A BLENDED HIGH RESOLUTION SNOW DEPTH ANALYSIS FOR NEXT GENERATION GLOBAL PREDICTION SYSTEM

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NGGPS PI MEETING

August 7, 2018

Project Team

- ***Dr. Cezar Kongoli (PI), ESSIC, University of Maryland College Park; Dr. Peter Romanov Co-I, NOAA-CREST, City University of New York***
- ***NOAA/NCEP Collaborators: Michael Ek and Jiarui Dong***
- ***Other Collaborators: Thomas Smith (NOAA/NESDIS), Ivan Csiszar (NOAA/NESDIS)***
- ***NOTE: Mike EK left NOAA, new NCEP POCS: Helin Wei and Jack Kain***

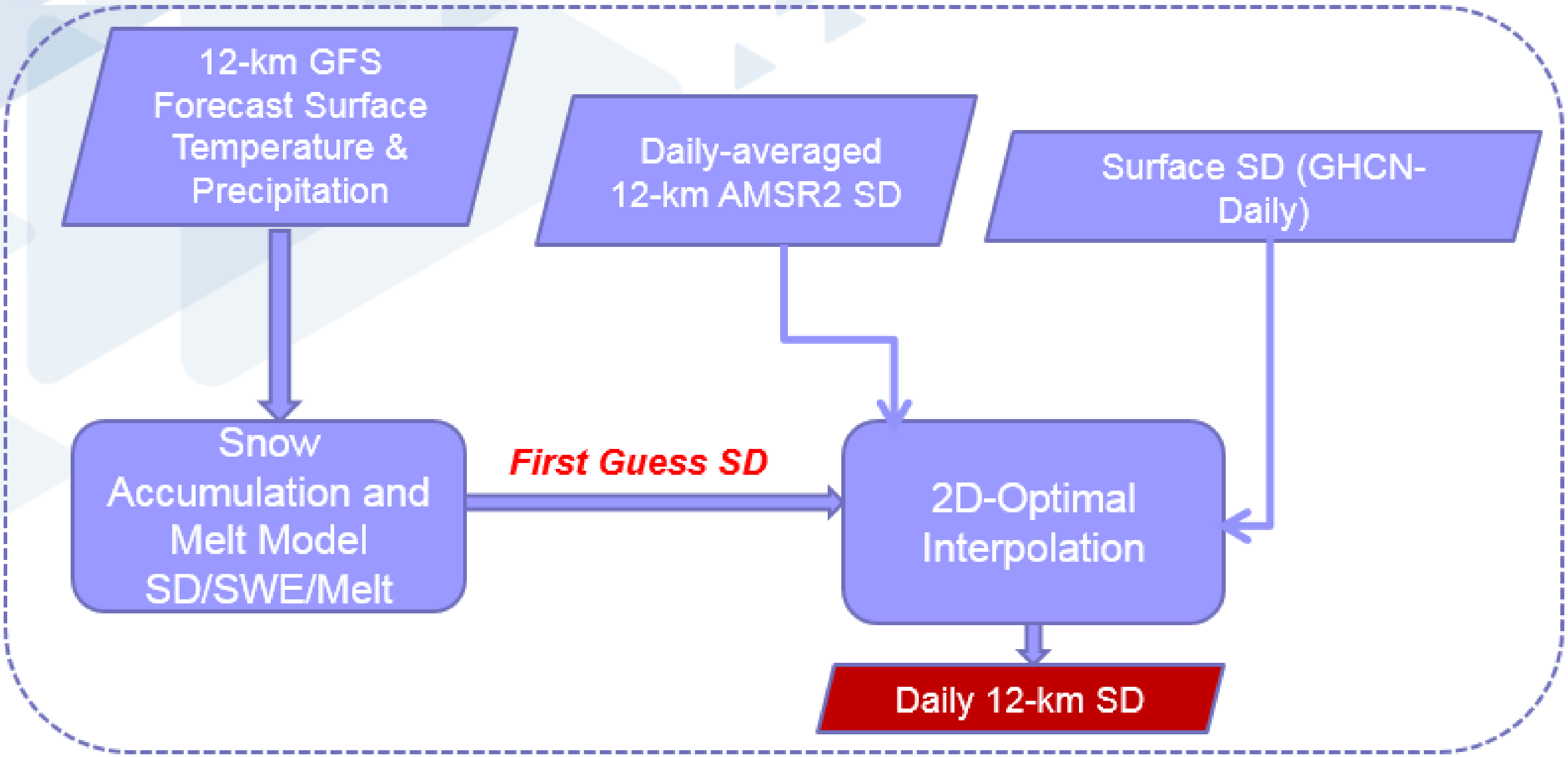
MOTIVATION

- NCEP GFS/CFS/NAM use 25-km USAF SNODEP product and 4-km NOAA's **I**nteractive **M**ulti-sensor **S**now and Ice Mapping system (IMS) to improve the accuracy of LSM (Noah)-modelled snow depth (SNODEP) and snow covered area (IMS).

