CASE STUDY 7

RENEWABLE ENERGY RESOURCE ASSESSMENT (USA, JAPAN)

SUMMARY

Title
Renewable Energy Resource Assessment (USA, Japan)

End users
Decision-support tool developers, research scientists, government agencies, industry organizations, international coordination agencies, power companies, energy management system companies, weather forecasting service companies

Intermediate users
Decision-support tool developers, research scientists, government agencies, industry organizations, international coordination agencies, power companies, energy management system companies, weather forecasting service companies

Application(s)
Climate monitoring, short-term forecasting and climatology

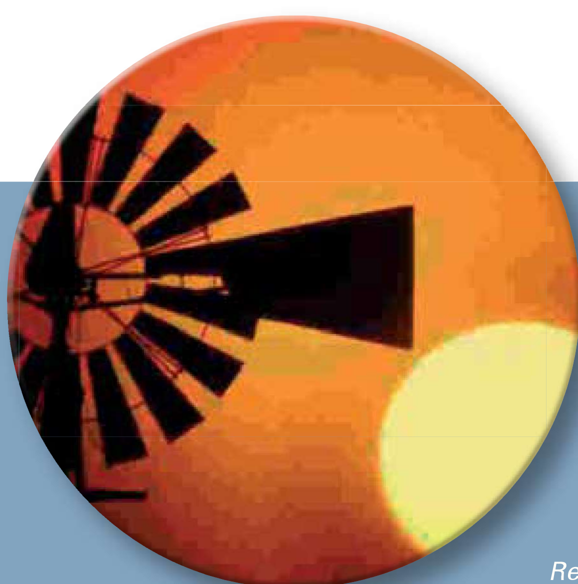
Models used
– USA: NASA Goddard Earth Observing System Model (GEOS-4), NASA Modern-Era Retrospective Analysis for Research and Applications (MERRA) reanalysis, NASA Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget (SRB)
– Japan: MIROC General Circulation Model (GCM) and NICAM non-hydrostatic cloud resolving model

Climate data records used
Air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget, ozone, aerosols, albedo, snow/ice coverage
International Satellite Cloud Climatology Project (ISCCP) datasets

Satellite observations used
– Imager Radiances and Cloud Retrievals: Geostationary and AVHRR VIS and IR channel radiances
– Top of Atmospheric radiation measurements: NASA Clouds and the Earth's Radiant Energy System (CERES), Geostationary weather satellites (Himawari, GOES, Meteosat series)
– Temperature and moisture profiles: indirect use of satellite measurements through data assimilation systems from NASA Global Modelling and Assimilation Office
– Column ozone: NASA Total Ozone Mapping Spectrometer (TOMS) and Ozone Monitoring Instrument (OMI)

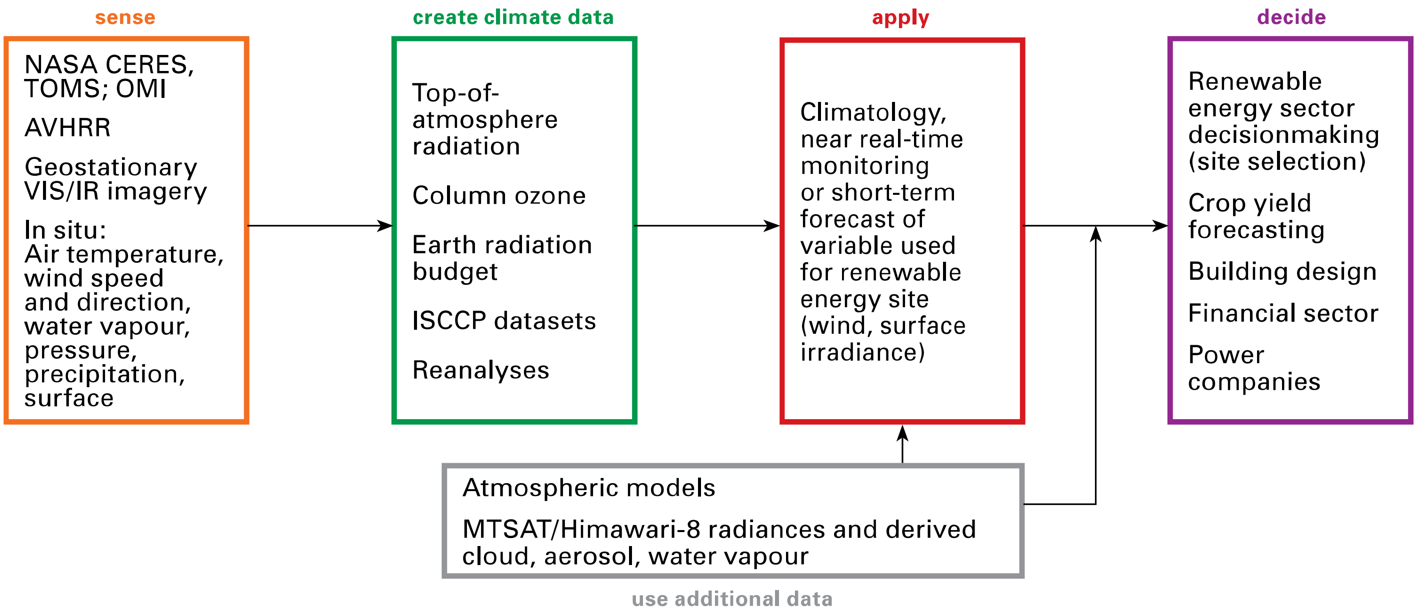
Agencies that produce records
– USA: NASA and NOAA
– Japan: Cooperative organization of Tokai University, University of Tokyo, Chiba University, Japan Meteorological Agency, and Toyama University

