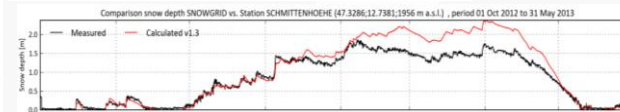
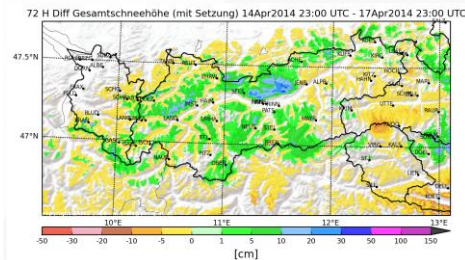
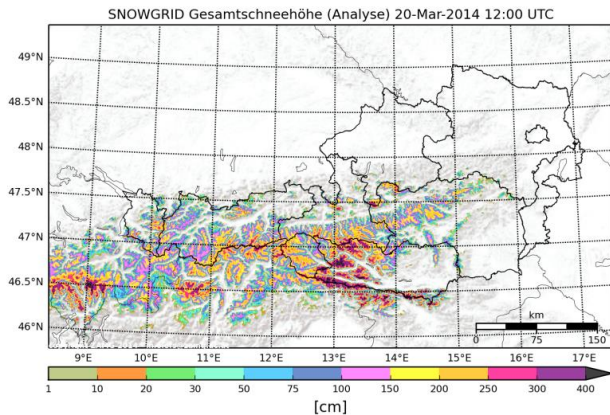


Operational snow cover modelling

Use of CryoLand Products for spatial validation at ZAMG



ZAMG
Zentralanstalt für
Meteorologie und
Geodynamik

M. Olefs¹, H. Bamberger², A. Kann³, C. Wittmann³, F. Meier³, J. Haslhofer⁴,
B. Niedermoser⁴, A. Neururer⁵, A. Studeregger⁶, A. Beck⁷, N. Blaumoser⁸

ZAMG – Zentralanstalt für Meteorologie und Geodynamik, ¹DMM-KLFOR, ²IT-APP, ³DMM-VHMOD,

⁴KS-KSSBG, ⁵KS-KSIBK, ⁶KS-KSGRZ, ⁷KS-KSOST, ⁸DMM-GEOPH.

Motivation for operational snow cover modeling

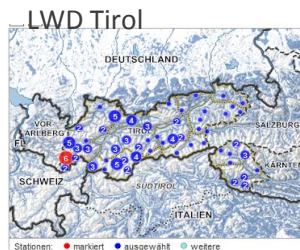
Situation until 2013

- Insufficient informations about spatial distribution of seasonal snow in AT (in-situ point measurements e.g. AWS, HS, HPC,...)
Satellite (no reliable quantitative information in Alps and only during clear-sky)
- Need for a spatially distributed snow cover model over entire AT

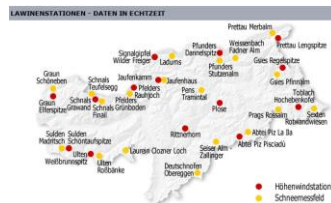
point measurements...

Sat data...

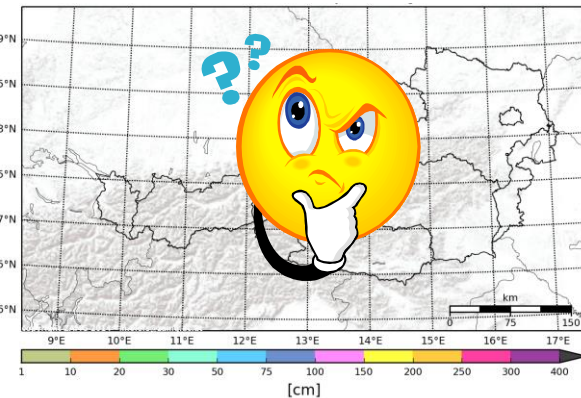
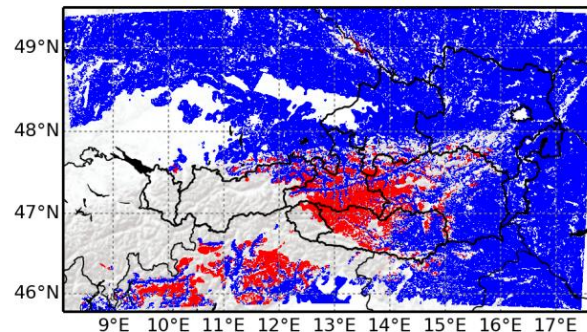
The spatial distribution of snow...



LWD Autonome Provinz Bozen - Südtirol



'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



Simple snow models can help combining the best of both worlds!

SNOWGRID: Overview



- Operational spatially distributed snow cover model with high spatial (100 m) and temporal (15 Minuten) resolution for INCA-L grid (Zürich-Bratislava, Nürnberg-Triest = ca. 28 Mio. Punkte!)
- Near realtime (Analysis), Reanalysis (back to Jan 2006) und forecast (ALARO/AROME up to +72 h)
- Upper BC: Meteo. Input from INCA. Lower BC: INCA ground temps
- Simple degree-day scheme and more complex energy balance mode, simple 2-layer snow model (swe-driven, considering e.g. time-variable heat content, snowline depression, settling), state variables are: swe, snow depth, average snow temp, liquid water content
- Topography: 100 m DEM (corrected NASA SRTM3 + add. Data)
- Calibration/Validation: >50 in-situ snow depth ground stations (ZAMG/AWS), 5 swe > 200 manual swe/snow depth meas. (since 2011), MODIS FSCA, data from HS,...
- Output grids: snow depth, SWE, average snow temp (+new snow in forecast mode)
- Current use of cryoland data: spatial validation only

