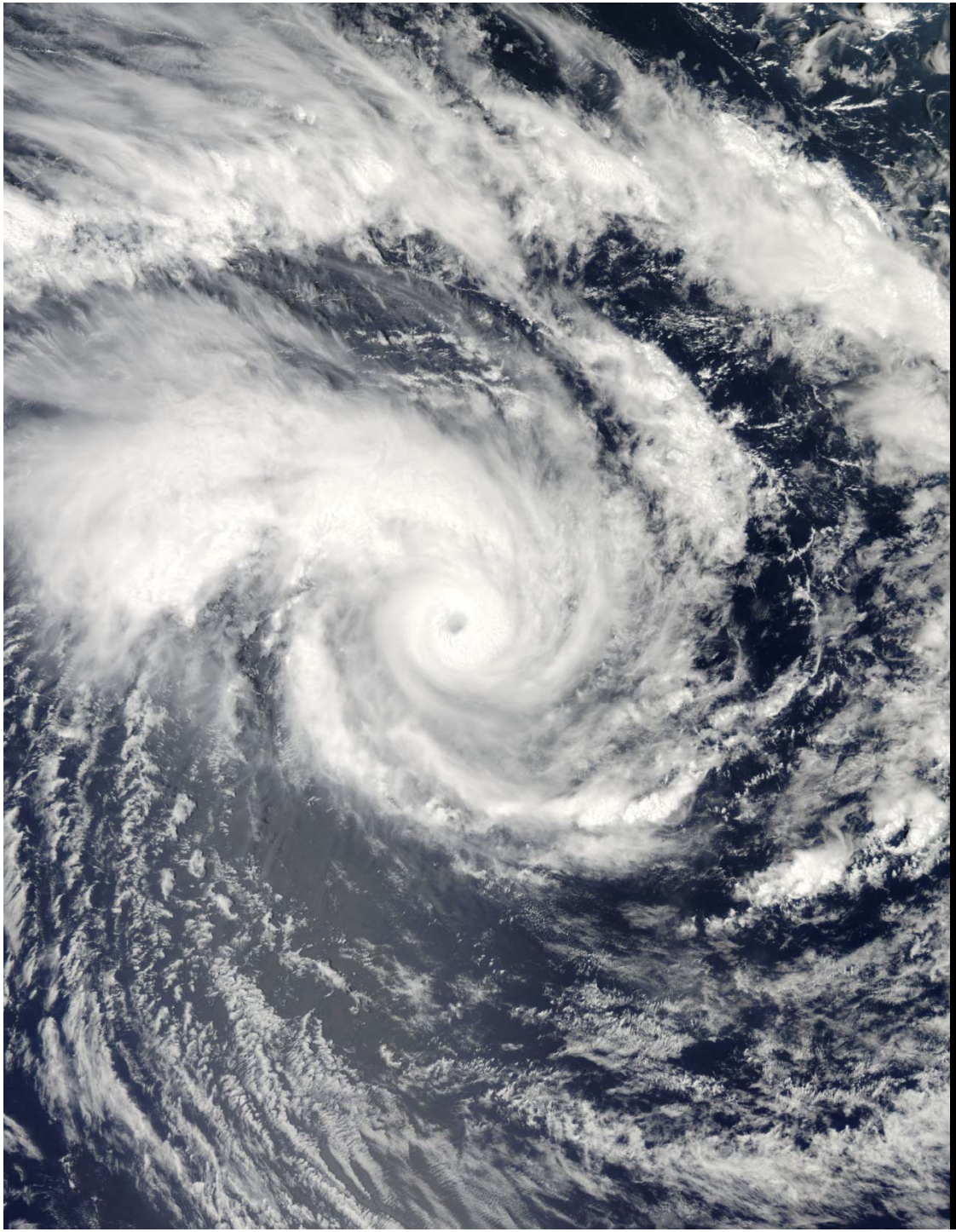
- Create storm surges along coasts (in excess of 6m)

- Heavy rains cause landslides and flooding (e.g., Hurricane Mitch)

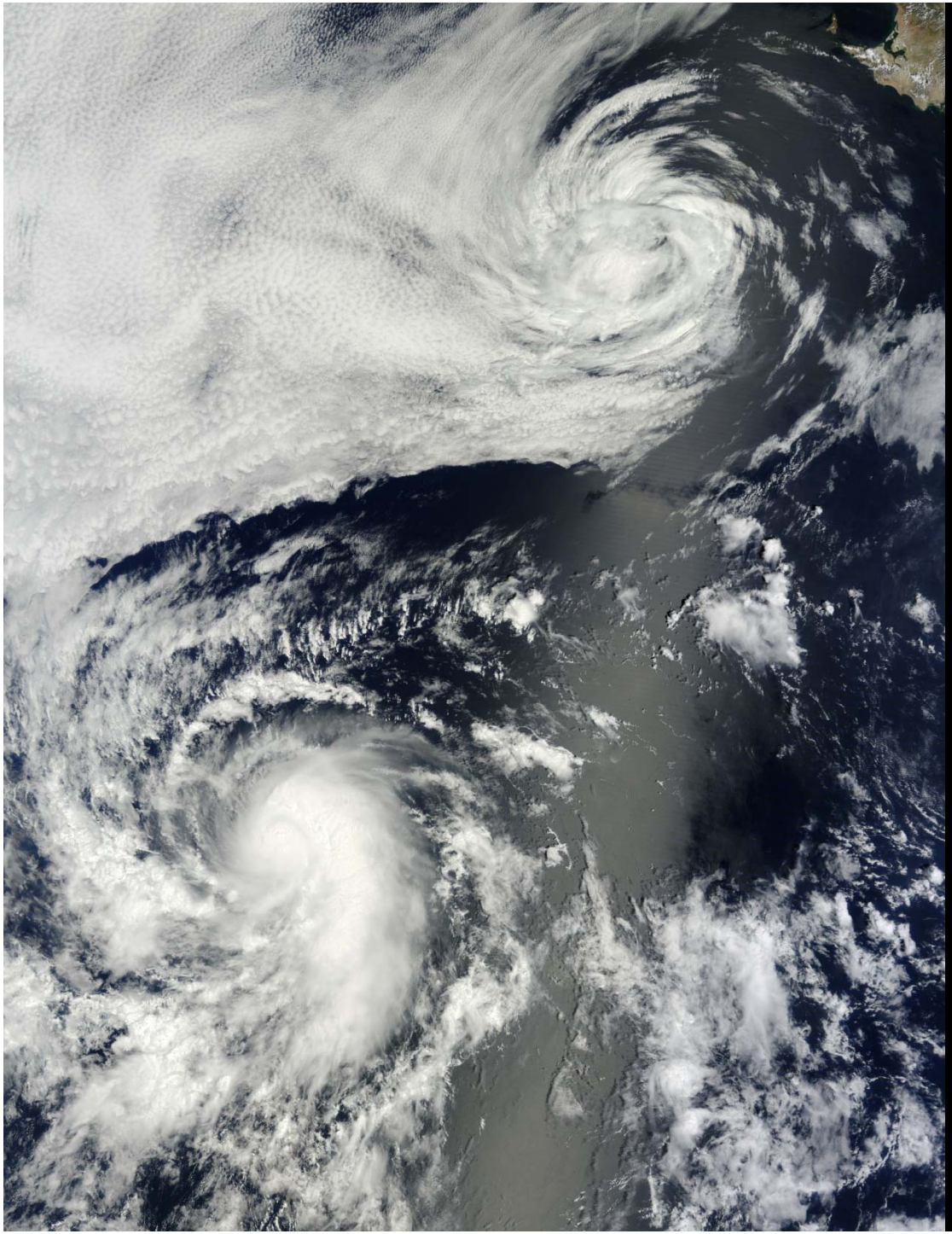
Tracks and Intensity of All Tropical Storms



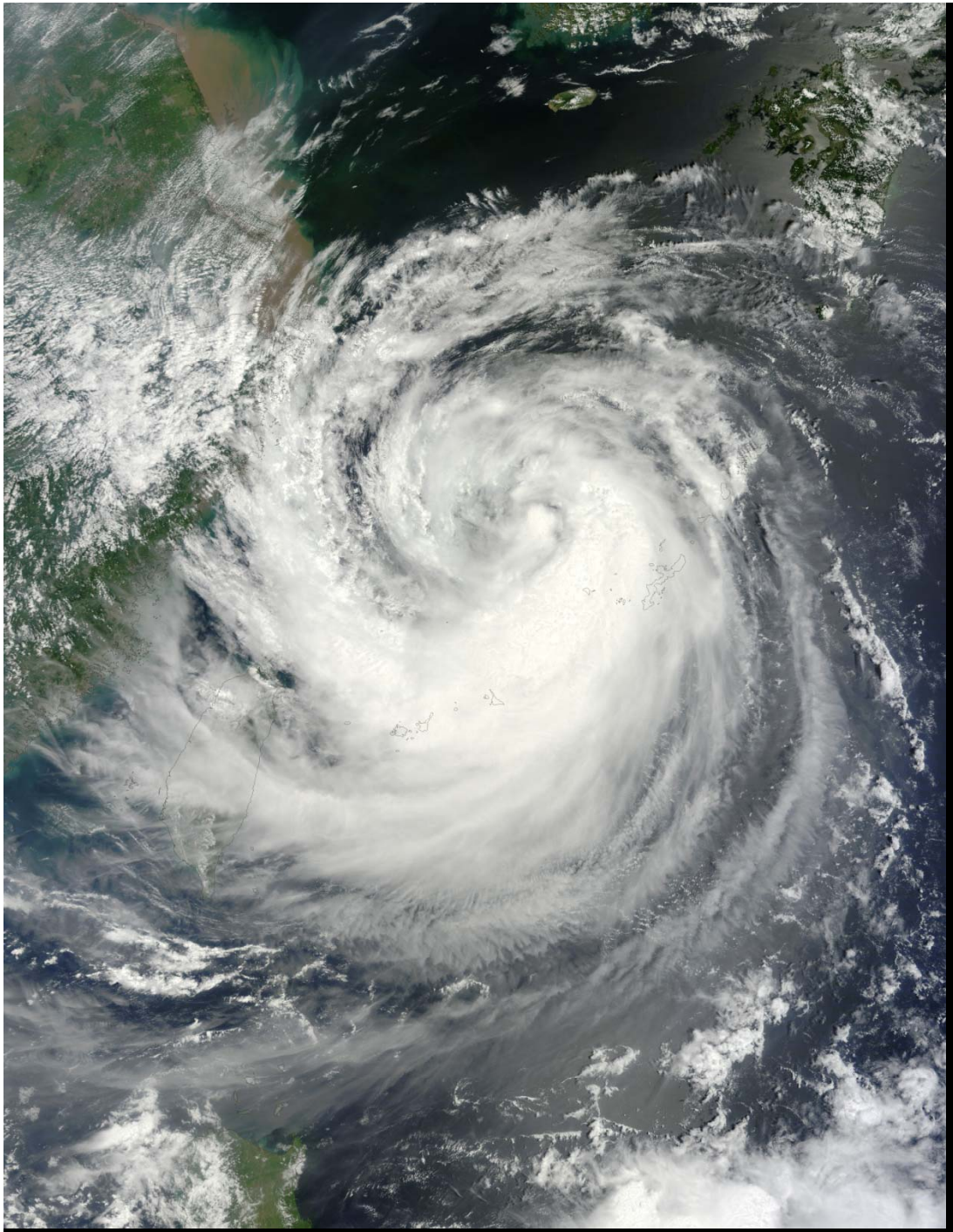
Tracks and Intensity of all tropical storms in National Hurricane Center and Joint Typhoon Warning Center databases through September 2006 (NASA)



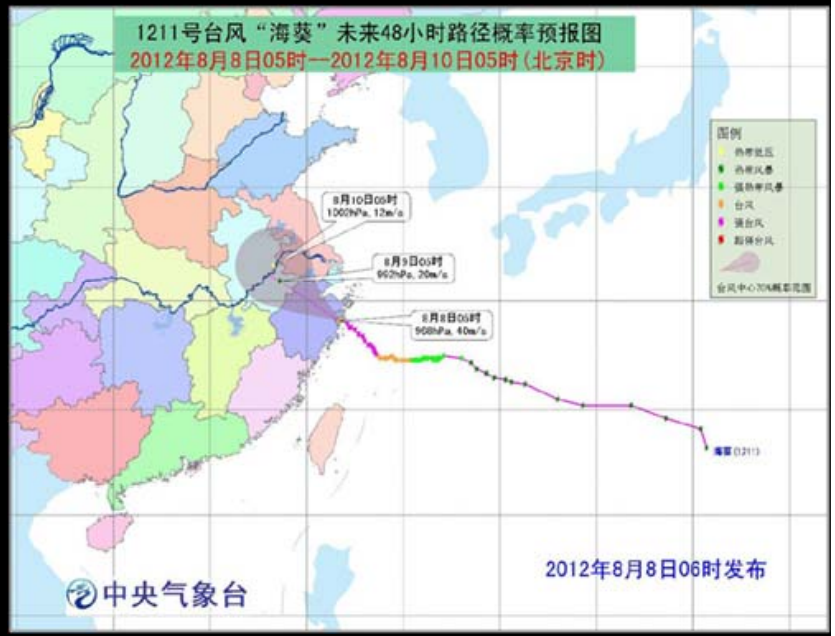
TROPICAL CYCLONE EDZANI, SOUTHERN INDIAN OCEAN, January 07 2010

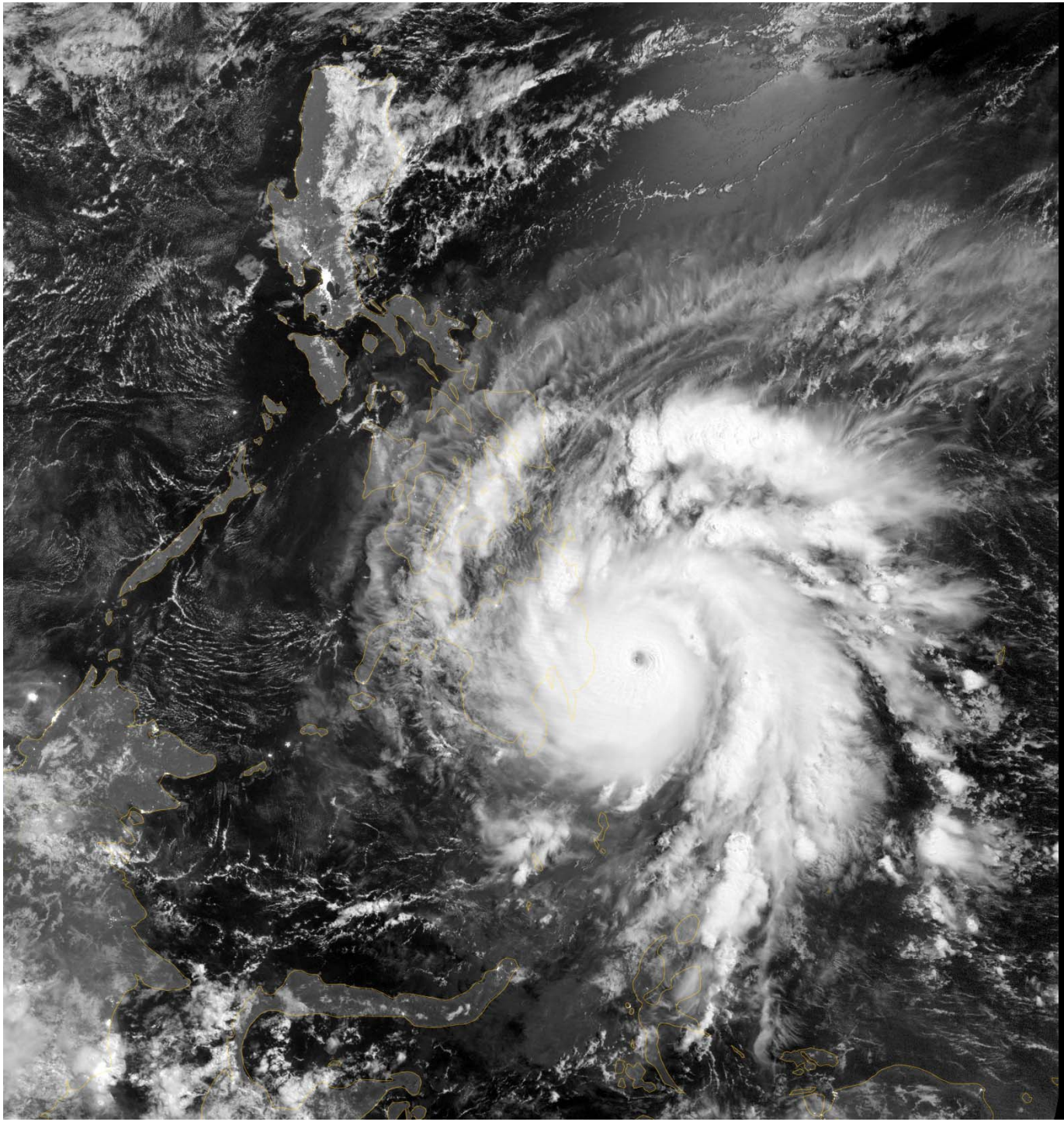


Typhoon development in the Eastern Pacific (September 16, 2012) ; Kristy (upper) and Lane (lower)



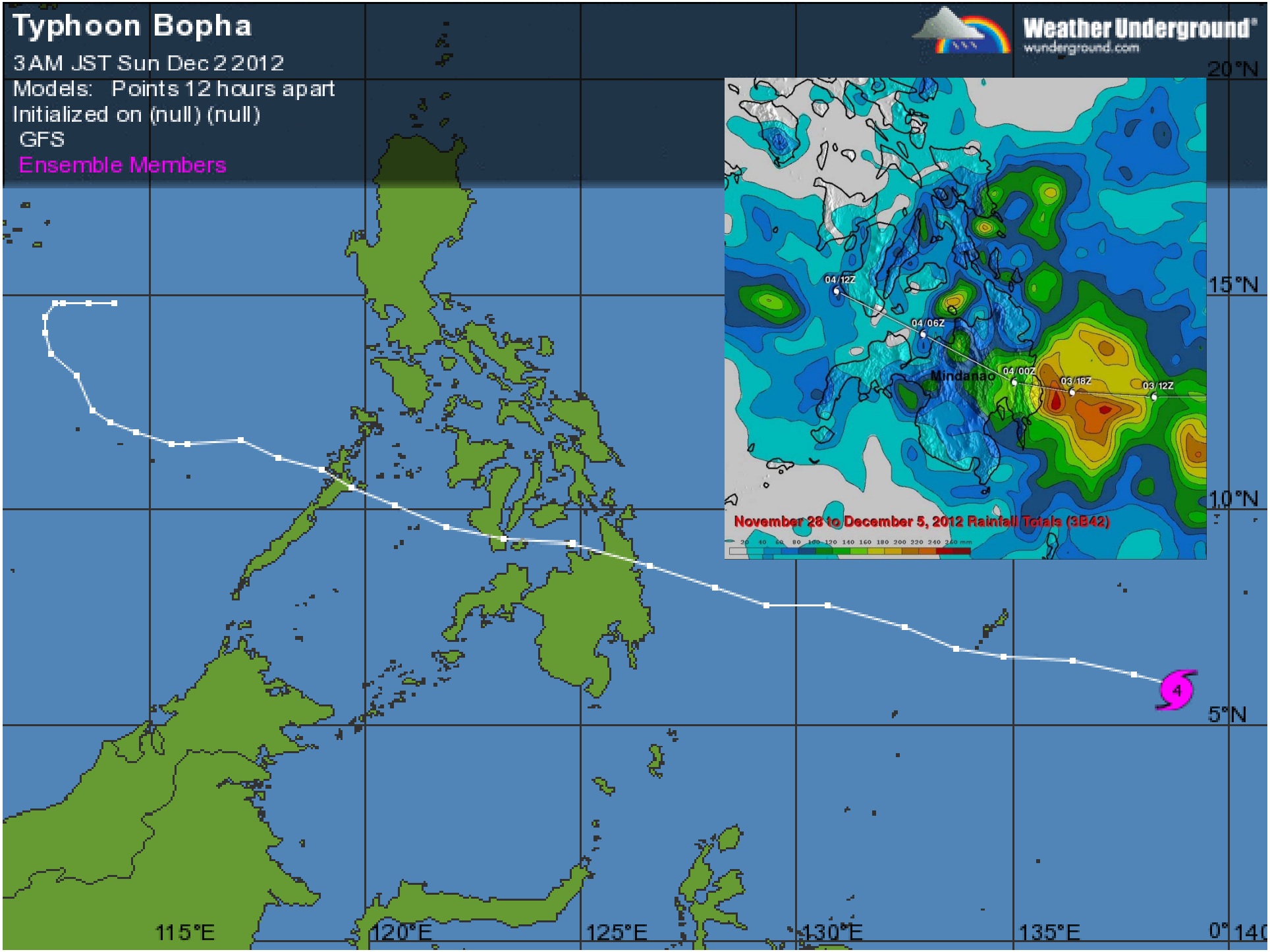
Typhoon Haikui off the east coast of China (August 6, 2012)

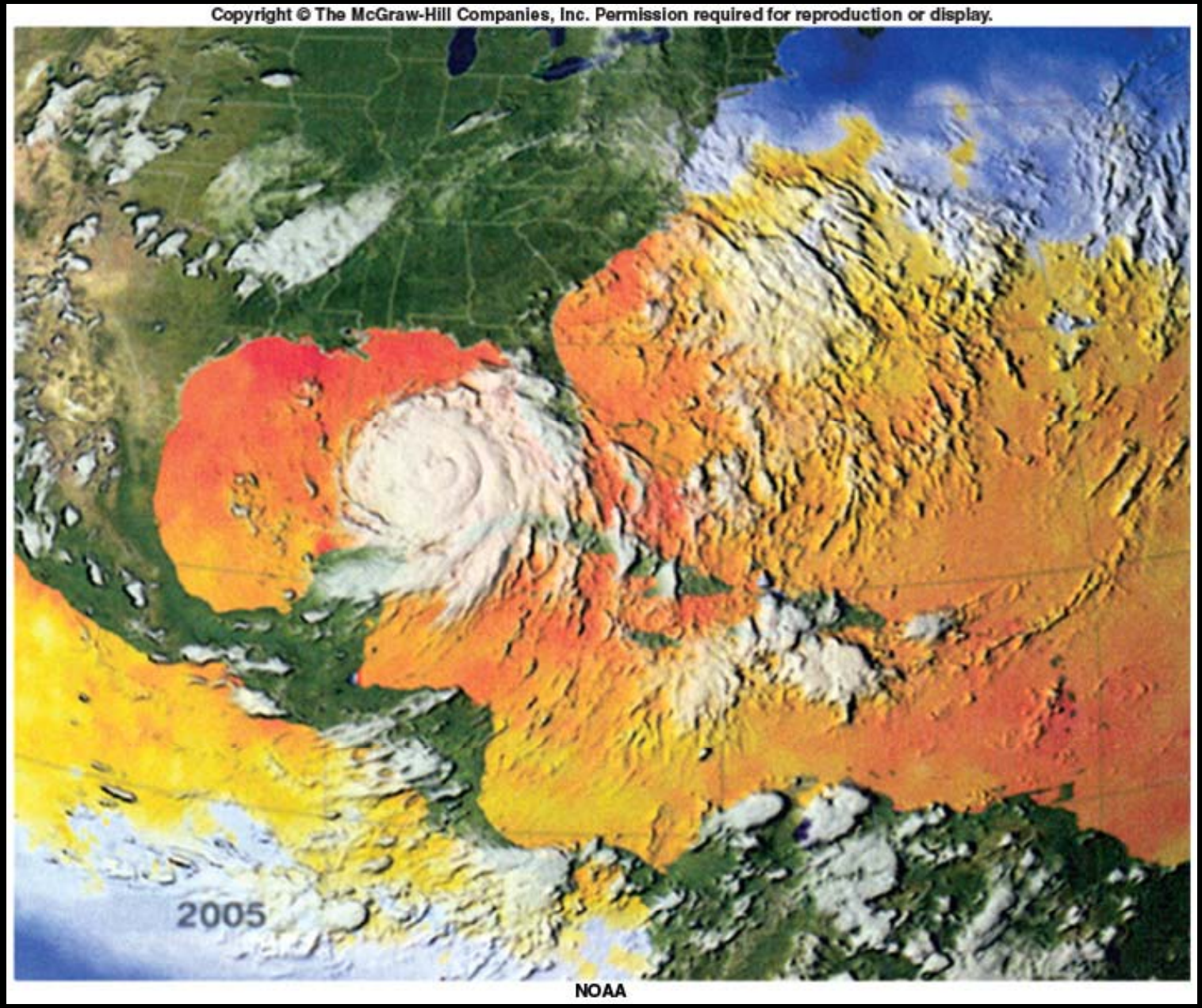




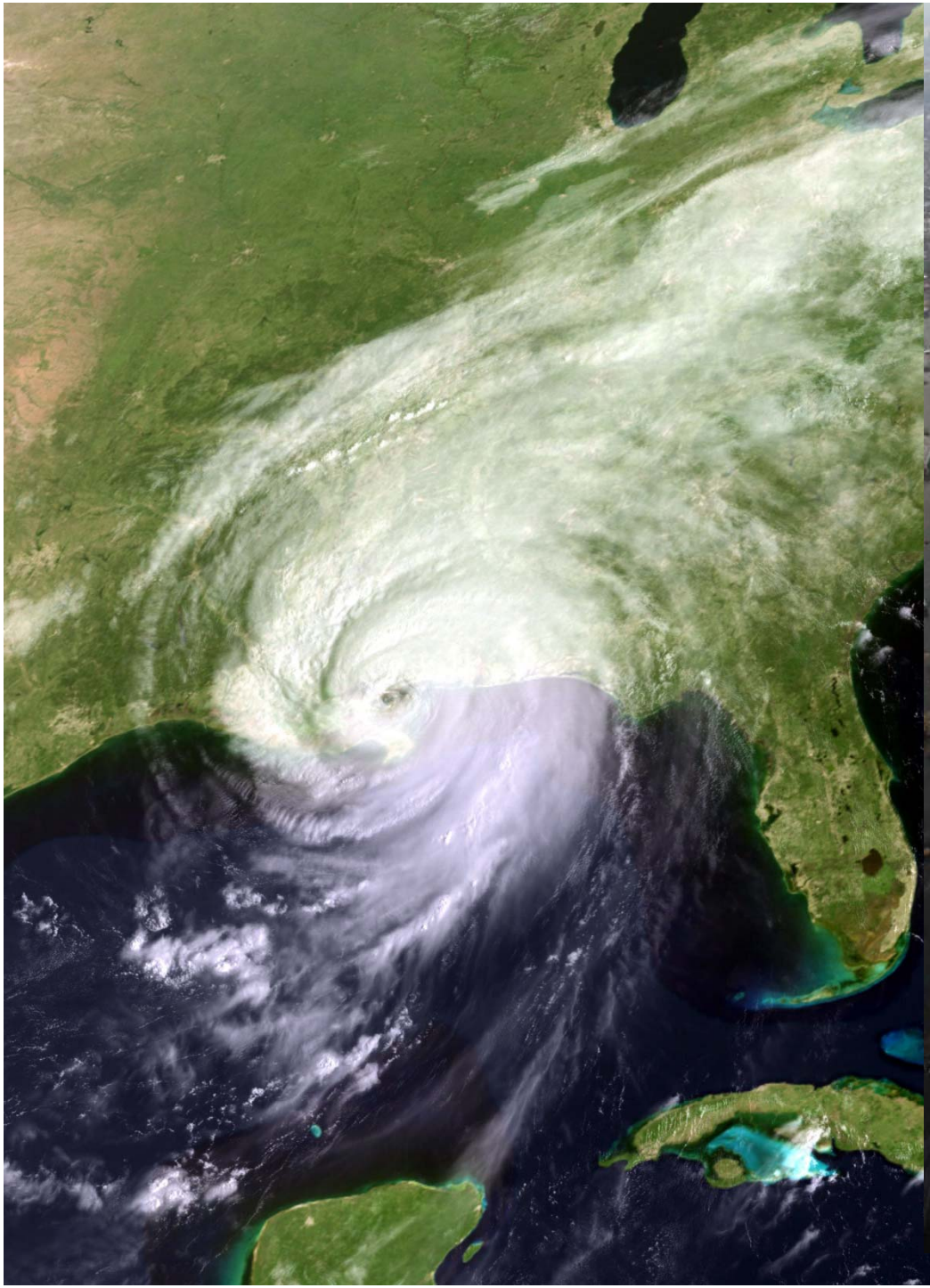
Typhoon Bopha (December 4, 2012)

