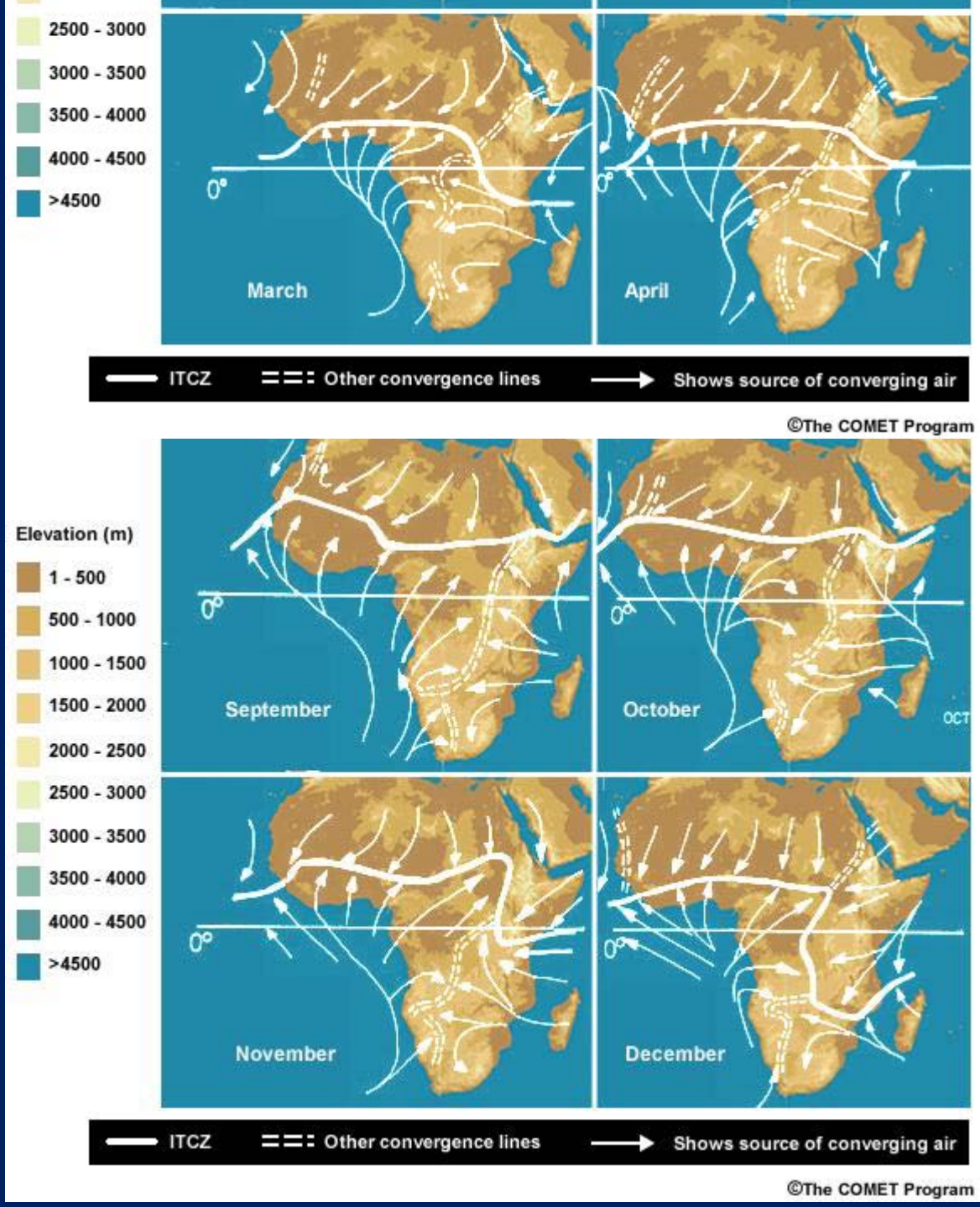
Uganda's climate: change and variability

Prof Chris Reason, UCT & Lead Author, WG1 AR5

- Regional circulation and climate
- Climate variability
- Long-term projections

Floods May 2013
Drought 2012



Seasonal movements in the ITCZ control rainfall over East Africa

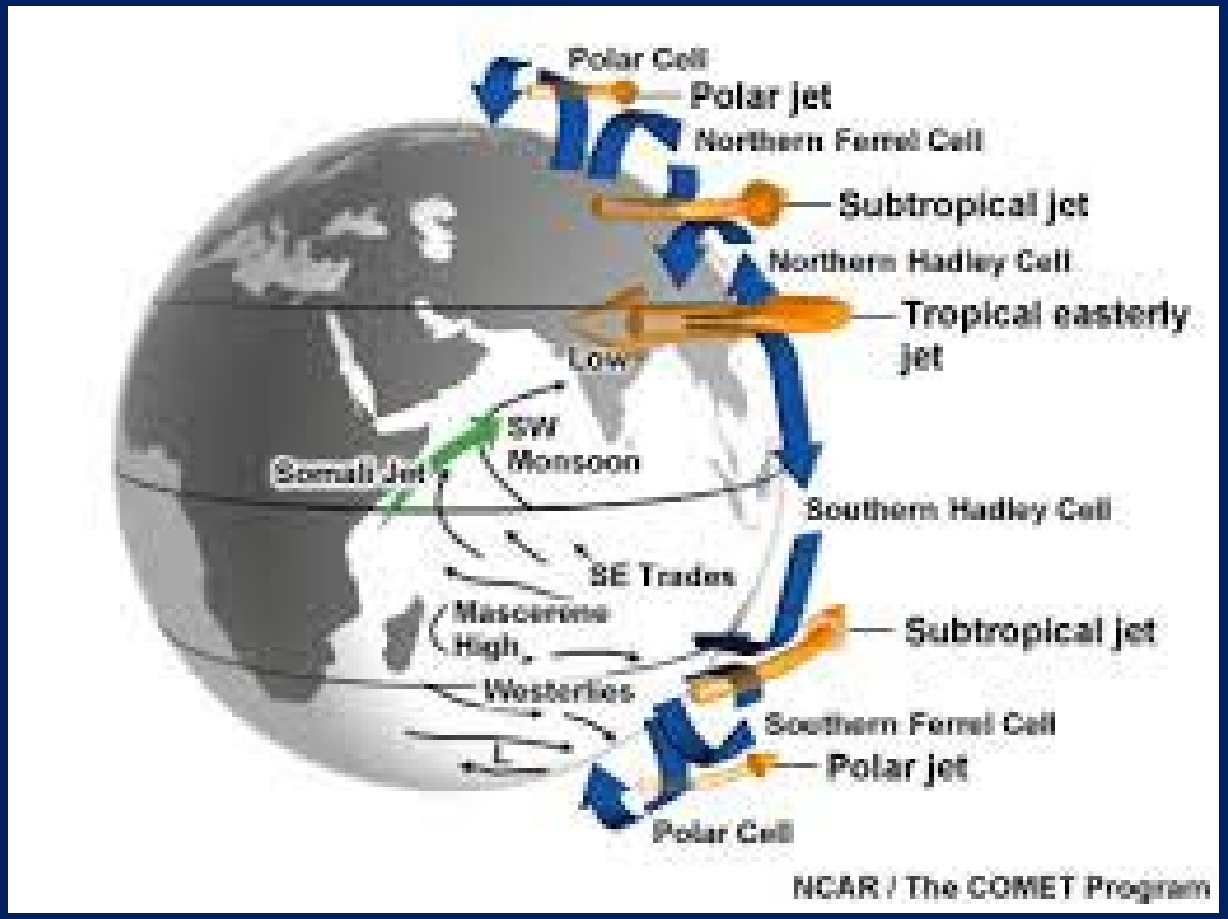
The ITCZ crosses the equator twice a year => OND & MAM rainy seasons

East African highlands and gaps (e.g. Turkana) exert strong Influences on regional rainfall

