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Weather extremes and their changes: phenomenology and empirical approaches

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WEATHER EXTREMES AND THEIR CHANGES: *PHENOMENOLOGY AND EMPIRICAL APPROACHES*

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Joint ICTP-IAEA Workshop on Vulnerability of Energy Systems to Climate Change and Extreme Events, Trieste, Italy, April 19, 2010

1. THE EXTREMES, AS THEY ARE

- IDENTIFICATION OF THE EXTREME EVENTS
- THE EXTREME EVENTS
- SIGNIFICANT CIRCULATION OBJECTS (MULTI-VARIABLE EFFECTS)
- ENVIRONMENTAL EFFECTS OF THE WEATHER EXTREMES

2. THE CLIMATE CHANGE AND THE EXTREMES (EMPIRICAL APPROACH)

- ANTHROPOGENIC GLOBAL WARMING: HOW SURE IT IS?
- EXPECTATIONS ON CHANGES IN THE EXTREMES
- EMPIRICAL APPROACH: DATA QUALITY AND CONCEPTUAL PROBLEMS
- WHAT CAN WE SEE FROM THE DATA?

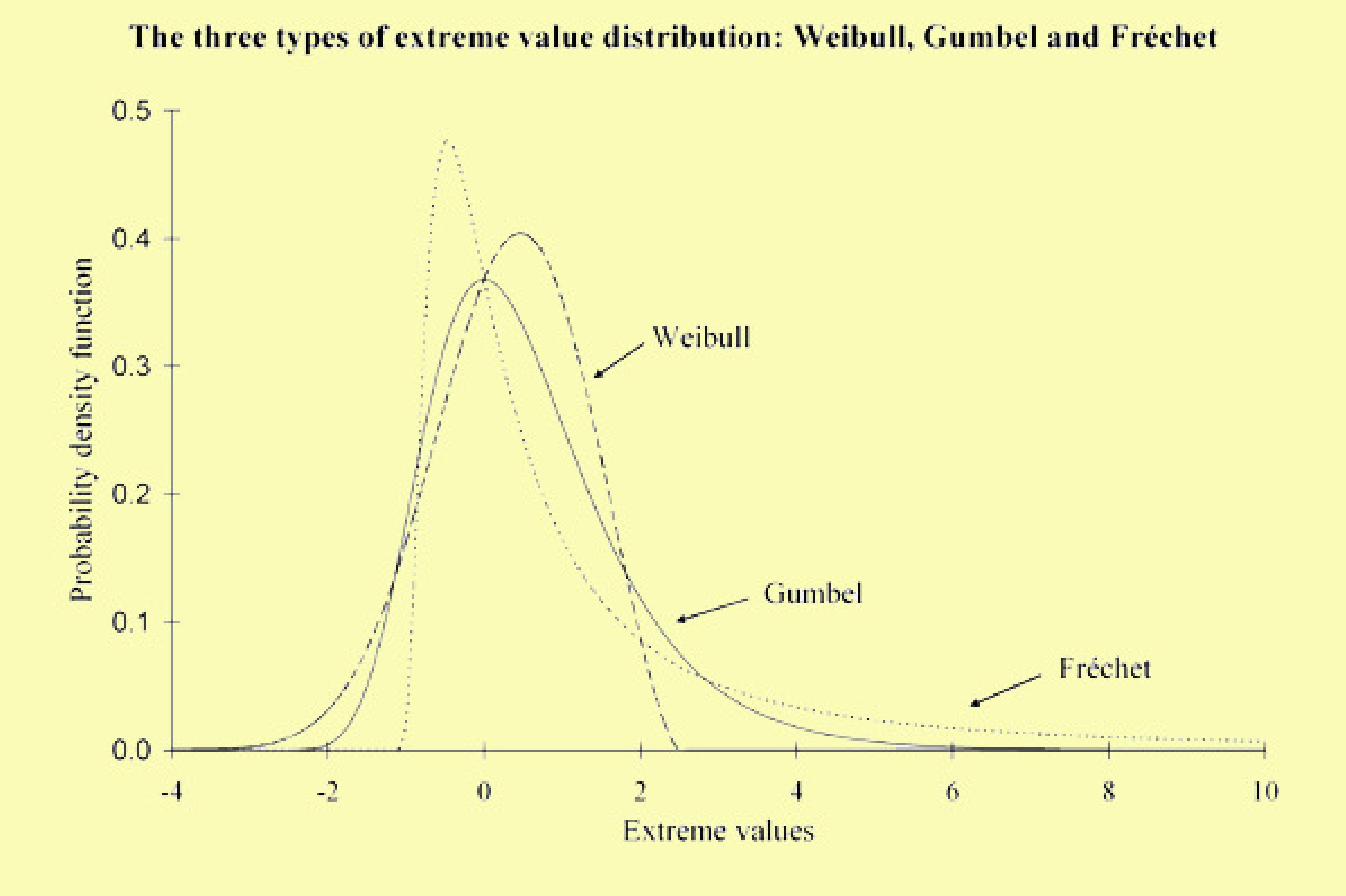
1. THE EXTREMES, AS THEY ARE
IDENTIFICATION OF THE EXTREME EVENTS

- Rare and moderate extremes, extremity in duration
- Univariate indices
- Multivariate extremities, transformed into indices
- Statistical vs. practical extremes

What is an extreme event?

- A rare event?
  - Select a threshold frequency
- An intense event?
  - Select a threshold to excess
- (An extreme in its impacts?
  - Not in focus of the present talk)

Selection of the distribution:
Source of quantitative uncertainty



Source: http://www.longin.fr/images/img_extreme_distribution.gif

WMO CCL (Commission for Climatology of WMO) / **CLIVAR** (Research Program on CLImate VARiability and Predictability)

Index/unit	Description
tnn/°C	absolute Tmin
dtn0/days	frost days Tmin < 0°C (FD)
itn0x/days	maximum number of frost days Tmin < 0°C (CFD)
dtn0e/days	frost days Tmin = 0°C
t17s/°C	heating degree days (HD17)
t20s°C	heating degree days
dtx0/day	ice days (ID)
dtx0e/day	ice days
ditnlnr/day	cold wave duration index (CWDI)
ditlnr10/day	cold spell days (CWFI)
itnlnr10/day	maximum duration of cold spell TNCW10 Climdex)
dtlnr10/day	Tavg < 10^{th} percentile of normal period (TG10p)
dtnlnr10/day	Tmin < 10^{th} percentile of normal period (TN10p)
dtxlnr10/day	Tmax < 10^{th} percentile of normal period (TX10p)

Index types: maxima, minima, duration, step over a threshold, (absolute or percentile)

Index/unit	Description
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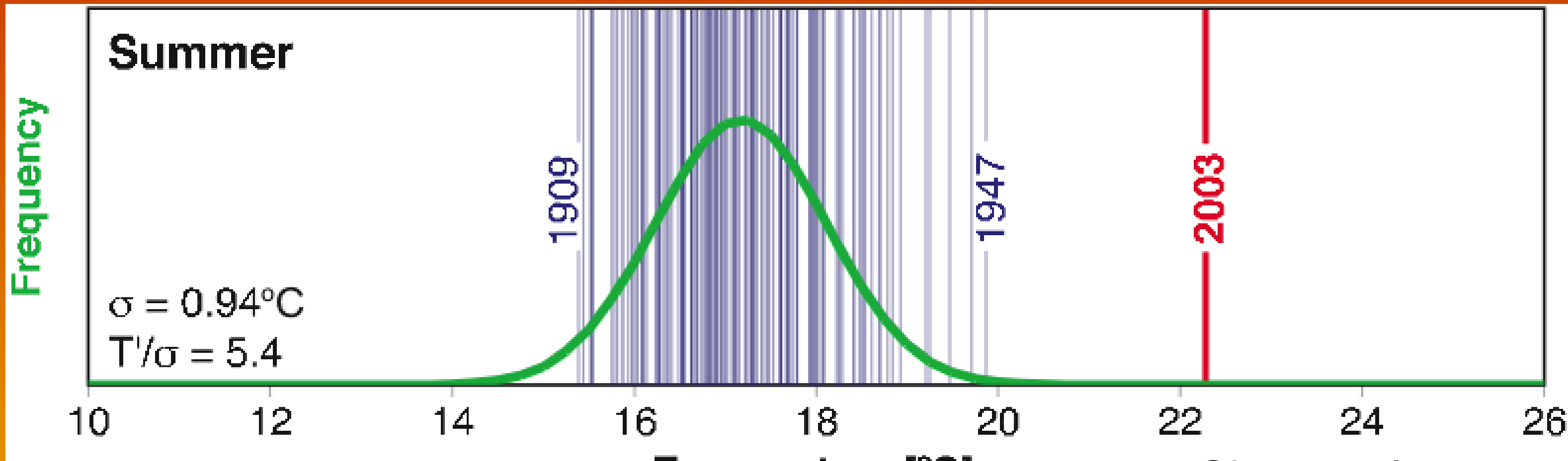
dtnlnr10/day	Tmin < 10^{th} percentile of normal period (TN10p)
dtxlnr10/day	Tmax < 10^{th} percentile of normal period (TX10p)

Practically: 10 % (moderate extreme)

Ways of extreme event indication

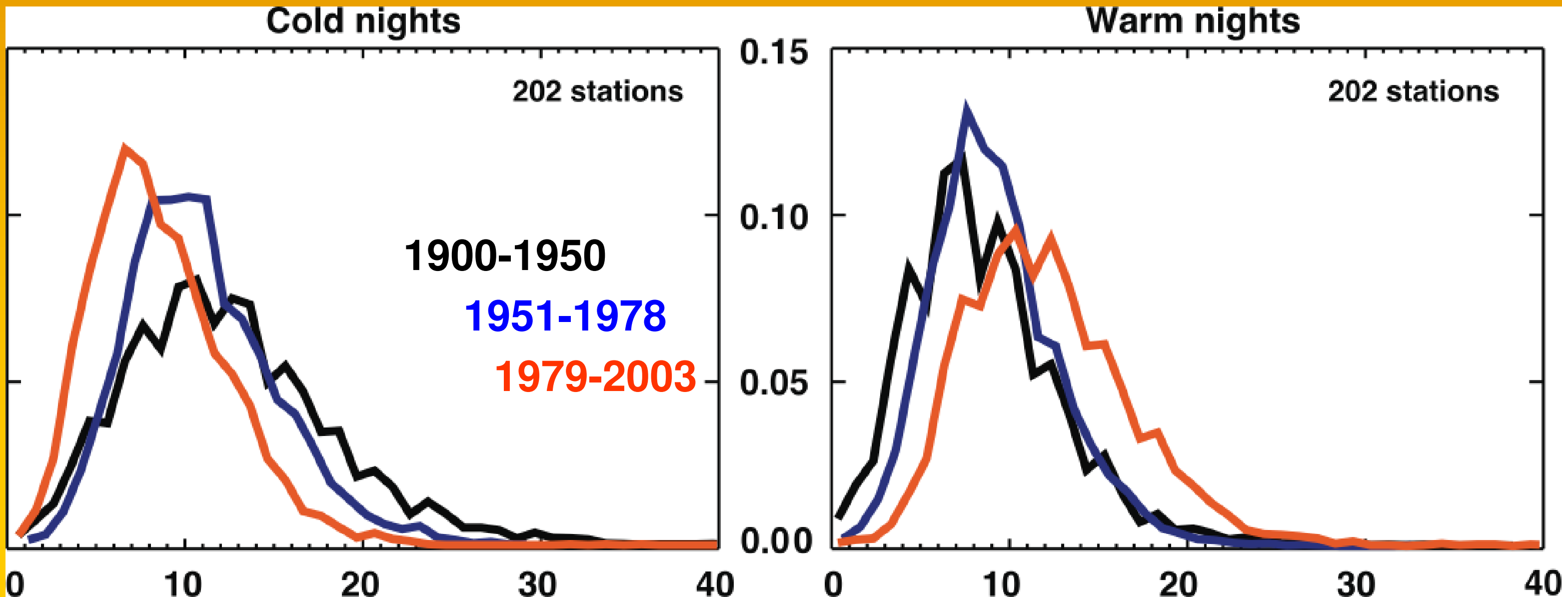


Shär et al., 2004

Tmin

Single event 17 C In CH

Alexander et al., 2006



Tmin

% in a year for a „10 % event"

Typical: Combined index instead of multivariate estimation

furnished by National Weather Service Gray, ME

Relative Humidity (%) — **Heat Index (Apparent Temperature)**

Air Temperature °F	40	45	50	55	60	65	70	75	80	85	90	95	100
110	136												
108	130	137											
106	124	130	137										
104	119	124	131	137									
102	114	119	124	130	137								
100	109	114	118	124	129	136							
98	105	109	113	117	123	128	134						
96	101	104	108	112	116	121	126	132					
94	97	100	103	106	110	114	119	124	129	135			
92	94	96	99	101	105	108	112	116	121	126	131		
90	91	93	95	97	100	103	106	109	113	117	122	127	132
88	88	89	91	93	95	98	100	103	106	110	113	117	121
86	85	87	88	89	91	93	95	97	100	102	105	108	112
84	83	84	85	86	88	89	90	92	94	96	98	100	103
82	81	82	83	84	84	85	86	88	89	90	91	93	95
80	80	80	81	81	82	82	83	84	84	85	86	86	87

With Prolonged Exposure and/or Physical Activity

Extreme Danger	Heat stroke or sunstroke highly likely
Danger	Sunstroke, muscle cramps, and/or heat exhaustion likely
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible
Caution	Fatigue possible

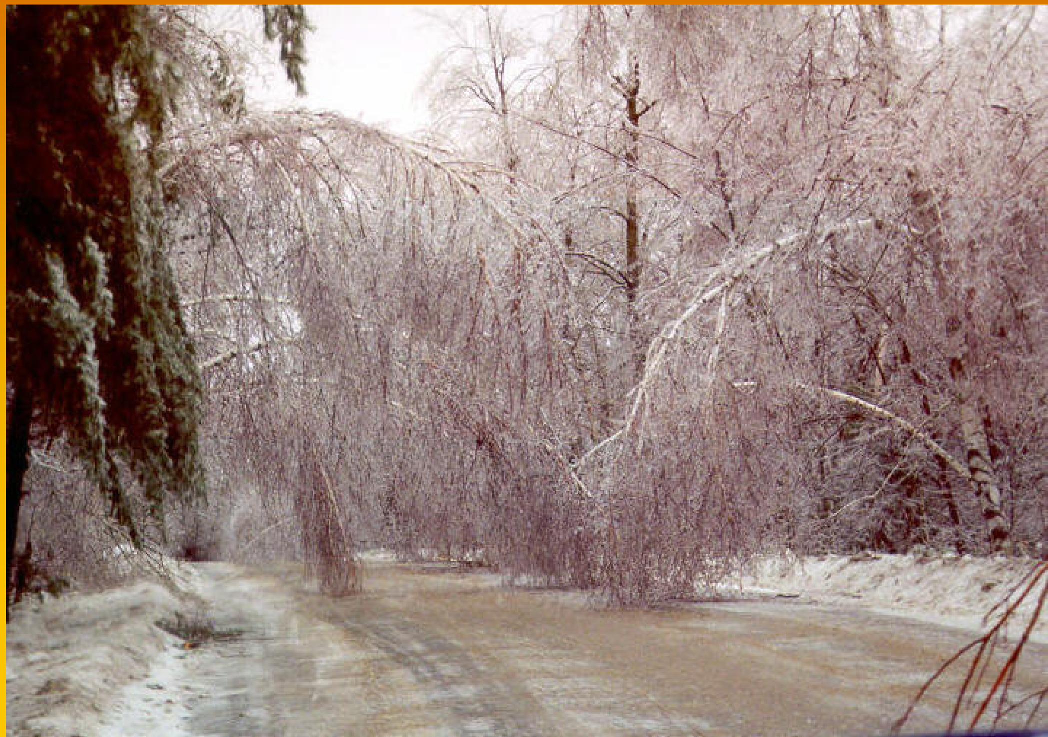
http://weblogs.cltv.com/news/weather/traffic/heatindexchart.gif

THE EXTREME EVENTS

- Heat, cold,
- Rain, freezing rain, hail
- Wind, lightning
- Extremes of long-term development

Temperature extremes

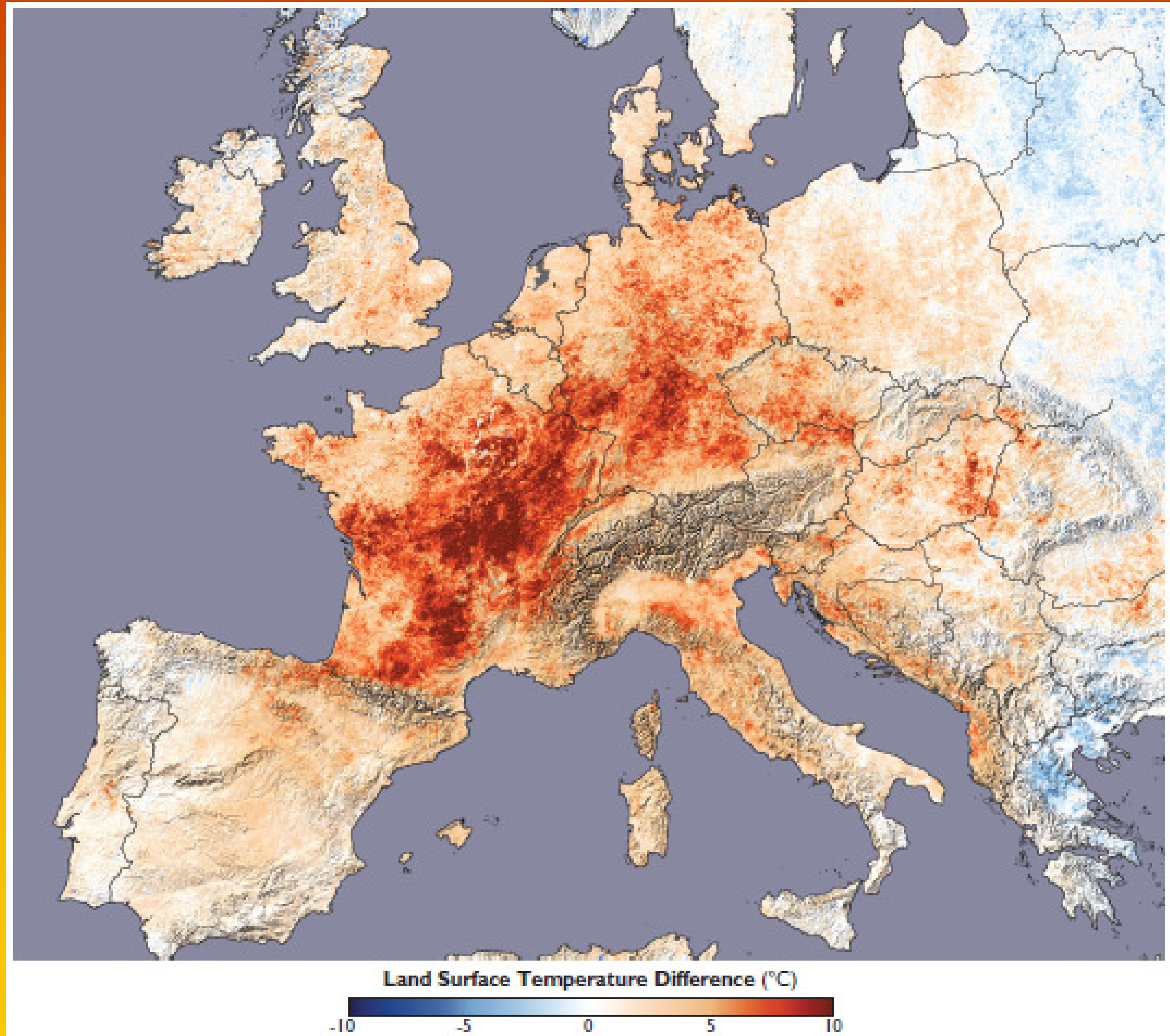
Cold waves



Caused by high pressure polar or arctic air

Heat-waves

Summer 2003.
Kinetic temperature
(irradiating surface
temperature)



King et al.,ed.: Our changing planet, 2009 p. 53

Heat-wave (cont.)

The summer of 1955 was one of the Northeast's hottest. At the time it was, in fact, Philadelphia's warmest on record, and sidewalk omelets were the rage. (Urban Archives, Temple University)

Rime

(and other forms of icing)

http://i158.photobucket.com/albums/t100/clyates/WhiteLodgeWalks/090101BeaconHill/0901010029w400.jpg

CLASSIFICATION OF THE ICE LOAD

Classification of Icing

Class	*General Description*	*Close Observation on tree branches*
None	No observable indication.	
Very Light	Not observable by front light but can be detected by back lighting the glaze on the branches.	Lower side of branches are not covered by ice.
Light	Observable by front lighting but no appreciable bending of branches.	Branches enclosed in ice 2mm on top side.
Light-Moderate	Small branches start to bend.	Thickness on top side 3mm and considerably thicker than bottom.
Moderate	Trunks of young birch trees start to bend. Icicles sometimes odserved.	Maximum thickness about 4mm on top.
Moderate-Heavy	Trunks of young birch trees bend to ground. Icicles sometimes odserved. Some branches are broken.	Maximum thickness about 5mm on top.
Heavy	Considerable damage on old trees. Continuous icicles on power lines.	Maximum thickness about 6mm on top.
Very Heavy	Telephone lines slack.	Maximum thickness about 10mm on top.
Extremely Heavy	Telephone lines break.	Maximum thickness about 12mm on top.

Source: **Christopher. C. Burt, 2007: Extreme Weather**

Freezing rain

Photo: Imre Bonta

Hailstorm

Hail stones can cause considerable damage to vehicles.

SWISSRE, 2005 (www.swissre.com)

HAILSTORM CLASSIFICATION

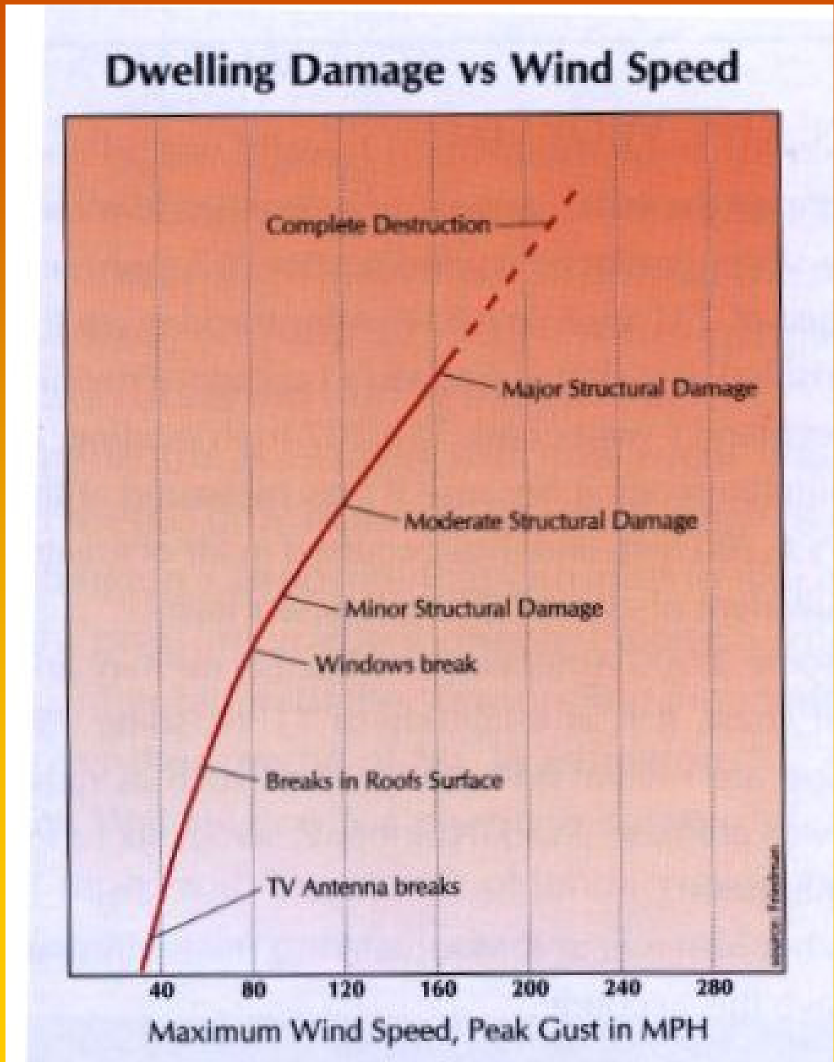
Hailstorm Intensity Scale

Intensity	General Description	Range of Hailstone Size During Hailstorm	
H0	None	.2"—.4"	pea-sized
H1	Makes holes in leaves and flower plants	.2"—.8"	marble-sized
H2	Strips leaves from plants, damages vegetables	.2"—1.2"	penny-sized
H3	Breaks glass panes, scrapes paint, marks wookwork, dents trailers, tears tents	.4"—1.8"	nickel-sized
H4	Breaks windows, cracks windscreens, scrapes off paint, kills chickens and small birds	.6"—2.4"	golf ball-sized
H5	Breaks some roof tiles and slates, dents cars, strips bark off trees, cuts branches from trees, kills small animals	.8"—3.0"	tennis ball-sized
H6	Breaks many roof tiles and slates, cuts through roof shingles and thatch, makes some holes in corrugated iron, breaks wooden window frames	1.2"—3.9"	baseball-sized
H7	Shatters many roofs, breaks metel window frames, seriously damages car bodies	1.8"—4.9"	grapefruit-sized
H8	Cracks concrete roofs, destroys other roofs, marks pavement, splits trees, can seriously injure people	2.4"—5.0"	softball-sized
H9	Marks concrete walls, makes holes in walls of wooden houses, fells trees, can kill people	3.2"—5.0"+	softball-sized
H10	Destroys wooden houses, seriously damages brick houses, can kill people	4.0"—7.0"+	volleyball-sized

