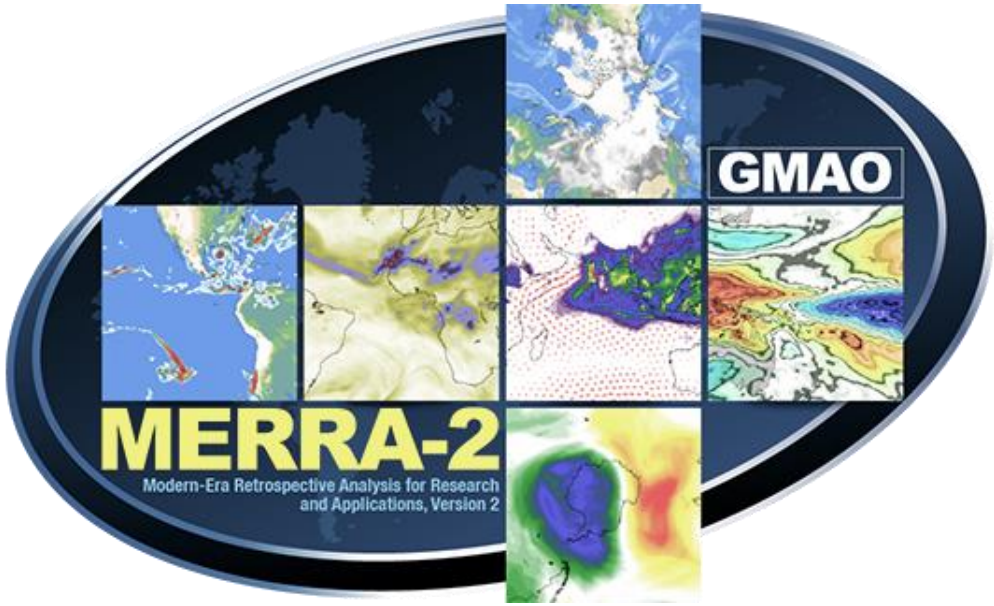
National Aeronautics and Space Administration

NASA GMAO Reanalyses and Prospects for Future Collaborations



Mike Bosilovich, Amal El Akkraoui, Nathan Arnold, Steven Pawson – Many others in the GMAO

With Contributions from Paul W. Stackhouse (NASA LaRC) and POWER

NASA Earth Action Strategy

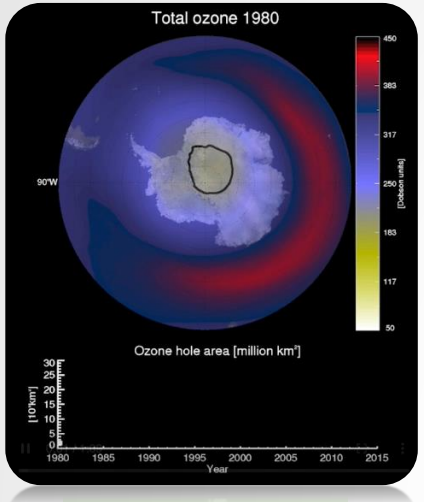
Adapted from Karen St. Germain, NASA HQ

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

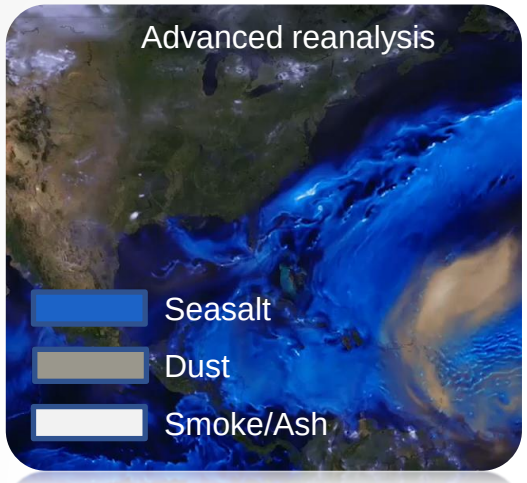
- Greenhouse gas monitoring
- Wildland fire risk & recovery
- Health & air quality
- Sea level & coastal risk
- Energy & sustainable infrastructure
- Agriculture & crops
- Disasters & Extreme Events
- Water Resources & Security
- Biodiversity & Ecosystem Change

GEOS Digital Replicas of the Physical Earth System

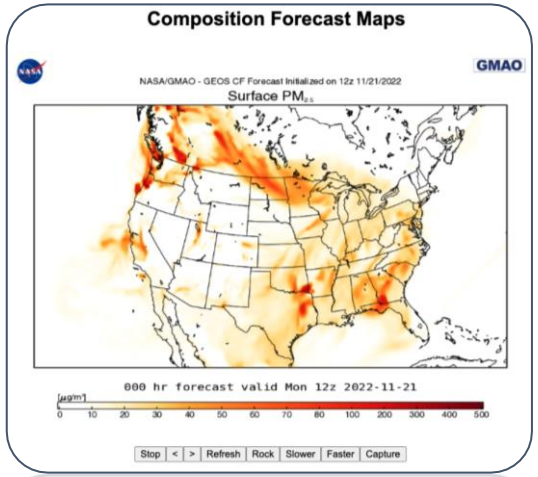
National Aeronautics and Space Administration



