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

Kensennuma City, Miyagi Prefecture , Japan, March 2011

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UNIVERSITY OF WATERLOO

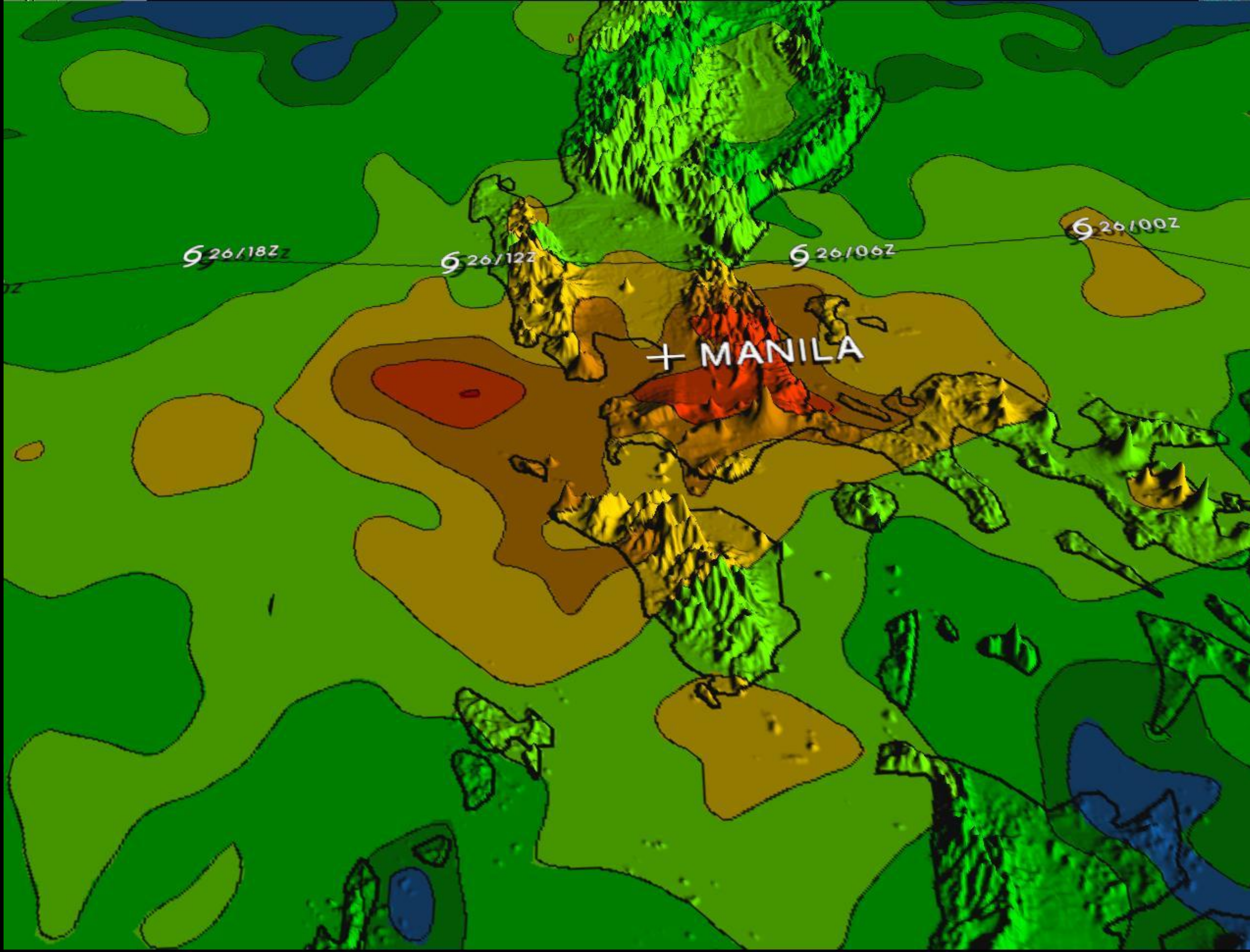
2011 JAPAN TSUNAMI - SITUATION AS OF DECEMBER 8, 2017

DEATHS – 15,894
MISSING – 2,546
TOTAL LIVES LOST – 18,440
FATALITIES + INJURED = 24,596 (75% FATALITY RATE)
DESTROYED HOUSES – 121,772
STILL IN TEMPORARY HOUSING ~34,000

CLIMATE-RELATED NATURAL DISASTERS

Philippine floods, September 2009

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



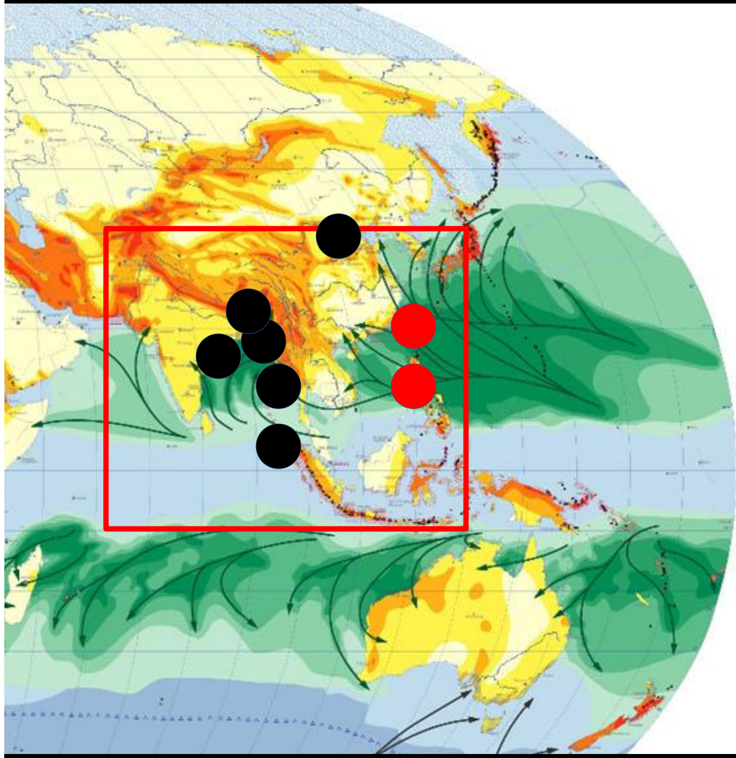
September 21–28, 2009 Rainfall Accumlation (3B42)

50 75 175 275 375 475 575mm

MAJOR NATURAL CATASTROPHES IN 2008 (data from Munch Re)

Date in 2008	Country/Region	Event	Fatalities (incl. Missing)	Overall losses (US$ M)	Insured losses (US$ M)
May	Mayanmar (Burma)	Cyclone Nargis	134,500	4,000	n/a
May	Sichuan, China	Earthquake (M7.9)	88,000	85,000	300
Sept	Caribbean, USA	Hurricane Ike	129	30,000	15,000
Aug-Sept	Caribbean, USA	Hurricane Gustav	100	10,000	5,000

Cyclone Nargis, Irrawaddy Delta, May 2008



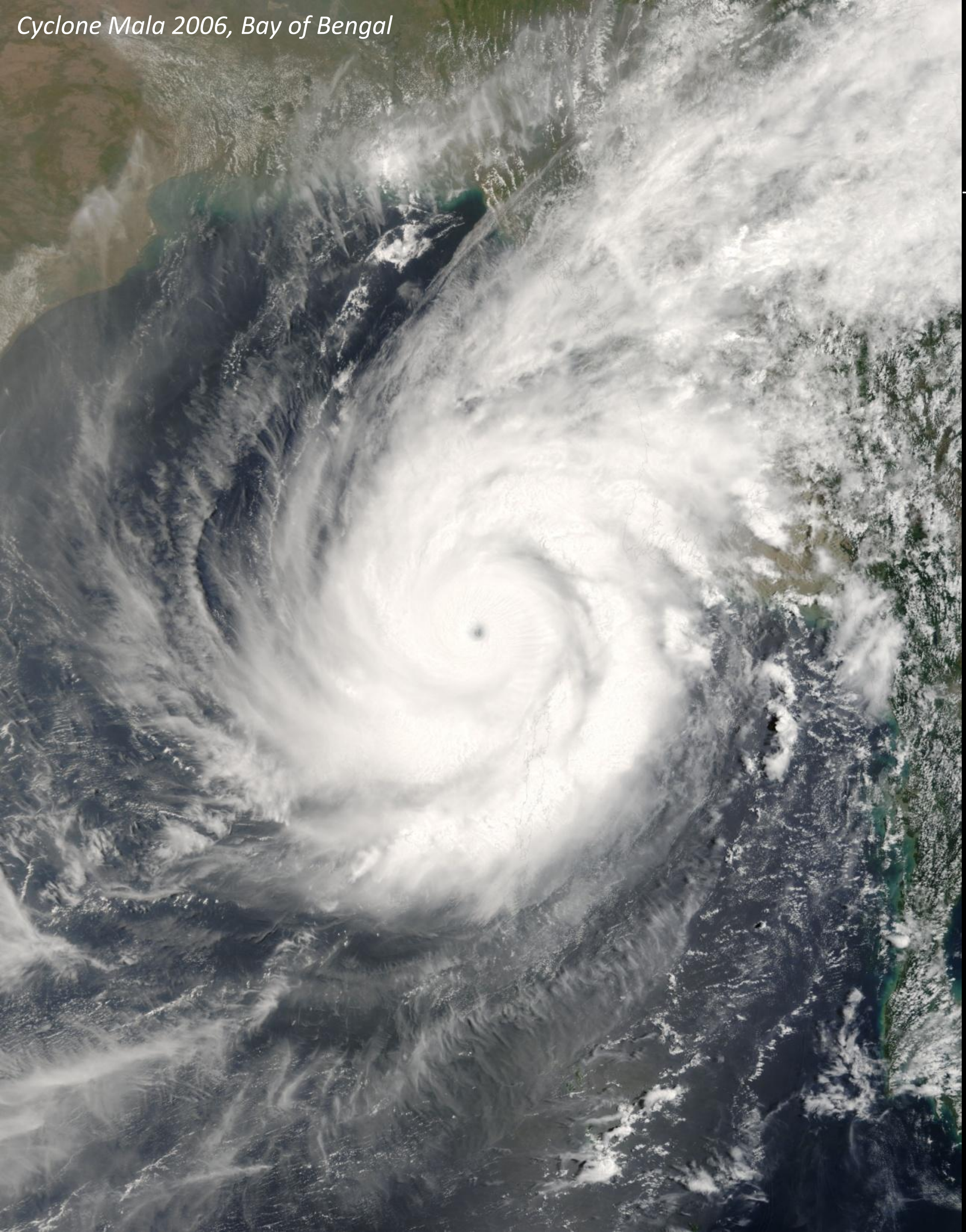
	DATE	HAZARD	COUNTRY	DEATHS
1	1970/11/14	Hurricane (Cyclone Bhola)	Bangladesh	400,000
2	1976/07/28	Earthquake (Tangshan Earthquake)	China	255,000
3	2004/12/26	Earthquake & Tsunami	South Asia	246,000
4	1991/04/30	Hurricane (Cyclone Gorky)	Bangladesh	140,000
5	2008/05/2-5	Hurricane (Cyclone Nargis)	Myanmar	134,500

DISASTERS IN ASIA WITH HIGHEST DEATH TOLLS SINCE 1970

NATURAL HAZARDS OF CONCERN IN EARTH 270 (v. 2017)

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)



1. 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**)

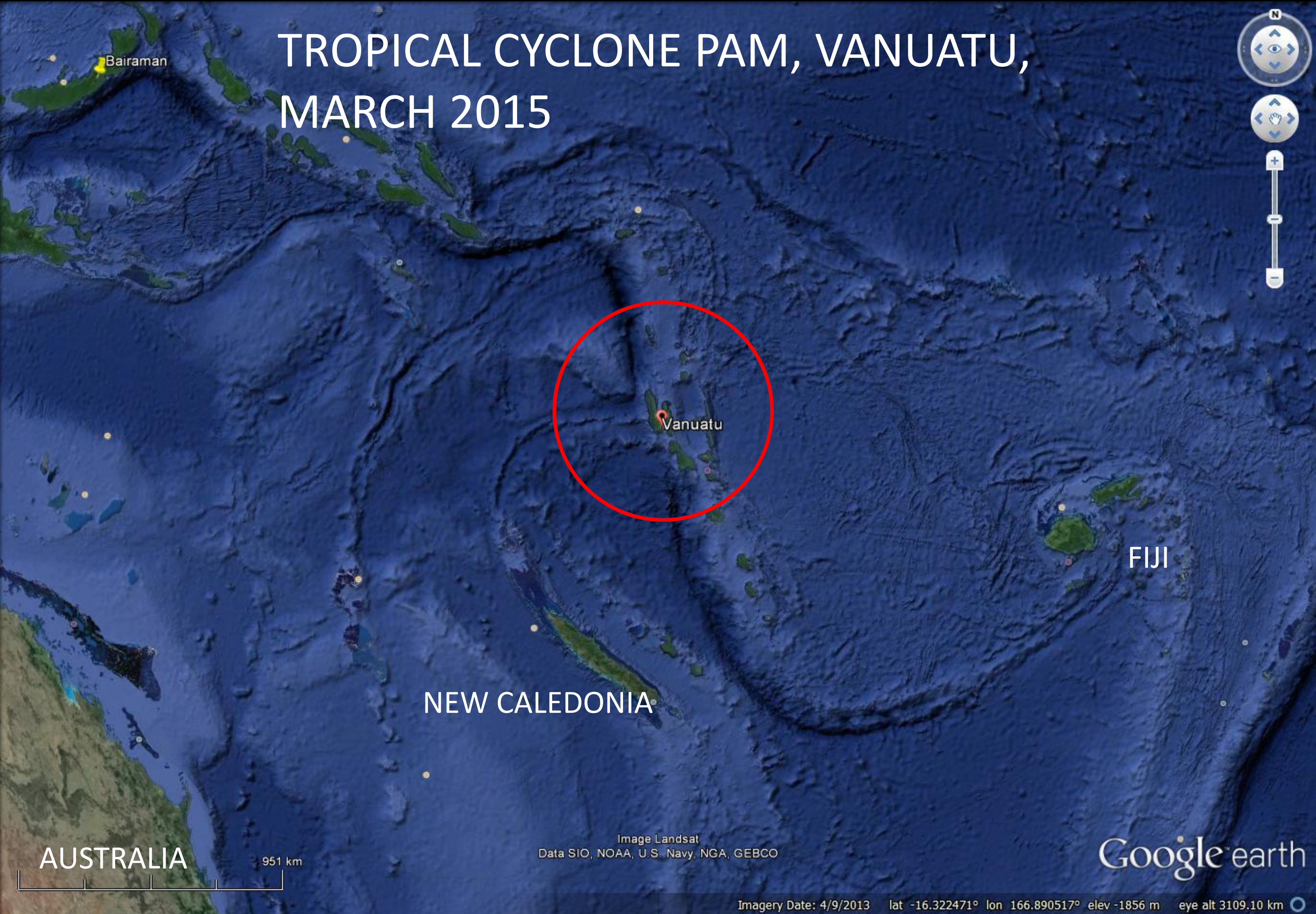
•Intensity a function of sea temperature

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

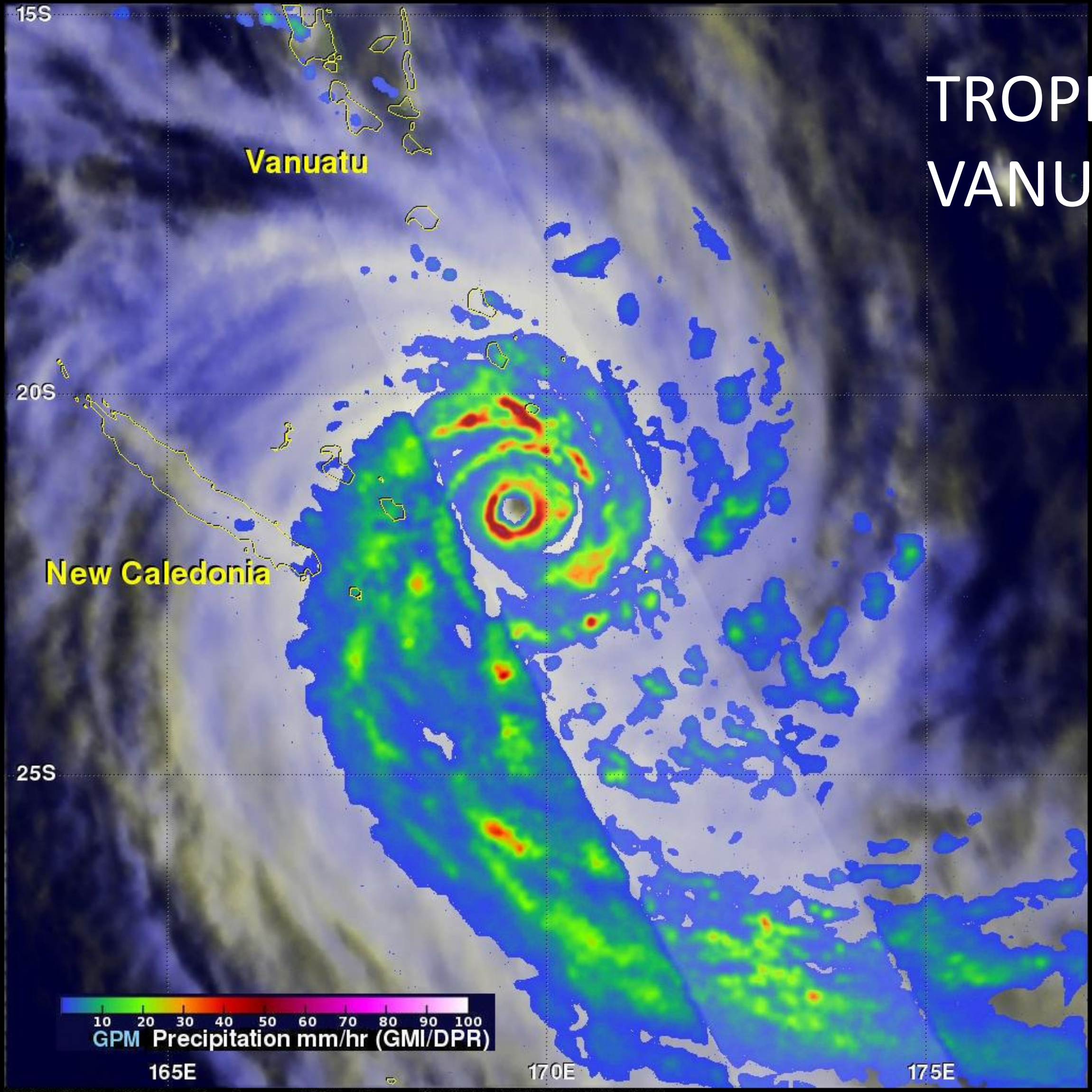
•Create storm surges along coasts (in excess of 6m)

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

TROPICAL CYCLONE PAM, VANUATU, MARCH 2015

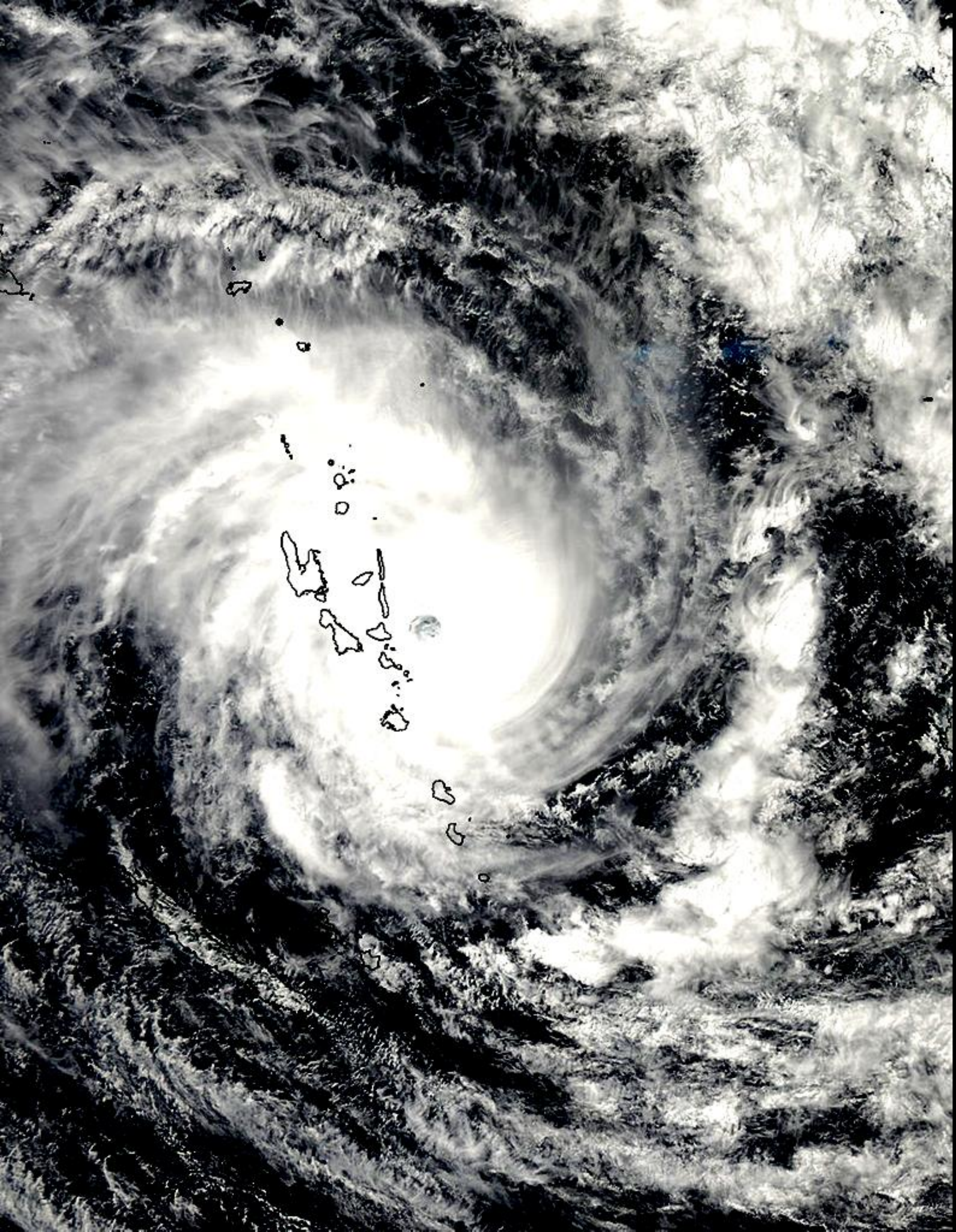


NASA-JAXA's GPM core satellite captured rain rates in Tropical Cyclone Pam at 03:51 UTC (2:51 p.m. local time) on March 14, 2015. Heaviest rain was falling at 50 mm per hour (red).



3/14/2015 0351Z Cyclone PAM (Over 0400Z MTSAT VIS/IR)

TROPICAL CYCLONE PAM, VANUATU, MARCH 2015

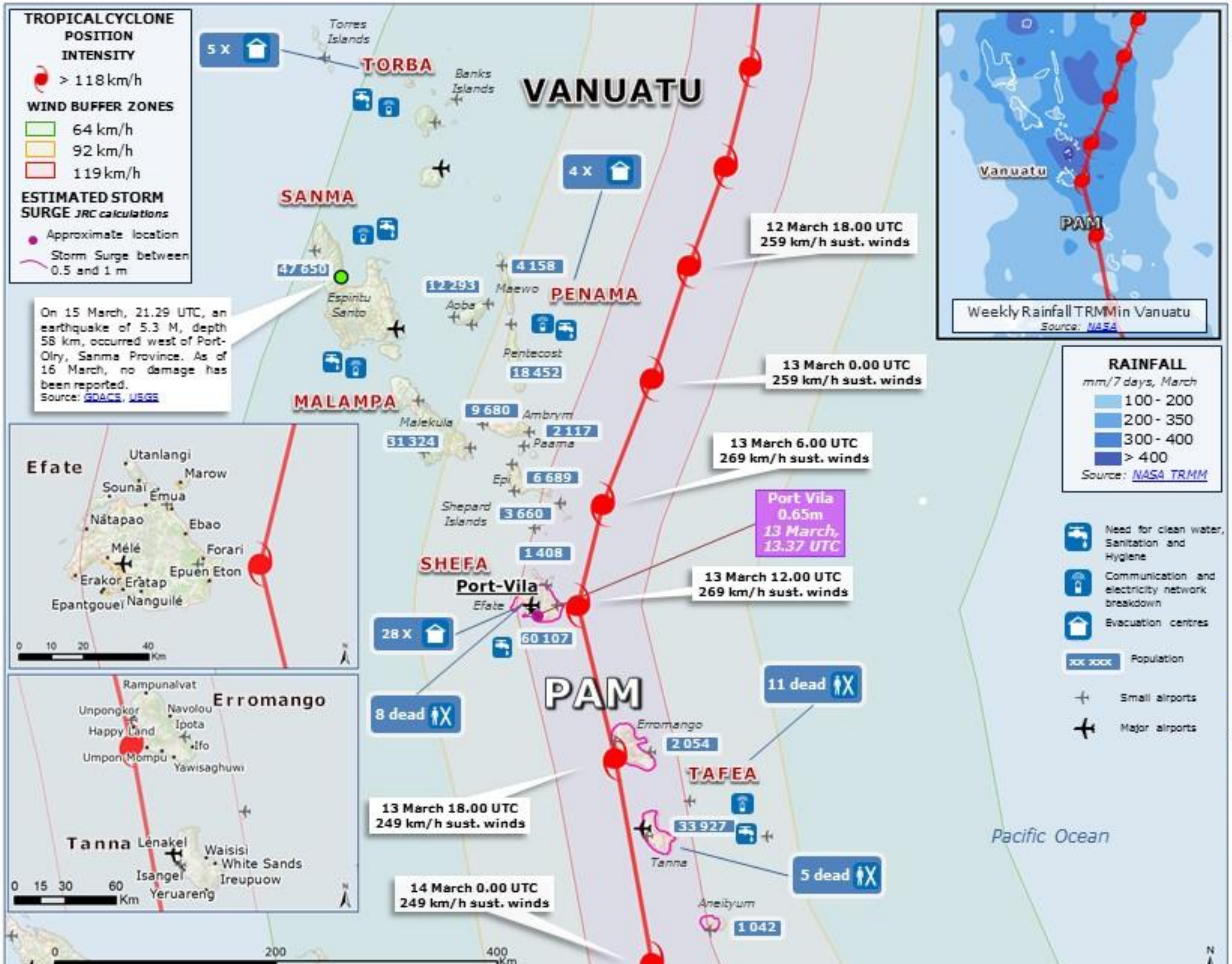


TROPICAL CYCLONE PAM, VANUATU, MARCH 2015

NASA's Aqua satellite captured a visible image of Pam on Friday, March 13, 2015 at 02:20 UTC. Pam's wide eye just east of Vanuatu's islands and thunderstorms wrapped tightly around the center.
Image Credit:
NASA Goddard MODIS Rapid Response Team

Emergency Response Coordination Centre (ERCC) – ECHO Daily map | 16/03/2015
Vanuatu - Tropical Cyclone PAM

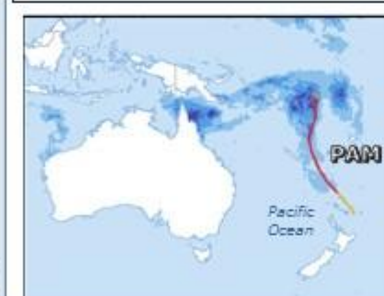
European Commission | Humanitarian Aid and Civil Protection



