Course Title: Sea Level Change - The Israeli case in World Perspective
(ANAR116)

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2021 Winter Quarter: 1/4/21 – 3/20/21

Course description: Can we save the coastal areas of the globe from drowning? Predictive sea-level models foresee Global sea-level rise in magnitudes of 0.8 – 1 meters above present mean sea level. The projected rise in sea level will jeopardize the 1 billion people living along the coast worldwide below elevations of 10 meters and infrastructures, wildlife, and recreational areas. There have been significant changes in sea level over the past 2 million years, both at the local and global scales, and a complete understanding of natural cycles of change and anthropogenic effects is imperative for future global development.

This course provides a general understanding of sea-level changes in different spatial and temporal scales and their driving factors and possible consequential scenarios. Students are introduced to the general terminology used in this field, coastal/marine sea-level indicators and their uncertainty levels, and corresponding dating methods. The course emphasizes appropriate commonly used sea-level research approaches and studies from the coast of Israel located in the southeastern part of the Mediterranean Sea. This coastal area is considered tectonically stable, has low isostatic rates, and has been constantly populated over the last 10,000 years. These characteristics make it an ideal location for understanding the general factors contributing to sea-level changes and the resulting implications. By the end of the course, students will have a clear understanding of how to interpret issues and news concerning one of climate change's most significant and enviable impacts. Toward the end of course possible environmental solutions will also be discussed.

Class	dates	Unit	Topic list	Themes
1	(1/5/21)	A	Intro blurb	• Class participants acquaintance • Course topics • Course aims, literature review of appropriate reading material and student assignments • Evaluation-pre course test
2 - 3	(1/7/21–1/12/21)	A	Climate 1	• The history of Sea-level research • Water cycles • Glaciers/Icecaps and their contribution to sea-level change • Long-period climate change during the Quaternary • Marine isotope stage timeline (MIS)
4 - 5	(1/14/21 – 1/19/21)	A	Climate 2	• Climate change and feedback mechanisms • Climate change forcing factors • Discussion of articles in general newspapers
6 - 7	(1/21/21-1/26/21)	B	100,000 of climate data: Late Pleistocene - Holocene transition	• Discussion of Genine et al. (1995) paper • Palaeo-climate proxies Last glacial maximum termination • Climate anomalies during the Holocene
8 - 9	(1/28/21 - 2/2/21)	B	Sea level change in global and temporal scales	• Measurement methods (in broad perspective) • Global/regional/local sea-level changes • Characterization of the earth (earth viscosity) • Eustatic, Isostasy, GIA • Short periodic sea-level changes • Discussion of Shtienberg et al. (2014) paper
10 - 11	(2/4/21 - 2/9/21)	B	Dating methods used in Israeli sea level research	• Classification of dating methods • Dendrochronology, Lake varves, ^{14}C, OSL, Ur/Thorium series • Uncertainty levels • Presentation prep.
12 - 13	(2/11/21 - 2/16/21)	B	Terrestrial and Coastal indicators found in the coast of Israel	• Discussion of Sivan et al. (2015) paper • The geophysical characteristics of the Israeli coast • Biological sea-level markers
14 - 15	(2/18/21 - 2/23/21)	B	Natural and humanmade sea-level indicators	• Coastal geomorphological and sedimentological markers • Humanmade features and archaeological indications • Discussion of Goodman-Chernov et al. (2016)
16 - 17	(2/25/21 - 3/2/21)	B	Green solutions for a better future	• Renewable; green alternative energy solutions • Greenhouse gas emissions reduction
18 - 19	(3/4/21 - 3/9/21)	C	Student presentations	• Student presentations
20	(3/11/21)	C	Final test preparations	• Course summery

				• Student questions • Test preview
21	3/16/21		Final test	• 40 multiple choice questions

Goals: During the extent of the course, the students will:

- Get an understanding of the forcing factors that contribute to global/relative sea-level changes.
- Acquire the relevant scientific terminology used in sea-level research.
- Learn how to identify coastal sea-level markers found on siliciclastic and bioclastic coasts of Israel's beaches and evaluate their uncertainty level.
- Classify coastal environments that are at risk and asses destruction scenarios leading to predicted sea-level rise.
- Assess standard methodologies that are of use in sea level research conducted in Israel.
- Differentiate fact from fiction regarding the sea-level change.
- Get acquainted with how to write a scientific report consisting of a problem and conclusion backed by scientific data.
- Develop a PowerPoint presentation from a scientific paper and present it to an academic audience.
- Improve practical reading and reviewing skills.

Unit Schedule

Unit A (Lecture 1 – 5)

Unit outcome:

General understanding of the sea level change fluctuation over the last 2 million years (Pleistocene - Holocene) and accepted terminology. Acquaintance with the forcing factors that contribute to the relative sea level change and how the climate varied over the Pleistocene - Holocene.

Lecture 1: Acquaintance, course description and introduction

Goals

We get to know each other, review the course topics, class activities as well as proposed reading material, student exercises and course grading. During this week we will also discuss the history of sea level research and the potential outcomes of sea level rise scenarios.

By the end lecture-1 the students will be able to:

1. Recognize the names of class participants and course instructor.
2. Get familiar with the course topics, student exercises and grading policy.
3. Discuss the course's objectives and aims.

This week's in class activity

During lecture-1 an initial 25 multiple question quiz will be handed out and filled out by the class participant. This quiz will assess the general knowledge of the students regarding the coastal characteristics, scientific terms and methodologies used in sea level research as well as studies conducted in the proximal vicinity of the Israeli coast (The quiz **will not** be reflected in the final grade and is only given for evaluation purposes of both the instructor and the class participants).

Optional reading material:

- Murray-Wallace, C.V., Woodroffe, C.D., 2014. Quaternary Sea-Level Change- A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Chapter 1).

Lecture 2 - 5: Climate

Goals:

During lectures 2-5 we will discuss the dominant mechanisms responsible for Quaternary sea-level alterations. These include effects of continental-scale ice sheets build-up, and their rapid decay at the end of glaciations. We will explore the long climate changes throughout the Quaternary as well as climate changing and feeding mechanisms.

By the end lecture 5 the students will:

1. Get acquainted of the global water cycles.
2. Get Familiar with the contribution of glaciers to global sea level changes.
3. Grasp the long period cyclic nature of sea level oscillation.
4. Understand climate feedback changing mechanisms.

Optional reading material and internet sites:

- https://blogs.egu.eu/divisions/cr/2016
- http://www.cru.uea.ac.uk/cru/info/causecc/

- Denton, G.H., Anderson, R.F., Toggweiler, J.R., Edwards, R.L., Schaefer, J.M., Putnam, A.E., 2010. The Last Glacial Termination. Science 328, 1652 - 1655.
- http://www.ncdc.noaa.gov/paleo/abrupt/data4.html
- Murray-Wallace, C.V., Woodroffe, C.D., 2014. Quaternary Sea-Level Change- A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Pages 256 - 262).

Class activity:

Class discussing of the differences between newspaper articles and scientific peer review papers

Home activity:

Selection a non-refereed journal article (see selected examples section for relevant links) and write a half a page summary of a chosen article from a non-refereed journal. Key points to include in the summery are - what is the main statements presented in the article and is it backed up with relevant scientific facts?

