Climate Change
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CIRES, University of Colorado, Boulder

Weiqing Han class March 18, 2021

250pm-405pm MDT

- Is Climate Change an existential threat?
- Top and bottom up view
- Observed Climate Change
- Model-Real World Comparisons
- Human climate Forcings
- Climate Misinformation
- Conclusion

Is Climate Change an existential threat?

Is Climate Change an existential threat?

https://www.bloomberg.com/news/articles/2020-12-19/biden-calls-climate-change-existential-threat-of-our-time

Biden Calls Climate Change 'Existential Threat of Our Time'

What is Climate Change?

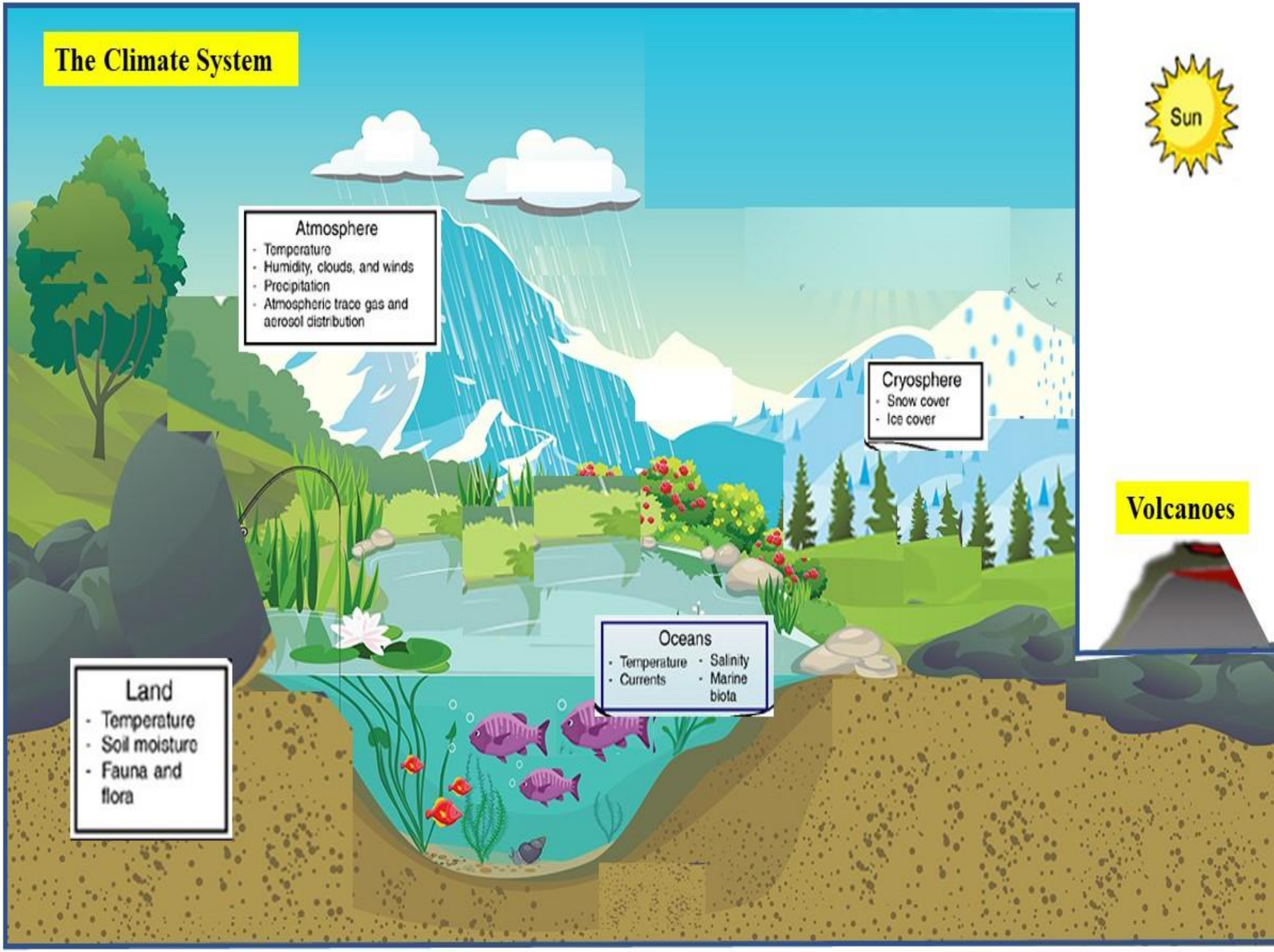
Global Warming is an increase in the global annual average heat content measured in Joules.

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

Global Warming is a Subset of Climate

The Earth's climate system is highly nonlinear: inputs and outputs are not proportional, change is often episodic and abrupt, rather than slow and gradual, and multiple equilibria are the norm.

<u>The assumption of a stable climate system, in the absence of human intervention, is a mischaracterization of the behavior of the real climate system</u>.


The Climate System
Atmosphere
- Temperature
- Humidity, clouds, and winds
- Precipitation
- Atmospheric trace gas and aerosol distribution
Sun
Cryosphere
- Snow cover
- Ice cover
Volcanoes
Oceans
- Temperature
- Currents
- Salinity
- Marine biota
Land
- Temperature
- Soil moisture
- Fauna and flora

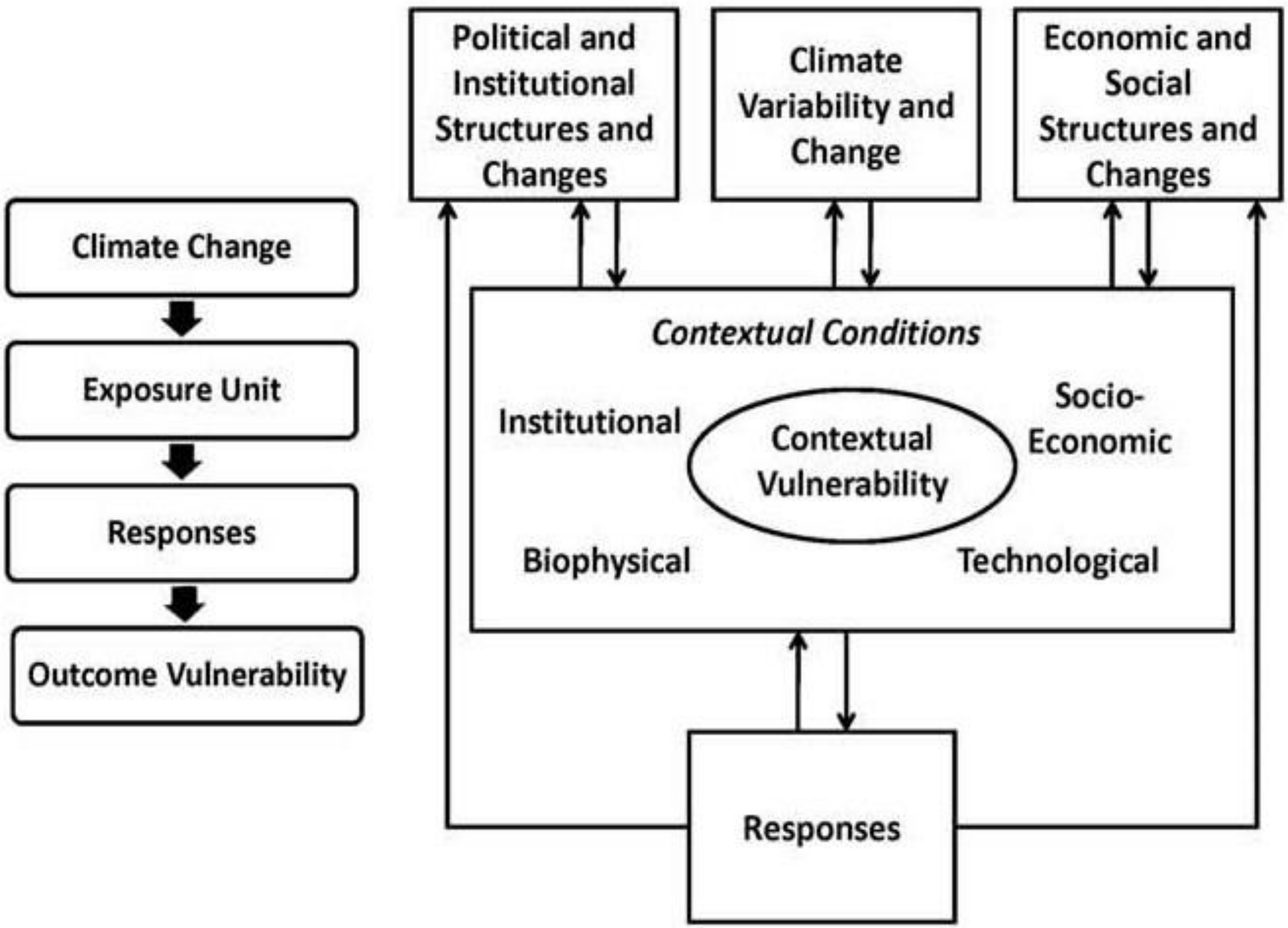
Two Approaches to Assessing Vulnerability

Top-down global model (GCM) driven perspective (IPCC; U.S. National Assessment, etc.)

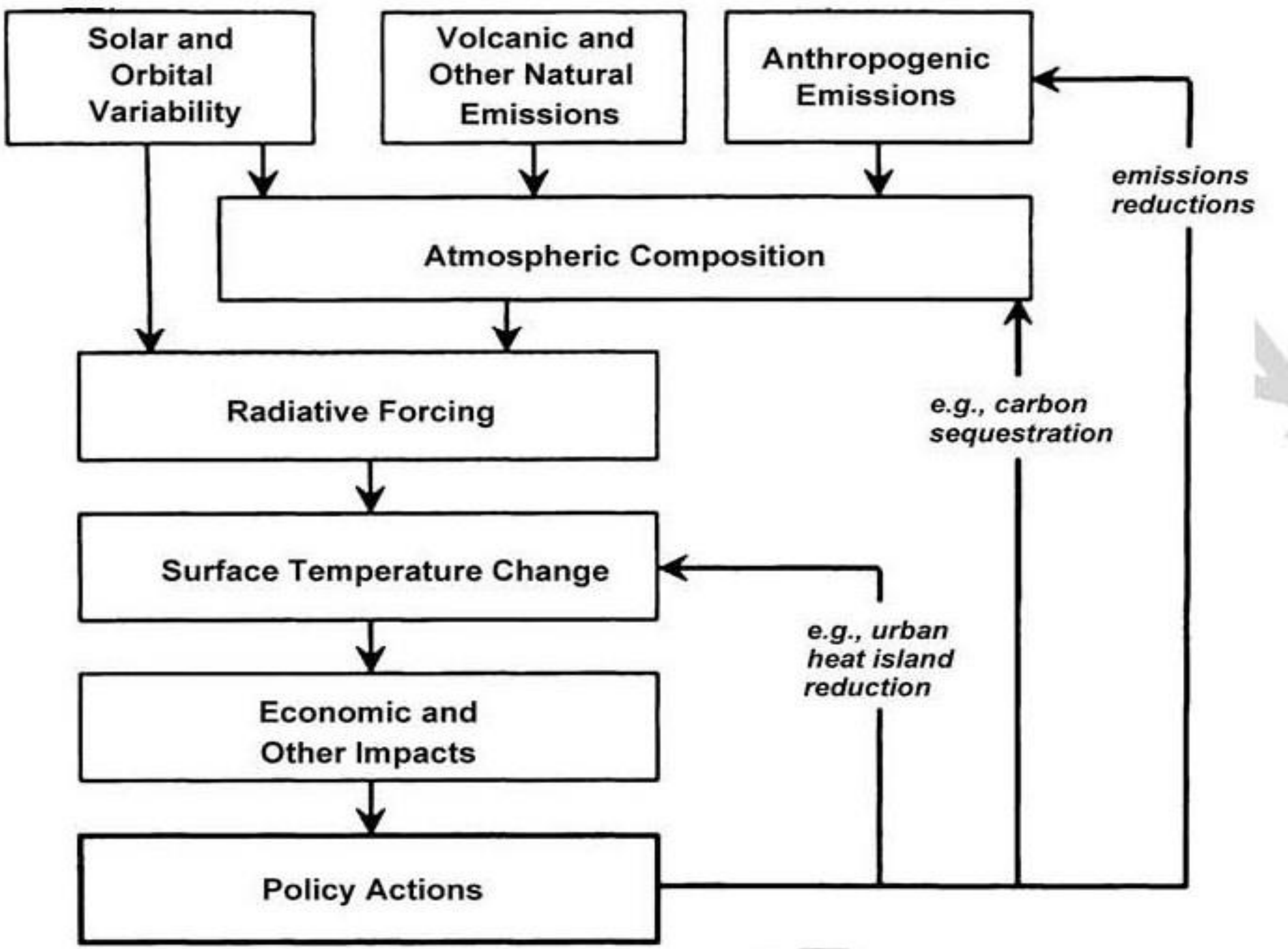
contrasted

with a Bottom-up resource based view

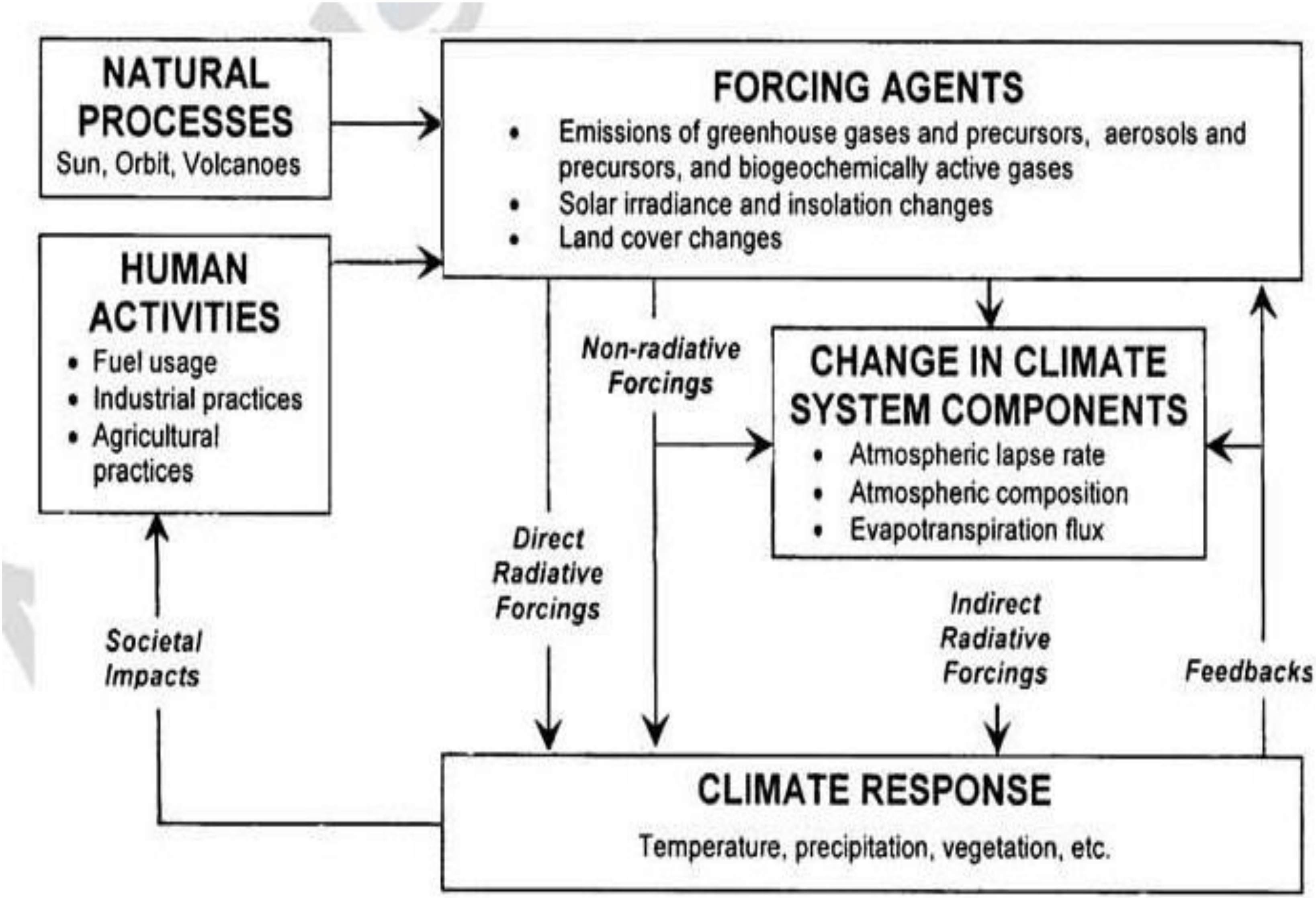
Framework depicting two interpretations of vulnerability to climate change: (left) outcome vulnerability and (right) contextual vulnerability. Adapted by D. Staley from the works of Füssel [2009] and O'Brien et al. [2007]



Conceptual framework showing how radiative forcing fits into the current climate policy framework (from National Research Council, 2005).



Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box (from National Research Council, 2005).