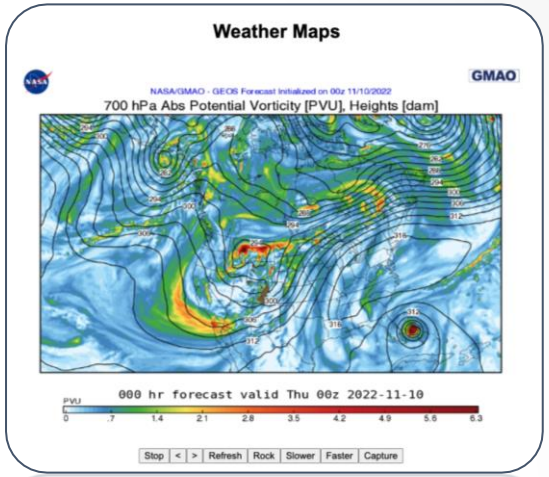
MERRA2



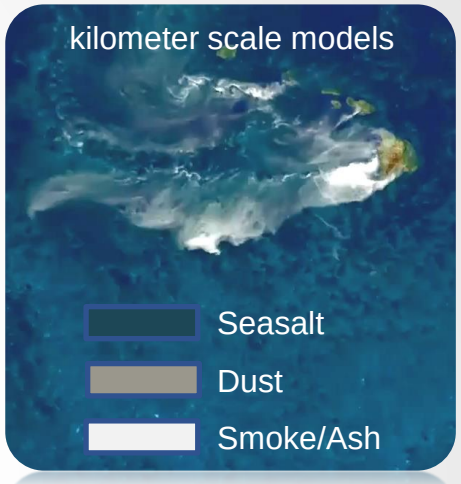
MERRA-21C



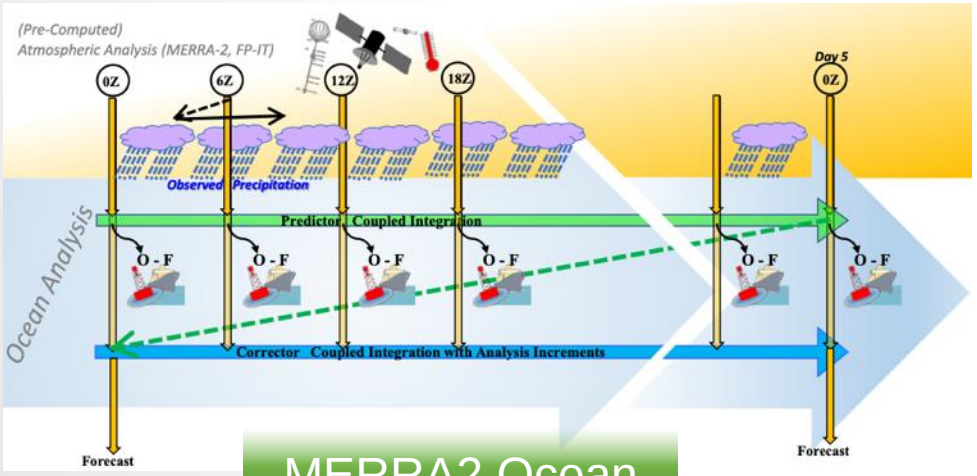
GEOS-CF



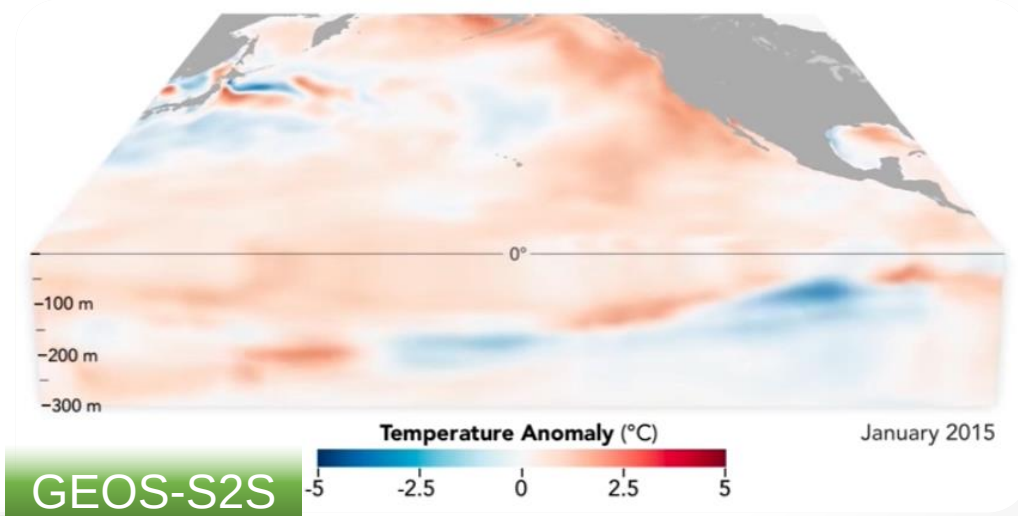
GEOS-FP



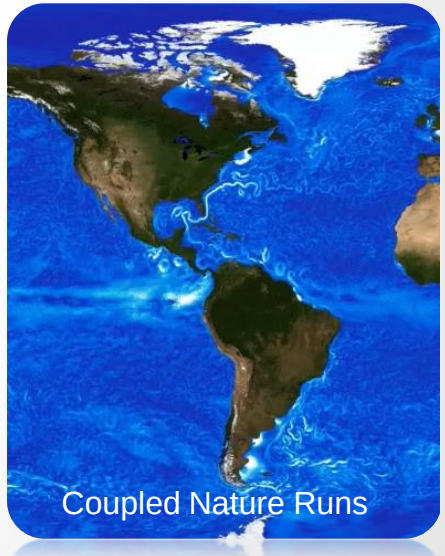
