GPC Newsletter

Issue #11

February 2019

APS TOPICAL GROUP ON THE PHYSICS OF CLIMATE

IN THIS ISSUE

Message from the Editor

This is the eleventh 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.

Welcome from the GPC Chair

Chris E. Forest, Pennsylvania State University

Welcome to the Spring 2019 GPC Newsletter.

We are excited to start a new year and continue providing a venue for Climate Science in the APS. In this letter, we have a number of items of interest including a summary of the IPCC Special Report on 1.5°C Global Warming provided by Penn State graduate students from our Climate System Dynamics class last fall. As a reminder, GPC has its own Twitter account, which may be followed for announcements about our meeting sessions, newsletter, etc. Please follow us at @APS_GPC.

(Continued on p. 2)

APS Fellows Nominations

APS GPC Members may nominate colleagues to become APS Fellows through GPC. You are invited to nominate those who have made exceptional contributions to promoting the advancement and diffusion of knowledge concerning the physics, measurement, and modeling of climate processes, within the domain of natural science and outside the domains of societal impact and policy, legislation, and broader societal issues.

(Continued on p. 2)

ARTICLE: Direct visualization of climate forcing by CO_2

Philip Nelson, University of Pennsylvania

I want to introduce my students to ideas of overriding importance, regardless of whether I'm teaching a course on that topic or indeed whether my department offers such a course at all. One such idea is climate, and Earth System science more generally, so I created a short module, called it "planetary physiology," and inserted it into my Biophysics course.

(Continued on p. 2)

ARTICLE: Summary of the IPCC Special Report on 1.5°C Warming

Lauren Dennis, Da Fan, Dapeng Feng, Qinxue Gu, Dong Wan Kim, Paul Mykolajtchuk, Zhu Yao, Aara'L Yarber

The following summary of the recent IPCC Special Report on 1.5°C Warming was prepared by the above named students in the Fall 2018 course METEO 570: Climate System Dynamics, *instructed by GPC Chair Chris E. Forest*

The IPCC special report on global warming of 1.5°C above pre-industrial levels **[1]** was released mid-semester as we were taking a graduate-level Climate System Dynamics class at Penn State University, and we paused our normal course schedule to read and examine the report.

(Continued on p. 4)

Welcome from the GPC Chair

(Continued from p. 1)

We are very excited about the upcoming March APS Meeting in Boston this year. The meeting will feature two formal scientific sessions sponsored by the Topical Group on the Physics of Climate, both on Monday March 4. Beginning at 11:15 am, we have our Invited Session B62 on "Detecting Signals in a Noisy Climate System" which will be held in Room BCEC 258C. Our speakers are Bruce Wielicki, Nicola Maher, Christian Proistosescu, Chia-Ying Lee, and Stephanie Dutkiewicz and they will discuss different methods for identifying signals in many parts of the Earth system. At 2:30 pm, Peter Weichman will chair our Focus Session C23 "Climate Physics: Feedbacks in the Earth System" in Room BCEC 158 with our invited speaker, Ariel Morrison, discussing: "Arctic cloud and sea ice feedbacks from satellite observations and a global climate model" along with eight contributed talks. More details about the two scientific sessions can be found inside this Newsletter.

The GPC Business Meeting (Session J45) will be held at 5:45 pm on Tuesday in Room BCEC 21. All GPC members are invited to participate.

For the considerable efforts of my colleagues whose terms on the Executive Committee finished in 2018, we thank you for your service. To Brad Marston, our Chair of the Nominations Committee and the keeper of institutional knowledge base of all things APS, thank you for keeping us on track this past year. To our past Chair, Michael Mann, thank you for guiding the ship and keeping me on track. We also owe major a thank you to our outgoing Secretary/Treasurer Don Lucas for his exemplary service. We all thank Peter Weichman for his substantial contribution as the Newsletter Editor.

Also, this year, we welcomed Maria Rugenstein of MPI, Mark Zelinka of LLNL, and Norman Loeb of NASA as new members of our Program Committee, and we welcome our new Executive Committee members: Vice Chair: Mary Silber, Secretary/Treasurer: Raymond Shaw, Members-At-Large: Katie Dagon and Daniel Rothman, and Student Member-At-Large: Adria Schwarber. I look forward to working with all of you this year and beyond.

For those at the March Meeting, you are invited to the GPC Climate Café to take place on Monday evening following the GPC sessions. This is an informal meeting where, over drinks and food, you can meet the March Meeting GPC speakers, as well as fellow GPC and other APS members. We'll discuss climate science, network, and chat with the Executive Committee members about GPC concerns. In keeping with the informal nature of the cafe, we will announce the venue for this year's Climate Cafe at the Monday sessions. All APS members are welcome to attend.

We look forward to seeing you in Boston!

APS Fellows Nominations

(Continued from p. 1)

Selection as an APS Fellow by one's professional peers is a great honor. The number of Fellows elected annually cannot exceed 0.5% of Society membership.

Any current APS member can initiate a nomination. The membership of APS is diverse and global, and the Fellows of APS should reflect that diversity. Fellowship nominations of women, members of underrepresented minority groups, and scientists from outside the United States are especially encouraged.

For information on how to nominate, and a list of current Fellows, please see the APS Fellows webpage.

The deadline for submitting fellowship nominations for review by the GPC Fellowship Committee is June 3, 2019. For further information regarding fellowship nominations, please email fellowship@aps.org

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ARTICLE: Direct visualization of climate forcing by CO_2

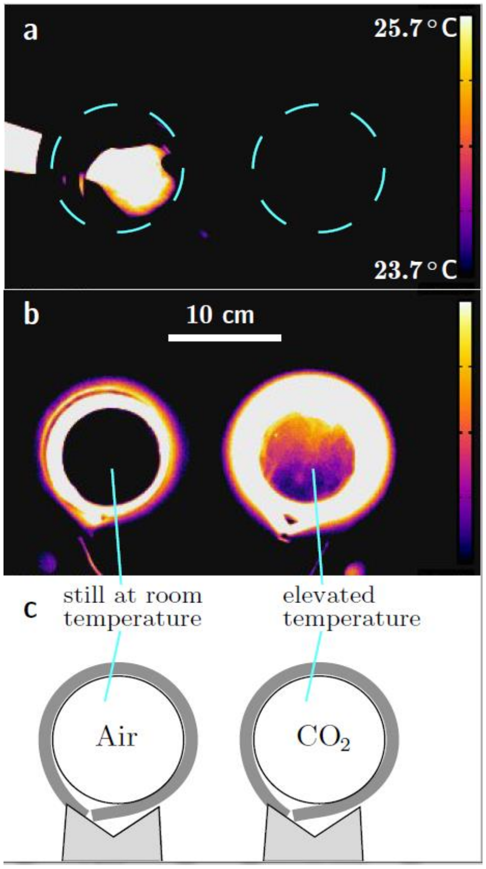
(Continued from p. 1)

