Analyzing solar wind data using Pandas to study an interplanetary magnetic cloud

PyData
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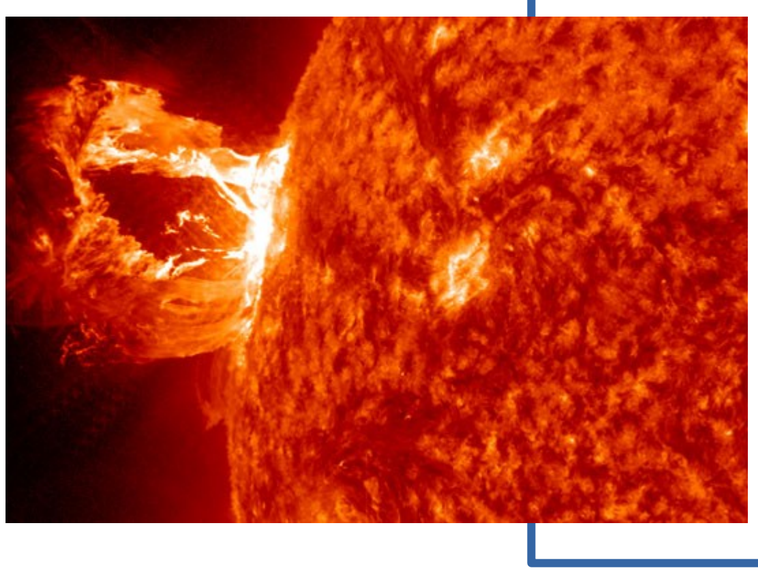


- Magnetic Clouds: subset of Interplanetary Coronal Mass Ejections, presenting a large and coherent rotation, and large value of the magnetic intensity.
- The goal: study an ICME that produced a geomagnetic storm (07 October 2015), affecting radio communications and the proper use of positioning system (e.g., GPS).
- Proccesing solar data obtained from in situ observations. Data was acquired by means of the ACE satellite (http://www.swpc.noaa.gov/products/ace-real-time-solar-wind, 2017).
- The criterium introduced by Elliott et. al. (2005) has been proved to be valid to indentify ICMEs.

Why Pandas

- Python usual coding language within the research group
- Data structure: similar to a table.Public avaible . Data has a 64 seconds resolution.
- Easy to read data

  *foriginal= pd.read_csv(file_,index_col=None,sep='\s+',**na_values=['-1.00000E+31']**)*

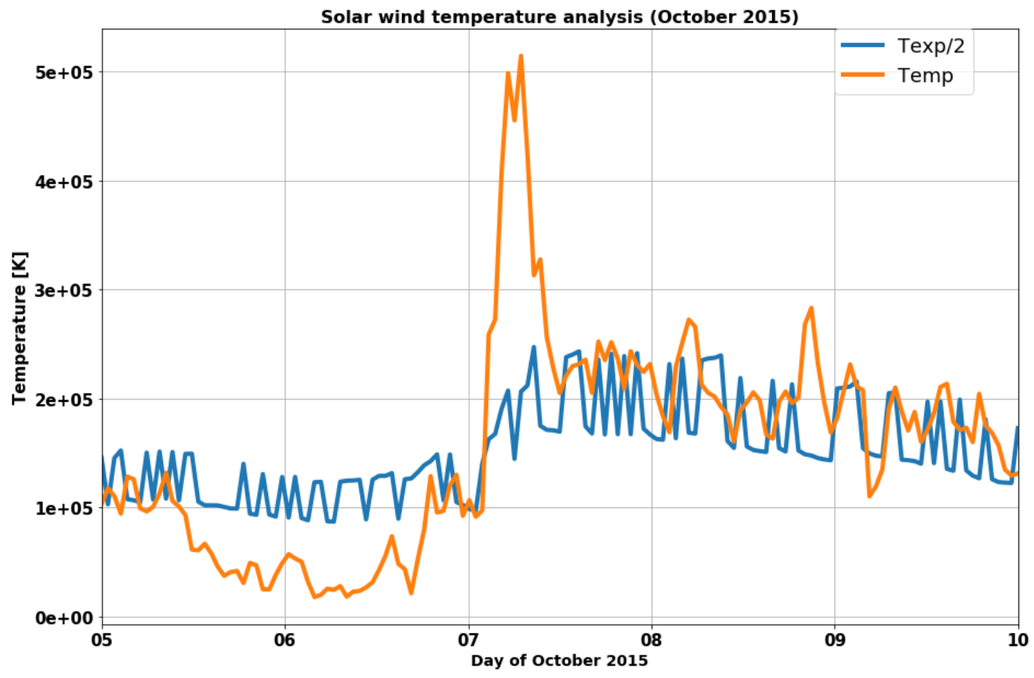
  Easy to parse data and handle special values such as missing data (avoiding problems when computing)
- Heterogeneus data within the frame (DateTime data and real values). Easy to use date and time (indexing by Date and Time for example).
- SQL-like grouping operations such as aggregation function (mean for each group)