Selected examples of non-refereed nonscientific journal articles:

- https://www.telegraph.co.uk/comment/columnists/christopherbooker/5067351/Rise-of-sea-levels-is-the-greatest-lie-ever-told.html
- https://ulmhawkeyeonline.com/22064/opinion/climate-change-in-america-a-cycle-of-misconception/
- https://www.heritage.org/environment/report/consequences-paris-protocol-devastating-economic-costs-essentially-zero

Rubric of student assignment

Half a page summary of a chosen article from a non-refereed journal

Criteria	Possible	Earned
A relevant publication from a popular journal/newspaper/web that discusses sea level change	1	

Main statements presented in the article	1	
State the possible readers that this article was written for	1	
Identify fact from fiction – was the papers statement backed up by actual results or at least a scientist/researcher (run a background check in google scholar) that conducted a study that verified the claims presented in the article?	2	
TOTAL	**5**	

Unit Schedule

Unit B (Lectures 6 – 17)

Unit outcome:

During this unit we will strengthen our understanding of sea-level and climate changes through lectures as well as peer review articles. Substantial time will be devoted for assessing scientific publication and understanding how to critique it. These topics will be the steppingstone before unit C in which the participating students will create a talk on a course related topic.

By the end of unit B the students will:

1. Improve their understanding on sea-level\climate change topics and relevant working methodologies.
2. Get acquainted with how to develop a PowerPoint presentation.
3. Strengthen their scientific reviewing skills.

Lectures 6 - 9: How do scientists reconstruct the climate and sea level of the past?

Goals:

During these lectures we will examine palaeo climate proxies and discuss how they are used for understanding climate changes and climate abnormalities over the last glacial – interglacial cycle. We will also talk over how sea level changes differ in various spatial scales as well as how global – local factors influence these changes.

By the end of these lectures the students will:

1. Understand the relationship of climate and sea level changes.

2. Understand the difference between global to local sea level changes.
3. Get familiar with short – long periodic sea level variation.
4. Identify subjective nonscientific and deceptive articles.

This week's in class activity:

- Class discussion on the working methodology presented in the paper by Genin et al. (1995) paper and its suitability for the research.
- A thorough review of Shtienberg et al. (2014). This review will include a discussion of the chosen methods used for answering the research questions as well as conclusions raised from the article.

Required reading:

- Genin, A., Lazar, B., Brenner, S., 1995. Vertical mixing and coral death in the Red Sea following the eruption of Mount Pinatubo. Nature 377, 507-510.
- Shtienberg, G., Zviely, D., Sivan, D., Lazar, M., 2014. Two centuries of coastal change at Caesarea, Israel: natural processes vs. human intervention. Geo-Marine Letters 34, 365-379.
- C.V. Murray-Wallace, C.D. Woodroffe, 2014. Quaternary Sea-Level Change- A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Pages 41-65).
- A. Rovere, P. Stocchi, M. Vacchi, 2016. Eustatic and relative sea level changes. Current Climate Change Reports, 2(4), 221-231.

Optional reading material and internet sites:

- https://blogs.egu.eu/divisions/cr/2016
- http://www.cru.uea.ac.uk/cru/info/causecc/
- http://www.ncdc.noaa.gov/paleo/abrupt/data4.html

Lectures 10 - 11: Dating methods used in sea-level research

Goals:

The students will get acquainted with radiometric dating methods as well as geoarchaeological temporal assessment technics that are used in sea level research. The introduction to these dating techniques will be presented by studies conducted in sea-level research.

By the end of lecture 11 the students will:

1. Be acquainted with the dating technics that are used in present day sea level/geomorphological/geological research around the globe.
2. Identify the best suited dating methodology for a specific spatial and temporal research.
3. Understand how to construct a PowerPoint presentation aimed for a scientific talk (i.e. seminar; conference).

Home activity:

A thorough review of Sivan et al. (2015) paper. This review will include a discussion of the dating result differences (OSL to ^{14}C) presented in it.

Required reading:

Sivan, D., Greenbaum, N., Cohen-Seffer, R., Sisma-Ventura, G., Almogi-Labin, A., Porat, N., Melamed, Y., Boaretto, E., Avnaim-Katav, S., 2015. Palaeo-environmental archive of groundwater–surface water interaction zone, the Kebara wetlands, Carmel coast, Israel. Quaternary International.

