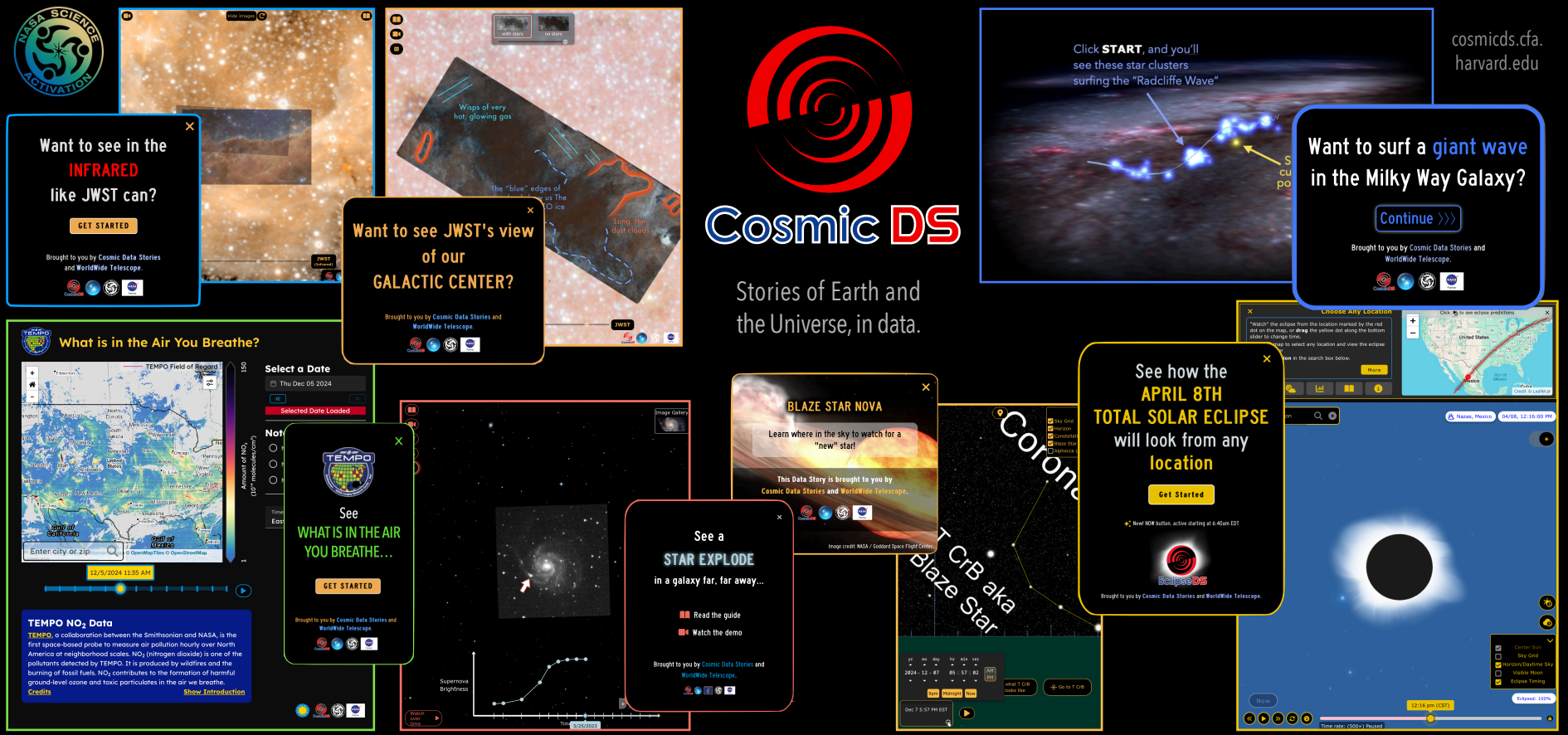
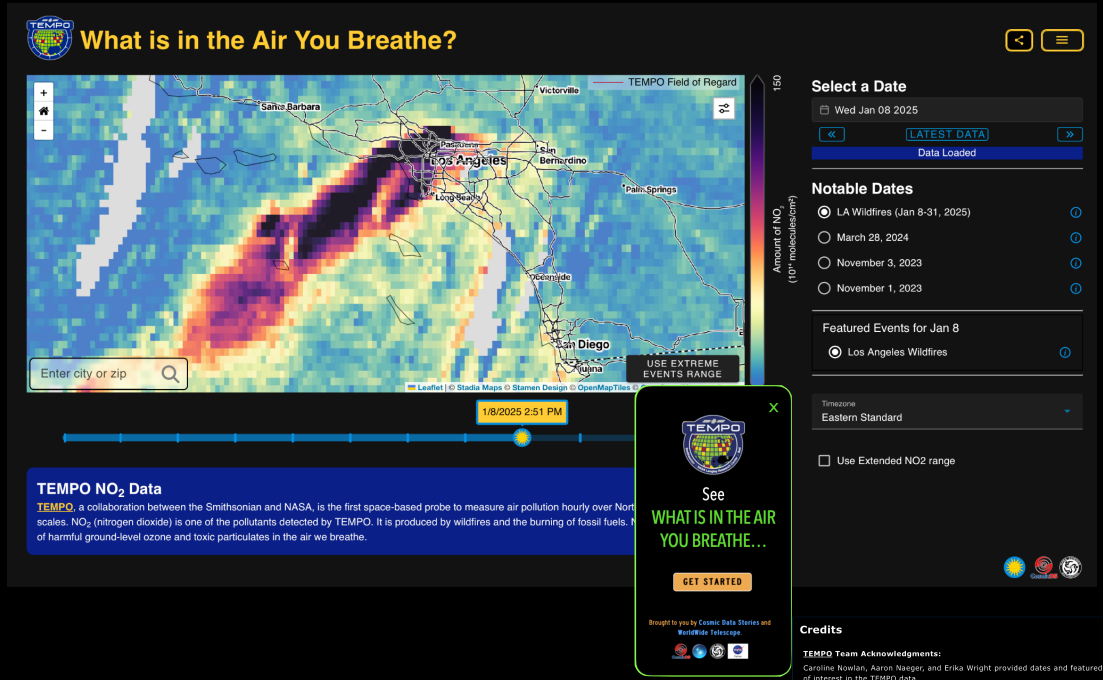