Then I called it "dipole interactions," and inserted it into my graduate Electrodynamics course, and so on. Eventually I realized that it was suitable for high school students as well. All of those audiences have been told repeatedly that atmospheric carbon dioxide is *bad*. And yet, this seems to them to be an abstract statement, and as such, open to dispute. The whole idea that air of any sort can absorb light of any sort seems contradicted by experience, so students relegate it to the long list of catechisms they repeat without conviction. For this reason, I wanted a direct demonstration of the infrared absorption of carbon dioxide. Many demonstrations can be found online, but most involve a physical thermometer, whose thermal mass is much greater than that of a manageable gas sample. The required irradiation times are long, and the direct connection to incoming radiation is therefore unobvious. Other demonstrations involve exotic apparatus, for example, a tunable laser.

Instead I proceeded as follows. Two cylindrical steel chambers (coffee cans) were prepared with both ends removed and replaced by thin windows (food wrap). One chamber was filled with dry air; the other with carbon dioxide. The first panel of the figure shows the chambers viewed end-on by an IR camera. The steel and the interior are invisible, because they are at the same temperature as the backdrop. Both cans seem transparent to IR (see the human hand clearly visible behind one of them), because the camera's sensitivity range excludes the main absorption band of CO_2. So students are surprised when I irradiate the cans briefly with identical broadband IR sources, switch the sources off, and observe a clearly visible temperature difference (second figure panel) that persists for up to a minute. In fact, it is easy to compute that just a few centimeters of CO_2 at room pressure absorbs essentially all incoming radiation in the main IR absorption bands. There is no comparable absorption in dry air. This demonstration can be done in just a few classroom minutes (see https://youtu.be/oel9zxZoipA and Philip G. Sieg et al., *The Physics Teacher* 2019 in press).

Of course, the pure CO_2 in the sample chamber is a far cry from the tiny concentration in Earth's atmosphere, but having seen this difference, students can grasp that a small concentration over a column depth of many kilometers can have a significant forcing effect. Also, the orange-hot IR source used in the demonstration peaks at wavelength around 3 µm, and hence mainly excites the absorption bands near 4.3 µm; Earth's emission instead mainly excites the bands near 15 µm. The main point, however, is that everything was identical between the two samples apart from something that *looked* identical but instead made a profound difference.

Now that I have shown them something real, I can talk to high school students about the historic rise of atmospheric CO_2 and its connection to known rates of fossil fuel consumption; to undergraduates about positive feedbacks in the climate system; to Ph.D. students about the difference between homonuclear diatomic molecules like O_2 and N_2 versus CO_2 and CH_4; and so on. Students may wish to study such topics further as research projects, possibly even leading to career choice.



Simple CO2 absorption demonstration.

GPC 2019 Executive

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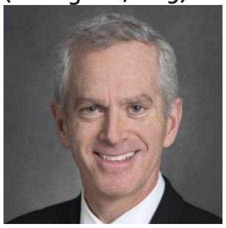

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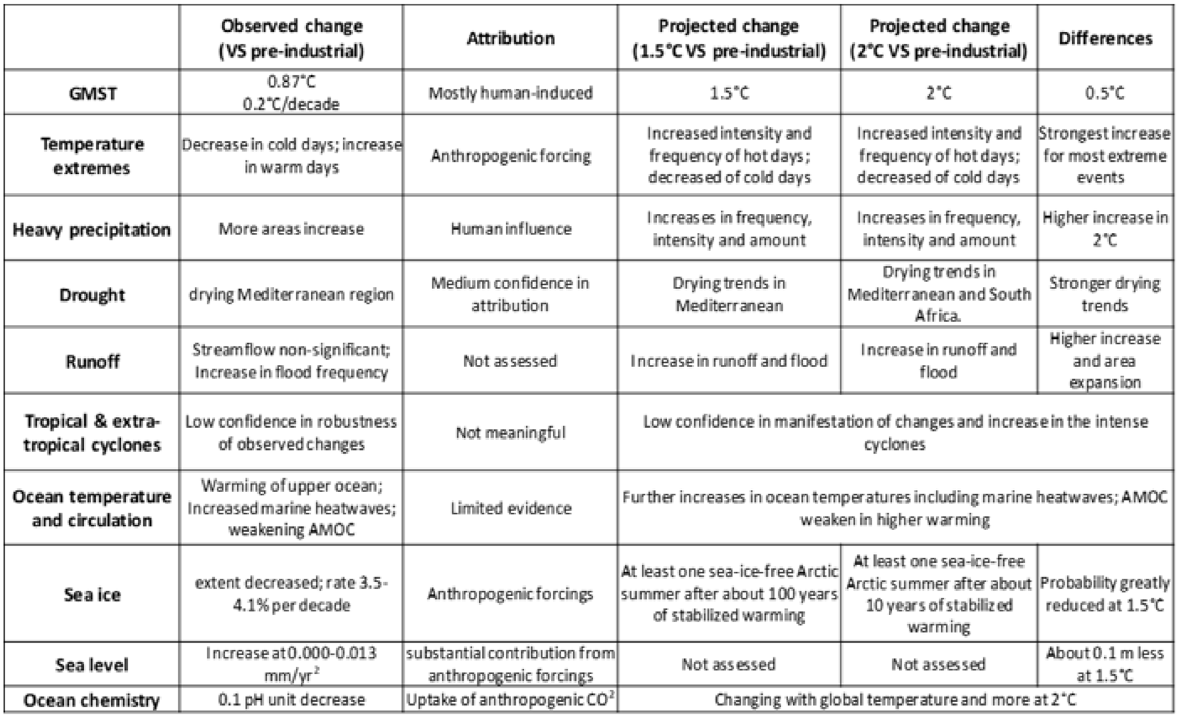
ARTICLE: Summary of the IPCC Special Report on 1.5°C Warming

(Continued from p. 1)