Source: **Christopher. C. Burt, 2007: Extreme Weather**

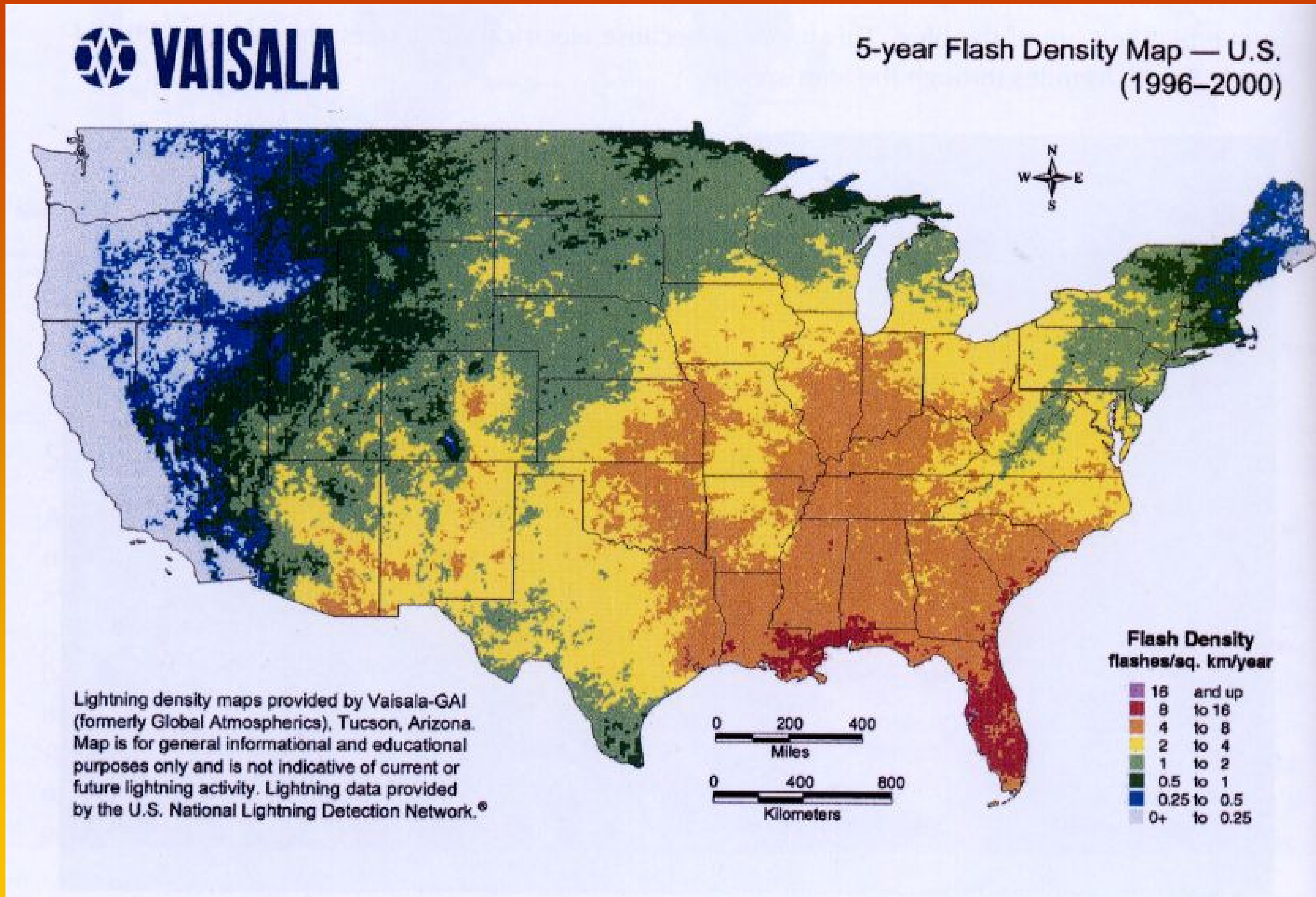
Wind

Lightning



Behav. Sci. Institute, Univ. Colorado, 1971

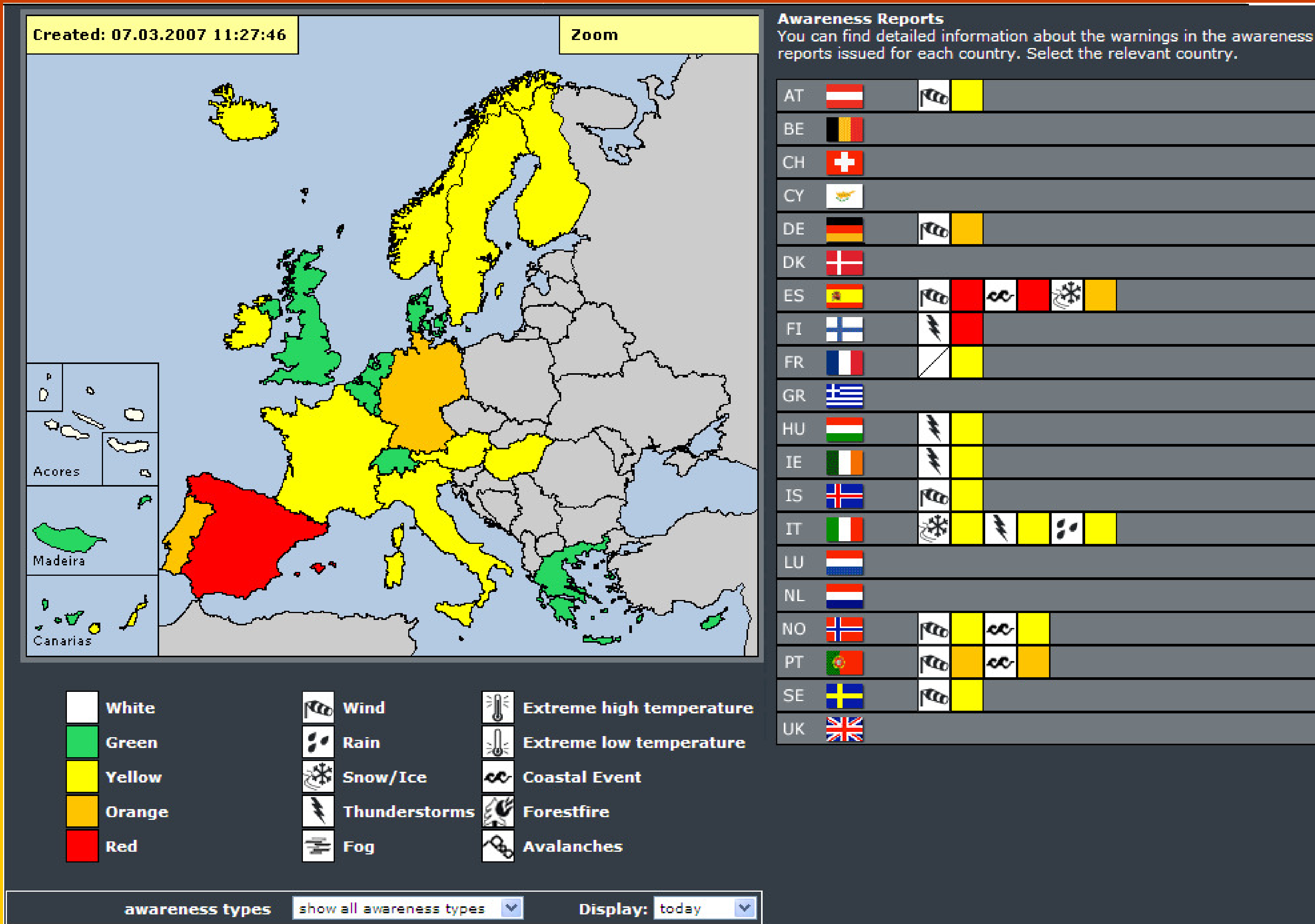
Frequency of cloud-surface lightning (1 / sq.km · yr)



This map shows the average number of lightning flashes detected per year per square kilometer for the period of 1996–2000. it gives a fairly good idea of where lightning is most likely to strike, although there is considerable variability from one year to the next.

Source: **Christopher. C. Burt, 2007: Extreme Weather**

OTHER EVENTS (SUBJECTS TO OPERATIVE WARNING)



meteoalarm
alerting europe for extreme weather

EUMETNET
The Network of European Meteorological Services

http://www.eumetnet.eu/

Extreme events with impact on agriculture

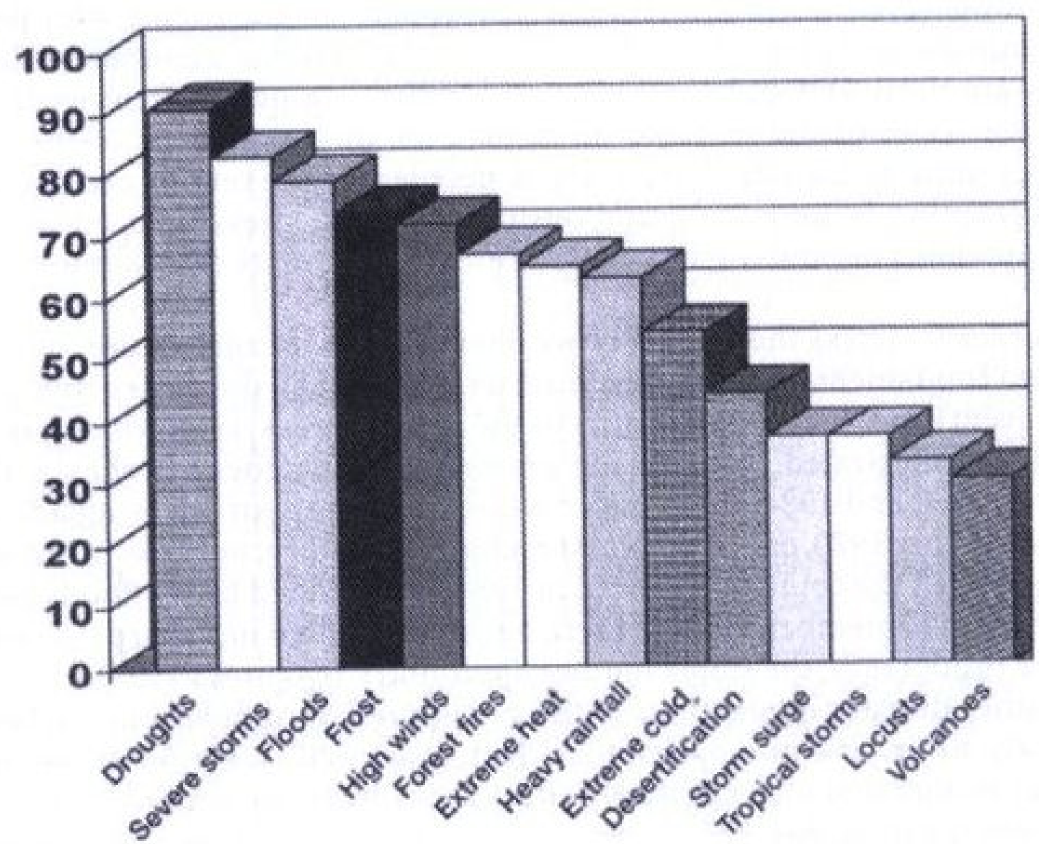
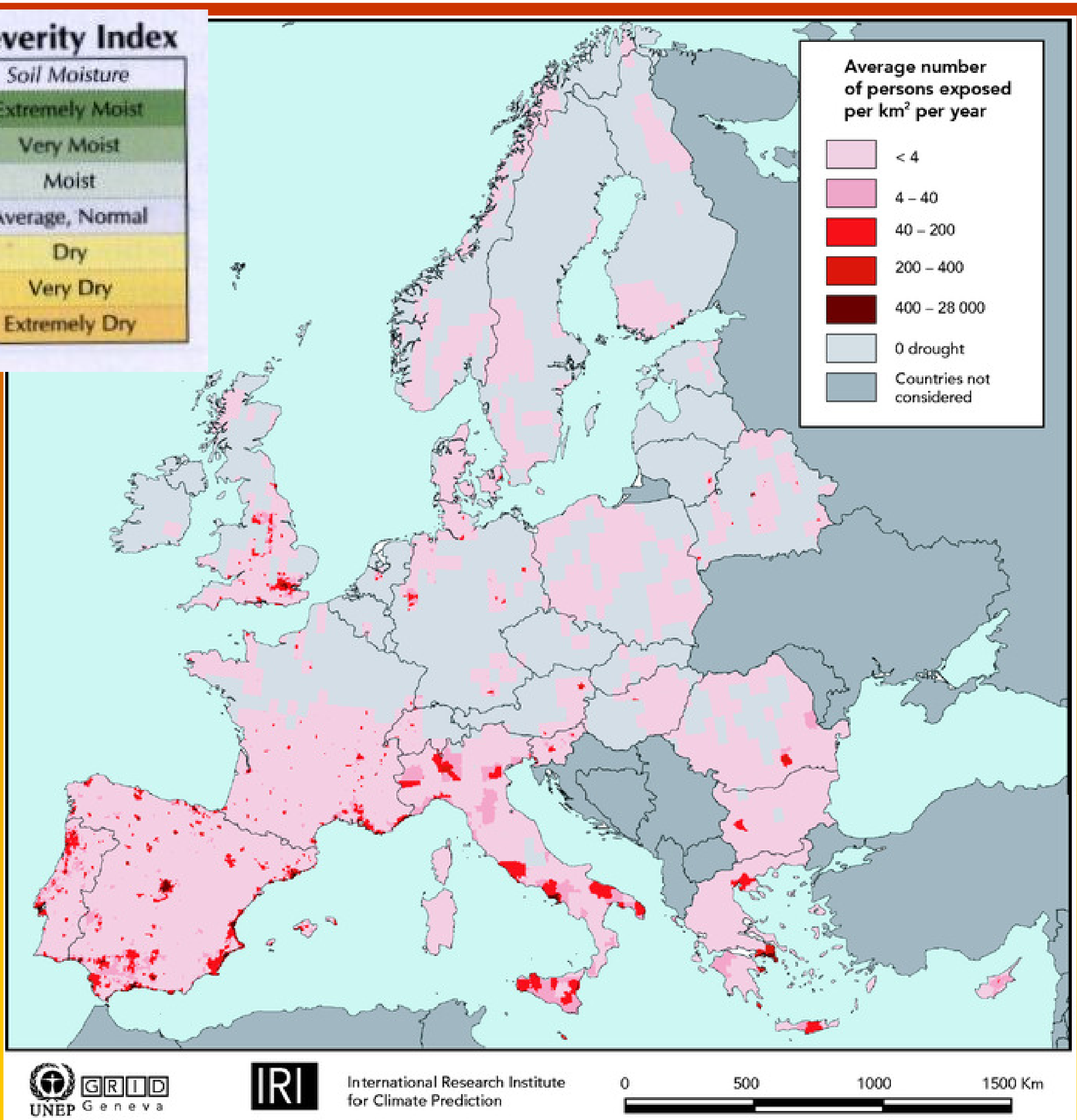


Fig. 6.1. Percentage of countries reporting agricultural impacts from extreme agrometeorological events

Source: **Shivakumar M.V.K., Motha R. P. and Das H.P., (eds.) 2005: Natural Disasters and Extreme Events in Agriculture,** Springer V.

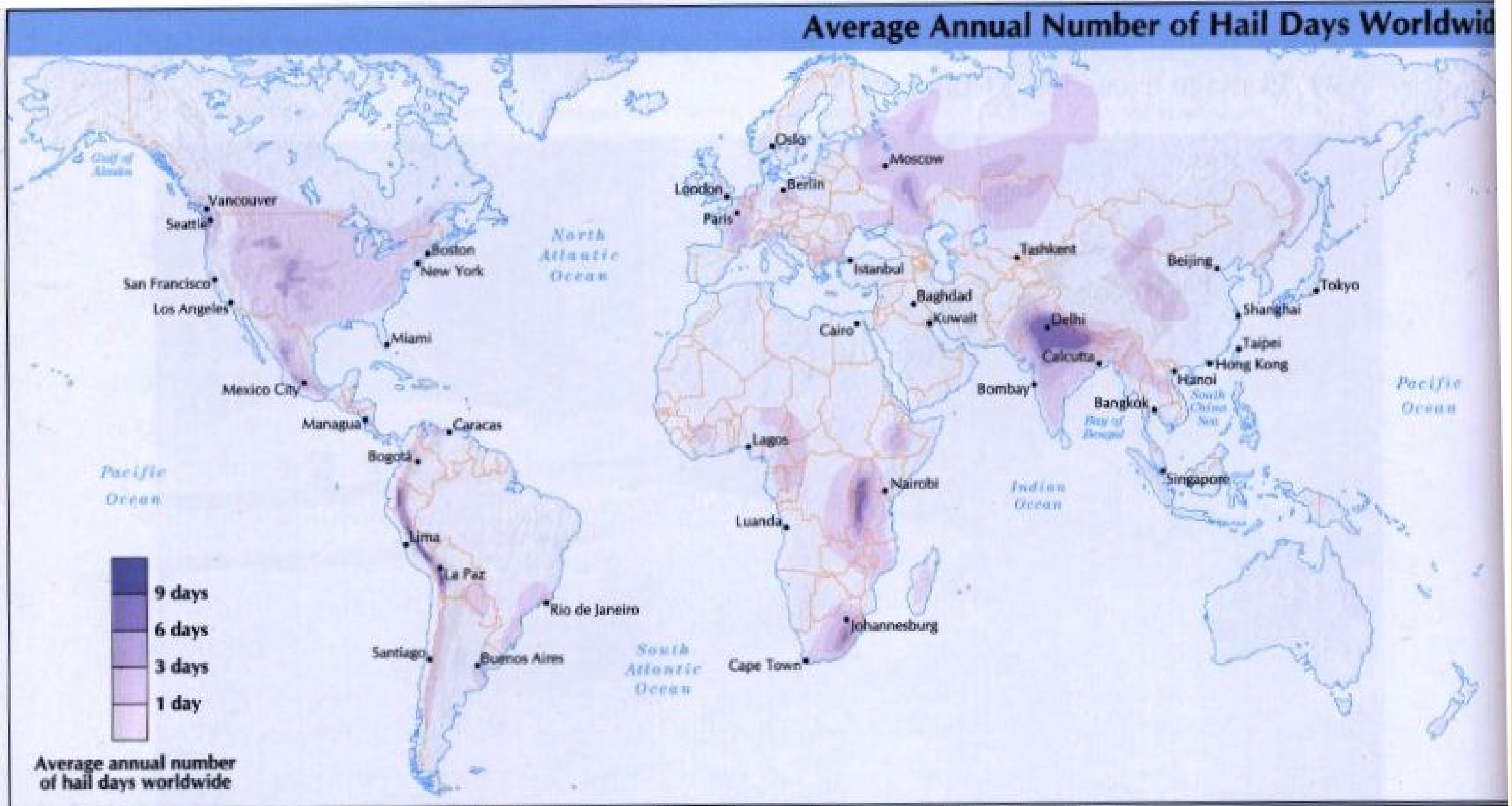
Palmer Drought Severity Index

Palmer Index	Soil Moisture
Above +4	Extremely Moist
+3 to +4	Very Moist
+2 to +3	Moist
-2 to +2	Average, Normal
-2 to -3	Dry
-3 to -4	Very Dry
Below -4	Extremely Dry



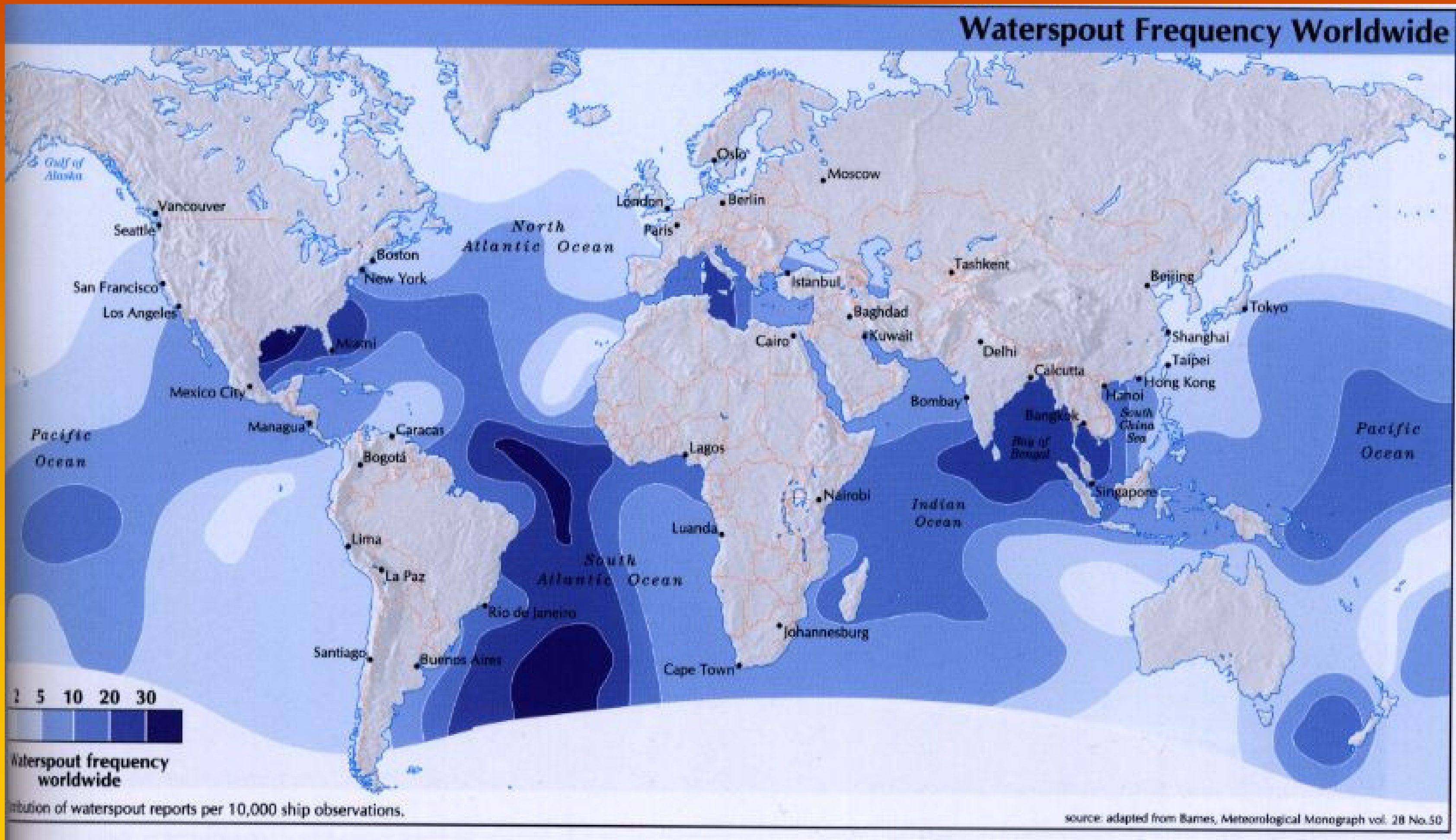
Number of persons per km^2 exposed to drought, in Europe

(http://reports.eea.europa.eu/environmental_issue_report_2004_35)

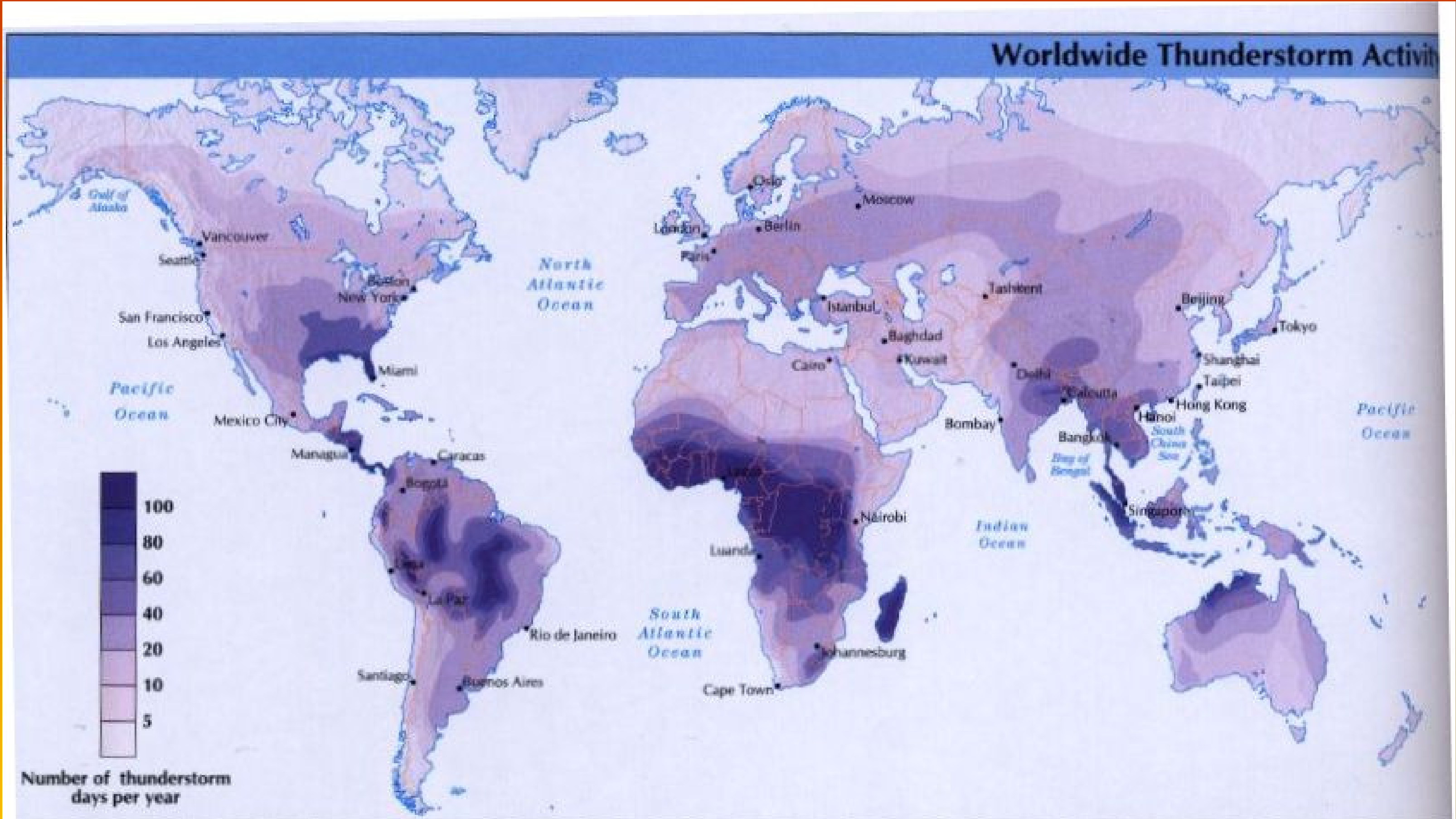


Regions of World with Highest Hail Frequency (avg. 6 or more days annually) Annual Number of Hail Days/Region	
10-15	Ganges Plain and Deccan Plateau of India, northern Bangladesh and Nepal
10-12	Andes of South America at elevations between 10,000 to 13,000 feet from Peru and Ecuador
9-11	plateau of western Kenya around Kericho
8-10	southeastern Wyoming and northeastern Colorado, USA
8-9	Transvaal region of South Africa and Lesotho
6-7	portions of Alberta, Canada around Edson and Red Deer
6-7	southern steppe of Russia: west of the Volga River between Gorky and Volgograd
6-7	plateau of central Mexico around Mexico City and Puebla
6-7	northern Kazakhstan
6	Kansu and Shensi provinces of China

