8th EARSeL workshop on Land Ice and Snow
Bern, Switzerland, 7-9 February 2017

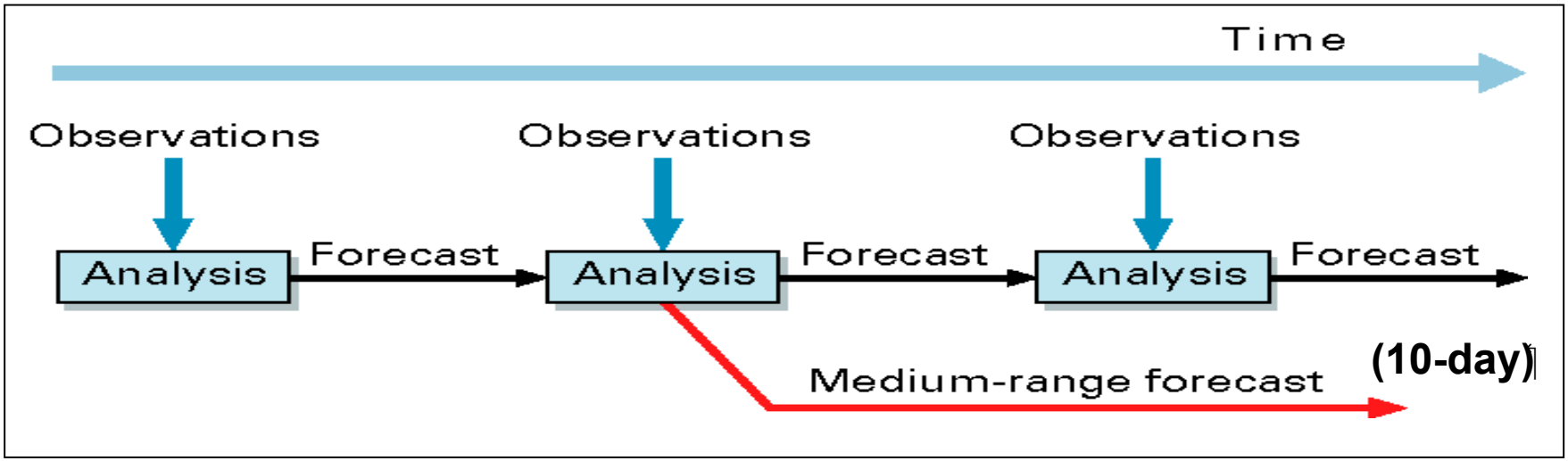
Snow data assimilation for Numerical Weather Prediction at ECMWF

P. de Rosnay, M. Dahoui, L. Isaksen

Thanks to many other colleagues

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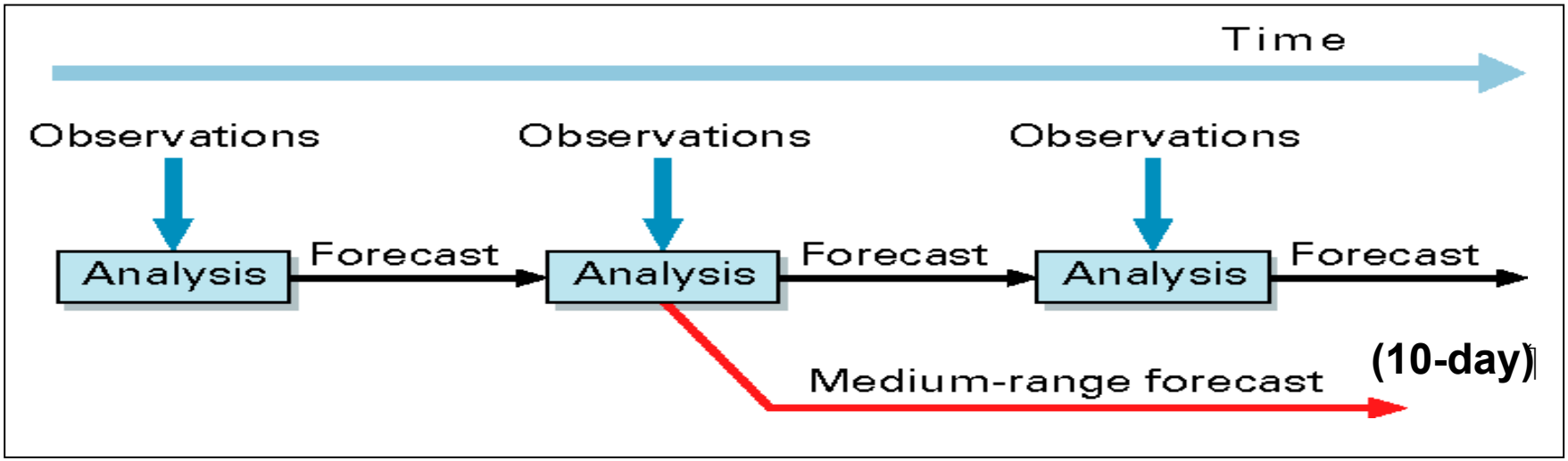
ECMWF Integrated Forecasting System (IFS)



- **Forecast Model:** GCM including the H-TESSEL land surface model (coupled)
- **Data Assimilation** → **initial conditions of the forecast model prognostic variables**
  - 4D-Var for atmosphere ; 3D-Var for ocean (for ensemble and seasonal)
  - Land Data Assimilation System

