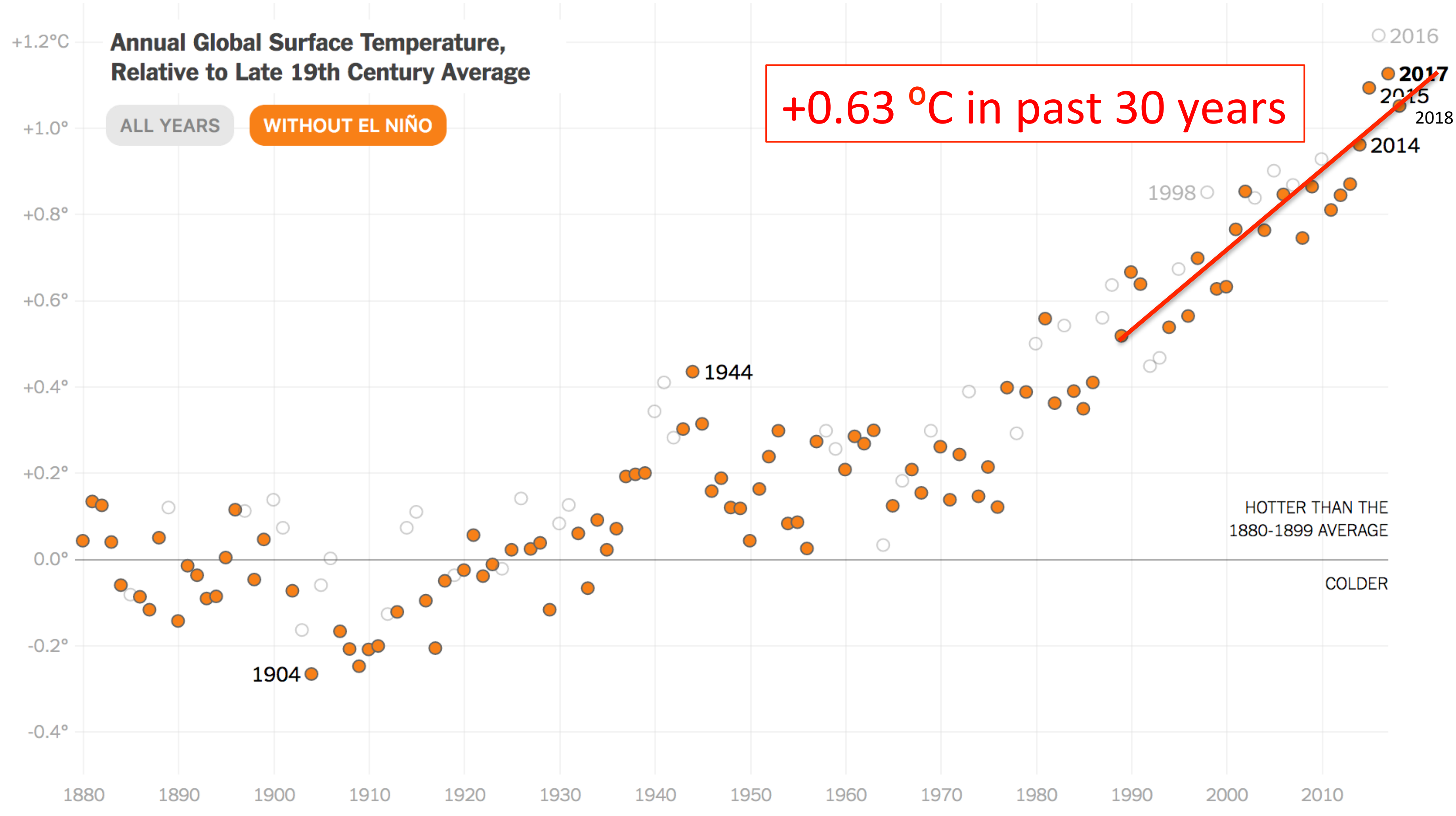
The climate of 2050:
changes that are certain

- How warm will it be?
- Terrestrial changes
- Marine changes
- Things you may want to know, but we don’t

"2017 was the 2nd hottest year on record. And that was without El Niño."



Source: NASA

New York Times, Jan 18, 2018

The climate of 2050:
changes that are certain

Terrestrial

- Temperature
- Precipitation: less in southern Europe
- Other: humidity, snowpack, sea ice

To a good approximation …

- The total warming depends on the *cumulative* amount of CO_2 that is added to the air
  - It is *not* dependent on the *rate* of CO_2 emissions
  - Methane & other greenhouse gases minor players today, and will be even less important in the future

- Uncertainty in temperature projections
  - In the short term (up to ~2050), depends on how clouds will respond to increasing CO_2 but *weakly* on *emission choices*
  - In the long run (beyond ~2050), uncertainty equally due to model uncertainty and emission choices

How warm will it be (compared to 1980-1999)?

	Utopia (RPC 4.5)	Split Difference (RCP 6.0)	Business as Usual (RCP8.5)
+2 ºC	**2108** (2065,2166)	**2080** (2066,2094)	**2055** (2047,2059)
+4 ºC		**2166** (2124, 2187)	**2097** (2082, 2107)

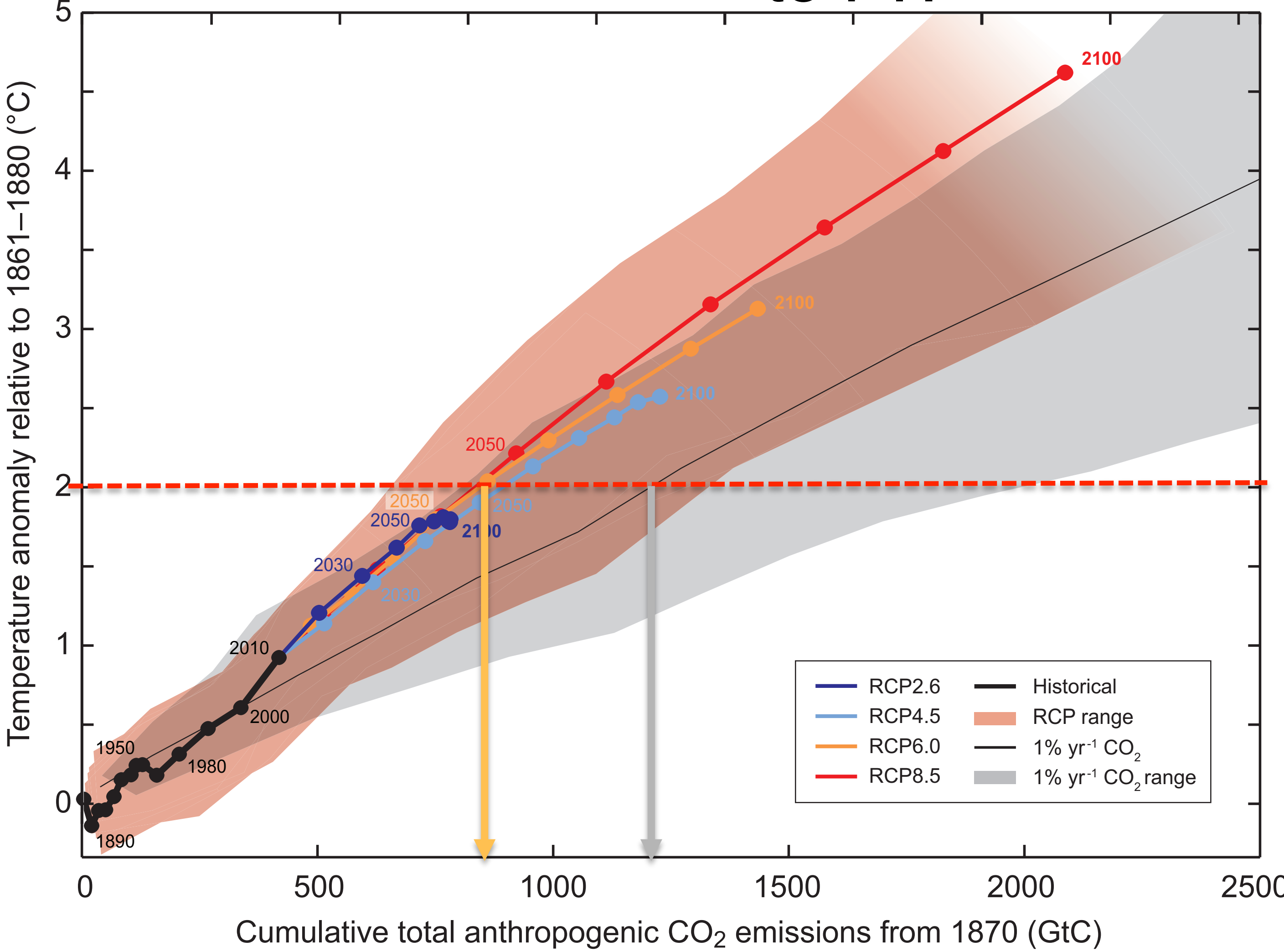
- A conservative estimate: +1.0 ºC warmer in 2050 than today
  - Similar to the warming observed 1850-2000
- Warmer than anytime in the past 3M years
- Projections for 2100: ~ +3 ºC warmer than today

