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ECMWF snow data assimilation

Patricia de Rosnay

Thanks to:
Ioannis Mallas, Mohamed Dahoui, Linus Magnusson, Louise Arnal, Ervin Zsoter, Lars Isaksen, Bruce Ingleby, Gianpaolo Balsamo, Gabriele Arduini,
and many more ECMWF colleagues, the HarmoSnow COST action team and the WMO GCW SnowWatch Team

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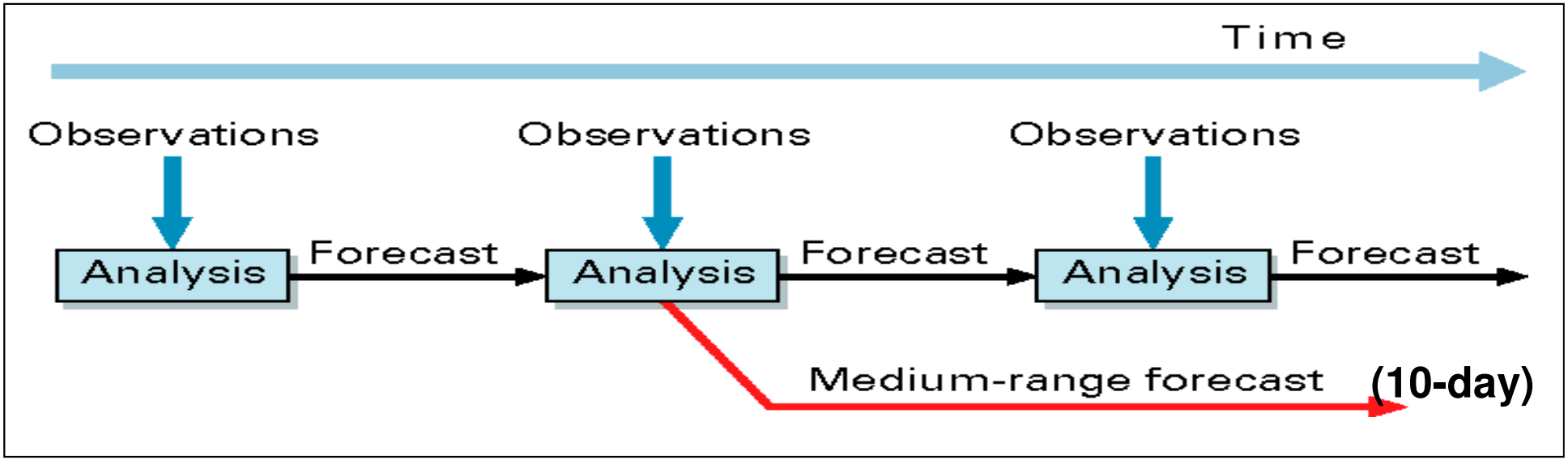
ECMWF Integrated Forecasting System (IFS)



- **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 (LDAS)

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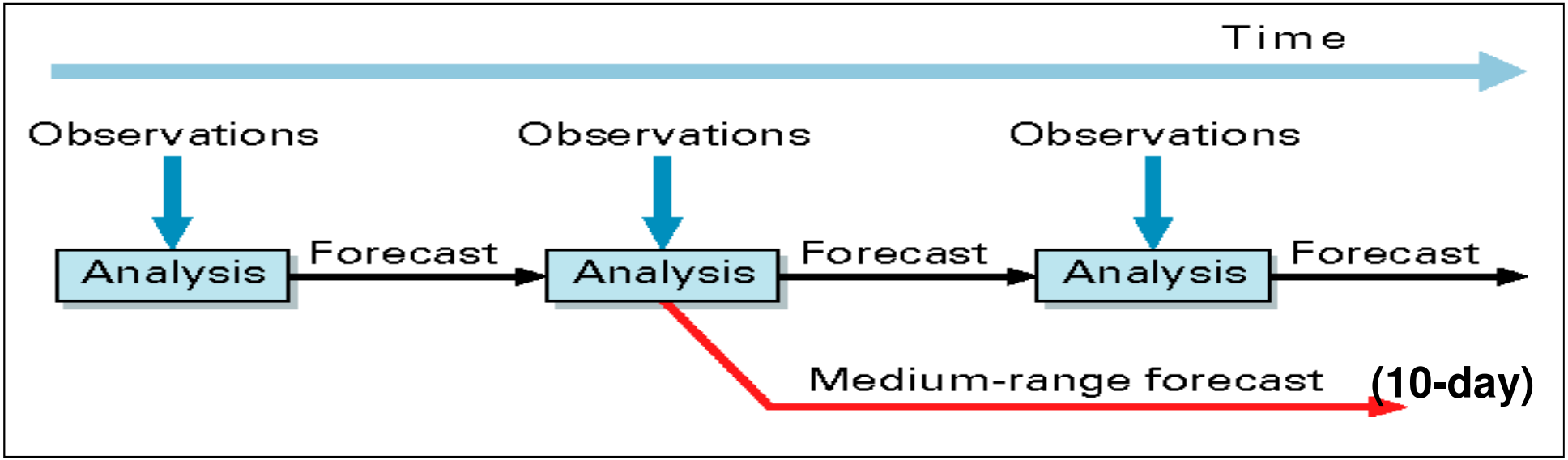

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  - **4D-Var for atmosphere ; 3D-Var for ocean (for ensemble and seasonal)**
  - **Land Data Assimilation System (LDAS): weakly coupled DA**

Land assimilation in ECMWF systems:

NWP HRES and EDA:	IFS (with 4D-Var, **LDAS**), 9km, 43r3 (2017)
ERA-Interim:	IFS (with 4D-Var, **LDAS**), 79km, 31r1 (2006)
ERA5:	IFS (with 4D-Var, **LDAS**), 31km, 41r2 (2016)
ERA-Land, ERA5/Land	H-TESSEL model only: no assimilaton
CERA-20C	IFS (with 4D-Var,NEMOVAR), 130km, 41r2 (no land DA)
CERA-SAT	IFS (with 4D-Var, NEMOVAR and **LDAS**), 62km, 42r1

