Observing climate change from space: Approach, Requirements, and Economic Value

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Charney Report, 1979

Concerning Anthropogenic Climate Change:

"In order to address this question in its entirety, one would have to peer into the world of our grandchildren, the world of the twenty-first century."

Foreword by Vern Suomi

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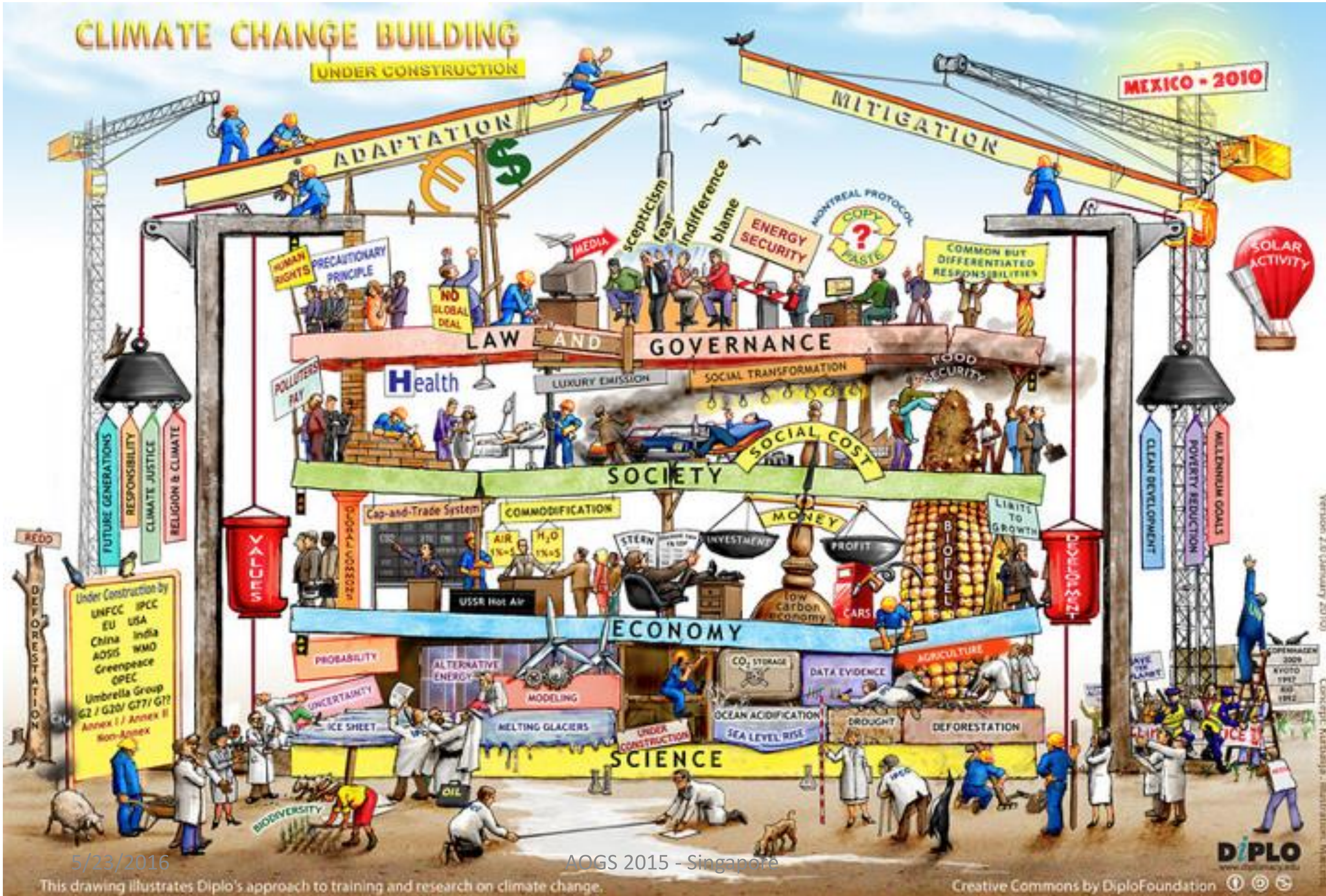
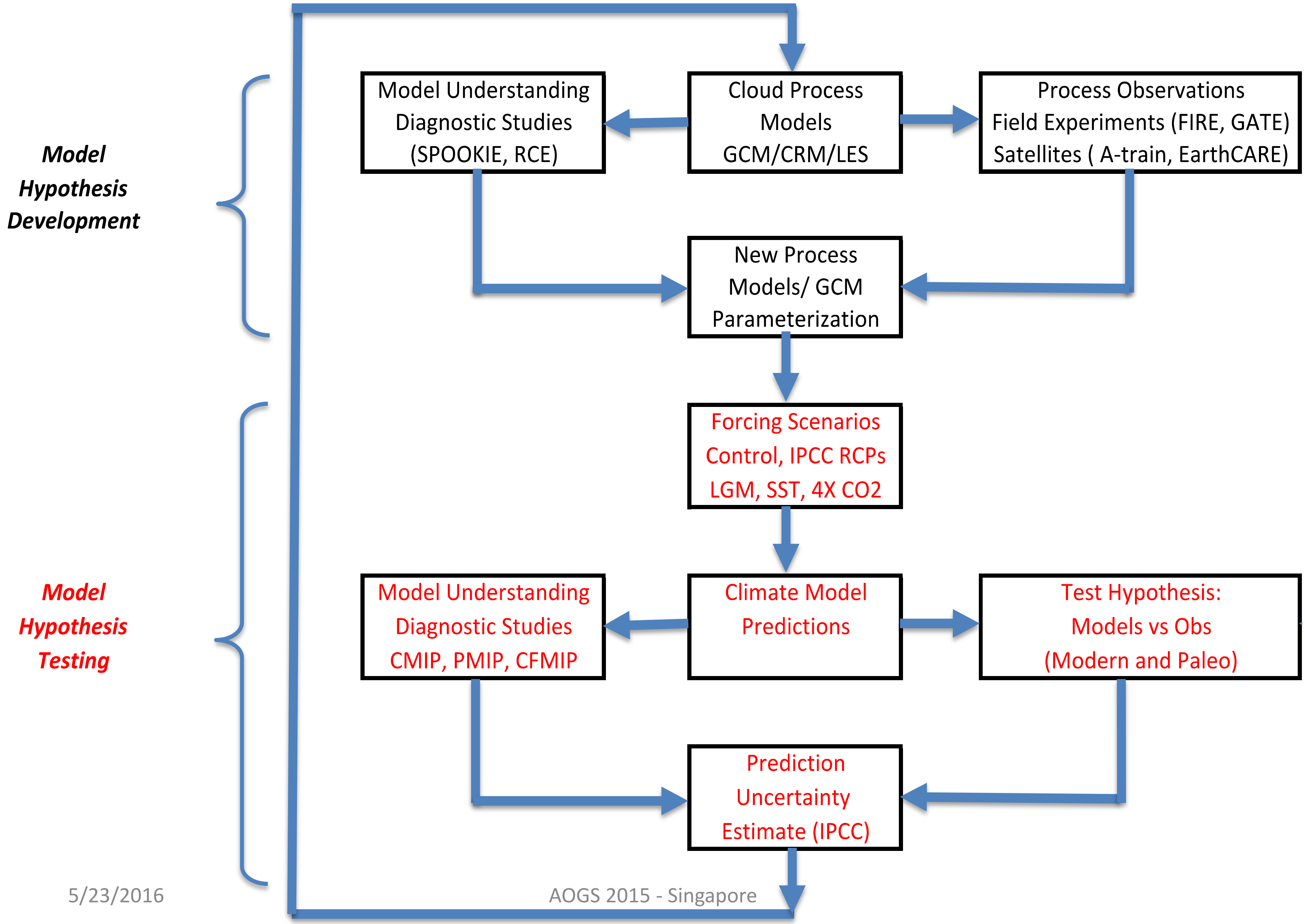
35 Years Later …



