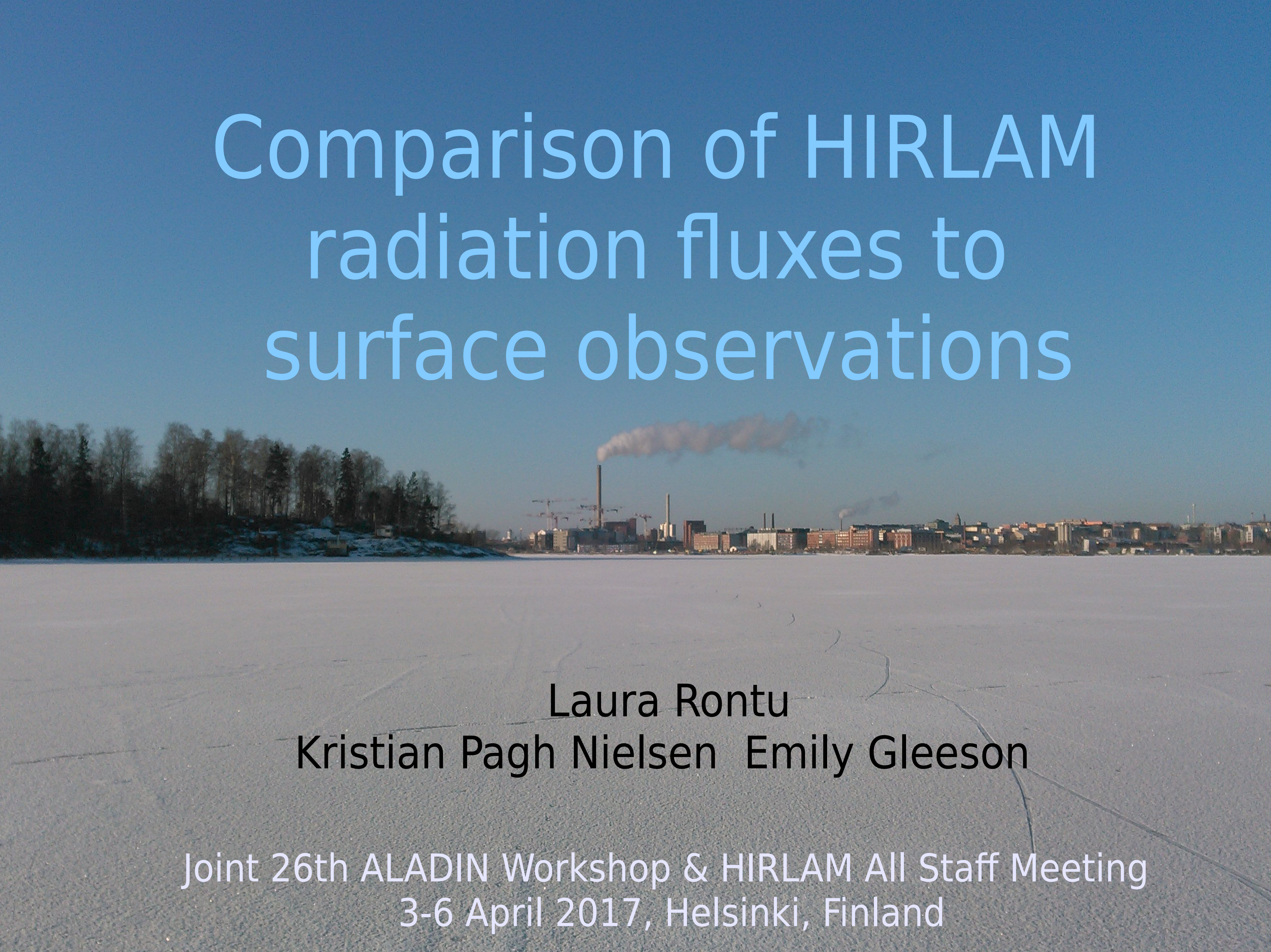
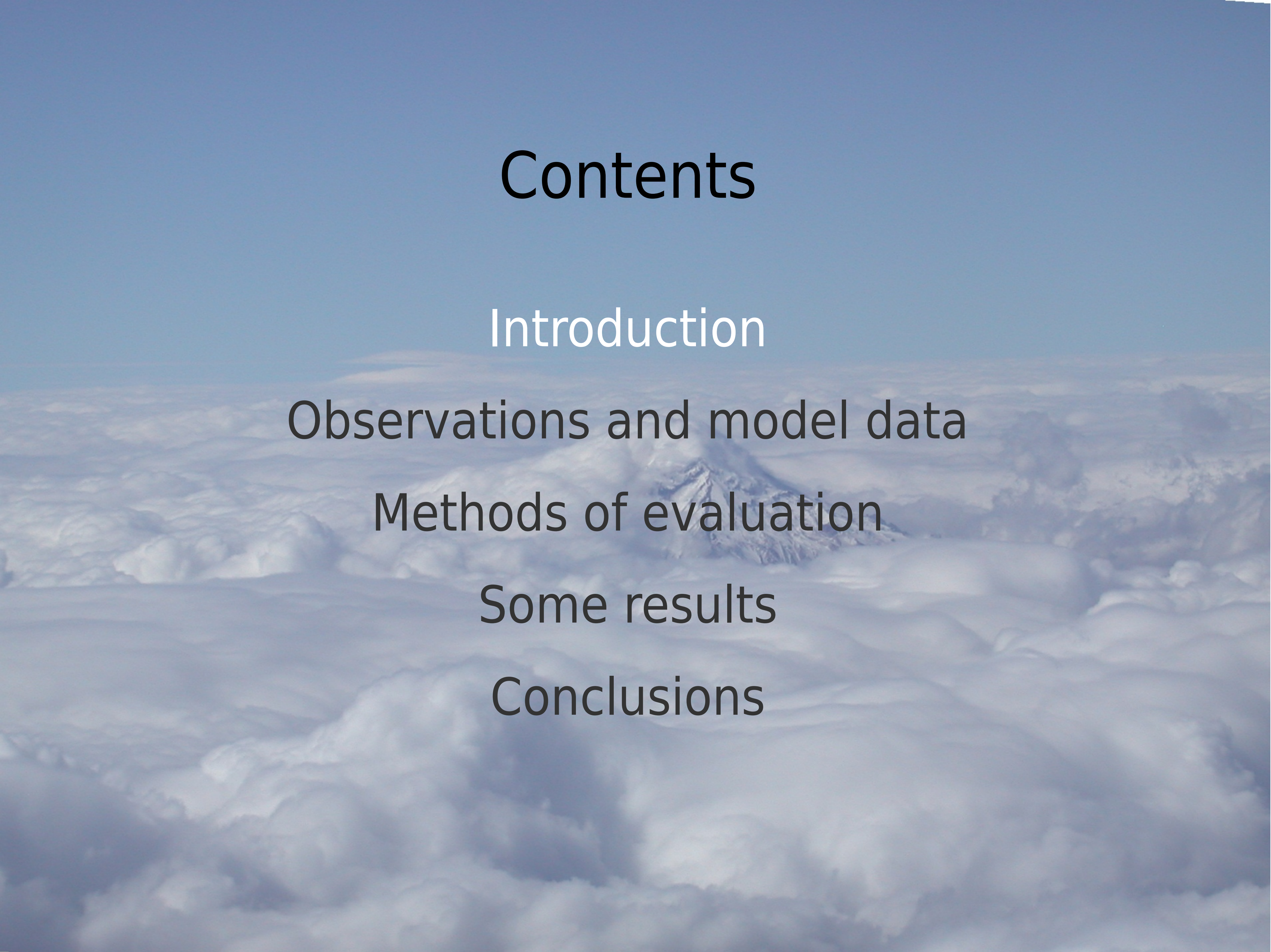


Comparison of HIRLAM radiation fluxes to surface observations

Laura Rontu
Kristian Pagh Nielsen Emily Gleeson

Joint 26th ALADIN Workshop & HIRLAM All Staff Meeting
3-6 April 2017, Helsinki, Finland



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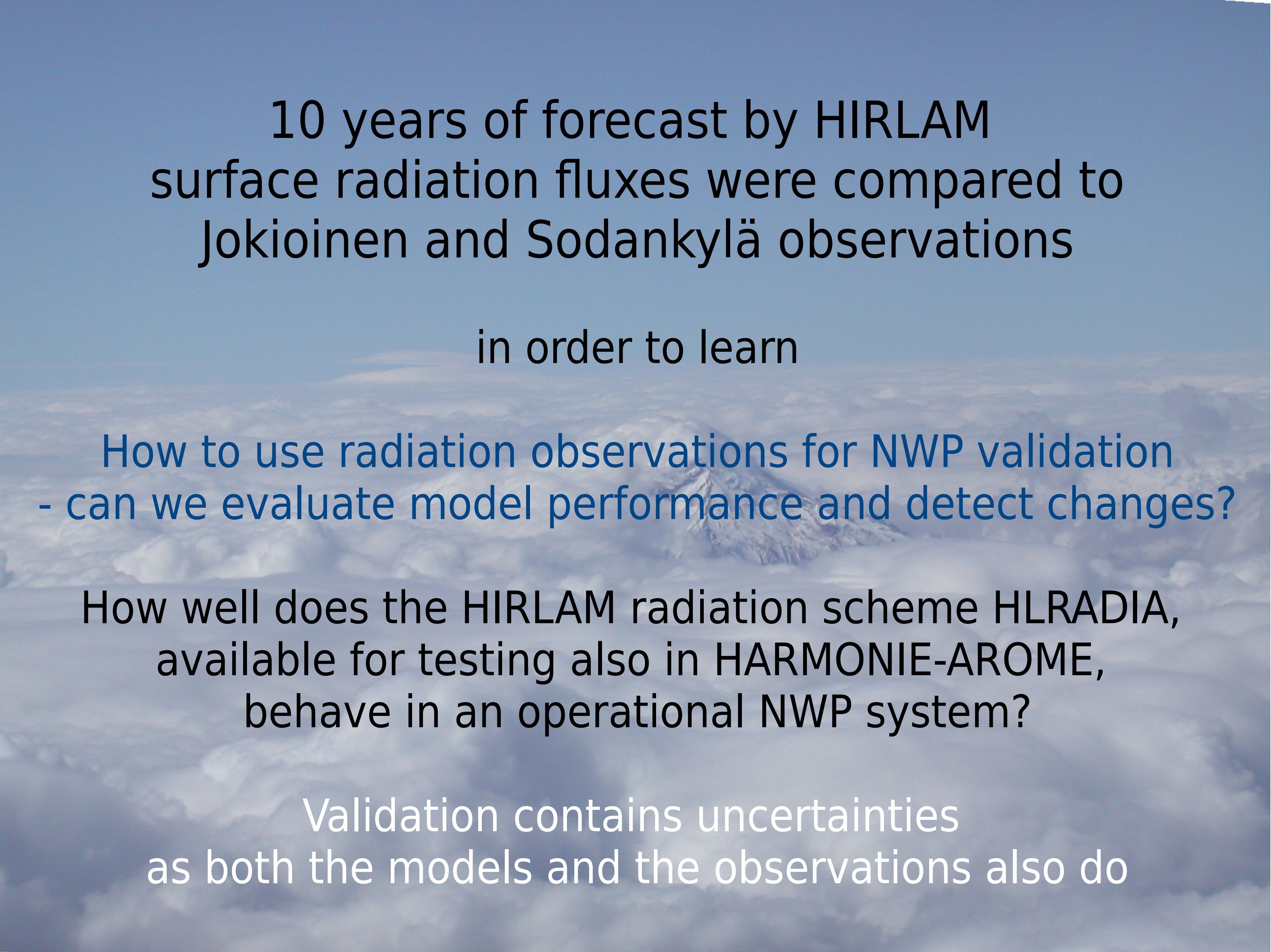


10 years of forecast by HIRLAM
surface radiation fluxes were compared to
Jokioinen and Sodankylä observations

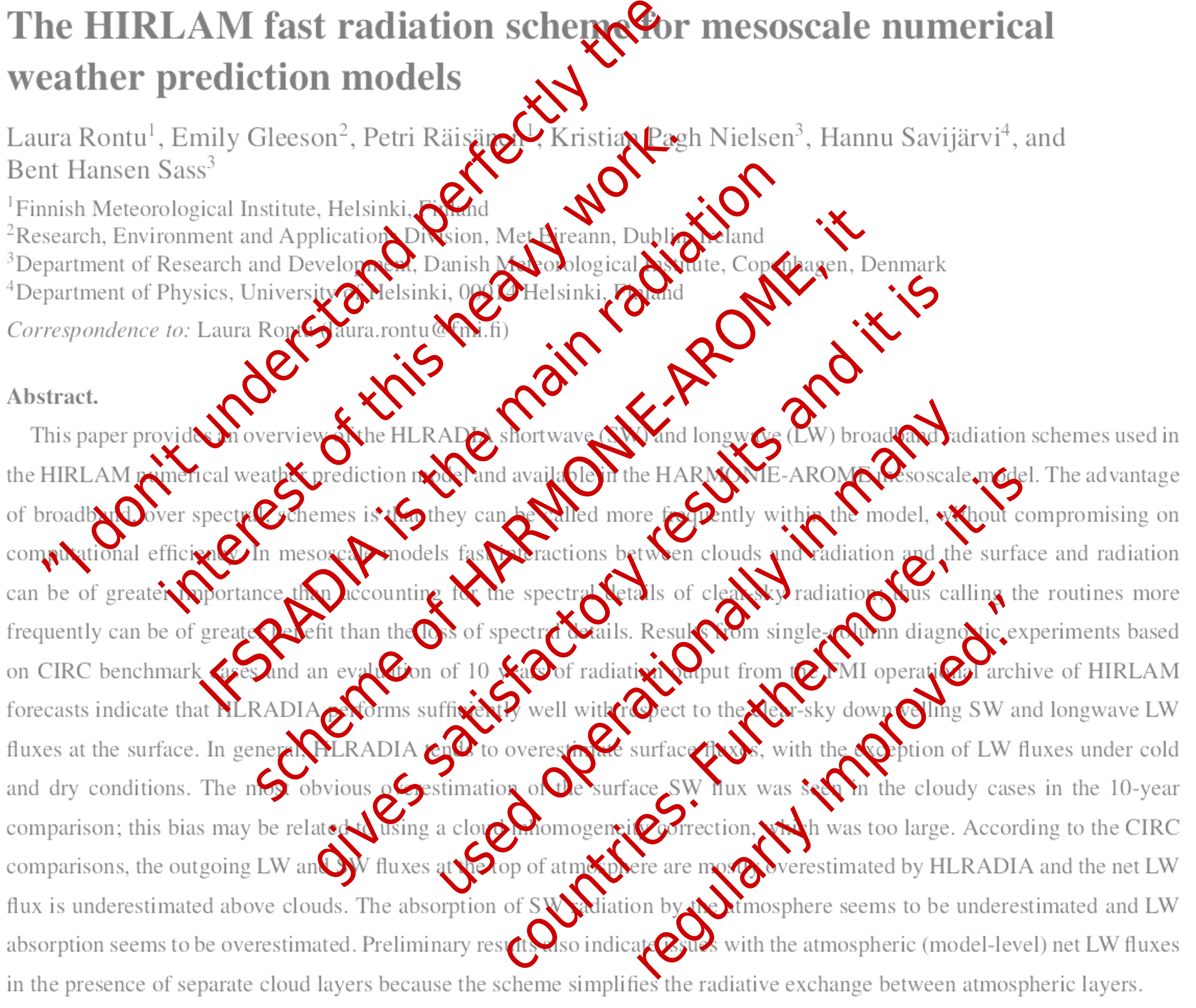
in order to learn

How to use radiation observations for NWP validation
- can we evaluate model performance and detect changes?

