Enabling Higher Penetration Solar Power in Microgrids

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Workshop on High Penetration Variable Renewables in Pacific Island Countries

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CSIRO ENERGY
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Introduction to CSIRO

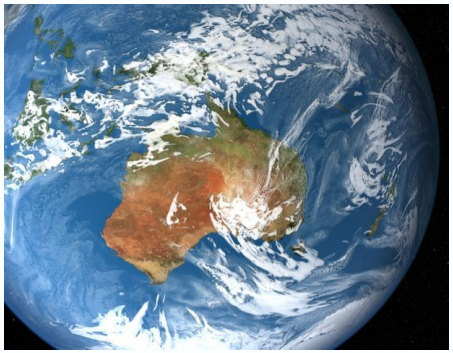
- **C**ommonwealth **S**cientific & **I**ndustrial **R**esearch **O**rganisation
- Australia's national science agency
- Established in 1926
- Over 5000 staff
- Annual budget ~A$1.2B
- 184 companies based on CSIRO IP
- 3500 patents granted or pending
- Currently working on projects in 68 countries
- Our Mission:
  - We deliver great science and innovative solutions for industry, society and the environment

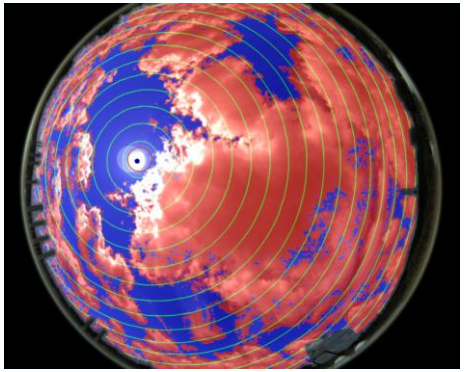
Technical challenges for RAPS systems

- Integration of renewable generation and energy storage – varying costs, technology options
- Balancing demand and generation for maintaining constant voltage and frequency
- Backup mechanisms – for scenarios such as extreme weather conditions or unexpected demand
- Maintenance of renewable power systems
- Scaling up of existing renewable systems – adding new generation or energy management system for example
- Curtailment of renewable generation

What?

- (Very) short-term ground-based solar forecasting for cost-effective integration of higher penetration solar power
- Novel machine vision and machine learning algorithms for image processing and irradiance/power forecasts
- Identifies and predicts local cloud movement and irradiance of 1 – 30 mins ahead, 10s resolution & update





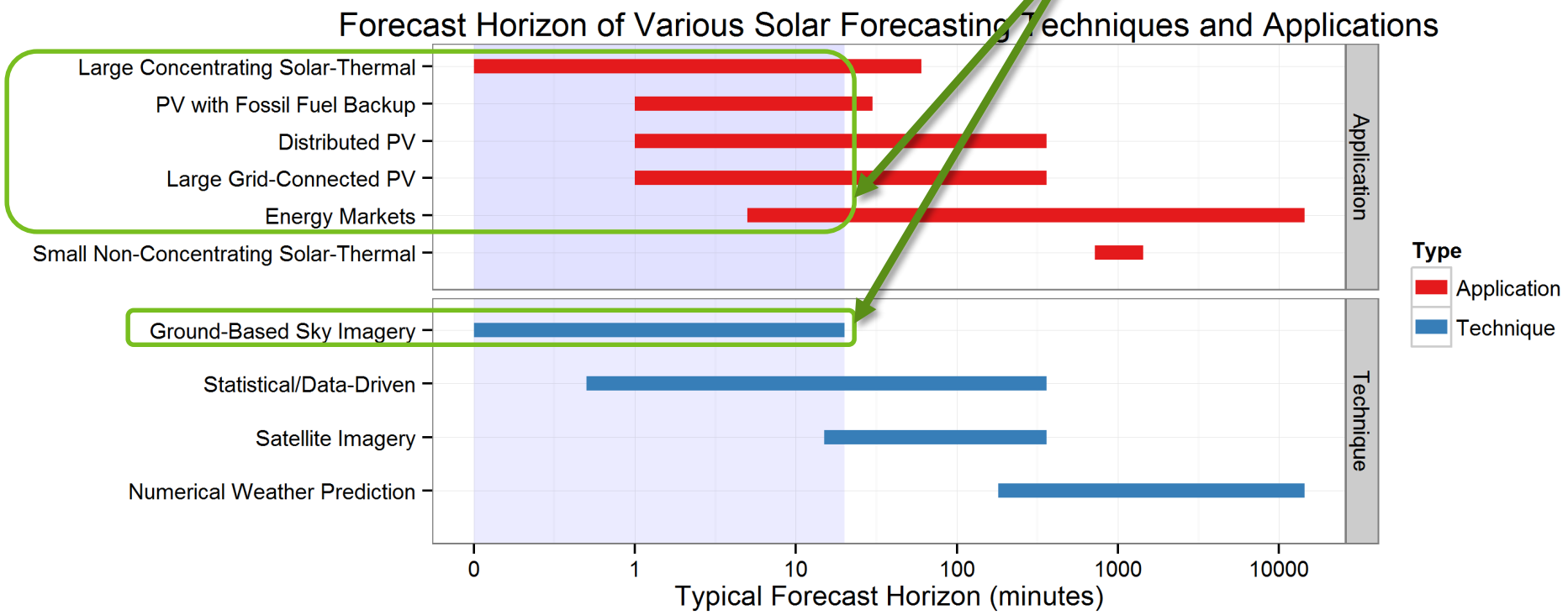
Why? Solar Forecasting Timeframes & Applications

Ground-based imagery (skycam) forecasting is useful for a range of applications

Fast update rate and high spatial resolution

Can forecast cloud movement accurately 1-30 min ahead

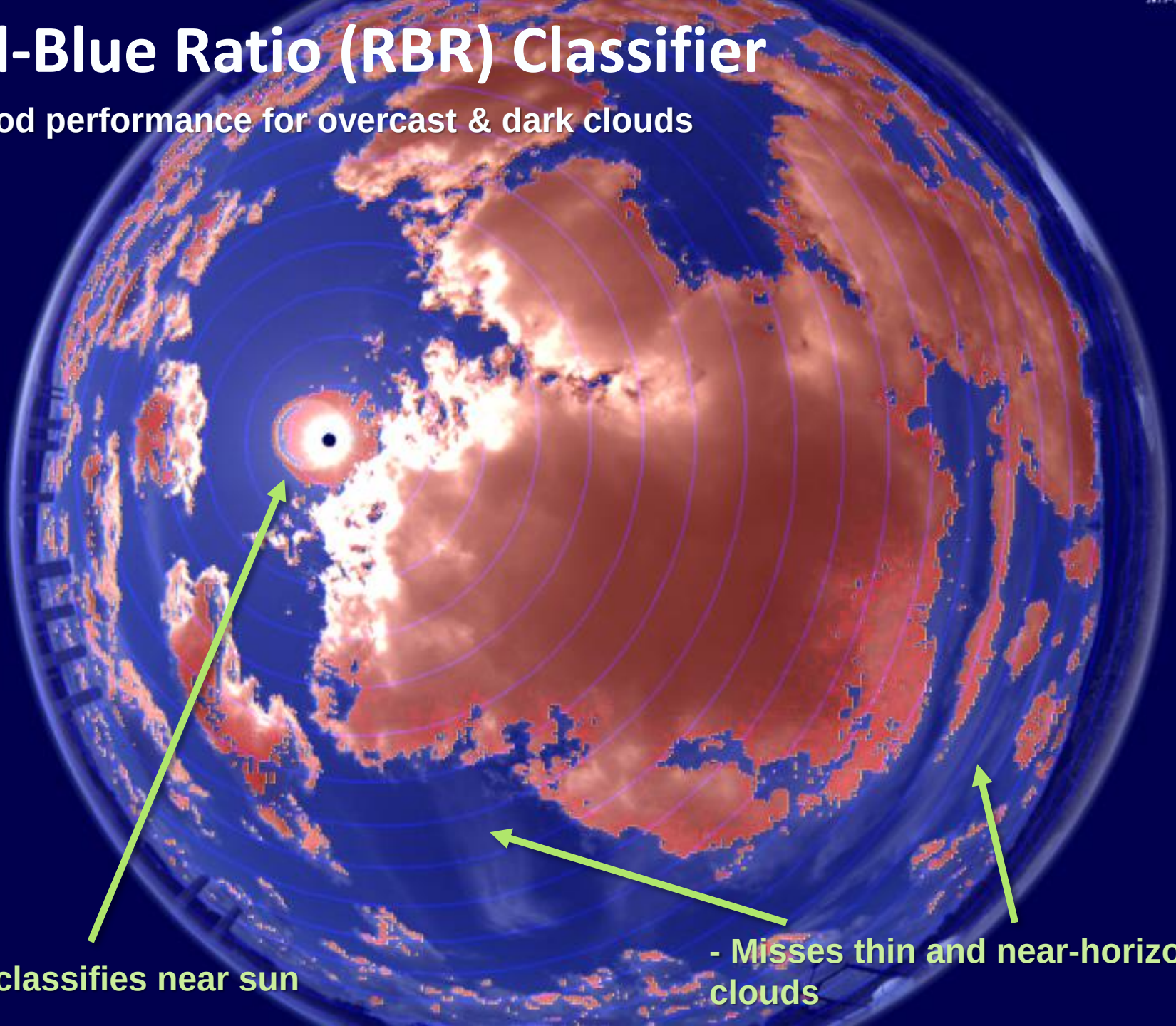
Short-term forecasting is suitable for many applications



