The Challenge of Providing Scientific Information on Policy-Relevant Scales

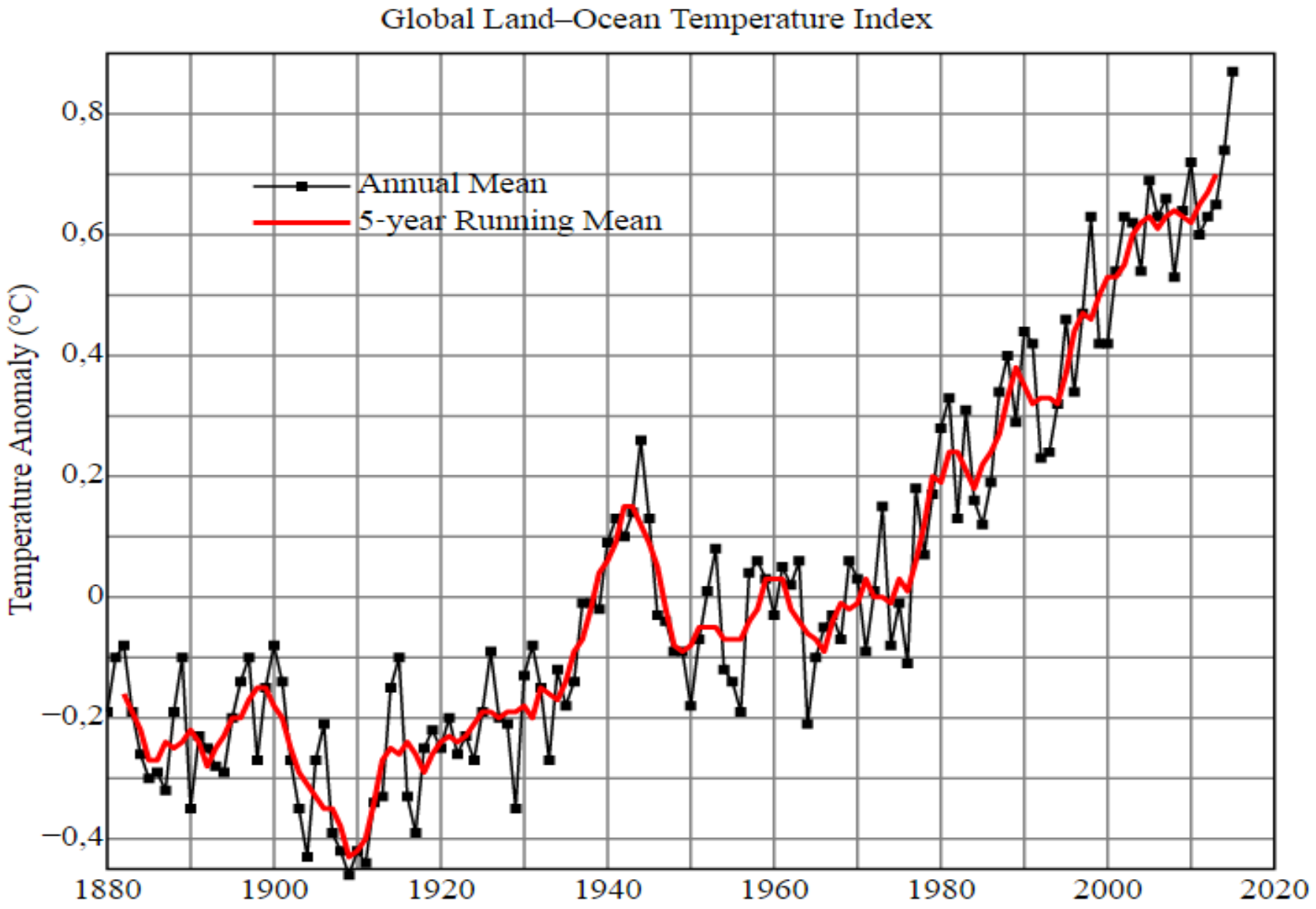
James Butler, Phil DeCola, Oksana Tarasova,
plus a cast of 100's . . .

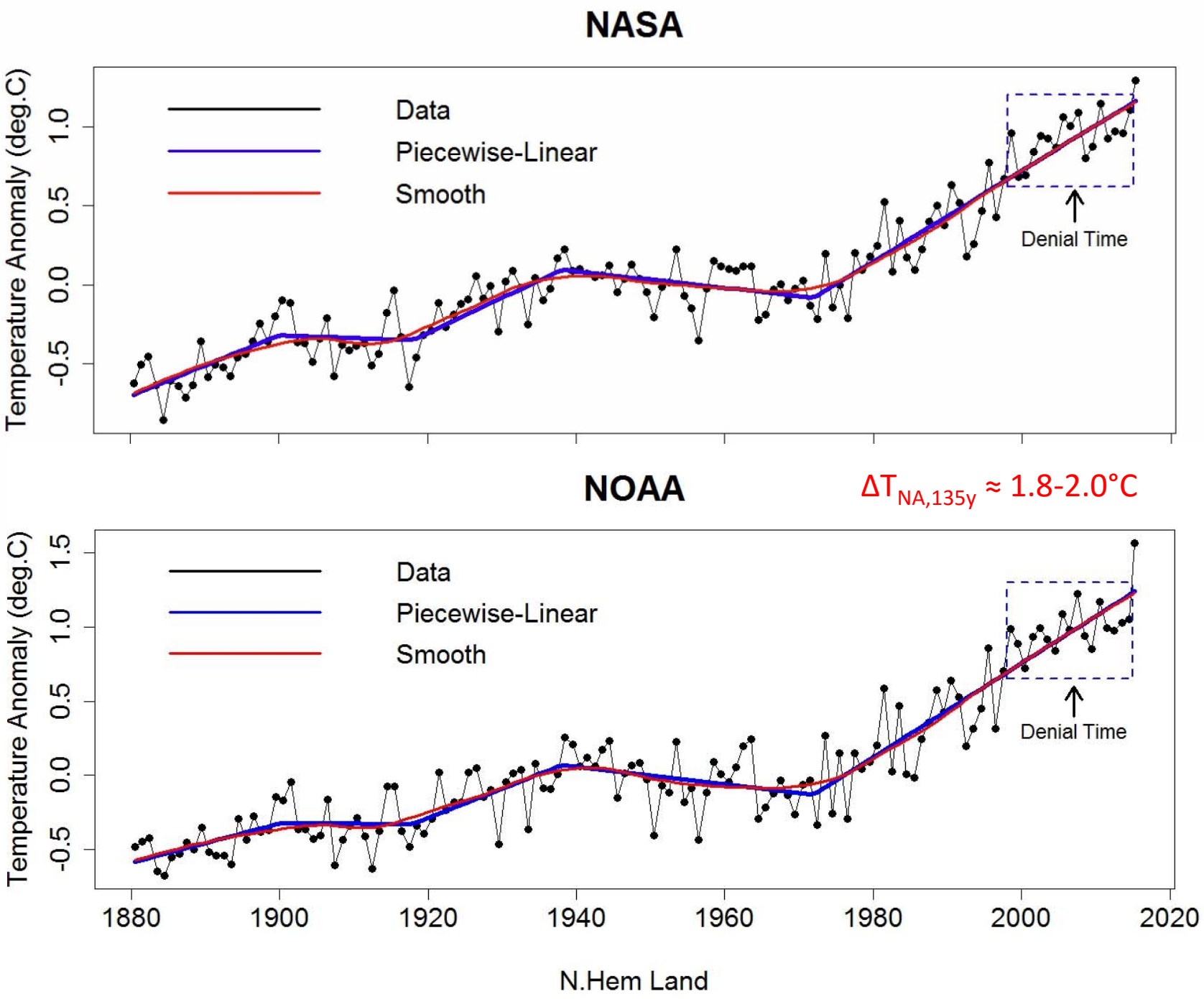
29 September 2016

Second ICOS Science Conference
Helsinki, Finland

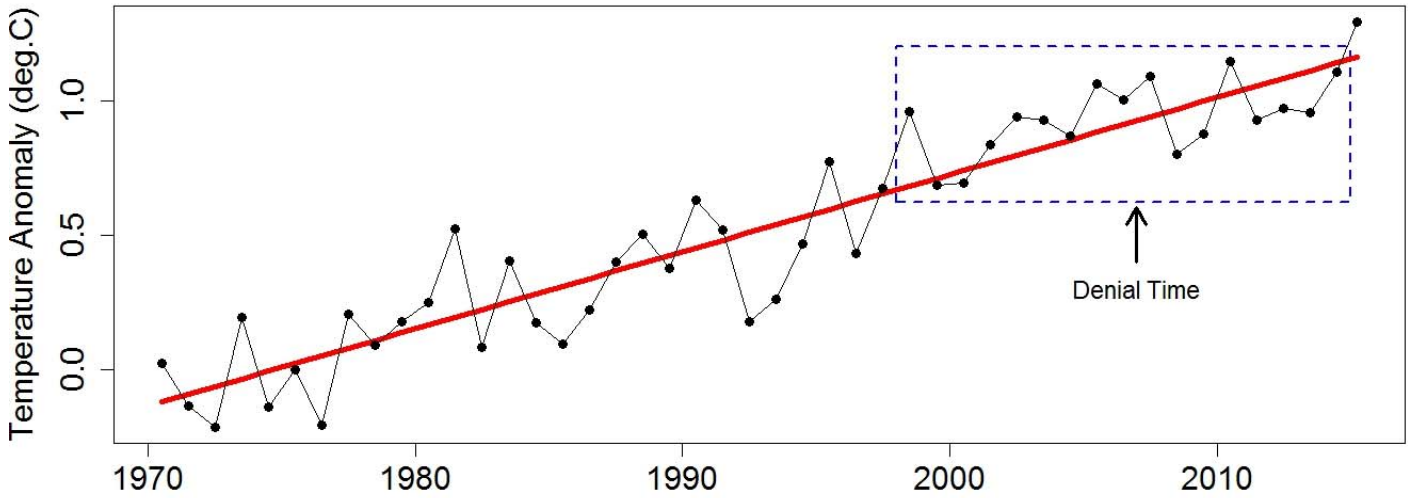
A few words about temperature

Global Average Temperature



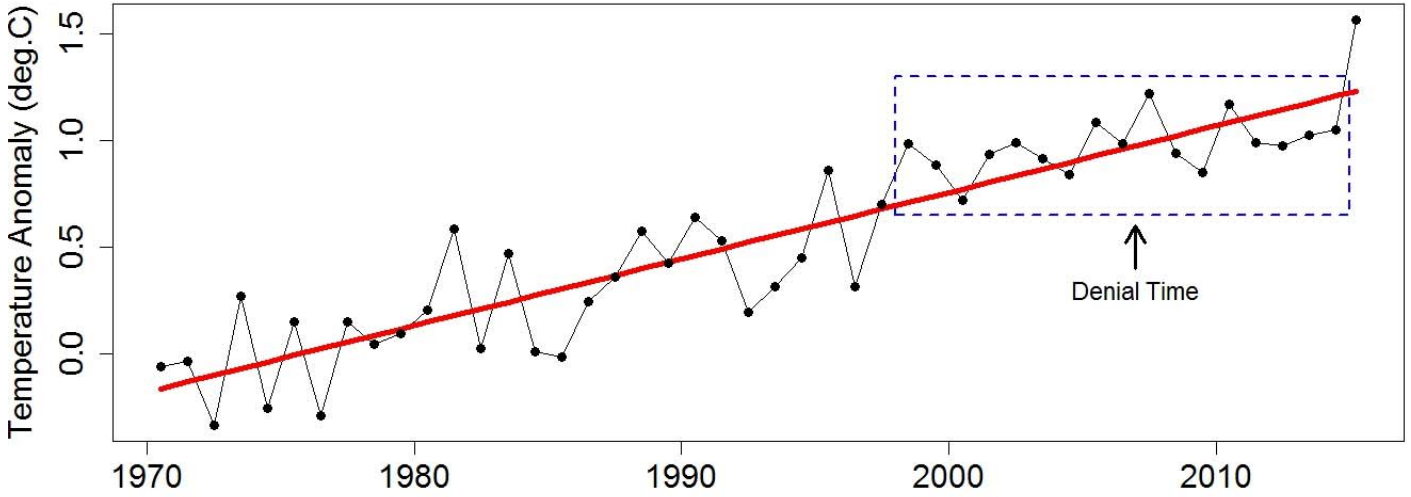

NASA
Temperature Anomaly (deg.C)
-0.5
0.0
0.5
1.0
Data
Piecewise-Linear
Smooth
Denial Time
NOAA
$\Delta T_{NA,135y} \approx 1.8\text{-}2.0°C$
Temperature Anomaly (deg.C)
-0.5
0.0
0.5
1.0
1.5
Data
Piecewise-Linear
Smooth
Denial Time
1880
1900
1920
1940
1960
1980
2000
2020
N.Hem Land

