TESTIMONY TO THE ENVIRONMENTAL RESOURCES AND ENERGY COMMITTEE, PENNSYLVANIA HOUSE OF REPRESENTATIVES

Patrick J. Michaels

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Governor Wolf's Executive Order 2019-7 on addressing climate change in Pennsylvania is largely based upon the 2018 Pennsylvania Climate Action Plan. Therefore my testimony is about that Plan. If it suffers from serious problems, that may call into question the basis for the Governor's Order. Therefore my testimony is largely directed towards the 2018 Plan.

The 2018 Pennsylvania Climate Action Plan [PCAP] is a formidable document that can serve as the basis for sweeping and extensive regulation of the emissions of greenhouse gases—mainly carbon dioxide and methane—from the Commonwealth of Pennsylvania.

My comments on it are largely along three lines;

1. The validity of the climate models that serve as its basis, and
2. The validity of the emission assumptions that underpin the plan, and
3. The amount of warming and sea level rise mitigated if Pennsylvania emissions were completely curtailed in the beginning of this century.

It will be demonstrated that, in general, these models simply do not work when simulating climate changes in recent decades, and that the emission assumption, known as "RCP 8.5"[1] is now recognized to be a gross exaggeration of changes in atmosphere of the future. In combination, use of the only working climate model (see below) and a more likely emissions scenario *negates the credibility of the Pennsylvania Climate Action Plan report*.

I'll begin with the observed behavior of the atmosphere versus model predictions in recent decades. The underlying data and the enclosed illustration were readily available at the time PCAP was published. The fact that they were ignored casts substantial doubt on the scientific credibility of the PCAP document.

[1]"RCP" means "representative concentration pathway" and the 8.5 is the change of downwelling energy, in this case 8.5 watts per square meter, that pathway would produce.

Figure 1 shows the predicted and observed average tropospheric temperature over the tropics. Predictions are the US Department of Energy's fifth Coupled Model Intercomparison Project (CMIP-5) model suite data that was readily available at the KNMI Climate Explorer site (https://climexp.knmi.nl/start.cgi).

A careful look at Figure 1 reveals that only one of the 102 model runs correctly simulates what has been observed. This is the Russian climate model INM-CM4, which also has the least prospective warming of all of them, with an equilibrium climate sensitivity (ECS) of 2.05^{o}C, compared to the CMIP-5 average of 3.4^{o}C.

If PCAP followed best scientific practice, it would use this model along with a more realistic projection of future emissions than it used (see below). This is similar to what operational meteorologists do every day. They generally *don't* take all the available daily forecast models and average them up, as some perform better or worse depending upon the daily weather situation. Instead, they rely on the one(s) that perform the best.

Had PCAP followed this best practice, its projected 2000-2050 statewide average warming would drop from 5.4^{o}F to 3.3^{o}, a reduction of 40%.

Christy and McNider (2017), in a paper readily available to the PCAP writing team, further demonstrated that the models are predicting several *times* more warming at altitude in the tropics than is being observed. (Reference: Christy, J.R. and R. McNider, 2017, *Asia-Pacific Journal of Atmospheric Sciences* volume 53, pages 511–518).

The implications of this error are manifold, as a substantial amount of moisture that falls as precipitation over Pennsylvania originates in the tropics. The amount that enters the air is determined by the temperature contrast between the surface and the upper reaches of the lower atmosphere. Getting this wrong (with too little contrast) means that precipitation forecasts for Pennsylvania are systematically underestimated in the PCAP.

In summary, on this point, it is clear that had PCAP used the working climate model and a realistic emissions scenario (see below) that it would have forecast less than half the warming that it did, likely rendering the issue much less emergent, with adaptation (which is already occurring) the most likely response, rather than a wholesale re-ordering of the lives of the Commonwealth's citizens.

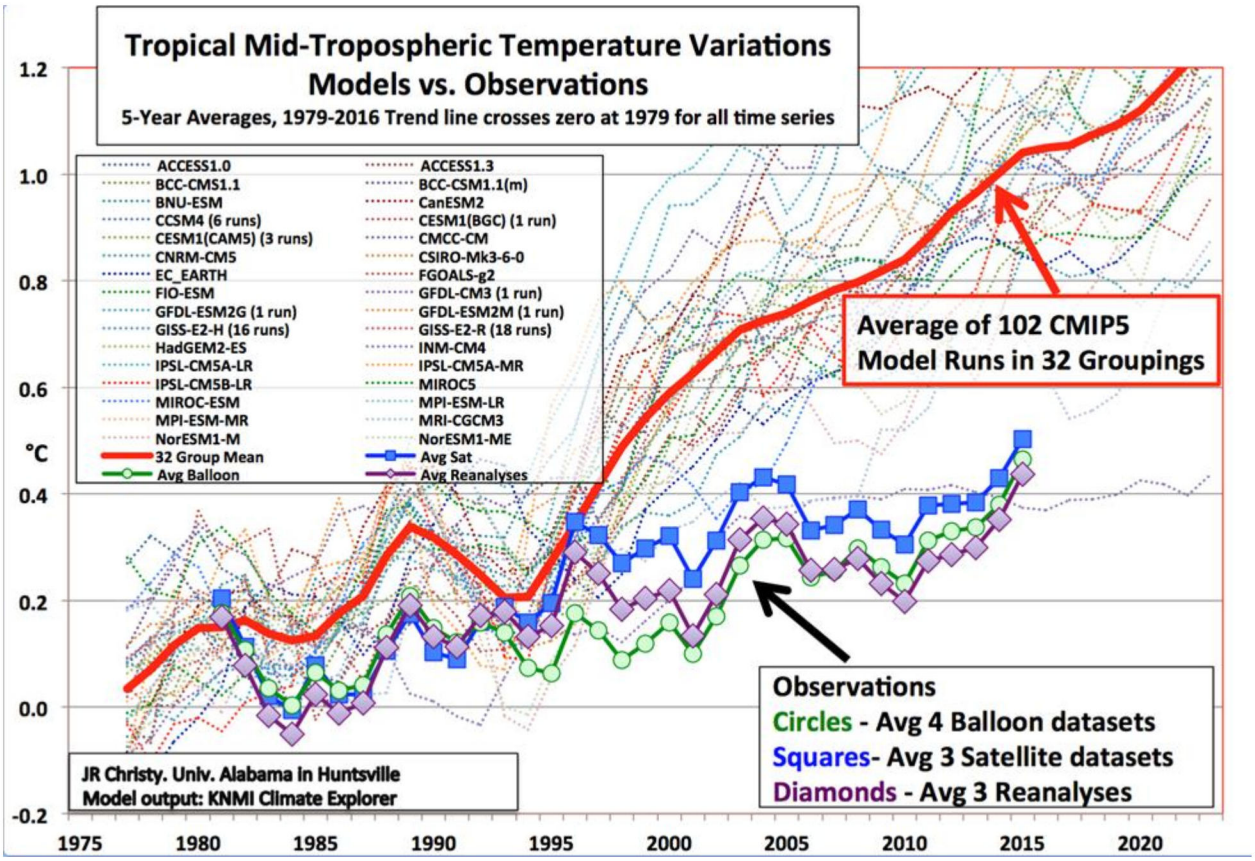


Figure 1. Solid red line—average of all the CMIP-5 climate models available at the time PCAP was written; Thin colored lines—individual CMIP-5 models; solid figures—weather balloon, satellite, and reanalysis data for the tropical troposphere. Source: Christy, J.R.: 2017, [in "State of the Climate 2016"], Bull. Amer. Meteor. Soc. 98, (8), S16-S17. DOI:1-.1175/2017BAMSStateoftheClimate.I.