IPCC Conclusions

Working Group I

"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia".[74]

"Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years".[75]

Human influence on the climate system is clear.[76] It is extremely likely (95-100% probability)[77] that human influence was the dominant cause of global warming between 1951 and 2010.[76]

Working Group II

"Increasing magnitudes of [global] warming increase the likelihood of severe, pervasive, and irreversible impacts"[78]

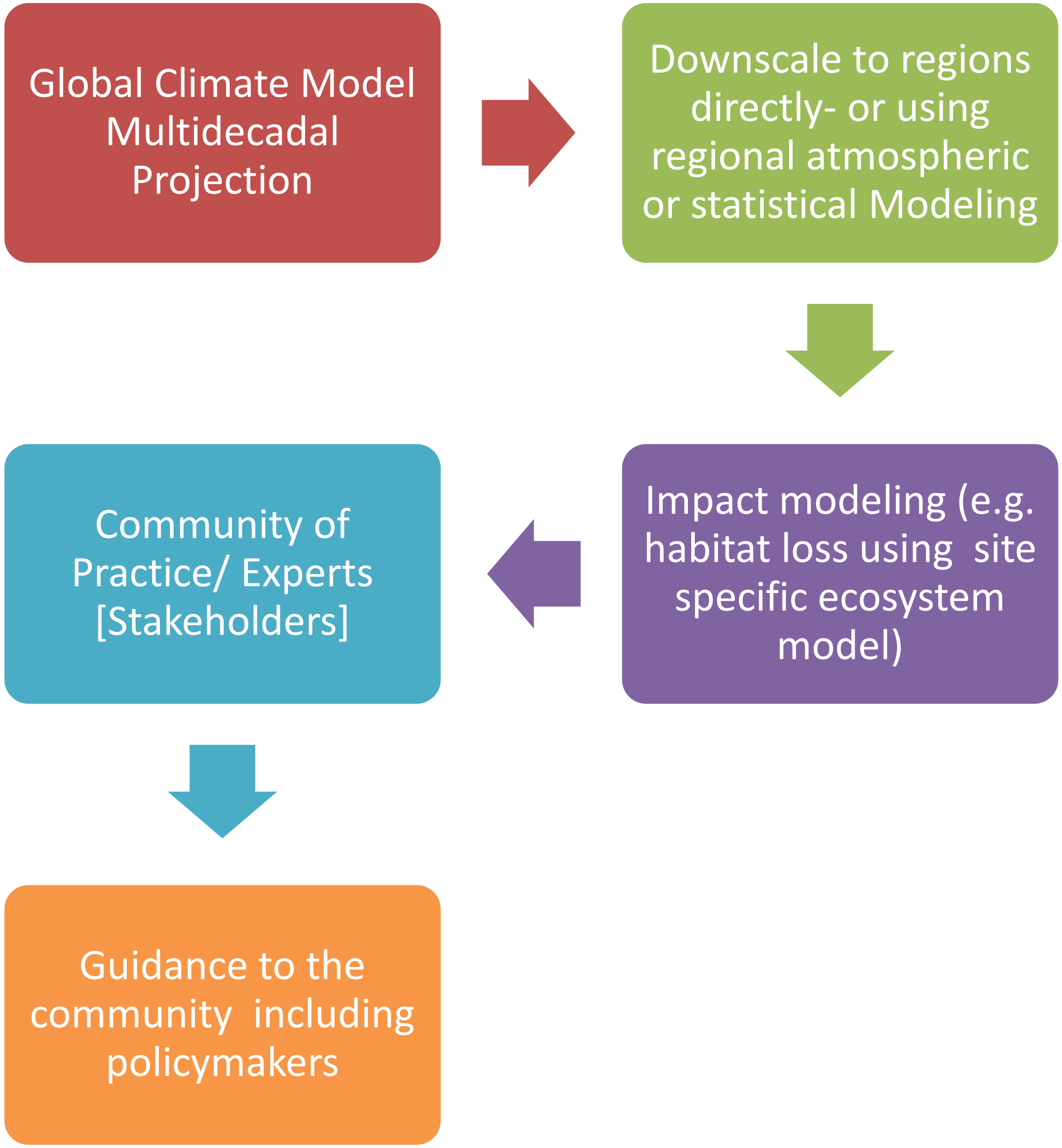
"A first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability"[79]

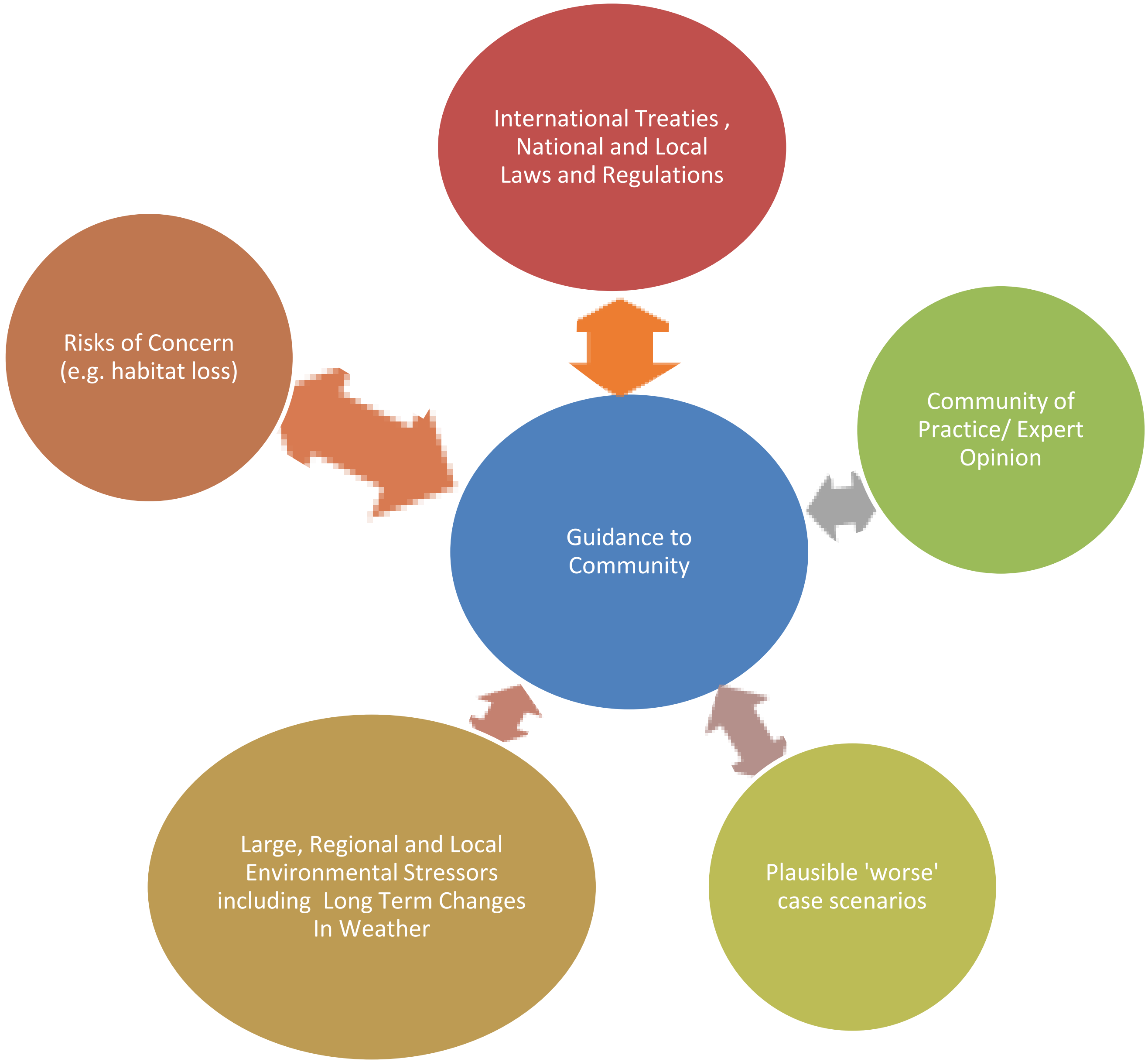
"The overall risks of climate change impacts can be reduced by limiting the rate and magnitude of climate change"[78]

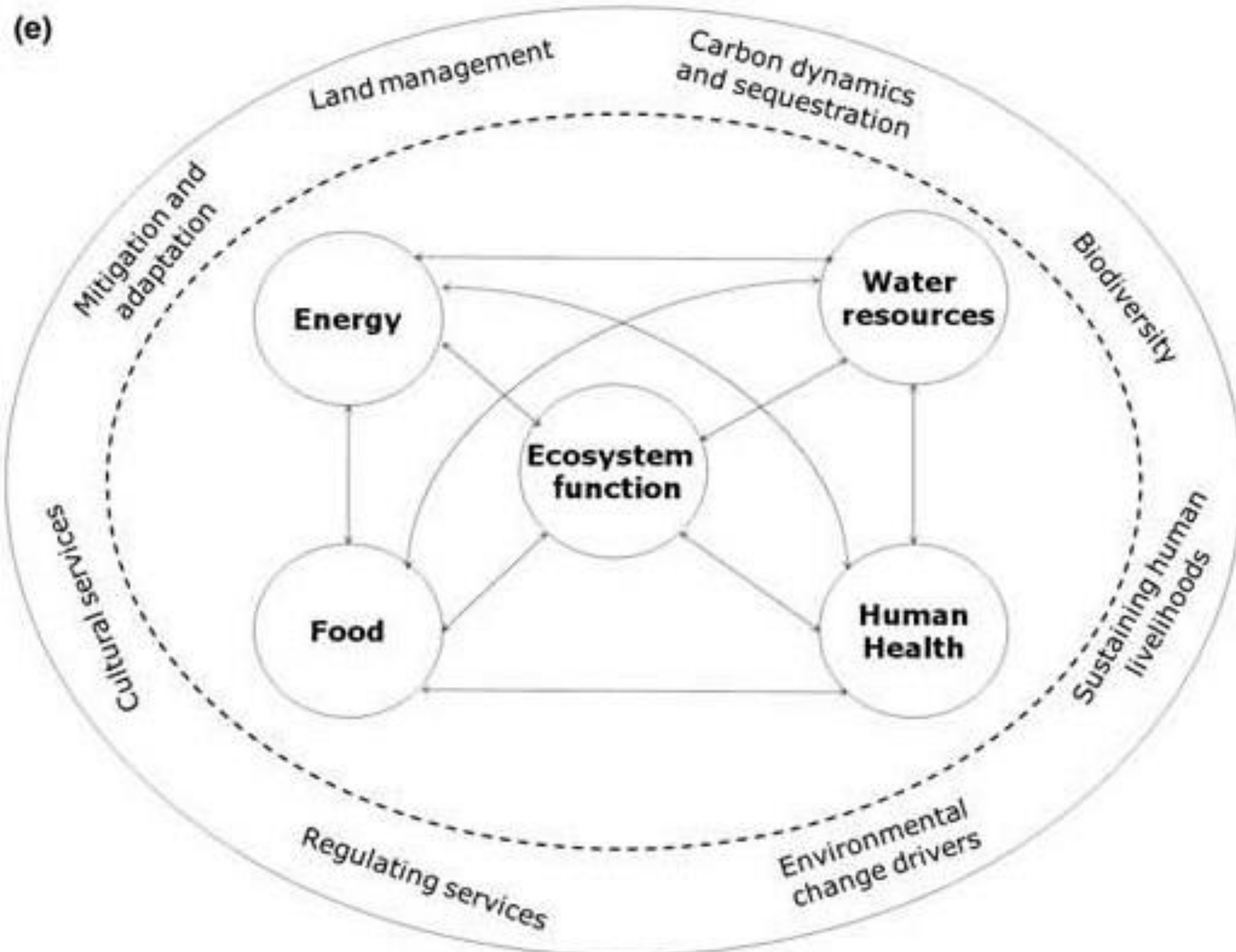
Working Group III

Without new policies to mitigate climate change, projections suggest an increase in global mean temperature in 2100 of 3.7 to 4.8 °C, relative to pre-industrial levels (median values; the range is 2.5 to 7.8 °C including climate uncertainty).[80]

"(T)he current trajectory of global annual and cumulative emissions of GHGs is not consistent with widely discussed goals of limiting global warming at 1.5 to 2 degrees Celsius above the pre-industrial level."[81] Pledges made as part of the Cancún Agreements are broadly consistent with cost-effective scenarios that give a "likely" chance (66-100% probability) of limiting global warming (in 2100) to below 3 °C, relative to pre-industrial levels.[82]


Global Climate Model Multidecadal Projection
Downscale to regions directly- or using regional atmospheric or statistical Modeling
Impact modeling (e.g. habitat loss using site specific ecosystem model)
Community of Practice/ Experts [Stakeholders]
Guidance to the community including policymakers


International Treaties , National and Local Laws and Regulations
Risks of Concern (e.g. habitat loss)
Community of Practice/ Expert Opinion
Guidance to Community
Large, Regional and Local Environmental Stressors including Long Term Changes In Weather
Plausible 'worse' case scenarios


(e)
Land management
Carbon dynamics and sequestration
Mitigation and adaptation
Biodiversity
Energy
Water resources
Ecosystem function
Food
Human Health
Cultural services
Sustaining human livelihoods
Regulating services
Environmental change drivers

Bottom-up Resource-Based Risk Assessment More Inclusive Than the Current Focus on the Top-Down Approach of the IPCC

