Drivers of Climate Change

SIT – Iceland and Greenland: Climate Change and the Arctic

Monday, 27 February 2017

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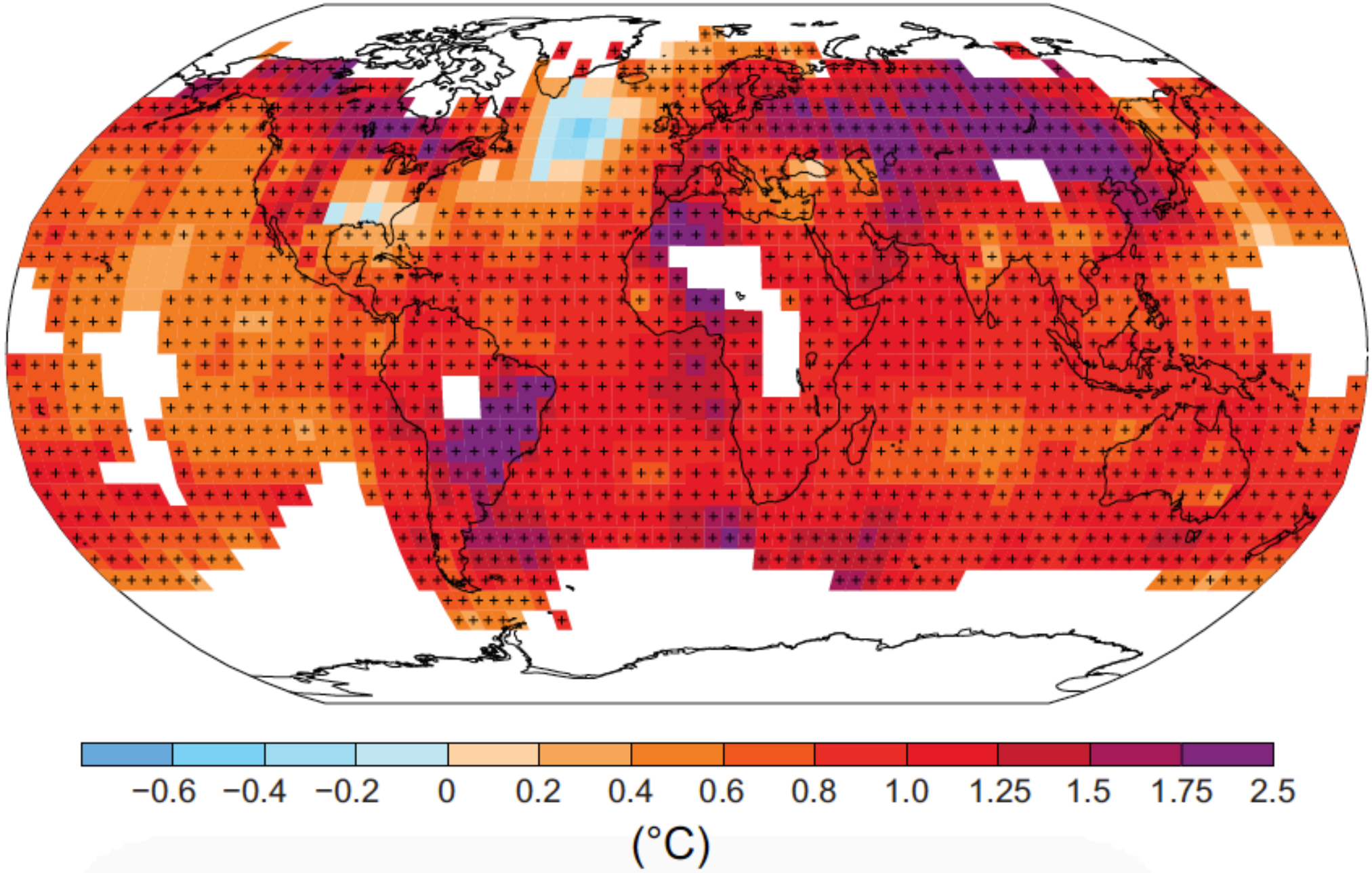
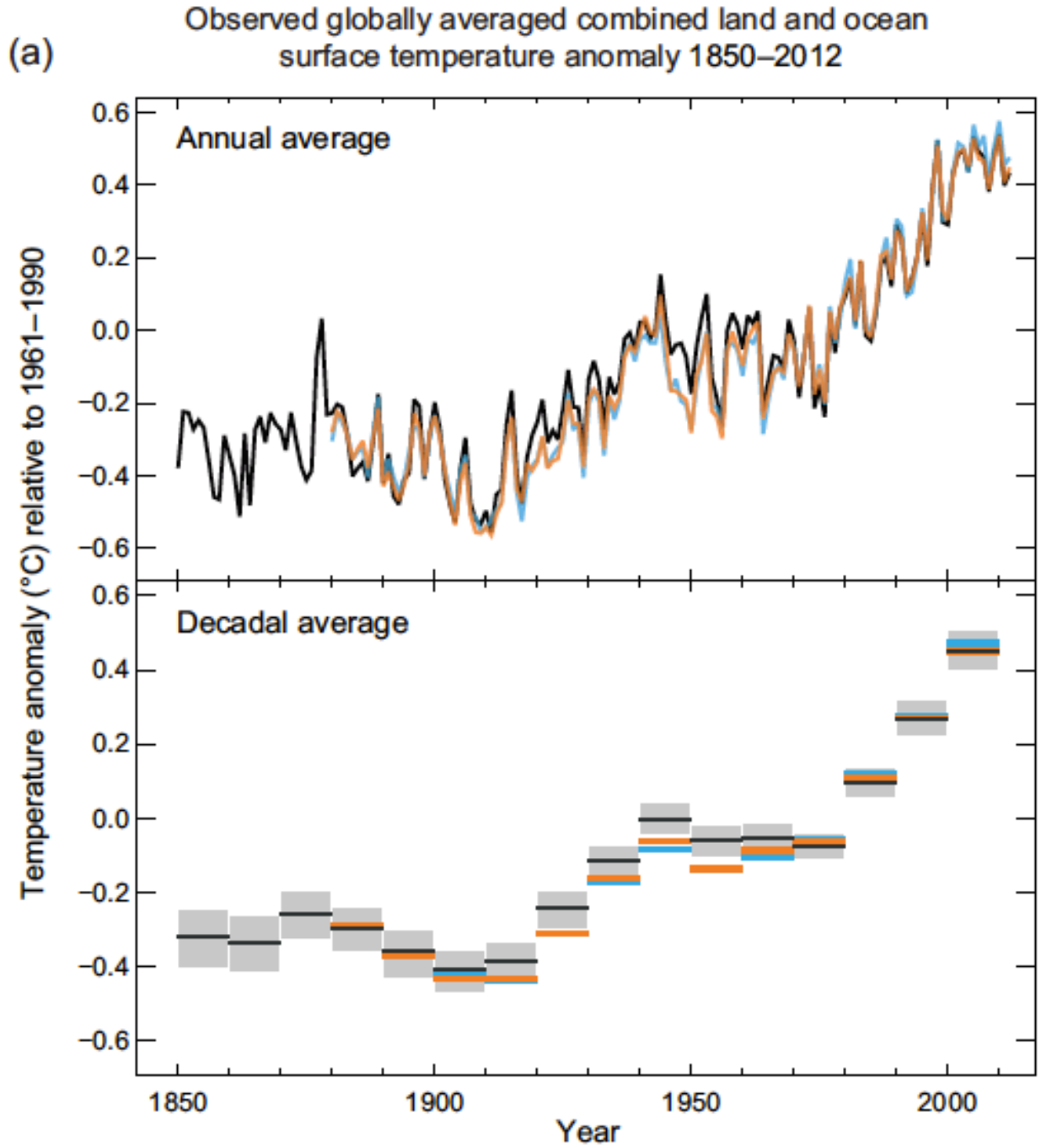
Observed patterns

