**GEO 3391 Sea-Level Rise: Impacts and Responses**

**Instructor:** Colin Polsky

**Term:** Fall 2015

**Credit hours:** 3

**Course description:** This course will survey causes and impacts of climate change and sea-level rise, and the resulting impacts on metropolitan south Florida. Issues related to the measurement and monitoring of sea level through recent and geological time will be explored. Long term issues related to Human-Environmental relationships considering dynamic trends in sea level and the ephemeral state of coastal landforms of south Florida will be considered. Students will be able to critique issues related to climate change and sea level rise through and understanding of natural and anthropogenic processes.

**Course Objectives:** By the end of the course, students should be able to

1) Identify global and local causes and impacts of climate change and sea-level rise

2) Differentiate various measurements and components of sea-level rise

3) Assess climate maps and data critically and objectively

4) Demonstrate understanding of the multiple interactions between the natural and built environment in the context of chronic sea-level rise and the exacerbation of acute hazards including hurricanes

5) Evaluate short and long term adaptation options and solutions to sustain South Florida's coastal populations and natural resources

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| **Week** | **Topics/Subtopics** | **Outside of Class Assignments** |
| 1. | An Introduction to Global Climate Change & Sea-Level Rise ·        Overview·        Causes·        Impacts·        Timescales·        Recent Estimates | Statement of Dr. Piers SellersDeputy Director, Sciences and Exploration DirectorateNASA Goddard Space Flight Center Before theCommittee on Commerce, Science, & TransportationSubcommittee on Science and Space United States Senate<http://www.commerce.senate.gov/public/?a=Files.Serve&File_id=1f5d907c-c4de-4390-8e73-ab16fb1e341c>NASA Activity - Monitoring Sea Level<http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11241>(Available for Download)Multi-year Arctic Sea Ice 2014 Animation:<http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4251&button=recent>Investigation 2: Causes of Climate Change ActivityConcentration of Atmospheric Carbon Dioxide Since the Industrial Revolution<http://www.ces.fau.edu/nasa/module-4/investigation-2.php> |
| 2. | **Measuring** Sea-Level Change ·        How is it measured? When? How has measurement changed over time?·        Proxy Measurements·        Tide Gages·        Satellite Altimetry·       Gravity Recovery and Climate Experiment (GRACE)  | Tides Tutorial <http://oceanservice.noaa.gov/education/kits/tides/lessons/tides_tutorial.pdf>READ CHAPTER 2 (p. 23-32): Measured Global Sea-Level RiseNational Research Council (NRC), Committee on Sea Level Rise in California, Oregon, andWashington, Board on Earth Sciences and Resources and Ocean Studies Board. Sea-Level Risefor the Coasts of California, Oregon, and Washington: Past, Present and Future; The NationalAcademies Press: Washington, DC, USA, 2012.available from: http://www.water.ca.gov/climatechange/docs/NRC\_SLR\_Draft-06-22-2012.pdf |
| 3. | Sea-Level **Components**·         Ice Sheet Mass Balance·       Thermal Expansion·      Glaciers, Ice Caps, and Ice Sheets·      Terrestrial Water Storage | NOAA Tide Gauge ActivityInvestigation 4: Impacts of Climate Change Activity – Sea Level over TimeREAD CHAPTER 4 (p. 39-63): Contributions to Global Sea-Level RiseNational Research Council (NRC), Committee on Sea Level Rise in California, Oregon, andWashington, Board on Earth Sciences and Resources and Ocean Studies Board. Sea-Level Rise |
| 4. | A **Geologic History** of Earth’s Changes in Sea-Level·         The mechanisms by which temperature, CO2, and sea level have always been linked·       How has Florida looked in the past?·         Abrupt (SLR pulses) versus gradual changes·         Why is it different this time? | Investigation 1: Causes of Climate Change ActivityHow Has the Concentration of Carbon Dioxide and Temperature Changed Over the Past 800,000 Years?<http://www.ces.fau.edu/nasa/module-4/investigation-1.php>Excerpts from Fletcher’s “Climate Change” and “geologic history of Earth” books |
| 5. | Looking at Maps and Data: **Objectivity & Uncertainty**·        Inundation maps: bathtub – static vs dynamic·       How you can tell if a map is misleading·       Underlying Data and Instrumentation: How can analysis misinterpret it?·       Two examples of “cherry-picking” | **(CSI Module)** Addressing Climate Skeptics' Claims<http://www.ces.fau.edu/nasa/module-7/>Two examples of “cherry-picking”<http://www.realclimate.org/index.php/archives/2011/07/is-sea-level-rise-accelerating/>http://www.forbes.com/sites/jamestaylor/2014/06/25/government-data-show-u-s-in-decade-long-cooling/<http://www.skepticalscience.com/graphics.php?g=47>worksheet on bothExcerpts from “Cartographic controversies”, “Lying with maps”, and “Map Appreciation” |
