A FINANCIAL APPROACH TO CLIMATE RISK

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CLIMATE ASSESSMENT

- Scientists say the climate is changing
- How bad will it be and what are the impacts on me and my children and their children?
- What will the governments of the world do?
- What new technologies might become available?
- THIS IS A LONG RUN RISK AND SHOULD BE TREATED WITH RISK MANAGEMENT TECHNIQUES..

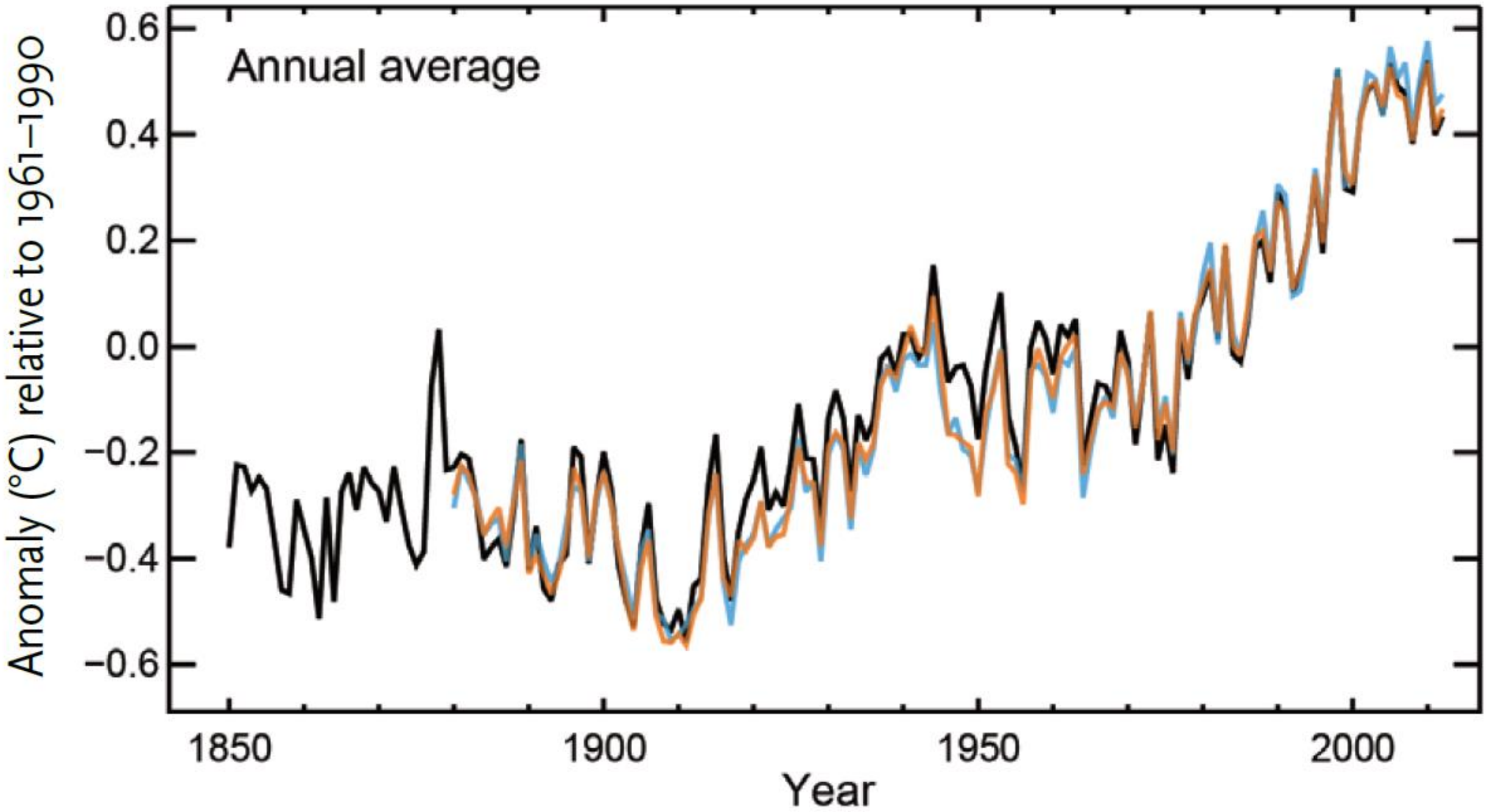
SCIENTIFIC BACKROUND

- GREENHOUSE GASSES
- CARBON CYCLE
- PUMPHANDLE
- TOP DOWN DAMAGES
- SOCIAL COST OF CARBON
- INVEST IN INNOVATION, INFRASTRUCTURE AND MITIGATION

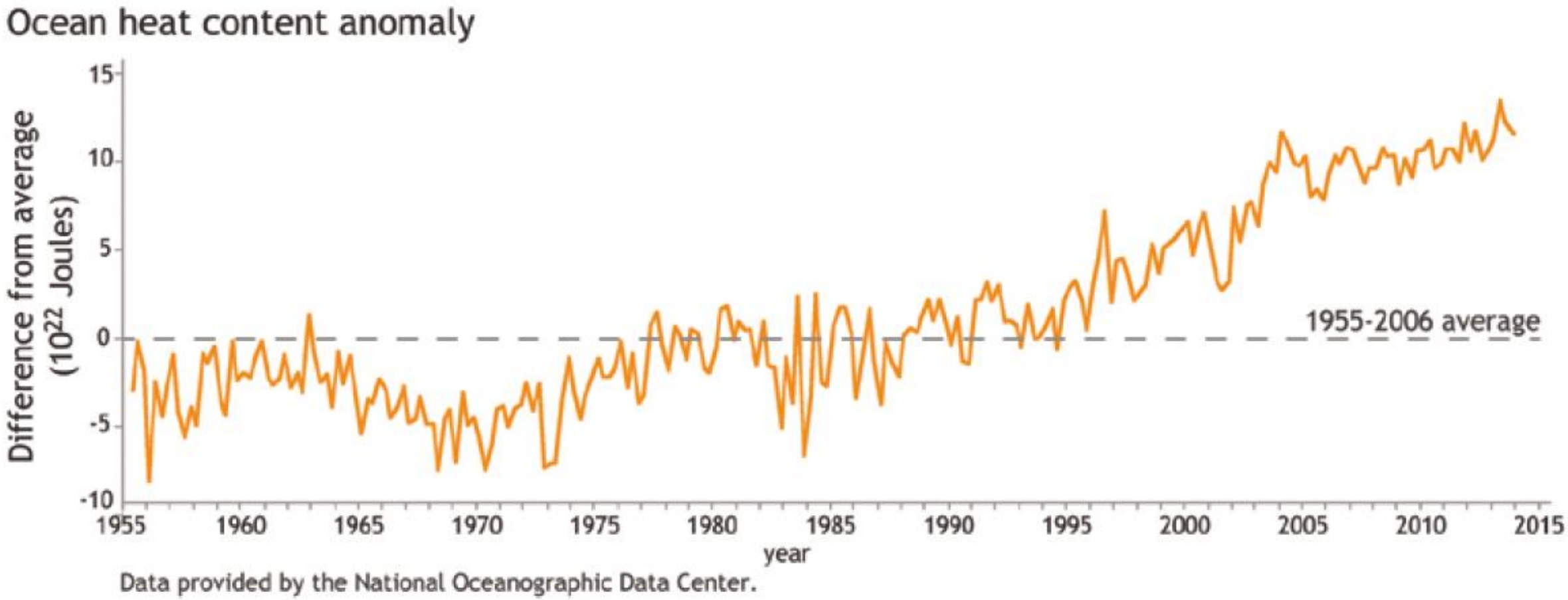
IS THE EARTH WARMING?

- How should we measure something like this? Time of day, time of year, location, land, water atmosphere? These are all complexities.
- Figure 1a. Earth's global average surface temperature has risen as shown in this plot of combined land and ocean measurements from 1850 to 2012, derived from three independent analyses of the available data sets.

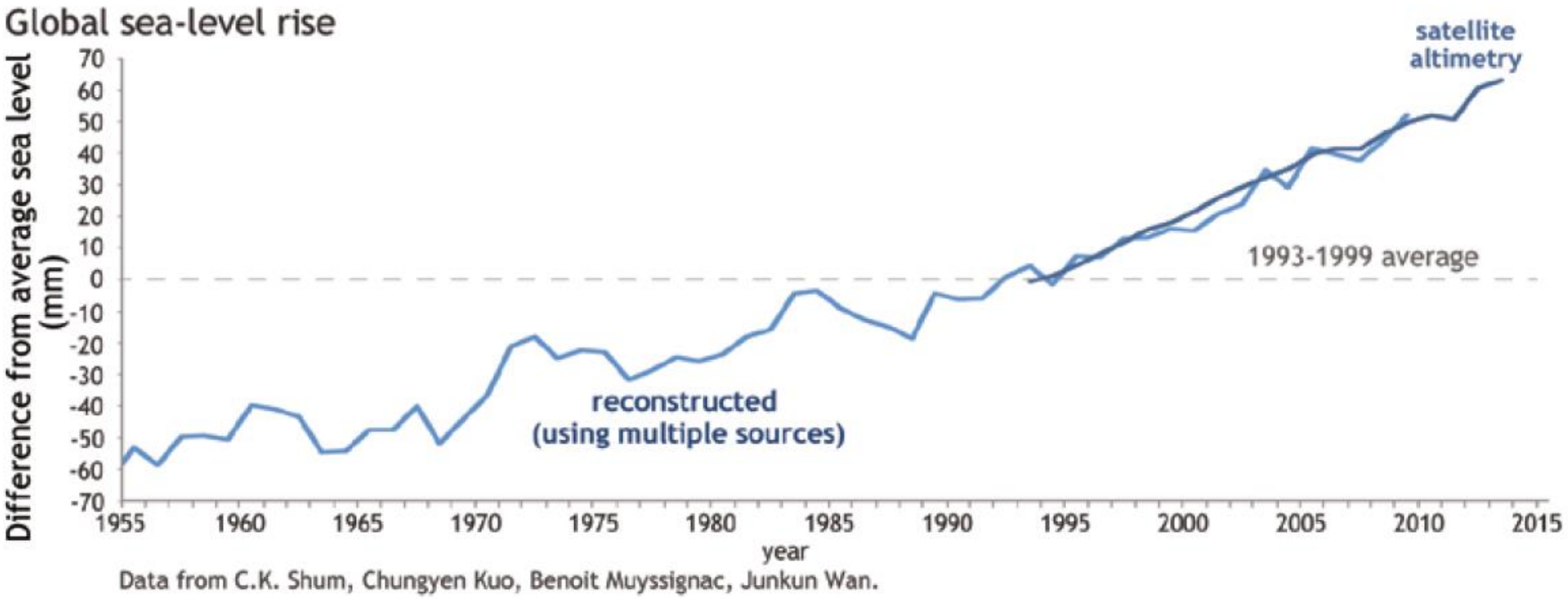
- The temperature changes are relative to the global average surface temperature of 1961–1990.
- *Source: IPCC AR5, data from the HadCRUT4 dataset (black), UK Met Office Hadley Centre, the NCDC MLOST dataset (orange), US National Oceanic and Atmospheric Administration, and the NASA GISS dataset (blue), US National Aeronautics and Space Administration.*


