Climate Threats: A More Inclusive Assessment Is Needed

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By

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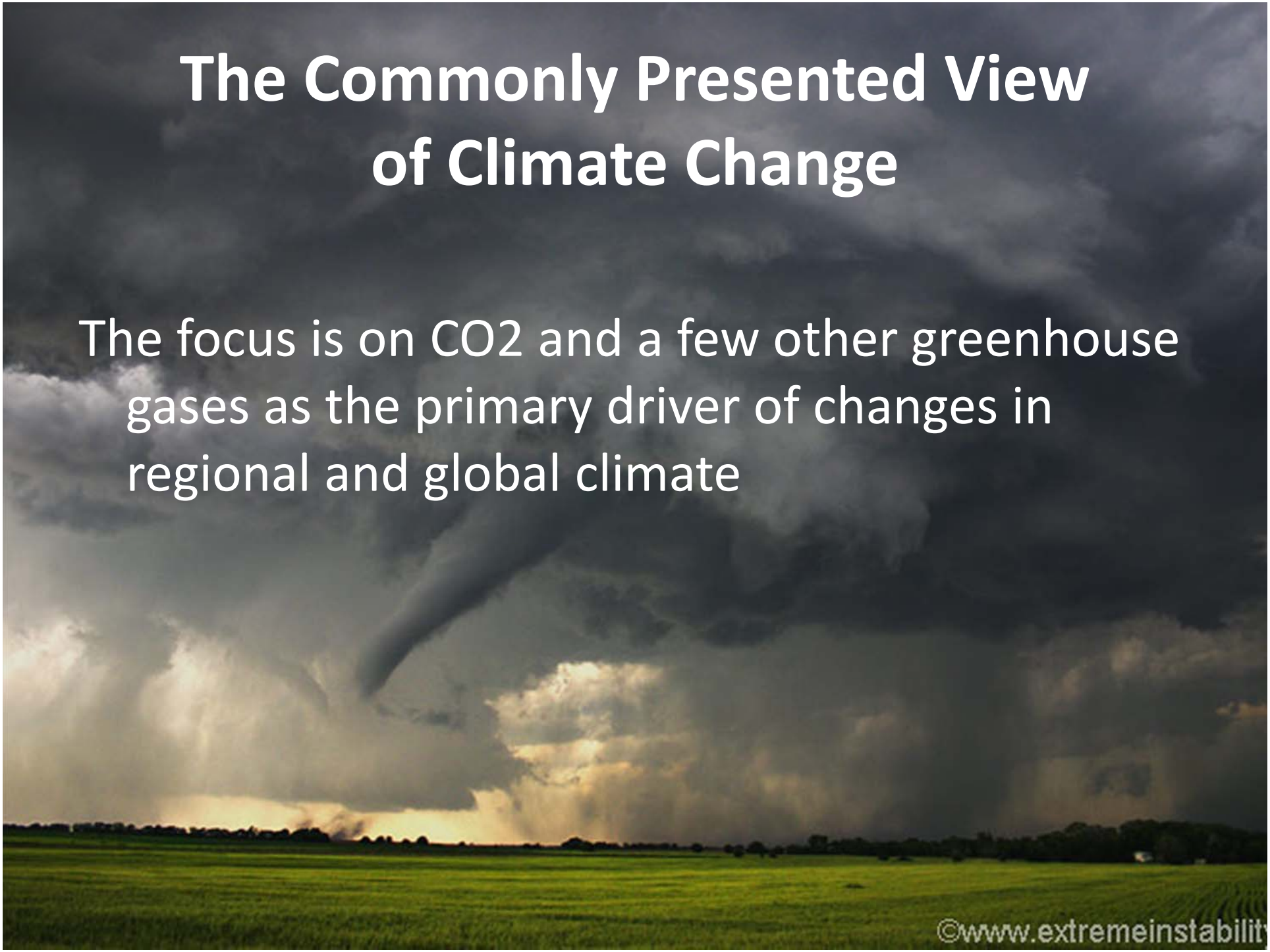
University of Colorado at Boulder – CIRES/ATOC

The Commonly Presented View of Climate Change

The focus is on CO_2 and a few other greenhouse gases as the primary driver of changes in regional and global climate



AGU Statement On Climate Change – 2013 -

http://onlinelibrary.wiley.com/doi/10.1002/2013EO340006/pdf

Amy Clement, Rosenstiel School of Marine and Atmospheric Science, University of Miami

John Farrington, Woods Hole Oceanographic Institute

Susan Joy Hassol, Climate Communication

Robert Hirsch, U.S. Geological Survey

Peter Huybers, Harvard University

Peter Lemke, Alfred Wegener Institute

Gerald North, Texas A&M University (panel chair)

Michael Oppenheimer, Princeton University

Roger Pielke Sr., University of Colorado at Boulder

Ben Santer, Lawrence Livermore National Laboratory

Gavin Schmidt, Goddard Institute for Space Studies, NASA

Leonard A. Smith, London School of Economics

Eric Sundquist, U.S. Geological Survey

Pieter Tans, National Oceanic and Atmospheric Administration


"Human-caused increases in greenhouse gases are responsible for most of the observed global average surface warming of roughly 0.8°C (1.5°F) over the past 140 years"
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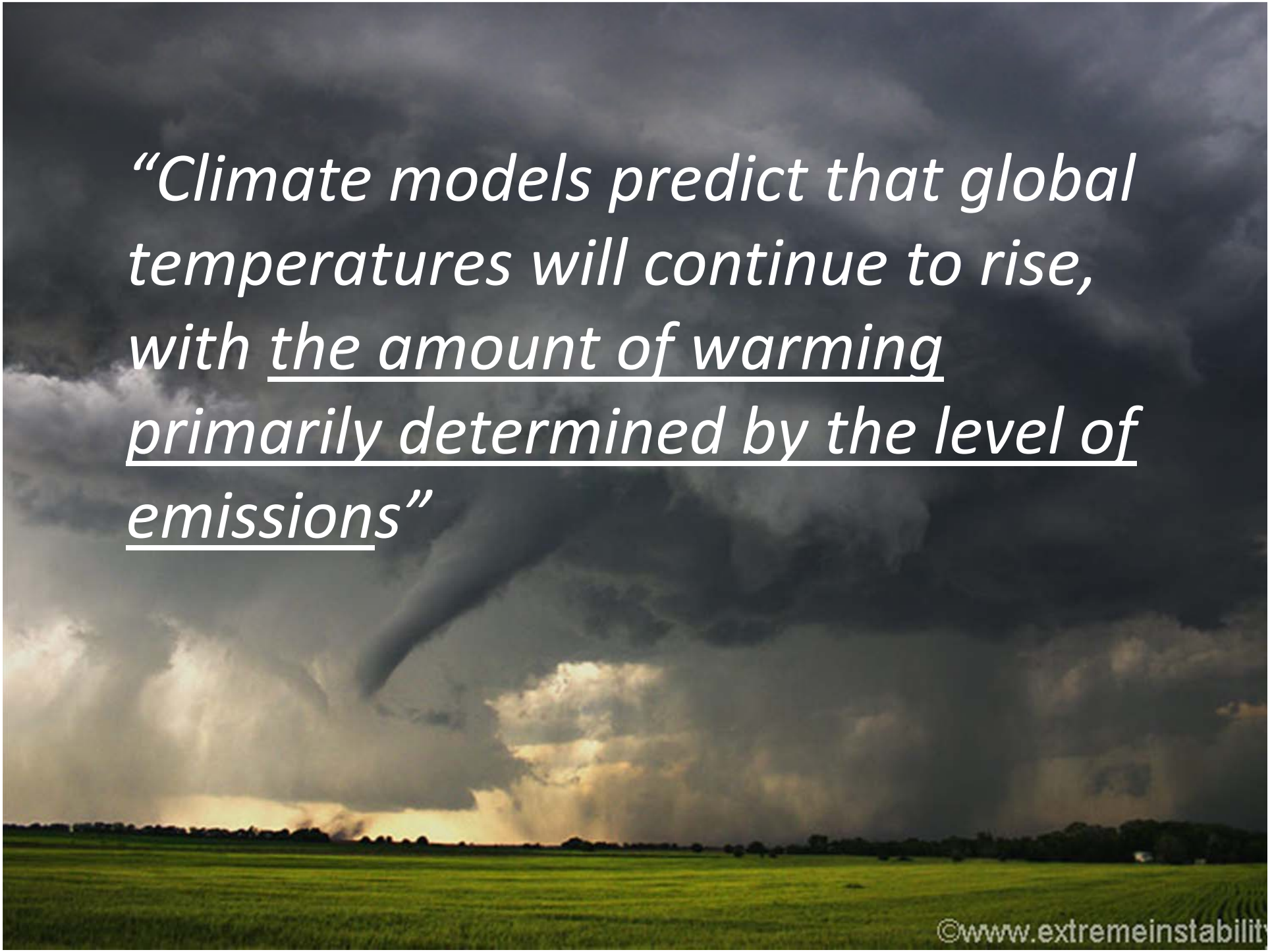
"Climate models predict that global temperatures will continue to rise, with the amount of warming primarily determined by the level of emissions"
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"Actions that could diminish the threats posed by climate change to society and ecosystems include substantial emissions cuts to reduce the magnitude of climate change"..
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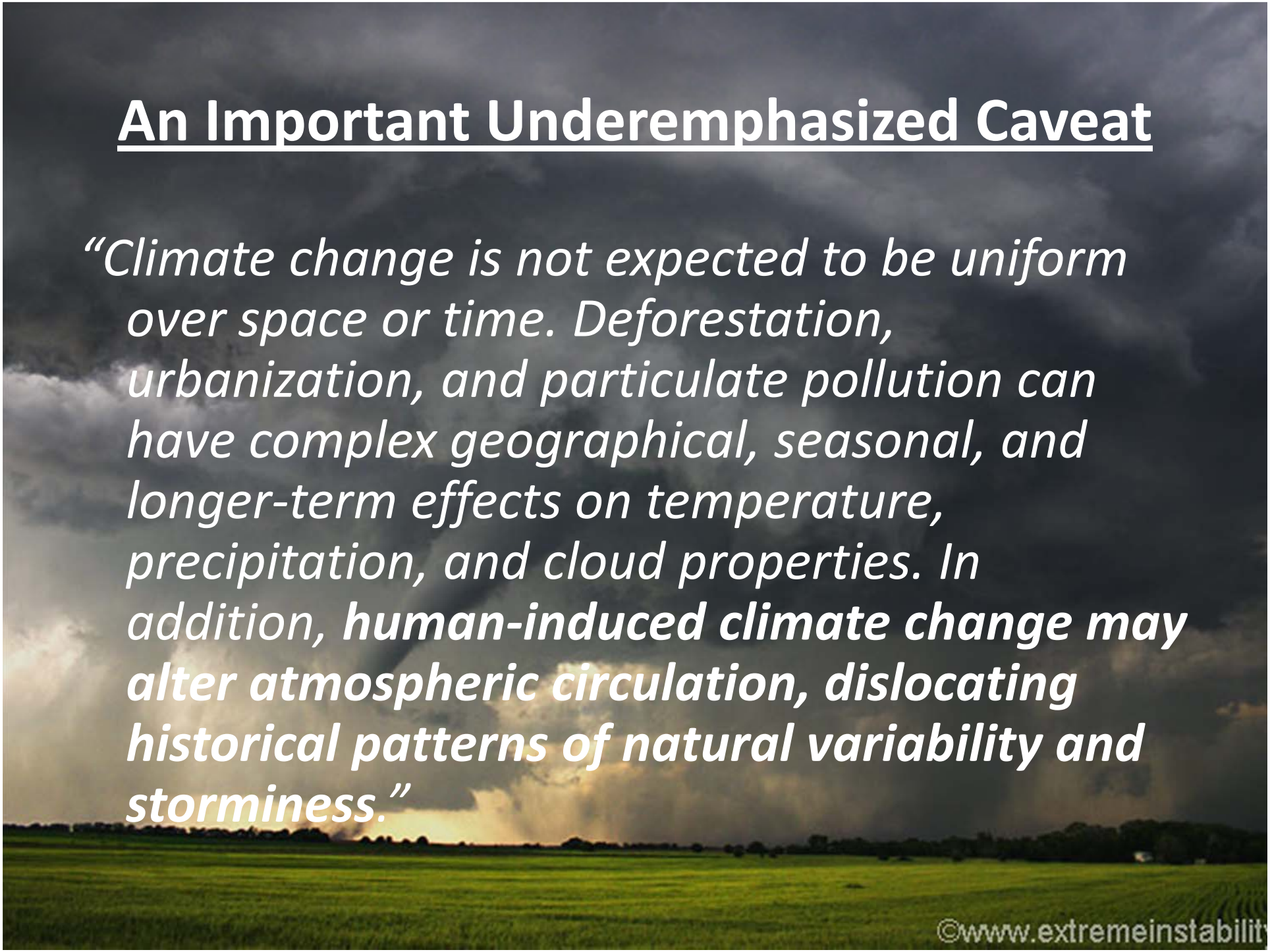
An Important Underemphasized Caveat
"Climate change is not expected to be uniform over space or time. Deforestation, urbanization, and particulate pollution can have complex geographical, seasonal, and longer-term effects on temperature, precipitation, and cloud properties. In addition, human-induced climate change may alter atmospheric circulation, dislocating historical patterns of natural variability and storminess."
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Climate Change Risk Management – AMS Report 2014

http://www2.ametsoc.org/ams/index.cfm/policy/studies-analysis/climate-change-risk-management/

Climate change risk management approaches generally fall into four broad categories:

1) mitigation—efforts to reduce greenhouse gas emissions;
2) adaptation—increasing society's capacity to cope with changes in climate;
3) geoengineering or climate engineering—additional, deliberate manipulation of the earth system that is intended to counteract at least some of the impacts of greenhouse gas emissions; and
4) knowledge-base expansion—efforts to learn and understand more about the climate system, which can help support proactive risk management.


"Climate change - caused by carbon pollution - is one of the most significant public health threats of our time,"
Environmental Protection Agency Head - Gina McCarthy
http://www.bbc.co.uk/news/business-24181341
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Obama states "changing climate" is more of a threat than "terrorism, instability, inequality, disease" [http://t.co/5gEdLwkEMl]

This Changes Everything: Capitalism vs. The Climate by Naomi Klein

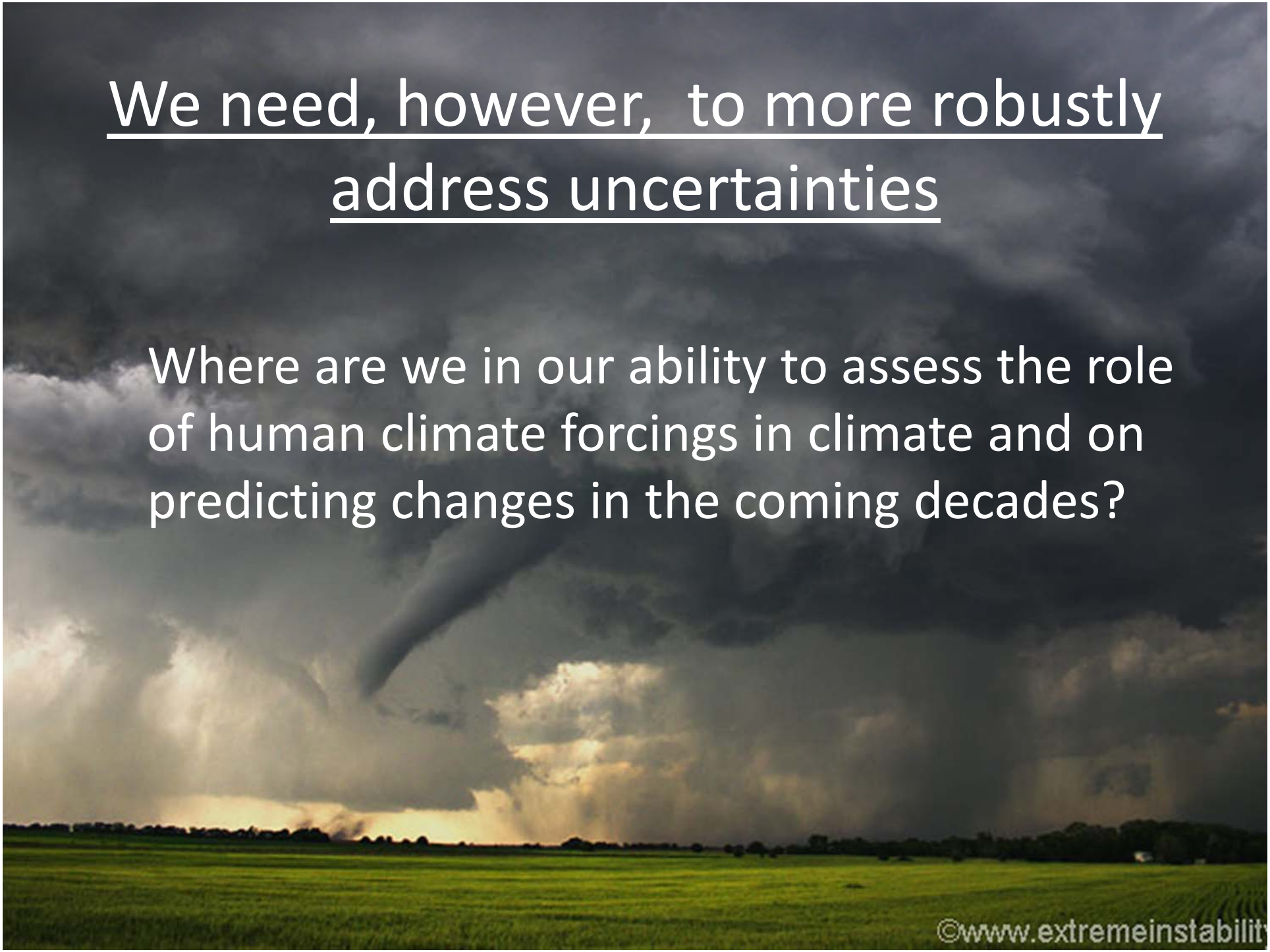
The most important book yet from the author of the international bestseller The Shock Doctrine, a brilliant explanation of why the climate crisis challenges us to abandon the core "free market" ideology of our time, restructure the global economy, and remake our political systems.

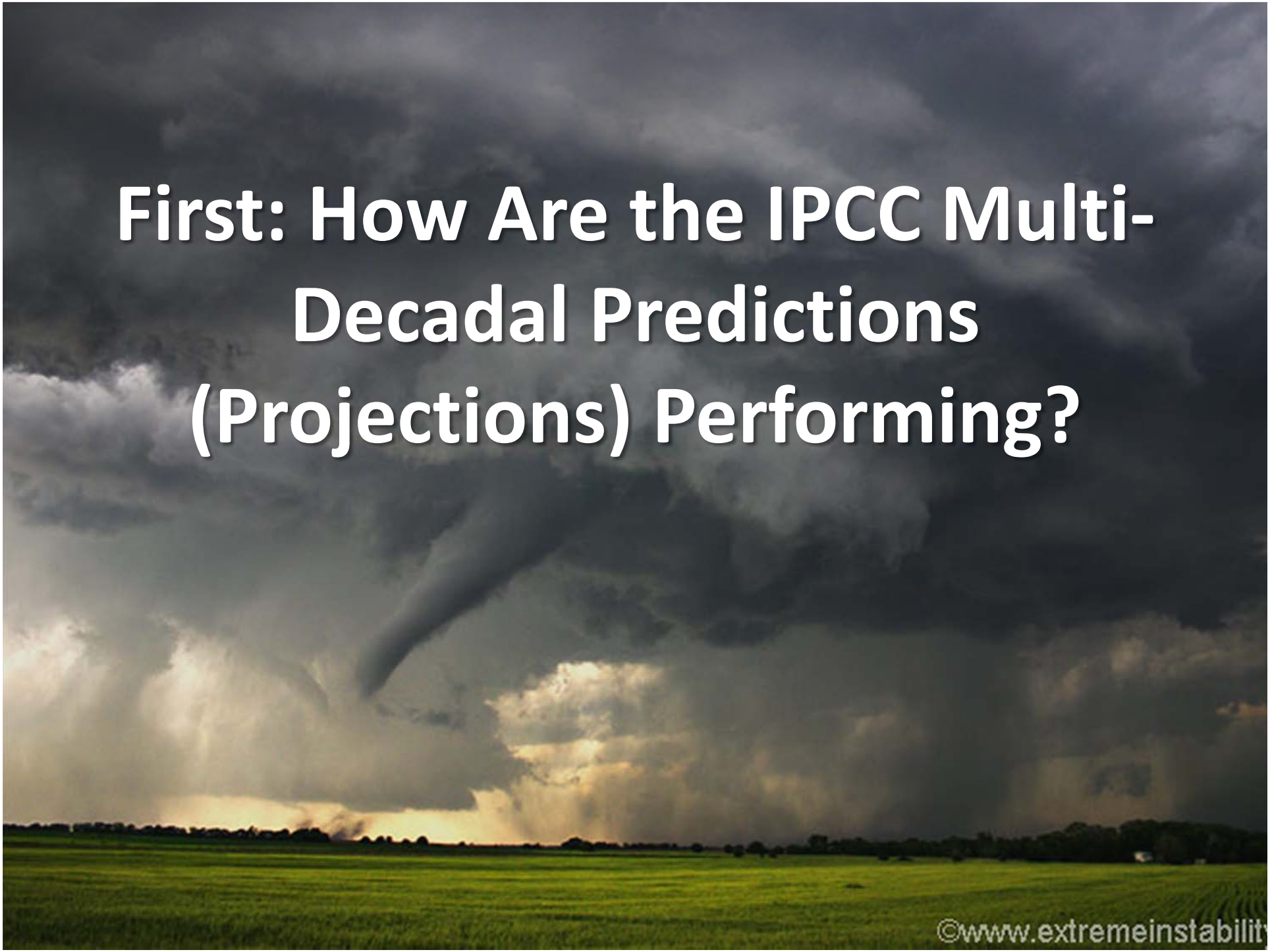
In short, either we embrace radical change ourselves or radical changes will be visited upon our physical world. The status quo is no longer an option.

....Klein meticulously builds the case for how massively reducing our greenhouse emissions is our best chance to simultaneously reduce gaping inequalities, re-imagine our broken democracies, and rebuild our gutted local economies.

http://www.amazon.com/This-Changes-Everything-Capitalism-Climate/dp/1451697384/ref=sr_1_cc_1?s=aps&ie=UTF8&qid=1413385756&sr=1-1-catcorr&keywords=naomi+klein


It’s about greenhouse gas emissions particularly CO2 as the “catalyst”.
©www.extremeinstabilit


We need, however, to more robustly address uncertainties
Where are we in our ability to assess the role of human climate forcings in climate and on predicting changes in the coming decades?
©www.extremeinstabilit


First: How Are the IPCC Multi-Decadal Predictions (Projections) Performing?
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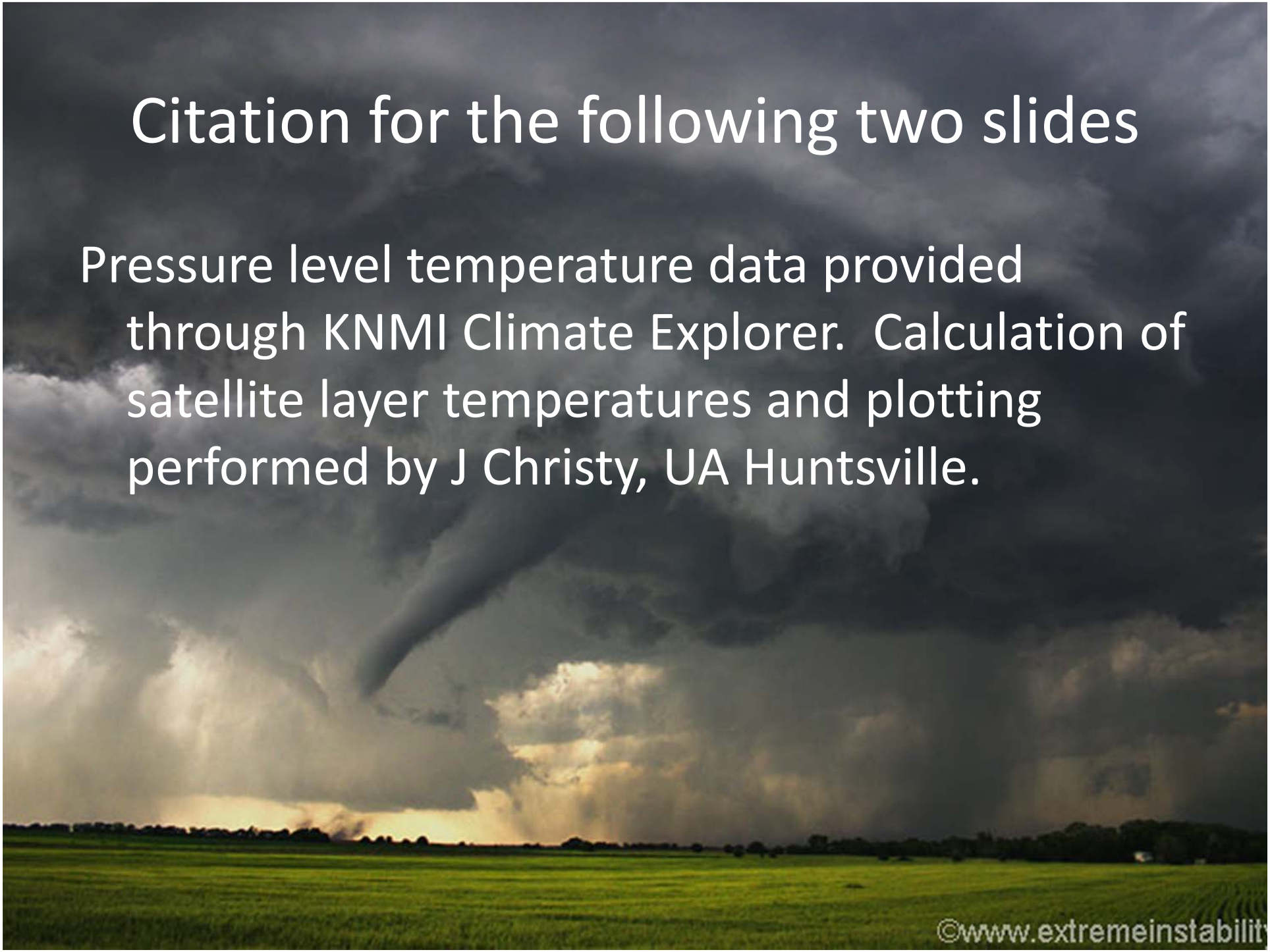
Necessary Conditions For Skillful Multi-Decadal Predictions of Extreme Events

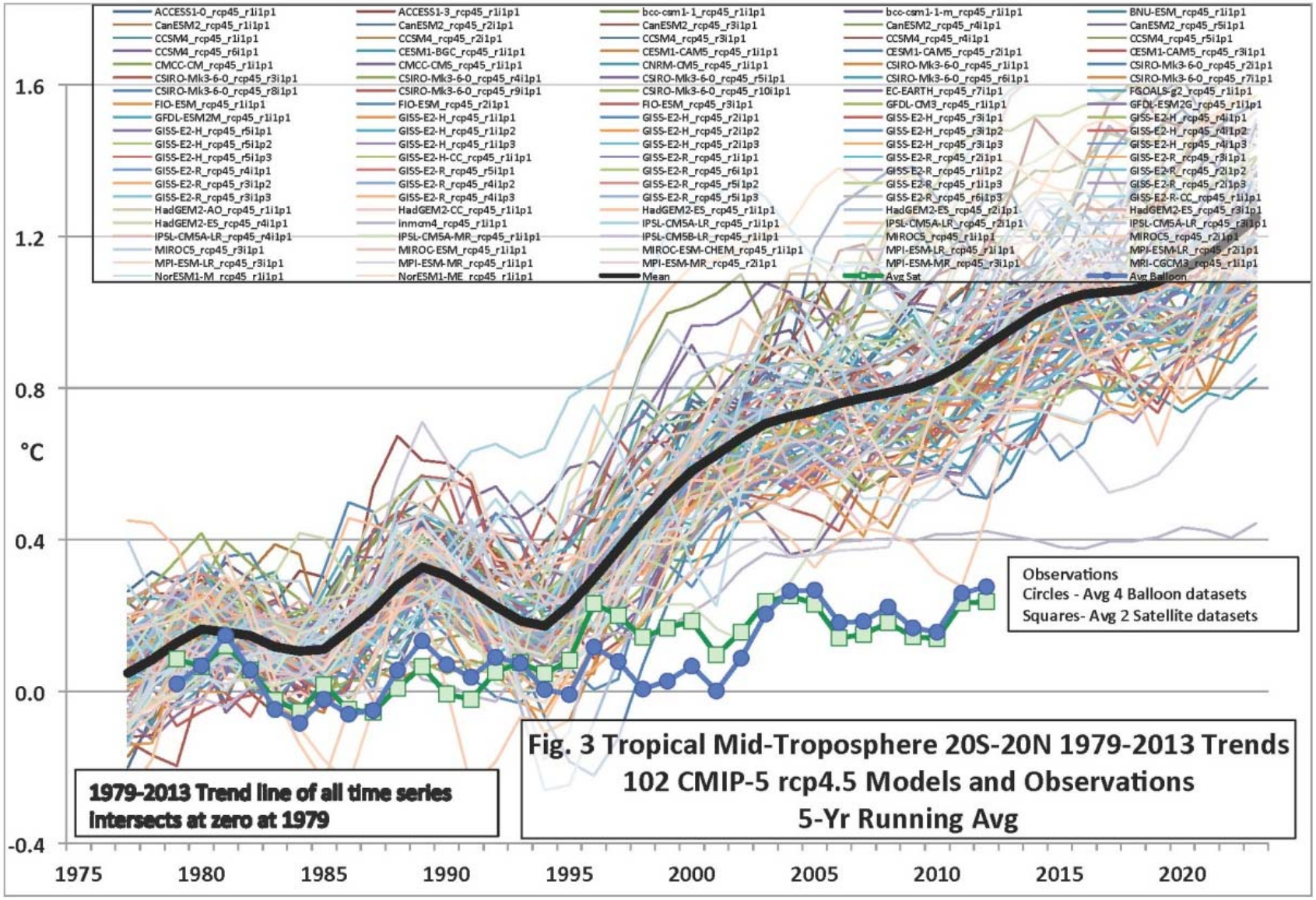
In hindcast runs (the last several decades), skillful predictions must be demonstrated which include:

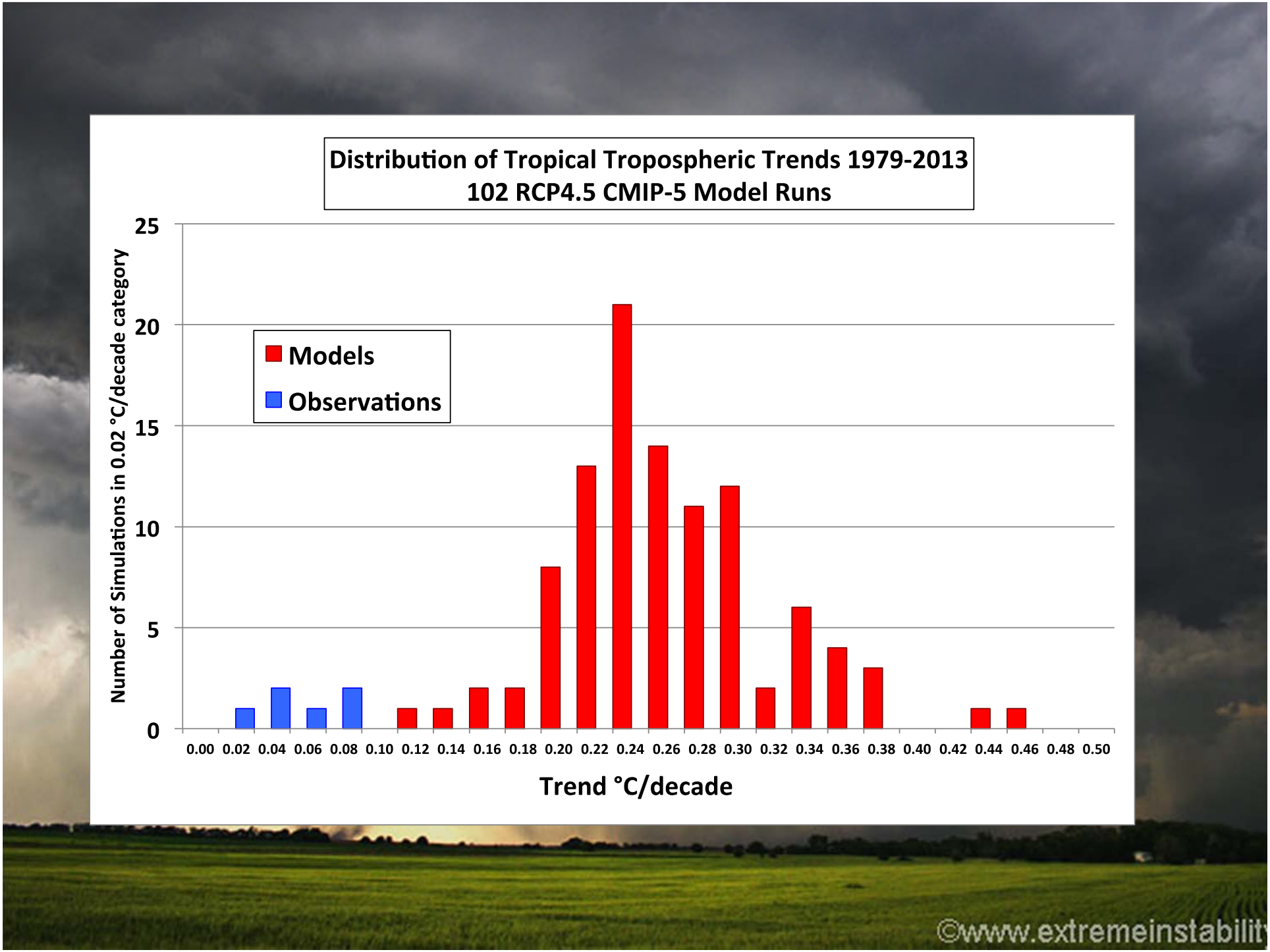
1. ***The average (annual, monthly, etc.) global, regional and local climate.***
2. ***The changes in these averages over the past several decades***
3. ***The statistics of extreme weather events***
4. ***The changes in these extremes over the last several decades.***



Citation for the following two slides

Pressure level temperature data provided through KNMI Climate Explorer. Calculation of satellite layer temperatures and plotting performed by J Christy, UA Huntsville.




