Operational Challenges for the Next 20 Years

Earth System Science @ 20 Symposium

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Moving Forward

- Originally intended to talk about successes in moving insights and observations from a research domain to operations
- But you already have heard many such examples and this audience knows of many more
- Thought it would be more appropriate at this point in the symposium to share some thoughts about new challenges for this type of transition

Why Are the New Challenges Different?

- Because human decisions and actions interact with Earth system processes more intimately than we perhaps have appreciated
- Earth System Science and remote observations have been powerful tools to improve our understanding
- But for changes coming at us, it is now crucial to think through how to incorporate a human dimension more thoroughly than before

Lessons from Several Fronts

- Includes (not a comprehensive list)
  - Ecosystem Services
  - Climate Change and Response
  - Decadal Survey
  - Including a Human Dimension…

Millennium Ecosystem Assessment Findings

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Overview of Findings

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel
- The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people
- The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals
- The challenge of reversing the degradation of ecosystems while meeting increasing demands for their services can be partially met under some scenarios that the MA has considered but these involve significant changes in policies, institutions and practices, that are not currently under way

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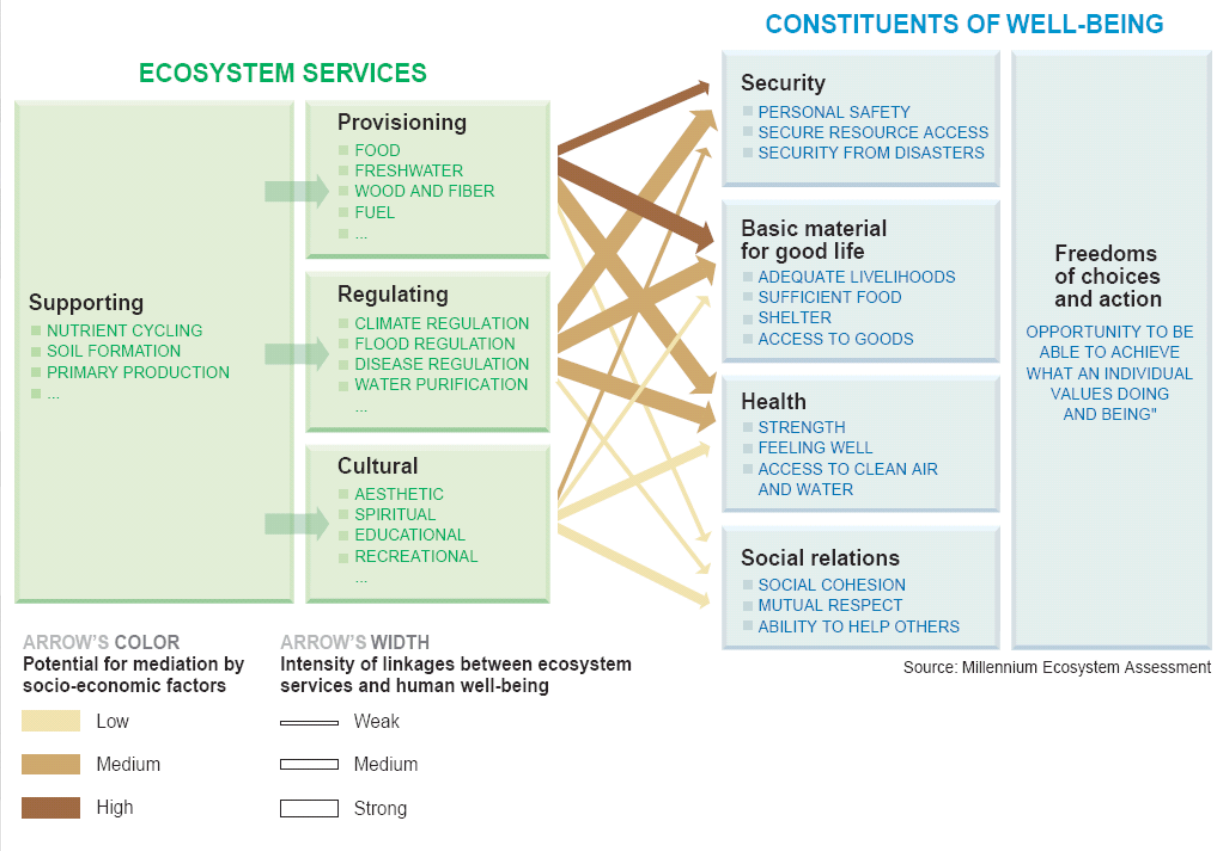
Focus: Ecosystem Services
The benefits people obtain from ecosystems



