What are the challenges and priorities for improved prediction and climate monitoring of the Arctic?

Irina Sandu

P. Bauer, J. Day, H. Lawrence, N. Bormann, G. Arduini, J. Farnan, L. Magnusson, T. Jung, K. Werner

ECMWF

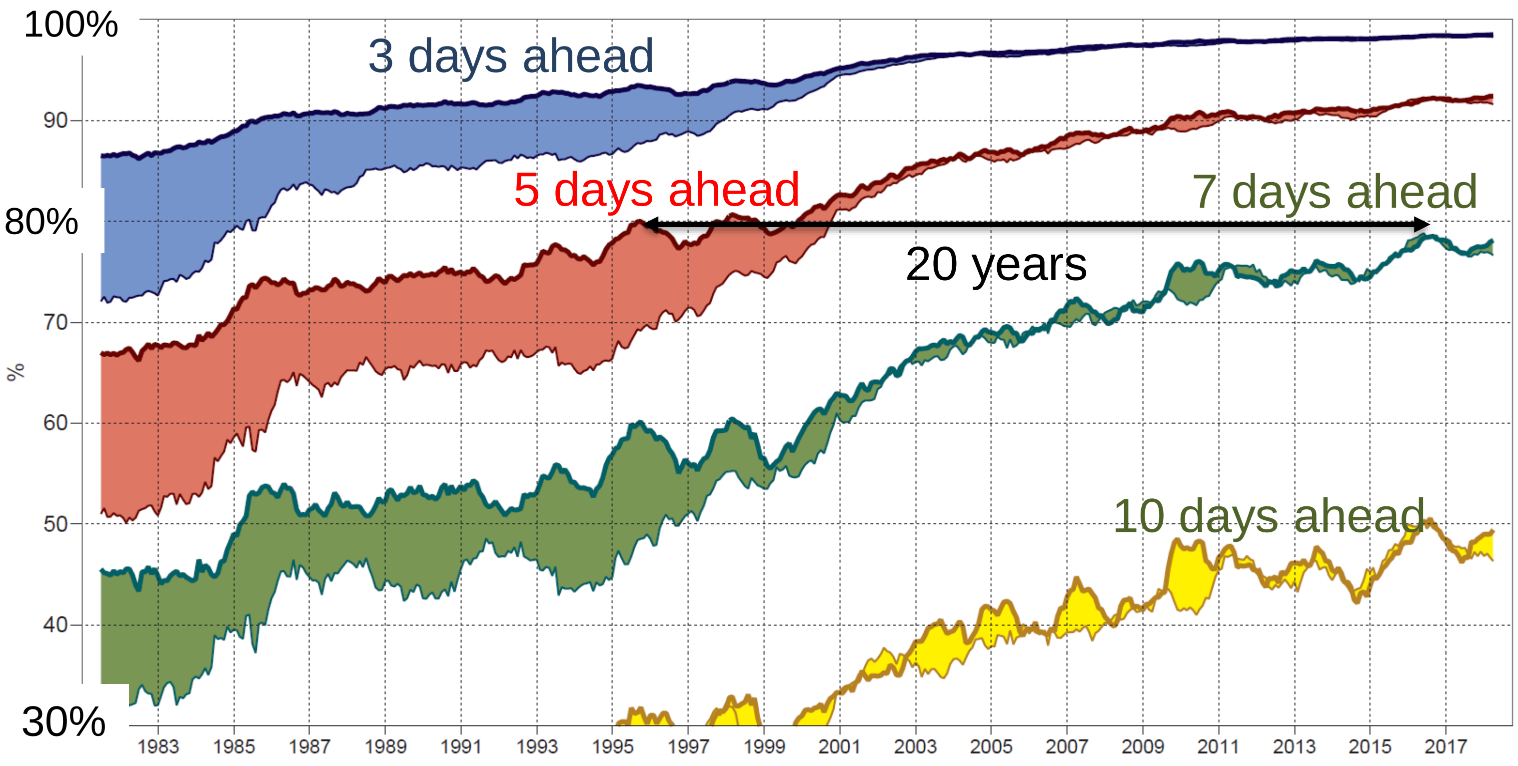
YOPP YEAR OF POLAR PREDICTION

WORLD METEOROLOGICAL ORGANIZATION

APPLICATE.eu Advanced prediction in polar regions and beyond

Weather forecasts experienced a quiet revolution

Anomaly correlation geopotential height 500hPa – **NH**/SH (ECWMF)



Global NWP systems of today,
i.e. ECMWF ten-day fc ~ 9 km, 137 levels

COMBINED advances in NWP key ingredients:

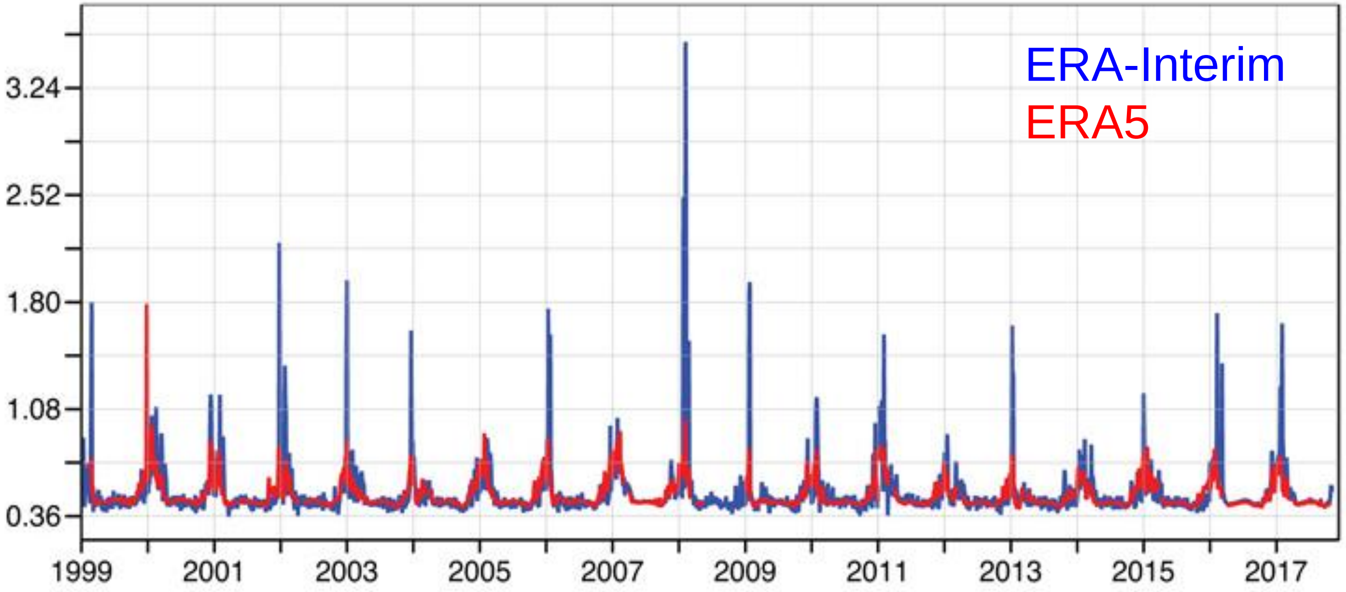
- science (physics, numerics, data assimilation)
- Utilisation of observations
- Supercomputing

ECMWF

Bauer et al. (2015)

Weather forecasts experienced a quiet revolution – and so did modern reanalysis

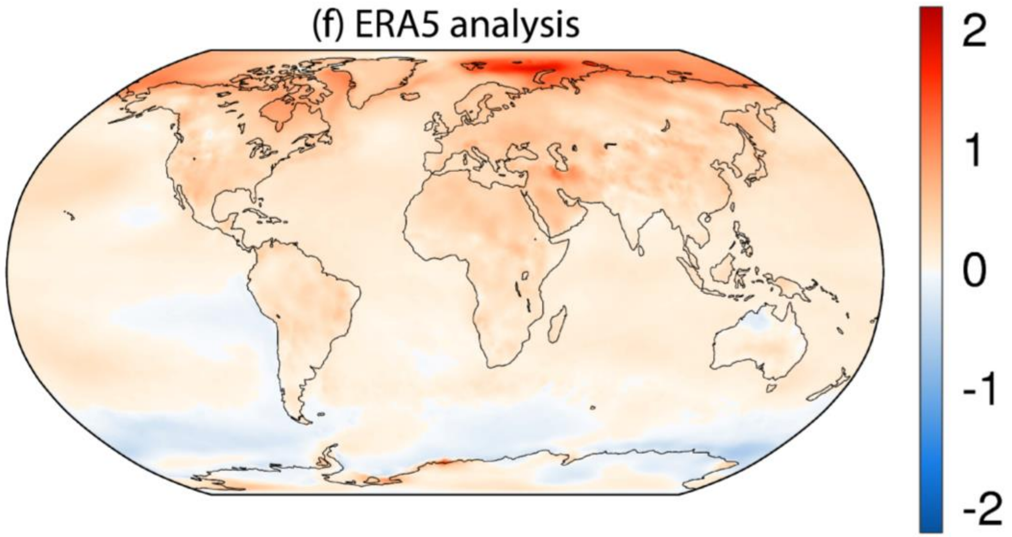
Much better representation of Sudden Stratospheric Warming events, due to changes in the Semi-Langrangian scheme (*Diamantakis, 2014*)