Source: **Christopher. C. Burt, 2007: Extreme Weather**



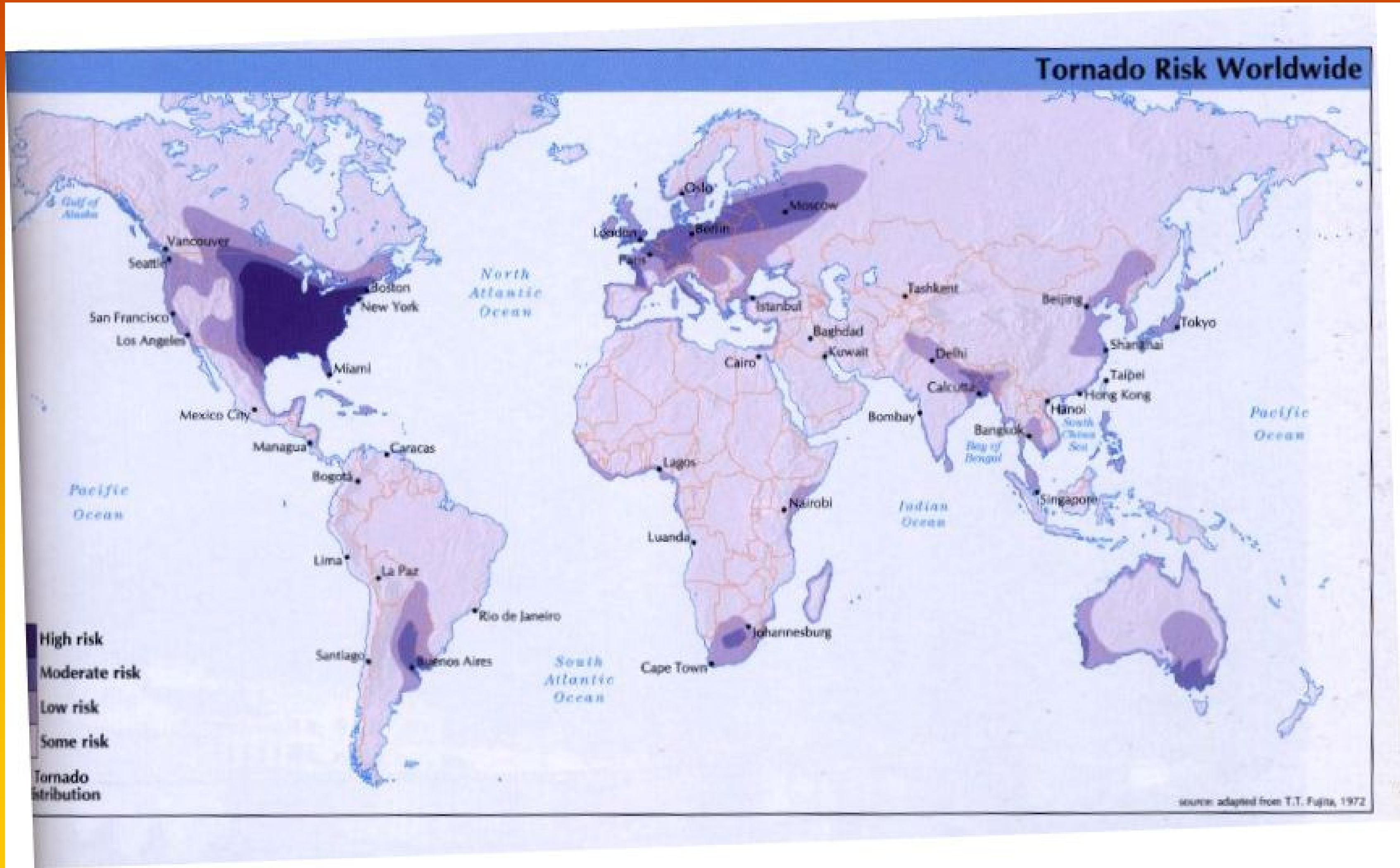
Source: **Christopher. C. Burt, 2007: Extreme Weather**



Selected Stormiest Places (Average Annual Number of Thunderstorm Days)						
Uganda	242 days	Kampala (most in the world)	Malaysia	180	Kuala Lumpur
Zaire	228	Bunia	Thailand	159	Klong Yai
Rwanda	221	Kamembe	Madagascar	140	Arivonimamo
Indonesia	218	Bandung (most in Southeast Asia)	Ecuador	109	Quito (most in Andes)
Nigeria	215	Calabar	India	108	Krishnagar and Sibsagar (most in Southern Asia)
Uganda	206	Entebbe	Peru	106	Huancayo
Brazil	206	Carauri	USA	100	Lakeland, Florida (most in USA)
Cameroon	201	Mamfe	Australia	100	Port George IV (most in Australia)
Panama	196	Madden Dam (most in Central America)	Lesotho	95	Mokhotlong (most in Southern Africa)

urce: World Meteorological Organization

Source: **Christopher. C. Burt, 2007: Extreme Weather**

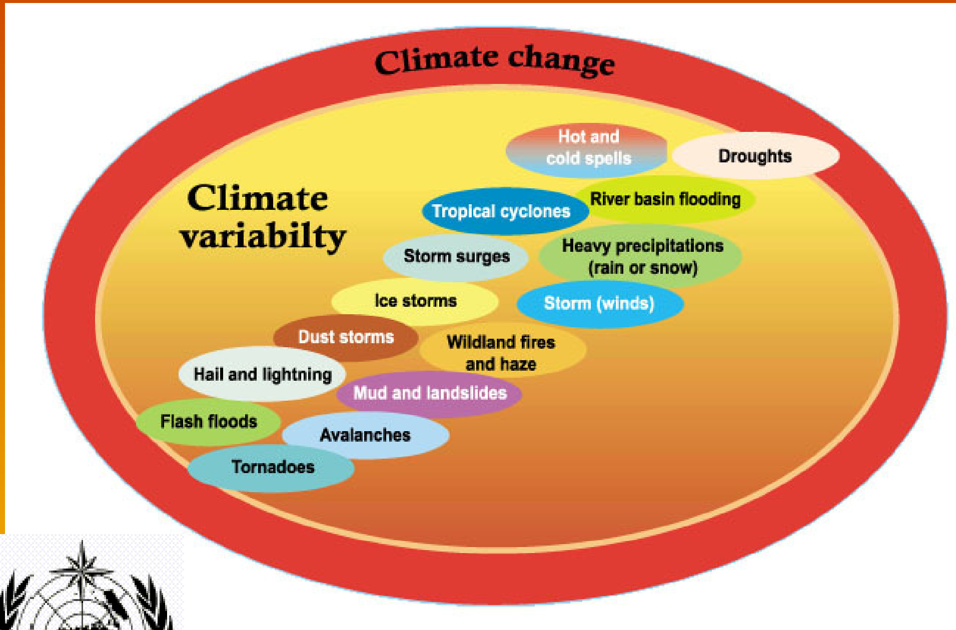


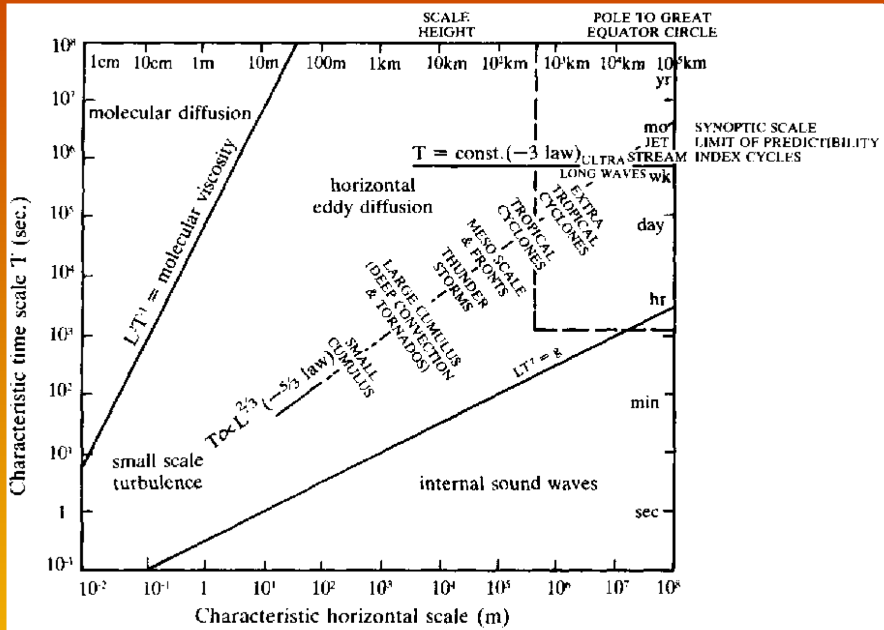
Source: **Christopher. C. Burt, 2007: Extreme Weather**

SIGNIFICANT CIRCULATION OBJECTS (MULTI-ELEMENT EFFECTS)

- Large-scale (ENSO, etc.)
- Cyclones, fronts, anti-cyclones
- Convective systems (tropical cyclone, etc.)

Space-time scales of extremes vs. objects

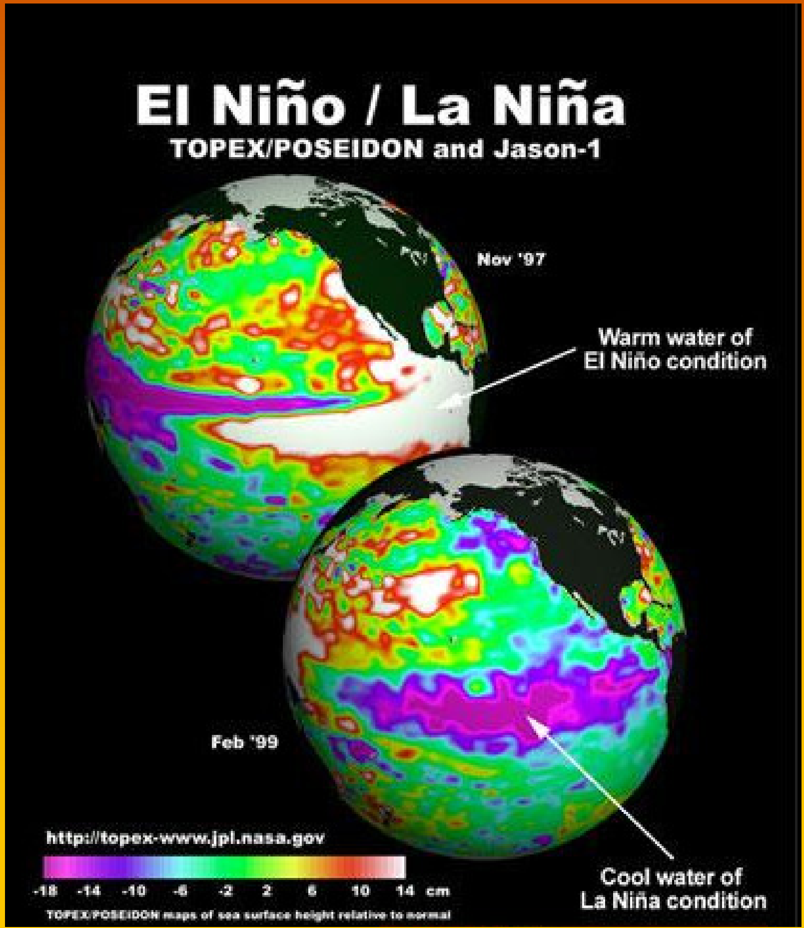




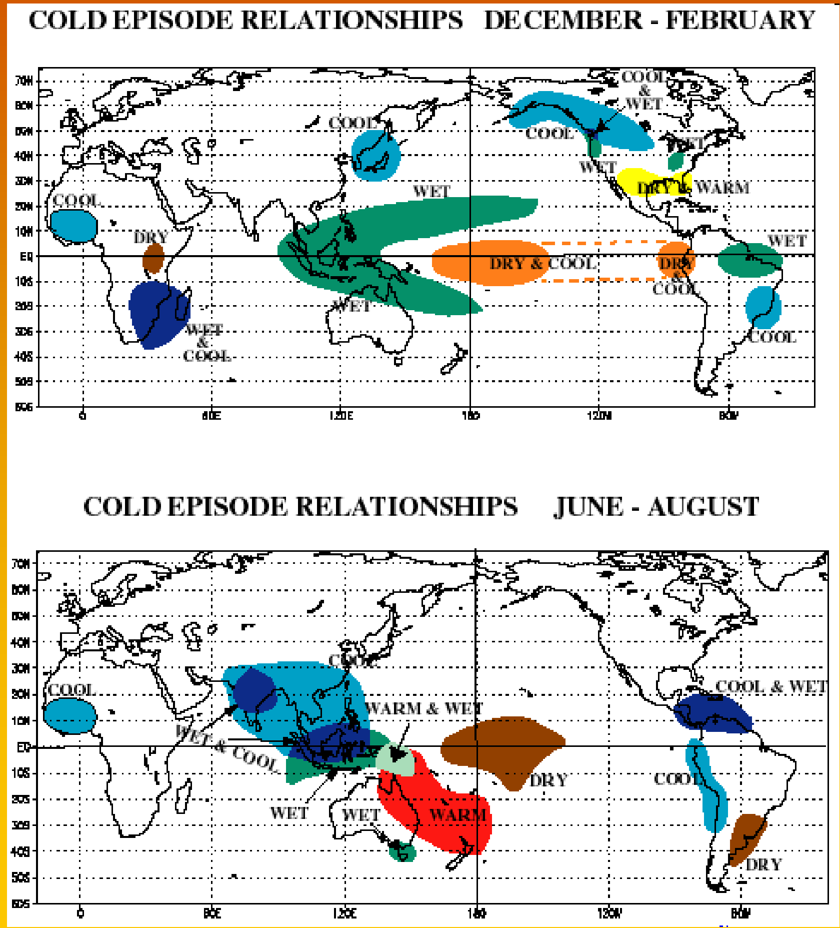
http://www.unu.edu/unupress/unupbooks/80635e/80635E3c.gif

Good news: no fast, but planetary, or local, but long-lasting extremes!

El-Nino / La Nina: long-term anomalies



http://topex.www.jpl.nasa.gov



http://www.exchangemagazine.com/morningpost/
with credit to NOAA, USA

Forest fire in Australia

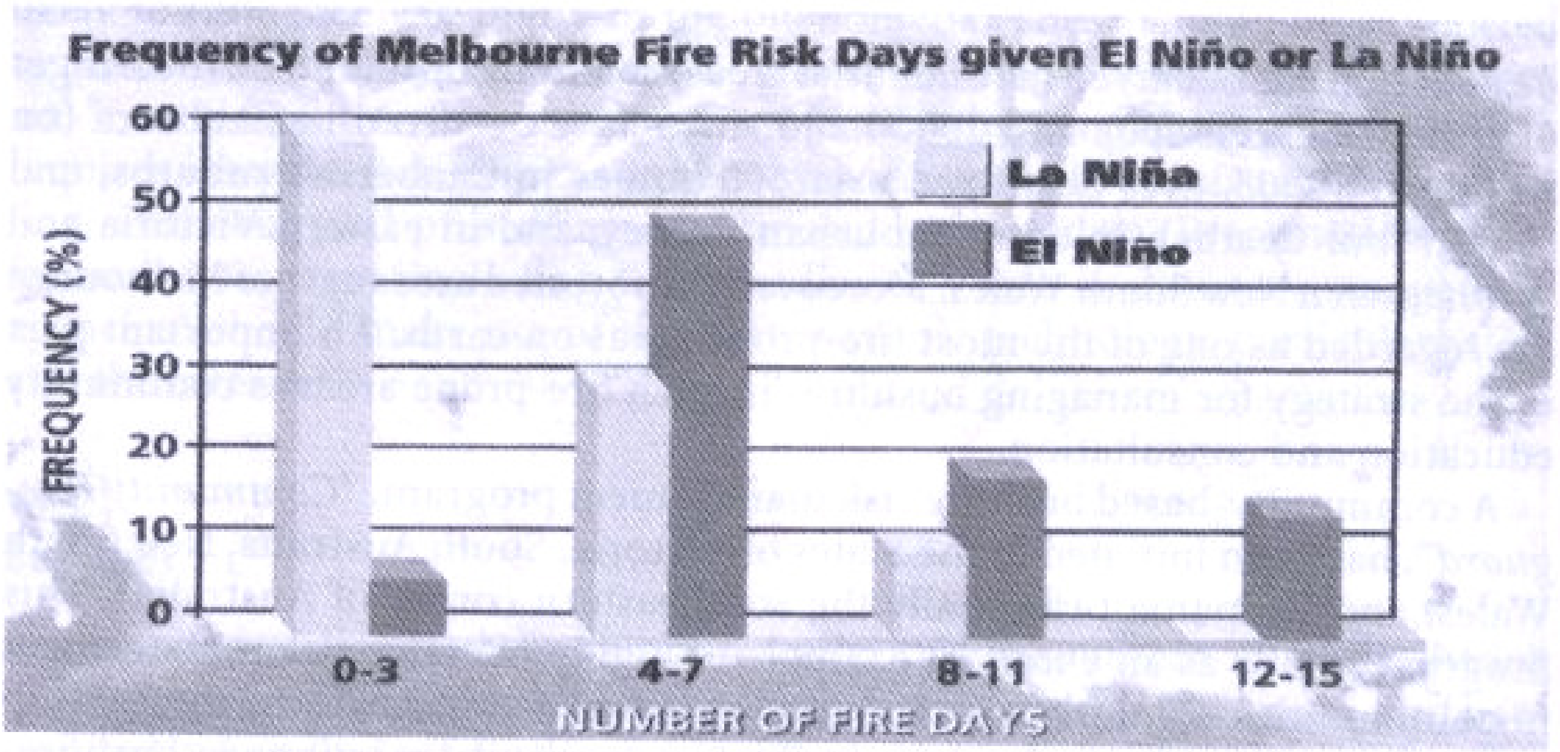
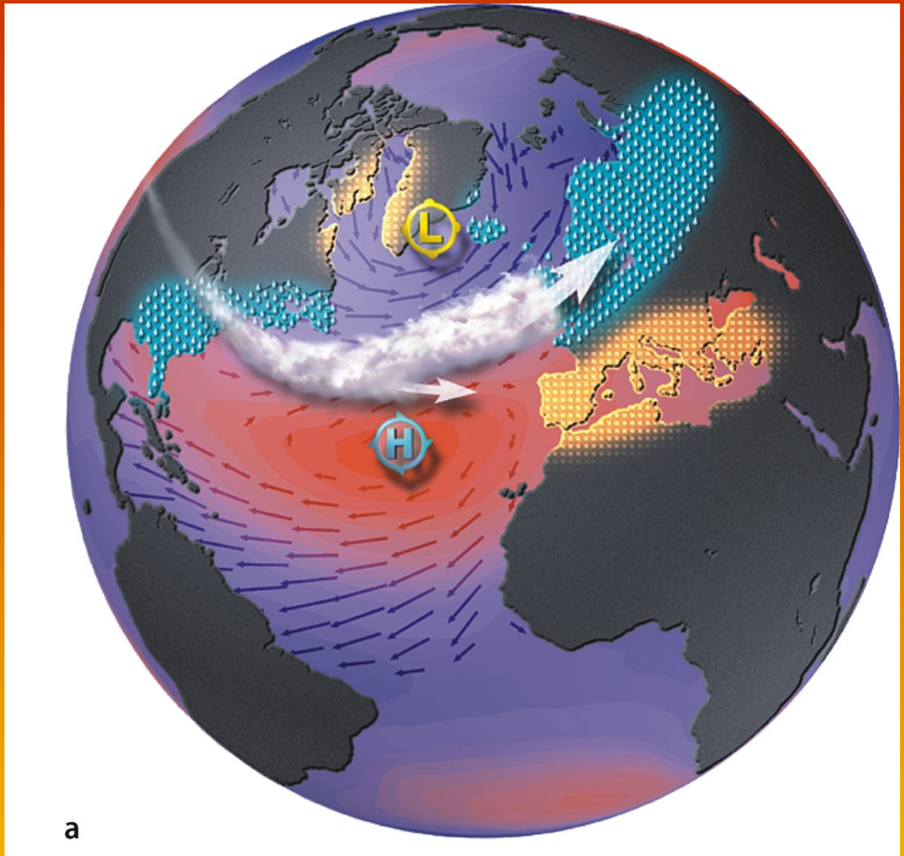
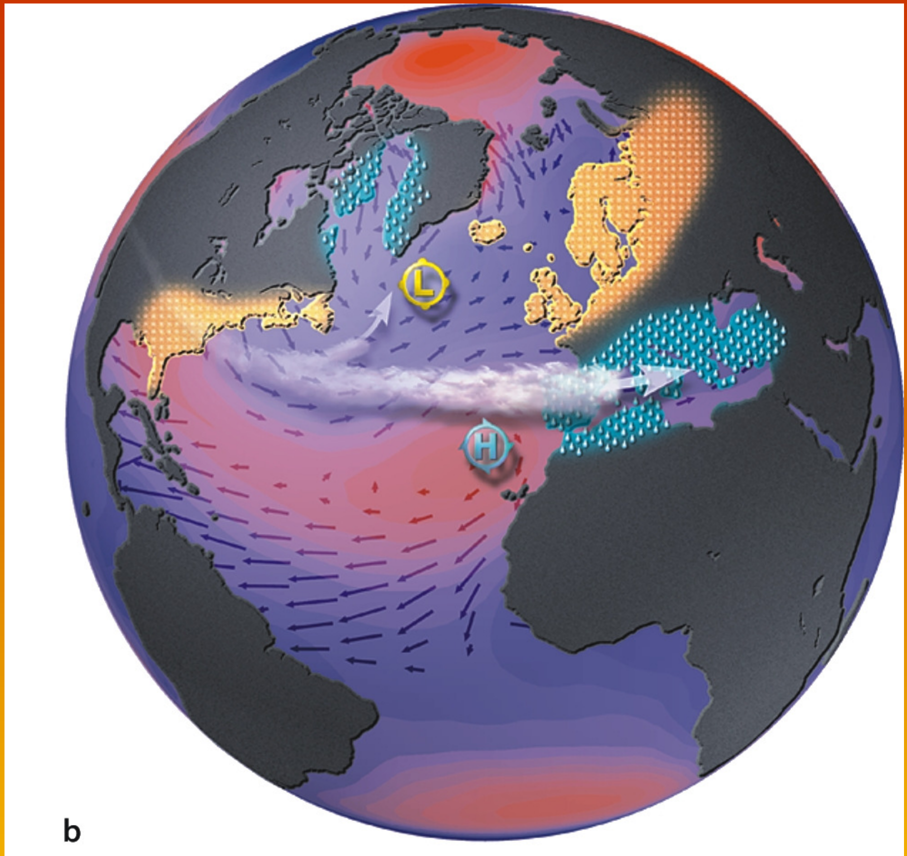


Fig. 13.2. Relationship between El Niño/La Niña and extreme fire danger days in the area around Melbourne, Victoria. *(Courtesy of Harvey Stern & Mark Williams, Australian Commonwealth Bureau of Meteorology, 1989)*

Source: **Shivakumar M.V.K., Motha R. P. and Das H.P., (eds.) 2005: Natural Disasters and Extreme Events in Agriculture,** Springer V.



