Field:

Biology / Life Sciences

Session Topic:

Evolution of Life on Earth - Where do we come from?

Introductory Speaker:

FUJISHIMA Kosuke, Institute of Science Tokyo

Title: Origin and evolution of Life: Bridging Geochemistry and Biochemistry

One of the big unanswered questions about the origin and evolution of life is whether there was a smooth transition from the simple chemicals found in early Earth's environment to the complex molecules we see in living things today. This is partly because, while the chemical space is extremely large, life on Earth was able to establish a mechanism to reinforce chemical processes that eventually led to synthesizing their own constituents using enzyme catalysts. This self-sustaining biological process, known as metabolism, is considered to have arisen and evolved in association with Earth's geochemical processes. In other words, the origin of life could be interpreted as a transition state from geochemistry to biochemistry (Figure 1). In modern life, information on the metabolic network process is stored as replicable nucleotide polymers known as DNA and RNA and expressed as proteins made of amino acids. Hence, the origin and evolution of functional biopolymers is another key question to be solved.

Under what environmental conditions could life emerge? In this biology session, each speaker will present their preferred geological environment that could support life or the chemical and molecular evolution leading to the emergence of life-like systems. I will first discuss how the unique benthic CO_2 pool in the deep sea can create relatively dry conditions that drive prebiotic nucleotide synthesis through condensation reactions (Figure 2). Dr. Katrina Twing (Weber State University), an expert in geomicrobiology, will share her research on microbial life and the chemistry that takes place at the alkaline hydrothermal vent. Dr. Hannes Mutschler (TU Dortmund University) will present his work on RNA synthesis in a water-air interface, simulating the porous volcanic rock environment of Early Earth. Together, we aim to showcase the diversity of approaches to addressing this big 'origins' question in biology.

Fig.1. Overview of the chemical evolution leading to life (Modified from Kitadai and Maruyama, 2018)

Fig.2. Summary of the deep-sea water/supercritical CO_2 ($scCO_2$) two-phase environment that drives nucleoside phosphorylation via condensation reaction

Glossary:

Chemical Space: The vast array of possible chemical compounds, structures, and reactions.

Enzyme Catalysts: Proteins or RNA enzymes (ribozyme) that accelerate chemical reactions.

Geochemical Processes: Chemical processes and interactions that occur within a planetary body, like Earth, involving minerals, rocks, and other inorganic components.

Biopolymers: Large molecules produced by living organisms, including proteins, nucleic acids (DNA and RNA), and polysaccharides.

Prebiotic Environments: Conditions on the early Earth that existed before the advent of life.

Background Review Article: Kitadai, N., & Maruyama, S. (2018). Origins of building blocks of life: A review. *Geoscience Frontiers*, *9*(4), 1117-1153.

Presentation Abstracts

Field: *Biology / Life Sciences* ***Session Topic:*** *Evolution of Life on Earth - Where do we come from?* ***Speaker:*** *Hannes Mutschler, TU Dortmund University*

Title: An Experimental Window to the Past: Modeling the Early Steps of Life on Earth Using Molecular Fossils and Simulated Conditions

Life on Earth is estimated to be between 3.8 and 4 billion years old. Over this time, it has developed a diverse range of life forms, from tiny microbes to enormous multicellular organisms. Despite their external differences, all living organisms share striking internal similarities: they consist of membrane-enclosed cells that house DNA-based genomes, RNA molecules, and proteins essential for various life processes. But how did cellular life emerge on early Earth? What conditions were necessary for this development? Can we recreate these conditions in the laboratory today to explore how primitive life might have started? Researchers from various fields including chemistry, biochemistry, biophysics, and geoscience are exploring these questions. They face the challenge of the complex nature of modern life, compounded by uncertainties about early Earth conditions and a lack of early biological records, which makes it difficult to trace life back to its origins. However, ancient molecular 'fossils' found within our cells, such as catalytic RNAs (or 'ribozymes'), provide insights into early biological mechanisms. These ribozymes are crucial for all known forms of cellular life. Our research focuses on understanding if ribozymes, along with other comparably simple biomolecules like peptides or lipids, can mimic key life processes, such as self-replication or compartmentalization under conditions that mimic the early prebiotic Earth. By recreating these putative ancient conditions, we aim to reduce biological complexity to explore what the simplest forms of life might have looked like, shedding light on the origins of life on Earth and perhaps elsewhere.

References:

[1] Lanier, K.A., Williams, L.D. The Origin of Life: Models and Data. *J Mol Evol* **84**, 85–92 (2017). https://doi.org/10.1007/s00239-017-9783-y

[2] Pressman, A., Blanco C., Chen, I.A. The RNA World as a Model System to Study the Origin of Life, Curr Biol 25, 953-963 (2015). The RNA World as a Model System to Study the Origin of Life. https://doi.org/10.1016/j.cub.2015.06.016

[3] Le Vay, K., Mutschler, H. The difficult case of an RNA-only origin of life. *Emerg Top Life Sci* **3**, 469–475 (2019). https://doi.org/10.1042/ETLS20190024

[4] Smoukov, S., Seckbach, J. and Gordon, R. (eds.) (2022) Conflicting Models for the Origin of Life Wiley-Scrivener, Beverly, Massachusetts, USA. https://doi.org/10.1002/9781119555568

Glossary:

RNA (Ribonucleic Acid):

A molecule similar to DNA that plays a crucial role in coding, decoding, regulation, and expression of genes in modern cells. It helps carry instructions from DNA to control the synthesis of proteins.

Ribozymes:

A type of RNA that can act as an enzyme, which means it can catalyze (speed up) chemical reactions in a cell, similar to proteins. Ribozymes are essential for several biochemical processes, most importantly protein synthesis.

Proteins:

Large, complex molecules that perform many critical functions in the body. They do most of the work in cells and are required for the structure, function, and regulation of the body's tissues and organs. Proteins are made up of smaller units called amino acids.

Peptides: Short chains of amino acids, which are the building blocks of proteins. Peptides are smaller than proteins.

Membrane:

A thin layer that surrounds cells or organelles within cells. It acts as a barrier, controlling what enters and leaves the cell. Membranes are primarily composed of lipids and proteins, and they play a key role in protecting and organizing cells.

Web addresses for further reading:

https://www.michaelcmarshall.com/blog/bbc-earth-the-secret-of-how-life-on-earth-began
https://www.scientificamerican.com/article/a-simpler-origin-for-life/
https://en.wikipedia.org/wiki/Abiogenesis
https://exploringorigins.org/

Presentation Abstracts

Field:
Biology / Life Sciences

Session Topic:
Evolution of Life on Earth - Where do we come from?