OSSEs



MERRA2 Ocean

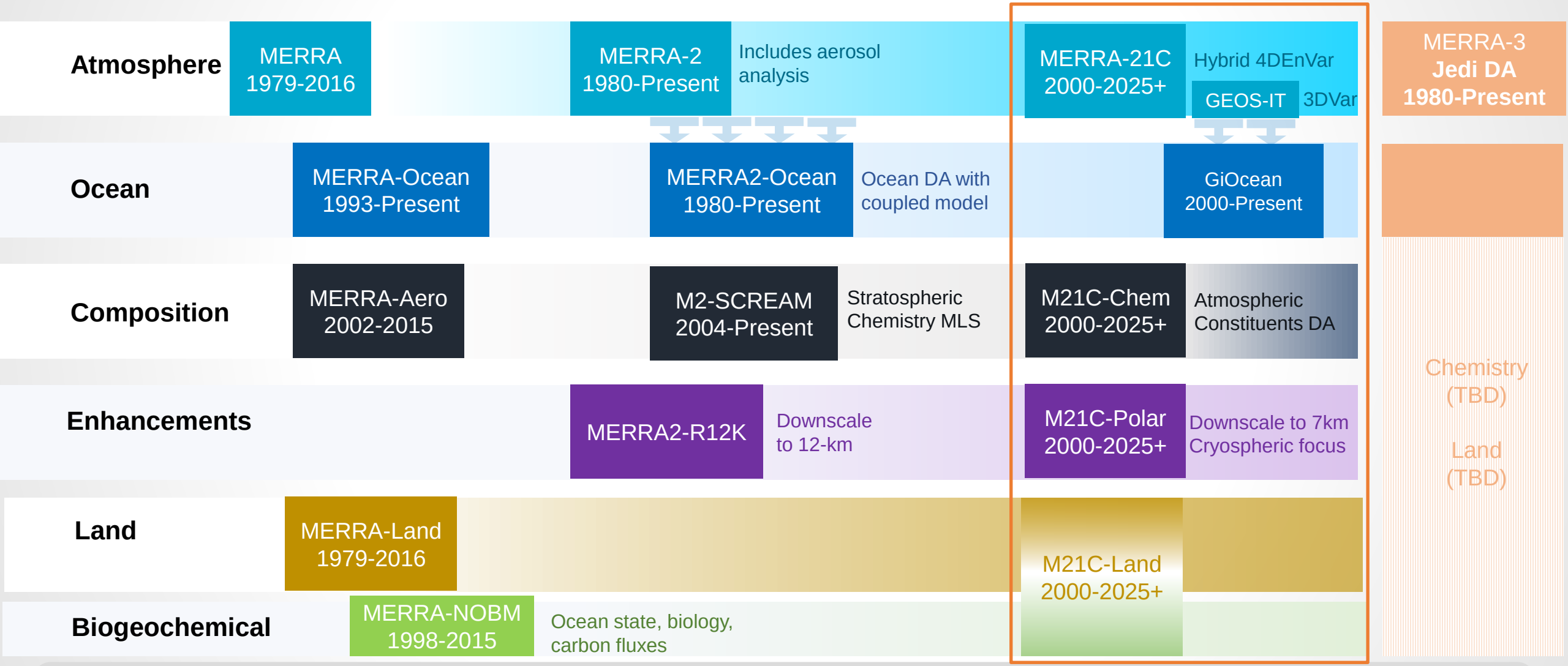


GEOS-S2S



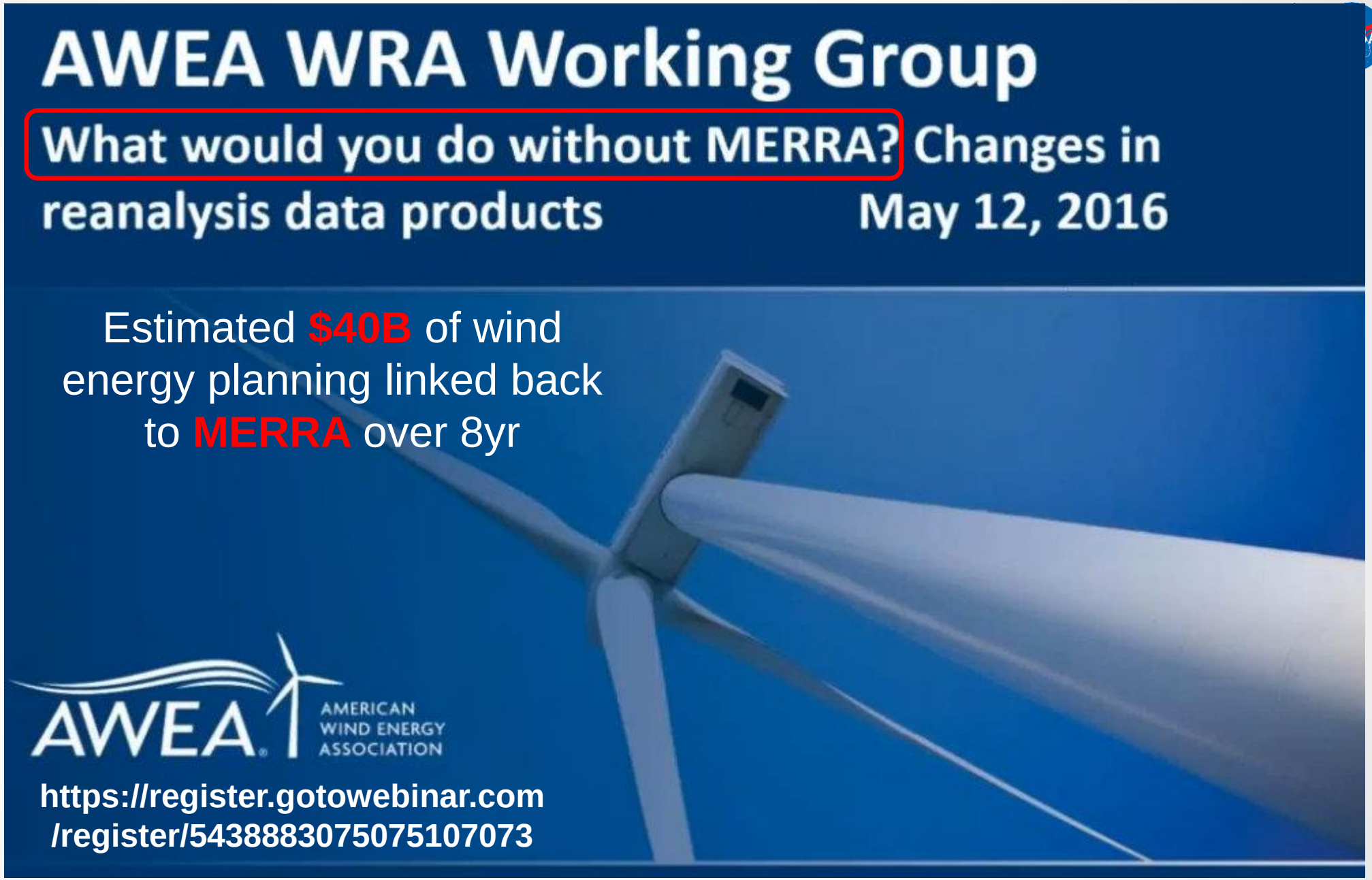
GMAO reanalysis products

A family of retrospective analysis products to support NASA's goal of Integrated Earth system reanalyses