Want to see in the INFRARED like JWST can?
GET STARTED
Brought to you by Cosmic Data Stories and WorldWide Telescope.
Want to see JWST's view of our GALACTIC CENTER?
Brought to you by Cosmic Data Stories and WorldWide Telescope.
Cosmic DS
Stories of Earth and the Universe, in data.
cosmicds.cfa.harvard.edu
Click START, and you'll see these star clusters surfing the "Radcliffe Wave"
Want to surf a giant wave in the Milky Way Galaxy?
Continue
Brought to you by Cosmic Data Stories and WorldWide Telescope.
What is in the Air You Breathe?
TEMPO Field of Regard
Select a Date
Thu Dec 05 2024
Selected Date Loaded
Enter city or zip
12/5/2024 11:55 AM
TEMPO NO2 Data
TEMPO, a collaboration between the Smithsonian and NASA, is the first space-based probe to measure air pollution hourly over North America at neighborhood scales. NO2 (nitrogen dioxide) is one of the pollutants detected by TEMPO. It is produced by wildfires and the burning of fossil fuels. NO2 contributes to the formation of harmful ground-level ozone and toxic particulates in the air we breathe.
Credits
Show Introduction
See WHAT IS IN THE AIR YOU BREATHE...
GET STARTED
Brought to you by Cosmic Data Stories and WorldWide Telescope.
See a STAR EXPLODE in a galaxy far, far away...
Read the guide
Watch the demo
Brought to you by Cosmic Data Stories and WorldWide Telescope.
BLAZE STAR NOVA
Learn where in the sky to watch for a "new" star!
This Data Story is brought to you by Cosmic Data Stories and WorldWide Telescope.
Image credit: NASA / Goddard Space Flight Center
Corona
T CrB aka Blaze Star
See how the APRIL 8TH TOTAL SOLAR ECLIPSE will look from any location
Get Started
New! NOW button, active starting at 6:40am EDT
EclipseDS
Brought to you by Cosmic Data Stories and WorldWide Telescope.
Choose Any Location
Nazas, Mexico
04/08, 12:16:00 PM
12:16 pm (CST)