Source: Millennium Ecosystem Assessment

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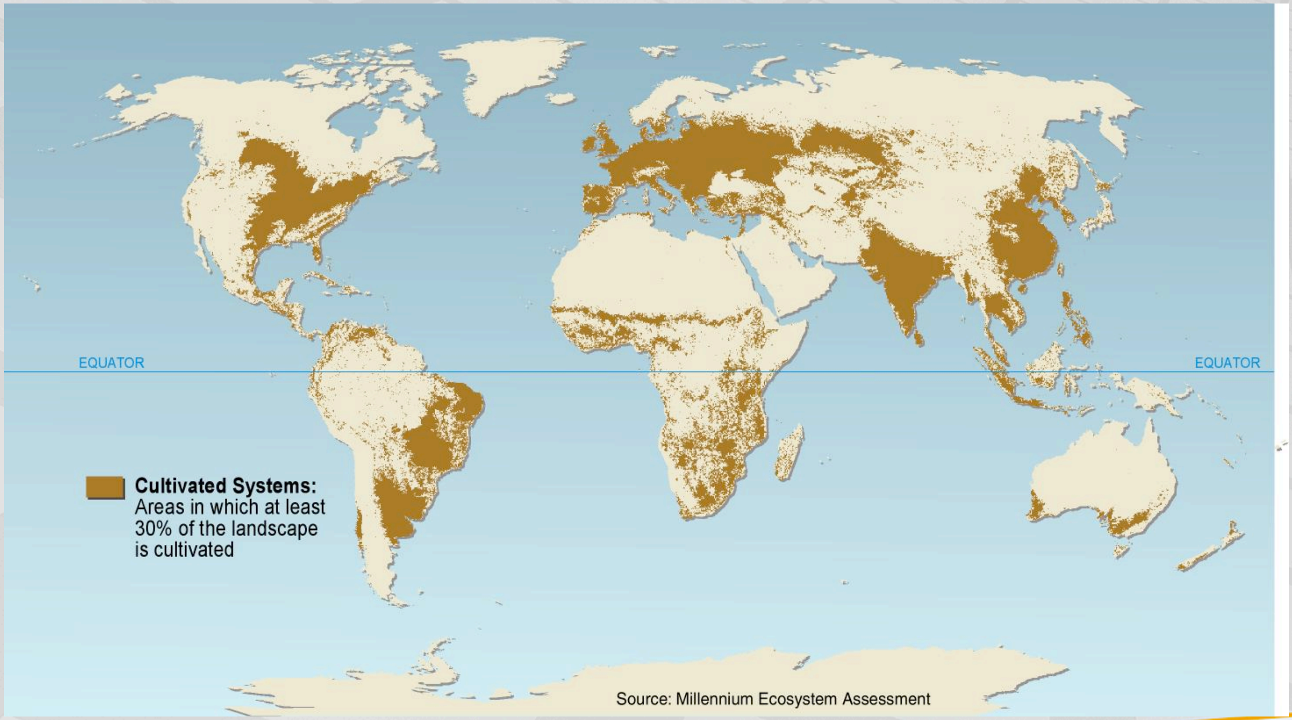
Finding #1

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history
- This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth

Unprecedented change in structure and function of ecosystems

- More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850.



Cultivated Systems in 2000 cover 25% of Earth's terrestrial surface

(Defined as areas where at least 30% of the landscape is in croplands, shifting cultivation, confined livestock production, or freshwater aquaculture)

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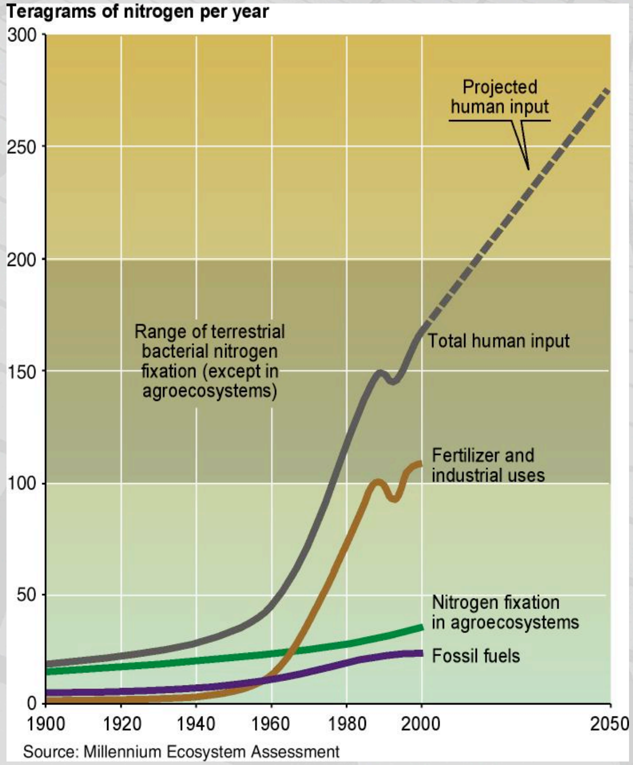
Unprecedented change: Biogeochemical Cycles

▶Since 1960:

- Flows of biologically available nitrogen in terrestrial ecosystems doubled
- Flows of phosphorus tripled

▶> 50% of all the synthetic nitrogen fertilizer ever used has been used since 1985

▶60% of the increase in the atmospheric concentration of CO_2 since 1750 has taken place since 1959

