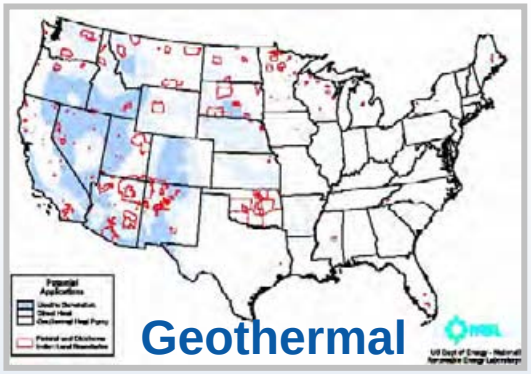
Solar Resource Assessment

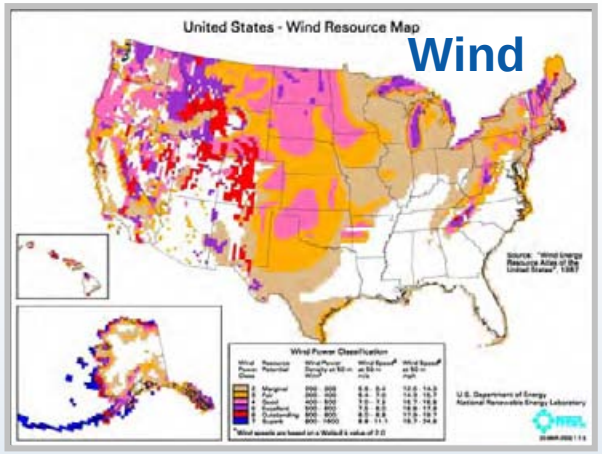
NAEMI Solar Electric & Thermal Training Workshop

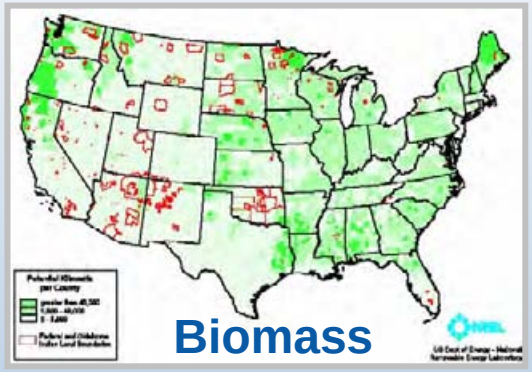
Roger Taylor
NREL

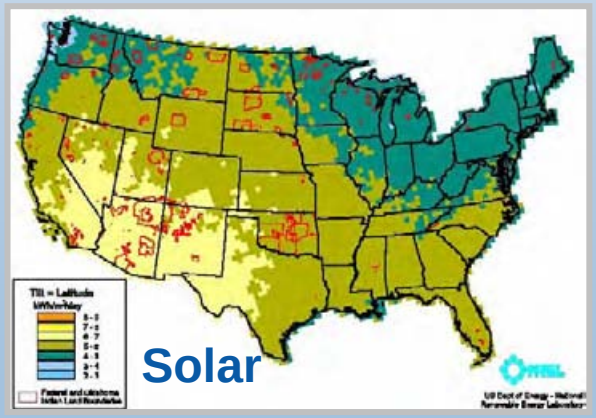
June 27-29, 2006

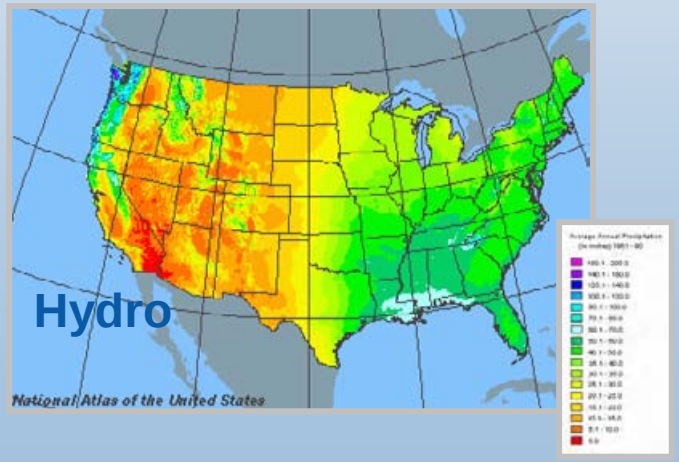
Renewable Resource Options











What is Resource Assessment?

Understanding the **spatial** and **temporal** variations of renewable energy resources:

» Solar Radiation
» Wind Power
» Bioenergy
» Geothermal
» Hydrological

For supporting:

- Production of electricity, heat, fuels and other products generally derived from non-renewable sources
- Energy efficiency opportunities (e.g., buildings, transportation, etc.)

Resource Assessment

Resource *DATA* → Technology *INFORMATION*

Maps

Databases

Models

Climate Summaries

Real-Time Data

Solar-based Technologies and Applications

Sources of Resource Data

- **National and International Government Sources**

  Provide access to long-term and experimental measurements

  - ✓ **Weather & Climate Records**
    - World Meteorological Organization (WMO)
    - Country-specific weather services
    - National Oceanic & Atmospheric Administration (NOAA)
    - US Department of Energy (DOE)
    - US Department of Defense
  - ✓ **Environmental Monitoring**
    - US Environmental Protection Agency (EPA)
    - Bureau of Land Management (BLM)
    - Nuclear Regulatory Commission (NRC)
    - State EPA, Health Departments, etc.
  - ✓ **Agricultural Interests**
    - US Dept of Agriculture
    - US Forest Service
  - ✓ **Other Related Data**
    - US Geological Survey (USGS)

Elements of Resource Assessment

- High resolution **spatial** data for site selection
- Historical **time-series** data for system design
- Specific data **elements** for technology options

  For example, Solar Utilization needs “Watts per square meter”:

  - Direct normal for concentrating solar power (10-sec)
  - Global for flat-plate collectors (daily)
  - Diffuse irradiance & illuminance for daylighting (monthly)
- Specified **confidence limits** of all information products

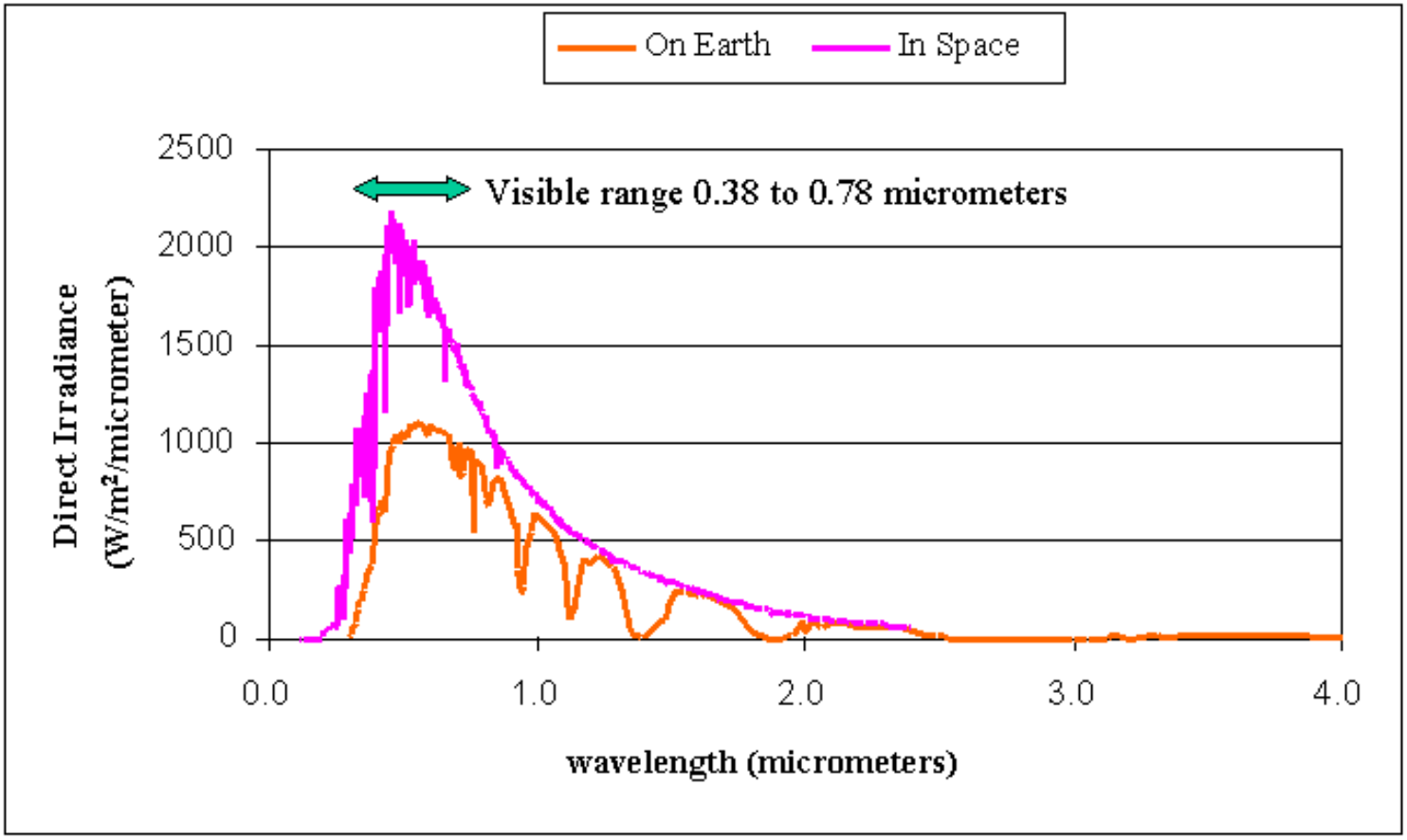
Consequences of Poor Resource Information