NASA



$\Delta_{TNA,45y} \approx 1.2°C$

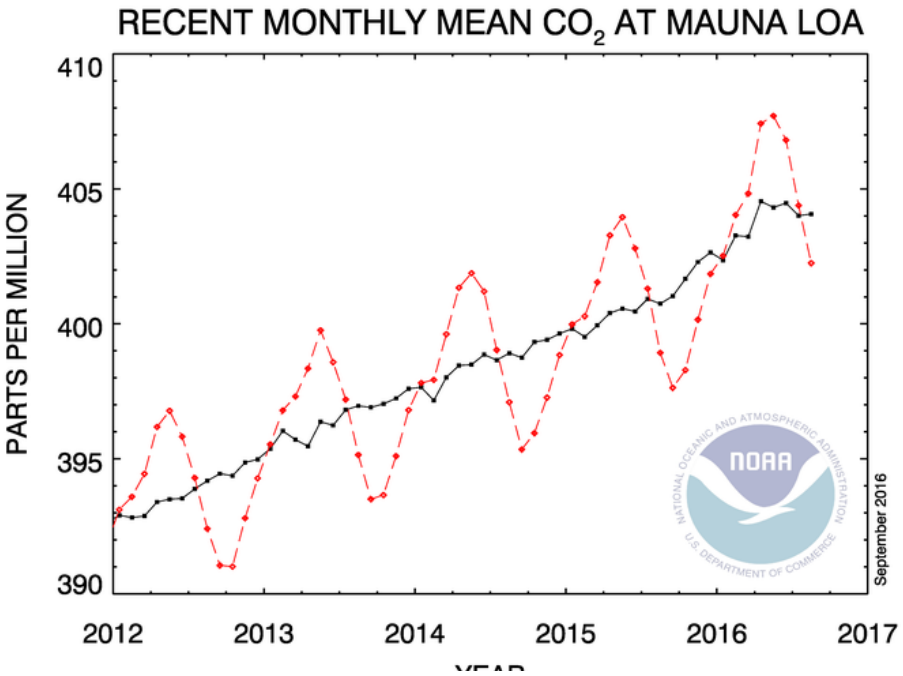
NOAA

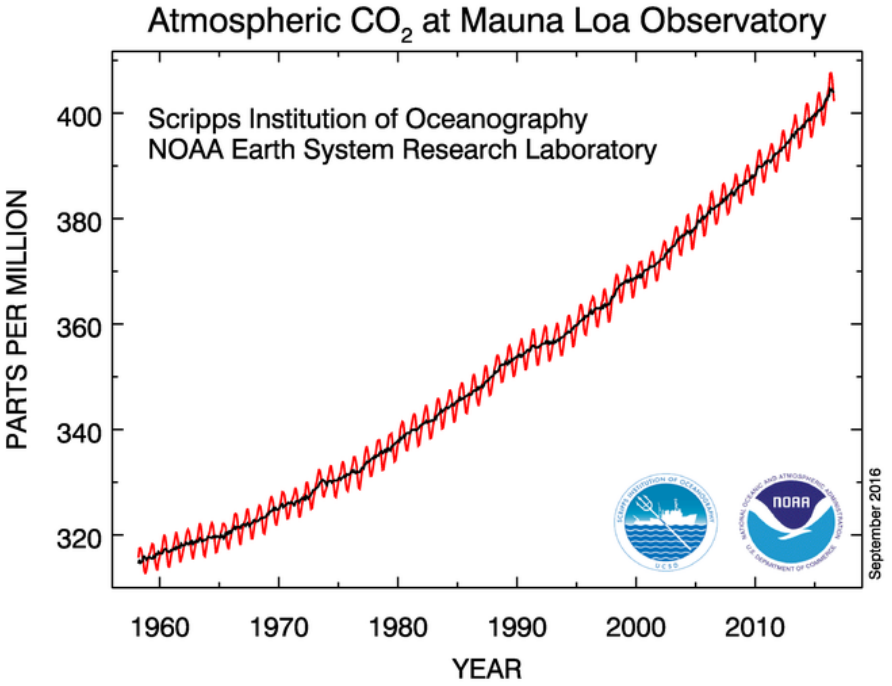


$\Delta_{TNA,45y} \approx 1.3°C$

N.Hem Land

A greenhouse gas
“refresher and update”





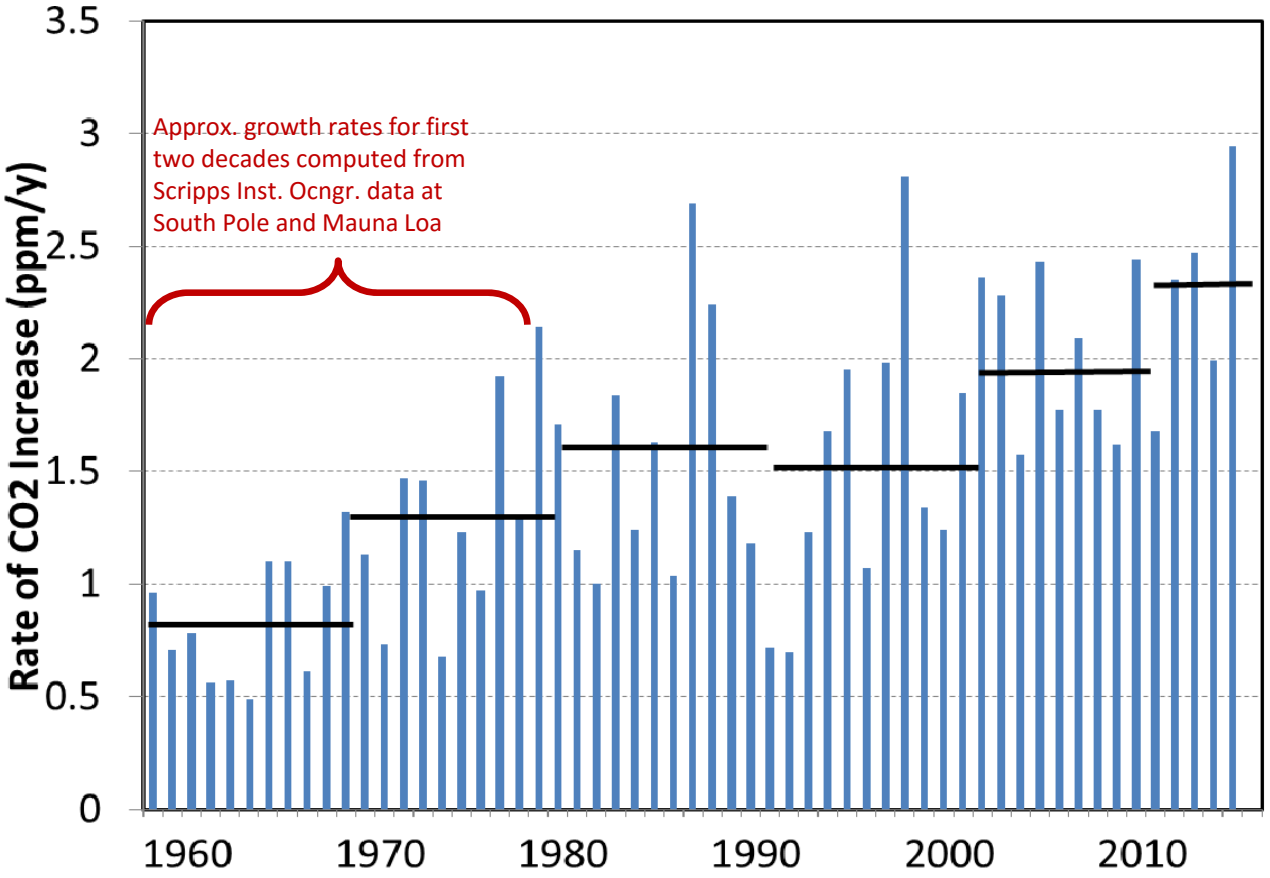
CO_2 at Mauna Loa

- August 2016
  - 402.25 ppm
- August 2015
  - 398.93 ppm
- Δ = 3.32 ppm

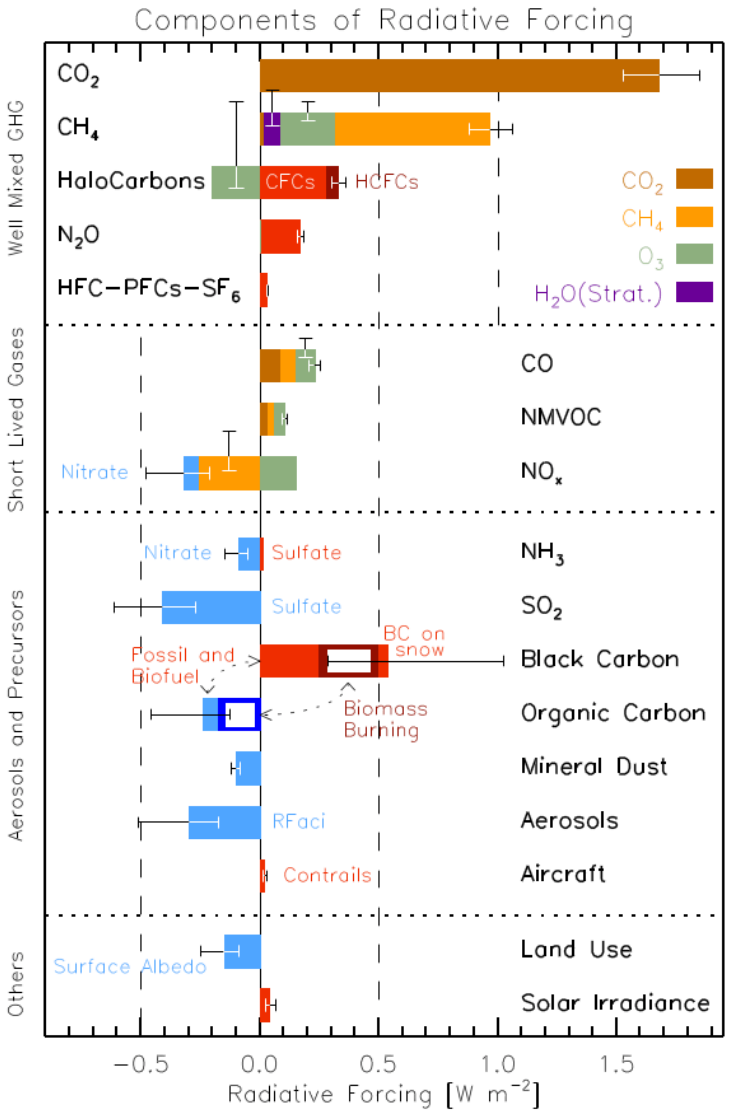
- Ouch …

Annual and Decadal Growth Rates

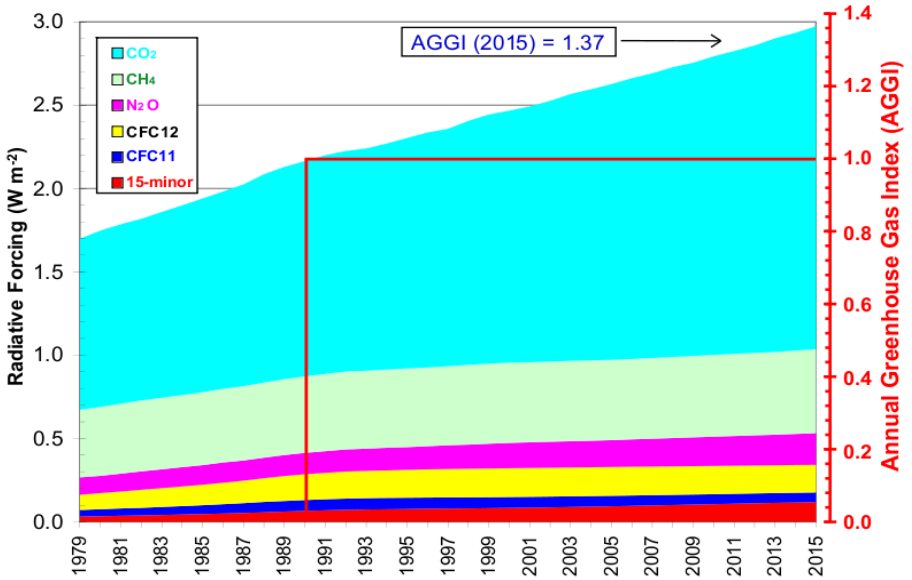
- The growth rate increases decadally
  - Variability is largely driven by the Earth System
- The Earth System continues to capture ~50% of emissions
  - Despite the increase in emissions
  - ~ First order uptake by oceans, perhaps land