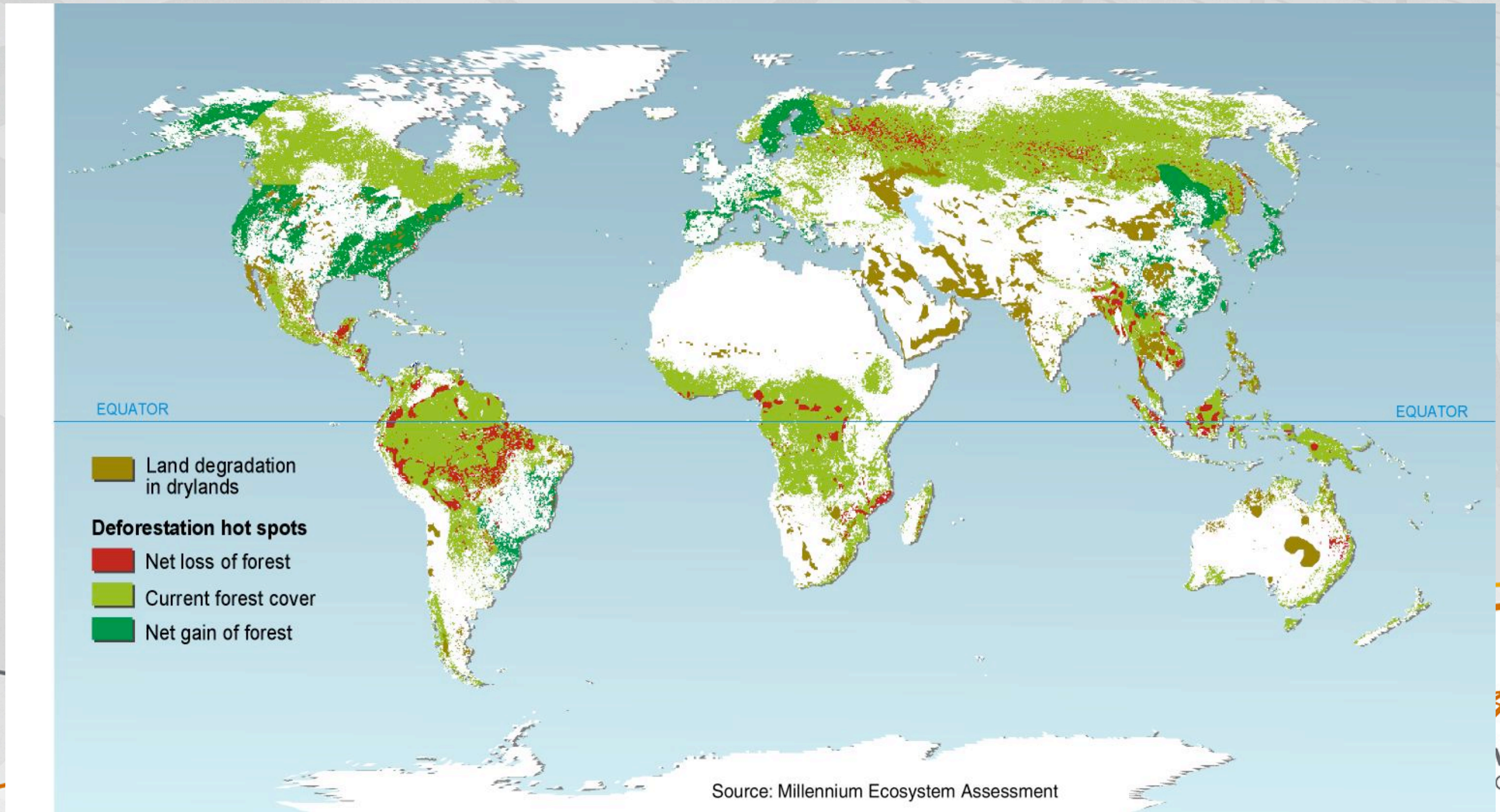


Human-produced Reactive Nitrogen

Humans produce as much biologically available N as all natural pathways and this may grow a further 65% by 2050

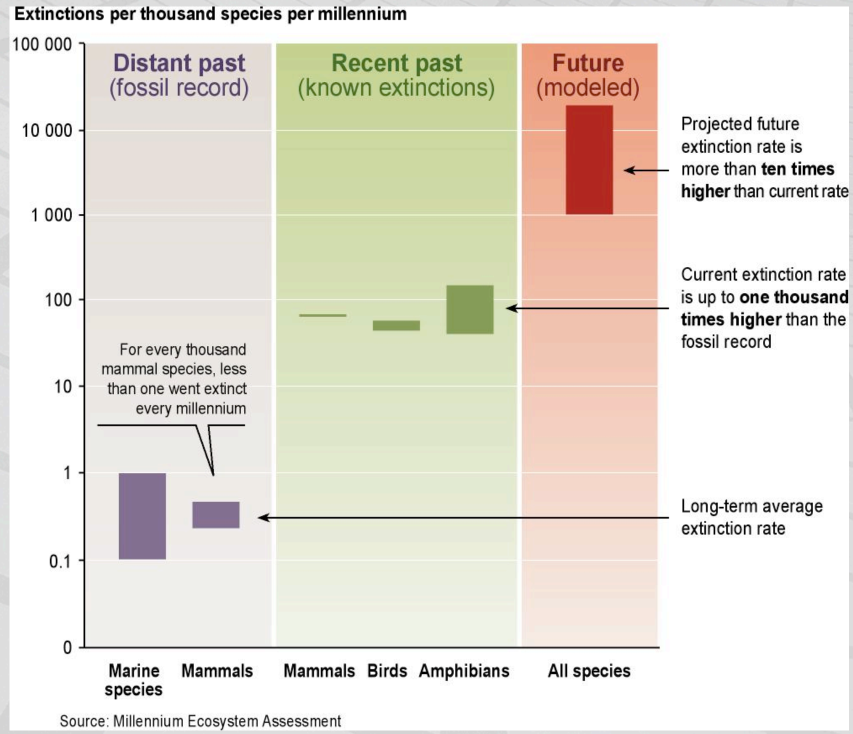
Some ecosystem recovery now underway but high rates of conversion continue

- Ecosystems in some regions are returning to conditions similar to their pre-conversion states
- Rates of ecosystem conversion remain high or are increasing for specific ecosystems and regions



Significant and largely irreversible changes to species diversity

- Humans have increased the species extinction rate by as much as 1,000 times over background rates typical over the planet's history (*medium certainty)*
- 10–30% of mammal, bird, and amphibian species are currently threatened with extinction (*medium to high certainty)*



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Finding #2

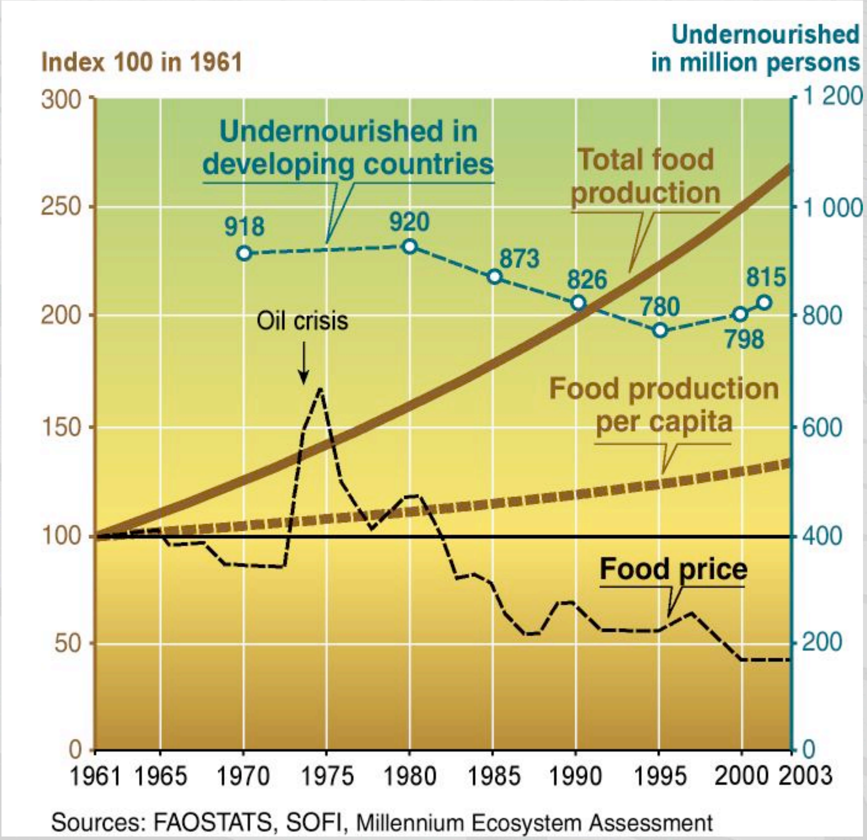
- The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs
- These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems

Changes to ecosystems have provided substantial benefits

- Rapid growth in demand for ecosystem services between 1960 and 2000:
  - world population doubled from 3 to 6 billion people
  - global economy increased more than sixfold
- To meet this demand:
  - food production increased 2 ½ times
  - water use doubled
  - wood harvests for pulp and paper production tripled
  - timber production increased by more than half
  - installed hydropower capacity doubled

Changes to ecosystems have provided substantial benefits

- Food production has more than doubled since 1960
- Food production per capita has grown
- Food price has fallen



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Industries based on ecosystem services still the mainstay of many economies

- Contributions of agriculture
  - Agricultural labor force accounts for 22% of the world's population and half the world's total labor force
  - Agriculture accounts for 24% of GDP in low income developing countries
- Market value of ecosystem-service industries
  - Food production: $980 billion per year
  - Timber industry: $400 billion per year
  - Marine fisheries: $80 billion per year
  - Marine aquaculture: $57 billion per year
  - Recreational hunting and fishing: >$75 billion per year in the United States alone

Degradation and unsustainable use of ecosystem services

- Approximately 60% (15 out of 24) of the ecosystem services evaluated in this assessment are being degraded or used unsustainably
- The degradation of ecosystem services often causes significant harm to human well-being and represents a loss of a natural asset or wealth of a country

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Global Change
Research Program

Global Climate Change Impacts in the United States

How has climate already changed?

How is it likely to change in the future?

How is climate change affecting us now where we live and work?

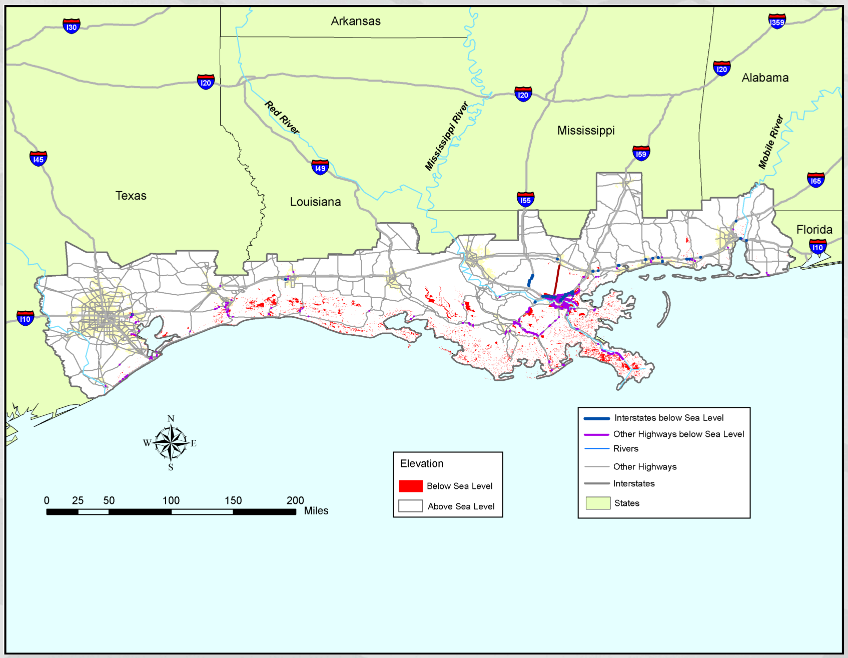
How is it likely to affect us in the future?

What are our options for responding?

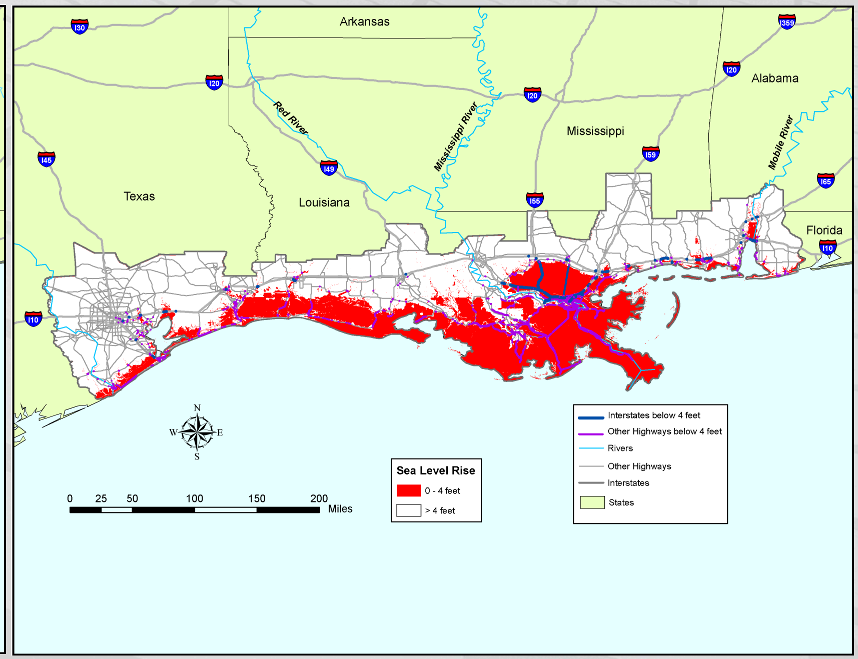
Results – Gulf Coast Study

Highways Vulnerable to Relative Sea Level Rise

Baseline (Present Day)



4 Feet of Sea Level Rise



Source: Cambridge Systematics analysis of U.S. DOT Data.

