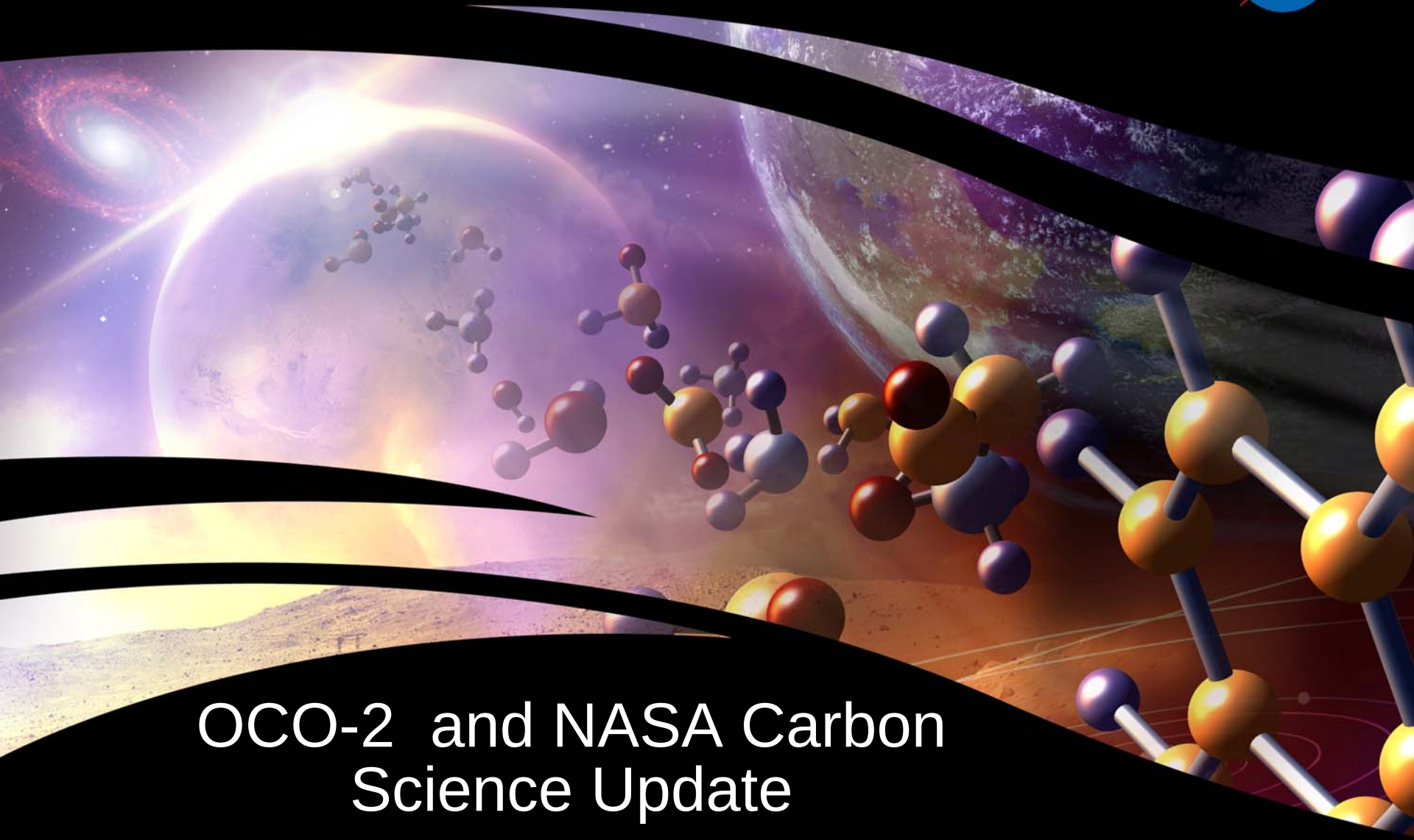
National Aeronautics and Space Administration



