GLOBAL WARMING: landscape implications

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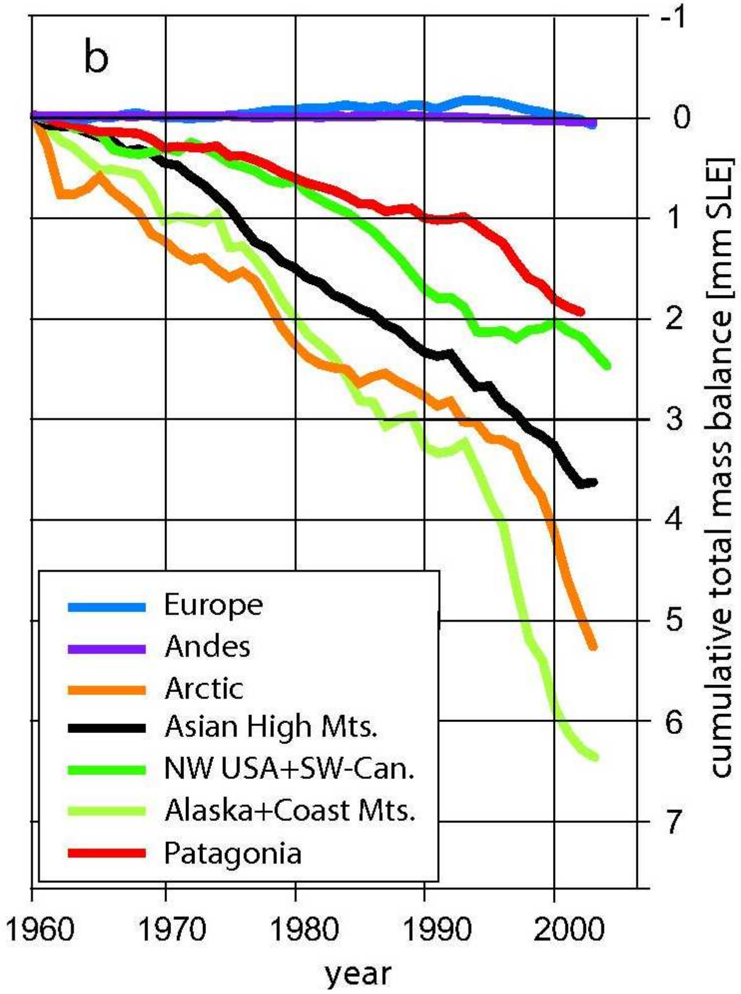
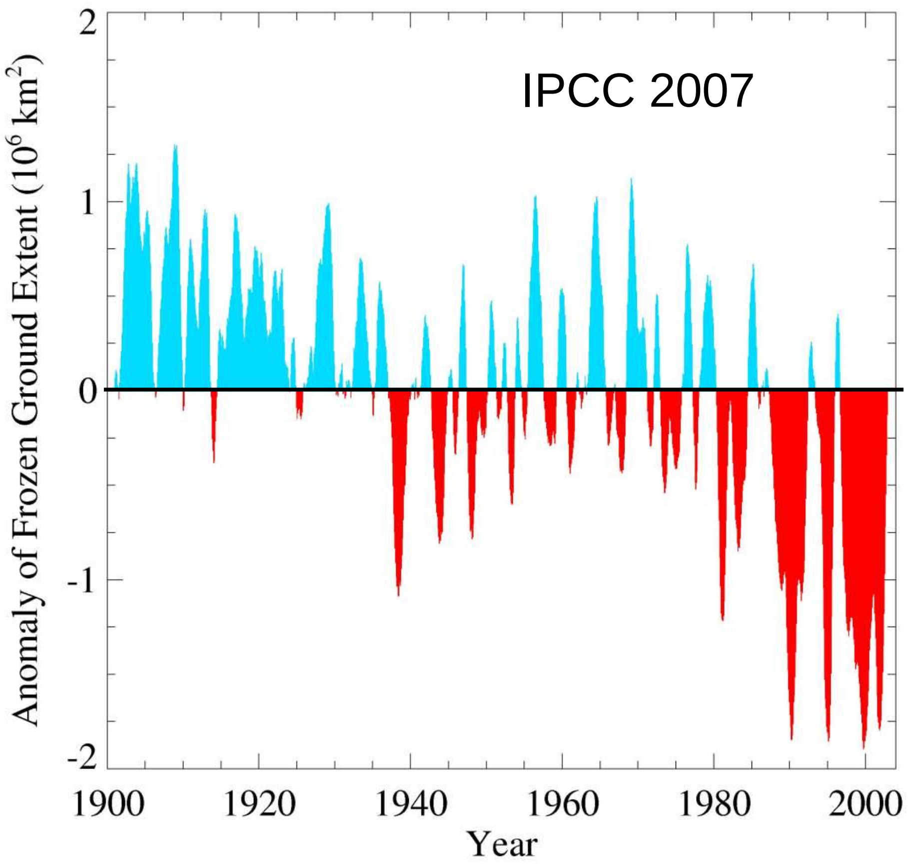
THE PROCESS OF CHANGE HAS STARTED