35 Years Later …

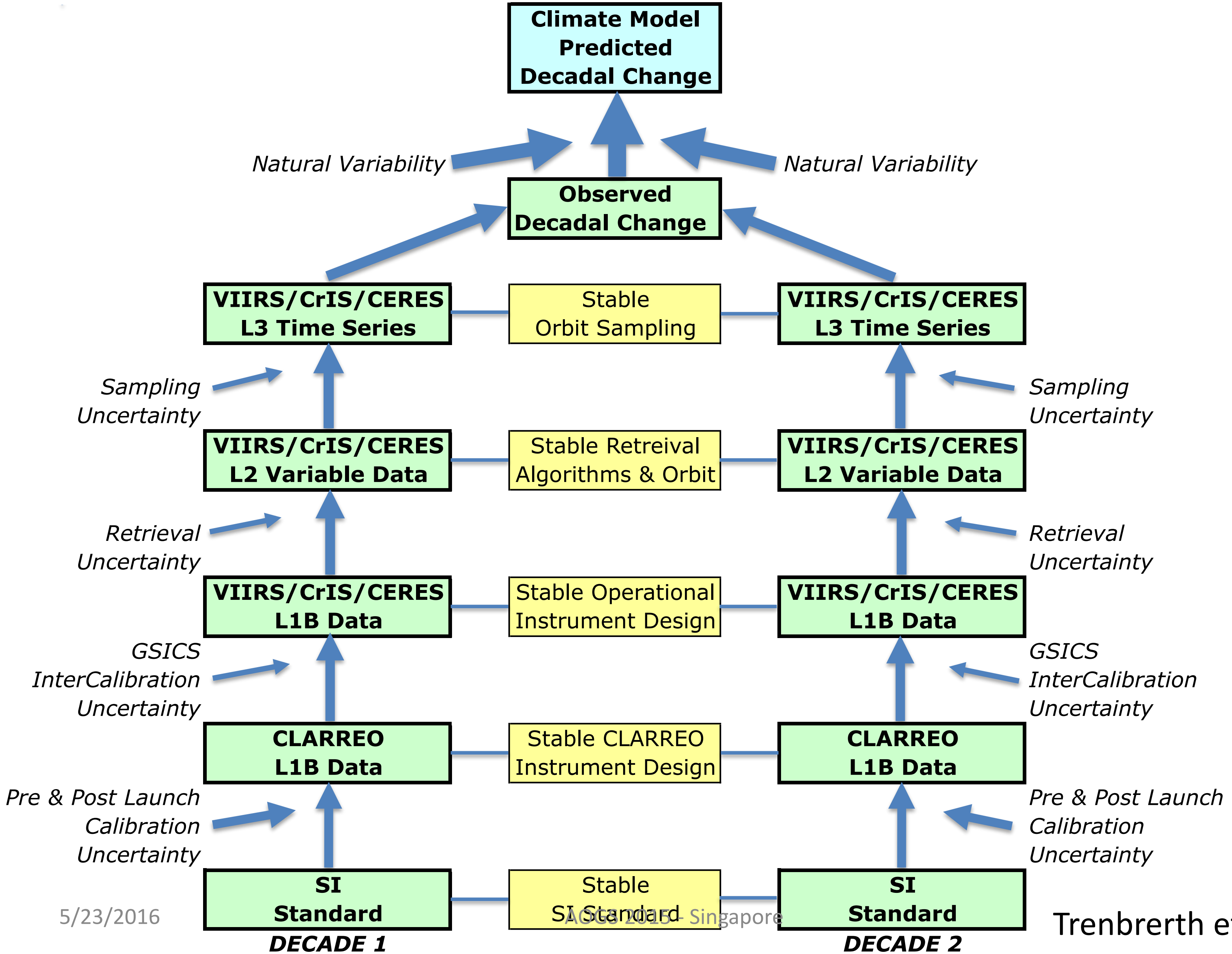
35 Years Later … More urgent, but …

- Lack of a climate observing system (vs. weather)
  - Climate is 10x the variables and 10x the accuracy of weather.
- Struggles to get sufficient resources for climate modeling
- Science questions typically qualitative not quantitative
  - Understand and explore vs rigorous hypothesis testing
  - Leads to intuitive "Seat of the Pants" requirements
  - After > 30 years of climate research: time to improve
- *What is the right amount to invest in climate science?*
  - Requires link of science to economics
  - Requires thinking outside narrow disciplines
  - Requires arguing for climate science, not our own science



