Nowcasting of Circumsolar Radiation

Vorhersage der Circumsolarstrahlung

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4. Fachtagung Energiemeteorologie,

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Knowledge for Tomorrow

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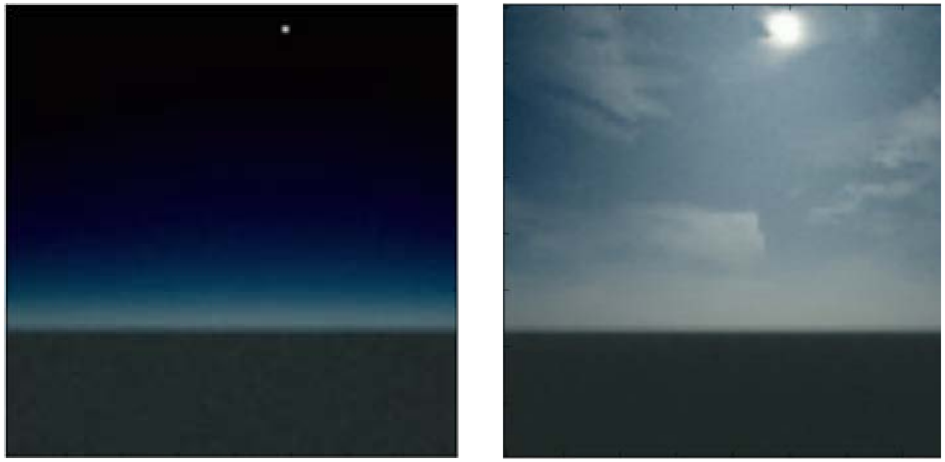
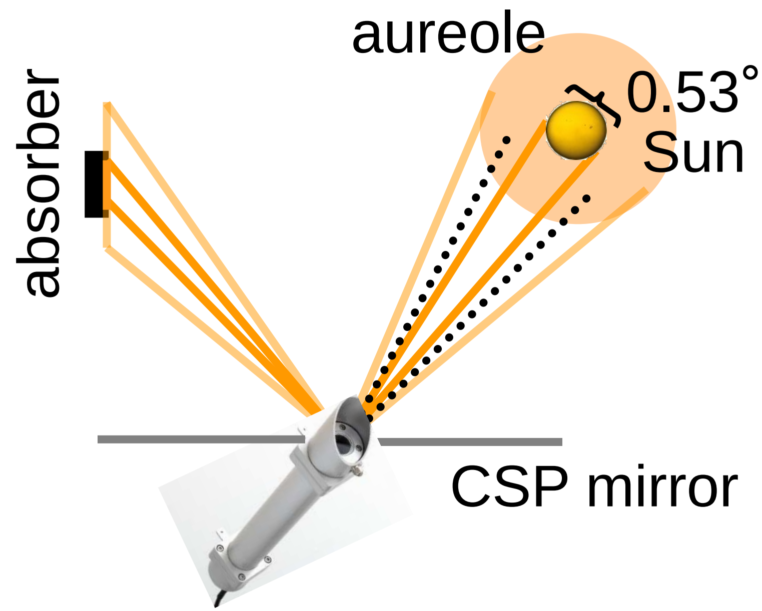
Circumsolar Radiation

Circumsolar radiation is the solar radiance around the Sun disc produced by forward scattering of aerosols and (cirrus) clouds.



MYSTIC radiative transfer simulation w and w/o cirrus (B. Reinhardt)



- **Pyrheliometers usually have larger opening angles than concentrating solar collectors that only use a fraction of CSR**
- **Direct radiation from radiative transfer models does not consider photons scattered into the fov of the instrument/collector**

Systematic overestimation/underestimation of collector performance

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Surface Measurements of Circumsolar Radiation

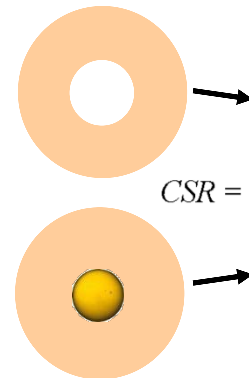
Plataforma Solar de Almeria (PSA):

CSR measurements 2013-2015

SAM: Sun and Aureole Measurement

Aeronet Sun Photometer

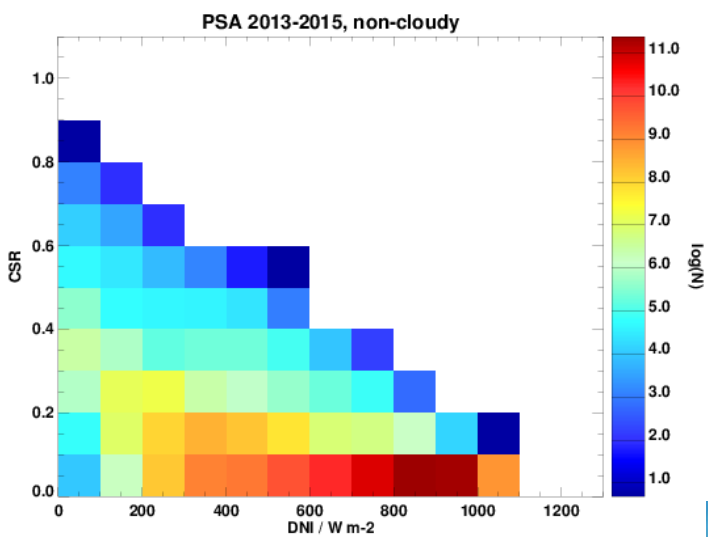
$\alpha = 0.266° - 2.5°$

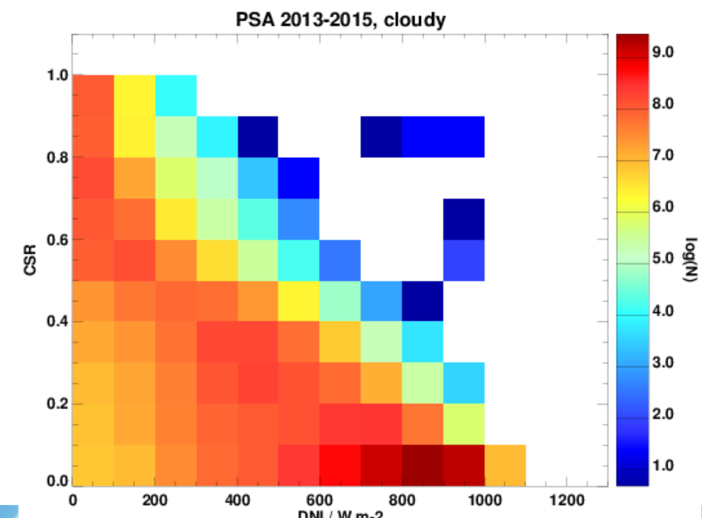


$$CSR = \frac{\int_{\alpha_{Sun}}^{\alpha_{Inst}} L(\theta)\sin(\theta)\,d\theta}{\int_{0}^{\alpha_{Inst}} L(\theta)\sin(\theta)\,d\theta}$$