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ECMWF Integrated Forecasting System (IFS)



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  - 4D-Var for atmosphere ; 3D-Var for ocean (for ensemble and seasonal)
  - Land Data Assimilation System

Different Systems:

NWP (oper):	IFS (with 4D-Var and LDAS), 9km, version 43r1 (2016)
ERA-Interim:	IFS (with 4D-Var and LDAS), 79km, version 31r1 (2006)
ERA5:	IFS (with 4D-Var and LDAS), 32km, version 41r2 (2016)
ERA-Interim-Land:	H-TESSEL LSM simulations (no LDAS), 79km, 37r2 (2011) driven by ERA-I atmospheric cond. corrected by GPCP

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Snow in the ECMWF IFS for NWP

Snow Model: Component of H-TESSEL **(Dutra et al., JHM 2010, Balsamo et al JHM 2009)**

Single layer snowpack

- Snow water equivalent SWE (m)
- Snow Density ρ_s

} **Prognostic variables**

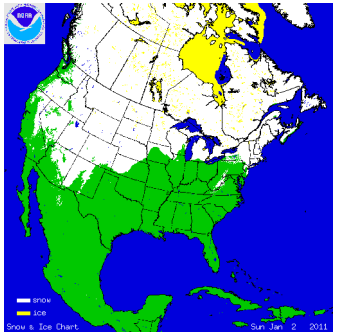
Observations: **de Rosnay et al ECMWF Newsletter 2015**

- Conventional snow depth data: SYNOP and National networks
- Snow cover extent: NOAA NESDIS/IMS daily product (4km)



Data Assimilation: **de Rosnay et al SG 2014**

- Optimal Interpolation (OI) is used to optimally combine the model first guess, in situ snow depth and IMS snow cover
- The result of the data assimilation is the analysis of SWE and snow density
- It is used to initialize the NWP system.



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Snow cover observations

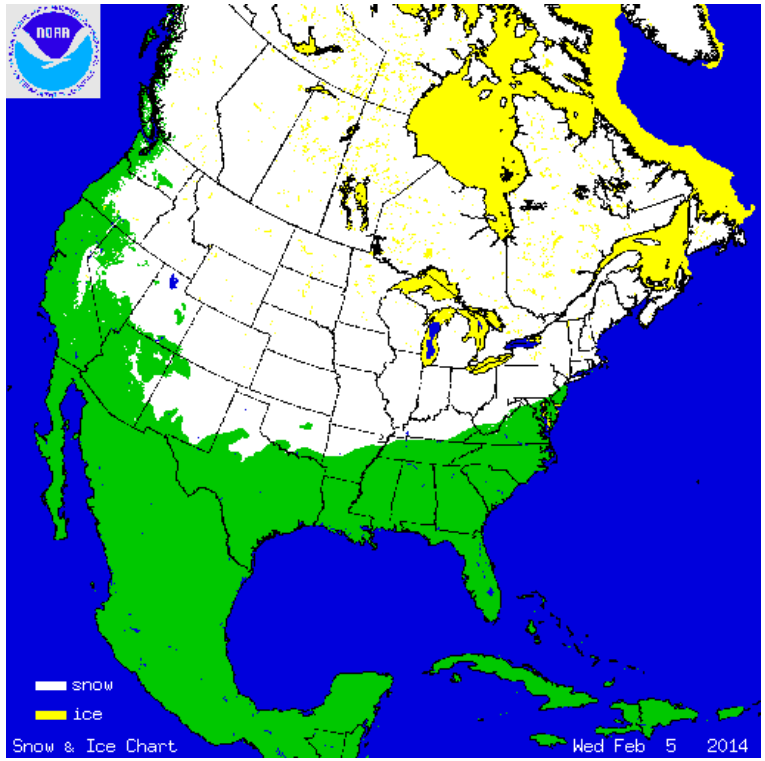
Interactive Multisensor Snow and Ice Mapping System (IMS)

- Time sequenced imagery from geostationary satellites
- AVHRR,
- VIIRS,
- SSM/I, etc….
- Station data

Northern Hemisphere product

- Daily
- Polar stereographic projection

NOAA/NESDIS
IMS Snow extent data



http://nsidc.org/data/g02156.html

Information content: Snow/Snow free

Data used at ECMWF:

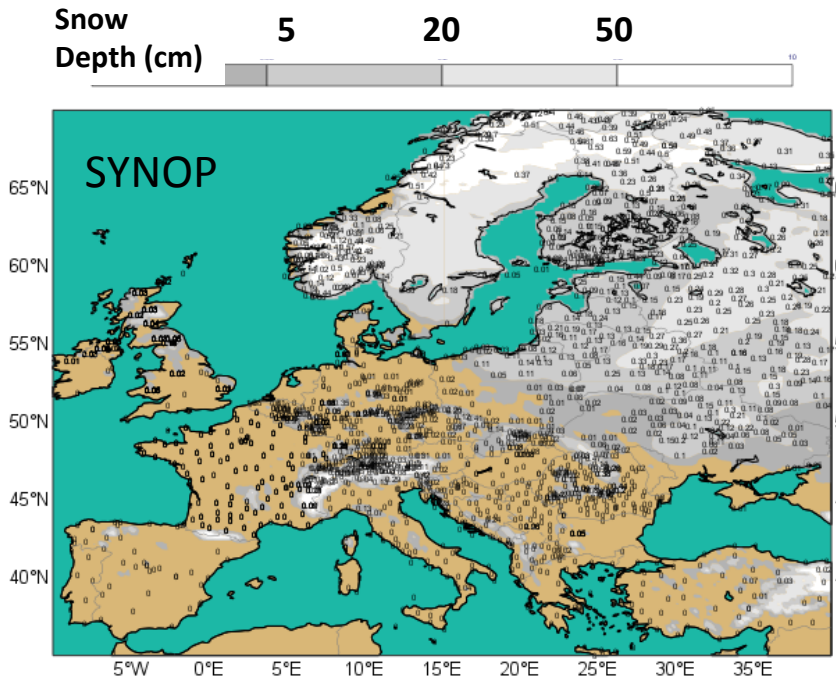
- **24km product** (ERA-Interim)
- **4 km product** (NWP, ERA5)

Latency:

Available daily at 23 UTC. Assimilated in the subsequent analysis at 00UTC

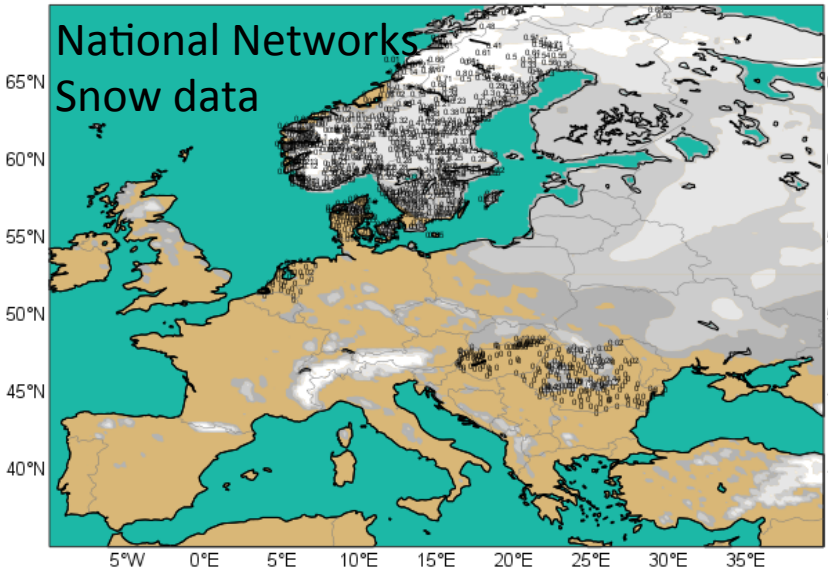
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Snow Observations
Snow SYNOP and National Network data in Europe



Available on the GTS (Global Telecommunication System)

2016 01 15 at 06UTC



Additional data from national networks from up to 7 countries:
Sweden, Romania, The Netherlands, Denmark, Hungary, Norway, Switzerland.

→ **Dedicated BUFR for additional national data**
(de Rosnay et al. ECMWF Res. Memo, R48.3/PdR/1139, 2011)

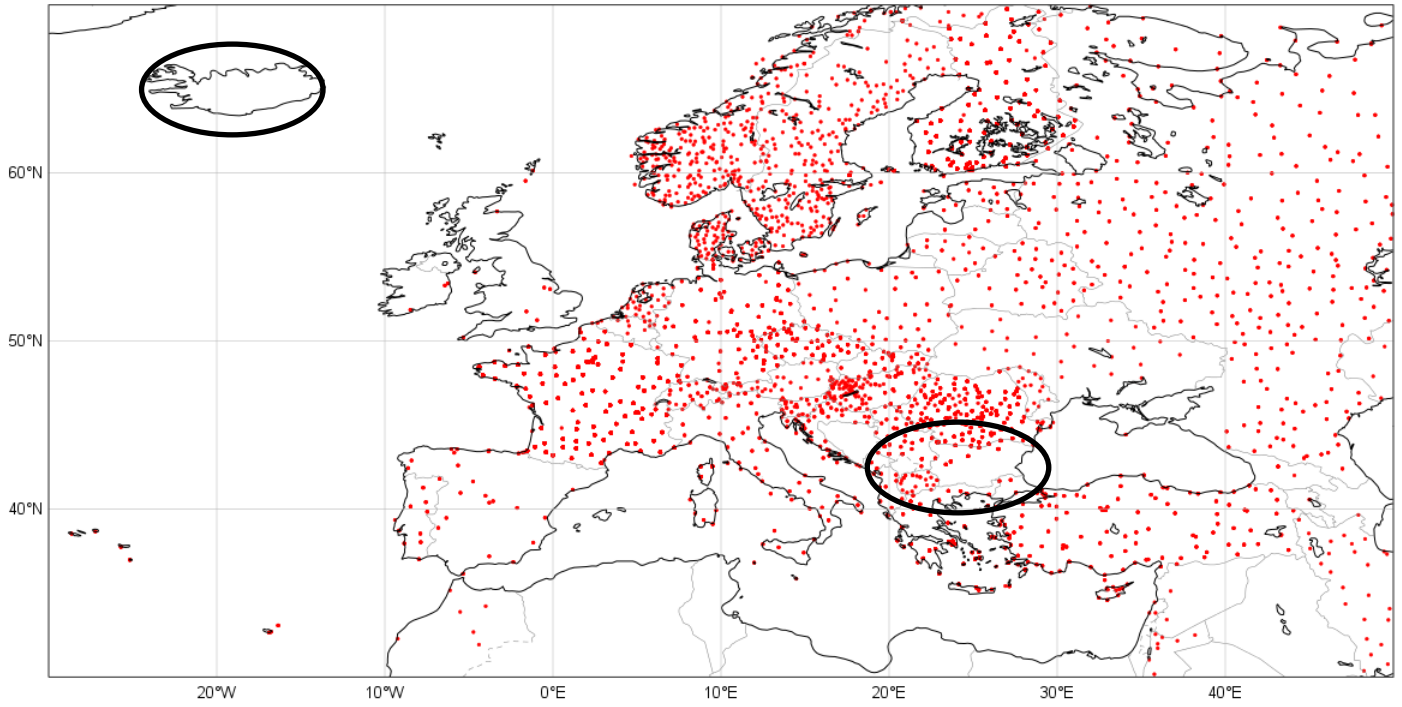
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Snow depth observations in Europe