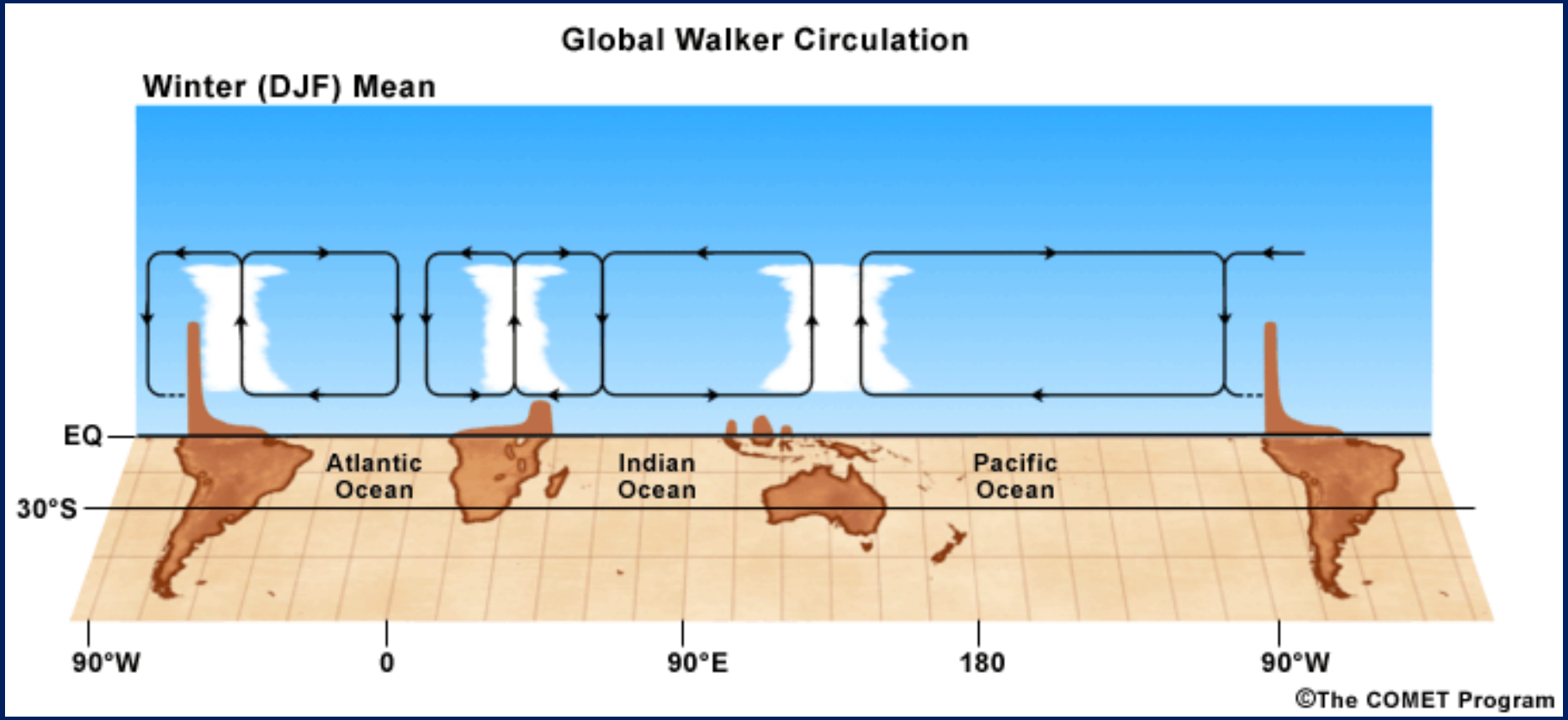
Turkana Jet

N Hem summer

Asian monsoon

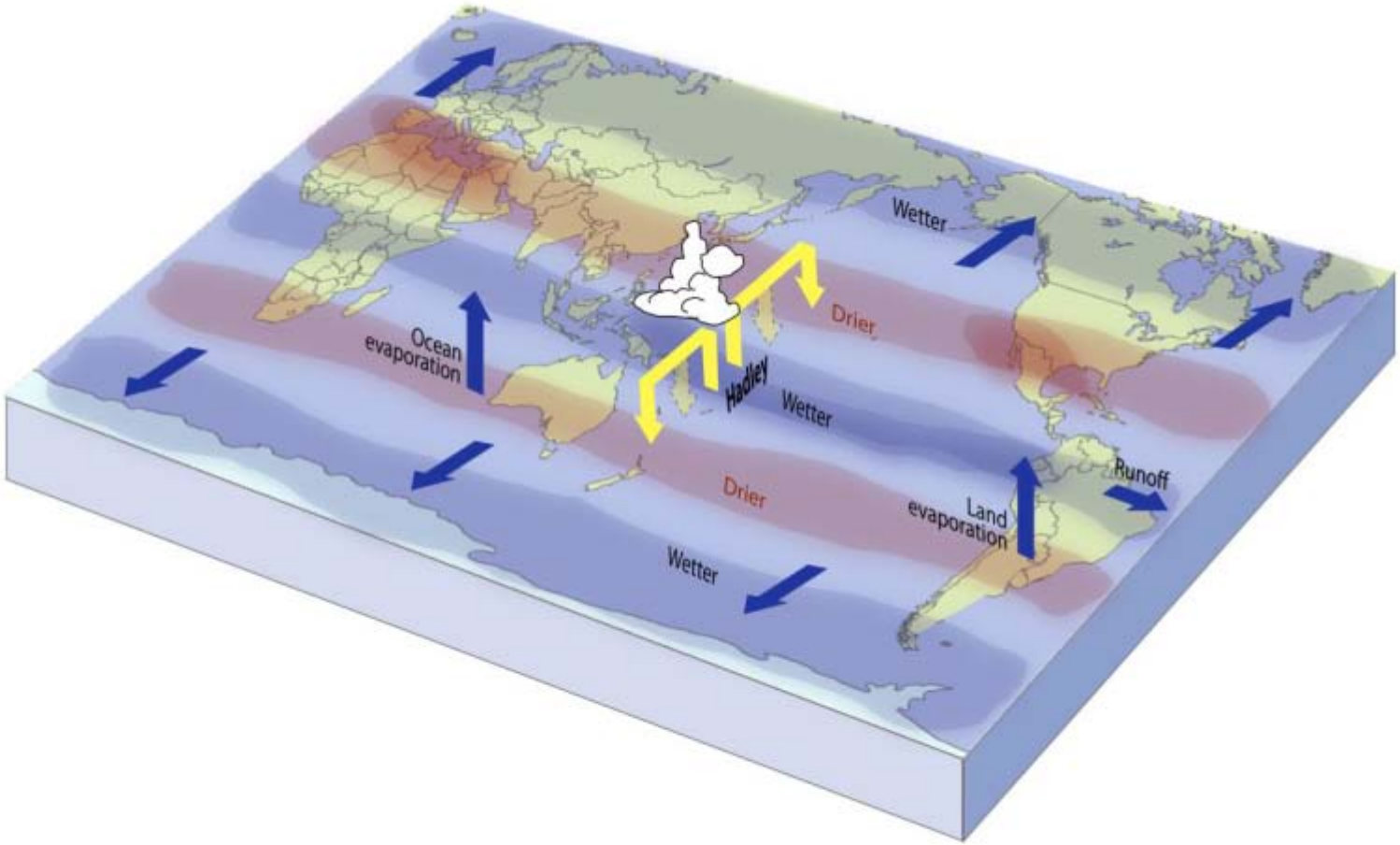


Extent of Hadley and Walker cells are important for tropical circulation and rainfall. The tropical Walker circulation is expected to weaken.



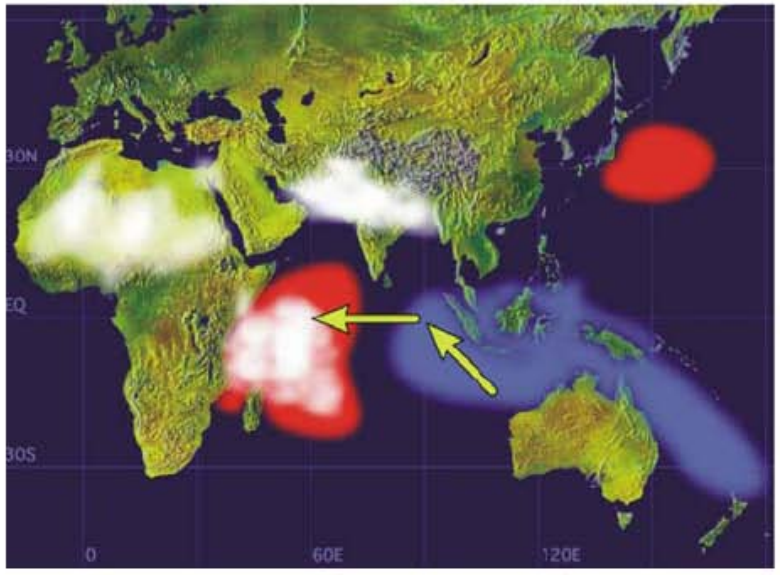
Extent of Hadley and Walker cells are important for tropical circulation and rainfall. The tropical Walker circulation is <u>expected</u> to weaken.

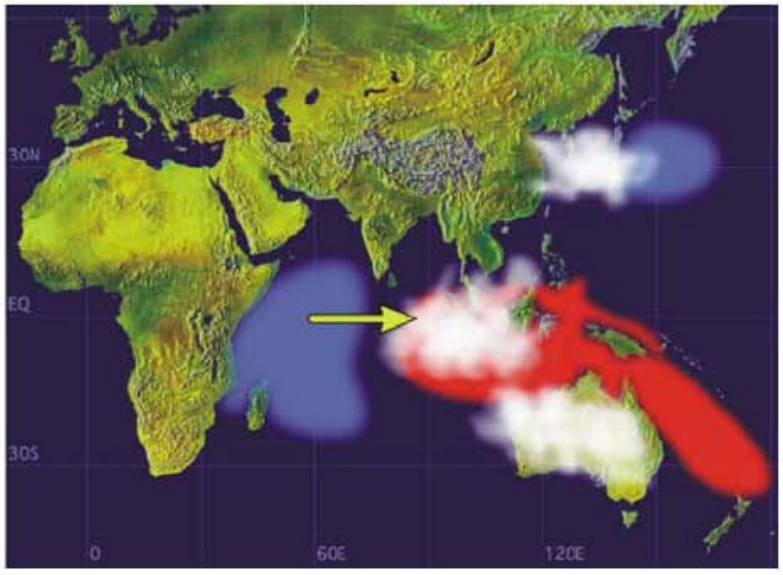
Hadley Cell projected to shift polewards , generally tropics expected to get wetter and subtropics drier. There is medium confidence that an increase in seasonal mean rainfall on the equatorward flank of the ITCZ will occur by the end of the century



Climate modes important for East Africa

- **El Nino Southern Oscillation (ENSO) - *SONDJF***
- **Indian Ocean Dipole (IODZM) – *OND***
- **MJO – variability within rainy season – 20-70 day timescale**
- ***ENSO and IOD are projected to remain dominant. MJOs are not well represented in models so difficult to project changes***





Why is climate variability important when considering climate change & development?

