Demonstration of Improved Solar Forecasting Incorporating HD Sky Imaging

Presentation to the BNL Community Advisory Council

December 13, 2018

Paul Kalb
Deputy Chair
BNL Environmental & Climate Sciences Dept.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

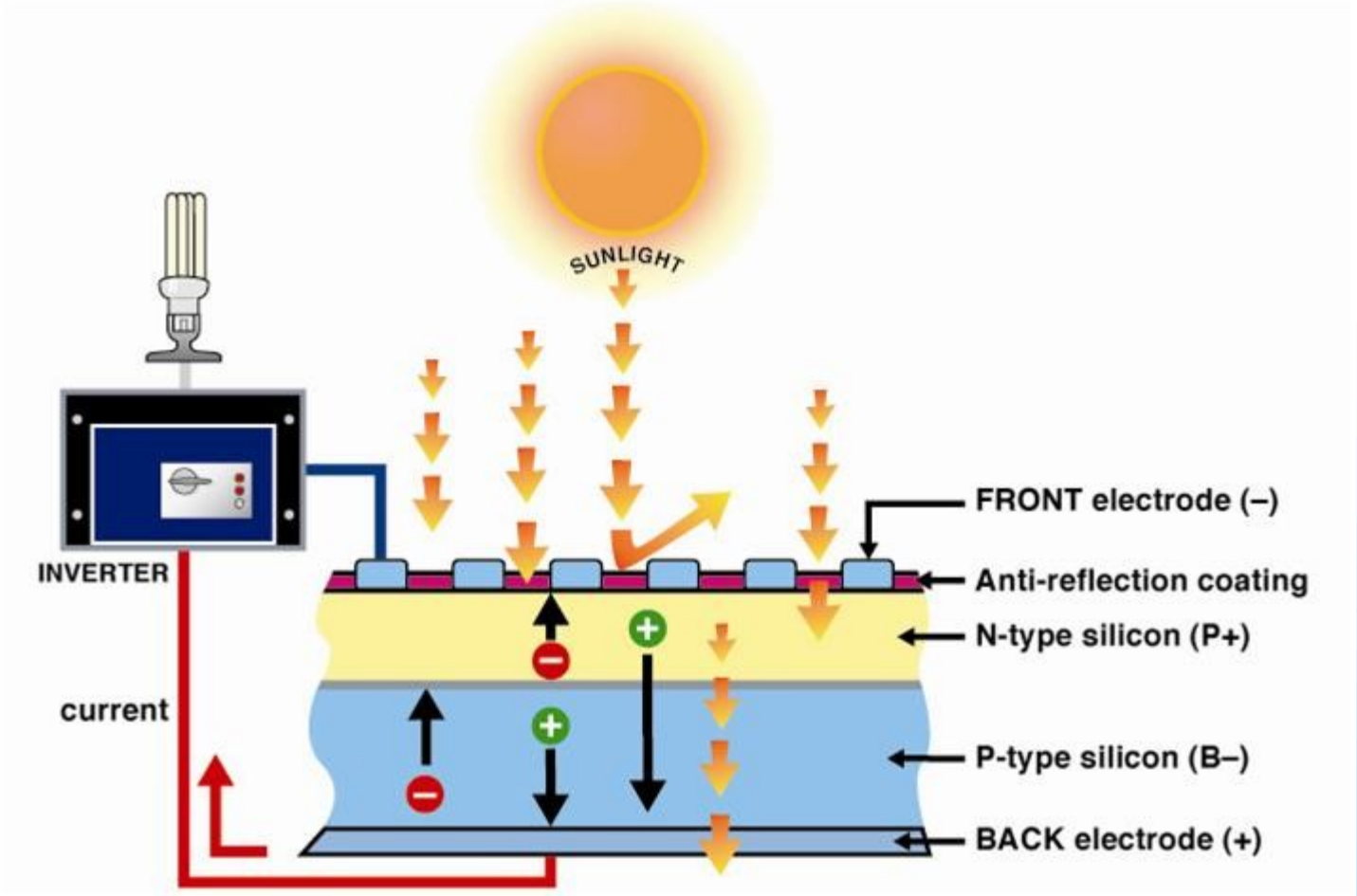
BROOKHAVEN NATIONAL LABORATORY
a passion for discovery

U.S. DEPARTMENT OF ENERGY | Office of Science

Overview

- *Background and Technology Needs*
- *Timescales and Strategies for Solar Forecasting*
- *BNL Now-Casting Technology*
- *Scale Up and Demonstration*
  - *Approach*
  - *System improvements*
  - *Deployment*
- *Work conducted to date and future plans*
- *Summary*

Solar Power 101

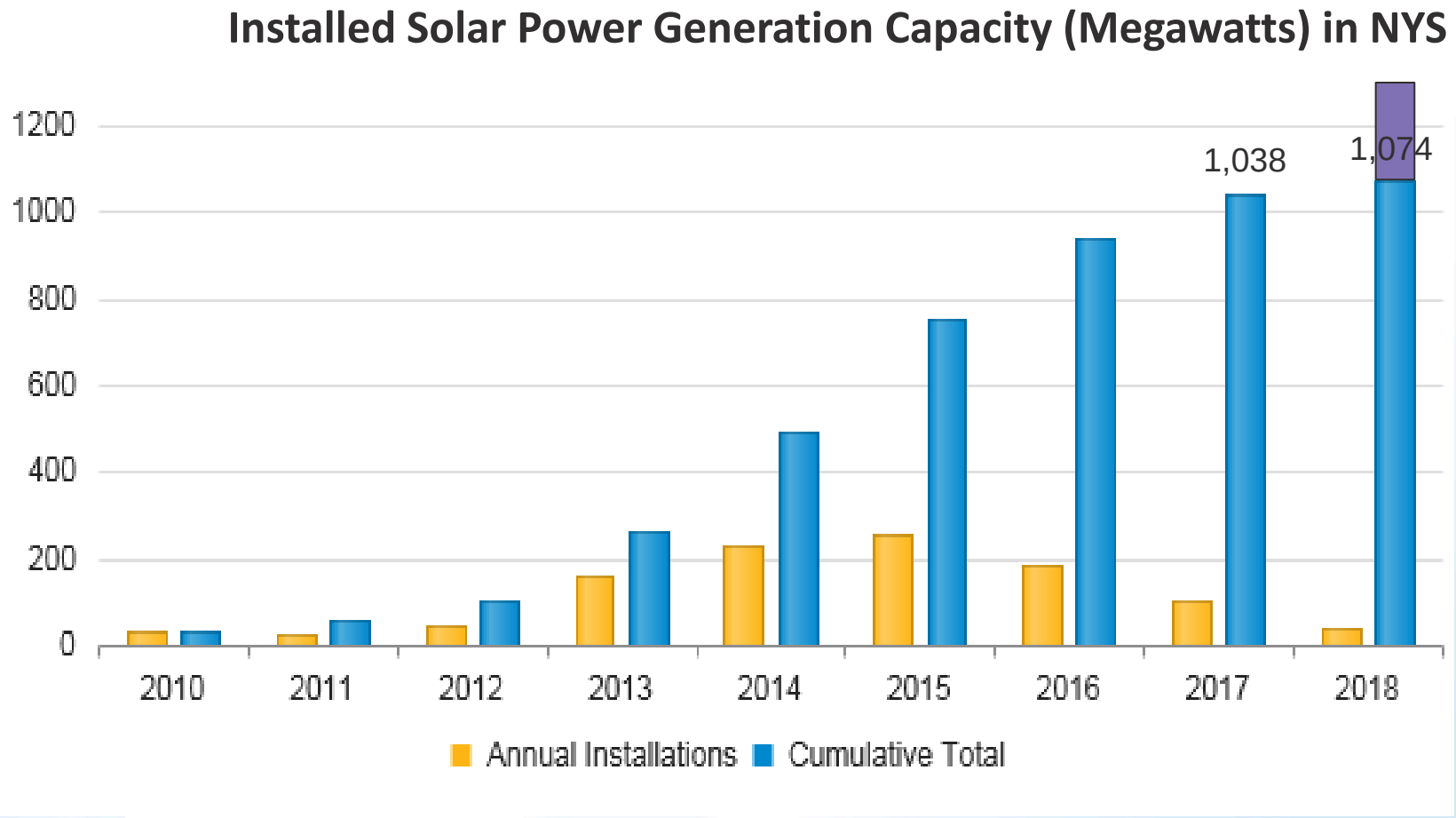


Challenge: Maintaining Grid Stability

- *Installation of both utility generating facilities and distributed roof-top solar is growing rapidly throughout the U.S. (**40.5%** in 2017 over 2016).*

