National Renewable Energy Laboratory
Innovation for Our Energy Future

NREL's FY09 CSP Resource Assessment Plans

Solar Resource Assessment Workshop
Denver, CO

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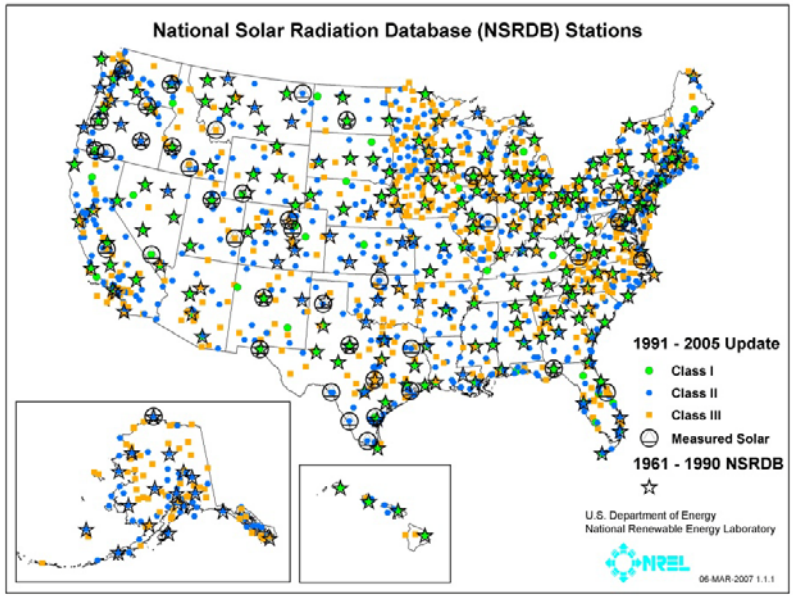
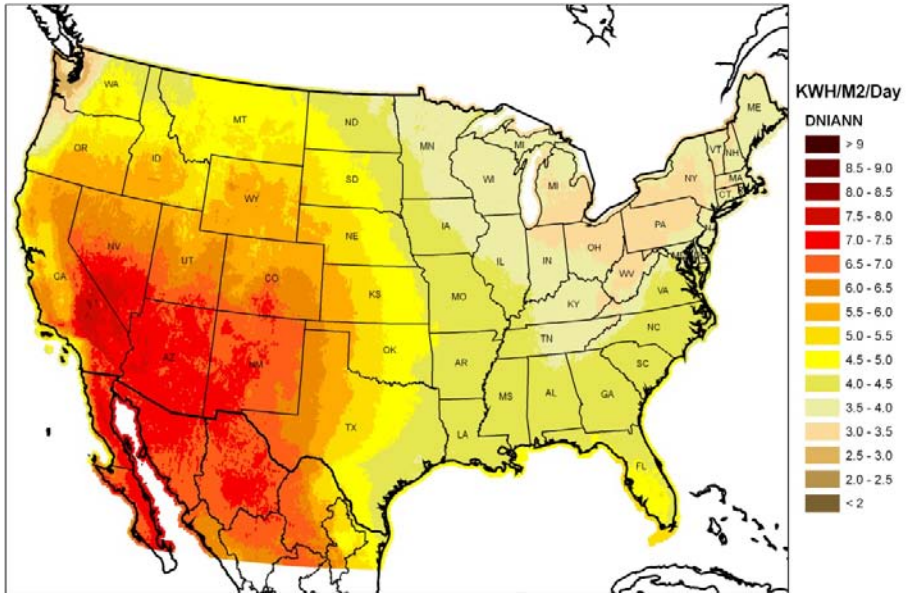
NREL/PR-550-44458

Major FY09 Major Goals

- Provide high-quality, reliable solar resource information to CSP industry (domestic, international)
- Qualify data accuracy in financial terms
- Develop data prediction methodologies





FY09 Task Outline: CSP Program

- Acquisition of Bankable Data
  - Establish CRADA's with developers and utilities
  - Install ~12 DNI measurement stations
  - Apply GIS tools to support siting decisions
- Resource Data Modeling and Forecasting
  - Enhance DNI models
  - Validate and benchmark short-term forecasts
  - Evaluate interannual variability and trends