- East Africa's food security, health of population and agricultural resources, power generation and GDP are strongly influenced by ENSO and the IOD
- Since ENSO & IOD are projected to remain dominant in future climate scenarios, it is crucial to understand them and how they may vary on decadal scales and longer
- Example of Lake Victoria and 1961 IOD induced floods
- Recent droughts and floods

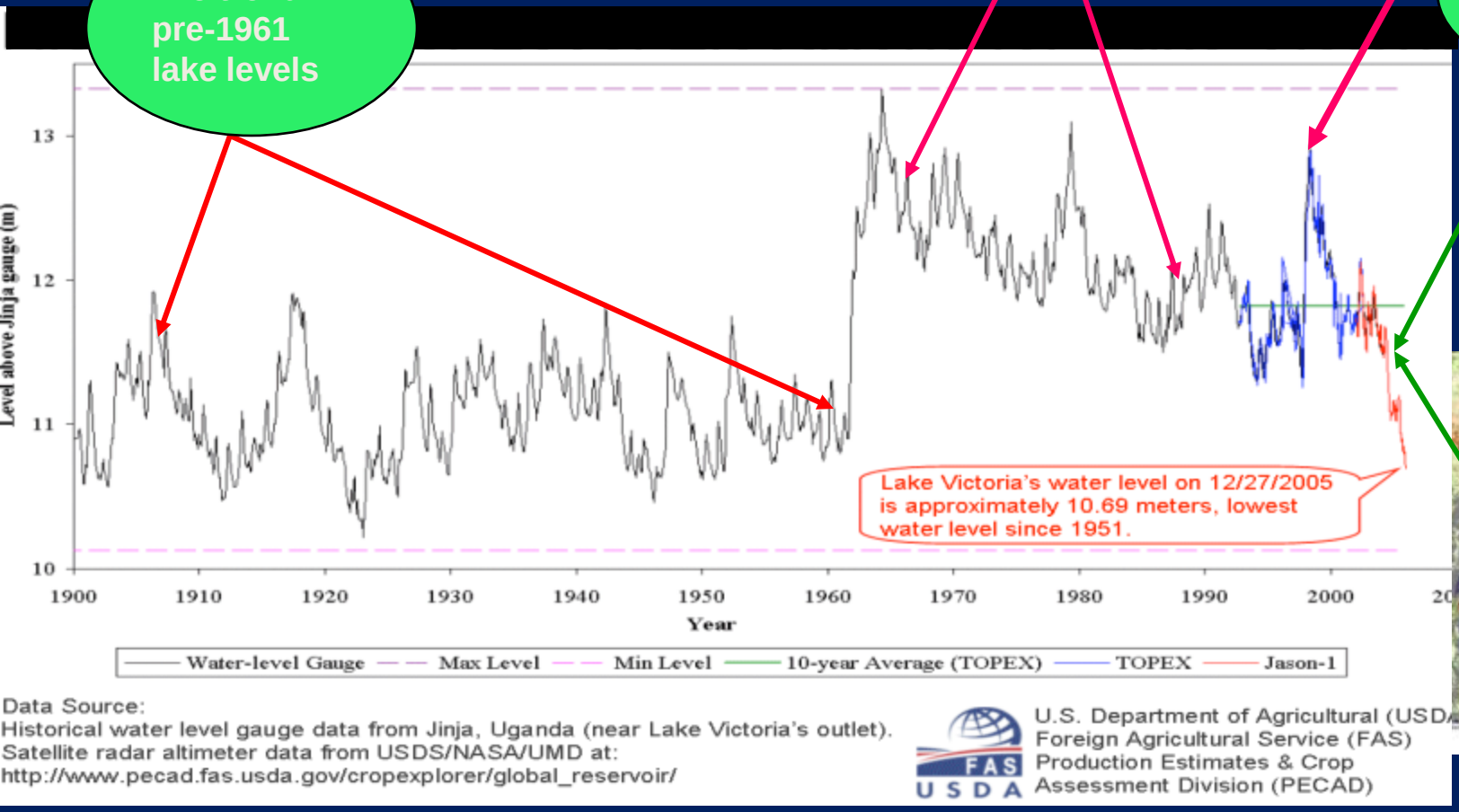
Dramatic Drop in Lake Victoria Level – courtesy Fred Semazzi

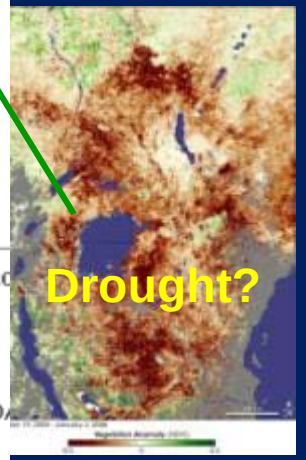
climate variability or excessive release?

ENSO-IOZM

"no trend" pre-1961 lake levels

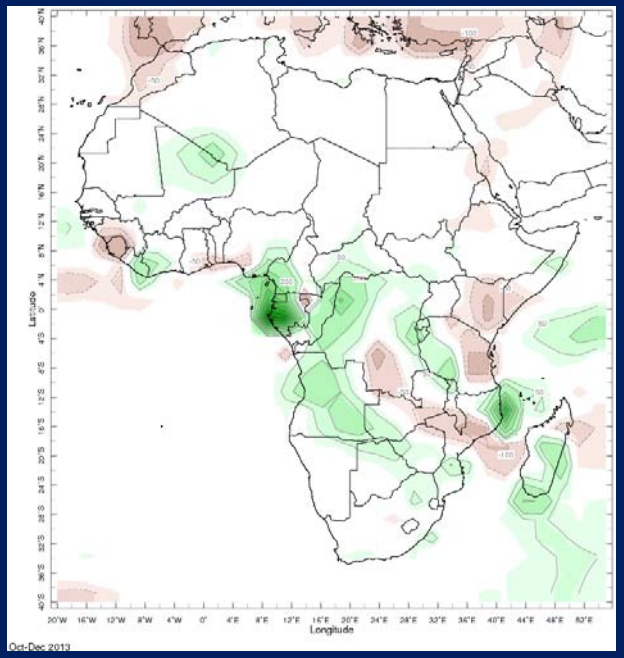
excessive release?

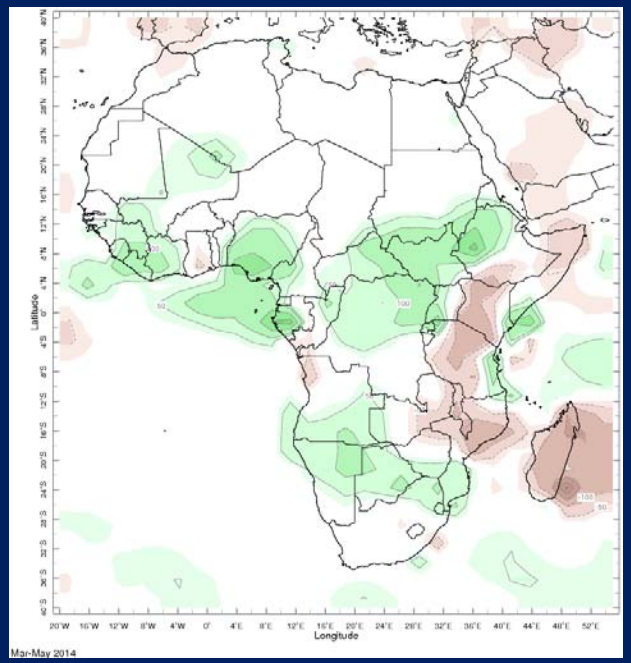


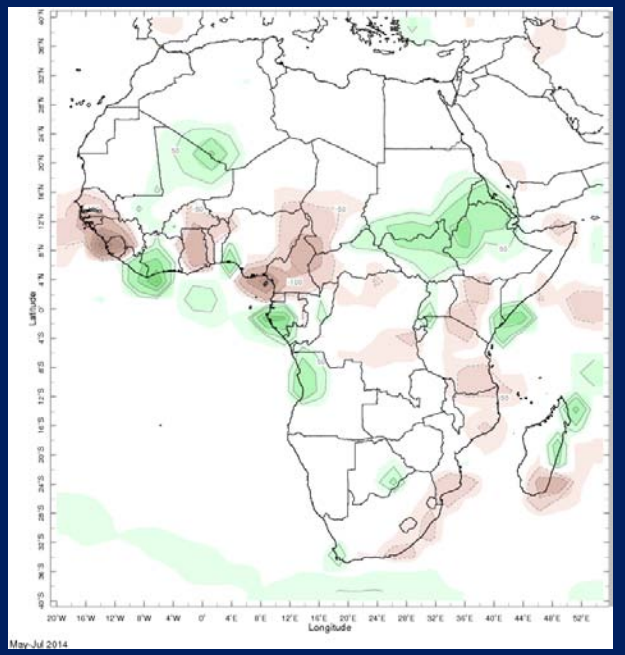


Data Source:
Historical water level gauge data from Jinja, Uganda (near Lake Victoria's outlet).
Satellite radar altimeter data from USDS/NASA/UMD at:
http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

U.S. Department of Agricultural (USDA)
Foreign Agricultural Service (FAS)
Production Estimates & Crop Assessment Division (PECAD)







