Turning **insight** into **action**.

OSIsoft. USERS CONFERENCE 2011

Short-term Solar Forecasting

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Agenda

- Value of Solar Forecasting
- Total Sky Imagery for Cloud Tracking
- Solar Forecasting Results
- Integration with OSIsoft Products

About UC San Diego's Microgrid

- 42 MW_p costumer microgrid
- 12 million ft^2 of buildings
- Self generate 82% of annual demand
  - 30 MW natural gas Cogen plant
  - 2.8 MW of Fuel Cells contracted
  - 1.2 MW of Solar PV installed, additional 2 MW planned

Business Challenge/Problem Addressed

- NREL / GE Western Wind and Solar Integration Study:

Use of state-of-art wind and **solar forecasts reduces WECC operating costs by up to 14%, or $5 billion/yr**, as compared to not using wind or solar forecasts for day-ahead unit commitment ($12-20/MWh of wind and solar generation). WECC operating costs could be reduced by an **additional $500 million/yr in the 30% case if wind and solar forecasts were perfect**.

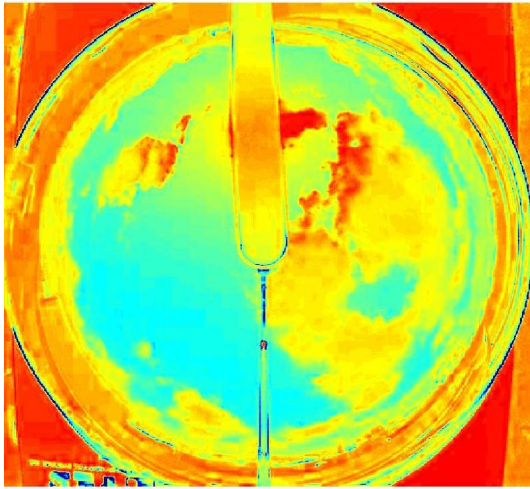
Background

- Solar photovoltaic output nearly linear with irradiance
- Day-ahead solar forecasting using numerical weather prediction
- Hour-ahead: satellites

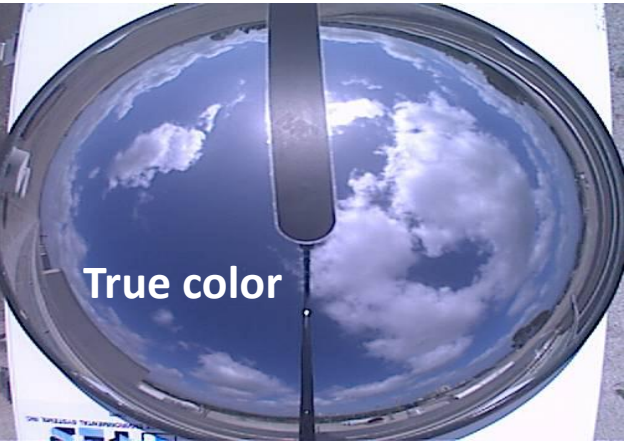
Challenge/Problem Detail

- Most clouds are unresolved in numerical weather prediction or satellite models
- Time interval for satellite imagery is 15 to 30 minutes