- *Utility scale PV solar power stood out among all forms of electricity generation in 2017, growing **47%** in output.*

Exponential Growth of Solar

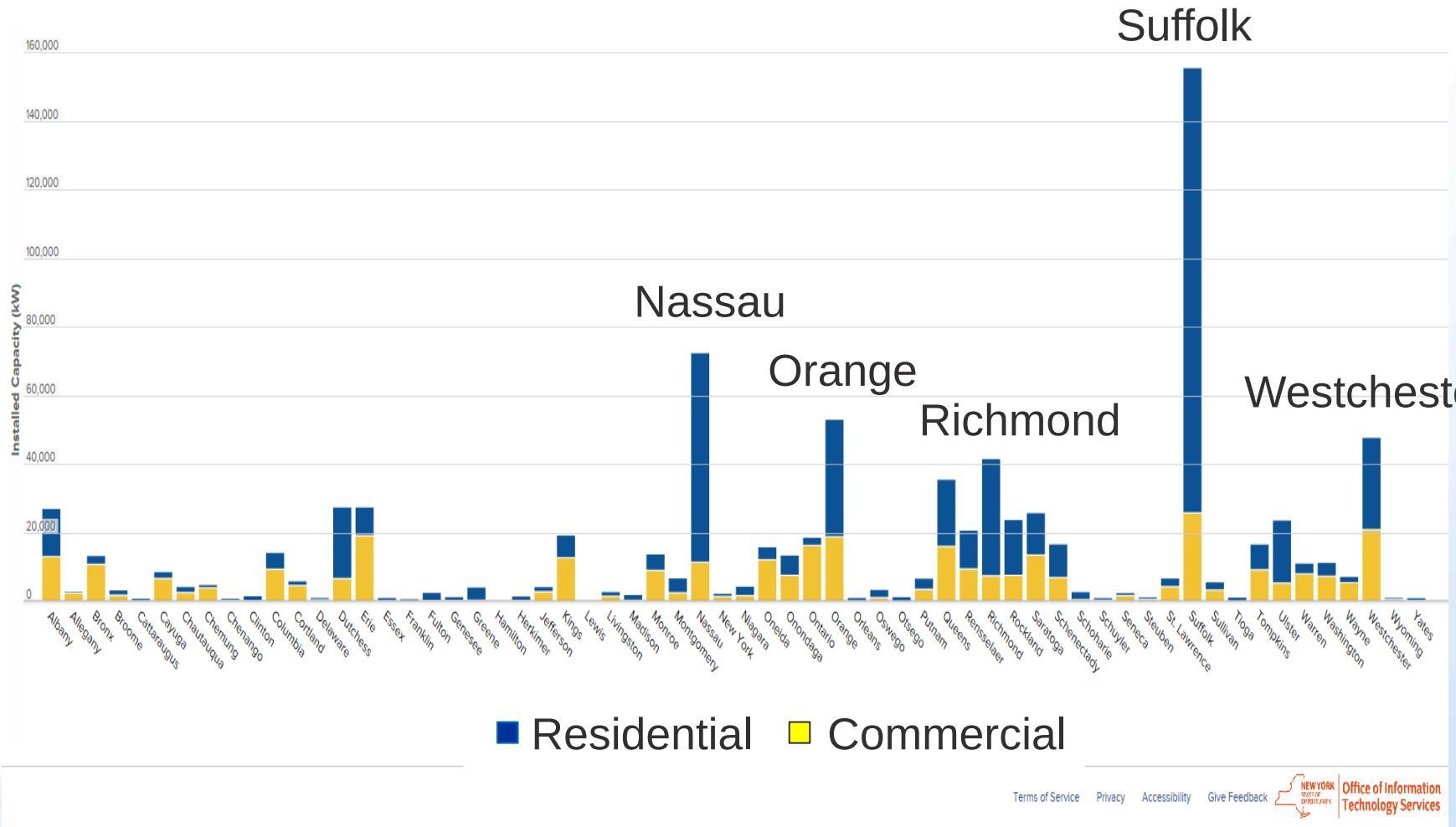


NY State is a Major Solar Producer

- *Solar Installed (MW): 1,462.93*
- ***National Ranking:11th (12th in 2017)***
- *State Homes Powered by Solar: 243,124*
- *Percentage of State's Electricity from Solar: 1.14%*
- ***Prices have fallen 47% over the last 5 years***
- *Solar Jobs: 9,012*
- *Solar Companies in State: 619*
- *Total Solar Investment in State $3810.17 Million*
- ***Growth Projection and Ranking: 3,265 MW over the next 5 years (ranks 5th)***
- *Number Of Installations: 102,508*

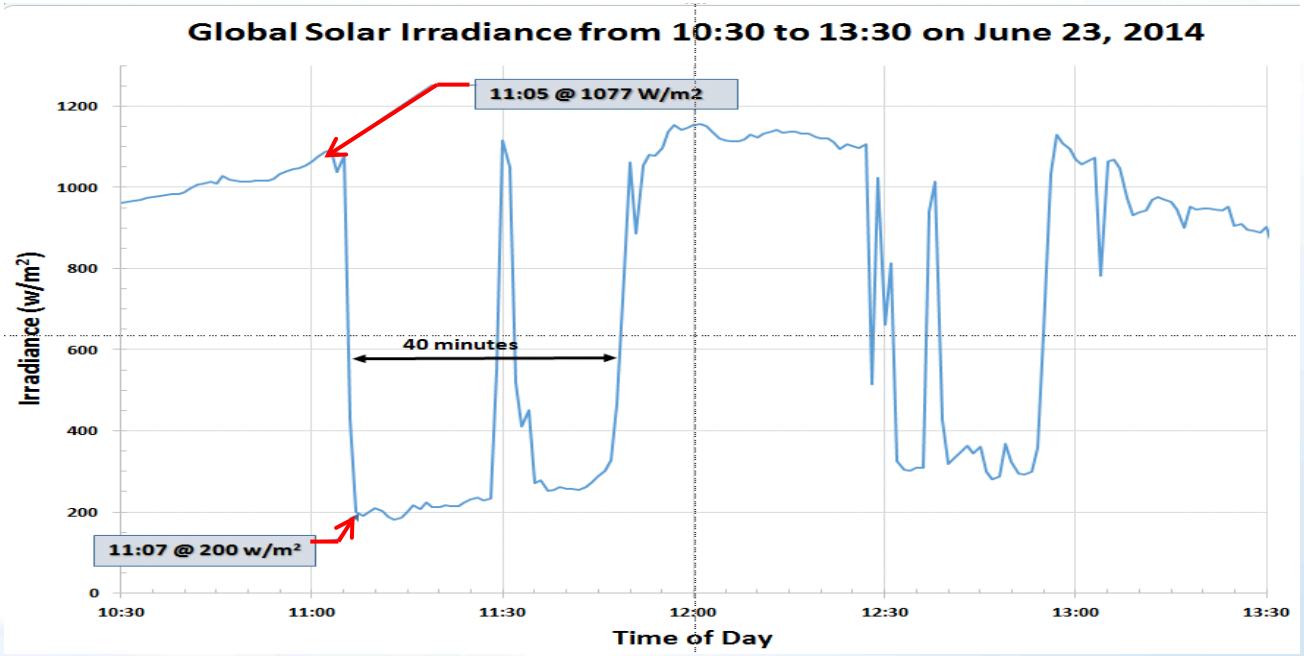
(Data Current Through Q2 2018)

