Digital Atlas of Direct Normal Irradiation (DNI) for Kingdom Saudi Arabia

Dr. Christoph Schillings

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

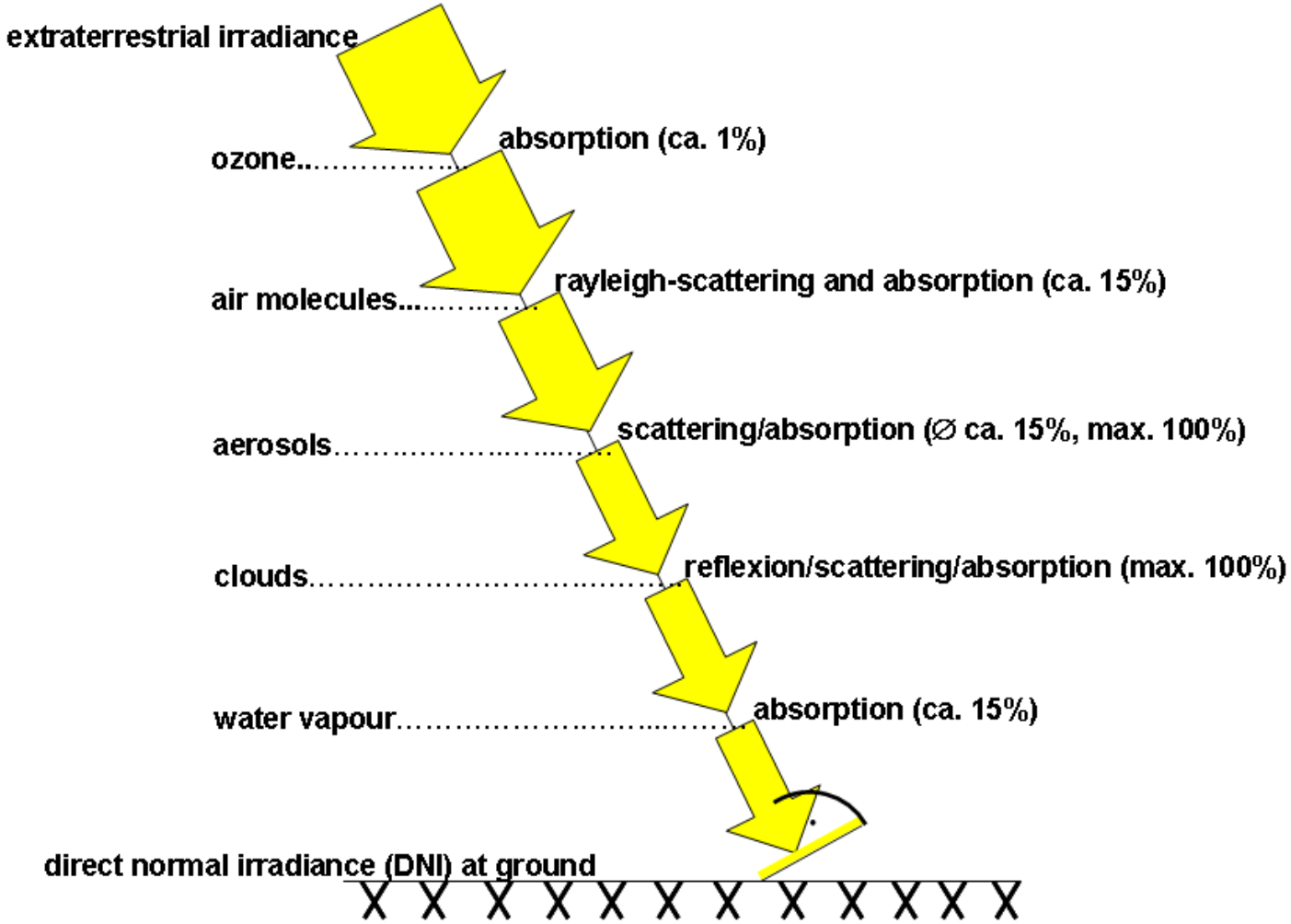
Why a Digital Solar Atlas?

Information on solar radiation (e.g. Direct Normal Irradiation for Concentrating Solar Thermal Power Plants) are needed for following issues:

- Potential assessment (solar atlas/map)
- Site Selection (solar atlas/map)
- Power Plant Layout (time series)
- Financing Issues (time series)

DLR, commissioned by KAUST and Saudi-Aramco, is developing a digital atlas of the Direct Normal Irradiation (DNI) for Kingdom Saudi Arabia.

