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APS TOPICAL GROUP ON THE PHYSICS OF CLIMATE

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Message from the Editor

This is the sixth GPC Newsletter, published twice per year. You, the GPC membership, can be of enormous value. We invite comments, event notices, letters, and especially specific suggestions for content. Any of the above, addressed to GPCnews@aps.org, will be gratefully acknowledged in a timely fashion.

GPC Contacts with Other Professional Societies

Juan Restrepo, GPC Chair

This year GPC embarked on pursuing formal arrangements with other professional societies, namely the American Geophysical Union (AGU) and the Society for Industrial and Applied Mathematics (SIAM). The goal of the arrangement is to enable APS, SIAM, and AGU members to participate in each other's meetings at member rates. Thus far, we have secured the enthusiastic support for the initiative from officers of AGU and SIAM (in broad terms). I am mostly working on the AGU and SIAM side of things (I am a member of these, as well as APS), and Brad Marston has been working the APS side. APS officers are open to the idea but the case needs to be presented formally to a wider set of APS officers and has to be discussed thoroughly before proceeding further. We hope that APS will take up the issue and discuss it sometime in the next few months.

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2016 APS Division of Fluid Dynamics Meeting

APS DFD meeting will take place in Portland, OR, Nov. 20-22. GPC is co-sponsoring 16 sessions on topics ranging from geophysical fluid dynamics, planetary and exoplanetary dynamics, convection and buoyancy driven flows, air-sea interactions, the cryosphere, atmospheric dynamics, waves and tides, rotating stratified flows, dynamos in the Earth's core, effects of fluid turbulence in advecting and dispersing phenomena, thermal/fluid processes, and large scale mixing.

2017 APS March Meeting

The upcoming 2017 APS March meeting will take place March 13-17 in New Orleans, LA. There will be a Focus and an Invited GPC session, along with a "Climate Cafe" informal gathering. The Focus session topic is "Natural Pattern Formation and Earth's Climate System" with tentative invited talks:

[1] "The Size Distribution of Earth's Lakes" by Barry Cael (MIT)
[2] "Patterns in Melt Ponds on Arctic Sea Ice" by Predrag Popovich (U. Chicago).

GPC members are encouraged to contribute abstracts (deadline Friday, November 11).

The invited session topic is "Extreme Events in a Changing Climate" with tentative talks:

[1] "Large deviation theory of abrupt transitions and extreme events in geophysical flows" by Eric Vanden-Eijnden (NYU),
[2] "The signal and the noise: forced and unforced changes in temperature distributions and the probability of extremes" by Karen McKinnon (NCAR)
[3] "Influence of Anthropogenic Climate Change on Planetary Wave Resonance and Extreme Weather Events" by Michael Mann (Penn State)
[4] "Human influence on tropical cyclone intensity" by Adam Sobel (Columbia)
[5] "Crazy Weather and the Arctic Meltdown: Emerging Connections" by Jennifer Francis (Rutgers)

GPC Contacts with Other Professional Societies – *continued from p. 1*

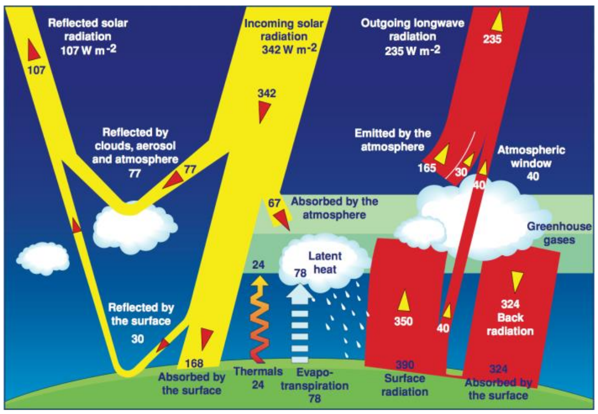
It is too early to describe in detail how this arrangement would work. Both AGU and SIAM are suggesting that particular groups within the parent organizations work out a formal memorandum of understanding (MOU) with a particular group from APS. Our idea is to create an MOU between AGU/NG (nonlinear geoscience), SIAM/GS (geosciences), and APS/GPC. We have verbal support from SIAM/GS and AGU/NG. We do not yet have the support from the rank and file within GPC, but will be asking for this once the APS gives us permission to pursue the idea further. Both AGU and SIAM have significant positive experience with these types of arrangements with other societies, and are willing to share their experiences and the benefits of these arrangements with APS or specifically, with APS/GPC.