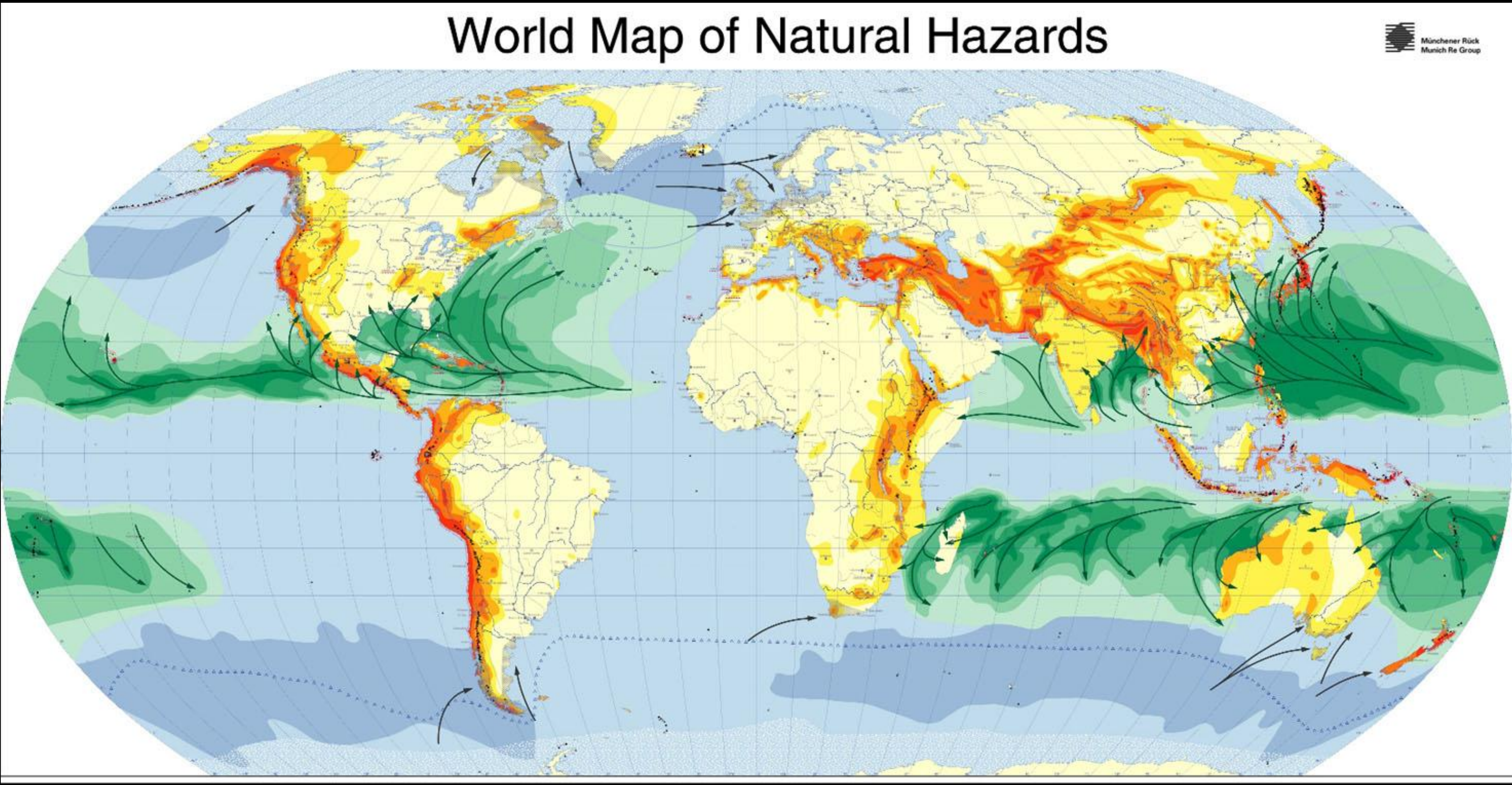
SITUATION

- The Government of Vanuatu reports 24 people dead. 3 300 people are sheltered in 37 evacuation centres on Efate Island, and Torba and Penama provinces. There is urgent need for more shelters, as well as clean water, sanitation and hygiene supplies for those left homeless and in evacuation centres. Worst affected are the provinces of Shefa, Tafea, Malampa and Penama; State of Emergency in Shefa; likely to be extended to other provinces (including Tafea). Total or near-total destruction of buildings and crops in Shepherd Islands.
- The airport in Port Vila has reopened, allowing military aircraft to bring in relief supplies and personnel.
- Telecommunication networks are down throughout the country.
- The National Disaster Management Office (NDMO) is coordinating the response, activated the National Emergency Operations Centre (NEOC). The Government is coordinating and collating the various offers of assistance. The Vanuatu Humanitarian Team (VHT) is supporting the Government and is a collaboration between Vanuatu based NGOs, the Red Cross, UN and government agencies.
- Several organizations are stepping up relief efforts (WFP, UNICEF, OXFAM, Save the Children, Vanuatu Red Cross, World Vision, ADRA, CARE). An UNDAC team arrived on 16 March 2015.
- As of 16 March 2015, according to the Food Security and Agriculture Cluster's Initial Briefing, crops across the country are severely damaged; banana crops and leafy vegetable crops are likely to have been destroyed. Loss of livestock and destroyed fisheries infrastructure have also been reported.
- ECHO expert from RSO Bangkok arrived in Port Vila on 16 March 2015. A second expert is expected to land tomorrow.

Sources: *ECHO, OCHA (1, 2, 3), GDACS, Vanuatu Government, Media*

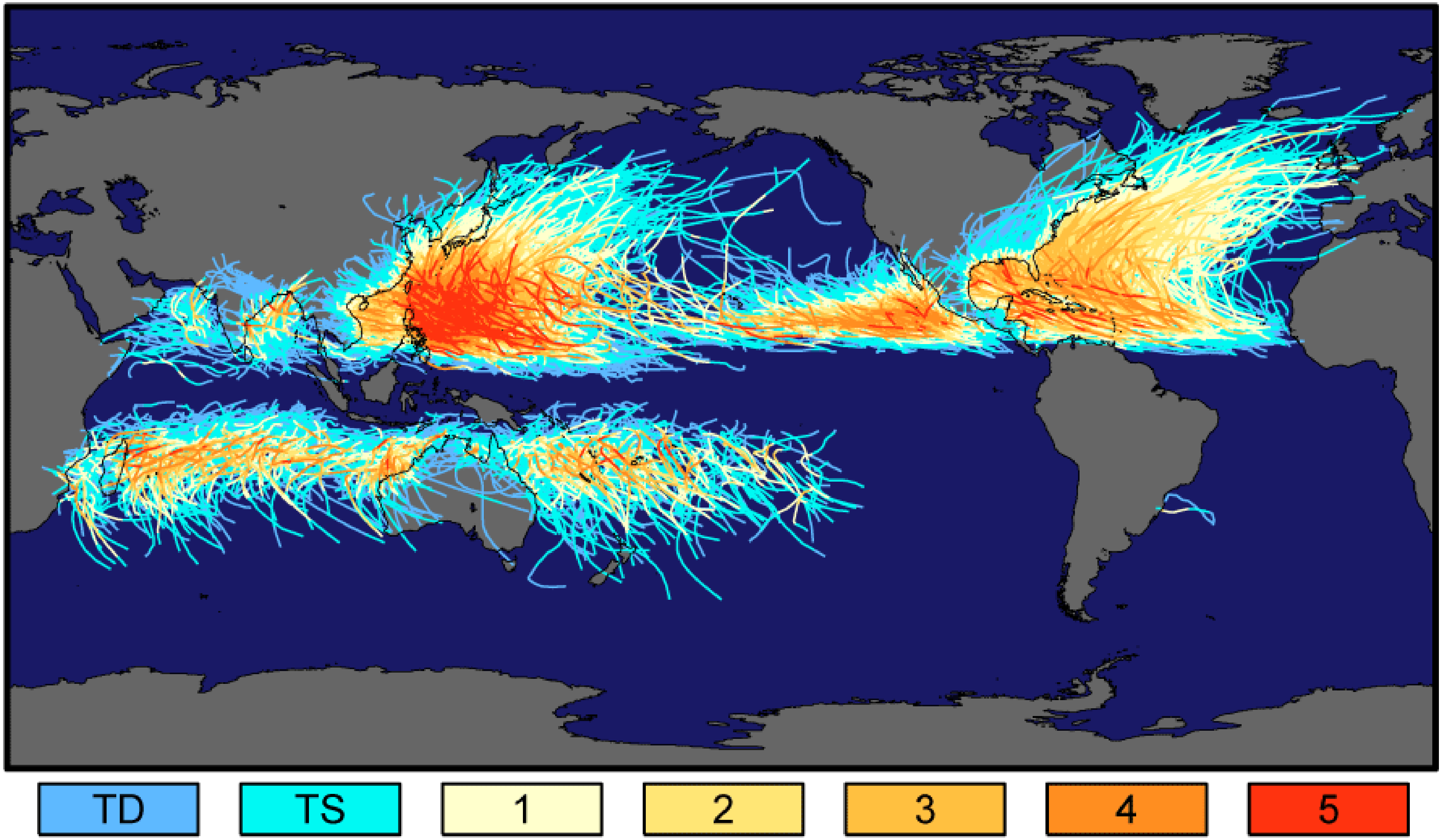


WORLD MAP OF NATURAL HAZARDS DEVELOPED BY THE MUNICH RE-INSURANCE COMPANY



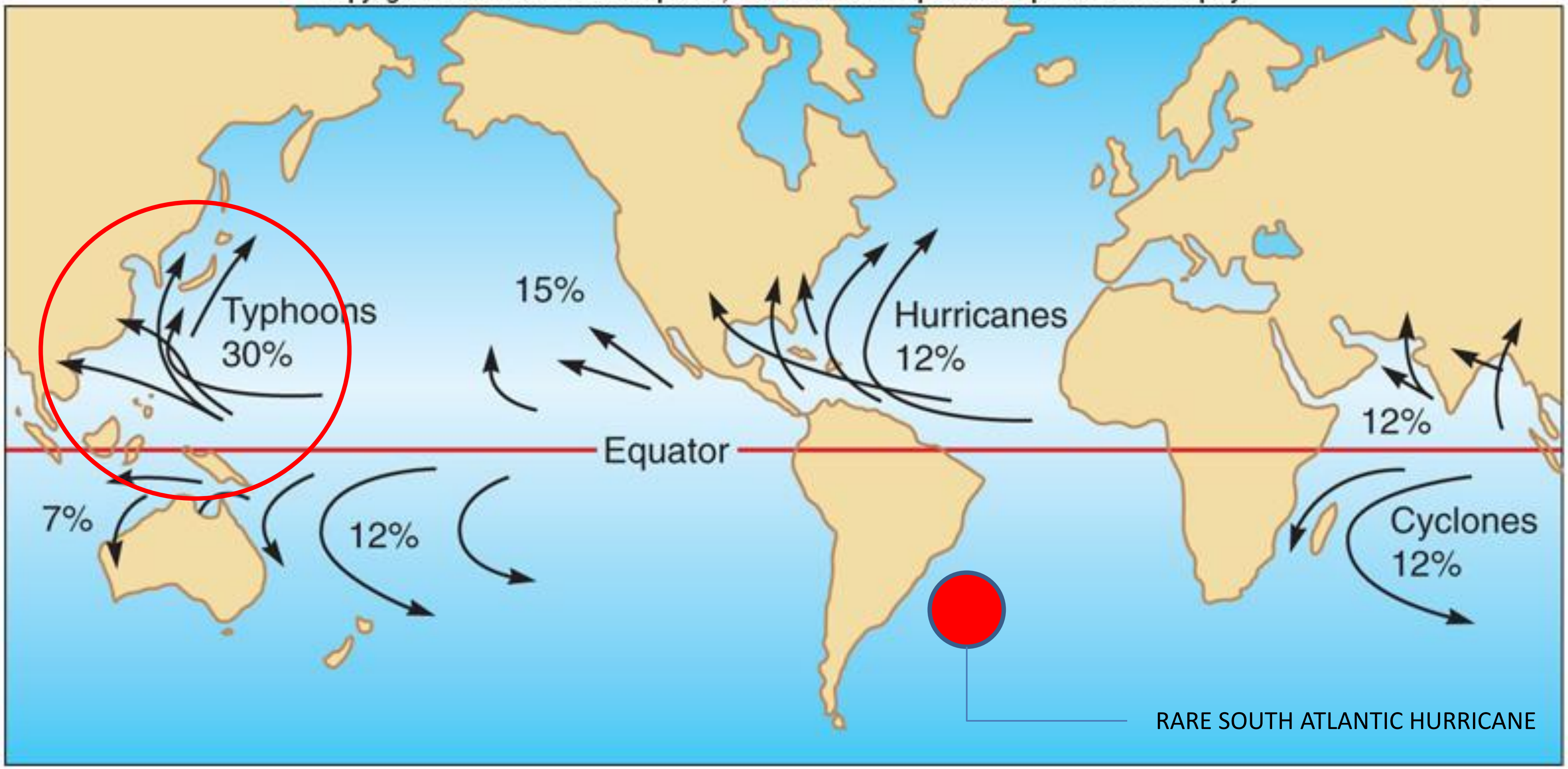
A world map of the distribution of natural hazard processes independent of human activity and distribution of population

Tracks and Intensity of All Tropical Storms



Saffir-Simpson Hurricane Intensity Scale

HURRICANES, TYPHOONS AND TROPICAL CYCLONES



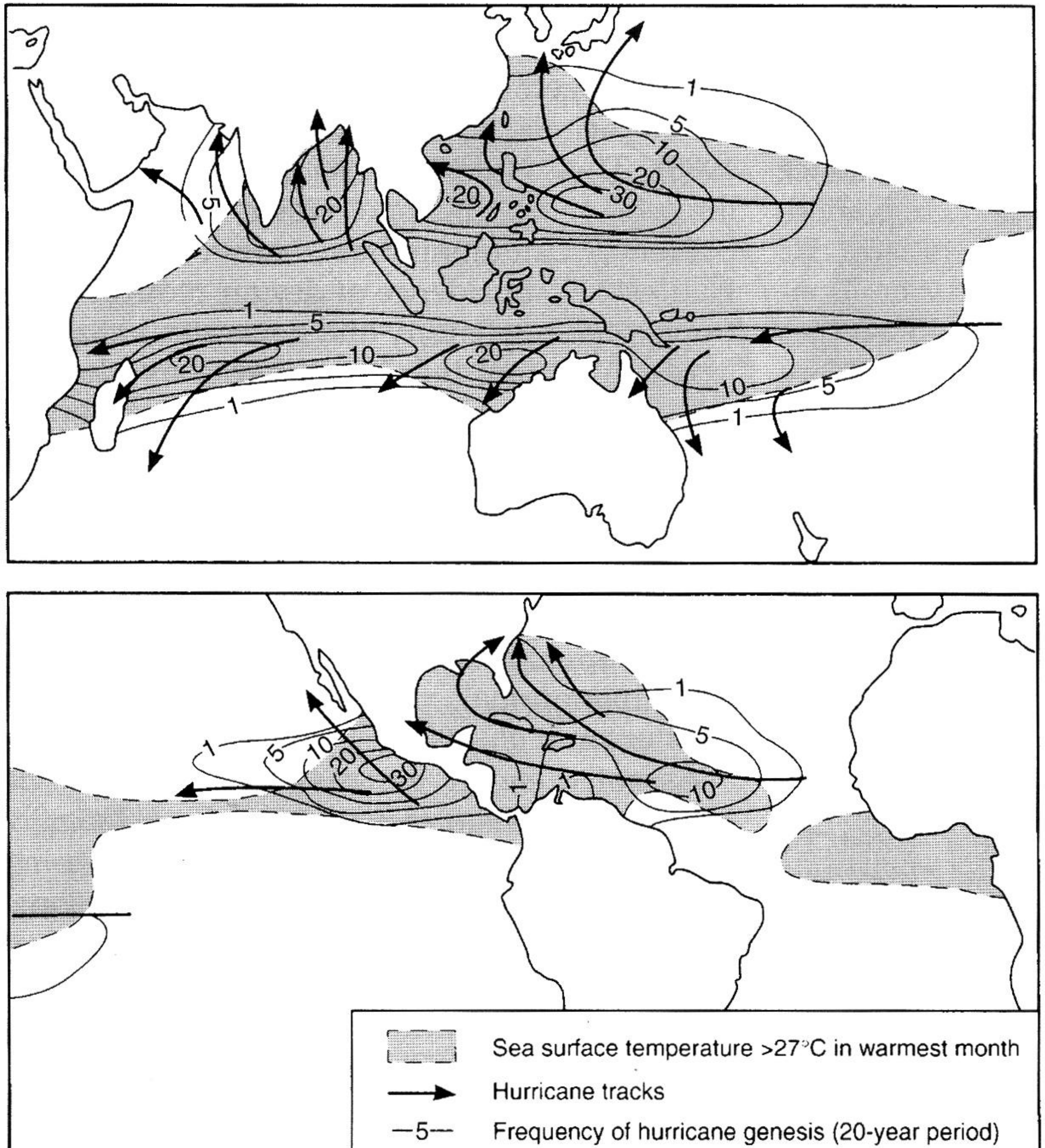
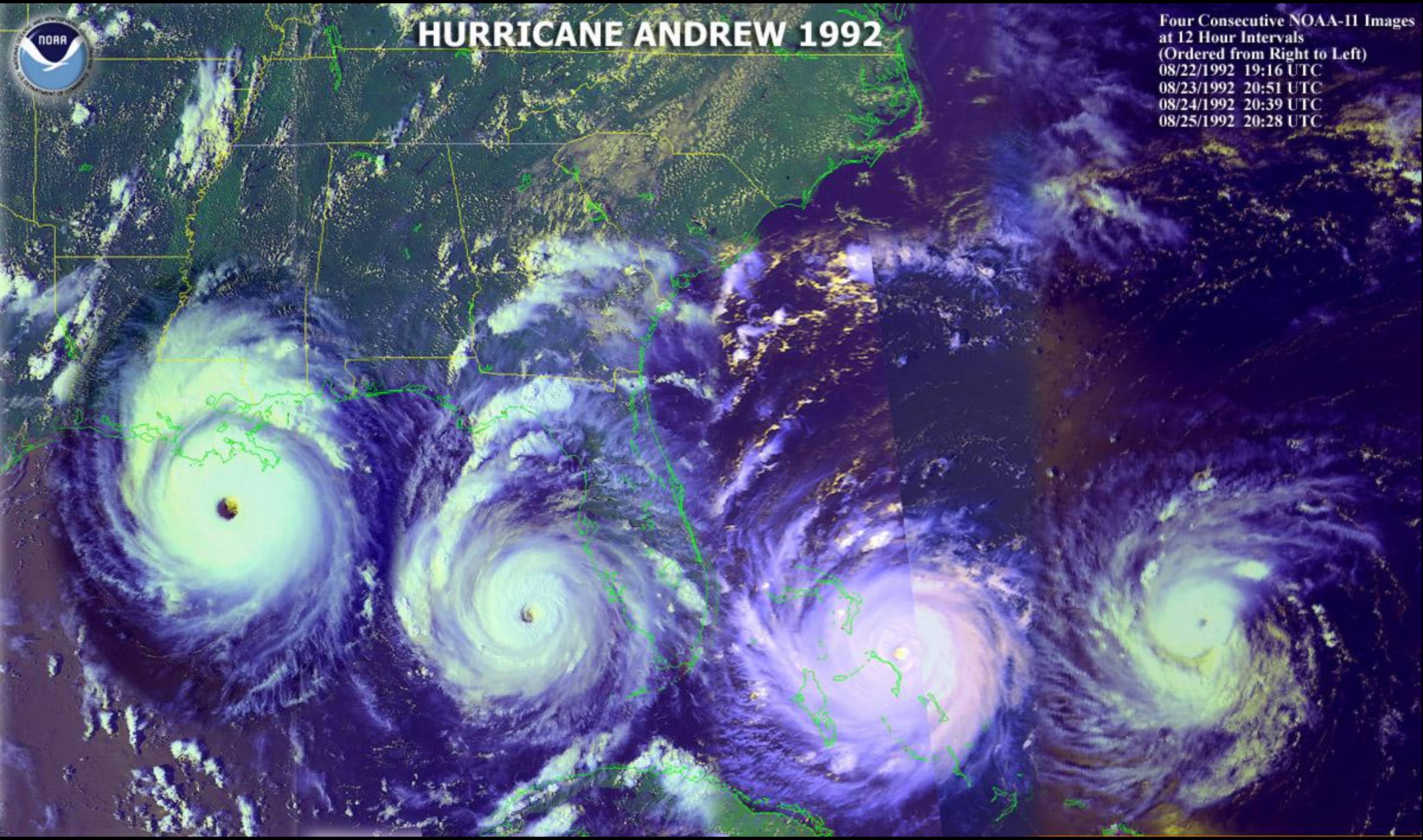


FIGURE 2.10 Contours of hurricane genesis frequency (in a 20-year period), showing the main formation basins. The main hurricane tracks, and areas that are warmer than 27°C in their warmest month, are also shown. (Reproduced from *Atmospheric Processes and Systems* by Russell D. Thompson, 1998 with permission from Routledge)

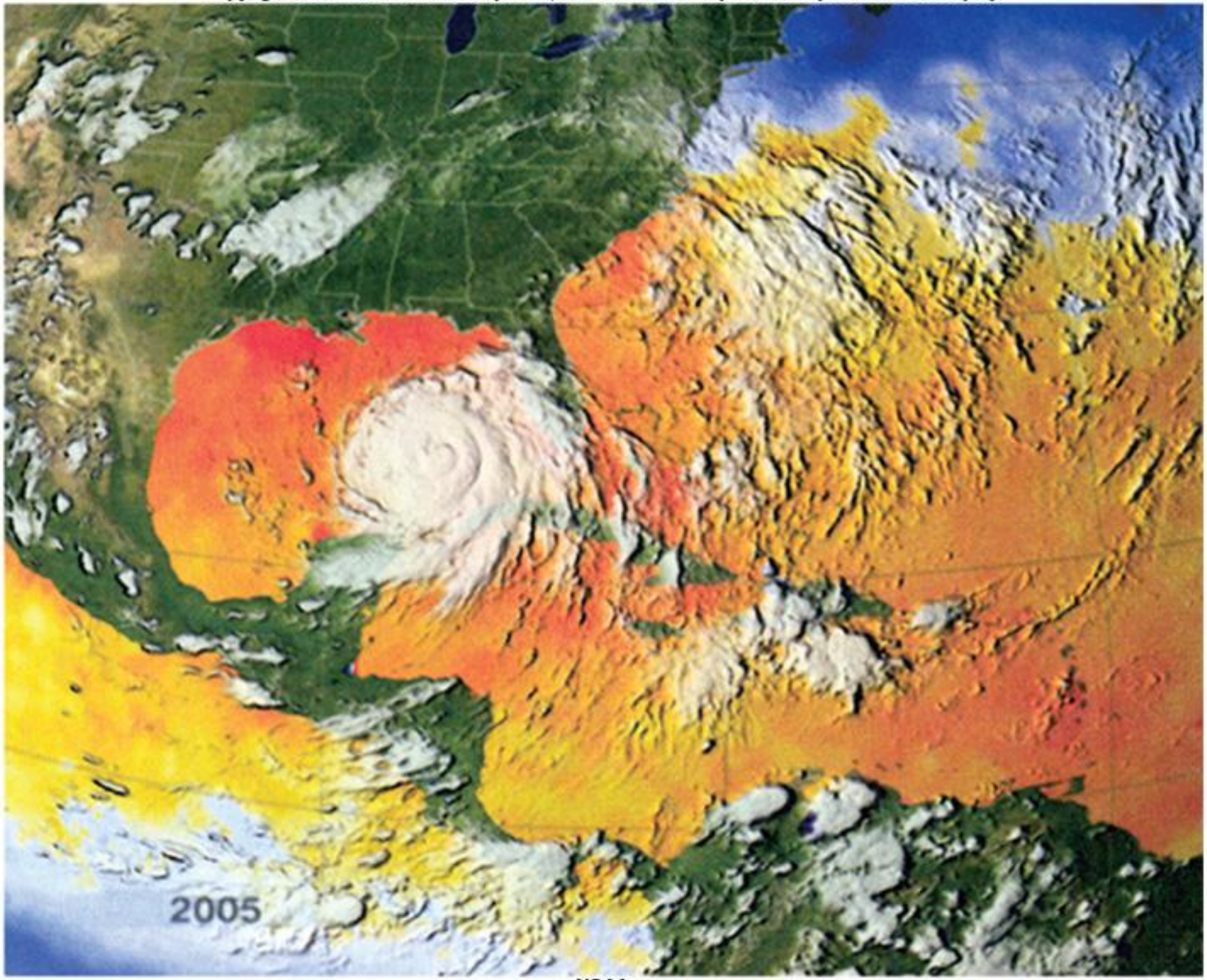


Third most powerful hurricane to hit USA in twentieth century; reached Category 5; only surpassed by Katrina (2005) in terms of damage costs (ca. $30 B)

TABLE 13.2

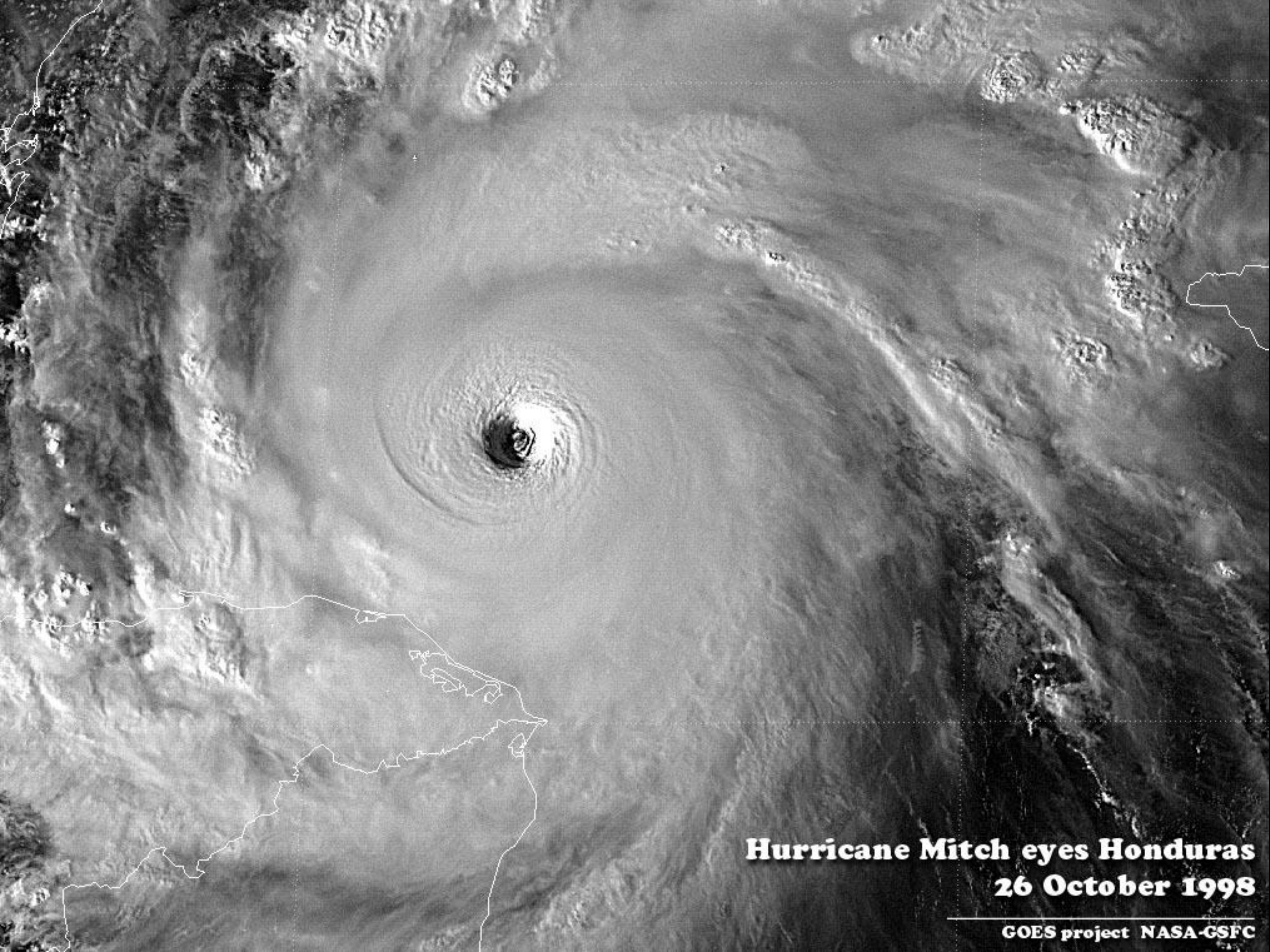
The 13 Deadliest Hurricanes in the United States Since 1990