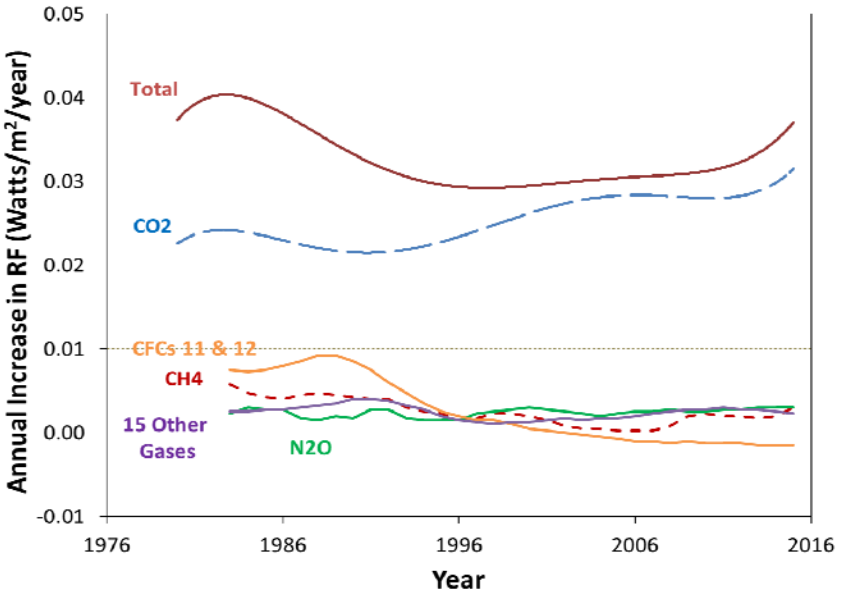
Radiative Forcing – Why we have climate change



Long lived Gases



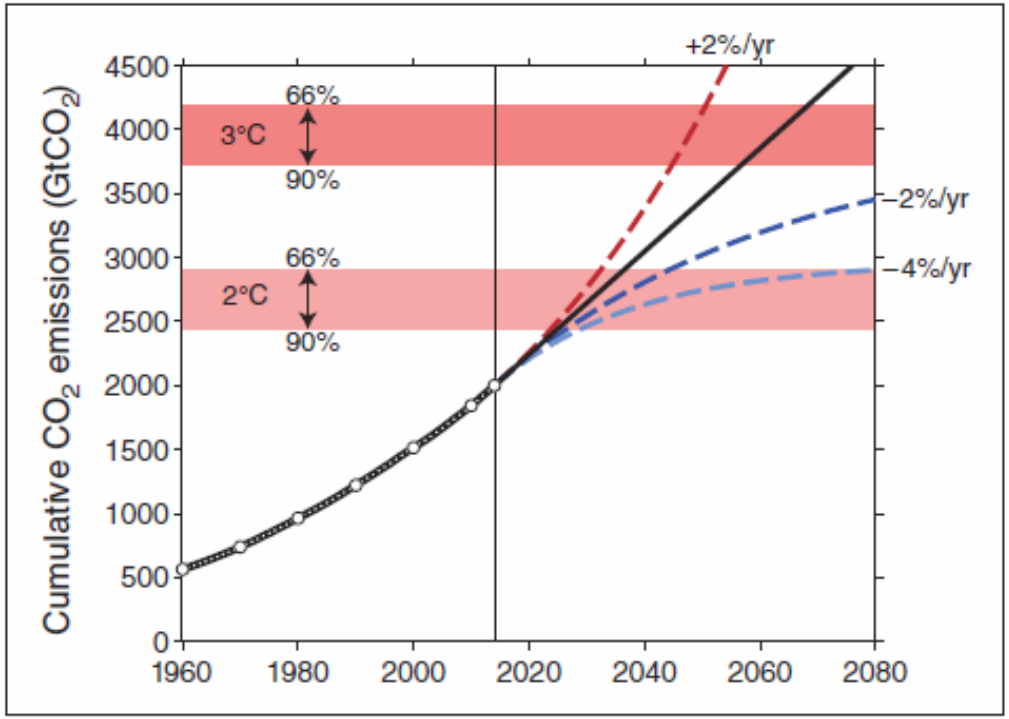
Rate of Change in Radiative Forcing



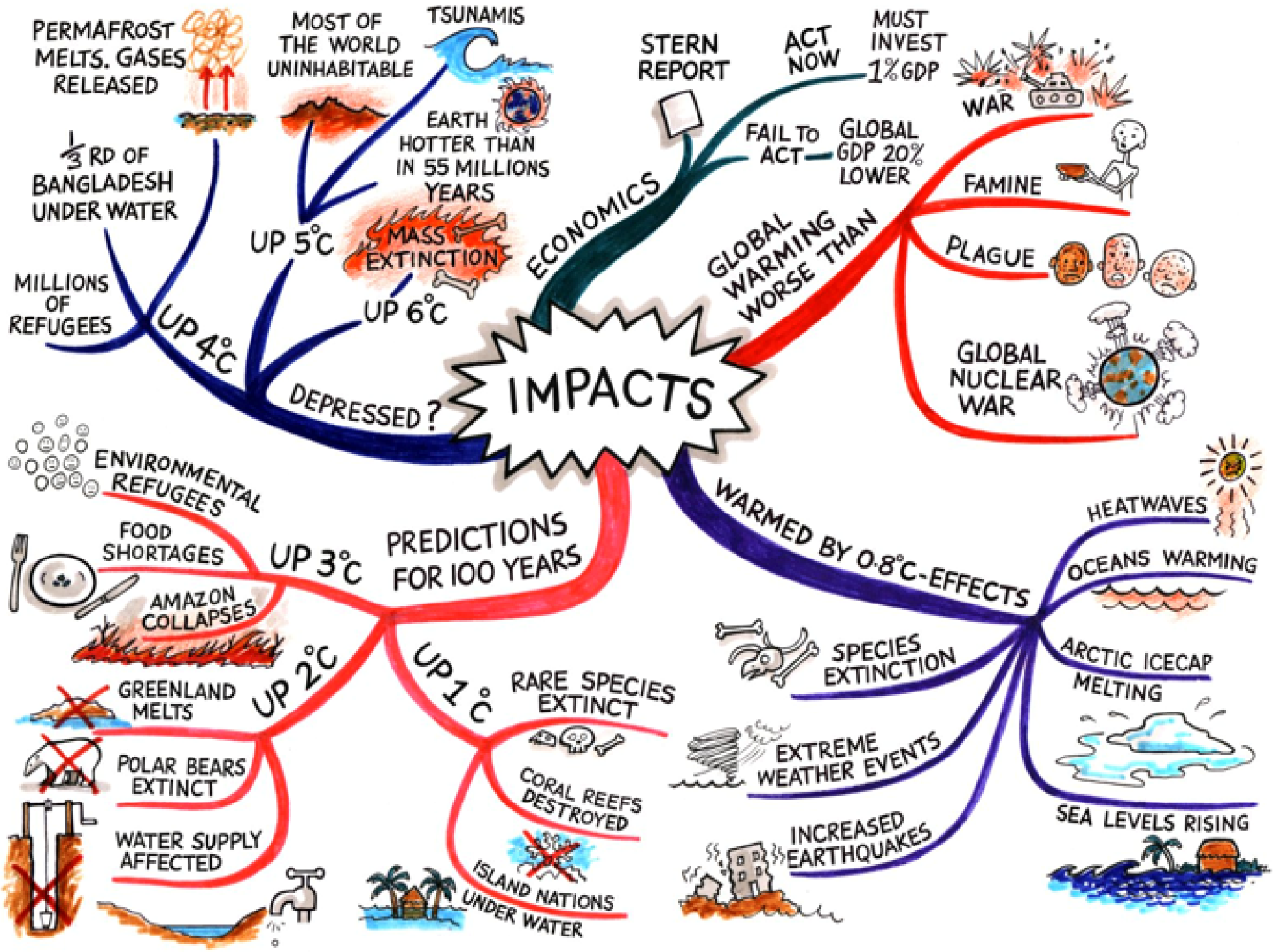
Something to think about -- Urgency

"CO_2 emissions are rising at a rate that could raise global temperature 2°C above preindustrial values within about 20 years and 3°C by midcentury"

-- Jackson et al., 2015



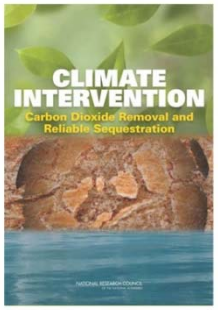
- 2°C global average = 6°C average over continents . . .
- (For US audience, that's ~11°F average over continents)
- 3°C global = ~9°C continental <u>average</u> (= ~17°F)

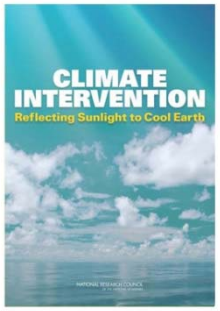

IMPACTS
PERMAFROST MELTS. GASES RELEASED
MOST OF THE WORLD UNINHABITABLE
TSUNAMIS
EARTH HOTTER THAN IN 55 MILLIONS YEARS
1/3 RD OF BANGLADESH UNDER WATER
MILLIONS OF REFUGEES
UP 4°C
UP 5°C
MASS EXTINCTION
UP 6°C
DEPRESSED?
ECONOMICS
STERN REPORT
ACT NOW
MUST INVEST 1% GDP
FAIL TO ACT
GLOBAL GDP 20% LOWER
GLOBAL WARMING WORSE THAN
WAR
FAMINE
PLAGUE
GLOBAL NUCLEAR WAR
ENVIRONMENTAL REFUGEES
FOOD SHORTAGES
UP 3°C
AMAZON COLLAPSES
PREDICTIONS FOR 100 YEARS
GREENLAND MELTS
UP 2°C
POLAR BEARS EXTINCT
WATER SUPPLY AFFECTED
UP 1°C
RARE SPECIES EXTINCT
CORAL REEFS DESTROYED
ISLAND NATIONS UNDER WATER
WARMED BY 0.8°C-EFFECTS
SPECIES EXTINCTION
EXTREME WEATHER EVENTS
INCREASED EARTHQUAKES
HEATWAVES
OCEANS WARMING
ARCTIC ICECAP MELTING
SEA LEVELS RISING

Supporting Society's Decisions

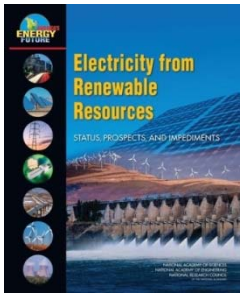
Communication

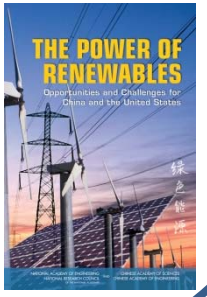
Inform Climate Intervention Decisions



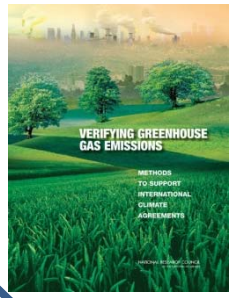


Support Development of Renewable Energy Options





Evaluate Success of Greenhouse Gas Emissions Reductions



A solution . . . ?

