Uncertainty in Climate Science (see PPT)

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Slide 1: Uncertainty in Climate Science -

Science is NOT Truth! Science, by definition, equates to varying degrees of uncertainty. Bookending the range of the uncertainty spectrum are hypotheses and theories. Hypotheses – suggested explanations for how things work, and based on observed evidence, offering potential prediction of phenomena whose correlative relationships may be causal – must be both testable and falsifiable. A hypothesis cannot be proven to be true; it can only be proven false. For a hypothesis to be elevated to theory – a rare and significant promotion – the hypothesis must survive multiple replications of results with a wide set of data, and it must be tested under a variety of circumstances. Even then, while uncertainty of a theory is minimized; it is never zero. Science is the constant process of trying to figure out how things *might* work.

How does one make policy decisions based on science, with uncertainty's role looming, often overlooked, underestimated, dismissed, and underreported? How does one trust consensus?

Historically, skepticism has fueled forward movement of scientific discovery. Uncertainty motivates inquiry. Conversely, certainty entrenches paradigms. Examples dot history of paradigms kept on life support with increasingly complicated constructs to explain phenomena or occurrences inconsistent with hypothesized dynamics and behavior – the 1600-year-long geocentric model being a most vivid example. Upending of faulty paradigms often relies on evolution of technology. New evidence reveals surprises – those "unknown unknowns". Ironically, those most educated in a field often are not the ones in history to have revolutionized thought. Lay persons and scientists of different specialties often were the ones who "saw" what was hidden from the hardened mental filters of those overly invested in a paradigm's survival. Skepticism has gotten a bad rap in recent years. Instead, it should be embraced. It is skepticism - not conformity - that provides the checks and balances to humans' tendency to see the expected.

So, how does one make good decisions in context of uncertainty? One must gather good evidence – not hearsay, not sound bites, nor "consensus". Good evidence can be garnered only through understanding how conclusions are reached - the methodology and data used to construct them. This is not easy, but just accepting what others say – their filtered conclusions - not investigating the scientific process employed in generating a conclusion, and not exploring alternate possible explanations for observed phenomena, destines its victims to the unintended consequences.

Slide 2: Seeing is Believing -

The image on this slide is startling - ice crashing into the sea. Seeing is believing… Photo-journalism is convincing. We believe our eyes, even though instinctively, we each realize the perils of falling prey to that impulse. Things are rarely as they appear…
Calving is what glaciers do normally! Glaciers calve where they meet the water. Calving is not the same as retreat.

But even retreat does not always have a clear-cut cause…Glaciers expand and contract, with or without humans on Earth to observe. They behaved this way, and often cyclically, on a variety of time scales, before atmospheric accumulations of CO_2.

But the picture makes the story simple: increasing temperatures, crumbling glaciers…
There are different kinds of glaciers. They all have personalities. Mountain glaciers attract particular attention. They advance and retreat seasonally and over time, in cold times and warm, often with adjacent glaciers exhibiting contradictory behavior, with one advancing and the other retreating. In short, their correlation to temperature is not straight-forward, in particular, not with the strange nature of mountain glaciers.

Time frame of observation plays a role in what is seen. In the Northern Hemisphere, glacier advance is at its approximate annual maximum in May; in September, it is at its minimum. Changes in cloud cover, angle of solar insolation, precipitation, and winds sculpt their impacts locally. Random yearly variations in behavior must be viewed cautiously; what appears a trend may quickly reverse. And trends don't always make sense in context of prevailing climate conditions….

Slide 3: Or Uncertainty…
For example: The confusing broader perspective as illustrated in this slide.
Shown here are glaciers from Glacier Bay in Alaska. This one – the Muir Glacier– has had its behavior well documented by the USGS (United States Geological Survey). Nestled between two mountains, its current classification is as a valley glacier. When it extended to the ocean years ago, when its terminus calved into the sea, it was called a tidewater glacier. Since that time, it has experienced dramatic retreat, but most occurred long before accumulations of anthropogenic CO_2 were an issue. Most of the retreat pre-dates 1950, and much of it occurred during the cold interval known as the Little Ice Age (several-century LIA ended ~ 1850).

On the right is a USGS Map of Alaska and Glacier Bay. Red lines show glacial terminus positions and dates during retreat of the Little Ice Age glacier (monitored since ~ 1750). (Green polygon outlines approximate area mapped by multi-beam system in May-June 2001.)

On the left is a long-term "time-lapse" view of Muir glacier. In both this sequence and the map's depiction of glacial retreat, one can see modern CO_2 forcing an unlikely culprit; retreat mostly pre-dates 1950, and much of it in the 19th, and even 18th, century.

Glaciers have been retreating in many places since the end of the Little Ice Age that ended in the mid-1800s. But glaciers, especially alpine (mountain/valley) glaciers, are not good thermometers. Adjacent ones can show opposite trends, where one is growing and another shrinking. Precipitation, winds, cloud cover, solar radiation, angle toward sun and weather storm-tracks, and internal temperature traits of glacier impact mountain-glacier growth/retreat. Temperature is not the only factor. There is little straight-forward about them.

Map/topic: http://wattsupwiththat.com/2012/01/17/james-balogs-inconvenient-glacial-canaries

Slide 4: Seeing is Believing -
The polar bear stranded on this isolated vestige of once-broad sea-ice cover is now the poster child for rising temperatures, caused by mankind, with impending doom implied.

How can one's heart not be broken at the sight of this stranded bear! And how can one for one second doubt mankind's role in a doom that is destined to destroy life as we know it!!! A picture is worth a thousand words. The message is obvious…Until you widen the camera lens' perspective…

Slide 5: Or Uncertainty –
It turns out the polar bear population has varied over time, with 1950 estimates ~5000. Low numbers then were a result of unrestricted hunting. Between 1965 and 1970, their numbers reached 8 to 10 thousand, and by 1984, eleven years after the Arctic treaty to protect the bears from overhunting was signed, their numbers peaked at ~25,000. Currently, there are b/n 22 and 25 thousand. Within that overall number, regional population differences exist – regional shifts likely in response to changing distribution of ice cover. These are often exploited for impact – either side. Western Hudson Bay shows a decline of 20 to 25%; while Canadian Bear population shows an increase of that amount, with increases from 12,000 bears to 15,000, with numbers in 2012 at their highest since 2002.

And what of the bears' fate? Can their evolutionary history give us insight? The polar bear lineage is traceable to a breakaway from the brown-bear line. It was long thought that this split from the brown bear occurred during the glacial periods, within the last couple of hundred thousand years, with the Arctic creature being better adapted to frigid temperatures than its brown-bear cousin. This conclusion on its adaptation led to speculation that the white giant's survival may be imperiled by present-day increasing temperatures. But recent studies have muddied the certainty. Research suggests the evolutionary split occurred anywhere between 6 million years ago and 350,000 years ago – a wide range of uncertainty. The Ice Ages began about 1.8 to 2.0 million years ago.

A shared genetic heritage of polar bears with brown bears may convey adaptability to changing ice-cover extent. A recent study finds polar bear foraging habits altered with changing ice conditions; their eating behavior, determined from comparing present-day scat remains with those of 40-plus years ago (a previous study), appears to be more flexible than previously assumed (Gormezano and Rockwell 2013), leading researchers to question whether the behavior is a response to "nutritional stress" or is simply an "expression of plastic foraging behavior".

The take-away message is two-fold: nature rarely continues along a linear path and what seems obvious and immutable, rarely is…

Slide 6: And the Experts Say –
We have all seen this figure – the "97%". The science is claimed to be settled: 97% of the world's climate scientists believe catastrophic global warming and other "problematic climate change" are happening and most of the cause is assignable to mankind.

Where did that come from? 75/77 = 97.4%! A study beginning with over 10,000 questionnaires ended with 77 participants, most from the U.S., with all but two agreeing with the paradigm as stated above.

Of course, the first observation that strikes a scientist is that science is not decided by popularity.

The conclusion – that at least half the T increase over the last century is manmade, at least most since 1950 - may be correct, but if it is, it is not because of popular opinion. That is my only point here. Don't be swayed by group-think. Be convinced by the data, methodology, and logic of interpretation. And if you aren't convinced, continue sleuthing!

There is background on all this; although motivation behind the inquiry is unclear. It seemed to start with an essay – The Scientific Consensus on Climate Change - written in 2004 by science historian Naomi Oreskes and published in *Science AAAS* Journal. She referenced the examination of 928 abstracts published in refereed scientific journals between 1993 and 2003. Her methodology was subject to considerable criticism. In fairness to her, she noted that the history of science teaches humility, alluding to the failed consensus-backed paradigms dotting centuries past of inquiry.

University of Illinois graduate student, Margaret Zimmerman, later (2008) wrote her masters thesis on the evolution of the climate consensus, followed by a paper (EOS 1/20/2009) that she co-authored with her advisor, Peter Doran – professor of earth and environmental sciences at the University of Illinois, Chicago. Doran and Zimmerman had conducted a poll. It consisted of 77 climatologists, 75 if whom "agreed", and two major questions that determined their opinions.

Subsequent to publication of the survey results, participating authors were given opportunity to voice comments. Many criticized the simplistic approach of the survey, an approach moldable to agenda, which appears to have been the end-result. A commonly voiced opinion was that the way the survey results were presented did not reflect the nuances of scientific thought on climate change. Media outlets were quick to promote the new study. Uncertainty is not well-packaged in sound bites, and thus uncertainty is no friend of journalism…

Slide 7: Which Experts? –
The 100% view: all agree that climate changes and we cause some of it…

Slide 8: Scientists Agree –
Temperatures have increased since 1850; CO_2 has increased since 1850; CO_2 is an infrared warmer and with no positive or negative feedbacks, a doubling of CO_2 will lead to a 1.1°C increase in temperature.