Installed Solar Capacity by Counties in NYS

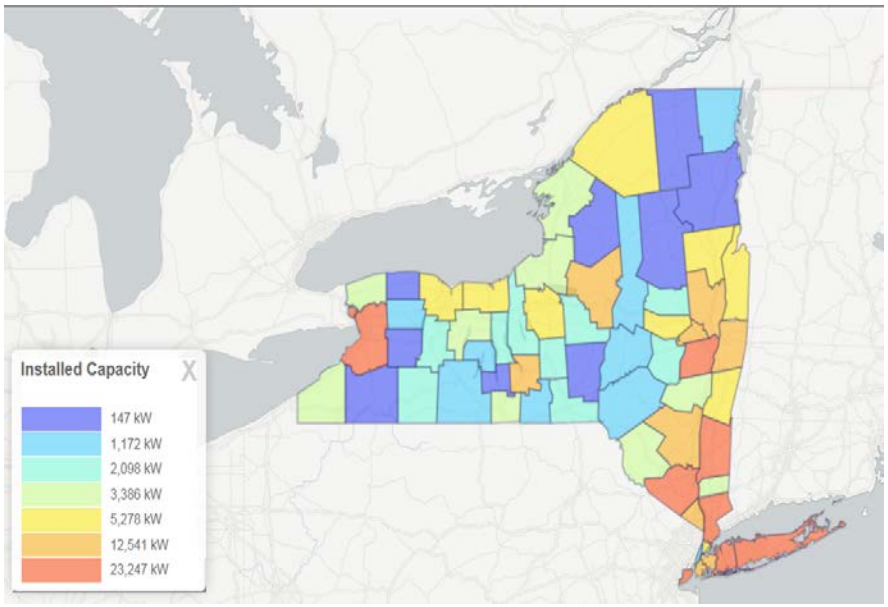


Large Solar Variability

- *As penetration grows, utilities must be able to handle typical solar variability*
- *Due to influence of off-shore weather, solar variability is much more of an issue in the **Northeastern US** (especially in the NYC metro area)*



Challenge: Maintaining Grid Stability



- *Solar variability and increased solar penetration heighten the importance of maintaining grid stability/load mgt. and the need to make rapid decisions for alternative supplies or storage of surplus energy*

Solution: Solar Forecasting

- *Solar forecasting allows utilities to predict the contributions from solar in near-term (≤ 30 min), short-term (≤ 6 hrs) and long term (≥ 24 hr) timescales*
- *New, state-of-the-art techniques for forecasting at each of these timescales were developed and integrated in a previous effort by the National Center for Atmospheric Research (NCAR) /BNL team under a project sponsored by the DOE Solar Energy Technology Office*
- *BNL currently collaborating with the Electric Power Research Institute (EPRI) and NCAR on a new project sponsored by the New York Power Authority (NYPA) and DOE to scale-up and enhance these techniques to cover regional forecasting in selected areas of NYS*

Newsday Coverage

March 18, 2013

A10 LONG ISLAND

Total Sky Imager, the lab's fisheye-lens digital camera, will take a 360-degree snapshot of the sky every 15 minutes.

Head in the... CLOUDS

Brookhaven Lab joins effort to forecast solar energy

When Paul Kalb looks up at the sky, he sees more than just clouds. The environmental scientist sees what he calls "the gray scale" — wispy puffs dimming the horizon — that the sun's energy," said Kalb, who heads the environmental sciences division at Brookhaven National Laboratory in Upton. Just how much, he adds, "depends on their degree and frequency."

resulting power.

The efforts are aimed at helping utility companies and other solar generators anticipate drops and surges in energy production due to cloud cover. A more-precise "solar

over the Long Island Solar Farm, a 200-acre, 32-megawatt array on the lab's property. The largest solar facility east of the Mississippi River, it generates enough renewable energy to power 4,500 households on Long Island. The farm is one of several such facilities, from Florida to

particles that hamper solar e ergy can move and chang shape in the sky — one of th most difficult measuremen for meteorologists to make.

The three-year project, pr marily funded by a $4.1 mi lion grant from the U.S. Ene gy Department, involves un versities, utilities, indepen dent systems operators, com mercial forecast provider and government labs, lik Brookhaven.

"The whole idea is to fore cast drops and surges in sola energy," said Sue Ellen Haup the NCAR researcher leadin the nationwide effort. "W need to know when the vari ability will occur so the utili ties can integrate the powe into the grid."

Once a solar forecastin model is tested, the tech niques will be widely dissemi

newsday.com

AY, MARCH 19, 2013

BNL Public Affairs Coverage

Dec. 7, 2018

Solar Base Station Gets Upgrade

Improvements will facilitate solar energy research conducted by scientists from Brookhaven Lab and outside institutions

December 7, 2018

(Clockwise from left) Brookhaven Lab Environmental and Climate Sciences Department (ECSD) Chair Allison McComiskey, consultant Dong Huang, Stony Brook University graduate student Chenxiao Xu, ECSD technician Gabriel Vignato, ECSD electronics engineer Andrew McMahon, project engineer Thomas McEvaddy of Brookhaven's Modernization Project Office, ECSD computational scientist Richard Wagener, and Brookhaven Meteorological Services Group Leader John Heiser are part of the team that contributed to the development of the newly installed solar base station seen above. Located on an elevated platform on the roof of a Brookhaven Lab building, the station is equipped with instruments for measuring the amount of energy coming from the sun and atmosphere. Utilities need such measurements to improve solar energy forecasting to maintain the stability of the power grid and to efficiently allocate

+ENLARGE

Forecasting Time Scales

Now-casting

Need to control variability for grid stability via real-time decisions on power distribution & storage

