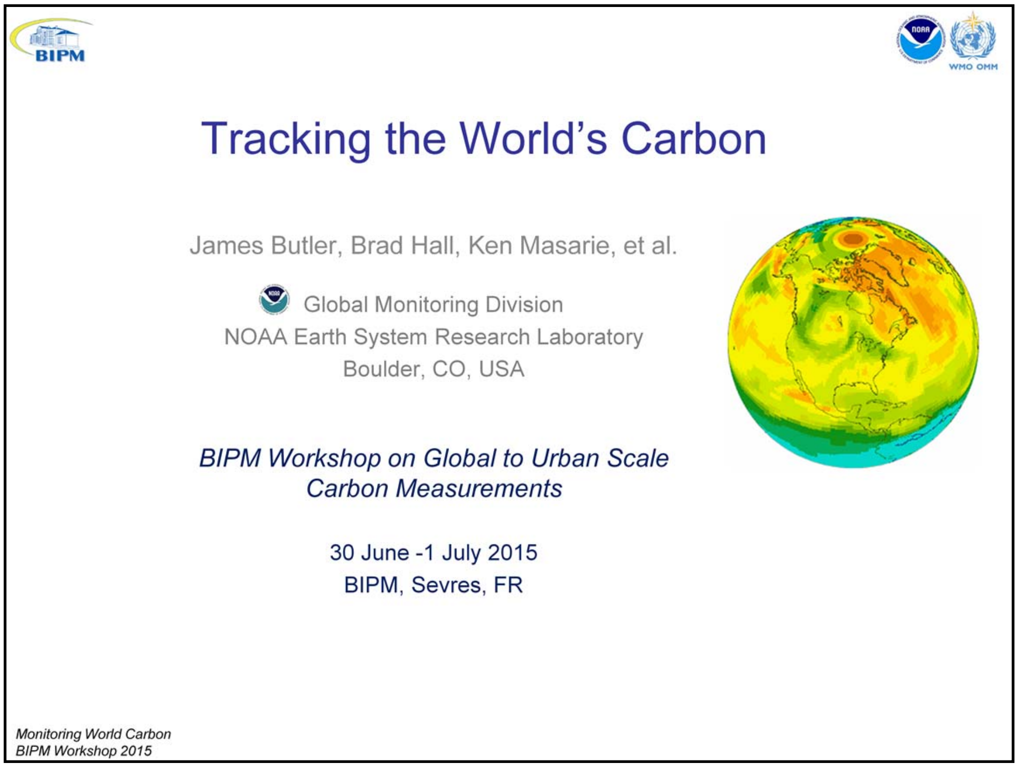

Many players have contributed to this – John Miller, Arlyn Andrews, Pieter Tans, Oksansa Tarasova, and a host of partners.

Whatever measurements are made supporting urban systems must be compatible with global networks.

Outline

- Context – The Problem
- Development of the global in situ network
- Getting sub-continental information
- Satellites
- Integrating measurements and delivering information

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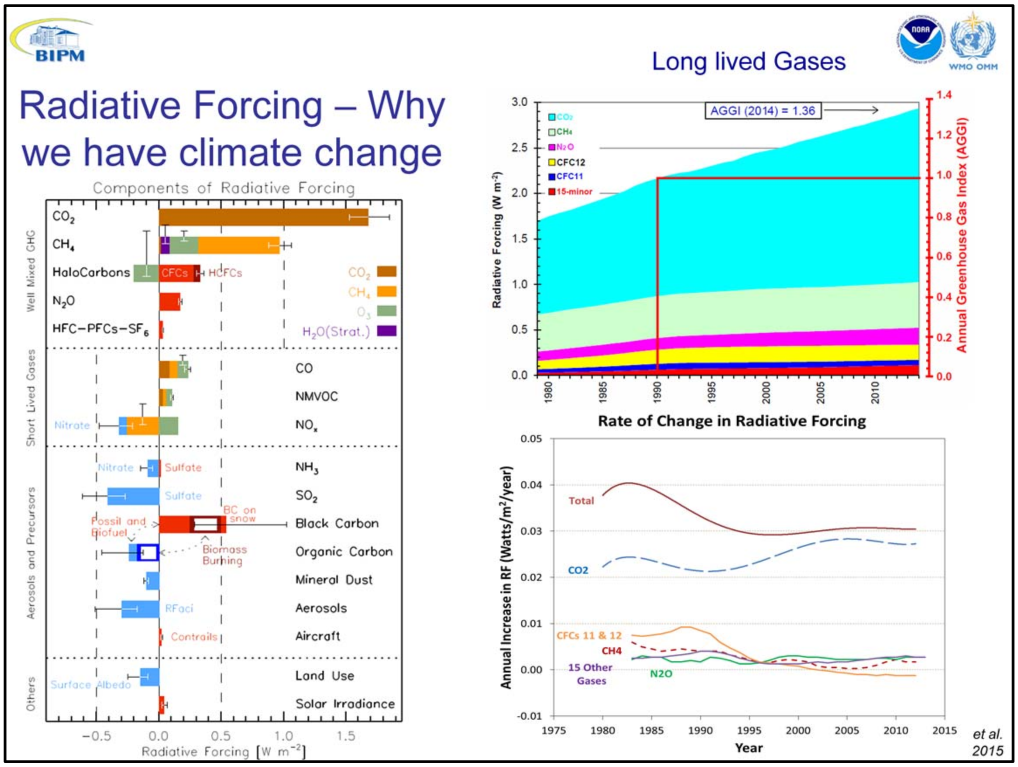
Context – The Problem



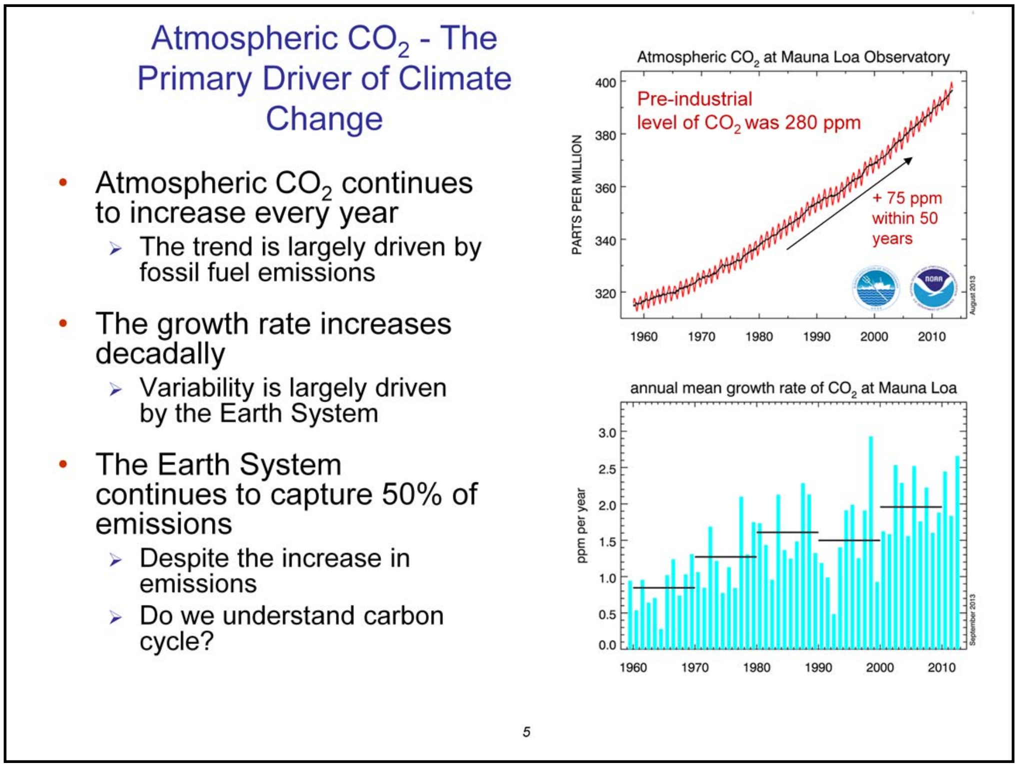
The reason we have climate change is increasing RF in Earth’s atmosphere

Long lived greenhouse gases are most important, as we’re stuck with them and their heating influence for a long time

Of these, the most important, by far, is CO2, owing to its high rate of increase.

We did get a break in CFC’s once the MP was instituted and acted upon, which gives us hope that things can be done.

Remember, the lower right plot is rates of increase, not amounts.



- What is happening with CO2?
- CO2 was 280 ppm before the industrial revolution and for the entirety of human civilization !! It’s increasing in the atmosphere at accelerating rates, which poses a real risk for our future well being
- Good news is bullet 3 – removal of immediate emissions by the Earth system continues at 50%, no matter how much is emitted
- IPCC (2007) noted that
  - (1) climate is changing, driven by greenhouse gases,
  - (2) CO2 is the most important GHG, and
  - (3) human activities are the cause.

