On moving the week-end from Saturday-Sunday to a sunnier, warmer and less cloudy option:

definition of a best-weekend indicator, retroactive analysis of ERA5 data and model forecast data

Abstract:

Since the establishment of the five-days working week at the beginning of the 20th century and the development of leisure oriented societies, hoping for a "nice week-end" meteorologically speaking has become an increasing preoccupation for many people in modern civilizations. If the holidays are usually mostly taken during summer months (June, July, August in the Northern hemisphere, December, January, February in the Southern one) for the obvious reason that the weather is "better" during this period of the year, the non working days established on Saturday and Sunday in the majority of the countries answers more to religious ancestral traditions and not to meteorological reasons.

In this article, after a short introduction about historical, societal and political reasons on the definition of the week-end, we will present a meteorological indicator defining the "touristic and leisure quality" of a week-end based on temperature, precipitation and demographical data. This indicator built, it will allow us to obtain, week by week, the "best 2 days week-end". Using era5 reanalysis hourly data from 1981 to present, we will try to detect trends (even if not physical for the reasons explained above) in the "best week end days", both at a local (point by point), regional and global scales. Finally, based on the observed patterns of the past in the reanalysis, we will analyze model outputs for the ten to twenty years to propose a week-end shift from Saturday-Sunday to the 2 best days.

History of the 7 days week, 2 days week-end and definition of the 2 days week-end around the world

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Definition of a "week-end-metorological-quality" indicator

a. Local formula of the indicator

Usually, in leisure oriented society, the definition of a good week end is based on the precipitation and temperature. In a first level quantification, the colder and rainier the day, the worse it will be rated, whereas that a blue sky and warm day will be considered more pleasant by most of the people.

The most important and first criteria we consider is the precipitation: the fewer hours of rain, the better. The second and third criteria are the temperature and cloudiness. At equal number of hours of rain during the day, a day will be considered better if the sky is less cloudy (lower total cloud cover) and warm.

As this indicator is touristic and societal, the weather at night shouldn't be taken into account and it will only consider the previously mentioned variables during the time range 8am-11pm (local time).

Based on these considerations, we build the following day_quality_indicator:

day_quality_indicator(date,latitude,longitude)=abs(((precip_score+temp_score+cloudiness_score)/110)*100)

where:

- precip_score = abs((Number_of_hours_with_no_precipitation)/time_interval)*100)

  0<precip_score<100, integer

- temp_score = (((tmax_in_time_interval-tmin_in_week)/(tmax_in_week-tmin_in_week)*10)/2

0<temp_score<5, real

- cloudiness_score = (100-mean_cloudiness_in_time_interval)/20

0<cloudiness_score<5, real

- time_interval = 30 hours (from 8am to 11pm during 2 days)
- tmax,tmin in K
- cloudiness in % (0-100)

With this formula, we obtain an indicator comprised between 0 and 100 indicating the quality of 2 consecutive days. The table below shows the value of the indicator for some discrete values of the parameters, to show how days compare with each other according to the different meteorological variables.

		Meteorological variables					**Intermediate scores**		
"Week-end"	**day_quality_indicator**	**Number_of_hours_with_no_precipitation**	**tmax_in_time_interval**	**tmin_in_week**	**tmax_in_week**	**mean_cloudiness_in_time_interval**	**precip_score**	**temp_score**	**cloudiness_score**
1 (Mon-Tue)	100,00	30	30	10	30	0	100	5	5
2 (Tue-Wed)	0,00	0	10	10	30	100	0	0	0
3 (Wed-Thu)	98,86	30	25	10	30	0	100	3,75	5
4 (Thu-Fri)	97,73	30	30	10	30	50	100	5	2,5
5 (Fri-Sat)	96,59	30	25	10	30	50	100	3,75	2,5
6 (Sat-Sun)	52,27	15	25	10	30	25	50	3,75	3,75
7 (Sun-Mon)	52,27	15	30	10	30	50	50	5	2,5
8 (Sun-Mon)	7,95	0	25	10	30	0	0	3,75	5

Table1: example of day_quality_indicators based on discrete values of meteorological variables

https://docs.google.com/spreadsheets/d/1YfSuxI9x2VlfgiYOHKsK2flSJghzGfeI3MTTzLdt0xU/edit?usp=sharing

Comparing some week-ends of this table, we can see that our indicator is able to reflect the "natural sensation of good or bad days".