Water resources

Ecosystem Health

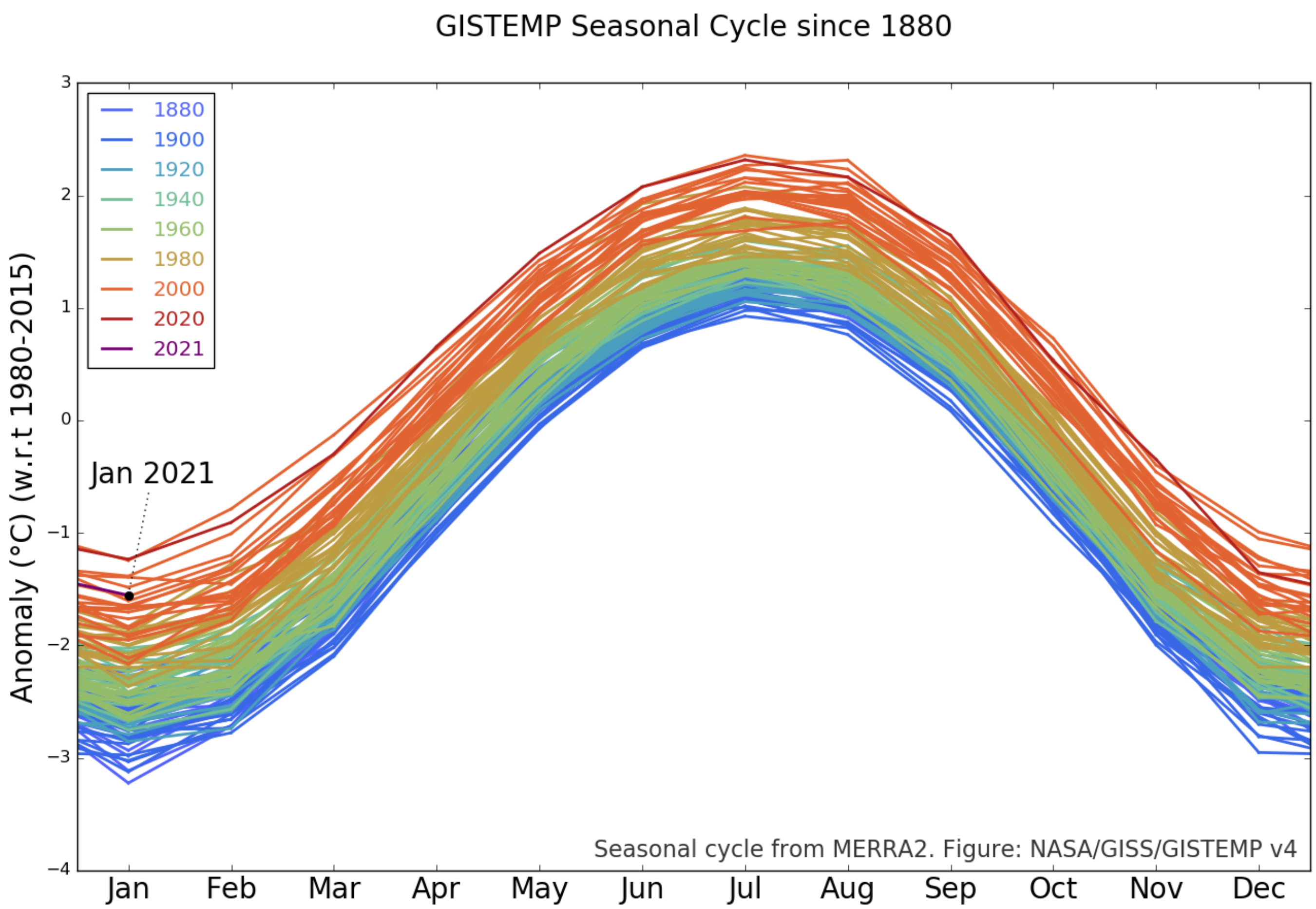
Energy

Human Health

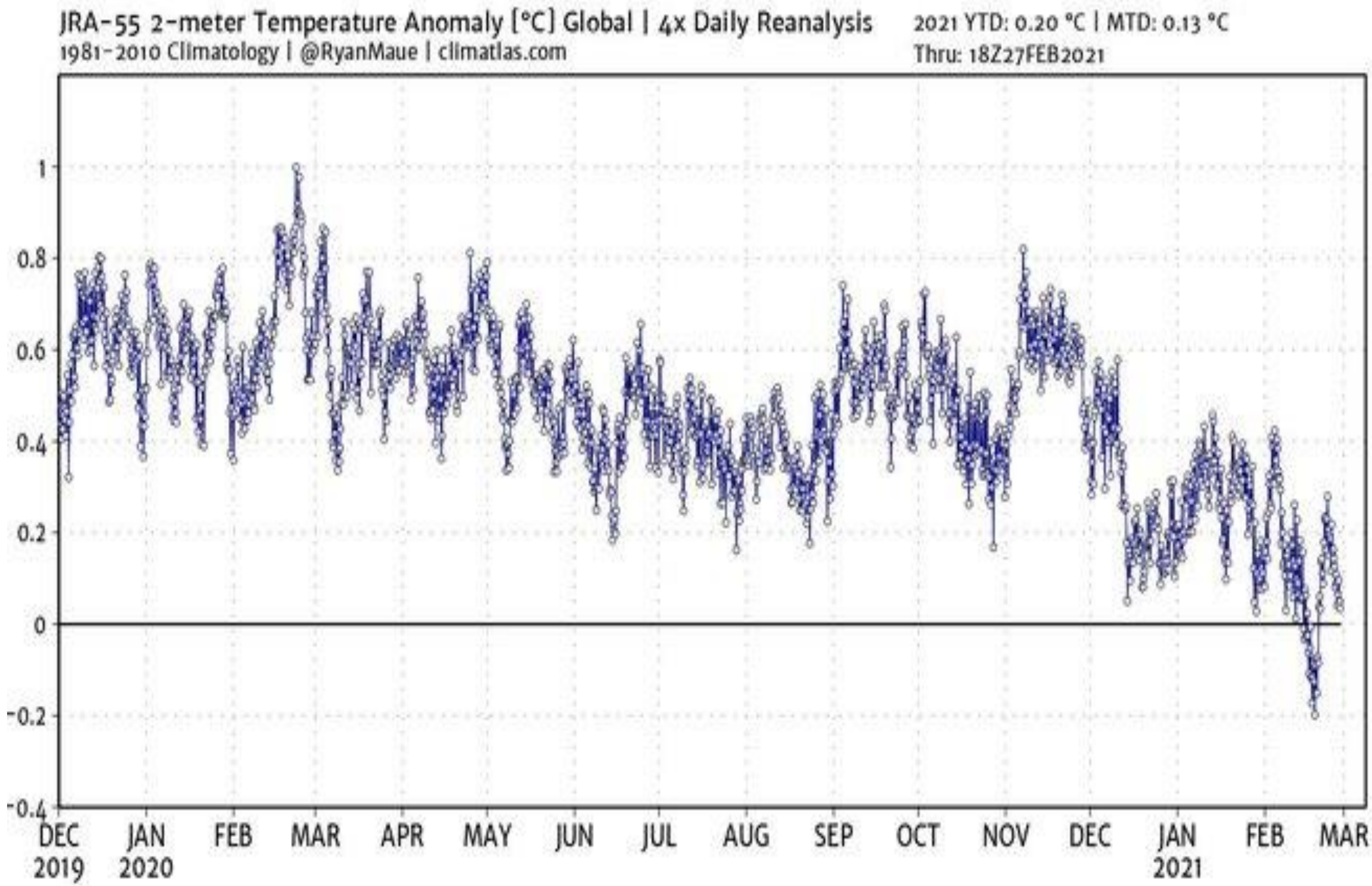
Food

Observed Climate Changes

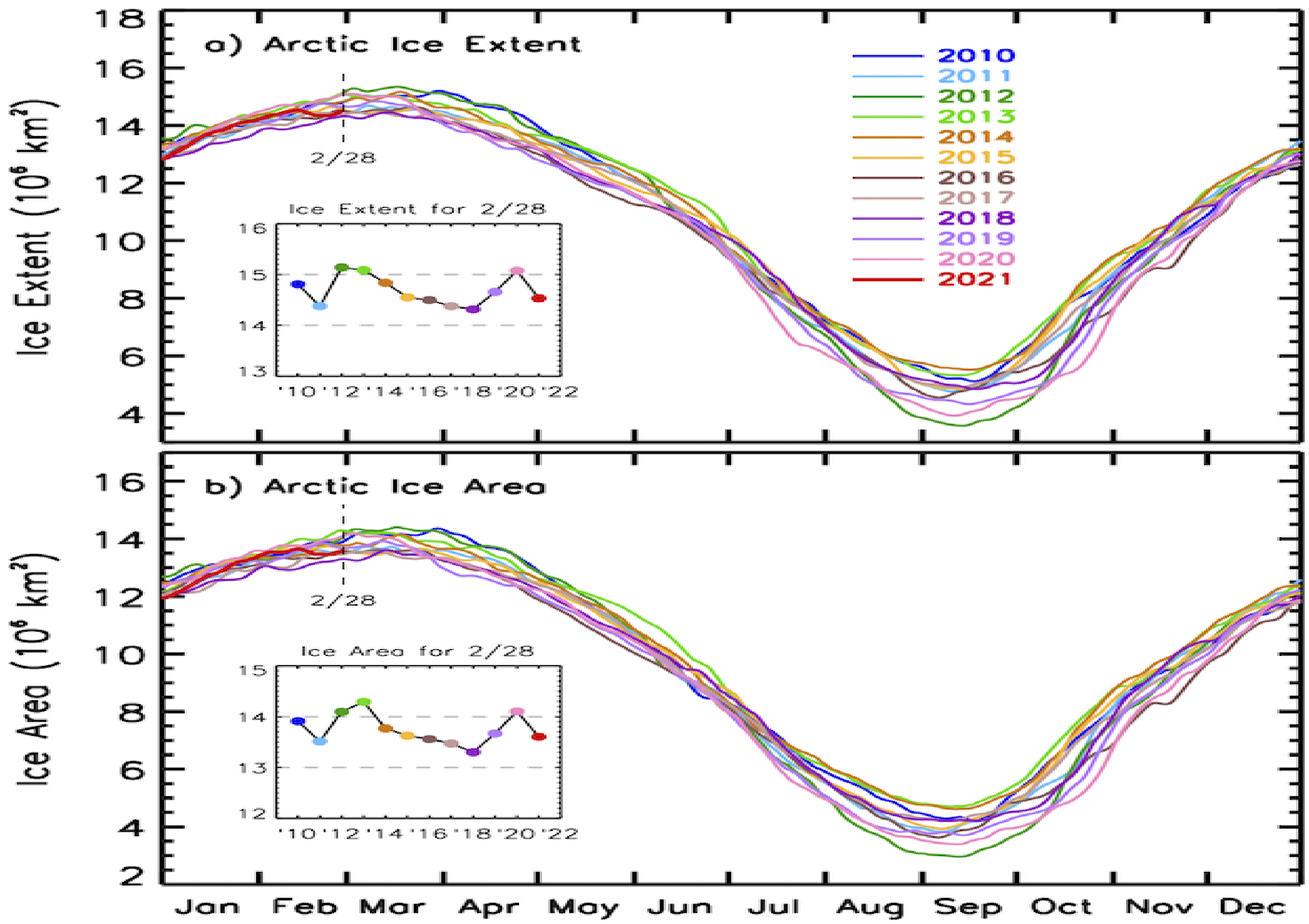
From https://data.giss.nasa.gov/gistemp/graphs_v4/graph_data/GISTEMP_Seasonal_Cycle_since_1880/graph.png



From Ryan Maue on twitter



https://earth.gsfc.nasa.gov/cryo/data/current-state-sea-ice-cover



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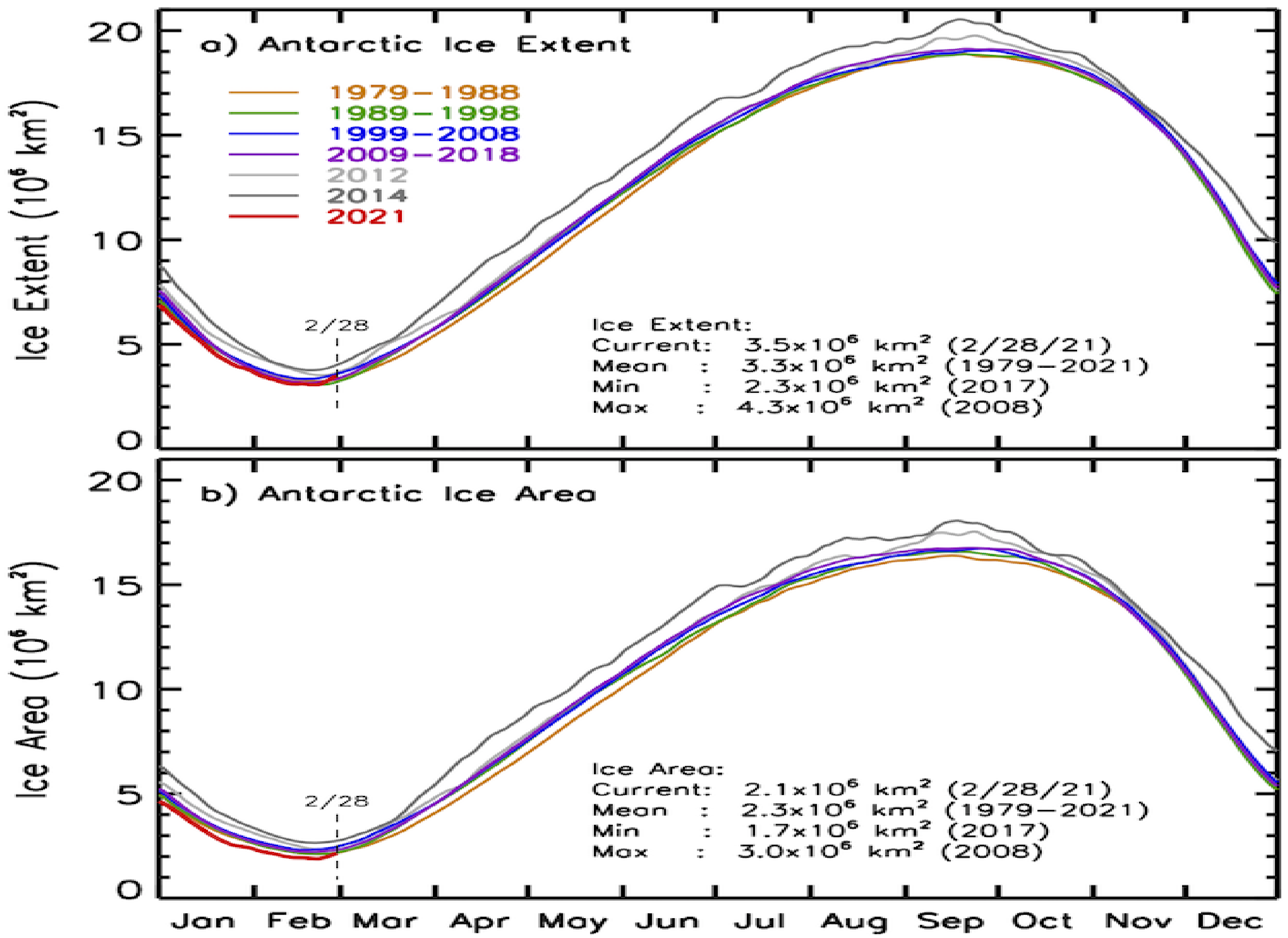
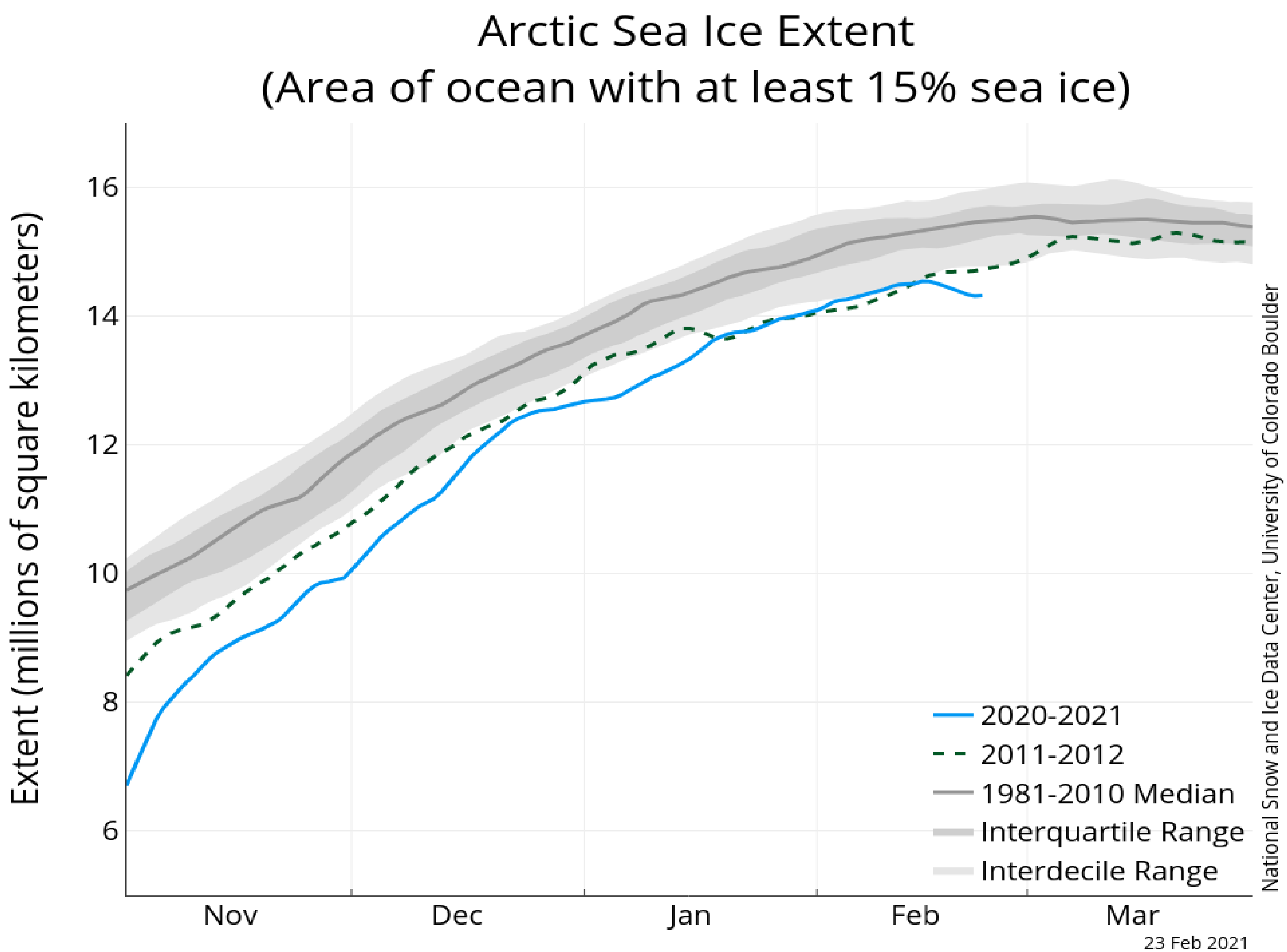


From http://nsidc.org/arcticseaicenews/



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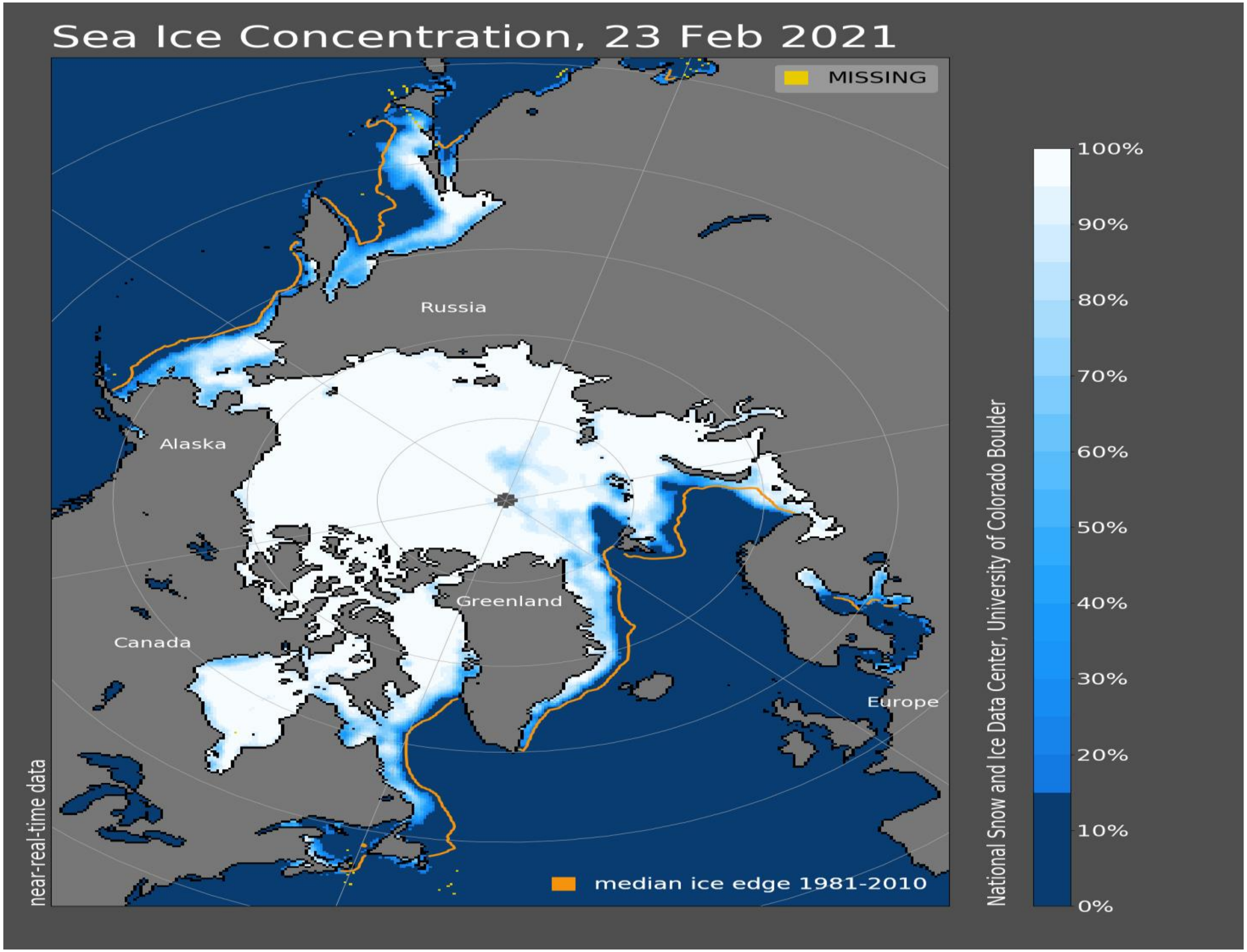

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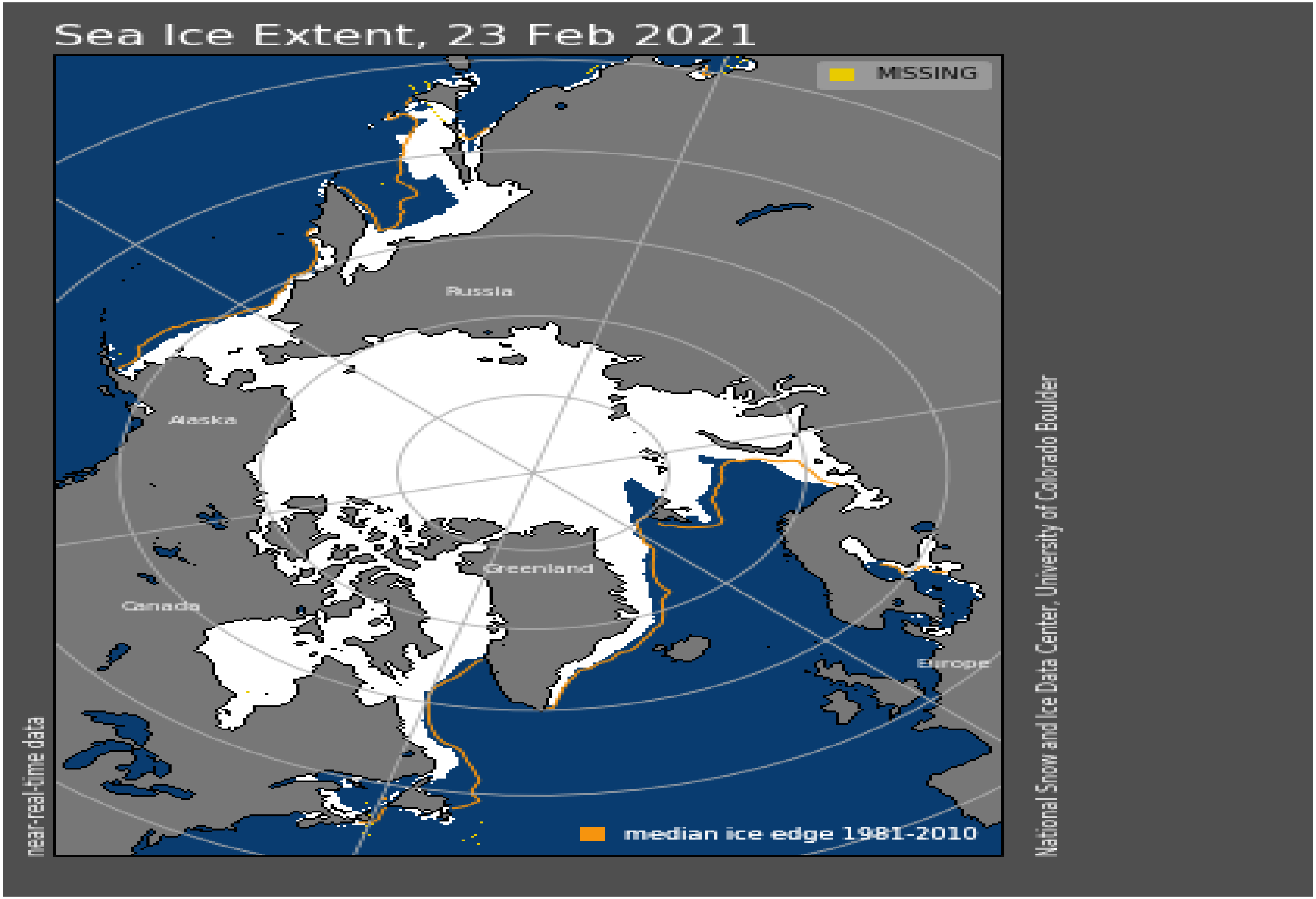
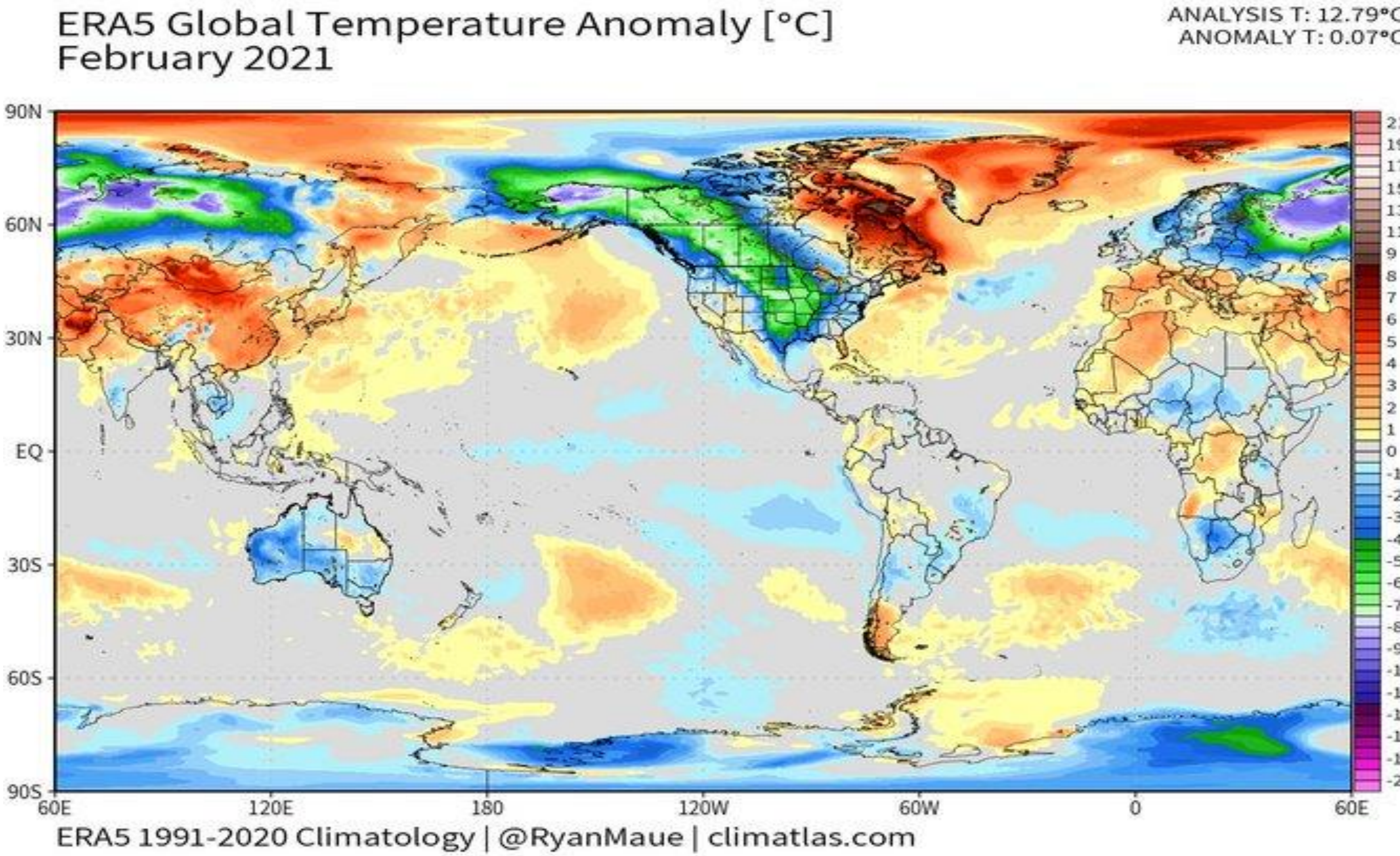


