HARMONIE radiation studies 2011-2016

Laura Rontu
Kristian Pagh Nielsen Emily Gleeson
Velle Toll Jan Masek

Joint 26th ALADIN Workshop & HIRLAM All Staff Meeting
4-8 April 2016, Lisbon, Portugal

Contents

RADIATIVE HEATING IN THE ATMOSPHERE

A SOURCE TERM IN THERMODYNAMIC EQUATION

$$\left(\frac{\partial T}{\partial t}\right)_{\mathrm{rad}} = -\frac{g}{c_p}\frac{\partial \mathcal{F}}{\partial p}$$

Radiative heating as divergence of the net radiation flux,

RADIATION BALANCE AT THE SURFACE

DOWNWELLING SWdn + ATMOSPHERIC LWdn
- REFLECTED SWup – LWup EMITTED BY SURFACE:
PART OF THE SURFACE ENERGY BALANCE

Parametrization of the radiative transfer

Solar (SW) radiation: scattering and absorption
Terrestrial (LW) radiation: emission, absoption, scattering

<u>In the air:</u>
Gas molecules
Cloud droplets and crystals
Aerosol particles

<u>Physico-chemical properties:</u>
Mass concentration
Size
Shape
Composition

<u>Grid-scale variables:</u>
T, qv, qi, ql, qr, qs
Aerosol (concentration)
Radiative fluxes

<u>Optical properties:</u>
Optical depth
Single scattering albedo
Asymmetry factor

Surface-atmosphere radiative interactions

Surface albedo and emissivity
Orographic radiation effects

Characteristics of surface types
Surface elevation

From the history

Draft plan (4)
LR 5 February 2008

HARMONIE radiation comparison

The aim of the model comparison experiment is to compare
HIRLAM-ALARO-AROME radiation parametrizations over c
terrain. The experiment should give information to underst
relative importance in mesoscale models of

1) advanced radiation transfer parametrizations in clear sky
(provided by the ECMWF radiation scheme within AROME)

2) accurate handling of cloud-radiation interactions

3) improved treatment of radiation surface-interactions, including

2008

Towards tailored radiation parametrizations for mesoscale NWP models?

Laura Rontu

FMI, Meteorological Research
International HIRLAM-B programme,
Physical parametrisations

With contributions by
Kristian Pagh Nielsen, DMI

SRNWP – EWGLAM meeting
Tallinn, 10-13 October 2011

2011

- Some hypotheses made by the authors seem to be very simplistic. For example, I wonder if it is really interesting to use radiative schemes with only one SW spectral band (especially in the case of wildfires, with aerosol optical properties highly dependent on wavelength), which are now scarcely used in NWP models. Another simplis-

2016

REQUIREMENTS FOR RADIATION PARAMETRISATIONS?

PARAMETRIZATION/ PROPERTY	**MESO-SCALE NWP**	**GCM**
GAS ABSORPTION AND EMISSION	Unbiased background	Detailed spectral calculations
CLOUD AND AEROSOL EFFECTS	Detailed in time and space (spectrum??)	Statistically correct in time and space
SURFACE-RADIATION INTERACTIONS	Detailed in time and space	(Seasonally) unbiased
INPUT TO RADIATION CALCULATIONS	Advanced cloud and aerosol content and microphysical properties, detailed surface properties, background gas concentrations	Statistically and climatologically reasonable gas, cloud, aerosol, surface content and properties
COMPUTATIONAL EFFICIENCY	HIGH	HIGH

http://srnwp.met.hu/Annual_Meetings/2011/download/monday/Rontu_EWGLAM_rad.pdf 2011

9 Radiation working weeks

The ultimate goal of this work is to make comparisons and improvements of the radiation schemes available in HARMONIE, i.e. the **IFS, ACRANEB and HLRADIA.** AROME physics has been chosen for the platform where all radiation routines can be compared in a clean way. Thus, calls of all three radiation routines are being implemented in **apl_arome.F90** (or apl_par.F90?), with common interfaces between radiation and clouds, aerosol and surface. In this framework, a clean comparison of any further developments inside the three radiation schemes is also possible. It is important to allow the radiation routines to concentrate on radiation and prepare the common input concerning cloud, aerosol and surface state before entering the radiation calculations.

Hirlam

Wiki | Timeline

wiki: HarmonieWorkingWeek / Radiation201604

HARMONIE Radiation Working Week 31st of March - 1th of A

Instituto Português do Mar e da Atmosfera, Rua C do Aeroporto 1749-077 Lisboa

Last modified 2016-03-07 8:43

Practical

Institutes	Participants in Tallinn	Online participants
Danish Meteorological Institute	Kristian Pagh Nielsen	
Met Éireann	Emily Gleeson	
Finnish Meteorological Institute	Laura Rontu	

Objectives

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Previous radiation working weeks

8. Tallinn November 2015 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation2015
7. Copenhagen April 2015 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation201
6. Copenhagen September 2014 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiati
5. Prague March 2014 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation201403
4. Helsinki October 2013 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation2013
3. Copenhagen February 2013 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiatior
2. Dublin October 2012 https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation20121
1. Helsinki April 2012

Contents

Testing of SW radiation fluxes in harmonie-37h1.radiation MUSC: IFS and hlradia against DISORT benchmark

- Diagnostic single column model framework
- Clear and cloudy sky without aerosol
- Condensate content and effective particle size prescribed
- No observations used

Nielsen, K. P., Gleeson, E., and Rontu, L.: Radiation sensitivity tests of the HARMONIE 37h1 NWP model, Geosci. Model Dev., 7, 1433-1449, doi: http://dx.doi.org/10.5194/gmd-7-1433-2014, 2014.

Testing of SW radiation fluxes in harmonie-37h1.radiation MUSC: IFS and hlradia against DISORT benchmark

- Found that results of the simple broadband hlradia are as good as those of spectral IFS scheme, especially for liquid clouds
- Suggested a new parametrization of liquid cloud optical properties for the IFS radiation (Nielsen scheme)
- Sketched a list of the next actions based on the comparison