How well does the HIRLAM radiation scheme HLRADIA,
available for testing also in HARMONIE-AROME,
behave in an operational NWP system?

Validation contains uncertainties
as both the models and the observations also do

Why still evaluate the simple old HLRADIA?



The HIRLAM fast radiation scheme for mesoscale numerical weather prediction models

Laura Rontu[1], Emily Gleeson[2], Petri Räisänen[1], Kristian Pagh Nielsen[3], Hannu Savijärvi[4], and Bent Hansen Sass[3]

[1]Finnish Meteorological Institute, Helsinki, Finland
[2]Research, Environment and Applications Division, Met Éireann, Dublin, Ireland
[3]Department of Research and Development, Danish Meteorological Institute, Copenhagen, Denmark
[4]Department of Physics, University of Helsinki, 00014 Helsinki, Finland

Correspondence to: Laura Rontu (laura.rontu@fmi.fi)

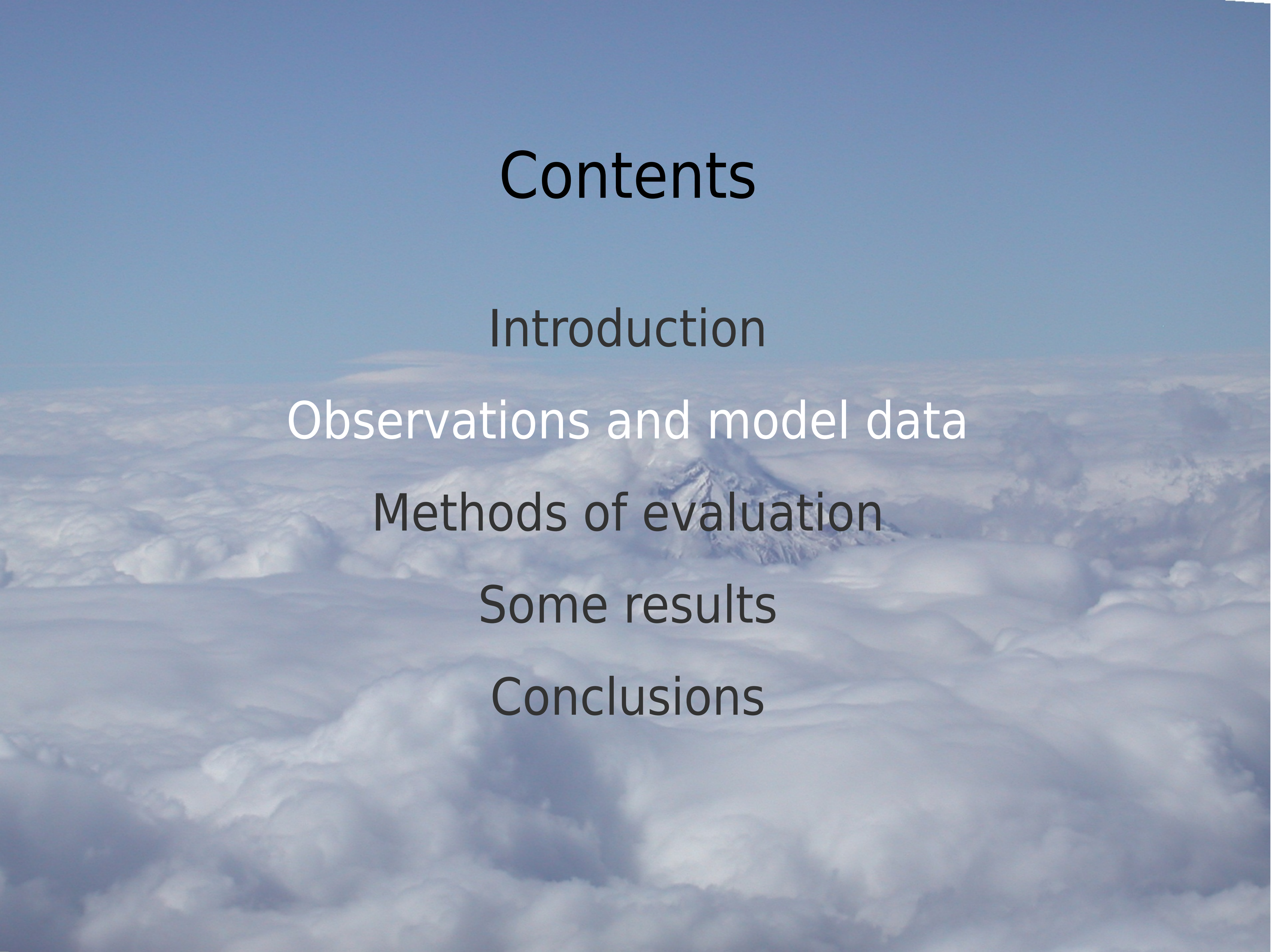
Abstract.

This paper provides an overview of the HLRADIA shortwave (SW) and longwave (LW) broadband radiation schemes used in the HIRLAM numerical weather prediction model and available in the HARMONIE-AROME mesoscale model. The advantage of broadband, over spectral, schemes is that they can be called more frequently within the model, without compromising on computational efficiency. In mesoscale models fast interactions between clouds and radiation and the surface and radiation can be of greater importance than accounting for the spectral details of clear-sky radiation; thus calling the routines more frequently can be of greater benefit than the loss of spectral details. Results from single-column diagnostic experiments based on CIRC benchmark cases and an evaluation of 10 years of radiation output from the FMI operational archive of HIRLAM forecasts indicate that HLRADIA performs sufficiently well with respect to the clear-sky downwelling SW and longwave LW fluxes at the surface. In general, HLRADIA tends to overestimate surface fluxes, with the exception of LW fluxes under cold and dry conditions. The most obvious overestimation of the surface SW flux was seen in the cloudy cases in the 10-year comparison; this bias may be related to using a cloud inhomogeneity correction, which was too large. According to the CIRC comparisons, the outgoing LW and SW fluxes at the top of atmosphere are mostly overestimated by HLRADIA and the net LW flux is underestimated above clouds. The absorption of SW radiation by the atmosphere seems to be underestimated and LW absorption seems to be overestimated. Preliminary results also indicate issues with the atmospheric (model-level) net LW fluxes in the presence of separate cloud layers because the scheme simplifies the radiative exchange between atmospheric layers.

"I don't understand perfectly the
interest of this heavy work.
IFSRADIA is the main radiation
scheme of HARMONIE-AROME, it
gives satisfactory results and it is
used operationally in many
countries. Furthermore, it is
regularly improved."

”Our model applications in the future will increasingly be devoted to very high resolution and rapid updates due to the needs of forecasting details in short time scales. In view of predictability challenges at high resolution it is desirable to run ensembles even at short forecast ranges. These must be executed as fast as possible and hence a fast but physically based radiation scheme such as HLRADIA is desirable. On the other hand, application of various radiation schemes may provide the ensembles with realistic physics perturbations.”

See the radiation poster by Gleeson et al. for illustration how the calling frequency of radiation schemes influenced forecast radiation fluxes and precipitation in a convective case.



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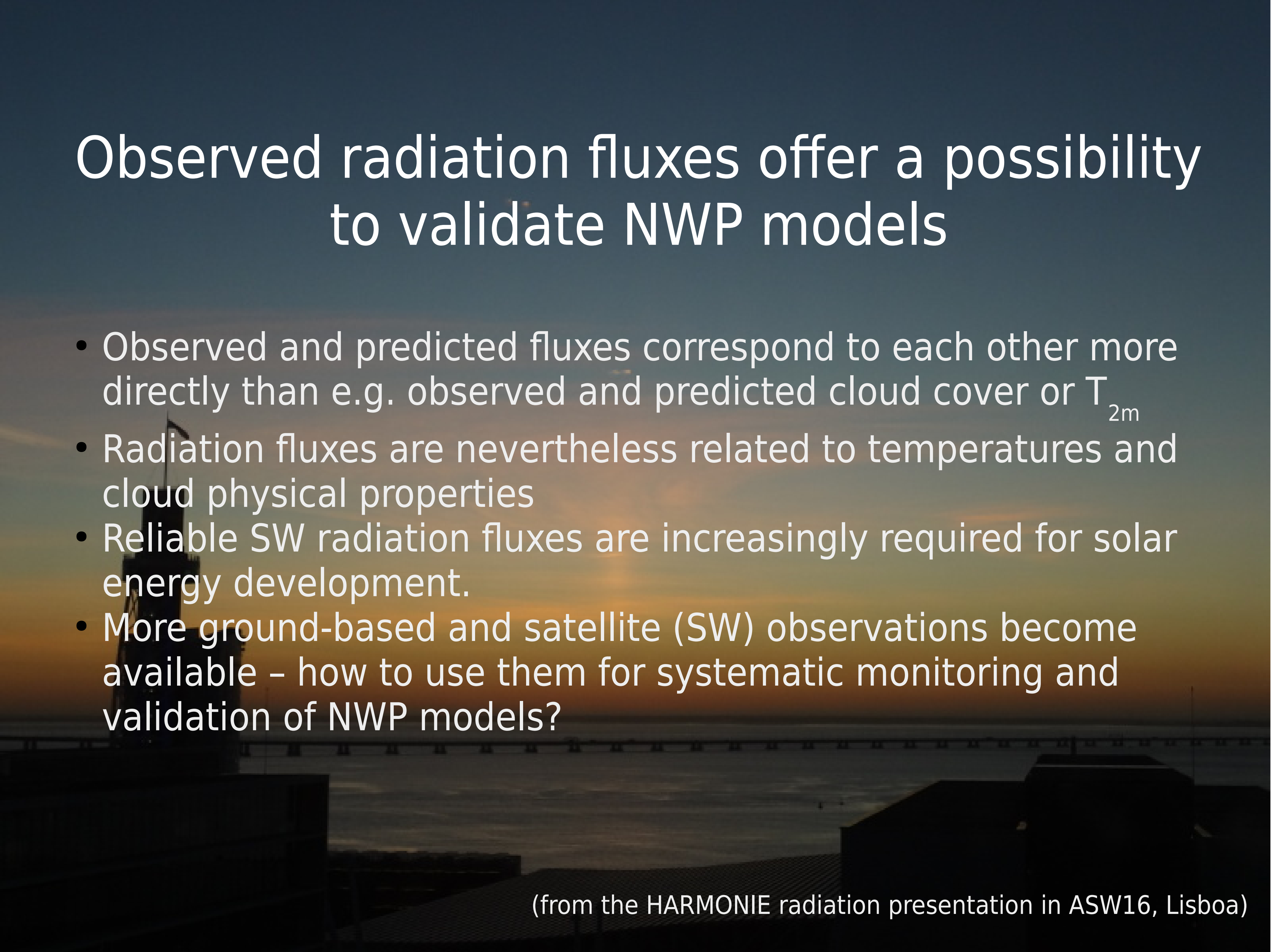


Observed radiation fluxes offer a possibility to validate NWP models

- Observed and predicted fluxes correspond to each other more directly than e.g. observed and predicted cloud cover or T_{2m}
- Radiation fluxes are nevertheless related to temperatures 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?

(from the HARMONIE radiation presentation in ASW16, Lisboa)

SURFACE RADIATION FLUXES MEASURED IN SODANKYLÄ OBSERVATORY

SWDN SWUP LWDN LWUP

How to use for monitoring and statistical validation?