- Week-end 1 has no precipitation and the temperature is the maximum of the week. Therefore it scores the maximum: 100.
- Week-end 2: raining always from 8am to 11pm 2 consecutive days. It obtains the minimum score, 0.
- Regardless of the temperature and cloudiness, week-ends 3-4-5 have less precipitation than 6-7 which have less than 8, and therefore score in this decreasing order.
- Week end 3 and 4 only differ by the cloudiness: cloudiness = 0, complete blue sky for week-end 3, cloudiness=50% for week-end 4, therefore week-end 3 is a bit better than 4.
- Same thing for 4 compared to 5 but with difference in temperature and 4 scoring better 5.
- Week-end 6 and 7 have the same precipitation, but temperature are slightly higher during 6 whereas cloudiness is less during 7. The score is the same, the temperature compensating the cloudiness.

Based on this, we can compute, for a given week, the indicator for a Monday-Tuesday week-end, a Tuesday-Wednesday, ... , 7 times until Sunday-following Monday week-end and select, for this week, which is the best option this week:

best_weekend(week,latitude,longitude) = max(day_quality_indicator(date,latitude,longitude), date=week_start_date-week_start_date+1,..,week_start_date+6-week_start_date+7)

From there, we can obtain a global map with, for each geographical point, the value of the best week-end (1 for Monday-Tuesday, 2 for Tuesday-Wednesday, 7 for Saturday-Sunday, 8 for Sunday-Monday).

Insert example map

Plotting one map for the all weeks of the period where we have data (1981-2018, see below), we can see the evolution of the best week-ends along the time.

b. Regional and global mean with population density ponderation

The previous indicator could be used to choose individually (person by person) which two days of the week not to work according to where they live, but in 99% of the cases, people are not free to decide which days of the week not to work and the decision of the definition of the week-end should be taken at a national level, if not continental or global. Today, as shown in the first paragraph, 90% of the countries have the week-end on Saturday-Sunday, whereas the 10 remaining percents are splitted by countries or region (confirm numbers with 1st paragraph).

In a first attempt, we could just say that the regional_best_weekend could be easily computed as the average of the best_weekend in the area of interest (country, Europe, North or South America, Maghreb, South East Asia, global,...).

But we should not forget that this is a societal indicator and that it is based on where people live. For example, it doesn't make sense to compute the global mean of the best_weekend indicator taking into account the weather in the oceans, or putting the same weight for the weather of Siberia than the one from the coastal area of China which is heavily populated. Indeed, choosing a Tuesday-Wednesday week-end for example should be much more based on the weather of high population density, as it impact more people.
Therefore, instead of a simple average, we propose to compute the regional_best_weekend as the average ponderated by the density of population.

In this study, we will use the "Gridded Population of the World (GPW-v4) produced by the NASA Socioeconomic Data and Applications Center (sedac). As explained on their website[1], GPW-v4 "models the distribution of human population (counts and densities) on a continuous global raster surface. (...) The essential inputs to GPW have been population census tables and corresponding geographic boundaries. The purpose of GPW is to provide a spatially disaggregated population layer that is compatible with data sets from social, economic, and Earth science disciplines, and remote sensing. It provides globally consistent and spatially explicit data for use in research, policy-making, and communications.".
In particular, we will use the "UN WPP-Adjusted Population Count, v4.11 from 2015[2] which provide estimates of population count for the years 2000, 2005, 2010, 2015, and 2020, consistent with national censuses and population registers with respect to relative spatial distribution, but adjusted to match United Nations country total.

Insert map of population, global map of indicator shown before, value of non ponderated global average and of ponderated average.

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[1] https://sedac.ciesin.columbia.edu/data/collection/gpw-v4

[2] https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-count-adjusted-to-2015-unwpp-country-totals-rev11

Analysis of the past trends of the indicator in real data (era5)

In this study, we will use the reanalysis data of ERA5[3] available on the Copernicus Climate Data Store (CDS).

ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. This principle, called data assimilation, is based on the method used by numerical weather prediction centres, where every so many hours (12 hours at ECMWF) a previous forecast is combined with newly available observations in an optimal way to produce a new best estimate of the state of the atmosphere, called analysis, from which an updated, improved forecast is issued. Reanalysis works in the same way, but at reduced resolution to allow for the provision of a dataset spanning back several decades. Reanalysis does not have the constraint of issuing timely forecasts, so there is more time to collect observations, and when going further back in time, to allow for the ingestion of improved versions of the original observations, which all benefit the quality of the reanalysis product.

ERA5 is available from January 1979 to present (June 2019) at an hourly resolution for our variables of interest (min and max temperature, precipitation and total cloud cover) at a 0.25°x0.25° regular latitude longitude grid.

- Timeseries of global best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of European best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of South-East Asia best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of Africa best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of USA best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of China best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of France best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of Germany best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of Brasil best_indicator, with mean and standard deviation from 1979 to present
- Timeseries of Indonesia best_indicator, with mean and standard deviation from 1979 to present

[3] https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview

Analysis of the plots

Model based forecast of the indicator

Conclusion