Development of the *in situ* Global Network

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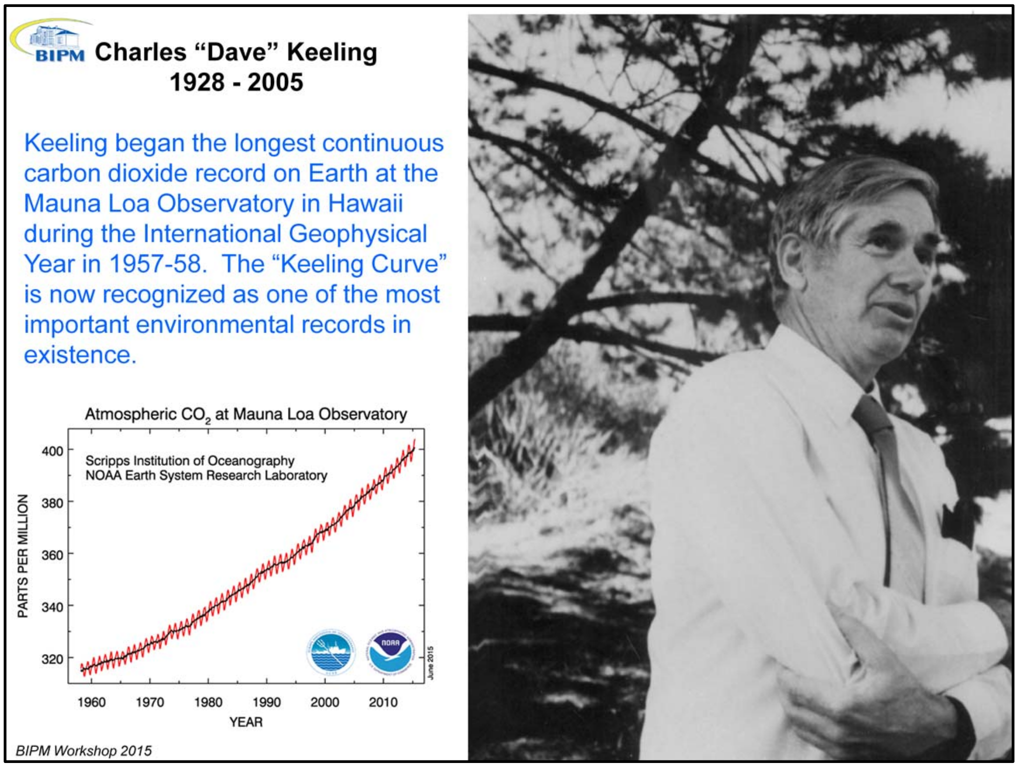
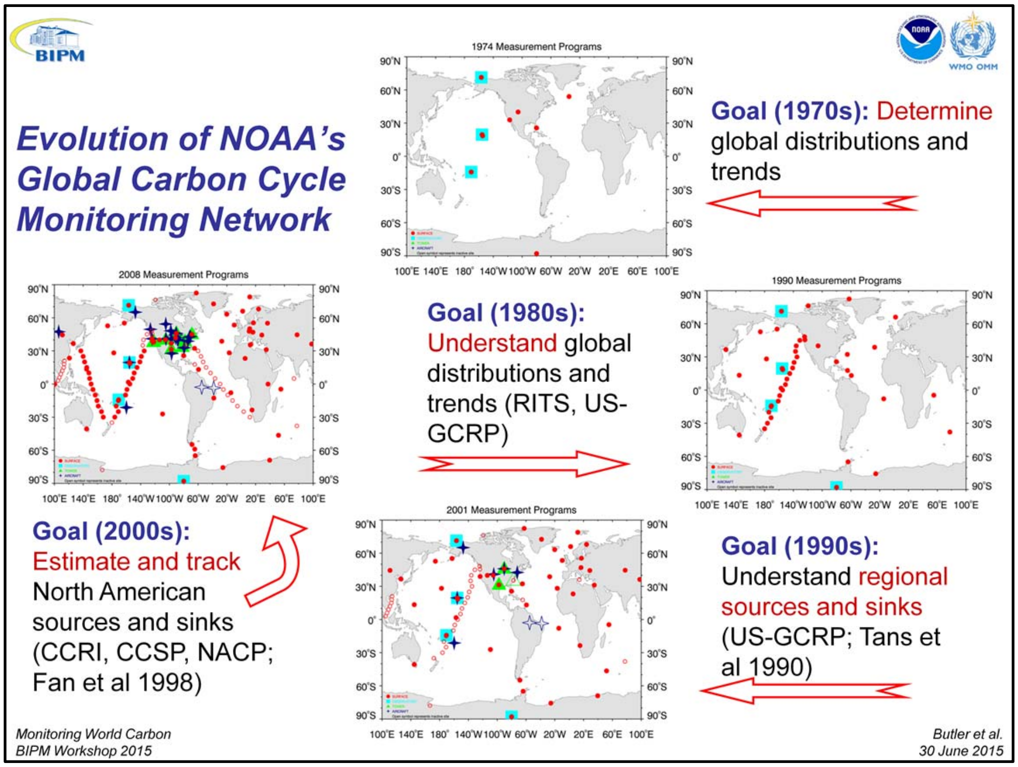


Dave Keeling started real-time atmospheric observations with measurements at MLO and SPO back in 1957 and 58.

Scripps since added several sites, but NOAA built a global network from them, and WMO GAW built from that network.

Scripps (Ralph K et al.) , NOAA, and WMO continue to collaborate.



Oksana will talk more about the WMO network, so I will focus on NOAA here.

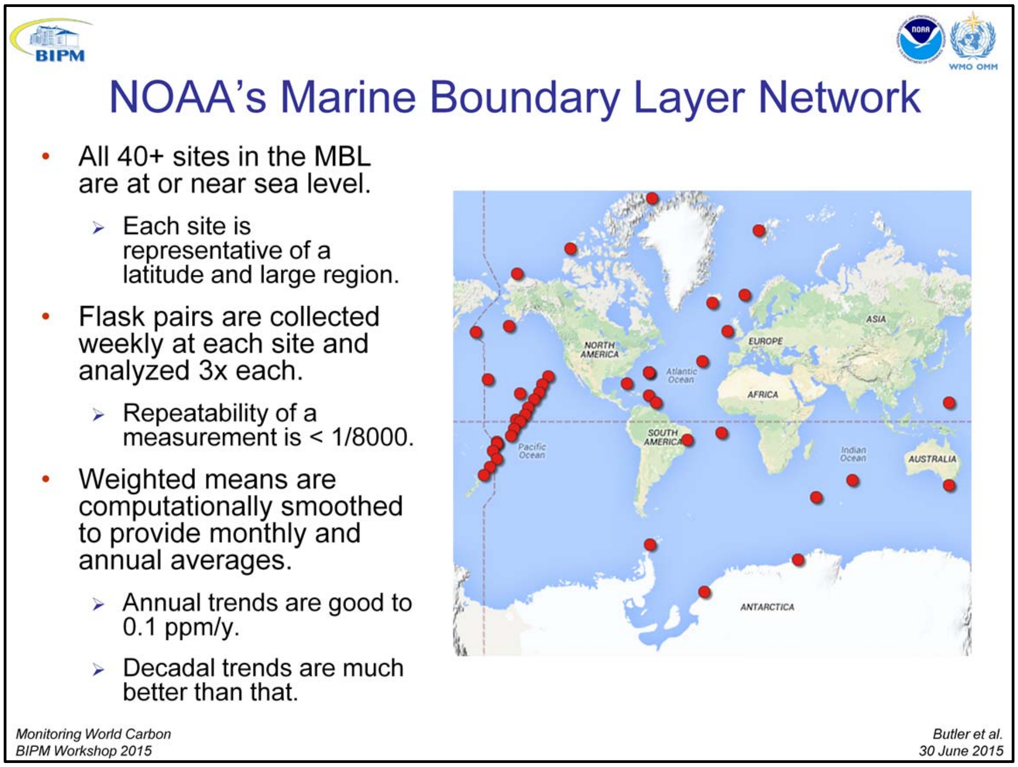
NOAA's global carbon cycle monitoring network has grown over the years owing to evolving scientific needs. This is shown in clockwise view, starting from the top.

➢In the 1970s, we just wanted to know the general distribution and growth of CO2 in the remote atmosphere. Few sites were required.

➢In the 1980s, we realized that the distributions were more complex with intrahemispheric variations, so we added sites to the network, still focusing on the remote atmosphere.

➢In the 1990s, our data demonstrated that there was a large northern hemispheric sink of carbon and that this sink was land based, so we addedcontinental sites to our system and began model development.

- In the past decade, our driver has been to quantify the North American sink of CO_2, requiring more measurements across the continent and measurements of vertical distributions of CO_2 and other gases. It is this effort that led to the development of CarbonTracker to explain these evolving observations.