Background: Attenuation / extinction of irradiation by the atmosphere



KSA Digital Solar Atlas: What is it about, what‘s behind?

Specification:

- averaged annual and monthly sums of DNI [kWh/m²]
- spatial resolution of ~1km² (= one pixel).
- covered time period 10 years (1996-2005)

Used data:

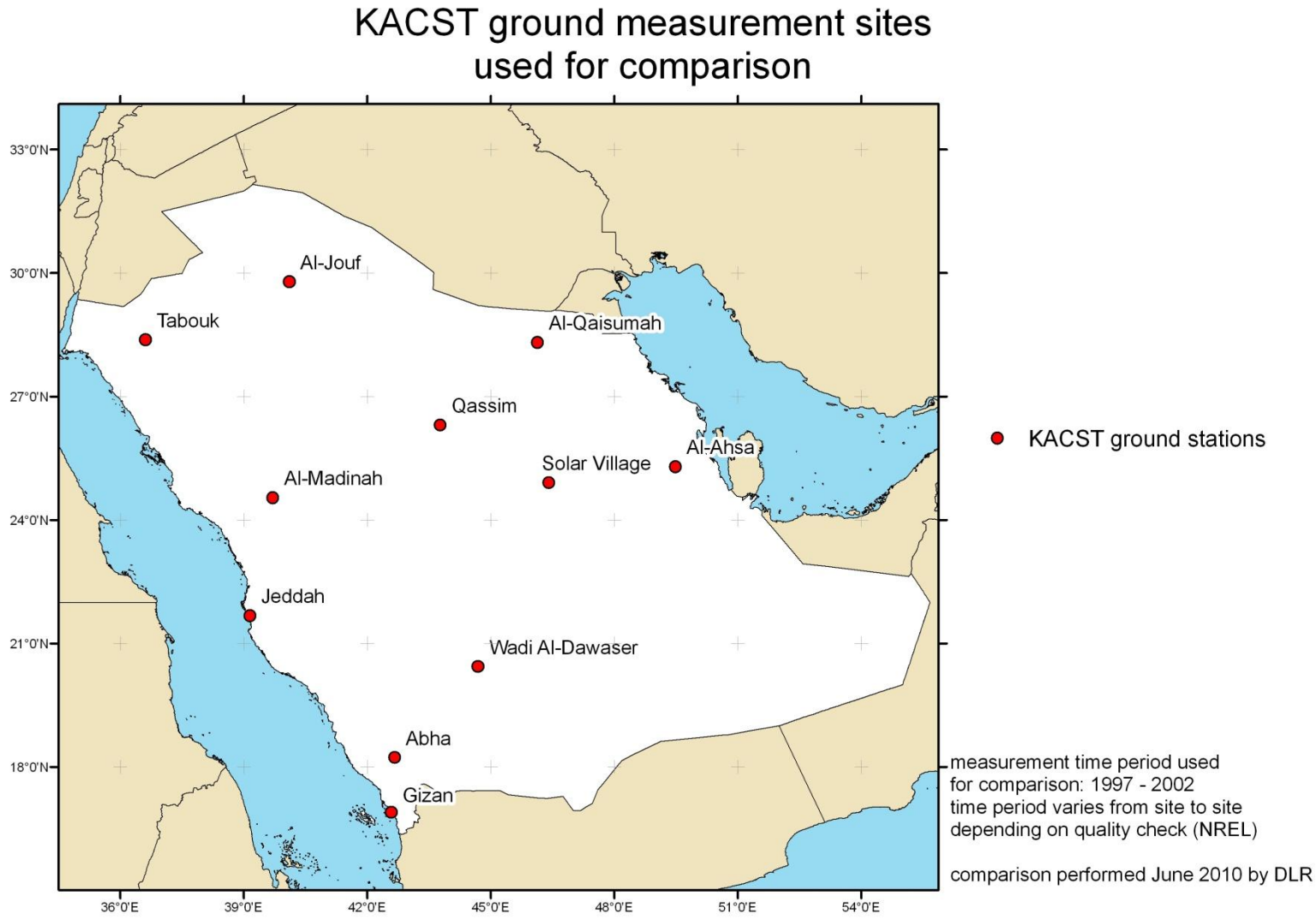
- METEOSAT data for **cloud** detection (2.5km x 2.5km)
- AEROCOM data for averaged monthly **aerosol** optical thickness (1° x 1°)
- NCEP/NCAR reanalysis data for daily **water vapour** (1.25° x 1.25°)
- TOMS satellite-measured data for monthly **ozone** (1.25° x 1.25°)
- GLOBE digital **elevation** model (1km x 1km)

- DLR-SOLEMI algorithm (v38) for DNI calculation

- Measured DNI data from 11 KACST ground sites for comparison/validation

Work is still in progress !