- Positive impact of assimilated observations of snow depth and snow cover area on predicted meteorological variables.

- GOAL: Develop a blended data assimilation-based snow depth (SD) analysis with improved accuracy and resolution.

DEVELOPED BLENDED ANALYSIS SCHEME



- 2D-Optimal Interpolation of in-situ SD in operational NWP at Environmental Canada (since 2000) and currently at ECMWF and JMA;
- Kalman-Filter based DA in NASA's Land Information System

2-DIMENSIONAL OPTIMUM INTERPOLATION

- **SD** increment *at analysis point k* Δ***SD$_k$*** is computed as the weighted average of observed increments Δ***SD$_i$*** surrounding *k*:

$$\Delta SD_k = \sum_{i=1}^{N} w_i \Delta SD_i$$

*ΔSD_i is the difference between the **observed SD** and the **first guess SD** at each observation point i [i = 1, N]*

- The vector of optimum weights at ***k*** is given by solving the set of N linear equations of the matrix form:

$$\underline{w} = (\underline{B} + \underline{O})^{-1} \underline{b}$$

$\underline{B}$ *is correlation matrix of background field errors between all pairs of observations*

$\underline{b}$ *is the correlation vector of background field errors between pairs of of observations and analysis point k*

$\underline{O}$ *is the covariance matrix of observational errors (normalized by the background error variance) between all pairs of observations*

2-DIMENSIONAL OPTIMUM INTERPOLATION (CON'T)

❖ Correlation coefficients for each term in $\underline{B}$ and $\underline{b}$ are computed following *Brasnett 1999. J of Applied Meteorol.*:

$$\mu_{ij} = \alpha(r_{ij})\beta(\Delta z_{ij})$$

μ_{ij} *is the correlation coefficient between each pair of observations or between each observation and analysis point,* r_{ij} *is the horizontal distance between pairs and* Δz_{ij} *elevation difference between pairs:*

2nd order autoregressive correlation function for distance

$\alpha(r_{ij}) = A*(1 + c r_{ij}) \exp(- c r_{ij})$ $\quad c = 0.005\ km^{-1}$ *(horizontal scale ≈ 420 km; A = 0.73)*

Square exponential correlation function for elevation

$\beta(\Delta z_{ij}) = \exp(- (\Delta z_{ij}/h)^2)$ $\quad h = 450\ m$ *(vertical scale = 450 m)*

$\underline{O}$ **=** $(\sigma^2_{o}/\sigma^2_{b})$ X I *where I is the identity matrix and* $(\sigma^2_{o}/\sigma^2_{b})$ is the observation error variance normalized by the background error variance (fixed at 0.6 for in-situ data)

PROJECT STATUS

❖ Processing Algorithm Completed**:**

- ✓ GFS data processing for snowmelt model to generate first guess SD (IDL);
- ✓ Gridding AMSR2 and GFS data inputs at 12-km resolution (IDL);
- ✓ 2D-OI Algorithm to produce final product (both Fortran90 and IDL) Product generation and evaluation for 2016-2017 winter season;

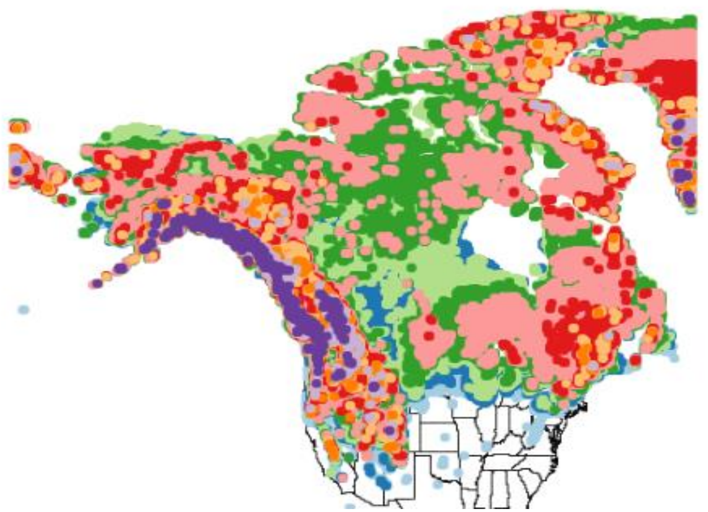
❖ Fortran 90-based 2D-OI algorithm runs much faster, approx. 5 minutes to generate one day of global product output;

