Economic Value Part 3:

Moving from Temperature Change to SW Cloud Radiative Forcing Change

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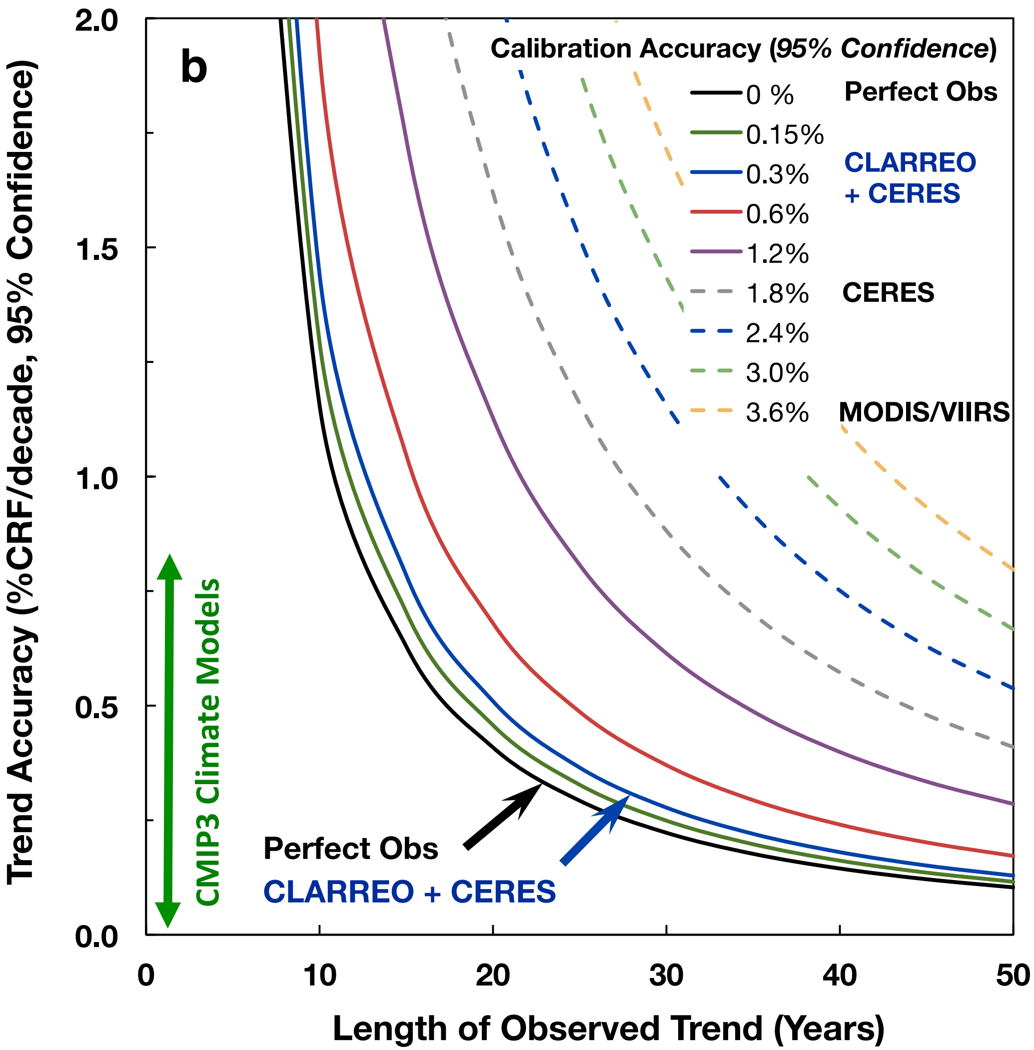
Outline

- Brief summary of first 2 papers using temperature change
- Moving to shortwave cloud radiative forcing change
- SW CRF results
- Future directions
- References