$\alpha = 0° - 2.5°$

32% cloudy measurements





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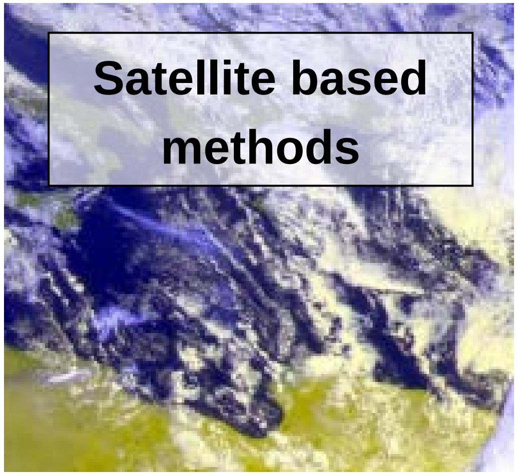
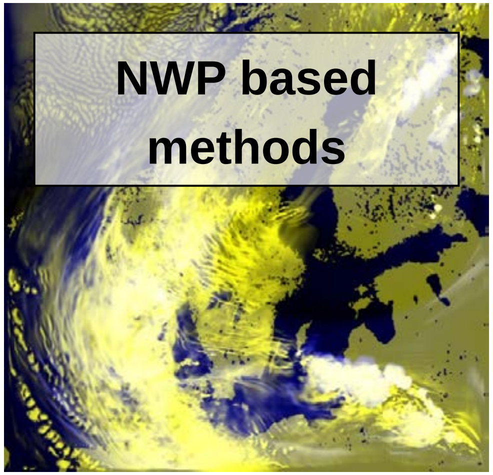
Wilbert 2014, Wilbert et al., 2013

Derivation and Nowcasting of Circumsolar Radiation





Goal

Implementation of a method for the consideration of scattered radiation into fov of instrument/collector for

- better site assessment
- optimised operation/monitoring of CSP plants

Parameterisation of Circumsolar Radiation: effective/apparent optical thickness

Shiobara und Asano, 1994

$$E_{dir} = E_0 \cdot e^{-\tau}$$

$$E_{tot} = E_0 \cdot e^{-\tau_{eff}}$$

$$\tau_{eff} = k \cdot \tau \qquad 0 < k < 1$$

$$(\tau_{eff} = \tau_{app})$$

$$k_{ice/aer}(\tau) \approx const \qquad \frac{\Delta k}{k} < 3\% \text{ für } (0 < \tau < 3)$$

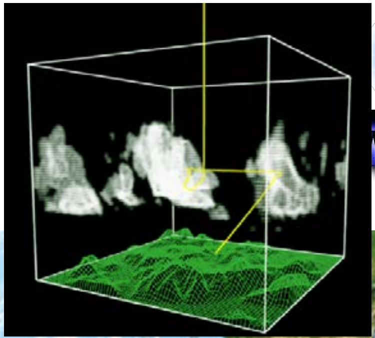
$$k_{ice} = k_{ice}(\alpha, r_{eff}, particle\ shape)$$: LUT

α: aperture angle

τ= measure for radiation extinction in cloud

r_{eff} = measure for cloud particle size distribution in cloud

Reinhardt et al., 2014



Parameterisation of Circumsolar Radiation: effective/apparent optical thickness

$$E_{dni} + E_{circumsolar} = E_0 \cdot e^{-\tau_{eff}} = E_0 \cdot e^{-\tau * k}$$

$$k_{ice/aer}(\tau) \approx const, \qquad 0 < k < 1$$

$$k_{ice} = k_{ice}(\alpha, r_{eff}, particle\ shape) \quad \text{LUT}$$

Shiobara und Asano, 1994

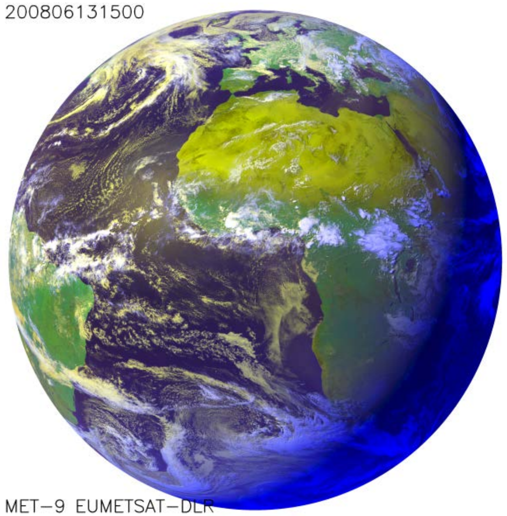
Requirements:

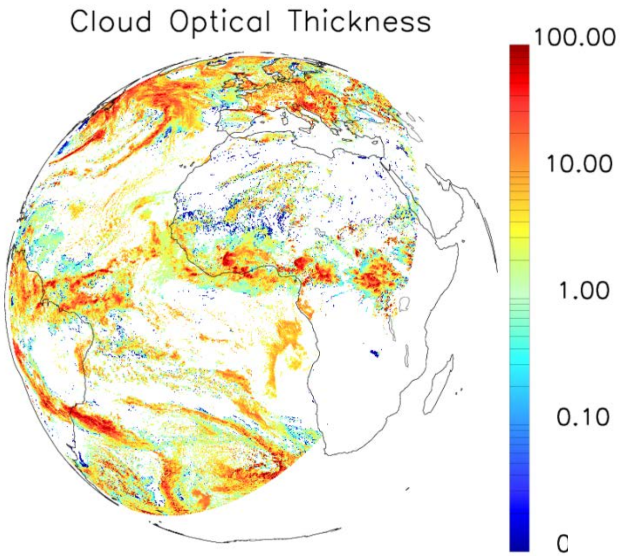
Independently of instrument, satellite sensor or NWP model:

1 optical thickness τ

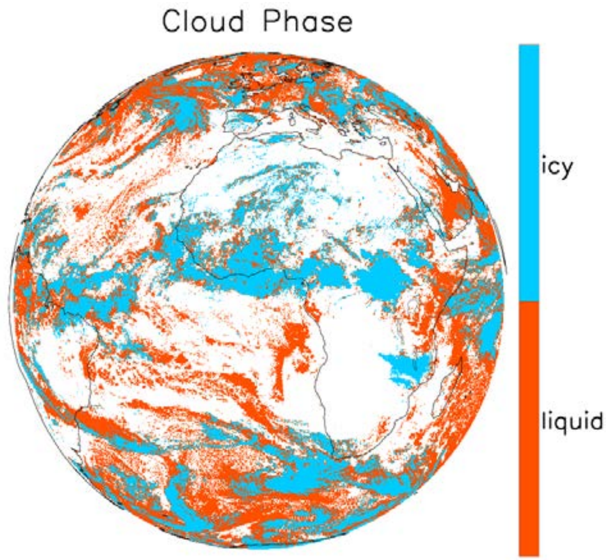
1 effective radius r_{eff}

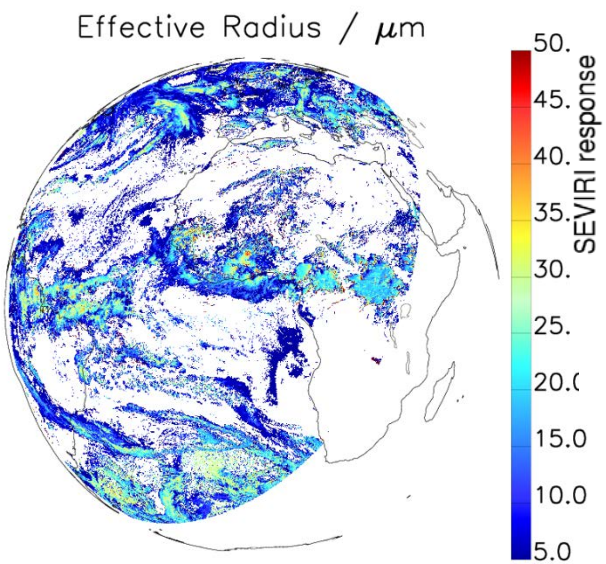
Cloud Input Parameters from MSG/SEVIRI Observations

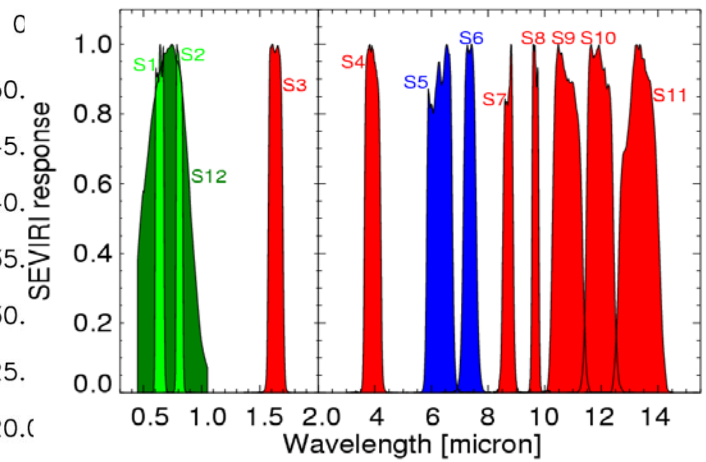




MSG/SEVIRI







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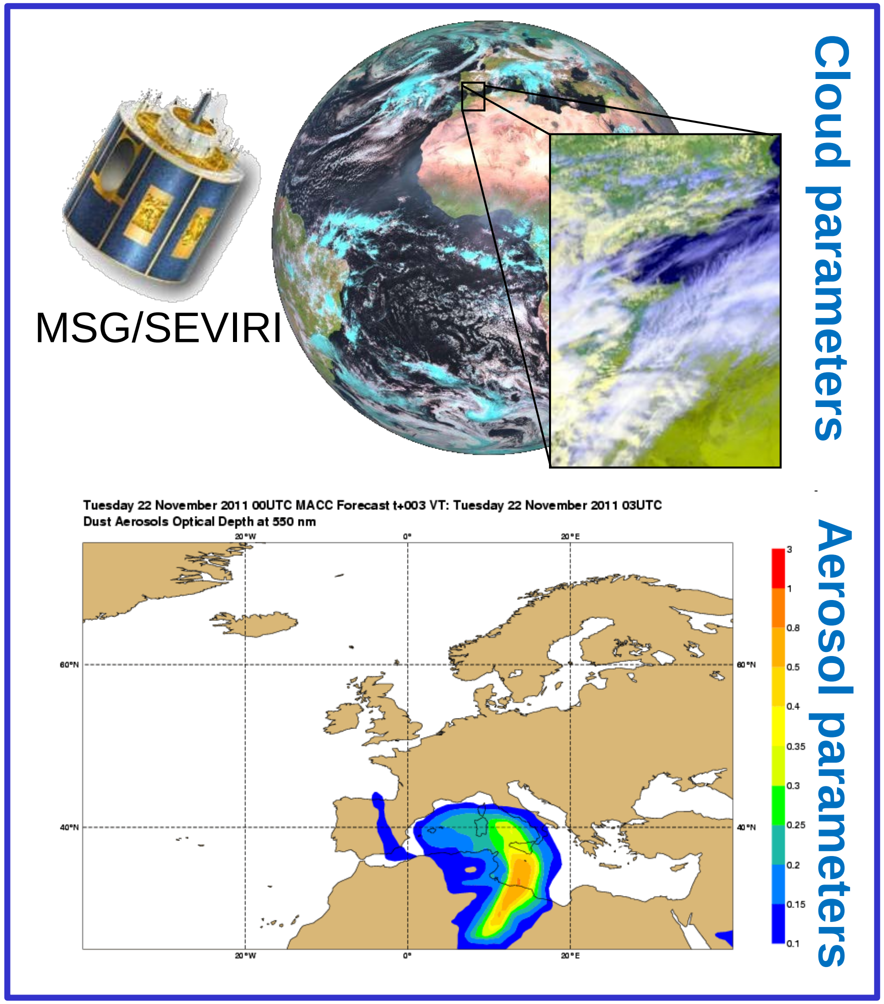
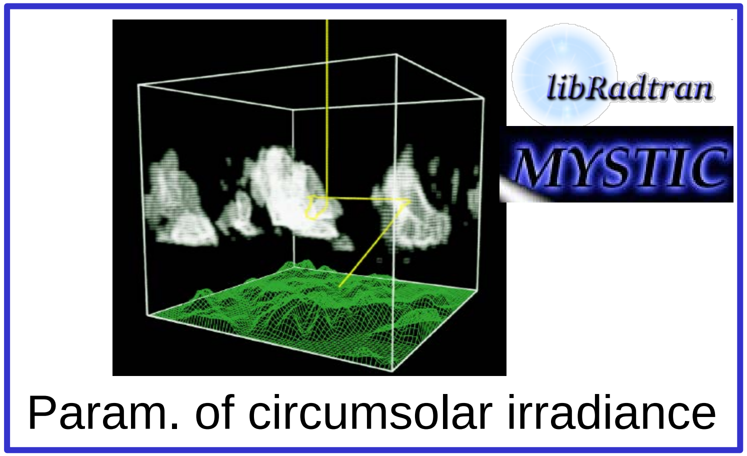
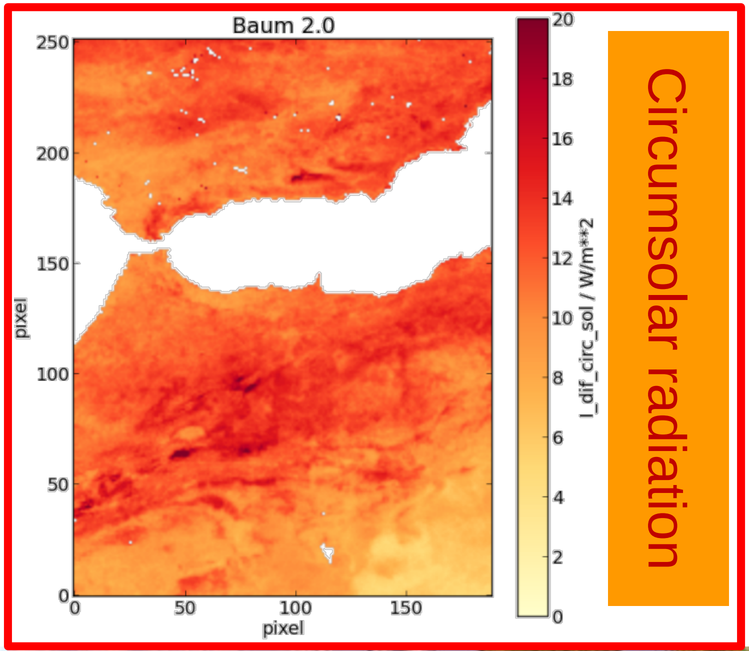
Bugliaro et al., 2011; Kox et al., 2014