Accuracy assessment



Overall accuracy (preliminary)

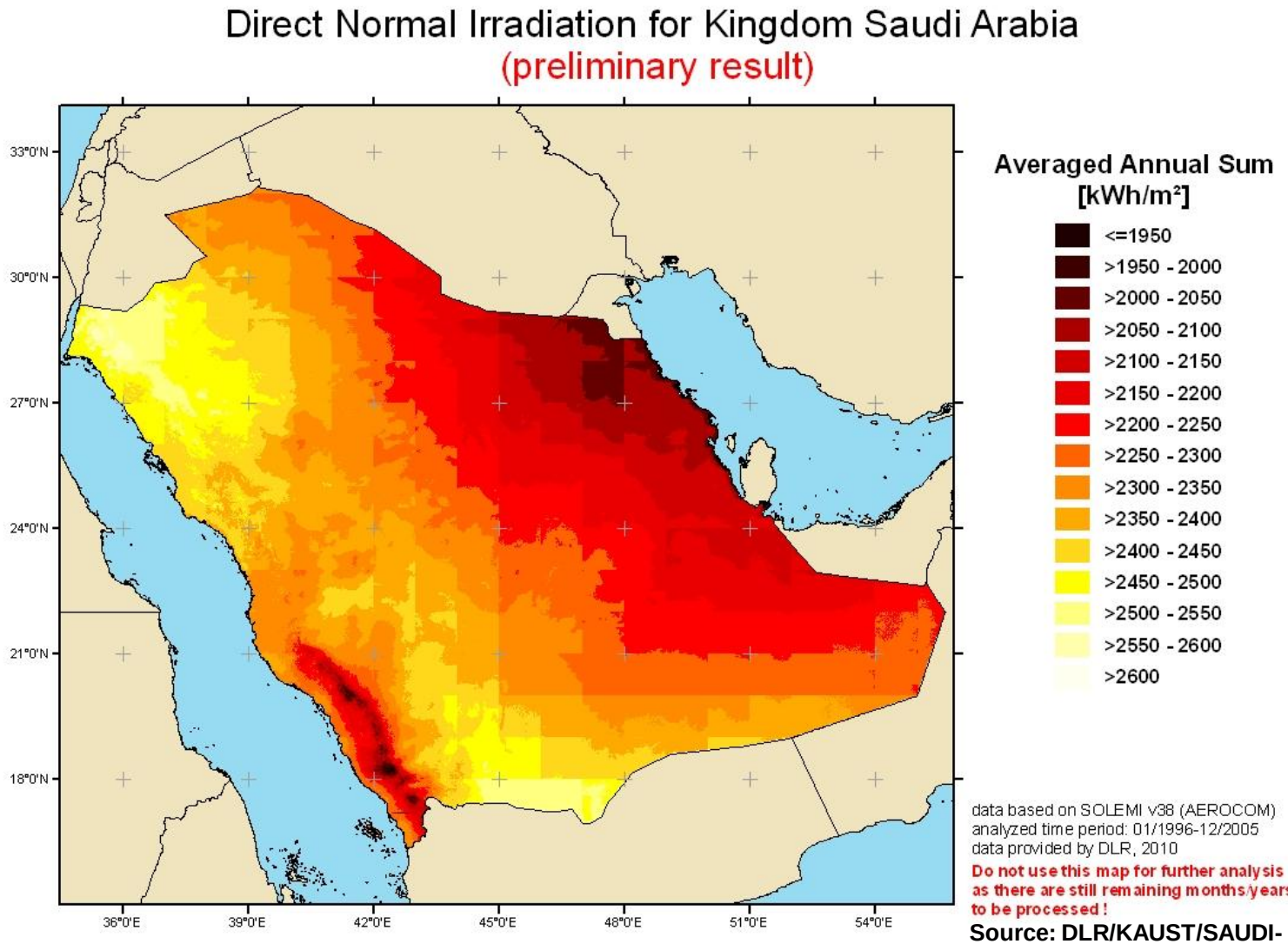
all sites	MBE [%]	RMSE [%]
hourly	2.86	38.66
daily	2.86	21.28
monthly	2.86	16.01
yearly	2.86	18.75*

***no representative value as some years still have missing months !**

Comparison based on 11 ground sites (KACST). Time period (1997-2002) varies from site to site depending on quality check of ground data (NREL).