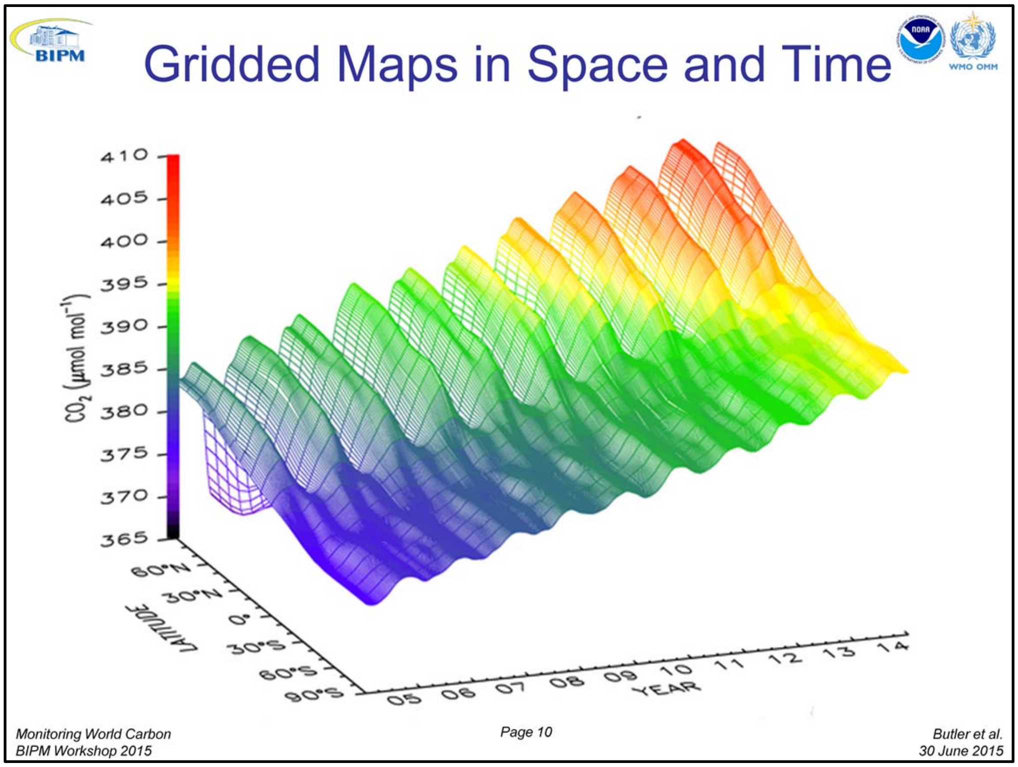


Within NOAA's network is this extremely valuable resource, our Marine Boundary Layer Network.

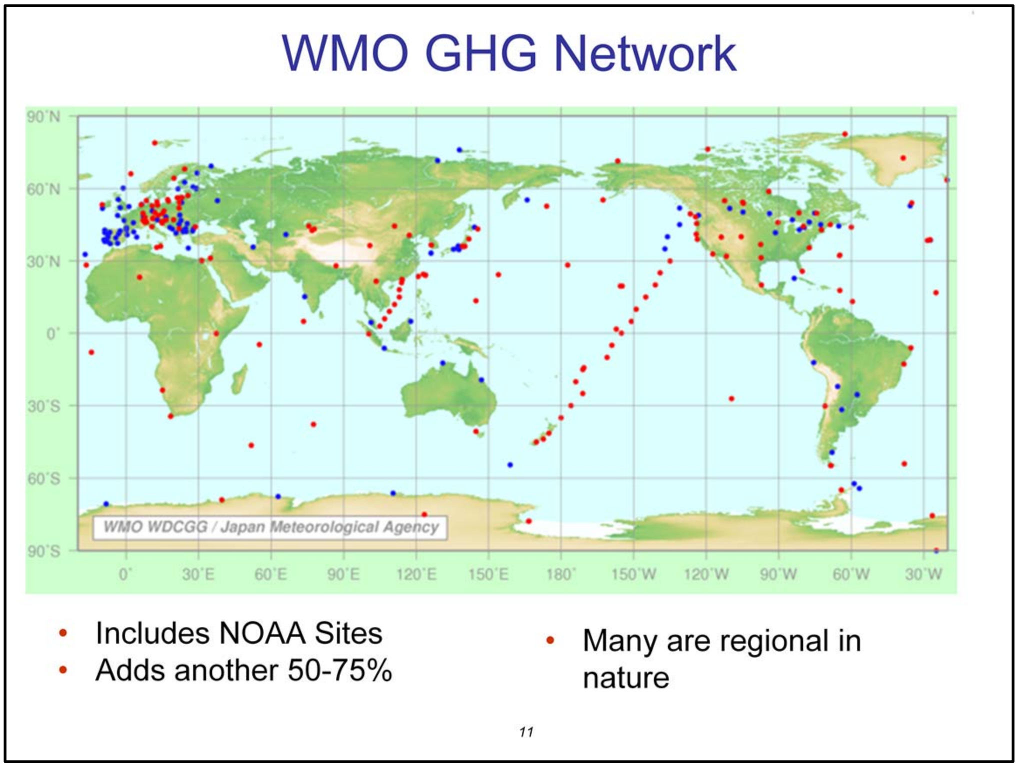
Identical sampling and analysis of all flasks, 1-week intervals, for decades.

No local or regional interference in measurements

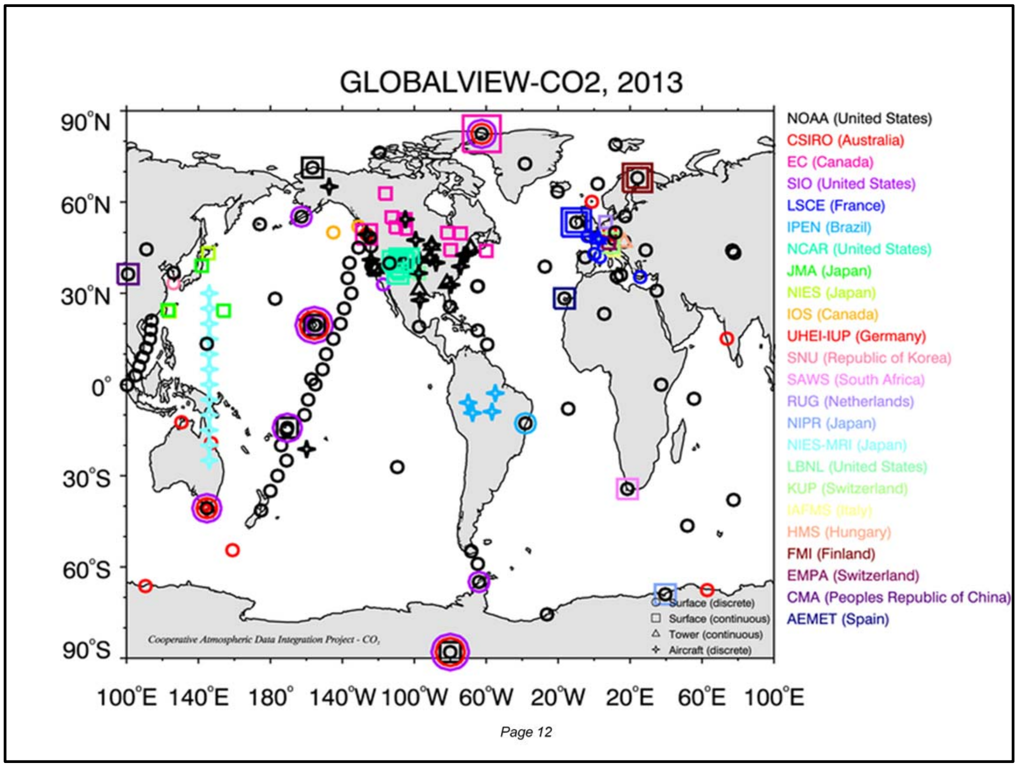
Best, most robust data on global trends and distributions out there. If you want a global average or a trend, this is it.



Maps from the MBL (visual or gridded data set) show large scale trends and distributions, reflecting activities of the world in general – physical and human-driven.



WMO has built on NOAA’s network, doubling the number of sites and allowing us to peek even further into terrestrial influences.

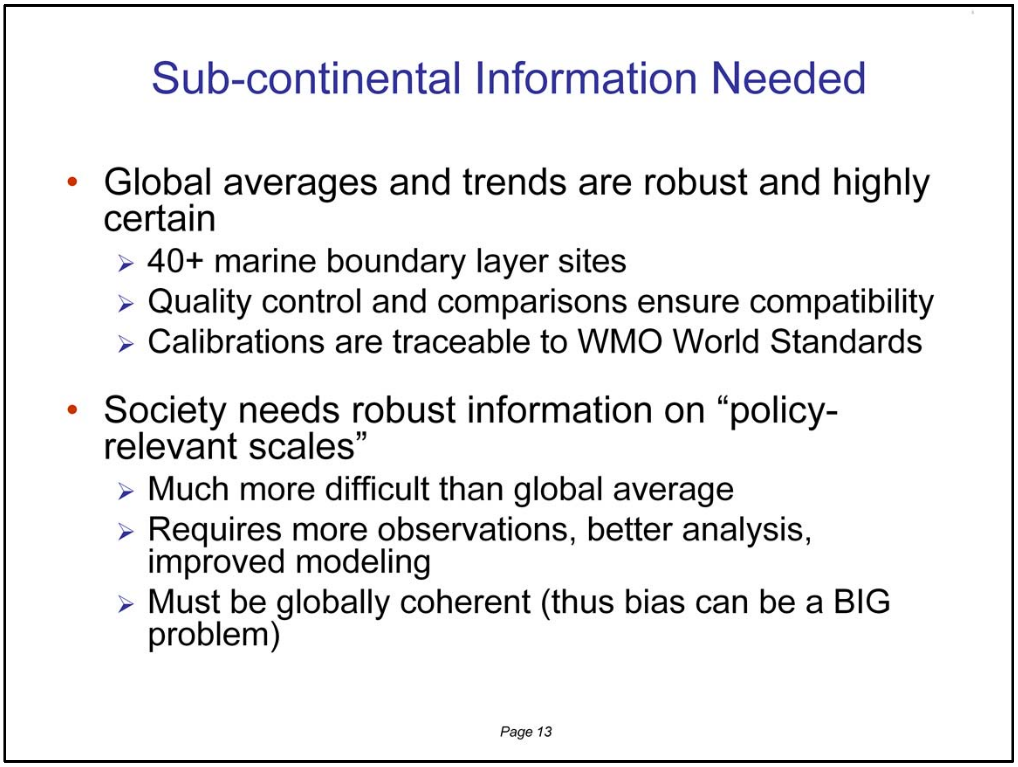


For example, from partners largely within the WMO GAW domain, we've been able to create GlobalView and ObsPak

These are designed to provide modelers with the data tools they need to answer continental and some sub continental questions, while ensuring consistency with global trends and distributions

A robust system of systems

Note the sites for dual, treble, quadruple, and even quintuple sampling



But, to answer today's questions, we need more.

