Promoting climate resilient development within SDC programs in East and Southern Africa
8-12 September 2014, Nairobi, Kenya

Climate Change and disaster risk reduction: the scientific context

Nick Brooks
nb@garama.co.uk

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Garama 3C Ltd

Presentation outline

- Climate change & variability – definitions, drivers, CO_2 trends
- Observed & projected changes in climate – IPCC findings
- Climate change & disaster risk

Climate change & variability: definitions, drivers & CO_2 trends

Climate change vs variability

Climate is what you expect, weather is what you get[1]

- **Climate** - meteorological conditions averaged over long period (typically 30 years)
- **Weather** - short-term variations in meteorological conditions (hrs, days, weeks...)

- **Climate variability** - "variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events."
- **Climate change**
  - IPCC – "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer" - whether due to natural variability or as a result of human activity.
  - UNFCCC - "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global *atmosphere* and which is in addition to natural climate variability observed over comparable time periods".

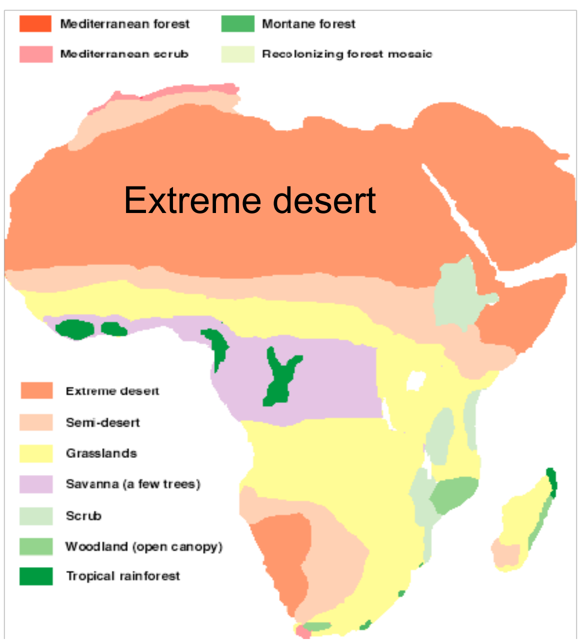
Definitions in quotes from Glossary of IPCC AR5 (2014)

[1] For origins see http://quoteinvestigator.com/2012/06/24/climate-vs-weather/

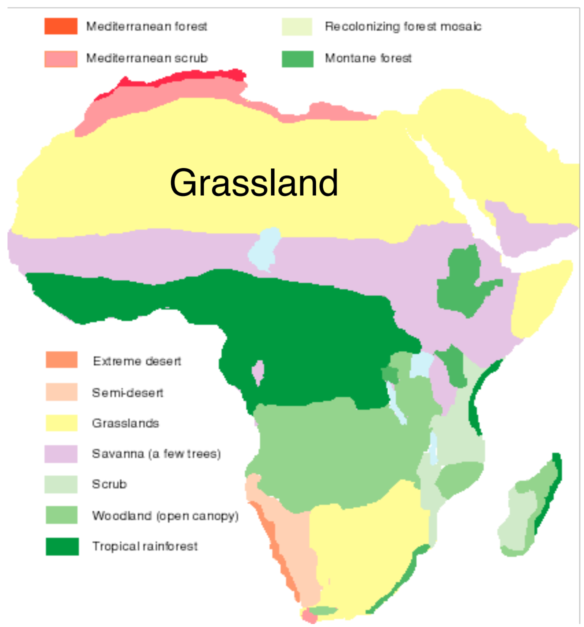
Natural drivers of climate change & variability

- Millions of yrs: plate tectonics, mountain building, etc
- Many millennia: orbital cycles (eccentricity, axial tilt, precession)[1]
- Centuries-millennia: above combined with internal variations, land surface changes
- Years to decades - solar variations, internal variability, ocean cycles[2]

21,000 years ago



9,000 years ago

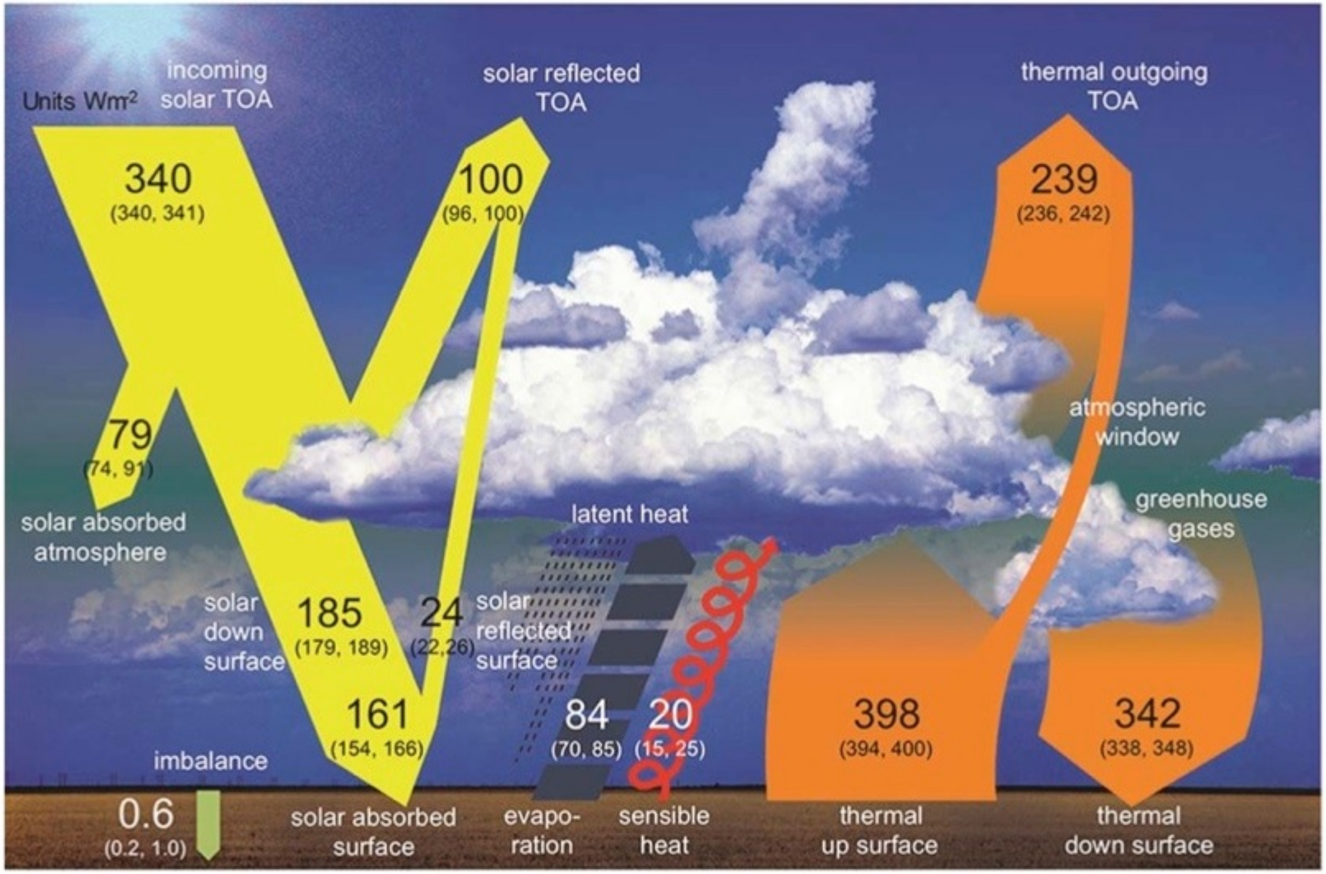


Present day

Potential vegetation zoning in Africa based on past and current climatic conditions, developed by Jonathan Adams (Oak Ridge Nat. Lab., USA) http://www.esd.ornl.gov/projects/qen/nercAFRICA.html

Human Drivers of climate change & variability

- Release of greenhouse gases (GHG) that accumulate in atmosphere, trapping heat
- Changes in land surface: affect albedo, hydrology, roughness (also release GHG)



Global mean energy budgets, from IPCC AR5 WG1 final draft, Ch2, Fig.2.11, p.127

Sources of greenhouse gas emissions

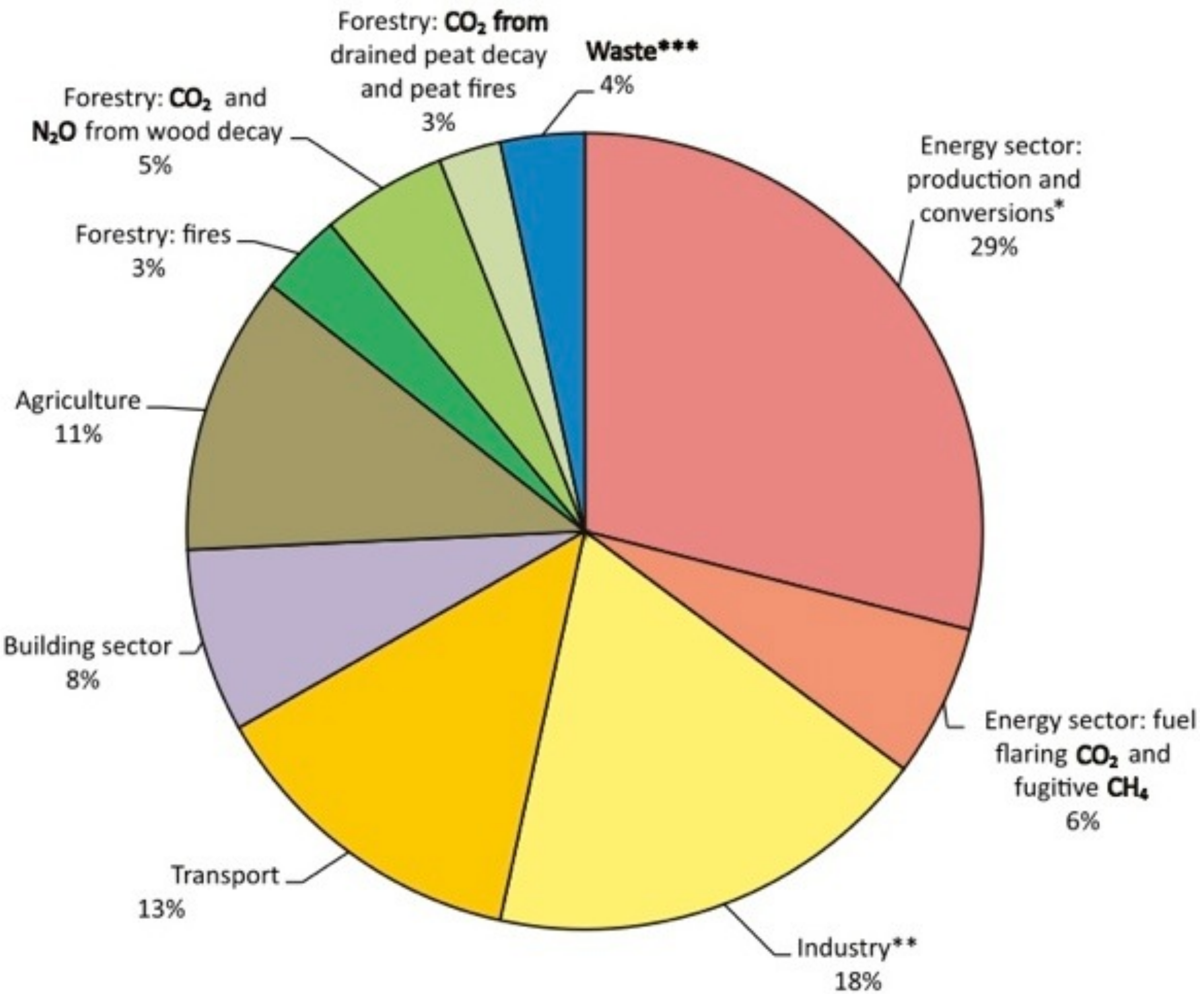
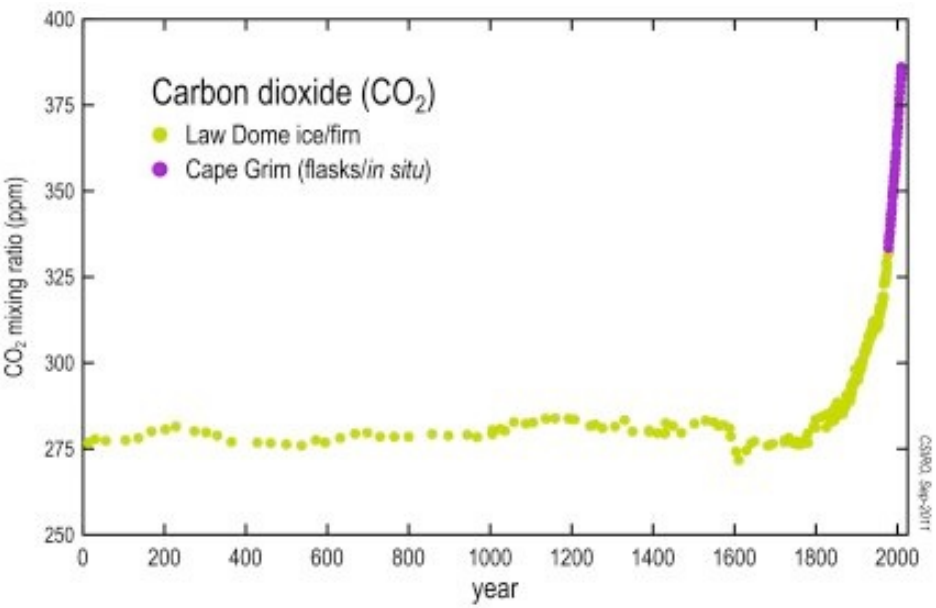


