Objectives of the Project & this Workshop

Keck Institute for Space Studies project:

Monitoring of Geoengineering Effects and their Natural and Anthropogenic Analogues

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Outline

- Context & motivation: why we’re here
- Research program (notional framework)
- Project objectives: Study & Development phases
- Study timeline
- Focus for the study
- Goals for this workshop
- Identifying priorities (examples)
- Workshop process & structure
- Guidelines & requests

Context & Motivation

- Increasingly serious discussion about publicly funded geoengineering research
  - Royal Society report (2009)
  - National Research Council (NRC), America's Climate Choices reports (2010)
  - Government Accountability Office (GAO) reports to congress (2010 and 2011, pending)
  - Bipartisan Policy Center Report (2011, pending)
  - National programs in UK, China

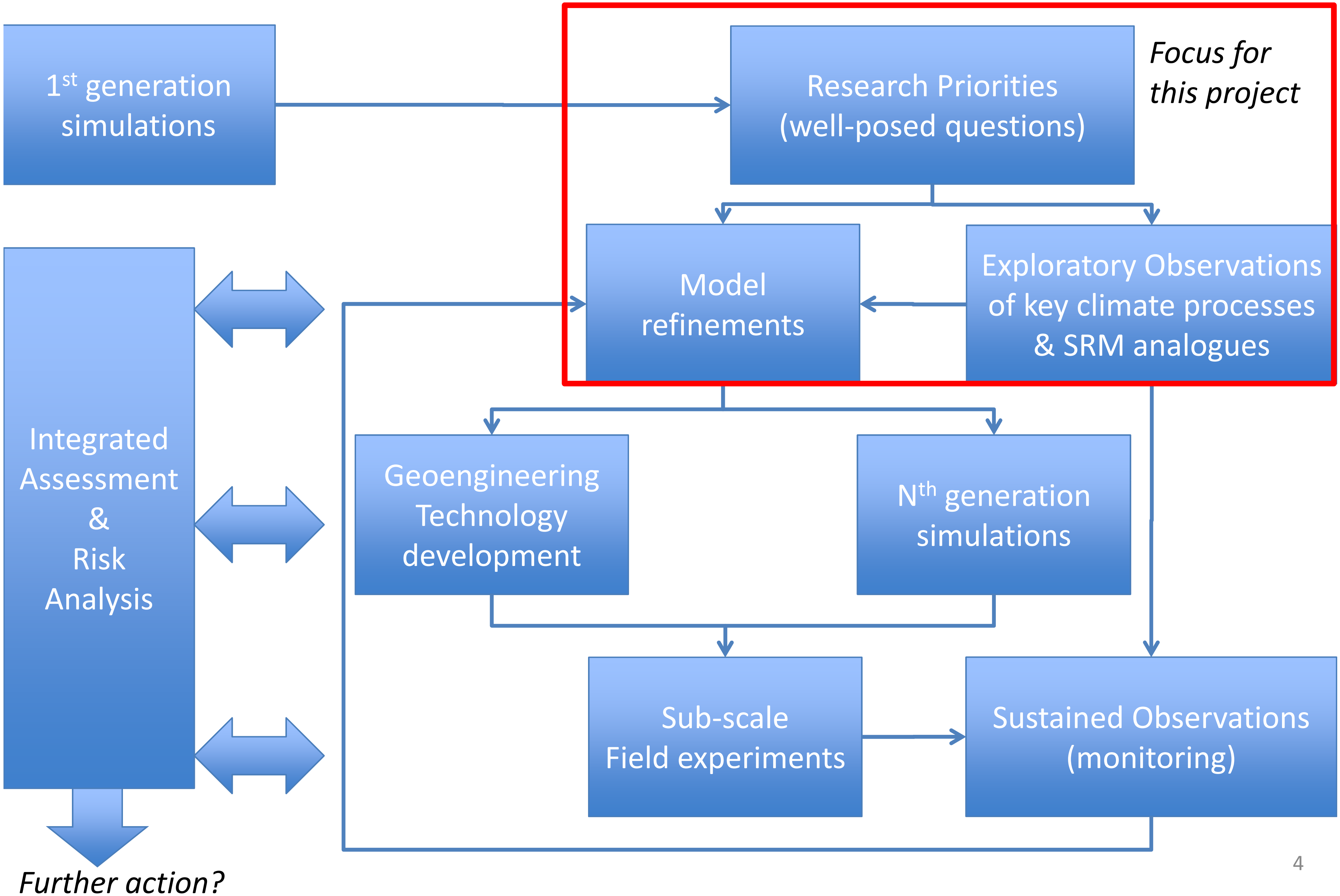
- No systematic enumeration of key research gaps and how to close them (yet)