When	Where	Number of Deaths
8 September 1900	Galveston, Texas	8,000
mid-September 1928	South Florida—Lake Okeechobee	2,500
29 August 2005	New Orleans, LA/Mississippi	1,836
mid-September 1919	Florida Keys/Corpus Christi, Texas	600
21 September 1938	New England, especially Rhode Island	600
2 September 1935	Florida Keys	408
27 June 1957	Hurricane Audrey—Morgan City, LA	390
14–15 September 1944	East Coast—Virginia to Massachusetts	390
mid-September 1926	Miami, Florida/Alabama	372
21 September 1909	Grand Isle, Louisiana	350
17 August 1915	Galveston, Texas	275
29 September 1915	New Orleans, Louisiana	275
17–18 August 1969	Hurricane Camille—Mississippi	256

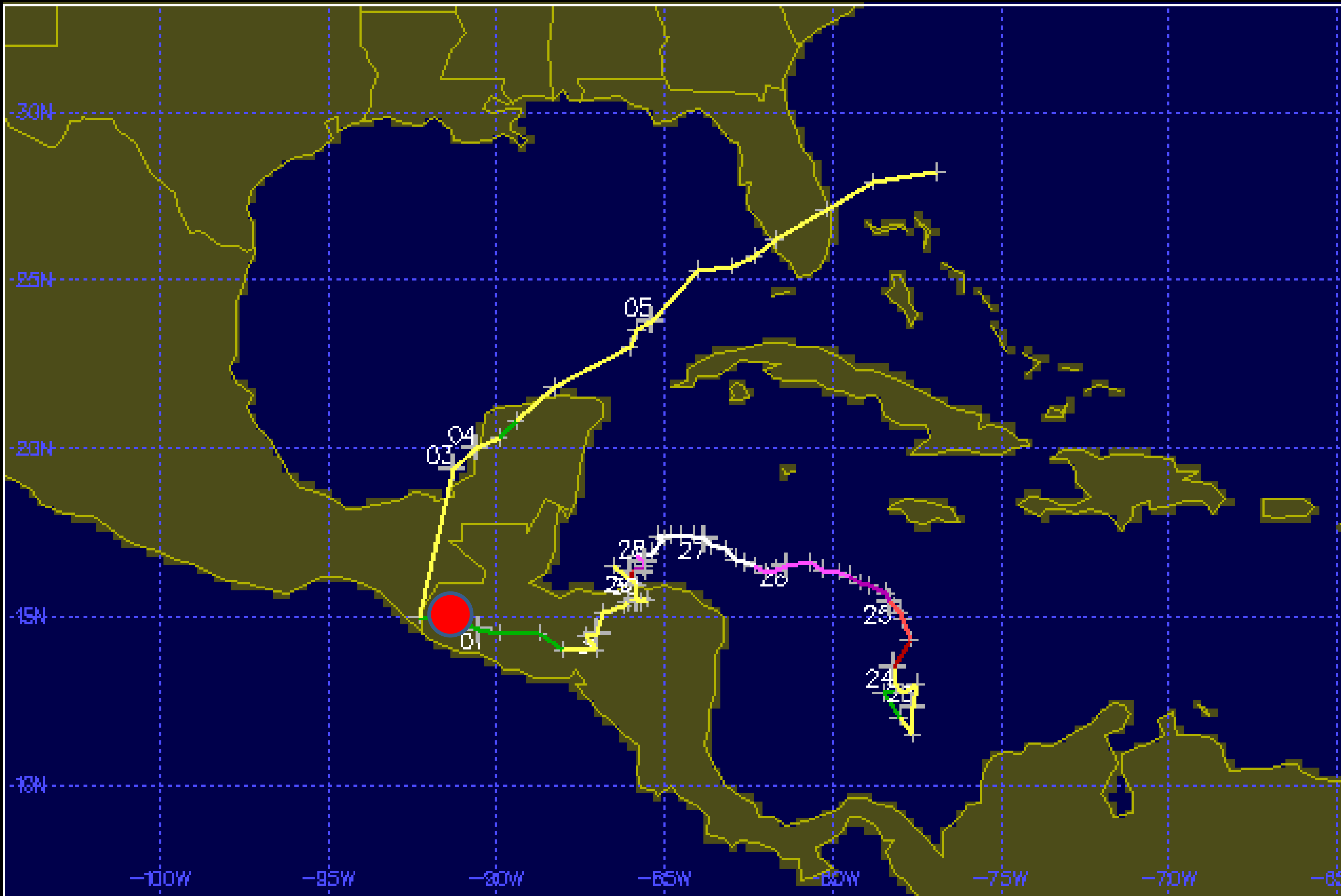


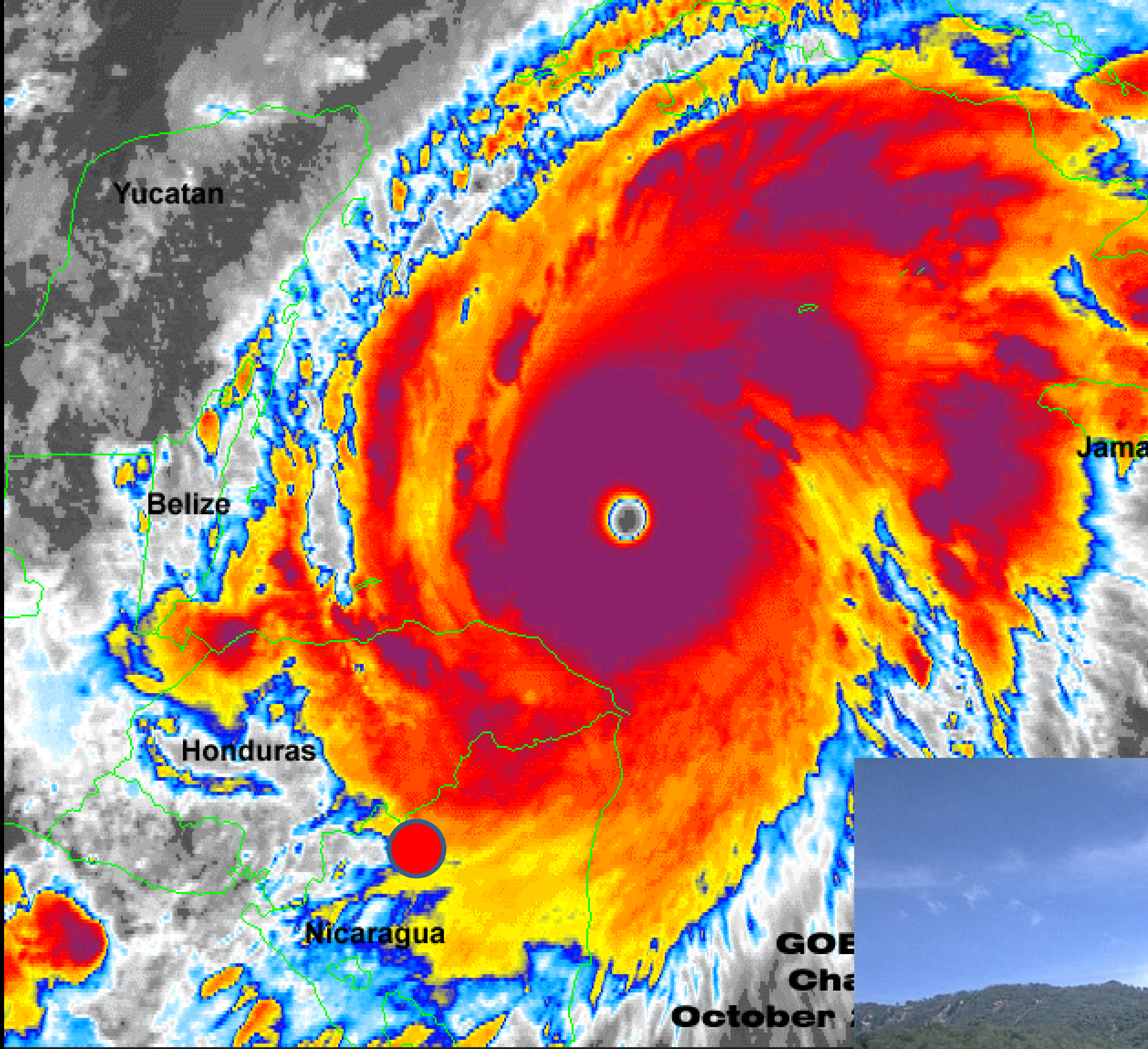
NOAA

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


Hurricane Mitch eyes Honduras
26 October 1998
GOES project NASA-GSFC

Hurricane MITCH 22 OCT–05 NOV 1998





CASITA VOLCANO LANDSLIDE DISASTER (NICARAGUA) DURING HURRICANE MITCH (1,650 deaths)

Casita Volcano rockslide-debris flow, Nicaragua, 1998

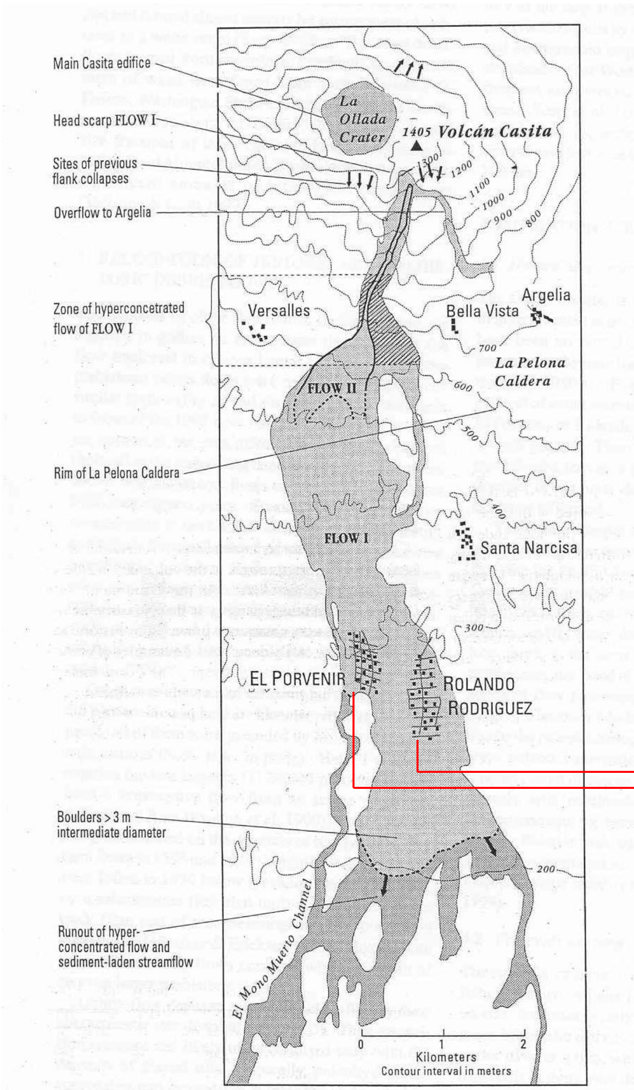
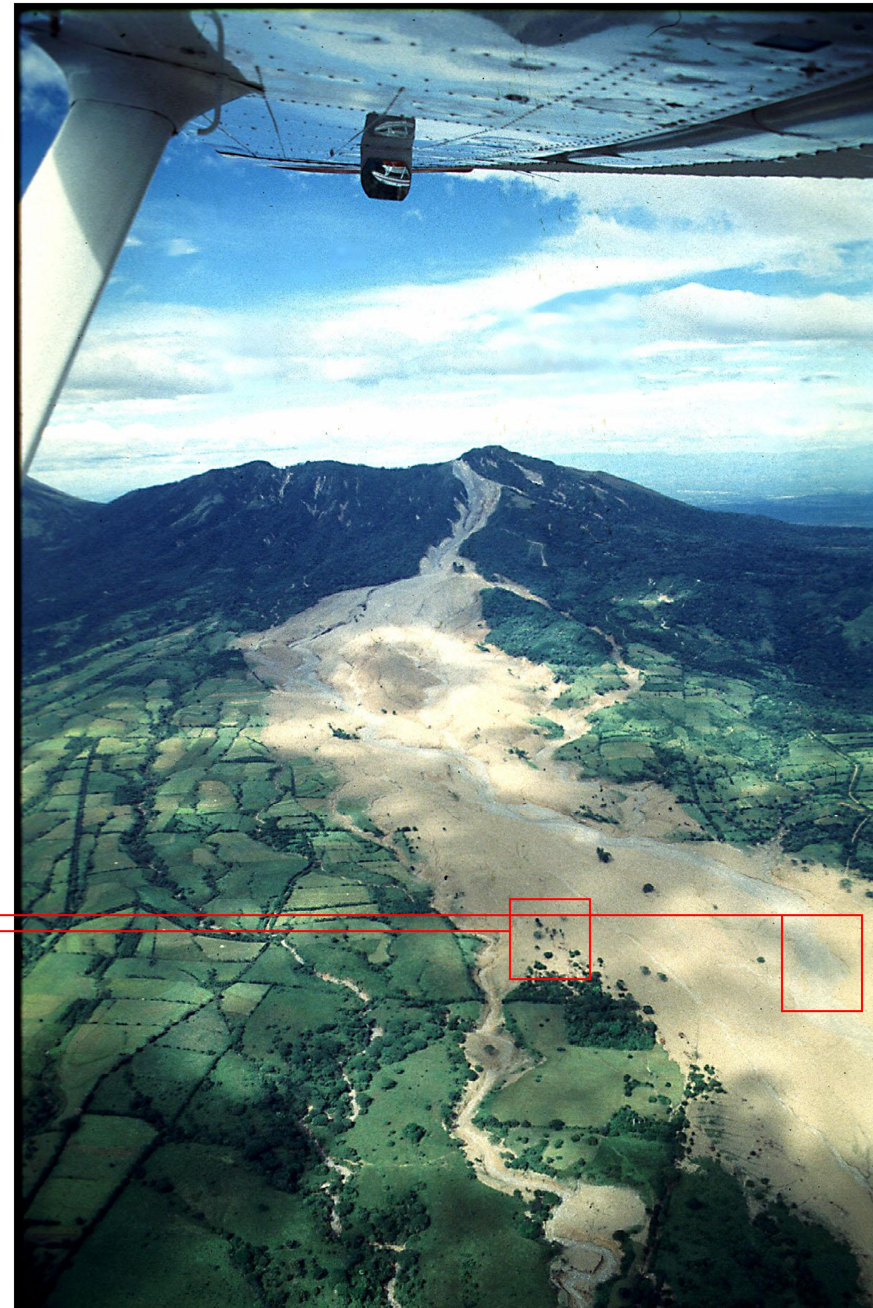


Figure 4. Map of 1998 Casita debris flow.

After Scott (2000), Fig. 4



Casita Volcano rockslide-debris flow, Nicaragua, 1998

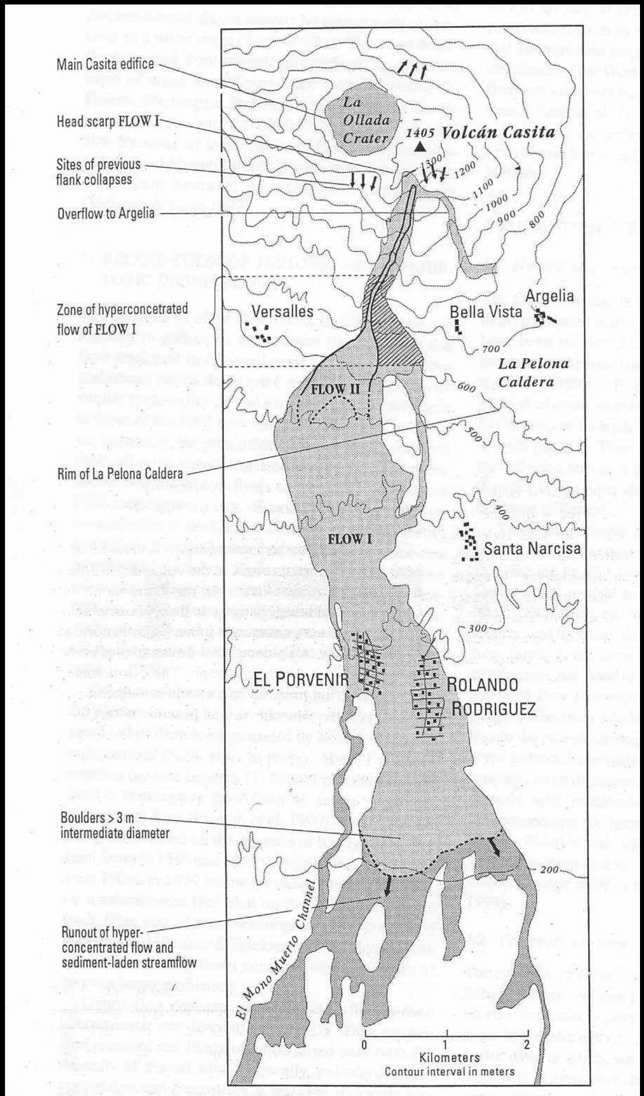
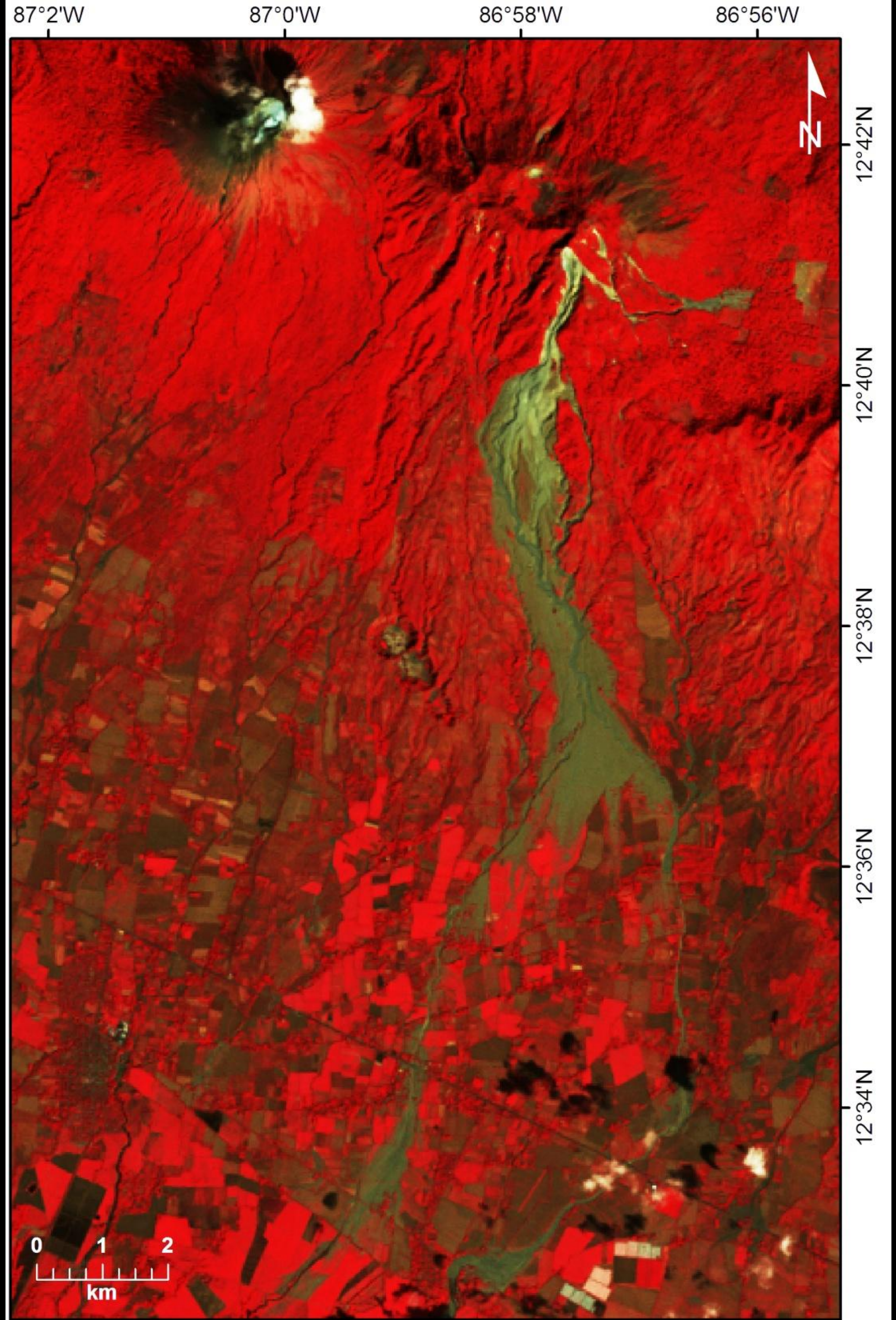
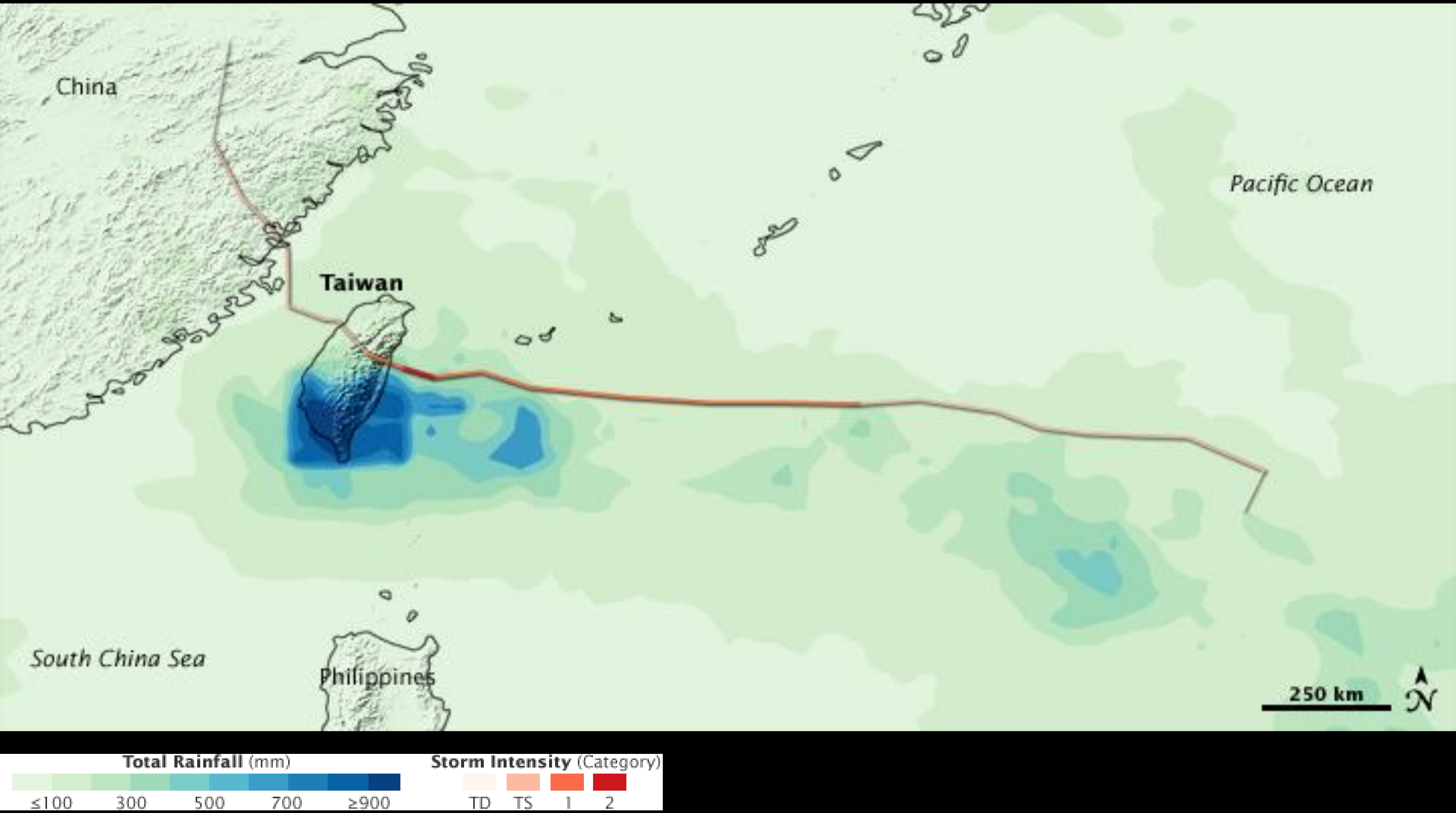


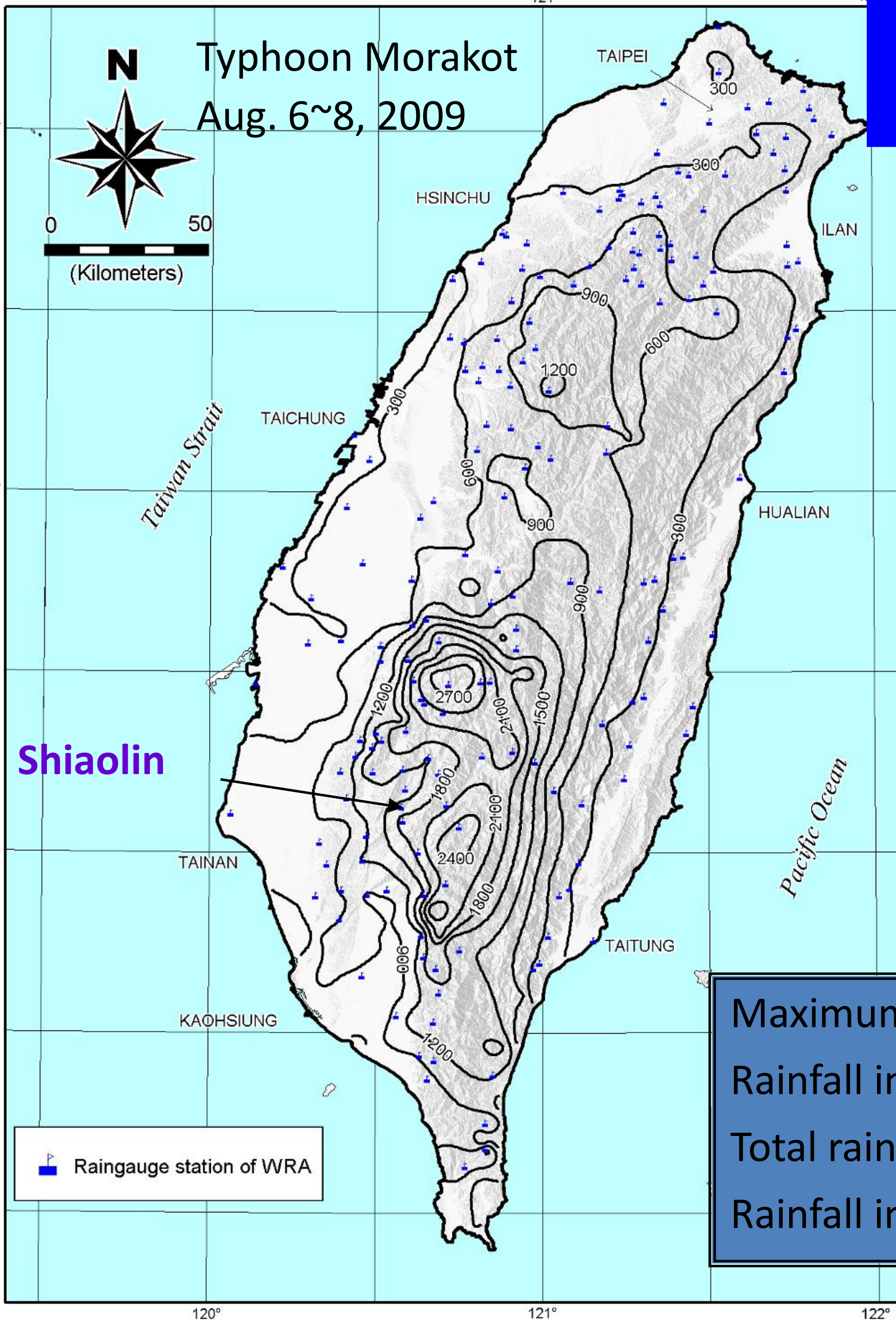
Figure 4. Map of 1998 Casita debris flow.

