Radiation and aerosol in HARMONIE forecasting system (HFS)

Laura Rontu
Kristian Pagh Nielsen Emily Gleeson
Velle Toll Jan Masek

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

Hirlam

ALARO working days
Wien, 12 – 14 May 2014

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ATMOSPHERIC RADIATION IN HARMONIE

ECMWF RADIATION SCHEME < 2007

Six spectral bands in SW
Rapid Radiative Transfer Model for LW
Cloud optical properties based on cloud cover, liquid water/ice content, temperature
Climatological ozone and aerosol

HIRLAM RADIATION SCHEME > 1990

One spectral band for SW and another for LW
Cloud optical properties based on cloud cover, liquid water/ice content, temperature
Simplified treatment of constant ozone and aerosol

ALARO RADIATION SCHEME (see in Jan's presentations)

Table 2.1 *Major changes in the representation of radiation transfer in the ECMWF forecasting system.*

Cycle	Implementation date	Description
SPM 32	02/05/1989	RT schemes from Univ.Lille
SPM 46	01/02/1993	Optical properties for ice and mixed phase clouds
IFS 14R3	13/02/1996	Revised LW and SW absorption coefficients from HITRAN'92
IFS 16R2	15/05/1997	Voigt profile in long-wave RT scheme
IFS 16R4	27/08/1997	Revised ocean albedo from ERBE
IFS 18R3	16/12/1997	Revised LW and SW absorption coefficients from HITRAN'96
IFS 18R5	01/04/1998	Seasonal land albedo from ERBE
IFS 22R3	27/06/2000	$RRTM_{LW}$ as long-wave RT scheme
		short-wave RT scheme with 4 spectral intervals
IFS 23R4	12/06/2001	Hourly, instead of 3-hourly, calls to RT code during data assimilation cycle
IFS 25R1	09/04/2002	Short-wave RT scheme with 6 spectral intervals
IFS 26R3	07/10/2003	New aerosol climatology adapted from Tegen et al. (1997), new radiation grid
IFS 28R3	28/09/2004	Radiation called hourly in high resolution forecasts
IFS 32R2	05/06/2007	McICA approach to RT with $RRTM_{LW}$ and $RRTM_{SW}$ revised cloud optical properties, MODIS-derived land albedo

How to obtain cloud* optical properties

Predicted cloud 3D properties in the model

ql, qi, cov, temperature

→

Diagnosed/parametrized 3D

cloud droplet and crystal size and geometry

droplet effective and crystal equivalent radia

assumed crystal shape (spherical, hexagonal ...)

→

Cloud 3D optical properties

SW optical depth, single-scattering albedo,

asymmetry factor

LW effective emissivity

*aerosols may be treated in similar way

a. Surface global solar flux in clear air

The global (direct + diffuse) downward solar radiation at the surface is obtained by reducing $S \cdot \sin(h)$ through the parameterized broadband depletions by:

i) ozone ultraviolet and visible absorption, mainly in the stratosphere. Here, using 0.35 cm (the global average) of O_3 at NTP, a simple curve $0.024 \cdot (\sin h)^{-0.5}$ gives a good fit to Lacis and Hansen's (1974, hereafter LH) more elaborate scheme. If more accuracy is needed, the amount x of ozone (in cm) may be given for each month and latitude with 0.024 replaced by $0.024 + (x - 0.35) \cdot 0.03$.

ii) H_2O and the smaller CO_2, O_2 overlapping infrared absorptions in the troposphere. A simple curve $0.11 \cdot (u/\sin h)^{0.25}$ gives a reasonable fit to Yamamoto's (1962) results (curve 6 in his Fig. 1) for the typical values of $u/\sin h \sim 0.1 \ldots 10$ cm where $u = u(0, \infty)$ is the pressure-scaled water vapor amount from (7).

iii) Rayleigh scattering from air molecules. The LH scheme was adopted, where the broadband albedo of pure Rayleigh scattering for direct solar beams is $0.28/(1 + 6.43 \cdot \sin h)$, and for the reflected beams, 0.0685. Comparison of these with Coulson's (1959) calculations shows that the LH parameterization is fairly good. Neglecting the (very small) multiple reflection effect, the backscattering from the reflected beams is simply $0.07 \cdot \alpha$, where α is the albedo of the surface in the visible part of the solar spectrum (~0.05 over sea, 0.2 over land, 0.7 over snow and ice).

With coefficients "aa" and "as" (≥1) for a crude inclusion of aerosol absorption and scattering as enhancing the gaseous and molecular effects listed above, the global surface flux is now given as

$$s^{\downarrow}(sfc) = S \sin h \{1 - 0.024(\sin h)^{-0.5} - \mathrm{aa} \cdot 0.11(u/\sin h)^{0.25} - \mathrm{as} \cdot (0.28/(1 + 6.43 \cdot \sin h) - 0.07\alpha)\}. \quad (16)$$

HLRADIA SW
one spectral band
clear sky (Savijärvi, 1990)
cloudy sky

3D cloud liquid and ice content and cloud fraction →
cloud liquid drop effective and ice crystal equivalent radia →
cloud absorption and transmission functions as fits to detailed spectral radiation transfer models and observations

<u>No</u> separate calculation of cloud radiative properties
Direct calculation of dT/dt_rad from top to bottom

HLRADIA LW
one spectral band

In each layer in atmosphere:

- Cooling to space
- Interaction with (maximum) cloud
- Interaction with the surface

but

no LW exchange between other layers

n**2 → n calculations

at each gridpoint at each time step

3D cloud liquid and ice content, cloud fraction, temperature → cloud liquid drop effective and ice crystal equivalent radia → effective emissivity

HARMONIE RADIATION COMPARISON

(First suggested around 2007)

The aim of the model intercomparison experiment is to compare and validate HIRLAM-ALARO-AROME radiation parametrizations over complex terrain. The experiment should give information to understand the relative importance in mesoscale models of

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

2) accurate handling of cloud-radiation interactions, needed time-resolution of radiation calculations

3) improved treatment of radiation surface-interactions, including sloping surface parametrizations.