Spatial validation with cryoland data: method

- Main product: MODIS FSCA, daily receipt of geotiff via ftp for INCA-L grid in EPSG31287, afternoon of same day
- Methodology: Following the guidelines and methods of snow extent validation concept - GLOBSNOW (Bippus et al., 2014; chapter 6)
- Methodology: need to convert model snow depth and satellite FSCA into common variable : binary snow covered area (BSCA) for each pixel
- Conversion of model snow depth into BSCA using 2 thresholds: 1, 15 cm
- Conversion of MODIS FSCA into BSCA using 2 thresholds: 15, 50 %
- Calculation of statistical parameters (POD, FAR (snow/no snow), Hit rate, Kuipers Skill
→ 4 Values for each score for every day **if > 50 %** of valid sat data available in INCA-L.

Spatial validation with cryoland data: method

Calculation of statistical parameters using a contingency table

Szenario	SNOWGRID Schnee	SNOWGRID kein Schnee
MODIS FSCA: Schnee	a	b
MODIS FSCA: kein Schnee	c	d

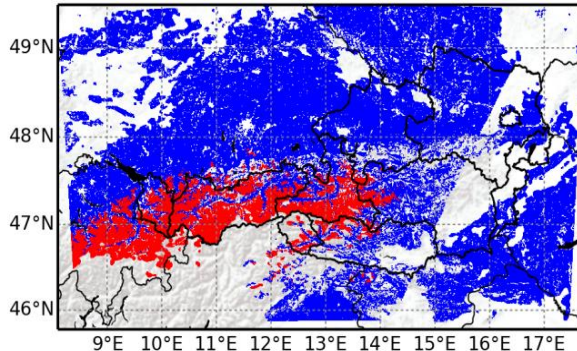
$$KSS = \frac{(a * d - c * b)}{((a + b) * (c + d))}$$

Binary Map of Snow Cover - Comparison of 'MODIS FSCA' & 'SNOWGRID' -

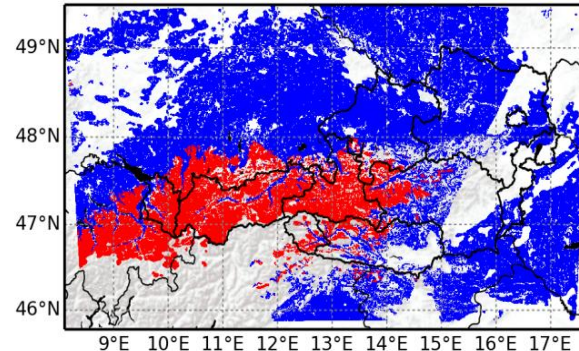
13-Oct-13 1200 UTC

(excluding clouds, forests, water bodies and glaciers)

'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



'SNOWGRID' Snow Depth (SD)
- Threshold: 1.0 cm SD -



13 October 2013
SNOWGRID overestimates
Early snow cover ->
Missing ground heat flux



POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	HR	KSS
0.857	0.987	0.617	0.001	0.986	0.844

Spatial validation with cryoland data: results

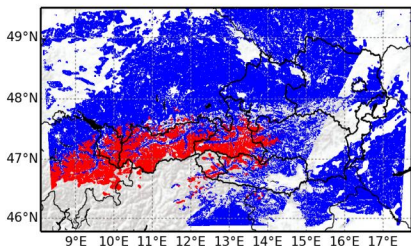
Oct

Binary Map of Snow Cover - Comparison of 'MODIS FSCA' & 'SNOWGRID' -

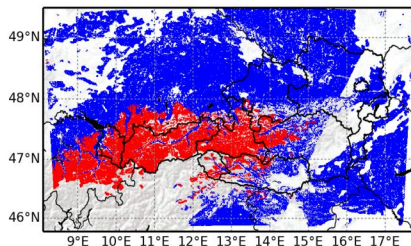
13-Oct-13 1200 UTC

(excluding clouds, forests, water bodies and glaciers)

'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



'SNOWGRID' Snow Depth (SD)
- Threshold: 1.0 cm SD -



POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	HR	KSS
0.857	0.987	0.617	0.001	0.986	0.844

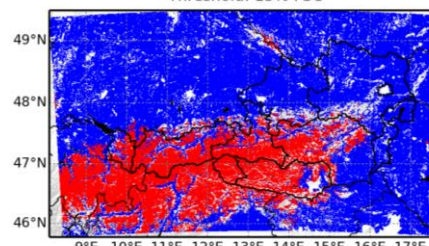
Feb

Binary Map of Snow Cover - Comparison of 'MODIS FSCA' & 'SNOWGRID' -

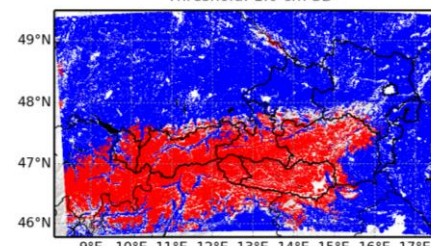
24-Feb-14 1200 UTC

(excluding clouds, forests, water bodies and glaciers)

'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



'SNOWGRID' Snow Depth (SD)
- Threshold: 1.0 cm SD -



POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	HR	KSS
0.971	0.969	0.081	0.011	0.97	0.94