OCO-2 and NASA Carbon Science Update

Michael H. Freilich

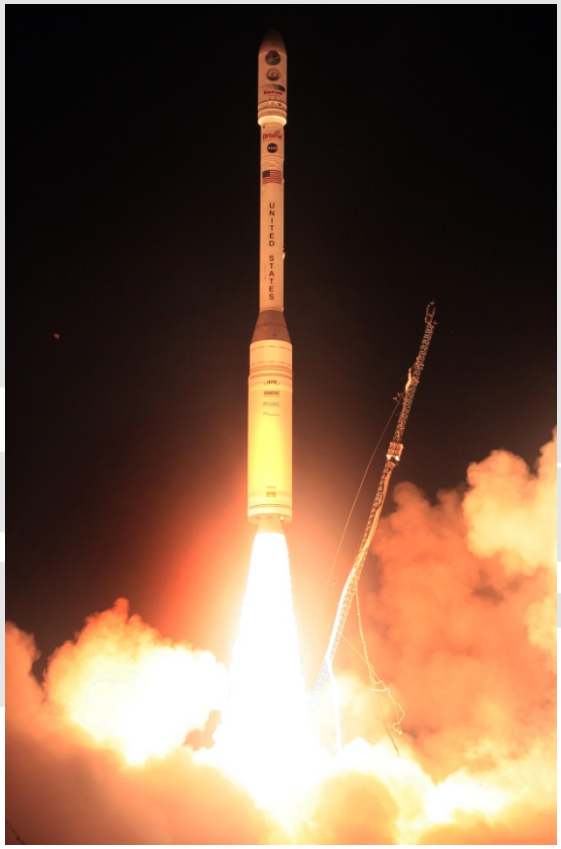
April 13, 2010

NASA Satellite Observations for Carbon

- **Land Cover and Terrestrial Ecosystem Properties** (systematic global time series of land cover/change, vegetation greenness/productivity, fires and burned area) (Landsat, EOS MODIS, NPP VIIRS)
- **Ocean Color and Ecosystem Properties** (systematic global time series of chlorophyll concentration/productivity, phytoplankton carbon, estimates of pCO_2) (SeaWiFS, EOS MODIS, QuikSCAT for pCO2)
- **Other Earth Surface Properties** (exploratory measurements of freeze-thaw status for growing season length; flooding duration and extent to improve estimates of CH_4 fluxes) (AMSR-E, QuikSCAT, foreign radars)
- **Vegetation Canopy Volume, Height , and Vertical Profile**
  - Radar - Regional/global measurements of vegetation volume scattering to estimate aboveground carbon storage in low biomass vegetation types (DESDynI, foreign radars)
  - Lidar - Globally distributed measurements of canopy height and vertical profile to accurately estimate aboveground carbon storage (ICESat, DESDynI)
- **Atmospheric Carbon Dioxide (CO_2) Concentration**
  - Coarse resolution estimates of CO_2 high in the atmosphere to improve/constrain atmospheric models (AIRS)
  - Accurate and precise estimates of CO_2 in the total atmospheric column, with good sensitivity to CO_2 low in the atmosphere, to locate and quantify surface sources and sinks of carbon (OCO-2)

Loss of OCO Mission

February 24, 2009
1:59 AM PST



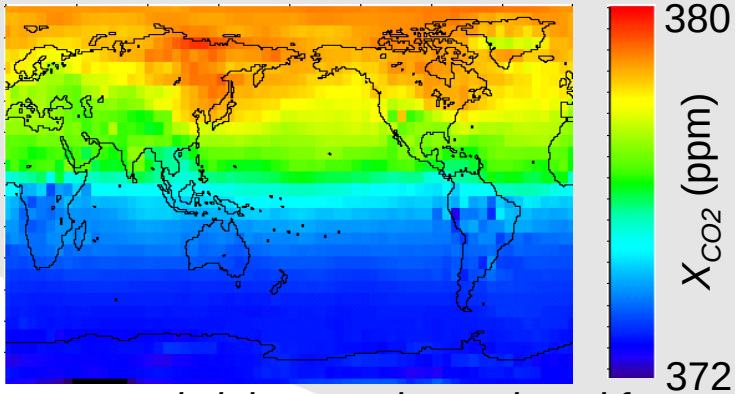
Approximately
17 minutes later

3

Orbiting Carbon Observatory 2 (OCO-2)

Mission Science Objective: Collect the first space-based global measurements of atmospheric CO2 with the precision, resolution, and coverage needed to characterize its sources and sinks on regional scales and quantify their variability over the seasonal cycle