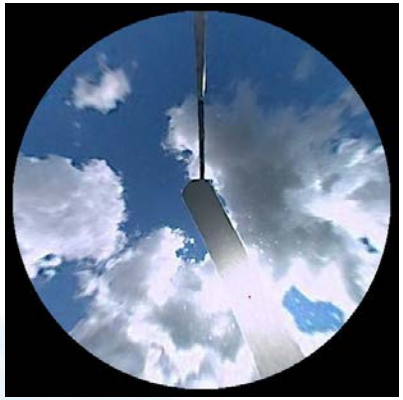
Short-term forecasting

Need to dispatch backup/stand-by power plants to meet demand

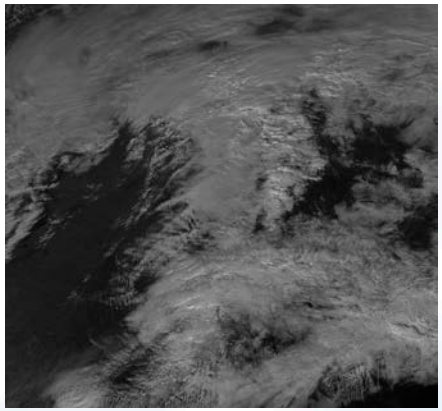
Long-term forecasting

Need for daily trading to minimize energy costs

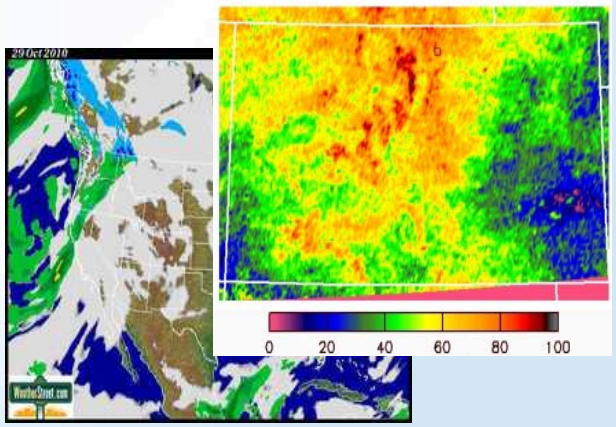
1min 30 min 6 hours 24+hours



Ground-based imagers



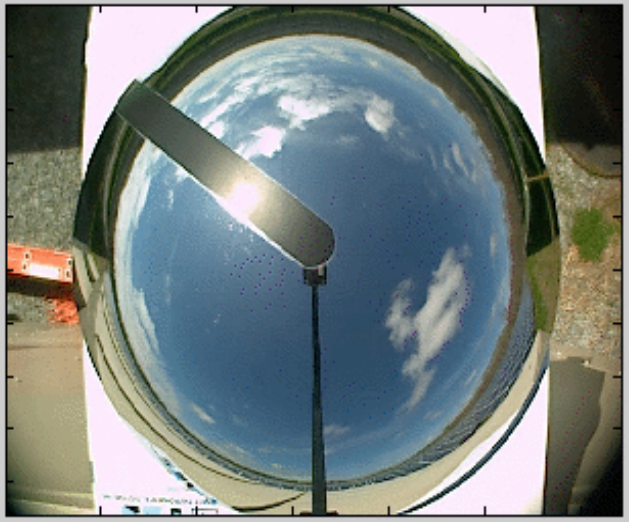
Satellite imagery



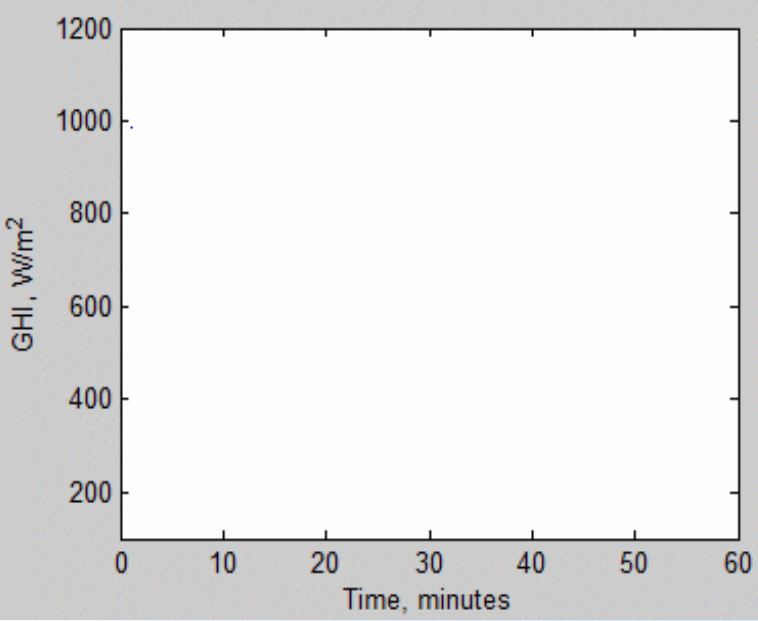
Numerical Weather Prediction Modeling

Ground Based Imaging

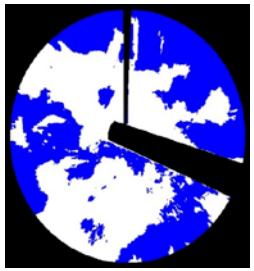
A network of sky imagers continuously collects real-time images of local clouds. Custom software is used to identify and track cloud movements, estimate the impact on solar production, and provide now-casting prediction



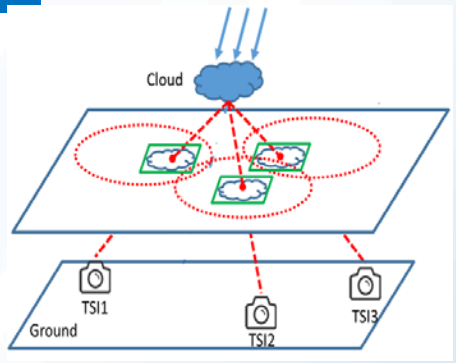
Total Sky Imager



BNL Now-Casting System Process Flow

Data collection, reduction, and management → Cloud detection → Cloud motion, tracking → 3D cloud location → Surface solar forecast → Forecast evaluation



*(Solar Energy 2015) [Solar' 15] Peng et al., "**3D Cloud Detecting and Tracking System for Solar Forecast Using Multiple Sky Imagers.**"*

BNL Now-Casting Improvements

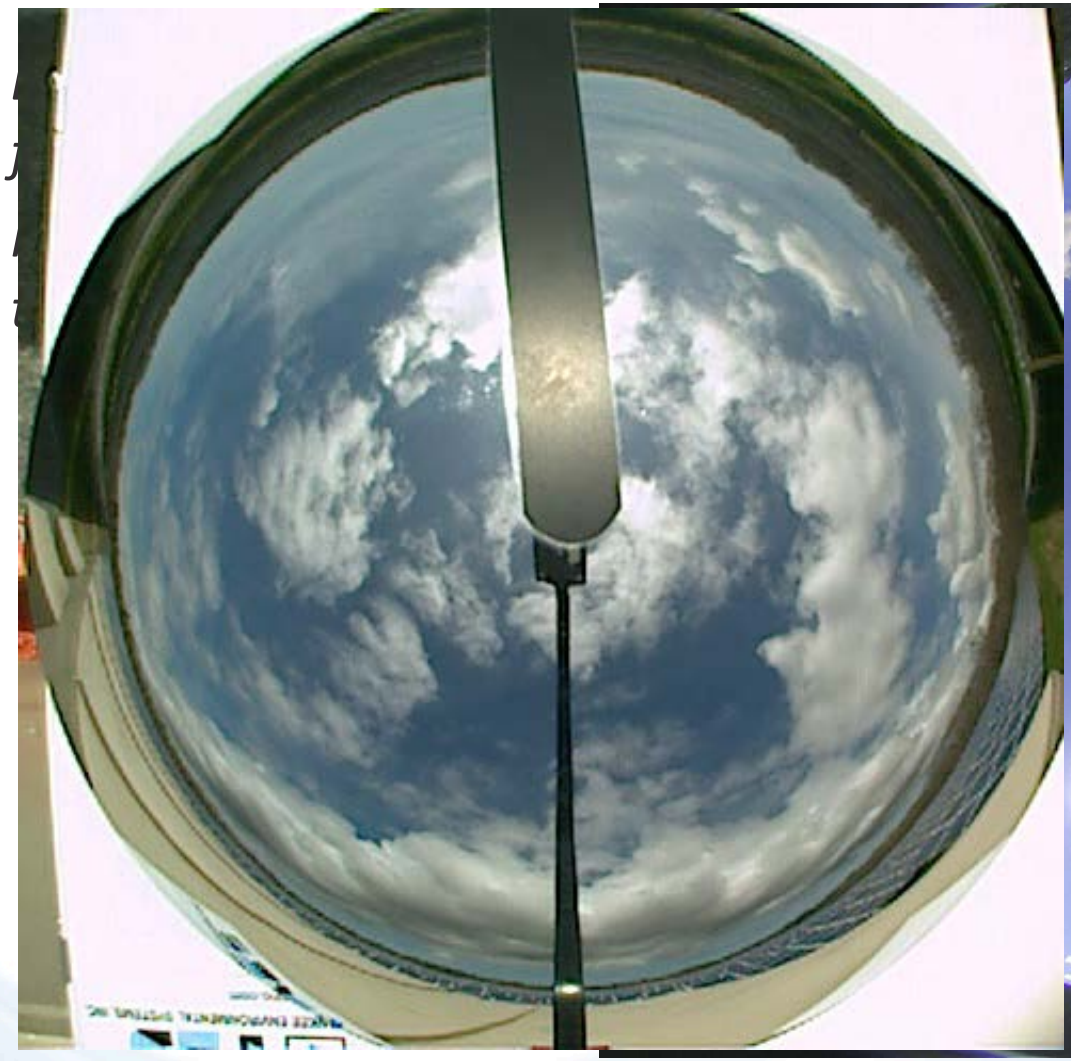
- *New, low-cost HD sky imagers based on off-the-shelf components facilitate widespread deployment*
- *Increased resolution and field of view results in doubling of forecast time horizon*
- *Multiple units provide info on cloud location, height, and impact*
- *Coordinated sensor network will expand forecast horizon and time window*
- *Custom software identifies and tracks clouds, calculates projected impact on solar energy production*