As important as it is to follow best scientific practice in forecasting is the assumed future emissions pathway.

-On page 5, PCAP states:

"This report adopts the Representative Concentration Pathway 8.5 (RCP 8.5). This pathway is the one that the world is currently on, and is one of two emissions pathways adopted by a large number of climate modeling groups."

RCP 8.5 is the most extreme emissions scenario employed in the most recent (2013) comprehensive report of the United Nations' Intergovernmental Panel on Climate Change (IPCC). Since the publication of PCAP in 2018, the use of RCP 8.5 has been roundly criticized.

In 2020, Zeke Hausfather and Glen Peters published an article in the prestigious journal *Nature* which began with the blunt statement, “Stop using the worst-case scenario for climate warming as the most likely outcome — more realistic baselines make for better policy.”

According to Hausfather and Peters, RCP 8.5 “paints a dystopian future that is fossil-fuel intensive and excludes any climate mitigation policies, leading to nearly 5 °C of warming by the end of the century.”

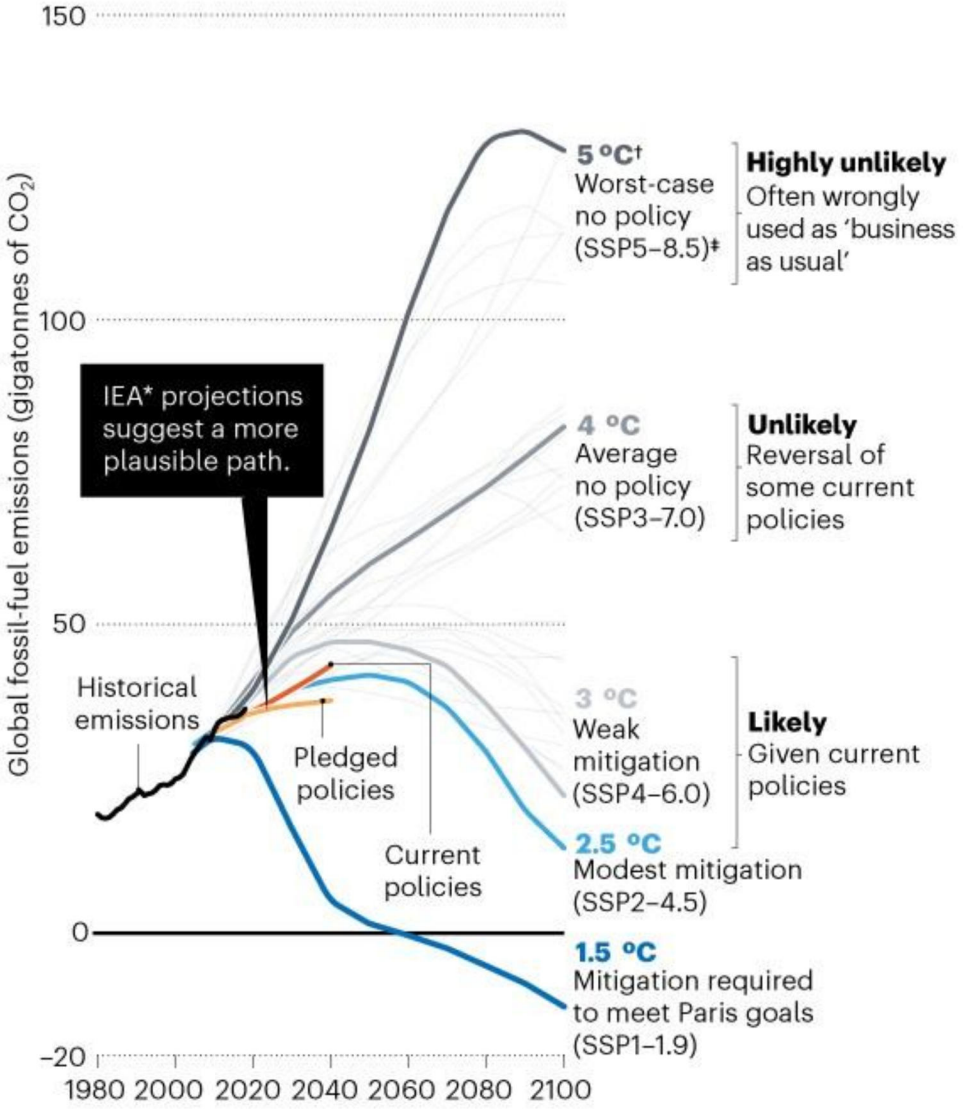
Sole reliance on RCP 8.5 invites strong criticism because of its unreality. Hausfather and Peters note that “Emission pathways to get to RCP8.5 generally require an unprecedented fivefold increase in coal use by the end of the century, an amount larger than some estimates of recoverable coal reserves.”

They conclude that “We must all — from physical scientists and climate-impact modellers to communicators and policymakers — stop presenting the worst-case scenario as the most likely one.” This includes the authors of the PCAP.

A sidebar, shown below, in the Hausfather and Peters article intercompares the various emissions scenarios, finding that the latest version of RCP 8.5 (called here “SSP5-8.5) in the upcoming (2022) IPCC Sixth Assessment report to be **Highly unlikely** often wrongly used as ‘business as usual’ [emphasis in original].

POSSIBLE FUTURES

The Intergovernmental Panel on Climate Change (IPCC) uses scenarios called pathways to explore possible changes in future energy use, greenhouse-gas emissions and temperature. These depend on which policies are enacted, where and when. In the upcoming IPCC Sixth Assessment Report, the new pathways (SSPs) must not be misused as previous pathways (RCPs) were. Business-as-usual emissions are unlikely to result in the worst-case scenario. More-plausible trajectories make better baselines for the huge policy push needed to keep global temperature rise below 1.5 °C.



*The International Energy Agency (IEA) maps out different energy-policy and investment choices. Estimated emissions are shown for its Current Policies Scenario and for its Stated Policies Scenario (includes countries' current policy pledges and targets). To be comparable with scenarios for the Shared Socioeconomic Pathways (SSPs), IEA scenarios were modified to include constant non-fossil-fuel emissions from industry in 2018.
†Approximate global mean temperature rise by 2100 relative to pre-industrial levels.
‡SSP5–8.5 replaces Representative Concentration Pathway (RCP) 8.5.

Figure 2. Sidebar showing various emissions pathways that accompanied the 2020 Nature article by Hausfather and Peters. Source: Hausfather, Z., and M. Peters, Nature, Vol 577, 618-620.