Distribution of Tropical Tropospheric Trends 1979-2013
102 RCP4.5 CMIP-5 Model Runs
Number of Simulations in 0.02 °C/decade category
25
20
15
10
5
0
Models
Observations
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.40 0.42 0.44 0.46 0.48 0.50
Trend °C/decade
©www.extremeinstabilit

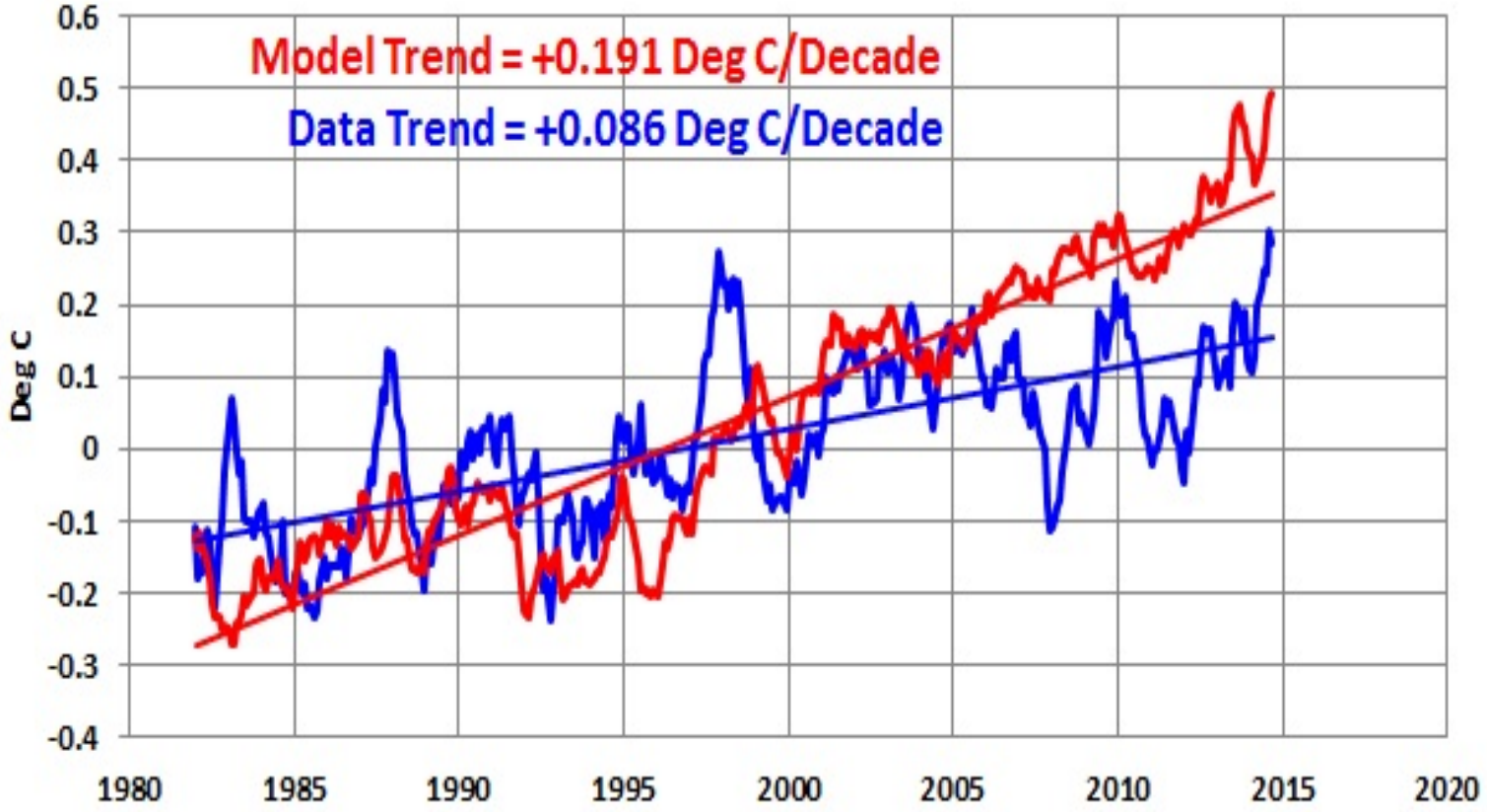
Model-Data Comparison

Global (90S-90N) Sea Surface Temperature Anomalies

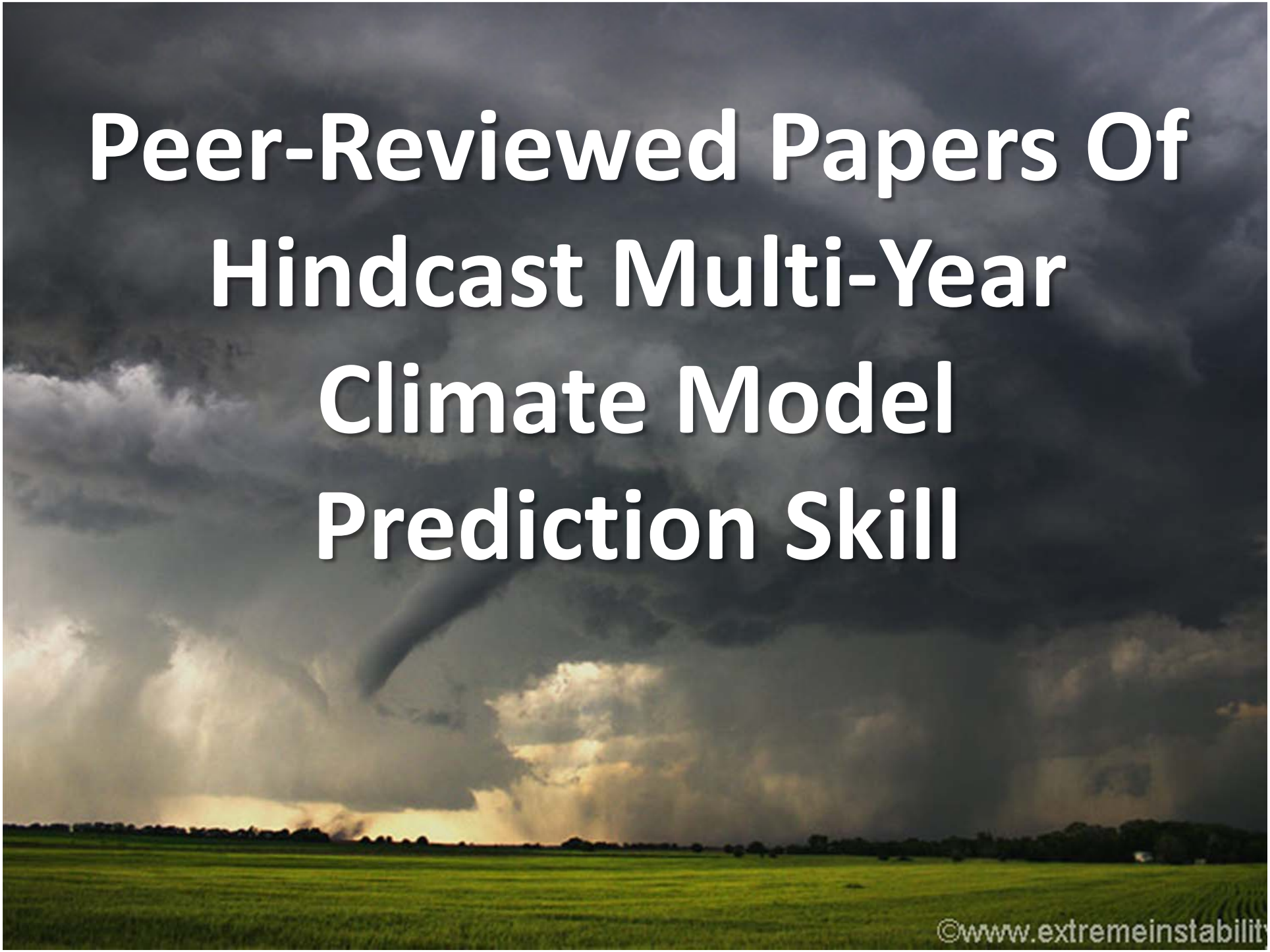
Model Mean: HADGEM2-ES Historic/RCP6.0

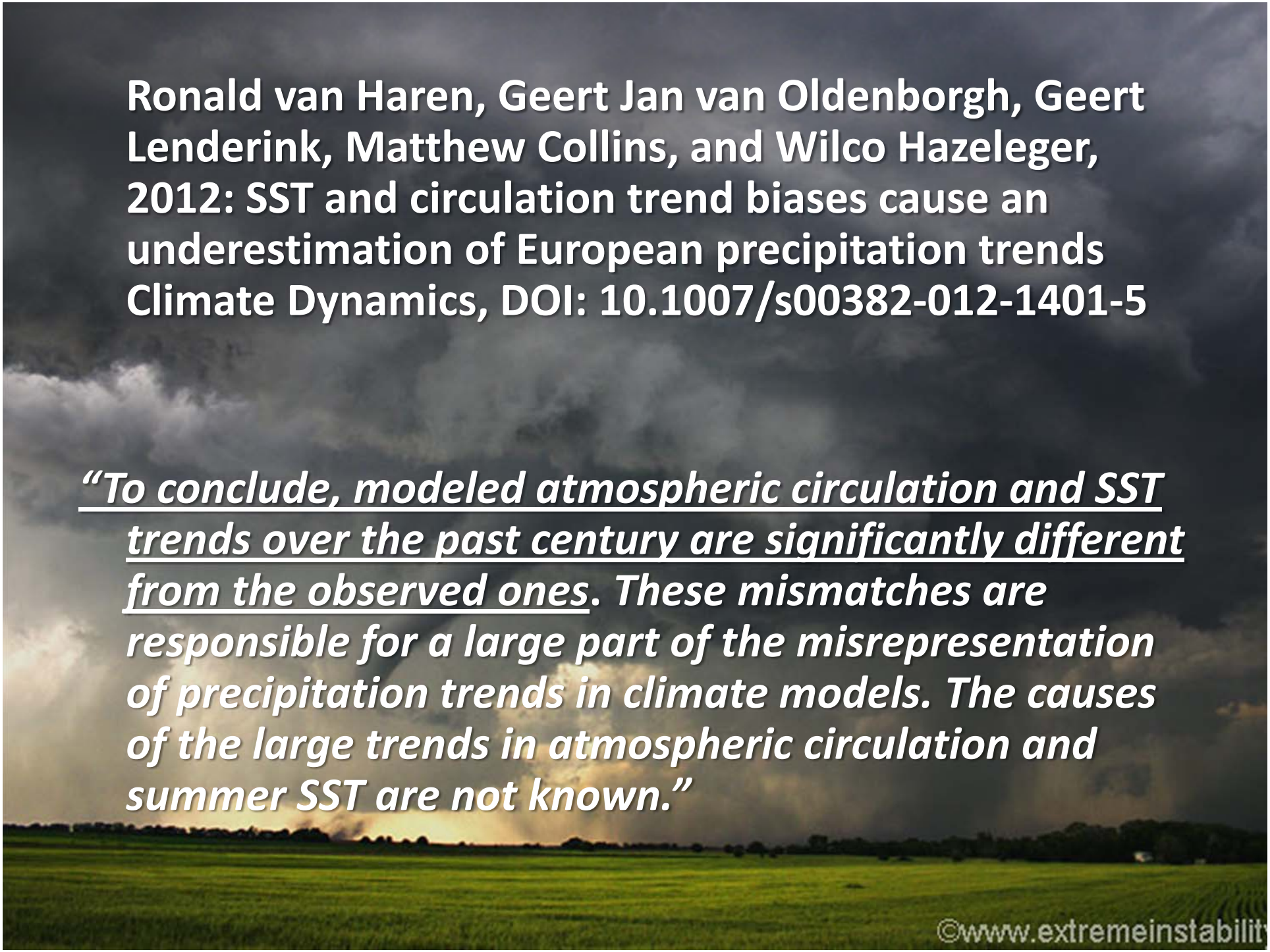
Data: Reynolds OI.v2

Jan 1982 to Sep 2014



Bob Tisdale


Peer-Reviewed Papers Of
Hindcast Multi-Year
Climate Model
Prediction Skill
©www.extremeinstabilit


Ronald van Haren, Geert Jan van Oldenborgh, Geert Lenderink, Matthew Collins, and Wilco Hazeleger, 2012: SST and circulation trend biases cause an underestimation of European precipitation trends Climate Dynamics, DOI: 10.1007/s00382-012-1401-5
"To conclude, modeled atmospheric circulation and SST trends over the past century are significantly different from the observed ones. These mismatches are responsible for a large part of the misrepresentation of precipitation trends in climate models. The causes of the large trends in atmospheric circulation and summer SST are not known."
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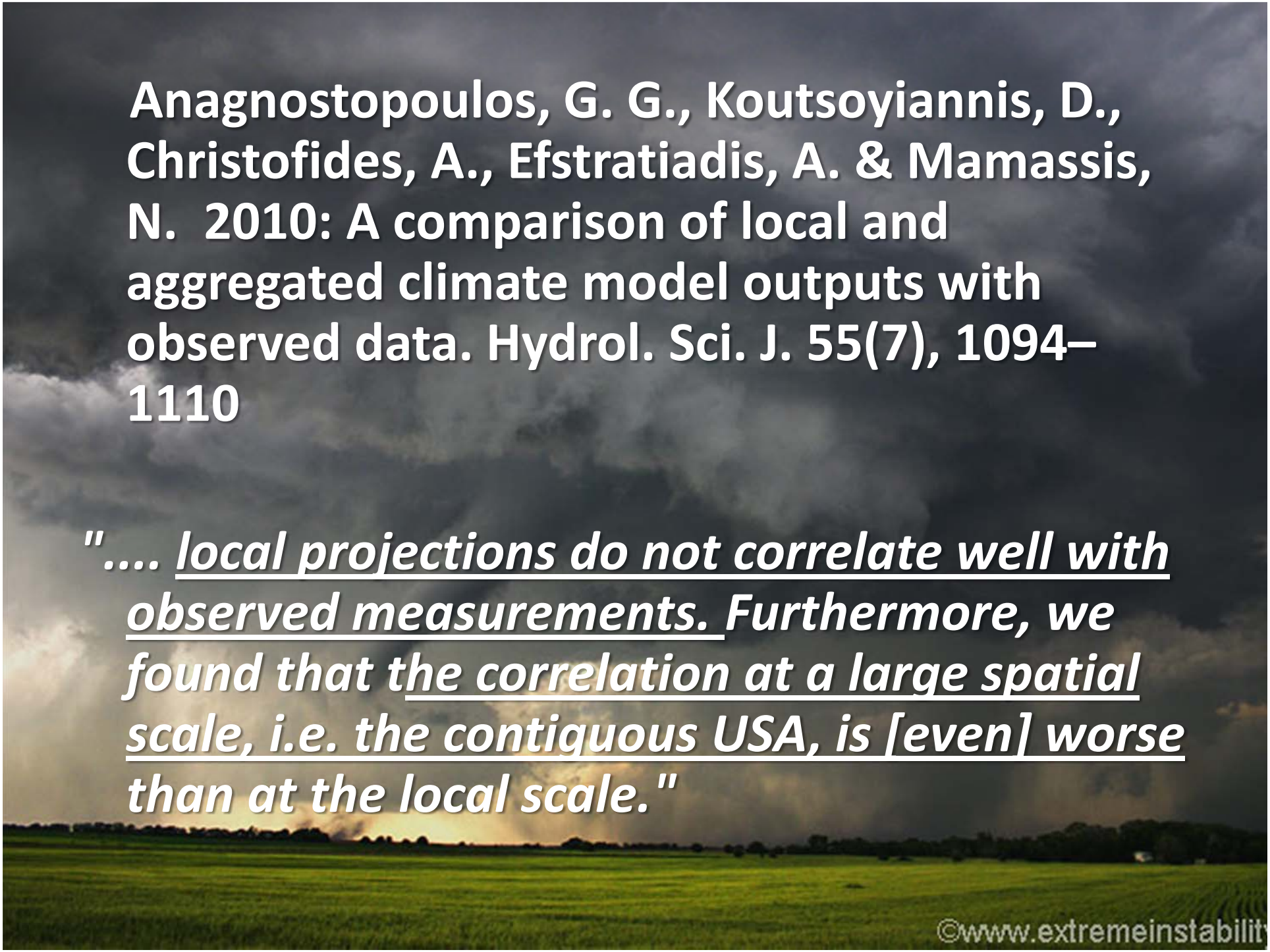
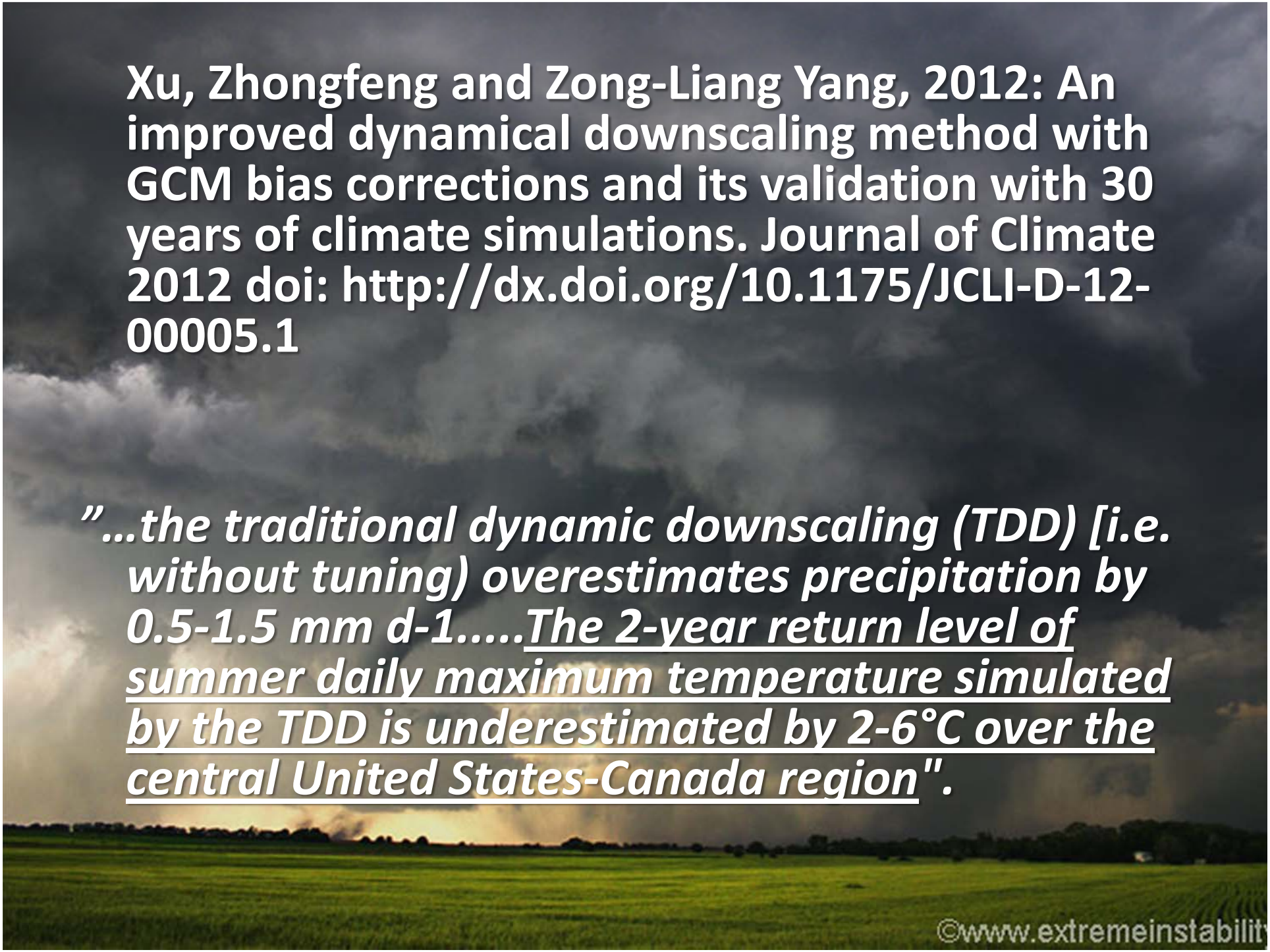

Anagnostopoulos, G. G., Koutsoyiannis, D., Christofides, A., Efstratiadis, A. & Mamassis, N. 2010: A comparison of local and aggregated climate model outputs with observed data. Hydrol. Sci. J. 55(7), 1094–1110
"…. local projections do not correlate well with observed measurements. Furthermore, we found that the correlation at a large spatial scale, i.e. the contiguous USA, is [even] worse than at the local scale."
©www.extremeinstabilit

Sun, Z., J. Liu, X. Zeng, and H. Liang, 2012: Parameterization of instantaneous global horizontal irradiance at the surface. Part II: Cloudy-sky component, J. Geophys. Res., doi:10.1029/2012JD017557

"Radiation calculations in global numerical weather prediction (NWP) and climate models are usually performed in 3-hourly time intervals in order to reduce the computational cost. This treatment can lead to an incorrect Global Horizontal Irradiance (GHI) at the Earth's surface, which could be one of the error sources in modelled convection and precipitation. …… An important application of the scheme is in global climate models….It is found that these errors are very large, exceeding 800 W m-2 at many non-radiation time steps due to ignoring the effects of clouds…."

Stephens, G. L., T. L'Ecuyer, R. Forbes, A. Gettlemen, J.-C. Golaz, A. Bodas-Salcedo, K. Suzuki, P. Gabriel, and J. Haynes , 2010: Dreary state of precipitation in global models, J. Geophys. Res., 115, D24211, doi:10.1029/2010JD014532.

"...models produce precipitation approximately twice as often as that observed and make rainfall far too lightly.....The differences in the character of model precipitation are systemic and have a number of important implications for modeling the coupled Earth system .....little skill in precipitation [is] calculated at individual grid points, and thus applications involving downscaling of grid point precipitation to yet even finer-scale resolution has little foundation and relevance to the real Earth system."