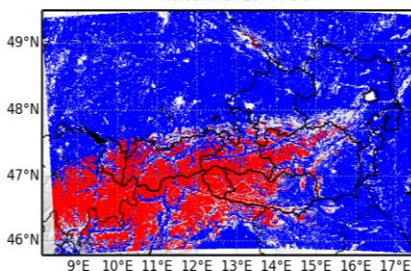
Mar

Binary Map of Snow Cover - Comparison of 'MODIS FSCA' & 'SNOWGRID' -

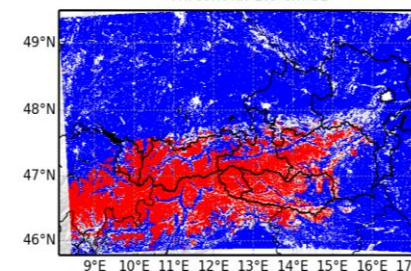
14-Mar-14 1200 UTC

(excluding clouds, forests, water bodies and glaciers)

'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



'SNOWGRID' Snow Depth (SD)
- Threshold: 1.0 cm SD -



POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	HR	KSS
0.944	0.977	0.073	0.018	0.969	0.921

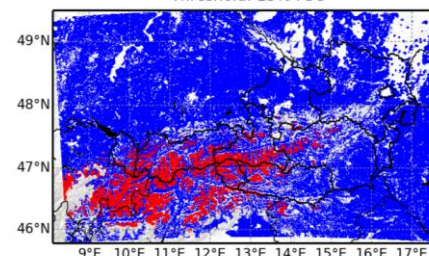
May

Binary Map of Snow Cover - Comparison of 'MODIS FSCA' & 'SNOWGRID' -

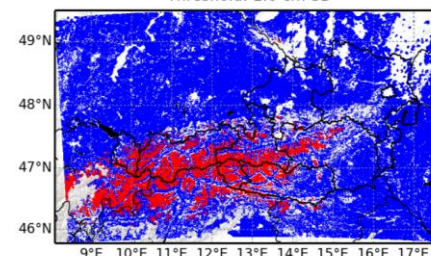
05-May-14 1200 UTC

(excluding clouds, forests, water bodies and glaciers)

'MODIS' Fractional Snow Cover (FSC)
- Threshold: 15% FSC -



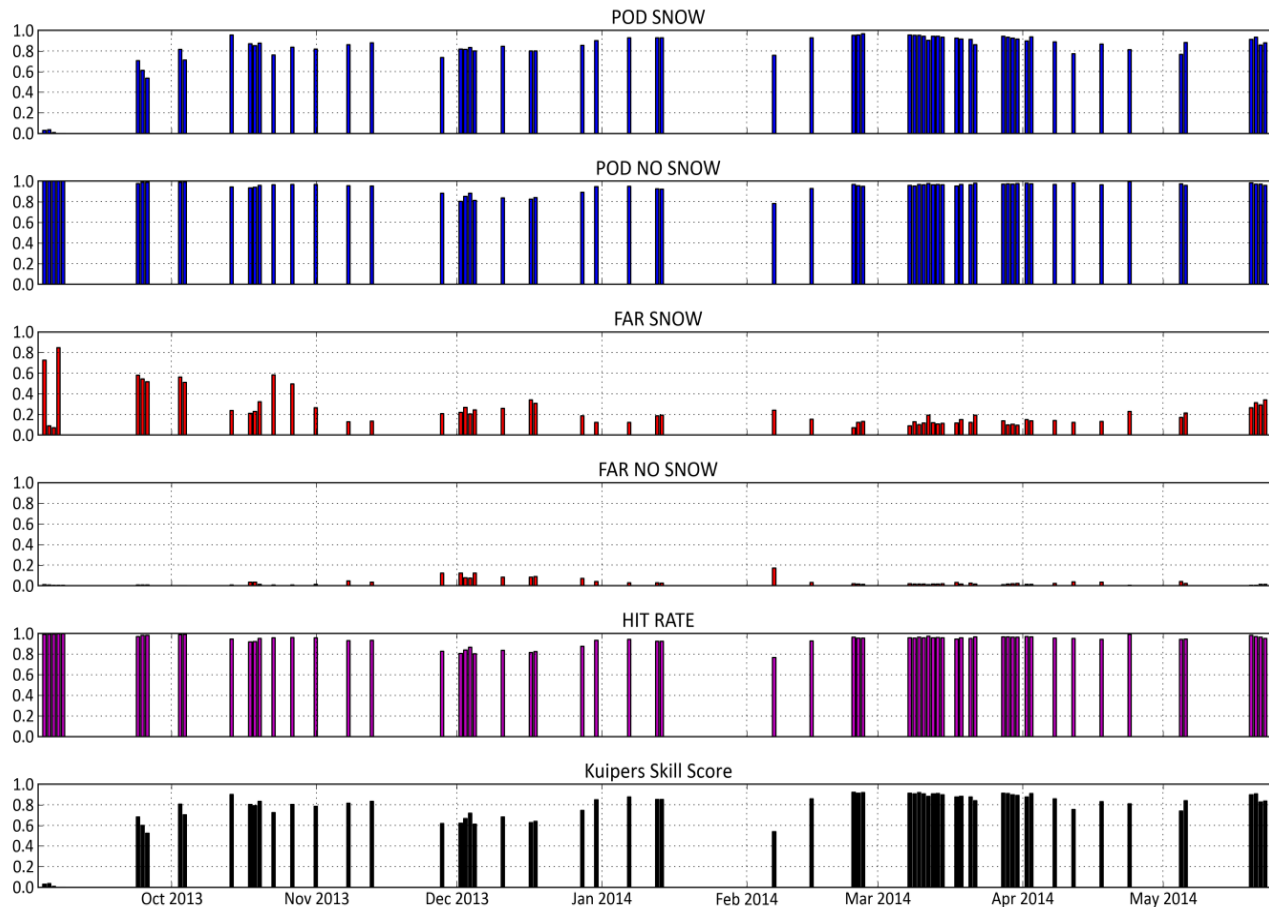
'SNOWGRID' Snow Depth (SD)
- Threshold: 1.0 cm SD -



POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	HR	KSS
0.898	0.967	0.158	0.02	0.955	0.864

Spatial validation with cryoland data: results

Season 2013/14 (SD tresh = 1 cm; FSCA tresh = 15 %)



Winter season 13/14
Oct-May
67 evaluable days

Defined sat data here as
„the truth“

Spatial validation with cryoland data: results



Season 2013/14: average statistical parameters over 67 days
4 threshold combinations

Datum	# Days < 50 % Cloudiness	SD Tresh [cm]	FSC Tresh [%]	POD_snow	POD_nosnow	FAR_snow	FAR_nosnow	Hit Rate	Skill Score
SNOWGRID									
Sep 13 - Mai 14	67	1	15	0,848	0,944	0,215	0,019	0,949	0,792
Sep 13 - Mai 14	67	1	50	0,874	0,909	0,353	0,010	0,924	0,783
Sep 13 - Mai 14	67	15	15	0,717	0,983	0,125	0,056	0,945	0,700
Sep 13 - Mai 14	67	15	50	0,762	0,956	0,259	0,036	0,939	0,719
Average				0,800	0,948	0,238	0,030	0,939	0,749
STARTCLIM MODEL	Mittel 2003, 2004, 2006 (noforest)	1	15	0,770	0,790	0,270	0,180	0,890	0,560
		1	50	0,650	0,850	0,230	0,240	0,870	0,500



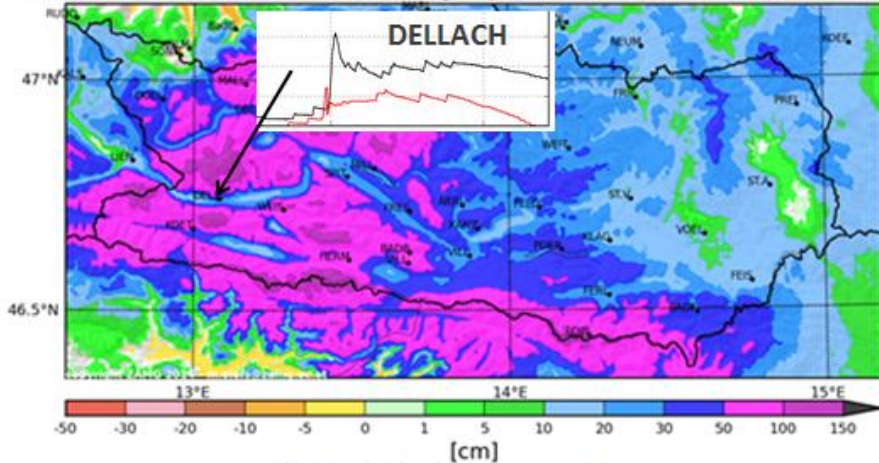
Average over 67 days (2013/14) : Skill score = 0.75
(compared to 0.53 for old very snow model using station data (GLOBSNOW comp))