- At-risk project definition and **approval**
- Unrealistic project **goals**
- Less than optimal **technology selection**
- Conservative design, driving up initial **costs**
- Project delays to conduct resource assessment (**additional** monitoring & analyses)

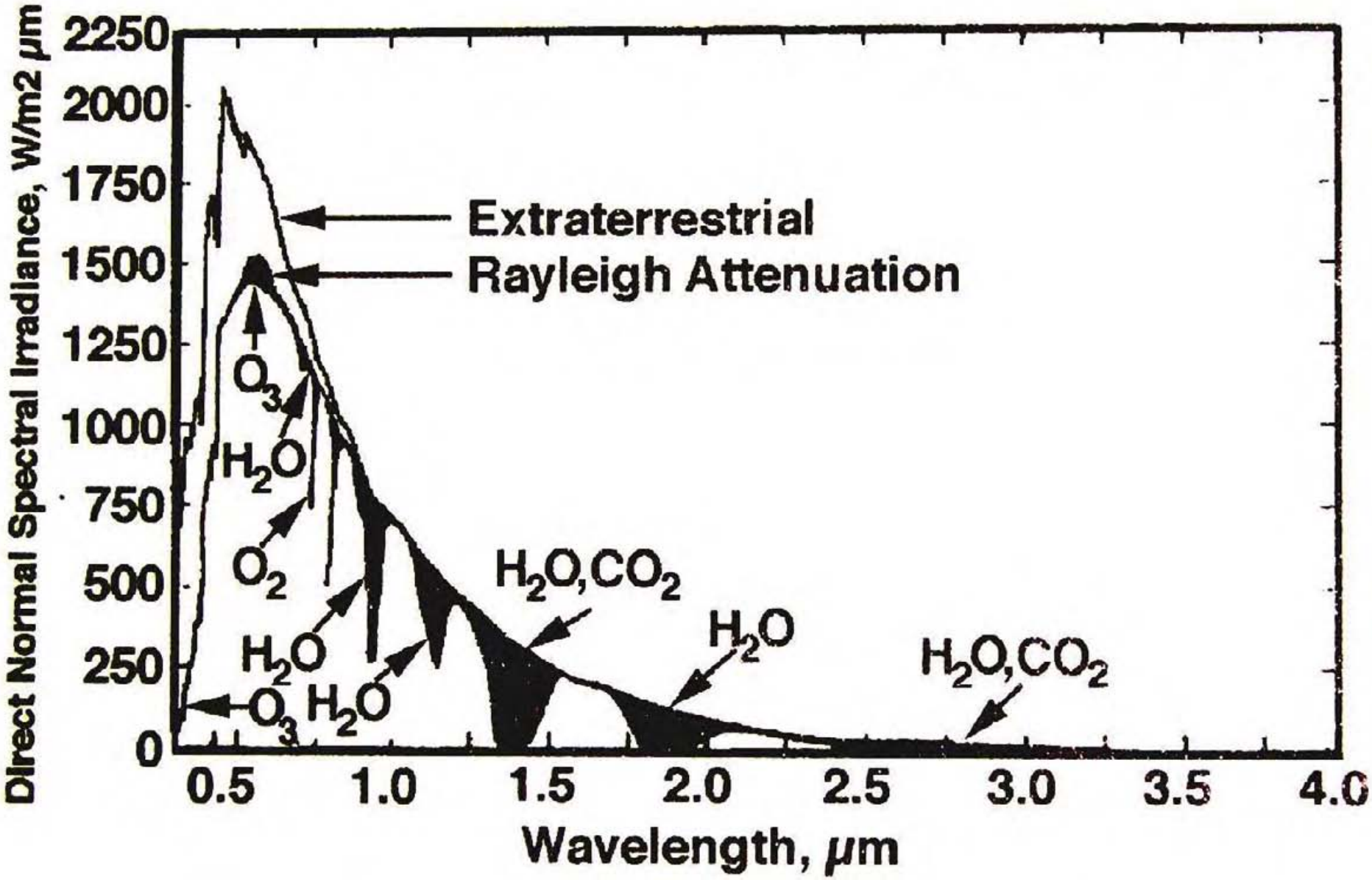
What Influences the Amount of Solar Radiation?

- Atmosphere
- Clouds
- Geography (Mountains, Oceans, Large Lakes)
- Latitude and Season
- Air Pollution and Natural Haze
- Volcanic Activity

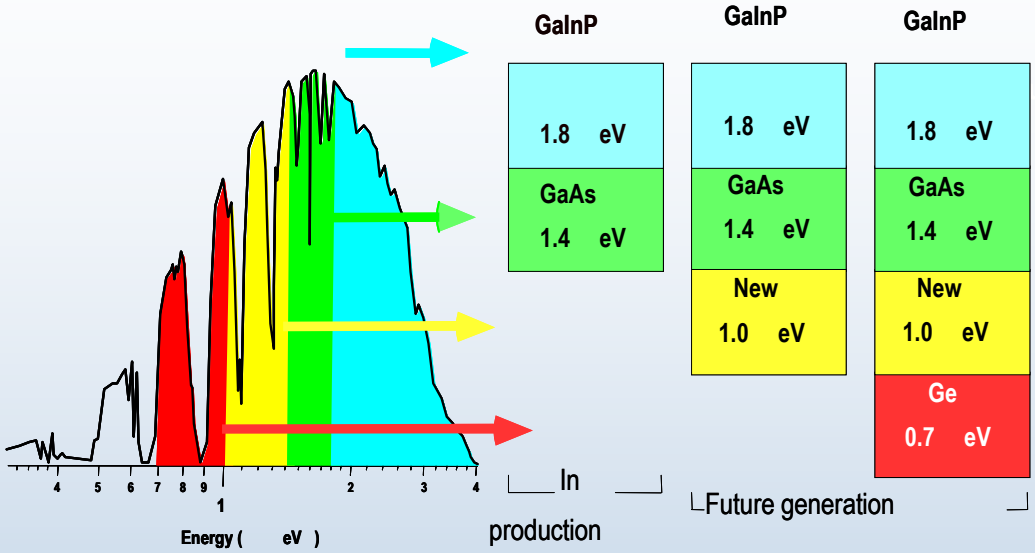
Solar Spectrum



- 6% ultraviolet, 48% visible, and 46% infrared light
- annual average radiation 1,366 W/m^2 in space, typically less than 1000 W/m2 on Earth.


Direct Normal Spectral Irradiance, W/m2 μm
2250
2000
1750
1500
1250
1000
750
500
250
0
Extraterrestrial
Rayleigh Attenuation
O3
H2O
O2
H2O
O3 H2O
H2O,CO2
H2O
H2O,CO2
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Wavelength, μm