Annual average
Anomaly (°C) relative to 1961–1990
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
1850
1900
1950
2000
Year

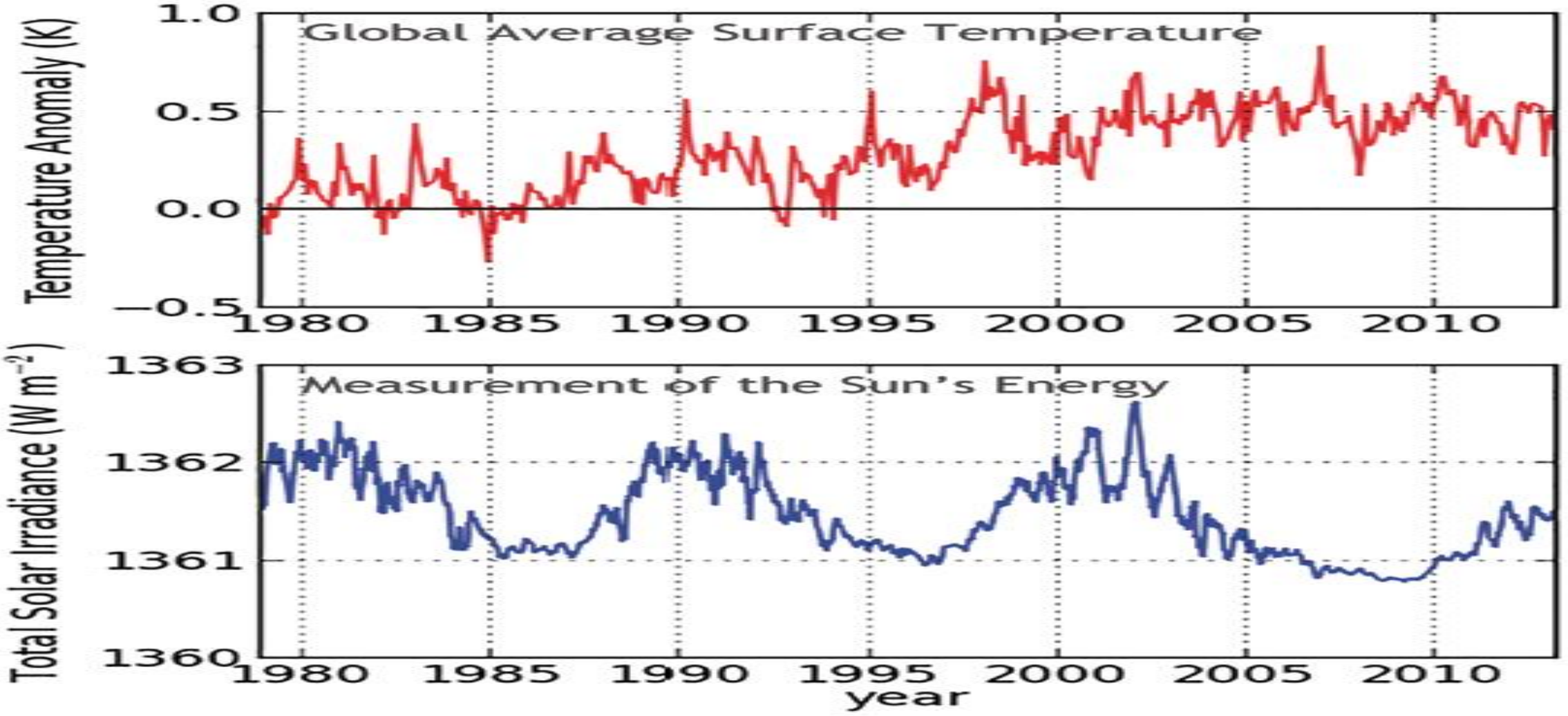
OCEAN HEAT CONTENT



GLOBAL SEA LEVEL



IS WARMING DUE TO THE SUN? NO!