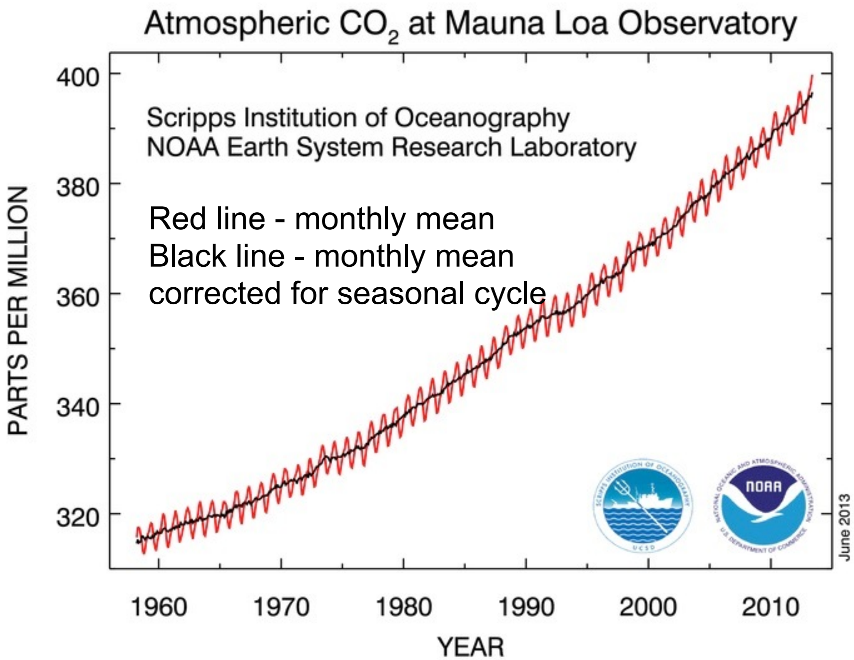
Figure 2.2a. Shares of sources of global greenhouse gas emissions in 2010 by main sector (in CO_2e using GWP values as used for UNFCCC/Kyoto Protocol reporting). *Source: JRC/PBL (2012) (EDGAR 4.2 FT2010)*

The Emissions Gap Report 2012, p.11. UNEP.
http://www.unep.org/publications/ebooks/emissionsgap2012/

Historical CO_2 concentrations

- CO_2 most important due to relative abundance
  - pre-industrial concentration: ~270-280 ppm
  - present concentration (2014): ~400 ppm **[401.3 ppm for June 2014*]**
  - increasing at ~2-3 ppm per year (http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html)

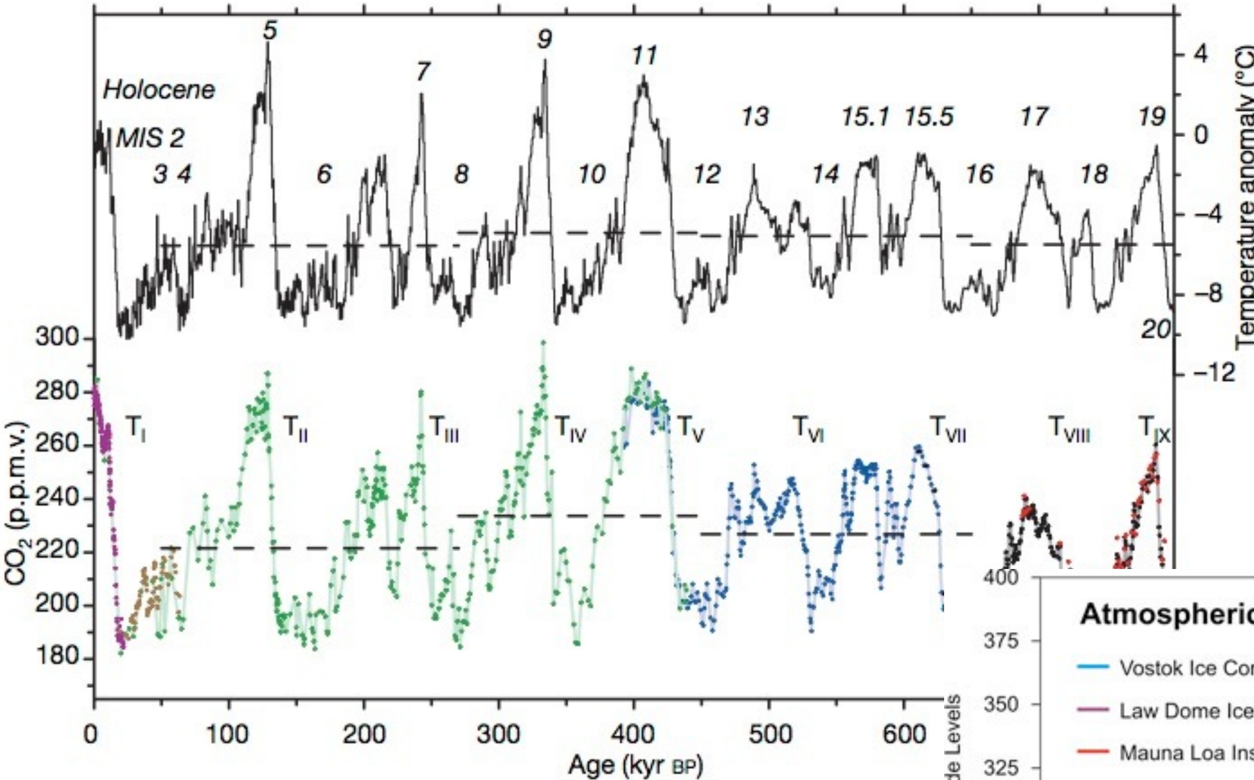


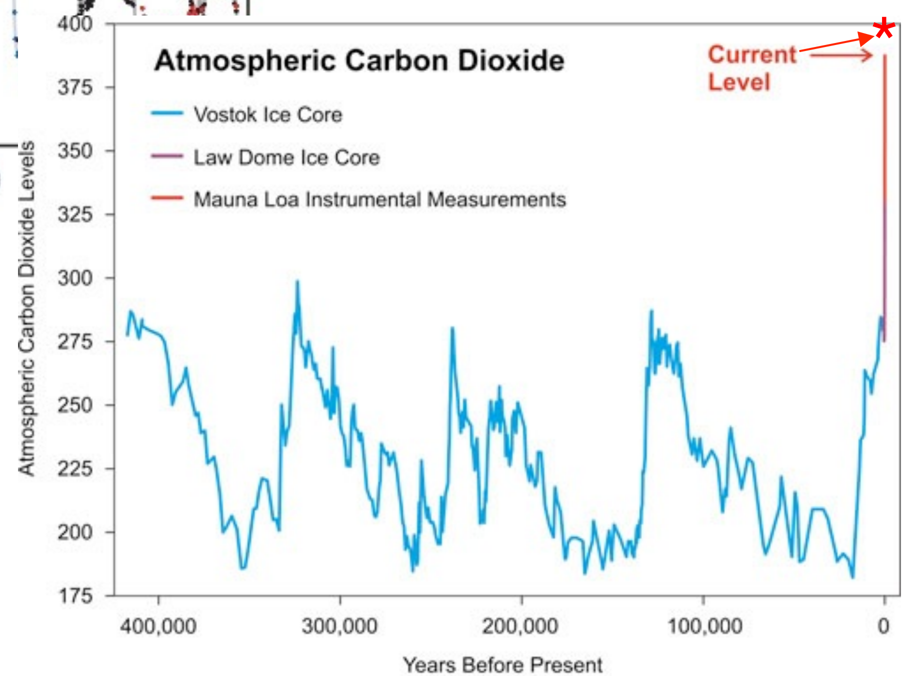


Left: CO_2 over past 2000 yrs based on records from Law Dome, Antarctica and direct measurements at Cape Grimm. (http://www.csiro.au/greenhouse-gases/). Right: Mauna Loa CO_2 measurements. Graphic via Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/)

*http://co2now.org/

CO_2 & temperature over glacial cycles





Above: Temperature (top) and CO_2 over the past 800,000 yrs. From Lüthi et al. 2008. Nature 453: 379-382.

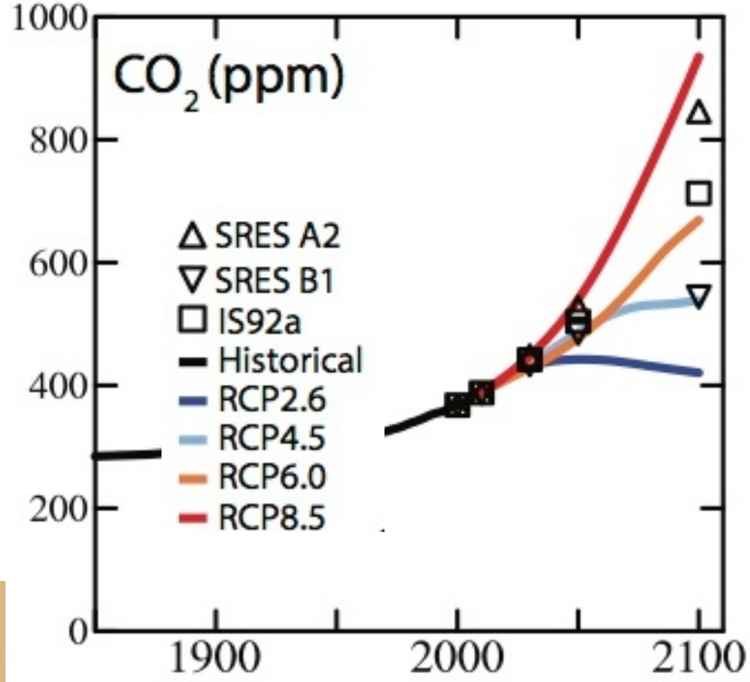
Right: 400,000 yr record with recent measurements

The 2° C target & concentration thresholds

Widespread agreement from COP16 (2010, Cancun) onwards to limit warming below 2° C above pre-industrial conditions (some advocate 1.5° C)

Following greenhouse gas concentrations (CO_2e[1]) give us ~50:50 chance of staying below specified warming

- ❑ 350 ppm → 1.5° C — Already exceeded
- ❑ 450 ppm → 2.0° C — Nearly there (2030s?)
- ❑ 550 ppm → 3.0° C — On track with current emissions. May not be stable – further warming
- ❑ 650 ppm → 4.0° C