Preliminary accuracy assessment as there are remaining months / years to be processes for the satellite modeling.

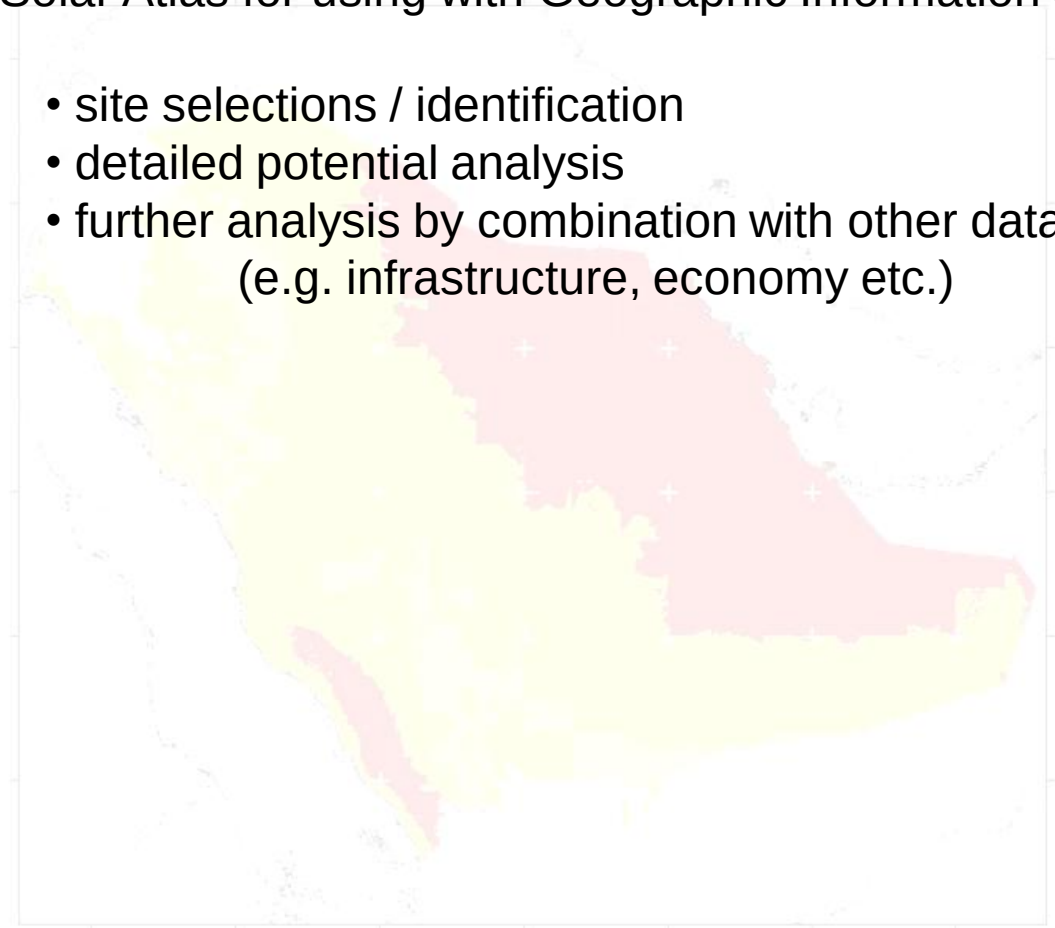
Potential Assessment / Site Selection



Source: DLR/KAUST/SAUDI- ARAMCO, 2010: internal study

Application

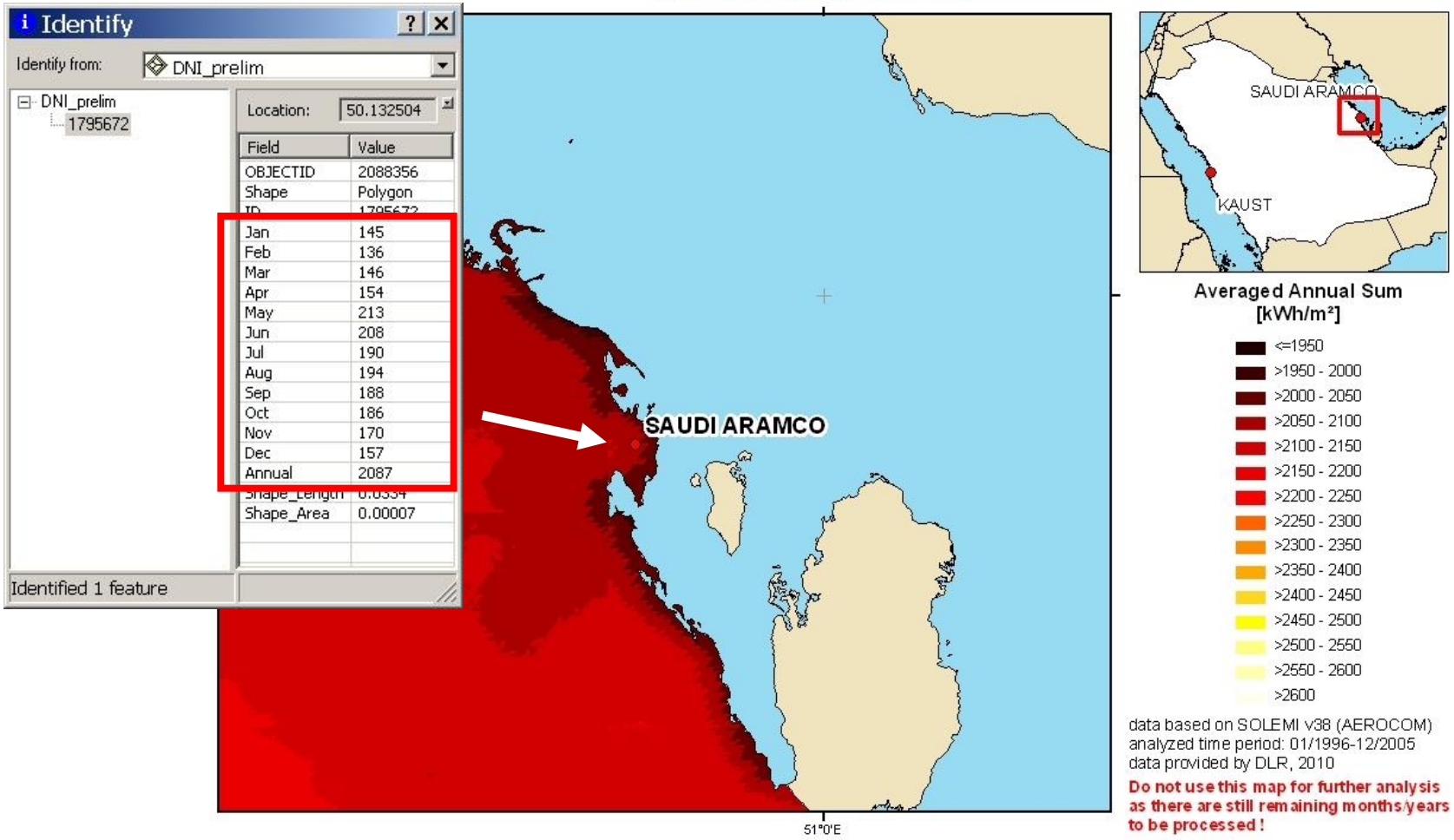
Digital Solar Atlas for using with Geographic Information System (GIS):



- site selections / identification
- detailed potential analysis