Tigchelaar et al 2018

ΔT (°C)	Year at which x% of CMIP5 models exceed temperature threshold ΔT				
	5%	**25%**	**50%**	**75%**	**95%**
RCP 4.5 (42 models)					
1	2019	2026	2033	2037	2048
2	2052	2065	*2108*	*2166*	-
3	*2113*	*2142*	-	-	-
4	*2187*	-	-	-	-
RCP 6.0 (25 models)					
1	2016	2029	2037	2045	2057
2	2051	2066	2080	2094	*2104*
3	2080	2096	*2125*	*2139*	*2151*
4	*2107*	*2124*	*2166*	*2187*	-
RCP 8.5 (39 models)					
1	2018	2023	2028	2031	2038
2	2042	2047	2055	2059	2068
3	2059	2065	2077	2083	*2099*
4	2075	2082	*2097*	*2107*	*2132*

Tigchelaar et al 2018

How likely is it we can keep the increase in global average temperature to be < 2°C relative to PI?



1200 Gt allowed if only CO2 changed

~800 Gt carbon in eCO2 allowed because of other GH gas increases

Global temperature depends on total cumulative emission

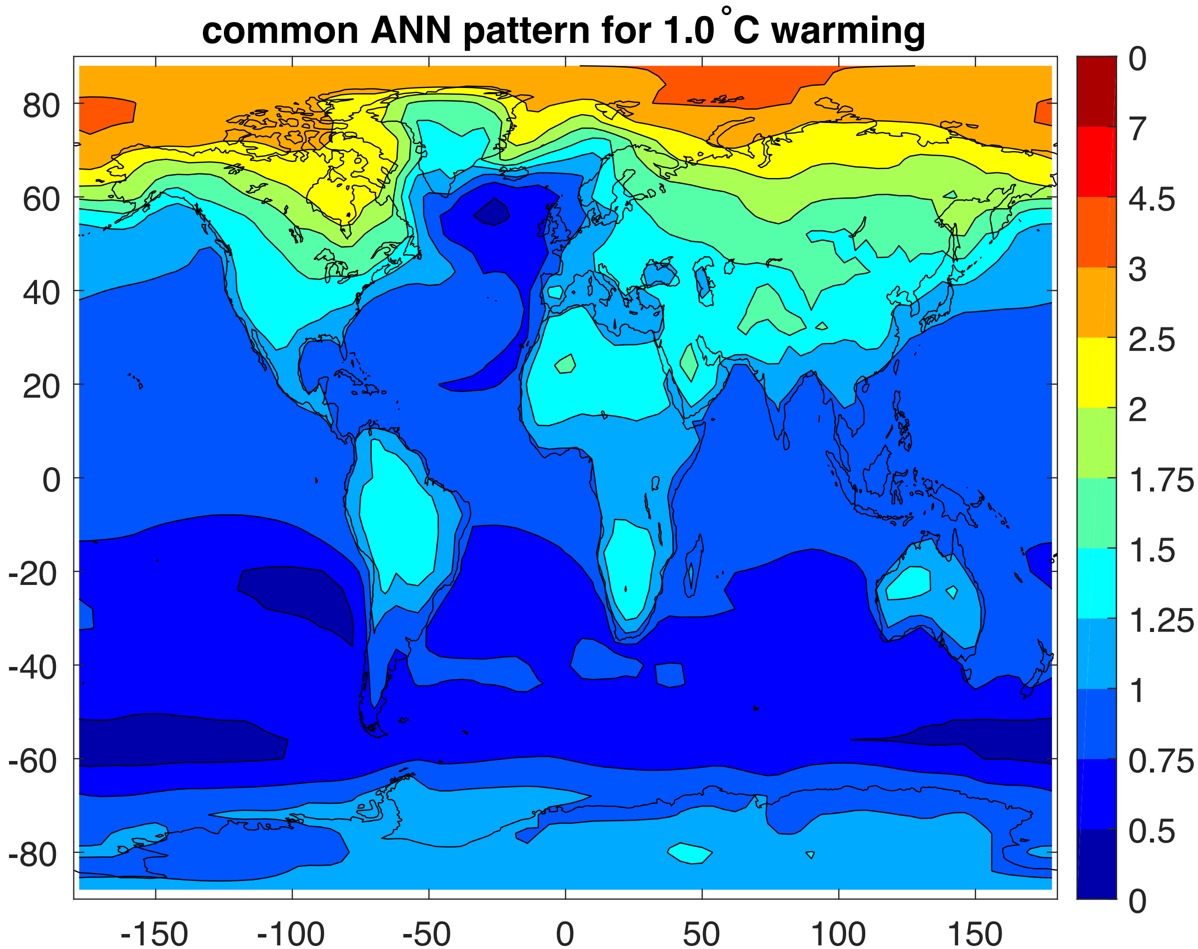
Hence, to limit the temperature rise to 2°C:

- total allowable C emission ~1200 Gt
- emissions to date = 515 Gt
- Allowed future emission = 685Gt (1200 – 515) between now and the end of time
- 68 years at current rate of emission (10 Gt/yr)

Fig. SPPM.10 IPCC 2013

What does a 1ºC warming by 2050 mean?