Speaker:
Katrian Twing, Weber State University

Title: Serpentinization and the Origin of Life

Alkaline hydrothermal vents have been hypothesized to be a site for the origin of life on Earth (and potentially elsewhere in the solar system), because of: a) proton gradients, b) redox gradients, and c) abiotically-generated organic molecules. Specifically, the geochemistry of these systems appears to provide a template for autotrophic metabolic pathways, such as methanogenesis and acetogenesis, which have been described as 'ancient' metabolic pathways. The geochemical process of serpentinization generates such conditions through water/rock reactions. Here I'll present geochemical and microbiological data from extant sites of serpentinization, such as the Lost City hydrothermal field, and discuss its relevance to early Earth environments and the origin of life.

Background Review Article:

Schwander L, Brabender M, Mrnjavac N, Wimmer JLE, Preiner M, Martin WF. (2023). Serpentinization as the source of energy, electrons, organics, catalysts, nutrients and pH gradients for the origin of LUCA and life. Front Microbiol. 14. doi: 10.3389/fmicb.2023.1257597

<u>Field:</u>
Chemistry / Materials Science

<u>Session Topic:</u>
Artificial photosynthesis – Solar energy conversion into chemicals

<u>Introductory Speaker:</u>
Gabriela Schlau-Cohen, Massachusetts Institute of Technology

Title: Design principles of photosynthesis: Bioinspired optimization of solar energy devices

Photosynthesis is the powerhouse of most life on Earth. Natural systems capture more energy in just an hour and a half than humans consume in an entire year. Remarkably, this energy capture occurs with near unity quantum efficiency, is robust to natural conditions, and uses only cheap and abundant materials. In the first steps of photosynthesis, light-harvesting proteins transport energy to the downstream molecular machinery to drive the biochemical reactions of water splitting and carbon dioxide fixation. The efficient and regulated transport through the light-harvesting proteins maintains the constant energy flow that is key to biomass production. Here, we discuss the design principles identified through studies of the light-harvesting proteins and how these principles may provide a blueprint for artificial solar energy devices.

Presentation Abstracts

Field:
Chemistry / Materials Science

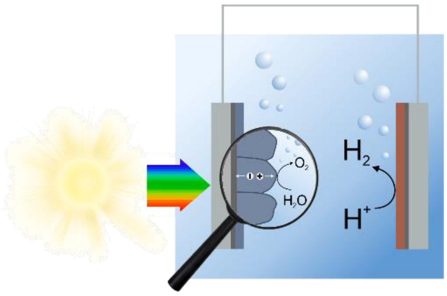
Session Topic:
Artificial photosynthesis – Solar energy conversion into chemicals

Speaker:
Johanna Eichhorn, Technical University of Munich

Title: Converting sunlight into storable chemical fuels

Among the biggest global challenges of the 21st century are the consequences of man-made climate change caused by the rising levels of CO_2 due to the ever-increasing consumption of fossil fuels. To slow down global warming and to overcome the current reliance on fossil fuels, a transition to a carbon-neutral society fueled by renewable energy sources will be crucial. Among all renewable sources, solar energy provides the highest potential to sustain future energy demands. However, solar energy is subject to large fluctuations due to the diurnal cycle and seasonal variations, which have to be balanced by storage solutions to ensure grid stability. Thus, economically viable conversion of solar energy to storable fuels will be important in satisfying the need for clean and reliable power.

One promising strategy for the direct conversion of sunlight into storable fuels is the realization of stable and efficient photoelectrochemical systems. Such photosystems typically have highly complex architectures composed of nanostructured materials with inherent nm to μm-scale heterogeneities, often controlling the critical processes of the macroscale system, such as efficiency and stability. To date, typical macroscale characterization techniques average the performance and material properties over the whole photoelectrode and conceal important nanoscale insights. My research group interrogates energy materials for solar water splitting on a scale from nano- to micrometers and reveals local reaction processes under realistic operation conditions. In this talk, I will discuss how we can resolve relevant nanoscale properties of energy materials and how we can use these insights from the nanoscale to learn about macroscopic performance and stability. The gained understanding will put forward a knowledge-driven approach for the rational design of durable and efficient solar fuel systems.



Further reading

J. Eichhorn, C. Kastl, J. K. Cooper, D. Ziegler, A. M. Schwartzberg, I. D. Sharp, and F. M. Toma, Nanoscale imaging of charge carrier transport in water splitting photoanodes, Nat. Commun., 9, 2597 (2018).

J. Eichhorn, C.-M. Jiang, J. K. Cooper, I. D Sharp, and F. M. Toma, Nanoscale heterogeneities and composition–reactivity relationships in copper vanadate photoanodes, ACS Appl. Mater. Interfaces, 13 (20), 23575 (2021).

Presentation Abstracts

Field:
Chemistry / Materials Science

Session Topic:
Artificial photosynthesis – Solar energy conversion into chemicals

Speaker:
HISATOMI, Takashi, Shinshu University

Title: Solar hydrogen production through photocatalytic water splitting

Photocatalytic overall water splitting (OWS) has been studied as a means to produce renewable solar hydrogen on a large scale. The author's group developed a $SrTiO_3$ photocatalyst that split water with an external quantum efficiency exceeding 90% via one-step excitation (Fig. 1a) by near-ultraviolet light [1], and a 100 m^2 photocatalytic solar hydrogen production system [2]. In addition, the hydrogen produced was shown to be applicable to the conversion of carbon dioxide to methane [3]. The author's group also demonstrated Z-scheme OWS (Fig. 1b) with a solar-to-hydrogen energy conversion efficiency (STH efficiency) exceeding 1.0% using a combination of doped $SrTiO_3$ and $BiVO_4$ [4]. However, the photocatalytic materials that show reasonable performance in OWS reactions are limited to oxides with a short absorption edge wavelength, and a STH efficiency above 5%, which is required for practical solar-to-chemical energy conversion, cannot be achieved due to insufficient sunlight absorption. Therefore, it is essential to develop non-oxide photocatalysts that are active under long-wavelength visible light.

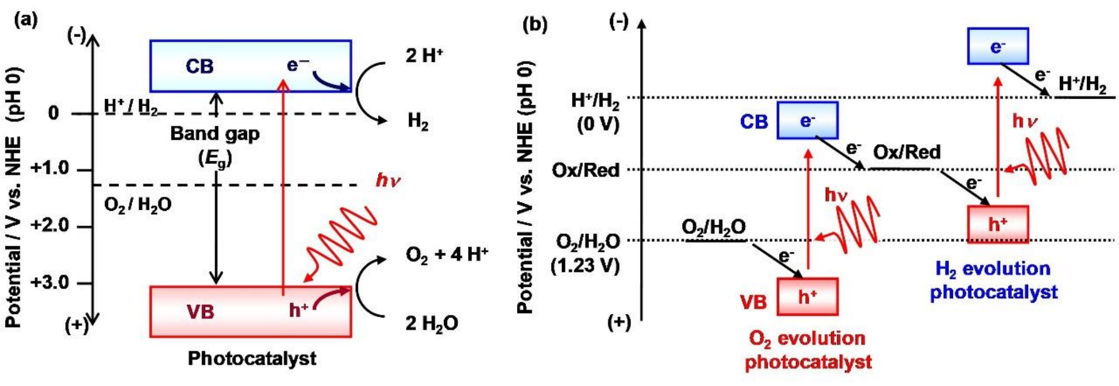


Fig. 1. Energy diagrams of photocatalytic water splitting based on (a) one-step excitation and (b) two-step excitation (Z-scheme). Adapted with permission from T. Hisatomi, J. Kubota and K. Domen, *Chem. Soc. Rev.*, **2014**, *43*, 7520 DOI: 10.1039/C3CS60378D. ©The Royal Society of Chemistry 2014.

