RFF-CMCC EIEE Seminar-Webinar

January 17, 2019 - h.12.30 pm

Using the social cost of carbon to value earth observing systems

Roger Cooke - Presenter
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We're a central focal point for research insights and policy solutions in Europe, with an international network of experts, policymakers, and stakeholders.

Q&A Session

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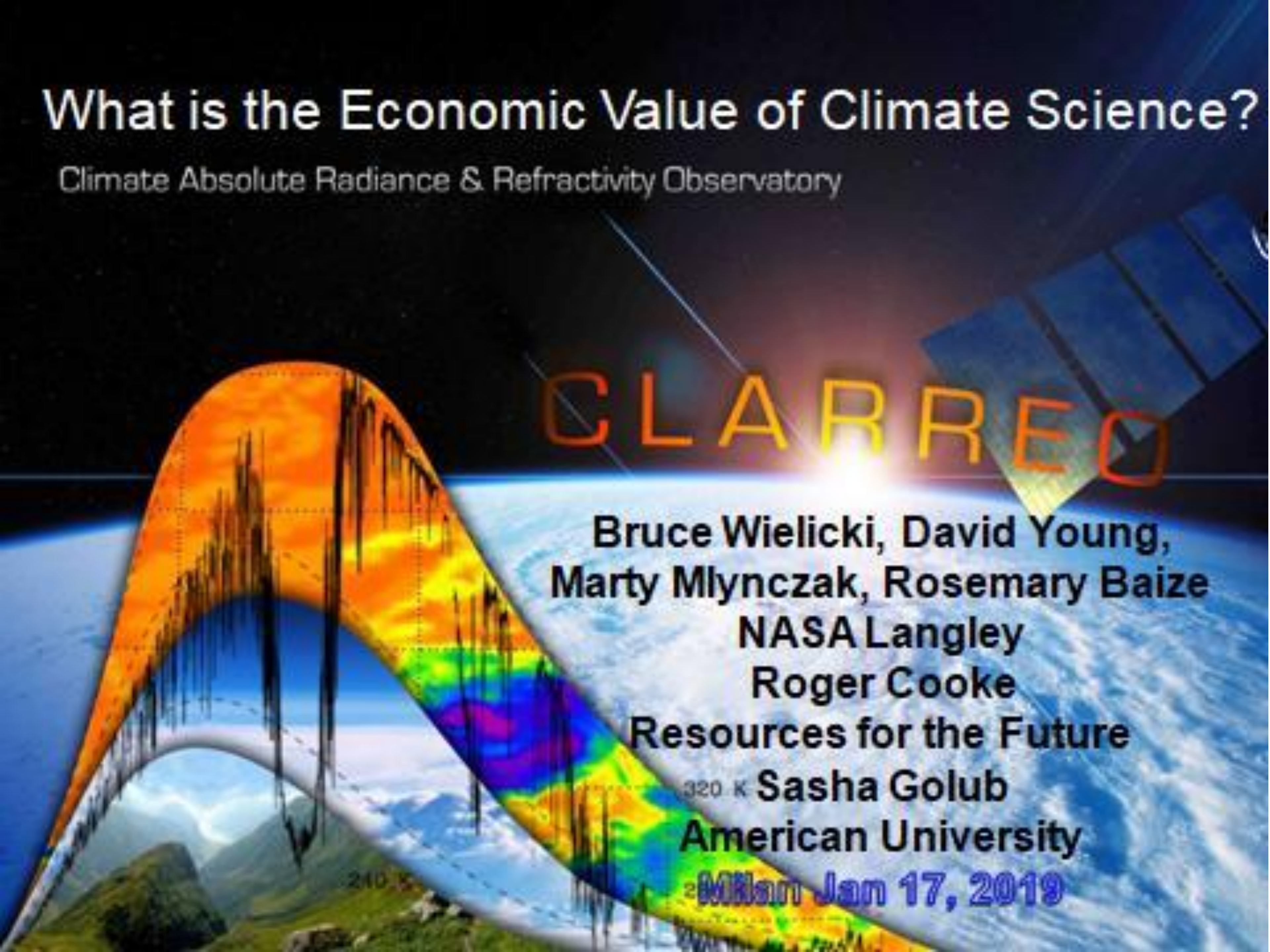
What is the Economic Value of Climate Science?

Climate Absolute Radiance & Refractivity Observatory



Bruce Wielicki, David Young,
Marty Mlynczak, Rosemary Baize
NASA Langley
Roger Cooke
Resources for the Future
Sasha Golub
American University