Landslides and floods triggered by heavy rains killed 1,427 people in the Philippines - the deadliest disaster of 2012 (in terms of loss of life)

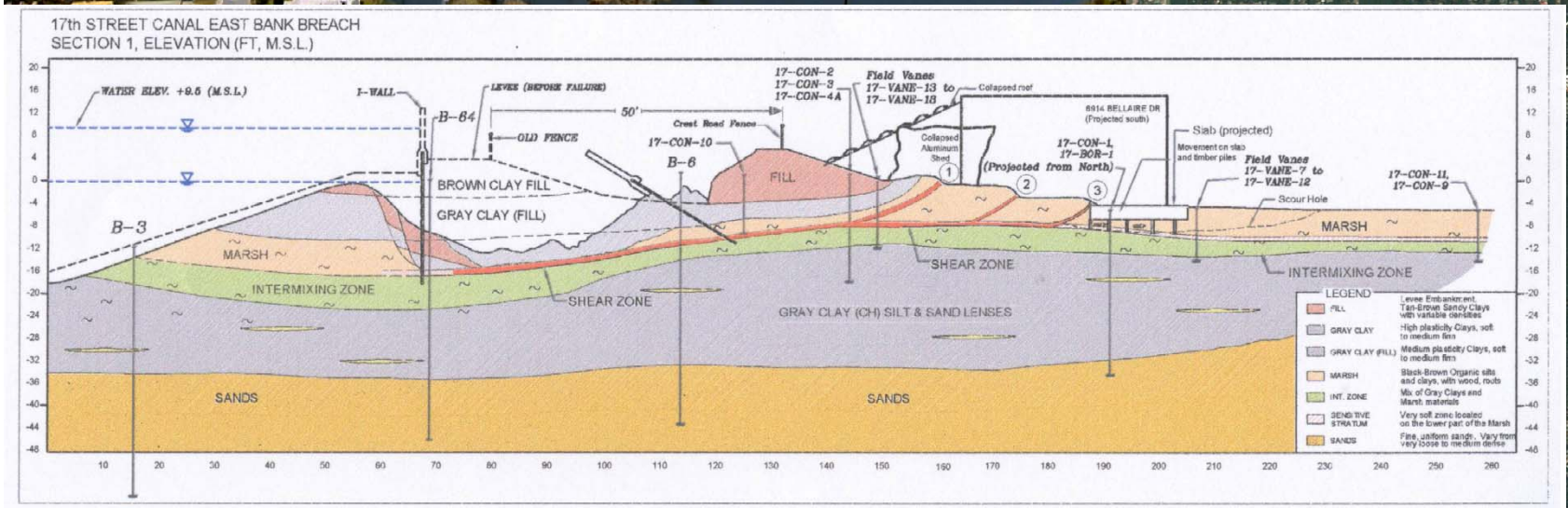

Typhoon Bopha
3AM JST Sun Dec 2 2012
Models: Points 12 hours apart
Initialized on (null) (null)
GFS
Ensemble Members
Weather Underground
wunderground.com
04/12Z
04/06Z
04/00Z
03/18Z
03/12Z
Mindanao
November 28 to December 5, 2012 Rainfall Totals (3B42)
20°N
15°N
10°N
5°N
115°E
120°E
125°E
130°E
135°E
0°
4



HURRICANE KATRINA (AUG 2005) MOVING TOWARD THE HOT WATERS OF THE GULF OF MEXICO

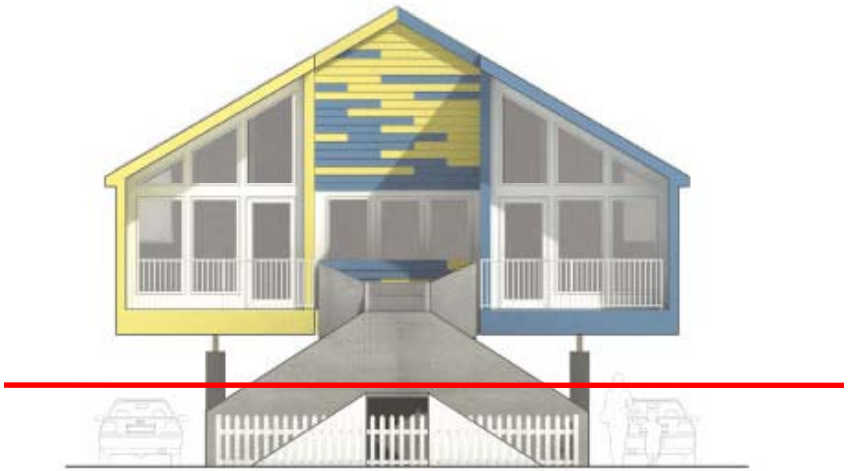


2005 HURRICANE KATRINA – FLOODING OF PARTS OF NEW ORLEANS RESULTED FROM FAILURE OF LEVEES FOUNDED ON DELTAIC SOILS



ARCHITECTURAL SOLUTIONS TO FLOOD HAZARD IN THE NEW NEW ORLEANS – DESIGNS BY BRAD PITT`S *MAKE IT RIGHT* FOUNDATION

Designs based on idea of raising house above expected maximum flood level and supporting the structure on columns



Floods in Northern England, November 2009

Flooding in Istanbul 2009

8. FLOODS (RIVER AND COASTAL)

Tewkesbury UK 2007

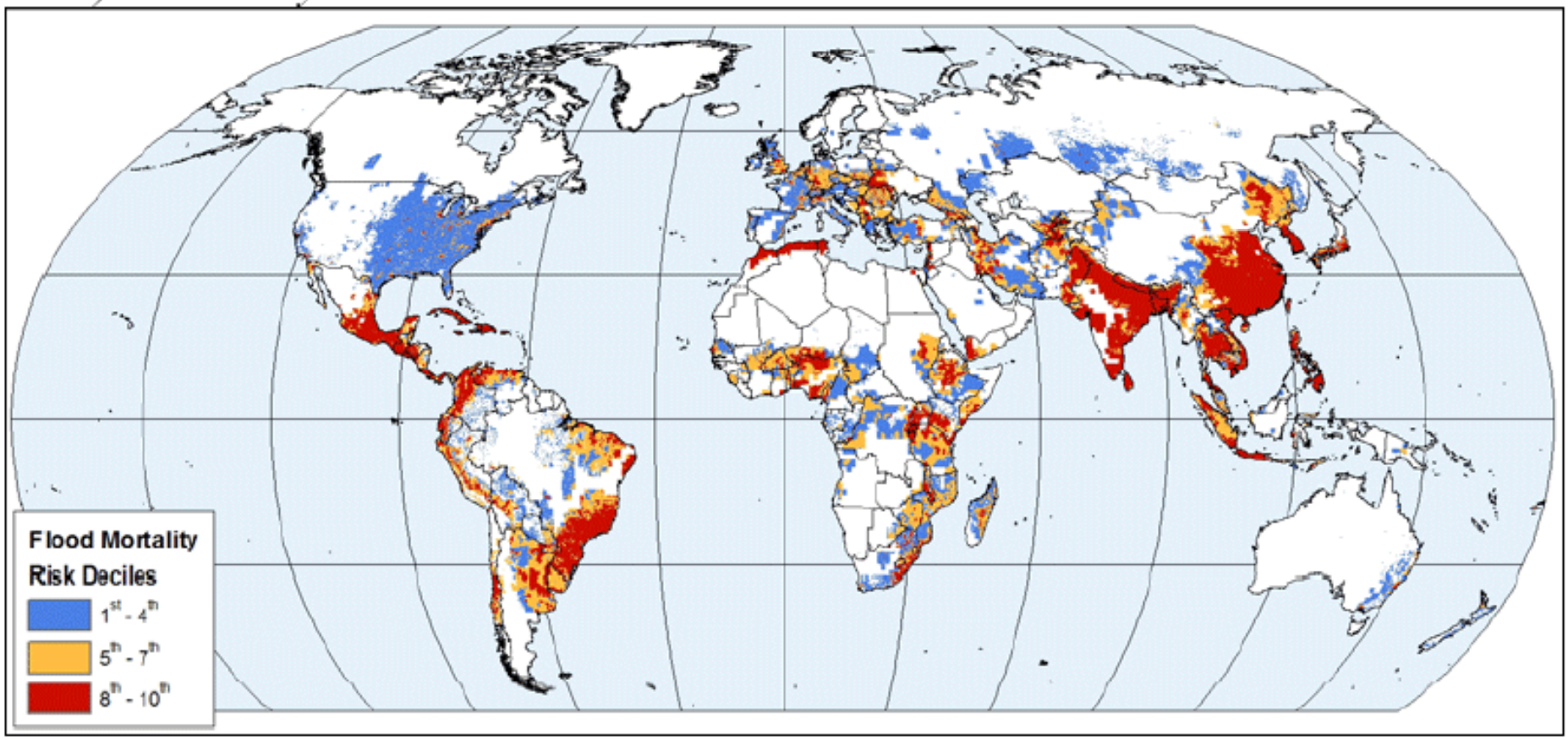
8A. RIVER FLOODS

- Floods occur when river discharge exceeds the capacity of the river channel

- Usually associated with heavy rains

Figure 4. Global distribution of flood risk.

a) Mortality



DFO Event # 2005-021- Eastern Greece - Evros River - Rapid Response Inundation Map

MODIS flood inundation limit
March 24, 2005:
March 6, 2005:

February 20, 2005:
MODIS data cloud free area
March 24, 2005:

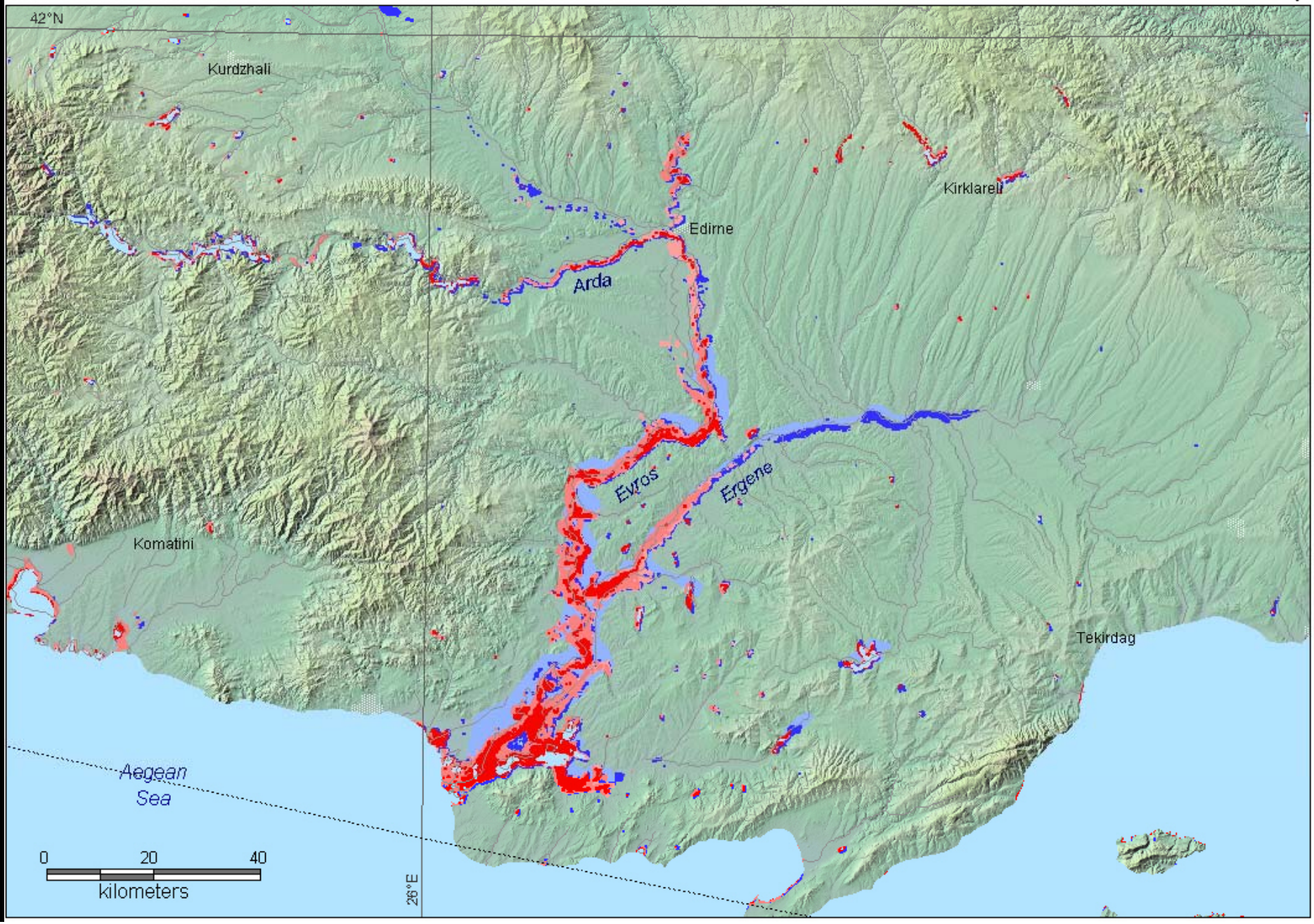
DCW Rivers
Urban Areas

MODIS reference water:
Flooded Lands in 2003:
1998:

Universal Transverse Mercator
UTM Zone 35 North - WGS 84 - Graticule: 2 degrees

Dartmouth College Hanover NH 03755 USA
Shaded relief from SRTM data

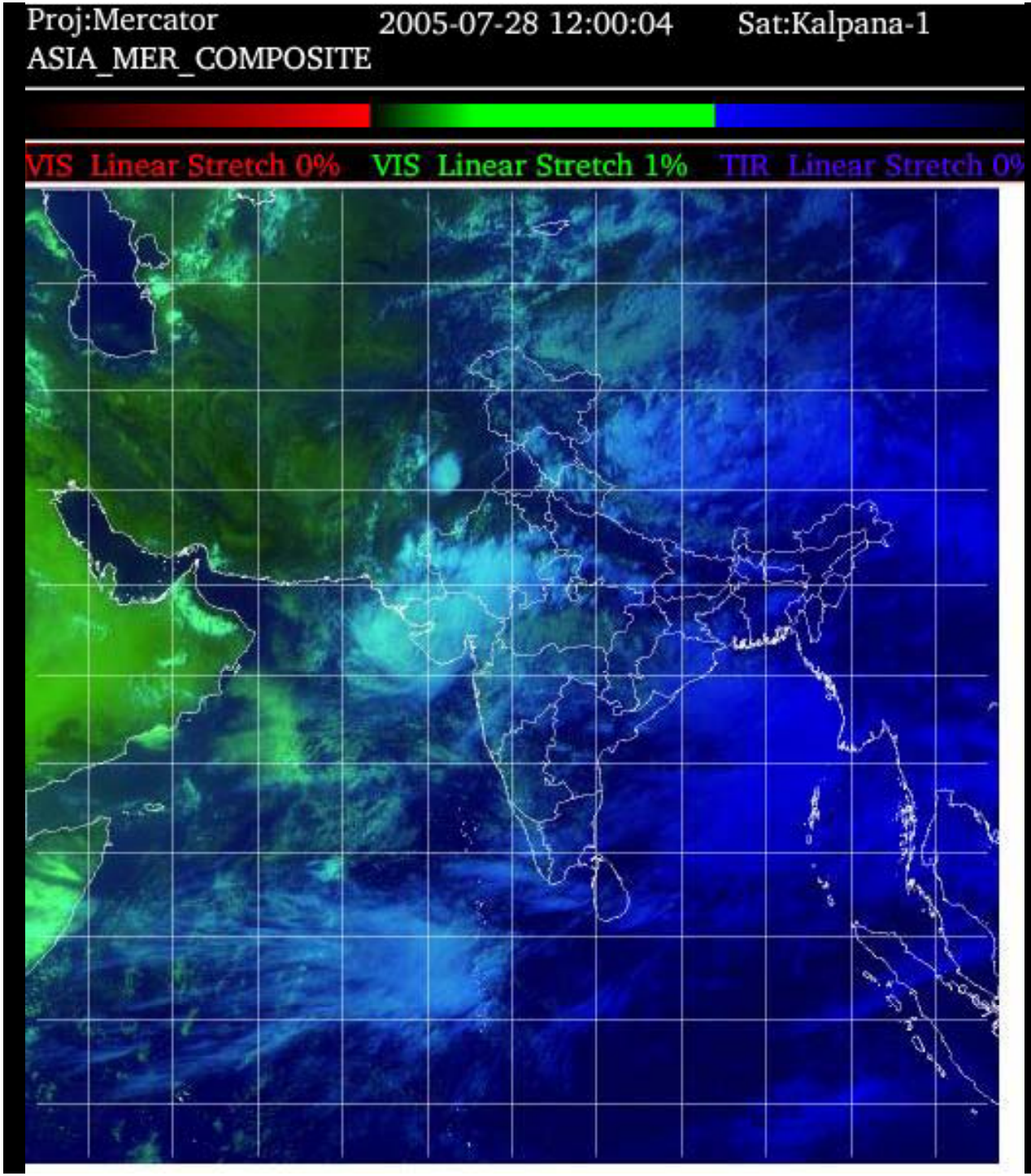
Work supported by
NASA grant NAG5-9470
Elaine K Anderson
G. R. Brakenridge



INDIA FLOODS – JULY 2005; VERY HEAVY MONSOON RAINS, MUMBAI (BOMBAY)

65 cm in one day (july 26)

- > 500 deaths
- Most killed in landslides
- Damage in excess of $110M



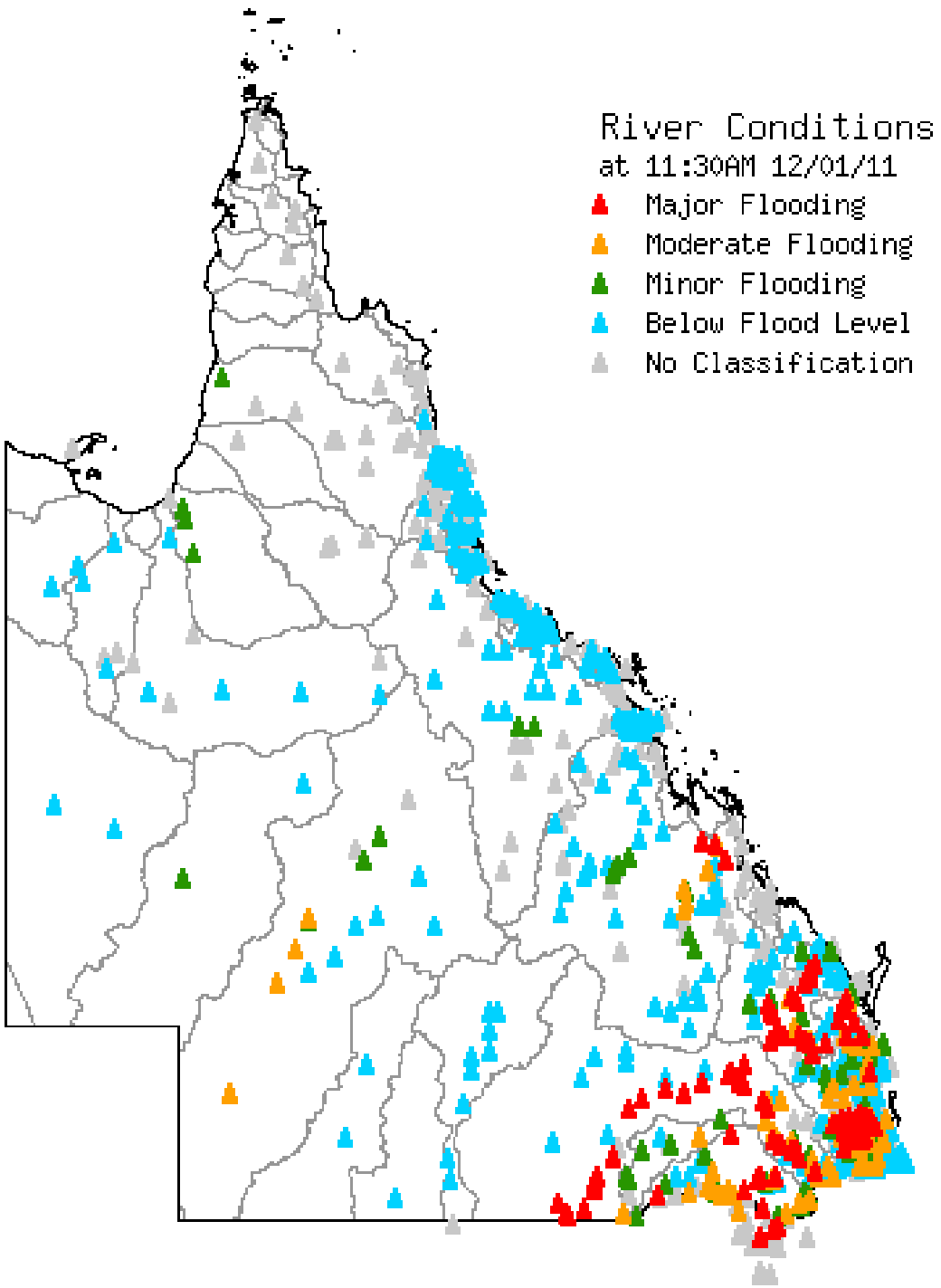
MUMBAI RAINS OF 2005 – WORLD RECORD RAINFALL

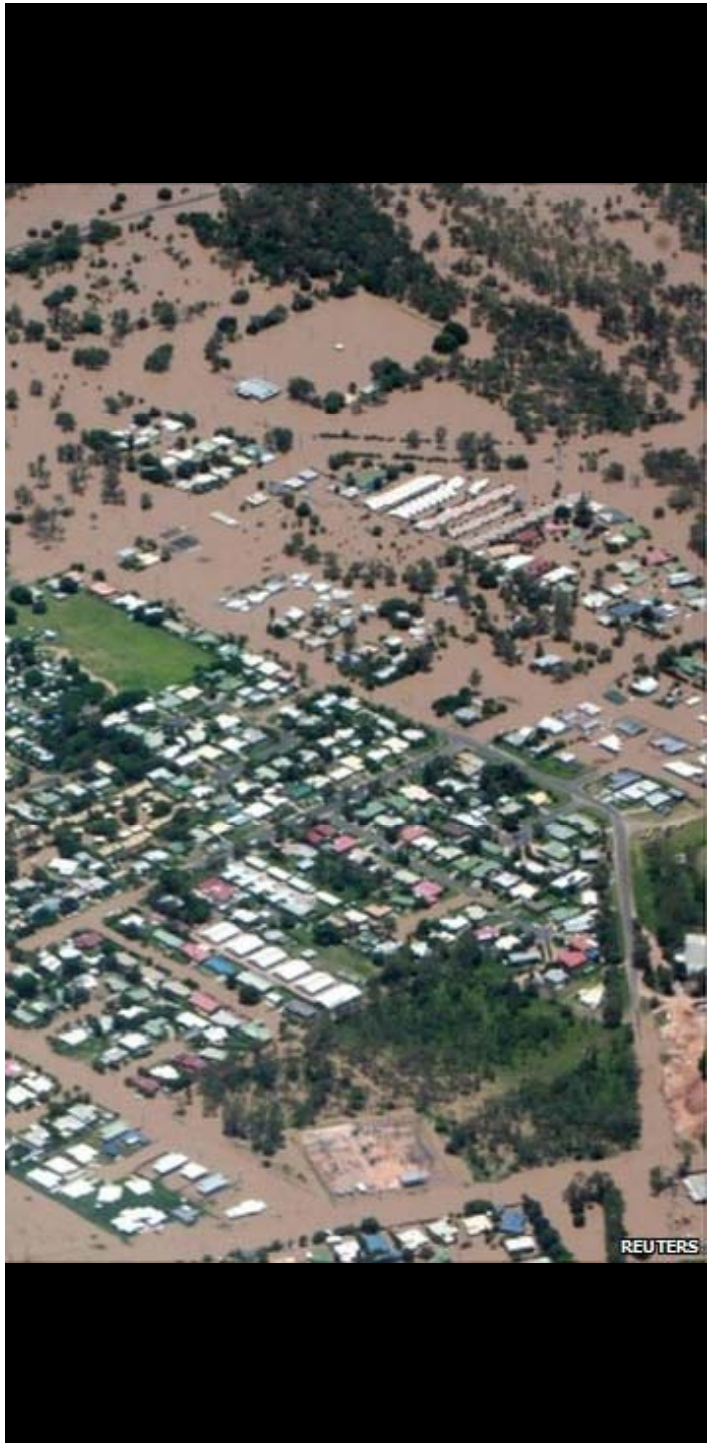
FLOODS IN EUROPE AUGUST 2002 RESULTED FROM EXTREME RAINFALL - >100 deaths; damage in Germany (9 Billion Euros), Austria (3.0 Billion Euros) and Czech Republic (2.5 Billion Euros)

Numerous historical buildings and museums were underwater in Dresden. The world-famous Semper Opera House and the Zwinger (photo) could not be defended despite colossal efforts on the part of hundreds of helpers. The art treasures in museums are often not insured, as many local authorities cannot afford the insurance premiums.