Circumsolar Radiation from MSG/SEVIRI (SFERA)







Reinhardt 2013, Reinhardt et al. 2014

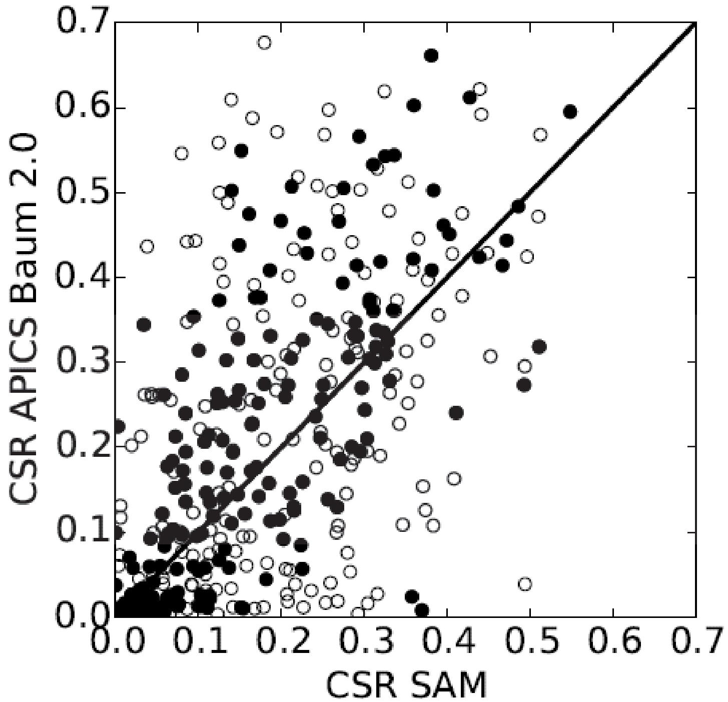
Solar Facilities for the European Research Area

Circumsolar Radiation from MSG/SEVIRI Observations

Validation against PSA surface measurements: May 2011 – April 2012

Optical Properties	$r_{\mathrm{rank,CSR}}$	r_{CSR}	MAD	RMSD	MRD	Bias	N
Baum v2.0	0.54	0.50	0.11	0.16	75 %	4 %	2021

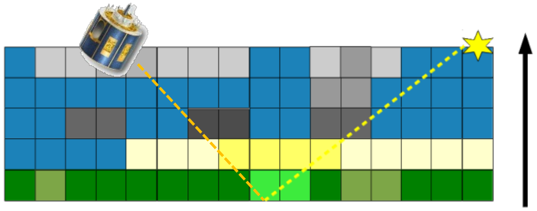
Validation against PSA surface measurements: May 2011 – June 2011



○ all data

● manually screened after cumulus

- Parallax correction
- Ice clouds from DLR, water clouds from EUMETSAT
- $\Delta t = 35$ min
- DNI > 200 W m^{-2}