Recent rainy seasons: Oct-Dec 2013, Mar-May 2014, May-Jul 2014

SST anomaly Jul/Aug 2014

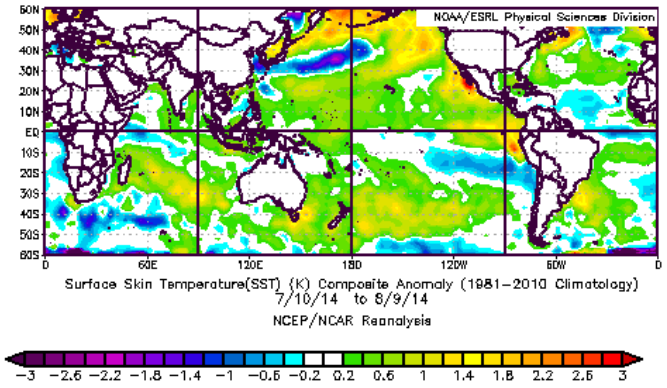
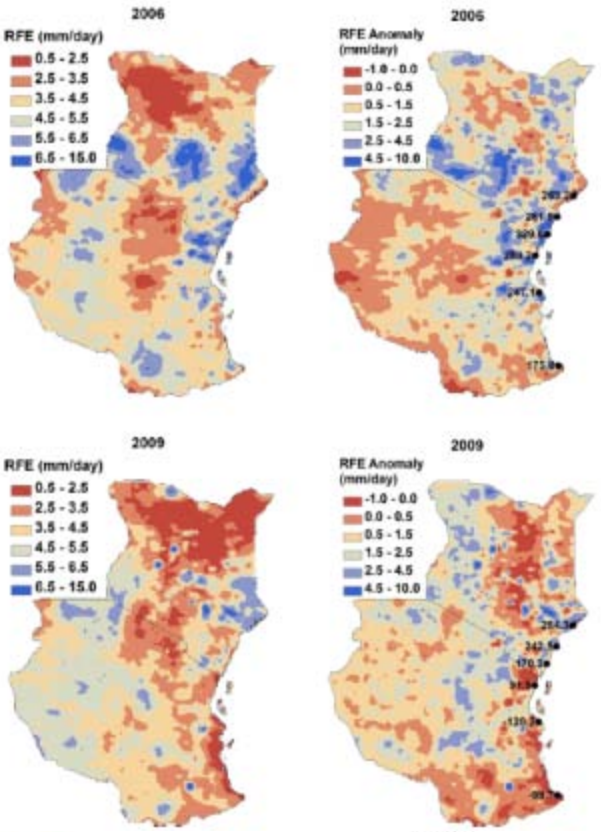


Fig. 4 RFE rainfall (mm/day) for 2006 and 2009 (*left hand plots*) and anomalies (*right hand plots*). Observed values at each station are printed



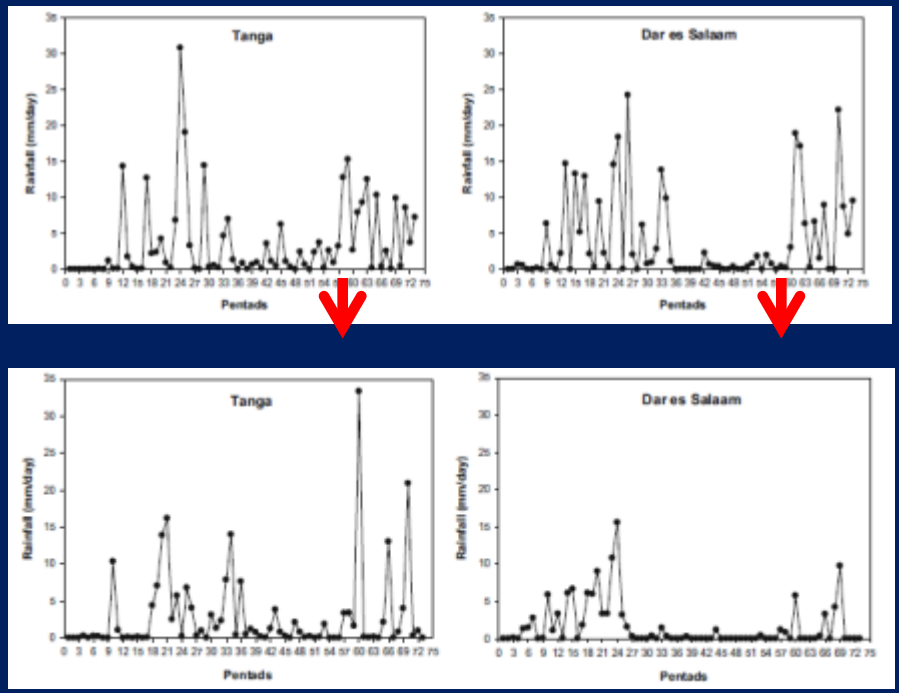
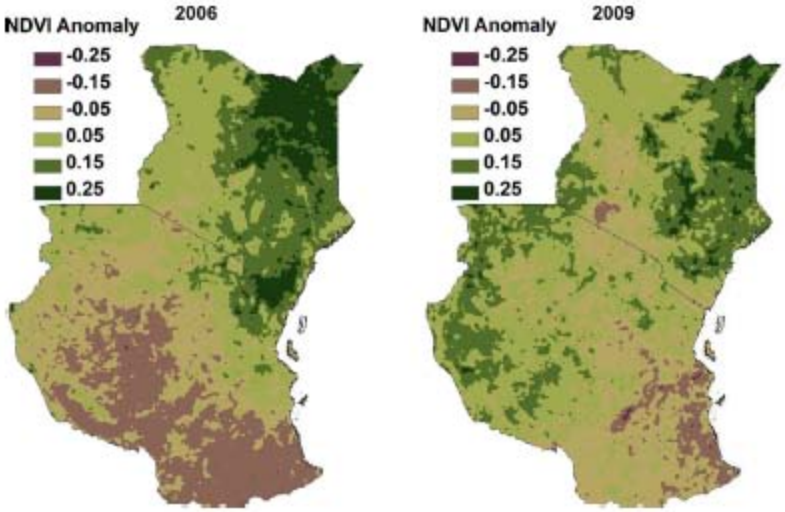


Fig. 5 Satellite-derived dekad Normalized Vegetation Index anomalies for **a** OND 2006 and **b** OND 2009



2006 and 2009 coastal flooding: ENSO / IOD Gamoyo et al (2014)

Projections for the Future

- Indian Ocean SST and regional precipitation
- ENSO
- Global SST and precipitation
- Temperature and precipitation extremes

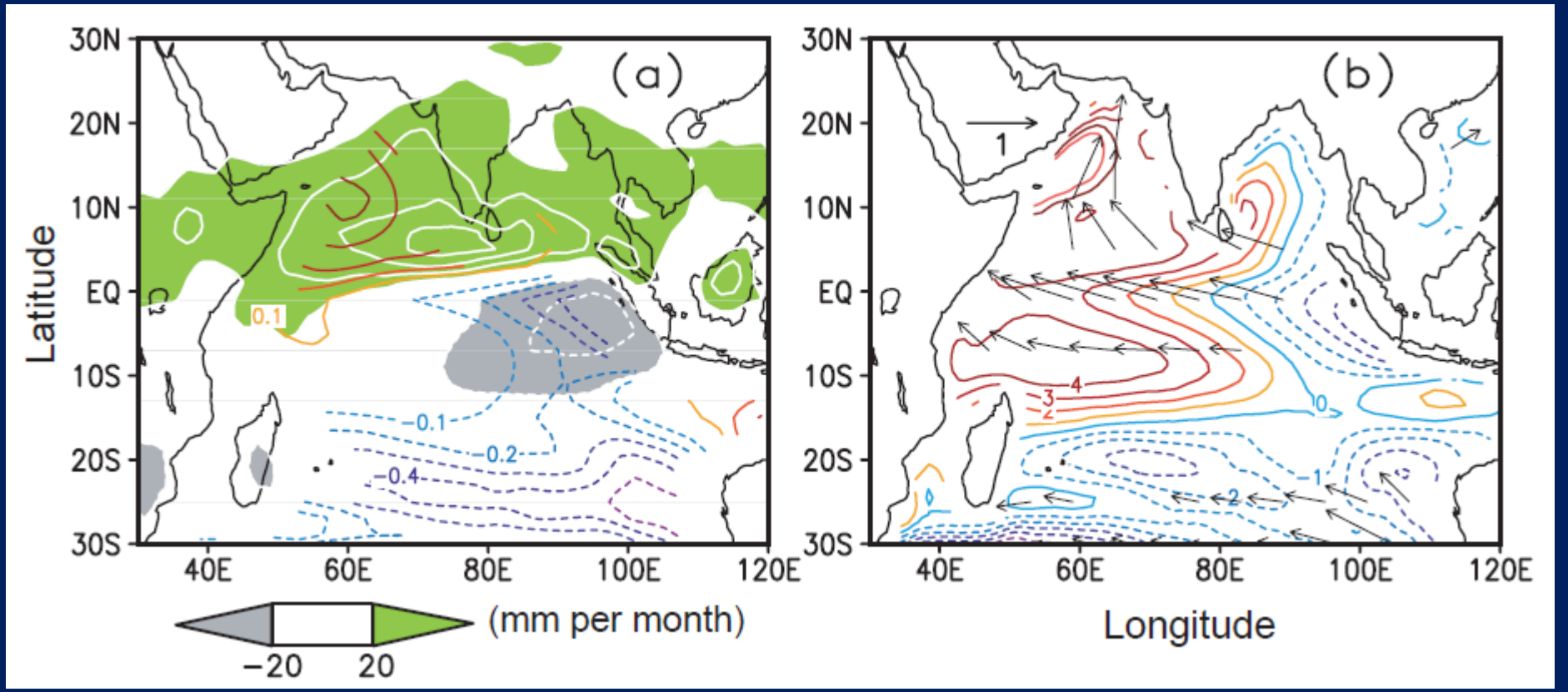
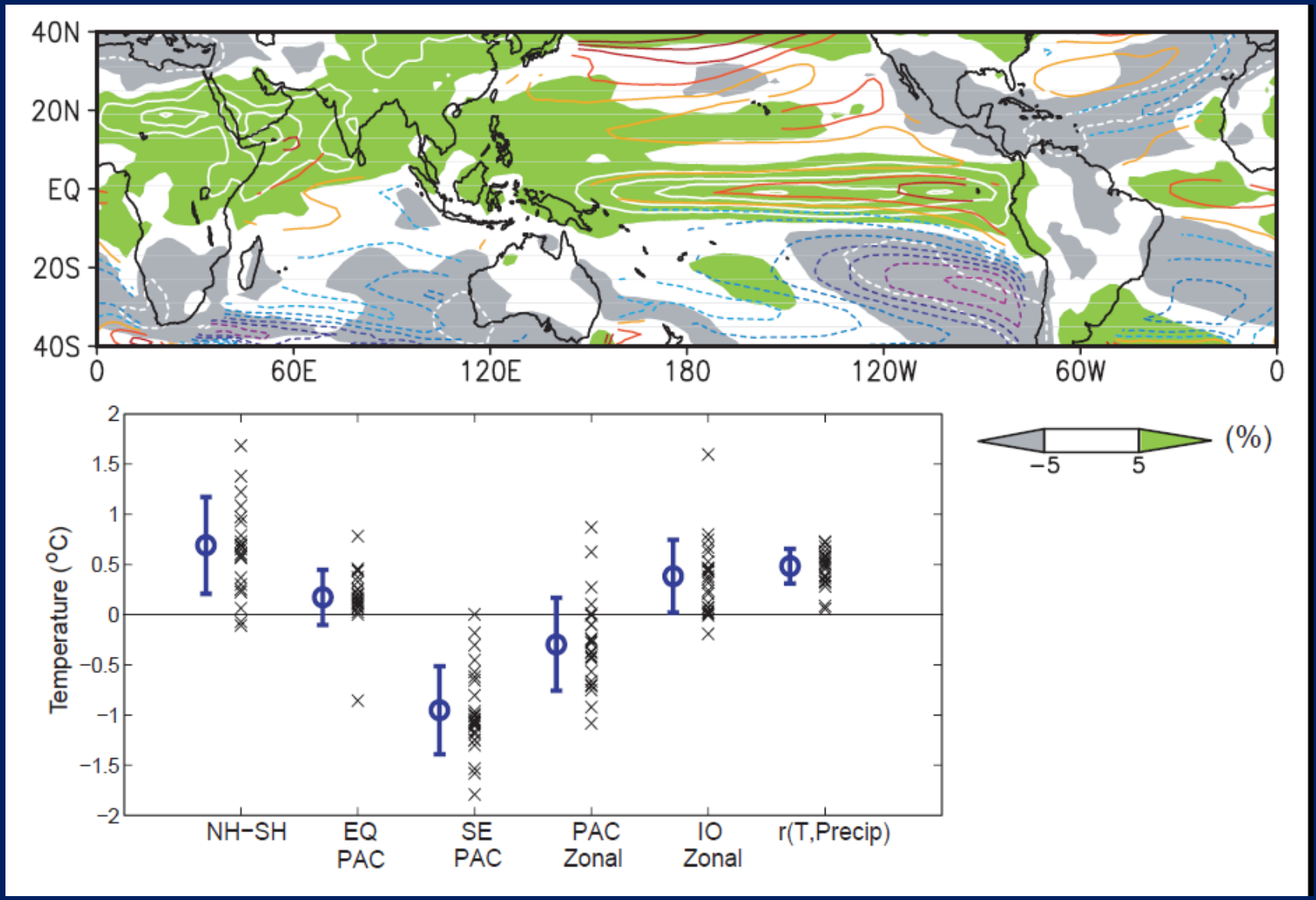