Reflected Solar Accuracy and Climate Trends



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

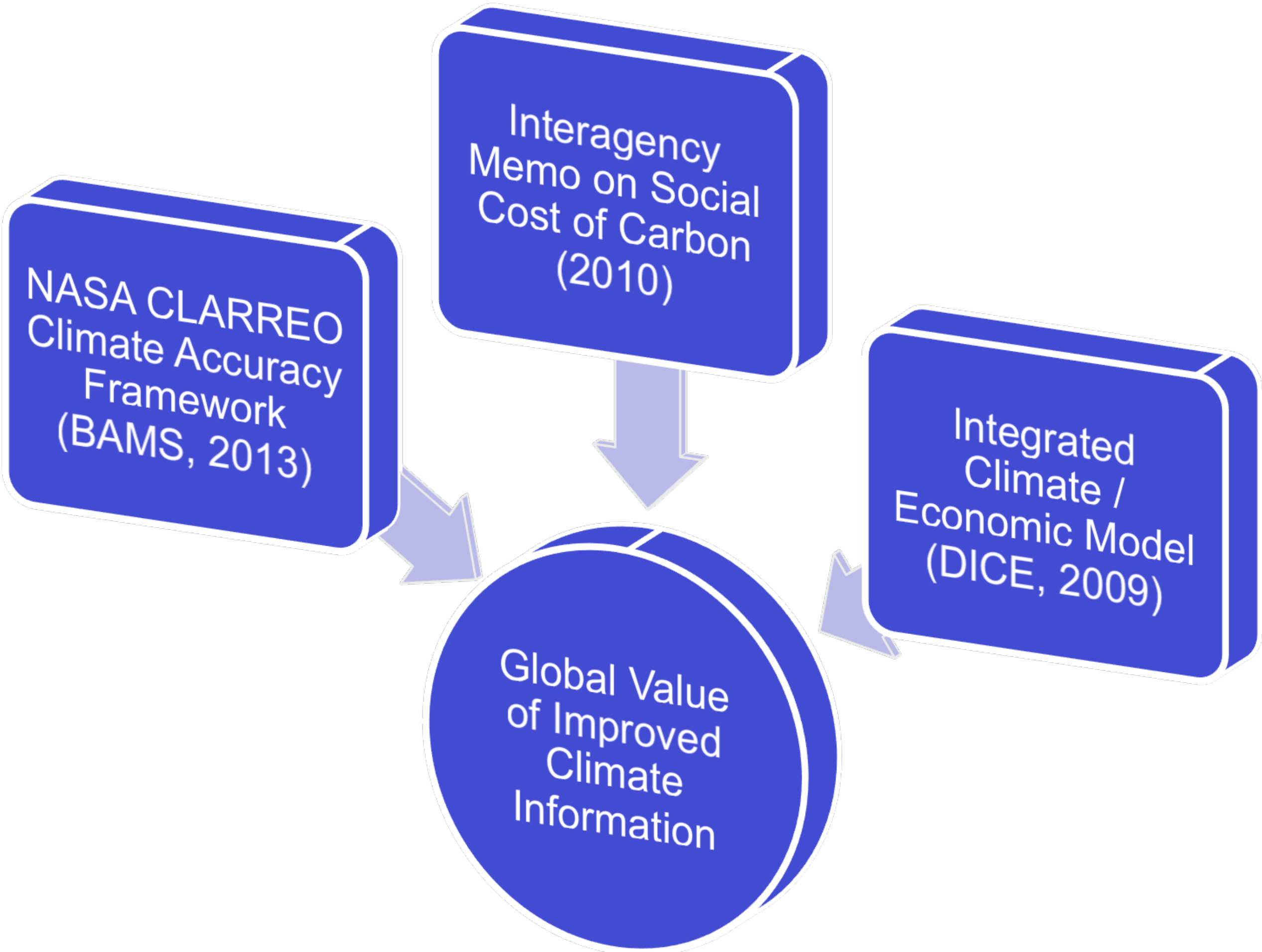
Climate Sensitivity Uncertainty = Cloud Feedback Uncertainty = Low Cloud Feedback = *Changes in SW CRF/decade (y-axis of figure)*

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

High accuracy is critical to more rapid understanding of climate change

What is the right amount to invest in climate science?



Cooke et al., Journal of Environment, Systems, and Decisions, 2014, paper has open and free distribution online: doi:10.1007/s10669-013-9451-8.
Cooke et al., Climate Policy, 2015, ISSN: 1469-3062

