Final Report on SolarPACES-Project "Standardizing and Benchmarking of Model-Derived DNI-Products - Phase 1"

Richard Meyer

Presentation to IEA SolarPACES ExCo 83
September 9th 2012, Marrakech, Morocco

Overview

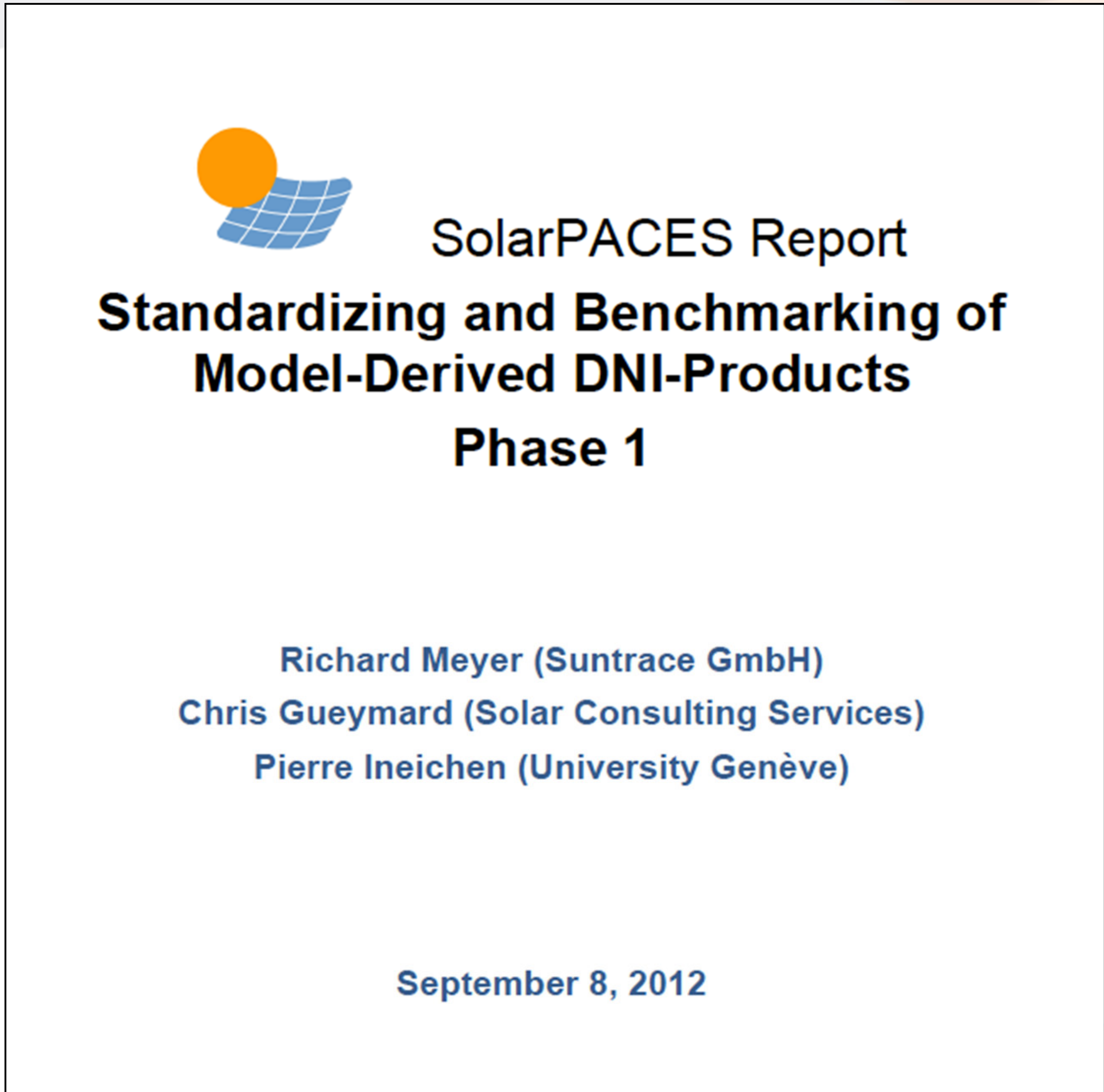
- Objectives of DNI benchmarking
- Quality parameters for model-derived DNI products
- Availability of reference data
- Preliminary benchmarking results for 23 sites in Europe and MENA
- Continuation of the activity

Objectives of DNI benchmarking

- provide quality statistics for model-derived historic DNI data products
- involve as many data providers as possible (public and private)
- cover all regions worldwide relevant for CSP (mainly latitudes <45°)derive results separated for regions if sufficient number of stations
- allow multiple data sets from the same provider, e.g.
  - products at various time resolutions, or
  - related to various spatial resolutions, or
  - successive versions or updates of products,
- differentiate results by using
  - all available stations,
  - only public stations (which the model developers might have used for training)
  - only non-public stations,
- execute comparisons over long time periods to reach stable and significant results and derive indications about variability

Status of the DNI-benchmarking project

Final report phase 1 submitted


SolarPACES Report

Standardizing and Benchmarking of Model-Derived DNI-Products

Phase 1

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Pierre Ineichen (University Genève)

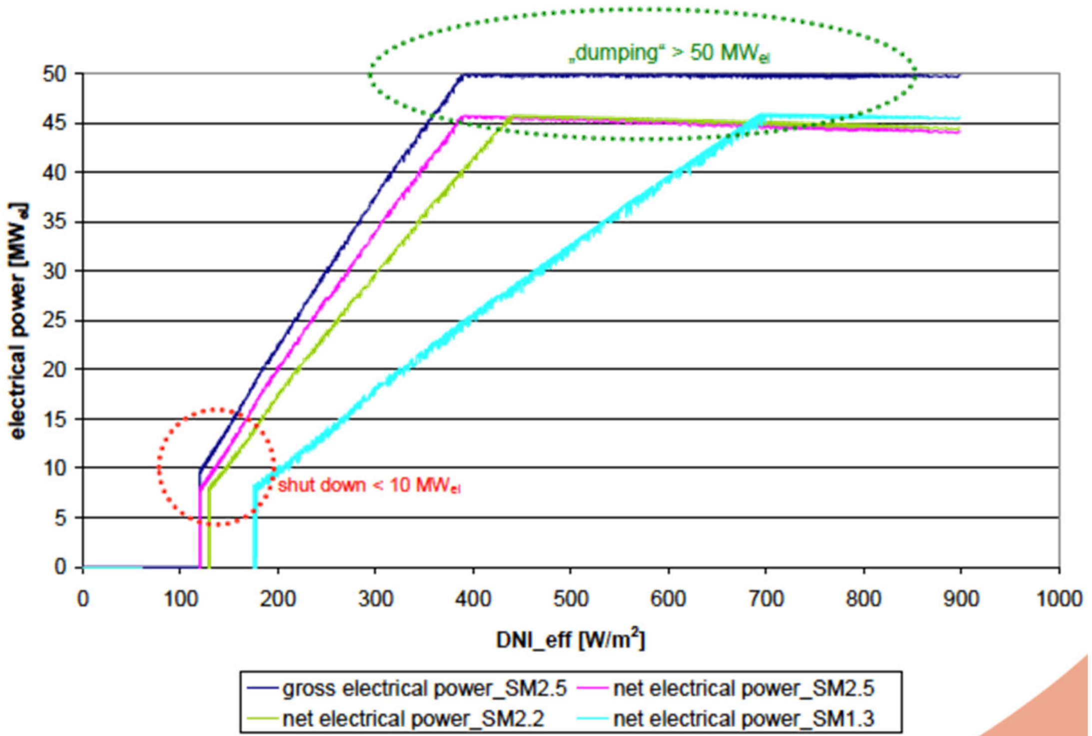
September 8, 2012

Quality parameters for model-derived DNI products

Goal: providing a set of statistical parameters for each delivered data product

Statistical parameters identified valuable for CSP

- mean bias MB,
- standard deviation of differences SD,
- root mean square deviation RMSD,
- Kolmogorov-Smirnov Integral KSI or similar for freq. distrib.
- CSP-performance-weighted DNI performance statistics.