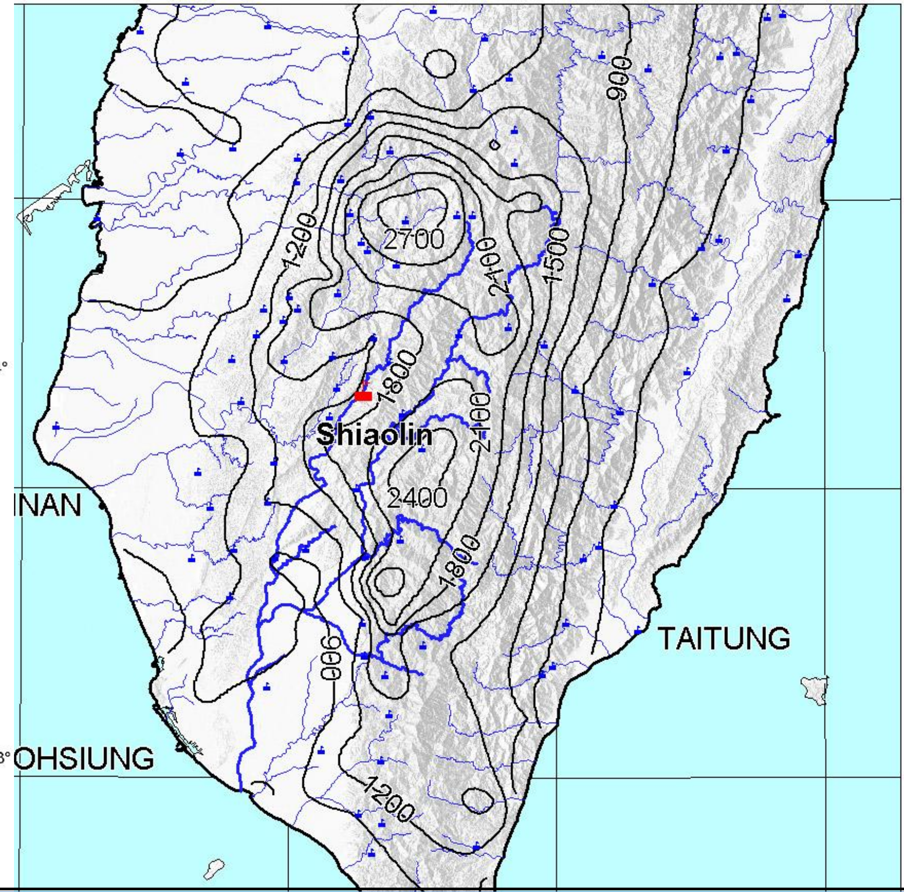


MORAKOT: A SLOW MOVING TYPHOON IN THE WEST PACIFIC, AUGUST 2009



Total Rainfall of Morakot
(Aug. 5~10, 2009)



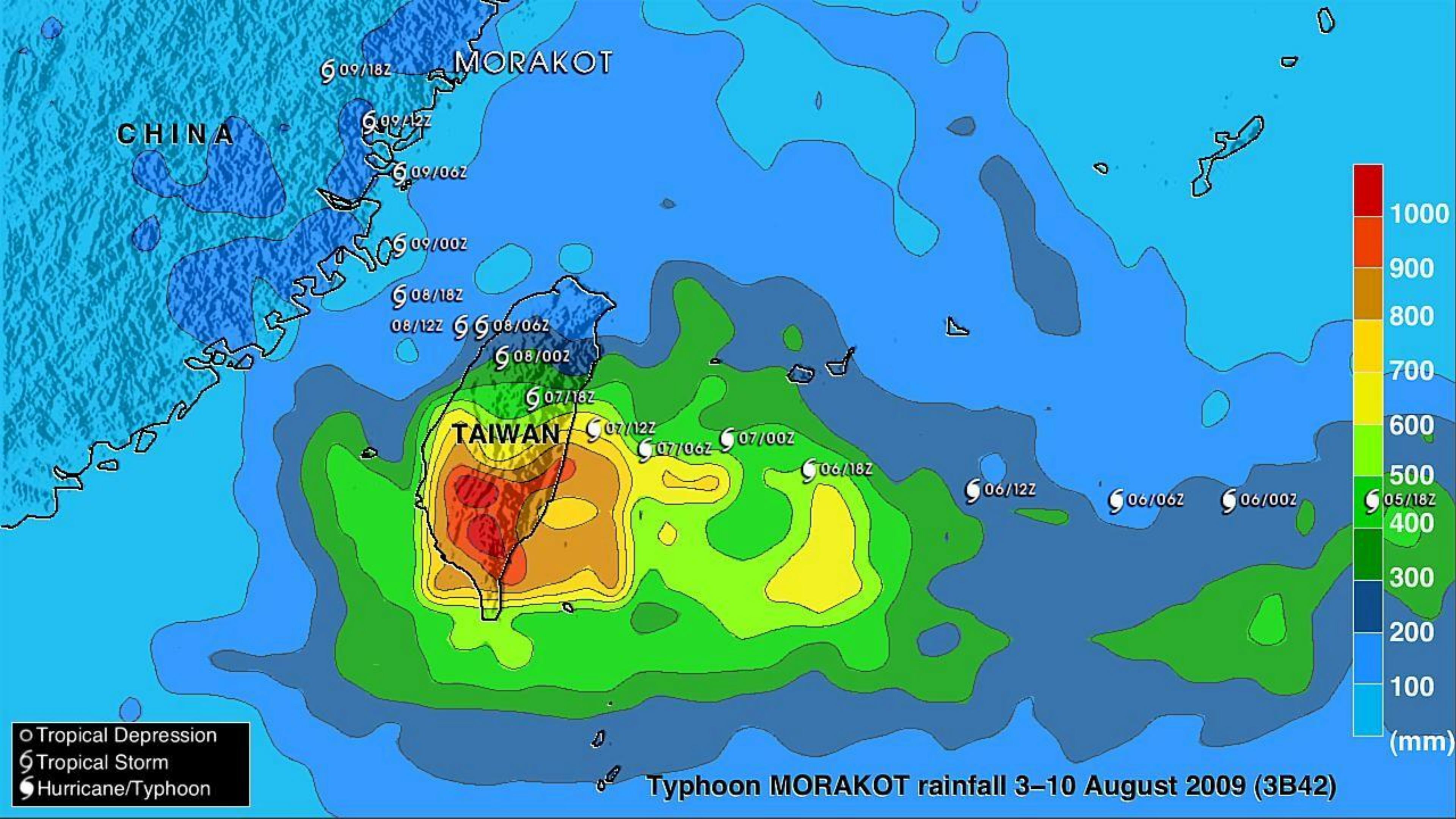


Maximum total rainfall: 2884 mm at Alishan station.

Rainfall intensity at Akishan: 123 mm/hr.

Total rainfall at Shiaolin: 1600 mm.

Rainfall intensity at Shiaolin~ 116 mm/hr.



The TRMM satellite measured almost half of the entire southern half of the island has in excess of 600 mm (shown in yellow shading) of rain. Within that are two areas in excess of 1000 mm (shown in red on the image) along the western slopes of the central mountain range.

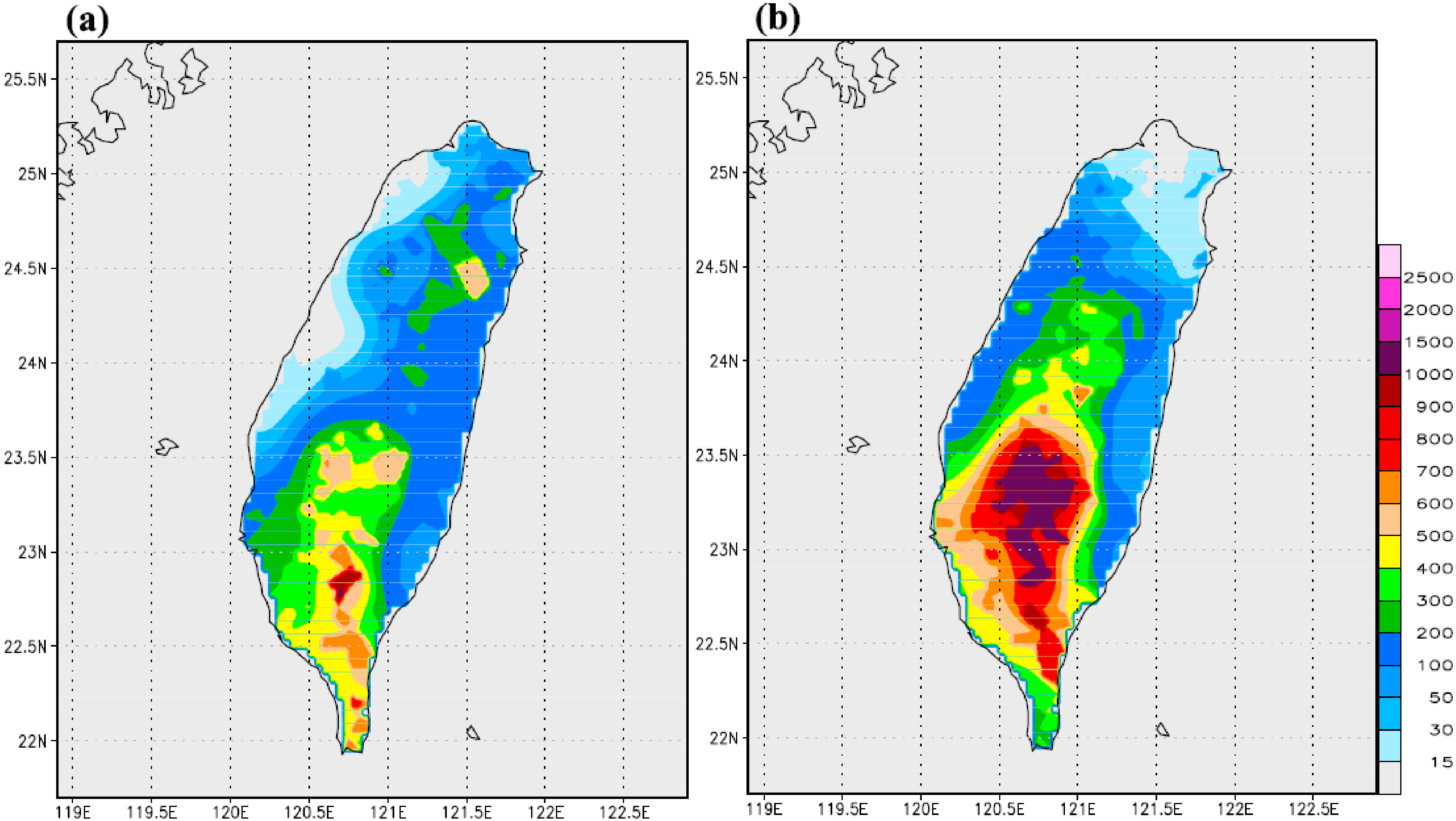


Figure 2. The 24 h observed rainfall (mm) accumulated (a) from 0000 UTC 7 August to 0000 UTC 8 August and (b) from 0000 UTC 8 August to 0000 UTC 9 August 2009.

Key features of Typhoon Morakot - a) most devastating weather event in Taiwan in last 50 years ($500 M damage; 700 deaths in flooding and landslides] b) Translation speed 20 km/hr > as it approached Taiwan slowed to 10 km/hr then further slowed to 5 km/hr c) Overall duration 64 h d) resulted in massive record-breaking rainfall – several stations recorded rainfall > 3000 mm in the period 6-9 August (max 24 hr rain ~ 800 mm – record for Waterloo 92 mm in 1991) : Data from Chien and Kuo (2011).


Air photo taken from helicopter by Mr. Chi.

Photos provided by C.T. Cheng.


Area: **278** Hectares
Average slope: **21** degrees
(at upper and middle section)
Slope height: **900** m
Death: ~**500**
FORMOSAT2 Aug. 17, 2009

Destruction of Shiaolin - ~500 deaths

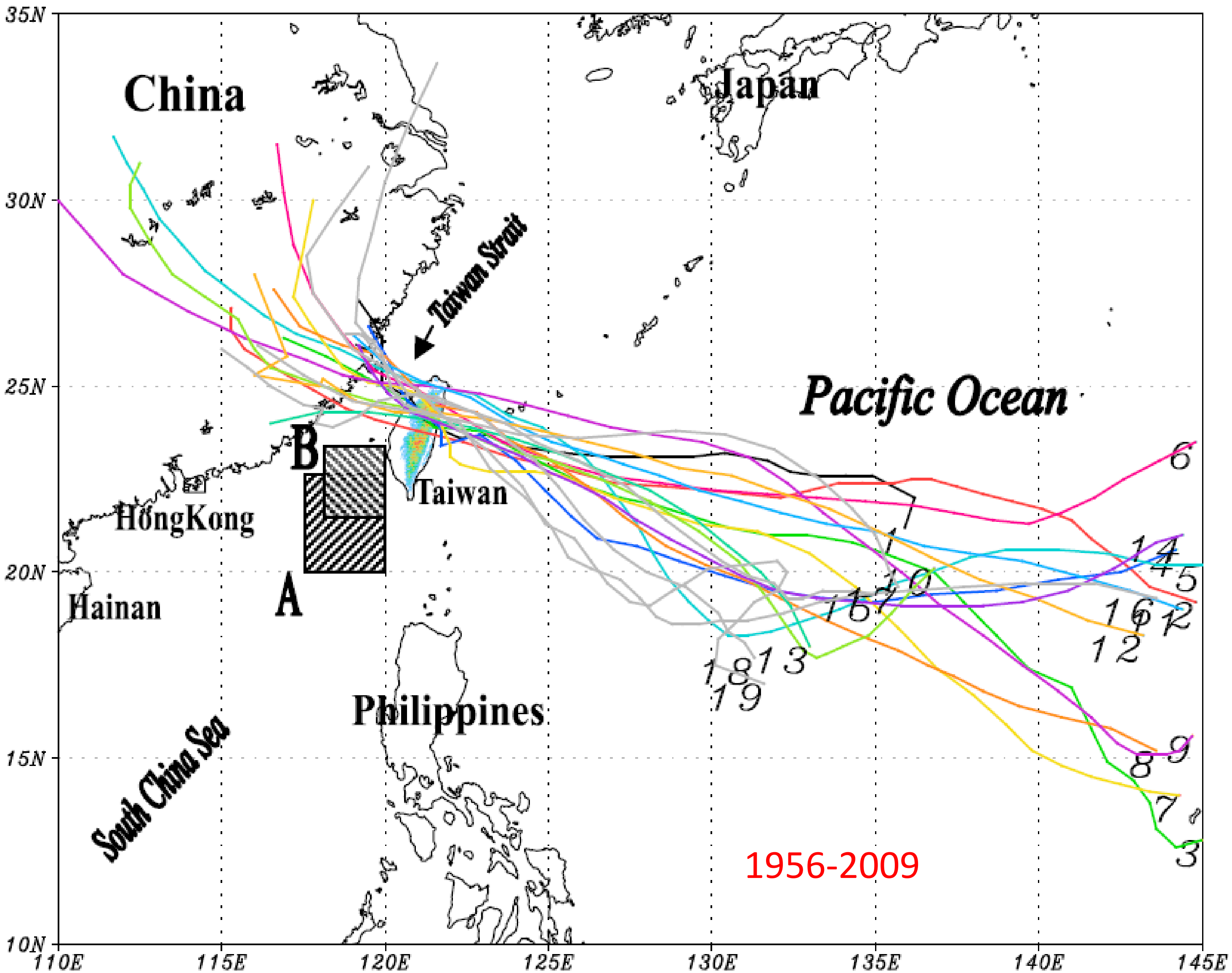
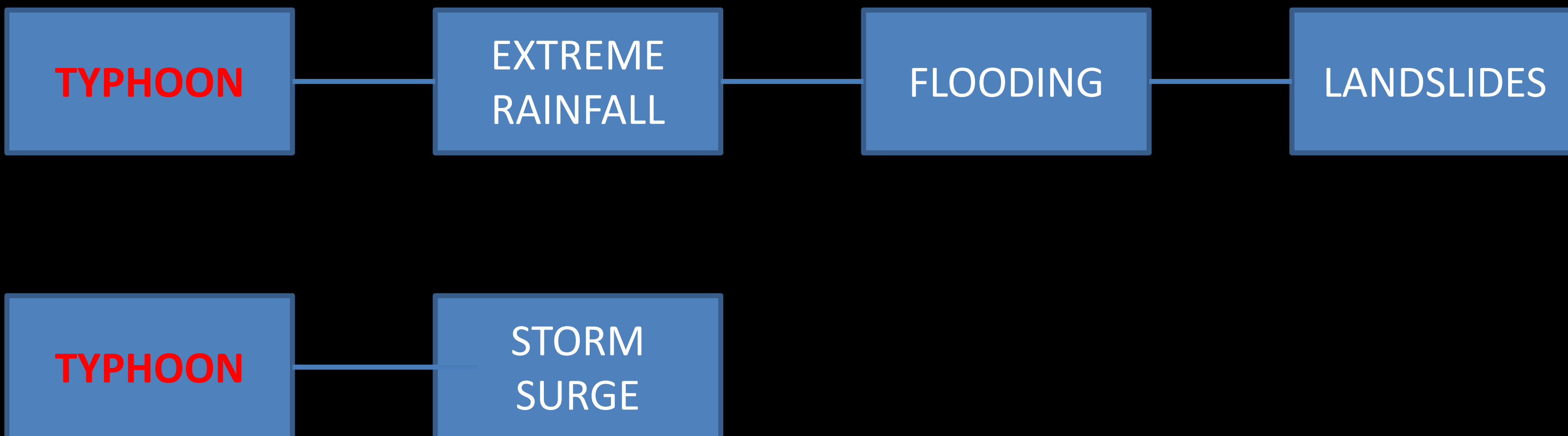


Figure 6. Tracks of 19 typhoons from the JTWC best track data, with identification numbers presented in chronological order; that is, number 1 is for Morakot (2009), 2 is for Longwang (2005), and so on. The small hatched box A denotes the rectangular area where the average winds and mixing ratio as shown in Table 2 and Figure 7 are computed. Box B is for precipitation.

THE CONCEPT OF PROCESS CHAINS (MULTIPLE PROCESS CHAINS)



A CHALLENGE IN HAZARD ASSESSMMENT

NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMATE1410

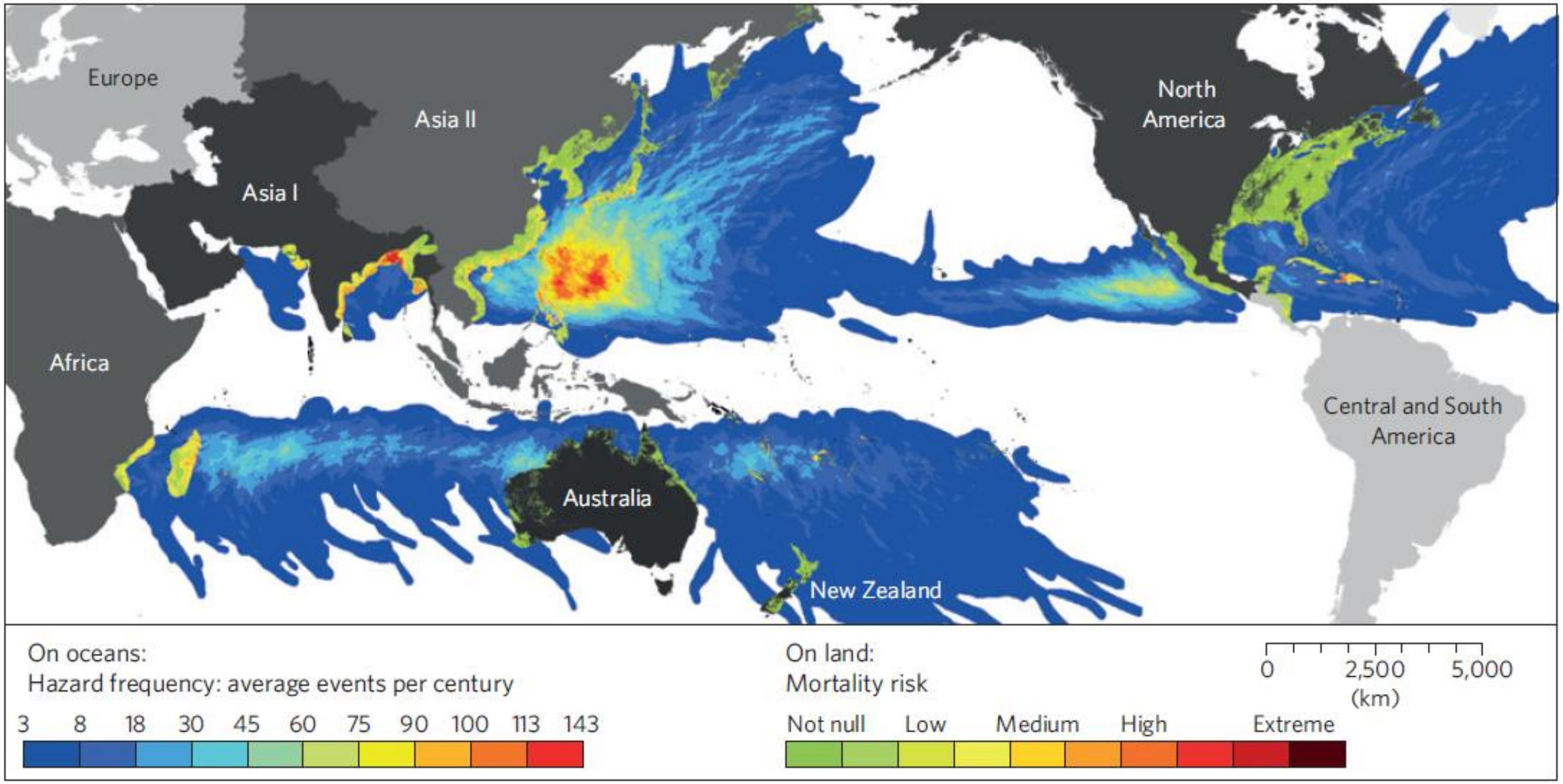


Figure 1 | Map showing distribution of hazard frequency and mortality risk from TCs for the year 2010. Estimates are applied to all pixels on a geographic grid. Mortality risk is categorized from low to extreme.

Peduzzi et al. 2012 *Global trends in tropical cyclone risk*

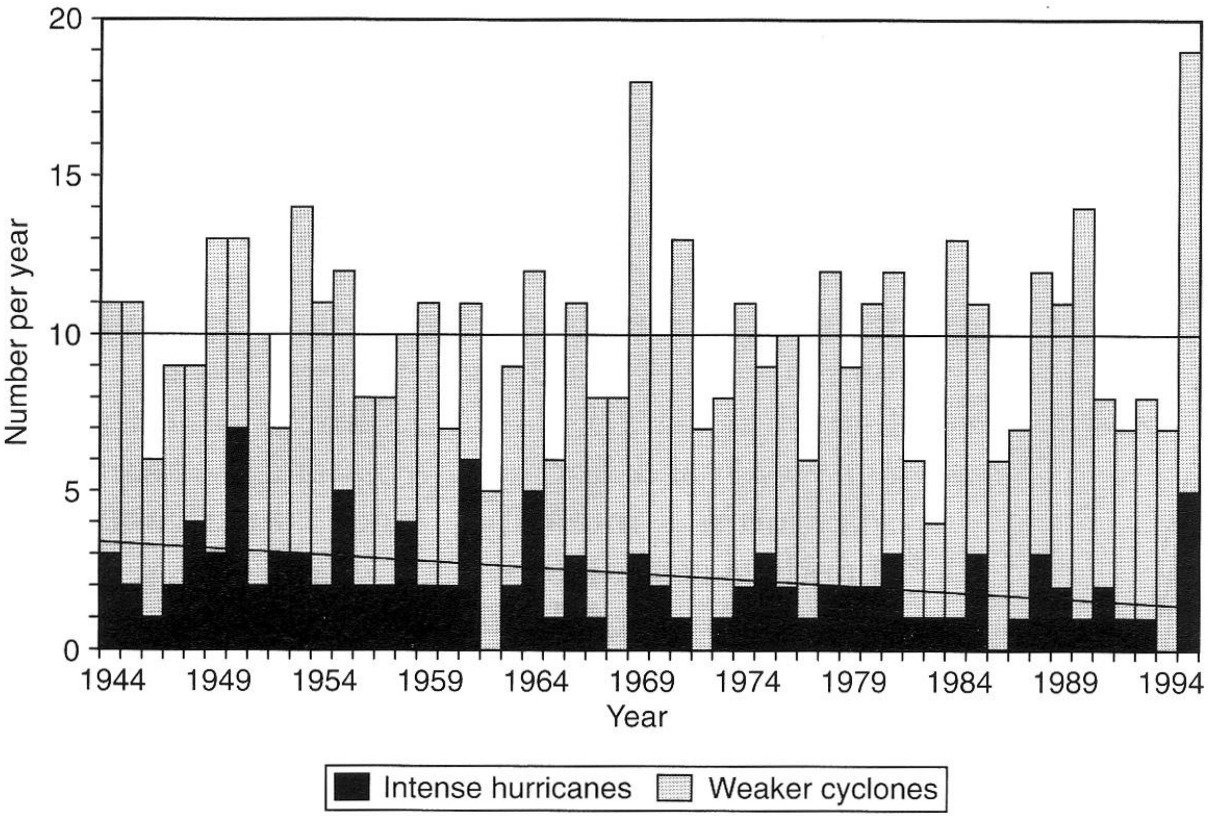


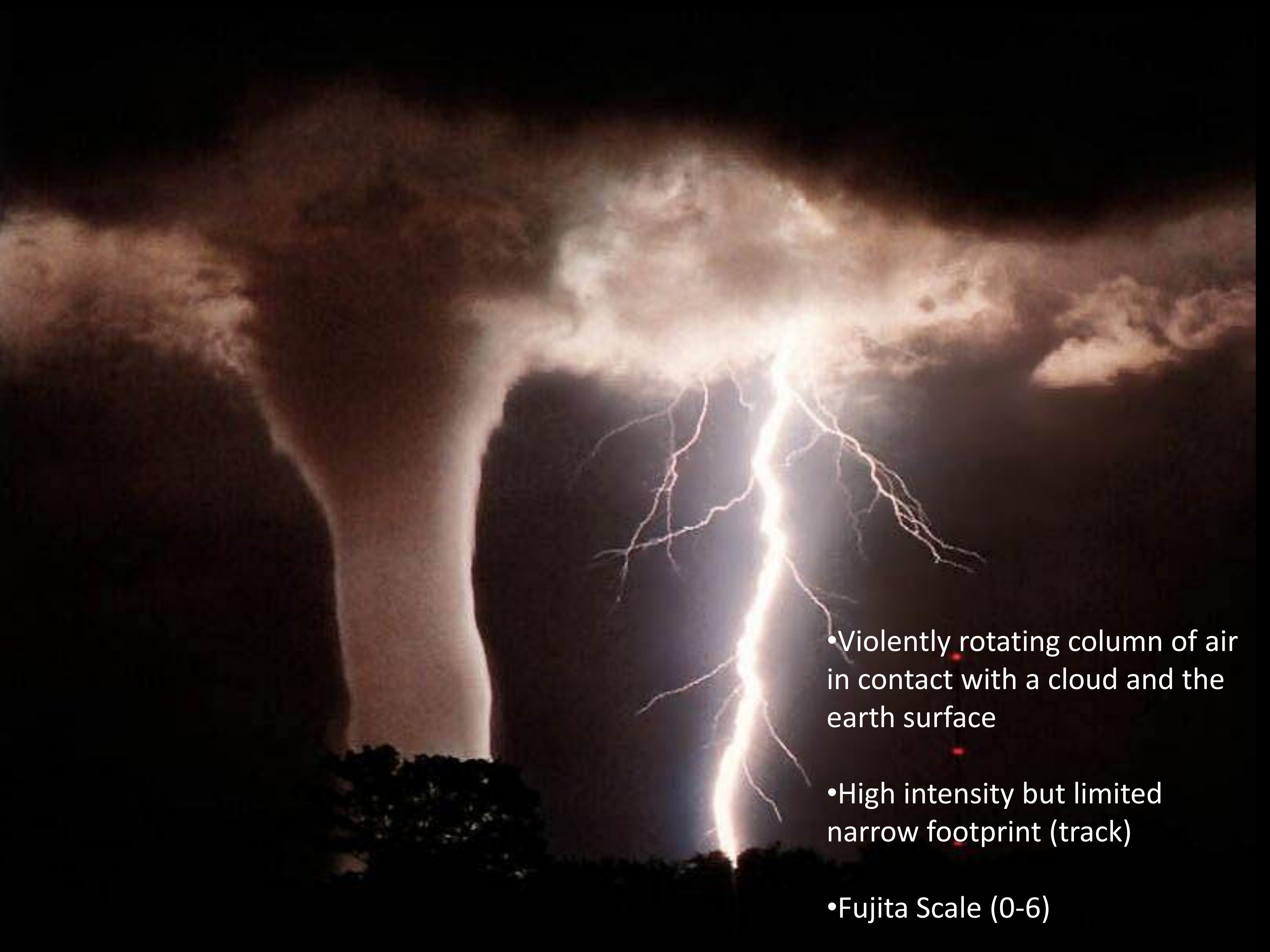
FIGURE 2.12 Annual frequency of tropical cyclones from 1944 to 1995 for the Atlantic basin. Dark bars are for major hurricanes only; light bars include all hurricanes, tropical storms and subtropical storms. Best-fit straight-line trends are also shown. (From Landsea *et al.*, 1996 with permission from the American Geophysical Union)