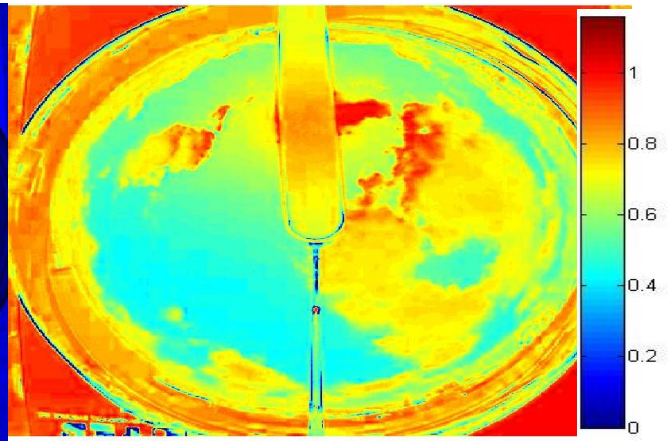
Solution: Total Sky Imager



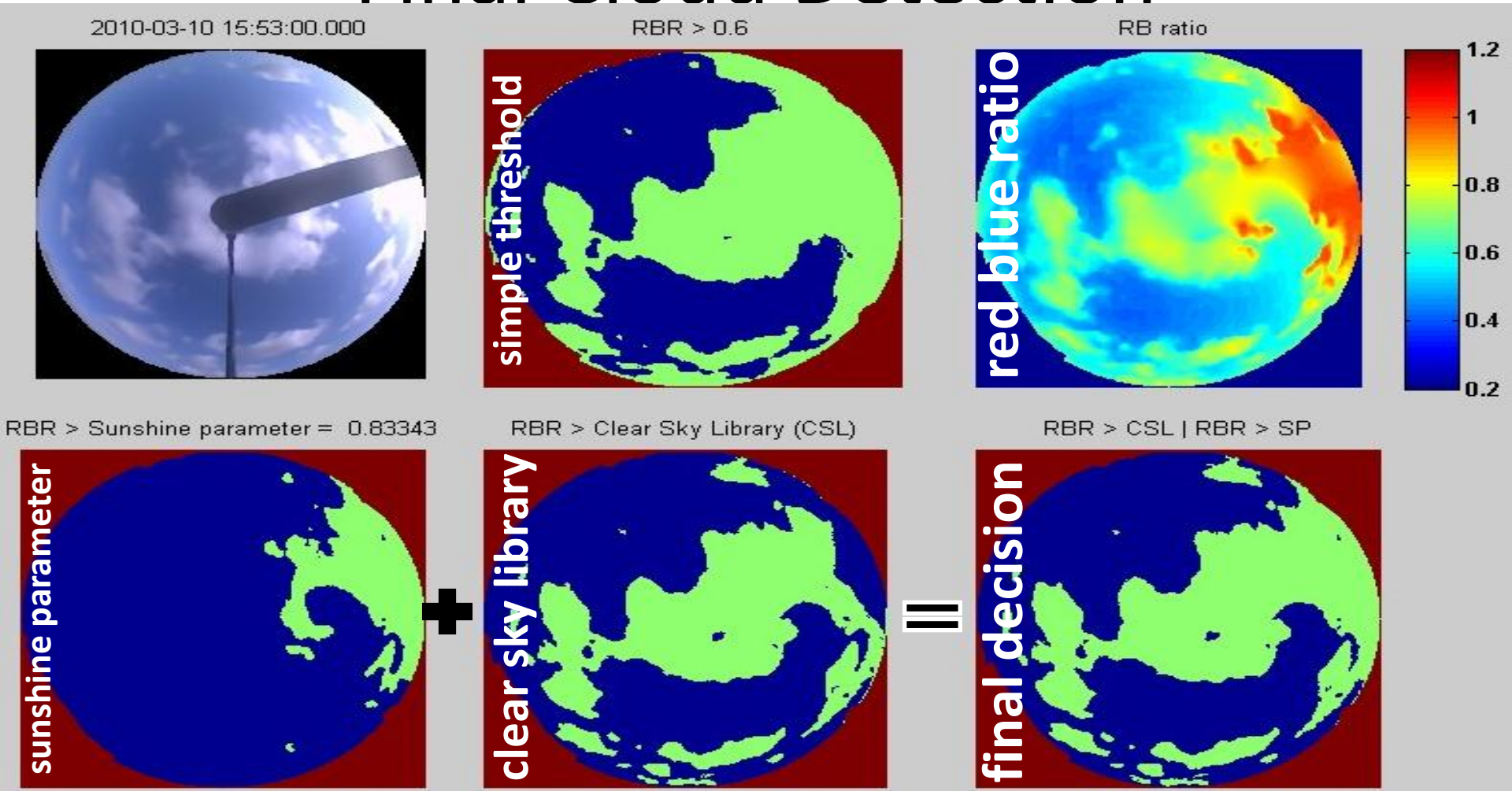
Automated Cloud Decision Algorithm:



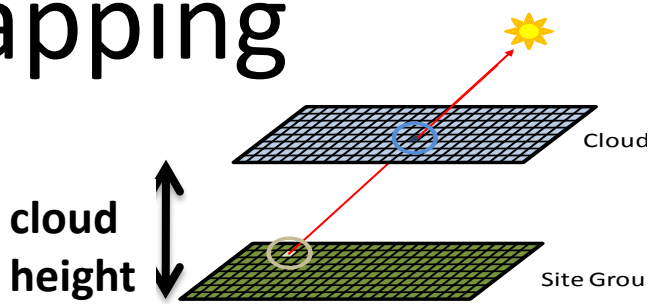
- Clear sky scatters shorter wavelengths (strong signal on blue channel, weak on red channel)
- Clouds scatter the visible wavelengths more evenly
- Ratio of red and blue channel provides information for cloud detection

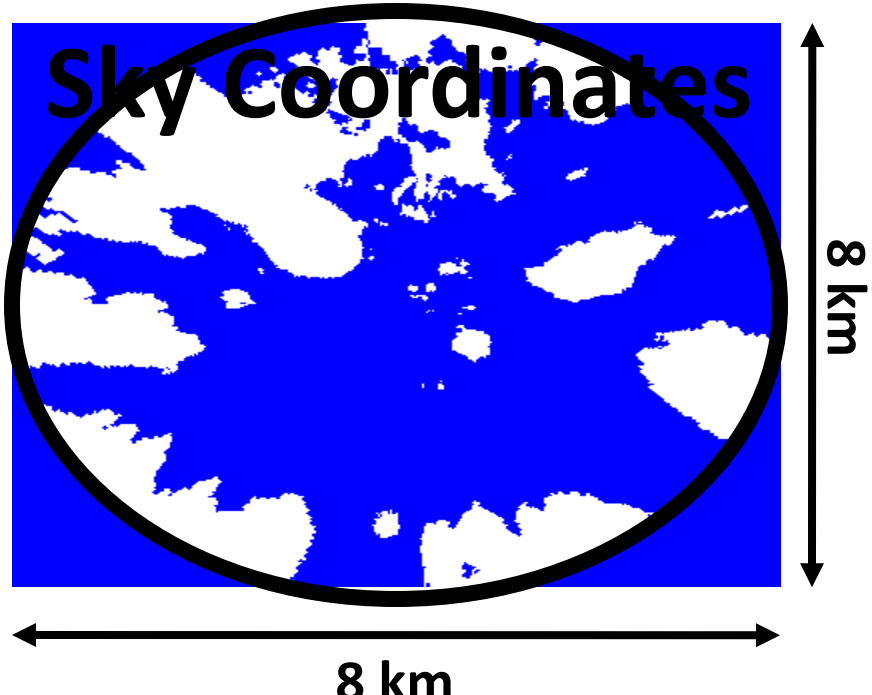


Final Cloud Detection



Cloud Mapping