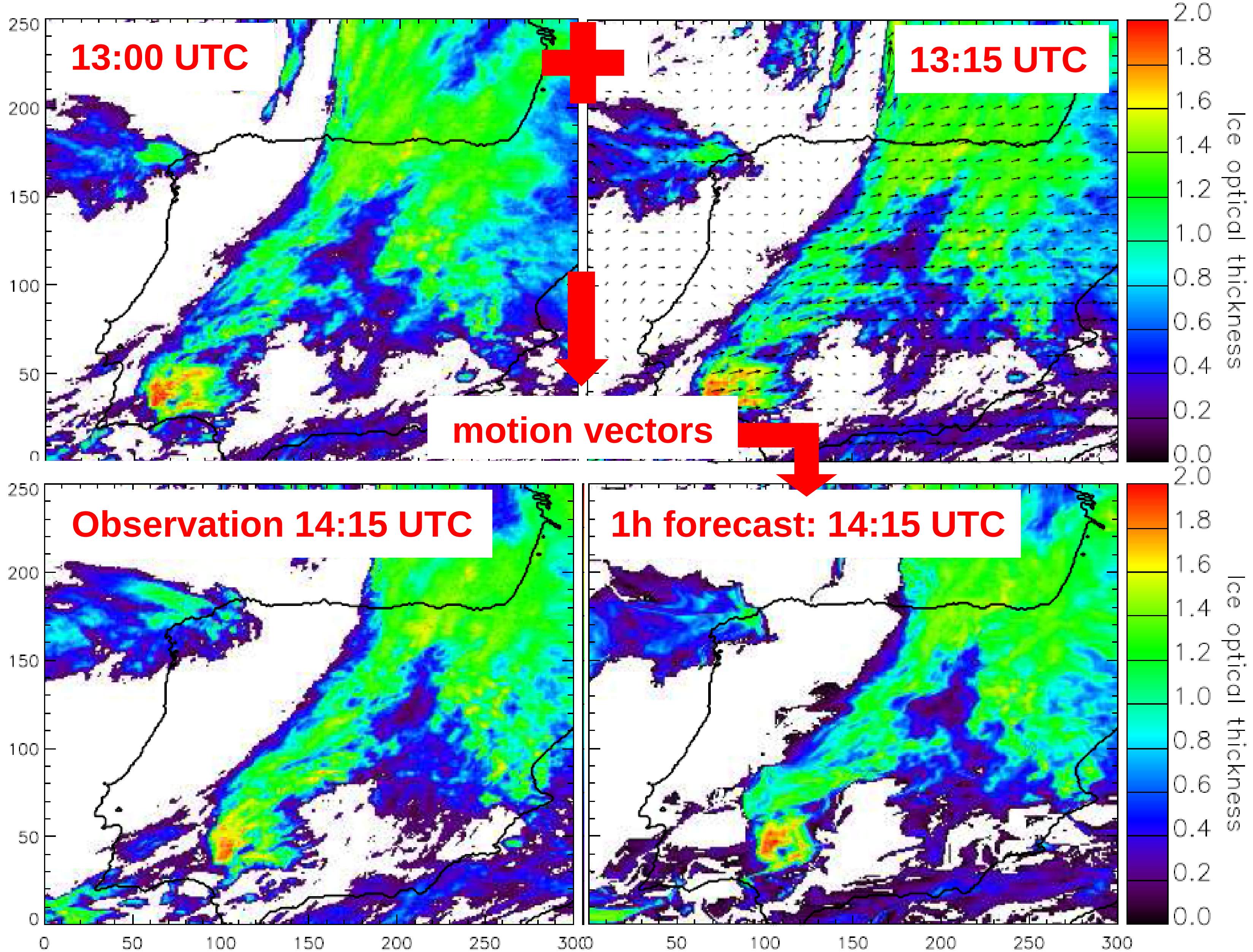


Reinhardt et al., 2014

Optical Properties	$r_{\mathrm{rank,CSR}}$	r_{CSR}	MAD	RMSD	MRD	Bias	N
Baum v2.0	0.79 (0.68)	0.75 (0.62)	0.08 (0.10)	0.12 (0.14)	62 % (62 %)	18 % (14 %)	220 (407)

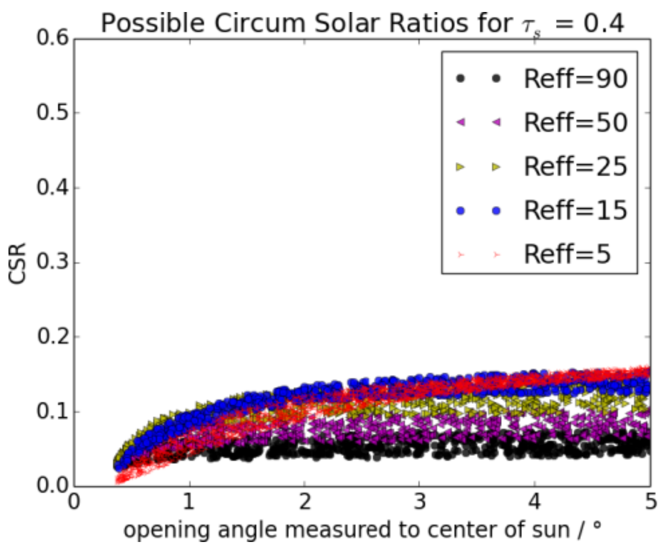
Cloud Input Parameter Nowcast with MSG/SEVIRI

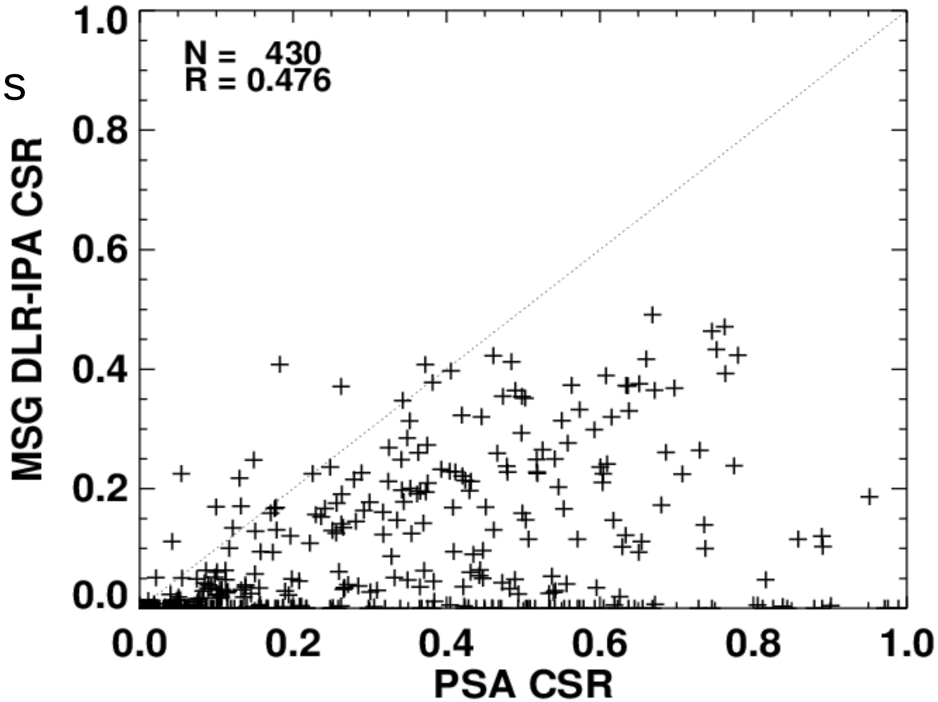
Sirch et al., in preparation



Circumsolar Radiation Nowcast with MSG/SEVIRI

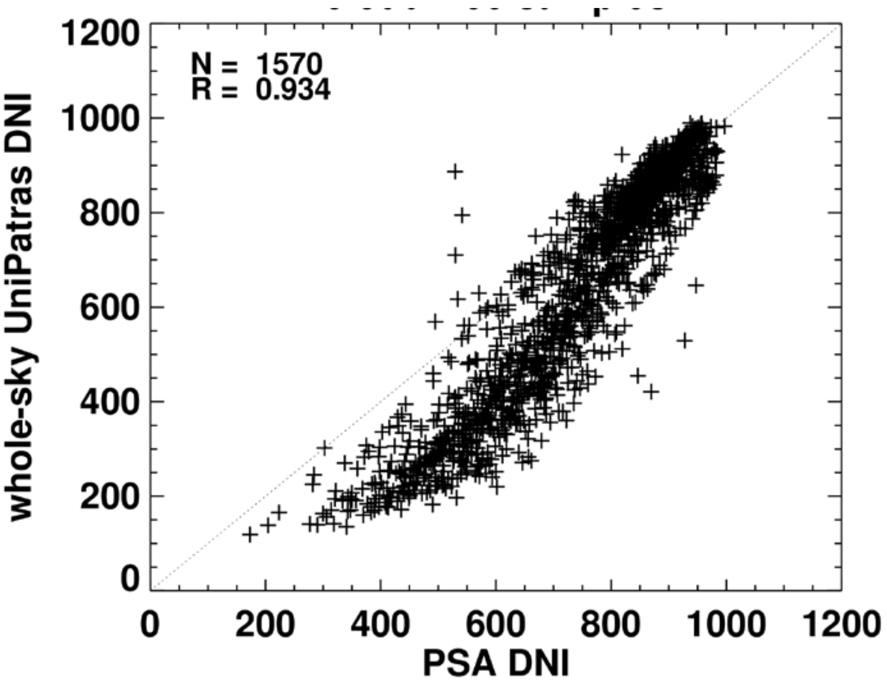
- March 2013
- No effective radius forecast, 25 µm selected for ice clouds
- Ice cloud and water cloud optical thickness
- 1h forecast started at every full hour
- No parallax correction
- CSR mean over 5x5 SEVIRI pixels
- Δt = 5 min