VOI Estimation Method

BAU Emissions

↓

Climate Sensitivity

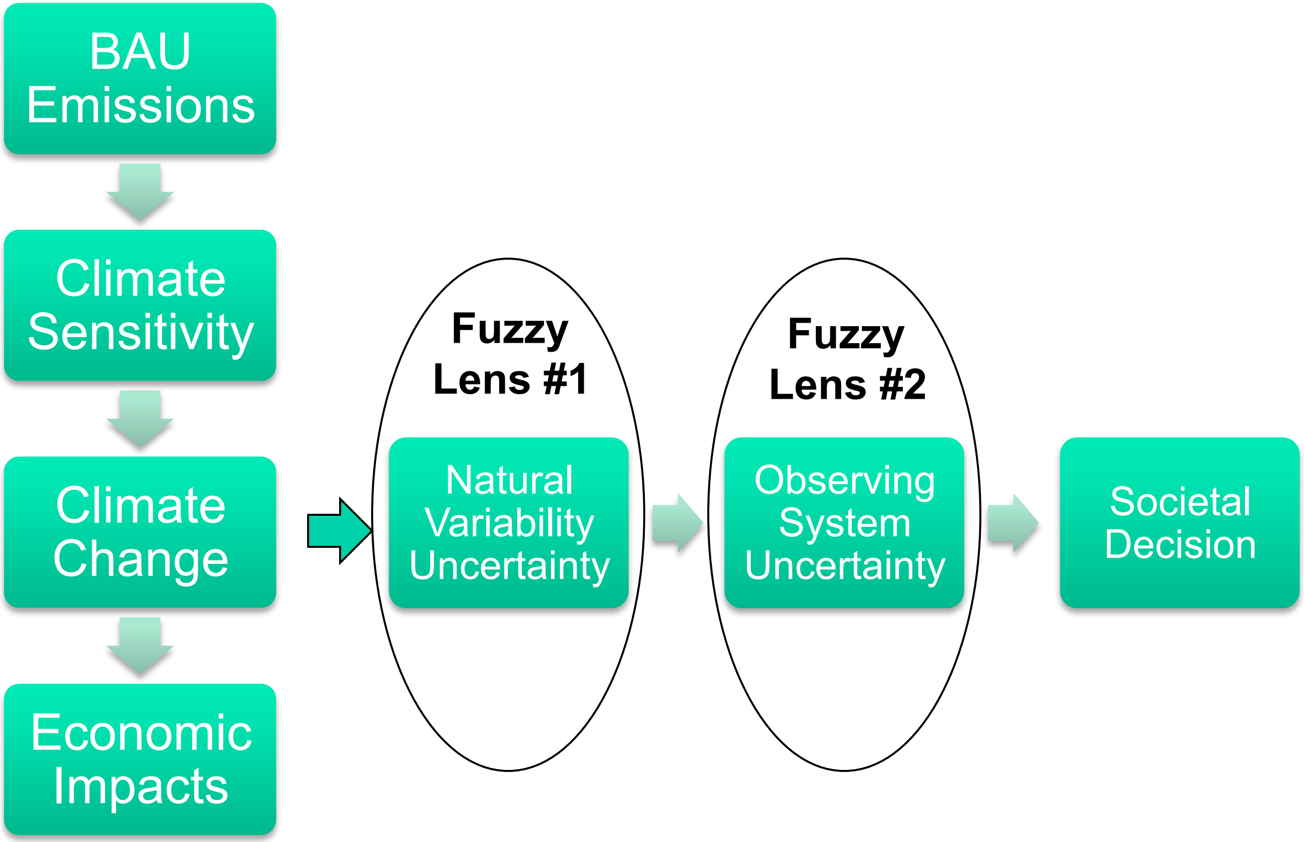
↓

Climate Change