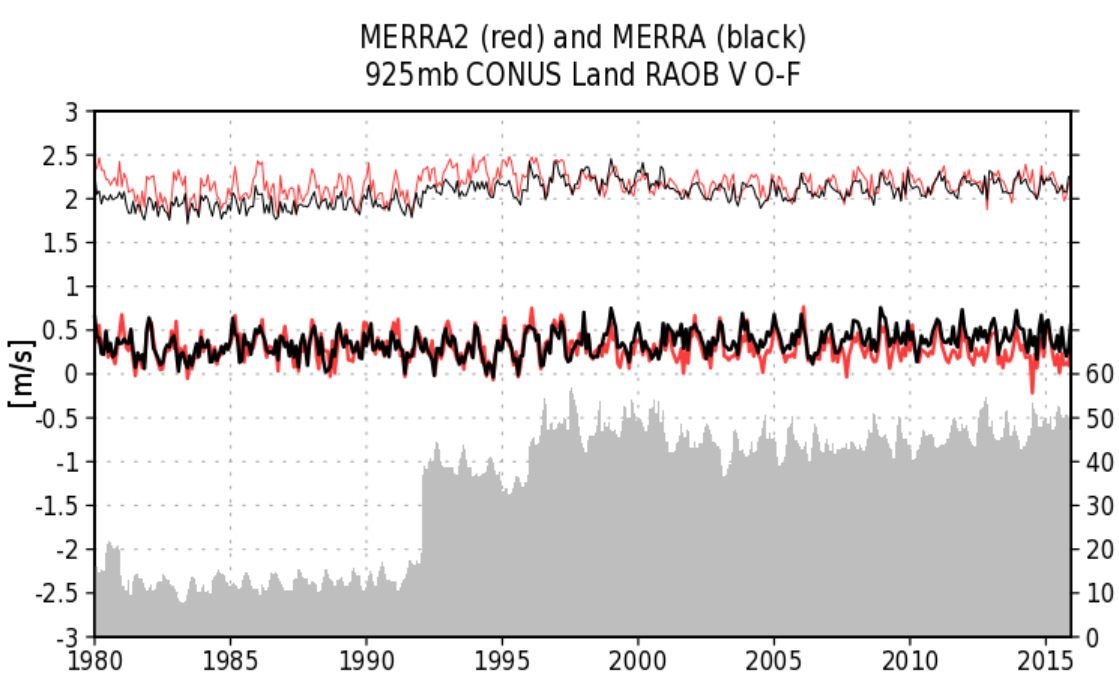


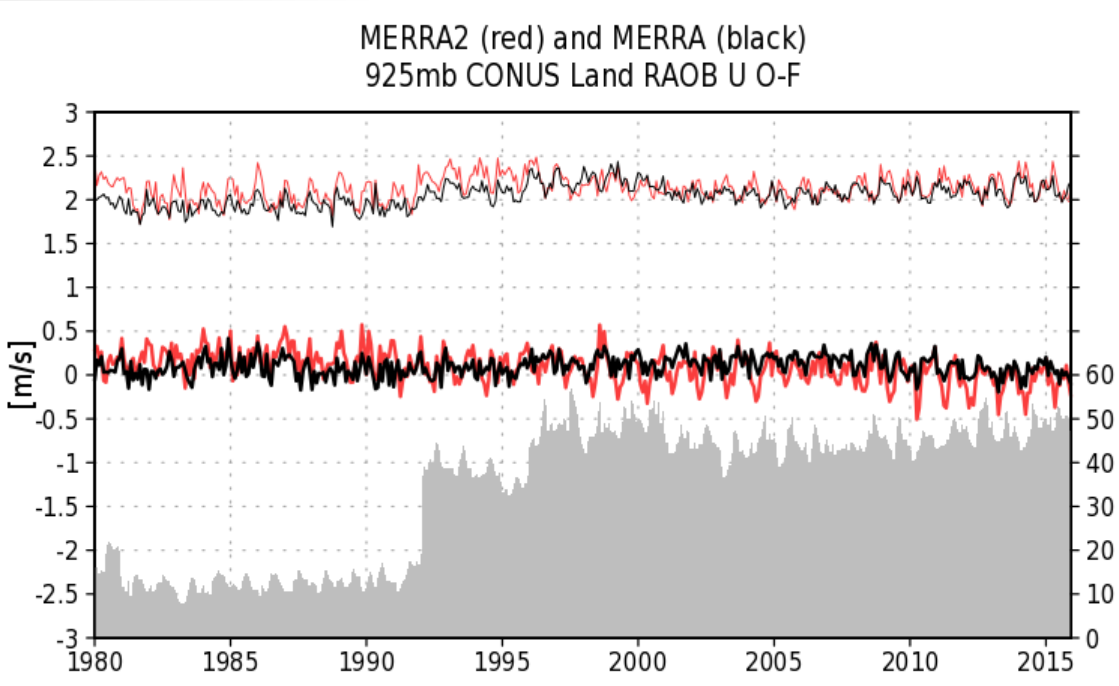
MERRA-2

Continued the legacy of MERRA 50m hourly winds



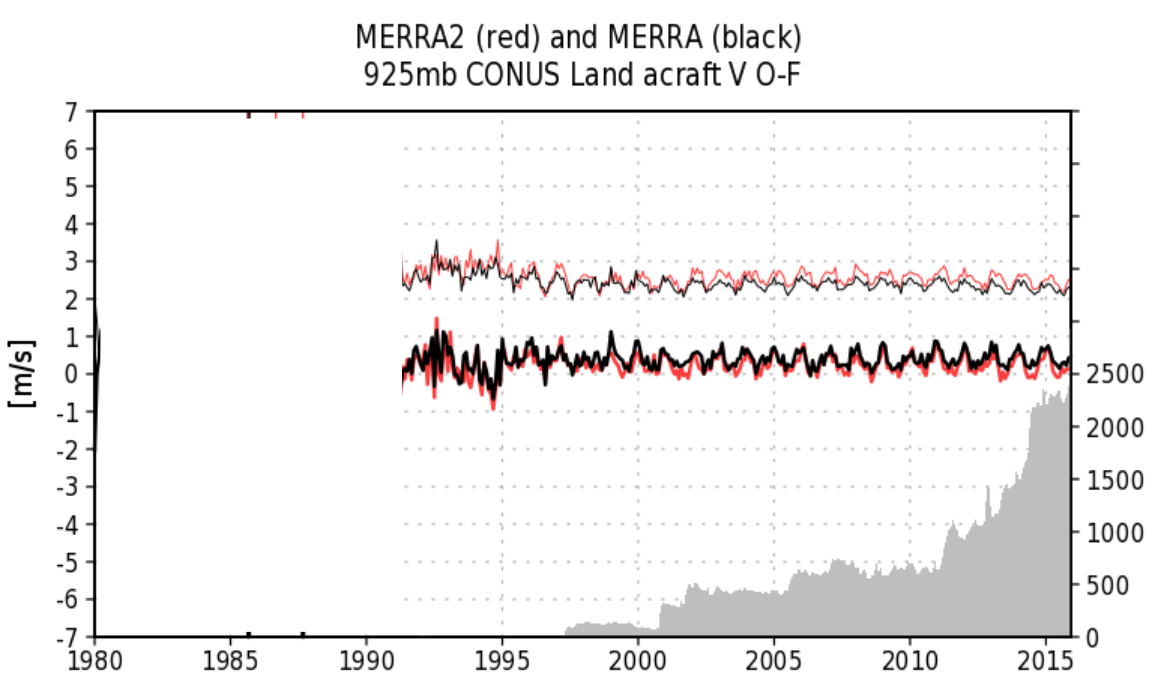
CONUS RAOB Statistics

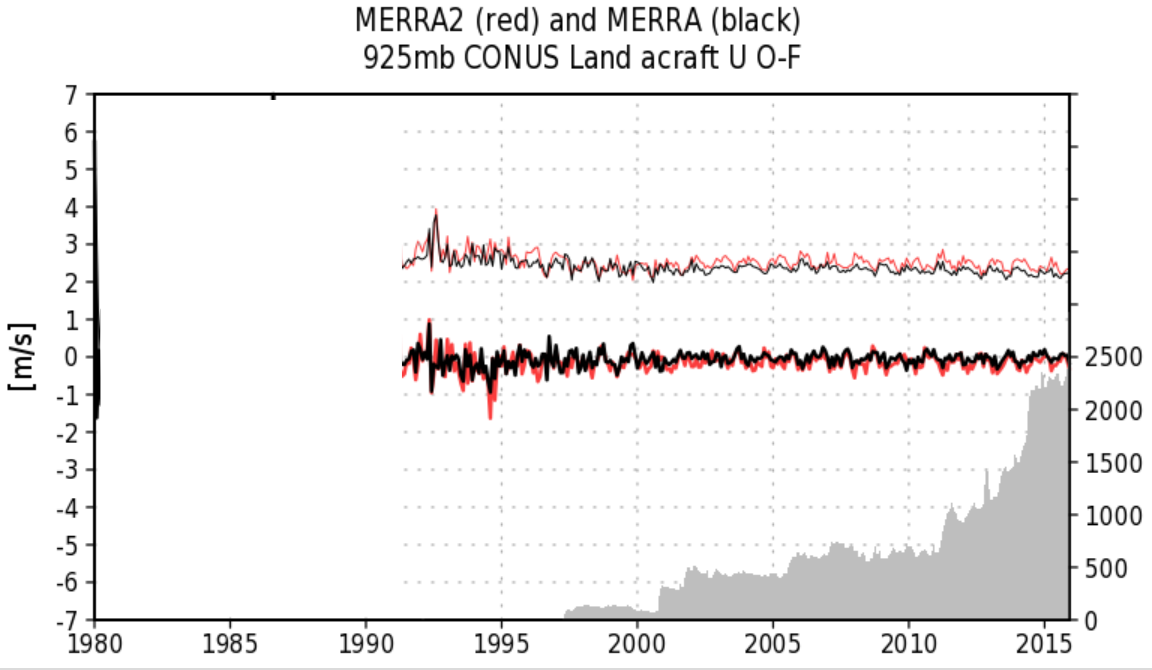




- Mandatory 925mb observation begins in early 1990s
- Note #, compared to aircraft obs
- Generally similar RMS between two systems
- Some MERRA-2 seasonality in the mean departure in the 2010s

Aircraft Statistics





- How reanalysis uses the observations
- Model Forecast departure from Aircraft winds is similar in mean (thick lines)
- RMS increases, owing to a change in the analysis that allows more observations in MERRA-2

MERRA-2 Extreme Detection Indices

Name	*Dim*	*Description*	*Units*
CDD	yx	consecutive dry days (maximum number of consecutive days when precipitation < 1 mm)	days
CSDI	yx	cold spell duration index (count when at least 6 consecutive days of min temperature < 10th percentile)	days
CWD	yx	consecutive wet days (maximum number of consecutive days when precipitation > 1 mm)	days
drydays	yx	count of days with < 1 mm of precipitation	1
DTR	yx	diurnal temperature range	K
HWA	yx	temperature on hottest heat wave day	K
HWD	yx	length of longest heat wave	days
HWF	yx	count of heat wave days	1
HWM	yx	average temperature anomaly on heat wave days	K
HMN	yx	count of heat wave events	1
LCS	yx	length of longest cold spell	days
LWS	yx	length of longest warm spell	days
PRCPTOT	yx	total precipitation on days with at least 1 mm	mm day^{-1}
R10mm	yx	count of days with at least 10 mm of precipitation	1
R20mm	yx	count of days with at least 20 mm of precipitation	1
R90d	yx	count of days with precipitation > 90th percentile	1
R90p	yx	total precipitation from days > 90th percentile	mm day^{-1}
R95d	yx	count of days with precipitation > 95th percentile	1
R95p	yx	total precipitation from days > 95th percentile	mm day^{-1}
R99d	yx	count of days with precipitation > 99th percentile	1
R99p	yx	total precipitation from days > 99th percentile	mm day^{-1}
RX1Day	yx	maximum one day precipitation amount	mm day^{-1}
RX5Day	yx	highest precipitation amount for a five day interval	mm day^{-1}
RX5Daycount	yx	count of five-day heavy precipitation periods	1
SDII	yx	ratio of total precipitation to the number of wet days	mm day^{-1}
T2M	yx	2-m temperature	K
TN10P	yx	percentage of time when daily min 2-m temperature < 10th percentile	%
TN90P	yx	percentage of time when daily min 2-m temperature > 90th percentile	%
TX10P	yx	percentage of time when daily max 2-m temperature < 10th percentile	%
TX90P	yx	percentage of time when daily max 2-m temperature > 90th percentile	%
wetdays	yx	count of days with >1 mm of precipitation	1
WSDI	yx	warm spell duration index (count when at least 6 consecutive days of max temperature > 90th percentile)	days