2009 Philippine Floods ; in Tropical Storm Ketsana, 42.4 cm of rainfall fell on Manila in 12 hours on September 26 exceeding September monthly average. Impact = hundreds of deaths; many hundreds of thousands displaced; billions of dollars of damage

Theodore Queensland [January 2011]


River Conditions
at 11:30AM 12/01/11
Major Flooding
Moderate Flooding
Minor Flooding
Below Flood Level
No Classification


REUTERS

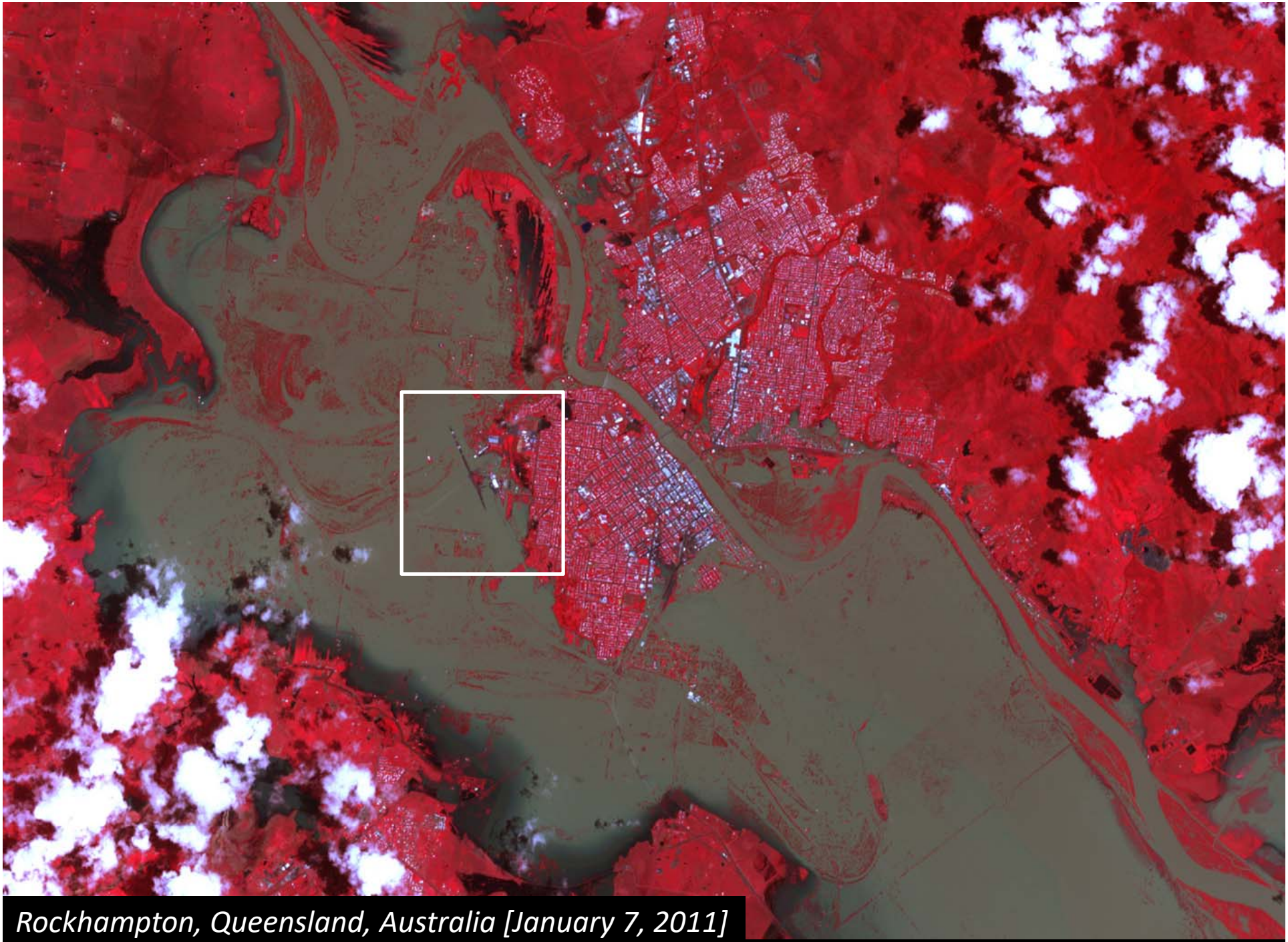
Brisbane, Queensland, Australia [January 13, 2011]

QUEENSLAND, AUSTRALIA FLOODS, DECEMBER 2010-JANUARY 2011

Emerald, Queensland

Rockhampton Airport, Queensland, January 2011

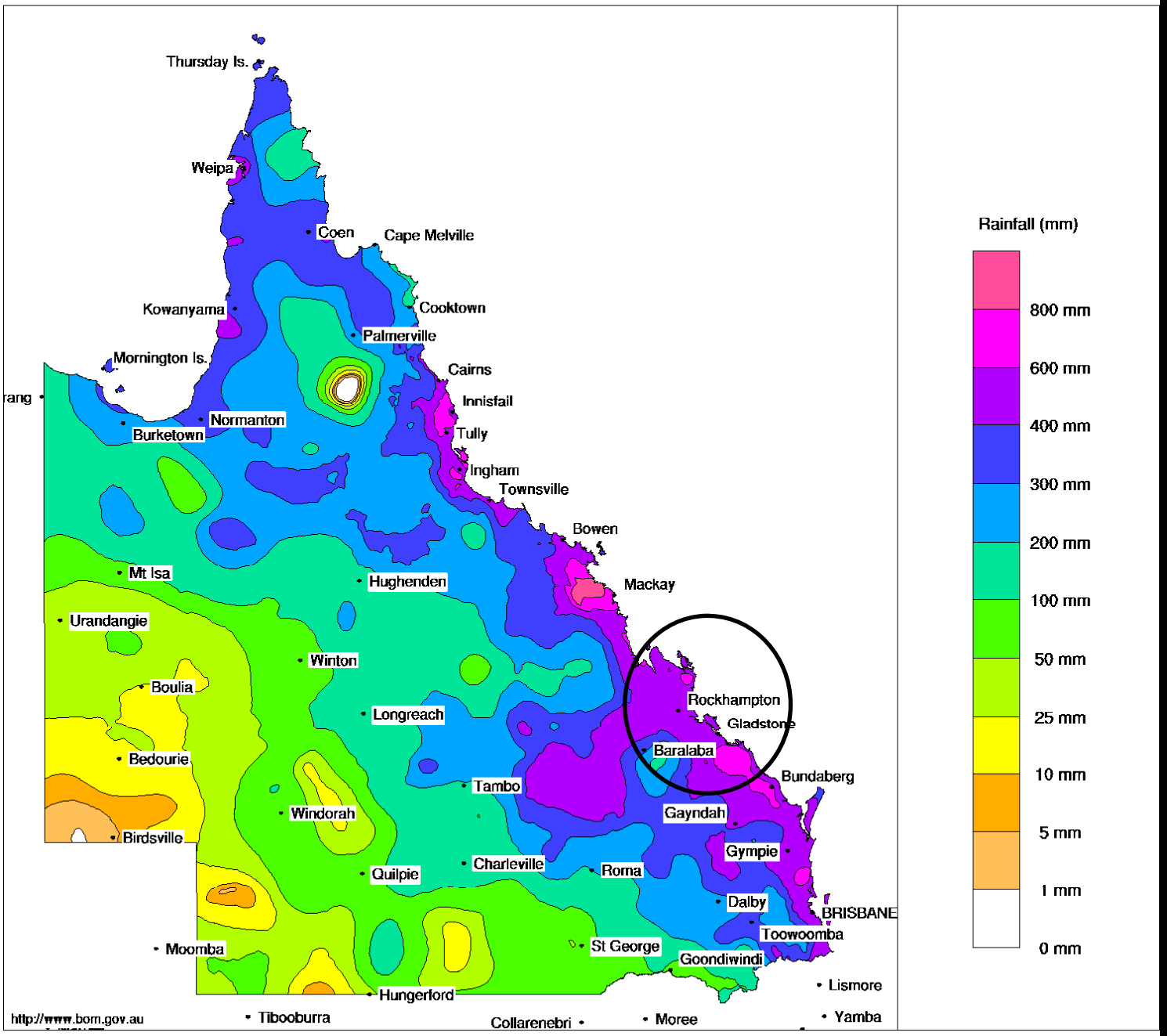
Rockhampton, Queensland, Australia [June 20, 2010]



Rockhampton, Queensland, Australia [January 7, 2011]

Queensland Rainfall Totals (mm) December 2010

Product of the National Climate Centre

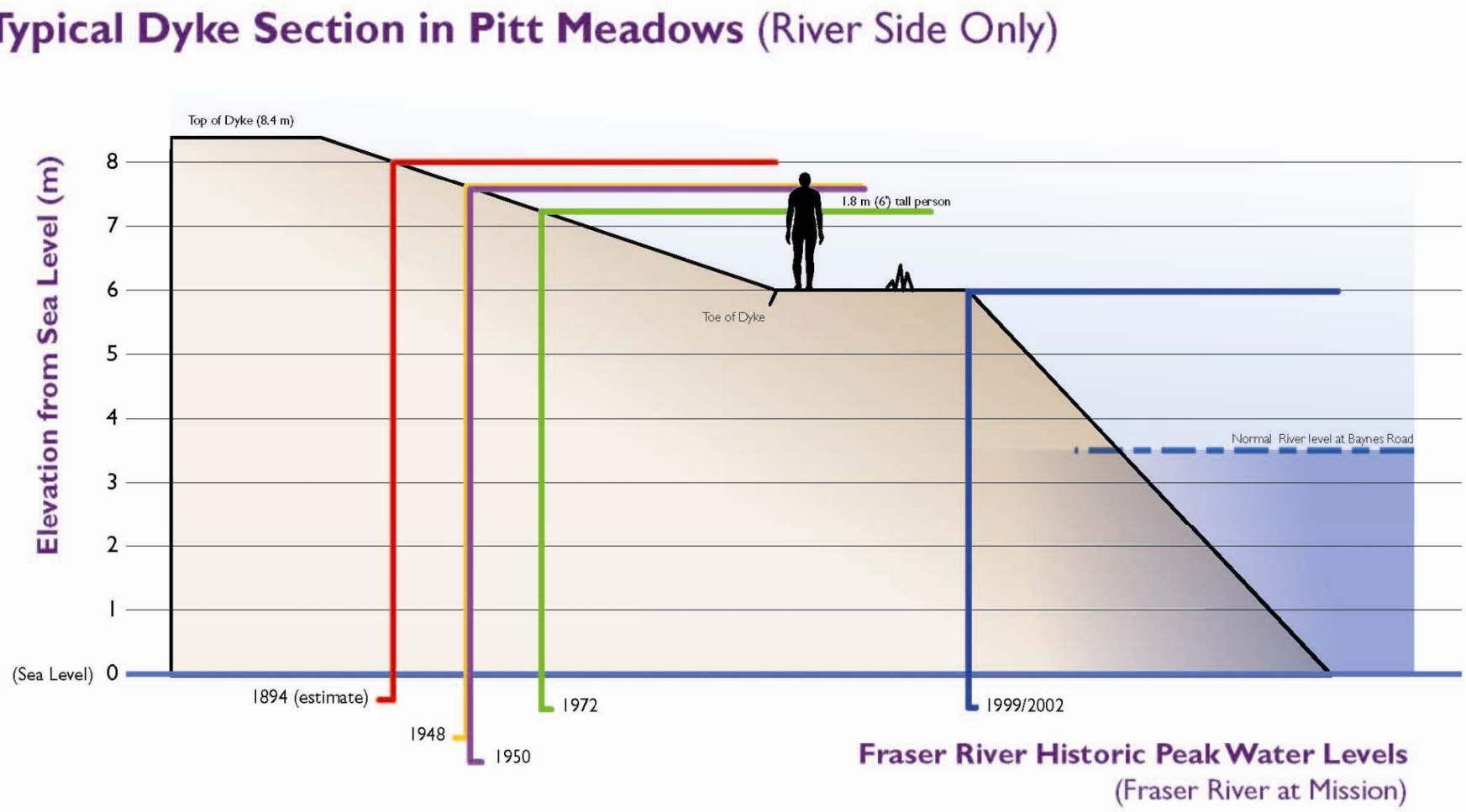


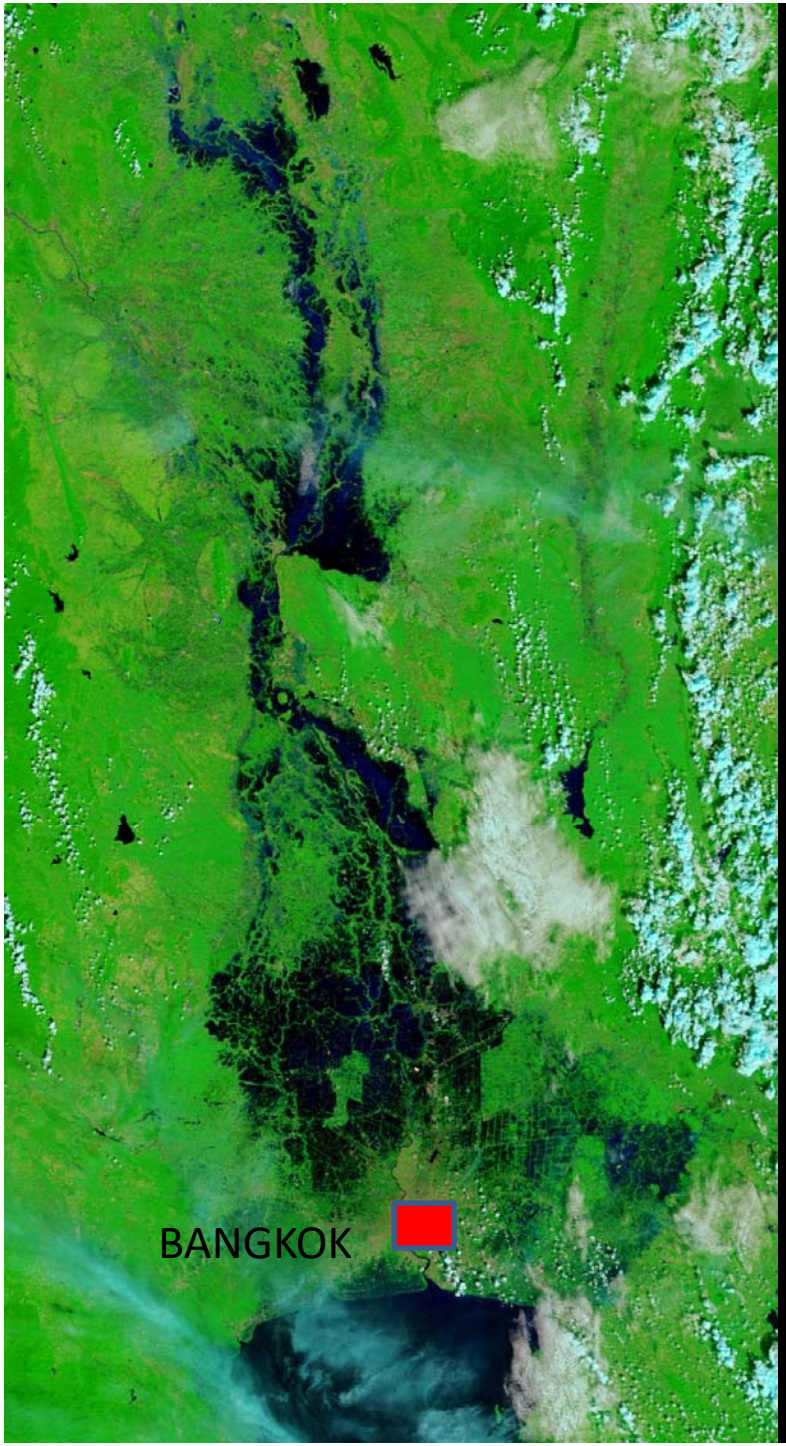
 ID code: AWAP

Issued: 03/01/2011

DECEMBER RAINFALL IN QUEENSLAND

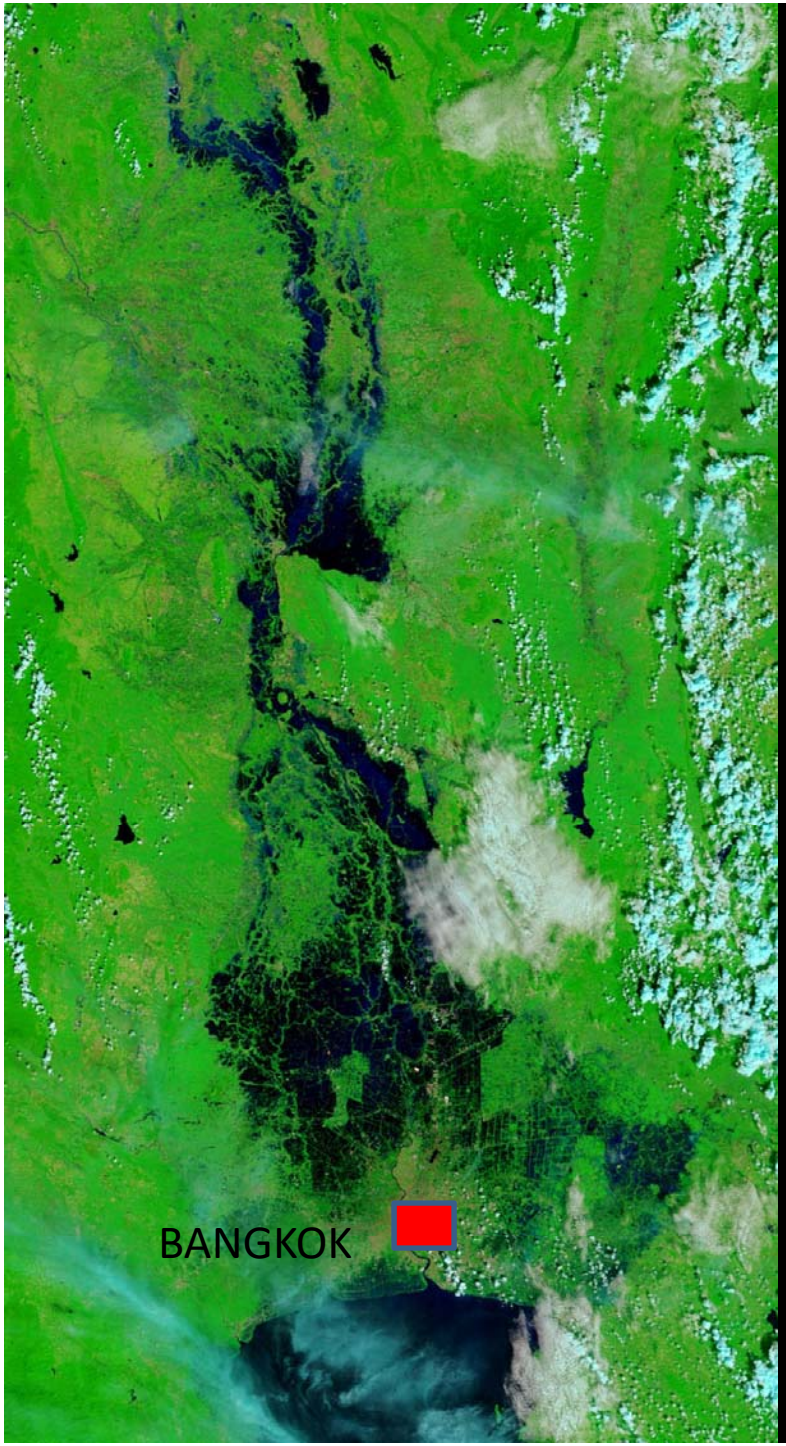
FLOOD MITIGATION- THE EXAMPLE OF FLOOD DEFENCES





2011 THAILAND FLOODS

- Developed over October and November 2011 on the Chao Praya River
- Approximately 750 deaths
- Most expensive (in terms of damage and insured losses) in Thai history [USD $8-11 B]
- World Heritage sites damaged
- One of the major disasters in 2011



2011 THAILAND FLOODS

8 December 2011 | Group

Press release

Munich Re expects losses from floods in Thailand to total around €500m

The widespread floods in Thailand, which reached their highest point in October and November, are the costliest natural catastrophe in the country's history. The economic losses are huge, since key industries are concentrated in the region north of the capital, Bangkok, and its environs. The consequences of the floods clearly show that prevention measures need to be strengthened in view of the country's high natural catastrophe exposure.

The claims burden for Munich Re is expected to be in the range of €500m net before tax. This estimate is still subject to uncertainty, as the water is draining away only very slowly and has still not fully receded in some areas. It therefore remains difficult to estimate losses in the worst affected industrial areas around Bangkok. The consequence of the floods includes not only damage to buildings but also, and more importantly, to the often expensive production facilities housed in them.

Board member Torsten Jeworrek: "Thailand is a wake-up call. In emerging countries of growing significance to the interconnected global economy, the provisions made for and adaptation to such natural hazards need to be improved in order to contain the losses." "The insurance industry is willing and able to help in this respect, primarily of course by carrying risks at commensurate prices, terms and conditions." The floods claimed the lives of some 600 people. Not only were hundreds of thousands of houses and vast expanses of farmland flooded, but also seven major industrial areas with production facilities belonging mainly to Japanese groups. A large number of electronic key component manufacturers were affected, leading to production delays and disruptions at client businesses. **Approximately 25% of the world's supply of components for computer hard drives is manufactured in Thailand and was thus directly impacted by the floods**.

BANGKOK FLOODS – DON MUANG AIRPORT [OCTOBER 31, 2011]

2011 MISSISSIPPI RIVER FLOODS

- Comparable to the super floods of 1927 and 1993
- Morganza Spillway (completed in 1954) opened for the first time in 1973 and opened again in 2011

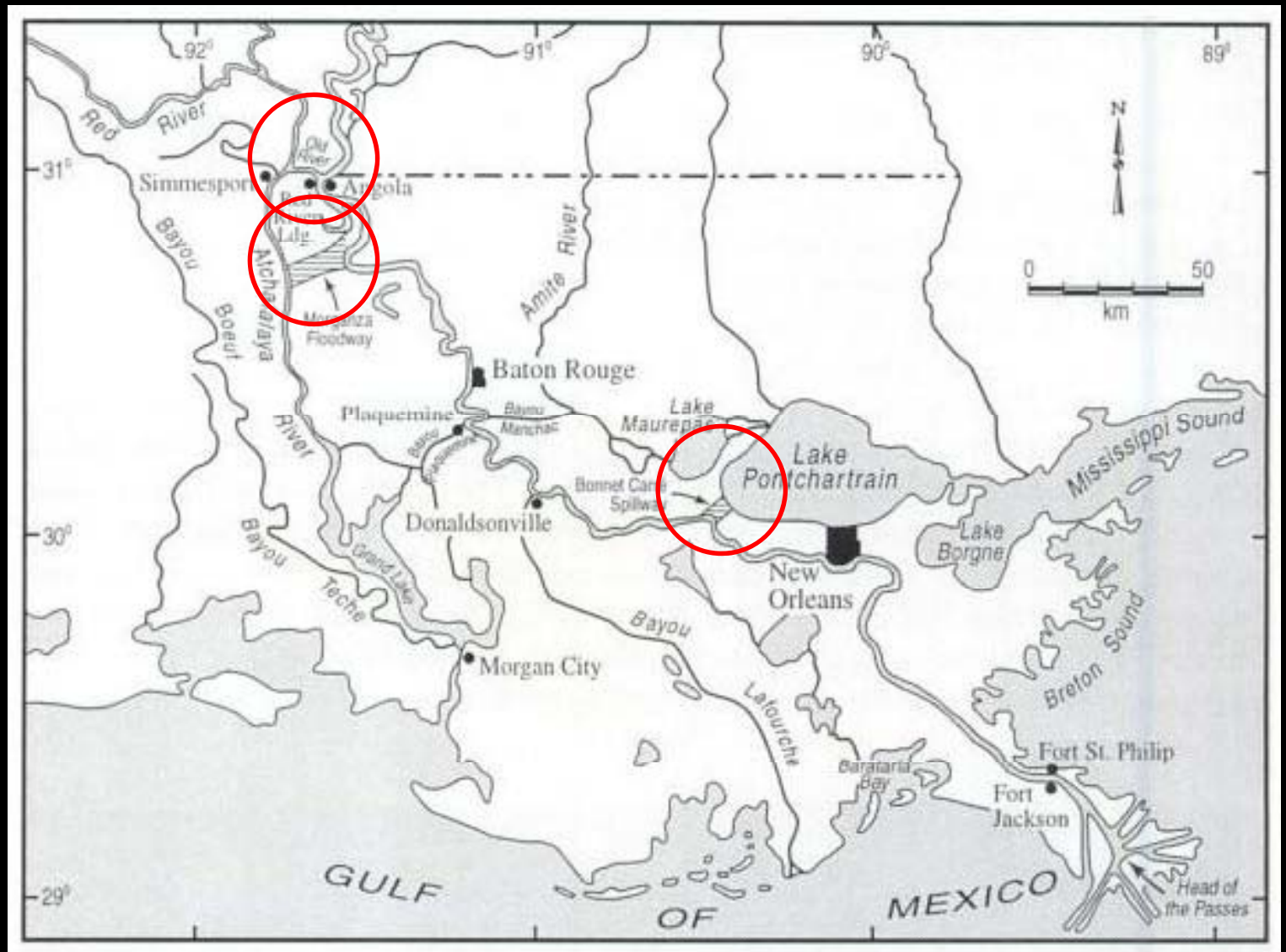
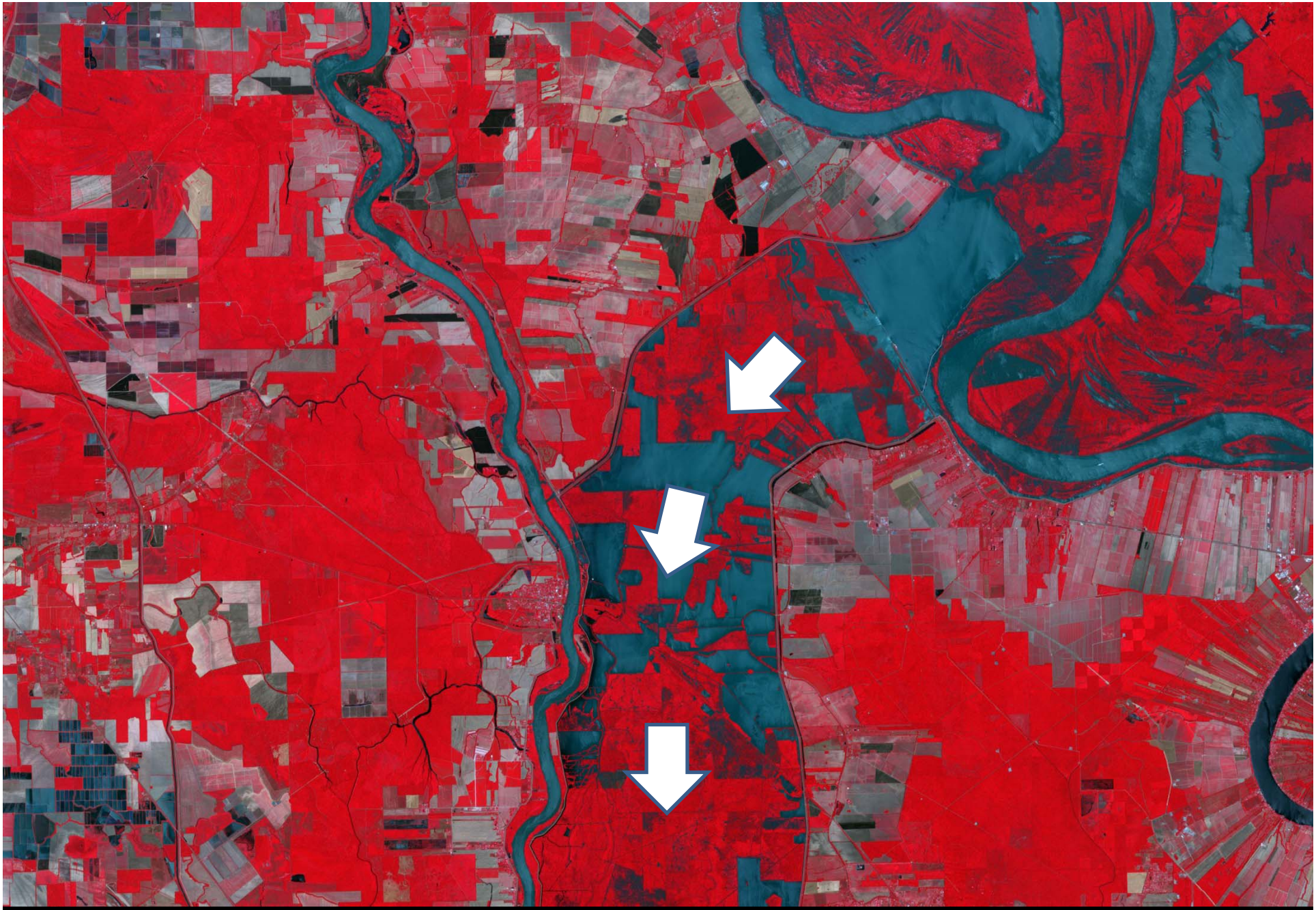


Fig. 3. The Lower Mississippi River and its distributaries and spillways.

