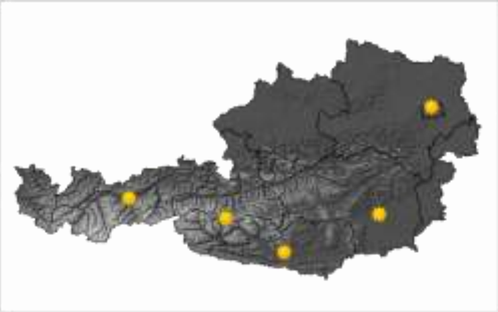
The Austrian radiation monitoring network ARAD

Ursula Weiser, BSRN Workshop, 25-29 April 2016

best practice and added value



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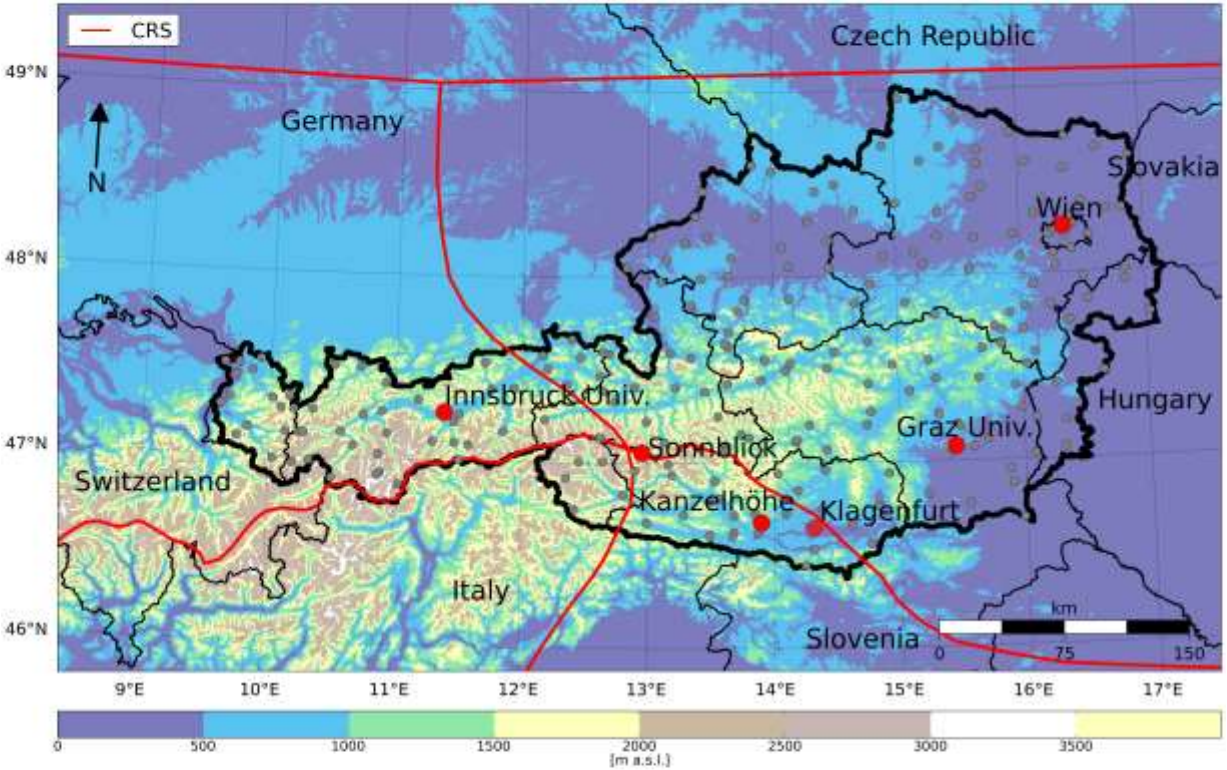
ARAD: aims and scopes



Advance:

- national climate monitoring

Support :

- satellite retrieval
- atmospheric modelling
- solar energy development

- downwelling solar and infrared radiation using suntracking devices
- instruments according to BSRN standards
- 5 stations (200 – 3100 m a.s.l.)
- station Sonnblick part of BSRN since 2013

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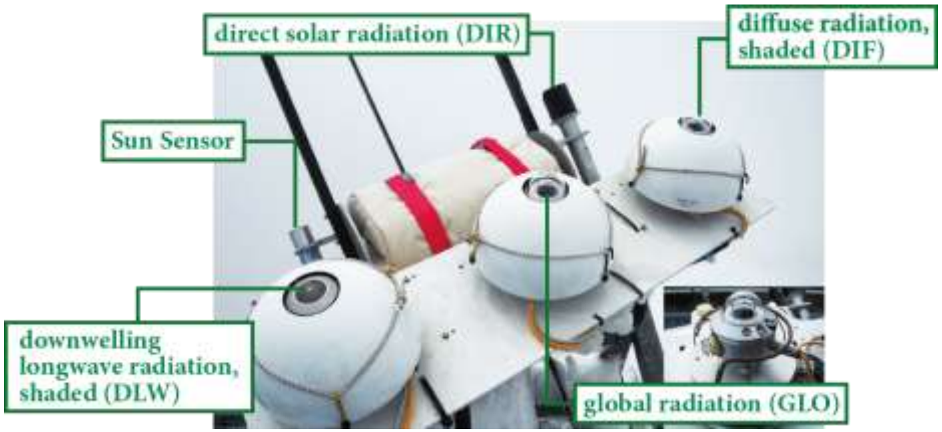
ARAD: instrumentation and methods