| 6. | Sea-Level Rise I·       Issues with drainage/stormwater management·       Slow creep: groundwater·       Coastal vs inland impacts | Zhang, K. (2011). Analysis of non-linear inundation from sea-level rise using LIDAR data: a case study for South Florida. Climatic Change, 106(4), 537-565.Eddins, Quinn, 2014, CBRE Research: Rising Tides, Increasing Risk: How the Insurance Industry’s Response to Global Climate Change Could Impact Commercial Real Estate InvestorsStanton, E. A. and Ackerman, F. 2007. Florida and Climate Change. The Costs of Inaction. Global Development and Environment Institute, Tufts University November 2007available from <http://www.ase.tufts.edu/gdae/Pubs/rp/FloridaClimate.html> |
| 7. | Sea-Level Rise II·         Risk Perception·         Accounting for socioeconomic vulnerability·         Public Health | Yale climate and health report - <http://www.climatechangecommunication.org/sites/default/files/reports/Global-Warming-Public-Health-October%202014%20FINAL.pdf>Moser, S. C. 2010. Now More Than Ever: The Need for More Societally Relevant Research on Vulnerability and Adaptation to Climate Change.” Applied Geography 30 (4): 464–474.Martinich, J., Neumann, J., Ludwig, L., & Jantarasami, L. (2012). Risks of sea level rise to disadvantaged communities in the United States. Mitigation and Adaptation Strategies for Global Change, 1-17. |
| 8. | Sea-Level Rise III·        Examples: Venice, Miami BeachMIDTERM EXAM | Rahmstorf, S. (2010). A new view on sea level rise. *Nature reports climate change*, 44-45.<http://www.nature.com/climate/2010/1004/full/climate.2010.29.html> |
| 9. | Hurricanes I·         Coastal Hazards·         Environmental Contamination | NOAA Storm Surge Overview<http://www.nhc.noaa.gov/surge/>Excerpts from Craig Colton’s writing on flood/storm surge threat |
| 10. | Hurricanes II·         Economic & Policy Implications·         Property and Infrastructure at Risk·         Insurance | Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change <http://www.ces.fau.edu/files/projects/climate_change/Fl_ResilientCoast.pdf> |
| 11. | Hurricanes III·        Examples: Galveston, New Orleans, the Netherlands, post-Sandy | Neumann, J. E., Emanuel, K., Ravela, S., Ludwig, L., Kirshen, P., Bosma, K., & Martinich, J. (2014). Joint effects of storm surge and sea-level rise on US Coasts: new economic estimates of impacts, adaptation, and benefits of mitigation policy. *Climatic Change*, 1-13. |
| 12. | Adaptation I : short term·         Soft/Hard protection·         Land-use changes·         Retrofitting assets·         Sustainable development | Adaptation Action Areas: Policy Options for Adaptive Planning for Rising Sea Levels[*https://southeastfloridaclimatecompact.files.wordpress.com/2014/07/final-report-aaa-11-6-13-1.pdf*](https://southeastfloridaclimatecompact.files.wordpress.com/2014/07/final-report-aaa-11-6-13-1.pdf)Alexander, K. S., Ryan, A., & Measham, T. G. (2012). Managed retreat of coastal communities: understanding responses to projected sea level rise. Journal of Environmental Planning and Management, 55(4), 409-433. |
| 13. | Adaptation II: long term·         Drastic measures·         Retreat: Shrinking Cities·         Whole new way of thinking! | Moser, S. C., Jeffress Williams, S., & Boesch, D. F. (2012). Wicked challenges at land's end: managing coastal vulnerability under climate change. Annual Review of Environment and Resources, 37, 51-78.Bierbaum, R., Smith, J. B., Lee, A., Blair, M., Carter, L., Chapin III, F. S., Fleming, P., Ruffo, S., Stults, M., McNeeley, S., Wasley, E., & Verduzco, L. (2013). A comprehensive review of climate adaptation in the United States: more than before, but less than needed. Mitigation and Adaptation Strategies for Global Change, 18(3), 361-406. |
| 14. | Environmental Impacts I·        Everglades Restoration·        The tradeoff between flood protection and preventing saltwater intrusion | Sea Level Rise In Everglades National Park<http://www.nps.gov/ever/naturescience/cceffectsslrinpark.htm>Recommendations for Everglades Restoration under a Future Climate Scenario <http://www.ces.fau.edu/ces/climate_change/everglades-recommendations-2014/final-report.php> |
| 15. | Environmental Impacts II·        Natural buffers and protection·        Co-benefits | Mitsova, D., & Esnard, A. M. (2012). Holding Back the Sea An Overview of Shore Zone Planning and Management. Journal of Planning Literature, 27(4), 446-459. |
| 16. | Environmental Impacts III·        Human Environment Interactions | Influence of Sea Level Rise on Natural Systems of the Greater Everglades 2011 <http://www.ces.fau.edu/files/projects/climate_change/FAU_SLR_Workshop_Factsheet_April2011_0.pdf> |