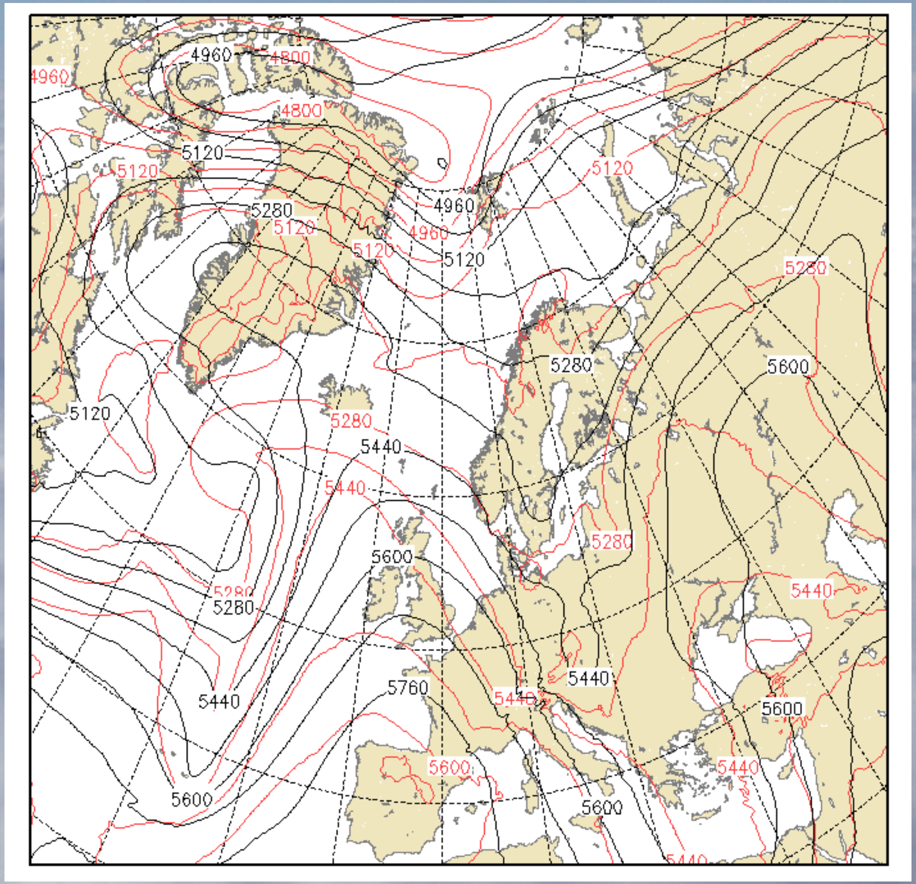
http://fminwp.fmi.fi/mastverif/

1st of April 2006 – 31st of March 2016

Hourly surface radiation observations from Sodankylä and Jokioinen

→ 3 hour averages for comparison

HIRLAM RCR forecast surface radiation fluxes fc+3h, fc+6h



+ SYNOP T_{2m}, N and HIRLAM T_{2m}

During the 10 years, also the FMI surface observations have changed

All SYNOP observations are now taken care by automatic weather stations (AWS)

Visual cloud cover observations were replaced by ceilometer (instead of octas in daylight conditions, we got quads at all times of day)

Measurement of downwelling longwave radiation started also in Jokioinen

Instruments were installed and removed, sometimes data were missing - as always in the operational work

During the 10 years, the FMI operational HIRLAM NWP system has changed, but not too much

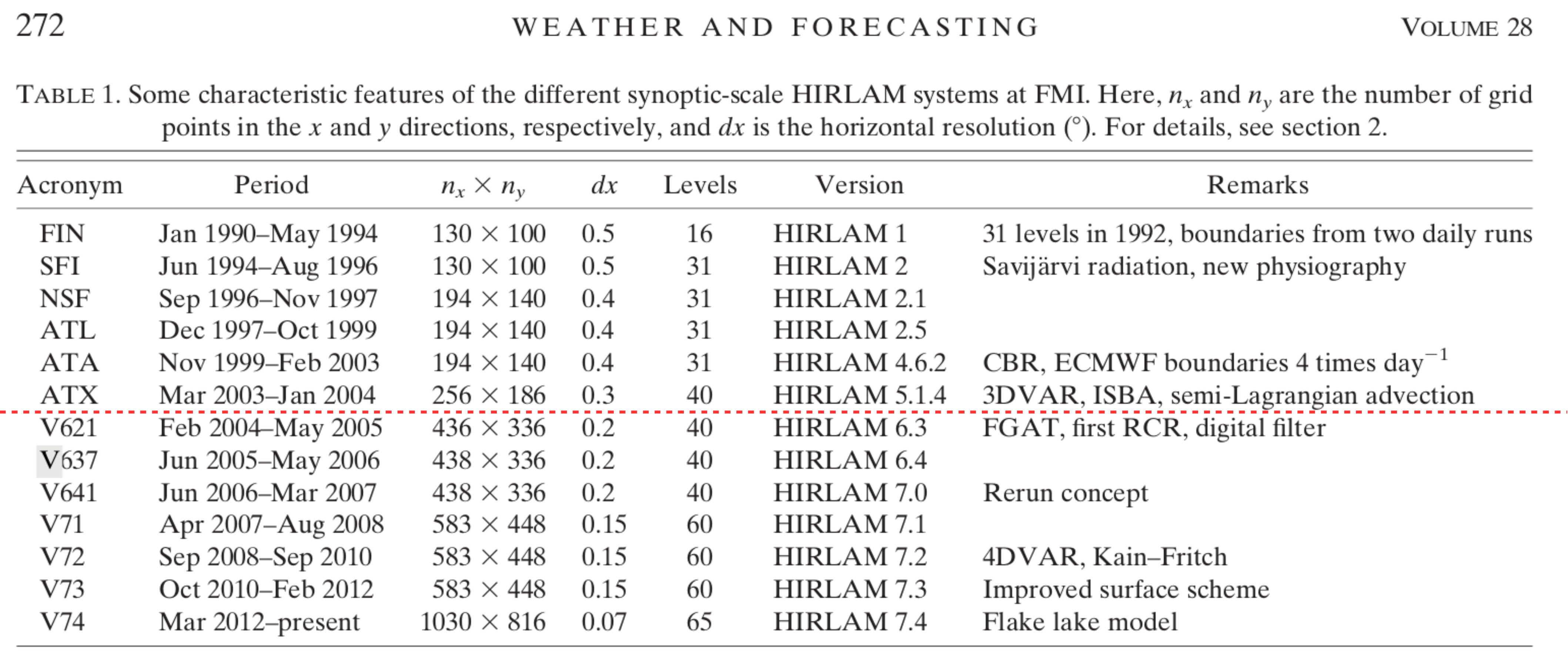


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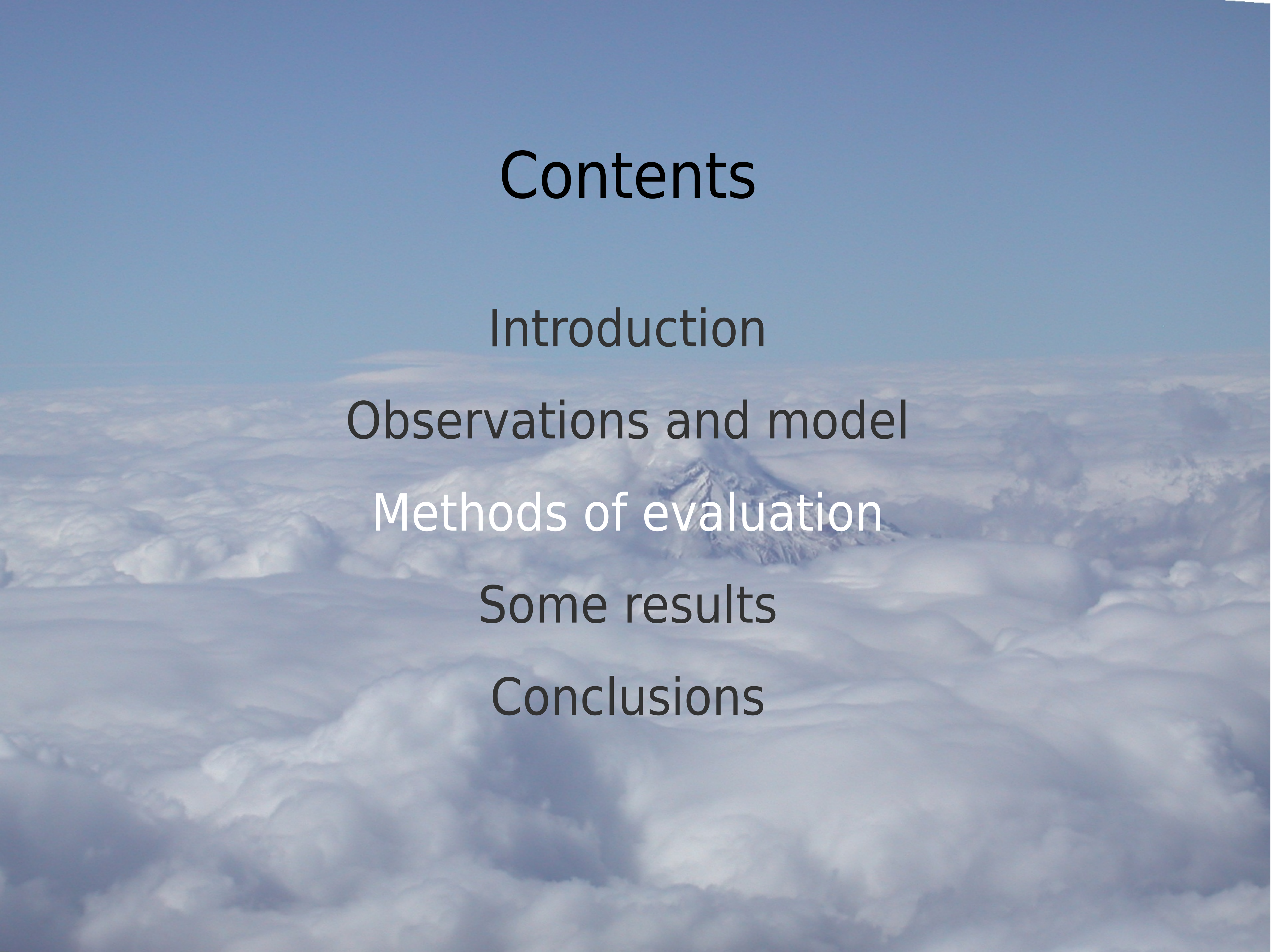
TABLE 1. Some characteristic features of the different synoptic-scale HIRLAM systems at FMI. Here, n_x and n_y are the number of grid points in the x and y directions, respectively, and dx is the horizontal resolution (°). For details, see section 2.

Acronym	Period	$n_x \times n_y$	dx	Levels	Version	Remarks
FIN	Jan 1990–May 1994	130 × 100	0.5	16	HIRLAM 1	31 levels in 1992, boundaries from two daily runs
SFI	Jun 1994–Aug 1996	130 × 100	0.5	31	HIRLAM 2	Savijärvi radiation, new physiography
NSF	Sep 1996–Nov 1997	194 × 140	0.4	31	HIRLAM 2.1	
ATL	Dec 1997–Oct 1999	194 × 140	0.4	31	HIRLAM 2.5	
ATA	Nov 1999–Feb 2003	194 × 140	0.4	31	HIRLAM 4.6.2	CBR, ECMWF boundaries 4 times day^{-1}
ATX	Mar 2003–Jan 2004	256 × 186	0.3	40	HIRLAM 5.1.4	3DVAR, ISBA, semi-Lagrangian advection
V621	Feb 2004–May 2005	436 × 336	0.2	40	HIRLAM 6.3	FGAT, first RCR, digital filter
V637	Jun 2005–May 2006	438 × 336	0.2	40	HIRLAM 6.4	
V641	Jun 2006–Mar 2007	438 × 336	0.2	40	HIRLAM 7.0	Rerun concept
V71	Apr 2007–Aug 2008	583 × 448	0.15	60	HIRLAM 7.1	
V72	Sep 2008–Sep 2010	583 × 448	0.15	60	HIRLAM 7.2	4DVAR, Kain–Fritch
V73	Oct 2010–Feb 2012	583 × 448	0.15	60	HIRLAM 7.3	Improved surface scheme
V74	Mar 2012–present	1030 × 816	0.07	65	HIRLAM 7.4	Flake lake model

Eerola, K., 2013. Twenty-one years of verification from the HIRLAM NWP system. Wea. Forecasting 28, 270–285. doi:10.1175/WAF-D-12-00068.1.