Low Cost HD Sky Imager

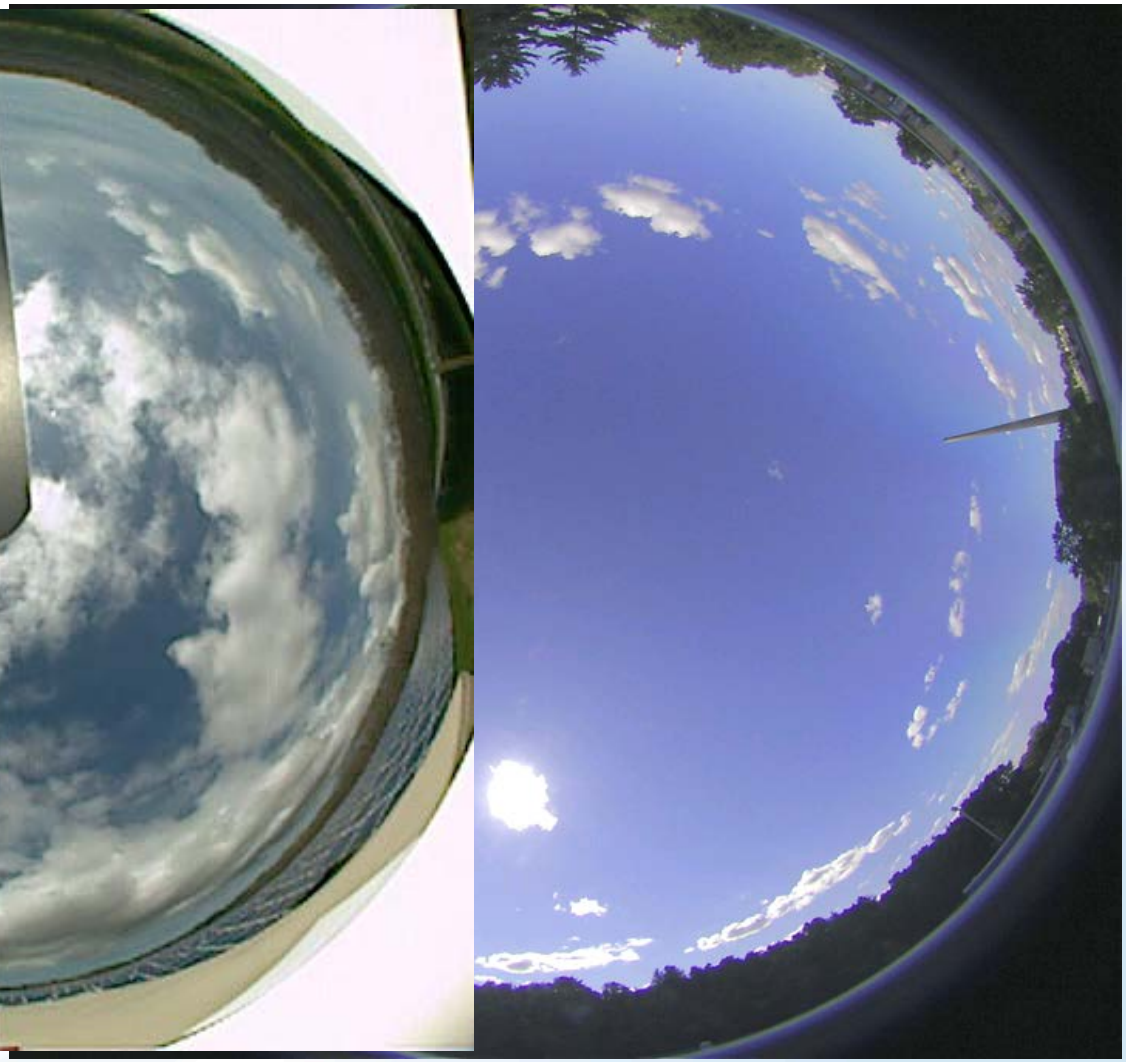
- *< $1500 each*
- *No moving parts (e.g., shadow band, sun blocker)*
- *Lightweight and easy to install*
- *12 megapixel resolution*
- *Control and data transfer via Internet*
- *Proven durability and reliability*
- *Sun-glare removal accomplished through software*

Low-Cost High Definition Sky Imager

- [illegible]
- [illegible]



TSI image

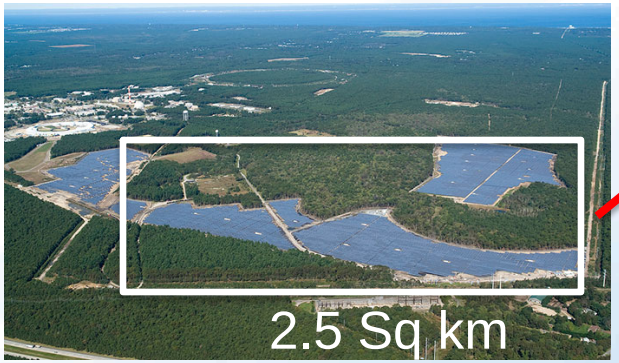


HD sky image

Scale Up and Demonstration

Project Objectives

- *Work with NYPA and utility industry to scale up solar forecasting technologies previously developed under DOE SETO support from localized solar generating facilities to broader regions, including distributed solar resources (DSR)*
- *Deploy multiple ground-based imager networks to expand near-term (0 – 30 min) NowCasting from current 2.5 km^2 to approx. 50 km^2 and modify forecasting model to develop a working prototype*



Project Objectives

- *Integrate regional forecasting to mid-range (up to 6 hrs) and long-range (up to several days) time horizons using WRF Solar and other advanced techniques*
- *Work with utilities and stakeholders towards implementation of forecasting technologies*

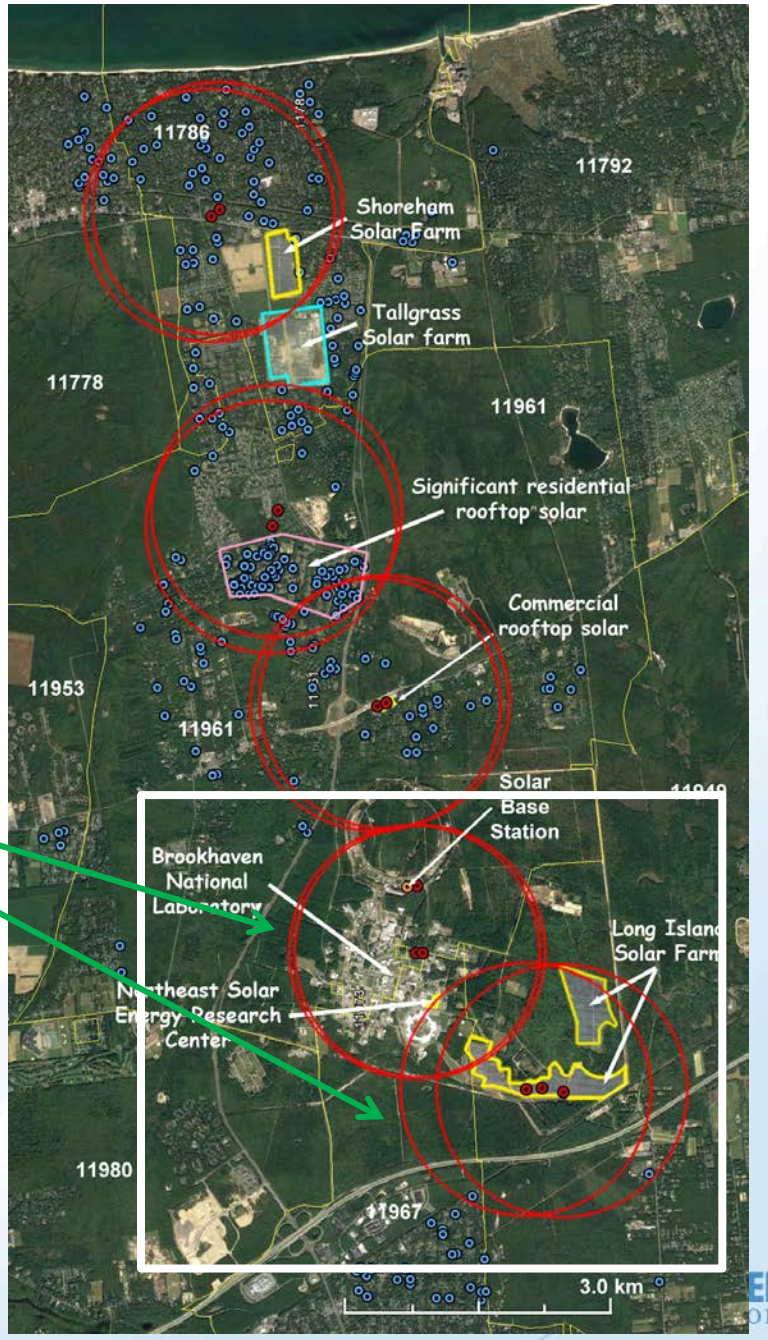
Task 1.1: Siting

Imager Footprint for 50 km^2 of Eastern Long Island extends from BNL, north to Shoreham

Task 1.1: Siting

Two of Five Ground-Based Imager Pairs Located on BNL Property

BNL is host site for the 32 MW Long Island Solar Farm and 1 MW research array (NSERC)



