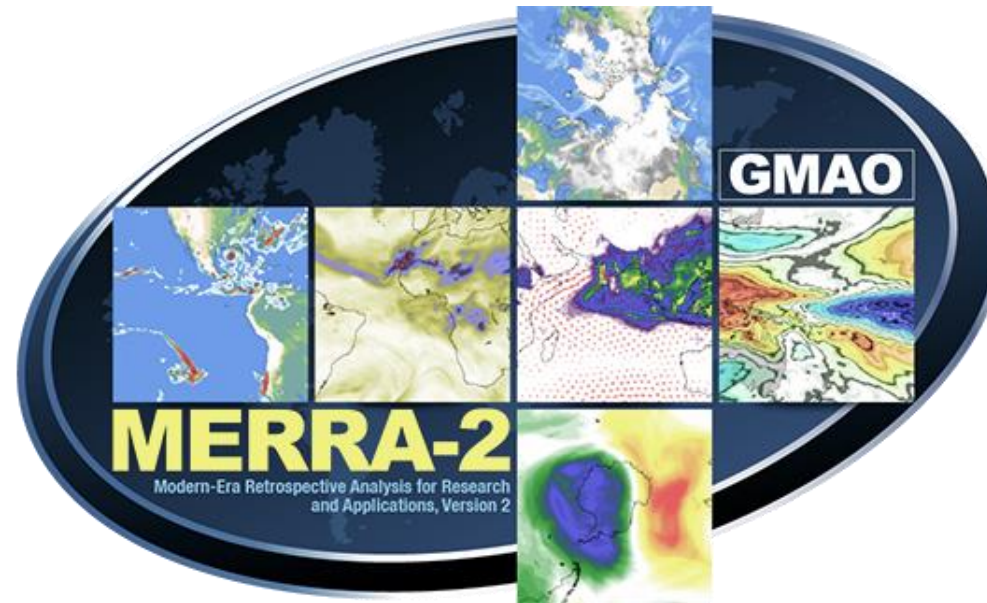


Applied uses of MERRA reanalyses: current and future prospects



Michael Bosilovich, Paul Stackhouse NASA (LaRC), Stephanie Schollaert Uz,
Amin Dezfuli, Natalie Thomas, Allison Collow

Global Modeling and Assimilation Office - NASA Goddard Space Flight Center

NASA Earth Action Strategy

Adapted from Karen St.
Germain, NASA HQ

Driving impact from \$1.5B in NASA observations and research to meet the needs
at federal, state, local, and tribal levels



- Greenhouse gas monitoring
- Wildland fire risk & recovery
- Health & air quality

- Sea level & coastal risk
- Energy & sustainable infrastructure
- Agriculture & crops

- Disasters & Extreme Events
- Water Resources & Security
- Biodiversity & Ecosystem Change



Giovanni - Data Selection

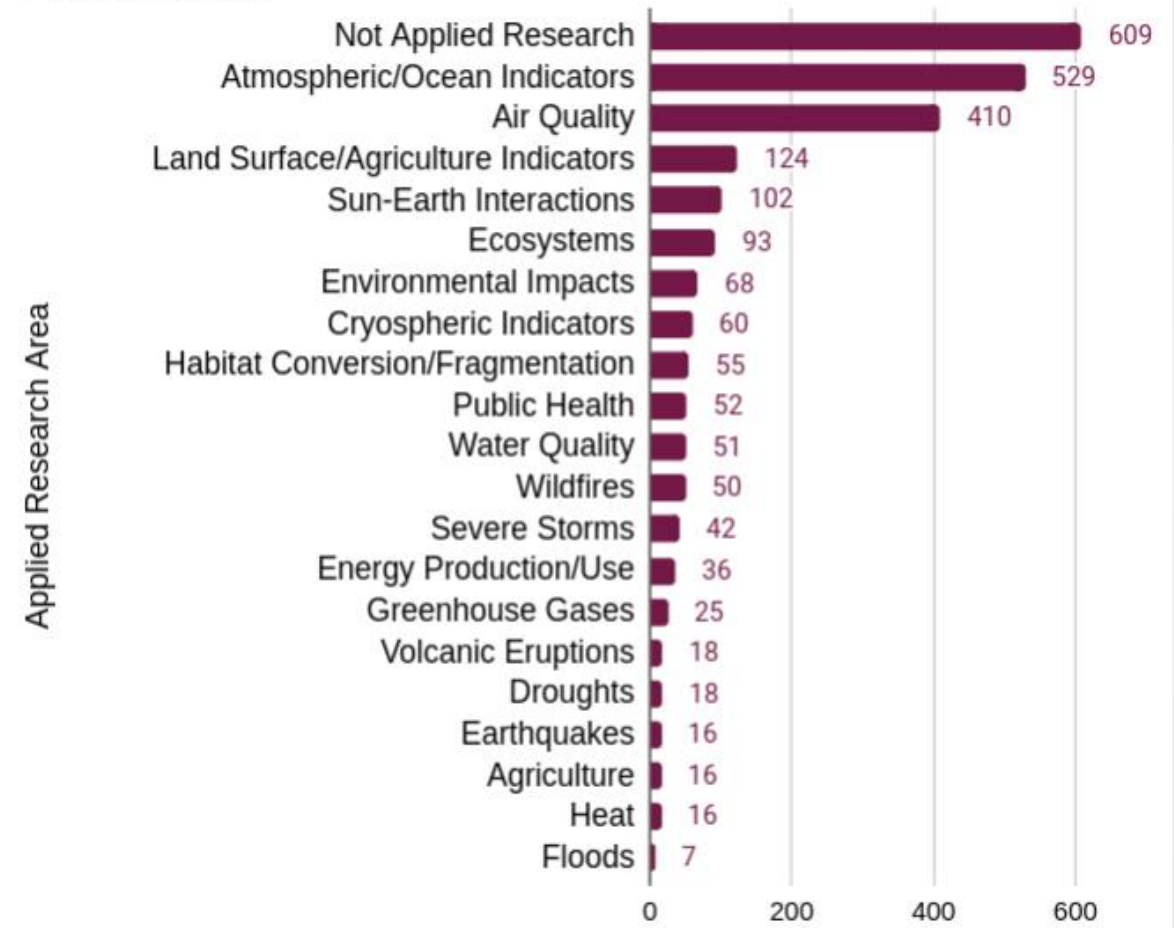
giovanni.gsfc.nasa.gov

MERRA-2 Applications and Use Cases

Use Cases

- Generalistic Assessments of the Potential of **Medical Drones in Urban Environment**: Based on Microscopic Travel Time Comparison with Ground-Based Services (near surface winds, [Wachter et al 2024](#))
- Enhanced joint hybrid deep neural network explainable **artificial intelligence model for 1-hr ahead solar ultraviolet index prediction** (cloud, AOT, TPW, [Prasad et al 2023](#))
- Quantifying the impact of inverter clipping on **photovoltaic performance** and soiling losses ($PM_{2.5}$, PM_{10} , [Micheli et al. 2024](#))
- Quantifying water evaporation from large reservoirs: Implications for **water management in water-stressed regions** ($T2m$, $Q2m$, $U10m$, $SWdn$, [Nevermann et al. 2024](#))