What is decided and what happens in the early to mid- 21st century will transform the world.

We need to provide the best possible information necessary to ensure the best decisions.

Getting Subcontinental Information

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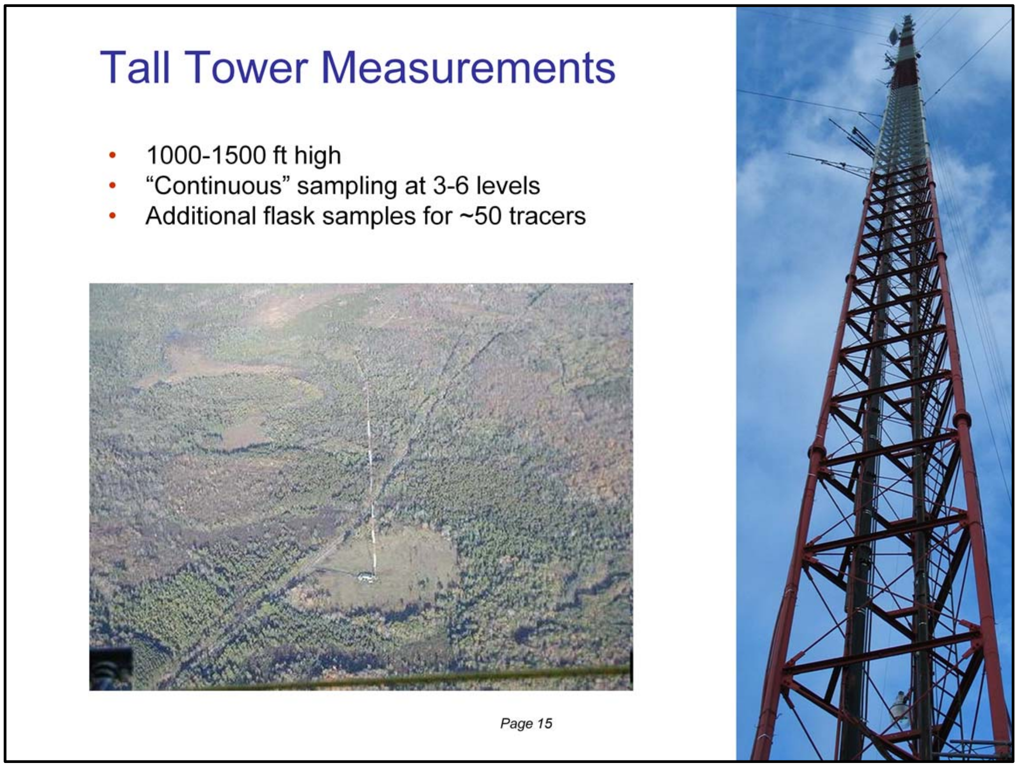
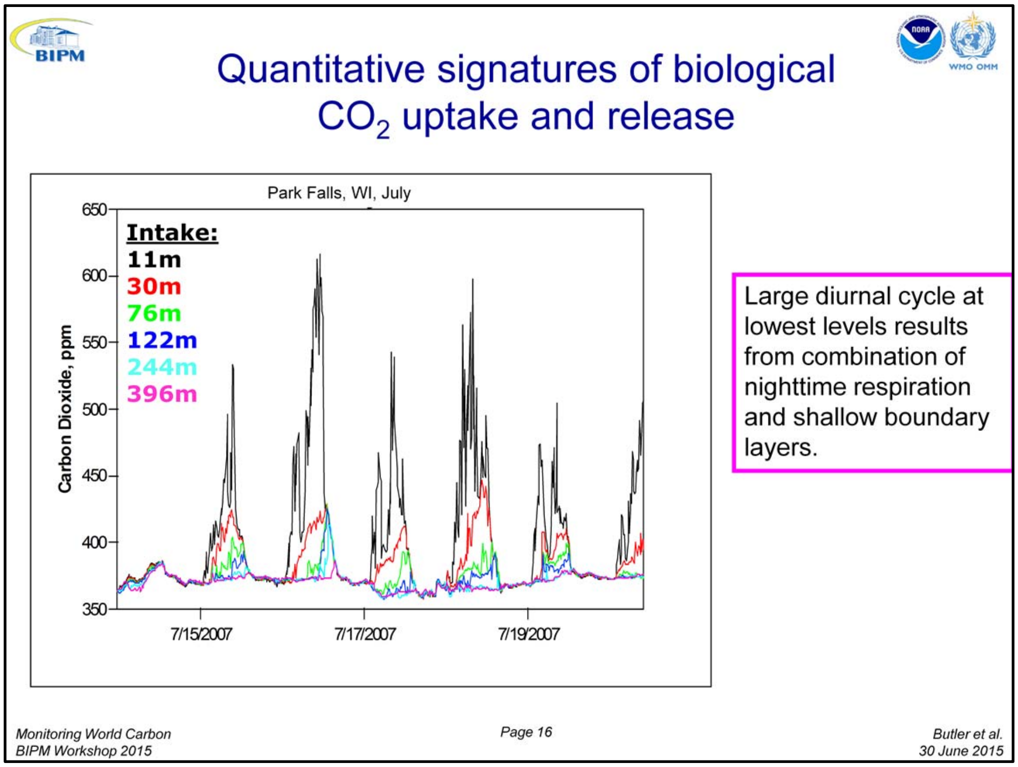


Going into the continents, tall towers, even medium towers are increasingly important

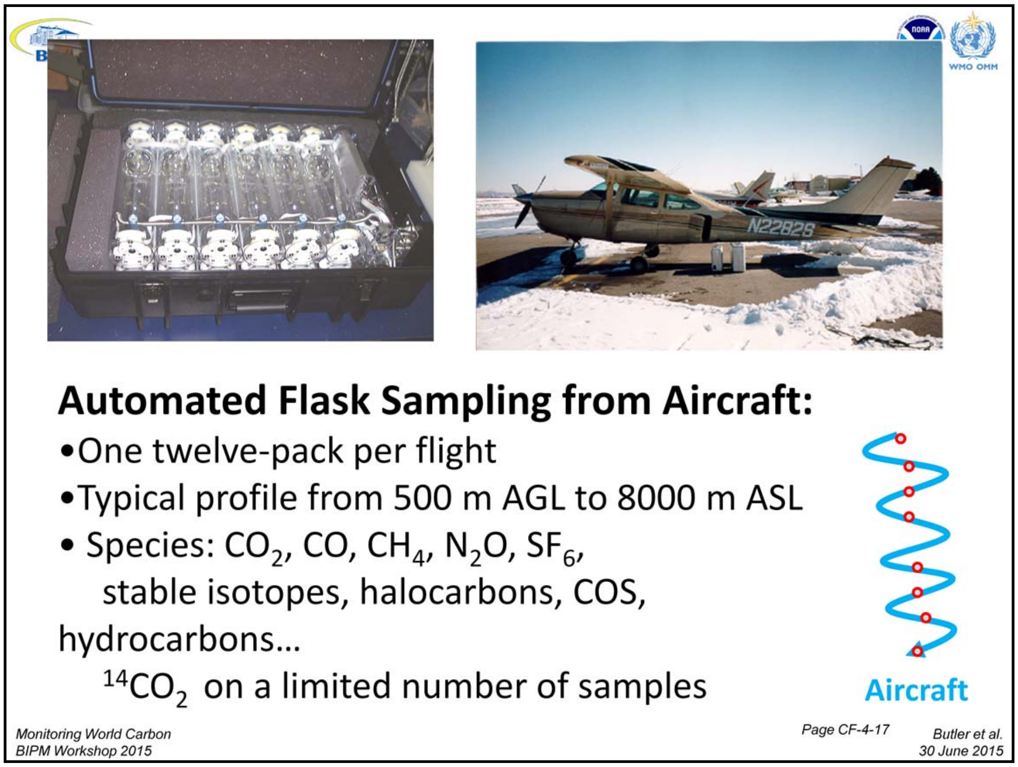
This is a NOAA tall tower; Europe is developing a network as well.