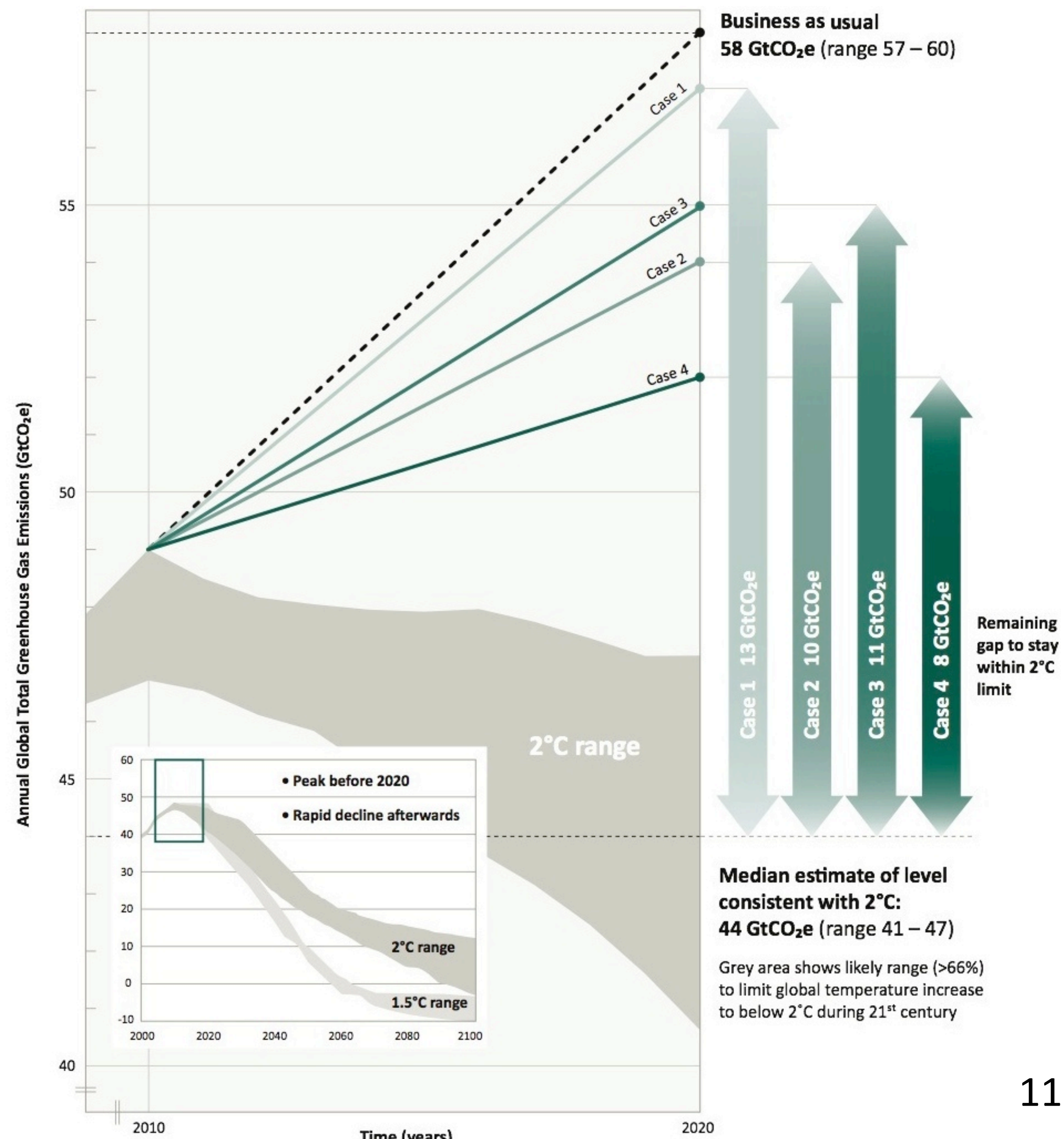
Historical & projected CO_2 (not CO_2e) concentrations for IPCC Representative Concentration Pathways, compared with old IPCC SRES scenarios. Higher emissions curves most closely reflect current trends. From IPCC AR5 Ch.8, p.674.

Sources and further information:
http://www.realclimate.org/index.php/archives/2011/01/getting-things-right/
http://www.skepticalscience.com/Carbon-dioxide-equivalents.html
http://www.iied.org/cop18-outcomes-doha-climate-talks
Viewig et al. 2013. Climate Action Tracker Update, 12 June 2013
[1]Expressed as CO_2 equivalent (CO_2e - CO_2 concentration that would give same warming as all GHGs combined). Current CO_2e is similar to CO_2 concentration if cooling effects of aerosols considered, otherwise ~490 ppm CO_2e (2011).

The 2° C target & the emissions gap

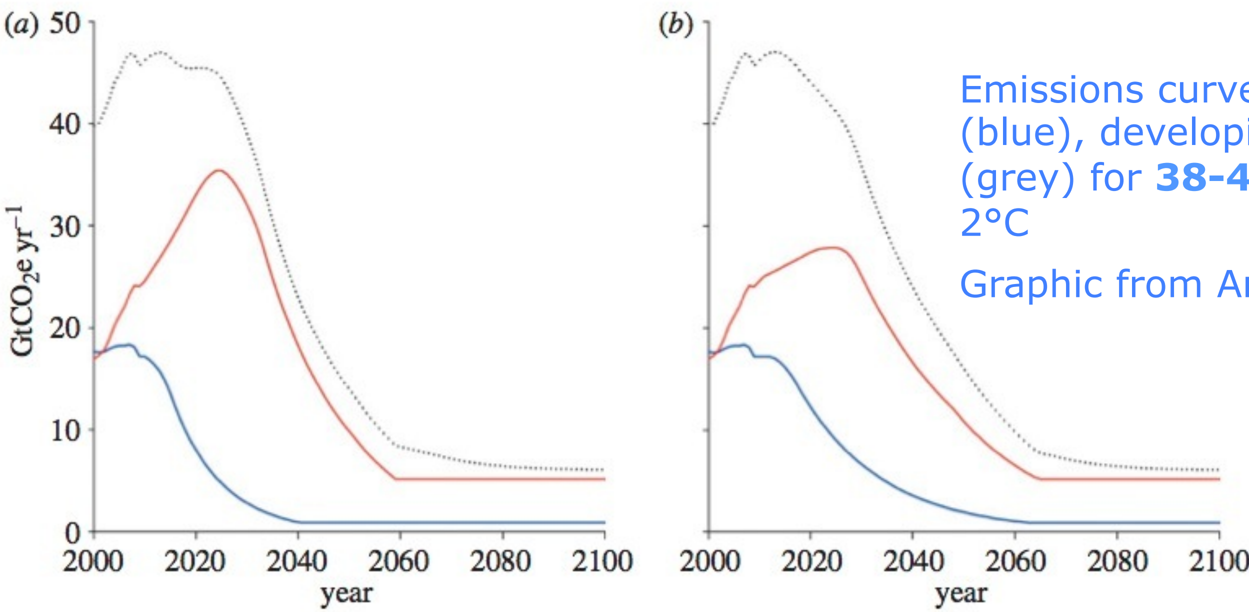
"Current global emissions are already considerably higher than the emissions level consistent with the 2°C target in 2020 and are still growing."

UNEP Emissions Gap Report, 2012



Necessary emissions reductions for 2° C

- Warming depends on cumulative emissions, not emissions in 2020 or 2050



Emissions curves for industrialised countries (blue), developing countries (red) & world (grey) for **38-48% chance** of not exceeding 2°C

Graphic from Anderson & Bows (2011: 33)

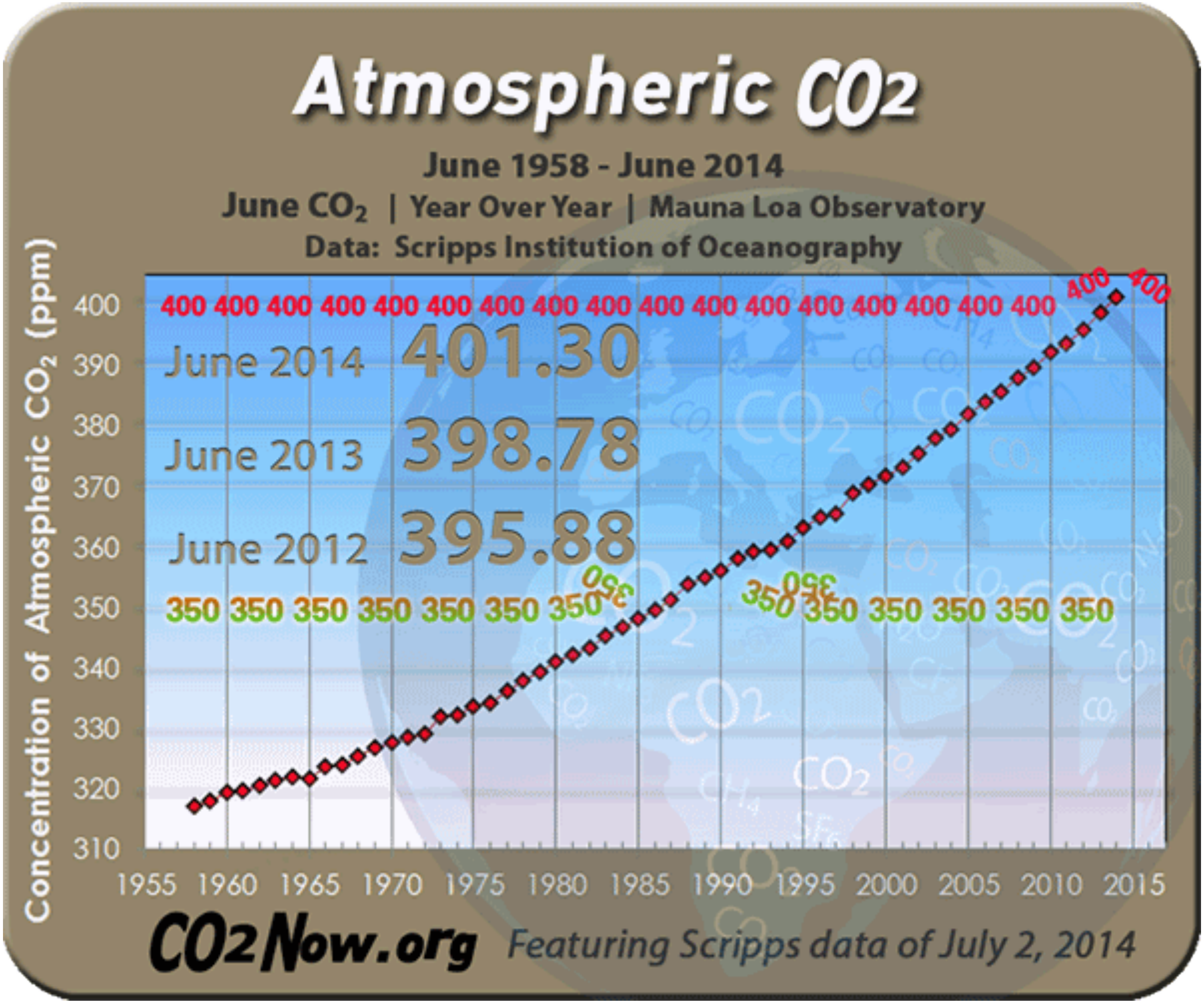
In above scenarios:

(a) DCs' emissions rise at 3% per yr, peak in 2025, then decline at 6% per yr; ICs emissions reduce at 10% per yr from 2010

(b) DCs' emissions rise at 1% per yr, peak in 2025, then decline at 4-5% per yr; ICs emissions reduce at 6% per yr from 2014

High (generous) end of IPCC cumulative emissions range for stabilising at 450 ppm CO_2e