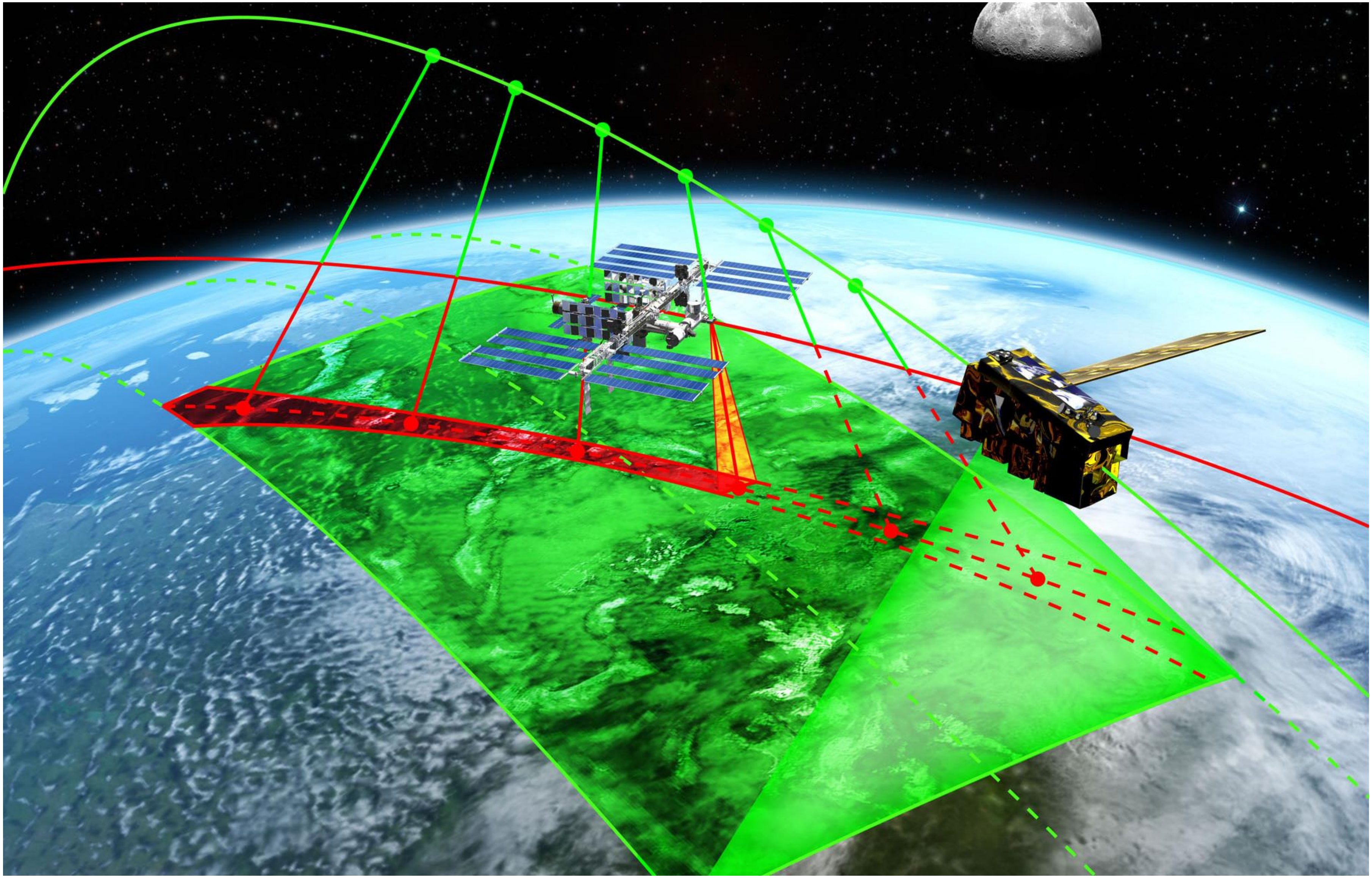
Milan Jan 17, 2019

Outline

- Science is an economic investment by the public
- We have no climate observing system, nor a plan to create one. Should we invest in one? Is it worth it?
- What is the economic value of an advanced climate observing system?
- Climate Absolute Radiance and Refractivity Observatory (CLARREO) Wielicki et al. (2013)

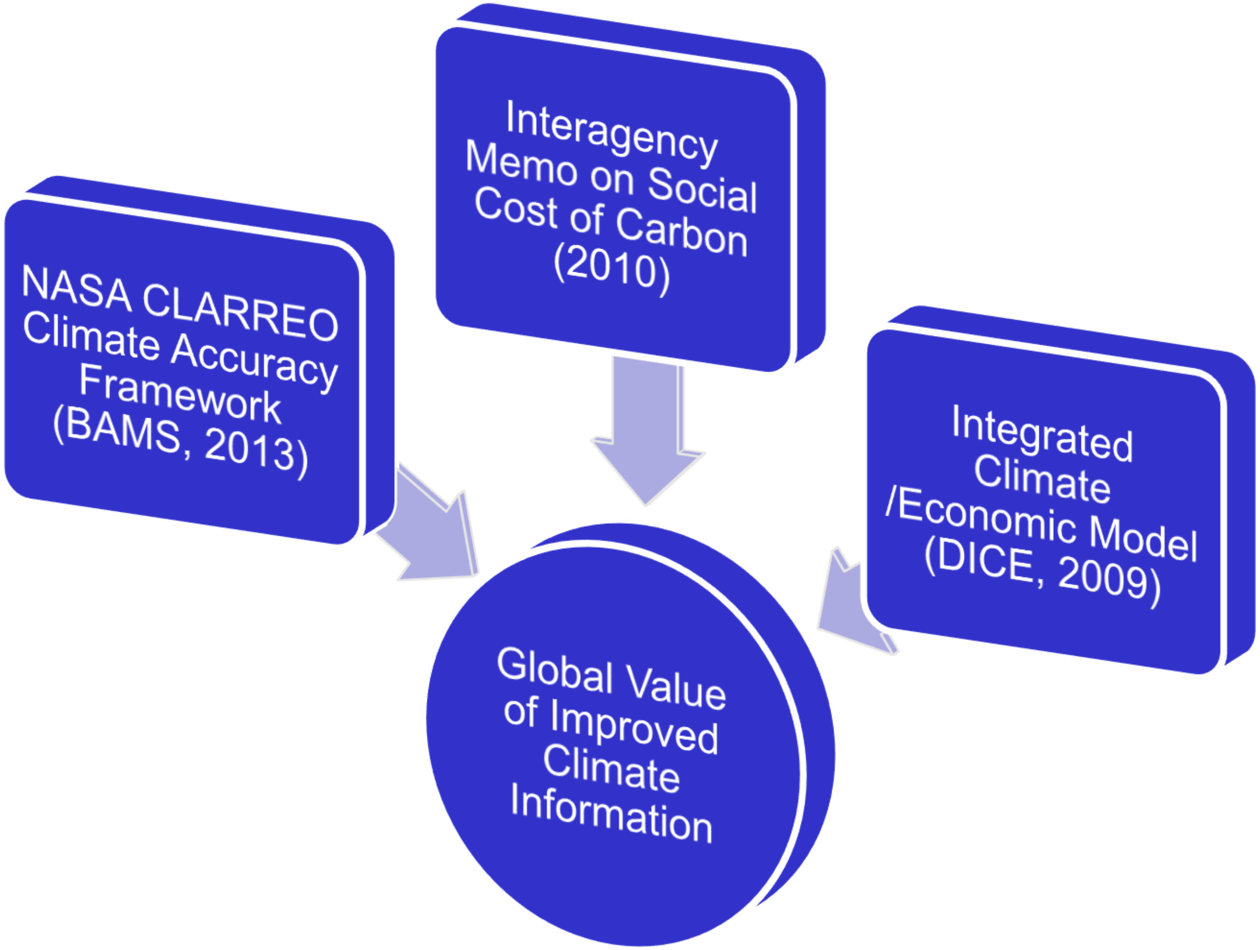
An Initial Next Step
Towards a Climate Observing System

CLARREO Pathfinder on ISS (2020)



CLARREO Pathfinder Begins in 2016!