HURRICANE MAGNITUDE AND FREQUENCY AND CLIMATE CHANGE

OFFICE HOURS

TUESDAY 10:30 – NOON

2. TORNADOES



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

- High intensity but limited narrow footprint (track)

- Fujita Scale (0-6)

Mowing the lawn at Three Hills, Alberta [June 2, 2017]

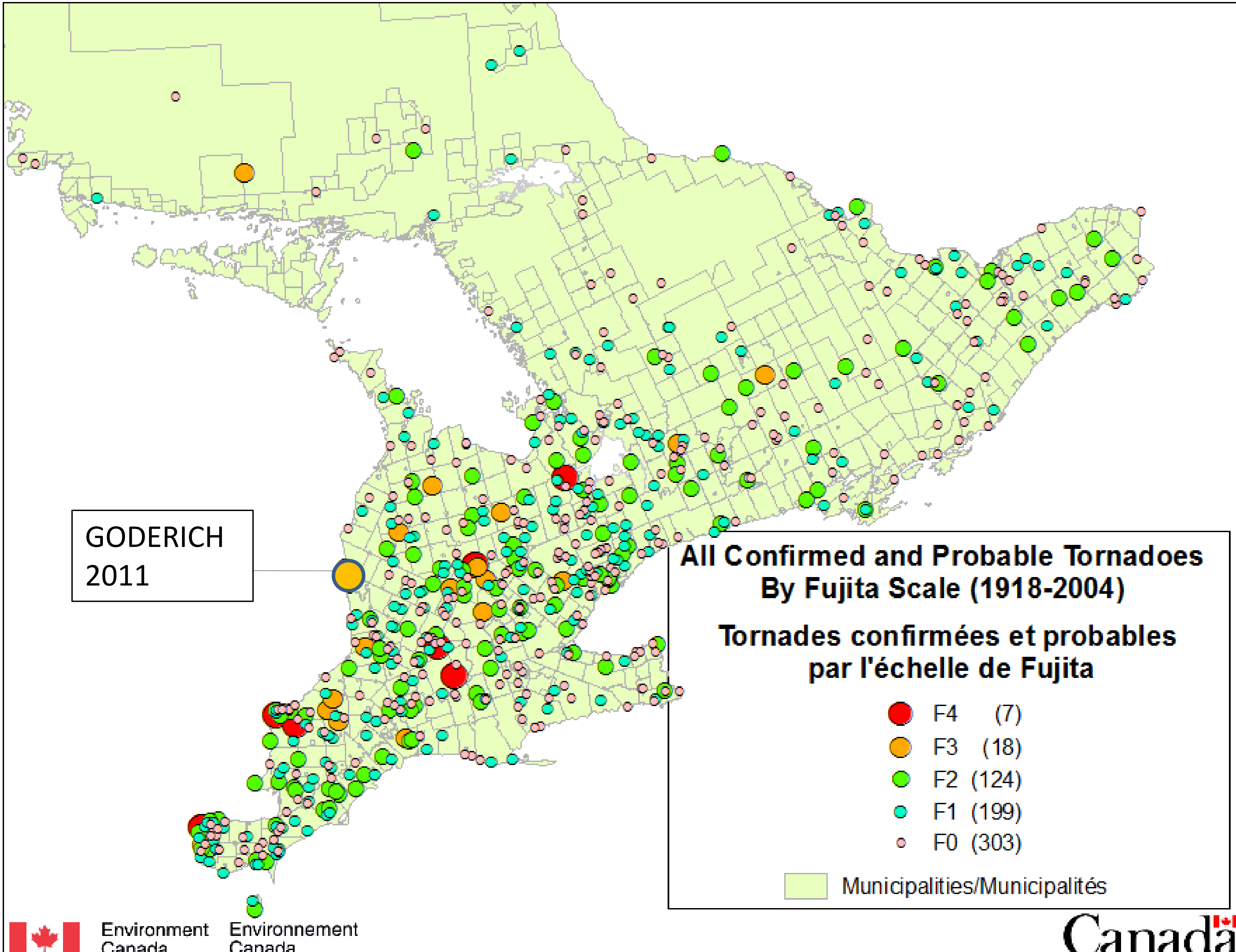
Greensburg, Kansas 2007 [11 deaths]

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

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



GODERICH
2011
All Confirmed and Probable Tornadoes By Fujita Scale (1918-2004)
Tornades confirmées et probables par l'échelle de Fujita
F4 (7)
F3 (18)
F2 (124)
F1 (199)
F0 (303)
Municipalities/Municipalités
Environment Canada
Environnement Canada
Canada

Vaughan, Ontario August 2009

Goderich Tornado (F3) August 23, 2011

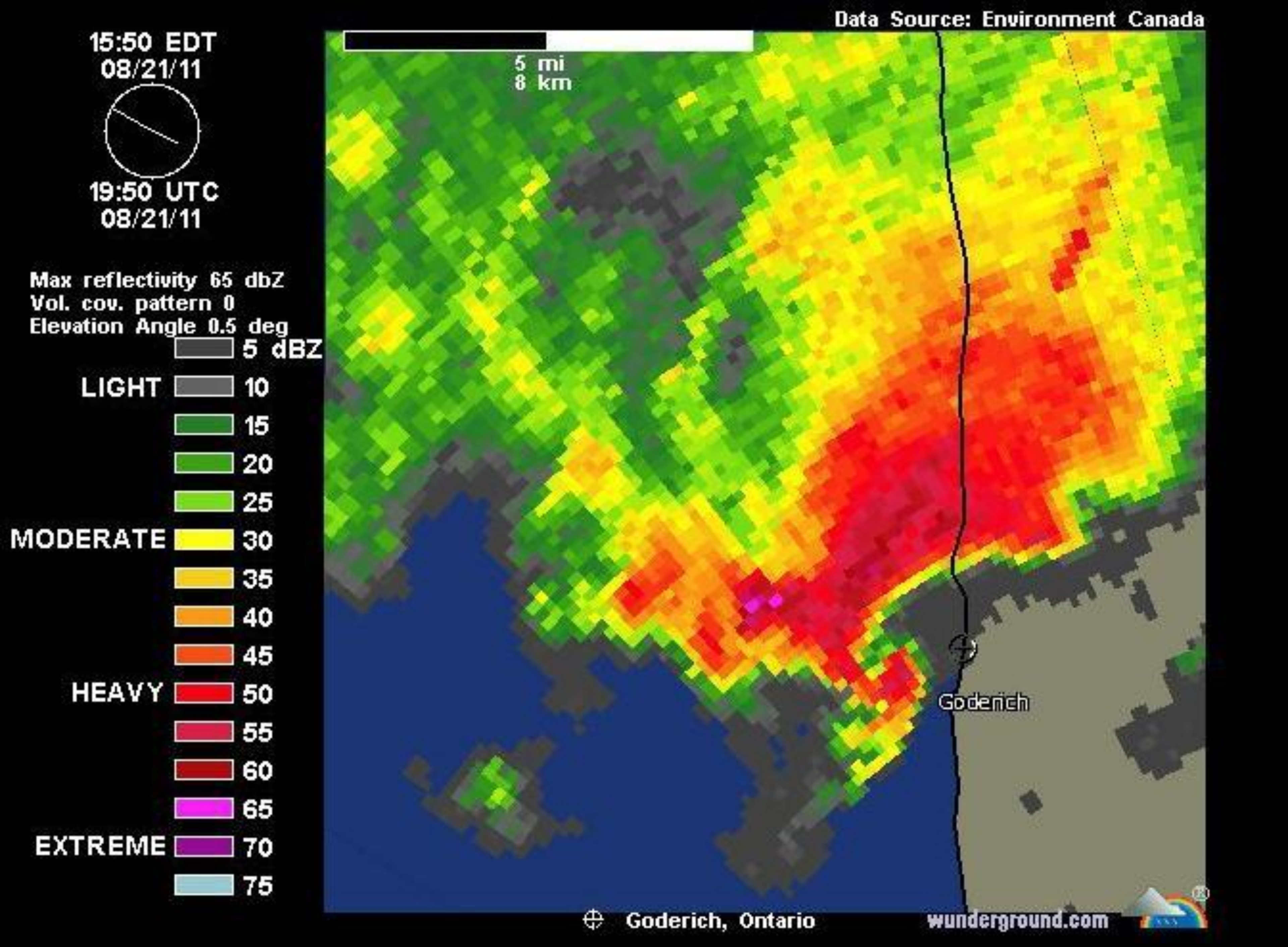
$75 M worth of damage ; no sirens
Track 20 km long; 1500 m wide in Goderich – 200 m wide further SE
Wind speeds up to 70-88 m/s

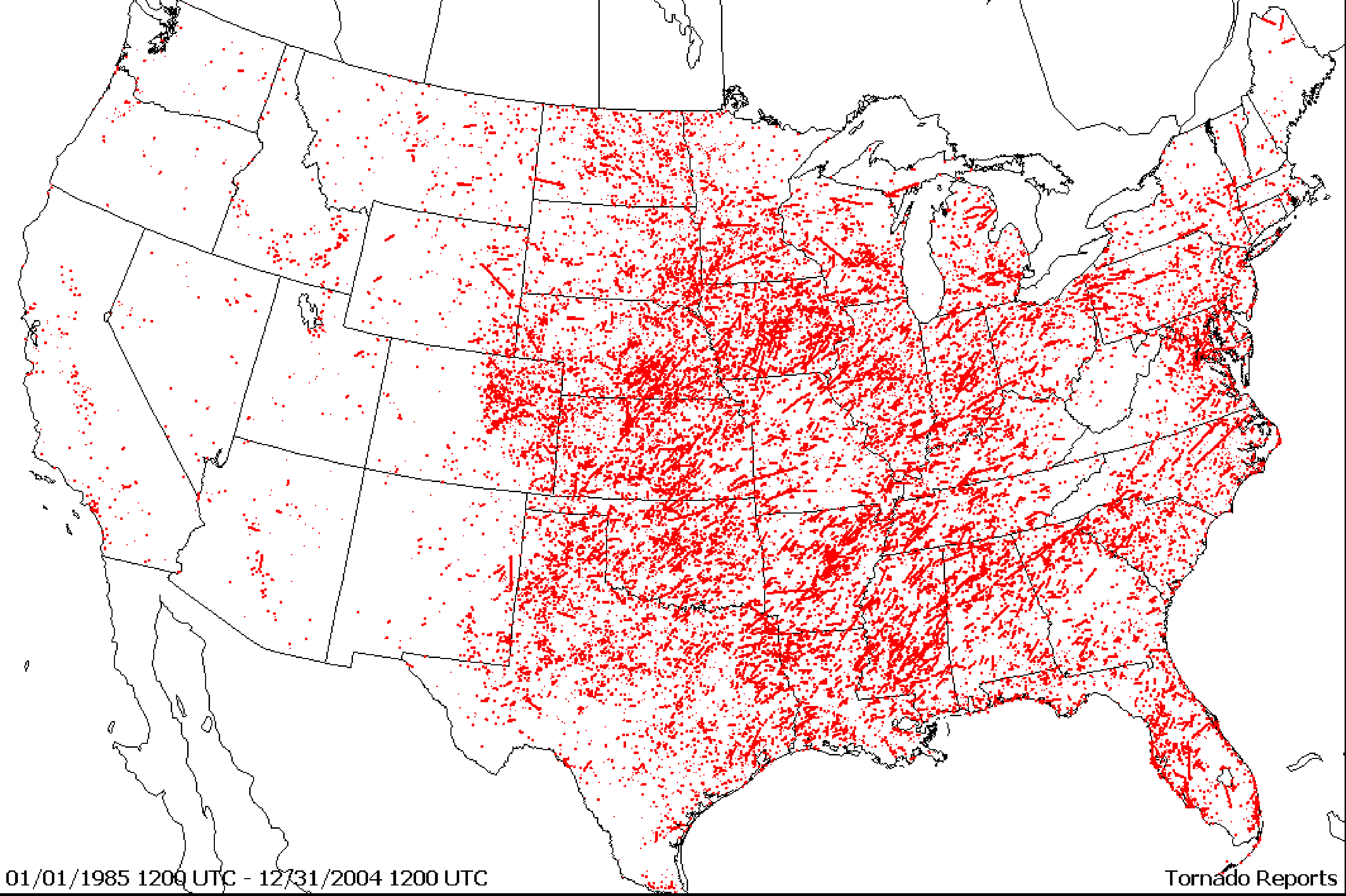
COLIN MCCONNELL/TORONTO STAR

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

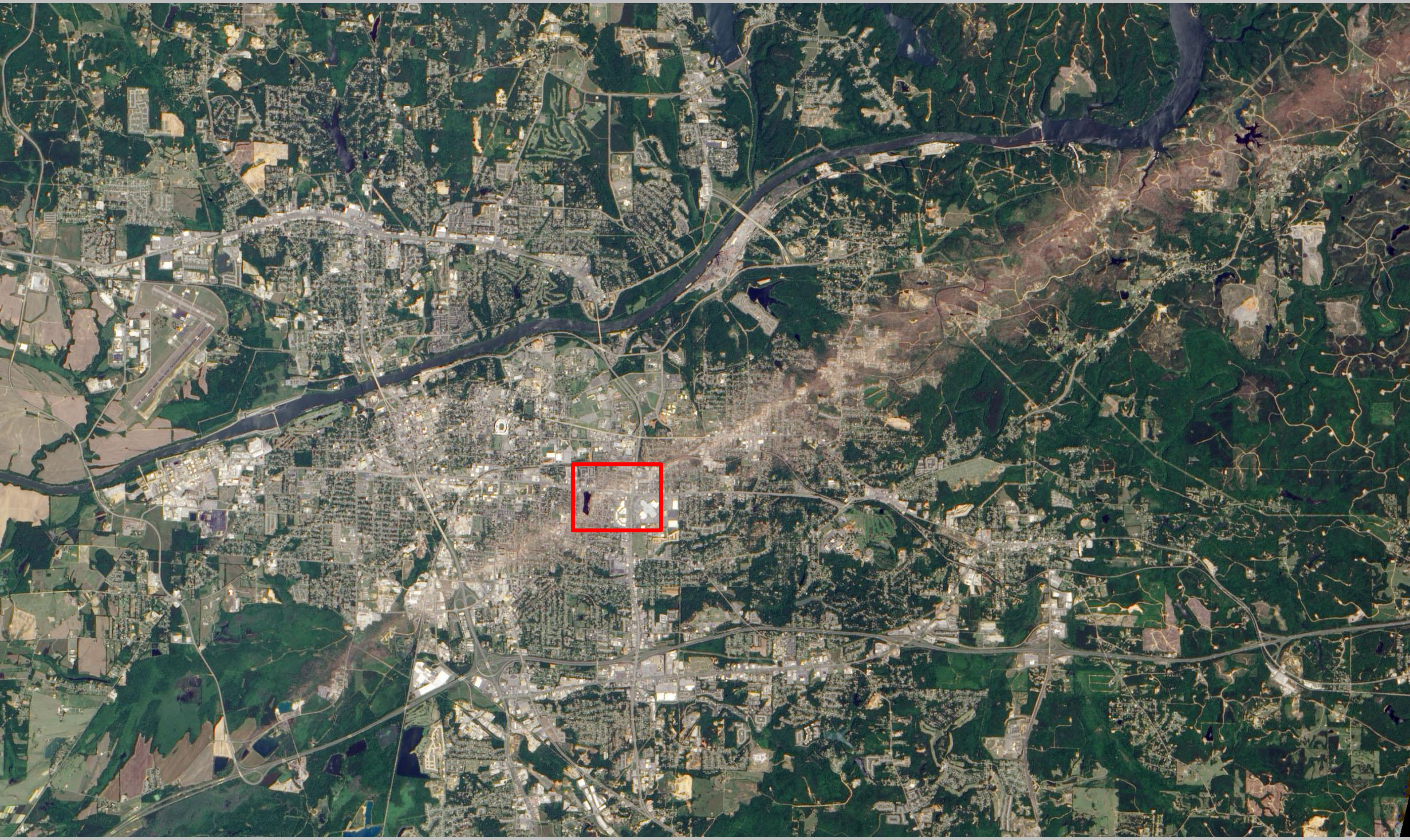
Tornado damage to Goderich United Church , 2011


Data Source: Environment Canada
15:50 EDT
08/21/11
19:50 UTC
08/21/11
5 mi
8 km
Max reflectivity 65 dbZ
Vol. cov. pattern 0
Elevation Angle 0.5 deg
5 dBZ
LIGHT 10
15
20
25
MODERATE 30
35
40
45
HEAVY 50
55
60
65
EXTREME 70
75
Goderich
Goderich, Ontario
wunderground.com



20,000 DEATHS IN 3,600 TORNADOES SINCE 1680

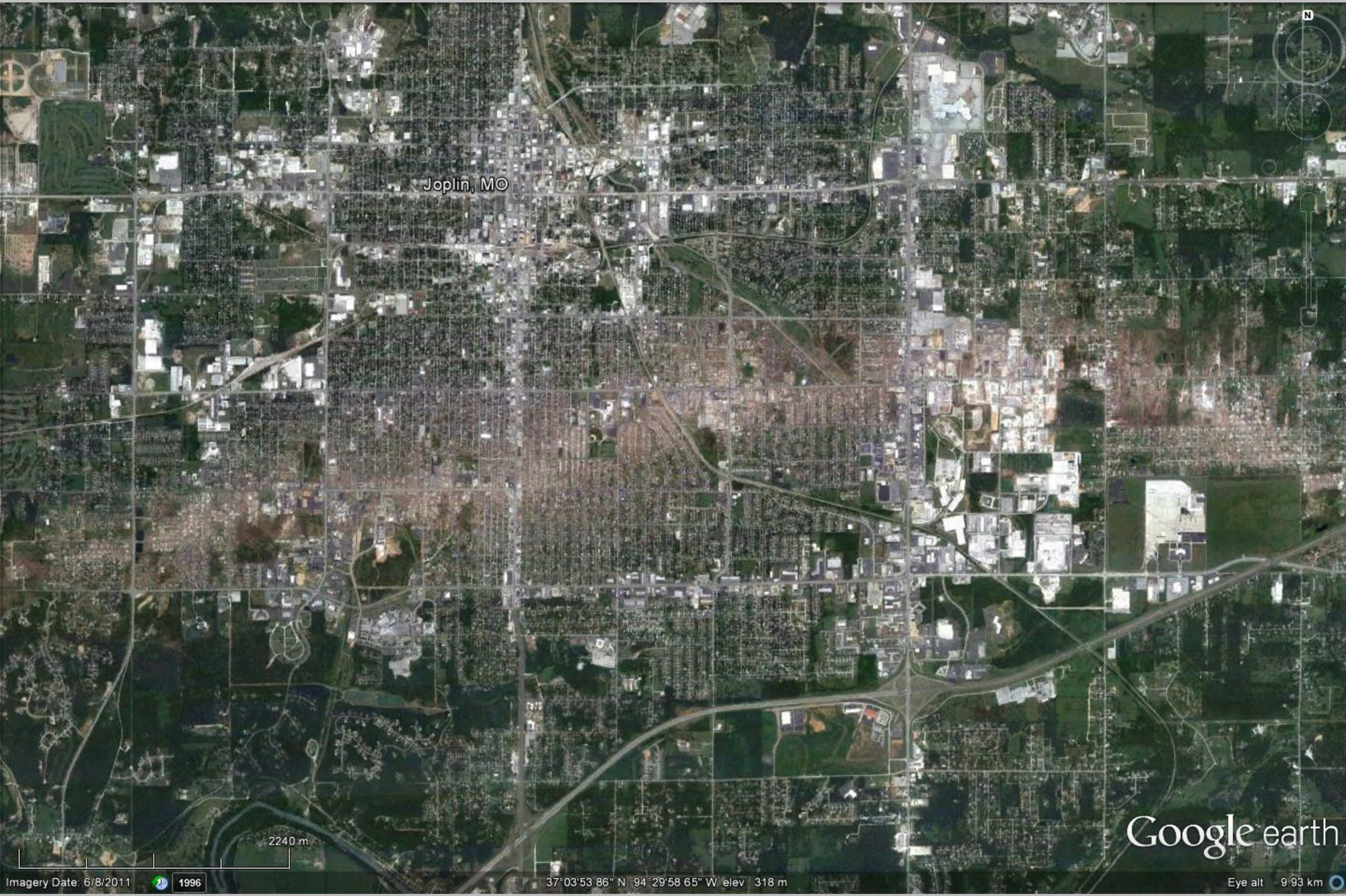
MANY DEADLY TORNADOES IN USA IN 2011



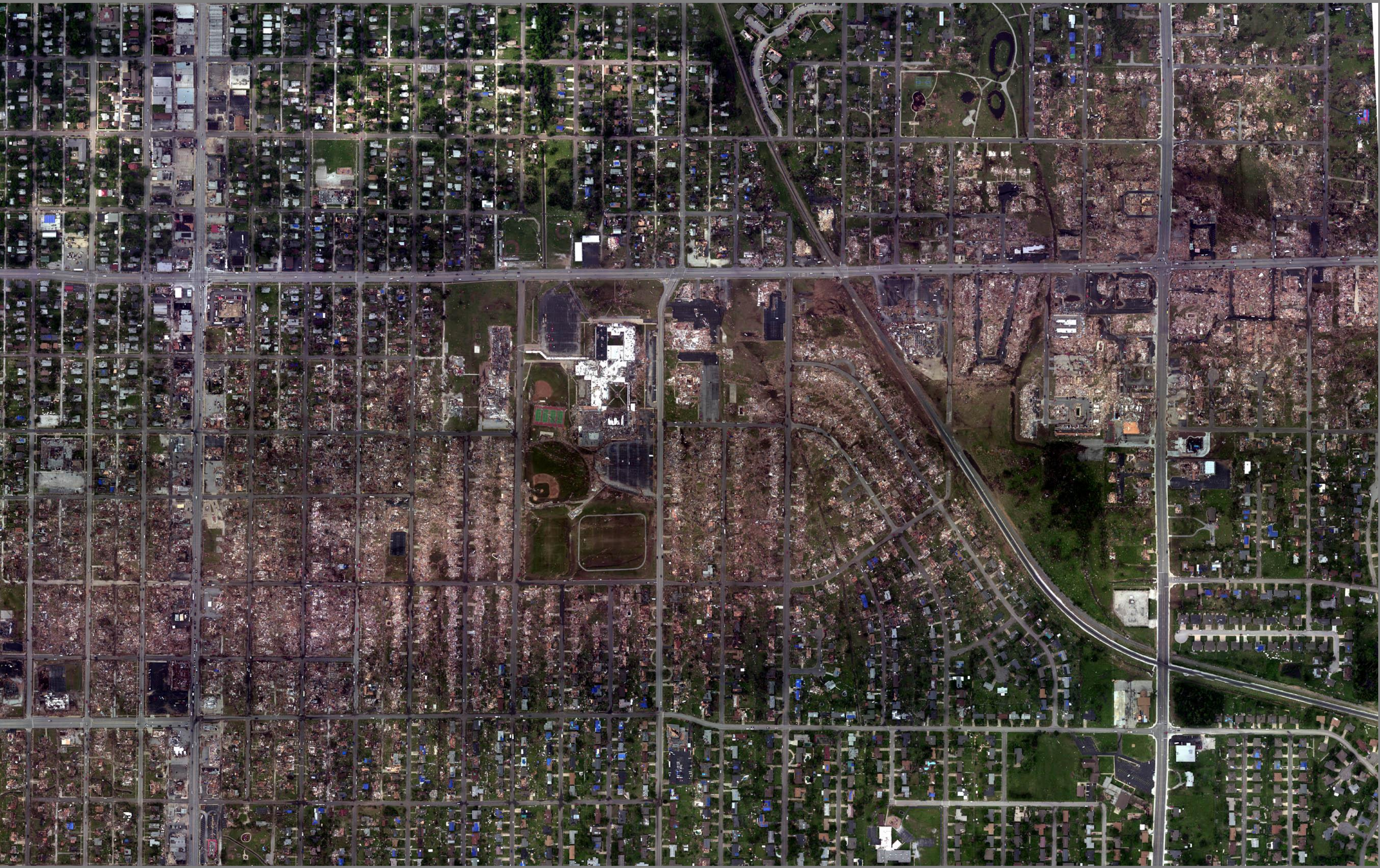
TORNADO TRACK, TUSCALOOSA, ALABAMA [27 April, 2011]