Slower reduction by DCs means no space for ICs' emissions

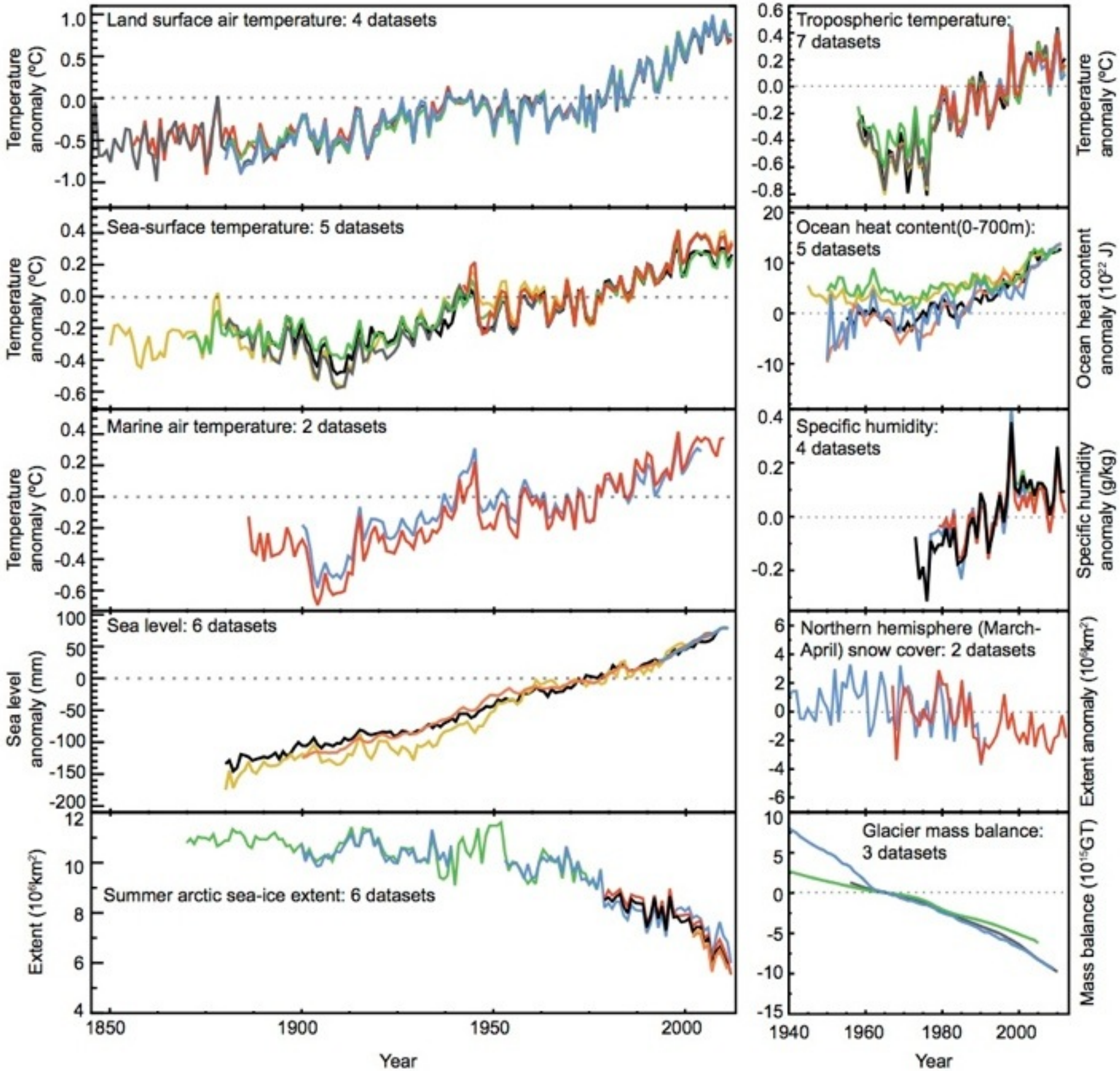


Atmospheric CO2
June 1958 - June 2014
June CO2 | Year Over Year | Mauna Loa Observatory
Data: Scripps Institution of Oceanography
Concentration of Atmospheric CO2 (ppm)
400 390 380 370 360 350 340 330 320 310
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
June 2014 401.30
June 2013 398.78
June 2012 395.88
CO2Now.org
Featuring Scripps data of July 2, 2014

Observed & projected changes in climate

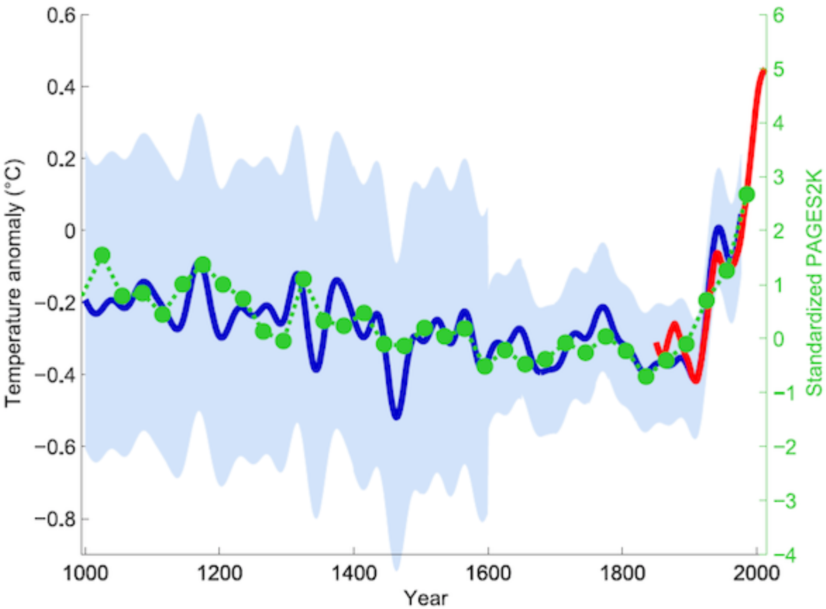
Including new results from the IPCC Fifth Assessment Report (AR5), available at http://ipcc.ch

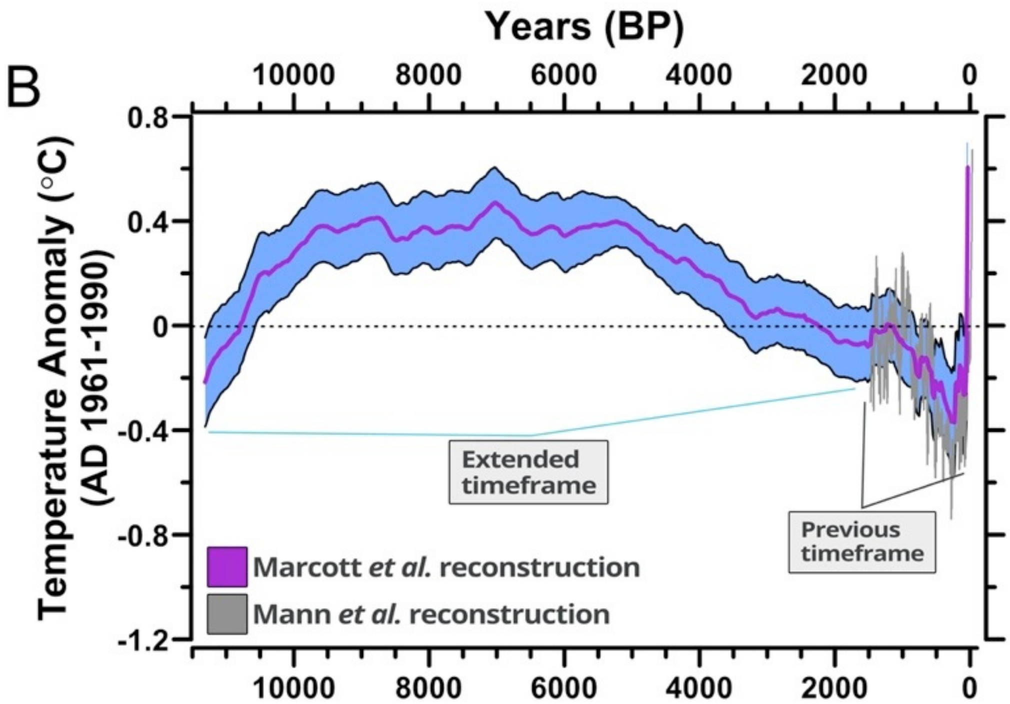
Multiple indicators of historical warming



IPCC AR5 WG1 Final Draft, Ch.2, FAQ 2.1 Figure 2, p.145

Recent warming in historical context



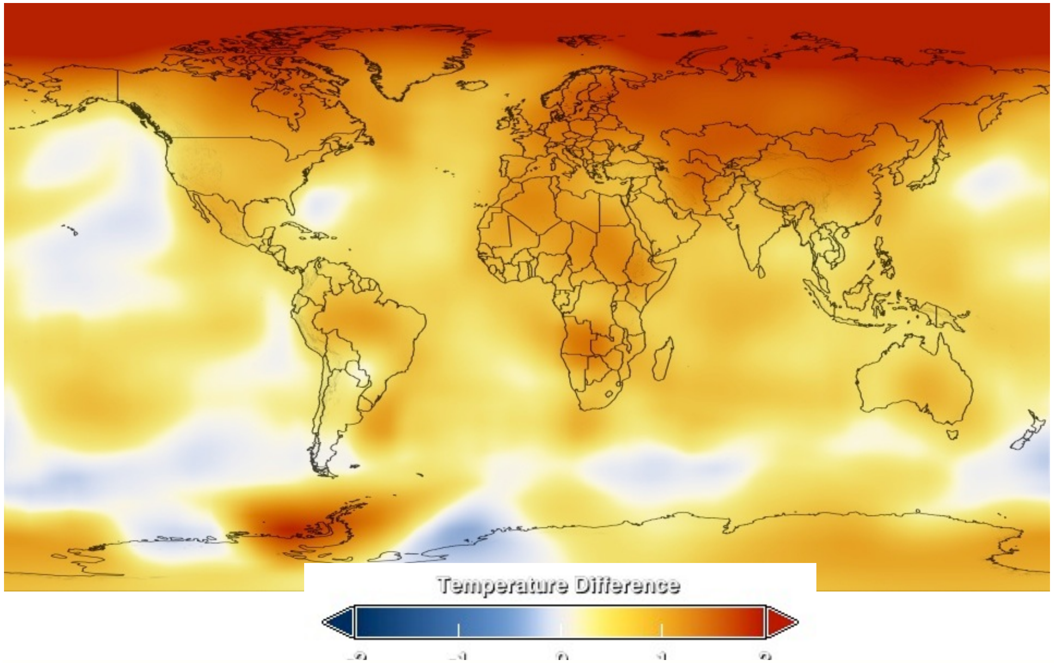


Left: 30-year average from new PAGES 2k reconstruction (green dots) and original hockey stick of Mann, Bradley and Hughes (1999) with uncertainty range (light blue). Red curve shows HadCRUT4 global mean temperature data from 1850 onwards. Graph by Klaus Bitterman, produced using data from PAGES 2k project[1].