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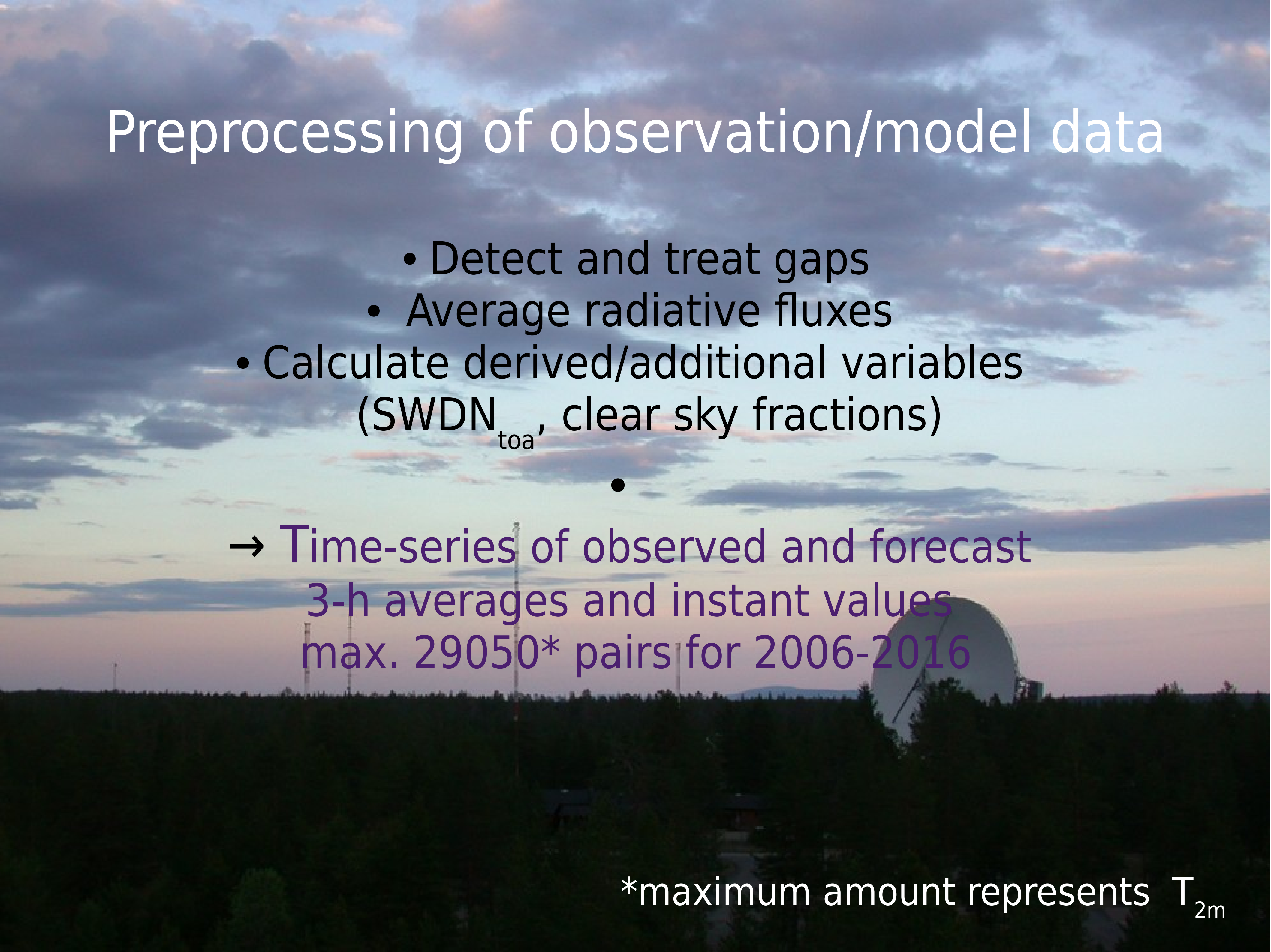
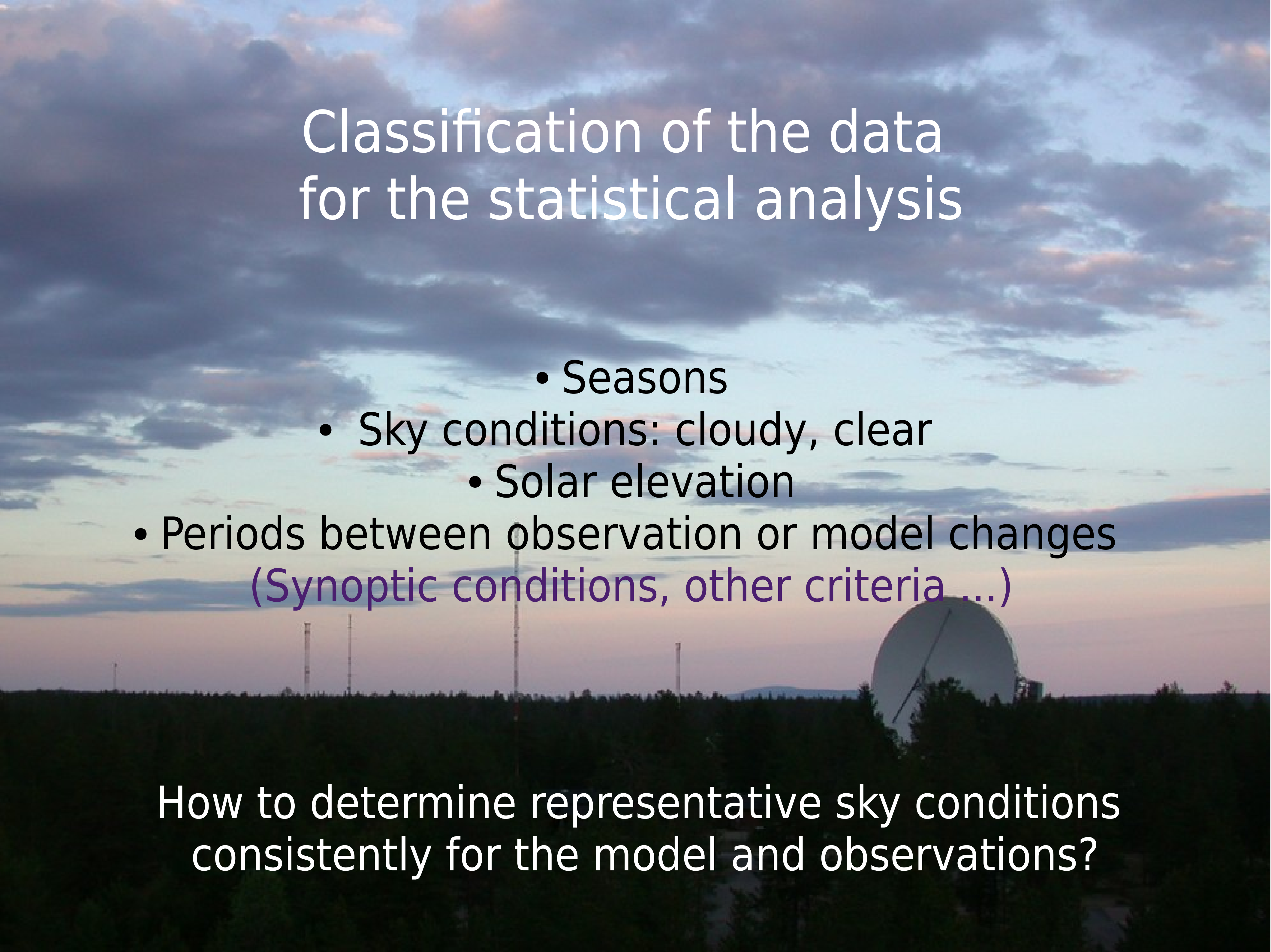
Preprocessing of observation/model data



- Detect and treat gaps
- Average radiative fluxes
- Calculate derived/additional variables (SWDN$_{toa}$, clear sky fractions)
-

→ Time-series of observed and forecast 3-h averages and instant values max. 29050* pairs for 2006-2016

*maximum amount represents T$_{2m}$

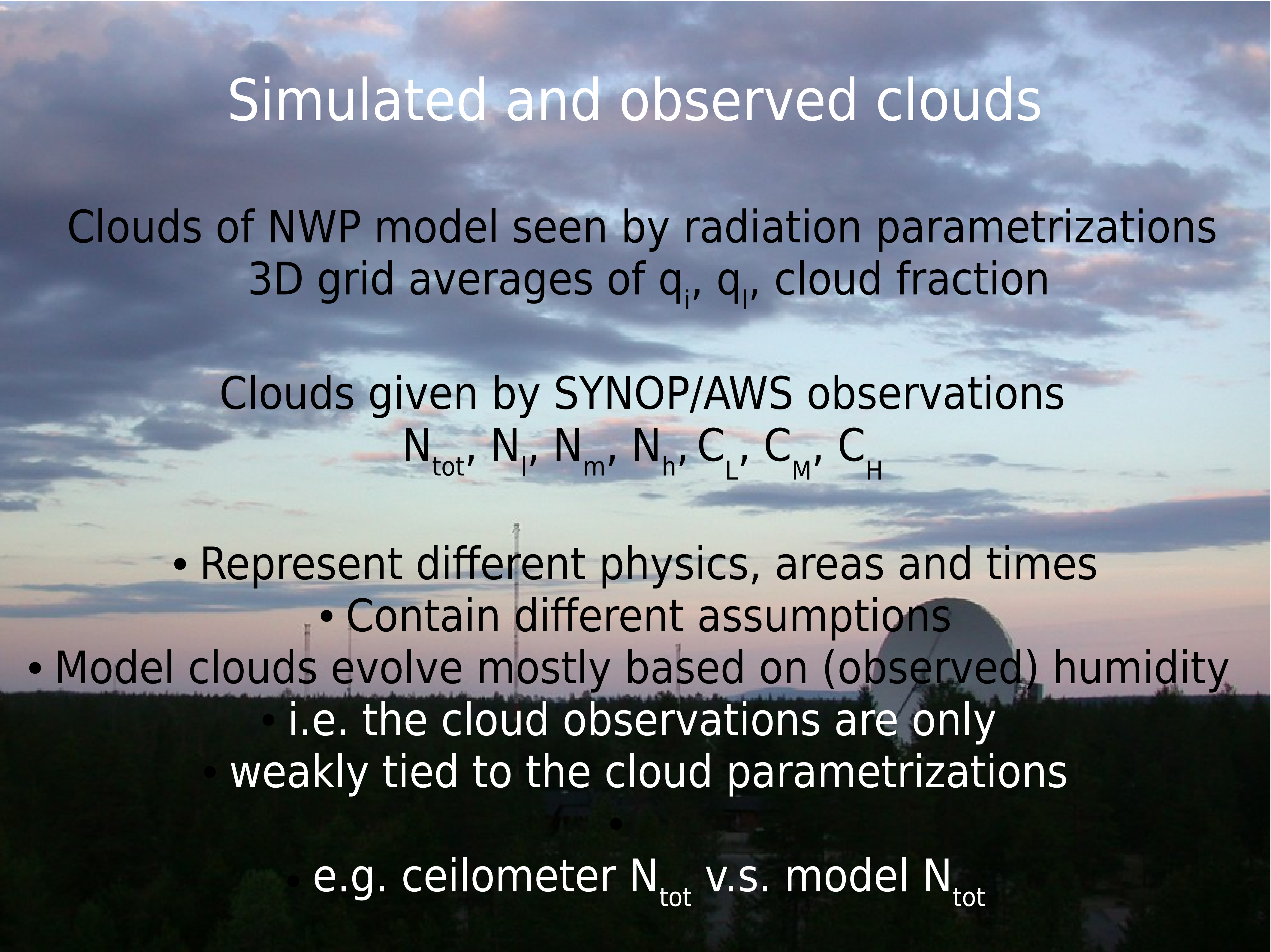


Classification of the data for the statistical analysis

- Seasons
- Sky conditions: cloudy, clear
- Solar elevation
- Periods between observation or model changes

(Synoptic conditions, other criteria ...)

How to determine representative sky conditions consistently for the model and observations?



Simulated and observed clouds

Clouds of NWP model seen by radiation parametrizations
3D grid averages of q_i, q_l, cloud fraction

Clouds given by SYNOP/AWS observations
N_{tot}, N_l, N_m, N_h, C_L, C_M, C_H

- Represent different physics, areas and times
- Contain different assumptions
- Model clouds evolve mostly based on (observed) humidity
- i.e. the cloud observations are only
- weakly tied to the cloud parametrizations
-
- e.g. ceilometer N_{tot} v.s. model N_{tot}

Cloud cover and fractions of clear sky

- How to compare observed/forecast clouds?
- How to classify radiation data according to sky conditions?

$$\mathrm{SFR8} = 1 - N_{tot}/8$$

$$\mathrm{SRF7} = \mathrm{SWD}/\mathrm{SWD}_{cle} = \mathrm{SWD}/(f_{tr} * S_o \cos\theta)$$

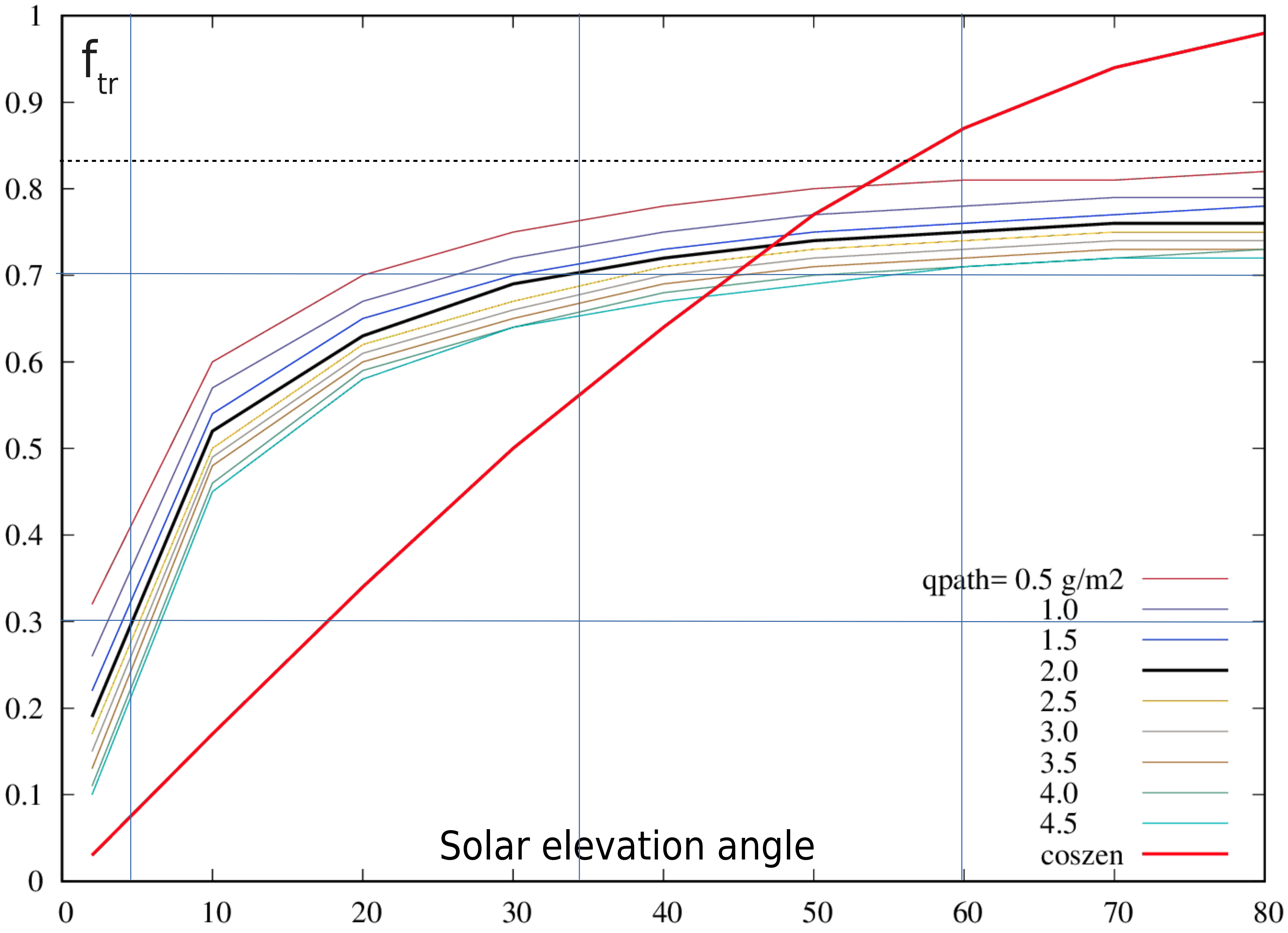
For estimation of the index SRF7, the factor f_{tr} was obtained based on the HIRLAM parametrizations, suggested by Savijärvi (1990) and explained by Gleeson et al. (2015):

$$f_{tr} = 1 - \frac{0.024}{\sqrt{cos\theta}} - aa \times 0.125(\frac{u}{cos\theta})^{0.25} - as \times (\frac{0.28}{1 + 6.43\sqrt{cos\theta}} - 0.056\alpha), \qquad (3)$$