What is the right amount to invest in climate science?



NASA CLARREO Climate Accuracy Framework (BAMS, 2013)

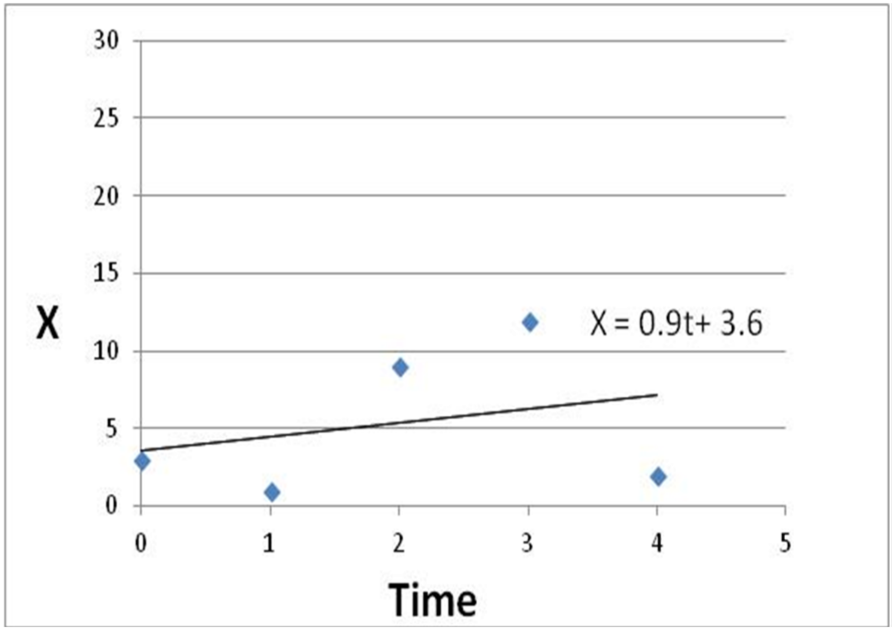
Interagency Memo on Social Cost of Carbon (2010)

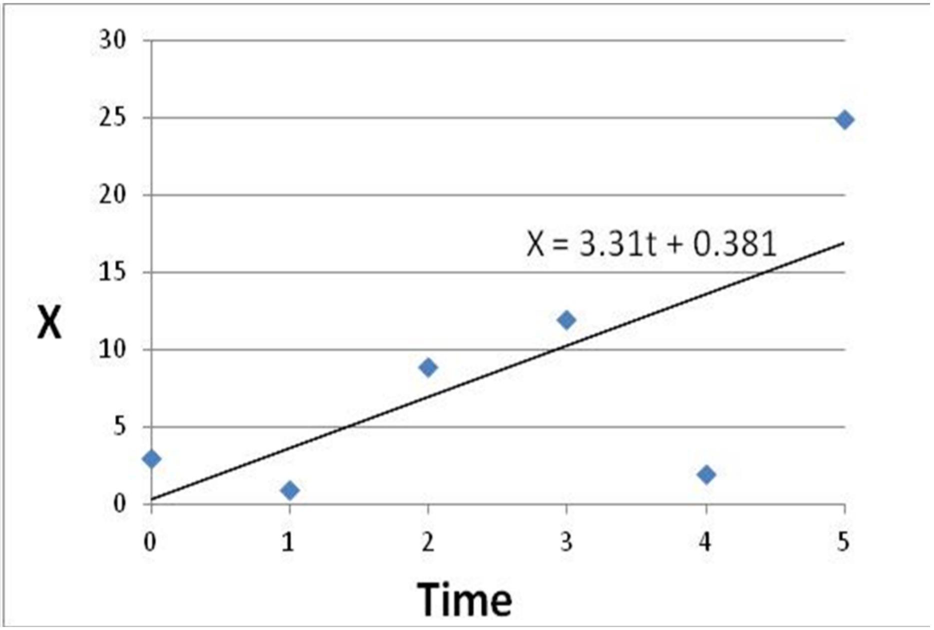
Integrated Climate /Economic Model (DICE, 2009)

Global Value of Improved Climate Information

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

Uncertainty in Observing Trends





$VAR(\Delta X) = 12(\Delta t)^{-3}(\sigma^2_{Nat}t_{Nat} + \sigma^2_{cal}t_{cal} + \sigma^2_{orbit}t_{orbit})$ (Leroy et al 2008)

Δt = the length of observation period [y]

σ^2_{Nat} = the variance of natural variability t_{var} = autocorrelation time scale of natural variability,

