

### Taking Earth Science to Actionable Decisions in Renewable Energy,

### Sustainable Infrastructure and Agroclimatology Sectors

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### What is POWER?

#### The Prediction Of Worldwide Energy Resources (POWER)<sup>1</sup>

Project aims to improve the capability for integrating environmental data from NASA Earth Observations (EO), regarding surface solar irradiance and related parameters, into decision making processes regarding energy and agriculture

As a NASA Applied Sciences project, POWER creates application ready datasets and improves the accessibility and usage of EO data supporting community research in **three focus areas**  Renewable Energy

### Assisting in Energy System Design

POWER's Renewable Energy Web Data Services provide access to parameters specifically tailored to inform the design of solar and wind powered renewable energy systems Building Energy Efficiency & Sustainability

### Informing Building Energy Efficiency

POWER's Sustainable Buildings Web Data Services provide industry-friendly parameters for the buildings community in customized formats for input to building decision support tools.



Space Administration

### Enhancing Food Security

POWER's Agroclimatology Web Data Services are designed to provide webbased access to industryfriendly parameters formatted for input to crop models contained within agricultural decision support tools.



National Aeronautics and Space Administration



Jill

I want to adopt green energy for my new facility. Will it be cost effective? I want to plan on when to sail my drone with payloads ? Will there be **enough sunlight** to power the drone ? I want to implement green energy solutions in my manufacturing facilities. Can I monitor the performance over time

Joshua

I want to **model the maize yield** response to Nitrogen Fertilizer Intervention I want to *determine the optimal solar water pump configuration* for our customers



Ben



## **POWER | 100% USER NEEDS DRIVEN**

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Ш Provision of free, customized, **N** value-added, application ready, trusted solar & meteorological data for both current and future climates. COMMUNITY 2 REQUIREMENTS Formats Software

Resolution

Cases

Parameters

Use



# **POWER** | UNDERSTANDING USER BARRIERS

National Aeronautics and Space Administration

**Finding** the Datasets



# **POWER | 100% USER NEEDS DRIVEN**





# **Data Products | Global** Surface Solar Radiation

- National Aeronautics and Space Administration
- s and NASA

- Hourly since 2001
- Daily, monthly back to Jan 1984





 Latency within 3-4 days (solar 5-6 days)







### Data Source | Global Surface Solar Radiation



Source	Tempo	ral Span	1	Temporal Average	Description				
Source	Start	End	Input	Output	Description				
GEWEX SRB 4.0	Jan 1, 1984	Dec. 31, 2000	Daily	Daily, Monthly, Annual, Multi-year	Satellite analysis from global cloud imagers (from geosynchronous and polar orbiters satellites) using radiative transfer lookup tables				
<u>CERES SYN1Deg</u> (Ed 4A)	Jan 1, 2001	End of SYN1Deg (current)	Hourly	Hourly, Daily, Monthly, Annual, Multi-year	Satellite analysis from CERES convolved with MODIS for scene and TOA fluxes, then uses radiative transfer with additional input from geosynchronous satellites and other inputs to produce surface fluxes				
CERES FLASHFlux	End of SYN1deg (current)	Near Real Time	Daily	Daily, Monthly, Annual, Multi-year	Satellite analysis of CERES (reflected solar) and MODIS (cloud imager) measurements (on Terra and Aqua satellites) providing daily averaged estimates of radiative fluxes within 5-6 days of real-time.				

### **Production System:**

- Daily solar data products from 1984 provided through 7 days of real-time at 1 Deg resolution
- SRB to CERES SYN1Deg, to FLASHFlux
- Hourly from 2001 through 3-4 months of observation

### **Production Data Timeline**





















# Data Source | Global Surface Meteorology

Sourco	Ter	mporal Span	Te	emporal Average	Description				
Source	Start	End	Input	Output	Description				
MERRA-2	Jan. 1, 1981	End of MERRA-2 (current)	Hourly	Hourly, Daily, Monthly, Annual, Multi-year	Atmospheric reanalysis with assimilated observations (1-2 months behind real time)				
<u>GMAO FP-IT</u> ( <u>GEOS 5.12.4</u> )	End of MERRA-2	Near Real Time	Hourly	Hourly, Daily, Monthly, Annual, Multi-year	Atmospheric reanalysis with assimilated observations with less assimilated observations, available within 2 days of real-time				
<u>IMERG</u>	Jan 1, 2001	Near Real Time	Daily	Daily	The Multi-satellite Retrievals for GPM (IMERG) algorithm provides estimates of precipitation in UTC time at 10 km resolution, available within 2 days of real-time.				

### Production System:

- Daily surface meteorology data products from 1981 provided through 3 days of real-time
- MERRA-2 to GEOS 5.12.4
- Data is at ~half degree spatial resolution

### **Production Data Timeline**













### **POWER** | UNDERSTANDING USER BARRIERS



#### Joshua

### **Finding** the Datasets

### **Data Interpretation |** Data Quality and Data Limitations



I want to implement green energy solutions in my **manufacturing** facilities and monitor the performance over time



### **POWER** | RELIABLE LATEST VERSION OF DATASETS





### How Is Data Parameter Quality Determined ?

![](_page_12_Picture_1.jpeg)

![](_page_12_Picture_2.jpeg)

POWER uses surface measurements to characterize data product uncertainty

Livit

Validation at various temporal scales (up to hourly) and assessments for value-added products as observations available

![](_page_12_Picture_6.jpeg)

See "Methodology Documentation" pages for more information and statistics

Methodology	1000W UNIN SUMISSI MARKEN, 1	🗞 NASA POWER   Docs	_
Introduction Data Sources Processing Communities	← → C' 🔒 pow	er.larc.nasa.gov/docs/methodology/	; DCess
Sections Energy Fluxes Source Data Solar Geom- Solar Flux V GEWEX SI CERES SY CERES FL	S NASA POW	<b>ER   Docs</b> logy Data Services Réferences Tutorials Gallery FAQs	upon comparisons ( tion (NCEI). Hourly a e compared against ogical parameter pro itative assessment c s. These statistics b ficient associated wi
Thermal IR \ Direct/Diffu: Solar Storag Derived Para	Methodology Introduction	POWER Data Methodology	
Tilted Surfa: Meteorology Citations	Data Sources Processing Communities	National Aeronautics and Space Administration (NASA), through its Earth systems and research providing data important to the study of climate ar climatologically averaged estimates of meteorological quantities and sur the base meteorological and solar data are provided in time series forma	based upon the surf e with the database next qualification is fered. Surface sites shrublands, grass a ss allows for a great the years of interest
	Sections Energy Fluxes	<ul> <li>shown to be sufficiently accurate to provide reliable solar and meteorolog</li> <li>measurements are sparse or nonexistent. The products offer two unique</li> </ul>	f
	Meteorology Citations	time. These two important characteristics tend to generate very large dat those with little experience or resources to explore these large data sets. archives are often in formats that present challenges to new users. To for	a N S

NASA's Earth Science Division Applied Sciences Program supports the dev formulated specifically for designated user communities with access to th

![](_page_13_Picture_0.jpeg)

![](_page_13_Figure_1.jpeg)

Uses Zhang et al., (2013) to process and quality control measurements

![](_page_14_Picture_0.jpeg)

### (Shortwave – SW or Global Horizontal Irradiance - GHI)

![](_page_14_Figure_2.jpeg)

# POWER | EVALUATING DOWNWARD LW FLUX TIME-SERIES

- Building Designers use downward LW to estimate building cooling as a function of time
- In the 1995 to 2020 data record, there is a discontinuity between SRB and CERES LW Flux
- Biases are region dependent though
- Our users are most interested in trends, variability and ranges (min-max) for their assessments
- We applied quantile mapping using overlapping years (2000-2010) to generate bias correction coefficients (1x1 Deg)

![](_page_15_Figure_6.jpeg)

![](_page_15_Picture_7.jpeg)

# **POWER** | VALIDATING CORRECTED LW FLUX TIME-SERIES

![](_page_16_Figure_1.jpeg)

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Space Administration

### **NOAA NCEI ISD Selected Surface Sites**

![](_page_17_Figure_1.jpeg)

# Surface Meteorology

# **POWER** | VALIDATING SURFACE METEOROLOGY | GLOBAL STATS

National Aeronautics and Space Administration

![](_page_18_Figure_1.jpeg)

Primary source of surface meteorology in POWER is MERRA-2

- Well documented system
- Extensively validated by scientific and applied science communities

In context of POWER users, we focus on verifying validation results in scientific literature and adding time-series validations

- Bias of temperature and dew point under 5% of mean value; varies little year to year in 4 decades of site comparisons
- Wind speed & Precip have higher RMS by percentage; Dependence on field magnitude & these can be highly variable within the 1 Deg grid

# **POWER | SURFACE METEOROLOGY VALIDATION OVER TIME**

### WHY POWER TEAM VALIDATES DATA?

- Number of surface stations have increased over time
- More max and min temperatures reports than mean temperature
- More analysis TBD with same set of long-term site data

Temperature changes over Antarctica, if real, it has implications

![](_page_19_Figure_6.jpeg)

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# - **POWER** | UNDERSTANDING USER BARRIERS

![](_page_20_Picture_1.jpeg)

#### Joshua

### **Finding** the Datasets

**Data Interpretation** | Data Quality and Data Limitations

Looks like Joshua should be all set to implement energy efficient solutions and performance monitoring system for their facilities ?