- further analysis by combination with other data
  (e.g. infrastructure, economy etc.)

Application example: Site identification / query

Direct Normal Irradiation for Kingdom Saudi Arabia
(preliminary result)

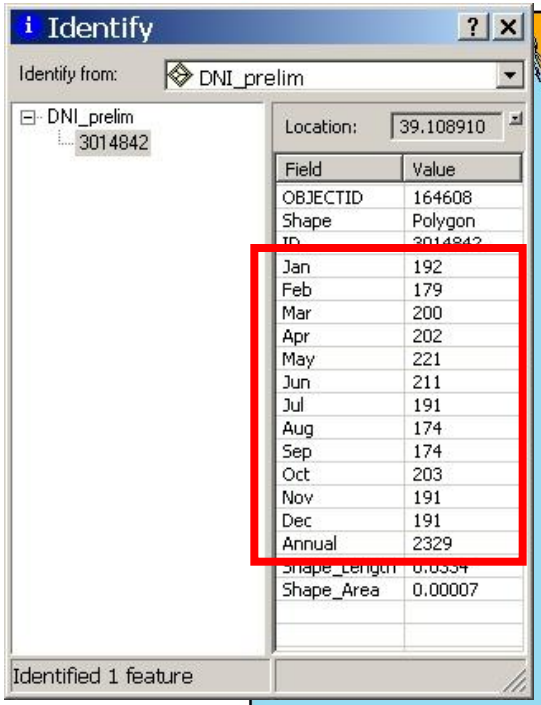


data based on SOLEMI v38 (AEROCOM)
analyzed time period: 01/1996-12/2005
data provided by DLR, 2010

Do not use this map for further analysis as there are still remaining months/years to be processed !