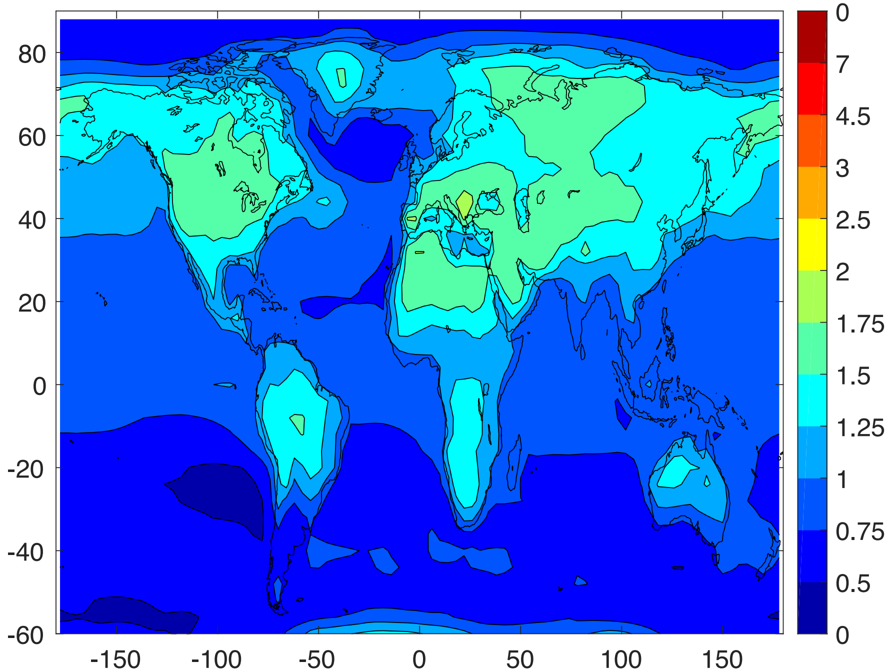
- All models produce the same pattern, which is well understood
  - More warming: over land than ocean; over the arctic than tropics



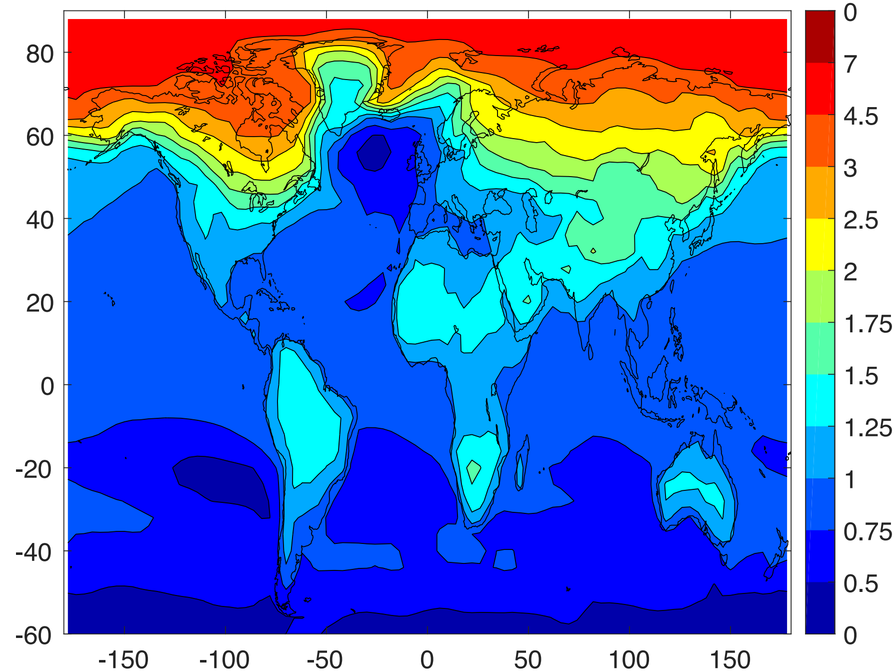
- Models vary in *amplitude* of warming pattern by -30% to +50%
  - Uncertainty *everywhere* is entirely due to w/ uncertainty in tropical cloud response

What does a 1ºC warming by 2050 mean?

June - August



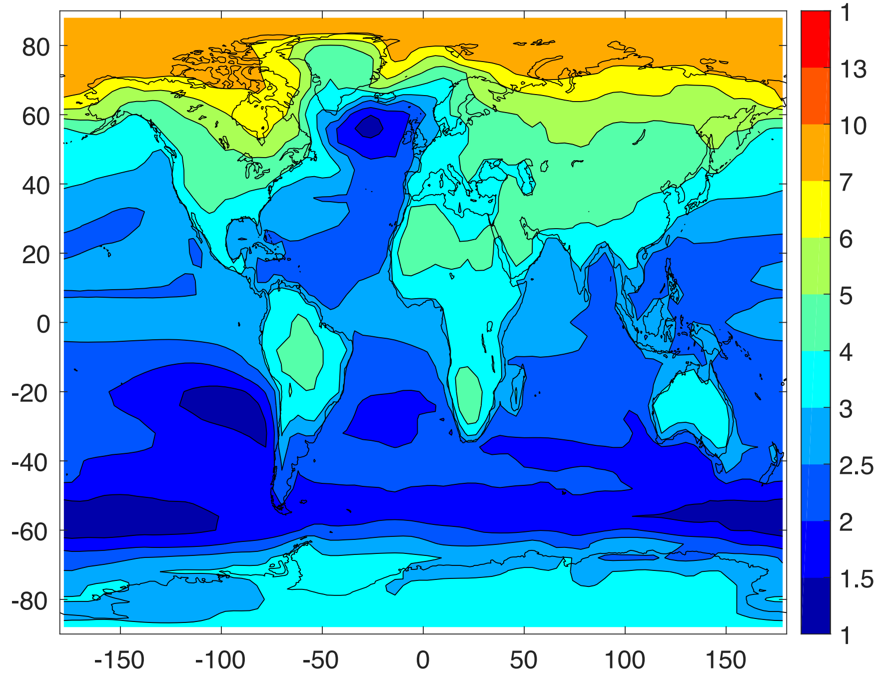
December - February



- **Midlatitude** growing season warms by 1.25 to 2ºC compared to now.
- All models produce the same patterns, which are well understood
  - More warming: over land than ocean, over the arctic than tropics; in winter than in summer
- Models vary in *amplitude* of pattern by -30% to +50%

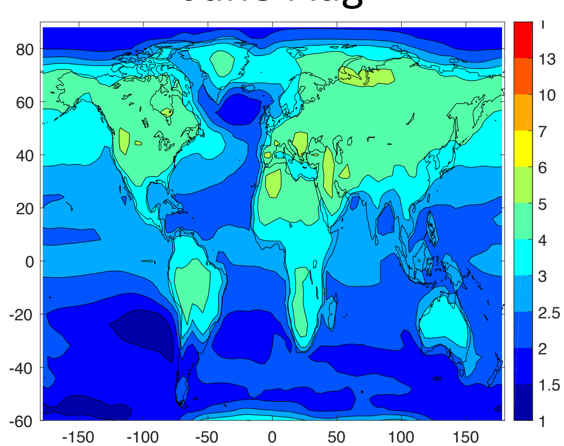
2090 most likely (3.0ºC warming)