1. Introduction

- High resolution NWP models resolve more details about local weather. Accurate treatment of cloud-radiation interactions and surface-radiation interactions thus becomes increasingly important in order to produce reliable weather forecasts.
- This work involves the use of **HARMONIE-MUSC cycle 38.1** and the accurate 1D radiative transfer model **DISORT** for testing the short-wave (SW) radiation parametrizations in HARMONIE.
- The IFS cy27 SW radiation scheme is the default scheme in **HARMONIE/AROME**. We have implemented 2 additional radiation schemes: **HLRADIA** (from HiRLAM, 1 SW band) and **ACRANEB** (v.2. from ALARO, 1 SW band).
- We are working on comparing and improving all 3 of these schemes. The first comparison results are already available in the discussion paper by Nielsen et al., 2014 [1].

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

Geoscientific Model Development
An Interactive Open Access Journal of the European Geosciences Union

| EGU.eu |

Short-wave radiation comparison

Geosci. Model Dev. Discuss., 6, 6775-6834, 2013
www.geosci-model-dev-discuss.net/6/6775/2013/
doi:10.5194/gmdd-6-6775-2013

Article | Discussion | Metrics | Related Articles

Review Status
This discussion paper is under review for the journal Geoscientific Model Development (GMD).

Radiation sensitivity tests of the HARMONIE 37h1 NWP model

K. P. Nielsen[1], E. Gleeson[2], and L. Rontu[3]

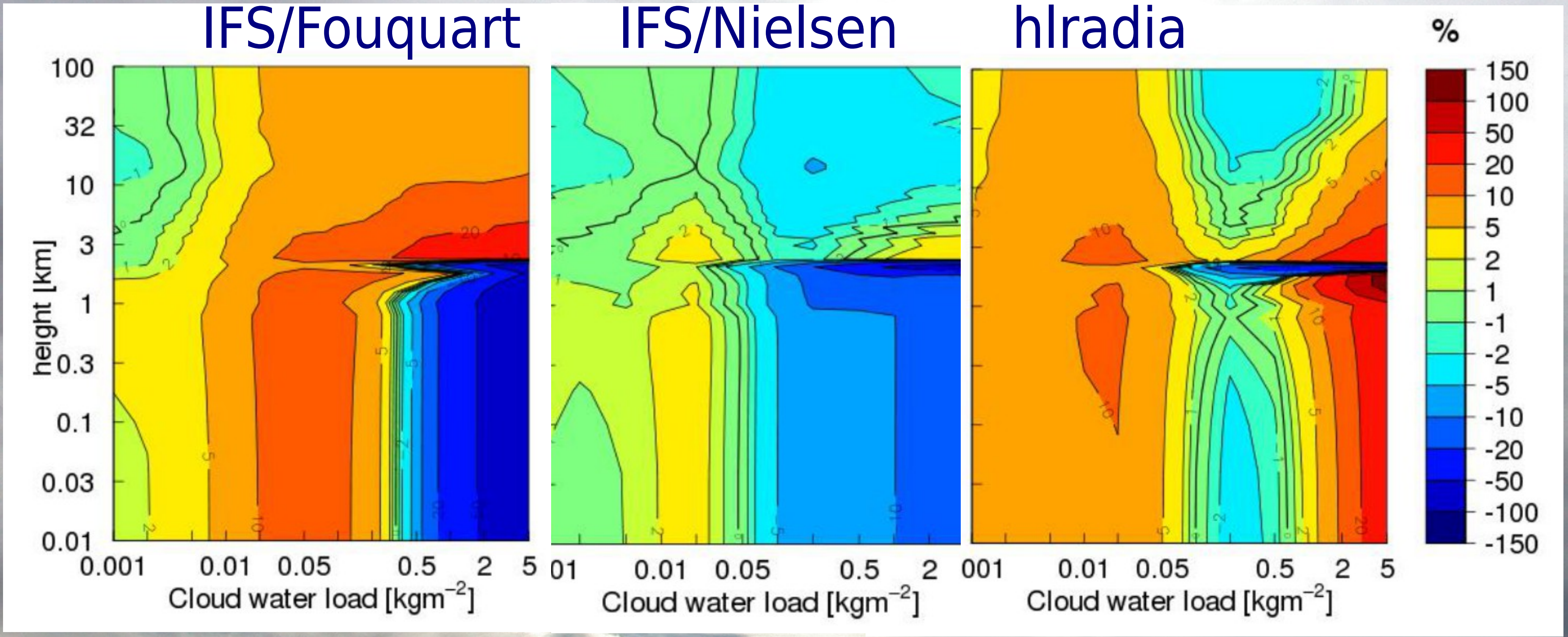
[1]Danish Meteorological Institute, Lyngbyvej 100, 2100, Copenhagen Ø, Denmark
[2]Met Éireann, Glasnevin Hill, Dublin 9, Ireland
[3]Finnish Metorological Institute, Erik Palménin Aukio 1, 00560 Helsinki, Finland

Abstract. It is essential to be able to identify which element of a numerical weather prediction (NWP) model or climate model causes biases in the model output compared with observations. With respect to shortwave (SW) radiation fluxes many elements affect the final results. Here we present a focussed study of the SW radiation schemes in the HARMONIE NWP model. Detailed calculations have been made with the DISORT model run in the libRadtran framework. These are used as a benchmark against which the NWP radiation calculations can be tested. Both models are given the same atmospheric properties as input. Several configurations of the IFS radiation scheme and the hlradia radiation schemes have been tested. The usefulness of the benchmarking tests is demonstrated and concrete strength and weaknesses of the radiation schemes are elucidated. The benchmark data may be used for testing radiation schemes in other NWP or climate models.

Citation: Nielsen, K. P., Gleeson, E., and Rontu, L.: Radiation sensitivity tests of the HARMONIE 37h1 NWP model, Geosci. Model Dev. Discuss., 6, 6775-6834, doi:10.5194/gmdd-6-6775-2013, 2013.