The 2015 Paris Agreement

PARIS2015
CONFÉRENCE DES NATIONS UNIES
SUR LES CHANGEMENTS CLIMATIQUES
COP21·CMP11

UNFCCC Process and GHG Monitoring: Both evolving from "Top Down" to "Bottom Up"

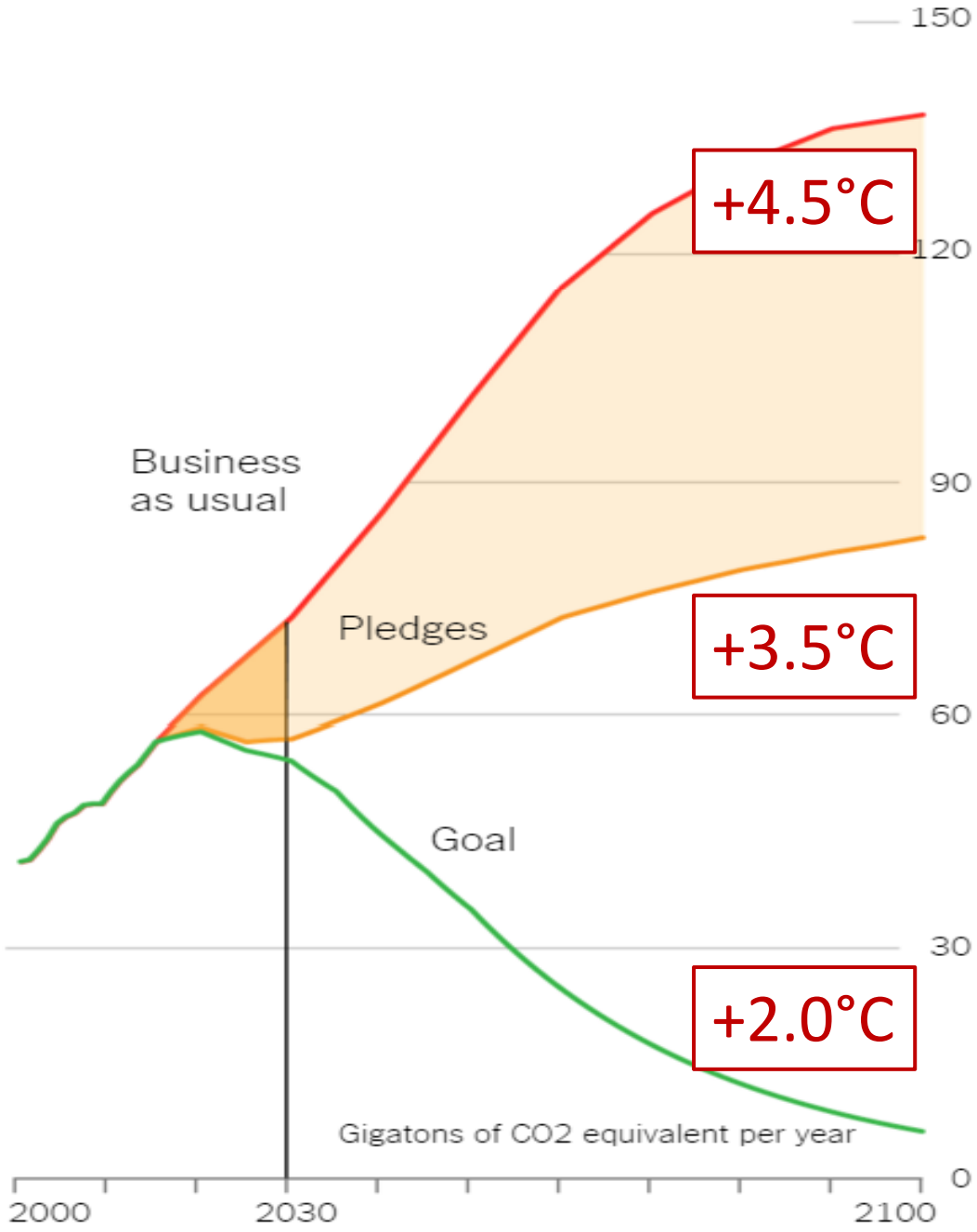
Then (2009)

Binding Multi-national Treaty Commitments

"we will verify your reported emissions"

A grand top-down GHG Information System

Advocates: Science Community!!!



A good start, but not enough….

Can science-based, evidence-based information help to guide us along solution pathways?

What do we have in place?

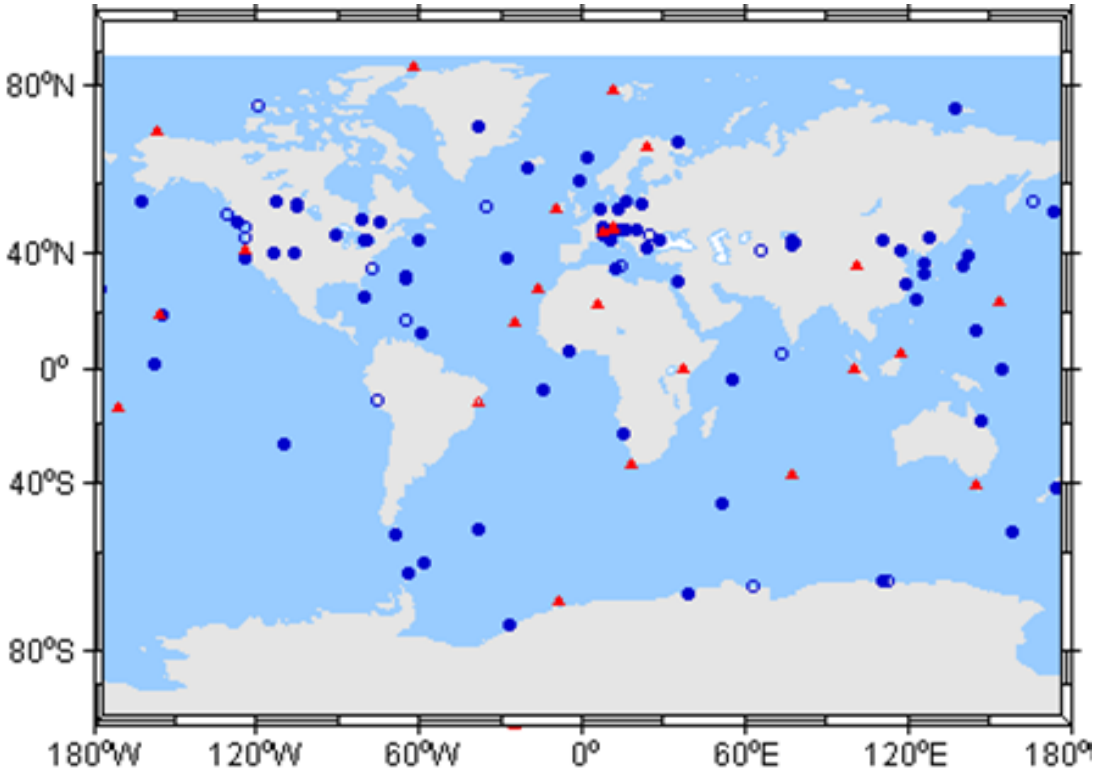
- **Current Observations**
  - WMO/GAW
    - NOAA
    - ICOS
    - CMA
    - Brazil
  - Earth Networks
  - Contrail
  - Fluxnet (e.g., Ameriflux)
  - NEON
  - TCCON
  - GOSAT (Ibuki)
  - Sciamachy*
- **Future Observations**
  - OCO-2**
  - IAGOS
  - C-14 effort over NA
  - Indonesia
- **Modeling**
  - CarbonTracker
    - US
    - EU
    - Asia
  - CAMS
  - NAME
  - Jena
  - Others . . .

An Integrated Global Greenhouse Gas Information System (IG^{3}IS)

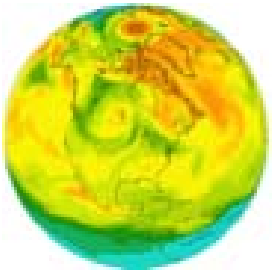
- **Goal:** Provide society with information that can aid in reducing GHG emissions
- Acknowledge that "everyone" is not on board with GHG emission reduction policies
- But many are – industry, municipalities, states, nations, regions
- Most have no clue what they are doing
- Misinformation is rampant

Gaps in current observing systems

- Insufficient density of observations over the ground, sea and in the free atmosphere
- Insufficient measurements of isotopes and co-emitted gases for source attribution
- Incompatible observations with different footprints and different approaches
- Insufficient complexity and performance of transport models on global, regional ,and local scales



An Integrated, Global, Greenhouse Gas Information System (IG^3IS)

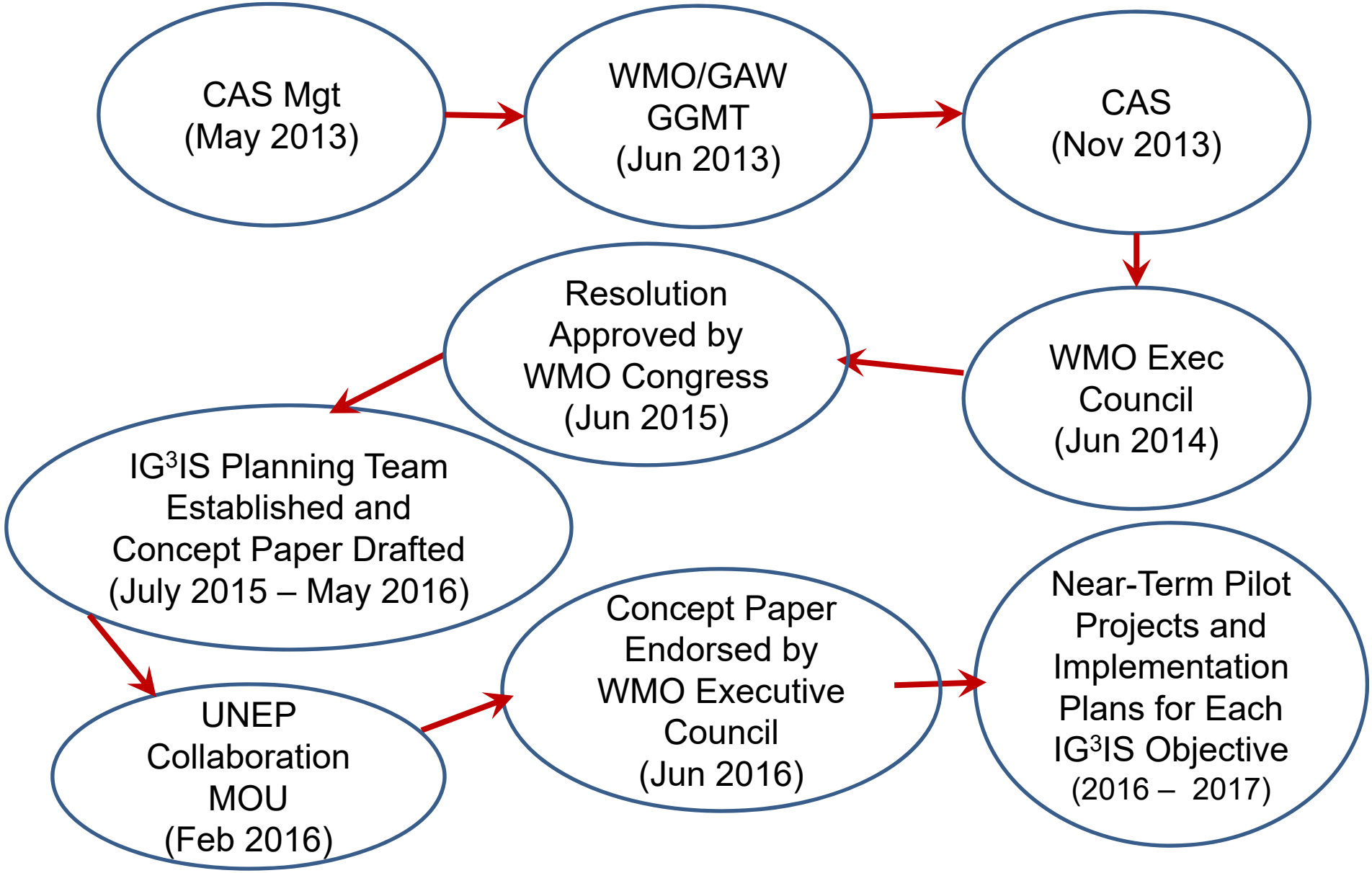


Despite some efforts to reduce emissions, greenhouse gases in the atmosphere continue to rise.

- **Over the next few years, governments will likely become more involved in efforts to limit atmospheric concentrations of greenhouse gases.**
  - Changes in emissions will vary by location and type
  - Strategies will vary by nation, region, and economic sector
  - Many nations are already pursuing such activities and some are coordinating efforts.
- **Any large-scale emission reduction effort requires independent information to succeed.**

  A suitable information system would include
  - ground-based and space-based observations,
  - improvements in transport and carbon-cycle modeling,
  - fossil fuel-use, terrestrial trends, and oceanic processes,
  - information about sources and sinks of greenhouse gases at sub-continental, policy-relevant scales.

