CLIM 751: PREDICTABILITY AND PREDICTION OF WEATHER AND CLIMATE – CONCEPTS AND PHENOMENOLOGY

Fall 2017 - Syllabus

Instructors: J. Shukla (office: 105, Research Hall, email: jshukla@gmu.edu)
James L. Kinter (office: 284 Research Hall, e-mail: ikinter@gmu.edu)

Guest Lecturers: See list.

Class Schedule: Wednesday 10:30 am – 1:10 pm (Room: Innovation 139)*

Course Homepage:

http://cola.gmu.edu/kinter/CLIM751/
http://mymasonportal.gmu.edu (Blackboard)
All reading materials will be posted on Blackboard.

Textbooks, Recommended and Supplementary Reading Materials:

Required Reading: See list.

Course Description:

This course covers fundamental aspects of weather and climate predictability. Using simple dynamical models, illustrates basic theorems on divergence of trajectories in phase space and fundamental periodicity properties of flow. Explores paradigms of turbulence, barotropic and baroclinic instability, and optimal linear growth to describe fundamental error growth mechanisms. Examines examples from real weather forecasting systems. Studies predictability of time averages with simple dynamical models and experiments using complex general circulation models and historical data analysis. Emphasizes roles of boundary conditions of sea surface temperature and soil moisture.

Course Requirements:

1. *Presentation of Selected Papers from the Literature*: 70%
2. *Data analysis project:* 30%

Each week, selected students will be assigned to present papers from the scholarly literature. All students are expected to read all the papers each week. One student will be asked to present the paper, and one student will be asked to summarize the impact of the paper, e.g., with a summary of the papers that have cited it since publication. All students are expected to conduct a data analysis exercise, using data sets provided for the course including long time series of re-forecasts and verifying observations. A separate assignment sheet describes the data analysis project.

* Will be shifted to Wednesday 2:45 – 5:25 pm (Room: Research 121)

Detailed Course Schedule (subject to minor adjustment)

Date	Week	Lecture	Topic
30 Aug	**1**	**Kinter/Shukla**	**Logistics; Introduction to Predictability & Prediction**
06 Sep	**2**	**Shukla/Adams**	**Predictability of Weather / CLIM 751 Data Analysis Project**
13 Sep	**3**	**Shukla**	**Dynamical Seasonal Prediction**
20 Sep	**4**	**DelSole**	**Unified Framework for Predictability / Predictability Measures**
27 Sep	**5**	**Krishnamurthy**	**Predictability of the South Asian Monsoon**
04 Oct	**6**	**Straus**	**Intraseasonal Predictability**
11 Oct	**7**	**Dirmeyer**	**Land Surface Predictability**
18 Oct	**8**	**Kinter**	**Predictability of Extreme Events**
25 Oct	**9**	**Kinter**	**Ensembles and Predictability**
01 Nov	**10**	**Huang**	**Seasonal Prediction of ENSO and Indo-Pacific Variability**
08 Nov	**11**	**Burls**	**The Ocean's Role in Tropical Climate Prediction**
15 Nov	**12**	**Buckley**	**Role of Ocean Dynamics in North Atlantic SST Anomalies**
22 Nov	**13**	**Thanksgiving break**	**NO CLASS**
29 Nov	**14**	**DelSole**	**Predictability of Decadal Variations and Climate Change**
06 Dec	**15**	**Students**	**Data Project Presentations**

PAPERS The papers listed below (subject to revision) are readings for each week of the course. The references below are labeled as follows:

- *A*: required (should be read by all students)
- *B*: recommended (optional reading)
- *P*: to be presented by students

1 – INTRODUCTION (no student presentations this week)

- *A*: Shukla, J. and J. L. Kinter III, 2006: Predictability of seasonal climate variations: A pedagogical review. In *Predictability of Weather and Climate*, T. Palmer and R. Hagedorn, eds. (Cambridge University Press, Cambridge, UK, 702 pp.), 306-341.

2 – WEATHER (no student presentations this week)

- *A*: Lorenz 1963: Deterministic Nonperiodic Flow. *J. Atmos. Sci*., 20, 130-141.
- *A*: Shukla, J., 1985: Predictability. Issues in atmospheric and oceanic modeling, Part II. Weather Dynamics. *Advances in Geophysics*, Vol. 28B. Editor: S. Manabe, Academic Press, Inc., pp. 87-122.