GTS Snow depth availability

SYNOP + national BUFR data

Status on 5 February 2017



In general, good coverage in Europe, but …

- Iceland : very few snow depth reports on the GTS (none for this date)
- Zero snow depth reporting is still an issue
- Bulgaria: more stations available but not on the GTS

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Snow reports from Bulgaria

HarmoSnow COST action ES1404 →contribute to improve in situ data exchange for NWP

→ NIMH in 2016 made the data available for 39 station (BUFR format, routinely produced)

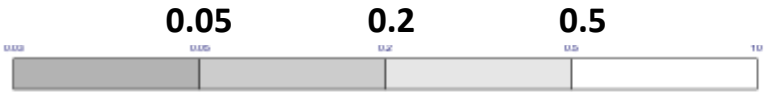
→ ECMWF data acquisition and assimilation (1 month test in oper config)

→ Suitable for operational use

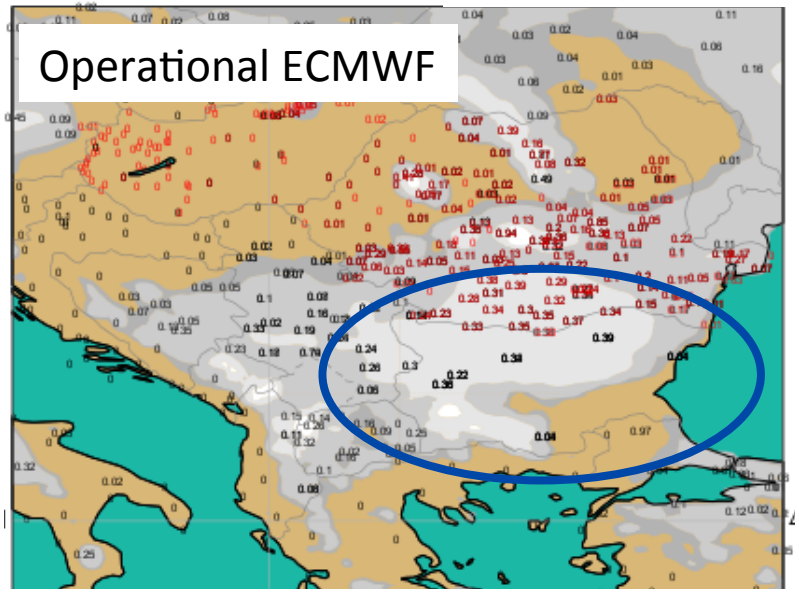
→ Recommendation to NIMH to make the data available on the GTS

de Rosnay et al., ECMWF Res Memo RD16-178, June 2016

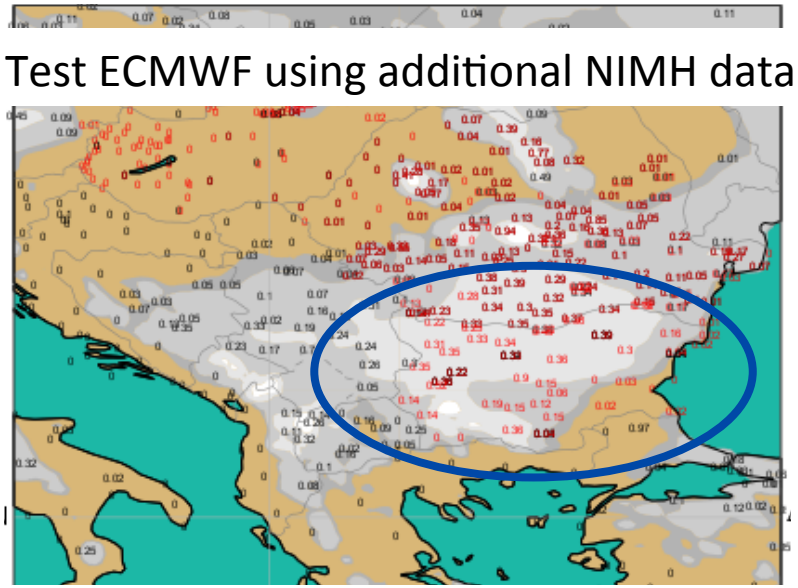
19 January 2016
Snow depth in m



Operational ECMWF



Test ECMWF using additional NIMH data



Lack of observations in Bulgaria

39 more stations provided by NIMH

Technical aspects (data format, acquisition, assimilation) solved.
Still in discussion to make the data effectively available for NWP