IG³IS programmatic evolution within WMO



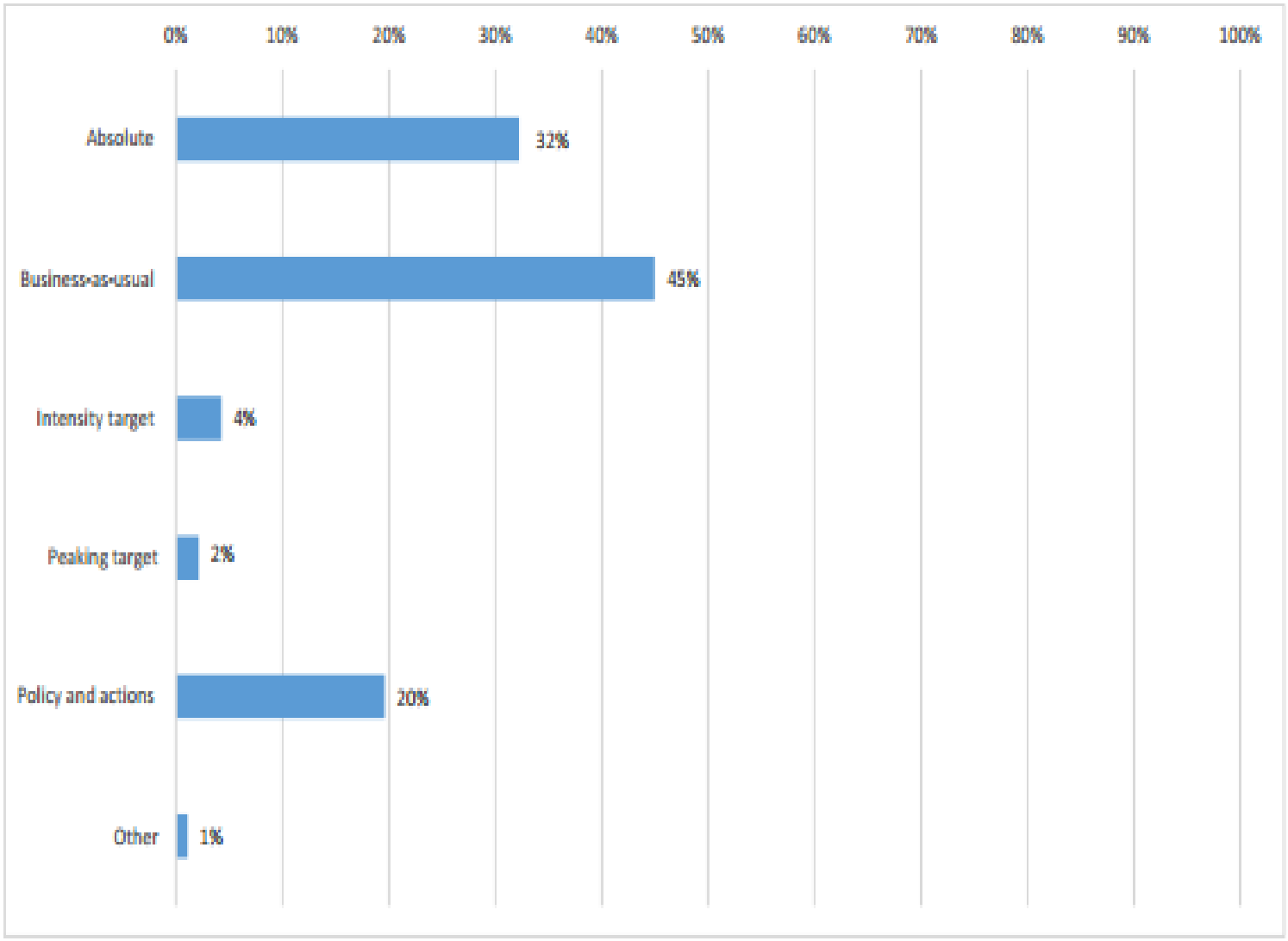
“Low Hanging” Fruit – 3-5 yr Horizon?

- Potential Near Term Achievements
  - $^{14}CO_2$ and Attribution
  - Methane Emissions
  - Urban Emissions
  - CFC-Replacements
  - Information Portal
- Longer Term Goals
  - Expanded Monitoring Networks
  - Improved Analyses
  - Han’s Uber Satellites . . .

A final thought . . .

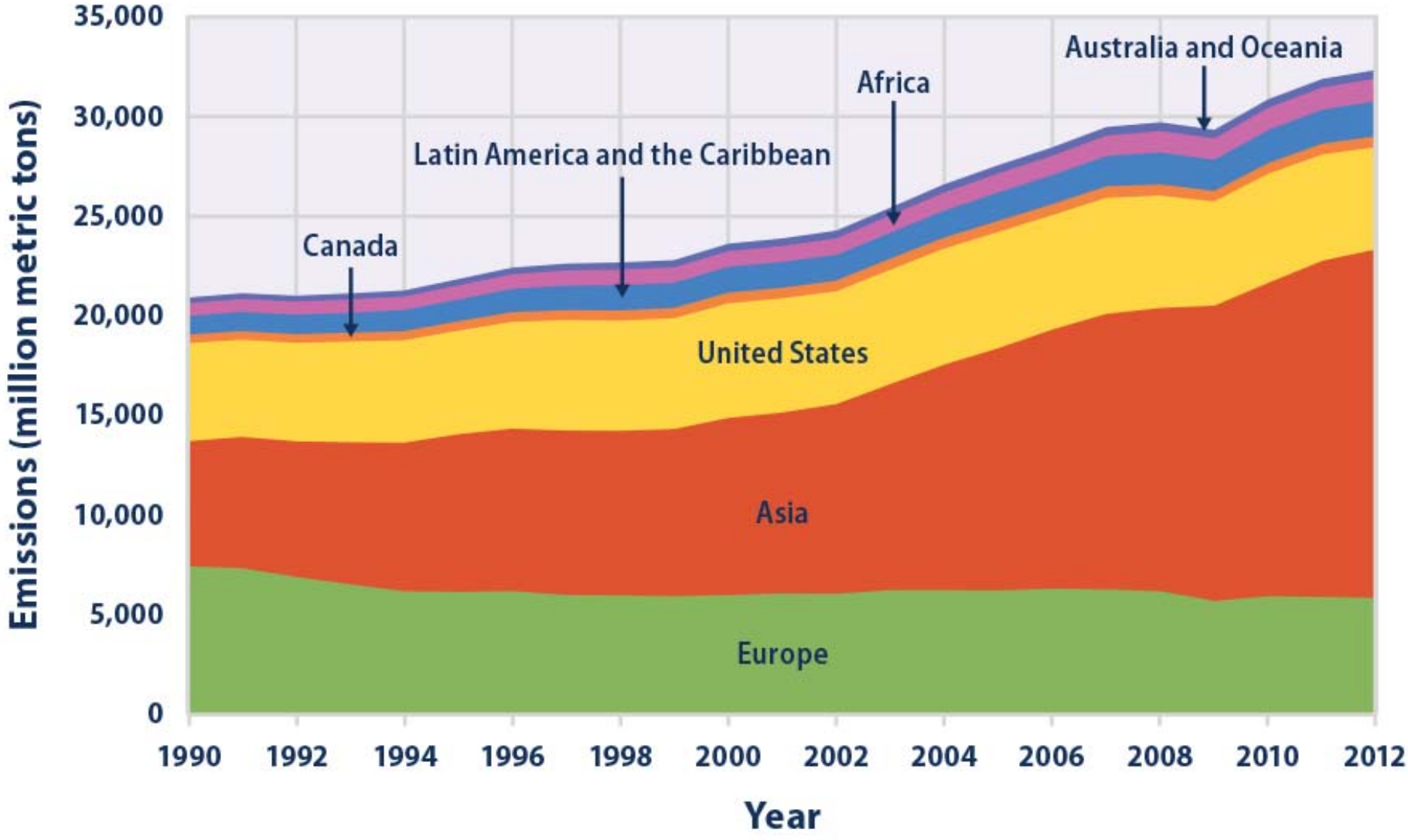
Figure 1

Types of mitigation target communicated in the intended nationally determined contributions

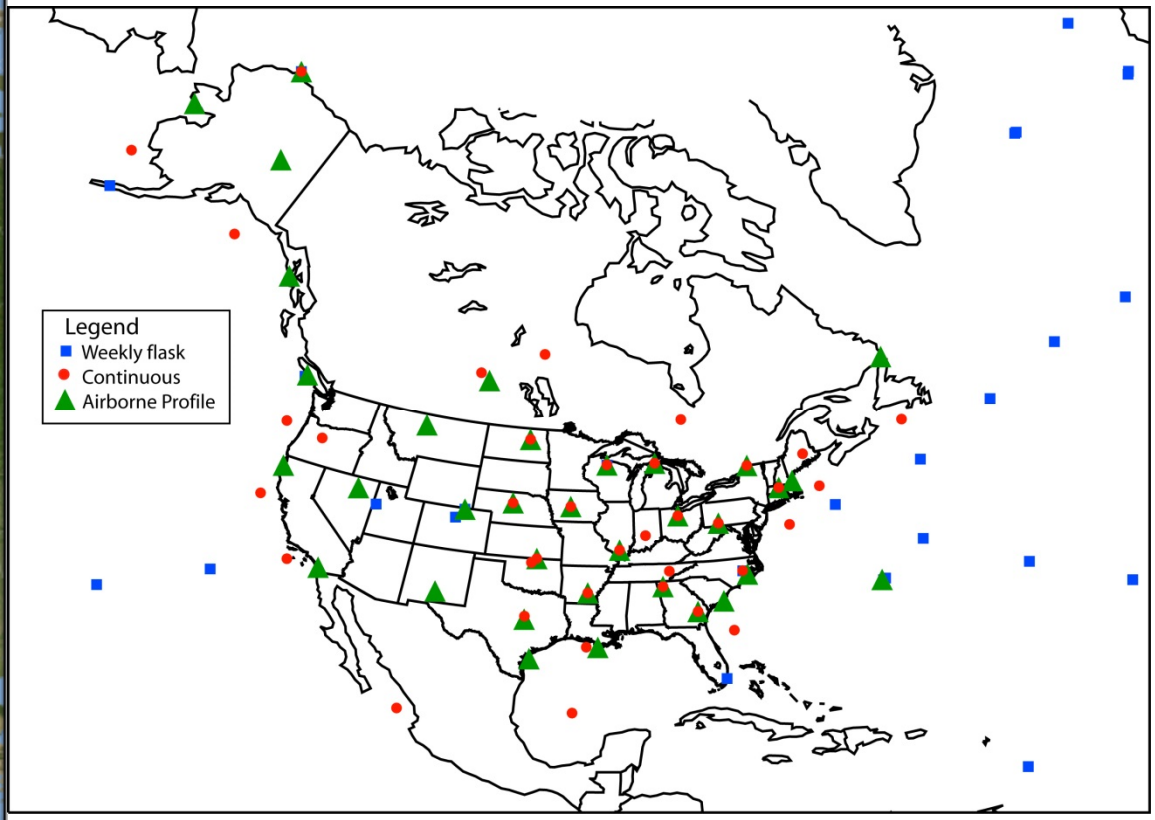


Note: The percentages shown are percentages of the Parties that submitted an INDC by 4 April 2016.