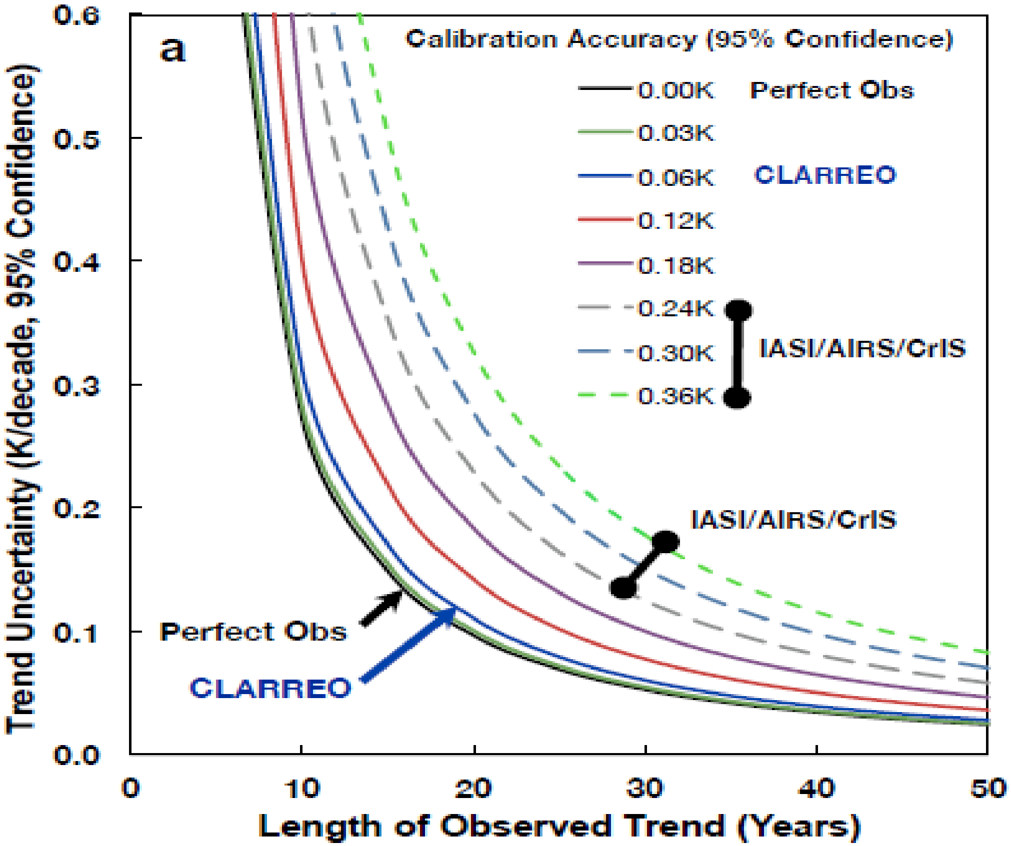
Similar *cal* and *orbit.*

X = global surface temperature *[C]*, ΔX has dimensions *[C/t]*, $VAR(\Delta X)$ has dimensions $[C^2/t^2]$, which is also the dimension of the terms $(s^2_i t_i) / \Delta t^3$.

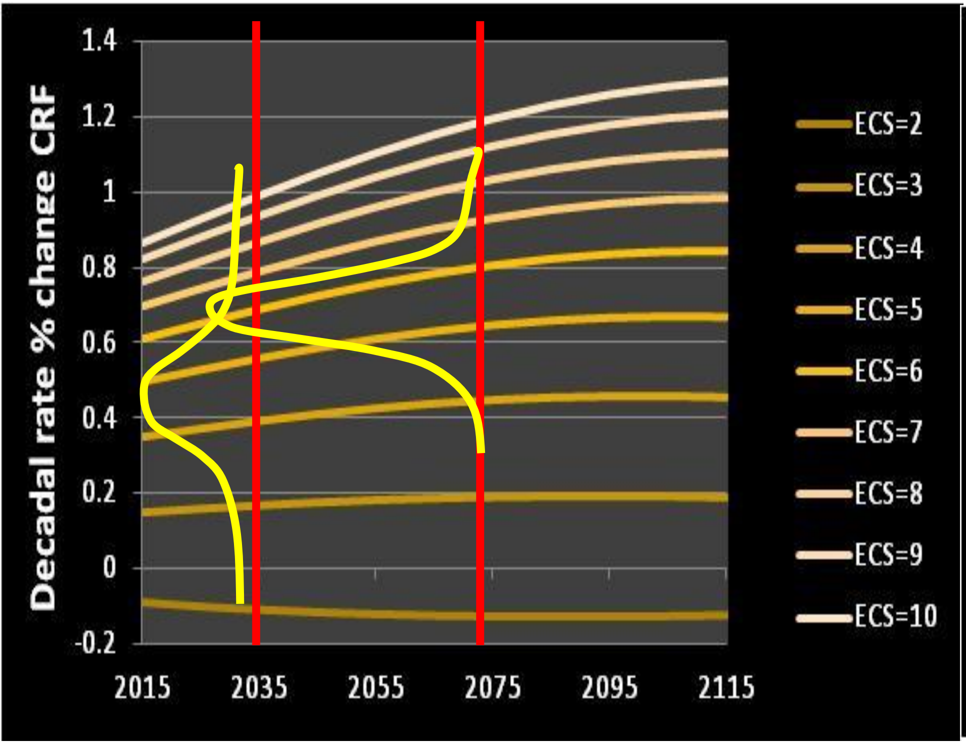
(a derivation is given in the Supplementary Online Material of Cooke et al 2013)*:*

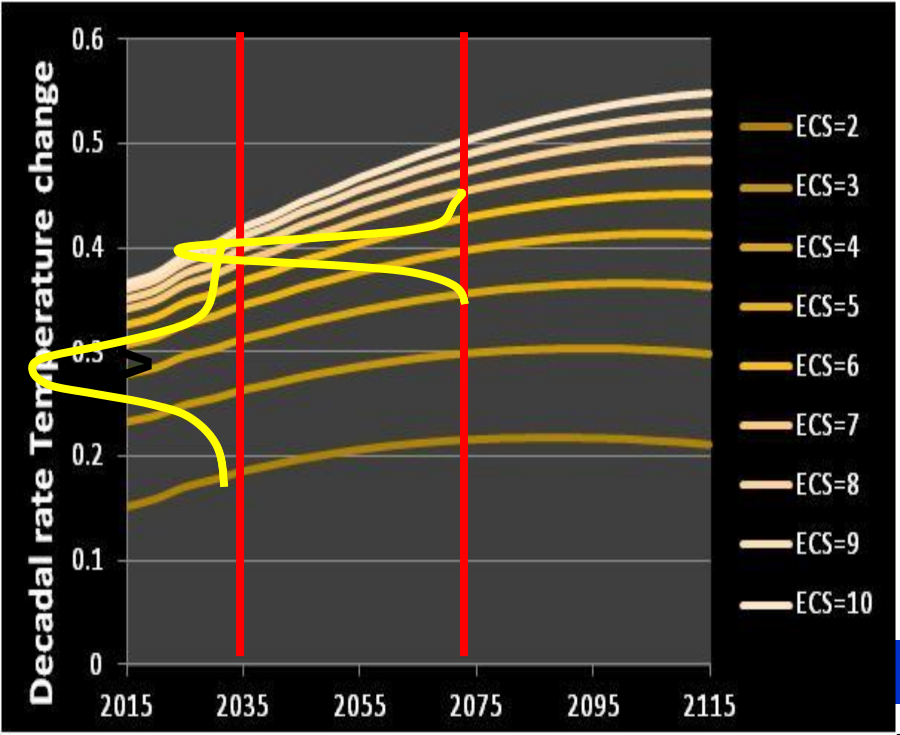
Table 2. Values of natural variability and observation uncertainties used in Fig. 2. From Wielicki et al. 2013.