- Climate
- Each of last three decades successively warmer
- Almost the entire globe has experienced warming

Observed change in surface temperature 1901–2012





0.85°C from 1880-2012

1983-2012 likely warmest 30-year period in last 1400 years

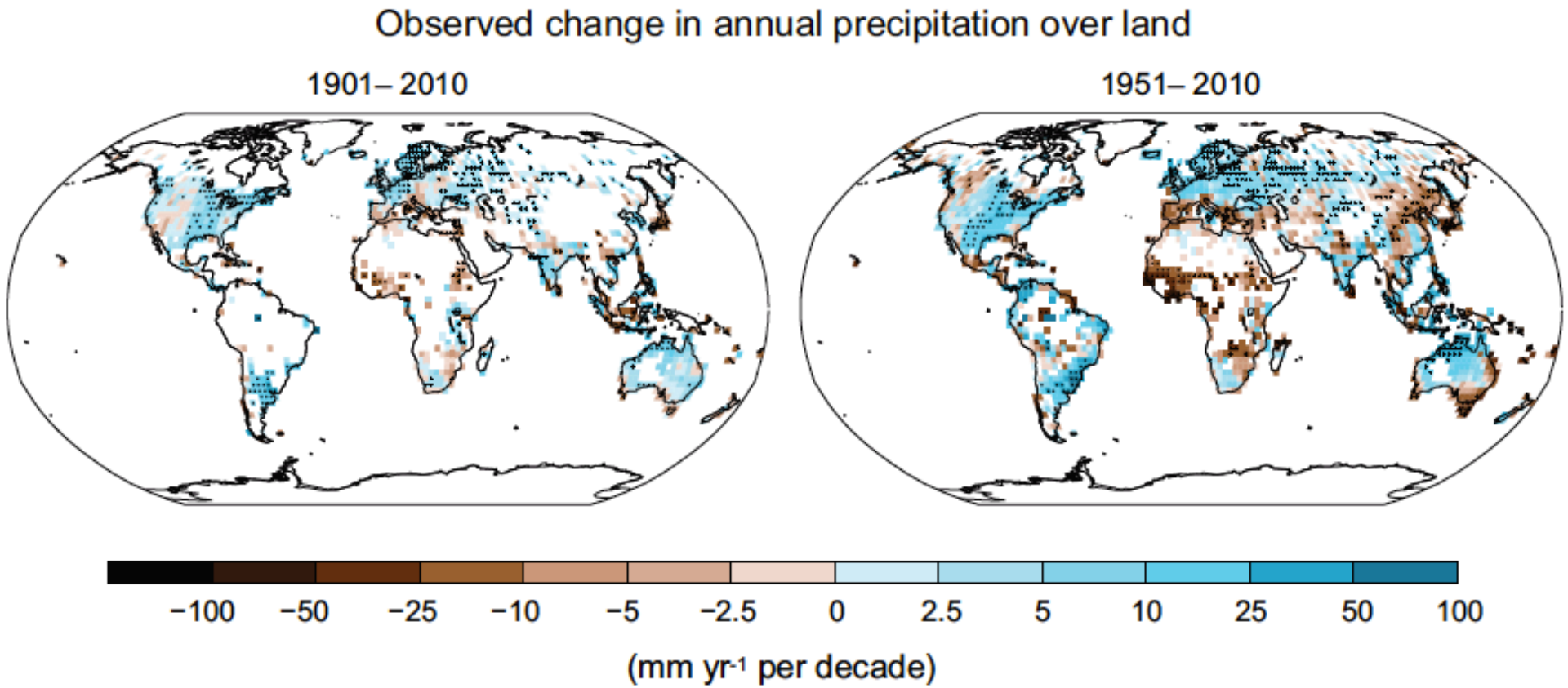
Analyzing trends

- Trends based on short-term records can be deceiving and don't reflect long-term trends

- Medieval Climate Anomaly (950-1250)
  - Warming occurred locally and was not coherent across regions

- Virtually certain that globally the troposphere has warmed since mid-20th century

Precipitation and extreme weather



Drivers of climate change

- Substances and processes that alter the Earth's energy budget

- Two main categories?

Drivers of climate change

- Substances and processes that alter the Earth's energy budget

- Two main categories
  - Natural
  - Anthropogenic

Natural?

Natural

- Solar irradiance
- Volcanic aerosols

Standard measurement for drivers

- Radiative forcing (RF)
  - Measure of flux
  - 2011 levels relative to 1750 levels
  - For emitted compounds, there is no difference in calculations of concentration-based and emission-based RF
  - W m^{-2}

Solar irradiance

- Solar output varies slightly over time

- RF from solar irradiance is 0.05 W m^{-2}
  - From 1986-2008, -0.04 W m^{-2}
    - Satellite data from 1978-2011 showing last solar minimum was lower than previous two

Stratospheric volcanic aerosols

- RF of -0.11 W m^{-2} from 2008-2011

- Short-term effect

Anthropogenic?