3 – DYNAMICAL SEASONAL PREDICTION

- *P*: Shukla, J., 1998: Predictability in the Midst of Chaos: A Scientific Basis for Climate Forecasting. *Science*, 282, 728-731.
- *A*: Lorenz, E. N., 1975: Climate predictability: The physical basis of climate modeling. *GARP Publication Series*, 16, WMO, 132–136.
- *A*: Shukla, J., 1981: Dynamical predictability of monthly means. *J. Atmos. Sci.*, 38, 2547-2572.
- *A*: Lorenz 1969: Three approaches to atmospheric predictability. *Bull. Amer. Meteor. Soc.,* 50**,** 345-351.
- *A*: Miyakoda, K. and J. Sirutis, 1985: Extended range forecasting**.** *Adv. Geophys.*, 28B**,** 55-85.

4 – UNIFIED FRAMEWORK (no student presentations this week)

- *A*: DelSole, 2017: Predictability in a Changing Climate (in revision).

5 – SOUTH ASIAN MONSOON

- *P*: Sperber, K. R., et al., 2013: The Asian summer monsoon: an intercomparison of CMIP5 vs. CMIP3 simulations of the late 20th century. *Climate Dyn*. 41, 2711-2744.
- *A*: Charney, J. G., and J. Shukla, 1981: Predictability of monsoons. *Monsoon Dynamics*, J. Lighthill, and R. P. Pearce, Eds., Cambridge University Press, 99-109.
- *A*: Krishnamurthy, V., 2017: Predictability of CFSv2 in the tropical Indo-Pacific region, at daily and subseasonal time scales. *Climate Dyn*, DOI: 10.1007/s00382-017-3855-y.
- *A*: Krishnamurthy, V., 2017: Seasonal prediction of South Asian monsoon in CFSv2. *Climate Dyn*. (in review).

6 – INTRASEASONAL

- *P:* Neena, J. M., J. Y. Lee, D. Waliser, B. Wang and X. Jiang, 2014: Predictability of the Madden-Julian-Oscillation in the Intraseasonal Variability Hindcast Experiment. *J. Climate*, 27, 4531-4543.
- *A:* Vitart, F., and F. Molteni, 2010: Simulation of the Madden-Julian Oscillation and its teleconnections in the ECMWF forecast system. *Quart. J. Roy. Meteor. Soc.,* 649B, 842–855.
- *A:* Lin, H., and G. Brunet, 2009: An observed connection between the North Atlantic Oscillation and the Madden-Julian Oscillation. J. Climate, 22, 364-380.
- *A:* Straus, D. M., and D. Paolino, 2009: Intermediate time error growth and predictability: tropics versus mid-latitudes. *Tellus,* 61A, 579-586.
- *B:* Ferranti, L., S. Corti and M. Janousek, 2014: Flow-dependent verification of the ECMWF ensemble over the Euro-Atlantic sector. *Quart. J. Roy. Meteor. Soc.*, 688A, 916–924.

7 – LAND SURFACE

- *P:* Koster, R. D., and M. J. Suarez, 2001: Soil moisture memory in climate models. *J. Hydrometeor*., 2, 558-570.
- *A:* Seneviratne, S. I., and R. D. Koster, 2012: A revised framework for analyzing soil moisture memory in climate data: Derivation and interpretation. *J. Hydrometeor*., **13**, 404-412, doi: 10.1175/JHM-D-11-044.1.
- *A:* Delworth, T., and S. Manabe, 1993: Climate variability and land-surface processes. *Adv. Water Resour*., 16, 3-20.
- *A:* Koster, R. D., M. J. Suarez, and M. Heiser, 2000: Variance and predictability of precipitation at seasonal-to-interannual timescales. *J. Hydrometeor*., 1, 26-46.
- *A:* Dirmeyer, P. A., 2005: The land surface contribution to boreal summer season predictability. *J. Hydrometeor.*, 6, 618-632 , doi: 10.1175/JHM444.1.
- *B:* Guo, Z., P. A. Dirmeyer, and T. DelSole, and R. D. Koster, 2012: Rebound in atmospheric predictability and the role of the land surface. *J. Climate,* 25, 4744-4749, doi: 10.1175/JCLI-D-11-00651.1.
- *B:* Shukla, J. and Y. Mintz, 1982: Influence of Land-Surface Evapotranspiration on the Earth's Climate. *Science,* 215, 1498-1501.