Cloud Classification – Unprocessed Image

Red-Blue Ratio (RBR) Classifier

+ Good performance for overcast & dark clouds

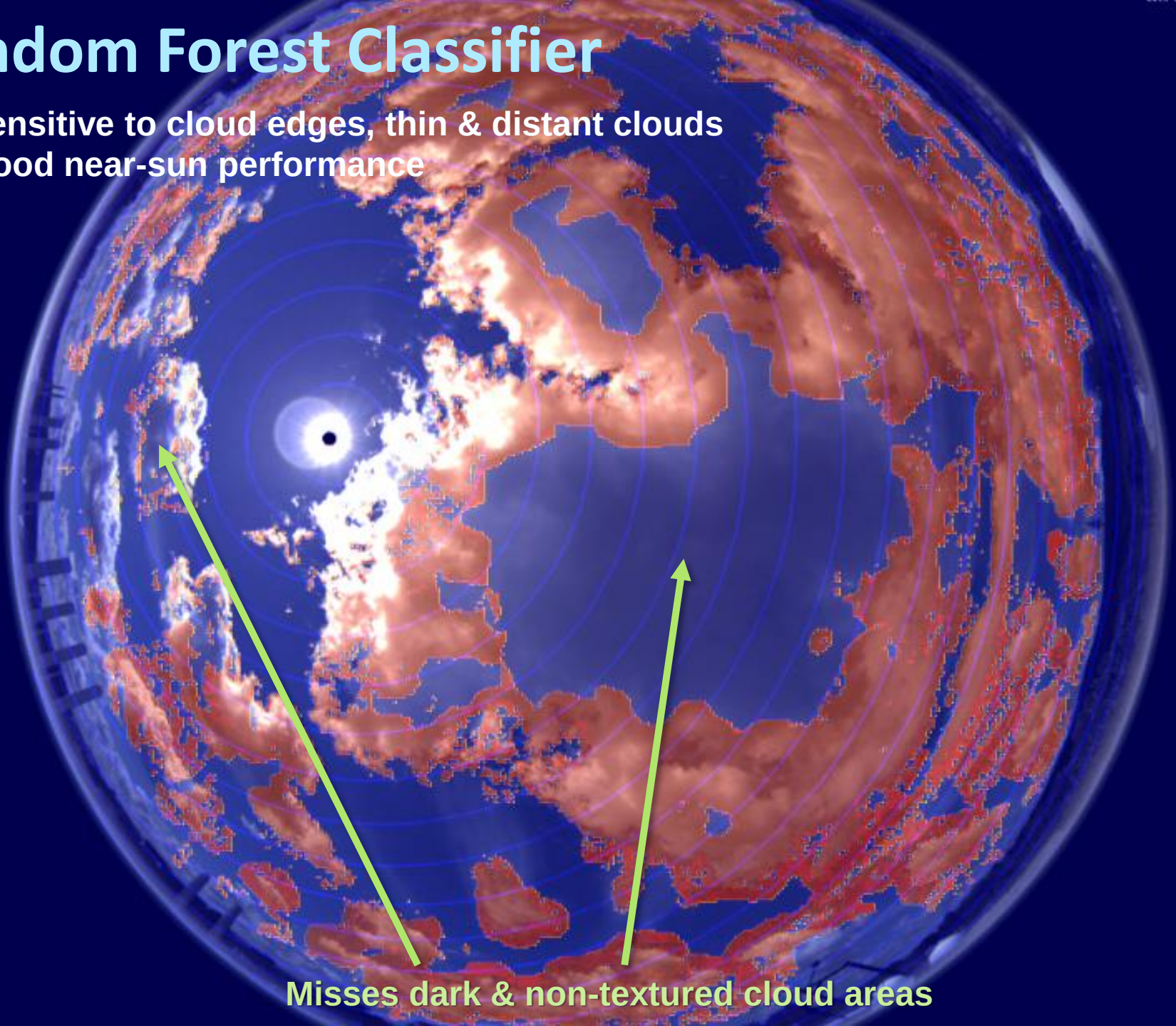


- Misclassifies near sun

- Misses thin and near-horizon clouds

Random Forest Classifier

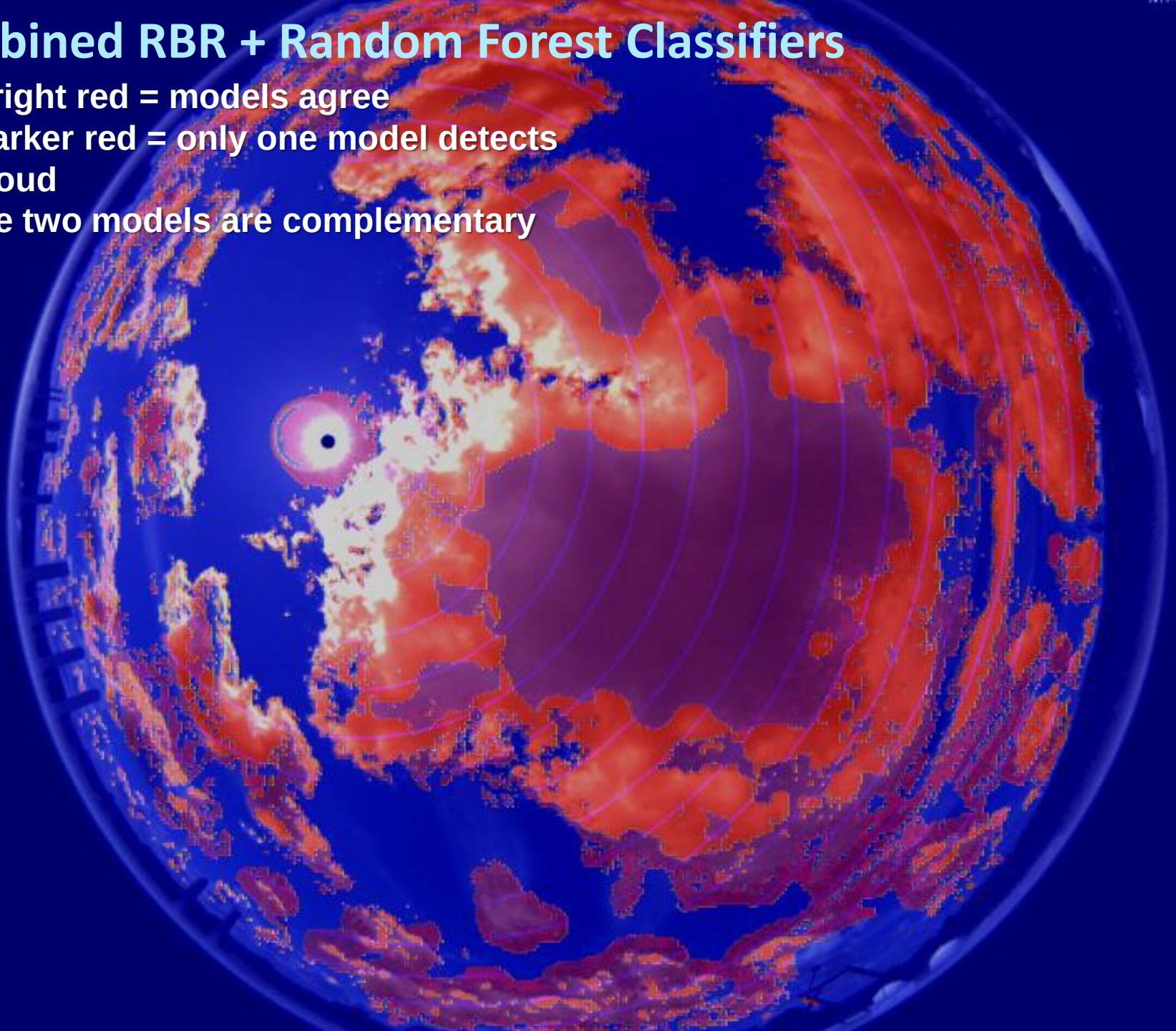
+ Sensitive to cloud edges, thin & distant clouds
+ Good near-sun performance