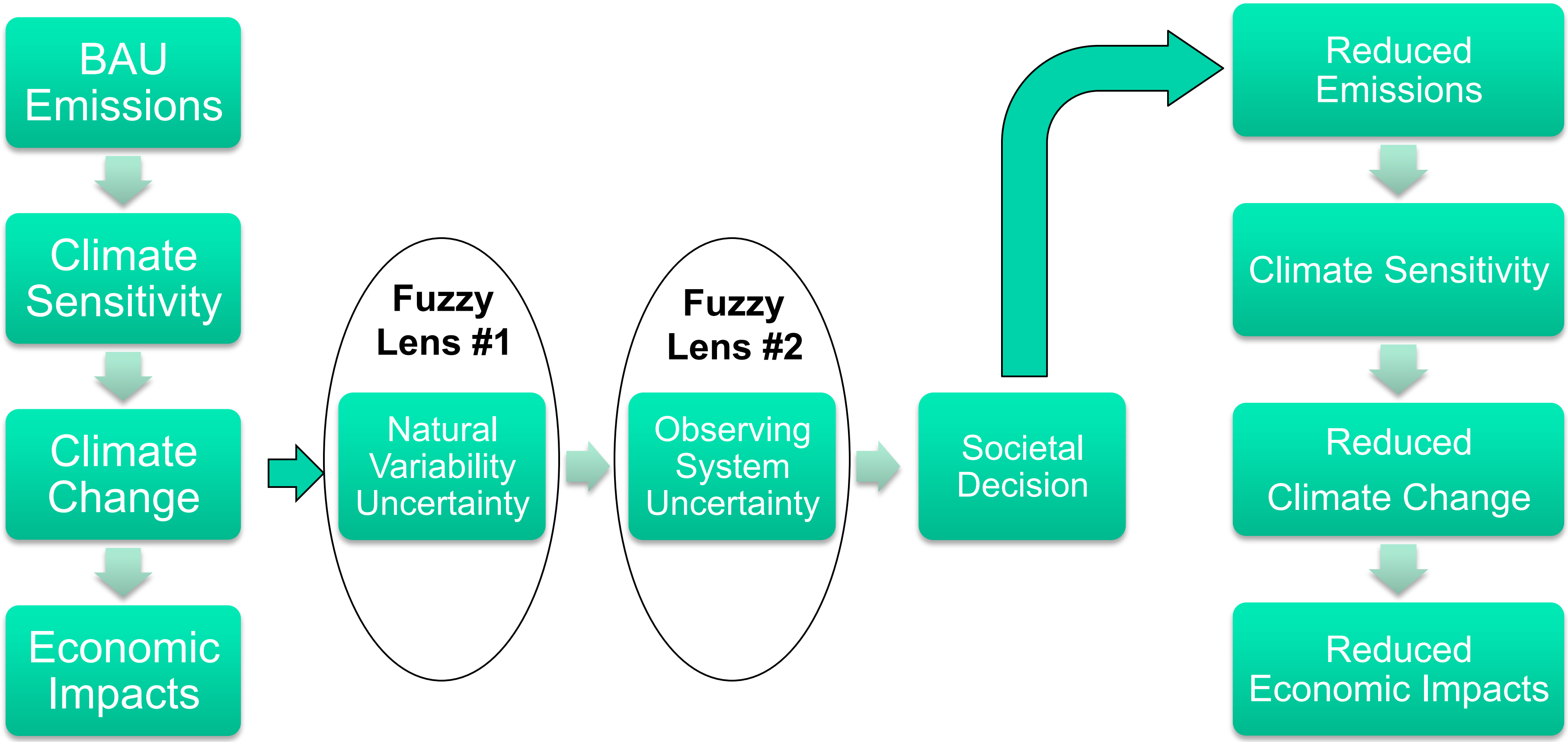
↓

Economic Impacts

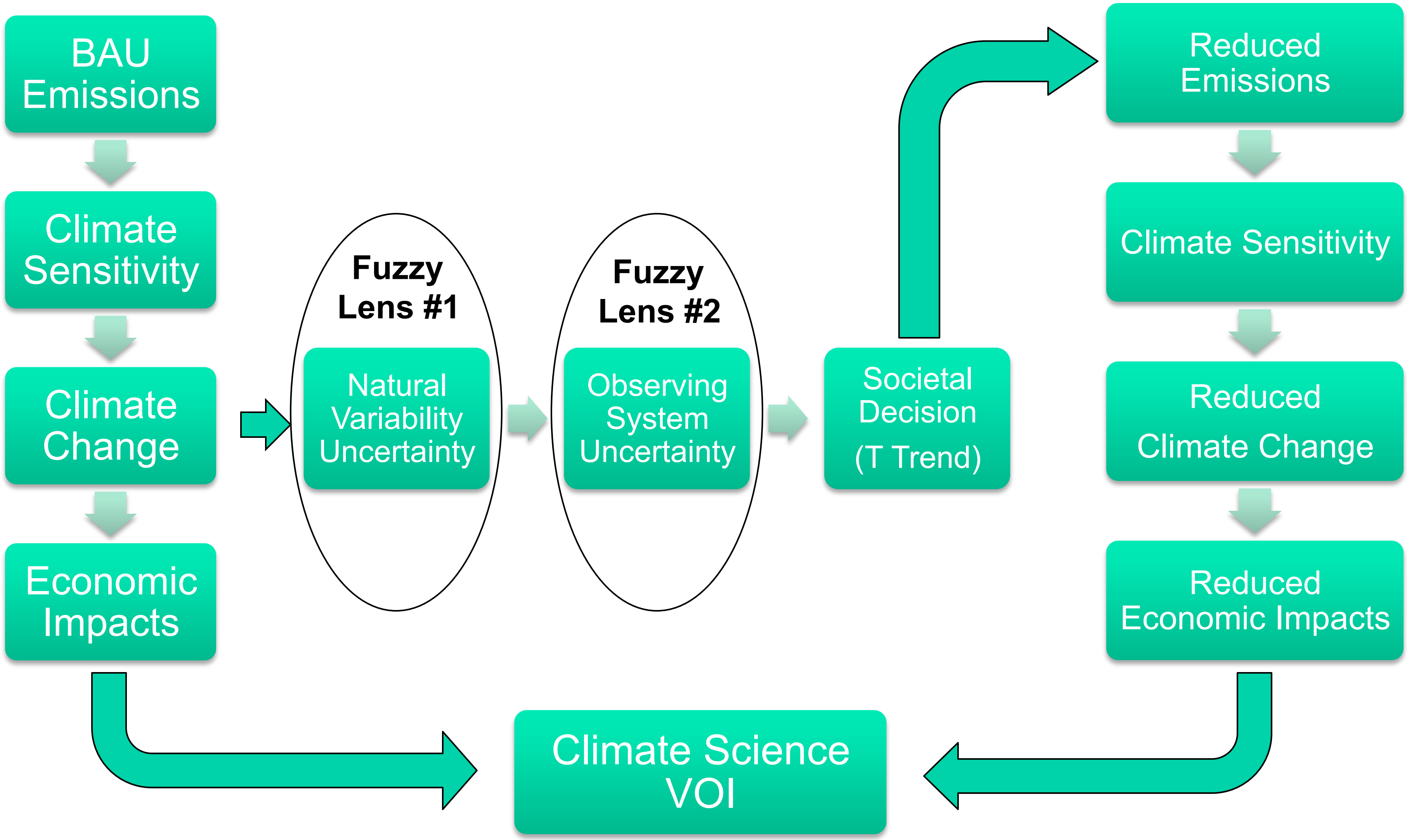
VOI Estimation Method