Note: CSP task activities are tightly linked with parallel activities in NCPV; all funding comes from DOE/EERE Solar Energy Technology Program

SOLRMAP Monitoring Station Deployments

Industry participants fund equipment and station operations

NREL funds design, deployment, and data processing/archiving

Numerous requests for participation

Tier 1 Station- Thermopile Radiometers

3 component measurements

Lower uncertainty (1% to 3%)

Optimal data QA

Tier 2 Station- Rotating Shadowband Radiometer

2 component measurements (calculates DNI)

Higher uncertainty (5% to 10%)

Single pyranometer

Tier 1

Tier 2

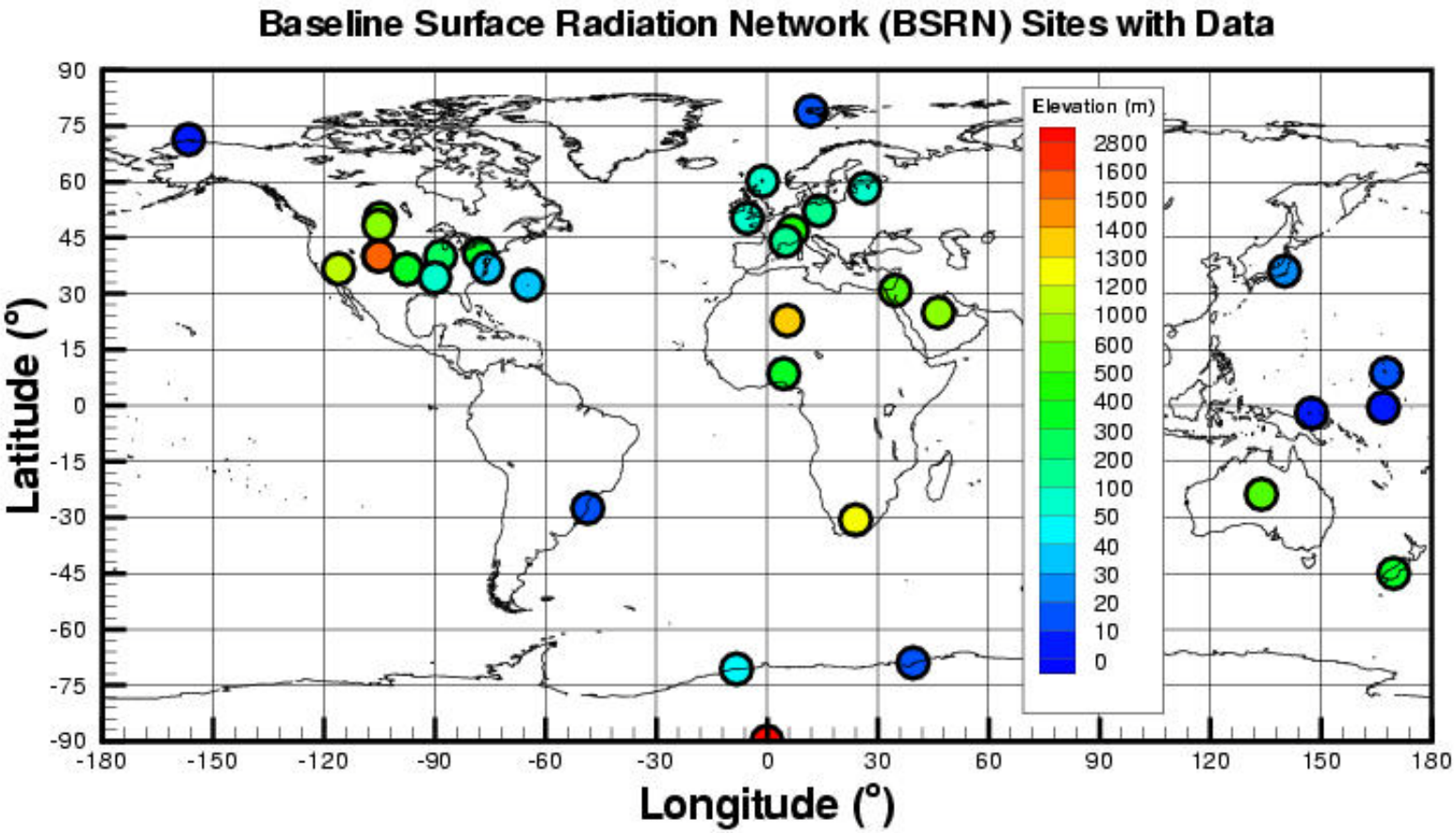
Resource Data Modeling and Forecasting

- Improve DNI modeling
  - Description of model accuracy
  - Aerosol optical depths
  - Temporal and spatial resolutions (sub-hourly, < 10-km)

