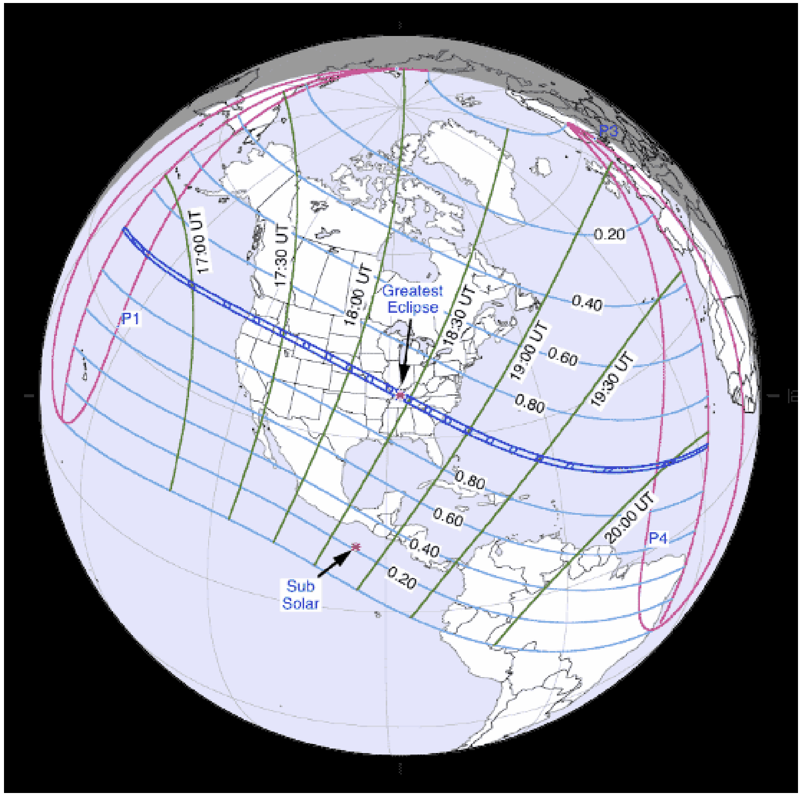
# IMPACT OF THE AUGUST 21 SOLAR ECLIPSE ON RENEWABLE ENERGY PRODUCTION IN CA

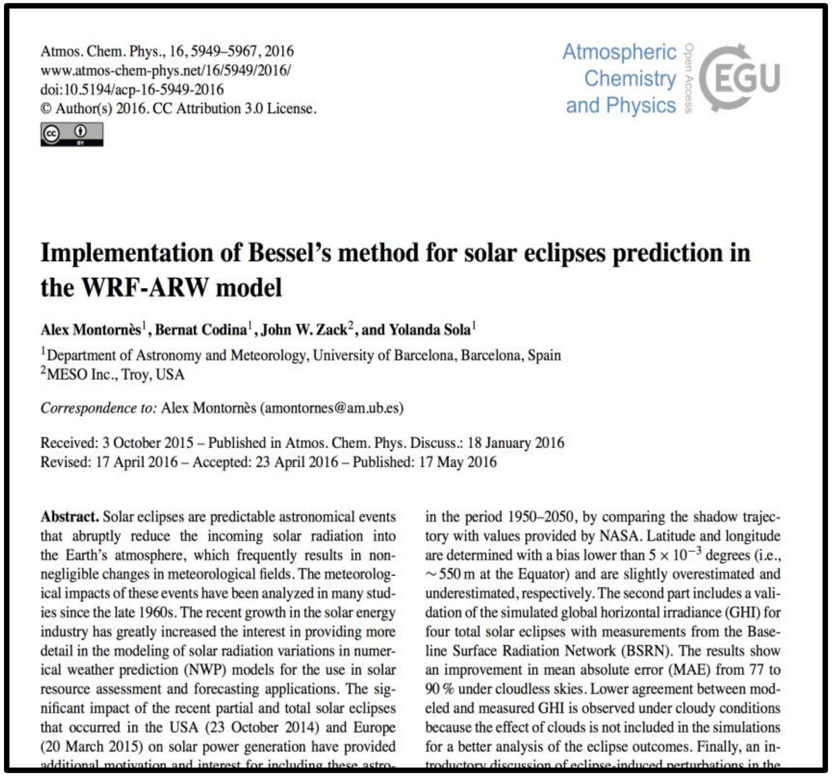
John W Zack

# THE ISSUE: SOLAR ECLIPSE OF AUGUST 21, 2017




- A total solar eclipse will occur over North America on August 21, 2017
- The eclipse will range from 60% to 90% of (from south to north) total in California
- The eclipse can potentially impact grid operations in several ways:
  - Solar generation
  - Wind generation
  - Load (temp and other wx variables)

# APPROACH TO ASSESS THE IMPACT:
# RUN WRF WITH SOLAR ECLIPSE MODULE



Atmos. Chem. Phys., 16, 5949–5967, 2016
www.atmos-chem-phys.net/16/5949/2016/
doi:10.5194/acp-16-5949-2016
© Author(s) 2016. CC Attribution 3.0 License.

Atmospheric Chemistry and Physics

**Implementation of Bessel's method for solar eclipses prediction in the WRF-ARW model**

**Alex Montornès[1], Bernat Codina[1], John W. Zack[2], and Yolanda Sola[1]**

[1]Department of Astronomy and Meteorology, University of Barcelona, Barcelona, Spain
[2]MESO Inc., Troy, USA

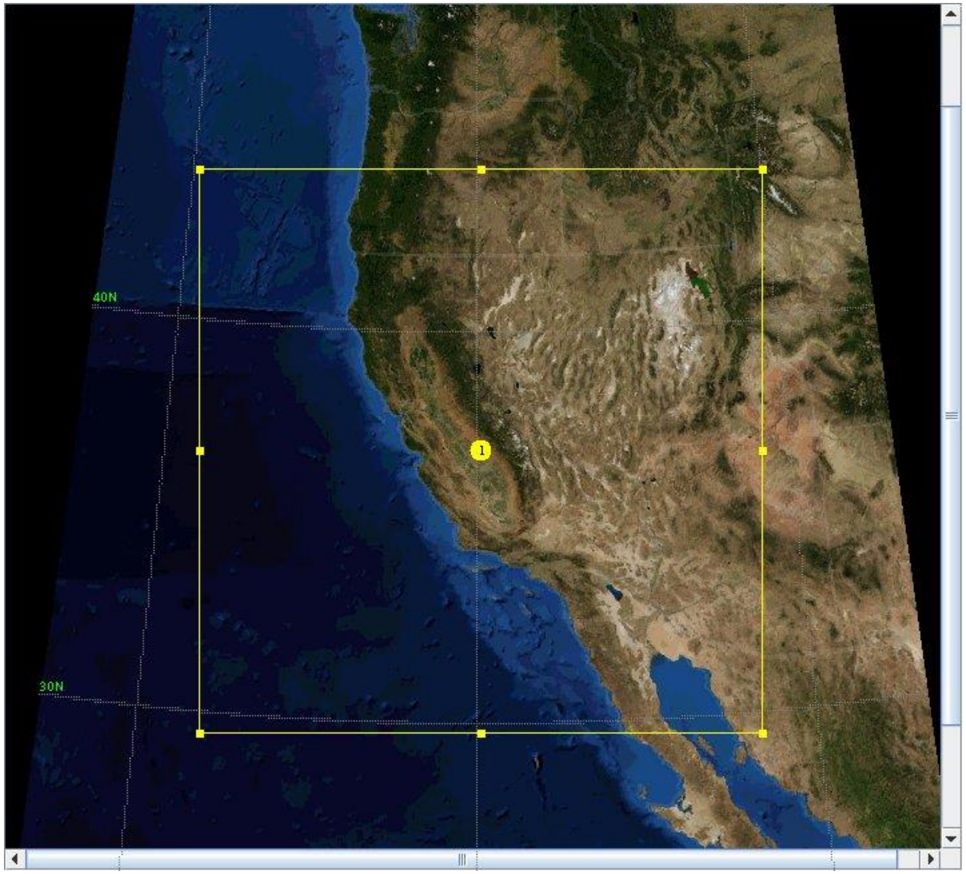
*Correspondence to:* Alex Montornès (amontornes@am.ub.es)

Received: 3 October 2015 – Published in Atmos. Chem. Phys. Discuss.: 18 January 2016
Revised: 17 April 2016 – Accepted: 23 April 2016 – Published: 17 May 2016