Uncertainty Source	Decadal Temperature Trends		
	σ (K)		τ
	CLARREO Improved COS	I/A/C Current system	years
Natural Variability	0.085	0.085	2.3
Calibration Uncertainty	0.03	0.18	5
Orbit Sampling uncertainty	0.018	0.018	1



To assess damages, relate ΔC/decade uncertainty to ECS uncertainty (idem Δ % cloud radiative forcing) for CLARREO and current EOS: SCC DICE





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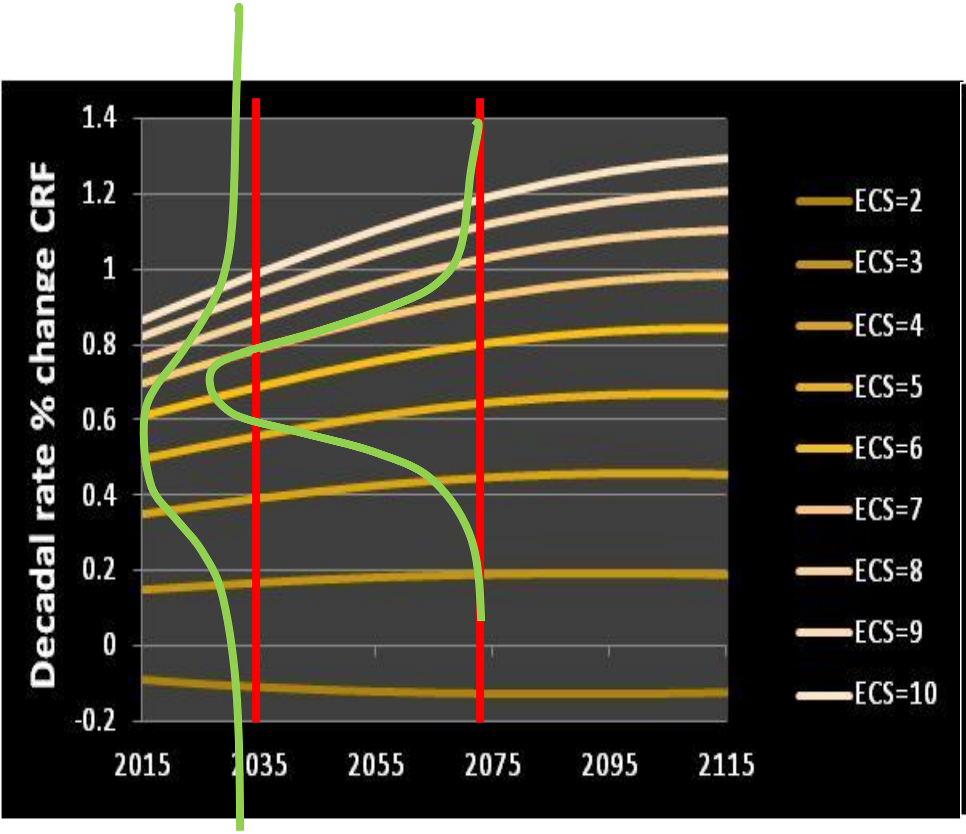
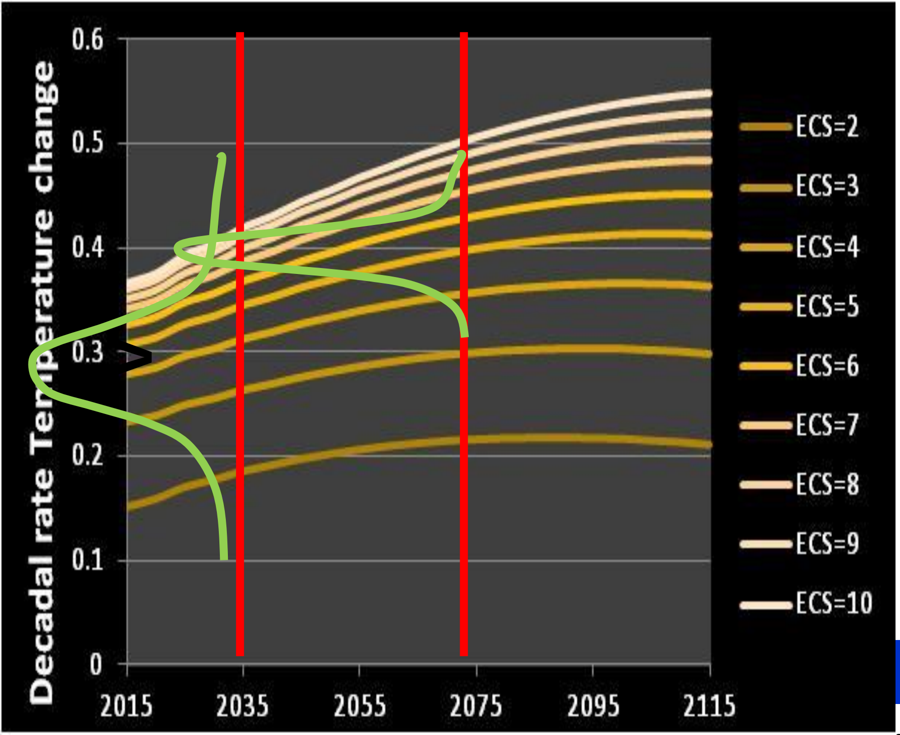
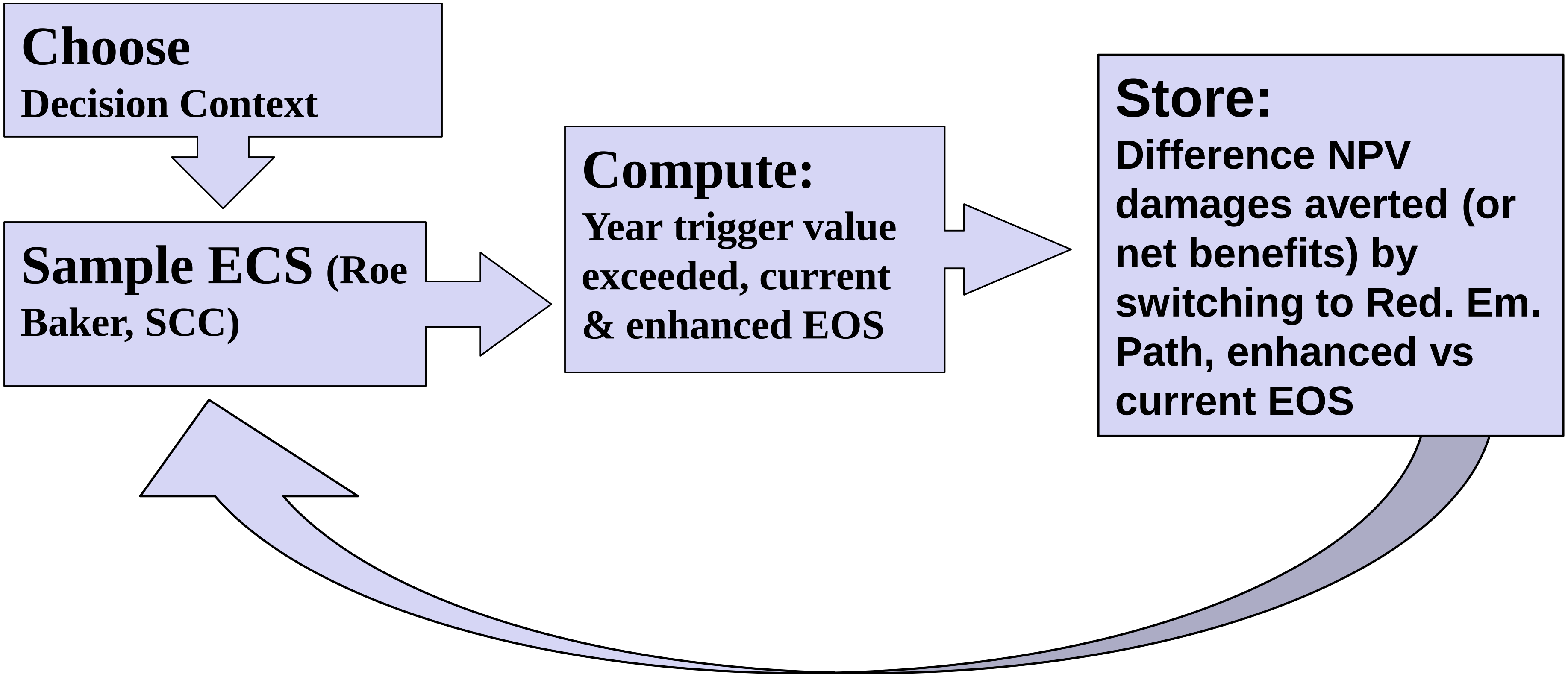




