Global Warming Dynamics

SIO 209 (2 units), winter quarter, 2016

Time: Tuesday 11:00 am – 12:20 pm; **place**: Nierenberg Hall 101
Instructor: Shang-Ping Xie, MESOM 323; Tel: 822-0053; sxie@ucsd.edu;
Class website: http://ted.ucsd.edu

The Intergovernmental Panel on Climate Change released its fifth assessment report (AR5) in 2014. What is in the report? What are the major scientific advances since AR4 (2007)? Specifically what does the report say about the role of ocean beyond the thermal inertia effect? The last question leads us to focus on regional climate change, for which ocean-atmospheric dynamics is important. Regional projections of future changes (e.g., in precipitation) are crucial for adaptation and represent a grand challenge for climate science that raises new questions for physical oceanography and atmospheric dynamics. The class discusses key papers that form the basis of AR5 and recent advances since AR5.

Class meets once a week. In the first two weeks, lectures will be given to introduce important concepts (radiative forcing, climate feedback, detection and attribution), and highlight important results in key chapters. In each of the following weeks a core paper for a topic in the list below is presented and discussed, followed by a mini-review of related research/applications. Students should read the core paper before and participate in the discussion during the class. They should present 1-2 core papers during the quarter. Registered students will receive two-unit credit.

Learning objectives: to gain an understanding of IPCC assessment process, key findings of the AR5, multi-model analysis, and latest developments in climate change science, especially regarding ocean's role.

Grading: letter or S/U. Class presentation 40%, participation 40%, and seminar reports 20%. Submit a report (~2 pages) on a seminar you are not presenting, and discuss the background, major findings, significance, and implications of the paper(s).

List of topics has been extensively updated since the last time the class was offered in 2014 winter to reflect the rapid advances in research. Corresponding AR5 sections are denoted in Italic (e.g., 14.3 refers to Chapter 14, section 3). AR5 chapters are available at http://ipcc.ch/report/ar5/wg1/. Choose topics you'd like to present and e-mail me your first and second choices. Also feel free to suggest topics not on the list (e.g., *12.4.3.1 Patterns of Surface Warming: Land-Sea Contrast, and Polar Amplification*). If more than one references are listed, the topical presenter needs to narrow down to one core paper and inform the reading group of the choice one week in advance. Only a subset of the topics will be covered because of time constraints.

Energy budget & ocean heat uptake: *AR5 Box 13.1, TS TFE.4 The Changing Energy Budget of the Global Climate System*

Murphy, D. M. *et al.* An observationally based energy balance for the Earth since 1950. *J. Geophys. Res.* **114**, D17107 (2009).

Xie, S.-P., Y. Kosaka & Y.M. Okumura, 2015: Distinct energy budgets for anthropogenic and natural changes during global warming hiatus. *Nature Geosci.*, 8, doi: 10.1038/NGEO2581.

Sources of uncertainties: *11.3.1.1 Uncertainty in Near-Term Climate Projections*

Hawkins, E., and R. Sutton, 2009: The potential to narrow uncertainty in regional climate predictions. *Bull. Amer. Meteorol. Soc.*, 90, 1095, doi: 10.1175/2009BAMS2607.1.

Wallace, J.M. C. Deser, B.V. Smoliak, and A.S. Phillips, 2013: Attribution of climate change in the presence of internal variability, In *Climate Change: Multidecadal and Beyond* (Eds: C.P. Chang et al.). World Sci. Series on Asia-Pacific Wea. & Clim., 6, 1-29, doi: 10.1142/9789814579933_0001. http://www.worldscientific.com/doi/abs/10.1142/9789814579933_0001

Global warming hiatus: *Box 9.2: Climate Models and the Hiatus in Global-Mean Surface Warming of the Past 15 Years*

Kosaka, Y., and S.-P. Xie, 2013: Recent global-warming hiatus tied to equatorial Pacific surface cooling. *Nature*, 501, 403-407.

Delworth, T.L. et al., 2015: A Link between the Hiatus in Global Warming and North American Drought. *J. Climate*, **28**, 3834–3845.

Southern Ocean heat uptake

Roemmich, D et al. 2015. Unabated planetary warming and its ocean structure since 2006. *Nature Clim. Change*. 5:240-245.

Frölicher, T. L., J. L. Sarmiento, D. J. Paynter, J. P. Dunne, J. P. Krasting, M. Winton, 2015, Dominance of the Southern Ocean in anthropogenic carbon and heat uptake in CMIP5 models. *J. Climate,* 28, 862-886.

Marshall, J. et al., The ocean's role in polar climate change: asymmetric Arctic and Antarctic responses to greenhouse gas and ozone. *Phil. Trans. Roy. Soc. A* 372, 20130040, 2014.

Ocean warming pattern: *14.3.0 Tropical phenomena*

Manabe, S., and R.J. Stouffer, 2007. Role of ocean in global warming. *J. Met. Soc. Japan*, **85B**: 385-403.