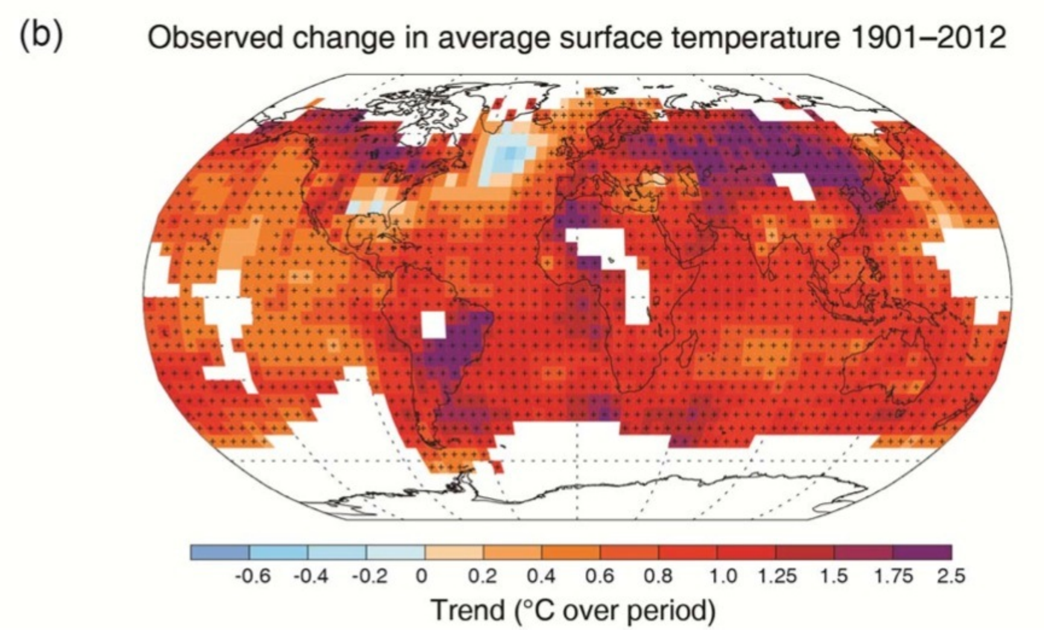
Right: Temperature reconstruction for the past 11,500 years. Graphic from Marcott et al. 2012, Science 339:1198-1201

[1]http://climatestate.com/2013/07/08/most-comprehensive-paleoclimate-reconstruction-confirms-hockey-stick/

Patterns of observed warming

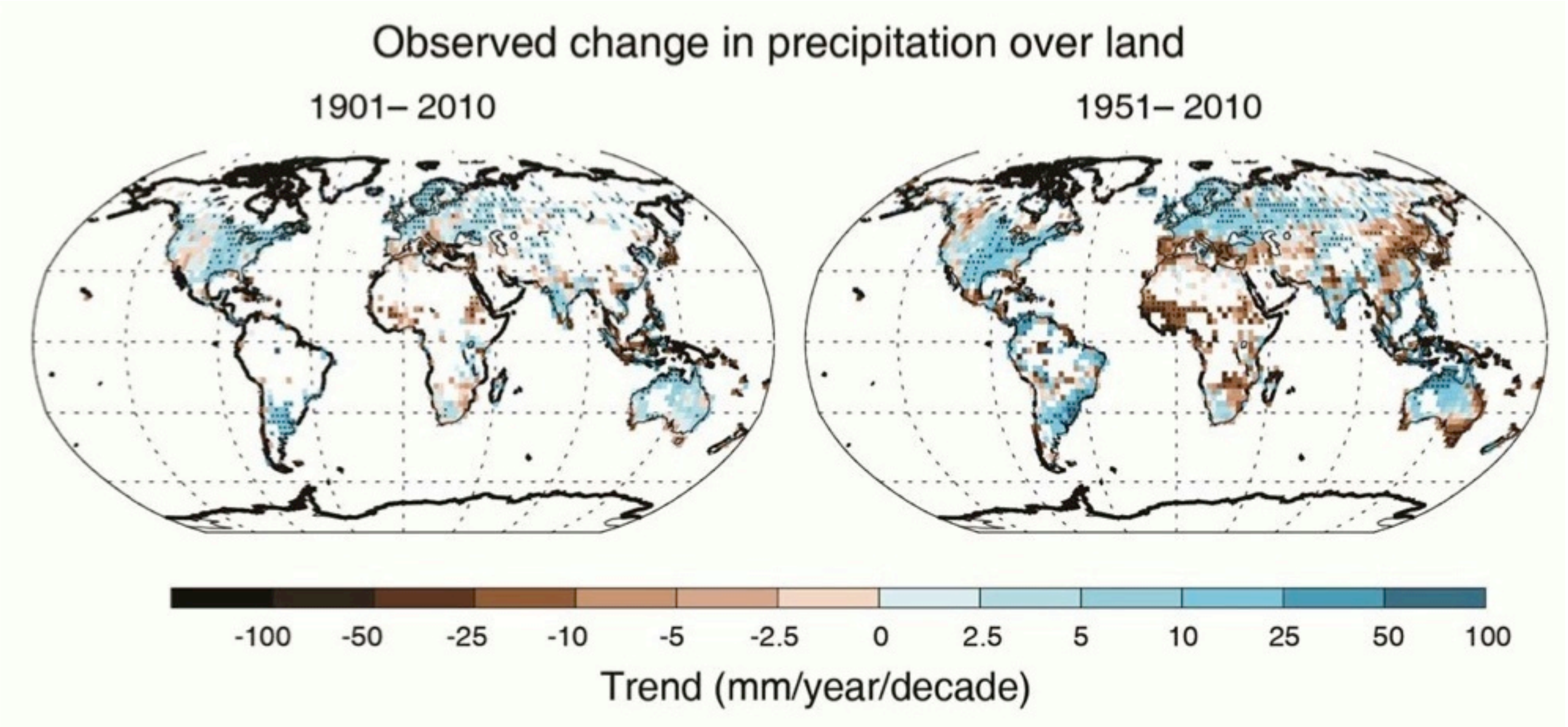


Difference in annual mean surface temperatures between two periods: 2005-09 average minus 1951-80 average.
Source: NASA: http://svs.gsfc.nasa.gov/vis/a000000/a003600/a003674/index.html



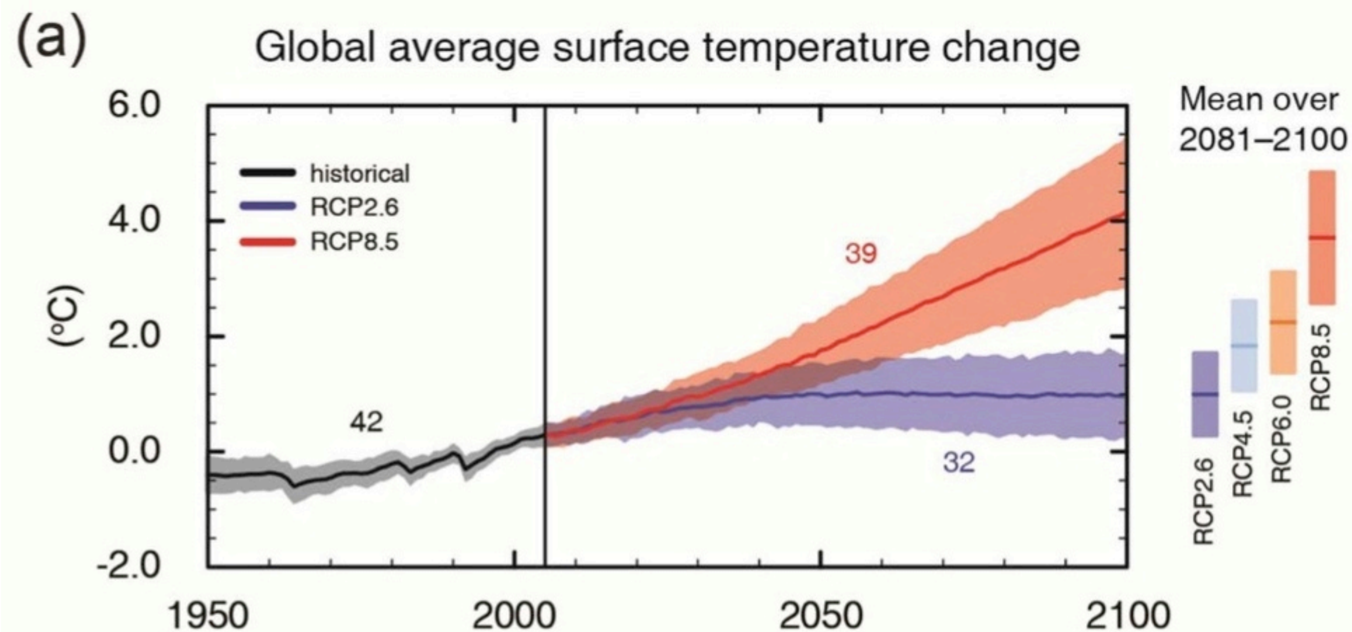
Trend in annual mean surface temperature from 1901 to 2012.
Source: IPCC AR5 WG1 Summary for Policymakers.

Observed precipitation changes



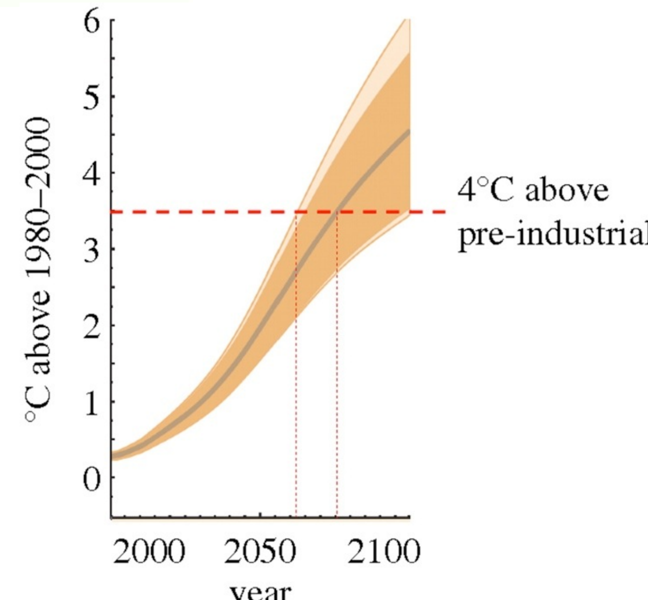
Trend in annual mean surface temperature from 1901 to 2012.
Source: IPCC AR5 WG1 Summary for Policymakers.

IPCC temperature projections



Above: Projected warming for lowest and highest emissions Representative Concentration Pathways from IPCC AR5 SPM (2013).

Right: High-emissions A1F1 projection from IPCC AR4 (2007), indicating possible 4° C warming by 2060s (earliest, worst case). From Betts et al. 2011.



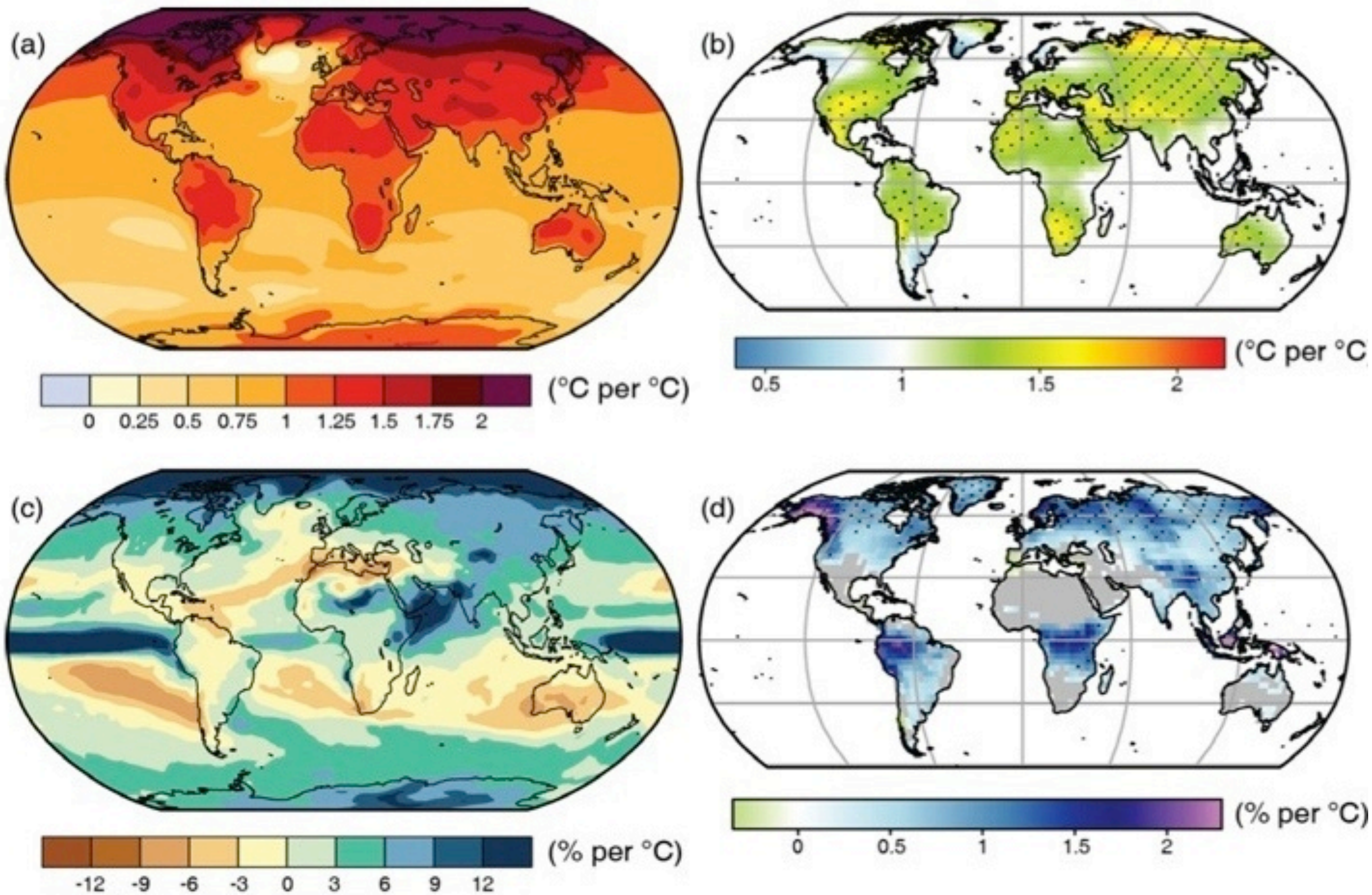
Projected rates of temperature & precipitation change

Regional warming per 1˚C global warming

Increase in Tmax per 1˚C global warming

Increase in precip. per 1˚C global warming

Increase in extreme precip. frequency per 1˚C global warming



Changes between recent 20 year periods and 2081-2100 in (a) mean surface temperature per 1˚C of global mean change, (b) 90th percentile of daily maximum temperature per 1˚C increase in global average maximum, (c) mean precipitation (% per 1˚C of global mean temperature change, (d) fraction of days with precipitation exceeding 95th percentile per 1˚C of global mean temperature change. Source: IPCC AR5 WG1 Ch.12.