Annual Mean

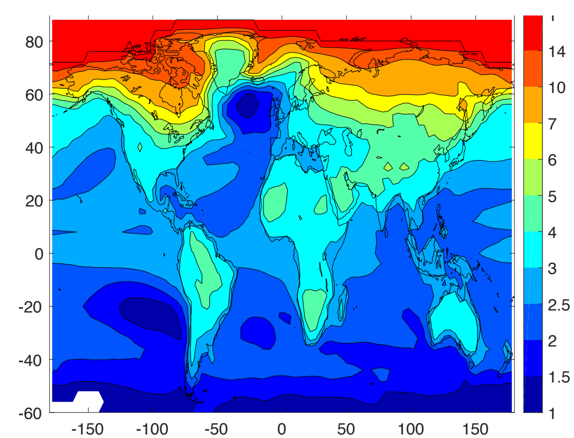


Note change in scale

June-Aug

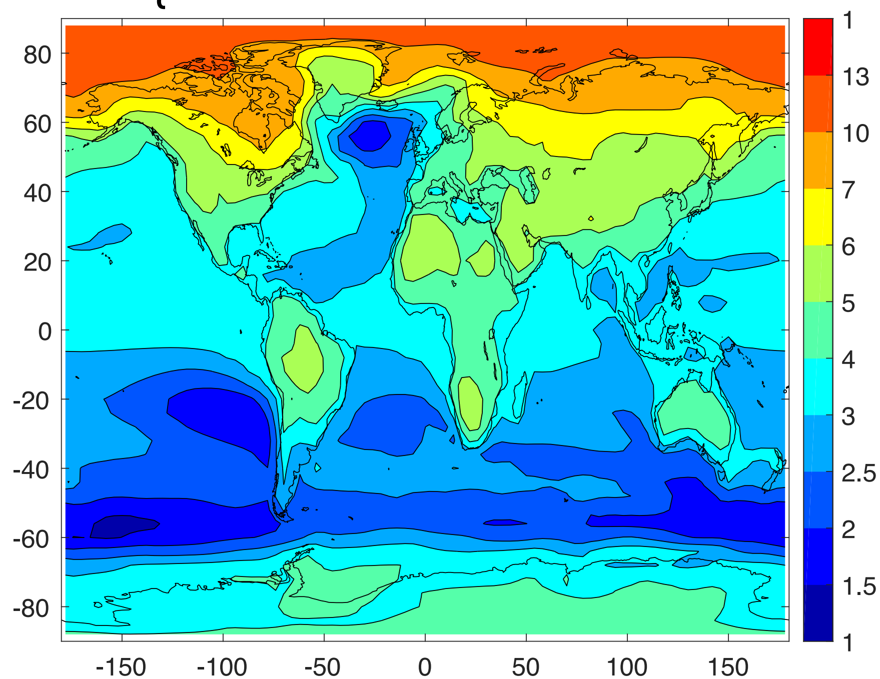


Dec-Feb



2090 with B.A.U. emissions (3.7ºC warming)

Annual Mean



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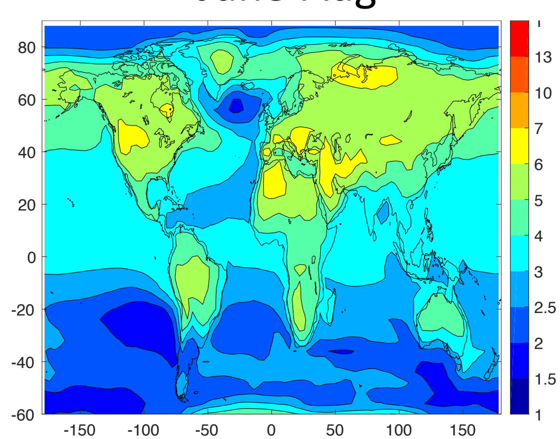
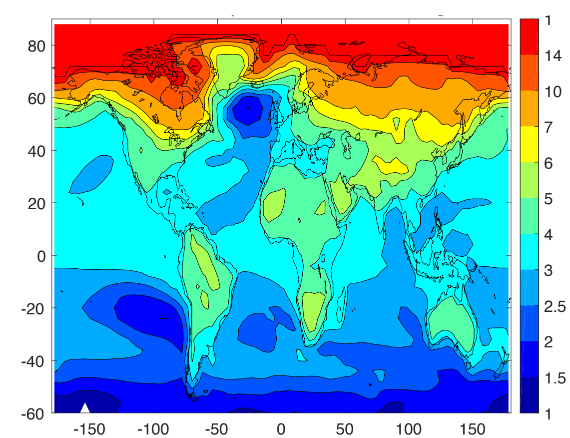