- Past national efforts to identify observational and modeling needs have not necessarily focused on addressing questions relevant to geoengineering
  - Opportunity to influence next Decadal Survey, etc

- Goal: any geoengineering-focused research, observations, and models should co-benefit climate science writ large (strengthen, not weaken the latter)

- This project is strictly intended to improve the basic science required for objective, robust risk assessments – NOT ADVOCACY FOR GEOENGINEERING

Research Program (notional framework)



Overall Project Objectives

- Study Phase (2011):
  - Enumerate priorities for improved scientific understanding of physical processes and impacts of geoengineering/analogues
  - Identify specific options to close gaps between needs and current capabilities – focused on but not limited to observational assets
  - Product: Report summarizing findings & recommendations
    - Itself a valuable contribution to the community
    - Rationale for follow-on Technical Development activity

- Technical Development Phase (2012-2014) – if selected:
  - TBD activities to help close selected gaps (e.g., instrument technology development, data analysis, &/or modeling tasks)

Goals for this Workshop

- Establish priorities for improved scientific understanding of (SRM & analogues) physical processes and impacts

- Identify *specific* gaps between those requirements and current & planned observational & modeling capabilities

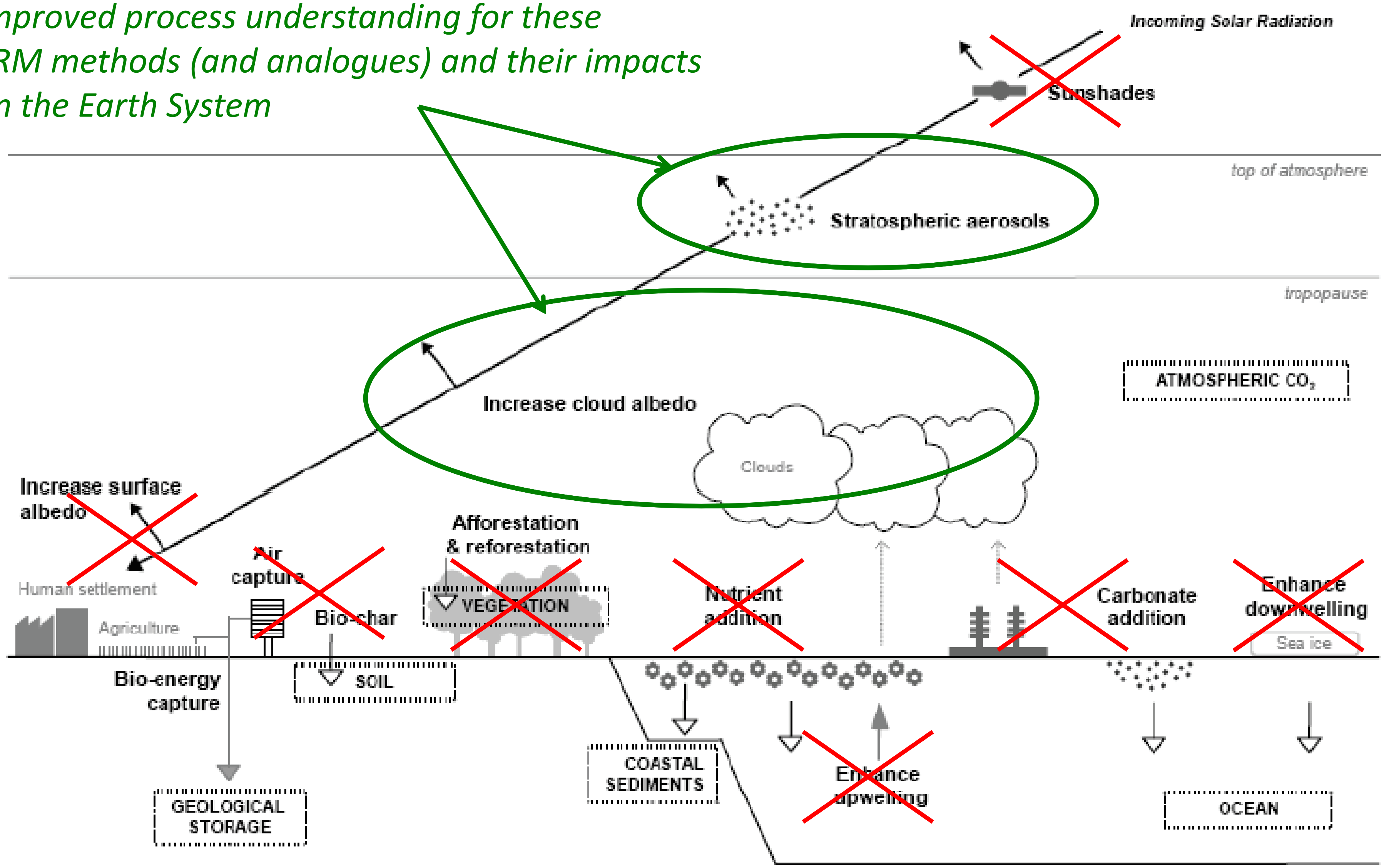
- Select focus topics for 2nd workshop → explore options for closing gaps with a follow-on Technical Development activity