Parameter	Manufacturer	Typ	ISO-9060 classifikation	Spectral range [nm]	sensitivities min/max/(mean) [uV/W/m²]	expanded uncertainty range min/max/(mean) [%]
DIR	Kipp & Zonen	CHP1	first class	200-4000	7,62/8,02/7,78	1,1/1,1/1,1
DIR	Hukseflux	DR02-T	first class	200-4000	10,05/11,93/10,97	1,3/1,5/1,4
GLO	Kipp & Zonen	CMP21	secondary standard	285-2800	8,29/12,75/9,52	1,4/1,5/1,5
GLO	Kipp & Zonen	CM22	secondary standard	200-3600	9,15/9,19/9,17	1,0/1,0/1,0
DIF	Kipp & Zonen	CMP21	secondary standard	285-2800	8,29/12,75/9,52	1,4/1,5/1,5
DIF	Kipp & Zonen	CM22	secondary standard	200-3600	9,15/9,19/9,17	1,0/1,0/1,0
DLW	Kipp & Zonen	CGR4/CG4	-	4500-42000	6,70/15,25/10,78	1,9/5,6/4,1

Data sampling: 1 Hz

1-minute statistics stored: min, max, std

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ARAD: instrumentation and methods

station setup

	Wien	Graz	Innsbruck	Sonnblick	Kanzelhöhe
Lat [°]	48,25	47,08	47,26	47,05	46,68
Lon [°]	16,36	15,45	11,38	12,96	13,90
Alt [m]	198	398	578	3109	1520
temp [°C]	10,4	9,8	9,4	-5,1	4,6
precip [mm]	651	885	911	2263	1103
topo type	Flat/Urban	Flat/Urban	Mountain valley/Urban	Mountain top/Rural	Mountain top/Rural
suntr. device	Solys 2	Kipp&Zonen 2 AP	Solys 2	Kipp&Zonen 2 AP	Solys 2
rad. Instr.	2xCMP21, 1xCHP1, 1xCGR4	2xCMP21, 1xCHP1, 1xCGR4	2xCMP21, 1xCHP1, 1xCGR4	2xCMP21, 1xDR02, 1xCGR4	2xCM22, 1XCHP1, 1xCG4
heating/vent device	PMOD-VHS	;enbrodt/self-design	PMOD-VHS	Eigenbrodt	Kipp&Zonen
operated by	ZAMG	ZAMG/Uni Graz	ZAMG/Uni Innsbruck	ZAMG	ZAMG/KSO
monitoring start	09.02.2011	31.08.2011	05.07.2011	01.01.2011	01.01.2013

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ARAD: calibration

- pyranometers:
  - comparison to working standard pyranometer (ZAMG Vienna) or sent to K&Z (indoor calibration procedure) (ISO 9847)
  - working standard against TMI cavity (ISO 9846)
- pyrheliometers:
  - direct comparison against TMI (ISO 9059)
  - TMI cavity participates regularly at IPC (traceability to WRR)
- pyrgeometers:
  - sent to K&Z (traceability to WISG)
- calibration interval:
  - annualy at BSRN Sonnblick
  - every 2 years at other stations

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ARAD: maintenance

maintenance by human observer:

- regular tasks: cleaning, levelling, visual inspection of: cables, heating/ventilation devices, control suntracking system, shading of instruments
- occasional tasks: cleaning of heating/ventilation system, service suntracker
- interval: once a week (daily at BSRN Sonnblick)
- regulated in a manual
- results entered in web interface, stored in central database (flagged as „wrong“)

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ARAD: data quality control (QC)

- **2** automated methods, **1** manual method
- **daily automated method:** script containing QC criteria (expanded version, Long and Shi (2008)):
  - checking of 61 quality criteria (integrity tests, outlier detections, min/max tests, comparison tests)
  - creation of quality flags
  - graphical summary
  - conversion of mV to W/m^2 (using calibration factors)
  - calculation of clear sky index (CSI, Marty and Philipona (2000))
  - storage of solar position
- **manual:** visual inspection of:
  - the graph of the daily automated QC
  - a near-realtime interactive data plot (updated every 5 minutes)
  - review of automated e-mail alerts (hourly)

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ARAD: data quality - average flag statistics 2012-2014

Flag	Wien [%]	Graz [%]	Innsbruck [%]	Sonnblick [%]
	GLO, DIF, DIR, DLW	GLO, DIF, DIR, DLW	GLO, DIF, DIR, DLW	GLO, DIF, DIR, DLW
Good (1)	99 / 98 / 98 / 96	93 / 96 / 96 / 95	92 / 93 / 94 / 91	81 / 74 / 85 / 81
Wrong (2)	1 / 1 / 0 / 0	6 / 3 / 2 / 2	1 / 1 / 0 / 0	16 / 24 / 13 / 14
Dubious (3)	0 / 0 / 1 / 3	0 / 1 / 1 / 3	0 / 0 / 0 / 3	1 / 1 / 1 / 3
Missing (255)	1 / 0 / 0 / 0	1 / 1 / 1 / 1	5 / 5 / 5 / 5	1 / 1 / 1 / 1
"Perfect"	94	88	89	67

„Perfect“ = percentage of all 4 measured parameters simulatneously flagged as „good“

