Abstract

This dissertation aims at improving our understanding of the mechanisms of interactions between physical processes within the climate system via two different approaches.

In the first part I have studied and utilized climate networks. These networks are a new application of complex networks to study climate variability. They consist of nodes representing the geographical location and links presenting the connections between those geographical locations. Climate networks have been proven to serve as an alternative for data representation, an analysis framework and a visualization tool for understanding the complexity of the Earth's climate system all at once. Among many mechanisms, the mutual interdependence between sea surface temperatures (SST) and precipitation (PCP) has not been completely studied so far in terms of global characteristics and spatial patterns. In this context, the globally most relevant phenomenon is the El Niño Southern Oscillation (ENSO), which strongly affects large-scale SST variability as well as PCP patterns all around the globe. Although significant achievements have been made to improve our understanding of ENSO's global teleconnections and climate impacts, there are many processes associated with ocean-atmosphere interactions in tropics and (extra)tropics, as well as remote effects of SST changes on PCP patterns that have not yet been unveiled or fully understood. Therefore, I have employed the recently introduced framework of coupled climate network analysis for characterizing dominating global co-variability patterns between SST and PCP. My analysis uncovers both local and remote statistical connections and demonstrates their dependence on the current ENSO phase (El Niño, La Niña or neutral phase). Thereby, the results allow identifying teleconnections between SST variations and global precipitation patterns, highlighting the potential of the employed methodology in improving climate variability diagnostics and statistical forecasts in future works. However, this knowledge is limited in terms of the evolution of interactions between SST and PCP. Many climatological processes happen among timescales, so in order to identify and interpret them, I needed to focus on different timescales. Therefore, I have extended the application of coupled climate networks to capture the interdependence between SST and PCP at multi-temporal scales. The results reveal that combining time-scale decomposition by means of a discrete wavelet transform with the concept of coupled climate network analysis unravel the scale-specific connections that are often overlooked at the original resolution of the data. The results show that the strongest correlations between SST and PCP at the scale of 8-16 month concentrate primarily at the Pacific ocean, while the corresponding pattern disappears gradually when increasing the timescale.

In the second part of this thesis, I have focused on simulations with with the COnsortium for Small scale MOdeling (COSMO) Climate Limited-area Modell (CCLM) and investigate the effects of Lake Sobradinho, a large reservoir in Northeastern Brazil, on the local near-surface atmospheric and boundary layer conditions.

In general, lakes are characterized by an elevated heat capacity and thermal inertia as well as a reduced roughness length and albedo. Therefore, their interaction with the atmospheric surface layer plays a significant role in the development of meteorological conditions, especially for synoptic scale processes. Despite the importance of considering lakes as a part of numerical weather prediction (NWP) systems, most methods fail to capture their specific interactions with the atmosphere and surrounding land. Either these methods attribute a single value of temperature to the whole water column of the lake (which is simple, but produces large errors in reproducing lake features), or they use turbulence closure models (a better method but computationally very expensive). In this thesis, the FLake model (Freshwater Lake model) is applied for obtaining the lake's vertical temperature profile, as it incorporates much of the essential physics and offers a reasonable compromise between physical realism and computational economy. By including FLake in CCLM, I was able to study Lake Sobradinho, the presence of which has a major effect on the regional climate of in Northeastern Brazil. I have simulated two alternative scenarios: (1) with the lake being replaced by the average normal native vegetation cover and (2) with the lake as it exists today, for two different two-month periods reflecting average and very dry conditions, respectively. The performance of the simulation is compared with data from surface meteorological stations as well as satellite data to ensure the model's ability to capture atmospheric conditions in the vicinity of Lake Sobradinho. The obtained results demonstrate that the lake affects the near-surface air temperature of the surrounding area as well as its humidity and wind patterns. Specifically, Lake Sobradinho cools down the air during the day and warms it during the night by 7 degrees depending on the large-scale meteorological conditions. Moreover, the humidity is significantly increased as a result of the lake's presence and causes a lake breeze. The observed effects on humidity and air temperature also extend over areas relatively far away from the lake. This results show that the FLake model presents important lake effects that otherwise would have been ignored, and leads to a correct interpretation of climate processes within the lake's surroundings.