Research Interests – Dr. Jonathan Friedemann Donges

International commitment to the appropriately ambitious Paris climate agreement and the United Nations Sustainable Development Goals in 2015 has pulled into the limelight the urgent need for major scientific progress in understanding and modelling the Anthropocene, the tightly intertwined social-environmental planetary system that humanity now inhabits. The Anthropocene qualitatively differs from previous eras in Earth's history in three key characteristics (Donges et al., 2017):

(1) There is planetary-scale human agency.
(2) There are social, economic and ecological networks of teleconnections spanning the globe.
(3) It is dominated by planetary-scale social-ecological feedbacks.

Bolting together old concepts and methodologies cannot be an adequate approach to describing this new geological era. Instead, we need a new paradigm in Earth System science that is founded equally on a deep understanding of the physical and biological Earth System – and of the economic, social and cultural forces that are now an intrinsic part of it. It is time to close the loop and bring socially mediated dynamics explicitly into theory, analysis and models that let us study the whole Earth System.

Based on this motivation, my research group focuses on understanding the complex structure and dynamics of the planetary social-technological-ecological (World-Earth) system in the Anthropocene. Major guiding research questions are:

- How do biophysical, climatic (e. g. Greenland and Antarctic ice sheets; thermohaline ocean circulation; Amazon rainforest) and social tipping elements (e. g. public opinion; behaviours, norms and values; the social movement on divestment from fossil fuels; climate-driven conflicts and migration) and the associated planetary boundaries and social transformations interact? **What is the potential for domino effects in these tipping networks in the World-Earth system, potentially leading to future "hot-house Earth" states** (Steffen et al., 2018)?

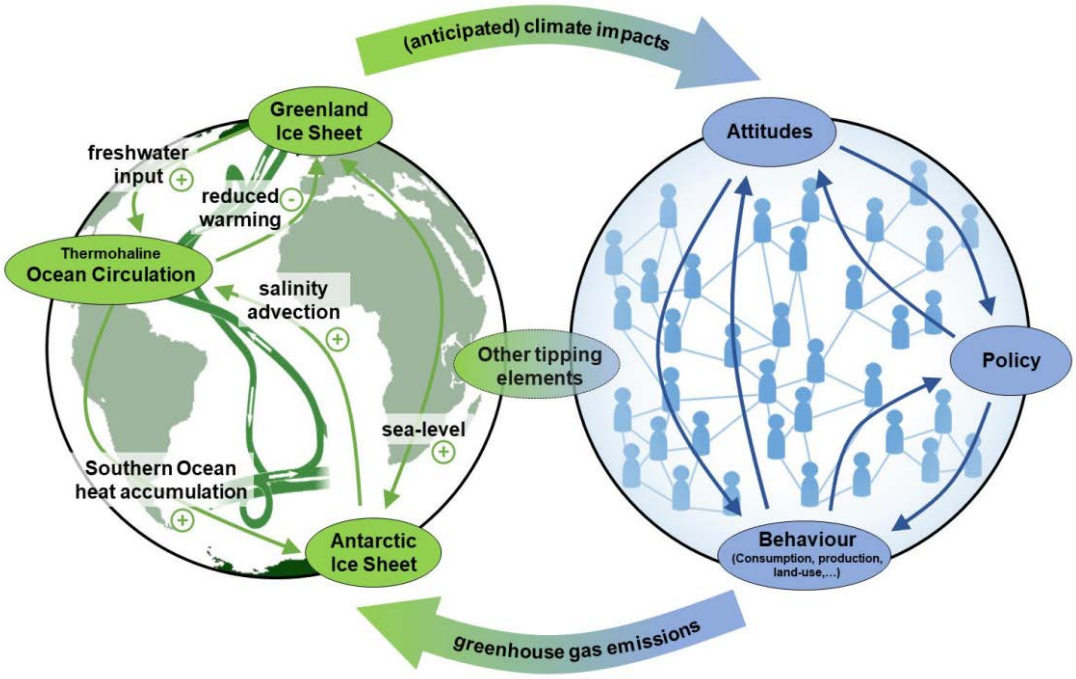

Fig. 1: Climatic and social tipping element interactions that may be decisive for future trajectories of the Earth system in the Anthropocene (Wiedermann et al., in review)

- **Under which conditions do safe and just spaces for humanity exist in the World-Earth system?** Can they be reached, how are they connected, what are their resilience properties? **How can the associated "Earth resilience" be defined and measured?**

- **How can novel integrated World-Earth models be constructed** that allow to investigate these dynamics of the planetary social-technological-ecological system in the Anthropocene including: human agency across scales, system-level effects of social-economic-ecological networks and complex coevolutionary feedback dynamics?