From @Ryan Maue



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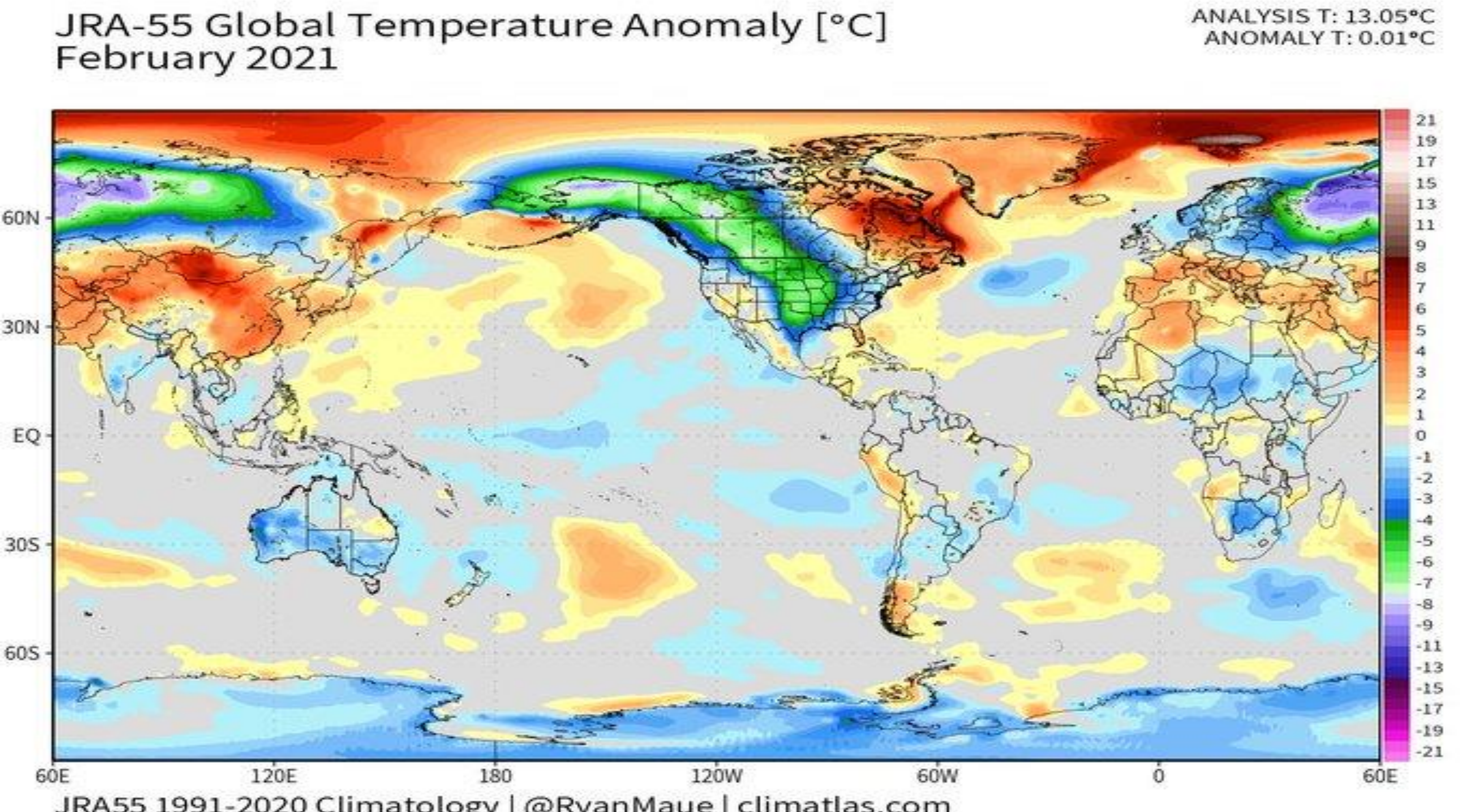
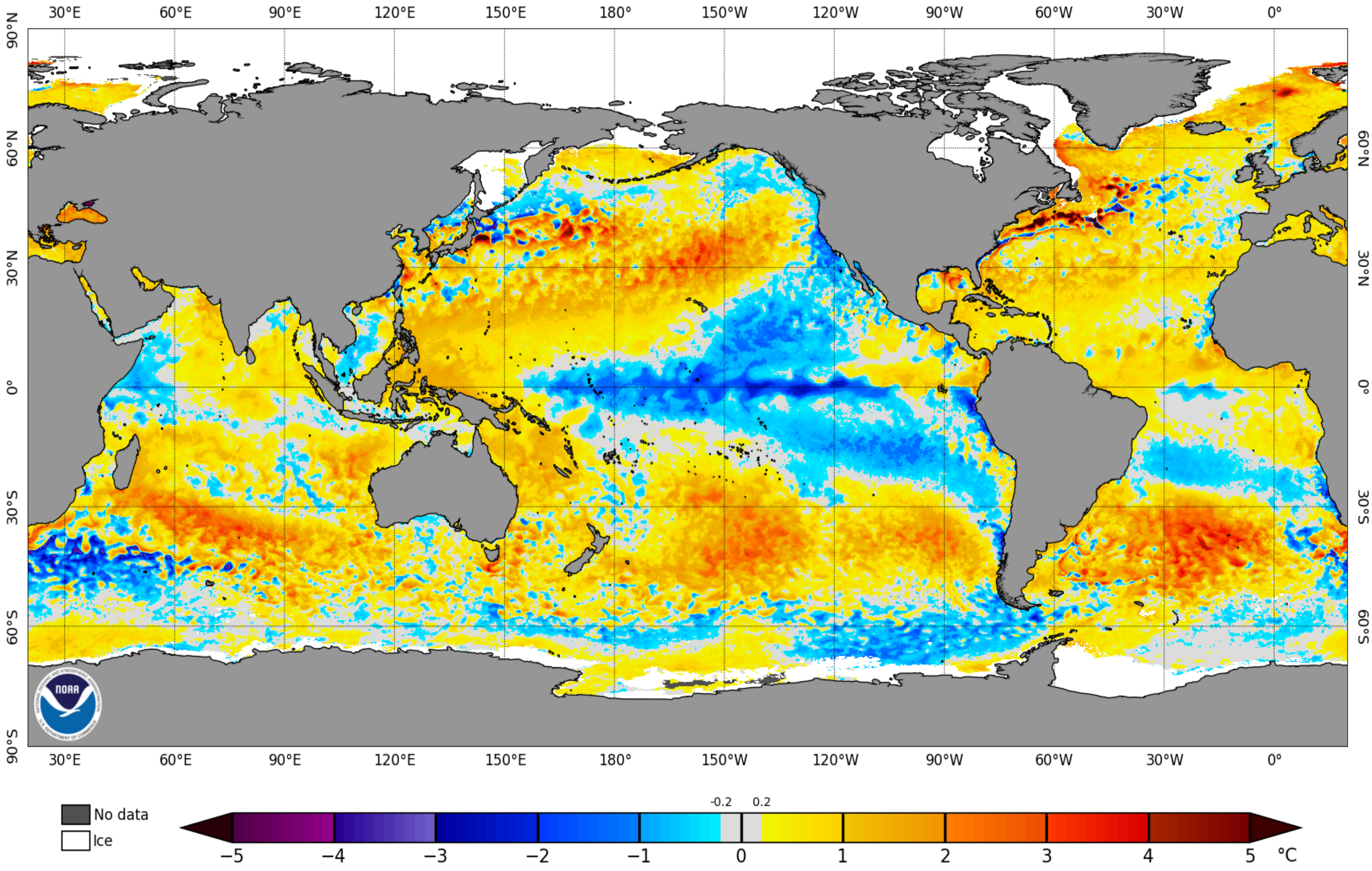


NOAA Coral Reef Watch Daily 5km SST Anomalies (v3.1)   27 Feb 2021



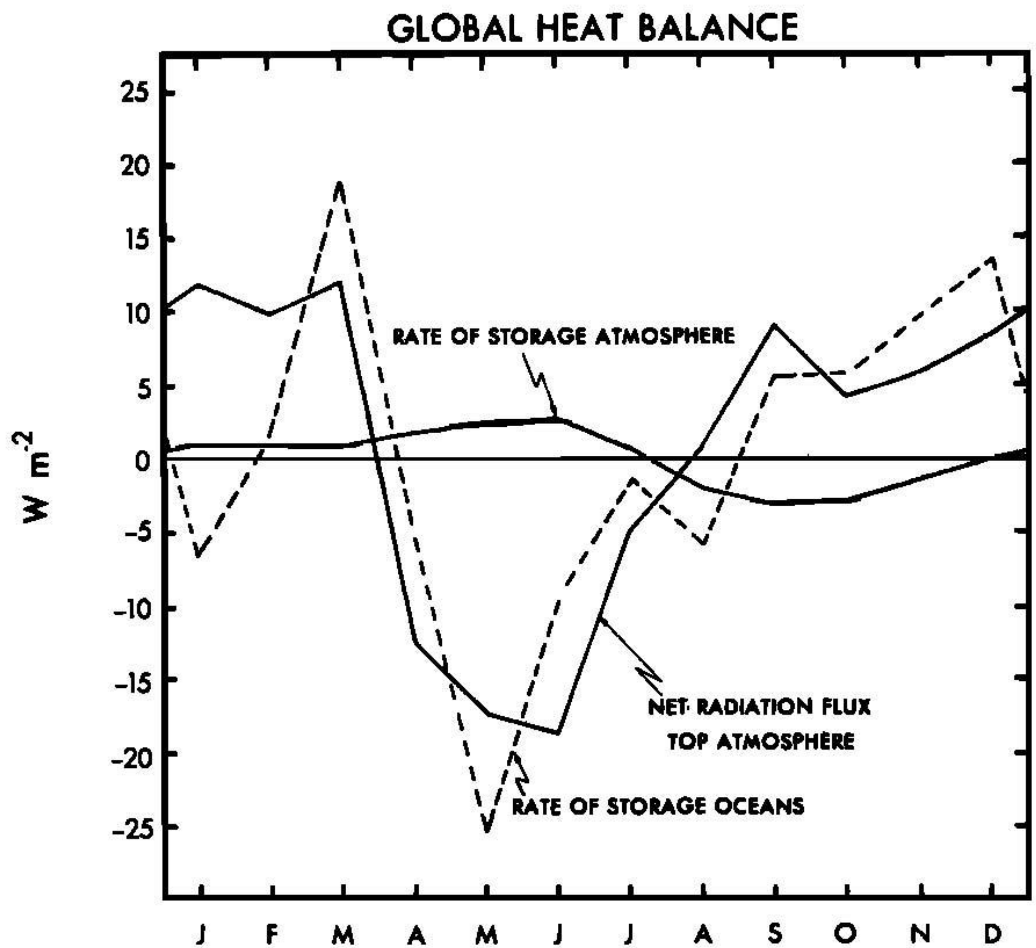
Changes in Ocean Heat Content most accurate Way to diagnose TOA global average radiative imbalance (i.e. climate system heat changes – "global warming") on seasonal and longer time scales

TOA Global Average Radiative Imbalance =

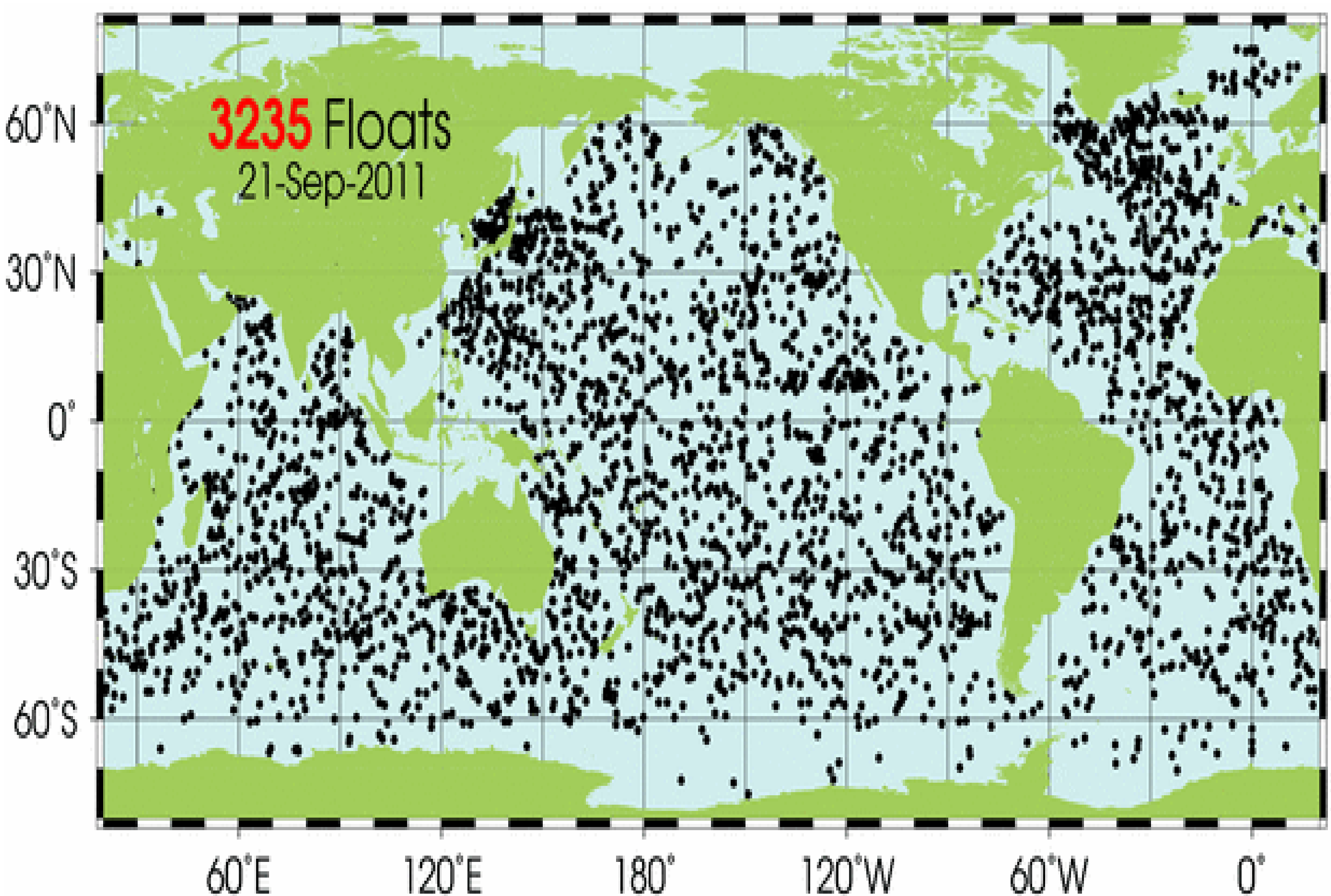
TOA Global Average Radiative Forcing + TOA Global Average Radiative Feedbacks

Pielke Sr., R.A., 2003: Heat storage within the Earth system. Bull. Amer. Meteor. Soc., 84, 331-335. http://pielkeclimatesci.wordpress.com/files/2009/10/r-247.pdf