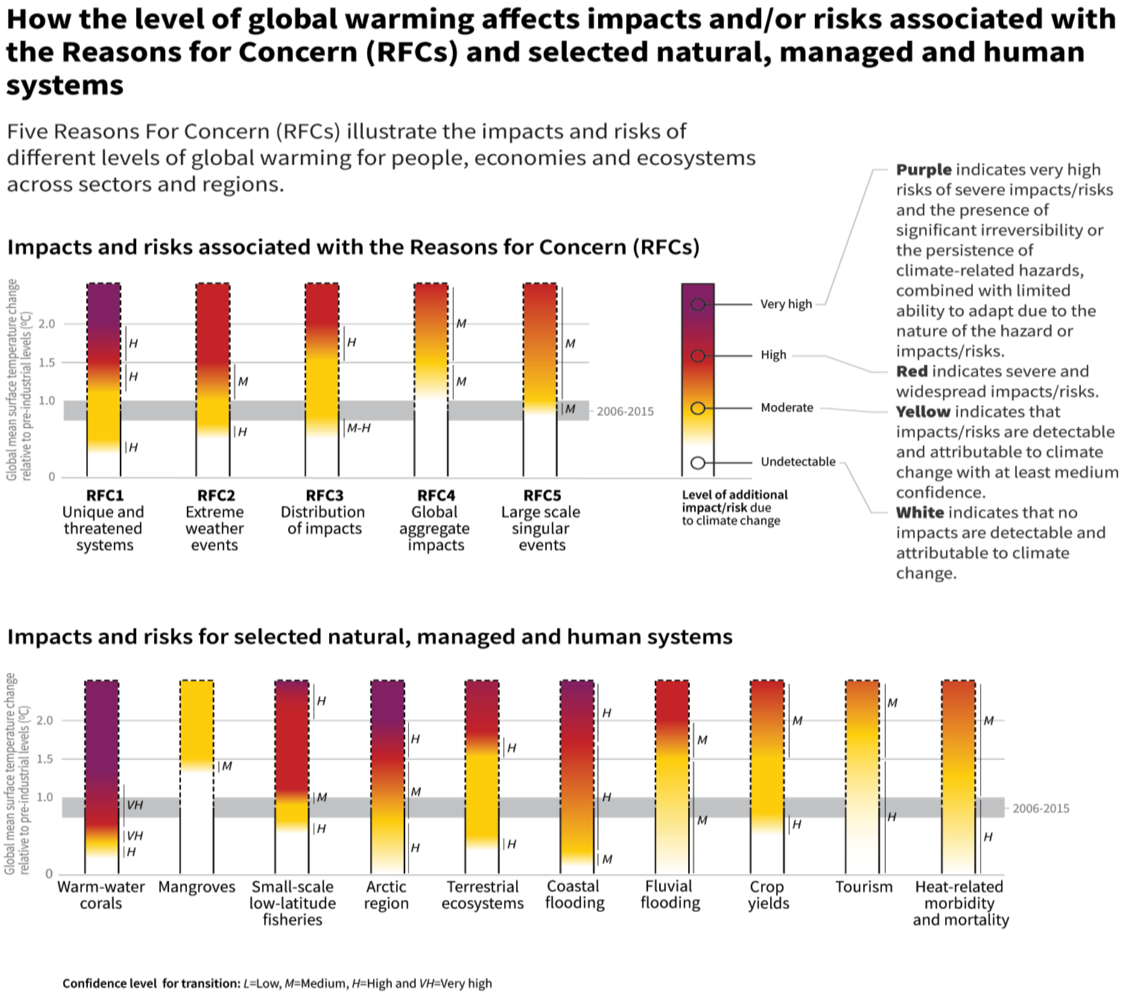
Below you will find our summary reflecting what we found most important within the chapters that we read. The report finds that many different pathways exist to reach either 1.5°C or 2°C warming, but that each pathway requires rapid and collective action, and in many cases, carbon capture technology as the accumulated CO_2 levels cause the temperature to overshoot our original goal and we need to remove carbon from the atmosphere to reach zero net emissions. We found that many tradeoffs and synergies exist within each of the pathways, but the Sustainable Development Goals introduced by the UN provide good guidance in considering ethical and equity concerns.

The IPCC special report outlines what global warming at 1.5°C or 2°C may look like for the globe, and pathways that the global community could take to limit an increase in average global temperature to 1.5°C or 2°C. A global warming of 1.5°C implies warmer mean temperatures compared to pre-industrial times in almost all locations on both land and ocean. Because of differential heating between land and sea, the mean increase in temperatures over land will be greater than 1.5°C in



	Observed change (VS pre-industrial)	Attribution	Projected change (1.5°C VS pre-industrial)	Projected change (2°C VS pre-industrial)	Differences
GMST	0.87°C 0.2°C/decade	Mostly human-induced	1.5°C	2°C	0.5°C
Temperature extremes	Decrease in cold days; increase in warm days	Anthropogenic forcing	Increased intensity and frequency of hot days; decreased of cold days	Increased intensity and frequency of hot days; decreased of cold days	Strongest increase for most extreme events
Heavy precipitation	More areas increase	Human influence	Increases in frequency, intensity and amount	Increases in frequency, intensity and amount	Higher increase in 2°C
Drought	drying Mediterranean region	Medium confidence in attribution	Drying trends in Mediterranean	Drying trends in Mediterranean and South Africa.	Stronger drying trends
Runoff	Streamflow non-significant; Increase in flood frequency	Not assessed	Increase in runoff and flood	Increase in runoff and flood	Higher increase and area expansion
Tropical & extra-tropical cyclones	Low confidence in robustness of observed changes	Not meaningful	Low confidence in manifestation of changes and increase in the intense cyclones		
Ocean temperature and circulation	Warming of upper ocean; Increased marine heatwaves; weakening AMOC	Limited evidence	Further increases in ocean temperatures including marine heatwaves; AMOC weaken in higher warming		
Sea ice	extent decreased; rate 3.5-4.1% per decade	Anthropogenic forcings	At least one sea-ice-free Arctic summer after about 100 years of stabilized warming	At least one sea-ice-free Arctic summer after about 10 years of stabilized warming	Probability greatly reduced at 1.5°C
Sea level	Increase at 0.000-0.013 mm/yr^2	substantial contribution from anthropogenic forcings	Not assessed	Not assessed	About 0.1 m less at 1.5°C
Ocean chemistry	0.1 pH unit decrease	Uptake of anthropogenic CO^2	Changing with global temperature and more at 2°C		

Table 3.2 from Chapter 3 of [1]



How the level of global warming affects impacts and/or risks associated with the Reasons for Concern (RFCs) and selected natural, managed and human systems

Five Reasons For Concern (RFCs) illustrate the impacts and risks of different levels of global warming for people, economies and ecosystems across sectors and regions.