**Abstract.** Solar eclipses are predictable astronomical events that abruptly reduce the incoming solar radiation into the Earth's atmosphere, which frequently results in non-negligible changes in meteorological fields. The meteorological impacts of these events have been analyzed in many studies since the late 1960s. The recent growth in the solar energy industry has greatly increased the interest in providing more detail in the modeling of solar radiation variations in numerical weather prediction (NWP) models for the use in solar resource assessment and forecasting applications. The significant impact of the recent partial and total solar eclipses that occurred in the USA (23 October 2014) and Europe (20 March 2015) on solar power generation have provided additional motivation and interest for including these astro- ... in the period 1950–2050, by comparing the shadow trajectory with values provided by NASA. Latitude and longitude are determined with a bias lower than $5 \times 10^{-3}$ degrees (i.e., ∼550 m at the Equator) and are slightly overestimated and underestimated, respectively. The second part includes a validation of the simulated global horizontal irradiance (GHI) for four total solar eclipses with measurements from the Baseline Surface Radiation Network (BSRN). The results show an improvement in mean absolute error (MAE) from 77 to 90 % under cloudless skies. Lower agreement between modeled and measured GHI is observed under cloudy conditions because the effect of clouds is not included in the simulations for a better analysis of the eclipse outcomes. Finally, an introductory discussion of eclipse-induced perturbations in the

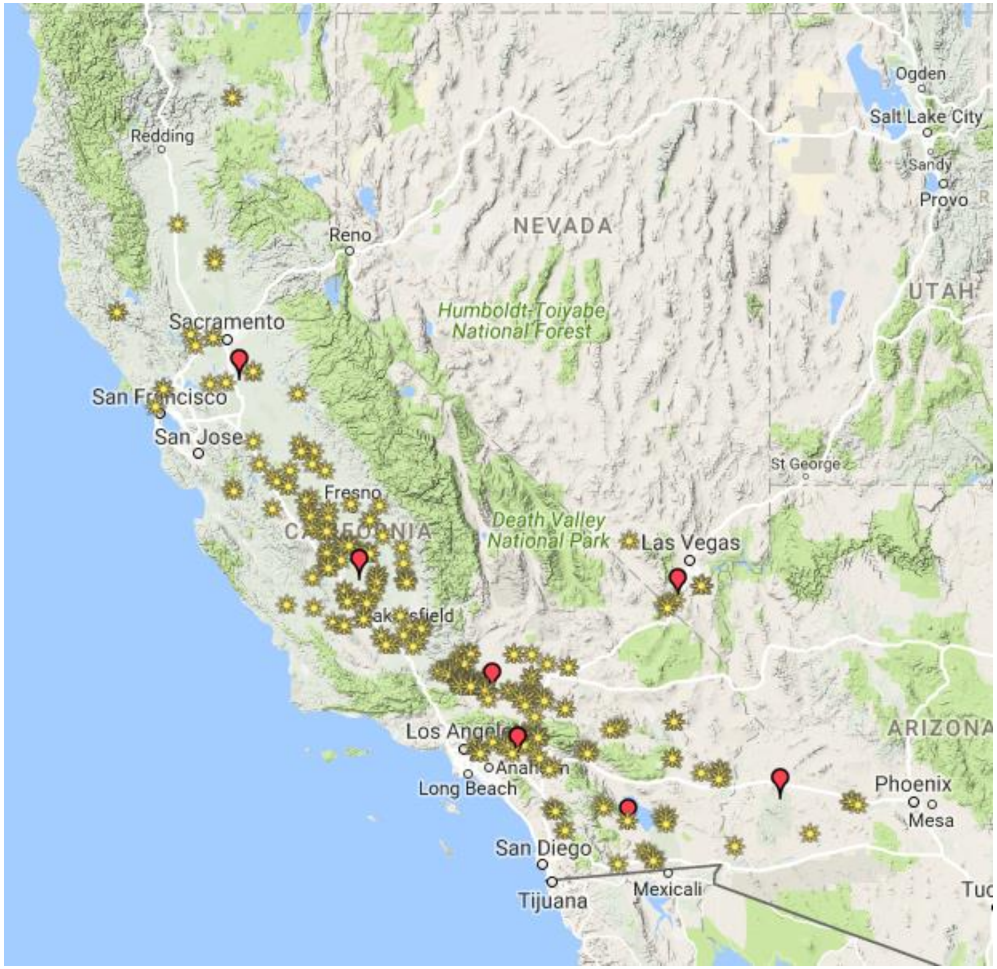
- WRF Solar Eclipse Module developed by Alex Montones at University of Barcelona
  - Documented in Journal of Atmospheric Chemistry and Physics
- 24 hr WRF forecasts initialized at 1200 UTC (5 AM PDT) on day of the eclipse
  - Weather from Aug 21 in 5 prior yrs
  - Initialized from GFS analysis
  - BCs from GFS forecast
- Solar Irradiance and winds extracted from WRF forecast for each utility-scale wind/ solar generation resource
  - Statistical power curve for each facility used to estimate production

# WRF CONFIGURATION



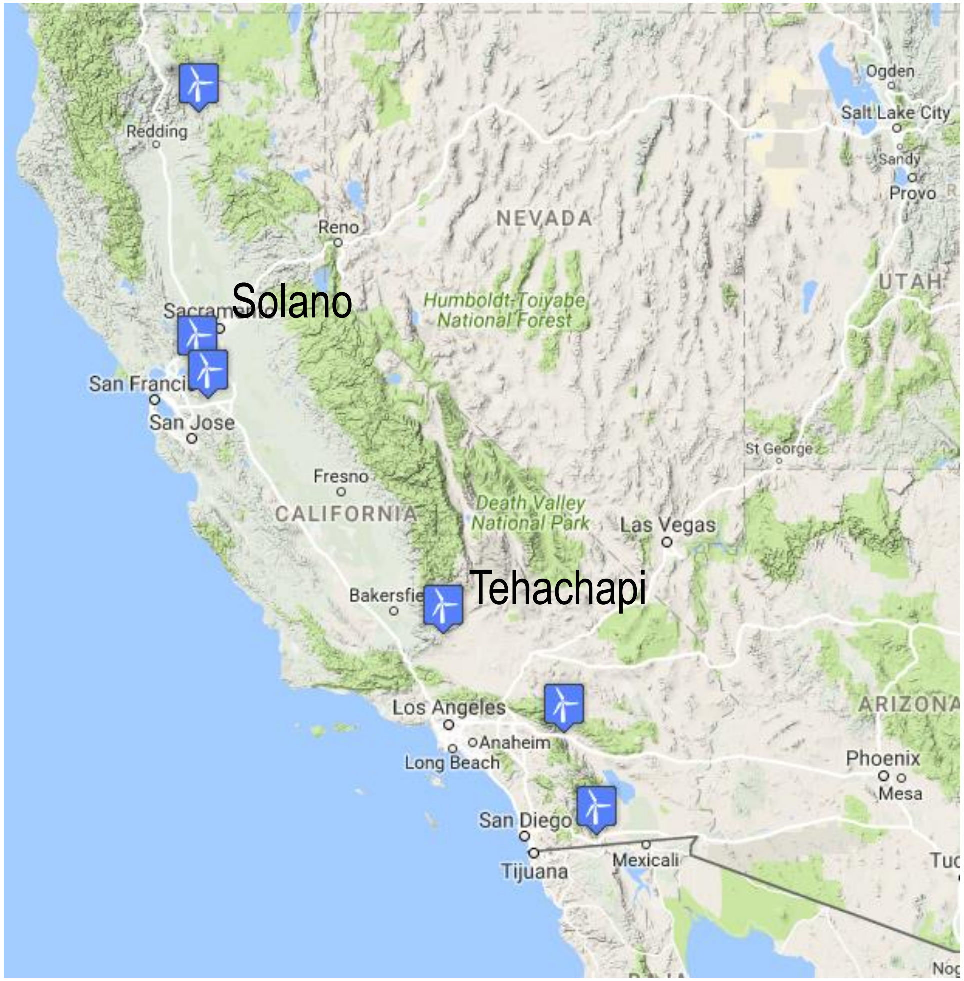

- 2.5 km grid resolution
- 50 layers
- Physics
    - Boundary layer: MYNN 2.5
    - Land surface: Pleim-Xsu
    - Short wave radiation: Goddard
    - Long wave radiation: Goddard
    - Microphysics: WSM6
    - Moist convection scheme: None