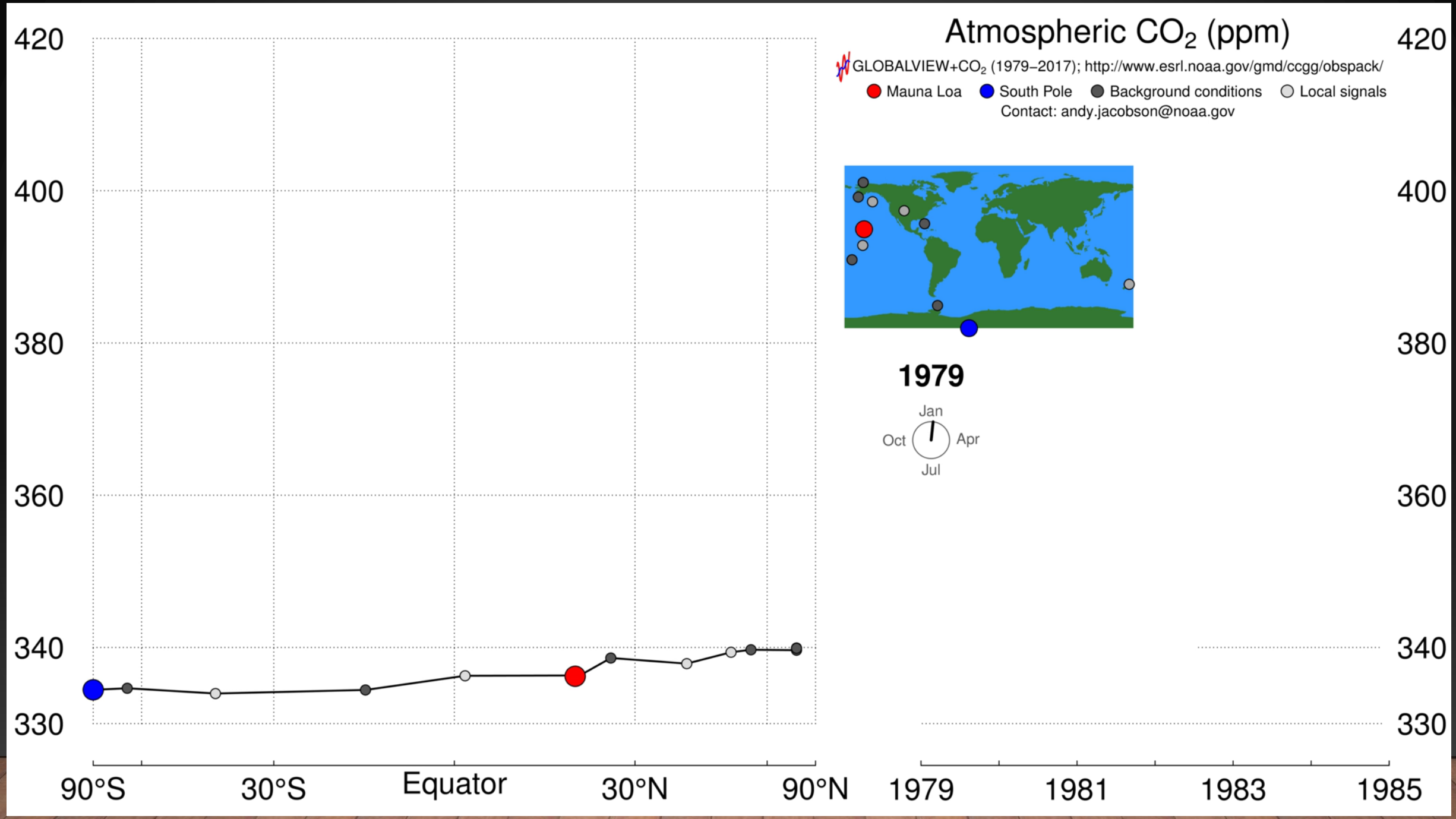


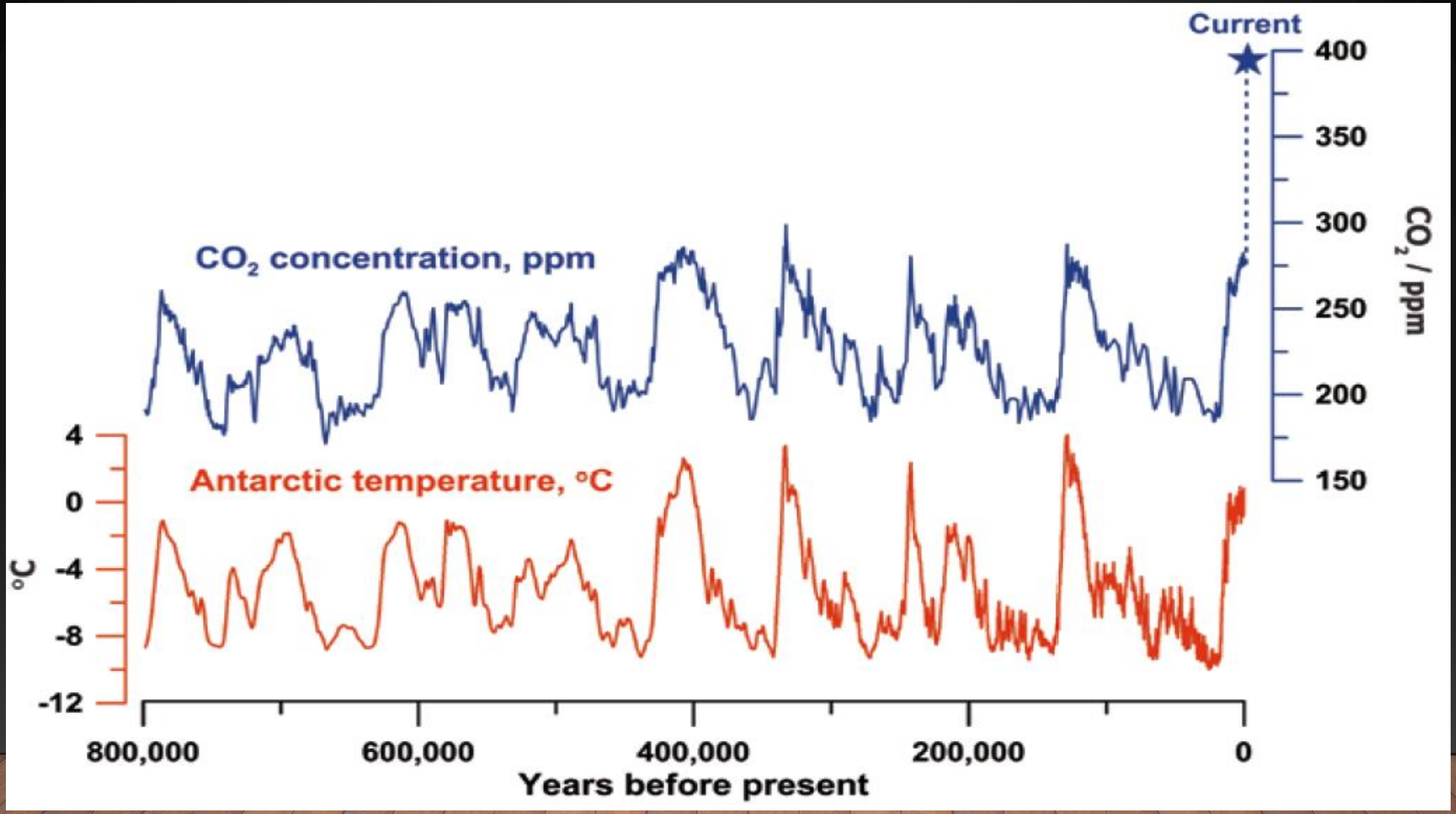
THE ROLE OF GREENHOUS GASES

- The most important is CO_2 or carbon dioxide. Also important are methane(CH_4), nitrous oxide(N_2 O) and halocarbons.
- These gases absorb infra-red radiation that is re-radiated from earth and act like a blanket around the earth.
- Carbon dioxide lasts a long time and is therefore the most dangerous. Methane is very opaque to infra-red but decays rapidly. We have acted to restrict CFCs to protect the ozone layer; this also reduced GHG.

CARBON CYCLE

- The amount of carbon on earth is essentially constant but its form and location changes slowly.
- Where is it stored?
  - Atmosphere -**750 billion tons of carbon**
  - Vegetation - **600 billion tons of carbon**
  - Soil and Organic Matter - **1,600 billion tons of carbon**
  - Coal, Oil and Gas - **3,300 billion tons of carbon**
  - Sedimentary Rock - **1,000,000,000 billion tons of carbon**
  - Ocean surface - **1,000 billion tons of carbon**
  - Deep ocean - **40,000 billion tons of carbon**
- It slowly transitions from one form to another. We are adding to the atmosphere faster than it is being removed by plants and the ocean.


Atmospheric CO_2 (ppm)
GLOBALVIEW+CO_2 (1979–2017); http://www.esrl.noaa.gov/gmd/ccgg/obspack/
Mauna Loa
South Pole
Background conditions
Local signals
Contact: andy.jacobson@noaa.gov
1979
Jan
Apr
Jul
Oct
420
400
380
360
340
330
90°S
30°S
Equator
30°N
90°N
1979
1981
1983
1985


Current
400
350
300
250
200
150
CO_2 / ppm
CO_2 concentration, ppm
Antarctic temperature, °C
4
0
-4
-8
-12
°C
800,000
600,000
400,000
200,000
0
Years before present

SCIENCE PREDICTIONS

- Last fall, IPCC produced its 1.5 degree report and the US government produced a National Climate Assessment.
- These both said we already are experiencing costs of climate change in storms, sea level rise, wild fires and migration of species.
- To achieve a temperature increase of less than 1.5 C would require massive changes over the next 10 years.

WHAT IS THE PROBLEM AND WHAT IS THE SOLUTION?

EXTERNALITY

- Carbon emissions are costless to the producer but impose costs on others both in the short and long run.
- Solutions are to charge for emissions or to regulate.
- Charging is complex and the correct price is hard to ascertain. Mechanisms are cap-and-trade or carbon emissions tax.
- The charge should be global and should be comprehensive.

REGULATION

- An alternative is regulation and subsidies

- This risks making counter productive restrictions.
- It may require the regulator to set priorities
- Subsidies to innovation may be effective or not
- Examples are LED lights, CAFÉ standards, Biofuels

THE SOCIAL COST OF CARBON

DEFINITION

- It is the present discounted value of the welfare damages resulting from an additional ton of CO2 emissions today.

- This assumes some baseline
- It assumes a damage model
- It assumes a discount rate
- It is the optimal Pigouvian tax and is also useful in cost benefit calculations

IAM

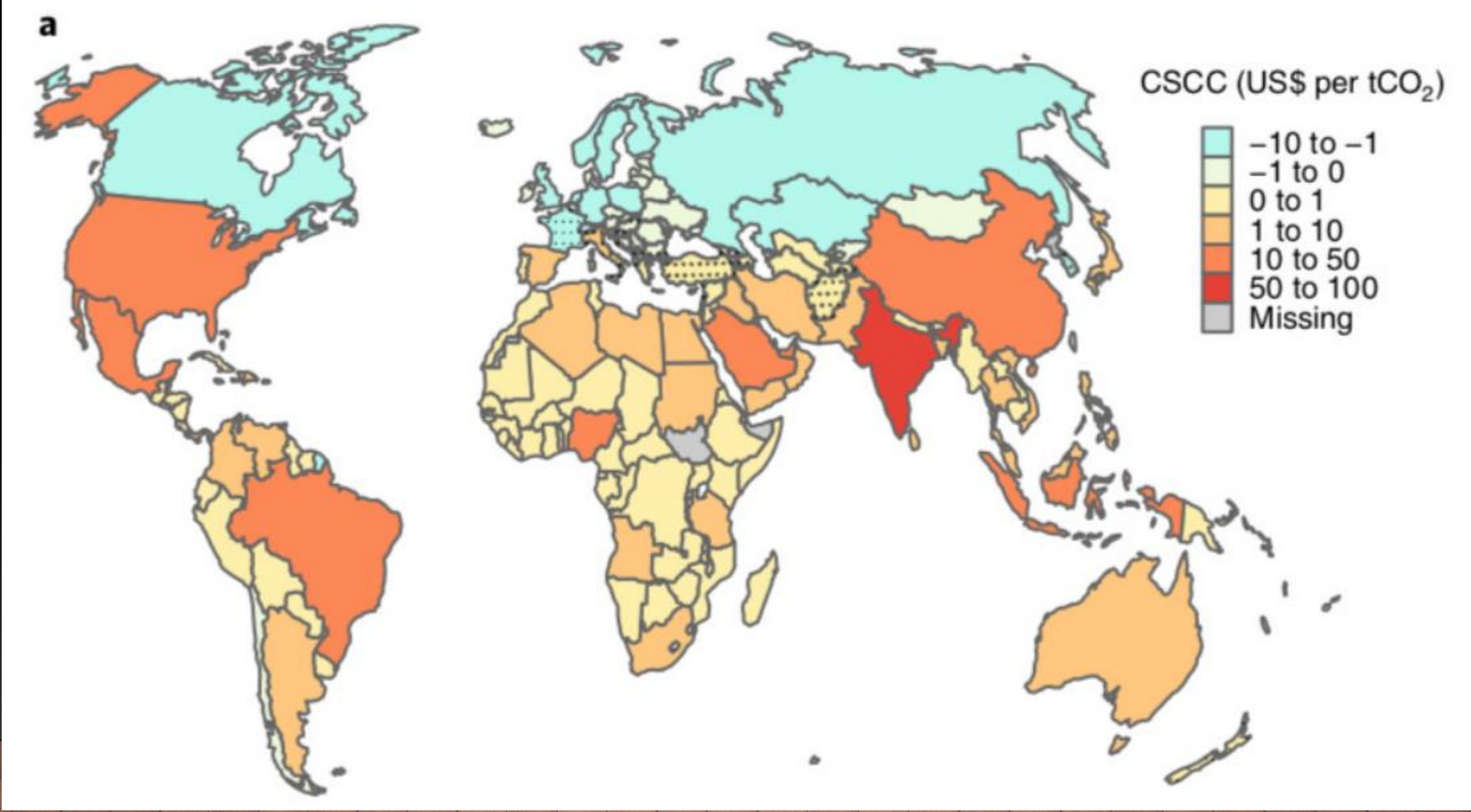
- The integrated assessment models can be used for this calculation.
- Nordhaus gets $25 from this. Obama administration $45.
- Trump administration has used as little as $1.
- This can also be done with "top down" damages. $417 in Ricke et al.(2018) in *Nature Climate Change.*

DISCOUNT RATE

- The appropriate rate has been assumed anywhere from 0% to 6%
- Is a market interest rate appropriate for intergenerational equity?
- What is the 100 year rate anyway?
- How should we risk adjust this rate?
- Giglio, Maggiori, Stroebel look at housing prices with 100 to 700 year leases and conclude that the market rate is below 2.6%
- The rate for risk reducing investments should be below the risk free rate.

RICKE'S APPROACH

- We observe that countries in temperate zones have higher per capital incomes and growth rates than either more tropical or colder countries.
- If this is structural (a big but potentially defensible assumption) then global warming will have different impacts on different regions of the world.
- The SCC is the sum of the global damages since a ton of carbon emitted anywhere affects the whole planet.


a
CSCC (US$ per tCO2)
−10 to −1
−1 to 0
0 to 1
1 to 10
10 to 50
50 to 100
Missing

A RECOMENDATION

- A COMPREHENSIVE GLOBAL PRICE FOR CARBON EMISSIONS AT A SUBSTANTIAL LEVEL WOULD RAISE MONEY THAT COULD REDUCE OTHER TAXES OR BE REBATED DIRECTLY
- IT WOULD ENCOURAGE RAPID SHIFTS OF RESOURCES TO LOWER CARBON TECHNOLOGIES PRODUCING NEW JOBS
- IT WOULD INCENTIVIZE RESEARCH AND DEVELOPMENT OF CARBON CAPTURE AND CLEAN ENERGY

WHAT CAN INVESTORS AND INDIVIDUALS DO?