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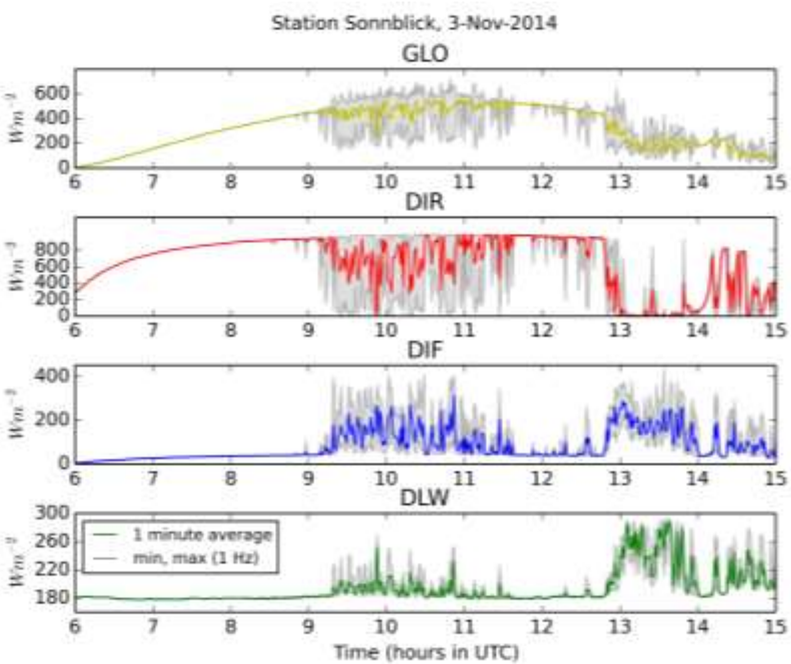
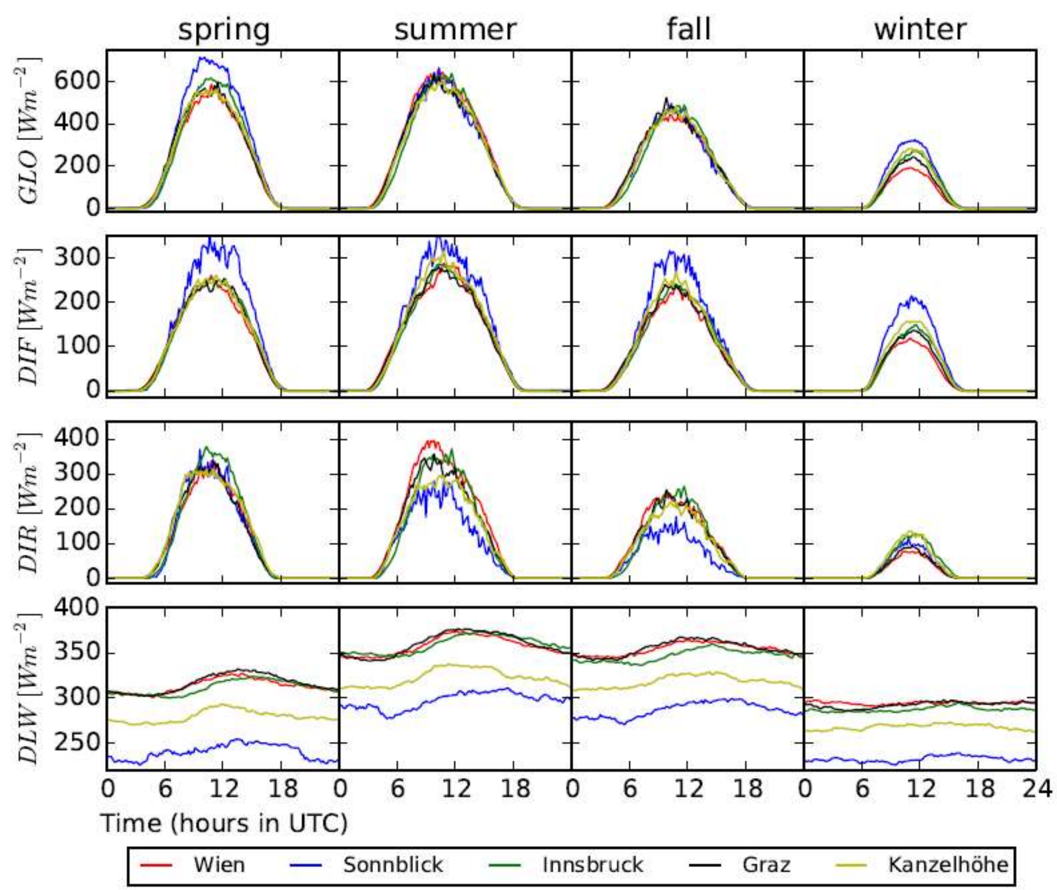
ARAD: data snippet

1 day Sonnblick data



seasonal mean daily courses (Dec 2013 - Nov2014)



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ARAD: uncertainty analysis – methodology

- uncertainty estimate of shortwave radiation fluxes at 5 ARAD sites
- methodology following Vuilleumier et al. (2014) and GUM (2008) and Reda (2011)
- 1 full annual cycle (1 July 2014 to 30 June 2015)
- components of combined standard uncertainty of measured irradiance:
  - sensitivity (calibration uncertainty, non-linearity, temperature dependance, aging)
  - raw signal (accuracy, resolution and offset DAQ)
  - statistical (STD of irradiance signal, when DIR varies slowly)
  - thermal offset (estimated from nighttime pyranometer data, lacking dome temperature meas. or capping experiments)
  - operational uncertainties (soiling, leveling, directional errors)

Vuilleumier, L., Hauser, M., Félix, C., Vignola, F., Blanc, P., Kazantzidis, A. and Calpini, B.: Accuracy of ground surface broadband shortwave radiation monitoring: Shortwave radiation monitoring accuracy, J. Geophys. Res. Atmospheres, 119(24), 13,838–13,860, doi:10.1002/2014JD022335, 2014

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ARAD: uncertainty analysis – results