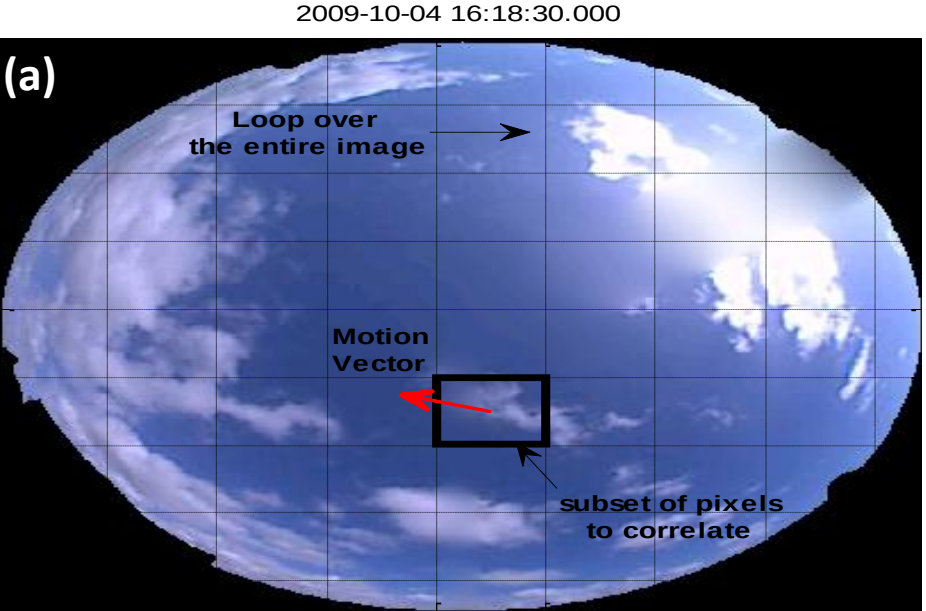


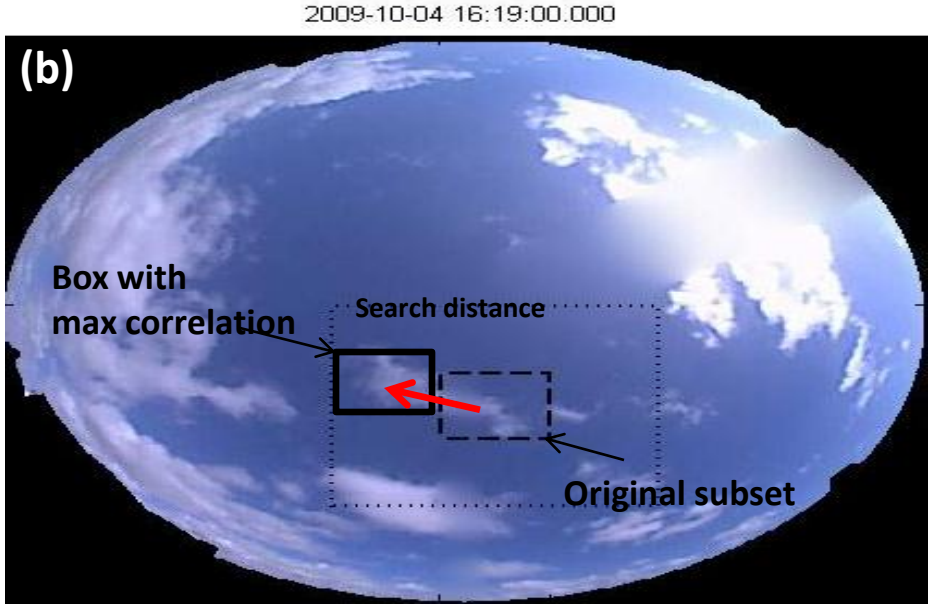
Cloud height ~ 1050 m

Cloud Tracking

Cross-correlation method

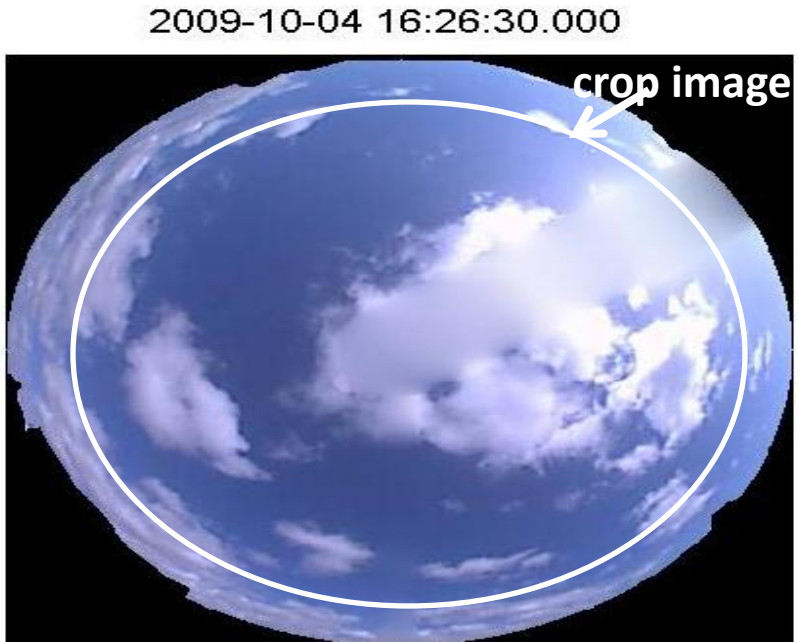
Using 2 images taken 30 sec apart, a region of pixels from (a) is correlated to (b) within a search distance. The location of the highest correlation is found and a motion vector is defined.