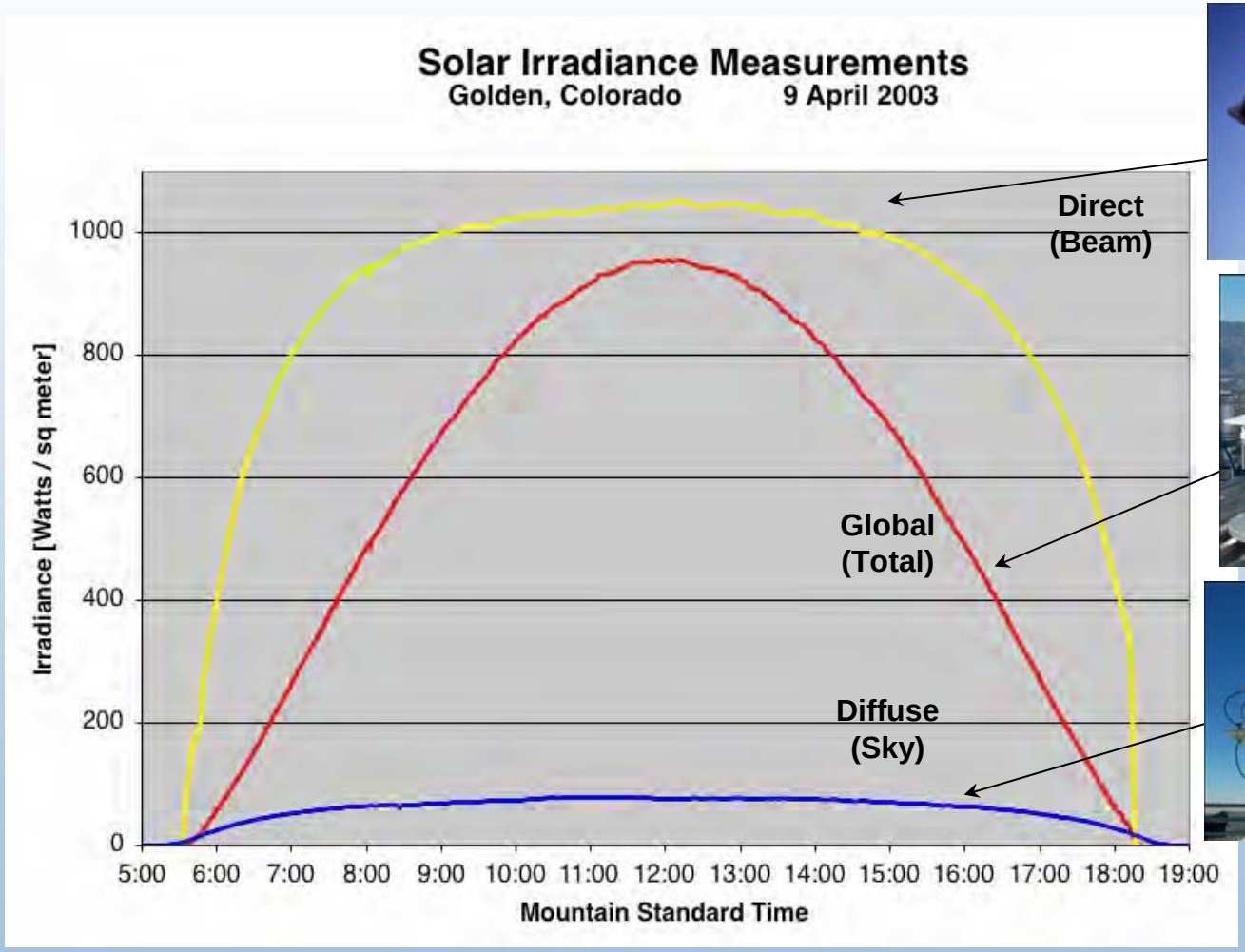
High-Efficiency and Concentrator PV



Efficiencies:	Si (up to 400X)	27
	GaAs (up to 1000X)	28
	GaAs/GaSb (100X)	32.6
	$GaInP_2$/GaAs (1X)	30.3
	$GaInP_2$/GaAs (180X)	30.2

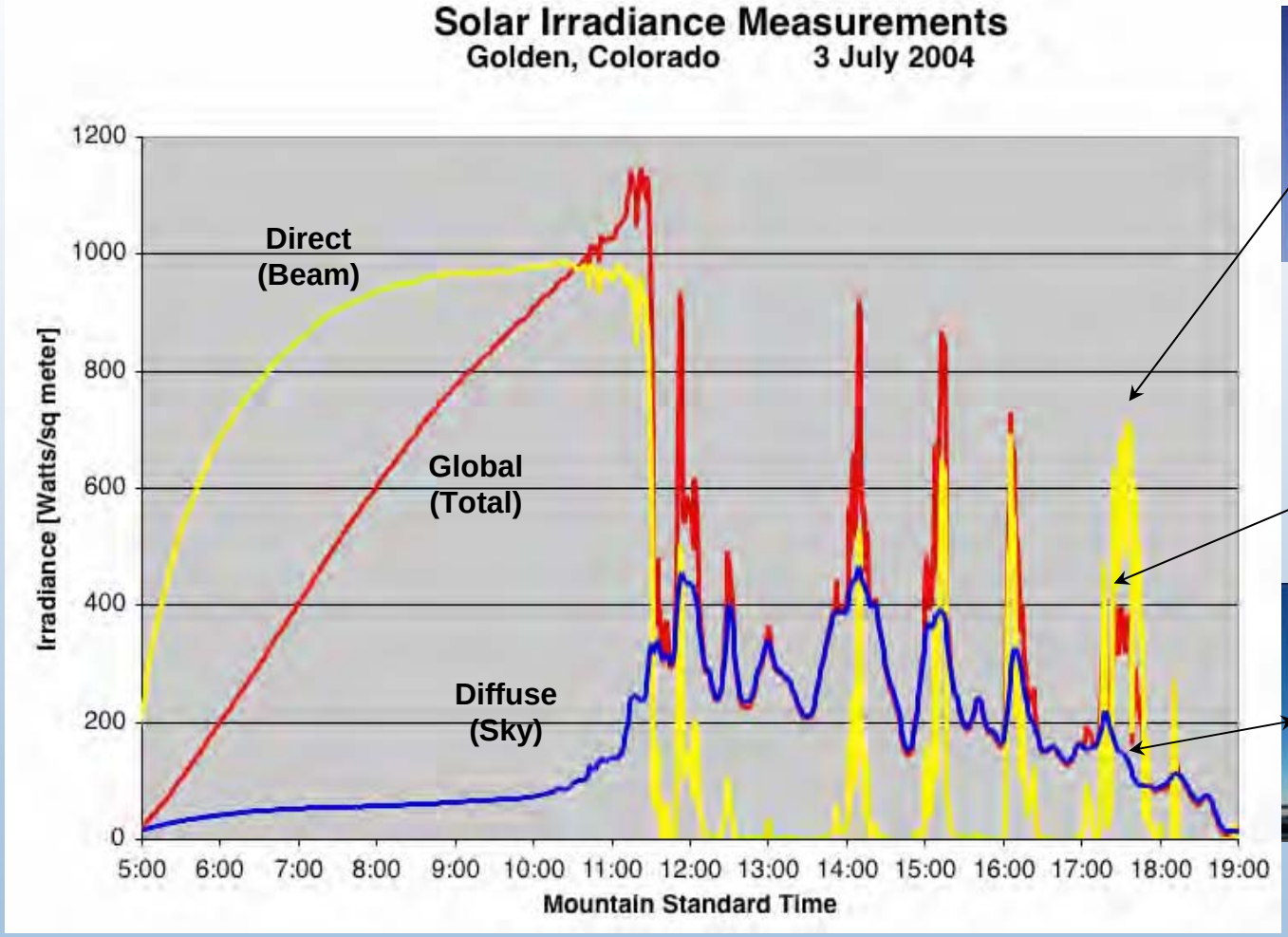
- Module efficiencies: 15-17% (Si);
- best prototypes: >20% (Si), >24% (GaAs)

Clear Sky



http://www.nrel.gov/srrl

Partly Cloudy Sky



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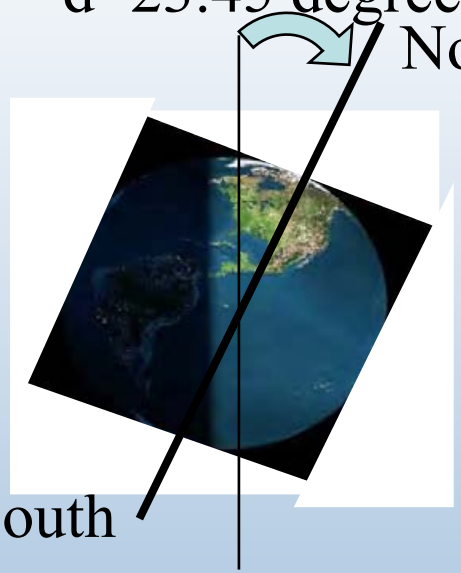
Declination, d, and the Seasons