Impacts and risks associated with the Reasons for Concern (RFCs)

Purple indicates very high risks of severe impacts/risks and the presence of significant irreversibility or the persistence of climate-related hazards, combined with limited ability to adapt due to the nature of the hazard or impacts/risks.
Red indicates severe and widespread impacts/risks.
Yellow indicates that impacts/risks are detectable and attributable to climate change with at least medium confidence.
White indicates that no impacts are detectable and attributable to climate change.

Impacts and risks for selected natural, managed and human systems

Confidence level for transition: *L*=Low, *M*=Medium, *H*=High and *VH*=Very high

Figure SPM2 from [1]

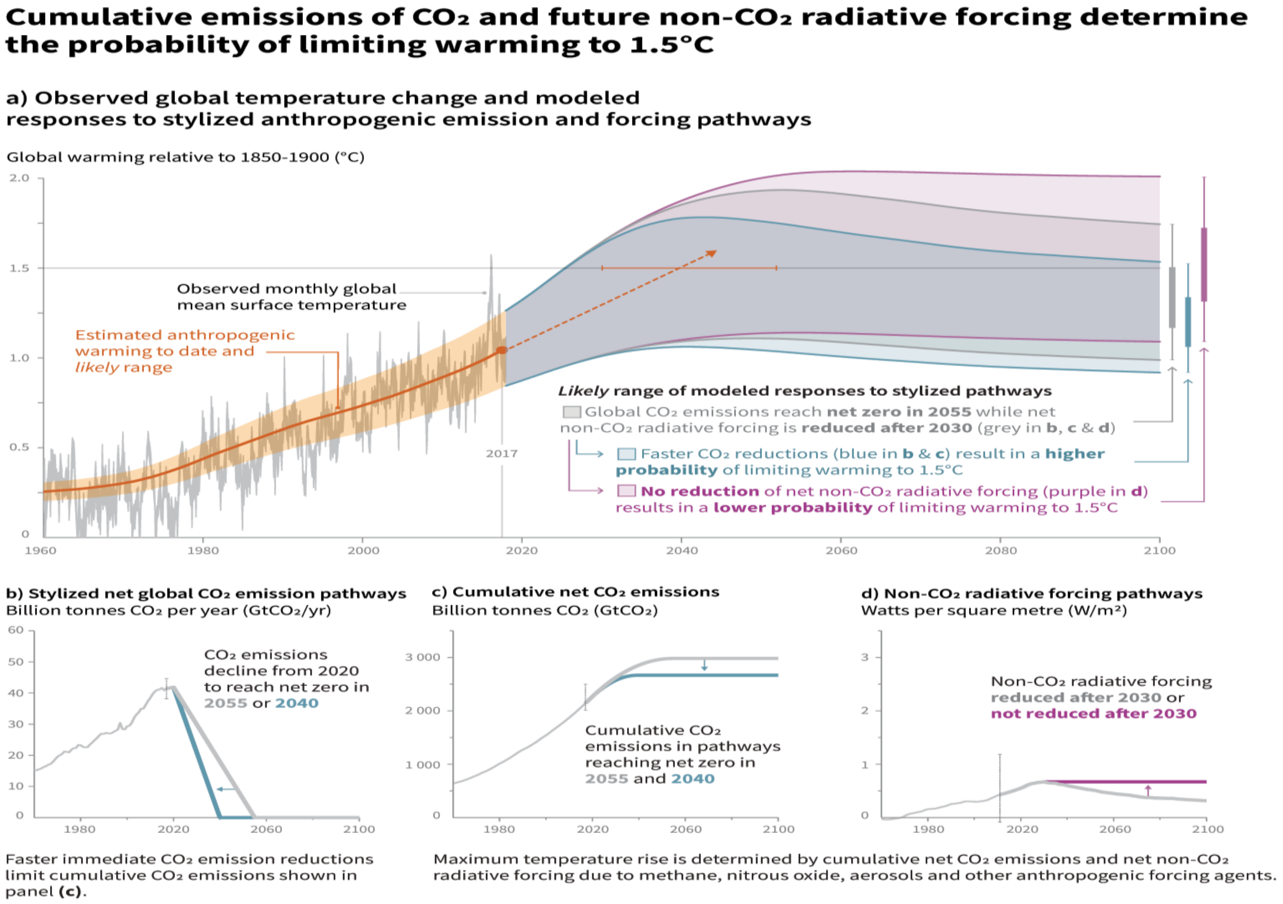
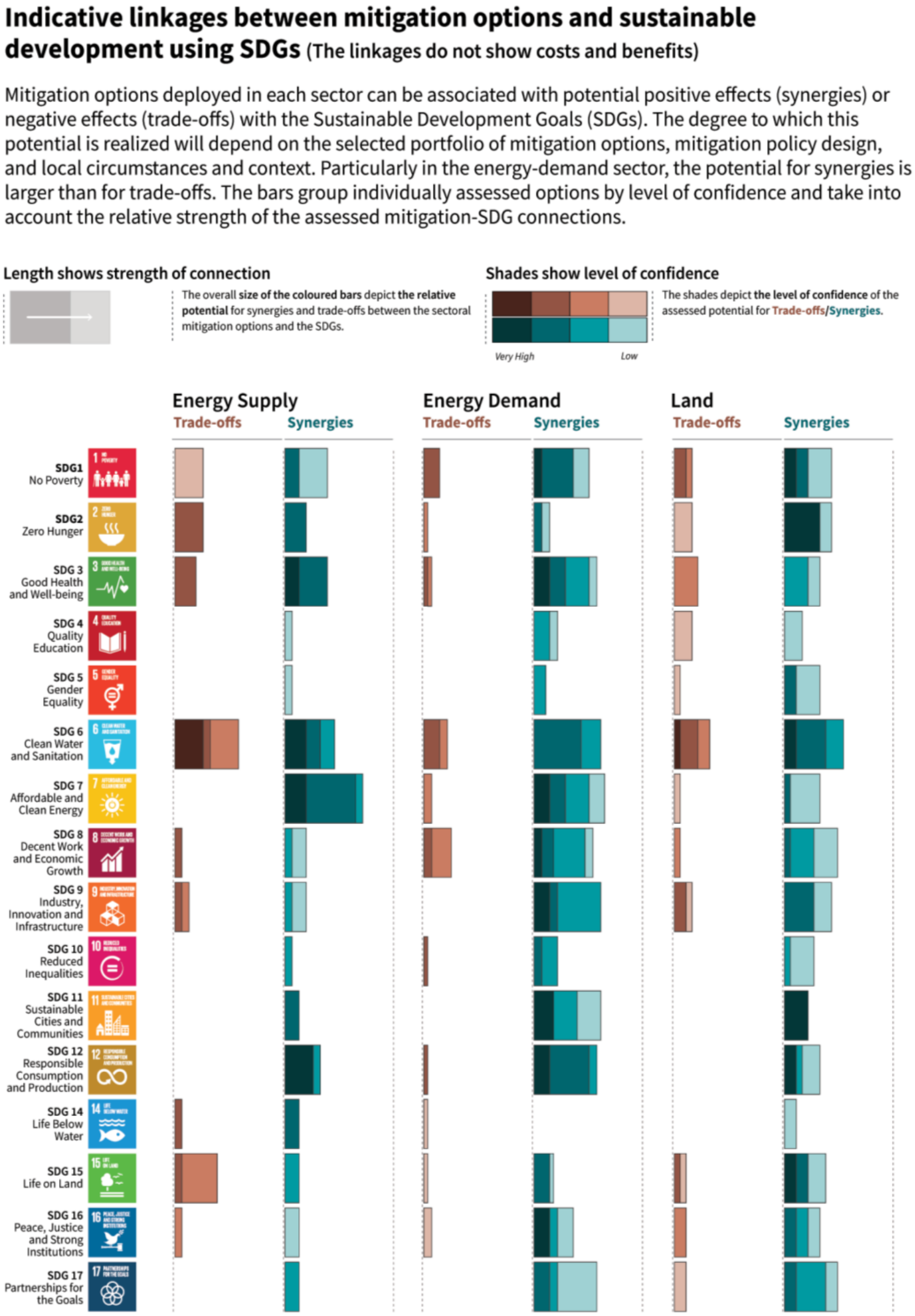