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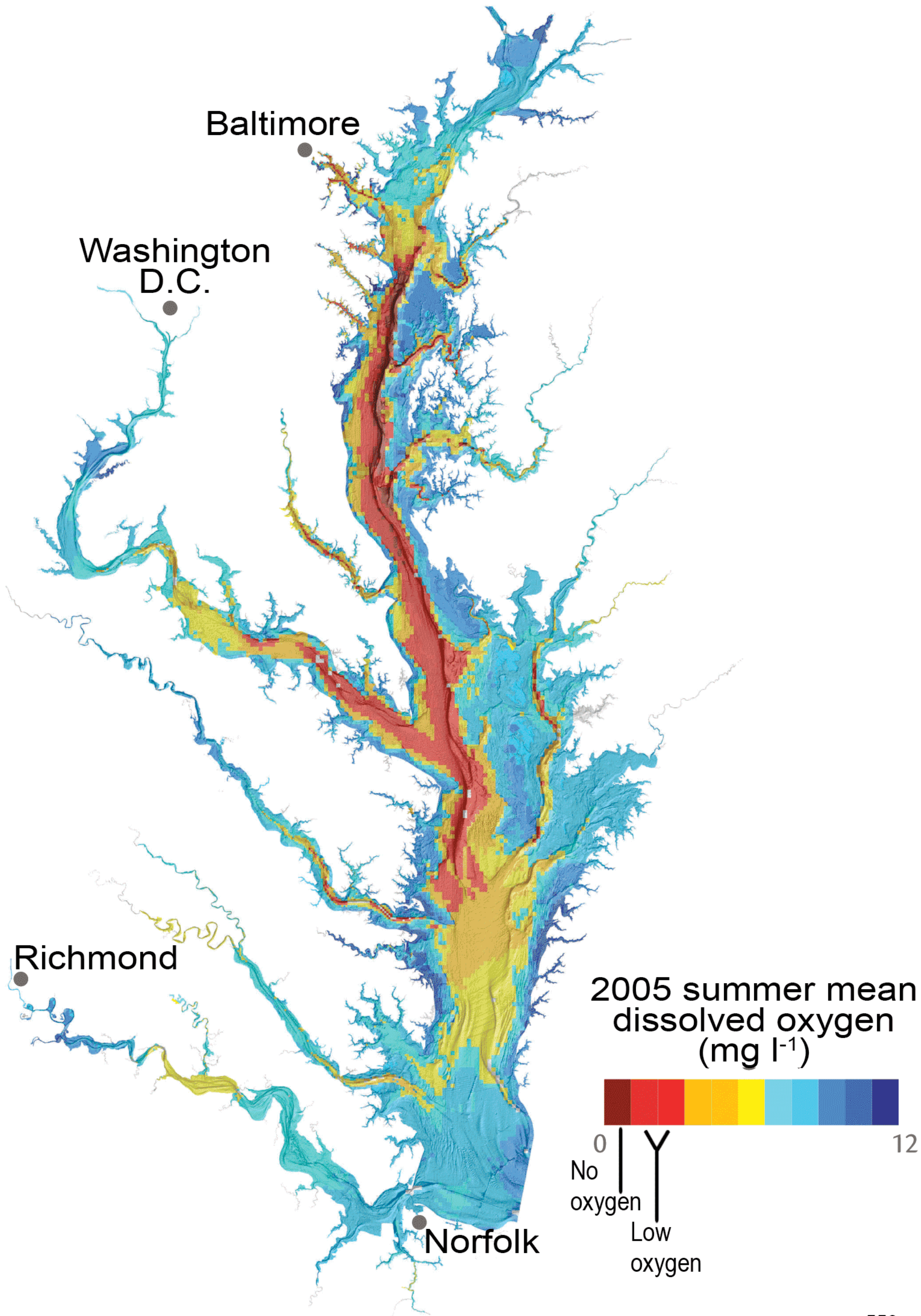
Dead Zones in the Chesapeake Bay