TUSCALOOSA TORNADO, ALABAMA, 27 April, 2011

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

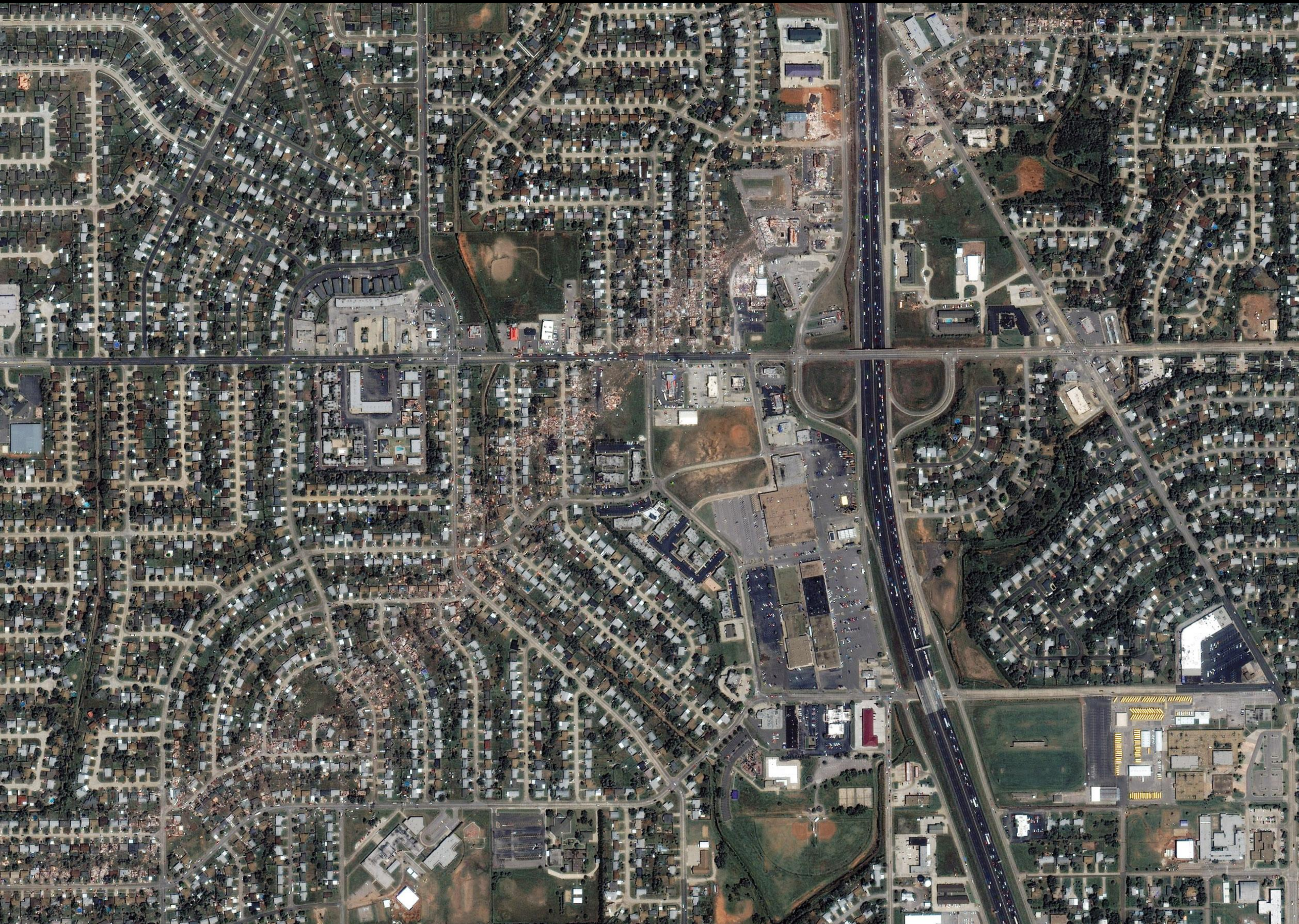


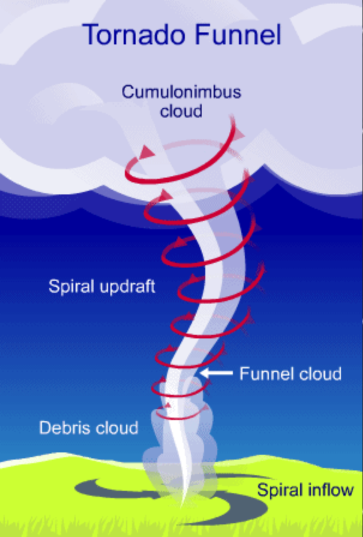
EF-5 TORNADO TRACK, JOPLIN, MISSOURI, MAY 22, 2011 (157 deaths and over 1,000 injuries: $6.7 B USD insured damage)

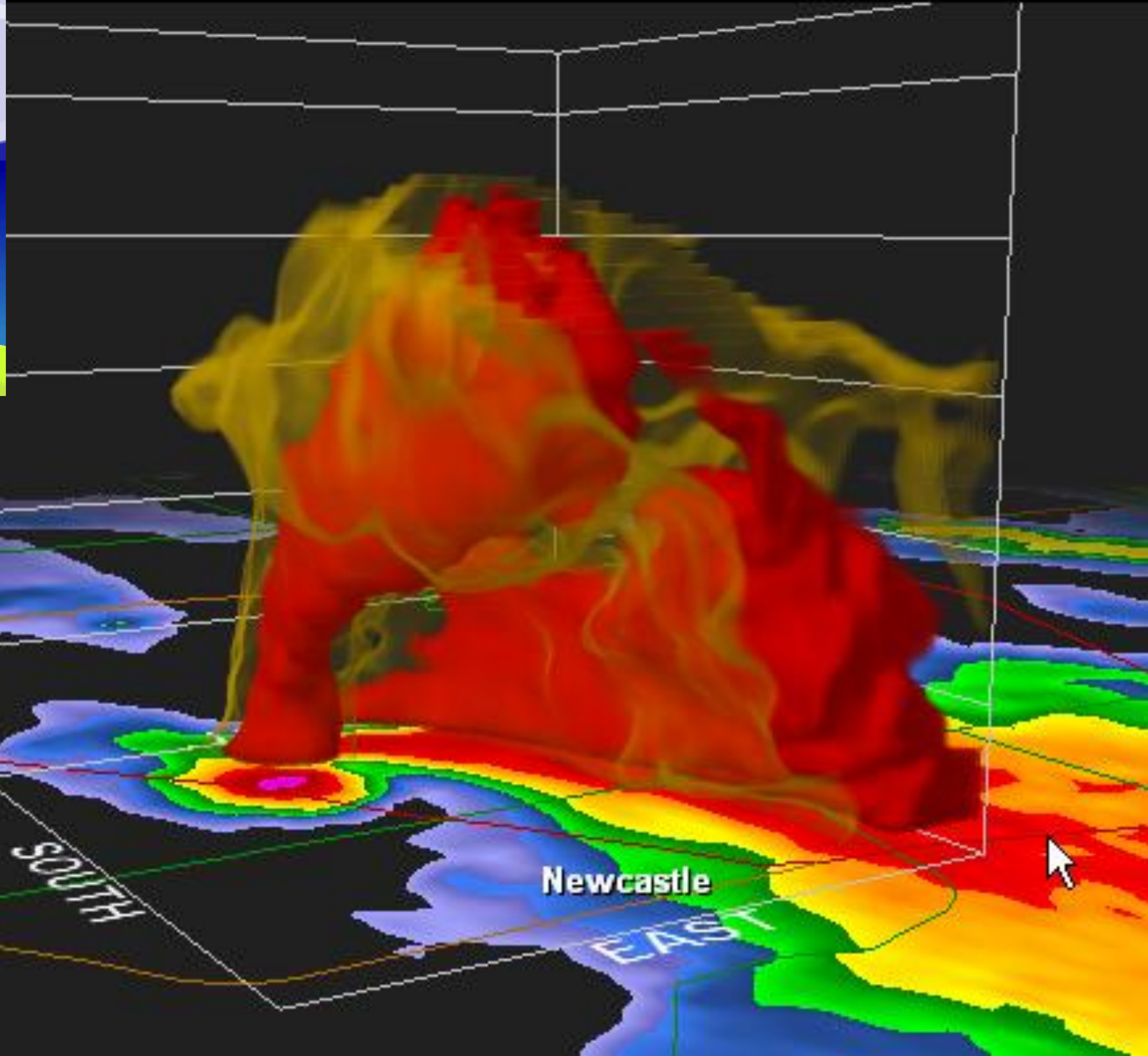


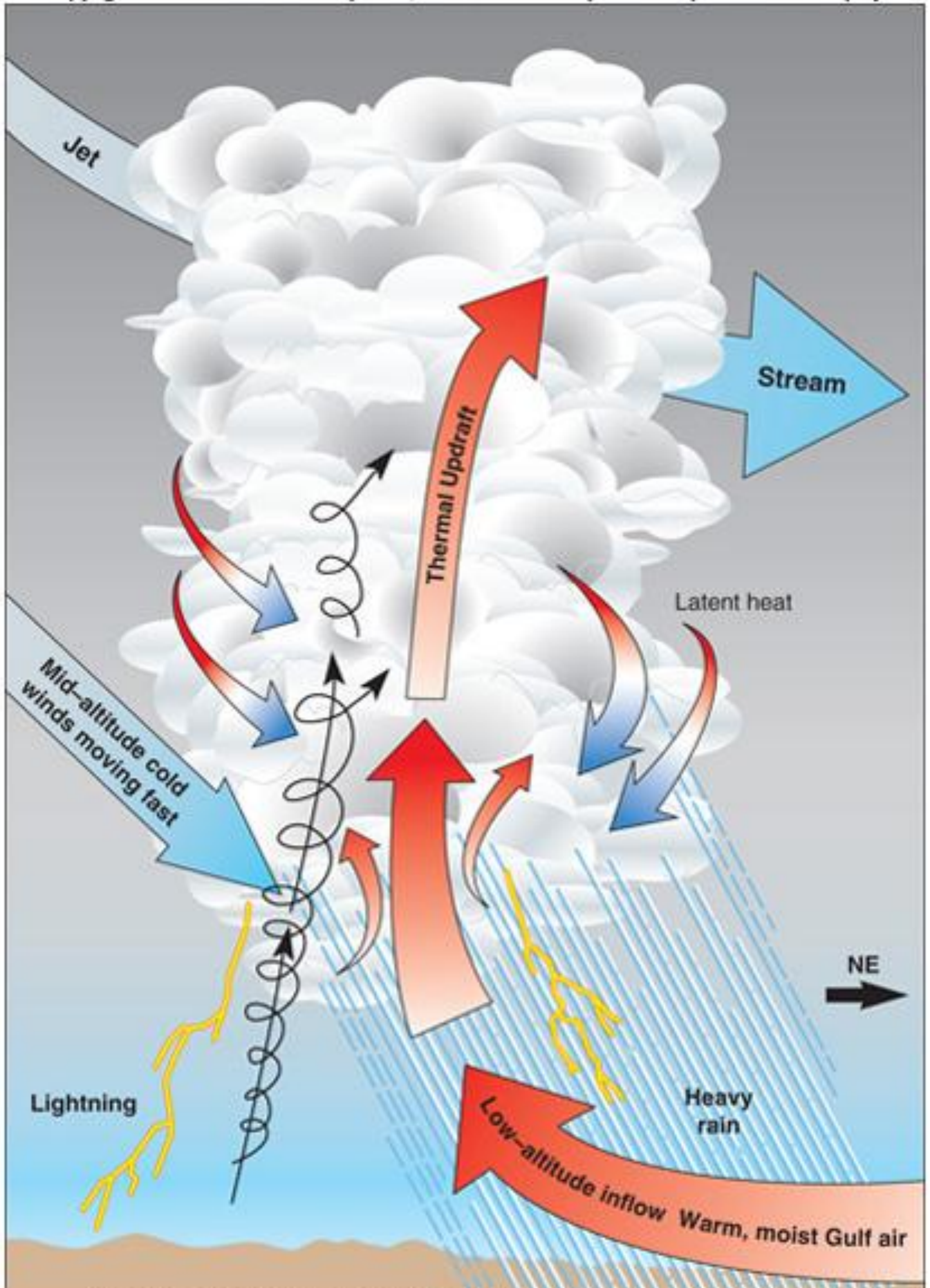
Large scale aerial photograph of Joplin, Missouri (May 24, 2011)

Moore, OK, May 2003; Swath of tornado damage (IKONOS Image)




Tornado Funnel
Cumulonimbus cloud
Spiral updraft
Funnel cloud
Debris cloud
Spiral inflow


SOUTH
Newcastle
EAST



J. Eagleman, *Severe and Unusual Weather, 1983; Van Nostrand Reinhold, New York*

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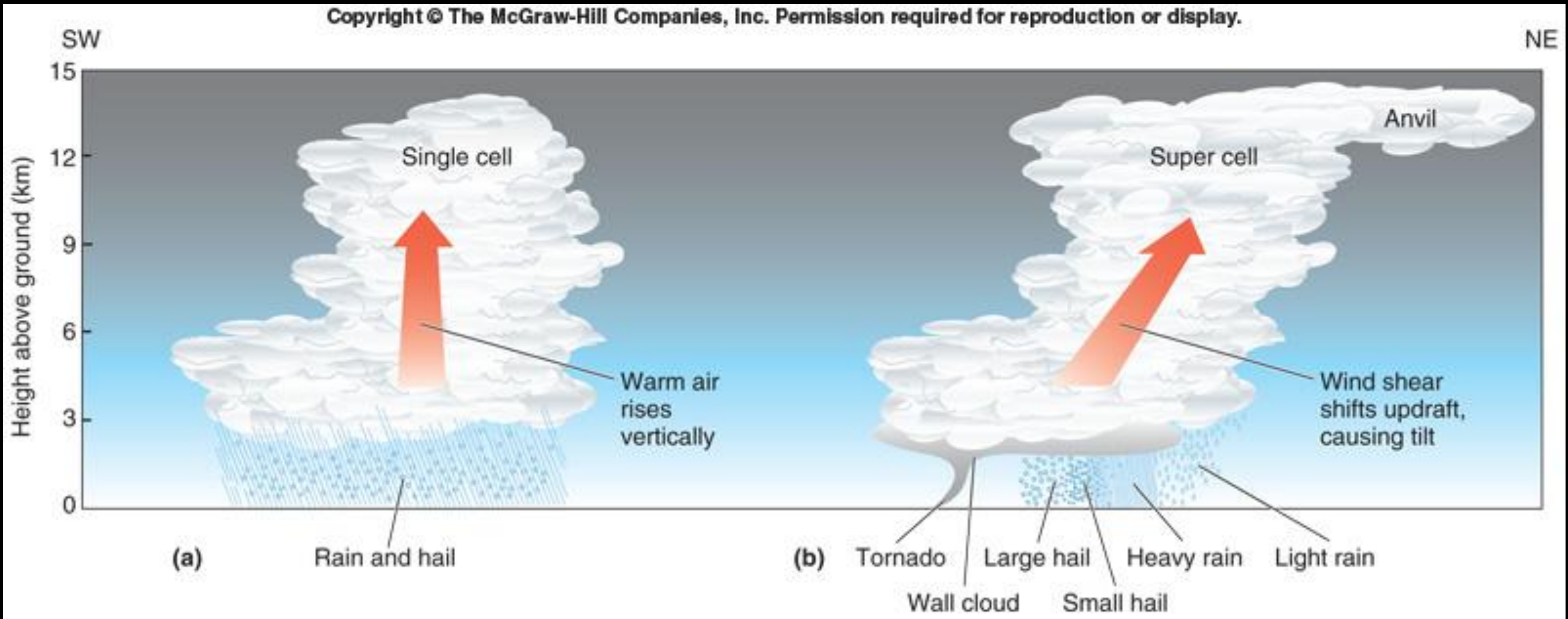
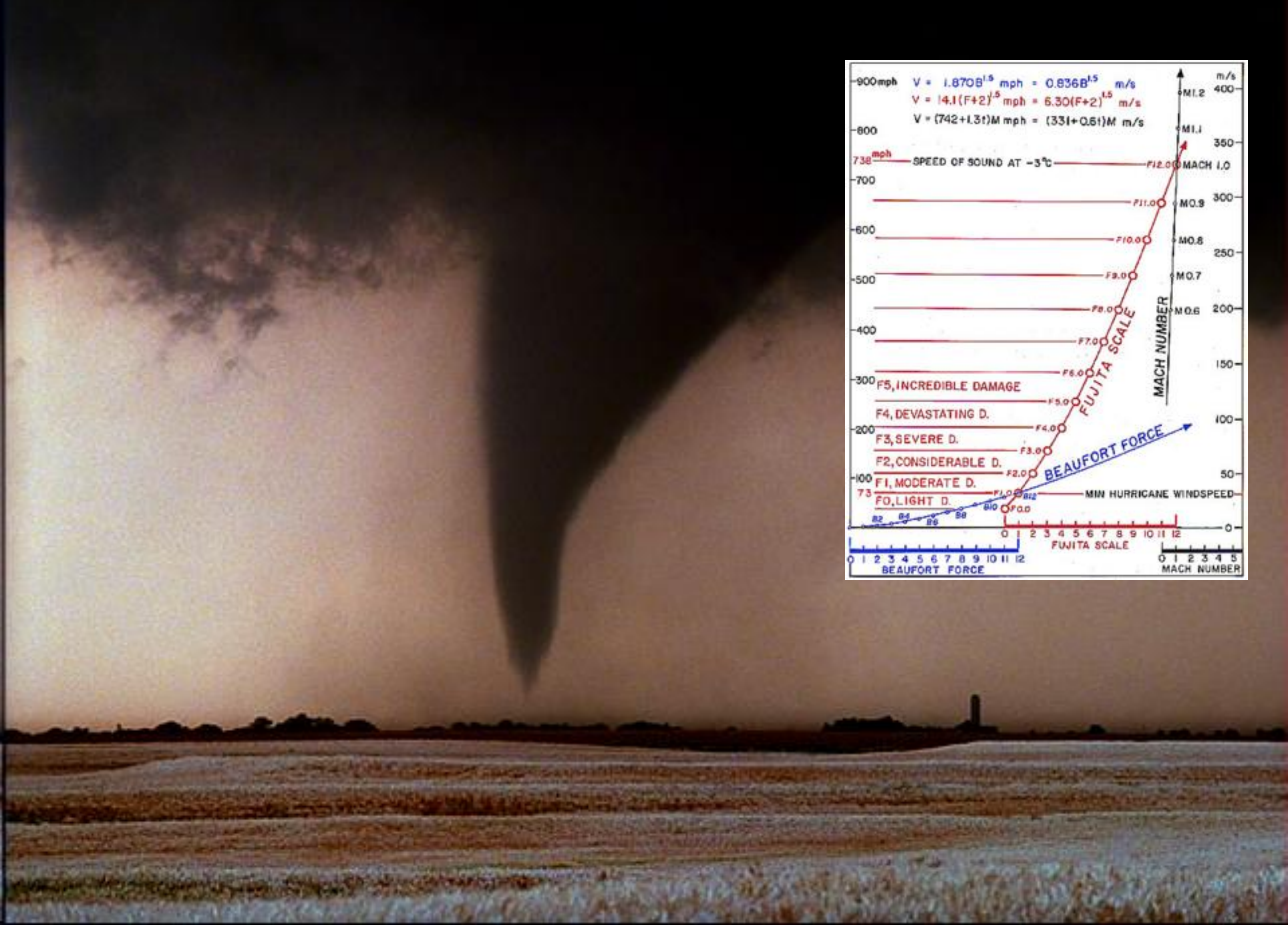
- FORMS IN ASSOCIATION WITH THUNDERSTORMS [SUPERCELLS CONTAIN ROTATING UPDRAFTS]
- UNSTABLE ATMOSPHERE IS ESSENTIAL
- ASSOCIATED WITH STRONG VERTICAL WIND SHEAR FORMING VORTEX TUBES
- UPDRAFT DRAWS IT INTO A THUNDERSTORM , TILTING IT
- LOWERS PRESSURE – INCREASES UPDRAFT
- CREATION OF REAR-FLANK AND FORWARD FLANK DOWNDRAFT
- INTERACTION WITH THE GROUND
- VERTICAL STRETCHING – INCREASE VELOCITY
- FORMATION OF FUNNEL CLOUD



TYPES OF THUNDERSTORMS

Tornado in Kansas

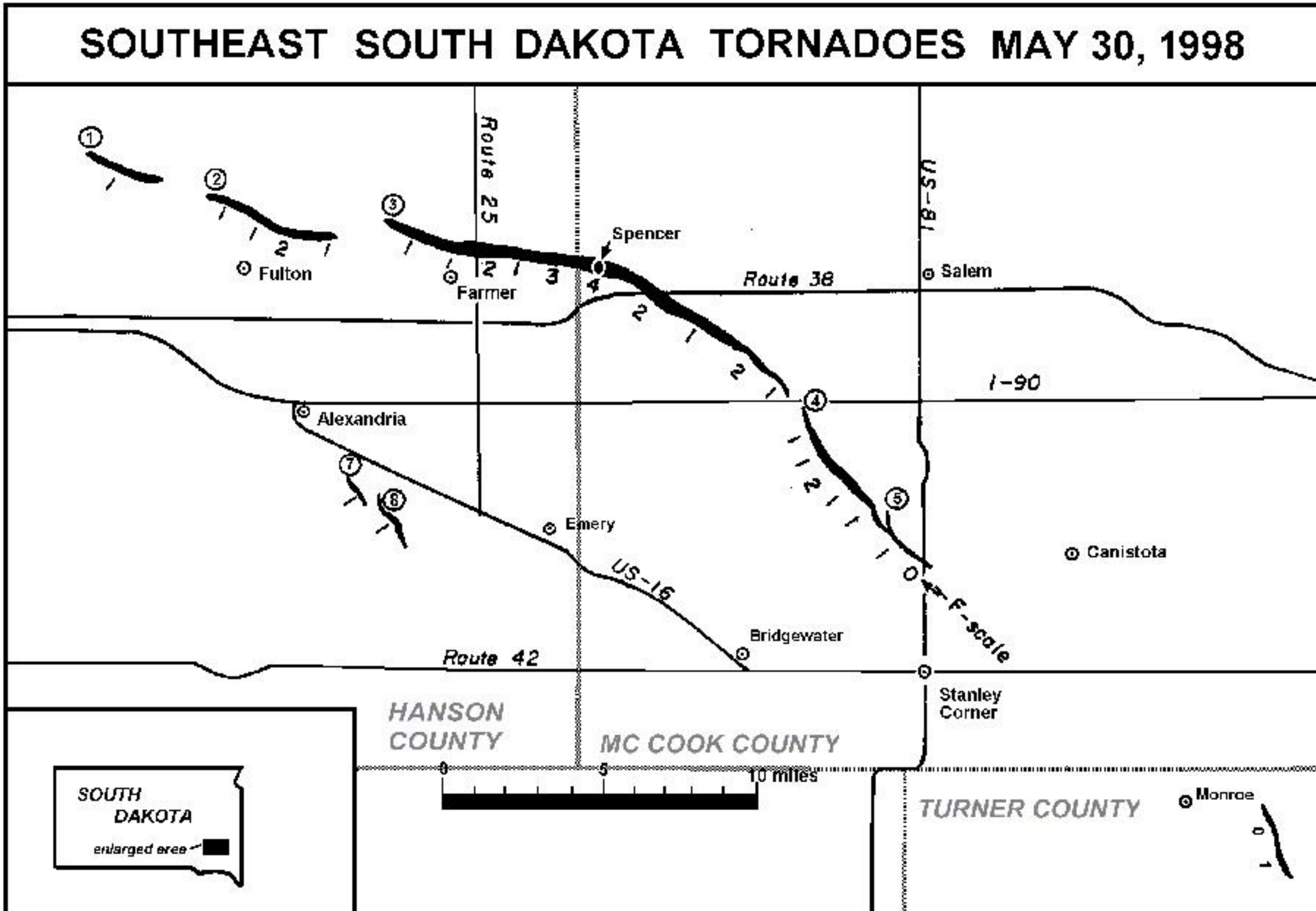


FUJITA WIND SCALE FOR TORNADOES

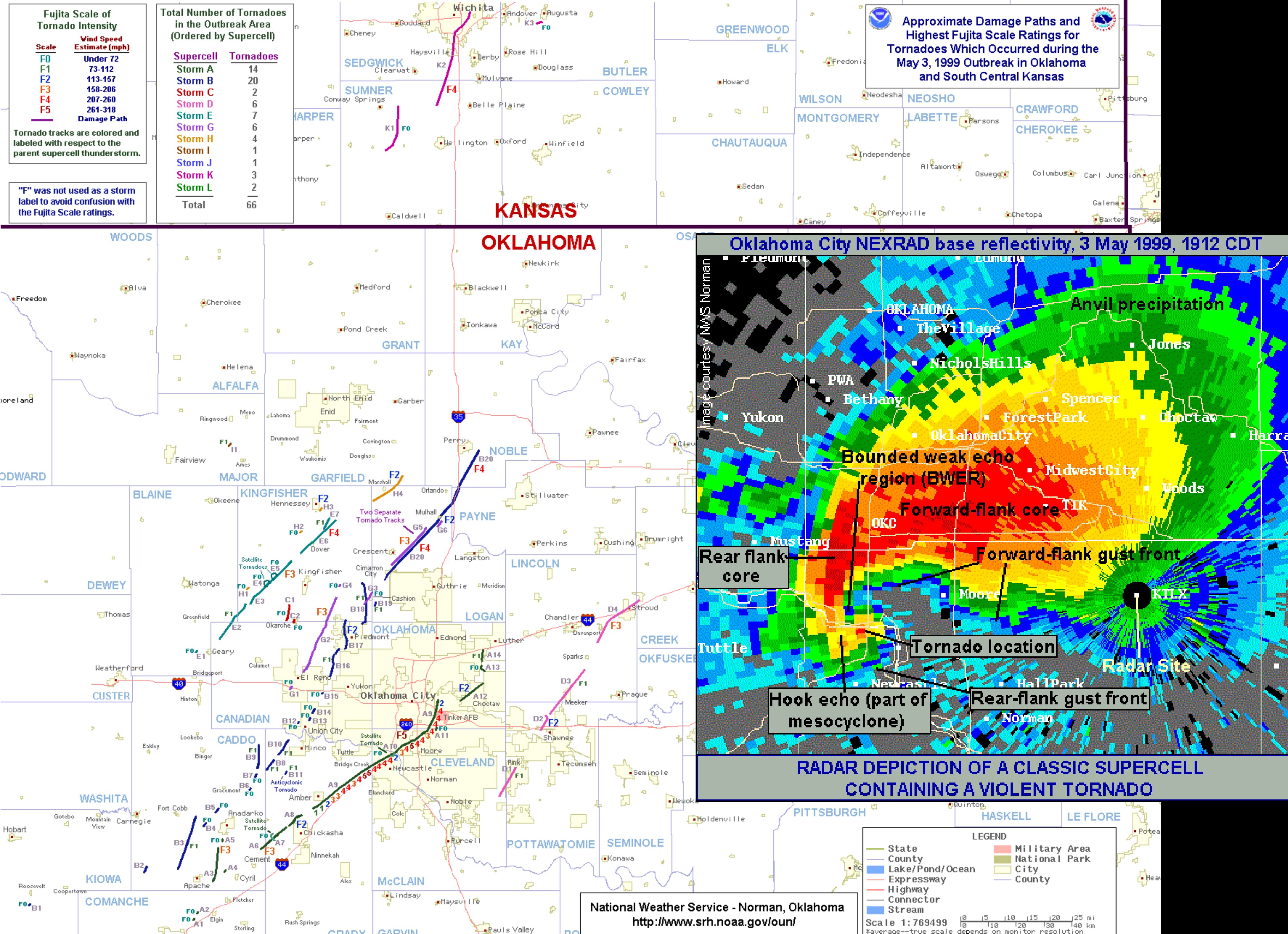
TABLE 12.8

Fujita Wind Damage Scale and US Tornadoes, 1992

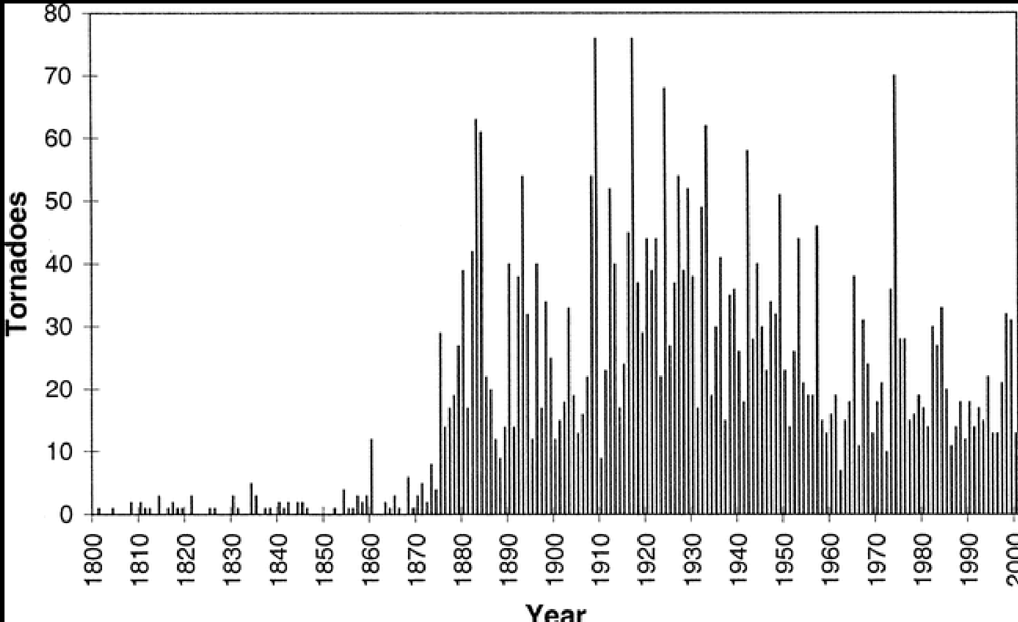
				Number	Percentage
F-0	under 72 mph	(32 m/sec)	light	696	54
F-1	73–112	(33–50)	moderate	411	32
F-2	113–157	(51–70)	considerable	129	10
F-3	158–206	(71–92)	severe	43	3
F-4	207–260	(93–116)	devastating	13	1
F-5	261–318	(117–142)	incredible	1	<1
F-6	>318	>142	not yet observed	0	0
				1,293 total	100