Sustainability of service (demonstration or ongoing)
– USA: Generation and delivery ongoing activity by NASA; some end-user engagement projects of limited duration
– Japan: Data are provided to research and education users free



Renewable energy

INFORMATION FLOW



DESCRIPTION

Background

As renewable energy is increasingly used in electric power systems, there has been increasing interest in the instability of renewable energy sources such as solar radiation and wind. The availability of these resources varies over time, independent of power demands; meteorology and geophysics can contribute to solving this problem. Clouds, aerosols, and water vapour are the most important atmospheric components that affect levels of solar irradiance reaching the ground. These components have been well examined and can be estimated.

Satellite-derived measurements

- Estimates of solar radiation (derived from multiple imagers and Earth radiation budget satellite sensors) scaled to the Earth's surface using measurements and satellite-derived climatologies of clouds, ozone, and aerosols;
- Measurements of surface winds (derived from meteorological reanalyses);
- A range of other atmospheric parameters, such as temperature and relative humidity used to assess the potential of renewable energy resources at a given location across a variety of scales ranging from the individual household to large solar thermal power generation projects.

Cloud cover is an important atmospheric phenomenon that affects ground-level solar radiation. The optical thickness and particle size of clouds are primary parameters for estimating solar irradiance. They are retrieved from multi-spectral images obtained from satellite sensors. One application for such cloud properties is to estimate the solar irradiance penetrating the atmosphere which subsequently reaches the ground. Ground-level solar irradiance can be estimated by fast radiative transfer calculations using inputs of cloud properties retrieved from satellite imagery.

In addition to the constellation of low Earth orbiting satellites, the constellation of meteorological geostationary satellites are useful for gathering such information because they observe the Earth (except for the Polar Regions) at high temporal frequency and moderate spatial resolution (around 1 km). A new generation of geostationary satellites, due to be introduced between 2015 and 2020 will dramatically improve performance. They will observe 16 spectral bands from visible to infrared every 10 minutes or more frequently. Satellite measurements such as from Himawari-8 will therefore be increasingly useful for wide-area monitoring of ground-level solar radiation at high spatial and temporal resolutions (Takenaka et al., 2009).

Global models

Developing global models that investigate cloud systems and solar radiation is important for renewable energy-related short-term forecasting. Non-hydrostatic cloud-resolving models are efficient for this purpose. Japan has been developing a model that is composed of the Nonhydrostatic Icosahedral Atmospheric Model and the Spectral Radiation-transport Model for Aerosol Species for estimating solar irradiance for a given time and location. Since the cloud evolution process is influenced by the existence and species of aerosols, it is important that models consider aerosol inventories and transport in addition to cloud evolution processes. Ground-level solar irradiance is currently estimated using global models. However, further improvements related to the cloud evolution process are needed, such as the downsizing of the grid system and assimilation of in situ data and other data sources. A general circulation model commonly used for estimating the climate system is also used for estimating solar radiation over ten-day time periods. Output from the general circulation model is useful for investigating power demands and estimating potential renewable energy over tens or hundreds of years. Models for short- and long-term forecasting of solar radiation need to be used for energy management systems, and relevant methods are still being improved (Nakajima et al., 2013). Those questions are addressed in the Terrestrial Energy Estimation by Diurnal Data Analyses project. The project investigates energy management systems and forms part of a research programme under the Japan Science and Technology Agency.