	Expanded					Standard[b]					Contribution (%)[a] ss					Contribution (%)[a] ls				
	WHW	GRZ	IBK	KSO	SON	WHW	GRZ	IBK	KSO	SON	WHW	GRZ	IBK	KSO	SON	WHW	GRZ	IBK	KSO	SON
Sensitivity factor (u_s)																				
DIR	1,28 %	1,28 %	1,28 %	1,49 %	1,53 %	0,65 %	0,65 %	0,65 %	0,76 %	0,78 %	15	14	10	74*	34	58*	76*	57*	87*	86*
GLO	1,90 %	1,98 %	1,98 %	2,55 %	1,53 %	0,97 %	1,01 %	1,01 %	1,30 %	0,78 %	1	1	1	5	0	61*	63*	63*	79*	46*
DIF	1,90 %	1,90 %	1,97 %	2,55 %	1,53 %	0,97 %	0,97 %	1,01 %	1,30 %	0,78 %	24	29	21	53*	17	92*	93*	94*	81*	33
Uncertainty of the raw signal U / of the DAQ (u_u)																				
DIR	10 µV	10 µV	10 µV	0,07 % + 2 µV	10 µV	5,77 µV	5,77 µV	5,77 µV	0,04 % + 1,15 µV	5,77 µV	75*	82*	83*	15	61*	1	1	1	≈ 0	0
GLO	10 µV	10 µV	10 µV	0,07 % + 2 µV	10 µV	5,77 µV	5,77 µV	5,77 µV	0,04 % + 1,15 µV	5,77 µV	1	1	2	0	1	≈ 0	≈ 0	≈ 0	≈ 0	0
DIF	10 µV	10 µV	10 µV	0,07 % + 2 µV	10 µV	5,77 µV	5,77 µV	5,77 µV	0,04 % + 1,15 µV	5,77 µV	48*	70*	56*	3	50*	2	2	2	≈ 0	1
Statistical Uncertainty (u_{stat})																				
DIR						0,37 %	0,29 %	0,22 %	0,25 %	0,29 %	5	3	1	8	5	19	15	7	9	12
GLO						0,33 %	0,29 %	0,22 %	0,3 %	0,4 %	≈ 0	≈ 0	≈ 0	≈ 0	0	7	5	3	4	12
DIF						0,23 %	0,21 %	0,15 %	0,62 %	1,1 %	1	1	≈ 0	12	33	5	4	2	18	66*
Operational uncertainties (u_{op})																				
1. Thermal effect																				
GLO	0	2 Wm^{-2}	1 Wm^{-2}	1 Wm^{-2}	1 Wm^{-2}	0	1,02 Wm^{-2}	0,51 Wm^{-2}	0,51 Wm^{-2}	0,51 Wm^{-2}	0	3	1	3	1	0	1	0	0	0
DIF	1 Wm^{-2}	0	1 Wm^{-2}	1 Wm^{-2}	1 Wm^{-2}	0,51 Wm^{-2}	0	0,51 Wm^{-2}	0,51 Wm^{-2}	0,51 Wm^{-2}	27	0	22	33	0	1	0	1	0	0
2. Directional error																				
GLO	10 Wm^{-2}	10 Wm^{-2}	10 Wm^{-2}	5 Wm^{-2}	10 Wm^{-2}	5,77 Wm^{-2}	5,77 Wm^{-2}	5,77 Wm^{-2}	2,89 Wm^{-2}	5,77 Wm^{-2}	98*	95*	96*	91*	97*	22	21	21	4	25
3. Soiling																				
DIR	0,8 %	0,4 %	1,0 %	0,3 %	0,2 %	0,41 %	0,2 %	0,51 %	0,15%	0,1 %	6	1	6	3	1	23	7	35	4	1
4. Levelling																				
GLO	0,76 %	0,8 %	0,91 %	1,02 %	0,9 %	0,39 %	0,41 %	0,46 %	0,52 %	0,46 %	≈ 0	≈ 0	0	1	0	10	10	13	13	16

ss = small signal (50 W/m²)
ls = large signal (1000, 500 W/m²)

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ARAD: uncertainty analysis – results

	Expanded (%)									
	ss					ls				
	WHW	GRZ	IBK	KSO	SON	WHW	GRZ	IBK	KSO	SON
DIR	3,33	3,48	4,04	1,72	2,62	1,68	1,46	1,69	1,6	1,64
GLO	22,88	23,25	23,04	11,84	22,95	2,43	2,49	2,5	2,87	2,25
DIF	3,86	3,55	4,28	3,51	3,74	1,98	1,97	2,03	2,83	2,66

ss = small signal (50 W/m²)
ls = large signal (1000, 500 W/m²)

- combined expanded uncertainty: 1.46 % - 23.25 %
- after correction of directional error and temp dependance: 1.4 % - 5.2 %
- BSRN target (which is larger) accuracies: 0.5 % (1.5 W/m²) (DIR), 2 % (5 and 3 W/m²) (GLO, DIF)
- after correction: 70 % of GLO, DIF for **ls** within or very close to BSRN target accuracies
- reduce uncertainty for **ss** GLO, DIF: DAQ accuracy, annual recalibration, thermal offset correction
- DIR: better instrumentation needed

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ARAD: data policy

- ARAD data freely available for „bona fide research purposes“ from ZAMG (klima@zamg.ac.at)
- data from BSRN station SON available at BSRN data archive: http://www.pangaea.de/tools/latest-datasets.rss?q=Project:BSRN+SON
- more informations about ARAD: http://www.zamg.ac.at/strahlung
- publication: Olefs et al.: The Austrian radiation monitoring network ARAD – best practice and added value, Atmos. Meas. Tech., 9, 1513-1531, 2016 http://www.atmos-meas-tech.net/9/1513/2016/

ARAD: examples of data use

improving sunshine duration observations

- Forgan-Method using 1-minute data statistics (mean, min, max) based on 1 Hz samplings of DIR (Forgan and Dyson, 2004).
- $SSD_{true} = SSD_{known} + A * SSD_{unknown} + B$
- $SSD_{known} = DIR_{min} > 120\ W/m^2$
- $SSD_{unknown}$: $DIR_{mean} > 120 \frac{W}{m^2}$ & $DIR_{max} > 120 \frac{W}{m^2}$ & $DIR_{min} < 120\ W/m^2$
- take 1 Hz measurements using a NIP Pyrheliometer as SSD_{true} and find A, B
- test site Vienna: calibration period (6 month), validation period (4 months)

Forgan, B., Dyson, P. , 2004. “Uncertainty in Daily Sunshine Duration from BSRN Minute Statistics.” In *8th BSRN Scientific and Review Workshop*. Exeter, UK.