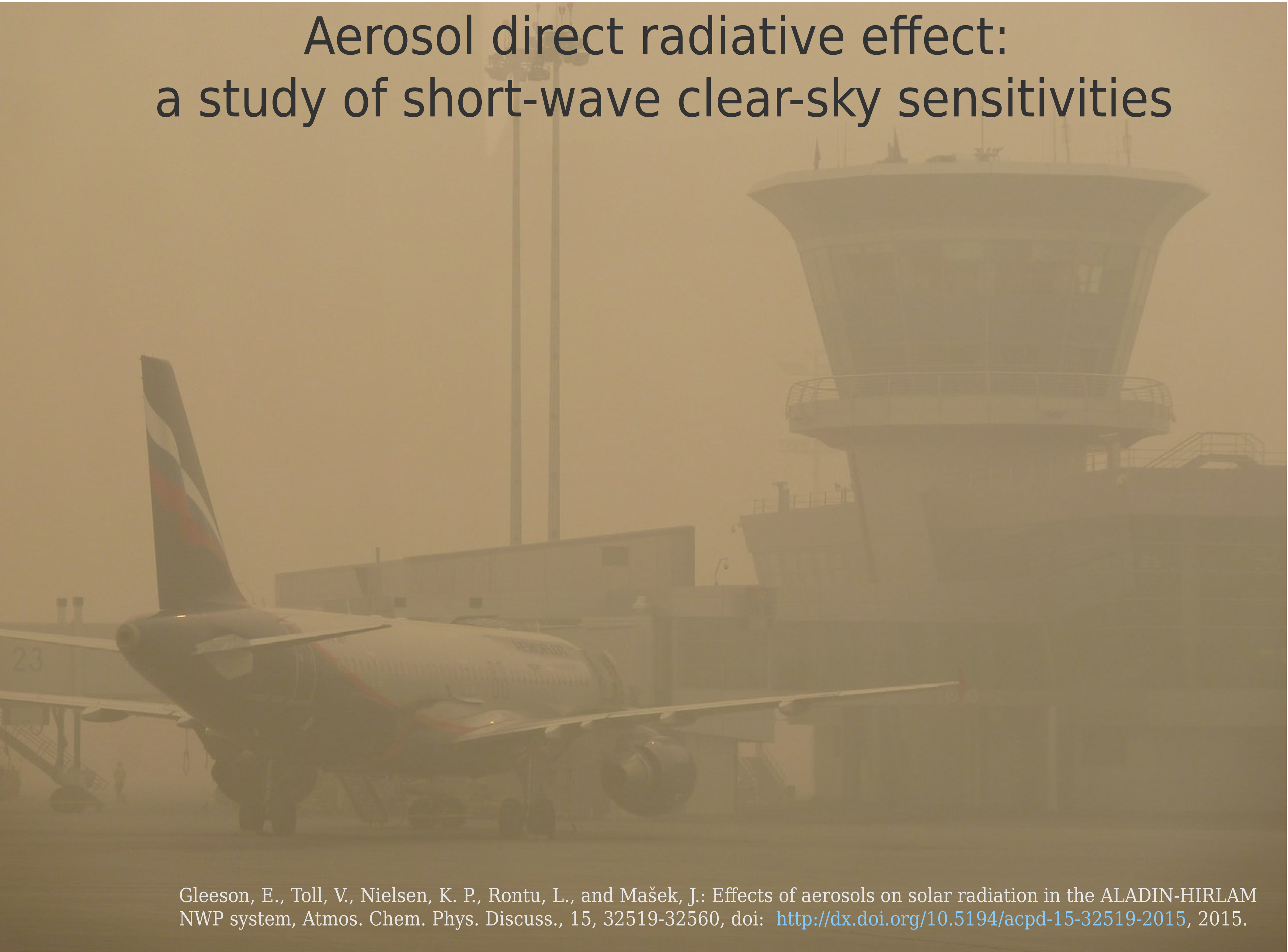
Nielsen, K. P., Gleeson, E., and Rontu, L.: Radiation sensitivity tests of the HARMONIE 37h1 NWP model, Geosci. Model Dev., 7, 1433-1449, doi: http://dx.doi.org/10.5194/gmd-7-1433-2014, 2014.

Suggestions for IFS & hlradia updates and testing

- The current choice of six spectral bands in HARMONIE/IFS should be re-assessed, as the first spectral band is irrelevant for NWP modelling.
- The effect of changing the SW **cloud inhomogeneity** factor from 0.7 (0.8) to 1.0 in all schemes should be tested against observations of global radiation in the framework of 3-D HARMONIE experiments. → Suggested to harmonie-40h1
- The effects on the general 3-D NWP results of using the **Nielsen cloud liquid** optical property parameterisation within the IFS scheme should be tested against observations of global radiation. → Suggested to harmonie-40h1
- In order to improve the delta-Eddington radiative transfer calculations, the possibility of using a variable average solar zenith angle for diffuse irradiances should be investigated. → Done, found minor impact
- The hlradia gaseous transmission coefficients should be tuned to the Kato-DISORT clear sky results presented here and for the other AFGL atmospheric profiles. → Done
- The impact of aerosols needs to be investigated. → Done

Nielsen, K. P., Gleeson, E., and Rontu, L.: Radiation sensitivity tests of the HARMONIE 37h1 NWP model, Geosci. Model Dev., 7, 1433-1449, doi: http://dx.doi.org/10.5194/gmd-7-1433-2014, 2014.

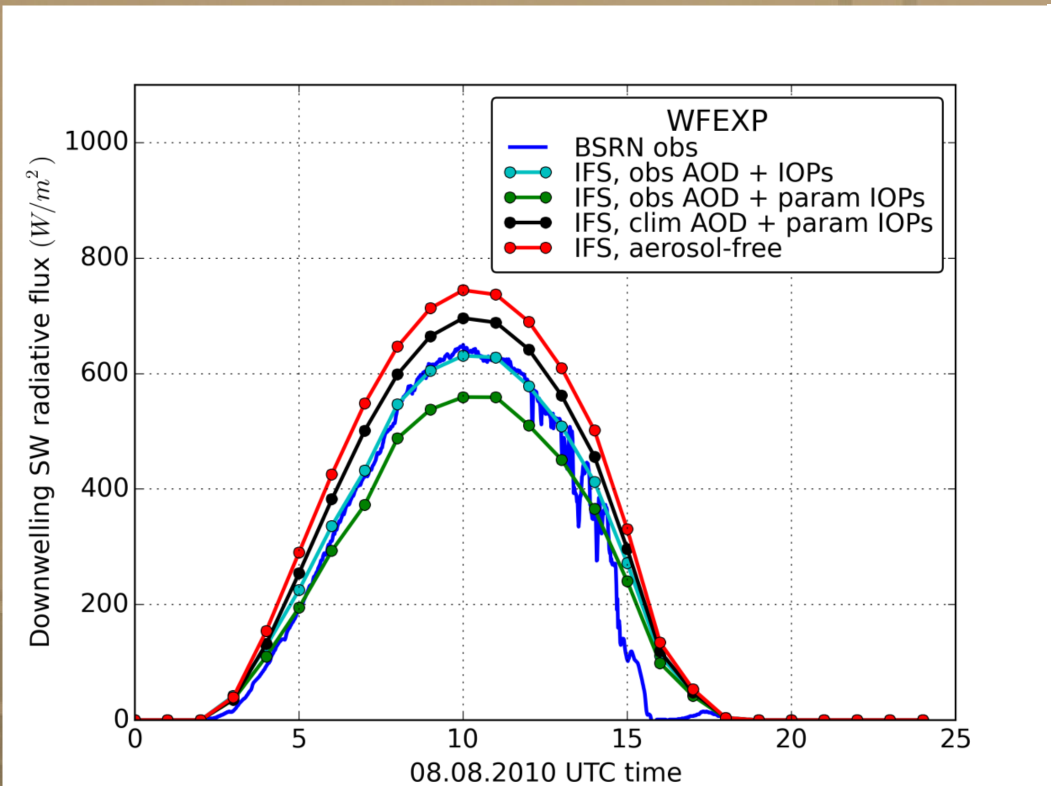
Aerosol direct radiative effect:
a study of short-wave clear-sky sensitivities