Xu, Zhongfeng and Zong-Liang Yang, 2012: An improved dynamical downscaling method with GCM bias corrections and its validation with 30 years of climate simulations. Journal of Climate 2012 doi: http://dx.doi.org/10.1175/JCLI-D-12-00005.1
”…the traditional dynamic downscaling (TDD) [i.e. without tuning) overestimates precipitation by 0.5-1.5 mm d-1.....The 2-year return level of summer daily maximum temperature simulated by the TDD is underestimated by 2-6°C over the central United States-Canada region".
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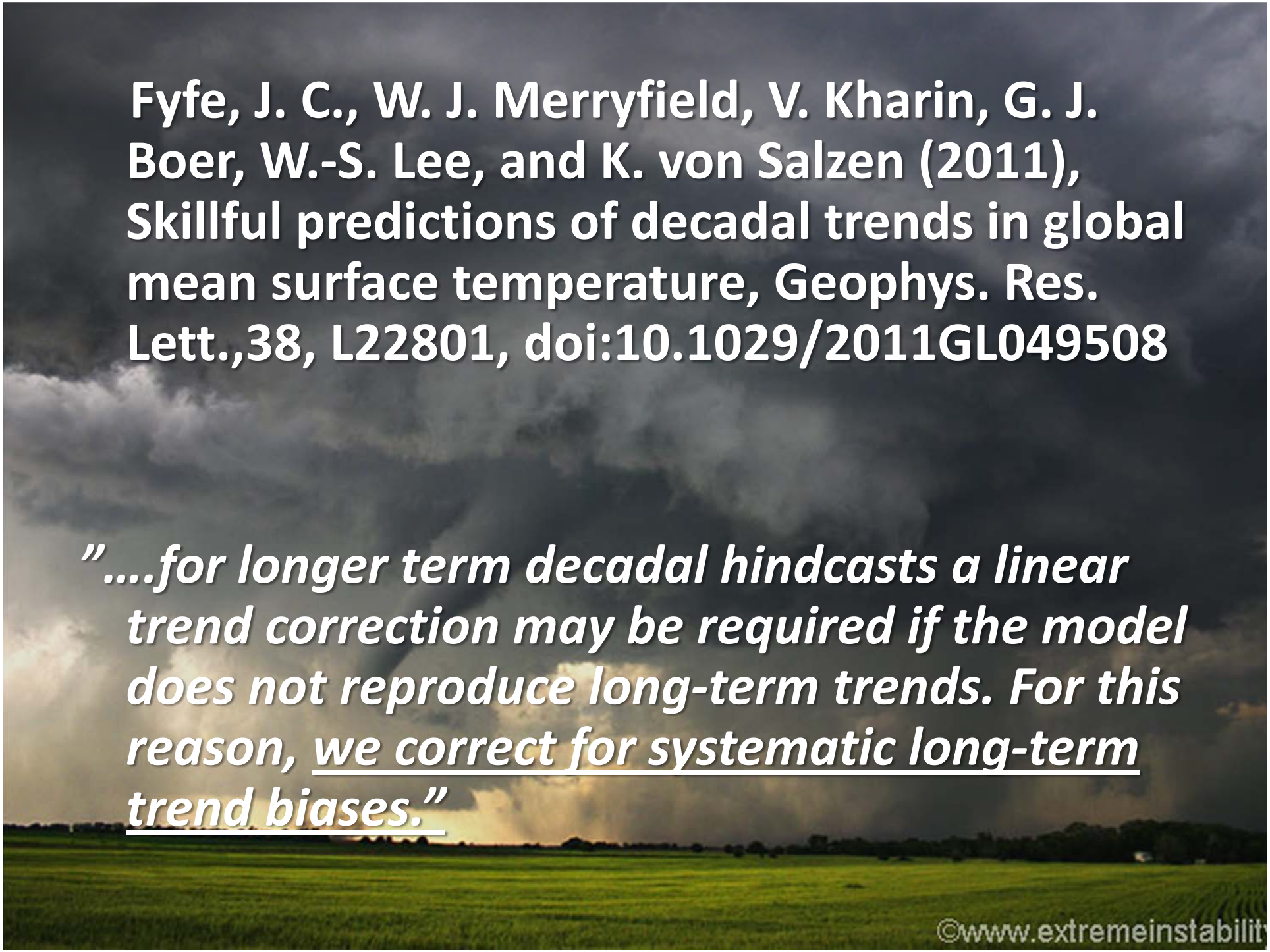
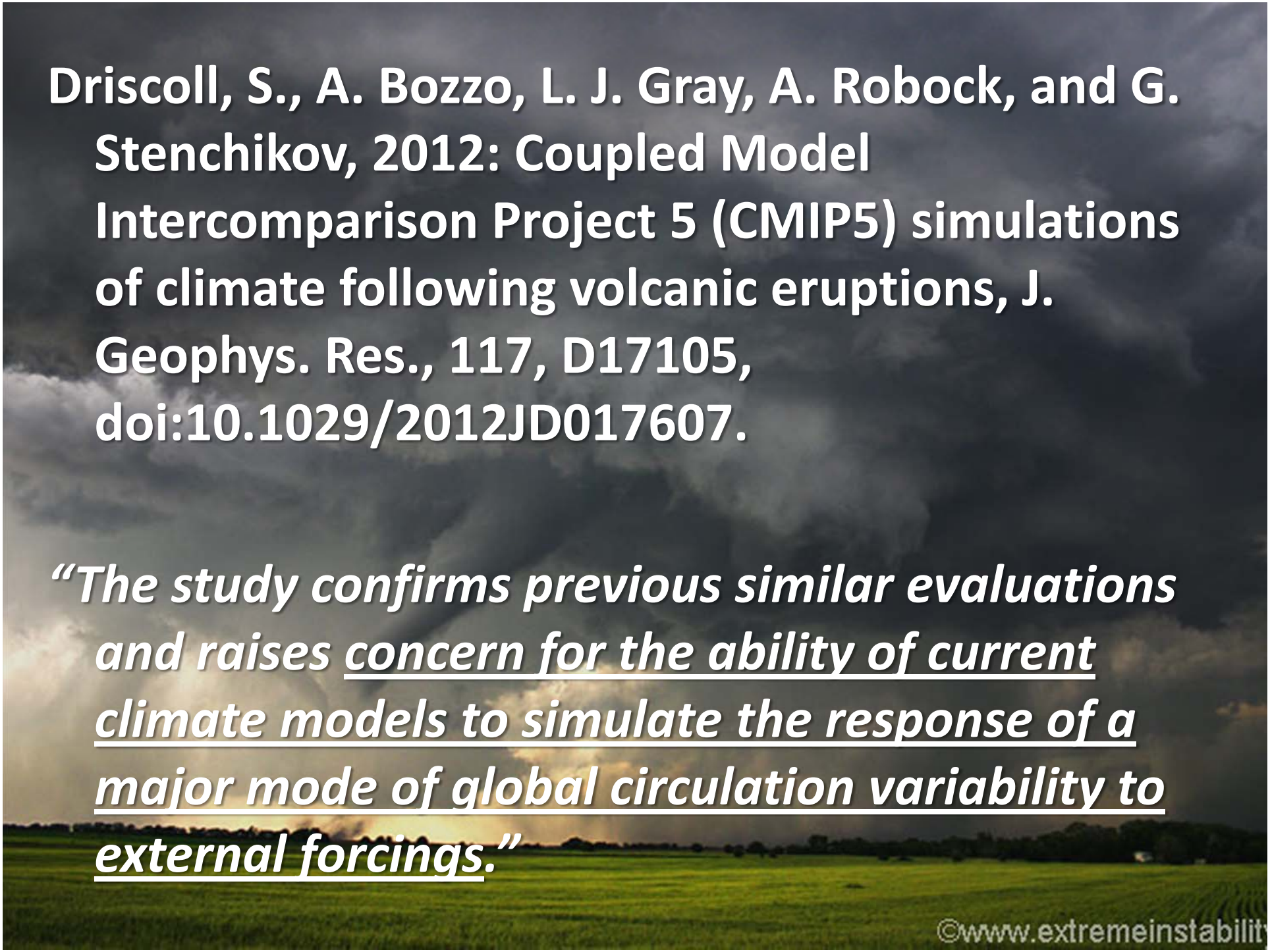
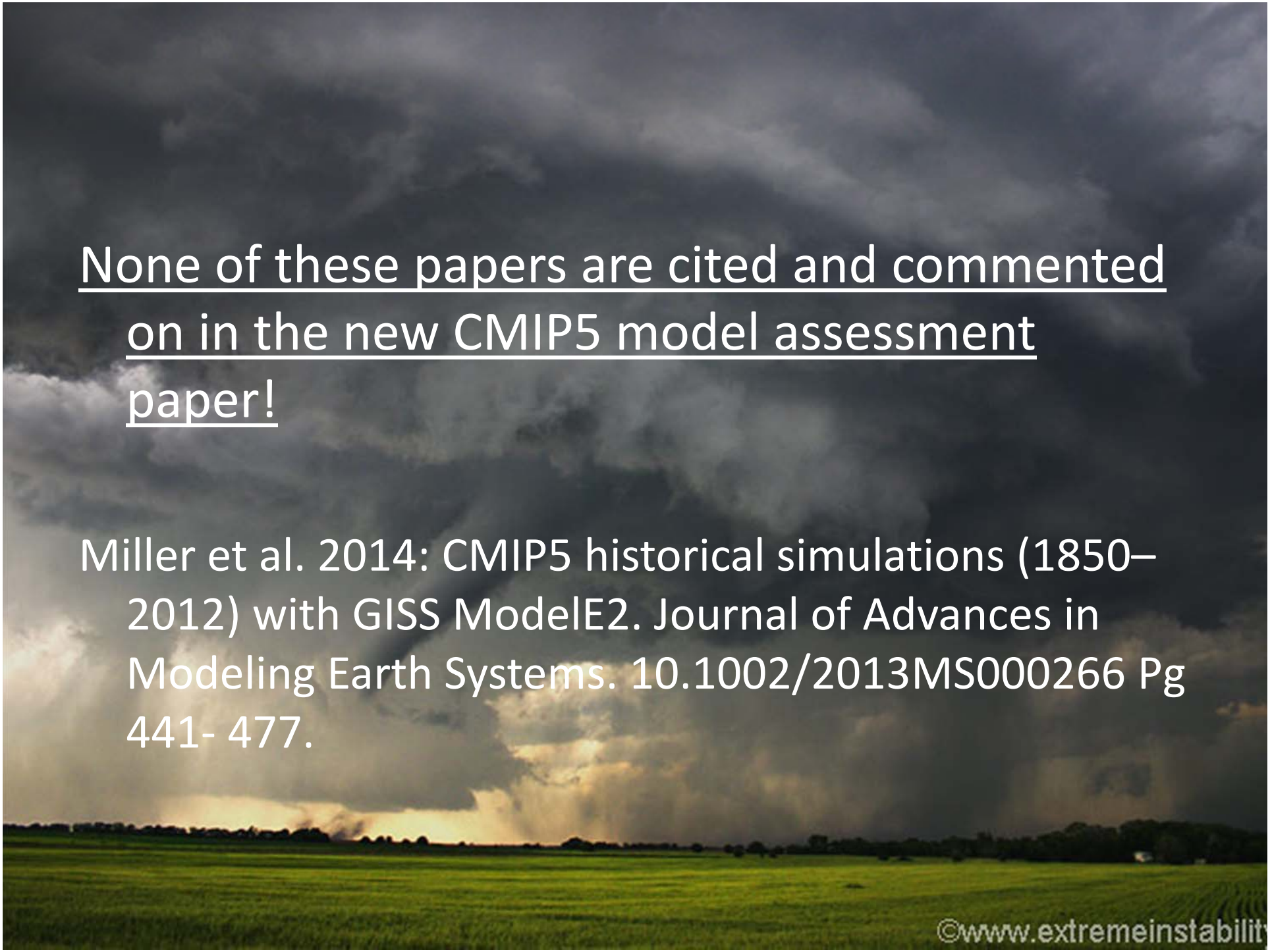

Fyfe, J. C., W. J. Merryfield, V. Kharin, G. J. Boer, W.-S. Lee, and K. von Salzen (2011), Skillful predictions of decadal trends in global mean surface temperature, Geophys. Res. Lett.,38, L22801, doi:10.1029/2011GL049508
”….for longer term decadal hindcasts a linear trend correction may be required if the model does not reproduce long-term trends. For this reason, we correct for systematic long-term trend biases.”
©www.extremeinstabilit


Taylor et al., 2012: Afternoon rain more likely over drier soils. Nature. doi:10.1038/nature11377. Published online 12 September 2012
"…the erroneous sensitivity of convection schemes demonstrated here is likely to contribute to a tendency for large-scale models to `lock-in' dry conditions, extending droughts unrealistically, and potentially exaggerating the role of soil moisture feedbacks in the climate system."
©www.extremeinstabilit


Driscoll, S., A. Bozzo, L. J. Gray, A. Robock, and G. Stenchikov, 2012: Coupled Model Intercomparison Project 5 (CMIP5) simulations of climate following volcanic eruptions, J. Geophys. Res., 117, D17105, doi:10.1029/2012JD017607.
"The study confirms previous similar evaluations and raises concern for the ability of current climate models to simulate the response of a major mode of global circulation variability to external forcings."
©www.extremeinstabilit


None of these papers are cited and commented on in the new CMIP5 model assessment paper!
Miller et al. 2014: CMIP5 historical simulations (1850–2012) with GISS ModelE2. Journal of Advances in Modeling Earth Systems. 10.1002/2013MS000266 Pg 441- 477.
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Necessary Conditions For Skillful Multi-Decadal Predictions of Extreme Events

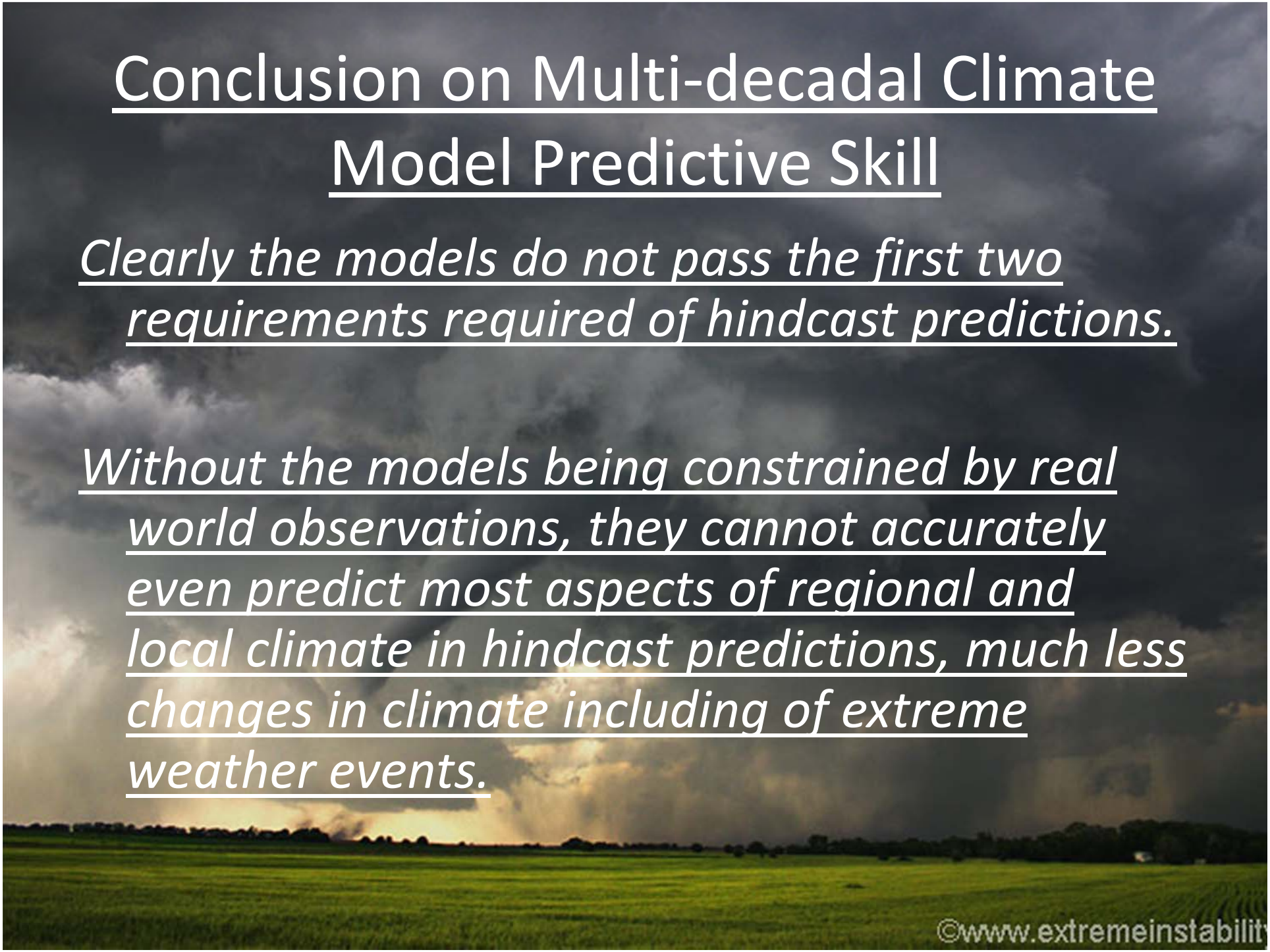
In hindcast runs (the last several decades), skillful predictions must be demonstrated which include:

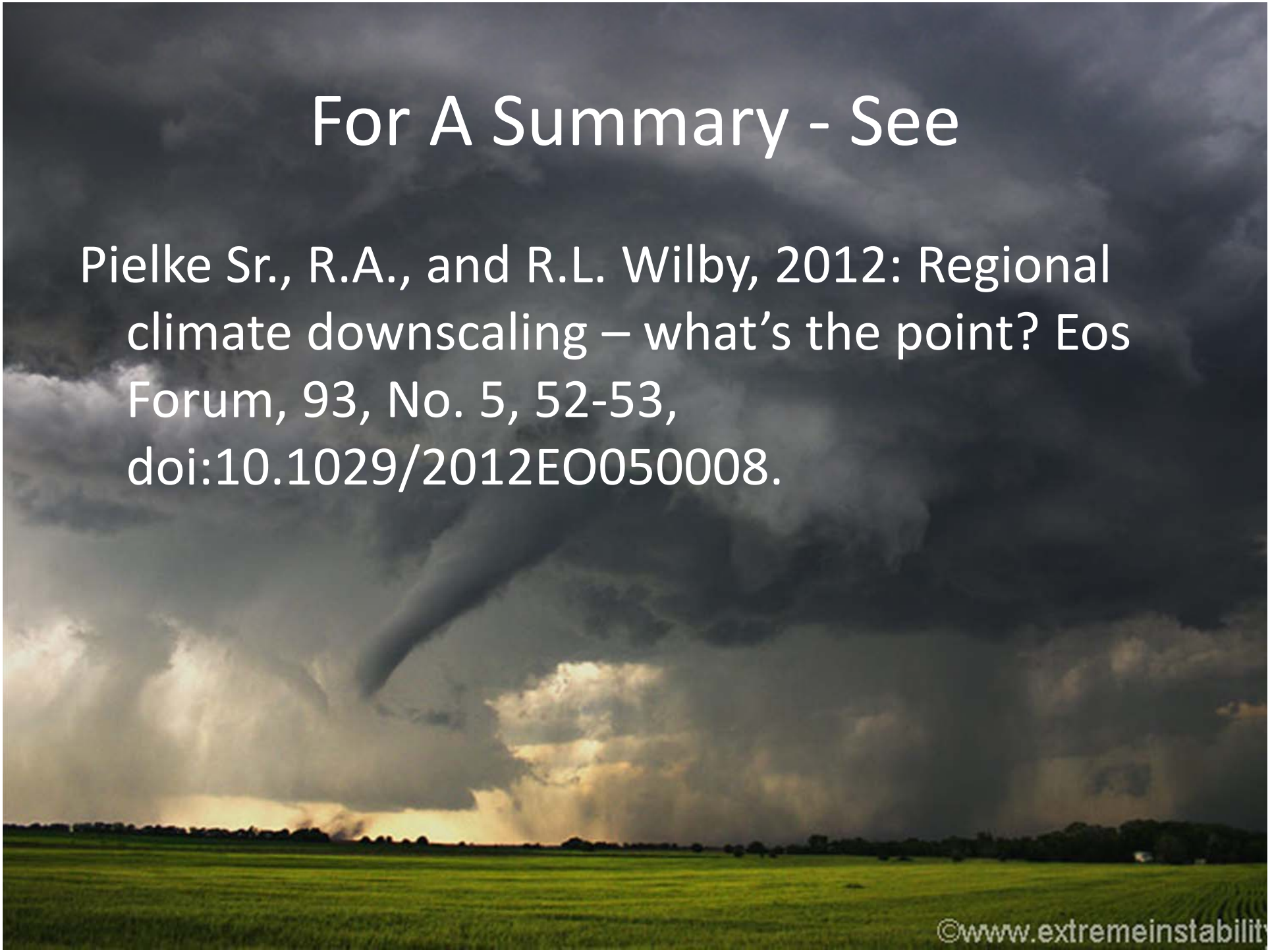
1. ***The average (annual, monthly, etc.) global, regional and local climate. POOR PERFORMANCE***
2. ***The changes in these averages over the past several decades. POOR PERFORMANCE***
3. ***The statistics of extreme weather events.***
4. ***The changes in these extremes over the last several decades.***

Conclusion on Multi-decadal Climate Model Predictive Skill

Clearly the models do not pass the first two requirements required of hindcast predictions.

Without the models being constrained by real world observations, they cannot accurately even predict most aspects of regional and local climate in hindcast predictions, much less changes in climate including of extreme weather events.





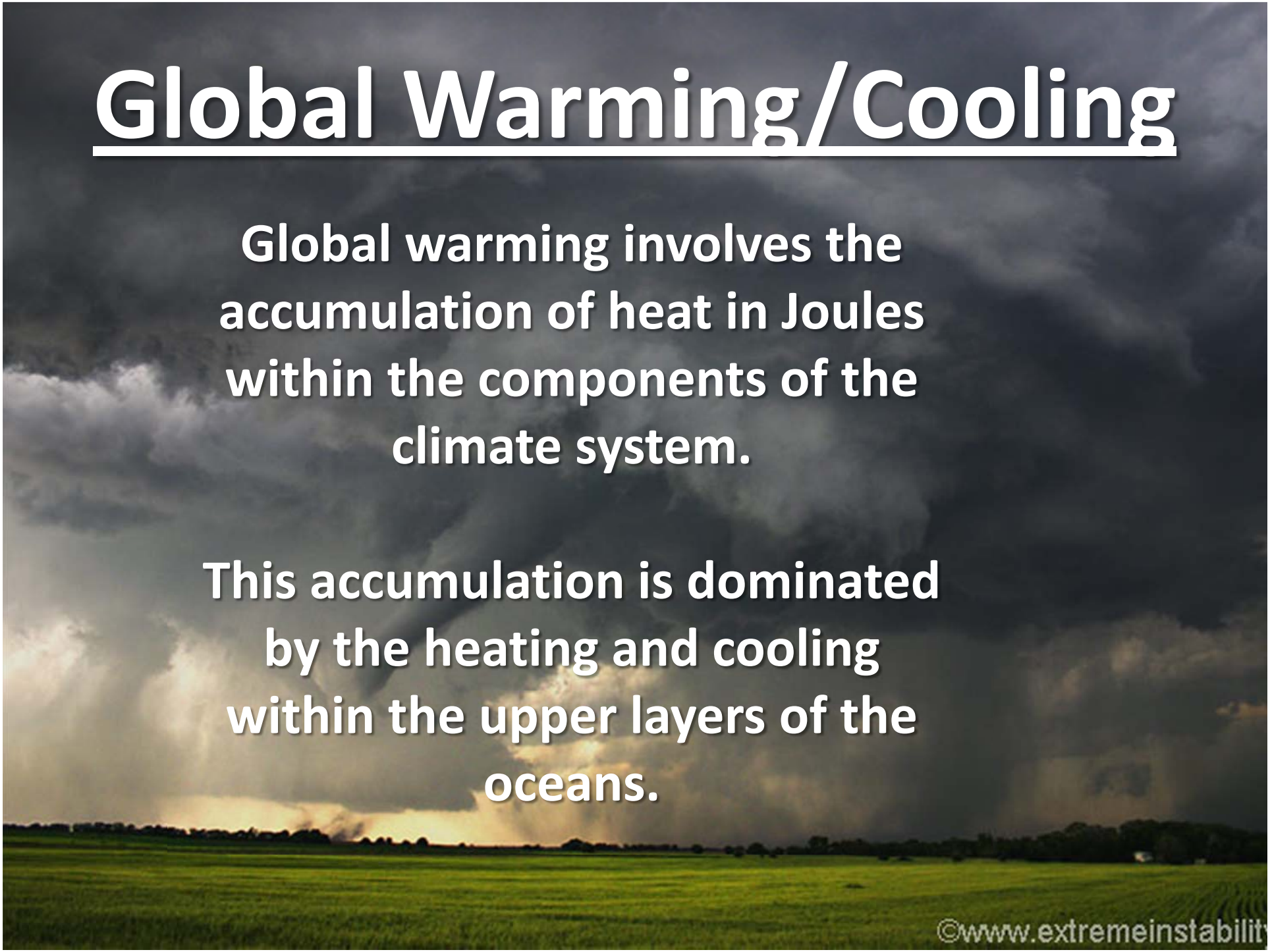
For A Summary - See

Pielke Sr., R.A., and R.L. Wilby, 2012: Regional climate downscaling – what's the point? Eos Forum, 93, No. 5, 52-53, doi:10.1029/2012EO050008.

Next, Let's Look At "Climate Change"

Global Warming << "Climate Change"

But lets look at Global Warming since that is where so much attention has been concentrated.


Global Warming/Cooling
Global warming involves the accumulation of heat in Joules within the components of the climate system.
This accumulation is dominated by the heating and cooling within the upper layers of the oceans.
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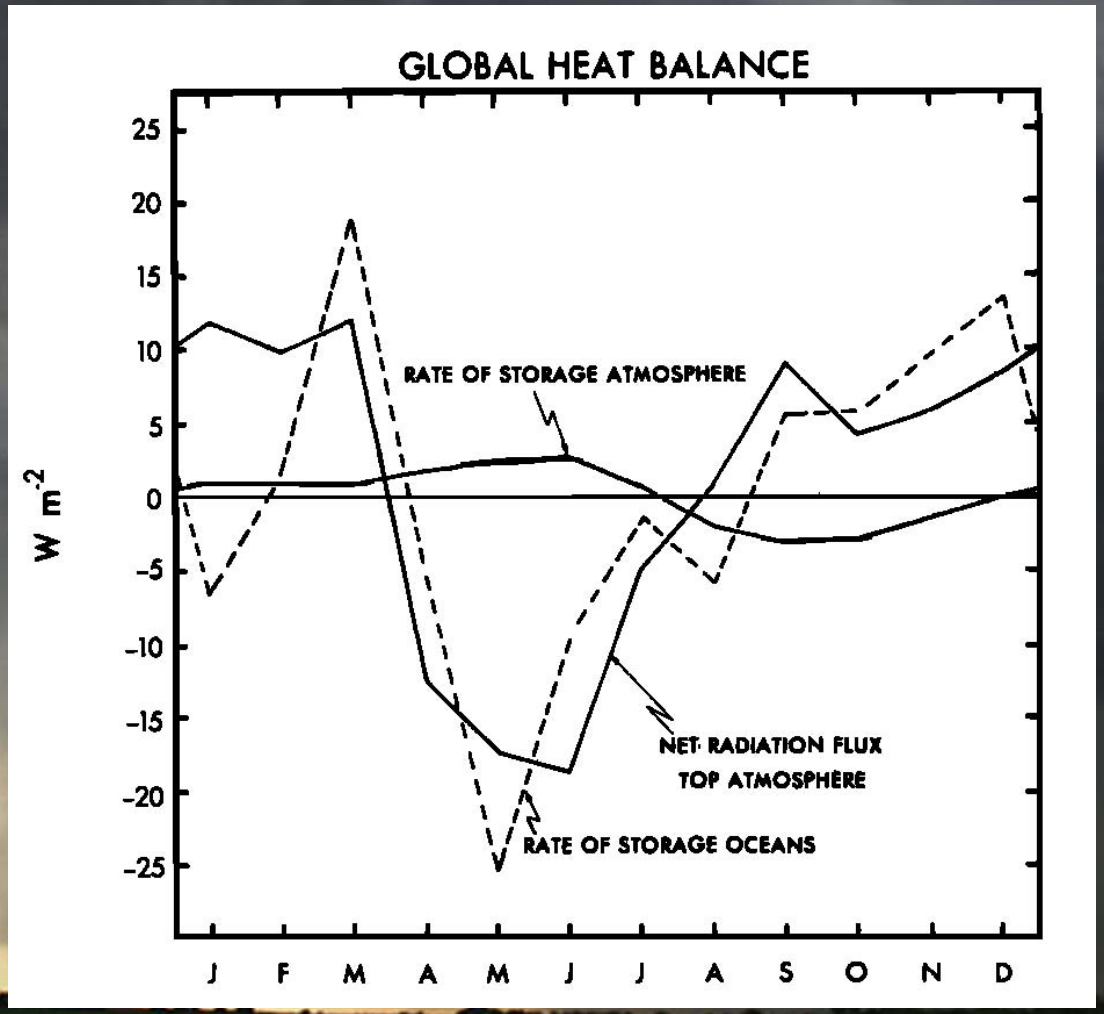
From Ellis et al. 1979

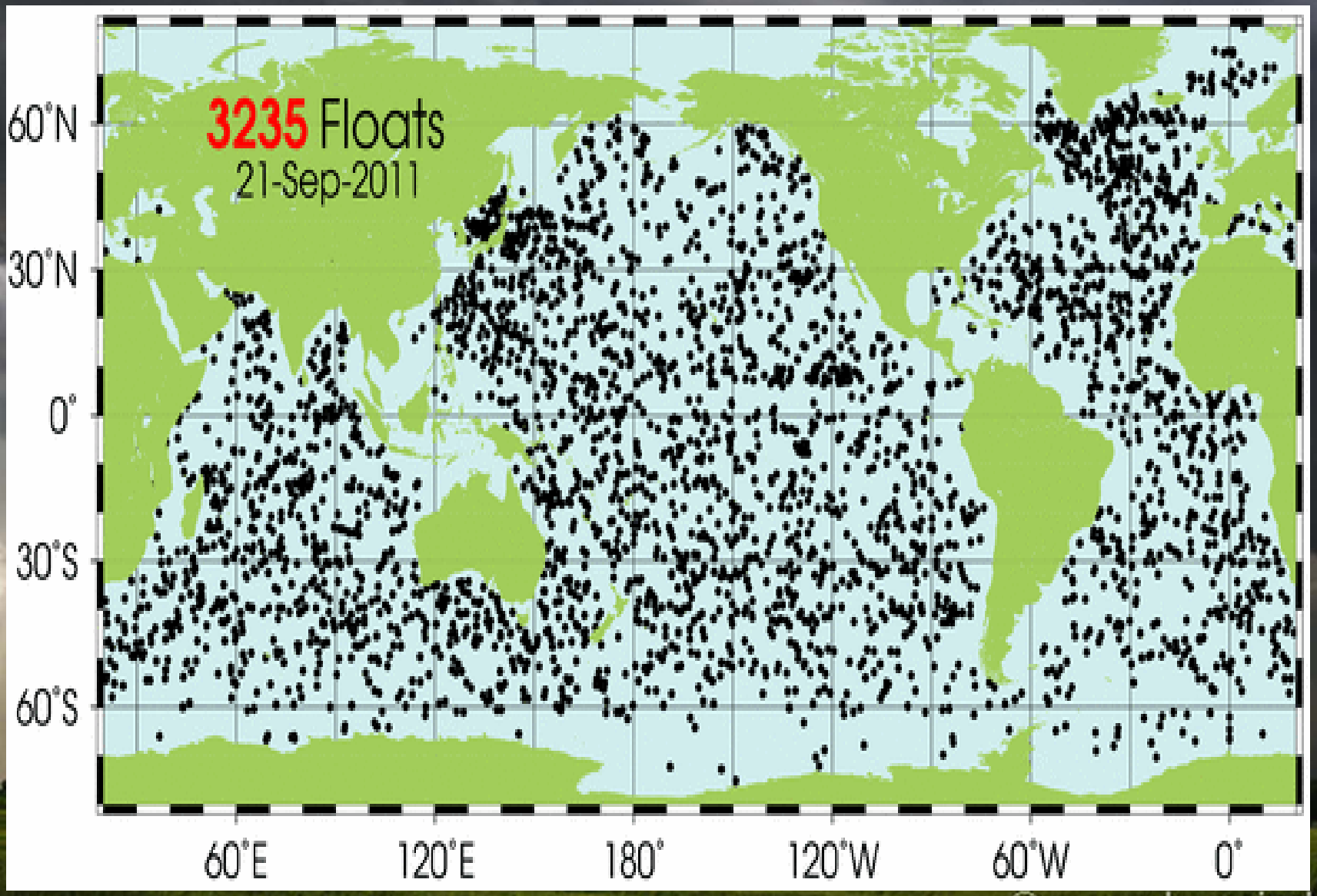


Statement by Jim Hansen

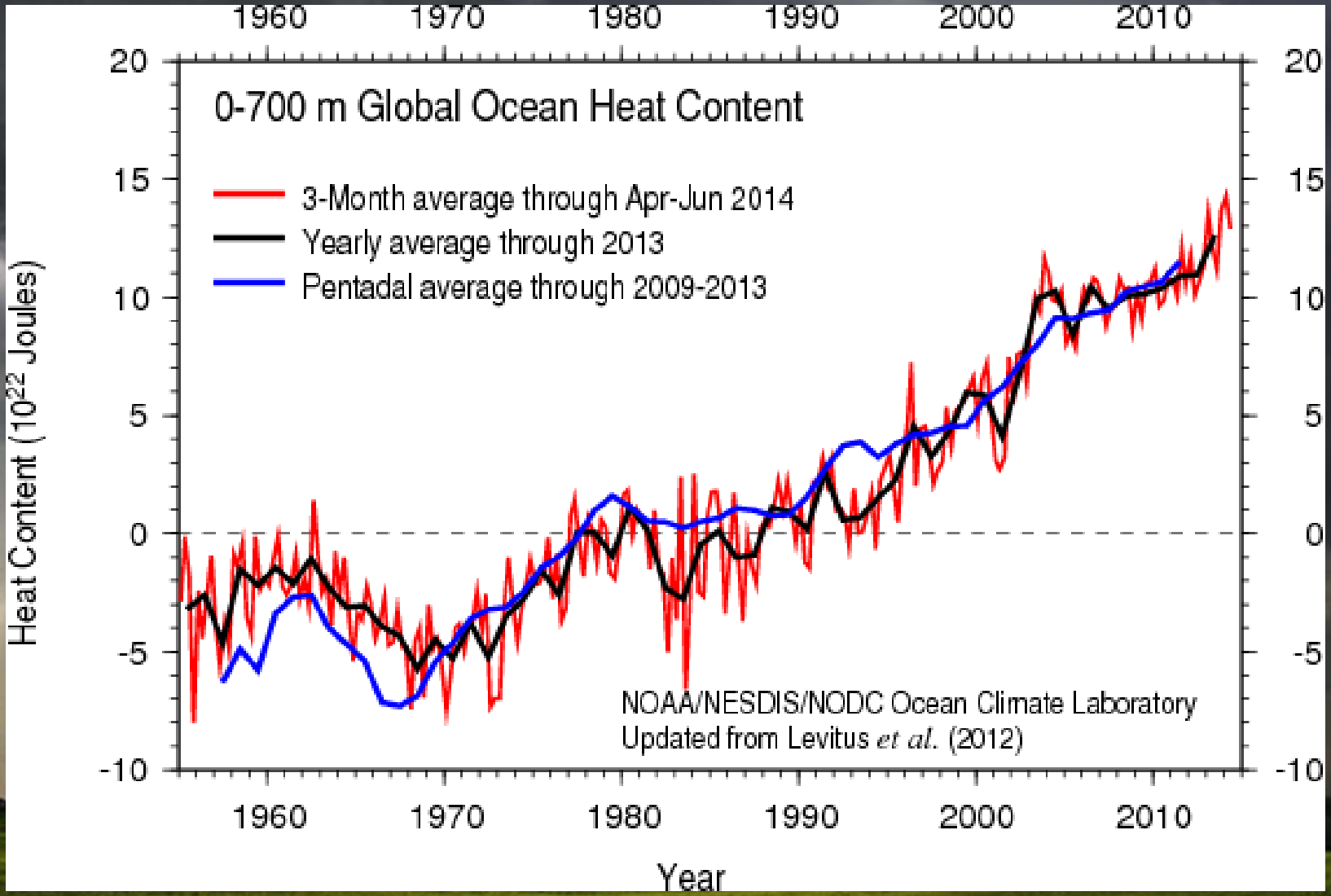
"Our simulated 1993-2003 heat storage rate was 0.6 W/m^2 in the upper 750 m of the ocean The decadal mean planetary energy imbalance, 0.75 W/m^2, includes heat storage in the deeper ocean and energy used to melt ice and warm the air and land. 0.85 W/m^2 is the imbalance at the end of the decade [end of the 1990s]".