Slide 9: But They Disagree On -
How much T has risen; how much of that is due to CO_2; how much due to urbanization; what the climate's sensitivity is; what nature's influence is; what role earth's intrinsic dynamics play; how well models represent all the dynamics involved; the integrity of the data; the sometimes claimed correlation between CO_2-warming and extreme weather; the reliability of the projected warming trend; if there really is a problem, especially one we can actually solve; and what the consequences of proposed solutions might be.

Slide 10: Let's Pull Back the Curtain – The "Oz" of Uncertainty -
We now begin the part of the talk where we will investigate the uncertainties in climate science. You surely know the "other side", the "settled" side, as that information is everywhere. In this presentation, information you are less likely to know about is detailed.

Uncertainty is not for the impatient, nor is it packable into pithy sound bites. But the ardor of exploring the complexities is worth your while, as your future depends upon your attention.

You may go away from this talk with your mind less decided, or even changed. Or you may go away with the opinion you come in with. If it is a more informed and deliberate opinion after the presentation, my job is done. This talk is not meant to indoctrinate or persuade you to think as I do; it is meant to confuse you, to puncture your credulity – your gullibility and willingness to believe or trust too easily, especially without proper or adequate evidence, as it is this credulity that is readily exploited by those who assume you either don't care or that you can't understand. Their intentions may be good, but the resulting impact may not be.

You will decide, in the end, if you fear the future due to mankind's influence on climate or if you think nature to be relatively resilient. Either way, kindness to Earth is a good thing – not a bumper-sticker slogan with more show than substance. And "kindness to Earth" is not necessarily defined by what the loudest voices urge. I cannot tell you what the climate will do, even though I have studied it for years. My studies over the decades reveal to me an earth that exhibits remarkable stability and adaptability, and is full of awe-inspiring surprises. Your revelation may differ. Just keep questioning. Keep thinking…
To evaluate the conclusion, one must evaluate the methods (and the data)!

Slide 11: What is the Evidence?
The goal: to determine how sure we are about the following:
1) Climate change - is it a problem?
2) Can we solve it?
3) How sure should we be about both?

Slide 12: Hard Evidence Must Exist!

This sampling of influential figures - Bill Nye, a former mechanical engineer turned comedy show writer and performer; Bill Gates, a computer genius businessman; of course, Al Gore, a former senator/former vice president; an astrophysicist, Neil deGrasse Tyson; Pope Francis; and Obama, the U.S. president – one questions how they could be wrong.

What has convinced them? What has convinced the majority of the world's leaders??? Is their collective view more perception fed by repetition? Is their response based on good intentions? And are these good intentions and strongly encouraged perceptions rooted in hard evidence? Are the data and observations leading to the hypothesis? Or is the hypothesis leading the conclusion? Sound hypotheses are built upon hard evidence, good data, and sound methodology. To ascertain uncertainties in the science, one must look beyond the pronouncements-of-assumption made through media outlets. One must uncover the hard evidence for impending catastrophic anthropogenic climate change. Where to look…

Slide 13: Media Supply "Evidence" –
We are familiar with the coverage that feeds our certainty that the science is settled, but does that coverage survive scrutiny? Is there thought behind the endless allusions to climate change when any "anomalous" weather event occurs???

Some examples are captured in the cartoons shown on the slide.
Note the odd replacement of "temperatures" with "heat index" values on weather maps on many of the broadcast shows. Seems the weather reports always emphasize the hot spots, the extreme weather, even if localized and "normal". And "normal" in climate is an average of a *chosen* 30-year reference period. Take note! That reference interval may well be one of relative cool (as in 1950s to 1980s).

As far as extreme events increasing with global warming: There is absolutely no scientific evidence for increased extremes in weather-related events due to warming. There is conjecture that extremes can be more extreme; yet little evidence backs that up. It is clear that with cooling intervals, the polar jet stream gets "wobbly" – the "polar vortex" often mentioned (recent years). This has to do with large-scale patterns, and nature does its part to reverse those patterns every thirty years or so. When those winds get wobbly, b/c the vortex weakens, cold air that remains corralled at the pole when strong winds prevail, spills out to lower latitudes when the winds weaken. This puts frigid air next to warm air along the tortuous (wobbly) path of weakened winds. The contrasts set the stage for clashes – extreme weather. But that is not global warming's fault!!! While one cannot dismiss a potential modifying role for anthropogenic warming in vortex integrity, changes in vortex dynamics are nothing new, and are naturally occurring, with an apparent temporal pattern of low-frequency variability.

Natural shifts, as described, play a role in extreme events. And perception of increases is related to timing. A 'shift' likely occurred in the early 2000s. But perception is further fed by hype, media coverage, migration of habitation into zones more vulnerable to extreme weather. Note, there are rarely first-time occurrences - events without precedents; often there are statements such as "not since 1875 or 1902…" That means they've happened before! Even when media coverage was not so thorough. So if such events occurred before, usually long before, what does that say about the suggestion that the event is tied to recent "climate change"?

Slide 14: Let's Dig Deeper –
Our approach will be to dig deeper, to look behind the scenes, and uncover uncertainties injected throughout every step of the "settled" science.

You will find:
<u>The Hypotheses</u> –there are at least two general views – contrasting ones – on climate variability
<u>The Models</u> – they are really no more than guesses and are, themselves, hypotheses.
<u>The Data</u> – quality is poor; adjustments have steepened temperature trend.
<u>The History</u> (of climate) – variability is a signature; yet data adjustments smooth history.
<u>Consensus</u> – man's history dotted with overturned consensuses. Science is not consensus.

Slide 15: How *Might* Climate Work?
<u>This slide shows the two general and contrasting views on climate behavior</u>:
1) One view involves external forcing on a passive system, with responses to that forcing mostly positive, meaning if the external forcing causes warming of the climate, more warming processes will follow in response, amplifying the initial signal. Regional processes respond independently to the externally imposed forcing. Internally generated variability that might damp the initial signal is thought to play, at most, a minimal role, and, where it does play a role, the influence is spatially local or regional, not hemispheric or global.

2) The other view is that internally generated dynamics play a strong role in climate behavior through collective interactions – network behavior – where network parts self-organize into a communal system, communicate (interact), and through this collection of interrelationships, conveys stability to the entire system. These described intrinsic dynamics are not mutually exclusive with external forcing, the forcing perhaps modifying the network's temporal pattern of variability; yet, the response of the interconnected system to external forcing is thought to be damped by the internal dynamics in this view of climate behavior.

Slide 16: "Consensus" Hypothesis –
This slide shows details relevant to the <u>**consensus hypothesis**</u>, a hypothesis based on the idea that external forcing dominantly influences climate.

With external forcing – natural and anthropogenic - on a mostly passive system comprised of non-interrelated "parts", resilience to perturbation is minimal. An instantaneous doubling of CO_2 (or CO_2-equivalent (includes methane, nitrous oxide, other greenhouse gases)) is theorized to result in a 3.7W/m^2 forcing, w/ expected 1.1ºC (~1.98ºF) T increase w/ no +/- feedbacks. (Logarithmic scale) Feedbacks are the wild card. They determine climate sensitivity (CS) – the realized T response to 2x CO_2. CS has been projected to be b/n 1.5ºC (2.7ºF) and 4.5ºC (8.1ºF), w/ AGW leaning to ~ 3ºC (5.4ºF). Current CO2 levels ~400ppmv. Baseline interglacial level ~280ppmv, so ~70% of 2x.

Certainty level is low to very low for most radiative forcings, as shown on figure. The only forcing well understood is the greenhouse-gas effect. Poorly understood forcings and feedbacks include: 1) Convection – a powerful cooling process – along with its associated clouds and precipitation – precipitation being nature's "way" of cooling the atmosphere; 2) aerosols – their direct and indirect effects: how they affect the longevity of cloud cover, the type of cloud, the size of droplets, and therefore the reflectivity of the cloud, etc – all impacting a cloud's cooling or warming effects; 3) solar – only direct effects somewhat understood. These are minimal. It is the indirect forcing - in a multitude of ways - that is significant in climate behavior. Many hypotheses exist, most not mutually exclusive. The chart of radiative forcings was from the IPCC report 2000; the levels of understanding remain the same today.

Feedbacks – both positive and negative – are assumed to occur. Which feedbacks, + or -, will dominate; that is the wild card. AGW assumes more + feedbacks, esp ↑ water vapor. Often it is asserted that warmer air can hold more water (vapor) than cooler air can. Water vapor is a strong greenhouse gas, stronger than CO2. The key word here is "can". A large glass can hold more water than a small one, but that does not say it does! This is where understanding of convection processes (and observed behaviors) come in. Eighty-five degree (F) [30C] air can hold a maximum of 4% water vapor. This would be 100% relative humidity. But average relative humidity values are closer to 70%, with subtropical regions hosting only 5%, on average. No conclusive evidence supports this assertion of warmer air holding more water vapor with increased global temperatures. Evaporation works to fill the air with water vapor and precipitation systems disallow it.

To make a point about feedback responses: W/o natural ghg (water vapor esp) in atmosphere, T would be ~ minus 1.7C (~+1.4F). But, w/o atmospheric convection whisking heat upward where it is efficiently lost to space, T would be closer to 60C (140F). The actual T, influenced by both greenhouse-gas warming and convective cooling, is ~14C (57.2F). Negative feedbacks, such as convection, are poorly understood and not well represented in models!

