

海外の発電予測技術の概要②

産業技術総合研究所 太陽光発電研究センター システムチーム 研究員
気象庁気象研究所 予報研究部 客員研究員
大竹 秀明

謝辞:本講演はJST CREST「太陽光発電の予測不確実性を許容する超大規模電力最適配分制御 (HARPS)」(研究代表者、東京工業大学井村教授、 Grant番号 JPMJCR15K1)の中において得られた成果の研究の一部を含みます。

開催日時:8月28日(月) 12:50~17:20
会場:東京理科大学森戸記念館第2フォーラム(1階)



国立研究開発法人 産業技術総合研究所

UVIG2017(6月 米国・アトランタ) 会場の様子



2017 Forecasting Workshop	
UVIG Wednesday, June 21, 2017	
Schedule of Events	
7:00 - 8:00 a.m.	Lobby
Breakfast	
8:00 - 10:00 a.m.	High Ballroom A
Session 3: Global VG Forecasting, Market Implementation and Operation, and R&D Experience with a Focus on Uncertainty	
10:00 - 10:15 a.m.	Lobby
Break	
10:15 a.m. - 12:00 p.m.	High Ballroom A
Session 4: Forecasting Benchmarking, Trials and Evaluations	
12:00 - 1:15 p.m.	Lobby
Lunch	
1:15 - 3:00 p.m.	High Ballroom A
Session 5: Distributed PV Forecasting and Market Integration: Where Are We Going?	
3:00 - 3:15 p.m.	Lobby
Break	
3:15 - 5:00 p.m.	High Ballroom A
Session 6: What's New Under the Sun?	
UVIG.ORG #UVIGATL	



- 気象会社、NOAA、NCAR、大学、研究機関、電力事業者、DOEが参加
- 150名程度が参加

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Session 1: Meteorology, Climate and the Electric Sector

Session 2: Where Is the Value in Improved Forecasts

Session 3: Global VG Forecasting, Market Implementation and Operation, and R&D Experience with a Focus on Uncertainty

Session 4: Forecasting Benchmarking, Trials and Evaluations

Session 5: Distributed PV Forecasting and Market Integration: Where are We Going?

Session 6: What's New Under the Sun? → Solar Eclipse

Session 7: Renewable Energy, Energy Trading, Market Evolution and the Role of Forecasting

Session 8: Changing Markets – Reliability, Economics and Forecasting in a Wind, Solar and Storage Future

Closing Session: Open Mike - Chair, Charlie Smith, UVIG



UVIG FORECASTING WORKSHOP AND TUTORIAL

APPLYING METEOROLOGY IN POWER SYSTEM PLANNING AND OPERATIONS

June 20-22, 2017

Renaissance Atlanta Midtown Hotel
Atlanta, GA

Tutorial

Chair - Part 1: **Sue Haupt**, NCAR: Background, Methods and Meaning of Uncertainty Forecasts

Sue Haupt, NCAR: Overview of Techniques and Issues Associated with Probabilistic Forecasting

Matt Wandishin, NOAA: Extracting Uncertainty Information from Probabilistic Forecasts

Eric Gritmit, Vaisala: Providing Uncertainty Information to End Users in the Electric Sector

Erik Ela, EPRI Open Discussion



UVIG FORECASTING WORKSHOP AND TUTORIAL


 APPLYING METEOROLOGY IN POWER SYSTEM PLANNING
 AND OPERATIONS

June 20-22, 2017

 Renaissance Atlanta Midtown Hotel
 Atlanta, GA

Tutorial

 Chair - Part 2: **Bob Zavadil**, Enernex: Applications and Value of Uncertainty Forecasts

Corinna Möhrle, WEPROG

Nick Steffan, ERCOT: Recent ERCOT Developments in Applications of Uncertainty
 Forecasts to System Operations

John Zack, AWS/Truepower: Applications of Uncertainty Forecasts to Extreme Net
 Load Prediction at HECO Bruce

Tsuchida, Brattle: Applications of Uncertainty Forecasts to Extreme Net Load Ramps

Frank Puyleart, BPA: Use of Uncertainty Forecasts in Decision Making in System
 Operations

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 保護された通信 | <https://energy.gov/eere/sunshot/funding-opportunity-announcement-solar-forecasting-2>

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ENERGY EFFICIENCY & RENEWABLE ENERGY

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Initiatives

SERVICES

EFFICIENCY

RENEWABLES

TRANSPORTATION

SUNSHOT INITIATIVE

 Funding Opportunity Announcement:
 Solar Forecasting 2

Home > Funding Opportunity Announcement: Solar Forecasting 2

Subprogram: Systems Integration

Funding Number: DE-FOA-0001649

Funding Amount: \$10 million

引用: <https://energy.gov/eere/sunshot/funding-opportunity-announcement-solar-forecasting-2>
 •Topic Area 1 : develop a test framework to benchmark solar irradiance and solar power
 forecasting models.