ECONOMIC RESPONSE TO LONG RUN RISKS

- Standard approach is to purchase insurance such as health, life, fire etc.
- It does not exist for climate change because it is non-diversifiable and no one is big enough to pay off
- Another solution is to buy a derivative that pays off in a bad outcome. But again these do not exist.
- Instead we can invest a portion of our portfolio in stocks that will outperform in the case that we have a bad climate outcome. These are Merton Hedge Portfolios

HOW DO WE FIND MERTON HEDGE PORTFOLIOS AND WHAT DO THEY COST?

- Asset managers have constructed many candidates and we can try to determine their cost and forecast how they will respond to bad climate outcomes.
- We will examine a variety of environmental funds that are publicly available.
- We will then propose new methodology to find portfolios with climate hedge features.

DYNAMIC HEDGE PORTFOLIOS

- Designing a portfolio that will protect against climate risk 50 years in the future is an impossible task.
  - The firms that are well positioned to prosper in a bad climate scenario today may not be the best in 50 years.
  - Today we do not know how severe the changes will be
  - We also do not know whether the biggest concern will be temperature, or storms or drought or other impacts.
- Consequently we propose a dynamic strategy which will periodically update the hedge portfolio.

VOLATILITY INSTITUTE, NYU STERN

PRINCIPLE INVESTIGATORS: JOHANNES STROEBEL AND ROBERT ENGLE

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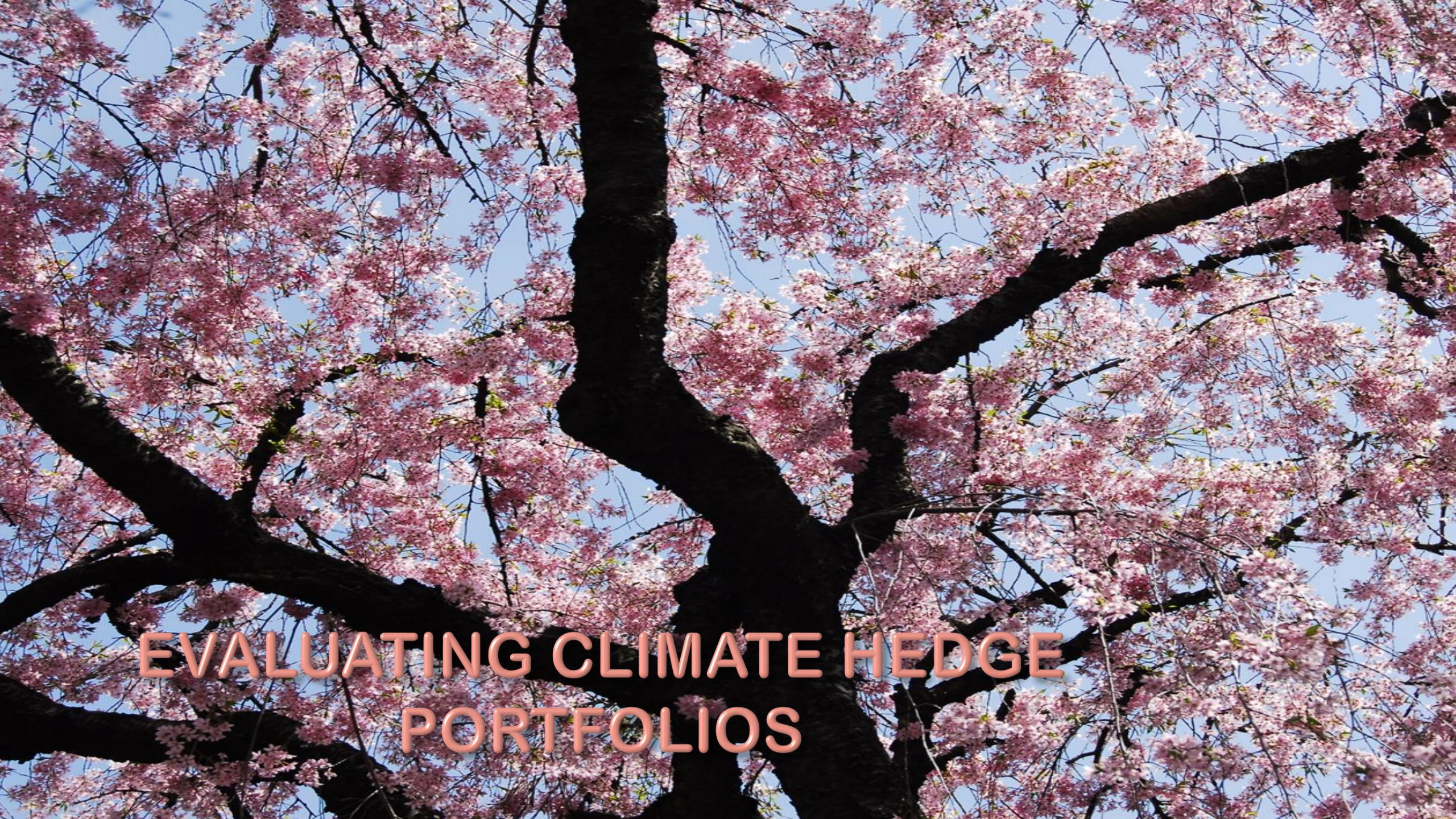
IN COLLABORATION WITH BRYAN KELLY AND STEFANO GIGLIO, YALE

SUPPORTED BY GENEROUS GRANTS FROM:

GLOBAL RISK INSTITUTE, TORONTO

NORGES BANK UNDER THE NFI PROGRAM, OSLO

NEW RESEARCH AT THE VOLATILITY INSTITUTE: FIND AND EVALUATE CLIMATE HEDGE PORTFOLIOS



EVALUATING CLIMATE HEDGE PORTFOLIOS

EVALUATION OF PUBLIC HEDGE PORTFOLIOS

- Three factor Fama French Alpha
- Sharpe Ratio
- 1Y, 3Y, 5Y, Max, Exponential Weight

- Compare with Benchmark
- Examine Long Short relative to SPY
- Examine Long Short relative to Stranded Asset Swap

PORTFOLIOS

- GREEN ETFs
  - ALTERNATIVE ENERGY
    - WIND
    - SOLAR
    - NUCLEAR
  - LOW CARBON
- MORNINGSTAR SELECTED FUNDS
  - LOW EXPOSURE TO FOSSIL RESERVES
  - CARBON FOOTPRINT < .5*SP500
  - HIGH RANKING ON E MEASURE OF ESG
  - INTERNATIONAL SUSTAINABLE

BENCHMARK PORTFOLIOS

- EAFE
- S&P500
- SPY-XLE : A portfolios long SPY and short XLE an energy ETF
- Stranded Assets: Long SPY short 70% XLE and short 30% KOL, a coal ETF. This is an approximation to the stranded asset portfolio designed by Litterman for WWF.

V-LAB CLIMATE RISK

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V-Lab: Real-time Financial Volatility, Correlation, And Risk ... - NYU
https://vlab.stern.nyu.edu/en/
The Volatility Laboratory (V-**Lab**) provides real time measurement, modeling and forecasting of financial volatility, correlations and risk for a wide spectrum of ...

Systemic Risk Analysis
Risk Analysis Overview - All Financials Total SRISK (US ...

Systemic Risk Analysis Of ...
Global Dynamic MES systemic risk analysis for World Financials.

Models
V-Lab Logo V-Lab. Analyses ▽ ... Documentation. Related ...

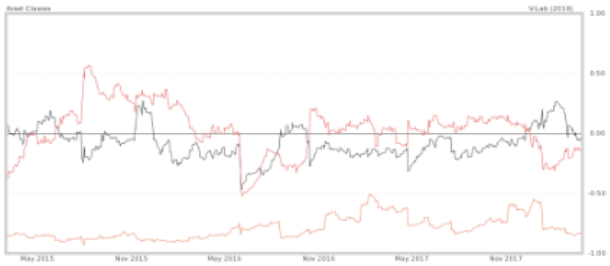
Climate Risk Analysis
Climate Risk. Last Update: May 9, 2018 at 1:14:26 AM GMT ...

Volatility Analysis

There are few guarantees in financial markets. However, we do know that volatility clusters and mean-reverts. But how long will it take to mean revert and, on average, to what level? Where are the 'host spots' of volatility in the world and in what sectors? We attempt to answer these questions and more in our Volatility Analysis section of V-Lab. Come see the many models meant to explain volatility and explore volatility dynamics.

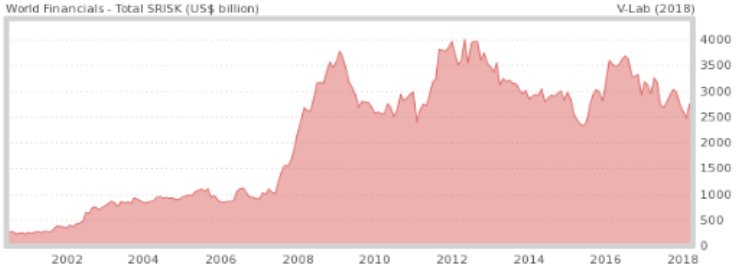
Correlation Analysis

The co-movement of asset prices is important in many financial market decisions, such as portfolio allocation, diversification, and hedging. In our Correlation Analysis section, we use econometric models to determine how these time series co-move, which assets are particularly correlated, and which are diverging in direction.



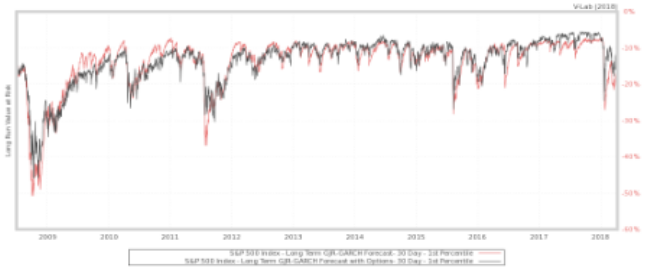
Systemic Risk Analysis

The Global Financial Crisis of 2008 revealed the degree of interconnectedness and fragility of the global financial system at the time. How badly would the equity values of financial institutions decline if there were another crisis today? What degree of capital shortfall would financial institutions suffer? Our Systemic Risk Analysis section of V-Lab simulates crises in domestic markets, as well as another global financial crisis, in an attempt to answer these questions.



