Improving Accuracy of Solar Forecasting

February 14, 2013

SunShot
U.S. Department of Energy

Solar Resource Forecasting

Objectives:

- Improve accuracy of solar resource forecasts
- Enable widespread use of solar forecasts in power system operations

Impacts:

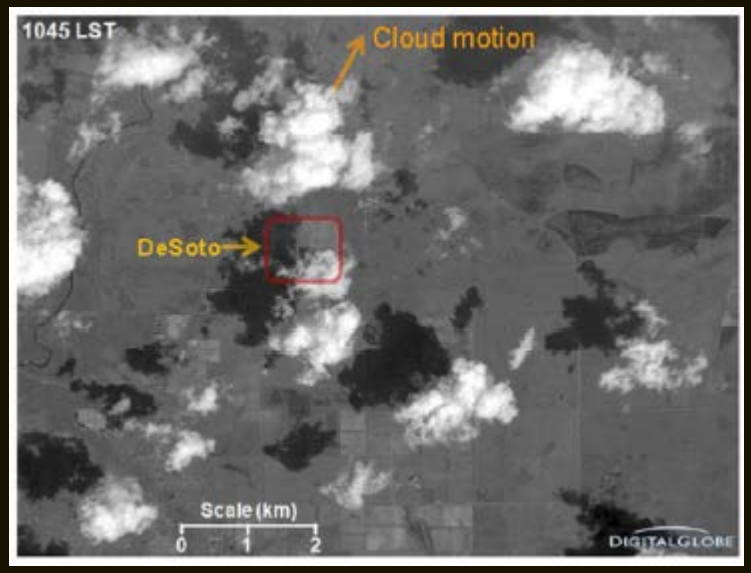
- Increase dependability of power output prediction
- Prepare for impending intermittencies to minimize grid impacts

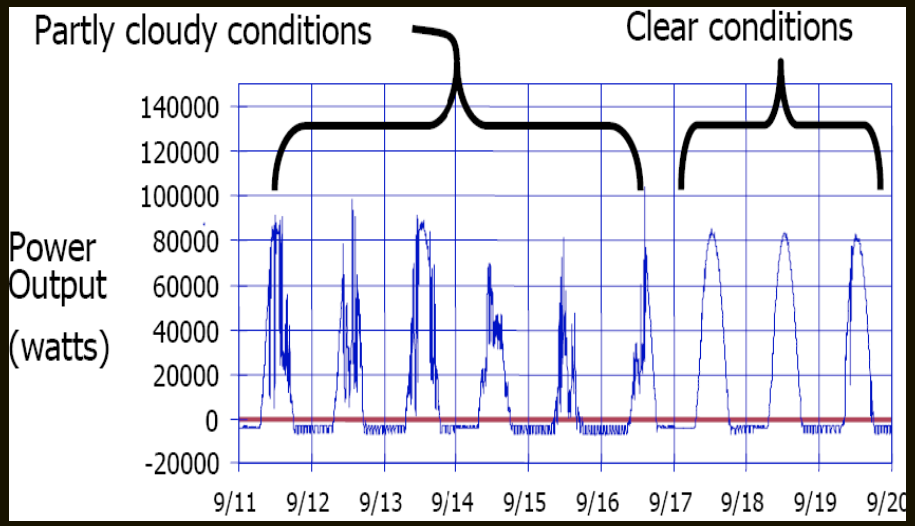
Focus Areas:

1) Develop Standardized Target Metrics
2) Develop Innovative algorithms and validate
3) Demonstrate value with utilities/system operators

Steps:

1) $9 Million Funding from DOE
2) Awardees: NCAR & IBM
3) Feb 25 Solar Forecasting Metrics workshop





Awardee 1: NCAR

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

BROOKHAVEN NATIONAL LABORATORY

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

New York Power Authority

SMUD

Hawaiian Electric Company

PENNSTATE

Colorado State University

University of Central Florida

LIPA
Long Island Power Authority

GWC
GLOBAL WEATHER CORPORATION

UNIVERSITY of HAWAI'I
MĀNOA

UNIVERSITY OF WASHINGTON

MDA

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aer
Atmospheric and Environmental Research