Draft Timeline

- May 2011: Workshop#1
  - Establish needs and major gaps
  - Identify focus topic(s) for Workshop#2
- Nov 2011: Workshop #2 (tentatively, week of Nov 14)
  - Further exploration/definition of focus topic(s)
  - Develop options for follow-on Technical Development Project
- Feb 2012: Submit NOI for Technical Development activity
- March 2012: Deliver Study Report
- Apr 2012: Submit Proposal for Technical Development activity

Focus for the Study

Improved process understanding for these SRM methods (and analogues) and their impacts on the Earth System



Lenton & Vaughan, ACP, 2009

Why this focus?

- Practicality: limited time & resources and objective of making measurable progress not compatible with a comprehensive study

- Why SRM and analogues?
  - Provides a unique opportunity to assess our understanding of the response of the climate system to associated changes in solar radiation
  - Analogues also fundamental to understanding climate change itself - how climate is forced by aerosol and respond through clouds & other influences
  - Understanding of CDR processes(carbon-cycle) is considered more mature

- Why stratospheric aerosols and cloud albedo?
  - Greater relevance to broader climate science than other SRM methods*
  - (relatively speaking) considered more practical and likely to receive serious attention than other SRM methods*

**space parasols, surface albedo mods, etc*

What's already being done

(ex: USGCRP goal area 3)

Goal 3	Reduce uncertainty in projections of how the Earth's climate and related systems may change in the future				
Focus 3.1	Improve characterization of the circulation of the atmosphere and oceans and their interactions through fluxes of energy and materials	37.6	38.5	44.4	DOC, DOE, DOI, NASA, NSF
Focus 3.2	Improve understanding of key "feedbacks" including changes in the amount and distribution of water vapor, extent of ice and the Earth's reflectivity, cloud properties, and biological and ecological systems	66.0	66.8	69.4	DOE, DOI, NASA, NSF
Focus 3.3	Increase understanding of the conditions that could give rise to events such as rapid changes in ocean circulation due to changes in temperature and salinity gradients	7.5	11.8	12.6	DOE, DOI, NASA, NSF
Focus 3.4	Accelerate incorporation of improved knowledge of processes and feedbacks into climate models to reduce uncertainty in projections of climate sensitivity, changes in climate, and related conditions such as sea level	84.1	89.8	103.0	DOC, DOE, NASA, NSF
Focus 3.5	Improve national capacity to develop and apply climate models	41.8	43.3	50.6	DOC, DOE, NASA, NSF
GOAL 3 TOTAL		236.9	250.1	279.8	

Example of Geoengineering research needs

(potential priorities for improved SRM process understanding)