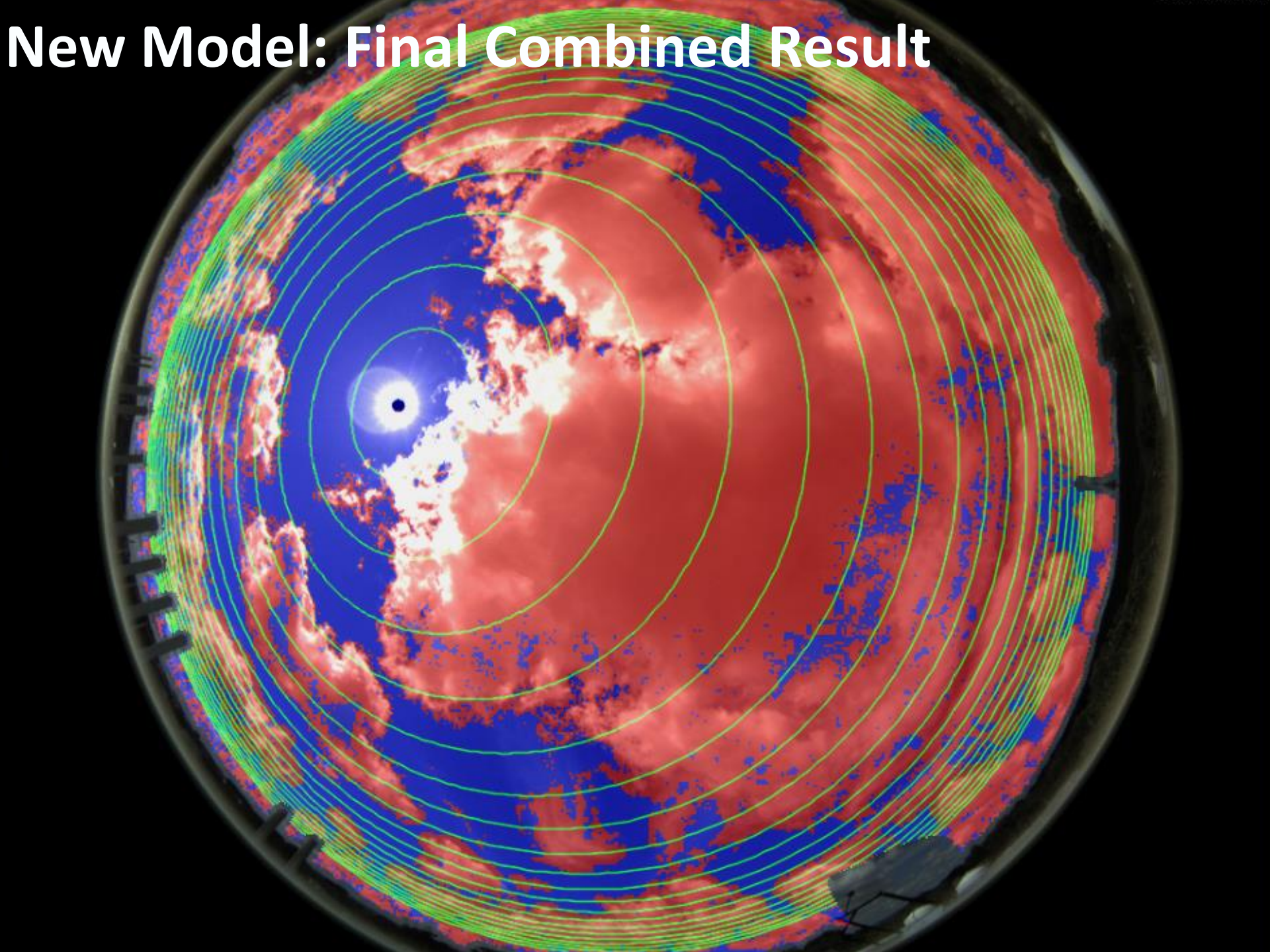
Combined RBR + Random Forest Classifiers