Figure SPM1 from [1]

most regions. The greatest such increase occurs in the northern high latitudes. Projections of 2°C warming show significant increases in mean precipitation in the Northern Hemisphere high latitudes compared to 1.5°C warming, although projections of precipitation are more uncertain than those of temperature. While distinct patterns of changes in extreme temperatures exist in many places, the greatest intensification of the hottest days of the year occur in mid-latitude land and the greatest intensification of the coldest days occur in high latitudes (both over land and oceans). Differences at 1.5°C versus 2°C warming are significant across the globe. Changes in heavy precipitation are less robust at the grid-cell scale but display increases over most land areas. Projections are consistent with temperature and precipitation trends that have been observed in the past as well as some observed changes for the global warming of 0.5°C. The attribution studies show anthropogenic forcing dominating as the primary cause for most changes. The associated hazards are summarized in the table and highlighted in the figure on the previous page (corresponding to **Table 3.2** and **Figure SPM2** in the report). Three main conclusions can be drawn from the table: (1) The projections are consistent with observed trend and changes; (2) Most changes can be attributed to anthropogenic activity with high confidence; (3) More significant impacts can be projected at 2°C compared with 1.5°C, such as more intensive and higher frequency extreme events, stronger trends, and larger change amounts (especially for sea ice and sea level).

The pathways to limit warming to the targets outlined in the report are framed in the context of limiting expense, achieving sustainable development goals, and considering ethical and equity concerns. These pathways all share rapid and profound near-term decarbonization of energy supply, greater mitigation efforts on the demand side, switching from fossil fuels to electricity in end-use sectors, reductions of comprehensive emissions in the coming decade including non-CO_2 emissions sources required for 2°C, considerable shifts in investment patterns, and Carbon Dioxide Removal (CDR) at scale before mid-century. While there are many pathways which consider different feasible technologies and socio-economic assumptions, most emissions pathways include a temperature overshoot of the goal before peaking and reducing temperatures before 2100 (**Figure SPM1** in the report, reproduced above). Most 1.5°C scenarios have a



Indicative linkages between mitigation options and sustainable development using SDGs (The linkages do not show costs and benefits)

Mitigation options deployed in each sector can be associated with potential positive effects (synergies) or negative effects (trade-offs) with the Sustainable Development Goals (SDGs). The degree to which this potential is realized will depend on the selected portfolio of mitigation options, mitigation policy design, and local circumstances and context. Particularly in the energy-demand sector, the potential for synergies is larger than for trade-offs. The bars group individually assessed options by level of confidence and take into account the relative strength of the assessed mitigation-SDG connections.

Figure SPM4 from [1]

peak in temperature in mid-century, while most of the 2°C scenarios peak after mid-century. Probabilities of overshooting goals are imprecise, but there is evidence that the probability of overshooting temperature targets is greater than 50% in all but the most stringent of pathways. All emissions scenarios outlined require zero net emissions in the future, and if we were to continue to limit emissions following the Nationally Determined Contributions (NDCs), we would need to reach net zero emissions in 0-8 years. In fact, most pathways show more stringent emissions reductions than NDCs. In the effort to reduce fossil fuel emissions, the pathways in the report explore lowering energy demand, electrifying energy services, decarbonizing the power sector, and decarbonizing non-electric fuel use in energy and end-use sectors.

Mitigation technologies included in most pathways rely greatly on afforestation and bioenergy with carbon capture and storage. Nearly all pathways include the latter, and avoiding an overshoot of the temperature goals will require carbon dioxide removal (CDR). CDR could be used in two ways: to achieve carbon neutrality very rapidly, or to create net negative emissions later and allow for a temperature overshoot. According to the report, technologies related to renewable energy, such as solar or wind energy, have been developed and deployed at scale while CO_2 capture technology has not yet. The latter may include building more natural CO_2 sinks or artificial removing from the air. Such efforts will help to reach the 1.5°C limitation on the increase in global average temperature, but financial limitations exist as well. The report also highlights the importance of removing "Short-Lived Climate Forcers" (SLCFs). Methane and black carbons are examples of SLCFs and removing these chemicals may contribute in a short term scale, while CO_2 mitigation would remain as the long term contribution.