http://www.geosci-model-dev-discuss.net/6/6775/2013/gmdd-6-6775-2013.html

Example of the short-wave radiation comparison

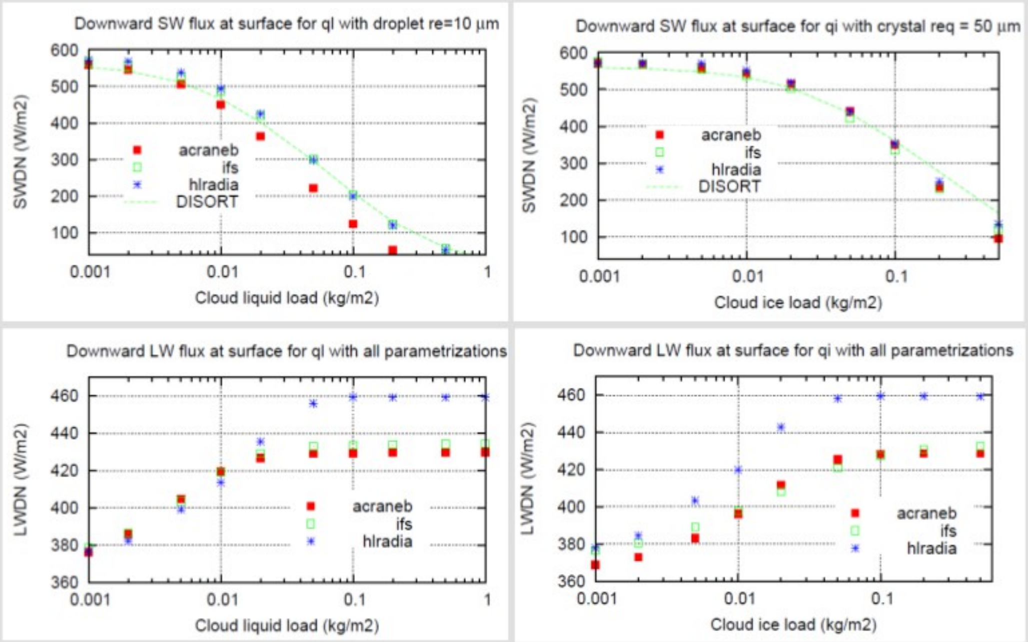


Net SW radiation difference from reference as a function of cloud water load and height

Comparing downward SW and LW radiation fluxes of IFS, hlradia, acraneb

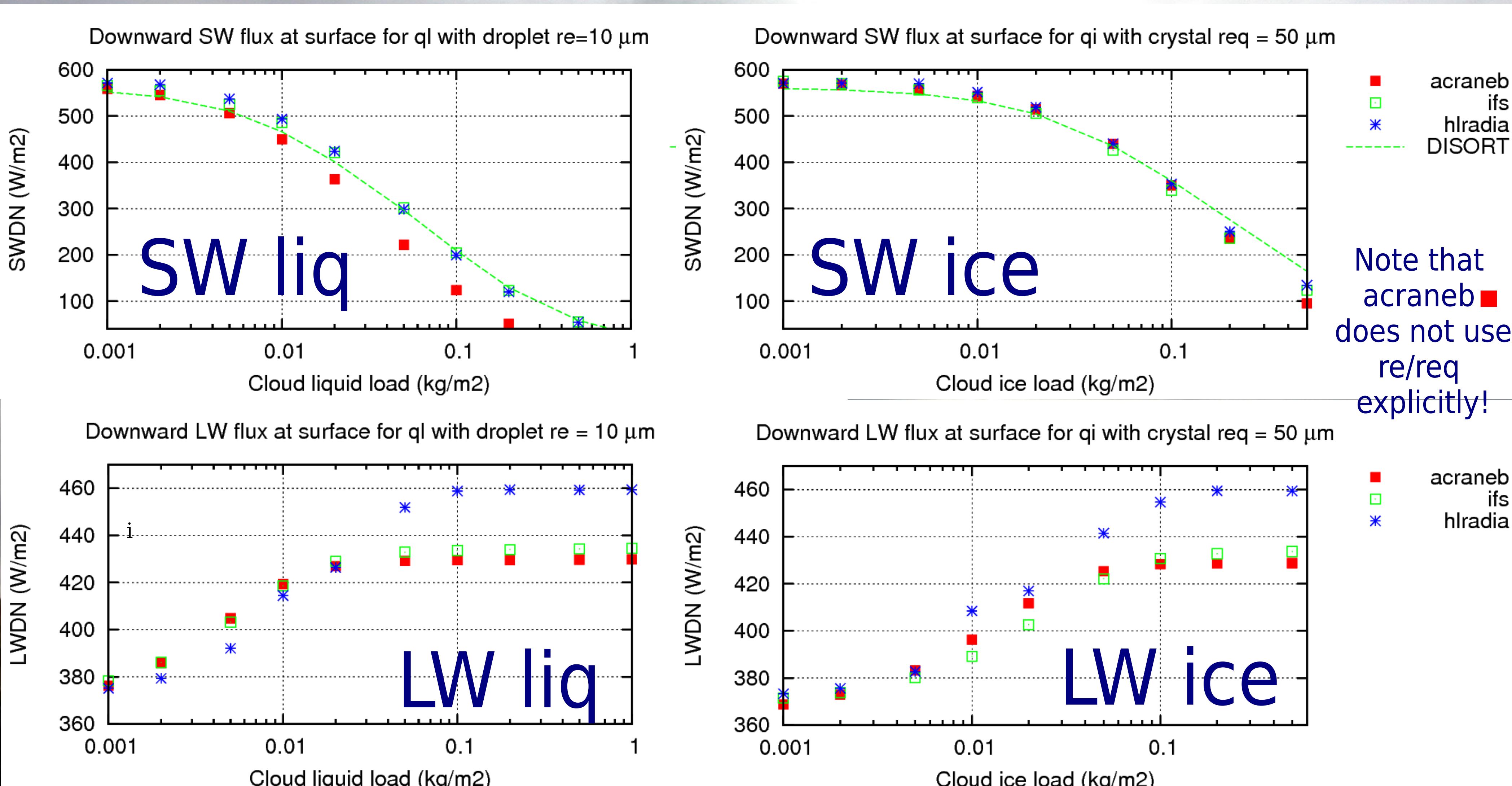
6. Comparison of cloud water/ice SW and LW fluxes in HARMONIE

- Here we compare the global SW surface radiation fluxes in HARMONIE-MUSC as a function of cloud liquid and ice loads using the IFS, HLRADIA and ACRANEB SW radiation schemes.
- The IFS scheme used incorporated the new Nielsen cloud liquid optical property scheme while for the cloud ice optical properties the Fu parametrizations were applied. HLRADIA contained the new clear sky tuned coefficients.
- All three schemes slightly overestimated SW transmission through the least dense clouds and underestimated the flux when the cloud ice load increased. Compared to DISORT and the other schemes, ACRANEB also underestimates the transmission for dense water clouds.
- We also compare the surface downwelling LW radiation for the IFS default RRTM scheme with cloud optical parametrizations by Fu and Smith-Shi and the default LW parametrizations in HLRADIA and ACRANEB.
- The ACRANEB and IFS results are similar while HLRADIA seems to overestimate the LW flux for dense liquid clouds and all ice clouds.