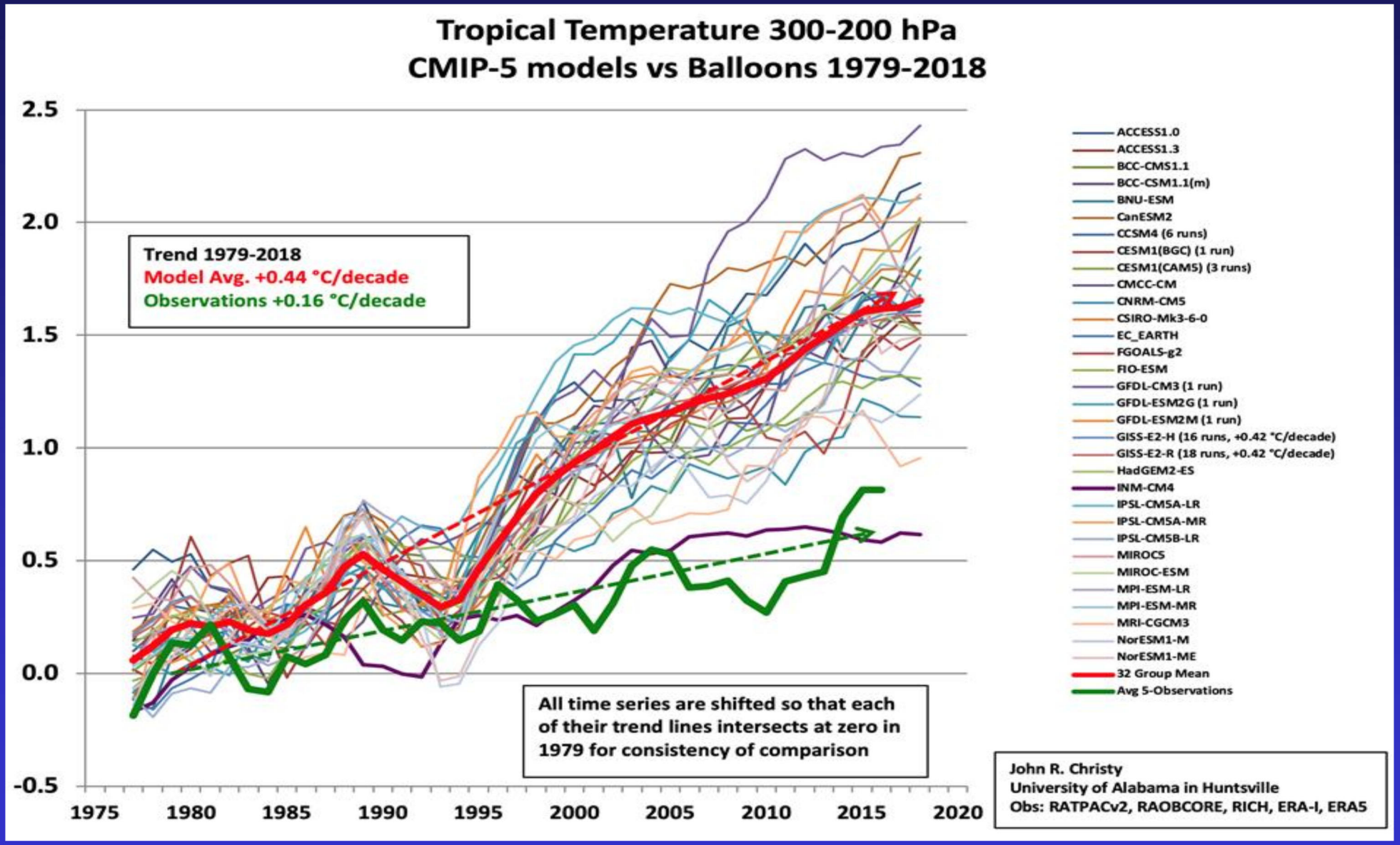
This strong language applies to the PCAP. As Hausfather told the BBC concerning his work, RCP 8.5 is "exceedingly unlikely".

As shown in Figure 2, the likely scenario, given policies that already exist, is an RCP value of between 4 and 6, instead of 8.5. This would reduce prospective warming by between 30 and 50%, as warming rises linearly with the RCP value. Using the most conservative version of the correct RCP value reduces warming another 1.6^{o}F, leaving a remainder from 2000-2050 of 1.7^{o}F, a far cry from the original PCAP value of 5.4^{o}.

As a thought experiment, suppose that Pennsylvania ceased any carbon dioxide emissions a decade ago. The EPA's Model for the Assessment of Greenhouse-Gas Induced Climate Change (the acronym *is* MAGICC) is the standard tool used to assess the climate impacts of any emissions reductions. Using its standard assumption of an equilibrium climate sensitivity of 3.0^{o}C, the amount of warming that a zero emissions Pennsylvania would mitigate 2050 is 0.14^{o}F and the amount of sea-level rise mitigated is 0.008 (eight-thousandths) of an inch. Both are too small to be able to measure with any confidence.

Summary of Comments

Using the model that works, the Russian INM-CM4, reduces prospective warming by 60%. Using the likely emissions pathway reduces this further by 30%, ultimately reducing the 2000-2050 warming to from 5.4^{o} to 1.7^{o}F, or approximately one degree Celsius. The amount of warming and sea-level rise mitigated by Pennsylvania under any circumstance could not be measured by 2050 (or 2100, for that matter). The Pennsylvania Climate Action Plan report, which serves as the basis for Governor Wolf's Executive Order 2019-07, needs to be dramatically revised, and should no longer be used as the basis for any policy proposals in its present form.


Tropical Temperature 300-200 hPa
CMIP-5 models vs Balloons 1979-2018
Trend 1979-2018
Model Avg. +0.44 °C/decade
Observations +0.16 °C/decade
All time series are shifted so that each of their trend lines intersects at zero in 1979 for consistency of comparison
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
ACCESS1.0
ACCESS1.3
BCC-CMS1.1
BCC-CSM1.1(m)
BNU-ESM
CanESM2
CCSM4 (6 runs)
CESM1(BGC) (1 run)
CESM1(CAM5) (3 runs)
CMCC-CM
CNRM-CM5
CSIRO-Mk3-6-0
EC_EARTH
FGOALS-g2
FIO-ESM
GFDL-CM3 (1 run)
GFDL-ESM2G (1 run)
GFDL-ESM2M (1 run)
GISS-E2-H (16 runs, +0.42 °C/decade)
GISS-E2-R (18 runs, +0.42 °C/decade)
HadGEM2-ES
INM-CM4
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC5
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
MRI-CGCM3
NorESM1-M
NorESM1-ME
32 Group Mean
Avg 5-Observations
John R. Christy
University of Alabama in Huntsville
Obs: RATPACv2, RAOBCORE, RICH, ERA-I, ERA5