- Bright red = models agree
- Darker red = only one model detects cloud

+ The two models are complementary

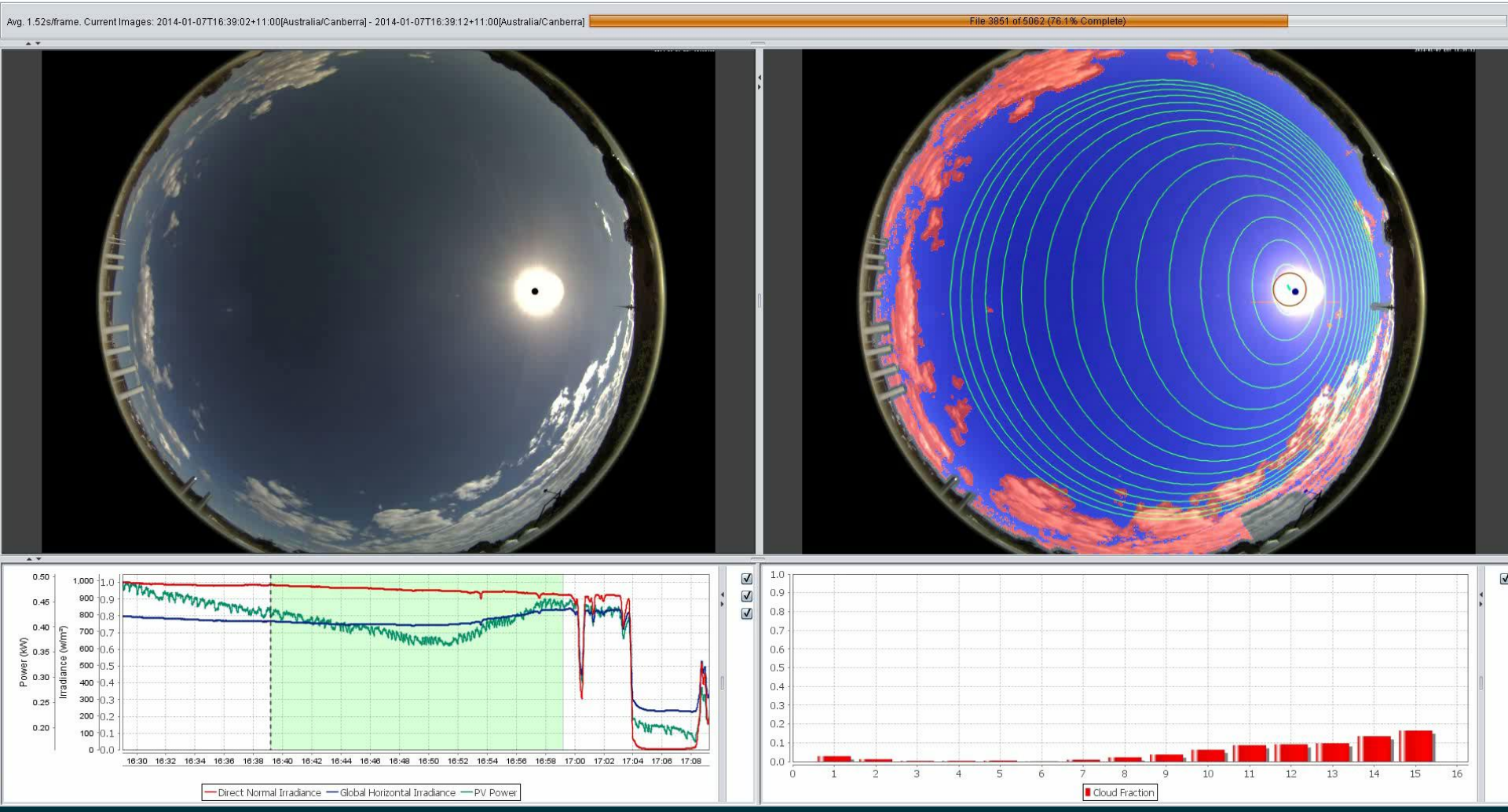


New Model: Final Combined Result



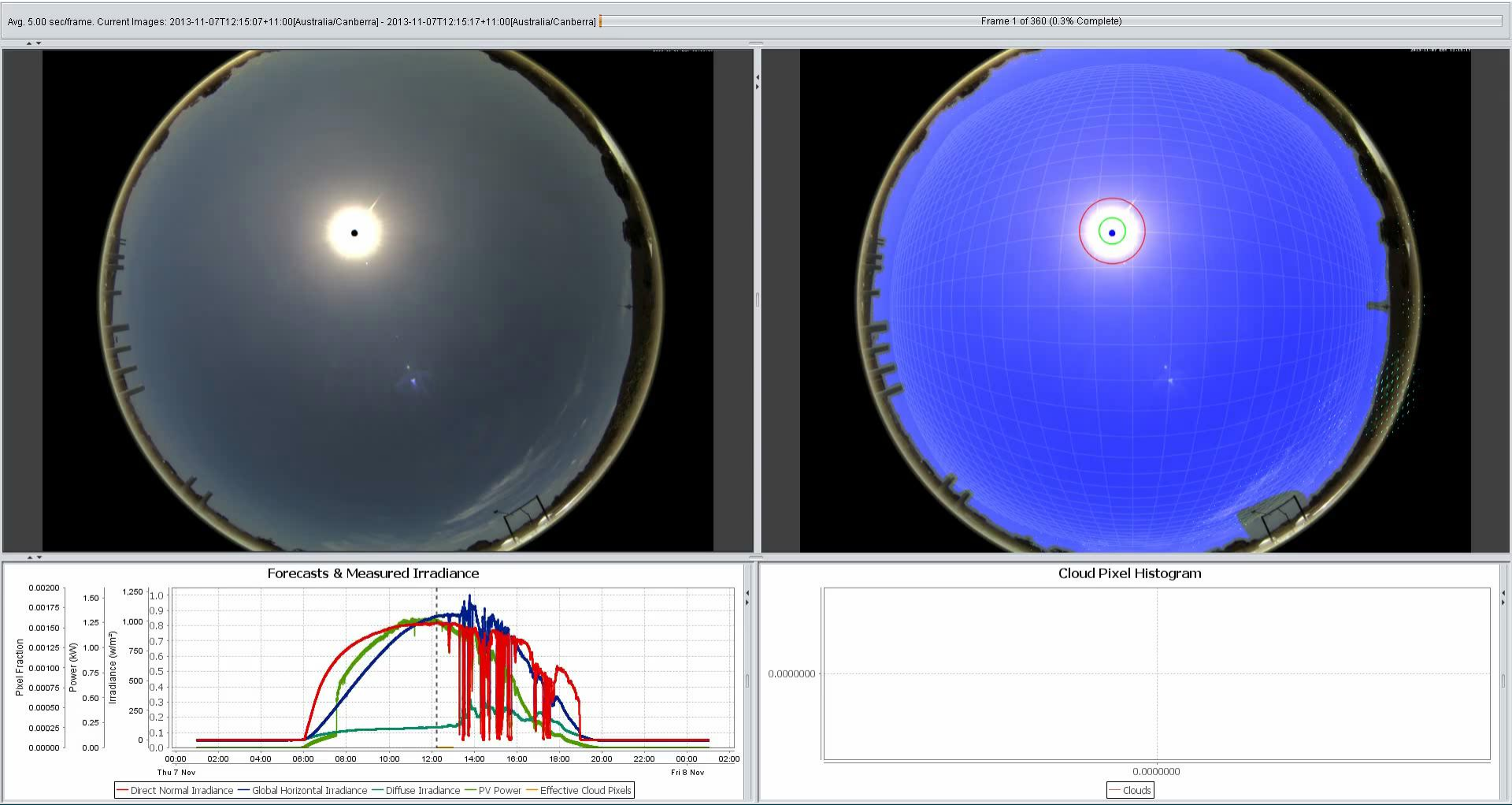
Cloud Presence Detection Demo

- Left chart: *measured* DNI, GHI, PV Power
- Red histogram bars show cloud % in concentric rings around sun
- Sharp increase, ~7 min before gives ample warning of shading event