GaN:ZnO, a solid solution of GaN and ZnO, has a unique property that its absorption edge wavelength becomes longer with increasing ZnO content [5]. Active GaN:ZnO is typically synthesized by nitriding starting materials under NH_3 flow, although the absorption edge wavelength of such GaN:ZnO is at most 480 nm due to the loss of ZnO component during the nitridation. The author's group invented a method to synthesize GaN:ZnO using Zn_3N_2 a nitriding reagent instead of NH_3 [6]. A representative product had a composition of $Ga_{0.42}Zn_{0.58}N_{0.42}O_{0.63}$ and absorbed visible light up to about 580 nm due to its high ZnO content. The obtained GaN:ZnO was active in visible-light-driven OWS and also applicable to Z-scheme OWS. The fabrication of long-wavelength photoresponsive GaN:ZnO will expand the possibilities for efficient photocatalytic solar hydrogen production.

References:

[1] Takata et *al. Nature* **2020**, *581*, 411.
[2] Nishiyama *et al. Nature* **2021**, *598*, 304.
[3] Yamada *et al. ACS Eng Au* **2023**, 3, 352.
[4] Wang *et al. Nat. Mater.* **2016**, *15*, 611.
[5] Maeda *et al. Chem. Mater.* **2010**, *22*, 612.
[6] Iwasa *et al.*, *Chem. Mater.* **2024**, *36*, 2917.

Glossary:

Overall water splitting:
【水の完全分解】A reaction in which water is decomposed into hydrogen and oxygen in a stoichiometric molar ratio of 2:1.

Solar hydrogen:
【ソーラー水素】Renewable hydrogen produced by overall water splitting using solar energy as the energy input.

Photocatalyst:
【光触媒】A semiconductor material that uses excited electrons and holes generated by the absorption of light to drive reduction and oxidation reactions simultaneously; more generally, a substance that absorbs light and uses the energy of the light to drive catalytic reactions.

External quantum efficiency:
【外部量子効率】The ratio of the number of photons used for the intended reaction to the number of photons supplied to the photocatalytic system.

Z-scheme:
【Z スキーム】Named after the electron transport system in photosynthesis, a scheme of overall water splitting based on two-step excitation of oxygen evolution photocatalysts and hydrogen evolution photocatalysts.

Solar-to-hydrogen energy conversion efficiency (STH efficiency):
【太陽光水素エネルギー変換効率】The ratio of the amount of energy stored as hydrogen as a result of water splitting reactions to the amount of solar energy provided to the photocatalyst system.

Absorption edge wavelength:
【吸収端波長】A threshold wavelength of light at which a semiconductor material begins to absorb light, determined by the band gap energy of the semiconductor material.

Presentation Abstracts

Background Review Article:

Hisatomi *et al. Next Energy* **2023**, *1*, 100006.
Segev *et al. J. Phys. D: Appl. Phys.* **2022**, *55*, 323003.
Hisatomi *et al. Nat. Catal.* **2019**, *2*, 387.
Hisatomi *et al. Faraday Discuss.* **2017**, *198*, 11.
Hisatomi *et al. Curr. Opin. Electrochem.* **2017**, *2*, 148.
Hisatomi *et al. Catal. Lett.* **2015**, *145*, 95.
Hisatomi *et al. Chem. Soc. Rev.* **2014**, *43*, 7520.
Hisatomi *et al.* Key goals and systems for large-scale solar hydrogen production; in Springer Handbook of Inorganic Chemistry; edited by Detlef Bahnemann, Antonio Otavio, and T. Patrocinio, published by Springer on June 26, 2022.

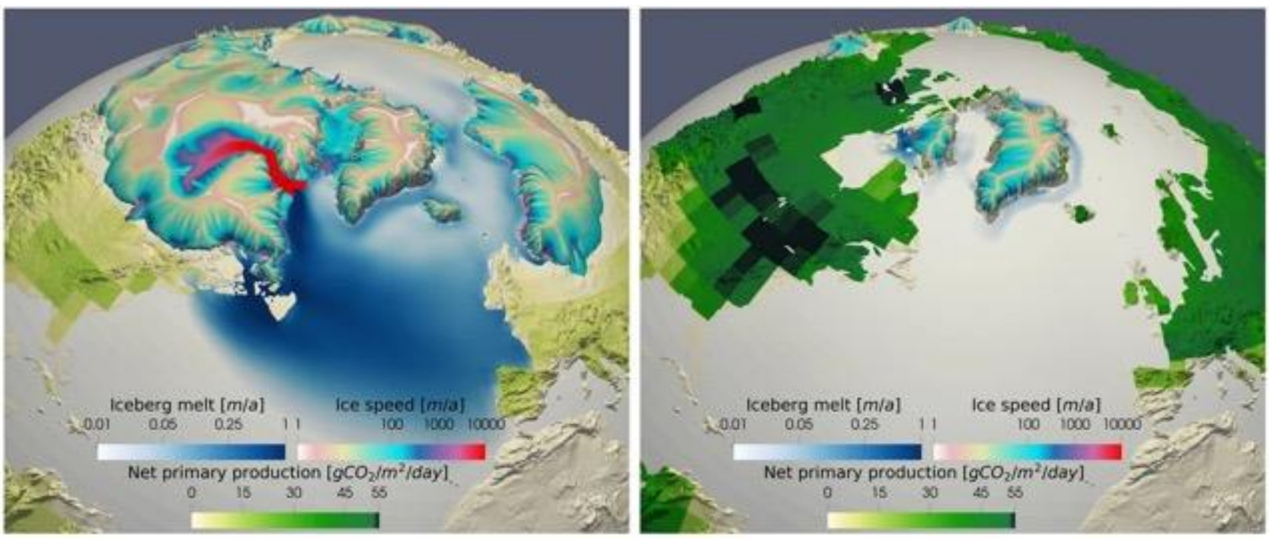
Field:
Earth Science / Geosciences / Environmental Sciences

Session Topic:
Points of no return? Ice-Ocean-Land interactions in the past and future Earth system

Introductory Speaker:
Marie-Luise Kapsch, Max Planck Institute for Meteorology, Hamburg

In recent decades the ice sheets of Greenland and Antarctica have decreased dramatically, and scientific projections suggest an increasing retreat in the future. As the major part of an ice sheet is located on land, the melting of ice sheets leads to a rise in sea level. Further, the melting of ice sheets can significantly alter the ocean and atmospheric circulation, due to the release of meltwater into the ocean and due to their kilometre thick height. This has not only climatic but also socio-economic implications.