**Course evaluation method**: Class attendance and participation will be 20% of the course grade. There will be 14 quizzes that count for 30 % of the total grade for the course, a midterm exam for 20% of the course grade and a cumulative final exam that is 30% of the course grade.

**Policy on late work and incompletes**: The quiz period will be open 7 days, from Monday 7am to the following Monday at 7am. Anyone not taking the quiz in that period will be deducted 5% per day late unless arranged in advanced and with good reason.

**Special course requirements**: NONE

**Required text:** There is a weekly lecture outline that the students will download and fill in which will be provided on Blackboard

**Course grading scale:**

**Cumulative Performance Grade**

>94% A

>90% - 94% A-

>87% - 90% B+

>83% - 87% B

>80% - 83% B-

>75% - 80% C+

>65% - 75% C

>60% - 65% C-

>57% - 60% D+

>53% - 57% D

>50% - 53% D-

<50% F

**Classroom etiquette policy:** University policy on the use of electronic devices states: “In order to enhance and maintain a productive atmosphere for education, personal communication devices, such as cellular telephones and pagers, are to be disabled in class sessions.”

**Disability policy statement:** In compliance with the Americans with Disabilities Act (ADA), students who requirespecial accommodation due to a disability to properly execute coursework mustregister with the Office for Students with Disabilities (OSD) - in Boca Raton, SU 133

(561-297-3880); in Davie, MOD 1 (954-236-1222); in Jupiter, SR 117 (561-799-8585); or at the Treasure Coast, CO 128 (772-873-3305) – and follow all OSD procedures.

**Honor Code policy statement:** Students at Florida Atlantic University are expected to maintain the highest ethicalstandards. Academic dishonesty, including cheating and plagiarism, is considered aserious breach of these ethical standards, because it interferes with the Universitymission to provide a high quality education in which no student enjoys an unfairadvantage over any other. Academic dishonesty is also destructive of the Universitycommunity, which is grounded in a system of mutual trust and places high value onpersonal integrity and individual responsibility. Harsh penalties are associated withacademic dishonesty.

**For more information,** see University Regulation 4.001 at <http://www.fau.edu/ctl/4.001_Code_of_Academic_Integrity.pdf>

**Supplementary/recommended readings:**

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., & Wreford, A. (2009). Are there social limits to adaptation to climate change? Climatic Change, 93(3-4), 335-354.

Alley, W. M. (2001). Ground water and climate. Groundwater, 39(2), 161-161.

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Arthur, J.D., Baker, A.E., Cichon, J.R., Wood, H.A.R., and Rudin, A. (2005) Florida Aquifer Vulnerability Assessment (FAVA): Contamination potential of Florida’s principal aquifer systems: Report submitted to Division of Water Resource Management, Florida Department of Environmental Protection, 148 p. Barlow, P. M. (2003). Ground water in freshwater-saltwater environments of the Atlantic coast Geological Survey (USGS).