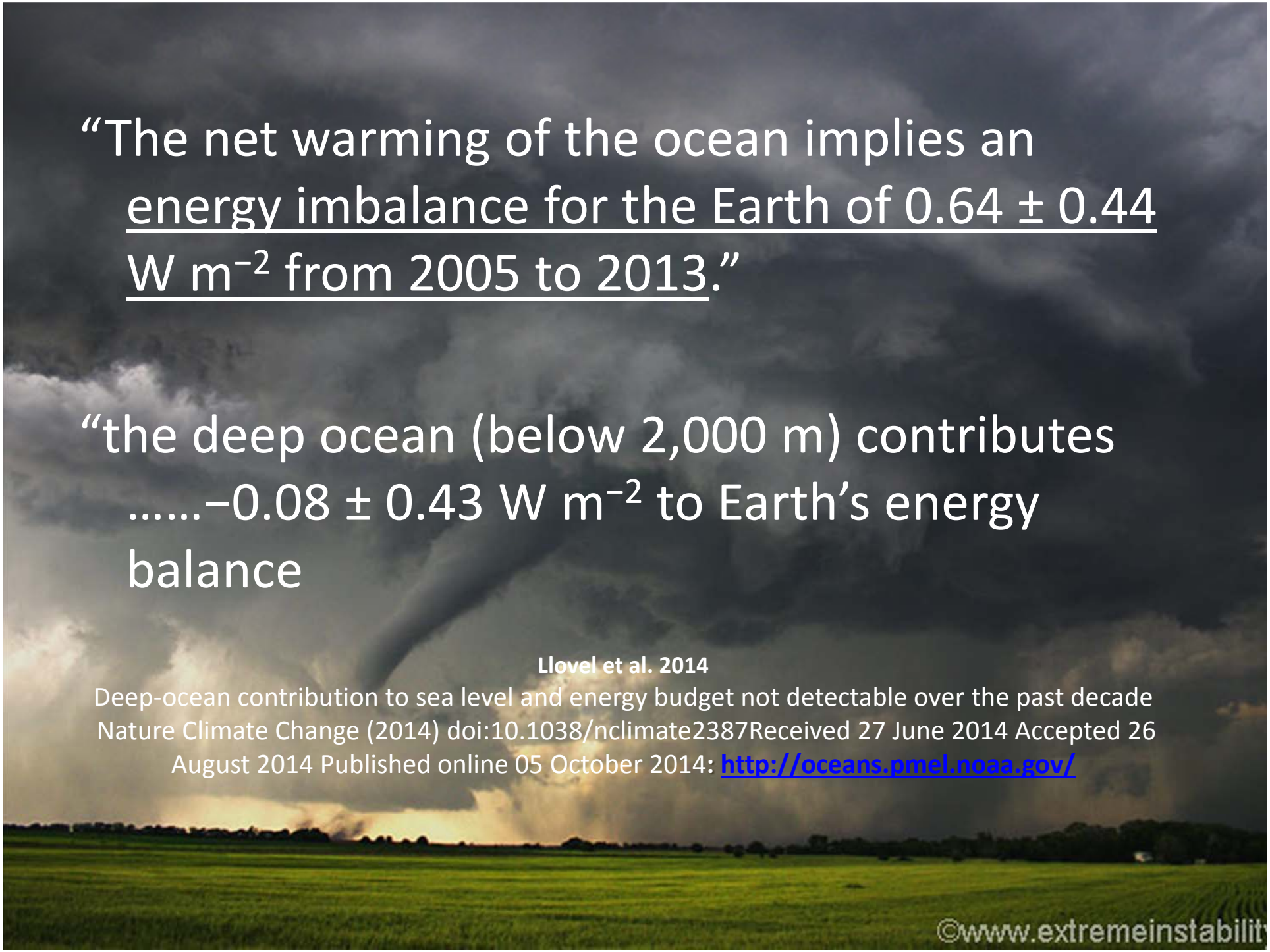
From Jim Hansen, 2005
[http://pielkeclimatesci.files.wordpress.com/2009/09/1116592hansen.pdf]

Argo Network



http://www.nodc.noaa.gov/OC5/3M_HEAT_CONTENT/




“The net warming of the ocean implies an energy imbalance for the Earth of 0.64 ± 0.44 W m^{-2} from 2005 to 2013.”
“the deep ocean (below 2,000 m) contributes ……–0.08 ± 0.43 W m^{-2} to Earth’s energy balance
Llovel et al. 2014
Deep-ocean contribution to sea level and energy budget not detectable over the past decade
Nature Climate Change (2014) doi:10.1038/nclimate2387Received 27 June 2014 Accepted 26 August 2014 Published online 05 October 2014: http://oceans.pmel.noaa.gov/
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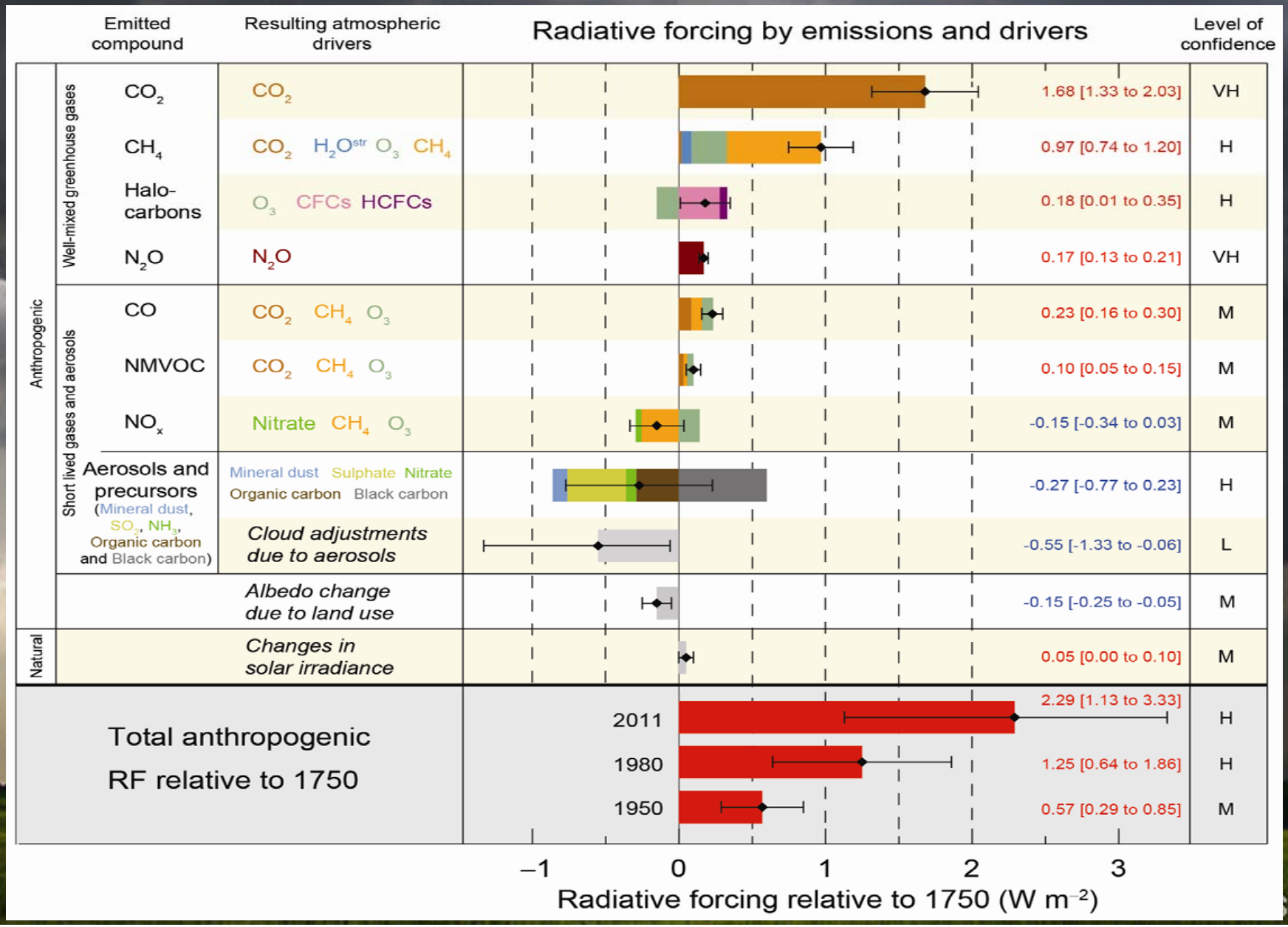
Levitus et al. (2012) reported that since 1955, the layer from the surface to 2000 m depth had a warming rate of 0.39 W m^{-2} ± 0.031 W m^{-2} per unit area of the Earth's surface which accounts for approximately 90% of the warming of the climate system. Thus, if we add the 10%, the 1955-2010 warming rate is 0.43 W m^{-2} ± 0.031 W m^{-2}.

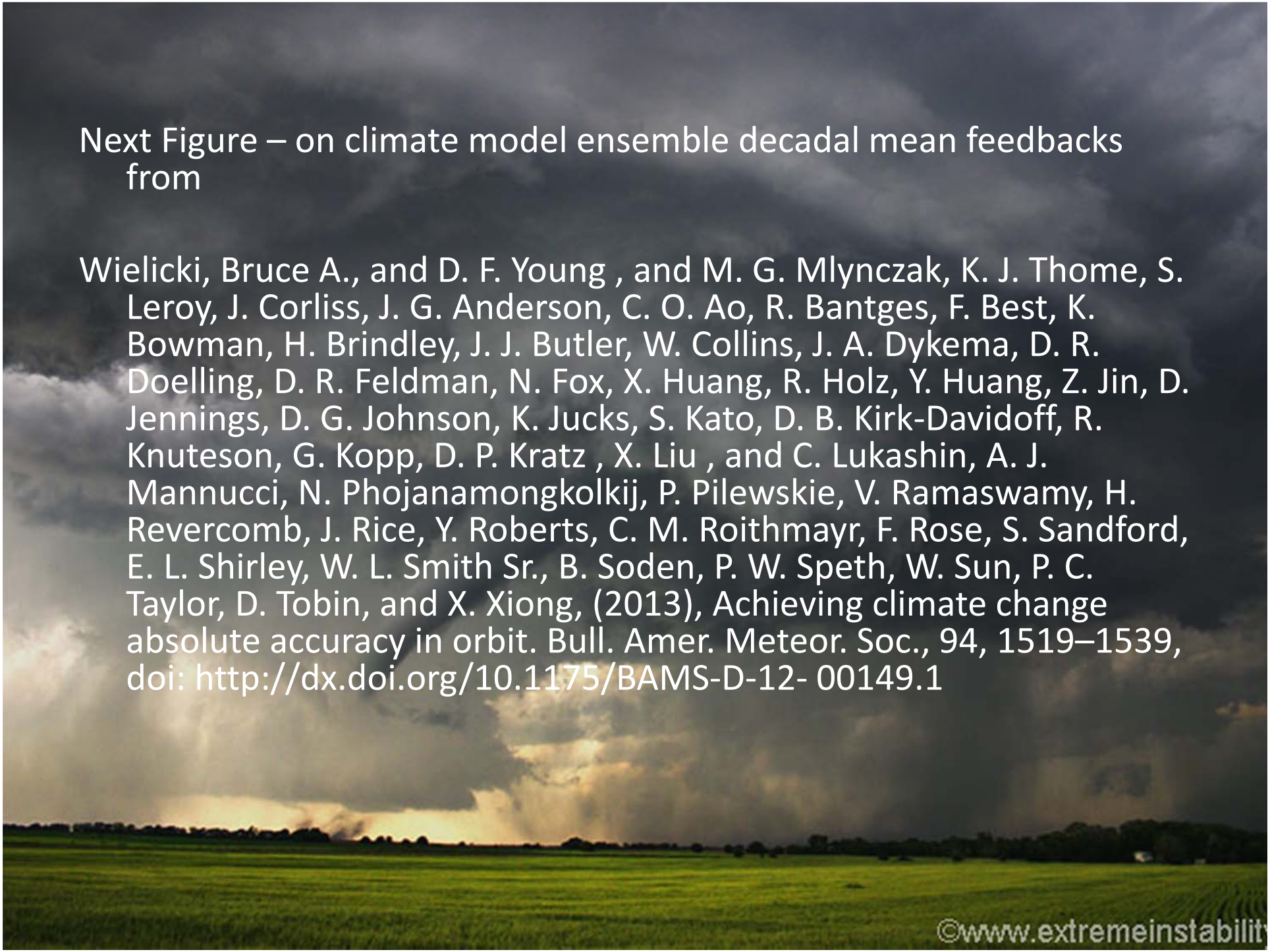
Levitus, S., J. I. Antonov, T. P. Boyer, O. K. Baranova, H. E. Garcia, R. A. Locarnini, A. V. Mishonov, J. Reagan, D. Seidov, E. S. Yarosh, M. M. Zweng (2012), World ocean heat content and thermosteric sea level change (0-2000), 1955-2010, Geophys. Res.


Global Radiative Imbalance = Global Radiative Forcings + Global Radiative Feedbacks
Radiative Forcing and Feedbacks are defined here as Radiative Flux Divergences on All Time Scales.
©www.extremeinstabilit


The Global Averaged Radiative Forcings
©www.extremeinstabilit

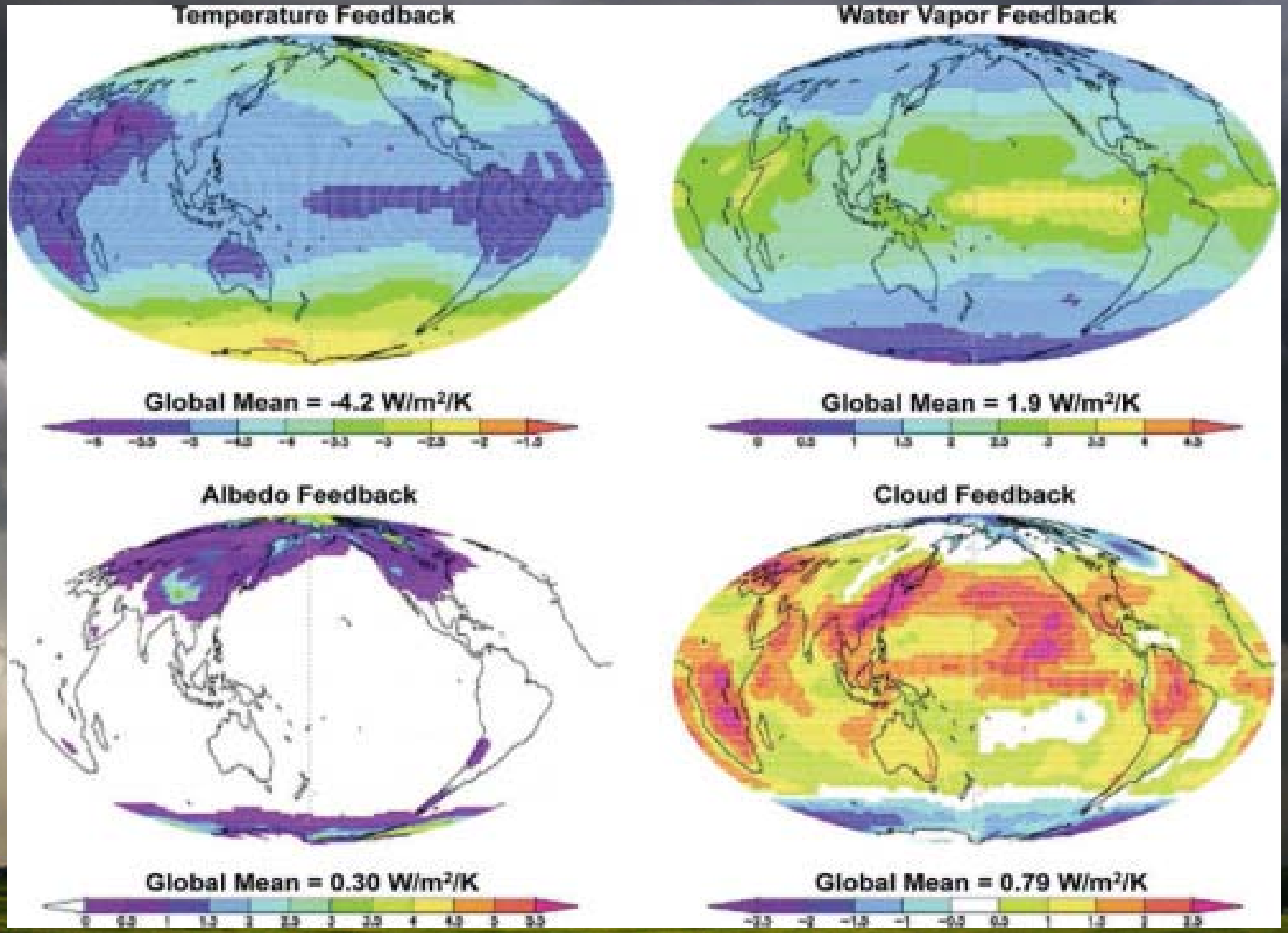
http://www.climatechange2013.org/report/reports-graphic/report-graphics/





Next Figure – on climate model ensemble decadal mean feedbacks from

Wielicki, Bruce A., and D. F. Young , and 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 , and 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, (2013), Achieving climate change absolute accuracy in orbit. Bull. Amer. Meteor. Soc., 94, 1519–1539, doi: http://dx.doi.org/10.1175/BAMS-D-12- 00149.1



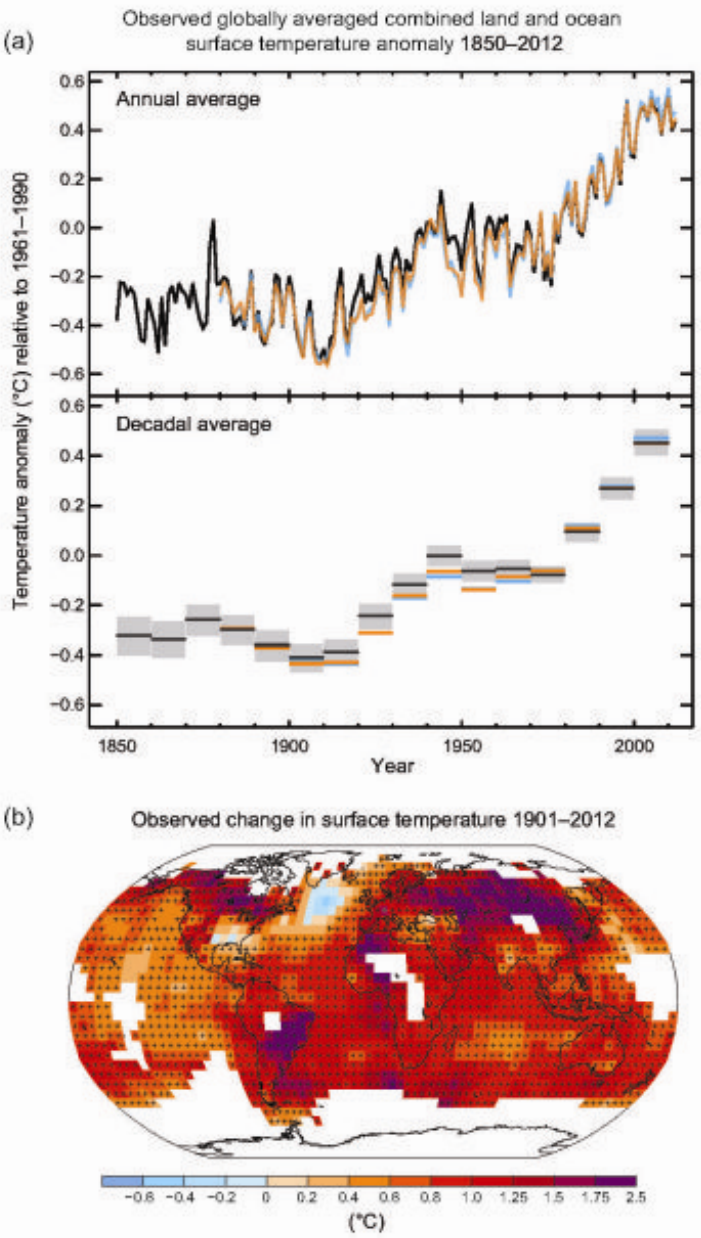
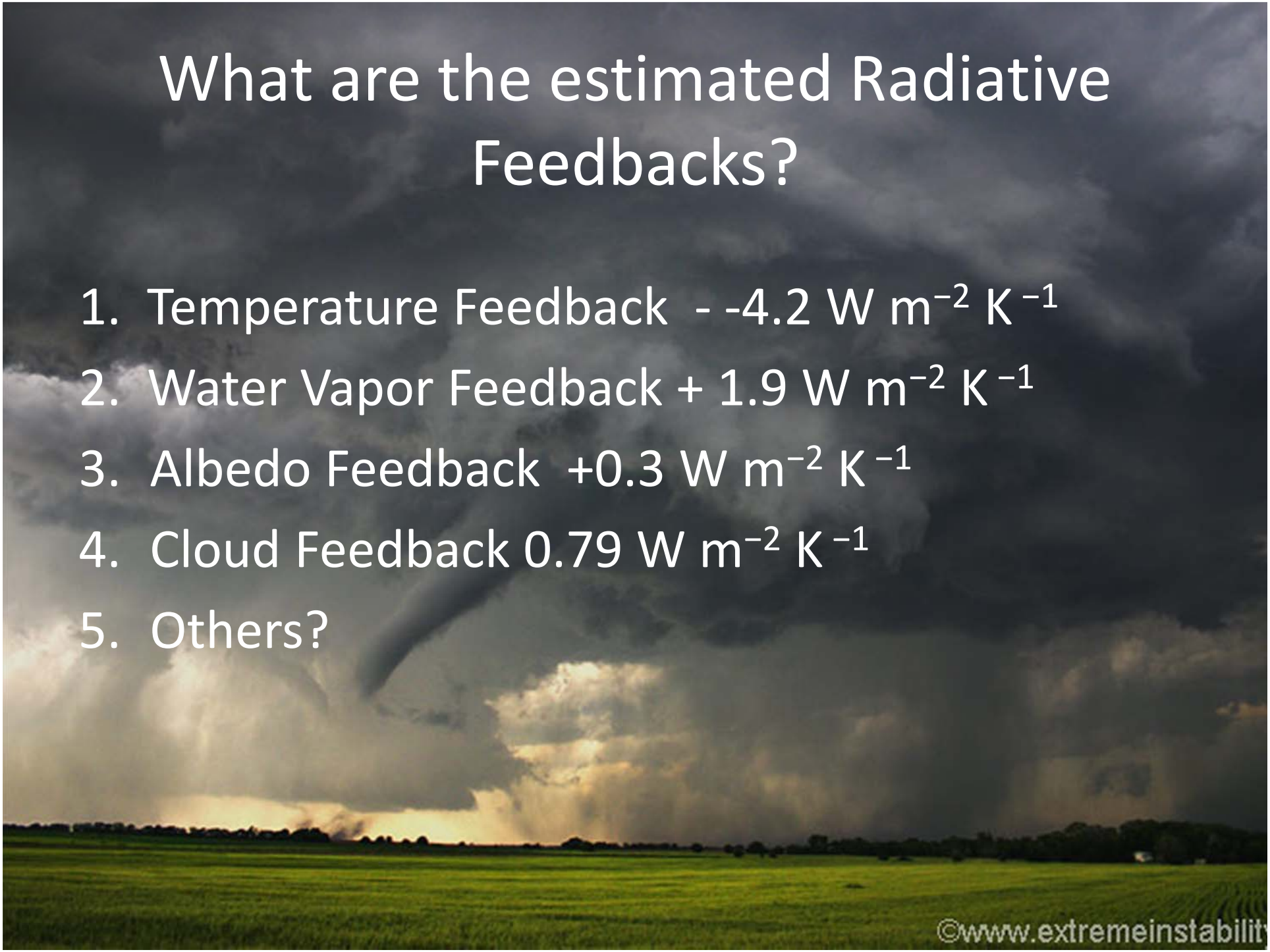
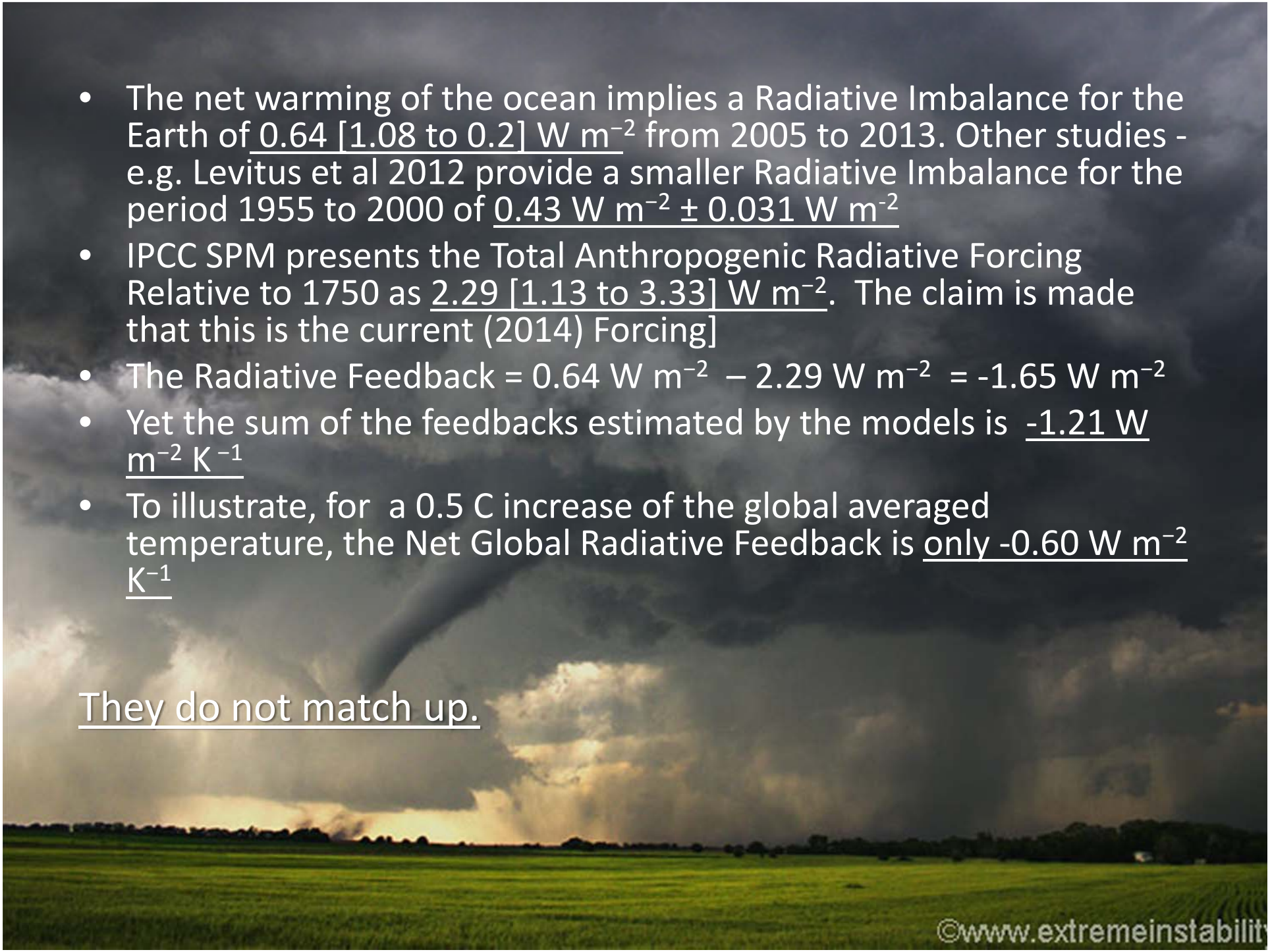


Figure SPM.1 | (a) Observed global mean combined land and ocean surface temperature anomalies, from 1850 to 2012 from three data sets. Top panel: annual mean values. Bottom panel: decadal mean values including the estimate of uncertainty for one dataset (black). Anomalies are relative to the mean of 1961–1990. (b) Map of the observed surface temperature change from 1901 to 2012 derived from temperature trends determined by linear regression from one dataset (orange line in panel a). Trends have been calculated where data availability permits a robust estimate (i.e., only for grid boxes with greater than 70% complete records and more than 20% data availability in the first and last 10% of the time period). Other areas are white. Grid boxes where the trend is significant at the 10% level are indicated by a + sign. For a listing of the datasets and further technical details see the Technical Summary Supplementary Material. (Figures 2.19–2.21; Figure TS.2)

What are the estimated Radiative Feedbacks?