Increased Glacier retreat since the early 1990s



Area of seasonally frozen ground in NH has decreased by 7% from 1901 to 2002

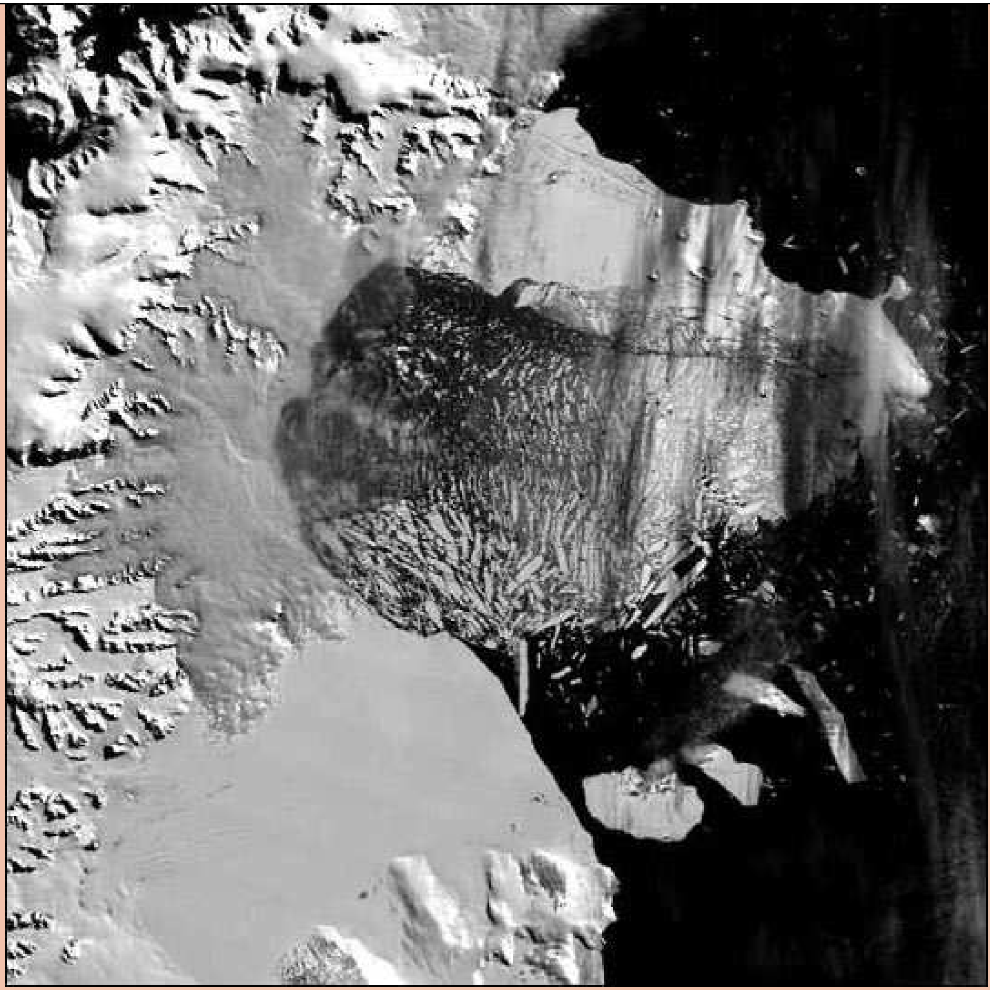
NORWAY

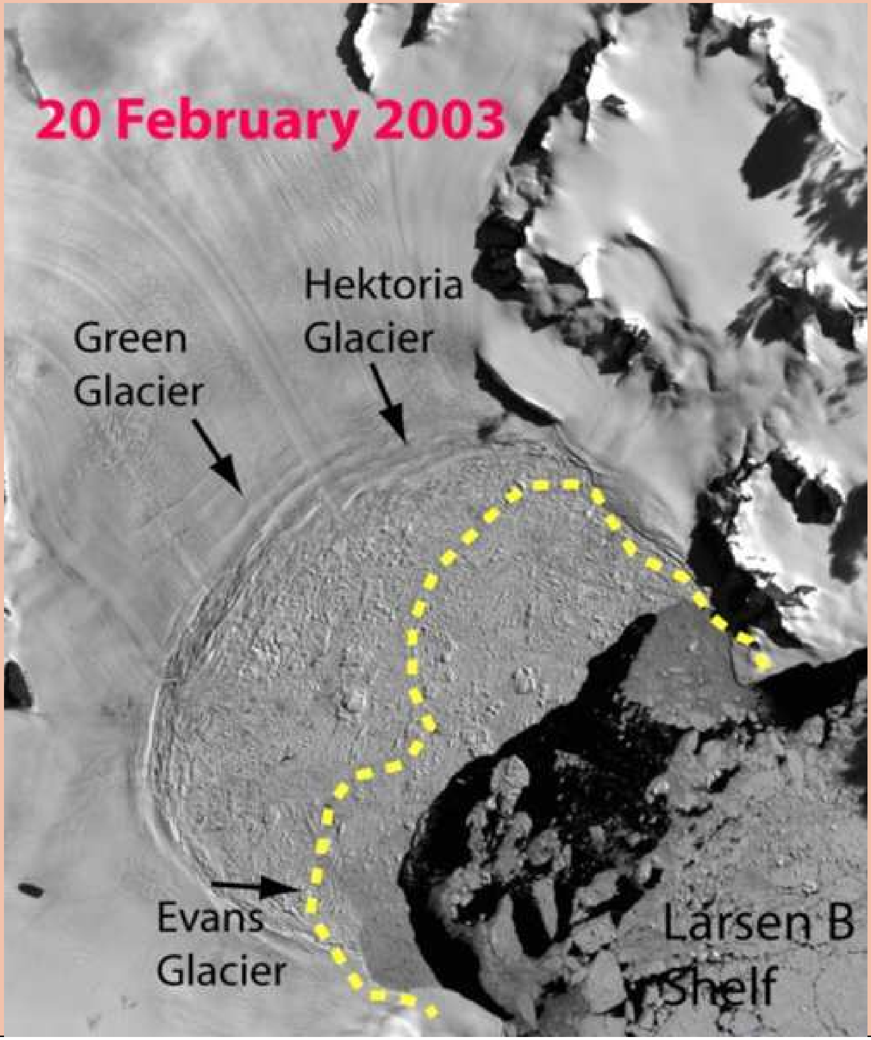
Nesje et al. (Global & Planetary Change, 60, 10-27, 2008) indicate that since 2000 Norwegian Maritime Mountain Glaciers have retreated remarkably fast (more than 100 m per year), even though in the early 1990s they had shown some advance in response to higher winter accumulation.

Svartisen

ALASKA

Tidewater glaciers retreat especially quickly – The Columbia glacier in Alaska retreated 13km between 1982 and 2000