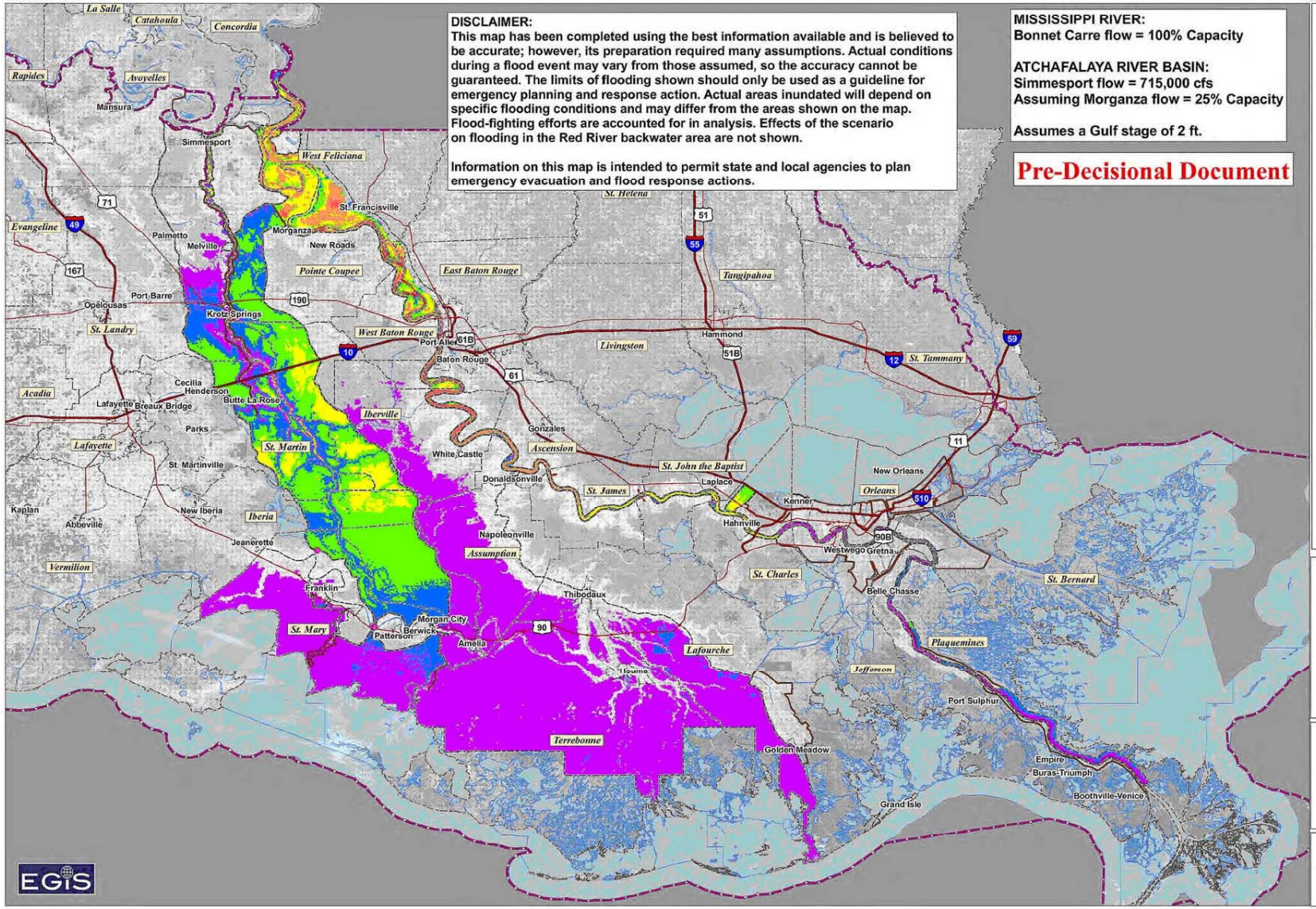


Morganza Floodway in operation, May 18, 2011

US Army Corps of Engineers
New Orleans District

Potential Inundation (Scenario 1a)

12 May 2011 @ 0800 HRS



DISCLAIMER:
This map has been completed using the best information available and is believed to be accurate; however, its preparation required many assumptions. Actual conditions during a flood event may vary from those assumed, so the accuracy cannot be guaranteed. The limits of flooding shown should only be used as a guideline for emergency planning and response action. Actual areas inundated will depend on specific flooding conditions and may differ from the areas shown on the map. Flood-fighting efforts are accounted for in analysis. Effects of the scenario on flooding in the Red River backwater area are not shown.

Information on this map is intended to permit state and local agencies to plan emergency evacuation and flood response actions.

MISSISSIPPI RIVER:
Bonnet Carre flow = 100% Capacity

ATCHAFALAYA RIVER BASIN:
Simmesport flow = 715,000 cfs
Assuming Morganza flow = 25% Capacity

Assumes a Gulf stage of 2 ft.

Pre-Decisional Document

Estimated Flood Depth

- 0 ft - 5 ft
- 5 ft - 10 ft
- 10 ft- 15 ft
- 15 ft - 20 ft
- 20 ft - 25 ft
- 25 ft - 30 ft
- 30 ft - 40 ft

Geographic Features

- Selected Channel Floodgate
- Flood Control Systems
- Analysis Boundary
- City Limits
- New Orleans District

NOTE: Future revisions of this map are expected to occur for changed forecasts.

Location Map

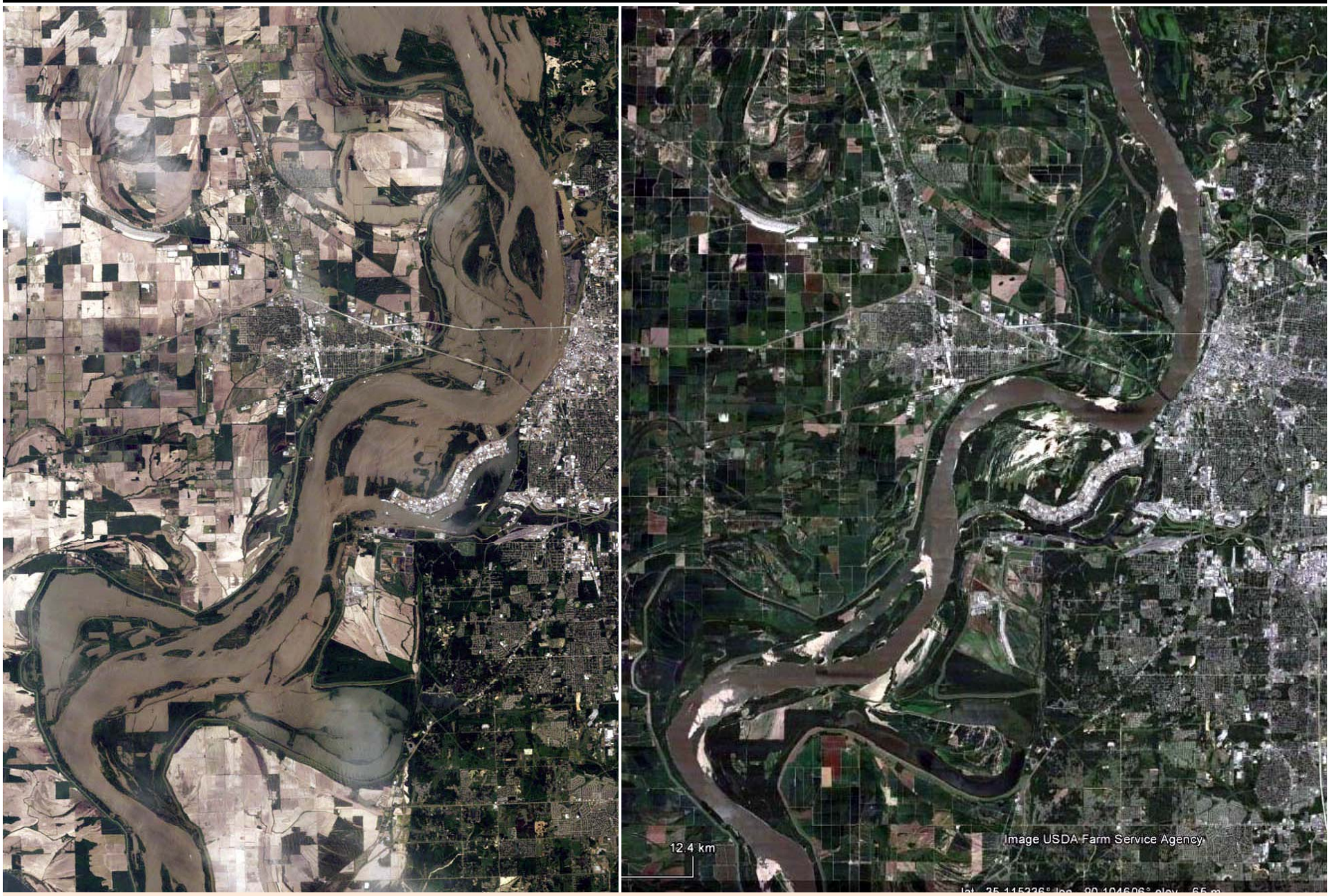
Miles 0 5 10 20

Potential Inundation Spring 2011 Flood (Scenario 1a)

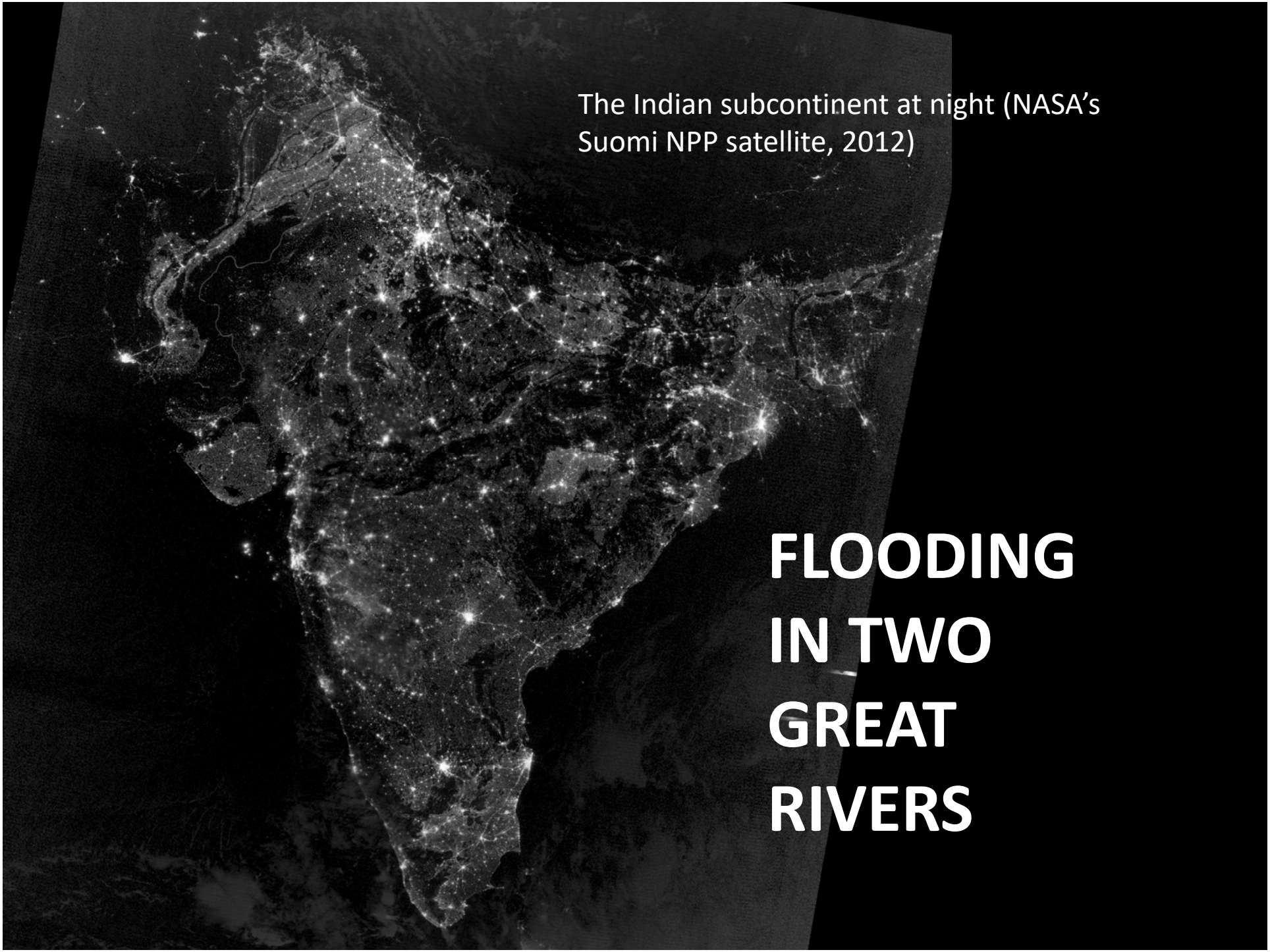
Date: 11 May 2011 - Version 1

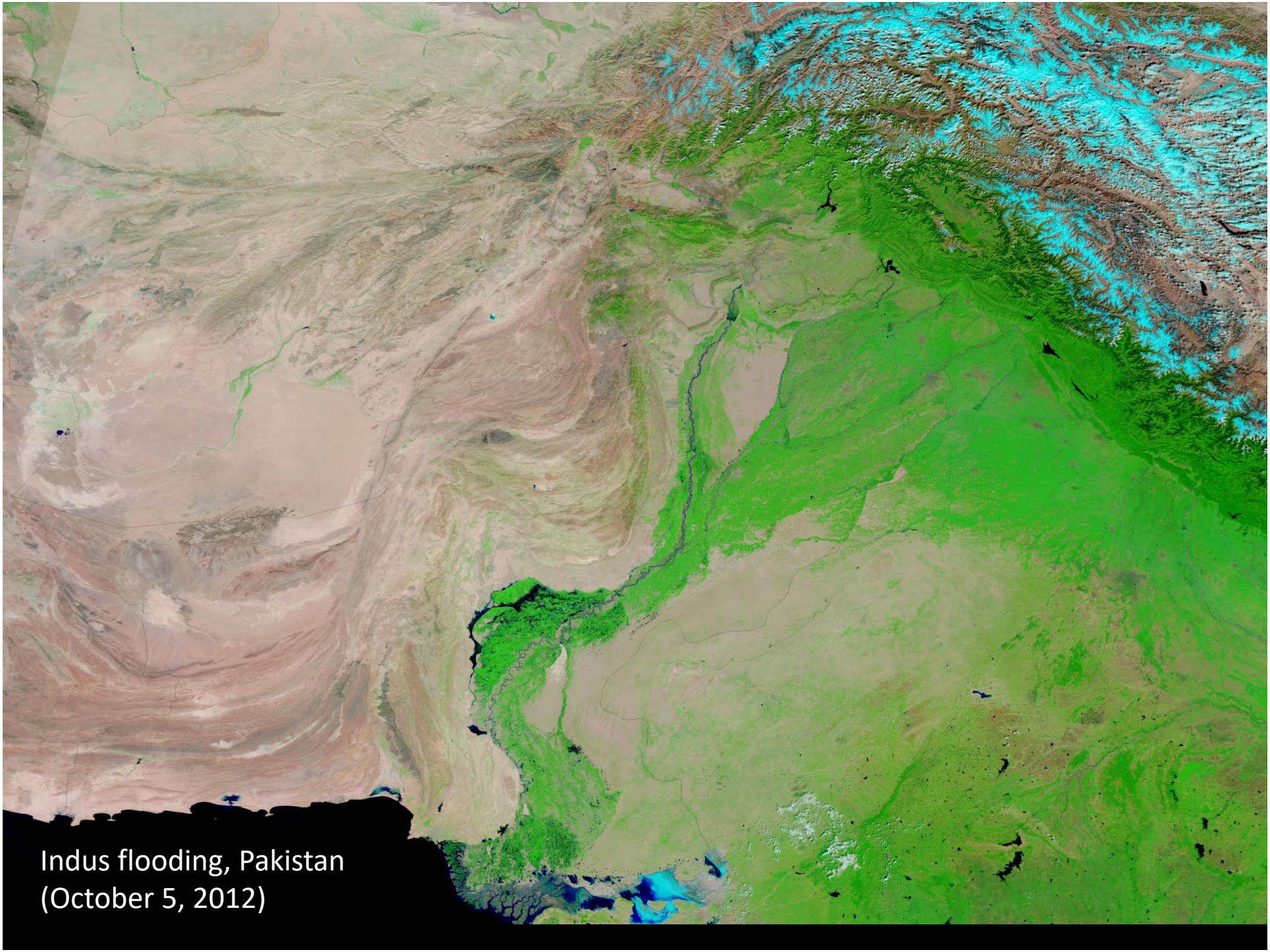
EGIS Map ID No. 11-051-009

Mississippi Valley, north of New Madrid, Missouri , May 3, 2011

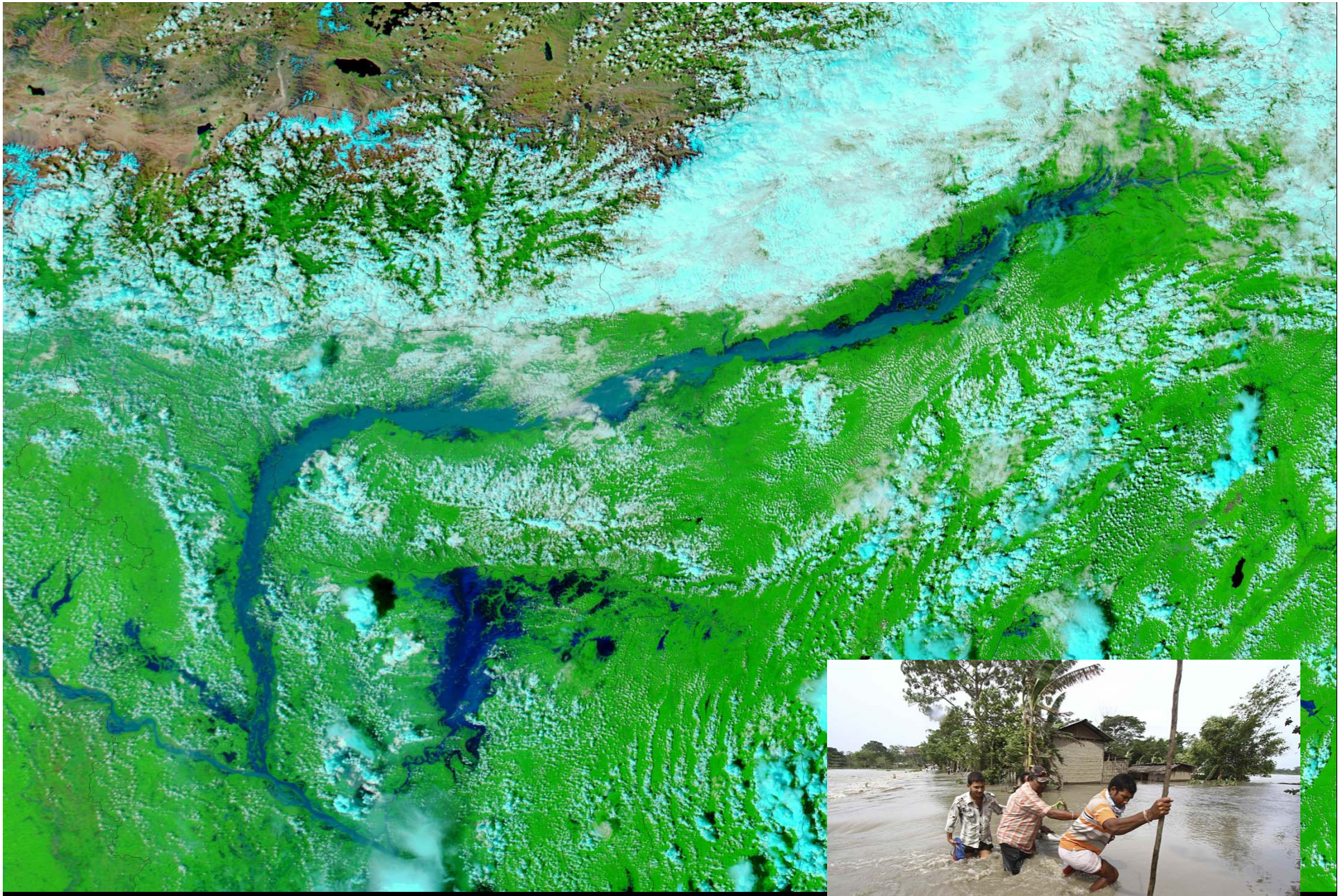


FLOODING OF THE MISSISSIPPI RIVER AT MEMPHIS, MAY 10, 2011


The Indian subcontinent at night (NASA's Suomi NPP satellite, 2012)
FLOODING IN TWO GREAT RIVERS

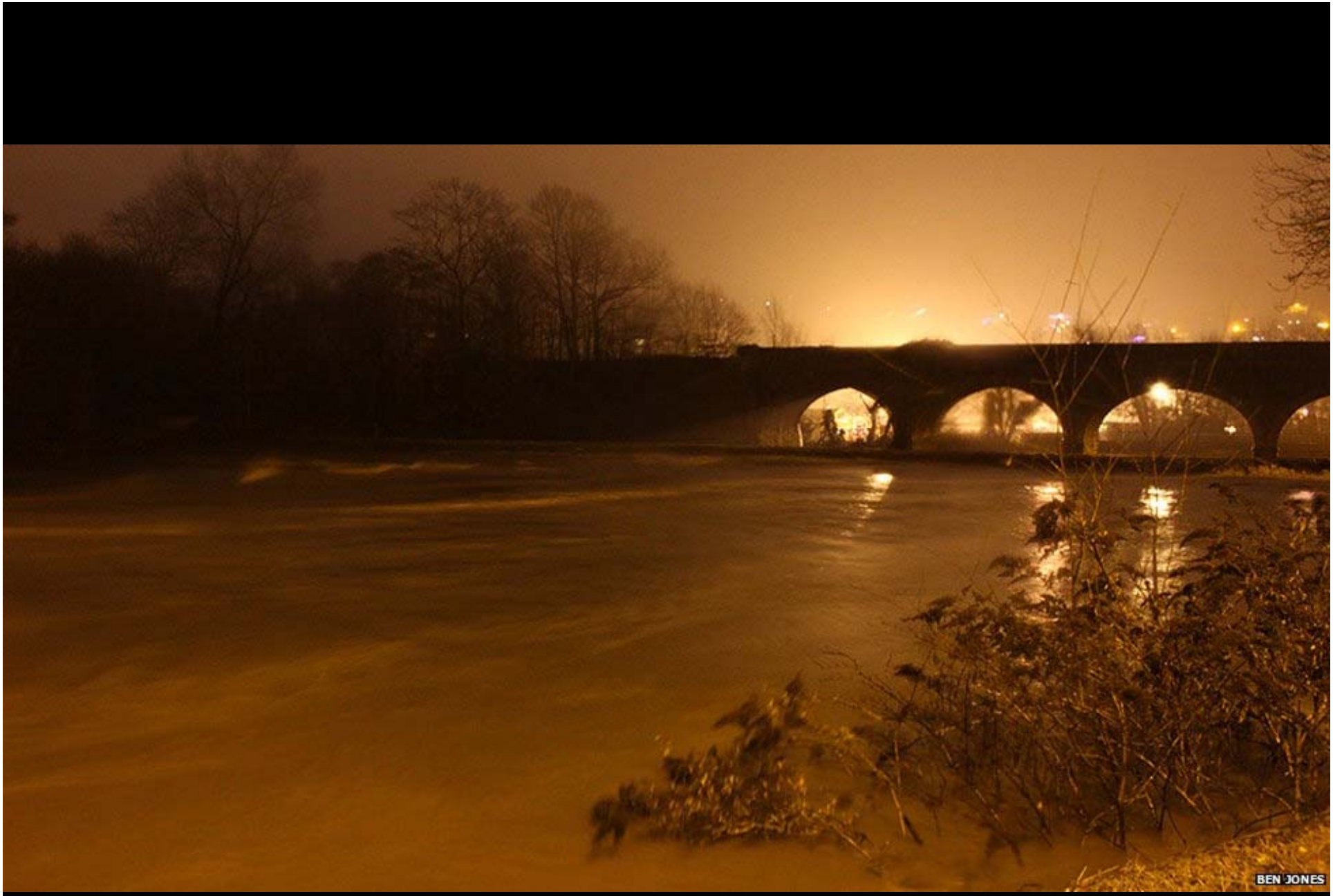


Indus flooding, Pakistan
(October 5, 2012)



Brahmaputra flooding (NE India) September 29, 2012

UK FLOODING 2012



River Neath, Port Talbot, UK [December 2012]

Severn Stoke, near Worcester, UK [Dec 12]

EXTREME WEATHER

Britain copes with record deluge

Rainfall records smashed as unrelenting downpours cause flooding, evacuations, with insurance claims expected to near $2-billion

PAUL WALDIE LONDON

Rain, drizzle and dampness are about as common to Britain as Wellington boots. But no one has seen anything like the wet weather that has saturated the country in recent weeks and smashed rainfall records that have been kept for more than 100 years.

From Scotland to Cornwall and just about everywhere in between, Britain has been soaked by unrelenting rainfall that has led to widespread flooding, evacuations, rail disruptions, road closures and landslides. More than a dozen counties, including all of Wales, remain at risk of flooding and officials have issued in excess of 300 local flood alerts and warnings. Flood insurance claims are expected to come close to $2-billion (Canadian).