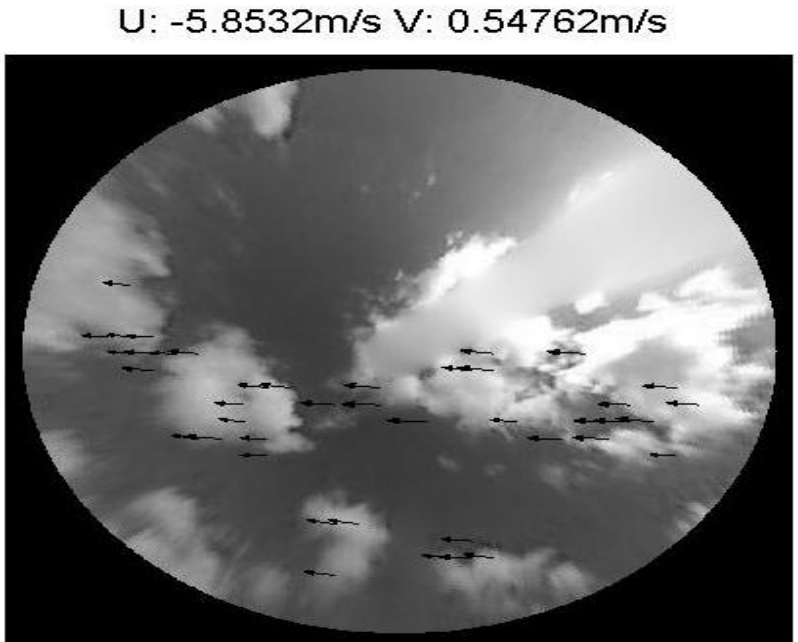




Cloud Motion Vectors

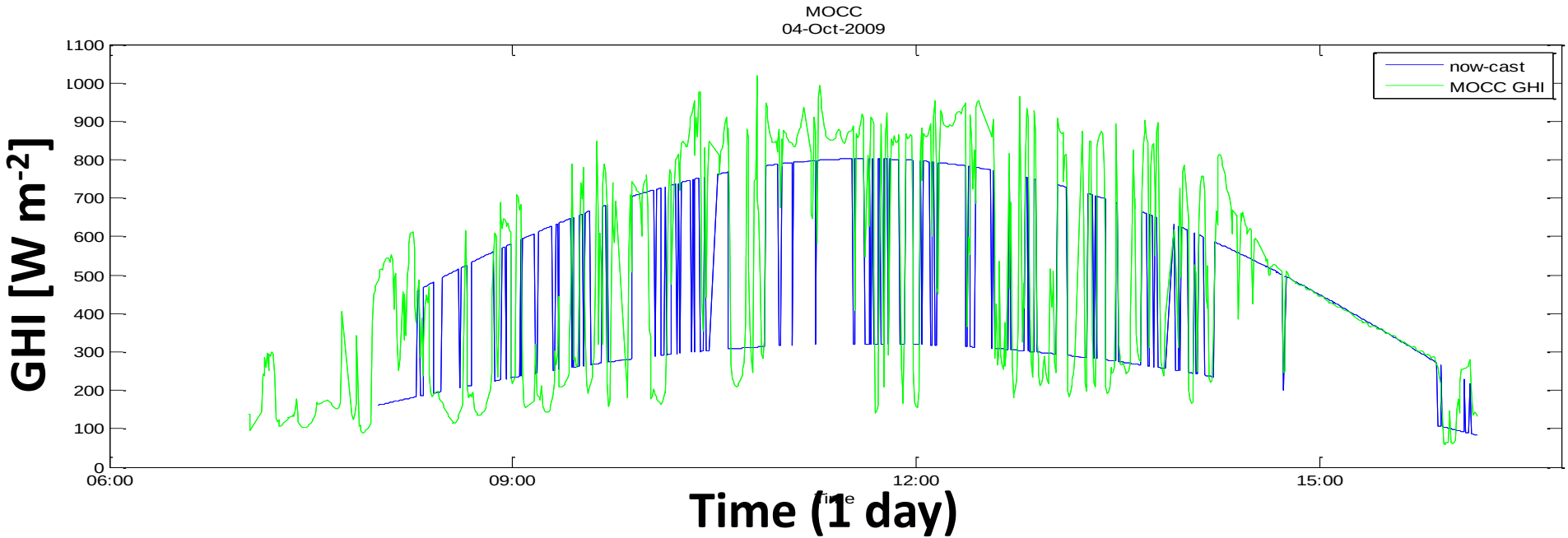
- Apply cross-correlation method
- Retain only vectors for which high correlation is obtained
- Assume homogeneous cloud velocity





Nowcasting results

- Movie
- Problems in the morning when shadowband covers sky over site
- Very good agreement in the afternoon