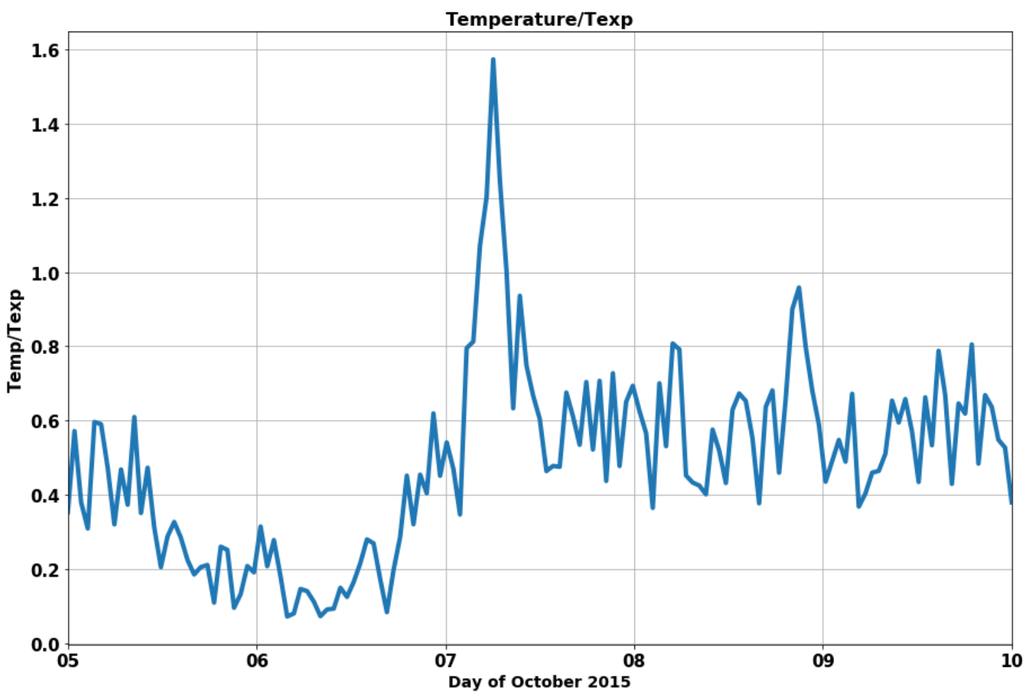
  grupo=df.groupby([df.index.year, df.index.month, df.index.day,df.index.hour])
  df_mean=grupo.mean()

