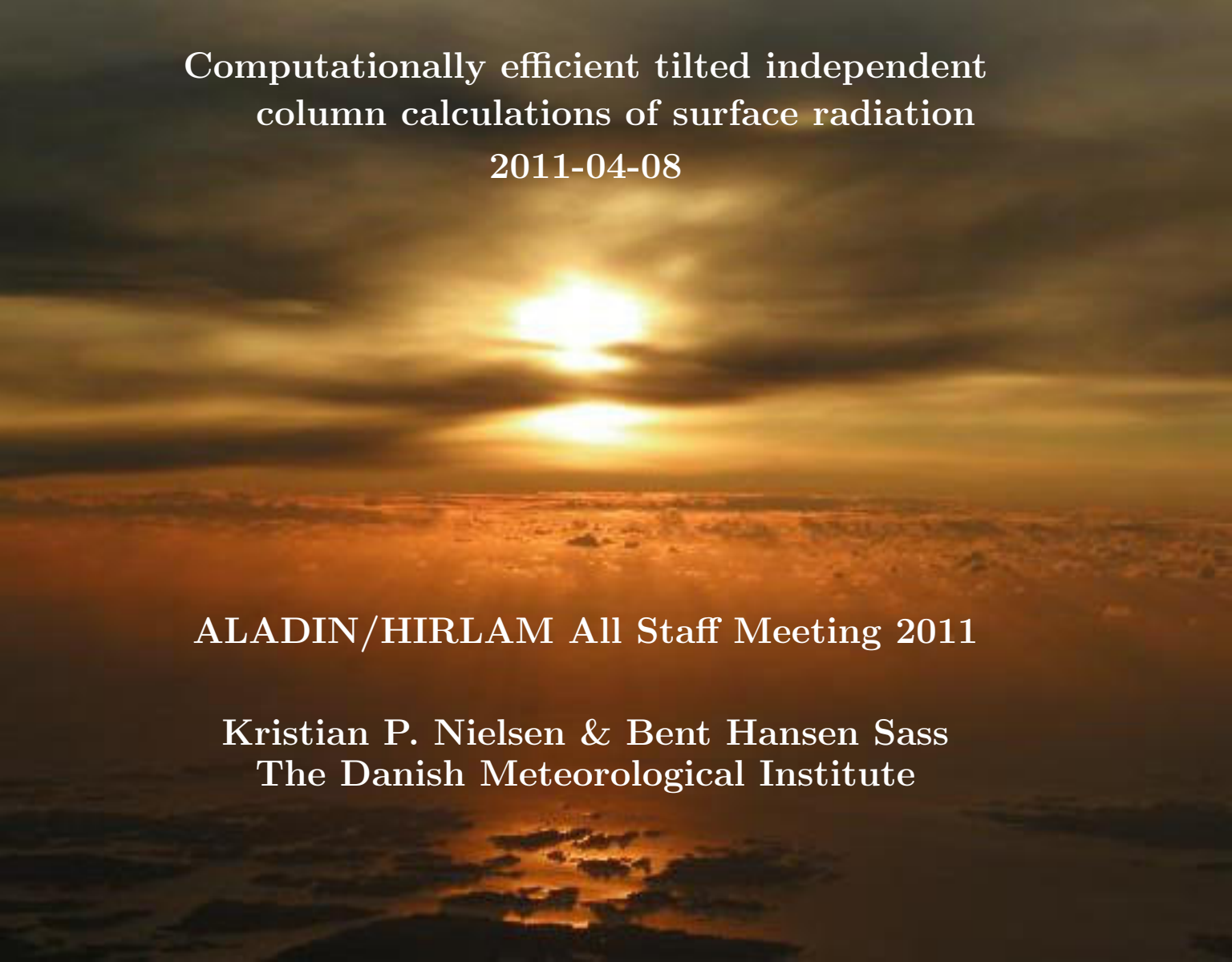

Computationally efficient tilted independent column calculations of surface radiation

2011-04-08

ALADIN/HIRLAM All Staff Meeting 2011

Kristian P. Nielsen & Bent Hansen Sass
The Danish Meteorological Institute

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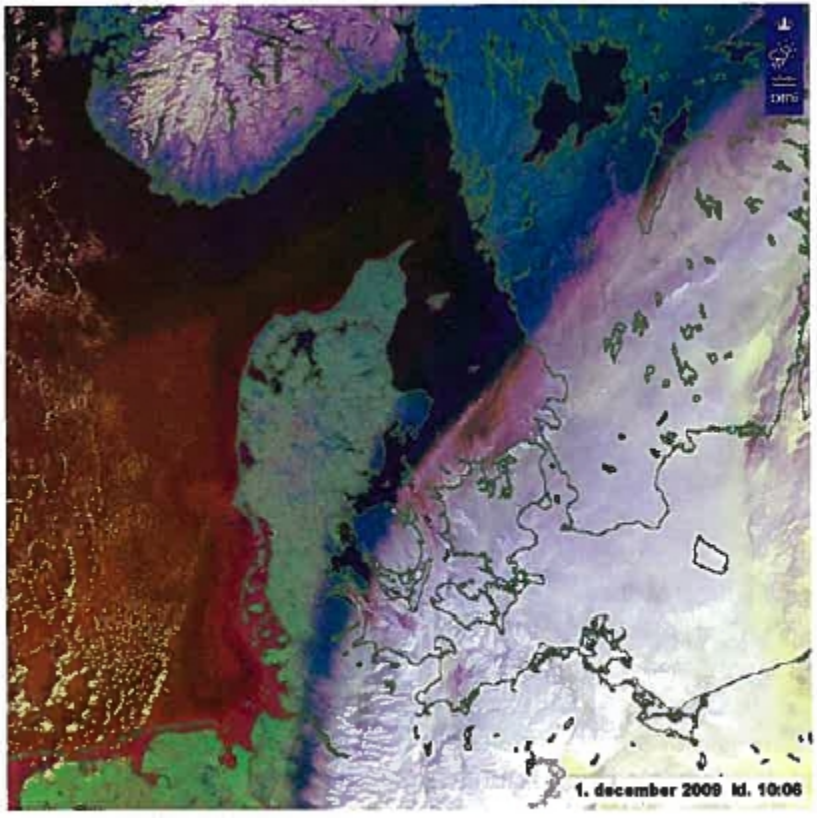
- Ulrik S. Korsholm, DMI.
- Brian Sørensen, KU/DMI.
- Xiaohua Yang, DMI.
- m.fl.

