ATS 753
Spring 2026
Prof. Kummerow

Simple inspection of the global energy budget reveals that the atmosphere loses a net 100W/m^2 of radiation to space. This net cooling is offset primarily by the release of latent heat by condensing water vapor in the atmosphere, that subsequently falls as rain. Since the temperature of Earth has not changed significantly in the last 10,000 years, it is clear that the water and energy cycles must be linked in an inextricable way. AT753 is designed to explore this connection between water and energy in the atmosphere. In order to retain a unifying theme, AT753 concentrates on examining the observations of atmospheric hydrologic parameters, and seeks to critically examine if current interpretations of the climate system are or are not justified based upon these observations.

The class will cover the distribution as well as radiative effects of water vapor, clouds and precipitation, current observational capabilities of these parameters and the use of these quantities in global numerical models. As far as feasible, each topic covered in class will consist of background material plus lectures and papers covering the current state of knowledge. Once the observational framework is established, the class will focus on predictions of the climate system and the degree to which these predictions can be verified with existing data. Homework will consist of reading papers and, where indicated, presenting summaries to the class for broader discussion. This is an integral part of this course as there will be no exams or class projects beyond the student led discussions.

All class material (including papers and lectures) can be found at:
http://rain.atmos.colostate.edu/courses/AT753
Username = AT753
Password = ACRC212

Useful books for personal library:

Liou, K.N., 1992: Radiation and Cloud Processes in the Atmosphere: Theory, Observations, and Modeling, Oxford University Press, new York, NY, 487 pp.

Peixoto, Jose P. and Abraham H. Ort, 1992: Physics of Climate, Springer Verlag, New York, NY, 520 pp.

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Required text: None
Useful texts for own library: Piexoto and Oort, 1992
Liou, 1992

Course Outline

Week 1
Jan. 19 – CSU Closed (MLK day)
Jan. 21 – Lecture: Class Overview and Introduction to Water and Energy budgets. Homework: Look over IPCC6 (Summary for Policy Makers) and find on conclusion that interests you. Be prepared to share in class on Jan. 26. ***https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf***

Week 2
Jan. 26 – Lecture: Review of Radiation and Radiative Fluxes Radiative Flux Observations.
Jan. 28 – Lecture: Radiative Flux Observations.

Week 3
Feb. 02 – Student Presentation of *Dines, 1917: The heat balance of the Atmosphere*. Lecture: Historical developments in W&E Budgets. Will discuss Dines, 1917 as well as S*impson, 1928: Further Studies in Terrestrial Radiation.*
Feb. 04 – Lecture: Greenhouse gases, water vapor and its measurements.

Week 4
Feb. 09 – 2 Student-led discussions of *VonderHaar, 2012: Weather and climate analyses using improved global water vapor observations,* and *Schröder, 2019: The GEWEX Water Vapor Assessment: Overview and Introduction to Results and Recommendations*. Lecture: Assessment of today's many water vapor observations and causes for consistencies/inconsistencies.
Feb. 11 – Lecture: Evaporation.
Week 5
Feb. 16 – Student led discussion of *Kiehl and Trenberth, 1997: The Earth's Annual Global Mean Energy Budget, and its update & Trenberth, Fassulo and Kiehl, 2009*: *Earth's Global Energy Budget. Pay attention to what the authors do vis a vis water vapor.* Lecture: Evaporation.

Feb. 18 – Lecture 8: Evaporation over oceans.

Week 6

Feb. 23 – Student led review of *Seager et al., 2003: Why is there an Evaporation Minimum at the Equator?* Lecture: Evaporation over land

Feb. 25 – Student led review of: *Ohmura & Wild, 2002: Is the Hydrologic Cycle Accelerating?* Lecture 10: Soil Moisture and soil moisture feedback

Week7

Mar. 02 – Lecture: Review of how well we know water vapor, evapotranspiration and the transport of heat and water vapor. Comparisons to Reanalyses and climate models

Mar. 04 – Lecture: Clear sky radiation

Week 8

Mar. 9 – Lecture 13: Clouds and Radiation

Mar. 11 – Student led discussion of *Ramanathan and Collins, 1991: Thermodynamic regulation of ocean warming by cirrus clouds ….*

Spring break

Week 9

Mar. 23 – Lecture: Cloud Climate Feedbacks.