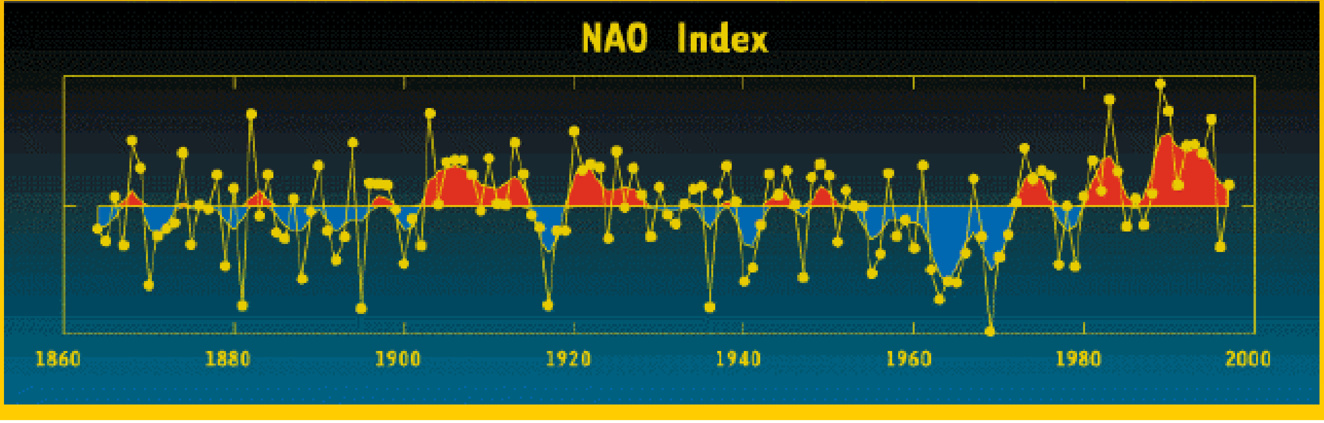


© Springer-Verlag Berlin Heidelberg 2005

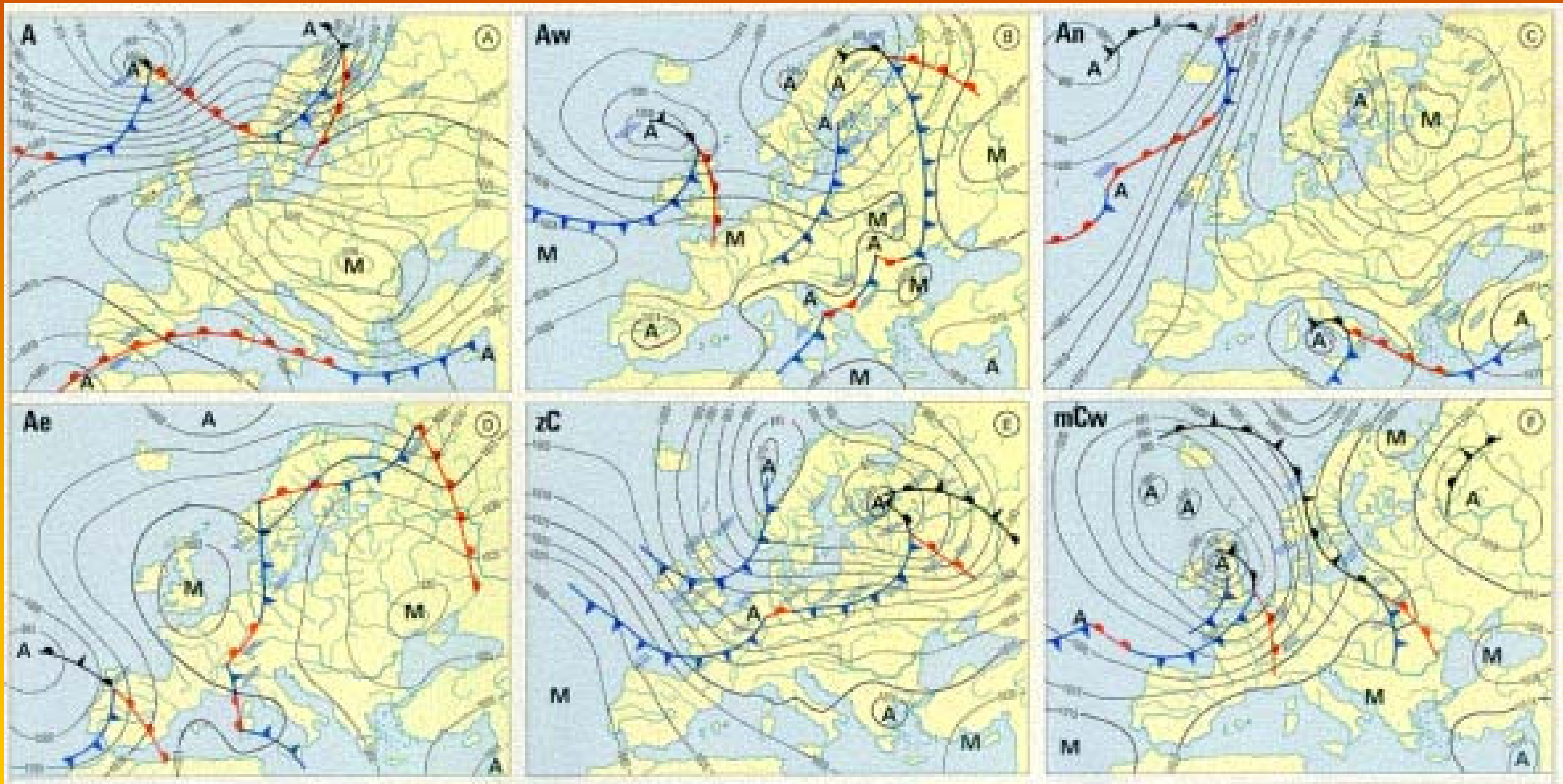
http://www.newx-forecasts.com/nao.html

North Atlantic Oscilation

Positive index: Dry in Central EU



CYCLONES, FRONTS AND ANTICYCLONES



A – low pressure centre (cyclone)

M – high pressure centre (anticyclone)

cold front   warm front

G. Péczely, 1984

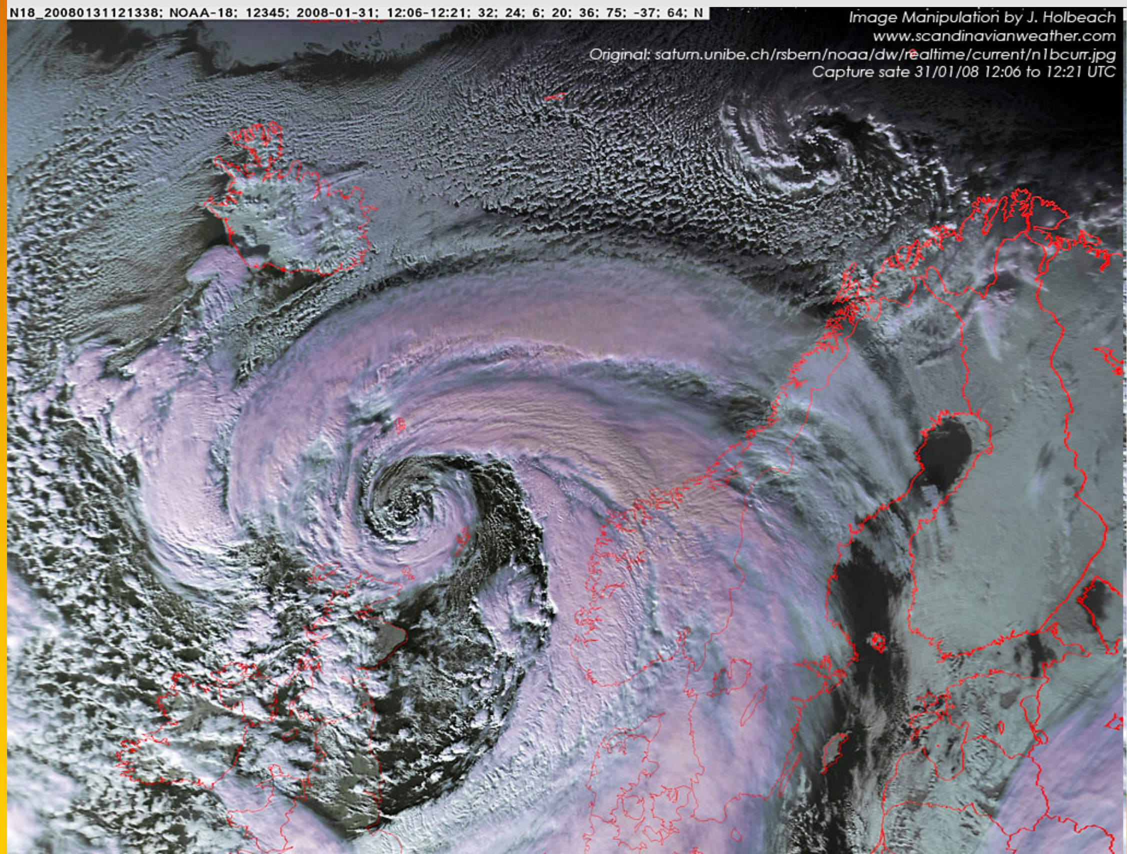
(selected types of circulation)

Extremely active temperate latitude cyclone

During the afternoon of 30 January 2008 rapid cyclogenesis over the North Atlantic led to the formation of storm Tuva within a few hours. The development was so explosive that even experts in the area of satellite image interpretation were surprised. The satellite image below, taken by Meteosat-9, shows this impressive spiral occlusion of the storm to the north of Scotland on 31 January 2008 at 08:00 UTC. As the storm approached Norway, on the west coast mean wind speeds of 95.8 km/h were measured, with gusts up to 121.3 km/h. Later in the day strong winds were also encountered in the Skagerrak, northern Denmark and along the west coast of Sweden.

Jan 31, 2008

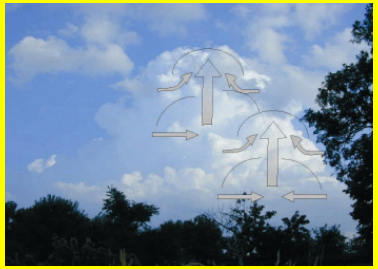
NOAA -18



http://forum.netweather.tv/topic/45397-satellite-photos-of-north-sea-storm-tuva/

Convective objects with compex sets of extremes

1. **Cumulus clouds (start)**

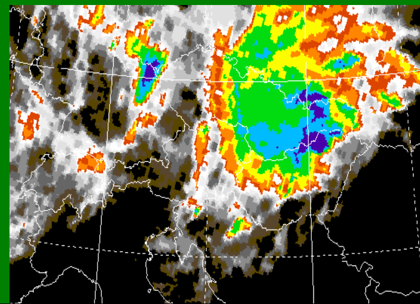


2. Local thunder-storms, not too dangerous

3. Multicell thunderstorm: heavy rain, haill, stormy wind.

4. Supercells: devastating wind and hail, heavy rain, often with tornado

5. **MCC**



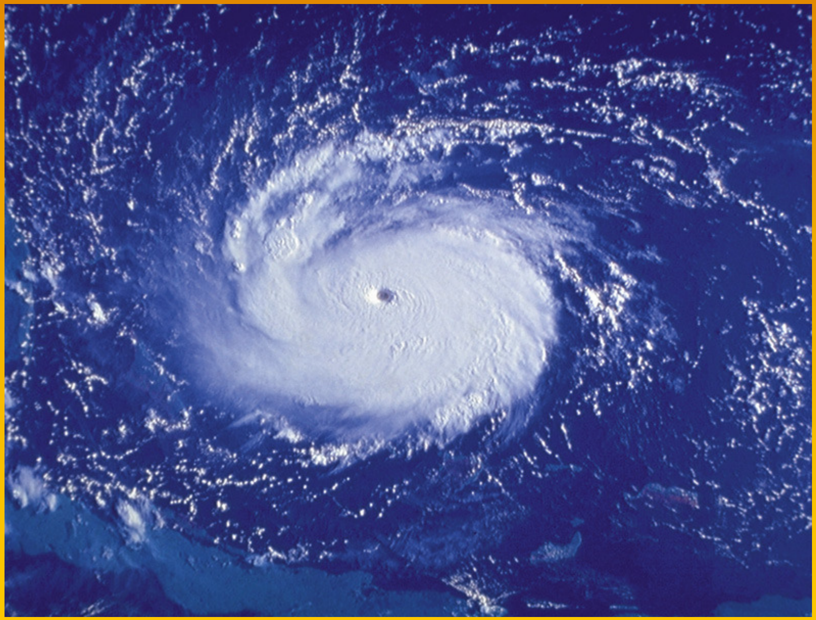
6. Thunderstorm lines squall lines, stormy wind, hail, intesive rain

7. Hurricane (3-500 km)

Credit: Dr. Ákos Horváth

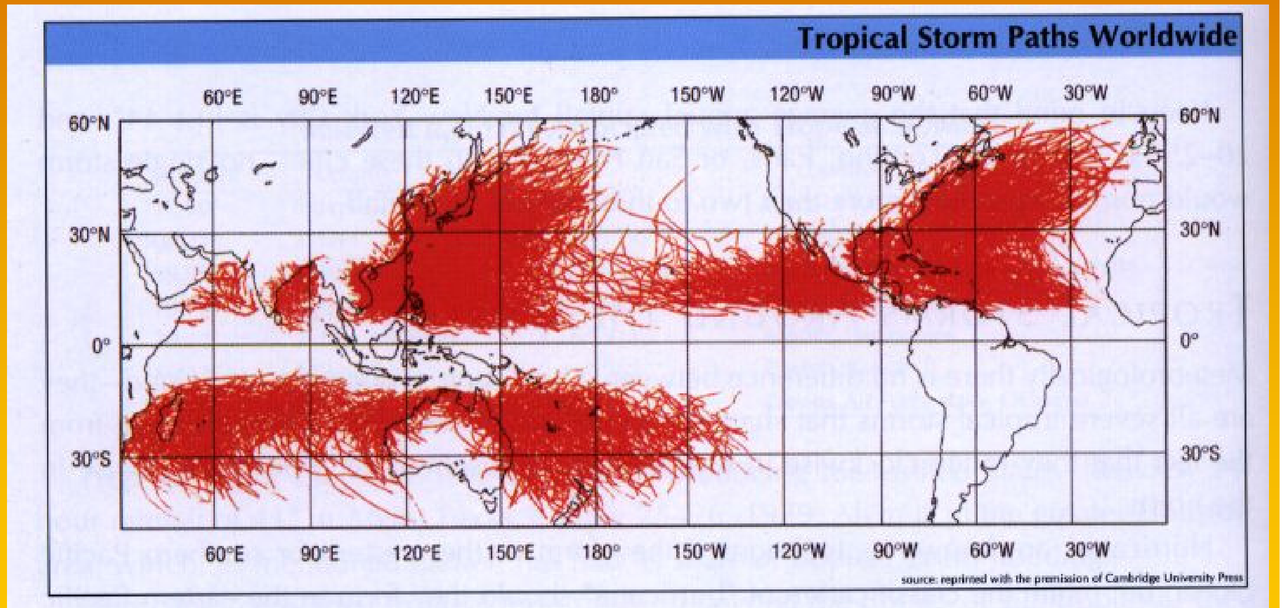
Hurricane structure

- Hurricanes have:
  - Circular cloud bands that produce torrential rain
  - The ability to move into the mid-latitudes
  - A central eye
- Weather extremes:
  - Storm surge,
  - Rain,
  - Wind



Origin and paths of tropical cyclones

- Tropical cyclones are intense low pressure storms created by:
  - Warm water
  - Moist air
  - Coriolis effect
- Includes:
  - Hurricanes
  - Cyclones
  - Typhoons



Map: **Christopher. C. Burt, 2007: Extreme Weather**

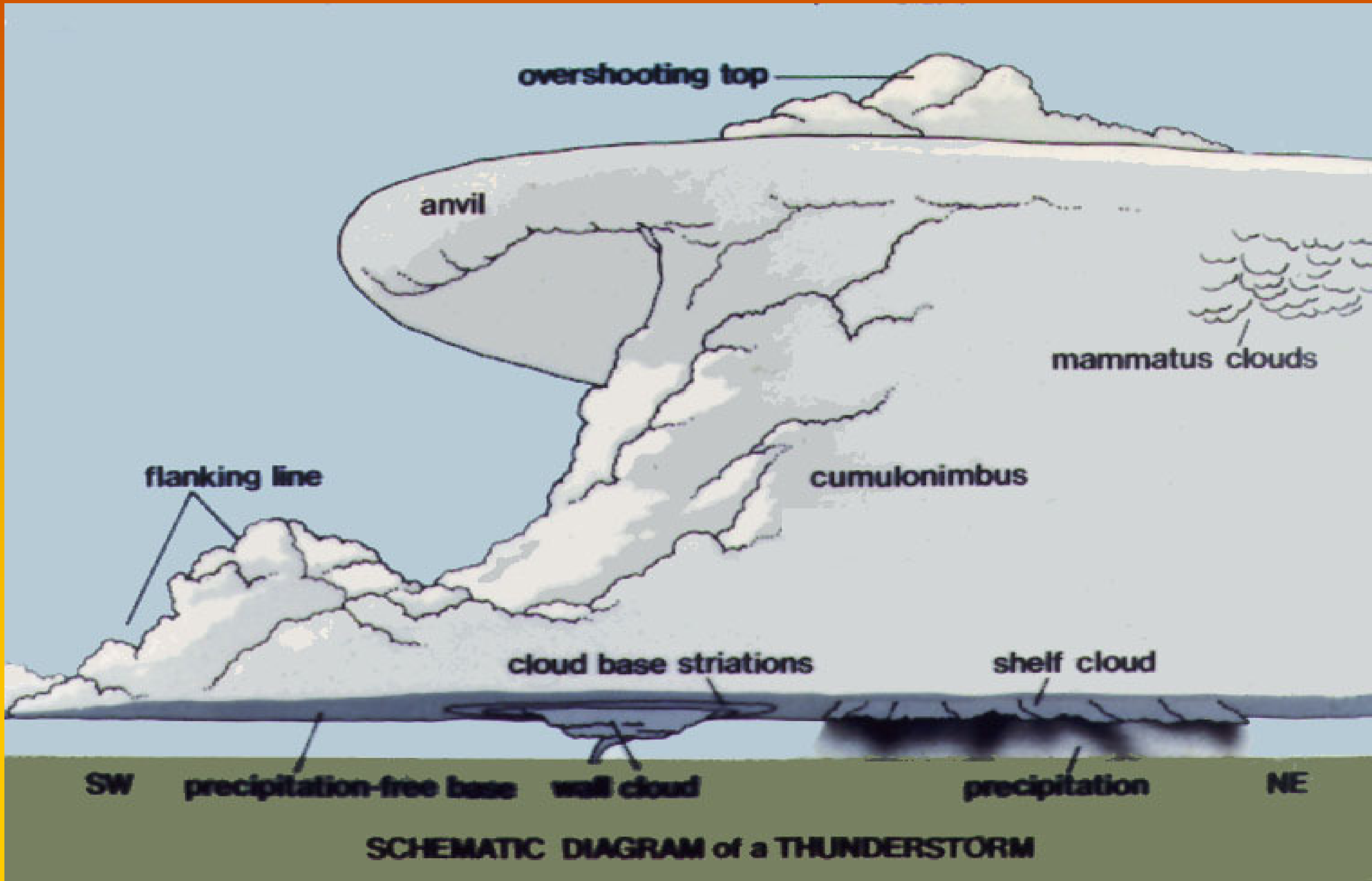
SAFFIR- SIMPSON HURRICANE SCALE

Saffir-Simpson Hurricane Scale

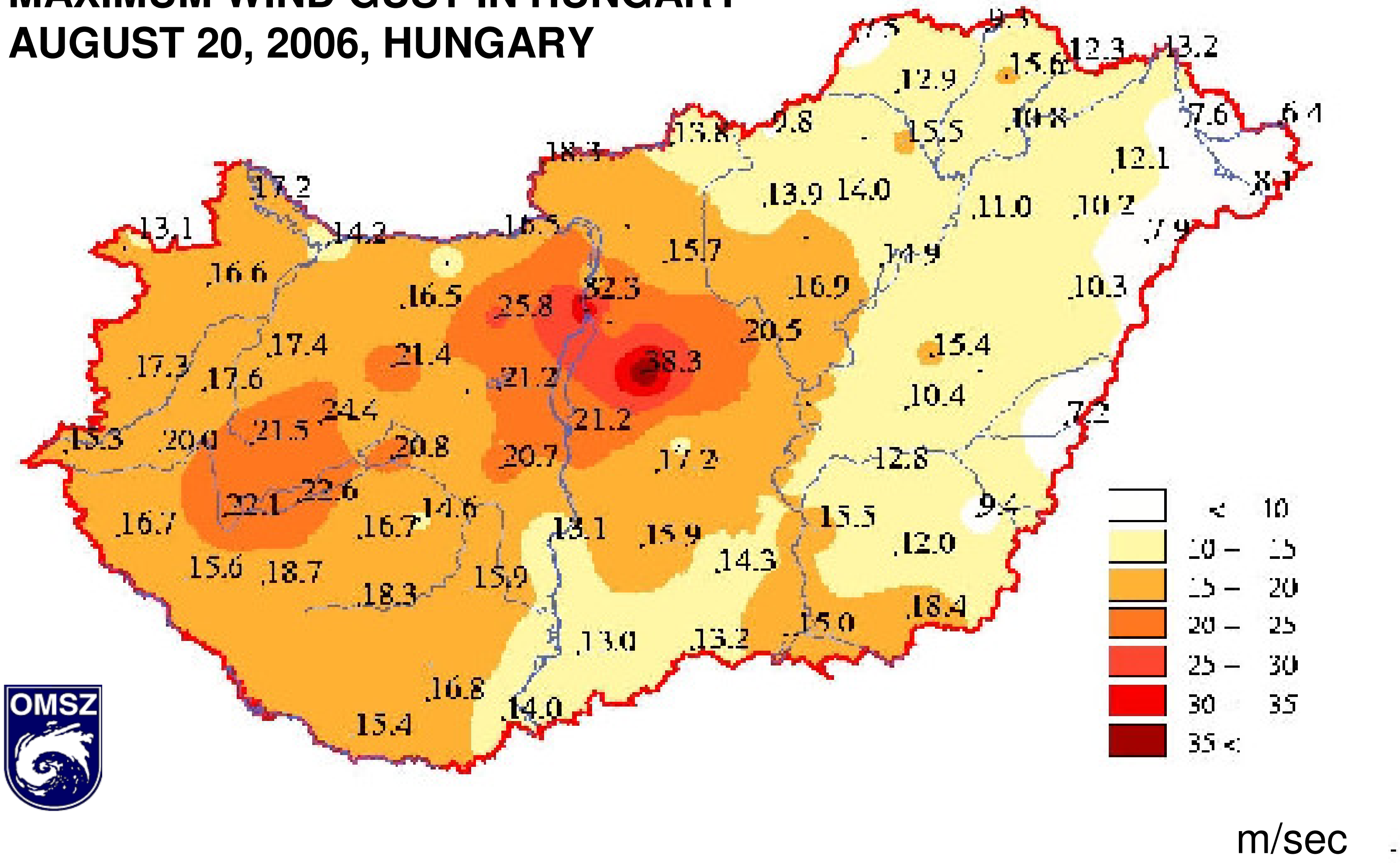
Category	Pressure	Wind Speed	Storm Surge	Damage
1	28.94" or higher *980 mb or higher*	74–95 mph *119–153 km*	4–5 ft *1.2–1.5 m*	Trees and shrubs lose leaves and twigs.
2	28.50 - 28.93" *965 - 979 mb*	96–110 mph *154–177 km*	6–8 ft *1.8–2.4 m*	Small trees blow down. Exposed mobile homes severely damaged. Chimneys blown from roofs.
3	27.91-28.49" *945-964 mb*	111–130 mph *178–209 km*	9–12 ft *2.7–3.6 m*	Leaves stripped from trees. Large trees blown down. Mobile homes demolished. Small buildings damaged structurally.
4	27.17-27.90" *920-944 mb*	131–155 mph *210–249 km*	13–18 ft *3.9–5.4 m*	Extensive damage to windows, roofs, and doors. Flooding to 6 miles inland. Severe damage to lower areas of buildings near exposed coast.
5	27.16" or lower *920 mb or lower*	155 mph or more *250 km or more*	18 ft or more *5.4 m or more*	Catastrophic. All buildings severely damaged, small buildings destroyed. Major damage to lower areas of buildings less than 15 feet above sea level to .3 mile inland.

Source: **Christopher. C. Burt, 2007: Extreme Weather**

A SUPERCELL


overshooting top
anvil
mammatus clouds
flanking line
cumulonimbus
cloud base striations
shelf cloud
SW
precipitation-free base
wall cloud
precipitation
NE
SCHEMATIC DIAGRAM of a THUNDERSTORM

MAXIMUM WIND GUST IN HUNGARY
AUGUST 20, 2006, HUNGARY



Extremely strong wind concentrated in a small location

Tornado

Fujita Tornado Scale

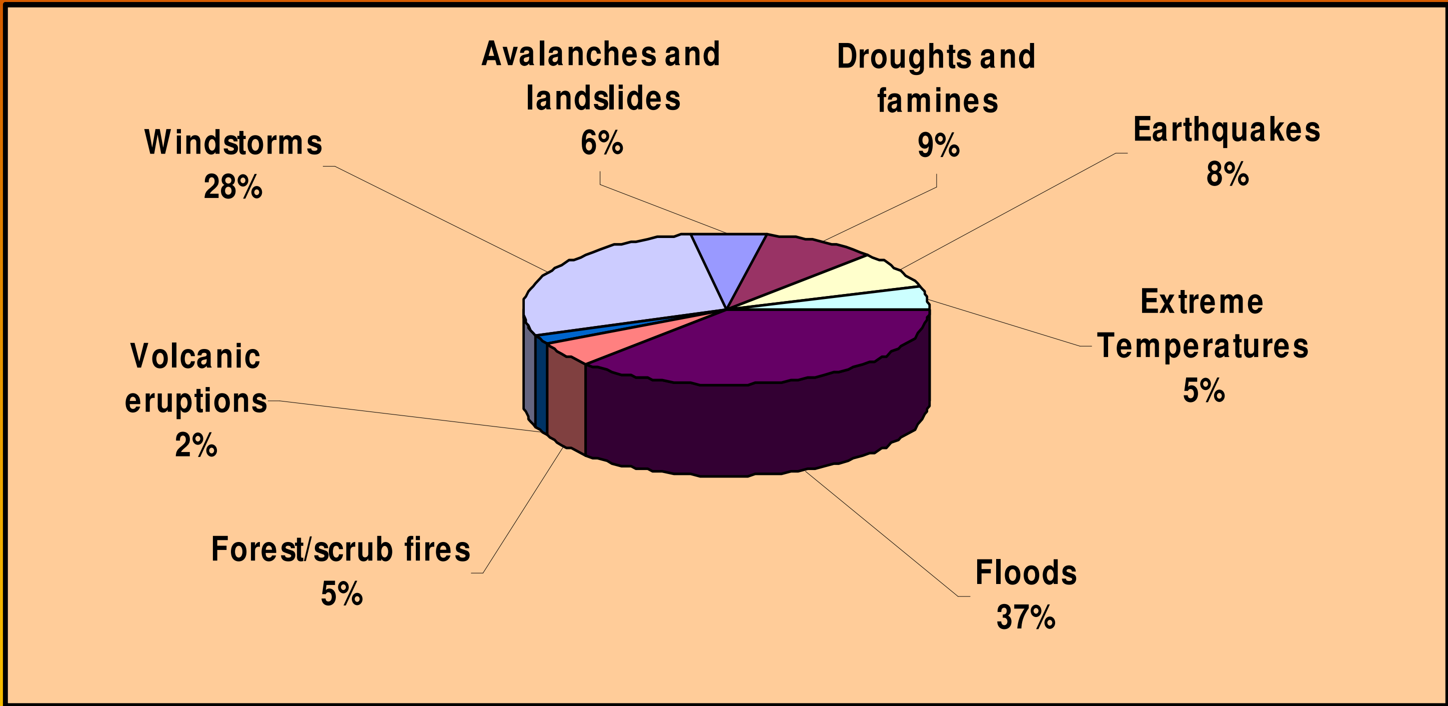
Rating	Wind Speed	Damage
F-0	40-72 mph 64-116 kmh	*Slight*. Some damage to chimneys, breaks branches off trees, pushes over shallow-rooted trees, damages sign boards.
F-1	73-112 mph 117-180 kmh	*Moderate*. The lower limit is the beginning of hurricane wind speed, peels surface off roofs, mobile homes pushed off foundations or overturned, moving autos pushed off the roads, attached garages may be destroyed.
F-2	113-157 mph 181-253 kmh	*Considerable*. Roofs torn off frame houses, mobile homes demolished, boxcars pushed over, large trees snapped or uprooted, light object missiles generated.
F-3	158-206 mph 254-331 kmh	*Severe*. Roof and some walls torn off well constructed houses, trains overturned, most trees in forest uprooted.
F-4	207-260 mph 332-418 kmh	*Devastating*. Well-constructed houses leveled, structures with weak foundations blown off some distance, cars thrown and large missiles generated.
F-5	261-318 mph 419-512 kmh	*Incredible*. Strong frame houses lifted off foundations and carried considerable distances to disintegrate, automobile sized missiles fly through the air in excess of 100 meters, steel re-inforced concrete structures badly damaged.