MINISTRY OF CLIMATE AND ENERGY

Tilted array modeling: Introduction



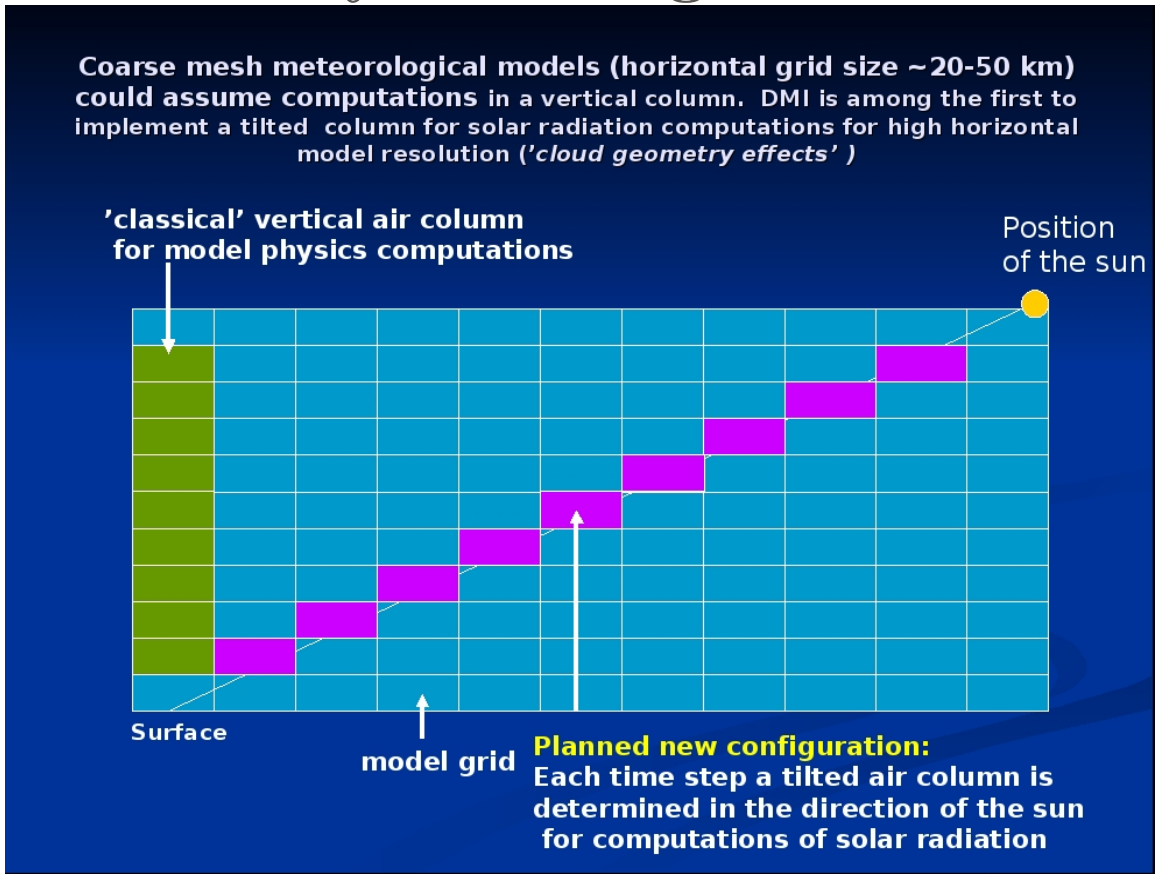
Visuelt NOAA-billede fra dmi.dk.

Vejret, **122**, februar 2010 • side 37

L. Rasmussen, Vejret, 2010; 122: 37.

MINISTRY OF CLIMATE AND ENERGY

Tilted array modeling: Introduction



Sass (2010), Hirlam Newsletter, 55B, 23–27.

MINISTRY OF CLIMATE AND ENERGY

Previous works

Varnai and Davies (1999)
Markowski and Harrington (2005)

Kathrin Wapler, PhD Thesis, München, 2007:

- TICA is a very good approximation for surface solar radiation, when compared to exact 3D-modeling.
- **When TICA is not applied, convective clouds have shorter lifetimes.**
- **The cloud shadows significantly affect the pattern of convection.**

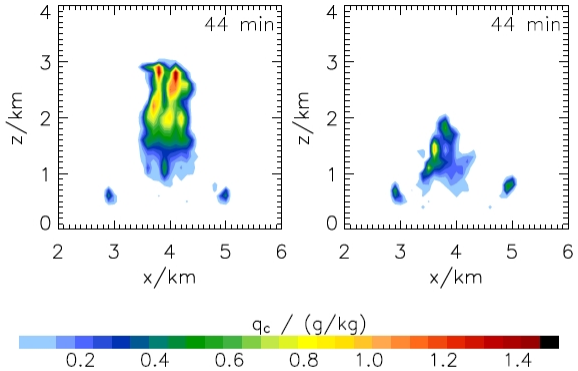


Abbildung 4.5: Vertikalschnitt des Wolkenwassermischungsverhältnisses nach 44 *min* der Simulationen mit EULAG (links) und mit EULAG-TICA30 (rechts).

MINISTRY OF CLIMATE AND ENERGY

Tilted array modeling: Theory

$$x_{tilt}(x,y,z) = \frac{Z(x,y,z)\tan(\theta_0(x,y))}{\lambda(x,y,z)}\sin(\phi_0(x,y) - \rho_{grid}(x,y)) \tag{1}$$

$$y_{tilt}(x,y,z) = \frac{Z(x,y,z)\tan(\theta_0(x,y))}{\phi(x,y,z)}\cos(\phi_0(x,y) - \rho_{grid}(x,y)) \tag{2}$$

$$\rho_{grid}(x,y) = -\tan^{-1}\left(\frac{\phi(x+1,y) - \phi(x-1,y)}{\cos(\phi(x,y))(\lambda(x+1,y) - \lambda(x-1,y))}\right) \tag{3}$$

Here,(x,y,z) are the regular array indices, (x_{tilt}, y_{tilt}, z) are the array indices of the tilted array, ρ_{grid} is the local rotation between the modeling grid and the geographical grid, Z is the geopotential height, θ_0 is the solar zenith angle, ϕ_0 is the solar azimuth angle, ϕ is the latitude and λ is the longitude.