Global CO_2 Emissions

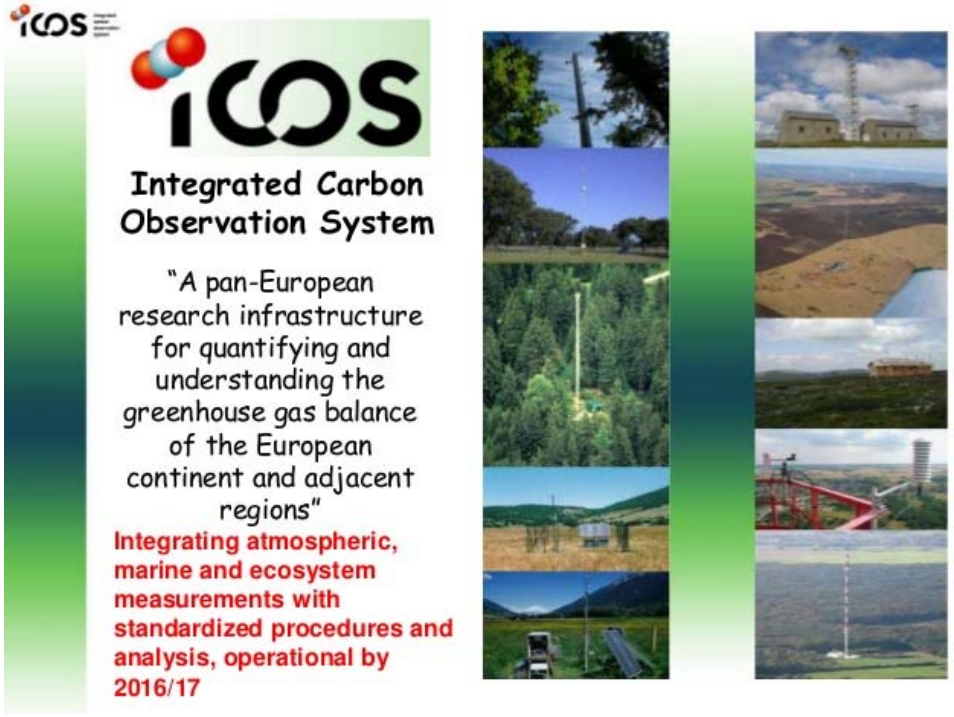


ICOS and CCSP

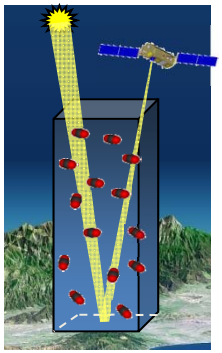


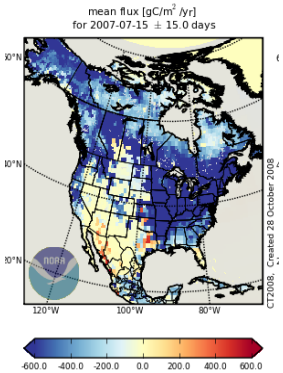
- US Carbon Cycle Science Program
  - Collaboration among 13 US agencies
  - Ocean and North American Programs
    - Science Advisory Groups
    - All scientists meeting
  - Distributed Data Sharing
  - 3 Science Advisory Groups

- Integrated Carbon Observation System
  - Research Infrastructure among 13 EU nations +
  - Central Facilities
    - Central Data Portal
  - National Networks
  - Monitoring Assemblies
  - Science Advisory Board



Satellites

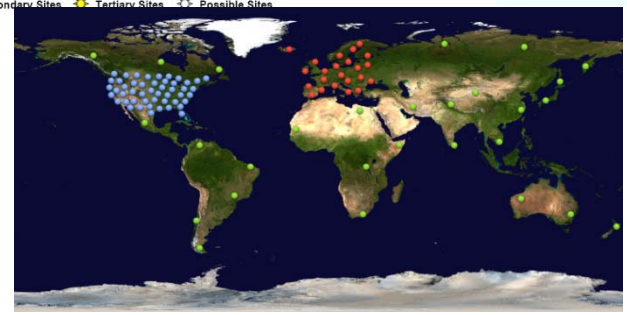




China

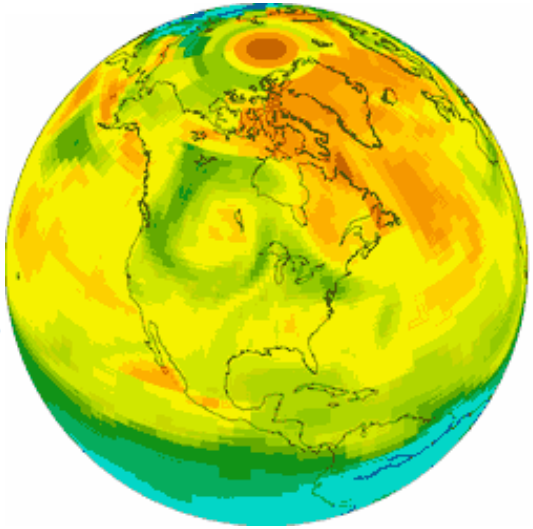
TCCON

Earth Networks



Questions?

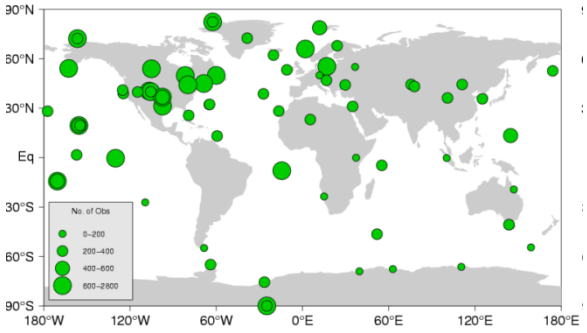
“Carbon Weather”



SE Asia

Brazil

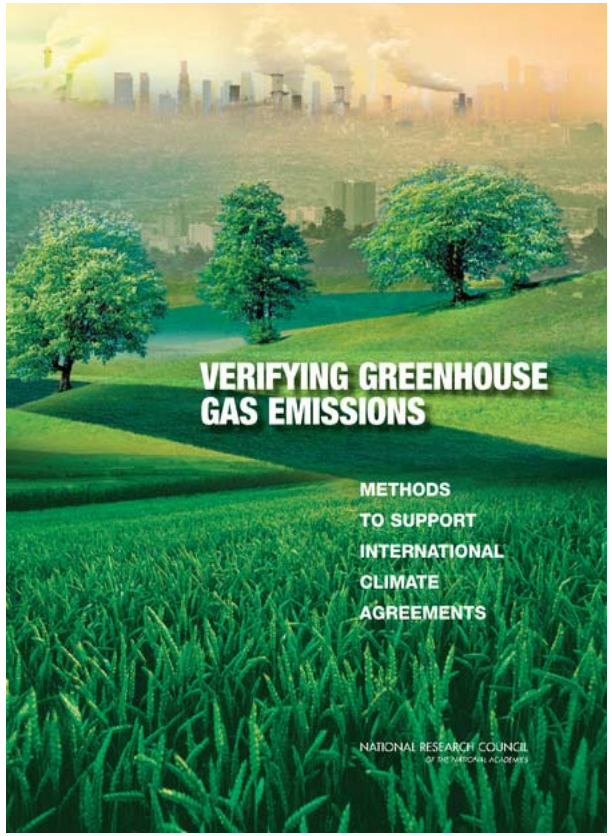
Current Network

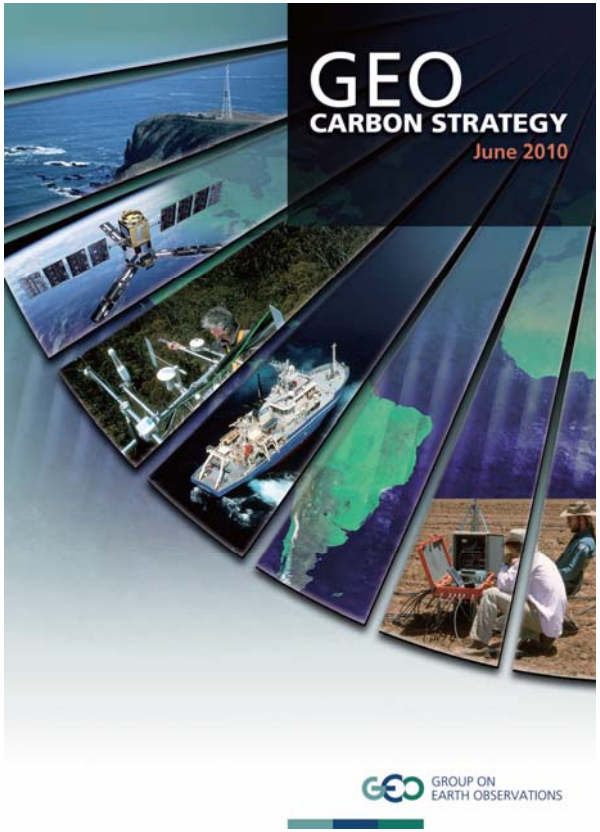


Backup Slides

GHG monitoring and reporting in 2010: atmospheric "top-down" and inventory "bottom-up"

Can atmospheric measurements and models "verify" inventories?





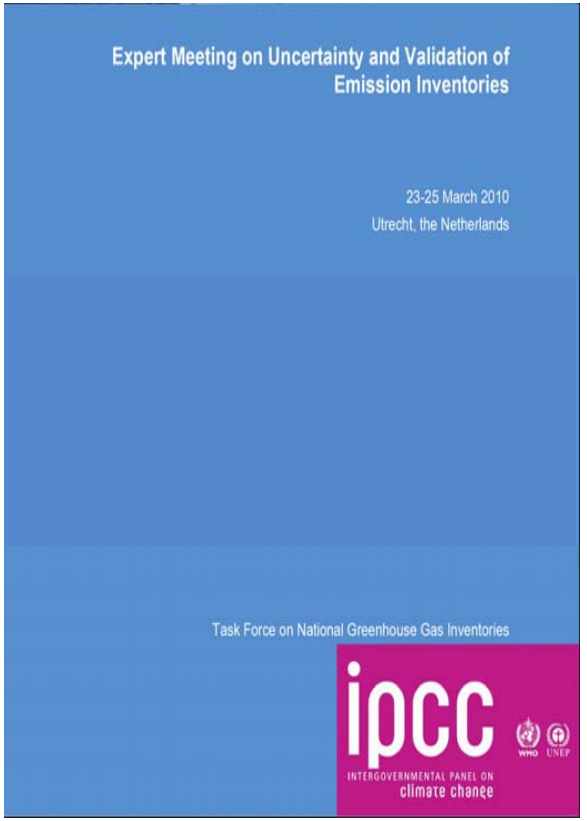
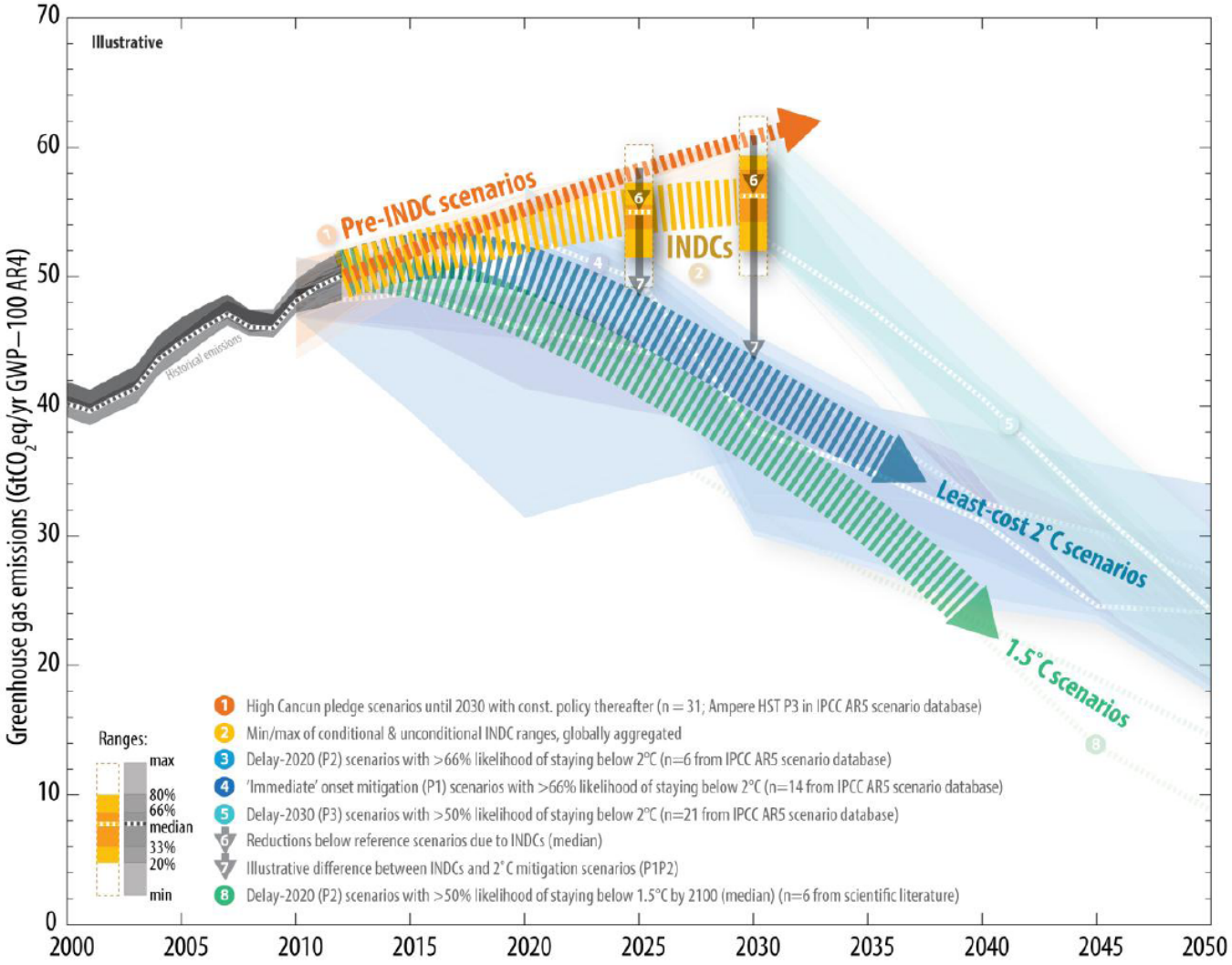


Figure 2

Comparison of global emission levels in 2025 and 2030 resulting from the implementation of the intended nationally determined contributions and under other scenarios

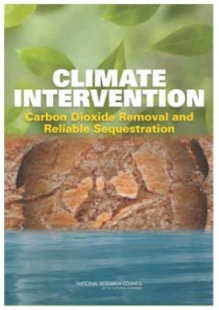


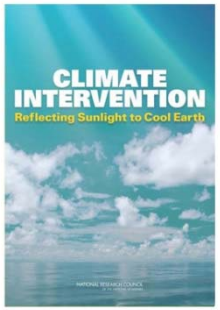
Sources: Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report scenario database, 1.5 °C scenarios from scientific literature (see footnote 19), IPCC historical emission database and intended nationally determined contribution quantification.