Availability of reference data: public measurements with DNI

Total of 183 stations, 178 below 45° latitude and 133 below 40°

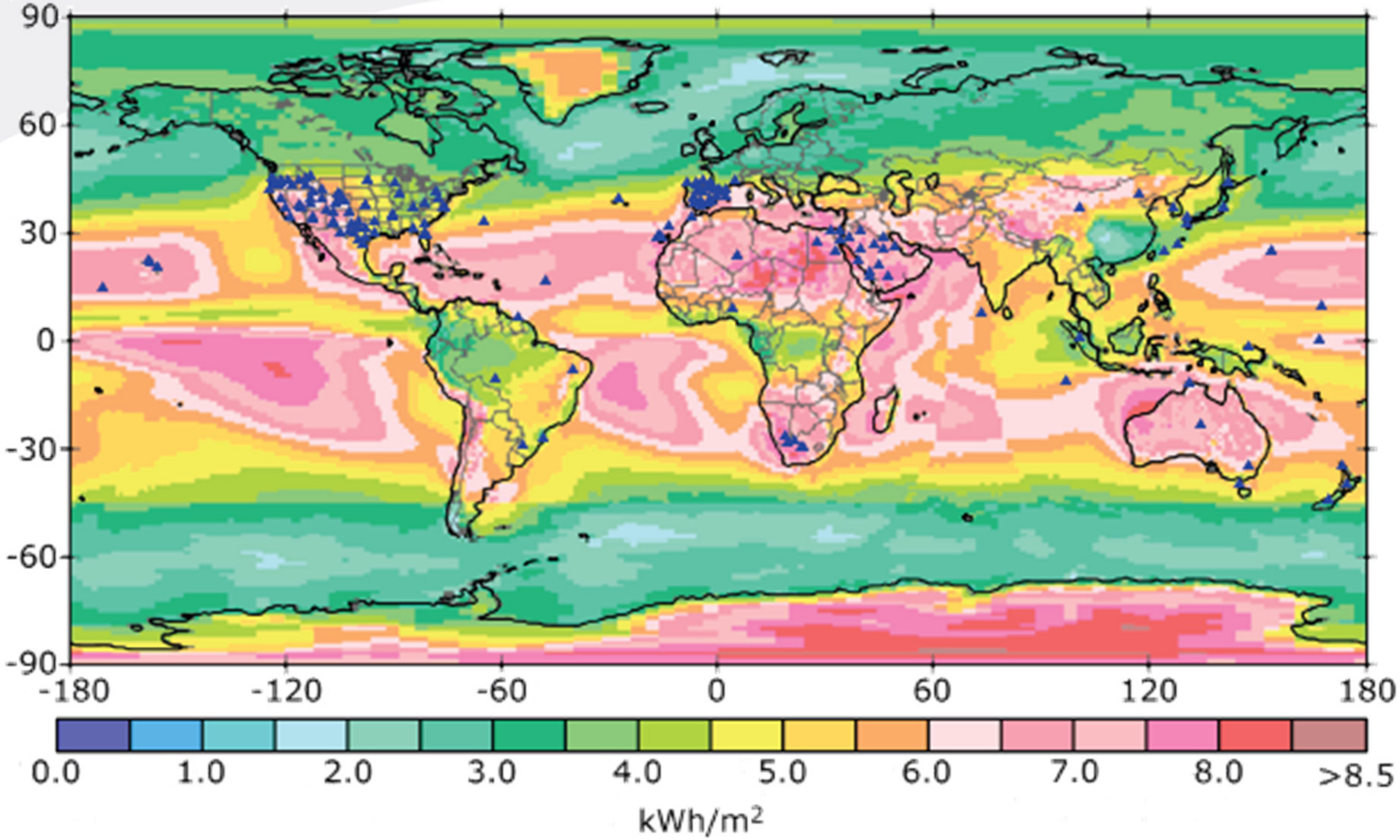


Fig. 2: Location of public stations (blue triangles), superimposed on a map of mean annual DNI based on the NASA-SSE dataset.