Tilted arrays

- Cloud cover
- Cloud water
- Cloud ice
- Specific humidity
- Temperature

. . . used to calculate

- Surface short wave radiation

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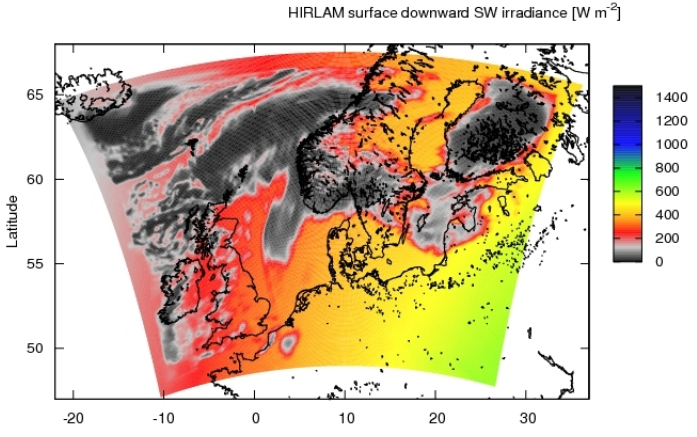
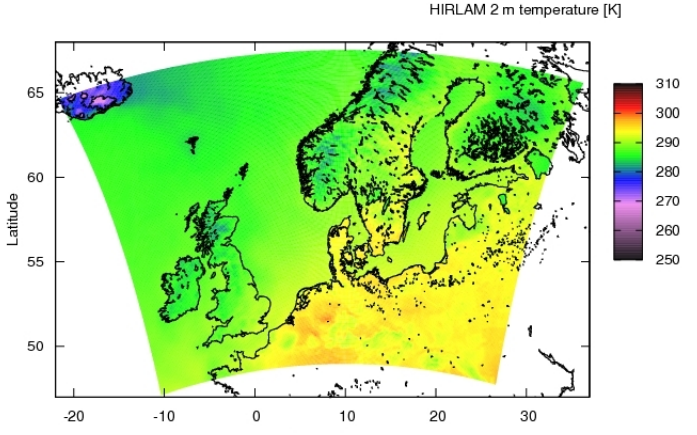
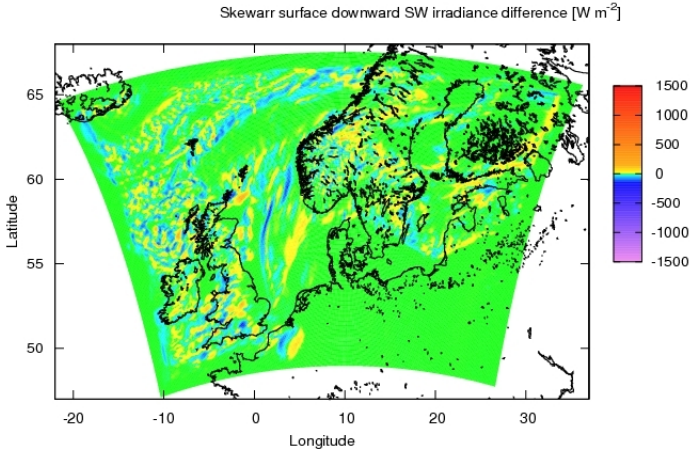
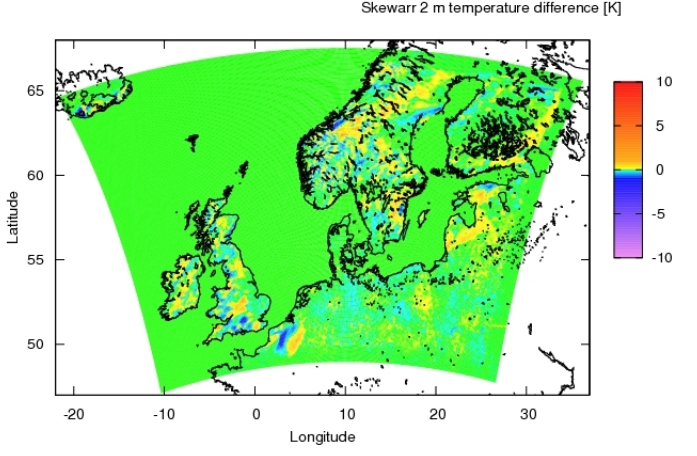
Tilted array modeling - First results (2009-09-01)