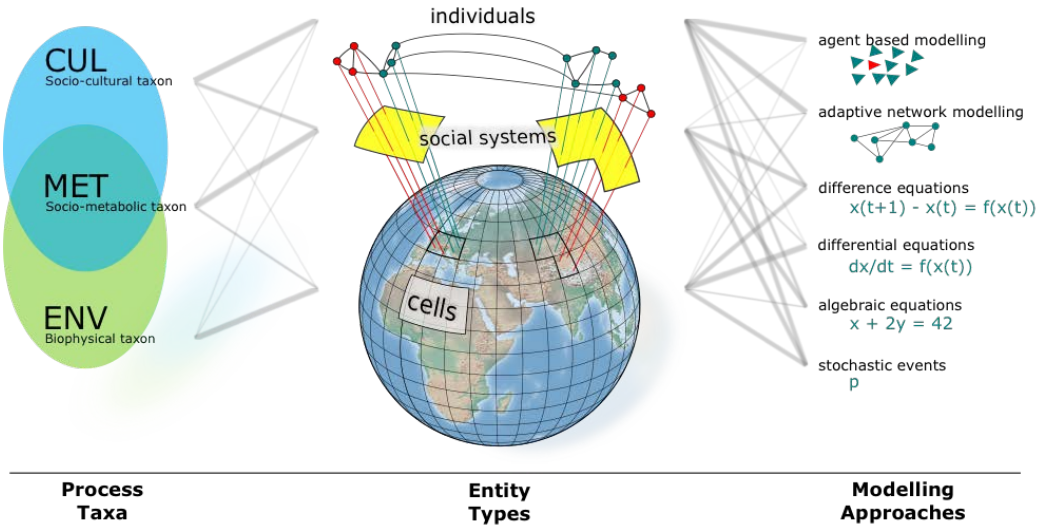

Fig. 2: The copan:CORE computer modelling framework allowing to integrate biophysical (climatic), socio-economic and socio-cultural processes in analyses of Anthropocene World-Earth system dynamics (Donges et al., 2018)

- How can **regime shifts and tipping points in the World-Earth system be detected and anticipated** based on empirical data? How can the complex interaction structure and time-evolution rules of social-technological-ecological networks be reconstructed from observational data?

- **What are the principles and techniques of a statistical mechanics of social-technological-ecological systems** aiming at: (i) understanding the emergence of macroscopic social-ecological patterns and dynamics from underlying processes at smaller scales, (ii) discovering necessary and sufficient conditions for the existence of tipping points and critical phase transitions and associated early warning signals, (iii) developing robust governance strategies and structures for these multi-scale systems? (e. g. Barfuss et al., 2018)

Selected references

W. Barfuss, **J. F. Donges**, S. J. Lade, and J. Kurths (2018), **When optimization for governing human-environment tipping elements is neither sustainable nor safe**, *Nature Communications* **9**, 2354.

J. F. Donges*, J. Heitzig*, W. Barfuss, J. A. Kassel, T. Kittel, J. J. Kolb, T. Kolster, F. Müller-Hansen, I. M. Otto, M. Wiedermann, K. B. Zimmerer, and W. Lucht (2018), **Earth system modelling with complex dynamic human societies: the copan:CORE World-Earth modelling framework**, *Earth System Dynamics Discussions*, in review, DOI: 10.5194/esd-2017-126, * Shared lead authorship.

J. F. Donges, R. Winkelmann, W. Lucht, S. E. Cornell, J. G. Dyke, J. Rockström, J. Heitzig, and H. J. Schellnhuber (2017), **Closing the loop: reconnecting human dynamics to Earth system analysis**, *The Anthropocene Review* **4**(2), 151-157.

W. Steffen, J. Rockström, K. Richardson, T. M. Lenton, C. Folke, D. Liverman, C. Summerhayes, A. D. Barnosky, S. E. Cornell, M. Crucifix, **J. F. Donges**, I. Fetzer, S. J. Lade, M. Scheffer, R. Winkelmann, and H. J. Schellnhuber (2018), **Trajectories of the Earth system in the Anthropocene**, *Proceedings of the National Academy of Sciences USA* **115**(33), 8252-8259.

M. Wiedermann, R. Winkelmann, **J. F. Donges**, C. Eder, J. Heitzig, A. Katsandiou, E. K. Smith (2019), **Can Antarctica tip climate policy?**, in review.