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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

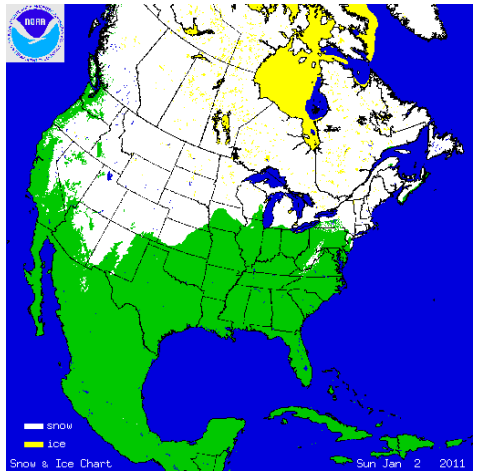
} **Prognostic variables**

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

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

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

- Optimal Interpolation (OI) in NWP and ERA5



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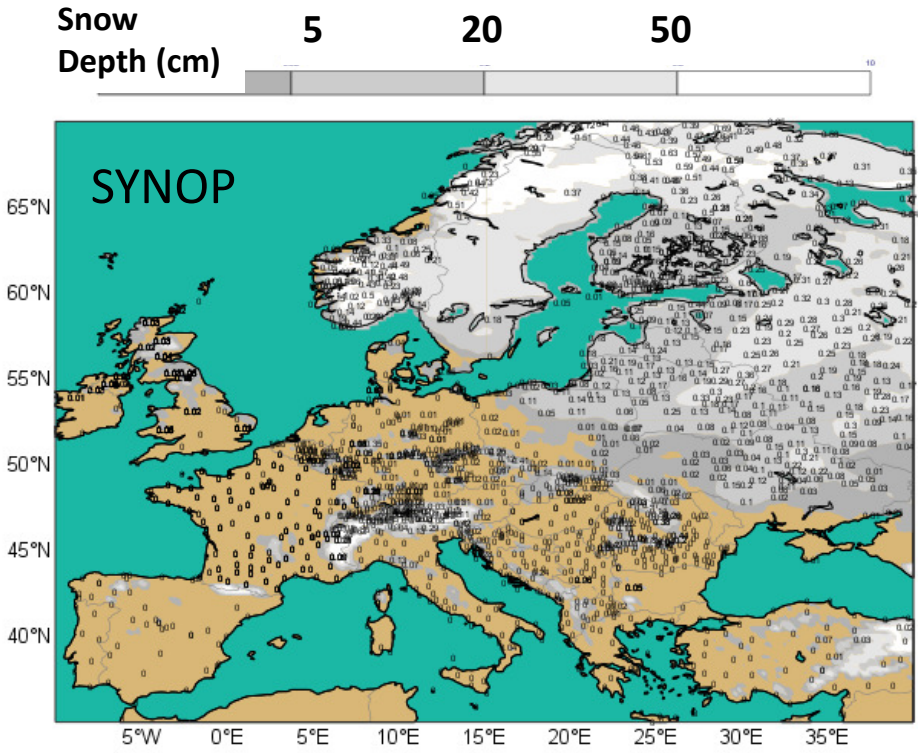
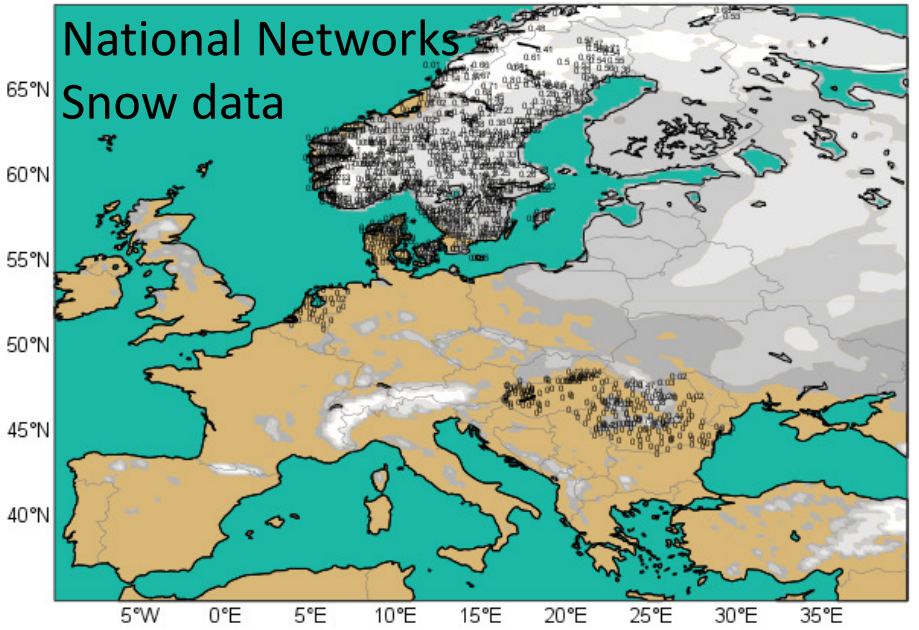
Snow Observations