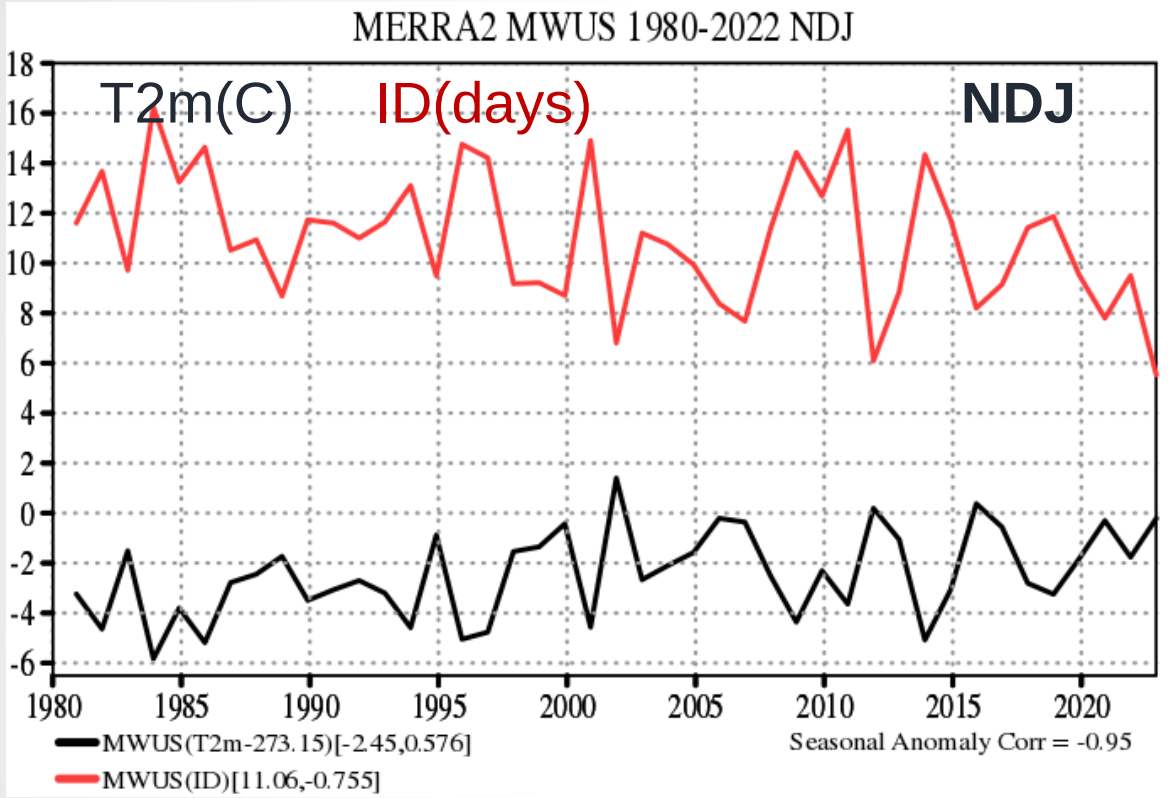
Developed over several years and recently updated to include 91-20 baseline climatology (Collow et al. 2023)

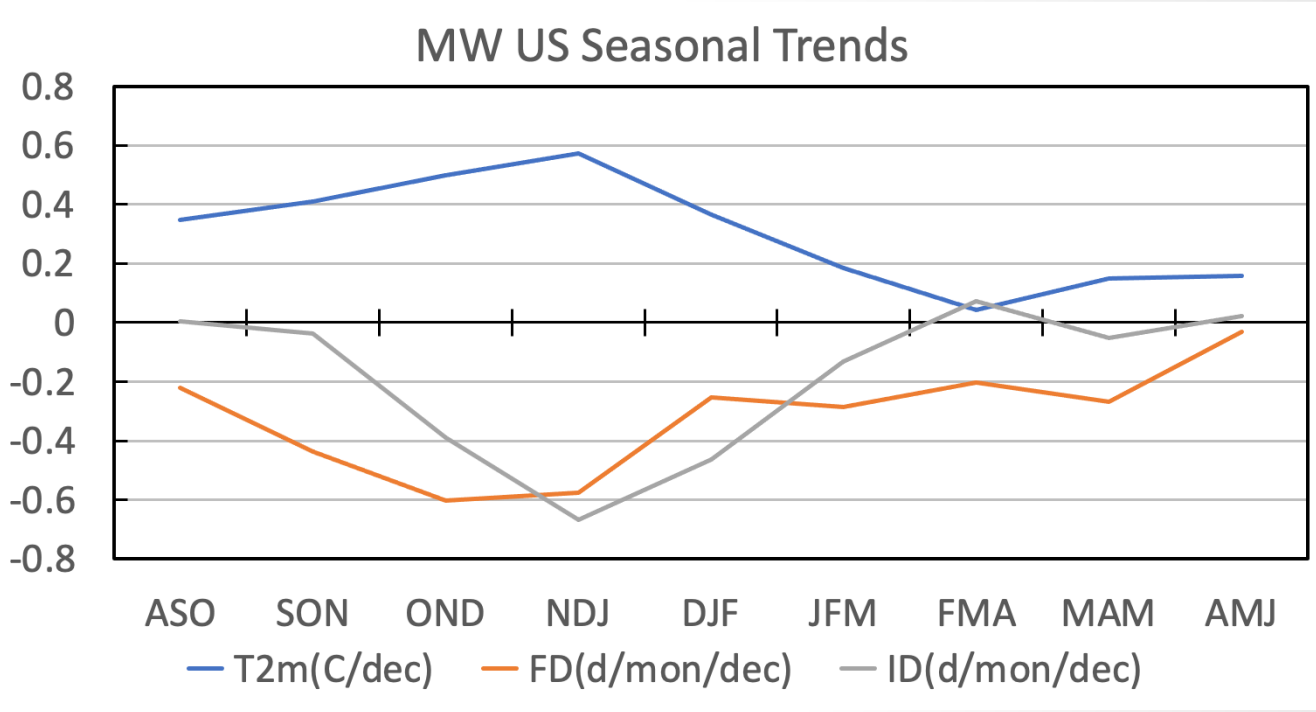
Needs wind indices

MERRA-2 Midwest Frost and Icing Days Trends

National Aeronautics and Space Administration

Some extremes shared with the Electric Power Research Institute (EPRI)





Icing Days (ID) - count of days when daily maximum 2m temperature is below freezing

Frost Days (FD) - count of days when daily minimum 2 m temperature is below freezing

