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Global assessment for reduction of solar photovoltaic potential due to meteorological and geomorphological limiting factors

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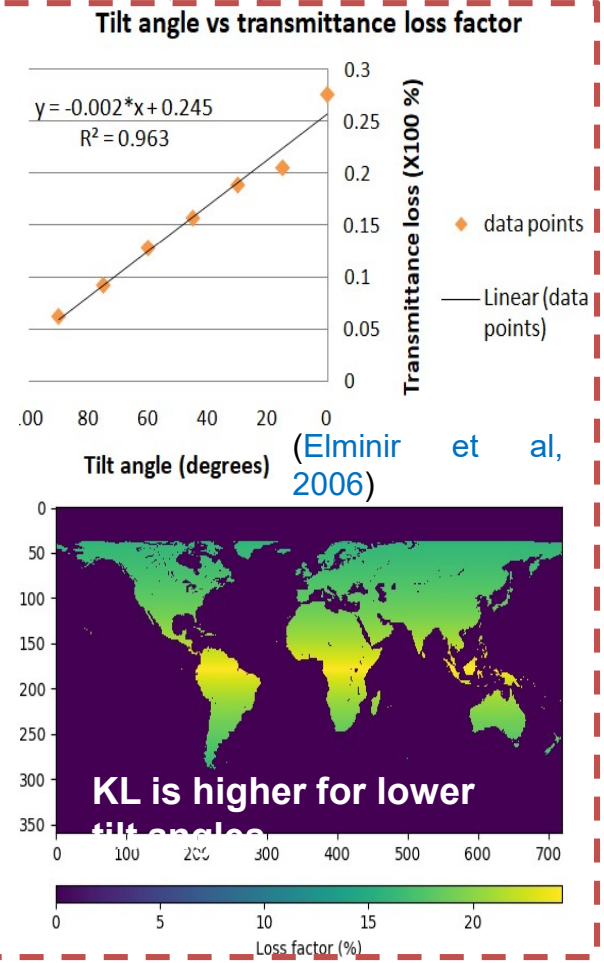
Solar PV cell efficiency reductions (%) due to dust deposition

$$\Delta\eta_D = K_L\left(\sum_{i=1}^{n} m_{di} \times m_{ri}\right)/n \quad \text{------(1)}$$

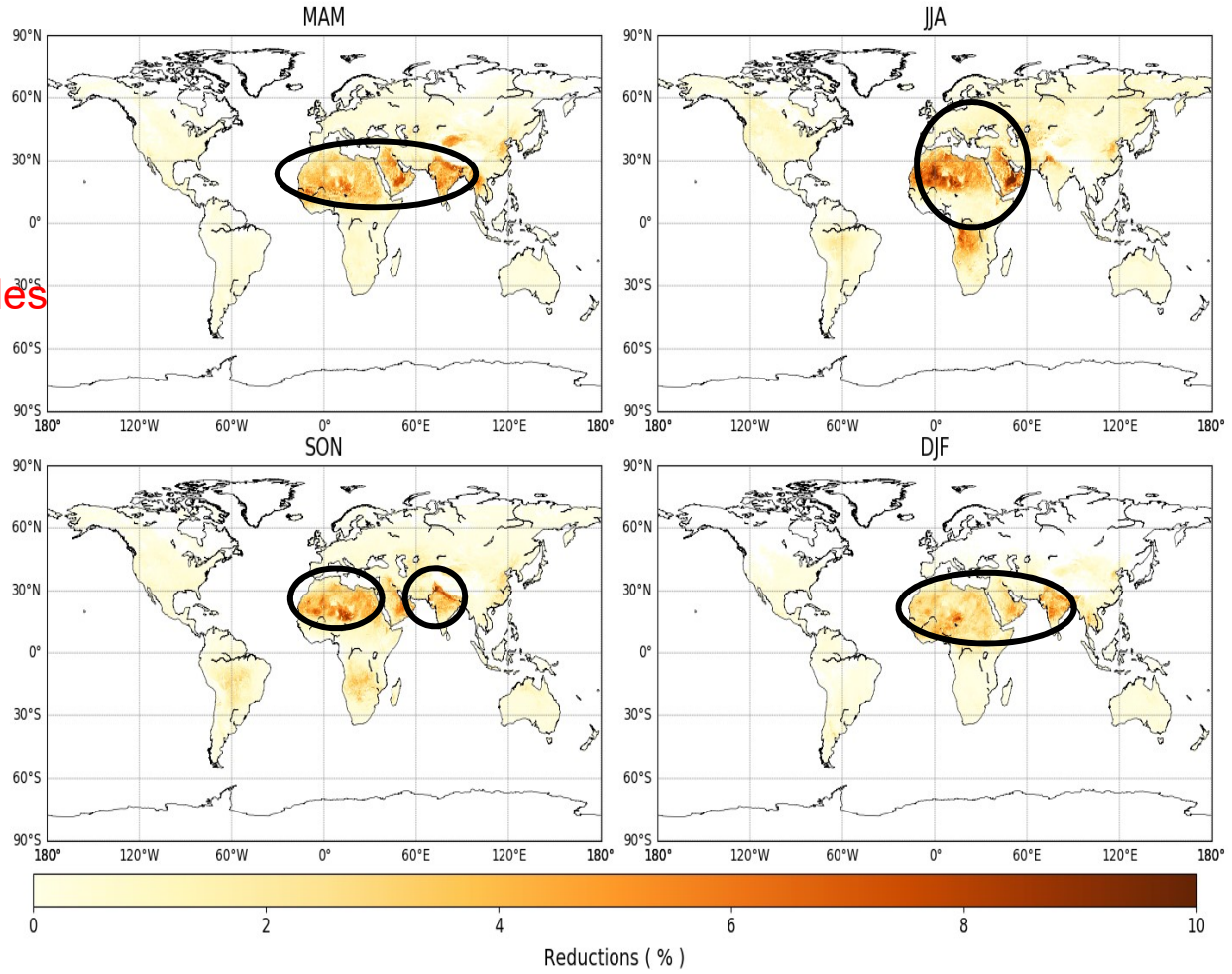
(KL =0.3 Sayigh, 1978)