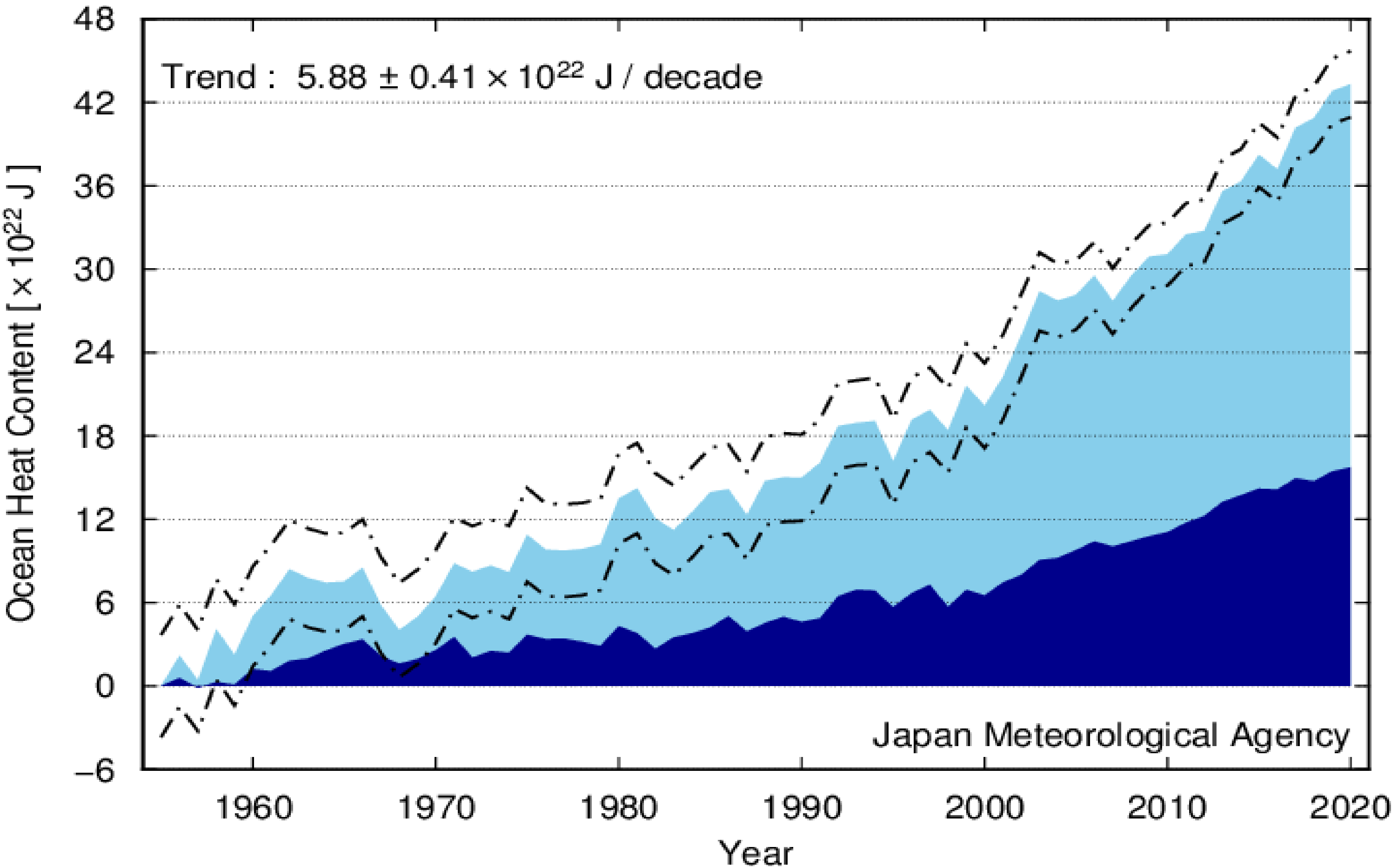
<u>Seminal paper on this subject</u>: **Ellis . J.S., T.H. Vonder Haar, S. Levitus, and A.H. Oort 1978: The annual variation in the global heat balance of the Earth. J. Geophys. Res., 83, 1958-1962.**



Argo Network



From https://www.data.jma.go.jp/gmd/kaiyou/english/ohc/ohc_global_en.html



From https://www.data.jma.go.jp/gmd/kaiyou/english/ohc/ohc_global_en.html

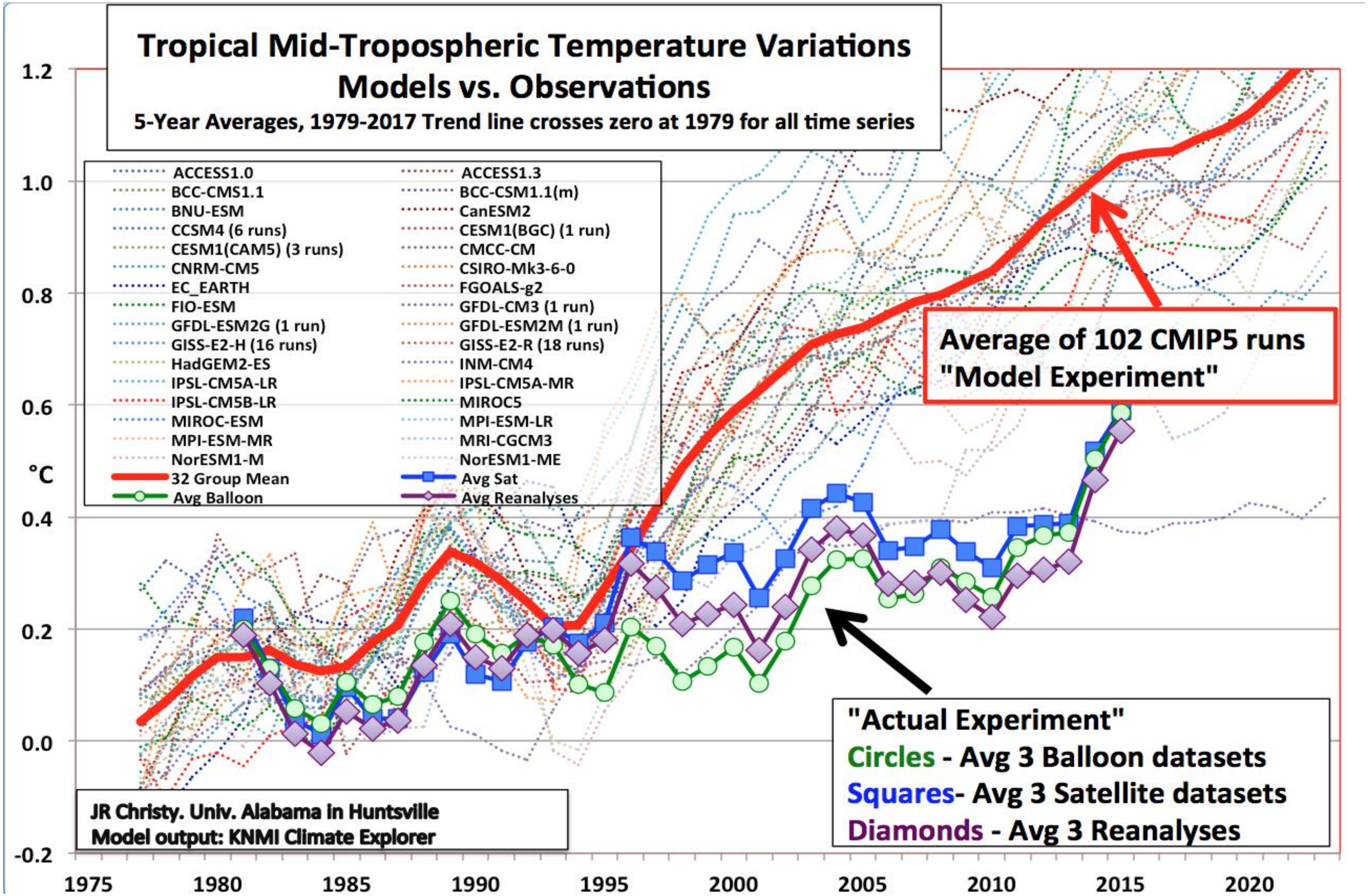
Oceans have a significant impact on the global climate because they cover about 70% of the earth's surface and have high heat capacity. According to the Intergovernmental Panel on Climate Change Fifth Assessment report (IPCC, 2013), more than 60% of the net energy increase in the climate system from 1971 to 2010 is stored in the upper ocean (0 – 700 m), and about 30% is stored below 700 m. Oceanic warming results in sea level rises due to thermal expansion, and impacts marine ecosystems.

It is virtually certain that globally integrals of 0 to 2000m ocean heat content (OHC) rose between 1955 and 2020 at a rate of 5.88 ± 0.41 × 10^{22}J per decade as a long-term trend with interannual variations (the range indicated by '±' represents a 95% confidence level). A rise of 0.020 ± 0.001°C per decade in the globally averaged 0 to 2000m ocean temperature accompanied the OHC increase. Oceans exhibited marked warming since the mid-1990s.

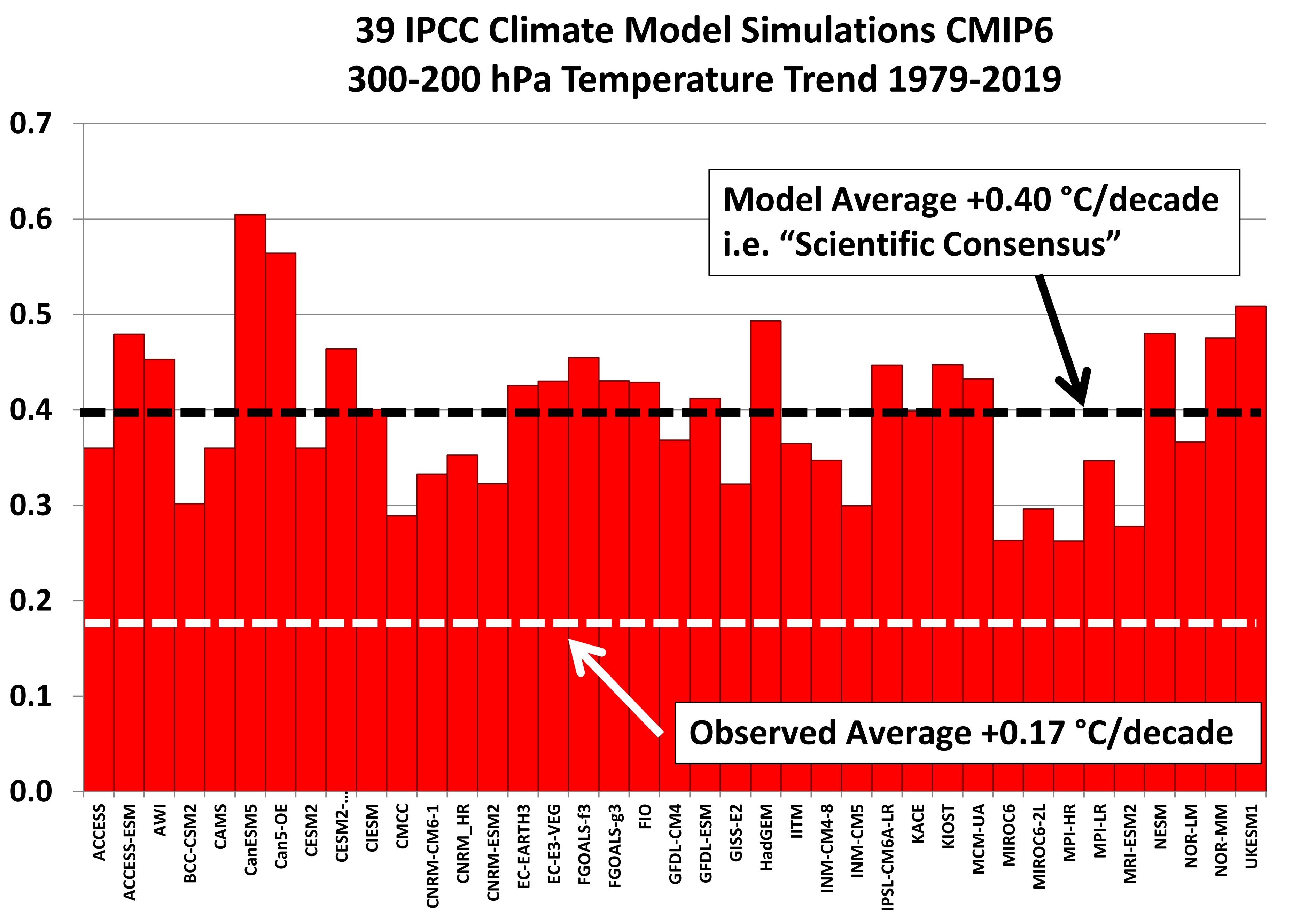
These long-term trends can be attributed to global warming caused by increased concentrations of anthropogenic greenhouse gases such as CO_2 as well as natural variability.

Model-Real World Comparisons

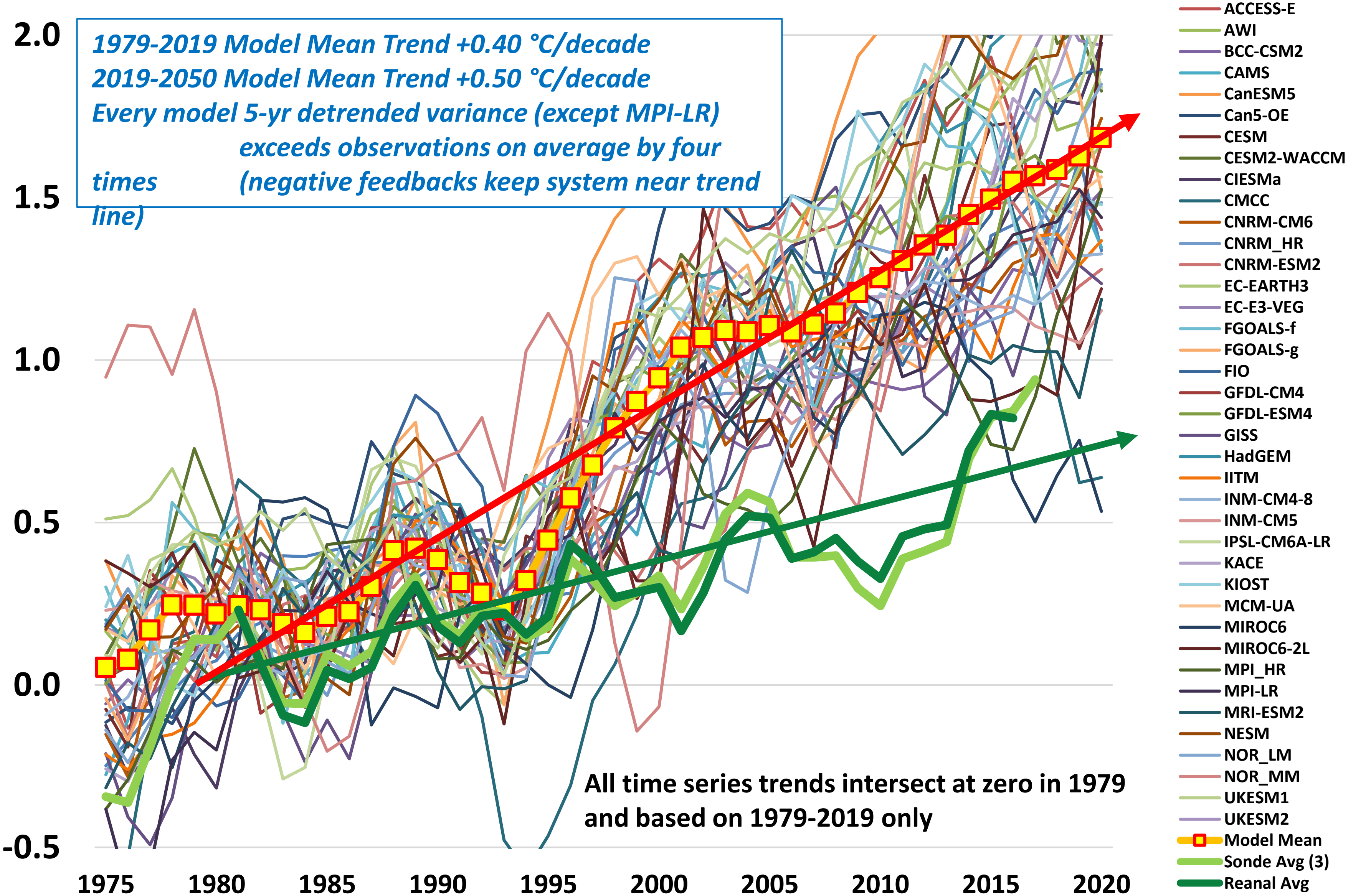
- Weather Prediction Models (hours out to 10-14 days or so) are constrained by real world observations. Many variables can be assumed constant over this time period (e.g. SSTs, vegetation type)
- Climate Models (progressively longer time periods do not have the ability to assume variables are constant, nor have observed data to prevent (constrain) models from deviating from reality.



