Seasonal Segmentation in the Extra Tropics Using the Annual Daily Mean Temperature Cycle

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Editorial

Seasons are recommended to be defined based on the annual cycle of daily mean temperature in extra tropical locations. Based on the periods throughout the year when the maximum and minimum temperature values, as well as the greatest warming and cooling (when the rate of temperature change is at its maximum or minimum), four metrics are calculated. These four measures were calculated for the ERA-Interim, JRA-55, and NCEP2 reanalysis products from 1980 to 2014. The results show that these four measures may accurately represent the start and end of sub periods throughout the year in any extra tropical region [1], and that they can be observed and utilized as a consistent technique to define seasons. The fluctuation of net radiation and near-surface circulation has a strong influence on the two more extreme metrics (dates for the maximum and minimum temperature). Diverse contributing elements influence the internal variability of the measures in regions with different climatic regimes, described in terms of land–atmosphere coupling conditions. In humid environments, net surface radiation is important for determining the maximum temperature date, whereas air circulation variability is important for determining the minimum temperature metric. Land–atmosphere interaction, both in summer and winter, has a crucial effect in the timing of the annual cycle in transitional zones [2].

The temperature yearly cycle is one of the most visible fluctuation patterns of the land–atmosphere system, controlling phonological and climatic processes across most of the planet, especially in extra tropical regions. Temperature is one of the primary elements that determines the vegetal growing season from a phonological standpoint [3]. The dynamics of natural ecosystems and the benefits they provide are determined by this reality. Temperature fluctuation spans numerous peak frequencies in climatology, ranging from diurnal to Milankovitch cycles. In extra tropical locations, the yearly temperature cycle is prominent, impacting other meteorological variables such as pressure, wind, and hence circulation patterns, and thus determining continental climates on regional and local scales. Seasonality can be defined in two ways depending on temperature: using the sinusoidal features of the annual cycle or using thresholds [4]. The first can capture phase variations and annual cycle amplitude at a local scale, allowing comparison of locations. It can display cold or hot periods, but it can't tell you when the seasons start or end, thus it's useful for figuring out sub seasonal temperature fluctuations and their effects on climatic and biological systems.

Apart from identifying different aspects of the temperature annual cycle (such as heating or cooling sub periods), it's critical to understand which systems and mechanisms influence those seasonal characteristics [5]. The main temperature modulator throughout the year is incoming solar radiation at the surface. The amount of solar energy reaching the earth's surface fluctuates throughout the year and at different latitudes, resulting in the astronomical seasons. Over the extra tropical regions, this cycle is more evident. Days of extreme maximum/minimum insolation (solstices) do not correspond with days of extreme maximum/minimum temperature, which are typically 30 days apart [6]. Surface characteristics, microclimates, the season of the year, degree of continentally, and orographic features all play a role in the extent of this delay. Coastal regions experience longer delays than those on the mainland [7].

Surface features and atmospheric circulation appear to be among the key elements that modify the annual temperature cycle on regional scales. The sensible (SHF) and latent (LHF) heat fluxes are strongly related to net surface energy. During the day, SHF is usually positive since it is proportional to the wind and the vertical temperature gradient at the surface. Meanwhile, LHF is linked to the evaporation or condensation of surface water, resulting in indirect heat transfer via subsequent phase shifts in the atmosphere's water [8]. Both fluxes are linked by the Bowen ratio (BW = SHF/LHF), which is commonly used in ecosystem energy budgets. The complexity of the processes involved in determining continental temperature seasonality, as well as the uneven geographic availability of high-quality observational data across extended time periods, particularly those related to surface energy balances, make observational analysis difficult. As a result, databases generated by numerical models can be very useful not only for understanding global processes (because to their physical consistency), but also for analyzing regions with little data. Reanalyzes are numerical systems based on the assimilation of meteorological data and forecast modeling over regular grids, with a variety of parameterizations, geographical and temporal resolutions, and parameterizations [9]. As a technique for representing near-surface air temperature and land–atmosphere interaction, ensembles of climate models or reanalyzes appear to perform better than any single model or reanalysis.