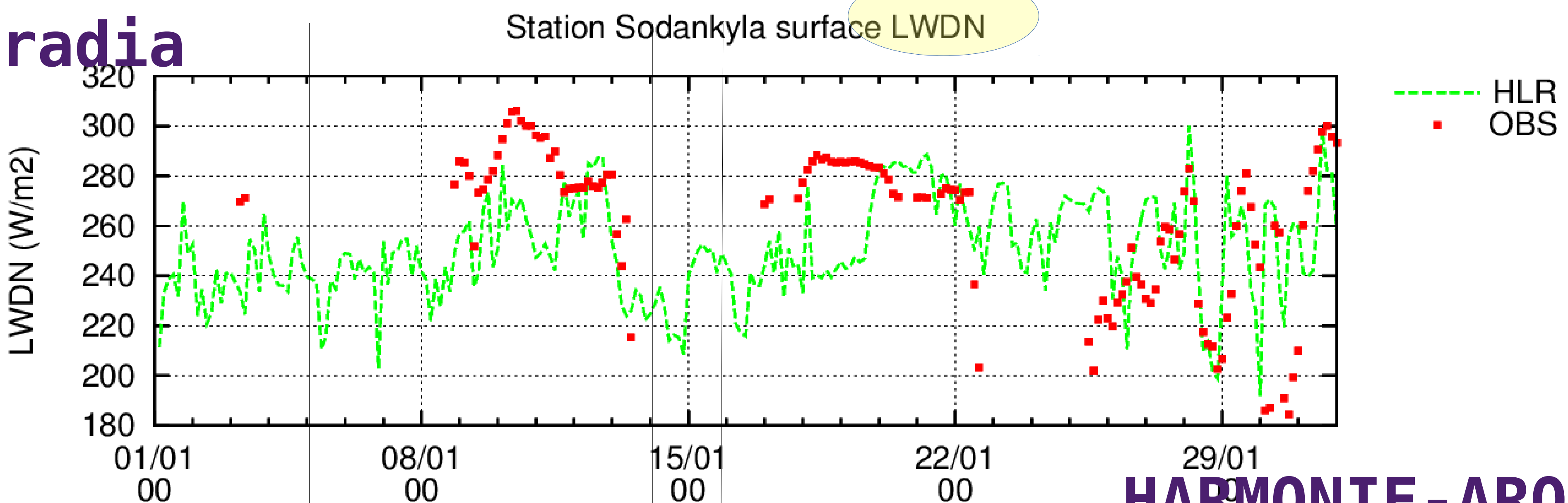


http://www.cnrm.meteo.fr/aladin/IMG/pdf/gleesonetal_radiationposter.pdf

Downward SW and LW fluxes in artificial liquid and ice clouds

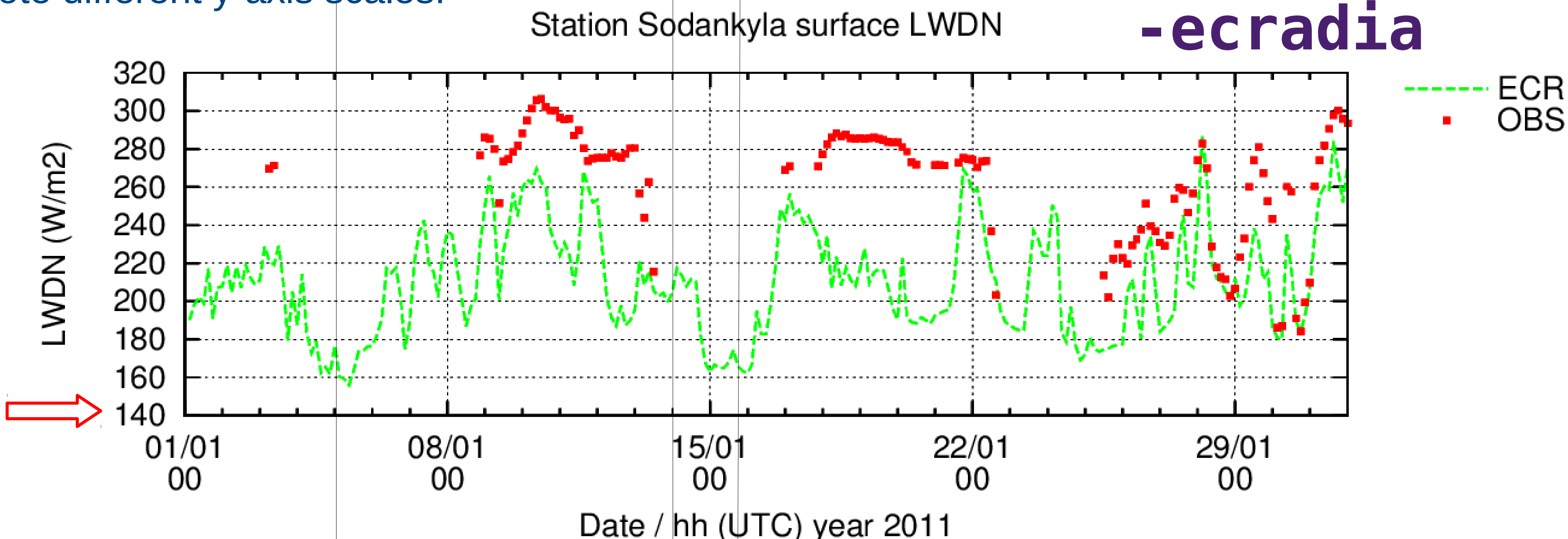


HARMONIE-AROME hlradia



HARMONIE-AROME -ecradia

Note different y-axis scales!