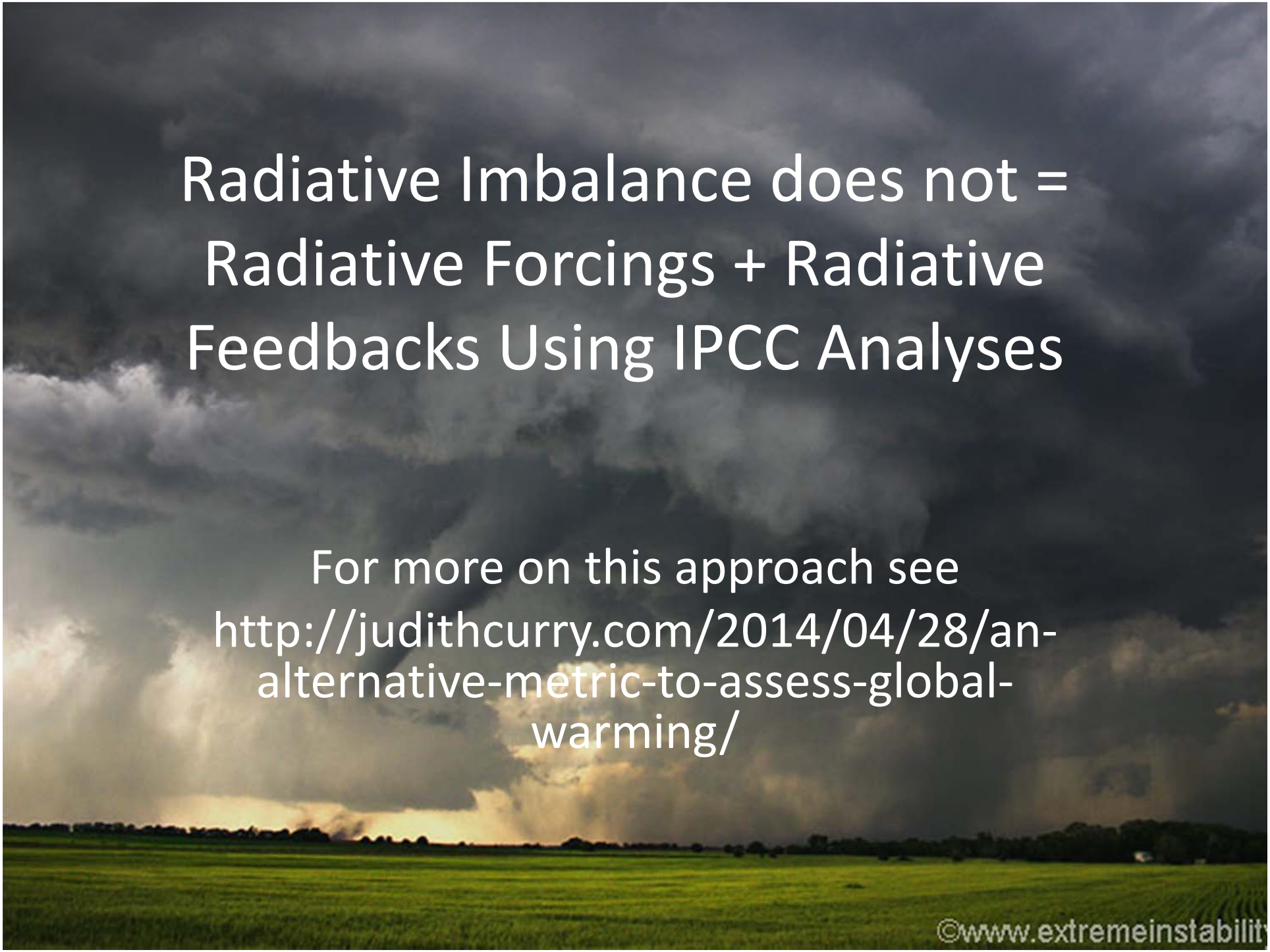
1. Temperature Feedback - -4.2 W m^{-2} K^{-1}
2. Water Vapor Feedback + 1.9 W m^{-2} K^{-1}
3. Albedo Feedback +0.3 W m^{-2} K^{-1}
4. Cloud Feedback 0.79 W m^{-2} K^{-1}
5. Others?

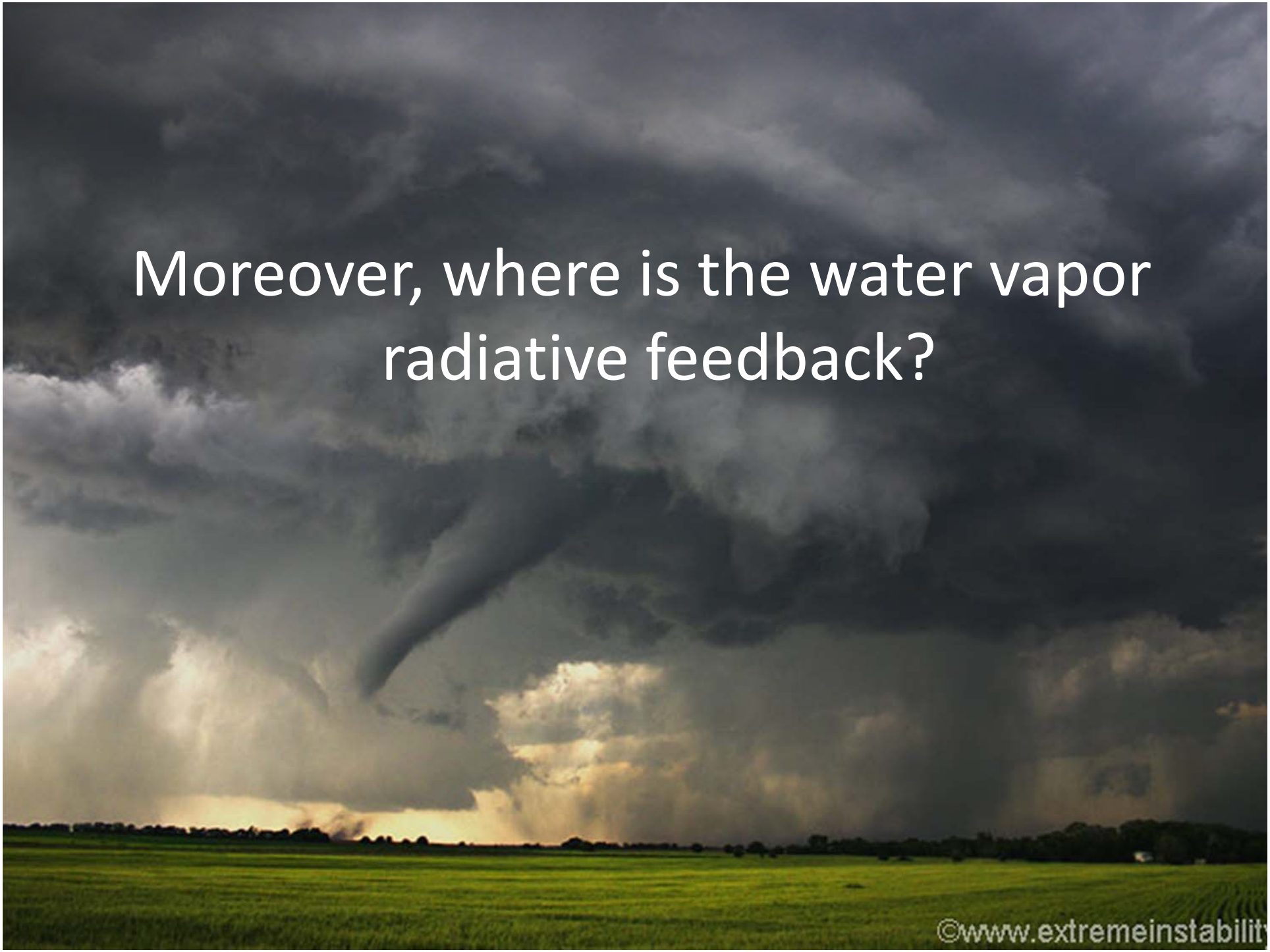




- The net warming of the ocean implies a Radiative Imbalance for the Earth of 0.64 [1.08 to 0.2] W m^{-2} from 2005 to 2013. Other studies - e.g. Levitus et al 2012 provide a smaller Radiative Imbalance for the period 1955 to 2000 of 0.43 W m^{-2} ± 0.031 W m^{-2}
- IPCC SPM presents the Total Anthropogenic Radiative Forcing Relative to 1750 as 2.29 [1.13 to 3.33] W m^{-2}. The claim is made that this is the current (2014) Forcing]
- The Radiative Feedback = 0.64 W m^{-2} – 2.29 W m^{-2} = -1.65 W m^{-2}
- Yet the sum of the feedbacks estimated by the models is -1.21 W m^{-2} K^{-1}
- To illustrate, for a 0.5 C increase of the global averaged temperature, the Net Global Radiative Feedback is only -0.60 W m^{-2} K^{-1}

They do not match up.


Radiative Imbalance does not = Radiative Forcings + Radiative Feedbacks Using IPCC Analyses
For more on this approach see http://judithcurry.com/2014/04/28/an-alternative-metric-to-assess-global-warming/
©www.extremeinstabilit


Moreover, where is the water vapor radiative feedback?
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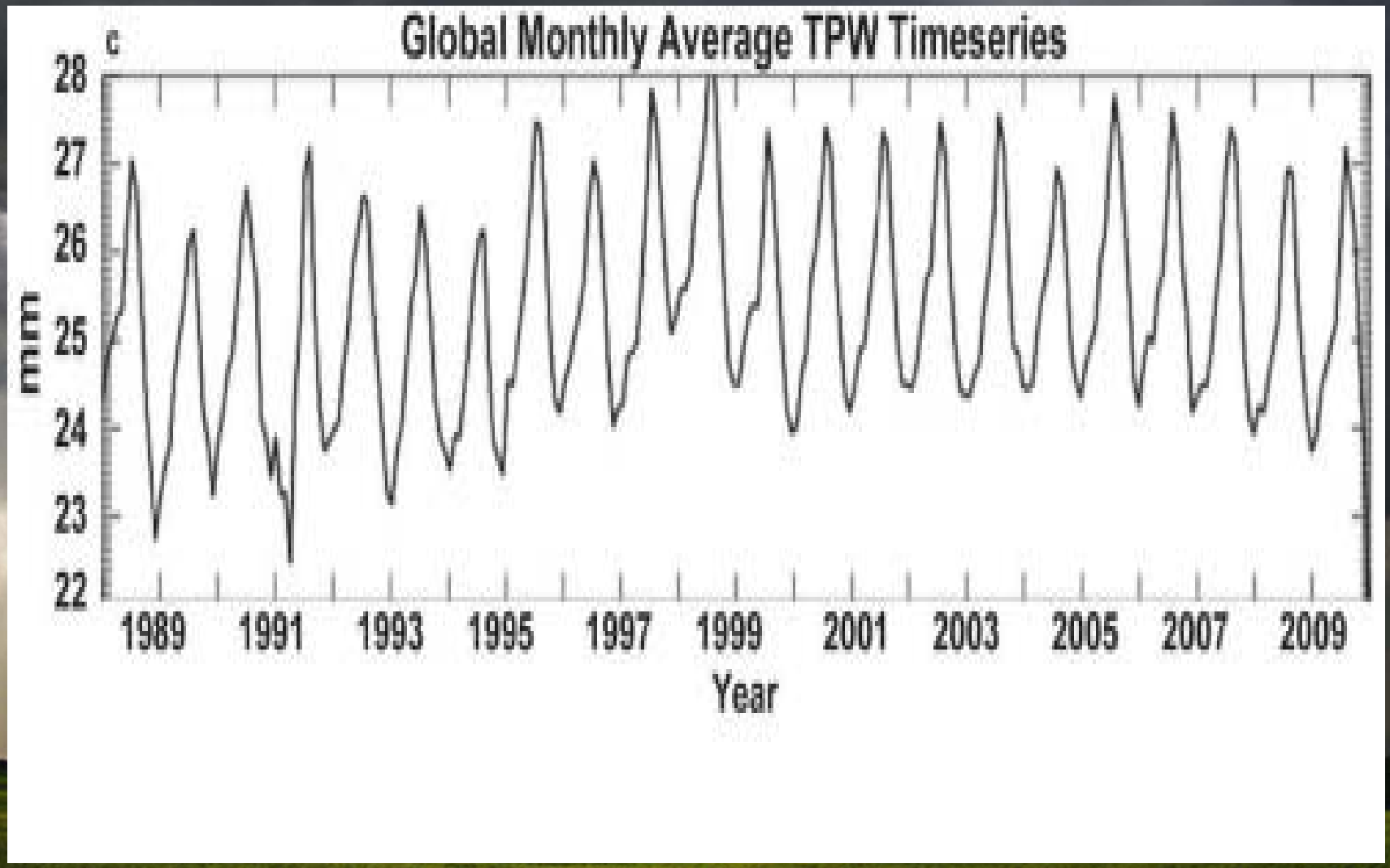
Vonder Haar, T. H., J. Bytheway, and J. M. Forsythe (2012), Weather and climate analyses using improved global water vapor observations, Geophys. Res. Lett.,doi:10.1029/2012GL052094.




Real world data also shows a more complex behavior than is commonly communicated by the media and in professional society statements.
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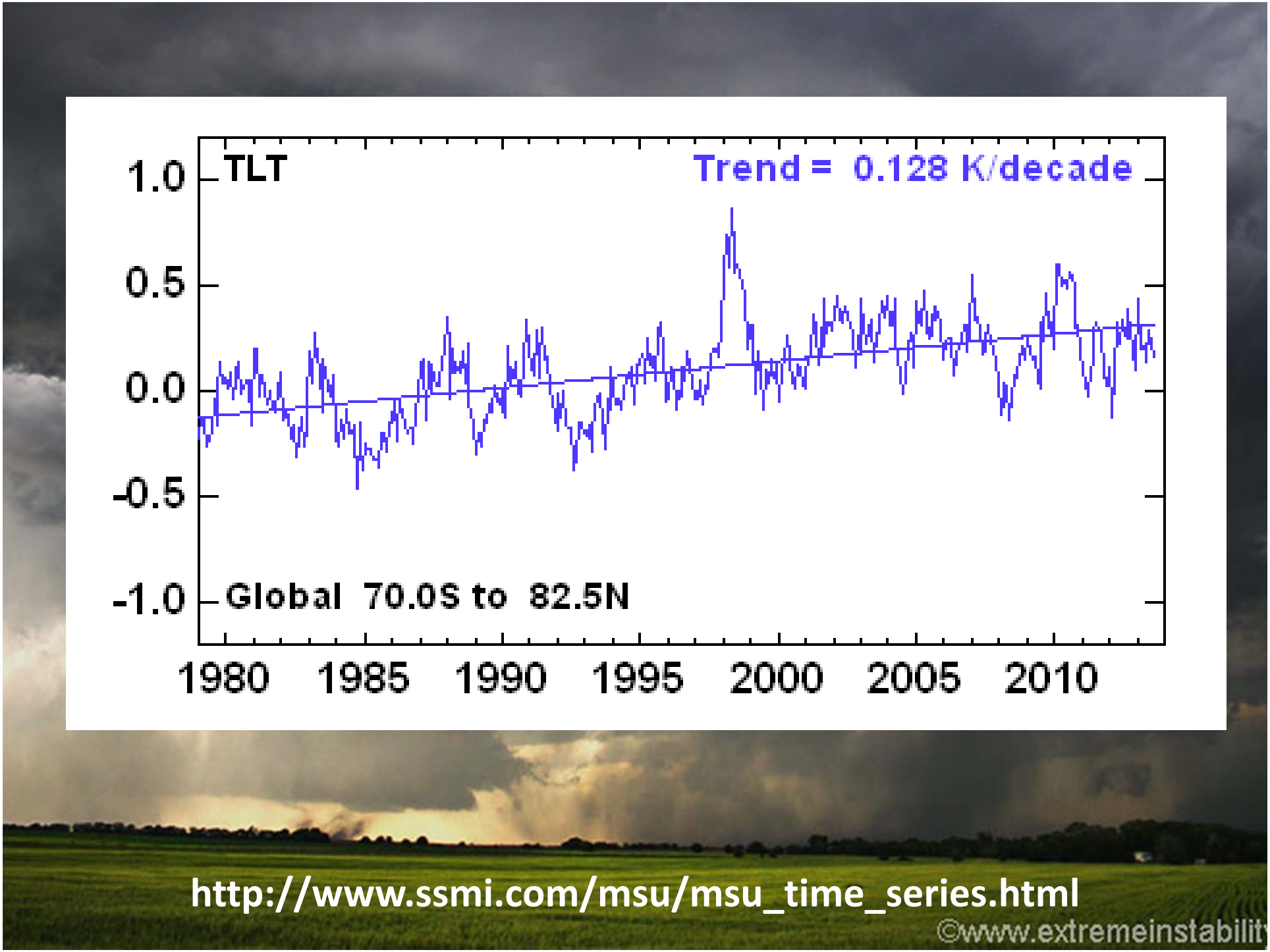
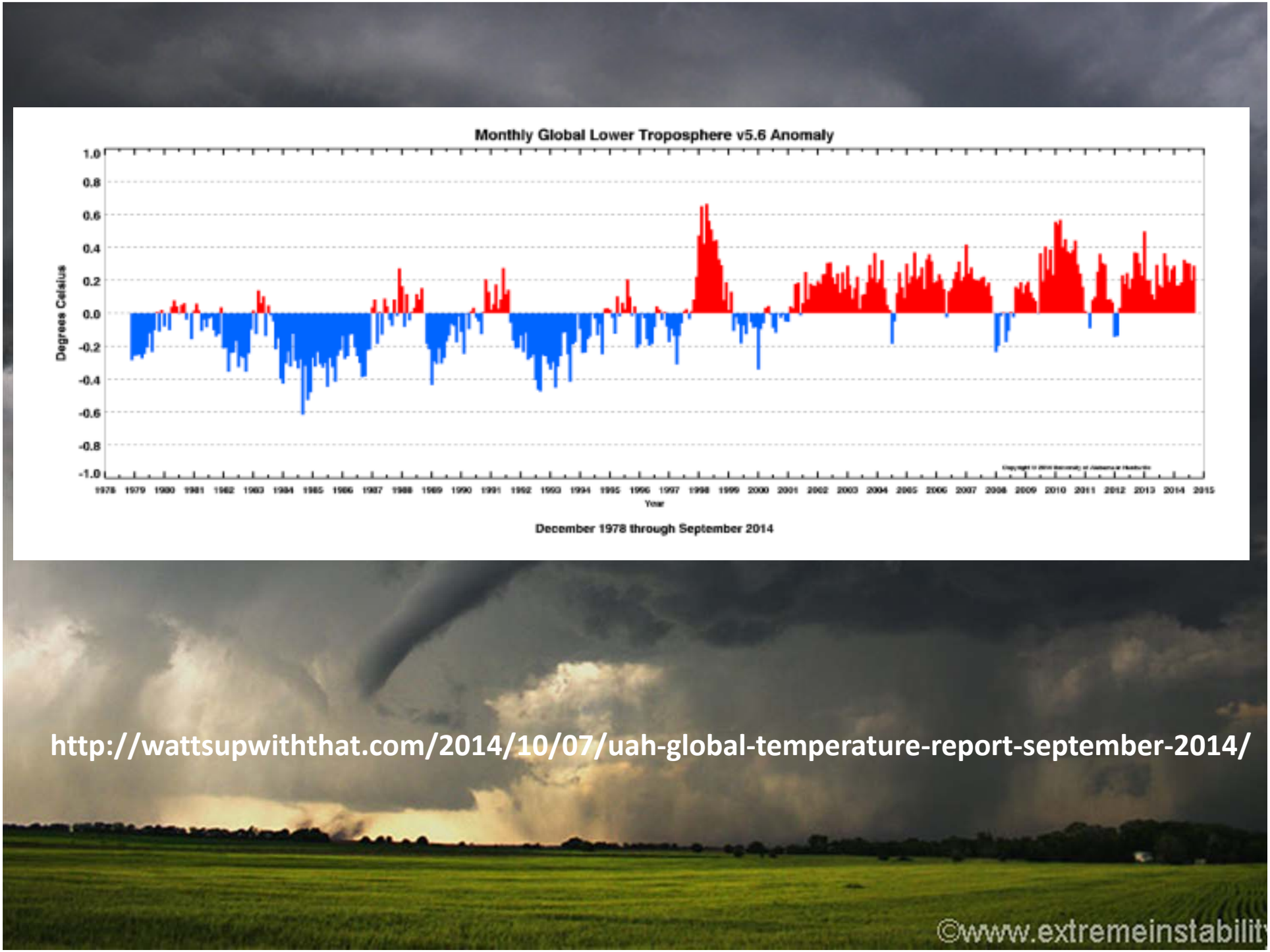
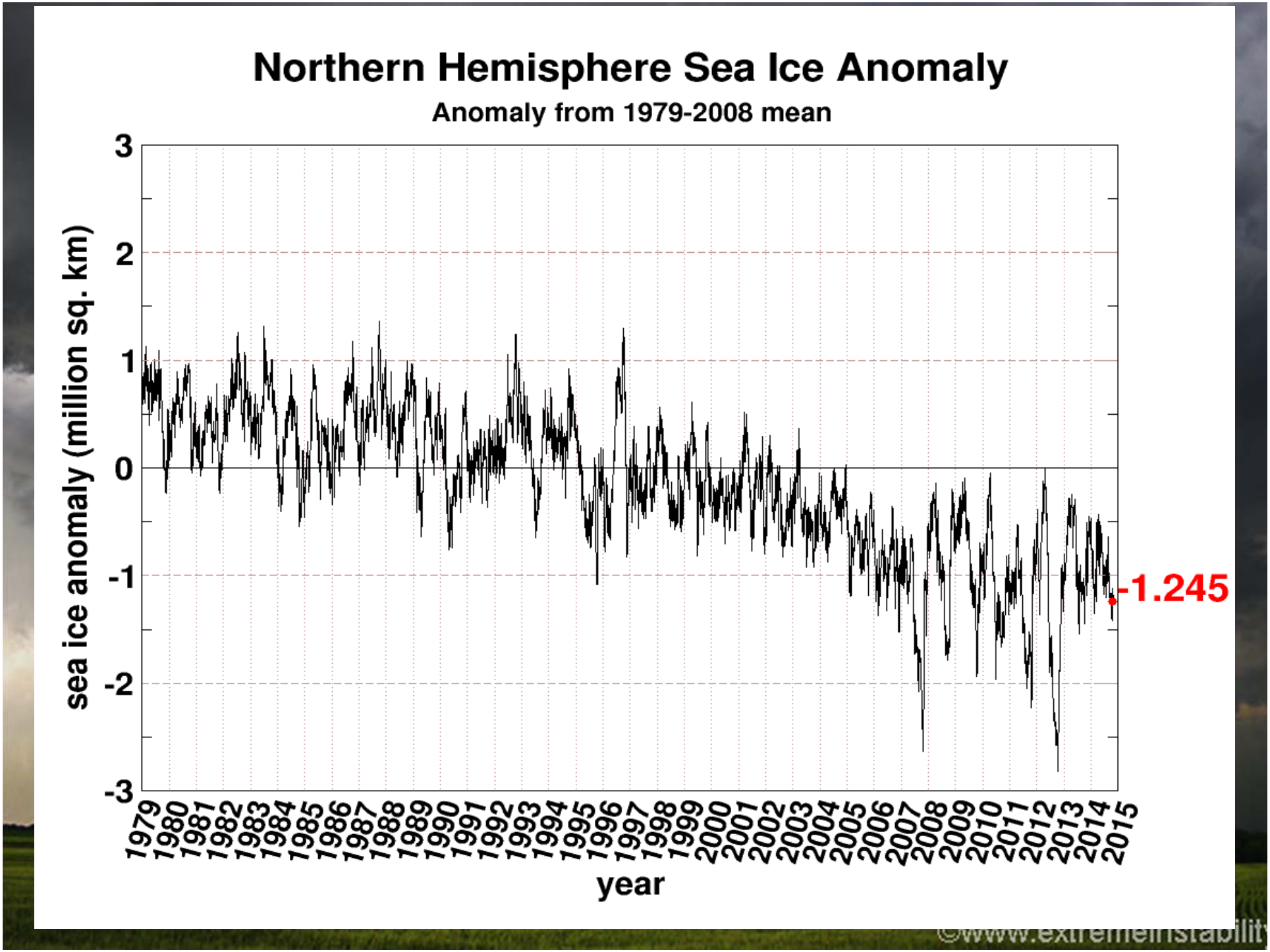

TLT
Trend = 0.128 K/decade
1.0
0.5
0.0
-0.5
-1.0
Global 70.0S to 82.5N
1980
1985
1990
1995
2000
2005
2010
http://www.ssmi.com/msu/msu_time_series.html
©www.extremeinstabilit


Monthly Global Lower Troposphere v5.6 Anomaly
Degrees Celsius
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Year
December 1978 through September 2014
http://wattsupwiththat.com/2014/10/07/uah-global-temperature-report-september-2014/
©www.extremeinstabilit


Northern Hemisphere Sea Ice Anomaly
Anomaly from 1979-2008 mean
sea ice anomaly (million sq. km)
3
2
1
0
-1
-2
-3
-1.245
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
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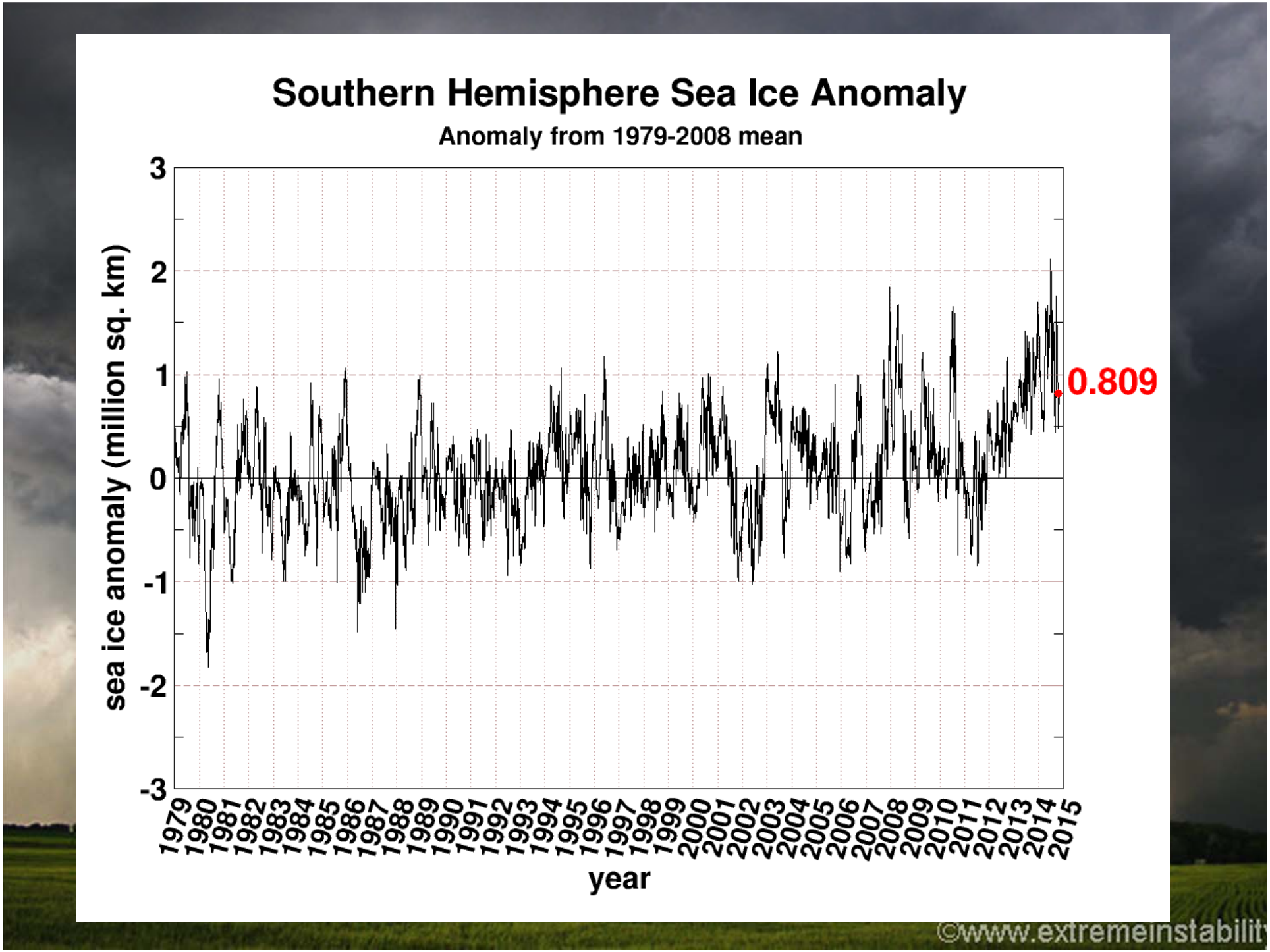
2007
2008
2009
2010
2011
2012
2013
2014
2015
year


Southern Hemisphere Sea Ice Anomaly
Anomaly from 1979-2008 mean
sea ice anomaly (million sq. km)
3
2
1
0
-1
-2
-3
0.809
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
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2012
2013
2014
2015
year
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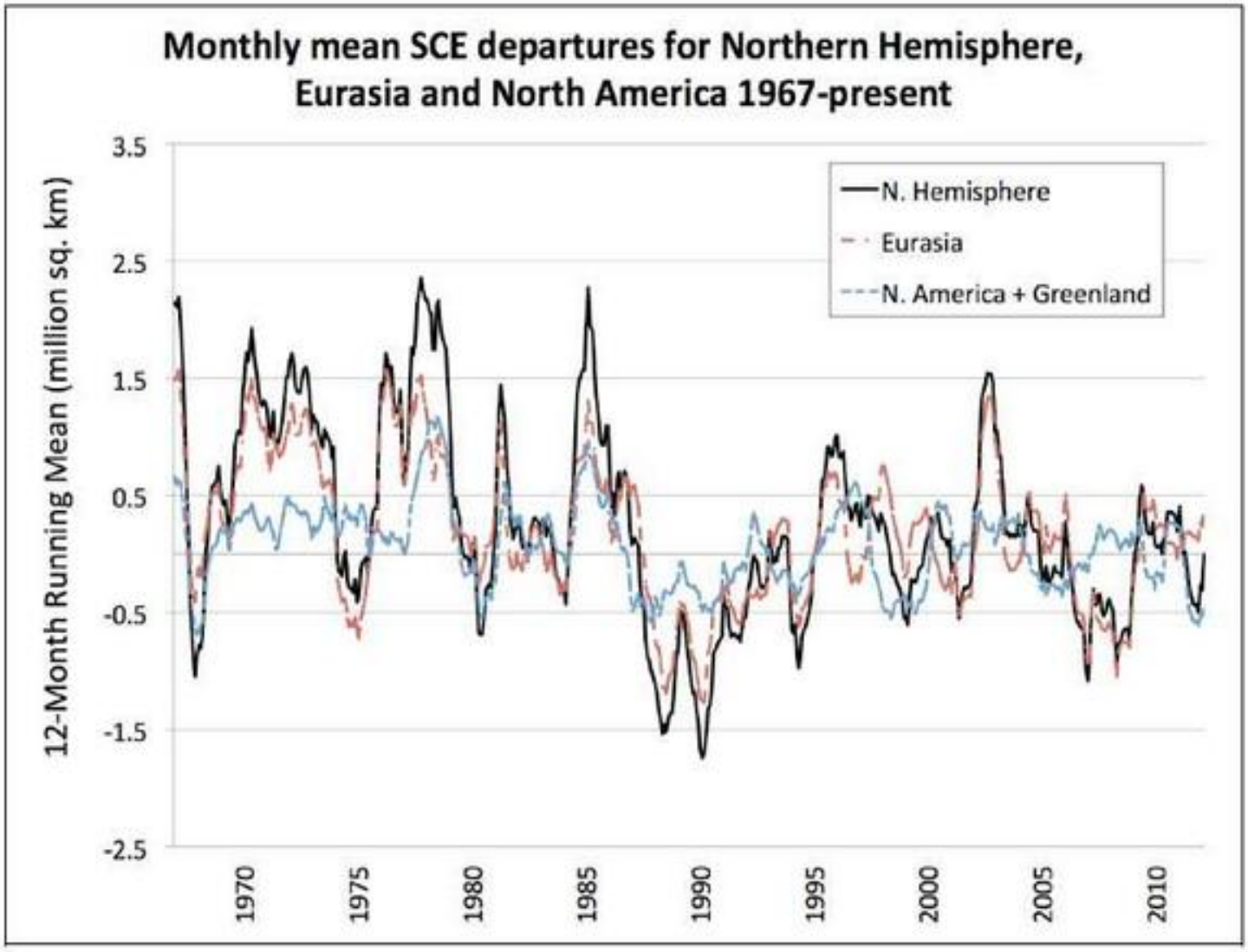
h/t Chris Beale 2013 annual NHem SCE report - Snow Cover




Moreover, climate change is much more than global warming
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However, what is “climate change”?