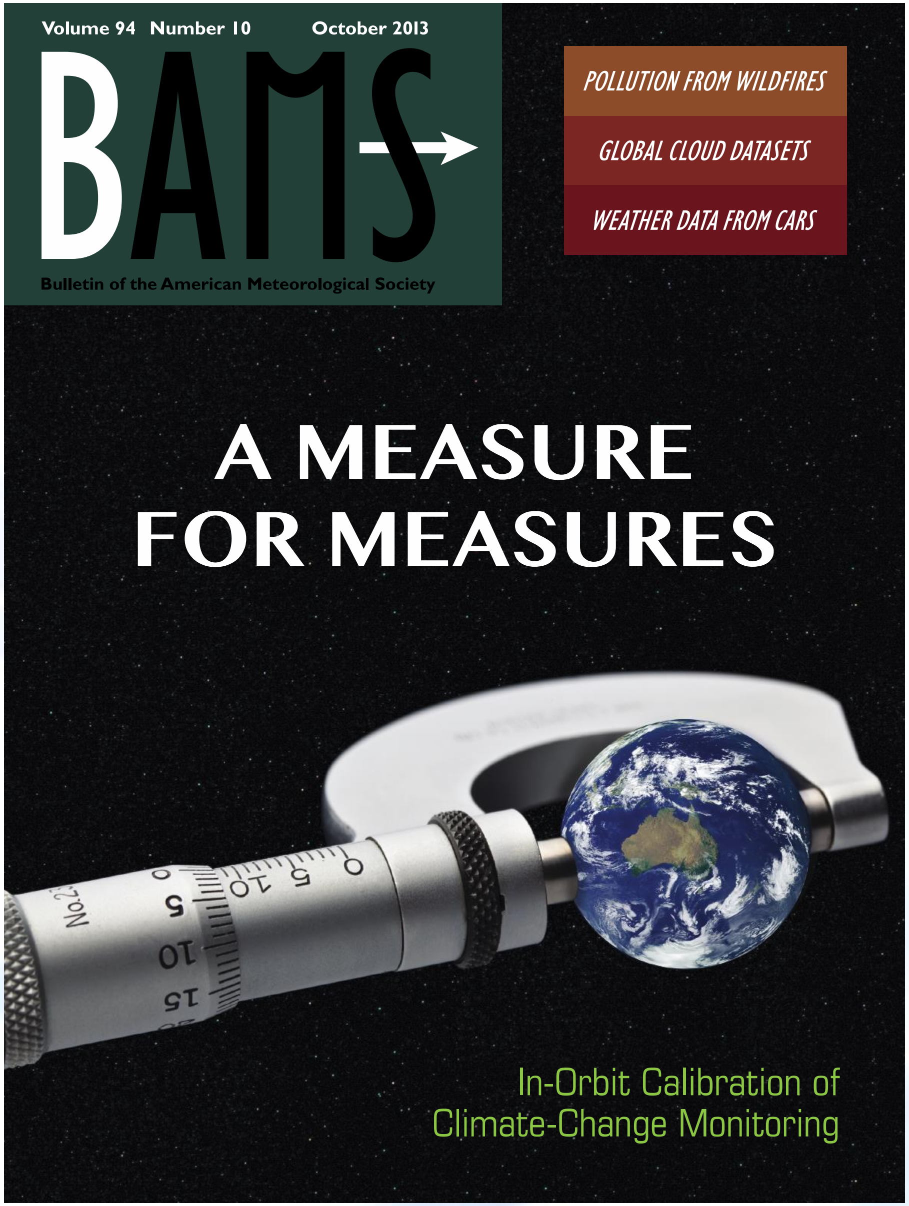
Model
Hypothesis
Development
Model Understanding
Diagnostic Studies
(SPOOKIE, RCE)
Cloud Process
Models
GCM/CRM/LES
Process Observations
Field Experiments (FIRE, GATE)
Satellites (A-train, EarthCARE)
New Process
Models/ GCM
Parameterization
Model
Hypothesis
Testing
Forcing Scenarios
Control, IPCC RCPs
LGM, SST, 4X CO2
Model Understanding
Diagnostic Studies
CMIP, PMIP, CFMIP
Climate Model
Predictions
Test Hypothesis:
Models vs Obs
(Modern and Paleo)
Prediction
Uncertainty
Estimate (IPCC)

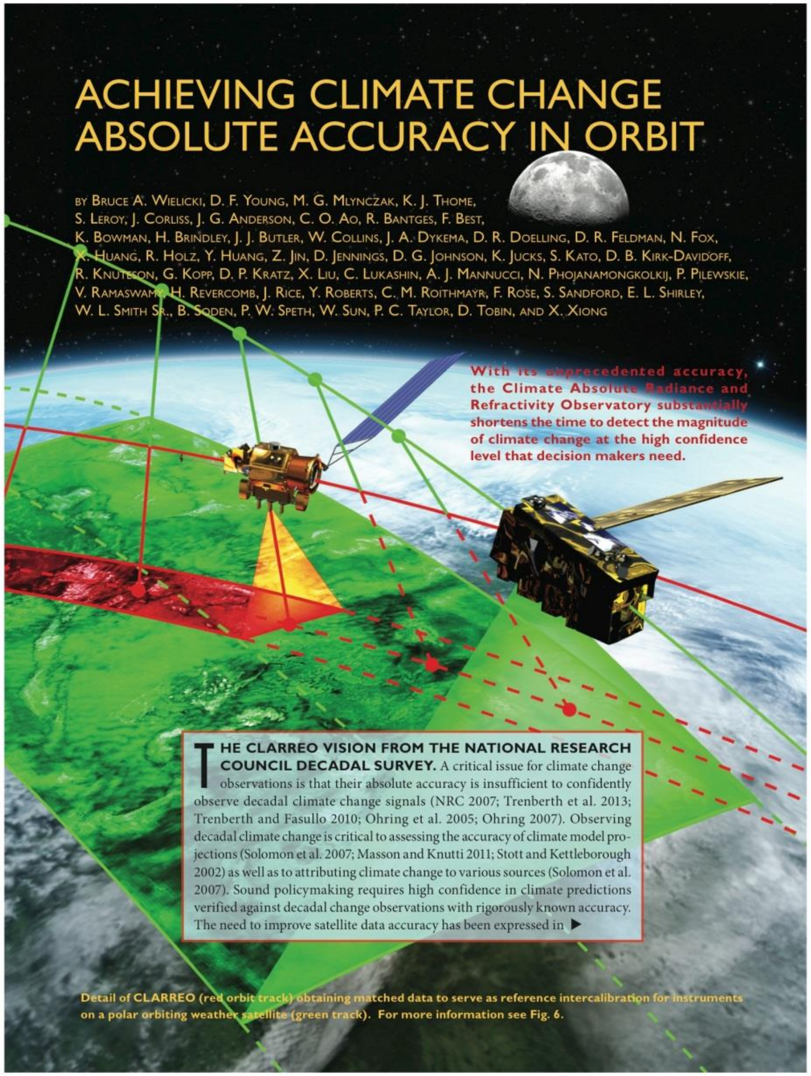
Accuracy of Climate Change Observations & Predictions