Applied Research Areas in MERRA-2 Dataset-Citing Publications

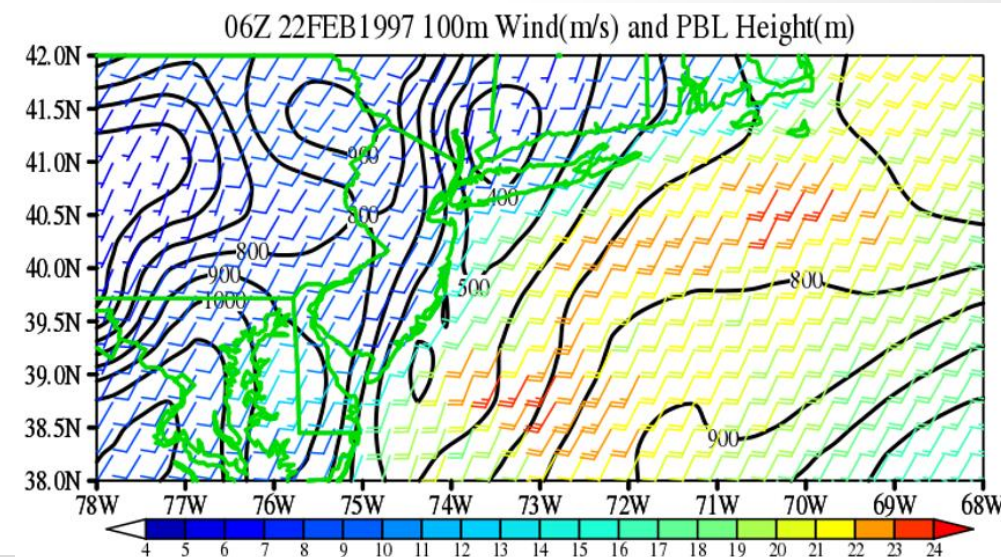


GES DISC Publication search – Identifies DOI and Alphanumeric short names, and so underestimates actual total citations

MERRA-2 Wind Energy Applications

- 50m Winds were included in MERRA in 2008, global one hourly data gained many users – AWEA estimated \$5B/yr projects from 2008-2016
- Major Wind Energy Users
 - American Wind Energy Association (AWEA)
 - Electrical Power Research Institute (EPRI)
 - International Energy Agency (IEA)
- [OA1-01] – “IEA Wind Topical Expert Meeting 111: Reanalyses for Wind Energy”; Rémi Gandoïn et al. – Connecting reanalysis development with the energy community

MERRA-21C to produce 100m,
200m and 300m meteorology in a
PBL collection

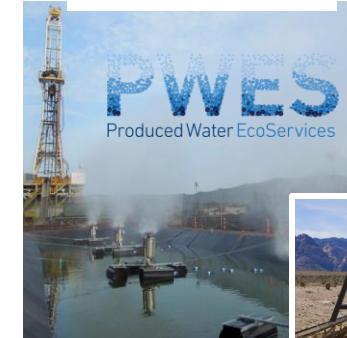




Prediction Of Worldwide Energy Resources

NASA Langley Research Center

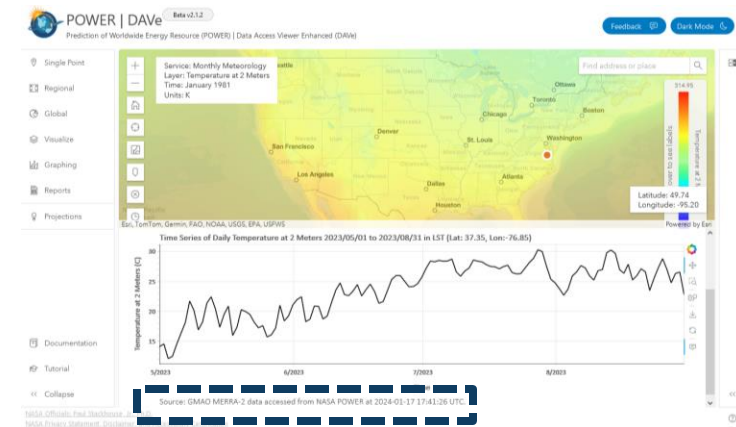
National Aeronautics and Space Administration



How do they use it? POWER's value-added datasets are used for research, development, applications, and more a for variety of impactful applications. For example:

- **Produced Water Ecoservices (PWES)** used precipitation, temperature, humidity, wind, and surface pressure parameters from **MERRA-2**, to **develop a system used to treat and return water** to its original value in Columbia. This group has successfully treated and returned 2 million barrels of water back into the ecosystem.
- **Terrasmart**, a solar panel installation company, created the Solar Instant Feasibility Tool (SIFT). SIFT uses surface radiation parameters and typical meteorological year data from MERRA-2 (as obtained from DOE NREL) to **identify the best system design for solar projects**.
- **Argonne National Labs** has used POWER-provided radiation and MERRA-2 metrological data to create **PV installation models to predict power generation over potential power outage windows** for both remote locations and America's Armed Forces.

PI: Paul W. Stackhouse Website: <https://power.larc.nasa.gov/> Email: larc-power-project@mail.nasa.gov



Above: POWER's Data Access Viewer enhanced (DAVE). Users can discover, access, visualize, subset and download MERRA-2 data from this tool. The DAVE provides metrological and radiation parameters, spanning from 1981 and 1984 respectively, until near real-time for hourly, daily, monthly, annually, and climatology time periods.