- Validate and benchmark short-term forecasts
  - IEA/SHC Task 36: "Solar Resource Knowledge Management"
  - Collaborations with NOAA, NASA

- Evaluate trends and interannual variability
  - Global "Dimming" and "Brightening"; climate change
  - Events (dust storms, volcanic eruptions)
  - Natural climate variations (ENSO, NAO)
  - Relate short term measurements to interannual variability

Global Sources of Benchmarking Data



Source: Taiping Zhang and Paul Stackhouse, NASA/Langley

Prioritized Forecasting Requirements

- Daily plant operations (load following)
  - Hourly, 15-minute “look ahead”
  - 105-minute (CAISO, PERP)
- Storage/Dispatch Scheduling (day ahead, 2-3 days)
  - Determined by value of power (storage vs. grid)
- System maintenance (7-day)
- System performance
  - Seasonal (lower priority)
  - Outages
- RE Standards (RPS); long-term cash flow analyses
  - Annual predictions (based on energy)
  - Interannual variability and long-term trends
  - Banking of REC’s

Approaches for DNI Predictions

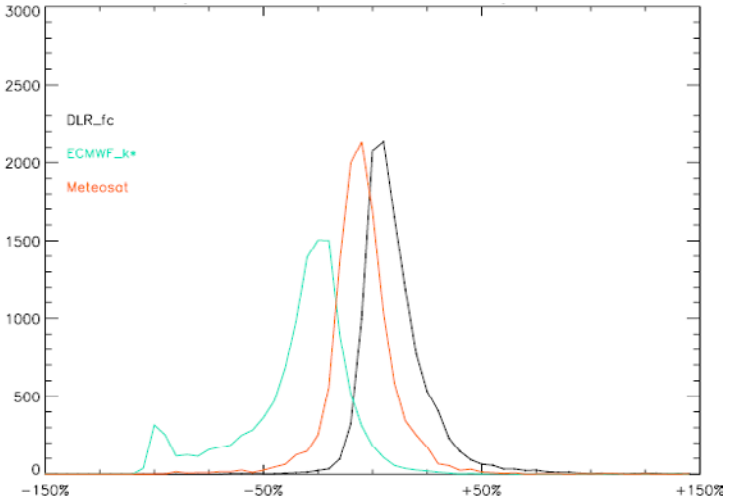
Short-Term (0-6 hours)
- Meteorological and sky-cover observations
- Satellite-based cloud motion vectors

Medium-Term (> 6-hours to 3-days)
- Numerical weather prediction models (ECMWF, NDFD)
- Downscaling using mesoscale models (MM5, WRF)

Long-term (weekly, seasonal annual, interannual)
- NOAA, NASA Climate prediction models
- GCM analyses published in IPCC reports
- Extrapolation of long-term weather records

Solar Forecasting in IEA/SHC Task 36: Solar Resource Knowledge Management

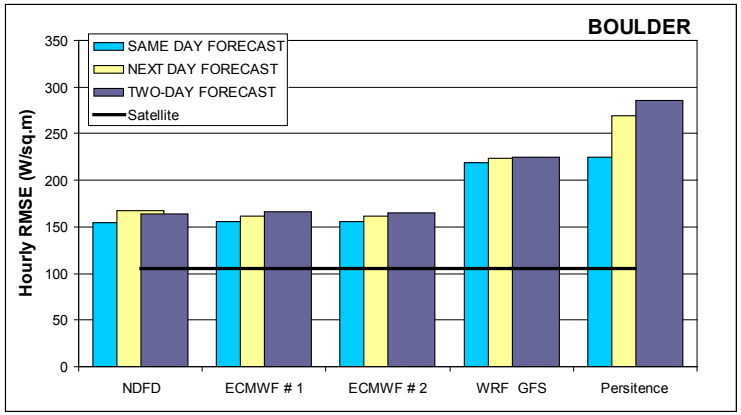
- Perez (U.S.), in collaboration with NASA
  - NDFD evaluations
  - GMAO (NASA) evaluations
  - Collaboration with Oldenberg
  - Cloud vector motion analysis (with NREL)
- DLR (Germany)
  - AFSOL Irradiance Forecasting System
  - Comparison of AFSOL with ECMWF
  - Comparisons with MM5