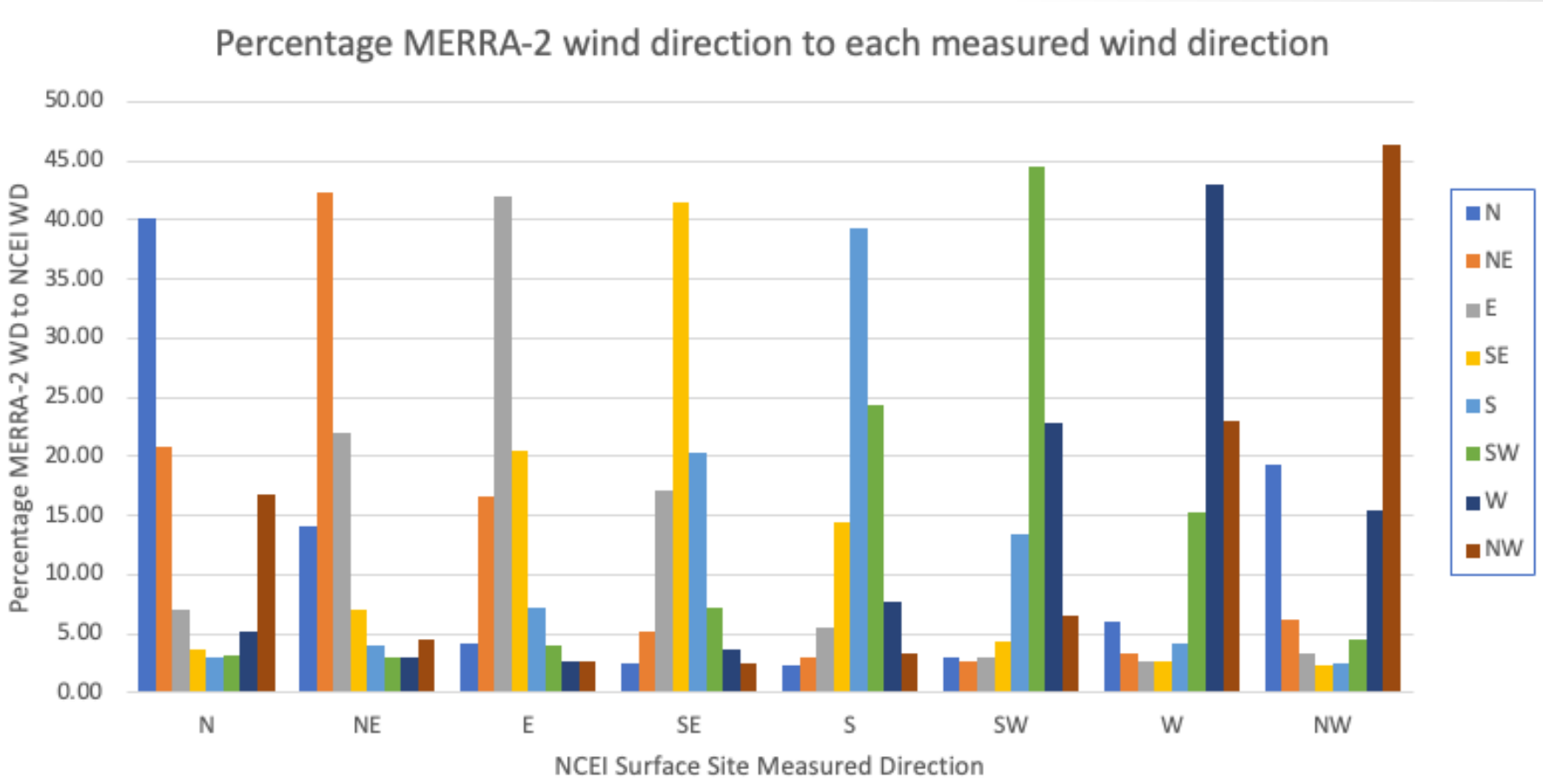
Midwest warming peaks in NDJ

Icing Days decreasing ~6.5% per month per dec

Frost days decreasing ~3.0% per month per dec

Applications of MERRA-2: POWER

- Prediction Of Worldwide Energy Resource (POWER) @LaRC
- Utilizes MERRA-2 for Meteorology (along side satellite derived obs)
- Hourly data available through a GIS portal
- Exploring future connections and transition to MERRA-21C



Courtesy Paul Stackhouse and Colleen Mikovitz (NASA LaRC)

Enabling Earth Action in Renewable Energy, Sustainable Infrastructure & Agroclimatology

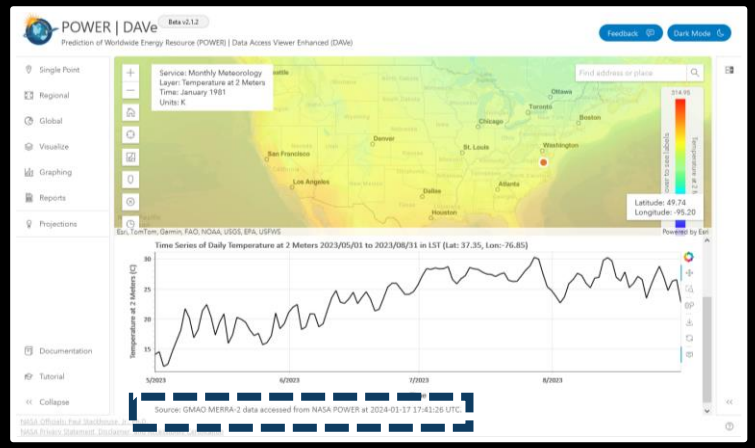
PI: Paul W. Stackhouse Website: https://power.larc.nasa.gov/ Email: larc-power-project@mail.nasa.gov

NASA Data: Time series and temporally averaged parameters spanning from 1981 to near-real time surface radiation from SRB and CERES mission, surface meteorological data, like wind speed, temperature, and humidity, etc., from MERRA-2 & GEOS FP-IT, and precipitation from GPM IMERG including several user focused derived value-added parameters. These and future climate projections from CMIP6 NEX-GDDP, are served by the NASA Prediction Of Worldwide Energy Resources (POWER) to support POWER's three user communities: renewable energy, sustainable infrastructure, and agroclimatology.

Who uses it? Through POWER's tools and services, close to 30,000 unique users (as estimated by unique IP addresses) request data parameters per month. User groups represent the non-profit, government, academic, research, and private sectors.

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 metrological data to create PV installation models used to predict probabilities of power generation over potential power outage windows for both remote locations and America's Armed Forces.



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 from1981 and 1984 respectively, until near real-time for hourly, daily, monthly, annually, and climatology time periods.

GSFC Contribution: - Michael Bosilovich, GMAO
Funding: - NASA Earth Action/Applied Science ; CERES Mission, AIST

POWER – DAVe example
power.larc.nasa.gov/beta/data-access-viewer/

National Aeronautics and Space Administration

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

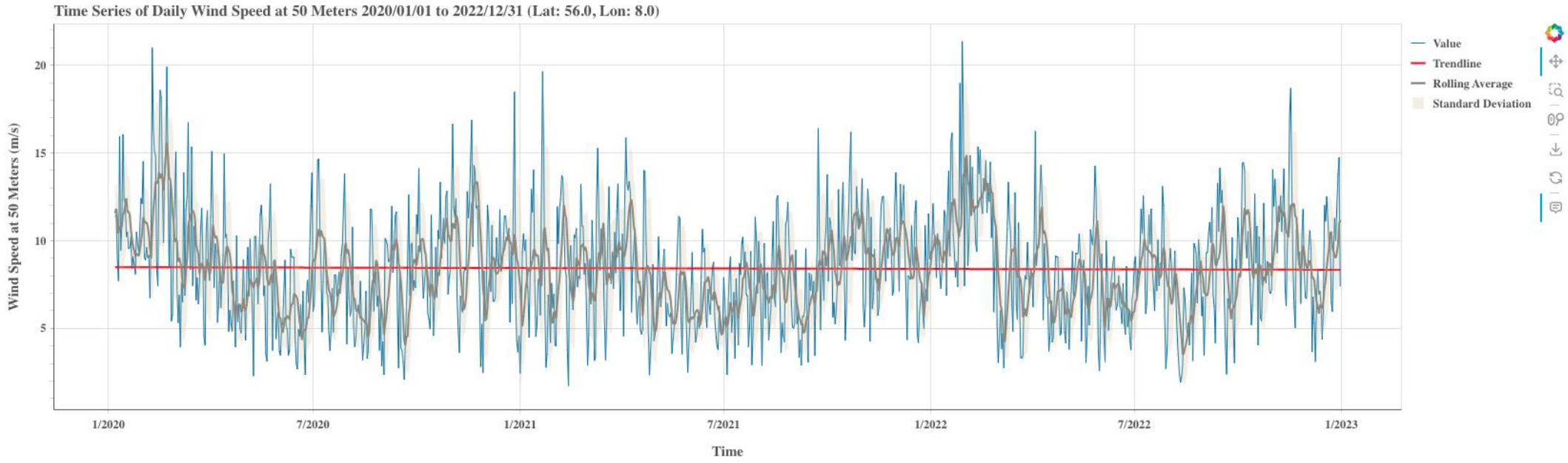
POWER | DAVe Beta v2.1.7

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

Feedback Dark Mode

Single Point
Regional
Global
Visualize
Graphing
Reports
Projections
Documentation
Tutorial
Collapse

Request Results



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

NASA Officials: Paul Stackhouse, Jr., Ph.D.