Climate change & disaster risk

Including new results from the IPCC Fifth Assessment Report (AR5) Final Draft Version, available at http://ipcc.ch

Climate change and disaster risk

RISKS result from the interaction of HAZARDS with VULNERABILITIES[1]

Risk: of a particular (undesirable) outcome/impact (e.g. disaster)

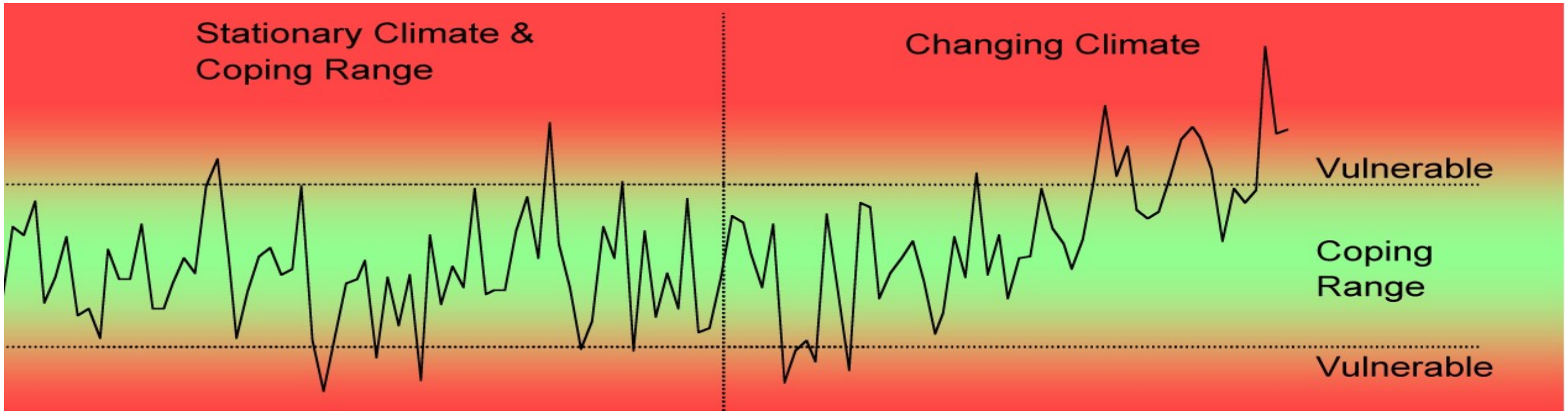
Hazard: a physical manifestation of climate change (i.e. climate stress)

Vulnerability: tendency of exposed system/population to be harmed

Climate change can exacerbate hazard component of risk by

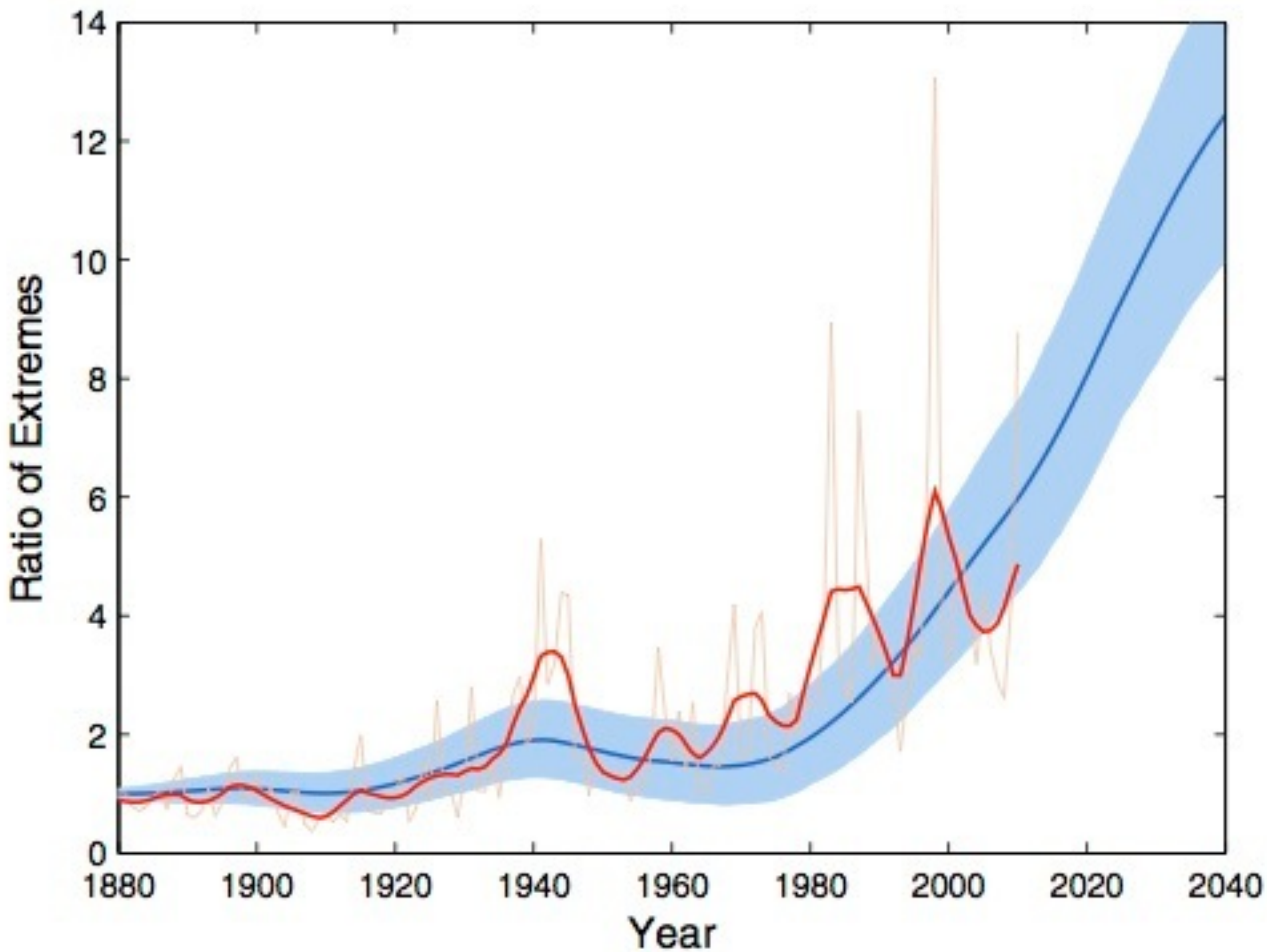
i. Making hazards more frequent or severe, meaning critical thresholds, beyond which systems/ populations cannot cope/are vulnerable, are crossed more often (heat, runoff, etc., see Figure)

ii. Triggering new hazards and irreversible long-term changes (e.g. droughts & storms in areas previously unaffected, sea-level rise, long-term drying, etc.)



[1]See Brooks 2003 for a more detailed discussion

Global projections of heat extreme frequency



Ratio of observed number of monthly heat records to number of records expected with no climate warming. Global averages. From Coumou et al. 2013. Climatic Change 118:771–782.

Climate change already affecting extremes

"The occurrence patterns of climate extremes and high-impact events and anomalies can be influenced by human-induced climate change and it is likely that the number and intensity of at least some of these types of events are consequently increasing." **WMO 2013: 26 (WMO-No. 1103)**

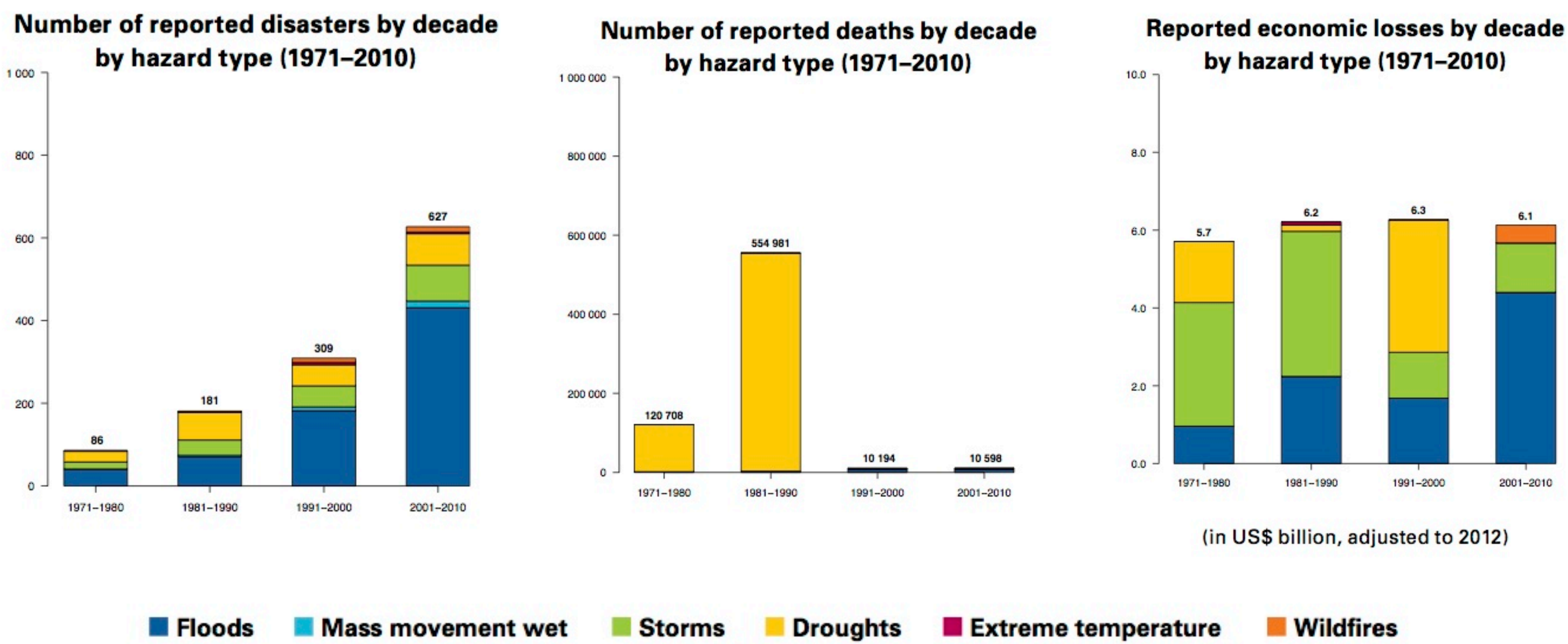
"For some types of extreme — notably heatwaves, but also precipitation extremes — there is now strong evidence linking specific events or an increase in their numbers to the human influence on climate."
Coumou & Rahmstorf 2012: 491 (Nature Climate Change 2)

Can attribute the following to climate change, at least in part:

- 2003 heatwave in Europe (Stott et al. 2004); 2010 Russian heat wave & Pakistan floods (Trenberth & Fasulo 2012); drought in SW US; record heat in numerous locations, unprecedented precipitation & flooding in some areas;
- Decline in March-May rains in E. Africa & December-February rains in S. Africa (Funk et al. 2008; Park Williams & Funk 2011)

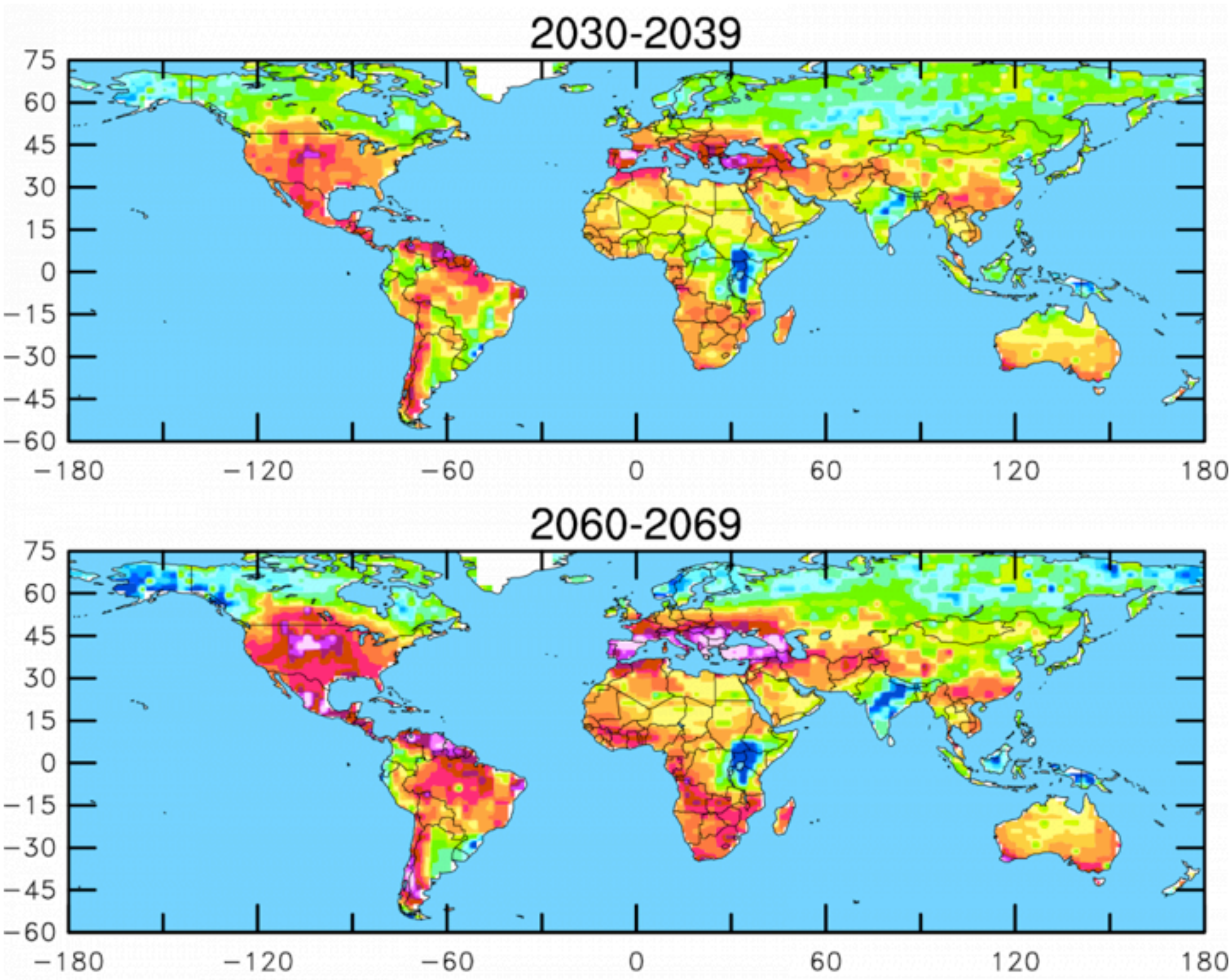
Disaster trends in Africa

- More frequent extremes, or better reporting?
- More severe/damaging floods, or increased exposure?



Reported disasters: frequency, deaths and economic losses (from WMO 2014)

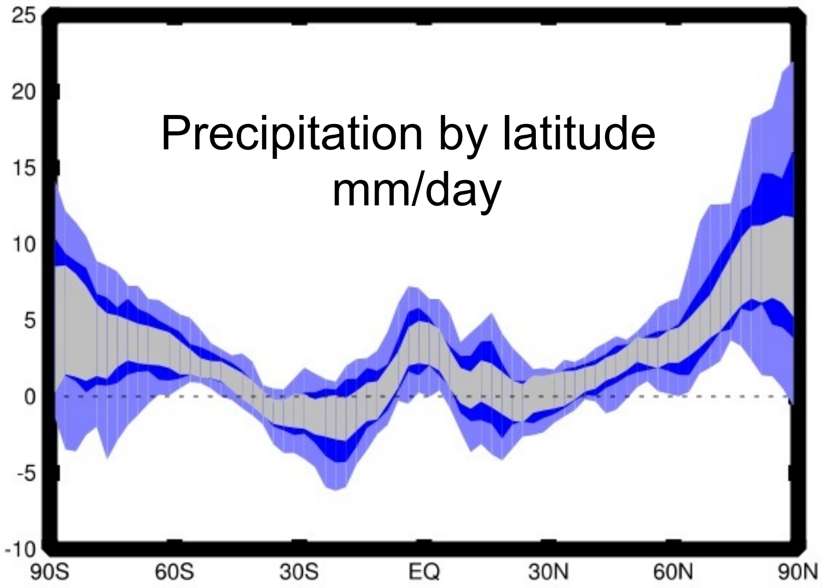
Projected drought changes

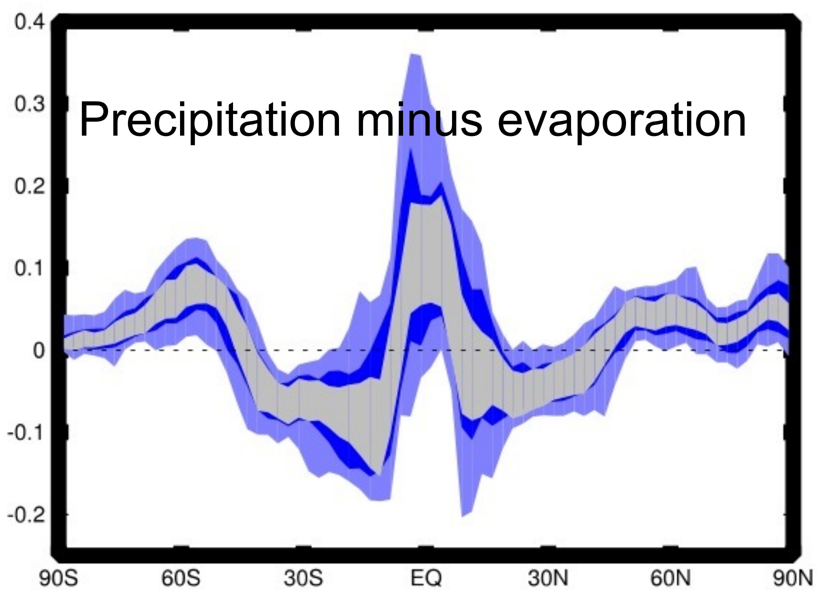


Projected drought based on calculation of Palmer Drought Severity Index under current emissions projections. UCAR.

http://www2.ucar.edu/atmosnews/news/2904/climate-change-drought-may-threaten-much-globe-within-decades

Near-term impacts on hydrological cycle





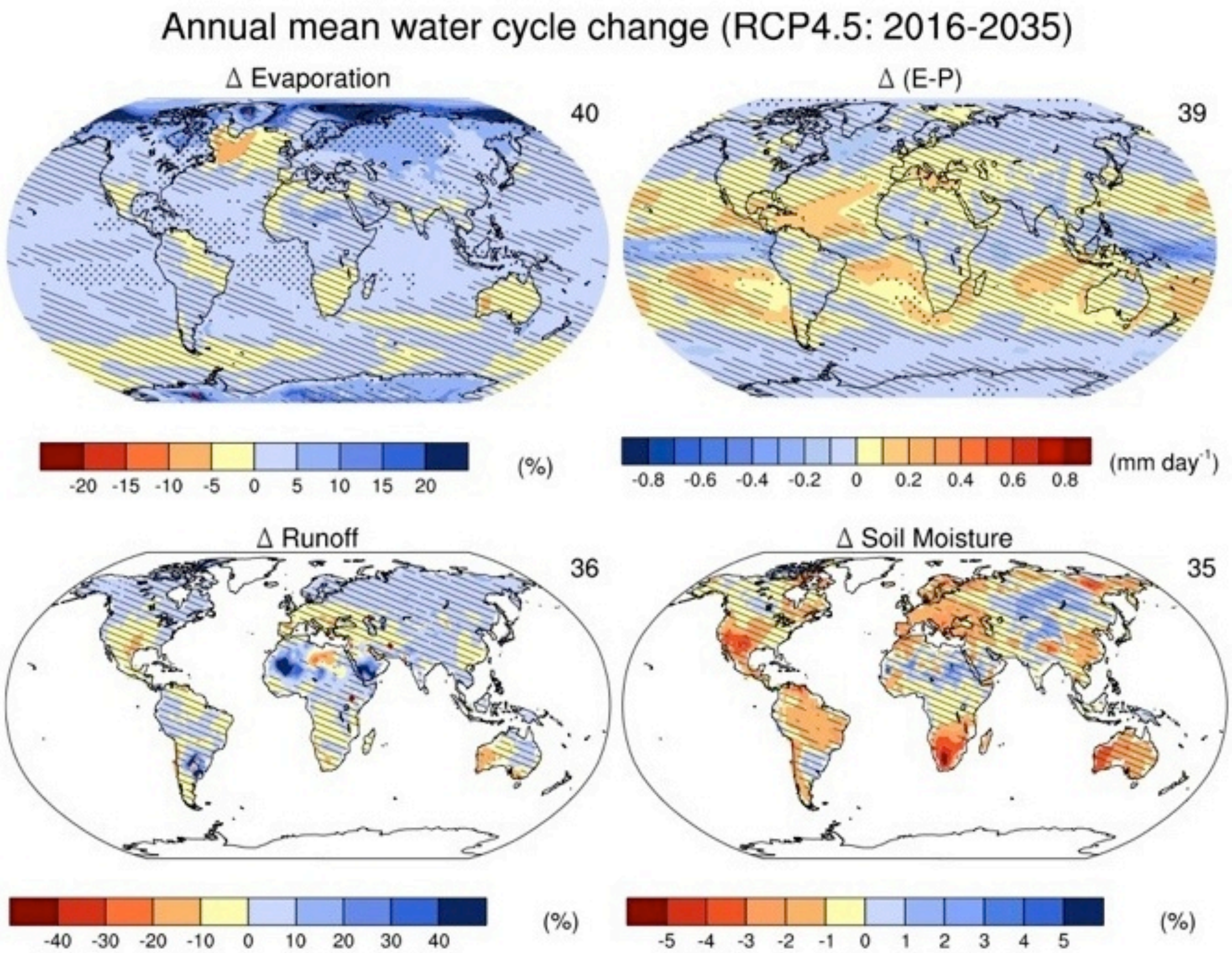
Projected changes in precipitation (top) and precipitation minus evaporation (bottom) between 1986-2005 and 2016-2035, in mm per day, averaged for bands of latitude.

Wetter conditions in equatorial regions and middle to high latitudes – greater flood risk

Drier conditions in higher-latitude tropical regions, subtropics, and lower latitude extra-tropical regions – greater drought risk

Source: IPCC AR5 WG1 Final Draft, Ch.11. Figure 11.13, p.123.