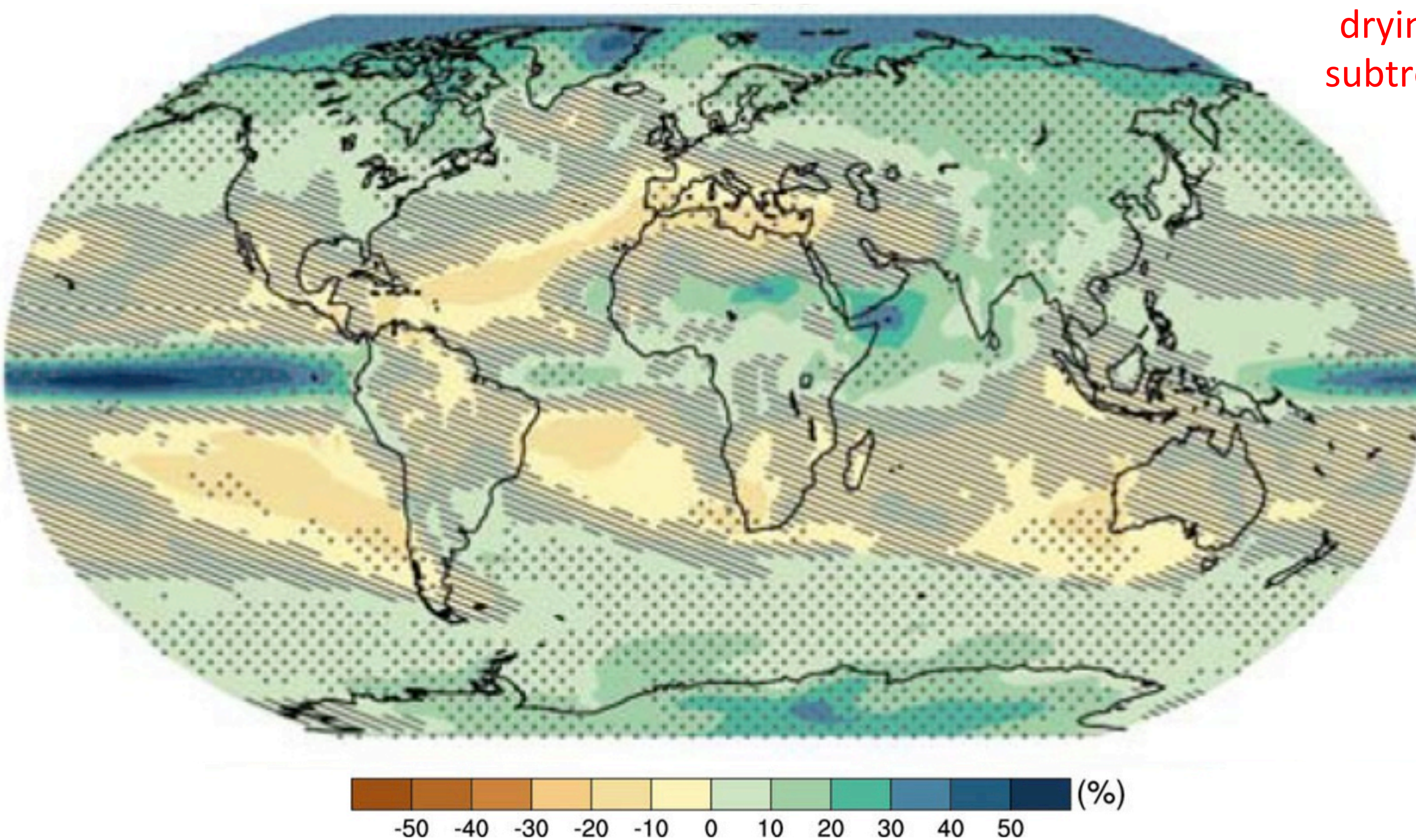
Dec-Feb



Projected Annual Precipitation

Detectable increase in high latitudes; drying in subtropics

Average over all Models

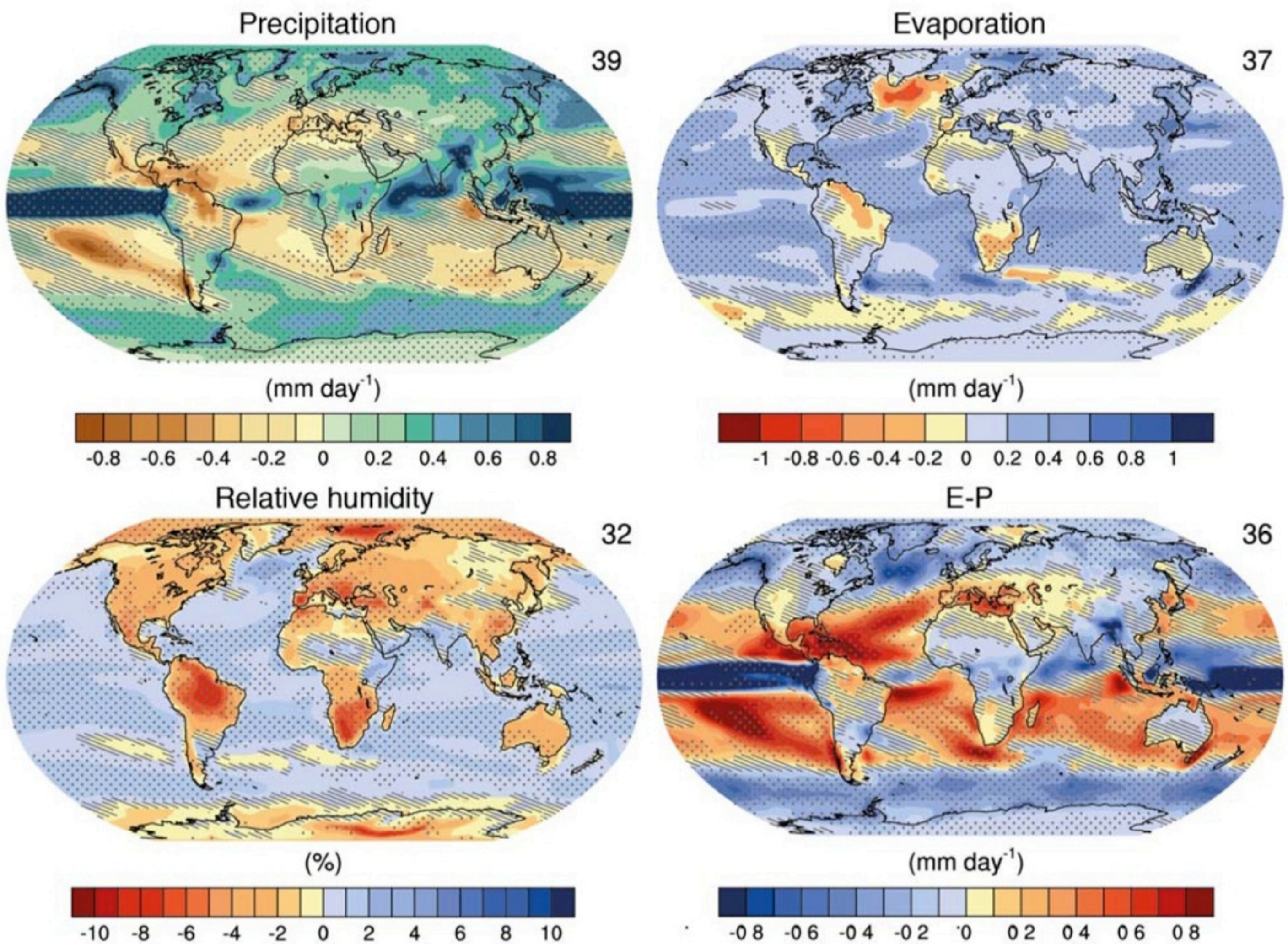


Hatching indicates areas where projected changes are small compared to the internal variability; stippling indicates regions where the projected changes in multi-model mean are at least two standard deviations greater than internal variability and where at least 90% of the models agree on the sign of change.

Figure TS.16

Annual Mean Hydrological Changes (RCP8.6)

2081-2100 relative to 1986–2005



Less precip & more evaporation → drying of soil

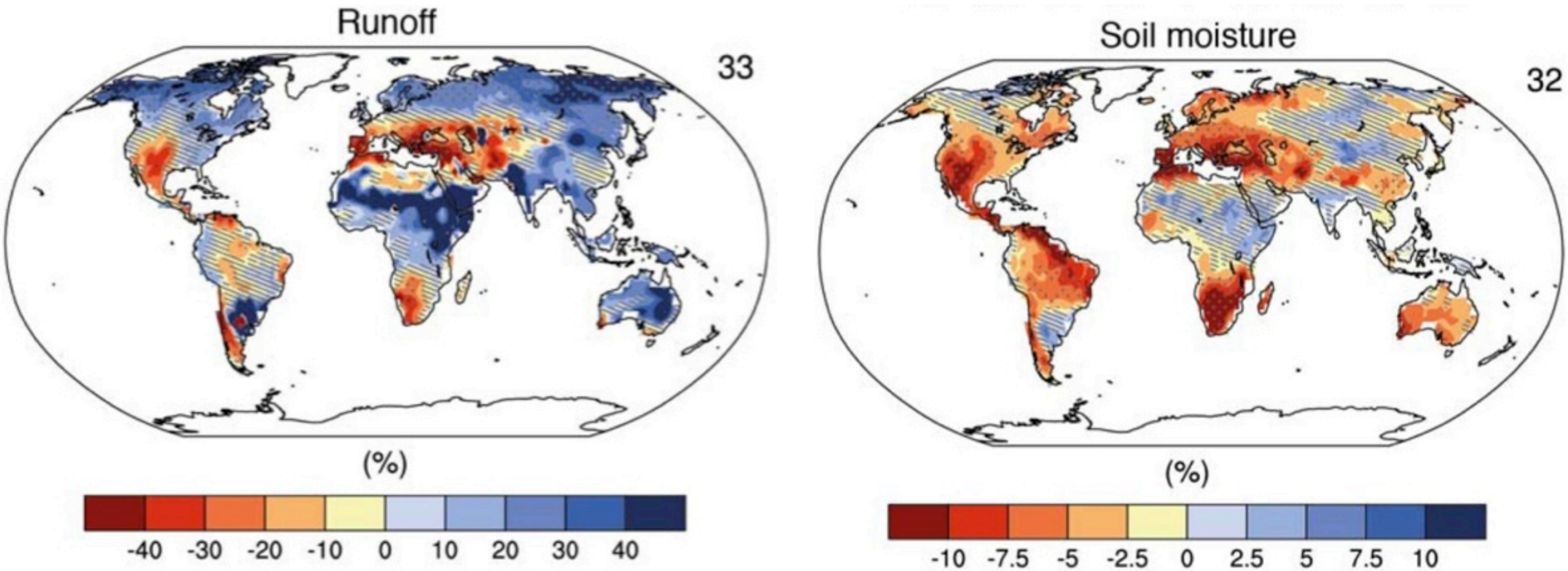
Hatching indicates areas where projected changes are small compared to the internal variability; stippling indicates regions where the projected changes in multi-model mean are at least two standard deviations greater than internal variability and where at least 90% of the models agree on the sign of change.