 •Topic Area 2 : develop irradiance forecasts that significantly improve on existing capabilities
 of irradiance forecasting

•Topic Area 3 : integrate solar power forecasts with utility management systems.

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UVIG Tutorial on Integration of Uncertainty Forecasts into the Power System Operations

Part 1: Background, Methods, and Meaning of Uncertainty Forecasts

Overview of Techniques and Issues Associated with Probabilistic Forecasting

Sue Ellen Haupt

National Center for Atmospheric Research
Research Applications Laboratory

UVIG Forecasting Workshop Tutorial

Atlanta, GA

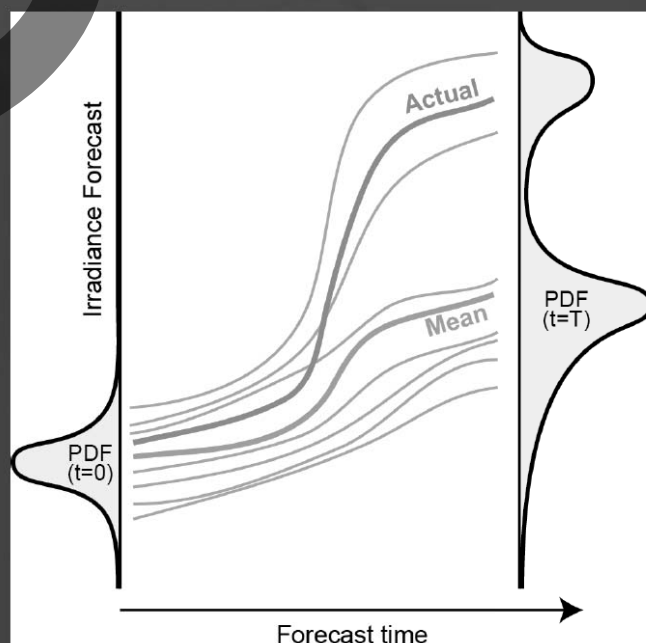
June 20, 2017

Dr. Sue Ellen Haupt氏 (NCAR) より提供

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Ensembles & Uncertainty Quantification

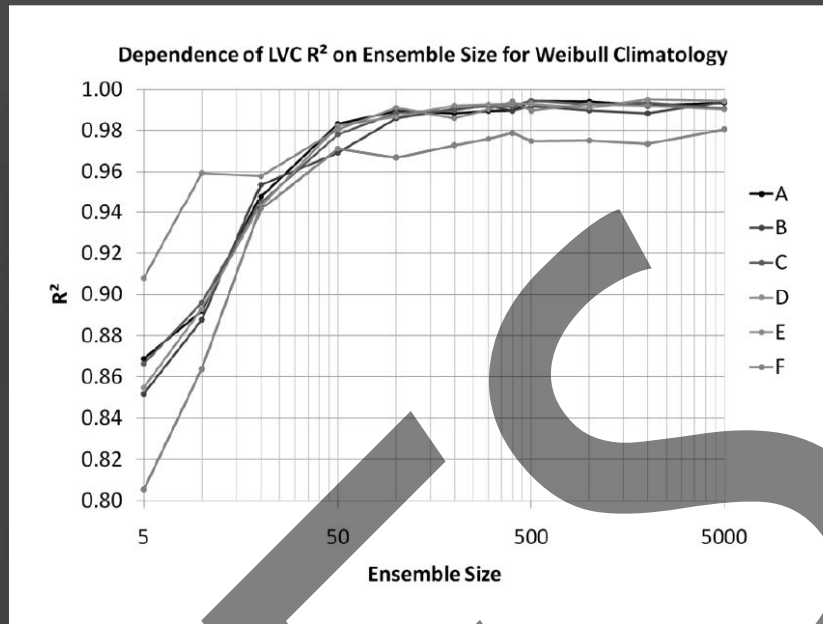
- Account for uncertainties due to imperfect initial conditions and model formulation
- Produce more accurate predictions than any single model realization
- Provide flow-dependent uncertainty estimates