# REGIONAL AGGREGATES: SOLAR CAPACITIES




| Region | Capacity (MW) |
|---|---|
| North San Joaquin Valley | 200 |
| South San Joaquin Valley | 2543 |
| Mojave | 3211 |
| Southern Nevada | 1255 |
| CO River Valley | 1613 |
| Coachilla/Imperial Valleys | 1029 |
| LA Basin | 128 |
| **System** | **9983** |

# REGIONAL CAPACITIES: WIND AGGREGATES

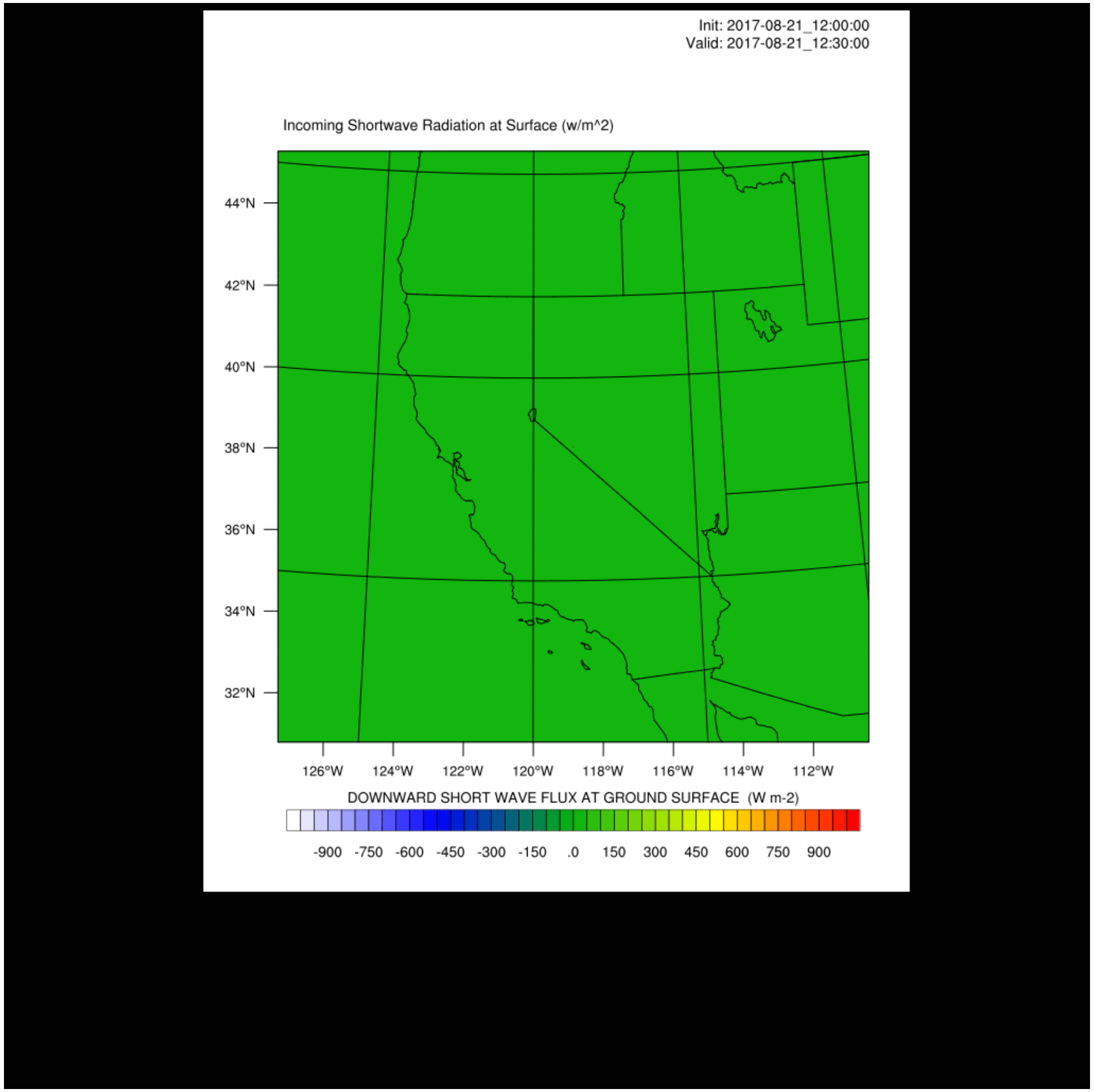



| Region | Capacity (MW) |
|---|---|
| Northern CA | 102 |
| Solano | 1010 |
| Altamont | 237 |
| Tehachapi | 2856 |
| San Gorgonio | 624 |
| Kumeyaay-Ocotillo | 470 |
| **System** | **5299** |

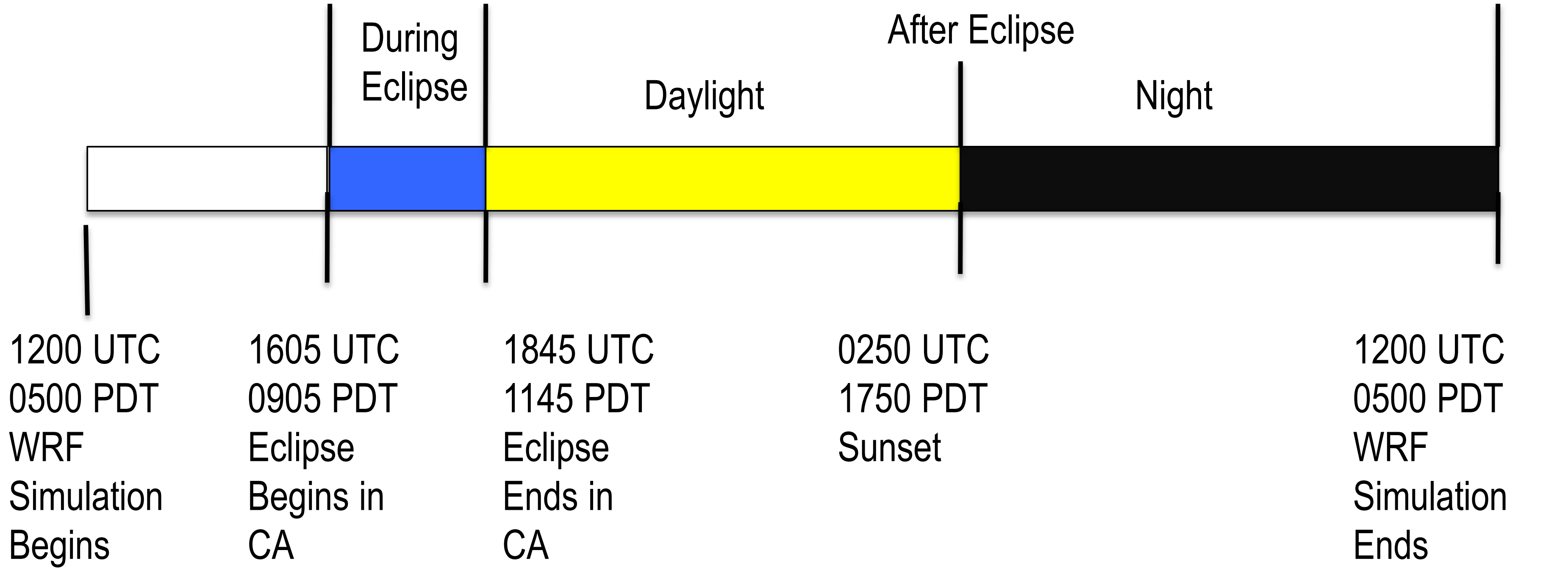
# LOAD FORECASTING REGIONS


| Region | # of Sites |
|---|---|
| N CA Coastal | 5 |
| N CA Inland | 6 |
| LA Coastal | 5 |
| LA Inland | 4 |
| San Diego | 4 |
| **System** | **24** |