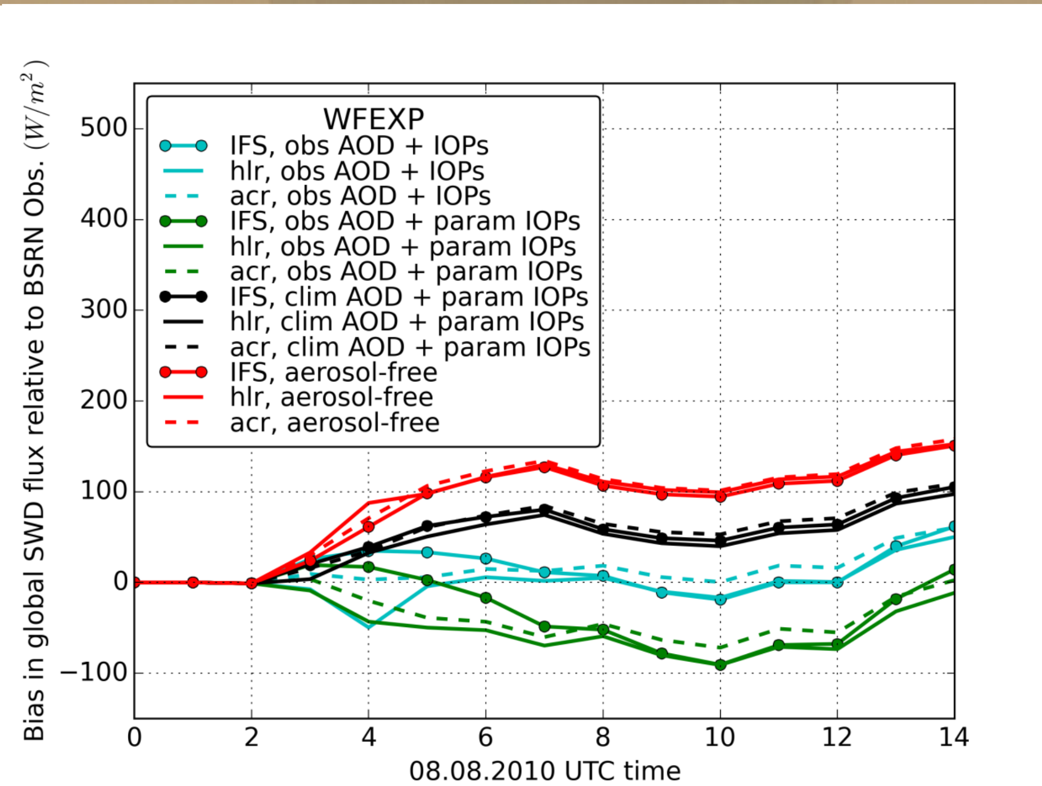


Gleeson, E., Toll, V., Nielsen, K. P., Rontu, L., and Mašek, J.: Effects of aerosols on solar radiation in the ALADIN-HIRLAM NWP system, Atmos. Chem. Phys. Discuss., 15, 32519-32560, doi: http://dx.doi.org/10.5194/acpd-15-32519-2015, 2015.

Aerosol direct radiative effect:
a study of short-wave clear-sky sensitivities

SWD observed and simulated with 3 radiation schemes using MUSC
Toravere, Estonia during 2010 Russian forest fires