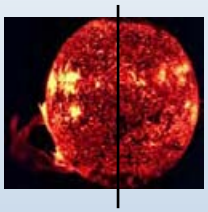
Summer Solstice,

d=23.45 degrees



Spring Equinox,

d= 0



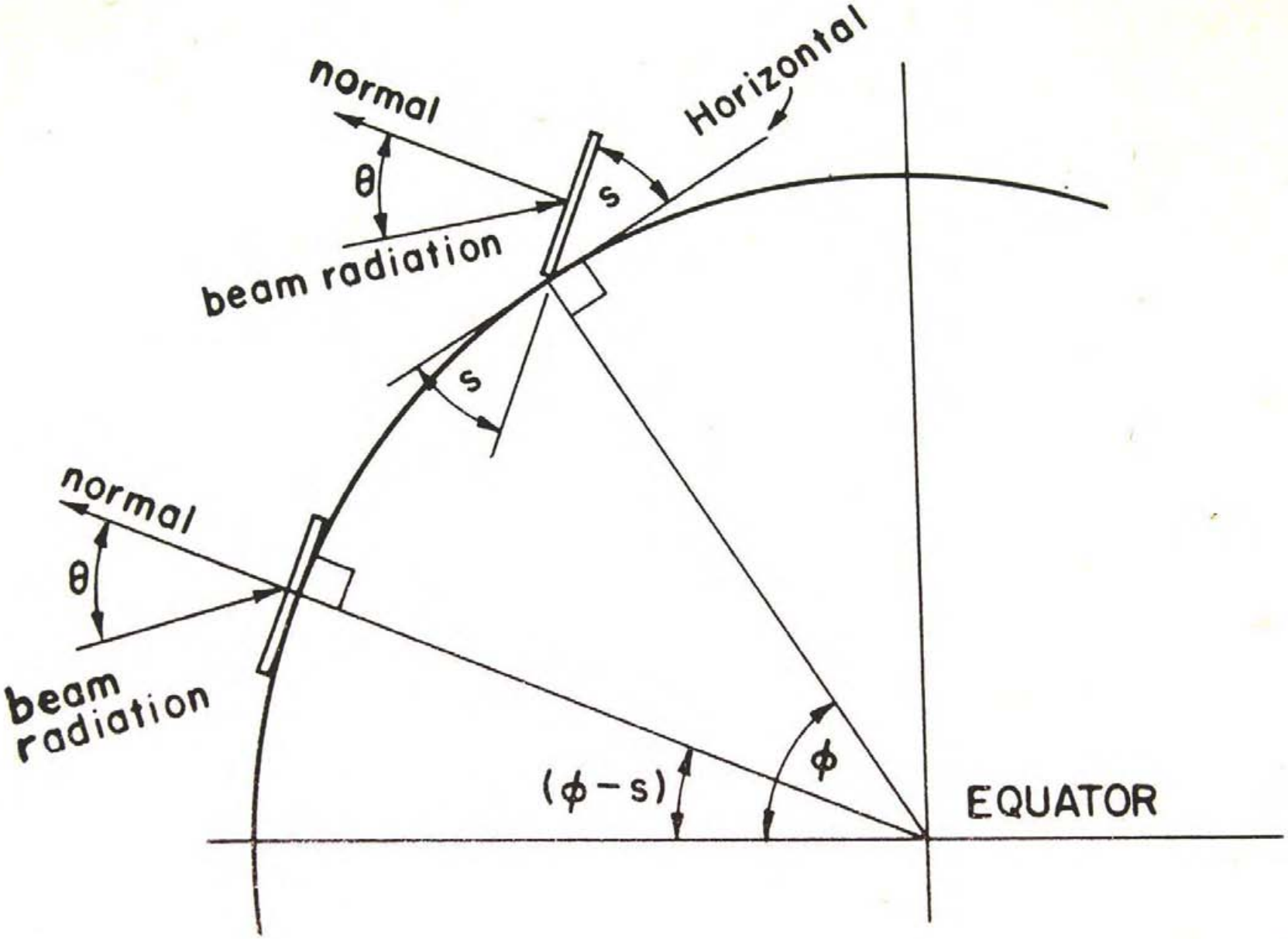
Sun

Fall Equinox,

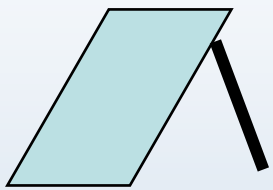
d=0

Winter Solstice,
d= -23.45 deg

Varies like a sine wave throughout the year.