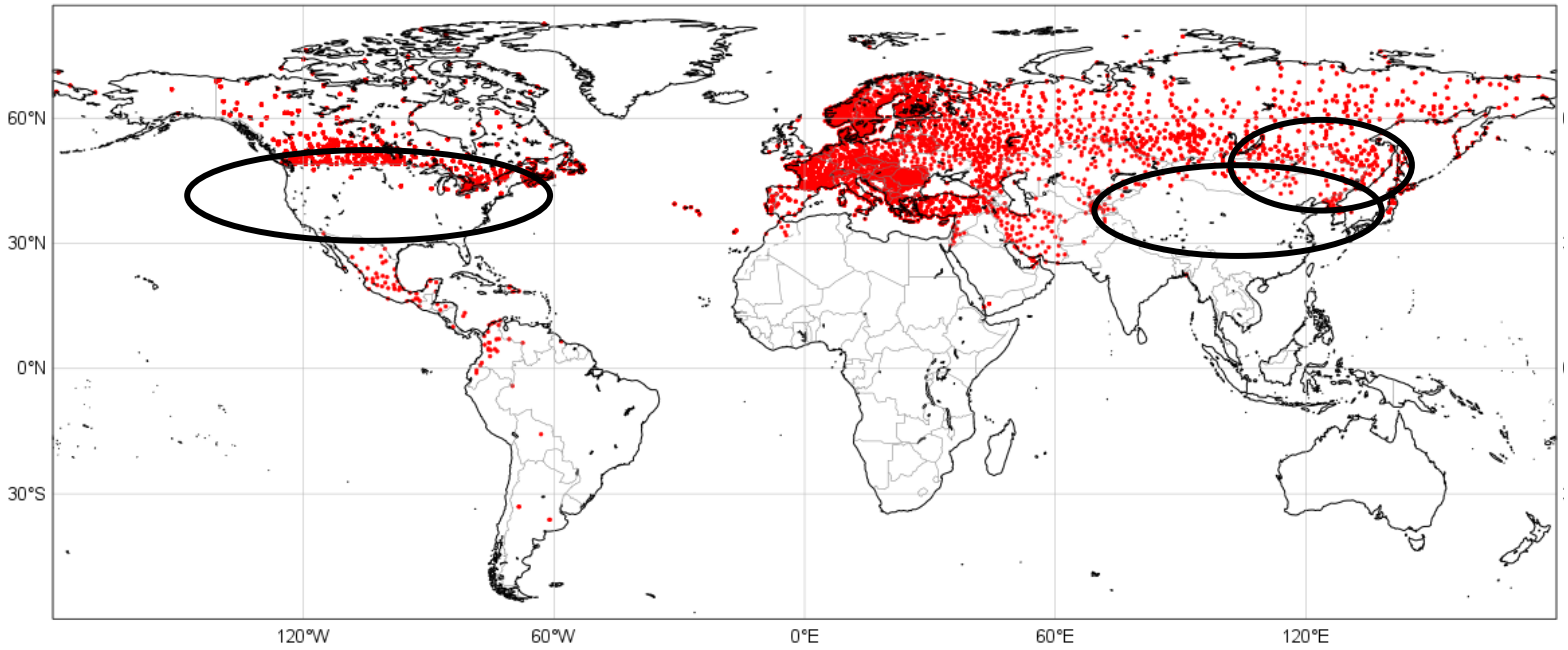
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Snow depth observations

GTS Snow depth availability

SYNOP TAC + SYNOP BUFR + national BUFR data

Status on 5 February 2017



- Gaps in USA, China and southern hemisphere
- NRT data exist and is available (more than 20000 station in the USA), but it is not on the GTS for NWP applications.
- However, we note an improvement in China (since status in de Rosnay et al, ECMWF NL article 143, 2015)

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Initiatives relevant to address snow observations availability on the Global Telecommunication System (GTS)

GCW Snow Watch Activity



Snow Watch reporting Handout 2015 (ECMWF/UKMO)

http://globalcryospherewatch.org/reference/documents/

COST action on Snow: HarmoSnow

"A European network for a harmonised monitoring of snow for the benefit of climate change scenarios, hydrology and numerical weather prediction".



http://www.cost.eu/COST_Actions/essem/Actions/ES1404

http://costsnow.fmi.fi/

NAEDEX (North America Europe data exchange)

Discussions NOAA/NCEP to improve availability of snow depth on the GTS

OSCAR

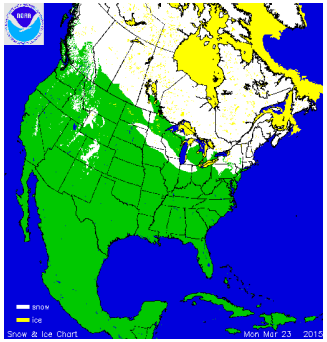
Observing Systems Capability Analysis and Review Tool

- New section for in situ surface data
- Relevant to use it to monitor snow depth data availability