Projected Shifts in Forest Types
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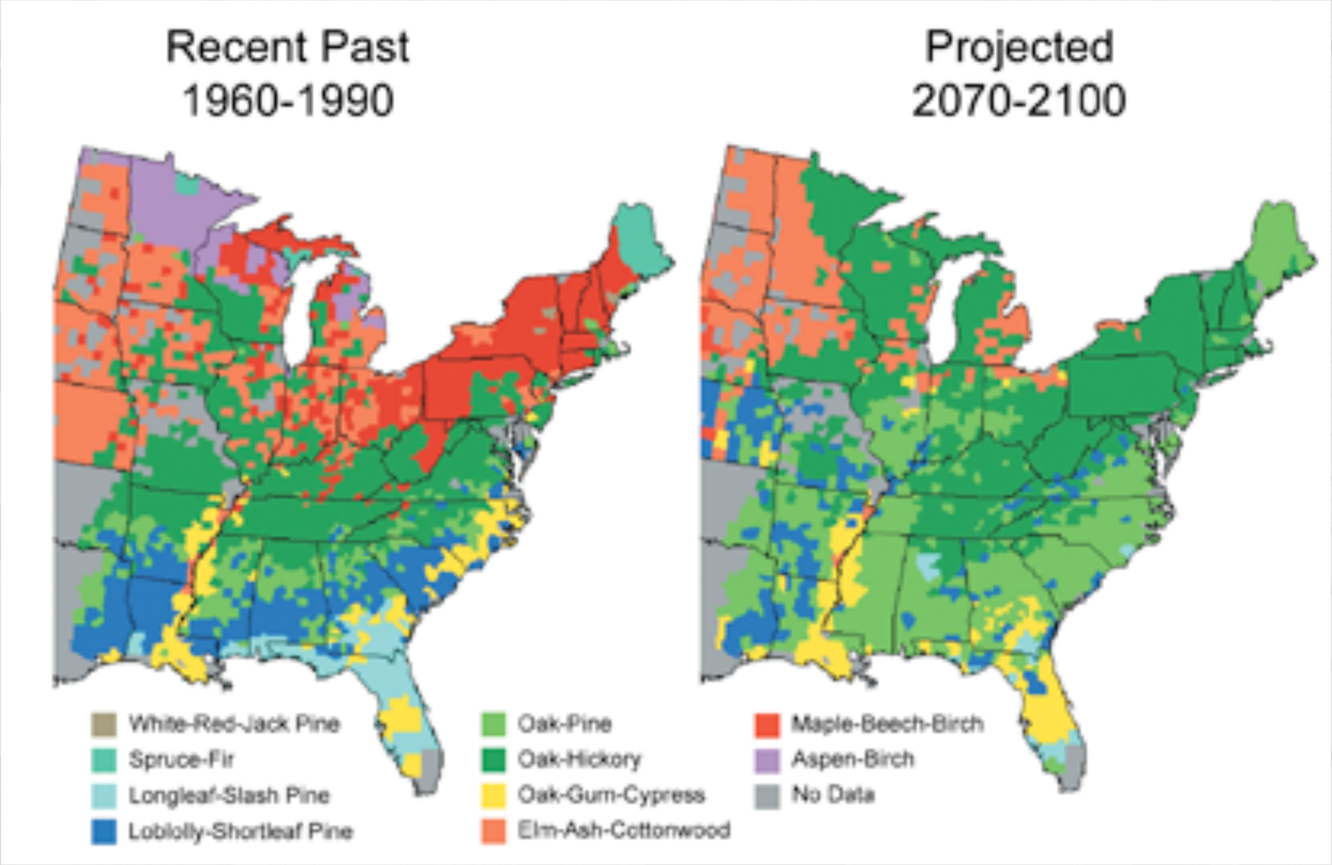
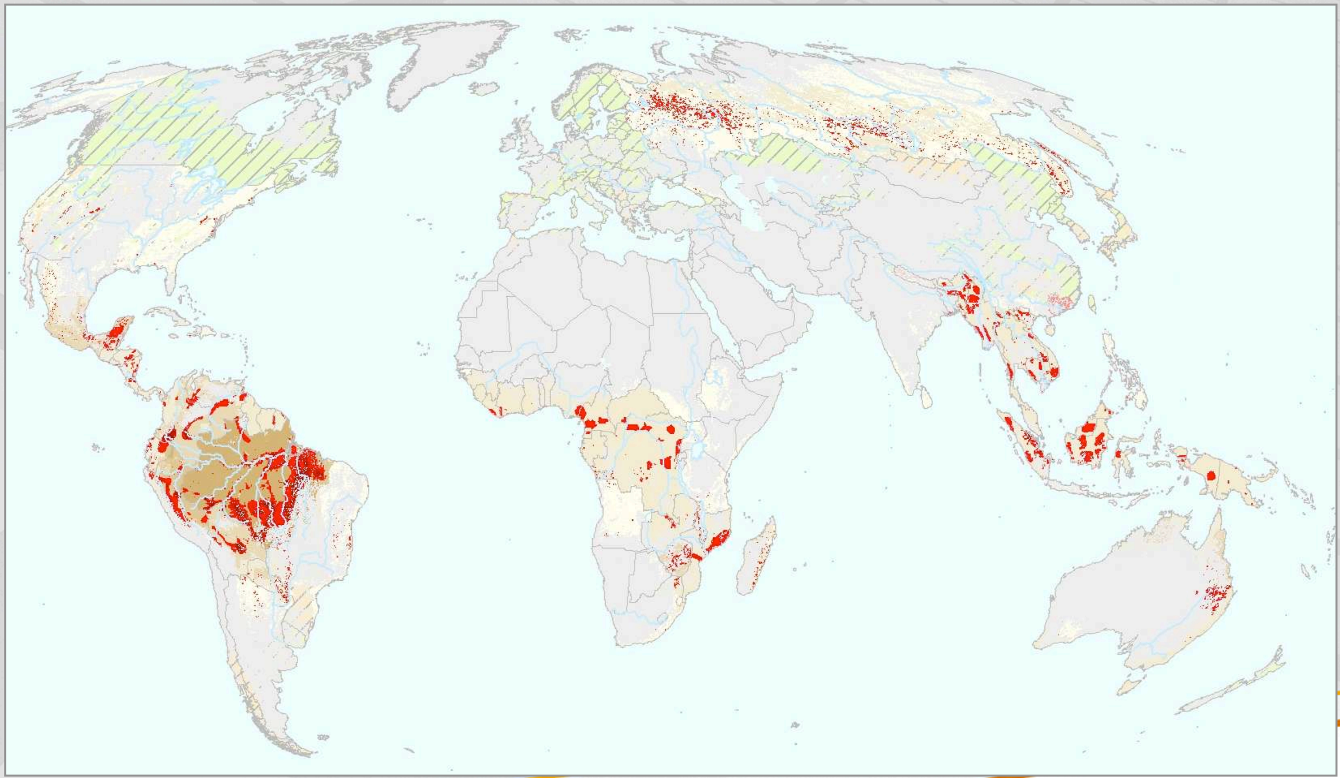


- ►The maps show current and projected forest types. Major changes are projected for many regions. For example, in the Northeast, under a mid-range warming scenario, the currently dominant maple-beech-birch forest type is projected to be completely displaced by other forest types in a warmer future.[243]