Slide 17: Alternate Hypothesis: Networks (Internal Dynamics key!) –
This slide refers to an alternate hypothesis of multidecadal climate behavior – the "stadium wave":

Network behavior – an intrinsic dynamic – dominates the signature of this hypothesized climate behavior. Stadium wave is a term that refers to one alternate hypothesis of multidecadal climate variability, the underpinning of which is signal propagation. The stadium wave describes climate behavior as a network of synchronized (matched rhythms; not necessarily synchronous timing) ocean, ice, and atmospheric indices through which a signal propagates sequentially across the Northern Hemisphere (and perhaps globally) via index interactions in an ordered lead-lag relationship – hence, the allusive term, “stadium wave”. The fundamental view upon which the stadium-wave hypothesis is built is that over long timescales, “parts” of a system organize into a network of interacting sub-systems, resulting in collective behavior. Intra-network interactions yield positive and negative feedbacks, together, generating oscillatory (regular, not necessarily periodic) behavior – a stabilizing factor. Network behavior is ubiquitous throughout natural and manmade systems. It is what accounts for observations such as “rebound”, stability, and communication among “parts”.

The stadium-wave hypothesis holds that the shared tempo of variability of the ocean, ice, and atmospheric indices is paced by the fluctuations of sea-surface-temperature distribution in the North Atlantic Ocean (the Atlantic Multidecadal Oscillation (AMO), which itself, is thought governed by the Atlantic sector of the Meridional Overturning Circulation (AMOC)). The timescale and amplitude of variability of the AMO may be influenced by external forcing, in addition to internal dynamics that influence system behavior. Thus, the stadium-wave hypothesis is not mutually exclusive with external forcing (natural and/or anthropogenic); although the hypothesis differs in that the propagating signal is thought to be internally driven, and therefore assigns a significant role for intrinsic behavior in observed climate change. The “global warming” (consensus) hypothesis assigns a minor role to intrinsic behavior.

Computer climate models are not able to capture the stadium-wave signal – likely a reflection of missing or poorly represented dynamics in model designs - but, an abundance of observed indices do capture the propagation. The stadium wave has been detected in a variety of geophysical indices, from variations in Earth’s rotational rate to ocean-fish populations (salmon, sardines, cod, haddock, etc.). Three hundred years of proxy records derived from tree-rings reflect the stadium wave’s propagating signature throughout, with markedly reduced amplitude and increased frequency prior to 1800.

Slide 18: “Stadium Wave”
The plot on the slide shows a collection of indices, participating in transmitting a climate signal across the Northern Hemisphere. The Northern Hemisphere surface average T (NHT) and Atlantic Multidecadal Oscillation (AMO) are shown in their ***negative*** polarity to better illustrate the sequence. Starting with the Atlantic, a cool North Atlantic in the early 1900s (maximum cold 1915) leads increased Eurasian Arctic sea ice (not shown) and increased polar-equatorial temperature gradient (not shown), and then leads to increased west-to-east basin-scale winds (AT*); a positive NAO (North Atlantic Oscillation) – related to warm weather, especially in Europe; a positive phase in the Pacific Ocean (Pacific Decadal Oscillation (PDO)), which is related to strong west-to-east winds and frequent and strong El Ninos; which (not shown) leads to increasing Arctic temperatures (not shown) and NHT, and related changes in sea-ice extent (not shown) in the Atlantic-Eurasian sector. This cascade of interactions among the ocean, ice, and atmosphere, initiated by a cool North Atlantic, generates a warming trend in both the Arctic T (not shown) and NHT, which both peaked in ~1940. Cooling NHT followed, with the reverse scenario, the seeds of which were planted throughout the events b/n 1915 and 1940. The cooling continues until the mid-late 1970s, and is ultimately reversed by negative feedbacks “planted” as the NHT cooled. An increasing ‘NHT-trend’ reaches a

peak (max temperatures) with a warm AMO around the turn of the century (~2005). It is projected that from this point, the Atlantic will cool; adjacent Eurasian sea ice will slowly rebound, west from the Western Eurasian Arctic region within the high latitudes of the eastern North Atlantic to the east, north of Siberia, toward the Pacific, accompanied by changing large-scale wind patterns and slowly cooling NHT. Maximum cool temperatures would be expected around 2030 to 2040, if the hypothesis holds.

Back & forth this multidecadal component of network indices oscillates, manifesting in changes in drought/precipitation/wind patterns, vortex behavior, rates of sea-level changes, Atlantic hurricane activity, latitudinal shifts in climate belts, El Nino frequency/intensity, marine fish populations, patterns of ocean-heat uptake, and more. This multidecadal component is superimposed on a century-scale linear trend, assumed to be caused by greenhouse-gas accumulations, but may be partly generated by solar or other causes. The stadium wave does not speak to the century-scale increasing trend, only the multidecadal component. In short, & perhaps counterintuitively, a cool (warm) ocean signal leads a warming (cooling) atmospheric one. See www.wyattonearth.net for further details and related publications.

* AT is an index measuring basin-scale wind patterns (zonal vs. meridional) and is related to the polar-vortex strength.

Slide 19: Comparing Hypotheses – (consensus (external F dominant) vs. alternate (large role for internal dynamics))

Comparing hypotheses: consensus hypothesis (anthropogenic global warming (AGW) dominated by external forcing. alternate hypothesis (stadium wave) assumes larger role for intrinsic dynamics.

Focus first on the left panel of the slide. A plot of temperature trend b/n 1880 and 2010 is shown. It is not linear; instead, there are pronounced "wiggles", with no T increase b/n ~1885 and 1915; 1940 and 1977; and a potentially similar "non-trend" beginning in 1998 (not circled). We call these "pauses", for ease of discussion.

The consensus AGW hypothesis explains the "wiggles" with various versions of time-varying recipes of external forcings. Success is subjective. In general, warming between 1915 and 1940 was dominated by stronger solar output; while warming post 1977 is assigned mostly to greenhouse gases. The cool "pause" of relatively flat temperatures mid-20th century is attributed to the cooling effect of anthropogenic aerosols. The apparent current pause – now controversial – is not yet understood in terms of external forcing variations.

Turning attention to the right panel of the slide: This is a plot of proxy indices representing indices of the stadium wave. Here, proxies are used to extend the record prior to the 20th century in order to more easily compare trends with the instrumental-based temperature plot to the left (proxy indices and instrumental overlap for the statistically captured multidecadal component of variability throughout the 20^{th} century, supporting its use here). Note: Plotted curves of NHT and AMO are negative! Thus, warming (cooling) temperatures are shown with downward (upward) pointing arrows.

Cooling trends are circled. Note the dates bounding the cooling trend of the multidecadal component of climate variability; they coincide with the flat-lined “pauses” circled on the plot to the left. Thus, according to the stadium-wave hypothesis, pauses tend to be associated with multidecadal cooling trends related to the network dynamics of the stadium wave, which, when mentally superimposed (not shown) on the more linear trend of centennial-scale warming, mimics “wiggles” in the instrumental temperature plot. On the other hand, “pauses”, according to the consensus hypothesis, are explained by varying combinations of natural and anthropogenic external forcings (see above). The external forcing (consensus) AGW hypothesis is not directly testable; models are invoked as a “test”, despite their being hypotheses, themselves. In the case of the stadium wave, statistical testing of spatio-temporal patterns supports a strong statistical significance for the propagation patterns (>97%) and a posited mechanism is consistent with observations; yet the true test will come in time. The stadium-wave hypothesis is falsifiable; albeit a decade or more are required. If NHT cools, accompanied by predicted changes in the systems represented by the network indices, then the hypothesis will survive, at least it will survive that test. If NHT does not cool and the processes behave differently than predicted, the hypothesis will fail. That is the way of science: A hypothesis must be falsifiable (i.e. testable) to be a product of science.
[MD = multidecadal (see slide)]

Slide 20: Modeled vs. Observational Data (they tell different stories) –
What do the data say??? Turns out that “it depends”. Modeled data don’t tell the same story as observational data!!!

Some have misinterpreted the stadium wave hypothesis, treating it as a threat to the AGW paradigm of a dominant role for external forcing and a minor role for internal dynamics. In fact, the two hypotheses aren’t necessarily mutually exclusive. Propagation-of-signal is likely intrinsic; but, on the other hand, timing of variability, tied largely to cadence of the AMO variability, is likely a combination of internal dynamics & external forcing.

Despite this absence of conflict regarding external forcings’ role in these hypotheses, Mann et al. 2014 imply there is a conflict. Following this assumption, they claim they can show, using modeled data, that the stadium wave propagation as an artifact of a step in methodology. Recall, modeled data do not capture the stadium-wave propagation.

KWCT 2014 rebutted Mann et al.’s work and showed how models fail at capturing the signals contained in the “real” data. This slide shows the spatial and temporal differences b/n real (observational) and model-simulated data. To generate an argument, KWCT employed the exact same methodology used by Mann et al. with one difference; they used “real” data with a modeled signature subtracted; on the other hand, Mann et al. used modeled data with a modeled signature subtracted. The results show propagation; Mann et al’s do not – KWCT speculates this to be a function of dynamics missing in the model, and therefore in the strictly modeled data Mann et al. use.

The spatial patterns of climate fingerprints can be seen in the slide's contrasting plots, as well. The take-home message is that the Mann et al. study's hypothesis was nullified by the work of KWCT – i.e. shown to be refuted, false.

Note: Results consistent with those in KWCT 2014 were found in Wyatt and Peters (2012), who used CMIP3 data. They were unable to generate the stadium-wave signal in any of 66 runs, pre-industrial and "business as usual (CO2 increasing)".