Xcel Energy
RESPONSIBLE BY NATURE®

SOLAR CONSULTING SERVICES
EXPERT ASSISTANCE IN SOLAR RESOURCE ASSESSMENT AND SOLAR ENERGY UTILIZATION

TELVENT
Smart Information for a Sustainable World

Empire State Development

Partner Roles

National Labs/ Collaborators	Universities / Collaborators	Forecast Providers	Utilities	ISOs/BAs
NCAR Brookhaven NREL NOAA Solar Consulting	Colorado State Penn State U U Hawaii U Cent Florida U Washington Stoneybrook U	Atmos & Environ. Res. Global Weather Corp MDA Info Syst Telvent DTN	LIPA, NYPA Xcel Energy Hawaiian Elect SMUD SCE Forecast clients	NYISO Xcel Energy CAISO SMUD Hawaiian Elect Forecast clients
• organize • lead research • run models • coord data streams • econ methods • lead evaluation • integrate results • coord workshops	• research • evaluation • data analysis • Metrics development • expert modeling • satellite processing • cloud tracking • distributed PV data	• input on metrics • interface w/ utilities & ISOs • implement own algorithm • provide real-time forecasts to clients • forecast feedback • research	• input on metrics • data for development • integrate into systems • real-time data • value assessment • workshop support	• input on metrics • data for development • integrate into systems • real-time data • value assessment • workshop support