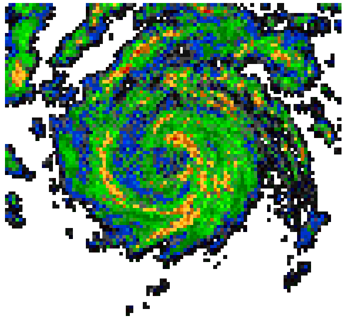


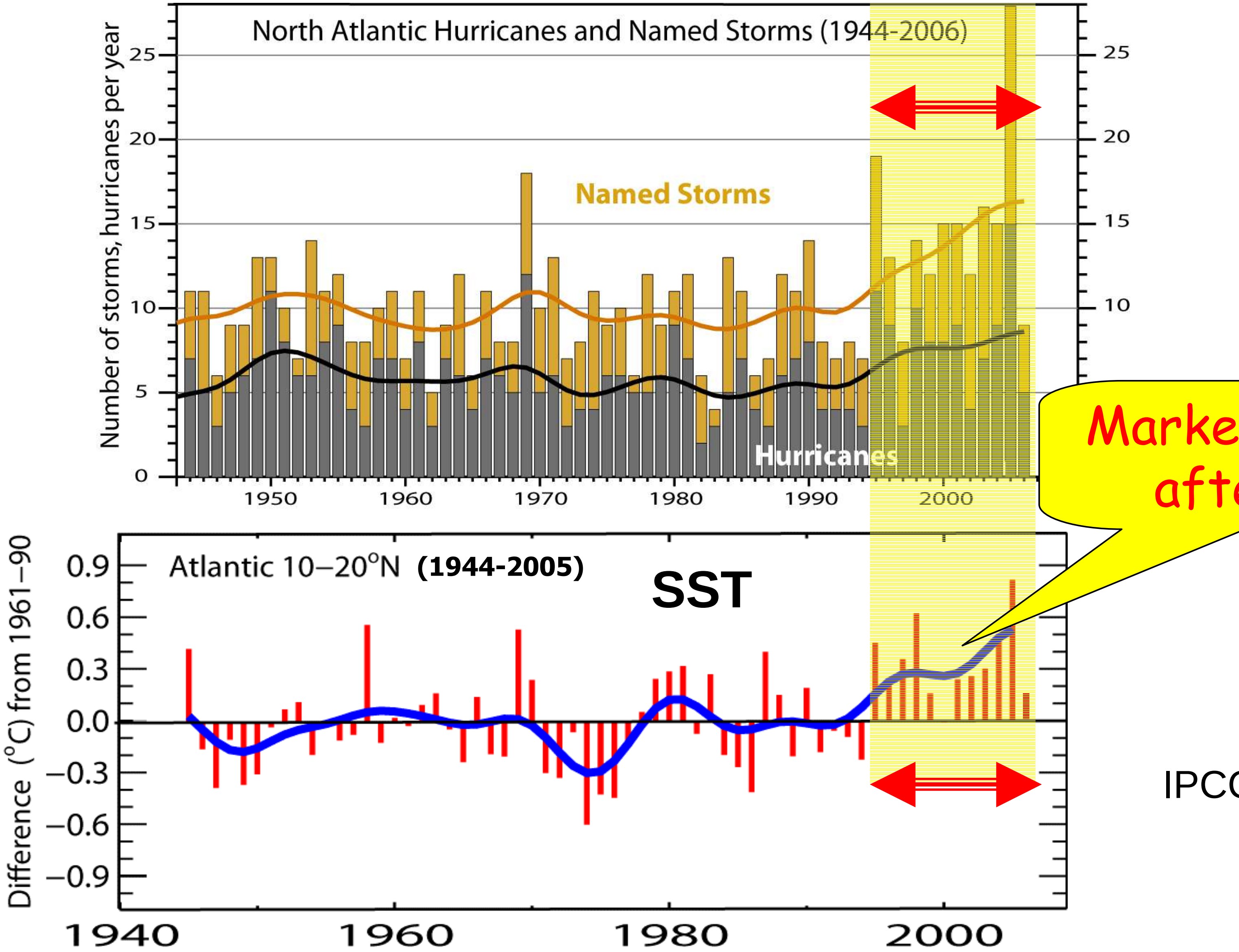
Larsen B ice shelf, Antarctica

SNOWPACK

Long term monitoring of mountain snowpacks in the W. USA and Europe have shown trends towards decreasing snowpack depth (50-75%) though this depends on such features as the North Atlantic Oscillation and degree of continentality

North Atlantic hurricanes have increased with SSTs





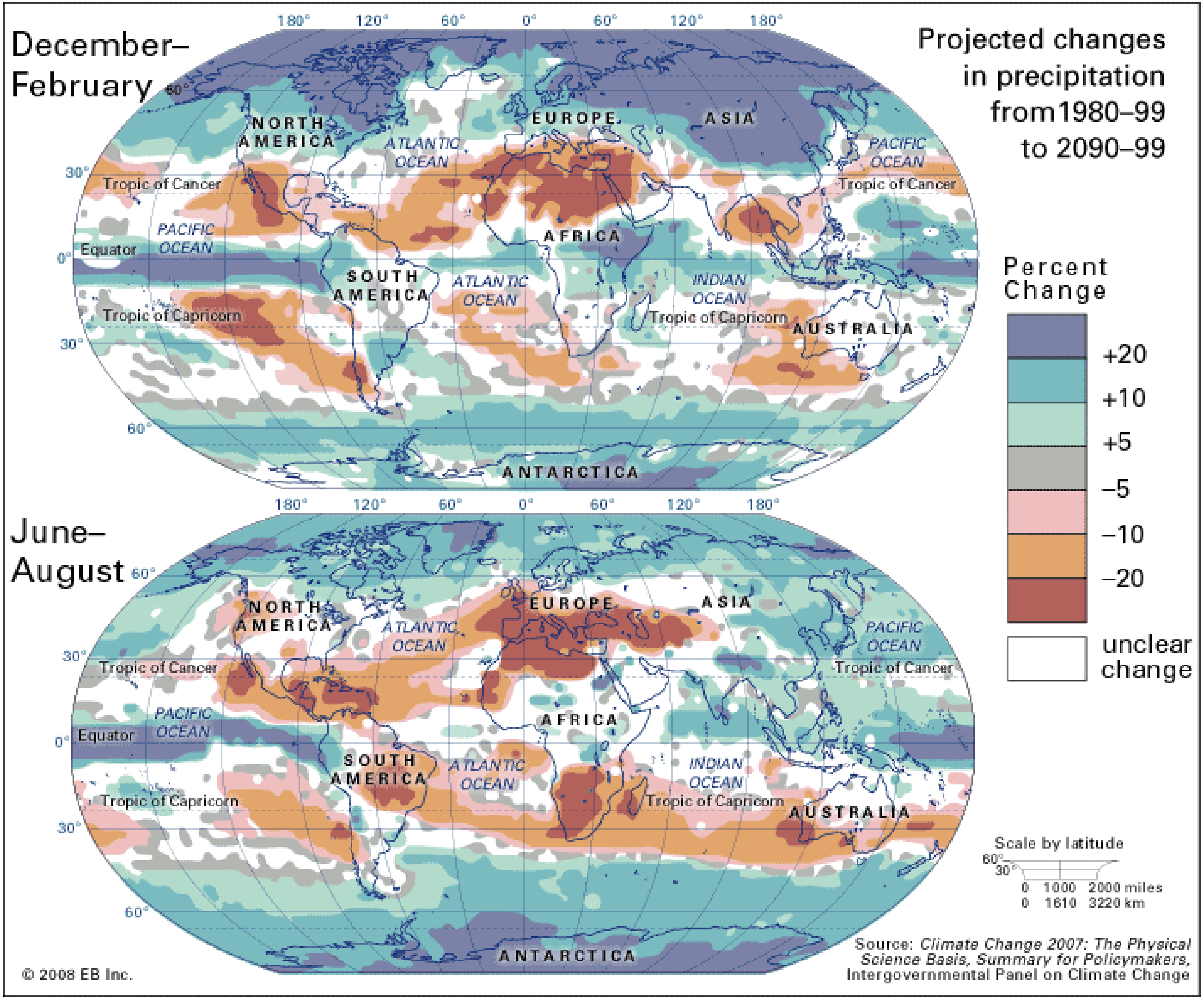
IPCC 2007

FIRE

- Warmer temperatures and less snowpack appear to be increasing the duration and intensity of wild fires in the western US
- Since 1986 there has been a 4x increase of major wildfires and a 6x increase in the area burned, compared to the period from 1970-1986 (Westerling et al., 2006).

SENSITIVITY

- Threshold reliance with respect to temperature, precipitation, crucial vegetation cover (e.g. Dunes, reefs, ice)
- Compound effects of climate change and other human actions (e.g. Subsidence)
- Susceptible features (weak, soft, close to sea-level, etc.)
- Areas where climate change will be very severe (e.g. Higher latitudes)



December–February
June–August
Projected changes in precipitation from1980–99 to 2090–99
Percent Change
+20
+10
+5
–5
–10
–20
unclear change
NORTH AMERICA
SOUTH AMERICA
EUROPE
ASIA
AFRICA
AUSTRALIA
ANTARCTICA
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
Tropic of Cancer
Equator
Tropic of Capricorn
180°
120°
60°
0°
30°
Scale by latitude
0 1000 2000 miles
0 1610 3220 km
Source: Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Intergovernmental Panel on Climate Change