RESEARCH AREAS	RESEARCH TASKS	POTENTIAL SYNERGIES	RELATED GCRP GOAL AREA*
A. OBSERVATIONS	A-1. Focused study to assess observational needs and gap for sustained monitoring of selected Essential Climate Variables with decision-relevant accuracy and space-time resolution to a) enable the required improvements in climate process understanding and b) detect geoengineering efforts (including unilateral efforts). Example: **robust detection of small changes in global radiative forcing, net irradiance, and/or albedo associated with SRM geonengineering and natural or serendipitous anthropogenic analogues (e.g., volcanoes, ship tracks, dust on snow, airplane contrails, etc)**	Climate adaptation science (USGCRP); requirements for an operational "climate service".	
B. INTEGRATED ANALYSIS	B-1. Define criteria for "climate emergency" scenarios (&/or tipping-point events) including quantiative thresholds and recommended detection methods to support risk analysis and establishing protocols for geoengineering deployment (particularly SRM methods). This evaluation must address both the physical environment and socio-economic issues.	Climate adaptation planning efforts (DOD, IC, USAID).	3.3
	B-2. Cross-cutting analysis (including application of control systems theory to the Earth System) of the efficacy, risks, and co-benefits of multi-pronged geoengineering actions in the presence of various other anthropogenic forcings (e.g., combination of GHG mitigation and air-quality management).	Climate adaptation planning efforts (DOD, IC, USAID).	
C. BASIC CLIMATE PROCESSES	C-1. Improved understanding of the **short- and long-term impacts of sulfate aerosol injection on stratospheric ozone**.		2.2
	C-2. Improved understanding of the **short- and long-term direct impacts of sulfate aerosol injection on tropospheric cloud and cloud-aerosol-radiative interactions.**		2.3
	C-3. Improved understanding of **stratospheric sulfur cycle/chemistry, particle aggregation, and evolution.**		

D. CLIMATE SYSTEM RESPONSES	D-1. Improved understanding of climate system and ecosystem (terrestrial and marine) response to high CO2 environments in the presence of sustained SRM geoengineering (modified radiative forcing). Research program focused on **precipitation patterns, sea-level rise, ecosystem productivity and biodiversity.**	Climate adaptation science (USGCRP) & climate adaptation (DOD, IC, USAID, etc).	
	D-2. Improved understanding of the impacts to atmospheric and ocean circulation associated with specific SRM geoengineering methods (surface albedo changes due to whitening, dust, and black carbon; boundary layer cloud albedo changes; and insolation modification). Studies of **atmo and ocean circulation changes** associated with different SRM geoengineering scenarios.	Climate adaptation science (USGCRP), climate adaptation planing (USAID, DOD, IC, NOAA, DOS).	3.1, 3.3
	D-3. Improved understanding of the impacts to key climate feedback mechanisms (e.g.,**tropospheric & stratospheric clouds**, carbon cycle, and **hydrologic cycle**) in response to specific SRM geoengineering perturbations (surface albedo changes due to whitening, dust, and black carbon; boundary layer cloud albedo changes; and insolation modification). Studies of **systematic perturbations to and responses (including e-folding times) of key climate feedback mechanisms**.	Climate adaptation science (USGCRP), climate adaptation planing (USAID, DOD, IC, NOAA, DOS). Improved understanding of key climate couplings/sensitivities for USGCRP, IPCC, etc.	3.2
	D-4. Improve understanding of the risks and potential co-benefits of ocean-based enhaced weathering (enhanced alkalinity) for CDR geoengineering, including connections with ocean acidification.	Climate adaptation science (USGCRP), climate adaptation planing including fisheries issues (USAID, DOD, NOAA, DOS).	
	D-5. Increase confidence in the efficacy, response time, and longevity of CDR methods including potential saturation of natural carbon reservoirs (terrestrial and marine) on space-time scales relevant to practical project implementaiton.	Climate adaptation science (USGCRP), climate adaptation planing (USAID, DOD, IC, NOAA, DOS).	

E. REGIONAL CLIMATE IMPACTS	E-1. Improved understanding of **regional climate change including seasonality and variability (e.g., near-surface winds, precipitation, ice cover, severe weather, etc**) associated with specific SRM geoengineering methods (surface albedo changes due to whitening, dust, and black carbon; boundary layer cloud albedo changes; and insolation modification).	Climate adaptation science (USGCRP), climate adaptation planing (USAID, DOD, IC, NOAA, DOS). Improved regional climate assessments (USGCRP, IPCC)	3.4
F. NON-CLIMATE RESPONSES	F-1. Improved understanding of the **direct impacts on terrestrial and marine ecosystems** from the application of specific SRM geoengineering methods (surface treatments, aerosol injection, diffuse solar radiation, etc).	Climate adaptation science (USGCRP), climate adaptation planing (USAID, DOD, IC, NOAA, DOS).	4.3
	F-2. Improve understanding of the risks and co-benefits of soil carbon sequestration for geoengineering including influence of pyrolysis on yield and stability, impacts of biochar on water, biodiversity, and soil fertility and production.	Climate adaptation science (USGCRP), USDA Farm Bill carbon mandate, DOI ESIA act carbon mandate, climate adaptation planning (USAID, DOD, IC, etc)	2.4
	F-3. Improve understanding of the risks of ocean fertilization for CDR geoengineering on marine ecosystems including fisheries and coral reefs and the effects of nutrient robbing and circulation changes (including combined impacts of acidification and warming).	Climate adaptation science (USGCRP), climate adaptation planing including fisheries issues (USAID, DOD, NOAA, DOS).	