Nowcast results

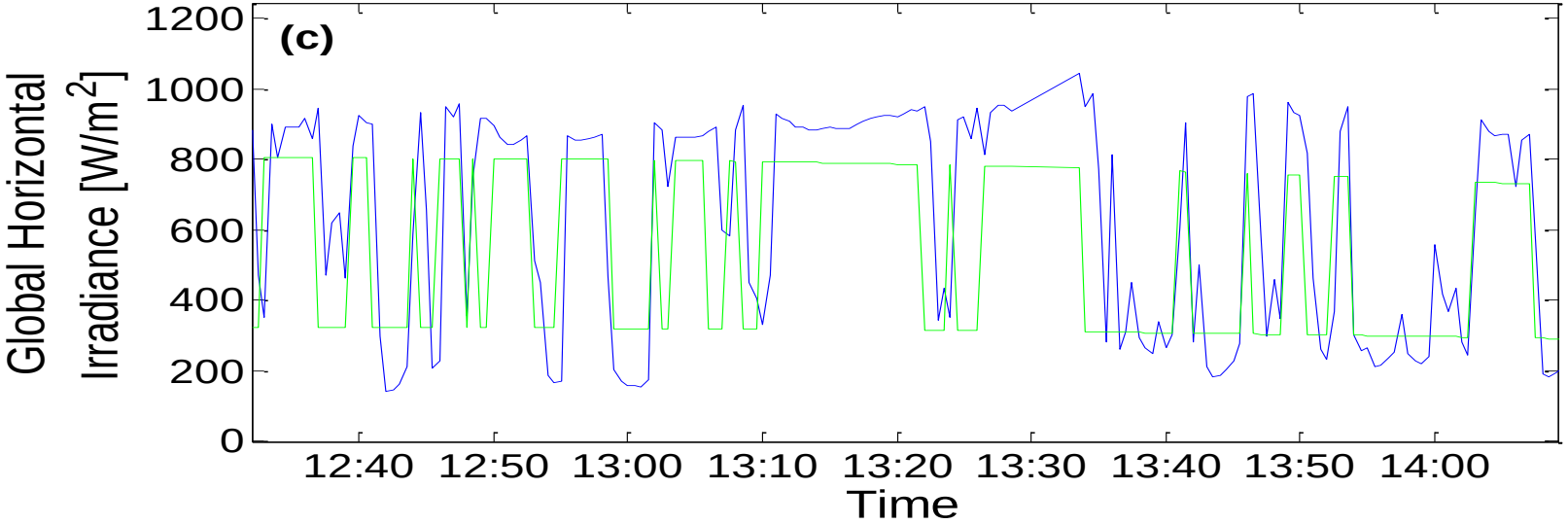
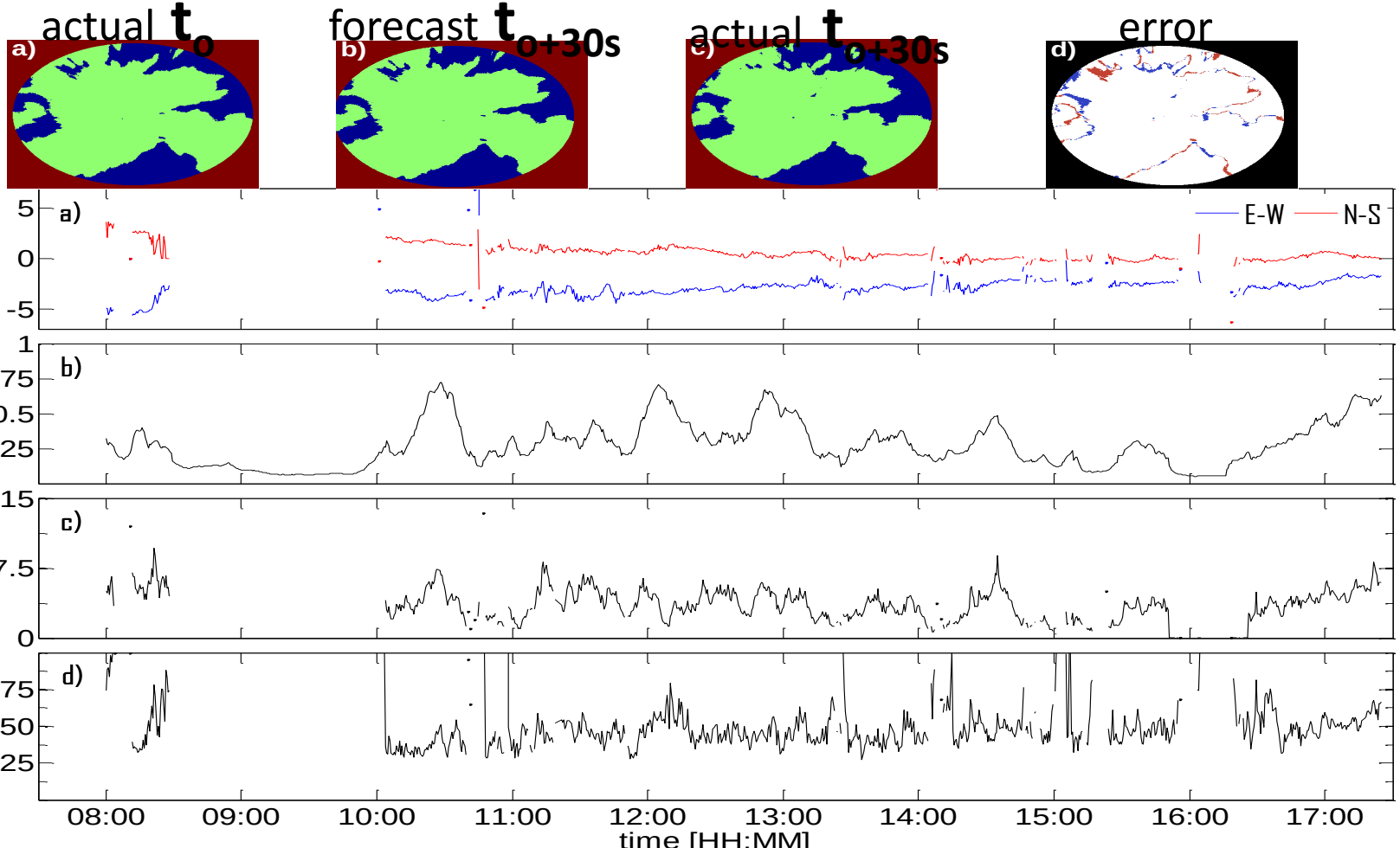


Table 5 Percentage co-occurrence of clear and cloudy conditions for measured/nowcast.