Long-Run VaR Analysis

Often, volatility is assumed to grow with the square root of time. However, this assumes independence between observations each day (i.e. today's volatility has no bearing on what volatility will be tomorrow). Since this is not the case, one must defer to more sophisticted methods in order to estimate long-run volatility. Our Long-Run Value-at-Risk section simulates the 1 month and 1 year risk of holding financial assets, both using only returns and also conditioning average future volatility on current options market data.

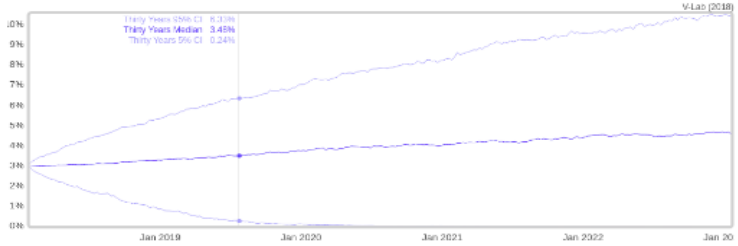


Liquidity Analysis

The liquidity of a financial asset reflects transaction costs and the ability to unwind large trades at reasonable prices. 'Liquidity spirals' often exacerbate stock market declines, such as what we saw in the last Global Financial Crisis. In the liquidity section we estimate and forecast the liquidity of a broad spectrum of financial assets.

Fixed Income Analysis

The future direction of interest rates has large implications for the the determination of discount rates, asset pricing, and firm capital structure. In addition, interest rates and their term structure are often used to infer economic forecasts of inflation, recession, and other key indicators. But where are rates headed in the long term? We forecast the distribution of treasury rates up to 5 years ahead from a 6-month bill to 30-year bond in the Fixed Income Section. We show upper and lower confidence intervals for future rates.



Climate Risk Analysis

Climate change is effecting the world via stronger, more severe weather events, rising sea levels, and in many other ways. Are these events and the risks imposed by climate change properly reflected in asset prices? Environmental risks can be thought of as long run risks which influence portfolio decisions. In our Climate Risk Analysis section. We examine the performance of publicly traded environmental portfolios, which can serve as a measure of the new information on environmental risk and a mechanism to hedge these risks.

WHAT DO WE EXPECT?

- Sustainable and Environmentally sound investments are very popular. Hence the prices are high.
- Other things being equal, we expect returns therefore to be low.
- We expect that these will differ from Markowitz optimal portfolios and therefore have lower Sharpe Ratios, just as we would expect for insurance.
- If the climate surprises the market and is worse than expected, then these portfolios should outperform.
- The benefit from climate investing is long term, not short term.

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Climate Risk

Last Update: March 22, 2019 at 5:42:46 AM GMT

Category: All

Time period: 1Y | 3Y | 5Y | Max | Exp. Weight

Benchmark	Return	Vol	Sharpe Ratio
iShares MSCI EAFE ETF	6.92%	13.34%	0.34
SPDR S&P 500 ETF Trust	12.13%	12.48%	0.78
SPY:US - XLE:US	7.84%	13.96%	0.56
Stranded Assets	-5.14%	13.96%	-0.37

				Fama-French Factors			
Security	Return	Vol	Sharpe Ratio	α	β	SMB	HML
Akre Focus Fund	19.22%	12.52%	1.35	3.67 (1.36)	0.87 (39.04)	-0.01 (-0.31)	-0.11 (-3.20)
iPath Global Carbon ETN	93.12%	81.70%	1.11	64.79 (1.81)	0.29 (0.96)	-0.05 (-0.11)	0.55 (1.20)
GMO Quality Fund	15.14%	12.10%	1.06	-8.92 (-1.40)	0.89 (53.60)	-0.18 (-5.19)	-0.16 (-4.38)
Amana Growth Fund	16.11%	13.28%	1.04	-8.51 (-1.41)	0.98 (28.15)	-0.02 (-0.82)	-0.27 (-13.76)
AMG Yacktman Fund	10.73%	8.21%	1.02	-9.81 (-1.20)	0.53 (9.17)	-0.05 (-0.56)	0.06 (1.91)
AMG Yacktman Focused Fund	11.55%	9.00%	1.02	-10.17 (-1.20)	0.53 (9.78)	-0.09 (-1.03)	0.03 (0.83)
Jensen Quality Growth Fund	14.22%	11.98%	0.99	-5.46 (-1.23)	0.93 (28.46)	-0.27 (-8.22)	-0.19 (-4.41)

INVESCO CLEANTECH ETF

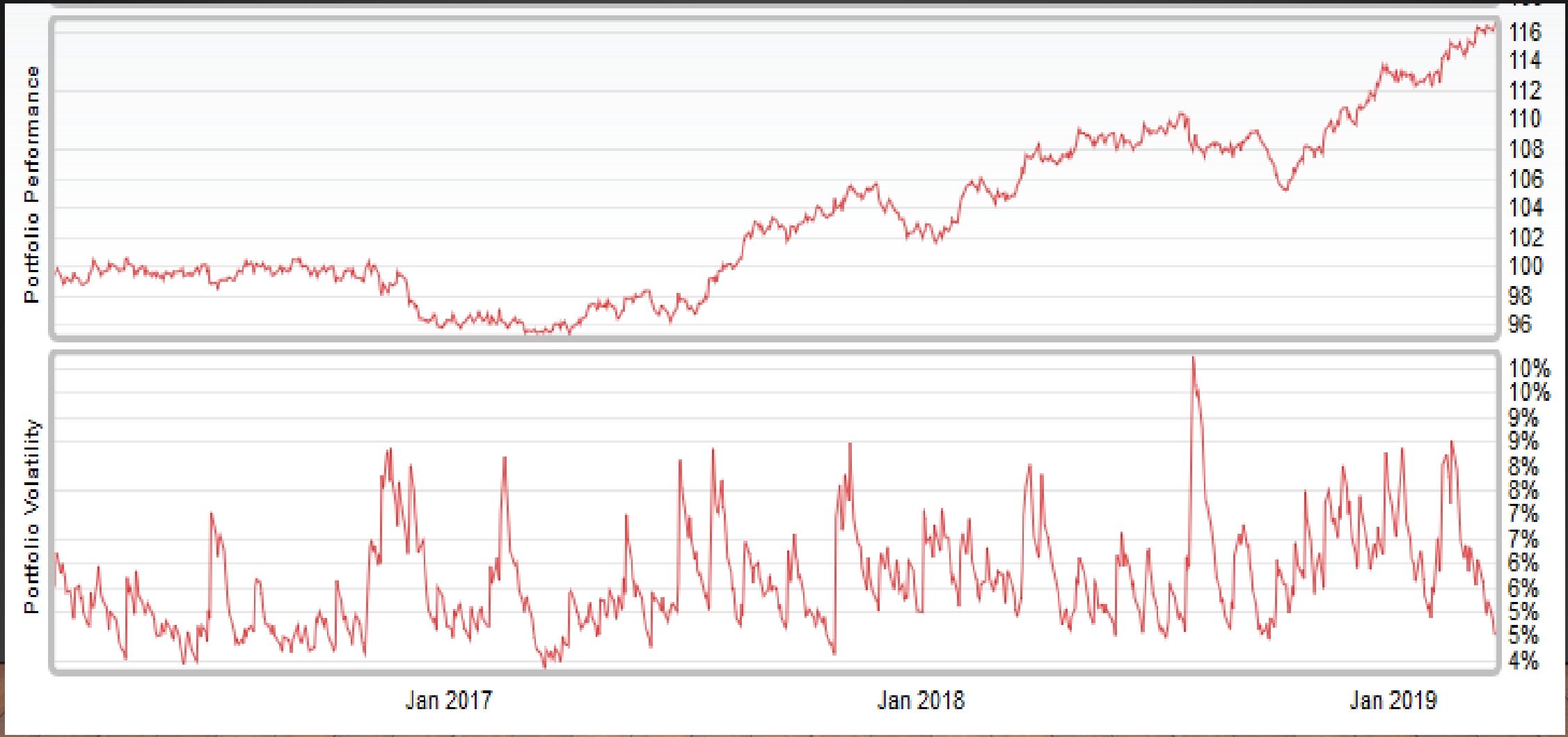
Top 10 Holdings	
Xylem Inc	3.53%
Eurofins Scientific SE	3.39%
Trimble Inc	3.33%
Autodesk Inc	3.29%
Novozymes A/S	3.20%
ABB Ltd	3.17%
Donaldson Company Inc	3.16%
Roper Technologies Inc	3.15%
SGS SA	3.09%
Vestas Wind Systems A/S	3.09%

AKRE FOCUS FUND

AKRE FOCUS TOP HOLDINGS

Top 10 Holdings	
American Tower Corp	12.63%
Mastercard Inc A	11.28%
Moody's Corporation	9.90%
Visa Inc Class A	8.85%
O'Reilly Automotive Inc	6.53%
Markel Corp	6.14%
SBA Communications Corp	5.27%
Roper Technologies Inc	5.22%
Dollar Tree Inc	4.95%
CarMax Inc	4.57%

VOLATILITY AKRE-SPX



ALTERNATIVE ENERGY ETFS

Climate Risk

Last Update: March 22, 2019 at 5:42:46 AM GMT

Category: Alternative Energy

Time period: 1Y | 3Y | 5Y | Max | Exp. Weight

Benchmark	Return	Vol	Sharpe Ratio
iShares MSCI EAFE ETF	6.92%	13.34%	0.34
SPDR S&P 500 ETF Trust	12.13%	12.48%	0.78
SPY:US - XLE:US	7.84%	13.96%	0.56
Stranded Assets	-5.14%	13.96%	-0.37