❖ Highly modular and easy to apply in operational applications in the future;

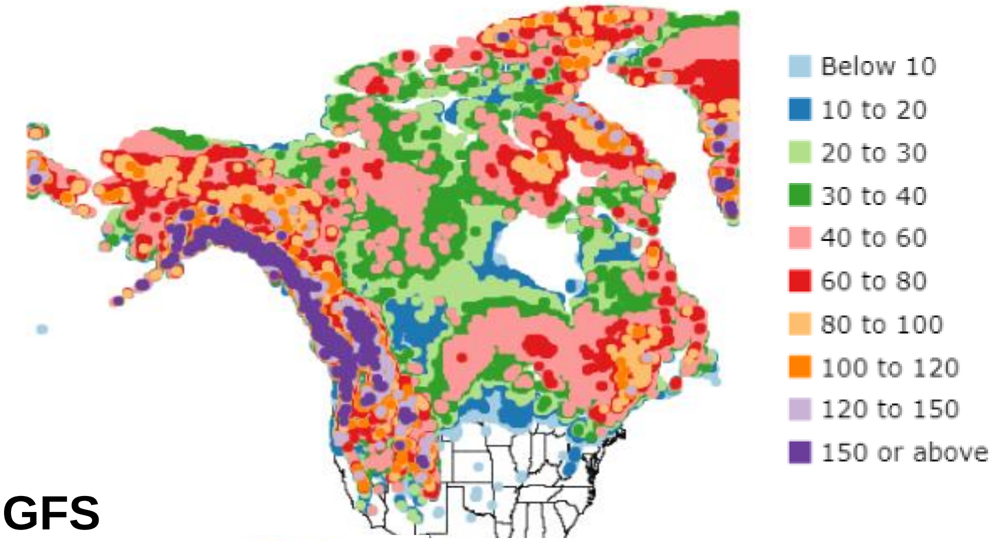
❖ Inter-comparisons with operational GFS SD product; evaluation with in-situ data (removed from input).

Example Evaluation: North America – January 1, 2017

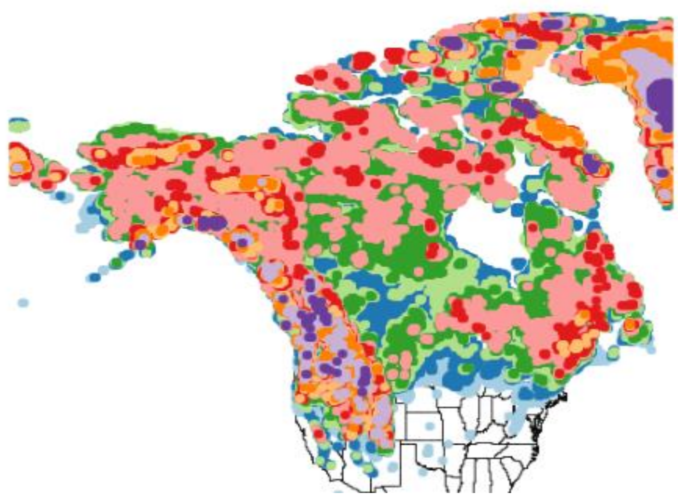
First Guess



Analysis



GFS



Elevation <= 1000 m

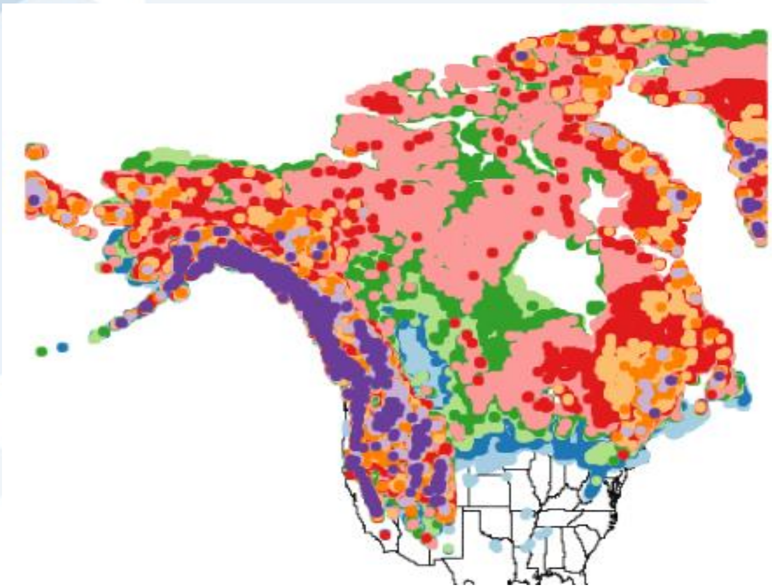
Snow Depth	Bias (cm)	RMSE (cm)
Analysis	2.1	17.0
First Guess	2.4	22.0
GFS	3.1	18.0