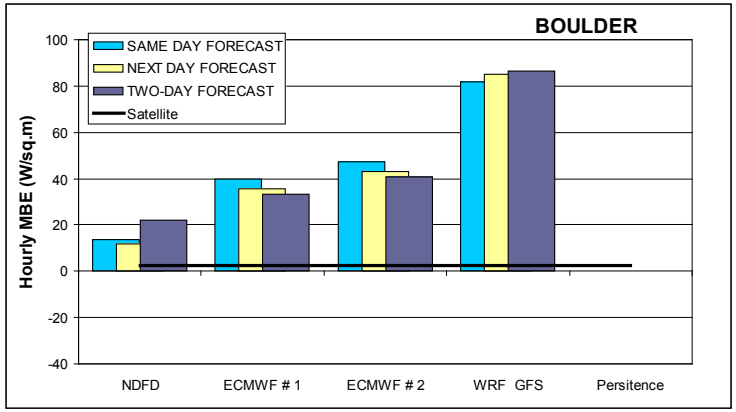


AFSOL direct
ECMWF direct
Meteosat-7 direct

Source: Breitkreuz, et. al

Performance of GHI forecasting schemes (top: RMSE, bottom: MBE)



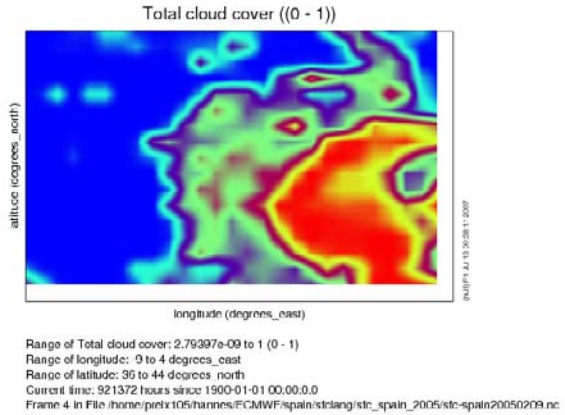


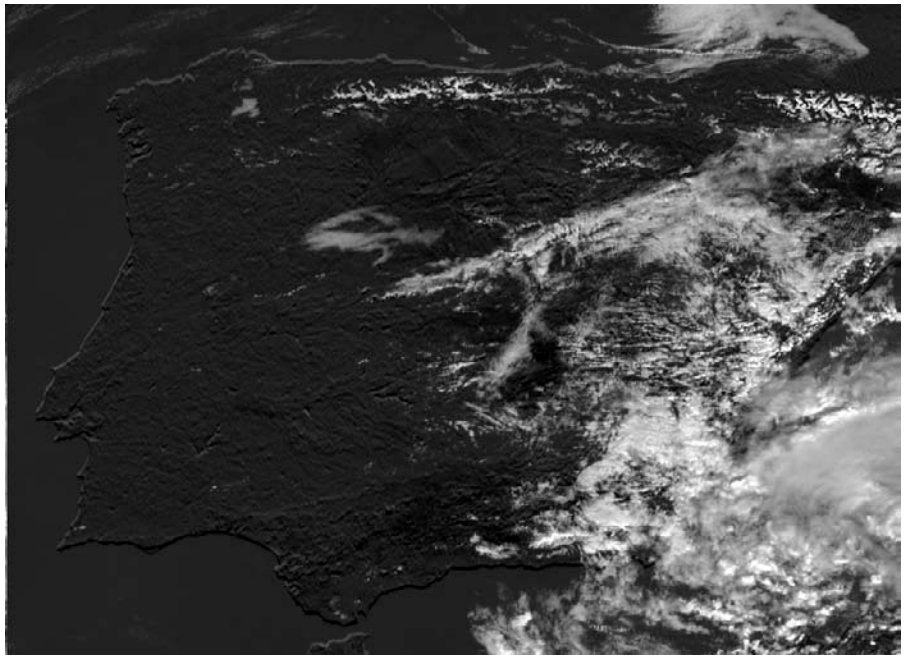
Source: Perez et. al

Solar Forecasting in IEA/SHC Task 36 (cont'd)