In the long-term past, several periods existed, during which ice sheets were exposed to strong climatic changes. For example, 21,000 years ago global average temperatures were about five Kelvin colder and sea level about 120 metres lower than today. Large ice sheets covered Greenland, Antarctica and parts of North America and Eurasia – a total of approximately eight percent of the Earth's surface (Fig. 1). About 19,000 years ago, temperatures began to rise (Fig. 2), and a large proportion of the ice sheets disappeared. Today, only the Greenland and Antarctic ice sheets remain. Due to the recent advances in climate modelling and the integration of ice sheet models in state-of-the-art Earth System Models, we can now disentangle the physical relationships between individual climate components, such as ice sheets, the atmosphere and ocean. This allows us to draw conclusions about the evolution of the climate in the long-term past and estimate uncertainties in future climate projections.



Presentation Abstracts

Fig. 1: Simulated north hemispheric ice-sheet extent at the Last Glacial Maximum (LGM; about 21,000 years before present; left) and around 1850 (right). The figures show ice velocity and net primary production through photosynthesis as well as meltwater input from icebergs to the ocean. © Clemens Schwannwell

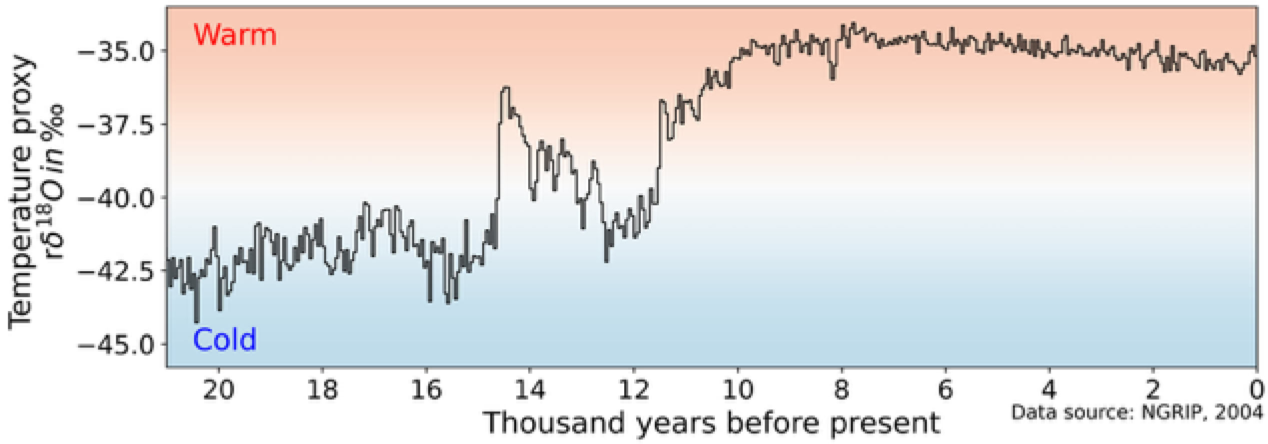


Fig. 2: Greenland temperature proxy derived through the North Greenland Ice Core Project (NGRIP). Greenland temperatures show a substantial increase between the LGM and 1850 with superimposed millennial-scale variability. This variability can in part be attributed to changes in ice sheets.

Further reading:

The role of ice-sheets in the climate system:

https://www.mpg.de/20647501/the-role-of-ice-sheets-for-the-climate

Tipping points in the Earth System:

Brovkin, V., Brook, E., Williams, J.W. *et al.* Past abrupt changes, tipping points and cascading impacts in the Earth system. *Nat. Geosci.* **14**, 550–558 (2021). https://doi.org/10.1038/s41561-021-00790-5

Examples of modeling efforts within our research group:

Kapsch, M.-L., Mikolajewicz, U., Ziemen, F., & Schannwell, C., 2022. Ocean response in transient simulations of the last deglaciation dominated by underlying ice-sheet reconstruction and method of meltwater distribution. Geophysical Research Letters, **49**, e2021GL096767. doi:10.1029/2021GL096767.

Schannwell, C., Mikolajewicz, U., Kapsch, M-L., Ziemen, A., 2024. A mechanism for reconciling the synchronisation of Heinrich events and Dansgaard-Oeschger cycles. *Nat Commun* **15**, 2961. doi.org/10.1038/s41467-024-47141-7.

Further information on research done at research group of Marie-Luise Kapsch:

https://www.mpg.de/21679168/F002_Focus_034-039.pdf

Field:
Earth Science / Geosciences / Environmental Sciences

Session Topic:
Points of no return? Ice-Ocean-Land interactions in the past and future Earth system

Speaker:
Pedro DiNezio, University of Colorado Boulder

Title: High Resolution Modelling Reveals Powerful Ocean-Atmosphere Interactions Driving Unprecedented Environmental Changes Worldwide

Numerical models of the climate system have revolutionized our understanding of our planet, providing unprecedented detail on the mechanisms driving global change. Although initially developed for studying anthropogenic global warming, models have become critical tools for predicting environmental changes at increasingly smaller scales needed for building resilient communities worldwide. However, as warming accelerates, many parts of the world are experiencing climate trends outside the range predicted by models, including droughts and sea level rise, suggesting that our understanding of the climate system is still incomplete. Our research over the past decade shows that ocean-atmosphere interactions in the tropics and in the mid-latitudes are critical due to powerful feedback loops amplifying regional responses. We discovered these mechanisms studying changes in the geological past that were also too large to be explained by models. The advent of Exascale computers is helping us explore these questions using high resolution models. This research is revealing exciting new details on how the ocean and the atmosphere interact paving the way for producing more accurate climate predictions.

Background Review Article:

"Are We Entering The Golden Age Of Climate Modeling?", Mark Betancourt, Eos, 21 November 2022. https://eos.org/features/are-we-entering-the-golden-age-of-climate-modeling

Field:
Earth Science / Geosciences / Environmental Sciences

Session Topic:
Points of no return? Ice-Ocean-Land interactions in the past and future Earth system

Speaker:
TAKAGI Haruka, The University of Tokyo

Title: A key to understand the past: Proxy carrier "Foraminifera", a behind-the-scenes contributor of climate research

To understand the upcoming climate change, it is crucial to examine not only what is happening now, but also to study what has happened in the past. So, what are paleoenvironmental reconstructions based on? These reconstructions rely on various indicators, the most important of which involve foraminiferal shells [1,2]. Foraminifera are marine protists that produce calcium carbonate shells, which are prevalent in marine sediments as microfossils. Since these shells are secreted form from seawater, their chemical composition can reflect the seawater's chemistry and also vary with the oceanic environment at the time of their formation. Scientists use these shells to reconstruct e.g., temperature, salinity, pH, primary production, etc… from centuries ago. For example, the ratio of different oxygen isotopes ($\delta^{18}O$) or magnesium/calcium ratio in foraminifera shells acts as a thermometer telling us about ocean temperature around Antarctica or Greenland at a time when no human beings have been to Antarctica or even before human beings are born in the Earth. Moreover, since the $\delta^{18}O$ of seawater changes with the volume of ice sheets, studying the stable isotope ratios of foraminifera shells is an activity to explore the interactions between the ocean, ice, and the marine biosphere.