Mar. 25 – Student led discussion of *Lindzen et al., 2001: Does the Earth have an Adaptive Infrared Iris?* Lecture: The Iris Hypothesis

Week 10

Mar. 30 – Lecture: Precipitation – Measurement systems. Why is it so hard?

Apr. 01 – Student led discussion: *Schlosser and Houser, 2007: Assessing a Satellite-Era of the Global Water Cycle.* Lecture: Remote sensing of precipitation and latent Heating

Week 11

Apr. 06 – Student led discussion: *Wentz et al., 2007: How much more rain will global warming bring?* Lecture: Radiative/Convective equilibrium

Apr. 08 – Student led discussion*: Trenberth, 2011. Changes in precipitation with climate change.* Lecture: Integrated Products

Week 12

Apr. 13 – Lecture: Large scale controls on precipitation [Held and Soden ‘06].

Apr. 15 – Student led discussion – *Muller, C. J., P. O'Gorman, 2011: An energetic perspective on the regional response of precipitation to climate change.* Lecture: Trends in regional precipitation

Week 13

Apr. 20 – Lecture 21: Constraining the global energy balance.

Apr. 22 – Student led discussion - *Stephens et al., 2004*: *Observational Evidence for the Mutual Regulation of the Tropical Hydrologic Cycle and Tropical Sea Surface Temperature.* Lecture: MJO and self-similar tropical precipitation regimes

Week 14

Apr. 27 – Lecture 24: Aerosols/Cloud/precipitation interactions. *Read: Stier et al., 2024: Multifaceted Aerosol effects on Precipitation.*

Apr. 29 – Student led discussion - *Koren et al., 2012. Aerosol-induced intensification of rain from the tropics to the mid-latitudes.* Lecture: Connecting the Carbon Cycle to the W&E cycles.

Week 15

May 04 – Lecture: Linking Radiation, the hydrologic cycle and climate change. Read *Allen and Ingram, 2002. Constraints on future changes in climate and the hydrologic cycle*

May 06 – Connecting W&E Cycle to own research. Student presentations of self-selected papers.

Books:

Peixoto, José P. and Abraham H. Oort, 1992: *Physics of Climate*, Springer Verlag, New York, NY, 520 p.

Liou, K. N. 1992: *Radiation and Cloud Processes in the Atmosphere: Theory, Observation, and Modeling*, Oxford University Press, New York, NY, 487 pp.

Papers (in order of appearance)

IPCC AR6 Synthesis Report. Climate Change 2021. The Physical Science Basis. Summary for Policymakers ***https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf***

Dines, W. H., 1917: The heat balance of the Atmosphere. Quart. J. of the Royal Meteor. Soc., 43, 151-158.

Vonder Haar, T. H., J. Bytheway and J. M. Forsythe, 2012: Weather and Climate Analysis using Improved Global Water Vapor Observations. *Geophys. Res. Letters*, 39, L15802

Schröder, M. M. Lockhoff, L. Shi, et al., 2019: The GEWEX Water Vapor Assessment: Overview and Introduction to Results and Recommendations. *Remote Sens.*, ***11***, 251. doi:10.3390/rs11030251

Kiehl, J. T. and K. Trenberth, 1997: The Earth's Annual Global Mean Energy Budget. *Bull. Amer. Met. Soc*., **78**, 197-208

Trenberth, Kevin E., J. T. Fasullo, J. Kiehl, 2009: Earth's Global Energy Balance. *Bull. Amer. Met. Soc*., **90**, 311-323

Lewis, J. M., 1995: The Story Behind the Bowen Ratio. *Bull. Amer. Met. Soc*., **76**, 2433-2442

Seager, R., R. Murtugudde, A. Clement, and C. Herweijer, 2003: Why is there an evaporation minimum at the Equator? *J. Climate*, **16**, 3793–3802.

