

AT 753
Spring 2022
Prof. Christian Kummerow

Required text: None

Useful texts for own library: Piexoto and Oort, 1992
Liou, 1992

Course Outline

Week 1

Jan. 17 – CSU Closed (MLK day)

Jan. 19 – Lecture 1: Introduction to Water and Energy budgets. Skim *IPCC Assessment Report 6 – The Physical Science Basis/Summary for Policymakers*. Focus on Water and Energy budget issues. Be prepared to share perspectives on Friday

Jan. 21 – Lecture 2: Review of Radiation and Radiative Fluxes

Week 2

Jan. 24 – Lecture 3: Radiative Flux Observations. Read *Dines, 1917: The heat balance of the Atmosphere*

Jan. 26 – Lecture 4: An historical perspective of the water and energy budgets.

Jan. 28 – Student-led discussion of *Dines, 1917: The heat balance of the Atmosphere*.

Week 3

Jan. 31 – Lecture 5: Water vapor as a greenhouse gas.

Feb. 2 – Lecture 6: Water vapor measurements. Read *VonderHaar, 2012: Weather and climate analyses using improved global water vapor observations & Schröder, 2019: The GEWEX Water Vapor Assessment: Overview and Introduction to Results and Recommendations*

Feb. 4 – Student led review 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 water vapor]

Week 4

Feb. 7 – Lecture 7: Evaporation. Read *Lewis, 1995: The Story behind the Bowen Ratio*.

Feb. 9 – Lecture 8: Evaporation over ocean.

Feb. 11 – Student led review of: *Seager et al., 2003: Why is there an Evaporation Minimum at the Equator?*

Week 5

Feb. 14 – Lecture 9: Evaporation over land

Feb. 16 – Lecture 10: Soil Moisture and soil moisture feedback

Feb. 18 – Student led review of: *Ohmura & Wild, 2002: Is the Hydrologic Cycle Accelerating?*

Week 6

- Feb. 21– Lecture 11: Water vapor transport - why does everyone use reanalyses?
Read: Mestas-Nuñez et al., 2005: Uncertainties in Estimating Moisture Fluxes over the Intra-Americas Seas.
- Feb. 23 – Lecture 12: Review of how well do we know water vapor, evapotranspiration and the transport of heat and water vapor?
- Feb. 25 –Lecture 13: Detour - Connecting the Carbon Cycle to the W&E cycles.

Week 7

- Feb. 28 –Lecture 14: Clear sky radiation. *Read Ramanathan and Collins, 1991: Thermodynamic regulation of ocean warming by Cirrus.*
- Mar. 2 – Lecture 15: Clouds and Radiation
- Mar. 4 – Student led discussion - *Ramanathan and Collins, 1991: Thermodynamic regulation of ocean warming by Cirrus.*

Week 8

- Mar. 7 – Lecture 16: Cloud Climate Feedbacks. *Read Lindzen et al., 2001: Does the Earth have an Adaptive Infrared Iris?*
- Mar. 9 – Lecture 17: The Iris hypothesis
- Mar. 11 – Student led discussions – *Rebuttals on Iris Hypothesis and comments on rebuttals (see reading list)*

Spring break

Week 9

- Mar. 21 – Lecture 18: Precipitation – Measurement options
- Mar. 23 – Lecture 19: Microwave remote sensing of Precipitation and latent Heating
- Mar. 25 – Student led discussion: *Schlosser and Houser, 2007: Assessing a Satellite-Era of the Global Water Cycle.*

Week 10

- Mar. 28 – Student led discussion: *Wentz et al., 2007: How much more rain will global warming bring?*
- Mar. 30 – Student led discussion: *Trenberth, 2011. Changes in precipitation with climate change.*
- Apr. 1 – Lecture 20: Radiative/Convective equilibrium

Week 11

- Apr. 4 – Lecture 21: The GEWEX Integrated Product - lessons learned
- Apr. 6 – Lecture 22: Trends in regional precipitation
- Apr. 8 – Student led discussion – *Muller, C. J., P. O’Gorman, 2011: An energetic perspective on the regional response of precipitation to climate change*

Week 12

- Apr. 11 – Lecture 23: Constraining the global energy balance. *Read: Held and Soden '06: Robust Responses of the Hydrological Cycle to Global Warming*
- Apr. 13 – Lecture 24: MJO and self similar tropical precipitation regimes
- Apr. 15 – Student led discussion - *Stephens et al., 2004: Observational Evidence for the Mutual Regulation of the Tropical Hydrologic Cycle and Tropical Sea Surface Temperature.*

Week 13

- Apr. 18 – Lecture 25: Aerosols/Cloud Cloud interactions.
- Apr. 20 – lecture 26: Aerosol/Precipitation interactions. *Read: Stier et al., 2022: Multifaceted Aerosol effects on Precipitation.*
- Apr. 22 – Student led discussion - *Koren et al., 2012. Aerosol-induced intensification of rain from the tropics to the mid-latitudes,*

Week 14

- Dec. 2 – Lecture 27: Water/Energy storage and Ocean circulation
- Dec. 4 – Lecture 28: Linking Radiation, the hydrologic cycle and climate change. *Read Allen and Ingram, 2002. Constraints on future changes in climate and the hydrologic cycle*
- Dec. 6 – Lecture 29: Water and energy storage over the Colorado River Basin – a local perspective

Week 15

- Dec. 9/11/13 – Connecting W&E Cycle to own research. Student presentations of self-selected papers.

Finals Week

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](https://doi.org/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. *Clim. 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. Vadelei 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

Rapp, A. D., C. Kummerow, W. Berg, and B. 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