Another mitigation strategy is land use and ecosystem change. Land use is intricately linked to agriculture. Improving the efficiency of food and crop production and altering dietary choices can impact the land use, food security and agricultural emission levels. In particular, emissions by livestock account for a large portion of greenhouse gas emitted from the food sector. Therefore, adjusting practices within the livestock industry coupled with a possible reduction in size as well as a greater integration of crops will guide toward a more sustainable agriculture system. However, these approaches are sensitive to the economy, geographical location, and political system of each country. Besides altering our own land use, preserving ecosystems is another important component of greenhouse gas mitigation. This method, in fact, is closely related to carbon capturing technology mentioned in previous paragraph. Increasing the size of biomass, which can sequester CO_2 can serve as a natural carbon sink.

In order for many of these technologies and efforts to be successfully implemented, particular societal choices must be made. The report explores assumptions about policy cooperation including immediate and cross-sectorial global cooperation, a phase-in of globally coordinated mitigation policy, and short-term oriented and regionally diverse global mitigation policy following NDCs until 2030. The report highlights the importance of the interaction between different governmental systems for mitigation and reaching the 1.5°C limitation. Mitigation and adaptation techniques can complement and enhance each other when different organizations work closely together, from national to local government, urban to rural, and private to public sectors. Both tradeoffs and synergies exist within many of these pathways and depend heavily on societal choices. There are tradeoffs between near-term ambition and transitional challenges, between the degree of overshoot and the use of CDR technology, and of course ethical and equity concerns.

In an effort to incorporate some of these ethical and equity concerns into pathways, the report incorporates Sustainable Development Goals (SDGs) into its analysis, which are 17 ambitious goals introduced in the United Nations (UN) 2030 Agenda for sustainable development for all countries by 2030 which "meets the needs of the present and future generations" (**Figure SPM4** from the report, reproduced on the previous page). These SDGs incorporate different dimensions of sustainability such as air pollution and health, food security and hunger, lack of energy access, and water security. An example of potential synergies exist within air pollution and health: mitigation strategies that reduce greenhouse gas emissions or the use of fossil fuels often also reduce air pollution because greenhouse gases and pollutants often come from the same sources. Other dimensions such as food security and hunger and carbon capture require tradeoffs: for example, land used for afforestation may compete with land used for food production, which could cause food security concerns. In order to address this tradeoff, the mitigation policies need to be designed in a way that protects the population at risk of hunger, like supporting food prices and improving productivity of agricultural production systems. Many developing countries lack access to clean and affordable energy, and some mitigation strategies could have disproportionately negative impacts on particular efforts in developing countries such as slowing down the transition to clean cooking fuels. In order to create an equitable situation, subsidies for cleaner fuels would be required to compensate the negative impact. Another tradeoff is between alternative fuels and water supply. Some low-carbon options like bioenergy and nuclear may increase the water demand in some regions. Therefore it is important to employ an integrated approach when developing water, energy and climate policy. In general, global warming of 1.5°C will result in greater inequality and have greater negative consequences for those living in poverty compared to current conditions. Compared to 2°C, the overall projected socio-economic losses compared to present day are less at 1.5°C, which indicates that it's much easier to achieve the SDGs for poverty eradication and reducing inequalities at 1.5°C warming. Achieving warming limited to 1.5°C, however, requires great collective action.

[1] IPCC, 2018: Summary for Policymakers (6 October 2018). In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.). World Meteorological Organization, Geneva, Switzerland, 32 pp.

GPC Executive Committee Members-at-Large, Assigned Council Representative, and Newsletter Editor:

Left to right: Douglas Kurtze (12/2019), Sharon Sessions (12/2019), Barbara Levi (12/2020), Isabel McCoy (12/20), Katie Dagon (12/21), Daniel Rothman (12/21), Student Member Adria Schwarber (12/19), Assigned Council Representative (DFD) Howard A. Stone, Peter Weichman (Newsletter Editor, 12/2020).

MARCH MEETING 2019
BOSTON, MA MARCH 4-8

GPC Climate Café

(7:30-10:00 pm, Monday March 4)

You are cordially invited to the GPC Climate Café!

The Climate Cafe will take place 7:30-10:00 pm Monday evening, where, over drinks and food, you can meet the March Meeting GPC speakers, as well as fellow GPC and other APS members. We'll discuss climate science, network, and chat with the Executive Committee members about GPC concerns. In keeping with its informal nature, we will announce the venue for the event at the Monday sessions. You are also invited to the **GPC business meeting (Session J45, 5:45-6:45 pm, Tuesday March 5, BCEC 211).**

All APS members are welcome to attend both!

GPC Invited Session: Detecting Signals in a Noisy Climate System

(Session B62, 11:15 am – 2:15 pm, Monday, March 4, Rm. BCAC 258C)

BRUCE WIELICKI
NASA Langley Research Center

Title: Insights regarding observational requirements for signal detection

Synopsis: Climate change signals must be detected against both the noise of internal natural variability as well as a wide range of uncertainties in the observing system.

Observing system uncertainties include SI traceable accuracy, instrument stability over a decade or longer, calibration across data gaps, changing instrument designs, changing sampling of the earth, and changing data analysis methods. Most current observations used for climate change signals were not designed with climate change uncertainties in mind (National Academy of Sciences Continuity Report for NASA, Nov. 2015). Examples are given of how to set requirements for climate change observations relative to anticipated climate change signals and climate system natural variability.

Given that we currently lack an observing system designed specifically for climate change, what would such a system look like? Design principles are provided, and examples are given of how more accurate observations can narrow key scientific uncertainties in climate change. Examples will also be presented of observations that can meet these much more challenging climate change requirements.

The lack of a designed climate observing system naturally raises the question of the societal return on investment of providing such a system. Recent published estimates using state of the art economic integrated assessment models (IAMs) suggest a return of ~ $50 per $1 invested. Society will be managing the Earth's Climate System actively or passively, wisely or unwisely, for the indefinite future. The world has had an internationally designed, committed, and shared weather observing system for many decades.