Elevation > 1000 m

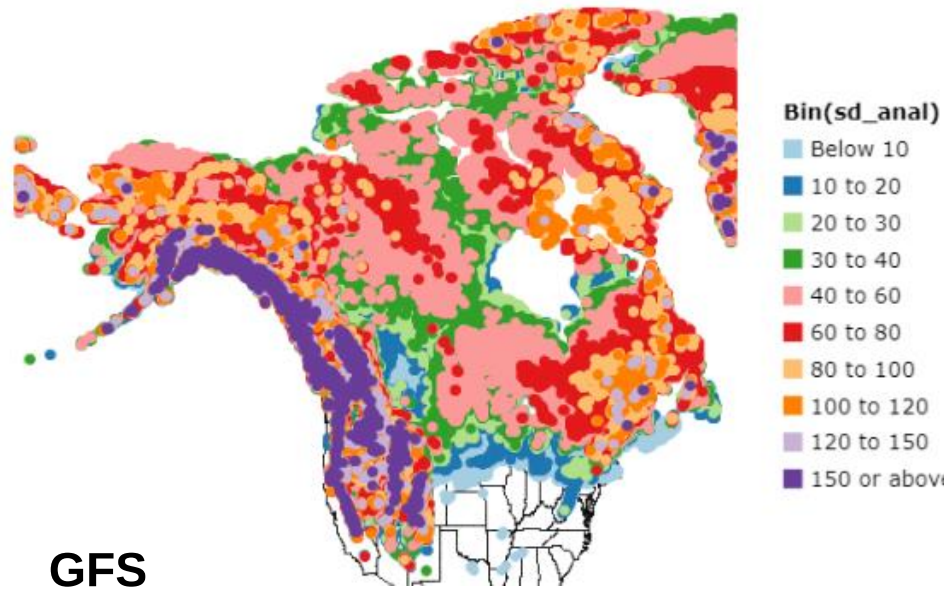
Snow Depth	Bias (cm)	RMSE (cm)
Analysis	1.9	29.0
First Guess	-5.7	27.0
GFS	5.2	23.0