England has already broken its record for annual precipitation along with several other regions. It's expected that Britain as a whole will set a new mark by the time revellers stagger home, wet, on New Year's Eve. Last week the national weather service, the Met Office, said that as of Boxing Day the UK had received 1,291.2 mm of rain in 2012. It has rained almost every day since, and forecasters said that just 46mm of rain were needed by Dec. 31 to make this the wettest year since

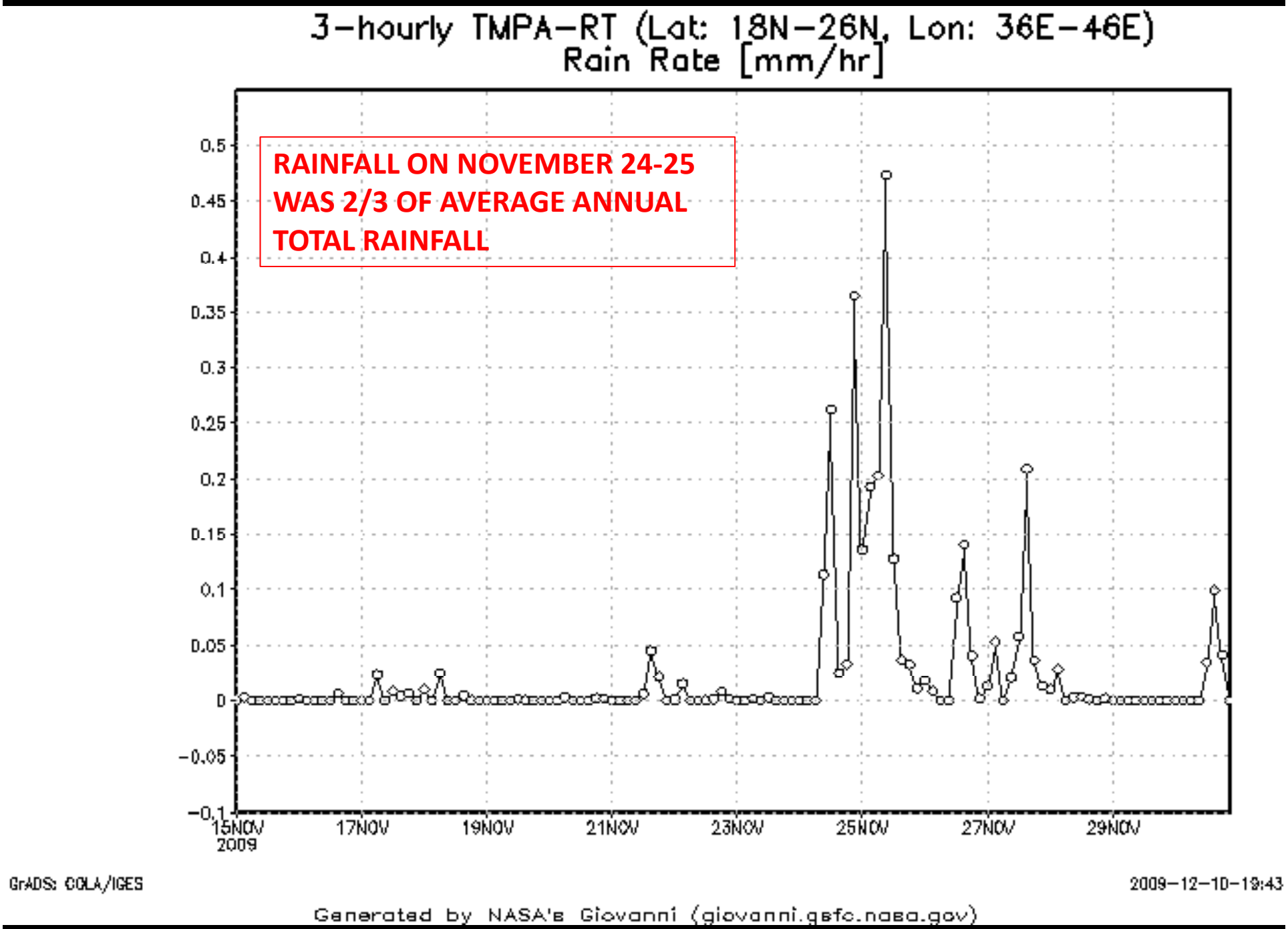
A property is surrounded by floodwater Sunday near Apperley, in Gloucestershire, after days of almost relentless rainfall. TIM IRELAND/ASSOCIATED PRESS

Flooding in Grimma, Germany [June 3, 2013] following heavy rainfall

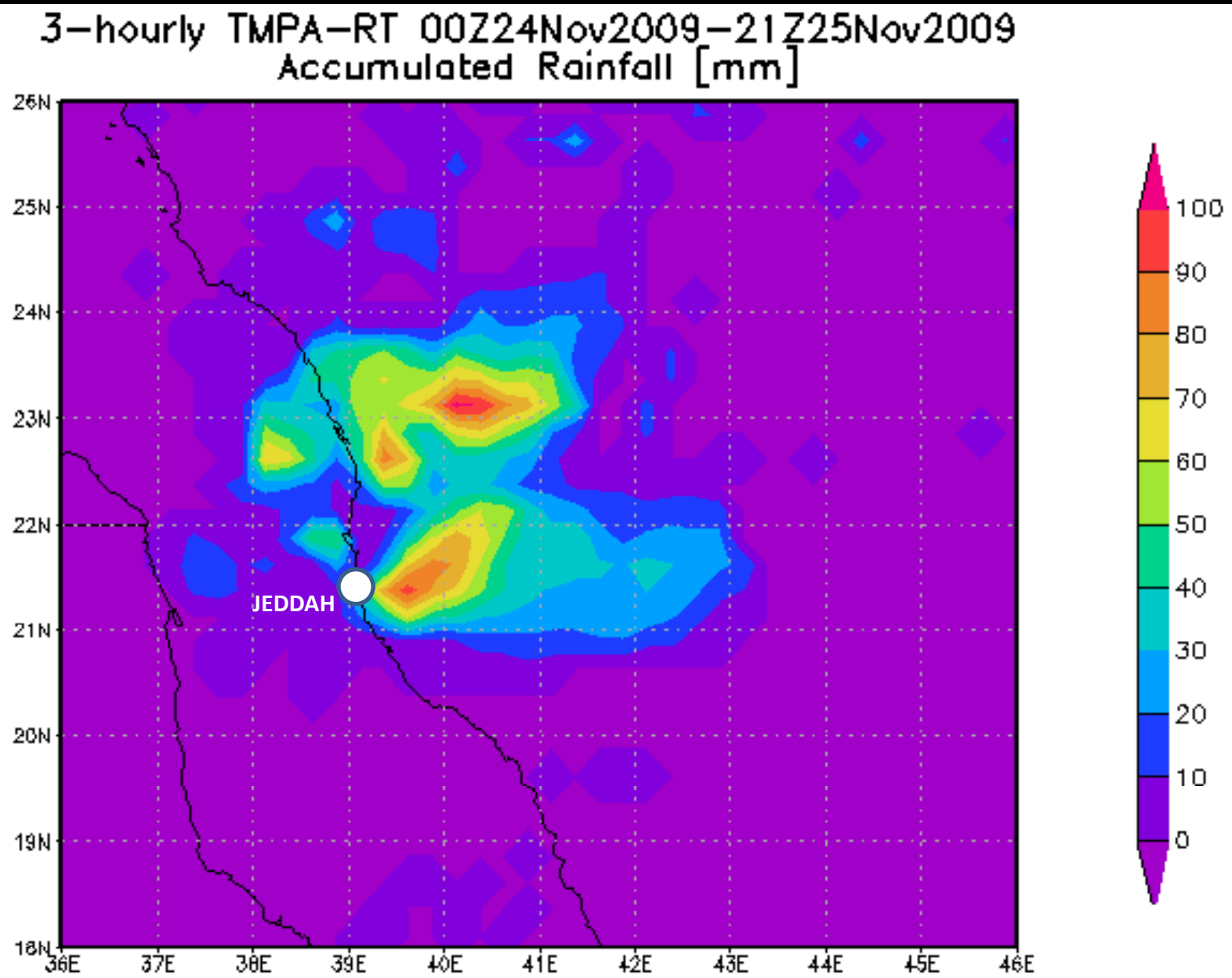
Flooding of the River Danube, Passau, Germany [June 3, 2013]

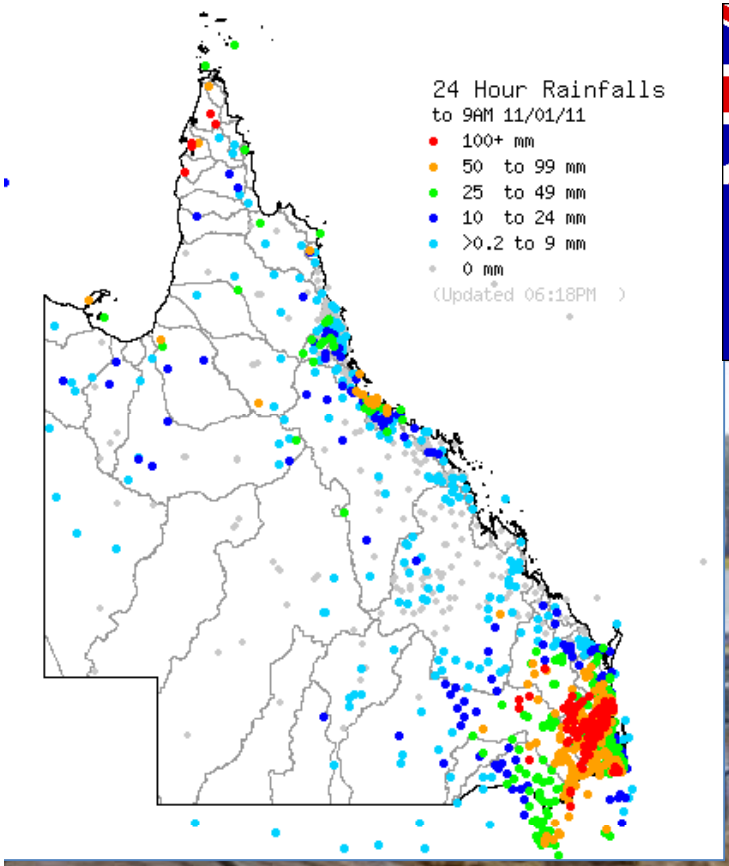
FLASH FLOODS (resulting from extreme and localised rainfall)

Jeddah, Saudi Arabia, November 2009 (>110 deaths); Due to the rarity of extreme rainstorms, Saudi cities lack the infrastructure to deal with heavy rain, such as having effective rain sewers and drainage channels


3-hourly TMPA-RT (Lat: 18N-26N, Lon: 36E-46E)
Rain Rate [mm/hr]
RAINFALL ON NOVEMBER 24-25
WAS 2/3 OF AVERAGE ANNUAL
TOTAL RAINFALL
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
15NOV
2009
17NOV
19NOV
21NOV
23NOV
25NOV
27NOV
29NOV
GrADS: COLA/IGES
2009-12-10-19:43
Generated by NASA's Giovanni (giovanni.gsfc.nasa.gov)

RAINFALL MEASURED BY NASA TRMM SATELLITE

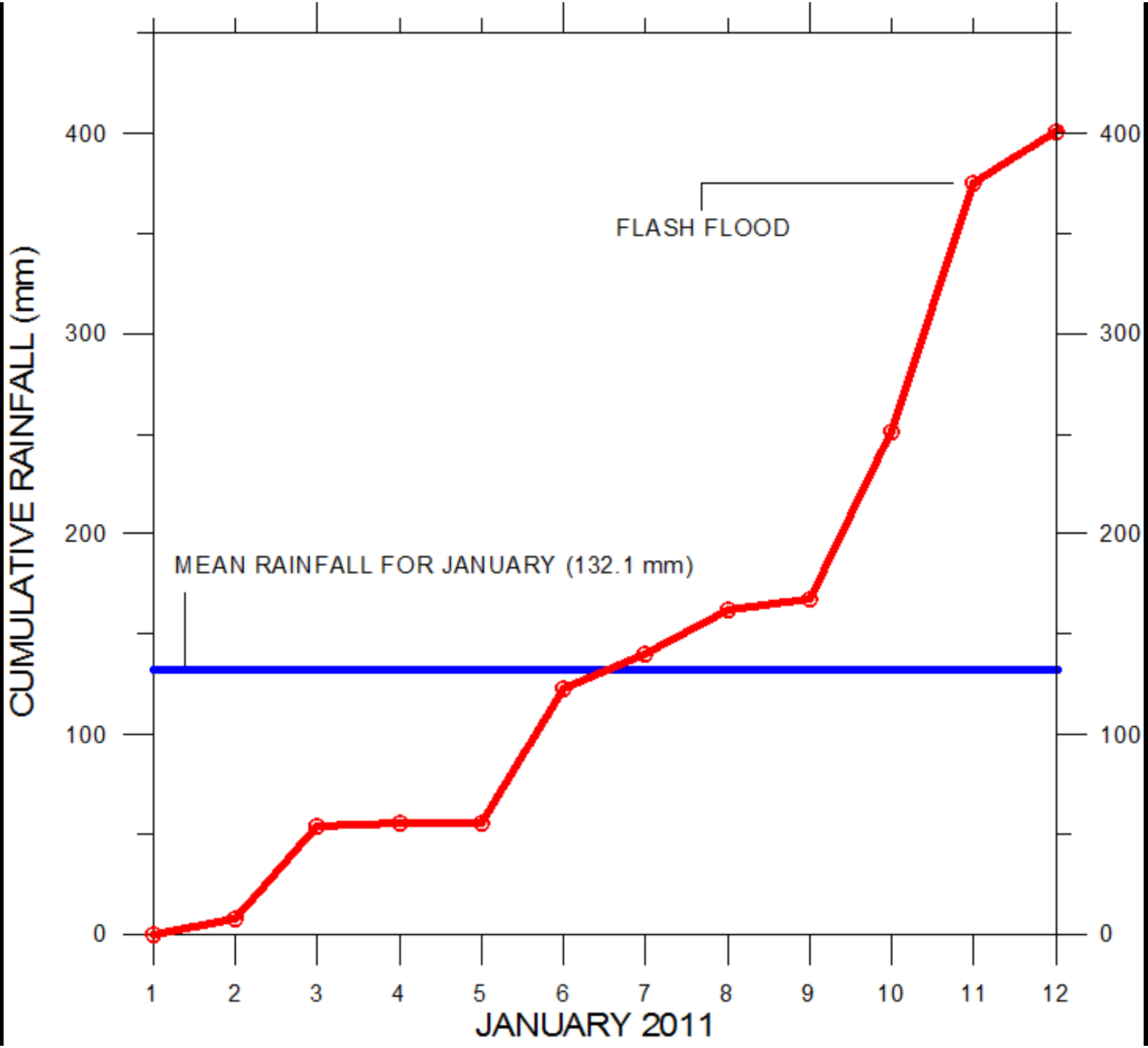




QUEENSLAND FLASH FLOOD, JANUARY 2011

Toowoomba, Queensland

EARLY JANUARY 2011 RAINFALL, TOOWOOMBA, QUEENSLAND

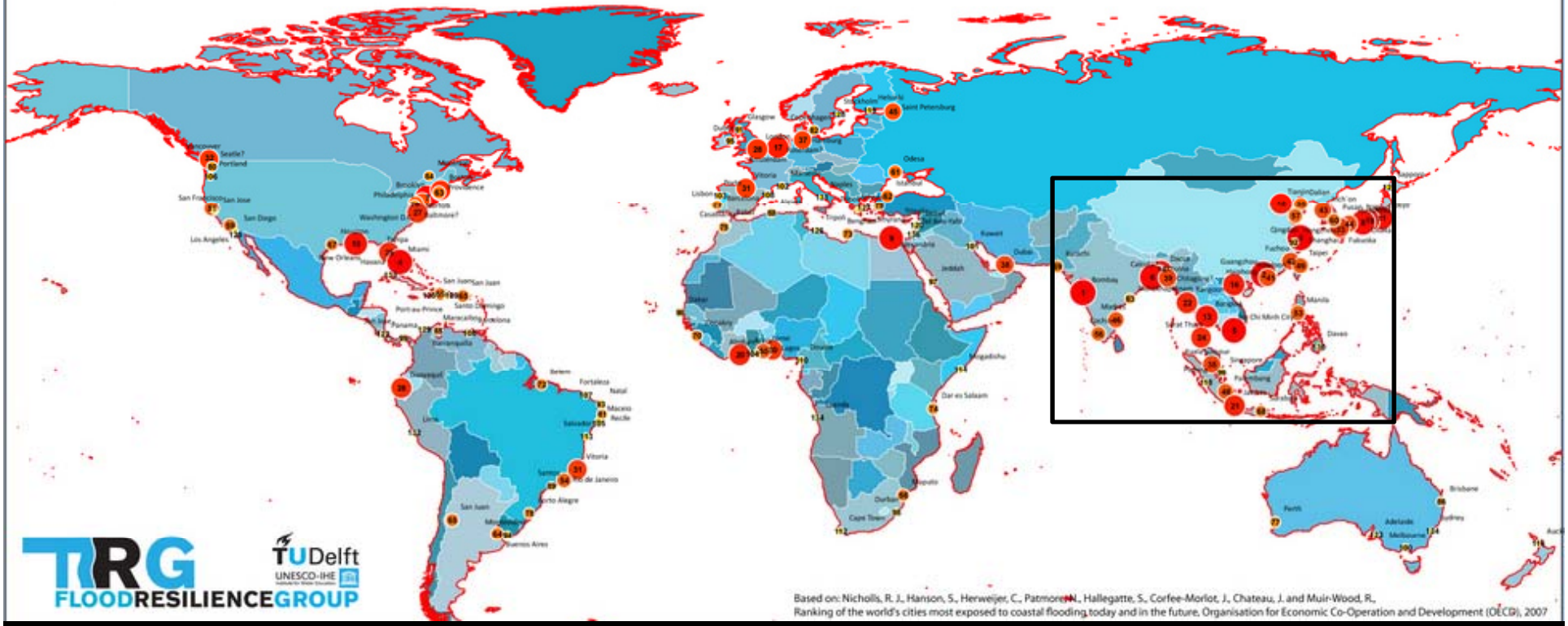


FLASH FLOODS DUE TO FAILURE OF CONSTRUCTED DAMS

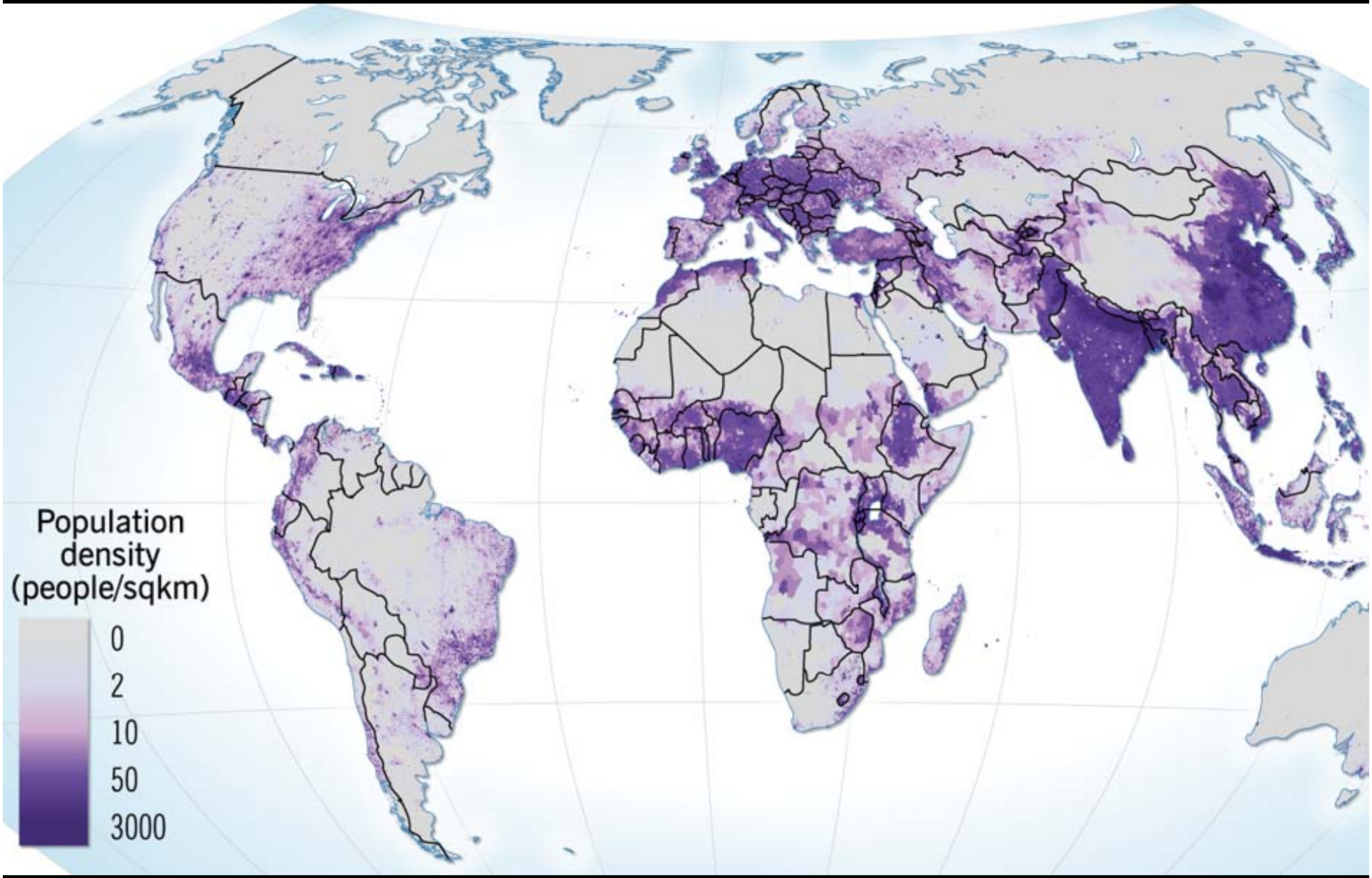
1889 Johnstown Flood, Pennsylvania; outburst flood due to failure of South Fork Dam after very heavy rains – 2,200 deaths

8B. COASTAL (SEA) FLOODS

Ranking of top 130 cities exposed to coastal flooding in 2005

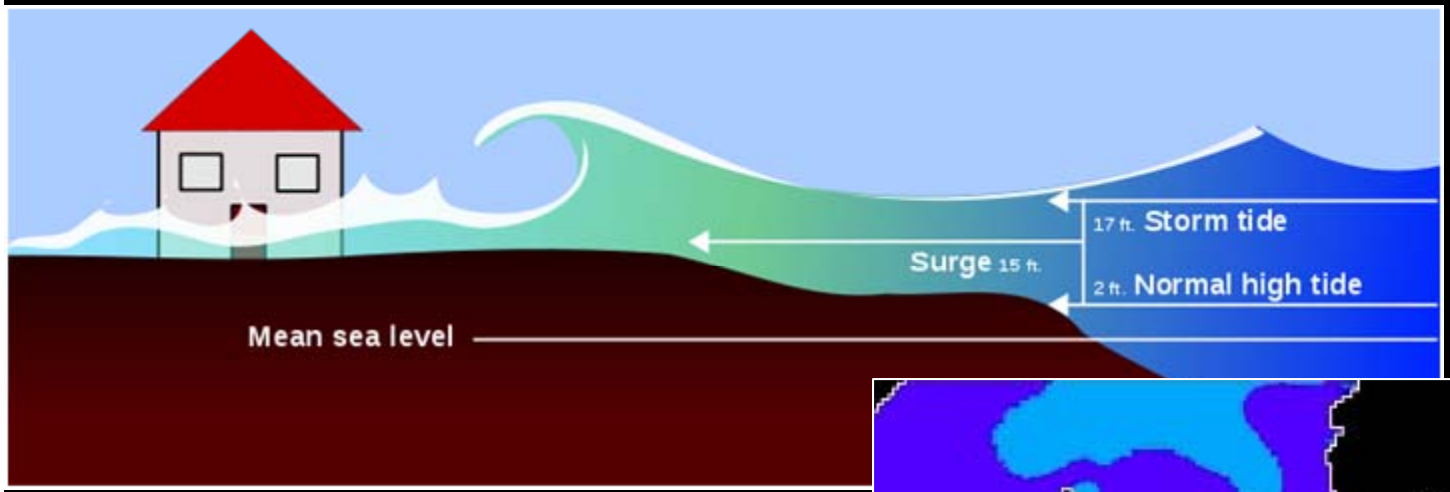


Based on: Nicholls, R. J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Chateau, J. and Muir-Wood, R., Ranking of the world's cities most exposed to coastal flooding today and in the future, Organisation for Economic Co-Operation and Development (OECD), 2007

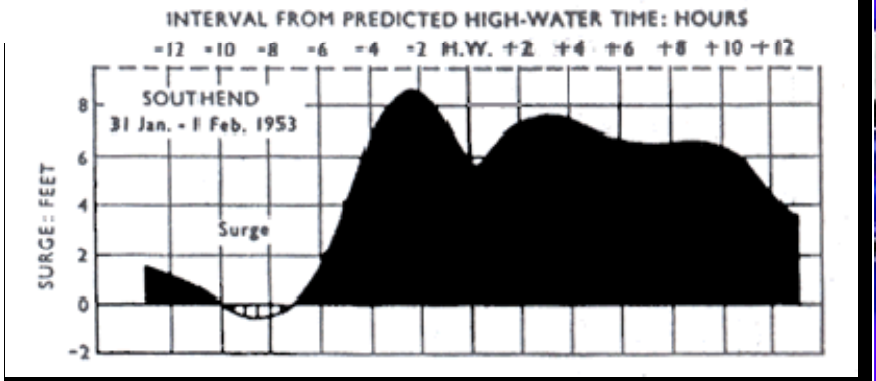


ABOUT 50% OF THE WORLD'S POPULATION LIVE WITHIN 60 km OF A COASTLINE

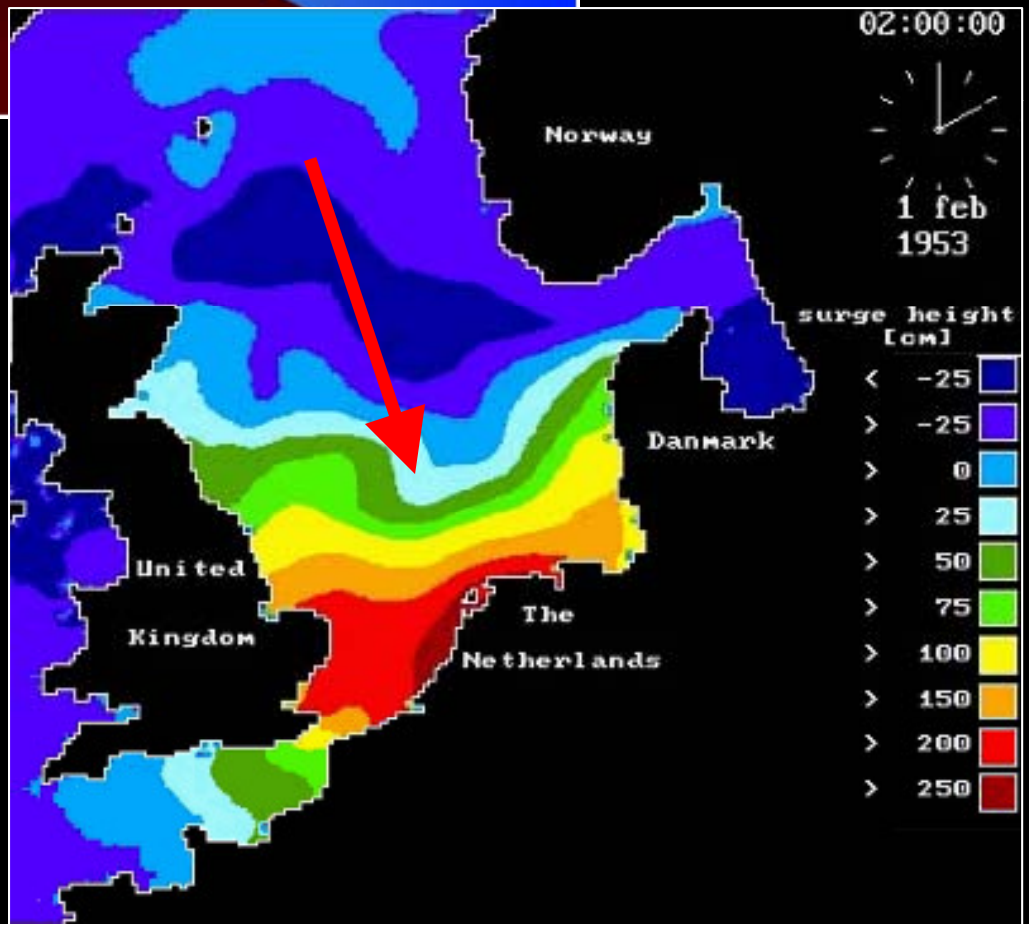
1953 NORTH SEA SURGE (~3.0 m) CAUSED CATASTROPHIC FLOODING IN ENGLAND AND THE NETHERLANDS