Application Regions

SMUD – 100 + 50 MW

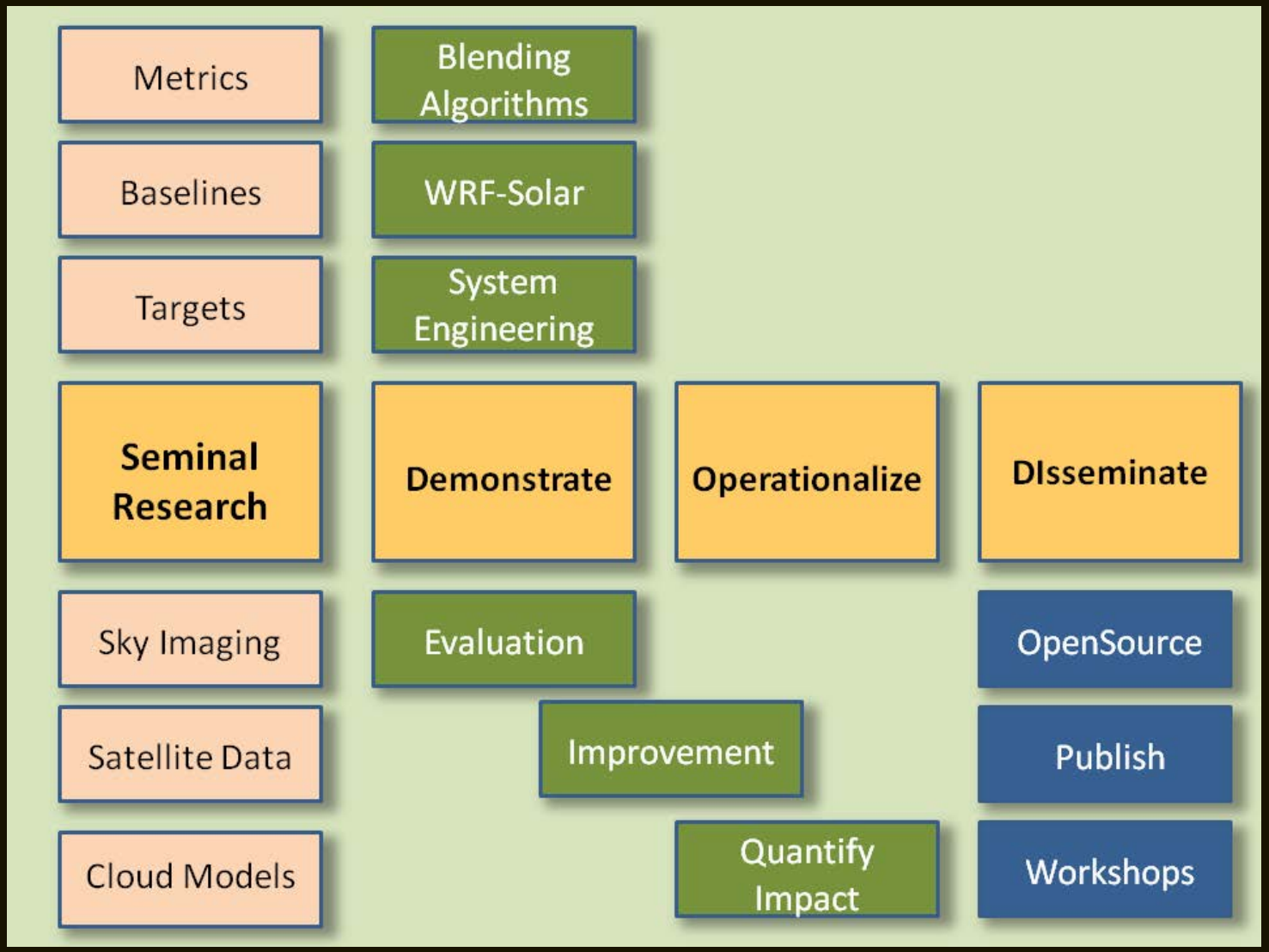
Xcel – 90 MW

LIPA – 32 MW

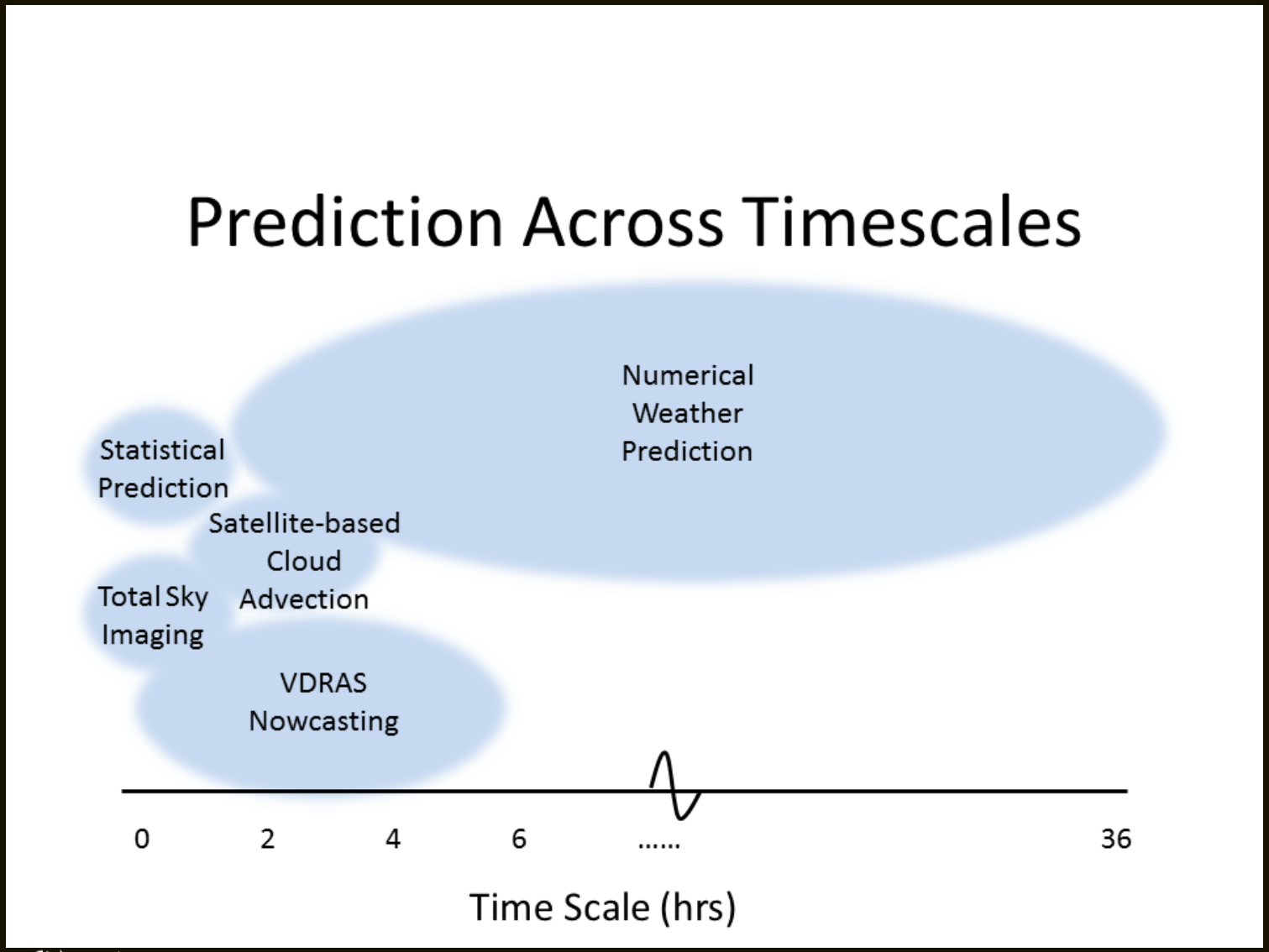
Florida– 110 sites

HECO– 43 MW

Project Concept