Cosmic DS

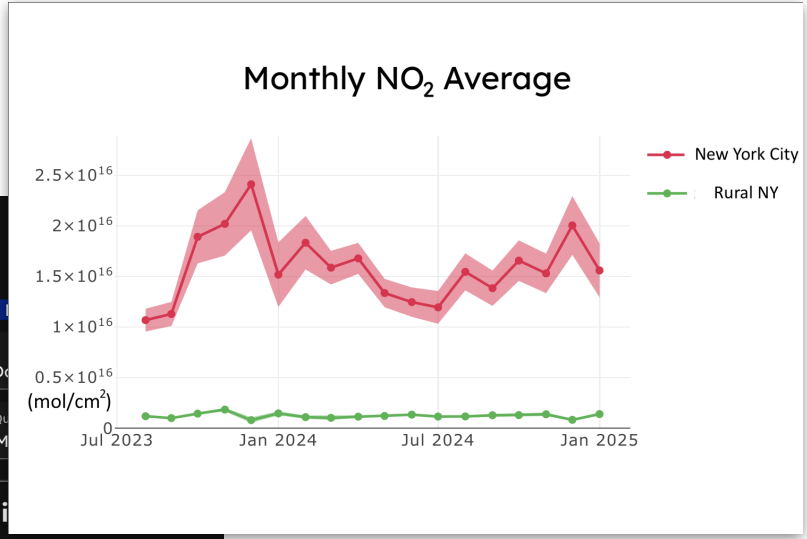
Digital Interfaces for Scientific Research

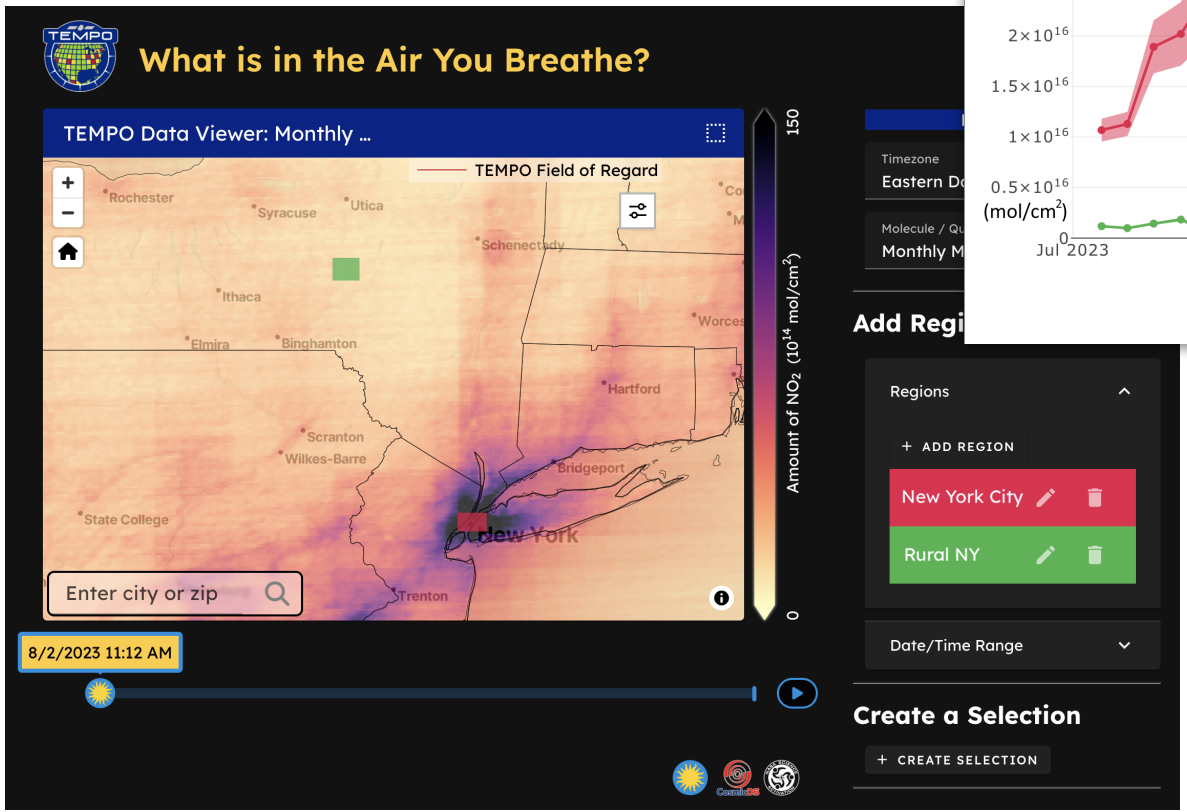


Alyssa Goodman, Center for Astrophysics | Harvard & Smithsonian

(Professor &) PI of CosmicDS, glue, and LIVE Environments

TEMPO + Exploratory Data Analysis
Enabled by glue & LIVE





glue
multidimensional data exploration

LIVE

CosmicDS

TEMPO

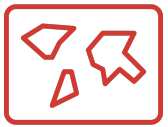
“graphs”

common statistical graphics

(scatterplots, histograms, tables, curves, overlays)

maps & images

(greyscale, color, contours, layer control…)

