New York Open Statistical Meetup

Hernando Cortina

hch@alum.mit.edu

Abstract

Hockeystick: Visualizing Global Heating with R

2023 is on track to be the hottest year in human history. Public interest in monitoring and tracking climate data is increasing rapidly. In this talk we will review the hockeystick R package designed to easily import and visualize climate data. There are a multitude of publicly-available climate data sources from a large variety of academic and scientific organizations around the world. However, for casual users without knowledge of the sources navigating these datasets can be daunting and error-prone.

The goal of the hockeystick¹ R package is to make essential global heating datasets easily available to nonclimate experts. hockeystick users can download the latest raw data from authoritative sources as well as view it via pre-defined ggplot2 charts. Datasets include atmospheric CO₂ and CH₄, carbon emissions, instrumental, reconstructed, and paleo ice-core temperature records, sea levels, hurricanes, and Arctic/Antarctic sea-ice. Daily land and oceans temperatures were recently added. All data is compiled from authoritative sources, traceable, and documented. hockeystick does not store any data itself, but serves as an API wrapper to always obtain the most up-to-date data. Users may work with the data frames returned by the package or use the pre-defined visualizations.

During the talk I will provide a short overview of the history of climate science and demonstrate this CRAN package, including a live demo.

Package demo

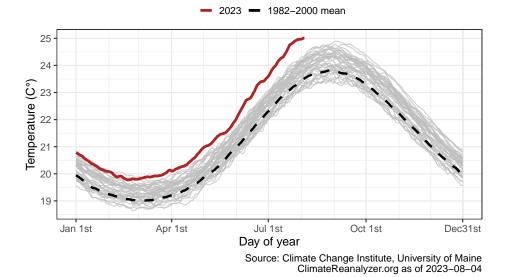
Retrieve NOAA/ESRL Mauna Loa CO₂ Observatory concentration data and plot:

```
library(hockeystick)
atlantictemp <- get_dailytemp(region='AS')
plot_dailytemp(atlantictemp, anomaly = F)</pre>
```

¹hockeystick: Download and Visualize Essential Climate Change Data. https://cran.r-project.org/package=hockeystick; https://cortinah.github.io/hockeystick/

North Atlantic Daily Average Sea Surface Temperature

Sea surface temperature since 1982 and mean

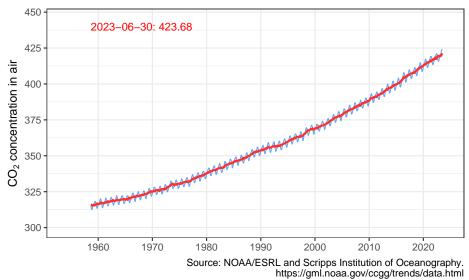


Retrieve NOAA/ESRL Mauna Loa CO₂ Observatory concentration data and plot:

```
ml_co2 <- get_carbon()
plot_carbon(ml_co2)</pre>
```

Atmospheric CO₂ (Keeling Curve)

Mauna Loa CO₂ monthly mean ppm

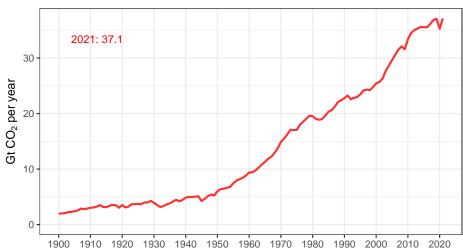


Retrieve GCP global ${\rm CO}_2$ emissions and plot:

```
emissions <- get_emissions()
plot_emissions(emissions)</pre>
```

Fossil Combustion CO₂ Emissions

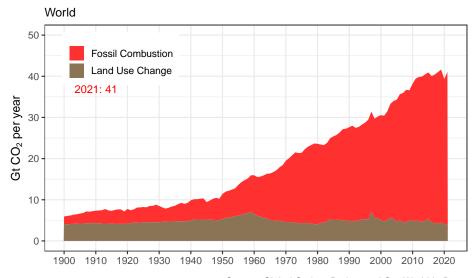
World



Source: Global Carbon Project and Our World In Data. https://github.com/owid/co2-data

plot_emissions_with_land(emissions)

Fossil + Land Use Change CO₂ Emissions

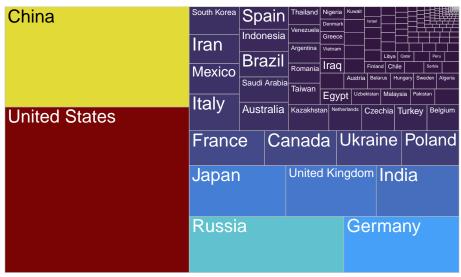


Source: Global Carbon Project and Our World In Data. https://github.com/owid/co2-data