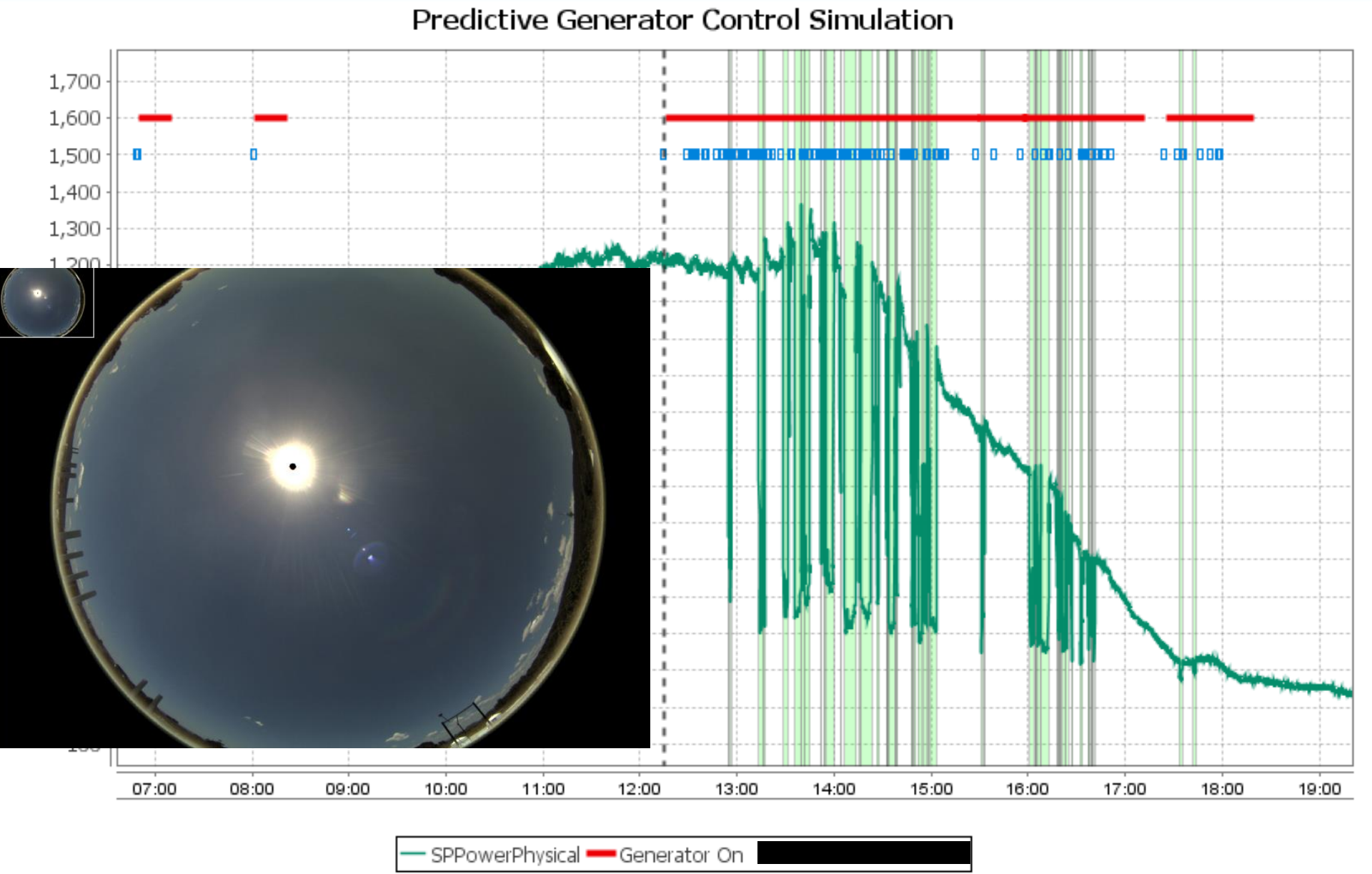


Cloud Motion Vector Forecasting Demo

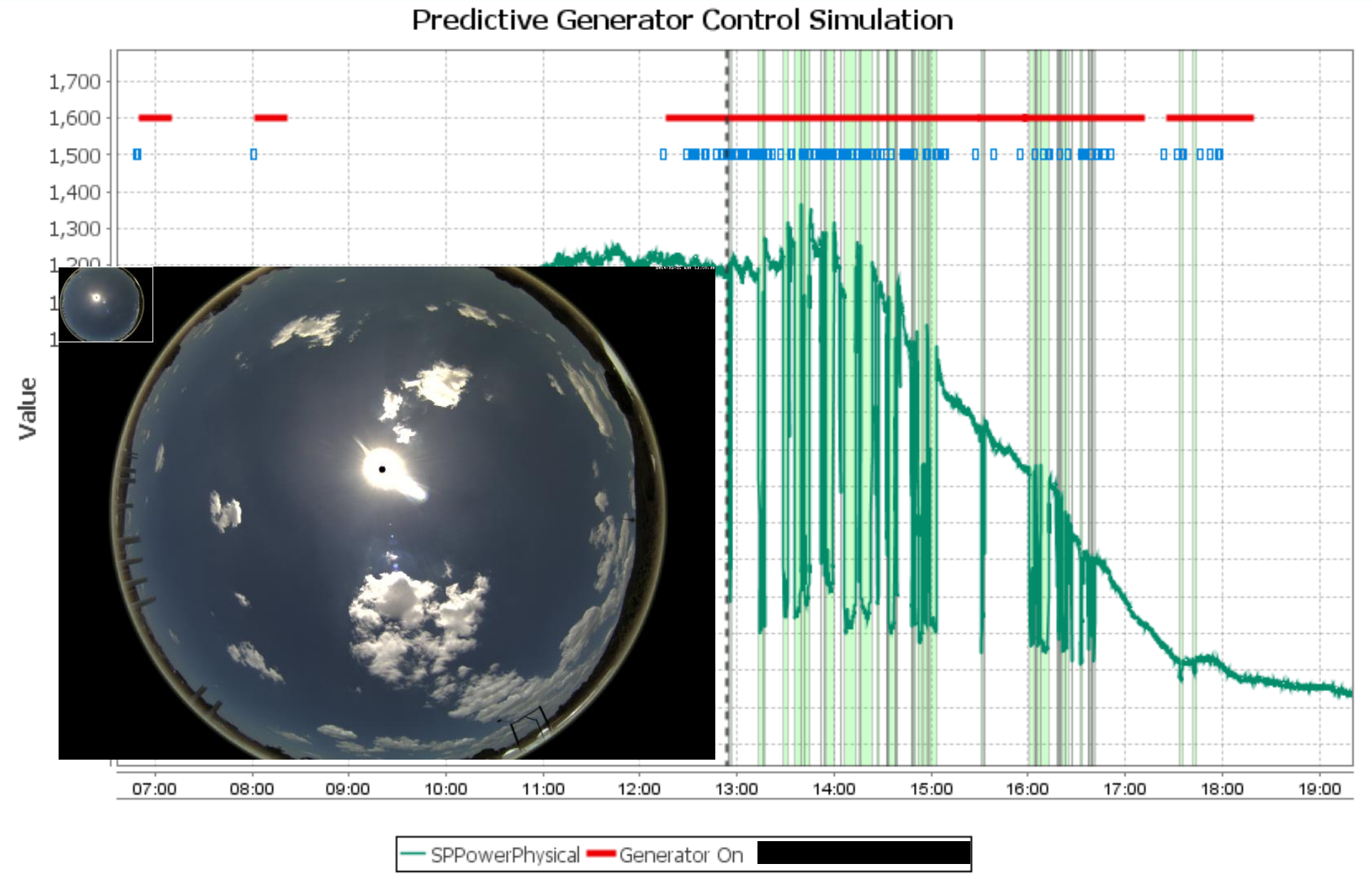
- Clear morning, intermittent afternoon, approaching cloud front
- Detected 25 minutes in advance of shade event
- Left chart: *measured* DNI, GHI, Diffuse, PV Power, and *forecast* Cloud Pixel Fraction