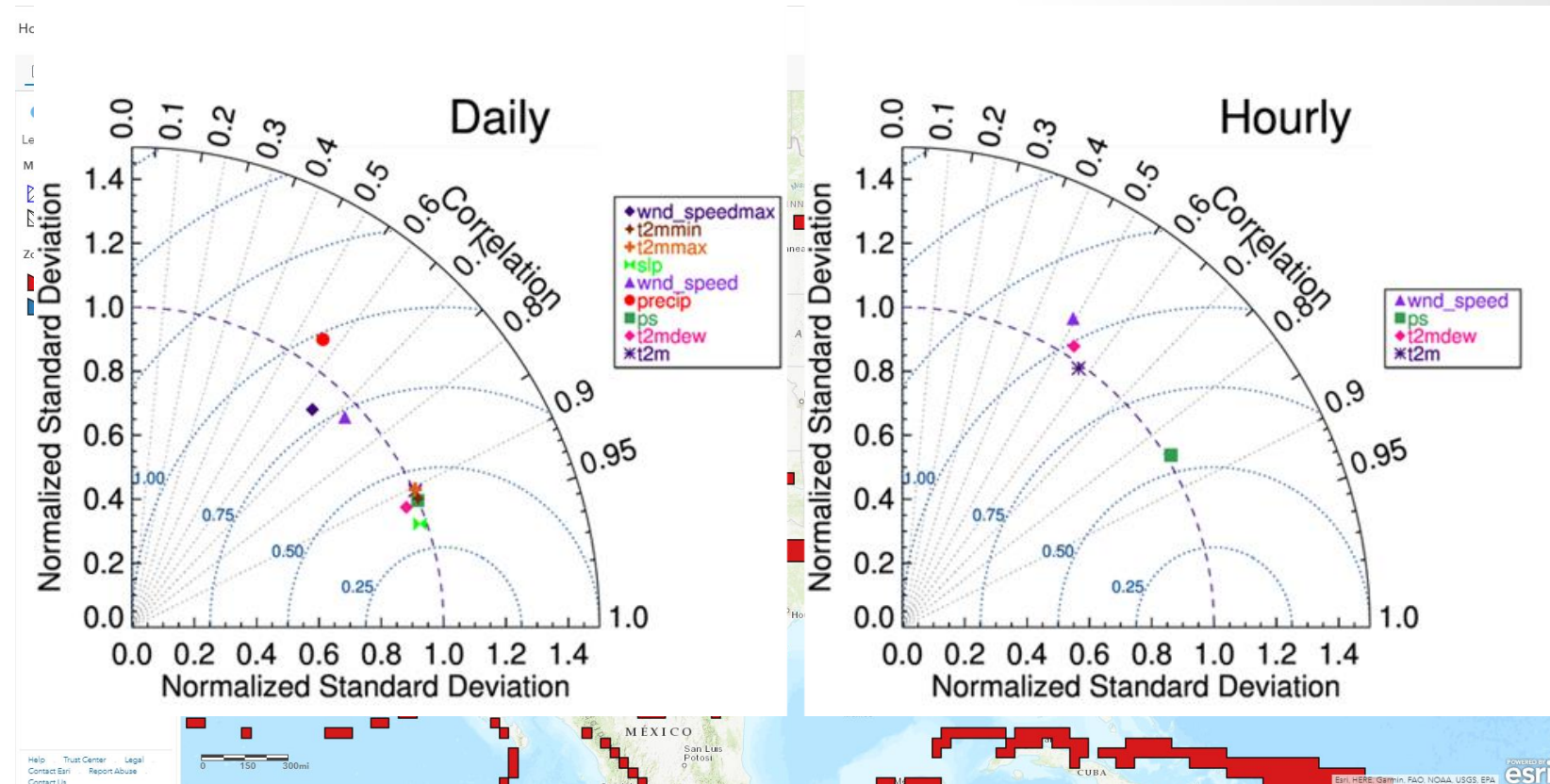


Global Modeling and Assimilation Office
gmao.gsfc.nasa.gov

Applications of MERRA-2: POWER

- Utilizes MERRA-2 for Meteorology (along side satellite derived obs)
- Thermal zones for building and HVAC design
- Hourly data available through a GIS portal
- Meteorology station evaluations
- Exploring future connections and transition to MERRA-21C

Thermal Moisture Zones Differences (1984-1998 to 2004-2018)



Courtesy Paul Stackhouse and
Colleen Mikovitz (NASA LaRC)

POWER – DAVe example

power.larc.nasa.gov/beta/data-access-viewer/

Please note this application is in active development. Forward bugs/enhancements to page curator.



POWER | DAVe

Beta v2.1.7

Prediction Of Worldwide Energy Resources (POWER) | Data Access Viewer Enhanced (DAVe)

Single Point

Regional

Global

Visualize

Graphing

Reports

Projections

Documentation

Tutorial

Collapse

Feedback

Dark Mode

Find address or place

Latitude: 54.62
Longitude: 8.14

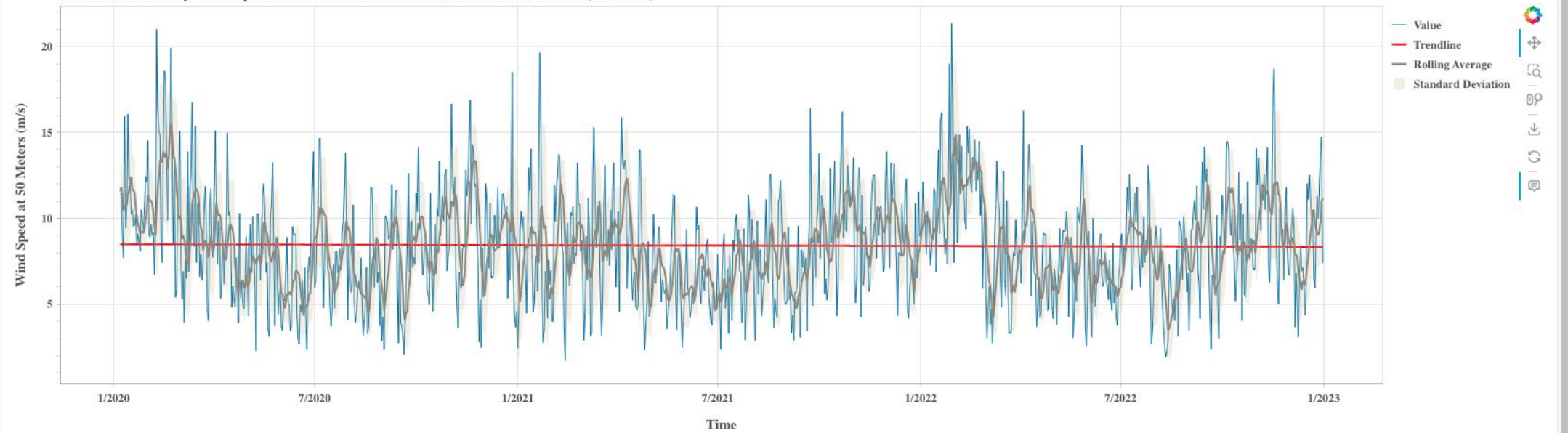


Esri, TomTom, Garmin, FAO, NOAA, USGS

Powered by Esri

Request Results

Time Series of Daily Wind Speed at 50 Meters 2020/01/01 to 2022/12/31 (Lat: 56.0, Lon: 8.0)