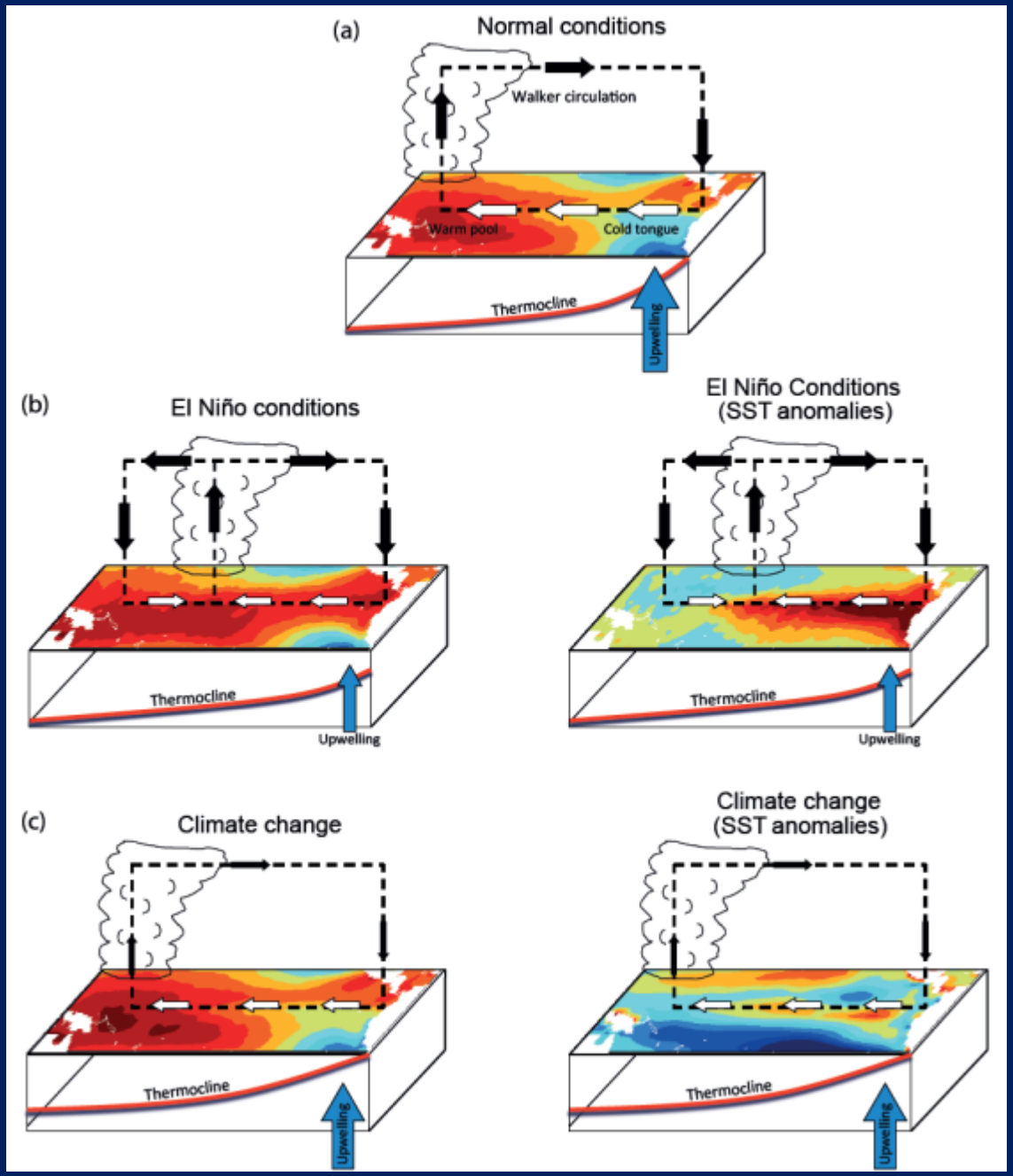
Figure 14.10: September to November changes in a 22-model CMIP5 ensemble (2081–2100 in RCP8.5 minus 1900–1949 in historical run). (a) SST (colour contours at 0.1 C intervals) relative to the tropical mean (20 S–20 N), and precipitation (shading and white contours at 20 mm per month intervals). (b) Surface wind velocity (m/s), and sea surface height deviation from the global mean (contours, cm). Over the equatorial Indian Ocean, ocean-atmospheric changes are in positive Bjerknes feedback, with the reduced SST warming and suppressed convection in the east.

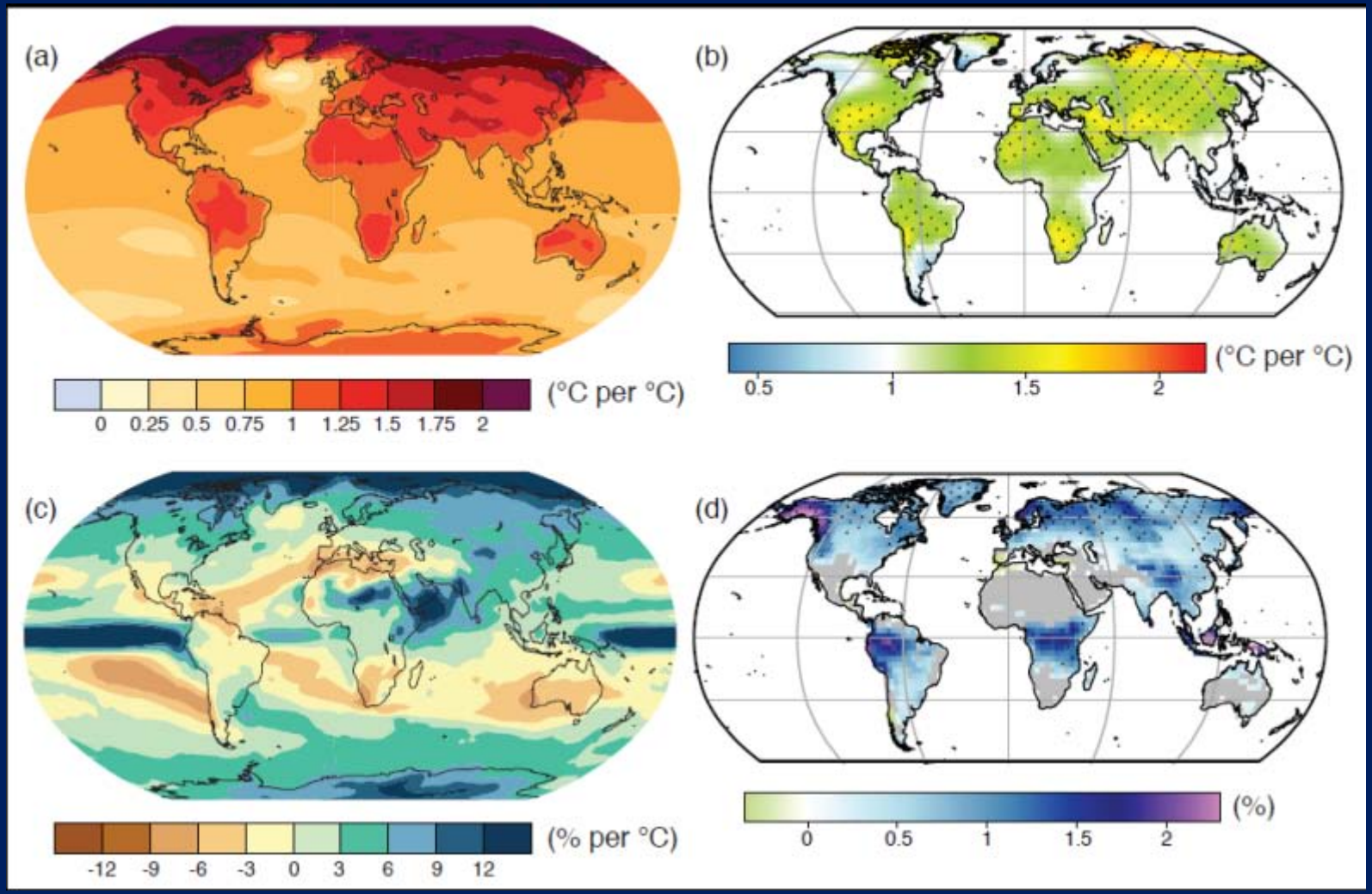
Projected weaker variances during IOD occur in both zonal wind and thermocline depth.