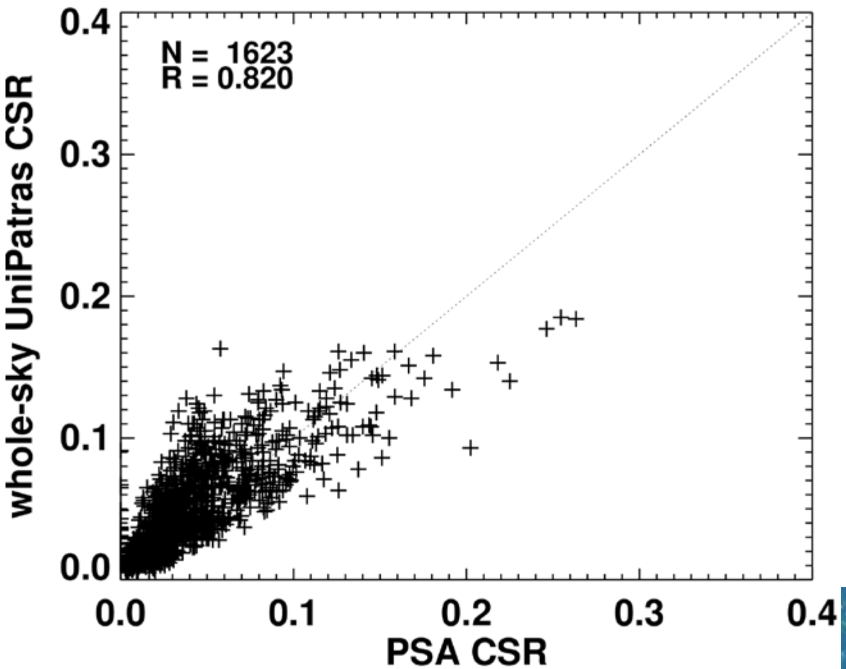




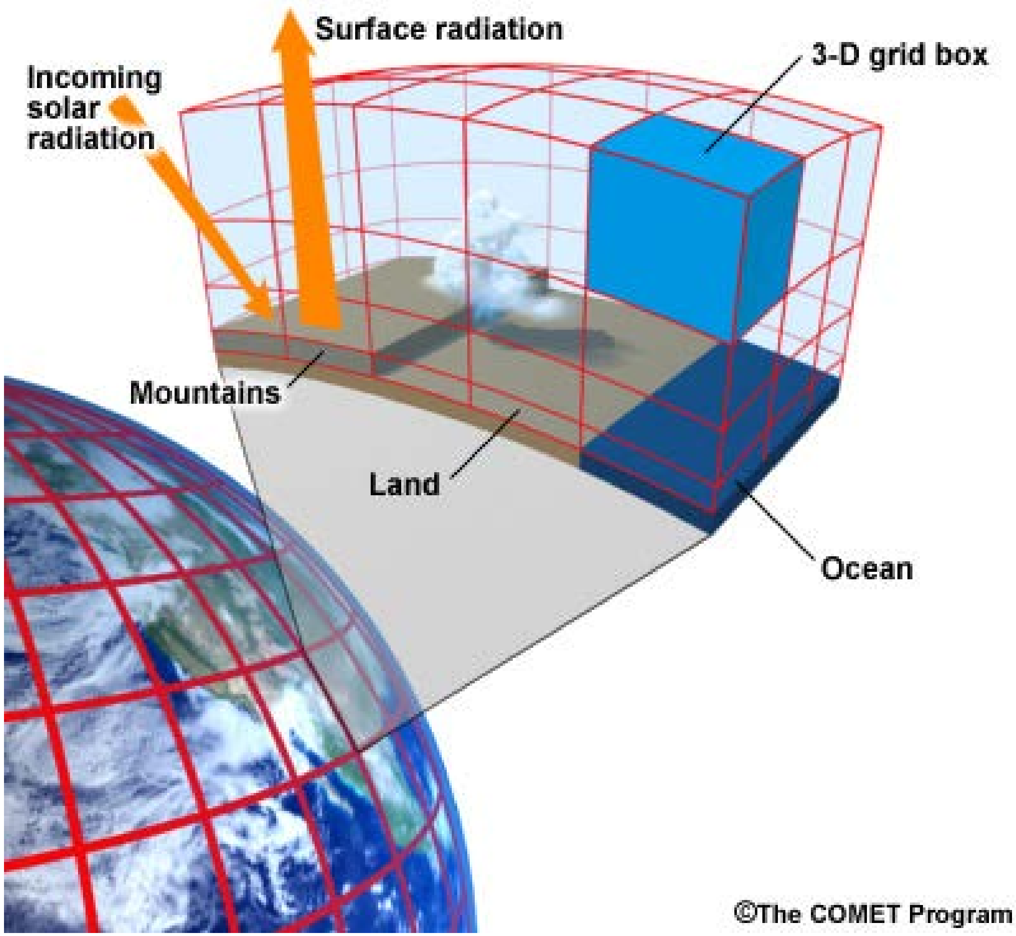
Circumsolar Radiation from Whole-Sky Observations

- Only clear sky observations
- Aerosol optical depth from whole-sky
- Δt = 2 min