Shade Event Prediction for Generator Control



Intermittent Day: Shade Event Prediction



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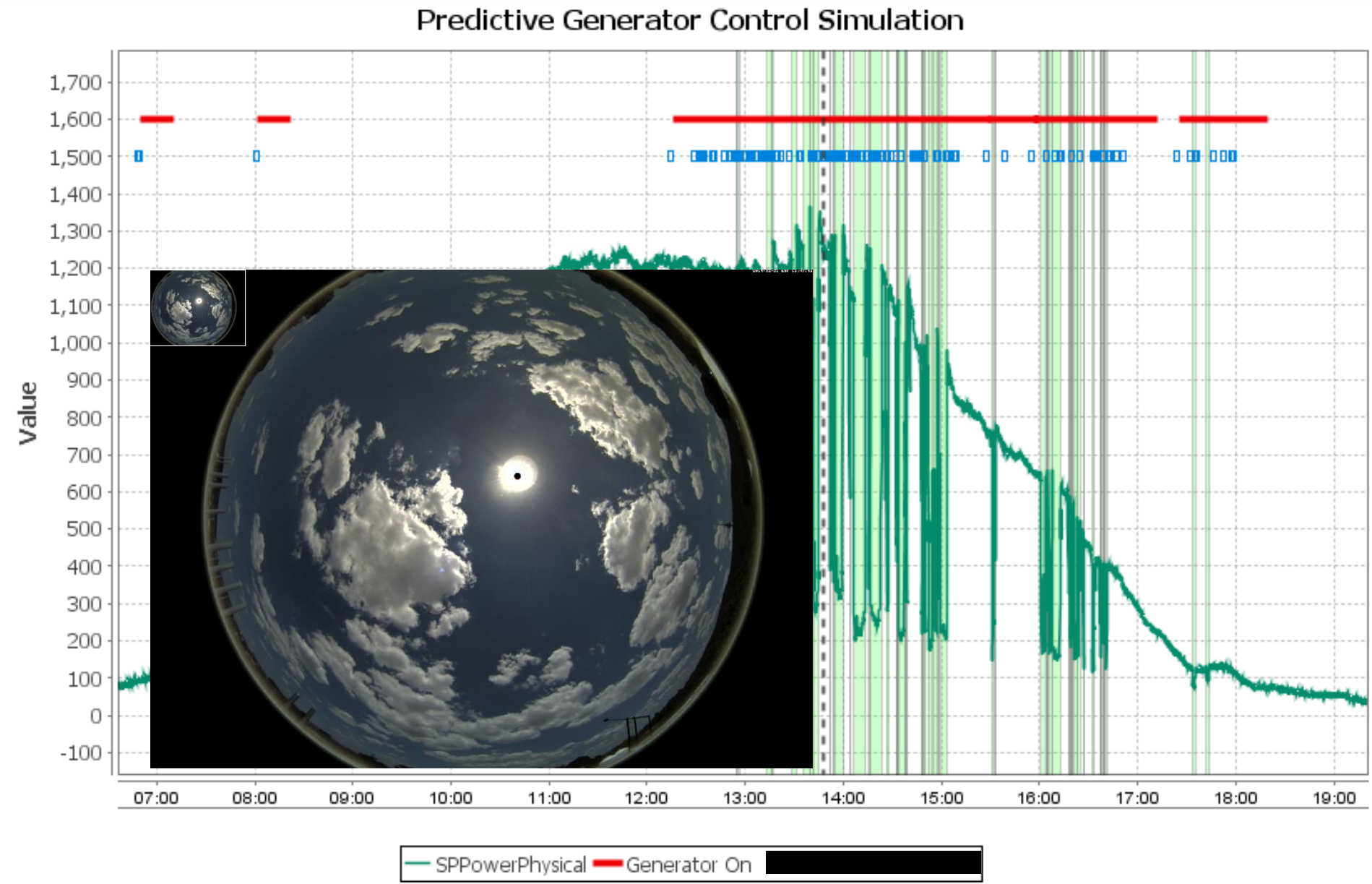
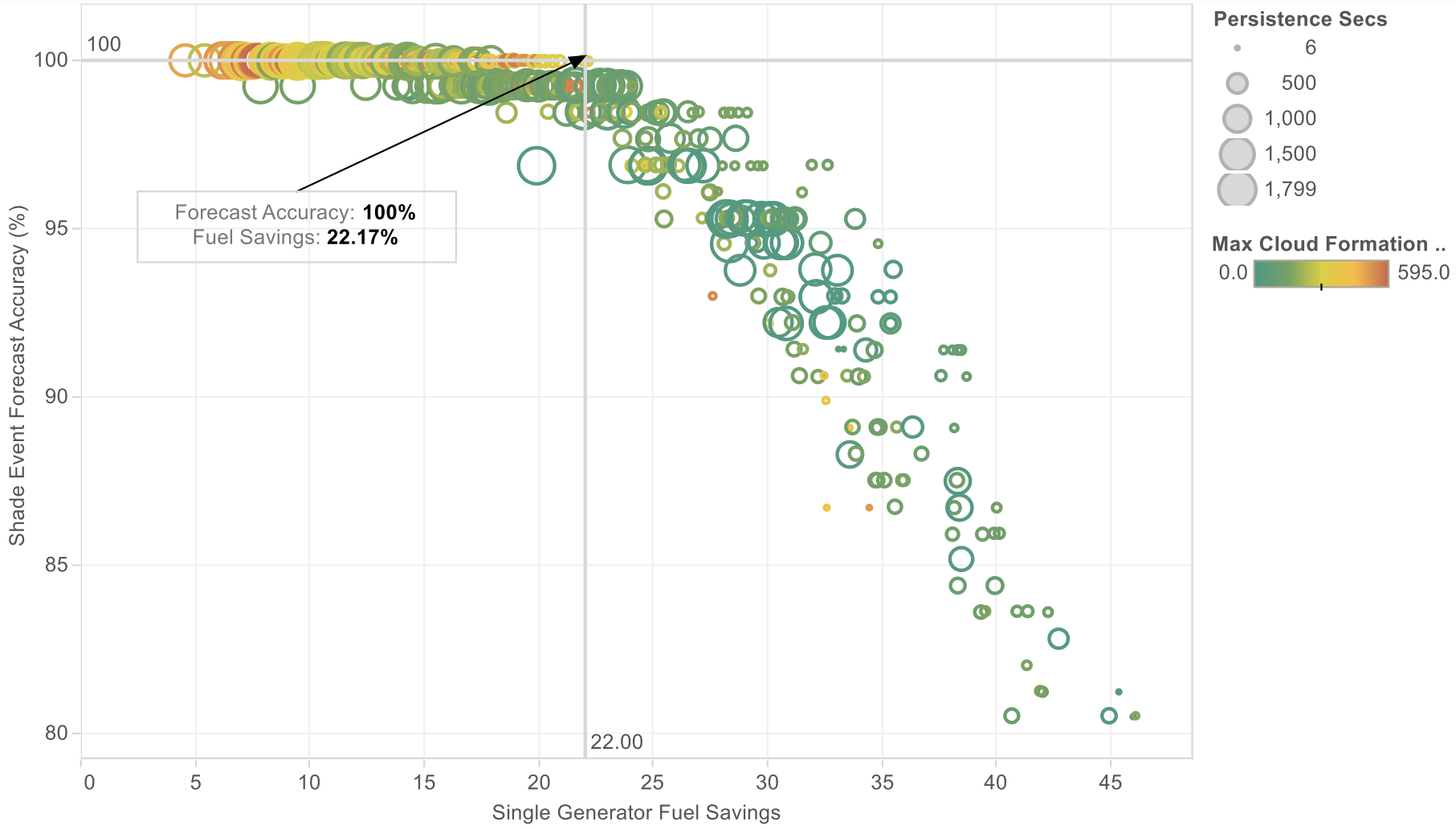