$$m_{di} = soiling\ mask\ \&\ m_{ri} = rainfall\ mask$$

Energy loss varies with tiltangles (Elminir et al, 2006)



(Elminir et al, 2006)



Max seasonal reductions:

Sub-Saharan Africa, The Middle East, South Asia and China for almost all season (reductions: 5-7%)

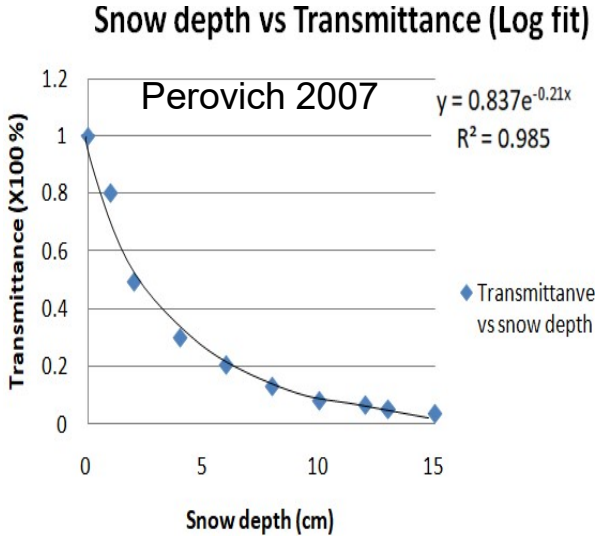
Solar PV cell efficiency reductions (%) due to snow covers

Snow depth (SND) = SNW x SCF/ ρ s -(2)