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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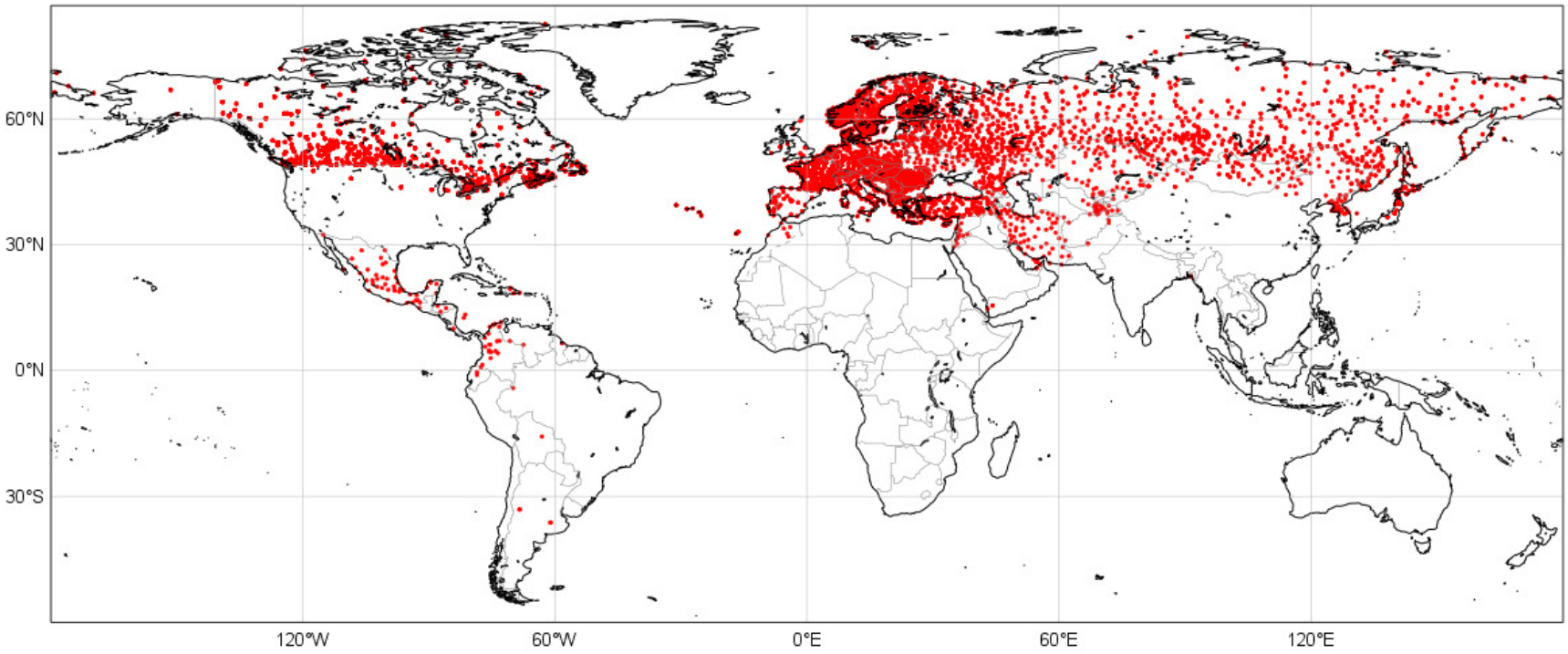
In situ snow depth observations

GTS Snow depth availability

SYNOP TAC + SYNOP BUFR + national BUFR data

Status on 5 February 2017



- Gap USA: NRT data exist and is available (more than 20000 station in the USA), but it is not on the GTS for NWP applications.
- Improvement in China (since status in de Rosnay et al, ECMWF NL article 143, 2015)
- Expected improvement over the US

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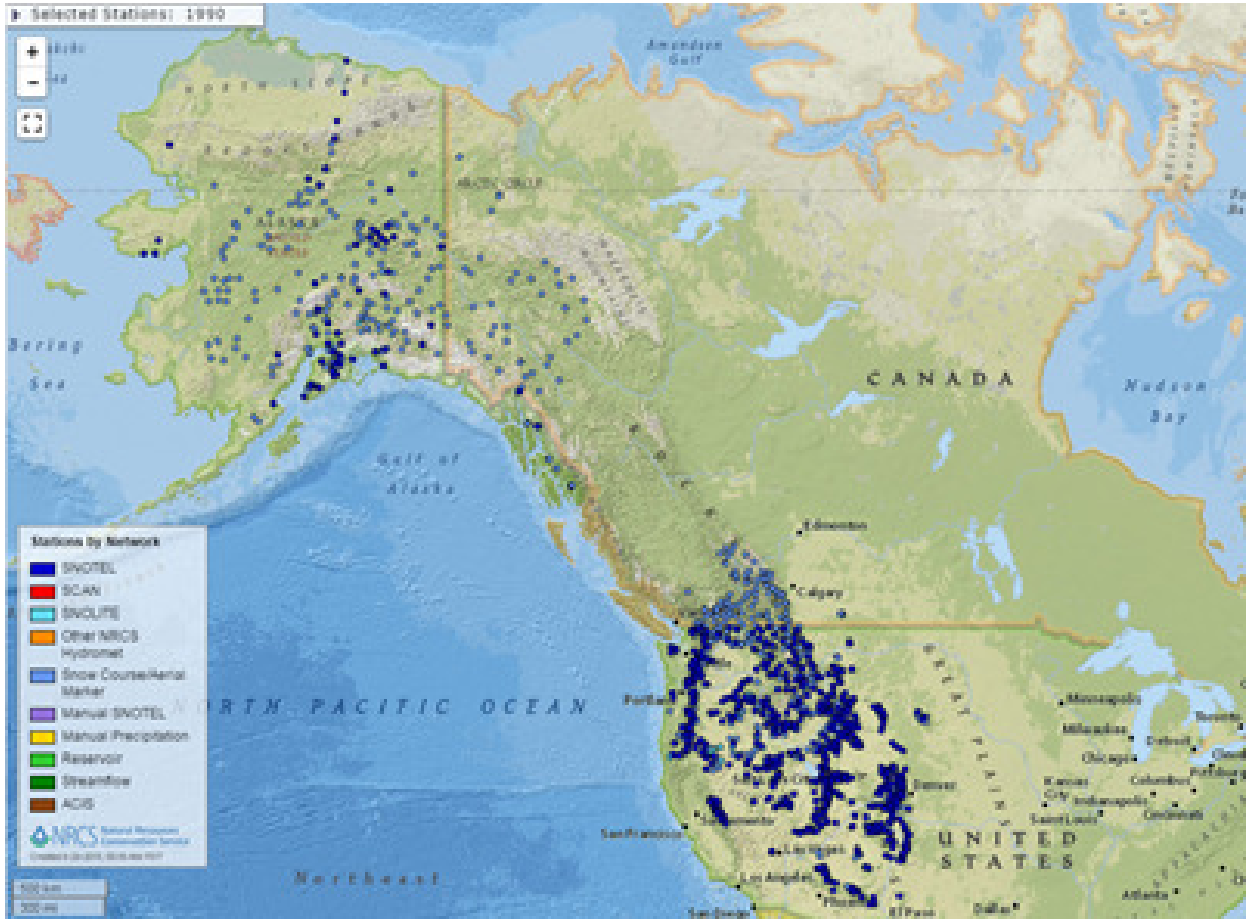
In situ snow depth observations