8 – EXTREME EVENTS

- *P*: Weisheimer, A., F. J. Doblas-Reyes, T. Jung, *and* T. N. Palmer, 2011: On the predictability of the extreme summer 2003 over Europe, *Geophys. Res. Lett.,* 38, L05704, *doi:*10.1029/2010GL046455.

- *A*: Pepler, A. S., L. B. Diaz, C. Prodhomme, F. J. Doblas-Reyes, A. Kumar, 2015: The ability of a multi-model seasonal forecasting ensemble to forecast the frequency of warm, cold and wet extremes. *Wea. Climate Extremes*, 9, 68-77.
- *A*: Gershunov, A., 1998: ENSO influence on intraseasonal extreme rainfall and temperature frequencies in the contiguous United States: Implications for long-range predictability. *J. Climate*, 11, 3192–3203.
- *A*: Namias, J., 1978: Multiple causes of the North American abnormal winter of 1976-77. *Mon. Wea. Rev*., 106 (1978), pp. 279–295.
- *B*: Della-Marta, P. M., J. Luterbacher, H. von Weissehfluh, E. Xoplaki, M. Brunet, H. Wanner, 2007: Summer heat waves over western Europe 1880-2003, their relationship to large-scale forcings and predictability. *Climate Dyn*., 29, 251-275.
- *B*: Miyakoda, K., T. Gordon, R. Caverly, W. Stern, and J. Sirutis, 1983: Simulation of a blocking event in January 1977. *Mon. Wea. Rev*., 111, 846-869.

9 – ENSEMBLES

- *P*: Becker, E. F., H. van den Dool, and Q. Zhang, 2014: Predictability and Forecast Skill in NMME. *J. Climate*, 27, 5891-5906.
- *A*: Hagedorn, R., F. J. Doblas-Reyes and T. N. Palmer, 2005: The rationale behind the success of multi-model ensembles in seasonal forecasting – I. Basic concept. *Tellus*, 57A*, 219–233.*
- *A*: Slingo, J. and T. N. Palmer, 2016: Uncertainty in weather and climate prediction. *Phil. Trans. R. Soc. A* (2011) 369, 4751–4767.
- *B*: Kirtman, B. P., D. Min, J. M. Infanti, J. L. Kinter III, D. A. Paolino, Q. Zhang, H. van den Dool, S. Saha, M. Pena Mendez, E. Becker, P. Peng, P. Tripp, J. Huang, D. G. DeWitt, M. Tippett, A. G. Barnston, S. Li, A. Rosati, S. D. Schubert, M. Rienecker, M. Suarez, Z. E. Li, L. Marshak, Y.-K. Lim, J. Tribbia, K. Pegion, W. J. Merryfield, B. Denis, E. F. Wood, 2014: The North American Multimodel Ensemble: Phase-1 Seasonal-to-Interannual Prediction; Phase-2 toward Developing Intraseasonal Prediction. *Bull. Amer. Meteor. Soc*., 95, 585-601.

10 – SEASONAL PREDICTION

- ENSO prediction
  - *P*: Jin, E. K. and J. L. Kinter III, 2009: Characteristics of tropical Pacific SST predictability in coupled GCM forecasts using the NCEP CFS. *Climate Dyn.,* 32, 675-691.
  - *A:* Zhu, J., B. Huang, L. Marx, J. L. Kinter III, M. A. Balmaseda, R.-H. Zhang, and Z.-Z. Hu, 2012: Ensemble ENSO hindcasts initialized from multiple ocean analyses. *Geophy. Res. Lett.,* 39, L09602, DOI:10.1029/2012GL051503.
  - *A:* McPhaden, M. J., A. Timmermann, M. J. Widlansky, M. A. Balmaseda, and T. N. Stockdale, 2015: The curious case of the El Niño that never happened. *Bull. Amer. Meteor. Soc*., 96, 1647-1665.
- Indian Ocean SST mechanism and prediction
  - *B*: Zhu. J., B. Huang, J.L. Kinter, and A. Kumar, 2015: Seasonality in predictive skill and predictable pattern of the tropical Indian Ocean SST. *J. Climate*, 28, 7962-7984.
  - *B*: Huang, B., and J. Shukla, 2007a: On the mechanisms for the interannual variability in the tropical Indian Ocean, Part I: The role of remote forcing from tropical Pacific. *J. Climate*, 20, 2917-2936.
  - *B*: Huang, B., and J. Shukla, 2007b: On the mechanisms for the interannual variability in the tropical Indian Ocean, Part II: Regional processes. *J. Climate*, 20, 2937-2960.