SNW: = Snow water equivalent (mm),

SCF = Snow cover fraction (0-100),

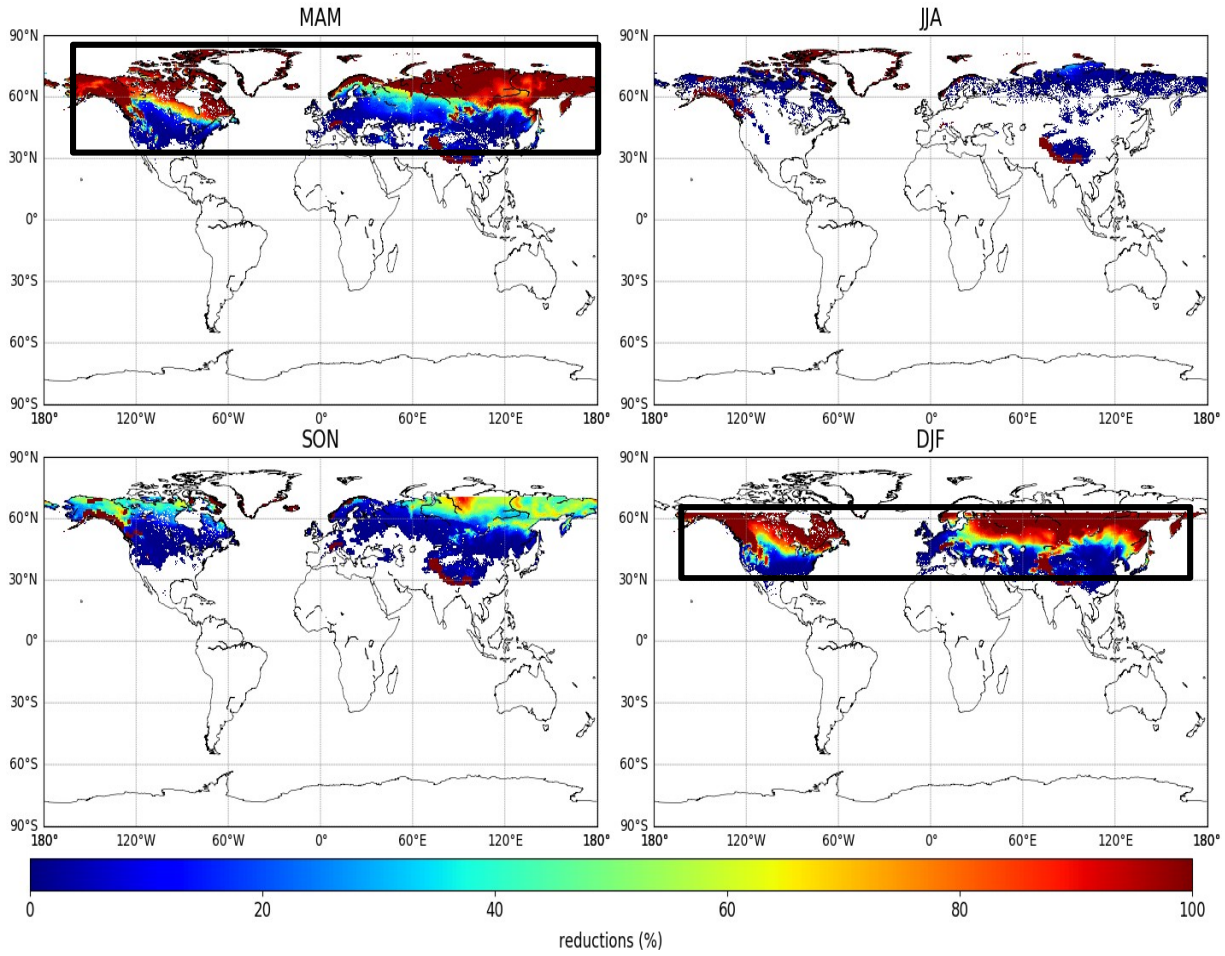
ρ s = snow density (g/cm3)



$$\Delta\eta_s = \sum_{i=1}^{n} \Delta s_i / n \qquad \text{---(3)}$$

Δs: daily snow reductions.

n: number of days in a season



Max seasonal reductions:

Northern Hemisphere (**45N-80N**) has maximum sesaonal reductions > **40%** during **MAM** & **DJF**

Solar PV cell efficiency reductions (%) due to temperature changes

$$T_{mod} = G_{POA} \times \{e^{(a+b*WS)}\} + T_a \quad (4)$$

G_{POA}: solar irradiance at the plane of an array;
E: Euler's constant, **WS:** wind speed (10m), **a** and **b:** empirical constants (King et al, 2004), **T_a**: near-earth surface temperature (2m)

$$T_{cell} = (\frac{G_{POA}}{G_{STC}}) \times \Delta Tcnd + T_{mod} \quad (5)$$

G_{STC}: irradiance at Standard Test Conditions, **ΔTcnd:** conduction temperature drop (King et al, 2004). $\Delta\eta/\Delta T$ Power temperature coefficient: −0.45%/°C