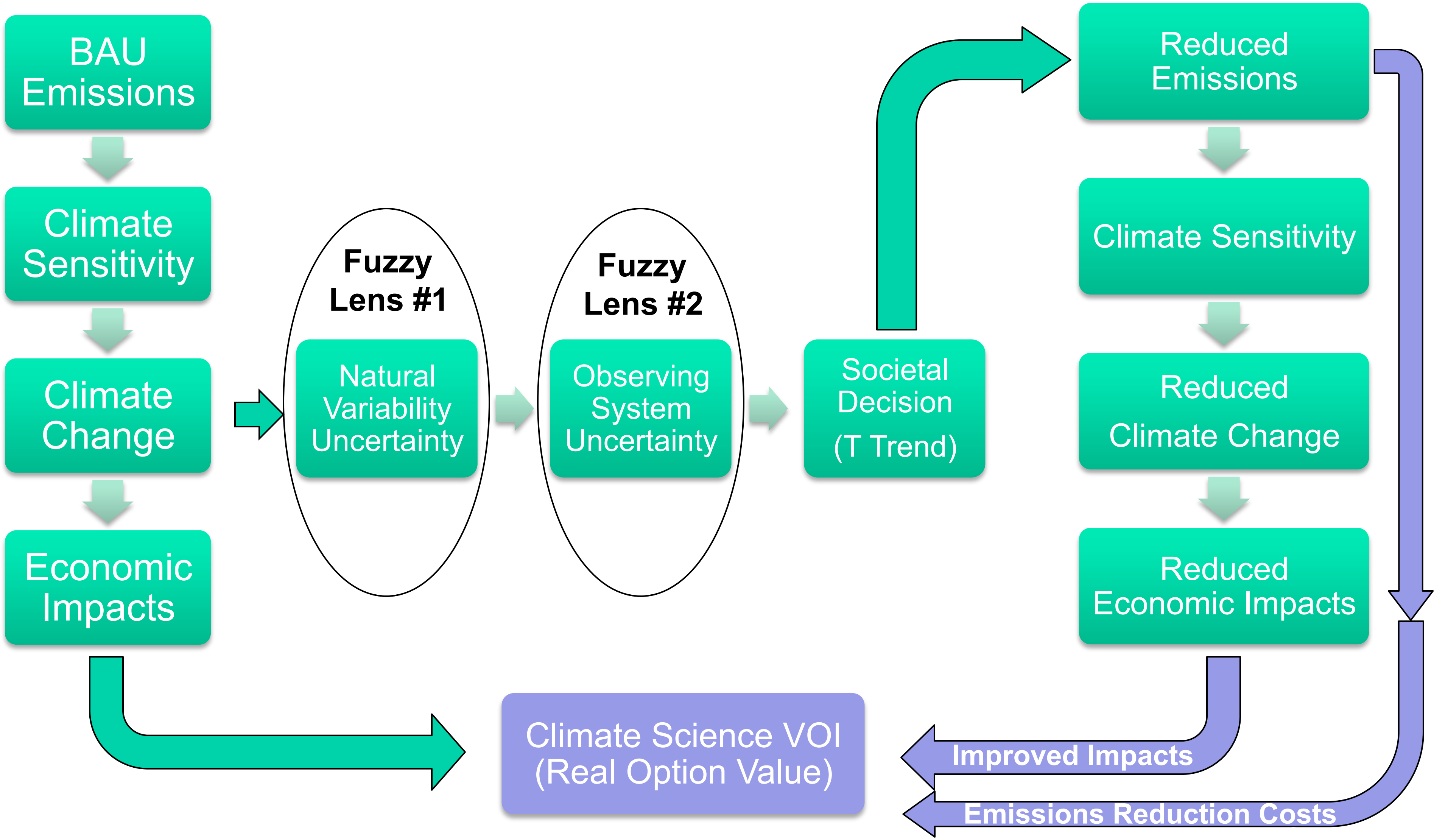
VOI Estimation Method



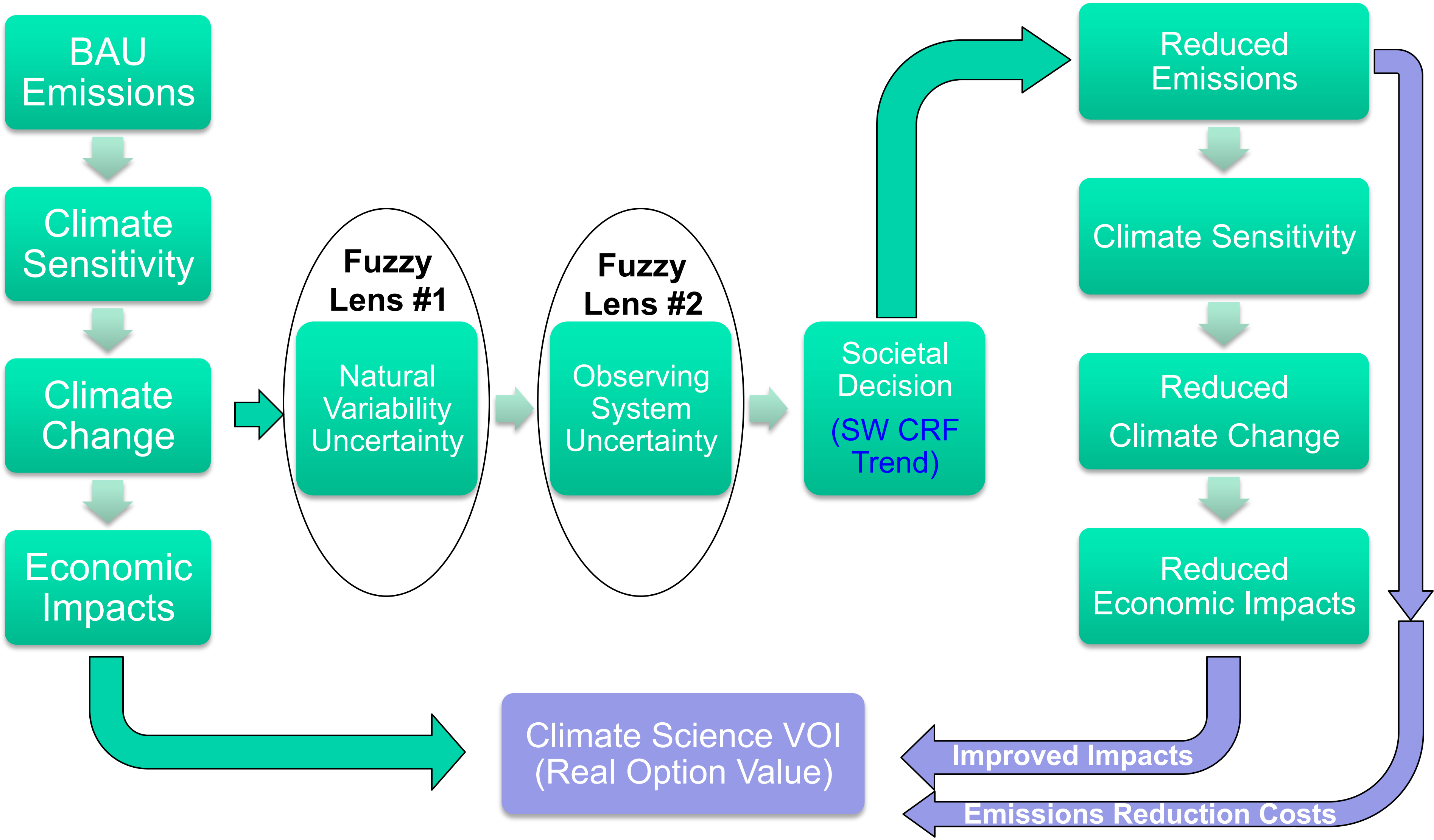
VOI Estimation Method: Cooke et al. 2014