Regional validation of snowline depression effect



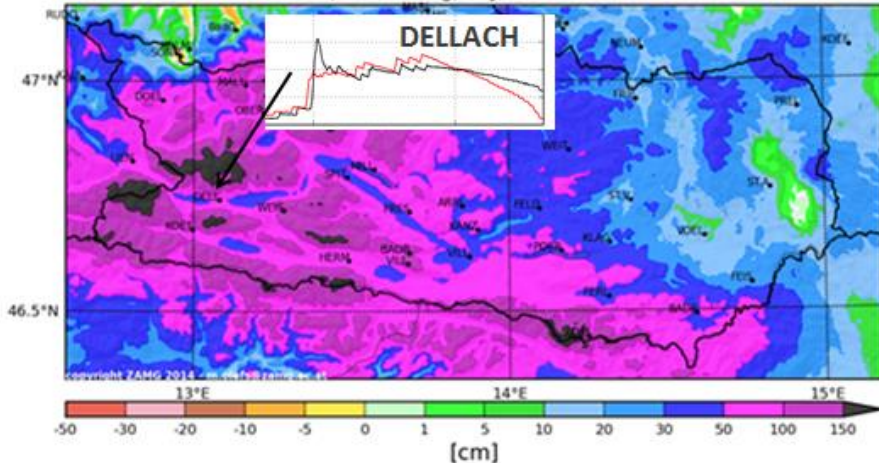
SNOWGRID ohne prec cooling

96 H Diff Gesamtschneehöhe (mit Setzung) 30Jan2014 07:00 UTC - 03Feb2014 07:00 UTC



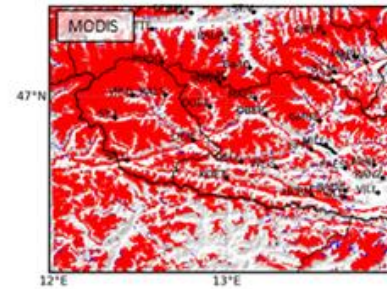
SNOWGRID mit prec cooling

96 H Diff Gesamtschneehöhe (mit Setzung) 30Jan2014 07:00 UTC - 03Feb2014 07:00 UTC

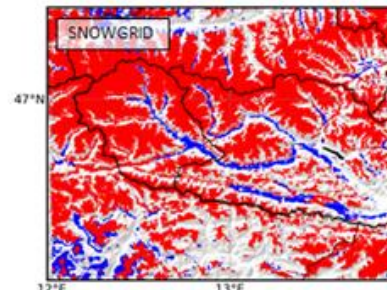


**Binäre Schneebedeckung
Kärnten/Osttirol, 14.3.2014**

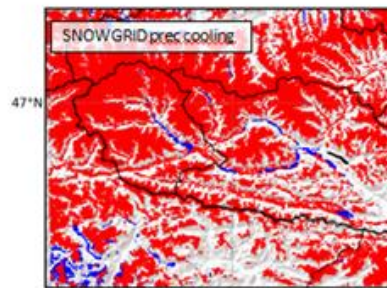
[2]



Satellitendaten
MODIS FSCA



SNOWGRID
ohne prec cooling



SNOWGRID
mit prec cooling



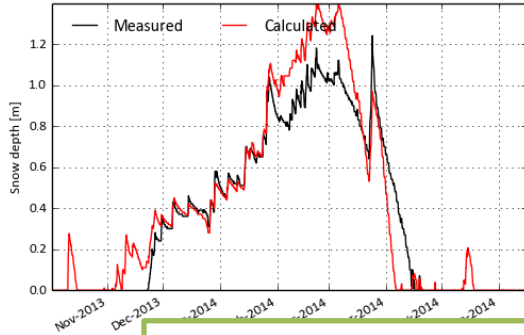
Schneefrei

Schneebedeckt

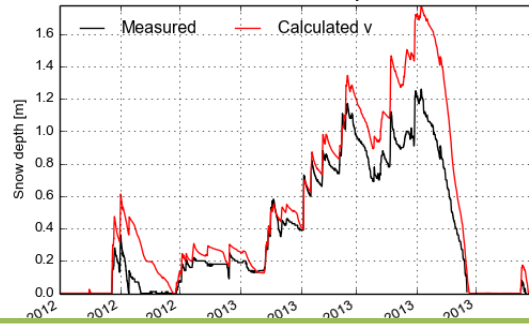
SNOWGRID: Validierung Punkte (Zeitreihen)

Comparisons with in-situ snow-depth time-series

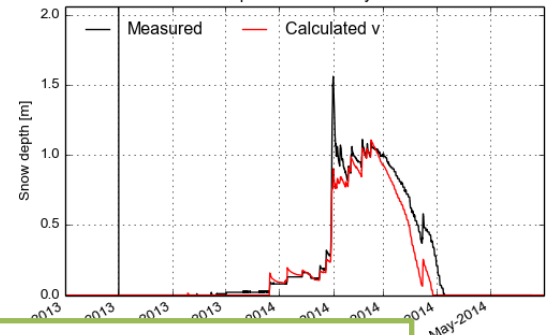
SNOWGRID vs. Station LECH_ARLBERG (47.21°N;10.1408°E;1442 m a.s.l.)
02 Oct 2013 to 16 Jun 2014



SNOWGRID vs. Station KANZELHOEHE (46.6772°N;13.9019°E;1520 m a.s.l.)
01 Oct 2012 to 31 May 2013



SNOWGRID vs. Station DELLACHIMDRAUTAL (46.7419°N;13.0828°E;628 m a.s.l.)
01 Sep 2013 to 31 May 2014

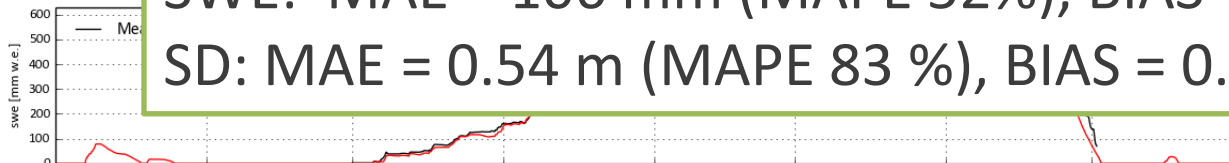


Overall performance (3 seasons):

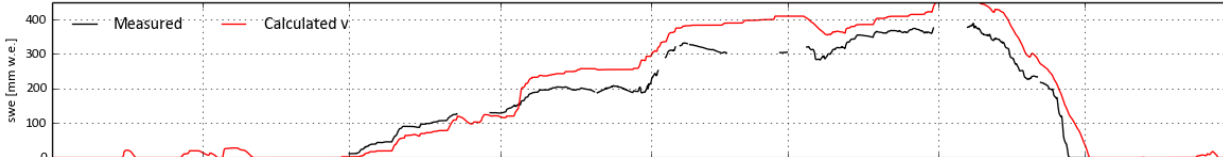
SWE: MAE = 106 mm (MAPE 52%), BIAS = 28 mm