normal
Horizontal
θ
s
beam radiation
s
normal
θ
beam
radiation
(ϕ − s)
ϕ
EQUATOR

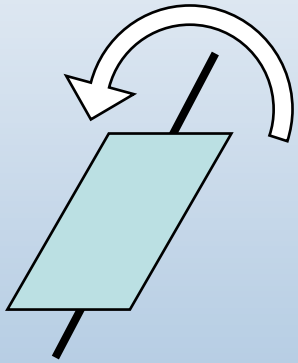
Fixed Tilt and Tracking



Fixed Tilt Facing Equator tilt=latitude

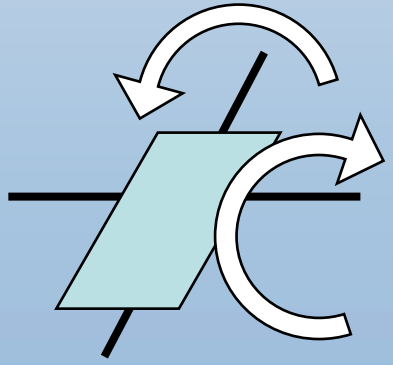
tilt<latitude for summer gain

tilt>latitude for winter gain

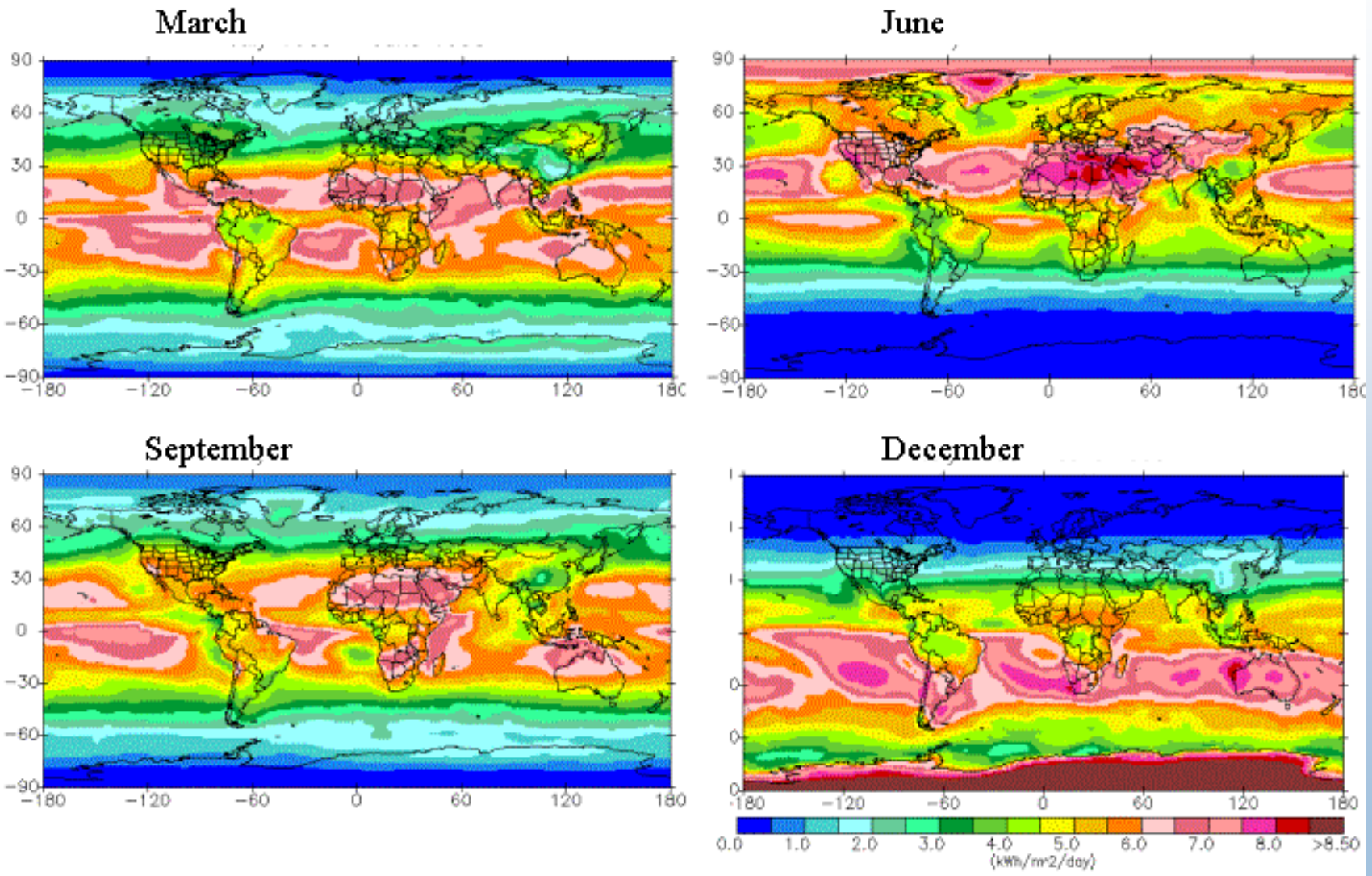


One Axis Tracking around axis tilted or flat

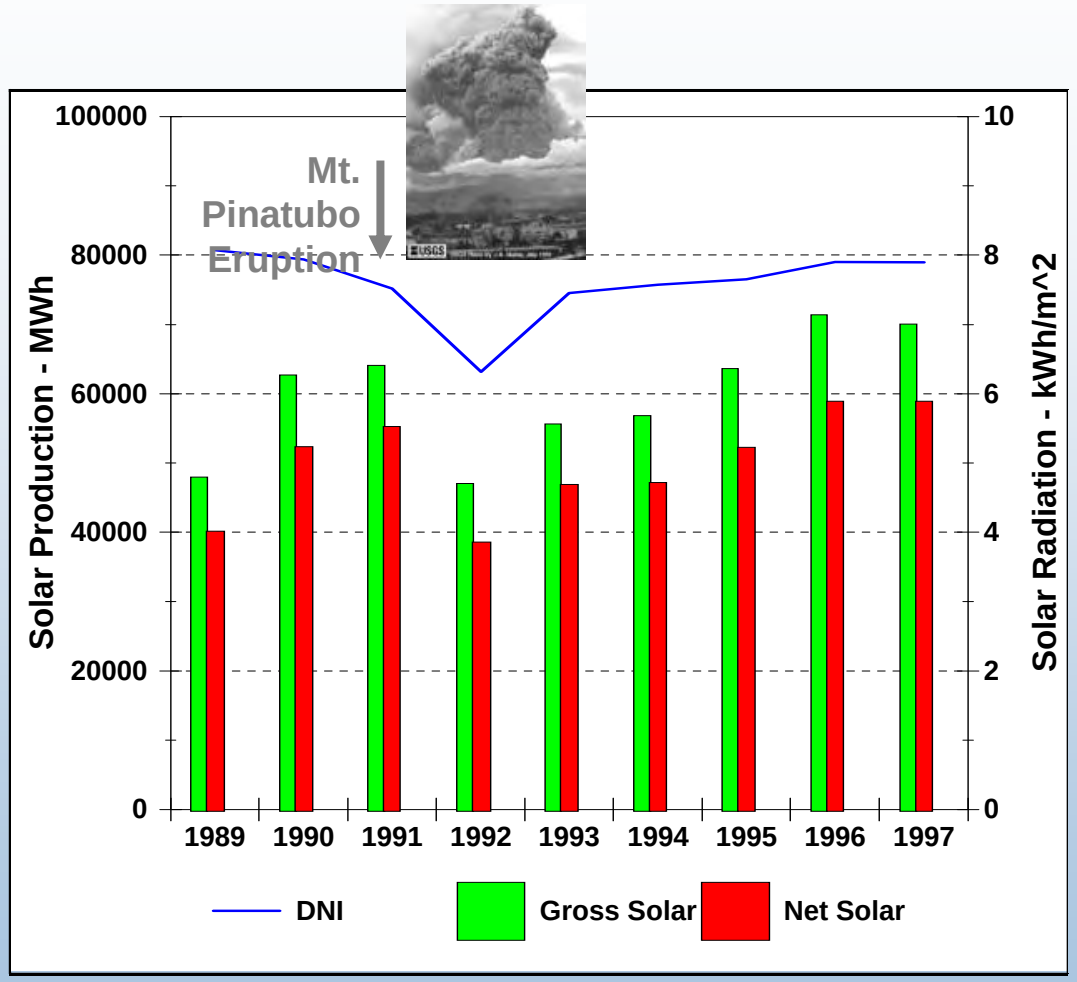
Two Axis Tracking both azimuth and altitude of sun around two axes