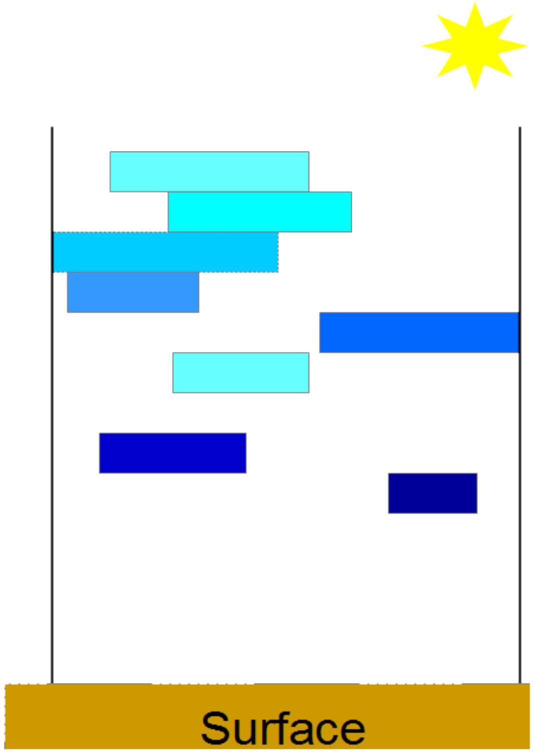




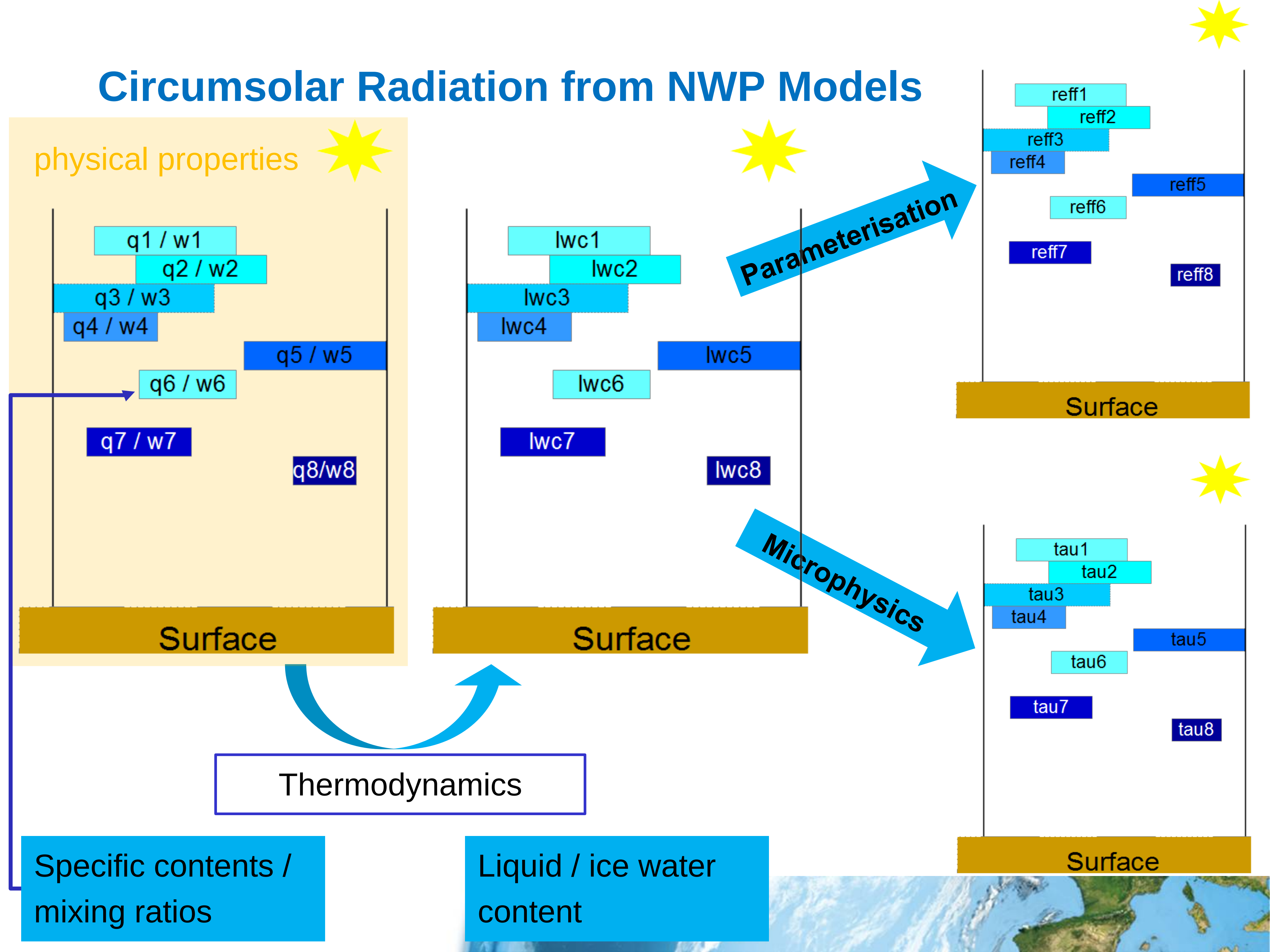
Circumsolar Radiation from NWP Models



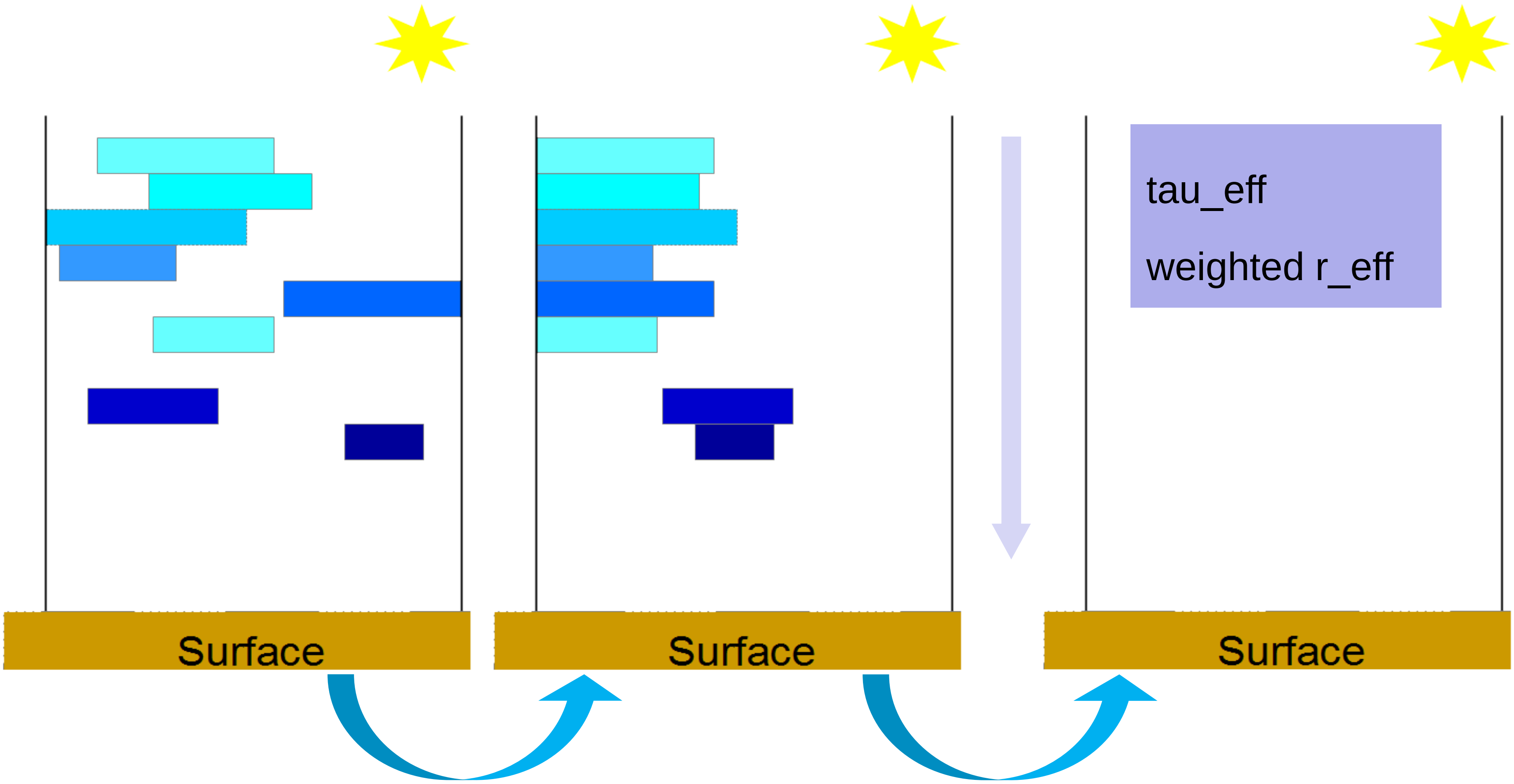
A NWP model describes reality using a series of vertical columns composed of a surface and a set of vertical atmospheric levels.