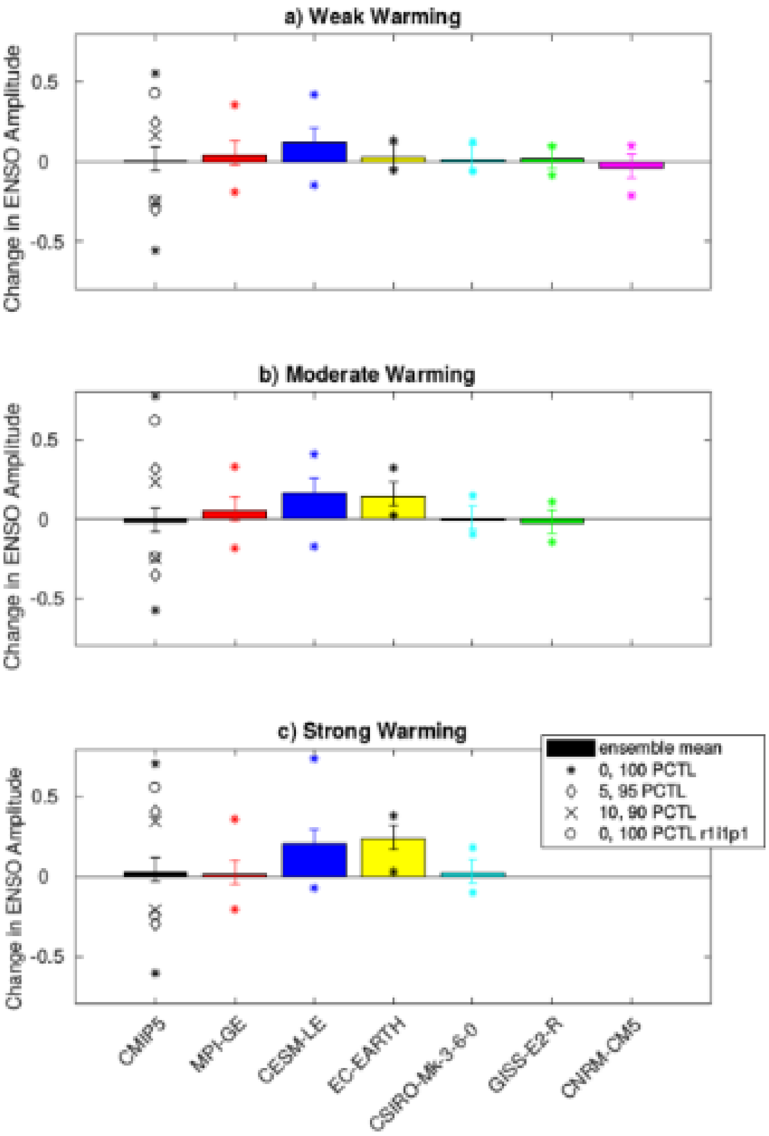
It is time to begin an equivalent international climate change observing system. The motivation for such systems are the same: a better future for society.

NICOLA MAHER
Max Planck Institute for Meteorology

Title: Detecting signals in the ocean circulations

Synopsis: The El Niño-Southern Oscillation (ENSO) is the dominant driver of interannual variability globally and has effects which are felt in many remote regions of the world. As such it is vital to assess the potential future changes of ENSO. However, there is little consensus on how ENSO sea surface temperature (SST) may change in a future with increasing greenhouse gas emissions and underlying warming (Bellenger et al., 2014; Collins et al., 2010; Guilyardi et al., 2012; Ham & Kug, 2016), with large differences found between different Coupled Model Intercomparison Project 5 (CMIP5) model projections (Collins et al., 2010; Guilyardi et al., 2012).

The range of projections of ENSO in the future could be due to differences in model physics, resulting in different projections from different models. However, the role of internal variability must also be considered, which occurs due to the chaotic



ENSO amplitude changes under three different scenarios. Ensemble mean (solid bars), 0th and 100th percentile (stars), 5th and 95th percentile (diamonds), 10th and 90th percentiles (crosses) of the change in Niño3 amplitude (standard deviation of sea surface temperature in the Niño3 region) compared to the preindustrial control amplitude. Shown for CMIP5 models (all ensemble members; black, 0th and 100th percentile for r1i1p1; black circles), MPI-GE (red), CESM-LE (blue), EC-EARTH (yellow), CSIRO-Mk-3-6-0 (pale blue), GISS-E2-R (green), and CNRM-CM5 (pink). Shown for (a) Historical (1975–2005), (b) RCP4.5 scenario (2050–2080), and (c) RCP8.5 scenario (2050–2080). The preindustrial control amplitude is estimated by taking the average standard deviation from the last eight independent 30-year periods of each model's control run and averaging these. We choose eight periods to correspond with the shortest preindustrial control simulation from CMIP5. The error bars show the variability in the preindustrial control. This variability on the mean estimate is found by using the 2000-year control run from the MPI-GE and estimating the possible changes in the mean estimate due to the control simulations being not long enough to capture the variability of ENSO. The error is the difference between using eight periods versus the whole control simulation (60 periods).

nature of the climate system. Such internal variations can result in different projections from single ensemble members of the same climate model. A large ensemble of a single model can be used to estimate changes in variability in this model, uncertainties due to future forcing, and together with other model ensembles can be used to address uncertainties in model physics.

Two large ensembles are used to quantify the extent to which internal variability can contribute to long-term changes in ENSO characteristics. We diagnose changes that are externally forced and distinguish between multi-model simulation results that differ by chance and those that differ due to different model physics. The range of simulated ENSO amplitude changes in the large ensemble historical simulations encompasses 90% of the Coupled Model Intercomparison Project 5 historical simulations and 80% of moderate (RCP4.5) and strong (RCP8.5) warming scenarios.

When considering projected ENSO pattern changes, model differences are also important. We find that ENSO has high internal variability and that single realizations of a model can produce very different results to the ensemble mean response. Due to this variability, 30-40 ensemble members of a single model are needed to robustly compute absolute ENSO variance to a 10% error when 30-year analysis periods are used.

CHRISTIAN PROISTOSESCU
Joint Institute for the Study of the Atmosphere and Ocean
University of Washington

Title: From months to Milankovitch: how time-scale dependent interactions in the coupled Earth system determine the spectrum of climate variability and response

Synopsis: Acting as both signal and noise, stochastic internal variability dominates the observational record of Earth's energy budget. While variability confounds estimates of anthropogenic climate change, it can also be leveraged for insight into the underlying physics, provided one understands both the governing stochastic processes, and the ways in which they are encoded in the statistics of observable quantities.

I will show how the frequency spectrum of Earth's temperature variability is determined by, and informs on, the climate system's radiative damping efficiency. This damping efficiency determines how much radiation the system sheds to space for a given change in surface temperature, and it is set by how the different components of the climate system – atmosphere, ocean, cryosphere, and the carbon cycle, interact across a range of timescales. The theoretical model for a timescale-dependent radiative damping efficiency is constrained by a combination of observations of broad-band variability drawn from both instrumental records as well as proxies of past climate change.