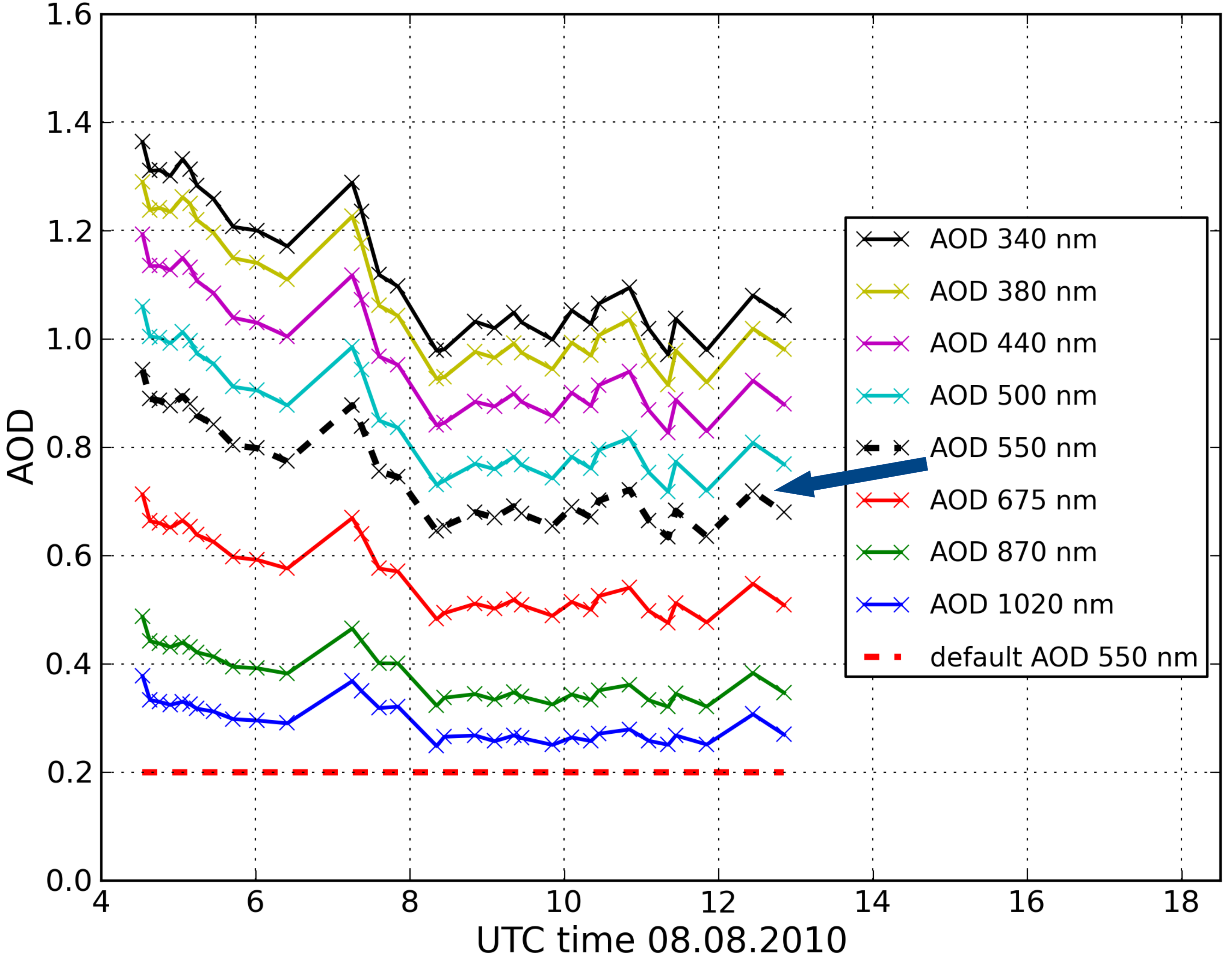


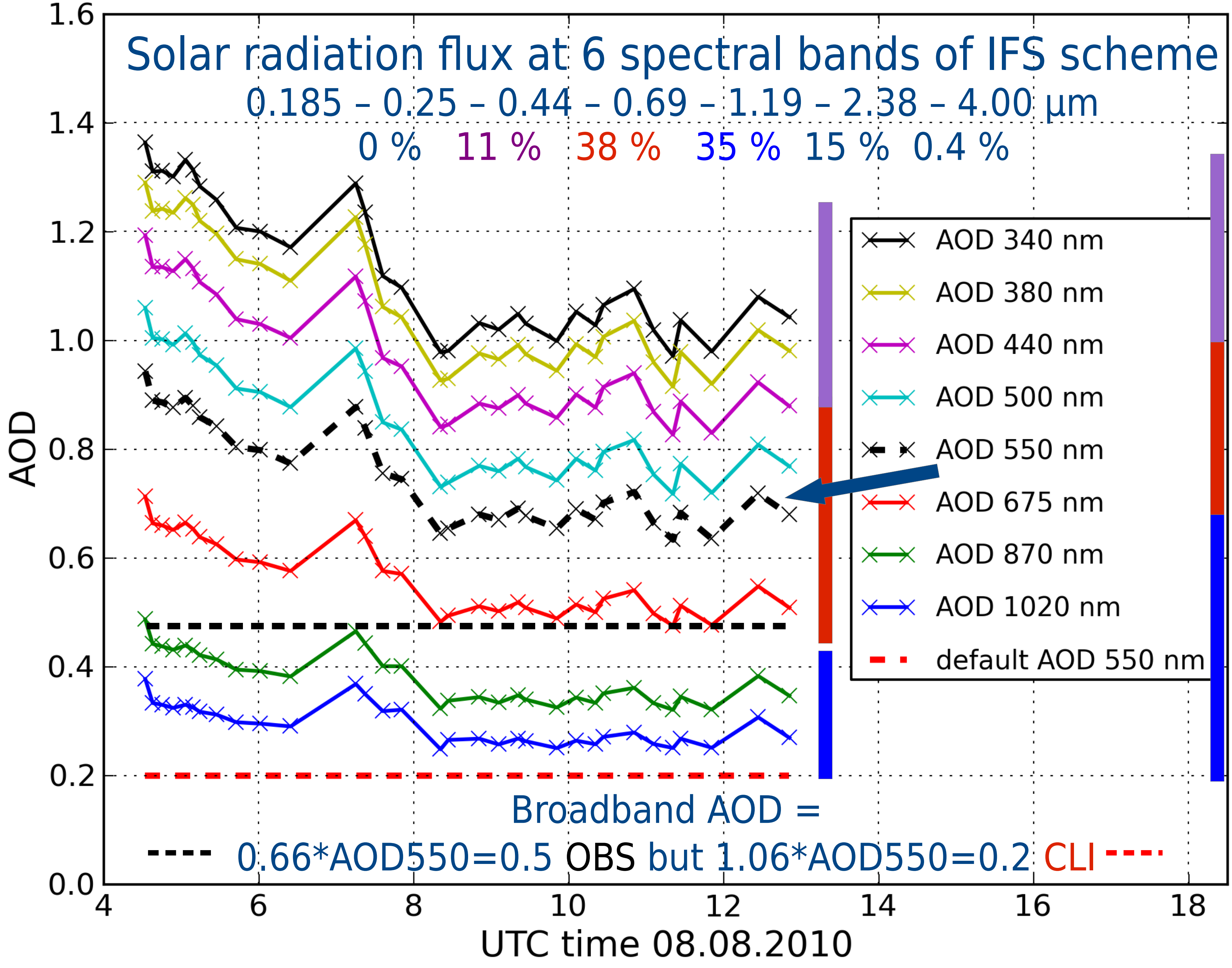
Optical properties of aerosol, not only the mass concentration, are important.

Broadband radiation schemes are O.K. compared to those resolving spectral details.

Gleeson, E., Toll, V., Nielsen, K. P., Rontu, L., and Mašek, J.: Effects of aerosols on solar radiation in the ALADIN-HIRLAM NWP system, Atmos. Chem. Phys. Discuss., 15, 32519-32560, doi: http://dx.doi.org/10.5194/acpd-15-32519-2015, 2015.

Observed aerosol optical depth at different wavelengths in Toravere





Solar radiation flux at 6 spectral bands of IFS scheme
0.185 – 0.25 – 0.44 – 0.69 – 1.19 – 2.38 – 4.00 µm
0 % 11 % 38 % 35 % 15 % 0.4 %
AOD 340 nm
AOD 380 nm
AOD 440 nm
AOD 500 nm
AOD 550 nm
AOD 675 nm
AOD 870 nm
AOD 1020 nm
default AOD 550 nm
Broadband AOD =
0.66*AOD550=0.5 OBS but 1.06*AOD550=0.2 CLI
AOD
UTC time 08.08.2010
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
4
6
8
10
12
14
16
18

Cloud, aerosol, radiation interactions

How to obtain consistent microphysics for precipitation and radiative transfer parametrizations?

Radiative effect of recent updates in HARMONIE-AROME microphysics – changing relations between the mass concentration of cloud and precipitation particles?

... ongoing work

Also linked to the direct and indirect aerosol effects

V.Toll, E.Gleeson, K.P.Nielsen, A.Männik, J.Mašek, L.Rontu, P.Post, 2016: Impacts of the direct radiative effect of aerosols in numerical weather prediction over Europe using the ALADIN-HIRLAM NWP system. Atmospheric Research, vol.172–173,163–173. doi: http://dx.doi.org/10.1016/j.atmosres.2016.01.003

Changes microphysics parametrizations for evolution of clouds influence the radiative transfer

Solar (SW) radiation: scattering and absorption
Terrestrial (LW) radiation: emission, absoption, scattering

<u>Physico-chemical properties:</u>
Mass concentration
Size??
Shape??
Composition??

<u>In the air:</u>
Gas molecules
Cloud droplets and crystals
Aerosol particles

<u>Grid-scale variables:</u>
T, qv, qi, ql, qr, qs
Aerosol (concentration)
Radiative fluxes

⬇

<u>Optical properties:</u>
Optical depth??
Single scattering albedo
Asymmetry factor

Size: parametrized/observation-based equivalent radius r_e of precipitating solid particles

https://hirlam.org/trac/attachment/wiki/HarmonieWorkingWeek/Radiation201511/Harmonie_RWD_Tallinn_2015_Petri_Raisanen.pdf

Contents

Introduction

Atmospheric comparisons

Surface interactions

Validation by radiation?

System aspects

Next steps

Surface albedo

- Dependence of surface properties
  – e.g. snow, forest, water – from surface description, statistics
- Albedo for <u>direct beam</u> and diffuse radiation
  – dependency on solar elevation
- Wavelengths of albedo
  – UV, visible, near-IR or according to the spectral resolution of atmospheric radiation parametrizations, <u>broadband</u>