Circumsolar Radiation from NWP Models



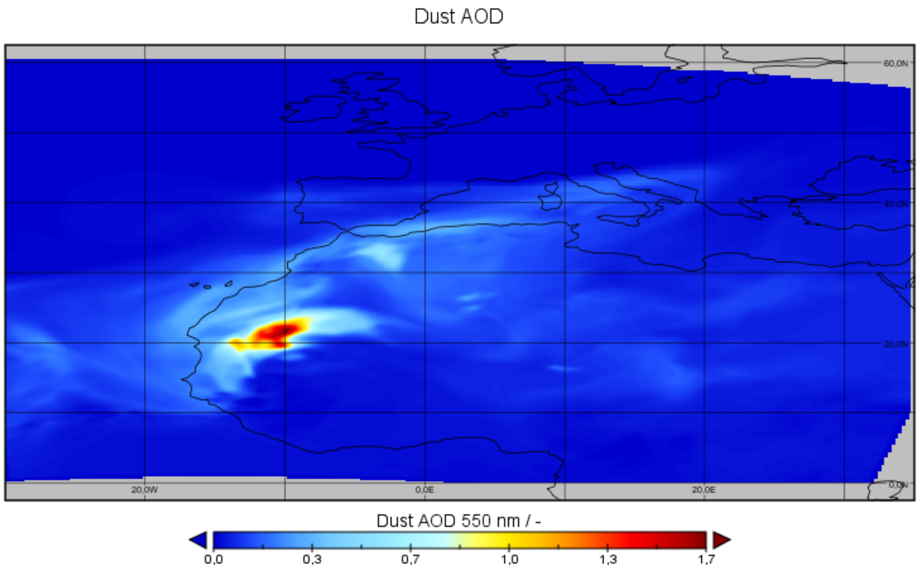
Circumsolar Radiation from NWP Models



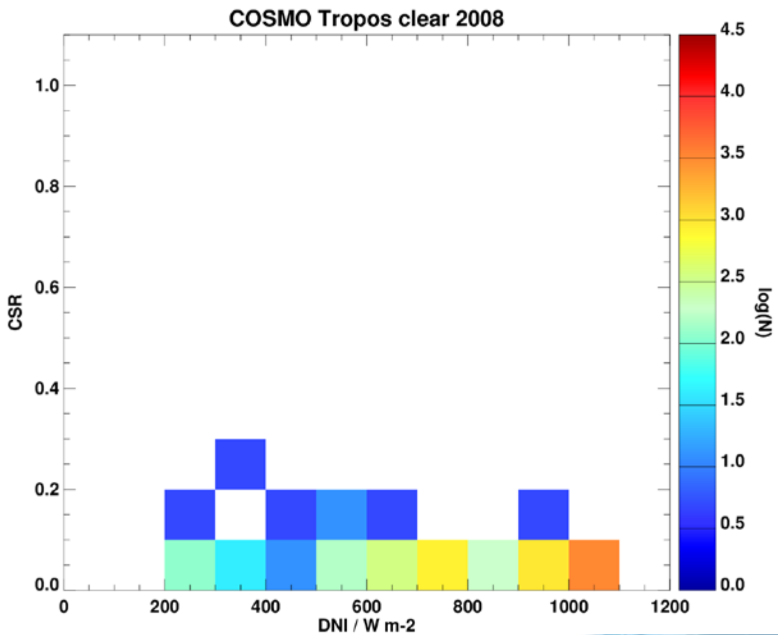
Cloud
overlap assumption

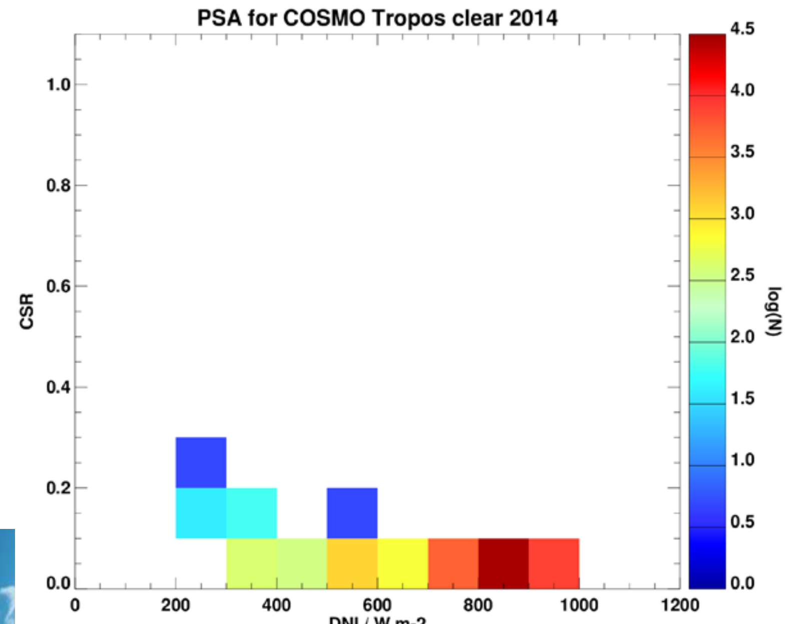
Derive effective cloud quantities by mimicking the original NWP radiative transfer model

Circumsolar Radiation from COSMO-MUSCAT



- Dust aod and clouds from COSMO-MUSCAT
- Plausibility check:
  June-September 2008 (COSMO) vs June-September 2014 (PSA)
- Δt = 10 min
- Only clear sky i.e. aerosol





Conclusions

- The method by Shiobara and Asano (1994) is a flexible method that can be applied to various kinds of input data
- Results for satellite data (clouds) are reasonably good (confirmed by additional data from meteotest/SEVIRI + DLR/IASI)
- Results for whole-sky cameras (aerosols) are good
- Results for NWP models (clouds+aerosols) are still uncertain

Outlook

- Extend/improve validation of CSR, especially for satellite/NWP data
- Extend/improve results for NWP models: evaluate additional data by SMHI/Harmonie, DLR/WRF, RIUUK/EURAD-IM

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