CHIA-YING LEE
Earth Institute
Columbia University

Title: The climate change signal in hurricanes: Today and in the near future

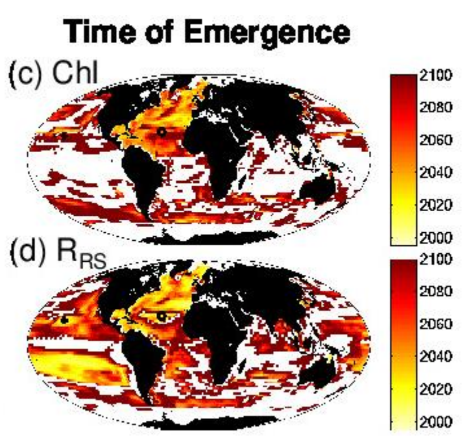
Synopsis: In this presentation I will discuss results from our ongoing research on detecting climate change signals in the recent history of hurricane activity. A question that is frequently asked during or after an extreme hurricane season like 2017 is whether such events are becoming more frequent, or are simply statistical flukes. Such questions are hard to answer using observational data alone, as the length of the high-quality hurricane record is too short. Therefore, we study this question using a combination of observations, statistical-dynamical downscale modeling, and high-resolution global dynamical model approaches. Simulations driven by data reanalysis will be used to estimate historical trends. Those driven by outputs from global climate models as well as those directly output from high-resolution global models are used to estimate the roles of radiative forcing, natural variability, and their combination. I will show comparisons of various climatological measures of TC activity from observations and model-based estimates for the current, pre-industrial, and near future periods. In addition to our work, I will also discuss other recent studies on detecting climate change signals in hurricane activity.

STEPHANIE DUTKIEWICZ
Earth, Atmospheric and Planetary Sciences
MIT

Title: Detecting signals in phytoplankton changes during recent past

Synopsis: Monitoring changes in marine phytoplankton is important as the latter forms the foundation of the marine food web and is crucial in the carbon cycle. Climate change is affecting marine phytoplankton by altering their nutrient, temperature, light and chemical environments. Often Chlorophyll-a (Chl-a) is used to track changes in phytoplankton, since there are global, regular satellite-derived estimates, and such studies suggesting complex, but as yet limited, patterns of long-term change over the last two decades. However, satellite sensors do not measure Chl-a directly. Instead, Chl-a is estimated from remote sensing reflectance (RRS): the ratio of upwelling radiance to the downwelling irradiance at the ocean's surface.

We use a unique ocean physics, biogeochemistry and ecosystem model that explicitly includes a representation of the ocean's optical properties to explore how climate change signals are manifested in Chl-a, phytoplankton communities, and ocean color over the course of the 21st century.



Time of emergence of climate change driven trend of altering marine ecosystem. Top panel: Chl-a (a proxy for phytoplankton biomass). Bottom panel: Remotely sensed reflectance (the ratio of the upwelling radiance to the downwelling irradiance) in the blue-green range. Only regions with statistically significant ($p < 0.05$) trends over the 21st Century are shown.

We show that RRS in the blue-green spectrum is likely to have a stronger and earlier climate change-driven signal than Chl-a. This is because RRS integrates not only changes to Chl-a, but also alterations in other optically important constituents.

Phytoplankton community structure, which strongly affects ocean optics, is likely to show one of the clearest and most rapid signatures of changes to the base of the marine ecosystem.

GPC Focus Session: Climate Physics: Feedbacks in the Earth System

(Session C23, 2:30 – 4:42 pm, Monday, March 6, Room BCEC 158)

Invited talk:

ARIEL MORRISON
Atmospheric and Oceanic Sciences
University of Colorado, Boulder

Title: Cloud and sea ice feedbacks and their interactions

Synopsis: Over the next century, the Arctic Ocean is projected to become seasonally sea ice-free. Assessing feedbacks between clouds and sea ice as the Arctic loses sea ice cover is important because of clouds' radiative impacts on the Arctic surface. Here, present and future Arctic cloud-sea ice relationships are assessed using spaceborne lidar observations and a fully-coupled global climate model that incorporates a lidar simulator. Using a novel surface mask that restricts the analysis to where sea ice concentration varies, we isolate the influence of sea ice cover on Arctic Ocean clouds during summer and fall. Summer cloud structure and fraction are nearly identical over sea ice and over open water, but more clouds are observed over open water than over sea ice in the fall. With future sea ice loss, modeled summer cloud fraction, vertical structure, and optical depth barely change, while the boundary layer deepens and clouds become more opaque over open water during fall. There is little evidence for a summer cloud-sea ice feedback but strong evidence for a positive cloud-sea ice feedback that emerges during non-summer months as the Arctic warms and sea ice disappears.

Contributed talks:

Thao N. Nguyen, Ivan A. Sudakov	Spatiotemporal Dynamics of Lake Patterns in a Changing Arctic Tundra Landscape
Juan Restrepo, Andrew Jensen, Robert Miller	Homotopy Importance Sampler For Noisy Dynamics
Emmanuel Sarpong, Damon Smith, Solomon Bililign	Application of the Rayleigh-Debye-Gans (RDG)theory for determining optical properties of biomass burning aerosols
Nadir Jeevanjee, David Romps	A theory for global precipitation change
Opeyemi Omole, Babatunde Adeyemi	Estimation of Hourly and Daily Clearness Indices and Diffuse Fraction, over Port Harcourt and Kano using National Centre for Environmental Prediction and National Centre for Atmospheric Research Satellite Data
Douglas Kurtze	Threshold dependence in the flip-flop model
Daniel Rothman	Threshold phenomena in the marine carbon cycle
William Collins, Daniel R. Feldman, Chaincy Kuo	Implications of Lorenz-Mie scattering by cloud droplets in an absorbing atmosphere for cloud feedbacks

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GPC Program Committee:

Left to right: Chris Forest (Chair), William Collins, Norman Loeb, Maria Rugenstein, Mark Zelinka

The role of the Program Committee is to work with the Executive Officers in scheduling contributed papers within areas of interest to the GPC and in arranging symposia and sessions of invited papers sponsored by the GPC at Society meetings. From time to time the Program Committee may also organize special GPC meetings and workshops, some with and some without the participation of other organization

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GPC Communications Committee

Left to right: Peter Weichman (Chair), Barbara Levi

The role of the Communications Committee is to have oversight of the Newsletter and any other publications that may be established by the GPC. The Communications Committee shall also be responsible for keeping the physics community and other interested communities informed about climate physics issues, activities, and accomplishments through the Newsletter, GPC website and email messages.