Trenbrerth et al. 2013

BAMS October, 2013





ACHIEVING CLIMATE CHANGE ABSOLUTE ACCURACY IN ORBIT

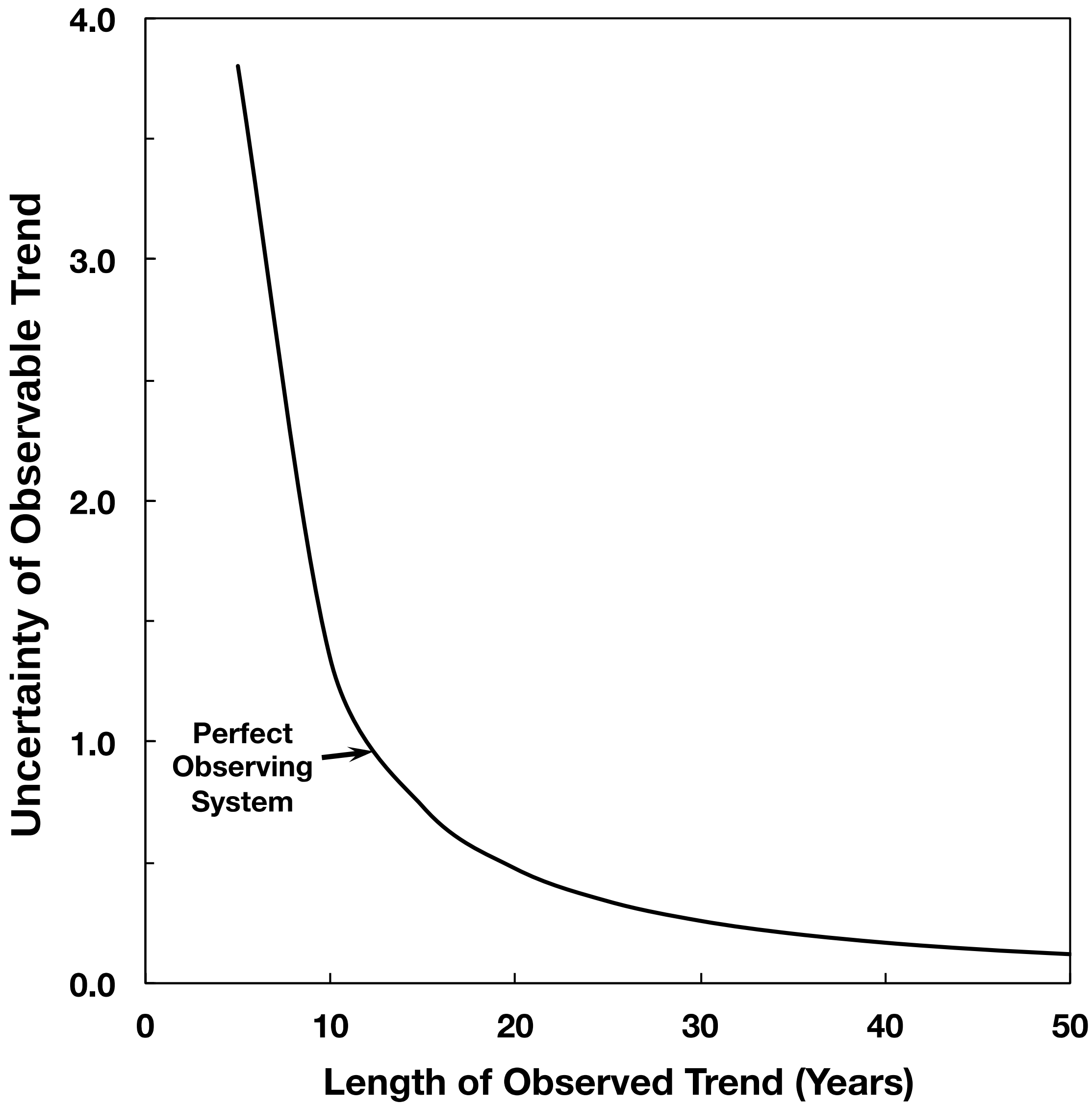
BY BRUCE A. WIELICKI, D. F. YOUNG, M. G. MLYNCZAK, K. J. THOME, S. LEROY, J. CORLISS, J. G. ANDERSON, C. O. AO, R. BANTGES, F. BEST, K. BOWMAN, H. BRINDLEY, J. J. BUTLER, W. COLLINS, J. A. DYKEMA, D. R. DOELLING, D. R. FELDMAN, N. FOX, X. HUANG, R. HOLZ, Y. HUANG, Z. JIN, D. JENNINGS, D. G. JOHNSON, K. JUCKS, S. KATO, D. B. KIRK-DAVIDOFF, R. KNUTESON, G. KOPP, D. P. KRATZ, X. LIU, C. LUKASHIN, A. J. MANNUCCI, N. PHOJANAMONGKOLKIJ, P. PILEWSKIE, V. RAMASWAMY, H. REVERCOMB, J. RICE, Y. ROBERTS, C. M. ROITHMAYR, F. ROSE, S. SANDFORD, E. L. SHIRLEY, W. L. SMITH SR., B. SODEN, P. W. SPETH, W. SUN, P. C. TAYLOR, D. TOBIN, AND X. XIONG

With its unprecedented accuracy, the Climate Absolute Radiance and Refractivity Observatory substantially shortens the time to detect the magnitude of climate change at the high confidence level that decision makers need.