Information has value only if it is used

Decision context: when we become 95% certain that GST rise ≥ 0.2C/decade, switch to reduced emissions path
Dice Optimal/ lim2.5C / Stern Gore



Choose
Decision Context

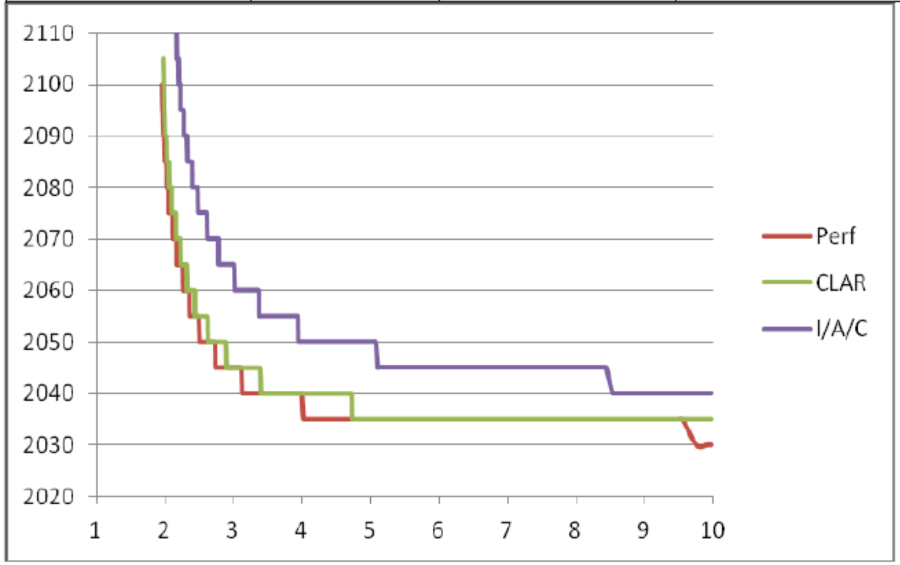
Sample ECS (Roe Baker, SCC)

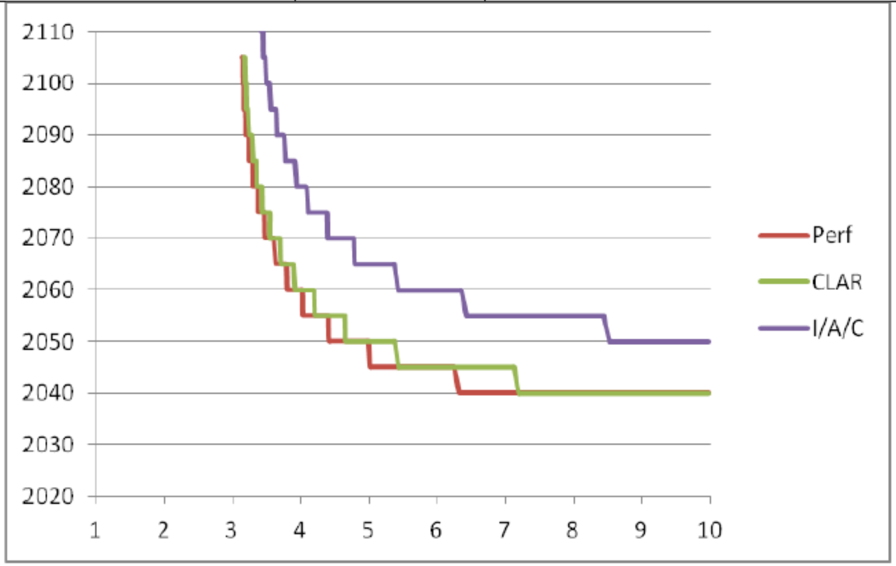
Compute:
Year trigger value exceeded, current & enhanced EOS