Key Science Products: Estimates of X_{CO2} with random errors and systematic biases no larger than 0.3% (1 ppm) along the measurement track on spatial scales of ≤ 1,000 km which are ≥10% cloud-free over both continents and oceans, on the sunlit hemisphere of the Earth at semi-monthly intervals, for at least 2 years



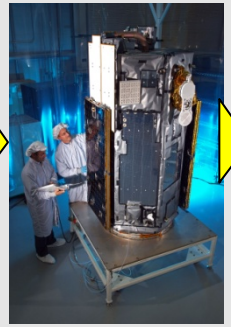
Sources and sinks must be retrieved from small (1-2 ppm) spatial variations in CO_2.

4

The OCO-2 Mission is Well Defined (based on the OCO mission, and benefits from Ibuki)

3-Channel Spectrometer (JPL)

Dedicated Spacecraft bus (OSC)

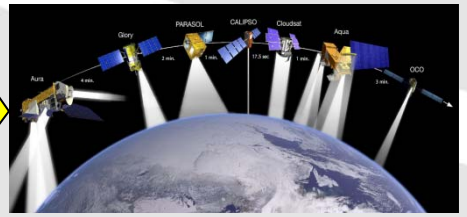


Dedicated Launch Vehicle (KSC)

Mission Ops (OSC)

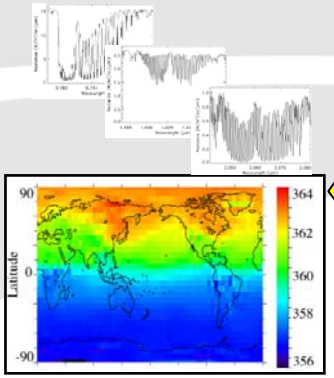
NASA GN (GSFC) and SN (TDRSS)

Formation Flying as part of the A-Train Constellation

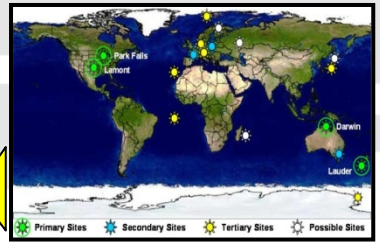


Ground Data Processing Center (JPL)