SD: MAE = 0.54 m (MAPE 83 %), BIAS = 0.5 m

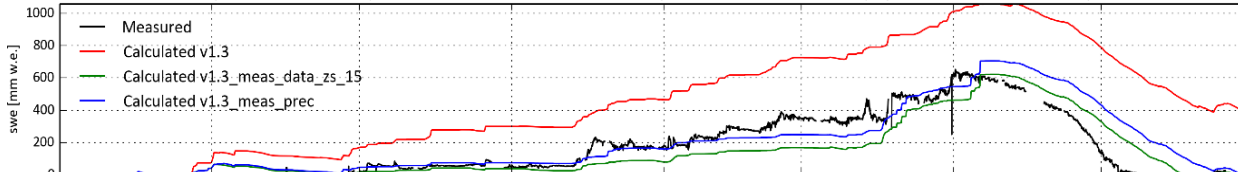
SWE



Comparison snow water equivalent SNOWGRID vs. Station Kuehrint (47.5769;12.9613;1420.0 m a.s.l.) , period 01 Oct 2012 to 31 May 2013



Comparison snow water equivalent SNOWGRID vs. Station Selenitza (46.429;14.2333;1536 m a.s.l.) , period 01 Oct 2012 to 31 May 2013

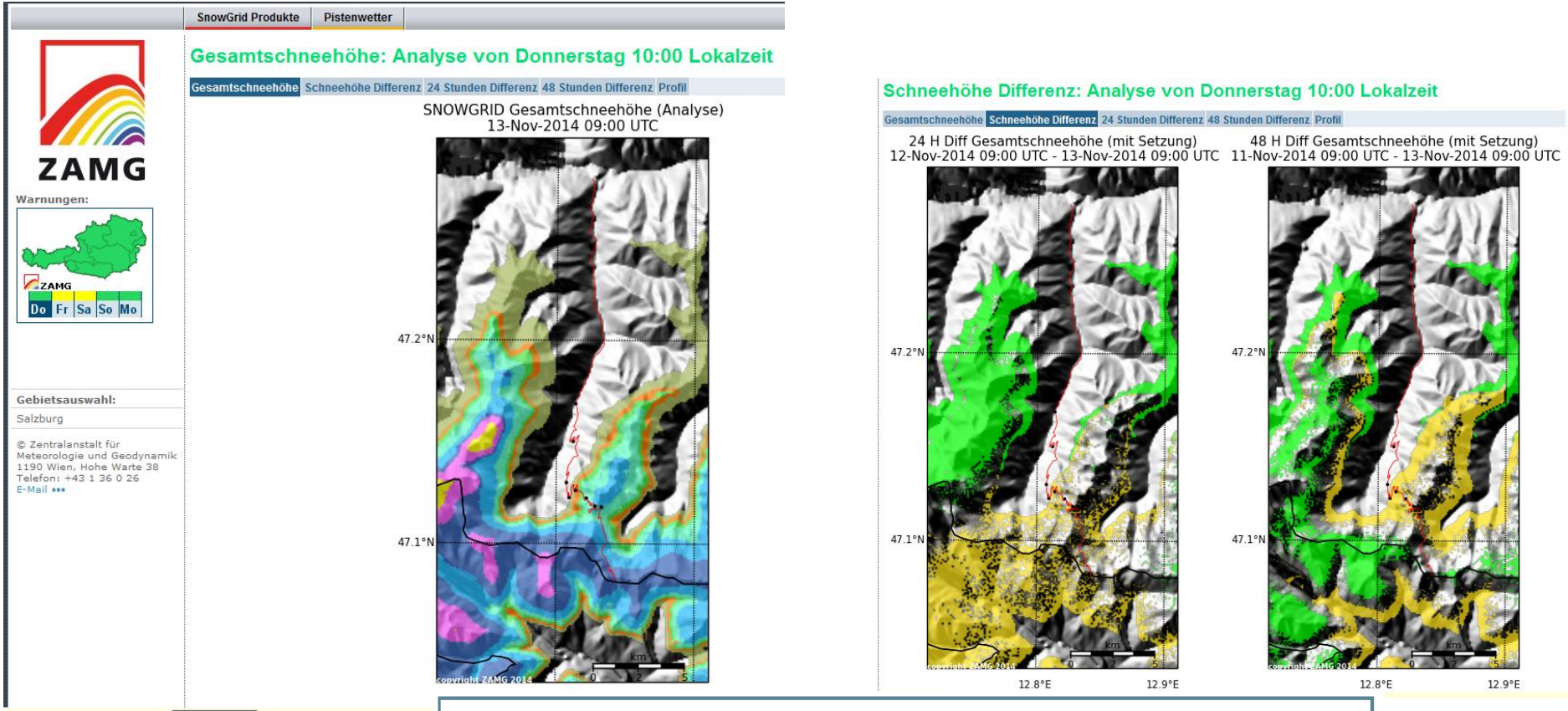


Kührint 12/13

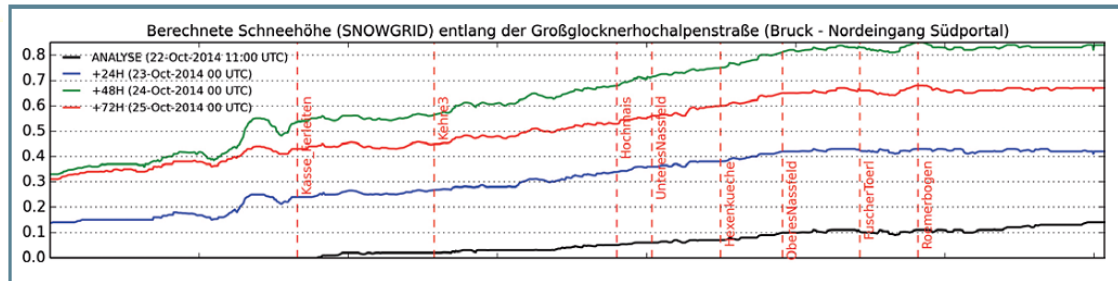
Selenitza 12/13

SNOWGRID: product example

Operational high alpine road weather product



Automated analysis & forecast
Of snow depth
along the road

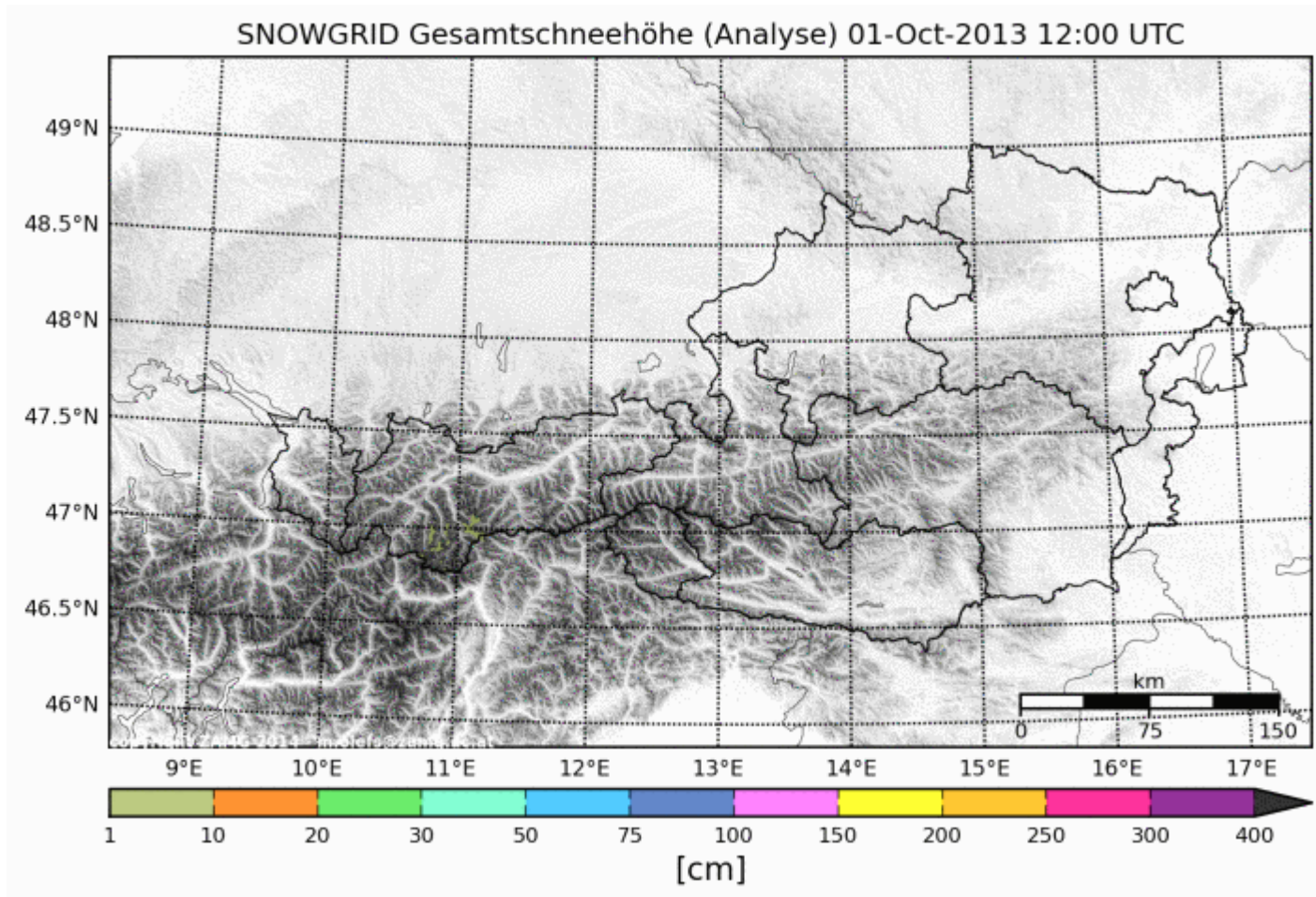


Conclusions and outlook



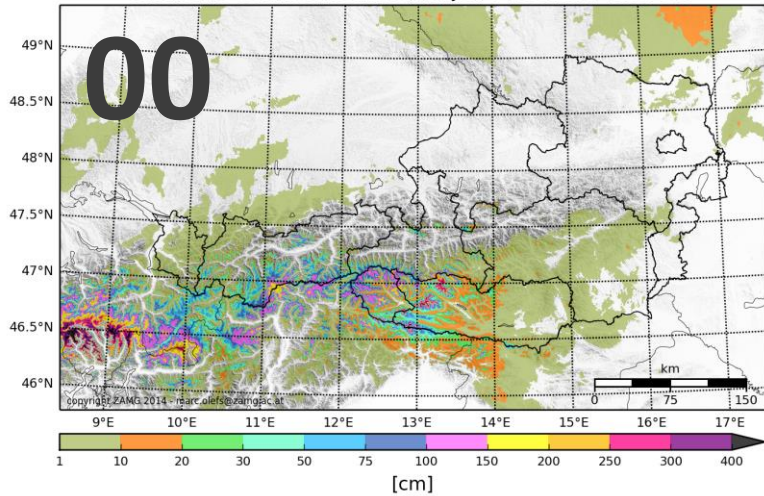
- ❖ Cryoland data are a very valuable and essential tool to:
 - (1) assess the spatial performance of the operational SNOWGRID model
 - (2) detect greatest weak points in the model
 - (3) improve individual processes in the model (e.g. snowline depression)
- ❖ Very good agreement between converted MODIS FSCA and SNOWGRID data (skill score = 0.75)
- ❖ Possible future use: coming soon: feasibility study of assimilation procedures of model data using sat and in-situ ground data (e.g. set the model snow mass to 0 if sat snow = 0)
- ❖ Continue evaluations considering the added-value of initializing high resolution NWP models (ALARO, AROME: 4.8 – 1 KM) with modelled snow cover (calibrated and/or corrected with sat data)
- ❖ Looking forward for: higher spatial resolution (sentinel), snow wetness, snow surface temp
- ❖ Benefit for large spectrum of users/customers:
Avalanche warning services, HS, HPC, road services, tourism