Results here show the variability you can find at one site in a few days

500-600 ppm at night down to ambient during the day

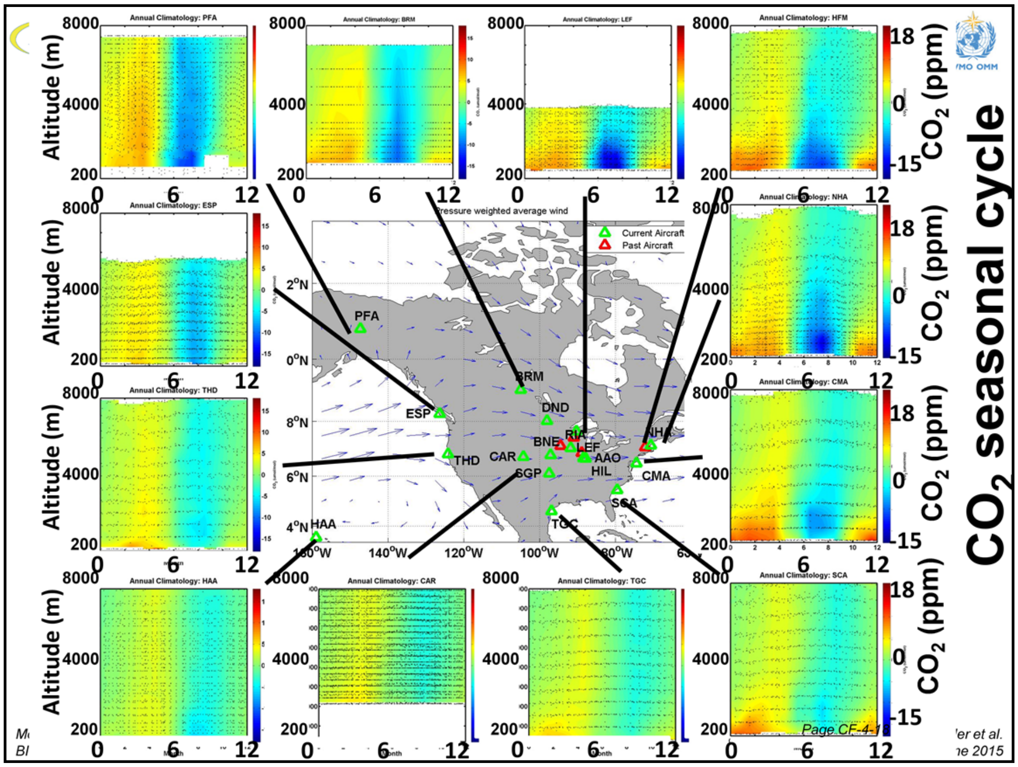
- meteorology
- respiration



Light aircraft have shown what we can do with vertical profiles to understand biological fluxes and physical transport

Inexpensive, frequent, and cover much of the troposphere (~63% at 8000 m), in and out of the boundary layer

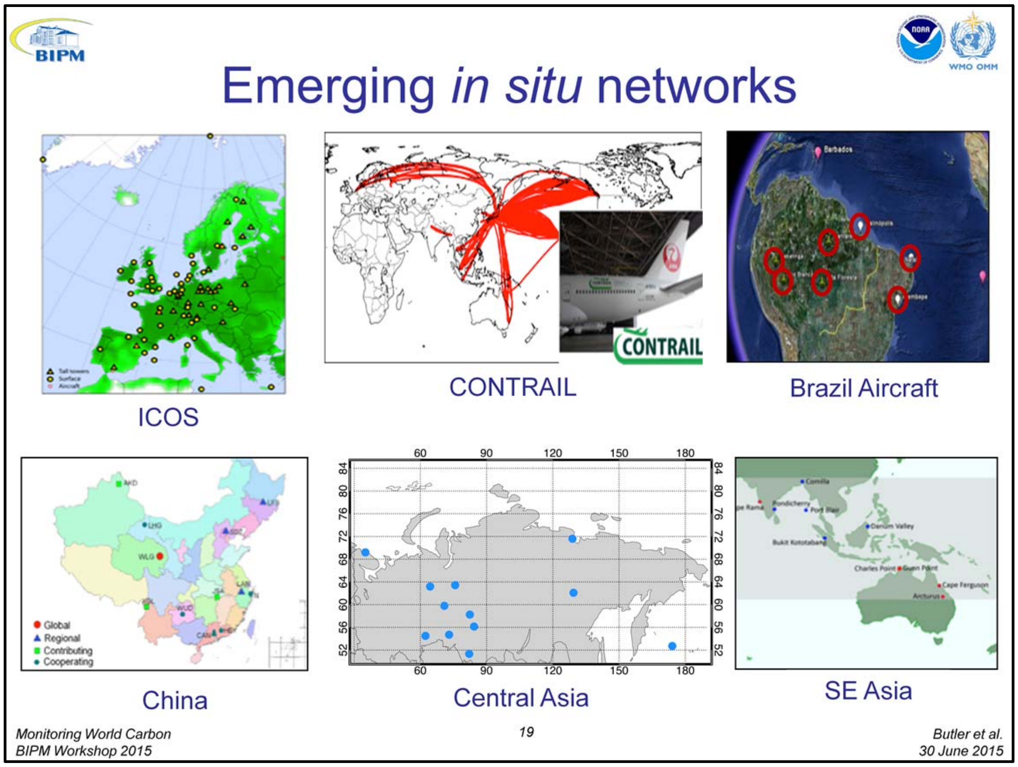
By sampling flasks, up to 50 gases can be measured, providing tracers and additional greenhouse gases to our suite



Climatology of 12 of 16 currently running the NOAA/ESRL carbon cycle aircraft project sites.

This dataset is made of 5000 flasks measurements a year or roughly 400 profiles a year (assuming 2-3 profiles a month at each site).

This view gives you a clear picture of the increase in amplitude in the seasonal cycle from west to east.



Largely through WMO cooperation, the number of networks is increasing

ICOS has towers, aircraft, and surface sites; includes flux and ecosystem measurements

CONTRAIL (NIES) gets tons of vertical profiles, but in limited areas; example for IAGOS et al.

Brazil is mostly light aircraft with an analyzing system identical to that in Boulder

China is surface sites with an analyzing system identical to that in Boulder

Central Asia is a Japanese NIES program

SE Asia is trying to organize across international boundaries to provide a coherent regional product

"New" Players for Observations

- IAGOS
  - Builds on efforts from MOSAIC (Euro airlines), CARIBIC (Lufthansa), and CONTRAIL (Japan Airlines)
  - Fourth package approved for CO_2 and CH_4 on commercial aircraft
    - Operational, but not much funding for instrument construction
  - Many airlines are interested in participating

- Earth Networks
  - Investing $25M over 5 years to enhance global network with ~100 sites
    - Enhancement of ~40% over existing network
    - Committed to high quality positions
- Satellites (Existing and *Forthcoming)
  - AIRS/IASI (passive, mid-tropospheric sensors)
  - SCHIAMACHY (passive sensor)
  - GOSAT (passive sensor, large footprint)
  - OCO-2 (passive sensor, small footprint)
  - *ASCENDS (active laser)

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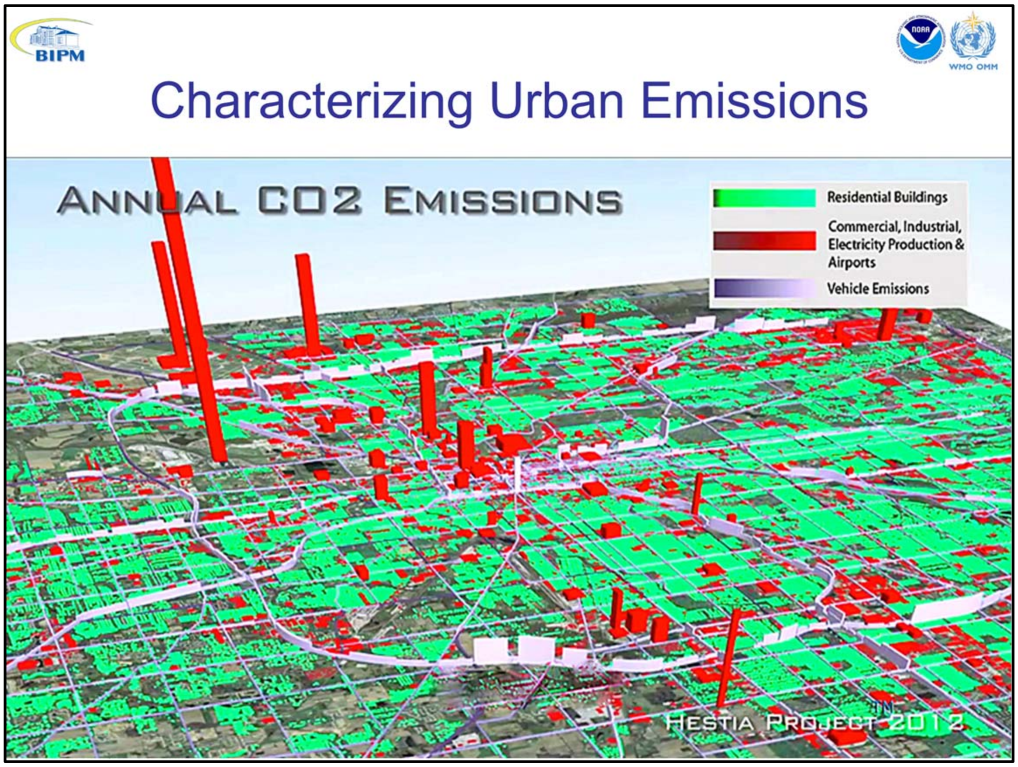
New players include multinational programs, private corporations, and satellite systems



70% of GHG emissions come from urban areas, yet we really understand them poorly.