University of Oldenburg

- Power prediction for PV systems
- Benchmarking of forecast procedures
- ECMWF Accuracies





Solar Forecasting in IEA/SHC Task 36 (cont'd)

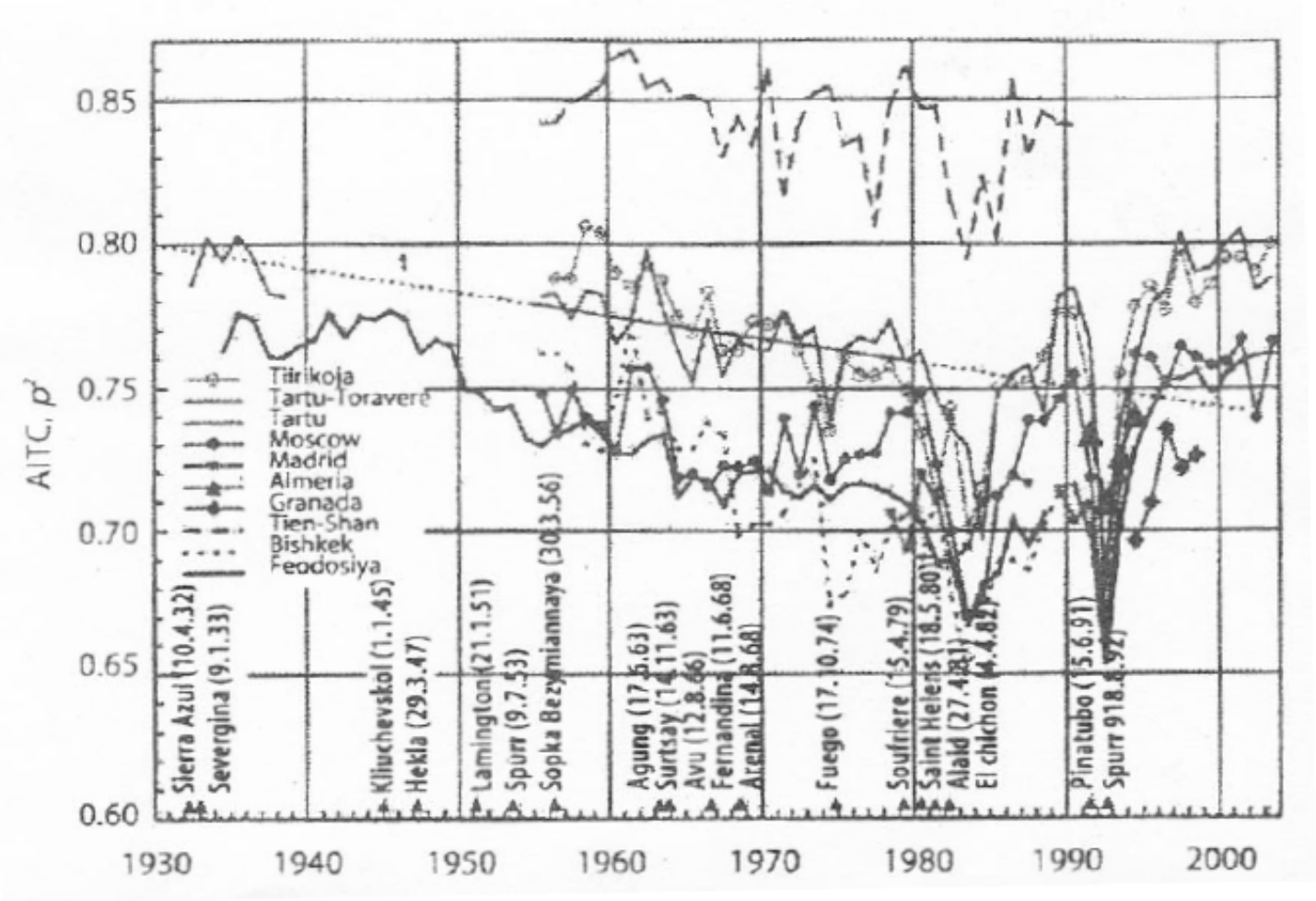
Environment Canada, NRCan
- Evaluate irradiance forecasts
- Relate to PV system performance
- Proposed coordination with NREL