Baker, P.G., & Cichon, J.R. (2009) Florida Aquifer Vulnerability Assessment (FAVA): A Ground-water Protection and Management Tool. Prepared For: The Department of Environmental Protection as part of the Florida Aquifer Vulnerability Assessment (FAVA) Phase II Project, Contract No.RM-059

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Bender, C. (2010). Broward & Miami-Dade counties will need alternative s& sources within 5 –10 years. FSBPA Conference, Clearwater, FL.

Bosello, F., Roson, R., & Tol, R. S. (2007). Economy-wide estimates of the implications of climate change: Sea-level rise. Environmental and Resource Economics, 37(3), 549-571.

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Broward County (2013) Climate Change Element of the Broward County Comprehensive Plan. Retrieved from: http://www.broward.org/PlanningAndRedevelopment/ComprehensivePlanning/Documents/ClimateChangeElement.pdf

Burkett, V., and Davidson, M. (2012). Coastal Impacts, Adaptation and Vulnerabilities: A Technical Input to the 2013 National Climate Assessment. Island Press, 216 pp.

Cazenave, A., & Nerem, R. S. (2004). Present‐day sea level change: Observations and causes. Reviews of Geophysics, 42(3).

Church, J. A., & White, N. J. (2011). Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics, 32(4-5), 585-602.

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Corner, A., Whitmarsh, L., & Xenias, D. (2012). Uncertainty, scepticism & attitudes towards climate change: Biased assimilation & attitude polarisation. Climatic Change, 114(3-4), 463-478.

Delusca, K., Tramblay, M., & Chouinard, O. (2004). Climate change, perceptions and perspectives: case study of coastal communities in south-eastern part of New Brunswick. Technical Report, Université de Moncton, New Brunswick.

Dillman, D. A. (2007). Mail & internet surveys: the tailored design method. Wiley New York.

Domenico, P. A., & Schwartz, F. W. (1998). Physical and chemical hydrogeology (Vol. 44). New York: Wiley.

Dominguez, J. M. L., & Wanless, H. R. (1991). Facies Architecture of a Falling Sea‐Level Strandplain, Doce River Coast, Brazil. Shelf sand and sandstone bodies: geometry, facies and sequence stratigraphy, 257-281.

Flugman, E., Mozumder, P., & Randhir, T. (2012). Facilitating adaptation to global climate change: Perspectives from experts & decision makers serving the Florida Keys. Climatic Change, 112(3-4), 1015-1035.

Frazier, T. G., Wood, N., Yarnal, B., & Bauer, D. H. (2010). Influence of potential sea level rise on societal vulnerability to hurricane storm-surge hazards, Sarasota County, Florida. Applied Geography, 30(4), 490-505.

Gedan, K. B., Kirwan, M. L., Wolanski, E., Barbier, E. B., & Silliman, B. R. (2011). The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. Climatic Change, 106(1), 7-29.

Gesch, D. B. (2009). Analysis of LiDAR elevation data for improved identification & delineation of lands vulnerable to sea-level rise. Journal of Coastal Research: Special Issue 53: pp 49-58.

Hammer-Klose, E. & R. Thieler. 2001. Coastal Vulnerability to Sea-Level Rise: A Preliminary Database for the US Atlantic, Pacific and Gulf of Mexico Coasts. Woods Hole, MA: United States Geological Survey.

Hanemann, W. M. (2008). What is the economic cost of climate change? Department of Agricultural & Resource Economics, UCB.

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. Proceedings of the National Academy of Sciences of the United States of America, 109(37), E2415-23.

Hanson, S., Nicholls, R., Ranger, N., Hallegatte, S., Corfee-Morlot, J., Herweijer, C., & Chateau, J. (2011). A global ranking of port cities with high exposure to climate extremes. Climatic Change, 104(1), 89-111.

Horton, B. P., Rahmstorf, S., Engelhart, S. E., & Kemp, A. C. (2014). Expert assessment of sea-level rise by AD 2100 & AD 2300. Quaternary Science Reviews, 84, 1-6.

Hunt, A., & Watkiss, P. (2011). Climate change impacts and adaptation in cities: a review of the literature. Climatic Change, 104(1), 13-49.