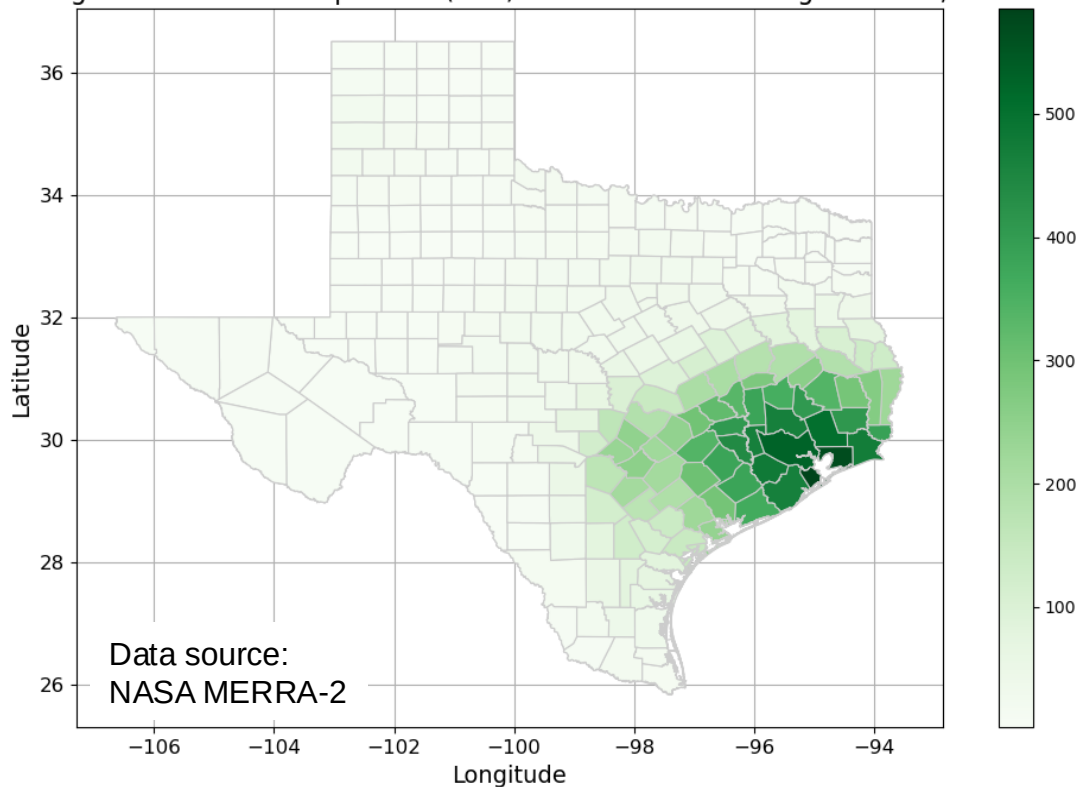
Source: GMAO MERRA-2 data accessed from NASA POWER at 2024-04-17 18:19:42 UTC.

Strategic Partnerships to reach new sectors

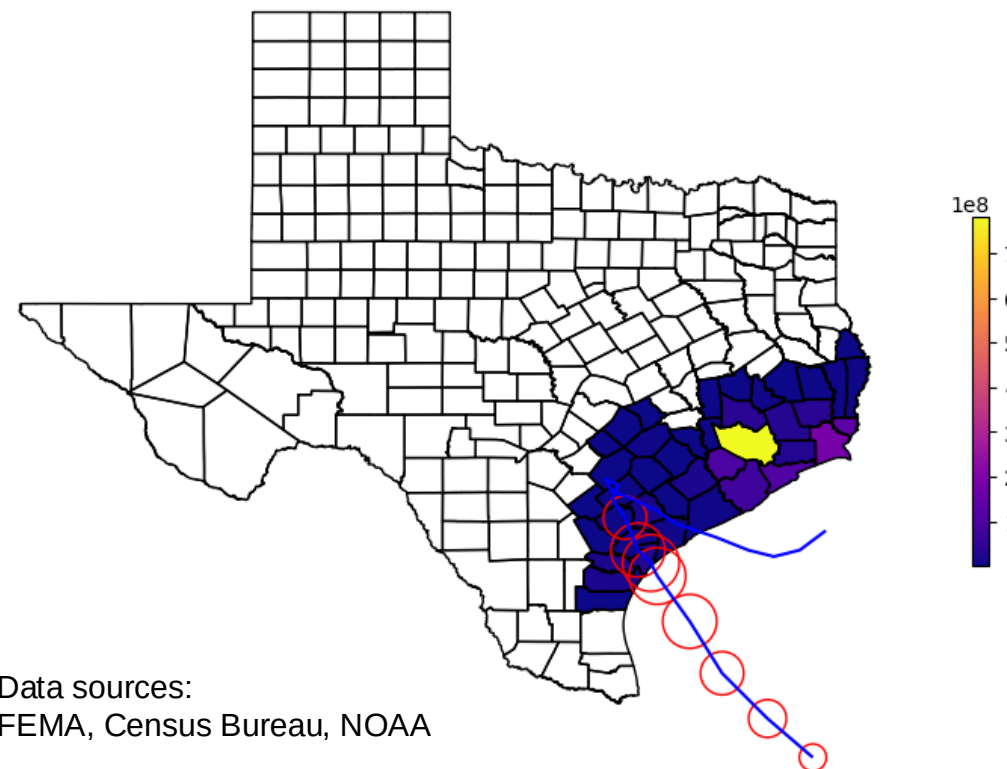


Pilot study between Goddard and U.S. Dept of the Treasury Office of Financial Research (OFR) on Hurricane Harvey to identify covariance between climatic factors and economic impact. Harvey was most significant tropical cyclone rainfall event in United States history, in scope and peak rainfall amounts, per the NOAA National Hurricane Center Tropical Cyclone Report. Highest total rainfall was 60.58 inches near Nederland, Texas. Final report in prep.

Average Cumulative Precipitation (mm) in Texas Counties August 24-28, 2017



Total Individuals and Household Program claims by County ($\times 10^8$ USD)



NASA Goddard contributors: Stephanie Schollaert Uz, Mike Bosilovich, Natalie Thomas, Helen

Amos, Alex Ruane, Gavin Schmidt, Alexey Shiklomanov



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Results expressed in this project are not necessarily the views of the Department of the Treasury or OFR