OCO Data Center

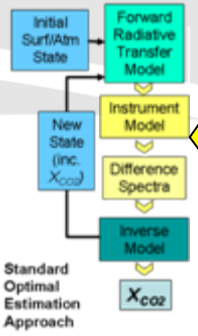


Validation Program

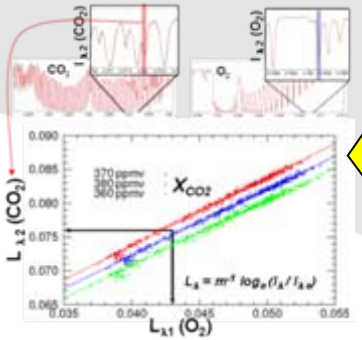


L2 X_{CO2} Retrieval

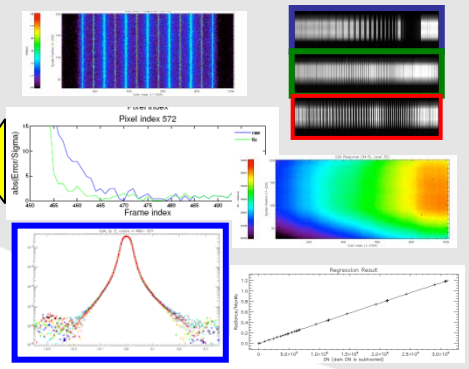
Full Physics Validation Model



Production: AOPD Model



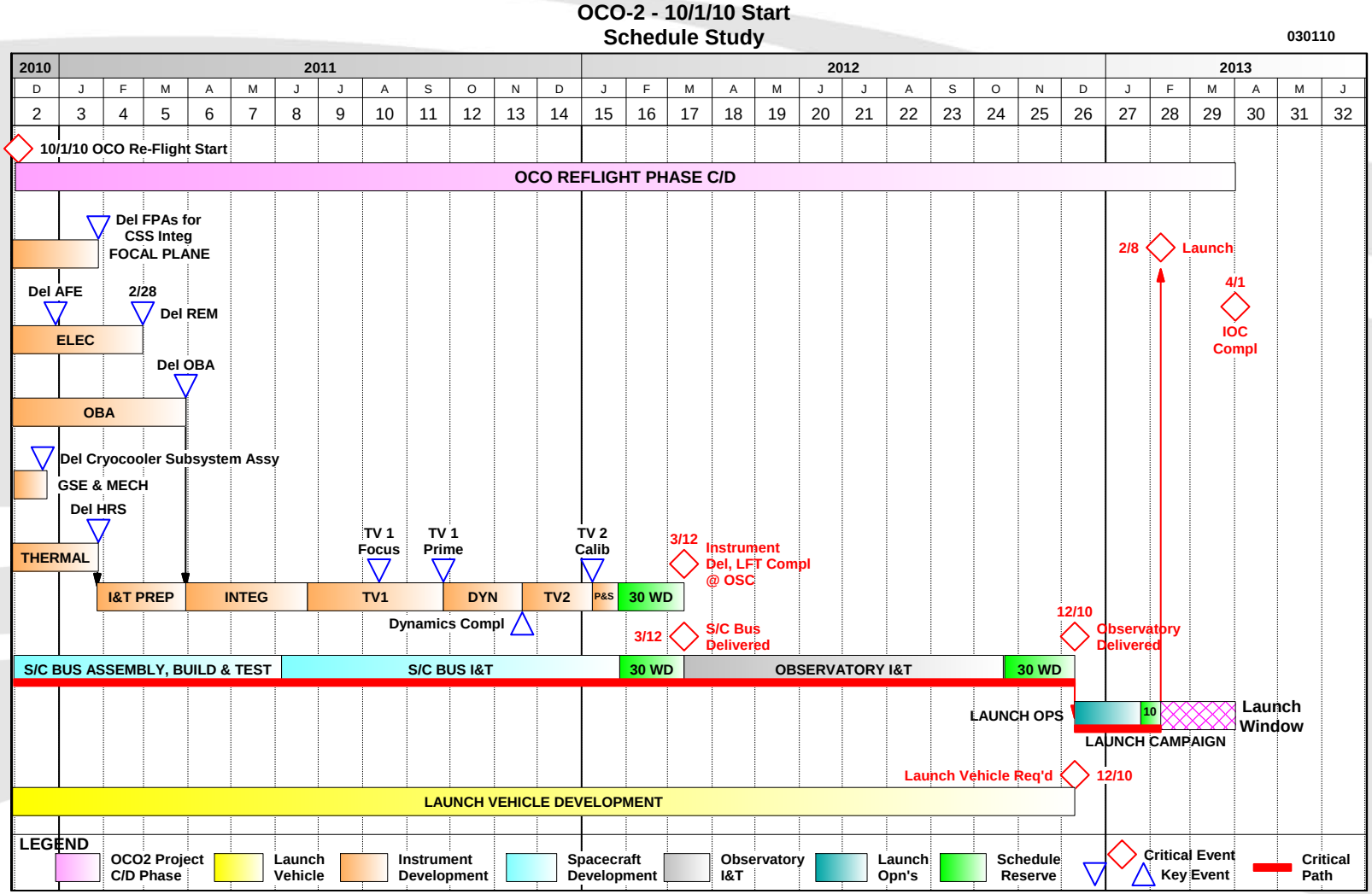
Calibration Program



Please visit http://oco.jpl.nasa.gov for more information

5

Draft Schedule from KDP-C to Launch



* Assumes an Oct 1, 2010 KDP-C

6

Drivers for 16.5-month Phase C

Instrument

- 5 months to complete component deliveries and prep for I&T
- 2.5 months of instrument integration
- 8 months of Incompressible Testing (instrument cannot be tested at the Observatory Level):
  - Thermal vacuum testing #1: 3 months
  - Dynamics Testing: 2 months
  - Thermal vacuum testing #2: 3 months
- 1 month of funded schedule reserve