More that 900 observations from the SNOTEL (Snow Telemetry) network, SCAN and COOP
Available on the GTS since August 2017, in SHEF (Std Hydrometeo. Exchange format)
-> conversion to WMO BUFR required



SNOTEL

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

GCW Snow Watch Team

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/

GODEX (Global Observation data exchange)

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

→ SNOTEL on the GTS in 2017!

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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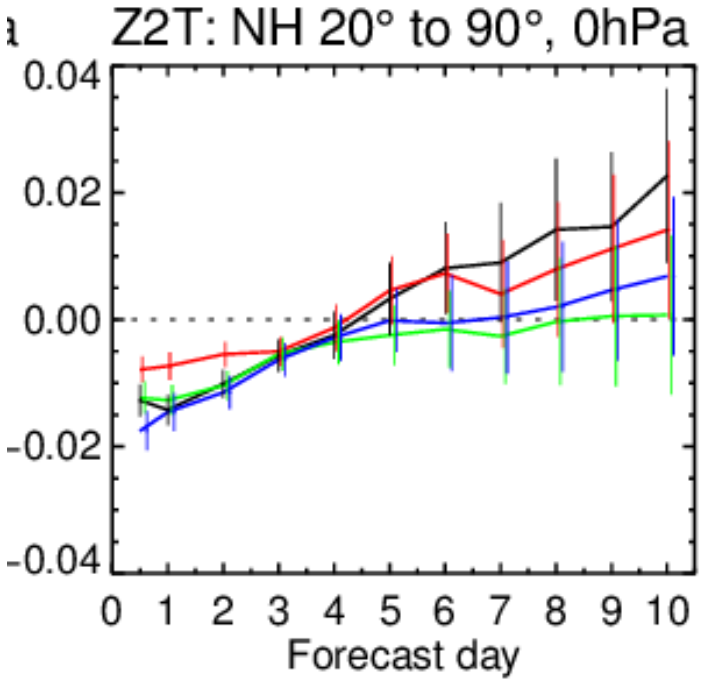
Observing System Experiments

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 DA)			
1- Snow DA: SYNOP+IMS	✓		✓
2- Snow DA: SYNOP+Nat (all in situ)	✓	✓	
3- Snow DA SYNOP+Nat+IMS (all)	✓	✓	✓



Impact on 10-day 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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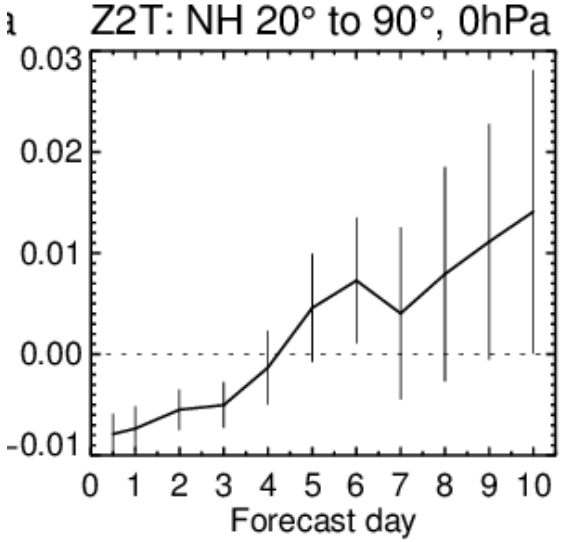
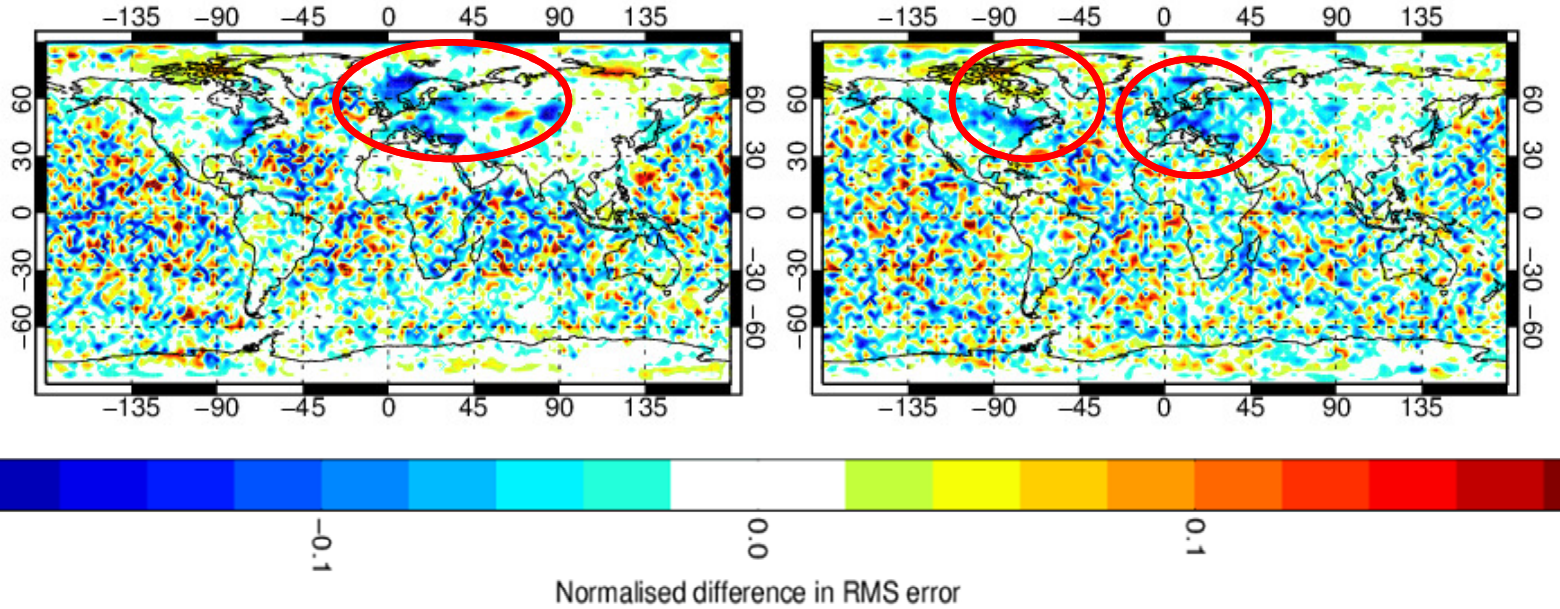
Impact of in situ snow data assimilation on T2m Forecasts(case 2-0)