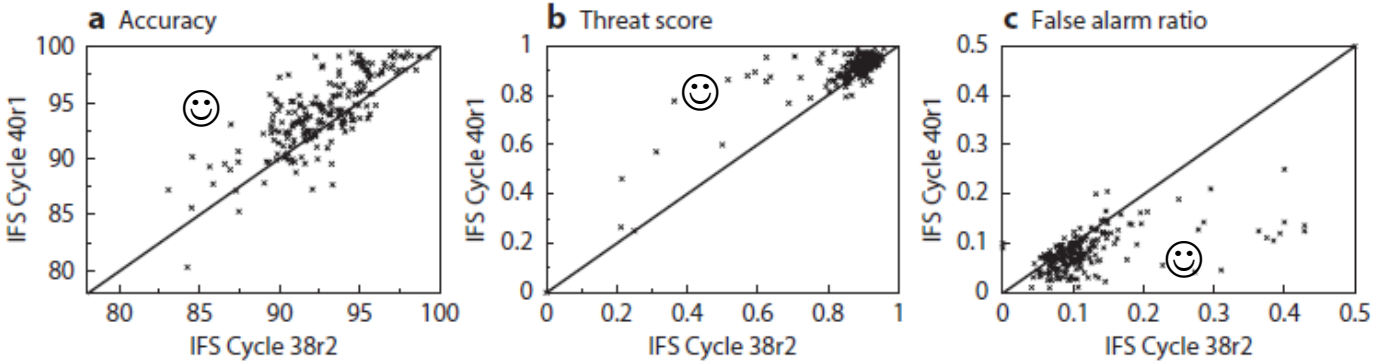
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Snow analysis: Forecast impact

Revised IMS snow cover data assimilation (2013)



Impact on snow October 2012 to April 2013
(using 251 independent in situ observations)



	Snow observed	No snow observed
Snow in analysis	a Hits	b False alarm
No snow in analysis	c Misses	d Correct no snow

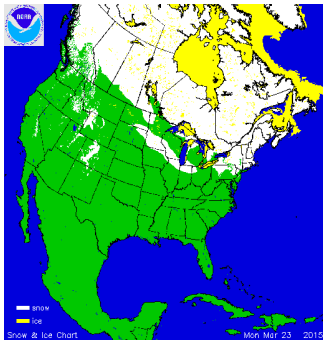
The following scores are used for the evaluation:

- Accuracy = a+d / (a+b+c+d)
- False alarm ratio = b / (a+b)
- Threat score = a / (a+b+c)

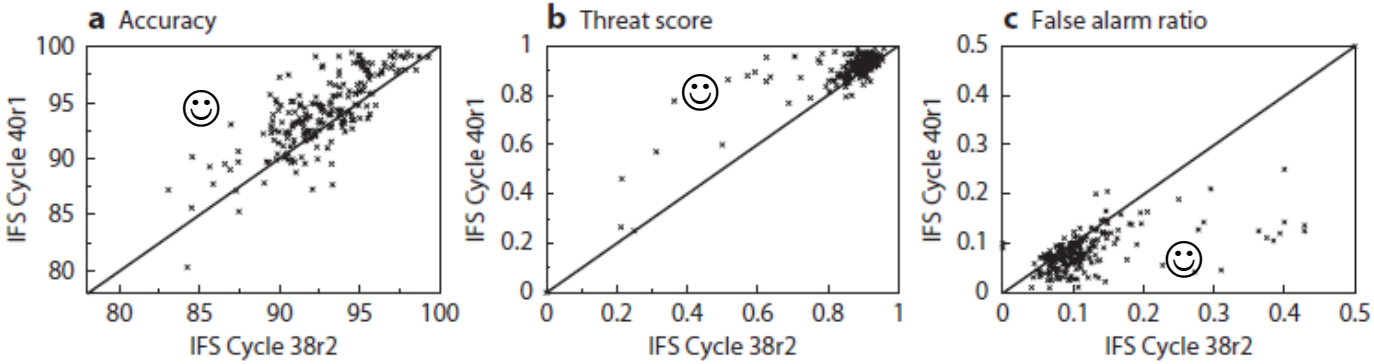
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Snow analysis: Forecast impact

Revised IMS snow cover data assimilation (2013)



Impact on snow October 2012 to April 2013
(using 251 independent *in situ* observations)



Impact on atmospheric forecasts

October 2012 to April 2013 (RMSE new-old)