# 2015 SIMULATION: DIFFERENCE IN SOLAR RADIATION

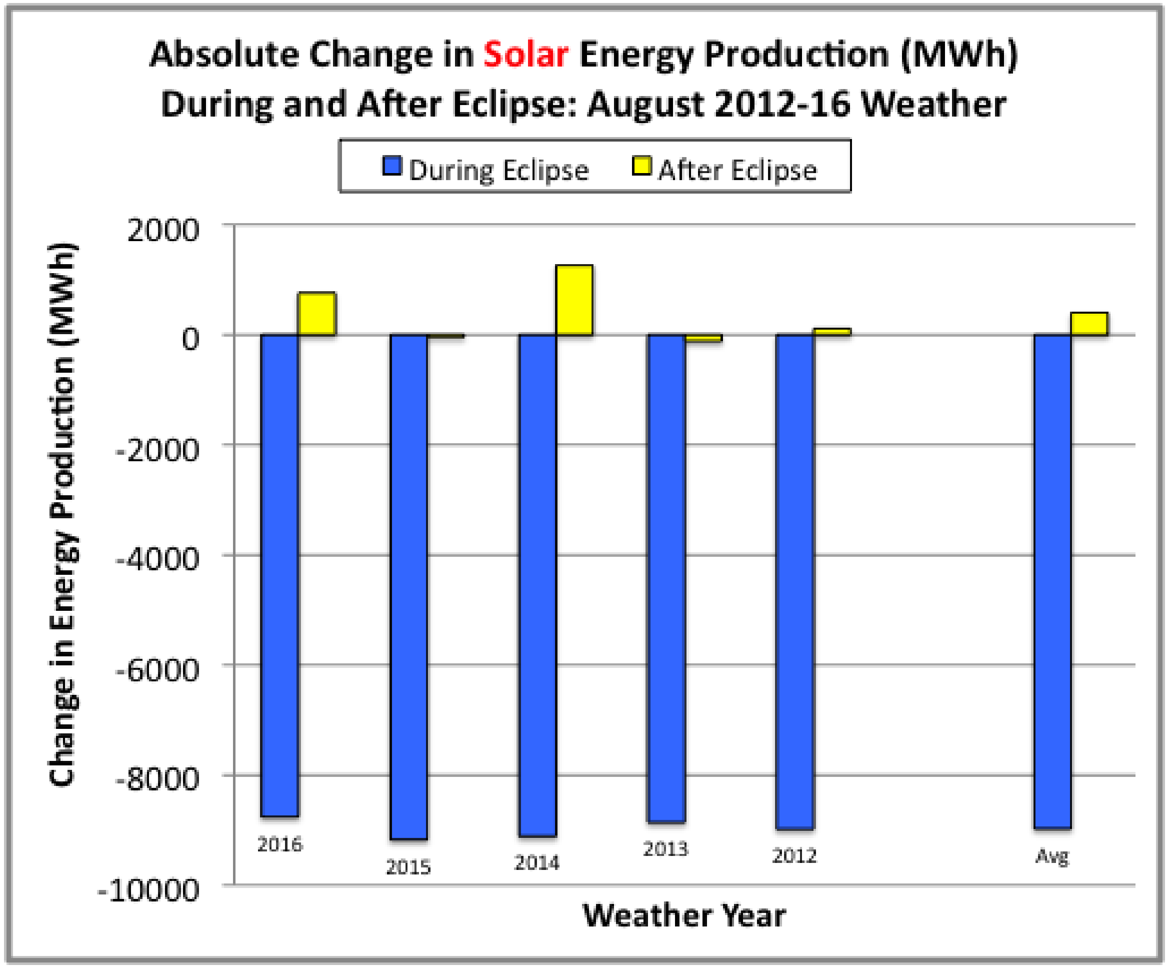


# ANALYSIS TIME LINE

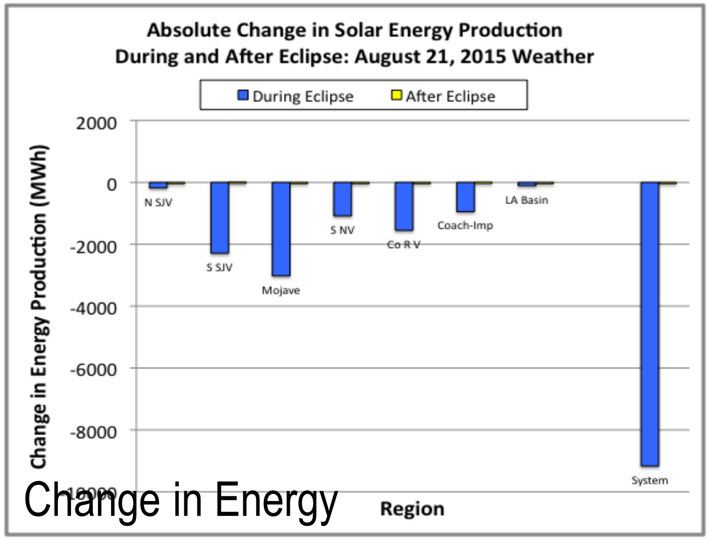


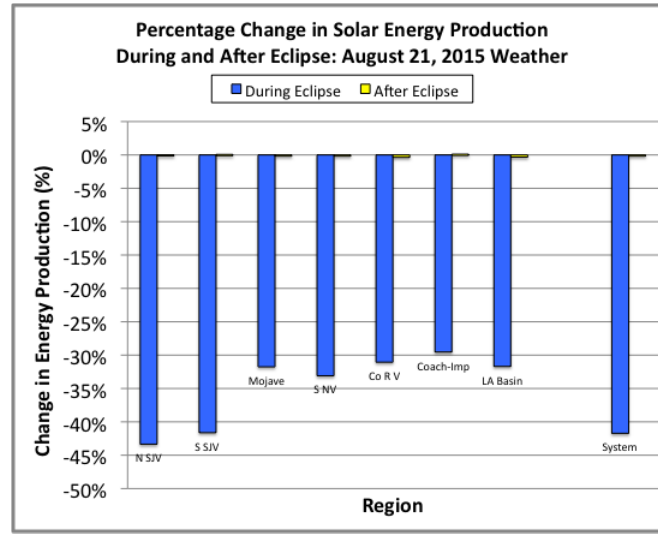
# IMPACT ON SOLAR-BASED GENERATION

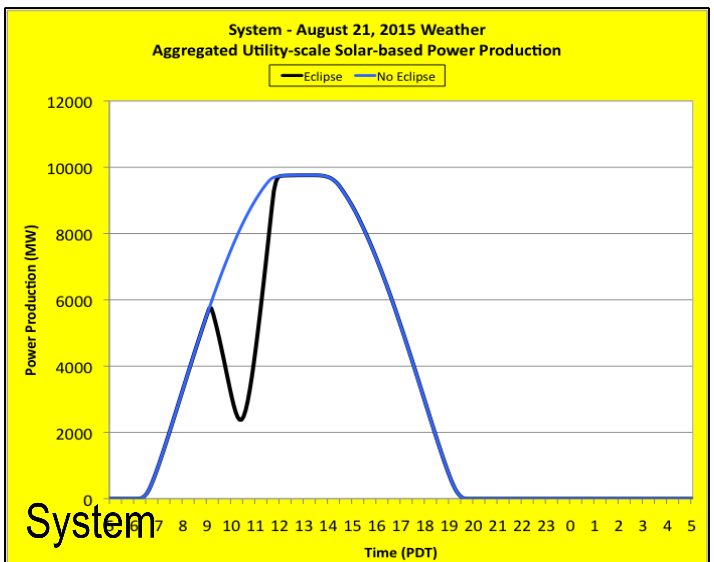
System-wide:
Absolute Change in Solar Energy Production (MWh)