POSSIBLE FUTURES

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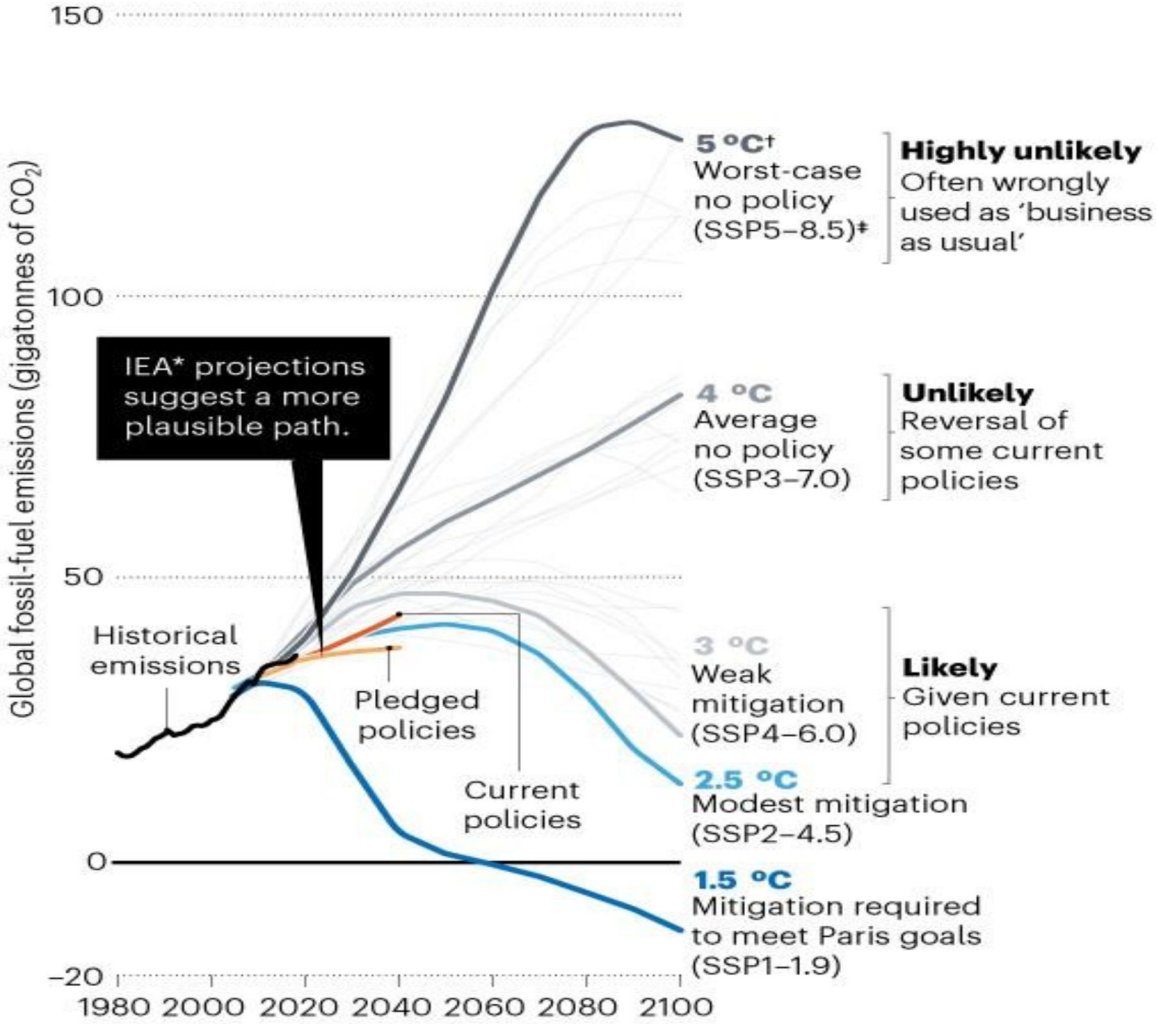
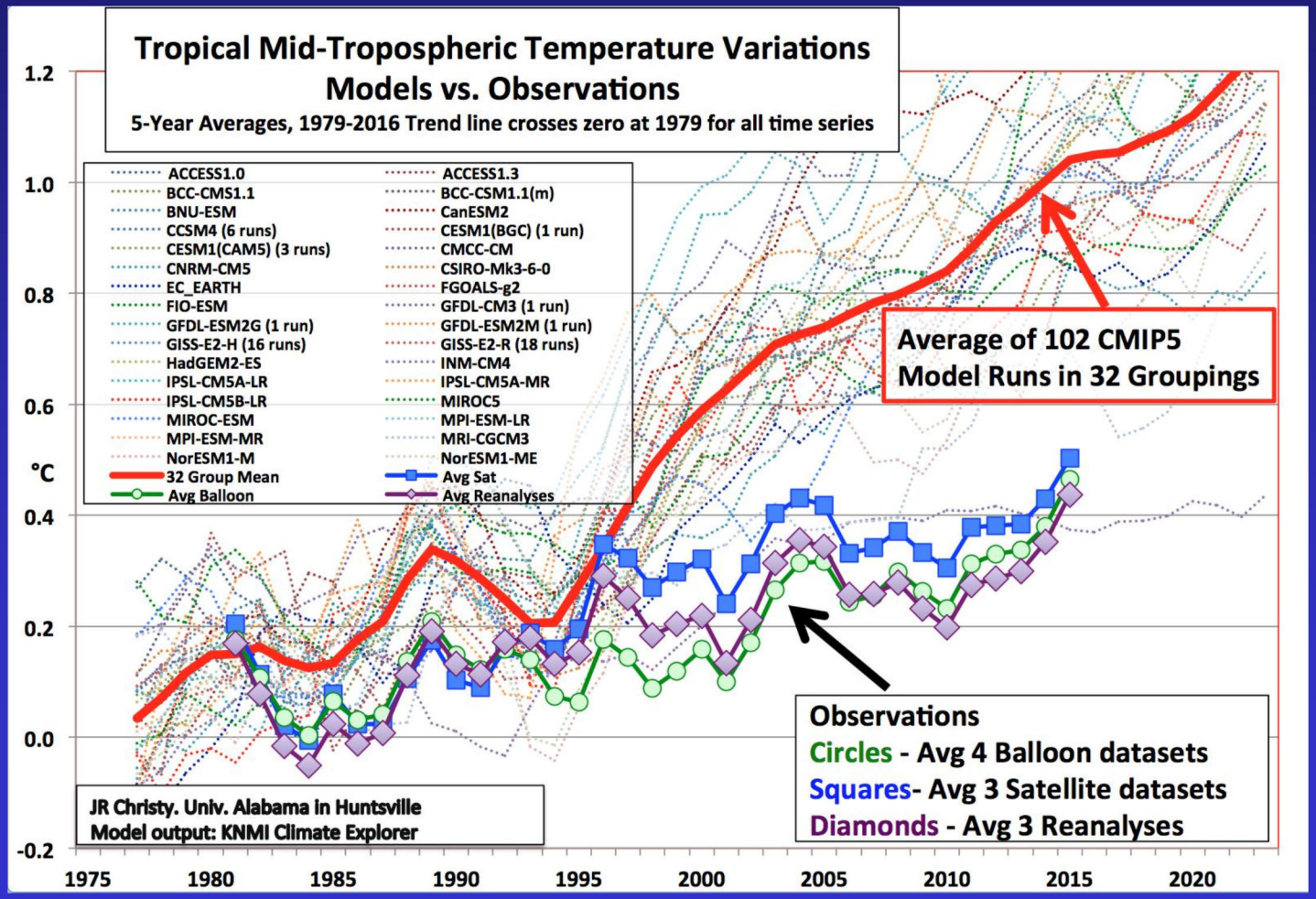
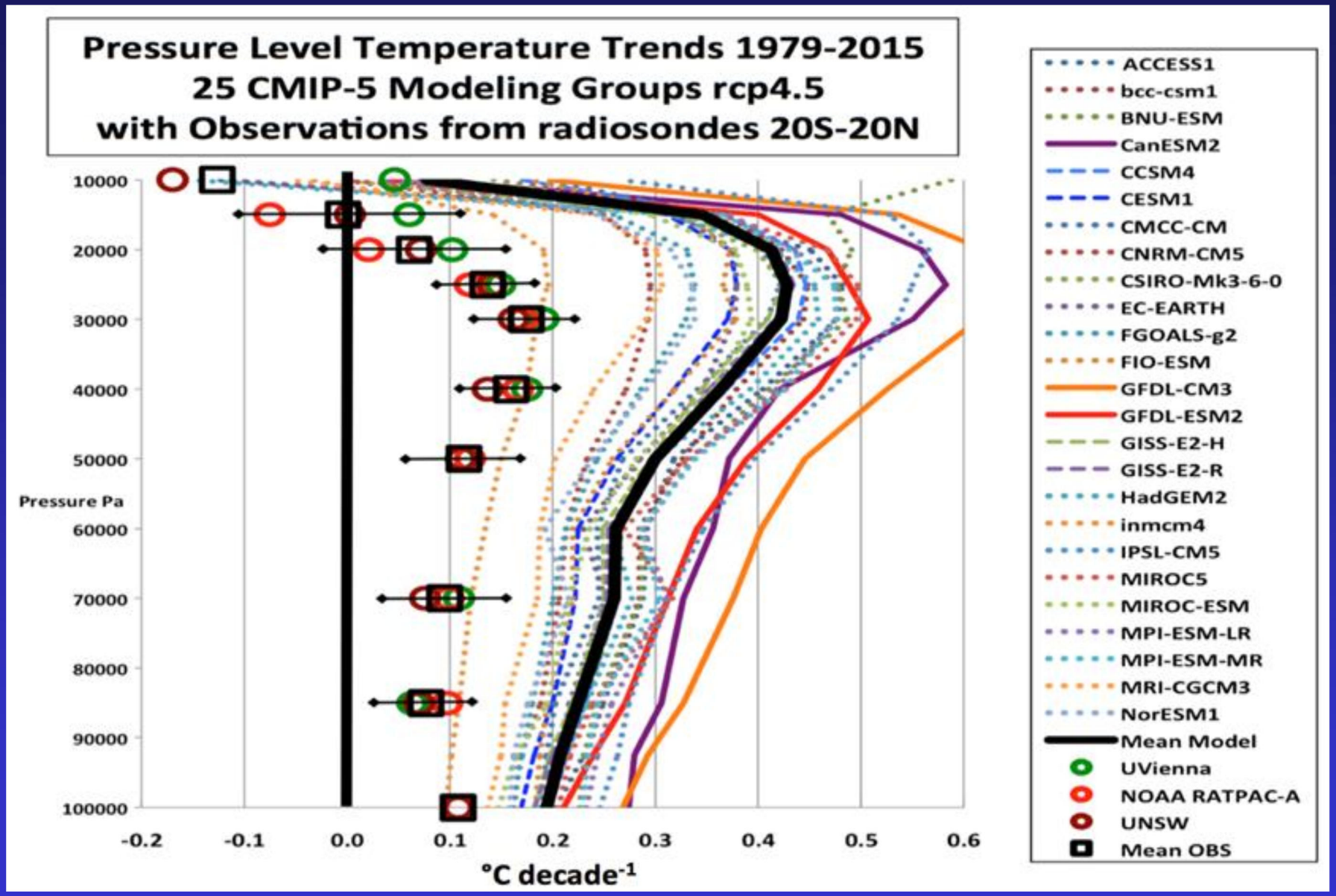
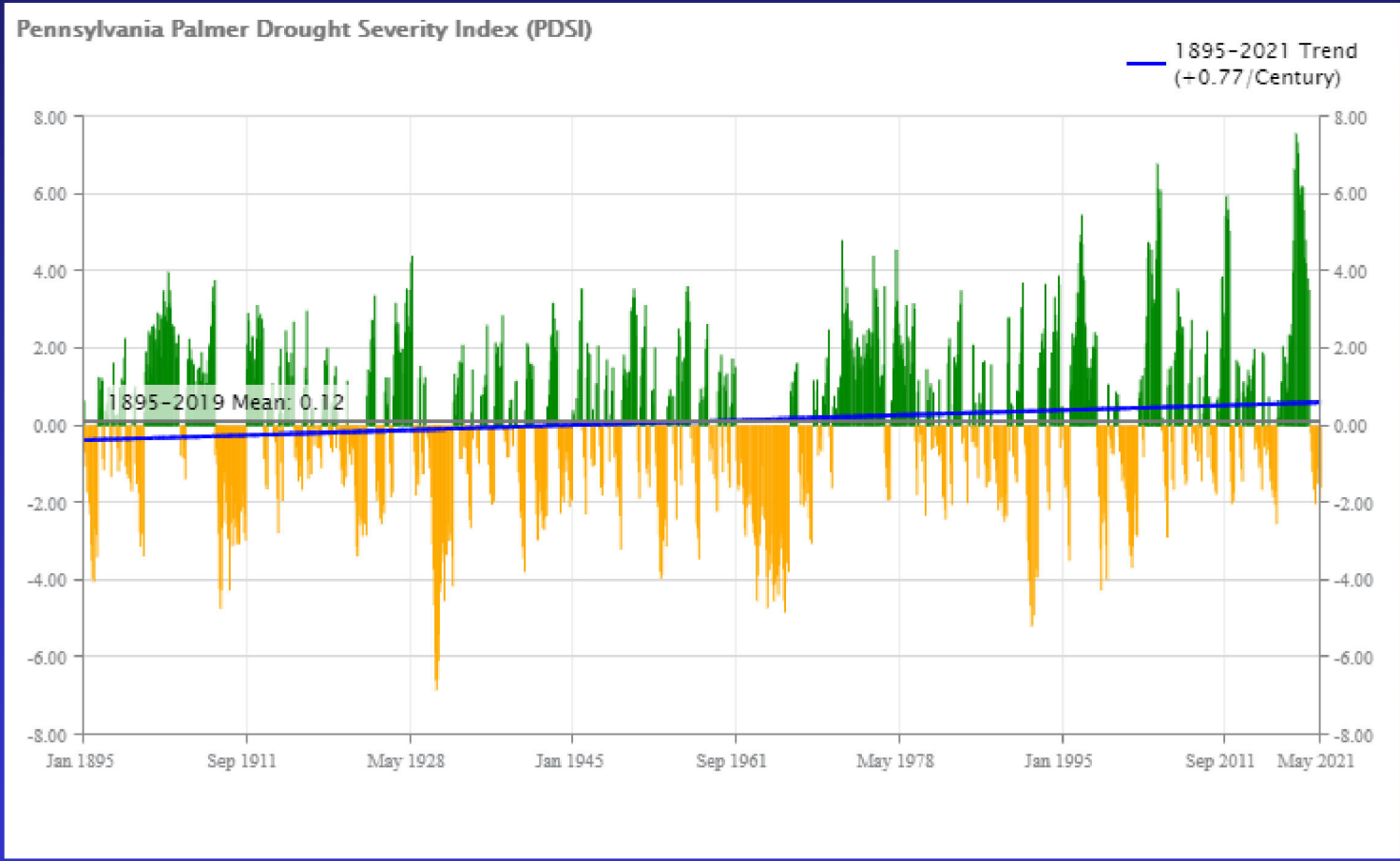