11 – OCEAN'S ROLE (no student presentations this week)

- *A*: Chang, P., T. Yamagata, P. Schopf, S. K. Behera, J. Carton, W. S. Kessler, G. Meyers, T. Qu, F. Schott, S. Sheyte, and S.-P. Xie, 2006: Climate Fluctuations of Tropical Coupled Systems – The Role of Ocean Dynamics. *J. Climate*, 19, 5122-5174.

12 – OCEAN DYNAMICS AND NORTH ATLANTIC SST

(Note: The student presentation includes one paper, a comment on that paper and a reply to the comment.)

- *P1*: Clement, Amy, K. Bellomo, L.N. Murphy, M. Cane, T. Mauritsen, G. Rädel and B. Stevens (2015). The Atlantic Multidecadal Oscillation without a role for ocean circulation, *Science*, 350, 320—324.
- *P2*: Zhang, Rong, R. Sutton, G. Danabasoglu, T.L. Delworth, W.M. Kim, J. Robson, and S.G. Yeager (2016), Comment on ``The Atlantic Multidecadal Oscillation without a role for ocean circulation", *Science*, 352, 1527—1527.
- *P3*: Clement, Amy, K. Bellomo, L.N. Murphy, M. Cane, T. Mauritsen, G. Rädel and B. Stevens (2016), Response to Comment on ``The Atlantic Multidecadal Oscillation without a role for ocean circulation", *Science*, 352, 1527—1527.
- *A*: O'Reilly, C.H., M. Huber, T. Woollings, and L. Zanna (2016), The signature of low-frequency oceanic forcing in the Atlantic Multidecadal Oscillation, *Geophys. Res. Lett.*, 43, doi: 10.1002/2016GL067925.
- *A*: Zhang, R. (2017), On the persistence and coherence of subpolar sea surface temperature and salinity anomalies associated with the Atlantic multidecadal variability, *Geophys. Res. Lett*., 44, doi:10.1002/2017GL074342.
- *A*: Buckley, M.W. and J. Marshall (2016). Observations, inferences and mechanisms of the Atlantic Meridional Overturning Circulation: a review. *Reviews of Geophysics*, 54, 5—63. doi: 10.1002/2015RG000493. ONLY required to read sections 2.4 and 6. The rest of the paper, particularly the introduction and section 2 may be useful background for students, particularly those not familiar with the oceanography of the Atlantic Ocean.
- *B*: Gulev, S. K., M. Latif, N. Keenlyside, W. Park, and K. P. Koltermann (2013), North Atlantic Ocean control on surface heat flux on multidecadal timescales, *Nature*, 499, 464–467, doi:10.1038/ nature12268.
- *B*: Delworth et al (2017), The central role of ocean dynamics in connecting the North Atlantic Oscillation to the extratropical component of the Atlantic Multidecadal Oscillation, *J. Climate*, 30, 3789—3805, doi: 10.1175/JCLI-D-16-0358.1.
- *B*: Cane, Mark A., A.C. Clement, L.M. Murphy, and K. Bellomo (2017), Low-Pass Filtering, Heat Flux, and Atlantic Multidecadal Variability, *J. Climate*, 30, 7529—7553, doi: 10.1175/JCLI-D-16-0810.1.

THANKSGIVING

14 – DECADAL & CLIMATE CHANGE

- *P*: Latif, M., and N. S. Keenlyside (2011), A perspective on decadal climate variability and predictability, *Deep Sea Res., Part II*, *58*(17–18), 1880–1894, doi:10.1016/j.dsr2.2010.10.066.
- *A*: DelSole, T., 2017: Decadal Prediction of Temperature: Achievements and Future Prospects. *Curr. Climate Change Rep*., doi: 10.1007/s40641-017-0066-x.
- *A*: Meehl, G. and coauthors, 2013, Decadal Climate Prediction: An Update from the Trenches, *Bull. Amer. Meteor. Soc.*, 95 (2), 243—267, doi: 10.1175/BAMS-D-12-00241.1.
- *A*: Hawkins, E. and R. Sutton, 2009: The potential to narrow uncertainty in regional climate predictions. *Bull. Amer. Meteor. Soc.*, 90 (8), 1095—1107, doi: 10.1175/2009BAMS2607.1.