Upper: HARMONIE-AROME FINLAND 37h1.1 with hlradia
Lower: HARMONIE-AROME FINLAND 37h1.2 with EC radiation

Laura Rontu, 2012
http://www.netfam.fmi.fi/Stable12

SURFACE-RADIATION INTERACTIONS

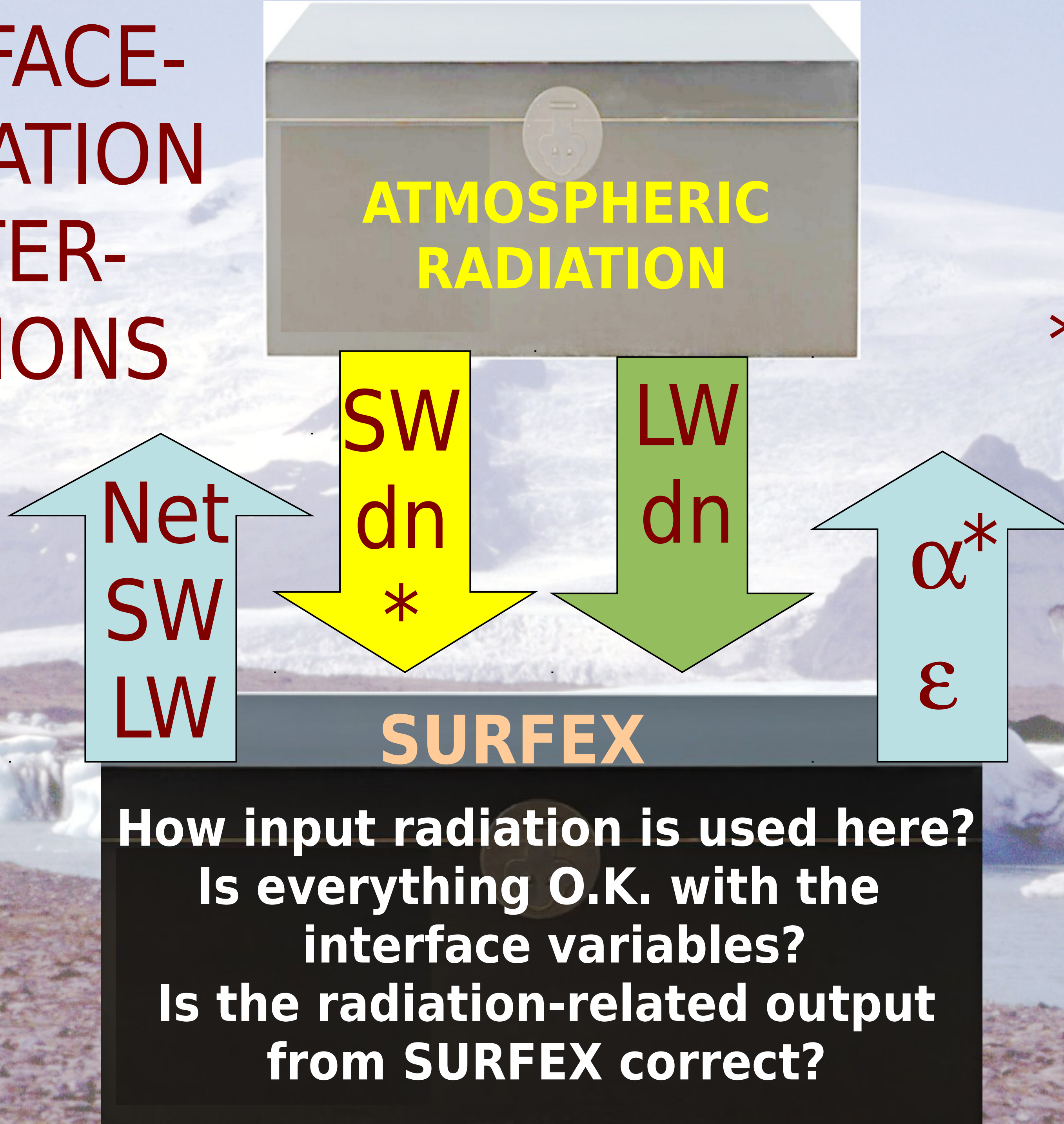
Surface albedo and emissivity variations:
vegetation, water, snow, ice, desert ...

Topography: elevation, slopes, valleys ...

Long-wave radiation effects
in the shallow stable boundary layer
– temperature inversions, stratus and fog

Good physiography and surface analysis required

SURFACE-RADIATION INTER-ACTIONS

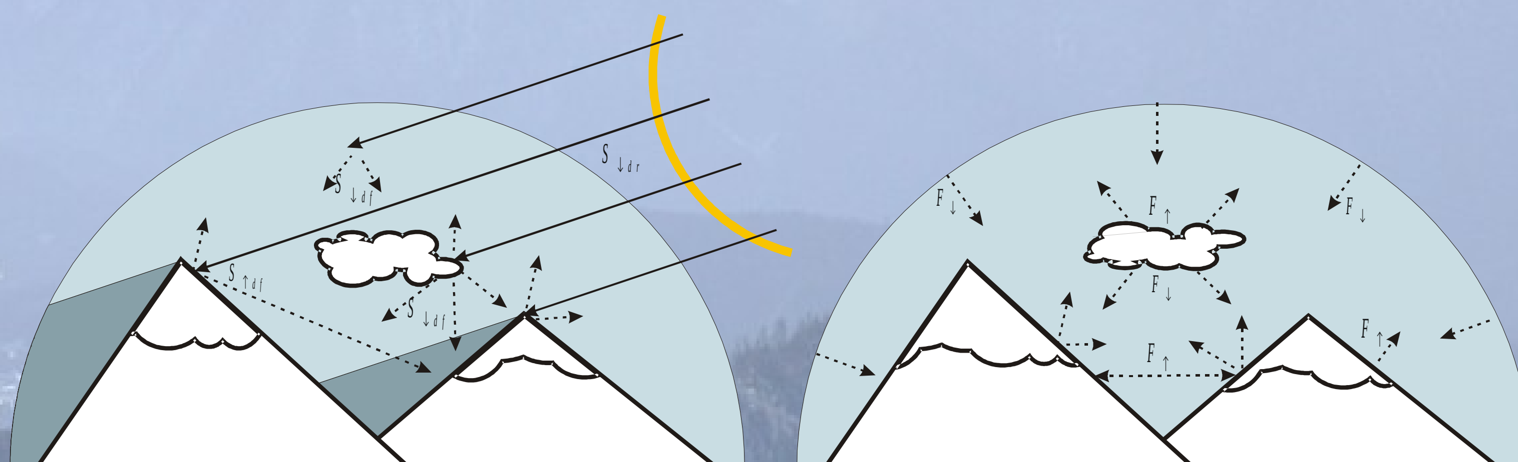


* Swdir Swdif

Orographic effects on radiation

Modification of downwelling LW and SW due to slopes and sky view

Consistent derivation of needed (subgrid-scale) orography variables



Operational in HIRLAM v. 7.4

Anastasia Senkova and
Laura Rontu, 2007

Orographic radiation parametrizations

To take into account slopes and limited sky view for the downwelling radiation fluxes