VOI Estimation Method: Cooke et al. 2016a



VOI Estimation Method: Cooke et al. 2016b



Cooke et al. 2014 Net Present Value Results

DELTA Mean Averted Damages Trillion USD (2008)						
Launch date	Switch to	Confidence	Trigger	2.5%	3%	5%
2020	DICE OPT	95%	0.2C/decade	17.55	11.67	3.14
2020	DICE OPT	**97.5%**	0.2C/decade	21.63	14.22	3.66
2030	DICE OPT	95%	0.2C/decade	14.79	9.16	1.88
2020	DICE OPT	95%	**0.3C/decade**	23.34	14.36	2.91
2020	**STERN**	95%	0.2C/decade	22.25	15.57	5.01
2020	**STERN**	**97.5%**	0.2C/decade	27.19	18.78	5.75
2020	**STERN**	**97.5%**	**0.3C/decade**	31.86	20.30	4.65
2030	**STERN**	**97.5%**	**0.3C/decade**	30.61	18.54	3.50

Cooke et al. 2016a Real Option Value Results

Table 4. Expected Surfeit Net Benefits in Base Case, by Year and by Discount Rate

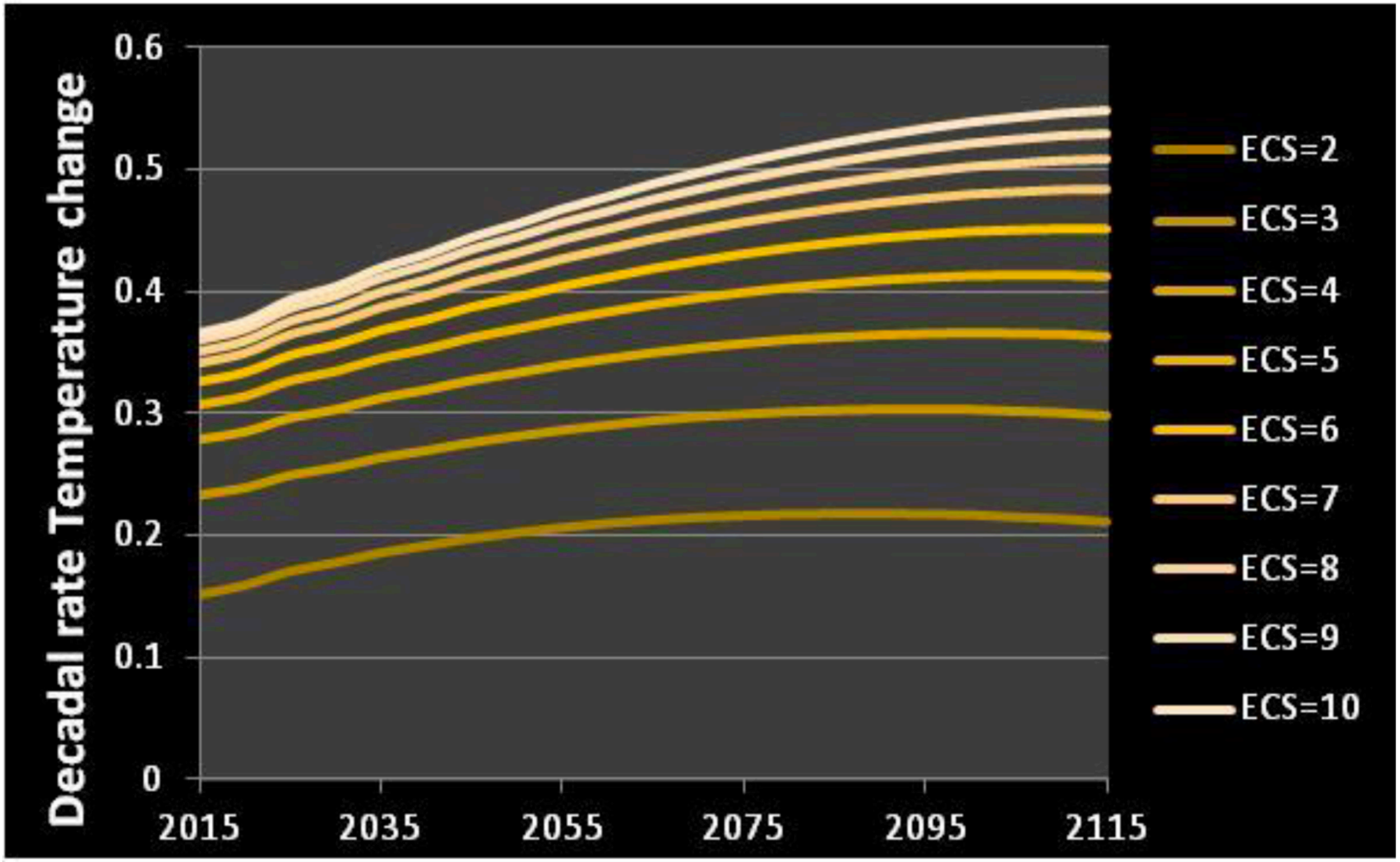
Real Option Value of Enhanced EOS			
Discount rate	2.50%	3%	5%
Real option value	16.70	9.00	1.07