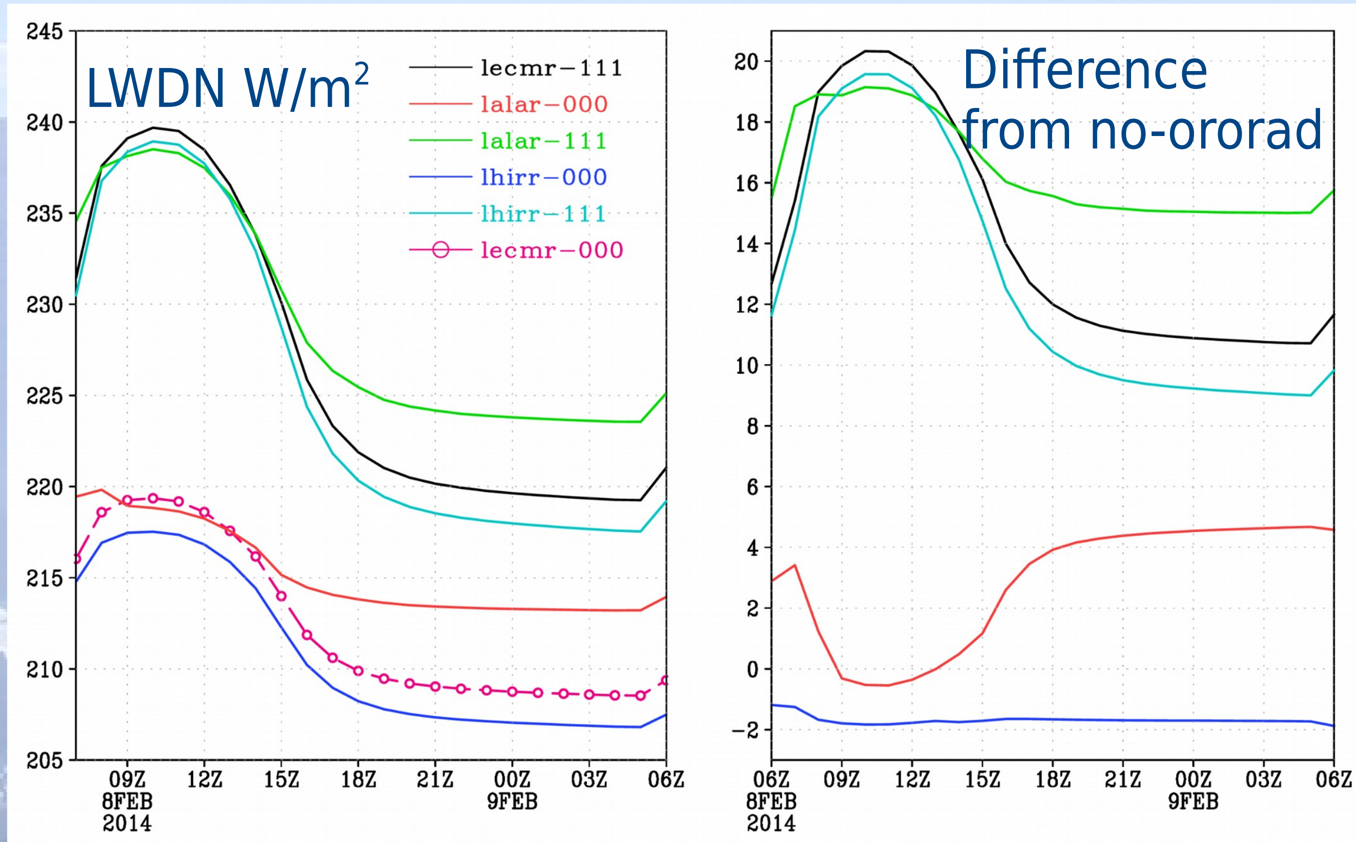
Albedo in the model

Lower boundary condition for (grid-scale) atmospheric radiation
Albedo used within the surface parametrizations?
How to introduce observed albedo via objective analysis?
Grid-scale effective albedo as model output = SWUP/SWDN (accumulated) – may contain also urban/<u>orographic</u> effects

Related poster: Mottram et al.: Glaciers of HARMONIE

Orographic radiation

Modification of surface downwelling and net radiation fluxes by slope, sky view and shadow factors after atmospheric radiation transfer calculations



A longwave example: the effect of orography is larger than the difference between radiation schemes

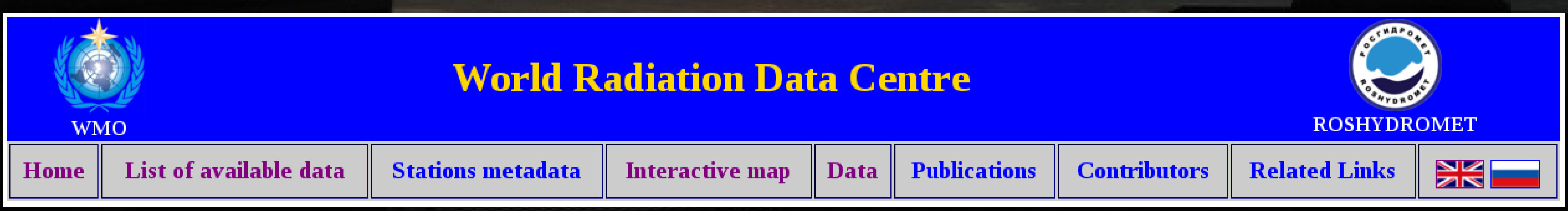
Rontu Laura, Wastl Clemens, Niemela Sami, 2016: Influence of the details of topography on weather forecast - evaluation of HARMONIE experiments in the Sochi Olympics domain over the Caucasian mountains, Frontiers in Earth Science,4,(13). doi: http://dx.doi.org/10.3389/feart.2016.00013

Contents

Observed radiation fluxes offer a possibility to validate NWP models

- Observed and predicted fluxes correspond each other more directly than e.g. observed and predicted cloud cover or T_{2m}
- Radiation fluxes are nevertheless related to temperature and cloud physical properties
- Reliable SW radiation fluxes are increasingly required for solar energy development.
- More ground-based and satellite (SW) observations become available – how to use them for systematic monitoring and validation of NWP models?

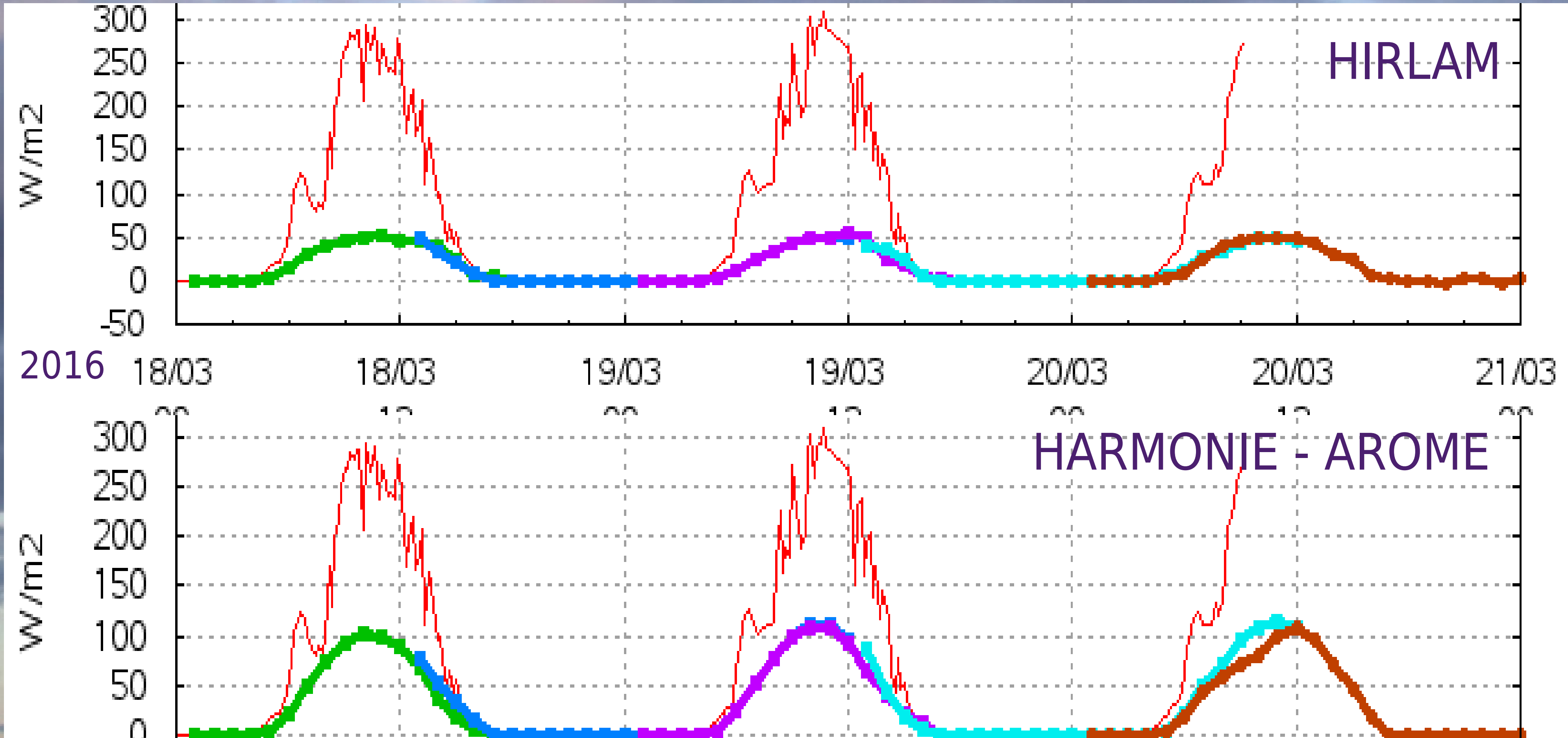
A possible source of ground-based observations?