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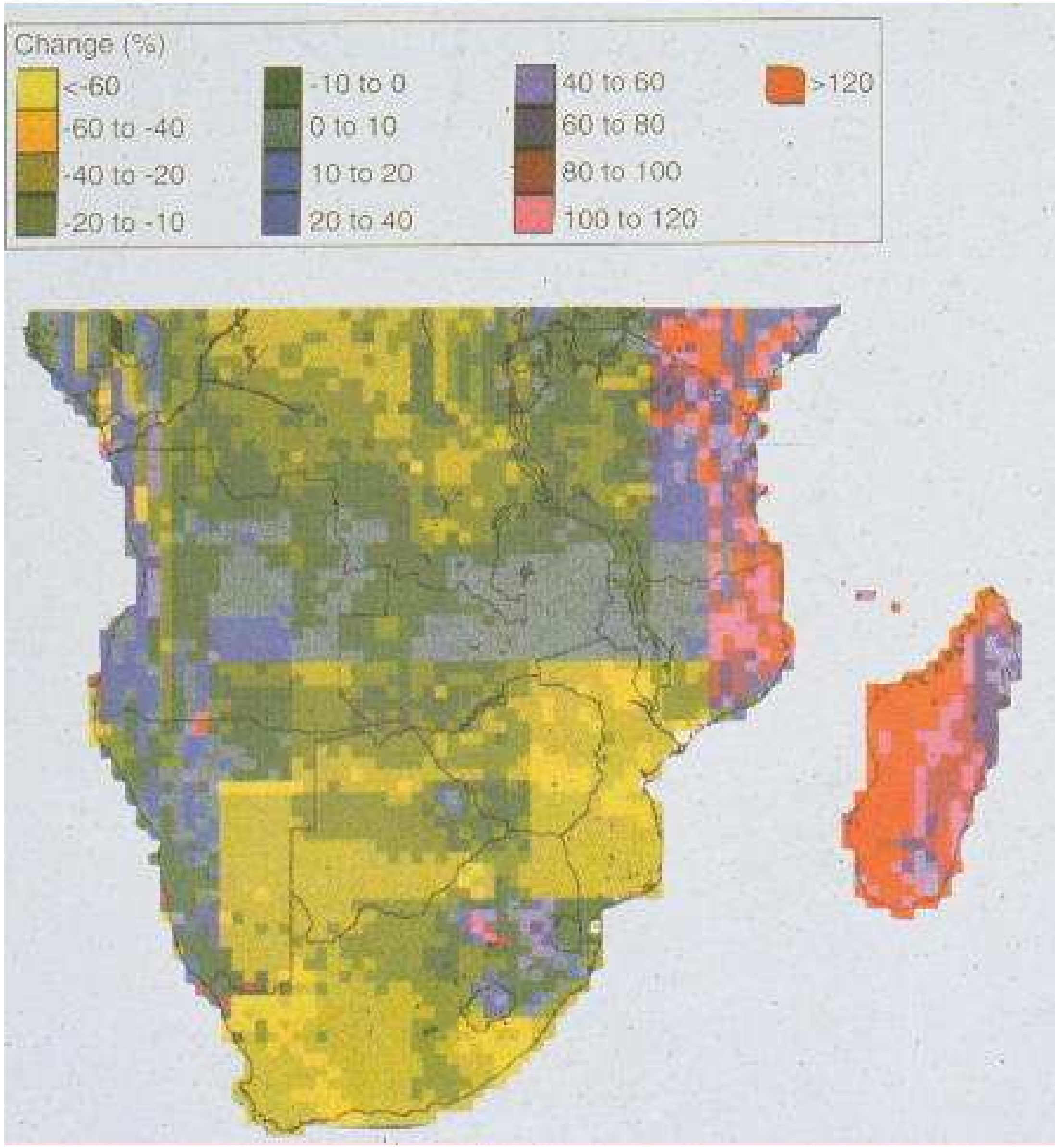
PRECIPITATION CHANGE

- Overall global increase
- Some intensification of tropical circulation
- Northward displacement of sinking Hadley cell air
- Increase in UK winter rainfall and decrease in summer rainfall
- More moisture availability in cold regions
- Changes in rainfall intensity

Amazonia Drought (2005) and potential forest die-back

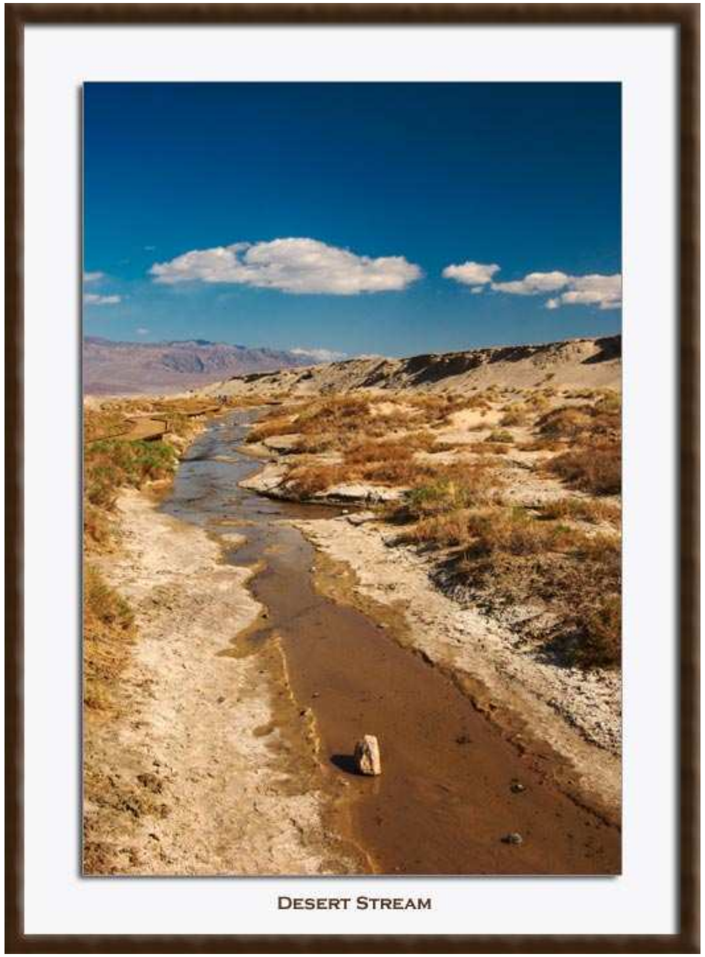
The Hadley Centre model suggests that precipitation averaged across Amazonia *could* be reduced from c 1800 mm to 1100 mm by the 2040s.



Hadley Centre predictions of change in runoff by 2050

STREAM RUNOFF

- In arid regions, an increase of temperature by c 2 degrees, and a reduction in precipitation of c 10% can lead to a discharge reduction of c 60 or more %.



A black blizzard in the dirty thirties

DUNE REACTIVATION

- Holocene history of instability
- The lesson of the Dust Bowl
- Stores of available surfaces as result of past climates
- Critical nature of rainfall/vegetation threshold for wind action

- .

Modelling by David Thomas suggests that from South Africa to Angola the whole Kalahari sandveld could be re-activated

HURRICANES

- Sea water temperature threshold of 27^{o}C
- Increase in geographical spread?
- Increase in intensity?
- Increase in frequency?
- Warm water is not the only control of hurricane formation

HURRICANE EFFECTS

- Slope destabilisation
- Scouring of river channels
- Inputs of sediment into reefs and lagoons
- Raised sea level – storm surges
- Increased wave attack on atolls, etc.