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Jacobs, K. (2014). Written Testimony - Kristin Jacobs, Commissioner, Broward County, FL. Environment and Public Works Clean Air and Nuclear Safety Subcommittee.

Jevrejeva, S., Moore, J., & Grinsted, A. (2010). How will sea level respond to changes in natural & anthropogenic forcings by 2100? Geophysical Research Letters, 37(7).

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Kleinosky, L. R., Yarnal, B., & Fisher, A. (2007). Vulnerability of Hampton Roads, Virginia to storm-surge flooding and sea-level rise. Natural Hazards, 40(1), 43-70.

Landers, J. (2014). Comprehensive Everglades Restoration Plan Must Account for Climate Change. Civil Engineering—ASCE, 84(9), 35-37.

Langevin, C. D., and Zygnerski, M. (2013). Effect of Sea‐Level rise on salt water intrusion near a coastal well field in Southeastern Florida. Groundwater, 51(5), 781-803.

Leatherman, S. P., Zhang, K., and Douglas, B. C. (2000). Sea-level rise shown to drive coastal erosion. Eos, Transactions American Geophysical Union, 81(6), 55-57.

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. Climatic Change, 77(1-2), 45-72.

Leiserowitz, A. A. (2005). American risk perceptions: Is climate change dangerous? Risk Analysis, 25(6), 1433-1442.

Li, X., Rowley, R. J., Kostelnick, J. C., Braaten, D., Meisel, J., & Hulbutta, K. (2009). GIS analysis of global impacts from sea level rise. Photogrammetric Engineering & Remote Sensing, 75(7), 807-818.

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Mozumder, P., Flugman, E., & Randhir, T. (2011). Adaptation behavior in the face of global climate change: Survey responses from experts and decision makers serving the Florida Keys. Ocean & Coastal Management, 54(1), 37-44.

Murley, J., Heimlich, B. N., & Bollman, N. (2008). Florida’s Resilient Coasts—A State Policy Framework for Adaptation to Climate Change. Florida Atlantic University Center for Urban and Environmental Solutions and National Commission on Energy Policy. Fort Lauderdale, Florida.

National Oceanic and Atmospheric Administration, Oceanic and Atmospheric Research (NOAA). (2012). Global sea-level rise scenarios for the US National Climate Assessment. US Department of Commerce, National Oceanic and Atmospheric Administration, Oceanic and Atmospheric Research, Climate Program Office. Retrieved from http://cpo.noaa.gov/sites/cpo/Reports/2012/NOAA\_SLR\_r3.pdf

National Research Council Board, Ocean Studies (NRC). (2012). Sea-level rise for the coasts of California, Oregon, and Washington: Past, present, & future. National Academies Press.

Nelson, Bill. Senator Bill Nelson subcommittee field hearing in Miami Beach, FL : Leading the way: Adapting to south Florida’s changing coastline: Committee on Commerce, Science, and Transportation: Subcommittee on Science and Space, U.S. Senate, City Hall, Commission Chambers - City of Miami Beach (2014).

Neumann, J. E., Hudgens, D. E., Herter, J., & Martinich, J. (2010). Assessing sea-level rise impacts: A GIS-based framework and application to coastal New Jersey. Coastal Management, 38(4), 433-455.

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Parkinson, R. W. (2009). Adapting to rising sea level: A Florida perspective. Sustainability 2009: The Next Horizon.

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Rise Scenarios for the US National Climate Assessment. NOAA Technical Report. National Oceanic and Atmospheric Administration, p. 37.

Pollard, D., & DeConto, R. M. (2009). Modelling west Antarctic ice sheet growth & collapse through the past five million years. Nature, 458(7236), 329-332.

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Rygel, L., O’sullivan, D., & Yarnal, B. (2006). A method for constructing a social vulnerability index: An application to hurricane storm surges in a developed country. Mitigation and Adaptation Strategies for Global Change, 11(3), 741-764.

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South Florida Regional Planning Council (SFRPC). (2012). Statewide regional evacuation study program: Chapter III regional behavioral analysis summary from South Florida Regional Planning Council.

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Weiss, J. L., Overpeck, J. T., & Strauss, B. (2011). Implications of recent sea level rise science for low-elevation areas in coastal cities of the conterminous USA. Climatic Change, 105(3-4), 635-645.

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