SURFACE RADIATION FLUXES MEASURED IN SODANKYLÄ OBSERVATORY

SWDN SWUP LWDN LWUP

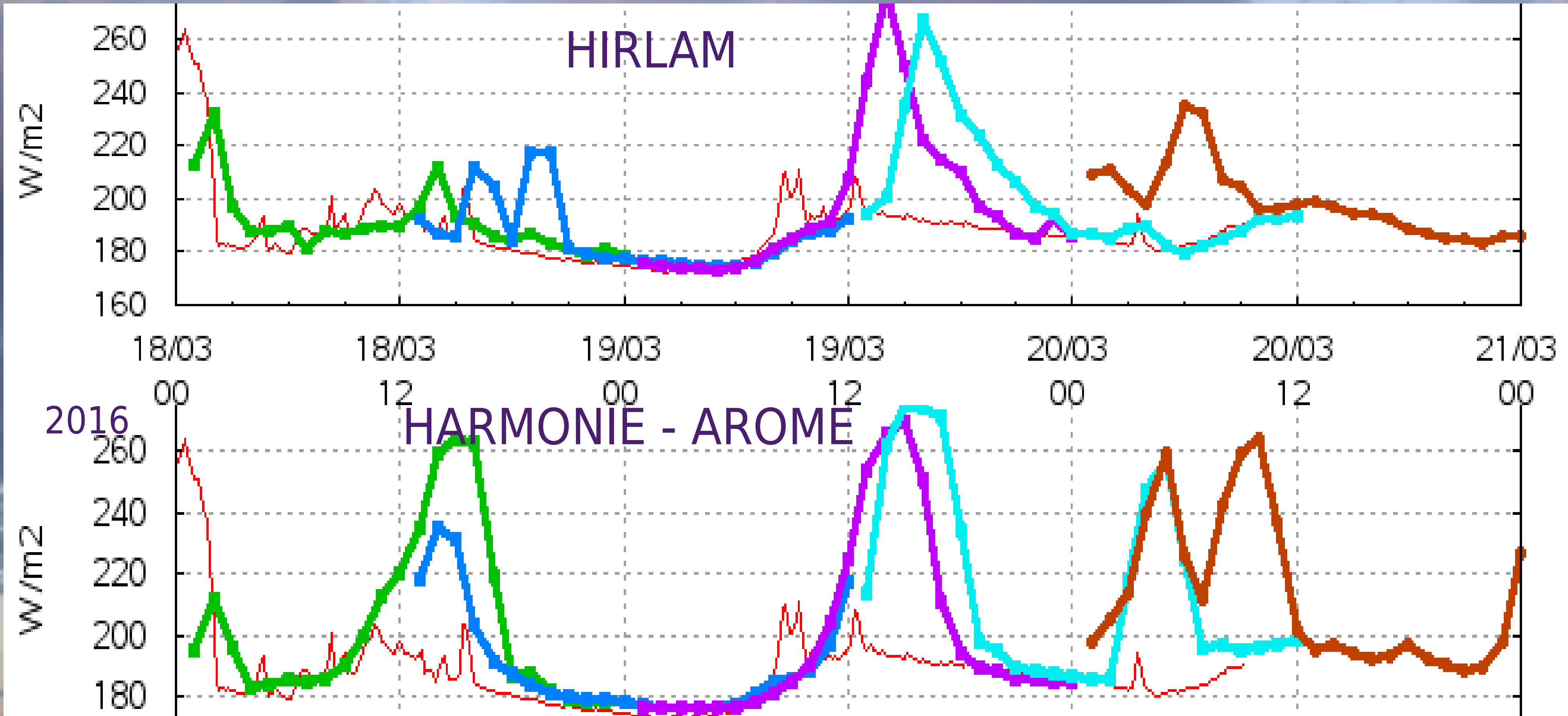
How to use for monitoring and statistical validation?



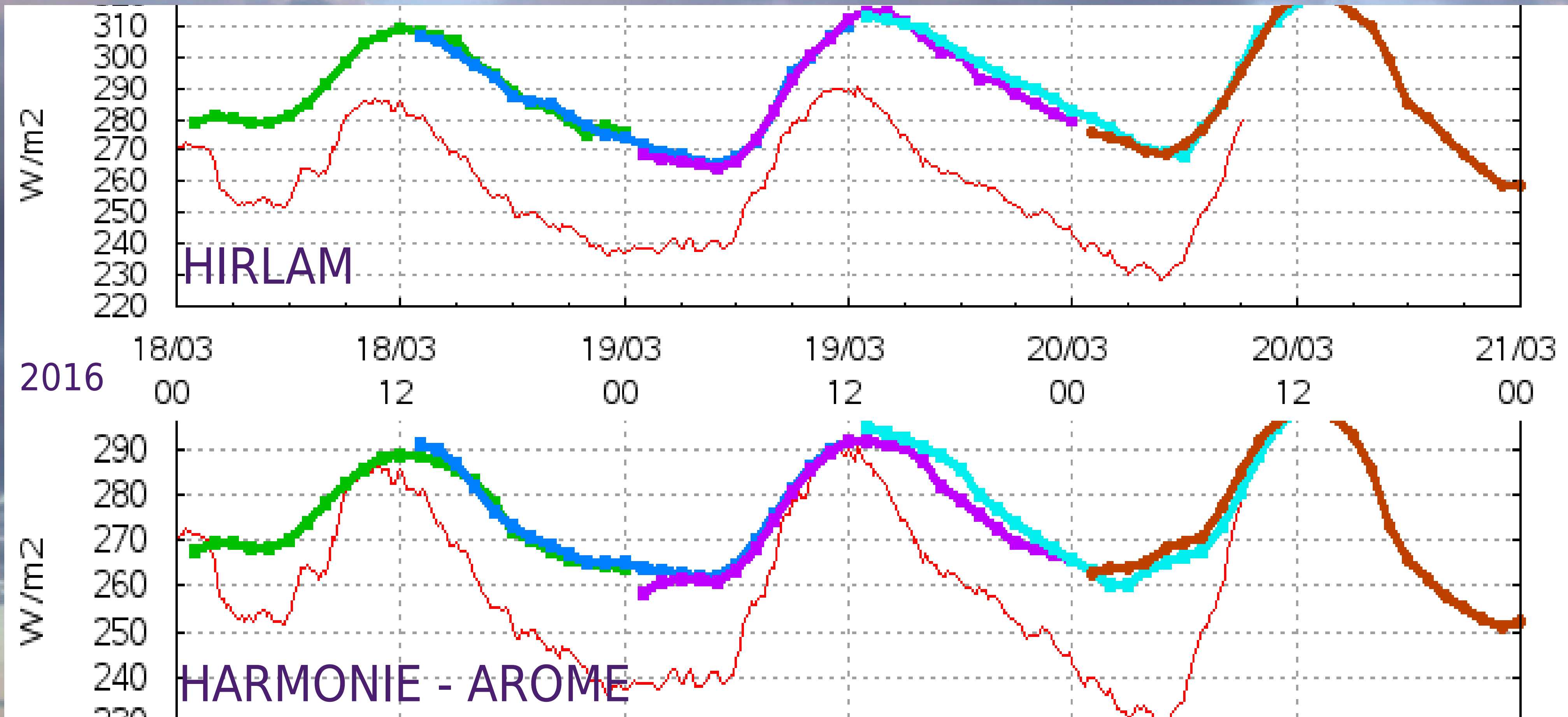
SWUP (reflected SW) is related to the surface albedo

