Solar and PV forecasting in Canada

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Presentation Plan

- Introduction
- How are PV forecasts generated?
- Solar and PV forecasting internationally
- Solar and PV forecasting in Canada
- Next steps

Introduction

- Currently, installed wind in Ontario: ~1.1 GW (4% of peak load)
  Implementing centralized wind forecasting (Pilot)

- RESOP (~525 MW)+FIT contracts (~651MW)+SAMSUNG (500 MW)
  ~1.7 GW of PV contracts
  (610 MW awaiting ECT)

Need for PV forecasts will depend on growth rate, but seems plausible given contracts & interest

First Light Solar Park, 9 MW
Photo credit: Dave Turcotte, CanmetENERGY

Needs and issues are similar for wind and PV forecasting

- Timeframes:
  - Weeks to months ahead: generation plant maintenance
  - Day-ahead forecasts: unit commitment
  - 3 hours ahead: reserves, balancing (Spare Generation On-line)
  - 1 hour ahead: intertie (import-export) transactions

- Better forecasts mean ↑reliability and ↓costs
  (See eg, "Wind Forecast Error Impacts on Efficiency", WPSC May 14, 2008)

- ***Forecast accuracy improves with experience, so earlier implementation will lead to better forecasts in the future
  Ex: German wind power prediction (WPMS): RMSE went from ~10% in 2001 to ~6.5% in 2005
  (Ernst B et al., Predicting the Wind, IEEE power & energy magazine, november/december 2007, p79-89)

- Some studies are now looking at large-scale integration of wind and PV together. Ex: US Western Wind and Solar Integration Study
  http://wind.nrel.gov/public/WWIS/

How are PV forecasts generated?

WEATHER FORECAST

1. Horizontal radiation

2. Ambient temperature

(Optional): wind speed, albedo

PV SYSTEM DATA

1.System location and orientation

2.Historical data or manufacturer specifications

FORECASTS OF RADIATION IN ARRAY PLANE AND BACK-OF-MODULE TEMPERATURE

PV POWER FORECAST

Solar and PV forecasting
State of the art: IEA SHC Task 36

International Energy Agency SHC Task 36 on Solar Resource Knowledge Management http://www.iea-shc.org/task36/index.html

(Solar/PV forecasting research from Germany, US, Spain, Switzerland,Austria, Canada)

SHC
INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

Some highlights:

- Best forecast depends on time horizon

  0 to ~6h: Persistence, cloud motion vectors, neural networks, etc.

  >~6h to a few days ahead: Numerical weather prediction (NWP) models and post-processing

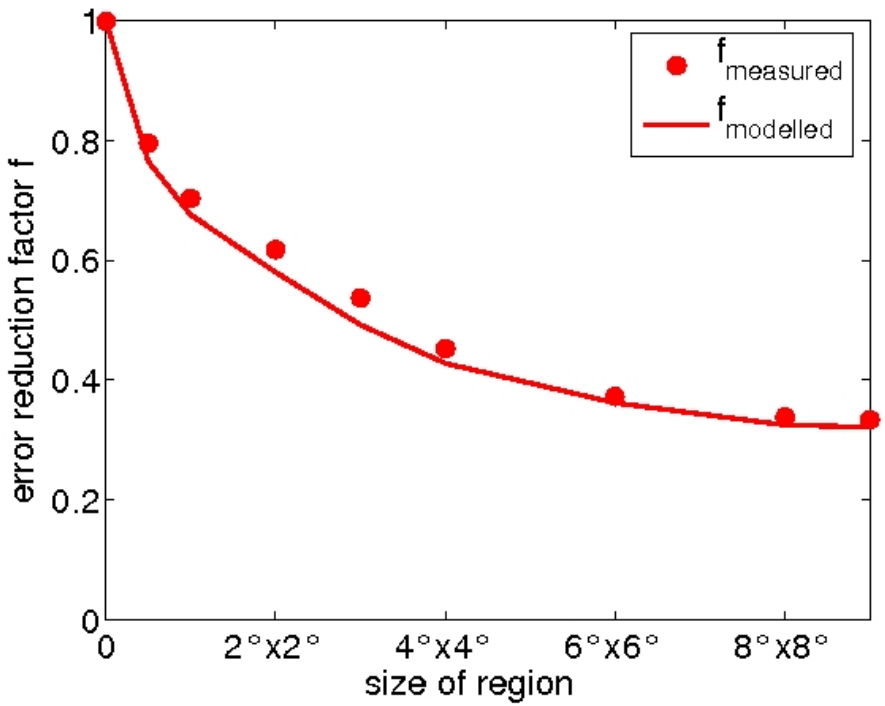
- Forecasts show greatest bias for intermediate skies (variable clouds)