A key subject of this meeting and one that needs more attention

Sources are legion in an urban zone, yet characterizing the region with measurements and tracers can help us understand the changes we observe

Satellites

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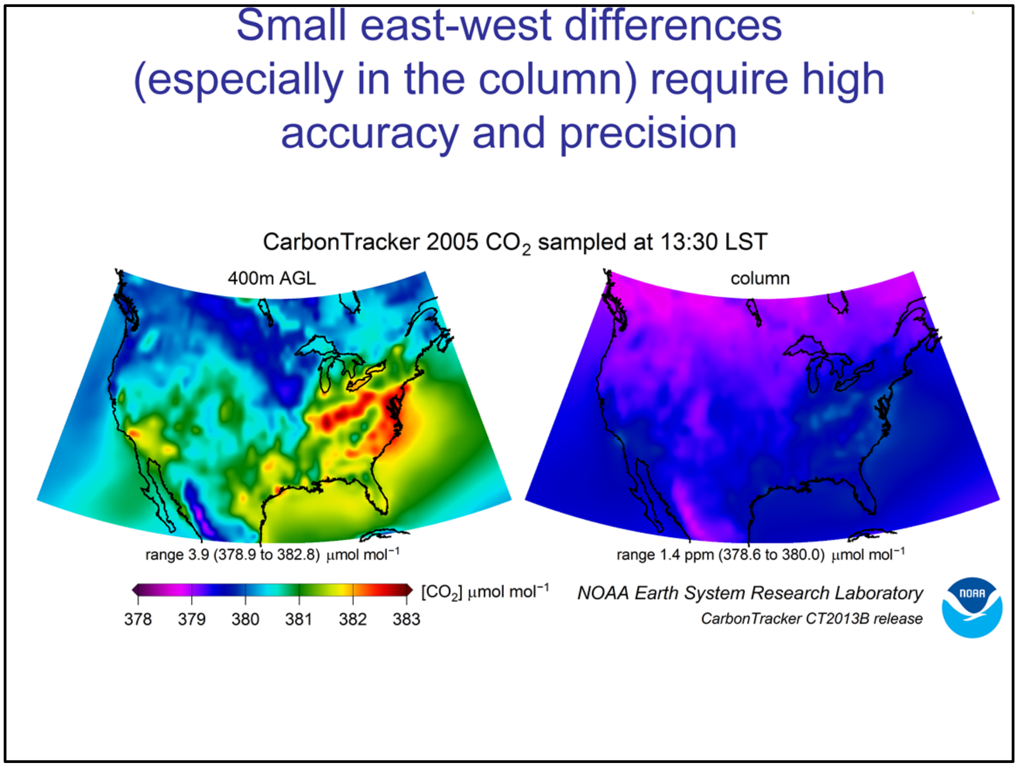
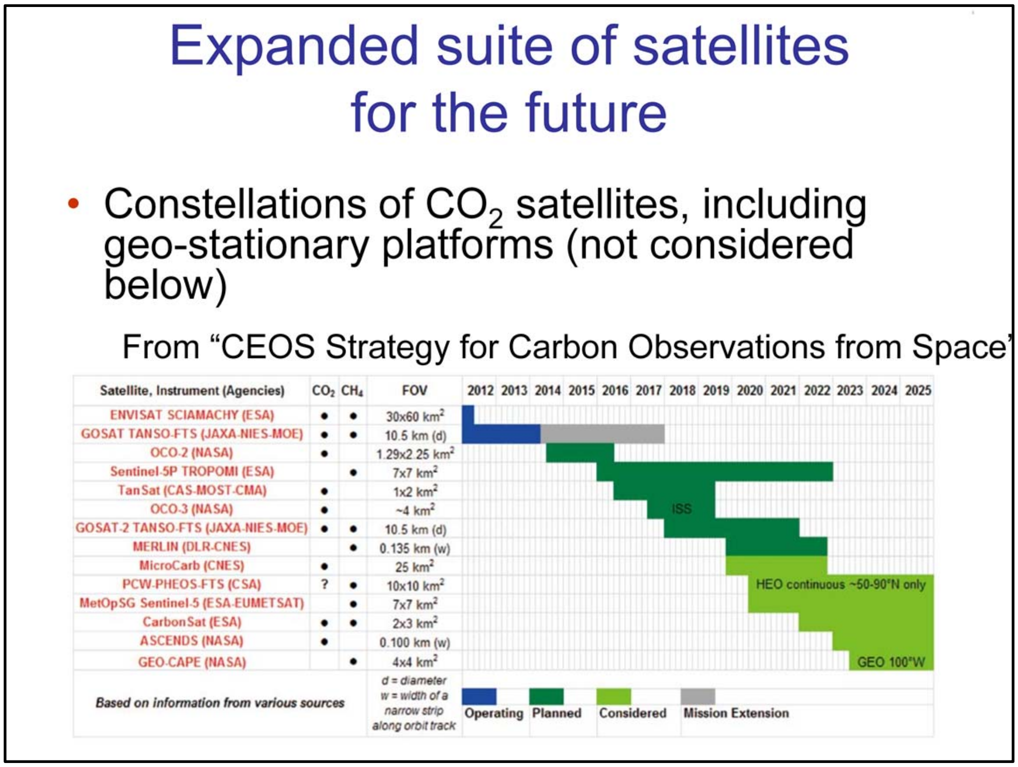


The E-W CO2 gradient across N America <u>in the boundary layer</u> is 3.9 ppm or 1% of total observed

For the total column of air, however, it is 1.4 ppm, or 0.3% of the total observed

It is a special problem for satellites; Detecting the amount is one thing, detecting a trend is another.

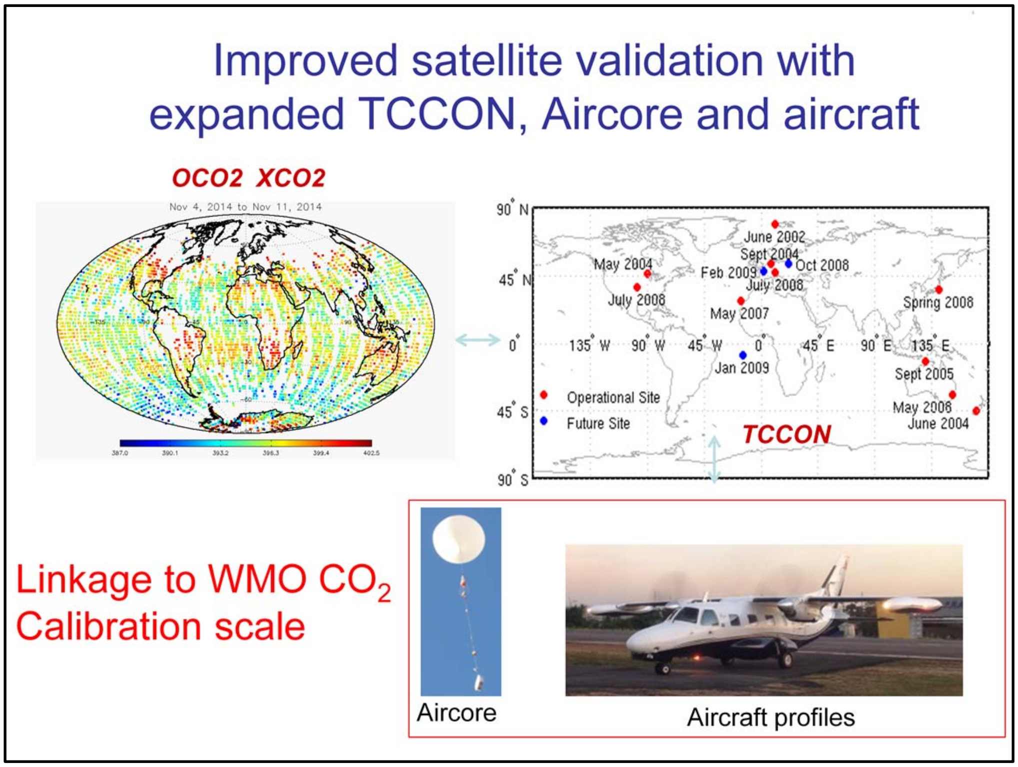
Focusing on hot spots may be the way to best use the satellite retrievals



The important thing here is how many CO2 satellites are planned over the next 15 years.

For sure, satellites cannot be counted on to deliver trends.

They do allow expansion of spatial coverage, especially where in situ samples are not possible.