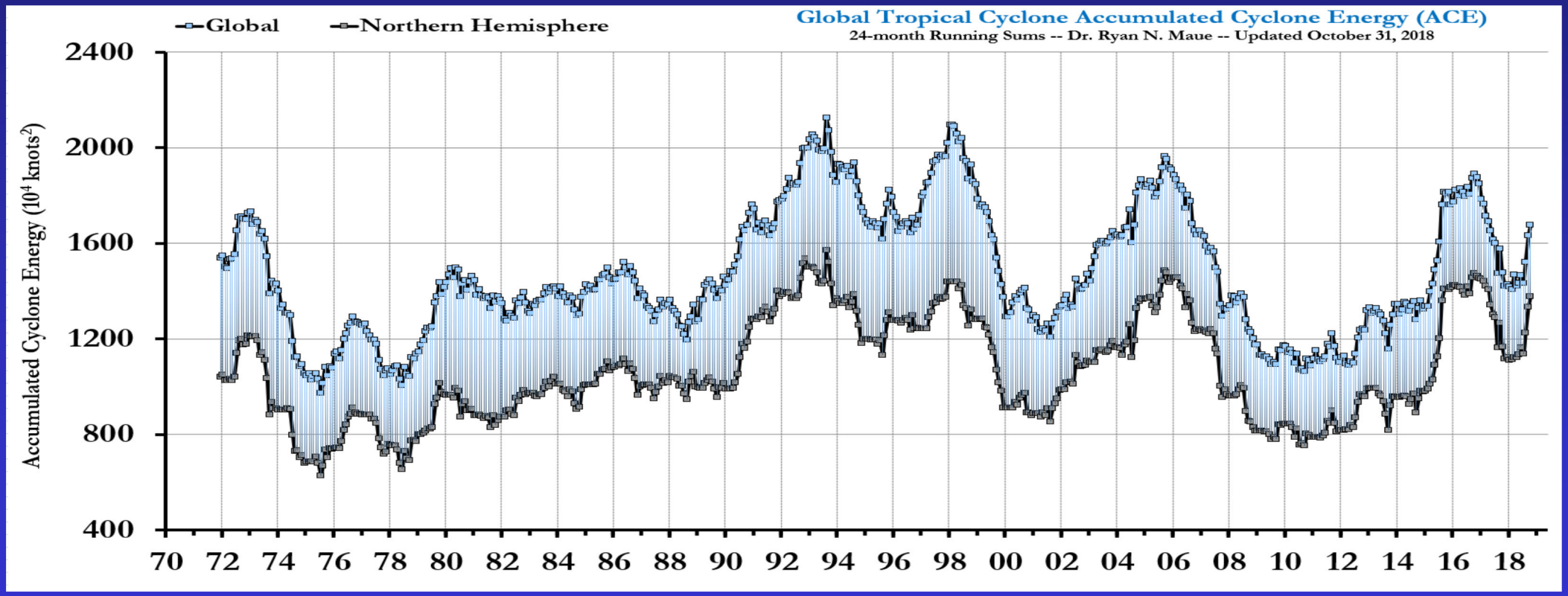
Growing disparity between models and observations ; 20N-20S, 37.5% of surface coverage