				Fama-French Factors			
Security	Return	Vol	Sharpe Ratio	α	β	SMB	HML
Invesco Cleantech ETF	14.91%	15.70%	0.80	-1.86 (-0.37)	0.93 (17.99)	0.36 (5.21)	0.09 (1.51)
VanEck Vectors Uranium+Nuclear Energy ETF	9.38%	12.38%	0.57	-3.42 (-0.47)	0.34 (6.98)	-0.14 (-2.11)	-0.11 (-1.23)
First Trust Global Wind Energy ETF	9.73%	14.77%	0.50	-5.91 (-0.70)	0.72 (8.40)	-0.02 (-0.19)	0.05 (0.49)
Invesco WilderHill Clean Energy ETF	11.80%	20.15%	0.47	-7.94 (-1.11)	1.05 (26.70)	0.64 (8.39)	0.04 (0.53)
First Trust NASDAQ Clean Edge Green Energy Index Fund	11.01%	19.15%	0.45	-6.94 (-1.22)	1.09 (32.19)	0.55 (8.05)	-0.10 (-1.44)
iShares Global Clean Energy ETF	5.38%	17.36%	0.18	-10.91 (-1.14)	0.86 (11.76)	0.07 (0.53)	0.05 (0.46)
VanEck Vectors Global Alternative Energy ETF	5.39%	17.15%	0.18	-8.83 (-1.20)	0.95 (18.58)	0.31 (3.47)	0.10 (1.21)
Invesco Global Clean Energy ETF	5.18%	16.82%	0.17	-6.94 (-1.07)	0.71 (7.19)	0.09 (1.17)	0.12 (1.01)

PERFORMANCE OF V-LAB FUNDS

Average FF Alpha by Window Length					
Category	1Y	3Y	5Y	EW	Max
Alternative Energy	-2.29	-7.35	-12.33	-7.42	-20.71
Fossil Fuel Free	-8.78	-6.99	-7.38	-7.46	-5.53
High Environmental Score	-10.05	-7.87	-8.11	-8.74	-4.15
International Sustainable	-12.2	-6.59	-8.28	-7.22	-6.49
Low Carbon	-9.59	-6.68	-7.07	-7.44	-4.93

Hedging Climate Change News

Robert Engle *NYU Stern*
Stefano Giglio *Yale*
Bryan Kelly *Yale*
Heebum Lee *NYU Stern*
Johannes Stroebel *NYU Stern*

RFS Climate Finance Workshop, October 2018

Our Approach

MERTON: When infeasible to directly hedge long-lived risks, it may be possible to replicate the infeasible hedge with a *dynamic strategy*

Sequence of *short-lived portfolios* that hedge *news* about long-term outcome

- Cochrane (1995): health insurance

Replaces idealized (and infeasible) long-dated, buy+hold derivative contract with actively managed portfolio that pays off upon the arrival of bad news about climate change each period

Great Idea! ...*in theory*

Our Approach

Leaves us with two very difficult questions to tackle:

1. What News? How do we determine incremental shocks to hedge to establish long-lived climate hedge?
2. Which Assets? How to identify portfolio best suited to hedge this news?

Our Contribution

Data + Econometrics to engineer Climate Hedge Solution

1. What News?

OBJECTIVE: Identify news about climate change

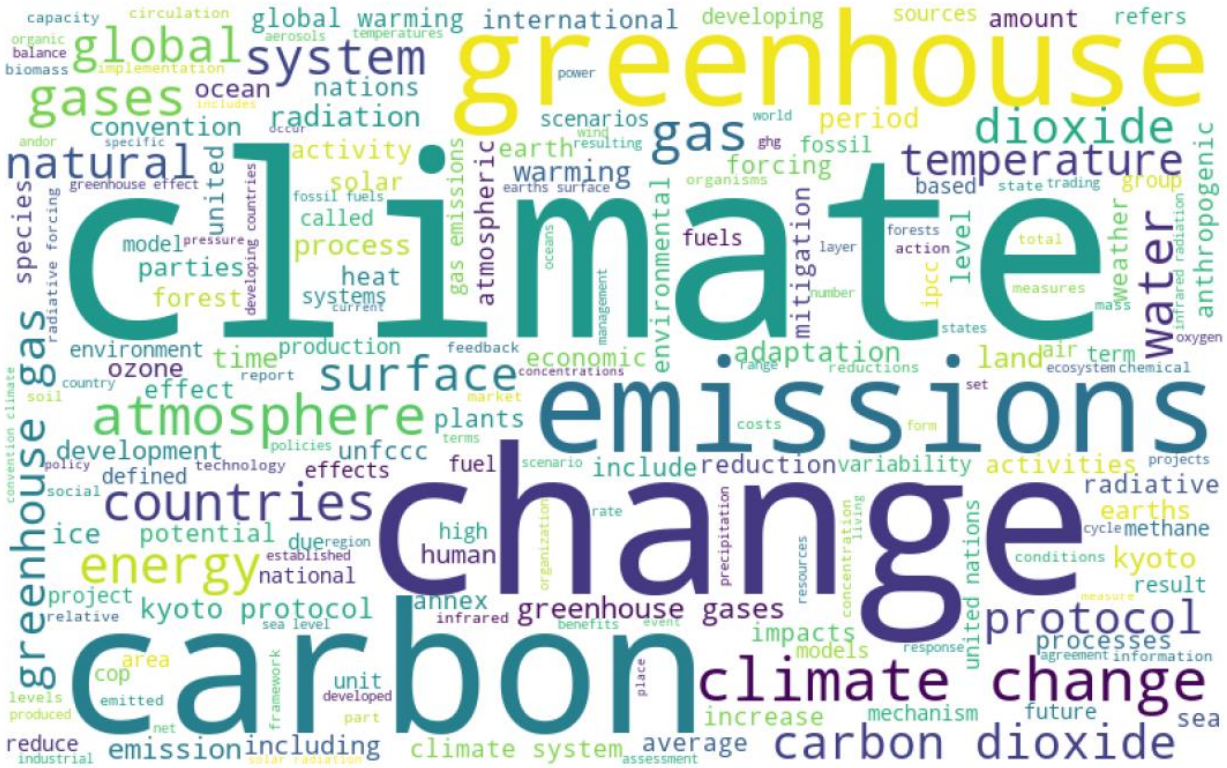
- Should be relevant to and salient for investors and hedgers concerned about climate risks
- There are many possibilities: traded prices (e.g., Anderssen et al. 2016), weather data, disaster events,...

OUR CHOICE: Extract news shocks from texts provided by media outlets. Two complimentary approaches.

- 1) Analyze reporting in most salient outlet (WSJ) and derive correlation of coverage with Climate Change Vocabulary - "WSJ Climate Change News Index"
- 2) Among major media outlets, track fraction of *negative* Climate Change news - "CH Negative Climate Change News Index"
- Note: Many degrees of freedom here – constrain to obvious choices

1. What News?

WSJ CC Index - Climate Change Vocabulary



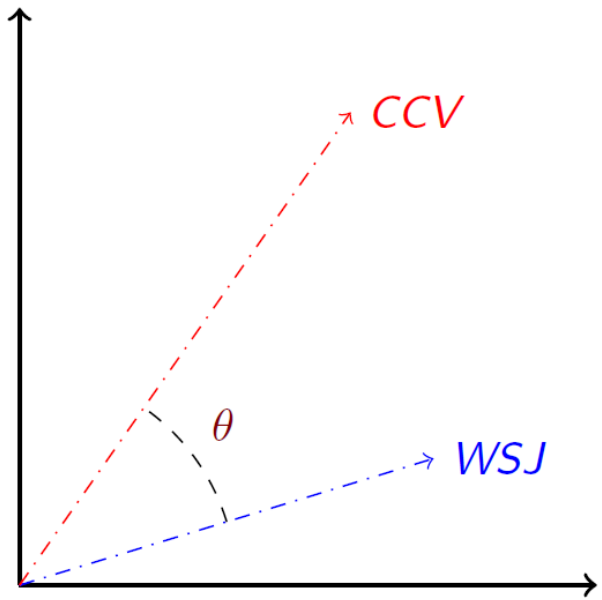
Construct Climate Change Vocabulary from authoritative texts

- 19 climate change white papers on from the IPCC, EPA, USGCRP
- 55 climate change glossaries (UN, BBC, IPCC, NASA, EPA, etc.)

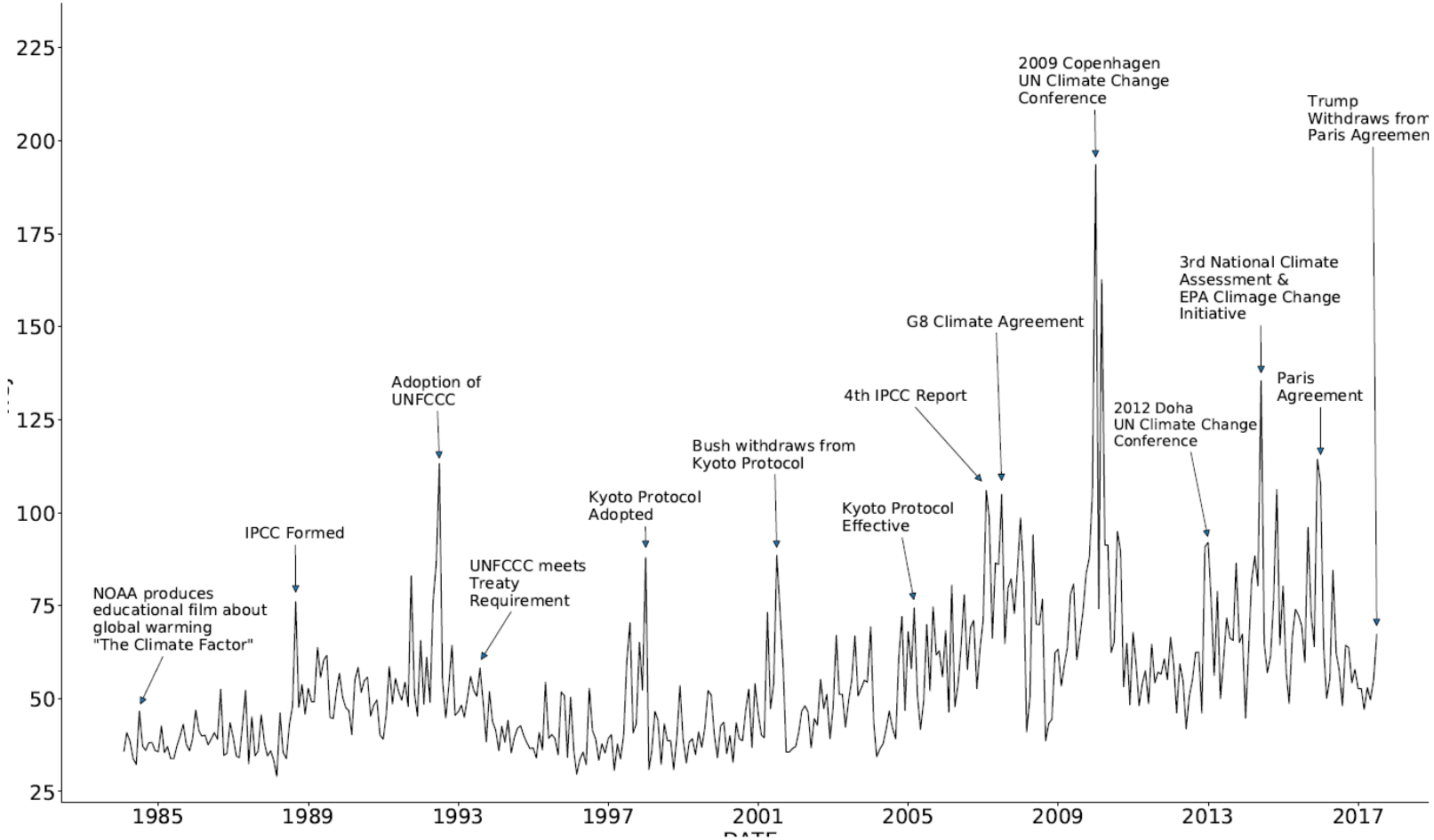
1. What News?