![](_page_20_Picture_6.jpeg)

I want to implement green energy solutions in my facility and monitor its performance over time

![](_page_21_Picture_0.jpeg)

### **POWER** | BARRIERS | HOW WILL USERS OBTAIN NASA DATA?

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Average Amount of Sunshine (All Sky Surface Shortwave Downward Irradiance) in a single location over the past 35+ years - Climatological Monthly/Annual Average

![](_page_21_Figure_4.jpeg)

#### Average Amount of Sunshine (All Sky Surface Shortwave Downward Irradiance) in a single location over the past 35+ years - Climatological Monthly/Annual Average

![](_page_22_Figure_3.jpeg)

![](_page_23_Picture_0.jpeg)

![](_page_23_Picture_2.jpeg)

### **Finding** the Datasets

- **Data Interpretation** | Data Quality and Data Limitations
- **Processing the Datasets** to extract the EXACT Parameter of interest
- Derived Parameters / Value-Added Data (Units, Formats)

![](_page_24_Figure_0.jpeg)

Different users require access to the same data in different ways!

# **Beyond Data Needs** | Breaking Accessibility Barriers

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![](_page_25_Figure_2.jpeg)

![](_page_25_Figure_3.jpeg)

![](_page_26_Picture_0.jpeg)

![](_page_26_Picture_2.jpeg)

### **Finding** the Datasets

![](_page_26_Picture_4.jpeg)

**Processing the Datasets** to extract the EXACT Parameter of interest

![](_page_26_Picture_6.jpeg)

Derived Parameters / Value-Added Data (Units, Formats)

![](_page_26_Picture_8.jpeg)

Different users require access to the same data in different ways!

![](_page_27_Picture_0.jpeg)

![](_page_27_Picture_1.jpeg)

### Different users require different ways to access the same data

![](_page_27_Figure_3.jpeg)

Creating trusted, value-added, easy-to-use Application Ready Data & Services

![](_page_28_Figure_0.jpeg)

Cloud-based POWER interface increases reliability and reduces delivery wait times for data orders

# Cloud Architecture (AWS – NASA's MCP ATO)

The POWER version three architecture that is currently in production is fully cloud optimized and hosted in AWS using serverless technology. This architecture includes all the previous functionality with the addition of enhanced analytics capabilities and direct access to the complete POWER Data archive in AWS S3 as Analysis Ready Cloud Optimized (ARCO) Zarr datasets. All with improved system reliability!

![](_page_29_Figure_3.jpeg)

# Jupyter Notebooks & POWER ARD on AWS

#### **Jupyter Notebooks:**

- The POWER project Jupyter<sup>®</sup> notebooks are available to help assess parameter (ARD) variability over time
- Allow users to interact with the POWER API in Jupyter Notebooks without the need for additional software.
- Provides step by step instructions on how to use the new data services and tools

Link: POWER Knowledgebase

#### **Key Features:**

 The POWER AWS allows users to directly access the POWER Analysis Ready Data (ARD) of ~8.5TB.

Link: POWER on AWS's Open Data Registry

![](_page_30_Picture_9.jpeg)

# **POWER** | Data Access Viewer (DAV)

![](_page_31_Picture_1.jpeg)

EARTH SCIENCE **APPLIED SCIENCES**  Analytic Data Services | Reports

#### **Building Climatic Design Conditions**

![](_page_32_Figure_2.jpeg)

#### **Climate Variability and Anomalies Report**

![](_page_32_Figure_4.jpeg)

![](_page_32_Figure_5.jpeg)