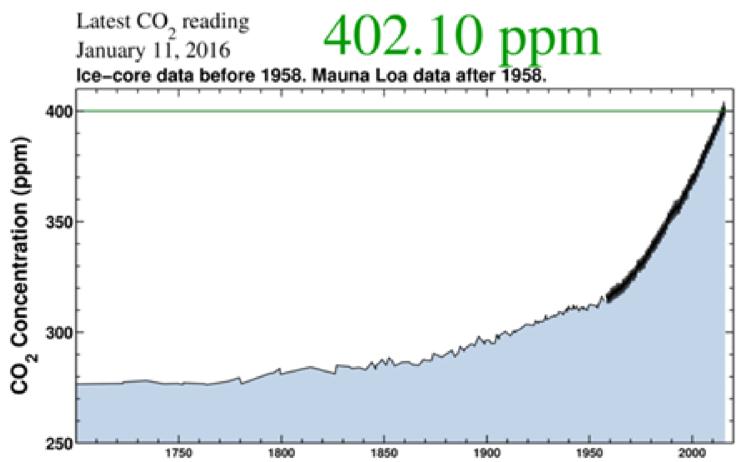
One objection raised within APS is that if GPC has this arrangement, what would keep other groups from enjoying that special arrangement? My answer is that ours should not be exceptional. Other groups should indeed be encouraged to pursue such arrangements. One can describe at length how exchanges among members, ideas, and points of view, adds value to our professional society membership.

I welcome comments and suggestions regarding this initiative.

Explaining Climate Change to the Public: A Personal View

Jonathan Allen, Physicist and RF Electronics Consultant





Most public discussions of climate change (CC) concentrate on weather station thermometer readings and images of melting glaciers. While these can illustrate the consequences of CC, this approach ignores the underlying mechanisms, and it leaves open the door to highlighting anecdotal examples to the contrary. As physicists, we would do much better by invoking our science to explain the mechanisms by which increasing concentrations of greenhouse gases must cause global temperatures to rise. This article offers some hints and suggestions that may improve one's presentation.

When speaking to a non-scientific audience, it may be necessary to start by describing how scientific theories develop, how they evolve, and how they may be challenged and corrected. The important point here is that the process must be based on evidence and rigorous logic and proceed by the accepted rules of science. We must especially avoid the fallacy of *argumentum ad consequentiam*, wherein one accepts or rejects an hypothesis based on whether one likes or dislikes the consequences of its being true.

Theory: In presenting science to a lay audience we also must strike a balance between oversimplifying, and scaring them away with heavy-duty math and terminology. I therefore begin with a simple demonstration of basic radiation theory. This also catches the audience's attention. I hold up a clear (unfrosted) incandescent lamp connected to a Variac and slowly raise the voltage. We see that rising filament temperature causes the light not only to brighten, but also to shift color from dull red to orange to white. Variacing down produces the opposite effect until there is no visible radiation. Yet even though the filament is too cool for incandescence, it still emits infrared heat radiation, similar to what one feels near a hot stove. These observations allow one to introduce the Stefan-Boltzmann Law (perhaps the only equation in the talk) which explains how radiation flux increases with temperature:

$$J^* = \varepsilon\sigma T^4$$

where J^* is the radiated flux, ε is the emissivity, σ is Boltzmann's constant (5.67×10^{-8} in SI units) and T is the absolute temperature. A consequence is that any surface emits some radiation, yet due to the fourth power of T, it rises and falls rapidly with temperature.

Again looking at the filament, the color change demonstrates the Planck relation wherein hotter bodies emit shorter wavelengths. Thus the sun at nearly 6000 K has its peak emission in the visible spectrum at about 0.5 micron, while the Earth, at about 300 K (1/20 the solar temperature) emits thermal radiation which peaks at about 10 microns (20 times the solar wavelength).

The Earth's thermal equilibrium results when the outgoing long wave thermal radiation balances incoming short wave solar radiation. Simple radiation theory, would give Earth an average temperature of -18°C, but this is about 33° cooler than it actually is. What accounts for the difference? It is the greenhouse effect wherein atmospheric gases such as CO_2

absorb and re-radiate the exiting long wave infrared radiation. At this point in the presentation, it would be wise to review the physics of the greenhouse effect. The greenhouse effect shifts the Earth's radiation balance to higher temperatures as gases such as CO_2 absorb and then re-radiate some of the infrared rays that would otherwise escape into space. The figure above, for example, shows the Earth's radiation balance, including the greenhouse effect. I recommend the APS Tutorial by David Hafemeister & Peter Schwartz [1]. A Google search for "Greenhouse Effect, images" will provide some excellent (and some not-so-good) figures.

Given the role of CO_2 in the GH effect, the next step is to show how the concentration of this gas has increased from 280 ppm since the start of the industrial revolution to 400 ppm today. Drawing again on Hafemeister's paper, it also helps to point out that the quantity of CO_2 released from fossil fuels since the industrial revolution began is about twice that added to the atmosphere (the other half has been absorbed in the oceans—also a problem). Furthermore, isotopic analysis of the extra CO_2 shows the distinct "fingerprint" of fossil fuel carbon. These points reinforce the argument that anthropogenic CO_2 accounts for the observed excess.