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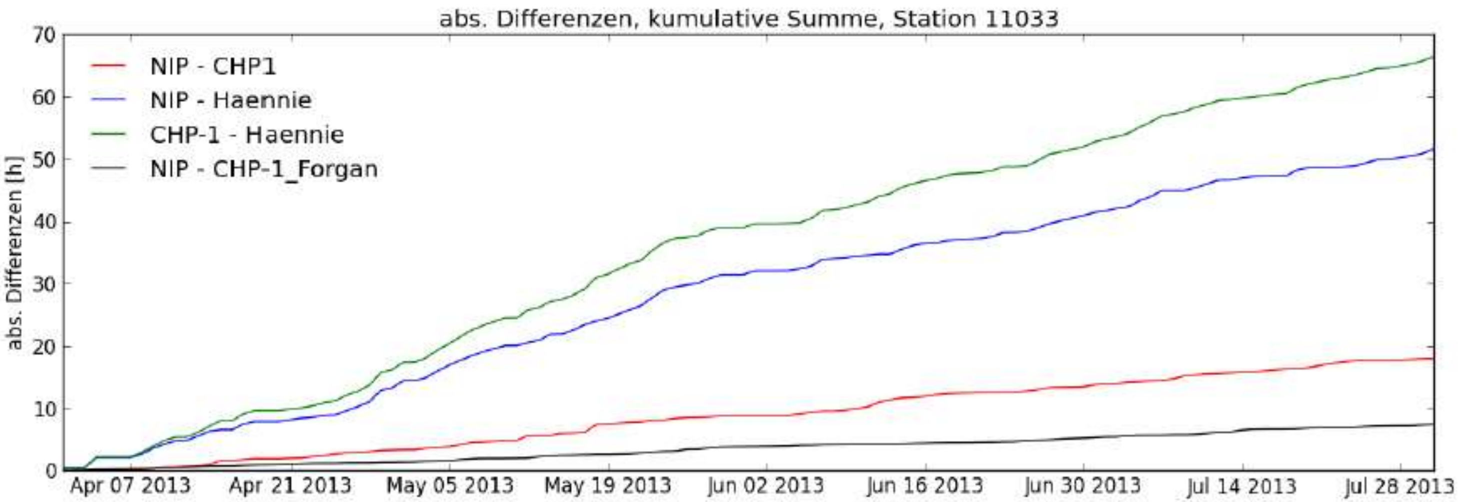
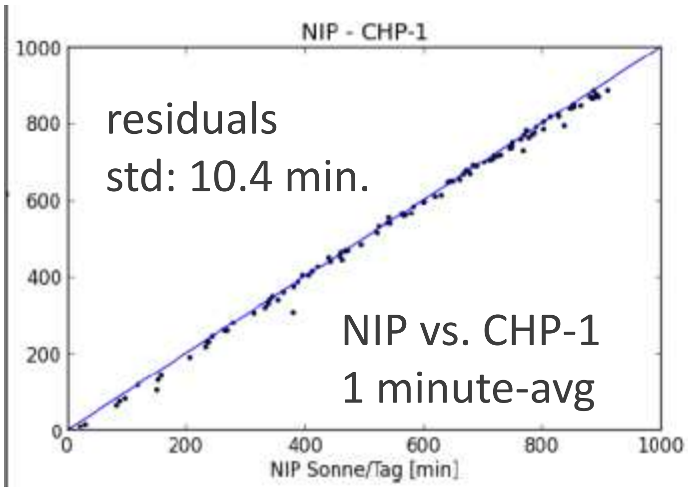
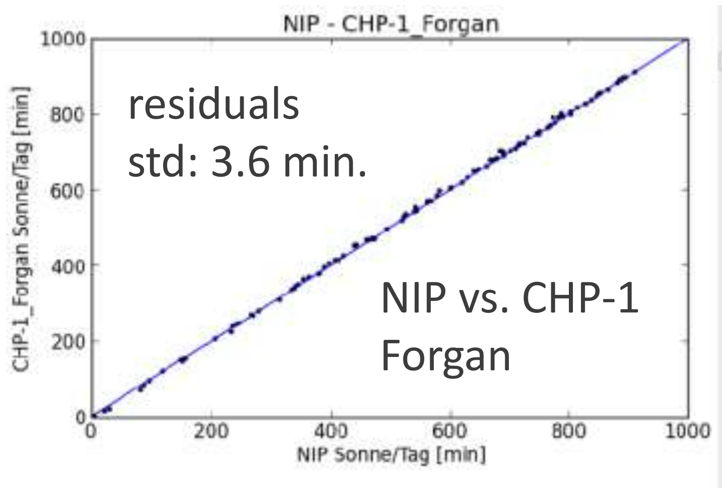
ARAD: examples of data use







reduction of mean daily differences:
1.8 % (8.9 min.) → 0.8 % (3.7 min.)