[Two essays "Disentangling forced from intrinsic variability" and "Is the stadium wave an illusion" (by M. Wyatt) are layperson-friendly exposés on how the stadium-wave researchers countered Mann et al's claim (Kravtsov et al. 2014: hereafter KWCT14 (Kravtsov, Wyatt, Curry, Tsonis 2014)) & is posted on the www.wyattonearth.net site, on publications page, for those interested.]

Slide 21: What You Learned (last section) –
More than one hypothesis can explain observations of climate behavior. Two contrasting views – relative roles of external forcing versus internal dynamics - dominate. Modeled data support one view (external forcing); observational data (intrinsic dynamics), the other.

Slide 22: Model Forecasts & Limitations –
The garbage cans are perhaps unfairly used here to catch your attention. In fact, computer climate models are great tools, but they, themselves, are hypotheses. In essence, when we use them to test a hypothesis, we are using a hypothesis to test a hypothesis. A major problem arises when researchers begin to consider their model outputs to be "reality". All projections of extreme increases in globally average temperature are based on model runs.

If models are hypotheses, then why use them? Climate science is cursed with the inability to easily test hypotheses. Time scales are large; data sets short by comparison; and most importantly, we cannot isolate "parts" of the climate system in order to test their individual roles and responses. Models were used initially to explore "parts" of the system. Designs gradually became more complex, incorporating numerous "parts".

What makes a model a hypothesis? Each one is an experiment, of sorts. A climate model can be thought of as a script – taking orders from computer programmers in the form of complex mathematical equations. Increased complexity of input is expensive and time-consuming. Simplifying is necessary. Lost is the ability to capture details of climate phenomena too large or too complex for the model-grid's scale of resolution. To compensate, some "assumed-to-be unimportant" phenomena are omitted entirely; other phenomena are parameterized, meaning simple empirical formulas are used to represent the collection of phenomena as best as understood, with adjustable coefficients inserted. These coefficients often are cited as being the "thermostat" for modelers, allowing the programmers to tweak the outcomes to "fit" expectations or observations. Examples of features/processes that are parameterized include: cloud behavior, sea-ice dynamics, deep-atmospheric convective processes, atmospheric-soil-vegetation interactions, and precipitation schemes. Many of these poorly understood phenomena are thought to be critical to climate's sensitivity to forcing, acting as negative feedbacks to initial forcing effects. It is unlikely any model incorporates all the necessary dynamics to simulate climate. Problem is, those "necessary" dynamics remain unknown, as do the "unknown unknowns"!

Models for climate study range from simple numerical models to complex ocean-atmospheric general circulation models (AOGCMs). The latter type is what is often implied when discussing "climate models". There is not one "model". The IPCC (Intergovernmental Panel on Climate Change) has endorsed a suite of models – over twenty modeling centers represented – that are used to assess climate response to fixed and increasing forcing by CO2. Model design "scripts" differ. Thus, identical input will generate *non*-identical output. Among a single model design, output will differ for the same input; this is due to the model run's "starting point", referred to as initial conditions. In the latter case, outcomes of same-model-designs are averaged together. The assumption is that differences due to different initial conditions will be eliminated with averaging. In the case of outputs from a variety of model designs, researchers sometimes average these together – justifications for this procedure vary and should be viewed with an element of caution. Climate models are iterative, meaning they use output as input, risking accumulation of error.

Error defined as difference b/n true value of a measurement and recorded value. Random error = variability, random variation, or "noise" in the system. It has no preferred direction and is expected to net to zero when averaged together. Impact of random error is minimized with large sample sizes. Systematic error, aka: bias, refers to deviations not due to chance, alone. It does have a preferred direction and magnitude and is not eliminated with averaging. Model dynamics refers to all processes described by the information (equations) transposed onto a calculation grid, whose mesh size is defined by its horizontal resolution.

Model dynamics attempt to simulate real climate and are not to be confused with climate dynamics – the collection of processes, most not well-understood and many, not-yet-identified – that together, result in the observed behavior.

Empirical: based on or concerned with, or verifiable by observation or experience rather than theory or pure logic. Empirical studies rely on observation of behavior.

Slide 23: What You Learned (last section) – Climate models are hypotheses, themselves. Input into a model is based on what we think we know. Model design is based on physical laws, parameterizations, and data. Parameterizations are not physical laws; they are assumed behavior, and/or estimates, based on observations. Output of a model run is never the same, even for the same model design. Different outputs often are averaged together (ensemble) for temperature projections. Increased precision does not mean increased accuracy.

Slide 24: What is Temperature?
Models simulate a variety of variables representing features of Earth's climate. The variable we most often hear about is temperature; specifically globally averaged T. So what is temperature? What is *average* temperature?

Heat is energy - a physical quantity; T is not. T is not heat; it is not energy or any physical quantity at all. T merely represents the local condition of surroundings that have come into equilibrium with the measuring device (thermometer). T represents the average translational (back and forth) motion of the molecules of the substance being measured; i.e. the average movement of molecules and atoms in a substance. Heat, on the other hand, is a measure of the movement of all the molecules and atoms: Heat is total movement; temperature is 'average' movement (locally).

Because T is the local condition of a system, there is no one temperature, only a temperature field. How does one choose that field? In "globally averaged temperature", we can't measure everywhere. There are infinite temperatures, most of which are unreachable (depths of ocean; heights of atmosphere). Not only are there infinite temperatures, there are numerous factors that influence temperature: soil moisture, vegetation, winds, reflective and absorption qualities of surfaces, proximity of water – solid, liquid, or vapor, etc. How does one choose a sampling of temperatures whose average will really tell us anything about the heat content of the climate system? Earth systems transport heat from where there is more to where there is less; thus, heat is constantly being re-distributed laterally and vertically in Earth's on-going planetary mission to rid itself of excess energy. How can local temperatures of a very limited area capture the heat energy of the planet in any meaningful way? Temperature really says less than might be assumed. So it becomes obvious that choice of location of where a temperature is measured influences any "average" taken.

Slide 25: Comparing Data: Model vs. Surface & Troposphere –
Take-Away Messages: 1) Modeled Temperature anomalies (Ta) show steeper trend than trends derived from either surface (thermometers) or lower tropospheric heights (satellite/balloon). Two plots on slide reflect this. 2) Also shown is a "pause" in surface and satellite/balloon, *not* in modeled values.

A recently recognized piece of evidence is that model predictions have tended to project much warmer temperatures than observations support. In addition, model-simulated surface-average temperature trends reconstructed for the past century differ from all other records of temperature data. In particular, a recent "hiatus" or "pause" in the trend of warming temperatures has persisted for b/n 18 to 20 years and is a feature reflected in all instrumental and proxy data records, but not in modeled data. Is the hiatus an illusion or an artifact of the data?

Note: Satellite-based instruments (mircrowave sounding units (MSU)) retrieve information (radiation from O atoms) from the atmosphere from the surface up to about 8km (actually, to ~12.5km, but more heavily weighted below) and from the retrieved information, temperatures are calculated – not an uncomplicated process. Satellite data have been collected since ~1978. Advantages over surface data include greater coverage; although problems do exist in polar satellite-retrieved measurements. A short data record is another disadvantage of satellite retrieval.

As with all instrumentation, there are problems. In particular, a cold bias (measured too cool) existed in some satellite data, mostly prior to about 1998; it has since been rectified. But other biases have been noted and later addressed. This feature of bias – warm and cold - in all types of measurements is more common than generally realized prevalent in all means of measuring, not just in satellites. Surface data are plagued with their own set of problems. Great efforts are made to correct systematic biases, but with each identified bias and each attempted correction, we are reminded of uncertainty. It hides in every facet of discovery…

Slide 26: And How About Other Data?
Take-away message: Surface T does not match either satellite or balloon-inferred Ts. Satellite inferred Ts almost match balloon inferred Ts.

This plot displays four temperature-anomaly records: surface T, sea-surface (SSTs), satellite, and balloon. We focus on the combined land and SST trend (in red), the satellite (blue), and the balloon (in black). Satellite and balloon mounted instrumentation collects data on the lower troposphere; while surface temperatures monitor the lower couple of meters. Note: greenhouse-gas theory predicts warming most and first in the lower troposphere, as this is where the gases absorb the infrared radiation and heat. These warmed molecules in the lower troposphere, concentrated particularly ~ 3 kilometers then radiate heat outward in all directions, some heat directed to Earth's surface; some laterally; and some upward, where it exits to space. This explains why the surface should heat less and later than the lower troposphere. But, note, surface temperatures reflect greater warming than satellite and balloon instruments detect. Is there a signal in the surface T in addition to the assumed greenhouse-gas-related signal???

1) A surface temperature record (this one includes both land and sea-surface temperatures (SSTs) and is known as the GISTemp record (a NASA data set: GISS (Goddard Institute of Space Studies) Surface Temperature Analysis). It is one of several surface-temperature records that measures the air just above the surface (and/or the SSTs).

2) The satellite Ts are retrieved from MSU (microwave sounding units) aboard satellites from the UAH group (University of Alabama, Huntsville). Measured is the lower troposphere (from surface to about 12km, with focus on the 3km region), where most of ghg warming is theorized to occur.

3) Weather-balloon mounted radiosonde units, in operation since 1958, measure the lower troposphere, a region captured in satellite measurements.

Slide 27: Surface T ≠ Tree-Ring Data –
Take-away message: Surface Ts do not match tree-ring data.

Implications are profound. Studies claiming long-term non-variability over the past few hundred to a thousand years have based conclusions on tree-ring data. If the tree-ring data do not pick up warming surface temperatures today, in particular, those since 1960, how "certain" can one be that tree-rings reflect accurately an *absence* of strong warming in the past? How certain can one be that tree-rings "worked" in the past, but somehow have failed in recent decades?