Global and Local Challenges

- Natural Resource Management



Interactions with Human Responses

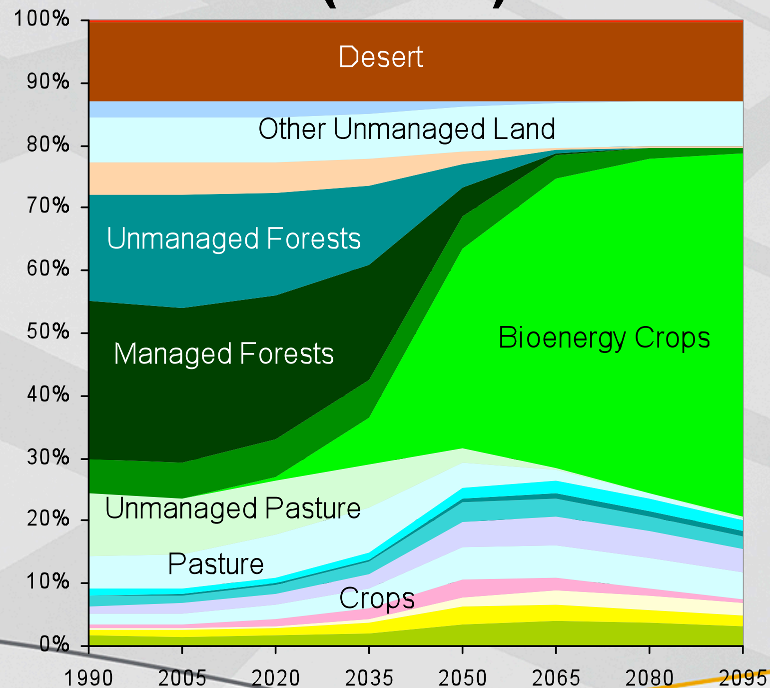
- There can be complicated interactions with human choices that affect the evolution of the planet
- Have the historical examples that I've talked about
- But have some crucial choices facing us that could operate in non-intuitive ways

An Example

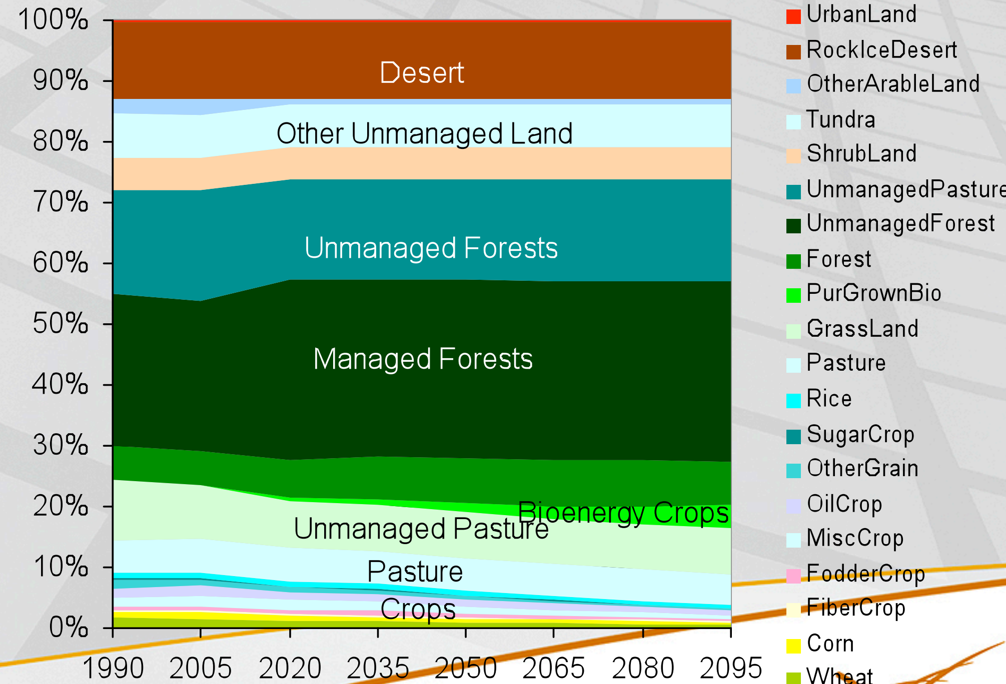
- Think about the issues associated with
  - Climate policy – What level of greenhouse gases do we want to end up with? How do we adapt to those changes that we cannot avoid?
  - Energy policy – What is the energy mix that allows us to meet that target?
  - Land use and agriculture – What effects on land resources might biofuels have as an element of those actions?

The Land Use Implications of Stabilizing at 450 ppm When Terrestrial Carbon is Valued

450 ppm Stabilization Scenario When Terrestrial Carbon is NOT Valued (FFICT)



450 ppm Stabilization Scenario When ALL Carbon is Valued (UCT)



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Conclusions

- Failure to value terrestrial carbon storage could have disastrous consequences for forests and other unmanaged ecosystems.
- Agriculture and forestry waste streams are an important bioenergy feedstock.
- We find that relative to a reference scenario, a larger stock of forests is desirable
  - Terrestrial carbon storage provides a service whose value increases throughout the century….
    - Which raises land rents and crop prices…
      - And this effect is independent of whether or not bioenergy is a competing crop.
- Improving crop yields has the potential to reduce land-use change emissions by hundreds of billions of tons of carbon over the 21st century.

Study "Vision"

"Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important for society as it seeks to achieve prosperity and sustainability."