Source: **Christopher. C. Burt, 2007: Extreme Weather**

ENVIRONMENTAL EFFECTS OF WEATHER EXTREMES

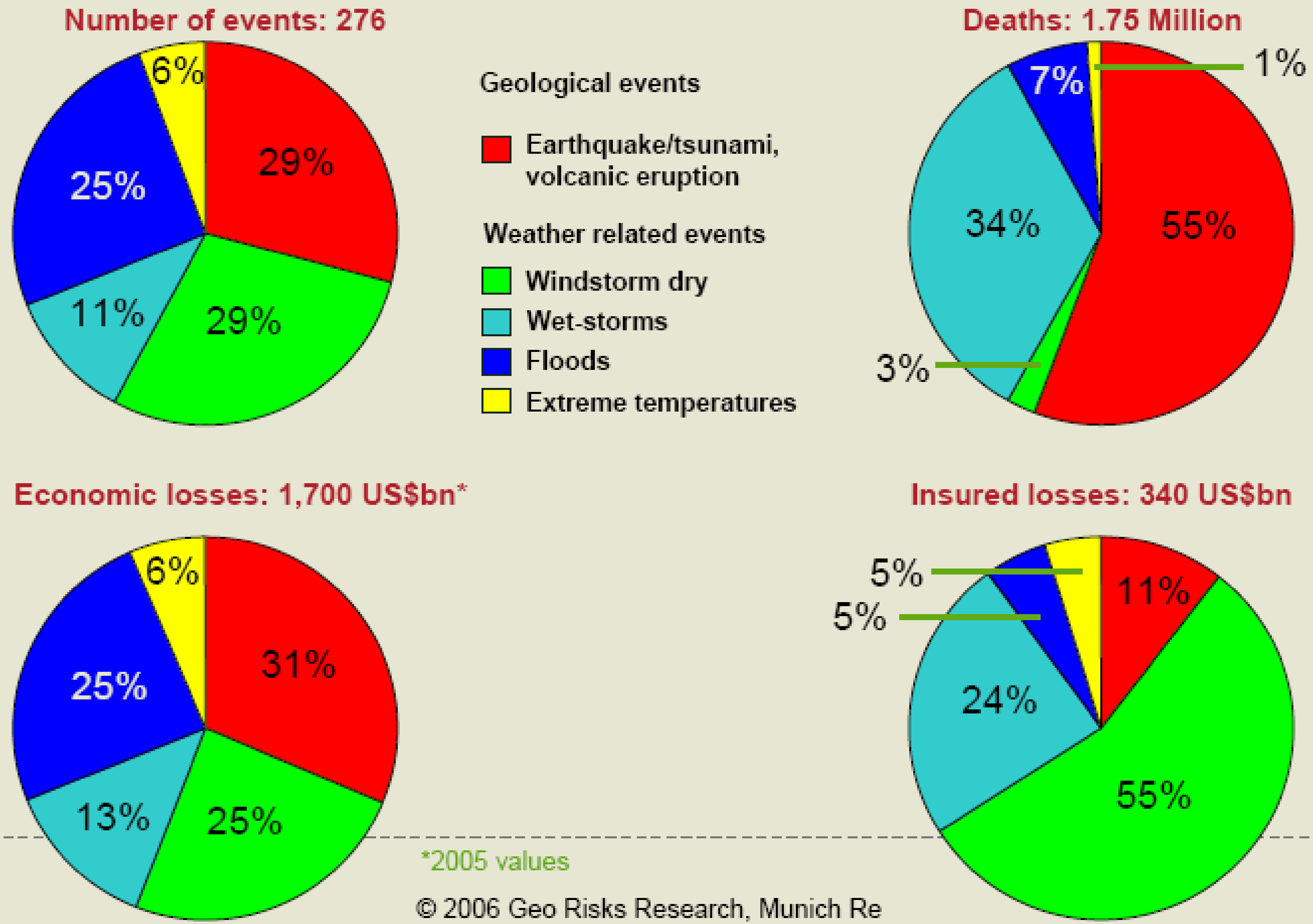
- Avalanche, freezing rain, ice storm, etc.
- Flooding
- Urban heat island

Global distribution of natural hazards (1993-2002)



About 90% are of hydrometeorological origin

Great Natural Disasters 1950 - 2005
Percentage distribution worldwide

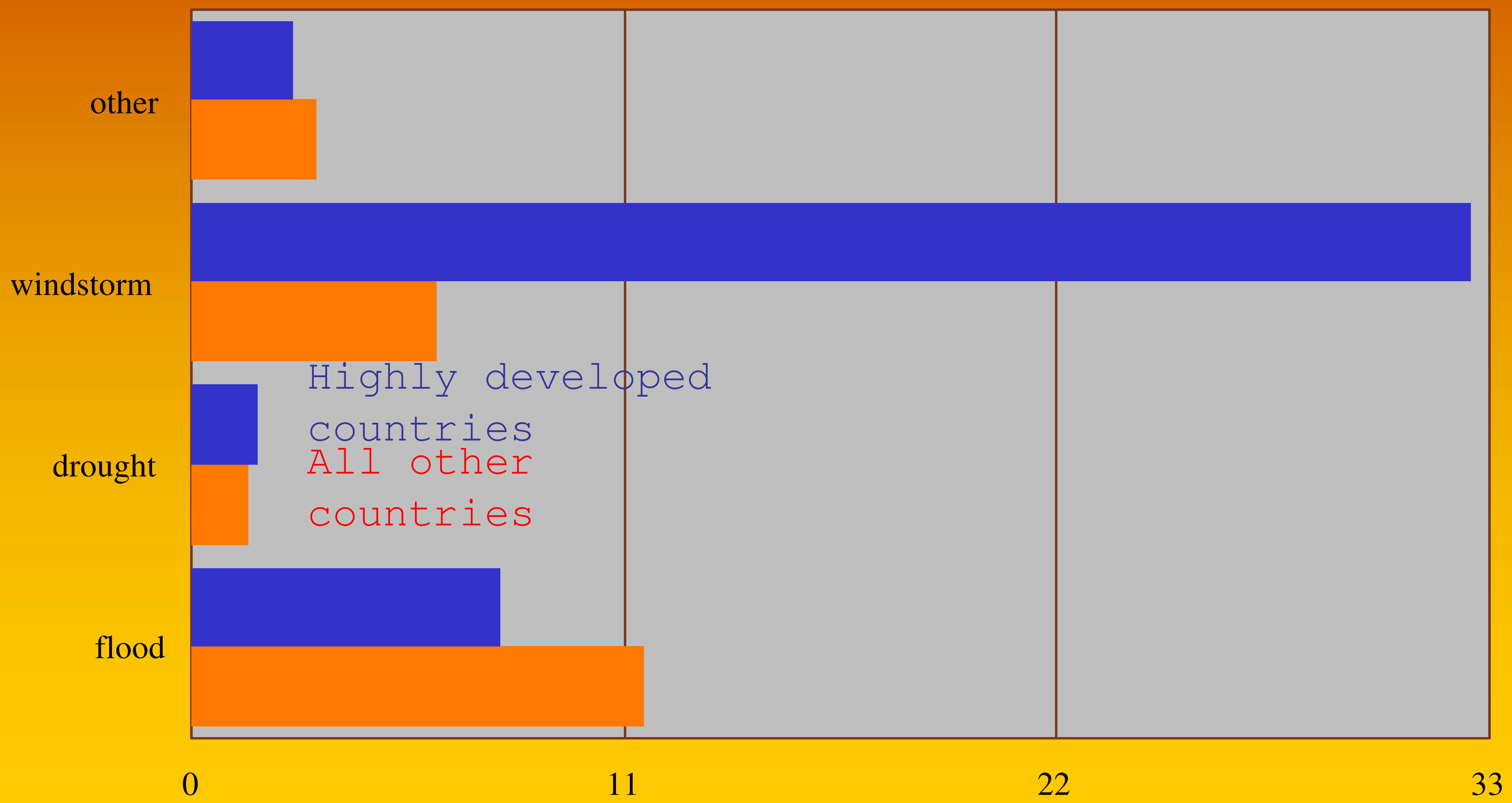


*2005 values

Global weather damage

Institute for Catastrophic Loss Reduction

Annual average disaster damage, $B(US)1997 - 2006



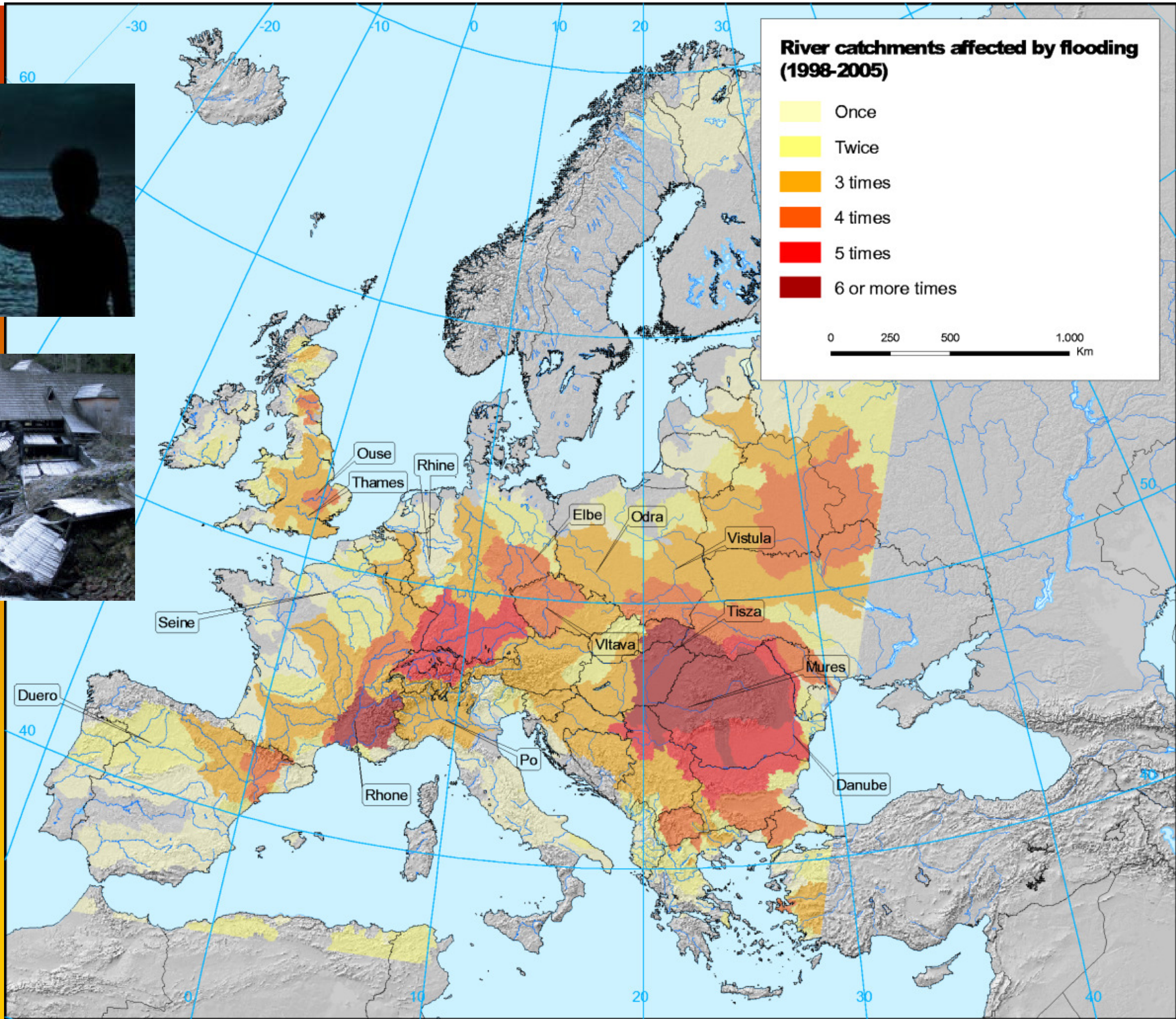
http://www.iclr.org/

Global weather fatalities

Institute for Catastrophic Loss Reduction

Annual average number of people killed, thousands, 1997 - 2006

http://www.iclr.org/

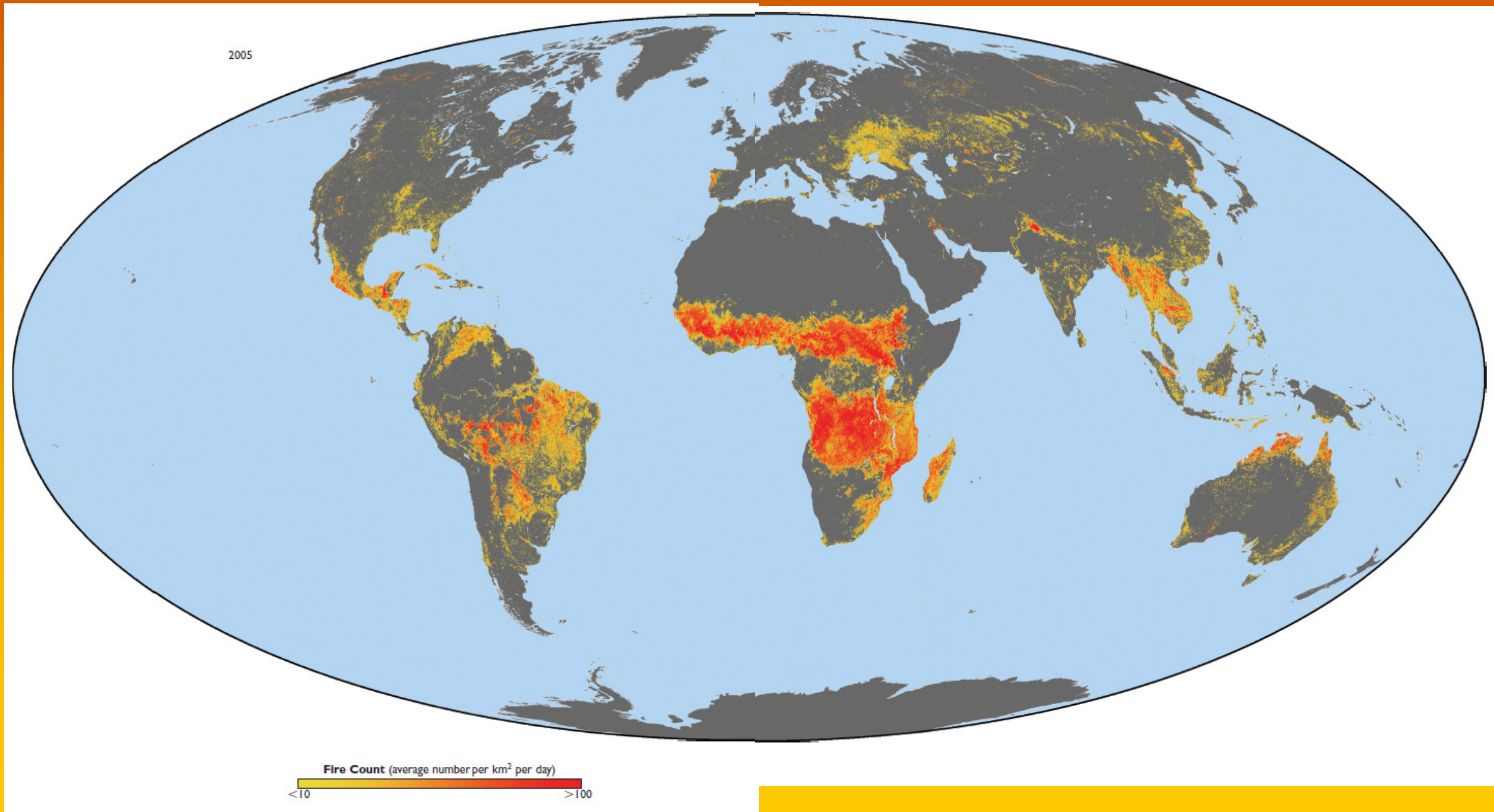


Frequency of strong floodings in Europe (1998-2005)
(http://reports.eea.europa.eu/environmental_issue_report_2004_35)

Flood at Budapest, HU in August 2002. Heavy rain for two weeks in Germany and Czech Republic, where it caused much more damage.

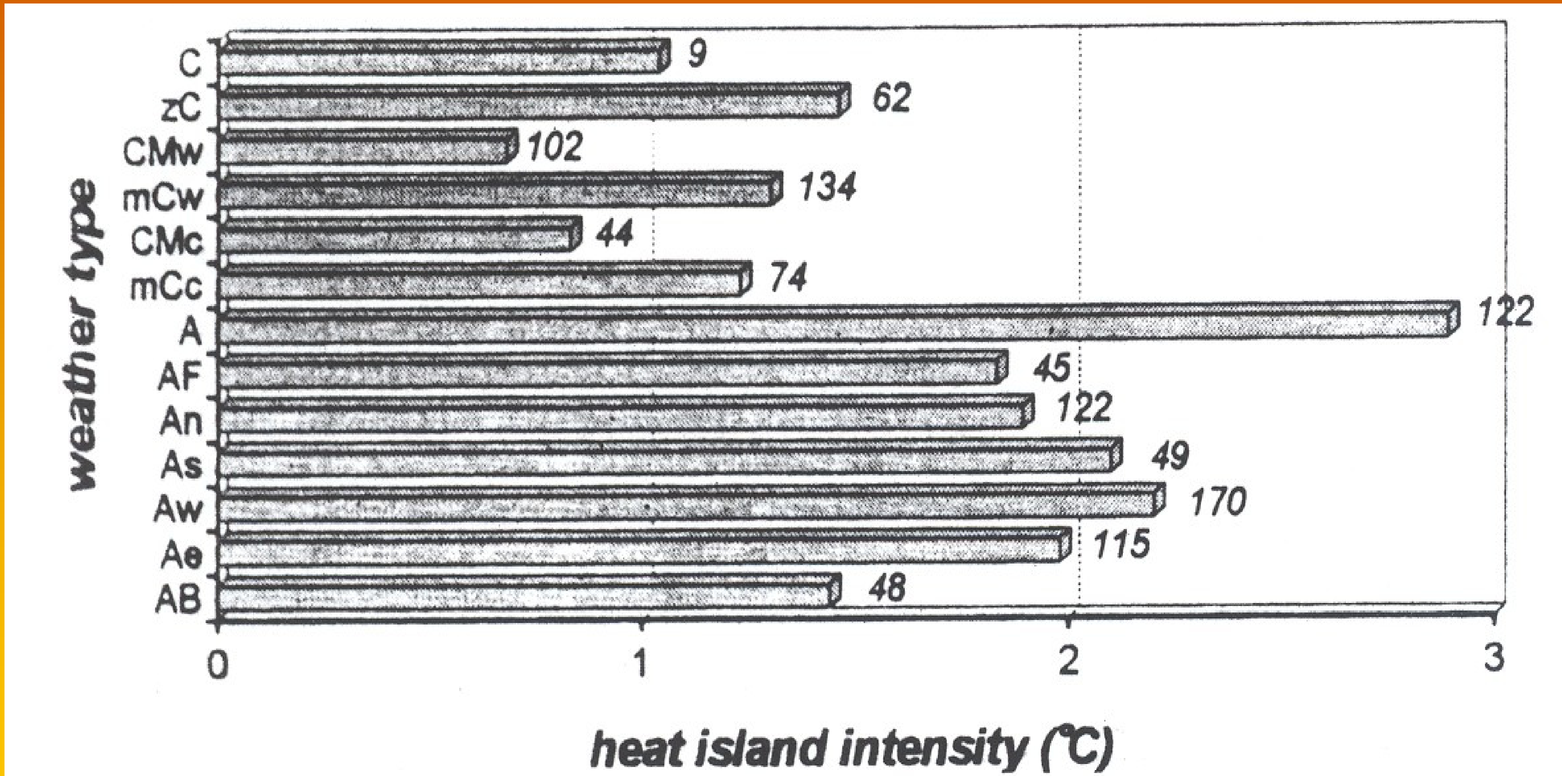
Flash-flood (Mátrakeresztes, HU 2006 June 6). Very fast thunderstorm with below 100 mm precipitation in centre. But the small river-shed collects water.

Forest fires in the world



King et al.,ed.: Our changing planet, 2009   pp. 268-269

Urban heat island effect, twice as strong as in cyclones (Szeged, HU 1978-1980)



More anticyclones, more intensive heat island without any new building

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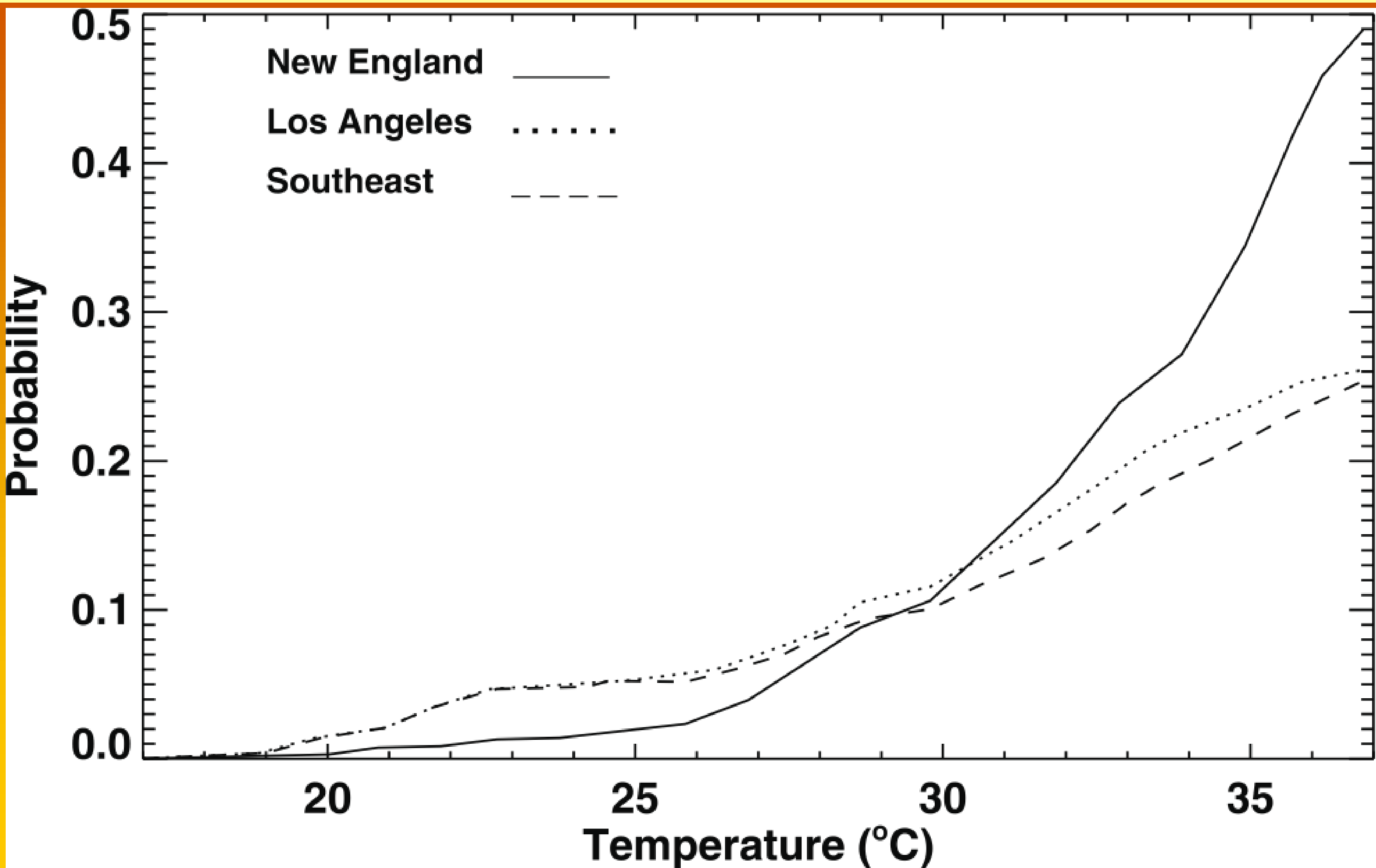
Unger J, 1996: Theoretical and Applied Climatology v. 54, 147-151