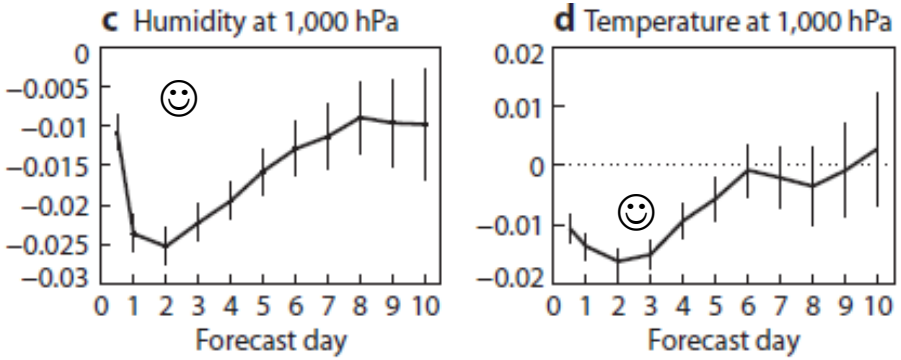


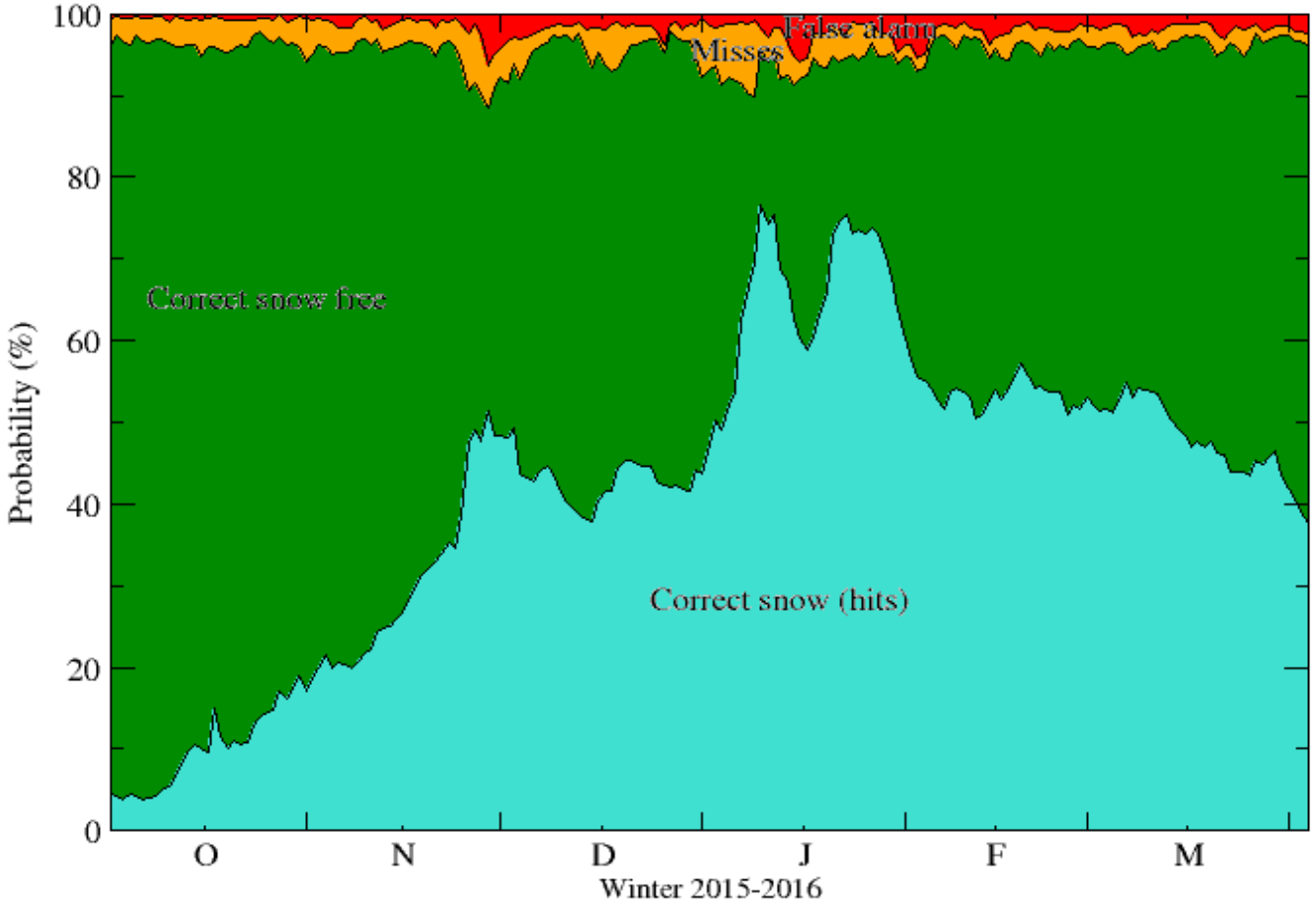
Figure 4 Impact of the revised snow analysis on the normalised root mean square error difference between IFS Cycles 40r1 and 38r2 (40r1 minus 38r2) for (a) humidity forecasts at 850 hPa;



de Rosnay et al., ECMWF NL 143, Spring 2015

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Operational snow analysis evaluation against in situ stations
North Hemisphere - winter 2015-2016

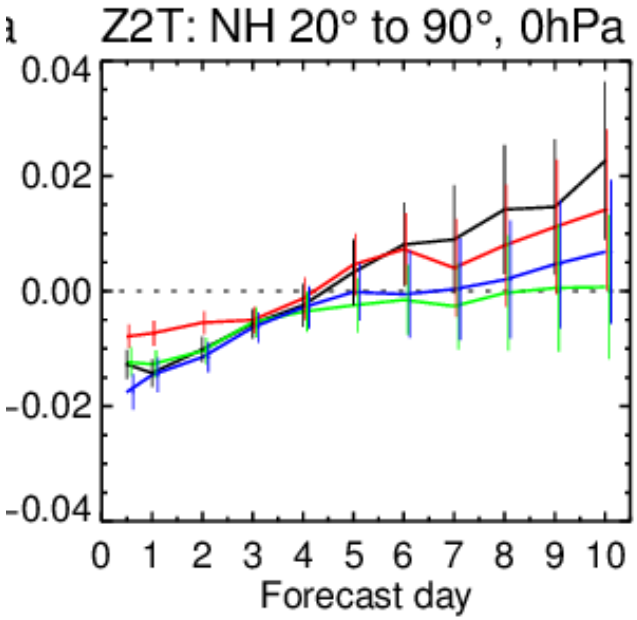


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Observing System Experiments