	CLR/CLR	CLR/CLD	CLD/CLR	CLD/CLD
September 14, 2009	56.1	20.6	8.1	15.2
October 4, 2009	55.2	9.9	3.2	31.7
March 4, 2010	59.2	18.3	7.8	14.6
March 10, 2010	54.2	12.8	4.2	28.9
Total	56.1	17.3	6.7	19.9

30 sec Forecast



1 to 5 minute forecast

Mean total matching error and total cap error for 30-sec to 5-min ahead forecast. Since errors during overcast and clear conditions are zero, the errors in the table are biased high.

	30 sec	1 min	2 min	3 min	4 min	5 min	Time until advection out of scene [min]
	e_{cap} [%]						
Sept 14, 2009	45.0	51.5	63.9	70.0	76.5	123	4 - 27
Oct 4, 2009	47.2	49.8	55.6	61.5	66.6	70.3	8 - 18
Mar 4, 2010	54.6	55.3	59.3	63.4	67.7	71.8	9 - 24
Mar 10, 2010	48.8	53.9	62.3	68.8	75.1	78.0	9 - 15

Error increases with forecast horizon, but 25% better than persistence after 5 minutes.

After 10 to 25 minutes the scene is advected out of the field of view.

Conclusions

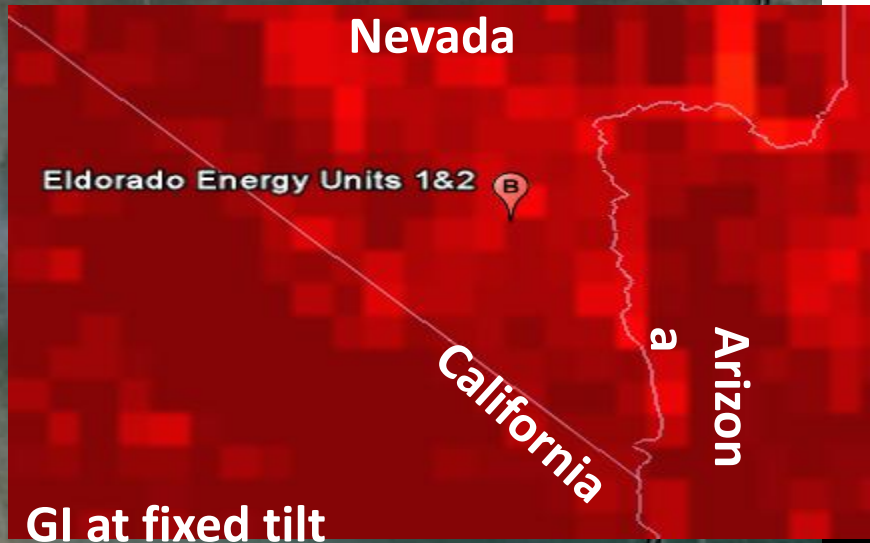
- Solar variability analysis tools developed
  - Quantify variability for different array sizes and geographic layout
  - Quantify ramp rates
- Demonstrated sky imagery in testbed at UCSD

Future Plans and Next Steps

- Conduct solar forecasting at 48 MW Henderson, NV solar power plant
- Inverter-level power output and meteorological data acquired through PI Server

48 MW
Data from each inverter and 10 meteorological stations
Statistical forecast methods (ARIMA)
Sky Imager Forecast
Ramp forecast for CAISO

Lat: 35° 46’ 52”
Lon: 114° 59’ 35’’
Optimum Tilt: 35o



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Questions

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Thank you