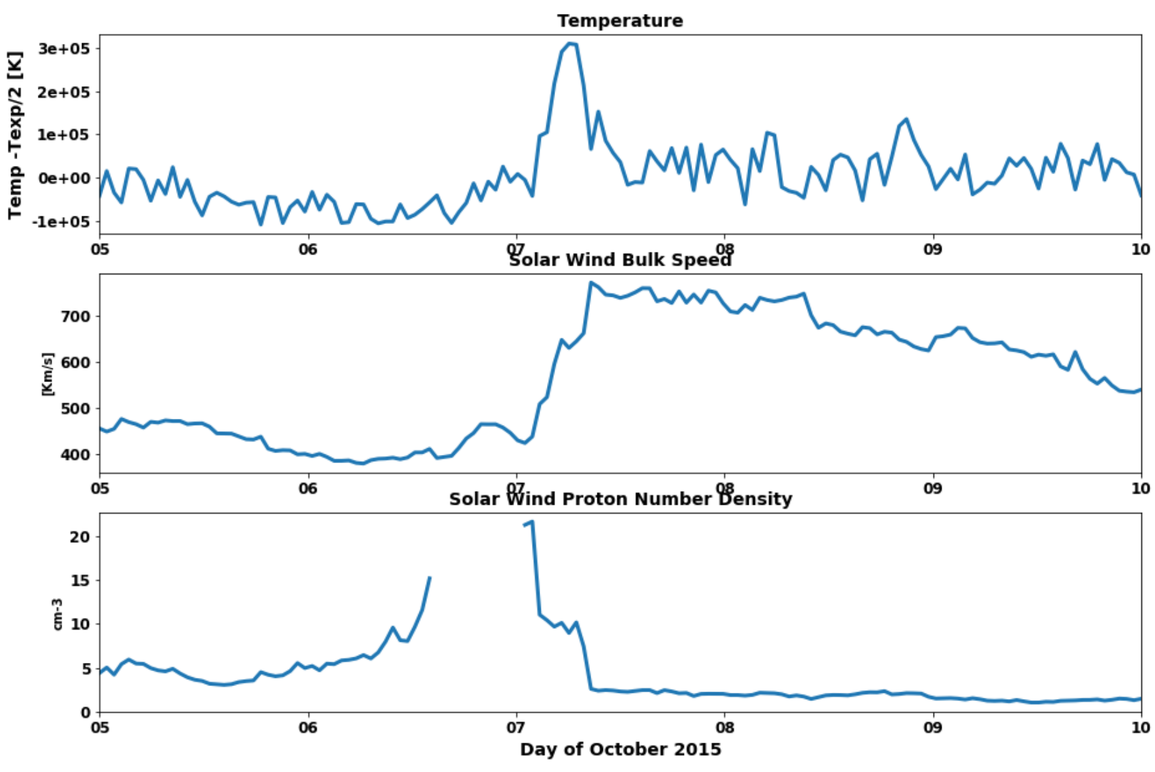
Proccesing & Results

- Solar wind proton temperature and speed are generally well correlated [Neugebauer and Snyder, 1966].
- The ‘‘expected temperature’’ (Texp) is an estimate of the temperature determined from solar wind speed measurements.
- Gosling et al. [1987] established the link between anomalously low temperature regions and ICMEs.
- Richardson and Cane [1995] found Tp/Tex < 0.5 to be a useful criterion for identifying ICMEs.
- Temperatures in compression regions associated with ICMEs are anomalously low relative to elevated temperatures typical for CIRs compressions
- Separating compression and rarefractions: plotting solar wind speed versus time. Positive slopes are labeled as compressions, and negative slopes are labeled as rarefactions. (slope <±2.2 x 10-4 km s-2,is labeled as ‘‘other’’)
- Formula for Texpected is (Elliott et.al., 2005):
  - Compressions: $T_{exp} = 640\,V - 1.59\,x\,10^5$
  -
  - Rarefactions: $T_{exp} = 459\,V - 1.18\,x\,10^5$

V[Km/s] and *Texp [K]*







Conclusions

- The implemented automatic method was able to reproduce the time window where the ICME was observed.
- This software may be used in a more authomatic maner in order to proccess several years of data.
- Also is planed to be use in some real-time processing and to be compared with complementary data for geomagnetic storms.

Elliott H. A. ,McComas D. J. ,Schwadron N. A. , Gosling J. T. ,Skoug R. M. , Gloeckler G. , and Zurbuchen T. H. (2005). An improved expected temperature formula for identifying interplanetary coronal mass ejections. JGR,doi:10.1029/2004JA010794.
Gosling, J. T., D. N. Baker, S. J. Bame, W. C. Feldman, and R. D. Zwickl (1987), Bidirectional solar wind electron heat flux events, J. Geophys. Res., 92, 8519.
Neugebauer, M., and C. W. Snyder (1966), Mariner 2 observations of the solar wind: 1. Average properties, J. Geophys. Res., 71, 4469.
Richardson, I. G., and H. V. Cane (1995), Regions of abnormally low proton temperature in the solar wind (1965 – 1991) and their association with ejecta, J. Geophys. Res., 100, 23,397.