All in situ data assimilated (SYNOP+Nat)

Compared to open loop, significant error reduction (NA, Europe) of short range T2m forecasts, but neutral at medium range

12h FC



24h FC

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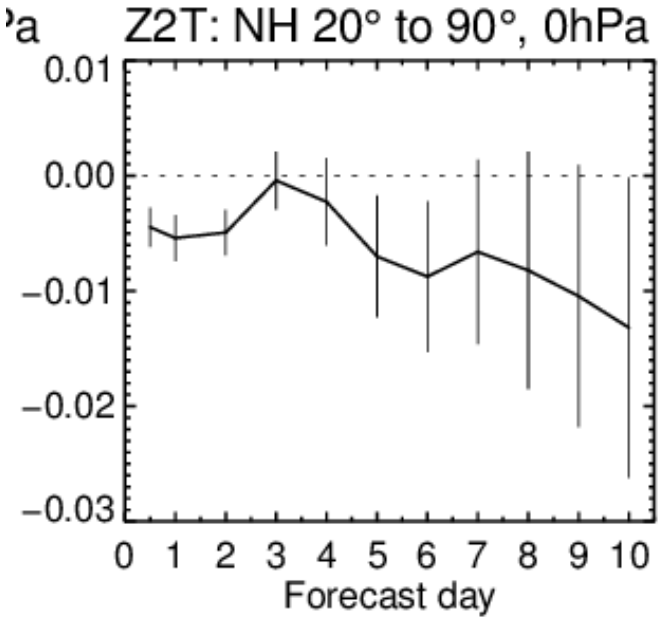
Impact of IMS snow cover (case 3-2)



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

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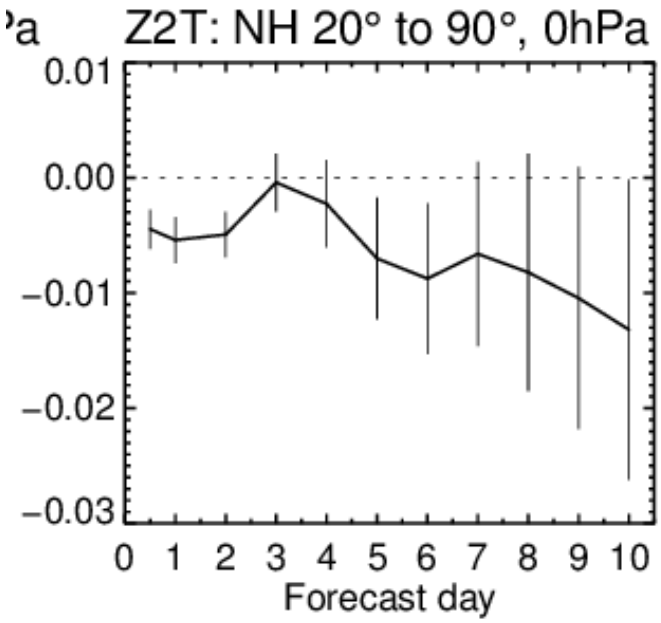
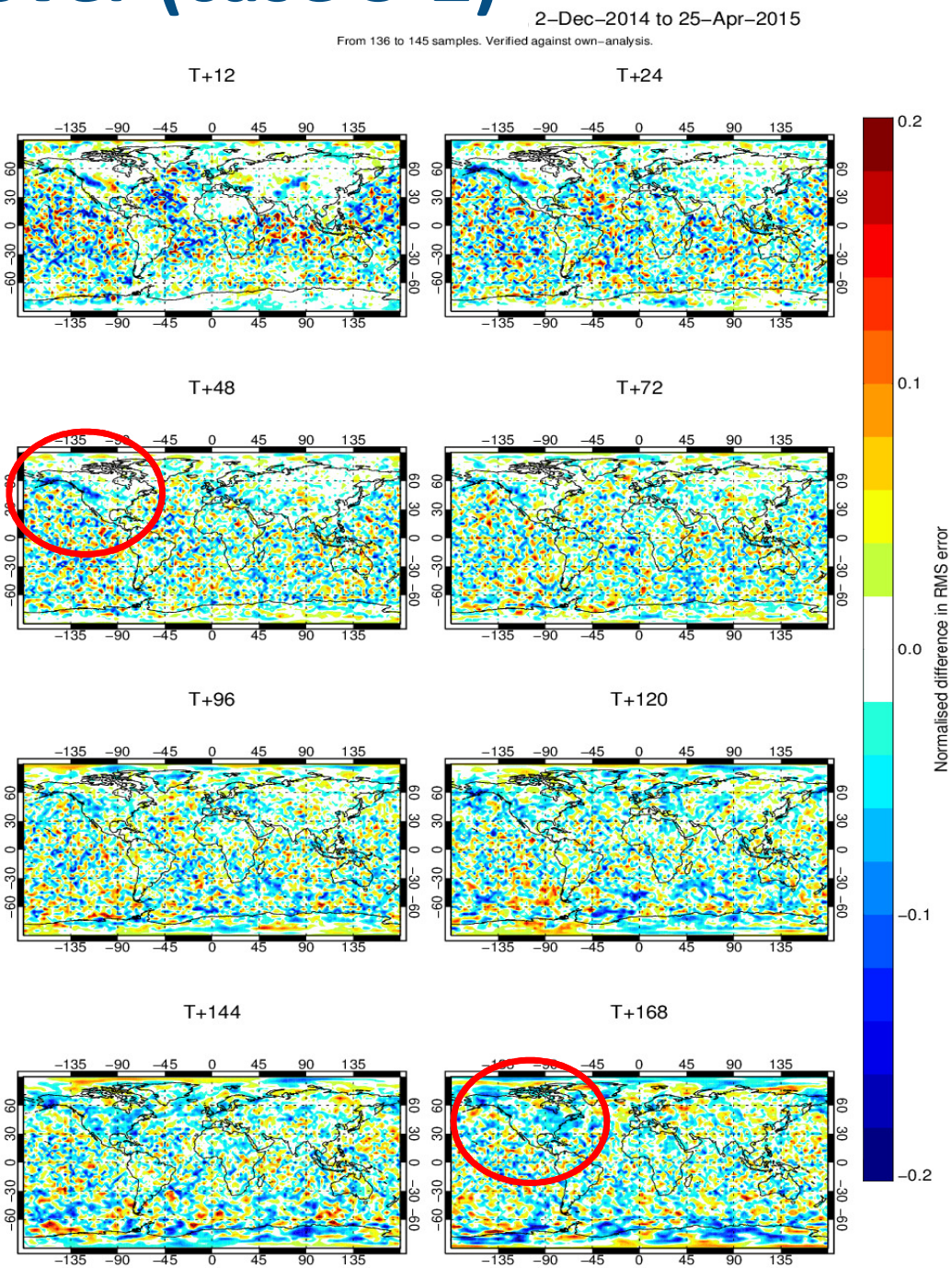
Impact of IMS snow cover (case 3-2)