Visualize cumulative emissions by country:

emissions_map()

1900-2021 Cumulative CO₂ Emissions by Country

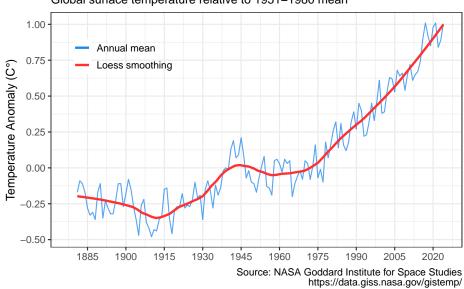


Source: Global Carbon Project and Our World In Data

Retrieve NASA/GISS global surface temperature anomaly data and plot:

anomaly <- get_temp()
plot_temp(anomaly)</pre>

Global Land-Ocean Temperature Index (LOTI) Global surface temperature relative to 1951–1980 mean

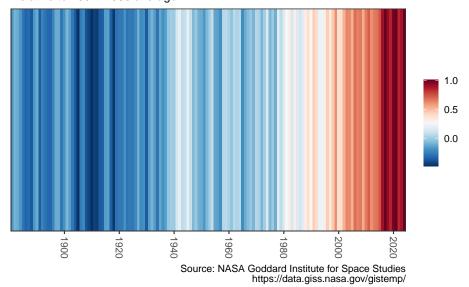


Visualize warming using Ed Hawkins styled "warming stripes":

warming_stripes()

Global surface temperature anomaly

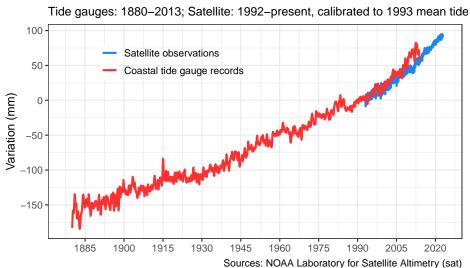
Relative to 1951-1980 average



Retrieve tide gauge and satellite sea level data and plot:

```
gmsl <- get_sealevel()
plot_sealevel(gmsl)</pre>
```

Sea Level Rise



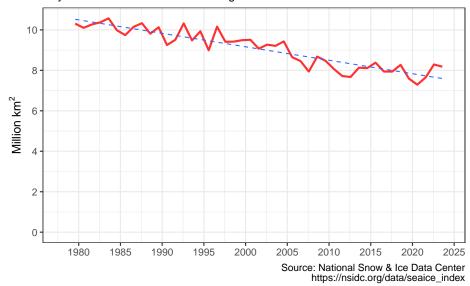
https://www.star.nesdis.noaa.gov/socd/lsa/SeaLevelRise
Commonwealth Scientific and Industrial Research Organisation (tide gauge)
https://research.csiro.au/slrwavescoast/sea-level/measurements-and-data/sea-level-data/

Retrieve July annual Arctic Sea Ice Index and plot:

```
seaice <- get_seaice()
plot_seaice(seaice)</pre>
```

Arctic Sea Ice

July mean sea ice extent. Linear regression in blue.

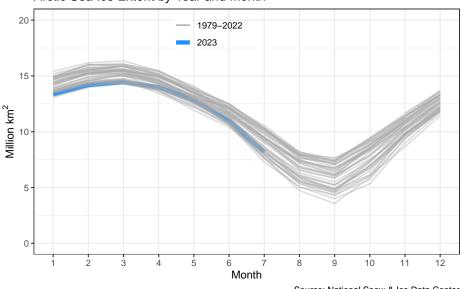


get_seaice() arguments can be modified to download Antarctic sea ice, and allow any month.

You can also visualize sea ice by month and year:

```
arcticice <- get_icecurves()</pre>
plot_icecurves(arcticice)
```

Arctic Sea Ice Extent by Year and Month

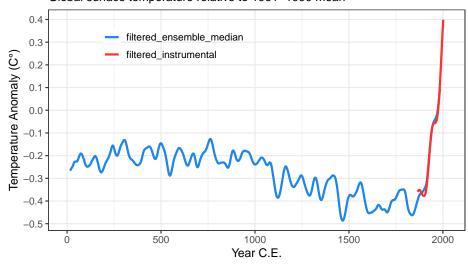


Source: National Snow & Ice Data Center https://nsidc.org/data/seaice_index

Retrieve Common Era temperature reconstruction and plot it with instrumental record:

```
anomaly2k <- get_temp2k()</pre>
plot_temp2k(anomaly2k)
```

Global Common Era Temperature Reconstruction Global surface temperature relative to 1961-1990 mean