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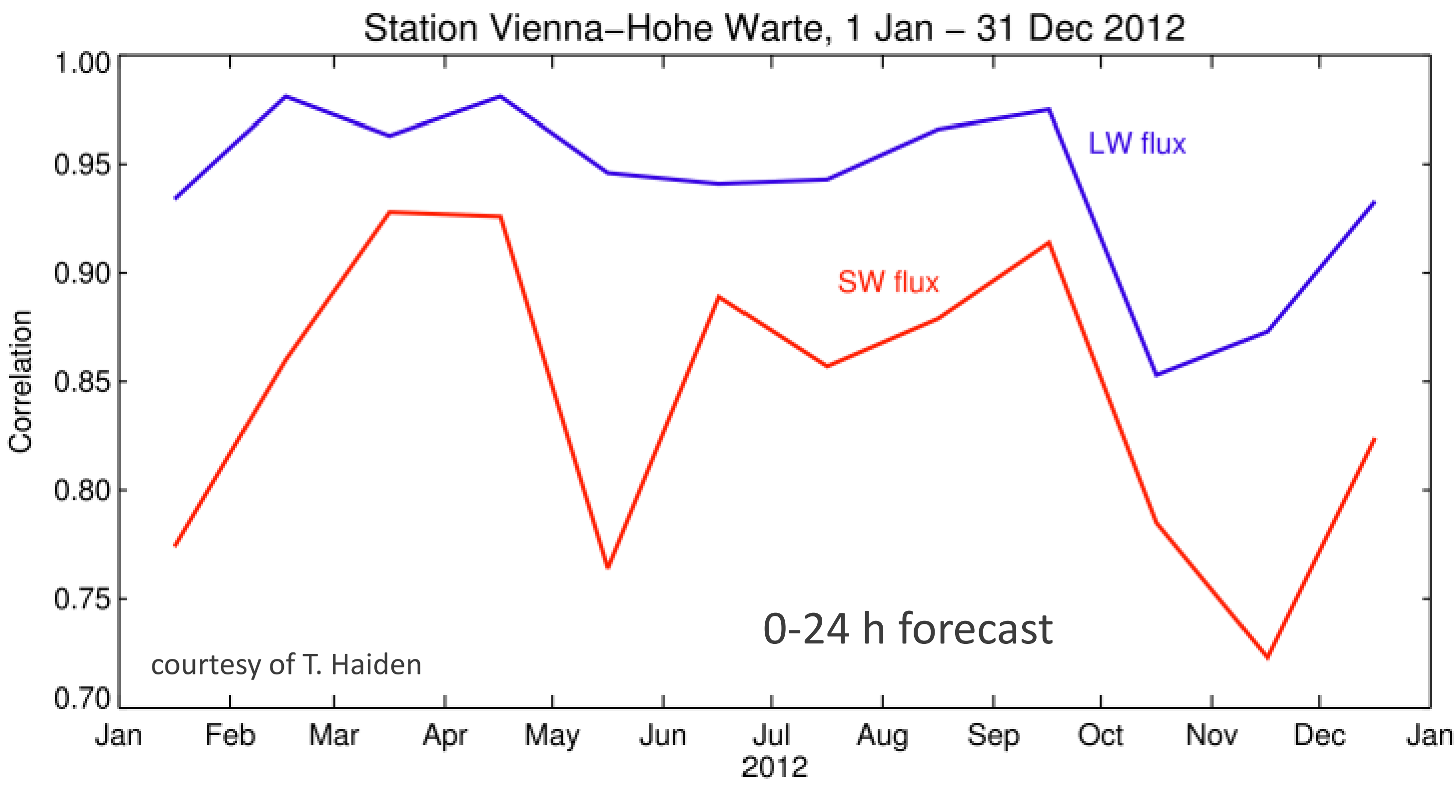
ARAD: examples of data use

validation of ECMWF forecasts (T. Haiden)



- monitoring of the operational forecast
- evaluation of new model versions

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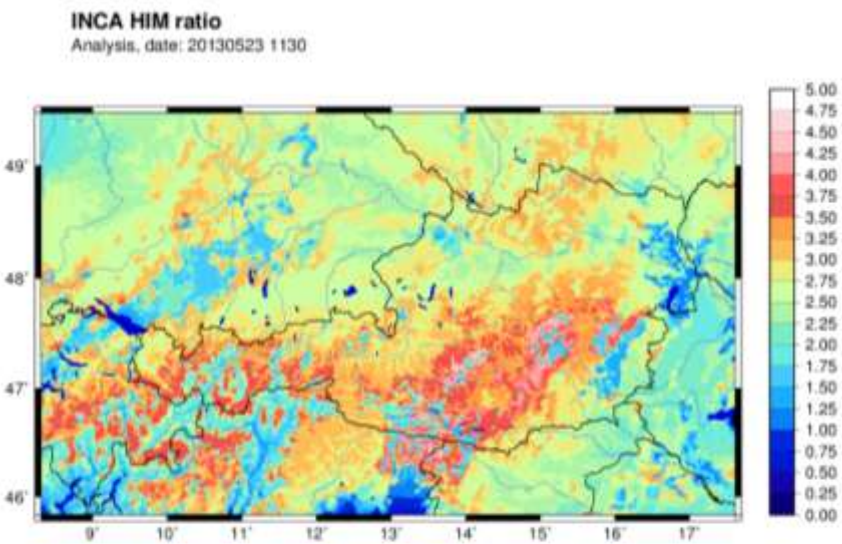
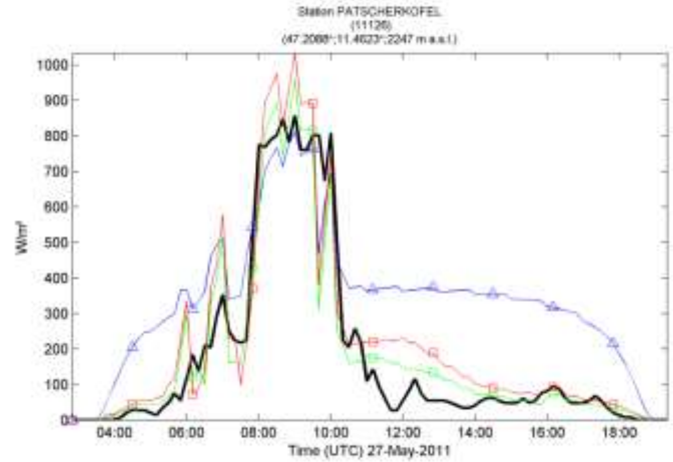
ARAD: examples of data use

analysis and forecasts of radiation and snow





- new cloud parameterization scheme for diffuse solar radiation of solar radiation model STRAHLGRID relating MSG-2 satellite cloud types to the ratio of all-sky measured to clear-sky modelled diffuse radiation

- also used in operational snow cover model SNOWGRID

- added-value of ARAD data for Alpine hydrology and cryosphere

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ARAD: visual impressions of station Sonnblick

What makes it such a special place ?