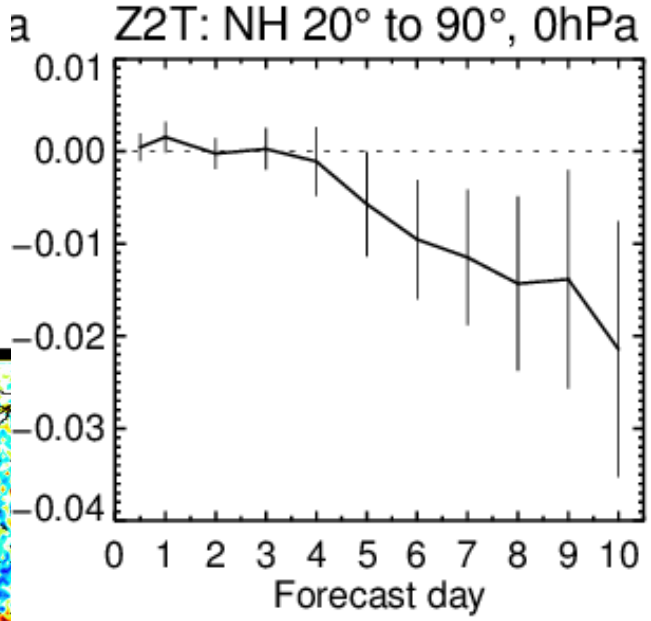


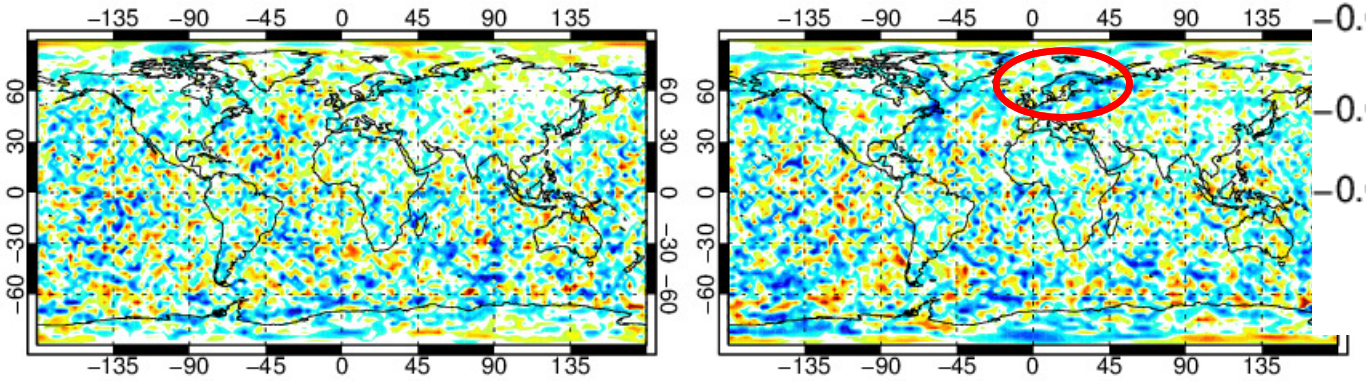
(Synop+Nat+IMS)
compared to
in situ data assimilated
(SYNOP+Nat)



Impact of National data (case 3-1)