Foraminifera have thus been utilized as "paleoenvironmental recorders" or "proxy carriers," but it is essential to remember they are living organisms. Their shell chemistry also mirrors biological and ecological influences, which superimpose on the theoretical value when the shell is secreted from seawater under isotopic equilibrium conditions [3]. However, our understanding of foraminifera as organisms is limited, and the variability in proxies and their underlying causes often remain unclear. In this presentation, I will discuss the biological effects on these proxies, share ecological studies I have conducted to investigate these effects, and introduce recent advancements in paleoenvironmental reconstruction using foraminifera.

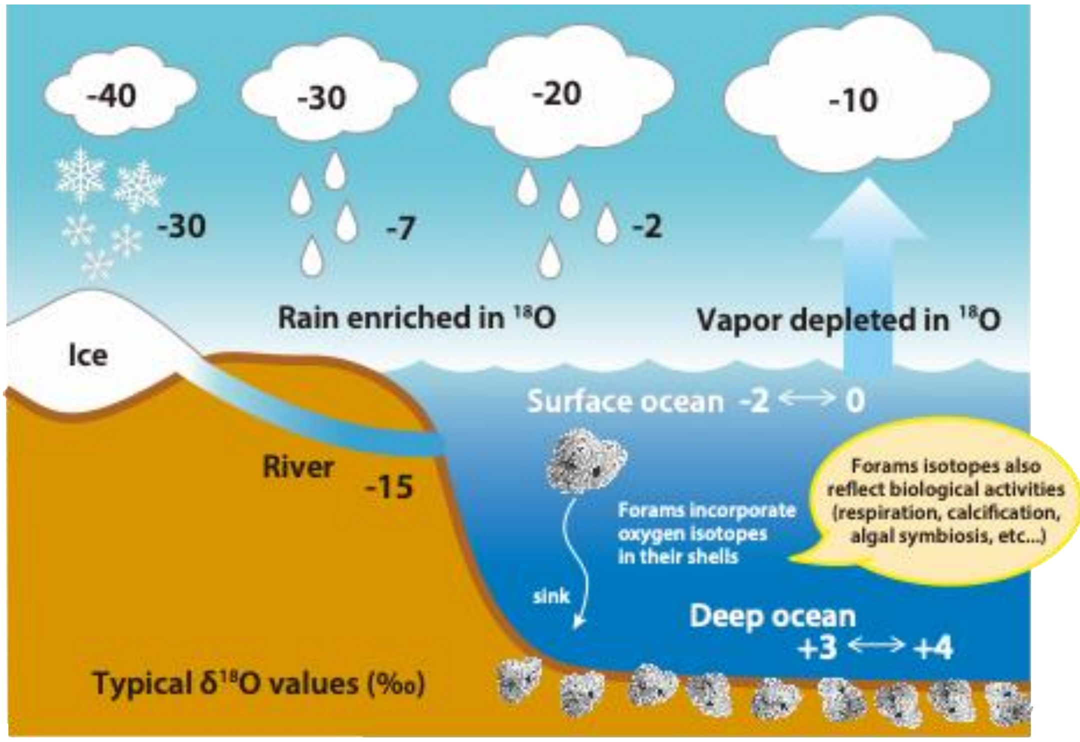


Fig. 1 Typical $\delta^{18}O$ values in the Earth's surface system. Foraminifera build their calcium carbonate ($CaCO_3$) shells using the surrounding sea water, but many biological activities can alter the isotopic composition of the site of calcification. Thus we need basic information on foraminiferal biological activities.
(Modified after https://open.oregonstate.education/climatechange/chapter/paleoclimate/)

References:

[1] Katz, M. E., B. S. Crame, A. Franzes, B. Hönisch, K. G. Miller, Y. Rosenthal, and J. D. Wright (2010): Traditional and emerging geochemical proxies in foraminifera. J. Foram. Res., 40, 165–192. 10.2113/gsjfr.40.2.165

[2] Ravelo, A., and C. Hillarie-Marcel (2007): The use of oxygen and carbon isotopes of foraminifera in paleoceanography. p. 735–764, In Proxies in Late Cenozoic Paleoceanography, edited by C. Hillaire-Marcel, and A. de Vernal, Elsevier, Amsterdam, Netherland.

[3] Bemis, B.E., Spero, H.J., Bijma, J., Lea, D.W. (1998): Reevaluation of the oxygen isotopic composition of planktonic foraminifera: experimental results and revised paleotemperature equations. Paleoceanography, 13, 150–160.

Glossary:

Foraminifera:

Marine protist that form carbonate shells. Important group of microfossils. There are planktonic and benthic species.

$\delta^{18}O$ of foraminiferal shell ($\delta^{18}Oc$):

Paleothermometer. Converting $\delta^{18}Oc$ to temperature is typically done using an empirical calibration, such as $T = 16.5 - 4.80(\delta^{18}Oc - \delta^{18}Ow - 0.27)$ [3], where T is temperature, $\delta^{18}Oc$ is the oxygen isotope composition of the carbonate, and $\delta^{18}O_w$ is the oxygen isotope composition of the water in which the carbonate was precipitated.

Field:
(Applied) Mathematics / Computer Science / Engineering

Session Topic:
Foundation Models

Introductory Speaker:
Zhiting Hu, University of California San Diego

Title: *From Language Models to World Models*

Large language models (like ChatGPT) are among the most powerful intelligent machines people have built to date. They have exhibited remarkable abilities in generating passages, conversing with humans, and assisting with decision making in real-world tasks. On the other hand, these models often fall short in consistent reasoning and can fail surprisingly in tasks that humans find easy (e.g. counting objects). In this talk, I'll review the progress and limitations of large language models, and discuss the concepts of "world models" as the next generation of foundation models. World models aim to simulate the consequences of actions on the world, and serve as a core component for human-level robust and versatile reasoning. For example, when planning to achieve a goal, humans use their internal world model to think about different actions and predict outcomes of each choice. This prediction helps refine the action plan to better attain the goal. I'll present the latest advances in world models (such as Pandora, https://world-model.ai), and discuss the opportunities in building more general world models for applications in human-AI collaboration, economy, scientific discovery, and beyond.