Long Island Solar Farm

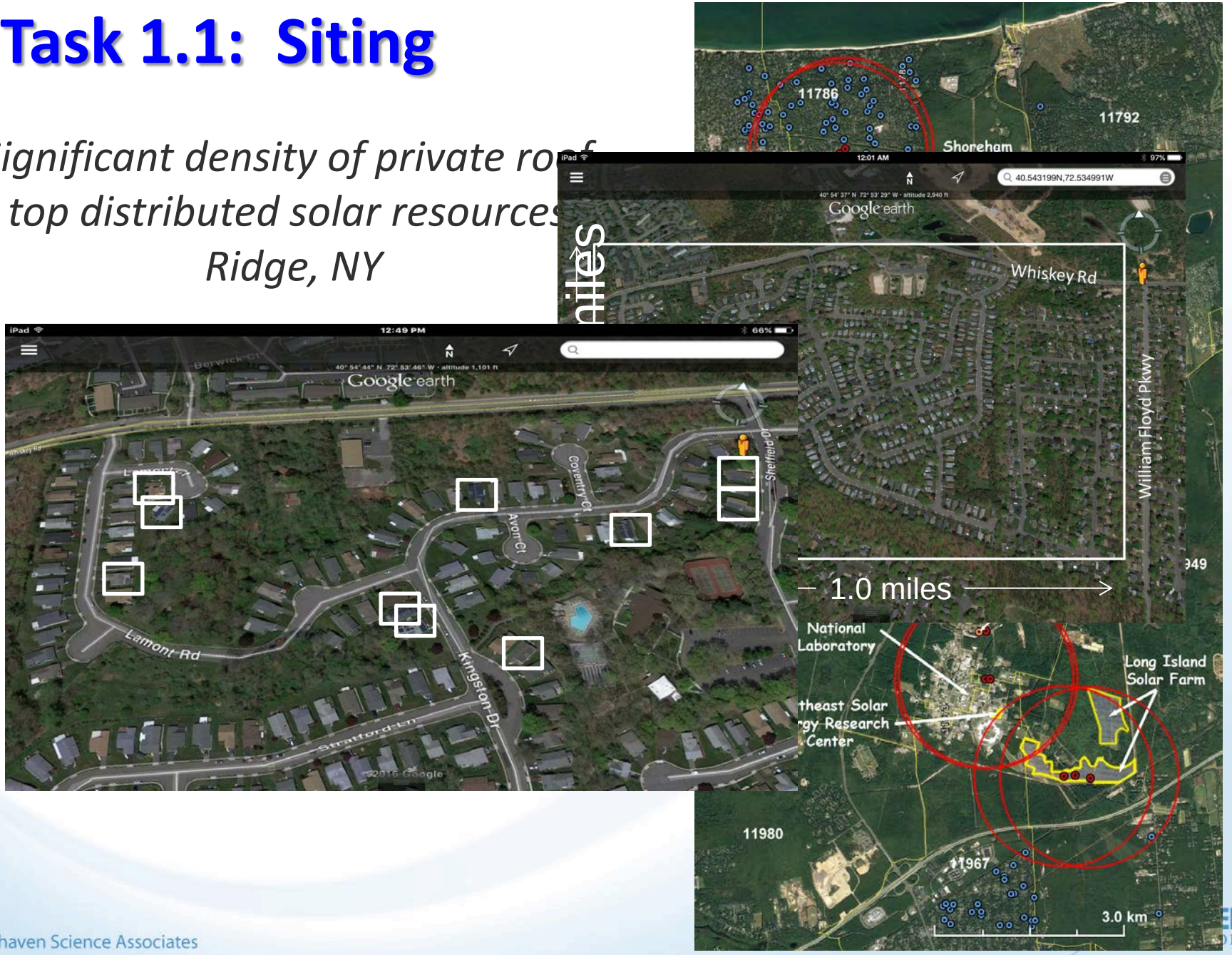
LISF, located at BNL, is the largest solar generating facility on the east coast

Task 1.1: Siting

Commercial Roof-top Distributed Solar Resources:
Storage facility, Ridge, NY

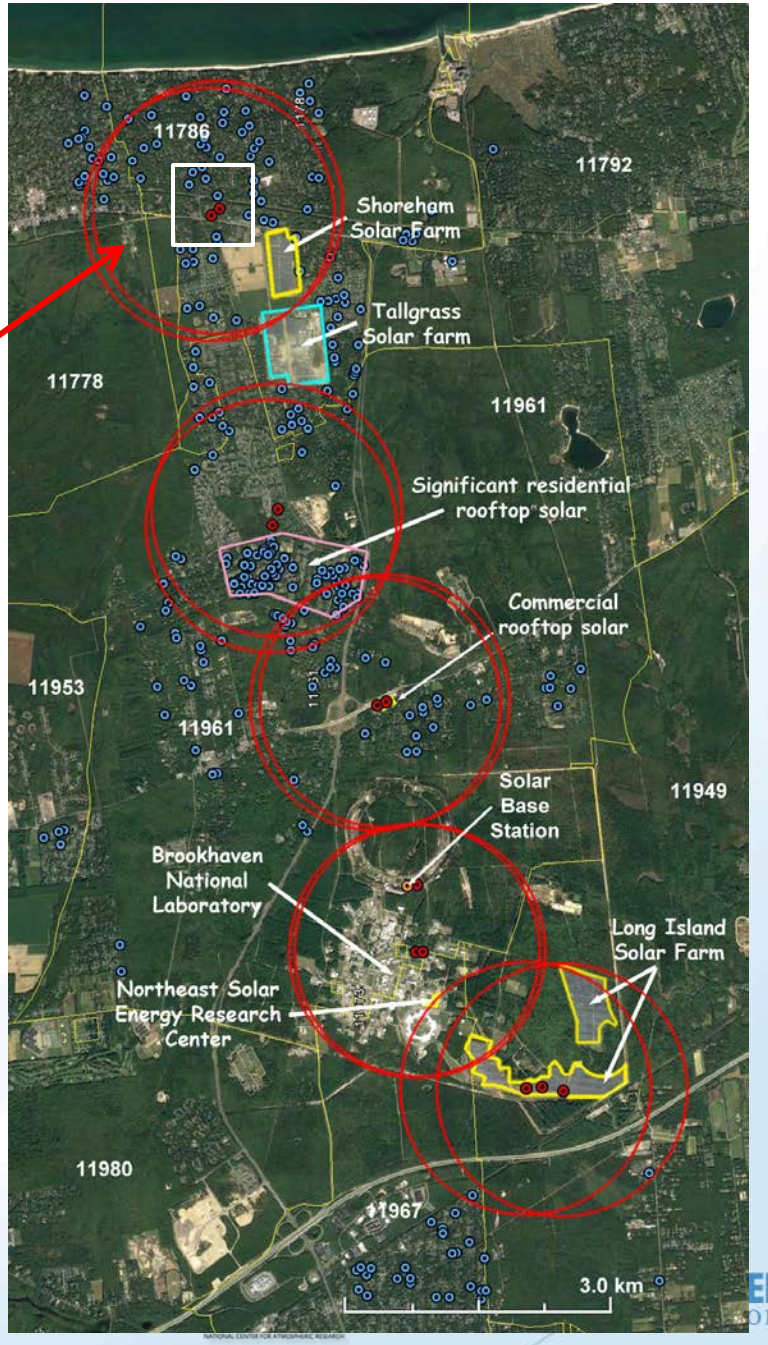
Task 1.1: Siting

Significant density of private roof top distributed solar resources Ridge, NY



Task 1.1: Siting

One pair of imagers located at Tesla Science Center, adjacent to operating Shoreham Solar Farm Facility (10 MW)