Winter 2014-2015 (December to April) - Assess the impact of the snow observing system

Expts	SYNOP	National Data	IMS snow cover
0- OL (no snow data assimilation)			
1- Snow DA: SYNOP+IMS	✓		✓
2- Snow DA: SYNOP+Nat (all in situ)	✓	✓	
3- Snow DA SYNOP+Nat+IMS (all)	✓	✓	✓



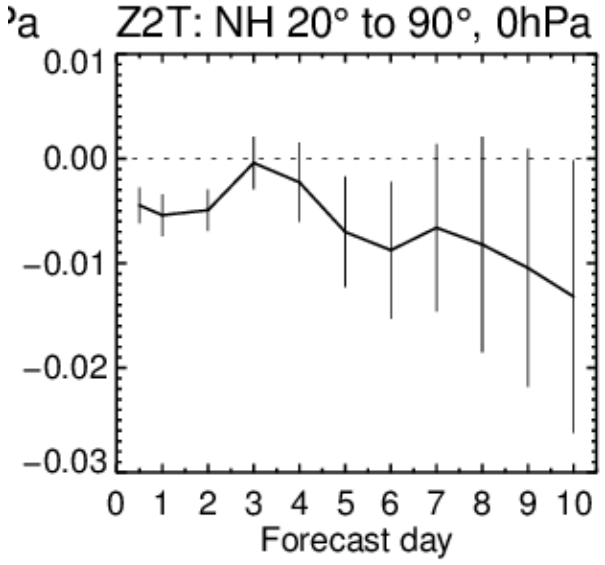
Impact on T2m Forecasts:
Normalized RMSE for T2m FC difference compared to the reference (OL)

SYNOP+IMS (1-0)
SYNOP+Nat (2-0)
SYNOP+Nat+IMS (3-0) -> oper

Best T2m Forecast when all observations, combining in situ and IMS, are assimilated.

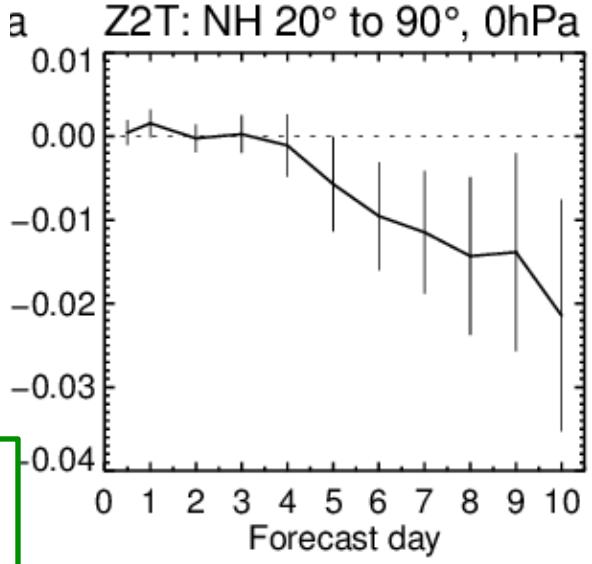
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Impact of IMS snow cover (case 3-2)



All data assimilated (Synop+Nat+IMS)
compared to all in situ data assimilated (SYNOP+Nat)
-> Further T2m forecasts error reduction,
significant at short range

Impact additional network
(case 3-1)



Impact of National data (case 3-1)

All data assimilated (SYNOP+Nat+IMS)
compared to SYNOP+IMS assimilation
-> Further T2m forecasts error reduction at medium range

Contribution& complementarities of each observation types to improve T2m forecasts at short and medium ranges

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Summary

- Major developments in the ECMWF data assimilation (DA) in the past few years; large impact on NWP
- OSEs shows that combined DA of in situ snow depth and IMS snow cover significantly improve T2m forecasts
- Gaps in in situ SD reporting, but additional National data contribute to improve near surface weather forecasts
- Nat. Met services encouraged to report snow depth on the GTS
- Contributions from Snow Watch(WMO BUFR), HarmoSnow COST action (Questionnaire, inventory), NAEDEX (US issue), OSCAR (great potential for monitoring SD report availability), …
- Challenges in retrieving snow mass from satellite measurements

  → Novel mission concepts required for SWE for NWP

  Importance of data latency for NWP

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Thank you for your Attention!

Useful links:

ECMWF LDAS: https://software.ecmwf.int/wiki/display/LDAS/LDAS+Home
Snow Watch: http://globalcryospherewatch.org/reference/documents/

HarmoSnow COST Action: http://www.cost.eu/COST_Actions/essem/Actions/ES1404
http://costsnow.fmi.fi/

ECMWF Land Surface Observation monitoring:
https://software.ecmwf.int/wiki/display/LDAS/Land+Surface+Observations+monitoring

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