To derive effective albedo for atmospheric radiation parametrizations

Parametrizations to be done in SURFEX, where the orography properties are known

Derivation of orographic parameters to be done by SURFEX/PGD

https://hirlam.org/trac/wiki/ororad

RENEWAL OF OROGRAPHY PARAMETERS

Take the most detailed global digital elevation data (SRTM – ASTER – Pan-Arctic DEM ...), improve & convert into needed by NWP input

Do (spectral) filtering in order to separate scales for derivation of variables for:

- Model dynamics
- Orographic buoyancy wave parametrisations (MSO)
- Smallest scale orographic effects on momentum fluxes (SSO)
- Orographic radiation parametrisations

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Aerosol plans in HARMONIE

Study the influence of atmospheric aerosol on meso-scale weather forecast in the framework of HARMONIE

- Potential importance of aerosol effects on NWP
- Starting point for learning and understanding in the HARMONIE framework
- To be suggested to HIRLAM-ALADIN work plan 2012

MUSCATEN Summer school 2011
OSENU, Odessa, 3-9 July 2011

Aerosol direct effects – notes from Odessa 2011

Implementation of improved aerosol direct effect handling into HIRLAM radiation (hlradia) ✔
- code by Kristian Nielsen & Bent Sass, DMI

Preliminary sensitivity studies using 1D HIRLAM and aerosol test data. Implementation of improved hlradia to HARMONIE AROME framework ✔

Testing within ENVIRO-HIRLAM, using available integrated aerosol ✔

Testing within HARMONIE AROME using climatological aerosol and comparing with ECMWF radiation scheme results started

Aerosol direct effects – notes from Odessa 2011

Introduction of external aerosol to HARMONIE for a case study over summer 2010 Russian forest fires, comparison with Enviro-HIRLAM results started

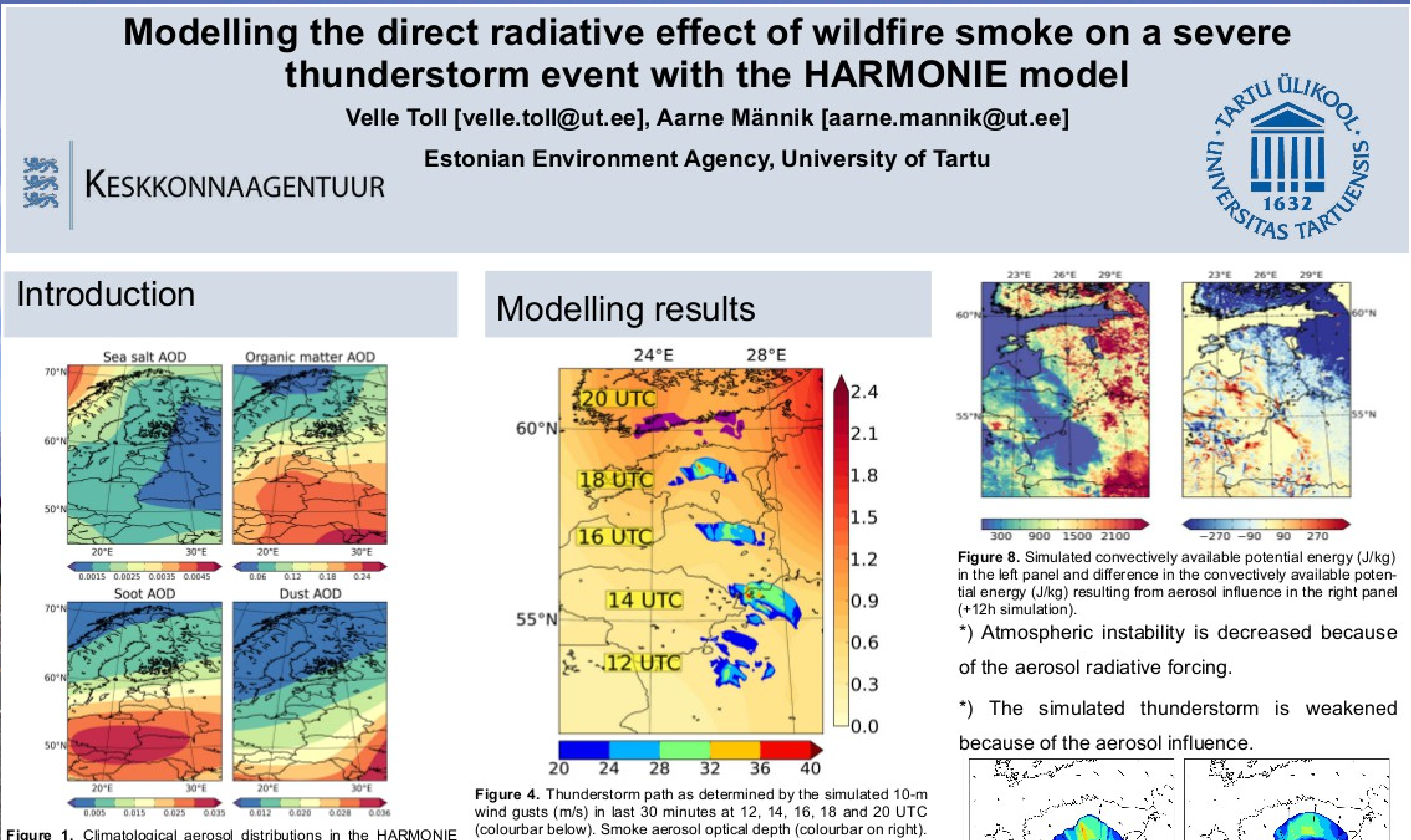
Feasibility study of aerosol and cloud microphysics interactions in HARMONIE – what could be improved in formulations and consistency between cloud and radiation handling to be done

Aerosol effects on atmospheric radiation

scattering and absorption of SW radiation

absorption/emission and scattering of LW radiation

+ indirect effect via cloud microphysics



Modelling the direct radiative effect of wildfire smoke on a severe thunderstorm event with the HARMONIE model

Velle Toll [velle.toll@ut.ee], Aarne Männik [aarne.mannik@ut.ee]

Estonian Environment Agency, University of Tartu

KESKKONNAAGENTUUR

Introduction

Sea salt AOD | Organic matter AOD | Soot AOD | Dust AOD

Figure 1. Climatological aerosol distributions in the HARMONIE

Modelling results

20 UTC | 18 UTC | 16 UTC | 14 UTC | 12 UTC

Figure 4. Thunderstorm path as determined by the simulated 10-m wind gusts (m/s) in last 30 minutes at 12, 14, 16, 18 and 20 UTC (colourbar below). Smoke aerosol optical depth (colourbar on right).