Task 1.2: Installation

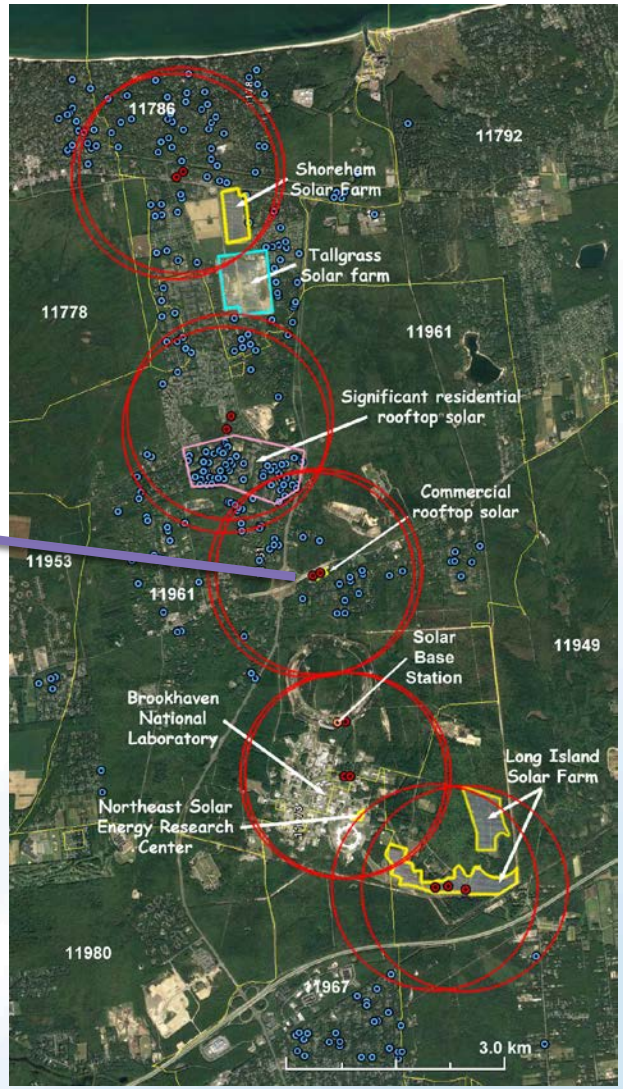
HD Sky Imager mounted on 10' tripod for roof mount at BNL

HD Sky Imager mounted on BNL Bldg 490 roof

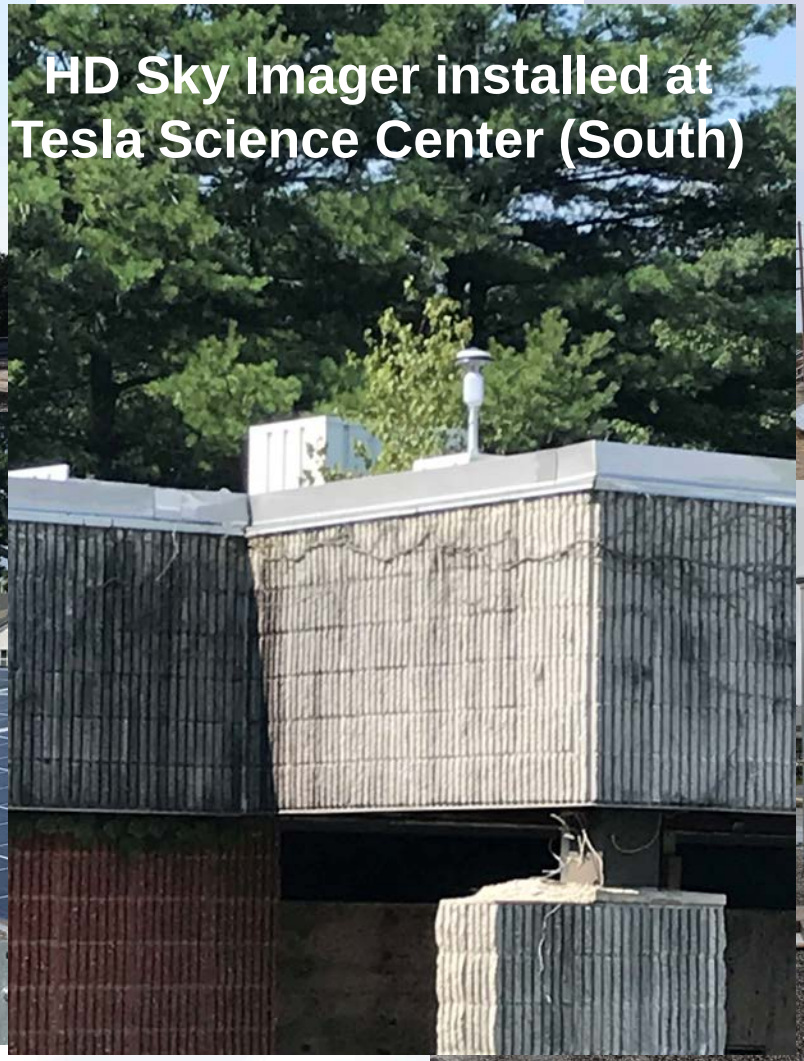
HD Sky Imager mounted at LISF Power Block 16

Task 1.2: Installation

HD Sky Imager installed at the Ridge, NY Fire Department



Task 1.2: Installation



HD Sky Imager installed at Tesla Science Center (South)

Installations at BNL Bldg. 815

Task 1.2: Installation

Research grade Solar Base Station

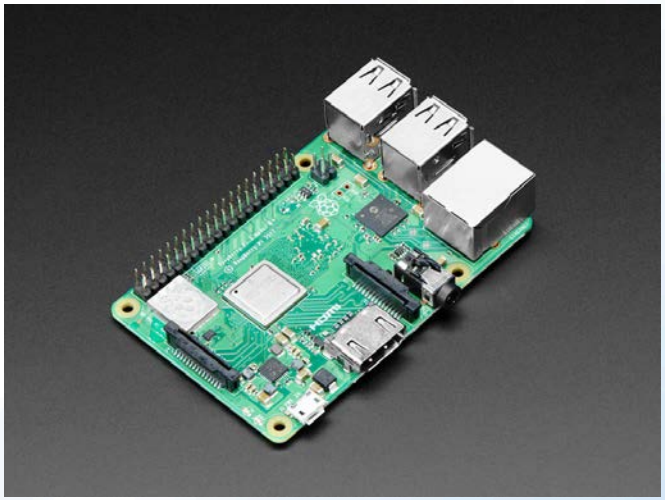
Task 1.2: Installation

- *DOE ARM Program provided 2 Infrared thermometers on loan*
- *Measure cloud base height based on known temperature gradient as a function of distance from the earth's surface*
- *Will be used to compare with calculated base height from multiple imagers*

Heitronics Infrared Radiation Thermometer (IRT)

Task 1.3: Data Communication/Collection

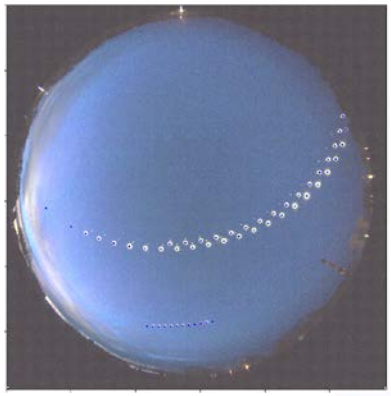
- *Data transmission for imagers is uploaded via internet connection (35Mbps)*
- *Testing local image pre-processing to expedite data transmission*



Task 1.3: Data Communication/Collection

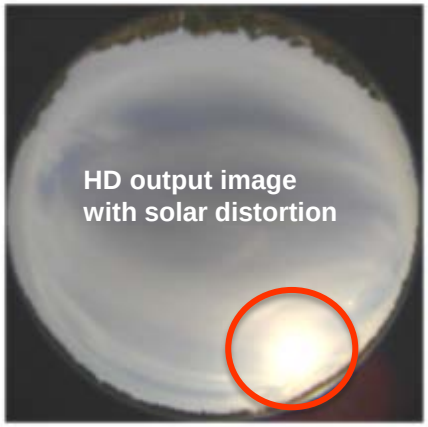
- *Image calibration (pixel to angle mapping)*