Tropical Mid-Tropospheric Temperature Variations
Models vs. Observations
5-Year Averages, 1979-2017 Trend line crosses zero at 1979 for all time series
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)
GISS-E2-R (18 runs)
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 Sat
Avg Balloon
Avg Reanalyses
Average of 102 CMIP5 runs
"Model Experiment"
"Actual Experiment"
Circles - Avg 3 Balloon datasets
Squares- Avg 3 Satellite datasets
Diamonds - Avg 3 Reanalyses
JR Christy. Univ. Alabama in Huntsville
Model output: KNMI Climate Explorer
°C
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020


39 IPCC Climate Model Simulations CMIP6
300-200 hPa Temperature Trend 1979-2019
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Model Average +0.40 °C/decade
i.e. "Scientific Consensus"
Observed Average +0.17 °C/decade
ACCESS
ACCESS-ESM
AWI
BCC-CSM2
CAMS
CanESM5
Can5-OE
CESM2
CESM2-...
CIESM
CMCC
CNRM-CM6-1
CNRM_HR
CNRM-ESM2
EC-EARTH3
EC-E3-VEG
FGOALS-f3
FGOALS-g3
FIO
GFDL-CM4
GFDL-ESM
GISS-E2
HadGEM
IITM
INM-CM4-8
INM-CM5
IPSL-CM6A-LR
KACE
KIOST
MCM-UA
MIROC6
MIROC6-2L
MPI-HR
MPI-LR
MRI-ESM2
NESM
NOR-LM
NOR-MM
UKESM1

5-yr Running mean 300-200hPa Tropical Temperature Anomalies
CMIP-6 (Historical + ssp245 after 2014)



John R. Christy, The University of Alabama in Huntsville

Examples of Climate Model Prediction Shortcomings

1. Stephens et al. (2010) wrote *"models produce precipitation approximately twice as often as that observed and make rainfall far too lightly...The differences in the character of model precipitation are systemic and have a number of important implications for modeling the coupled Earth system ...little skill in precipitation [is] calculated at individual grid points, and thus applications involving downscaling of grid point precipitation to yet even finer-scale resolution has little foundation and relevance to the real Earth system."*

2. van Haren et al. (2012) concluded from their study with respect to climate model predictions of precipitation that *"An investigation of precipitation trends in two multi-model ensembles including both global and regional climate models shows that these models fail to reproduce the observed trends... A quantitative understanding of the causes of these trends is needed so that climate model based projections of future climate can be corrected for these precipitation trend biases.. To conclude, modeled atmospheric circulation and SST trends over the past century are significantly different from the observed ones."*

3. Xu and Yang (2012) find that without tuning from real world observations, the model predictions are in significant error. For example, they found that *“the traditional dynamic downscaling (TDD) [i.e. without tuning) overestimates precipitation by 0.5-1.5 mm d-1...The 2-year return level of summer daily maximum temperature simulated by the TDD is underestimated by 2-6C over the central United States-Canada region."*

https://scitechdaily.com/princeton-study-new-climate-models-with-high-climate-sensitivity-are-implausible/

4. Princeton Study: New Climate Models With High Climate Sensitivity Are Implausible

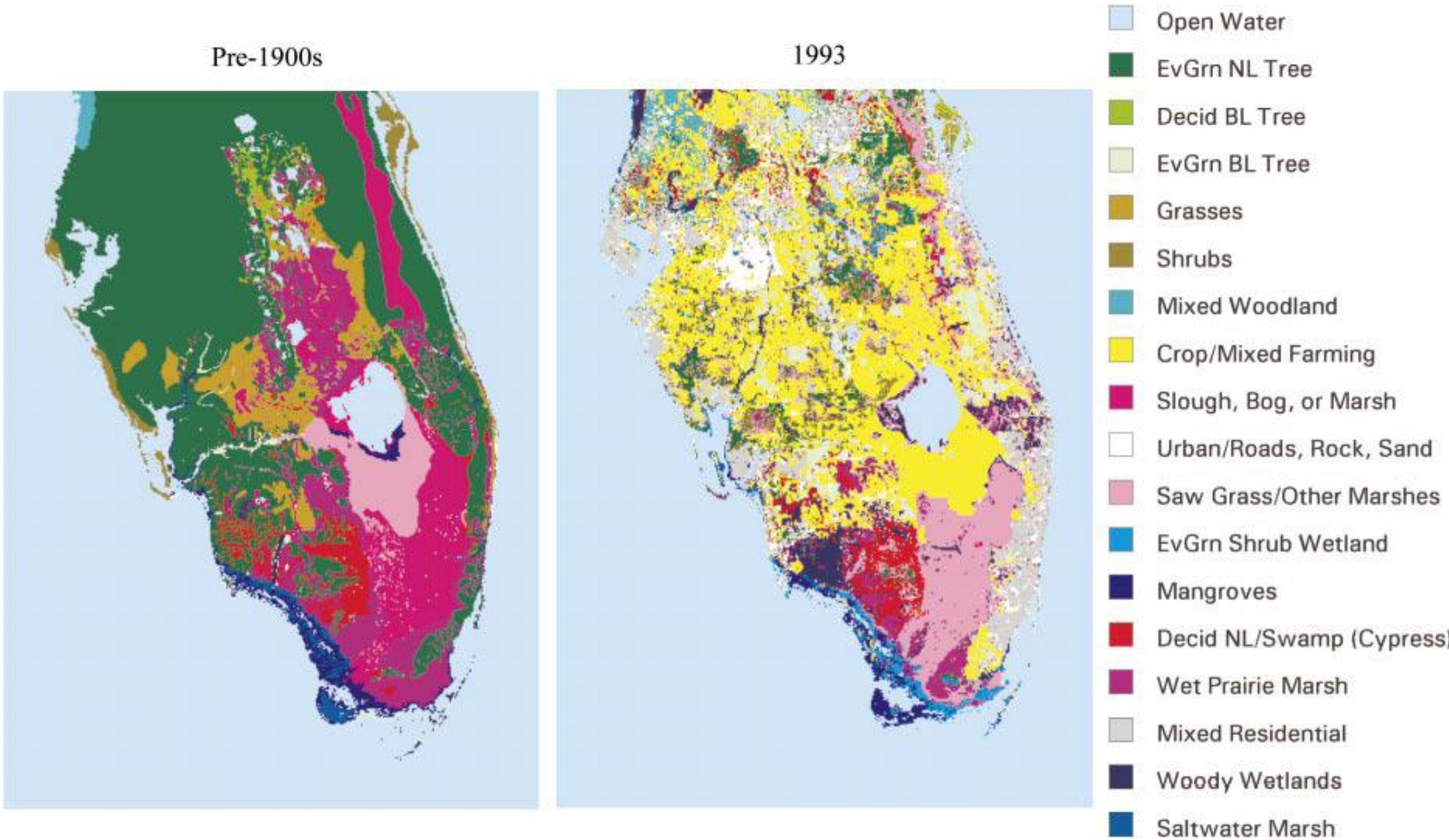
"Researchers at Princeton University and the University of Miami reported that newer models with a high "climate sensitivity" — meaning they predict much greater global warming from the same levels of atmospheric carbon dioxide as other models — do not provide a plausible scenario of Earth's future climate."

Human Climate Forcings

Human Climate Forcings

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

From Marshall et al. 2004



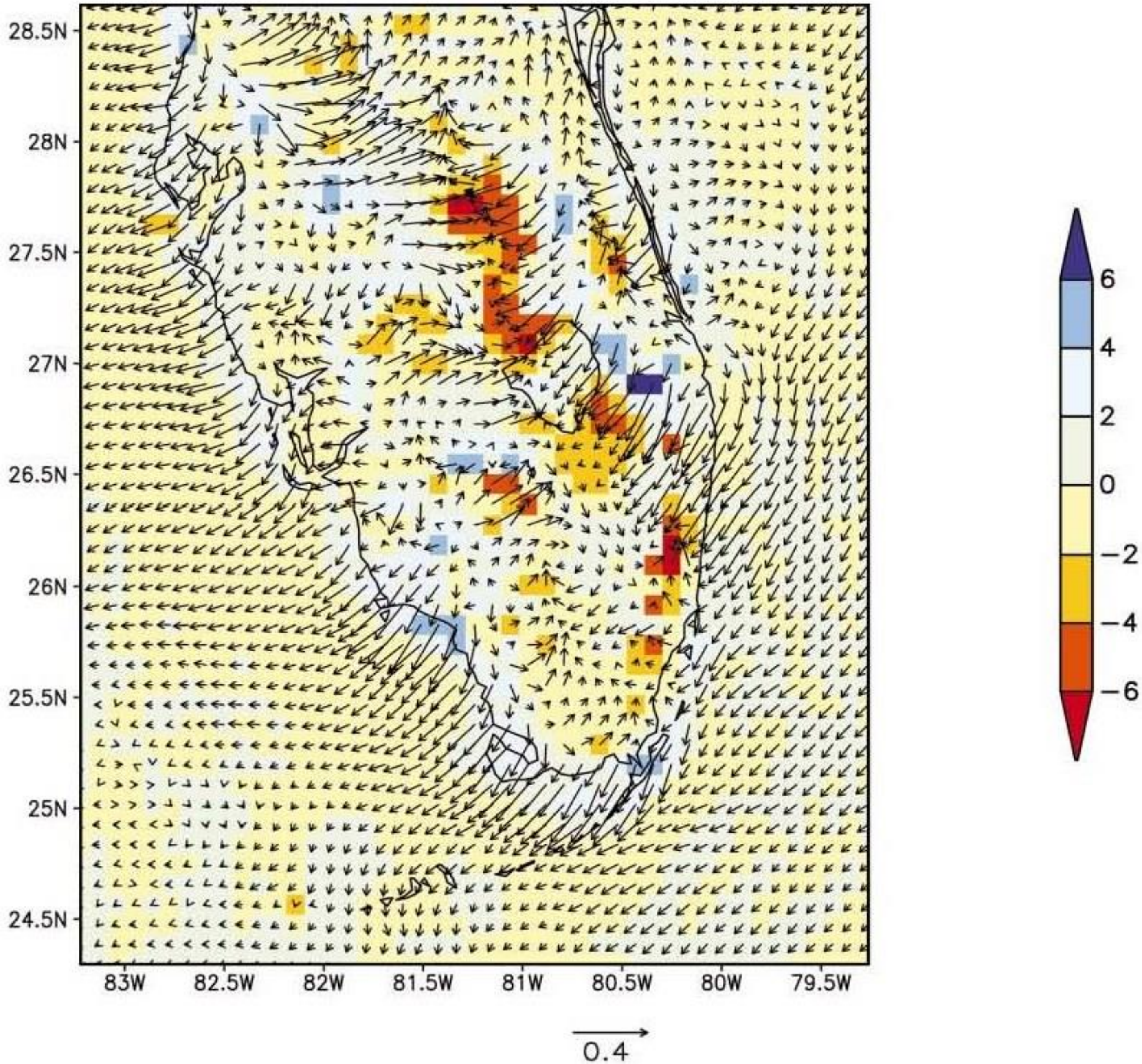


FIG. 17. Difference (1993 minus pre-1900 case) of the fields shown in Fig. 16.

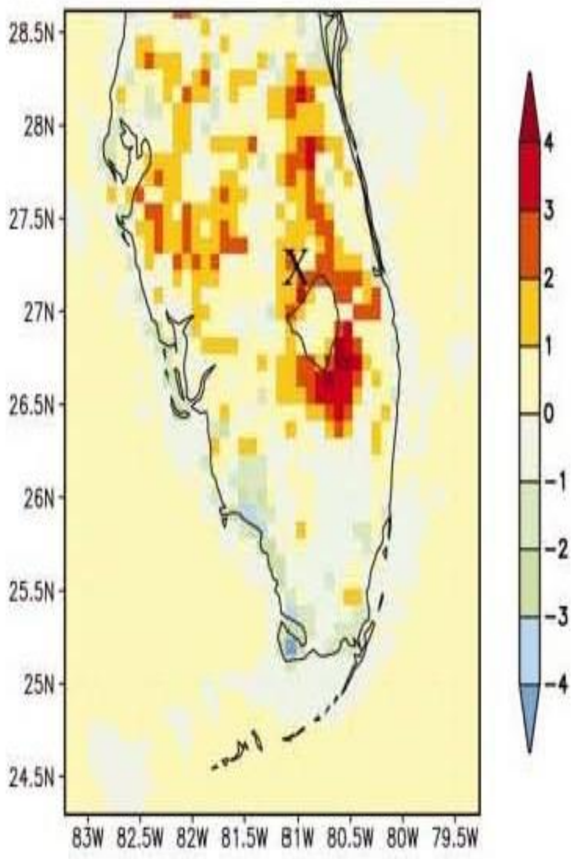


FIG. 13. Two-month average of the daily max shelter-level temperature from the model simulations of Jul–Aug 1989 with (top) pre-1900 land cover, (middle) 1993 land use, and (bottom) the difference field for the two (1993 minus pre-1900 case).

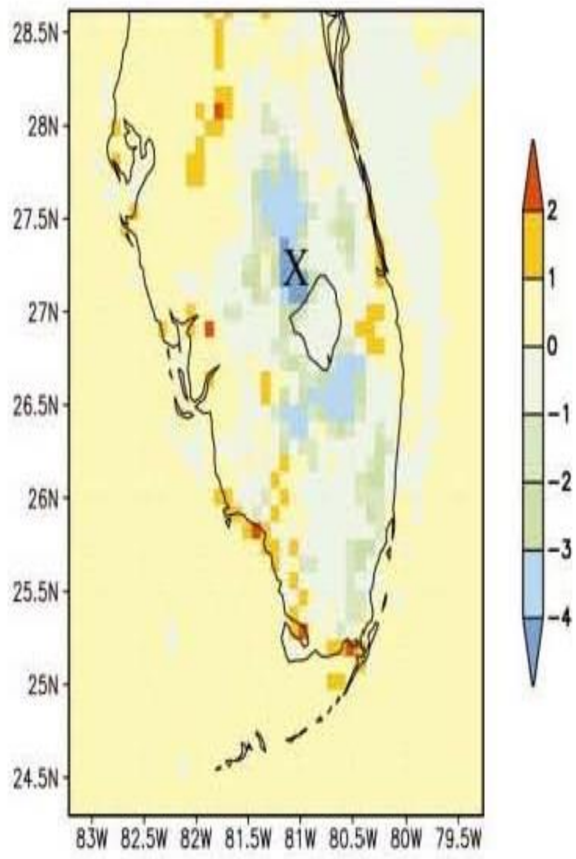
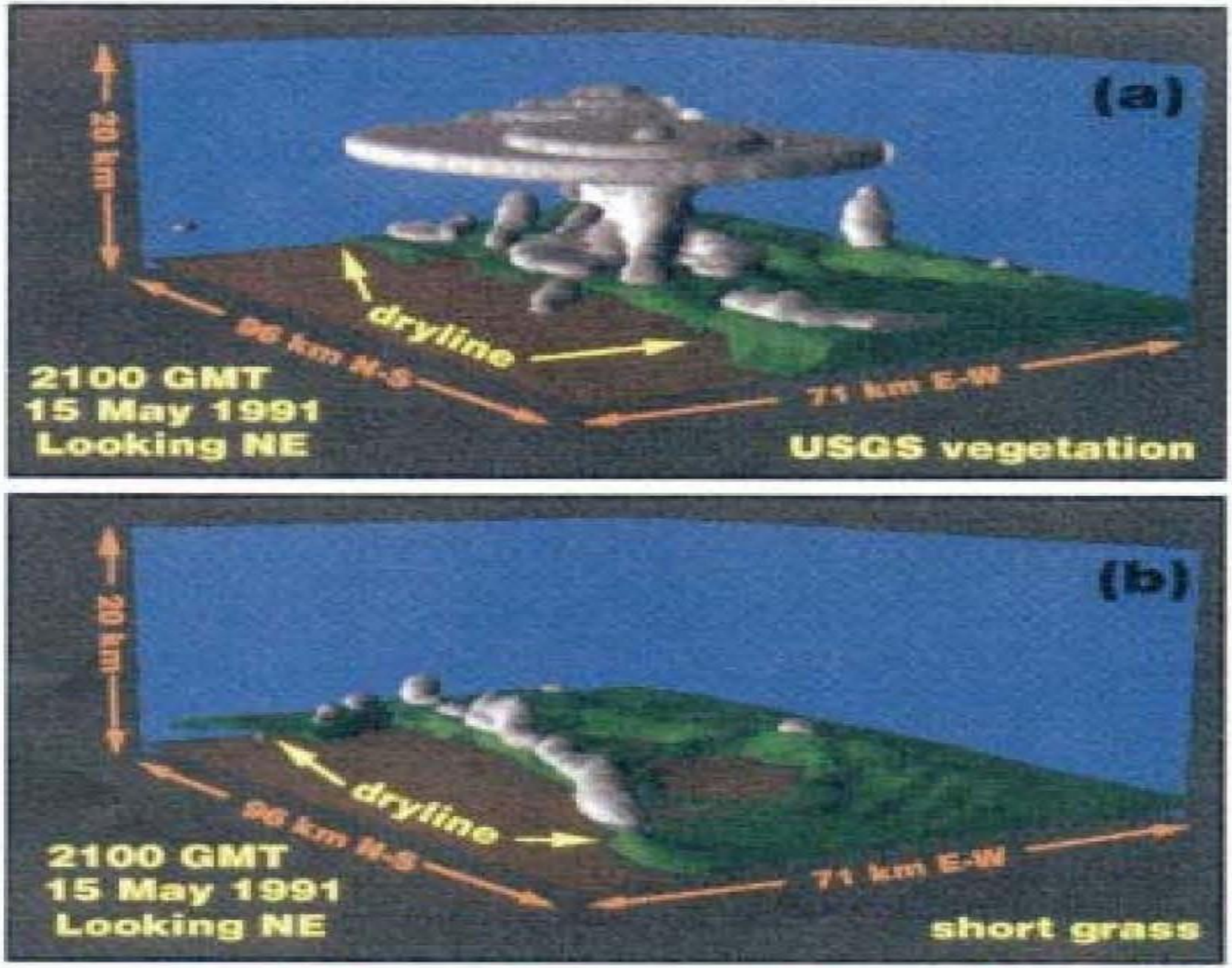
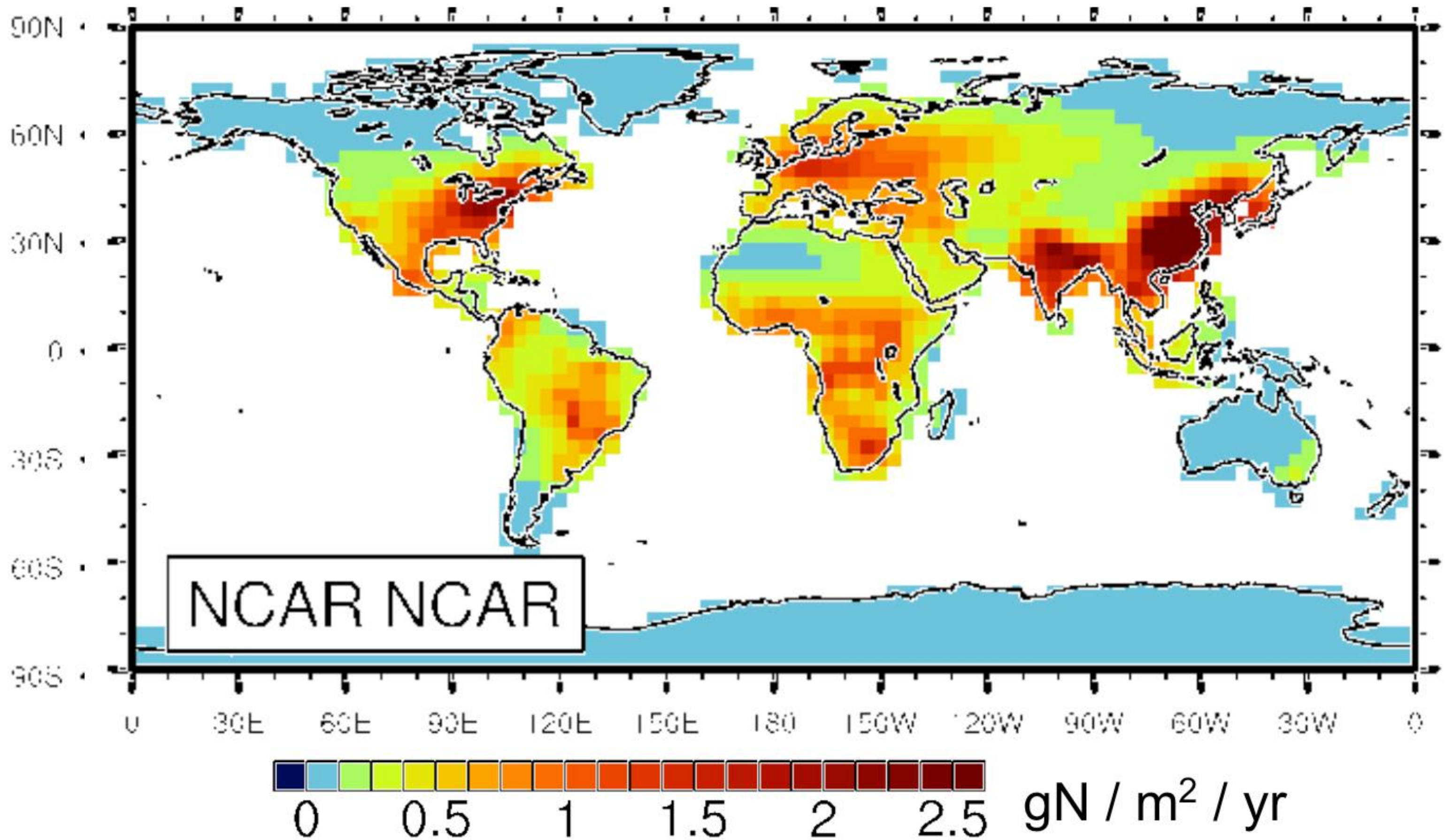