Availability of reference data: non-public measurements with DNI

Many more than expected

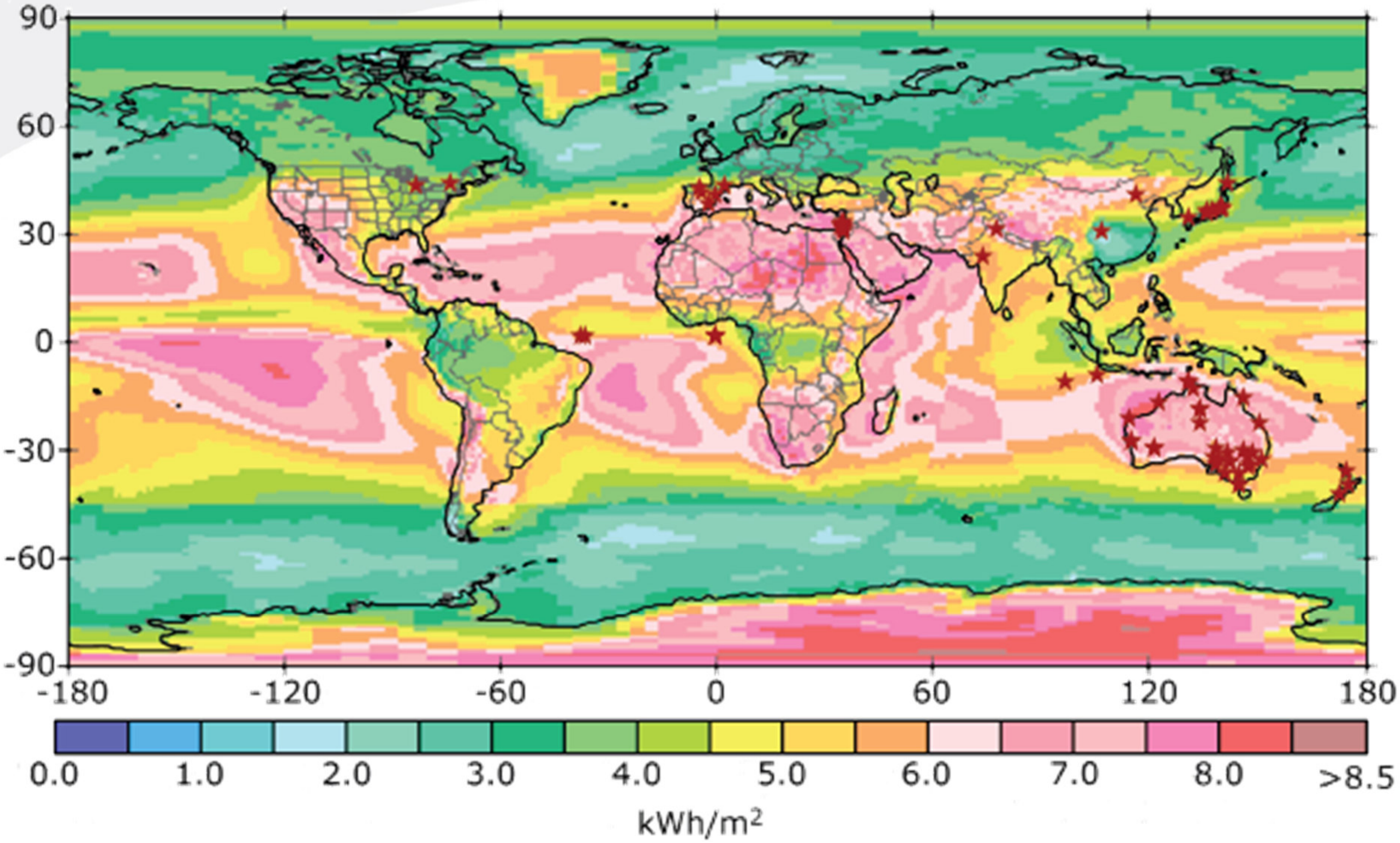
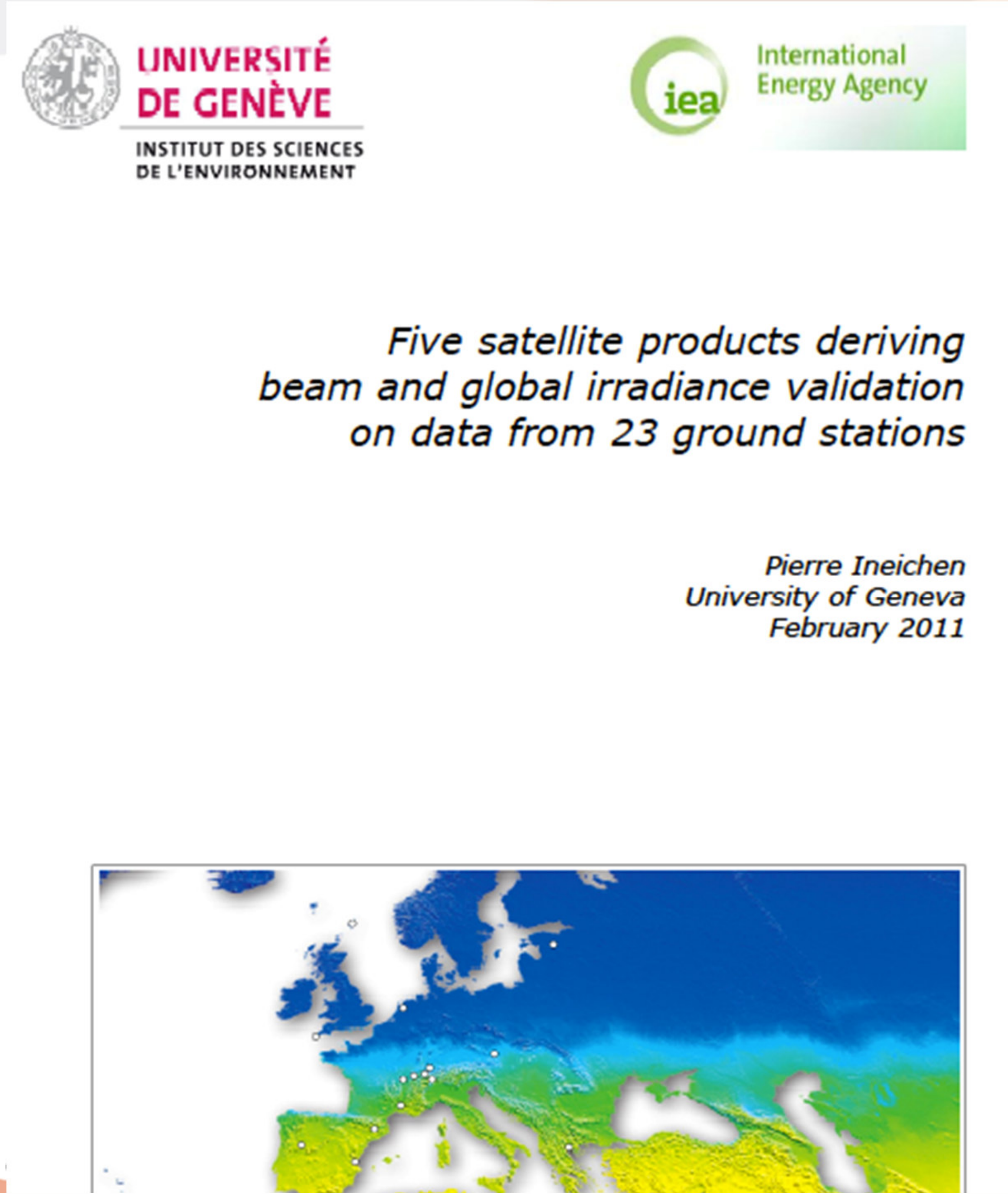


Fig. 3: Same as Fig. 2, but for private or non-public stations.

Preliminary benchmarking results for 23 sites in Europe and MENA

Pierre Ineichen published extensive report


UNIVERSITÉ DE GENÈVE
INSTITUT DES SCIENCES DE L'ENVIRONNEMENT

International Energy Agency

Five satellite products deriving beam and global irradiance validation on data from 23 ground stations