In addition to surface temperature-anomalies being larger than those derived from satellite and weather balloon data, surface temperature-anomalies are greater than proxy data based on tree-ring information. The trend difference between proxy-estimate T and surface-measured T began around1960 and has become increasingly greater since. This "divergence problem" was first recognized in the 1990s. It is further noted that *most warming of surface temperatures over the last few decades has occurred NOT in maximum daily temperatures, but rather in daily minimum temperatures*. It is the latter that has had the greater impact on average daily/annual temperature trends. Significant to note, *tree rings do not capture this increasing minimum-T signature*. They capture the maximum summer temperatures, instead. Uncertainty…

Slide 28: Reanalysis "Data": packaged mix!

Caution: What is real??? Reanalysis – a "packaged mixture" in one data set!!!

We've touched lightly on the different types of data sets – surface land, SSTs, and satellite & balloon-based instrument records of the lower troposphere. There is another type of surface-temperature information; although one should not call it "data". It is a model-generated product. Problem is, as with model results in general, the simulations are often accepted, or at least communicated to the public, over time, as "real"! These "products" are used in some recent climate studies and a reader would be hard-pressed to recognize that the conclusions were based on "products" simulated by models rather than based on "real data". So consumers beware!

The basic idea behind reanalysis data is to fill gaps in data records – temporally and spatially. To do that, reanalysis methodology uses modeled output based on inverse modeling. In essence, they work backwards to get input. Existing data are used to give insight into climate behavior, to "guess" what might be happening in those gaps where there is no information. These data are then converted into a best-guess algorithm that is input into a model along with existing data and parameterizations reflecting a chosen "climate sensitivity" – i.e. reflecting how the modelers assume climate behaves. Then the model is run with this output-converted-to-input for a specified time step, predicting a future outcome for that given time step. Then that new, updated output is put back into the next time-step model run, etc. Output used as input describes an iterative (repeating-step) model technique – a recipe for accumulated errors, errors rooted in sparse "real" data coverage or biases in data-collection methods, for examples. Accumulated errors can generate temperature predictions from a variety of model runs that are wildly different from one another, as can be seen in this plot of model-output. Some of the predictions reflect snowball-Earth type temperatures; while others have temperatures sky high. These and other less desired results are discarded. "Good" ones are selected – of course, that being a subjective interpretation. Because the model dynamics are extremely complex, their workings are opaque; thus, one can never know what the complex model dynamics were that generated those "good" results. So each "data" product starts with "guesses"…(See: Xu & Powell (2011); online posts by Willis Eschenbach)

Slide 29: Mixing "Real" with "Modeled" –

Consumers beware here too! Mixing Data Sets: Real data sets with modeled.

An increasing number of recent climate studies employ a method ("semi-empirical method") whereby the researchers combine observational (real) data with modeled data. This approach *differs from the reanalysis* in that it *does not use the real data to generate modeled data*. In the mixing case presented on this slide, the two data sets remain distinct and are subtracted from one another. This differencing procedure, using modeled with observed data sets – termed "semi-empirical" analysis - has its value; yet readers can easily be lulled into thinking everything is "real".

One common use of the semi-empirical method is by researchers who assume (according to consensus hypothesis) that the "wiggle" in the 20th century temperature trend was generated by varying proportions of natural and anthropogenic external forcings. In attempts to ascertain the relative role of an internally generated component in climate behavior, this forced trend is "modeled" – i.e. made to be what they assume it must be. They take whatever outcome their particular modeled version generates and then subtract this model-estimated external-forcing signature from "real" data. Sometimes they use real data of surface temperatures (global or hemispheric) to subtract the modeled data from. Other times they use real sea-surface-temperature data of the AMO or some other climate-phenomenon index to subtract the forced signal from. The residual signal that remains after the modeled signal is removed from real data is assumed to be "intrinsic". Caveat: typically, because the temperature "wiggle" is attributed to forced behavior (as predicted by the consensus hypothesis), and is not attributed to internal variability, when it is fully removed from the real data, minimal variability remains, if at all, in the residual. This leads to the "proof" that external forcing exerts dominant control over climate variability; & a minimal role for internal variability.
More uncertainties….

Slide 30: What You Learned (last section) –
Temperature is not heat. It is a local measure – average of molecular motion - of the substance with which the measuring device has come into equilibrium. And *average* temperature is a statistic, not a physical quantity.
Four categories of measured temperature were discussed – surface, satellite-retrieved, balloon, and proxy. None match model temperatures.
Surface temperature-trends do not match satellite & balloon T-trends; satellites and balloons measure lower troposphere.
Reanalysis products and semi-empirical analyses involve modeled data.

Slide 31: If trends don't match, change them!
<u>Take-away message</u>: Raw data is adjusted, sometimes justifiably (yet still injecting uncertainty), yet sometimes, arguably not justifiably, adding more uncertainty!!!
Raw data have all been changed – 20% of it changed 16 times in the last 2 and a half years. This plot shows NOT the average surface T trend between 1880 and 2010, but rather the trend of *changes* made in the temperature anomalies (1880 to 2010) between May 2008 and May 2015.

Take the month of January for comparison b/n 1915 and 2000. In May of 2008, the difference b/n January temperature anomalies for those years was 0.39ºC. As of May 2015 note, the difference is 0.52ºC (almost a degree F).

Justifications for data changes find root in problems with techniques used in measuring temperature that introduce biases – non-random errors (difference b/n measured value and true value) – to the record. These problems comprise a long list: number of stations reporting changing over time; stations moving; station environments becoming contaminated by urbanization or changes in vegetation or cover, etc over time; changes in methodology – changing times of measuring T; changing instrumentation; changing precision, and on and on. As far as SST biases – changing methods and changing coverage of measuring dominate the record problems – buckets, ship engine intake, buoys, satellite retrieval, etc. Thus, faced with what appear to be numerous corrupted data points, data crunchers try to imagine what skews in temperature trends must have resulted from these different changes that had nothing to do with real climate changes, just methodology-related changes. Then the data crunchers attempt to adjust the data to rid the record of the flaws. Easier said than done! And while one assumes that good intentions motivate the adjustments, one thing is obvious: temperatures adjustments prior to 1950 have resulted in a substantial cooling of the early century (20th) and adjustments made after 1950 have substantially warmed the record; consequently, the trend of temperature increase has significantly steepened over the years – a product of data changes. Is this an accurate reflection of reality? Uncertainty…

Investigations into the frequently changing data base, changing more and more frequently in recent years, have led to some conclusions: human error; assumptions on physics, conditions, and how climate works; overconfidence in algorithms; and human flaw of seeing what expect to see, has led to some to cry foul over what appear to be temperature-trend adjustments made to match model output, which has increasingly diverged from all other temperature records, including the surface T record.

Now, as the surface temperatures get "warmer" with these adjustments, an interesting consequence occurs: the anomalies are larger, much larger, than those detected in the lower troposphere by satellites and weather balloons. This vertical T profile is not consistent with greenhouse-gas theory, where the lower troposphere should show greater increases in T change than the surface. (See work by (e.g.) Roger Pielke, Sr., Anthony Watts, among others, on documentable station adjustment issues. Jim Steele (following slides) and J. Marohasy for undocumentable ones.)

Slide 32: Assumed Climate Behavior –
Adapted from the chapter *Why Average is Not Good Enough* in Jim Steele's book: Landscapes and Cycles: An Environmentalist's Journey to Climate Skepticism.

Natural influences have been identified that explain much of the observed trends (wiggles and all) over the last hundred-plus years. One involves the Pacific – a coupled ocean-atmospheric circulation pattern that generates distinctive SST-distribution patterns in the North Pacific Ocean. Variability in this distribution pattern – known as the Pacific

Decadal Oscillation (PDO) - occurs on a couple of time scales; the one of interest here is the dominant one, the multidecadal timescale – 50 to 80 years. During the 20th century, the time scale of variability centered on about 60 years. During positive phases of the PDO, El Nino events in the tropical Pacific are more frequent and more intense than during the negative phases of PDO. La Ninas are more frequent during negative phases. El Nino is associated with increased temperatures, particularly adjacent to the west coast of California. The positive phase of PDO peaked twice during the 20th century – once around 1930 and again around 1990, as seen in the upper panel on the slide. Evidence for its impact on western California can be seen in the raw data shown in the lower panel. Minimum raw temperatures are shown in the solid line. Minimum adjusted temperatures are depicted by the dashed line. While a multidecadal trend is pronounced for the PDO, its secular-scale (i.e. century-scale) trend is essentially zero. This is essentially what would be seen in the Cuyamaca, CA plot using the raw data. But adjustments eliminated the 1930 peak by cooling the temperatures early century. Temperatures post-1950 were mostly untouched, until the late 1990s. Those were adjusted slightly upward. Hence, the record reflects a non-zero temperature-anomaly trend, a rather steep one. So what's going on? Now the multidecadal variability is muted and the century-scale trend steepened. Fixing the data fairly? Justifiably? Based on assumptions of behavior? Whatever the motivation, recognize the added uncertainty…

Slide 33: Homogenization: Blending Trends –

Take-away message: Climate data bases are tweaked, their trends made to match – i.e. blended or homogenized. The assumption behind this operation is that temperatures within a general area should all show the same trend. If that trend is not reflected in a given T record, trend adjustments are made in the "non-conforming" record. If problems at that data's station are documented - meaning flaws in the temperature measurements are due to flaws in measuring - the trend-adjustment (via homogenization) is accepted as necessary. Many stations whose data are adjusted do not have a history of station issues. Adjustments made at these stations are considered unjustified and feed the polarization b/n "warmers" and "deniers". Arguments flood from each side. Of importance here is the uncertainty, regardless of the supporting or weakening arguments!