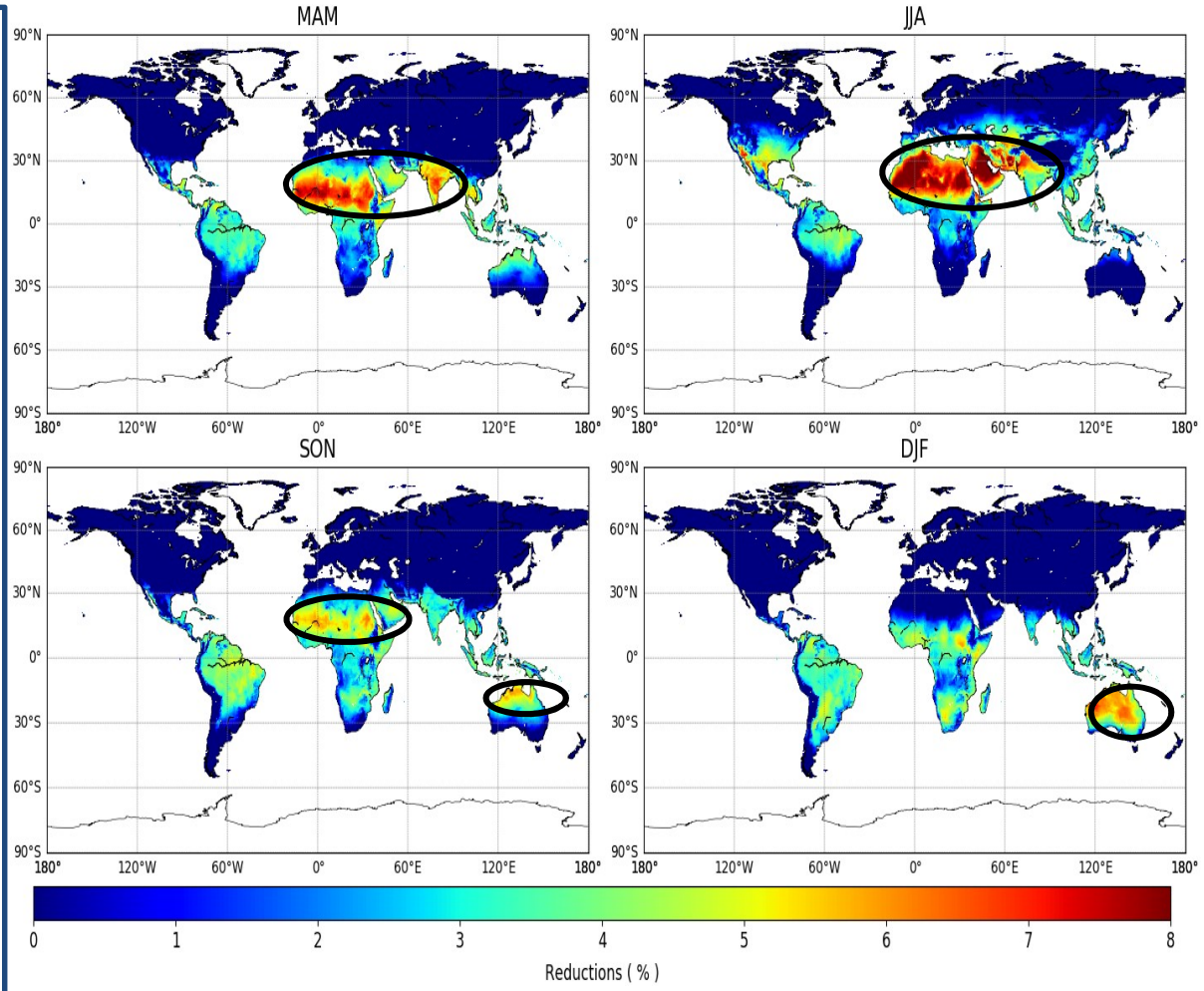
$$\Delta\eta_T = (\frac{\Delta\eta}{\Delta T})(\sum_{i=1}^{n} T_{cell} - T_{STC})/n \quad (6)$$

n: number of days in a season

Monocrystalline silicon cSi (80% market share)

Płaczek-Popko (2017)

Empirical eqs. by SANDIA lab (USA) has the best results among all (Zounie et al (2018))