Meteotest (Switzerland)
- MM5 Validation (GHI)
- 0-2 days
- 30-km resolution
- Future: WRF Validation (10-km resolution)

ASiC (Austria)
- Management of district heating

University of Jaén, southern Spain (Andalusia)
- MM5, enhanced resolution (1-km) using GIS
- Topographic effects (slope, shading)
- Future: 10-year projections to evaluate climate change

Long Term Trends: the Story of Global "Dimming" and "Brightening"



Source: Ohvril et al. (2005)

Current Understanding of Global "Dimming/Brightening"

"Dimming" from 60s to late 80s, "brightening" since

- Most noticeable in DNI
- Rough correlation to cloud cover trends
- But, also correlates to aerosol trends in some areas

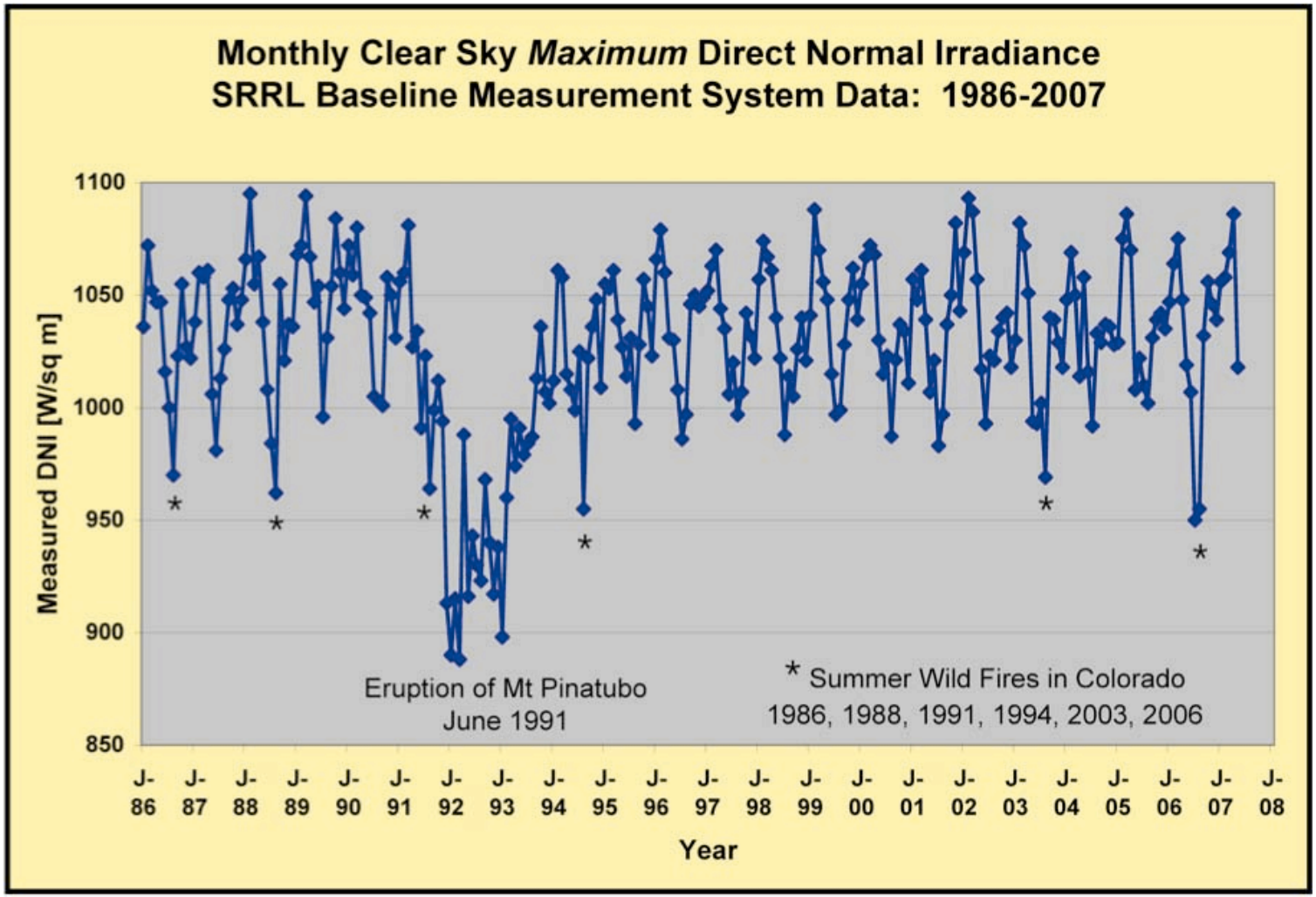
As a consequence: Rise in global temperature accelerates in recent decades