Example Evaluation: North America – February 1, 2017

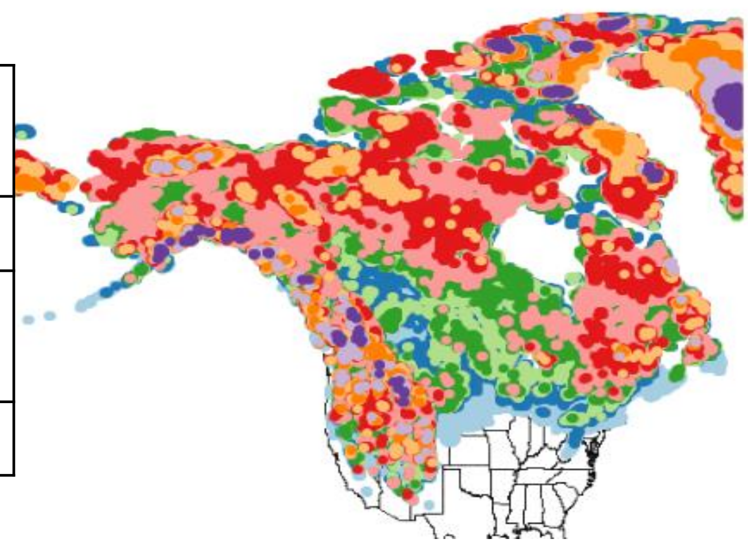
First Guess



Analysis



GFS



Elevation <= 1000 m

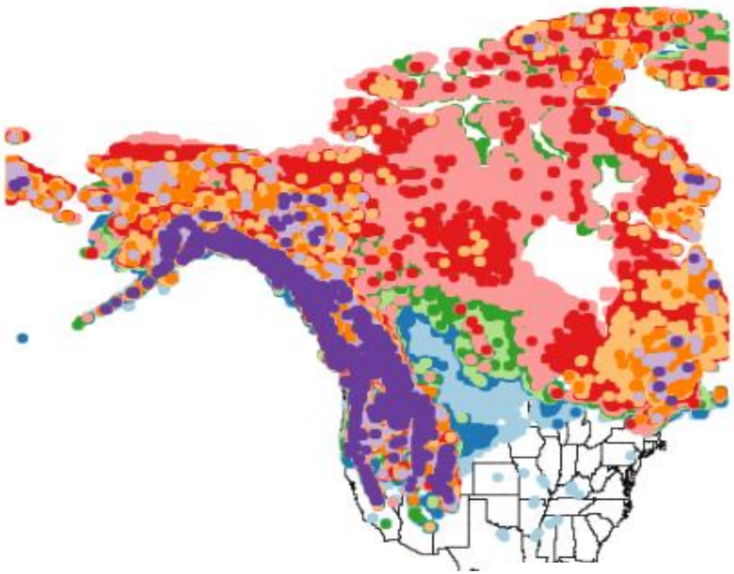
Snow Depth	Bias (cm)	RMSE (cm)
Analysis	3.4	19.0
First Guess	2.7	23.0
GFS	2.5	22.0

Elevation > 1000 m

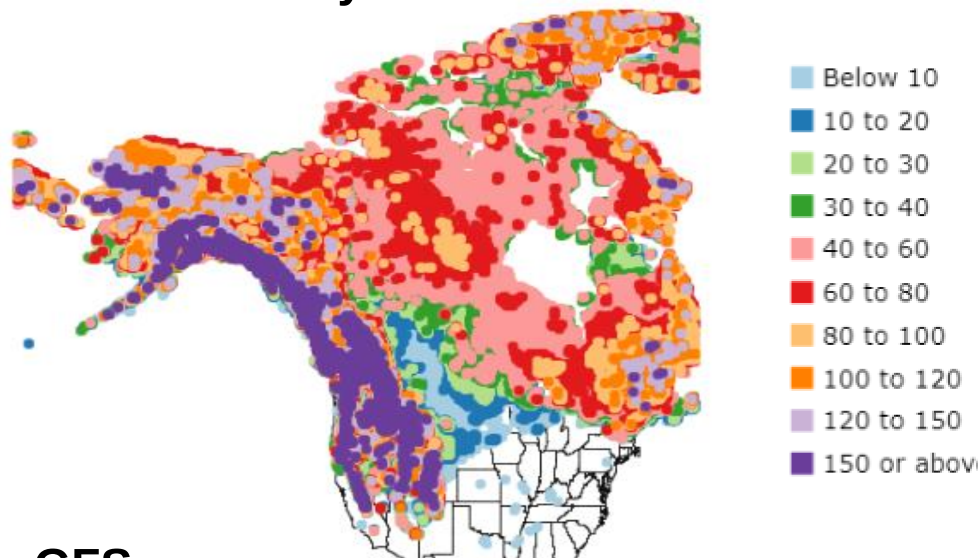
Snow Depth	Bias (cm)	RMSE (cm)
Analysis	-2.1	36.0
First Guess	-10.0	37.0
GFS	-32.0	57.0

Example Evaluation: North America – March 1, 2017

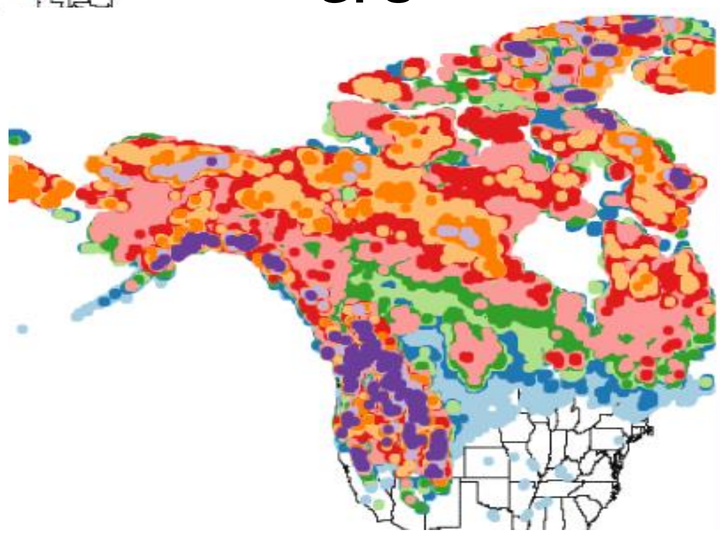
First Guess



Analysis



GFS



Elevation <= 1000 m

Snow Depth	Bias (cm)	RMSE (cm)
Analysis	1.2	27.0
First Guess	0.2	31.0
GFS	-2.0	34.0