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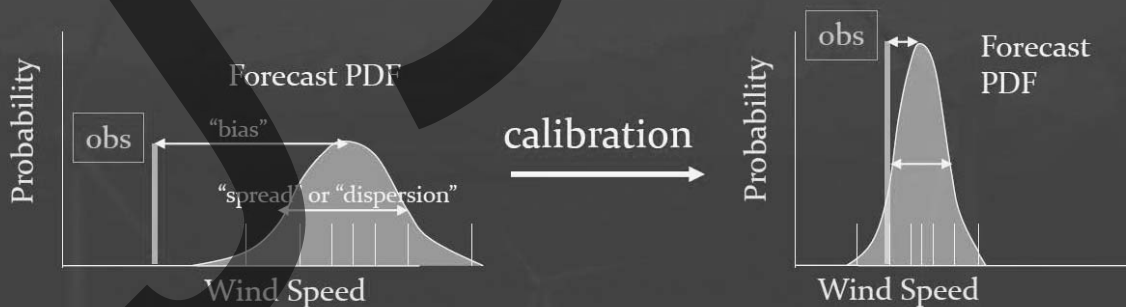
How Many Members are Needed?



Good spread-error correlation only with very large ensembles (order hundreds).
From Kolczynski et al. (2011, MWR).

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How do we improve the Match?



- Centered (the right answer)
- Sharp (narrow range)
- Reliable (quantile predicted matches quantile observed averaged over time)

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Summary

- The atmosphere is inherently Chaotic
- Ensemble prediction embraces and quantifies the uncertainty, producing
 - Better mean forecasts
 - Estimates of uncertainty
- The ensemble should be calibrated
- Research is showing
 - Better ways of creating ensembles
 - Better ways of blending ensemble information via postprocessing
- Such probabilistic forecasts can enhance decision-making



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Interview & Questionnaire Results: Use of Forecasting...



iea wind

Trading type	day-ahead market	intra-day market	ancillary services	reserve market
percent [%]	92	63	25	29

Business hours:	24/7	7-- 22	9-5
percent [%]	60 (64)	5	35

Trading Model:	price taker	price maker
percent [%]	78 (80)	22 (20)

Type of forecast	single forecast	multiple forecasts
percent [%]	36 (37)	68

Knowledge of Ensemble Forecasting	Knowledge	Use EPS Forecasts	work after OPR rules
percent [%]	71	21	38