FIG. 14. Same as Fig. 13, except for daily min temperatu

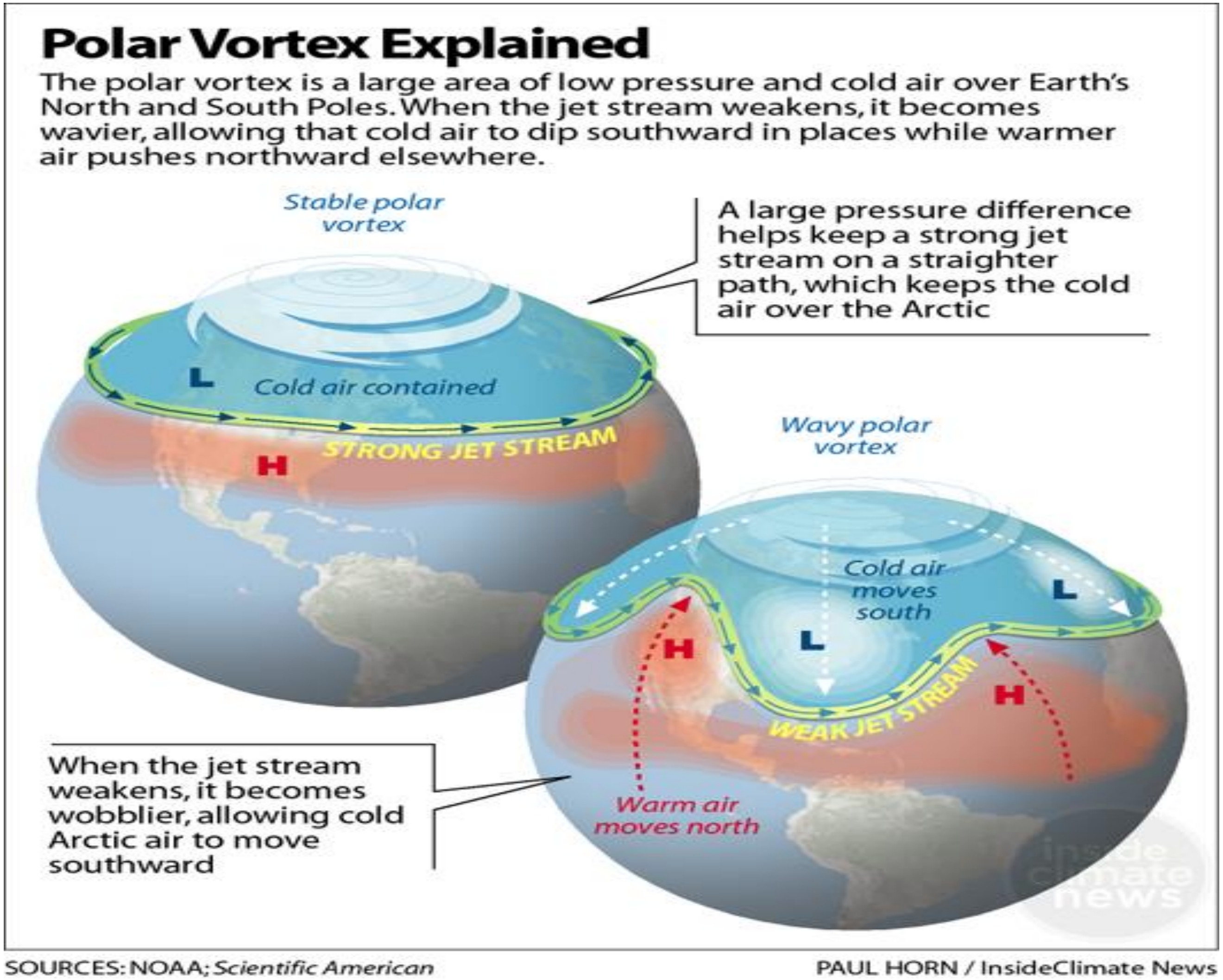

(a)
20 km
dryline
96 km N-S
71 km E-W
2100 GMT
15 May 1991
Looking NE
USGS vegetation
(b)
20 km
dryline
96 km N-S
71 km E-W
2100 GMT
15 May 1991
Looking NE
short grass

Nitrogen Deposition



- Climate Misinformation

Erroneous Claim: Strong Polar Jet Confines Cold Air To Arctic



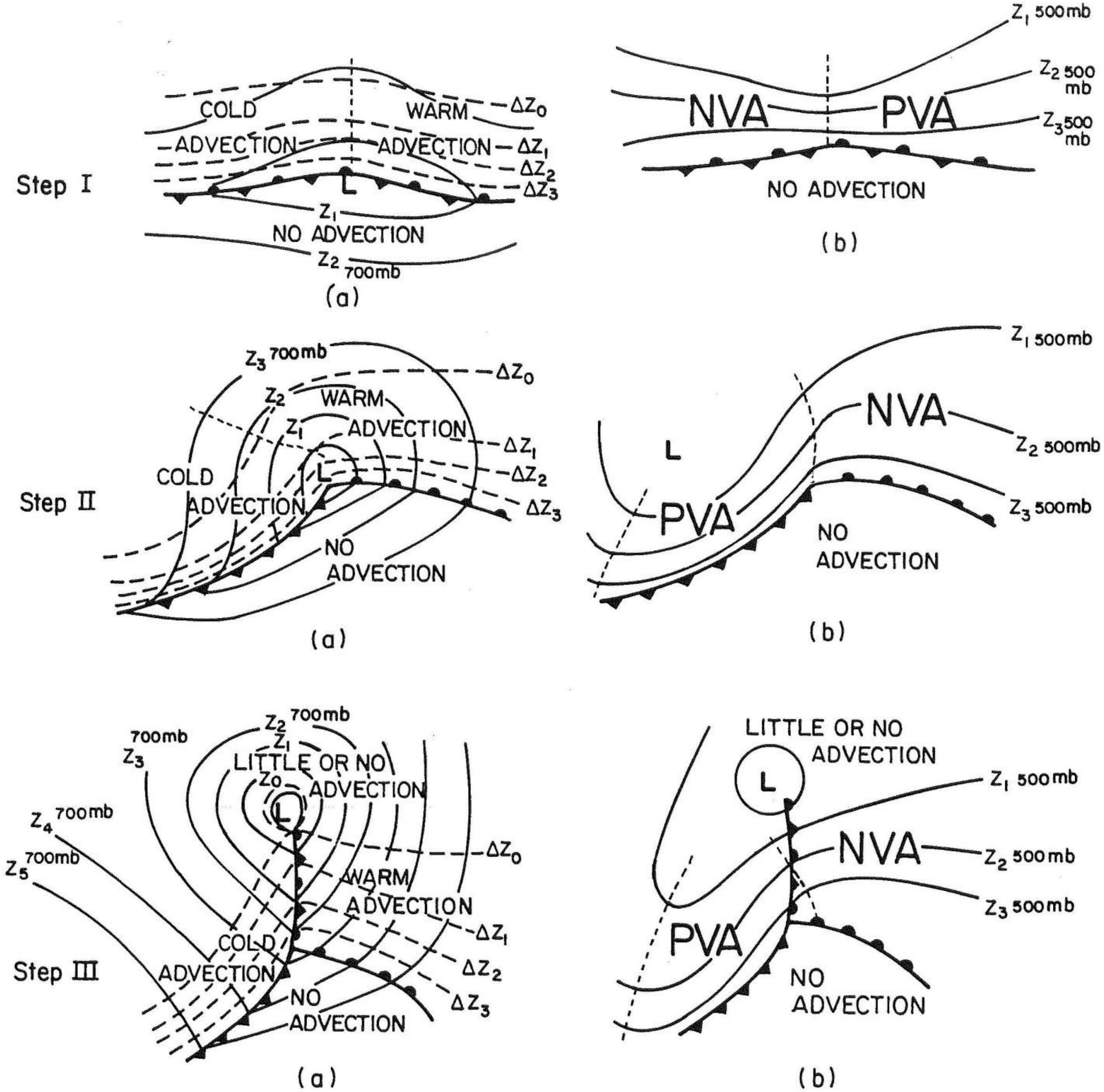
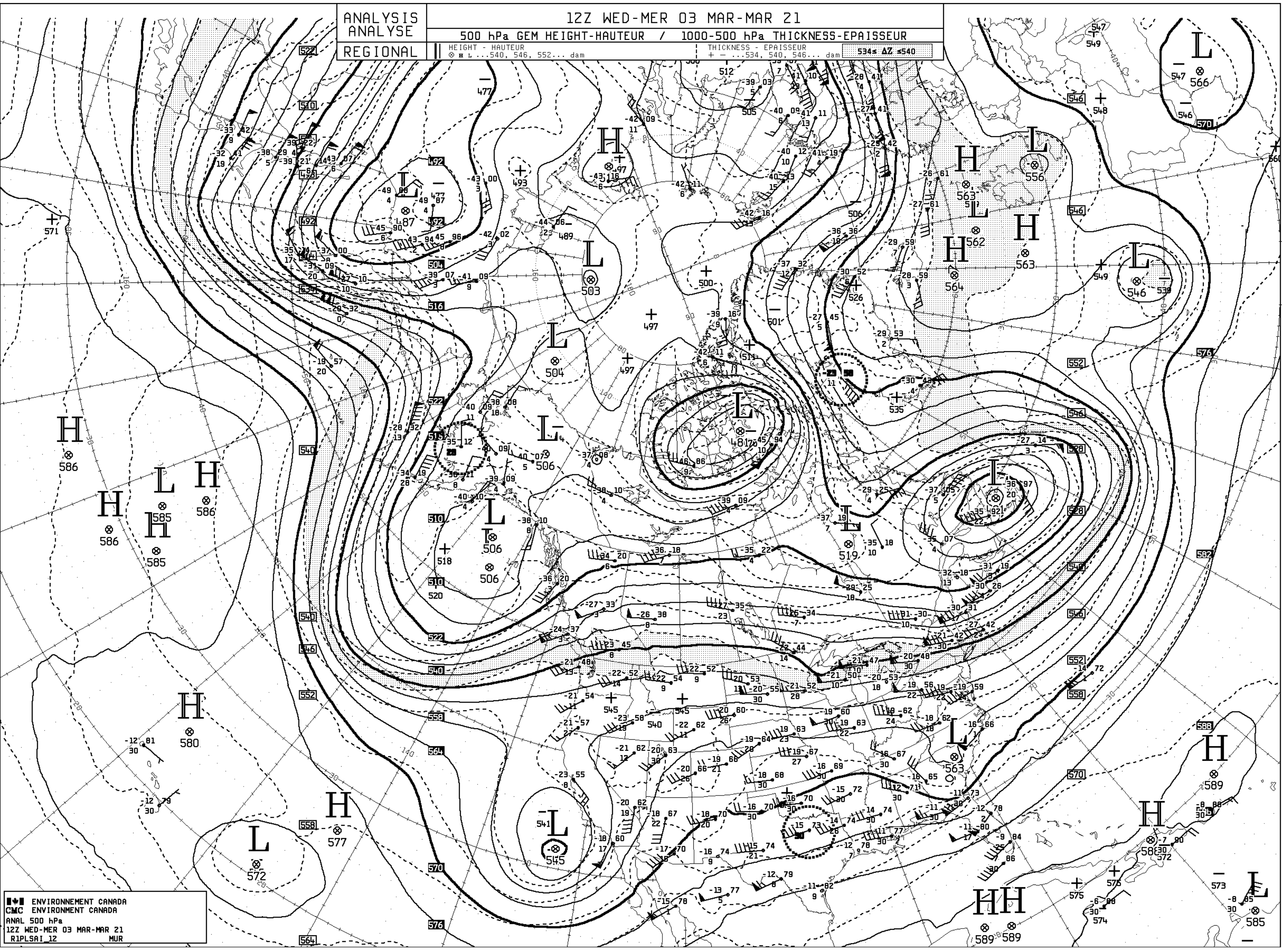
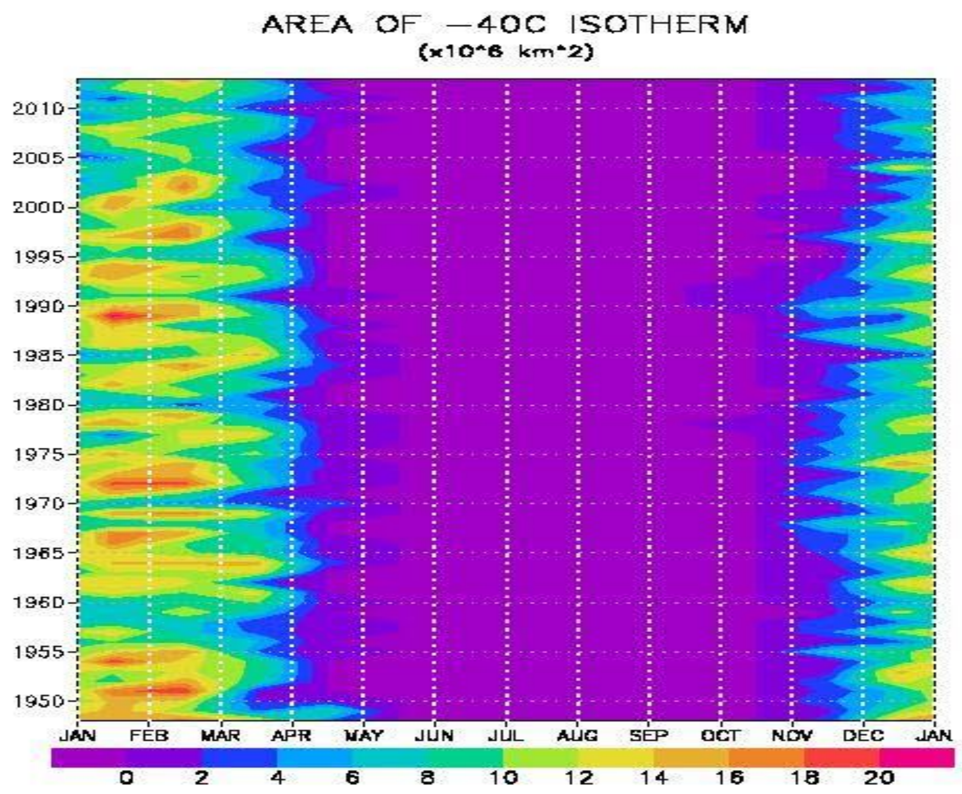


Figure 3.20: Schematic illustration of thickness advection and vorticity advection associated with extratropical cyclone development. The 700 mb height contours (solid lines), 1000-500 mb thickness contours (dashed lines), and surface frontal location are given in (a). The 500 mb height contours (solid lines) and surface frontal location are shown in (b).

Chase et al2015: Bracketing mid-tropospheric temperatures in the Northern Hemisphere: An observational study 1979 - 2013. J. Climatol. Weather Forecasting

We examine mid-tropospheric temperatures in the Northern Hemisphere using the 500 mb pressure surface from reanalysis data as a representative level. This standard analysis level is significant meteorologically (i.e. for frontal identification and jet stream dynamics) and climatologically (e.g. changes in long term front and jet structures would be expected to extend throughout the troposphere as would tropospheric warming). We find that 500 mb temperatures are bracketed between about –42°C and –3°C with very few excursions beyond these brackets suggesting a limiting physical process or processes. In this paper we update the data for the –42°C limit which we have proposed in previous papers, document the –3°C limit for the first time, and briefly discuss the possible physical mechanisms responsible for this observed temperature bracketing concluding that the limits on both maximum and minimum temperatures are due to convective processes. This self-regulation of tropospheric temperatures [by baroclinic instability] constrains changes in jet stream and baroclinic storm dynamics and therefore constrains changes in climate variability.


ANALYSIS
ANALYSE
REGIONAL
12Z WED-MER 03 MAR-MAR 21
500 hPa GEM HEIGHT-HAUTEUR / 1000-500 hPa THICKNESS-EPAISSEUR
HEIGHT - HAUTEUR ...540, 546, 552... dam
THICKNESS - EPAISSEUR ...534, 540, 546... dam
534≤ ΔZ ≤540
ENVIRONNEMENT CANADA
CMC ENVIRONMENT CANADA
ANAL 500 hPa
12Z WED-MER 03 MAR-MAR 21
R1PLSAI_12 MUR


AREA OF −40C ISOTHERM
(x10^6 km^2)
2010
2005
2000
1995
1990
1985
1980
1975
1970
1965
1960
1955
1950
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN
0 2 4 6 8 10 12 14 16 18 20

Conclusions

- Is Climate Change an existential threat?

  Use inclusive Contextual Vulnerability Approach to assess.

- Observed Climate Change

  Climate always has changed even without the effects of human activities. There is no “stable” climate.