Minimum Ts have increased at 3x the rate of max Ts since 1950. Urban landscapes resist nighttime cooling; thus population growth is correlated with min T increases. Without similar long-term increases in max Ts, heat is not accumulating in the deep atmosphere; yet, average daily and annual Ts will reflect an increase (due to the merging of maximum that show little or no increases with strongly increasing minimum temperatures).

The plot of Tahoe City (left plot on slide) shows raw, unadjusted data: max T (solid black line) and min T (dotted line). They closely track one another until the 1950s, after which min Ts increased, likely UHI (urban heat island). Because no station contamination would explain this increase, the min T trend is assumed "correct". Max Ts showed no trend.

On right figure, plots of two neighboring stations illustrate how assumptions can be flawed. The explanation follows:

Adjustments are termed 'homogenization', in reference to a blending of temperature-anomaly trends. Based on the assumption that neighboring T-recording stations should reflect identical century-scale T-anomaly trends, a deviation from the "neighborhood" trend – one or more "neighbors" - sends up a red flag, indicating it is an outlier – a mistake. A computer identifies the "mistake" & applies a pre-determined algorithm to adjust the outlier's T-trend so that it matches the neighboring station trends. *Caveats emerge*: 1) neighboring stations, which can be scores to several hundreds of kilometers apart, can exhibit strikingly different T-trends due to localized effects of topography, ground cover, and proximity to lake or ocean influences; 2) absence of an increasing trend may be assumed to be a mistake, as it would violate what one expects to see. This is illustrated by comparing two stations: Marysville, CA, which is a documented contaminated station, and Orland, CA, which is not. Somehow contamination at the Marysville's station location - amidst asphalt, against walls, and near air-conditioner exhaust fans was overlooked – its pronounced T trend assumed "correct" (see plot). On the other hand, Orland (right side of right figure), an *un*contaminated station, appeared the outlier. Its data trend was "unexpected"! So it was adjusted to fit Marysville's. To do so, min Ts of the 1930s/40s in Orland were cooled. Look at the raw data (solid black) in the 1930s and 1940s on both plots. Both plots reflect elevated min Ts. Now, look at the '50s & '60s. Raw min Ts in Orland decreased, & a flat trend persisted until a~1977, after which they begin to increase to a maximum value in the 1990s. These T peaks are related to PDO (previous slide). But the PDO peak in the 1990s that *should* have been captured in the T trend in Marysville is obscured by a continuously rising trend in the later century. (Keep in mind; we are not describing individual Ts, just the trends!). That trend is the one *artificially* generated by the contaminated station. Since the computer "thought" it was a "good" trend, consistent w/ climate expectations, and Orland's was not, Orland's was changed to match the "wrong" trend! Such examples are not isolated. The problem is worldwide. Uncertainty…

Slide 34: Monthly Bias in U.S. Adjustments –

Take-away message: Adjustments seem suspicious with 1) larger (increasing values) adjustments made for cooler months and 2) increasingly larger adjustments made post-1990. See post by Walter Dnes for more information.

The upper graph shows plotted data for U.S. temperatures 1970 to 2013 derived from the USHCN (U.S. historical climate network). Twelve different colored lines represent individual months for each of those years. Consistently, the cold months are adjusted (upward) more than the warmer months. Of course, this "fits" with the ghg theory that more T increase occurs in winter months with CO_2 warming than during warmer months. After 1970, the difference in monthly adjustments increases, with the greatest increases applied to February, March, and January Ts, in that order.
The lower plot to the right shows the 12 individual lines representing each month of the year for the time span from 1872 to 2013. This plot gives perspective on the pronounced upward adjustments applied to all months, and in particular, the cold months. Note also that temperatures in the 1930s and 1940s are adjusted downward, minimizing the natural warming that archival evidence and long-time records have reflected.

These are the "real" data…The question is begged: how real are the real values???

Slide 35: Down-Under Adjusts Similarly!
Australia's temperature record exhibits one of the fastest warming trends in the world. Jennifer Marohasy – a climate scientist who regularly posts articles concerning the Bureau of Meteorology's handling of homogenized data – has been exposing inconsistencies in the temperature adjustments. She has found evidence to suggest much of that warming is an artifact of unjustifiable homogenization, accounting for two-thirds of temperature increases recorded since 1945. Australia, like the U.S. and much of the world, tends to cool the past and warm the modern decades. In Australia, the "manmade" cooling is prior to 1971.

Changes are known to be made even when no documented equipment change or site re-location. There are cases when such unwarranted adjustments have converted cooling trends into warming ones – the town of Rutherglen is an example. To make these changes, they use a distant location (Hillston) to make the comparison. "Neighboring" can mean a station up to 600 km away!

Also, the charge is that "cluster homogenization" is occurring, where instead of adjusting the trend of an outlier to the trend of the majority, changes to trends of an entire cluster of stations is done, thereby creating a revised "majority" trend.

Furthermore, it is claimed that stations used to generate the T average have changed over time (unwarranted), from stations measuring cooler climates to stations representing warmer ones. The same # of stations are used (134: 100 rural, 34 urban), but with warmer regions replacing cooler ones, another warm bias in injected into the average T. The increase in the minimum T trend is higher than the max T, as is seen in numerous records: Tmin increase 0.37C since 1910. maximum T is only 0.09C.

Brazil, Africa, China, and Russia suffer similar issues. Malintent? Maybe not. But uncertainty in our data bases grows by the year, especially since the end of the 20th century. And again, for every seeming incongruity identified, there are numerous posts attacking the messengers of this information. Tit-for-tat is endless. Despite the "rights" and "wrongs", the bottom line remains profoundly important – adjustments have altered the data sets, especially in the last several years. Data downloaded yesterday may not exist next week. The uncertainty injected into analysis and analysis results is intractable and unquantifiable. Our conclusions become increasingly difficult to trust, especially on finely resolved scales!

Slide 36: What You Learned (last section) –
Temperature records are compromised by biases in measuring; these are documentable issues and adjustments are made in attempt to compensate flaws. These adjustments (homogenization (adjusting in order to blend trends with neighboring stations)) are justifiable. Adjustments are sometimes made on stations where no documented issues exist, leading to compounding of uncertainties in data base.

Slide 37: Did the Warming Pause? 1998-2015 –
Take-away message: Despite quantitative differences among surface, satellite, balloon, and proxy T records, all show "pause" in warming since 1998, continuing to today (2015). NOAA asserted that the hiatus was not real, but merely an artifact of poor data, prompting more surface-data adjustments. These recent adjustments succeed in minimizing the pause and generating record-high temperatures. Right? Wrong? Uncertainty…

Despite differences in magnitude of changes in different data sets; and despite all the adjustments of surface-temperature trend made, effectively cooling the 1930s and 1940s and warming the years after ~1950, especially after 1980, a "pause" in that warming trend seemed to kick in around the turn of the century.

Potential explanations for the hiatus range from increased La Ninas and/or enhanced ocean-heat-uptake, a wobbly polar vortex, or a change in large-scale wind patterns, or ocean-circulation regimes. All are reasonable explanations and none mutually exclusive with one another and all being consistent with the alternate hypothesis (stadium wave) for multidecadal changes – with a strong role for intrinsic dynamics.

To the camp focused mostly on external forcing as the mechanism for all climate change, the hiatus made no sense. Neither a decrease in solar output nor increased aerosol cooling could account for the observed warming pause. At first, a few years of no warming could be assigned to random variability according to the "consensus" hypothesis. Then the "pause" reached the decade mark.

Computer-climate modelers, not married to a particular dynamic to explain the observation, asserted that their results showed that a "pause" of up to fifteen years could, indeed, occur "randomly", within the margin-of-error. But then the hiatus extended to 17, now 18 years, beyond what models could support. Tree rings, satellites, and even land/ocean based stations and buoys seemed to pick up the "no-trend".

At this point, director (Tom Karl) of NOAA's data center (formerly NOAA's NCDC (National Climate Data Center), recently changed to NOAA's NCEI (National Center for Environmental Information)), argued that the hiatus was *not* in the surface data; he claimed any perceived pause was an artifact of poor data (Karl et al. 2015). This signaled that more adjustments were needed. More uncertainty introduced into the data used to analyze how climate works!!! That story follows.

Slide 38: Maybe We Can Adjust Some More –
Take-away message: Recent T adjustments applied to data post-1998 minimize/eliminate hiatus. Some researchers (Karl et al. 2015) argue that the perceived hiatus was an artifact of poor data. Their paper reflects recent corrections to that data (described below). The most extreme adjustments were those made to the SSTs and Arctic Ts.

A newly revised data set recently has been released. NOAA adjustments to SSTs essentially doubled the warming rate during the interval between January 1998 and

December 2010 – increasing SST values that had been used as a reference* for NOAA's previous data base (*reference SST data: HadNMAT2 (replaced December 2010)). Most changes to the new data set have been made on the SSTs measured post-1998. Despite good data being available for SSTs during this period, an upward adjustment of 0.12ºC was applied to all SSTs to "blend" these temperatures with longer-running T records taken from engine intake channels – an acknowledged source of warm bias. This strikes an odd note with some, as good ocean data have been available throughout that time and for years before. Over the last two decades, buoy measurements, not affected by this bias, have increased in density, replacing the latter shipboard method. In other words, a warm bias in the last two decades would be minimal, at best. Tom Karl of NOAA's data center justifies the adjustment, noting the 0.12C correction could have been made by deducting from the problematic data generated by shipboard measurements, but he chose to instead add it to the "good' measurements of data since that time (1940s). Arguing continues back and forth from both sides. Regardless of which arguments sway you, the bottom line is <u>uncertainty</u> mounting in the data bases!!!!