Regional variations where brightening not seen

- e.g. China and India, European Arctic

Overall, a very complicated and unproven situation…

DNI Trends Observed at SRRL, 1986-2008



Source: Tom Stoffel, NREL

Trends from ISCCP/ISIS Analysis: 1984 - 2004

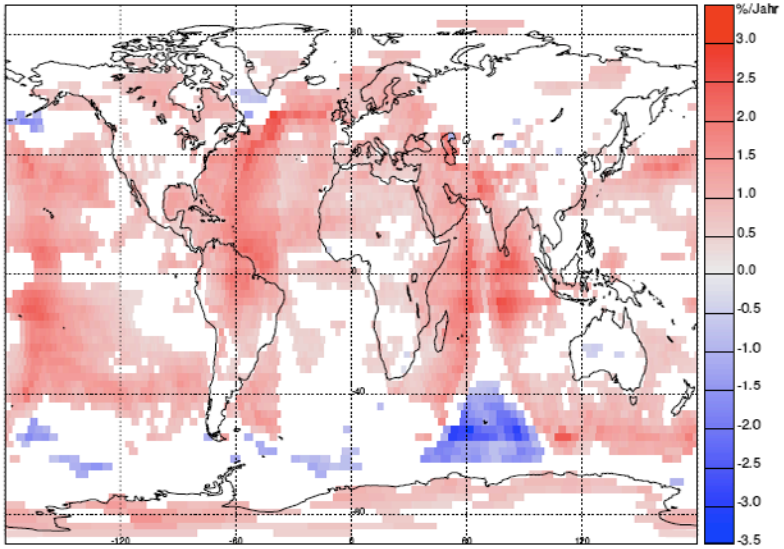


Abbildung 5.16: Signifikante Trends der Direktnormalstrahlung zwischen 1984 und 2004. Der maximale Anstieg von +2.8% pro Jahr ergibt sich im Nordatlantik, die größte Abnahme von -3.4% pro Jahr wird für Gitterboxen im südlichen Indischen Ozean errechnet.

Direct Normal Insolation (DNI)

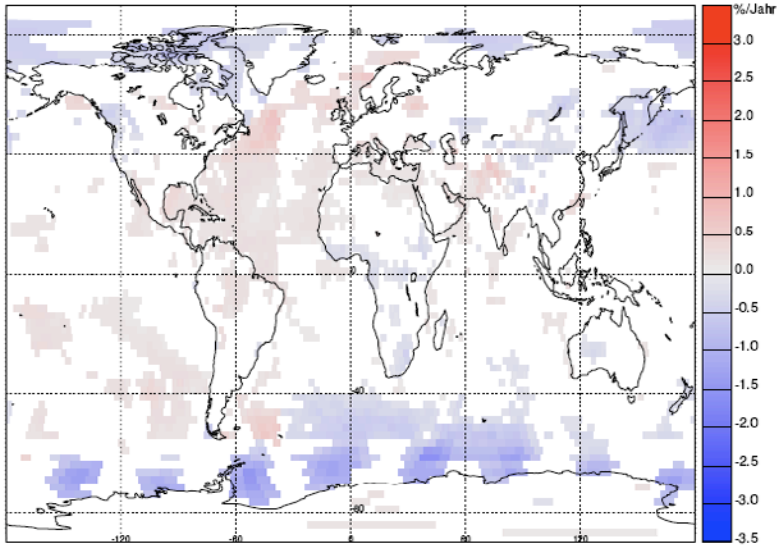


Abbildung 5.15: Signifikante Trends der Globalstrahlung zwischen 1984 und 2004. Der maximale Anstieg von 0.7% pro Jahr ergibt sich im Nordatlantik vor der Südspitze Grönlands, die größte Abnahme von -1.6% pro Jahr wird für Gitterboxen im Südpolarmeer errechnet.