Anthropogenic

- Greenhouse gases
- Short-lived gases
- Aerosols

Greenhouse gases

Greenhouse gases

- CO_2
- CH_4
- N_2O
- Halocarbons

Short-lived gases

Short-lived gases

- CO
- NO_x

Aerosols

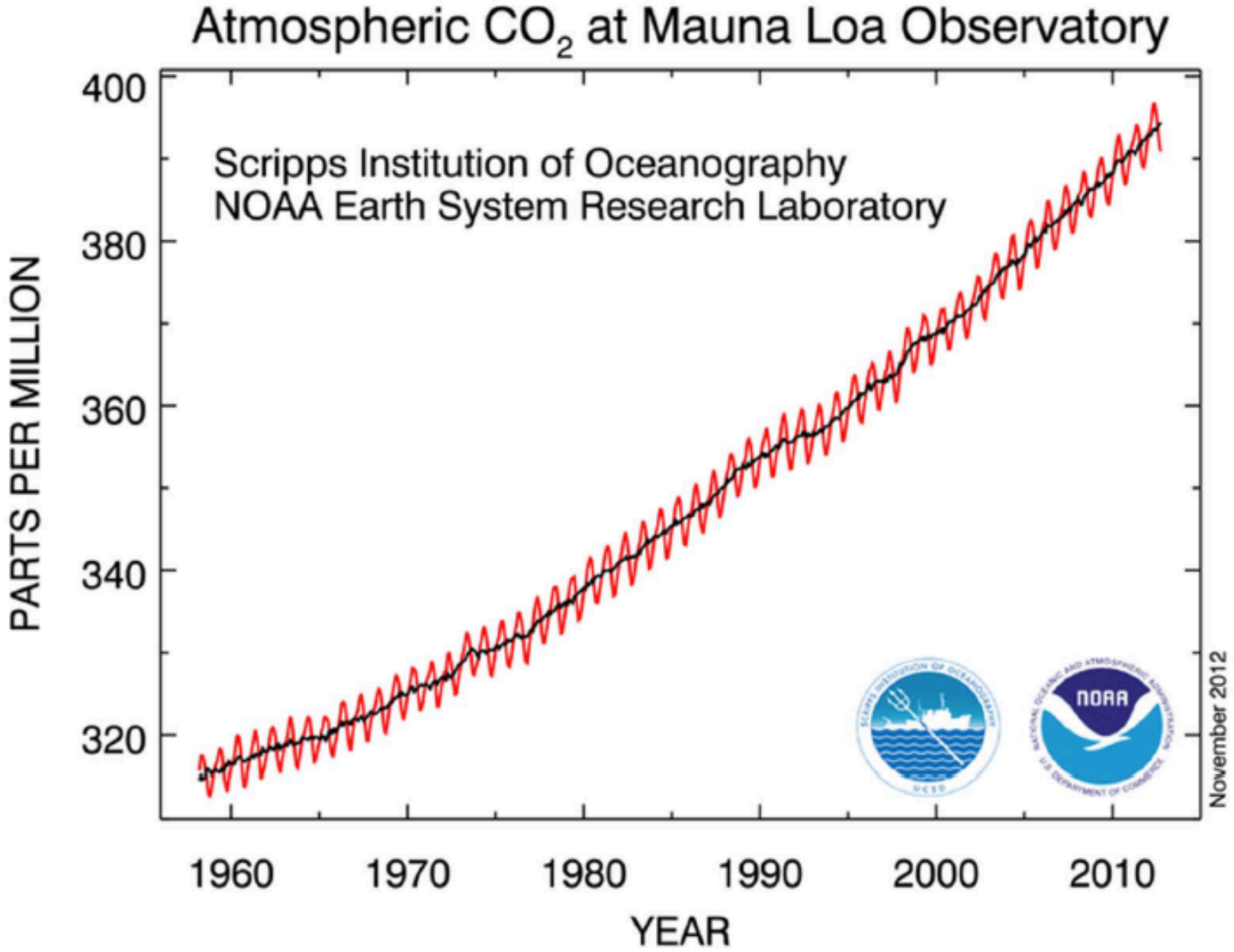
Aerosols

- Mineral dust
- SO_2
- NH_3
- OC
- Black C

Greenhouse gases: CO_2

Greenhouse gases: CO_2

- Fossil fuels
  - Heat, electricity, transportation
  - 2011 – 33.2 Gt
    - Coal (43%), oil (36%), natural gas (20%)
- Land use changes
  - Deforestation – removal of C sink
  - 2011 – 3.3 Gt
- Industrial processes
  - Cement, steel, chemical and petrochemical
- *Natural sources larger than anthropogenic



http://www.esrl.noaa.gov/gmd/ccgg/trends/

Greenhouse gases: CH_4

Greenhouse gases: CH_4

- Fossil fuels
  - Production, distribution, combustion (33%)
  - 110 Mt y_{-1}
- Livestock (27%)
- Landfills and waste (16%)
- Burning of biomass (11%)
- Rice production (9%)
- Biofuels (4%)