El Nino and IOD-like anomalies by the end of the century relative to the end of the previous century

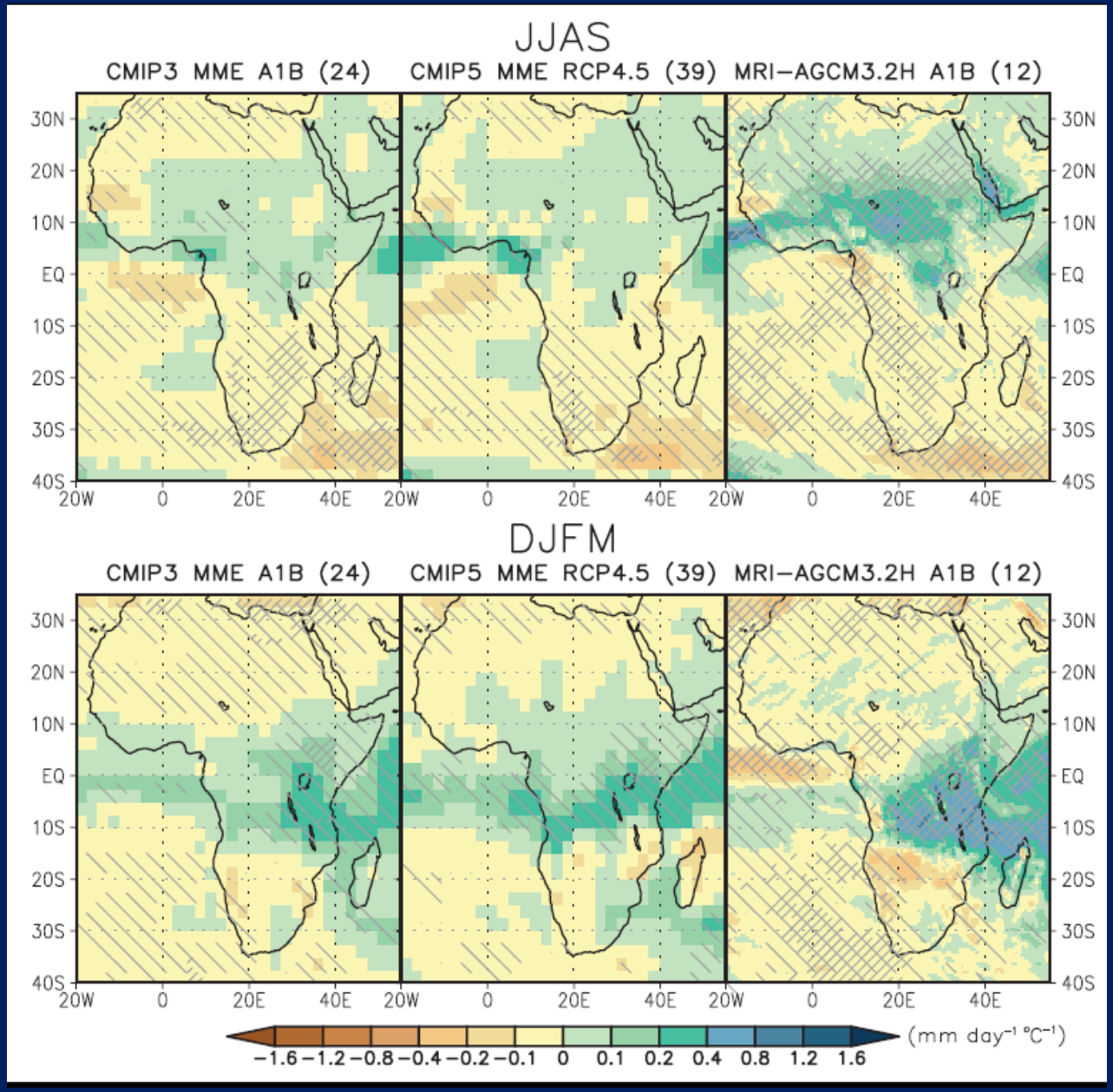
ENSO & projected changes in the tropical Pacific

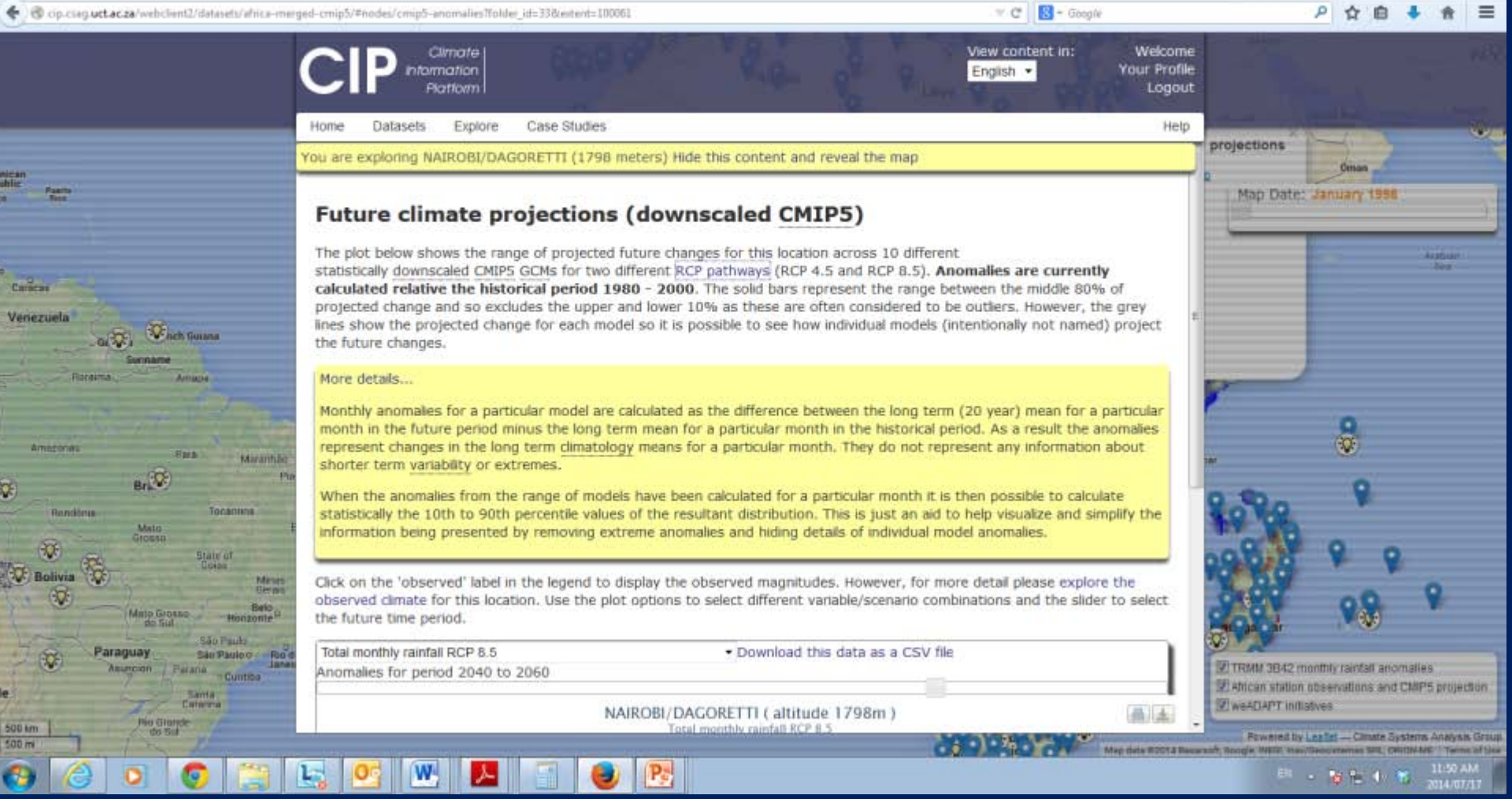




Projected 21st century changes in annual mean and annual extremes (over land) of surface air temperature and precipitation: (a) mean surface temperature per °C of global mean change, (b) 90th percentile of daily maximum temperature per °C of global average maximum temperature, (c) mean precipitation (in % per °C of global mean temperature change), and (d) fraction of days with precipitation exceeding the 95th percentile. Panels (a) and (c) projected changes in means between 1986-2005 and 2081-2100 from CMIP5 simulations under RCP4.5 scenario; Panels (b) and (d) projected changes in extremes over land between !980-1999 and 2081-2100 .