Store:
Difference NPV damages averted (or net benefits) by switching to Red. Em. Path, enhanced vs current EOS

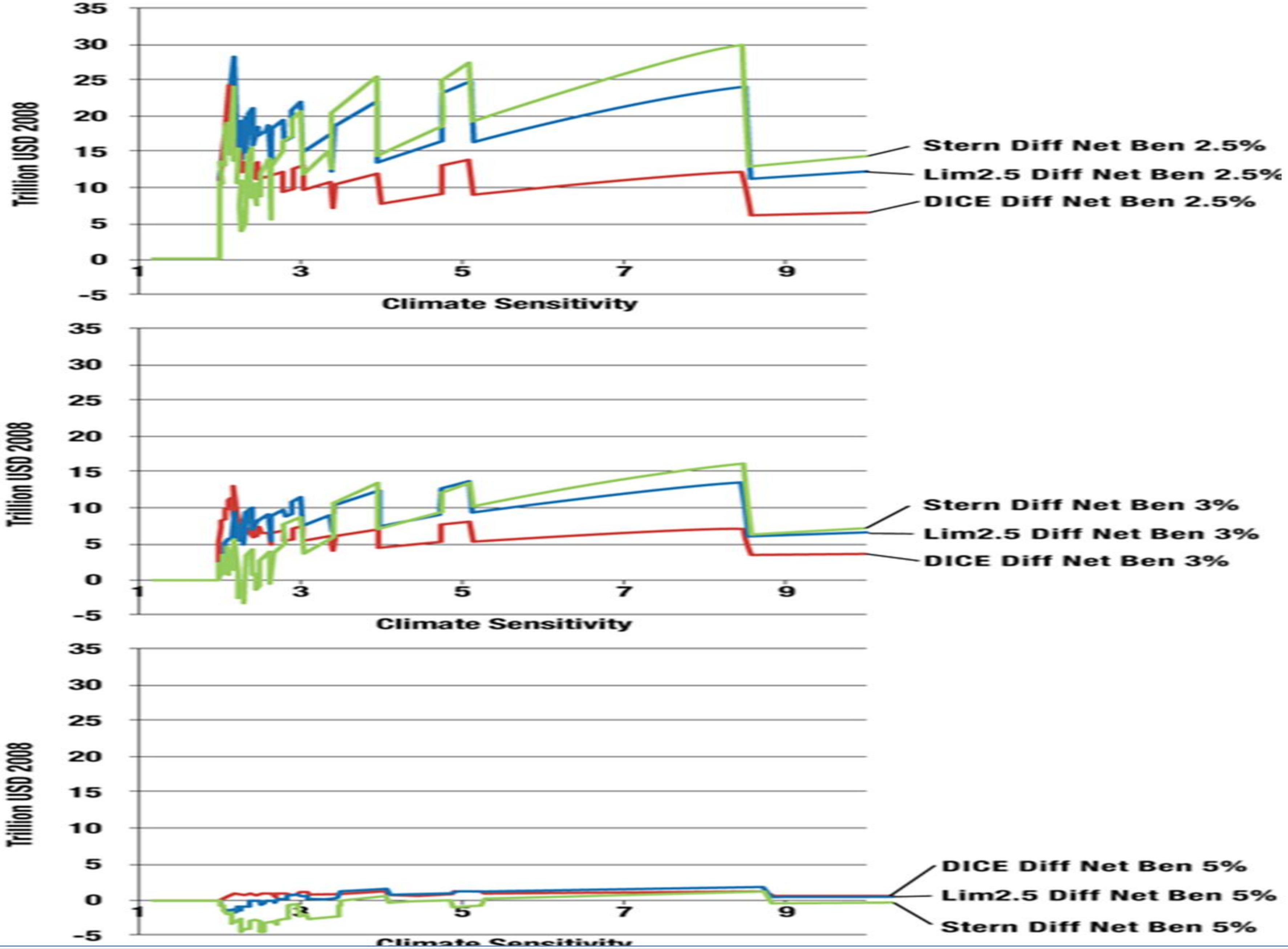
decadal temperature rise

launch 2020	conf 95%	trigger 0.2C		launch 2020	conf 95%	**trigger 0.3C**





Surfeit expected net benefits (trill USD 2008 for enhanced vs current EOS, triggering on GST rise > 0.2C/decade, with 95% probability



NPV Mean averted damages: Sensitivity

Table 7 CLARREO VOI results for decadal temperature rise

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

Base Case: triggering on CLARREO vs I/A/C Tril USD (2008)

		2.5%	**3%**	**5%**
Surfeit NPV mean **averted damages** NPV	DICE Opt	17.55	11.67	3.14
	Stern Gore	22.25	15.57	5.01
Surfeit NPV mean **net Benefits**	Dice Opt	9.99	5.93	0.99
	Lim 2.5	15.41	8.33	0.55
	Stern Gore	14.71	6.54	-1.21
Surfeit NPV mean net Benefits, **Real Option Value**				
		16.7	9	1.07

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

Table 3 Real Option Value of Enhanced CRF and Enhanced GST measurements

Enhanced Systems Real Option Value: Surfeit Expected Net Benefits Relative to Current Systems (trillion USD 2008)						
	GST			**CRF**		
trigger value	0.2C			-0.1		
Confidence	95%			95%		
Launch Year	2020			2020		
discount rate	2.5%	3%	5%	2.5%	3%	5%
	16.7	9	1.07	38.88	20.08	2.00

The major conclusion is that the surfeit expected net benefits of the Enhanced versus the Current EOS are larger when triggering on decadal change CRF (Table 6) than when triggering on decadal change in temperature (Table 4).