Figure 8. Simulated convectively available potential energy (J/kg) in the left panel and difference in the convectively available potential energy (J/kg) resulting from aerosol influence in the right panel (+12h simulation).

*) Atmospheric instability is decreased because of the aerosol radiative forcing.

*) The simulated thunderstorm is weakened because of the aerosol influence.

http://www.cnrm.meteo.fr/aladin/IMG/pdf/asm_2014_toll_mannik.pdf

Where to take the aerosols from?

Use climatological aerosol?
- present-day HARMONIE

Grow own aerosol in an
integrated NWP-ACT model?
- too heavy for NWP application

Take ”analysed” aerosol
from coupled ACT models?
- MACC, SILAM

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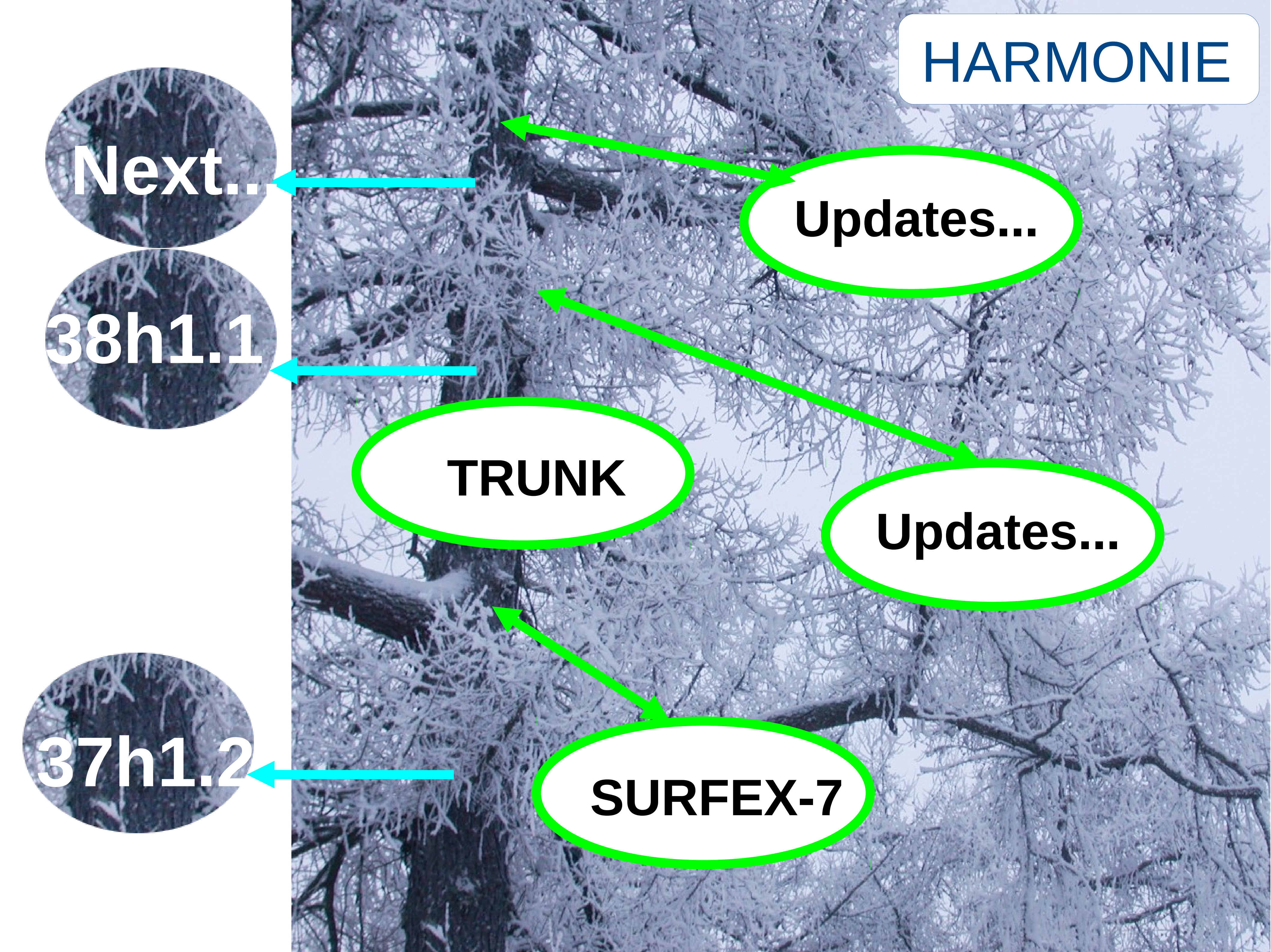
HARMONIE development policies

- **HARMONIE development aims at operational application, but there is no common operational system within HIRLAM. There is no singe lead centre sharing its own computing resources within HIRLAM (but ECMWF resources are widely used)**
- **HARMONIE versions are based on Toulouse cycles of IFS-Arpege (e.g. cy38t1). Meteo France represents also HIRLAM in phasing with ECMWF. HIRLAM participates in phasing in Toulouse, suggesting updates developed and applied within the HARMONIE cycles**
- **Local operational systems are built on default versions of HARMONIE (e.g. harmonie-38h1.1), which include code, scripts, tools. There are branches for development, e.g. harmonie-38h1.radiation.**
- **All HIRLAM contributions and tools are aimed at development of the common NWP system in the common framework. They are open for all participants of HIRLAM-ALADIN collaboration and available in the central repository hirlam.org**