Global Horizontal Insolation (DNI)

Source: Sina Lohmann, PhD Thesis (2006)

DNI Effects: El Nino/Southern Oscillation (ENSO)

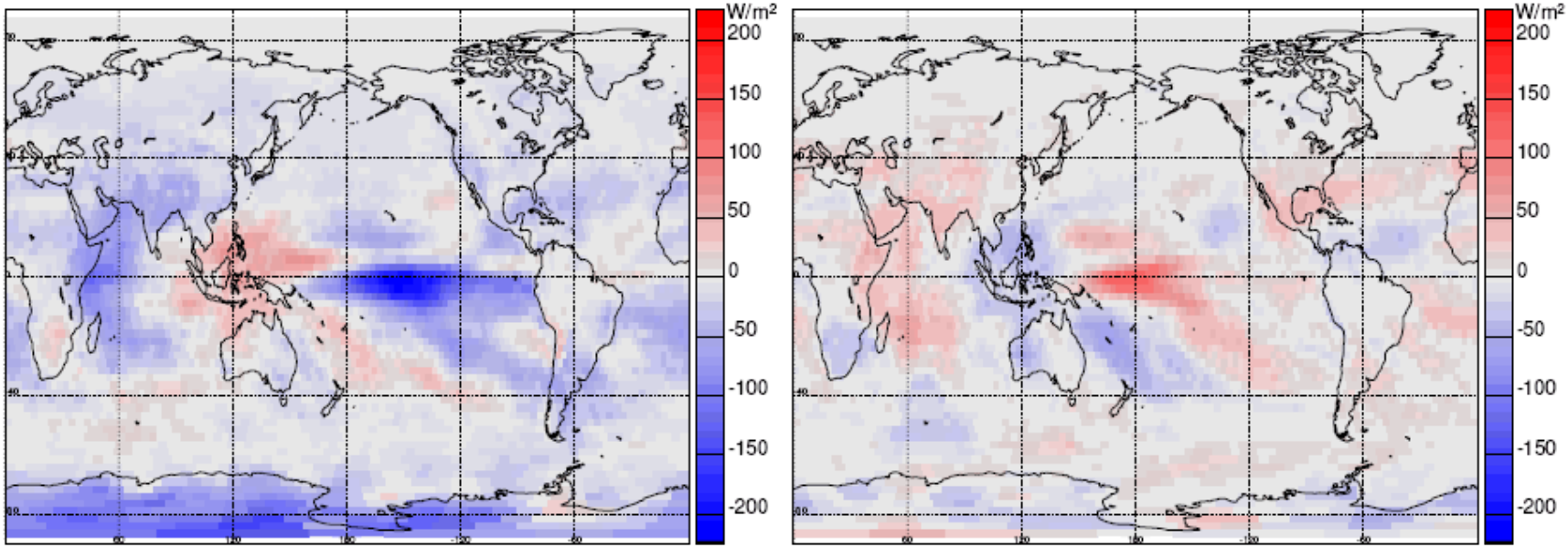


Abbildung 5.24: Anomalien der Direktnormalstrahlung die Monate Dezember/Januar/Februar in El Niño-Situationen (links) und La Niña-Situationen (rechts). Die Maximal- und Minimalwerte sind in Tabelle 5.9 angegeben.

Source: Sina Lohmann, PhD Thesis (2006)

Program Focus - Summary

- SOLRMAP measurement activities
- GIS analysis of domestic, international data sets
- DNI model enhancements
- Short-term forecast methodologies
- Long term trends and variability

Continuation of Operating Agent Support to IEA/SHC Task 36 and WFO support (e.g. USAID, SWERA) assures connections to key international data sources