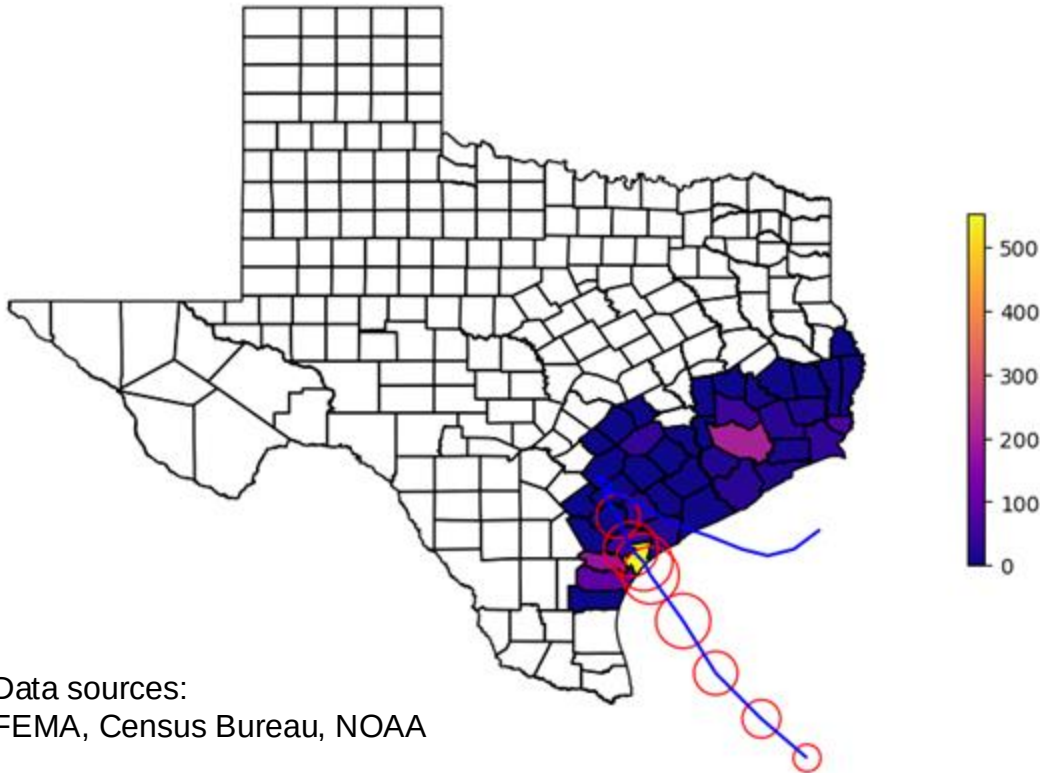
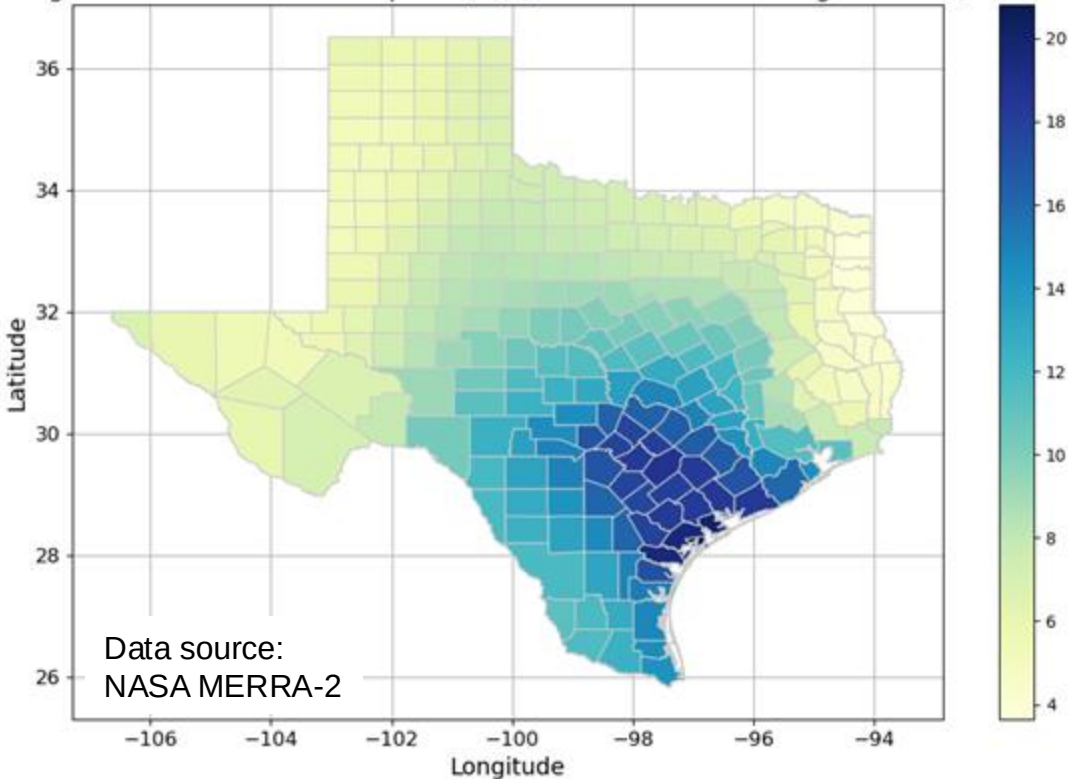


Strategic Partnerships to reach new sectors

Pilot study between Goddard and U.S. Dept of the Treasury Office of Financial Research (OFR) on Hurricane Harvey to identify covariance between climatic factors and economic impact. Harvey was most significant tropical cyclone rainfall event in United States history, in scope and peak rainfall amounts, per the NOAA National Hurricane Center Tropical Cyclone Report. Highest total rainfall was 60.58 inches near Nederland, Texas. Final report in prep.