Frequeny of step over the US Standard (0.08 ppm) in 8-hours ozone concentration



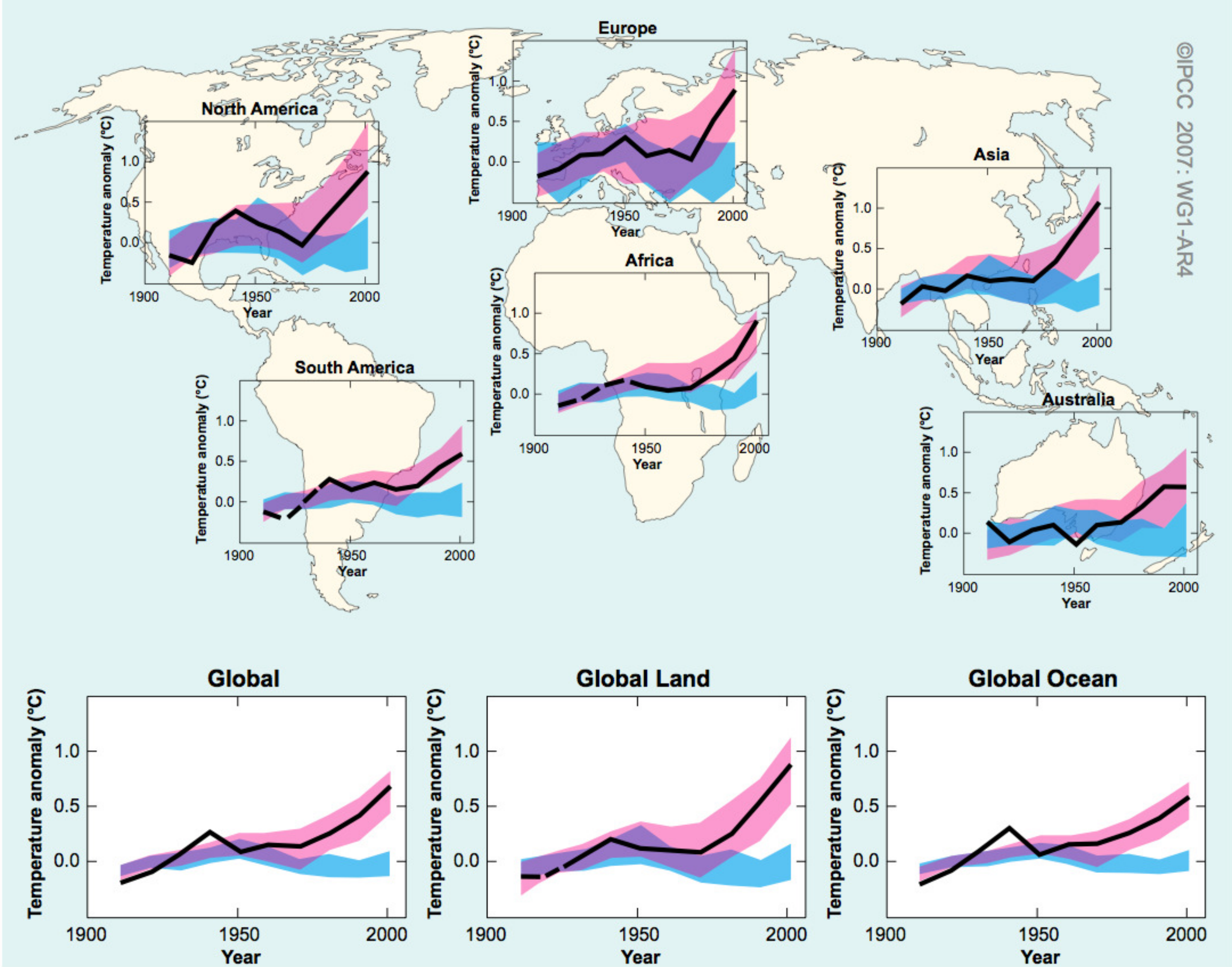
(Lin et al., 2001)

2. CLIMATE CHANGE AND THE EXTREMES

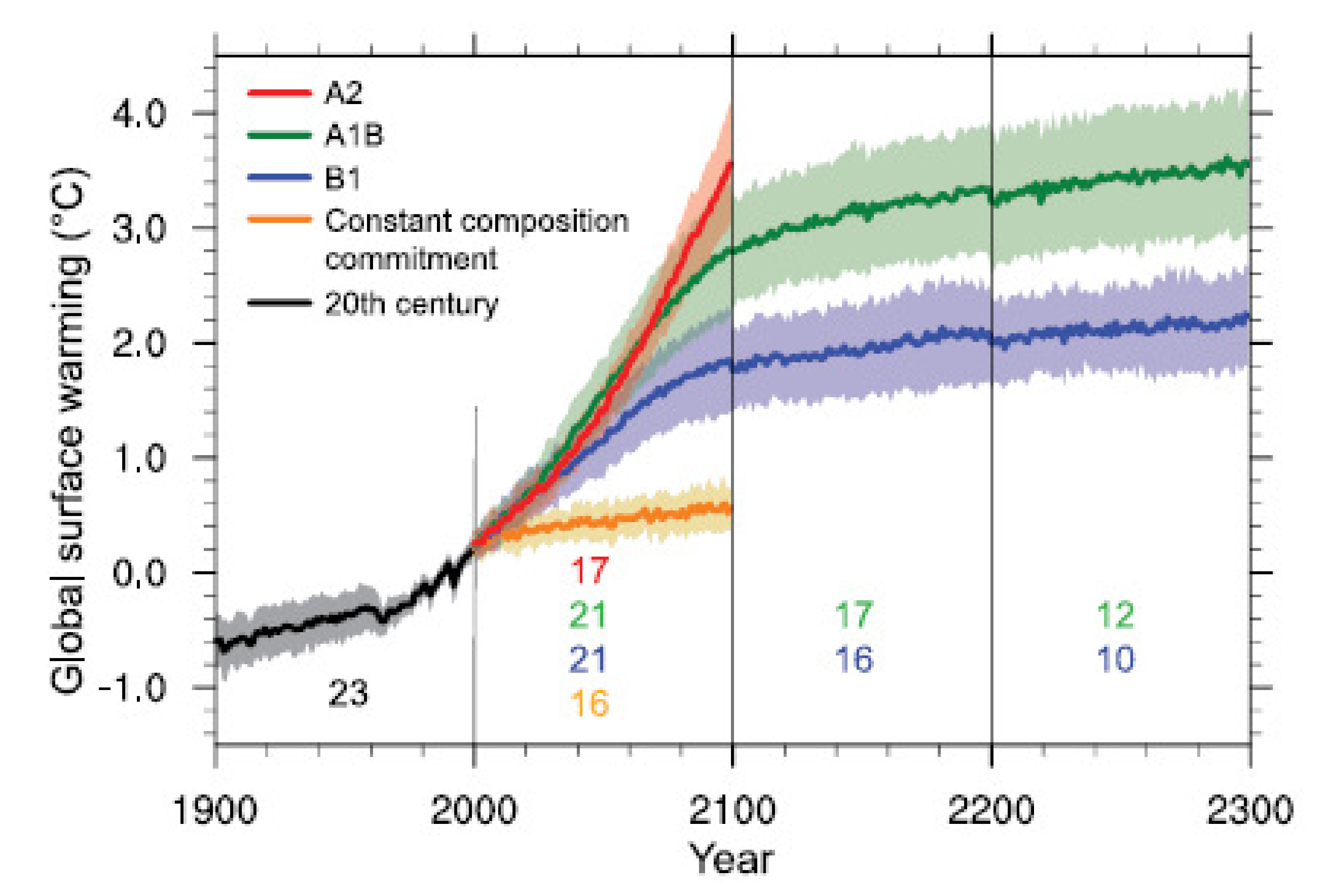
ANTHROPOGENIC WARMING: HOW SURE?

- Global changes detected, anthropogenic origin is “very likely”
- Should be stopped before 2 (3) K, but the slowdown starts after 20-30 years, only
- Critical jumps: out of the present scope

Our knowledge on the climate system and the external forcings describes the past!



IPCC AR4, 2007 –simulation with (red) and without (blue) anthropogenic factors

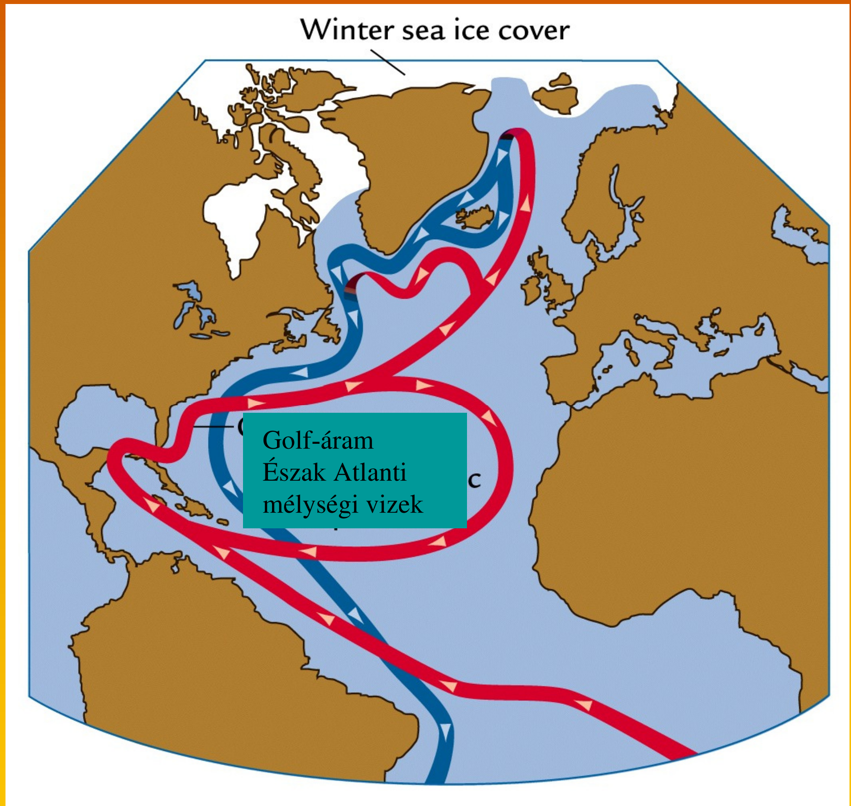


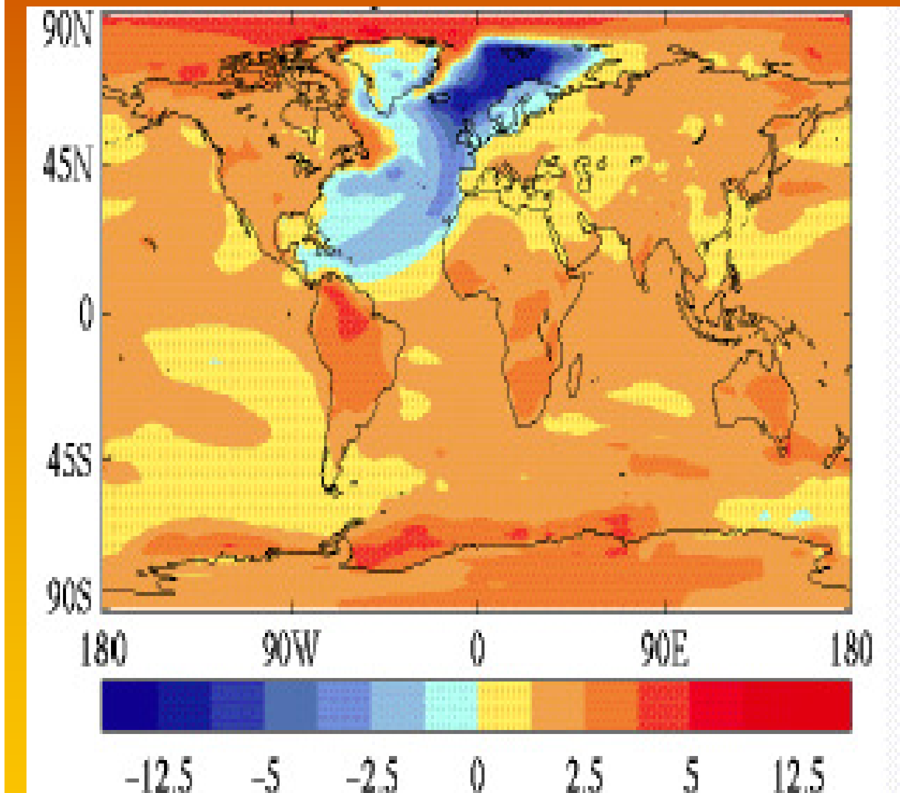
IPCC AR4, 2007

Figure 10.4. *Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th-century simulation. Values beyond 2100 are for the stabilisation scenarios (see Section 10.7). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the coloured numbers given for each period and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5.4.6 for uncertainty estimates).*

No climate surprises are considered:

- Too far in time (ca. 3 K or more)
- Not even sure if ever
- If still, would be so different, that nothing could be said empirically



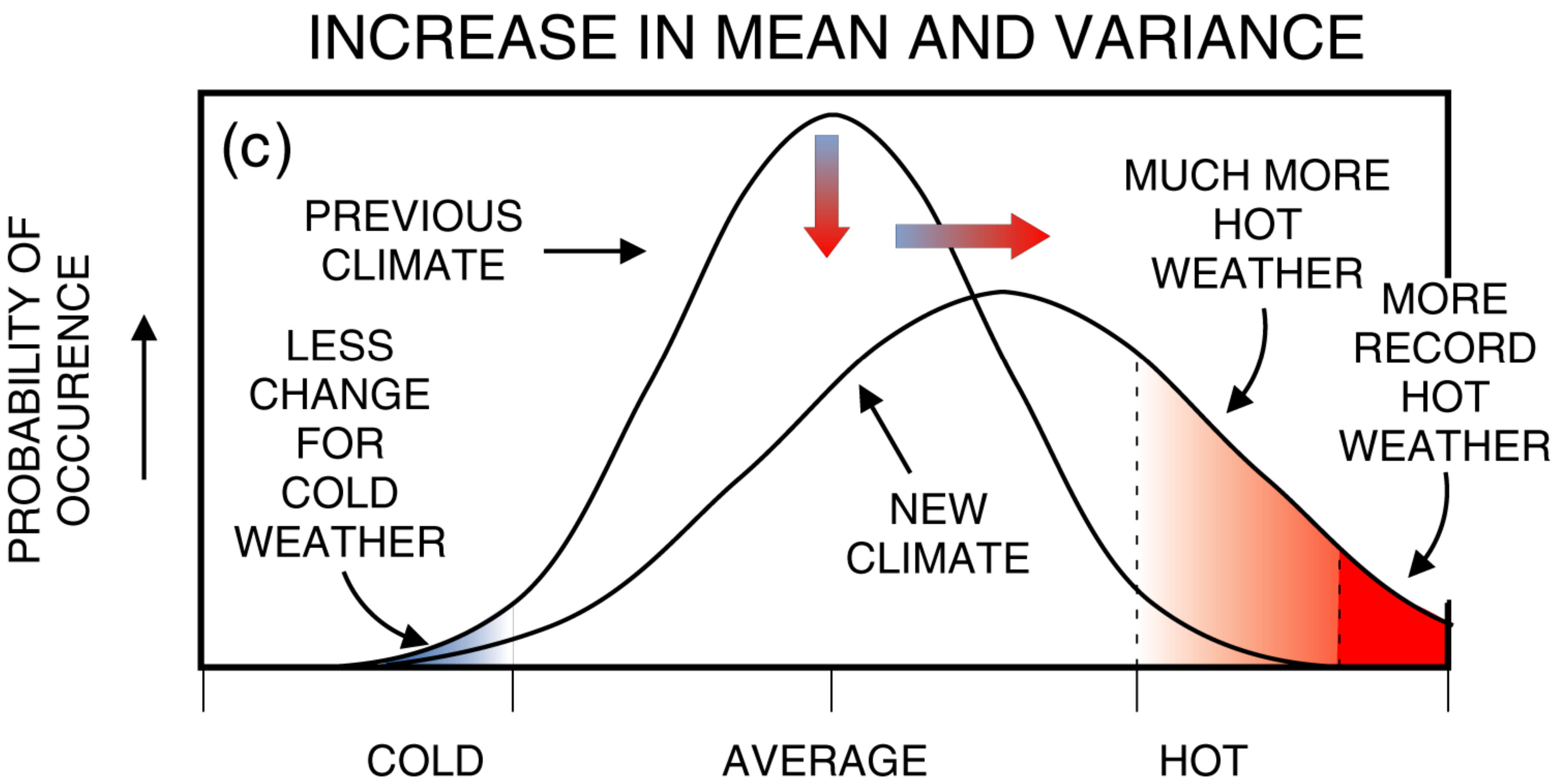


The ocean conveyor belt (Broecker, 1987)

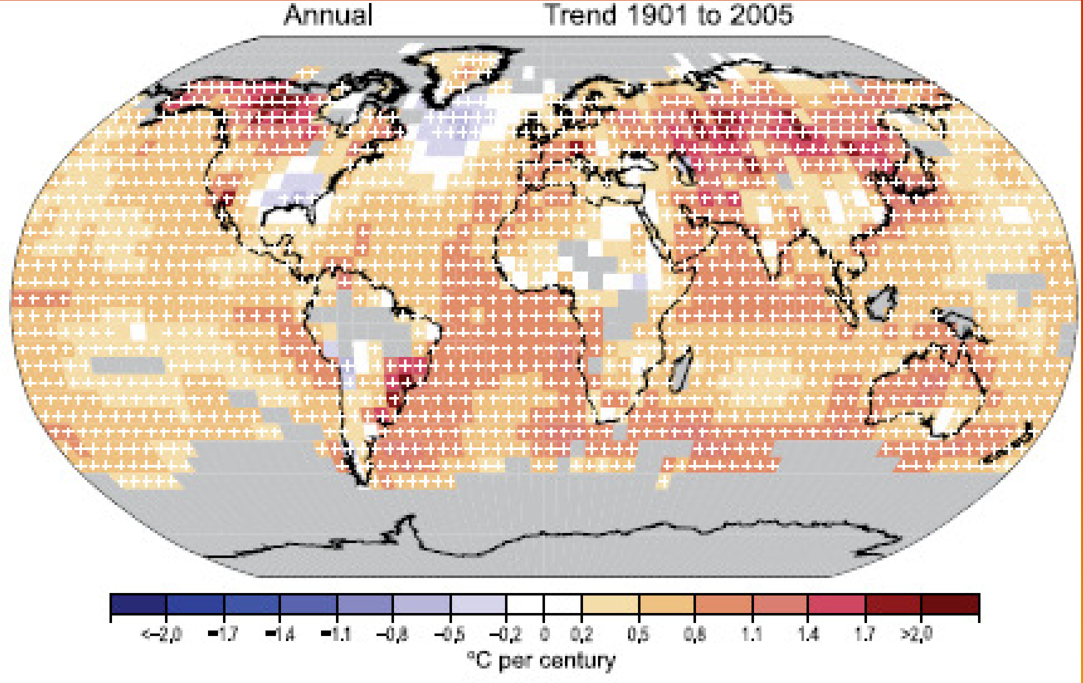
Even if it fully stops due to GG-forcing, rather new climate, but not an ice-age! (Source: **Wood et al., 2003)**

EXPECTATIONS ON CHANGES IN THE EXTREMES

- Statistical schemes (rare, moderate, duration)
- Physical pros (higher energy, water vapour, lapse rate), contras (horizontal differences)
- Free decadal variations of the variability?

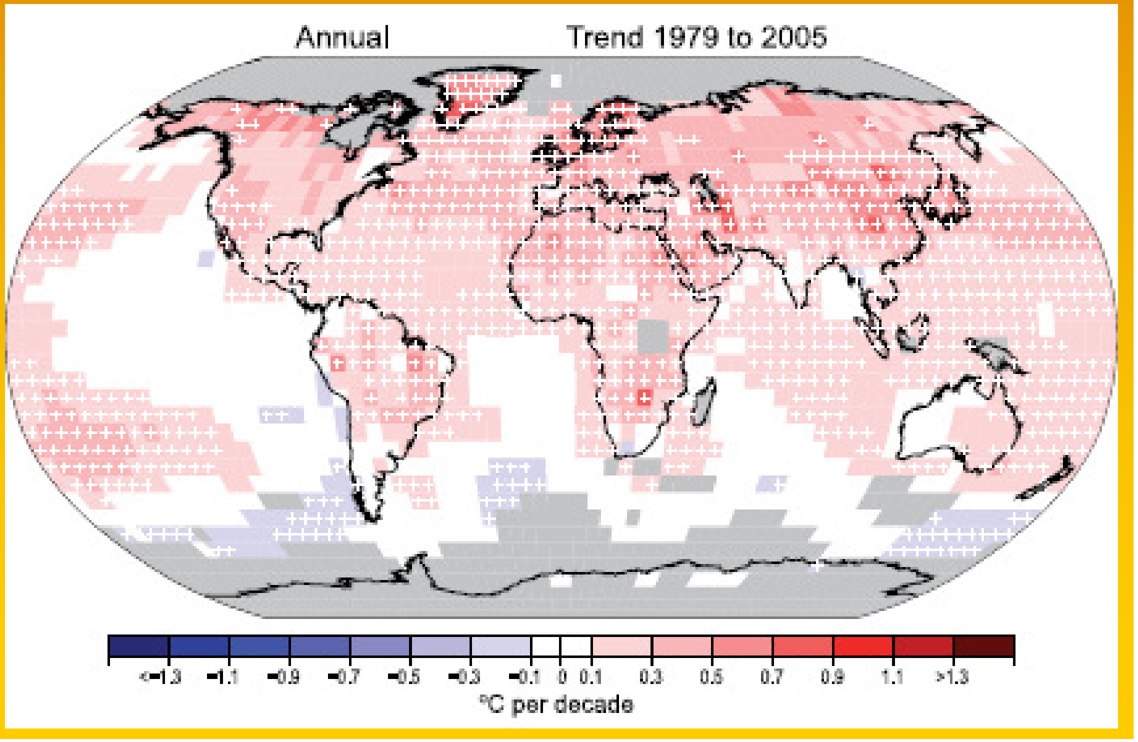


Much bigger percentage changes in extremes



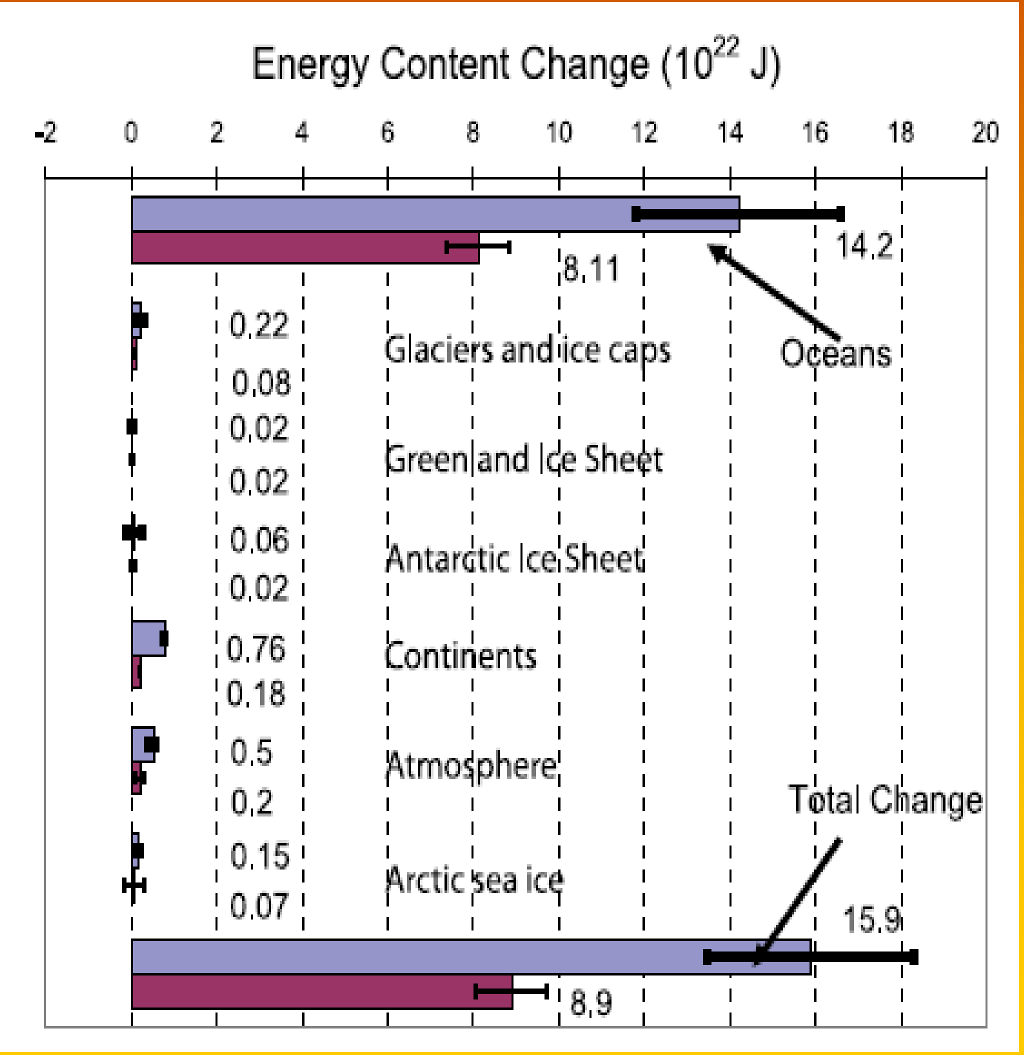
Increasing temperature:
more energy to concentrate
in dangerous objects