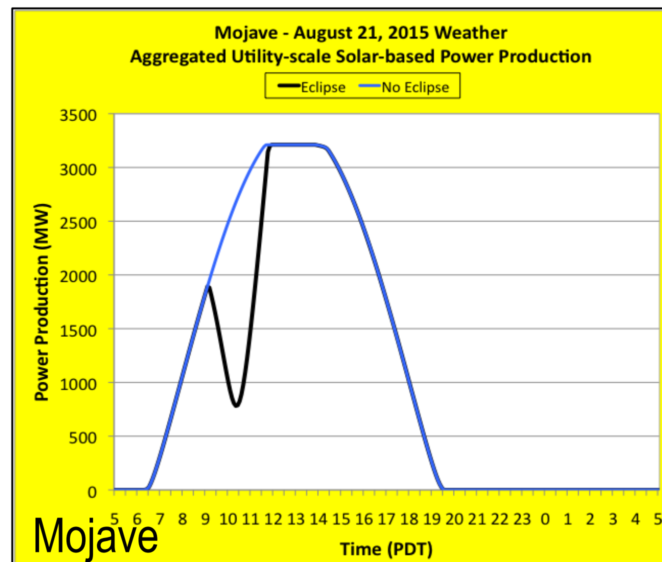


# SOLAR GEN PROFILES: 2015 – CLEAREST CASE

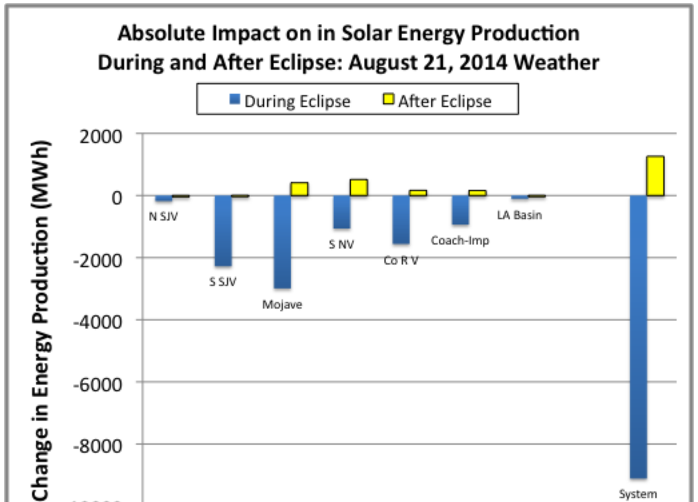


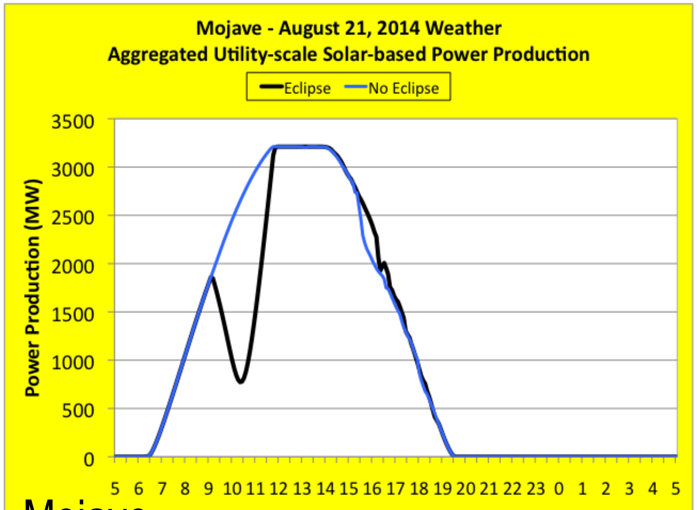



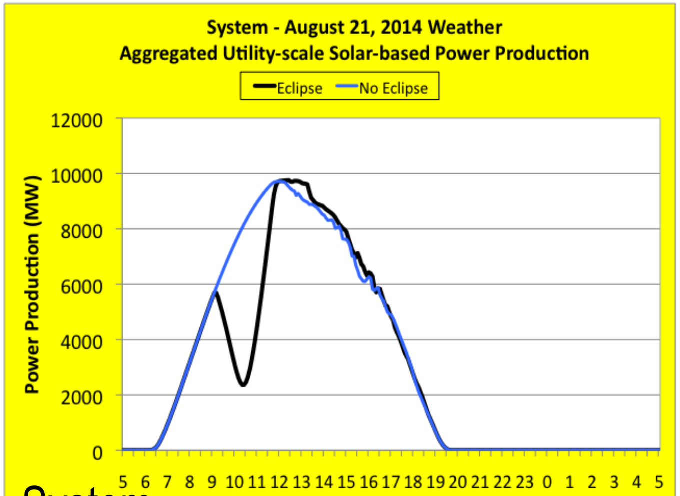
# SOLAR GEN PROFILES: 2014 – CASE WITH CLOUDS



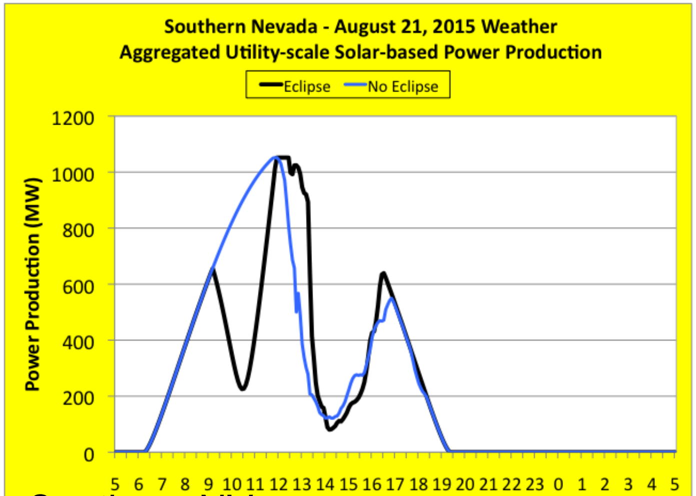

Change in Energy




Mojave



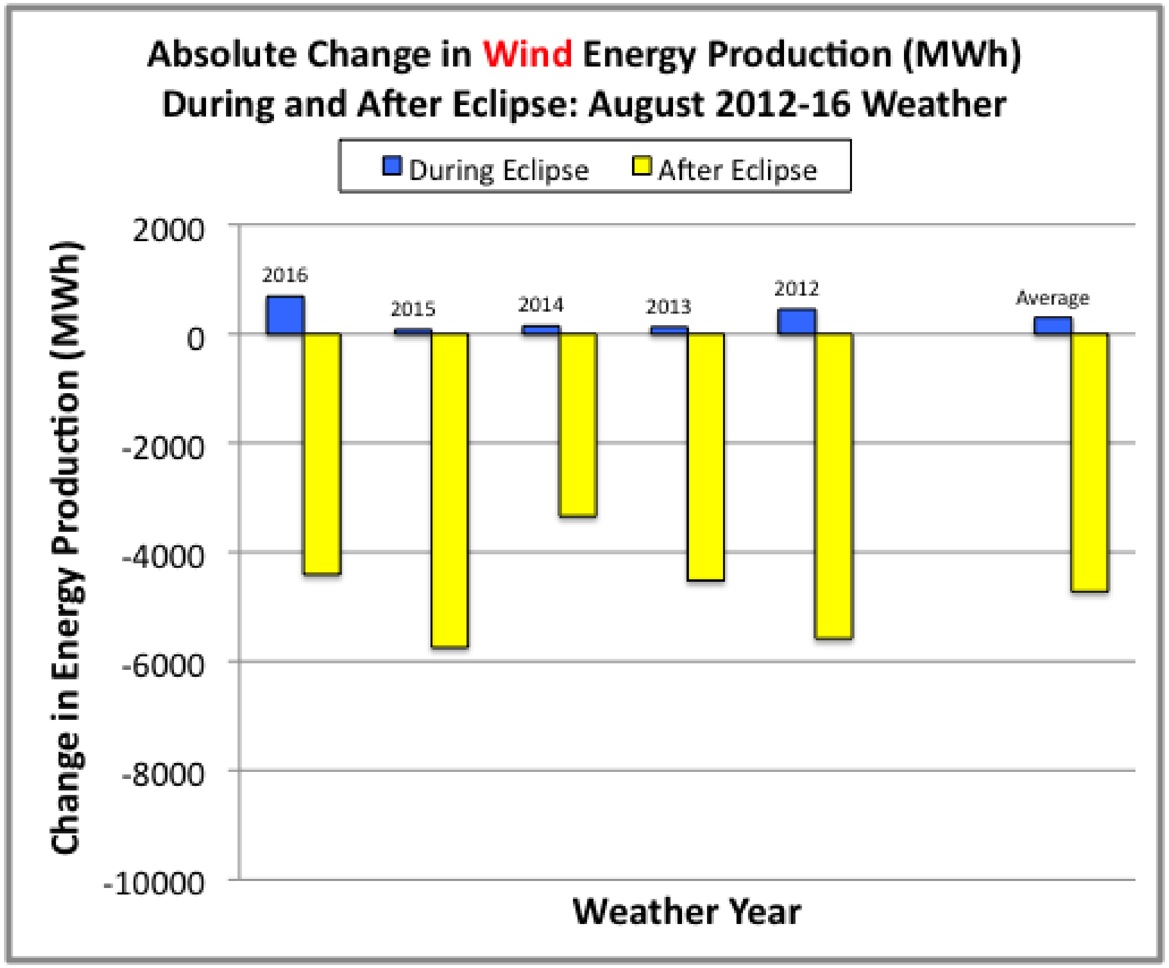

System




Southern NV

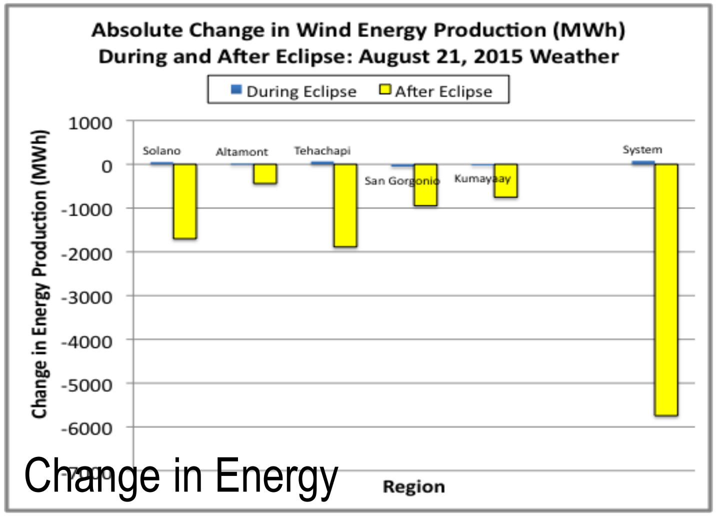
# IMPACT ON WIND-BASED GENERATION

System-wide:
Change in Wind Energy Production (MWh)