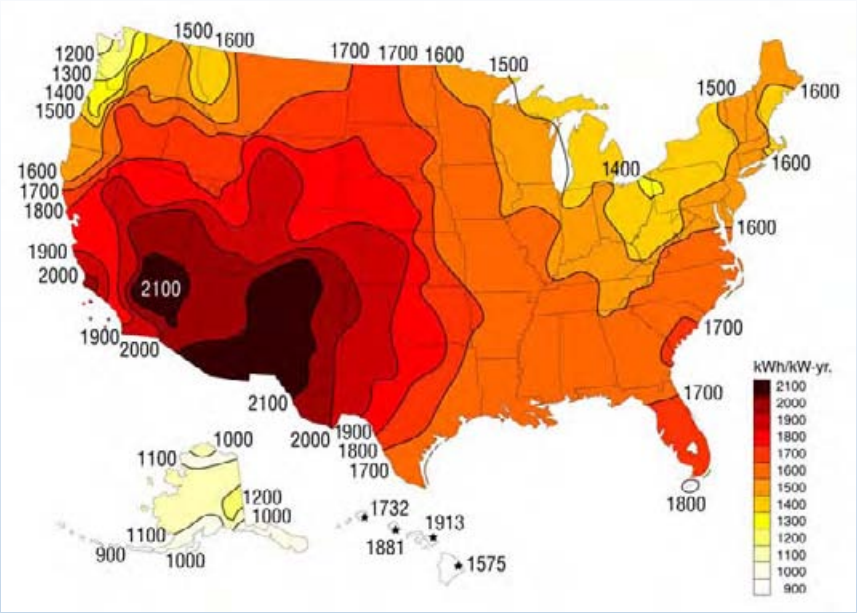
Daily Average Solar Resource



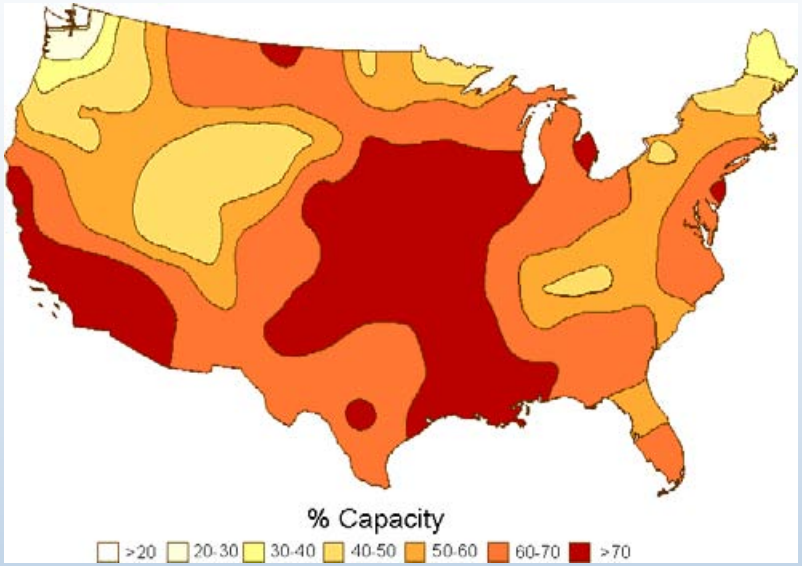
SEGS VI Historical Performance



PV Energy kWh/kW-yr



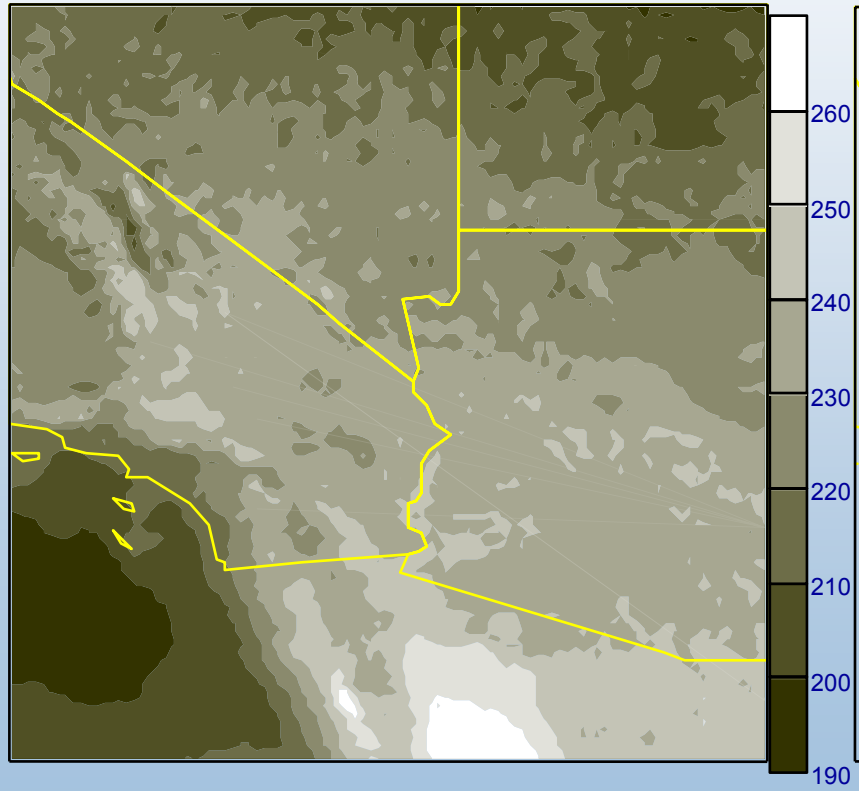
PV Effective Load Carrying Capacity



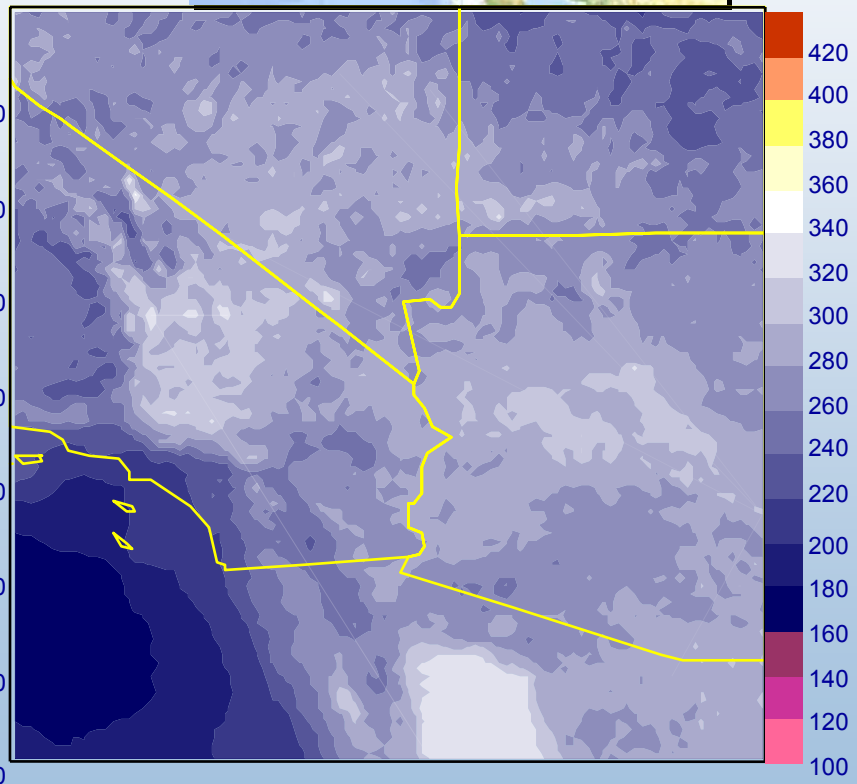
Source: Christy Herig (NREL) and Richard Perez (SUNY/Albany)

- PV can provide peak shaving in many parts of U.S.

Satellite-Derived Techniques Provide Improved Site-Time Coverage (SUNY/Albany)

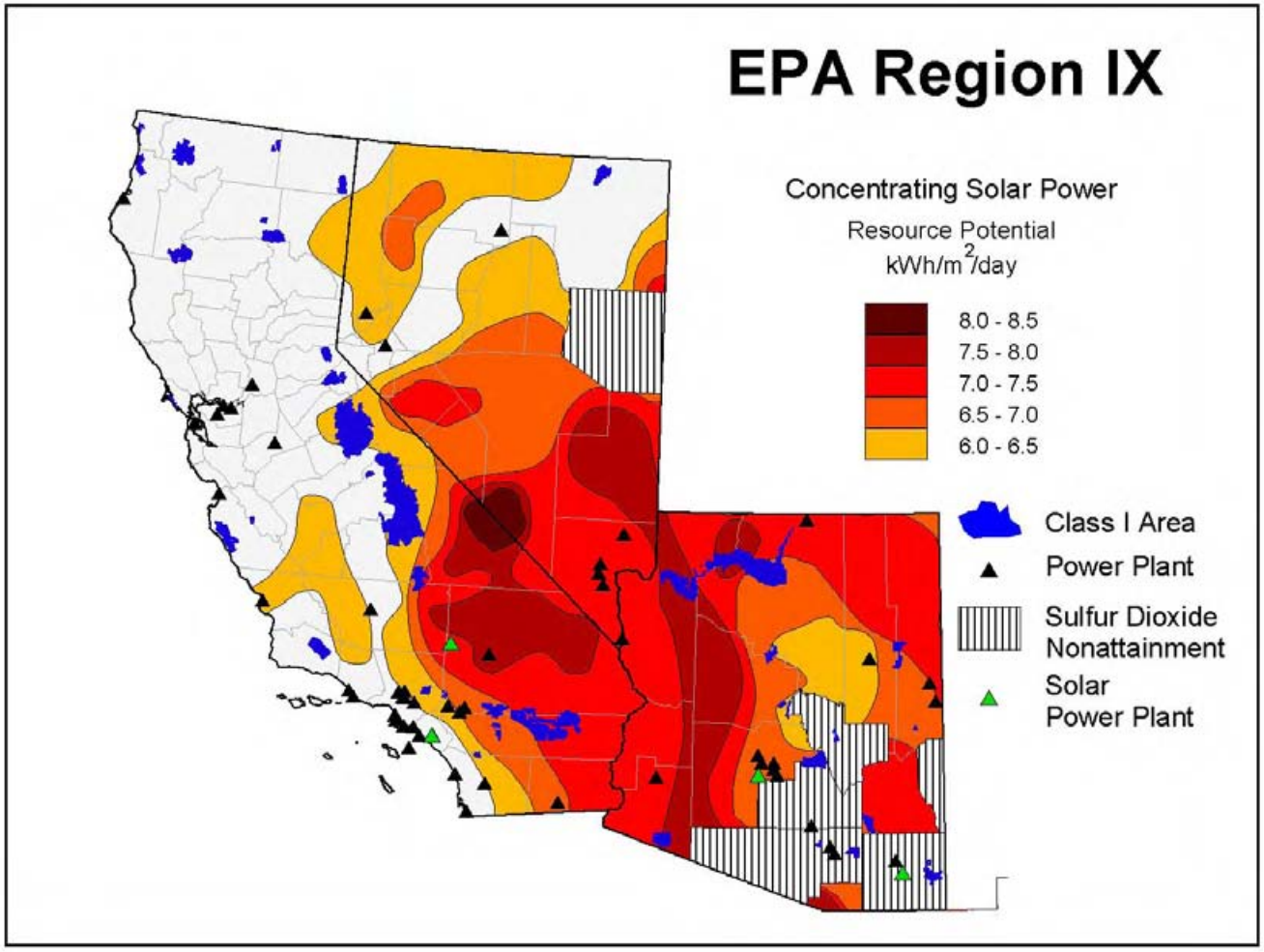


GLOBAL IRRADIANCE (average W/sq.m)



DIRECT IRRADIANCE (average W/sq.m)

An Integrated Analysis Utilizing GIS can Assist With Energy and Environment Planning Efforts



http://rredc.nrel.gov

RReDC
Renewable Resource Data Center

General Information

- News
- Links

Special Features

GLOSSARY

PVWatts

KidzLinks

ENERGY TIDBITS

Unit Conversions

Introduction

Welcome to the Renewable Resource Data Center (RReDC). The RReDC is supported by the National Center for Photovoltaics (NCPV) and managed by the Department of Energy's Office of Energy Efficiency and Renewable Energy. The RReDC is maintained by the Electric and Hydrogen Systems Center at the National Renewable Energy Laboratory.

The RReDC provides information on several types of renewable energy resources in the United States, in the form of publications, data, and maps. An extensive dictionary of renewable energy related terms is also provided. The News section announces new products on the RReDC.

Information by Resource

Biomass Resource Information

Geothermal Resource Information

Solar Resource Information

Wind Resource Information

Dynamic Maps and GIS Data

Related Information

National Center for Photovoltaics

EERE
Office of Energy Efficiency and Renewable Energy

NREL
National Renewable Energy Laboratory

NREL: Dynamic Maps, GIS Data, and Analysis Tools Home Page - Microsoft Internet Explorer

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NREL National Renewable Energy Laboratory

Innovation for Our Energy Future

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Dynamic Maps, GIS Data, & Analysis Tools

- About NREL GIS
- Maps
- Data & Analysis Tools

The Dynamic Maps, GIS Data and Analysis Tools Web site provides dynamically-generated maps of renewable energy resources that determine which energy technologies are viable solutions in national and international regions.

This site also provides access to our FTP site where you can download data and Geospatial Toolkits.

The National Renewable Energy Laboratory's Geographic Information System (GIS) team analyzes wind, solar, biomass, geothermal, and other energy resources and inputs the data into the GIS—Geographic Information System. Read more about NREL's GIS team and the map server that creates the dynamically generated maps.