#### Windrose Report Table by NREL Classes

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value for m	issing mod	el data:	cannot be	computed	or out o	f model	availabil	ity range	: -999				
Parameter(s	): -	-											
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	c	LASS_1: 0	)-1.5 m/s										
		LASS_2: 1	.5-3.0 m/	S									
		LASS_3: 3	.0-4.4 m/	s									
		LASS 5: 5	1-5.6 m/	\$									
	č	LASS 6: 5	.6-6.0 m/	s									
	C	LASS_7: 6	.0-6.4 m/	s									
	c	LASS_8: 6	.4-7.0 m/	s									
	9	LASS_9: 7	.0-9.4 m/	s									
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	c	LASS 3: 3	.0-5.6 m/	s									
	c	LASS_4: 5	.6-6.4 m/	s									
	C	LASS_5: 6	.4-7.0 m/	s									
		LASS_6: 7	.0-7.5 m/	S									
		LASS_7: 7	.5-8.0 m/	5									
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	č	LASS 10:	11.9+ m/s	-									
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WD_AVG	Wind D	irection	Average W	ind Speed	(m/s)								
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END WEADER	LINECTION	CLH22_1	CLASS_2	CLASS_S	CLHSS_4	CLASS_5	CLASS_0	CLR55_/	CLASS_0	CLH22_9	CLX22_10	WD_PC1	WD_AVG
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	040.0	1.42			0.05	0.02	0.01	0.00	0.00	0.00	0.00	6.87	2.28
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WR10M WR10M	067.5	1.42 1.53 1.44	4.69	2.89	0.41 0.16	0.02 0.10 0.06	0.01 0.04 0.02	0.00 0.02 0.01	0.00 0.01 0.01	0.00	0.00 0.00 0.00	6.87 9.68 7.15	2.28
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WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M	045.0 067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34	0.05 0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.09 0.09 0.13 0.13	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.02 0.03 0.03	0.01 0.04 0.02 0.01 0.01 0.00 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.00 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.01 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.00 0.01 0.01 0.02 0.03 0.02	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.18 2.31 2.33 2.48
WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M	045.0 067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.49	0.05 0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.09 0.13 0.13 0.41 0.95	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.02 0.02 0.03 0.08 0.03 0.08 0.23 0.23	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.00 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.01 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.31 2.33 2.48 2.32 2.48 2.32 2.48 2.32
WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M	045.0 067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0 337.5	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13	0.05 0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.13 0.13 0.13 0.13 0.41 0.95 1.02	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.02 0.02 0.03 0.08 0.03 0.08 0.23 0.23 0.48 0.45	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.02 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.31 2.33 2.48 2.82 3.28 3.14
WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M WR10M	067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0 337.5 ALL	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.00 47.60	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68	0.05 0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.09 0.13 0.13 0.13 0.41 0.95 1.02 4.23	0.02 0.10 0.06 0.00 0.00 0.02 0.02 0.02 0.03 0.03 0.03	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.00 0.02 0.01 0.02 0.02	0.00 0.01 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86 100.02	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.18 2.31 2.33 2.48 2.82 3.28 3.14
WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M	067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0 337.5 ALL 000.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68 3.79	0.05 0.41 0.16 0.09 0.09 0.09 0.09 0.09 0.13 0.13 0.41 0.95 1.02 4.23 0.59	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.03 0.03 0.03	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.02 0.02 0.02	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86 100.02 7.95	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.33 2.48 2.31 2.33 2.48 3.28 3.14 4.12
WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M	067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 315.0 337.5 ALL 000.0 022.5	1.42 1.53 1.44 1.33 1.01 1.05 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.46	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85 1.73	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.68 3.49 3.13 22.68 3.79 3.75	0.041 0.16 0.09 0.11 0.03 0.09 0.09 0.09 0.13 0.13 0.41 0.95 1.02 4.23 0.59 0.53	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.02 0.03 0.03	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.01 0.00 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 108.60 100.02 7.95 6.80	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.31 2.33 2.48 2.82 3.28 3.14 4.12 3.77
WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M	067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 225.0 247.5 270.0 292.5 315.0 337.5 ALL 000.0 022.5 045.0000000000	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.20 1.51 21.09 0.63 0.46 0.54	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85 1.73 1.63	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68 3.79 3.75 4.06	0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.09 0.13 0.13 0.13 0.13 0.13 0.42 1.02 4.23 0.55 0.53 0.53	0.62 0.10 0.06 0.08 0.00 0.02 0.02 0.02 0.03 0.03 0.03 0.48 0.45 1.76 0.45 1.76 0.41 0.16	0.01 0.04 0.02 0.01 0.01 0.00 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.02 0.01 0.02 0.02 0.02	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86 100.02 7.95 6.80 7.27	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.31 2.31 2.33 2.48 2.82 3.28 3.14 4.12 3.77 3.87
WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M	067.5 090.0 112.5 135.0 157.5 280.0 202.5 225.0 247.5 215.0 292.5 315.0 337.5 ALL 080.0 022.5 0 245.0 045.0 067.5	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.54 0.54 0.54	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85 1.73 1.63 1.63 1.63	2.89 1.69 0.77 0.41 0.39 0.53 0.79 0.80 2.03 0.53 0.79 0.80 3.49 3.49 3.75 4.06 5.24	0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.13 0.41 0.95 1.02 4.23 0.55 0.65 1.18 0.65	0.62 0.10 0.06 0.06 0.02 0.02 0.02 0.02 0.03 0.08 0.23 0.08 0.23 0.45 1.76 0.41 0.16 0.21 0.21 0.21 0.22	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.00 0.01 0.00 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 108.60 100.02 7.95 6.80 7.27 9.93	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.31 2.33 2.48 2.82 3.24 3.14 4.12 3.77 3.87 4.51
WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M WR18M	067.5 090.0 112.5 135.0 202.5 225.0 247.5 247.5 247.5 247.5 247.5 25.0 337.5 315.0 337.5 ALL 000.0 022.5 045.0 060.5 090.0 067.5	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.46 0.54 0.54 0.54	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.81 4.81 4.81 4.81 1.85 1.73 1.66 1.48 1.66 1.45	2.89 1.69 0.77 0.41 0.39 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68 3.79 3.75 4.06 5.24 3.81 2.44	0.41 0.16 0.03 0.11 0.03 0.09 0.09 0.13 0.13 0.13 0.13 0.13 0.13 0.55 1.05 0.55 0.65 1.18 0.55 0.24	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.02 0.03 0.08 0.03 0.08 0.23 0.48 0.43 0.48 0.45 0.41 0.16 0.21 0.61 0.20 0.00	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.01 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.01 0.01 0.03 0.03 0.03	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.25 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 108.60 100.02 7.95 6.80 7.27 9.93 6.90 4.72	2.28 2.64 2.42 2.15 2.06 1.95 2.14 2.33 2.48 2.33 2.48 3.28 3.14 4.12 3.77 4.51 4.51 4.00 3.57
WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRIOM WRSOM WRSOM WRSOM WRSOM	067.5 090.0 112.5 135.0 157.5 180.0 247.5 225.0 237.5 315.0 337.5 ALL 000.0 022.5 045.0 337.5 045.0 900.0 112.5 090.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.46 0.54 0.52 0.39	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 2.64 3.30 4.01 47.60 1.85 1.73 1.63 1.63 1.63 1.48 1.48 1.48	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 0.80 1.34 2.03 3.13 22.68 3.79 3.75 4.06 5.24 3.81 2.44 3.81	0.41 0.16 0.09 0.11 0.03 0.09 0.13 0.13 0.41 0.95 1.02 4.23 0.53 0.53 0.53 0.53 0.54 0.53 0.54 0.53 0.53 0.54 0.53 0.55 0.53 0.55	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.03 0.03 0.03 0.03	0.01 0.04 0.02 0.01 0.00 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.02 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.00	0.80 0.80 0.80 0.80 0.81 0.81 0.81 0.82 0.83 0.83 0.83 0.83 0.83 0.81 0.81 0.81 0.81 0.81 0.81 0.81 0.81	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.21	2.28 2.64 2.45 2.15 2.06 1.95 2.14 2.33 2.48 2.32 3.28 3.14 4.12 3.77 3.87 4.51 4.00 3.57 3.37
WRIGM WRIGM WRIGM WRIGM WRIGM WRIGM WRIGM WRIGM WRIGM WRIGM WRSGM WRSGM WRSGM WRSGM WRSGM	067.5 090.0 112.5 135.0 157.5 205.0 202.5 225.0 247.5 270.0 292.5 247.5 270.0 337.5 315.0 337.5 4LL 000.0 062.5 090.0 112.5 135.0 112.5 135.0 125.5	1.42 1.53 1.44 1.33 1.44 1.15 1.00 1.15 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.46 0.54 0.54 0.52 0.37 0.39 0.47	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.94 2.64 3.30 3.56 4.01 1.85 1.73 1.63 1.63 1.63 1.63 1.48 1.45 1.48 1.45	2.89 1.69 0.77 0.41 0.39 0.51 0.63 0.79 3.49 3.13 22.68 3.79 3.75 4.06 5.24 4.06 5.24 1.244 1.45	0.41 0.16 0.09 0.11 0.03 0.09 0.09 0.13 0.13 0.41 0.41 0.95 1.02 4.23 0.53 0.55 1.18 0.56 0.24 0.13 0.56 0.24	0.02 0.10 0.06 0.03 0.00 0.02 0.02 0.02 0.03 0.03 0.03	0.01 0.02 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.80 0.00 0.00 0.00 0.01 0.01 0.01 0.02 0.03 0.02 0.03 0.03 0.03 0.03 0.03	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.86 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.21 3.24	2.28 2.64 2.45 2.06 1.95 2.14 2.31 2.31 2.33 2.48 2.28 3.14 4.12 3.77 3.87 4.51 4.00 3.57 3.33
WR10M           WR10M </td <td>040.0 067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 215.5 270.0 215.5</td> <td>1.42 1.53 1.44 1.33 1.01 1.15 1.06 1.17 1.19 1.13 1.23 1.63 0.46 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54</td> <td>4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 2.64 3.36 4.01 1.85 1.73 1.66 1.48 1.66 1.48 1.45 1.08 1.48 1.48</td> <td>2.89 1.69 0.77 0.41 0.39 0.63 0.51 0.63 0.79 3.49 3.49 3.49 3.49 3.49 3.49 3.49 3.75 5.24 3.79 3.75 5.24 3.40 5.24 3.40 5.24 3.40 5.24 3.44 1.45</td> <td>0.41 0.16 0.99 0.11 0.03 0.09 0.09 0.09 0.09 0.13 0.13 0.13 0.41 0.59 0.53 0.59 0.53 0.55 0.55 0.55 0.55 0.55 0.55 0.55</td> <td>0.02 0.06 0.06 0.00 0.00 0.02 0.02 0.02</td> <td>0.01 0.02 0.01 0.01 0.02 0.02 0.02 0.02</td> <td>0.00 0.02 0.01 0.02 0.02 0.02 0.02 0.02</td> <td>0.00 0.01 0.01 0.02 0.02 0.02 0.02 0.02</td> <td>0.00 0.00 0.00 0.00 0.01 0.01 0.01 0.01</td> <td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0</td> <td>6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.21 3.22</td> <td>2.28 2.64 2.45 2.06 1.95 2.14 2.18 2.31 2.48 2.82 3.248 3.248 3.248 4.12 3.77 3.87 4.51 4.00 3.57 3.33 3.10 3.24</td>	040.0 067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 215.5 270.0 215.5	1.42 1.53 1.44 1.33 1.01 1.15 1.06 1.17 1.19 1.13 1.23 1.63 0.46 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 2.64 3.36 4.01 1.85 1.73 1.66 1.48 1.66 1.48 1.45 1.08 1.48 1.48	2.89 1.69 0.77 0.41 0.39 0.63 0.51 0.63 0.79 3.49 3.49 3.49 3.49 3.49 3.49 3.49 3.75 5.24 3.79 3.75 5.24 3.40 5.24 3.40 5.24 3.40 5.24 3.44 1.45	0.41 0.16 0.99 0.11 0.03 0.09 0.09 0.09 0.09 0.13 0.13 0.13 0.41 0.59 0.53 0.59 0.53 0.55 0.55 0.55 0.55 0.55 0.55 0.55	0.02 0.06 0.06 0.00 0.00 0.02 0.02 0.02	0.01 0.02 0.01 0.01 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.00 0.00 0.00 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.21 3.22	2.28 2.64 2.45 2.06 1.95 2.14 2.18 2.31 2.48 2.82 3.248 3.248 3.248 4.12 3.77 3.87 4.51 4.00 3.57 3.33 3.10 3.24
HEIGM WRIDM WRIDM WRIDM WRIDM WRIDM WRIDM WRIDM WRIDM WRIDM WRIDM WRSDM WRSDM WRSDM WRSDM WRSDM	067.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 270.0 292.5 270.0 292.5 315.0 337.5 ALL 000.0 067.5 045.0 090.0 112.5 135.0 157.5 180.0 202.5 185.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.60 1.51 21.09 0.63 0.46 0.54 0.54 0.54 0.52 0.37 0.47 0.43	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.94 2.64 3.30 3.56 1.83 1.63 1.63 1.63 1.63 1.48 1.48 1.48 1.48 1.18	2.89 1.69 6.77 0.41 0.51 0.63 0.63 0.63 0.80 1.34 2.03 3.49 3.75 4.06 5.24 3.81 2.44 1.45 1.44 1.45	0.49 0.49 0.11 0.09 0.09 0.09 0.09 0.09 0.09 0.13 0.41 0.95 1.02 4.23 0.53 0.55 1.18 0.55 1.18 0.56 0.13 0.66 0.13 0.66 0.13 0.66 0.14 0.05 0.14 0.09 0.14 0.09 0.14 0.09 0.14 0.09 0.15 0.09 0.14 0.09 0.09 0.14 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.0	0.02 0.06 0.06 0.08 0.02 0.02 0.02 0.02 0.02 0.02 0.08 0.03 0.08 0.03 0.08 0.03 0.08 0.03 0.08 0.03 0.04 0.01 0.01 0.00 0.00 0.00 0.00 0.00	0.01 0.02 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.02 0.01 0.02 0.01 0.02 0.03 0.08 0.03 0.08 0.03 0.03 0.03 0.03	0.00 0.01 0.01 0.00 0.00 0.00 0.00 0.02 0.02	0.00 0.00 0.00 0.00 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.29 3.91 4.22 4.18 5.42 7.49 11.05 10.66 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.21 3.24 3.380	2.28 2.64 2.15 2.06 1.95 2.14 2.33 2.48 2.33 2.48 2.33 3.14 4.12 3.77 3.87 4.51 4.00 3.57 4.51 4.00 3.33 3.10 3.24
WR10M           WR50M           WR50M           WR50M           WR50M           WR50M           WR50M           WR50M	647.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 247.5 277.0 292.5 315.0 247.5 277.5 277.0 292.5 315.0 000.0 022.5 000.0 022.5 000.0 122.5 000.0 122.5 135.5 13	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.60 1.51 21.09 0.63 0.64 0.54 0.54 0.54 0.54 0.54 0.54 0.47 0.47 0.43 0.47	4,69 3.77 2.56 1.71 1.76 1.64 2.67 1.99 1.94 2.64 3.30 3.30 4.01 47.60 1.85 1.73 1.66 1.48 1.45 1.45 1.48 1.45 1.48 1.18 1.18 1.18	2.89 1.69 0.77 0.41 0.51 0.51 0.51 0.79 0.80 3.13 22.68 3.79 3.75 3.75 3.75 3.75 4.24 3.81 2.44 1.45 1.244 1.44 1.49	0.41 0.16 0.89 0.11 0.03 0.99 0.09 0.09 0.09 0.13 0.13 0.13 0.13 0.55 1.02 0.55 1.18 0.65 1.18 0.65 0.24 0.15 0.24 0.15 0.24 0.16 0.17 0.16 0.17 0.16 0.12 0.12 0.12 0.12 0.12 0.12 0.12 0.12	0.02 0.00 0.06 0.08 0.00 0.02 0.02 0.02 0.02 0.02 0.03 0.03	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.01 0.02 0.01 0.02 0.02	0.00 0.01 0.01 0.00 0.02 0.02 0.02 0.02	0.00 0.00 0.00 0.00 0.01 0.01 0.01 0.01	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 108.60 7.95 6.90 4.72 3.21 3.24 3.32 3.80 4.22 7.32 108.00 7.27 9.93 6.90 4.72 3.24 3.32 3.24 3.32 4.32 4.32 4.32 4.3	2,28 2,64 2,15 2,06 1,95 2,14 2,31 2,33 2,48 3,14 4,12 3,28 3,28 3,28 3,28 3,28 3,28 3,28 3,2
WFI E MM           WFI E MM <t< td=""><td>643.6 667.5 135.0 112.5 135.0 157.5 180.0 202.5 278.0 247.5 278.0 279.0 279.0 279.0 279.0 279.0 279.0 279.0 277.0 279.0 277.0</td><td>1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.07 1.19 1.13 1.23 1.60 1.17 1.19 1.13 1.23 1.61 21.09 0.63 0.46 0.54 0.52 0.39 0.47 0.46 0.47 0.47 0.47</td><td>4,69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85 1.73 1.63 1.66 1.48 1.45 1.08 1.45 1.08 1.45 1.09 1.31 1.20</td><td>2.89 1.69 0.77 0.41 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68 3.79 3.75 4.06 5.24 3.81 2.44 1.45 1.44 1.45 1.44 1.45</td><td>0.09 0.11 0.09 0.11 0.09 0.09 0.13 0.13 0.41 0.95 4.23 0.53 0.53 0.53 0.53 0.53 0.53 0.53 0.5</td><td>0.02 0.10 0.06 0.03 0.00 0.00 0.00 0.00 0.00 0.0</td><td>0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02</td><td>0.00 0.02 0.01 0.01 0.02 0.01 0.02 0.02</td><td>6.00 6.01 6.01 6.02 6.00 6.00 6.02 6.02 6.02 6.02 6.02</td><td>6.86 6.80 6.80 6.80 6.80 6.81 6.81 6.81 6.83 6.83 6.83 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.82 6.83 6.84 6.84 6.84 6.84 6.84 6.84 6.85</td><td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0</td><td>6.87 9.68 7.15 4.80 3.29 3.91 4.22 4.18 5.42 7.49 11.05 6.80 7.27 9.93 6.90 4.72 3.21 3.24 4.23 3.80 4.22 3.80 4.22 3.80 4.22 4.23 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.22</td><td>2.28 2.64 2.15 2.065 2.14 2.33 2.48 3.14 4.12 3.77 4.51 4.00 3.57 3.10 3.24 3.24 3.24 3.27 4.51 4.00 3.57 3.10 3.24 3.27 3.24 3.27 3.24 3.27 3.24 3.27 3.27 3.27 3.27 3.27 3.27 3.27 3.27</td></t<>	643.6 667.5 135.0 112.5 135.0 157.5 180.0 202.5 278.0 247.5 278.0 279.0 279.0 279.0 279.0 279.0 279.0 279.0 277.0 279.0 277.