SOUTHEAST SOUTH DAKOTA TORNADOES MAY 30, 1998
Route 25
US-81
Spencer
Fulton
Farmer
Salem
Route 38
I-90
Alexandria
Emery
US-16
Canistota
F-scale
Bridgewater
Route 42
Stanley Corner
HANSON COUNTY
MC COOK COUNTY
TURNER COUNTY
Monroe
0 5 10 miles
SOUTH DAKOTA
enlarged area

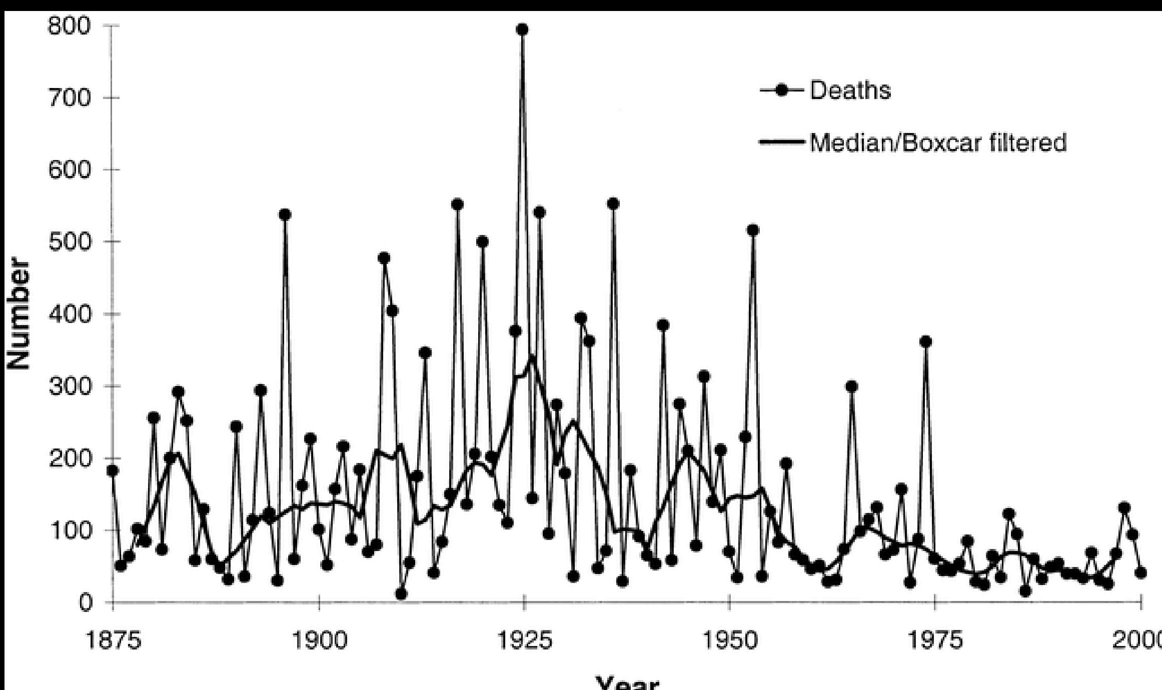
1989 OKLAHOMA CITY TORNADO ~ 40 DEATHS



Fujita Scale of Tornado Intensity
Scale | Wind Speed Estimate (mph)
F0 Under 72
F1 73-112
F2 113-157
F3 158-206
F4 207-260
F5 261-318
Damage Path
Tornado tracks are colored and labeled with respect to the parent supercell thunderstorm.
"F" was not used as a storm label to avoid confusion with the Fujita Scale ratings.
Total Number of Tornadoes in the Outbreak Area (Ordered by Supercell)
Supercell | Tornadoes
Storm A 14
Storm B 20
Storm C 2
Storm D 6
Storm E 7
Storm G 6
Storm H 4
Storm I 1
Storm J 1
Storm K 3
Storm L 2
Total 66
Approximate Damage Paths and Highest Fujita Scale Ratings for Tornadoes Which Occurred during the May 3, 1999 Outbreak in Oklahoma and South Central Kansas
KANSAS
OKLAHOMA
Wichita
SEDGWICK
SUMNER
BUTLER
COWLEY
GREENWOOD
ELK
WILSON
NEOSHO
MONTGOMERY
LABETTE
CRAWFORD
CHEROKEE
CHAUTAUQUA
HARPER
Oklahoma City NEXRAD base reflectivity, 3 May 1999, 1912 CDT
Image courtesy NWS Norman
Anvil precipitation
Bounded weak echo region (BWER)
Forward-flank core
Forward-flank gust front
Rear flank core
Tornado location
Hook echo (part of mesocyclone)
Rear-flank gust front
Radar Site
KTLX
RADAR DEPICTION OF A CLASSIC SUPERCELL CONTAINING A VIOLENT TORNADO
Two Separate Tornado Tracks
Satellite Tornadoes
Anticyclonic Tornado
Oklahoma City
WOODS
ALFALFA
GRANT
KAY
NOBLE
GARFIELD
MAJOR
BLAINE
KINGFISHER
LOGAN
PAYNE
LINCOLN
DEWEY
CUSTER
CANADIAN
OKLAHOMA
CADDO
CLEVELAND
GRADY
McCLAIN
WASHITA
KIOWA
COMANCHE
GARVIN
POTTAWATOMIE
SEMINOLE
CREEK
OKFUSKEE
PITTSBURGH
HASKELL
LE FLORE
LEGEND
State
County
Lake/Pond/Ocean
Expressway
Highway
Connector
Stream
Military Area
National Park
City
County
Scale 1:769499
*average--true scale depends on monitor resolution
National Weather Service - Norman, Oklahoma
http://www.srh.noaa.gov/oun/



NUMBER OF KILLER TORNADOES PER YEAR 1800 – 2000 (USA)



DEATHS PER YEAR IN USA TORNADOES 1875-2000

Does Global Warming Influence Tornado Activity?

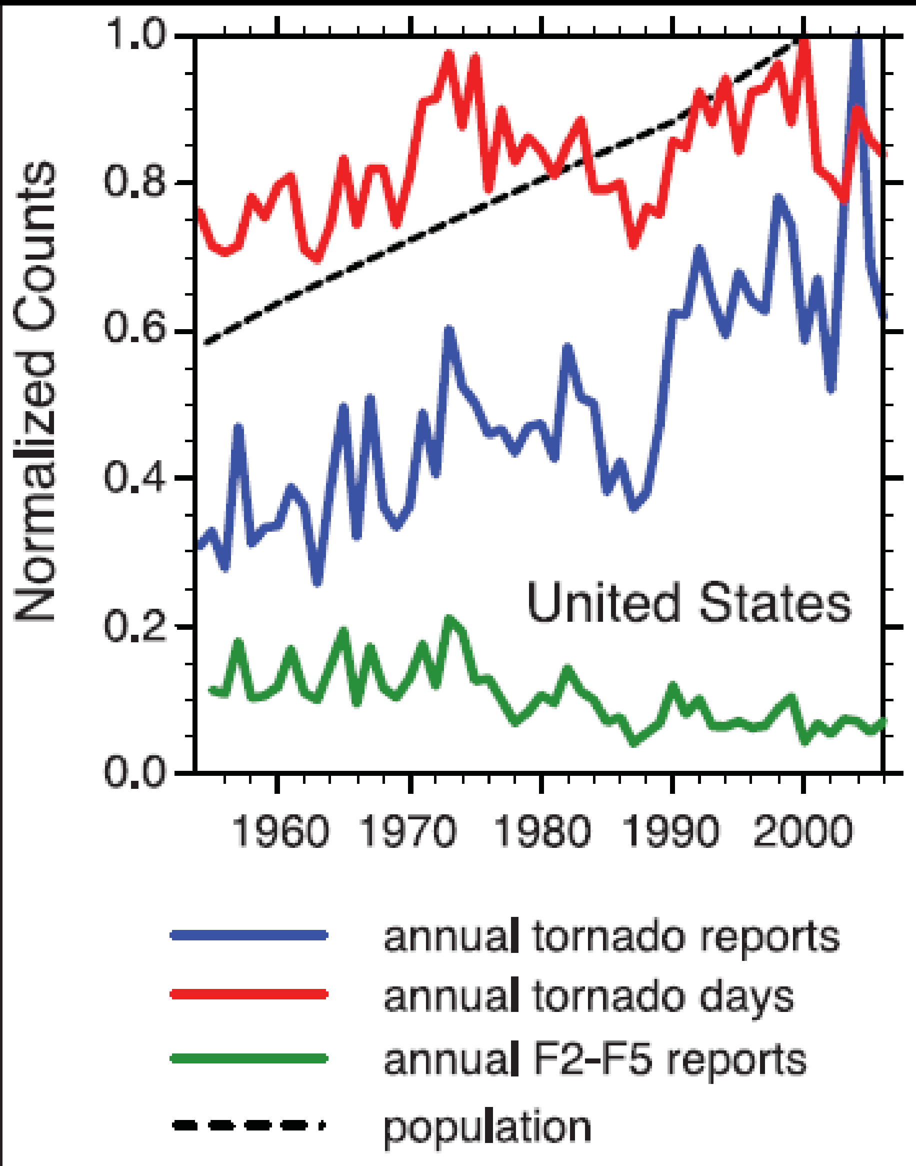
PAGES 553–554

Tornadoes and other severe thunderstorm phenomena frequently cause as much annual property damage in the United States as do hurricanes, and often cause more fatalities (see http://www.nws.noaa.gov/om/hazstats.shtml). In 2008, there were 2176 preliminary tornado reports logged through mid-December, with 1600 "actual counts" (duplicate reports removed) through September, the highest total in the past half century (Figure 1). The mass media have covered these events extensively, and experts have been deluged with requests for expla-

designed essentially for the verification of forecasts rather than for research-quality climate studies, meaning that maintaining consistency throughout the historical reporting record has not been a specific priority. Reliance on human reports leaves trends subject to external influences such as population growth, although some regions such as the southern Great Plains do not reflect the congruous long-term trends in tornado occurrence and population growth seen throughout the entire United States (Figure 2).

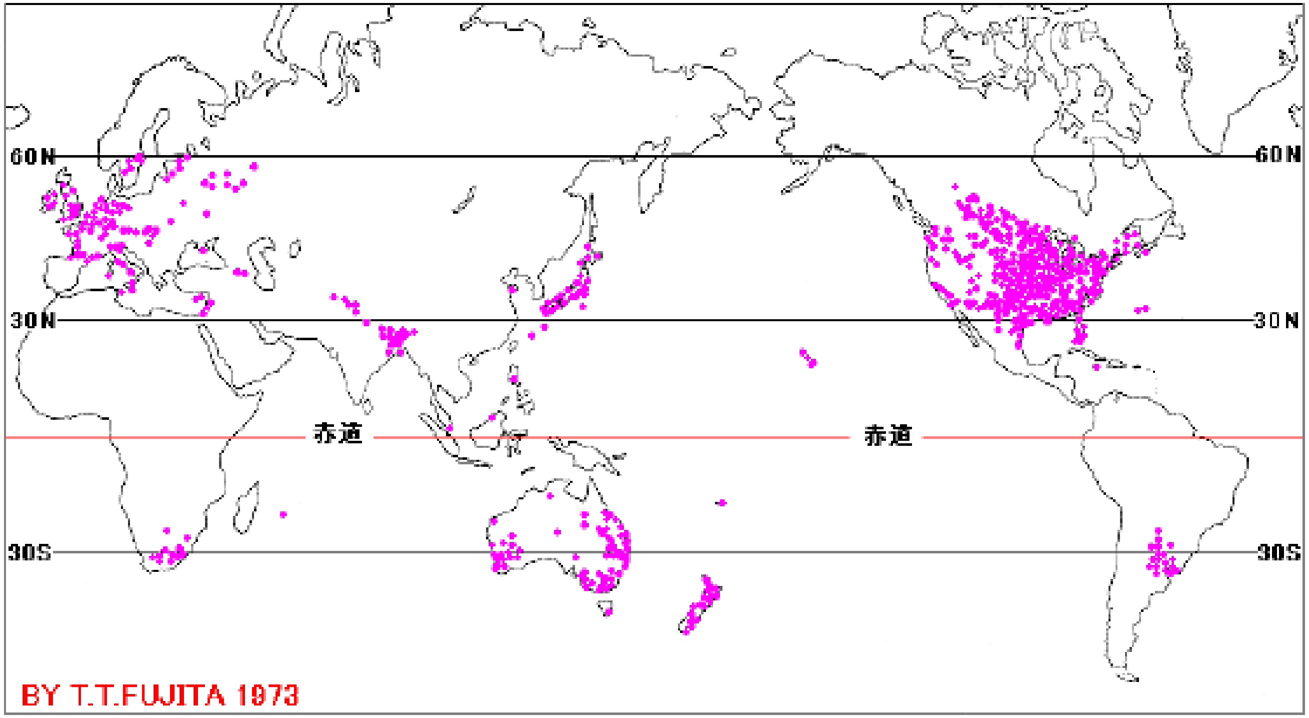
Interestingly, the number of tornadoes classified as the most damaging (rated F2–F5

Eos, December 30 2008



1.0
0.8
0.6
0.4
0.2
0.0
Normalized Counts
1960
1970
1980
1990
2000
United States
annual tornado reports
annual tornado days
annual F2-F5 reports
population

Nguyen

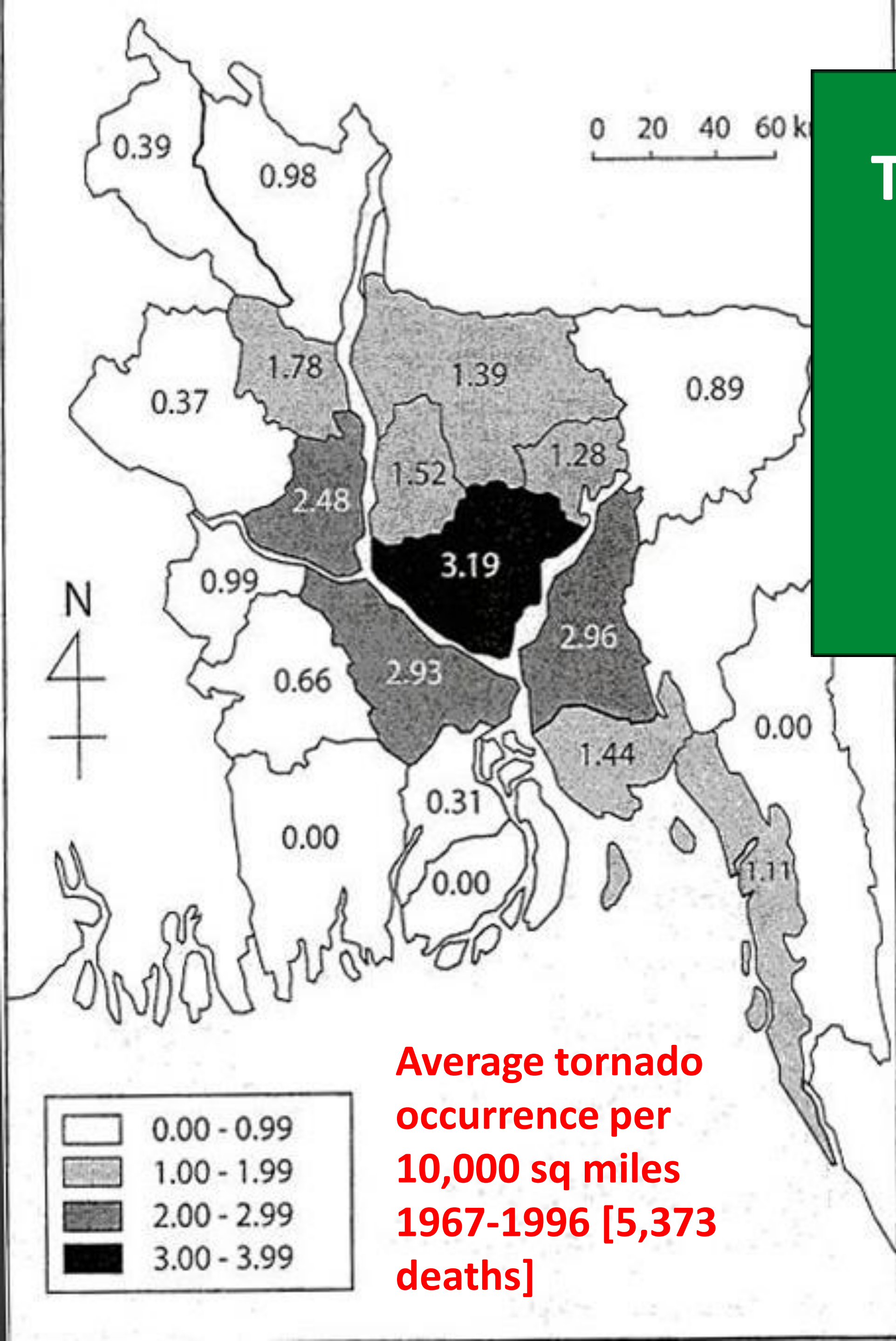


世界のトルネード(地上たつまき)分布。毎年約1000個のたつまきが地球上に発生している。
発生回数のトップはアメリカ。日本、ヨーロッパ、オーストラリアなどの温帯国にもしばしばおこるが、
熱帯には少なく、寒帯にはほとんどない。

図1　世界で発生したトルネードの分布

[出典]藤田哲也:たつまき－上　渦の驚異、共立出版(1973),表紙裏

Figure 1. The distribution of tornadoes over the world (Fujita, 1973).

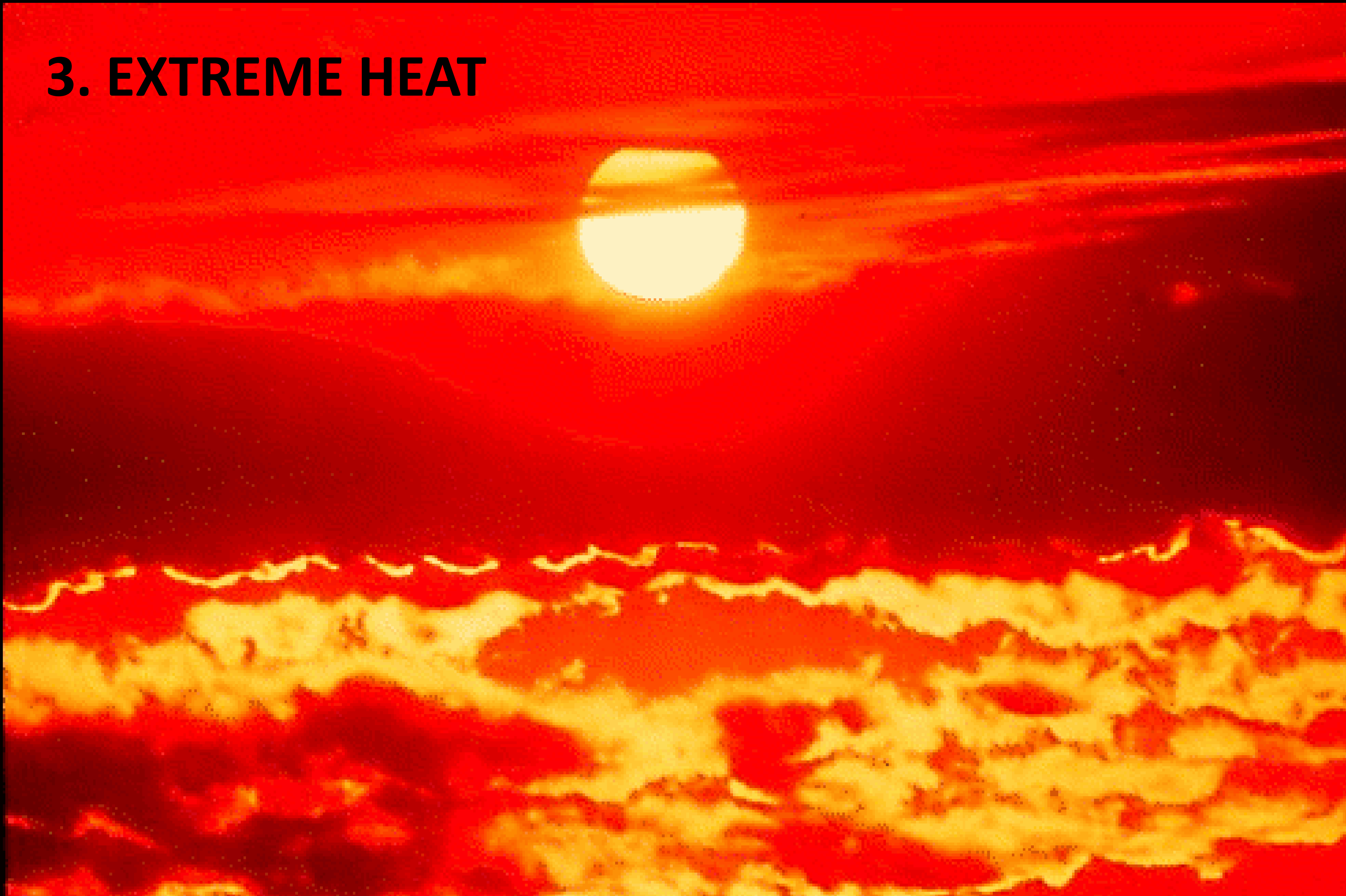


Average tornado occurrence per 10,000 sq miles 1967-1996 [5,373 deaths]

TORNADOES IN BANGLADESH

May 1989 – 1,000 Deaths
May 1996 - 700 Deaths
April 2004 – 111 Deaths

3. EXTREME HEAT



EXTREME HEAT I - DROUGHT AND FAMINE

- CHRONIC HAZARD
- SLOW TO DEVELOP HAZARD
- SHORT-LONG TERM PERTURBATION IN REGIONAL WEATHER PATTERNS

DUST BOWL OF THE 1930s IN USA AND CANADA

Oklahoma, 1937

Stratford, Texas, 1935

EXTREME HEAT II – HEATWAVE

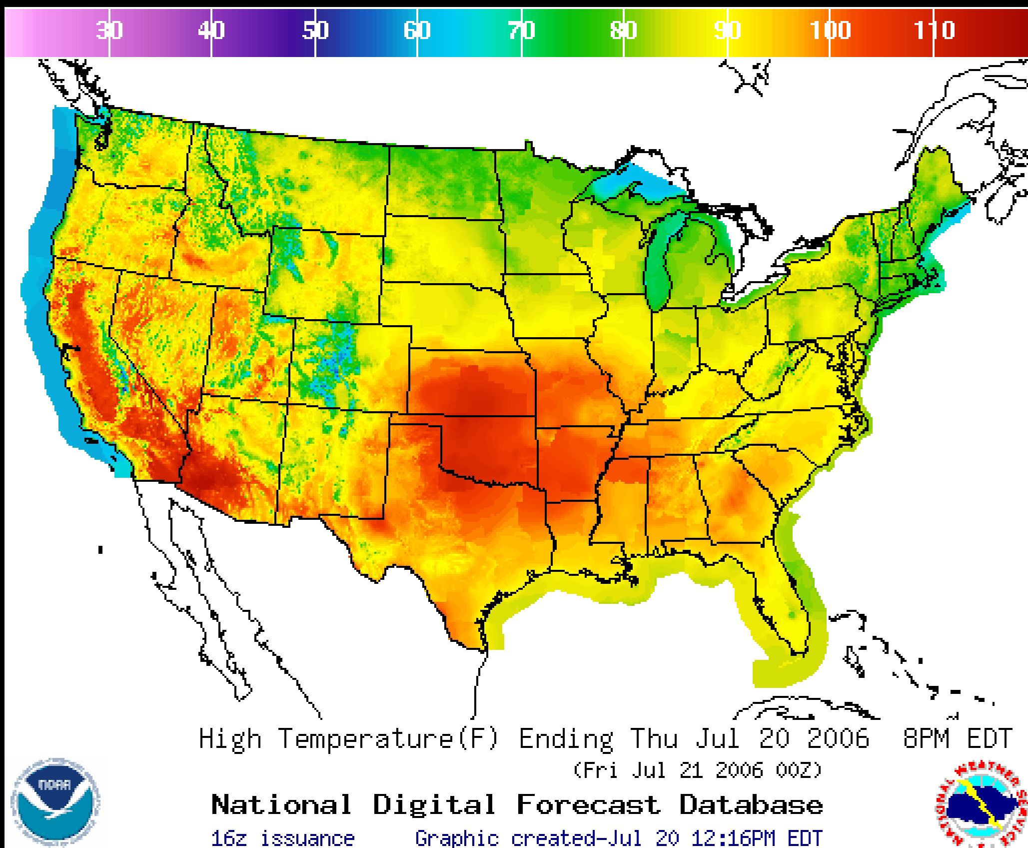
PERSISTENT HIGH TEMPERATURE - SILENT KILLER

TABLE 12.3

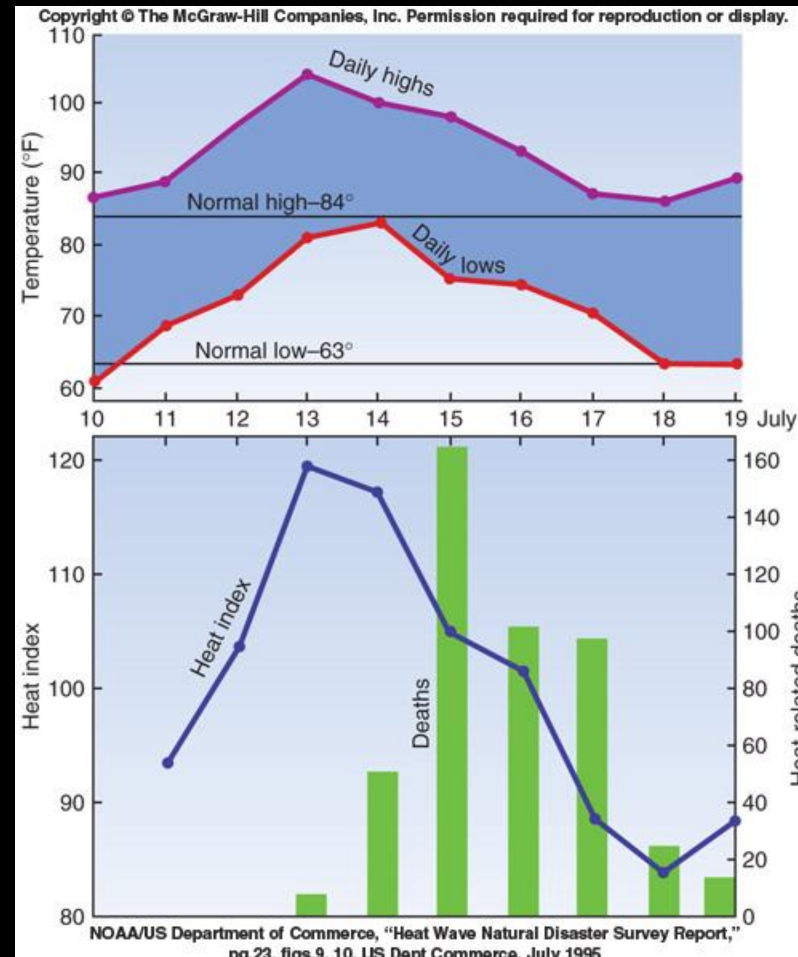
Deaths Due to Severe Weather in the United States, 1988–2004

Event	Average Yearly Deaths
Heat	148
Flood	83
Cold	75
Tornado	52
Lightning	52
Hurricane	18
	428 fatalities per average year

Source: *National Weather Service, (2006) Hazstats.*

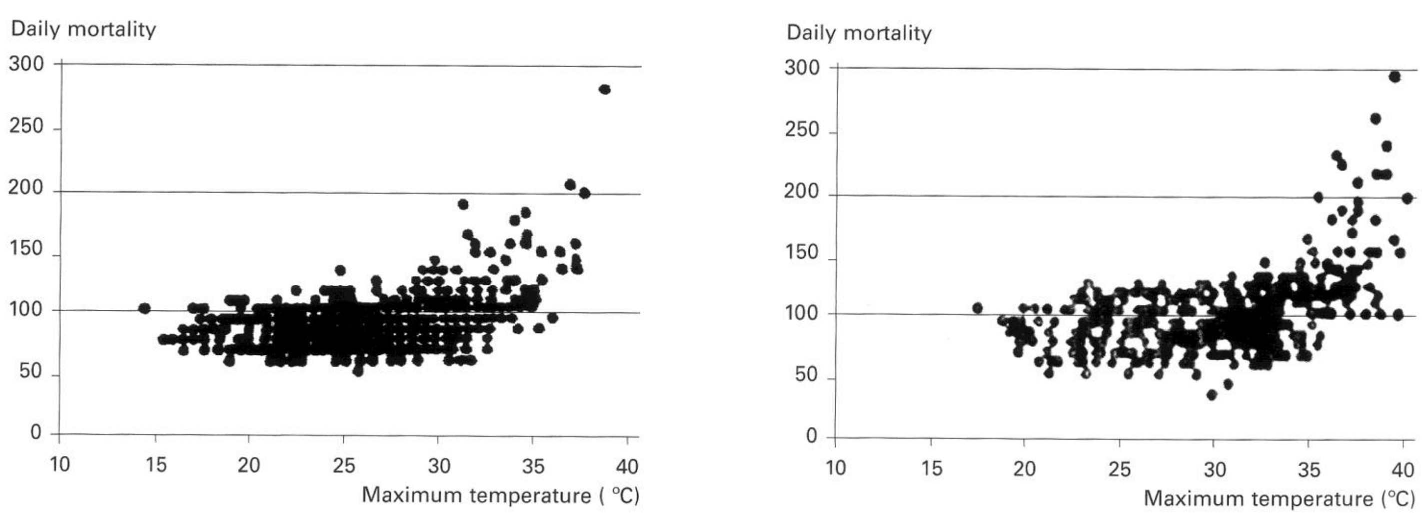


2006 HEAT WAVE



CHICAGO HEAT WAVE – JULY 1995

Temperature and mortality in New York and Shanghai.