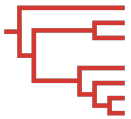


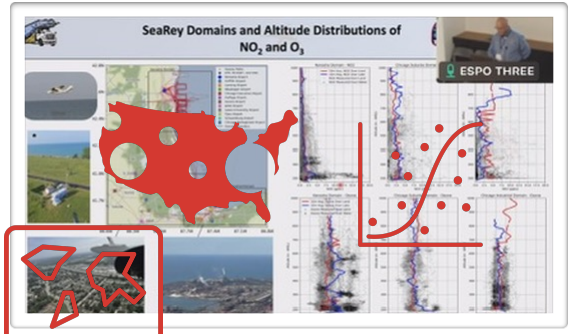
3D displays

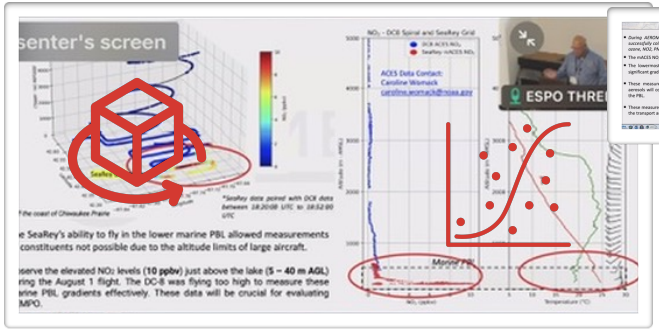
(scatter plots, volumetric rendering, sliders…)

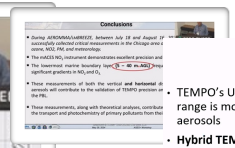
specialized & custom charts

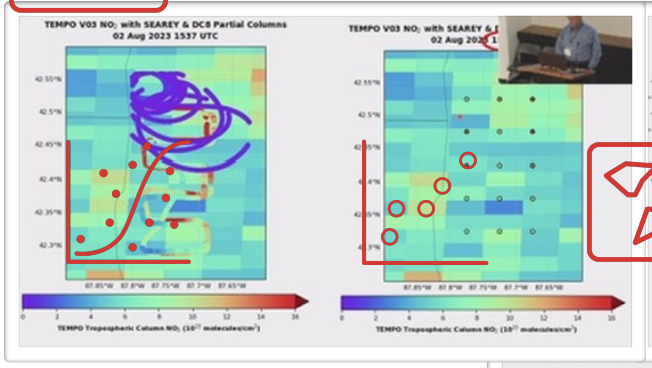
(dendrograms, polar plots, + domain-specific options)

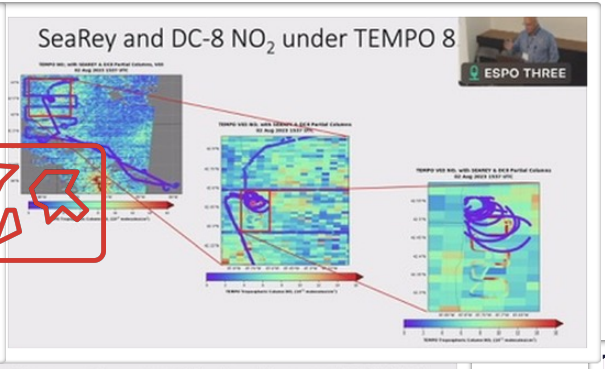


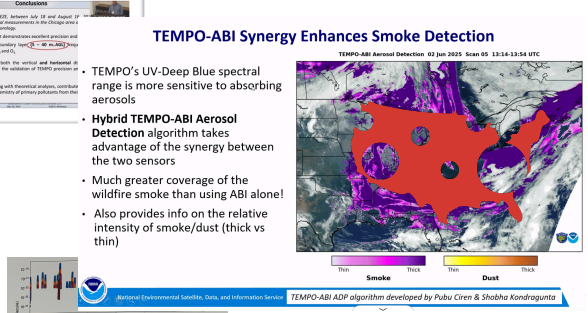

SeaRey Domains and Altitude Distributions of
NO_2 and O_3
ESPO THREE


senter's screen
ESPO THREE
Caroline Womack
caroline.womack@nasa.gov
e SeaRey's ability to fly in the lower marine PBL allowed measurements
constituents not possible due to the altitude limits of large aircraft.
serve the elevated NO_2 levels (10 ppbv) just above the lake (5 – 40 m AGL)
ring the August 1 flight. The DC-8 was flying too high to measure these
rine PBL gradients effectively. These data will be crucial for evaluating
MPO.