- 前日予測、当日予測のニーズが高い。アンシラリーサービスへの利用も。
- アンサンブル予報について知識としてはあっても(7割)、利用は2割に。

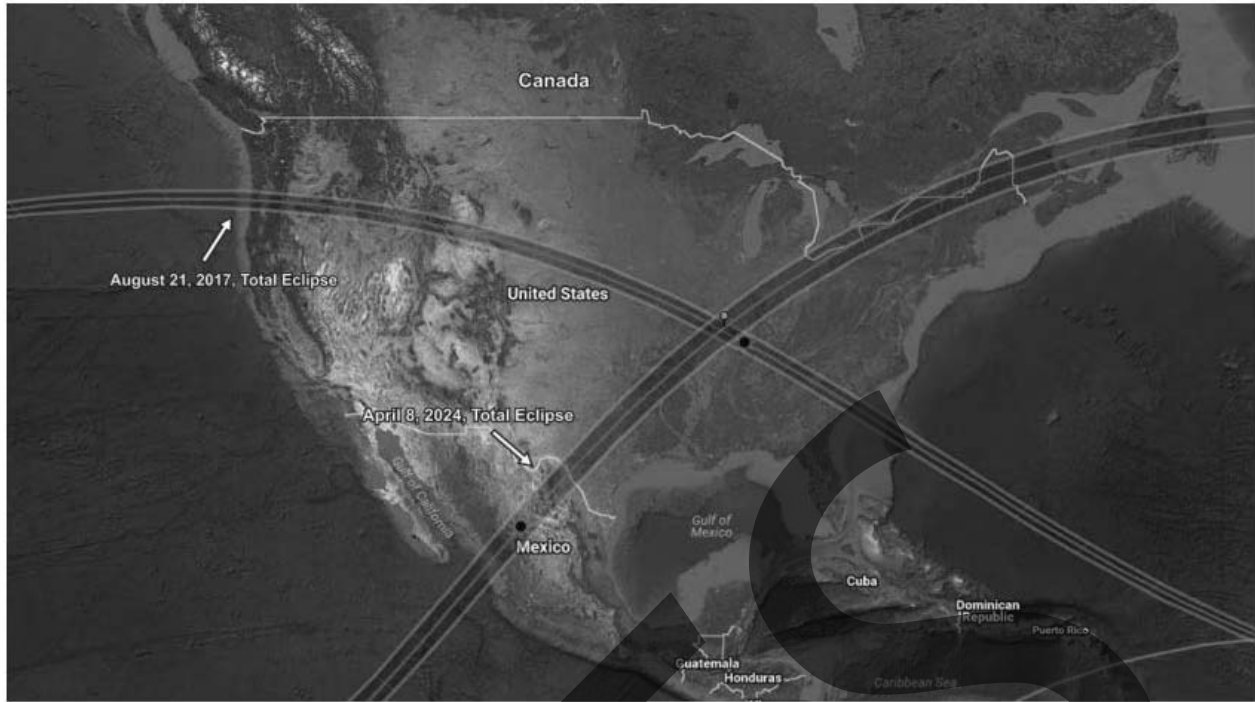


Figure 1.1: Solar Map—Projected Trajectory of the 2017 and 2024 Total Solar Eclipses⁵

引用: A Wide-Area Perspective on the August 21, 2017 Total Solar Eclipse White Paper, April 2017
http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/Solar_Eclipse_2017_Final_4-25-17.pdf

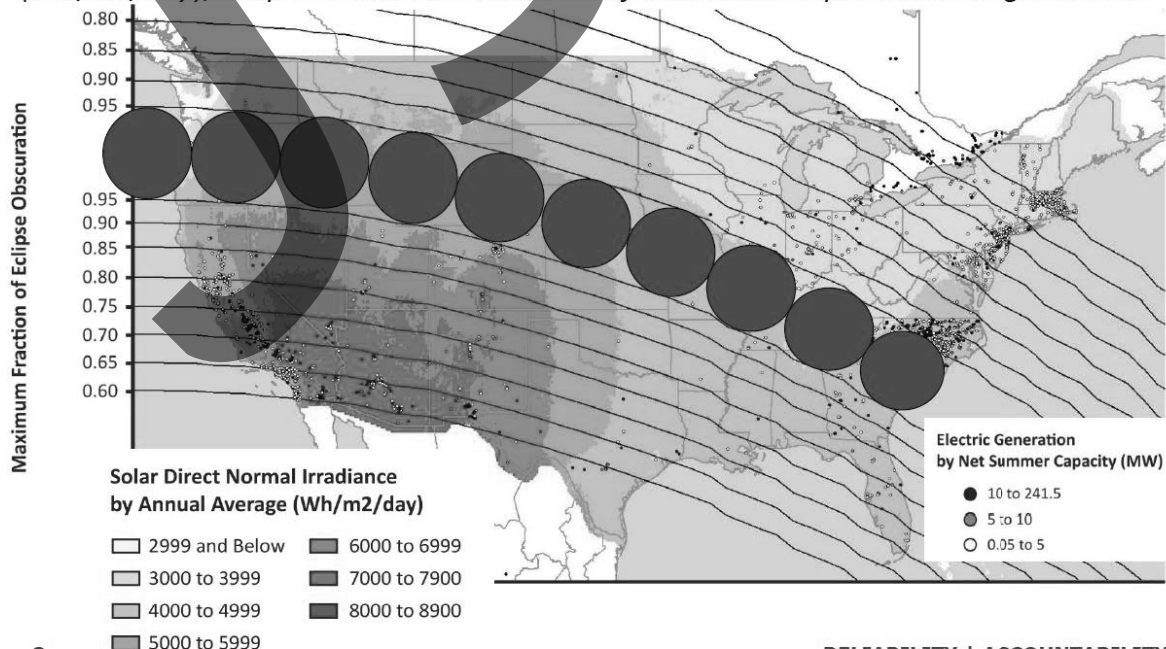
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NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Eclipse Path and Eclipse Bands

Figure 1. U.S. Map showing direct normal irradiance by annual average (Wh/m²/day), eclipse bands and locations of transmission photovoltaic generators



- 米国・南西部は日射、PVのポテンシャルが高い地域
- 日食の影響で地上のPV発電が低下→ 計画的な予備力の確保が必要

RELIABILITY | ACCOUNTABILITY

NERC

NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

August 21, 2017 Solar Eclipse

UVIG Workshop Presentation Session #6

Nicole Segal, PhD
Reliability Assessments Department
June 21, 2017

RELIABILITY | ACCOUNTABILITY



➤ UVIG2017では、“日食のPV・風力への影響”が一つのセッションに

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Nicole Segal氏(NERC)より提供

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
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Atmospheric
Chemistry
and Physics
EGU