1 ft = .3048 m

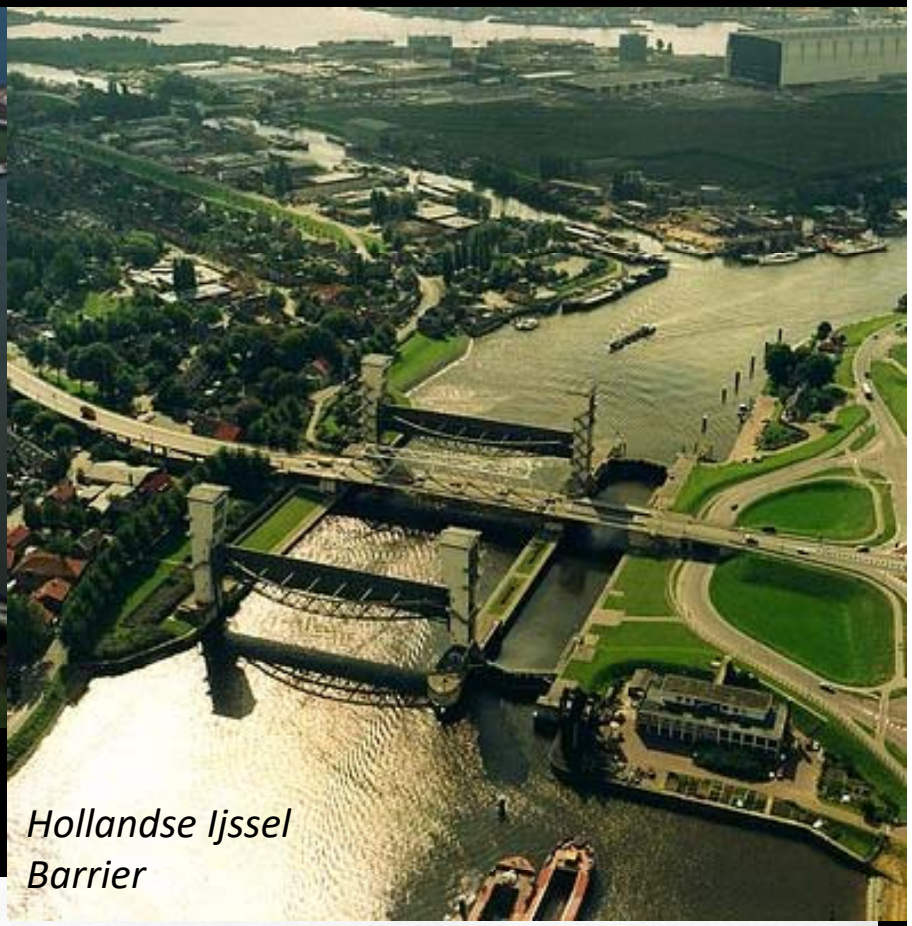


IN THE COASTAL FLOODING CAUSED BY THE STORM SURGE 1,835 PEOPLE DIED IN HOLLAND AND 307 DIED IN EASTERN ENGLAND

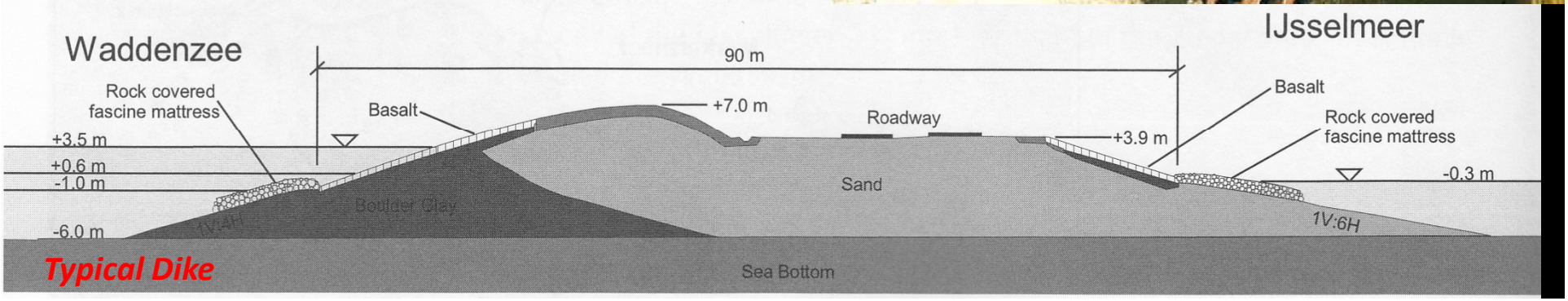


STORM SURGE COASTAL DEFENCES - THE NETHERLANDS

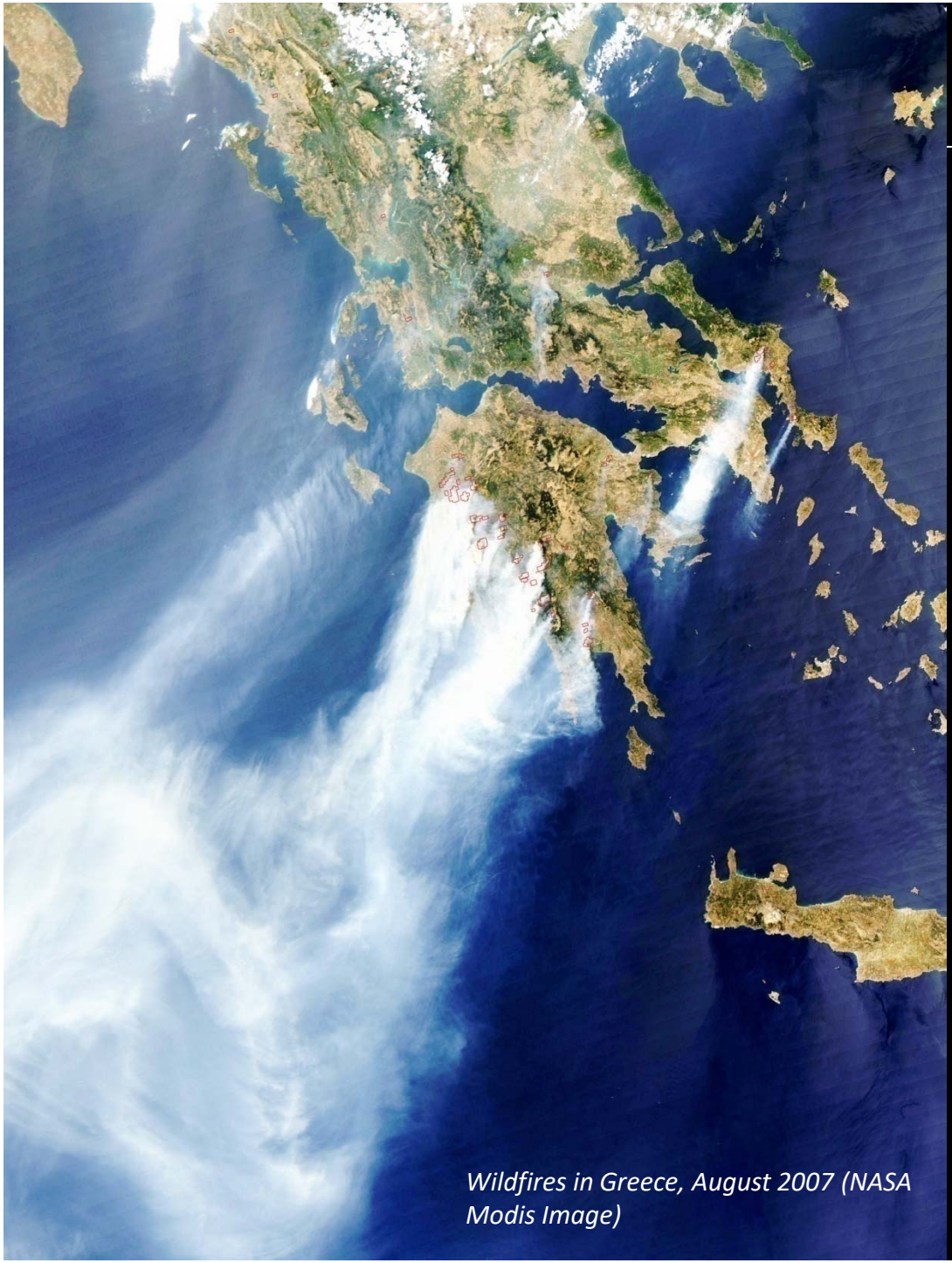
Maeslant Barrier



Hollandse Ijssel Barrier



Typical Dike



Wildfires in Greece, August 2007 (NASA Modis Image)

9. WILDFIRE

- Fire is the rapid combination of oxygen with carbon, hydrogen, and other elements of organic material in a reaction that produces, flame, heat and light.

- Natural v. Man-made (Arson); may involve massive destruction of property

- Fire Material, Fire Weather, Fire Topography

CALIFORNIA FIRES OCT 2007

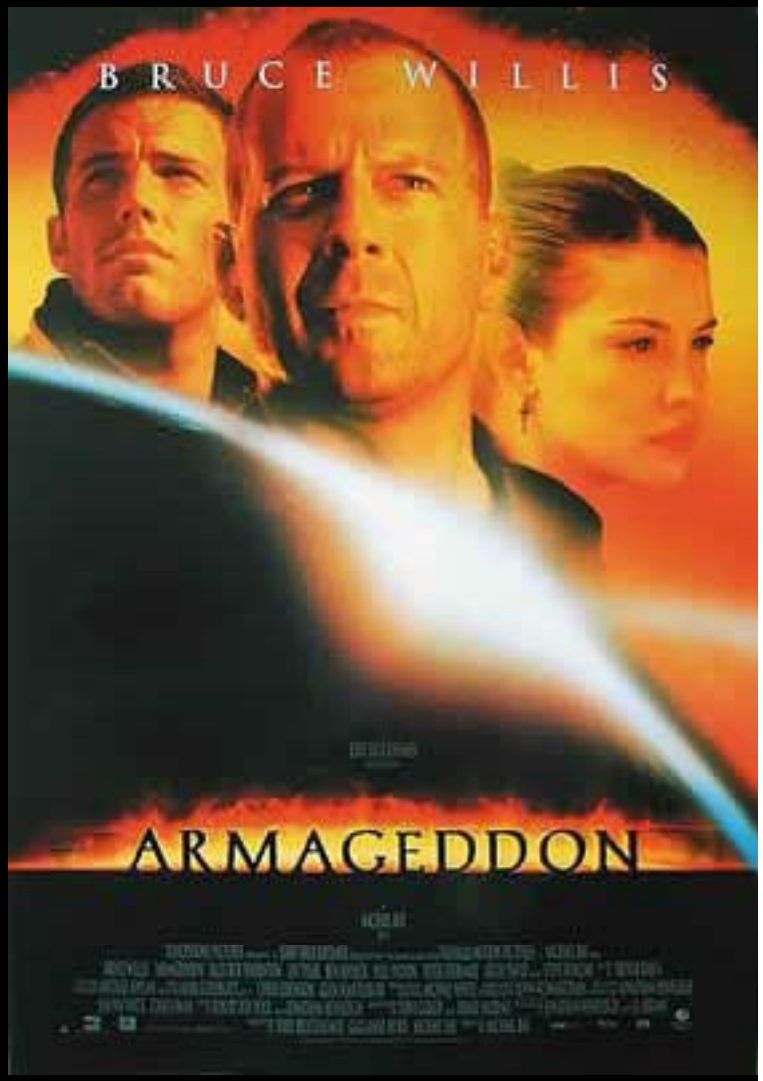
CALIFORNIA FIRES OCTOBER 2007

European Space Agency (ESA) image of October 2007 California Fires

10. EARTH IMPACT HAZARDS

Manicouagan Crater, Quebec (100 km in diameter); 214 million years old

DISTRIBUTION OF KNOWN TERRESTRIAL IMPACT CRATERS (after R.A.F. Grieve, Geological Survey of Canada)



ASTEROID IMPACT : VERY LOW PROBABILITY BUT EXTREMELY HIGH CONSEQUENCES = ?

MITIGATION _____

NASA SPACEGUARD

http://impact.arc.nasa.gov/

United Nations to lead efforts to defend Earth from asteroids

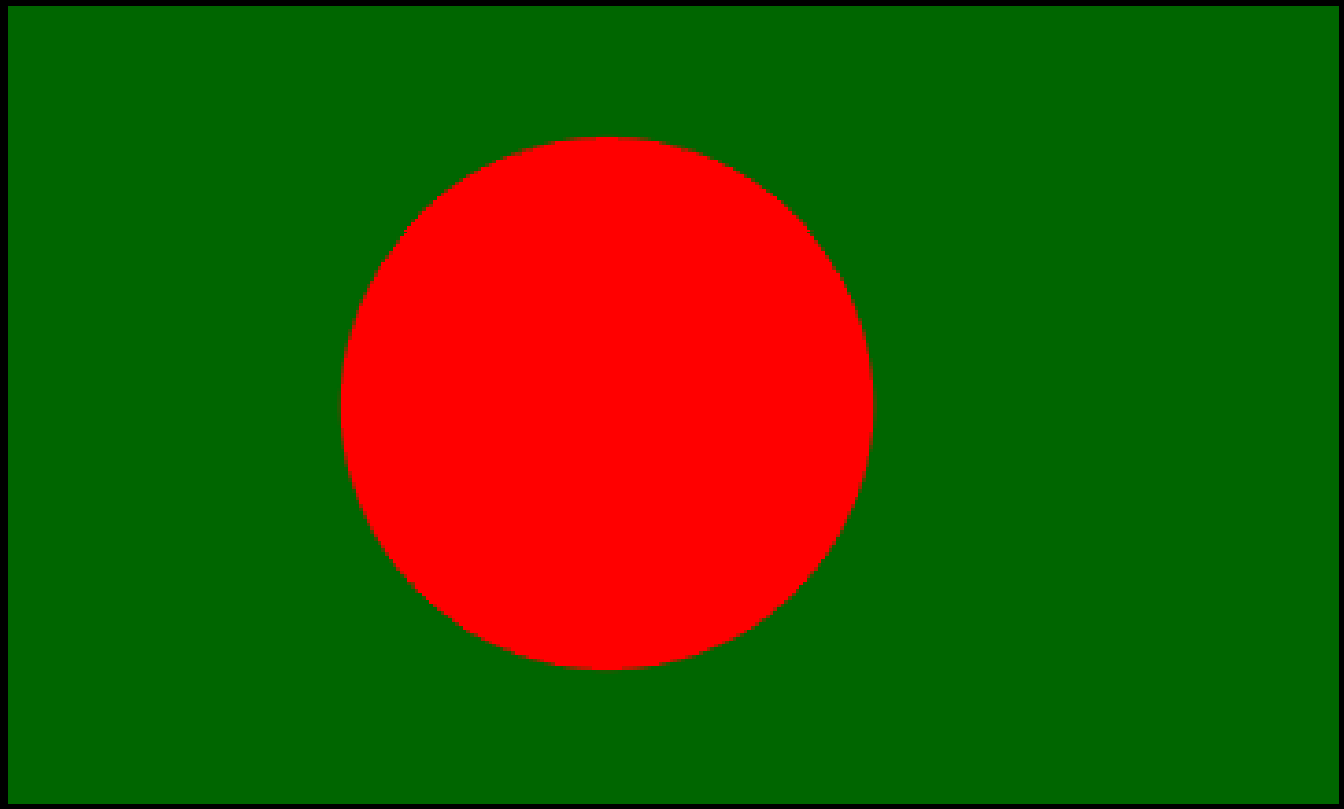
The United Nations plans to coordinate international efforts to defend the Earth from the threat posed by asteroids

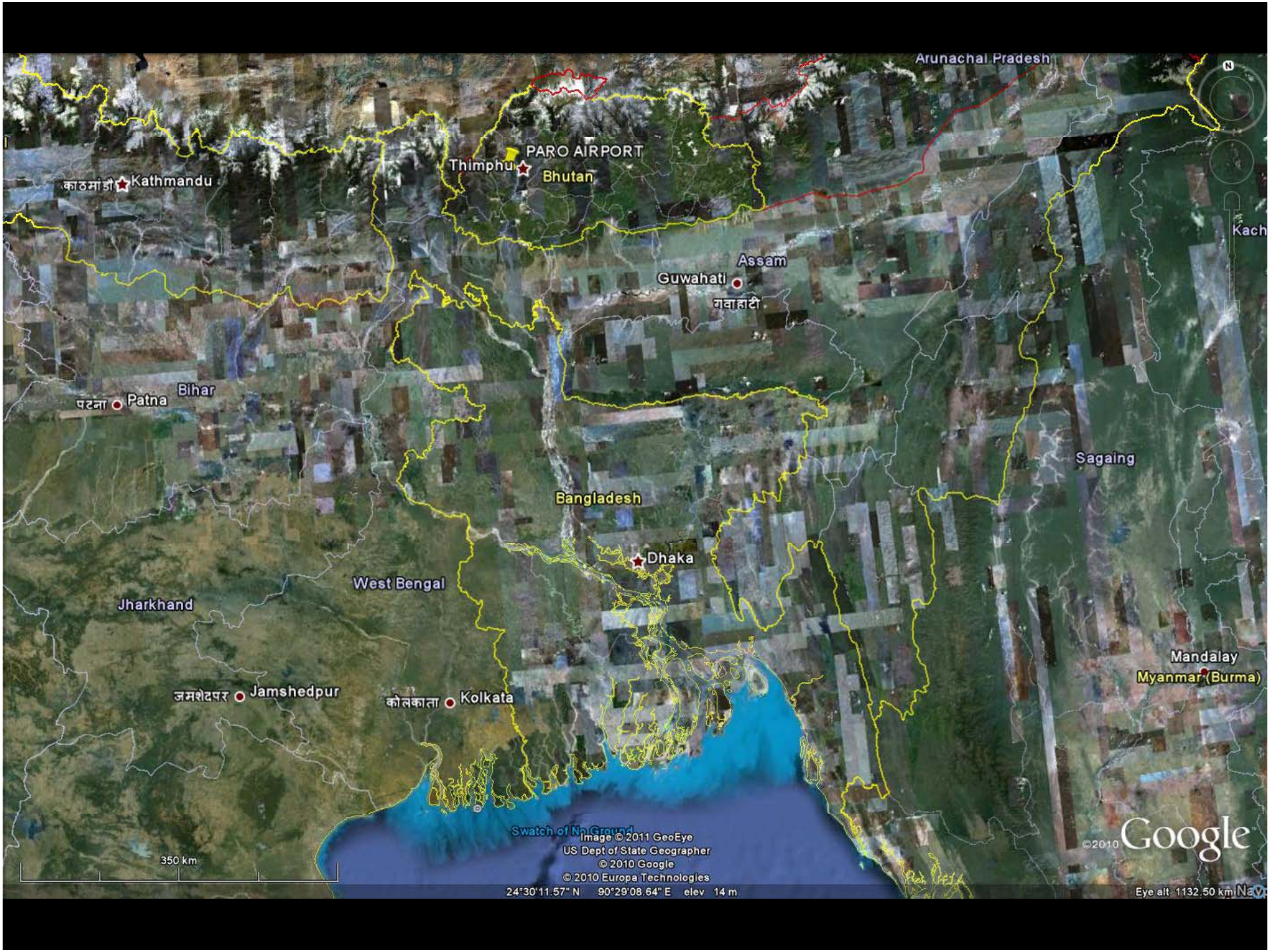
The United Nations plans to coordinate international efforts to defend the Earth from the threat posed by asteroids Photo: Alamy

By Richard Gray, Science Correspondent

7:01AM GMT 30 Oct 2013

DISASTERS AND NATURAL HAZARDS – THE CASE OF BANGLADESH

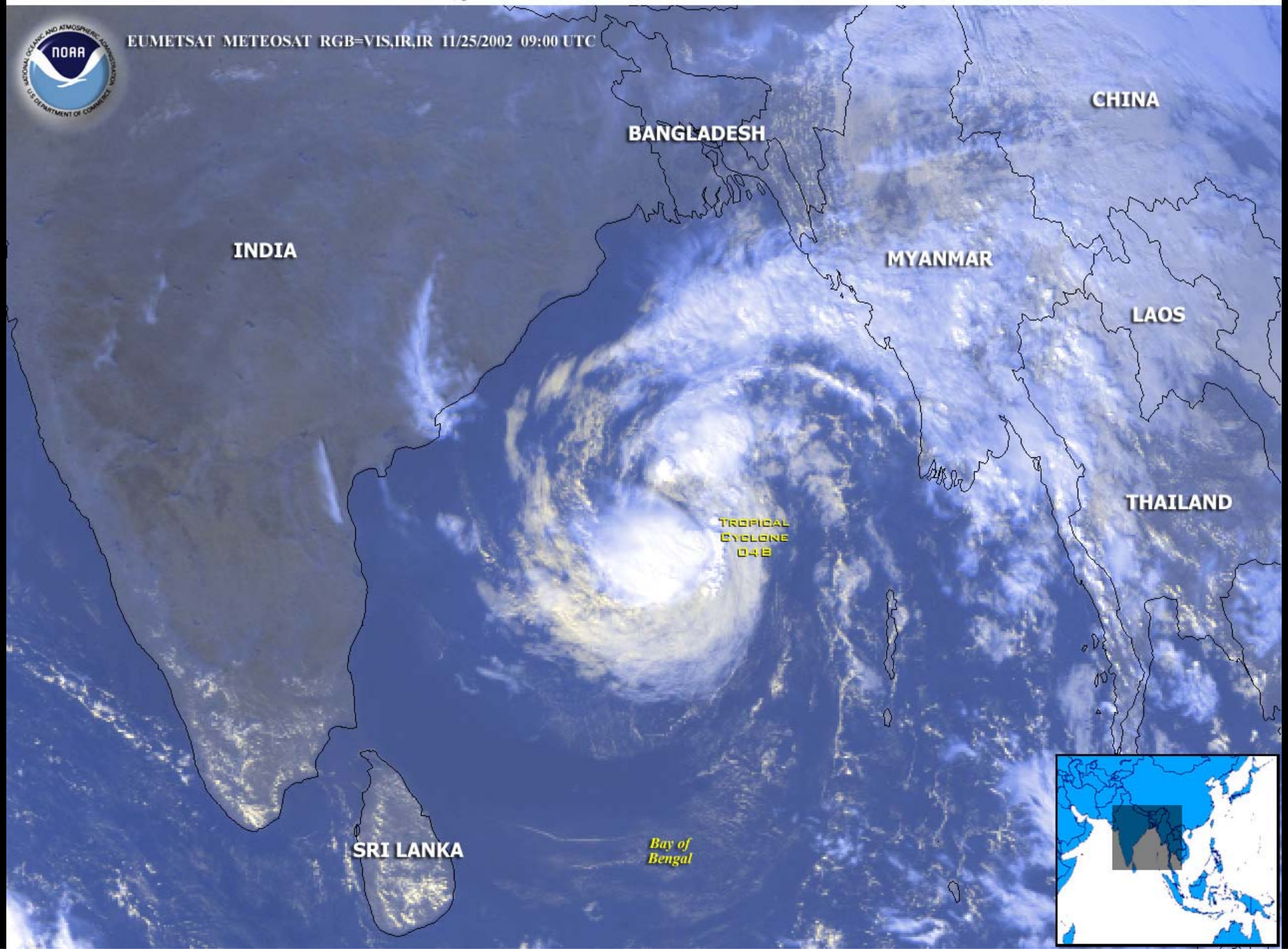



Arunachal Pradesh
PARO AIRPORT
Thimphu
Bhutan
काठमांडो Kathmandu
Assam
Guwahati
गुवाहाटी
Kach
Bihar
पटना Patna
Sagaing
Bangladesh
Dhaka
West Bengal
Jharkhand
Mandalay
Myanmar (Burma)
जमशेदपर Jamshedpur
कोलकाता Kolkata
Swatch of No Ground
Image © 2011 GeoEye
US Dept of State Geographer
© 2010 Google
© 2010 Europa Technologies
24°30'11.57" N 90°29'08.64" E elev 14 m
Eye alt 1132.50 km
©2010 Google
350 km

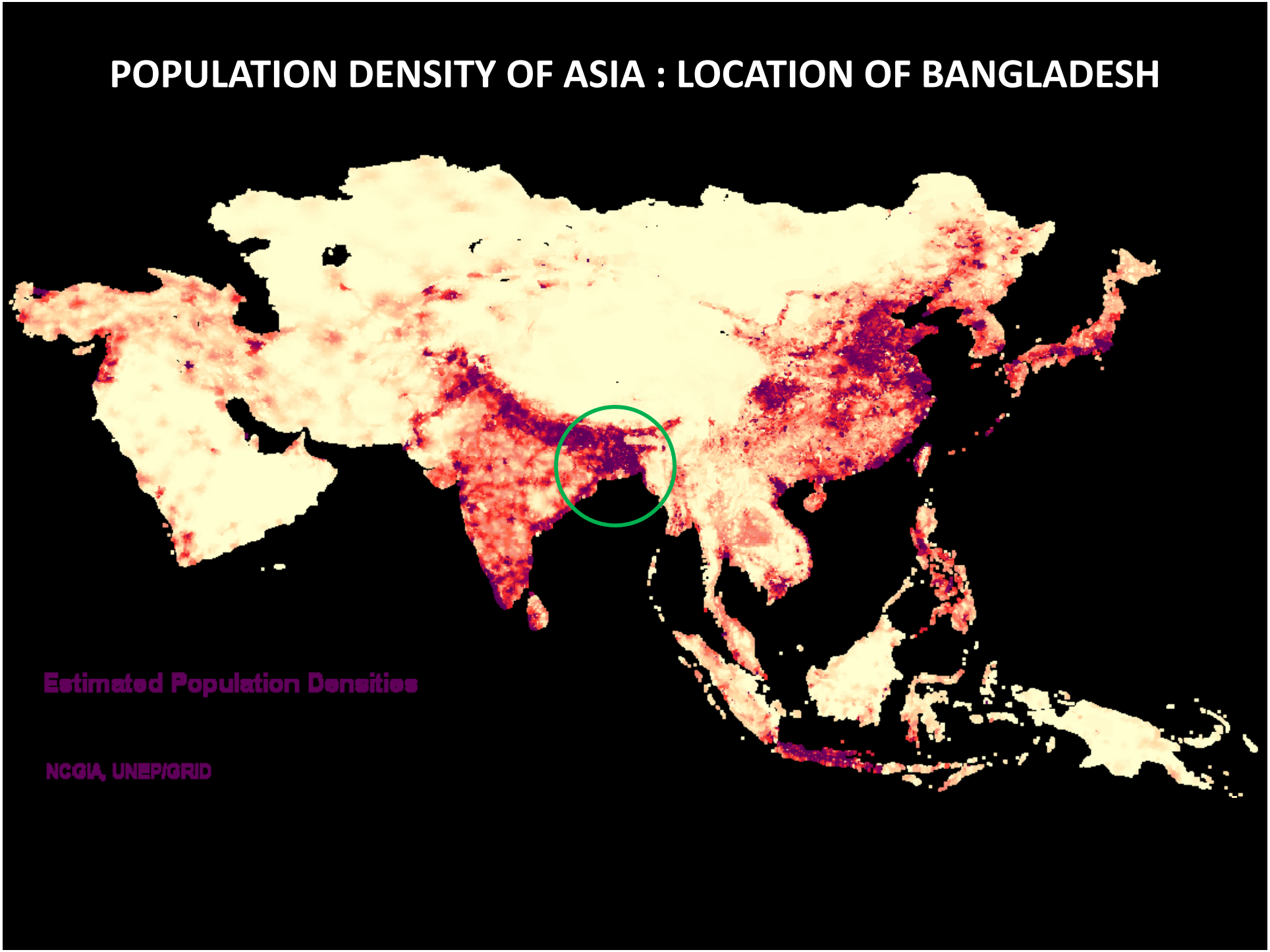

1. STORM SURGES CAUSED BY TROPICAL CYCLONES
2. RIVER FLOODING (Ganges and Brahmaputra)
3. TORNADOES
4. LANDSLIDES

Tropical Cyclone 04B was located over the Bay of Bengal near 15.2N 87.4E at 12:00 UTC. The storm has been moving westward at 5 knots with maximum sustained winds estimated at 35 knots, gusts to 45 knots.