THE CLARREO VISION FROM THE NATIONAL RESEARCH COUNCIL DECADAL SURVEY. A critical issue for climate change observations is that their absolute accuracy is insufficient to confidently observe decadal climate change signals (NRC 2007; Trenberth et al. 2013; Trenberth and Fasullo 2010; Ohring et al. 2005; Ohring 2007). Observing decadal climate change is critical to assessing the accuracy of climate model projections (Solomon et al. 2007; Masson and Knutti 2011; Stott and Kettleborough 2002) as well as to attributing climate change to various sources (Solomon et al. 2007). Sound policymaking requires high confidence in climate predictions verified against decadal change observations with rigorously known accuracy. The need to improve satellite data accuracy has been expressed in ▶

Detail of CLARREO (red orbit track) obtaining matched data to serve as reference intercalibration for instruments on a polar orbiting weather satellite (green track). For more information see Fig. 6.

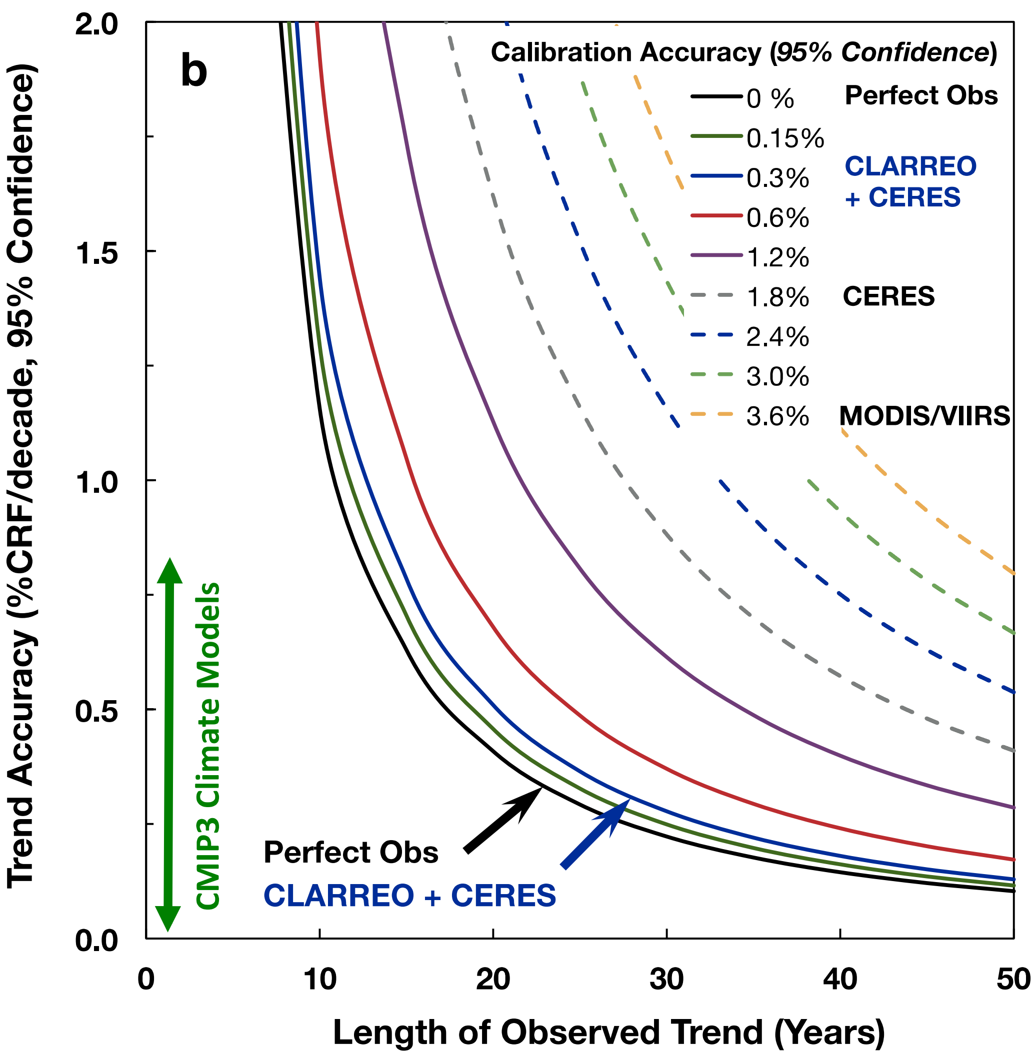
Accuracy Requirements of the Climate Observing System



The length of time required to detect a climate trend caused by human activities is determined by:

- *Natural variability*
- *The magnitude of human driven climate change*
- *The accuracy of the observing system*