HURRICANES AND WARMING

- Knutson & Tuleya’s (2001) simulations suggest 5-12% increase in wind speeds for 2.2 degree C rise in SST
- Emanuel (2005) has found hurricanes have become increasingly destructive as SSTs have warmed over last 30 years

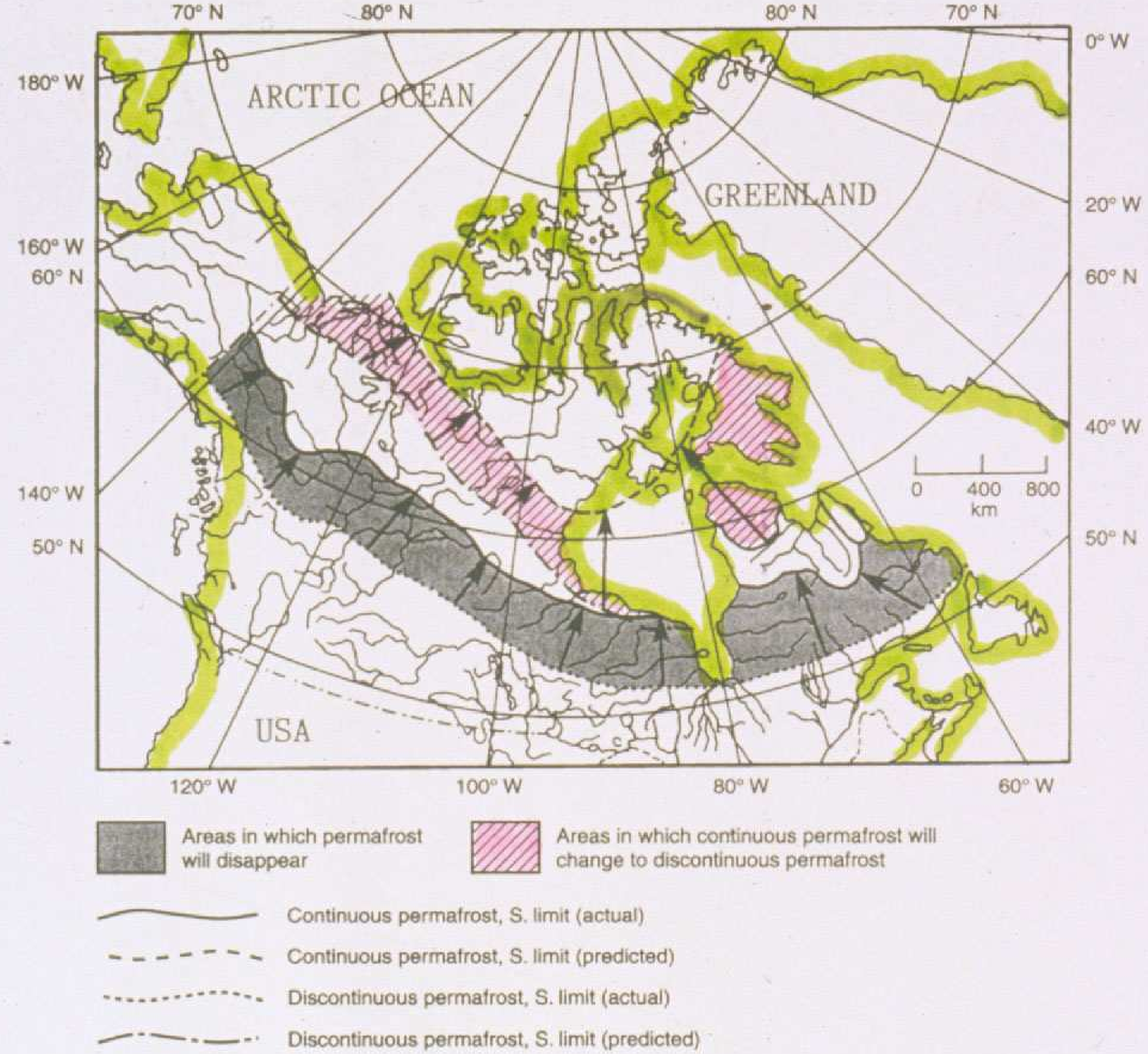
NEW ENGLAND 1938

THE RHINE – SHABALOVA ET AL

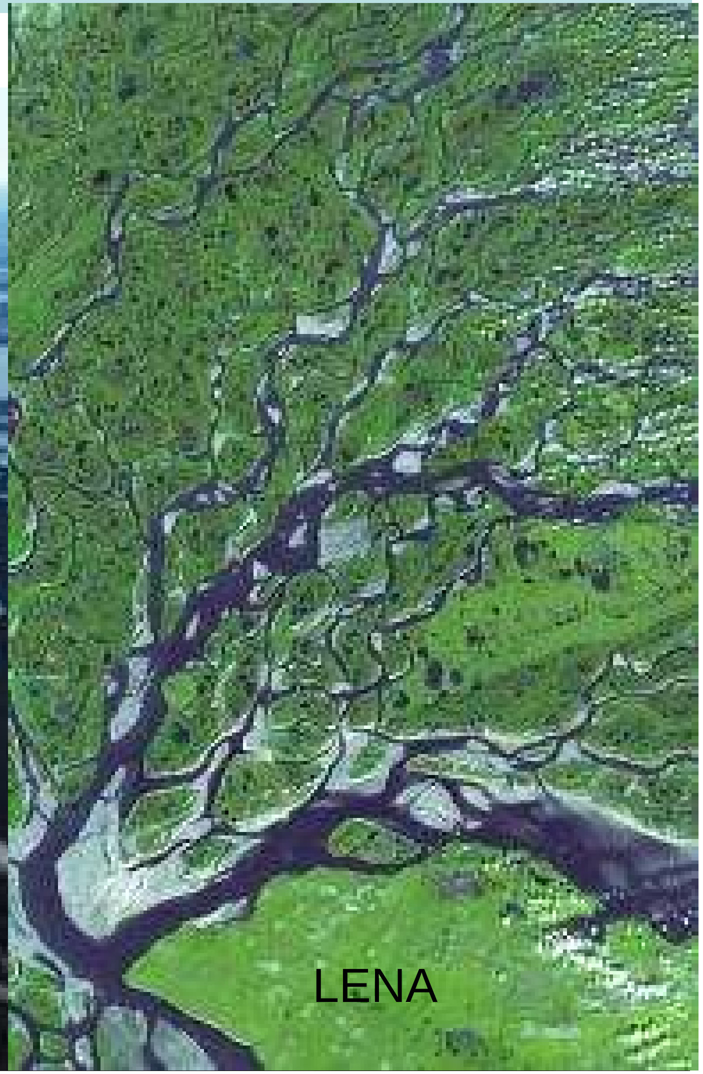
- The Rhine’s discharge will become markedly more seasonal with mean discharge decreases of about 30% in summer, and increases by about 30 percent in winter by the end of the century
- The summer decrease is due to decrease in precipitation + increase in evapotranspiration
- The winter increase is caused by increased precipitation, reduced snow storage and increased early melt