Optional reading material and internet sites:

- https://c14.arch.ox.ac.uk/oxcal.html (this is a free software used for calibration of ^{14}C results)
- Murray-Wallace, C.V., Woodroffe, C.D., 2014. Quaternary Sea-Level Change - A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Pages 135 – 158; 162 - 168).
- Liritzis, I., Singhvi, A.K., Feathers, J.K., Wagner, G.A., Kadereit, A., Zacharias, N., Li, S.-H., 2013. Luminescence Dating in Archaeology, Anthropology, and Geoarchaeology. 1-75.

Lectures 12 - 13: Palaeo- biological sea level markers

Goals:

During lectures 12-13 we will discuss the use of biological markers that are used in present day research for assessing sea level variations. We will read two peer review scientific papers of studies that conducted in the Israeli coast and thoroughly review them.

By the end of lecture 13 the students will:

1. Understand Israel's coastal geomorphological cherectoristis.
2. Be acquainted with paleo- biological sea level markers that are found in the Israeli coast and are used in present day research.
3. Strengthen scientist review skills.

In class activity:

A through scientific review of Sivan et al. (2015) paper will be held in class. We will discuss the background, research methods, results, discussions and conclusions. Following the presentation, a class debate will be held debating on the strengths and weakness of the studies.

Required reading:

- Murray-Wallace, C.V., Woodroffe, C.D., 2014. Quaternary Sea-Level Change- A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Pages 79 – 129).
- Goodman-Tchernov, B., Katz, O., 2016. Holocene-era submerged notches along the southern Levantine coastline: Punctuated sea level rise? Quaternary International 401, 17-27.
- Shtienberg, G., Dix, J., Waldmann, N., Makovsky, Y., Golan, A., Sivan, D., 2016. Late-Pleistocene evolution of the continental shelf of central Israel, a case study from Hadera. Geomorphology 261, 200-211.

Lectures 14 - 15: Geomorphological) and Archeological sea-level indicators

Goals:

During lectures 14 - 15 we will discuss natural coastal and manmade sea level indicatours that are used in present day research. We will read a peer review scientific paper of a study that conducted in the Israeli coast and thoroughly review it.

By the end of lecture 15 the students will:

1. Be acquainted with the geomorphological (natural) as well as archaeological construction build in the coastal setting and discuss how these indicators are used in present day sea level research.

2. Strengthen scientific review skills.

In class activity:

A through scientific review of Goodman-Chernov et al. (2016) paper will be held in class. We will discuss the background, research methods, results, discussions and conclusions. Following the presentation, a class debate will be held debating on the strengths and weakness of the studies.

Home activity:

Two-page review of a chosen article that assesses sea-level/climate change.

Rubric of student assignment 2

Criteria	Possible	Earned
Selection of a relevant publication from a peer reviewed journal	2	
Summary (including: research aims/hypothesis/questions, methods, results and discussions)	5	
Main finds	3	
Some points to raise in the review • Are the research questions clear? • Are the selected methods suitable for answering the research questions? • Is the discussion backed up by the results • Are the conclusions backed up by the working results?	5	

• Do the conclusions answer the research quietens? • Strength and weaknesses of paper		
TOTAL	**15**	