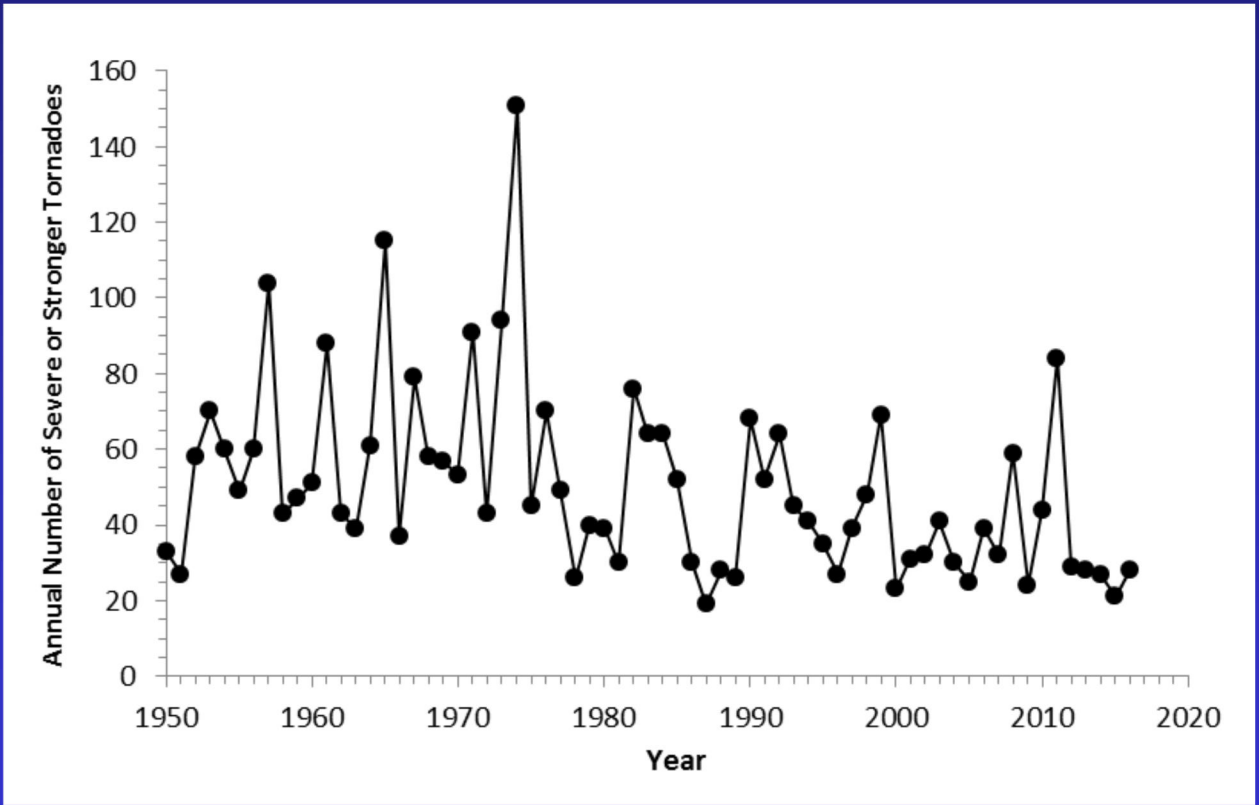

Pressure Level Temperature Trends 1979-2015
25 CMIP-5 Modeling Groups rcp4.5
with Observations from radiosondes 20S-20N
Pressure Pa
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
°C decade-1
ACCESS1
bcc-csm1
BNU-ESM
CanESM2
CCSM4
CESM1
CMCC-CM
CNRM-CM5
CSIRO-Mk3-6-0
EC-EARTH
FGOALS-g2
FIO-ESM
GFDL-CM3
GFDL-ESM2
GISS-E2-H
GISS-E2-R
HadGEM2
inmcm4
IPSL-CM5
MIROC5
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
MRI-CGCM3
NorESM1
Mean Model
UVienna
NOAA RATPAC-A
UNSW
Mean OBS


Pennsylvania Palmer Drought Severity Index (PDSI)
1895-2021 Trend
(+0.77/Century)
1895-2019 Mean: 0.12
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
Jan 1895
Sep 1911
May 1928
Jan 1945
Sep 1961
May 1978
Jan 1995
Sep 2011
May 2021