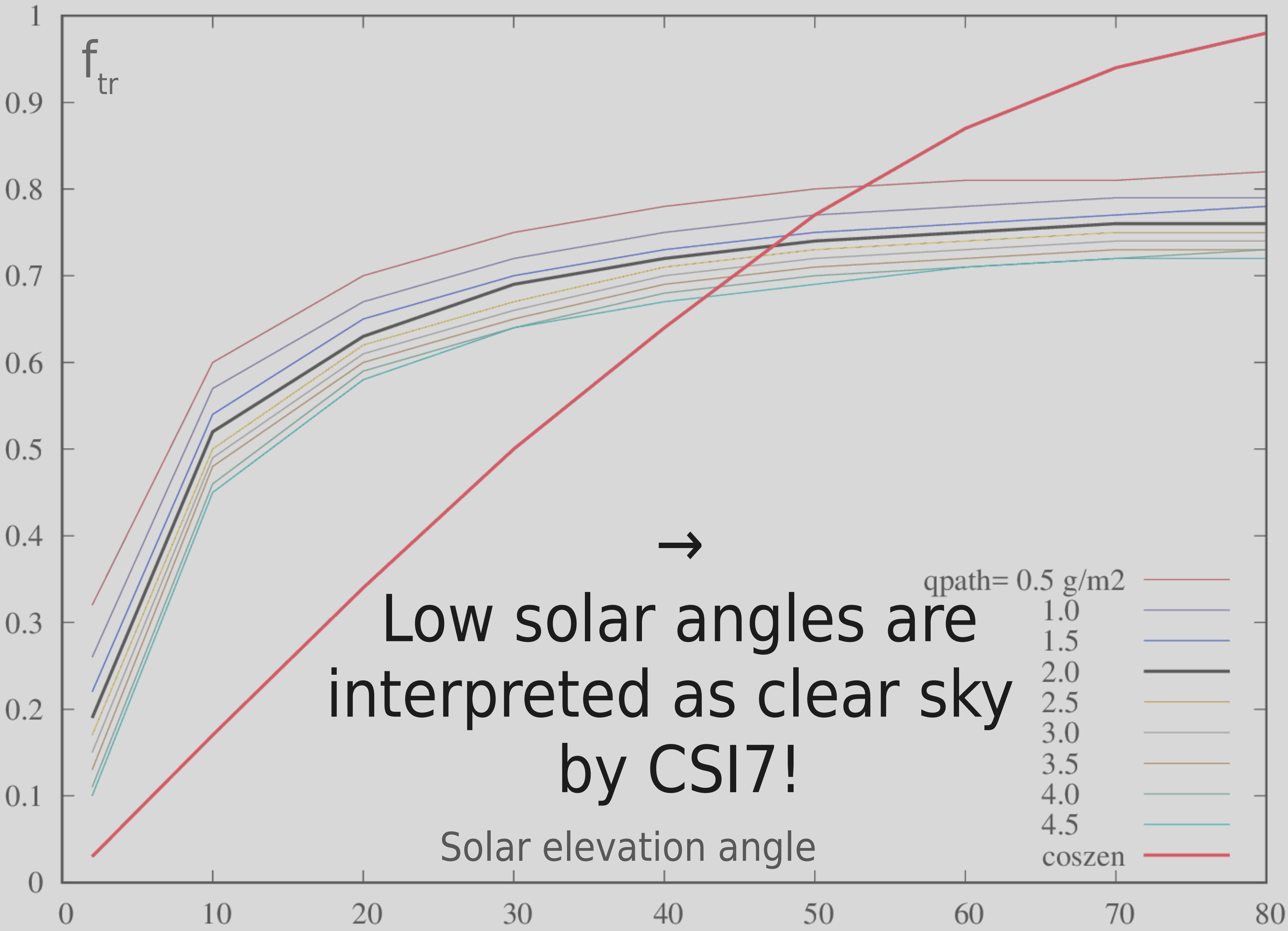
where u is the integrated water vapour content and α is the surface (direct beam) albedo. Absorption and scattering by aerosol can be crudely estimated by using the coefficients aa (= 1.20) and as (= 1.25), respectively. The R.H.S terms of Eq. 3 are related to absorption of the solar radiation by ozone and water vapour (the term proportional to u is the dominating term in Eq. 3), the Rayleigh scattering of the incoming beam and backscattering of the reflected radiation from the atmosphere to the surface.

$$\mathrm{SFR6} = \mathrm{SWD}/\mathrm{SWD}_{cle} = \mathrm{SWD}/(0.83 * S_o \cos\theta)$$

Clear-sky transmission factor f_{tr} for CSI7



Clear-sky transmission factor f_{tr} for CSI7

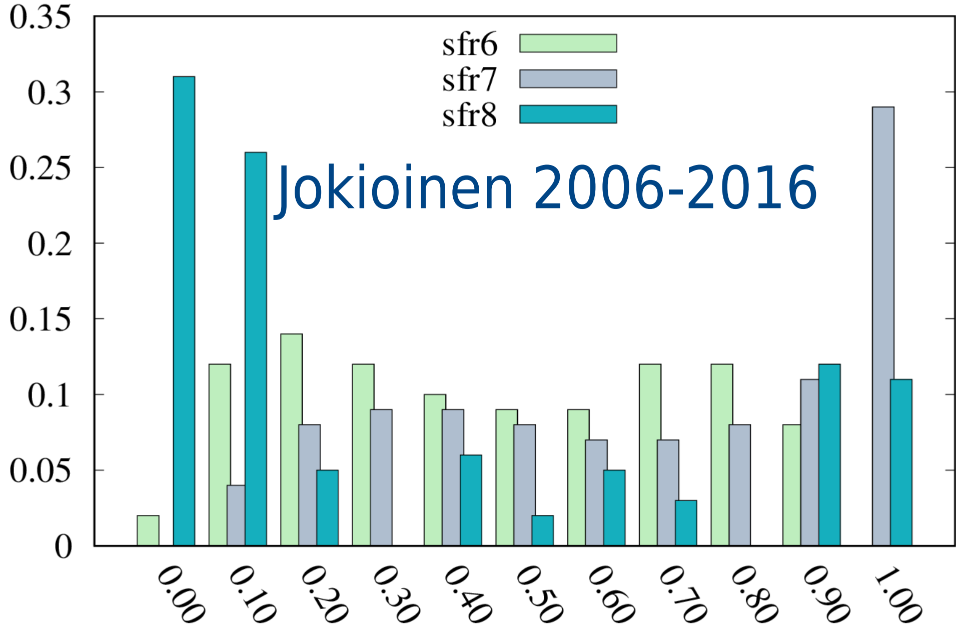


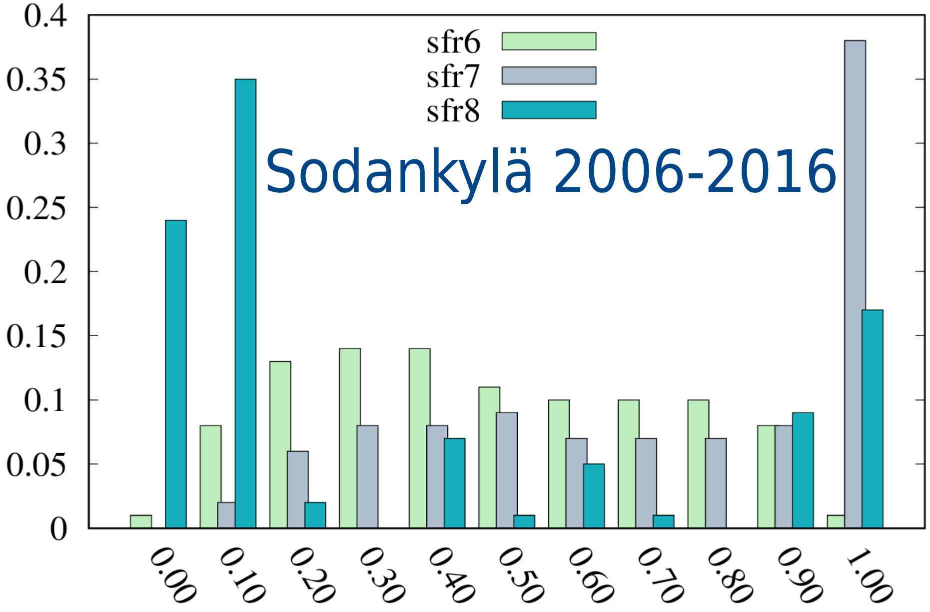
→

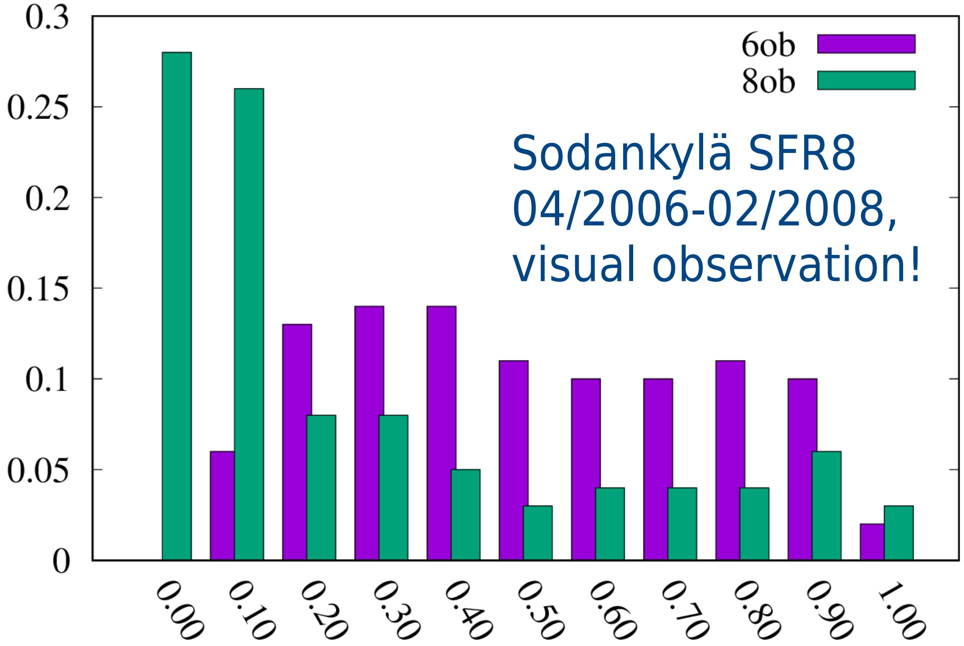
Low solar angles are interpreted as clear sky by CSI7!

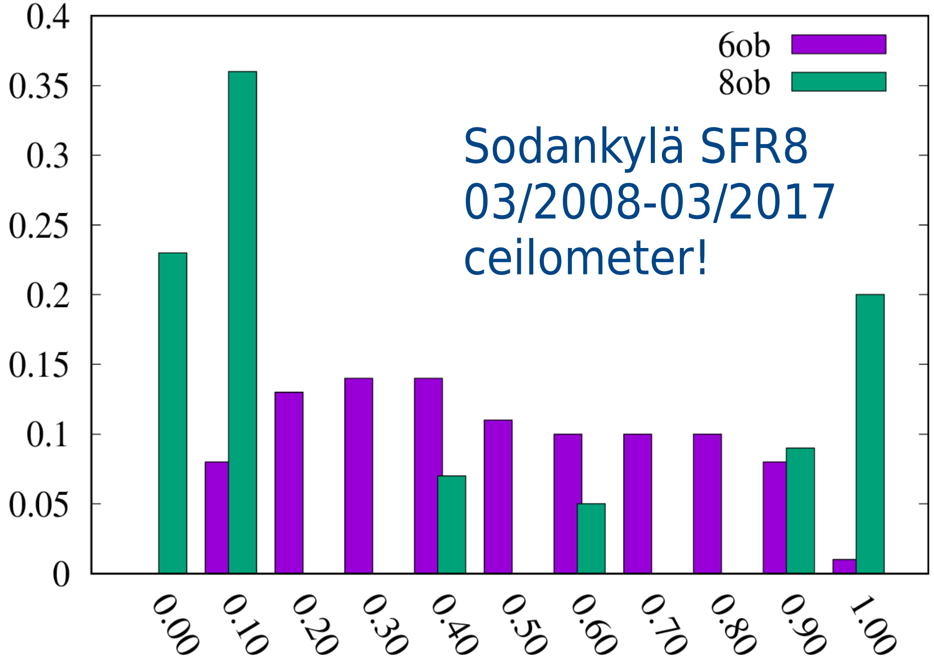
Observation-based clear sky fractions in Jokioinen and Sodankylä