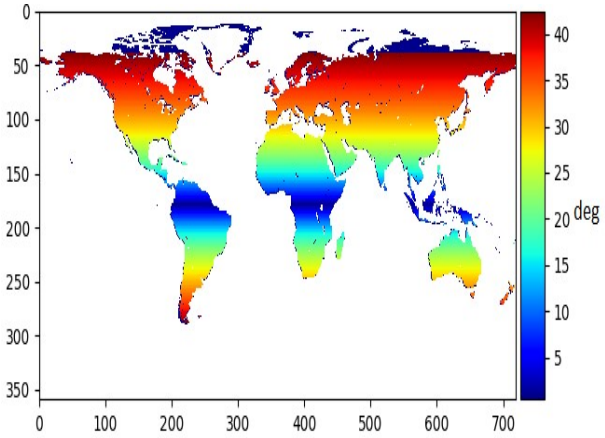


Max seasonal reductions:

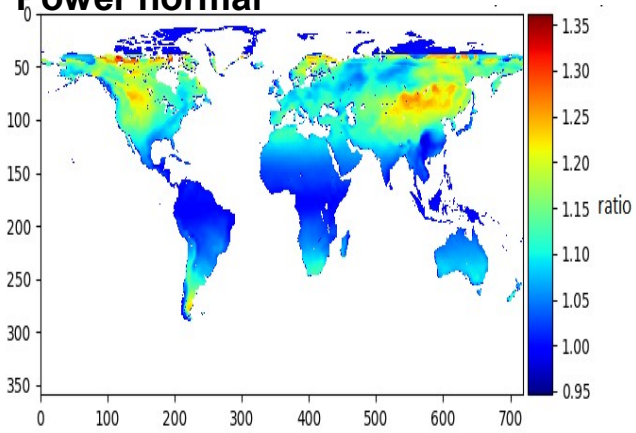
1. **Sub-Saharan Africa (8.71%) & Middle East (7.73%)** for **JJA**
2. **Australia (6.07%)** for **DJF**

Geomorphologic corrections and calculation of Performance Ratio (PR)

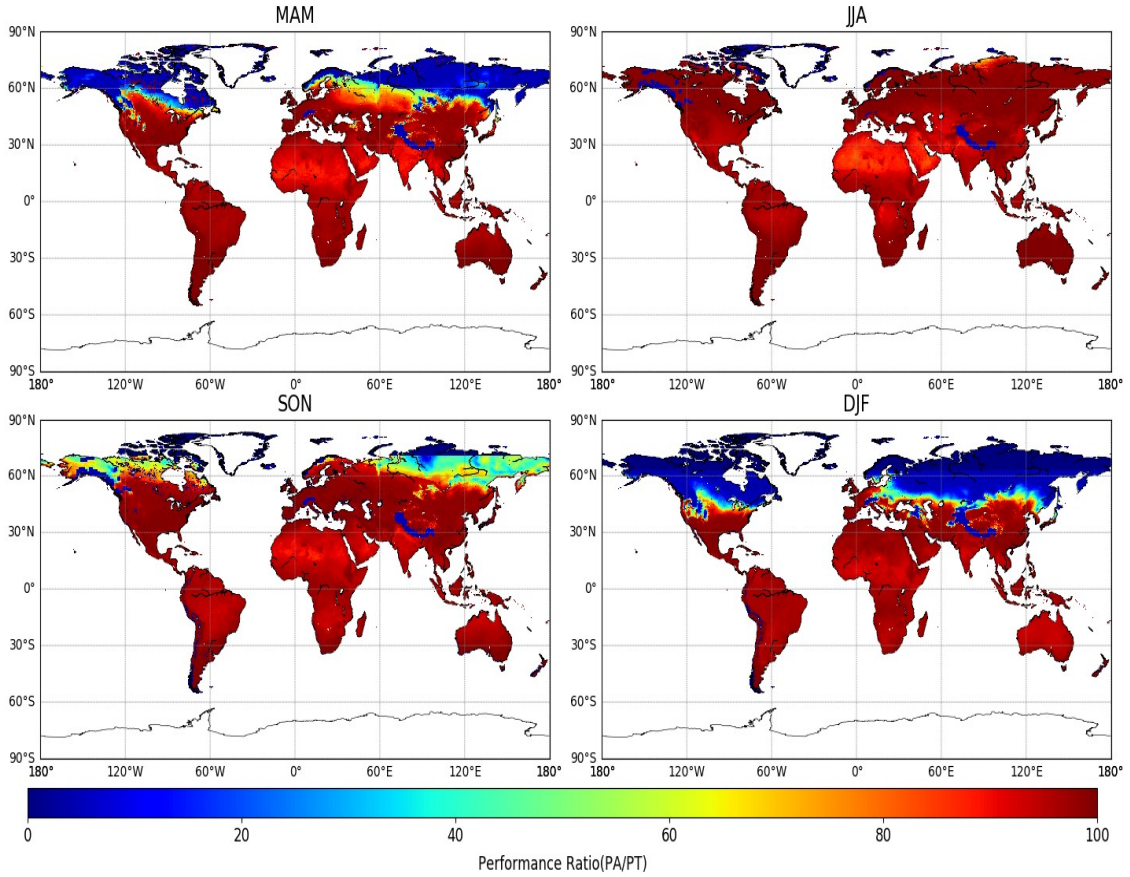
Optimum tilt-angles (Jacobson et al, 2017)