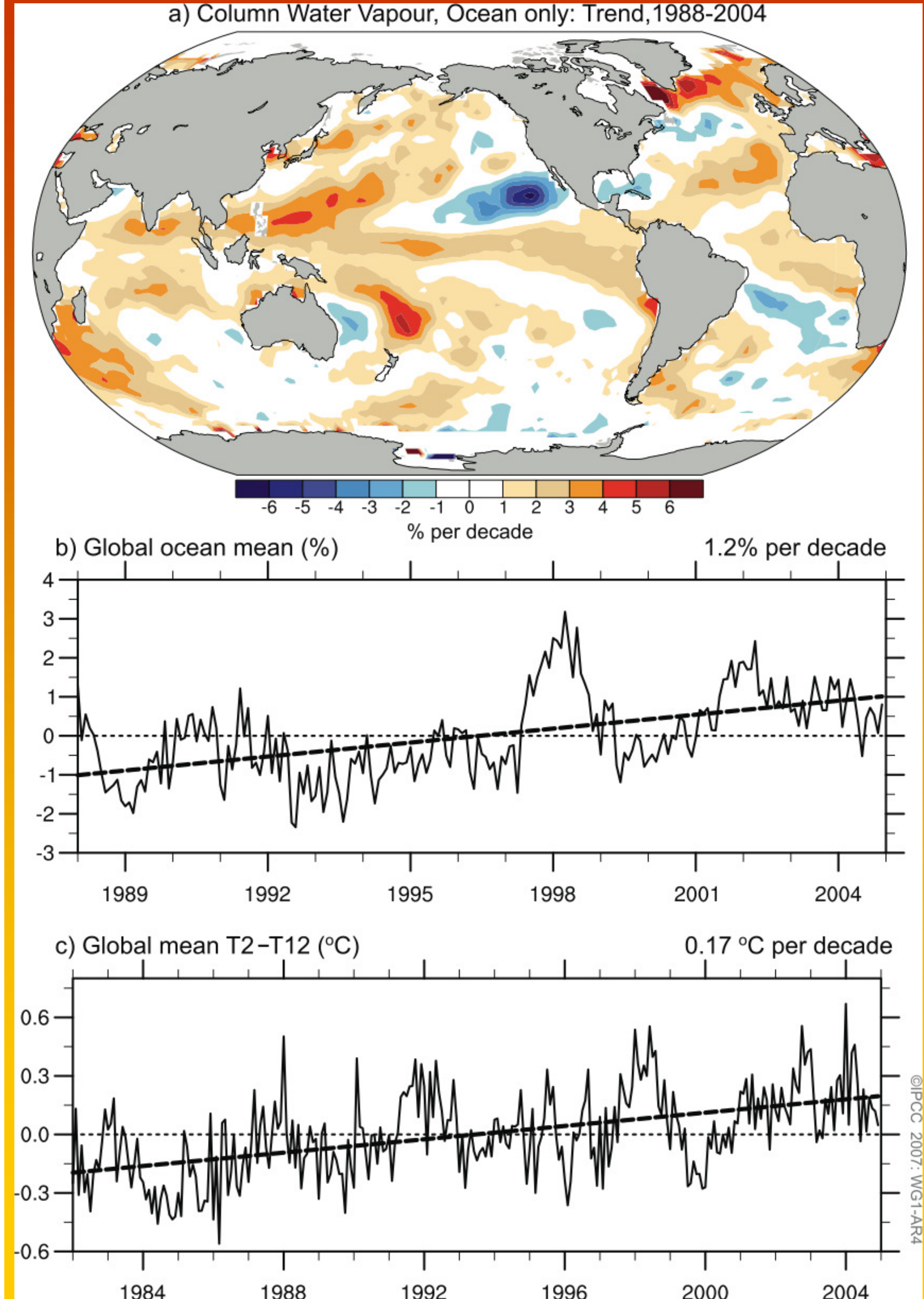
IPCC AR4, 2007



ENERGY-CONTENT OF ALL DOMAINS INCERASED

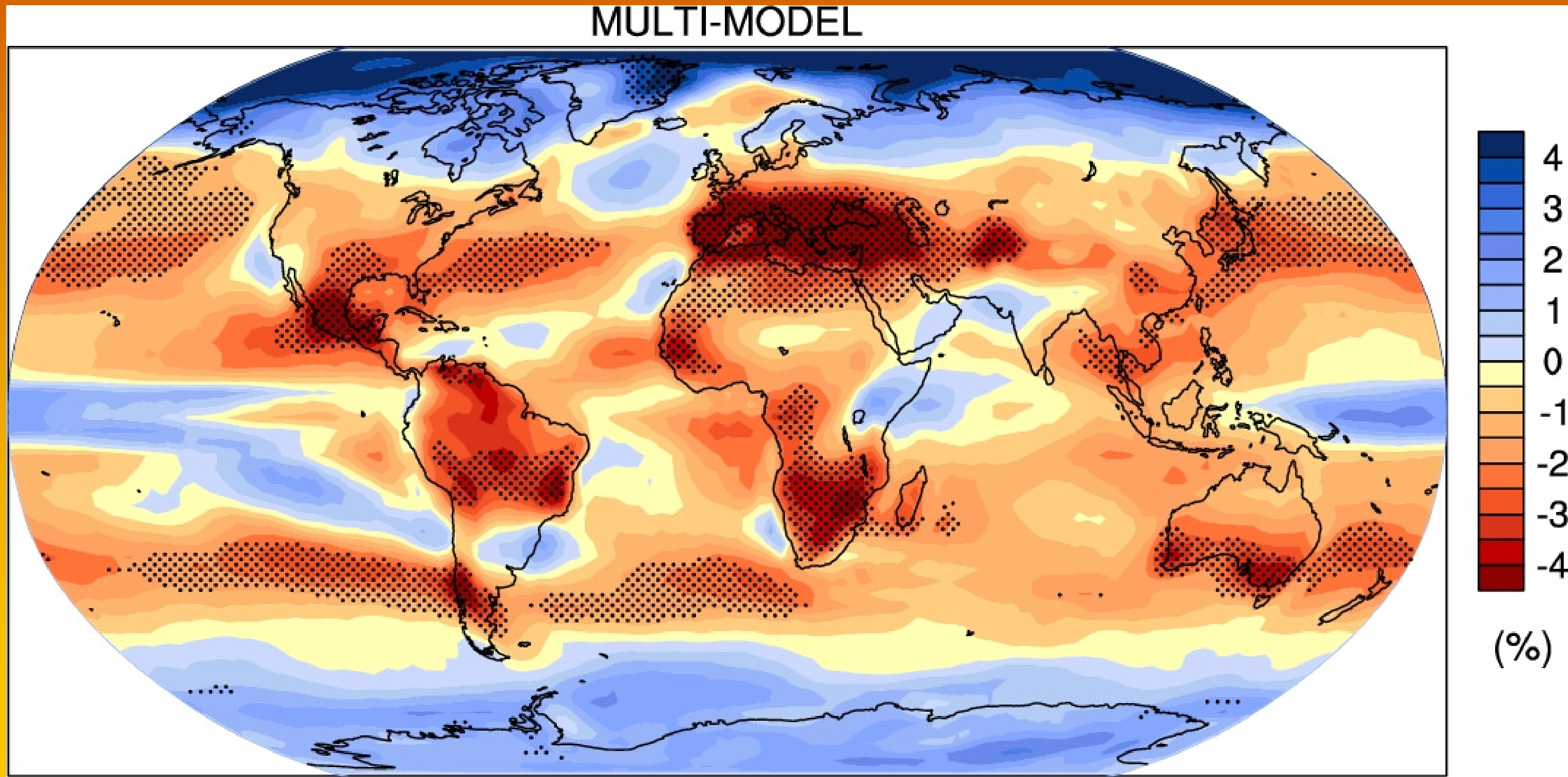
IPCC, 2007





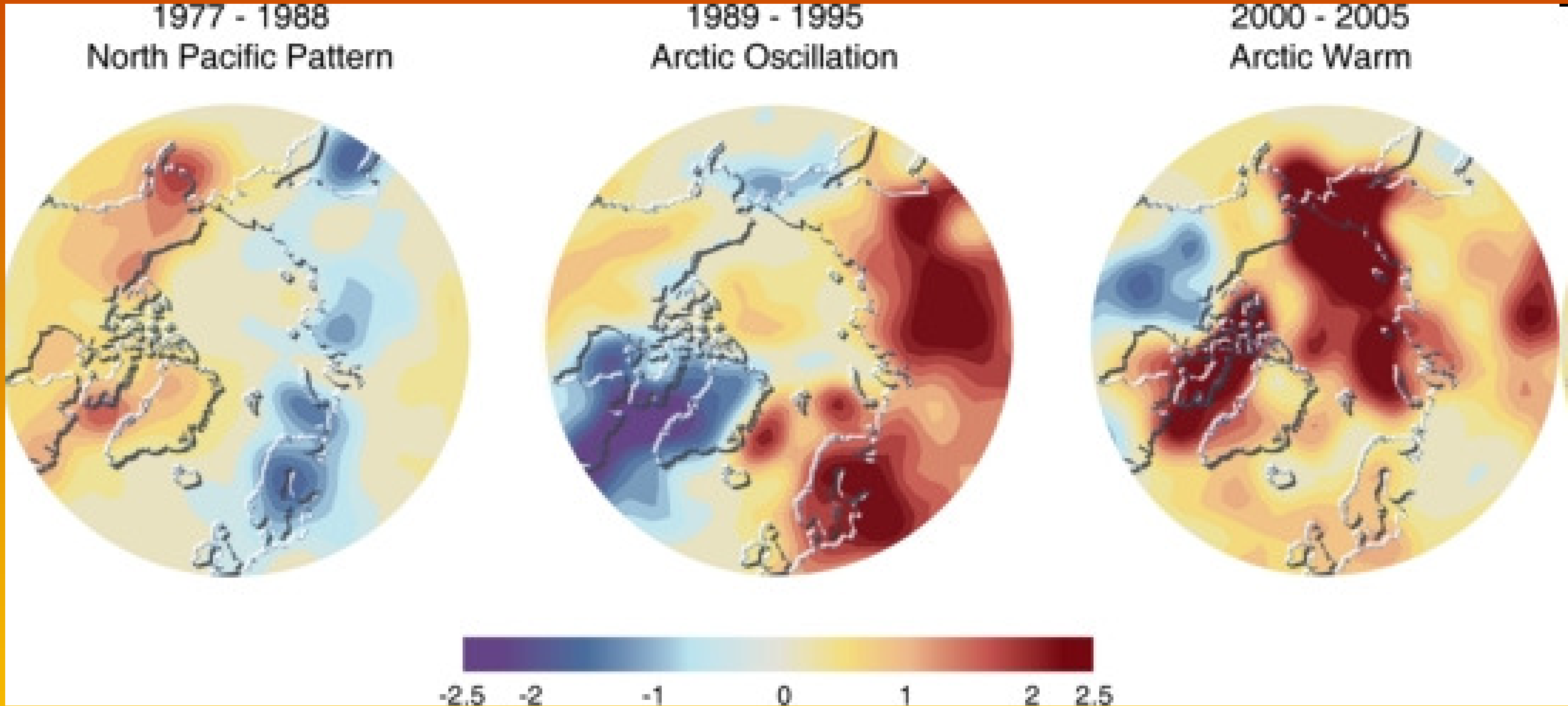
Enhanced water content in the atmosphere: more latent energy, more rain and more intense convection (IPCC AR4: Fig. 3.20 and 3.21)

Changes in the cloudiness: Additional effect to the warming!



A 19 available GCMs *(IPCC WG-I, 2007: Chapter 10, Supplement)*

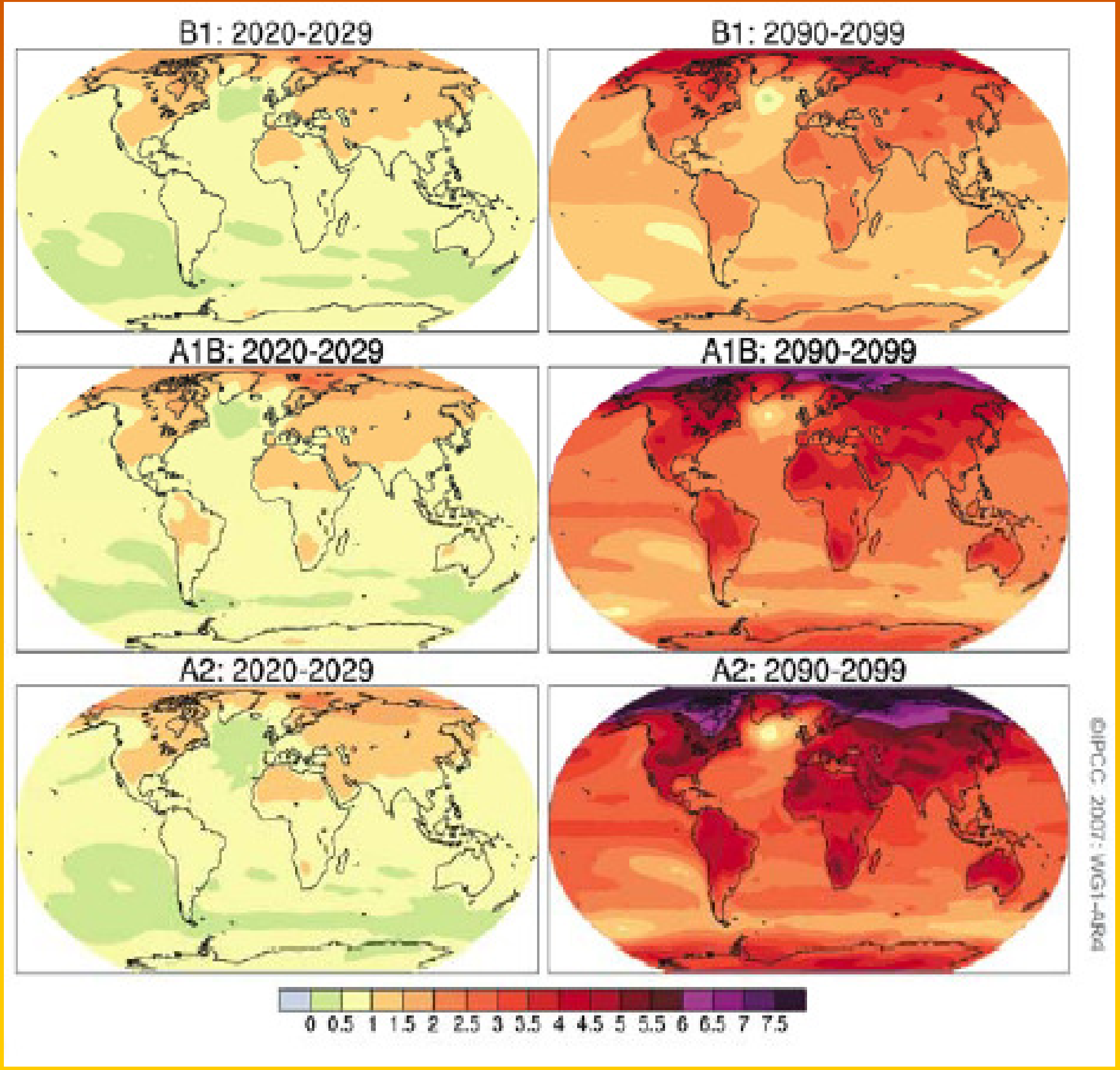
But, strong internal variability



Air temperature anomalies in selected periods of recent NH warming

NOAA/ESRL (2007). Climate composites. NOAA/ESRL Physical Sciences Division, Boulder, CO. http://www.cdc.noaa.gov/cgi-bin/Composites/ printpage.pl

But: smaller Eq. – Pole and ocean-continent differences (GCM!)



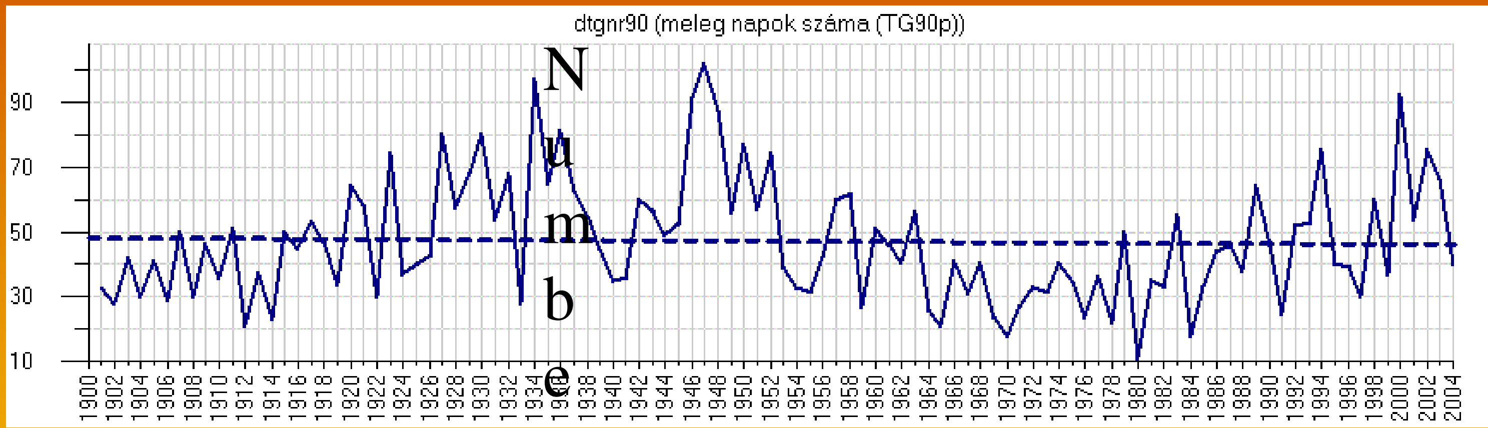
IPCC AR4, 2007

EMPIRICAL APPROACH: DATA QUALITY AND CONCEPTUAL PROBLEMS

- Missing or erroneous data, inhomogeneity, lack of long sub-daily series
- Past tendencies: Regression with the time, or with the global temperature?

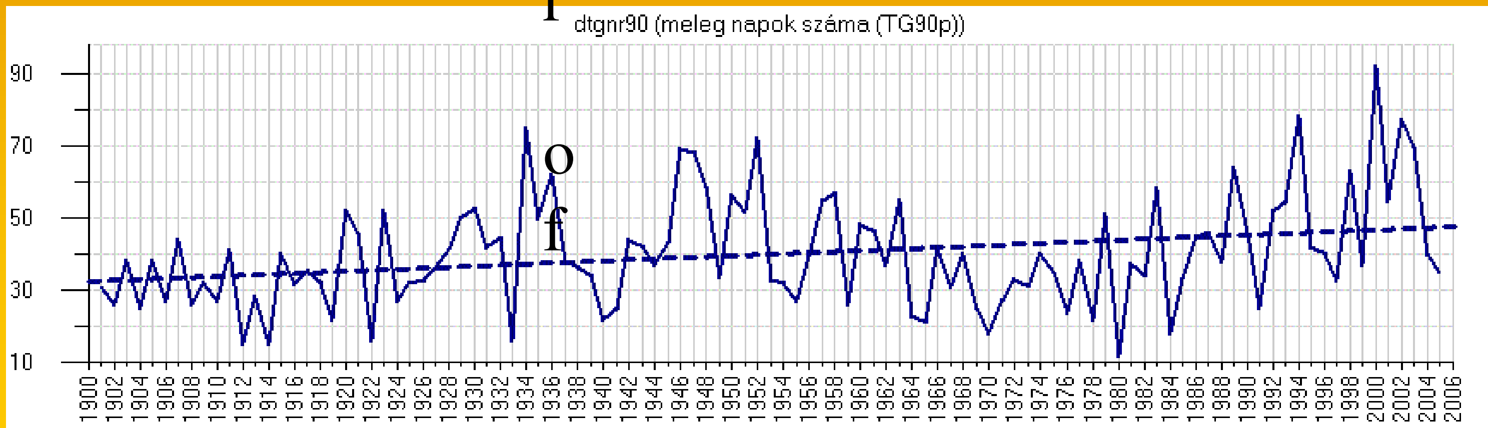
EXTREME INDEXES (without and with homogenisation: Number of days higher than the 90% frequency – any month)

Orig.



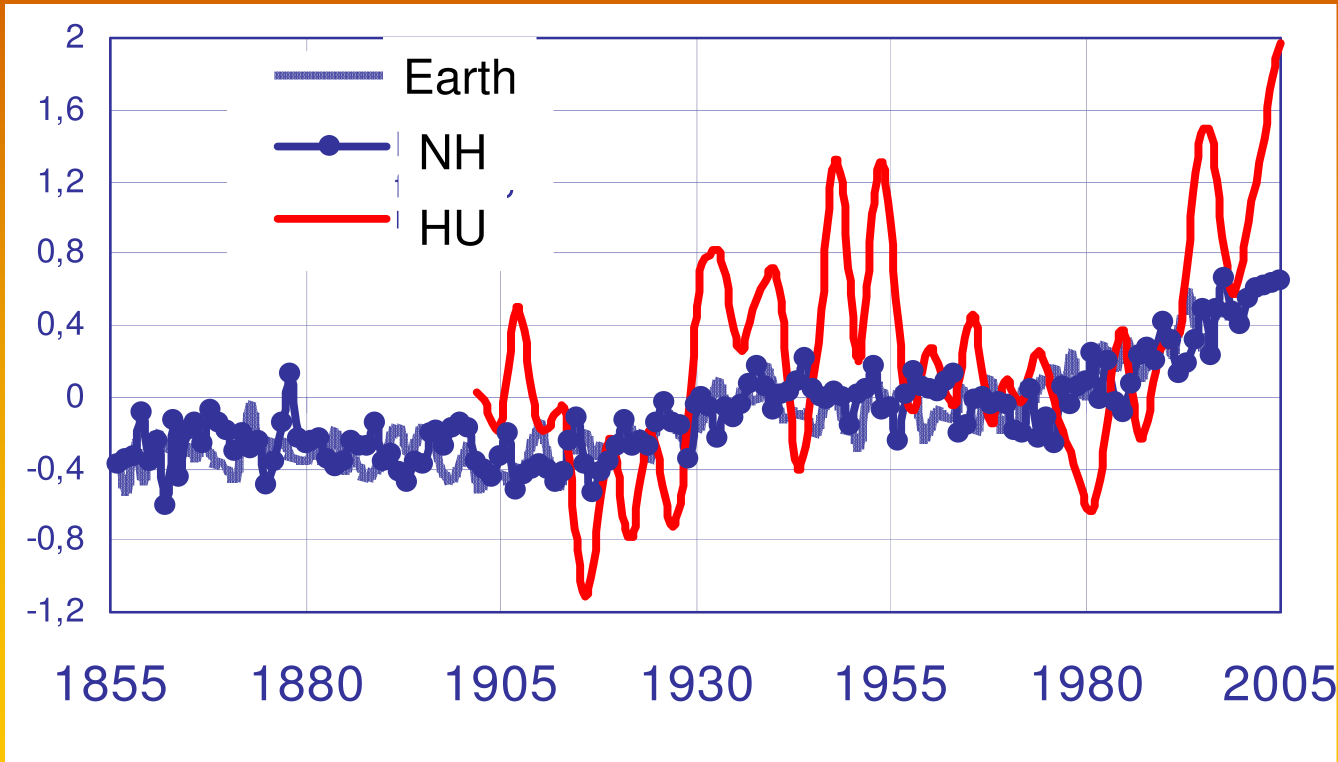
Dtgnr90 (CCL/CLIVAR): No of warm days

Homog.



(Lakatos M., 2007)

Conceptual problem: Trends with the global temperature, but not with time, alone!



Summer temperature in HU **(Lakatos M. and Mika J., 2007)**

WHAT CAN WE SEE FROM THE DATA?