- *B*: Doblas-Reyes and coauthors, 2013, Initialized near-term regional climate change prediction. Nature Communications, 4, 1715. doi: 10.1038/ncomms2704.
- *B*: IPCC, 2013 (Chapter 10): Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge and New York, 1535 pp. (available from http://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter10_FINAL.pdf).
- *B*: Meehl, G. and coauthors, 2009: Decadal prediction. Can it be skillful?, BAMS, 90 (10), 1467--1485, doi: 10.1175/2009BAMS2778.1.

Goals and Learning Outcomes:

The course will:

1. *Provide a background in the scientific problem of weather and climate predictability*. Students will gain an in-depth understanding of how and why weather and climate may be predictable. Students will have the opportunity to critically review the scholarly literature on the predictability of variations of the Earth system at time scales of days to decades. The emphasis on both the nature of scientific findings and the impact that individual papers have had on subsequent scholarship ensure that students will gain an appreciation for the practice of professional scientific inquiry.

2. *Provide knowledge and skills necessary to conduct original quantitative research in predictability*. By have access to a current research-quality data set for analysis and manipulation, the students will develop the ability to work with high-volume geophysical data from a variety of sources.

3. *Reinforce oral and written communication skills*. Students will present papers from the literature, evaluate the impact these papers have had on the scientific body of knowledge, and critically examine the results reported in the literature. Students will write reports on the findings of their calculations with research-quality data sets, with the potential to submit truly new findings for peer-reviewed publication.

Academic Integrity:

Mason is an Honor Code university; please see the University Catalog for a full description of the code and the honor committee process. The principle of academic integrity is taken very seriously and violations are treated gravely. What does academic integrity mean in this course? Essentially this: when you are responsible for a task, *you* will perform that task. When you rely on someone else's work in an aspect of the performance of that task, you will give full credit in the proper, accepted form. Another aspect of academic integrity is the free play of ideas. Vigorous discussion and debate are encouraged in this course, with the firm expectation that all aspects of the class will be conducted with civility and respect for differing ideas, perspectives, and traditions. When in doubt (of any kind), please ask for guidance and clarification. As in many classes, there will be a project in this class designed to be completed within small study groups. With collaborative work, the names of all the participants should appear on the work. Collaborative projects may be divided up so that individual group members complete portions of the whole, provided that group members take sufficient steps to ensure that the pieces conceptually fit together in the end product.

Please note: The homework for this course should be your own work, not done in collaboration with other students.

Diversity

George Mason University promotes a living and learning environment for outstanding growth and productivity among its students, faculty and staff. Through its curriculum, programs, policies, procedures, services and resources, Mason strives to maintain a quality environment for work, study and personal growth.

An emphasis upon diversity and inclusion throughout the campus community is essential to achieve these goals. Diversity is broadly defined to include such characteristics as, but not limited to, race, ethnicity, gender, religion, age, disability, and sexual orientation. Diversity also entails different viewpoints, philosophies, and perspectives. Attention to these aspects of diversity will help promote a culture of inclusion and belonging, and an environment where diverse opinions, backgrounds and practices have the opportunity to be voiced, heard and respected.

The reflection of Mason's commitment to diversity and inclusion goes beyond policies and procedures to focus on behavior at the individual, group and organizational level. The implementation of this commitment to diversity and inclusion is found in all settings, including individual work units and groups, student organizations and groups, and classroom settings; it is also found with the delivery of services and activities, including, but not limited to, curriculum, teaching, events, advising, research, service, and community outreach.

Acknowledging that the attainment of diversity and inclusion are dynamic and continuous processes, and that the larger societal setting has an evolving socio-cultural understanding of diversity and inclusion, Mason seeks to continuously improve its environment. To this end, the University promotes continuous monitoring and self-assessment regarding diversity. The aim is to incorporate diversity and inclusion within the philosophies and actions of the individual, group and organization, and to make improvements as needed.

GMU Email Accounts:

Students must use their Mason email accounts to receive important University information, including messages related to this class. See http://masonlive.gmu.edu for more information.

Disability Accommodations:

If you are a student with a disability and you need academic accommodations, please see me and also contact the Office of Disability Services (ODS) at 993-2474. All academic accommodations must be arranged through the ODS. http://ods.gmu.edu

Other Useful Campus Resources:

Mason has several support services for students. Please go to http://ctfe.gmu.edu/teaching/student-support-resources-on-campus/ for a directory of services.

University Policies:

The University Catalog, http://catalog.gmu.edu, is the central resource for university policies affecting student, faculty, and staff conduct in university academic affairs. Other policies are available at http://universitypolicy.gmu.edu/. All members of the university community are responsible for knowing and following established policies.