PERIGLACIAL AREAS

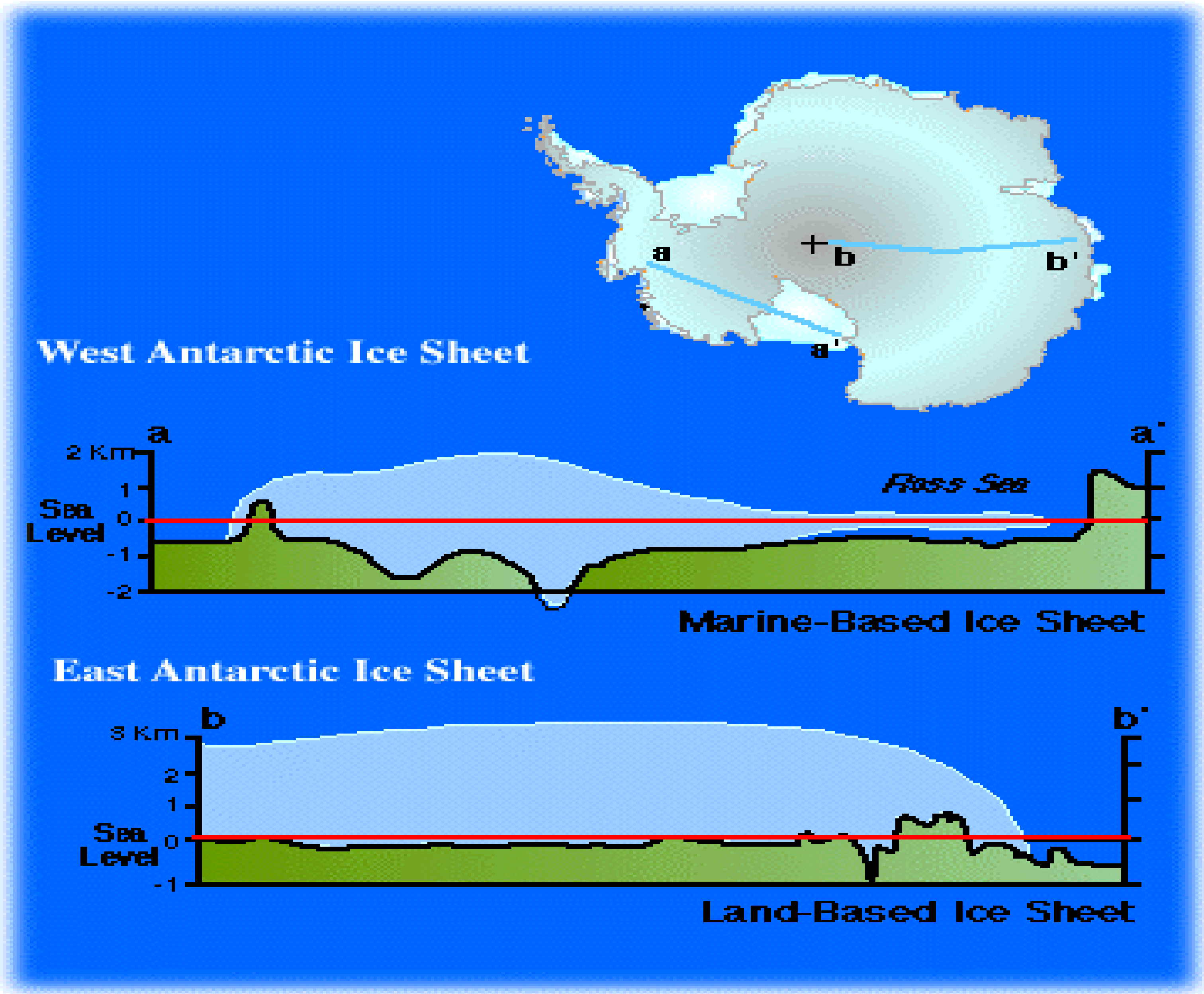
- Retreat of permafrost
- Thermokarst
- Removal of glue from slopes
- Erosion of shores and banks
- Deeper active layer – debris flows, etc.
- Change in runoff seasonality
- Changes in groundwater recharge


70° N
80° N
80° N
70° N
0° W
180° W
ARCTIC OCEAN
GREENLAND
20° W
160° W
60° N
60° N
40° W
0 400 800
km
140° W
50° N
50° N
USA
120° W
100° W
80° W
60° W
Areas in which permafrost will disappear
Areas in which continuous permafrost will change to discontinuous permafrost
Continuous permafrost, S. limit (actual)
Continuous permafrost, S. limit (predicted)
Discontinuous permafrost, S. limit (actual)
Discontinuous permafrost, S. limit (predicted)

THERMOKARST



Shishmaref, Alaska



West Antarctic Ice Sheet
a
b
b'
a'
2 Km
1
0
-1
-2
Sea Level
Ross Sea
Marine-Based Ice Sheet
East Antarctic Ice Sheet
3 Km
2
1
0
-1
Sea Level
Land-Based Ice Sheet

THE BIG ISSUE

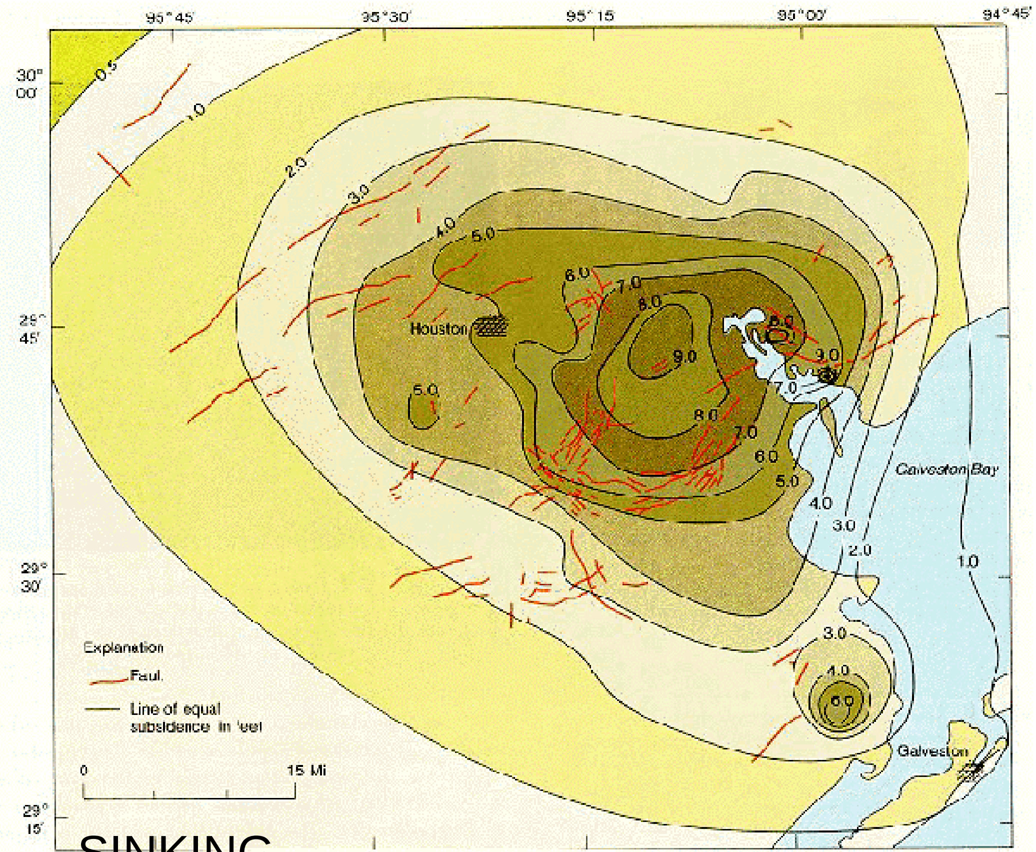
- Ice sheets will be subjected to increased ablation (melting), the buoyancy effects of rising sea levels, the effects of ice shelf disappearance on wave attack, and the wasting effects of warmer oceans
- On the other hand, higher temperatures will lead to more snowfall and thus to higher rates of accumulation


Nesje et al 2008 suggest that by 2100, 98% of Norwegian Glaciers are likely to disappear and that glacier area may be reduced by c 34%

SEA LEVEL RISE

- During the 20th century the rate of rise averaged c 1.5-2.0 mm per year
- During the 21st century the rate of rise is likely to be c 5 mm per year