- Forecast accuracy improves as the size of the geographic region and the number of stations increase

Forecast for ensembles of stations

error reduction factor
$f = rmse_{mean} / rmse_{single}$
depends on
size of region:

- for Germany:
  reduction of errors
  to 1/3 (13%)
- for ca. 300km x 300km
  reduction of errors
  to 1/2 (19%)



PV forecasting in Germany (U. of Oldenburg + Meteocontrol GmbH)

- At end of 2009, ~9 GWp of PV installed in Germany

- University of Oldenburg + Meteocontrol GmbH have implemented PV forecasts for 2 control areas of the German grid with ~5.4 GWp of installed PV (April 2010)

  (See: Lorenz et al. 2010, Regional PV power prediction for improved grid integration, Proceedings of the 25th EU PVSEC, Valencia, Spain)

- Method involves detailed upscaling from forecasts for 383 "representative systems" to forecasts for >200 000 PV systems which takes into account:
  - Geographic distribution of systems (longitude, latitude)
  - Distribution of system orientations (azimuth, tilt)
  - Distribution of module types (mono c-Si, poly c-Si, CdTe, CI(G)S, a-Si)

Upscaling PV forecasts in Germany

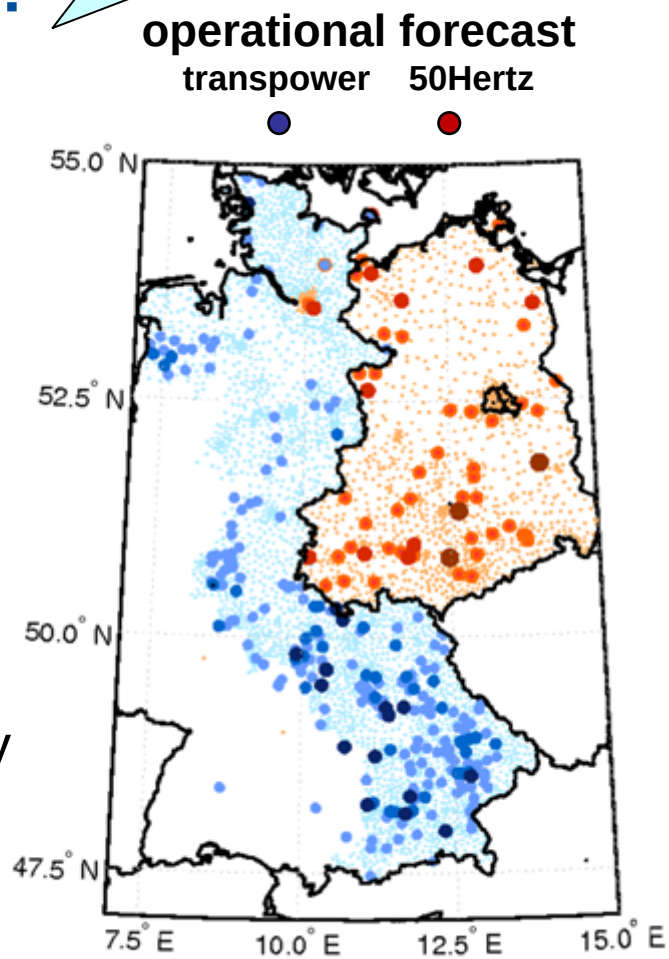
Regional PV power prediction: up-scaling

How can the overall energy production of thousands of systems be described?