Pierre Ineichen
University of Geneva
February 2011

Preliminary benchmarking results for 23 sites in Europe and MENA

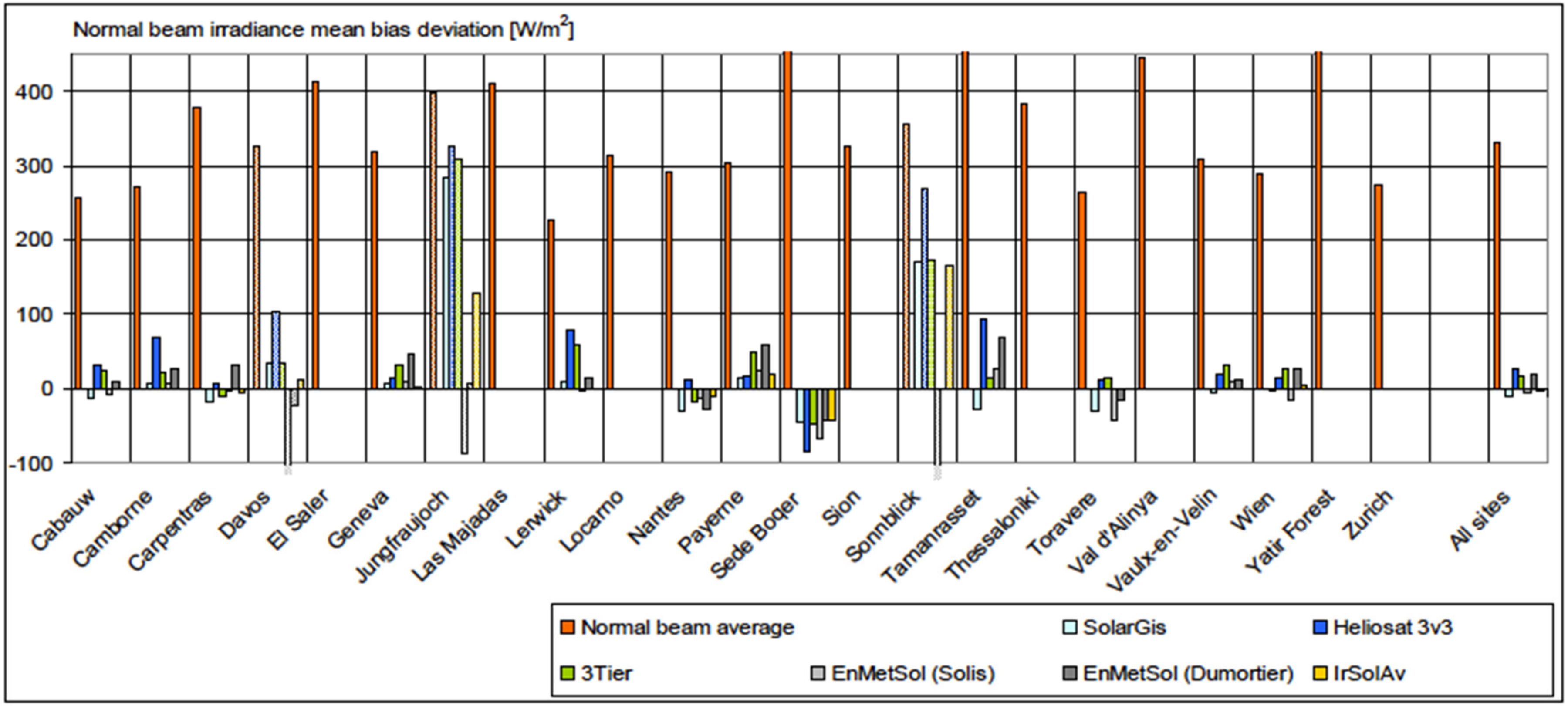


Figure 22 Average beam irradiance and absolute mean bias difference

Preliminary benchmarking results:
rSD of hourly data 20 % to 100 %

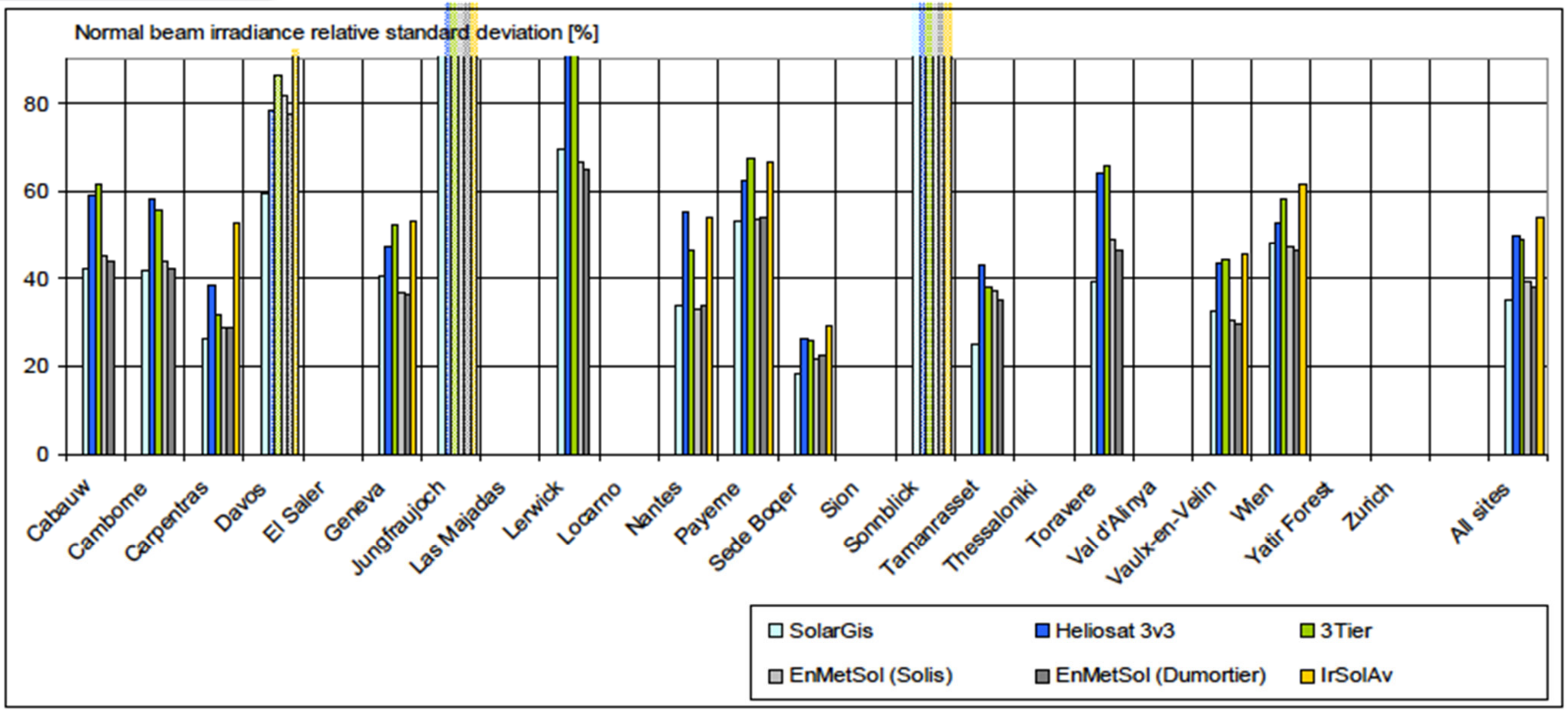
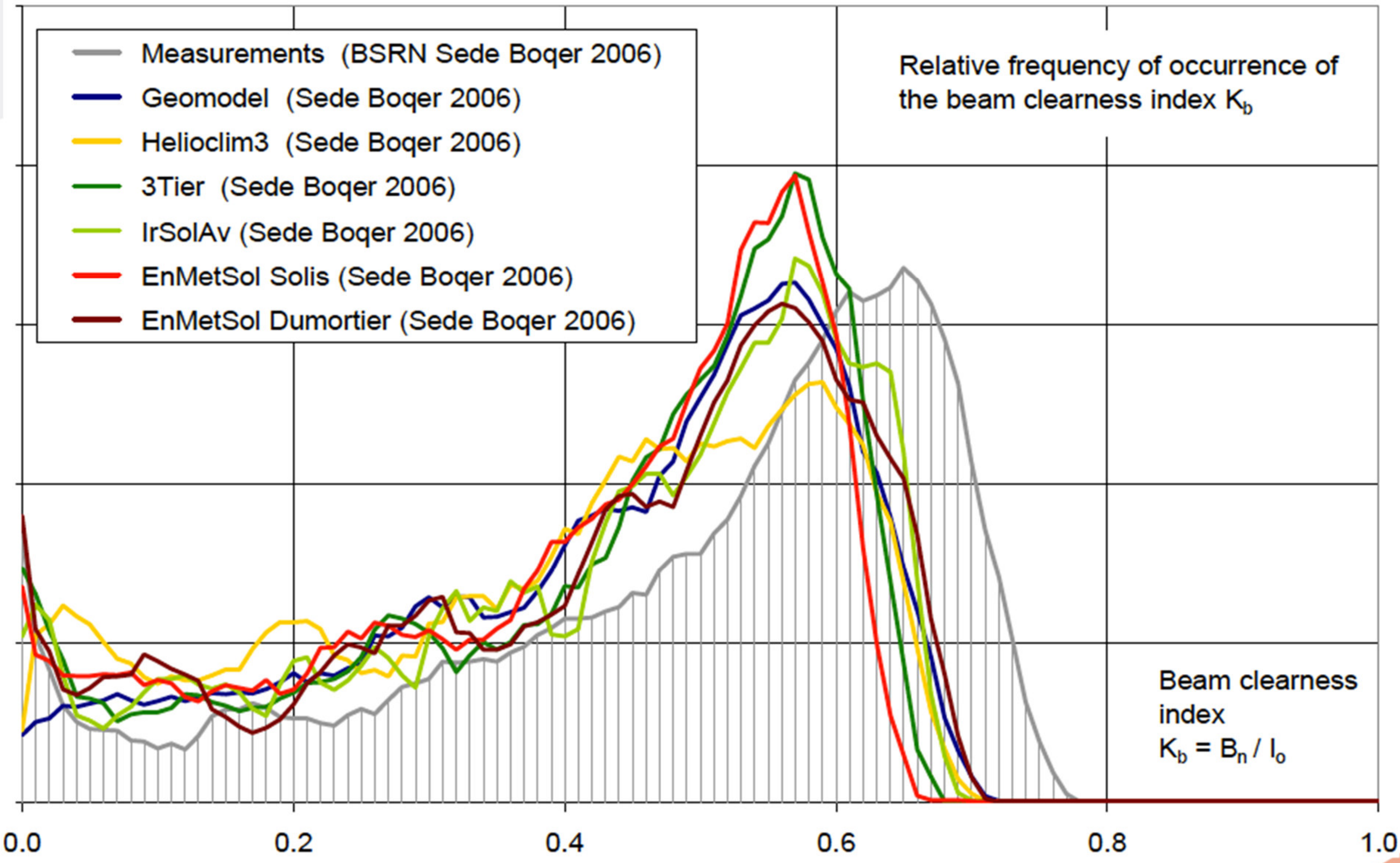


Figure 23 Relative standard deviation for the beam irradiance.