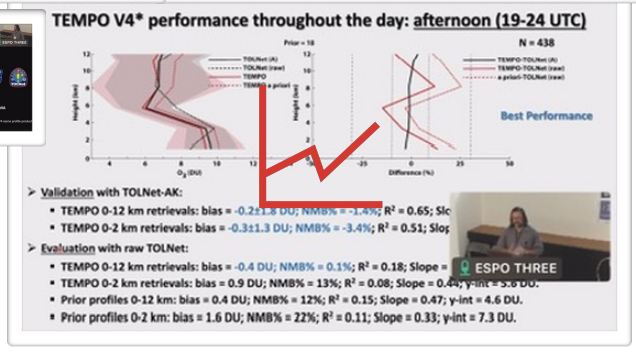

Conclusions

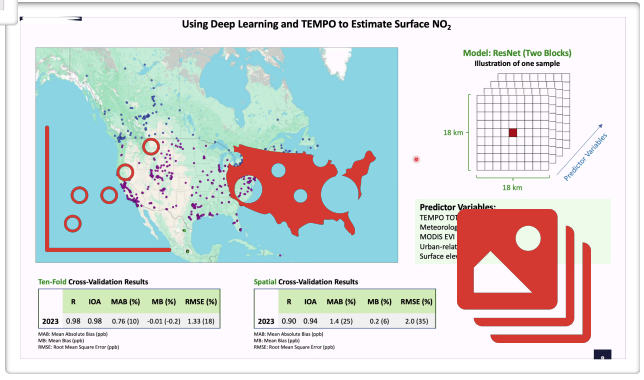

TEMPO V03 NO_2 with SEAREY & DC8 Partial Columns
02 Aug 2023 1537 UTC
TEMPO V03 NO_2 with SEAREY & DC8 Partial Columns
02 Aug 2023 1
TEMPO Tropospheric Column NO_2 (10^{15} molecules/cm^2)
TEMPO Tropospheric Column NO_2 (10^{15} molecules/cm^2)


SeaRey and DC-8 NO_2 under TEMPO 8
ESPO THREE

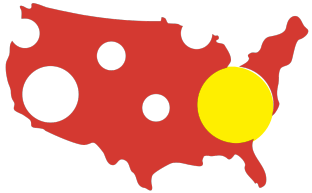

TEMPO-ABI Synergy Enhances Smoke Detection
TEMPO's UV-Deep Blue spectral range is more sensitive to absorbing aerosols
Hybrid TEMPO-ABI Aerosol Detection algorithm takes advantage of the synergy between the two sensors
Much greater coverage of the wildfire smoke than using ABI alone!
Also provides info on the relative intensity of smoke/dust (thick vs thin)
TEMPO-ABI Aerosol Detection 02 Jun 2025 Scan 05 13:14-13:54 UTC
Thin
Thick
Smoke
Thin
Thick
Dust
National Environmental Satellite, Data, and Information Service
TEMPO-ABI ADP algorithm developed by Pubu Ciren & Shobha Kondragunta

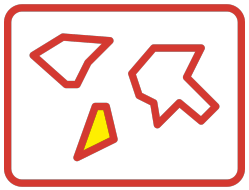
Validation of TEMPO V4* tropospheric profiles using TOLNet
Matthew Johnson
Earth Science Division
NASA Ames Research Center
2023 TEMPO/GeoCAPE ACCP Joint Science Team Workshop
Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA
August 24, 2023

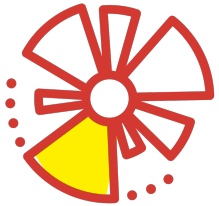

TEMPO V4* performance throughout the day: afternoon (19-24 UTC)
Prior = 10
N = 438
TOLNet (A)
TOLNet (raw)
TEMPO
TEMPO a priori
TEMPO-TOLNet (A)
TEMPO-TOLNet (raw)
a priori-TOLNet (raw)
Best Performance
Height (km)
O_3 (DU)
Difference (%)
Validation with TOLNet-AK:
TEMPO 0-12 km retrievals: bias = -0.2±1.8 DU; NMB% = -1.4%; R^2 = 0.65; Slo
TEMPO 0-2 km retrievals: bias = -0.3±1.3 DU; NMB% = -3.4%; R^2 = 0.51; Slo
Evaluation with raw TOLNet:
TEMPO 0-12 km retrievals: bias = -0.4 DU; NMB% = 0.1%; R^2 = 0.18; Slope =
TEMPO 0-2 km retrievals: bias = 0.9 DU; NMB% = 13%; R^2 = 0.08; Slope = 0.44; y-int = 5.8 DU.
Prior profiles 0-12 km: bias = 0.4 DU; NMB% = 12%; R^2 = 0.15; Slope = 0.47; y-int = 4.6 DU.
Prior profiles 0-2 km: bias = 1.6 DU; NMB% = 22%; R^2 = 0.11; Slope = 0.33; y-int = 7.3 DU.
ESPO THREE