*USGCRP goal areas 4.2 and 5.2 are associated with adaptation planning and span many of these topics

Things to consider

- For each key research question, what are:
  - The observational needs? (parameter, accuracy, precision, frequency, coverage, &resolution)
  - Our current & planned observational capabilities?
  - Gaps between needs & observational capabilities?
  - Recommended priorities for closing gaps?
  - Similar questions for models?

- How far should we go in terms of addressing impacts (e.g., non-climate processes such as terrestrial & marine ecosystem response)?

- For observations, consider:
  - Platforms (land, ocean, air, space) – including regional vs global foci
  - Sensing methods (sample acquisition, in-situ measurement, passive & active remote sensing)

- For satellite observations in particular, consider challenges imposed by
  - Budget cuts (e.g., CLARREO, DESDynI)
  - Programmatic delays (e.g., NPP/JPSS)
  - Launch mishaps (e.g., Glory)
  - Limited life (e.g., Cloudsat, SORCE, TES, etc)

Observations matrix

- (spreadsheet example)

Workshop process/structure

- Tues & Wed
  - Mornings
    - Plenary discussion of "what do we need to know" (with leading comments by several speakers)
    - Plenary discussion of current/planned observational capabilities
  - Afternoons
    - Plenary post-doc/student presentations
    - Break-out discussions to elaborate on morning sessions

- Thurs morning
  - Writing time (capture key points from Breakouts)
  - Plenary session for synthesis & discuss next steps

Guidelines & requests

- Please provide copies of presentations or key reference material on memory stick before leaving this week (for Project Wiki page)
- In group discussions please ask focused questions and express key points, but share the floor with others
- Focus on end-objective: making quantitative, measurable progress addressing one or more key gaps – not just a report
- Goal is to make presentations publicly available (KISS website) but all discussions are confidential until/unless all attendees agree to release

Thanks!

backup

Recommended Research Requirements from Royal Society report (2009) – box 5.1

4. General research priorities for all SRM methods should include:

• Life cycle analysis of the fi nancial and carbon costs associated with the development and implementation of the method;

• Estimates of effectiveness at achieving the desired climate state, technical effi ciency and costs;

• Time between deployment and achieving the intended effect on climate, and delay between cessation of an activity and climate response, and other environmental impacts;

• Assessment of the full range of climate effects including properties other than global mean temperature, and including the extent and spatial variation of the impacts;

• Investigation into the effects on atmospheric chemical composition and on ocean and atmospheric circulation;

• Detailed modelling studies to resolve seasonal and regional effects as well as global and annual averages;

• Modelling, theoretical studies and long-term empirical research into the impacts and consequences of persistent high CO2 concentrations in a low temperature world for ecosystem processes and ecological communities.

5. Additional R&D priorities for specifi c SRM methods should include:

• *Surface albedo methods*: Climate modelling studies of local effects on atmospheric circulation and precipitation.

Evaluation of ecological, economic and social impacts (including aesthetics);

• *Cloud albedo methods*: Impacts on regional ocean circulation patterns and biological production, near surface winds, and regional effects on climate over land; methods for CCN creation and delivery, and small-scale experimental fi eld trials;

• *Stratospheric albedo methods*: Effects on monsoons, stratospheric ozone, and high-altitude tropospheric clouds. Assessment of possible feedback processes including stratospheric-tropospheric exchange, and the carbon and hydrological cycles, and regional scale modelling. Evaluation of aerosol size and distribution effects, improved estimates of source strength and delivery methods;

• *Space based albedo methods*: Modelling studies on effectiveness and climate effects including impacts on regional climate and weather patterns including changes in seasonality and variability, impacts on polar ice cover and ocean circulation. Desk based engineering design studies on likely feasibility, effectiveness, timescales for development and for deployment and costs of proposals.