The graphs show the number of fatalities as a function of the maximum temperature. At elevated temperatures, the numbers of deaths increase enormously.

Source: McMichael, A. J., et al., 1996. Climate Change and Human Health, WHO/WMO/UNEP

EUROPEAN HEAT WAVE – JULY 2003

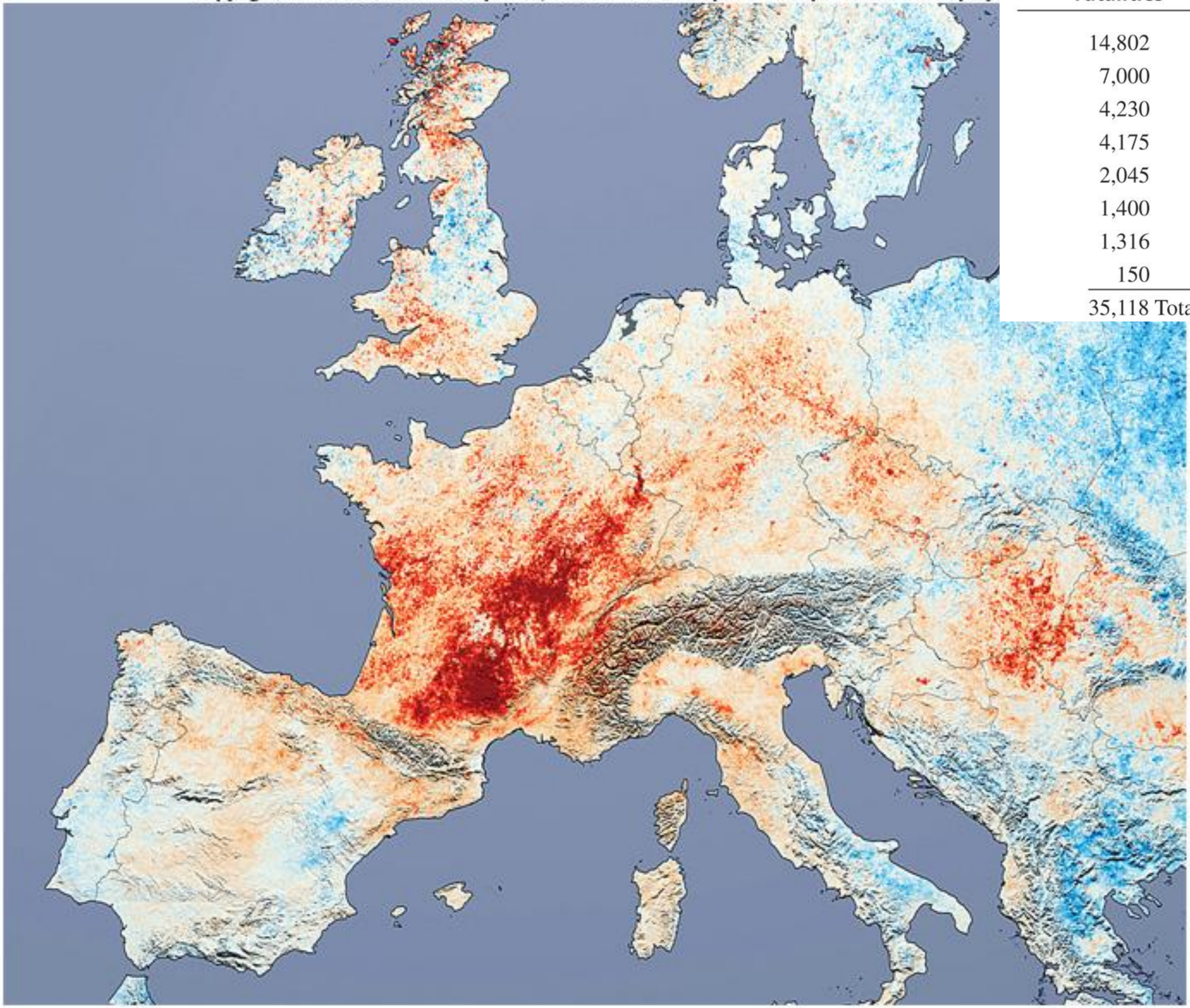


TABLE 12.4

Heat Wave Deaths in Europe, August 2003

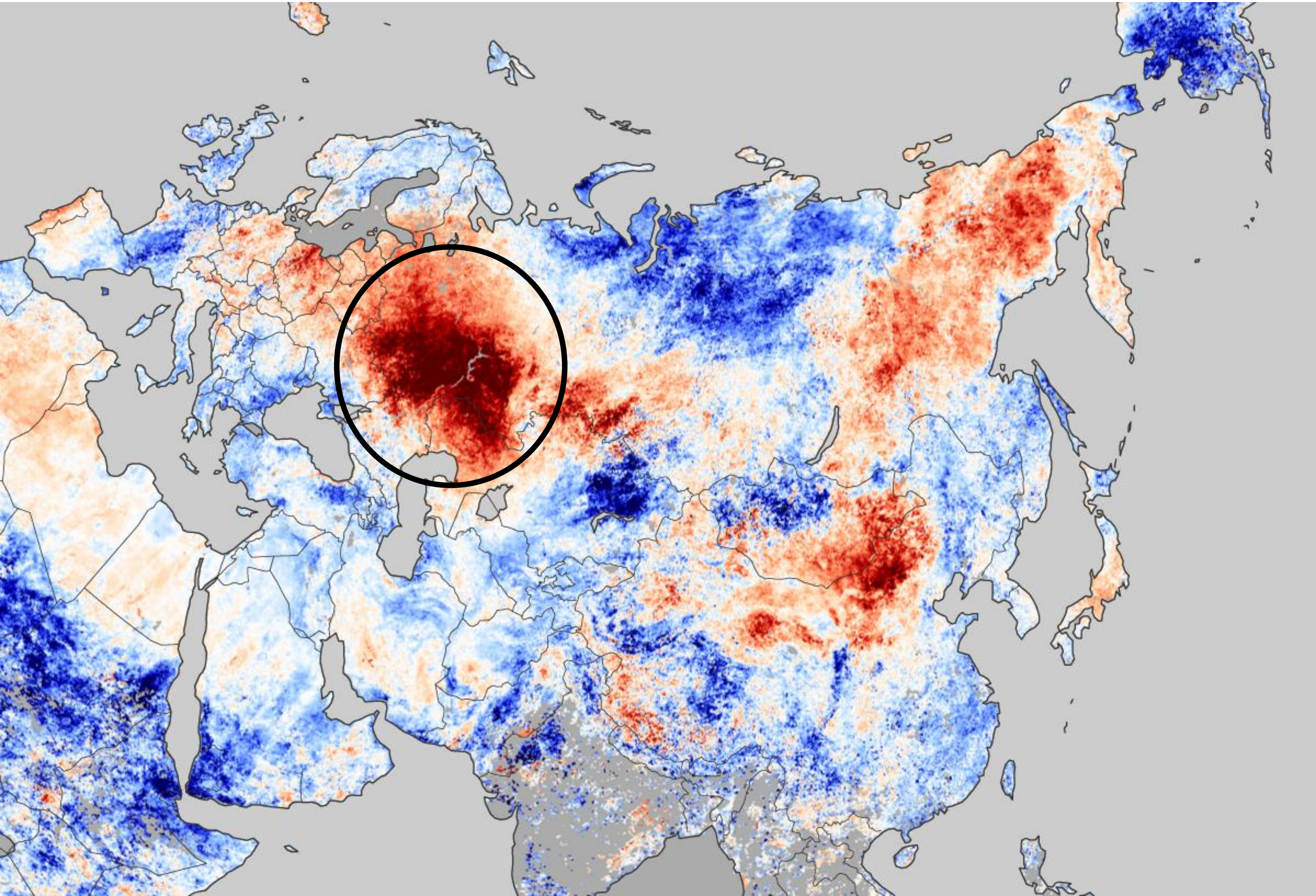
Fatalities	Country
14,802	France
7,000	Germany
4,230	Spain
4,175	Italy
2,045	United Kingdom
1,400	Netherlands
1,316	Portugal
150	Belgium
35,118 Total deaths	

Red areas are 10 °C hotter than July 2001

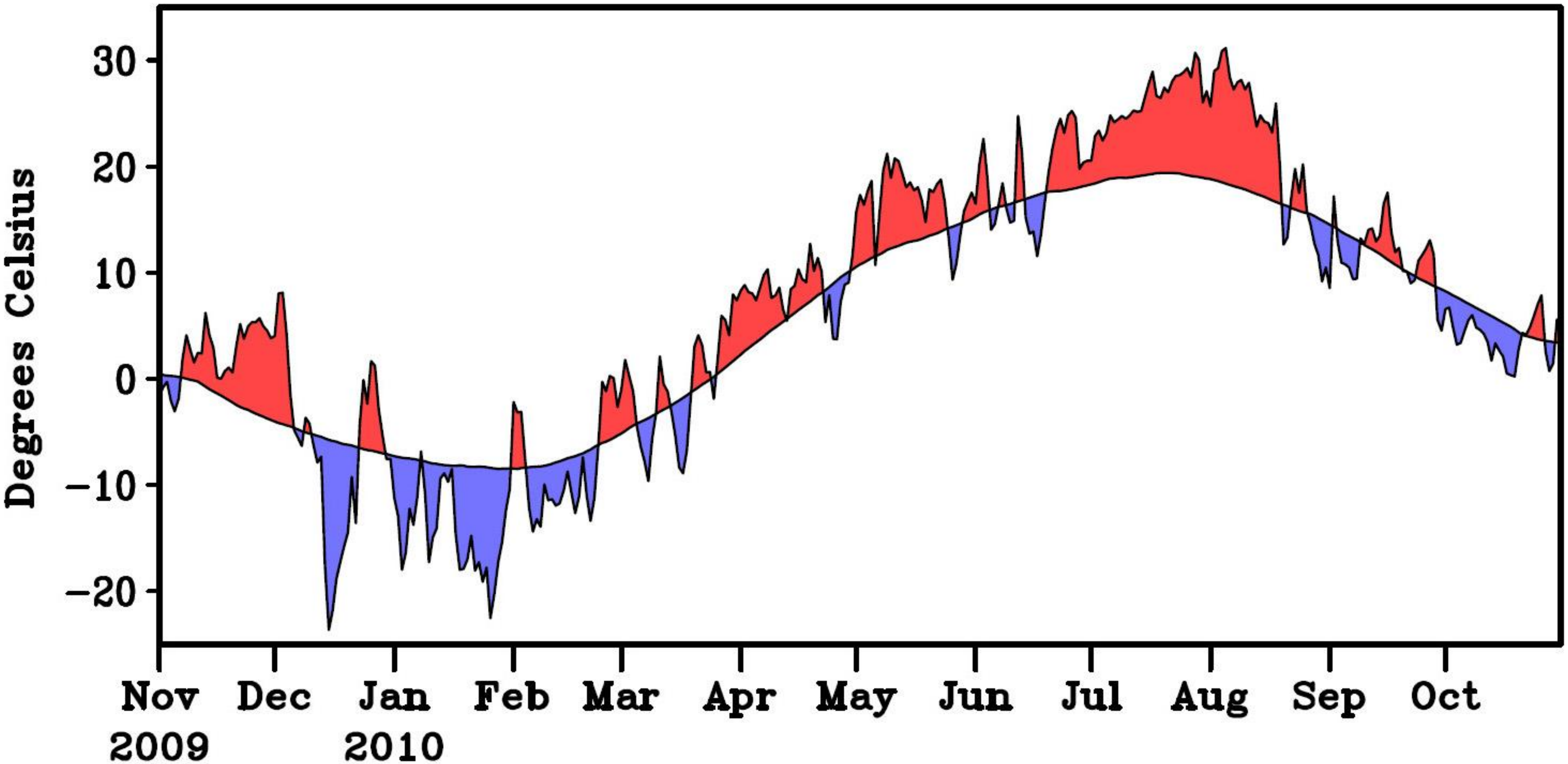
EXTREME HEAT III – WILDFIRE

CALIFORNIA FIRES OCTOBER 2007

LAND SURFACE TEMPERATURE ANOMALIES IN EURASIA JULY 20-27, 2010 (Deep Red = Greatest Above Anomaly; Deep Blue = Greatest Below Anomaly) *NASA Data*



Moscow Daily Average Temperature

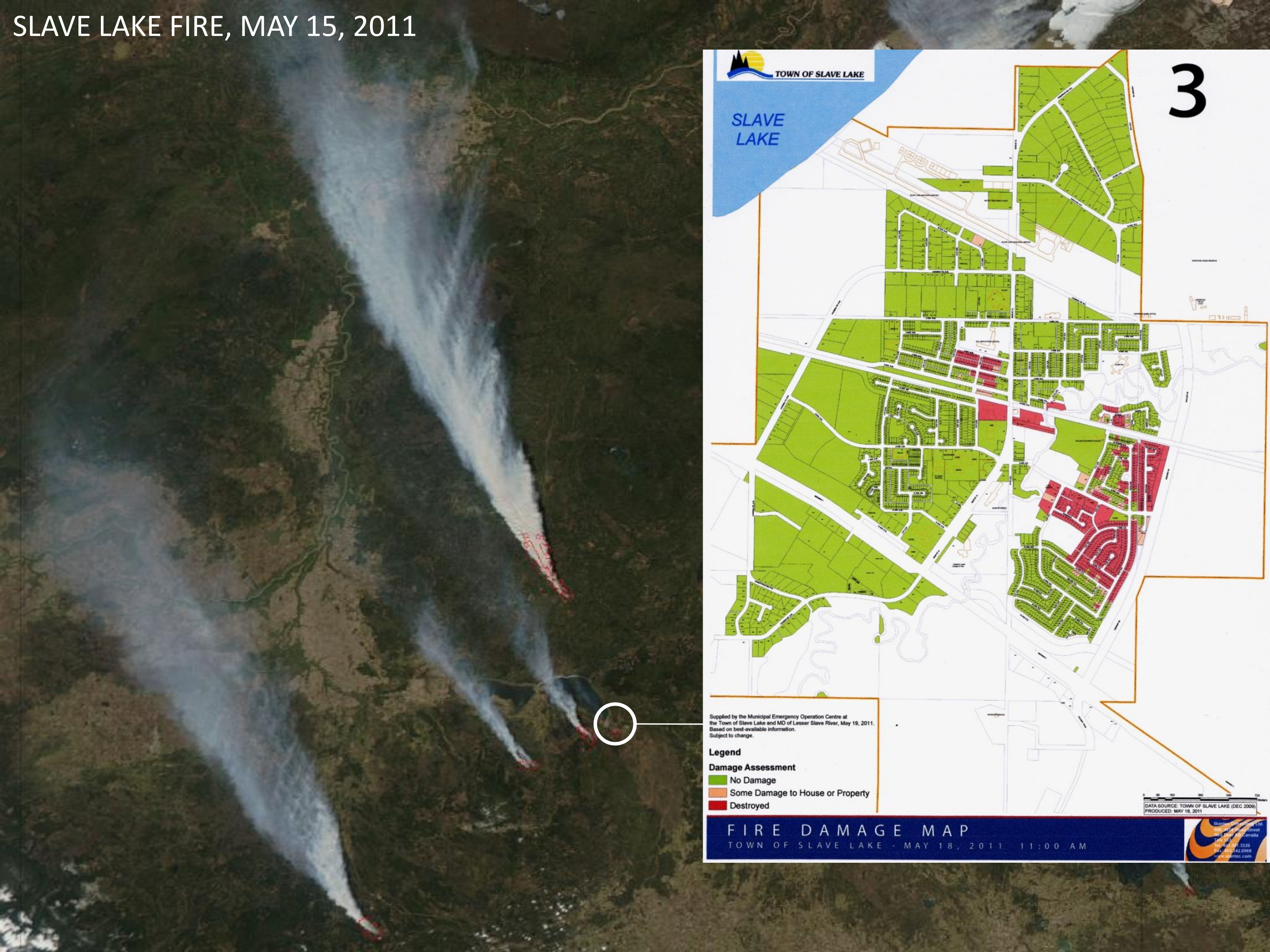


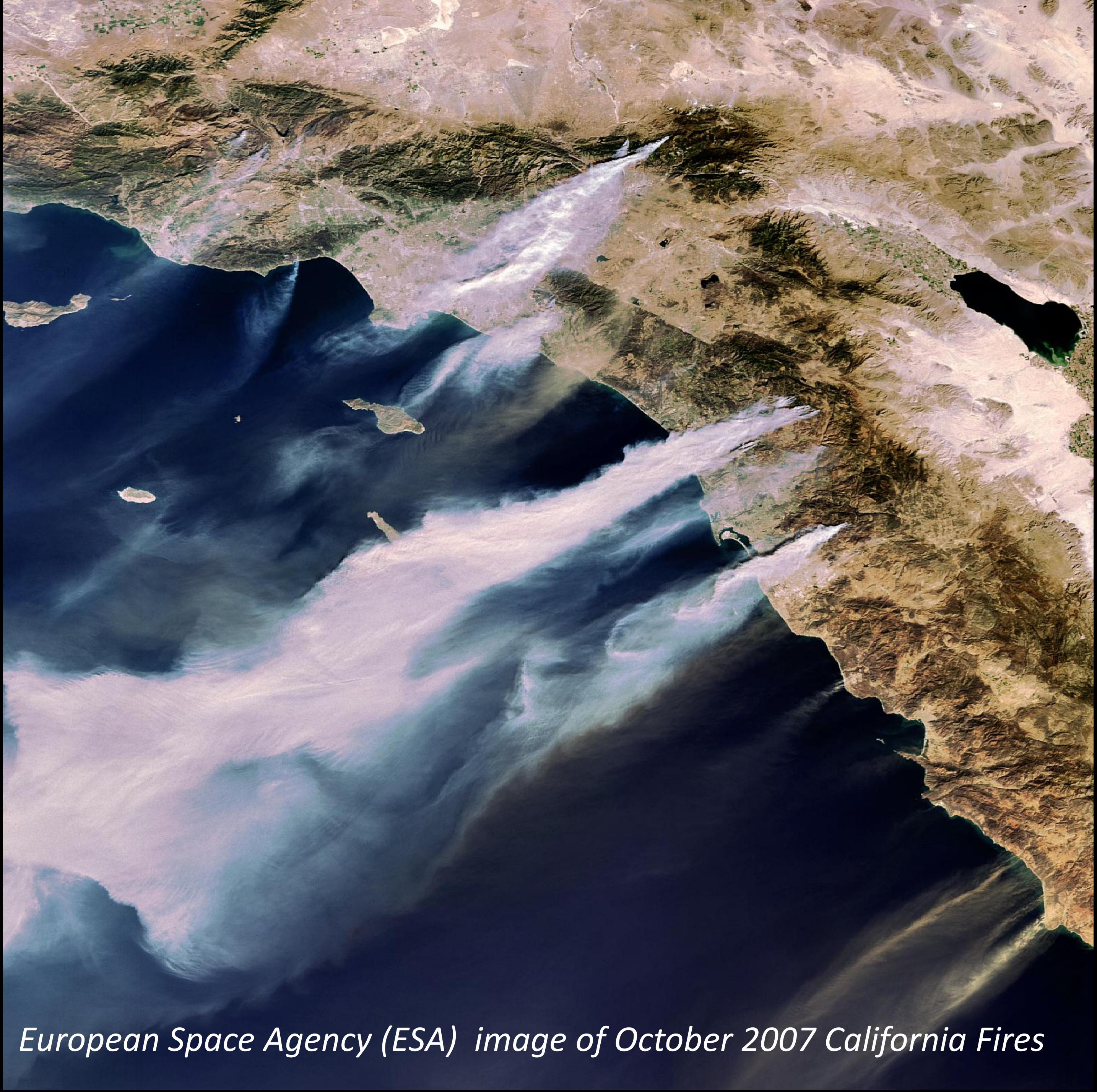
WESTERN RUSSIA HEATWAVE AND WILDFIRES JULY-AUGUST 2010

Ilyushin - 76 water bomber in action near Moscow

WILDFIRE AT SLAVE LAKE, ALBERTA [May 15, 2011]

•Canada's second costliest disaster in terms of insured losses [$700 M]
•433 lots destroyed and 84 damaged


SLAVE LAKE FIRE, MAY 15, 2011
TOWN OF SLAVE LAKE
3
SLAVE LAKE
Supplied by the Municipal Emergency Operation Centre at the Town of Slave Lake and MD of Lesser Slave River, May 19, 2011. Based on best-available information. Subject to change.
Legend
Damage Assessment
No Damage
Some Damage to House or Property
Destroyed
DATA SOURCE: TOWN OF SLAVE LAKE (DEC 2009)
PRODUCED: MAY 18, 2011
FIRE DAMAGE MAP
TOWN OF SLAVE LAKE - MAY 18, 2011 11:00 AM



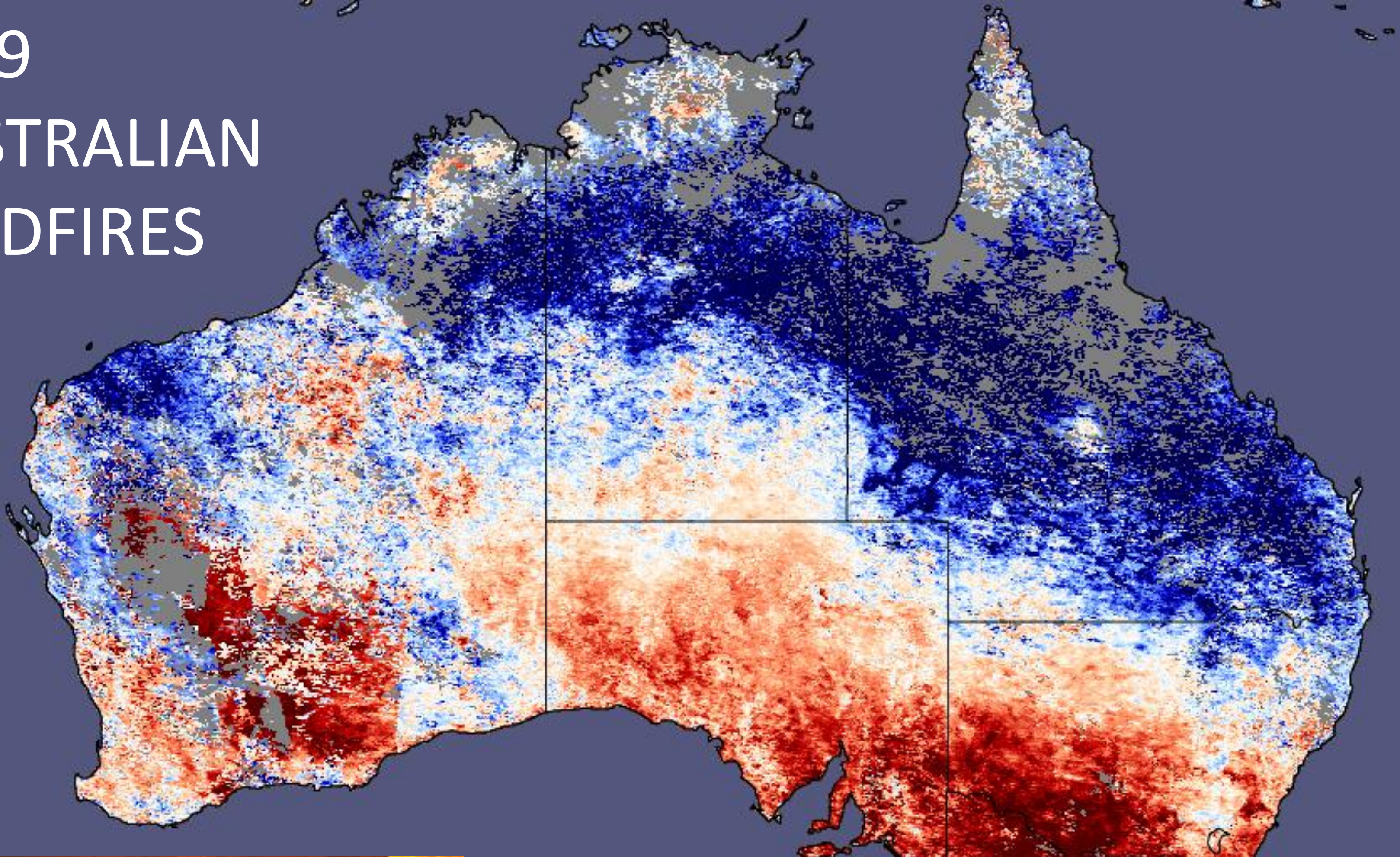
European Space Agency (ESA) image of October 2007 California Fires

2009 CALIFORNIA WILDFIRES


21


SUPERTANKER

2009 AUSTRALIAN WILDFIRES



NASA map of land-surface temperature anomalies (compared to long term mid-summer average) during January-February 2009 heatwave; ~ 200 deaths and >$1 B in damage.

FORT McMURRAY FIRES May 2016

Wildfires spark biggest-ever loss for Canada's insurance industry

Wildfires in Canada were another cause of large insurance losses in 2016. The cause of the wildfires is still under investigation, and could be the result of human activity.[3] Due to dry conditions and strong winds, once triggered, fires spread rapidly through the forests of Alberta. The town of Fort McMurray was evacuated, and many homes there were completely destroyed. Economic losses were USD 3.9 billion. The area is the heart of Canada's oil sands production with a high concentration of insured economic assets. As such, the insured losses were around USD 2.8 billion. This is one of the costliest wildfire events in insurance industry history, and it is the biggest loss the Canadian insurance sector has ever experienced.

NATURAL HAZARDS OF CONCERN IN EARTH 270 (v. 2017)

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)