Fundamental Research: Solar Forecasting System

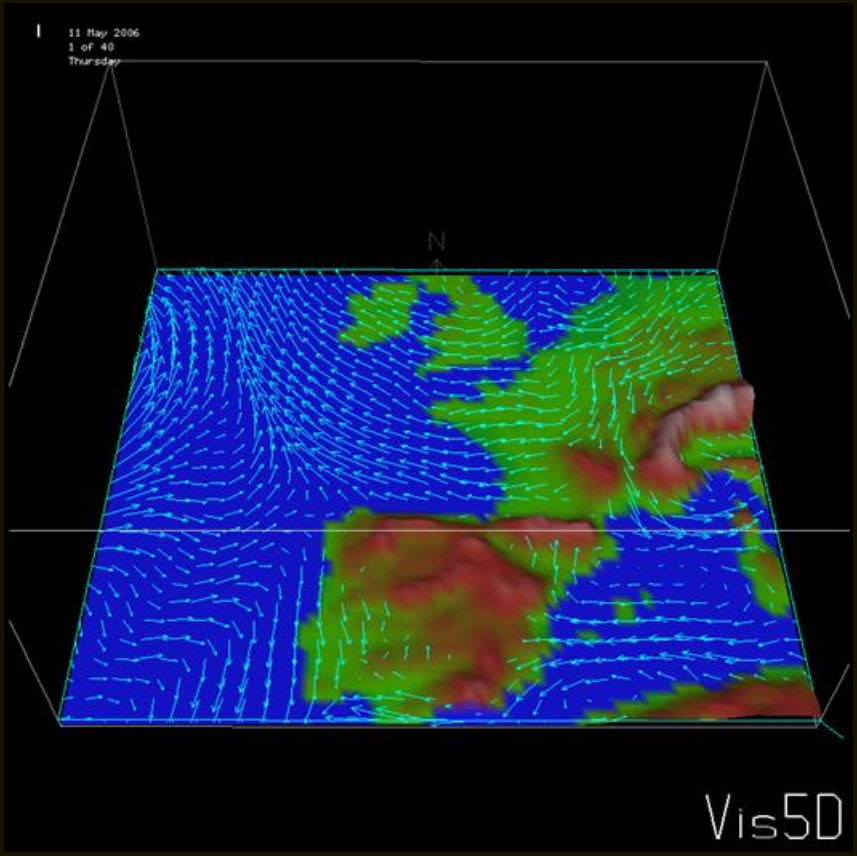


WRF-Solar

Weather Research & Forecasting Model

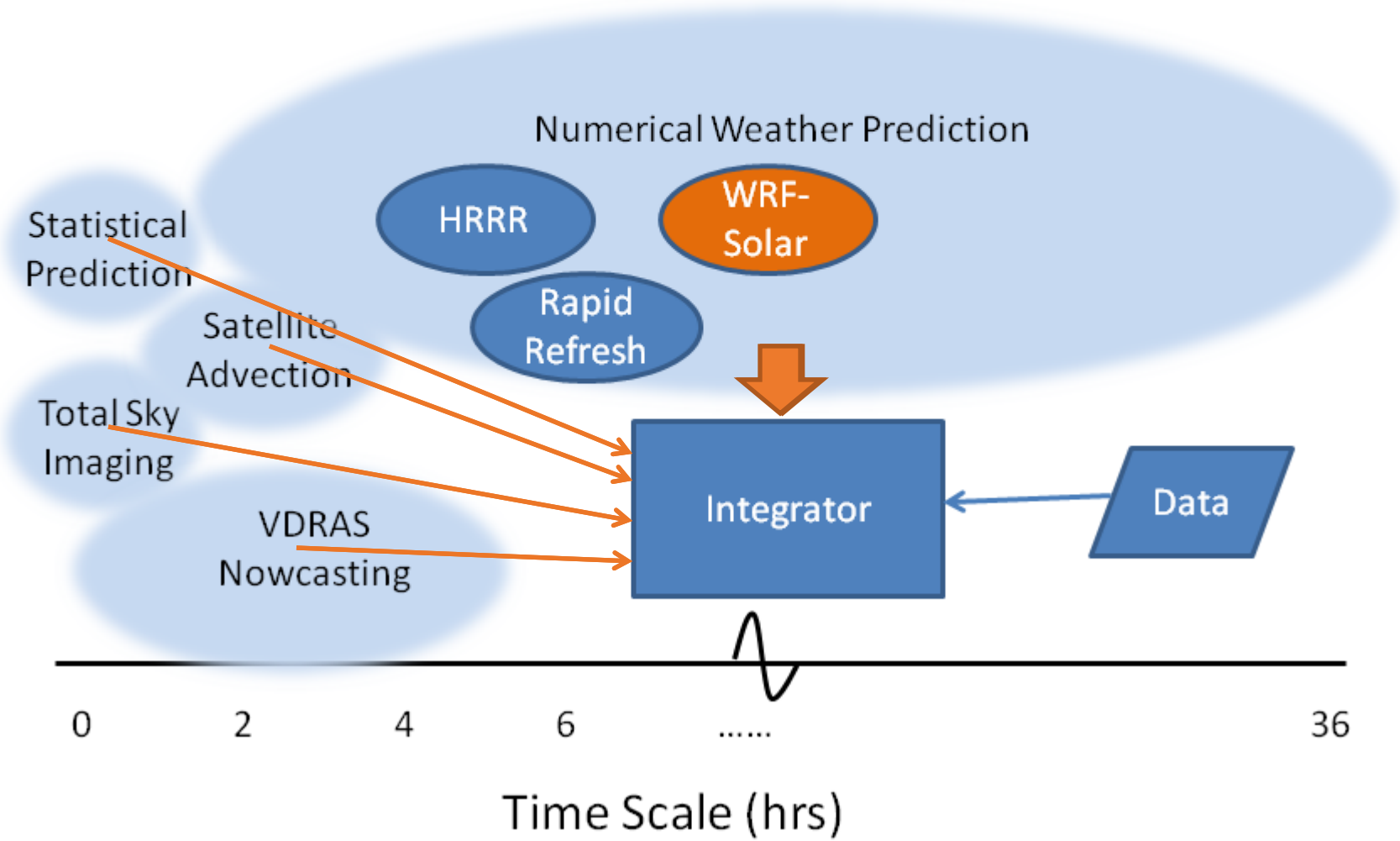
Solar version with improved:

- Satellite data assimilation
- Cloud physics parameterization
- Convective parameterization
- Clear-sky aerosol estimation
- Radiative transfer modeling
- Collaborate with NOAA to make relevant for operations