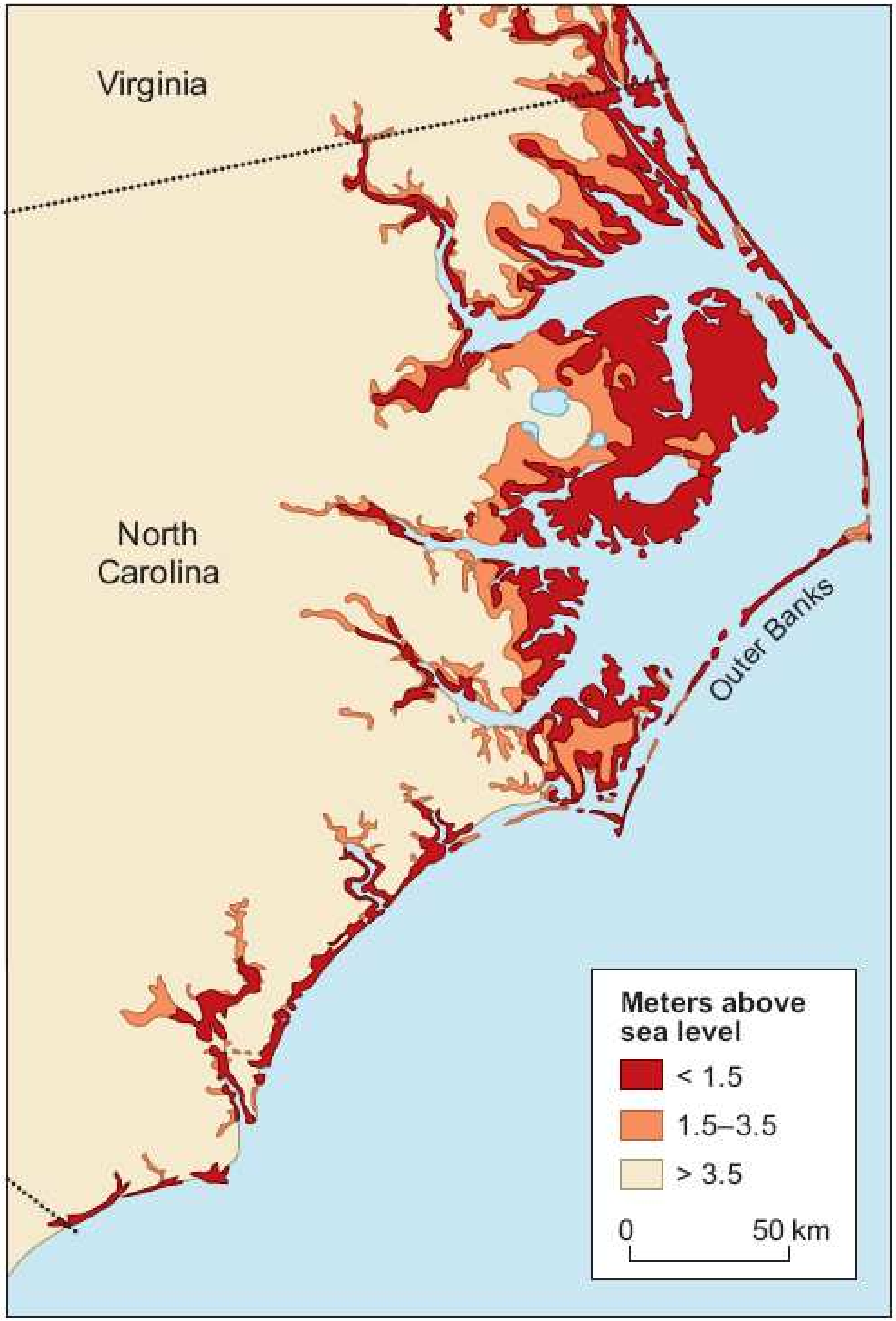
Houston/Galveston



SINKING

Deltas, atolls
Tectonic sinking
Isostatic compensation
Groundwater and hydrocarbon removal
Compaction of organic sediments