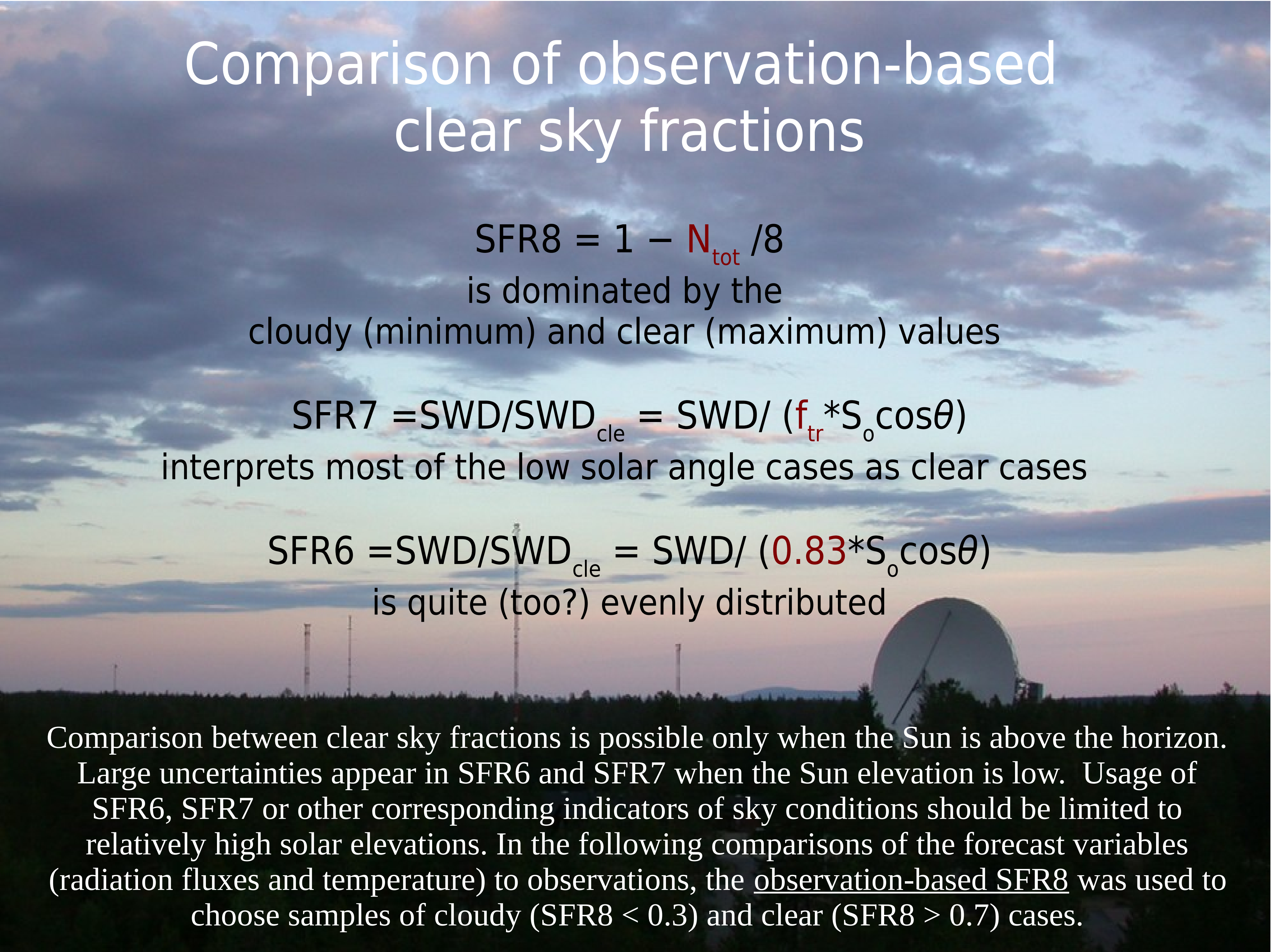
X-axis: (left) cloudy → (right) clear











Comparison of observation-based clear sky fractions

$$SFR8 = 1 - N_{tot}/8$$

is dominated by the
cloudy (minimum) and clear (maximum) values

$$SFR7 = SWD/SWD_{cle} = SWD/(f_{tr} * S_o \cos\theta)$$

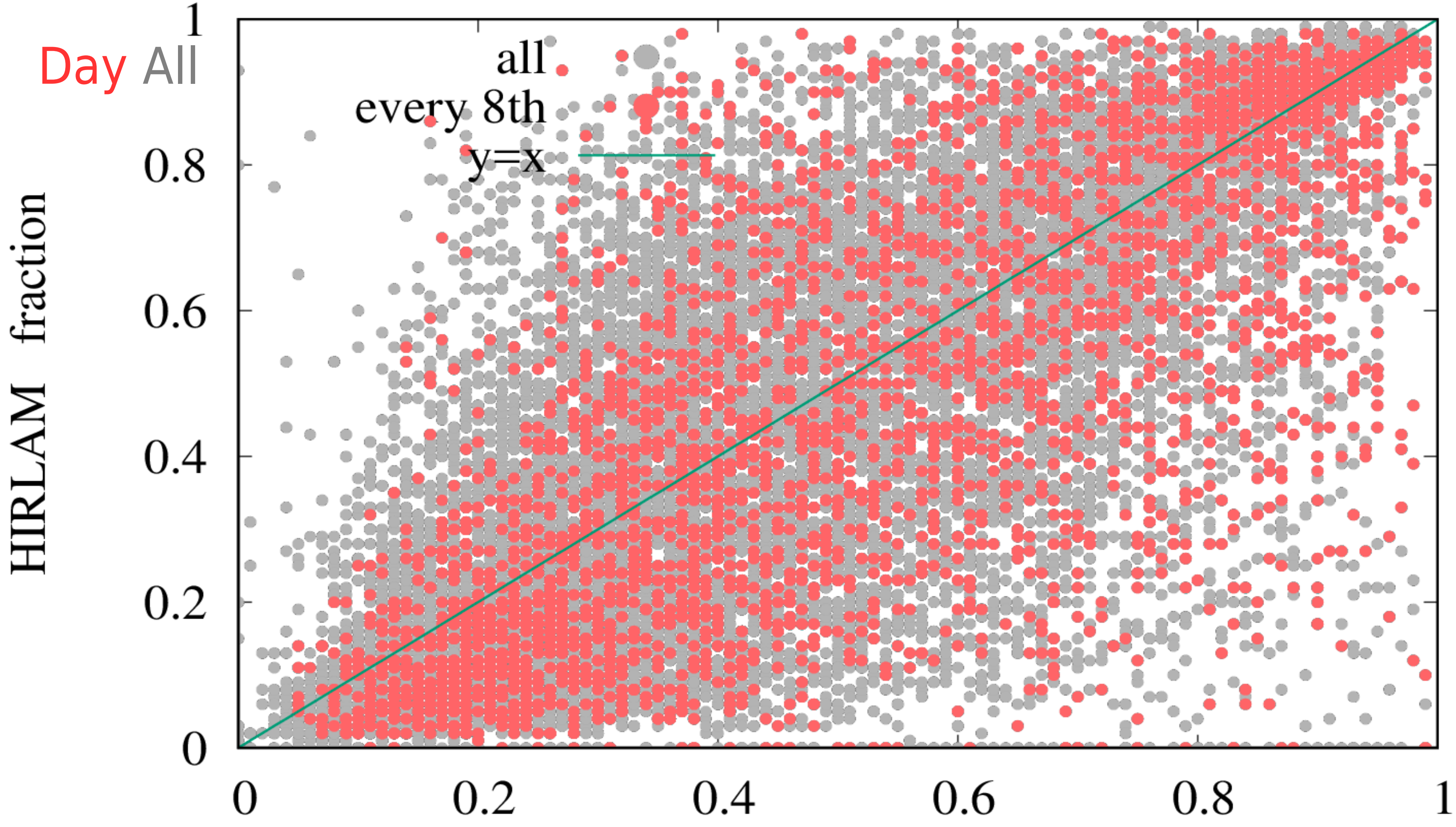
interprets most of the low solar angle cases as clear cases

$$SFR6 = SWD/SWD_{cle} = SWD/(0.83 * S_o \cos\theta)$$

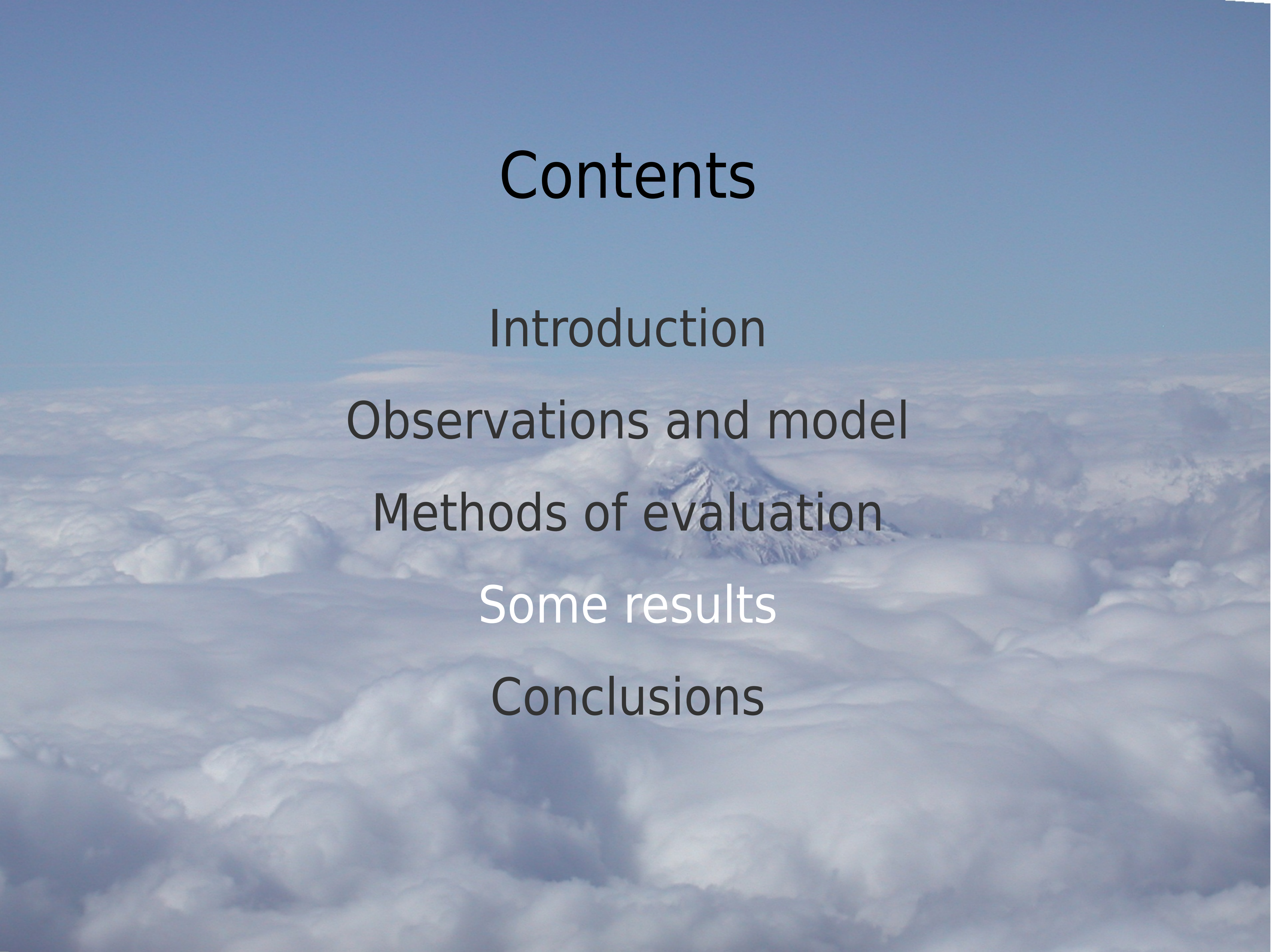
is quite (too?) evenly distributed

Comparison between clear sky fractions is possible only when the Sun is above the horizon. Large uncertainties appear in SFR6 and SFR7 when the Sun elevation is low. Usage of SFR6, SFR7 or other corresponding indicators of sky conditions should be limited to relatively high solar elevations. In the following comparisons of the forecast variables (radiation fluxes and temperature) to observations, the observation-based SFR8 was used to choose samples of cloudy (SFR8 < 0.3) and clear (SFR8 > 0.7) cases.

HIRLAM v.s. OBSERVED SFR6
Sodankylä 2006 - 2016



Observed fraction



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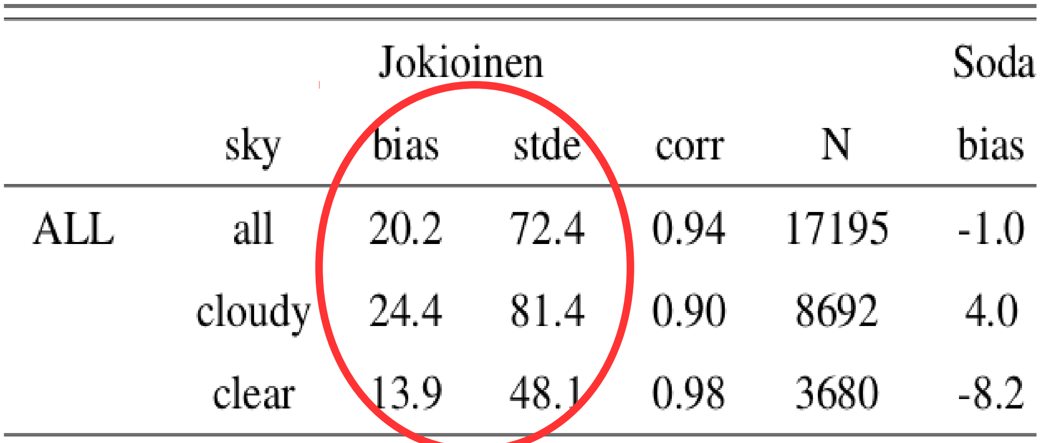
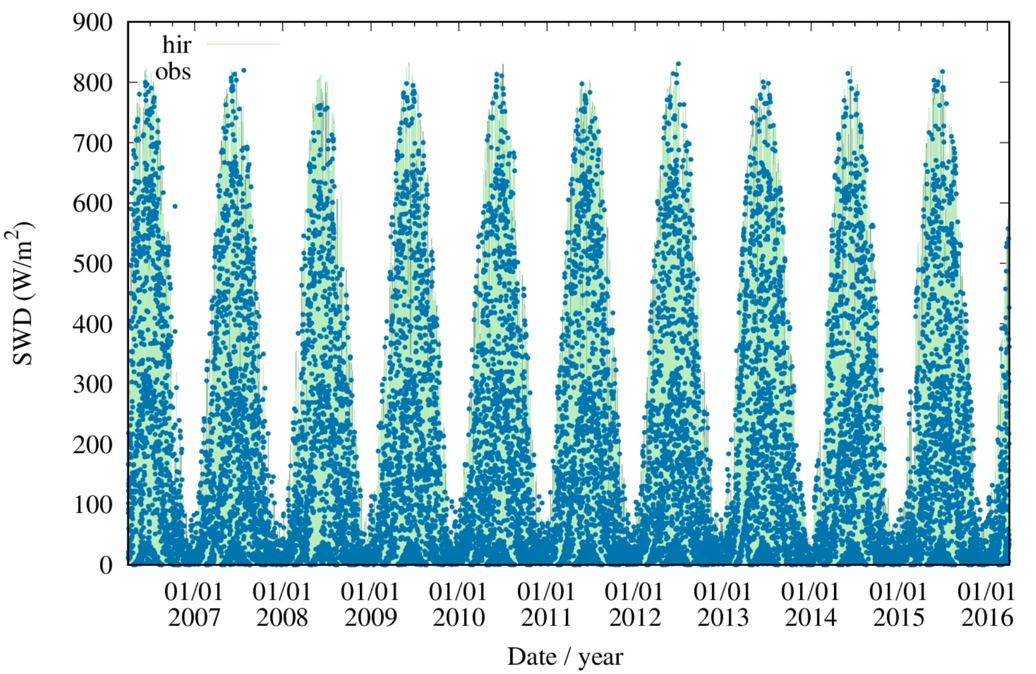
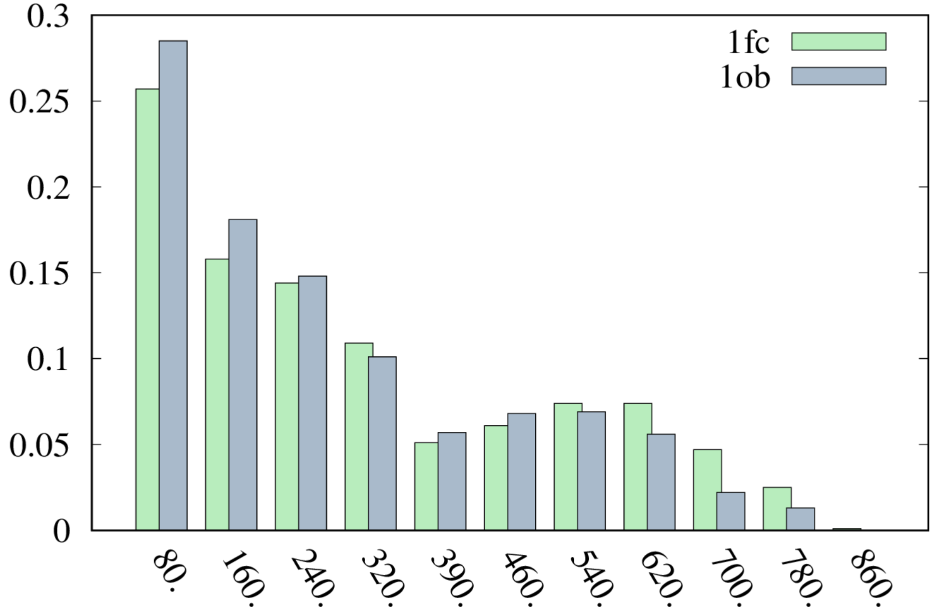
Global shortwave downward flux SWDS Jokioinen 2006-2016