Total Individuals and Household Program claims count for destroyed property

Average Maximum 10m Wind Speed (m/s) in Texas Counties August 24-28, 2017



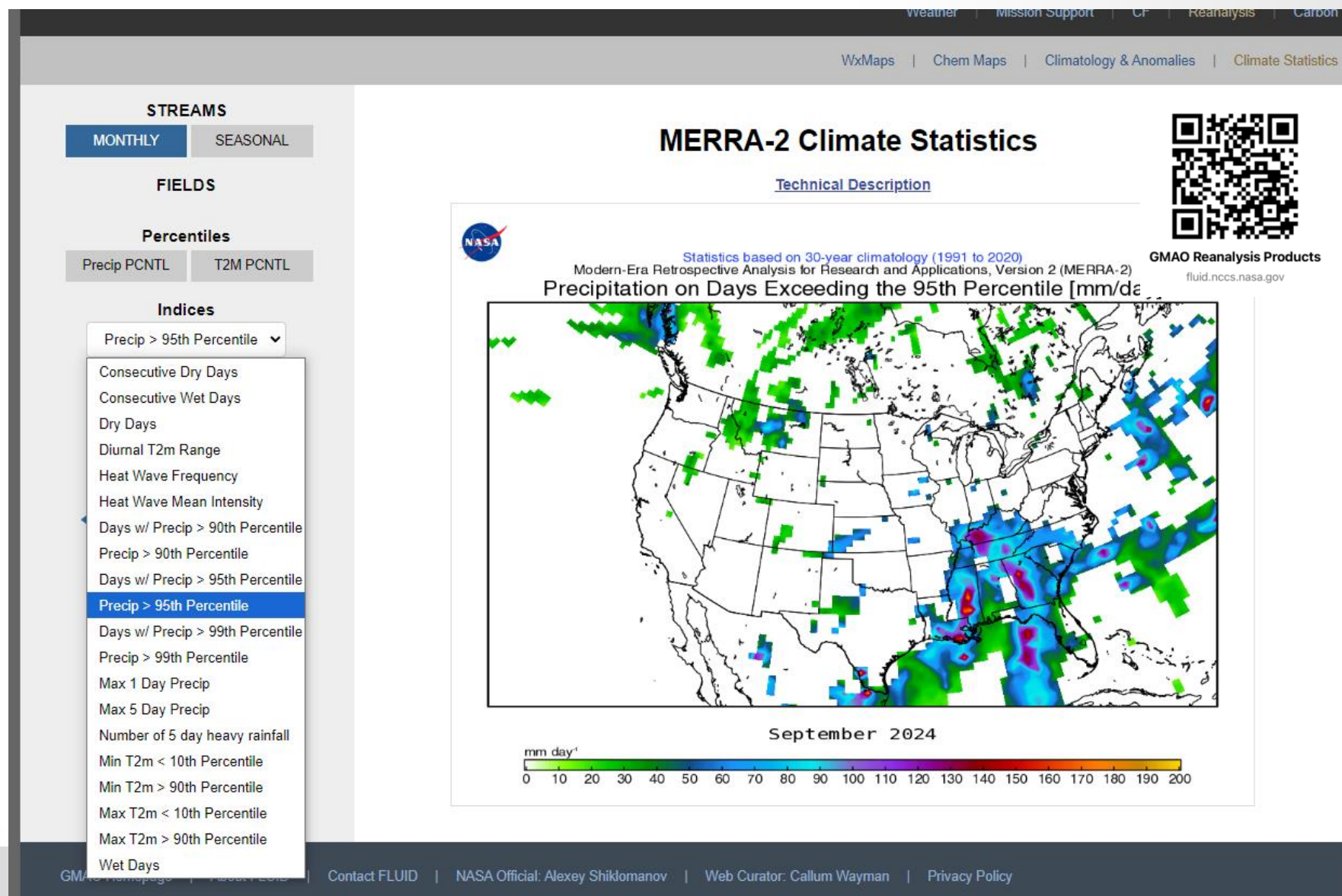
NASA Goddard contributors: Stephanie Schollaert Uz, Mike Bosilovich, Natalie Thomas, Helen Amos, Alex Ruane, Gavin Schmidt, Alexey Shiklomanov

Results expressed in this project are not necessarily the views of the Department of the Treasury or OFR

FLUID – Weather, Climate and Statistics viewer

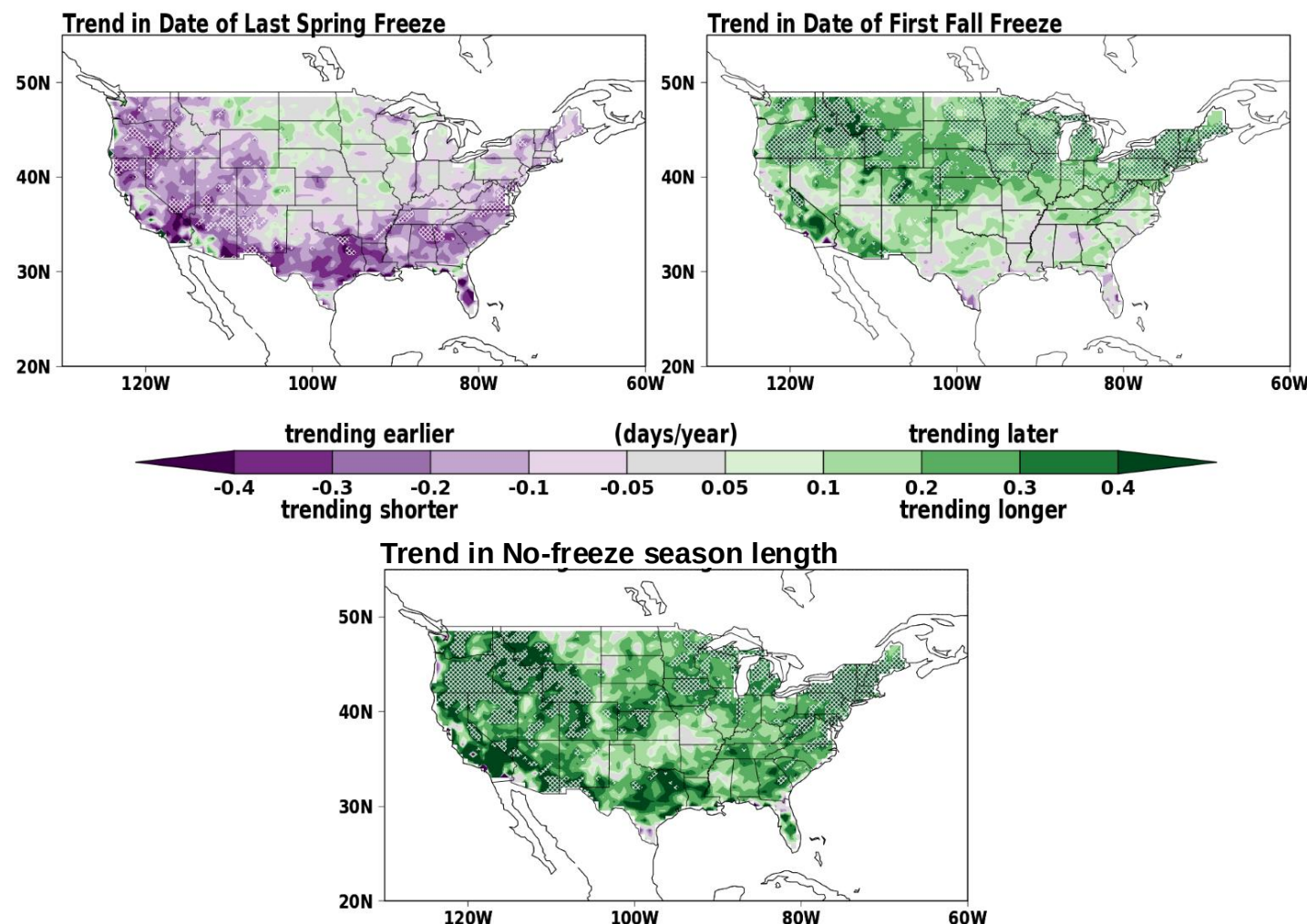
- Framework for Live User-Invoked Data (FLUID)
- 3hr Weather Maps
- Monthly and Anomalies
- Climatology
- Extreme Diagnostics
- Images and Animations

Extreme Diag
Data Access →



MERRA-2 Trends in Seasonal Freezes

- Developing diagnostics around freezing points (e.g. Ruane et al. 2022, Climate Impact Drivers)
 - Date of last spring freeze
 - Date of first fall freeze
 - No-freeze season
- Connections to modes of variability
 - West of Rocky Mountains relate to EP/NP mode
 - Little or no connections to ENSO, PNA etc.