Background Review Article:

Hu, Zhiting, and Tianmin Shu. "Language Models, Agent Models, and World Models: The LAW for machine reasoning and planning." arXiv preprint arXiv:2312.05230 (2023). https://arxiv.org/abs/2312.05230

Field:
(Applied) Mathematics / Computer Science / Engineering

Session Topic:
Foundation Models

Speaker:
Oliver Eberle, Technische Universität Berlin

Title: Analyzing the Inner Workings of Foundation Models: Towards Insights, Transparency, and AI Safety

Foundation models (FMs) represent a significant advancement in machine learning by separating the computationally intensive task of data representation from the numerous possible downstream applications. While this has led to a rapid uptake of FMs in the sciences, industry, and society at large, their inner works remain only partially understood, posing a risk for their widespread adoption. To ensure broad applicability of these models, it is crucial for them to maintain a certain level of transparency and trustworthiness. In this talk, I will present recent contributions to the field of Explainable AI (XAI) within the context of FMs. Focusing on a layer-wise decomposition of these complex models allows a detailed analysis of their prediction strategies. This approach reveals relevant model strategies, providing a starting point for enhancing the understanding of FMs and ensuring compliance with critical aspects of AI safety.

Field:
(Applied) Mathematics / Computer Science / Engineering

Session Topic:
Foundation Models

Speaker:
ISOGAWA Mariko, Keio University

Title: Privacy Preserving data-based Human State Estimation

Measuring and estimating human state such as human pose (2D/3D positions of each human joint) has various potential applications including in-store customer assistance, rescue operations during disasters, and monitoring the elderly indoors. Traditionally, many methods for estimating a human state based on large-scale data captured by general cameras have been proposed. However, such data often includes personal information, such as the user's face. How can we address these privacy issues? In my talk, I will introduce a method to estimate human state based on measurement information that contains sparser data than general cameras, such as acoustic signals [1], wireless signals [2], and silhouette information [3], as one possible solution to this issue. We are also working on using measurement information called transient images [4], which retain the intensity and timing information of light as it reaches the sensor.

In contrast to general images composed of millions of pixels, such sparse information usually has very limited spatial resolution. Therefore, it is relatively difficult to identify individuals from these measurement data, which is privacy-preserving. At the same time, this means that estimating a human state from such sparse information is challenging. However, our proposed method addresses this by leveraging machine learning techniques and approaches such as generating synthetic datasets.

References:

[1] Shibata et al., "Listening Human Behavior: 3D Human Pose Estimation with Acoustic Signals", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp.13323-13332, 2023.

[2] Amaya and Isogawa, "Adaptive and Robust mmWave-based 3D Human Mesh Estimation for Diverse Poses", IEEE International Conference on Image Processing (ICIP), pp. 455-459, 2023.

[3] Hori et al., "Silhouette-based 3D Human Pose Estimation Using a Single Wrist-mounted 360° Camera", IEEE Access, vol. 10, pp. 54957-54968, 2022.

[4] Isogawa et al., "Optical Non-Line-of-Sight Physics-based 3D Human Pose Estimation", IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 7013-7022, 2020.

Presentation Abstracts

Field:
Physics / Astrophysics

Session Topic:
Nuclear fusion - The future of clean energy?

Introductory Speaker:
Athina Kappatou, Max Planck Institute for Plasma Physics, Garching, Germany

The world's energy demand is dramatically increasing. In the future, this demand must be met while mitigating the negative impact on the environment. Nuclear fusion promises a sustainable solution to our energy needs, offering safe, clean and abundant energy without carbon emissions.

Nuclear fusion for energy production aims to replicate the process powering the sun, by fusing light atomic nuclei to release large amounts of energy. Fusion reactions require extreme temperatures, at which the fusion fuel is a plasma. Two main concepts are investigated to confine this hot plasma: Magnetic Confinement Fusion (devices such as tokamaks and stellarators), and Inertial Confinement Fusion.

Achieving fusion energy production is a monumental challenge. Sustaining the fusion reactions in order to achieve a burning plasma is both a physics and an engineering challenge, requiring research at the frontiers of science from scientists and facilities worldwide.

Despite the challenges, recent years have seen astonishing progress in fusion research. In the Joint European Torus (UK) tokamak, a world record of fusion energy of 69MJ was achieved, using only 0.2mg of deuterium-tritium fuel [1]. The National Ignition Facility (US) achieved fusion ignition, i.e. releasing more energy than injected [2]. The stellarator Wendelstein 7-X (Germany) has demonstrated that plasmas can be maintained in steady state [3].

As fusion holds immense potential as the future of clean energy, we are working to resolve the remaining challenges. The path forward looks to ITER, the world's largest tokamak experimental fusion reactor. In parallel, fusion pilot plants concepts are being developed, aiming to demonstrate fusion energy for commercial purposes.

References:

[1] M. Maslov et al, "*JET D-T scenario with optimized non-thermal fusion*", Nucl. Fusion 63 112002 (2023), https://doi.org/10.1088/1741-4326/ace2d8

[2] H. Abu-Shawareb et al (The Indirect Drive ICF Collaboration), "*Achievement of Target Gain Larger than Unity in an Inertial Fusion Experiment*", Phys. Rev. Lett. 132, 065102 (2024), https://doi.org/10.1103/PhysRevLett.132.065102

[3] O. Grulke et al, "*Overview of the first Wendelstein 7-X long pulse campaign with fully water-cooled plasma facing components",* Nucl. Fusion, submitted

Glossary:

Plasma:

A hot, ionized gas (electrons separated from the nuclei)

Fusion fuel:

A deuterium-tritium mixture is the most promising fusion fuel due to its high fusion reaction cross sections, yielding a high energy output. Deuterium is abundant in seawater. Tritium, not naturally occurring, can be produced from lithium.

Magnetic Confinement Fusion:

One of the two approaches for controlled fusion power production. In the presence of a magnetic field, the charged particles in the plasma are forced to gyrate around the field lines. Complex magnetic fields can therefore be used to confine the fusion fuel (plasma) aiming to control fusion reactions and generate thermonuclear fusion power.

Tokamak:

Donut shaped fusion reactor, in which a toroidal field produced by external coils and a poloidal field due to the current flowing in the plasma are combined to create a helical magnetic field that can confine the fusion plasma. The plasma current is induced by a transformer coil, and as a result tokamaks operate in a pulsed mode.

Stellarator:

Donut shaped fusion reactor in which the helical field that confines the plasma is achieved only with external coils. It does not require a transformer, and can operate in steady state.

Inertial Confinement Fusion:

In this approach for controlled fusion power production, strong lasers or ion beams are used to compress and heat the fusion fuel

Burning plasma:

A burning plasma can primarily heat itself with the energy of the helium nuclei produced as a result of the deuterium-tritium fusion reactions.