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.07 1.19 1.13 1.23 1.60 1.17 1.19 1.13 1.23 1.61 21.09 0.63 0.46 0.54 0.52 0.39 0.47 0.46 0.47 0.47 0.47	4,69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.30 3.56 4.01 47.60 1.85 1.73 1.63 1.66 1.48 1.45 1.08 1.45 1.08 1.45 1.09 1.31 1.20	2.89 1.69 0.77 0.41 0.51 0.63 0.79 0.80 1.34 2.03 3.49 3.13 22.68 3.79 3.75 4.06 5.24 3.81 2.44 1.45 1.44 1.45 1.44 1.45	0.09 0.11 0.09 0.11 0.09 0.09 0.13 0.13 0.41 0.95 4.23 0.53 0.53 0.53 0.53 0.53 0.53 0.53 0.5	0.02 0.10 0.06 0.03 0.00 0.00 0.00 0.00 0.00 0.0	0.01 0.04 0.02 0.01 0.01 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.02 0.01 0.02 0.02	6.00 6.01 6.01 6.02 6.00 6.00 6.02 6.02 6.02 6.02 6.02	6.86 6.80 6.80 6.80 6.80 6.81 6.81 6.81 6.83 6.83 6.83 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.81 6.82 6.83 6.84 6.84 6.84 6.84 6.84 6.84 6.85	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.29 3.91 4.22 4.18 5.42 7.49 11.05 6.80 7.27 9.93 6.90 4.72 3.21 3.24 4.23 3.80 4.22 3.80 4.22 3.80 4.22 4.23 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.21 3.22 3.22	2.28 2.64 2.15 2.065 2.14 2.33 2.48 3.14 4.12 3.77 4.51 4.00 3.57 3.10 3.24 3.24 3.24 3.27 4.51 4.00 3.57 3.10 3.24 3.27 3.24 3.27 3.24 3.27 3.24 3.27 3.27 3.27 3.27 3.27 3.27 3.27 3.27
WR10M           WR50M           WR50M           WR50M           WR50M           WR50M           WR50M           WR50M           WR50M	647.5 090.0 112.5 135.0 157.5 180.0 202.5 225.0 225.0 225.0 337.5 ALL 000.0 002.5 337.5 ALL 000.0 007.5 002.5 135.0 125.5 135.0 157.5 135.0 157.5 135.0 000.0 000.0 125.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 157.5 135.0 135.0 137.5 135.0 137.5 135.0 137.5 135.0 137.5 135.0 137.5 135.0 137.5 135.0 137.5 135.0 137.5 135.0 135.0 137.5 135.0 137.5 135.0 135.0 137.5 135.0 135.0 137.5 135.0 135.0 135.0 137.5 135.0 135.0 135.0 137.5 135.0 157.5 135.0	1.42 1.53 1.44 1.33 1.01 1.15 1.00 1.06 1.17 1.19 1.13 1.23 1.51 21.09 0.63 0.46 0.45 0.54 0.54 0.54 0.47 0.49 0.43 0.47 0.43 0.45 0.58	4,69 3.77 2.56 1.71 1.76 1.64 2.64 3.30 3.56 4.01 47.60 1.85 1.63 1.63 1.63 1.63 1.63 1.63 1.48 1.48 1.48 1.48 1.48 1.48 1.48 1.48	2.89 1.69 0.77 0.41 0.53 0.51 0.53 0.50 1.34 2.03 3.49 3.43 22.68 3.79 3.75 5.24 1.44 1.45 1.44 1.44 1.49 1.81 2.81 2.81 3.39	0.41 0.16 0.49 0.11 0.09 0.09 0.09 0.13 0.41 1.02 1.02 1.02 1.02 1.02 0.53 0.55 1.18 0.56 0.24 0.15 0.56 0.24 0.15 0.24 0.17 0.27 0.27 0.74	0.02 0.10 0.06 0.03 0.00 0.00 0.02 0.02 0.02 0.03 0.03	0.01 0.04 0.02 0.01 0.02 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.00 0.02 0.01 0.02 0.03 0.03 0.03 0.03 0.03 0.03 0.03	6.00 6.01 8.00 6.00 6.00 6.00 6.00 6.02 6.02 6.02 6	6.86 6.86 6.86 6.86 6.81 6.81 6.81 6.81	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.26 3.36 3.91 4.22 4.18 5.42 7.49 11.05 100.02 7.95 6.80 7.27 9.93 6.90 4.72 3.24 3.24 3.24 3.324 3.80 4.01 5.37 7.38	2,28 2,64 2,45 2,15 2,05 1,95 2,14 2,31 2,33 2,48 2,32 3,28 3,14 4,12 3,77 4,51 4,00 3,57 4,51 4,00 3,57 3,33 3,10 3,24 4,357 4,57 2,64 2,155 2,165 2,
WR1 EM	647.6 690.0 112.5 135.0 157.5 225.0 247.5 225.0 247.5 225.0 337.5 045.0 042.5 045.0 00	1.42 1.53 1.44 1.34 1.01 1.15 1.00 1.01 1.01 1.17 1.19 1.23 1.60 1.17 1.19 1.23 1.60 0.63 0.46 0.54 0.41 0.52 0.37 0.39 0.47 0.46 0.47 0.425 0.455 0.62	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 1.94 2.64 3.36 4.01 1.85 1.63 1.63 1.63 1.63 1.63 1.63 1.63 1.68 1.48 1.48 1.48 1.48 1.48 1.48 1.99 1.131 1.31 1.31 1.35	2.899 0.77 0.41 0.39 0.51 0.79 0.51 0.51 0.51 0.51 0.51 0.51 0.51 0.51	0.41 0.16 0.49 0.11 0.09 0.09 0.09 0.13 0.41 0.95 0.42 0.53 0.53 0.53 0.53 0.53 0.53 0.53 0.53	0.02 0.10 0.06 0.06 0.09 0.09 0.02 0.02 0.02 0.02 0.02 0.03 0.08 0.03 0.08 0.03 0.08 0.03 0.08 0.03 0.08 0.03 0.045 0.02 0.03 0.045 0.02 0.03 0.045 0.03 0.040 0.02 0.03 0.040 0.02 0.03 0.0400 0.0400 0.0400 0.0400000000	0.01 0.04 0.02 0.01 0.02 0.02 0.02 0.02 0.02 0.02	0.00 0.01 0.01 0.01 0.01 0.02 0.02 0.02	6.00 6.01 6.00 8.00 8.00 8.00 8.00 8.00 8.00 8.00	0.00 0.00 0.00 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.01 0.00 0.00 0.01 0.000 0.000000	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 4.80 3.29 3.91 4.22 4.18 5.42 7.49 11.05 100.86 100.86 100.86 100.86 7.27 9.93 6.80 7.27 9.93 6.90 4.72 3.21 3.24 3.32 3.80 4.28 4.01 5.37 7.38 11.04	2,28 2,64 2,42 2,15 2,16 1,95 2,14 2,33 2,48 2,33 2,48 2,33 2,48 3,24 4,12 3,27 4,51 4,00 4,00 3,57 3,30 3,10 4,57 3,57 3,64 3,57 3,64 3,57 3,64 3,57 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,52 3,57 4,55 3,57 4,55 4,57 4,57 4,57 4,57 4,57 4,57 4
WR10M           WR50M           WR50M </td <td>647.5 090.0 112.5 135.7 135.7 202.5 205.0 247.5 278.0 247.5 278.0 247.5 278.0 247.5 278.0 002.5 315.0 337.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 115.0 135.0 115.0 135.0 115.0 135.0 115.0 135.0 115.0 135.0 120.2 220.0 224.0 225.0 224.0 225.0 225.0 224.0 225.0 237.5 235.0 237.5 23</td> <td>1.42 1.53 1.44 1.33 1.01 1.13 1.00 1.06 1.17 1.19 1.23 0.43 0.45 0.51 0.45 0.45 0.47 0.43 0.47 0.43 0.42 0.58 0.58 0.58 0.58</td> <td>4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 2.64 3.30 3.56 1.49 1.99 1.94 47.60 1.63 1.63 1.63 1.63 1.63 1.48 1.45 1.48 1.48 1.48 1.48 1.48 1.48 1.48 1.48</td> <td>2.89 9.67 0.41 0.51 0.51 0.51 0.51 0.51 0.51 0.51 0.5</td> <td>0.09 0.41 0.16 0.09 0.13 0.09 0.13 0.41 0.41 0.45 1.02 4.23 0.65 1.18 0.65 1.18 0.65 1.18 0.65 1.18 0.65 0.24 0.65 0.24 0.65 0.17 0.27 0.45 0.41 0.45 0.41 0.09 0.13 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.0</td> <td>0.02 0.10 0.06 0.00 0.00 0.02 0.02 0.02 0.02 0.0</td> <td>0.01 0.04 0.02 0.01 0.02 0.02 0.02 0.02 0.02 0.02</td> <td>0.00 0.02 0.01 0.01 0.01 0.02 0.03 0.03 0.03 0.03 0.03 0.03 0.03</td> <td>6.00 6.01 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8</td> <td>6.00 6.00 6.00 6.00 6.00 6.01 6.00 6.01 6.01 6.03</td> <td>0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0</td> <td>6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 180.02 7.95 6.90 4.72 9.93 6.90 4.72 3.21 3.24 3.32 4.38 4.01 5.37 7.38 10.84 10.84</td> <td>2.282 2.644 2.422 2.15 2.666 1.95 2.144 2.18 2.33 2.48 2.233 3.14 4.52 3.344 4.52 3.344 4.52 3.344 4.52 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.54 3.57 3.54 5.57 3.54 5.57 5.57 5.57 5.57 5.57 5.57 5.57 5</td>	647.5 090.0 112.5 135.7 135.7 202.5 205.0 247.5 278.0 247.5 278.0 247.5 278.0 247.5 278.0 002.5 315.0 337.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 112.5 135.0 115.0 135.0 115.0 135.0 115.0 135.0 115.0 135.0 115.0 135.0 120.2 220.0 224.0 225.0 224.0 225.0 225.0 224.0 225.0 237.5 235.0 237.5 23	1.42 1.53 1.44 1.33 1.01 1.13 1.00 1.06 1.17 1.19 1.23 0.43 0.45 0.51 0.45 0.45 0.47 0.43 0.47 0.43 0.42 0.58 0.58 0.58 0.58	4.69 3.77 2.56 1.71 1.76 1.64 2.07 1.99 2.64 3.30 3.56 1.49 1.99 1.94 47.60 1.63 1.63 1.63 1.63 1.63 1.48 1.45 1.48 1.48 1.48 1.48 1.48 1.48 1.48 1.48	2.89 9.67 0.41 0.51 0.51 0.51 0.51 0.51 0.51 0.51 0.5	0.09 0.41 0.16 0.09 0.13 0.09 0.13 0.41 0.41 0.45 1.02 4.23 0.65 1.18 0.65 1.18 0.65 1.18 0.65 1.18 0.65 0.24 0.65 0.24 0.65 0.17 0.27 0.45 0.41 0.45 0.41 0.09 0.13 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.0	0.02 0.10 0.06 0.00 0.00 0.02 0.02 0.02 0.02 0.0	0.01 0.04 0.02 0.01 0.02 0.02 0.02 0.02 0.02 0.02	0.00 0.02 0.01 0.01 0.01 0.02 0.03 0.03 0.03 0.03 0.03 0.03 0.03	6.00 6.01 8.00 8.00 8.00 8.00 8.00 8.00 8.00 8	6.00 6.00 6.00 6.00 6.00 6.01 6.00 6.01 6.01 6.03	0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.0	6.87 9.68 7.15 3.36 3.29 3.91 4.22 4.18 5.42 7.49 11.05 180.02 7.95 6.90 4.72 9.93 6.90 4.72 3.21 3.24 3.32 4.38 4.01 5.37 7.38 10.84 10.84	2.282 2.644 2.422 2.15 2.666 1.95 2.144 2.18 2.33 2.48 2.233 3.14 4.52 3.344 4.52 3.344 4.52 3.344 4.52 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.64 3.57 3.54 3.57 3.54 5.57 3.54 5.57 5.57 5.57 5.57 5.57 5.57 5.57 5