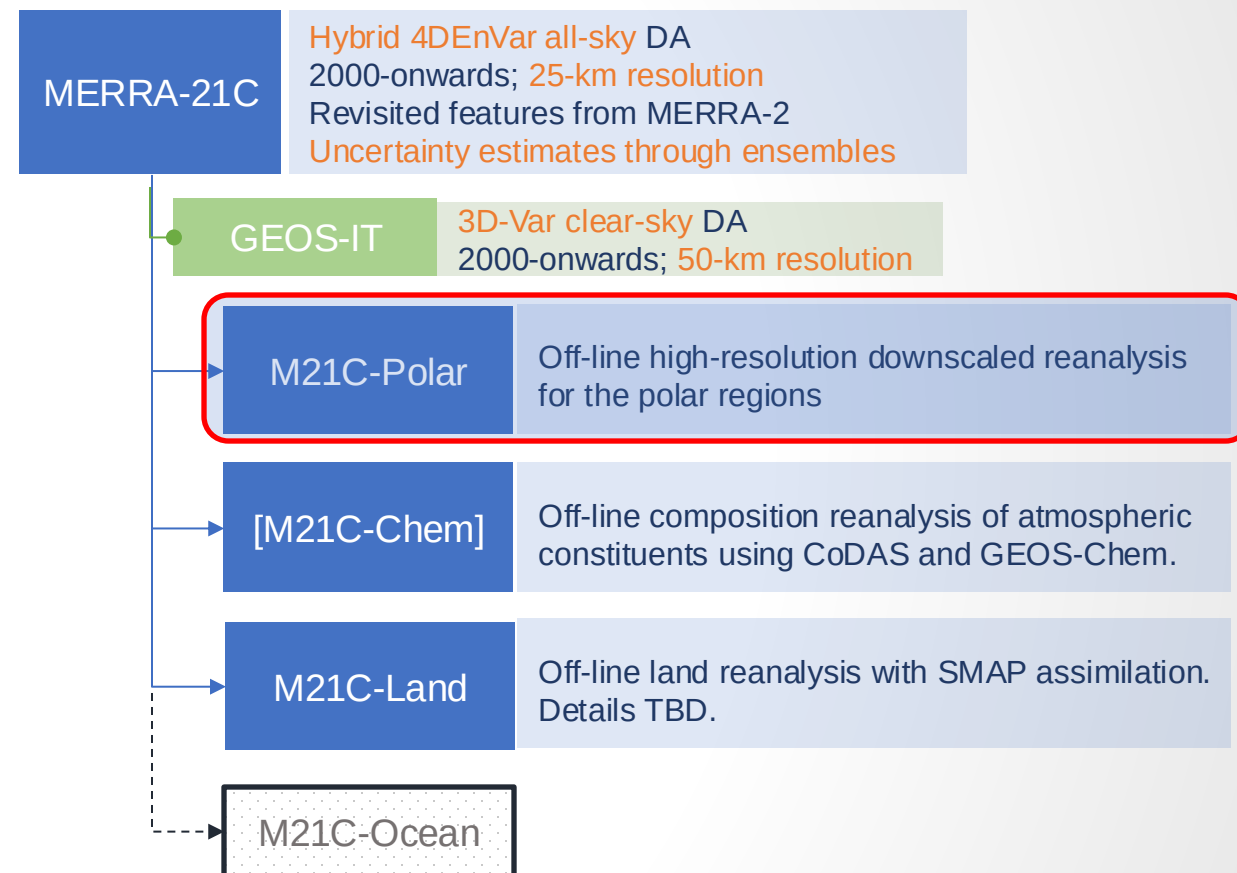
MERRA-21C (Production Began Summer 2024)

An enhanced Atmospheric Reanalysis for the early 21st century

MERRA-21C builds on the advances introduced after MERRA-2 to produce an enhanced atmospheric reanalysis for the early 21st Century.

- Targeting clouds/precipitation and surface energy balance through enhanced use of observations
- Added fire weather index
- Bridging the gap from NASA's EOS observations to the post-EOS observations
- Opportunity to update operational observations to current versions
- Begins in 2000

Beyond an atmosphere-only reanalysis, MERRA-21C will underpin reanalyses of other Earth components.





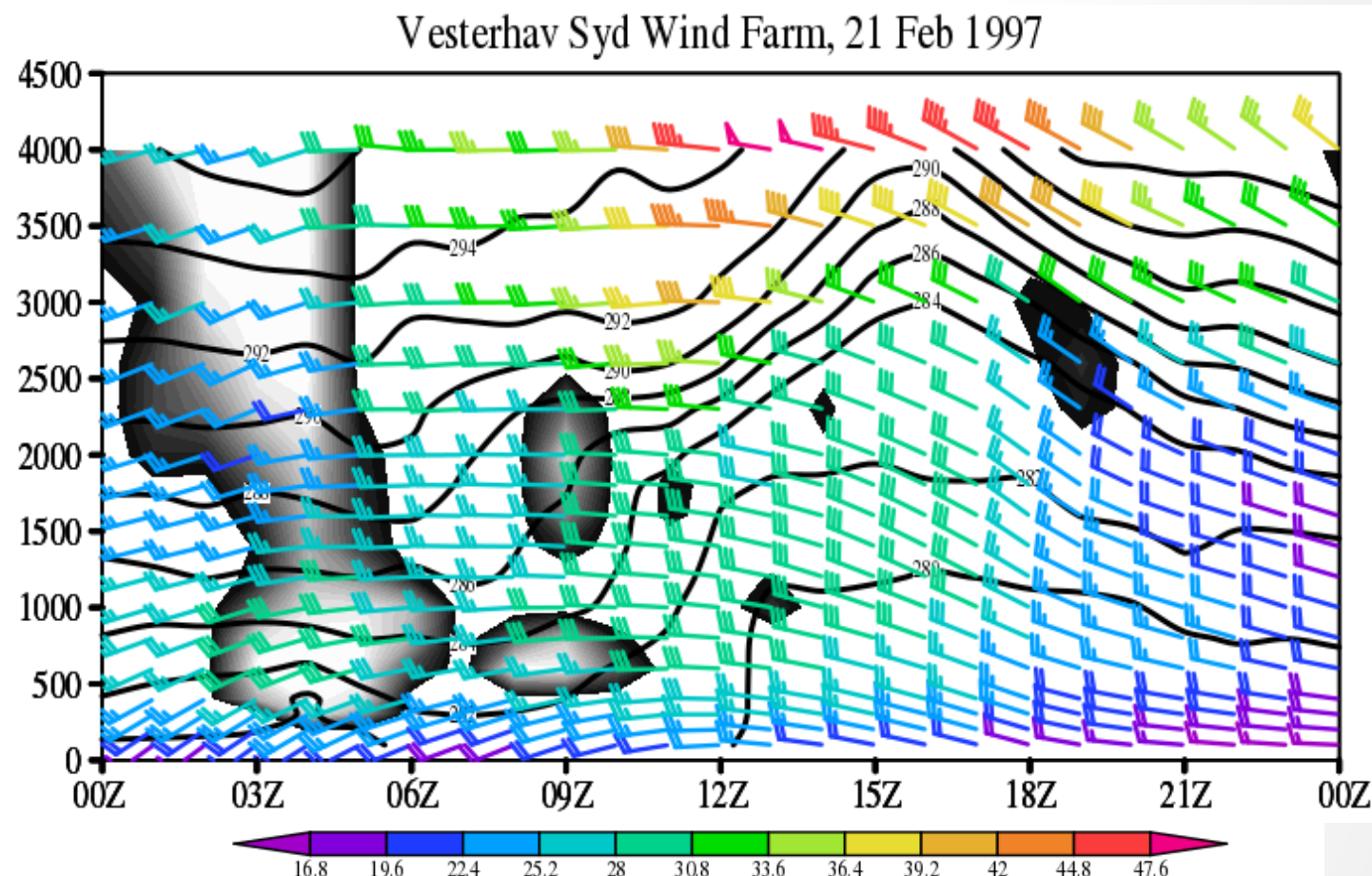
A PBL-focused constant-height collection for the M21C reanalysis