Weather forecasts at various time scales (from daily to seasonal to climatic) are used to optimize load forecasts by power utilities, to better integrate intermittent sources of energy into the electrical grid and to aid longer-term infrastructure planning. While not strictly related to terrestrial climate change, space weather observations (made in the near space environment) assist in the prediction of potential damage to national grids, due to solar energetic particle precipitation, a phenomenon which follows multiple time scales.

Validation

Validation of solar radiation estimated from satellite measurements and model simulations is important for the quality control of data. Japanese researchers use the SKYNET ground validation system, which includes pyranometers, sun photometers and other kinds of radiometers. This provides not only measurements of direct and diffuse components of solar radiation, but also measurements of atmospheric parameters, such as aerosol and cloud properties that affect solar irradiance due to scattering and absorption. Solar radiations obtained from SKYNET have been compared with results estimated from geostationary weather satellites. The results showed that the root mean square error (RMSE) was around 80 W/m^2. Cumulus clouds with a spatial scale of several hundred metres increase the RMSE, because the horizontal spatial resolution of geostationary weather satellite imagery is generally 1 km or larger. More information about SKYNET can be found at http://atmos.cr.chiba-u.ac.jp/.

Research and end-use examples

In the United States of America, the need for customized data projects that are easily accessible and useable by non-technical end users was recognized through stakeholder engagement (Zell et al., 2008). The NASA Langley Research Center produced a 22-year dataset of energy-relevant quantities called the Surface Meteorology and Solar Energy (SSE) dataset. The long data time series allows for examination of the effects of interannual variability and long-term trends which are possibly related to climate change impacts. NASA is presently funding a project to add Geographic Information System capability to SSE and support mobile device access. The project will enable expanded usage while still supporting the older text based delivery systems and will provide simpler pathways for future data enhancements.

NASA, DLR, the École des Mines de Paris and other organizations have worked with the International Energy Agency to improve solar resource standardization using space-based and surface-based data sources (http://task46.iea-shc.org/). As a boundary organization with connections to multiple government and industry end users International Energy Agency can improve the uptake and enhance the value of space-based measurements for a large set of decisionmaking purposes.

The RETScreen clean energy project analysis software is run by Natural Resources Canada. It is an example of an end-to-end project where data from Earth observations are directly ingested into a decision support tool. NASA has partnered with Natural Resources Canada since 2000 by providing data from the SSE dataset as input into the RETScreen system. The global NASA SSE dataset augments input parameters in regions where ground-based data are sparse or non-existent. RETScreen uses both ground-based and satellite-derived climate data in a seamless fashion, via a city database or a direct query to SSE in the case of queries submitted online. As a result, the end-user is not concerned with the IT challenges of importing unfamiliar datasets into the decision support system. RETScreen is freely available on the Web at http://www.retscreen.net and is used globally. Natural Resources Canada provides manuals, video tutorials, and on-site training throughout the world. The decision support tool is used to evaluate a wide range of renewable energy and energy efficiency technologies from resource assessment, emission reduction and financial viability perspectives for small-scale projects to large-scale power generation projects (Eckman and Stackhouse, 2012).

RETScreen director Greg Leng commented: "The RETScreen Clean Energy Management Software now has more than 430 000 users in every country and is available in 36 languages that cover two-thirds of the world's population. Solar and climate data are key inputs into the software. Satellite-derived data provided by NASA has been used by most of these users to implement thousands of renewable energy, energy efficiency, and cogeneration projects across the globe."

NASA has also maintained a partnership with the United States National Renewable Energy Laboratory (NREL) and provided data products for use in the HOMER distributed power optimization model. While this decision support tool is now being developed privately, a version continues to be available free of charge at http://www.homerenergy.com/. HOMER is a computer model that enables the evaluation of design options for both off-grid and grid-connected power systems for remote, stand-alone and distributed generation applications. HOMER uses a variety of NASA data products, including the SSE dataset, as meteorological and solar energy inputs to the model. These data products are obtained via a direct query to the SSE web service (similar to the RETScreen link to SSE) making them readily available to the user. The HOMER system is now maintained and distributed by Homer Energy LLC and has been downloaded by over 50 000 users worldwide.

Researchers at the NASA Langley Research Center are working with the heating and air conditioning industry, and the United States Department of Energy to explore the utility of space-based observations to improve and update standards manuals for the heating and air-conditioning industries.

References

Eckman, R.S. and P.W. Stackhouse Jr., 2012: CEOS contributions to informing energy management and policy decisionmaking using space-based Earth observations. *Appl. Energy*, 90:206–210.

Nakajima, T., H. Takenaka, D. Goto, S. Misawa, J. Uchida and T. Y. Nakajima, 2013: Measurements and modelling of the solar radiation budget. *Journal of the Japan Society for Simulation Technology*, 199–207.

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