Spacecraft

- 7.5 months to complete component delivery, subsystem assembly, and functional test
  - Pacing hardware items are Spacecraft Structure, Central Electronics Unit, Attitude Power Electronics, and Power Regulation Electronics
- 8 months of Spacecraft Integration and Test
  - Mechanical Integration: 2 months
  - Electrical Integration: 3 months
  - Functional Test: 1 month
  - Thermal Vacuum Test: 1 month
  - Comprehensive Performance Test: 1 month
- 1 month of funded schedule reserve

7

Rebuild Background

NASA Activities Since Launch Vehicle Failure

- Revalidated science need by NASA-convened community research team (April 09) and unsolicited NRC Letter Report (July 09)
- Expanded already-planned science collaboration with JAXA for GOSAT/Ibuki validation, advancement of carbon science, accelerated maturity of OCO algorithms/processing
- Examined replacement options
  - Instrument on ISS; OCO instrument+TIRS on new s/c in constellation with LDCM; “Carbon Copy” direct rebuild of OCO instrument/spacecraft as free-flyer with dedicated launch; Co-manifest launch of LDCM(+TIRS) and Carbon Copy on single Atlas-V
- Initiated proactive schedule risk reduction
  - Purchased key obsolete instrument components
  - Procured long-lead EEE parts for instrument
  - Leveraged/continued NUSTAR and OSC work-around for obsolete s/c computer

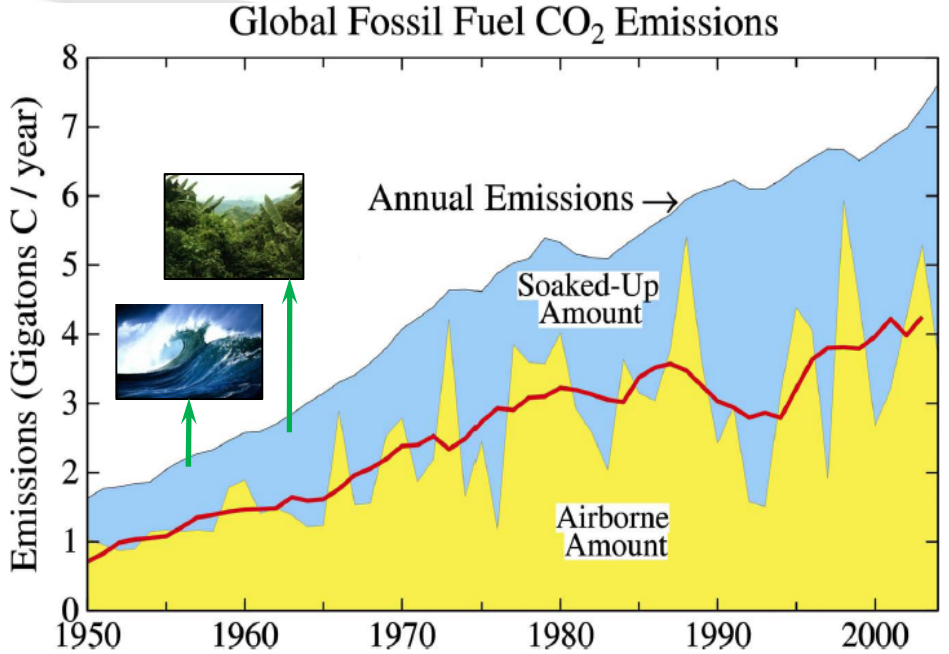
In Sept 2009 NASA presented a plan to OSTP/OMB for a “Carbon Copy” direct rebuild, dedicated launch

- OCO instrument (JPL) and spacecraft (OSC) rebuilds with minimum design changes
- Taurus-XL launch vehicle
- A-Train (1330 sun-synchronous orbit)
- 28-month development
  - Feb 2012 launch readiness date with 1 Oct 2009 authority to proceed
- $331M Life-Cycle Cost (LCC)

8

The Mystery of the Missing CO_2

- Humans have added >200 Gt C to the atmosphere since 1958
- Less than half of this CO_2 is staying in the atmosphere
- Where are the *sinks* that are absorbing over half of the CO_2?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?



Global fossil fuel CO_2 emissions with division into portions that remain airborne or are soaked up by the ocean and land.

Source: Hansen and Sato, *PNAS*, **101**, 16109, 2004.

5

Precise, systematic, global measurements are essential to identify these CO_2 sinks and determine how they how they will respond to climate change

9