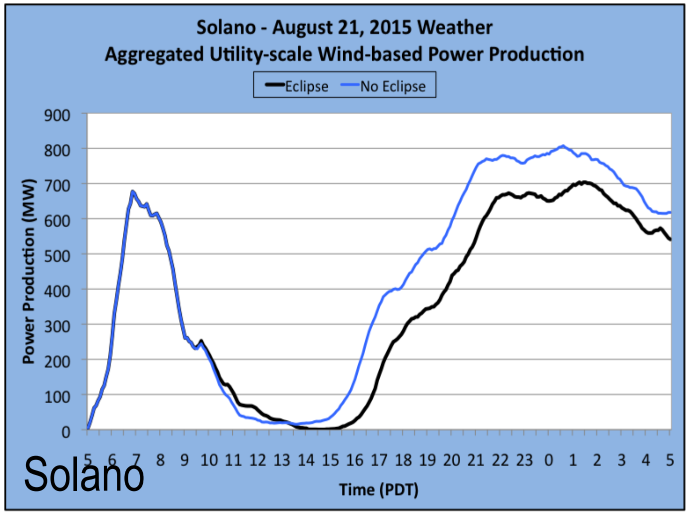



UL AWS TRUEPOWER

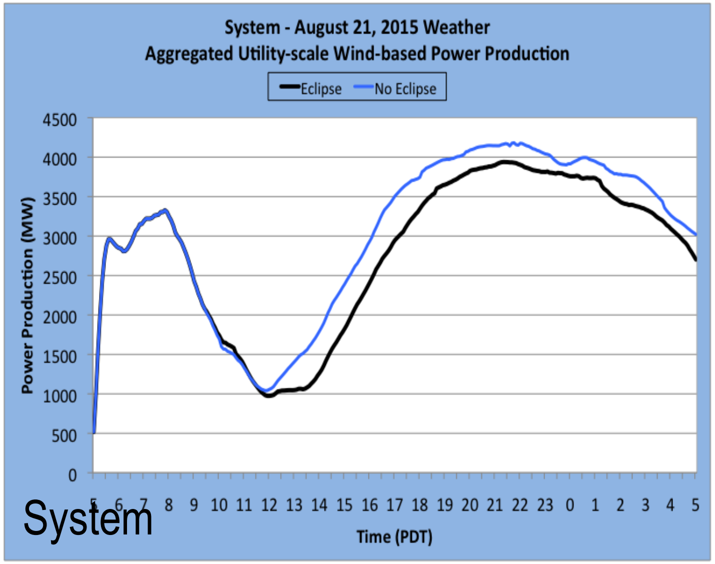
# WIND GEN PROFILES: 2015 – WESTERLY FLOW



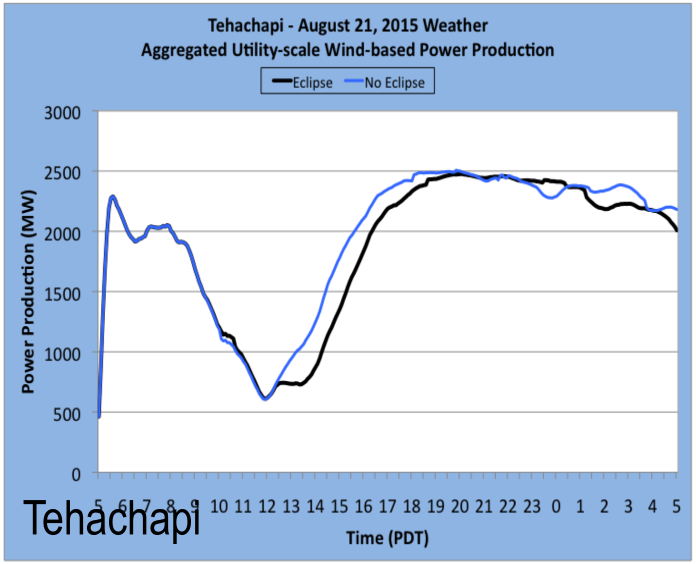

Change in Energy




Solano



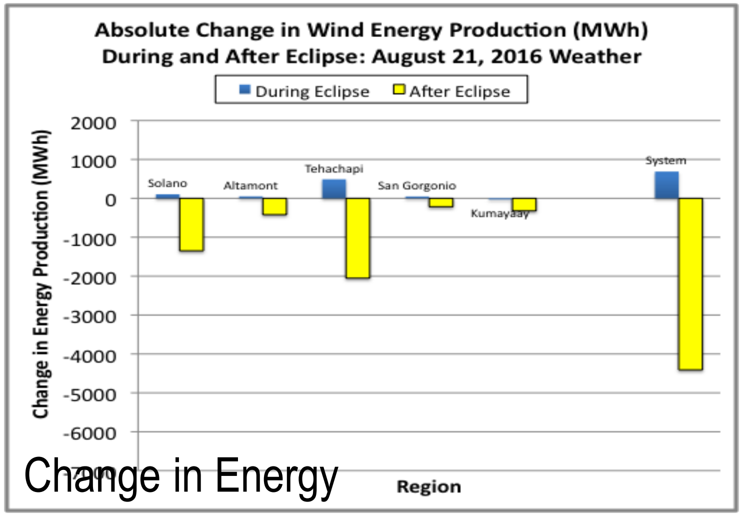

System



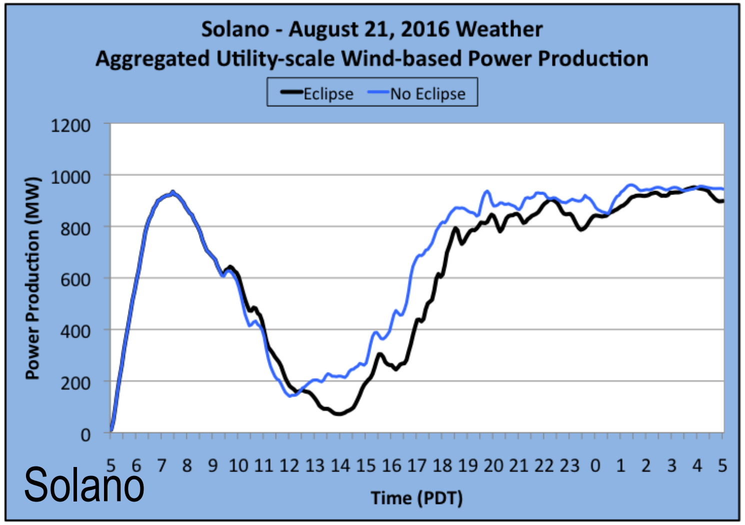

Tehachapi

AWS TRUEPOWER

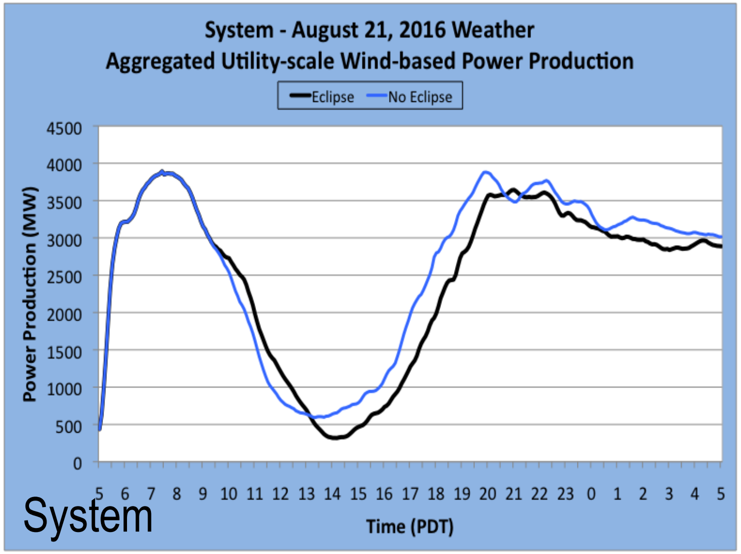
# WIND GEN PROFILES: 2016 – WEAK UPPER FLOW