- Newly added collection is PBL-focused, on constant surface-relative heights, with high vertical and temporal resolution.
- Previous 3D collections (e.g. in MERRA-2) used either constant pressure levels or native model levels.
 - Pressure levels offer greater ease-of-use for end users studying free troposphere, but not well suited for looking at PBL!
 - **Constant surface-relative heights** would be analogous for PBL studies.
- Anticipating greater community interest in PBL following US Decadal Survey, in addition to traditional near-surface users

Collection 1: hourly instantaneous

State variables

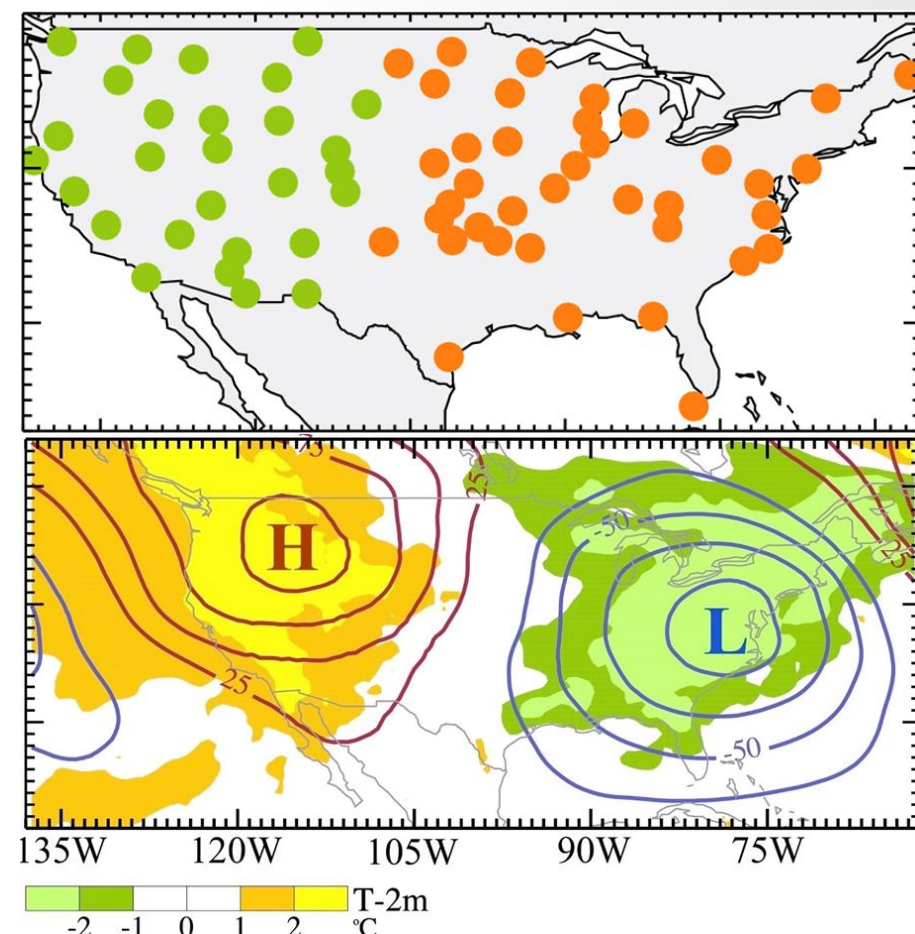
T – Temperature
U – Zonal wind
V – Meridional wind
OMEGA – Vertical wind
QV – Specific humidity
QL – Liquid water
QI – Ice water
CLOUD – Cloud fraction
PL – pressure
QT – Total water
SL – Liquid water static
 energy ($=c_p T + gZ - L_v^* QL$)
KH – scalar diffusivity
KM – momentum diffusivity



PA4-36—Thu. Oct 31, 2024, 3:15 PM - 4:45 PM

Applications of MERRA-2 data for avian migration, biomass burning, and dusty atmospheric rivers – Dezfuli et al.

- **Bird migration linked to large-scale climate**
 - Identify large-scale climate features in each region that control the environmental conditions influencing bird migration.
- **Impact of subtropical highs on fire emission**
 - Combined effects of strengthened emissions and cross-equatorial southerly winds in the S. Atlantic control interannual variability of black carbon in West Africa.
- **Atmospheric rivers bring flood & dust**
 - A distinct characteristic of ARs in the Middle East region is their contribution to dust transport from the major sources along their pathways.



T-2m (shading) and 300-hPa GHT in spring for 2005 minus 2010, years with notably east-west contrast in arrival dates of migratory birds. a Rossby wave stands out.



Summary

- Probably too many applications of reanalyses to keep track
- Development continues
- What is missing? Or, what can be done during processing time that can help facilitate use by decision makers?
(Keeping in mind that we are constrained by other limitations)
- Inclusion in ICR6 is an excellent step forward but could also account for a conference itself



Thank you for this opportunity!

Contact:

Michael.Bosilovich@nasa.gov



MERRA-2

gmao.gsfc.nasa.gov

<https://gmao.gsfc.nasa.gov/reanalysis/>

<https://fluid.nccs.nasa.gov/reanalysis/>

<https://power.larc.nasa.gov/>

<https://science.nasa.gov/earth/in-action/>



GMAO Reanalysis Products

fluid.nccs.nasa.gov