Greenhouse gases: N_2O

Greenhouse gases: N_2O

- Agriculture (67%) – 4.5 Mt y^{-1}
  - Manure and fertilized soils (42%), runoff and leaching of fertilizer (25%)
- Fossil fuel consumption and industrial processes (10%)
- Biomass burning (10%)
- Atmospheric deposition (9%)
- Human sewage (3%)

- *Natural sources larger than anthropogenic

Greenhouse gases: halocarbons

Greenhouse gases: halocarbons

- Ozone depletion
- Long-standing awareness

Short-lived gases: CO and NO_x

Short-lived gases: CO and NO_x

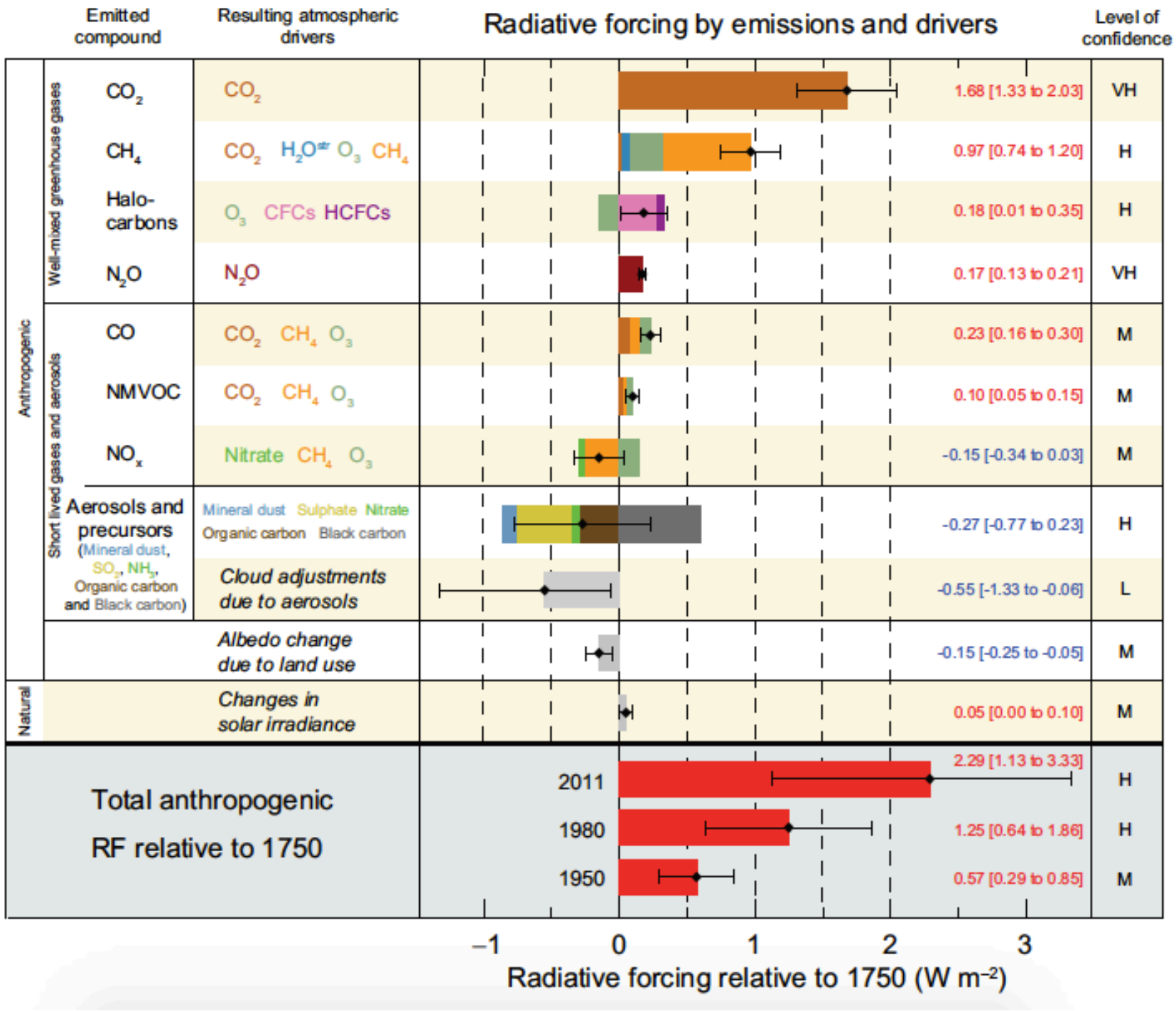
- CO: incomplete combustion of fossil fuels and biomass
- NO_x: combustion