- ✓ only summit observatory of the earth above 3000 m, continuously active for 125 years!
- ✓ uninterrupted meteorological time-series since 1886
- ✓ today: modern transdisciplinary, environmental observatory (GAW site)

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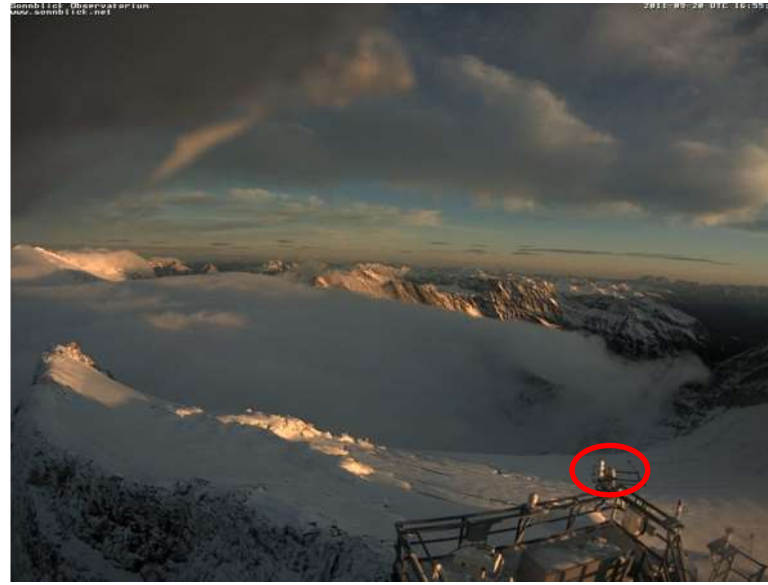
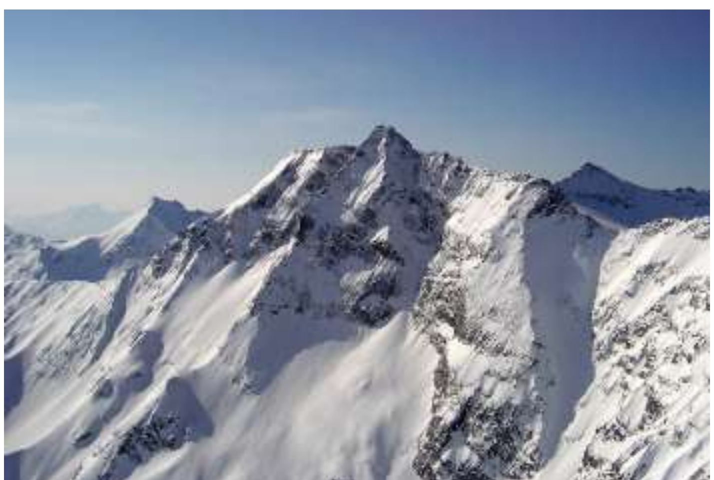
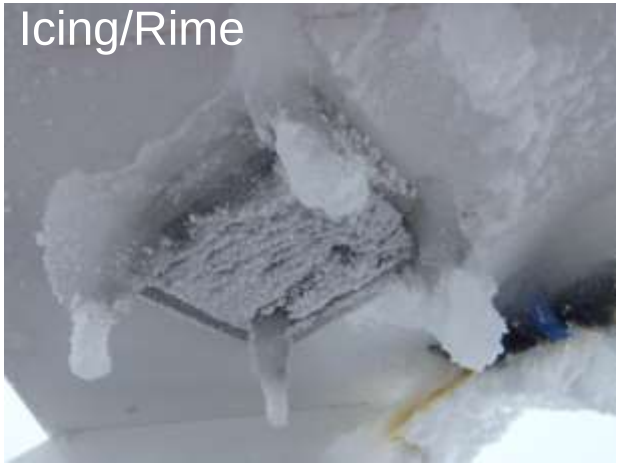
ARAD: visual impressions of station Sonnblick



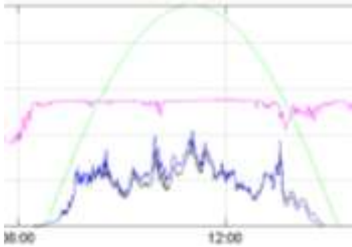


ARAD: special modifications at Sonnblick

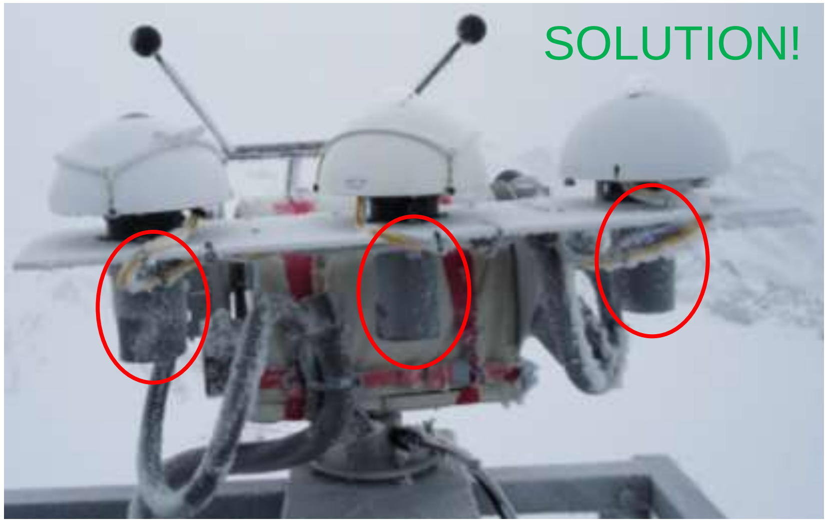


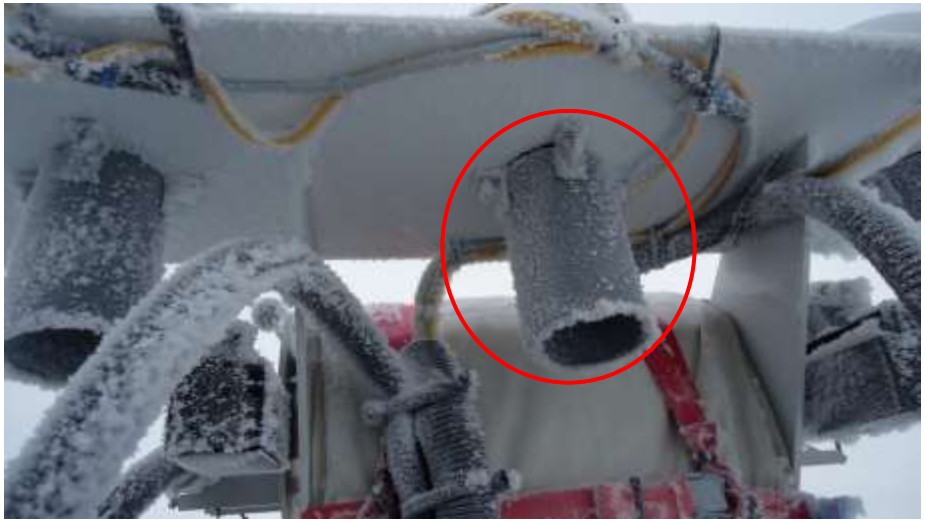
original inlet of heating/ventilation unit (grid) beneath the sensor platform