12-Month Predictive Diesel Control Simulation



Trial conducted

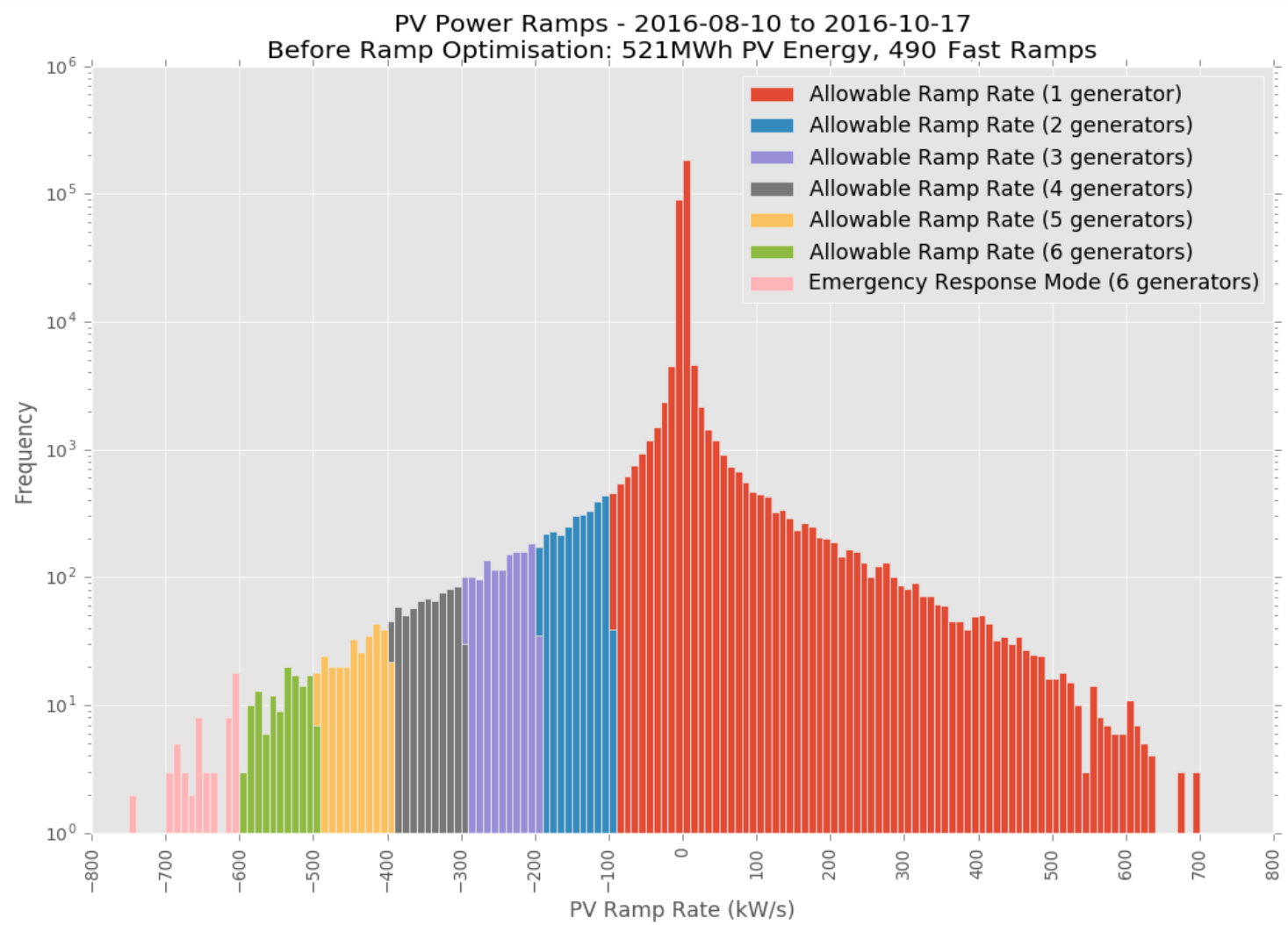
Site: Weipa, Queensland

- 1.2MW PV
- 6 X 4.5MVA diesel generators
- No energy storage

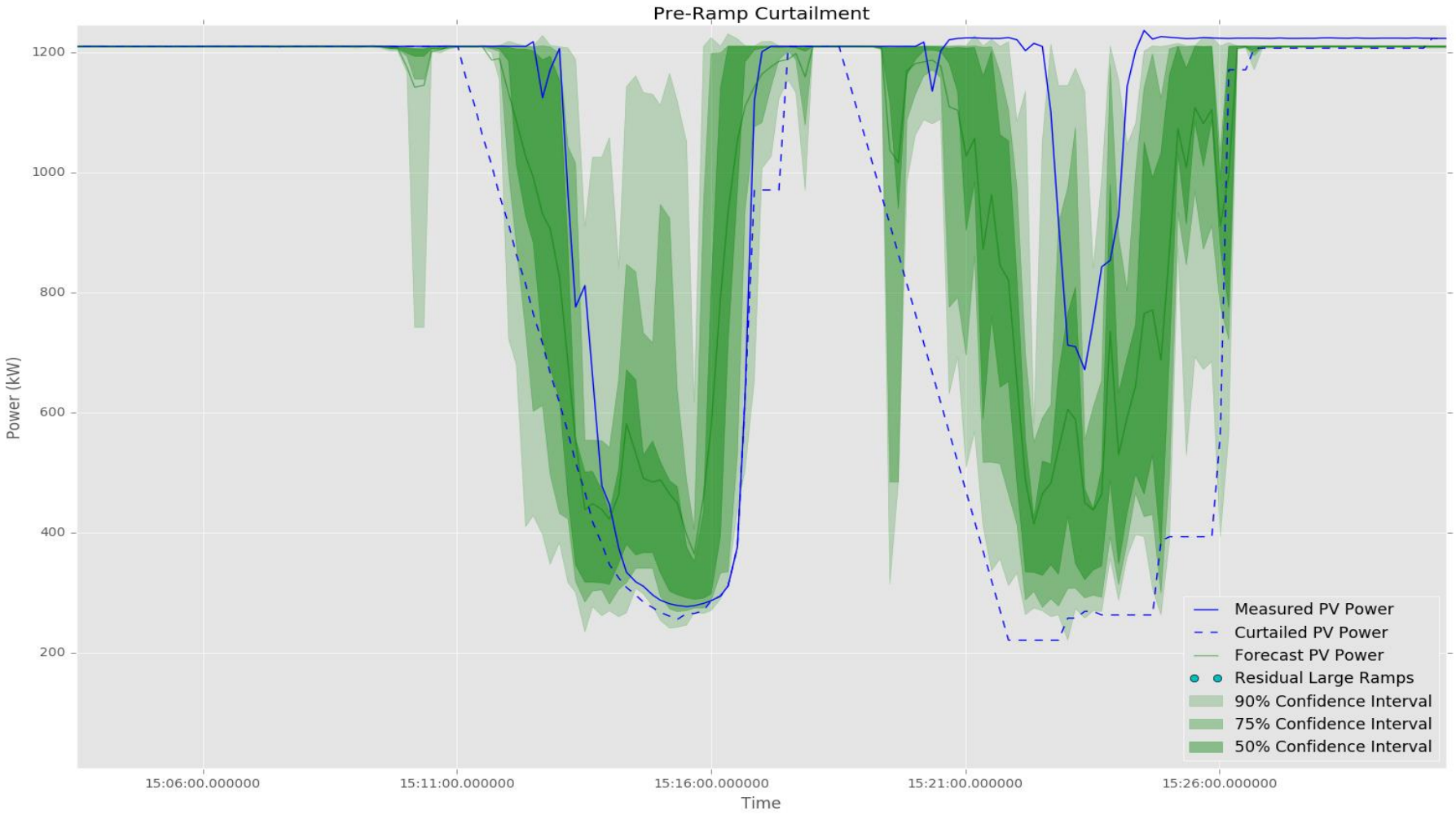
Data collected:

- Skycam images (every 10s)
- PV system output (every 5s)
- Diesel generation (every 5s)
- Network (every 5s)