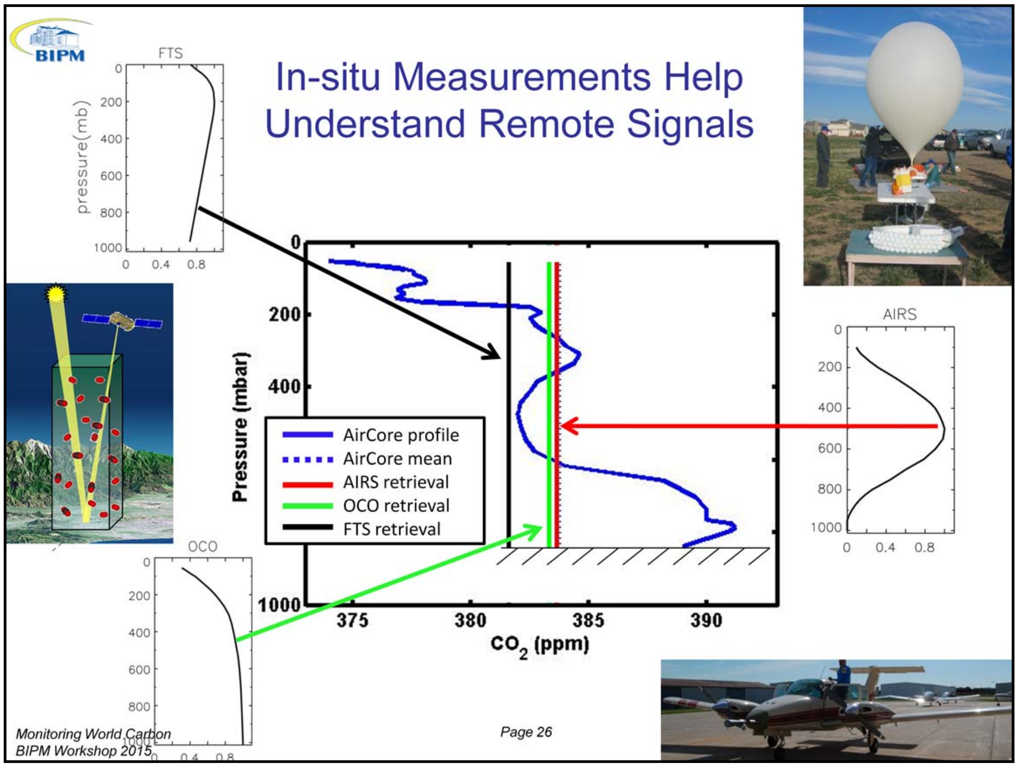


To make the most of the satellite retrievals, we need ground-based valildation.

How does one best compare in situ and remotely sensed measurements?

This is a challenge, but we think it can be done.

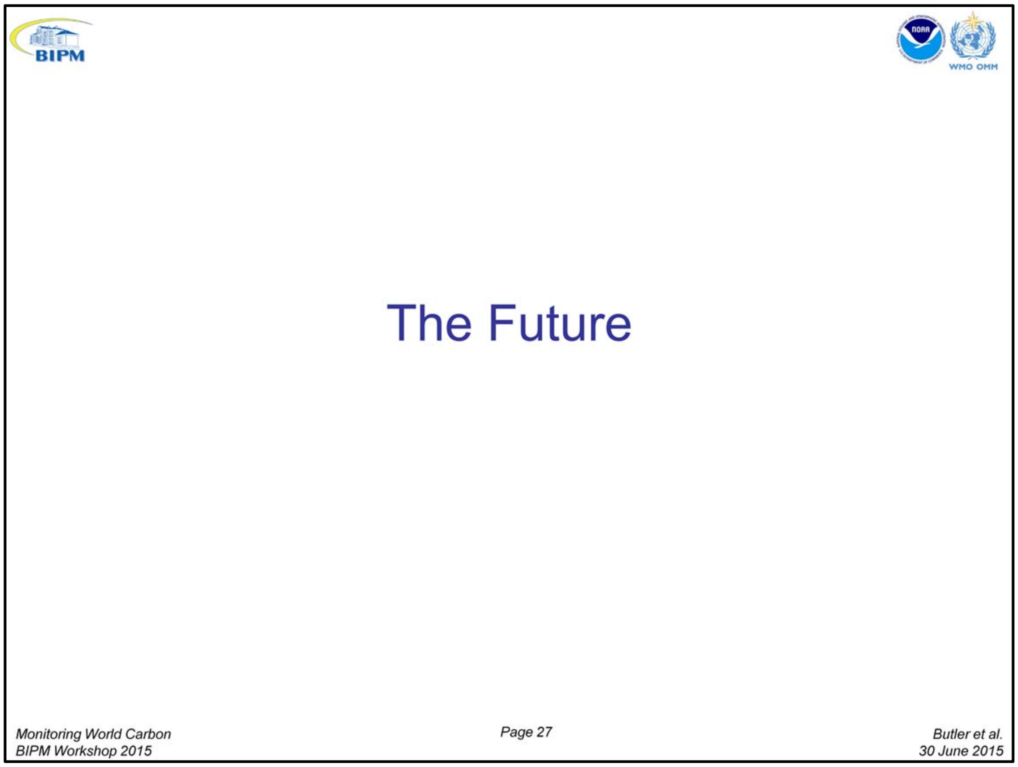
The latest “toy” in this game is Air-core.



Comparing in situ measurements with remote signals.

In situ measurements are traceable to World Calibration Scales, ultimately to SI units.

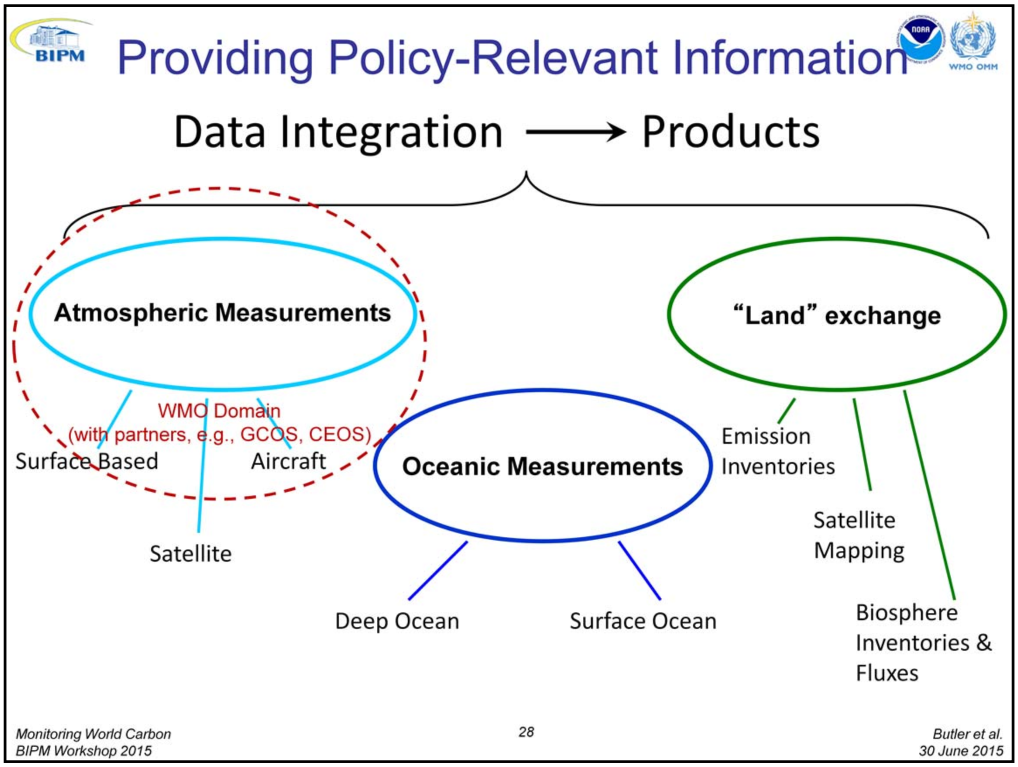
Demonstrating compatibility reduces bias.



To provide useful information on GHGs requires understanding of the carbon and some other cycles, including the ocean and land reservoirs.

WMO’s domain is the atmosphere.

But, all these are connected and information needs to be shared among them.