Preliminary benchmarking results: All models underestimate the freq. of high DNI at this site



Preliminary benchmarking results: frequency distribution could be improved

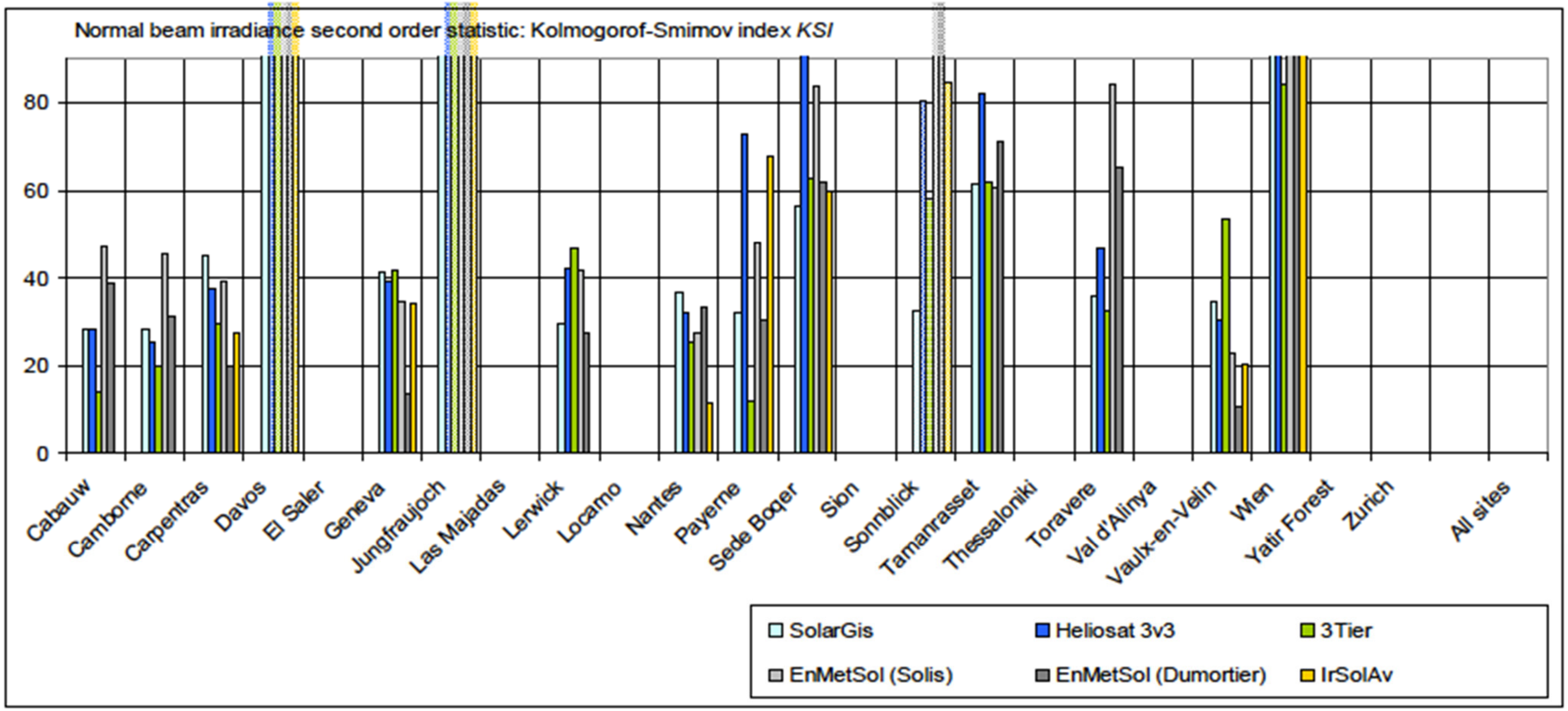


Figure 24 Second order statistics *KSI* for the **beam** irradiance

Continuation of the activity

Actual worldwide DNI benchmarking exercise could be organized like this:

1. Define standards for DNI-time-series products
2. Detailed project organization and secure funding
3. Prepare a detailed project organization and secure funding
4. Prepare a workshop to inform stakeholders
5. Gather measured datasets and check their quality
6. Ask data providers for satellite-derived DNI data products
7. Check compliance of DNI data products with the agreed file formats
8. Perform the statistical analysis
9. Prepare internal & public technical reports

Thank you

Bonus track

Proposal for a workshop at 2013 SolarPACES

Venue for an experts workshop could cover the following topics:

- Importance of independent benchmarking to improve the credibility of data suppliers
- Statistical tests — what the CSP industry wants to know
- Discussion about the benchmarking criteria — scientific vs. commercial considerations
- Previous experiences with measured data from various sites —what interpretation errors to avoid
- Definition of common data formats for the modeled and measured data
- Proposal on how to conduct a fair benchmarking
- Ways of dealing with possibly confidential data and publication of results

Work packages – phase 1

WP1: Proposing criteria for the benchmarking process
WP2: Drafting standards for the satellite-derived data sets
WP3: Exploring available ground-based measurements
WP4: Defining quality check routines for measurements
WP5: Organizing the actual benchmarking
WP6: Coordination of the activity and production of the report

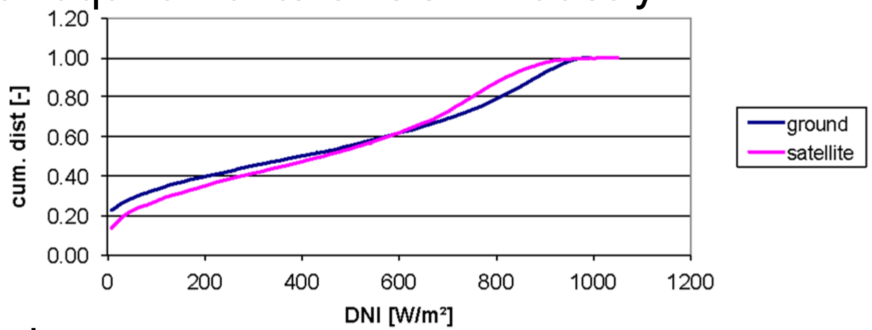
WP1: Proposing criteria for the benchmarking

Proposed rules for the benchmarking process:

- apply these measures in a well defined way: relate results
  - to identical time periods (trivial - but was not always done in comparisons),
  - to same time resolutions,
  - to comparable spatial resolution (if possible).
- apply classic measures for inter-comparability to earlier work: mean bias MB and root mean square deviation RMS
- use additional measures, more specific to requirements of CSP industry:
  - consider only data with sun height > 5°
  - filter for CSP-relevant DNI-intensity:

    DNI > 250 W/m²

    as for lower DNI solar thermal plants usually not operating

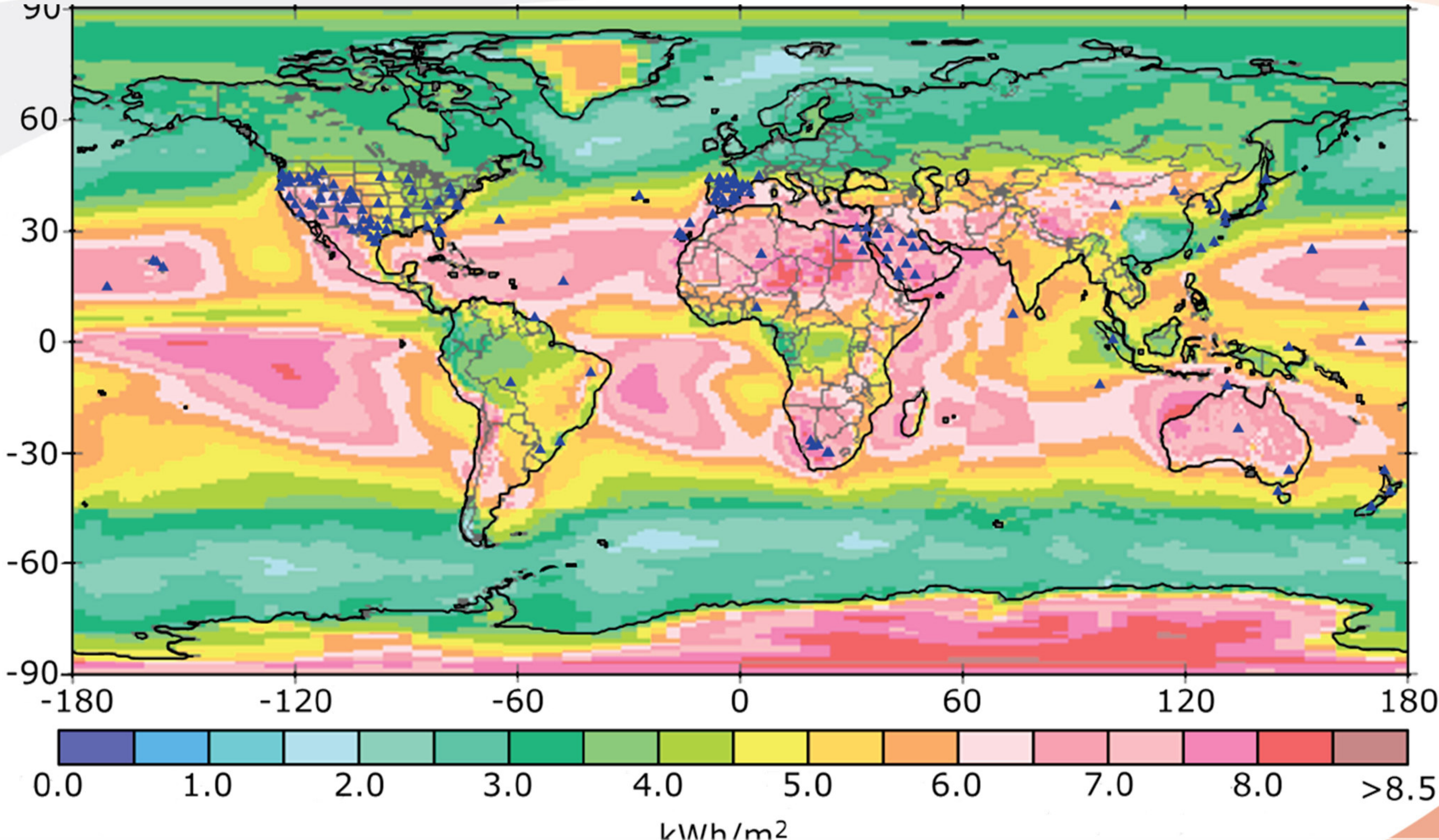


  - effective DNI_{eff} taking into account sun angles but fully applicable only for NS-aligned parabolic trough => therefore not applied
  - KSI (Kolmogorov-Smirnov-Integral) useless for CSP (Chhatbar & Meyer 2011)
  - Alternatively proposing an integral measure “CSP-weighted KSI”

WP2: Drafting standards for solar radiation time-series products

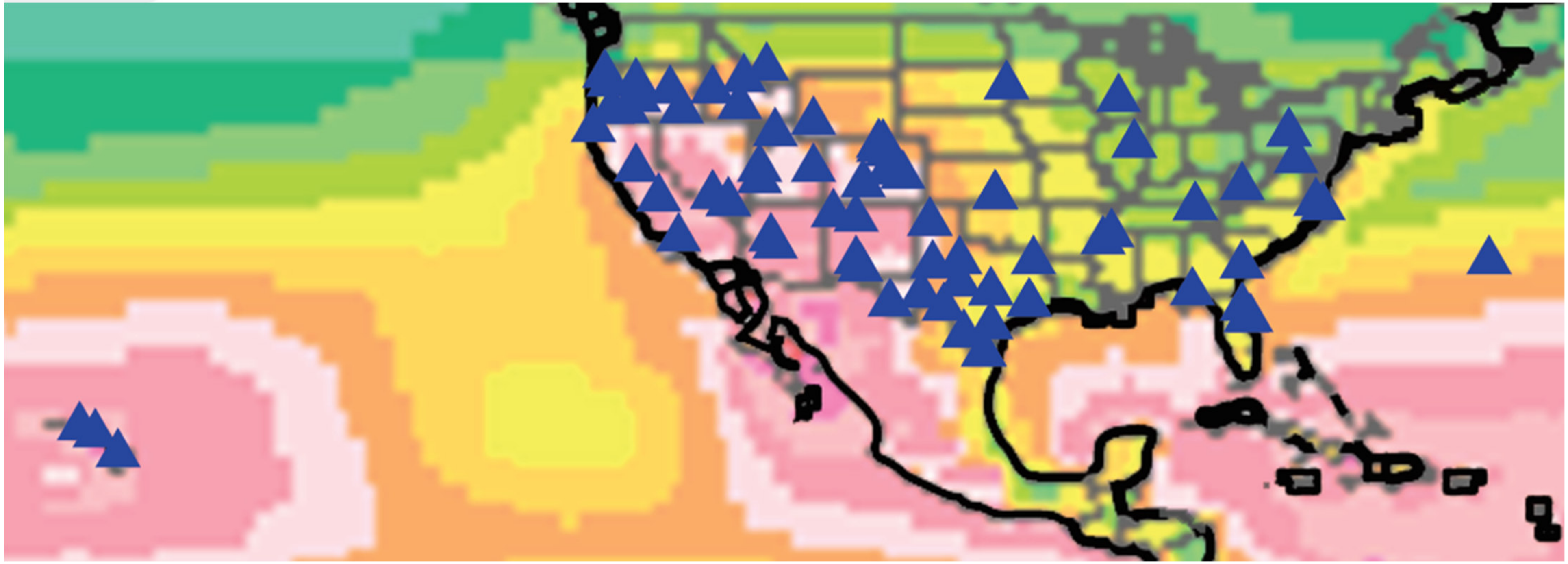
- Commonly accepted format for DNI-data:
  - Used today in CSP industry:
    - TMY3-data format as used in SAM
      - TMY3 has advantage of having data channels (columns) for uncertainty of each property and relatively easy to create comma-separated ASCII-format
      - But misses extensive header for meta data
    - MESOR (EU-project)
      - Allows very specific well defined header
      - Blank separated ASCII-format
      - Allows free time steps and begin and end => shorter and longer than one year
  - Both format types lead to very large file sizes, especially, when < 60 min and various auxiliary meteo data and uncertainty information shall be carried.
- Commonly used formats in remote sensing & meteorology are well-defined binary files like netCDF or HDF.
  - Both allow detailed meta-data and multiple channels and low file sizes
  - Easy I/O with existing software tools in most languages like C, Matlab etc.
  - But format not yet applicable in common performance simulation tools