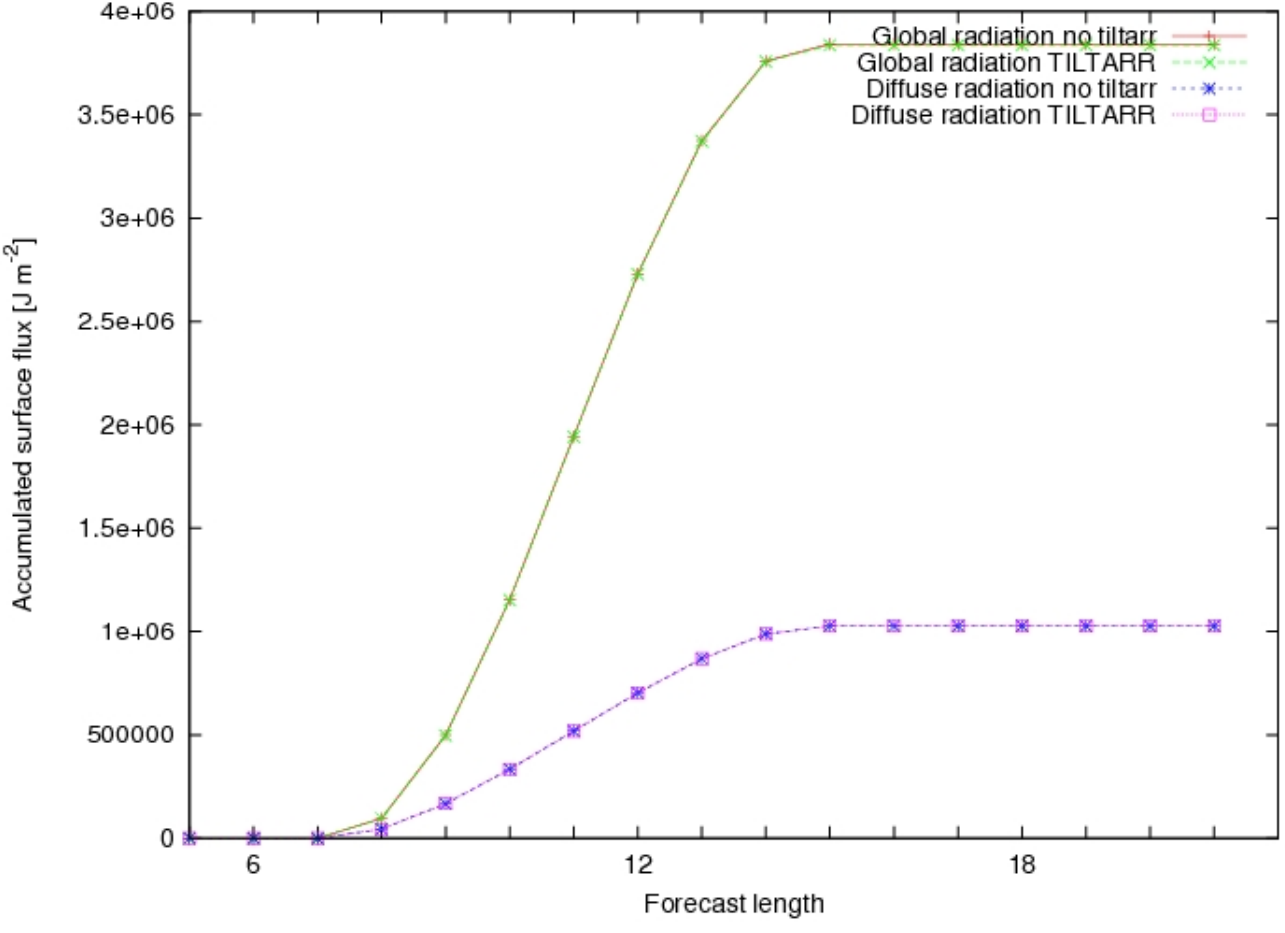






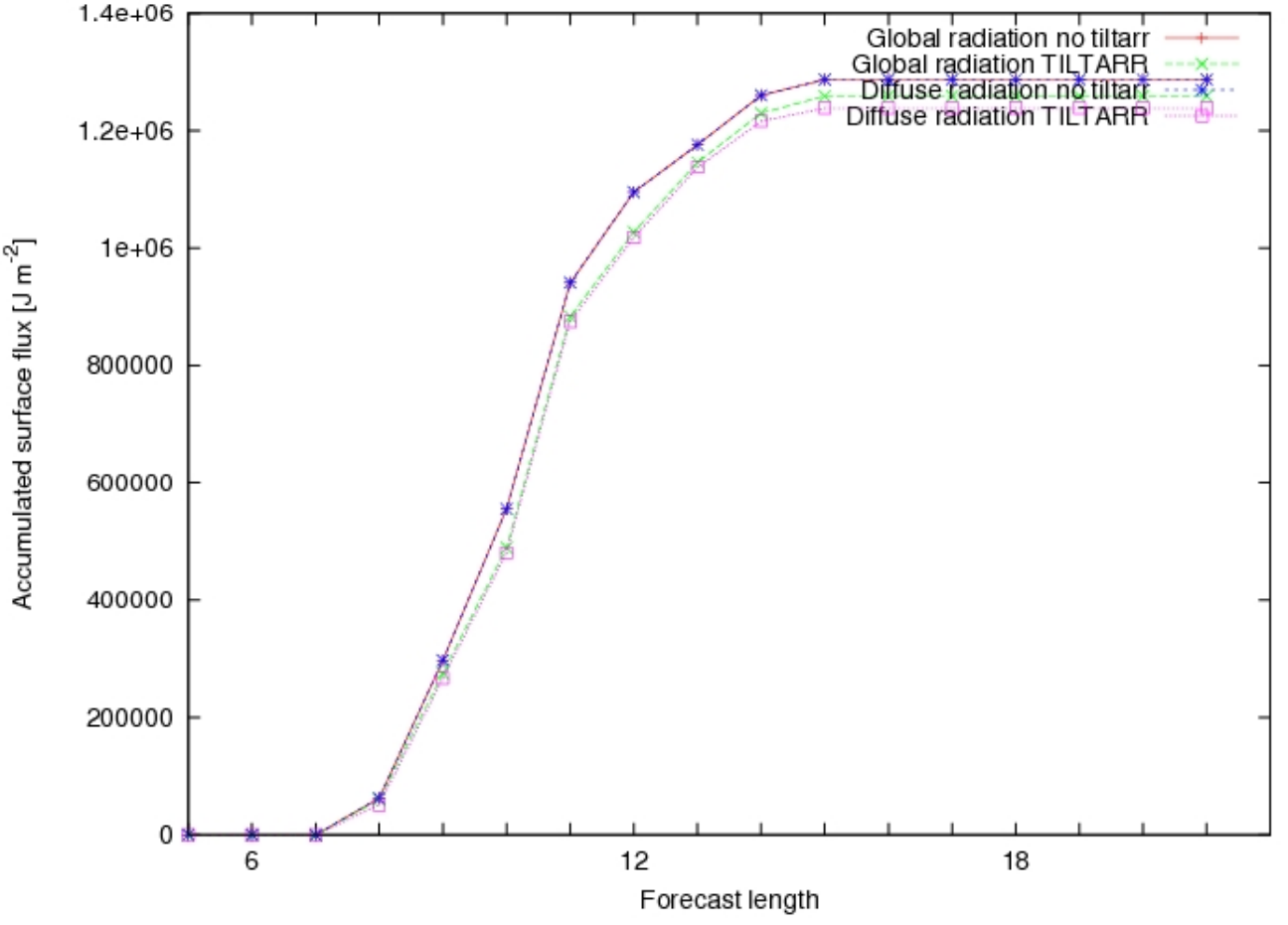


Results for clear sky conditions



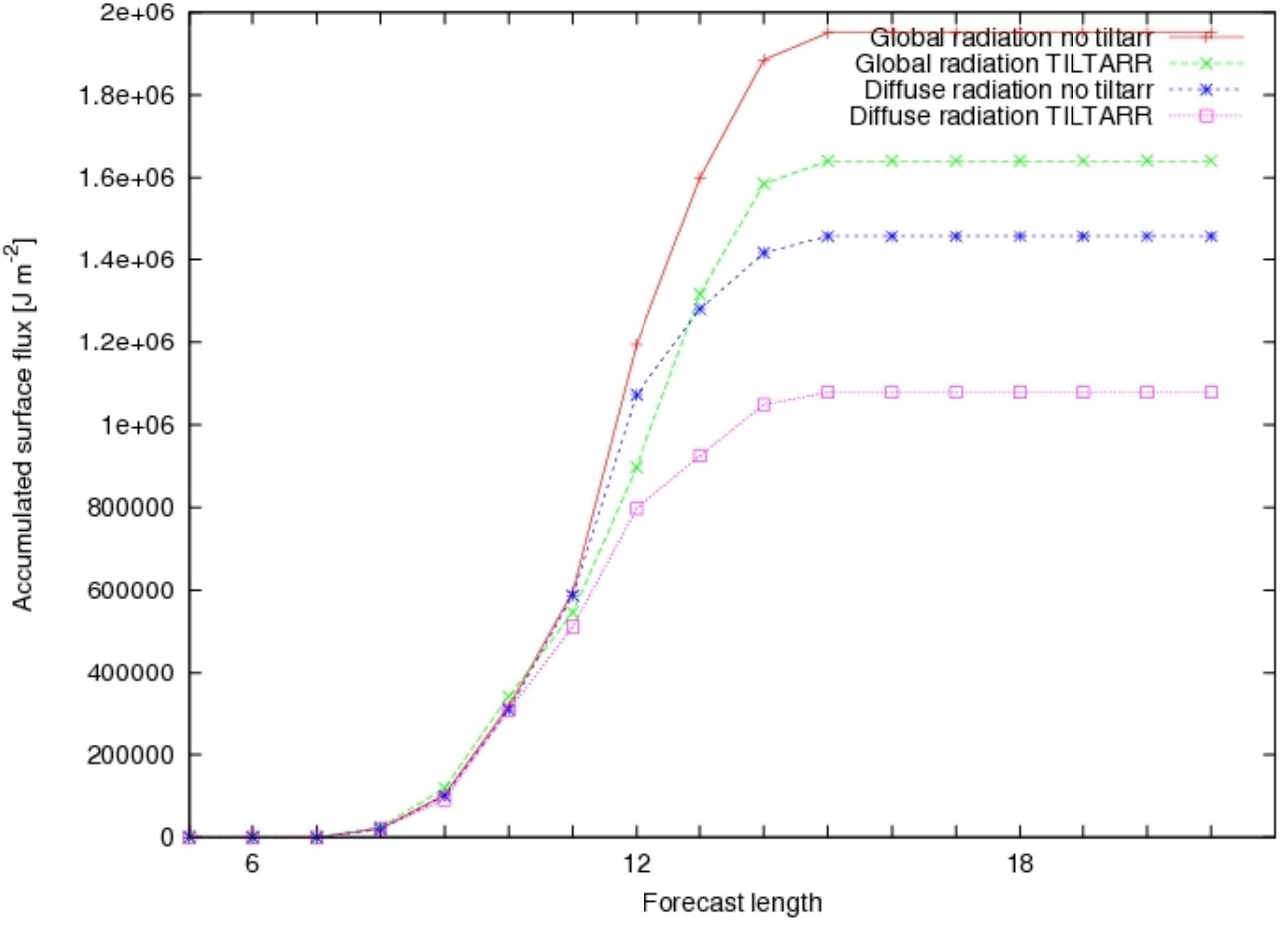
Station 6135: Flakkebjerg, 2009-11-20.