Recent Pubs

- Betsy Weatherhead, Bruce Wielicki and V. Ramaswamy, Mark Abbott, Tom Ackerman, Bob Atlas, Guy Brasseur, Lori Bruhwiler, Tony Busalacchi, Jim Butler, Chris T. M. Clack, Roger Cooke, Lidia Cucurull, Sean Davis, Jason M. English, David Fahey, Steven S. Fine, Jeffrey K. Lazo, Shunlin Liang, Norm Loeb, Eric Rignot, Brian Soden, Diane Stanitski, Graeme Stephens, Byron Tapley, Anne M. Thompson, Kevin Trenberth, Donald Wuebbles, (2018) **Designing the Climate Observing System of the Future**, Earth's Future, 23 January 2018 DOI: 10.1002/2017EF000627. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017EF000627
- Cooke, R.M. & Wielicki, B. (2018) **Probabilistic reasoning about measurements of equilibrium climate sensitivity: combining disparate lines of evidence**, Climatic Change. Climatic Change, 151(3), 541-554 https://doi.org/10.1007/s10584-018-2315-y
- Cooke, Roger M. Golub, Alexander, Wielicki, Bruce A. , Young, David F. Mlynczak, Martin G. Baize, Rosemary R. (2015) **Integrated Assessment Modeling of Value of Information in Earth Observing Systems,** Climate Policy ISSN: 1469-3062 (Print) 1752-7457: http://www.tandfonline.com/doi/full/10.1080/14693062.2015.1110109
- Cooke, Roger M. Wielicki, B.A., Young, D.F. and Mlynczak, M.G., (2013) **"Value of Information for Climate Observing Systems"** Environment, Systems and Decisions, DOI 10.1007/s10669-013-9451-8 https://clarreo.larc.nasa.gov/pdf/articles/VOI-ForClimateObservingSystems_Springer.pdf

FUTURE

- Updated SCC
- Combining disparate lines of evidence (eg GCT and CRF)
- Economic case for COS
- Carbon cycle uncertainty

THANKS

Questions

Q&A Session

To participate in the Q&A Session, please use
the “Questions” menu provided by the Go-to-Webinar system

Forthcoming CMCC Webinar

Cumulative impacts assessment in marine areas: a multi-disciplinary approach supporting adaptive management of the Adriatic sea

January 29, 2019 – h. 12:30 pm CET

Presenter: Elisa Furlan, RAAS Division, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy and Università Ca'Foscari Venezia, Italy

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If you have any further question about the webinar, please email: webinar@cmcc.it

We use the equations from Soden et al. (2008) to relate decadal change in CRF to equilibrium climate sensitivity (ECS) as defined in IPCC (2013). Let R_f denote the total anthropogenic radiative forcing of climate change by greenhouse gases, aerosols, and land change. T_s is global average surface temperature, and λ is climate sensitivity. Following Soden et al. (2008):

$$\Delta R_f/\Delta T_s = \lambda = \lambda_p + \lambda_L + \lambda_w + \lambda_\alpha + \lambda_{csw} + \lambda_{clw}. \tag{1}$$

Note $\Delta R_f/\Delta T_s$ is expressed in units of Wm^{-2}K^{-1}. The feedbacks are as follows:

λp = plank temperature feedback (pure σT4: i.e., no atmosphere) ~ –3.2

λL = temperature lapse rate feedback ~ –0.6

λw = water vapor feedback ~ +1.6

λα = snow and ice surface albedo feedback ~ +0.3

λcsw = shortwave cloud feedback (this is what we vary to get cloud feedback relationship to sensitivity and SW CRF)

λclw = longwave cloud feedback (not given separately in the IPCC report; using Soden and Vecchi 2011, Figure 3 top, and averaging for all 12 of the climate models they used) ~ + 0.35

Positive magnitude is a positive feedback, and negative magnitude is a negative feedback.

We use estimates from the IPCC AR5 report, chapter 9, Figure 9.43, and Table 9.5, CMIP5 mean (red dot in the figures) for everything except the LW cloud feedback, which is not given in the IPCC report. LW cloud feedback is taken from Soden and Vecchi (2011).

$$\lambda = \lambda_p + \lambda_L + \lambda_w + \lambda_\alpha + \lambda_{csw} + \lambda_{clw}. \tag{2}$$

Solving for λ_{csw} with the values above,

$$\lambda_{csw} = \lambda - (-3.2) - (-0.6) - (+1.6) - (+0.3) - (+0.35) = \lambda + 1.55 \tag{3}$$

λ is simply related to the equilibrium climate sensitivity *(ECS)*, as used in DICE, where ΔCO_2 denotes a doubling of atmospheric CO_2 concentration:

CLARREO Pathfinder Mission Summary

- Demonstrate CLARREO calibration accuracy spectrometers (IR and RS) on International Space Station
- Nominal launch is in 2020, nominal operations 2 years
- At least one and potentially both spectrometers: final decision ~ mid-2016 (depends on final funding levels and international collaboration
- Class D low cost mission
  - Instrument design life 1 year at 85% probability, ~ 50% of achieving 4 yrs
- Demonstrate CLARREO level SI traceability in orbit
- Demonstrate CLARREO Reference Intercalibration for VIIRS, CERES, and CrIS instruments
- Take intercalibration observations for additional sensors (LEO, GEO) but Pathfinder budget only covers L0 processing for these orbit crossings
- If demonstrate success, then request funding to process full data stream and additional instrument intercalibration events, as well as nadir spectral benchmarking observations.

CLARREO Pathfinder on ISS

- Lessons learned from CLARREO Pathfinder will benefit a future CLARREO mission
  - Reduced risk
  - Demonstration of higher accuracy calibration approaches
  - Prove that high accuracy SI-traceability can be transferred to orbit
  - Show that high accuracy intercalibration is achievable
- CLARREO Pathfinder will demonstrate highest accuracy radiance and reflectance measurements from orbit
  - First on-orbit SI-traceable reflectance with uncertainty <0.5% (k=2)
  - First on-orbit SI-traceable temperature with uncertainty <0.1 K (k=3)
- Lessons learned from CLARREO Pathfinder will produce benefits across many NASA Earth Science Missions and International Missions
  - Improved laboratory calibration approaches
  - Development and testing of innovative on-orbit SI-traceable methods
  - Transfer calibration to sensors in operation at time of CLARREO Pathfinder
  - Improved lunar irradiance standard

CLARREO Pathfinder will improve accuracy across Earth Sciences

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)
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

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)

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*.