Near-term changes in the water cycle



Water cycle changes for period 2016-2035 relative to 1985-2005. IPCC AR5 WG1 FInal Draft, CH2. 11, p.107

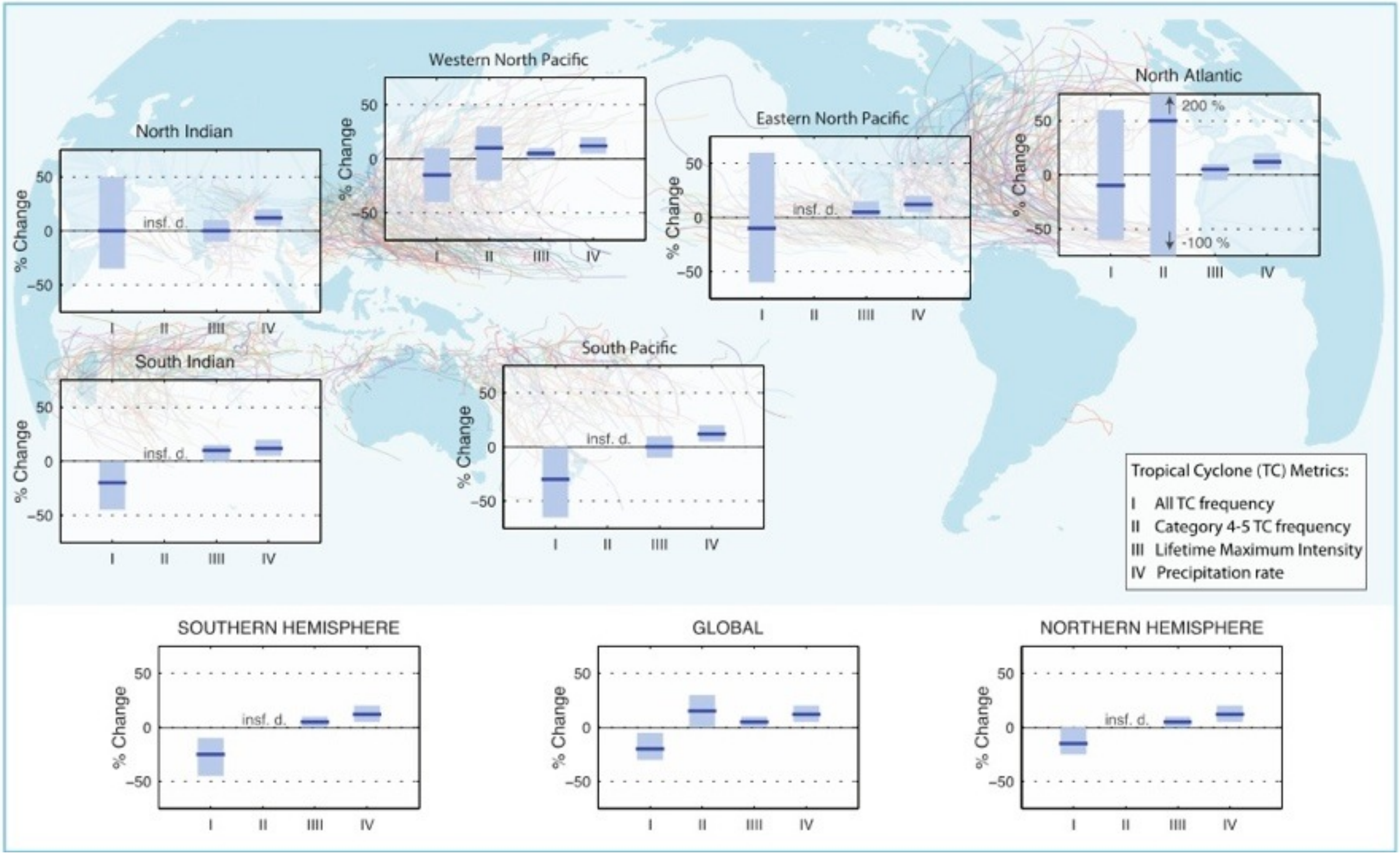
Climate change & flood risk

- Increases in rainfall intensity may increase risk of flash and river flooding – driven by stronger evaporation, greater atmospheric moisture & other changes
- Flood risk may increase alongside drought risk as rainfall occurs in smaller number of more intense precipitation events
- Future evolution of rainfall intensity in East & Southern Africa uncertain
- Changes in land surface, e.g. driven by deforestation, urbanisation, etc. can make floods more severe by concentrating runoff
- Population growth, rural-urban migration & growth of informal settlements may increase urban flood risk

Flooding of Zambezi, photo by Peter Casier/World Food Programme, via Flickr Creative Commons

Remnants of road destroyed by flooding, near Dar es Salaam, Tanzania, photo by Nick Brooks

Tropical storms



Expected changes in tropical storm behaviour (frequency, category 4-5 frequency, intensity, precipitation rate) for 2081-2100 relative to 2000-2019, based on expert judgment interpretation of models. Blue lines represent ‘best guess’. IPCC AR5 WG1, Ch.14, Figure 14.17, p.1250.

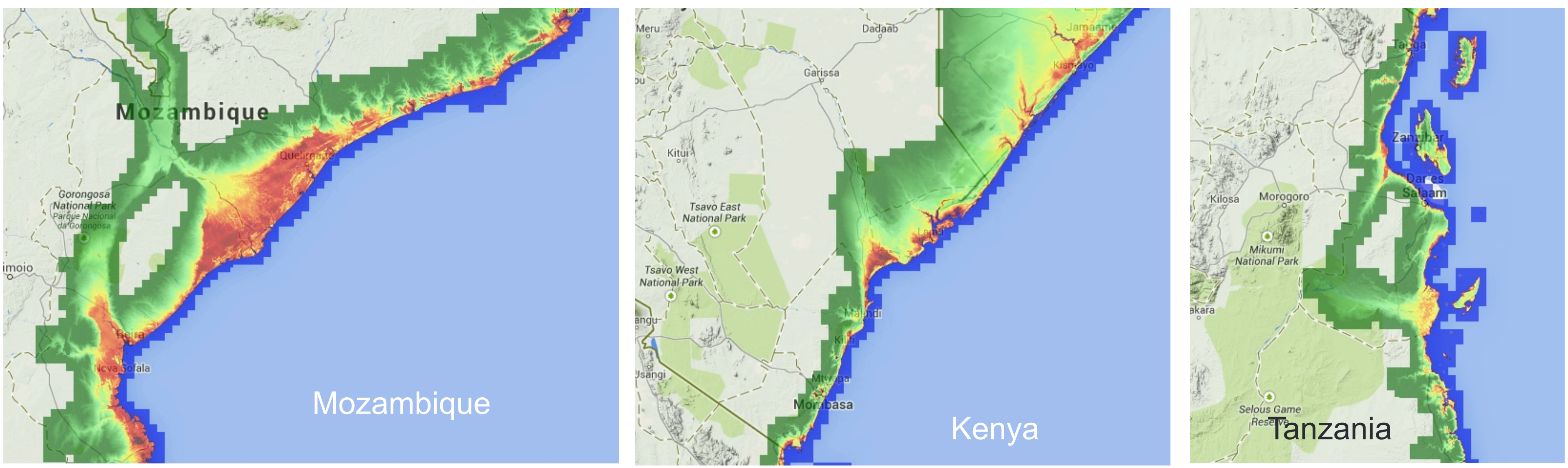
Risks from sea-level rise

- IPCC (2013) range of ~0.3-1m by 2100; others up to ~2m by 2100[1]
- Common estimates ~0.6-1.2m by 2100[2]
- Past levels suggest 20-30m for 3°C warming, rates of 1.6m per century[3]

⇨ Increased coastal flood & erosion risks, long-term risks to habitability, agricultural production, coastal ecosystems, economy, food security, health, disaster risk

⇨ SLR will combine with other impacts such as changes in storms, acidification

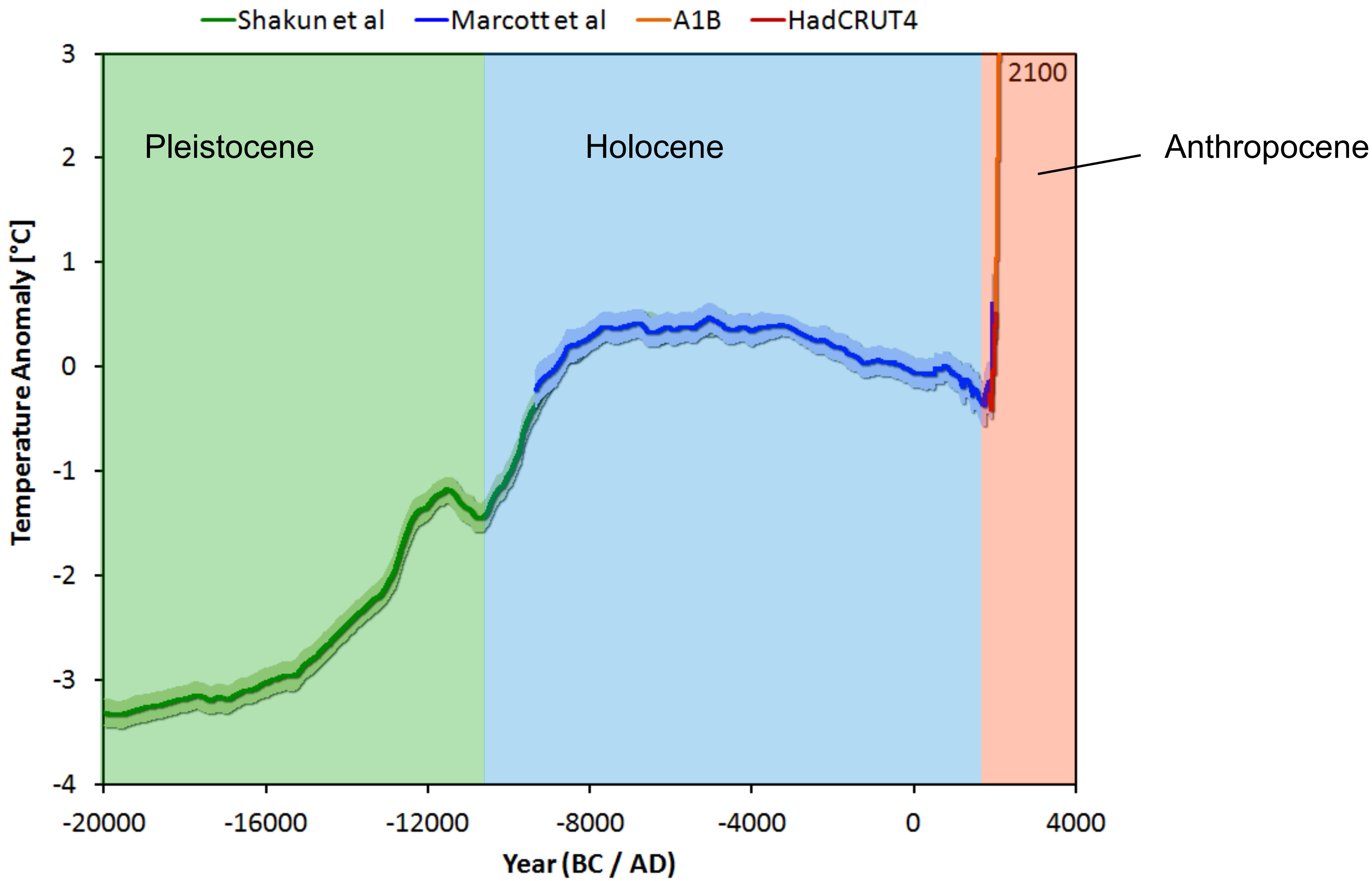
⇨ Population growth, migration, economic development will increase people, assets at risk



Above: Orange/red indicates areas below 10m above mean sea-level. Produced using Sea Level Rise Explorer[4]

[1]Nicholls et al. 2010; [2]Science 2011 vol. 334, p.1616; Orlić & Pasarić 2013; [3]Rohling et al. 2008, 2009; [4]http://www.globalwarmingart.com/. See also Brown et al. 2011; Hallegate et al. 2013; http://start.org/programs/cities-at-risk

A new geological era



Global temperature variation since the last ice age 20,000 years ago, extended until 2100 for a medium emissions scenario with about 3 degrees of global warming. Graph: Jos Hagelaars, via RealClimate: http://www.realclimate.org/index.php/archives/2013/09/paleoclimate-the-end-of-the-holocene/