SNOWGRID: Animation Saison 2013/14

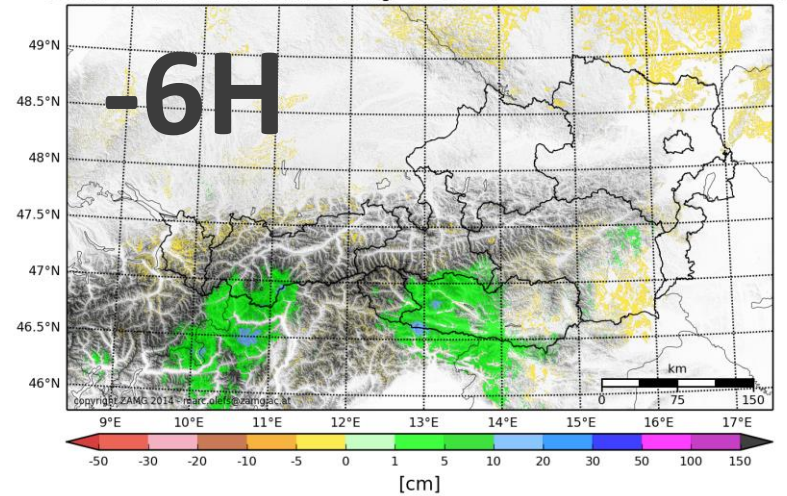


Thanks a lot for your attention!

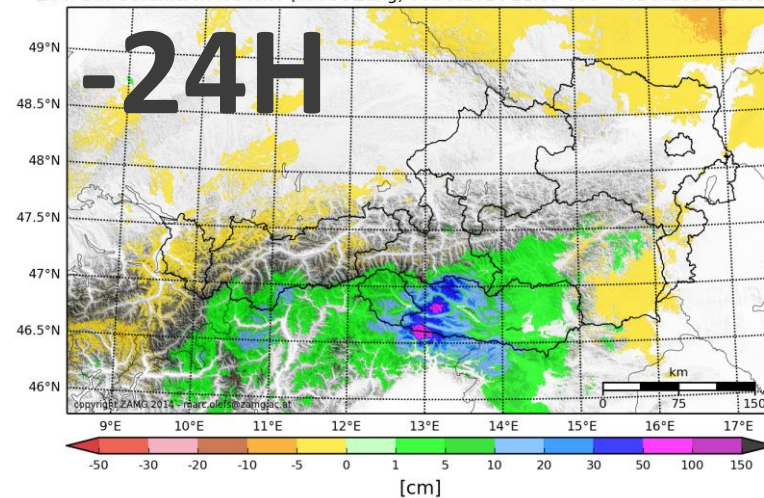
SNOWGRID Gesamtschneehöhe (Analyse) 04-Dec-2014 10:00 UTC



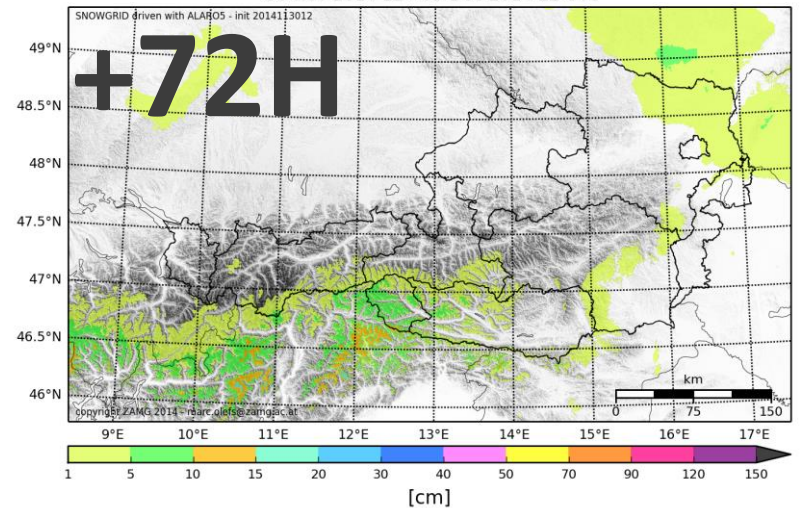
6 H Diff Gesamtschneehöhe (mit Setzung) 04Dec2014 04:00 UTC - 04Dec2014 10:00 UTC



24 H Diff Gesamtschneehöhe (mit Setzung) 03Dec2014 11:00 UTC - 04Dec2014 11:00 UTC



72-H Prognose kumulative Neuschneesumme (Schneehöhe; mit Setzung, ohne Schmelze)
30-Nov-2014 12 - 03-Dec-2014 12 UTC



marc.olefs@zamg.ac.at