The other data adjustment involved the Arctic. The Arctic includes land areas and ocean regions covered either seasonally or year-round by sea ice. When there is ice present, even during the summer melting process, surface Ts remain at 0ºC. The data for the Arctic region do not include directly measured values for the regions covered by sea ice. Instead, land T measurements are extended, by extrapolation, over these areas. Thus, the surface Ts for the sea ice regions are interpolated (inferred) by using land values, which, during summer months, rise well above 0ºC, while the sea-ice regions often remain at 0ºC. This method thereby introduces substantial warm biases. An additional source of uncertainty comes from infills for Arctic Ts that are interpolated from distances as great as 1200 km.

<u>Upper left-side plot:</u> Curves of three plotted data sets of sea-surface-temperatures (SSTs) are shown for the years 1998 to 2015. Two of the plotted data sets are "old" versions. One is the HAD1SST (blue) set and the other the Reynolds O1v2 set (olive green). Both of these data records include satellite-based SST information. Satellite data show little to no T trend b/n 1998 and 2015.

The third plotted data set shows the newly revised (or "corrected") SST data. The correction to the data involves, among other things, the elimination of satellite data from the record. This revised data set is the ERSST.v4 (extended reconstructed SST version 4) record generated by NOAA's NCEI data center (i.e. Karl et al. 2015). The "corrected" SST trend shows a 0.062ºC/decade increase since 1998.

<u>Lower right-side plot</u>: Trends of Land and sea-surface T anomalies b/n 1998 and 2015. Five data sets are represented. Two (NCEI & GISS LOTI (Goddard Institute for Space Studies Land and Ocean Temperature Index)) show significant increasing trends; while the others show moderate (HADCRUT) to minimal trends (satellite based: UAH and RSS).

The sharply increasing recent trends in the NCEI and GISS LOTI records derive from the same source – a revised SST data base that excludes satellite information (ERSSTv4 discussed above: shown in upper left-side plot).

Slide 39: Hiatus "Disappears" from Surface T –
Thomas Karl (NOAA data center's director), under assumption that "hiatus" was an artifact of bad data, led a research group to test that hypothesis (Karl et al. 2015: Possible artifacts of data biases in the recent global surface warming hiatus). They did so using entirely new ("corrected") data that NOAA just "revised". (See previous slide).

The end result can be seen in the plot (NOAA) on the lower left. A full view of adjustments made to temperatures, ones made between October 2000 and May 2015, is shown in the upper right plot. Note that the majority of adjustments made in this approximate five-year period were applied in April and March of 2015! In this upper right plot, the horizontal line marks a 0 temperature anomaly. From the plot, a similar pattern emerges – the "natural warm peaks in the 1930s and 1940s have been adjusted so they are colder than the original data, and all temperature anomalies after 1975 are adjusted upward. The net result of the mix of anomaly adjustments is a steep increasing temperature trend since the late 1800s.

As a result of these most recent adjustments, the hiatus in warming 1998 to 2015 has disappeared. The surface data are beginning to show what modeled data show – that surface temperatures are warming.

In fact, the year 2014 has been identified as the warmest year on record – warmer by 0.02ºC. Ironically, that amount is small compared to the margin-of-error, which is five times that at 0.1ºC. On top of that, initial reports showed only 38% certainty according to NASA's GISS, with NOAA's NCEI weighing in at a 48% certainty. And in reality, given the unaccounted for biases discussed in the adjustments and their attendant assumptions, that certainty level appears to be overestimated.

Note, satellites give different results: 2014 6th warmest in 18y, and the late 1930s are suspected to have been as warm if not warmer (no satellites then).
[Conundrum: if surface Ts are warming and lower troposphere Ts are not, then the ghg-"theory" needs revision, as the data are inconsistent with the hypothesis!]

Right? Wrong? – More importantly, what is the uncertainty of the "settled" science?

Slide 40: What You Learned (last section) –
The preceding section was packed with information. The bottom line is that data have been changed; the changes - typically cooling the first half of the 20th century and warming the latter half, thusly steepening the century-scale linear trend – are accompanied by varying degrees of justification – all contributing to the uncertainty of the data sets used to analyze climate.

With the “corrected” data, the previously documented “hiatus” in warming since 1998 has “disappeared”, and with the disappearance of the pause, the revised data show 2014 to be the warmest year on record since instrumental records began in 1880.
History, according to adjustments made to the data, is changing!

Slide 41: They Said it Was Hot – quotes in news 1920s to 1940s
Slide 42: Then They Said it Was Cold – quotes in news 1970s

Slide 43: And Here’s the Long-held View:
The constant pattern evident throughout climate history is variability, whether due to CO2, continental configuration, latitudinal placement of landmasses, topography, ground cover; life; solar variability; orbital changes affecting distribution of solar insolation; periods of intense volcanic activity; meteorite hits; ocean circulation changes and “opening” gateways (e.g. Panama) and effect on oceanic transport of heat; buildup of ice (latecomers – Antarctica ~33mya and Greenland ~7mya), etc.

Figure in upper left: Note over 90% of 4.6by history warmer than today.
Reasons for climate behavior are numerous and varied; sources of variability related to time scale of that variability.

Figure bottom center: Closer in, the last glacial ended about 10kya. Climate warmed, at first with fits and starts, but ultimately peaked in the Holocene Climate Optimum, spanning roughly from 8kya to 4kya, with a cool dip around 5-6kya. Lesser warm intervals occurred around 2kya (Roman Climate Optimum), then ~1kya (Medieval Warm Period). Cold episodes punctuate the record, the most recent being the LIA from ~1300 to 1850, with variability within. Currently, the Modern Warm Period.

Figure upper right: The Medieval Warm Period and Little Ice Age are viewed in more detail in this figure.

Slide 44: But Adjustments Changed That!
This slide shows one of the “Hockey Stick” graphs – this one describes the shape of the T curve over the last thousand years. (There have been a variety of hockey sticks generated by Mann and colleagues. All have stirred controversy.)

All hockey sticks (Mann et al.) consist of a controversial collection of proxies, many of which have been proved to not capture the current warming trend; thus, casting doubt that tree rings should have captured full warming in the past. Onto this proxy-generated-“trend’ are spliced instrumental records (sharply upwardly trending) to show the “blade” of the hockey stick shooting skyward. Detractors note the questionable practice of joining together dissimilar data sets. The end-of-record steep increase in T mutes all previous variability in the record, supporting Mann’s claim that at no time in recent history have Ts been so high and variability from lower Ts been so extreme. This conclusion countered conclusions generated by decades of previous research. Subsequent studies have supported those previous studies of greater variability in the past. Unraveling past behavior is rife with caveats.

Methodology and data used in the hockey stick analyses have not held up well to scrutiny. Many identified flaws in methodology and data selection weakened the conclusions of Mann and his research team. The only conclusion could be that warming was now likely greater than any time in the last four hundred years. That 400-year time frame puts us in the late 1500s to early 1600s, right in the middle of the Little Ice Age, from which climate emerged slowly beginning around 1850.

Note, one of the biggest flaws in the data used by Mann's team were tree rings that have been shown in modern times to NOT capture the warming signal of measured surface Ts. It should be obvious that creating a T trend using tree rings in the early years and adding a short splice of surface instrumental Ts results in a false visual.

Slide 45: What You Learned (last section) –
Climate variability nothing new. Changing data change perception of past variability.

Slide 46: "Consensus": Often Wrong –
Science has always been a story of revision. Paradigms come and go. Limitations of technology, egos, hardened mental filters, and the like can contribute to a flawed paradigm's endurance. Science is not truth! Science is the constant process of trying to figure out how something *might* work!!! Science is defined by degrees of uncertainty. Consensus plays no role in scientific validity.

Some examples:
The geocentric model endured over 1600 years (Aristotle to Copernicus/Kepler/Newton). Ptolemy epicycles kept the flawed paradigm on life support.

Think Galileo and the Church – which one saw the sun at the solar-system center (heliocentrism)?

Age of Earth, too, was an evolving concept, with "young" age often promoted by the most revered and degreed earth scientists of the day.

Reasons for adopting flawed conceptual models of physical processes were justified to a degree: lack of technology to support existence of alternate model (heliocentrism, for example). Typically the best educated perpetuated the paradigm. Those not immersed in the field and not financially tied to the discipline were the ones who saw through a different filter and revolutionized a science that was not necessarily their area of expertise!

Slide 47: How Today's Consensus Evolved –
Slide: The flow-chart above is divided vertically in half.
The <u>left side</u> shows the IPCC* conclusions and goals feed the federal funding for grants given to scientists to study, specifically, the effect of anthropogenic CO_2 emissions on climate behavior (AGW: anthropogenic global warming). This is the "external-forcing-dominant" paradigm. Thus, the funding feeds the AGW hypothesis. In turn, the

hypothesis inspires the computer-climate-model designs. The modeled output, in turn, has led slowly to the observed data being adjusted, as the observed data records tend to be inconsistent with "theory". The data, while fed by models and hypothesis, in turn, feed the hypothesis. Studies supporting the consensus hypothesis are easily published, review processes more streamlined and lenient than with studies whose conclusions do not support the hypothesis or are neutral. This all dove tails with media promotion, typically highlighting only AGW-supporting conclusions and not the methodology and data used to derive the conclusion, and not the author's noted limitations and weaknesses of the study and its conclusions.

The right side shows the fate of a non-AGW hypothesis: The IPCC does not fuel funding for the hypotheses that are not "AGW", those that tend to argue for a strong role for internally generated dynamics (intrinsic variability). In the case of an alternate hypothesis, the data inspire the hypotheses. The historical data feed the hypothesis. Modeling with the atmosphere–ocean coupled general circulation models (AOGCMs) used for IPCC-related research do not support these hypotheses; it is assumed that critical dynamics are either absent or poorly represented in the AOGCMs.