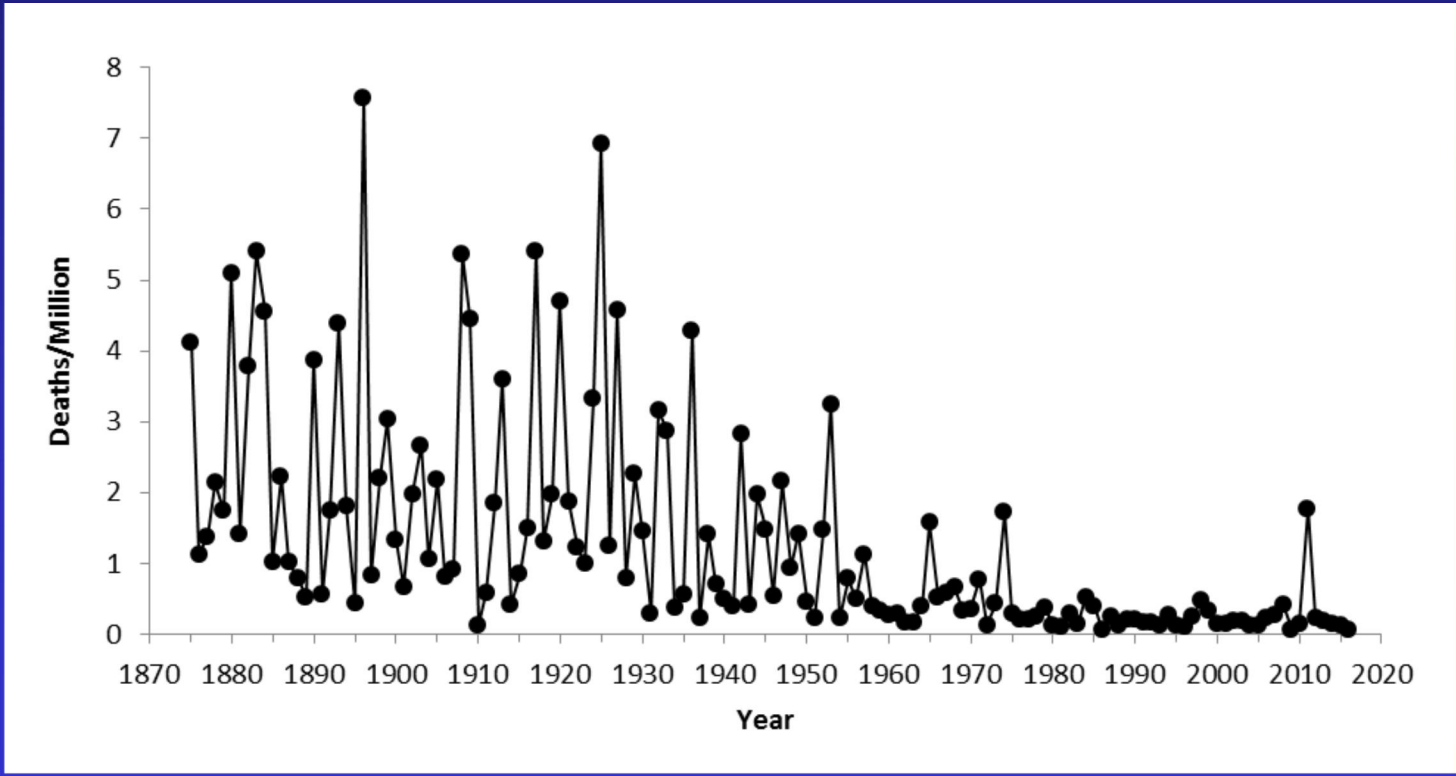
HURRICANE REALITY
Accumulated Cyclone Energy Index



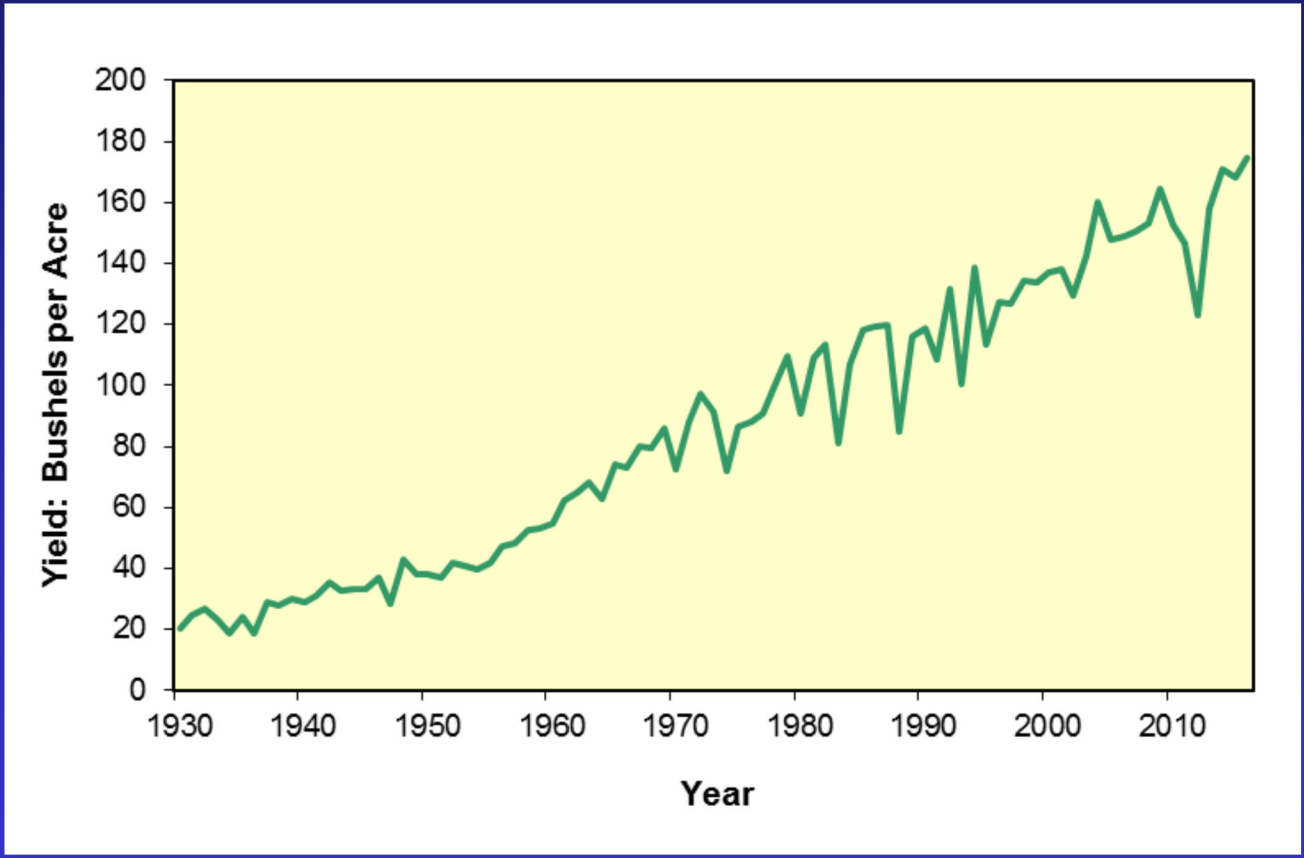
Annual Number of F3,4,5 Tornadoes in U.S. (1950-2016)