Application & Demonstration

Prediction Across Timescales



Awardee 2: IBM

Roles

Solution Approach

1. **Big Data Processing Technologies**
   - Leverage Terabytes and beyond

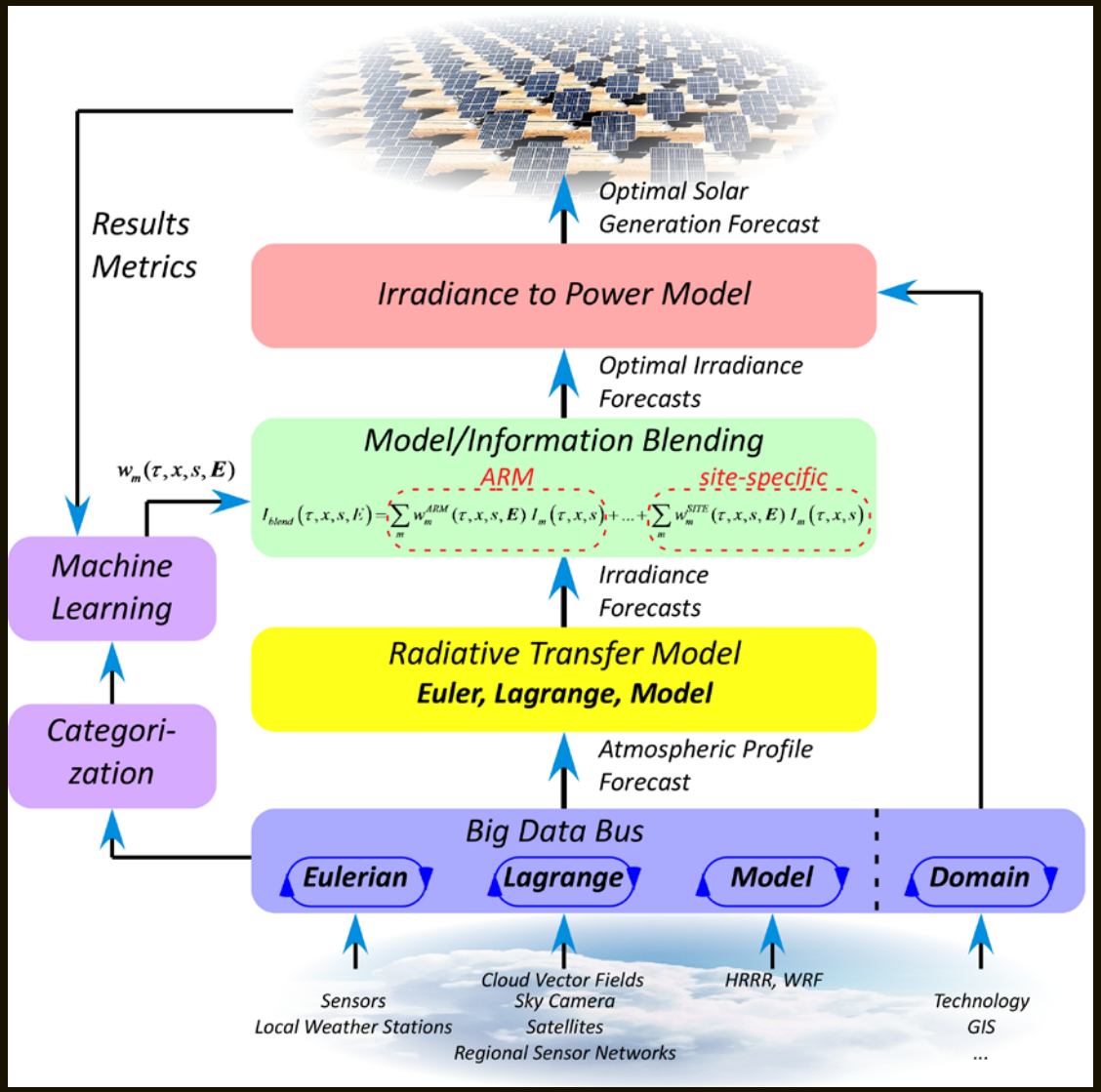
2. **Adaptive deep machine learning**
   - A Watson Jeopardy! like approach to blend optimally different models and to ensure maximum scalability and adaptability

3. **ARM and/or SURFRAD/ISIS data set for training of the machine learning algorithm to include cloud physics**

- **Assemble a multi-disciplinary team that brings expertise in cloud physics, solar data collection, advanced computational methods, large-scale computing, commercial software development, and solar energy deployment.**

- **Balance between machine-learning, data-driven, model-driven, heuristic, deterministic and probabilistic methods.**

Radiance to Power Modeling



Big Data Bus & Inputs

- **Big Data Bus and Inputs**
  - Eulerian Information:
    - Local weather station (temperature, wind direction etc.),…
  - Lagrangrian Models:
    - Sky imaging systems
    - Cloud propagator forecast system (by Northrop Grumman)
  - Models:
    - NOAA models
    - Third-party models
    - …
  - Domain Information (Solar Power Plant Specs)
  - Other data sources
- **Common data model (so that other third-party models can be included)**
- **Leverage big data processing technologies to ensure scalability**

Deep Machine Learning via *Adaptive Mixture of Experts*

- **Approach**
  - Initial training on ARM and/or ISIS/SURFRAD data
  - Continuous training once the system is operational at other sites
  - "Adaptive mixture of experts" approach to obtain optimal blending coefficients, $w_m^{ARM}(\boldsymbol{\tau},x,s,\boldsymbol{E})$ and $w_m^{SITE}(\boldsymbol{\tau},x,s,\boldsymbol{E})$
  - Apply Deep Learning using multi-layered neural nets that have demonstrated notable recent successes in areas such as feature extraction from images and speech recognition

- **Similarities to the Watson Jeopardy! Challenge**
  - Large amount of structured and unstructured data
  - Classification required depending on the type of question (here weather situation)
  - Various models / expert systems which have different strengths and weaknesses depending on weather situation

Initial Application and Validation

Deploy technology in at least two diverse test sites (totaling more than 10 MW of solar power) and demonstrate significant in forecasting accuracy as measured by

- The set of new metrics derived in this project;
- Traditional metrics (root mean square error, mean bias error, mean absolute error).