Reflected Solar Accuracy and Climate Trends



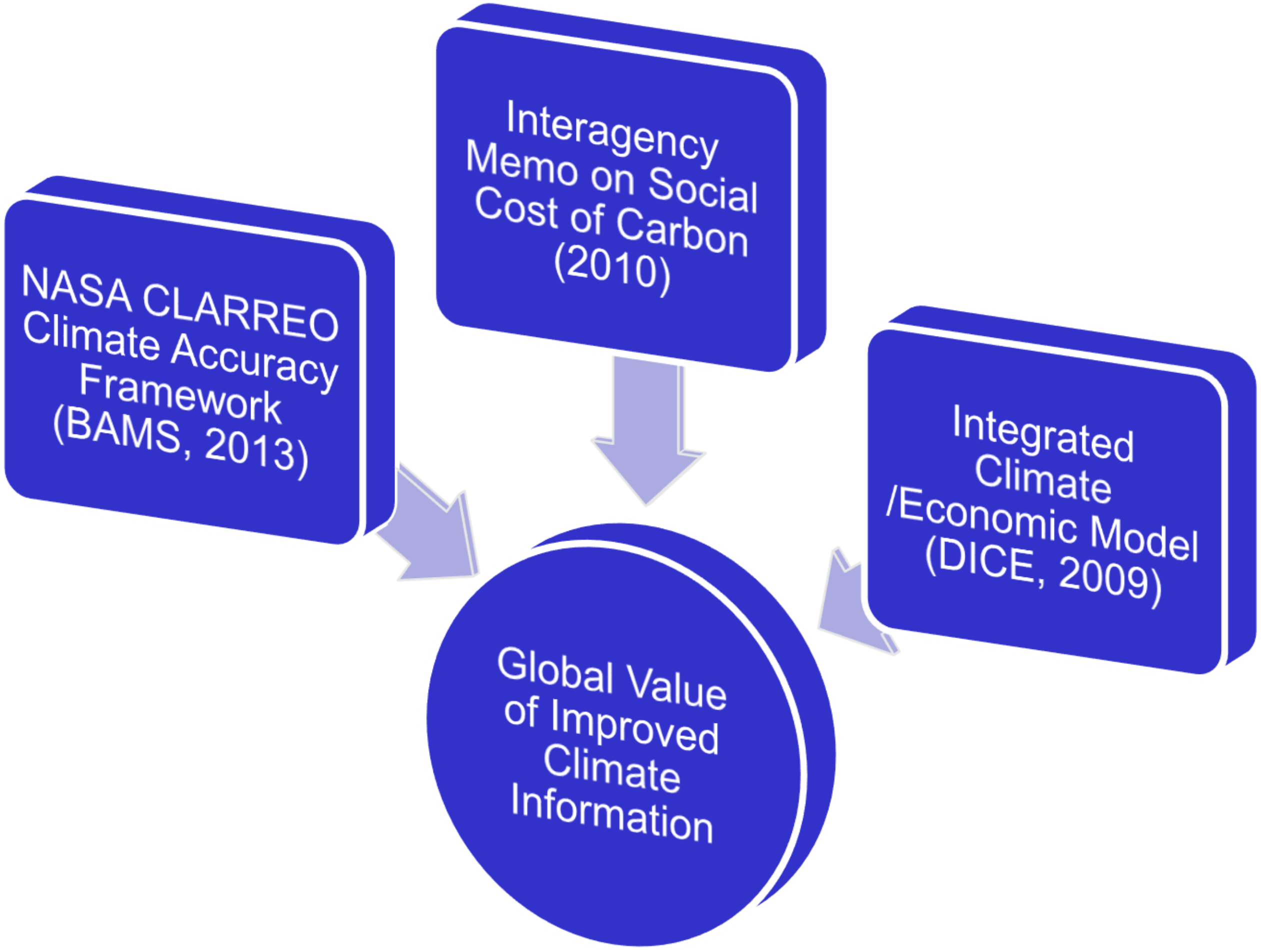
Climate Sensitivity Uncertainty is a factor of 4 (IPCC, 90% conf) which =*factor of 16 uncertainty in climate change economic impacts*

Climate Sensitivity Uncertainty = Cloud Feedback Uncertainty = Low Cloud Feedback = *Changes in SW CRF/decade (y-axis of figure)*

Higher Accuracy Observations = CLARREO reference intercal of CERES = *narrowed uncertainty 15 to 20 years earlier*

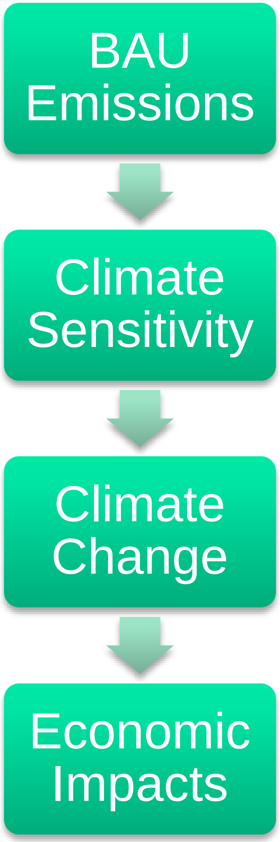
Wielicki et al. 2013, Bulletin of the American Meteorological Society

What is the right amount to invest in climate science?