Application example: Site query / identification

Direct Normal Irradiation for Kingdom Saudi Arabia
(preliminary result)



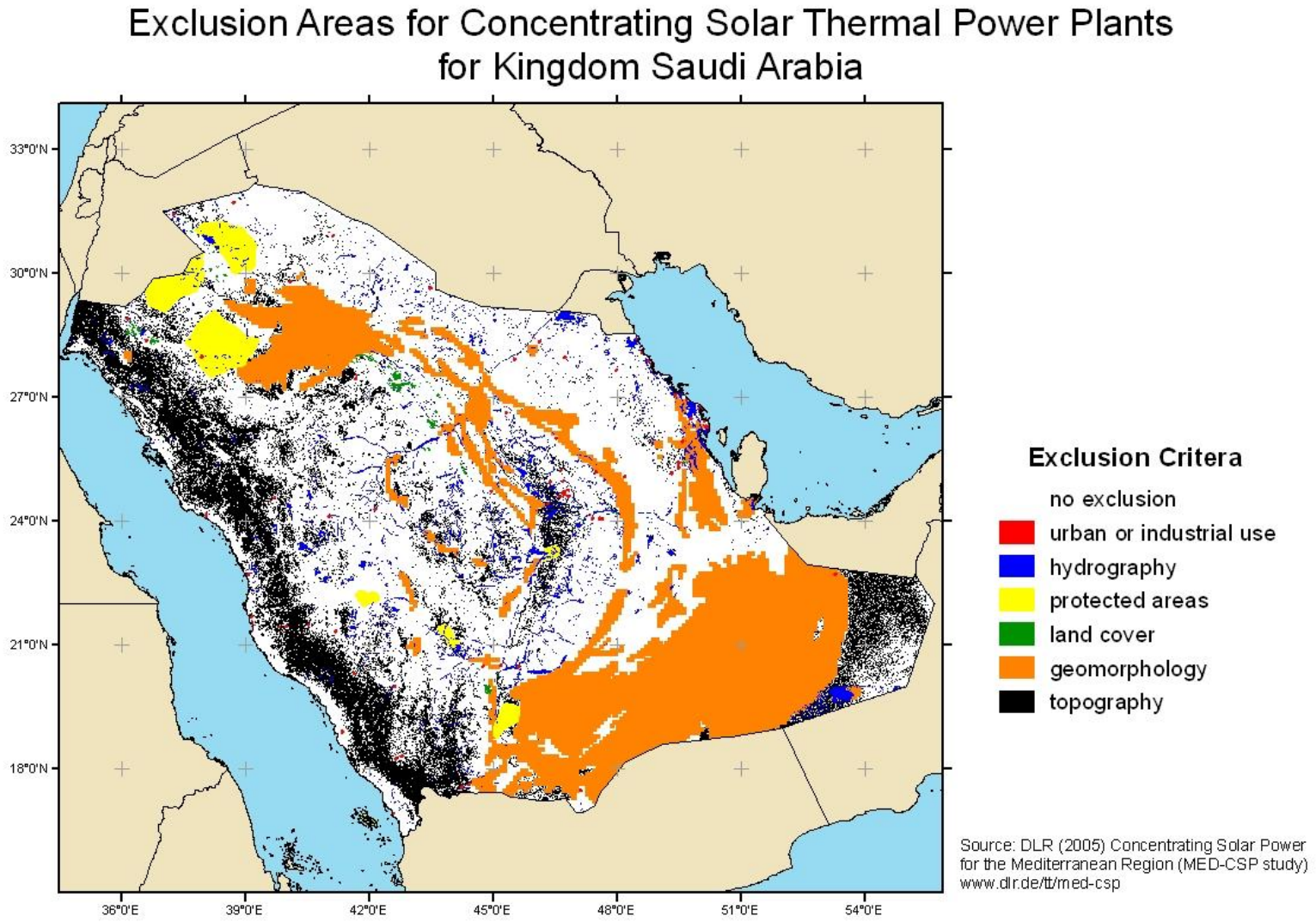
Averaged Annual Sum [kWh/m²]