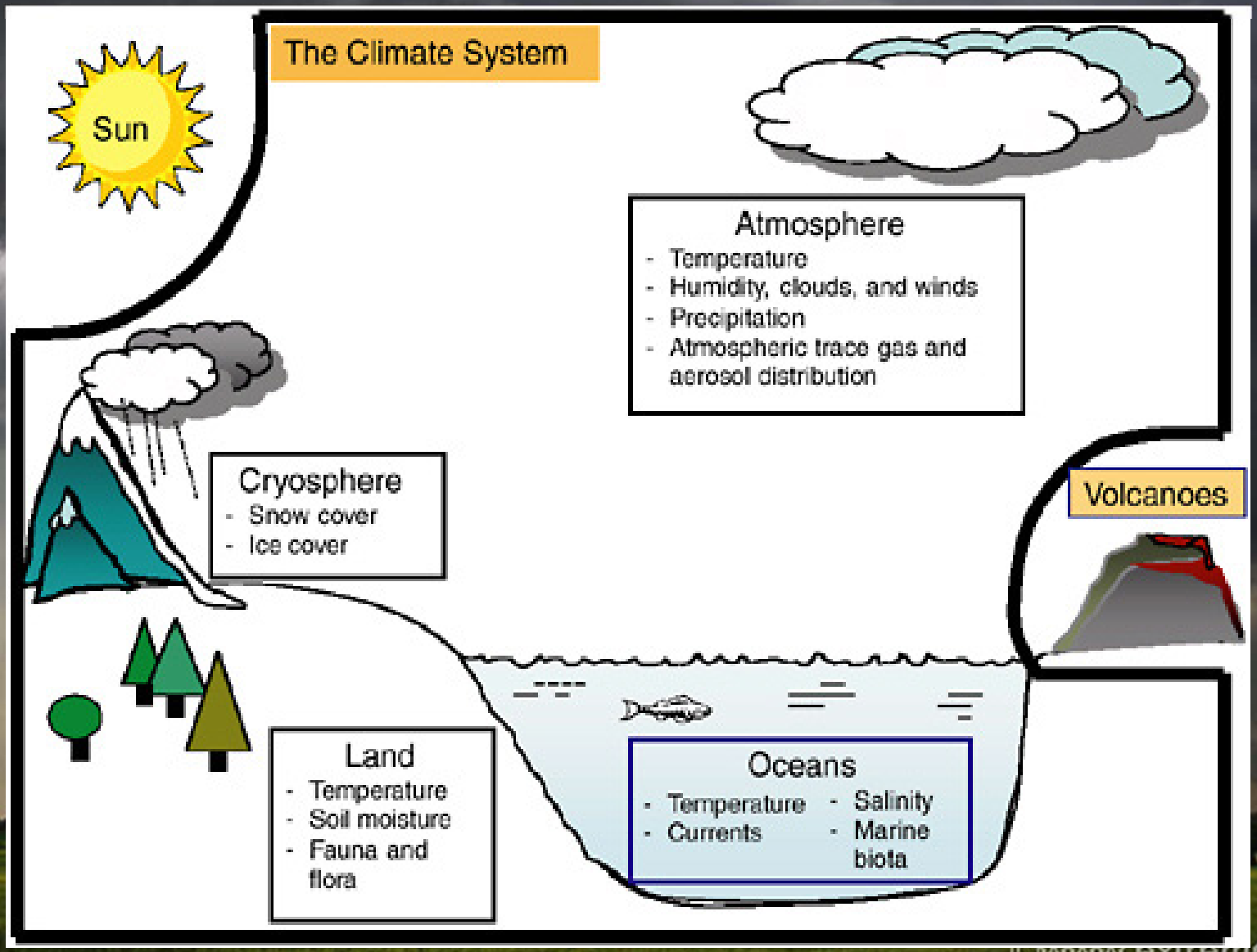
Climate Change is any multi-decadal or longer alteration in one or more physical, chemical and/or biological components of the climate system.

Climate change includes, for example, changes in fauna and flora, snow cover, etc which persist for decades and longer. Climate variability can then be defined as changes which occur on shorter time periods.

Also Climate Is Much More Than Climate Change.

Indeed, the addition of the word “Change” is redundant. Climate is always changing, just like the weather.

Source: National Research Council, 2005: Radiative forcing of climate change: Expanding the concept and addressing uncertainties.

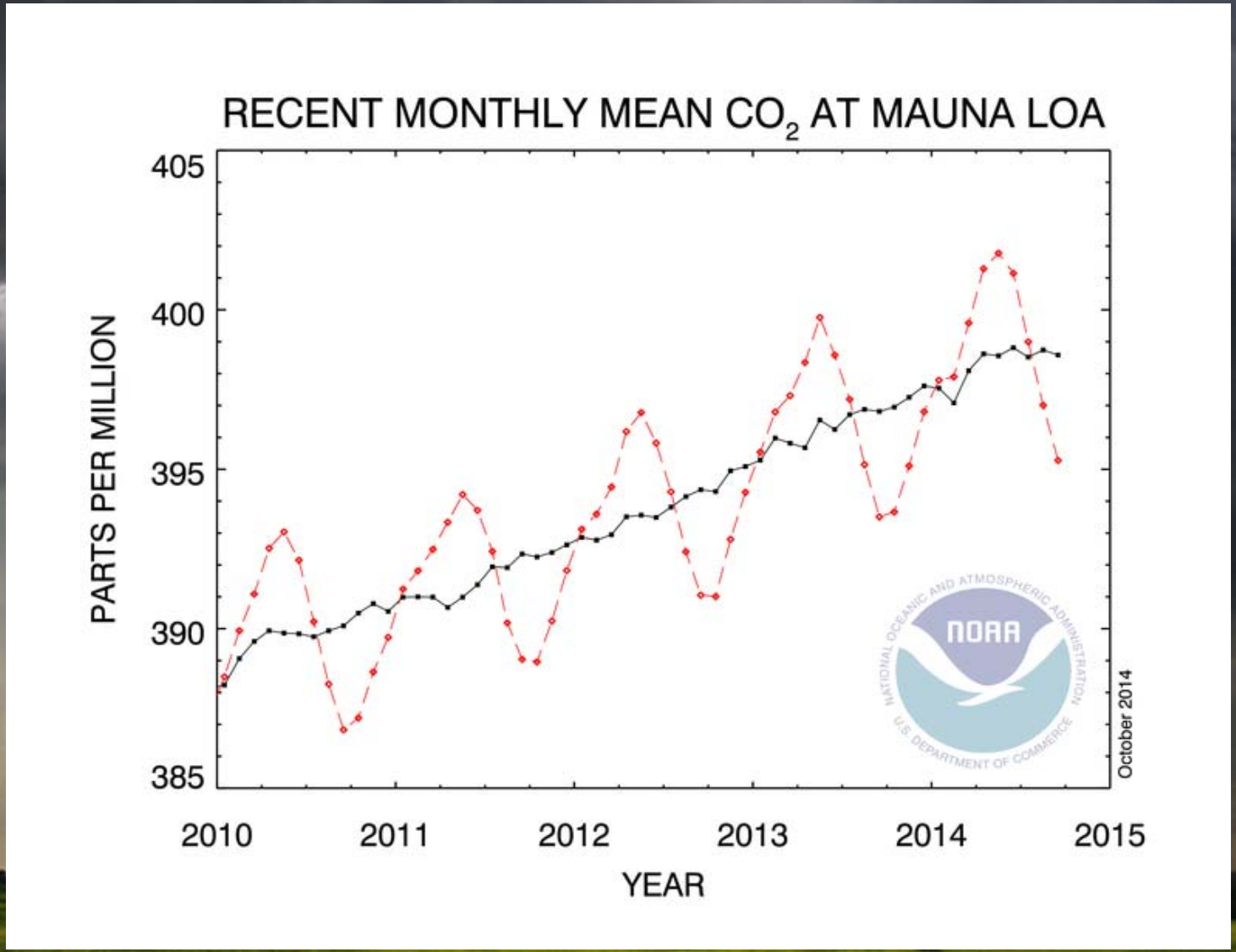


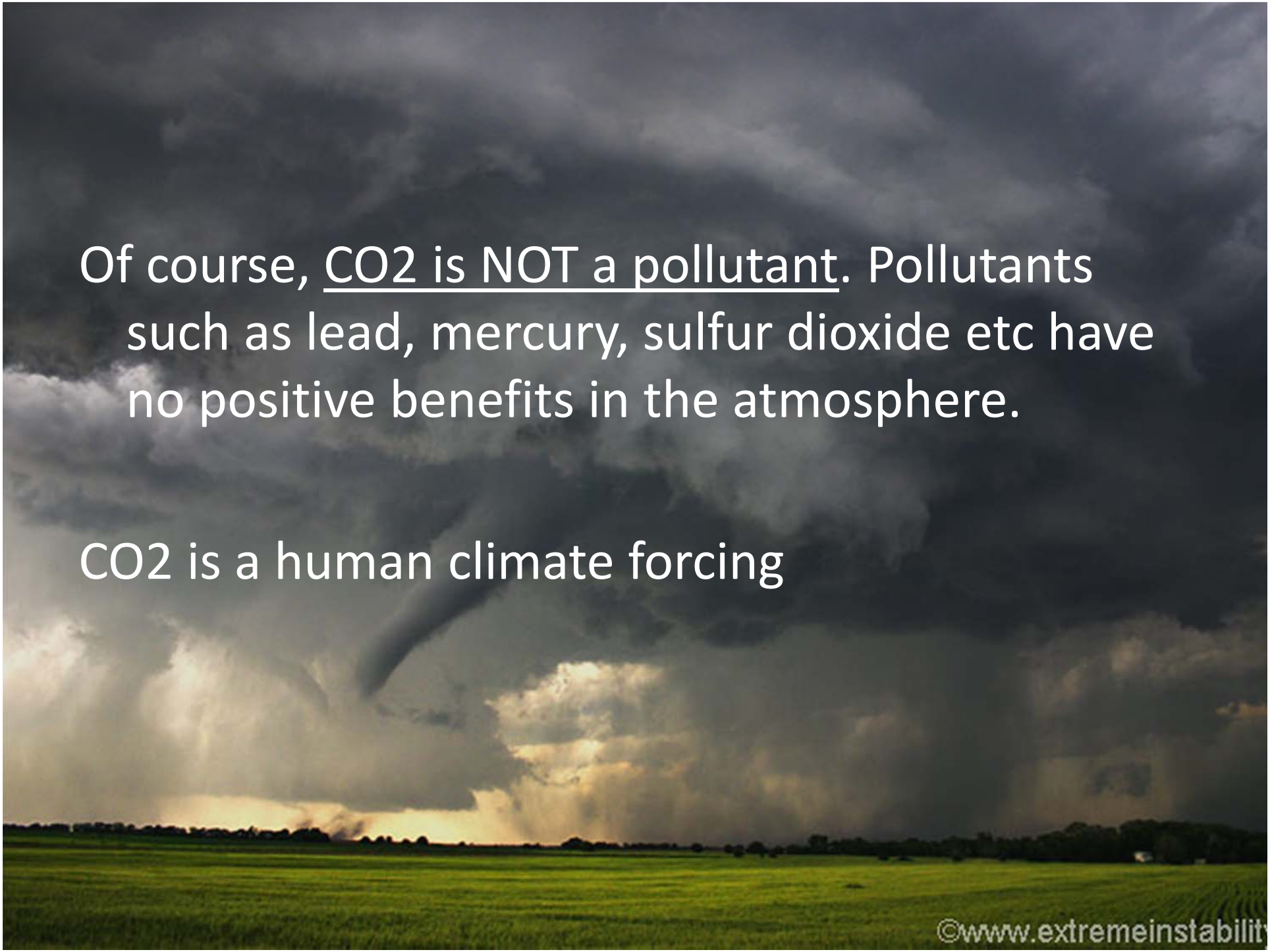
Human Climate Forcings

Human Climate Forcings

- The influence of the human input of CO_2 and other greenhouse gases on regional and global radiative heating
- The influence of human-caused aerosols on regional (and global) radiative heating
- The effect of aerosols on clouds and precipitation
- The influence of aerosol deposition (e.g. soot; nitrogen) on climate
- The effect of land cover/ land use on climate
- The biogeochemical effect of added atmospheric CO_2

http://www.esrl.noaa.gov/gmd/ccgg/trends/




Of course, CO2 is NOT a pollutant. Pollutants such as lead, mercury, sulfur dioxide etc have no positive benefits in the atmosphere.
CO2 is a human climate forcing
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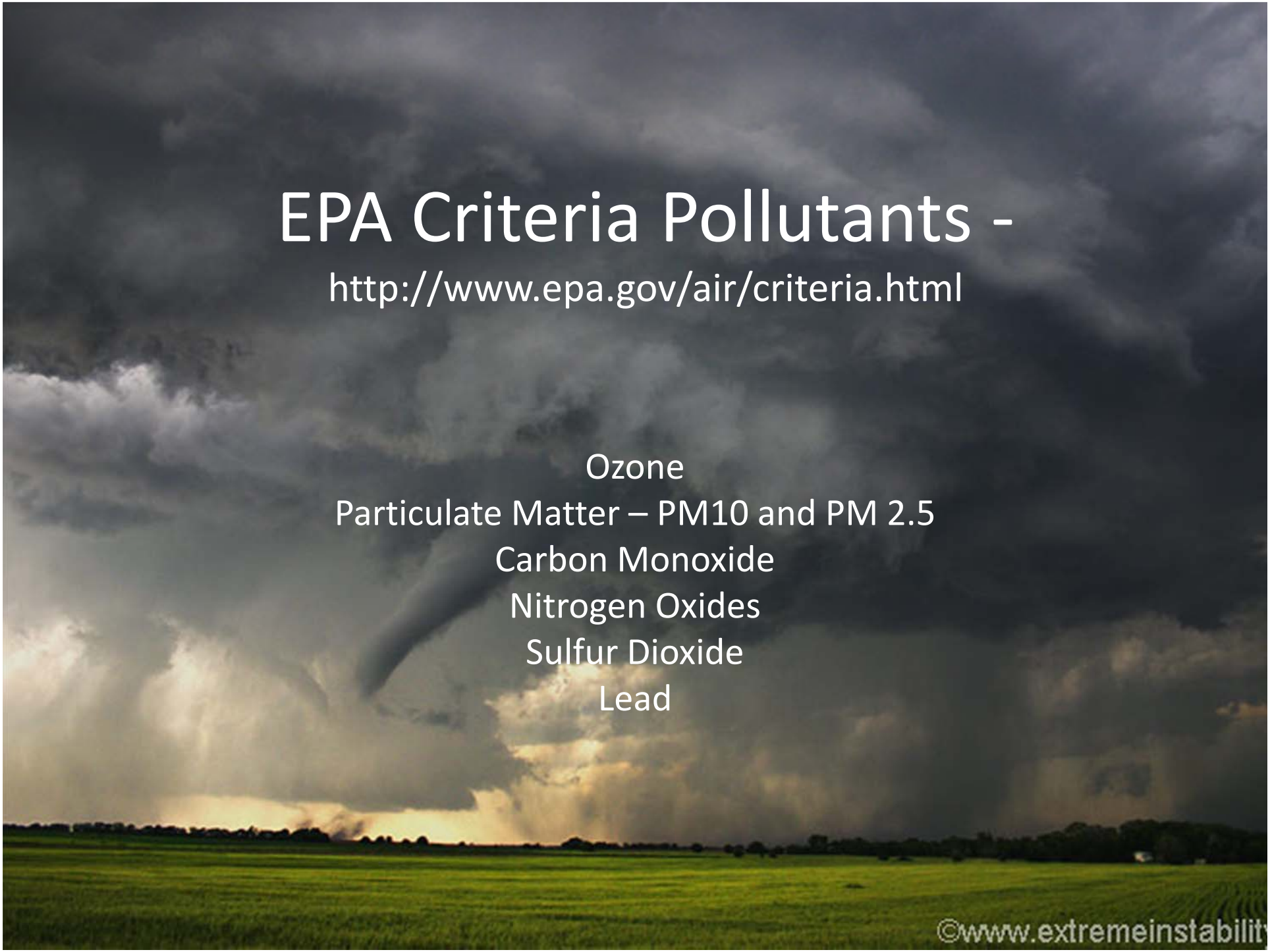
EPA Criteria Pollutants -
http://www.epa.gov/air/criteria.html
Ozone
Particulate Matter – PM10 and PM 2.5
Carbon Monoxide
Nitrogen Oxides
Sulfur Dioxide
Lead
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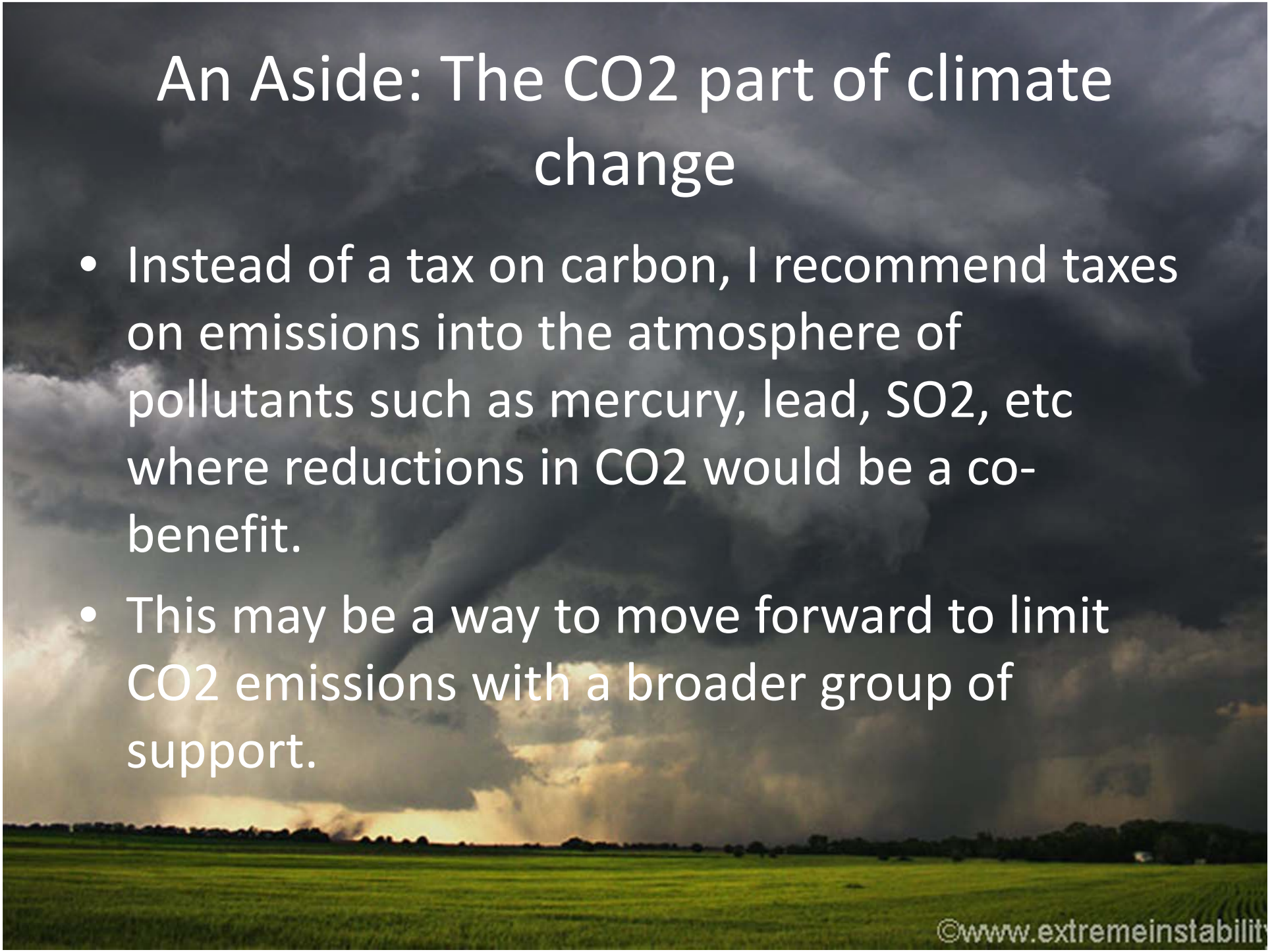

An Aside: The CO2 part of climate change

- Instead of a tax on carbon, I recommend taxes on emissions into the atmosphere of pollutants such as mercury, lead, SO2, etc where reductions in CO2 would be a co-benefit.
- This may be a way to move forward to limit CO2 emissions with a broader group of support.

LAND USE/LAND COVER CHANGE


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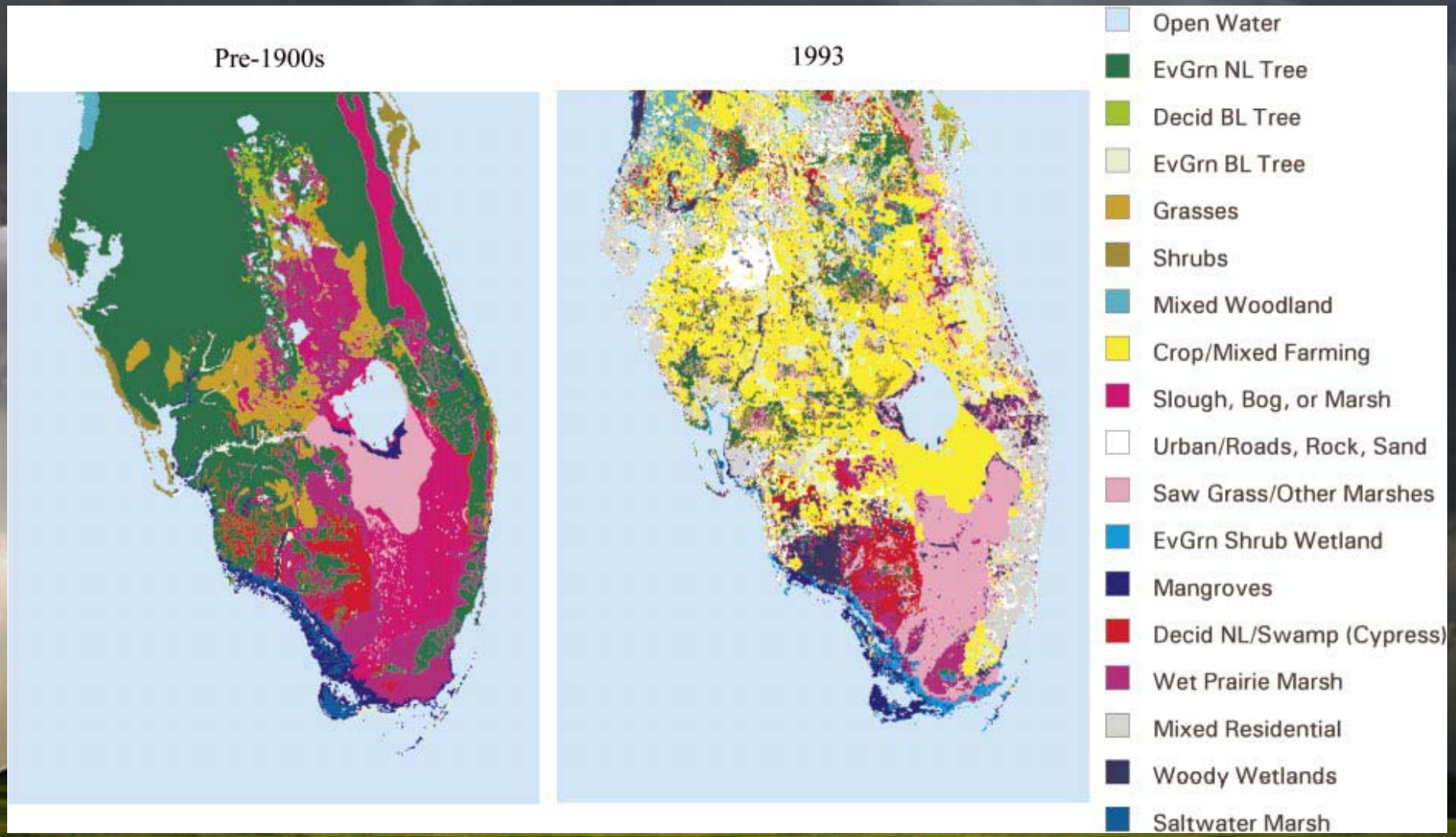
From Marshall et al. 2004




Aerosols
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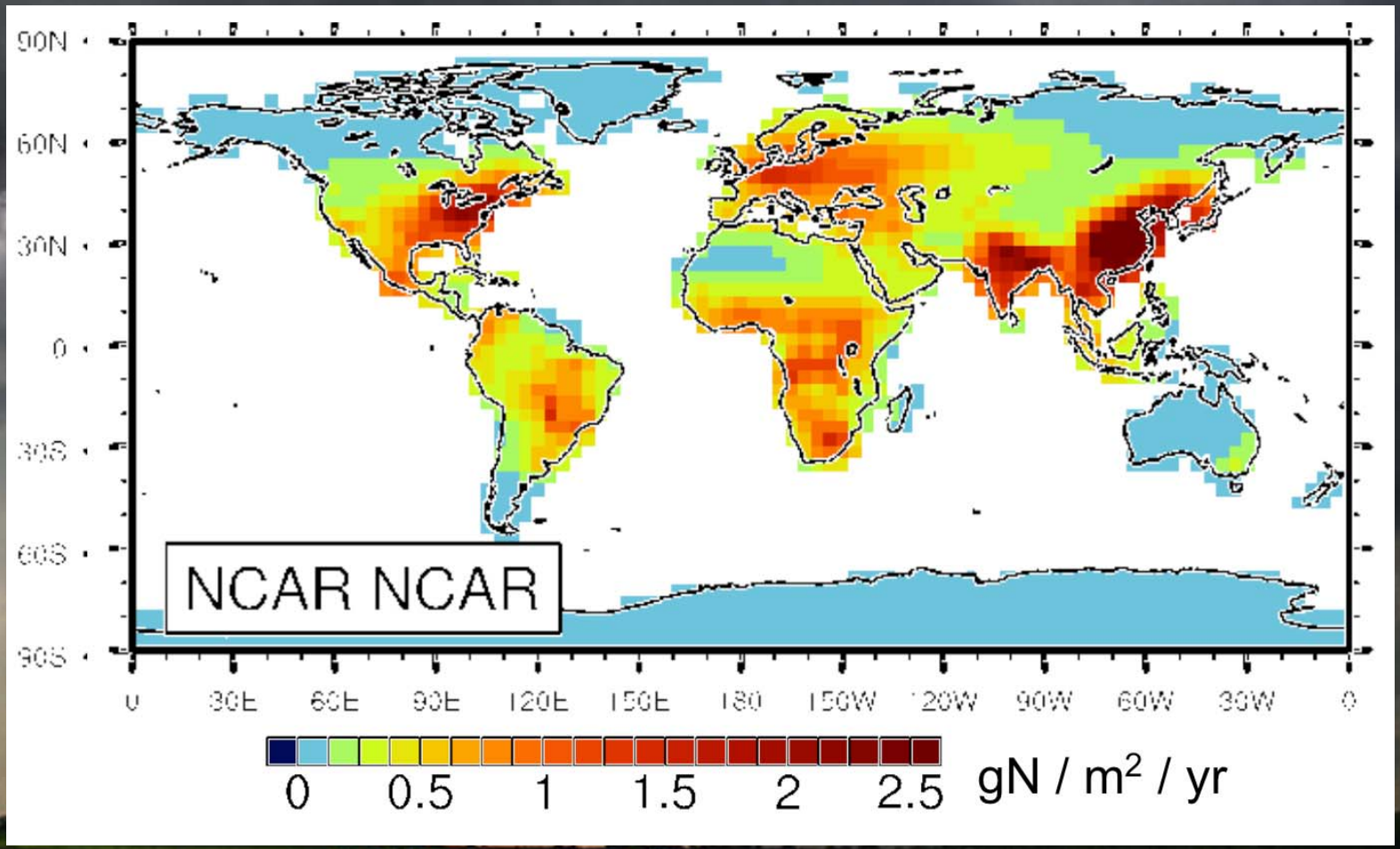
Nitrogen Deposition