Printable Version

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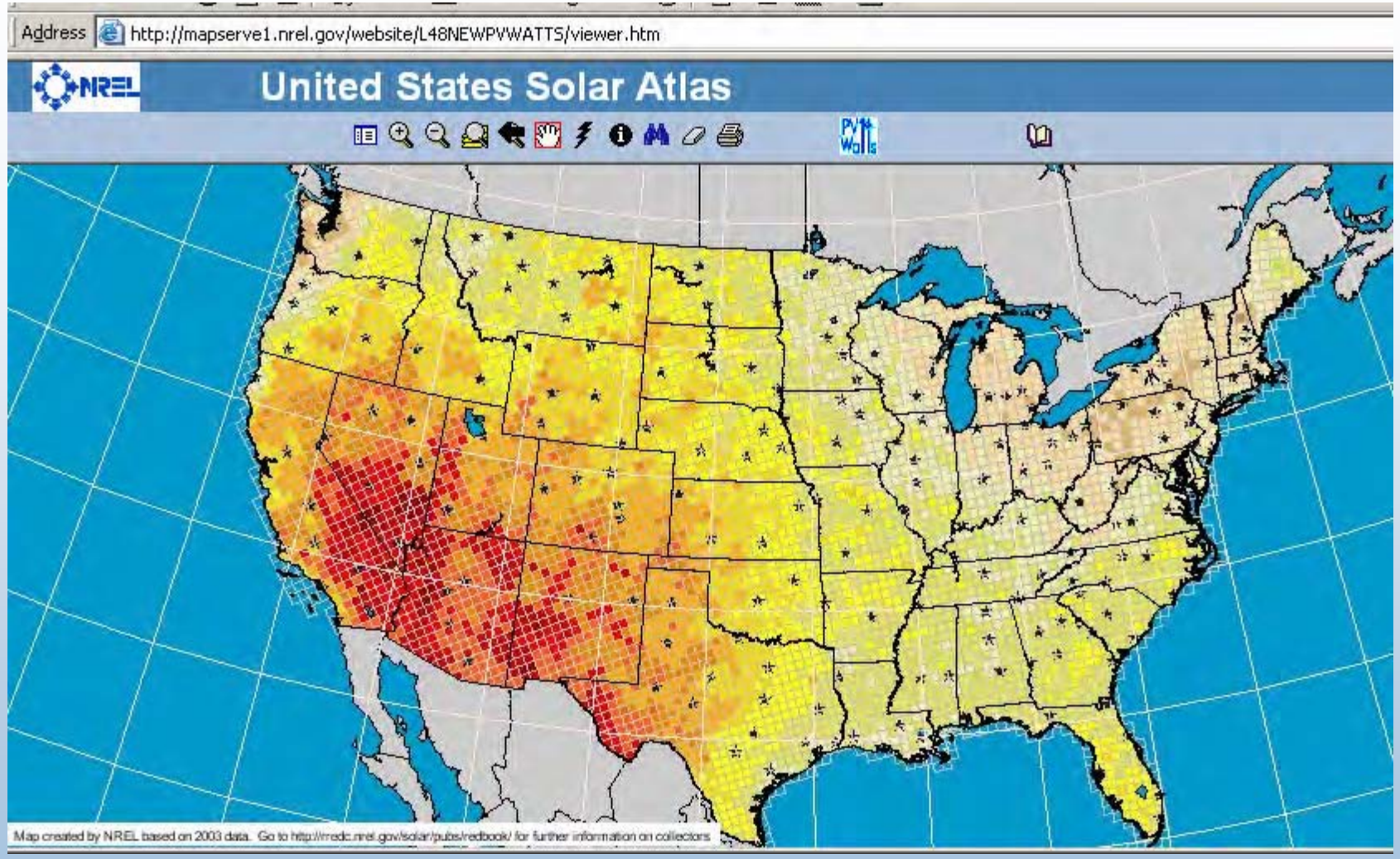
Site Map

FEATURE

Solar Resource Maps for the United States


Address
http://mapserve1.nrel.gov/website/L48NEWPVWATTS/viewer.htm
NREL
United States Solar Atlas
PV Watts
Map created by NREL based on 2003 data. Go to http://rredc.nrel.gov/solar/pubs/redbook/ for further information on collectors

http://rredc.nrel.gov

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National Renewable Energy Laboratory

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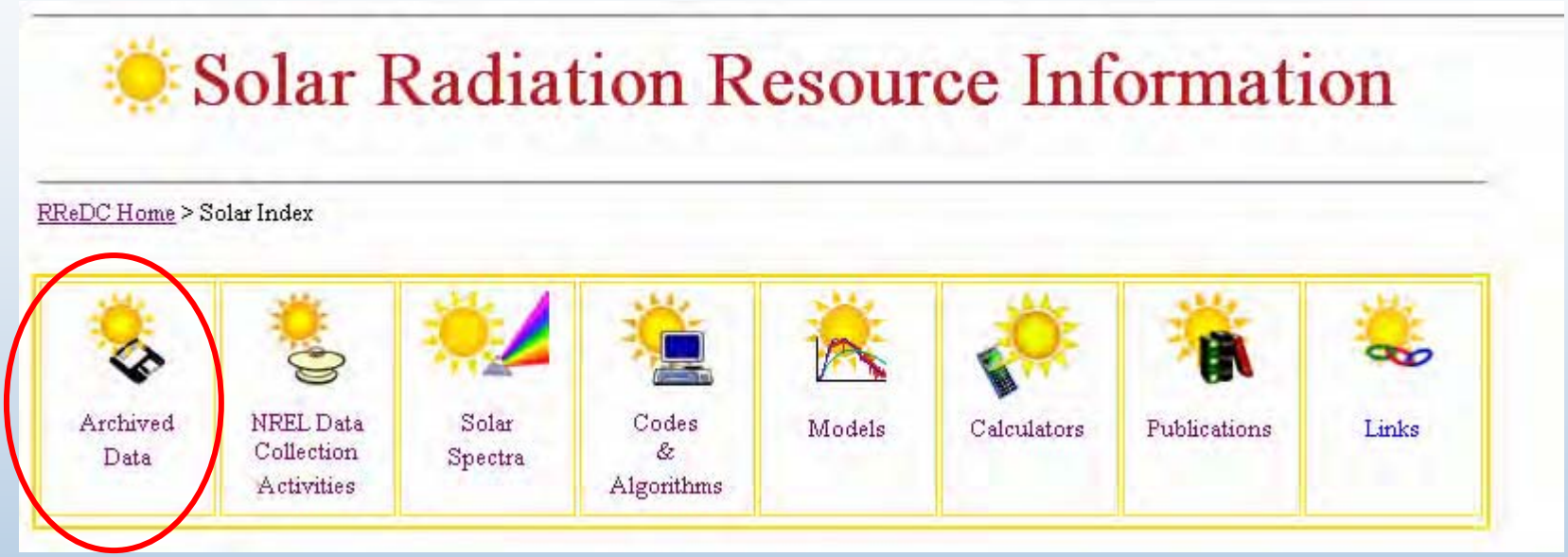