WP3: Available ground-based measurements:
1) public measurement sites with DNI



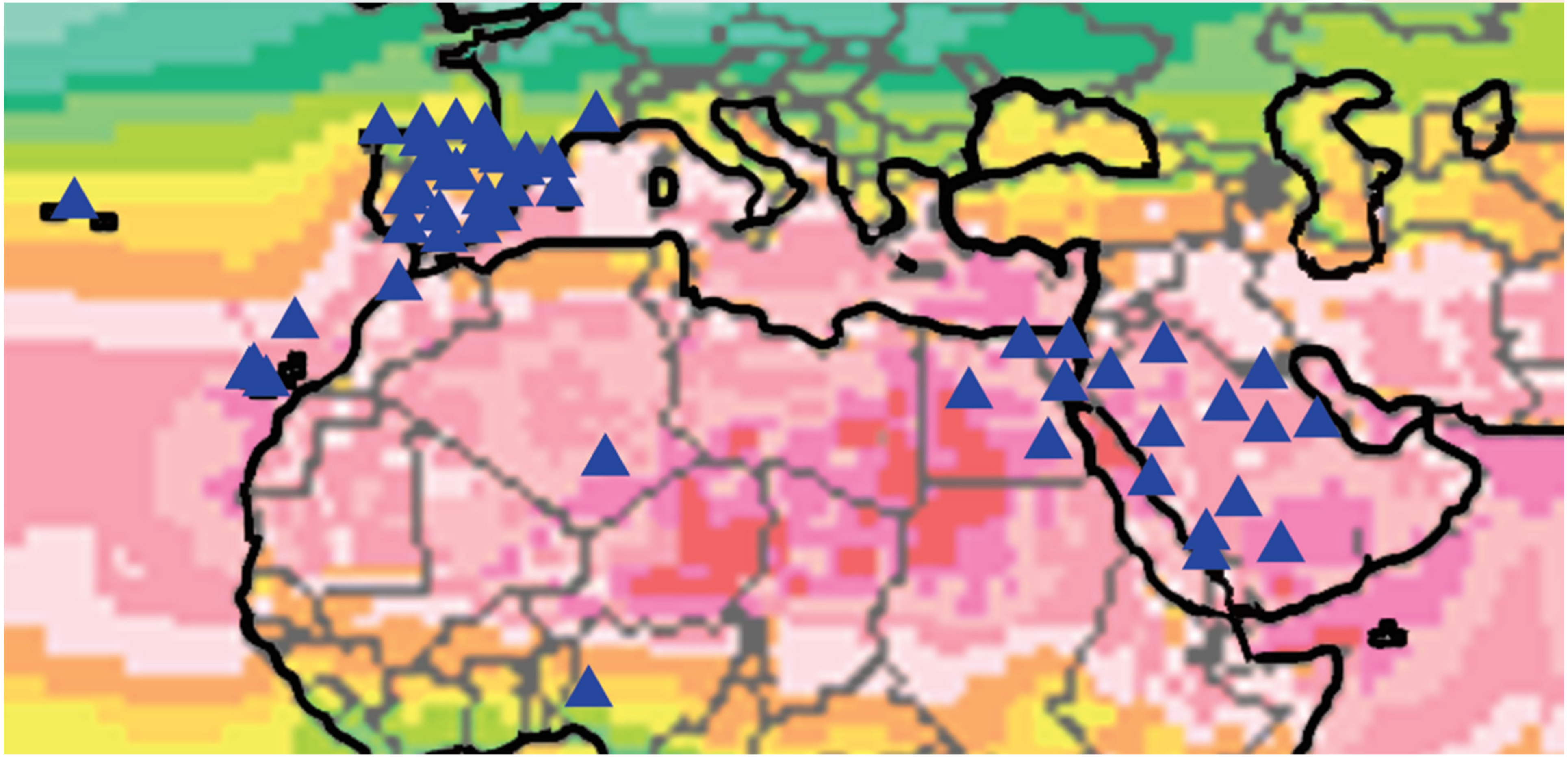
Total of 183 stations, 178 below 45° latitude and 133 below 40°

WP3: Available ground-based measurements: 1) public measurement sites with DNI - USA



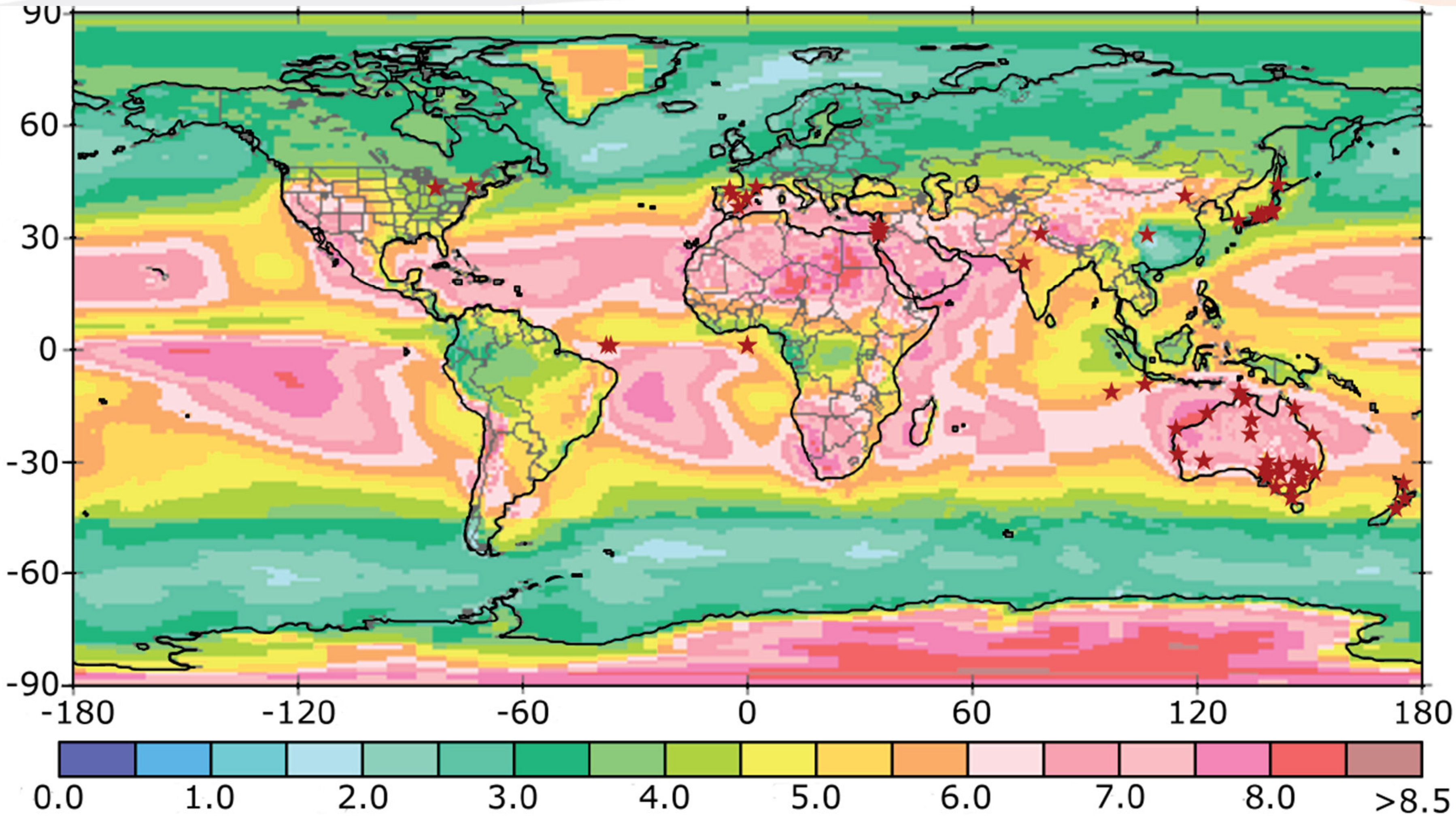
More than expected – good availability & quality