- Model-Real World Comparisons

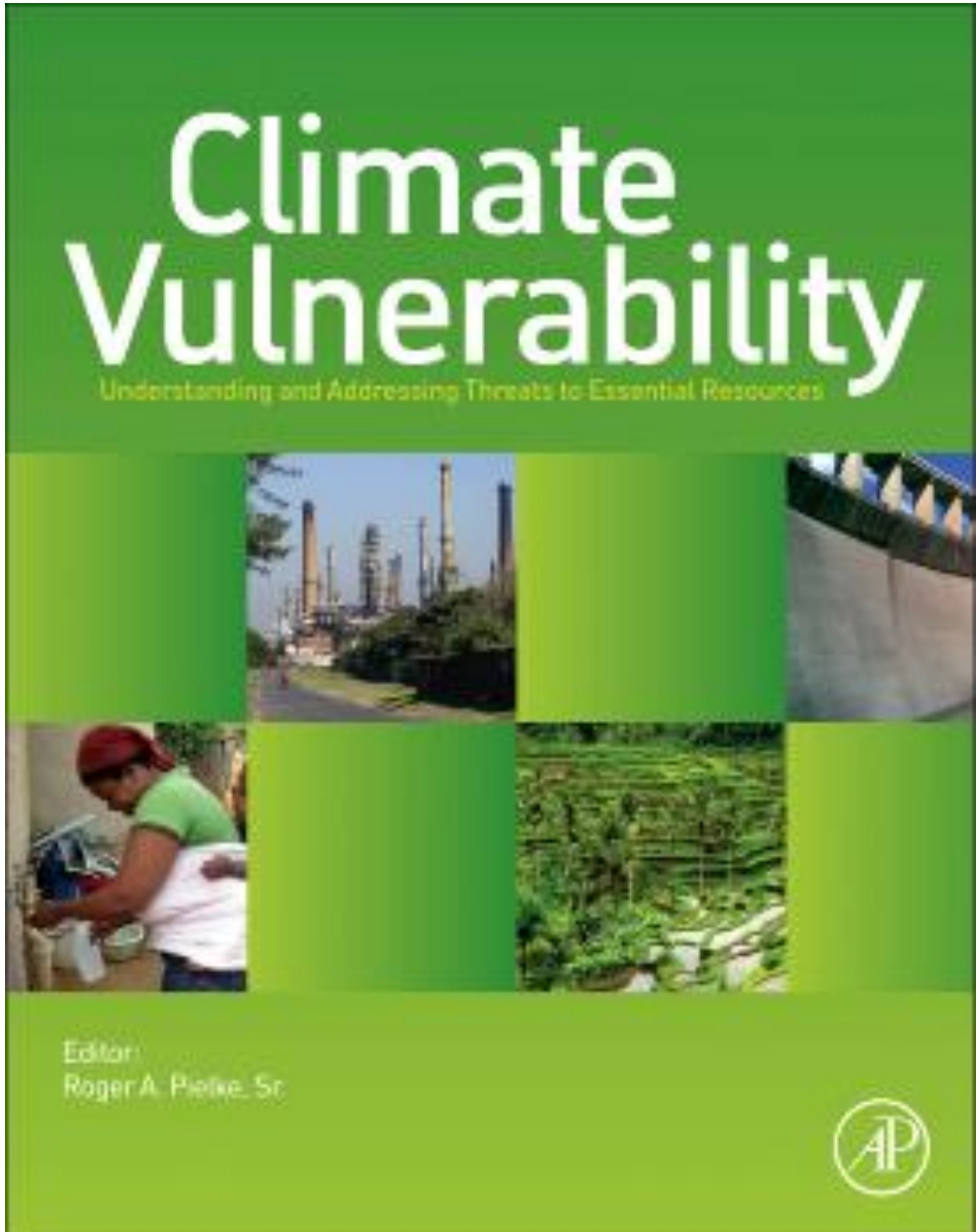
  Models have poor demonstrated skill at prediction changes in regional climate statistics on multidecadal time scales

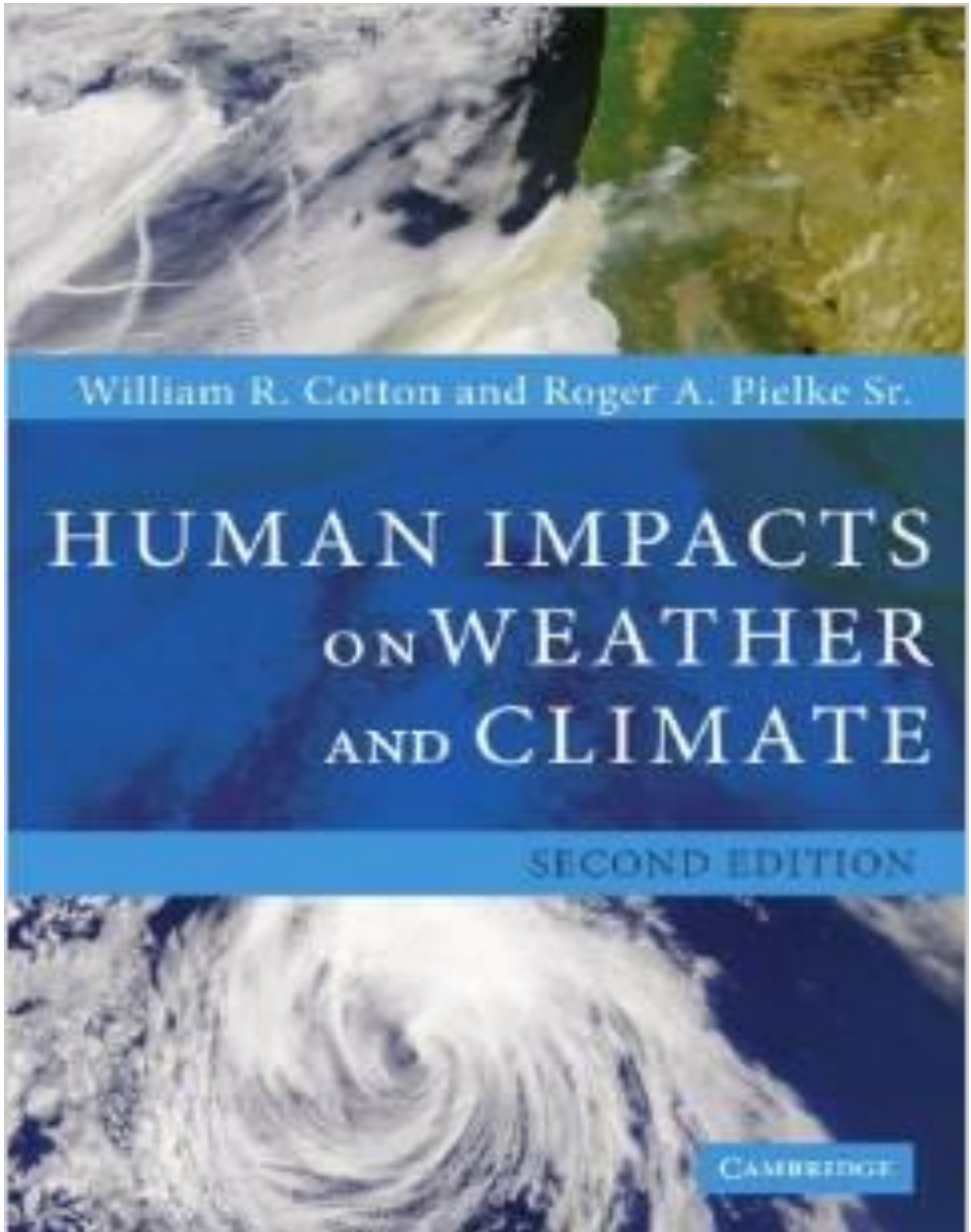
- Human climate Forcings

  Human forcing involve much more than the radiative effects of added CO_2 and other GHGs.

- Climate Misinformation

  Claims of erroneous presentations of climate dynamics should be robustly assessed and either refuted or confirmed.


Climate
Vulnerability
Understanding and Addressing Threats to Essential Resources
Editor:
Roger A. Pielke, Sr.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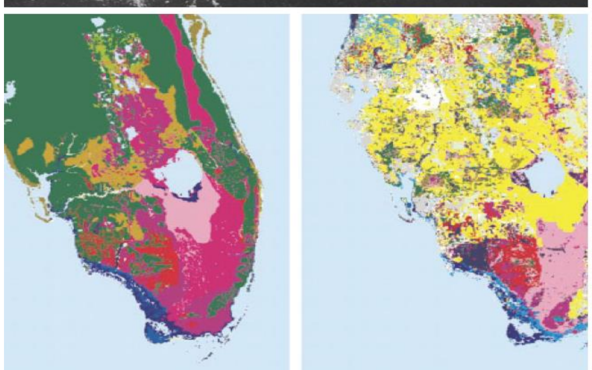

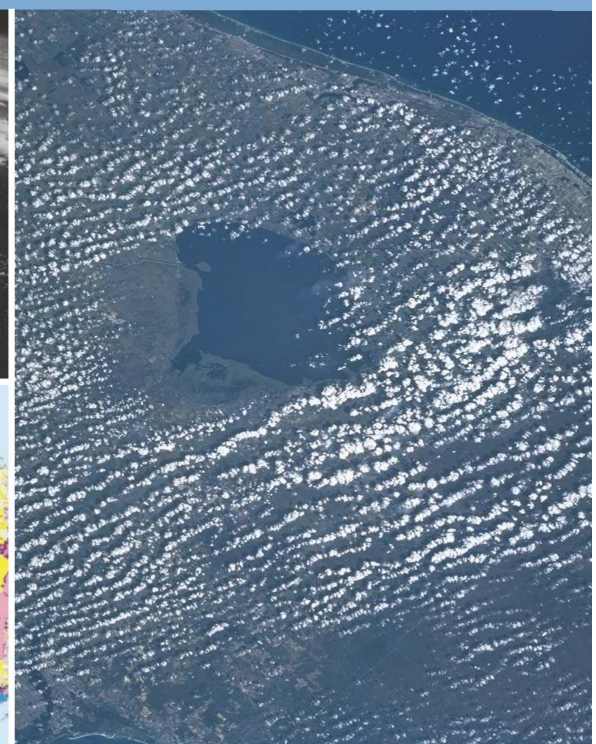

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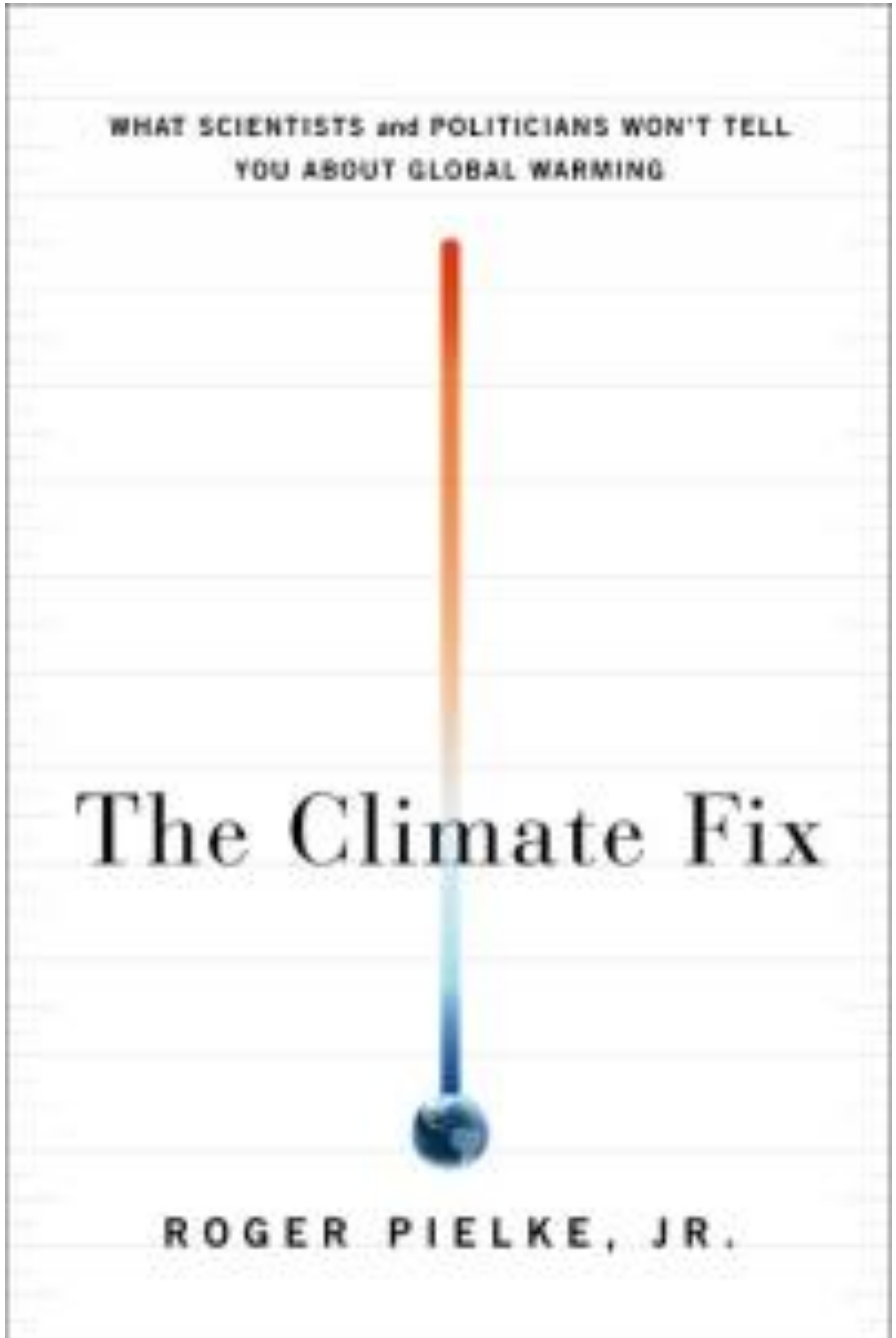
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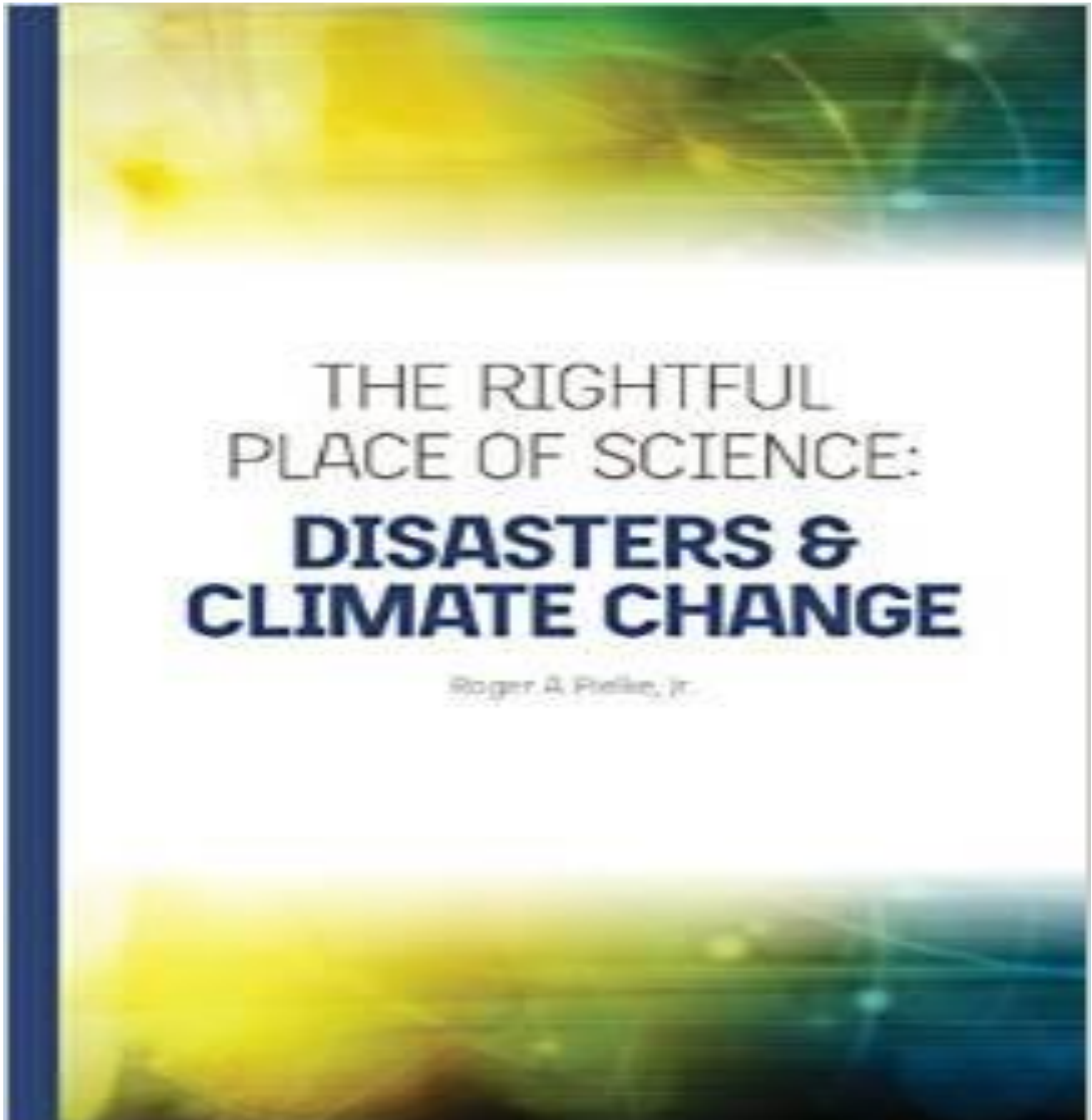
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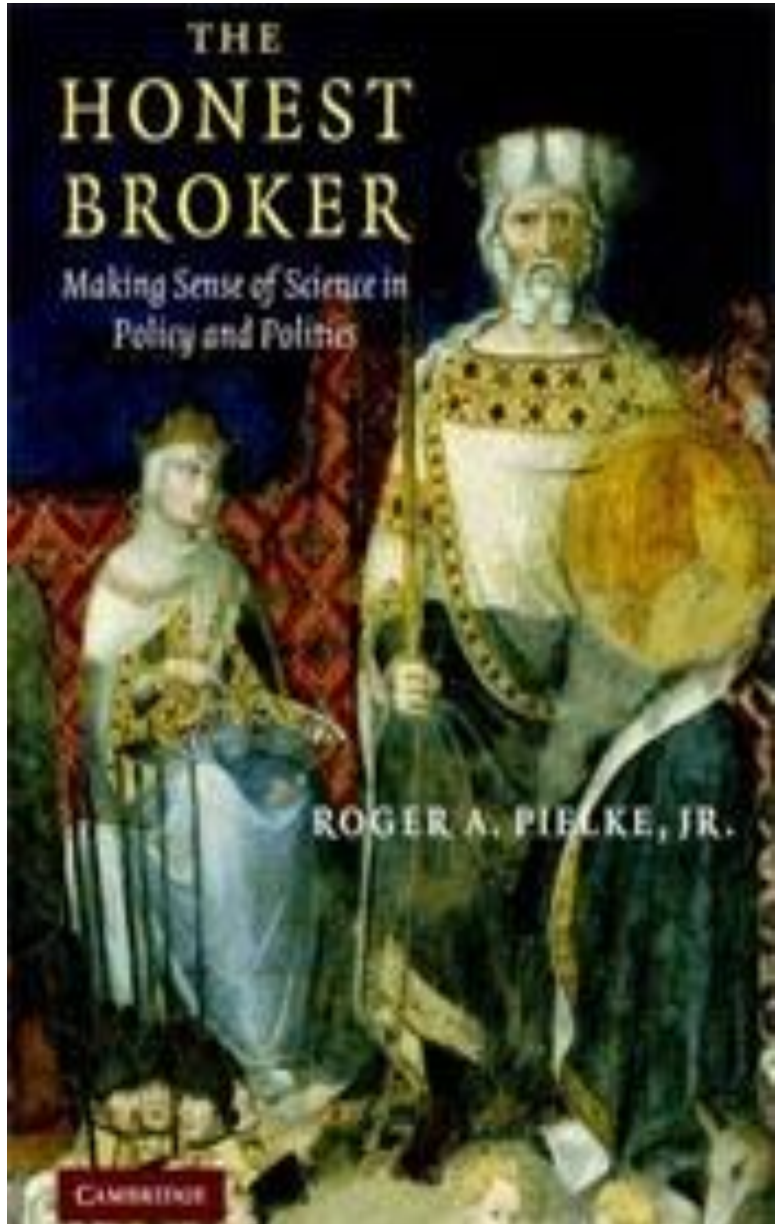
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National Research Council, 2005: **Radiative forcing of climate change: Expanding the concept and addressing uncertainties.** Committee on Radiative Forcing Effects on Climate Change, Climate Research Committee, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., 208 pp.

Kabat, P., Claussen, M., Dirmeyer, P.A., J.H.C. Gash, L. Bravo de Guenni, M. Meybeck, R.A. Pielke Sr., C.J. Vorosmarty, R.W.A. Hutjes, and S. Lutkemeier, Editors, 2004: **Vegetation, water, humans and the climate: A new perspective on an interactive system**. Springer, Berlin, Global Change - The IGBP Series, 566 pp.

Cotton, W.R. and R.A. Pielke, 1995: Human impacts on weather and climate, Cambridge University Press, New York, 288 pp.