Background information:

"Fusion basics", Max Planck Institute for Plasma Physics:
https://www.ipp.mpg.de/986351/fusionbasics_en.pdf

"The chase for fusion energy", Philip Ball, Nature, Vol 599, 2021 (Springer Nature Limited): https://www.nature.com/immersive/d41586-021-03401-w/index.html

https://www.iter.org/sci/whatisfusion

Breaking new ground: JET tokamak's latest fusion energy record shows mastery of fusion processes: https://euro-fusion.org/eurofusion-news/dte3record/

Pictures:

Presentation Abstracts

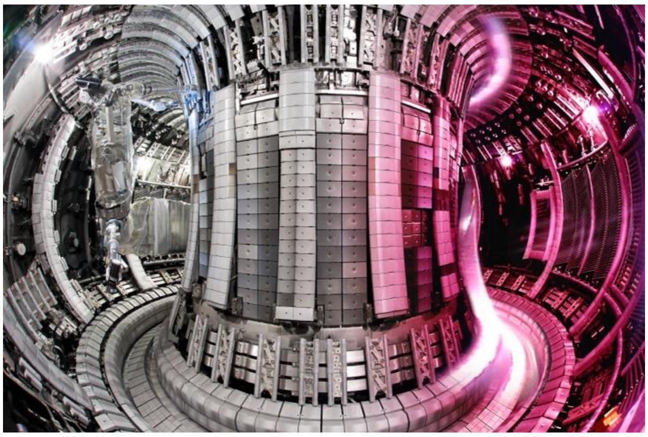


Fig. 1 Interior of the JET tokamak with a photo of the plasma overlaid (Source: The United Kingdom Atomic Energy Authority and EUROfusion)

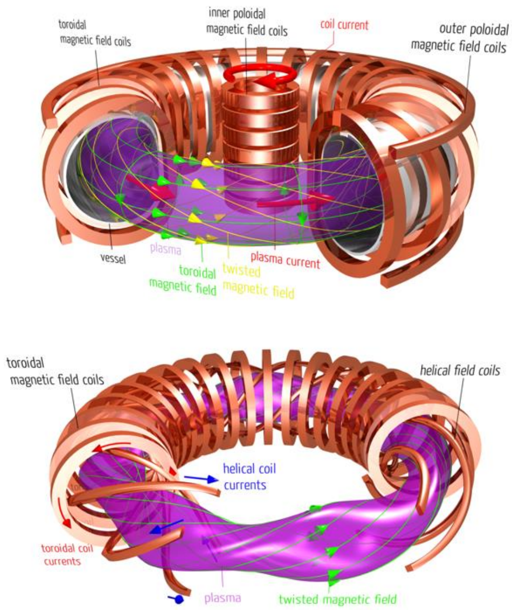


Fig. 2 The tokamak and stellarator principles (Source: MPI for Plasma Physics, Graphic: Dr. Christian Brandt)

Field:
Physics / Astrophysics

Session Topic:
Nuclear fusion - The future of clean energy?

Speaker:
Daniel Casey, Lawrence Livermore National Laboratory (LLNL)

Title: Ignition in the Laboratory and Understanding Implications for Fusion Energy

For half a century, researchers across the globe have worked to harness the potential for fusion energy to provide clean electrical power for the indefinite future. Inertial Fusion Energy (IFE) is one of two major fusion energy approaches. The recent achievement of ignition and gain (or fusion energy / driver energy) G >1 in inertial confinement fusion (ICF) using lasers at the National Ignition Facility (NIF) has increased interest in IFE as a practical fusion energy solution. Demonstrating ignition in the laboratory was a grand scientific challenge and yet harnessing that fusion energy will be yet another grand engineering challenge on the road to fusion power production.

One of the central questions facing an IFE reactor system is whether inertial fusion targets can produce significant energy gain, reliably, cheaply, and rapidly when integrated with the full reactor system. Ignition experiments have shown a sensitivity to enhanced radiation losses induced by impurities from the capsule shell material mixing into the burning fusion fuel (mix) and implosion asymmetries because both effects compete with fusion heating. The maximum target gain in ICF depends on a competition between fusion heating and losses (from expansion, radiation, and conduction).

It is therefore critical to assess how these issues might impact hypothetical IFE power systems. In this talk, we will discuss ongoing work to realize higher fusion gains at the NIF and understand how these results might translate to high gain fusion power systems.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344. LLNL-ABS-868324.

References:

- S. Fujioka, "Nuclear-Fusion Reaction Beats Breakeven." Physics 17, 14 (2024).
- S. Atzeni and D. Callahan (2024). "Harnessing energy from laser fusion." Physics Today 77(8): 44-50.
- O. A Hurricane, et al., "Physics principles of inertial confinement fusion and U.S. program overview." Reviews of Modern Physics 95(2): 025005 (2023).
- The ICF Indirect Drive collaboration, "Achievement of Target Gain Larger than Unity in an Inertial Fusion Experiment." Physical Review Letters 132(6): 065102 (2024).

***Figure 1**: A false color image of a fusion experiment on the NIF showing an intense burst of light and plasma produced during the*

Field:
Physics / Astrophysics

Session Topic:
Nuclear fusion - The future of clean energy?

Speaker:
MOTOJIMA Gen, National Institute for Fusion Science

Title: Research towards particle control of the high-temperature plasma treated in nuclear fusion

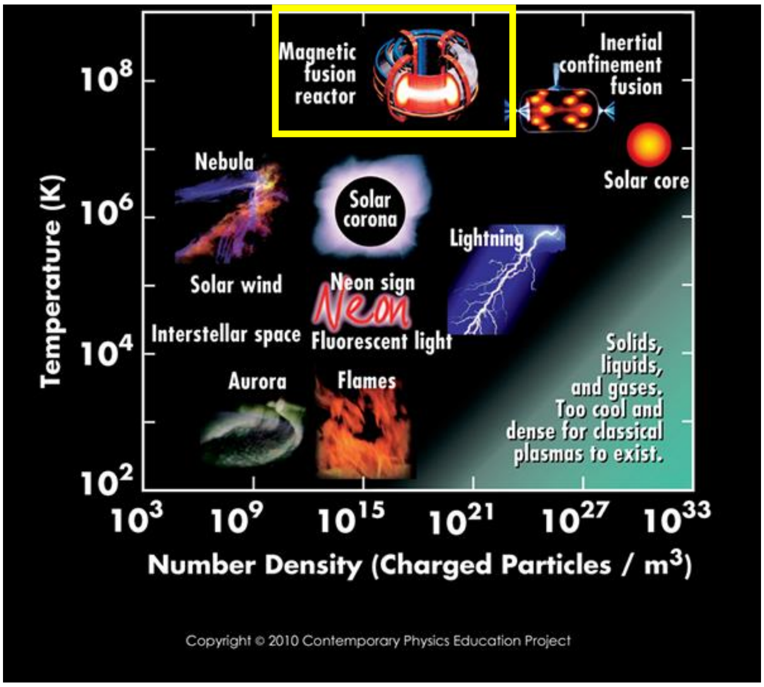


Fig. 1 Characteristics of typical plasmas.
Credit: 2010 Contemporary Physics Education Project
https://lasers.llnl.gov/science/understanding-the-universe/plasma-physics

Nuclear fusion is the process of forcing together two light atomic nuclei like hydrogen and creating a heavier one, in which massive amounts of energy (associated with mass defect) can be extracted. Nuclear fusion is a common reaction in the stars including the Sun. Research into the realization of fusion power as a key energy source has been conducted for more than 70 years [1]. The typical density in the fusion realized on Earth is so small, therefore the temperatures of over 100 million degrees Celsius (high temperature plasma condition), higher than the Sun, are required to produce nuclear fusion reaction (Fig. 1). In such a super high temperature, the main challenge is how to confine and control very hot plasmas stably.