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

Alex Montornès¹, Bernat Codina¹, John W. Zack², and Yolanda Sola¹

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

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

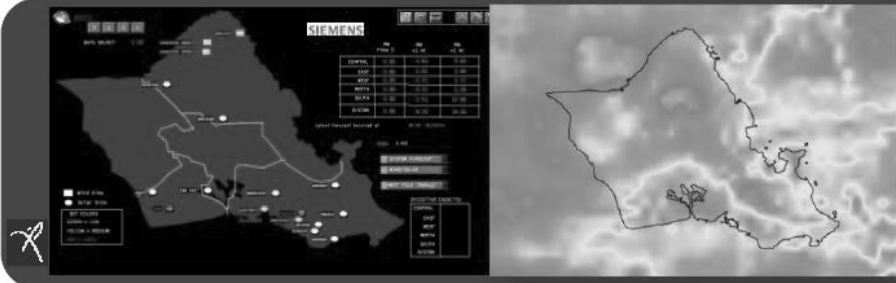
Received: 3 October 2015 – Published in Atmos. Chem. Phys. Discuss.: 18 January 2016
Revised: 17 April 2016 – Accepted: 23 April 2016 – Published: 17 May 2016

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-

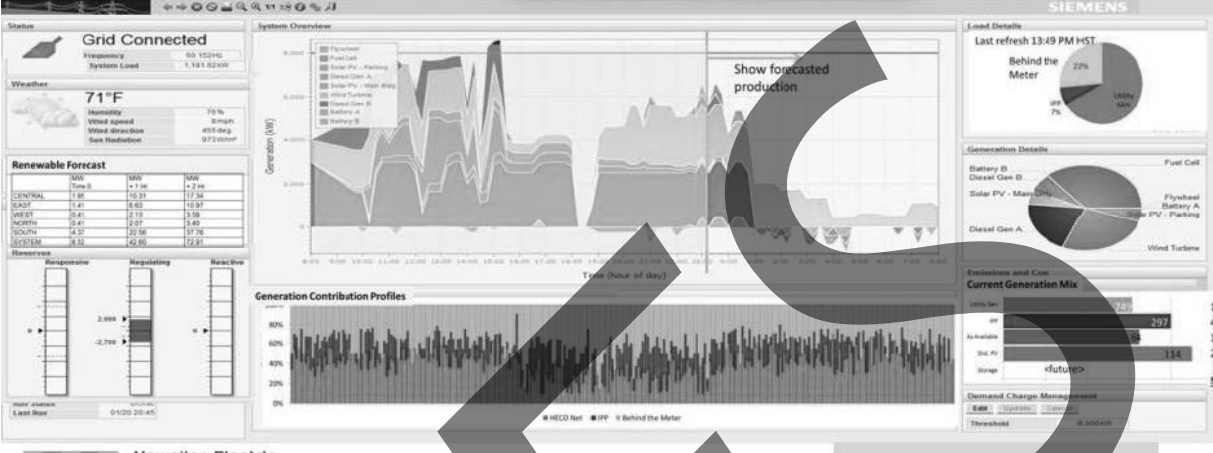
in the period 1950–2050, by comparing the shadow trajectory with values provided by NASA. Latitude and longitude are determined with a bias lower than 5×10^{-3} degrees (i.e., ~50 m at the Equator) and are slightly overestimated and underestimated, respectively. The second part includes a validation 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 shadow 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

3. Integrating Load and VDER into Grid Tools



- Geographic displays
- Link System Impact with Weather Features
- Post Event analysis & Reviews with Ops increase awareness



Source: SEAMS for SHINES

John Zack氏(AWS Truepower)より提供

国立研究開発法人 産業技術総合研究所



JST CREST EMS領域

太陽光発電予測に基づく調和型電力系統制御のためのシステム理論構築

太陽光発電予測に基づく 調和型電力系統制御の実現に向けて

井村 順一 (東京工業大学)

デジタル電力シミュレータを備えたコラボレーションルーム

各数理モデルの協調効果をブレインストーミング的に検討



<HARPS ACCEPT>

HARPS電力システムモデル，電源構成モデル，電力市場モデル，中間層モデルを組み合わせ，各研究者が開発した各種の時空間レベルの制御手法を組み込んだデジタル電力シミュレーションを実行

<HARPS Forecast>

全国の日射量実績・予測のデータベースとインターフェイス

<HARPS Database>

OCCTO公開情報，JEPX価格，PV導入量，建物床面積などのデータをストレージ上でデータベース化

<HARPS OASIS>

研究成果の外部公開

国立研究開発法人 産業技術総合研究所

資料：山口先生（東京理科大）提供

Reuniwatt: 衛星を活用した短時間予測サービス



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— **Reuniwatt** —

Solar forecasting

Climatic I.S.