Xie, S.-P., C. Deser, G.A. Vecchi, J. Ma, H. Teng, and A.T. Wittenberg, 2010: Global warming pattern formation: Sea surface temperature and rainfall. *J. Climate*, 23, 966-986.

Roe, G.H., N. Feldl, K. C. Armour,Y.-T. Hwang & D.M. W. Frierson, The remote impacts of climate feedbacks on regional climate predictability. *Nature Geosci*., 8, 135–139 (2015).

Precipitation change: Global perspective. *7.6 Processes Underlying Precipitation Changes*, *12.4.5.2 Patterns of Projected Average Precipitation Changes*

Vecchi, G. A. & B. J. Soden, 2007. Global warming and the weakening of the tropical circulation. *J. Climate*, **20**: 4316–4340.

Chadwick, R., Boutle, I. & Martin, G. Spatial patterns of precipitation change in CMIP5: why the rich do not get richer in the tropics. *J. Clim.* **26**, 3803-3822 (2013).

Precipitation change: regional perspective. *14.3.0-1 Tropical phenomena*

Seager, R., Naik, N. & Vecchi, G., 2010: Thermodynamic and dynamic mechanisms for large scale changes in the hydrological cycle in response to global warming. J. Clim. 23, 4651-4668.

Ma, J., and S.-P. Xie, 2013: Regional patterns of sea surface temperature change: A source of uncertainty in future projections of precipitation and atmospheric circulation. *J. Climate*, 26, 2482-2501.

Ocean salinity change: *3.3 Changes in Salinity and Freshwater Content*; *10.4.2 Ocean Salinity and Freshwater Fluxes*

Durack, P., S. Wijffels & R. Matear, 2012: Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science*, **336**, 455-458.

Hadley cell broadening, *11.3.2.4.3 Tropical circulation*

Lu, J., G. Vecchi & T. Reichler, 2007: Expansion of the Hadley cell under global warming. *Geophys. Res. Lett.*, doi:10.1029/2006GL028443, L06805.

Scheff, J. & Frierson, D. Twenty-first-century multimodel subtropical precipitation declines are mostly midlatitude shifts. *J. Clim.* **25**, 4330-4347 (2012).

ENSO: *14.4 El Nino-Southern Oscillation*

Power, S., Delage, F., Chung, C., Kociuba, G. & Keay, K. Robust twenty-first-century projections of El Nino and related precipitation variability. *Nature* **502**, 541-545 (2013).

Zhou, Z.-Q. *et al*., 2014: Global warming-induced changes in El Nino teleconnections over the North Pacific and North America. *J. Clim.*, 27, 9050-9064.

Seager, R., N. Naik & L. Vogel, 2012: Does global warming cause intensified interannual hydroclimate variability? *J. Clim.*, **25**: 3355-3372.

Tropical cyclones: *14.6.1 Tropical Cyclones*

Knutson, T.R., J.J. Sirutis, S.T. Garner, G.A. Vecchi & I.M. Held, 2008. Simulated reduction in Atlantic hurricane frequency under twenty-first-century warming conditions. *Nature Geosci.*, **1**: 359-364.

Zhao, M. & Held, I. M. TC-permitting GCM simulations of hurricane frequency response to sea surface temperature anomalies projected for the late-twenty-first century. *J. Clim.* **25**, 2995-3009 (2012).

Extratropical storms: *12.4.4.3 Extratropical Storms: Tracks and Influences on Planetary-Scale Circulation and Transports; 14.6.2 Extra-Tropical Cyclones*

Chang, E. K. M., Y. Guo & X. Xia (2012), CMIP5 multimodel ensemble projection of storm track change under global warming, *J. Geophys. Res*., 117, D23118, doi: 10.1029/2012JD018578.

Yin, J. H. A consistent poleward shift of the storm tracks in simulations of 21st century climate. *Geophys. Res. Lett.* **32**, L18701 (2005).

Regional sea level change: *13.6 Regional Sea Level Changes*

Yin, J. J., S. M. Griffies, and R. J. Stouffer, 2010: Spatial variability of sea level rise in twenty-first century projections. *J. Climate*, **23**, 4585-4607.

Timmermann, A., S. McGregor, and F.-F. Jin, 2010. Wind effects on past and future regional sea level trends in the southern Indo-Pacific. *J. Climate*, **23**: 4429–4437.

Major review papers

Bony, S. *et al*., 2015: Clouds, circulation and climate sensitivity. *Nature Geosci.*, 8, 261-268.

Cai, W. *et al*., 2015: ENSO and greenhouse warming. *Nature Clim. Change* 5, 849–859.

Collins, M. *et al.,* 2010: The impact of global warming on the tropical Pacific ocean and El Nino. *Nature Geosci.* **3**, 391-397.

Knutson, T.R. *et al*. 2010: Tropical cyclones and climate change, *Nature Geosci.*, 3, 157 – 163.

Shepherd, T. G., 2014: Atmospheric circulation as a source of uncertainty in climate change projections. *Nature Geosci.* **7**, 703-708.

Xie, S.-P. *et al.*, 2015: Towards predictive understanding of regional climate change. *Nature Clim. Change*, 5, 921-930