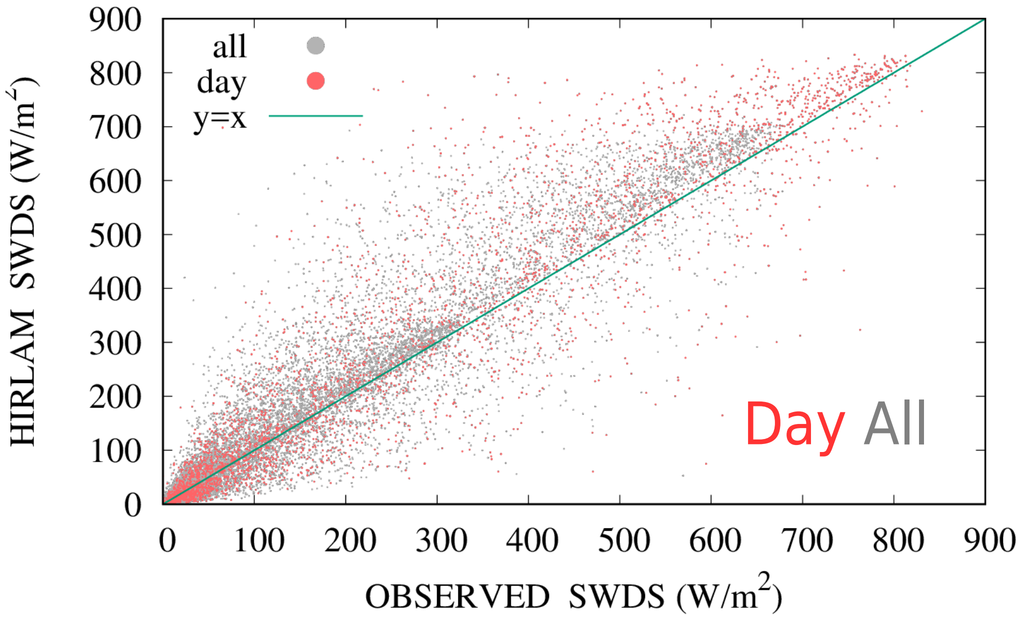


		Jokioinen				Soda
	sky	bias	stde	corr	N	bias
ALL	all	20.2	72.4	0.94	17195	-1.0
	cloudy	24.4	81.4	0.90	8692	4.0
	clear	13.9	48.1	0.98	3680	-8.2