PV output power ramps



Solar forecasting to reduce ramp rates



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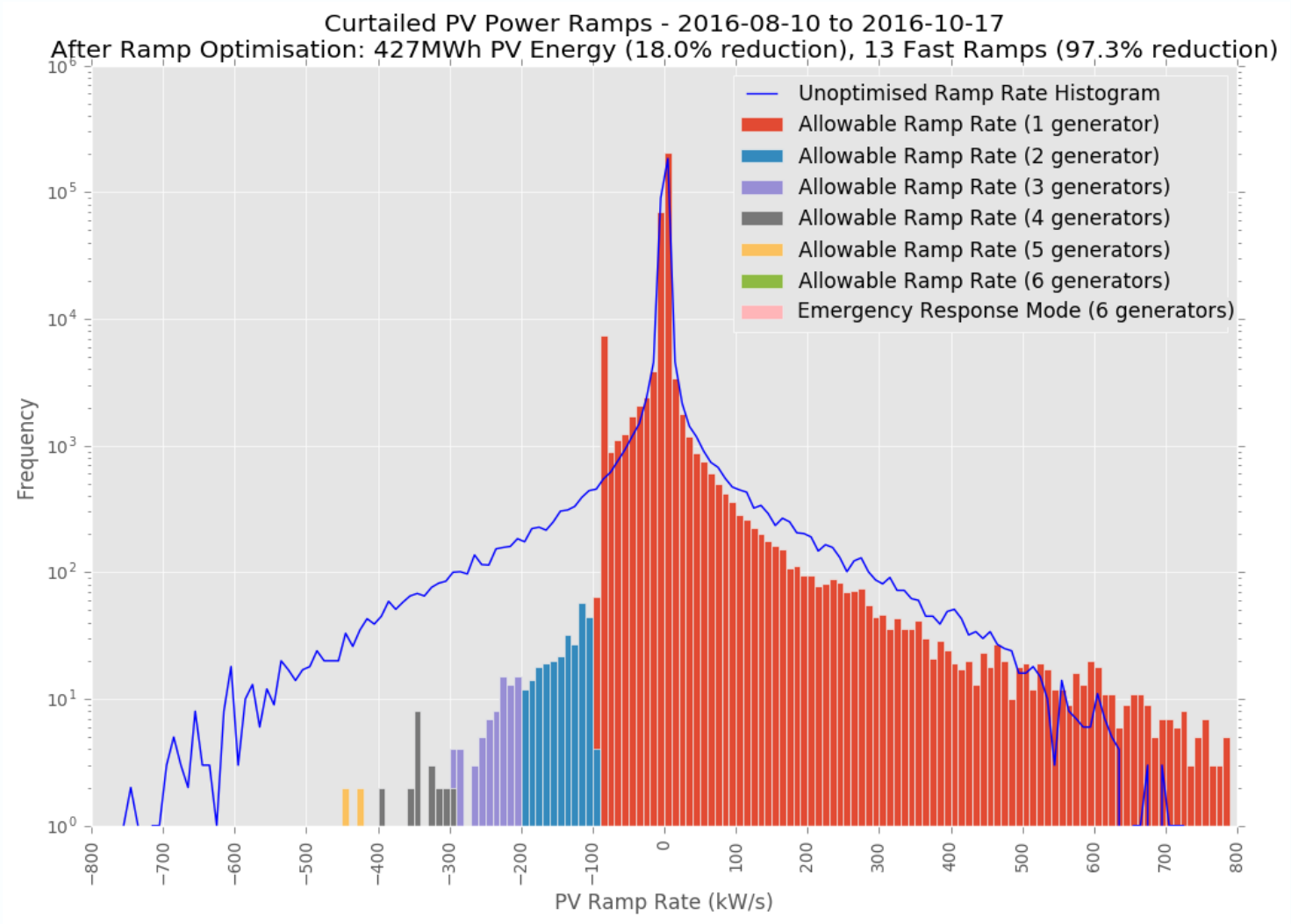
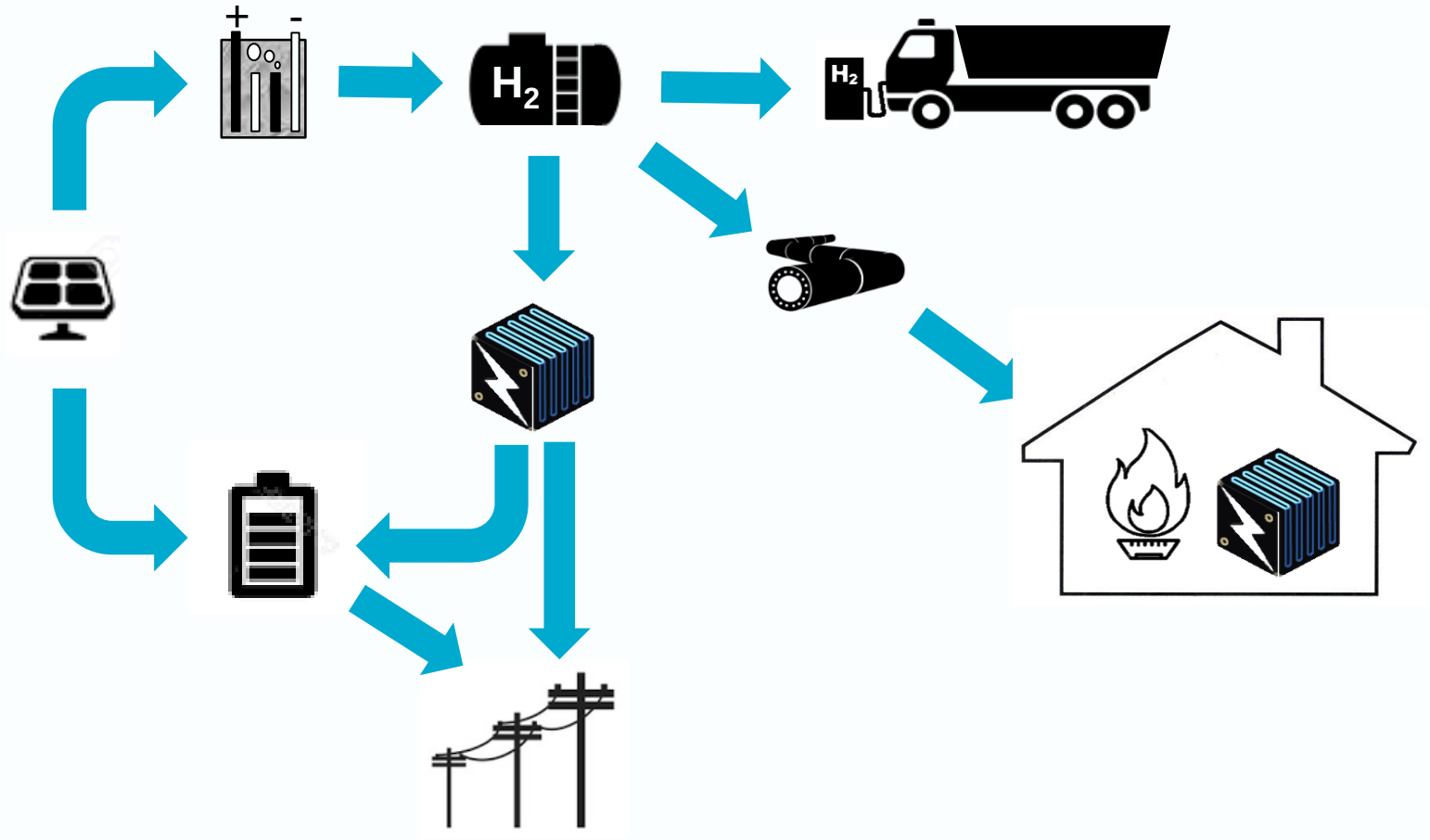


The Product – in the field

Hydrogen-based RAPS options



Conclusions

- Solar forecasting is needed for cost-effective integration of high-penetration solar power in microgrids
- Algorithms developed were able to forecast solar power variability to an extent that reduced the number of high ramp events by 97% (from 490 to just 13 events during the test period)
- Higher penetration of solar can be achieved without the need to upgrade existing diesel generator set to compensate for high ramp rate events
- May lead to the reduction of wear and tear on generators, leading to increased time between required maintenance, resulting in financial savings

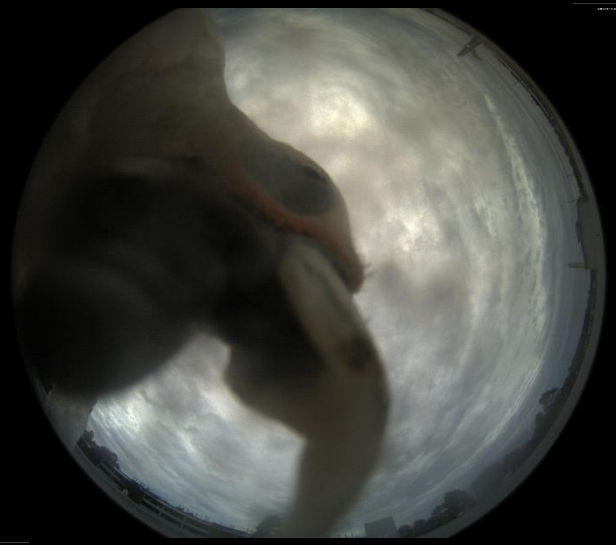
What do we need to do better?

- Develop more cost-effective ways of integrating various generation, storage and load control devices
- Obtain better understanding of the challenges for deployment and maintenance of renewables-based microgrids

What support is needed?

- High-quality high-resolution operational data
- Detailed cost data taking into account remoteness factor
- Information on challenges faced by PIC Utilities and Governments for higher penetration VRE integration

Other applications: Vandal Detection!?



Thank You

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