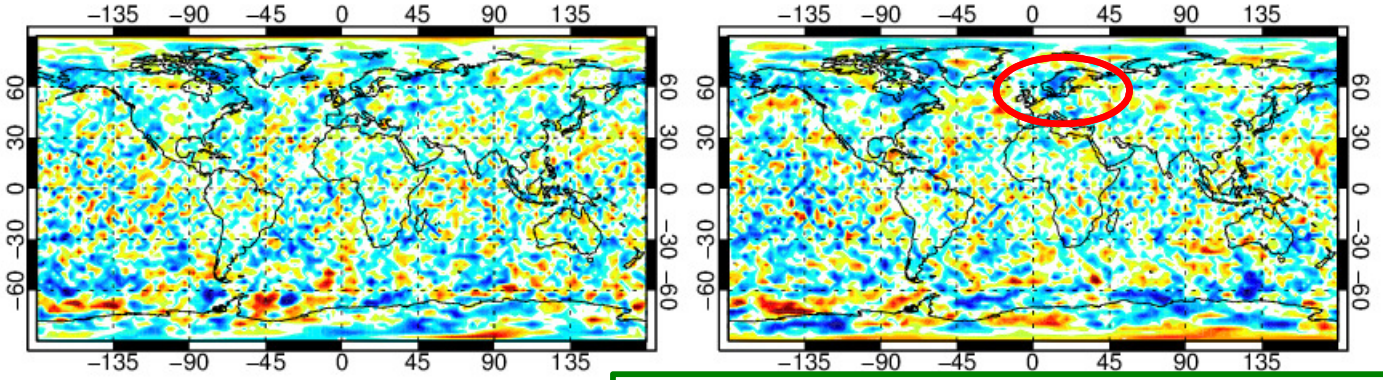
All data assimilated (SYNOP+Nat+IMS)
compared to SYNOP+IMS assimilation
-> Further T2m forecasts error reduction at medium range





T+144

T+168

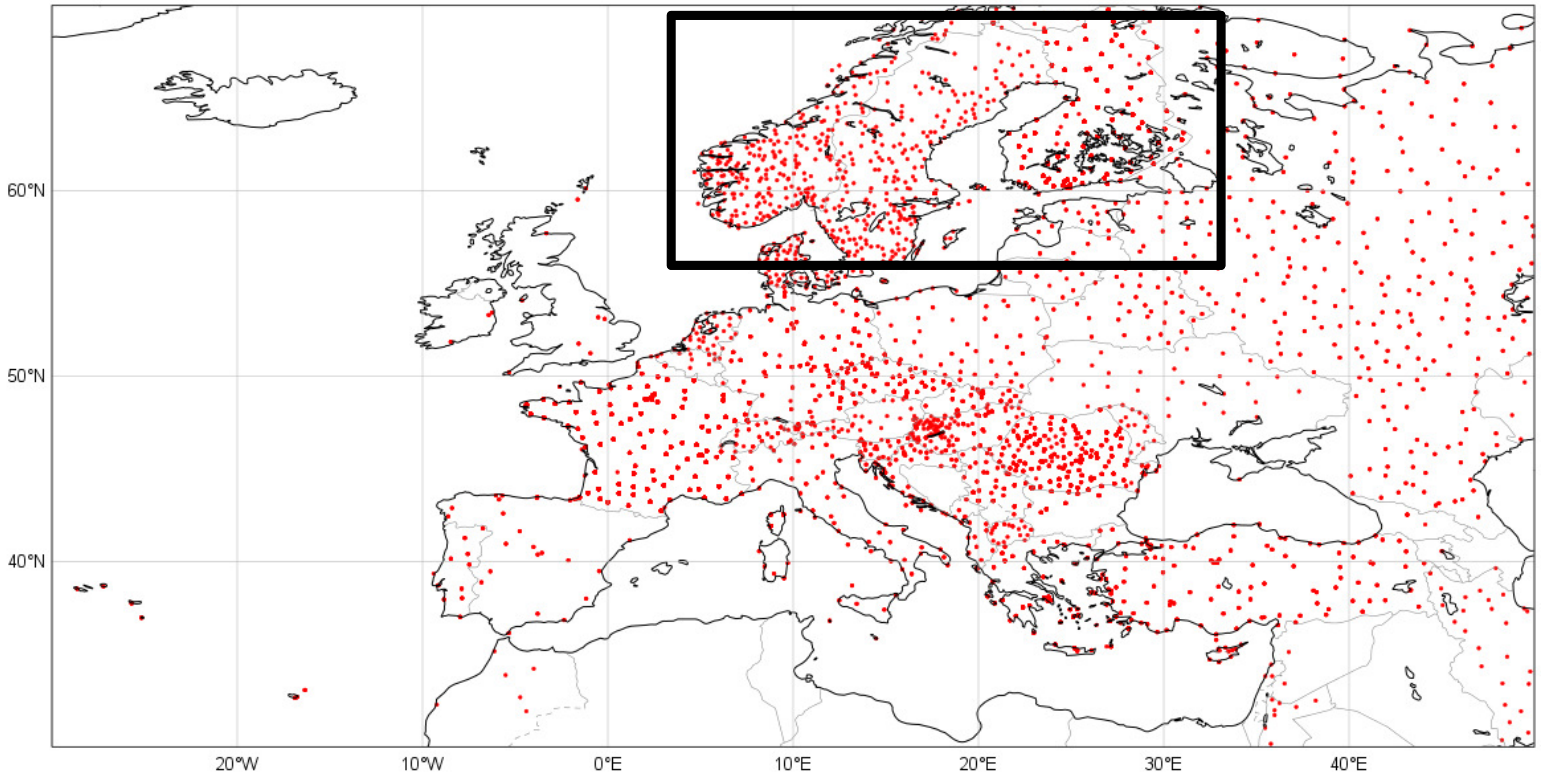


Contribution& complementarities of each observation types to improve T2m forecasts at short and medium ranges

Snow depth observations in Europe

SYNOP + national BUFR data

(GTS)



Very good coverage of snow observations in Scandinavia

→ Impact on extended range forecasts ?

→ Impact on river discharge?