Consequences: Having laid the foundation, it is now appropriate to show the warming trend. The graph of global mean surface temperature by Hansen and Sato is clear and current [2]. There are also, however, positive feedback mechanisms which compound and exacerbate the warming one would observe from CO_2 alone. Water vapor is also a greenhouse gas. For each degree C rise in surface temperature caused by CO_2, the vapor pressure of water rises by about 0.7%, thus raising its atmospheric concentration, which then adds to the warming effect. This evaporates even more water, creating a positive feedback loop. Another positive feedback occurs when rising temperatures melt areas of ice and snow whose whiteness reflects incoming solar radiation. The now exposed ground and sea are dark so they absorb more sunlight, thereby causing even more warming, etc.

This is a good point at which to discuss the oft cited effects of global warming on ecology and human society. NASA and other organizations offer excellent lists.

Thermodynamics: One contribution which we physicists can offer is an explanation of atmospheric thermodynamics. Specifically, the atmosphere behaves as a heat engine, or an ensemble of engines, which exploit temperature differences to produce work. Just as a steam engine operates between the hot boiler and cool condenser to deliver work, the atmospheric engine depends on the temperature difference between the warm surface of the ground and oceans, compared to the cold upper atmosphere. Here, the work manifests itself as wind and weather. As the Carnot Equation indicates, raising the Earth's land and ocean surface temperatures versus the cooler upper atmosphere causes the engine to deliver more work in the form of intensified weather events such as wind and storms. Kerry Emanuel has written some excellent papers analyzing this effect for hurricanes [3]. Assisting this effect is that the vapor pressure of surface water also rises by about 0.7%/K, making more water vapor (including its latent heat) available for intensified storms. Note that non-technical people may need an explanation of what a heat engine or more specifically a steam engine is. A diagram may help.

Almost every week the TV news reports another record breaking storm, yet the news services present these as though each was an isolated instance of a wrathful weather god. While it is still difficult to attribute individual events to CC, the statistics of their increased frequency and intensity are clear. One can draw an analogy to epidemiology where a disease has a background level, but a sudden rise in its occurrence suggests a specific cause.

Questions: The audience will undoubtedly raise questions for which it pays to prepare replies. Here are a couple of examples:

1. *Hasn't climate changed in the past long before human industry?*

The answer here is that such changes have occurred on time scales of 10^4 to 10^5 years, not decades as in the present case. Furthermore, these ancient changes were not random but caused by the Milankovitch Cycle [4,5] which is astronomically based and periodic (with more than one frequency component). Furthermore, the currently observed temperature rise is not consistent with the Milankovitch cycle.

2. *What about the effect on the economy of moving to "green" energy?*

This is not strictly a scientific question, hence lies mainly outside the GPC purview, but does require a response. In comparing the relative costs of green energy versus fossil fuels, we have to include what economists call externalities. Thus it is not simply renewable vs. nonrenewable energy, but also the potential human and ecological costs of CC, including catastrophic weather events and loss of coastal lands with sea level rise.

[1] http://www.aps.org/units/fps/newsletters/200807/hafemeister.cfm
[2] http://www.columbia.edu/~jeh1/mailings/2016/20160926_BetterGraph.pdf
[3] Emanuel, K., "Hurricanes: Tempests in a Greenhouse," *Physics Today*, August, 2006.
[4] https://en.wikipedia.org/wiki/Milankovitch_cycles
[5] http://math.ucr.edu/home/baez/glacial/glacial.pdf

GPC Elections

The upcoming GPC election features openings for Vice Chair and Member-at-Large (two positions). The election is to be held in October and elected candidates would begin their terms in January 1, 2017. The GPC Nominating Committee (chaired by John Wettlaufer, and including also Mary Silber, Renate Wackerbauer, and Jack Whitehead) is in the process of seeking input on as diverse a range of candidates as possible. Prospective candidates are considered for their scientific standing and activity, their history of involvement with GPC and the APS, their perspective on the activities of the Group, and their likelihood of service to GPC if elected.

The position of the Vice Chair of GPC (currently held by Michael Mann) is a four-year commitment: after a year as vice chair the officer becomes in successive years the chair-elect (currently Brad Marston), chair (currently Juan Restrepo), and then past chair (currently John Wettlaufer) - each with distinct duties. The chair officers play a crucial role in providing leadership in organizing the scientific content of the March Meeting and other meetings and in representing climate physics within the American Physical Society.

The members-at-large (two positions, replacing Morgan O'Neill and Sharon Sessions) serve a three-year term; they constitute the fellowship committee, help select the invited symposia and invited talks for the March Meeting and provide advice on issues important to the GPC. Identifying excellent candidates who can provide a broad view of the diverse field that is climate physics is key to maintaining the vitality of GPC.

