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<th>Project Name</th>
<th>Solar Symposium</th>
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<td>Challenges of Solar Forecasting</td>
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Challenges of Solar Forecasting

Craig Collier
Garrad Hassan America, Inc.

California ISO Solar Symposium
January 29, 2009
Irradiance Prediction

Refinement with Data, Relevant Predictors

Regime-Based Bias Corrections

Optimal Irradiance Prediction

BASICS

clouds
aerosols
solar flux

Rapid Update Cycle (RUC)

North American Mesoscale (NAM)

Global Forecast System (GFS)

Weather Forecasting & Research Model (WRF)

Commercial Providers
Rapid Update Cycle (RUC)

Water vapor... the only absorber / scatterer and independent of wave length

O$_3$, CO$_2$, BC missing ... all important

Only downward fluxes are attenuated
May underestimate diffuse Flux due to backscattering

All wavelengths scattered equally...
Rayleigh ~ Non-Selective

Intensity of scattering is, in reality, inversely proportional to wavelength.
A layer is all or nothing...

Can underestimate transmission

Can feedback on itself (atmospheric longwave absorption reduced… resulting in unrealistic stratifications).

Sensitivity largest when & where cloud is less uniform (i.e., convective environments)

Thus, the predicted irradiance is only as good as the convection scheme (simple Grell, better for midlatitudes)
North American Mesoscale (NAM) – WRF

- Water vapor (predicted), \( \text{CO}_2 \) (constant), \( \text{O}_3 \) (seasonally-varying)...
- Aerosols not explicitly considered except with TOA adjustment, not particularly troublesome except in regions with high aerosol concentrations that vary temporally.
- Ozone is seasonally varying but zonally constant.

- Attenuation of both downward and upward fluxes with dependence on wavelength.
- Spectral band-averaging extremely simplified, shifts the burden to dynamics of water vapor transport and microphysics to get longer wavelength SW energy correct.
Cloud fraction diagnosed via predicted RH (stratiform) BMJ convection scheme (convective).

Moisture sensitive to biases in wind simulation, surface flux parameterizations, precipitation.

Stratiform cloud in adjacent layers... 100% cloud for both.

Homogenized convective cloud (constant fraction in multiple layers).
Global Forecast System (GFS)

Both upward and downward diffuse fluxes subject to attenuation, wavelength dependent.

Broadband approach more sophisticated than the NAM, particularly for absorption.

As in NAM, radiances still quite vulnerable to errors in water vapor transport, microphysics.

- water vapor (predicted), CO\textsubscript{2} (constant), O\textsubscript{3} (predicted), O\textsubscript{2} (predicted), aerosols (fully 3D)

  no transport or sources/sinks for aerosols
Cloud fraction diagnosed via predicted cloud condensate (an “obvious predictor”) and RH.

Random cloud overlap, regardless of cloud type, height.

Radiant flux attenuation dependent on water phase, temperature, and particle size.

Highly sensitive to temperature errors.
IRRADIANCE PREDICTIONS

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Persistence  NWP + refinement  NWP

0  +2  +4  +6  +8  +10  +12  ...  +24 hours
- Refinement techniques not well-established or proven.

- For horizons of less than 6 hours, the idea is to define a number of readily-observable predictors on to which we can regress the first-pass solution.
- For longer horizons, we rely on bias correction techniques.

- An example: *cloud forecasts are the largest source of error to surface irradiance forecasts*. Cloud predictions are linked to convection parameterizations, which may be biased in timing by onset of cloud formation.

  Measure diurnal biases on convective days from the irradiance measurements (feedback) and apply correction when the atmospheric conditions recur.

- Predicted diurnal maximum in rainfall

- Actual maximum

\[ \begin{align*}
0 & \quad 6 \\
12 & \quad 18 \\
\end{align*} \]
CONCLUSIONS

• Solar forecasting relies on a variety of different NWP models for the irradiance prediction.

• Predictions less accurate on cloudy days and times of large solar zenith angle than on clear days and at midday.

• NWP schemes for radiation / cloud interaction vary significantly, and simplicity is traded at the expense of increased computational time. All are highly sensitive to moist thermodynamics (including convective processes). Understanding these biases may allow for effective treatment of diurnal timing biases given the appropriate forecast conditions.

• A number of Earth Observing Systems are available to provide well-validated predictors on short-time scales.
• Decomposition of the global irradiance into diffuse and direct components relies upon semiempirical modeling, still evolutionary.

Orgill (1977)
Perez (1997)
Skartveit (1998)
THANK YOU

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