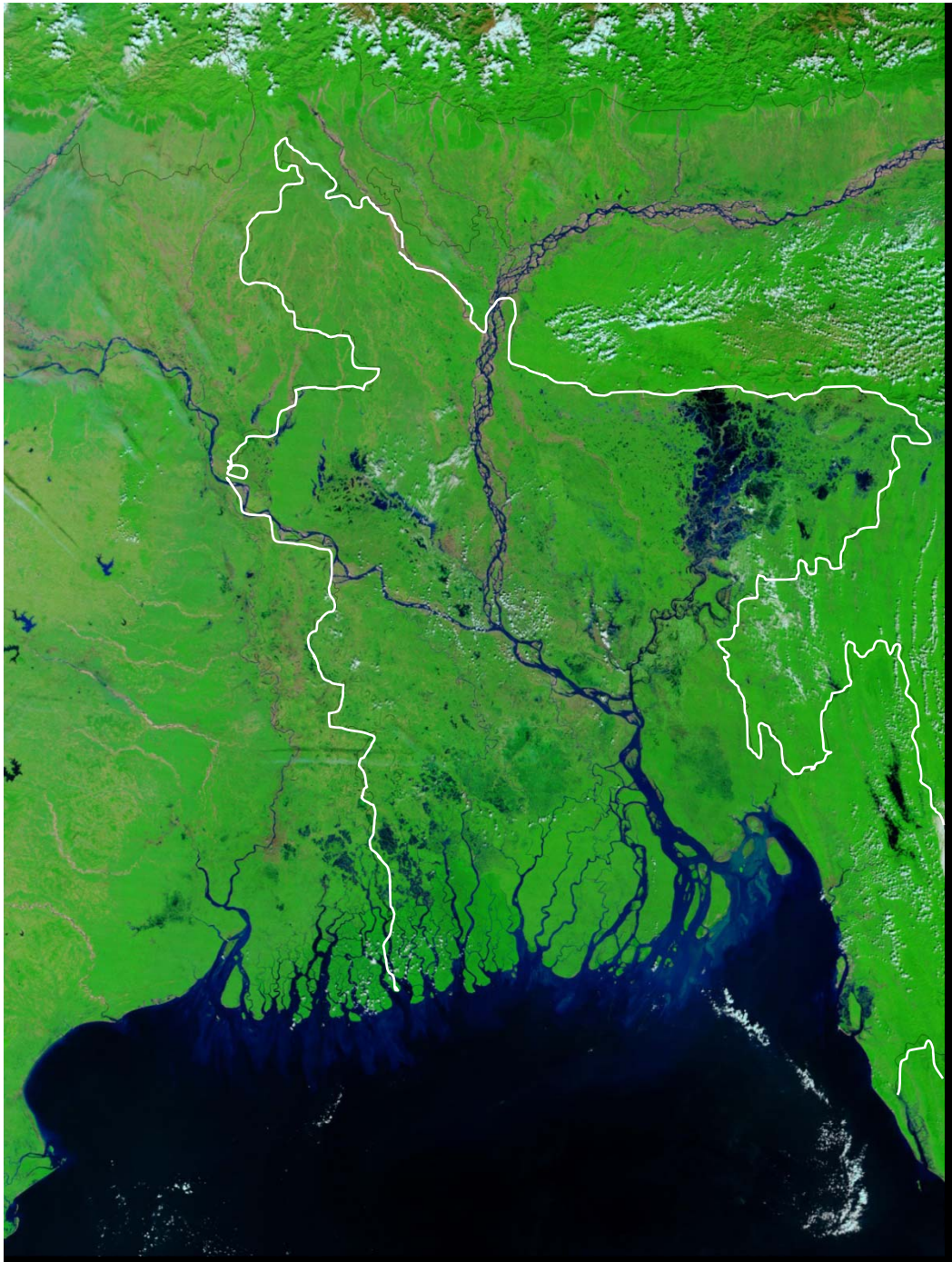
CREDIT: NOAA

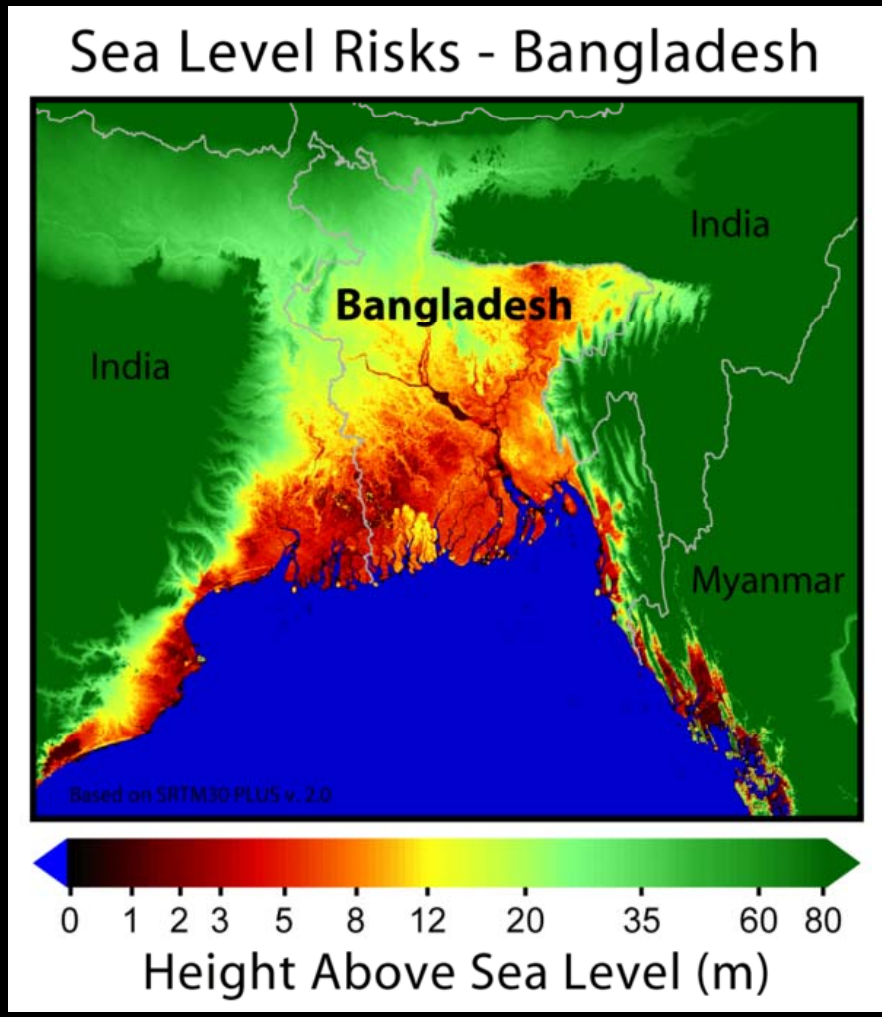


POPULATION DENSITY OF ASIA : LOCATION OF BANGLADESH

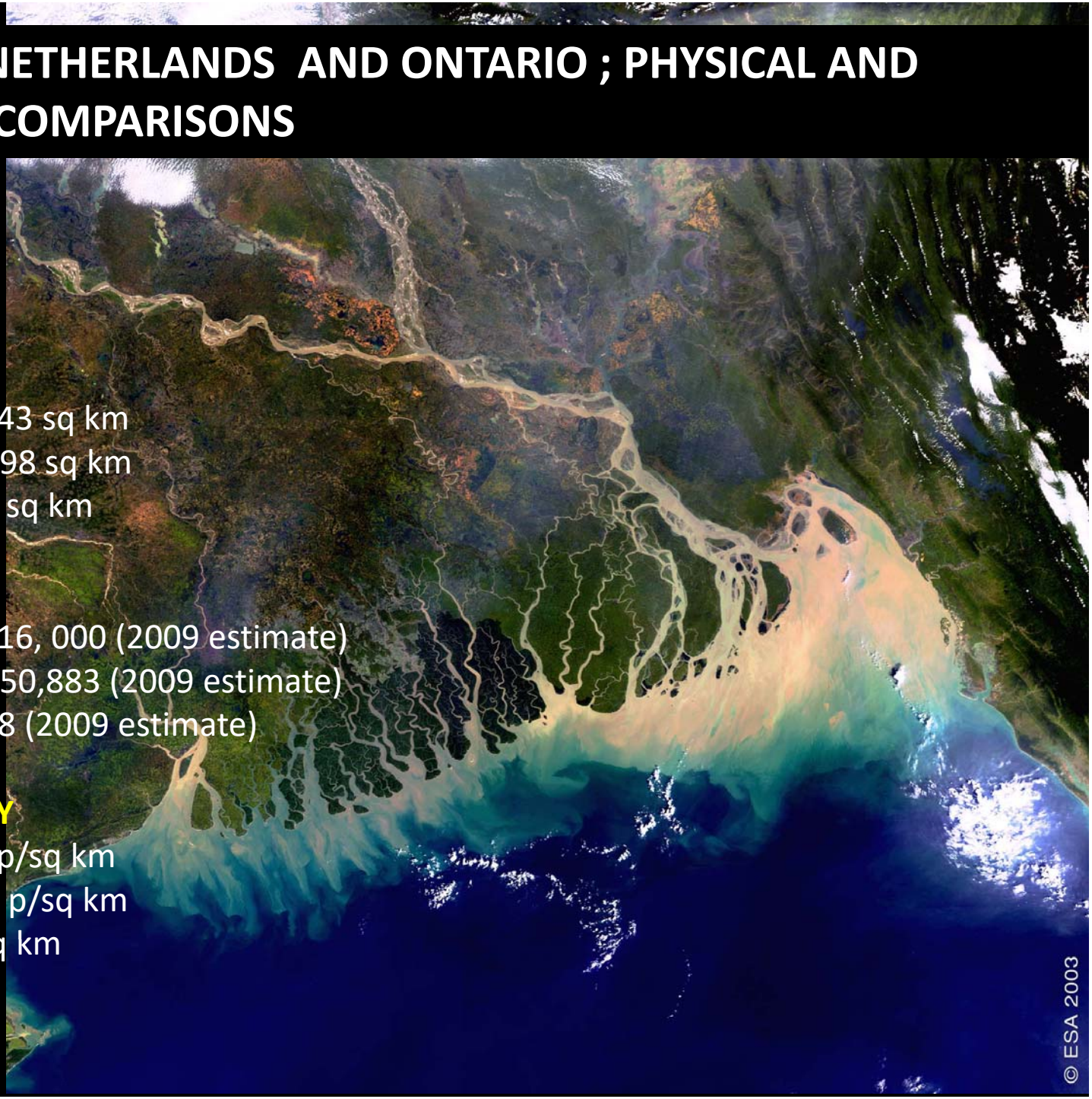


PHYSICAL SETTING OF BANGLADESH





BANGLADESH , NETHERLANDS AND ONTARIO ; PHYSICAL AND DEMOGRAPHIC COMPARISONS

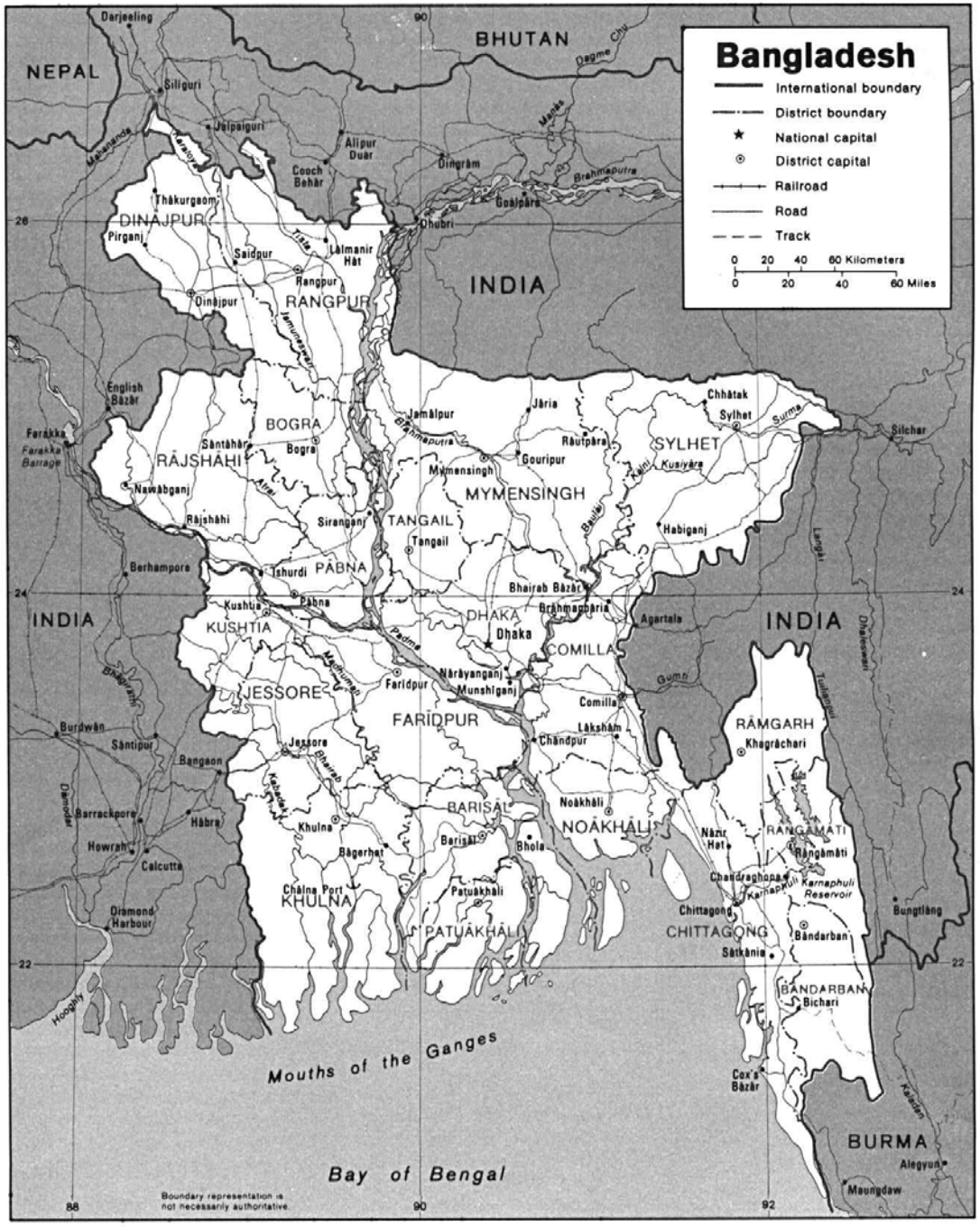


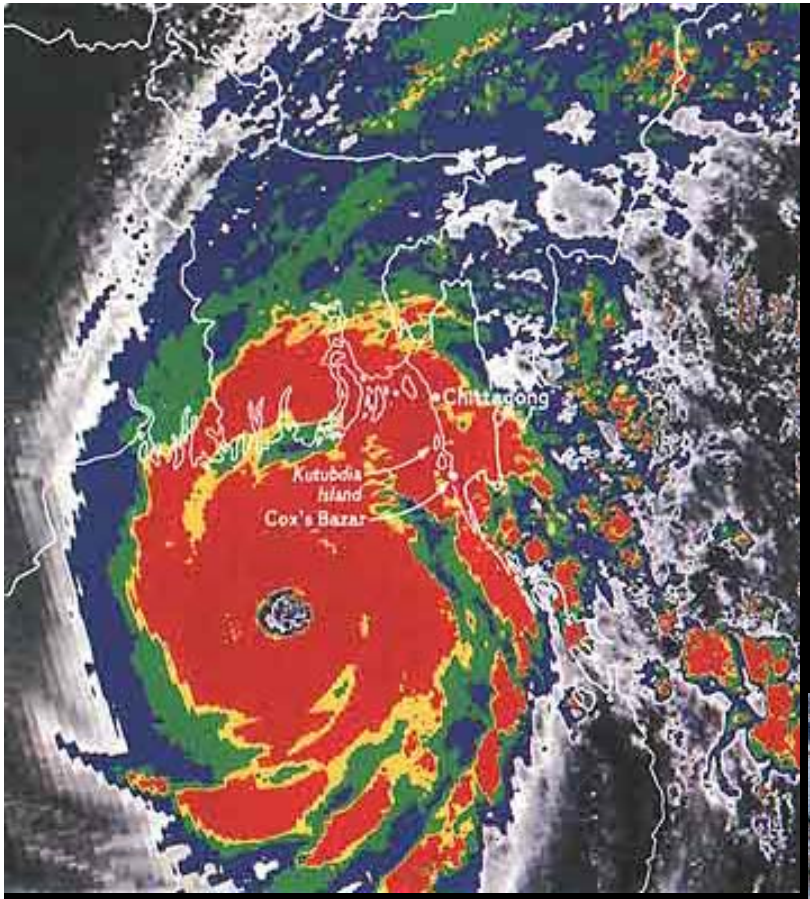
AREA
NETHERLANDS – 41,543 sq km
BANGLADESH – 143.998 sq km
ONTARIO – 1,076,395 sq km

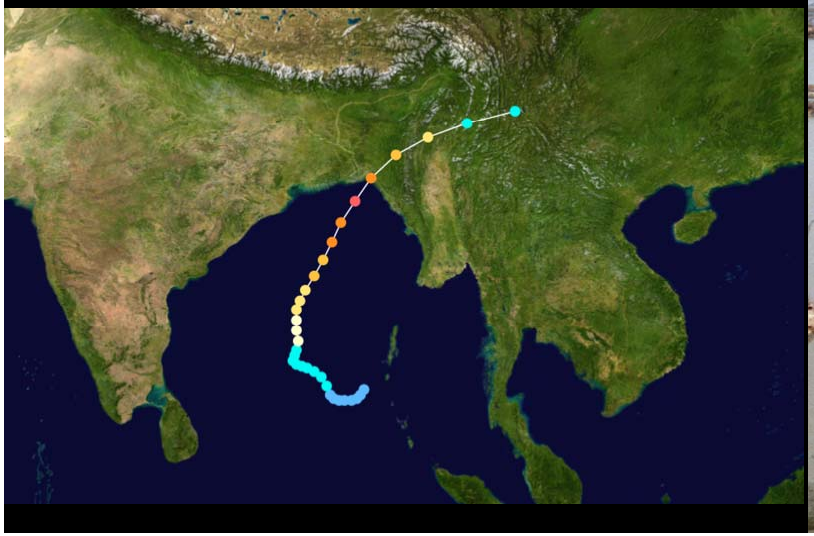
POPULATION
NETHERLANDS – 16,716, 000 (2009 estimate)
BANGLADESH – 156,050,883 (2009 estimate)
ONTARIO – 13,014,018 (2009 estimate)

POPULATION DENSITY
NETHERLANDS – 402 p/sq km
BANGLADESH – 1,084 p/sq km
ONTARIO – 12.09 p/sq km

Cyclone Bhola 1970; 400,00 deaths







1991 Cyclone Bangla (aka Gorky); 140,000 deaths

DFO Event # 2007- 219 - Bangladesh - Cyclone Sidr - Rapid Response Inundation Map

MODIS flood inundation limit
November 19, 2007:
November 18, 2007:
November 16, 2007:

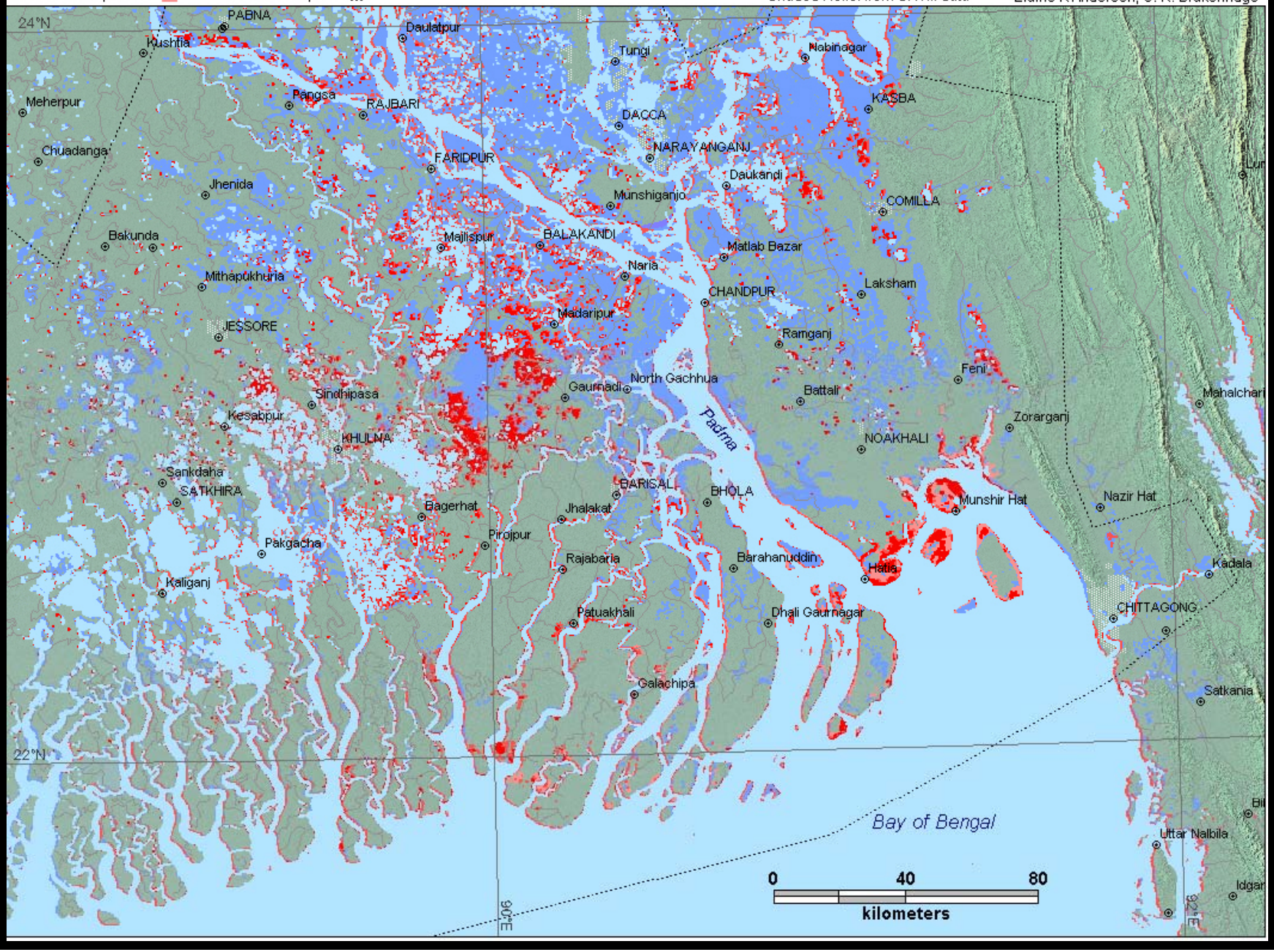
Maximum Observed Inundation Limit 1998 - 2007:
MODIS cloud free area November 19, 2007:

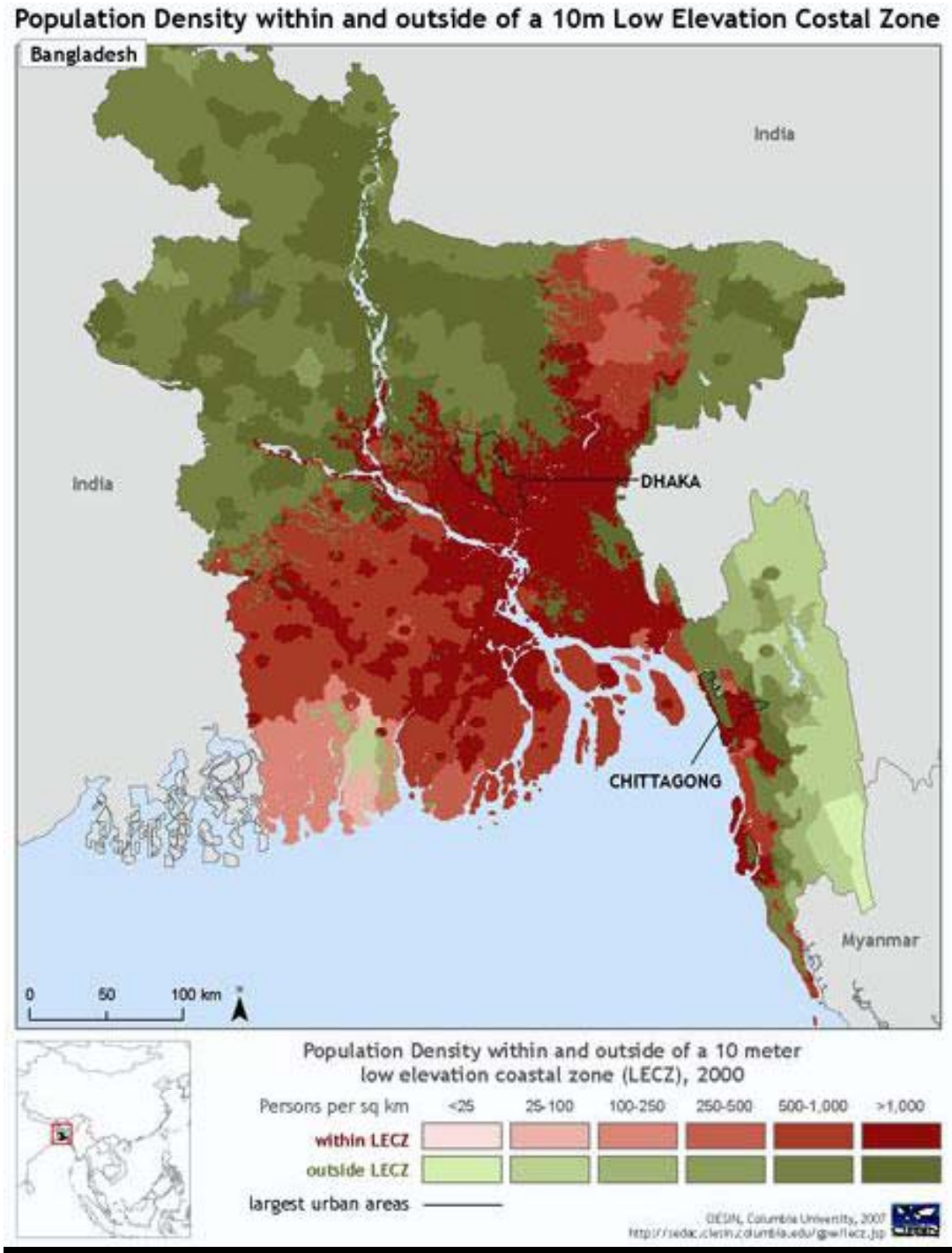
GLIDE#: TC-2007-000208-BGD

MODIS November 12, 2007 reference water:
DCW Rivers: — Urban Areas:

Universal Transverse Mercator
UTM Zone 45 North
WGS 84 - Graticule: 2 degrees
Shaded Relief from SRTM data

Dartmouth Flood Observatory
Dartmouth College
Hanover, NH 03755 USA
Elaine K.Anderson, G. R. Brakenridge



