CLARREO Status

CERES Science Team Meeting

NASA GISS

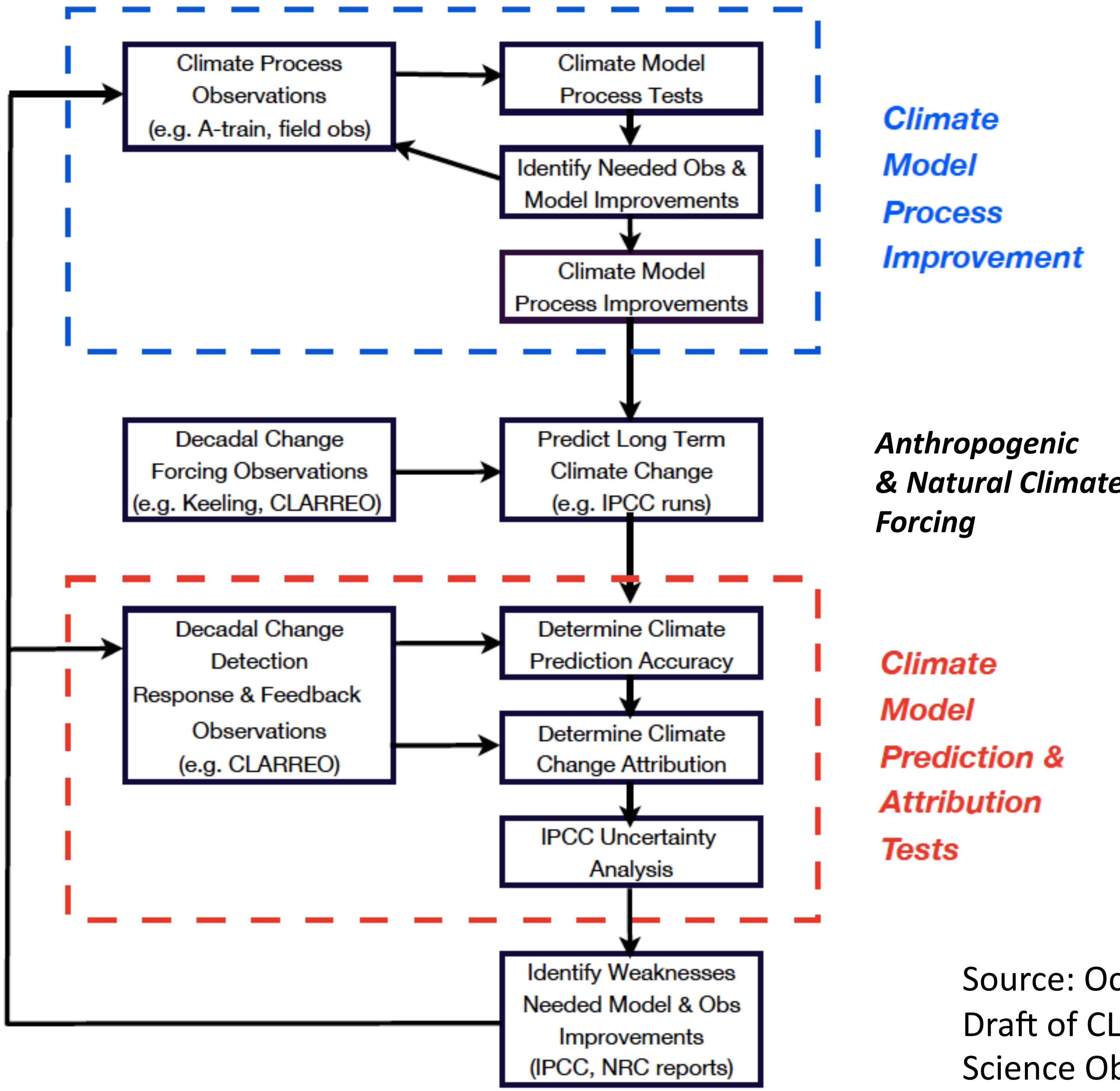
Oct 27-29, 2008

CLARREO Time Line

- NRC Decadal Survey Mission (Tier 1)
- In pre-phase A studies now
- Mission Concept Review ~ Fall, 2009
- Phase A 2010
- Phase B 2011
- Launch 2015/16
- Actual rate of progress depends on future NASA Earth Science funding levels