- <=1950
- >1950 - 2000
- >2000 - 2050
- >2050 - 2100
- >2100 - 2150
- >2150 - 2200
- >2200 - 2250
- >2250 - 2300
- >2300 - 2350
- >2350 - 2400
- >2400 - 2450
- >2450 - 2500
- >2500 - 2550
- >2550 - 2600
- >2600

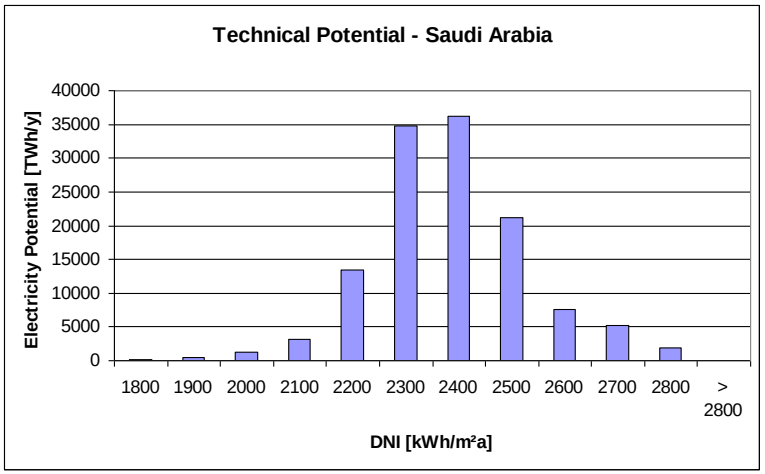
data based on SOLEMI v38 (AEROCOM)
analyzed time period: 01/1996-12/2005
data provided by DLR, 2010

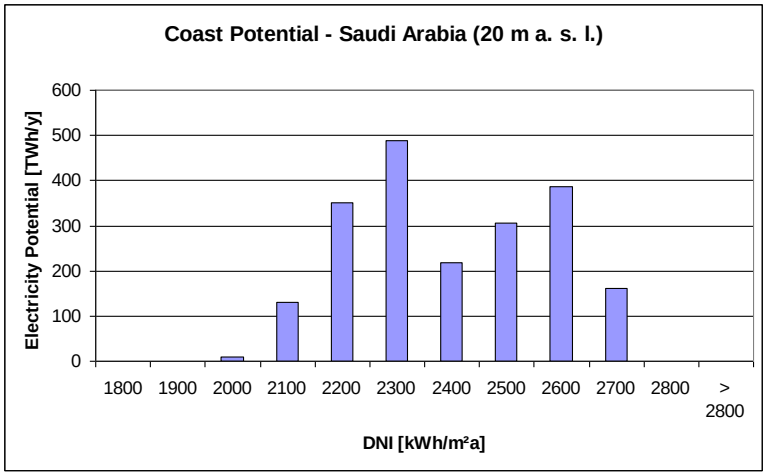
Do not use this map for further analysis as there are still remaining months/years to be processed !

Application example: potential assessment, spatial analysis

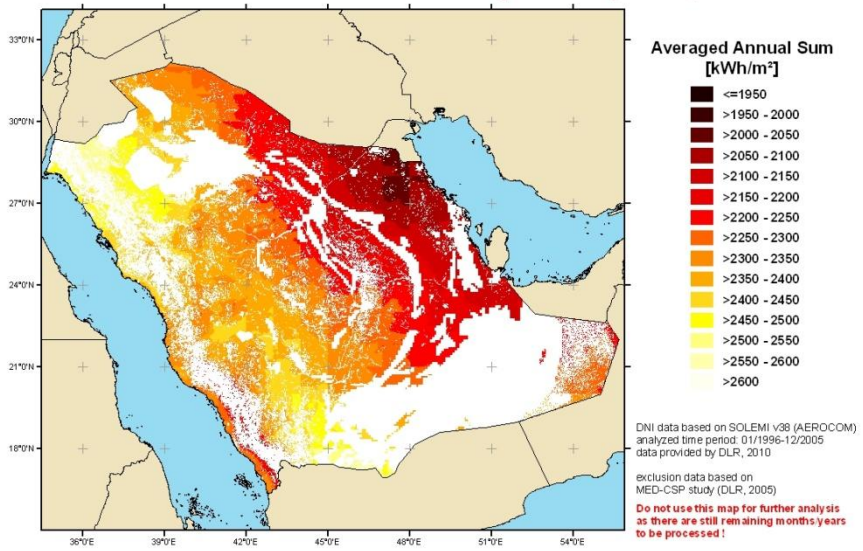


Application example: CSP potential assessment, detailed spatial analysis





Direct Normal Irradiation for Kingdom Saudi Arabia
combined with exclusion data (preliminary result)