Figure TFE.1 Fig 2

Annual Mean Hydrological Changes (RCP8.6)

2081-2100 relative to 1986–2005

Average over all Models



Less precip & more evaporation → drying of soil in the western US, southern Europe, southern African and Brazil

Hatching indicates areas where projected changes are small compared to the internal variability; stippling indicates regions where the projected changes in multi-model mean are at least two standard deviations greater than internal variability and where at least 90% of the models agree on the sign of change.

Figure TFE.1 Fig 2

The climate of 2050:
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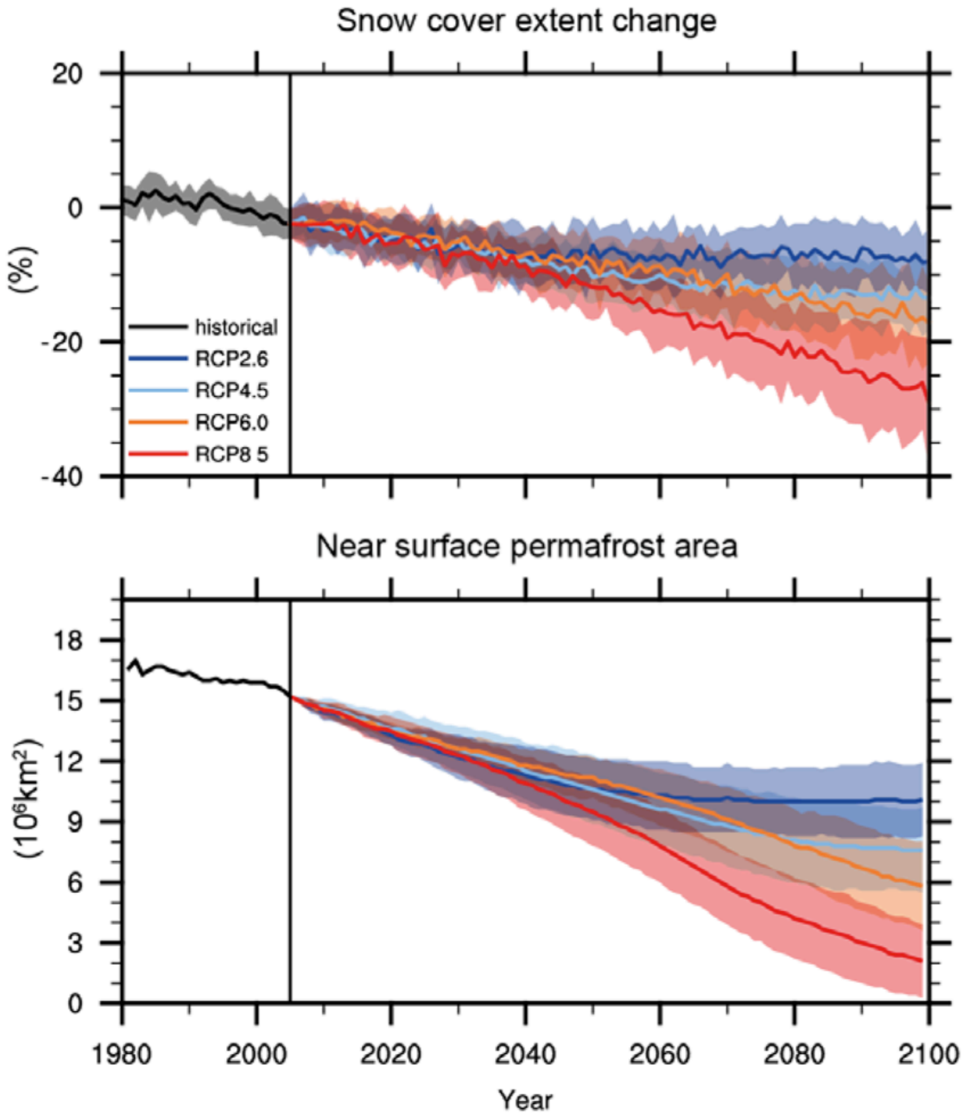
Other

- Less cold days and nights; more warm days and nights
- Less frost days
- Hotter and more frequent “extremely hot days”
- Hotter and more frequent heat waves, extreme droughts and floods
- Over land:
  - specific humidity increases (~4%)
  - relative humidity decreases (~4%)
- NH area covered by snow in winter/spring decreases by ~10%
- Sea ice area and thickness reduced
- On average, a 15 cm rise in sea level

Projected NH Land Ice and Snow



Change in Area Covered in March/ April (reference period 1986–2005)

- ~20% decrease in area covered by snow
- ~70% decrease in area covered by permafrost

Figure TS.18

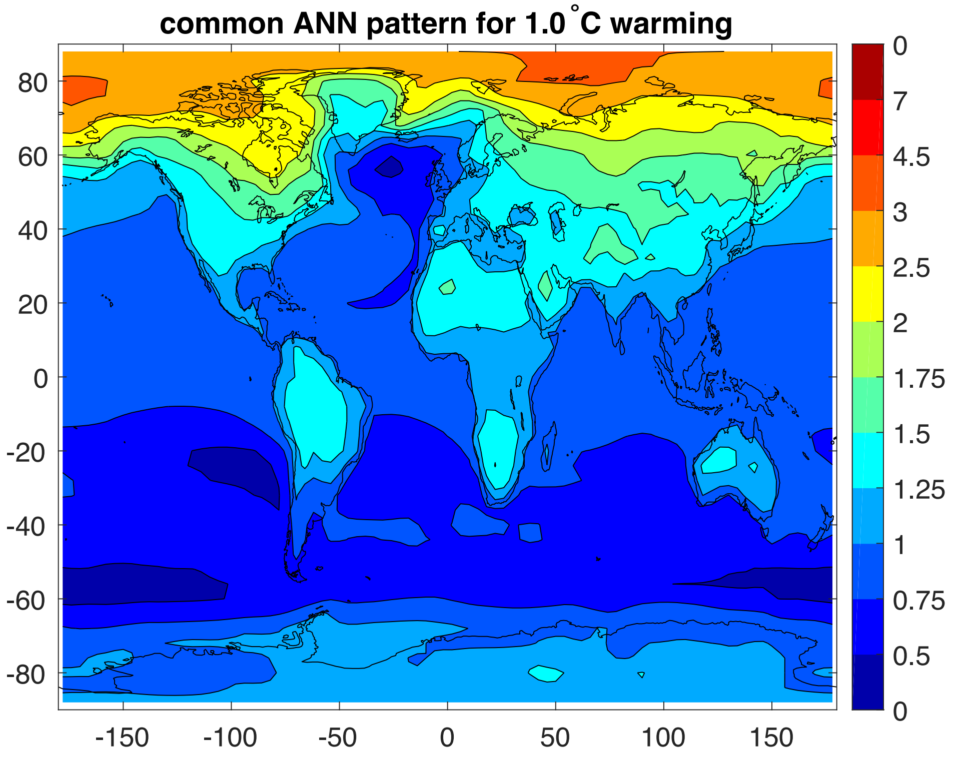
The climate of 2050:
changes that are certain