CLARREO Objectives

- Highly Accurate SI traceable decadal change spectral benchmark, NIST in orbit.
- Climate Change Absolute Accuracy: 0.1K, 0.2% both 95% confidence
- Accuracy requirements set for climate decadal change observations for temperature, water vapor, cloud decadal changes.
- Accuracy? IR: deep well phase change blackbody sources, Solar: deep well mechanically cooled active cavity detectors (1000 times more sensitive)
- IR spectra: ~ 3.5 to 50 micron wavelength: mid and far-infrared
  - Nadir only, ~ 100 km fov, ~ 1 cm^-1 spectral resolution, 1 to 3 orbits
  - Likely need for pointing if to calibrate geostationary imagers (angle/time/space match at all latitudes)
  - Likely both spectral benchmark and calibration of other sensors including inteferometers (CrIS, IASI, AIRS), imagers (MODIS, VIIRS, Landsat), broadband radiation (CERES, GERB). Need to characterize spectral response functions prelaunch.
- Solar reflected spectra: ~ 0.40 to 2.5 micron wavelength
  - Nadir for benchmark, ~ 1 km fov across 100 km swath, ~ 2 nm spectral resolution needed for intercalibration of typical 20 nm wide imager channels: e.g. MODIS.
  - Pointing capability likely needed for intercalibration angle/time/space matching
  - Pointing increases sampling a factor of 10, scattering angle sampling for polarization verification
  - Polarization at selected wavelengths for characterizing sensitivity to polarization
  - Spectral benchmark sampling still under study. Solar time/space sampling much tougher than infrared
  - Includes solar irradiance for total and spectral at high accuracy for solar irradiance monitoring
- GPS refractivity. For high vertical resolution temperature 5km – 30km altitude, a combined metric of water vapor and temperature change below 5km.
- APS-like multi-angle high accuracy (0.1%) polarization continuity needed for aerosol forcing. Optimal orbit likely a continuation of GLORY 130LT orbit.



Source: Oct 2008 Draft of CLARREO Science Objectives

CLARREO Approaches

(i) science questions that CLARREO will address directly with current technology and without the need for any other observations. This category is primarily the mid-infrared spectra (~ 3 to 15 µm wavelengths), and GPS.

(ii) science questions that CLARREO will address directly with expected definition study and IIP confirmation of recent advances in metrological technology and sampling strategies. This category is primarily applicable to the new observations of the Far-Infrared Earth emitted spectra (~ 15 to 100 µm) and the spectra of solar radiation reflected from the Earth and incident on the Earth (~ 0.3 to 2.5 µm).

(iii) science questions that CLARREO will address in combination with other satellite solar and infrared sensors such as operational weather sensors, most commonly using a transfer of CLARREO SI traceability to other instruments through intercalibration in orbit. Examples here would include current and future instruments such as AIRS, CrIS, IASI, MODIS, VIIRS, and CERES.

Source: Oct 2008
Draft of CLARREO
Science Objectives

CLARREO Science Questions (Draft)

Table 1. CLARREO Science Questions

Science Question ("change over time" = decadal change)	CLARREO Science Impact	CLARREO Observable (SI traceable)	CLARREO Implementation Approaches
Climate Forcing: Natural and Anthropogenic			
1) How is aerosol direct effect radiative forcing changing over time? How accurately is this forcing change represented in climate models?	**Critical**	Solar Reflected Spectra Polarization	(ii), (iii)
2) How is solar radiative forcing changing over time? How accurately is this forcing change represented in climate models?	**Critical**	Total and Spectral Solar Irradiance	(i), (iii)
3) How is the anthropogenic greenhouse gas radiative forcing changing over time? How accurately is this forcing change represented in climate models?	*Important*	Mid IR Spectra	(i)
4) How is radiative forcing due to land use changing over time? How accurately is this forcing change represented in climate models?	*Important*	Solar Reflected Spectra	(iii)
5) How is the aerosol indirect effect radiative forcing changing over time? How accurately is this forcing change represented in climate models?	Substantial	Solar Reflected Spectra Polarization	(iii)