Technologies

Resources

News

Company

Intraday solar forecasts with HourCast

Intraday solar forecasts are obtained through the treatment of real time satellite images coming from several geostationary satellites. The forecasts are available for any site on the planet. Reuniwatt's forecasting method is based on the clouds' motion vector. This method has been recognised by solar experts as the most efficient on the market.



引用：<http://reuniwatt.com/en/intraday-solar-forecasts/>



Solar

Reuniwatt, meteocontrol team up for nowcasts, forecasts in Asia

May 17 (Renewables Now) - Reuniwatt, a French firm specialising in solar forecasting, and meteocontrol GmbH will partner for real-time and intraday forecasts in Asia, the "largest global expanding market in the solar industry".

Germany-based meteocontrol said today that under the partnership it will rely on Reuniwatt's real-time estimations, or "nowcasts", and intraday forecasts for the Asian portfolio. The French company's method for providing the service is based on "the most performing" techniques to convert satellite images into solar irradiance maps.

"We are absolutely convinced that meteocontrol's solutions are essential for all asset owners and we are very proud to accompany such a market leader on their Asian adventure," Nicolas Schmutz, CEO and founder of Reuniwatt, said.

China, India and Japan together have over 53 GW of utility-scale solar power generation capacity, while the world has a bit more than 100 GW in total, a recent report by wiki-solar.org says. Systems smaller than 4 MW are not in that calculation.

China's Shunfeng International Clean Energy (HKG:1165), or SFCE, in 2014 acquired meteocontrol. The latter offers monitoring solutions and support in planning, implementation and operation management.

More stories to explore



Xian. Author: Muhammad Taslim Razin. License: Creative Commons, Attribution-ShareAlike 2.0 Generic.

引用: <https://renewablesnow.com/news/reuniwatt-meteocontrol-team-up-for-nowcasts-forecasts-in-asia-569031/>

国立研究開発法人 産業技術総合研究所

ご清聴ありがとうございました

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参考資料

国立研究開発法人 産業技術総合研究所

← → ↻ 保護された通信 | <https://www.uvig.org/resources/2017-forecasting-workshop/>



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2017 Forecasting Workshop

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本講演で紹介したUVIG2017(およびそれ以前の資料)はWEBよりダウンロード可能
引用: <https://www.uvig.org/resources/2017-forecasting-workshop/>

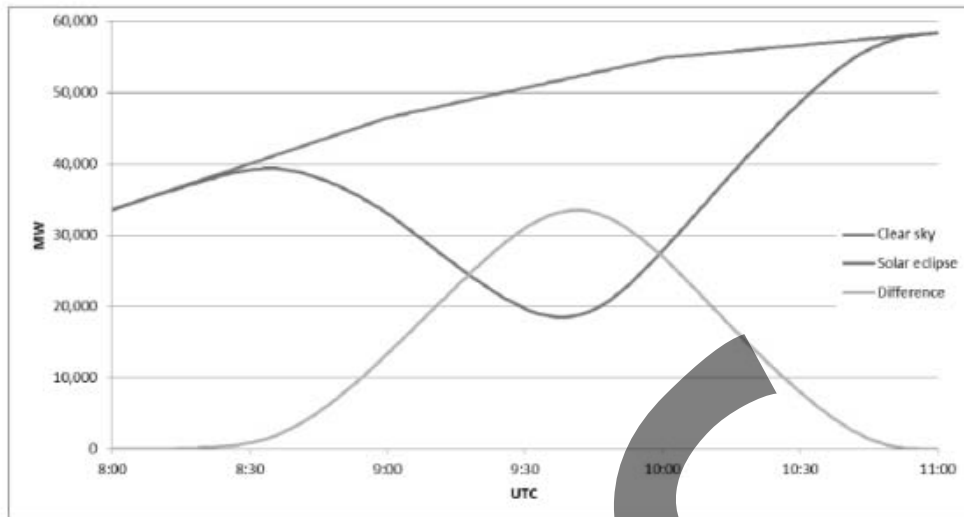


Figure 1.2: Comparison of expected infeed from solar on March 20 during clear sky conditions with and without solar eclipse^{7, 8}

- 欧州では2015年3月20日午前に日食によるPVの出力変動
- 最大3500万kWの出力変動が短時間に生じる恐れ
- 送電運用などのネットワーク体制が重要

引用: A Wide-Area Perspective on the August 21, 2017 Total Solar Eclipse White Paper, April 2017
http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/Solar_Eclipse_2017_Final_4-25-17.pdf

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IEA Wind Task 36 setup of industry interviews



Questions were separated into 2 categories:

General character to identify:

- the type of business
- the size of the organisation
- the span of the business processes
- the possible existing barriers

Forecasting & uncertainty to identify:

- the forecasting products used today
- the knowledge & awareness of probabilistic products
- the challenges that hinder the implementation of new products

Get a broad overview of state-of-the-art use of forecasting and uncertainty in the power market

- 単に予測情報を出すだけでなく、実際にどのようなシーンでどう使うか。
- 予測データを使う側の意識調査も。今後の改善点の整理のほか、教育的側面も今後必要。

Components of Forecasting Improvement Effort

- 1. Gather More Data:** Deploy targeted network of 6 sensors based on observation targeting analysis
- 2. Optimize NWP Configuration:** Conduct WRF configuration sensitivity tests for a sample of 30 large ramp cases to determine best configuration for wind forecasting in the Tehachapi Pass area
- 3. Improve NWP Data Assimilation of Local Area Data:** Implement Hybrid EnKF/GSI data assimilation approach (flow dependent data blending to more accurately spread the influence of point measurements for model initialization)
- 4. Apply Latest Machine Learning (ML) Tools to NWP MOS:** Improve ability to correct regime-based systematic errors (biases) in NWP forecasts
- 5. Improve Time Series Prediction for 0-3 hr Forecasts:** Exploit information in off-site data (project sensor data and non-project off-site sensors) through application of latest ML methods

©2011 AWS Truepower, LLC

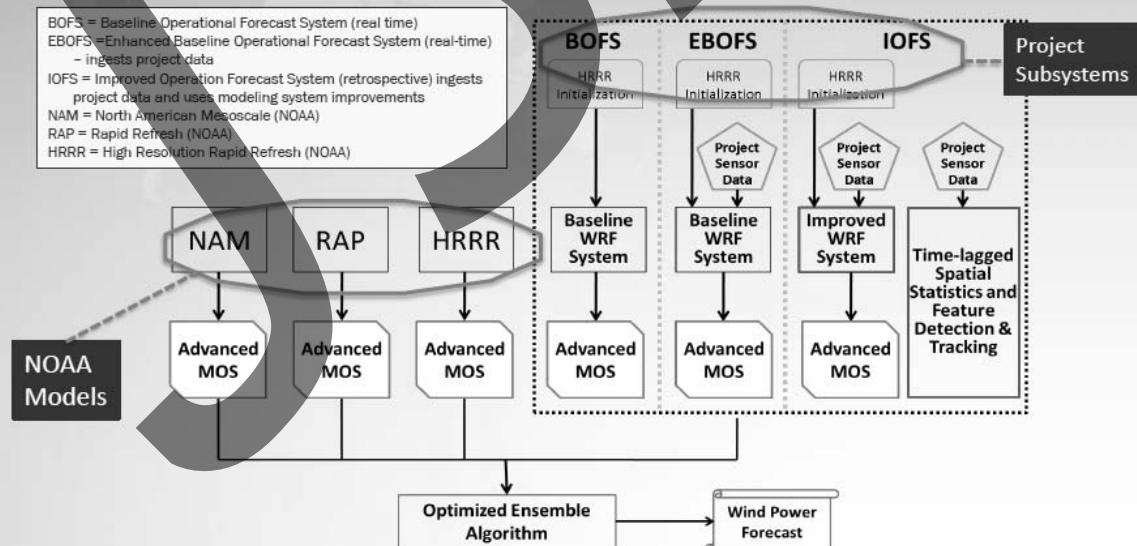


John Zack氏 (AWS Truepower) より提供

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5

Evaluation Experiment Design



- Generate forecasts from three versions of the system over a one-year evaluation period
- Evaluate the differences in performance among the forecasts produced by each version



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CREST HARPSの取り組み

系統運用層

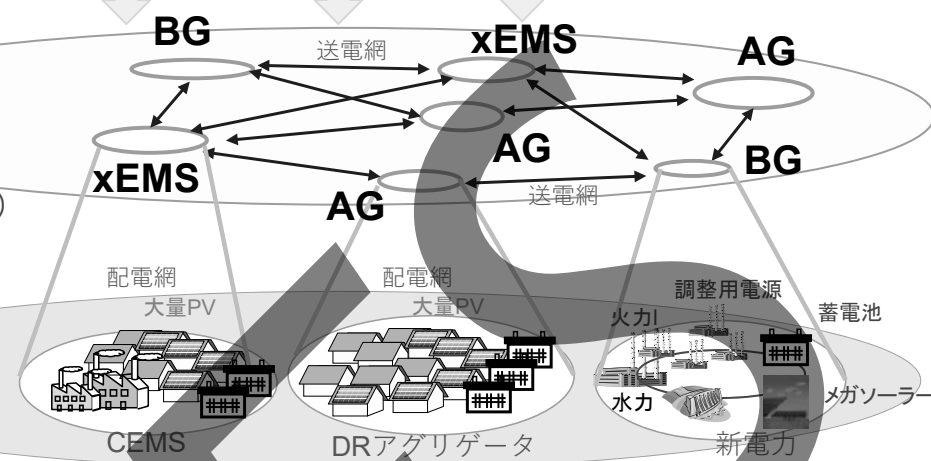
(現在の電力会社相当)