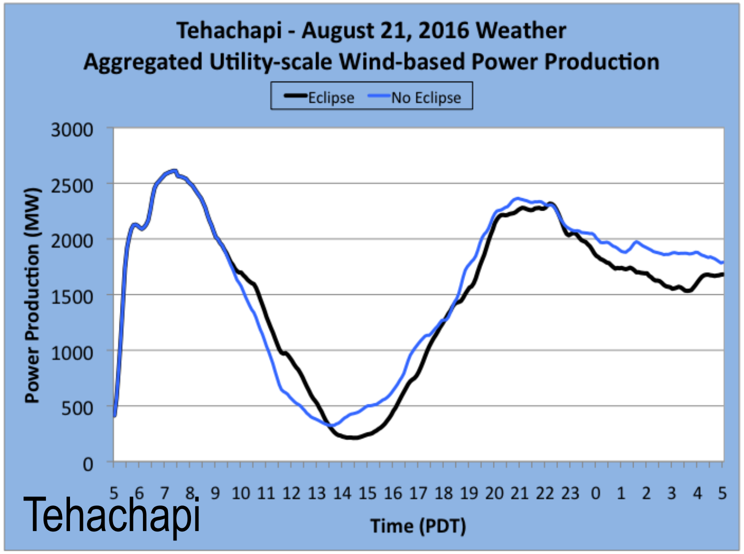

Change in Energy




Solano



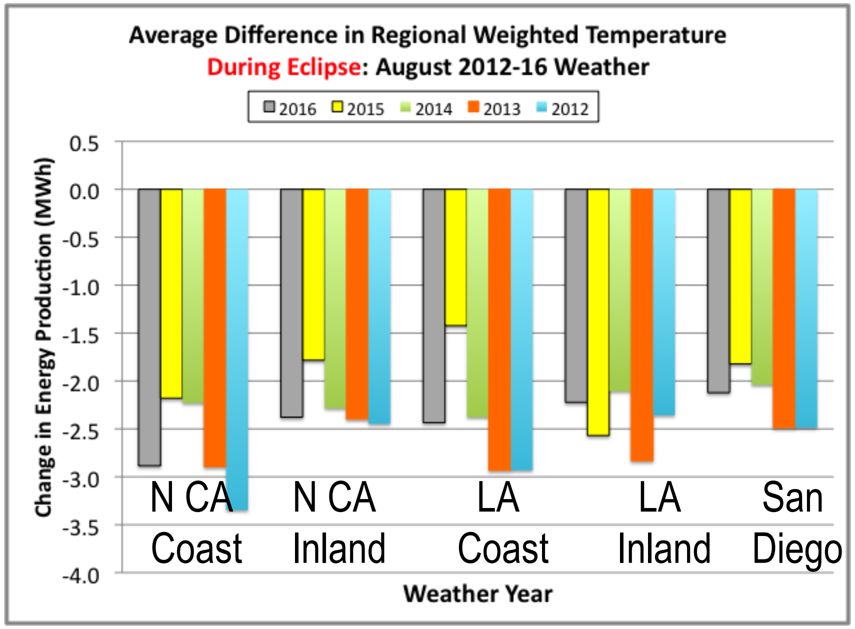

System

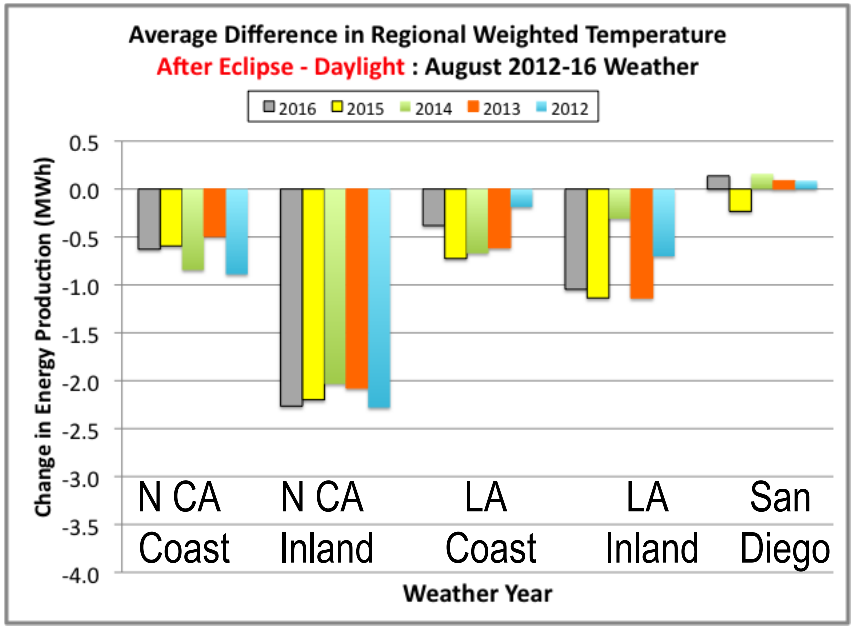



Tehachapi

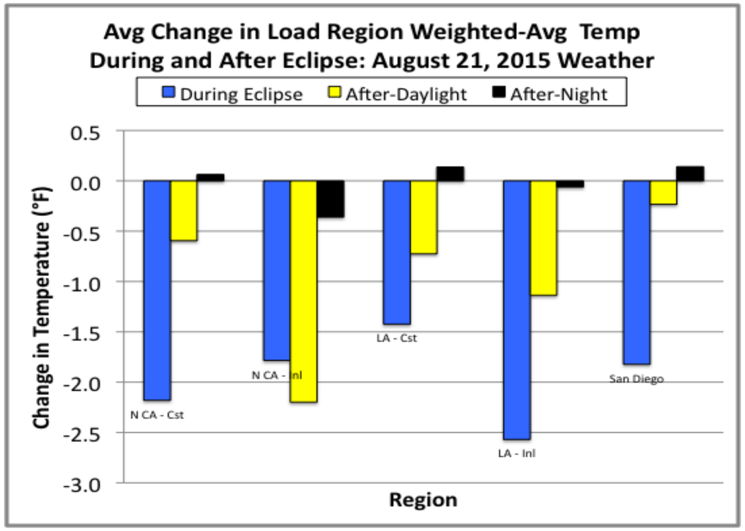
# IMPACT ON TEMPERATURE

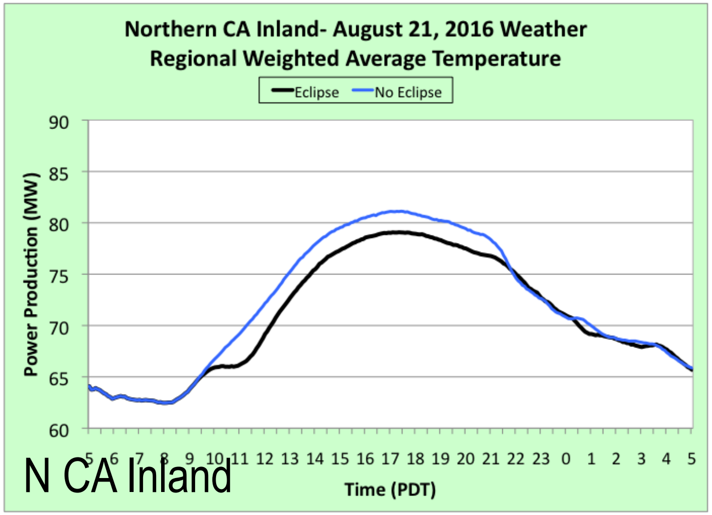
Load Model Regions:
Difference in Weighted Average Temperature