Central valley, California

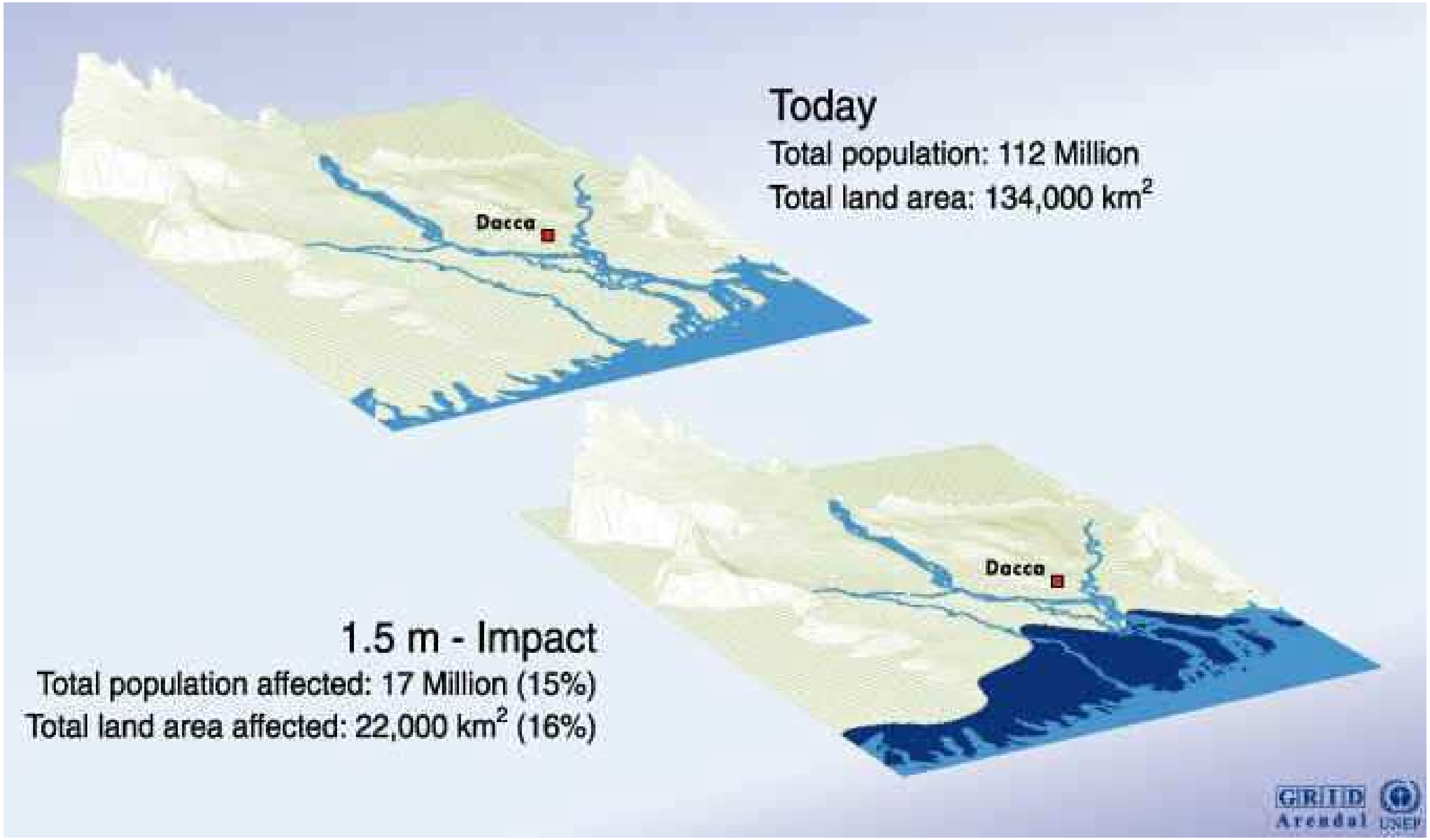


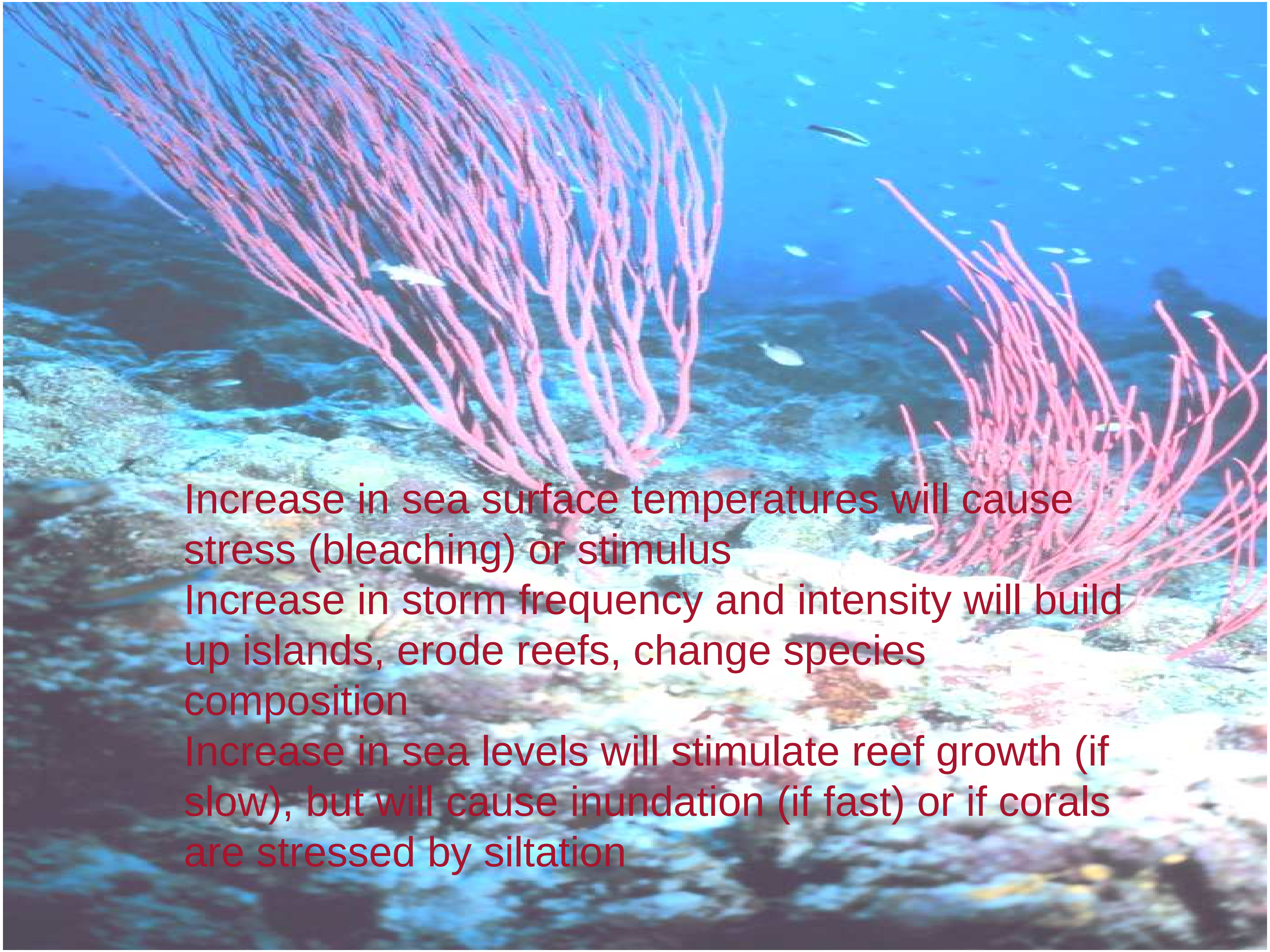
SENSITIVE COASTS

Beaches
Salt marshes
Mangrove swamps
Deltas
Coral reefs
Lagoons

MISSISSIPPI BIRDSFOOT

BANGLADESH AND THE GANGES/BRAMAPUTRA DELTA




Increase in sea surface temperatures will cause stress (bleaching) or stimulus
Increase in storm frequency and intensity will build up islands, erode reefs, change species composition
Increase in sea levels will stimulate reef growth (if slow), but will cause inundation (if fast) or if corals are stressed by siltation

SALT MARSH VULNERABILITY

- Less sensitive – areas of high sediment input, areas of high tidal range (with high sediment transport potential), areas with effective organic accumulation
- More sensitive – areas of subsidence, areas of low sediment input, slow growing mangroves, micro-tidal areas, reef settings (lack of allogenic sediment), constrained by sea walls

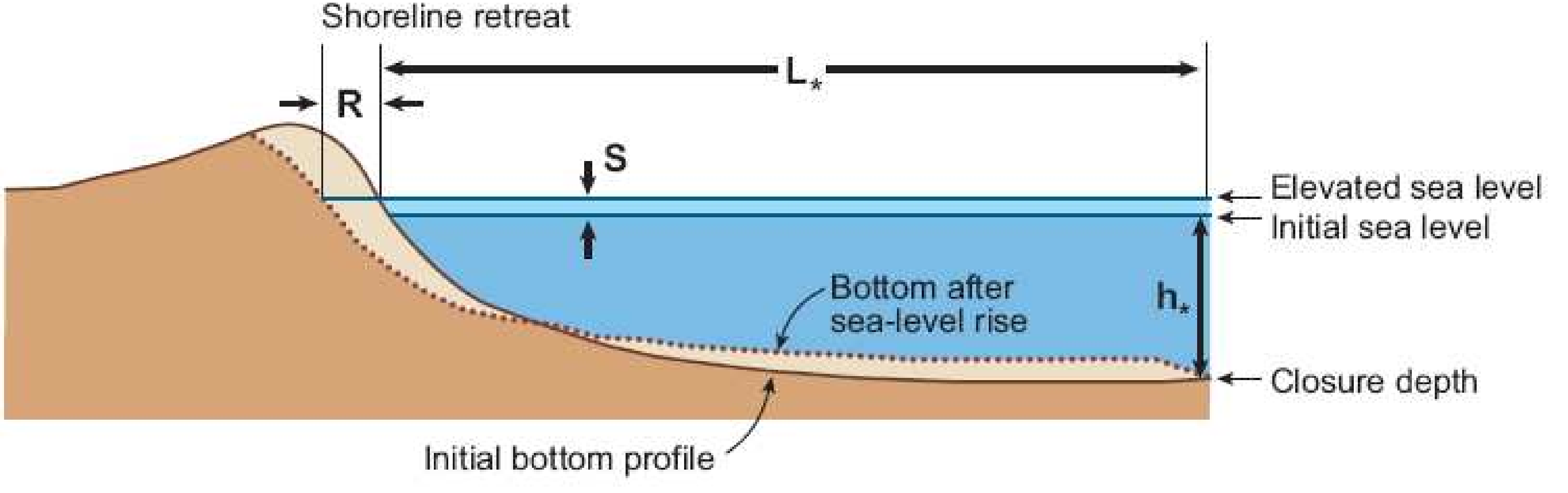


Figure 5

The Bruun rule of shoreline retreat (after Cooper & Pilkey 2004).

About 100 m of erosion for each 1 m rise in sea level for sandy beaches