➡ representative subsets:

$$P_{all,pred} = \frac{P_{all,nom}}{P_{rep,nom}} P_{rep,pred}$$

almost no loss in accuracy,
if the representative subset correctly reflects the basic properties of the complete data set



Evaluation of regional forecasts: data sets

- control areas of “transpower“ and “50Hertz“
- period: July 2009 – April 2010
- intra-day and day-ahead **forecasts**, delivered at 7:00UTC
- comparison to **measured power**
  - monitoring data base of meteocontrol GmbH: installed power of more than 1GW$_{peak}$
  - same representative data set as predictions with modified up-scaling approach

Results (all hours of the day):
RMSE’s: ~4-5% of rated power
Bias: ~ 1% of rated power
(Comparable to wind forecast accuracy)

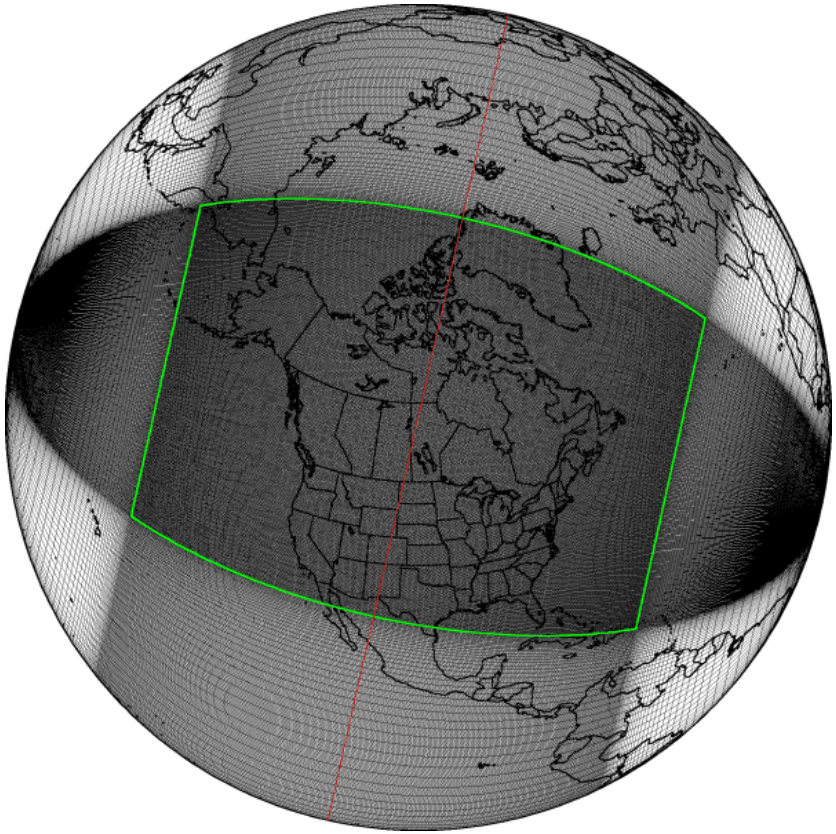
Canadian solar and PV forecasts

- Collaboration between Natural Resources Canada and Environment Canada within IEA SHC Task 36 (Timeline: 2008- March 2011)

- Main activities:
  - Evaluate Canadian Meteorological Centre (CMC) solar forecasts against data from ground stations

  - Develop, evaluate and improve PV power forecasts based on CMC solar forecasts for Canadian PV systems (focus on Ontario)

Numerical weather prediction at Environment Canada



Regional run of the CMC's Global Environmental Multiscale (GEM) model

Numerical weather prediction (NWP) models are computer simulations of the evolution of the atmosphere based on initial observations (satellites, weather stations).

Forecasts from the Canadian Meteorological Centre (Environment Canada) available online, free at:
http://www.weatheroffice.gc.ca/grib/index_e.html