経済性・環境性・公平性・快適性を考慮し、市場（前日, 1時間前, リアルタイムなど）も活用した次世代の系統制御

Balancing Group
X_Energy Management System

中間層 アグリゲータ

(発電事業者, 小売り業者)



ユーザー層

中間層の役割は？ 中間層を含めて全体を最適に設計するには？

国立研究開発法人 産業技術総合研究所 資料: 井村先生(東京工業大)提供



CREST HARPS: OASISシステム

2015年度：日射予測データの表示

2016年度：ひまわり8号可視光実績, 日射量実績, JEPX価格・取引量, OCCTO
需要のデータを表示できるように改良



赤色: 日射(PV) 過大予測 → 実際、PV小
青色: 日射(PV) 過小予測 → 実際、PV大

● 予測誤差を加味した広域エリアでの電力システムの制御、運用を議論

国立研究開発法人 産業技術総合研究所 資料: 山口先生(東京理科大)提供

7th Solar Integration Workshop

International Workshop on Integration of Solar Power into Power Systems

With Special Topic **STORAGE**

24-25 October 2017
Berlin, Germany

[Home](#) | [Workshop](#) | [Program](#) | [Fees & Registration](#) | [Submissions](#) | [Venue & Accomodation](#) | [Sponsors](#) | [Contact](#)

Welcome to Berlin!

The 7th International Workshop on the Integration of Solar Power into Power Systems will be held in **Berlin/Germany, from 24 to 25 October 2017** and is an essential part of the **Berlin Workshop Week**.

Participants from power system operators, transmission and distribution grid operators, solar inverter manufacturers, universities and research institutes, and consulting companies will convene in Berlin for the 7th Solar Integration Workshop.

Special Topic **STORAGE**

One special focus of the Solar Integration Workshop will be storage integration. Many renewable energy sources like solar and wind energy produce variable power. Storage systems provide a way to level out the imbalances between supply and demand. Thus, electricity production need not be drastically scaled up and down to meet momentary consumption. Instead, transmission from the combination of generators plus storage facilities is maintained at a more constant level. Storage systems constantly grow in their usability, efficiency and number of use cases. More than enough reason to discuss the development in storage integration in detail and dedicate this year's special topic to storage.

News

- > Solar & Wind Dinner
- > Preliminary Workshop Program published now!
- > Registration now open!
- > Berlin Workshop Week 2017

Downloads

- Preliminary Workshop Program (as of 13 August 2017)
- Call for Papers Flyer 2017

引用: <http://solarintegrationworkshop.org/>

加藤文佳、2017: 学界情報: 6th Solar Integration Workshop 報告、電気学会論文誌B (電力・エネルギー部門誌), Vol. 137 (2017) No. 8 P NL8_3

16th Wind Integration Workshop

International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants

25 - 27 October 2017
Berlin, Germany

[Home](#) | [Workshop](#) | [Program](#) | [Fees & Registration](#) | [Submissions](#) | [Venue & Accomodation](#) | [Sponsors](#) | [Contact](#)

Welcome to Berlin!

The 16th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants will be held in **Berlin/Germany, from 25 to 27 October 2017** and is an essential part of the **Berlin Workshop Week**.

Participants from power system operators, transmission and distribution grid operators, wind turbine manufacturers, universities and research institutes, and consulting companies will convene in Berlin for the 16th Wind Integration Workshop.

One special focus of this year's Wind Integration Workshop will be **ancillary services**: one of today's most significant questions when it comes to the integration of wind power into power systems and also one of the most sought-after topics at last year's workshop. That's why this year's Wind Tutorial on 24 October 2017 will be dedicated to a related topic: Ancillary Services and Wind Power Plants – Status and Experiences.

News

- > Wind Tutorial
- > Preliminary Workshop Program available now!
- > Registration now open!
- > Partner Events 2017
- > Best Papers 2016

Downloads

- Preliminary Workshop Program (Updated 20

引用: <http://windintegrationworkshop.org/>

安田 陽、2017: 学界情報: 15th Wind Integration Workshop 報告、電気学会論文誌B (電力・エネルギー部門誌) Vol. 137 (2017) No. 6 P NL6_3