Results for overcast conditions



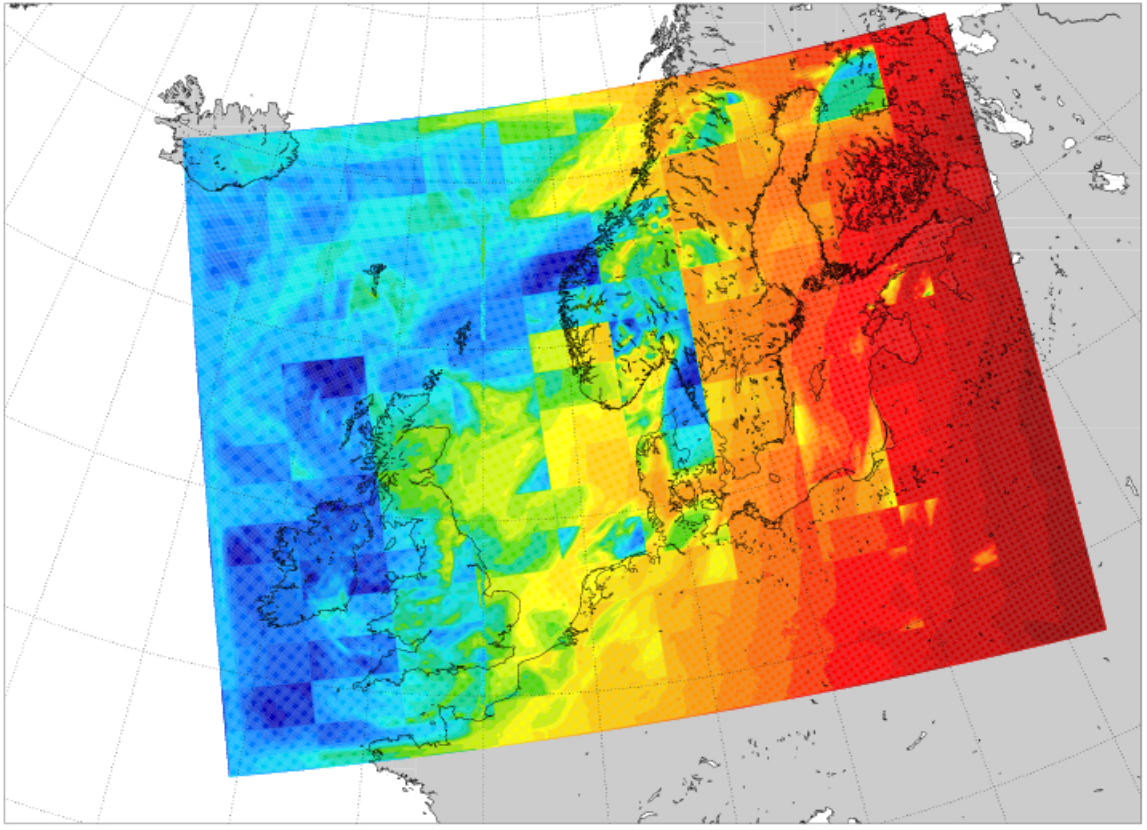
Station 6156: Holbæk, 2009-11-23.

Results for mixed cloud conditions



Station 6068: Isenvad, 2009-11-23.

Problem with tilted arrays



Tilted array modeling - SLSWAP

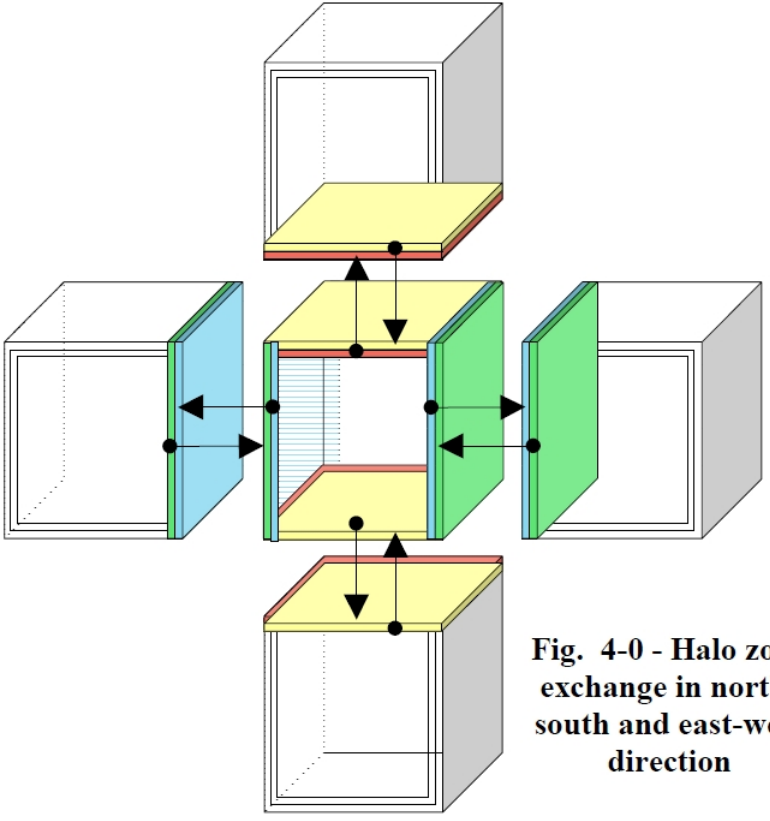


Fig. 4-0 - Halo zone exchange in north-south and east-west direction

Boerhut (2003).