WSJ CC Index - Building an Index of Climate Change News

Our first measure describes fraction of *The Wall Street Journal* dedicated to climate change topics each day



In particular, COSINE SIMILARITY, $\cos(\theta)$, between each day's WSJ edition and the Climate Change Vocabulary, represented as vectors of word counts (TF-IDF)



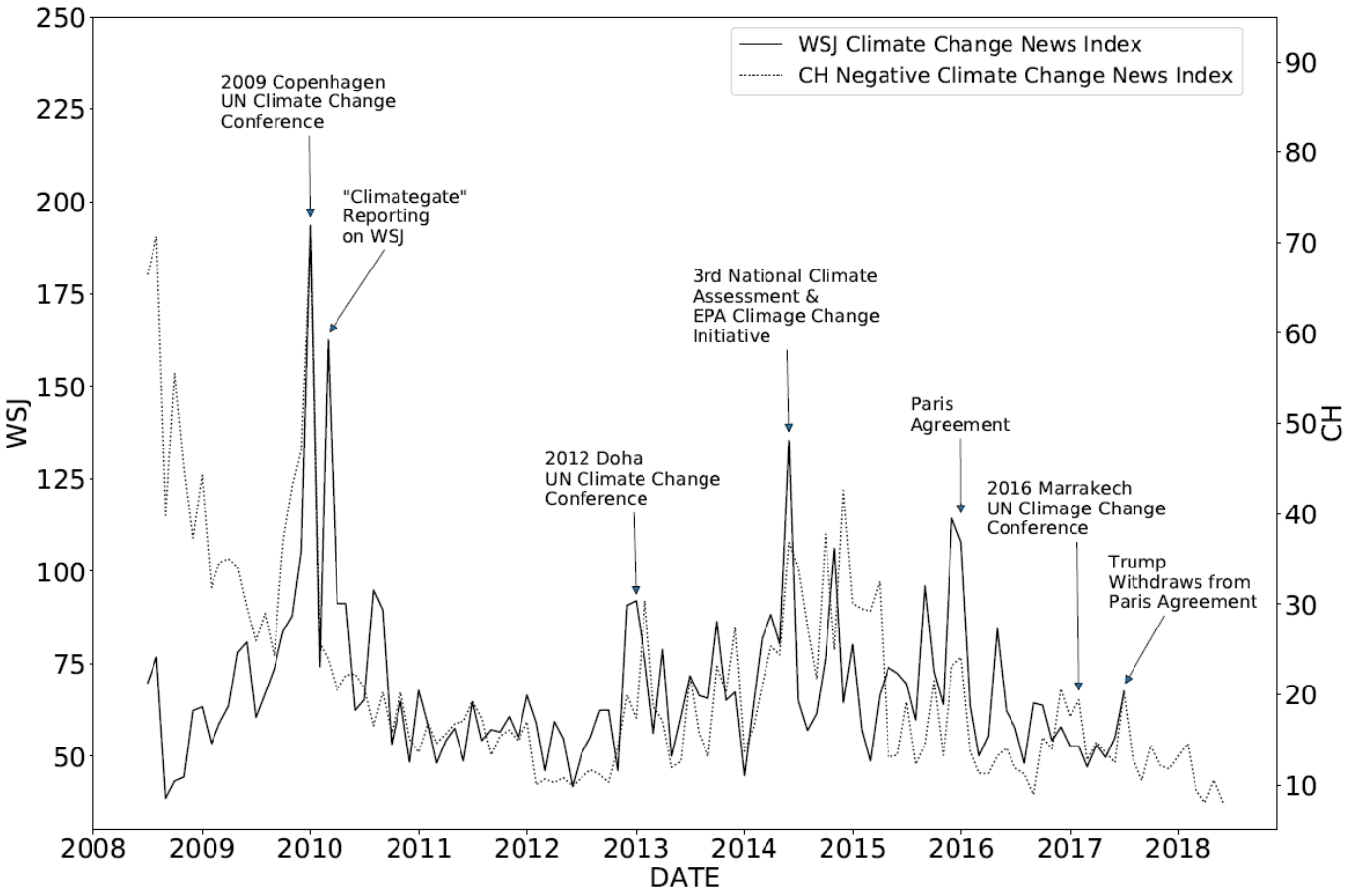
This is a *level* measure. Climate change news shocks are AR(1) *innovations* to monthly index

1. What News?

CH Negative Climate Change News Index

Our second measure represents fraction of news articles about climate change topics with negative sentiment each day

- Starting in 2008, Crimson Hexagon collects massive corpus from major media outlets and provides fraction of news articles dedicated to certain search terms by "sentiment" of article.
- Use search phrase "Climate Change", restrict to news media and explore share of articles with negative sentiment



Two measures move together but not identically (e.g., idiosyncratic Climategate reporting by WSJ)

2. Which Assets?

OBJECTIVE: Build portfolio that maximally hedges climate news shocks

Primary Challenges: Short sample, No "easy" hedges

Our solution:

- Impose structure/parsimony on estimation (confronts limited time series)
- Construct hedge from a large universe of assets

Emphasize *out-of-sample* performance

- Reliable solution must work in unknown future (mechanical success in-sample)

Emphasize *interpretability* of portfolio

- What types of assets constitute good hedges

2. Which Assets? Econometric Methodology.

Define a simple asset pricing model:

$$\underbrace{r_t}_{n\times 1} = (\underbrace{\beta_{CC}}_{n\times 1}\underbrace{\gamma_{CC}}_{1\times 1} + \underbrace{\beta_{CC}}_{n\times 1}\underbrace{(CC_t - E[CC_t])}_{1\times 1}) + (\underbrace{\beta}_{n\times p}\underbrace{\gamma}_{p\times 1} + \underbrace{\beta}_{n\times p}\underbrace{v_t}_{p\times 1}) + \underbrace{u_t}_{n\times 1}$$

- CC_t : climate change factor defined as AR(1) innovation in new index
- v_t : p other (tradable or non-tradable) risk factors

Our object:

- Find a hedge portfolio with unit exposure to CC_t

Traditional approach:

- Fama-MacBeth regressions
- Two potential drawbacks : 1) Measurement errors on factors 2) Constant risk exposures

2. Which Assets? Econometric Methodology.

$$CC_t = \xi + w' Z'_{t-1} r_t + e_t$$

Our choice is mimicking portfolio regressions + time varying risk exposures

- Z_t : a vector of individual firm level characteristics at t
- r_t : a vector of individual firm level return at t

Rationale:

- Mimicking portfolio approach is free to measurement error of factors if a return space (r_t) spans the same space as the true factors, (CC_t, v_t). (Giglio and Xiu, 2018)
- By conditioning portfolio weights with firm characteristics, the model captures the time variation in risk exposures (Kelly et al, 2018)

2. Which Assets? Econometric Methodology.

Two-step Estimation Approach to Construct Hedge Portfolio

STEP 1: Form characteristic-sorted portfolio using market characteristics (Size, B/M) and environmental characteristics (MSCI Score, Sustainalytics Score)

STEP 2: Mimicking portfolio regression of CC_t on characteristic-sorted portfolio $Z'_{t-1} r_t$

$$CC_t = \xi + w' Z'_{t-1} r_t + e_t$$

The fitted value $\hat{w}' Z'_{t-1} r_t$ is time series of returns to *replicating portfolio* of climate news shocks

$\star$

Given historical (time t) estimates of w and current (time t) firm chars, now feasible to construct out-of-sample hedge of time $t+1$ climate news

$\star$

Can study which stocks the portfolios buys and sells at each t

Data

- Firm-Level Climate Exposures: Environmental Score
  - MSCI (EX KLD): aggregates 23 environment assessment criteria (e.g., "Carbon Emissions," "Energy Efficiency")
  - SUSTAINALYTICS: aggregates environmental sustainability scores in 59 categories (e.g., "Waste Reduction," "Low Carbon Intensity")
  - Substantial within-industry variation.
  - Use both absolute and cross-sectionally ranked measures
- Stock return and Characteristics : CRSP/Compustat
- Period : September 2009 to December 2016

Results

Full-Sample Regression : CH Negative Climate Change News Index

	(1)	(2)	(3)	(4)	(5)
$Z_{t-1}^{SUS\_A\prime} r_t$	0.266*				
	(0.141)				
$Z_{t-1}^{SUS\_R\prime} r_t$		12.286**			
		(5.864)			
$Z_{t-1}^{MSCI\_A\prime} r_t$			1.089		
			(2.173)		
$Z_{t-1}^{MSCI\_R\prime} r_t$				6.641	
				(8.696)	
r_t^{XLE}					-0.092
					(0.252)
r_t^{PBD}					0.036
					(0.196)
$Z_{t-1}^{HML\prime} r_t$	-4.536**	-4.390*	-5.934***	-5.919***	-5.520**
	(2.272)	(2.260)	(2.182)	(2.177)	(2.519)
$Z_{t-1}^{SIZE\prime} r_t$	-0.137	-0.179	0.210	0.100	0.501
	(0.761)	(0.753)	(0.880)	(0.856)	(0.770)
$Z_{t-1}^{MKT\prime} r_t$	0.315	0.314	0.287	0.295	0.297
	(0.208)	(0.206)	(0.219)	(0.216)	(0.400)
Constant	-0.115	-0.137	0.313	0.306	0.376
	(0.868)	(0.859)	(0.857)	(0.847)	(0.902)
R-Squared	0.125	0.133	0.090	0.094	0.089
N	88	88	88	88	88