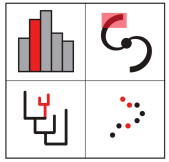

Using Deep Learning and TEMPO to Estimate Surface NO_2
Model: ResNet (Two Blocks)
Illustration of one sample
18 km
18 km
Predictor Variables
Predictor Variables:
TEMPO TO
Meteorolo
MODIS EVI
Urban-relat
Surface ele
Ten-Fold Cross-Validation Results
R IOA MAB (%) MB (%) RMSE (%)
2023 0.98 0.98 0.76 (10) -0.01 (-0.2) 1.33 (18)
Spatial Cross-Validation Results
R IOA MAB (%) MB (%) RMSE (%)
2023 0.90 0.94 1.4 (25) 0.2 (6) 2.0 (35)

selections propagate across all graphs







What is  glue?

multidimensional data exploration

It’s not an acronym.

It is open-source software that
glues data,
glues graphs &
glues tools.

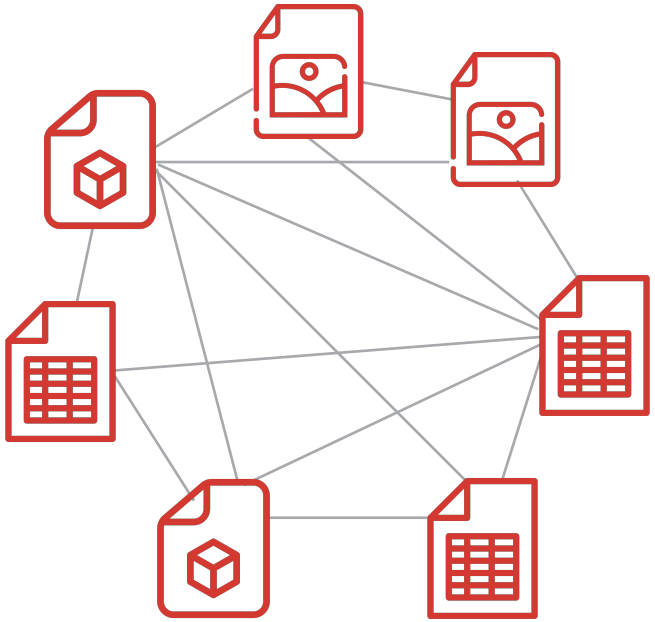
data

numbers (tables, arrays, spreadsheets)

images & maps (FITS, JPEG, GIS and more)

data cubes (3D, 4D, and more)

data files' common attributes are **glued**



avoiding the need to merge data files

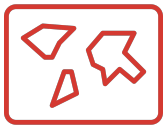
“graphs”

common statistical graphics

(scatterplots, histograms, tables, curves, overlays)

maps & images

(greyscale, color, contours, layer control…)

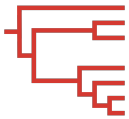


3D displays

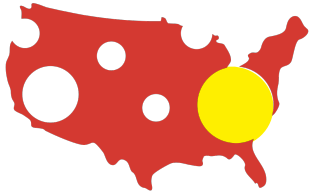
(scatter plots, volumetric rendering, sliders…)

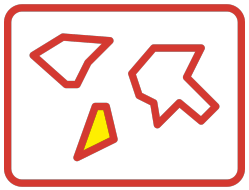
specialized & custom charts

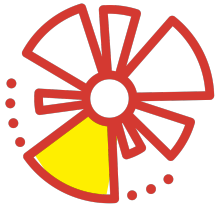
(dendrograms, polar plots, + domain-specific options)



selections propagate across all graphs



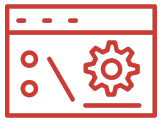




for real-time data exploration & insight

tools

plug-ins (user-defined formats, plots, layouts…)



web services (across domains)

command-line (built-in terminal, scriptable)

for easy customization

glues data,
glues graphs &
glues tools.

glueviz.org

BONUS: save, share, or publish what you learn—

save “sessions” to continue where you left off

export graphics

use/export to Jupyter environments

export to plot.ly (javascript)

export to augmented reality

learn how at glueviz.org.