Ohmura, A., and M. Wild, 2002: Is the Hydrologic Cycle Accelerating? *Science*, **298**, 1345-1346.

A. Mestas-Nuñez et al., J. of Hydromet. '05 Uncertainties in Estimating Moisture Fluxes over the Intra-Americas Seas.

Ramanathan, V. and W. Collins, 1991: Thermodynamic regulation of Ocean Warming by Cirrus Clouds Deduced from Observations of the 1987 El Niño. *Nature*, **351**, 27-32.

Lindzen, R. S. M.-D. Chou, and A. Y. Hou, 2001: Does the Earth have an adaptive infrared iris? *Bull. Amer. Met. Soc*., **82**, 417-432.

Schlosser, A., and P. R. Houser: 2011: Assessing a Satellite-Era Perspective of the Global Water Cycle. J. Clim., **20**, 1316-1338. DOI:10.1175/JCLI4057.1

Wentz, F. J., L. Ricciardelli, K. Hilburn and C. Mears, 2007: How much more rain will global warming bring? *Science*, **317**, 233–235.

Trenberth, K. 2011: Changes in precipitation with climate Change. Cllim. Res., **47,** 123–138

Muller, C. J., P. . O'Gorman, 2011: An energetic perspective on the regional response of precipitation to climate change. *Nature Climate Change*, **1**, 266-271.

Held, I. M., and B. J. Soden, 2006: Robust Responses of the Hydrological Cycle to Global Warming. *J. Clim*.**, 19,** 5686-5699.

Stephens, Graeme L., Peter J. Webster, Richard H. Johnson, Richard Engelen, and Tristan L'Ecuyer, 2004: Observational evidence for the mutual regulation of the tropical hydrological cycle and tropical sea surface temperatures, *J. Climate*, **17**, 2213–2224.

Stier, P., S. C. van den Heever, M. Christensen et al., 2022: Multifaceted aerosol effects on precipitation. Nat. Geosci., (submitted)

Koren, I., O. Altaratz, L. A. Remer, G. Feingold, J. Vaderlei Martins, and R. H., Heiblum,2012: Aerosol-induced intensification of rain from the tropics to the mid-latitudes, *Nature Geoscience*, **5**, 118 - 122.

Some of the Adaptive Iris rebuttals:

Dennis L. Hartmann and Marc L. Michelsen, 2002: No Evidence for Iris. *Bulletin of the American Meteorological Society*, Volume 83, Issue 2 (February 2002) pp. 249–254

Halstead Harrison, 2002: Supplement to Comments on "Does the Earth Have an Adaptive Infrared Iris?" *Bulletin of the American Meteorological Society*, Volume 83, Issue 4 (April 2002) pp. 598–598

Richard S. Lindzen, Ming-Dah Chou, and Arthur Y. Hou, 2002: Comment on "No Evidence for Iris". *Bulletin of the American Meteorological Society*, Volume 83, Issue 9 (September 2002) pp. 1345–1349

Bing Lin, Bruce A. Wielicki, Lin H. Chambers, Yongxiang Hu, and Kuan-Man Xu, 2002: The Iris Hypothesis: A Negative or Positive Cloud Feedback? *Journal of*

Climate, Volume 15, Issue 1 (January 2002) pp. 3–7

Ming-Dah Chou, Richard S. Lindzen, and Arthur Y. Hou, 2002: Comments on "The Iris Hypothesis: A Negative or Positive Cloud Feedback?" *Journal of Climate*, Volume 15, Issue 18 (September 2002) pp. 2713–2715

ANITA Rapp, C. Kummerow, Wes. Berg, and Brian Griffith, 2005: An Evaluation of the proposed mechanisms of the adaptive infrared iris hypothesis using TRMM VIRS and PR measurements. *J. Clim*., **18**, 4185-4194