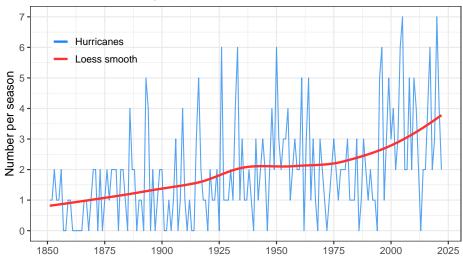
Source: PAGES2k Consortium, NOAA https://www.ncei.noaa.gov/access/paleo-search/study/26872

Retrieve NOAA HURDAT2 hurricane data and plot:

hurricanes <- get_hurricanes()
plot_hurricanes(hurricanes)</pre>

North Atlantic Hurricane Basin

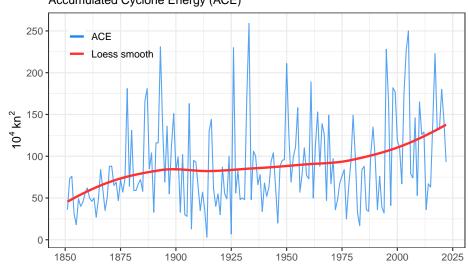
Major Hurricanes (category 3-5)



Source: NOAA Hurricane Research Division, HURDAT2 re-analysis https://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html

plot_hurricane_nrg(hurricanes)

North Atlantic Hurricane Basin Accumulated Cyclone Energy (ACE)



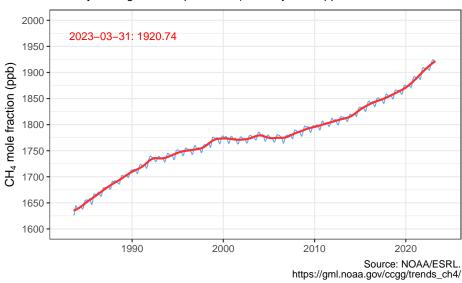
Source: NOAA Hurricane Research Division, HURDAT2 re-analysis https://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html

Retrieve NOAA/ESRL CH₄ Globally averaged mean data and plot:

```
ch4 <- get_methane()
plot_methane(ch4)</pre>
```

Atmospheric Methane

Globally Averaged Atmospheric CH₄ monthly mean ppb

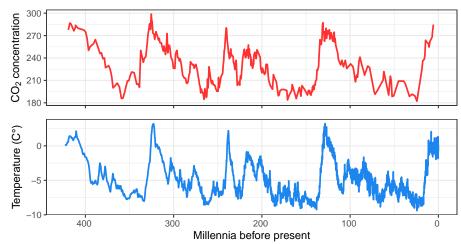


Retrieve Vostok paleo ice core data and plot:

```
vostok <- get_paleo()
plot_paleo(vostok)</pre>
```

Paleoclimate: The Link Between CO₂ and Temperature

420,000 years from the Vostok ice core, Antarctica.



Source: U.S. Department of Energy ESS–DIVE http://cdiac.ess–dive.lbl.gov/ftp/trends/co2/vostok.icecore.co2 http://cdiac.ess–dive.lbl.gov/ftp/trends/temp/vostok/vostok.1999.temp.dat

Acknowledgments

- Carbon Dioxide concentrations: Dr. Pieter Tans, NOAA/GML (https://gml.noaa.gov/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography.
- Global temperature anomaly: GISS Surface Temperature Analysis (GISTEMP), version 4. GISTEMP Team, 2020: NASA Goddard Institute for Space Studies. https://data.giss.nasa.gov/gistemp/
- Warming Stripes design from Ed Hawkins' Climate Lab. https://www.climate-lab-book.ac.uk/2018/warming-stripes/. In addition grateful to Dr. Dominic Royé for posting his approach to plotting them using ggplot2, which warming_stripes() is based on. https://dominicroye.github.io/en/2018/how-to-create-warming-stripes-in-r/
- Sea level data: NOAA Laboratory for Satellite Altimetry (sat) and Commonwealth Scientific and Industrial Research Organisation (tide gauges)
- Sea Ice Index: National Snow & Ice Data Center. Data Archive: https://nsidc.org/data/explore-data
- Vostok carbon dioxide and temperature data: https://cdiac.ess-dive.lbl.gov/trends/co2/vostok.html
- Common Era reconstructed temperature data: PAGES2k Consortium and NOAA).
- Hurricanes: National Oceanic and Atmospheric Administration HURDAT Atlantic Hurricane Database Re-analysis Project, particularly Dr. Chris Landsea.
- Carbon Dioxide emissions: Global Carbon Project and Our World In Data
- Methane: Lan, X., K.W. Thoning, and E.J. Dlugokencky, NOAA Global Monitoring Laboratory (https://gml.noaa.gov/ccgg/trends_ch4/).
- Thank you to Dirk Eddelbuettel for providing the .isConnected function from his tint package to test for internet connectivity.