Optional papers for review

- Barkai, O., Katz, O., Mushkin, A., Goodman-Tchernov, B.N., 2017. Long-term retreat rates of Israel's Mediterranean Sea cliffs inferred from reconstruction of eroded archaeological sites. Geoarchaeology.
- Benjamin, J., Rovere, A., Fontana, A., Furlani, S., Vacchi, M., Inglis, R.H., Galili, E., Antonioli, F., Sivan, D., Miko, S., Mourtzas, N., Felja, I., Meredith-Williams, M., Goodman-Tchernov, B., Kolaiti, E., Anzidei, M., Gehrels, R., 2017. Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review. Quaternary International 449, 29-57.
- Dean, S. Horton B.P., Evelpidou N., Cahill N., Spada G., Sivan D., 2019. Can we detect centennial sea-level variations over the last three thousand years in Israeli archaeological records? Quaterany Science Reviews 210, 125-135.
- Felsenstein, D., Lichter, M., 2013. Social and economic vulnerability of coastal communities to sea-level rise and extreme flooding. Natural Hazards 71, 463-491.
- Galili, E., Nir, Y., 1993. The submerged Pre-Pottery Neolithic water well of Atlit-Yam, northern Israel and its palaeoenviromental implications. The Holocene 3, 265-270.
- Galili, E., Zviely, D., Ronen, A., Mienis, H.K., 2007. Beach deposits of MIS 5e high sea stand as indicators for tectonic stability of the Carmel coastal plain, Israel. Quaternary Science Reviews 26, 2544-2557.
- Galili, E., Şevketoğlu, M., Salamon, A., Zviely, D., Mienis, H.K., Rosen, B., Moshkovitz, S., 2016. Late Quaternary beach deposits and archaeological relicts on the coasts of Cyprus, and the possible implications of sea-level changes and tectonics on the early populations. Geological Society, London, Special Publications 411, 179-218.
- Hinkel, J., Klein, R.J.T., 2009. Integrating knowledge to assess coastal vulnerability to sea-level rise: The development of the DIVA tool. Global Environmental Change 19, 384-395.

- Katz, O., Mushkin, A., 2013. Characteristics of sea-cliff erosion induced by a strong winter storm in the eastern Mediterranean. Quaternary Research 80, 20-32.
- Lichter, M., Zviely, D., Klein, M., Sivan, D., 2010. Sea-Level Changes in the Mediterranean: Past, Present, and Future – A Review. 15, 3-17.
- Murray-Wallace, C.V., Woodroffe, C.D., 2014. Quaternary Sea-Level Change- A Global Perspective. Cambridge University Press, University Printing House, Cambridge CB2 8BS, United Kingdom. (Pages 369 – 498).
- Mushkin, A., Katz, O., Crouvi, O., Alter, S.R., Shemesh, R., 2016. Sediment contribution from Israel's coastal cliffs into the Nile's littoral cell and its significance to cliff-retreat mitigation efforts. Engineering Geology 215, 91-94.
- Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. Science, 315, 368-370.
- Rohling, E.J., Frumkin, A., Avnaim-Katav, S., Shtienberg, G., Stein, M., 2016. Eastern Mediterranean sea levels through the last interglacial from a coastal-marine sequence in northern Israel. Quaternary Science Reviews 145, 204-225.
- Sisma-Ventura, G., Sivan, D., Shtienberg, G., Bialik, O.M., Filin, S., Greenbaum, N., 2017. Last interglacial sea level high-stand deduced from well-preserved abrasive notches exposed on the Galilee coast of northern Israel. Palaeogeography, Palaeoclimatology, Palaeoecology 470, 1-10.
- Shirman, B., 2004. East Mediterranean sea level changes over the period 1958-2001. Israel Journal of Earth Sciences, 53, 1-12.
- Sivan, D., Schattner, U., Morhange, C., Boaretto, E., 2010. What can a sessile mollusk tell about neotectonics? Earth and Planetary Science Letters 296, 451-458.
- Sivan, D., Sisma-Ventura, G., Greenbaum, N., Bialik, O.M., Williams, F.H., Tamisiea, M.E.,
- Sivan, D., widowinski, S., Lambeck, K., Galili, E., Raban, A., 2001. Holocene sea level changes based on archeological sites off northern Israel Palaeogeography, Palaeoclimatology, Palaeoecology 167, 101-117.
- Sivan, D., Lambeck, K., Toueg, R., Raban, A., Porath, Y., Shirman, B., 2004. Ancient coastal wells of Caesarea Maritima, Israel, an indicator for relative sea level changes during the last 2000 years. Earth and Planetary Science Letters 222, 315-330.