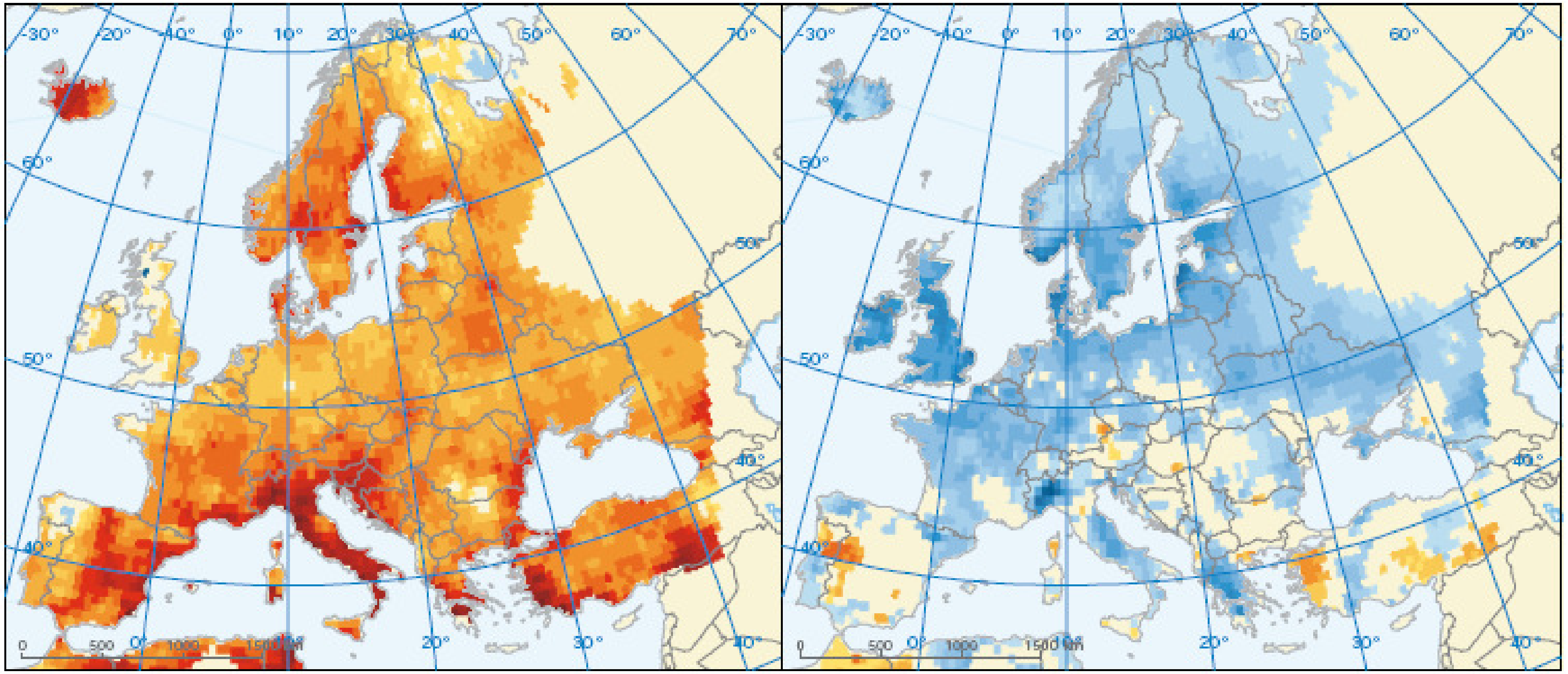
- Results from the IPCC AR4 (1 table)
- Post-AR4 developments

IPCC Fourth Assessment (2007)

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

OBSERVED TRENDS IN A MONOTONOUSLY WARMING PERIOD

Map 5.6 Observed changes in warm spells and frost days indices 1976–2006

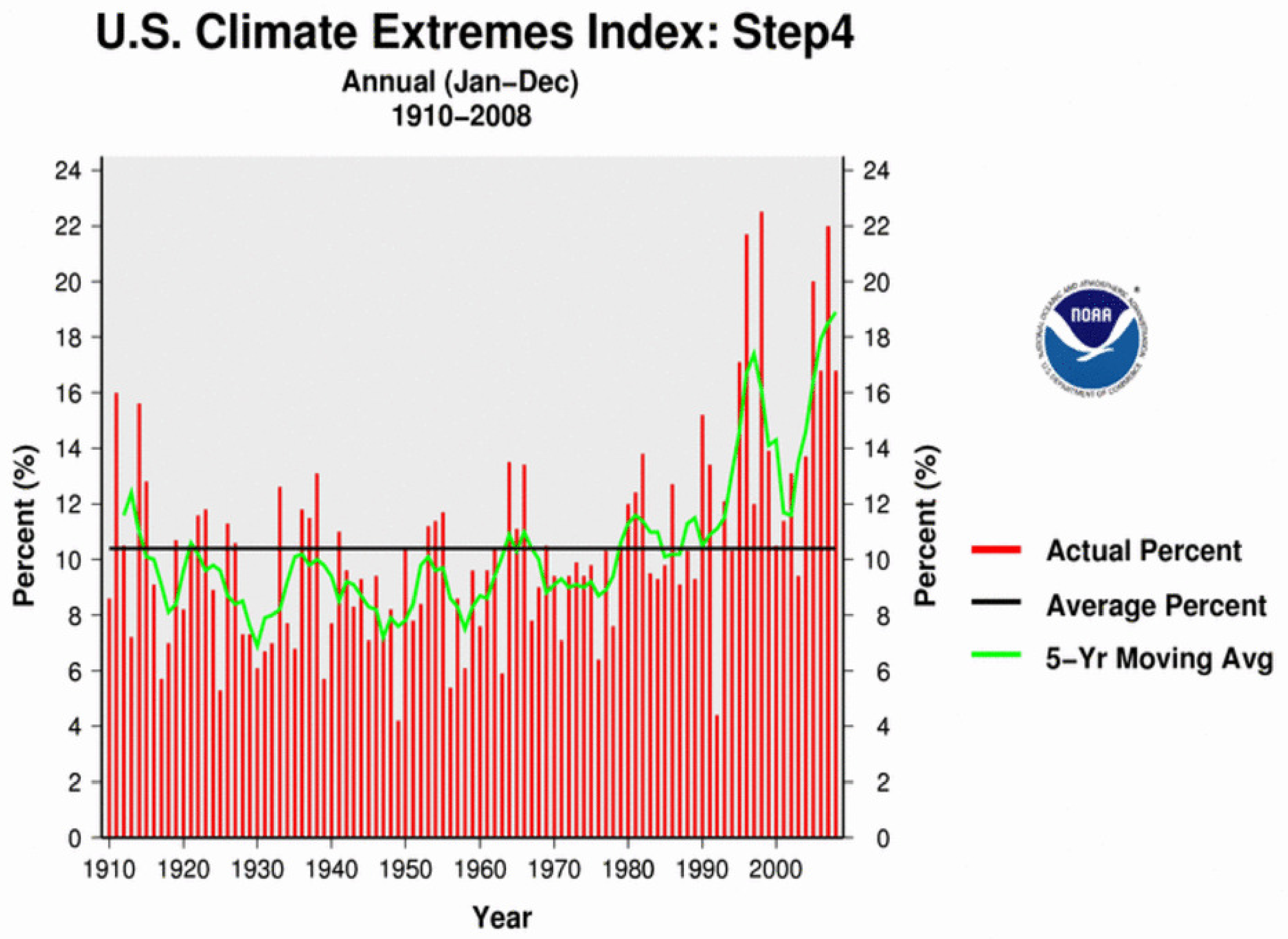


Observed changes in duration of warm spells in summer (left) and frequency of frost days in winter (right), in the period 1976–2006

Days per decade

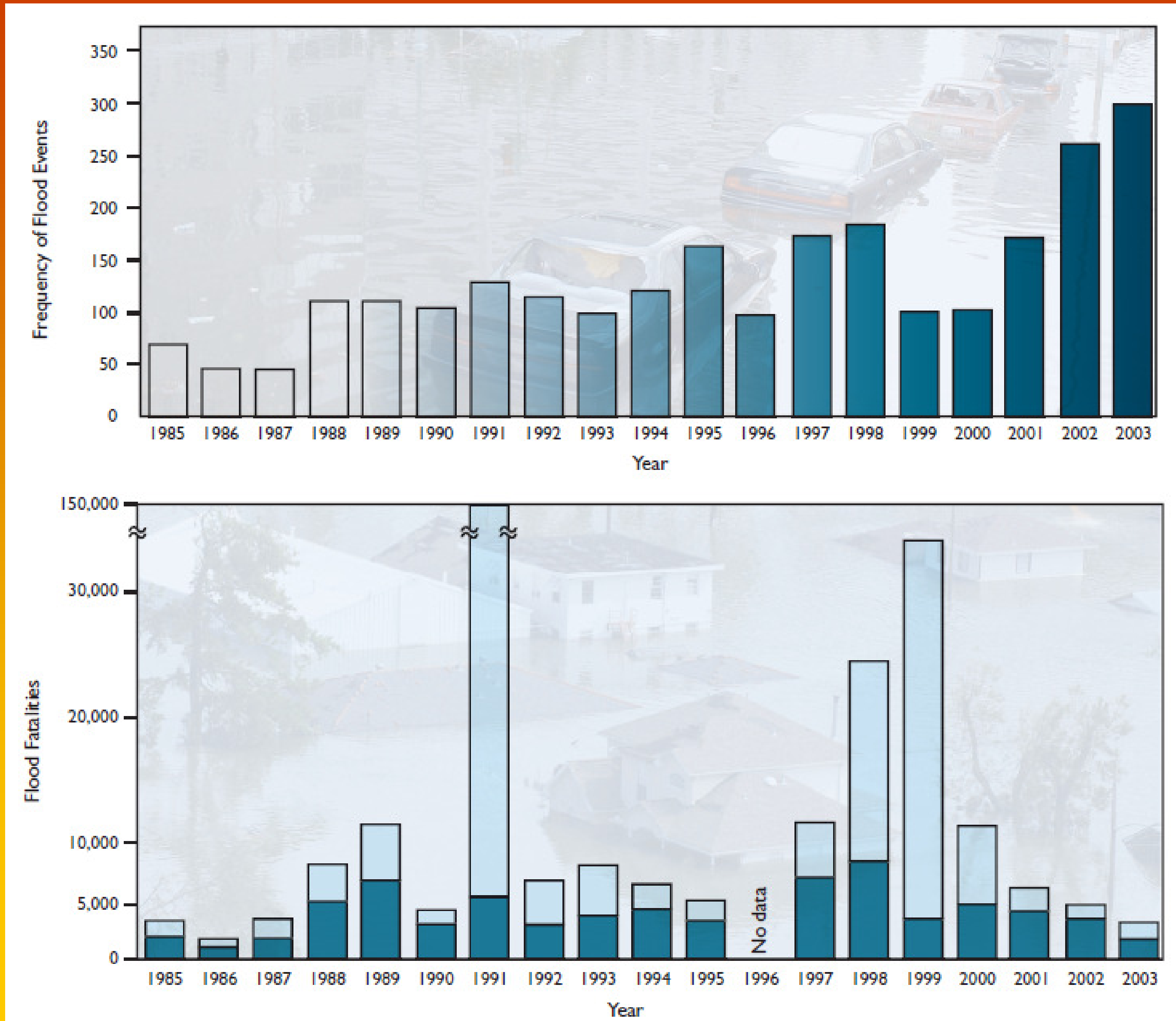
– 10 – 9 – 8 – 7 – 6 – 5 – 4 – 3 – 2 – 1 0 1 2 3 4 5 6 7 8 9 10

Source: The climate dataset is from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl).



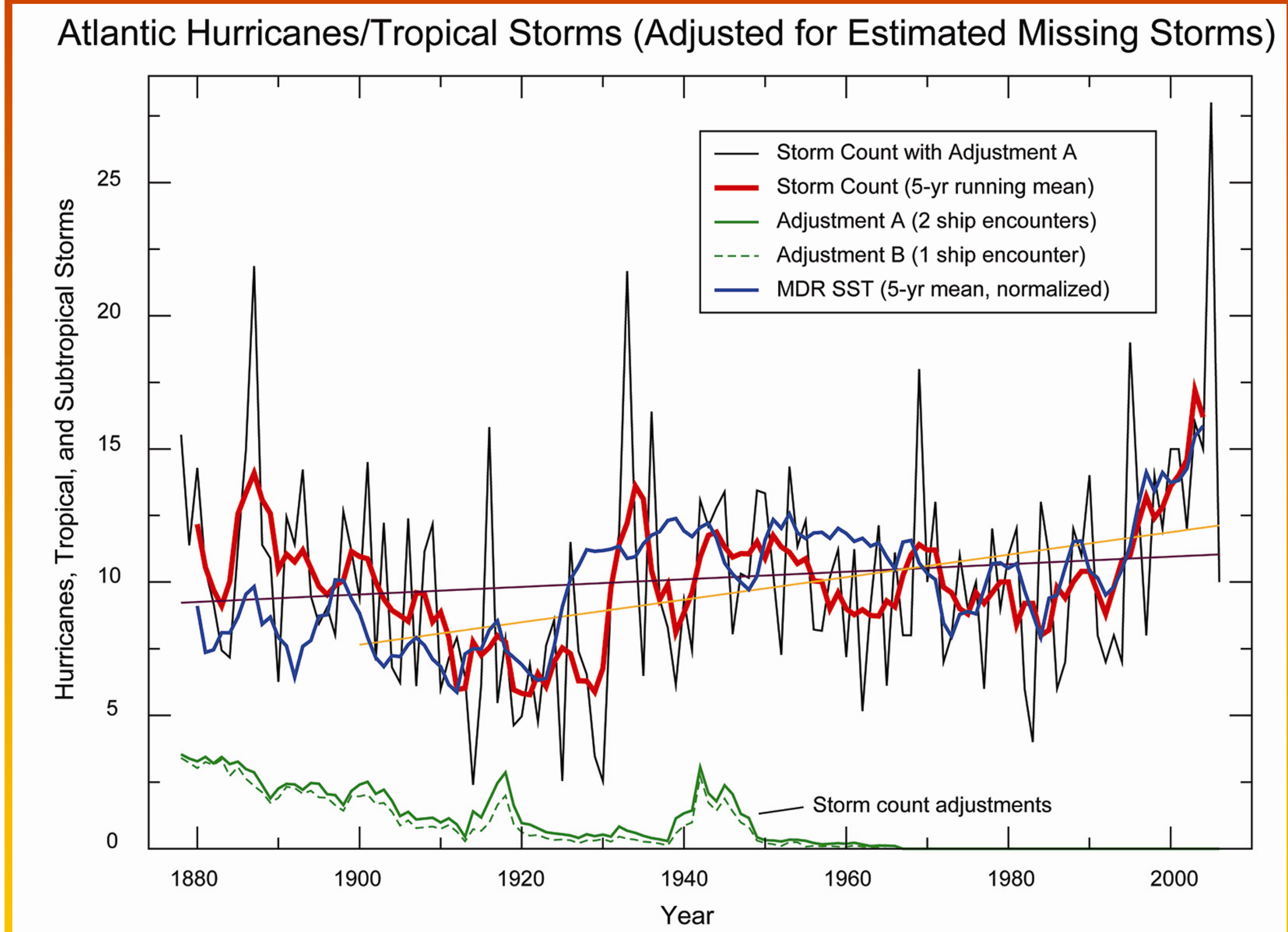
http://climateprogress.org/wp-content/uploads/2009/03/cei-4-08.gif

TRENDS IN WORLD-WIDE FLOODING!



King et al.,ed.: Our changing planet, 2009 p. 103

HURRICANES – corrected for missing observations



Atlantic hurricanes and tropical storms for 1878-2006, adjusted for missing storms.

Black curve is adjusted annual storm count,

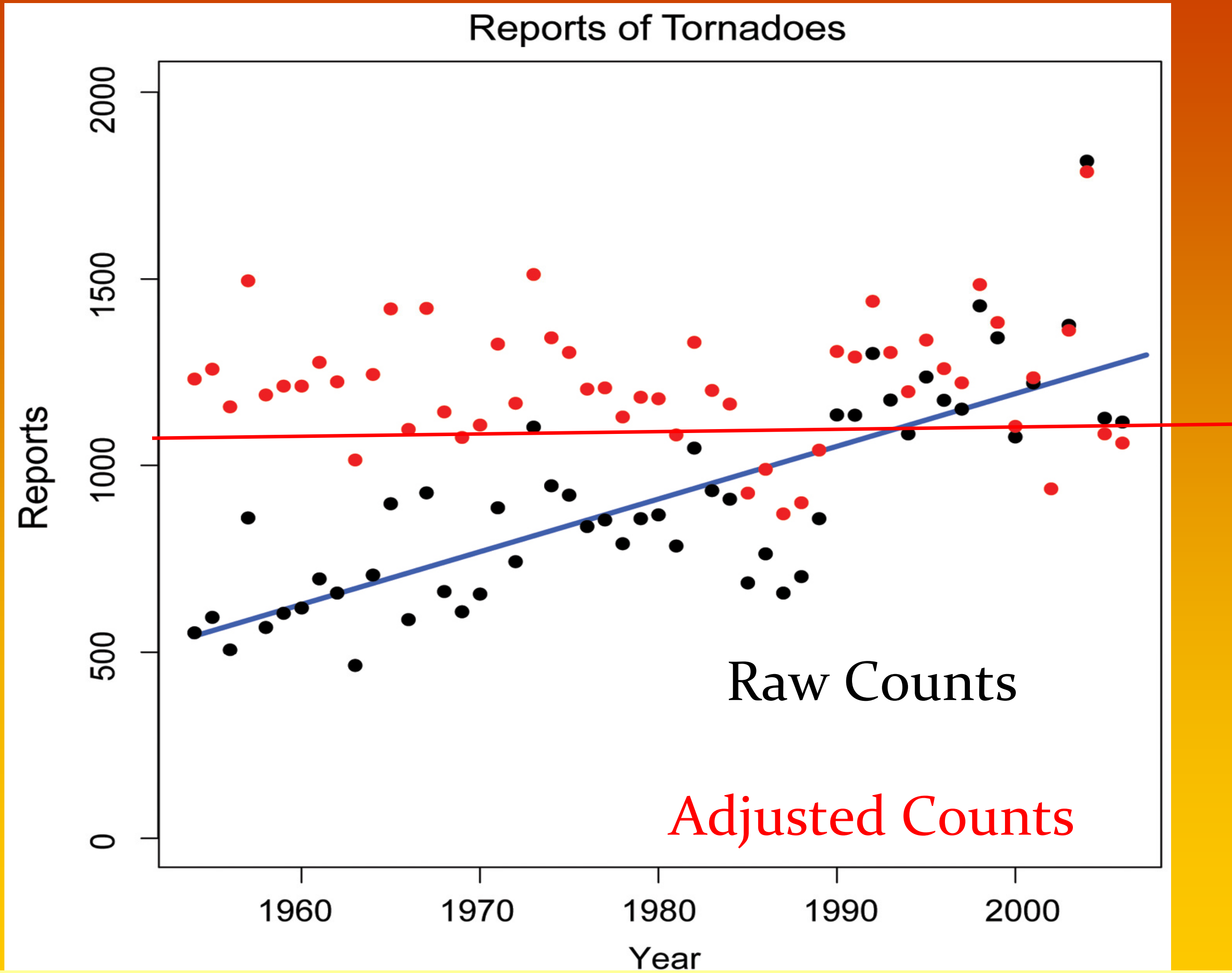
Red curve is 5-year running mean, and

Blue curve is a normalized 5-year running mean SST index for Main Development Region

EASTERLING, D. R., 2009: *IPCC WG-2 Scoping Meeting, OSLO March 23, 2009*

http://www.ipcc-wg2.gov/AR5/extremes-sr/ScopingMeeting/extremes_speakers.html

Tornadoes (USA): corrected series!



EASTERLING, D. R., 2009: *IPCC WG-2 Scoping Meeting, OSLO March 23, 2009*

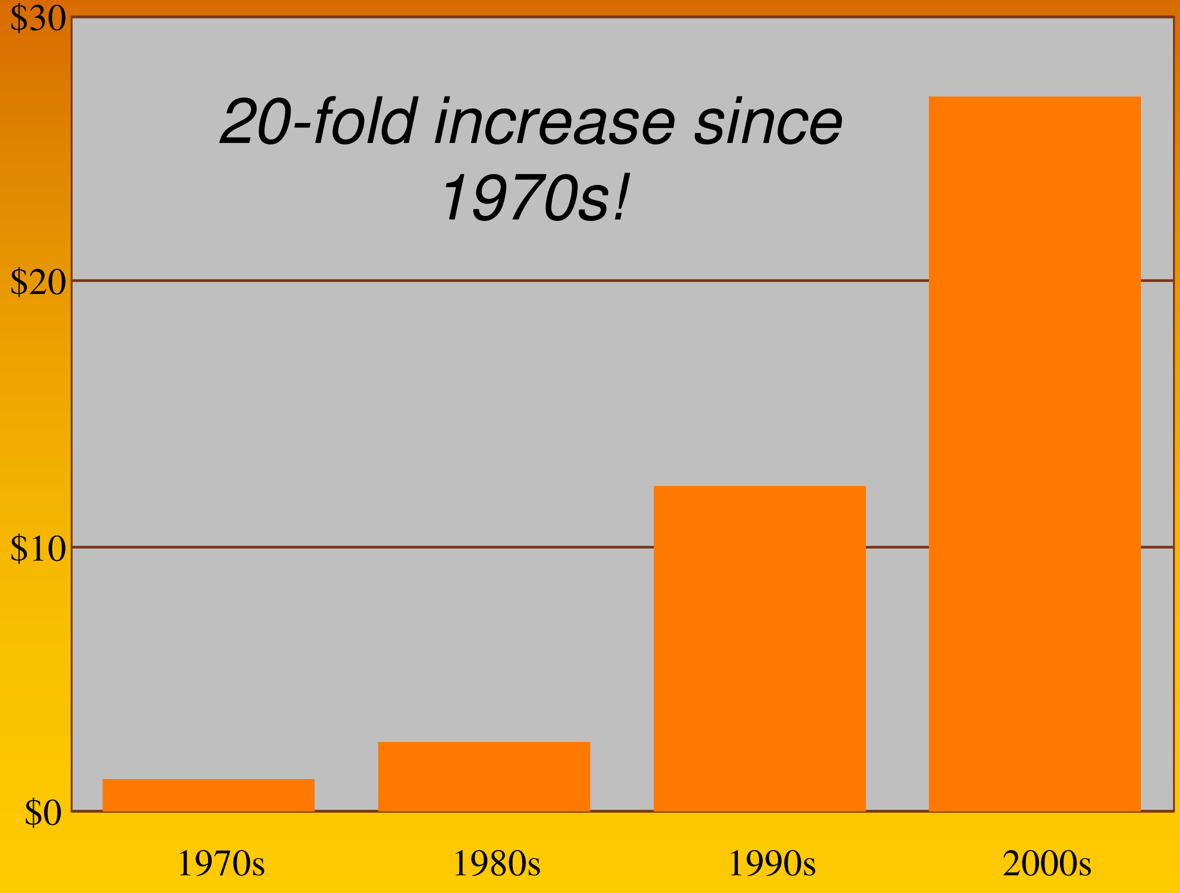
http://www.ipcc-wg2.gov/AR5/extremes-sr/ScopingMeeting/extremes_speakers.html

Severe weather claims paid

Institute for Catastrophic Loss Reduction

Building resilient communities

Annual global insurance disaster claims, US$B



More people and infrastructure at risk

Aging infrastructure

Changing climate (?!)

http://www.iclr.org/

USA Climate Change Science Program

(Kunkel et al., 2008)

- there has been…an increase in extreme high temperatures and a reduction in extreme low temperatures
- heavy downpours have become more frequent and more intense in recent decades over most of North America and now account for a larger percentage of total precipitation
- averaged over the continental U.S.A. and southern Canada…there is no indication of an overall trend [*drought*]
- Atlantic tropical storm and hurricane destructive potential has increased
- northward shift in the tracks of strong low-pressure systems (storms) in both the North Atlantic and North Pacific over the past fifty years

NICOLLS, N., 2009: *IPCC WG-2 Scoping Meeting, OSLO March 23, 2009*

http://www.ipcc-wg2.gov/AR5/extremes-sr/ScopingMeeting/extremes_speakers.html

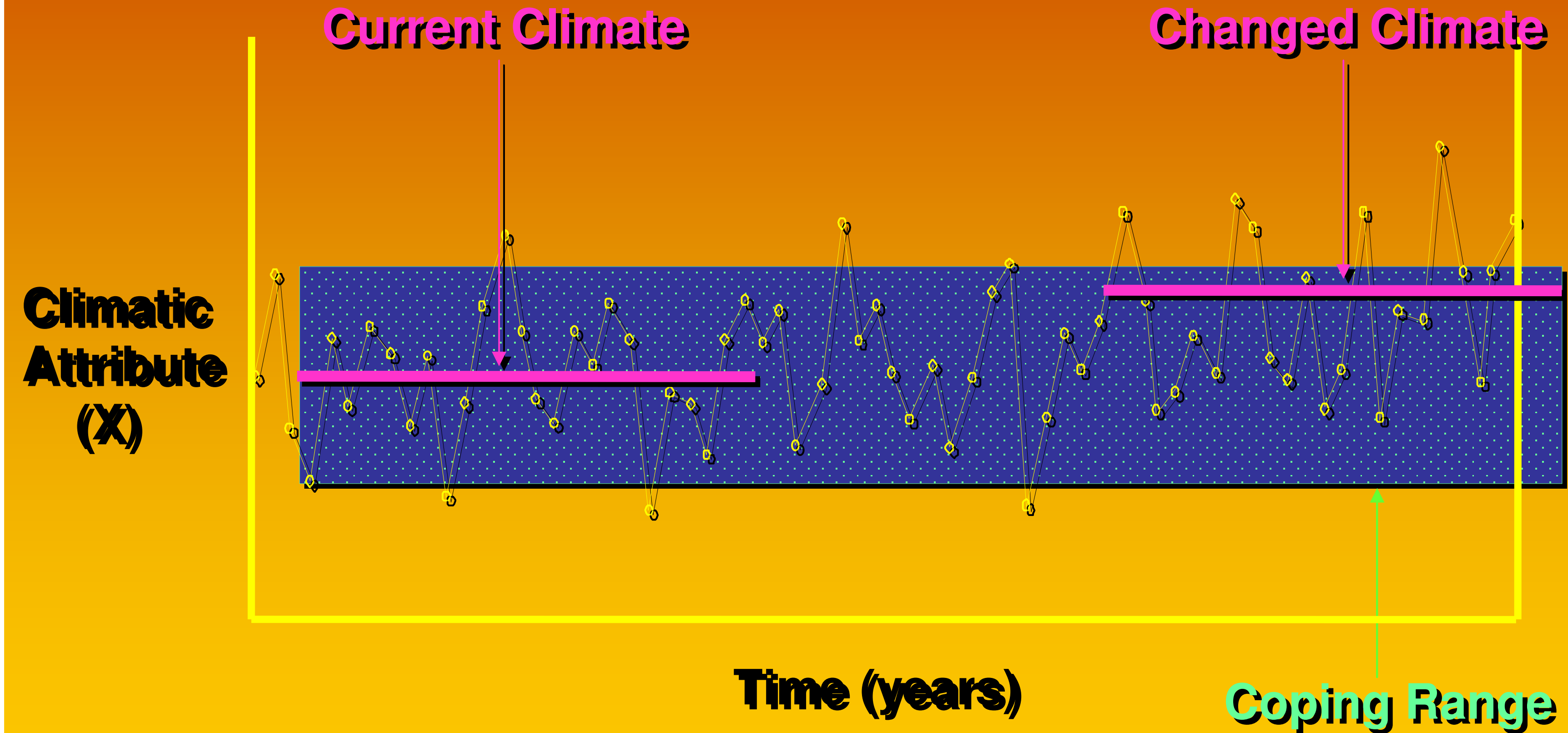
Outstanding questions

- Hot and cold days/nights
  - Relationship to changes in mean temperatures; are extremes changing faster than average temperatures?
- Heavy rainfall events
  - Are these increasing even where total rainfall is declining?
- Drought
  - What is the influence of warming; circulation changes?
- Tropical cyclones
  - Spatial variations in trends - links to ocean temperature
- Extra tropical storms
  - Spatial variations in trends - links to general circulation
- El Niño - Southern Oscillation
  - Has there been a trend to more or stronger Niño events?

NICOLLS, N., 2009: *IPCC WG-2 Scoping Meeting, OSLO March 23, 2009*

http://www.ipcc-wg2.gov/AR5/extremes-sr/ScopingMeeting/extremes_speakers.html

Climate Change Extremes and Coping Range



What is worth doing: adjust the thresholds to expected changes of the mean, at least!

CONCLUSIONS (1):

- It is possible to describe the extremes exactly.
- The recent frequency and threshold step-overs are mostly known.
- Too many, too dangerous even without any climate change.
- Several circulation complexes exist with multi-element effects.
- These precursor objects are also quantified in many regions and could be further re-analysed.

CONCLUSIONS (2):

- No uniform change in the different extremes. Changes in the mean climate state may cause changes of different direction in the extremes.
- Data and conceptual problems occur
- Shift of temperature generally leads to increase of warm and decrease of cold extremes. Diurnal and shorter precipitation amounts increase in many regions.
- Droughts may be more severe in drying areas due to parallel rise of temperature and sunshine duration.
- More strict empirical conclusions: better data, causal understanding of the circulation changes, and (longer and stronger warming).

THANK YOU FOR YOUR ATTENTION!

OMSZ

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DEPARTMENT OF GEOGRAPHY EGER