<u>Regional run of GEM</u>

15 km grid over North America, Δt=7.5 min

0-48 hours ahead, from 00, 06, 12 and 18Z

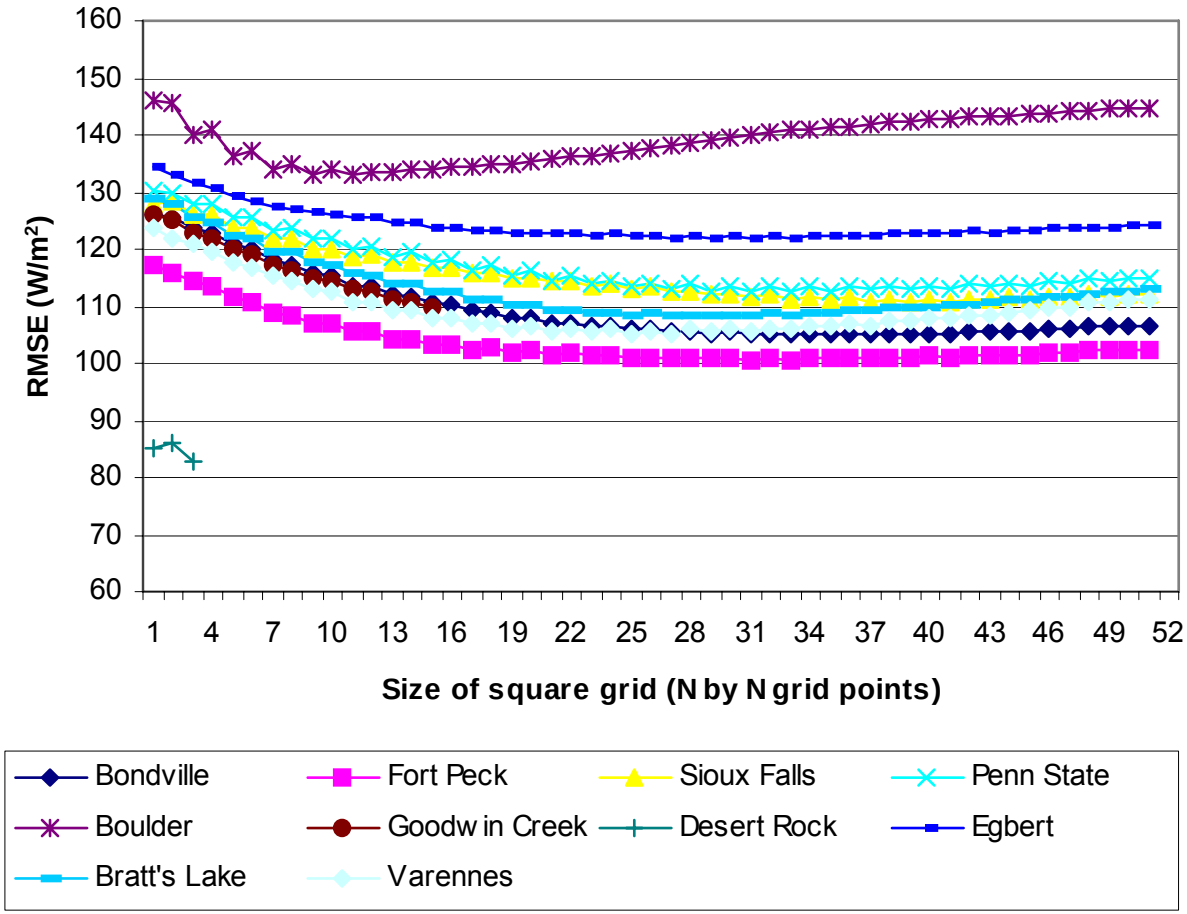
Test of CMC solar forecasts

- Test of Canadian Meteorological Center's GEM regional solar forecasts against data from 10 North American ground stations completed
- Results (nearest grid point):

  Biases: 6-45 W/m^2 (1-10% of mean)

  RMSEs: 85-146 W/m^2 (16-36% of mean)
- Breakeven with persistence : after 2 - 3 hours