White asterisks: modified and modeled data. .Red dotted line: no correlation. Blue arrow: arrow points from end member that supports the other. .Red arrow: arrow points to end member being driven by other member. Red dashed double arrow means the two end members are consistent or supportive of one another.

*The Intergovernmental Panel on Climate Change (IPCC) assesses the scientific, technical and socio-economic information relevant for the understanding of the risk of ***human***-induced ***climate change***.

Slide 48: Charisma Spreads Consensus –

Power of charisma… Compelling and persuasive communication skills and ability to manipulate mass opinion play strong roles in effective messaging. It is up to the individual to ascertain validity of the message – accepting a paradigm requires good evidence, not group opinion. Consider the uncertainty.

One example of persuasive communication:

"We should not talk to the politicians about our doubt or the uncertainties of our model output; we should keep that among ourselves, when we are talking to other scientists. It is our moral duty to express certainty."

As quoted from a well-known NCAR scientist presenting at a class of mine on the deficiencies of computer modeling being done for the IPCC. (2007)

Other examples of "effective (mis) communication":

PORT-OF-SPAIN, Trinidad and Tobago -- Caribbean nations face "very, very scary" rises in sea level and intensifying hurricanes, and Florida, Louisiana and even northern California could be overrun with rising water levels due to global warming triggered by carbon-based greenhouse gases, Energy Secretary Steven Chu said Saturday.

Chu's comments followed meetings with environmental ministers attending the fifth Summit of the Americas. He did not shy away from the most perilous predictions about the potential effects of global warming.

He said global temperatures have already risen by 0.8 degree C, that another 1 degree increase was certain to occur and "there's a reasonable probability we can go above 4 degrees Centigrade to 5 and 6 more.“

"So imagine a world 6 degrees warmer. It's not going to recognize geographical boundaries. It's not going to recognize anything. So agriculture regions today will be wiped out," Chu said.

"I think the Caribbean countries face rising oceans and they face increase in the severity of hurricanes. This is something that is very, very scary to all of us. The island states in the world represent -- I remember this number -- one-half of 1 percent of the carbon emissions in the world. And they will -- some of them will disappear," he added.
Chu said the United States would not be spared, either.

"Let me state what the official IPCC (the United Nations Intergovernmental Panel on Climate Change) prediction is: It (sea levels) could go up as much as three-quarters of a meter in this century, but there is a reasonable probability it could be much higher than that," Chu said.

Slide 49: What You Learned (last section) –
Evolution of consensus – good intentions, entrenched filters, politics

Slide 50: Signs of Doom?
No evidence-based correlation for CO2 warming and increases in occurrence of extreme weather events exists. Perception of such develops due to: population distribution, increased media coverage, increased videos/cell-phones. Warmer global Ts would reduce T contrasts, upon which extreme weather feeds. Multidecadal variability is apparent in behavior and occurrence of Atlantic hurricanes, polar-vortex-strength variations, drought, and precipitation patterns.

Sea-level-rise (SLR) is problematic to measure; to compare against historical measurements; & to assign cause. In some places the land is rising; in others, sinking – not related to AGW. Cyclical component. Rate of SLR was at least as high in the 1930s. SL was 3 to 5 meters higher than today in the last interglacial (Eemian) about 130ky to 115ky ago. Current best-guess for SLR is ~2mm/year (estimates: ~ 1.8 to 3.3mm/year; data poor). About half this due to steric (thermal) expansion, not increased water.

Ice sheets are tricky. Some are melting. Some are near volcanic or geyser underground activity (both Greenland and Antarctica). West Antarctica is under influence outside polar vortex and impacted by warming winds encircling the vortex. The remaining 98% to 99% of Antarctica is cooling and sea ice is increasing at an accelerating pace. Sea ice in Arctic has declined from its maximum extent, which existed in late 1970s, just when satellite coverage coincidentally begam. Ice extent was minimal in 1930s and 1940s (archival and Russian data). Able to contribute less to sea-level increases, mountain glaciers often are featured in photographic documentaries to underscore global warming. Mountain glaciers are not good thermometers. Adjacent glaciers can and do exhibit contradictory trend. These glaciers, in particular, are poorly correlated to global warming, their dynamics strongly tied to precipitation, incoming solar radiation. Complex.

Fish-population changes in distribution related to natural climate cycles. Phenology – timing of seasonal activities of flora and fauna – not presented exactly as is. E.g: much of the response is related to 30-y trends in ocean and atmospheric circulation patterns. Simple correlations rare. The much-hyped butterfly shift by C. Parmesan in 1999 was misrepresentative. While a third shifted north (highlighted), meaning the southern boundary was evacuated; 2/3 of the species simply expanded their range northward, keeping the same southern boundary. Small % shifted southward. T link not supported.
And polar-bear populations: In the 1950s, estimates of population were ~ 5000 – low #s due to hunting. B/n 1965 and 1970, increased to 8 to 10 thousand. 1984, peak: 25,000. Current, b/n 22,000 and 25,000. In some regions, such as Western Hudson Bay, a decline is seen of ~20 to 25% over last decade. But the Canadian bear population has increased by that percentage over the last decade, from 12,000 to 15,000. Correlation unclear.

Have these changes happened before? Are the changes fairly and accurately reported??? Perception plays a role. Selection of results, perhaps inadvertently due to "expectations", plays a role too. For more information, see posted "potential consequences of global warming" on "investigations" page on www.wyattonearth.net.

Slide 51: What You Learned (last section) –
Things aren't always what they seem, and never as simple as they appear.

Slide 52: Do We Act "Just in Case"?
There is the view point that we should just 'do something', just in case… And argument can be made for this opinion. But arguments can be made against too. It is imperative in your personal assessment of the level of uncertainty with which you are comfortable regarding the anthropogenic component of climate change – taking into consideration the hypothesis, funding, data, models, and politicization – to weigh this level against proposed solutions, making mental note of the economic and environmental unintended impacts. In addition, examine the human element in effecting solutions – i.e. will all countries comply? If not, and if CO2 knows no boundaries, what happens globally? How does that affect those who abide by rules? Regulations in one country will push offenders to a non-regulated country. The list of questions to ask oneself is long… And most importantly, what "correction' in the climate-change trend can be effected? Will our best intentions curtail warming significantly? If not, are there other, more drastic solutions not involving CO2 regulations, but by changing planetary albedo? Or do we fund efforts to adapt to inevitable change?

Recently, the government sidestepped the usual Congressional-approval protocol for policy changes by re-classifying carbon as a pollutant, allowing the EPA to then impose regulations on CO2. CO2 is no more a pollutant than water vapor, but such is politics. States would be required to reduce emissions by 32% from the 2005 levels by 2030.

A quick peek at the handy "carbon-tax T-savings calculator" (http://www.cato.org/carbon-tax-temperature-savings-calculator (Pat Michaels of CATO Institute)), shows if the U.S, alone, reduces CO_2 by 40% (a greater reduction than what the EPA is pushing), under assumption that climate sensitivity is 2C (low end), the global T increase averted by 2050 is 0.016C and by 2100 is 0.033C. If CS = 4.5C, the T-increase averted by 2050 = 0.025C and by 2100, 0.056C! If all industrialized nations reduced their emissions by 20% and CS = 3ºC, by 2050, a 0.025C and by 2100, a T-increase of 0.045ºC would have been averted. While I cannot guarantee the accuracy of this "calculator", you see where this estimated projection is going.

And w/ good intentions, conversion to renewable resources, such as wind and solar, have issues too. Wind: Just a few months ago, the German medical community requested a halt to further turbine installation until the health impacts of turbine-associated low-frequency noise can be further studied. Perhaps stories of dying sheep and goats due to sleep deprivation and reported human problems of headaches, dizziness, nausea and insomnia associated with noise from the whapping blades hold merit. Birds and bats are casualties - hundreds of thousands each year, with trickle-down consequences on insect populations (increasing mosquitoes, for one). Costs and fossil-fuel energy use are a dirty secret, a consequence of "on-demand" backup requirements, consequent of wind's inconsistent presence. Local weather changes result from turbine-altered wind patterns. Solar: Manufacturing-related leakage of SF_6 and NF_3 – ghg 23,000 and 17,000x as potent as CO_2; reduced albedo (reflectivity) in desert areas due to acreage covered in black panels; and birds vaporizing in flight over hot panels. "Clean" trucks, newer than 5y, in Europe, are associated with unexpected increases (34%) in black carbon emissions – soot – a warming agent.

These points are a small sampling of the many documented issues of re-designing our energy use. Not that re-structuring would not be worthwhile to strive toward, but we have talked about this goal for at least forty years and little progress has been made. It must be realized that every source of generating and transmitting energy comes with trade-offs. None are without flaws and detriments.
Deciding on action is difficult, a personal opinion. Understanding the level of scientific certainty of the proposed problem is one step toward that decision. The next step is to gain insight into potential solutions to the proposed problem; to assess their effectiveness; become aware of potential unintended consequences; and to weigh all this information against what other problems – more absolute in their nature and solvability – might be neglected in lieu of attention focused here. No "solution" comes without costs. No energy resource is without negative impact. With monetary resources finite, ask yourself what global problems are most pressing and yet most solvable? With the uncertainties laid out before you, consider: Where does "climate change" fall within that category of most pressing and most solvable?

Slide 53: What You Learned (last section) –No action comes without impact; good intentions, unintended consequences –
Slide 54: What You Learned (full summary in brief)
Slide 55: Consensus and Science – some thoughts on "the signal and the noise"…
Slide 56: The End…