![](_page_33_Picture_0.jpeg)

## How do POWER's APIs work?

![](_page_33_Figure_2.jpeg)

![](_page_33_Picture_3.jpeg)

The POWER Project APIs support programatic access to the entire data catalog. The APIs provide community specific data products for independent use, directly embeed into applications, and for POWER Data Access Viewers.

#### Hosting in AWS Lambda:

The microservices provide data at all temporal levels including hourly, system endpoints, and all the analytical reports.

# - Geospatial Feature & Image Services

POWER provides Esri® ArcGIS Image and Feature Services that allow users to efficiently interact with the POWER data in Geographic Information System (GIS) applications and related tools.

**Image Services:** new image services for annual radiation, annual meteorology, monthly radiation, and monthly meteorology.

**Feature Services:** global long-term ASHRAE<sup>®</sup> building climate thermalmoisture zones, 4-year rolling thermal zones, and period differences

#### Available on:

Esri Living Atlas of the World

NASA ArcGIS Online (AGOL)

NASA ArcGIS Enterprise

![](_page_34_Figure_8.jpeg)

## **POWER evolved with User Needs**

![](_page_35_Figure_1.jpeg)

![](_page_35_Picture_2.jpeg)

WCRP SRB v1

![](_page_35_Picture_4.jpeg)

face Downward SW Flux - W m

**CERES FLASHFlux** Total Data Requests exceeding 326 million

![](_page_35_Picture_7.jpeg)

WCRP/GEWEX SRB v2.5

![](_page_35_Picture_9.jpeg)

**CERES SYN1Deg** 

# **POWER Users** I Impact of Modern Technology Adoption

![](_page_36_Picture_1.jpeg)

+ + + + + +

### POWER fulfills <sup>+</sup>7 + million data requests for over 30,000 unique users *per month*

![](_page_36_Figure_4.jpeg)

![](_page_36_Picture_5.jpeg)

https://power.larc.nasa.gov

![](_page_37_Picture_0.jpeg)

# **POWER |** REVISITING COMMUNITY OF USERS

National Aeronautics and Space Administration

Ben

![](_page_37_Picture_3.jpeg)

![](_page_37_Picture_4.jpeg)

I want to adopt green energy for my new facility. Will it be cost effective? I want to plan on when to fly my drone with payloads ? Will there be enough sunlight to power the drone ?

![](_page_37_Picture_7.jpeg)

I want to implement green energy solutions in my facility and monitor its performance over time

I want to model the maize yield response to Nitrogen Fertilizer Intervention

Margaret

I want to determine the optimal solar water pump configuration for our customers

### Renewable Energy Development

### Wicked Joe Organic Coffees

"The benefits of solar, in our view, go far beyond the financial considerations or return on investment. While some regions may have 'more optimal' conditions for solar, we believe that any place where the sun shines is a good place for solar."

-Bob Garver, Wicked Joe Founder

Wicked Joe Coffee utilized RETScreen<sup>™</sup> and POWER data to determine that a glazed solar wall would result in 40% more heat savings of approximately \$10,000 per year.

![](_page_38_Figure_5.jpeg)

### Renewable Energy Development

### Natural Resources Canada's RETScreen<sup>®</sup> Clean Energy Management Software Platform

World's leading clean energy decision making software for benchmark, feasibility, performance, and portfolio analysis related to nergy efficiency, heating and cooling, power generation and cogeneration, with 732,000+ registered users. POWER provides global data as climatological averages that are embedded in the software and near-real time data obtained via a direct connection to POWER.

![](_page_39_Figure_4.jpeg)

#### **RENEWABLE ENERGY** | SOLAR PANEL PERFORMANCE MONITORING

### CustomerFirst Renewables Is Using Data from POWER to Monitors Five Solar Fields in North Carolina

Variability of Solar Radiation is used to assess performance of solar panels and identify potential system problems

![](_page_40_Figure_3.jpeg)

#### RENEWABLE ENERGY | COMMERCIAL USAGE FOR VIABLE OPERATIONS PLANNING

SAILDRONE is using Data from POWER to determine viable operations season and make strategic engineering tradeoff decisions

### **Hourly Solar Radiation**

Intensity of solar radiation determines how much electricity can its drone's solar panels generate

- Prioritize adding solar or reducing loads on drone ?
- Modify contract to support a mission?

![](_page_41_Picture_6.jpeg)

### **Building Energy** Efficiency & Sustainability

12/31/1984

8 Subarctic/Arctic

### **American Society of Heating, Refrigerating** and Air-Conditioning Engineers (ASHRAE)

The POWER project is working with ASHRAE professional association to make their Climatic Design Conditions report available to the public with POWER data globally.

Using MERRA-2, POWER creates Global ASHRAE Building Climate Zone maps, as well as "rolling" climate zones from 4-year means to illustrate the changes in time from 1984 through 2021.

