1. Introduction

Continuum temperature variability represents the response of the Earth's climate to deterministic external forcing. Scaling regimes are observed which range from hours to millennia with low frequency fluctuations characterizing long-term memory in weather and climate: (i) In the tropical atmosphere 1/f scaling ranging from hours to weeks is found for several variables; it emerges as superposition of uncorrelated pulses with individual 1/f-spectra. (ii) The daily discharge of the Yangtze shows 1/f within one week to one year, although the precipitation spectrum is white. (iii) Beyond one year mid-latitude sea surface temperatures reveal 1/f-scaling in large parts of the global ocean. Long-term memory on time scales up to millennia reveal global sea surface temperature and Greenland ice core records (GISP2, GRIP) using δ¹⁸O temperature proxy data during the Holocene. Complex atmosphere-ocean general circulation models reproduce this behavior quantitatively without solar variability, interacting land-ice and vegetation components and can be interpreted, to a first order, as a two-layer heat diffusion process forced by uncorrelated stochastic atmospheric surface fluxes. But more research is required.

2. Recent Highlights

**Extremes:** The link to long-term memory has been established by the recurrence time statistic, which follows a Weibull distribution with parameters determined by long term memory alone (first publication, combining shorter and longer time scales). Furthermore, updated non-linear trend-analysis of drought and wetness based on delay-coordinate singular spectrum analysis revealed the recently observed trend change (first publication). And the dynamics of the extreme Russian summer heatwave 2010 dynamics has been analyzed [1].

**Predictability:** Applicability of fluctuation theorem is demonstrated in the GCM environment indicating ‘return of skill’ in terms of largest local Lyapunov exponents being negative (first publication with spectrum of dynamical cores of A-GCMs); that is, a return of forecast-skill in identical twin predictability experiments is dynamically possible up to a relatively high model resolution [2].

**Prediction in weather and climate:** (i) Weather (Hurricane tracks) predictions being used in Weather Services (Bureau of Meteorology) are based on a non-linear dynamics approach. (ii) For climate prediction (Yangtze River Basin, Tibetan Plateau), a biased bootstrap Ansatz has been applied for Eastern Asian watersheds: Yangtze River and Tibetan Plateau [3].

**Hysteresis:** The suite of hysteresis model analyses, ranging from the conventional approaches of static to dynamic hysteresis with adiabatically and continuously changing external parameters has been amended by the novel memory hysteresis, by prescribing trendy greenhouse gas concentrations ([4] first publications on transient and abrupt changes including low-order model interpretation).

**Theories:** Empirical laws governing the Earth’s climate have been derived for the rainfall-runoff chain (linking climate-vegetation-soil compartments on catchment scale (Schreiber formula) and the worldwide maximum rainfall depth-duration scaling (or Jennings law) ([5] first theoretical publication).

**Climate and Vegetation:** To complement geographical presentation of remote sensing vegetation information, a physical state space diagram is used to analyze functional climate relations. Interannual
variability of dryness is lowest where the largest climate mean NDVI values of greenness (forests) occur. Thus, measures of interannual variability may be included in Budyko’s classical framework of geobotanic analysis of the Earth’s surface climates [6].

3. Outlook

Lakes in the tropics and mid-latitudes are indicators of regional paleoclimates, for which a novel Ansatz is being developed. It is based on the equilibrium water and energy balances and a previously derived equation of state to combine catchment and lake eco-hydrology. This Ansatz provides climate estimates using only the lake-catchment area ratio [7]. Likewise, the changing ocean-continent area ratio can be estimated employing the maximum entropy production principle to parameterize the underlying complex dynamics. Eco-hydrology and freshwater sources of islands and their role in global climates can be analysed analogously.

An eco-hydrological state space is introduced spanned by water and energy related physical flux ratios characterizing the unused (or excess) water- and energy supply. Direction and magnitude of trajectories in this state space provide the attribution of change to (i) external or climate induced impact versus (ii) internal or anthropogenic causes. This state space analysis can be extended to include remote sensing information (like vegetation-greenness) which, projected onto the state space, is applied to problem climates of the Earth (the Tibetan Plateau, the Amazon and the S-American Altiplano).

Arid regions in long-term climate equilibrium are affected by shorter term internal variability of drought and wetness. The underlying dynamics is related to an information flow associated with teleconnection patterns induced by wave-trains modulated by feedbacks through synoptic scale perturbations, wave-breaking etc. Their representation and predictability by Global Climate Models is subject of future analyses focusing on the role played by soil moisture.

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