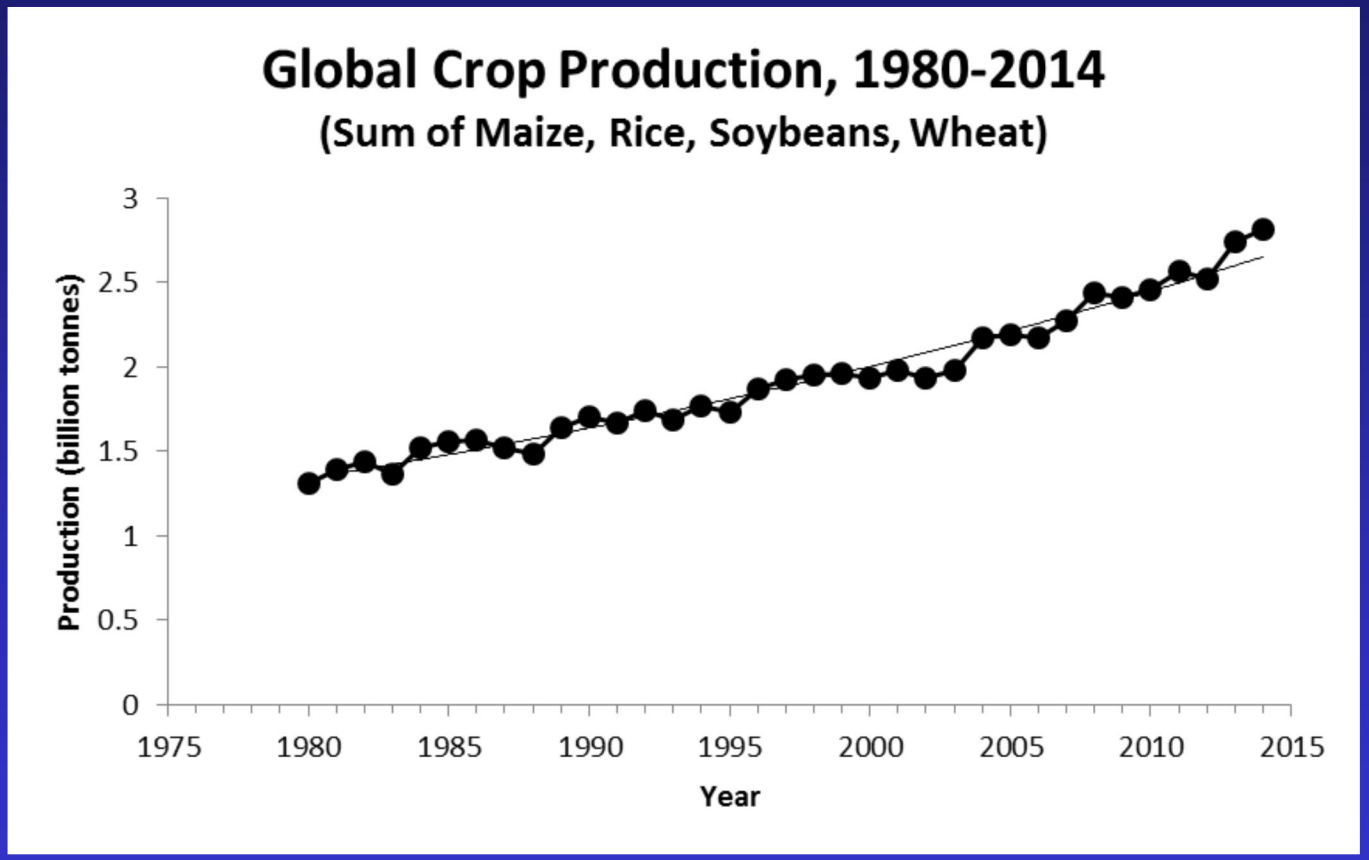
Annual U.S. Tornado Death Frequency (1875-2016)



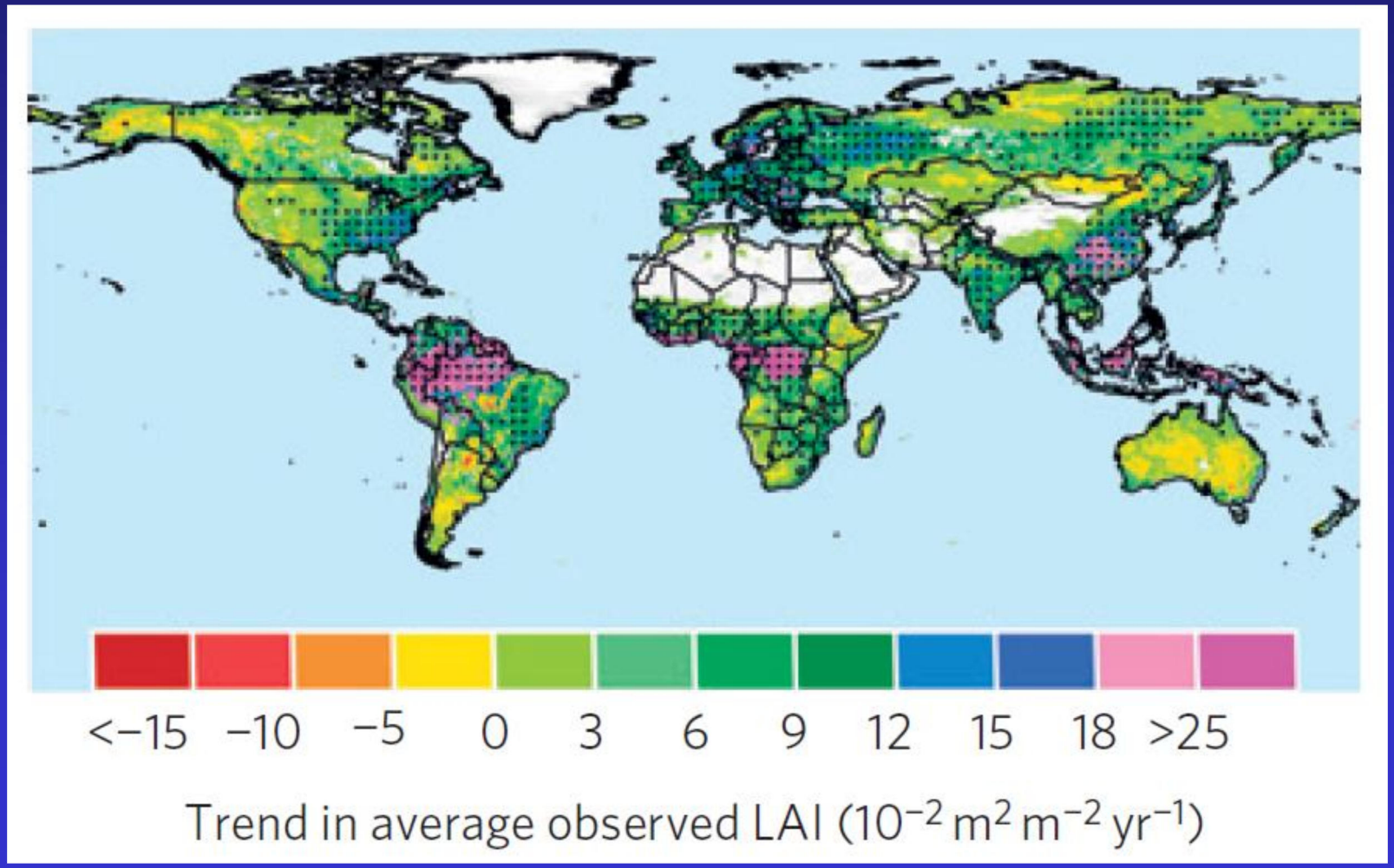
U.S. Corn Yield (1930-2016)



Global Crop Production



Spatial Trends in Leaf Area Index (1982-2009) (Zhu et al. 2016)



CAUSES OF GREENING (Zhu et al., 2016)

- Carbon Dioxide Increase: 70%
- Nitrogen Deposition: 9%
- Climate Change: 8%
- Land Cover Change: 4%

TOTAL HUMAN: 91%