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CLARREO Science Questions (Draft)

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Science Question ("change over time" = decadal change)	**CLARREO Science Impact**	**CLARREO Observable (SI traceable)**	**CLARREO Implementation Approaches**
Climate Response: Change Detection, Attribution, and Prediction Accuracy			
6) How is the vertical temperature and water vapor structure in the atmosphere changing over time? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	**Critical**	Mid-IR Spectra GPS	(i), (ii), (iii)
7) How are cloud properties (fraction, optical depth, emissivity, height, temperature, phase, particle size) changing over time? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	**Critical**	Mid-IR, Far-IR Spectra Solar Reflected Spectra	(iii)
8) How is the nadir infrared radiance emission spectra of the Earth at TOA changing over time? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	**Critical**	Mid-IR Spectra Far-IR Spectra	(i), (ii), (iii)
9) How is the nadir solar reflectance spectra of the Earth at TOA changing over time? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	**Critical**	Solar Spectral Irradiance Solar Reflected Spectra	(ii)
10) How are the solar reflected, infrared emitted, and net radiative fluxes at TOA changing over time for clear and all-sky? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	**Critical**	Mid-IR, Far-IR Spectra Solar Reflected Spectra	(iii)
11) How are the amplitude and phase of diurnal cycles of Earth emitted and reflected spectra changing over time? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	*Important*	Mid-IR, Far-IR Spectra Solar Reflected Spectra	(i), (ii)
12) How is vegetation responding to climate change, including ocean color? What part of the change is consistent with anthropogenic forcing? How accurately do climate models predict the changes?	*Important*	Solar Reflected Spectra	(iii)

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CLARREO Science Questions (Draft)

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Science Question ("change over time" = decadal change)	CLARREO Science Impact	CLARREO Observable (SI traceable)	CLARREO Implementation Approaches
Climate Feedbacks and Climate Sensitivity			
13) What is the amplitude of cloud feedback? How accurately is it represented in climate models?	**Critical**	Mid-IR, Far-IR Spectra Solar Reflected Spectra	(iii)
14) What is the amplitude of water vapor feedback and lapse rate feedback? How accurately is it represented in climate models?	**Critical**	Mid-IR, Far IR Spectra GPS	(i), (ii)
15) What is the amplitude of surface snow and ice albedo feedback? How accurately is it represented in climate models?	**Critical**	Solar Reflected Spectra	(iii)
16) How is the net radiative energy balance of the earth, a key measure of climate sensitivity, changing over time? How accurately is it represented in climate models?	**Critical**	Mid-IR, Far-IR Spectra Solar Reflected Spectra	(iii)

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CLARREO: Why Now?

- Testing the accuracy of climate model predictions is testing on decadal time scales.
- Decadal change signals are small but critical: accuracy required is a factor of 10 beyond normal weather or process study missions.
- New developments in the last decade in technology for more accurate space sensors:
  - Mechanical cooled cryogenic active cavity detectors: SI traceable to the watt
    - NIST SIRCUS and similar NPL approaches to then trace the cavity to other sensors/optics
  - Deep blackbody cavity sources with multiple phase change detectors: SI to the Kelvin
  - GPS refractivity: SI traceable to time
  - New polarization for single scatter (aerosols, vegetation, cloud top, e.g. APS, POLDER)
  - Greatly increased experience with intercalibration in orbit (e.g. CERES)
  - New Far-IR interferometer high altitude balloon flight (FIRST)
  - Improved use of cavities for total and spectral solar irradiance (e.g. SORCE, TSIS)
  - Experience with improved IR sounding spectrometers (e.g. AIRS, IASI, TES, CrIS)
  - Greatly improved understanding of space/time/angle sampling (e.g. CERES)
- Lack of a designed climate observing system (CCSP strategic report, NRC)
- Urgency: the launch of CLARREO will mark the start of a space based decadal climate observing SYSTEM. Not complete, but a huge step forward
- CLARREO is crosscutting many key climate science questions.