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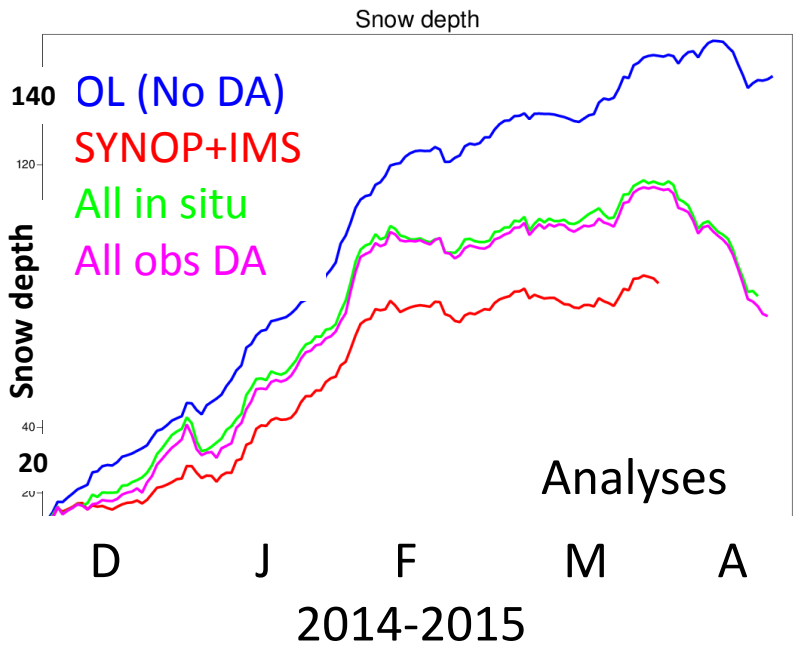
Observing System Experiments

→ Extended Range impact

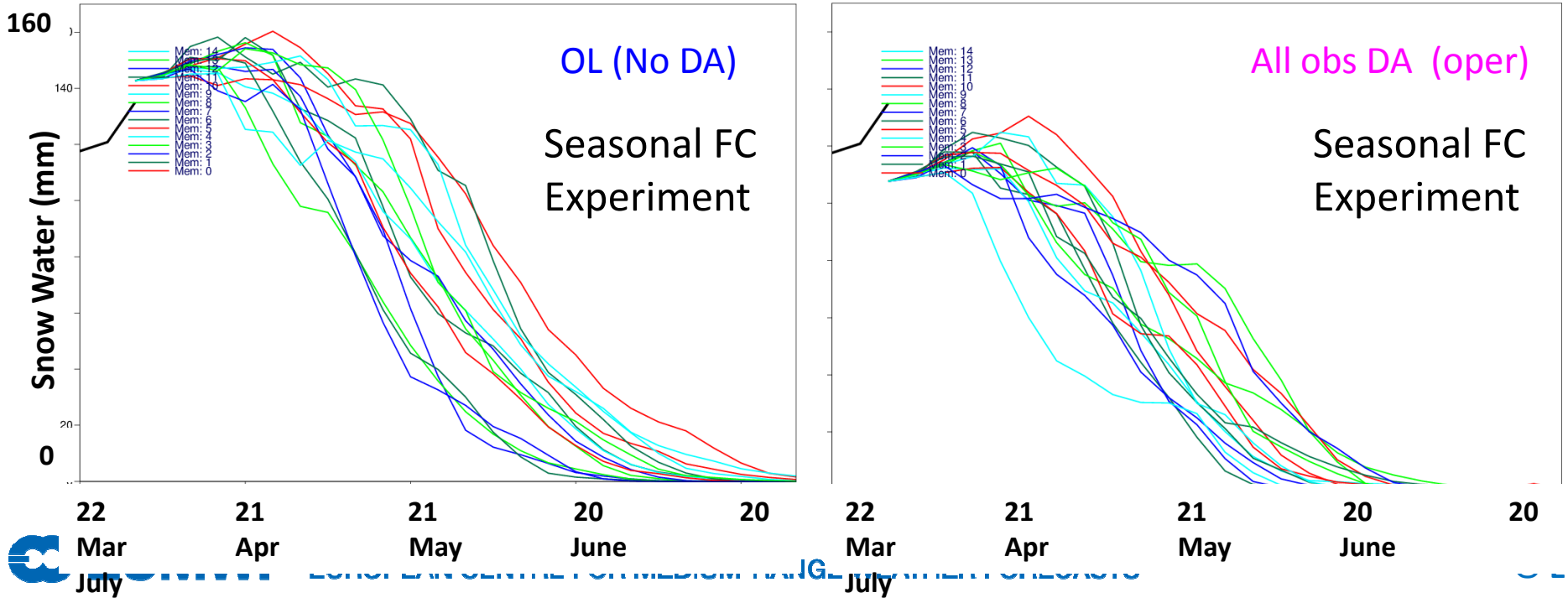


Linus Magnusson, Louise Arnal

Model too long to melt snow → OL has more snow

Ongoing: Impact of snow data assimilation on Seasonal forecast and river discharge in Scandinavia

Earlier melting in seasonal forecasts with in situ snow DA



Summary

- Major developments in the ECMWF data assimilation (DA) in the past few years; large impact on NWP; also benefit ERA5.
- On-going model developments (multi-layer snowpack)
- OSEs show that combined DA of in situ snow depth and IMS snow cover significantly improve medium-range (10-day) T2m forecasts
- Gaps in situ SD reporting, but additional National data contribute to improve near surface weather forecasts
- Impact of snow data assimilation on seasonal forecasts
- Nat. Met services encouraged to report snow depth on the GTS
- Contributions from Snow Watch(WMO BUFR), HarmoSnow COST action (Questionnaire, inventory), GODEX (US issue), OSCAR (great potential for monitoring SD report availability), …
- Gap in satellite observation for snow water measurements (several new concepts in discussion)

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Thank you for your Attention!

Useful links:

LDAS:
https://software.ecmwf.int/wiki/display/LDAS/LDAS+Home

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

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