Note: Trigger = 0.2C/decade, sigma = 1.65 (95% Confidence), launch 2020 (from Cooke et al. 2015)

Real Option Value is in $Trillion of U.S. dollars

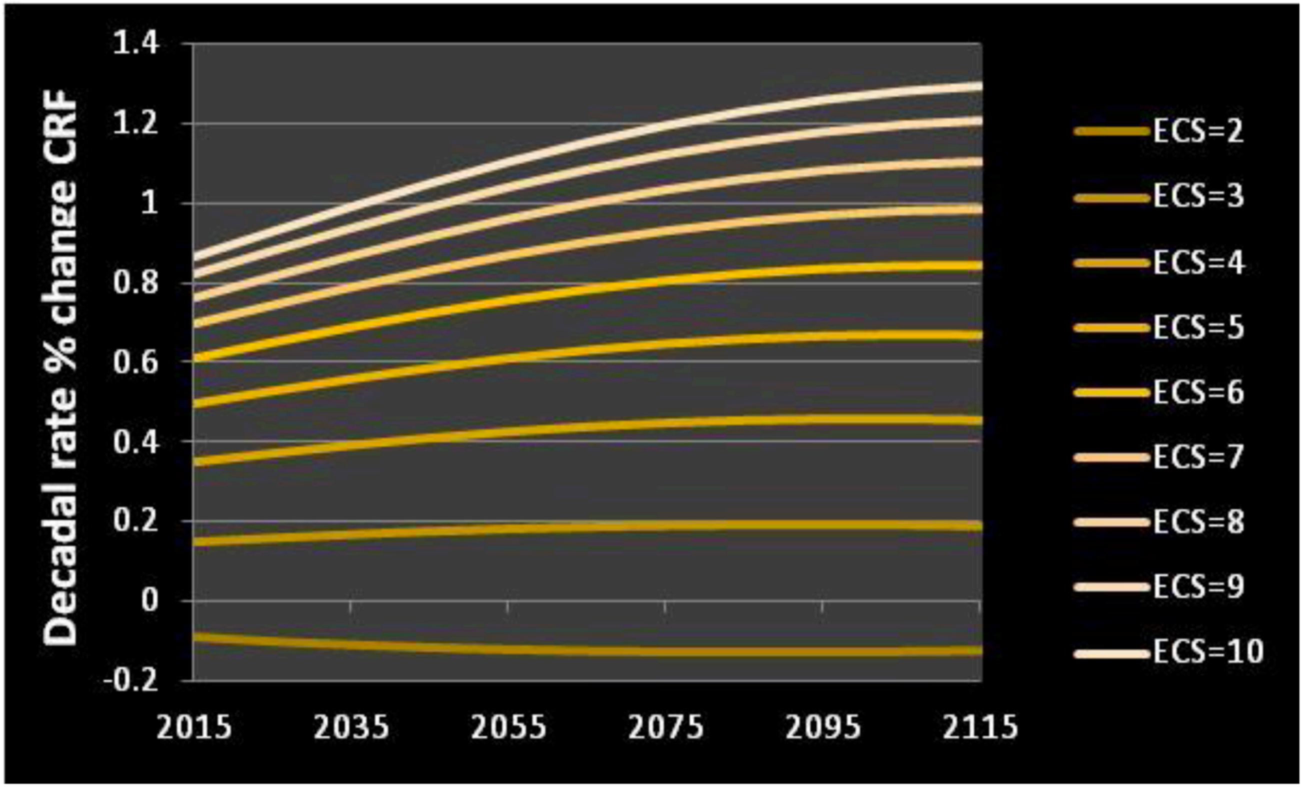
Decadal Temperature Change Vs Climate Sensitivity

