Please note:
All information is under embargo, including via social media, until 0900 GMT Monday, 24 October
The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2015

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12th annual Greenhouse Gas Bulletin will be released on 24 October 2016
Carbon dioxide (CO₂)

- The globally averaged CO₂ mole fraction in 2015 was 400±0.1 ppm (144% of pre-industrial level).
- The increase in annual means from 2014 to 2015, 2.3 ppm, is larger than the increase from 2013 to 2014 and the average growth rate for the past decade (~2.08 ppm yr⁻¹).
- The higher growth rate in 2015 compared with the previous years is due to increased natural emissions of CO₂ related to the most recent El Niño event.
Methane (CH$_4$)

- The globally averaged CO$_2$ mole fraction in 2015 was $1845\pm2$ ppb (256% of pre-industrial level).

- The increase in annual means from 2014 to 2015, $11$ ppb, is larger than the increase from 2013 to 2014 and the average growth rate for the past decade ($\sim 6$ ppb yr$^{-1}$).

- Increased CH$_4$ emissions from wetlands in the tropics and from anthropogenic sources at mid-latitudes of the northern hemisphere are likely causes of renewed CH$_4$ growth.
The globally averaged CO₂ mole fraction in 2015 was $328\pm0.1$ ppb (121% of pre-industrial level).

The increase in annual means from 2014 to 2015, 1 ppb, is similar to the increase from 2013 to 2014 and larger than the average growth rate for the past decade (0.89 ppb yr⁻¹).

The likely causes are an increase in use of fertilizer uses in agriculture and increased release of N₂O from soils due to excess of atmospheric nitrogen deposition related to air pollution.
Why do we measure GHG?

- 37% increase in total radiative forcing by all LLGHGs since 1990
- 1.3% increase in radiative forcing from 2014 to 2015
- Total impact corresponds to a CO$_2$-equivalent mole fraction of 485 ppm

Impact on climate
Where do we go with climate (Options?)

“CO₂ 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.”

Two or Three Degrees: CO₂ Emissions and Global Temperature Impacts by Robert B. Jackson, Pierre Friedlingstein, Josep G. Canadell, and Robbie M. Andrew

(The Bridge, 2015)
Paris Agreement – limit the temperature increase by 2C by limiting emissions

It is what you **HAVE** in the atmosphere, not **only** what you **PUT** in the atmosphere, that controls the temperature.

Calculations are for year in 2011

Human (9GtC in) – ocean (2.3GtC out) – biosphere (2.6GtC out)
2015: Changes in greenhouse gases strongly influenced by El Niño
How to get emissions?

- “Bottom-up” measurements (SELF REPORTING)
  - Emissions reporting
  - Reported and “verified” offsets
  - Site-specific measurements

- “Top-down” measurements
  - Comprehensive atmospheric observation system
  - Ecosystem and ocean observations
  - Inverse modelling

- Combination of above

NDCs are evaluated every 5 years -> are we on the right track?
Where can we cut more?
Are oceans and biosphere are working as expected?

Assuming that we know ocean and biospheric uptake
Complexity of carbon cycle

- Identification of sinks needs dedicated measurements
- CO$_2$ uptake by oceans lead to ocean acidification
- Knowledge of terrestrial and ocean sinks is essential for definition of anthropogenic contribution
**Goal:** Support the success of post-COP21 actions of nations, sub-national governments, and the private sector to reduce climate-disrupting GHG emissions through a sound-scientific, measurement-based approach that:

- reduces uncertainty of national emission inventory reporting,
- identifies large and additional emission reduction opportunities, and
- provides nations with timely and quantified guidance on progress towards their emission reduction strategies and pledges (e.g., NDCs)

Concept paper approved by EC-68
Example from UK report to UNFCCC: Methane

- Early (1990s) mismatch with the inventory.
- Difficult to understand, most likely cause is landfill emissions but retrospectively challenging to investigate.
- Inspired DECC to expand the network from 1 to 4 stations.
Example from Switzerland: Methane

• Great match between national total ("bottom-up" and "top-down") but incorrect spatial distribution

(S. Henne et al., 2016)
Example of additional emission reduction opportunities

**Tier 1: Satellite detects hotspot region**

500 km

**Tier 2 (Blue boxes):**
Aircraft spectrometers estimates local fluxes & attributes source sectors

**Tier 3: Plume Imaging**
Aircraft map point sources

50 km

**Tier 4 (not shown):**
Surface observations

Enhanced Activity Data

Dairies

Oil fields

Kern River oil field

Taft dairies

Elk Hills oil field

Pixel size 1.5 m
Multiple cities

Paris
Melbourne
Sao Paulo
“Nesting” – from the planet to a building

• Global consistency
• Consistency across scales
• standardization
Thank you
Merci
• Photosynthesis uses energy from the sun to **convert inorganic air (CO₂)** to living biomass!

• Most of this energy is released through respiration (back to CO₂) when plants are eaten by animals, bacteria, people
Some of the stored solar energy in biomass can be preserved in fossilized remains.
We dig this stuff ("fossil fuels") up and **burn it**, harvesting the stored energy to power civilization.
The Global Carbon Cycle

About half the CO₂ released by humans is absorbed by oceans and land.

“Missing” carbon is hard to find among large natural fluxes.
Carbon Sources and Sinks

- Half the carbon from fossil fuels remains in the atmosphere
- The other half goes into land and oceans
- Ocean sink results from chemistry and circulation
- Land sink was unexpected: “plants are growing faster than they’re dying!”
Where Has All the Carbon Gone?

• Into the oceans
  • Solubility pump (CO$_2$ very soluble in cold water, but rates are limited by slow physical mixing)
  • Biological pump (slow “rain” of organic debris)

• Into the land
  • CO$_2$ Fertilization (plants eat CO$_2$ … is more better?)
  • Nutrient fertilization (N-deposition and fertilizers)
  • Land-use change (forest regrowth, fire suppression, woody encroachment … but what about deforestation?)
  • Response to changing climate (e.g., Boreal warming)
The Land
The Breathing Land

Net Ecosystem Carbon Exchange

Photosynthesis

Leaf Respiration

CO₂ Storage

Bole Respiration

Root Respiration

Microbial Respiration

Litter Respiration
The Oceans
Vertical Structure of the Oceans

- Warm buoyant “raft” floats at the surface
- Cold deep water is only “formed” at high latitudes
- Very stable, hard to mix, takes ~1000 years!
- Icy cold, inky black, most of the ocean doesn’t know we’re here yet!
CO₂ Dissolves in Seawater

- CO₂ is much more soluble in cold water
- Dissolves into cold polar water and sinks
- Travels along surfaces of constant temperature
- Upwelling and warming in tropical waters releases CO₂ to the air
Sloshing Across the Pacific

- Huge accumulation of deep warm water in W. Pacific

- Relaxation of Trade Winds allows warm water to flow eastward
CO₂ Rose Fast in 2015

- Half of CO₂ from fossil fuel goes into storage on land and in the oceans
  - Strong El Niño in 2015 affected both land and ocean carbon uptake
  - Warmer oceans dissolved less CO₂
  - Tropical droughts reduced plant growth
  - Extremely mild winter in northern land allowed respiration and decomposition
- CO₂ growth rate was almost twice as fast as normal!
www.climatecentral.org/workshops-and-webinars

21 October 2016
2015 WMO
Greenhouse Gas Bulletin

21 October 2016