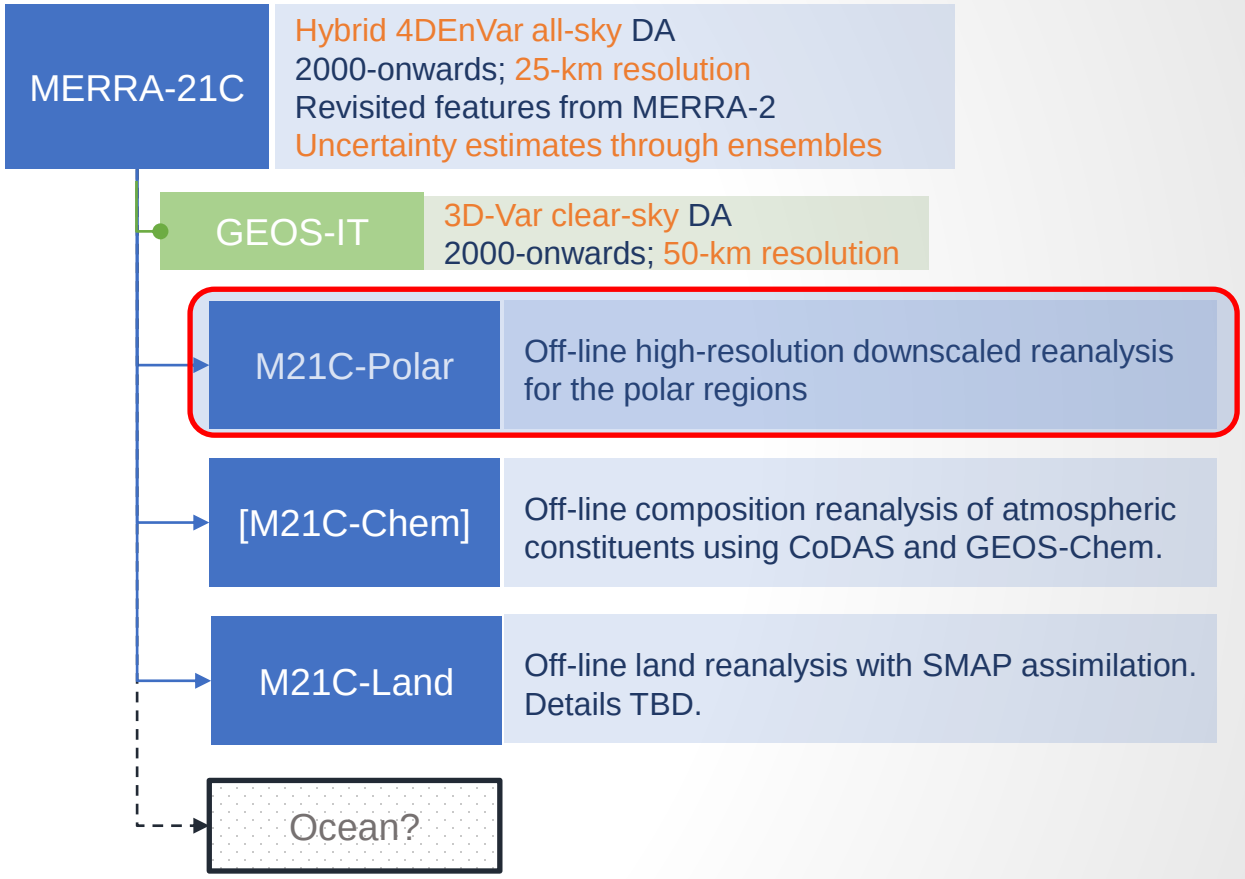
MERRA-21C (Production Beginning Spring 2024)

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
- 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

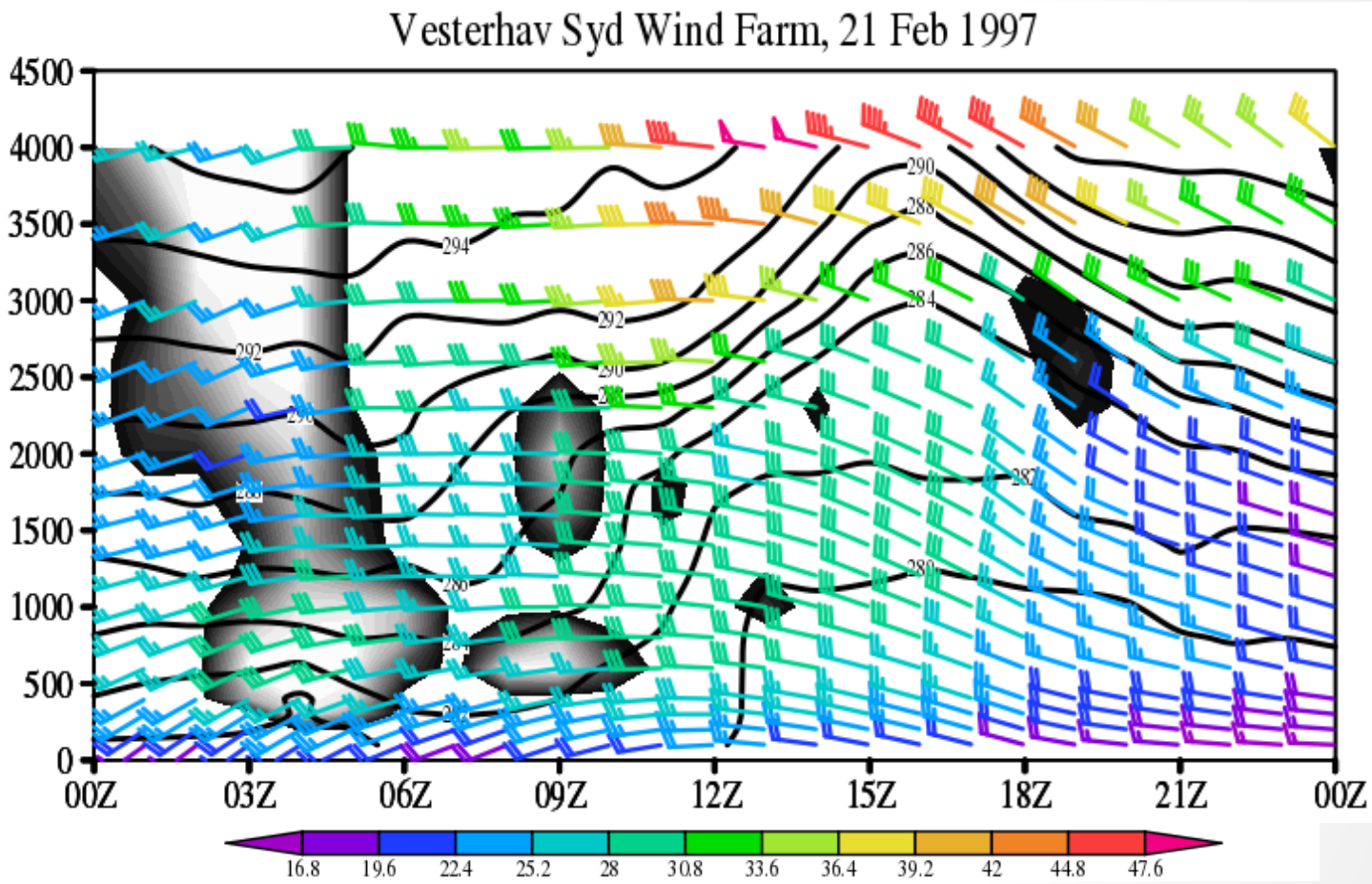
- Proposed collection is PBL-focused, on constant surface-relative heights, with high vertical and temporal resolution.

- 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_pT + gZ – L_v*QL)
KH – scalar diffusivity
KM - momentum diffusivity