The Human Influence on Climate is Everywhere!
The IPCC and other assessments have failed to properly assess these influences.
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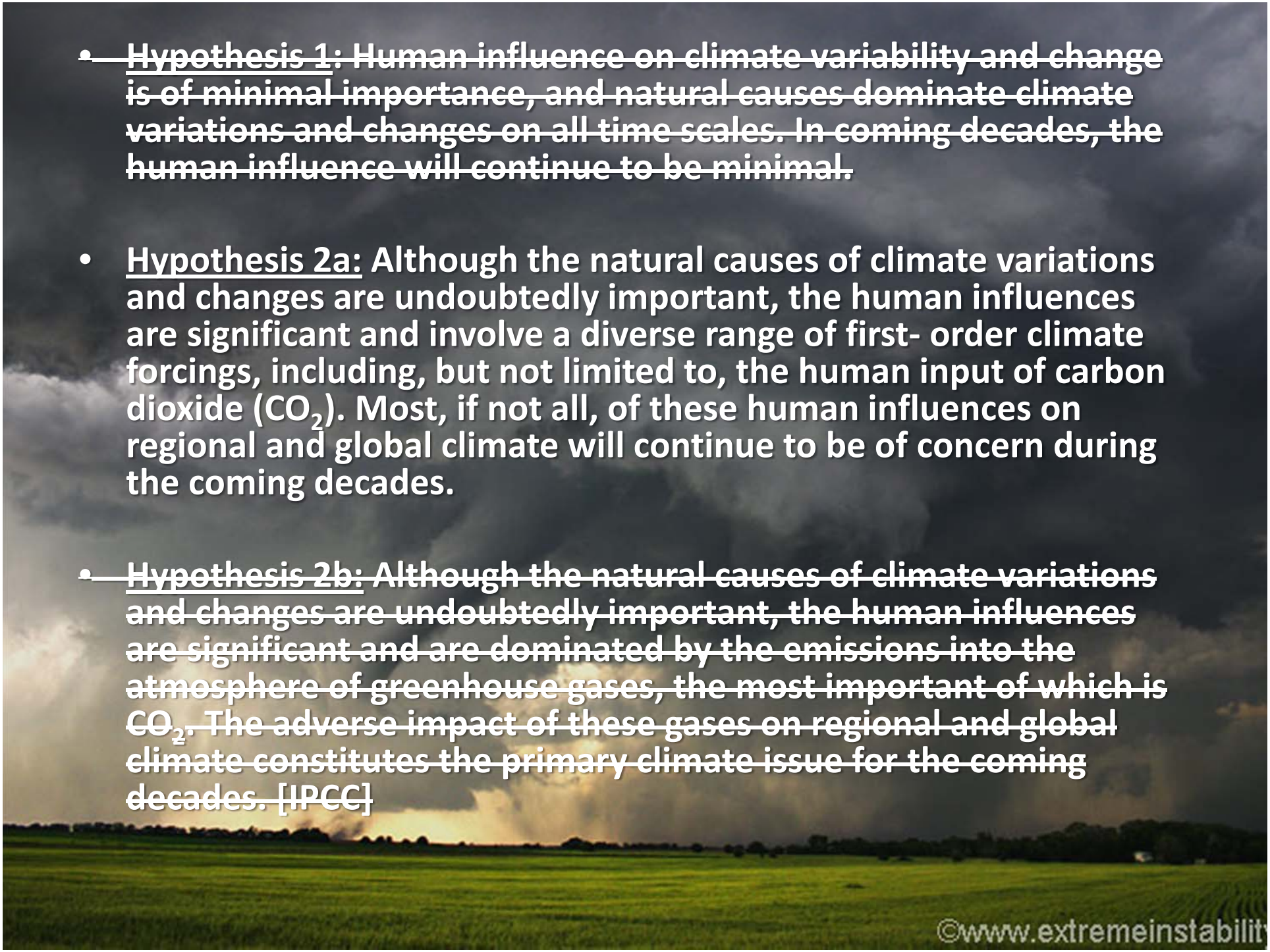
And Then There Are The Natural Climate Forcings

- Solar
- Volcanic
- Internal atmospheric/ocean circulation variability [PDO, NAO, ENSO, etc]
- Other


• ~~Hypothesis 1: Human influence on climate variability and change is of minimal importance, and natural causes dominate climate variations and changes on all time scales. In coming decades, the human influence will continue to be minimal.~~
• Hypothesis 2a: Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and involve a diverse range of first- order climate forcings, including, but not limited to, the human input of carbon dioxide (CO_2). Most, if not all, of these human influences on regional and global climate will continue to be of concern during the coming decades.
• ~~Hypothesis 2b: Although the natural causes of climate variations and changes are undoubtedly important, the human influences are significant and are dominated by the emissions into the atmosphere of greenhouse gases, the most important of which is CO_2. The adverse impact of these gases on regional and global climate constitutes the primary climate issue for the coming decades. [IPCC]~~
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As Mike Hulme of the University of East Anglia writes of two views:

1) “The overwhelming scientific evidence tells us that human greenhouse gas emissions are resulting in climate changes that cannot be explained by natural causes. Climate change is real, we are causing it, and it is happening right now.”

or

2) “The overwhelming scientific evidence tells us that human greenhouse gas emissions, land use changes and aerosol pollution are all contributing to regional and global climate changes, which exacerbate the changes and variability in climates brought about by natural causes. Because humans are contributing to climate change, it is happening now and in the future for a much more complex set of reasons than in previous human history.”

As Mike Hulme writes

”….these two different provocations – two different framings of climate change – open up the possibility of very different forms of public and policy engagement with the issue. They shape the response.

http://theconversation.edu.au/youve-been-framed-six-new-ways-to-understand-climate-change-2119


A New Approach Is Needed!
We Need To Replace The IPCC Top-Down Approach To Predict Future Environmental And Social Risk With A Bottom-Up Resource-Based Assessment of Vulnerability
Our Key Resources Are Water, Food, Energy, Ecosystem Function and Human Health
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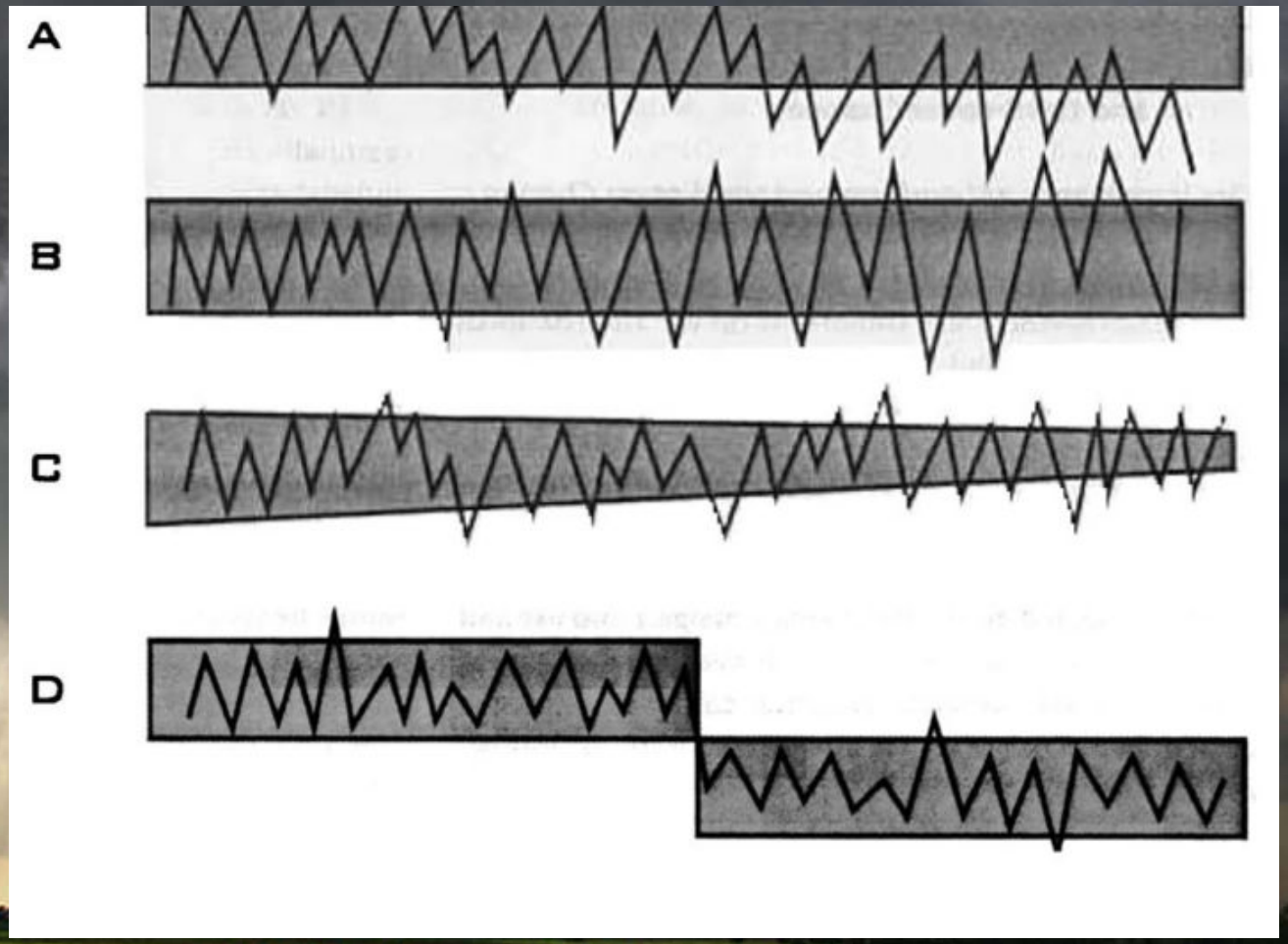
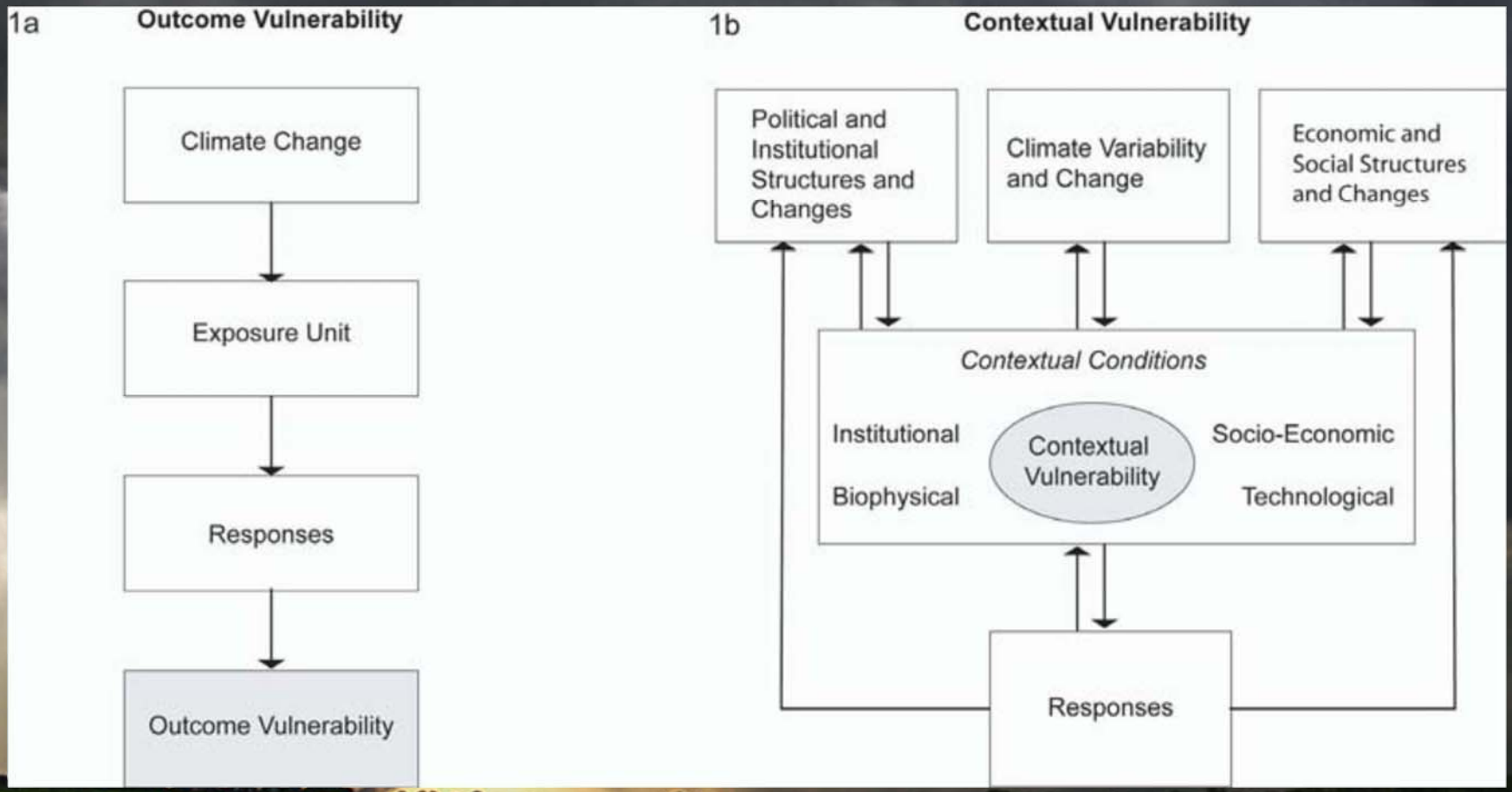
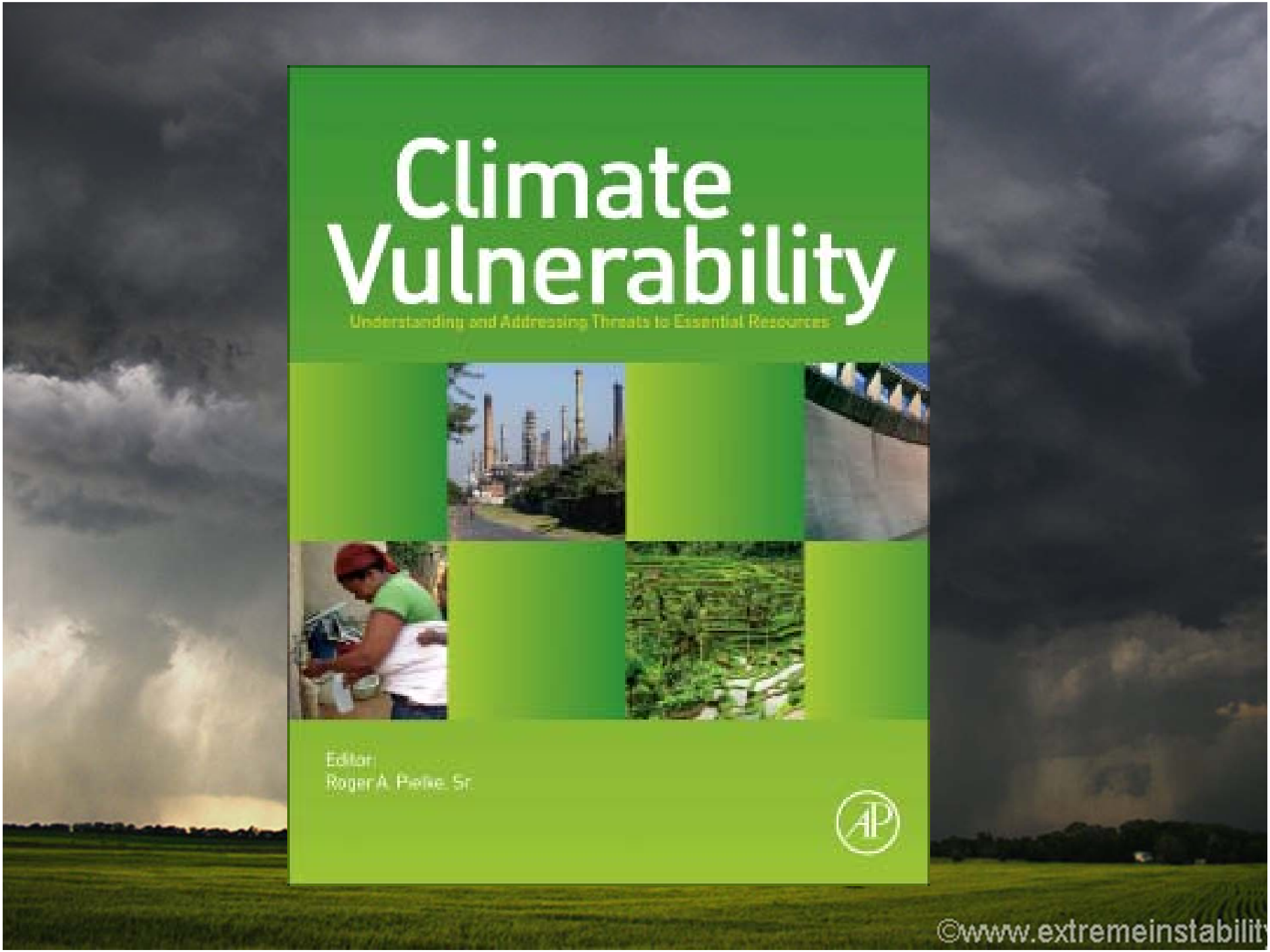
How Vulnerability Can Change Over Time



O'Brien et al., 2007: Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy* 7 (1): 73–88




Climate
Vulnerability
Understanding and Addressing Threats to Essential Resources
Editor:
Roger A. Pielke, Sr.
AP
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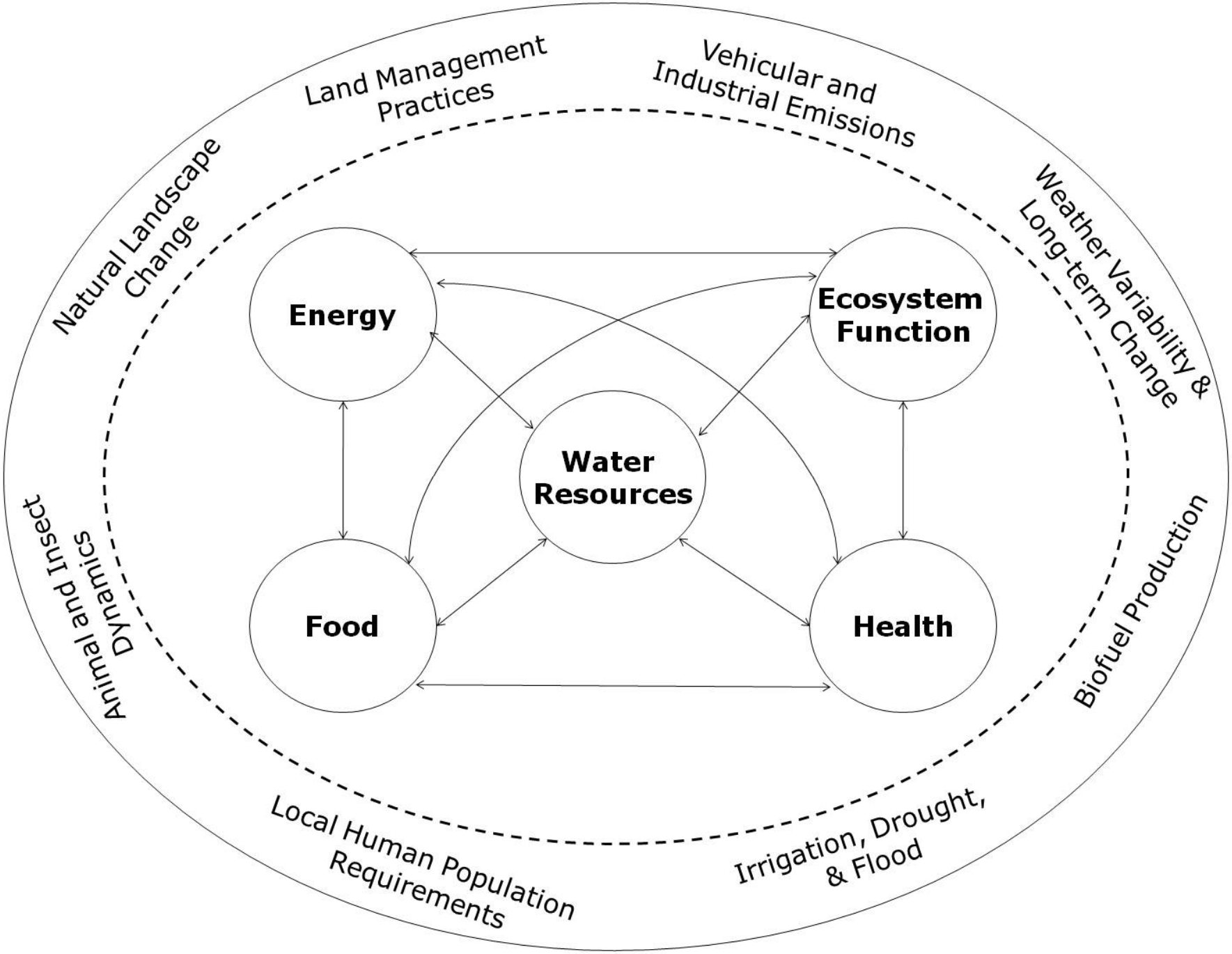
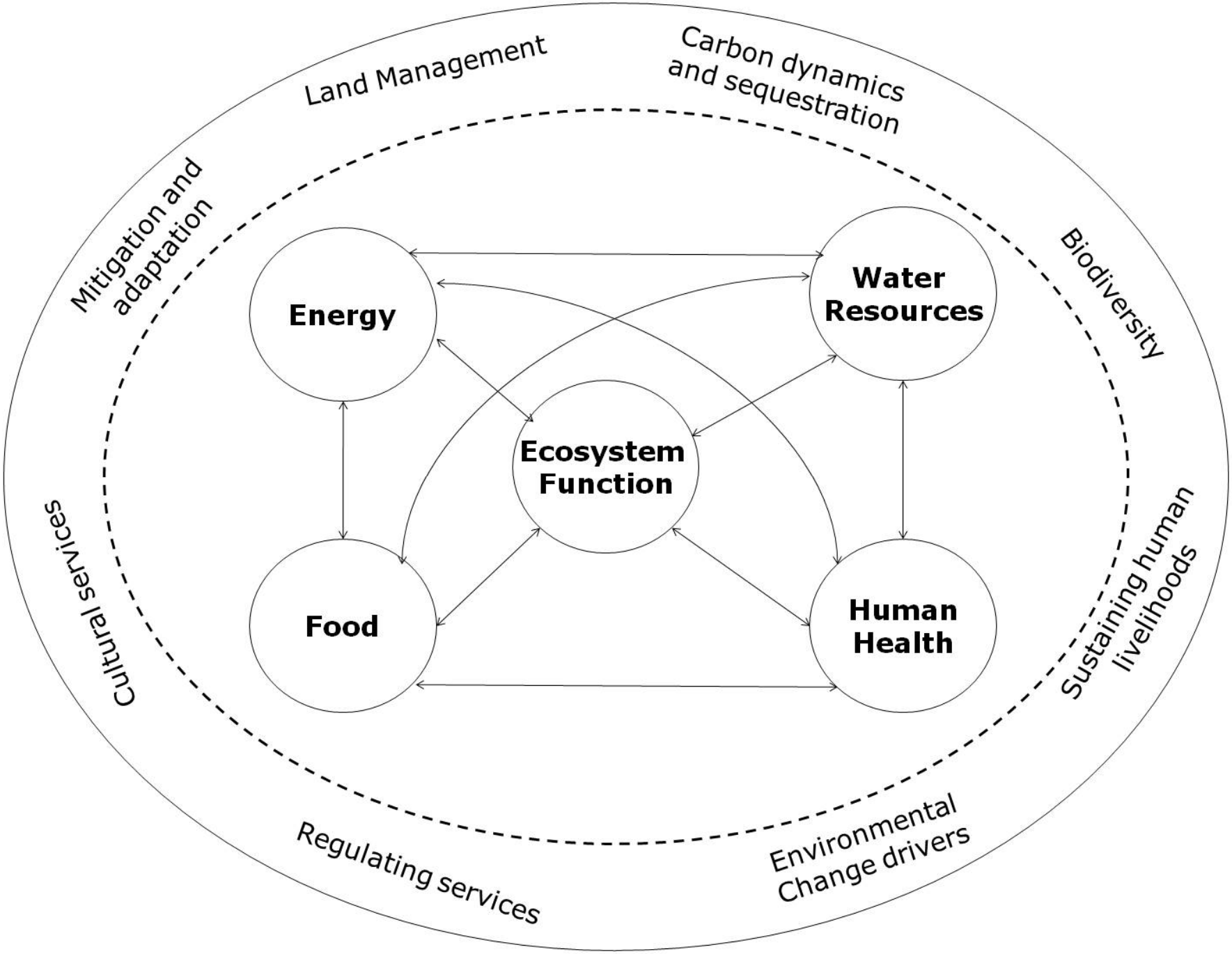
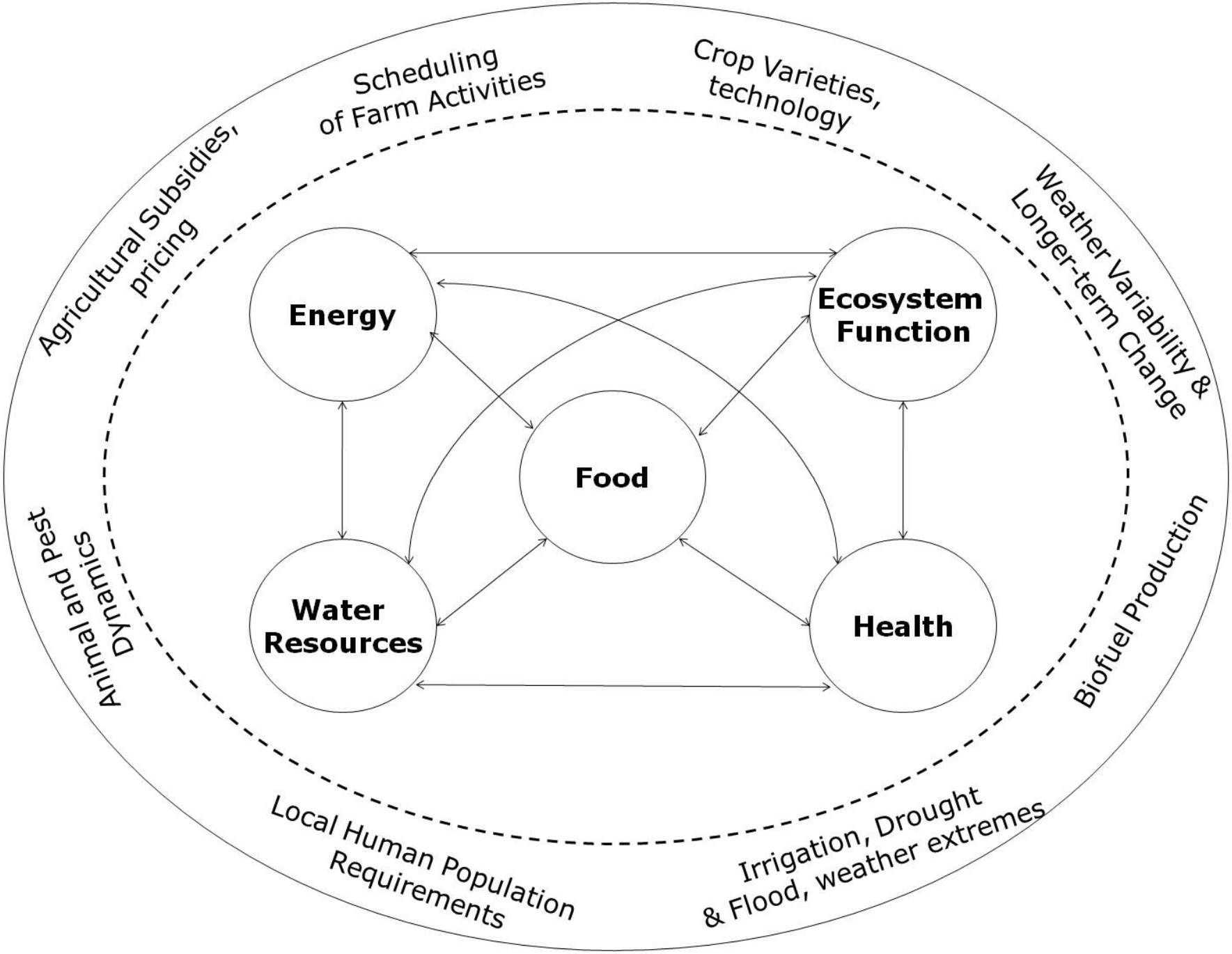
Questions For Stakeholders On The Bottom-Up Approach

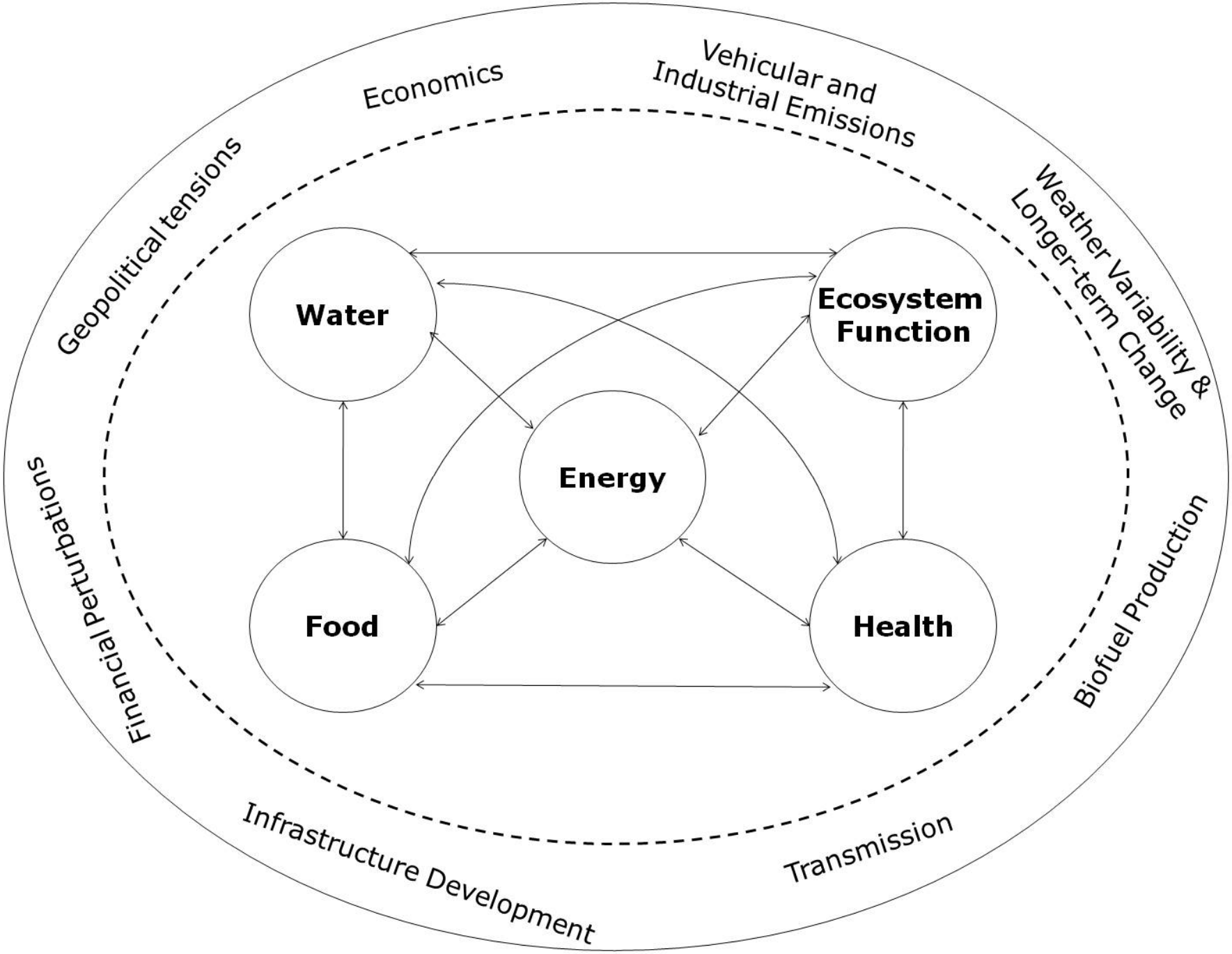
1. Why is this resource important? How is it used? To what stakeholders is it valuable?
2. What are the key environmental and social variables that influence this resource?
3. What is the sensitivity of this resource to changes in each of these key variables? (This may include but is not limited to, the sensitivity of the resource to climate variations and change on short (days); medium (seasons) and long (multi-decadal) time scales).