HARMONIE
Next...
Updates...
38h1.1
TRUNK
Updates...
37h1.2
SURFEX-7

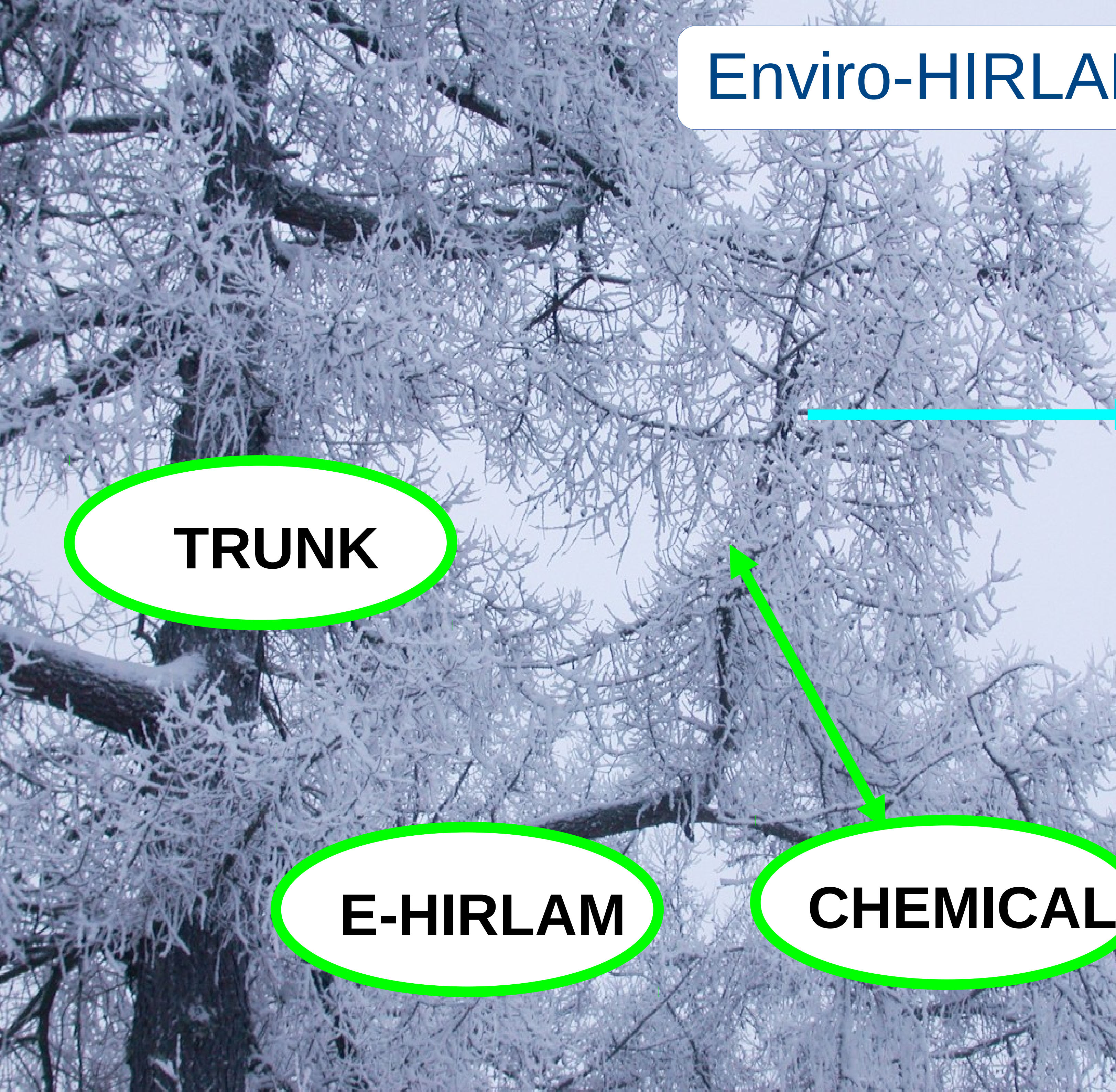
HIRLAM-B aims at close cooperation
with the developers
of the integrated and coupled ACT

HARMONIE Forecasting System HFS
is available in hirlam.org code repository
for development of ACT integrated to NWP

→ Enviro-HARMONIE as an
independent branch of HFS?

but integrated chemistry is not a priority for
HARMONIE NWP!

Enviro-HIRLAM



Harmonie-38h1.radiation branch

Contains development versions in AROME framework

ECMWF radiation (IFS)

Acraneb-2 (ALARO)

Hlradia with aerosol (HIRLAM)

Aims at consistency and implementation into the flexible physics interface (> cy40)

Used for 3D and 1D experimenting

Harmonie_MUSC_cy38h1

Single-column playground
for physics developers

Fully compatible with harmonie-38h1.x
(including also the same SURFEX)

Test experiments bring code
e.g. from the radiation branch

Tools for handling input and output

Using hirlam.org wiki pages for communication

https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation201403 Hakukone: Google

https://hirlam.org/trac/wiki/HarmonieWorkingWeek/Radiation201403

https://hirlam.org/trac/wiki/phys-dyn

https://hirlam.org/trac/wiki/ororad

High Resolution Limited Area Model HIRLAM

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HARMONIE Radiation Working Week ¶

CHMI, 10th of March - 12th of March 2014

Last modified 2014-04-11 9:11

Practical

- Participants:
  - Met Éireann: Emily Gleeson
  - Danish Meteorological Institute: Kristian Pagh Nielsen
  - Czech Hydrometeorological Institute: Jan Masek
  - Finnish Meteorological Institute: Laura Rontu

Objectives

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

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Online Integrated Modelling of Meteorological and Chemical Transport Processes

Young Scientist Summer School

University of Aveiro, Portugal
6-11 July 2014

Welcome!

The COST Action ES1004 "European framework for online integrated air quality and meteorology modelling (EuMetChem)" is organizing the Young Scientists Summer School on "Online Integrated Modelling of Meteorological and Chemical Transport Processes", which will take place from July 6th to 11th at the University of Aveiro, Portugal.

previous Summer School editions:

2011 | Ukraine

2008 | Russia

The Summer School aims to join young scientists and researchers from the numerical weather prediction, air quality and climate communities, and to apply integrated modelling of both meteorological and chemical processes to understand the links between atmospheric composition, weather and climate. The main focus is on regional/urban scale models applied for chemical weather forecasting and feedback mechanisms between meteorological and atmospheric pollution processes.

The programme covers the following topics:

- Fundamentals of atmospheric processes & modelling
- Surface and atmospheric boundary layer processes
- Atmospheric chemical transport modelling
- Aerosol physico-chemistry and modelling
- Evaluation and application

And will include training exercises with different on-line models.

Join us from 6th to 11th July! Please, browse our site for further information.

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dao departamento de ambiente e ordenamento | universidade de aveiro um campus que pensa 1973.2013 | cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY | World Meteorological Organisation


THANK YOU!