Figure 3. Decadal Temperature Change [C] for Different ECS as Function of Year



SW CRF Decadal Change Vs Climate Sensitivity

Figure 2. Percentage Change in CRF for Different ECS as Function of Year and ECS



Sensitivity Analysis: SW CRF Results

Real Option Value of Enhanced EOS					
2.5%	3%	5%	Trigger	Confidence	Launch
33.30	17.19	1.79	–0.10	1.28	2020
34.02	17.41	1.71	0.00		
32.65	16.67	1.54	0.10		
30.18	15.27	1.35	0.20		
28.01	14.08	1.18	0.30		
21.68	10.86	0.82	0.50		
14.03	7.00	0.49	0.70		
4.19	1.99	0.10	1.00		
38.81	19.89	1.99	–0.10	1.65	
38.81	19.62	1.81	0.00		
36.34	18.16	1.57	0.10		
33.36	16.68	1.39	0.20		
31.08	15.45	1.21	0.30		
23.21	11.52	0.81	0.50		
14.70	7.24	0.47	0.70		
4.23	1.98	0.09	1.00		
45.83	22.79	2.03	–0.10	2.30	
44.36	21.90	1.83	0.00		
41.22	20.32	1.61	0.10		
37.57	18.41	1.37	0.20		
34.04	16.68	1.16	0.30		
24.59	12.05	0.78	0.50		
14.90	7.25	0.43	0.70		
3.13	1.45	0.06	1.00		
33.78	17.00	1.61	–0.10	1.65	2025
28.60	14.15	1.29	–0.10		2030
23.35	11.33	0.96	–0.10		2035
17.66	8.25	0.65	–0.10		2040

Real Option Value
$ Trillions of U.S. dollars (2008)

Summary of Results

- SW CRF as a climate sensitivity trigger shows larger economic value than temperature trigger (factor of 2)
  - SW CRF decadal change signal varies more directly with climate sensitivity and over a wider range of signal
  - CLARREO reflected solar calibration advance is larger (factor of 5 to 10) than infrared (factor of 3 to 5)
  - Shorter autocorrelation time for natural variability of SW CRF: not related to the 5 year ENSO time scale as seen for temperature
- Future work will use Bayesian Belief Net approach to combining multiple sources of evidence with varying uncertainty in setting the societal trigger (e.g. temperature trends + SW CRF trends)
  - Closer to the way IPCC or society makes decisions: consistency over a wide range of evidence

Caveats

- Economics estimates have large uncertainties, but they can both increase or decrease the current economic VOI costs.
- Examples that would increase economic value:
  - The following climate change costs are not included in the 2010 U.S. Social Cost of Carbon Memo:
    - *Ocean acidification,*
    - *International conflicts caused by refugees of climate change,*
    - *Species loss*
    - *Unexpected accelerations such as arctic methane or carbon dioxide greenhouse gas emissions as climate warms*
    - *Larger than expected sea level rise (e.g. recent Hansen et al 2016 paper just released on nonlinear sea level rise rates)*
- Examples that would decrease economic value:
  - Unexpected societal shift to rapidly eliminate CO2 emissions well beyond the recent Paris agreement (factor of 2 to 4 faster reductions)
  - Unexpected early technological breakthrough in cost reduction of renewable energy (e.g. sudden factor of 4 reduction in solar, wind, battery costs by 2020)

Summary

- Current observations used for climate have an even larger economic value than those shown here: without them we would not even know climate change was happening. Current global climate science research investment ~ $4 Billion U.S. per year
- Further investments to triple this level to $12 Billion per year to build an international Climate Observing System would pay back ~ $50 for every $1 invested (NPV, 3% discount rate)
- Second Cooke et al Paper improves and includes carbon emissions reduction costs but reaches similar conclusions.
- New studies confirm these first two paper results:
  – An independent analysis by Hope et al 2015 "The $10 trillion value of better information about the transient climate response. Phil. Trans. R. Soc. A 373: 20140429. http://dx.doi.org/10.1098/rsta.2014.0429
  – A third Cooke et al paper using shortwave cloud radiative forcing trends for cloud feedback/climate sensitivity constraint as a societal decision trigger instead of temperature trends: increases VOI to about 20 Trillion. Includes carbon emissions reduction costs.

Conclusion

- Even large (factor of 5) changes in the economic analysis leave the conclusion unchanged*:*
- *Return on Investment of a New Climate Observing System would range from 10:1 to 250:1*
- *A New Climate Observing System would be one of the most cost effective investments society could make to provide a stable economic future*.

References

- Cooke, R., B. A. Wielicki, D. F. Young, and M. G. Mlynczak, 2014: Value of Information for Climate Observing Systems. Journal of Environment, Systems, and Decisions, *Environ Syst Decis*, 34, 98–109, DOI 10.1007/s10669-013-9451-8.

- Cooke, R., A. Golub, B. A. Wielicki, D. F. Young, M. G. Mlynczak, R. R. Baize, 2016a: Real Option Value of Earth Observing Systems. *Climate Policy*, DOI: 10.1080/14693062.2015.1110109, 16pp.

- Cooke, Roger M. Golub, Alexander, Wielicki, Bruce, Mlynczak, Martin , Young, David, Baize, Rosemary Rallo (2016b) Real Option Value for New Measurements of Cloud Radiative Forcing, RFF DP 16-19.

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Backup Slides

Economics: The Big Picture

- World GDP today ~ $80 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

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

Advanced Climate Observing System:

Return on Investment: $50 per $1

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

Results and Sensitivity to Assumptions

World Wide Economic Benefits

Parameter Change	CLARREO/Improved Climate Observations VOI (Trillion US 2015 dollars, NPV) 3% discount rate
Baseline*	$11.7 T
BAU => AER	$9.8 T
0.3C/decade trigger	$14.4 T
2030 launch	$9.1 T

*** Baseline uses 0.2C/decade trigger, 95% confidence in trend, BAU => DICE optimal emissions, 2020 launch**

- **Delaying launch by 10 years reduces benefit by $2.6 T**

Each year of delay we lose $260B of world benefits