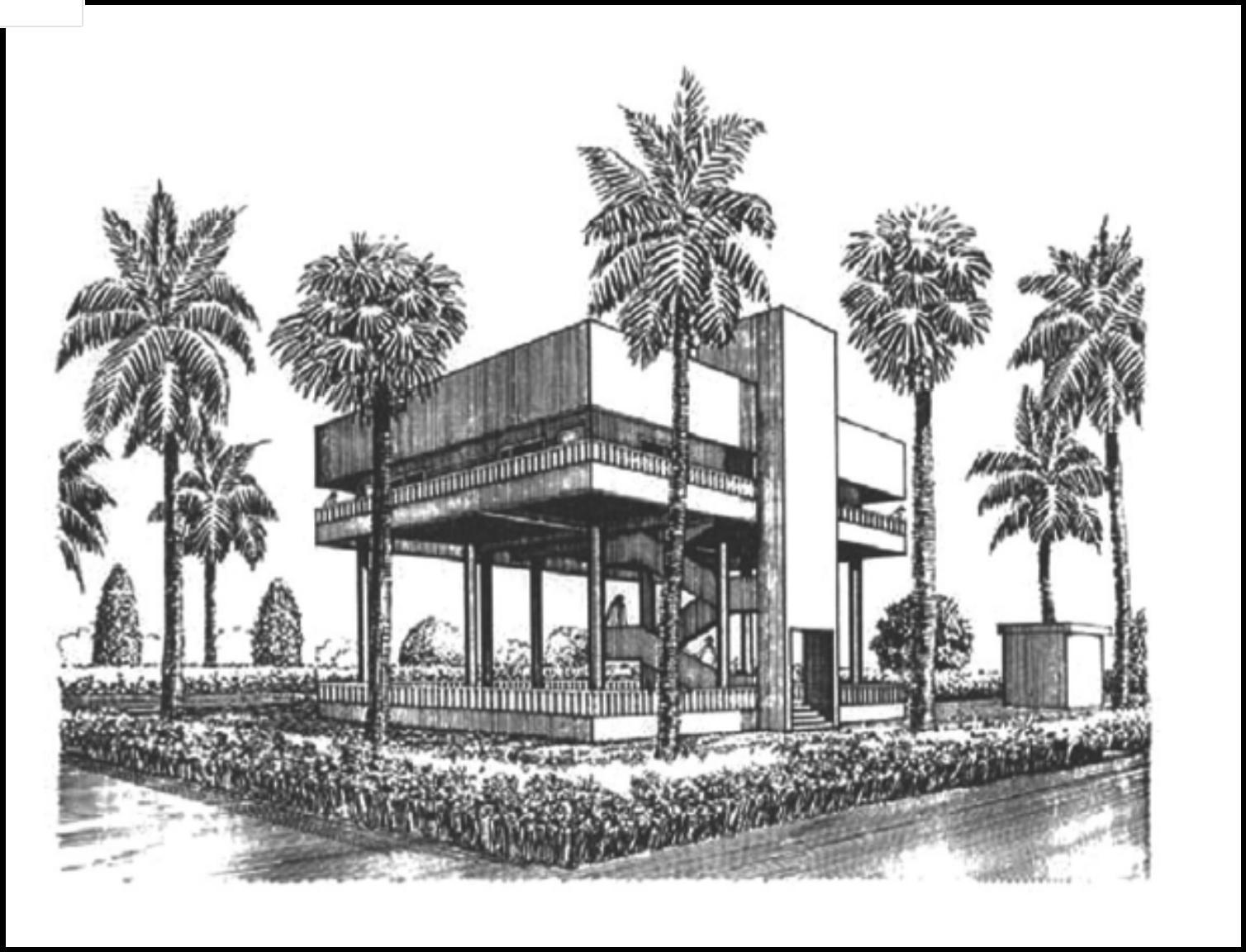


Cyclone shelter, Bangladesh

Fertile soils, intensive agriculture, dense population

dst

dst



Architectural drawing of cyclone shelter, Bangladesh

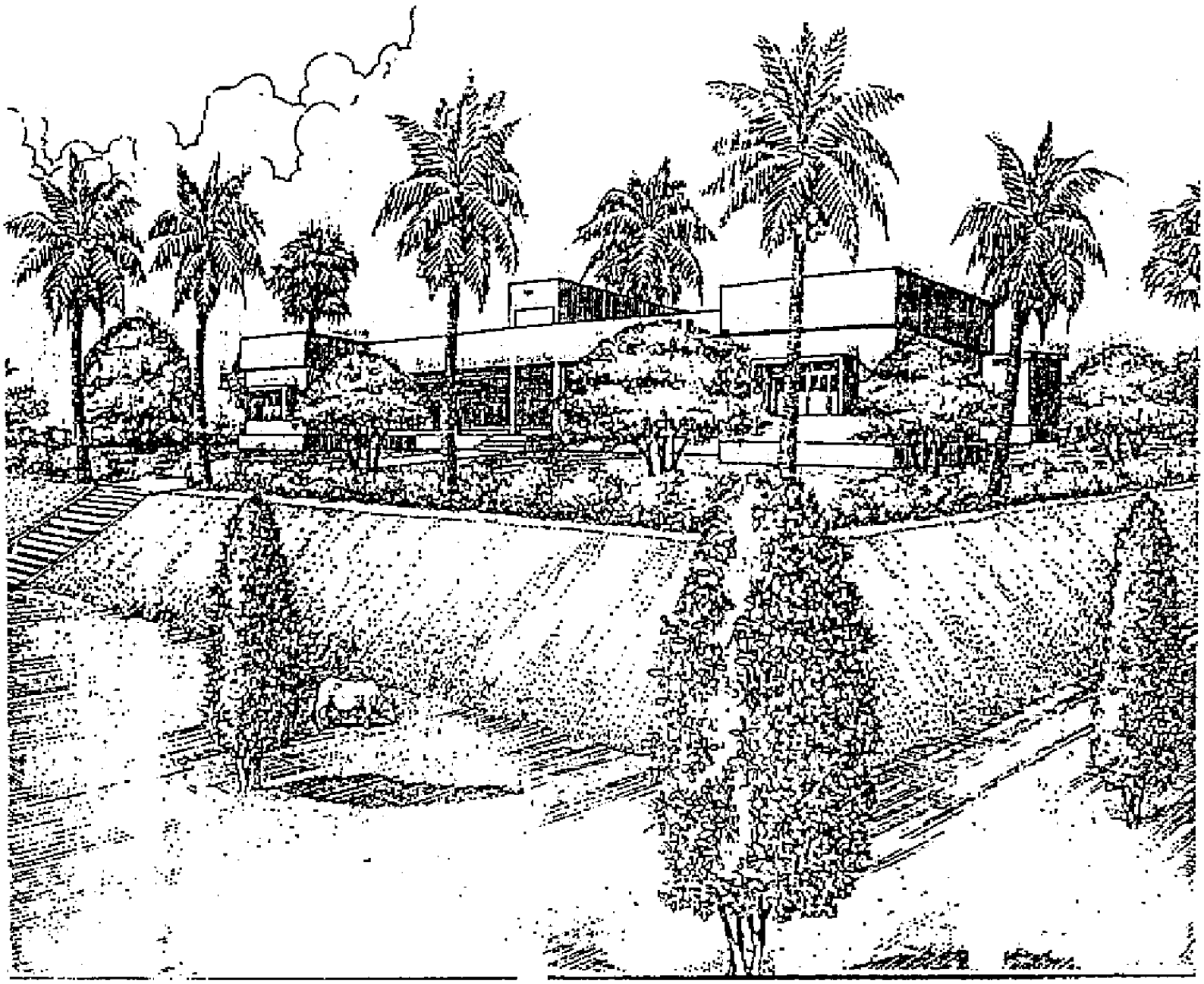
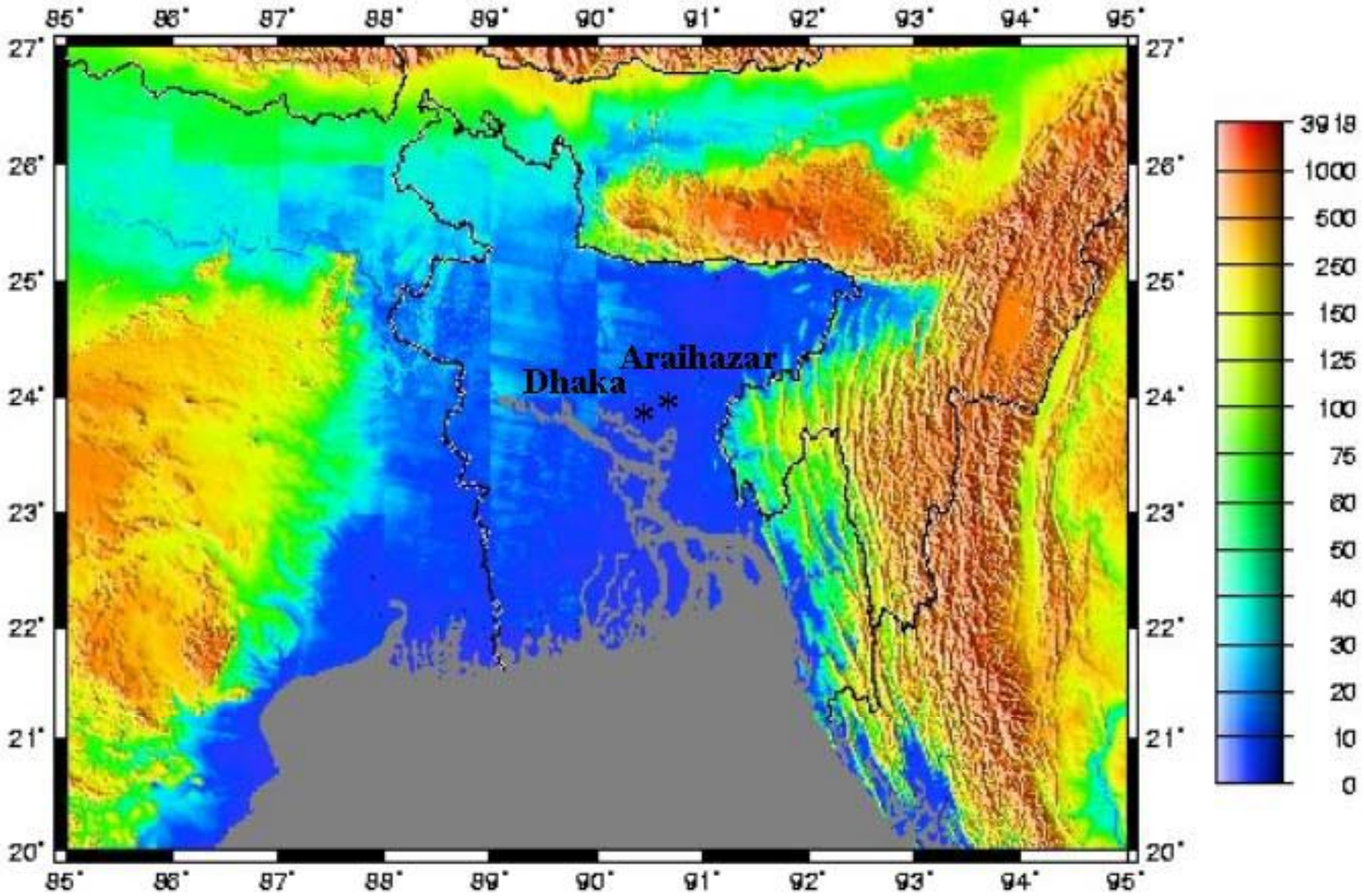


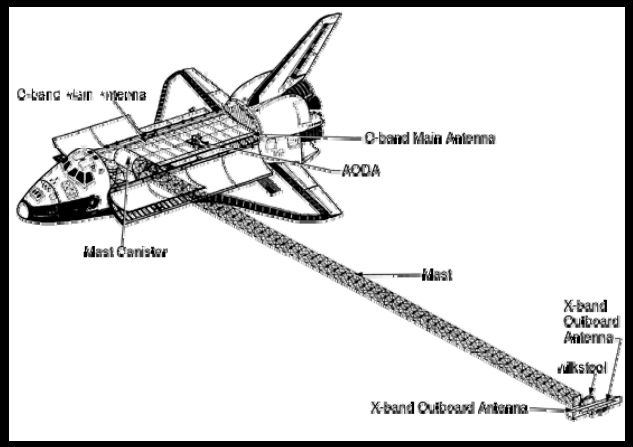
Figure 2. Typical Multipurpose Cyclone Shelter on a *Killa*

CYCLONE SHELTERS IN BANGLADESH – EFFECTIVE MITIGATION AGAINST STORM SURGE HAZARD

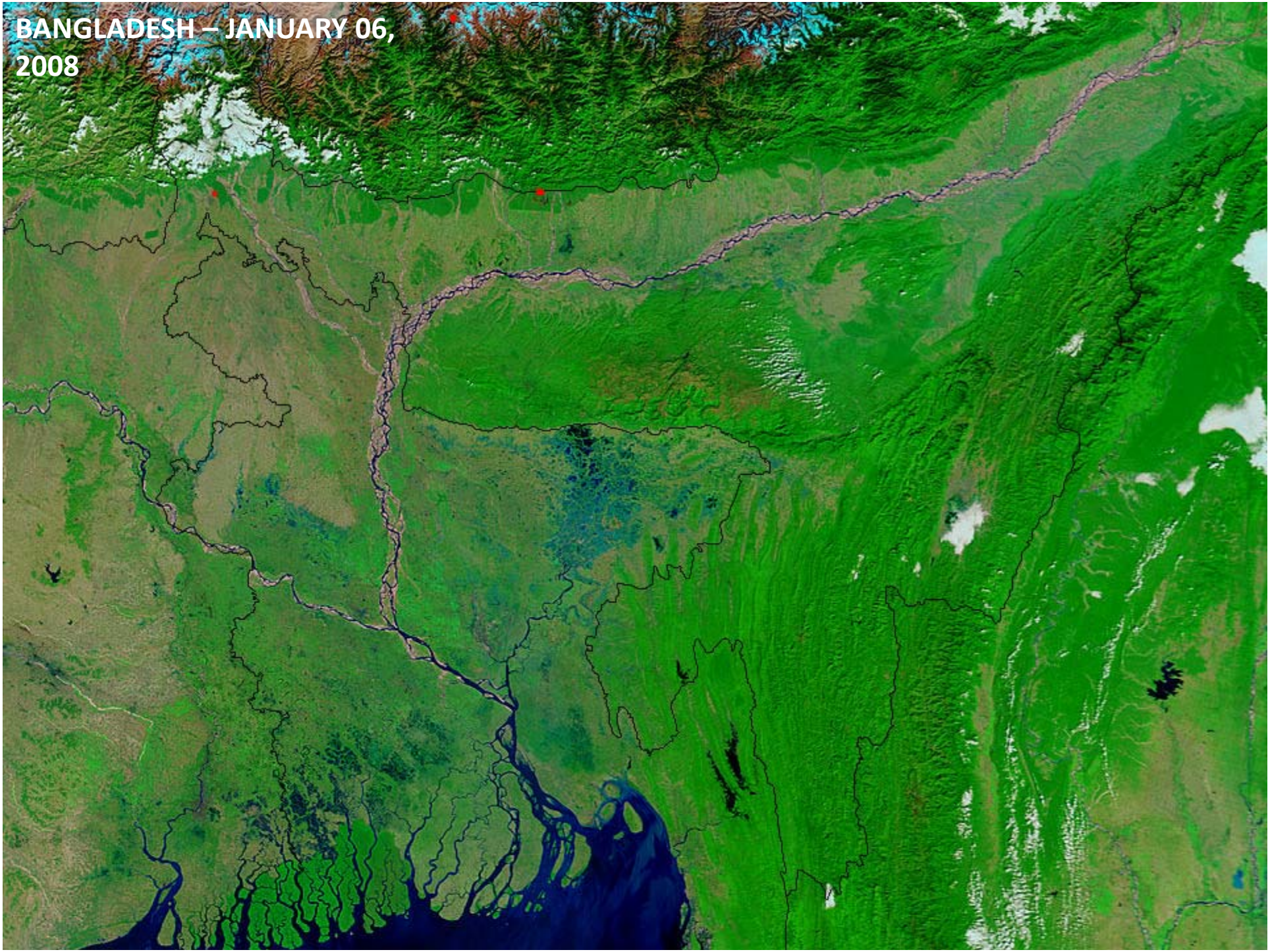


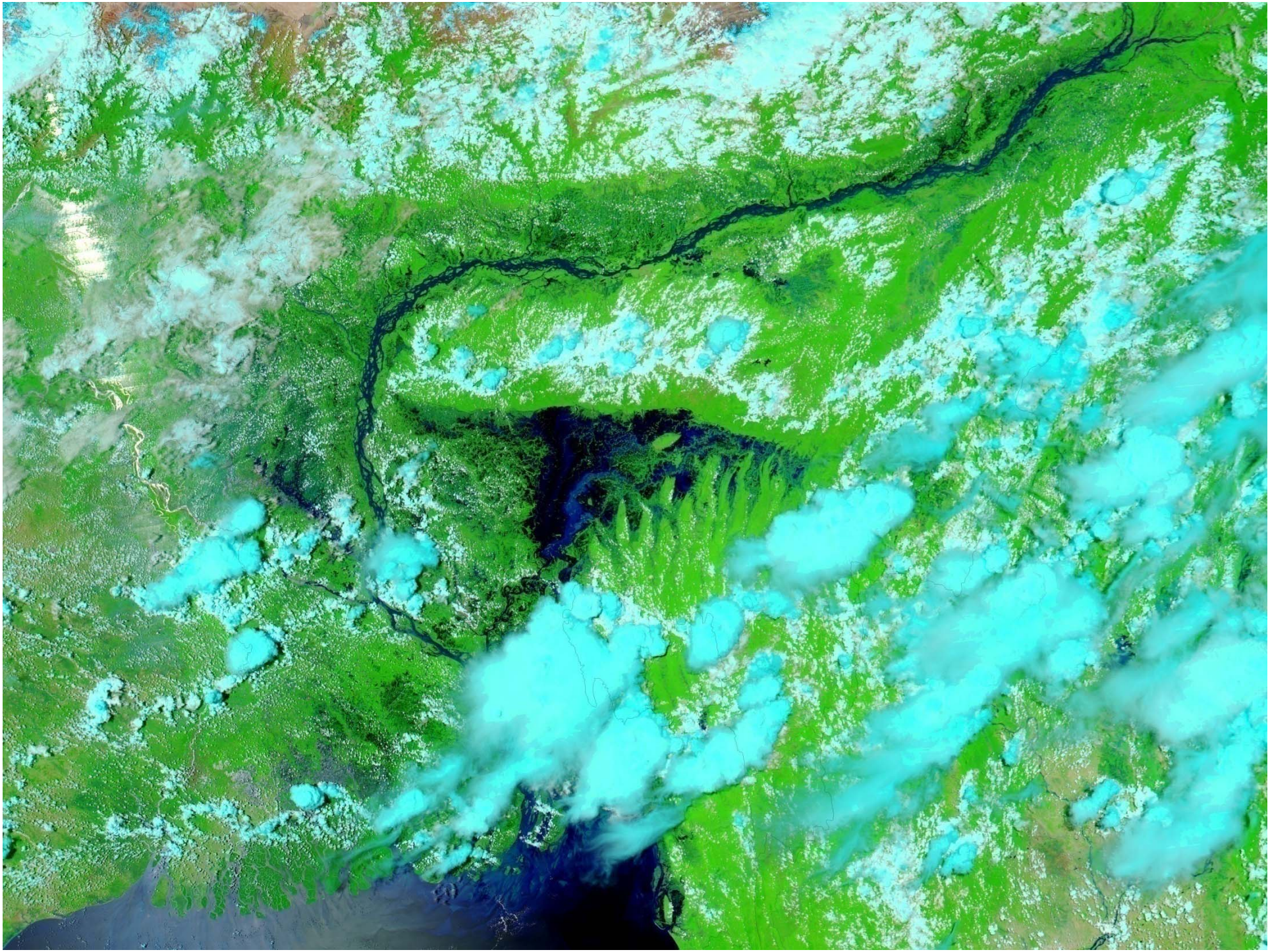
Source: M. Steckler, LDEO, based on GTOPO30 digital elevation model (USGS EROS Data Center).

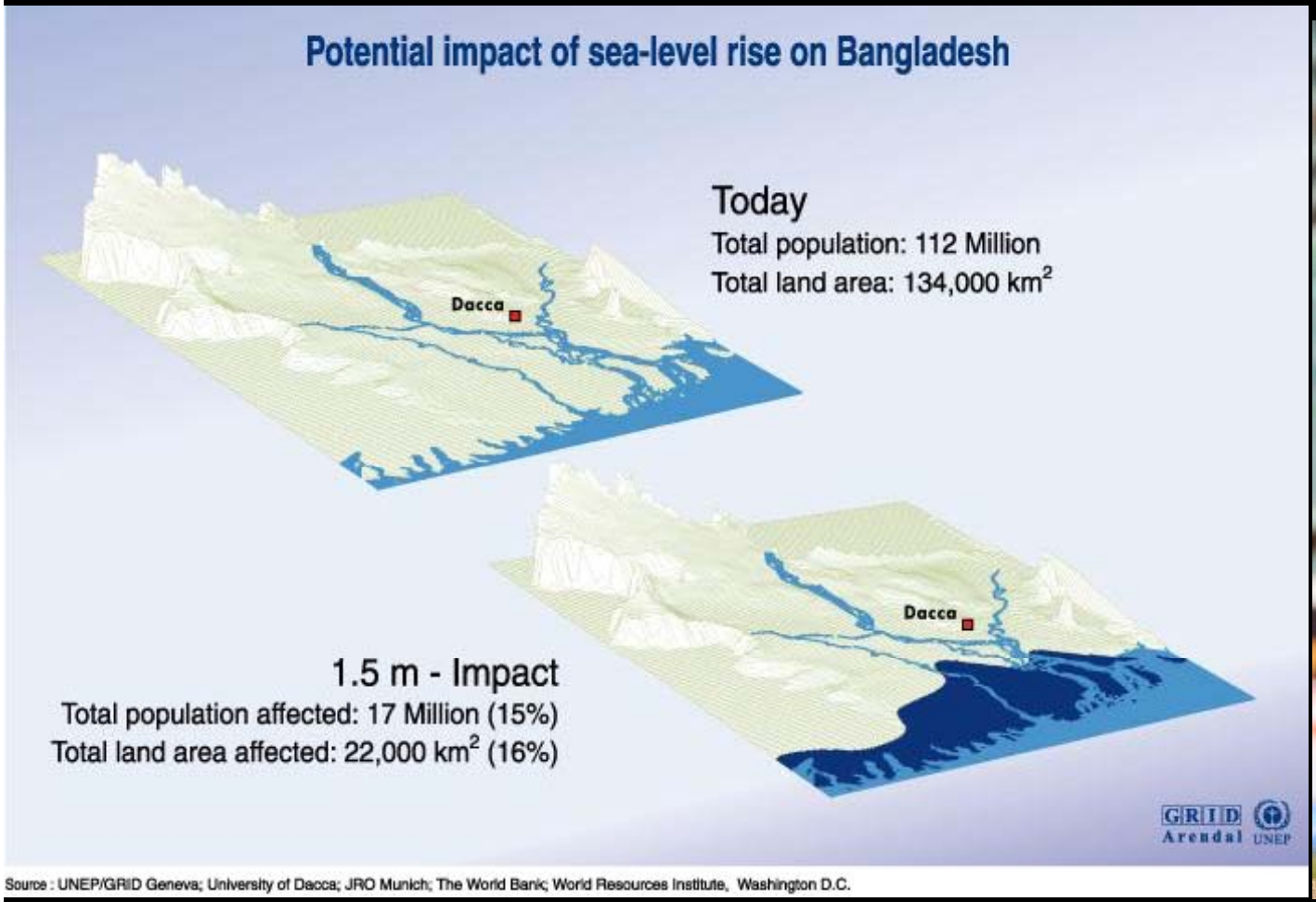
HOW DO WE GET DETAILED MAPS OF ANY PLACE IN THE WORLD ?



SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM) ; 11 DAYS IN FEBRUARY 2000


BANGLADESH – JANUARY 06, 2008





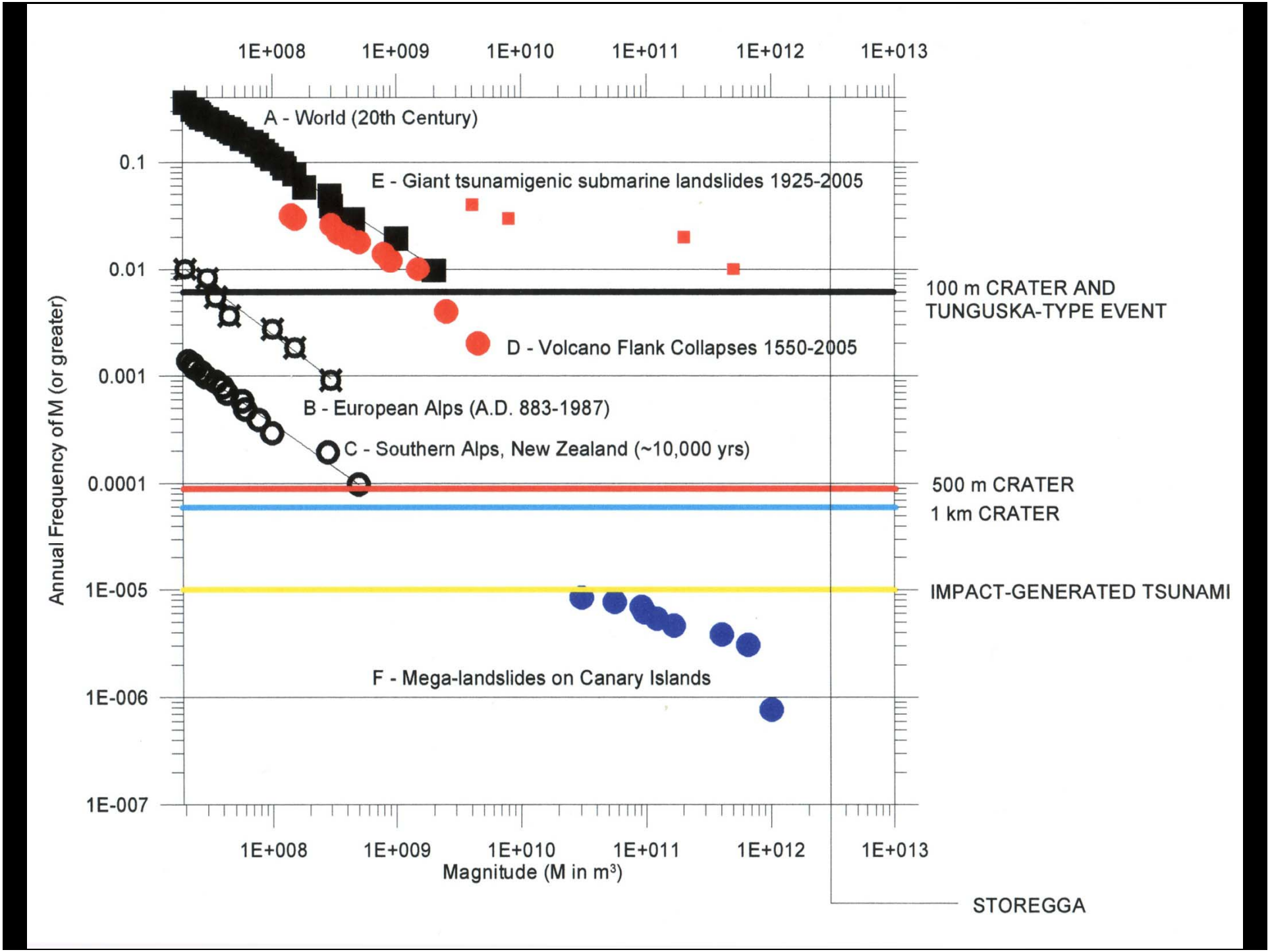
Use of digital terrain models to forecast impact of seal level rise

Rangpur, July 2007

EARTH 270 – DISASTERS AND NATURAL HAZARDS

11 THEMES

1. Processes involved in natural hazards involve energy release, the level of which defines its magnitude
2. Disasters result from energy release from natural processes impacting on humans and human activities
3. Disasters are defined in terms of immediate losses
4. Magnitude and frequency – large magnitude events are less frequent than smaller events
5. How natural is natural ? – the impact of human activities
6. Mitigation 1 – can we prevent them from happening?
7. Mitigation 2 - if not can we design warning systems to minimise impact
8. Mitigation 3 – if not can we build more resistance (e.g., building codes, education)
9. The role of environmental change, in particular climate change in determining the magnitude and frequency of energy release
10. Some places on Earth are inherently more hazardous than others – the geography of hazard
11. Together with population patterns this gives great variation in GeoRisk around the World – the geography of risk


1E+008
1E+009
1E+010
1E+011
1E+012
1E+013
A - World (20th Century)
E - Giant tsunamigenic submarine landslides 1925-2005
D - Volcano Flank Collapses 1550-2005
B - European Alps (A.D. 883-1987)
C - Southern Alps, New Zealand (~10,000 yrs)
F - Mega-landslides on Canary Islands
0.1
0.01
0.001
0.0001
1E-005
1E-006
1E-007
Annual Frequency of M (or greater)
Magnitude (M in m³)
100 m CRATER AND
TUNGUSKA-TYPE EVENT
500 m CRATER
1 km CRATER
IMPACT-GENERATED TSUNAMI
STOREGGA