Light hatching denotes where more than 66% of models (or members) have the same sign with the ensemble mean changes, while dense hatching denotes where more than 90% of models (or members) have the same sign with the ensemble mean changes.





Downscaled CMIP5 projections for particular stations

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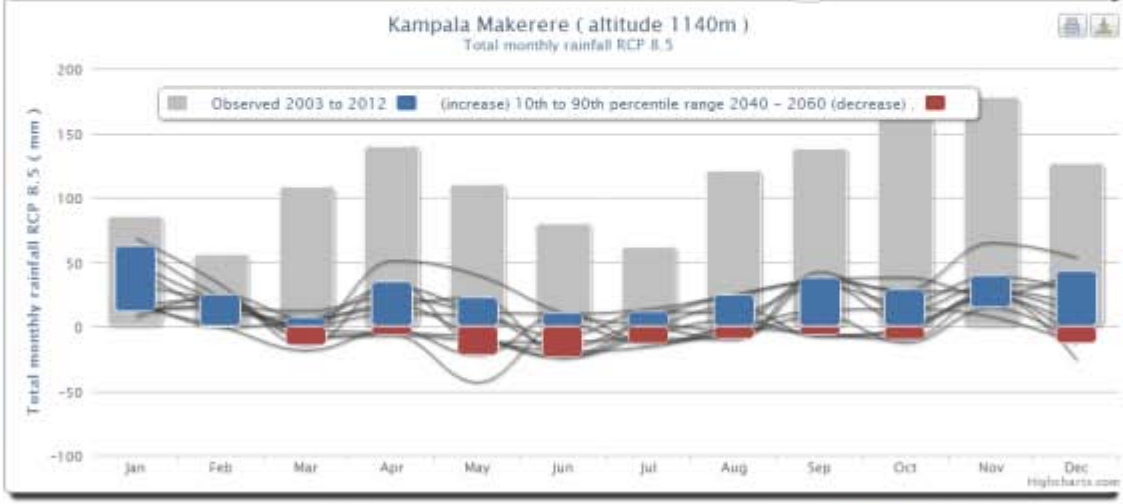
More details...

Click on the 'observed' label in the legend to display the observed magnitudes. However, for more detail please explore the observed climate for this location. Use the plot options to select different variable/scenario combinations and the slider to select the future time period.

Total monthly rainfall RCP 8.5 ▾ Download this data as a CSV file

Anomalies for period 2040 to 2060



Map Date: January 1998

TRMM 3B42 monthly rainfall anomalies
African station observations and CMIP5 projection
weADAPT initiatives

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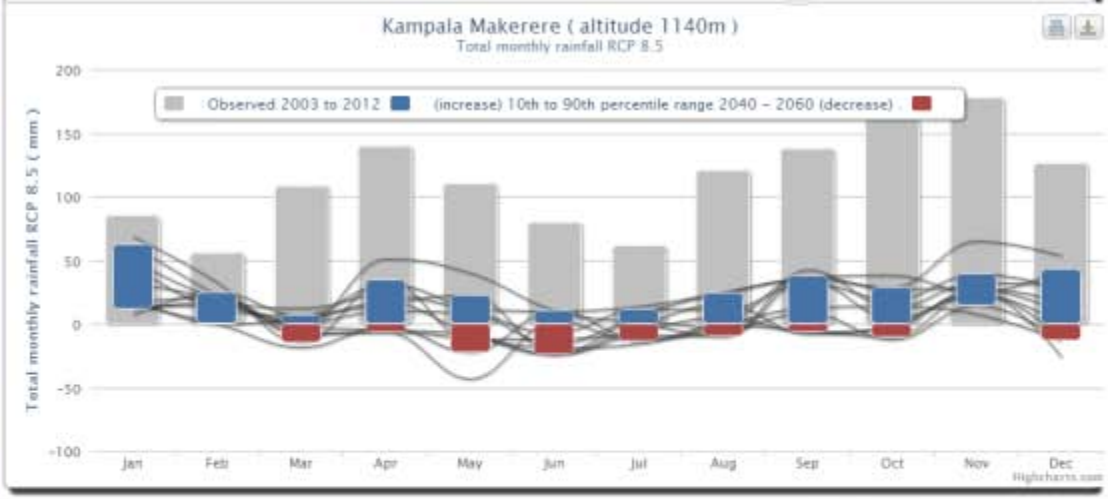

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Summary

- It is ***very likely*** that all of Africa will continue to warm during the 21st century. Equatorial Africa (including East Africa) is projected to warm less than either southern Africa or North Africa

- In general, tropics are expected to get wetter and subtropics drier. However, for East Africa, there is ***medium confidence*** in model projections for little change in mean annual precipitation. Increased rainfall is ***likely*** for the short rains but there is ***low confidence*** in projections for the long rains.

- There is ***high confidence*** that ENSO will remain the dominant mode of natural climate variability in the 21st century but changes in intensity are ***uncertain.*** IOD is ***very likely*** to remain active throughout 21st century – this together with enhanced warming in the western Indian Ocean affects climate extremes in East Africa and increases precipitation during the short rains season

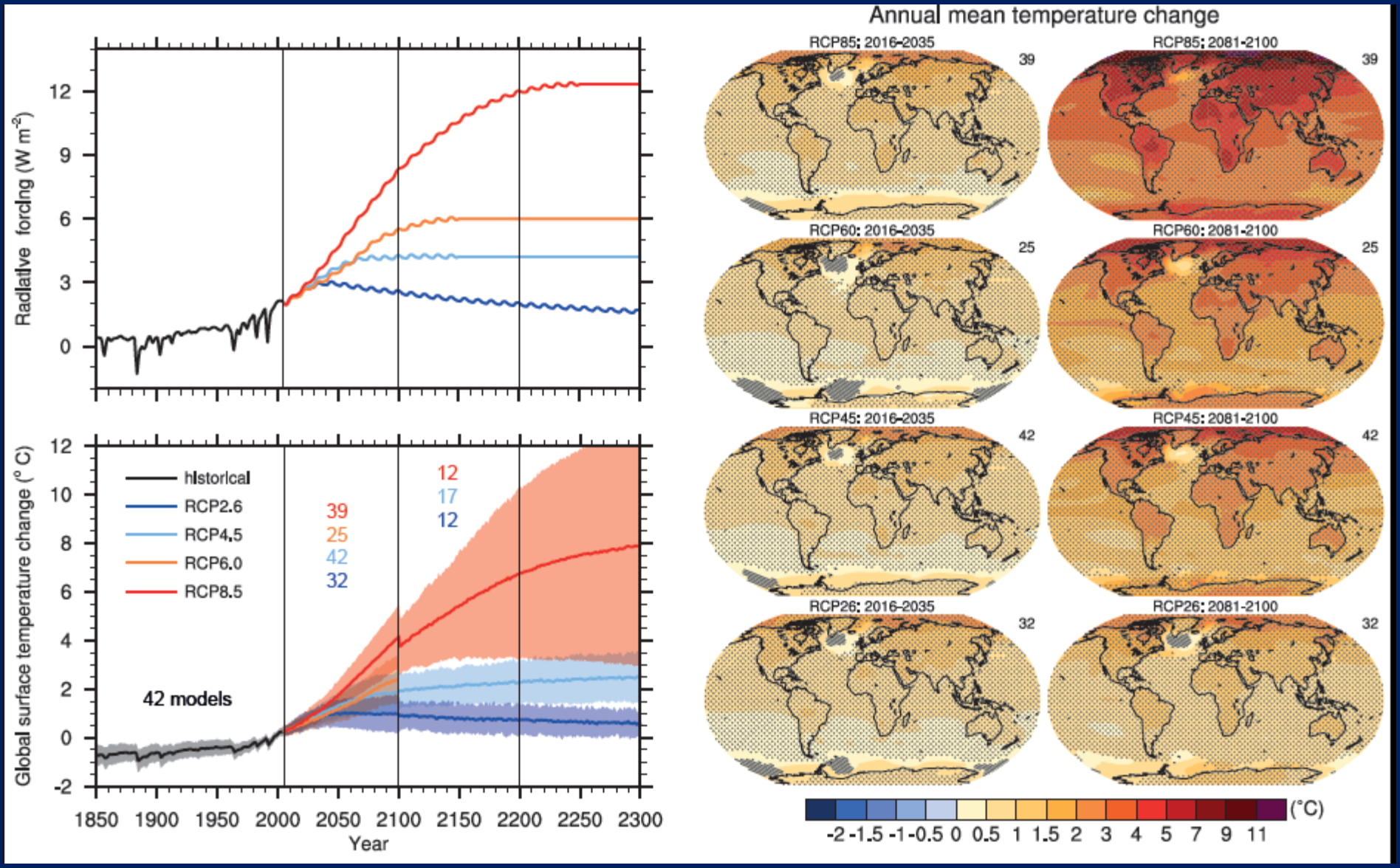

Radiative forcing (W m-2)
12
9
6
3
0
Global surface temperature change (° C)
12
10
8
6
4
2
0
-2
historical
RCP2.6
RCP4.5
RCP6.0
RCP8.5
39
25
42
32
12
17
12
42 models
1850 1900 1950 2000 2050 2100 2150 2200 2250 2300
Year
Annual mean temperature change
RCP85: 2016-2035
39
RCP85: 2081-2100
39
RCP60: 2016-2035
25
RCP60: 2081-2100
25
RCP45: 2016-2035
42
RCP45: 2081-2100
42
RCP26: 2016-2035
32
RCP26: 2081-2100
32
(°C)
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11

Figure TS.15). {12.4.1}

Under the assumptions of the concentration-driven RCPs, GMSTs for 2081–2100, relative to 1986–2005 will *likely* be in the 5 to 95% range of the CMIP5 models; 0.3°C to 1.7°C (RCP2.6), 1.1 to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5) (see Table TS.1). With high confidence, the 5 to 95% range of CMIP5 is assessed as *likely* rather than *very likely* based on the assessment of TCR (see TFE.6).