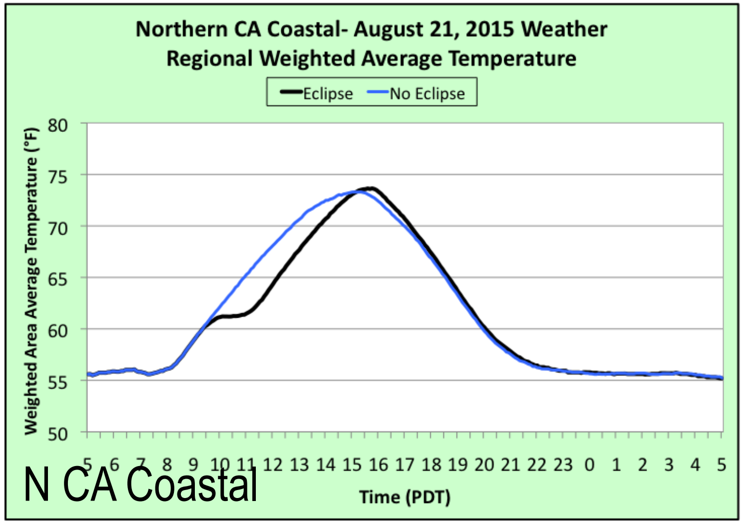


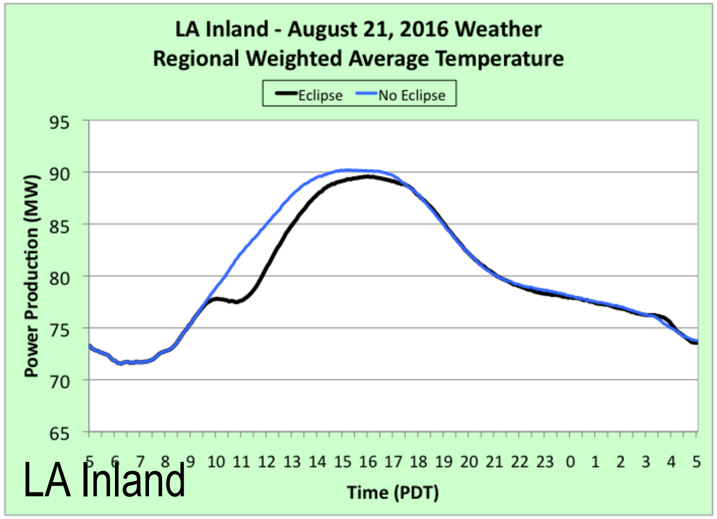



# TEMPERATURE PROFILES: 2015 – WESTERLY FLOW CASE

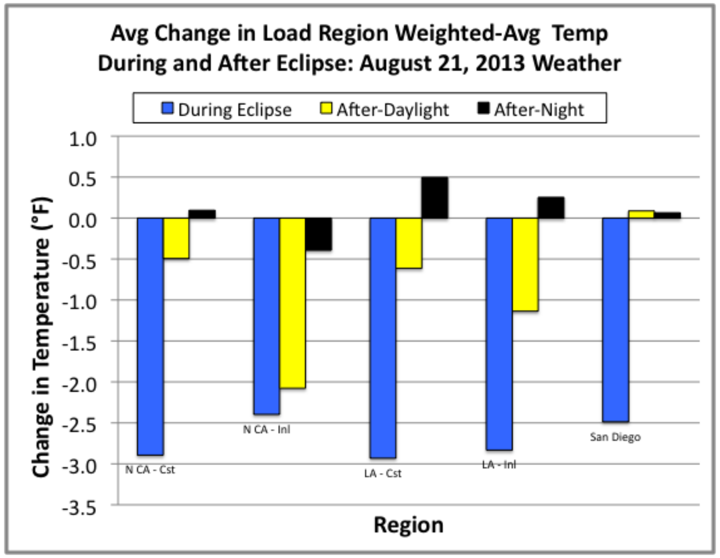


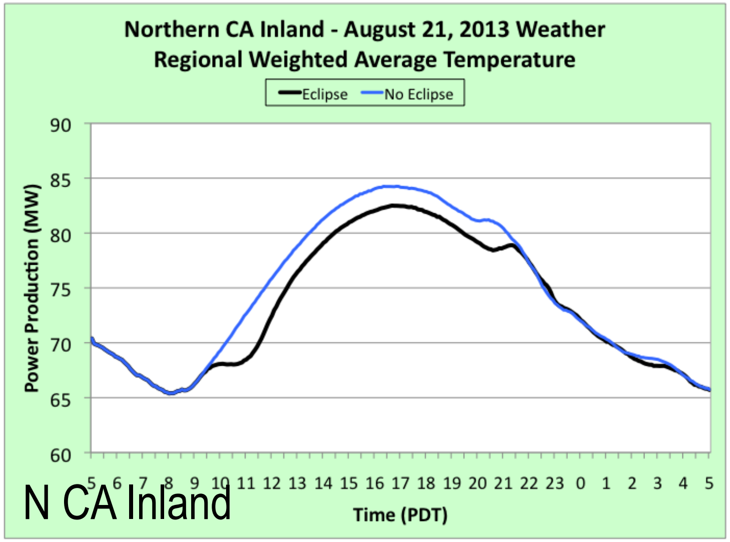



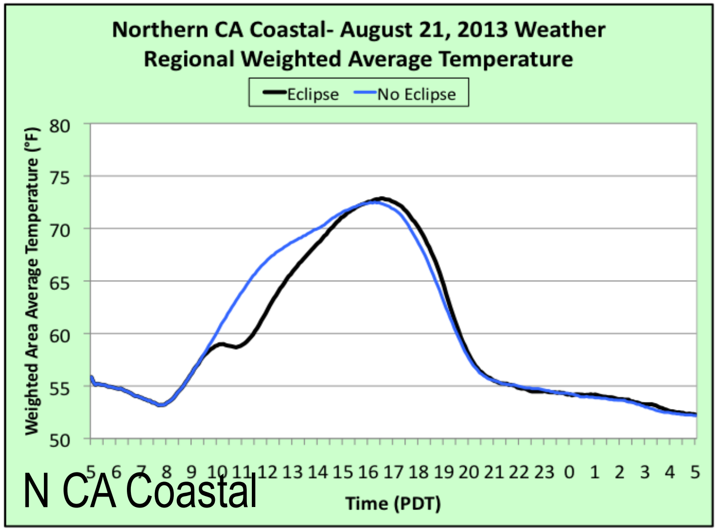



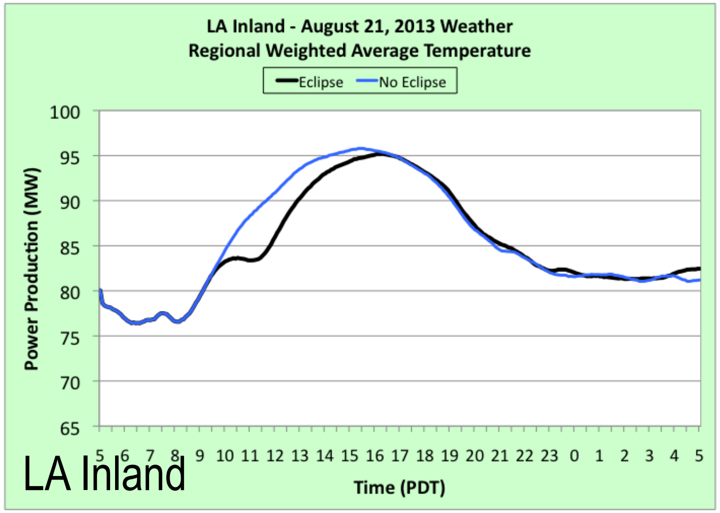



# TEMPERATURE PROFILES: 2013 – SOUTHERLY FLOW CASE



# SUMMARY

- A version of the WRF model was used to simulate the potential impact of the August 21, 2017 eclipse on solar radiation, wind and temperature over CA
- Simulations executed for Aug 21 in the previous 5 years (2012-2016)
- Impact on **solar generation**
  - Solar gen reduced by an average of 9000 MWh during eclipse period
  - Slight increase in solar gen in afternoon after eclipse
- Impact on **wind generation**
  - On average, wind gen increased very slightly during eclipse
  - Wind gen decreased by 3000 to 6000 MWh after the eclipse (afternoon and overnight)
- Impact on **temperature**
  - Average temperature reduction of 2 to 3 F and peak of 5 to 6 F during eclipse period
  - 1.5-2.5 F reduction in temperature persisted thru the afternoon in N CA Inland areas