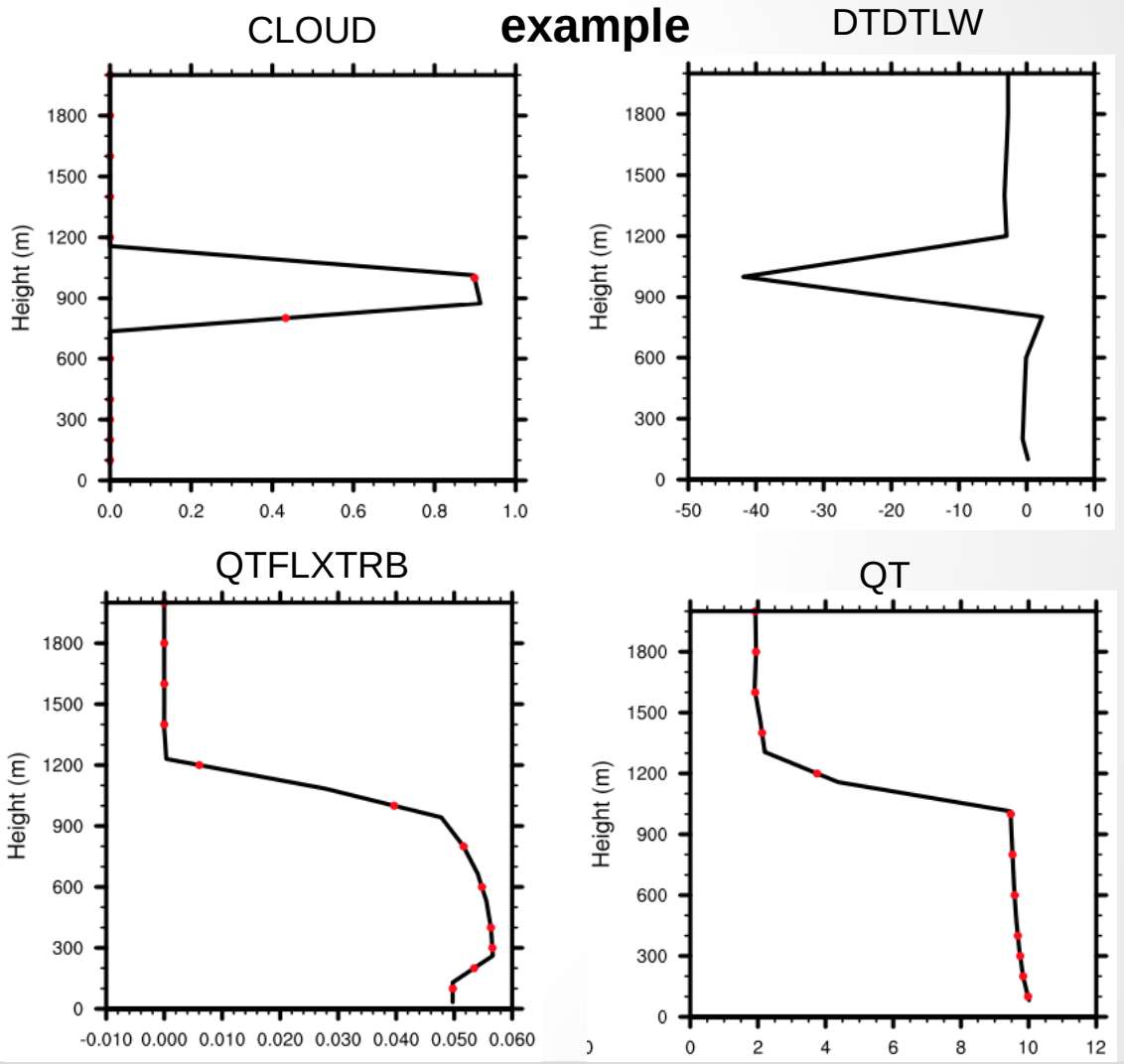
17 levels(m): 100 200 300 400 600 800 1000 1200 1400 1600 1800 2000 2300 2600 3000 3500 4000

Collection 2: two-hourly time-averaged

Vertical fluxes:
SLFLXTRB – Turbulent flux of Energy
QTFLXTRB – Turbulent flux of Total Water
UFLXTRB – Flux of U Momentum
VFLXTRB – Flux of V Momentum

Tendencies:
DTDTLW - Tendency of LW radiation
DTDTSW - Tendency of SW radiation

StCu example



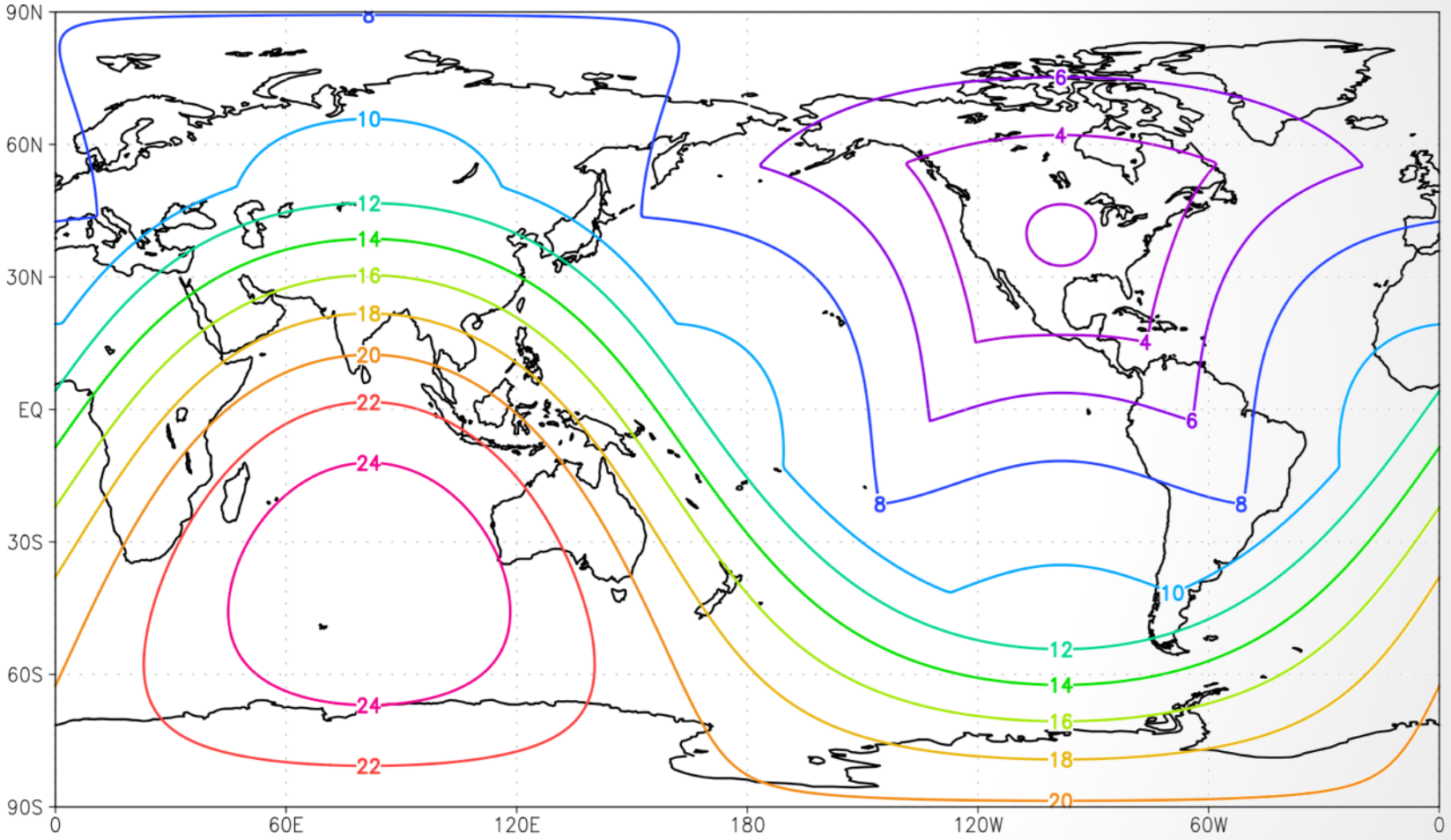
GEOSgcm – Refined Grid

Stretched Cubed-Sphere Horizontal Grids
CONUS

Grid Name	Res (km)
c270	100 – 16km
c540	50 – 8km
c1080	25 – 4km
c2160	12 – 2km

- **Replay** – Use an existing reanalysis with a differently configured model
- Potential to replay MERRA-21C on a stretch grid for ~4km North American reanalysis
- *Not yet a project – Stay Tuned!*

GEOS Experimental Stretched Grid



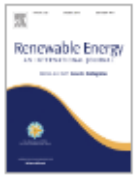
c1080 CONUS Stretched Grid Cell Length (km)

Future Collaboration

- Past connections with the wind energy community have been thin
  - Optimistic to hear what the outcomes here are for continued communications
- Knowledge exchange
  - Evaluation – independent data or metrics
  - Additional information/output – what do we not write out, but could?

ELSEVIER

Renewable Energy
Volume 126, October 2018, Pages 322-331



ERA5: The new champion of wind power modelling?

Jon Olauson [a b]

[a] Division of Electricity, Department of Engineering Sciences, Uppsala University, Sweden
[b] Integration of Renewable Energy Sources Group, KTH Royal Institute of Technology, Stockholm, Sweden

Thank you for this opportunity!

Contact:

Michael.Bosilovich@nasa.gov

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

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

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