The primary aspects of the annual cycle timing as determined by T2M proposed metrics, including those related to the dates of maximum and minimum rhythm change (rapid warm-up and cool-down): DXT, DXN, DXWARM, and DXCOOL [10]. On both hemispheres, the analysis areas range from the Tropics to 60° latitude. For the 1980–2014 periods, this idea was applied to three independent reanalyses (ERA-Interim, JRA-55, and NCEP2). Three processes were investigated in order to better comprehend inter annual fluctuations of such measurements. Extreme measurements (DXT and DNT) exhibited comparable patterns, lagging the respective astronomical solstice by 20 to 30 days on average. Although the overall finding is well-known [11], it has only been briefly recorded in scientific literature and is not based on the more often used reanalysis databases. Over extra tropical zones, there are 30-day delays between solar incoming energy and temperature extremes. As a result, this might be considered a noteworthy outcome of the proposed methodology. When inland values are compared to coastal values, smaller delays (days of extreme temperature closer to astronomical value) are found over vast regions, which is also in agreement with prior findings [12].

The NH has a greater spatial contrast than the SH, which could be due to the oceanic influence on the measures. As a result, energy income/outcome in continental regions, where heat capacity is smaller than in the ocean, leads to an earlier day of maximum/minimum temperature (DXT/DNT). The oceanic impact smooth the temperatures across the SH, resulting in a more homogenous geographical pattern for the day of temperature extremes, and hence the computed metrics, which reduces the inland/coast disparity [13]. It's reasonable to assume that the variables analysed, which are relevant at the land–atmosphere interface and are connected to energy budget (NR, BW) and atmospheric circulation (near-surface wind), will help with understanding the metrics' timeliness. At the same time, there are certain flaws in this analysis. The methodology's weaknesses, for example, when it fails to account for intra-seasonal fluctuation of the specified variables, which could be significant. Second, the reanalysis products' limitations (the global models used, the assimilation methodologies with the available observations). Third, the intricate feedbacks between land, atmospheric boundary layer, and large-scale circulation have inherent internal unpredictability [14]. Low or non-significant correlations between seasonal measures and climate factors reveal these challenges. However, we believe that our findings are usually consistent and represent many factors that influence the yearly temperature cycle's timing. These mechanisms (which are connected to net surface radiation variability, land–temperature coupling, and atmospheric flux) differ depending on the climate regime and season. A more in-depth examination of climate regimes is now available [15].

The annual daily temperature cycle across extra tropical land regions has been proposed to be characterized using the computation of four critical dates (metrics) from the yearly cycle features. The findings suggest that it is a useful approach for quantifying the annual cycle's sub periods (seasons) and describing inter annual variability in comparison to other variables representing physical processes. The four dates depict values that have a consistent geographical pattern and are linked to astronomical dates [16]. Surface energy fluxes, such as land–atmosphere coupling processes and circulation variability, are the key mechanisms that could explain inter annual fluctuations of these parameters. The DXT and DNT measurements are clearly influenced by near-surface air circulation (which introduces oceanic influence as well as cold or warm flows) and net surface radiation. It's useful to think about the many climatic regimes associated with land–atmosphere connection. Summer radiation variability is critical for the timing of DXT in humid places where there is no land–atmosphere interaction, but winter circulation variability is most significant for DNT. The partitioning of energy between latent and sensible heat fluxes is a dominant factor for the timing of metrics in transition regions, where land–atmosphere coupling plays an important role in the energy balance, though summer circulation variability is also important, causing DXT dates to be advanced or delayed [17].

Finally, in arid locations, radioactive processes dominate the annual temperature cycle. The present study on the timing of the annual temperature cycle and possible coadjutant factors on global and inter annual scales was made possible by the fact that reanalyses provide comprehensive and physically consistent information on atmospheric conditions at regular intervals and over periods of several decades. While reanalyses have flaws, the most significant disadvantage is that their faults and uncertainties are not quantified and are frequently misunderstood. Our study contributes to a clearer explanation of this uncertainty by comparing reanalysis datasets, calculating the spread of the metrics derived with the different reanalyses, and analysing the relevance of the ensemble results. Other gridded temperature databases from observational products and climate models can be used with our method. It can also be used to analyse phonological seasons by analysing the annual cycle of various meteorological variables and vegetation indices. The authors' proposed method for computing seasons is somewhat complementary to one they previously described, which is based on thresholds associated with the 25th and 75th percentiles of maximum and minimum daily temperature with the goal of examining various ways to characterizing the annual temperature cycle [18].

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