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Examples and Lessons

- No stable institutional home for receiving recommendations about benefits in either NASA or NOAA
- Need to have processes in NASA and NOAA that recognize the actual benefits that are generated in addition to their scientific foundation
- Communities have vastly different experiences in using these observations and therefore abilities to generate recommendations

Scientific and Societal Imperatives

Climate change and impacts

Ice sheets, sea level, and ocean circulation

Shifts in precipitation and water availability

Transcontinental Air Pollution

Shifts in ecosystems response to climate change

Human health and climate change

Extreme events, including severe storms, heat waves, earthquakes and volcanoes

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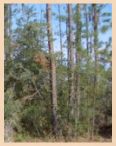
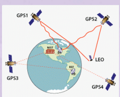


Changes in carbon storage in vegetation

DESDynI
Launch 2010-2013



Pressure/ temperature/ water vapor profiles

GPSRO
Launch 2010-2013

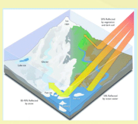
Estimate of flux of low-salinity ice out of Arctic basin

ICESat-II
Launch 2010-2013

Aerosol and cloud types and properties

ACE
Launch 2013-2016

Absolute spectrally resolved IR radiance



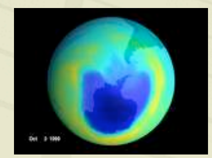
Incident solar and spectrally resolved reflected irradiance

CLARREO
Launch 2010-2013

CO_2 measurements: Day/night, all seasons, all latitudes

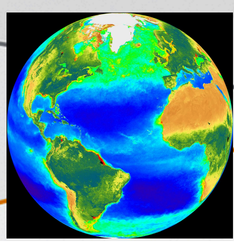
Connection between climate and CO_2 exchange

ASCENDS
Launch 2013-2016



Vertical profile of ozone and key ozone precursors

GACM
Launch 2016-2020



***Societal Challenge:* Climate Prediction**
Robust estimates of primary climate forcings for improved climate forecasts, including local predictions of the effects of climate change

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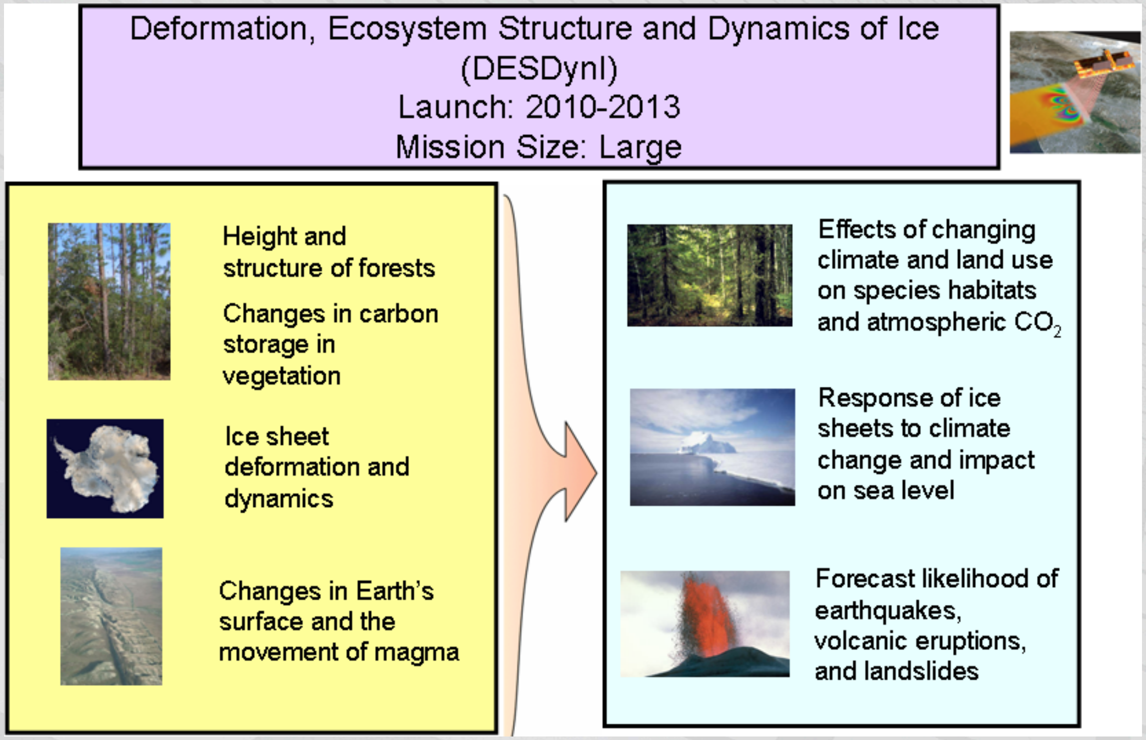

Mission and Payload: This mission combines two sensors that, taken together, provide observations important for solid-Earth (surface deformation), ecosystems (terrestrial biomass structure) and climate (ice dynamics). The sensors are: 1) an L-band Interferometric Synthetic Aperture Radar (InSAR) system with multiple polarization, and 2) a multiple beam lidar operating in the infrared (~ 1064 nm) with ~ 25 m spatial resolution and 1 m vertical accuracy. The mission using InSAR to meet the science measurement objectives for surface deformation, ice sheet dynamics, and ecosystem structure has been extensively studied. It requires a satellite in 700-800 km sun-synchronous orbit in order to maximize available power from the solar arrays. An eight day revisit frequency balances temporal decorrelation with required coverage. Onboard GPS achieves cm-level orbit and baseline knowledge to improve calibration. The mission should have a 5 year life time to capture time-variable processes and achieve measurement accuracy.

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What Are the Bottom Lines?

- Serious strategic challenges already before us
- Need observations to help address
- Have had successes in reaping both societal and scientific benefits before
- What to do to enhance that capacity?
- How does our mission and program selection fit our assessment of challenges?

Concluding Thoughts

- There are significant new operational challenges that lie ahead in the next two decades
  - Monitoring climate drivers – carbon, especially
- But also understanding other changes that clearly affect the evolution of the Earth system
  - Land management and its implications for biogeochemistry and the physical climate system
  - Understanding the vulnerability and responses of societal resources – from food supply to infrastructure
  - Understanding and monitoring the sustainability of the ecological services on which our safety and prosperity depend
- We need structures in our institutions that enable these concerns to be met appropriately for both observations and modeling