ITER (International Thermonuclear Experimental Reactor) is currently under construction at seven poles (more than 40 countries) around the world, and although it faces various technical challenges as the first of a kind, the project is progressing steadily under international cooperation. Not only technical issues but also physical problems are remained to be solved.

The first topic of the presentation will be related to the hydrogen particle control in fusion plasmas. Here, the particle control must be taken into account the interactions between the plasmas and plasma facing components, because it must be realized under strong heat loads from the plasma (stronger than those in atmospheric entry of a space shuttle!). The speaker has developed strong particle exhaust system with a cryo-adsorption vacuum pump, which is installed in narrow area with the optimized material of activated carbon for hydrogen adsorption. As a result, higher plasma confinement with strong particle exhaust is established.

The speaker has spined out the activated carbon of its molding technique to establish functional materials that can absorb and inactivate viruses, and has made a start-up company to implement this into society, not just to realize nuclear fusion. Such a new possibility will be also discussed.

References:

[1] Guido Van Oost, “Fundamentals of Magnetic Fusion Technology”, INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamentals of Magnetic Fusion Technology, Non-serial Publications , IAEA, Vienna (2023) https://www.iaea.org/publications/14898/fundamentals-of-magnetic-fusion-technology

Glossary:

Fuel control in fusion plasma:

Assuming a magnetic confinement fusion reactor fuelled with deuterium and tritium, the nuclear burn-up rate of the supplied hydrogen fuel is a few per cent. The hydrogen fuel that is not burnt must be pumped out of the reactor and circulated back into the fuel supply system. At the time, the hydrogen fuel must be separated from the helium produced by the fusion reaction and impurities used to control the plasma heat load to plasma facing materials, making fuel cycle probability an issue.

Field:
Social Sciences

Session Topic:
Conceptions of Place and Space:
The Politics and Social Dynamics of Contemporary Place-making and Spatial Negotiation

Introductory Speaker:
SHIMPO Naomi, University of Hyogo

Title: Conflicts between place-making and spatial negotiation: Thinking from community gardens

Placemaking is the process and philosophy of creating public spaces that enhance the vitality of a city and promote health, happiness, and well-being. To achieve this, professionals and government agencies create public spaces by understanding the needs and desires of local people, or community members take action based on a more grassroots approach. The movement dates back to the 1960s, when Jane Jacobs and William H. White argued for building cities for people, not cars and shopping centers [1][2]. In the 1970s, Jan Gehl also wrote, "First life, then spaces, then buildings. The other way around never works." [3] Today, as many people feel the dehumanizing effects of over-optimized cities, more attention is being paid to placemaking.

Creating a place often involves spatial negotiations with landowners and local governments that regulate land use. In other words, various emotional or legal constraints arise. As a result, placemaking sometimes does not progress well, or places that have been painstakingly created may disappear after a certain period of time.

For example, community gardens are spaces in a city where people grow vegetables, fruits, flowers, etc. They can be seen as places where a wide range of people come gather to engage in various activities and to enjoy being there. The governance of these gardens ranges from top-down to bottom-up [4], but it is common that they are often based on temporary land contracts. As a result, gardeners are often required to make an effort to continue using the land.

It is a challenge how we can create a system to regulate spaces by respecting the will to create a good place.

Figure Community gardens in Japan

References:

[1] Jacobs, J., 1961, The Death and Life of Great American Cities. Random House.

[2] Whyte, W. H., 1968, The last landscape. Doubleday.

[3] Gehl, J., 2008, Life between buildings, Sixth Edition. Island Press.

[4] Fox-Kämper et al., 2018, Urban community gardens: An evaluation of governance approaches and related enablers and barriers at different development stages. Landscape and Urban Planning, 170, 59-68.

Field:
Social Sciences

Session Topic:
Conceptions of Place and Space:
The Politics and Social Dynamics of Contemporary Place-making and Spatial Negotiation

Introductory Speaker:
Noa K. Ha, German Centre for Integration and Migration Research (DeZIM)

Title: Representations of Place and Contestations of Space: Politics of Public Space and the European City of Berlin in New Germany

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In my contribution, I will analyse Berlin as a case study as the new capital of reunified Germany in post-Cold War Europe. The focus of my analysis is the urban practices of racialised communities in German post-migrant society, in which questions of belonging and national identity are also structured through urban representation and access. These social negotiations about spatial resources and cultural negotiations of representation are embedded in new narratives of the European and the European city, which have taken on a new significance since the end of the Cold War. The urban development policy guidelines and representations of Berlin as a new Capital - from the city centre plan to the Humboldt Forum - will be juxtaposed with the urban practices of street vendors and the demonstrations of refugees. In these juxtapositions, the negotiations over the long period since reunification will be presented, how they have been partially established and how they reveal new lines of conflict and areas of negotiation.

Analysing Berlin as a continuous field of negotiations about resources, belongings and place making will contribute to the panels overarching question of the extent to which notions of space and place are important fields for negotiating power structures and creating urban livelihoods.

Presentation Abstracts

Field:
Social Sciences

Session Topic:
Conceptions of Place and Space:
The Politics and Social Dynamics of Contemporary Place-making and Spatial Negotiation

Introductory Speaker:
Vanessa Watts, McMaster University

Title: (New) Frontiers of Place and Space: Indigenous Cosmologies and the Social

In North America, Indigenous peoples have been studied by governments and scientists for over two centuries. As they emerged and became institutionalized, the social sciences accelerated the study of Indigenous peoples. For the most part, Indigenous people were objects of study rather than researchers; Indigenous voice therefore has been largely absent in the articulation of Indigeneity within academic research. Maori scholar Linda Tuhiwai Smith (1999) argues that the Enlightenment era and the pursuit of knowledge in the 'new world' resulted in the view that Indigenous peoples were of a subhuman nature, and that resulting research during this time would facilitate a superior-inferior binary between the researcher and the researched. Thus, colonization manifests not only as a physical quest but also an epistemic one. This paper explores how both nature and Indigenous peoples are objectified in processes of exploration and exploitation, leading to the attempted suppression of Indigenous onto-epistemologies. This suppression is hardly abstract, having real, material consequences. By examining these dynamics, this paper will critically reassess how Indigenous knowledge systems are treated and the need to resist ongoing colonial influences amidst so-called "new" frontiers.

Background Review Article:

Watts, V. (2013). Indigenous place-thought and agency amongst humans and non humans (First Woman and Sky Woman go on a European world tour!). Decolonization: Indigeneity, education & society, 2(1).
https://jps.library.utoronto.ca/index.php/des/article/view/19145