Terrestrial

- Temperature
- Precipitation: less in southern Europe
- Other: relative humidity, snowpack, sea ice

Marine

- Upper ocean warming
- Small surface salinity increase in subtropical Atlantic (~0.3%)
- Surface ocean acidifies by 15% in 2050; 50% by 2090



Ocean Salinity Changes

over the next 30 years or so

Changes are small, however: typically +/- 0.3%

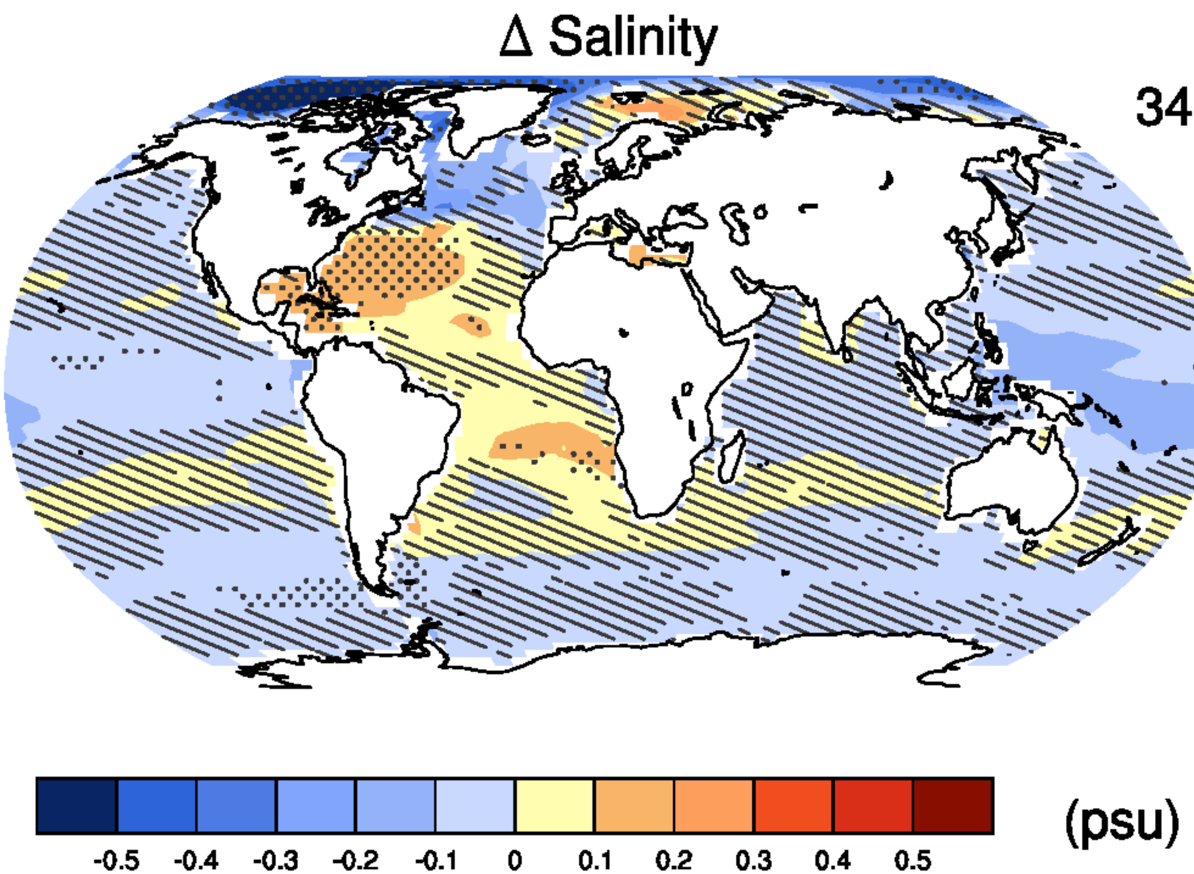


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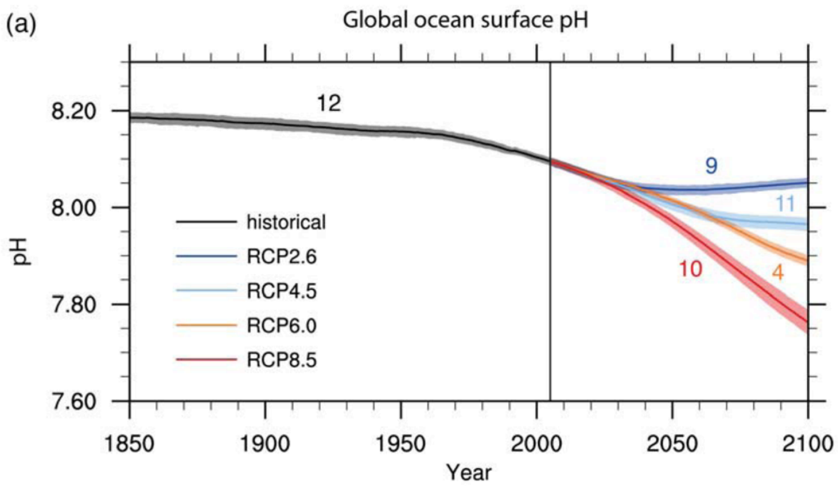
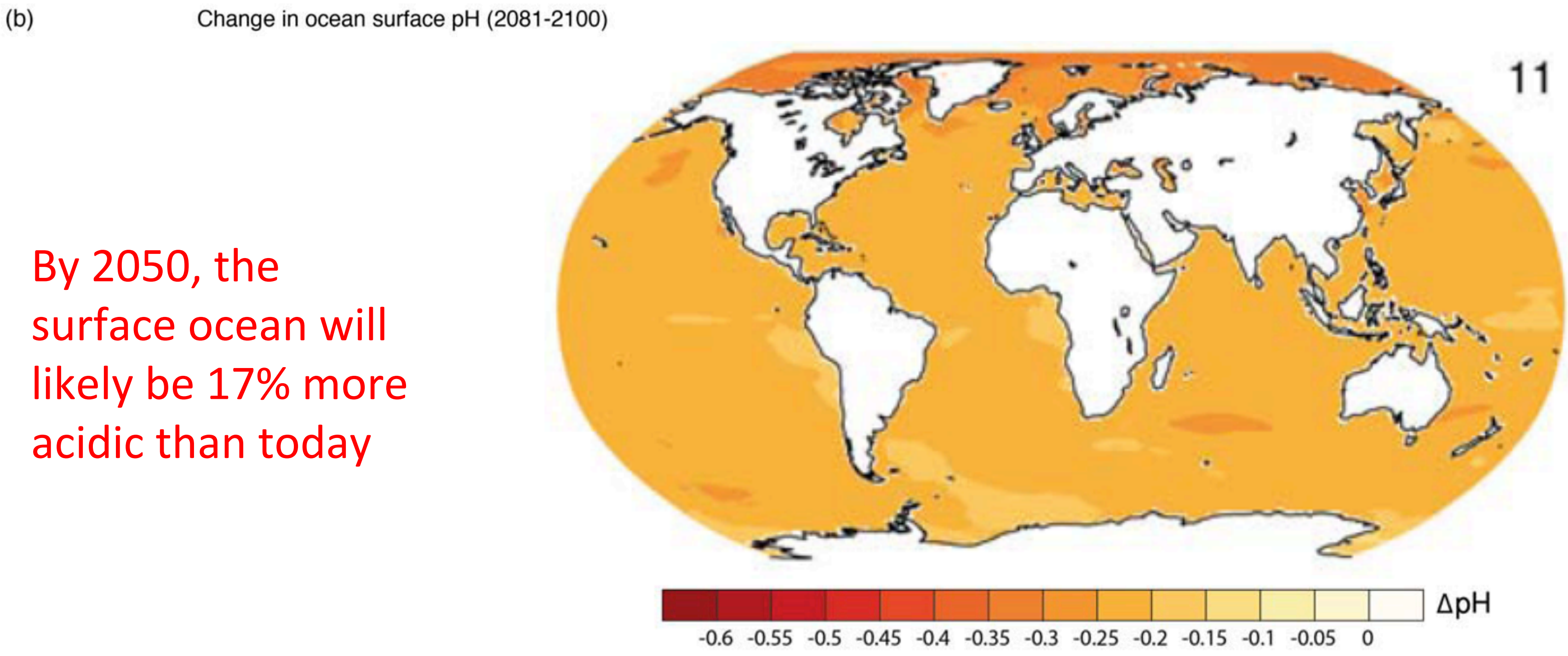
Fig. 11.20

Projected changes in surface ocean pH

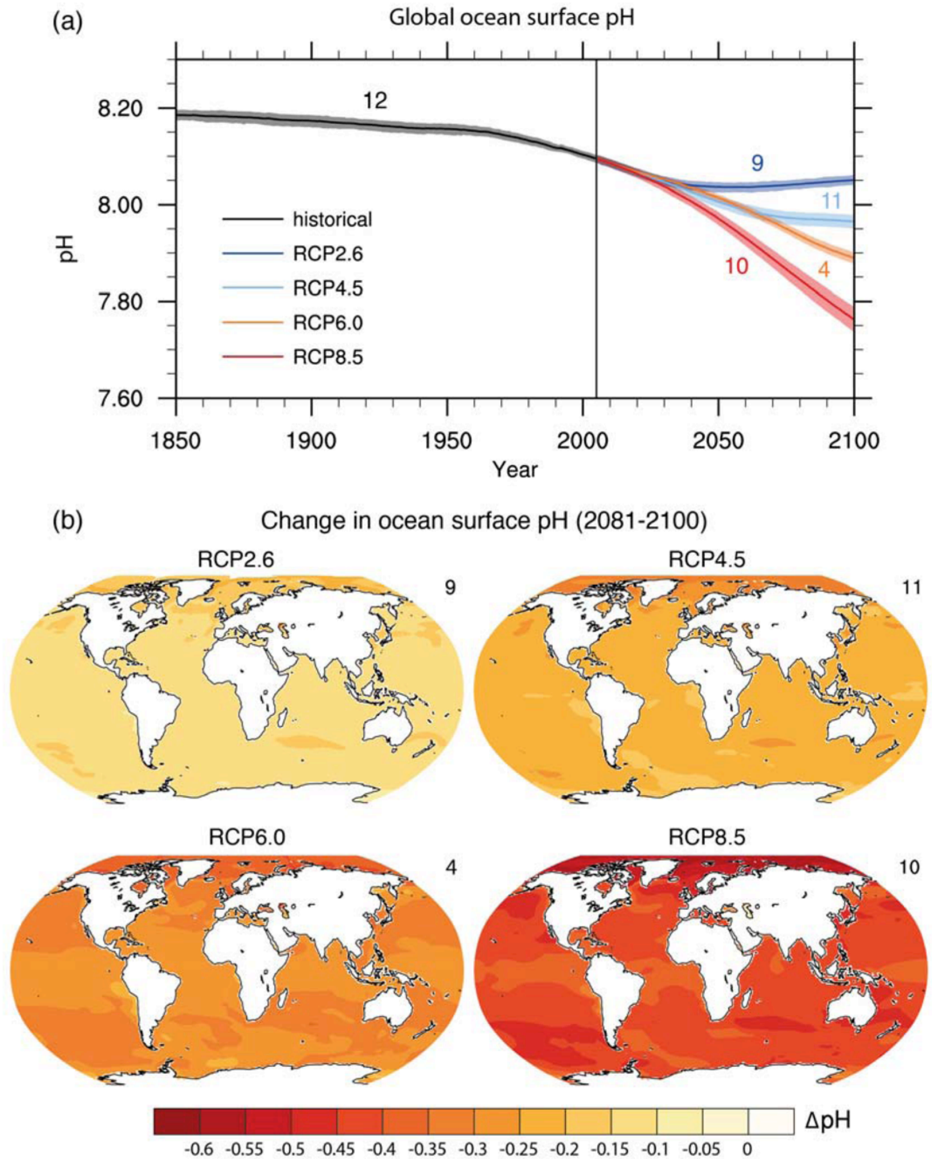




By 2050, the surface ocean will likely be 17% more acidic than today

Figure TS.20

Projected changes in surface ocean pH



The global ocean will be 2 to 3 times more acidic

Figure TS.20

The climate of 2050:
changes that are certain

Terrestrial

- Temperature
- Precipitation: less in southern Europe
- Other: relative humidity, snowpack, sea ice

Marine

- Upper ocean warming
- Near surface salinity changes
- Ocean acidification

Things you may want to know, but we don't (yet)

- Soil moisture, precipitation, changes in weather *variability*, etc..
- Winds

How long would forcing by humans last if we suddenly stopped emitting everything?

- Carbon Dioxide
  - About 1/2 removed in **3000 years** (absorbed in the deep ocean)
  - Most gone by 10,000 years
- Methane
  - About 70% removed in 10 years (absorbed into soil)
  - Most gone by 20 years
- CFCs
  - 50 to 20,000 years, depending on compound
- Aerosols
  - In troposphere, about 5 days
  - In stratosphere, about 2 years

Editorial note: Carbon credits for reducing methane will, at best, waste money. It will likely lead lead to *more* CO_2 in the atmosphere.