WP3: Available ground-based measurements:
1) public measurement sites with DNI – MENA



Many more than expected – but availability & quality needs to be checked

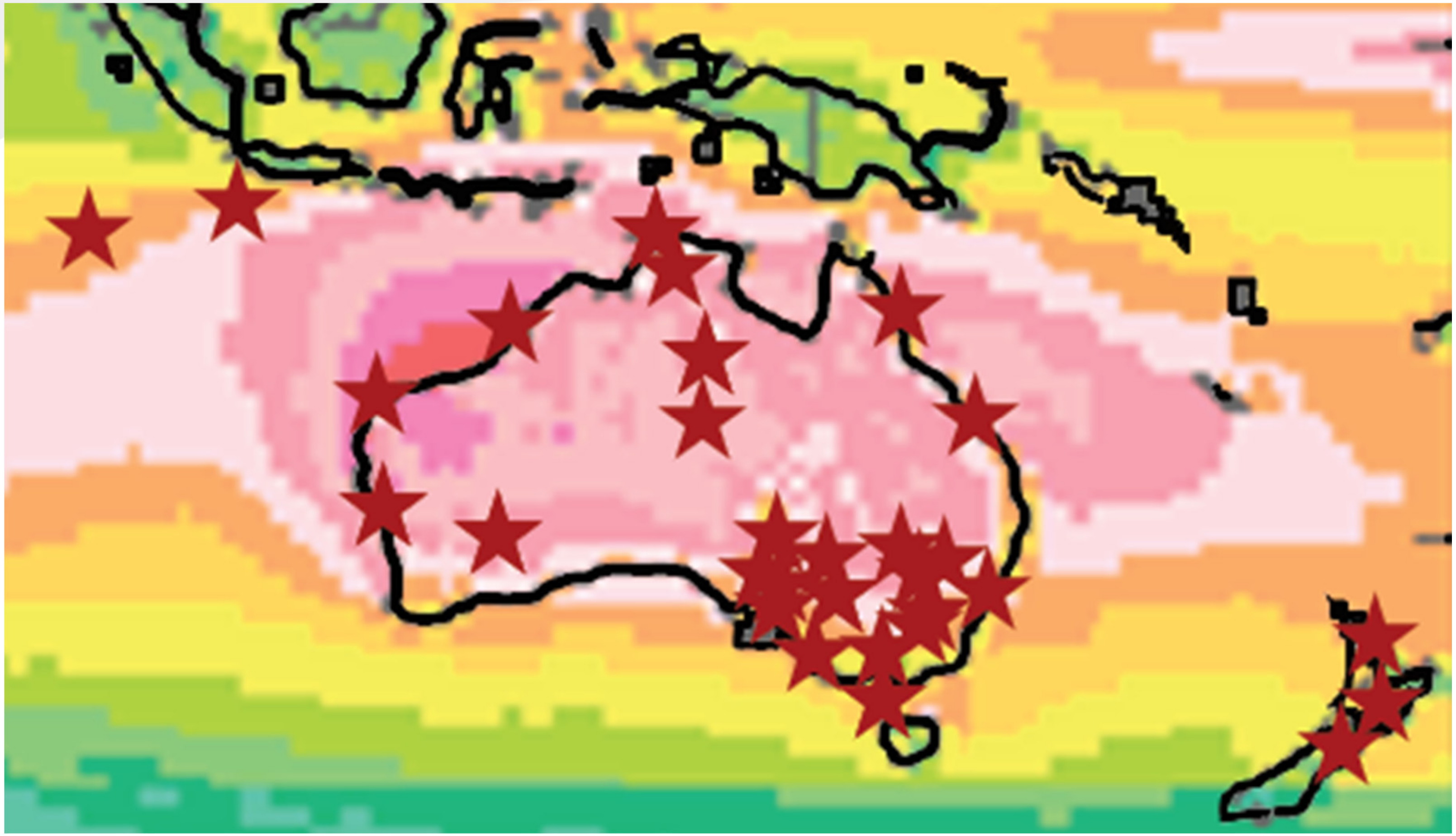
WP3: Available ground-based measurements: 2) non-public measurement sites with DNI



Total of 73; all below 45° latitude, and 56 below 40°

Likely many more of project developers – but hard to find & difficult to access

WP3: Available ground-based measurements: 2) non-public measurements with DNI - Australia



Most stations here of Australian BOM – thus not really private

WP3: Available ground-based measurements: 2) non-public measurement sites with DNI

- The unknown DNI sites operated by project developers are those, which would be most valuable, as these offer a true blind test of the modeled data without danger of data incest.
- But project developers hardly would give access for either strategic reasons (confidentiality) or simply avoiding the work to prepare the data for handing over.
- However, many projects stranded and data there should be easier to access.

- At least 1000 EUR per complete year of good DNI data should be paid to make it and compensate for effort to prepare the data

Availability of reference stations

- CSP-relevant countries with lack of good DNI measurements are setting up good measurement networks
  - Chile: 12 stations just set up
  - India: 51 stations just set up (SRRA-network)
  - MENA-region: German enerMENA-project set up precision stations in 4 countries around the Mediterranean Sea
- Established networks with good DNI stations identified & may give limited access
  - Australia: BOM approx. 12 pyrheliometer stations
  - Israel: 7-9 stations of the Negev radiation study
  - South Africa: ESKOM offers limited access to their 4 pyrheliometer stations

- Proposal for a CSP-weighted integral value for fast identification of suitability of DNI time-series data set for realistic CSP performance

WP4: Defining quality check routines for selection of the measurements

Reviewed

- MESOR routines or
- SERI QC
- NASA routines or

Best off all routines should be applied

Application in Phase 2 still will be very time-consuming, due to many different station types and practices of DNI measuring.

All have specific types of errors and do not allow generalized approach.

WP5: Organizing the actual benchmarking

- Presentation of the plans and invitation to participate in Phase 2 at SolarPACES Symposium in September 2011:
- Execution of benchmarking: first round 2012
- Analysis of results and presentation of results: Fall 2012

STANDARDIZING AND BENCHMARKING OF MODELED DNI DATA PRODUCTS

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1. Introduction

Direct normal irradiance (DNI) is the 'fuel' of concentrating solar power (CSP) systems. The intensity and distribution of DNI are dominating factors for the design and performance of CSP plants. Due to the significant short-term and long-term variability in DNI, CSP analysts must obtain DNI data time series—not just mean annual averages. It has been shown that a relatively accurate annual value might be predicted by satellite-based models, but with large errors in monthly values [1]. Using probabilistic performance simulations, which also take the uncertainty of many technical parameters into account, it has been shown that the uncertainty and variability in annual DNI at a site is the single greatest cause of uncertainty when predicting the energy production of a CSP plant [2]. In addition to the need for verifiable accuracy in monthly-average DNI, realistic performance simulations of a CSP installation depend on reliable time-series of DNI and ancillary meteorological variables, such as temperature. Many simulation tools use only a synthetic year (referred to as TMY). To avoid power output prediction errors of typically ≈ 10 %, such TMY data sets must well represent