Abbreviations: AR4 = Fourth Assessment Report of the Intergovernmental Panel on Climate Change, GWP = global warming potential, INDC = intended nationally determined contribution, IPCC AR5 = Fifth Assessment Report of the Intergovernmental Panel on Climate Change, n = number of scenarios, yr = year.

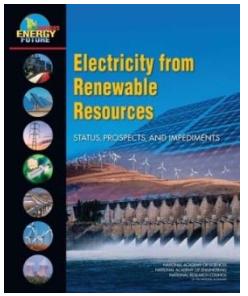
Supporting Society's Decisions

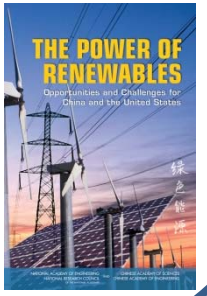
Inform Climate Intervention Decisions



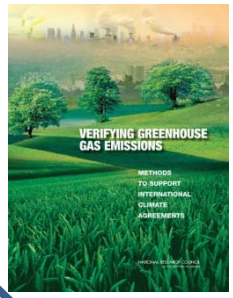


Support Development of Renewable Energy Options

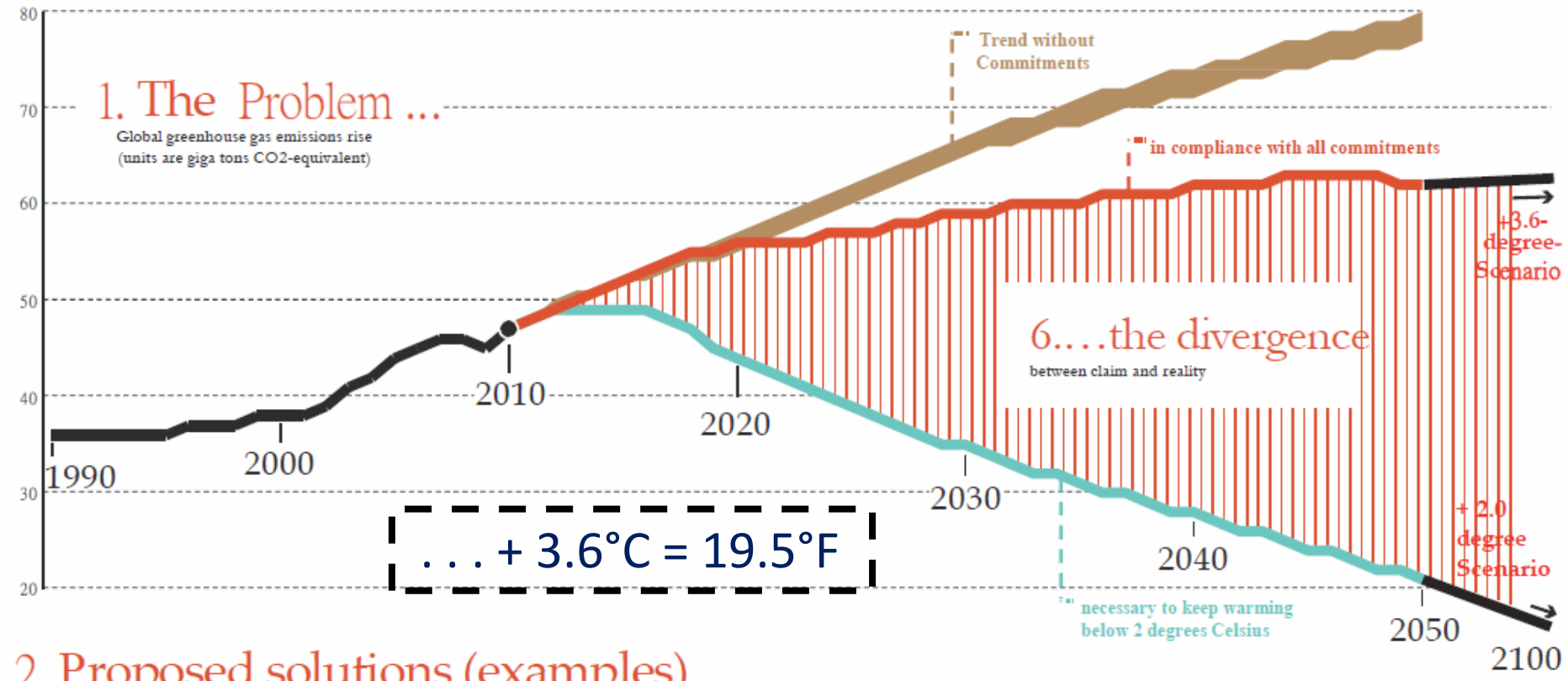




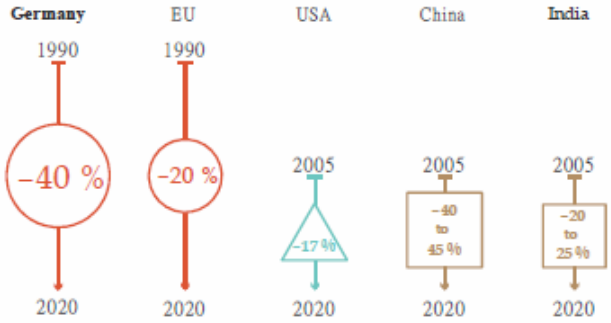
Evaluate Success of Greenhouse Gas Emissions Reductions



The Tricks of Climate Politicians



2. Proposed solutions (examples)



The commitments are not easily comparable. For example, the reduction targets of Germany and the EU refer to different base years than the USA. China and India have entirely different approaches: They do not want to cap their absolute emissions, but moderate their increase relative to economic growth.

Today — +3.6 Degrees — 2100

In total, the current commitments would lead to a 3.6 degrees Celsius warming in 2100.

CLIMATE CHANGE

Carbon Crucible

What are the data and modeling requirements for gauging the success of mitigation strategies in reducing greenhouse gas emissions?

Melinda Marquis[1,2*] and Pieter Tans[2]

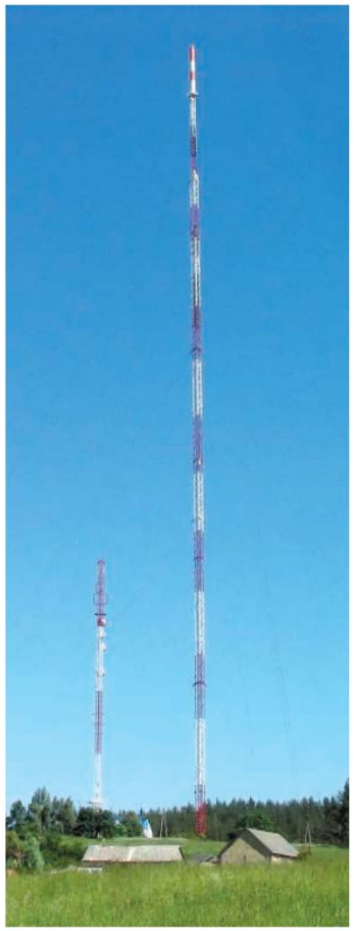
Atmospheric measurements show that the carbon dioxide (CO_2) concentration in the atmosphere is currently ~385 parts per million (ppm) and rising fast. But this value is a global average that tells us nothing about the regional distribution of greenhouse gas emissions. As the world embraces myriad mitigation strategies, it must gauge which strategies work and which do not. Gaining such understanding will require a greenhouse gas monitoring system with enough accuracy and precision to quantify objectively the progress in reducing emissions, including regional efforts like those in California, New England, and elsewhere.

The current sparse network of observation sites across North America and elsewhere allows us to resolve annual continental fluxes of CO_2. But successful mitigation requires fluxes to be resolved within much smaller regions—on the order of the size of a European country such as France or a U.S. state such as Kansas. Current ground-based measurement technology can provide the required precision, but the number of measurements is insufficient. Data are collected by numerous agencies around the world, yet an integrated system is needed that uses all available data and ensures rigorous quality control for data collection and data analysis.

A powerful way to use all these data is in a data assimilation system, which combines diverse (and often sparse or incomplete) data and models into a unified description of a physical/biogeochemical system consistent with observations. Components of such systems include models of terrestrial photosynthesis (removal of CO_2, called a sink) and respiration (a source of CO_2), models of ecosystem emissions and uptake of other greenhouse gases, models of gas exchange between atmosphere and oceans, and models of gas emissions from wildfires—all grounded in observations.

The current grid scale for such assimilation systems—such as CarbonTracker, the first data assimilation system to provide CO_2 flux estimates (*1*, *2*)—is limited to ~100 km or larger, primarily due to computer resource limitations. Currently sparse atmospheric greenhouse gas data force us to make the assumption that source variations are coherent over very large spatial scales. More observation sites would make the systems more strongly data-driven. Data assimilation systems also need more refined estimates of fossil fuel emissions, and better process understanding to provide greater detail in emission patterns. Lastly, better models of atmospheric transport will increase the resolution and decrease biases of the data assimilation system. Our ability to distinguish between distant and nearby sources and sinks is limited by how accurately transport models reflect details of the terrain, winds, and atmospheric mixing near the observation sites.

National emissions inventories (which are required by the U.N. Framework Convention on Climate Change) are key data sets for assimilation systems. Inventories are mostly based on economic statistics, which are used to estimate how much of each greenhouse gas enters or leaves the atmosphere (*3*). They are reasonably accurate for CO_2 from fossil fuels (within ~10%) in many developed countries but less so in developing countries and on regional scales. Inventory emission estimates are much less reliable for other CO_2 sources, such as deforestation, and for other major greenhouse gases; for example, the contributions of natural wetlands, rice farming, and cattle to the global methane



The advantages of height. Atmospheric measurements are made on the tall tower (300 m). The tower, located near Bialystok in eastern Poland, is part of the CarboEurope tall tower network. Similar networks exist in North America and more sparsely in other parts of the world.