glueviz.org

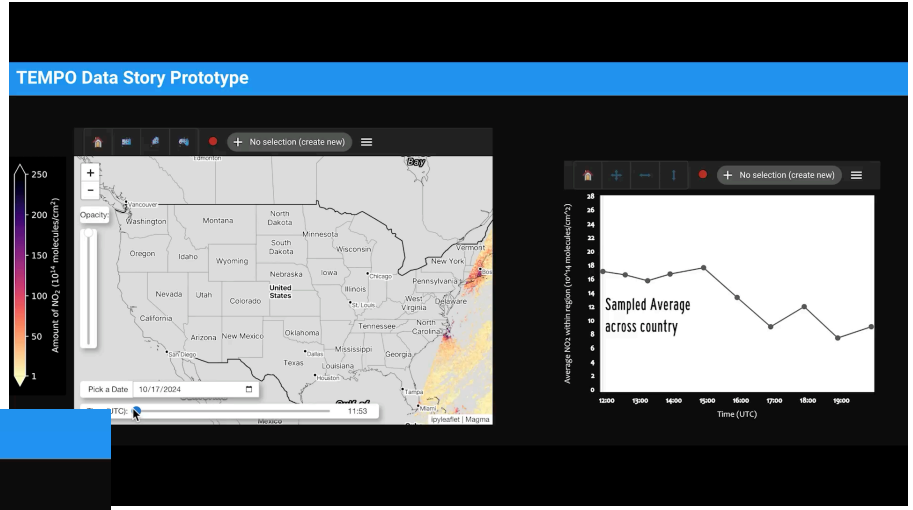
supported by

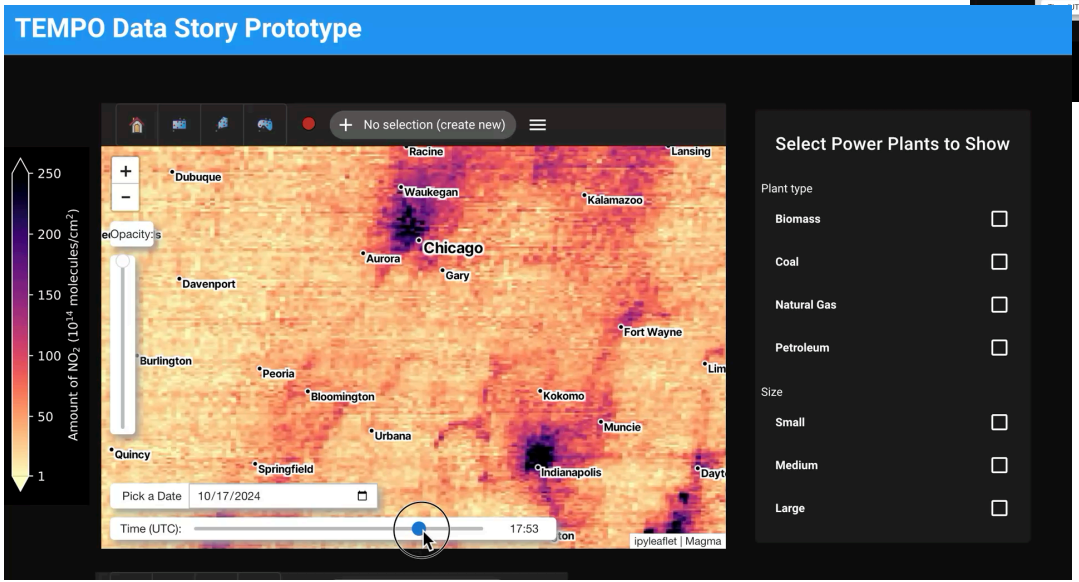
glue solutions inc.

GORDON AND BETTY MOORE FOUNDATION

TEMPO + Exploratory Data Analysis

Enabled by glue & LIVE





glue
multidimensional data exploration

LIVE

CosmicDS

TEMPO

LIVE

LIVE Environments

About LIVE | Capabilities | Tech | Who are we? | Learn More

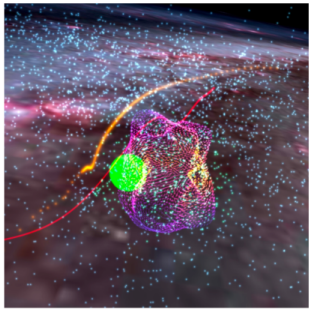
Linkable Interactive Visualization Exploration (LIVE) Environments

What is LIVE?