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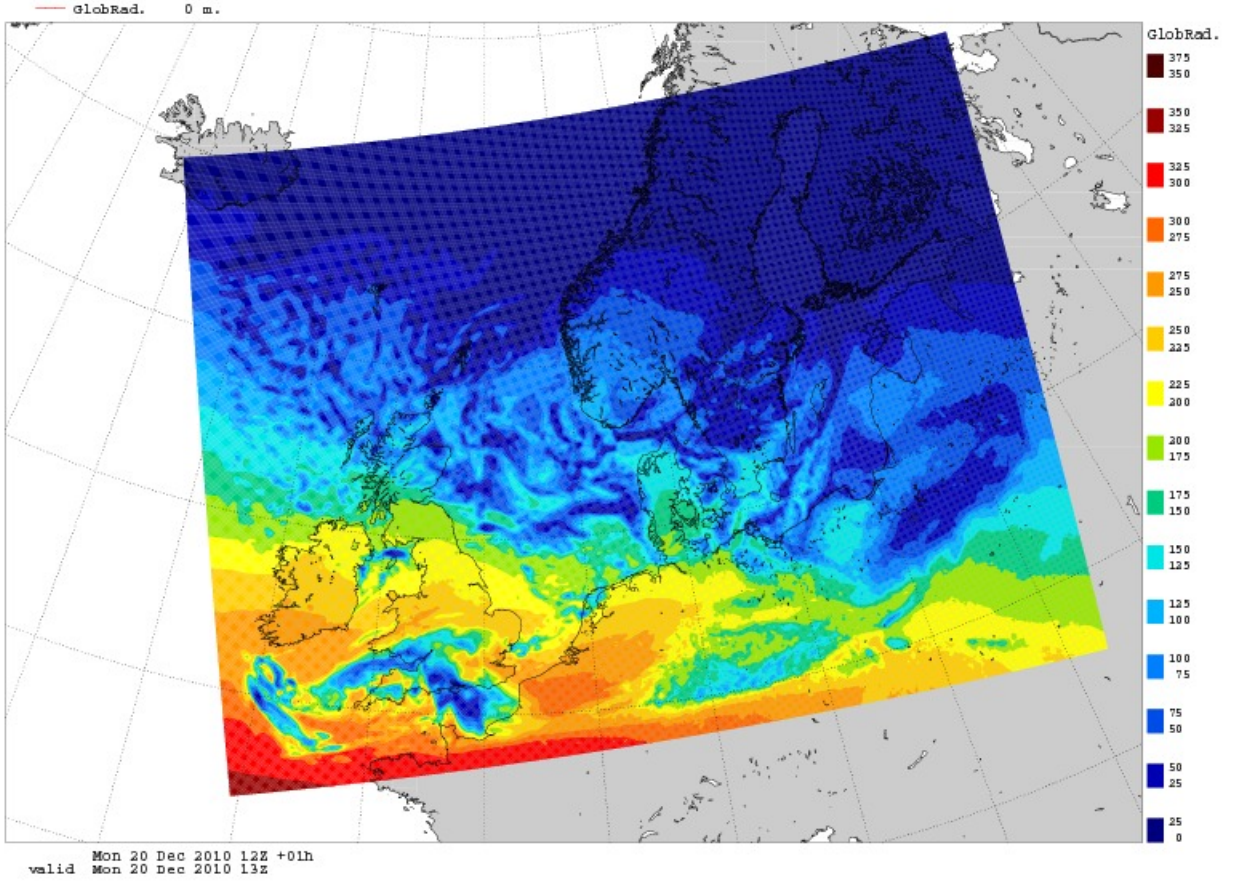
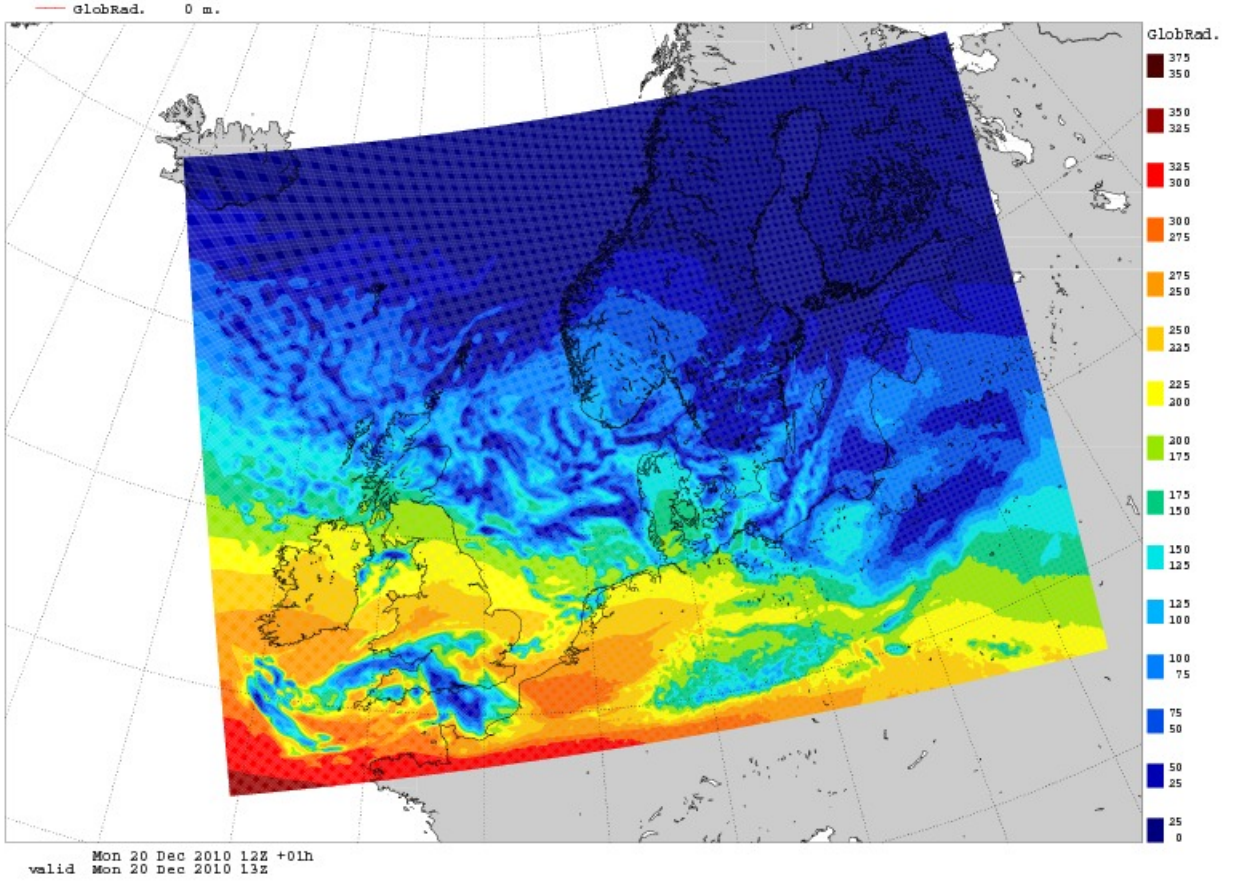
With tilted array modeling