Providing Policy-Relevant Information
BIPM
WMO OMM
Data Integration ⟶ Products
Atmospheric Measurements
WMO Domain
(with partners, e.g., GCOS, CEOS)
Surface Based
Aircraft
Satellite
Oceanic Measurements
Deep Ocean
Surface Ocean
“Land” exchange
Emission
Inventories
Satellite
Mapping
Biosphere
Inventories &
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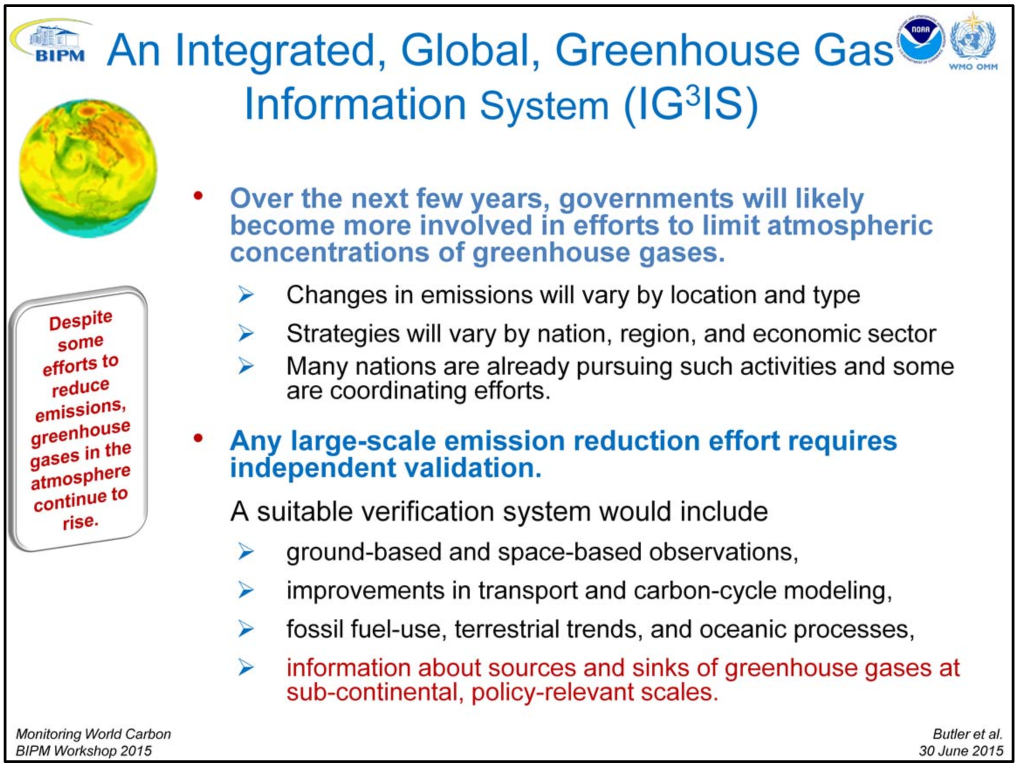
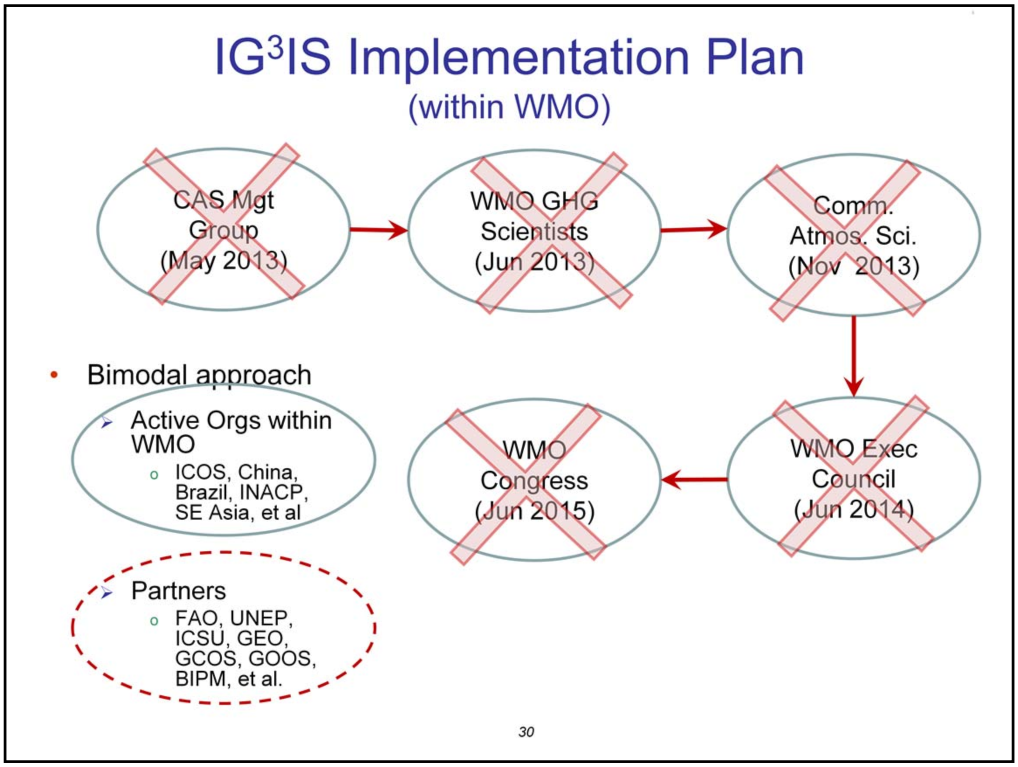


Focus on two main bullets here

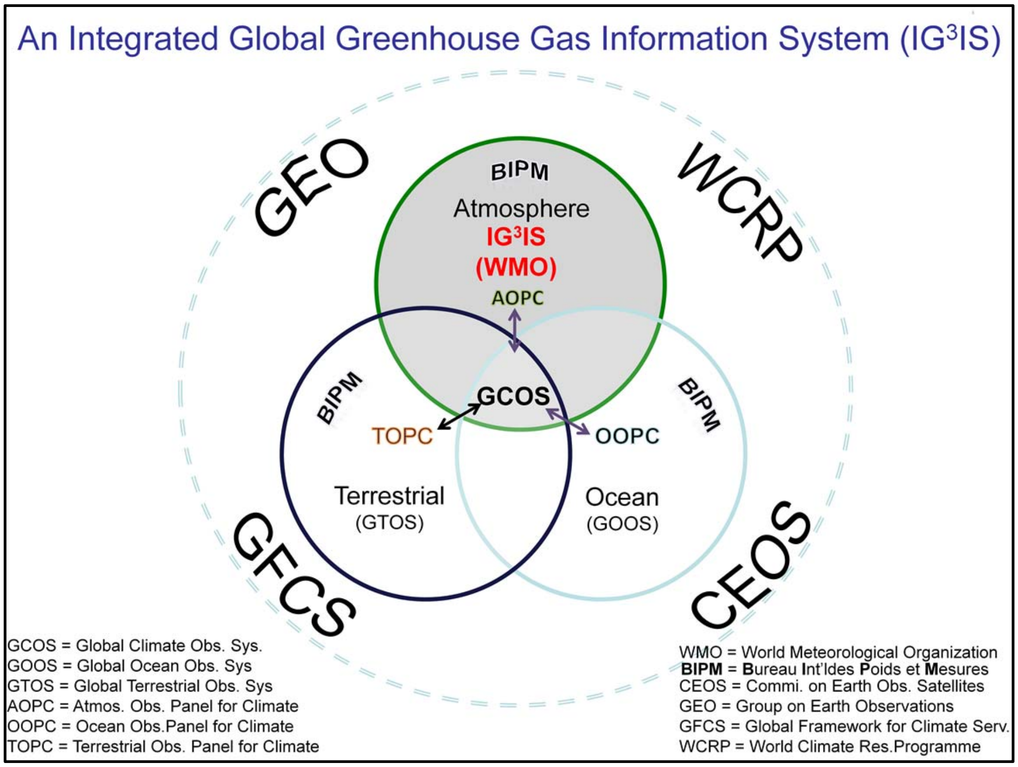


WMO is going forward today with an implementation plan for integrating atmospheric measurements and coordinating other bodies.

All approvals are in and we are now proceeding.

Partners, internal and external, will be important to its success.

It includes addressing urban emissions.

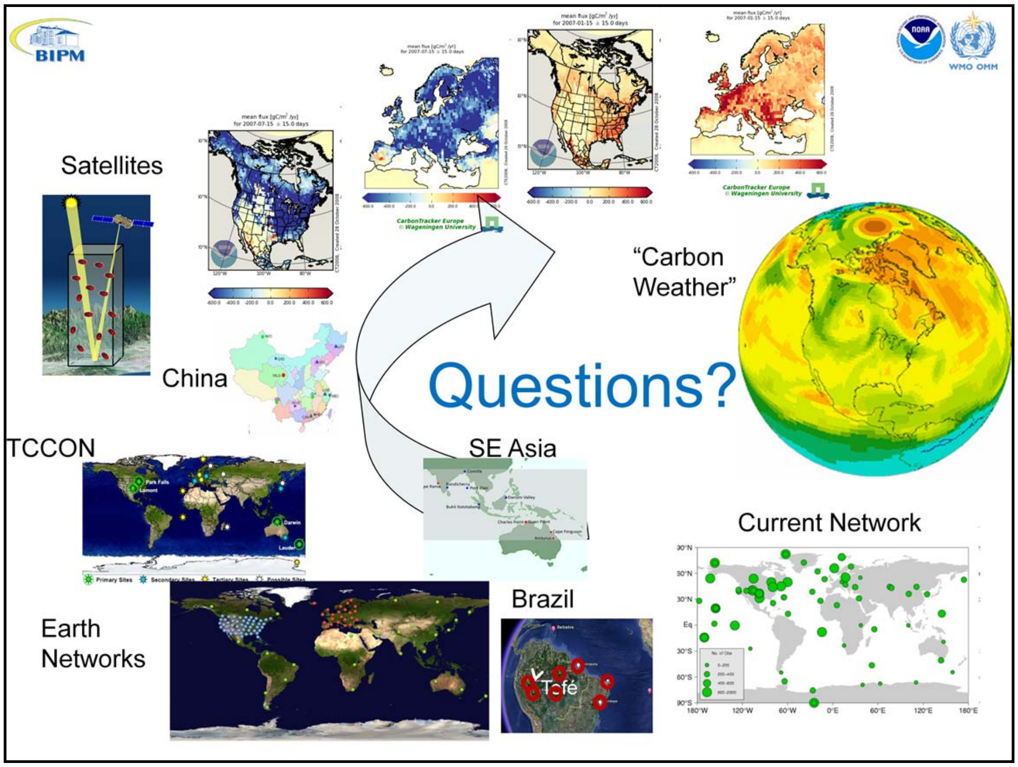


This is a thought diagram and shows how international agency and program roles overlap and suggests a path for success.

Metrology Institutes have a role

-- ensure traceability of all measurements to international units and scales

-- advance measurement approaches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