New Oxford Journal: Dynamics and Statistics of Climate

The Dynamics and Statistics of the Climate System (Oxford) is a new interdisciplinary journal, and will publish its first issue in mid-2017. Several GPC members are on the Advisory Board as well as on the Editorial Board of the Journal. Work that has been featured by contributing or invited authors at GPC-sponsored sessions at DMOP, DFD, GSNL and Annual March Meetings will find DSCS to be a perfect venue for their research.

The journal encourages the interaction between physicists, statisticians, mathematicians, computer scientists and earth scientists in the development of new models and methods applied to the analysis of the climate system.

The new journal seeks to:

- Provide a home for research which straddles the scope of a number of journals across disciplines, and which will be developed in a form and with sufficient background to be accessible to a wide range of climate scientists
- Make a significant contribution towards the understanding of the climate system at all levels
- Provide the base upon which quantitative climate research will continue to grow and develop.

The new journal will publish research on the mathematical, statistical, physical and computational aspects of the climate system, including, but not limited to:

(1) *Techniques:* Calibration, tuning and emulation, Computational modeling, Data assimilation, Deterministic and stochastic PDE techniques, Dynamical systems and bifurcation theory, Ensemble techniques, Model hierarchies, Multiple scales, Numerical algorithms, Risk and sensitivity analysis, decision support systems, Statistical mechanics, Stochastic parameterization, Theory and estimation of extreme events, Uncertainty quantification and prediction.

(2) *Applications:* Atmospheric sciences, Biogeochemistry, Climate variability, Ecosystem dynamics, Geoengineering, Geophysical fluid dynamics, Hydrology, Ice dynamics and structure, Oceanography, Paleoclimate, Resilience and tipping points, Severe impacts, Sustainability.

Upcoming Events and Other Links of Interest

1. The New Journal of Physics volume *Focus on Stochastic Flows and Climate Statistics* (Brad Marston and Paul Williams, editors) brings together original research articles from leading groups that advance our understanding of the physics of climate. The collection brings together articles on stochastic models, turbulence, quasi-linear approximations, climate statistics, statistical mechanics of atmospheres and oceans, jet formation, and reduced-form climate models. The hope is that the issue will encourage more physicists to think about the climate problem.
2. Model Hierarchies Workshop, Princeton NJ November 2-4, 2016
3. Pan Ocean Remote Sensing Conference, Fortaleza, Brazil, November 3-11, 2016.
4. 28th Conference on Severe Local Storms, Portland, OR, November 7-11, 2016.
5. School on Climate System Prediction and Regional Climate Information, Dakar, Senegal, November 21-25, 2016.
6. Climate Variability Across Scales (CVAS), Hamburg, Germany, November 28-30, 2016.
7. Summer School on Atmospheric Composition and Dynamics, Reunion Island, France, November 28-December 3, 2016.
8. Hans Sigrist Symposium 2016 - The Human Fingerprint on the Earth System, University of Bern, Switzerland, December 2, 2016.
9. AGU Fall meeting, Dec. 12-16, San Francisco, CA.
10. 97th American Meteorological Society Annual Meeting: 'Observations lead the way', Seattle, WA, January 22-26, 2017.
11. International Symposium on the Cryosphere in a Changing Climate, Victoria University of Wellington, New Zealand, February 13-18, 2017.
12. European Geosciences Union General Assembly 2017, Vienna, Austria, April 23-28, 2017.
13. PAGES 3rd Young Scientists Meeting (YSM), Morillo de Tou, Spain, May 7-9, 2017.
14. Climate, Oceans and Society Challenges & Opportunities, Busan, Korea, May 30-June 2, 2017.
15. AMS AOFD meeting, Portland, OR June 26-30, 2017.
16. MPIPKS Dresden meeting, "Climate Fluctuations and Non-equilibrium Statistical Mechanics: An Interdisciplinary Dialogue," Dresden, Germany, July 9-August 5, 2017.
17. Aspen Center for Physics "Vorticity in the Universe: From Superfluids to Weather and Climate, to the Universe," Aspen CO, August 27 to September 17, 2017 (organized by James Cho, Brad Marston, and Juan Restrepo).
18. Fourth International Conference on Earth System Modelling (4ICESM), Hamburg, Germany, August 28-September 1, 2017.
19. KITP Program on "Planetary Boundary Layers in Atmospheres, Oceans, and Ice on Earth and Moons", UC Santa Barbara, CA, April 2-June 22, 2018 (application deadline is Dec. 18, 2016).

Image Credits

P. 2: http://ceres.larc.nasa.gov/images/rad_bal.png

P. 2: http://4.bp.blogspot.com/-ojSd4on2SyU/VpZTxM1-azI/AAAAAAAAThI/LEe-h-T89ro/s1600/co2_800k_zoom.png