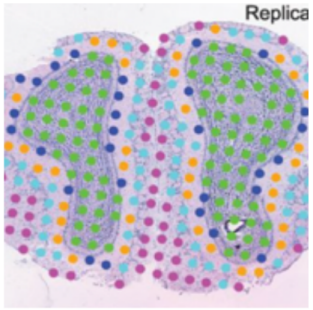
LIVE lets anyone build
"Linkable Interactive Visualization and Exploration" Environments.

LIVE is free, open-source, and helps with shared data and visualization challenges across astronomy (LIVE Astro), biology (LIVE Bio) and GIS (LIVE GIS).

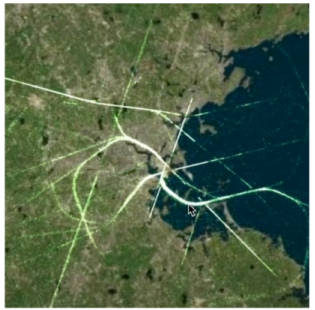
LIVE is not just infrastructure—it is the foundation of an emerging open-source ecosystem. LIVE collaborators are building out science demonstration projects to refine and ensure the platform's utility, extensibility, and long-term sustainability.



LIVE Astro



LIVE Bio



LIVE GIS

Software (red outline= used as part of LIVE today)	Function	Browser (B) Desktop (D) Python anywhere (P)	(Filter by) Usage	Priority Level	Description	Level of Connection to LIVE as of 2025 1=working 2=prototype 3=discuss'ns underway 4=not yet	GitHub Link	Coordinatiing Contacts
GeoJupyter	GIS	B		1	collaborative cloud based tool to analyze and visualize geospatial data in JuypterLab.	2	github.com/geojupyter/	Pangeo & Jupyter
JupyterGIS	GIS	B		1	geospatial extensions for Jupyter notebooks	2	github.com/geojupyter/ju	GeoJupyter / Pangeo
Leaflet	Maps	B		1	Interactive maps for web applications	1	github.com/Leaflet	LeafletJS community
GeoPandas	Data Analysis	Py		2	Geospatial data analysis with pandas	3	github.com/geopandas/	GeoPandas community / NumFOCUS
Cryocloud	Community Platform	B		3	Cloud platform for cryosphere research	4	github.com/CryoInTheClou	NASA Cryosphere teams
Pangeo	Community Platform	B		3	Scalable geoscience data analysis platform, ecosystem built around Dask, xarray, Jupyter	4	github.com/pangeo-data/	Pangeo community
OpenSpace	Earth & Sky Viewer	D		1	3D space visualization platform (used w/glue and WWT in MilkyWay3D.org)	1	github.com/OpenSpace	American Museum of Natural History/NASA
WorldWide Telescope (WWT)	Earth & Sky Viewer	D, B		1	displays all-Sky and whole-Earth images with inset image and data overlay options	1	github.com/WorldWideTel	SAO/Harvard
					2-D visualization system for Jupyter, based on			Jupyter

AWS CLIMATE IMPACT COMPUTING PROPOSAL FOR “TEMPO LIVE,” 2024

PROJECT ABSTRACT / EXECUTIVE SUMMARY

Integration across the heterogeneous data sources needed to responsibly and effectively address challenges and choices posed by climate change remains remarkably difficult. In this work, we will use the opportunity presented by the stream of high temporal- and spatial- resolution satellite imaging data made possible by the new TEMPO (Tropospheric Emissions Monitoring of Pollution) satellite to create an **extensible, scalable, data integration and exploratory analysis environment (“TEMPO LIVE”) usable by researchers, public officials, and learners alike.** TEMPO leaders are collaborators and are based at the Harvard-Smithsonian Center for Astrophysics.

Thanks to our and our collaborators’ efforts in building web frameworks (e.g. Jupyter environments, Solara) and exploratory data analysis tools (glue, glupyter) and recently their union as **“LIVE environments''** and **“LIVE GIS,''** our team has abundant expertise on how to build and promote open-source online environments for data retrieval, integration, analysis, and sharing. However, even though our colleagues at NASA, the Smithsonian Institution, and NOAA are using a variety of Amazon services to provide access to TEMPO data, **current TEMPO plans do not include clear paths to real-time interactive data exploration or easy integration with *in-situ* pollution monitoring, demographic, health, or economic data sets.** In seeking direct collaboration with Amazon, HDSI and FAS RC experts, we seek to pilot the faster data access techniques, **easier integration of relevant raster, vector, and geo-referenced tabular data sources**, and **efficient hosting resource-intensive web services** needed to enable much broader use of TEMPO data, and to bring TEMPO LIVE from research-to-operations (R2O) level scale.