- observed: local (here: snow, with the typical albedo=0.8)
- model: grid average, bird's-eye view (here over forest)

→ SWUP is **not** comparable between model and observation

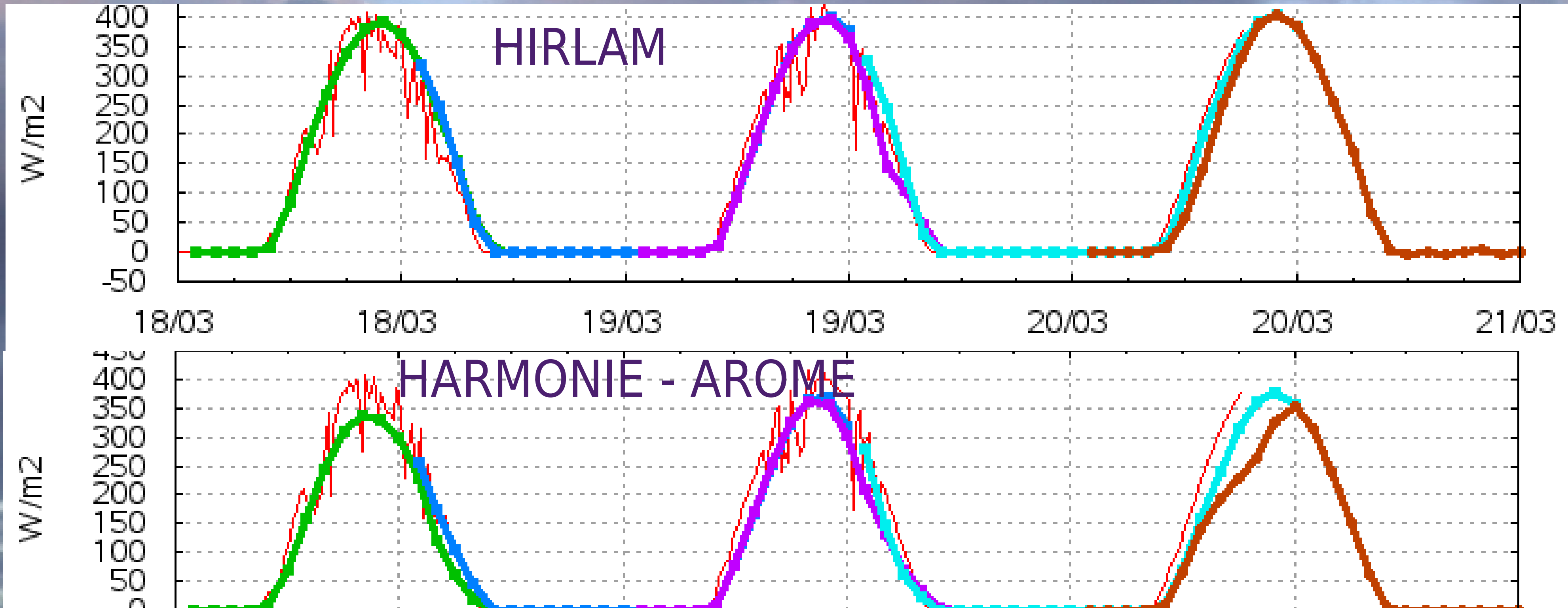


LWDN is (also during night!) related to:
- cloud water path, cloud cover, (bottom) temperature
- low level air temperature, humidity



LWUP is related to the surface temperature

- observed: local, open land (here snow-covered)
- model: grid-average, bird's-eye view (here over forest)



SWDN is related to
- cloud water path, cloud particle size, cloud cover
- clear sky: specific humidity

CSI = Clear Sky Index v.s. total cloudiness?

http://www.cnrm.meteo.fr/aladin/IMG/pdf/nl5.pdf

Shortwave Radiation Experiments in HRMONIE : Tests of the cloud inhomogeneity factor and a new cloud liquid optical property scheme compared to observations, Emily Gleeson, Kristian Pagh Nielsen, Velle Toll, Laura Rontu, Eoin Whelan (p. 92)

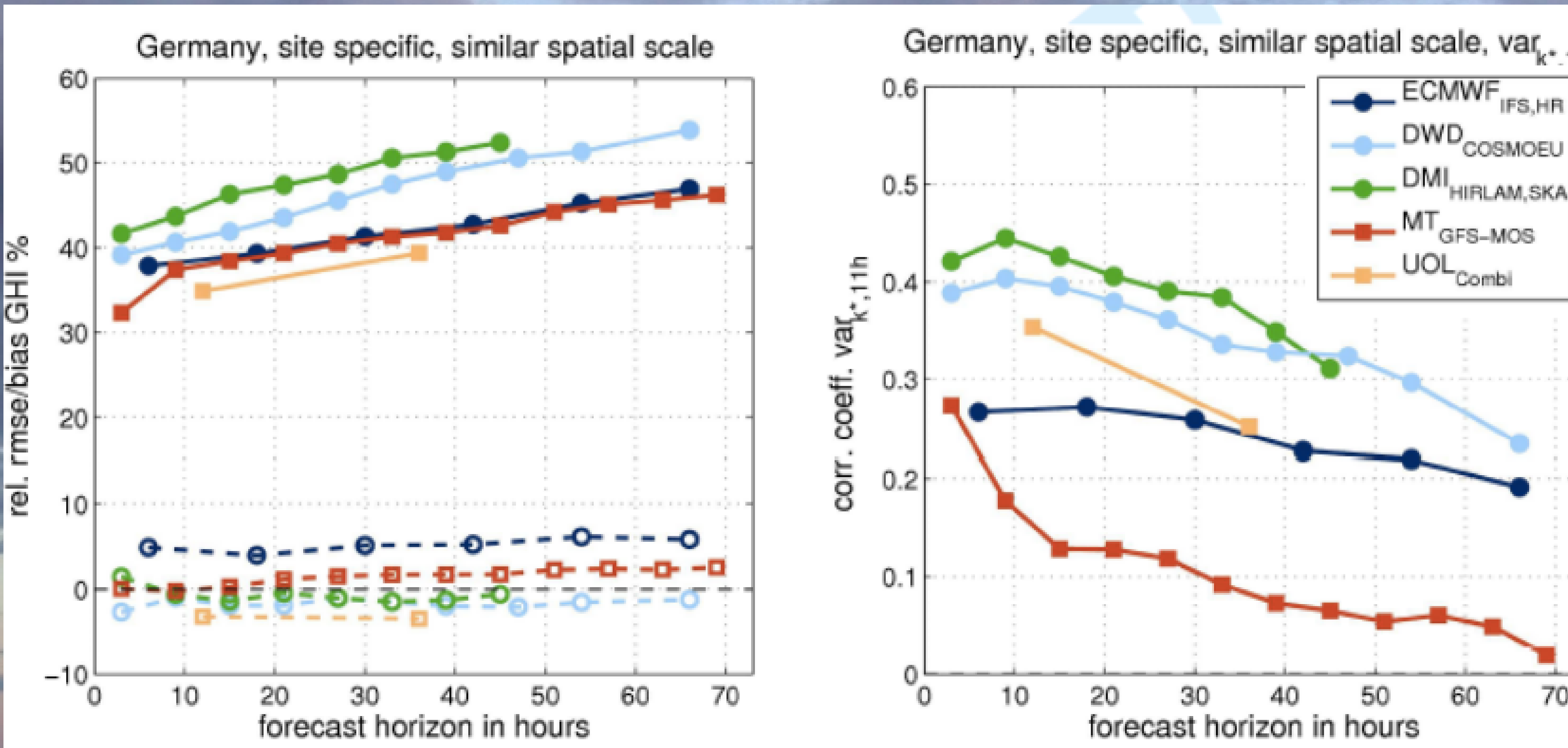


Fig 6: Relative RMSE and BIAS depending on forecast horizon (given as average for each horizon interval) for GHI predictions (left) and correlation coefficients of variability predictions (right). Dataset: Germany 18 sites. 3.4.13-26.2.14, DMO evaluation on similar spatial scale (version2). (left: $GHI_{clear}>0$, right: $\cos\Theta_Z>0.2$). $GHI_{meas,mean}=220W/m^2$.