	Buil	dir	ng	C	lim	at	ic	De	esi	gn	C	or	ndi	tio	ns	
	Latitude: 29.6106 Coldest Heat Month 99.6% 1 -0.2 Hottest Month	Long -82. ing DB 99% <b>1.8</b>	P itude: 2603 DP -5.6 Ann C 4%	Elevati Elevati Humid 99.6% HR 0.0 Cooling I	Climatic on: 28.3 ual Heat fication D MCDB MCDB oling, De DB/MCWB	Design StdPres ng and P/MCDB DP -3.2 humidi	Conditi : 14.68 Humid and HR 99% HR 0.0 fication %	ons (MI Time ification MCDB , and El	RRA-2 a Period: 2 2019 Design Colo 0 WS 2.7 Thalpy Ev.	and SRE 2014 - Condition lest more 4% MCDB Design aporatio	B/CERES Note: 0 Ith WS/M WS 2.7 Condito N WB/MC	) .5 x 0.5 Da ICDB MCDB MCDB	Degree ( ita MCWS// 99.6 MCWS	CWD to % DB PCWD PCWD	CWD to	STANDAR
I	Month DB Range 7 12.5 0.4% DP HR 35.8 20.0	о. DB <b>35.8</b> Deh MCDB	MCWB umidificat DP 25.3	DB 34.7 :lon DP/ 1% HR 20.0	MCWB MCDB and MCDB	DB 33.6 1 HR DP 25.0	2% HR 20.0	WB 28.4 MCDB	MCDB 0. Enth	WB   28.1 4% MCDB	MCDB Enthalp 1 Enth	WB   27.8   27.8   27.8   27.8	MCDB	MCWS	PCWD Extreme Max WB 29.6	DIVATIVATI
ľ	Extreme Anni 1% 2.5% 6.0 5.2	Jal WS 5% <b>4.5</b>	DB WB	Min 3.6 5.4	me Annua ean Max 37.4 29.2	Stan devi Min 1.8 2.9	ation Max 1.6 0.4	n=5 Min -4.9 -7.5	years Max 38.6 29.5	n=10 Min -6.0 -9.2	9 years Max 39.6 29.7	n=20 Min -7.0 -10.8	eme Ter years Max 40.5 29.9	n=50 Min -8.3 -12.9	e years Max 41.7 30.1	
	Temperatures, Degree-Days and Degree- Hours	DBAvg DBStd HDD10. HDD18. CDD10. CDD18. CD123. CDH23.	Annual 21.2 0.7 0 59 3 535 0 4302 3 1747	Jan 11.5 2.2 40 204 100 7	Feb 15.3 3.0 8 95 168 20	Mar 17.3 1.8 2 63 240 45	Apr 21.3 1.3 0 8 350 109	Design May 25.1 1.1 0 475 218	Un Jun 27.1 0.9 0 524 275	Jul 27.9 0.8 0 563 306	Aug 27.5 0.4 0 555 298	Sep 26.0 0.8 0 495 246	Oct 22.3 1.4 0 8 397 148	Nov 17.2 2.1 3 61 235 44	Dec 15.6 2.1 6 95 199 31	
	Wind	WSAvg	2.3	2.7	2.6	2.6	2.6	2.3	2.0	1.7	1.9	2.1	2.6	2.4	2.5	
	Precipitation	PrecAvg PrecMax PrecMin PrecStd	811 1383 3 637	53 125 3 48	44 94 2 39	45 146 1 53	41 99 2 41	45 108 1 40	86 202 3 76	77 156 5 68	145 268 3 123	173 394 1 155	38 92 2 37	44 101 2 46	31 80 5 27	
	Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4% 2% 5% 10%	DB MCWB DB MCWB DB MCWB DB MCWB	15.2 11.2 15.0 11.0 14.4 10.7 13.6 10.1	18.2 16.0 18.1 15.9 18.1 15.8 17.9 15.7	19.3 15.2 19.2 15.2 19.2 15.1 19.2 15.1	22.9 18.4 22.9 18.4 22.9 18.3 22.8 18.1	26.8 19.4 26.7 19.4 26.5 19.4 26.2 19.4	28.1 23.0 28.1 23.0 28.1 23.0 28.1 23.0 28.1 23.0	29.4 23.8 29.3 23.8 29.1 23.8 28.7 23.8 28.7 23.8	28.1 24.2 28.1 24.2 28.0 24.2 27.9 24.2	27 1 23 4 27 1 23 4 27 0 23 3 26 9 23 1	24.3 20.1 24.3 20.0 24.2 19.8 24.0 19.5	20.2 17.7 20.1 17.5 19.7 17.1 19.1 16.5	19.1 16.3 18.9 16.0 18.5 15.5 17.9 14.6	See Appendix C for approval dates. This Standard is under continuous maint Committee his established a documente
	Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4% 2% 5% 10%	WB MCDB WB MCDB WB MCDB WB MCDB	11.2 15.2 11.0 15.0 10.7 14.4 10.1 13.6	16.0 18.2 15.9 18.1 15.8 18.1 15.6 18.0	15.2 19.3 15.2 19.3 15.1 19.2 14.9 19.2	18.4 22.9 18.3 22.8 18.0 22.6 17.5 22.4	19.4 24.1 19.3 24.1 19.2 24.1 19.0 24.1	23.0 26.5 23.0 26.5 23.0 26.5 22.9 26.5	23.8 27.9 23.8 27.9 23.8 27.9 23.8 27.9 23.8 27.8	24.2 27.7 24.2 27.7 24.2 27.7 24.2 27.7 24.2 27.6	23.4 27.1 23.4 27.1 23.3 27.0 23.1 26.9	20.1 24.3 20.0 24.1 19.8 23.8 19.4 23.3	17.7 20.2 17.4 20.1 17.0 19.7 16.2 19.1	16.3 19.1 16.0 18.9 15.5 18.5 14.6 17.9	Confinition has each and a documents timely, documented, consensus action o change can be found on the ASHRAE <sup>®</sup> w The latest edition of an ASHRAE Stan ASHRAE Customer Service, 180 Techno 6/8-539-2129. Telephone: 404-636-844
	Mean Daily Temperature Range	5% DB 5% WB	MDBR MCDBR MCWBR MCDBR MCWBR	11.5	11.8	12.5	12.3	12.1	9.5	9.0	8.4	8.4	10.2	11.6	10.7	reprint permission, go to www.ashrae.or © 2021 ASHRAE ISSN 1041-2
	Clear Sky Solar Irradiance	ta ta Ebn, Edn,	ub ud noon noon													

3.2 3.94 5.02 5.97 6.45 5.84 5.43 5.38 4.79 4.48 3.53 2.95 1.12 1.42 1.53 1.64 1.6 1.72 1.65 1.44 1.44 0.99 1.05 0.94

![](_page_42_Picture_5.jpeg)

ANSI/ASHRAE Standard 169-2021 (Supersedes ANSI/ASHRAE Standard 169-2020) Includes ANSI/ASHRAE addenda listed in Appendix C

### **Climatic Data for Building Design Standards**

#### ee Appendix C for approval dates

his Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

a latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from SHRAE Customer Service, 180 Technology Parkway NW, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 78-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For ission, go to www.ashrae.org/permission

![](_page_42_Picture_12.jpeg)

cludes Web-based access to climatic data, design conditions, figures, and tables equires Adobe Acrobat® and Microsoft Excel®)

#### Thermal Climate Zone 0 Extremely Hot 1 Very Hot 2 Hot 3 Warm 4 Mixed 5 Cool 6 Cold 7 Very Cold

POWER Rolling Climate Thermal Zones 1984 to 2021

#### SUSTAINABLE INFRASTRUCTURE | BUILDING PERFORMANCE ASSESSMENT

**3M Company** implements strategies to increase energy efficiency and reduce carbon emissions in the manufacturing facilities it manages

Time series data used for retrofitting decisions

Monitoring and assessment of post decision implementation

Using RETScreen<sup>®</sup> Clean Technology tool and time series data (verify ISO 50001 energy standards)

![](_page_43_Figure_5.jpeg)

### Agroclimatology Applications: Partners

### Decision Support System for Agrotechnology Transfer (DSSAT)

POWER data supports the Decision Support System for Agrotechnology Transfer (DSSAT) tool, an agriculture ecosystem by the Global Food Systems Institute & Department of Agricultural and Biological Engineering at the University of Florida (UF). The DSSAT tool can be used for:

- Modeling crop yield prediction
- Estimating crop maturity dates
- Harvest progression over time
- Assessing the potential impact of climate change on global food security

#### DSSAT

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#### DSSAT Version 4.8.0.0 Crops Documentation He PRun + C Experiments | Z Data | Output Y 🚼 Cereals 9:00:00, Sat. 1 May 2021 DTSP8502.RD EFFECTS OF APPL, N & ENVIR, ON RICE DSSAT v4.8 9:00:00, Sat, 1 May 2021 IRM78601.RD TRRLMUNOZ JAN 86 LIREASE INHIBITIORS IRRI, LOS BANOS, IRRIG. & N STUDY, 1980 9:00:00, Sat. 1 May 2021 IRPI8001.RIX IRRI, PILA JAN 85 UREASE INHIBITORS 15N IRPL8501.RIX 9:00:00, Sat. 1 May 2021 PULL0001.RD PAUL LUDHTANA, WATER BALANCE STUDIES, 200 9:00:00, Sat. 1 May 2021 LIAFDOO11 RTY PLANT DENSITY \* NITROGEN 2000 LIAE PAKISTAN 9:00:00, Sat. 1 May 2021 9:00:00, Sat. 1 May 2021 UAFD0012.RI PLANT DENSITY # IDDICATION 2000 LIAE DAKISTA × Preview Experimental Data 11 teeedling +0kgN

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Request DSSAT

DSSAT is Free of charge

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> DSSAT Version 4.8 released in May 2021.

> DSSAT Version 4.7.5 released in April 2019.

What is DSSAT?