What's already being done

(ex: USGCRP goal area 1)

Focus Area	Description (from *CCSP Strategic Plan*)[1]	Budgets ($M)[2] FY 2007	FY 2008 Estimate	FY 2009 Request	Agencies
Goal 1	**Improve knowledge of the Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and changes**				
Focus 1.1	Better understand natural long-term cycles in climate [e.g., Pacific Decadal Variability (PDV), North Atlantic Oscillation (NAO)]	39.6	43.6	47.3	DOC, DOE, DOI, NASA, NSF
Focus 1.2	Improve and harness the capability to forecast El Niño-La Niña and other seasonal-to-interannual cycles of variability	37.0	35.4	37.1	DOC, DOE, DOI, NASA, NSF
Focus 1.3	Sharpen understanding of climate extremes through improved observations, analysis, and modeling, and determine whether any changes in their frequency or intensity lie outside the range of natural variability	35.8	37.0	42.0	DOC, DOE, DOI, NASA, NSF
Focus 1.4	Increase confidence in the understanding of how and why climate has changed	38.4	39.2	43.8	DOE, DOI, NASA, NSF, SI
Focus 1.5	Expand observations and data/information system capabilities	173.7	191.1	240.4	DOC, DOE, DOI, NASA, NSF, SI
GOAL 1 TOTAL		**324.5**	**346.3**	**410.6**	

What's already being done
(ex: USGCRP goal area 2)

Goal 2	Improve quantification of the forces bringing about changes in the Earth's climate and related systems				
Focus 2.1	Reduce uncertainties about the sources and sinks of greenhouse gases, emissions of aerosols and their precursors, and their climate effects	94.1	96.2	103.9	DOC, DOE, DOI, DOT, NASA, NSF
Focus 2.2	Monitor the recovery of the ozone layer and improve the understanding of the interactions of climate change, ozone depletion, tropospheric pollution, and other atmospheric issues	27.3	28.1	30.8	USDA, DOE, NASA
Focus 2.3	Increase knowledge of the interactions among emissions, long-range atmospheric transport, and transformations of atmospheric pollutants, and their response to air quality management strategies	39.1	40.4	43.0	NASA, NSF
Focus 2.4	Develop information on the carbon cycle, land cover and use, and biological/ecological processes by helping to quantify net emissions of carbon dioxide, methane, and other greenhouse gases, thereby improving the evaluation of carbon sequestration strategies and alternative response options	127.6	132.0	134.2	USDA, DOC, DOE, DOI, NASA, NSF, SI
Focus 2.5	Improve capabilities to develop and apply emissions and related scenarios for conducting "If…, then…" analyses in cooperation with CCTP	3.0	3.0	3.0	DOE
GOAL 2 TOTAL		291.0	299.6	314.8	

What's already being done

(ex: USGCRP goal area 4)

Goal 4	**Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes**				
Focus 4.1	Improve knowledge of the sensitivity of ecosystems and economic sectors to global climate variability and change	62.5	60.8	62.8	USDA, DOE, DOI, DOT, EPA, NASA, NSF, SI
Focus 4.2	Identify and provide scientific inputs for evaluating adaptation options, in cooperation with mission-oriented agencies and other resource managers	56.5	57.9	57.5	HHS, DOI, DOT, EPA, NSF
Focus 4.3	Improve understanding of how changes in ecosystems (including managed ecosystems such as croplands) and human infrastructure interact over long time periods	40.1	43.1	39.7	USDA, DOC, DOI, DOT, NASA, NSF, SI
GOAL 4 TOTAL		**159.1**	**161.8**	**160.0**	

What's already being done
(ex: USGCRP goal area 5)

Goal 5	Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change				
Focus 5.1	Support informed public discussion of issues of particular importance to U.S. decisions by conducting research and providing scientific synthesis and assessment reports	57.9	52.2	52.8	USDA, DOI, EPA, NASA, NSF, SI
Focus 5.2	Support adaptive management and planning for resources and physical infrastructure sensitive to climate variability and change; build new partnerships with public and private sector entities that can benefit both research and decisionmaking	62.0	66.1	72.0	USDA, DOC, DOI, USAID, EPA, NASA, NSF
Focus 5.3	Support policymaking by conducting comparative analyses and evaluations of the socioeconomic and environmental consequences of response options	18.4	20.8	19.0	USDA, DOE, DOI, EPA, NASA, NSF, SI
GOAL 5 TOTAL		**138.3**	**139.1**	**143.8**	