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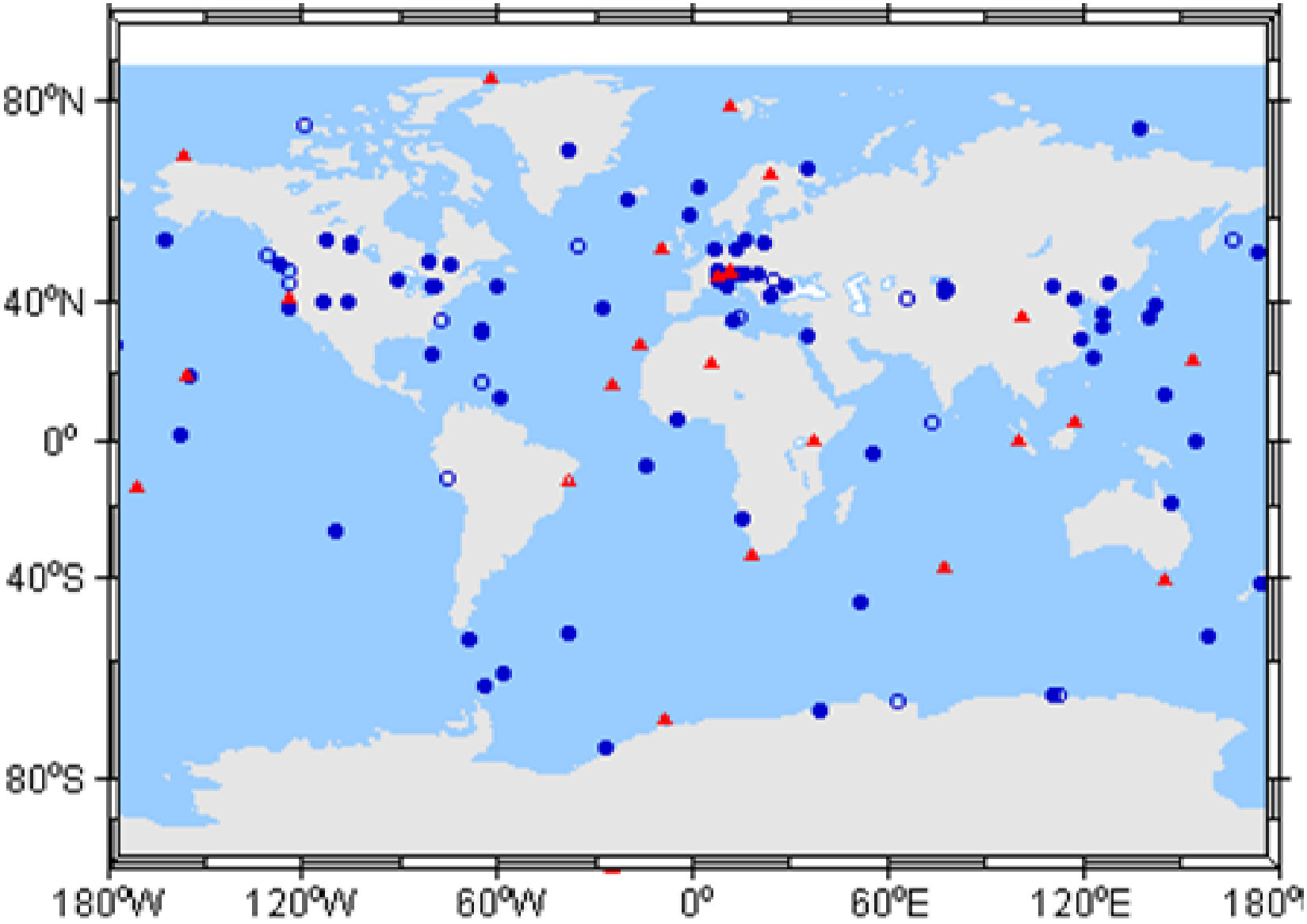
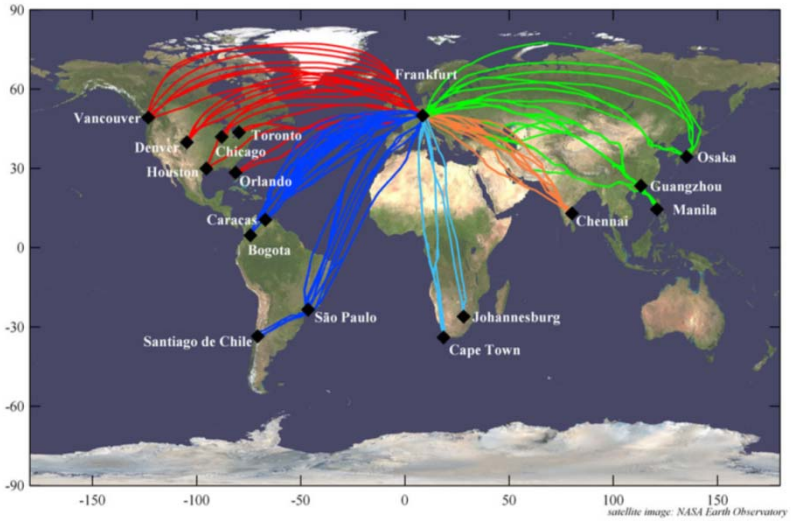
Carbon Crucible – The Future Demands New and Expanded Approaches

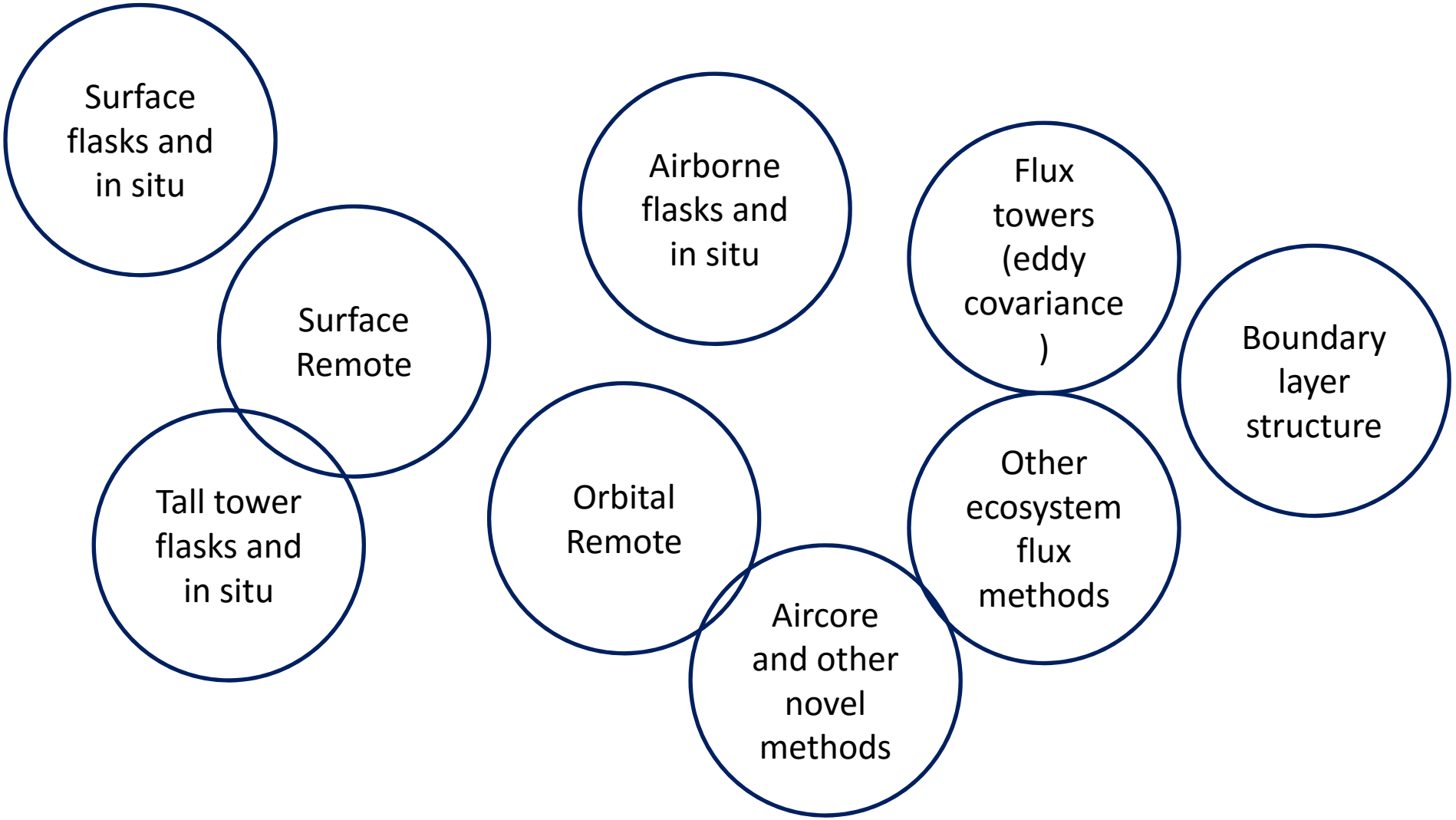
- Increased Observations
- Improved Transport Models
- Enhanced Reanalysis

Global Monitoring Network for Atmospheric Greenhouse Gases



- NOAA network
- ICOS network
- CMA et al networks




Surface flasks and in situ
Surface Remote
Tall tower flasks and in situ
Airborne flasks and in situ
Orbital Remote
Aircore and other novel methods
Flux towers (eddy covariance)
Other ecosystem flux methods
Boundary layer structure

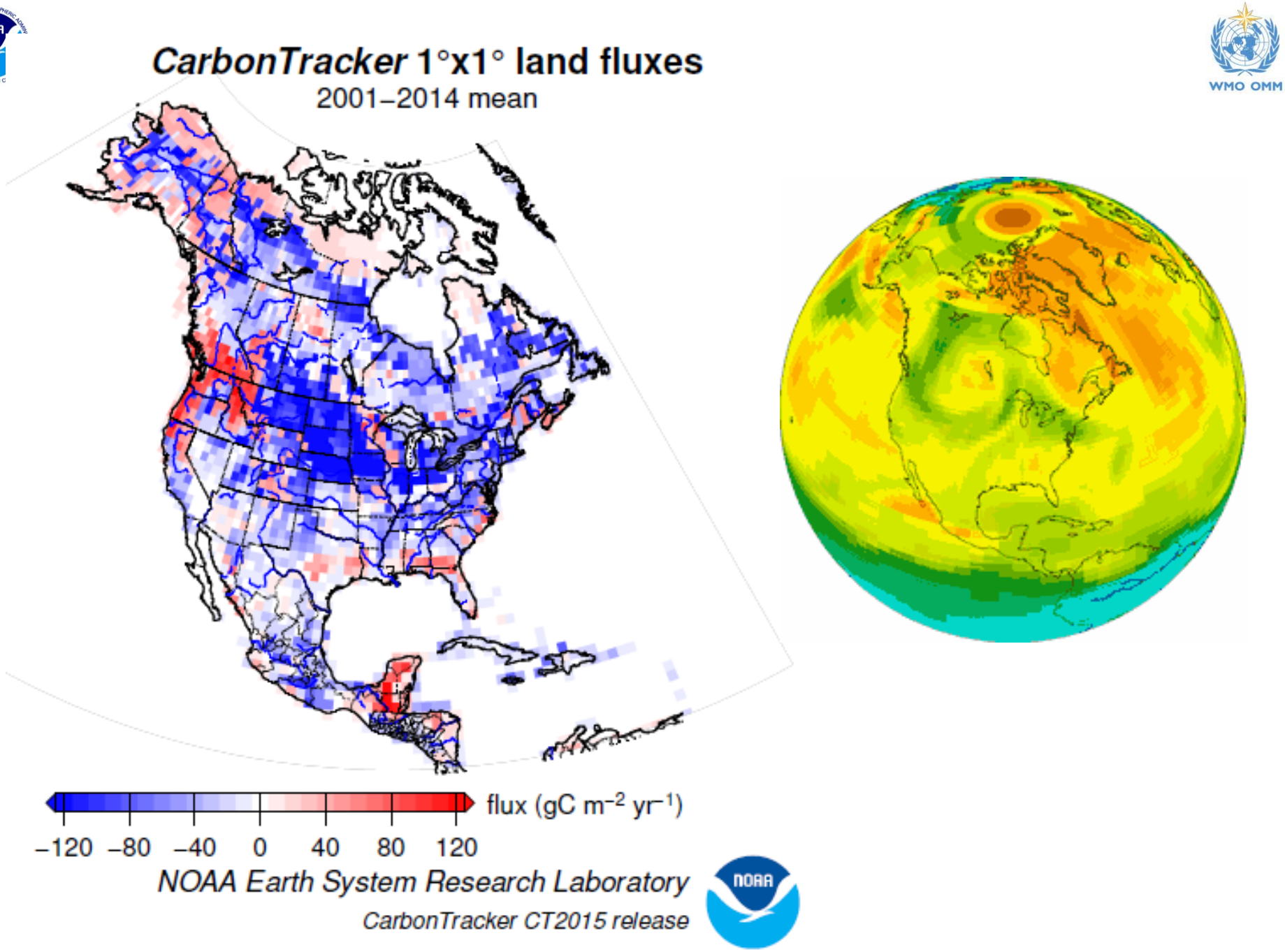
So, What is WMO Doing?

- WMO Capabilities

  - WMO Global Atmosphere Watch
    - Long term observing network for greenhouse gases
    - Other observing networks for atmospheric composition (e.g., aerosols, ozone)
    - Support for “megacities” research

  - World Weather Research Programme
    - Improving forecast models
      - Seasonal to sub-seasonal predictions (with WCRP)
      - Polar Prediction Program (with WCRP)
      - Tropical Meteorology
      - Others . . Improving transport resolution

  - World Climate Research Programme
    - Improving climate models
    - Focused efforts, e.g., extreme events, statistical downscaling, etc.


CarbonTracker 1°x1° land fluxes
2001–2014 mean
flux (gC m−2 yr−1)
−120 −80 −40 0 40 80 120
NOAA Earth System Research Laboratory
CarbonTracker CT2015 release

We need to do better . . .