D ecision Support System for Agrotechnology Transfer (DSSAT) is software application program that comprises dynamic crop growth simulation models for over 42 crops. DSSAT is supported by a range of utilities and apps for weather, soil, genetic, crop management, and observational experimental data, and includes example data sets for all crop models. The crop simulation models simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics. DSSAT has been applied to address many real-world problems and issues ranging from genetic modeling to on-farm and precision management to regional assessments of the impact of climate variability and climate change. DSSAT has been used for more than 30 years by researchers, educators, consultants, extension agents, growers, private industry, policy and decision makers, and many others in over 174 countries worldwide. Learm more. The Ministry of Agriculture in Ethiopia used DSSAT to model the maize yield response to Nitrogen Fertilizer Intervention

Historical (34 year) and Near-Real-Time solar and weather data from NASA POWER was used in DSSAT

![](_page_44_Figure_16.jpeg)

Absolute difference in maize yield after additional fertilizer application

### Agroclimatology Applications

### **Earth Observing Satellite Data Analytics (EOSDA)**

The main focus of EOSDA is the global agricultural sector, providing reliable information of crop development, crop disease, and yield forecast to their clients. These outcomes are very dependent on weather, so accurate estimation of past and current weather is very important. EOSDA developed crop growth monitoring system that runs operationally from independent modules that are integrated to monitor crop behaviour and produce crop yield forecasts, where NASA POWER meteodata is a key input.

![](_page_45_Figure_4.jpeg)

#### AGROCLIMATOLOGY | SOLAR WATER PUMPING SIZING SUPPORT TOOL

# The **Davis & Shirtliff Group** in East Africa uses **SolarCal** to determine the optimal solar water pump configuration for their customers

**D&S** developed an application called **'SolarCalc'** that uses data from POWER to compute how many solar panels (including their arrangement) are needed to power different types of Solar-powered Water Pumps

![](_page_46_Picture_3.jpeg)

# What are POWER's Impacts on the Community?

![](_page_47_Figure_1.jpeg)

![](_page_48_Picture_0.jpeg)

![](_page_48_Picture_1.jpeg)

New & Improved Datasets from → Providers (SMAP, TEMPO, including predictive data!)

Enhanced Data Production
Technologies

Increased User Community ►--→ Engagement & Communication (e.g Validation Tool PRUVE)

![](_page_49_Picture_0.jpeg)

NASA-wide project to assess building system sustainability for operations, maintenance and planning according to Federal regulations

Assess and utilize NASA Earth Exchange (NEX) Global Downscaled Data Product from CMIP6 model data products:

22 of 26 models utilized; runs out to 2100 3 SSPs processed

60°S-90°N, all longitudes; downscaled to 20 km; daily temporal resolution

9 parameters including: T, Tmin, Tmax, RH (q), Wind Speed, Precip, SWdown, Lwdown

22 Member Ensemble for each SSP processed to assess CCD/HDD at each center

![](_page_49_Figure_7.jpeg)

**EARTH SCIENCE** 

### Time Series Usage: Climate Projections Analysis for Sustainability Assessments

# • Produce long time series to capture scenario changes

- Apply bias correction (using surface obs and POWER data for each parameter)
- Input into decision support tool
- Estimate differences in energy, GHG load and cost for archetypical and/or specific buildings
- Utilize CDD/HDD/Precipitation to create maps of estimate global building climate zones
  - Can assess changes in climate zone changes relative to individual and/or ensembles of models

![](_page_50_Figure_7.jpeg)

# Roadmap | Online Data Validation Tool (PRUVE)

![](_page_51_Picture_1.jpeg)

Currently working on a new webapplication called PaRameter Uncertainty ViEwer (PRUVE)

A system built on **open-source frameworks** to support the computation, discoverability, and visualizations of data uncertainty.

#### **Key Features:**

- No-coding access
- Prototype to include ~3,000 surface sites
- Dynamic data visualization available for each site
- Creates maps, plots, and conducts spatial analysis on the fly
- User selectable point based descriptive statistics
- User selectable site based intercomparison
- Advanced custom plotting for specific use cases

![](_page_51_Figure_12.jpeg)

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# The PaRameter Uncertainty ViEwer (PRUVE)

POWER   PRUVe Tool	Descriptive Statistics	Advenced Plats	Dark Mode
A Terminology	^	<u>Visualizations</u> Visualizations	~
Slope of Comparison	+	Box Plot	+
Average Absolute Deviation	+	Histogram	+
Aircrafts	+	Stacked Area Chart	+
Root Mean Square		Line Graph	-
The RMS value of a set of values (or a continuous-time waveform) is the square root of the arithmetic square of the function that defines the continuous waveform. In physics, the RMS current value can a current that dissipates the same power in a resistor. <sup>#</sup>	c mean of the squares of the values, or the also be defined as the "value of the direct	T when we may =	A line chart or line graph, also known as curve chart, is a type of chart which displays information as a series of data points called 'markers' connected by straight line segments. It is a basic type of chart common in many fields. It is similar to a scatter plot except that the manual straight the second or different but straight the constraints of the second or different but straight to a scatter plot except that the manual straight to a scatter plot except that the manual straight to be determined by the second or different but straight to a scatter plot except but the scatter but second or different but straight to a scatter plot except that the scatter but straight to a scatter but scatter but straight to a scatter but scatter but scatter but straight to a scatter but scatter
FAQs	^	WWW WWWWWW THE	measurement points are ordered (typically ov their x- axis value) and joined with straight line segments. A line chart is often used to visualize a trend in data over intervals of time – a time series – thus the line is often drawn chronologically. In these cases they are known as
How do I make a comparison between two data points?	+		run charts.
How do I compare two datasets?	+		
Manual Languages a short based off a single sector?	<u> </u>		

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**USER ENGAGEMENT** | 2<sup>nd</sup> Annual Global Community Summit National Aeronautics and Space Administration (GloCo)

### SAVE THE DATE : October 11-12<sup>th</sup>, 2023

NASA Prediction Of Worldwide Energy Resources HOME ABOUT SPEAKERS SCHEDULE EVENT RECORDINGS

#### NASA POWER Global Community (GloCo)

ummit event held on 21-22, September 2022.

You can view the event materials, agenda, and recordings below. By clicking this link, you can access a Summary Report from the Summit

#### Summit

2022 POWER Global Community (GloCo) Summit Play all

This September, the NASA Prediction Of Worldwide Energy Resources (POWER) Project (https://power.larc.nasa.gov) hosted its very first Global Community (GloCo) Summit on renewabl.

![](_page_53_Picture_9.jpeg)

2022 POWER GloCo Day 1 **Getting Started** 

NASA Farthdata

91 views • 1 month add

- 2022 POWER GloCo Day 1: NASA Applied Sciences, Dr...
- NASA Earthdata 🕥 31 views + 1 month ago

NASA Farthdata 37 views · 1 month ago

2022 POWER GloCo Day 1: 2022 POWER GloCo Day 1: Sustainable Infrastructure. **POWER Journey & Roadmap** NASA Earthdata 📀

24 views • 1 month ago

Resources (POWER) Project hosted its first annual Global -22, marking the 25th year of providing global solar and orld. The goals of this event were to inform users of new, on services, identify new requests and requirements, and while identifying new user communities and partnership and had over 580 registrants. Over the two-day event, que attendees representing 24 countries

2022 POWER GloCo Summary Report

The POWER GloCo Summit is a **FREE** two-(half) day hybrid event on **October 11-12**<sup>th</sup>, 2023, hosted by the NASA POWER Project Team.

Stay tuned for more GloCO announcements, including information for how to submit a lightning talk presentation, soon!

Learn more about the NASA POWER Project

Watch new product capability demonstrations

Engage in community-driven breakout sessions

Hear how users are utilizing NASA POWER products

# **Connect with POWER & Learn More**

![](_page_54_Picture_2.jpeg)

### **Explore POWER's docs &** learning resources!

- → Esri<sup>®</sup> ArcGIS StoryMap
- → POWER Services Dashboard
  - → <u>API Landing Pages</u>
  - Methodology Docs

![](_page_54_Picture_8.jpeg)

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

### Submit your user stories & **POWER-featured publications!**

→ The team <u>keeps a list of</u> <u>presentations, papers, & projects</u> that have used POWER Data.

![](_page_54_Picture_13.jpeg)

### **Energy Webinars**

![](_page_54_Picture_15.jpeg)

![](_page_54_Picture_16.jpeg)

### **Reach out to POWER directly!**

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falguni.patadia@nasa.gov

![](_page_54_Figure_20.jpeg)

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![](_page_55_Picture_0.jpeg)

### Thank you!

Email: <u>larc-power-project@mail.nasa.gov</u> Website: <u>https://power.larc.nasa.gov</u>

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- Taiping Zhang, Colleen Mikovitz, Bradley Hegyi, & Neha Khadka Science Systems and Applications, Inc. (SSAI)

https://www.earth data.nasa.gov/learn /articles/poweroverview

![](_page_55_Picture_8.jpeg)

![](_page_55_Figure_9.jpeg)

Examples of the tools and charting resources available through the enhanced POWER DAV. A video from the 2022 POWER Global Community Summit<sup>Ed</sup> provides a demonstration of the enhanced DAV. Credit: NASA POWER.

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