- Portfolios based on the Sustainaltyics E-Scores hedge 13% of the in-sample variation in negative climate news
- Outperforms hedges based on XLE and PBD

Results

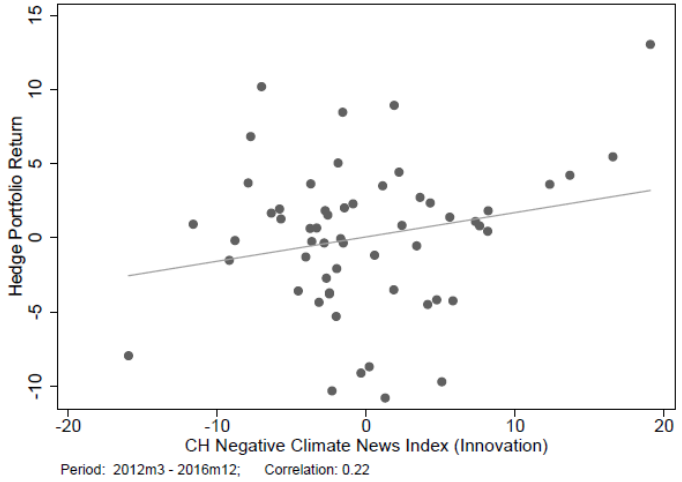
Full-Sample Regression : WSJ Climate Change News Index

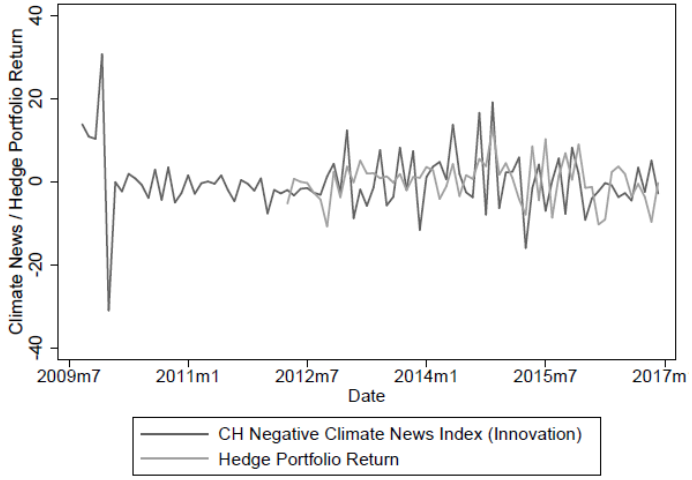
	(1)	(2)	(3)	(4)	(5)
$Z_{t-1}^{SUS\_A\prime} r_t$	1.416***				
	(0.436)				
$Z_{t-1}^{SUS\_R\prime} r_t$		67.789***			
		(17.834)			
$Z_{t-1}^{MSCI\_A\prime} r_t$			12.658*		
			(6.849)		
$Z_{t-1}^{MSCI\_R\prime} r_t$				53.743*	
				(27.401)	
r_t^{XLE}					0.085
					(0.810)
r_t^{PBD}					0.208
					(0.630)
$Z_{t-1}^{HML\prime} r_t$	1.221	2.309	-5.862	-5.941	-6.772
	(7.019)	(6.873)	(6.878)	(6.858)	(8.093)
$Z_{t-1}^{SIZE\prime} r_t$	-5.680**	-6.034**	-5.511*	-5.459**	-2.765
	(2.350)	(2.289)	(2.773)	(2.696)	(2.474)
$Z_{t-1}^{MKT\prime} r_t$	0.783	0.789	0.841	0.789	0.091
	(0.642)	(0.628)	(0.692)	(0.680)	(1.285)
Constant	2.894	2.673	4.659*	4.891*	5.959**
	(2.681)	(2.613)	(2.700)	(2.669)	(2.897)
R-Squared	0.153	0.187	0.083	0.088	0.047
N	88	88	88	88	88

- Portfolios based on the Sustainaltyics E-Scores hedge 19% of the in-sample variation in climate news
- Outperforms hedges based on XLE and PBD

How Closely Does Hedge Portfolio Track Climate Change News?

Out-of-sample evaluation : CH Negative Climate Change News Index

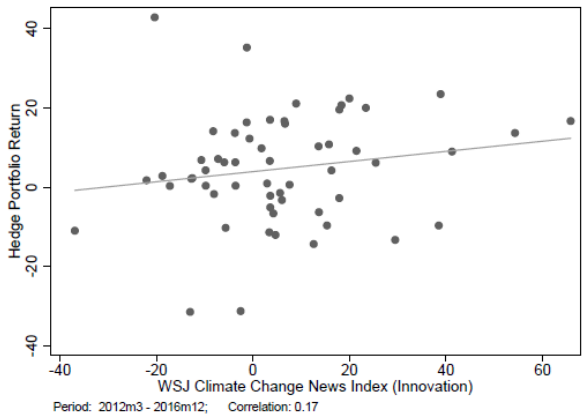


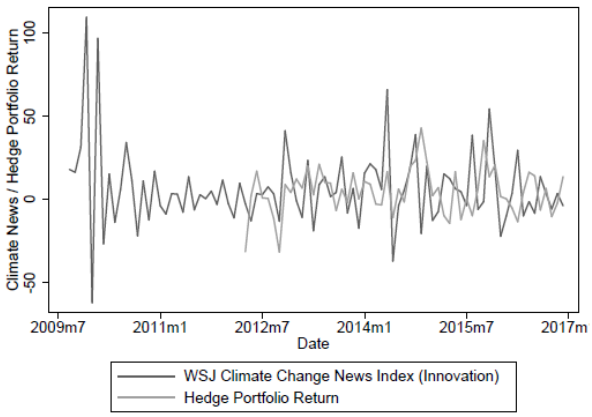


	$CC^{NegNews}$	$H_{OOS}^{SUS\_A}$	$H_{OOS}^{SUS\_R}$	$H_{OOS}^{MSCI\_A}$	$H_{OOS}^{MSCI\_R}$	H_{OOS}^{ETF}	r_t^{XLE}	r_t^{PBD}
$CC^{NegNews}$	1.000	0.217	0.183	0.179	0.175	0.157	-0.066	0.063
$H_{OOS}^{SUS\_A}$		1.000	0.992	0.869	0.865	0.780	-0.412	0.061
$H_{OOS}^{SUS\_R}$			1.000	0.852	0.850	0.767	-0.353	0.112
$H_{OOS}^{MSCI\_A}$				1.000	0.998	0.961	-0.387	0.096
$H_{OOS}^{MSCI\_R}$					1.000	0.960	-0.367	0.127
H_{OOS}^{ETF}						1.000	-0.410	0.119

How Closely Does Hedge Portfolio Track Climate Change News?

Out-of-sample evaluation : WSJ Climate Change News Index





	CC^{WSJ}	$H_{OOS}^{SUS\_A}$	$H_{OOS}^{SUS\_R}$	$H_{OOS}^{MSCI\_A}$	$H_{OOS}^{MSCI\_R}$	H_{OOS}^{ETF}	r_t^{XLE}	r_t^{PBD}
CC^{WSJ}	1.000	0.174	0.206	0.013	0.019	-0.005	0.068	0.111
$H_{OOS}^{SUS\_A}$		1.000	0.973	0.688	0.677	0.427	-0.138	0.185
$H_{OOS}^{SUS\_R}$			1.000	0.621	0.624	0.349	0.004	0.272
$H_{OOS}^{MSCI\_A}$				1.000	0.998	0.861	-0.097	0.294
$H_{OOS}^{MSCI\_R}$					1.000	0.852	-0.039	0.350
H_{OOS}^{ETF}						1.000	-0.141	0.190

Hedge Portfolio: Biggest Longs and Shorts

Sustainalytics E-Score (absolute)		MSCI E-Score (absolute)	
Top Negative Portfolio Weights	***SIC2***	***Top Negative Portfolio Weights***	***SIC2***
General Building Contractors	15	General Building Contractors	15
Water Transportation	44	Nondepository Institutions	61
Coal Mining	12	Auto Repair, Services, & Parking	75
Insurance Agents, Brokers, & Service	64	Communications	48
Holding and Other Investment Offices	67	Water Transportation	44
Insurance Carriers	63	Insurance Carriers	63
Top Positive Portfolio Weights	***SIC2***	***Top Positive Portfolio Weights***	***SIC2***
Railroad Transportation	40	Chemical & Allied Products	28
Transportation by Air	45	Textile Mill Products	22
Furniture & Homefurnishings Stores	57	General Merchandise Stores	53
Textile Mill Products	22	Lumber & Wood Products	24
Building Materials & Gardening Supplies	52	Building Materials & Gardening Supplies	52
Tobacco Products	21	Tobacco Products	21

Sustainalytics E-Score (absolute)		MSCI E-Score (absolute)	
Top Negative Portfolio Weights	***SIC2***	***Top Negative Portfolio Weights***	***SIC2***
Coal Mining	12	Water Transportation	44
Water Transportation	44	Petroleum & Coal Products	29
Insurance Agents, Brokers, & Service	64	Motion Pictures	78
Mining Non-Metallic Minerals, Except Fuels	14	Communications	48
Transportation Services	47	Security & Commodity Brokers	62
Security & Commodity Brokers	62	Oil & Gas Extraction	13
Top Positive Portfolio Weights	***SIC2***	***Top Positive Portfolio Weights***	***SIC2***
Building Materials & Gardening Supplies	52	Pipelines, Except Natural Gas	46
Tobacco Products	21	Tobacco Products	21
Food & Kindred Products	20	Miscellaneous Manufacturing Industries	39
Paper & Allied Products	26	Lumber & Wood Products	24
Textile Mill Products	22	Paper & Allied Products	26
Furniture & Homefurnishings Stores	57	Textile Mill Products	22

Conclusion

Propose approach for protecting investor portfolios against adverse effects of climate change

Obstacles to practical climate hedge solution abound. We navigate by

- Taking short-term dynamic perspective on fundamentally long-lived risk
- Identifying shocks to long-lived effects by measuring climate change news that is relevant and salient for market participants

Results promising: Stable out-of-sample hedges, courtesy of

- (Very) parsimonious statistical model...
- ...exploiting third-party climate sensitivity assessments of assets

Many unexplored degrees of freedom

- Measuring climate news; E-Scores; Hedge Assets
- Exciting follow-on work

What is in their future?