Lorenz et al., 2016? (under review in J.Photovoltaics)

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System aspects & Next steps

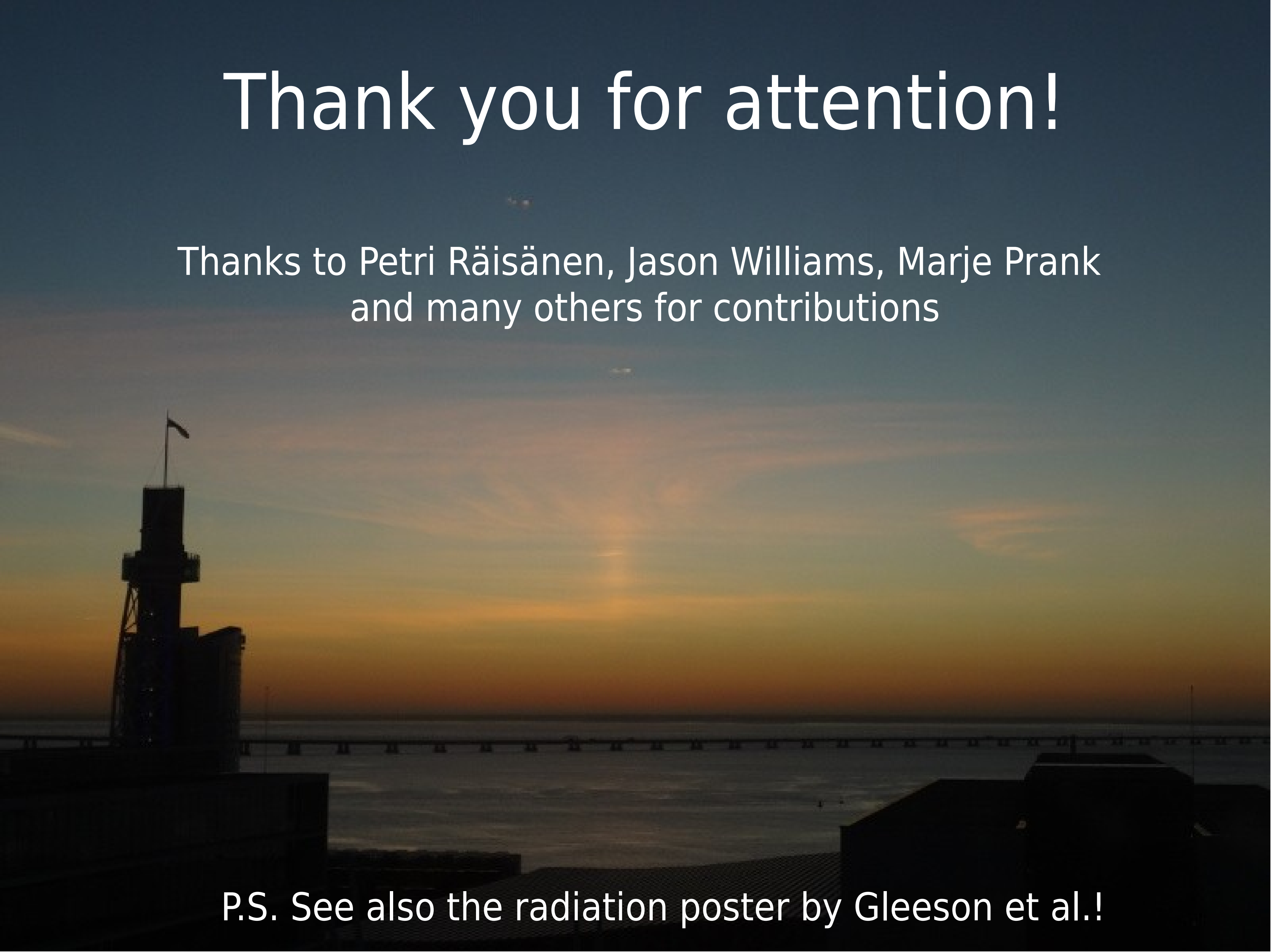
Three schemes, interfaces, convergence of physics

Ororad or how to update the system via SURFEX?

How to use MUSC as a reasearcher’s diagnostic tool?

How to introduce external aerosol data to the system?

How to introduce radiation observations for NWP validation?



Thank you for attention!

Thanks to Petri Räisänen, Jason Williams, Marje Prank
and many others for contributions

P.S. See also the radiation poster by Gleeson et al.!

http://www.cnrm.meteo.fr/aladin/IMG/pdf/nl5.pdf
Shortwave Radiation Experiments in HARMONIE : Tests of the cloud inhomogeneity factor and a new cloud liquid optical property scheme compared to observations, Emily Gleeson, Kristian Pagh Nielsen, Velle Toll, Laura Rontu, Eoin Whelan (p. 92).

Progress and plans in the ARPEGE and AROME models physics, Yann Seity, Jean-Marcel Piriou, Yves Bouteloup, Alexandre Mary, Sébastien Riette, Benoit Vié, Rachel Honnert, Clemens Wastl, Laura Rontu, Christoph Wittmann (p. 79)

Parameterization of orographic effects on surface radiation in AROME-SURFEX, Clemens Wastl, Alexandre Mary, Yann Seity, Laura Rontu, Christoph Wittmann (p. 81)

Comment on: “Impact of changes in the formulation of cloud-related processes on model biases and climate feedbacks” by Carlo Lacagnina, Frank Selten and A. Pier Siebesma (J. Adv. Mod. Earth Syst. 2014; 6(4): 1224-1243), Kristian Pagh Nielsen & Emily Gleeson (p. 165)

Nielsen, K. P., Gleeson, E., and Rontu, L.: Radiation sensitivity tests of the HARMONIE 37h1 NWP model, Geosci. Model Dev., 7, 1433-1449, doi: http://dx.doi.org/10.5194/gmd-7-1433-2014, 2014.

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Kangas, M., Rontu, L., Fortelius, C., Aurela, M., and Poikonen, A.: Weather model verification using Sodankylä mast measurements, Geosci. Instrum. Method. Data Syst. Discuss., 5, 577-598, doi: http://dx.doi.org/10.5194/gid-5-577-2015 , 2015

Rontu Laura, Wastl Clemens, Niemela Sami, 2016: Influence of the details of topography on weather forecast – evaluation of HARMONIE experiments in the Sochi Olympics domain over the Caucasian mountains, Frontiers in Earth Science,4,(13). doi: http://dx.doi.org/10.3389/feart.2016.00013

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https://hirlam.org/trac/raw-attachment/wiki/HarmonieWorkingWeek/Radiation201511/Harmonie_RWD_Tallinn_2015_Petri_Raisanen.pdf