Aerosols

- Mineral dust
- SO_2
- NH_3
- OC
- Black C

Aerosols

- Mineral dust – mostly natural from deserts
  - Human-induced land use changes account for about 25%
- SO_2 – burning of fossil fuels
- NH_3 - agriculture
- OC – fossil fuels
- Black C – incomplete combustion of fossil and biofuels and biomass


Emitted compound
Resulting atmospheric drivers
Radiative forcing by emissions and drivers
Level of confidence
Anthropogenic
Well-mixed greenhouse gases
Short lived gases and aerosols
Natural
CO2
CH4
Halo-carbons
N2O
CO
NMVOC
NOx
Aerosols and precursors (Mineral dust, SO2, NH3, Organic carbon and Black carbon)
Cloud adjustments due to aerosols
Albedo change due to land use
Changes in solar irradiance
CO2
CO2 H2O* O3 CH4
O3 CFCs HCFCs
N2O
CO2 CH4 O3
CO2 CH4 O3
Nitrate CH4 O3
Mineral dust Sulphate Nitrate
Organic carbon Black carbon
1.68 [1.33 to 2.03]
VH
0.97 [0.74 to 1.20]
H
0.18 [0.01 to 0.35]
H
0.17 [0.13 to 0.21]
VH
0.23 [0.16 to 0.30]
M
0.10 [0.05 to 0.15]
M
-0.15 [-0.34 to 0.03]
M
-0.27 [-0.77 to 0.23]
H
-0.55 [-1.33 to -0.06]
L
-0.15 [-0.25 to -0.05]
M
0.05 [0.00 to 0.10]
M
Total anthropogenic RF relative to 1750
2011
1980
1950
2.29 [1.13 to 3.33]
H
1.25 [0.64 to 1.86]
H
0.57 [0.29 to 0.85]
M
−1
0
1
2
3
Radiative forcing relative to 1750 (W m−2)

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes	
			Early 21st century	Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely*	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely* (nights only)	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** on a global scale *Likely* in large parts of Europe, Asia and Australia {2.6} *Medium confidence* in many (but not all) regions *Likely*	***Likely***[a] {10.6} Not formally assessed *More likely than not*	Not formally assessed[b] {11.3}	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely* more land areas with increases than decreases[c] {2.6} *Likely* more land areas with increases than decreases *Likely* over most land areas	***Medium confidence*** {7.6, 10.6} *Medium confidence* *More likely than not*	*Likely* over many land areas {11.3}	***Very likely*** over most of the mid-latitude land masses and over wet tropical regions {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	***Low confidence*** on a global scale *Likely* changes in some regions[d] {2.6} *Medium confidence* in some regions *Likely* in many regions, since 1970[e]	***Low confidence*** {10.6} *Medium confidence*[f] *More likely than not*	*Low confidence*[g] {11.3}	***Likely*** *(medium confidence)* on a regional to global scale[h] {12.4} *Medium confidence* in some regions *Likely*[e]
Increases in intense tropical cyclone activity	***Low confidence*** in long term (centennial) changes *Virtually certain* in North Atlantic since 1970 {2.6} *Low confidence* *Likely* in some regions, since 1970	***Low confidence***[i] {10.6} *Low confidence* *More likely than not*	*Low confidence* {11.3}	***More likely than not*** in the Western North Pacific and North Atlantic[j] {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970) {3.7} *Likely* (late 20th century) *Likely*	***Likely***[k] {3.7} *Likely*[k] *More likely than not*[k]	*Likely*[l] {13.7}	***Very likely***[l] {13.7} *Very likely*[m] *Likely*

Arctic

- Greenland ice sheet loss
  - 1992-2001 – 34 Gt yr^{-1}
  - 2002-2011 – 275 Gt yr^{-1}
- Northern hemisphere snow cover extent 1967-2012
  - Decreased 1.6% per decade in March and April
  - Decreased 11.7% per decade in June
  - No statistical increase in any month
- Permafrost temperature early 1980s-mid 2000s
  - Warming of up to 3°C in AK
  - Warming of up to 2°C in Russia and northern Europe
    - Considerable reduction in thickness and areal extent

Why?