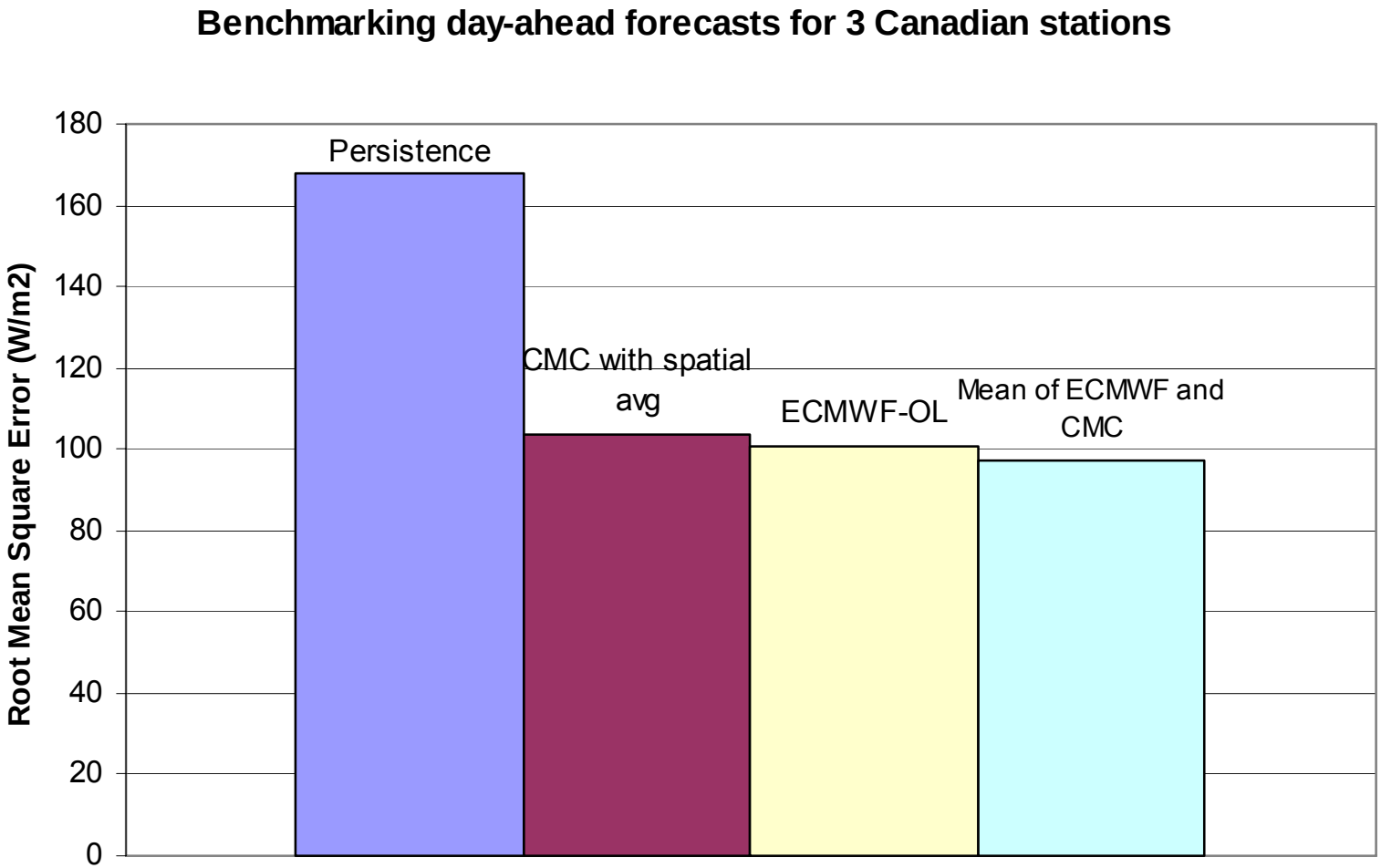
Post processing of forecasts: Spatial averaging



- 9 - 17 % reduction in RMSE from averaging over square grid centered on station

- For this one-year period, optimal averaging is over ~ 30 pts × 30 pts (~ 450 km × 450 km)

CMC forecasts “vs” German (ECMWF-OL) forecasts



PV forecast for Varennes system

- 5.4 kW* monocrystalline PV sub-array in Varennes (South-facing, 45° tilt) *Pstc actual is ~3.8 kW

- Training period:
  April 2007 - March 2008
- Test period:
  April 2008 - June 2008

- Well instrumented system:

GHI, in-plane irradiance, direct, diffuse, Tamb, Tmodules, wind, relative humidity, etc.
monitored at 1 minute level

PV forecast test results to date (daylight hours only)

	GHI forecast	Gi forecast	PV power forecast
RMSE	125 W/m^2 **27.6 % of mean**	133 W/m^2 **29.4 % of mean**	421 W **33.8 % of mean** **11.1% of Pstc**
Bias	15.0 W/m^2 **3.3 % of mean**	19.6 W/m^2 **4.3 % of mean**	104 W **8.3 % of mean** **2.7 % of Pstc**

Note: If consider nighttime as well, RMSE is 7.9 % and bias is 0.9 % of Pstc

Discussion/Feedback

- How can we facilitate data sharing from PV systems in Ontario to further develop forecasts?
- What forecasting horizons are of particular interest to IESO and other stakeholders (ex: day ahead, few hours ahead, extreme events, etc.)
- What accuracy metrics (besides bias, RMSE or MAE) are most relevant?
- Other concerns or key issues with large-scale PV grid penetration (similarities/differences with wind)?

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Thank you!

Photo credit: Dave Turcotte, CanmetENERGY