Lab calibration



Field Calibration

- *Improved solar image distortion module prepared*



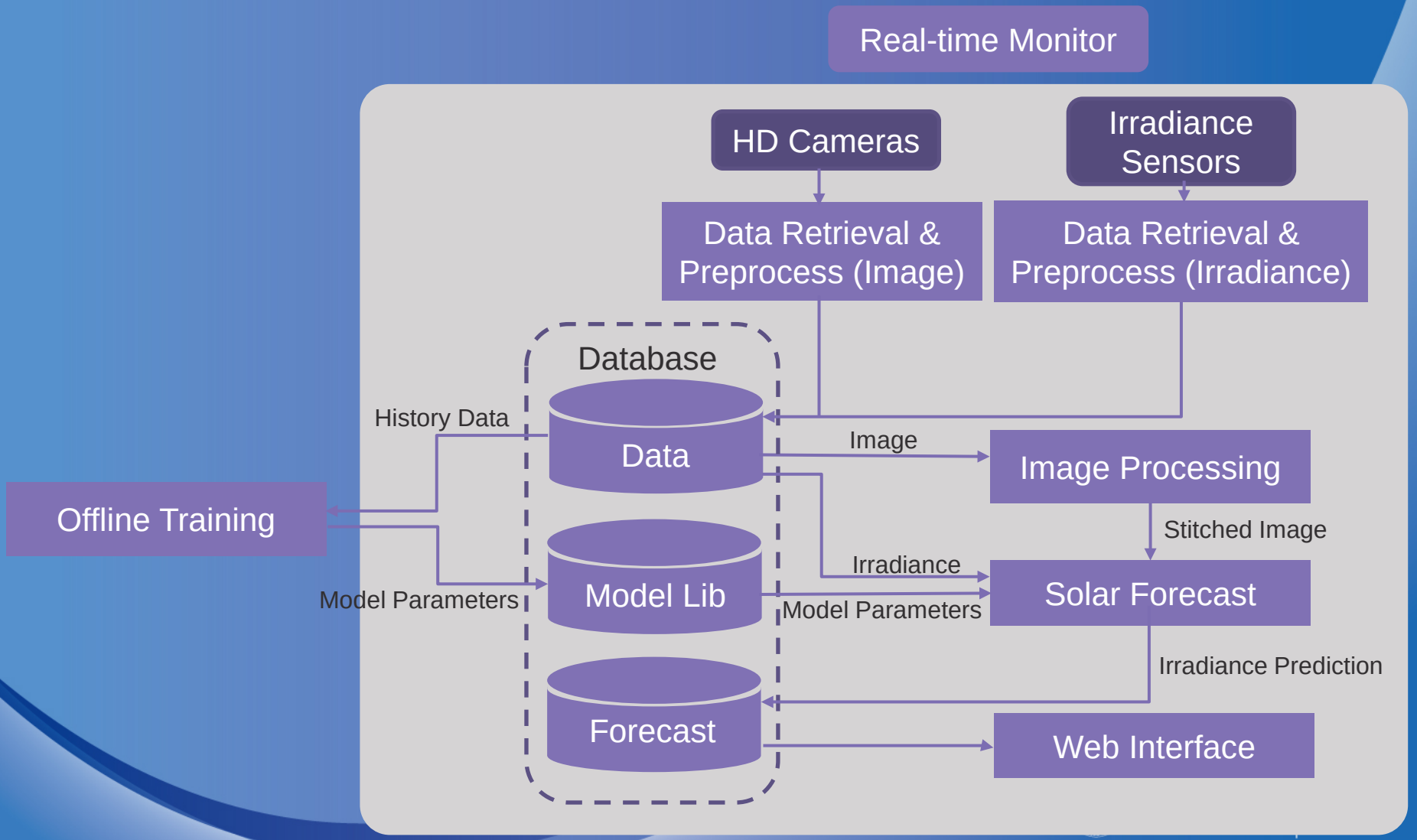
Task 1.3: Data Communication/Collection

Typical HD Sky Imager Output

Task 1.4: Algorithm Development

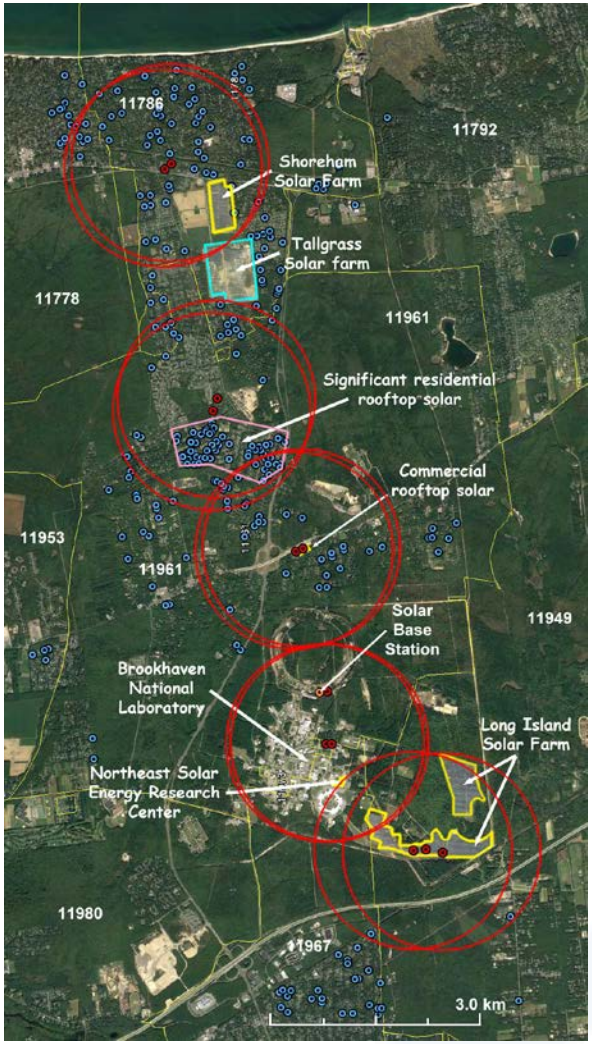
- *Design framework for multi-imager network processing*
- *Modify image processing from old TSI imager format to new HD format*
- *Prepare modules for image stitching/integration of multiple imager networks*

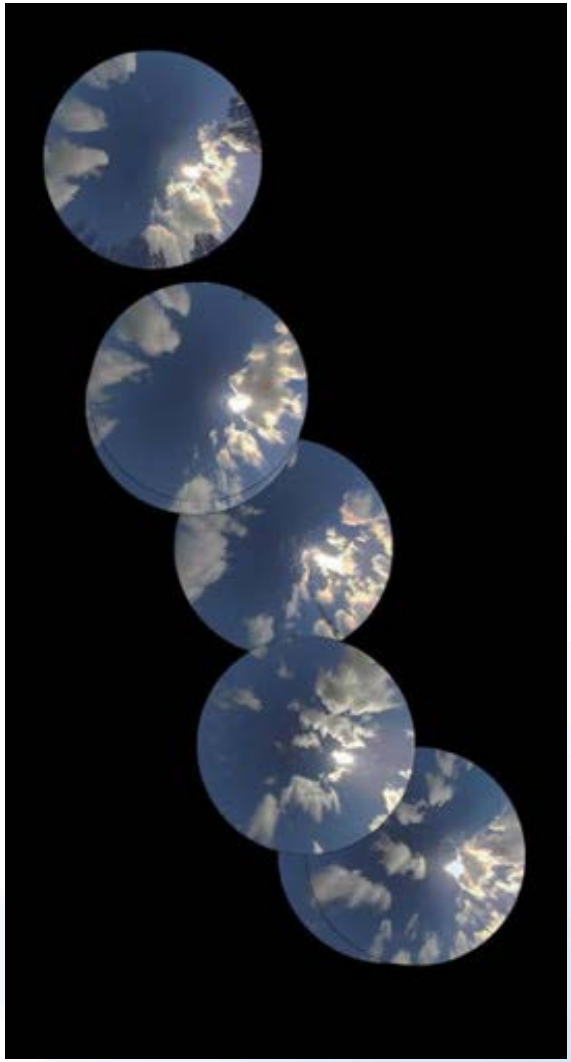
Task 1.4: Algorithm Development



Solar Forecast Framework

Stitched Image for Regional Forecasting





Path Forward

- *At the conclusion of Phase II, feasibility of regional Nowcasting will be confirmed and demonstrated in one 50 sq km region*
- *Additional leveraged support is currently being sought (e.g., from NYSERDA, NYPA, and DOE) for Phase III to:*
  - *Extend to other regions in NYS and facilitate comparison of diverse geographical areas*
  - *Continue the effort to demonstrate effectiveness and accuracy of the approach by operating the networks through a full seasonal cycle*
  - *Expand the distance between networks to determine our ability to accurately interpolate, setting the stage for widespread state-wide deployment*

Discussion/Questions