- Toker, E., Sivan, D., Stern, E., Shirman, B., Tsimplis, M., Spada, G., 2012. Evidence for centennial scale sea level variability during the Medieval Climate Optimum (Crusader Period) in Israel, eastern Mediterranean. Earth and Planetary Science Letters 315-316, 51-61.
- Vunsh, R., Tal, O., Yechieli, Y., Dean, S., Levanon, E., Sivan, D., 2018. Evaluating ancient coastal wells as sea-level indicators from the coast of Israel. Geoarchaeology 33, 403-416.
- Zviely, D., Bitan, M., DiSegni, D.M., 2015. The effect of sea-level rise in the 21st century on marine structures along the Mediterranean coast of Israel: An evaluation of physical damage and adaptation cost. Applied Geography 57, 154-162.
- Zviely, D., Sivan, D., Ecker, A., Bakler, N., Rohrlich, V., Galili, E., Boarreto, E., Klein, M., Kit, E., 2006. Holocene evolution of the Haifa Bay area, Israel, and its influence on ancient tell settlements, The Holocene, pp. 849-861.
- Zviely, D., Klein, M., 2004. Coastal cliff retreat rates at Beit-Yannay, Israel, in the 20th century. Earth Surface Processes and Landforms 29, 175-184.

Lectures 16 - 17: Alternative and green solutions for altering sea-level/climate change

Goals:

During lectures 16 - 17 we will discuss the use of fossil fuel and how it led to our current climate change crisis that is influencing global sea level rise. Then we will touch on alternative and green energy resources as well as novel technics that can help reduce atmospheric greenhouse gasses. Time will be saved for questions regarding the student presentation that will take place in lectures 18-19.

By the end of lecture 17 the students will:

1. Be acquainted with the devastative effect of hydrocarbon use have on our planet and how it effects sea level rise.
2. Be introduced to sustainable solutions that could help solve the current global environmental crisis.

Unit Schedule

Unit C (lecture 18 - 20)

Unit outcome:

This unit will sum up the course with a general review of what was learned in class through student presentation and final test. Specific time is saved for student questions regarding what was taught in class over the quarter. A pre-test of 30 multiple choice question test will be handed out to the class participants. The pretest will help to better prepare the students for the final exam as well as reflect whether the instruction was satisfactory.

Unit C outcome:

During this unit the students will present a chosen article (options of relevant papers can be seen in the reading material lists given in this syllabi). Each presentation should take no more than 10 minutes and include an introduction, research questions/hypothesis, methods, results, discussion and conclusions as well as 1 – 2 minutes for class question. The presentation will end after a thorough evaluation will be made stating the research strength and weaknesses. The talk will simulate participation in an academic seminar or scientific conference and will display the various aspects learned during this course.

By the end of unit C the students will:

1. Get acquainted with how to develop a PowerPoint presentation.
2. Improve presentation skills.
3. Get accustomed to working/presenting under a timeline.
4. Strengthen their scientific reviewing skills.

Rubric of assignment 3 - Class presentation

Student presentation of a scientific paper followed by a student-class review of the presented work (unit C). The presented work is the chosen paper that the students reviewed in assignment 2.

Criteria	Possible	Earned
Well organized presentation consisting of an introduction, research questions, hypothesis, methods, results discussion and conclusions.	8	
Delivery is clear and fluid, using vocal variety and eye contact	4	
Presentation finishes within the time limit (the presentation should be shorter than 10 minutes), without having to be stopped by the instructor. The presentation includes a summery and main conclusion.	4	
The presenter will discuss the strength of the paper and its weaknesses. This evaluation will be done as if he/she is reviewing the paper for a peer reviewed journal	4	
TOTAL	**20**	

Final exam

The final exam will conclude the course by 40 multiple choice questions that include 4 possibilities with only one correct answer. The test will cover all of the topics learned in class and will be worth 40 points of the overall grade.