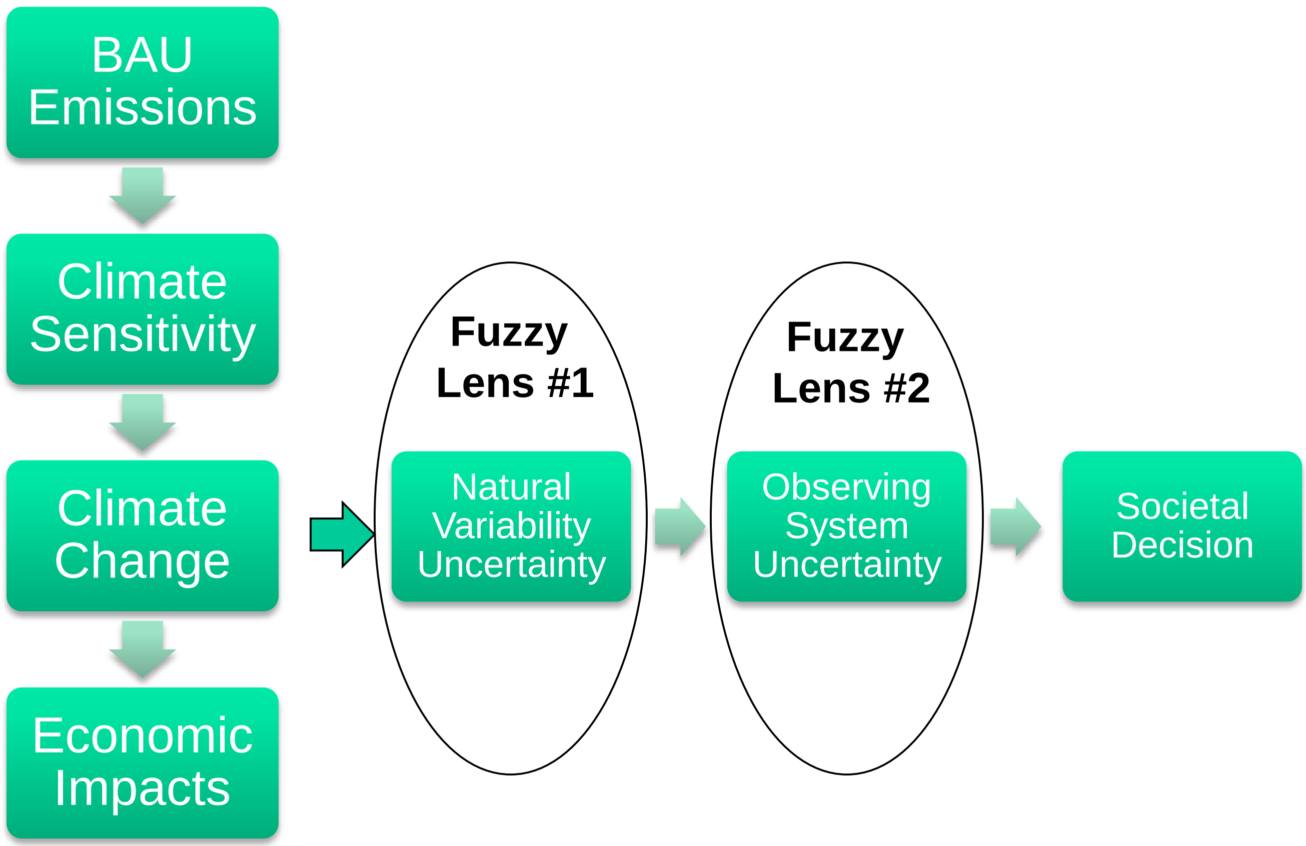


Cooke et al., Journal of Environment, Systems, and Decisions, July 2013, paper has open and free distribution online: doi:10.1007/s10669-013-9451-8