lead to reduced airflow and thus to ice formation around glas domes



measurment errors difference GLO vs. DIF





ARAD: special modifications at Sonnblick

What is the main problem for data quality at Sonnblick?

7 MAR 2013, 06:45 UTC, T -6°C, RH 94%, 61 km/h SW,

„medium to strong“ rime event

Hoarfrost!

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ARAD: special modifications at Sonnblick

pyrheliometer with heated front window (24 V/2 W heating power)
good confidence in thermal offsets: 94 % of DNI nighttime values >= -1 W/m²

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ARAD: summary

- ✓ ARAD comprises currently 5 stations following largely BSRN quality standards
- ✓ Sonnblick (3106 m a.s.l.) is BSRN station since 2013
- ✓ ARAD as example for state-of-the-art radiation monitoring at national level
- ✓ detailed uncertainty estimates can give valuable insights into possible improvements
- ✓ large combined expanded uncertainties for small signals of GLO (~50 W/m^2) are due to directional errors and can be corrected using the calibration certificates
- ✓ combined expanded uncertainties should be provided operationally to all users
- ✓ the BSRN target accuracy for DIR can only be achieved with improved instrumentation

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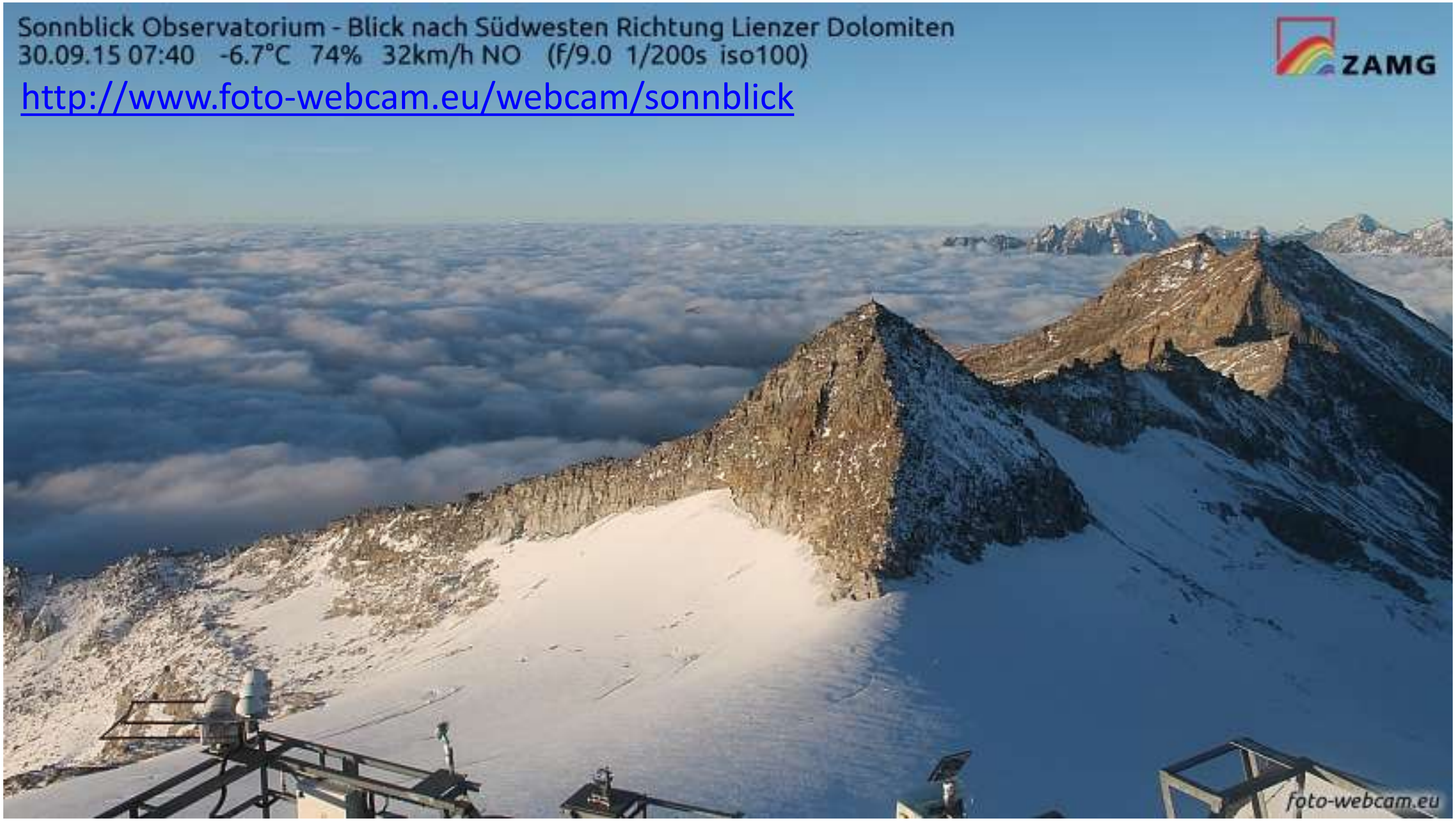
thank you very much for your attention!



http://www.foto-webcam.eu/webcam/sonnblick

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