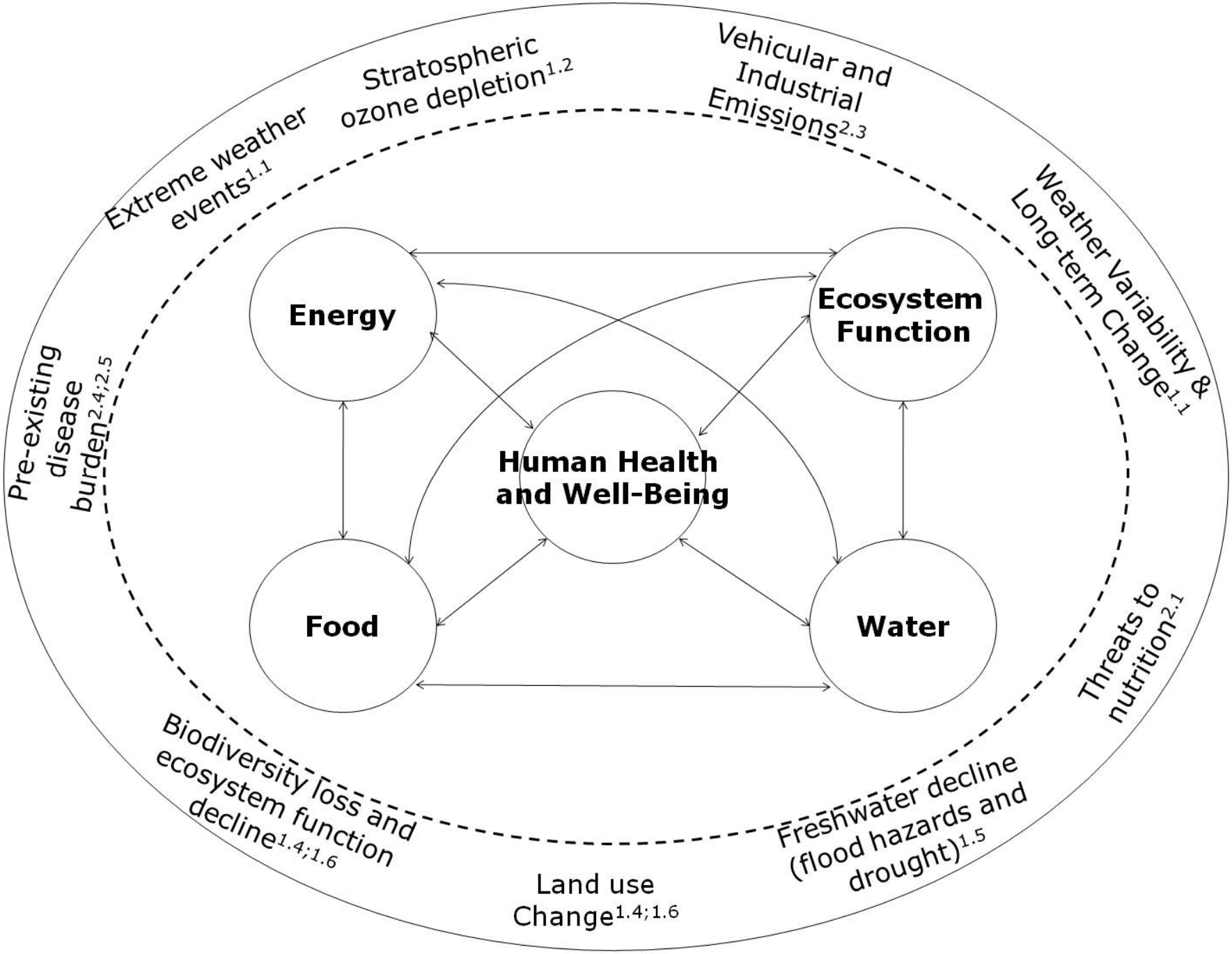
4. What changes (thresholds) in these key variables would have to occur to result in a negative (or positive) outcome for this resource?
5. What are the best estimates of the probabilities for these changes to occur? What tools are available to quantify the effect of these changes? Can these estimates be skillfully predicted?
6. What actions (adaptation/mitigation) can be undertaken in order to minimize or eliminate the negative consequences of these changes (or to optimize a positive response)?
7. What are specific recommendations for policymakers and other stakeholders?

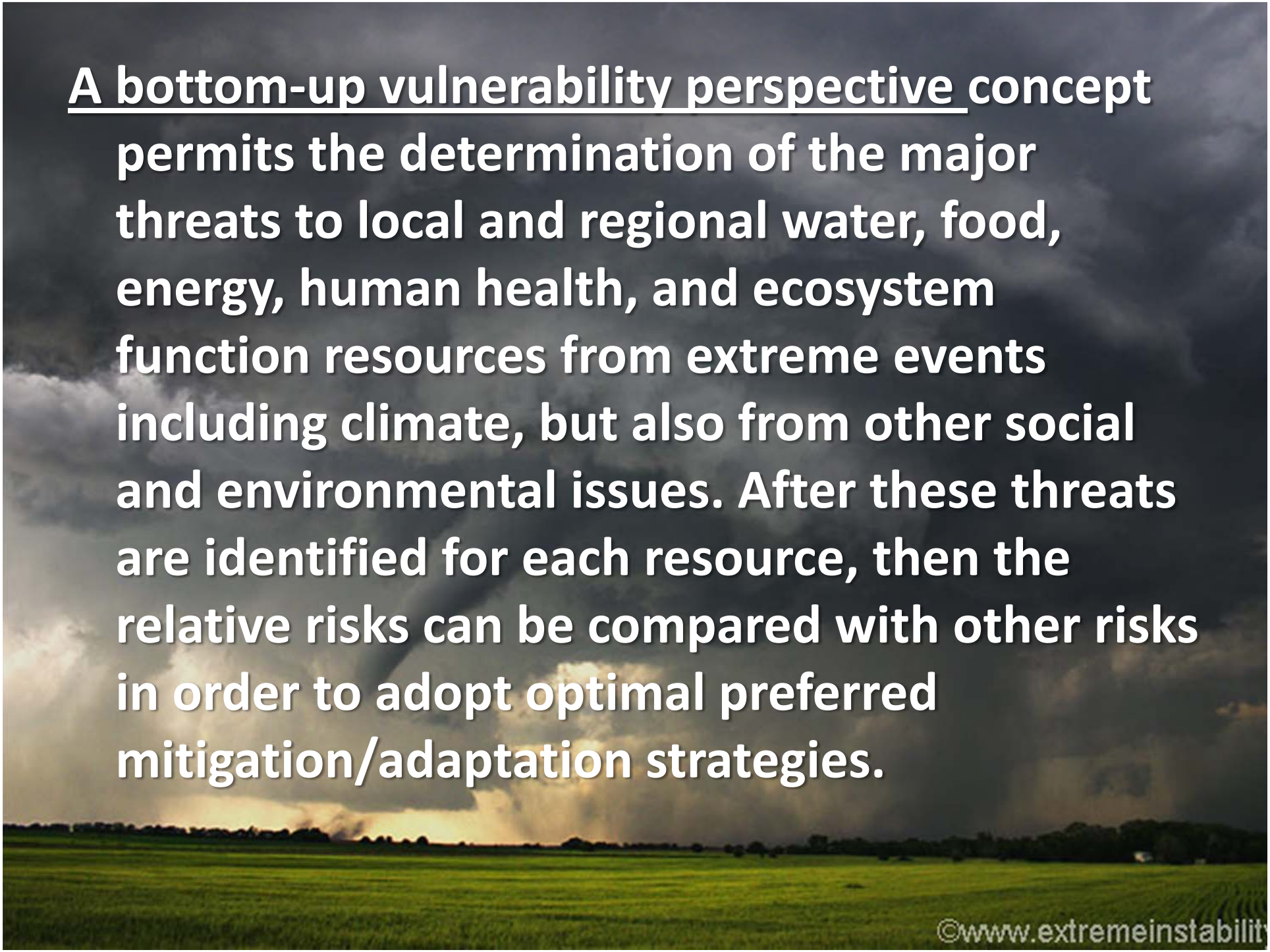

Land Management Practices
Vehicular and Industrial Emissions
Natural Landscape Change
Weather Variability & Long-term Change
Energy
Ecosystem Function
Water Resources
Food
Health
Animal and Insect Dynamics
Biofuel Production
Local Human Population Requirements
Irrigation, Drought, & Flood


Land Management
Carbon dynamics and sequestration
Mitigation and adaptation
Biodiversity
Cultural services
Sustaining human livelihoods
Regulating services
Environmental Change drivers
Energy
Water Resources
Ecosystem Function
Food
Human Health


Scheduling
of Farm Activities
Crop Varieties,
technology
Agricultural Subsidies,
pricing
Weather Variability &
Longer-term Change
Energy
Ecosystem
Function
Food
Water
Resources
Health
Animal and Pest
Dynamics
Biofuel Production
Local Human Population
Requirements
Irrigation, Drought
& Flood, weather extremes


Economics
Vehicular and Industrial Emissions
Geopolitical tensions
Weather Variability & Longer-term Change
Water
Ecosystem Function
Energy
Food
Health
Financial Perturbations
Biofuel Production
Infrastructure Development
Transmission


Extreme weather events1.1
Stratospheric ozone depletion1.2
Vehicular and Industrial Emissions2.3
Weather Variability & Long-term Change1.1
Pre-existing disease burden2.4;2.5
Energy
Ecosystem Function
Human Health and Well-Being
Food
Water
Threats to nutrition2.1
Biodiversity loss and ecosystem function decline1.4;1.6
Land use Change1.4;1.6
Freshwater decline (flood hazards and drought)1.5


A bottom-up vulnerability perspective concept permits the determination of the major threats to local and regional water, food, energy, human health, and ecosystem function resources from extreme events including climate, but also from other social and environmental issues. After these threats are identified for each resource, then the relative risks can be compared with other risks in order to adopt optimal preferred mitigation/adaptation strategies.
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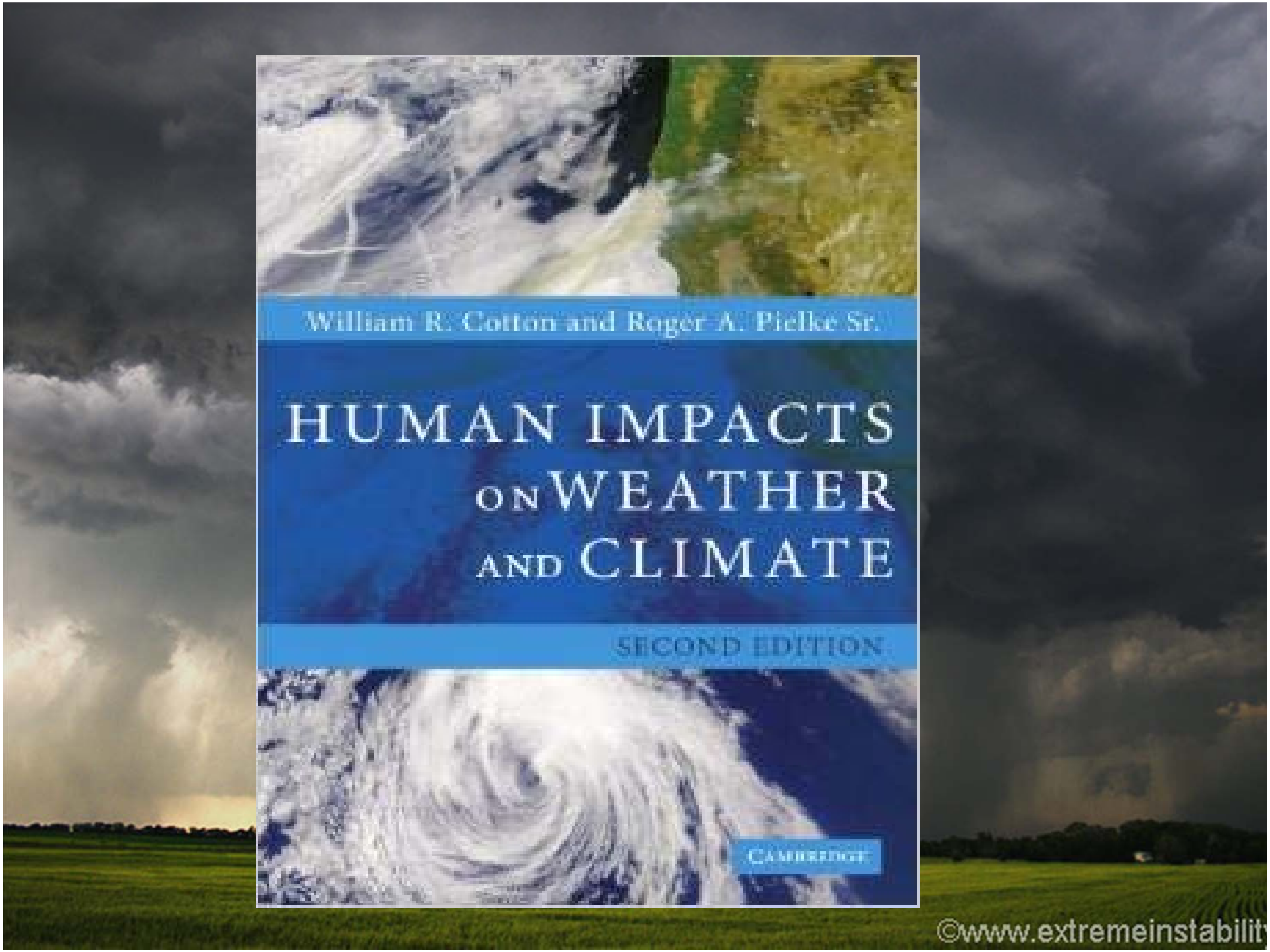
William R. Cotton and Roger A. Pielke Sr.
HUMAN IMPACTS
ON WEATHER
AND CLIMATE
SECOND EDITION
CAMBRIDGE
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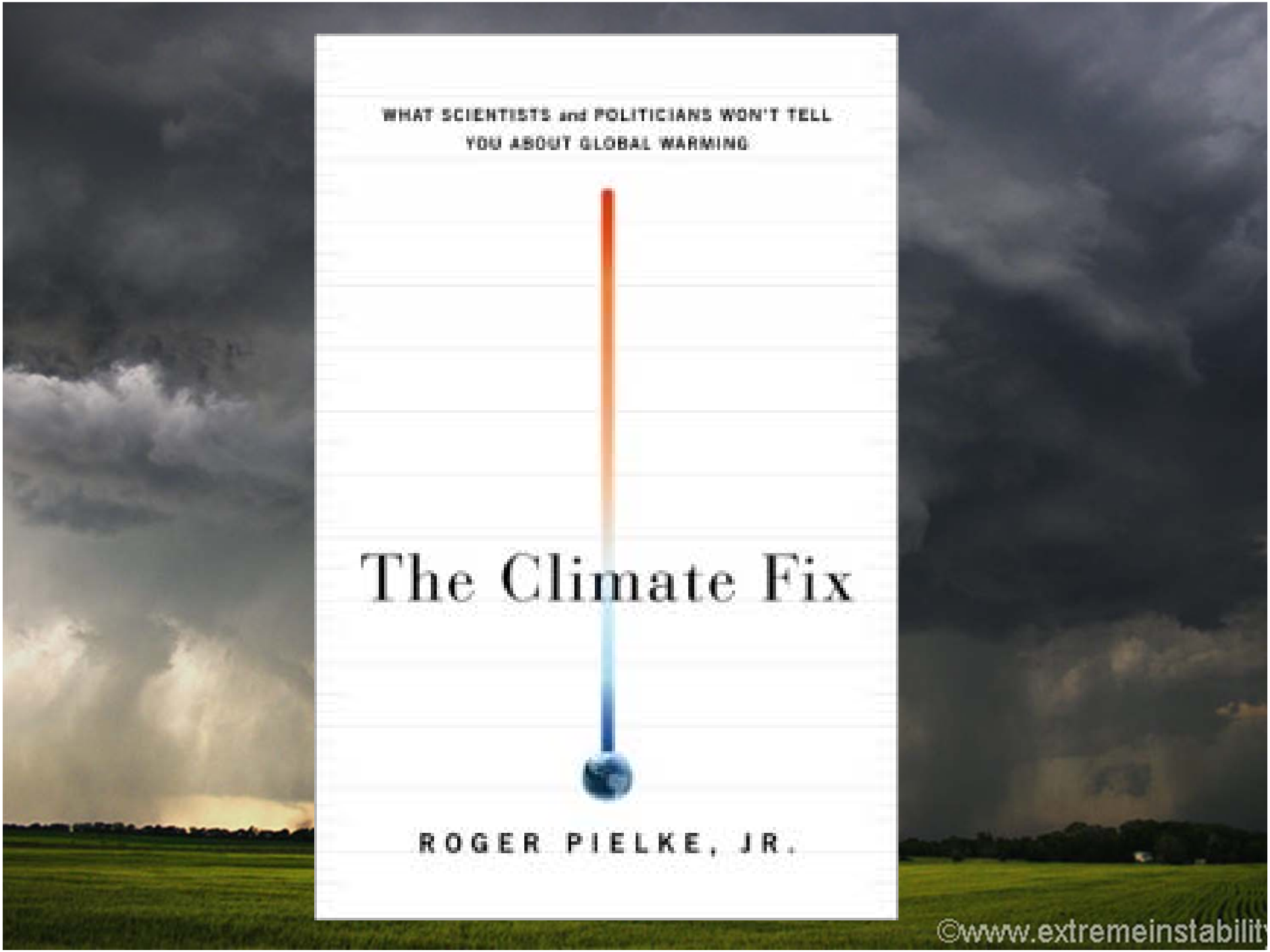
WHAT SCIENTISTS and POLITICIANS WON'T TELL
YOU ABOUT GLOBAL WARMING
The Climate Fix
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CLIMATE CHANGE
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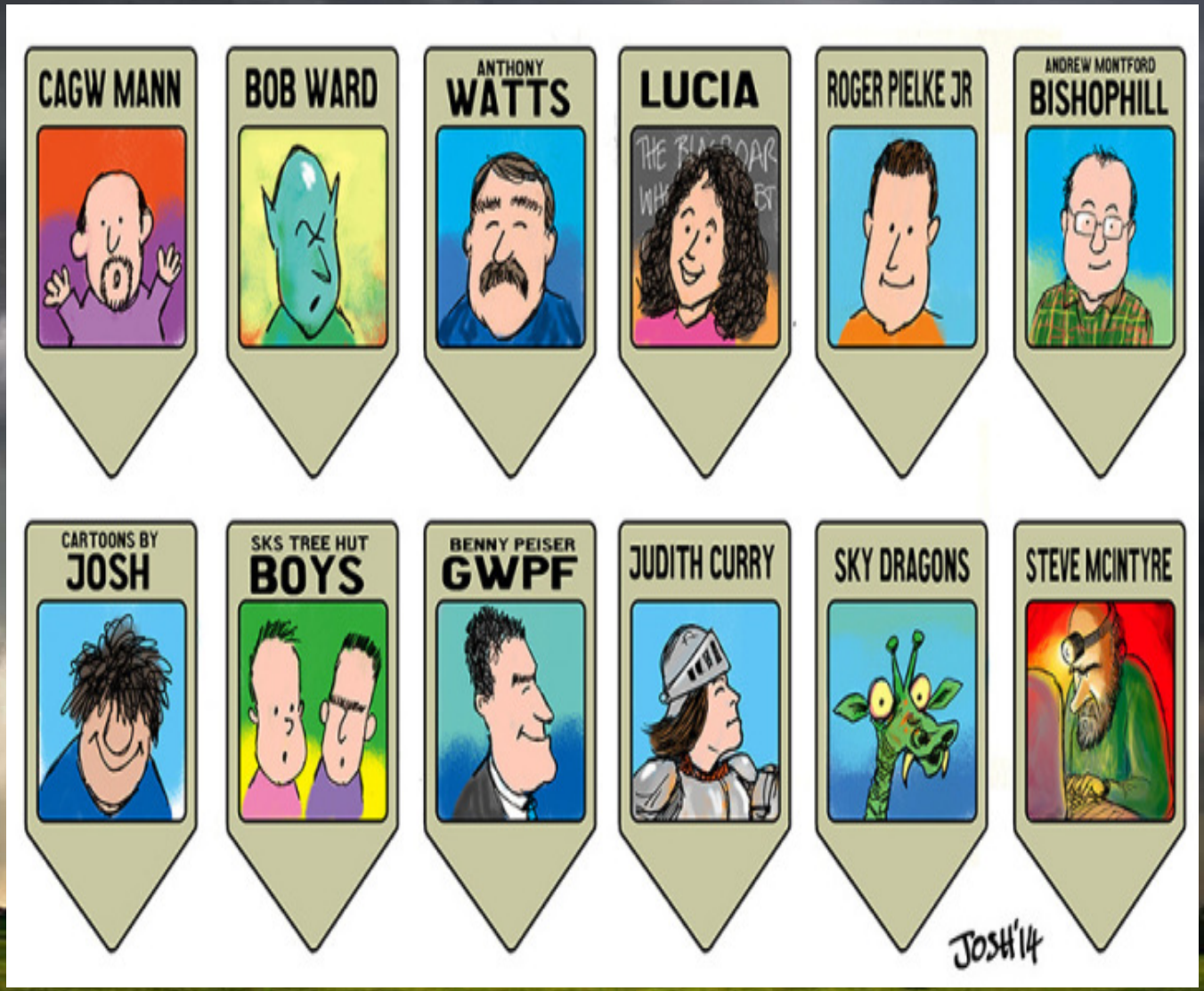

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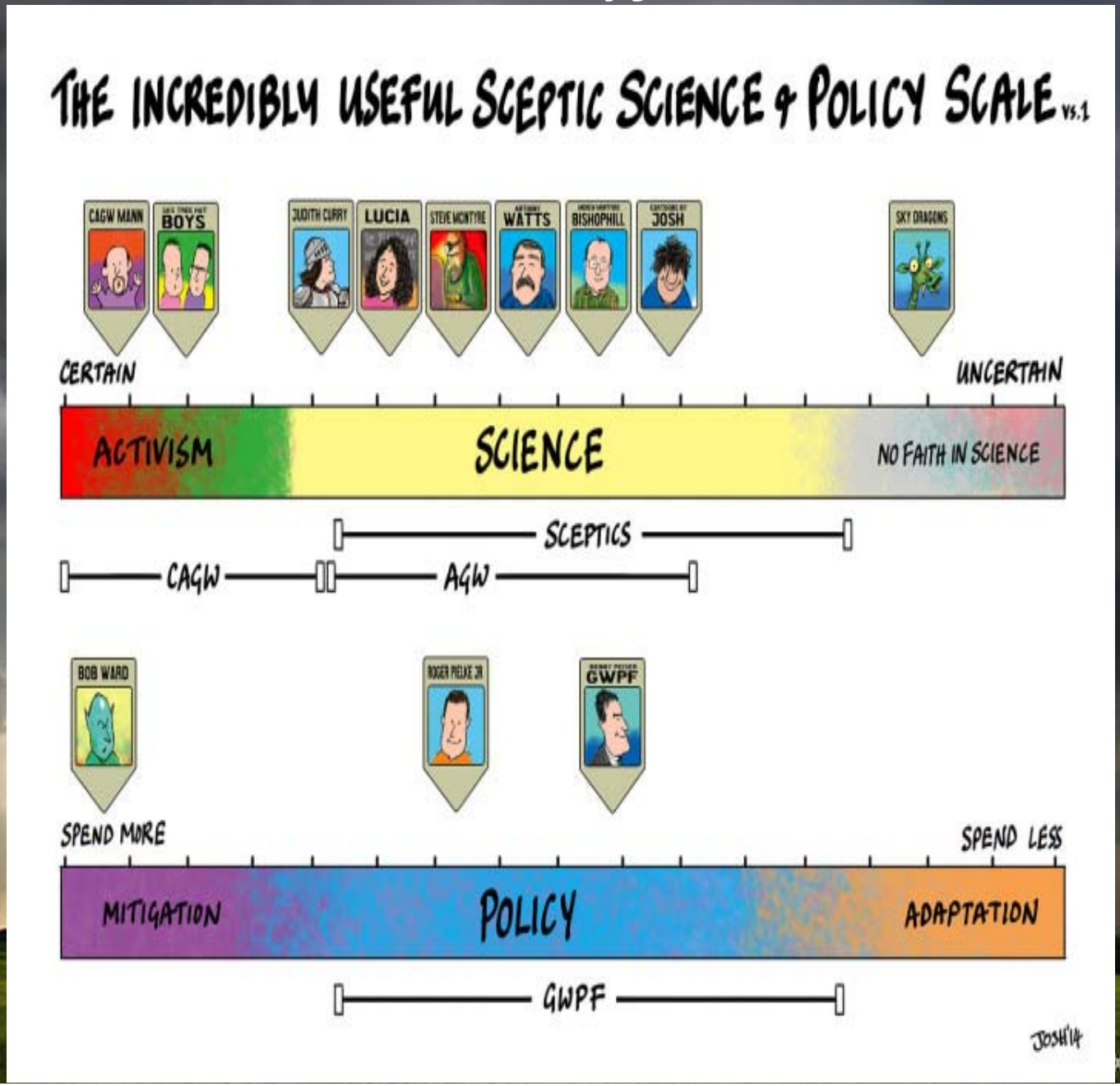

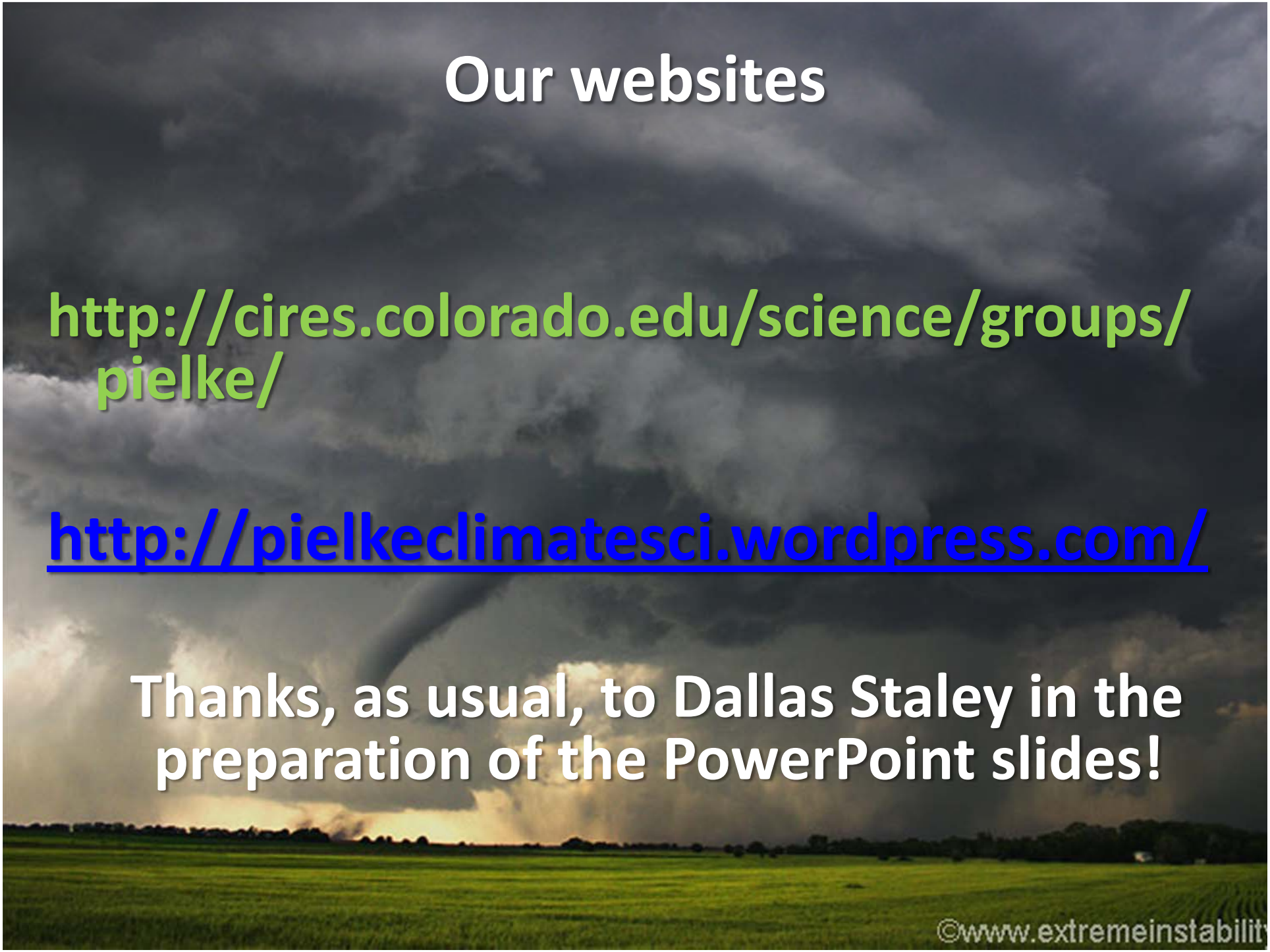
Our websites
http://cires.colorado.edu/science/groups/pielke/
http://pielkeclimatesci.wordpress.com/
Thanks, as usual, to Dallas Staley in the preparation of the PowerPoint slides!
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