Solar Radiation Resource Information - Microsoft Internet Explorer

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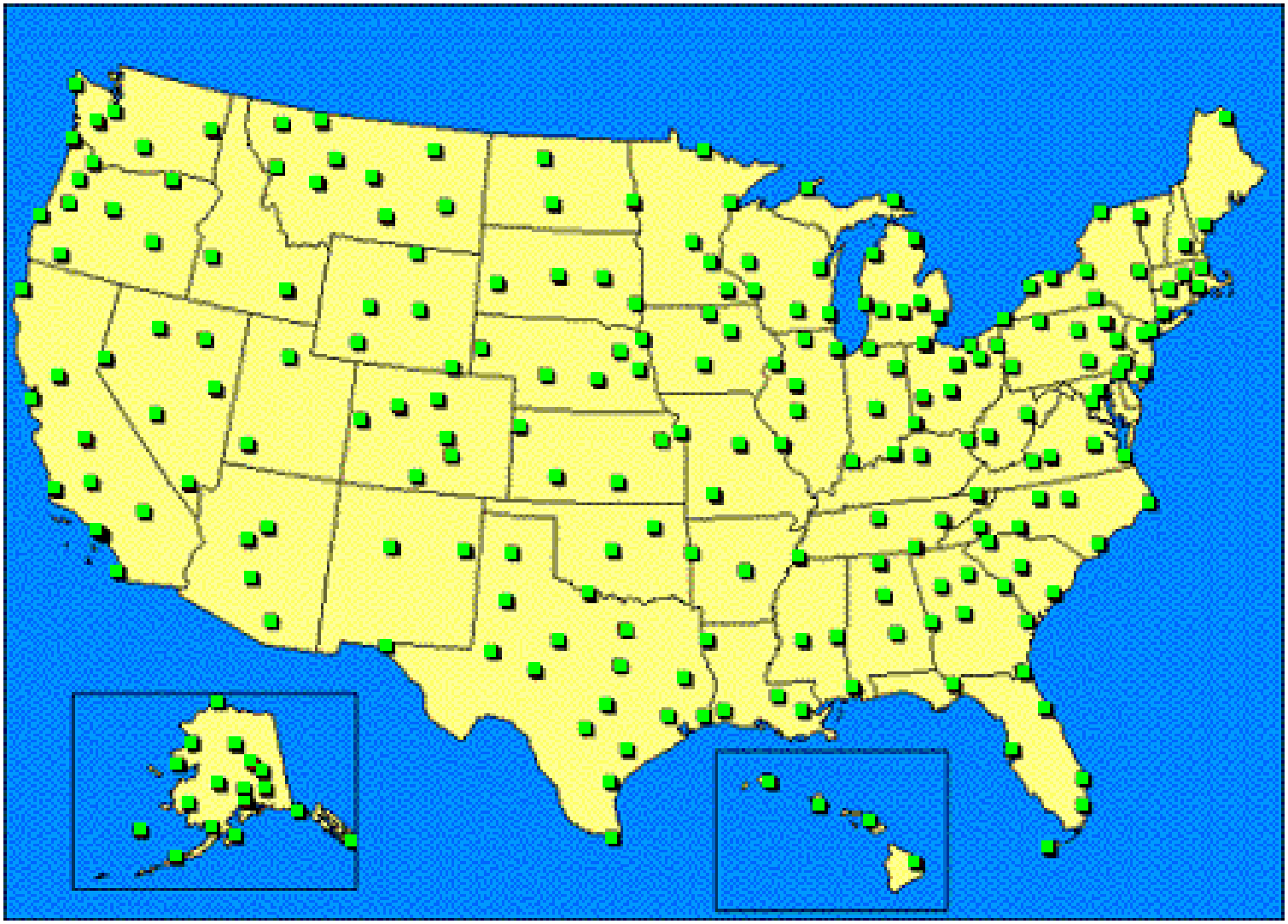
Archived Data

- Data Files
  - Broadband Solar Radiation Data
    - The HBCU Solar Radiation Monitoring Network, 1985-1996
    - The National Solar Radiation Data Base
      - Daily Statistics Files (DSFs)
      - Hourly Data Files (HDFs)
      - The Solar Radiation Data Manual For Buildings
        - 30-year (1961-1990) average of solar radiation and illuminance for each month
      - The Solar Radiation Data Manual For Flat-Plate and Concentrating Collectors
        - Averages of solar radiation for each of the 360 months during the period 1961-1990
        - 30-year (1961-1990) average of monthly solar radiation for each month
      - Typical Meteorological Year 2 (TMY2)
    - NOAA's Network (1977 - 1980): 39 Sites
    - The Solar Energy Meteorological Research and Training Sites Network
    - The WEST Associates' Network (1976 - 1980)
  - NREL's Circumsolar Data Base
  - NREL's Spectral Solar Radiation Data Base

- U.S. Solar Radiation Resource Maps
  - Atlas for The Solar Radiation Data Manual For Flat-Plate and Concentrating Collectors
  - Solar Maps on NREL's Internet Map Server

237 NSRDB Sites



NSRDB - Microsoft Internet Explorer

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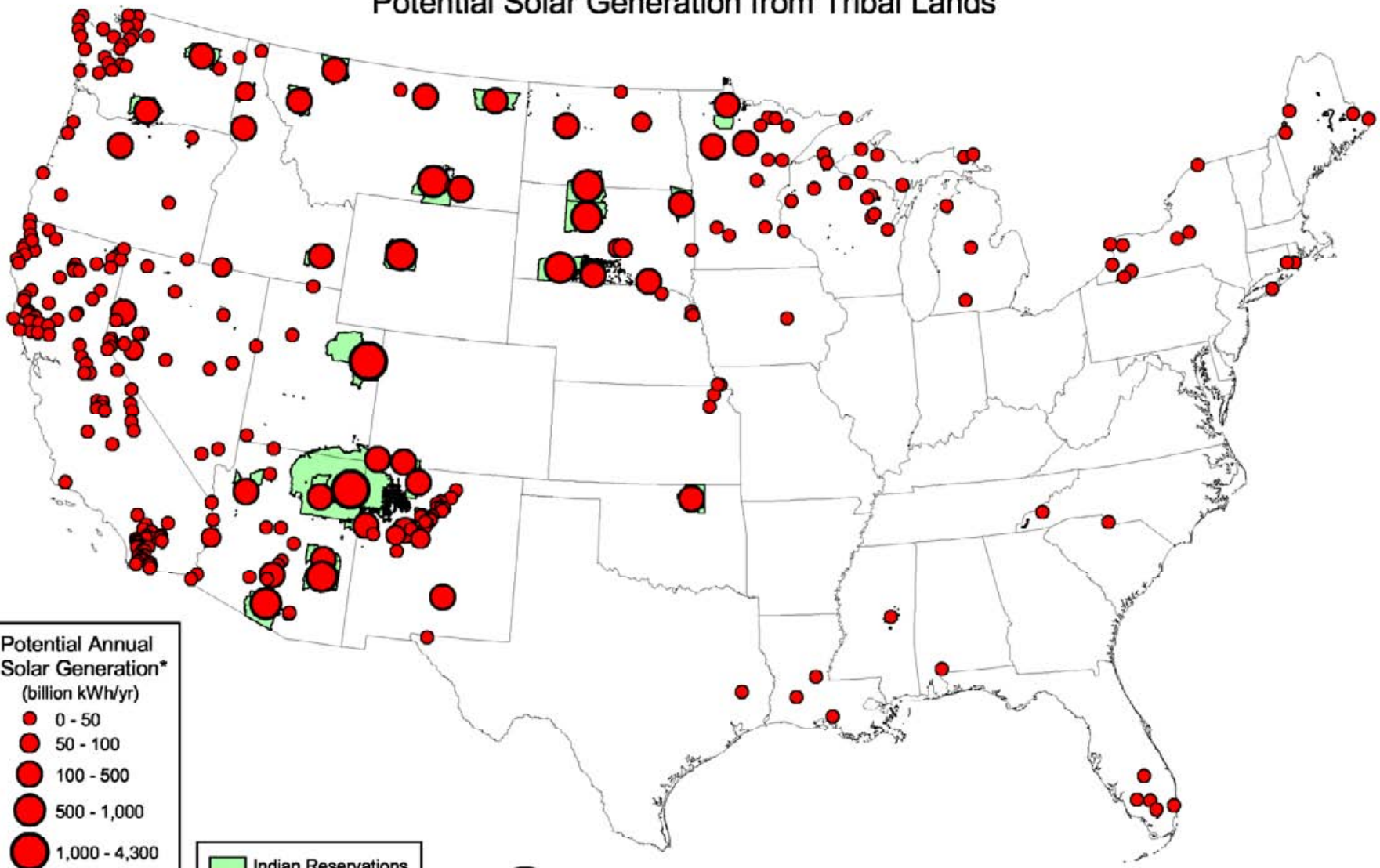
National Solar Radiation Data Base

Available Data Sets

The National Solar Radiation Data Base (NSRDB) contains 30 years (1961-1990) of solar radiation and supplementary meteorological data fro in the U.S., plus sites in Guam and Puerto Rico. The following data products are available:

- Daily Statistics Files (NOTE: These files are MONTHLY averages of daily totals)
- Hourly Data Files
- Solar Radiation Data Manual for Buildings
  - 30-year (1961-1990) average of solar radiation and illuminance for each month
- Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors
  - Averages of solar radiation for each of the 360 months during the period 1961-1990
  - 30-year (1961-1990) average of solar radiation for each month
- TMY2 Files
- U.S. Solar Radiation Resource Maps
  - Atlas for The Solar Radiation Data Manual For Flat-Plate and Concentrating Collectors
  - Atlas for The Solar Radiation Data Manual For Buildings - Temporarily unavailable.

Potential Solar Generation from Tribal Lands



Potential Annual Solar Generation*
(billion kWh/yr)

- 0 - 50
- 50 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 4,300

Indian Reservations

Total Tribal Solar Generation Potential: 17,606 Billion kWh/yr

U.S. Total Electric Generation (2004 Est.): 3,853 Billion kWh/yr (EIA)

* Generation estimated using annual average solar resource from a tilt = latitude collector. The formula is: Resource (kWh/m^2/day) * 365 * Area (m^2) * 0.03, where 0.03 represents solar panels covering 30% of the total reservation area with a panel efficiency of 10%.

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

DHJul3004solgen