Eff. power ratio = Power optimum
Power normal



PR = Power actual (includes corrections)
Power theoretical

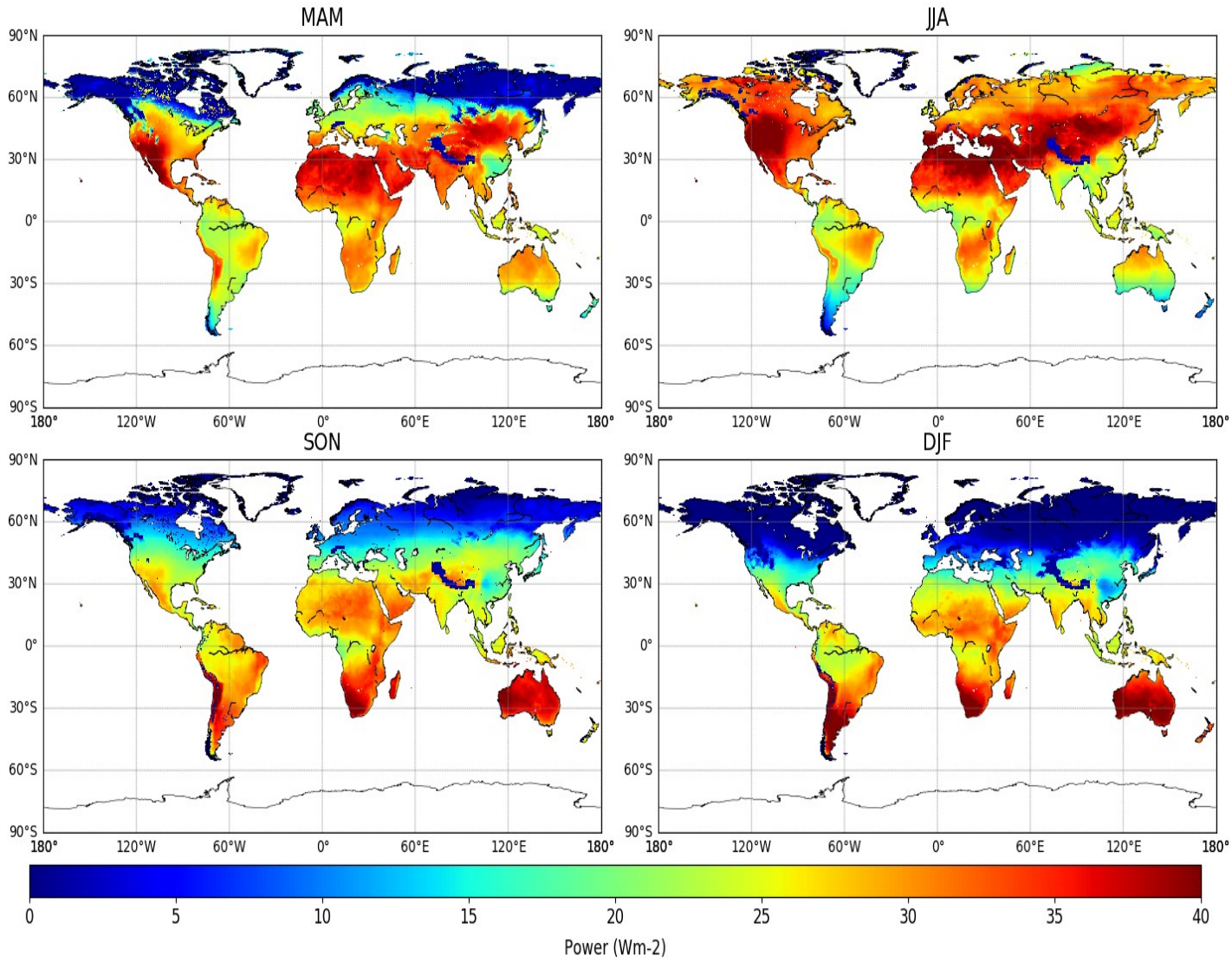


Upper Northern Hemisphere has lower PR during winter seasons due to **snow covers**. While **Sub-Saharan Africa, China & South Asia** has lower PR due to **soiling and temperature** affects.

Seasonal mean of actual estimated solar PV potential

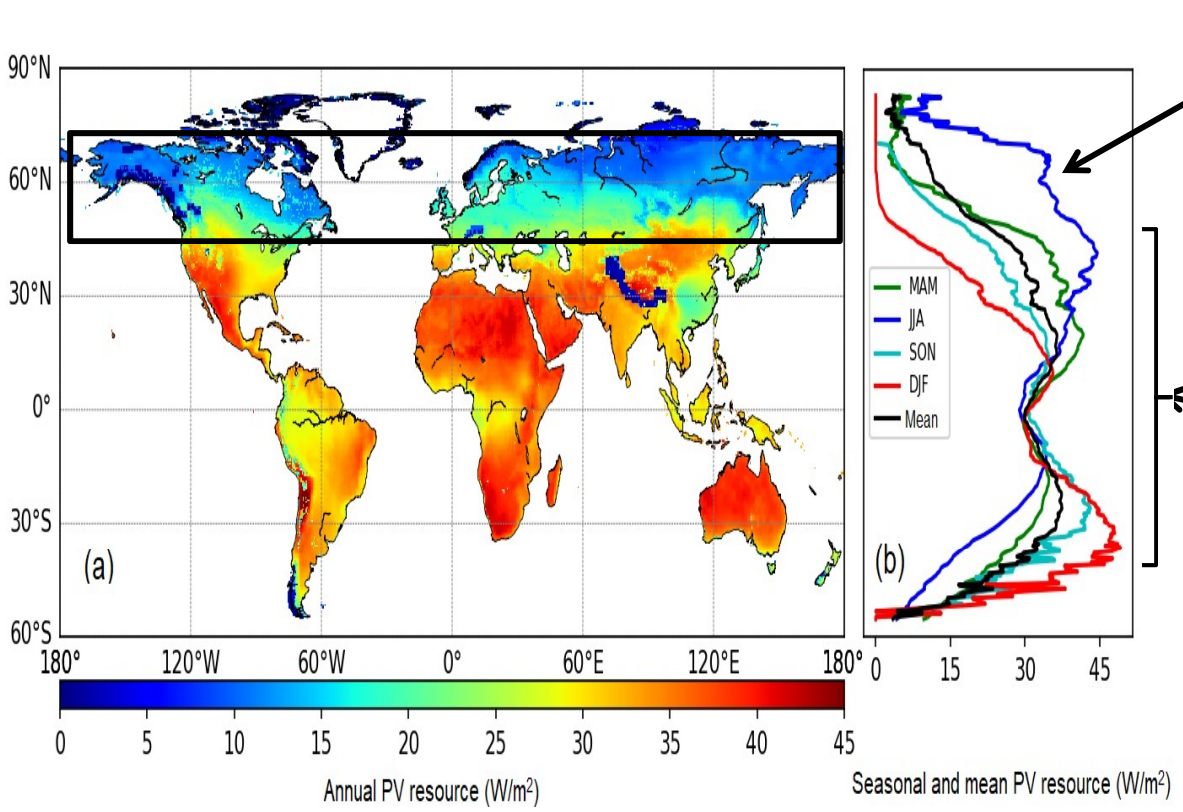
Estimated Potential= SWR x PR x cell efficiency

Cell efficiency= **15 %** (Tyagi et al, 2013)



Higher **PV potential (>30W/m2) near equator** during **(MAM & JJA) and 20-60° South** for **(SON & DJF)**

Annual final solar PV potential (W/m2)



Snow covers

Good solar PV resource (45S-45N)

Snow has most annual potential reductions (19.45%), while dust and temperature reduces 5.7% and 7% power output respectively.