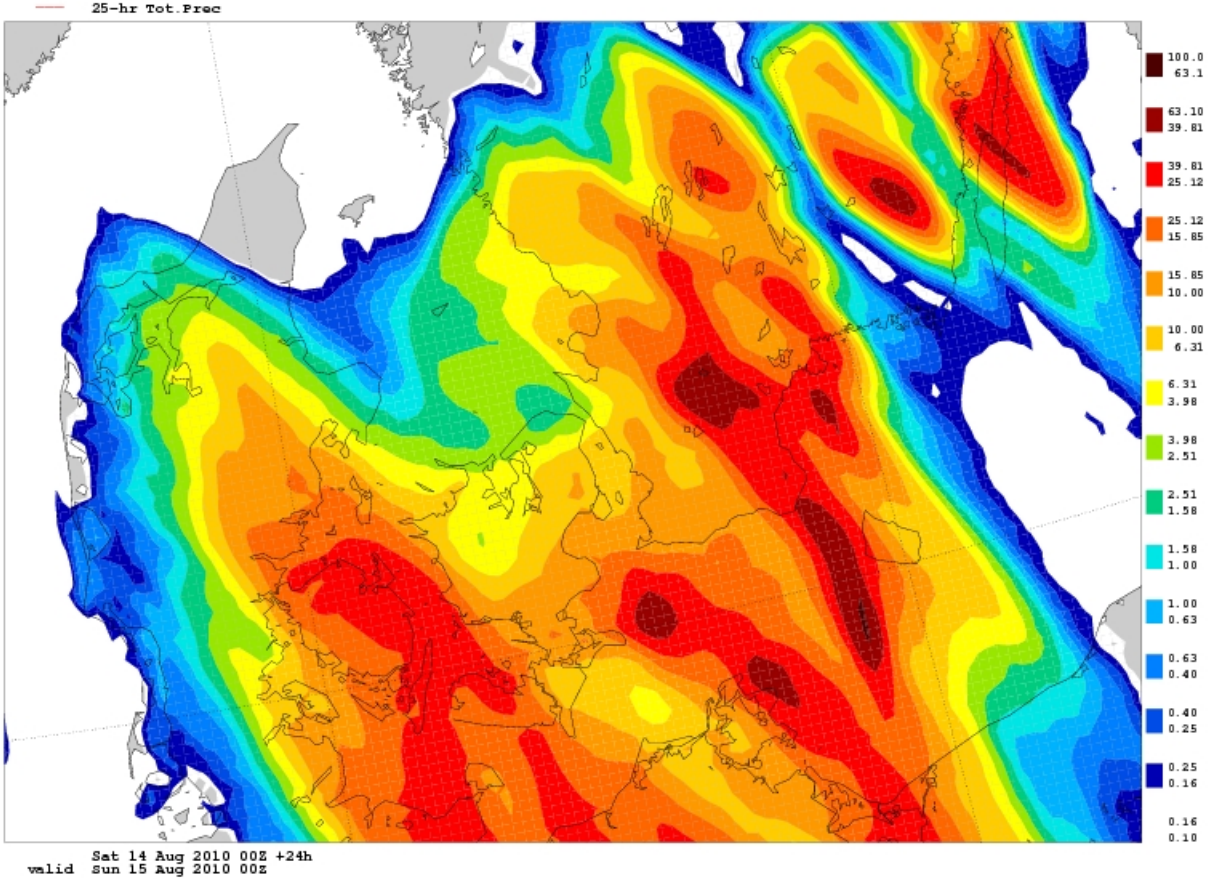


Without tilted array modeling



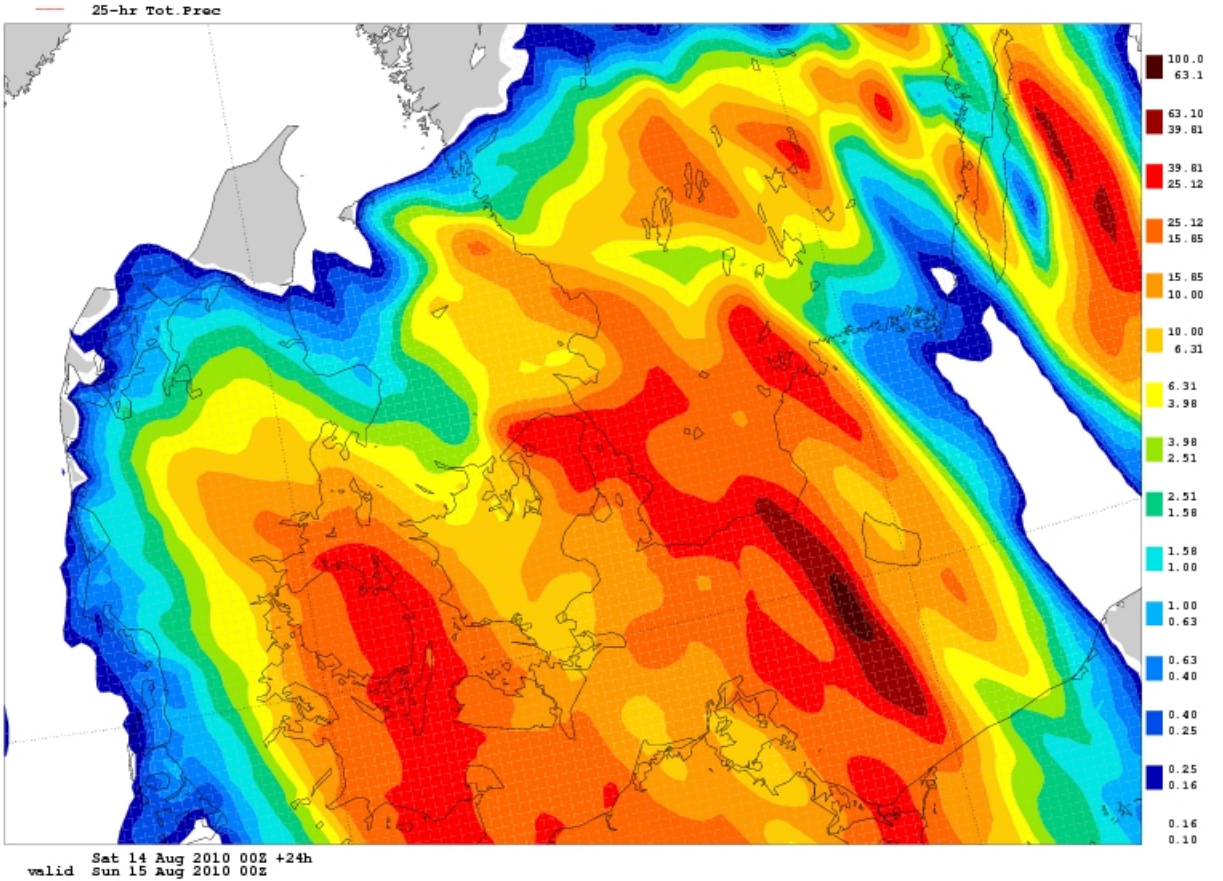
Without tilted array modeling

24-hour precipitation 2010-08-14 0 UTC +24h



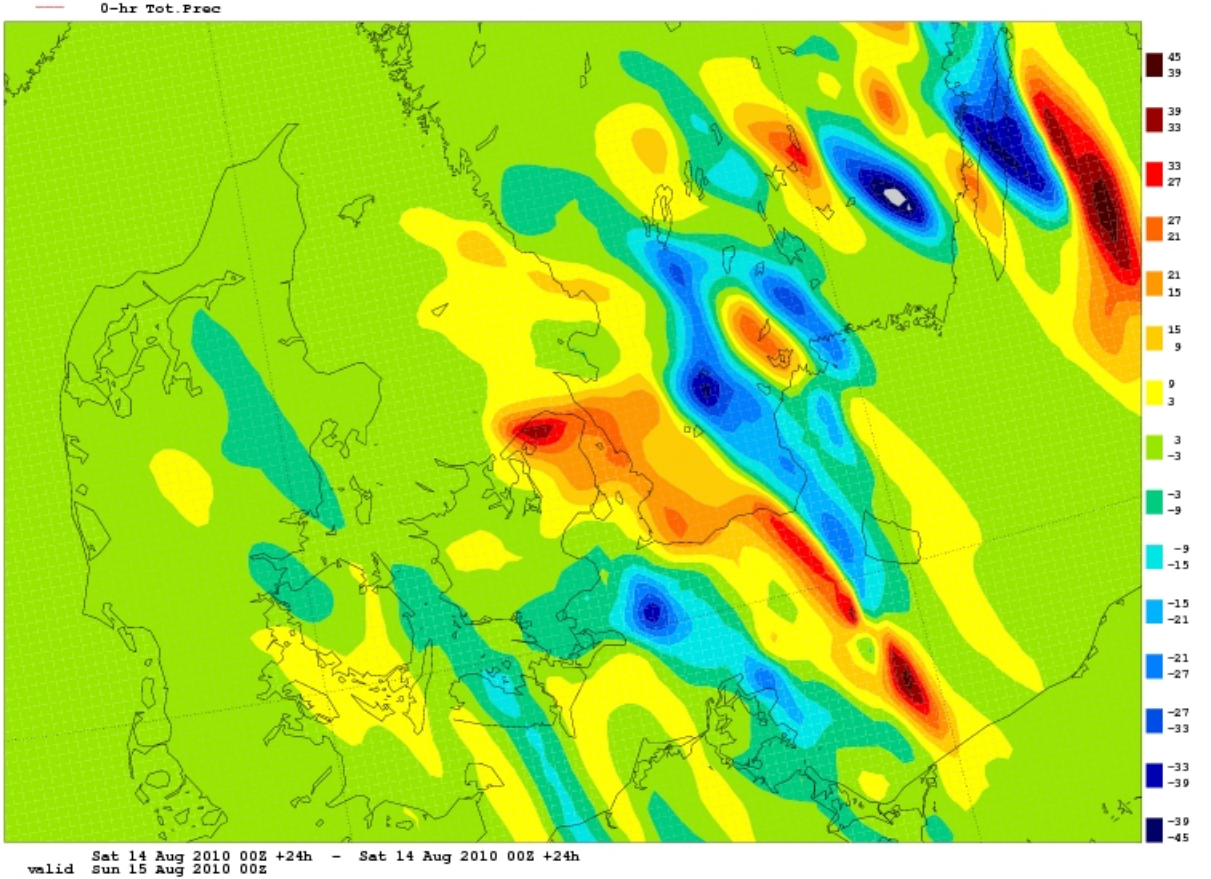
With tilted array modeling

24-hour precipitation 2010-08-14 0 UTC +24h



Tilted array modeling difference

24-hour precipitation 2010-08-14 0 UTC +24h



Further aspects of 3D-radiation

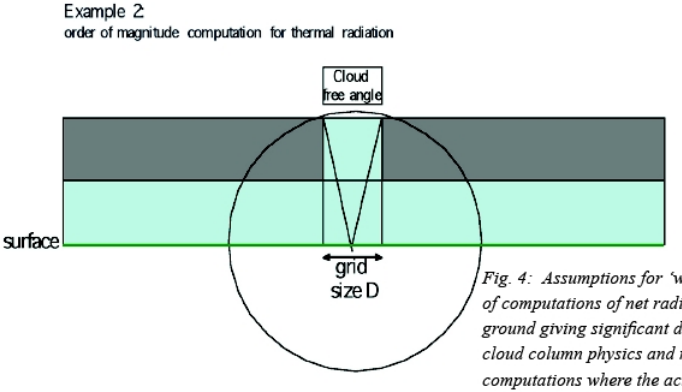


Fig. 4: Assumptions for 'worst case' type of computations of net radiation at the ground giving significant differences between cloud column physics and more realistic computations where the actual sky view (cloud free cone) is taken into account, integrating radiance over the half sphere above the ground – cloud layers of big horizontal extent exist outside the vertical 'column' (cylinder) !

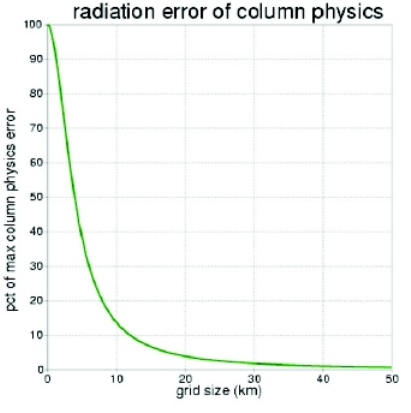


Fig. 5: Results for thermal radiation in stratifom cloud conditions.
Maximum error occurs when the grid size goes to very small values considering a cloud free column while in reality the surroundings are covered by a large cloud sheet radiating like a black body towards the ground. The figure shows the percentage of the maximum error (~98 W/m²) as a function of grid size, arising from executing column physics under the specified conditions.

Concluding remarks

- **We have deviced a method for implementing tilted array modeling, which is only 1.09 times slower than a regular NWP run;**
- **Tilted array modeling significantly affects the strength and distribution of convective precipitation;**
- **Further aspects of 3-D radiative transfer could also be implemented;**
- **How to proceed?**

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