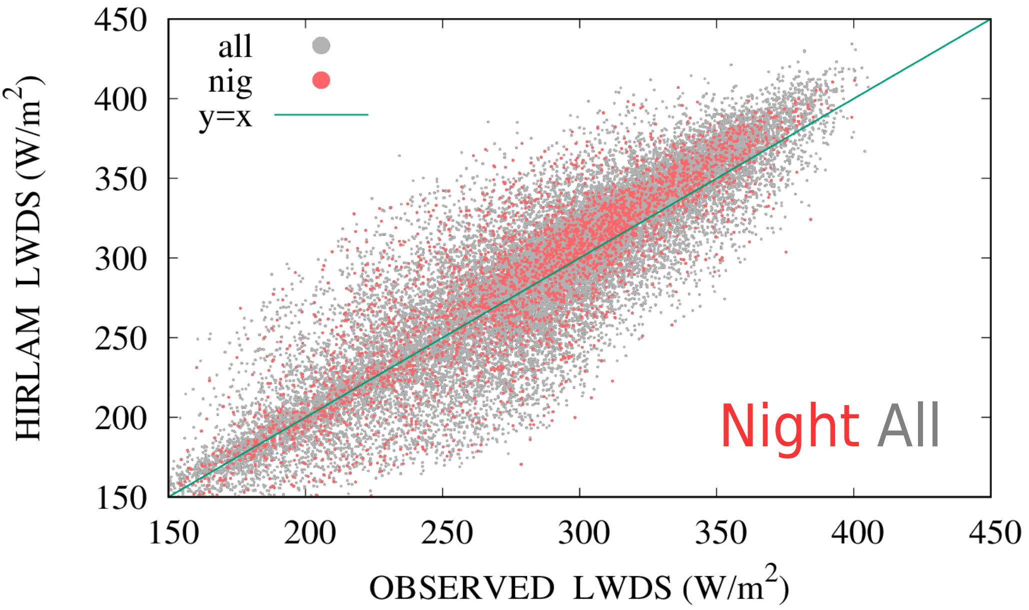
Cloudy: CSI8<0.3 Clear CSI8>0.7

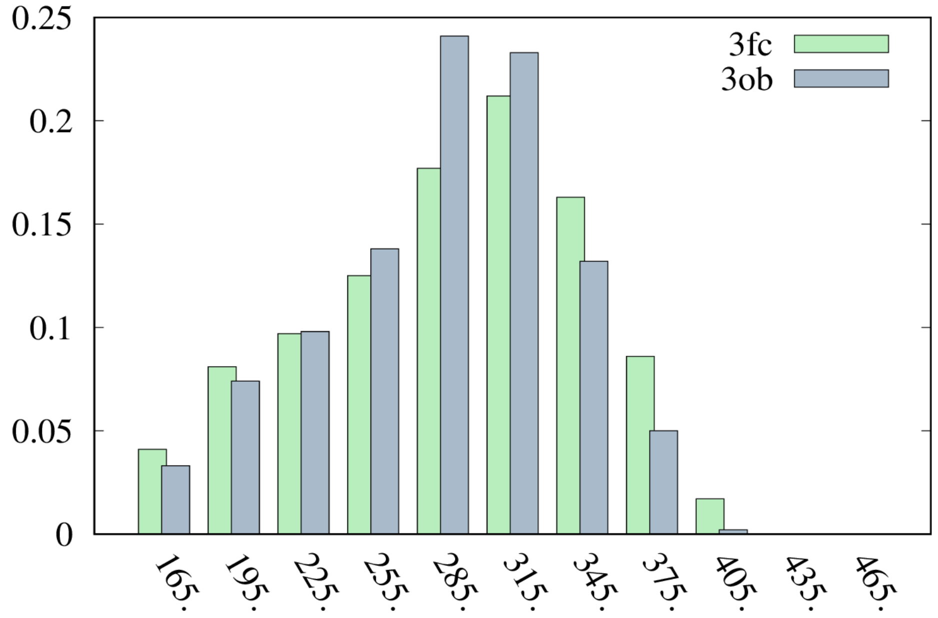


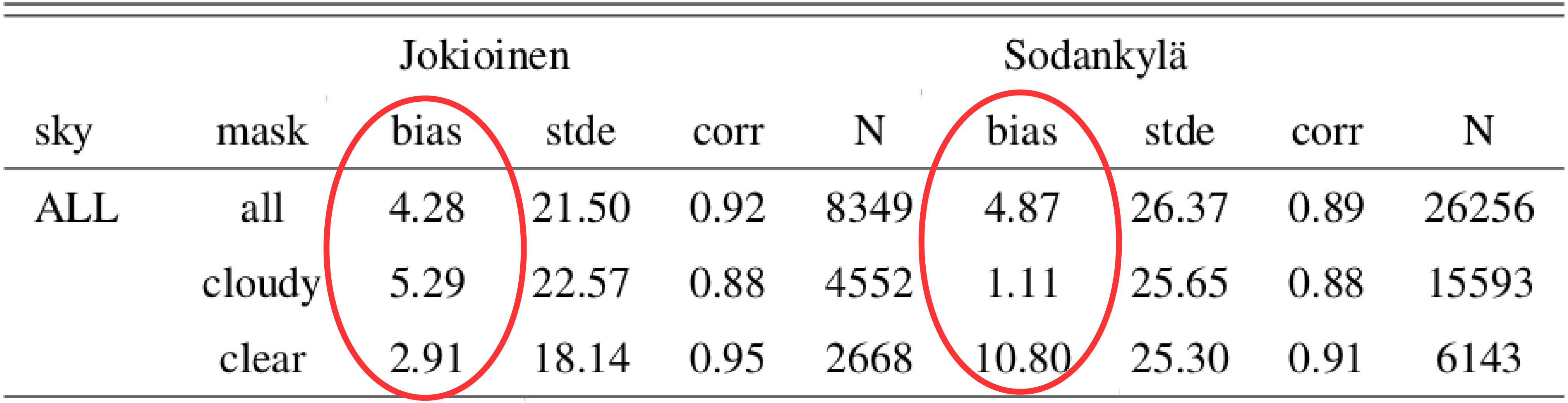




Longwave downward flux LWDS Sodankylä

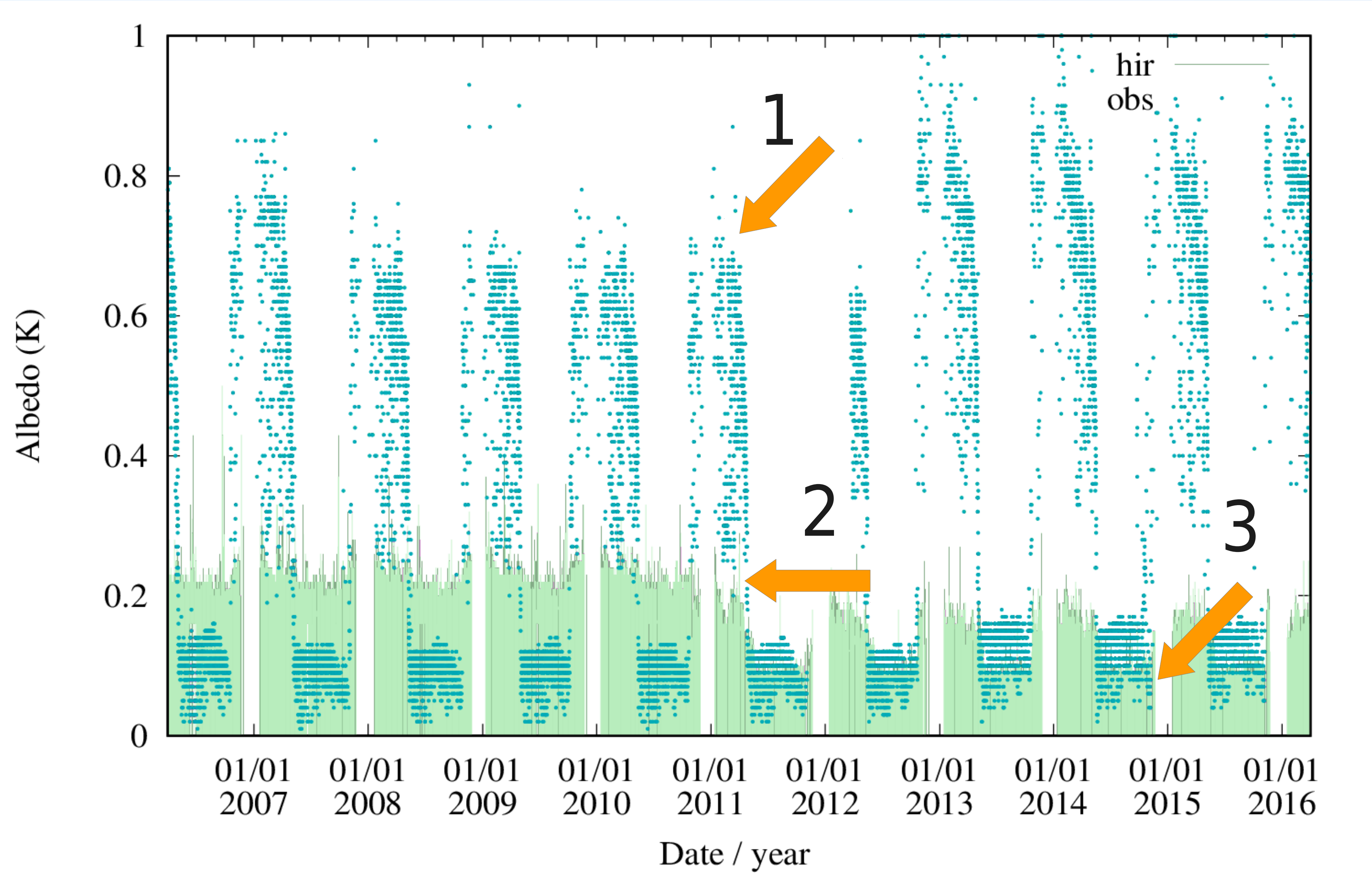




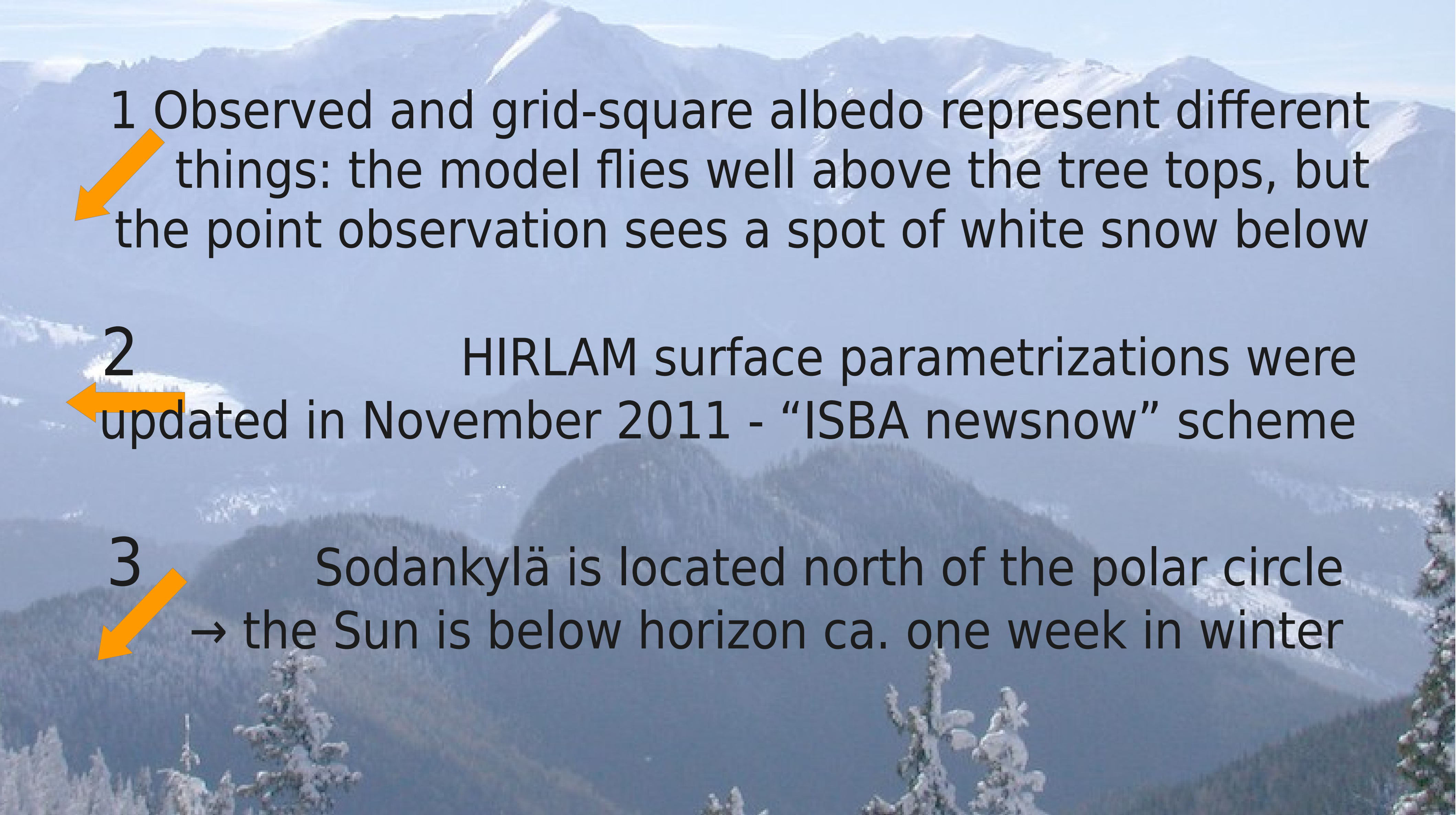


		Jokioinen				Sodankylä			
sky	mask	bias	stde	corr	N	bias	stde	corr	N
ALL	all	4.28	21.50	0.92	8349	4.87	26.37	0.89	26256
	cloudy	5.29	22.57	0.88	4552	1.11	25.65	0.88	15593
	clear	2.91	18.14	0.95	2668	10.80	25.30	0.91	6143

Reflected shortwave flux SWDU → Albedo Sodankylä 2006-2016



Reflected shortwave flux SWDU → Albedo Sodankylä 2006-2016



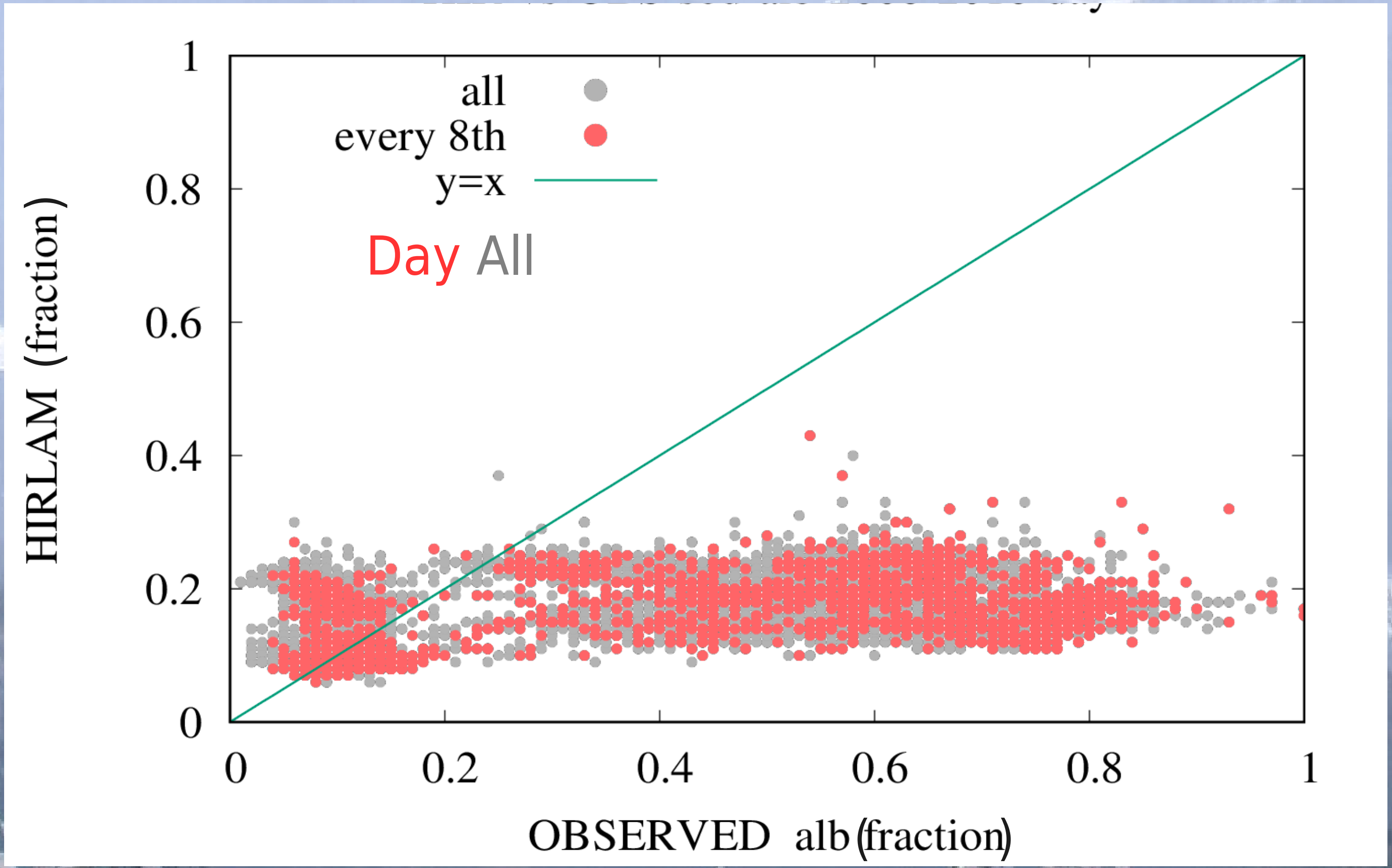
1 Observed and grid-square albedo represent different things: the model flies well above the tree tops, but the point observation sees a spot of white snow below

2 HIRLAM surface parametrizations were updated in November 2011 - “ISBA newsnow” scheme

3 Sodankylä is located north of the polar circle → the Sun is below horizon ca. one week in winter

Reflected shortwave flux SWDU → Albedo Sodankylä 2006-2016

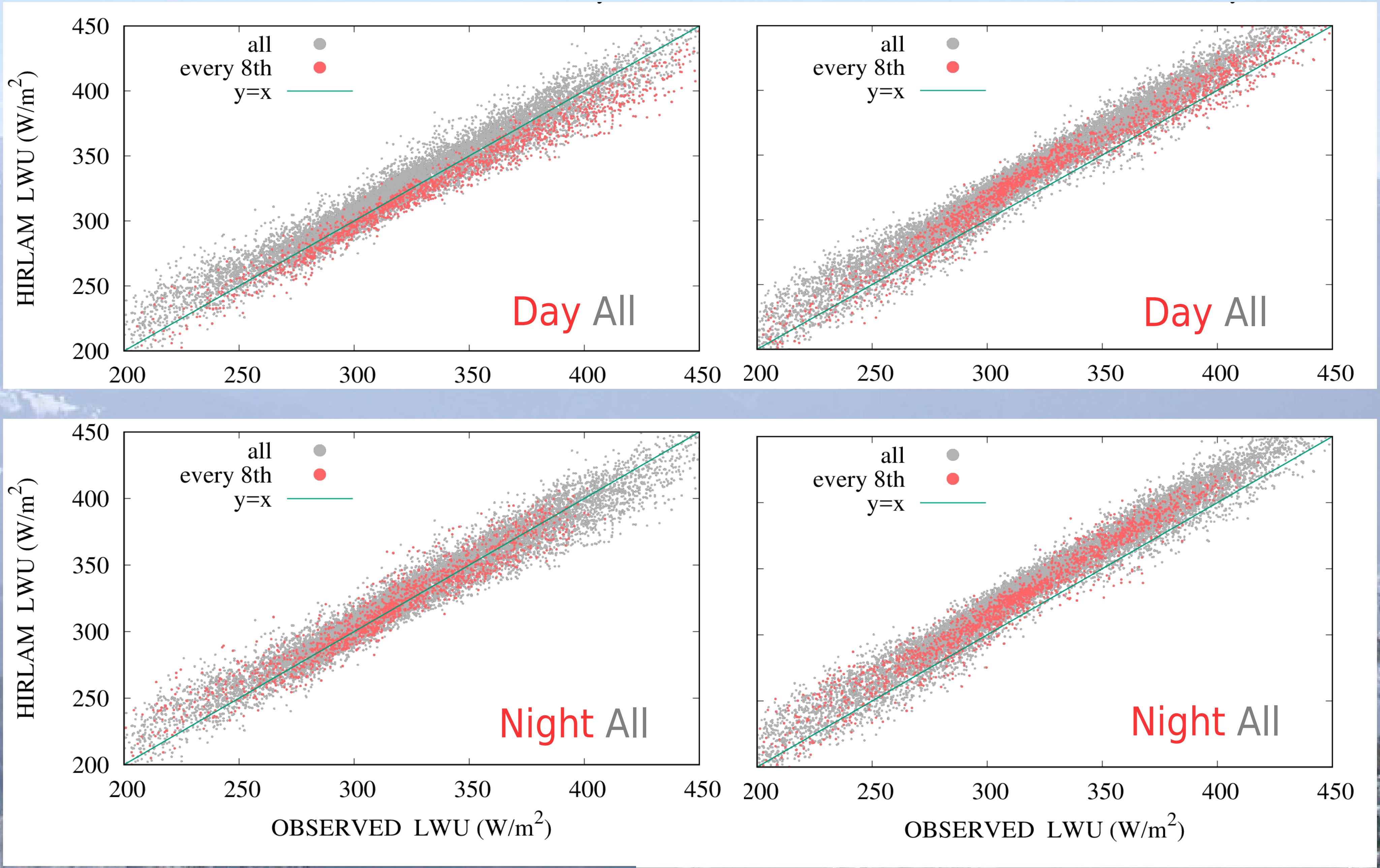
1 Observed and grid-square albedo represent different things: the model flies well above tree tops, but the point observation sees a spot of white snow below



Longwave upward flux LWUS Sodankylä

2006-2010 old ISBA

2011-2016 ISBA newsnow



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Conclusions

During 2006-2016 HIRLAM performed generally well compared to surface radiation measurements at two Finnish meteorological station. Small systematic underestimation the SW absorption and overestimation of the LW absorption by the atmosphere was found.

The SWDS bias of max. 20 Wm^{-2} may be due to the assumed inhomogeneity correction of 20% of the cloud condensate content.

The LWDS bias of max. 5 Wm^{-2} could be avoided by modifying an extra correction term of ca. +15 Wm-2 due to an assumed effect of “other greenhouse gases”.

Radiation fluxes showed large variability due to cloud variations. Classifying the model and observation data according to cloudiness contains large uncertainties, especially for solar radiation when the solar elevation is low.

The reflected SW radiation (→ albedo) shown by the model grid-average values and observed locally are not comparable due to the representativity error. Upwelling LW flux (→ T_{surf}) suffers less of this problem, thus LWUP observations might be used, to some extent, to measure the performance of model’s T_{surf}

Thank you for attention!

Thanks to

Hannu Savijärvi, Petri Räisänen, Bent Hansen Sass
Anders Lindfors, Jan Mašek

Parametrization of the radiative transfer

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

Physico-chemical properties:
Mass concentration
Size
Shape
Composition

In the air:
Gas molecules
Cloud droplets and crystals
Aerosol particles

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

Optical properties:
Optical depth
Single scattering albedo
Asymmetry factor

Surface-atmosphere radiative interactions

Surface albedo and emissivity
Orographic radiation effects

Characteristics of surface types
Surface elevation

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)

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