TS.5.5.2 Projected Long-term Changes in Regional Temperature

There is *very high confidence* that globally averaged changes over land will exceed changes over the ocean at the end of the 21st century by a factor that is *likely* in the range 1.4 to 1.7. In the absence of a strong reduction in the Atlantic Meridional Overturning, the Arctic region is projected to warm most (*very high confidence*) (Figure TS.15). As

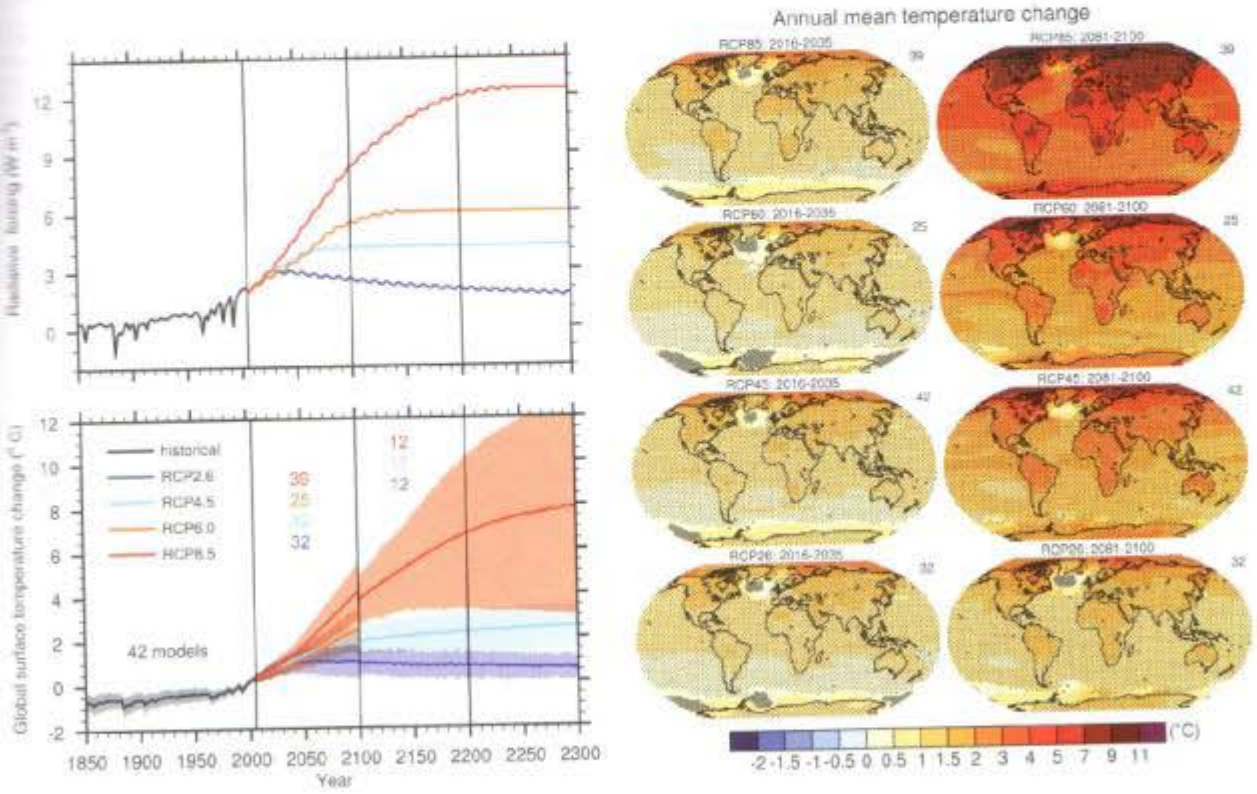
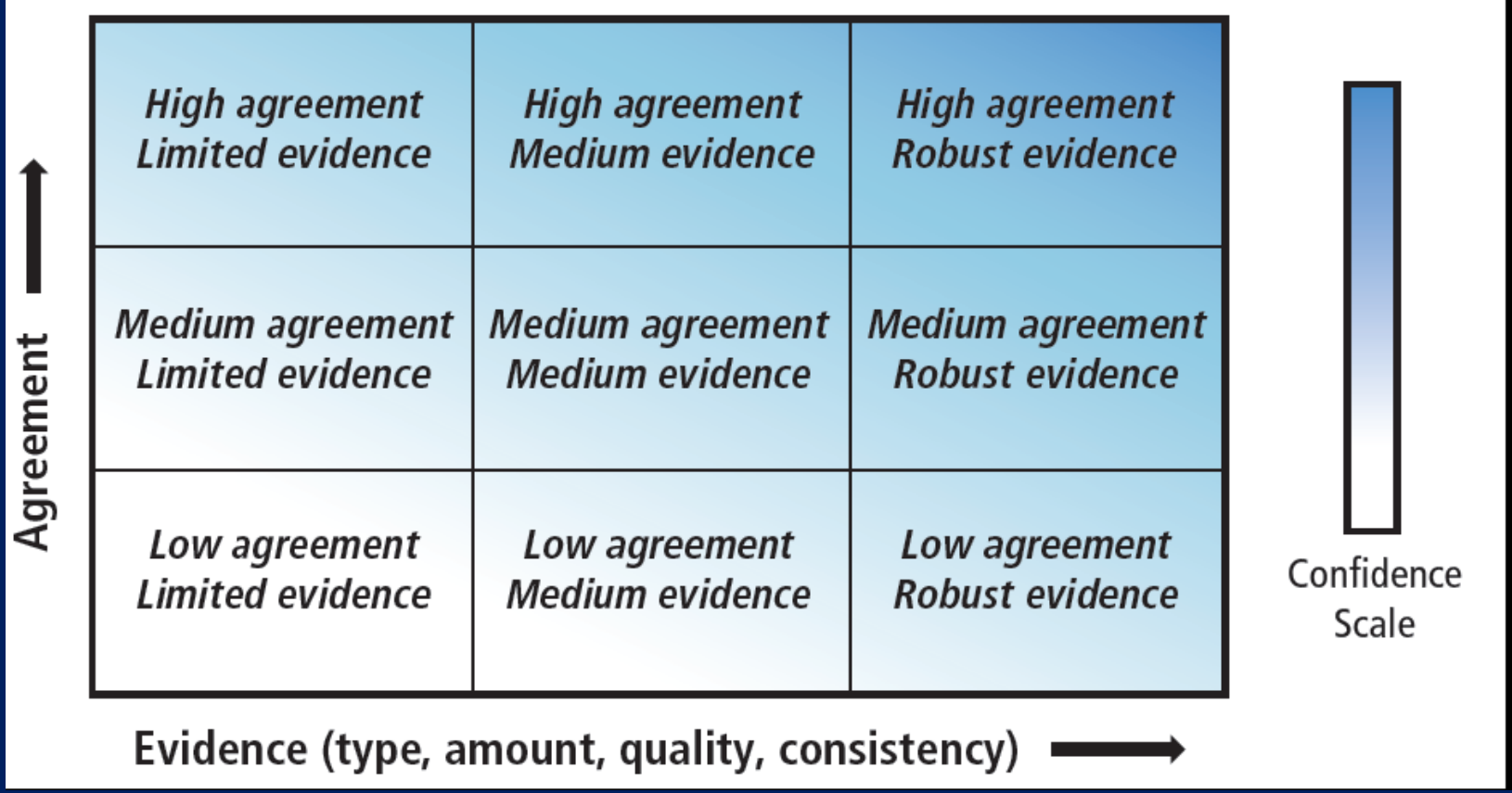


Figure TS.15 | (Top left) Total global mean radiative forcing for the four RCP scenarios based on the Model for the Assessment of Greenhouse-gas Induced Climate Change (MAGICC) energy balance model. Note that the actual forcing simulated by the CMIP5 models differs slightly between models. (Bottom left) Time series of global annual mean surface air temperature anomalies (relative to 1986–2005) from CMIP5 concentration-driven experiments. Projections are shown for each RCP for the multi-model mean (solid lines) and ±1.64 standard deviation (5 to 95%) across the distribution of individual models (shading), based on annual means. The 1.64 standard deviation range based on the 20 yr averages 2081–2100, relative to 1986–2005, are interpreted as *likely* changes for the end of the 21st century. Discontinuities at 2100 are due to different numbers of models performing the extension runs beyond the 21st century and have no physical meaning. Numbers in the same colours as the lines indicate the number of different models contributing to the different time periods. Maps: Multi-model ensemble average of annual mean surface air temperature change (compared to 1986–2005 base period) for 2016–2035 and 2081–2100, for RCP2.6, 4.5, 6.0 and 8.5. Hatching indicates regions where the multi-model mean signal is less than one standard deviation of internal variability. Stippling indicates regions where the multi-model mean signal is greater than two standard deviations of internal variability and where 90% of the models agree on the sign of change. The number of CMIP5 models used is indicated in the upper right corner of each panel. Further detail regarding the related Figures SPM.7a and SPM.8.a is given in the TS Supplementary Material. {Box 12.1; Figures 12.4, 12.5, 12.11; Annex I}



Term*	Likelihood of the outcome
Virtually certain	99–100% probability
Very likely	90–100% probability
Likely	66–100% probability
About as likely as not	33–66% probability
Unlikely	0–33% probability
Very unlikely	0–10% probability
Exceptionally unlikely	0–1% probability

* Additional terms (*extremely likely:* 95–100% probability, *more likely than not:* >50–100% probability, and *extremely unlikely:* 0–5% probability) may also be used when appropriate.