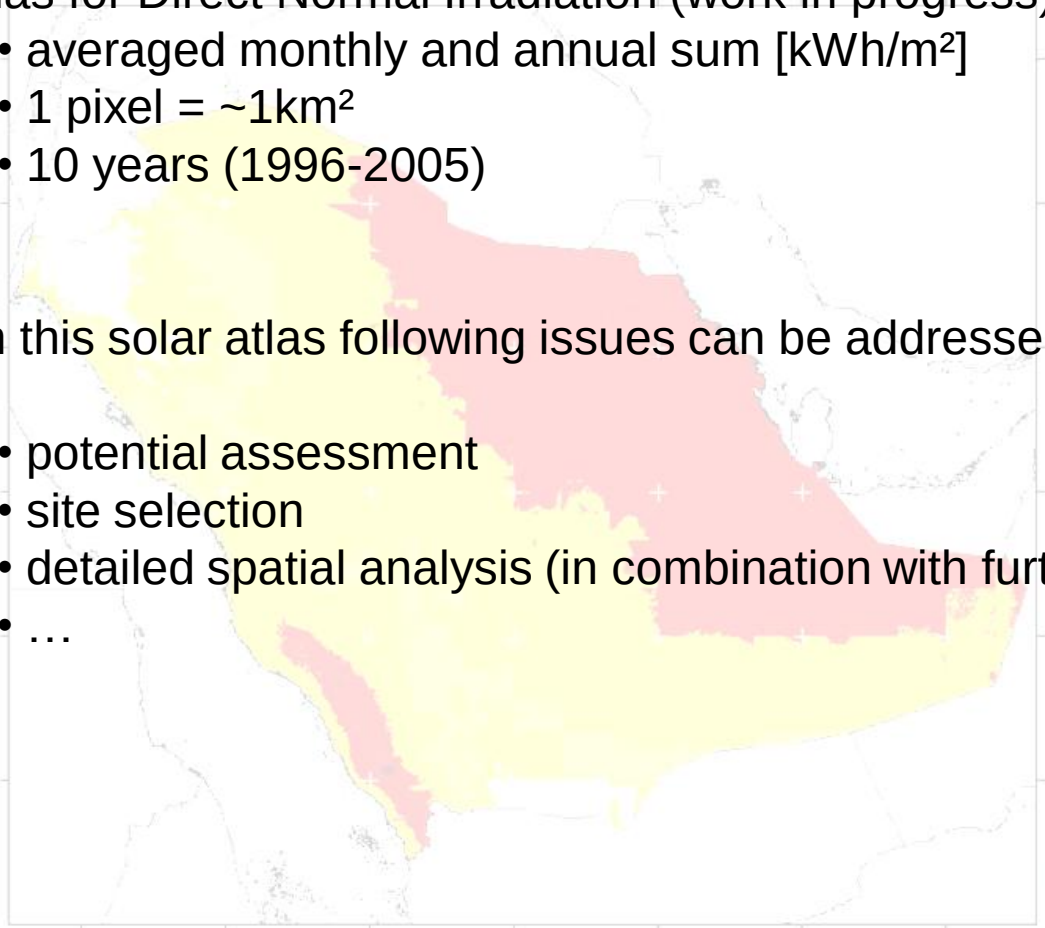
CSP Economic Potential:	**124560 TWh/y (DNI > 2000 kWh/m²/y)**
Power Demand 2000:	**119 TWh/y**
Power Demand 2050:	**305 TWh/y (Scenario CG/HE)**
Tentative CSP 2050:	**135 TWh/y (Scenario CG/HE)**
CSP Coastal Potential:	**2055 TWh/y (< 20 m a. s. l.)**
Water Demand 2050:	**99 TWh/y (Power for Desalination)**

Source: DLR (2005): Concentrating Solar Power for the Mediterranean Region
MED-CSP – study (www.dlr.de/tt/med-csp)

Conclusion

Digital Atlas for Direct Normal Irradiation (work in progress):

- averaged monthly and annual sum [kWh/m²]
- 1 pixel = ~1km²
- 10 years (1996-2005)



Based on this solar atlas following issues can be addressed:

- potential assessment
- site selection
- detailed spatial analysis (in combination with further relevant data)
- …

Thank you very much
for your attention!

Contact:

Dr. Christoph Schillings
DLR-Institute of Technical Thermodynamics
Systems Analysis and Technology Assessment

++49/(0)711-6862 784
christoph.schillings@dlr.de