Elevation > 1000 m

Snow Depth	Bias (cm)	RMSE (cm)
Analysis	-6.7	54.0
First Guess	-14.7	56.0
GFS	-20.2	60.0

Overall Results

Jan. 1, 2017

Snow Depth (cm)	n	Bias(Mean)	Bias(Median)	RMSE
Analysis	640	1.7	0.7	16.0
First Guess	640	1.9	1.0	19.1
GFS	640	4.3	3.9	19.8

Feb. 1, 2017

Snow Depth (cm)	n	Bias(Mean)	Bias(Median)	RMSE
Analysis	260	2.7	2.8	23.3
First Guess	260	0.5	0.8	27.3
GFS	260	-3.3	0.4	33.7

Mar. 1, 2017

Column	n	Bias(Mean)	Bias(Median)	RMSE
Analysis	564	3.6	1.2	27.2
First Guess	564	0.80	0.7	30.7
GFS	564	-1.1	0.1	32.7

MOST RECENT PAPERS AND FUTURE PRESENTATIONS

Journal Paper:

"Kongoli, C., P. Romanov, S. Helfrich, R. Dong, M. Ek and T. Smith. 2018. A blended snow depth analysis for the next generation global prediction system, International Journal of Ecosystems and Ecology Science (IJEES) Vol. 8 (2): 189-192 (2018)".

American Geophysical Union 2018:

Abstract #466947

A High-Resolution Blended Snow Analysis for the Next Generation Global Prediction System

NOAA 2018 General Modelling and Meeting Fair Exhibit:

A Blended Snow Analysis for Weather and Hydrologic Prediction Models

FUTURE WORK

- Optimize scheme parameters to improve seasonal accuracy especially over complex terrain;

- Evaluate the impact of satellite data and density of in-situ stations;

- Upscale SD to 4-km resolution using 4-km IMS snow cover extent

- Compare results with other data assimilation schemes, e.g. KF-based analyses

- Develop SWE analysis in addition to SD

OTHER RELEVANT PUBLICATIONS

Anderson, E.A. (1976), A Point Energy and Mass Balance Model of a Snow Cover, NOAA Technical Report NWS 19, 150 pp., U.S. Dept. of Commerce, Silver Spring, Maryland.

Brasnett B,1999. A global analysis of snow depth for numerical weather prediction. *J Appl Meteorol* 38:726–740.

Cressman G.,1959.An operational objective analysis system. *Mon Weather Rev* 87(10):367–374.

de Rosnay P. , G. Balsamo, C. Albergel , J. M-S. Lars I, 2012. Initialisation of land surface variables for Numerical Weather Prediction, *Surv Geophys* DOI 10.1007/s10712-012-9207-x .

Kongoli, C. and S. Helfrich, 2015.A multi-source interactive analysis approach for Northern hemispheric snow depth estimation Proceedings of the Geoscience and Remote Sensing Symposium (IGARSS), IEEE International, Milan, Italy, DOI: 10.1109/IGARSS.2015.7325878

Kongoli, C. Romanov, P. S. Helfrich, J. Dong, M. Ek and T. Smith, 2017. Blended high-resolution snow depth analysis for NOAA's Next Generation Global Prediction System (NGGPS), 2017 NOAA Satellite Conference, July 16-18, College University of New York (CUNY), New York

Kongoli, C. Romanov, P. S. Helfrich, J. Dong, M. Ek and T. Smith, 2017. Proceedings of the 7th International Conference on Ecosystems (ICE2017), ISBN: 978-9928-4248-7-7 *DOI: 10.13140/RG.2.2.10618.49601*, June 2-5, Tirana, Albania

Lee, Y-K, C. Kongoli, and J. Key, 2015. An in-depth evaluation of NOAA's snow heritage algorithms", *J. Atmos. Oceanic Technol.*, **32**, 2319–2336.

Solantra, T. M. 2012: Simulating snow maps for Norway: description and statistical evaluation of the seNorge snow model. *The Cryosphere* 6, 1323-1337.