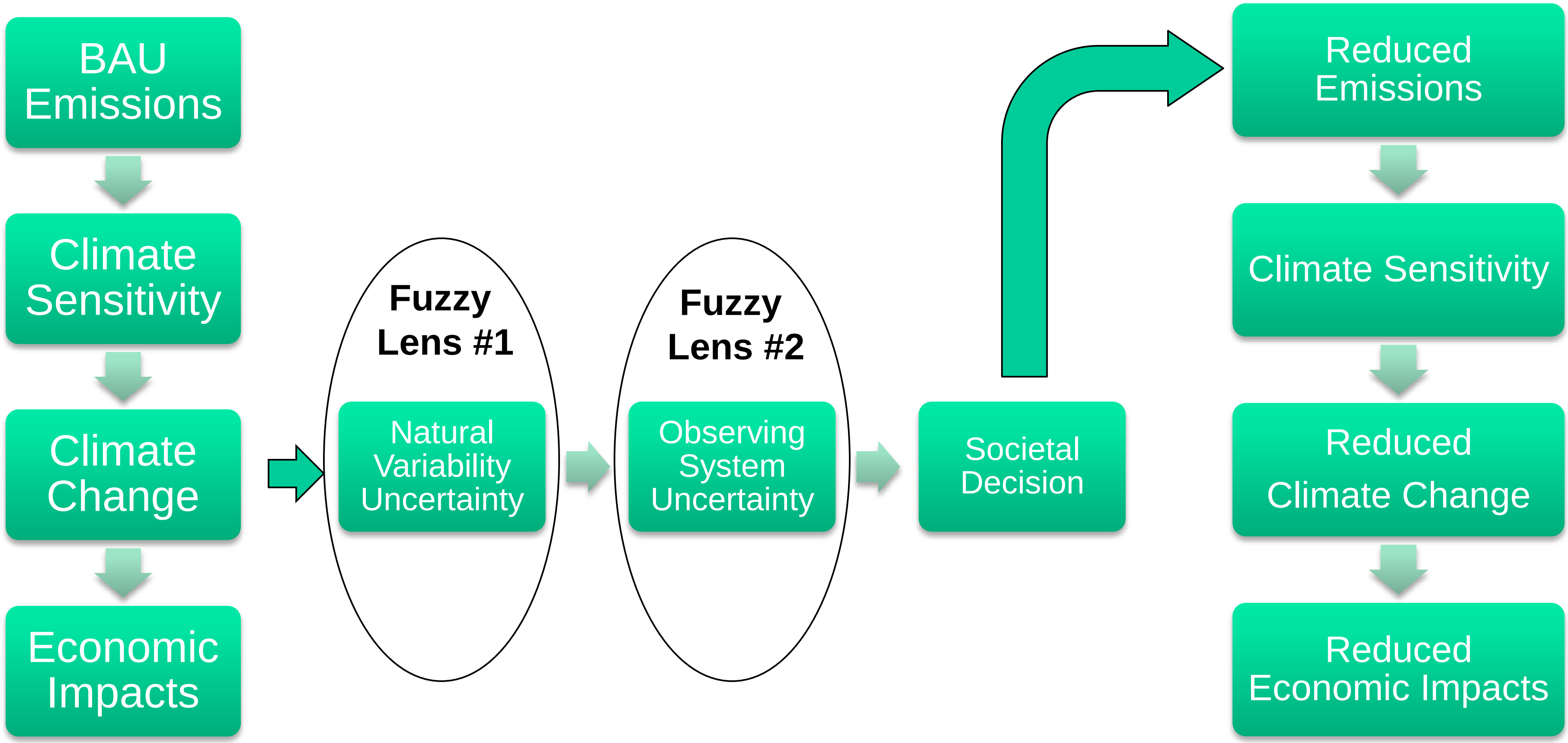
VOI Estimation Method



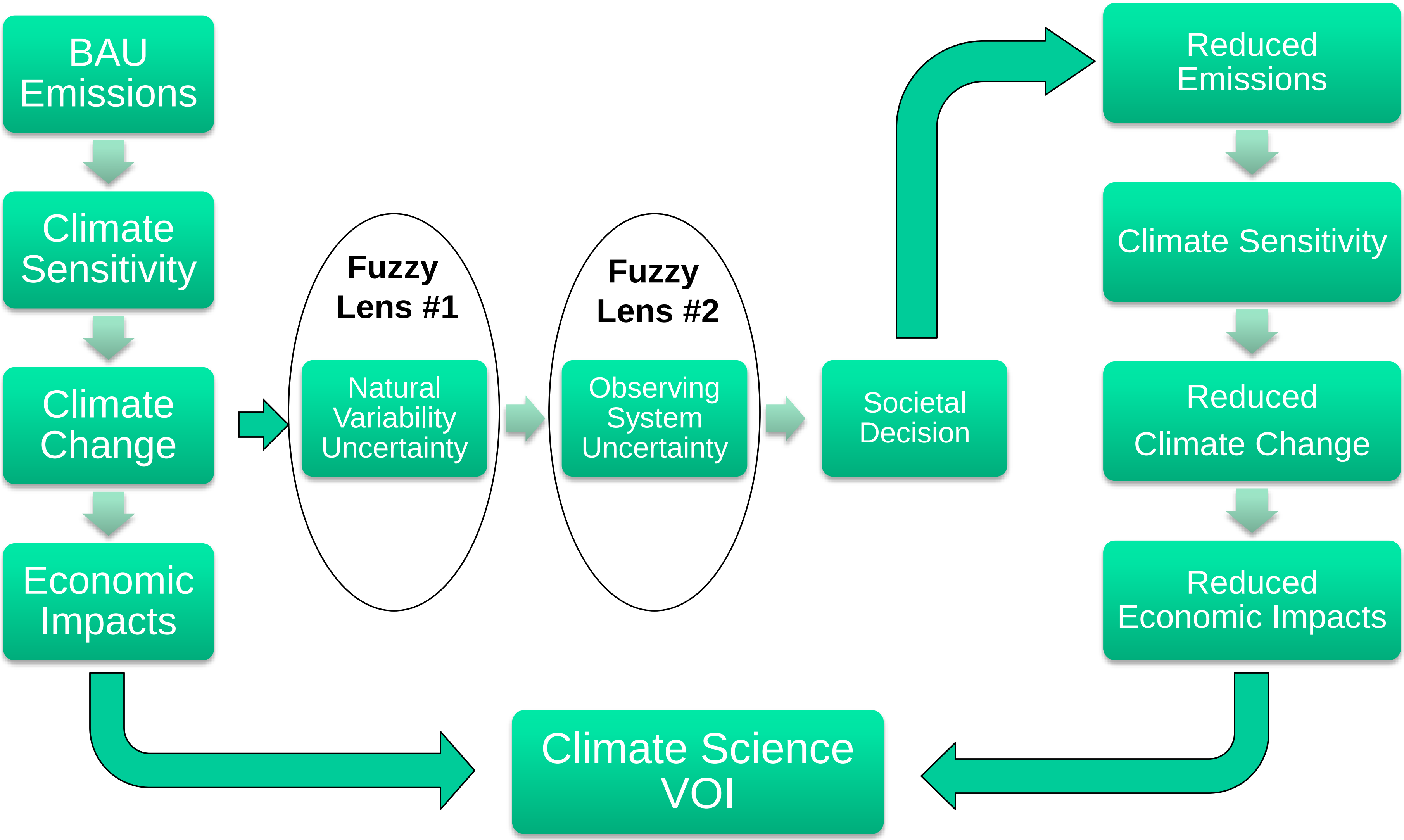
VOI Estimation Method



VOI Estimation Method



VOI Estimation Method



Economics: The Big Picture

- World GDP today ~ $70 Trillion US dollars

- Net Present Value (NPV)
  - compare a current investment to other investments that could have been made with the same resources

- Discount rate: 3%
  - 10 years: discount future value by factor of 1.3
  - 25 years: discount future value by factor of 2.1
  - 50 years: discount future value by factor of 4.4
  - 100 years: discount future value by factor of 21

- Business as usual climate damages in 2050 to 2100: 0.5% to 5% of GDP per year depending on climate sensitivity.

VOI vs. Discount Rate

Run 1000s of economic simulations and then average over the full IPCC distribution of possible climate sensitivity

Discount Rate	CLARREO/Improved Climate Observations VOI (US 2015 dollars, net present value)
2.5%	$17.6 T
3%	$11.7 T
5%	$3.1 T

Additional Cost of an advanced climate observing system:
~ $10B/yr worldwide
Cost for 30 years of such observations is ~ $200 to $250B (NPV)

Even at the highest discount rate, return on investment is very large

VOI vs. Discount Rate

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Discount Rate	CLARREO/Improved Climate Observations VOI (US 2015 dollars, net present value)
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5%	$3.1 T

Advanced Climate Observing System:

Return on Investment: $50 per $1

Cost of Delay: $650B per year

Even at the highest discount rate, return on investment is very large

Climate Observations: No Long Term Plan

- Global Satellite Observations without long term commitments
  - Radiation Budget (e.g. CERES)
  - Gravity (ice sheet mass) (e.g. GRACE)
  - Ice Sheet Elevation (e.g. ICESAT/Cryosat)
  - Sea Level Altimetry (e.g. JASON)
  - Sea surface Salinity (e.g. Aquarius)
  - Cloud and Aerosol Profiles (e.g. CALIPSO/Cloudsat, EarthCARE)
  - Precipitation (e.g. GPM, CloudSat/EarthCARE)
  - Soil Moisture (e.g. SMAP)
  - Ocean surface winds (e.g. QuickSCAT)
  - Carbon Source/Sinks (e.g. OCO)
  - Methane/Carbon Monoxide (MOPPIT)
  - In orbit Calibration References (e.g. CLARREO)
- Surface and In-situ observations have similar issues

Suggested Directions

- Quantitative Science Questions
  - Hypothesis Tests not "improve and explore", think Higgs Boson
- Observing System Simulation Experiments (OSSEs)
  - Improve observing system requirements
  - Move from "base state" to "climate change" climate model tests
- Higher Accuracy Observations for Climate Change
  - See BAMS Oct 2013 paper for example: broadly applicable
- Economic Value of Improved Climate Observations and Models
  - See J. Env. Sys. Decisions paper for example: broadly applicable

Summary

Lack of accuracy = delayed knowledge

We lack a climate observing system capable of testing climate predictions with sufficient accuracy or completeness

At our current pace, its seems unlikely that we will understand climate change even after another 35 years.

We cannot go back in time and measure what we failed to observe.

Its time to invest in an advanced climate observing system