Modern reanalysis, i.e. ERA5 ~ 32km, 137 levels

Great tools for climate monitoring of the Arctic

Linear trends in 2m temperature (K/decade) for 1979-2017



ECMWF

Copernicus Europe's eyes on Earth

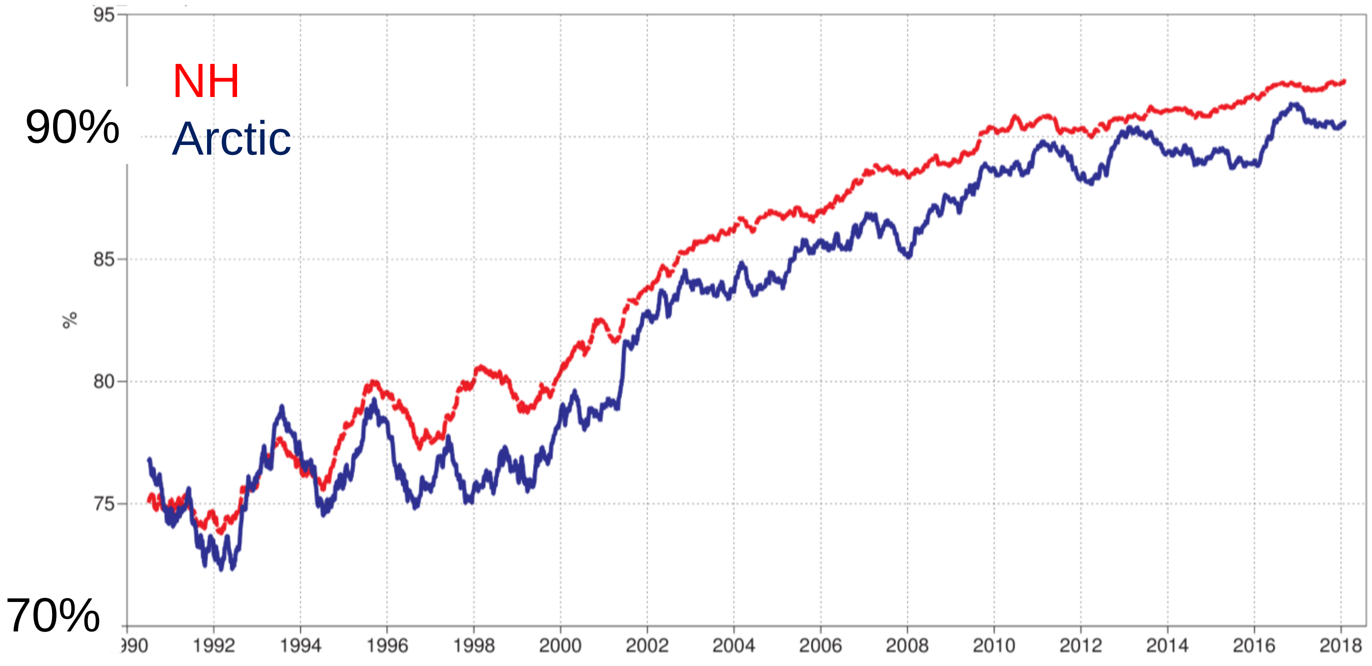
Climate Change Service

climate.copernicus.eu

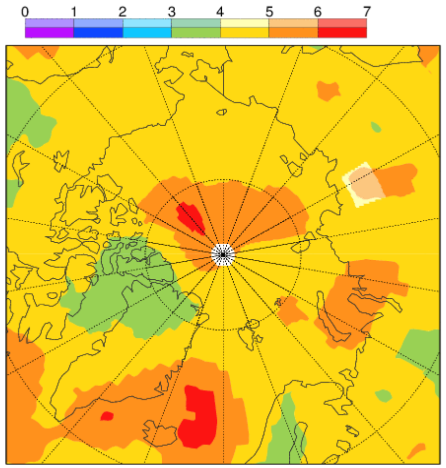
T. McNally, A. Simmons

Yet, forecast skill remains lower in the Arctic

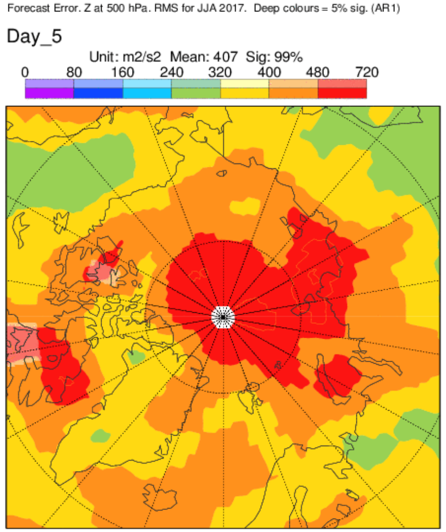
Anomaly correlation geopotential height 500hPa, 5 days ahead



RMSE geopotential height
500hPa, 5 days ahead



Winter



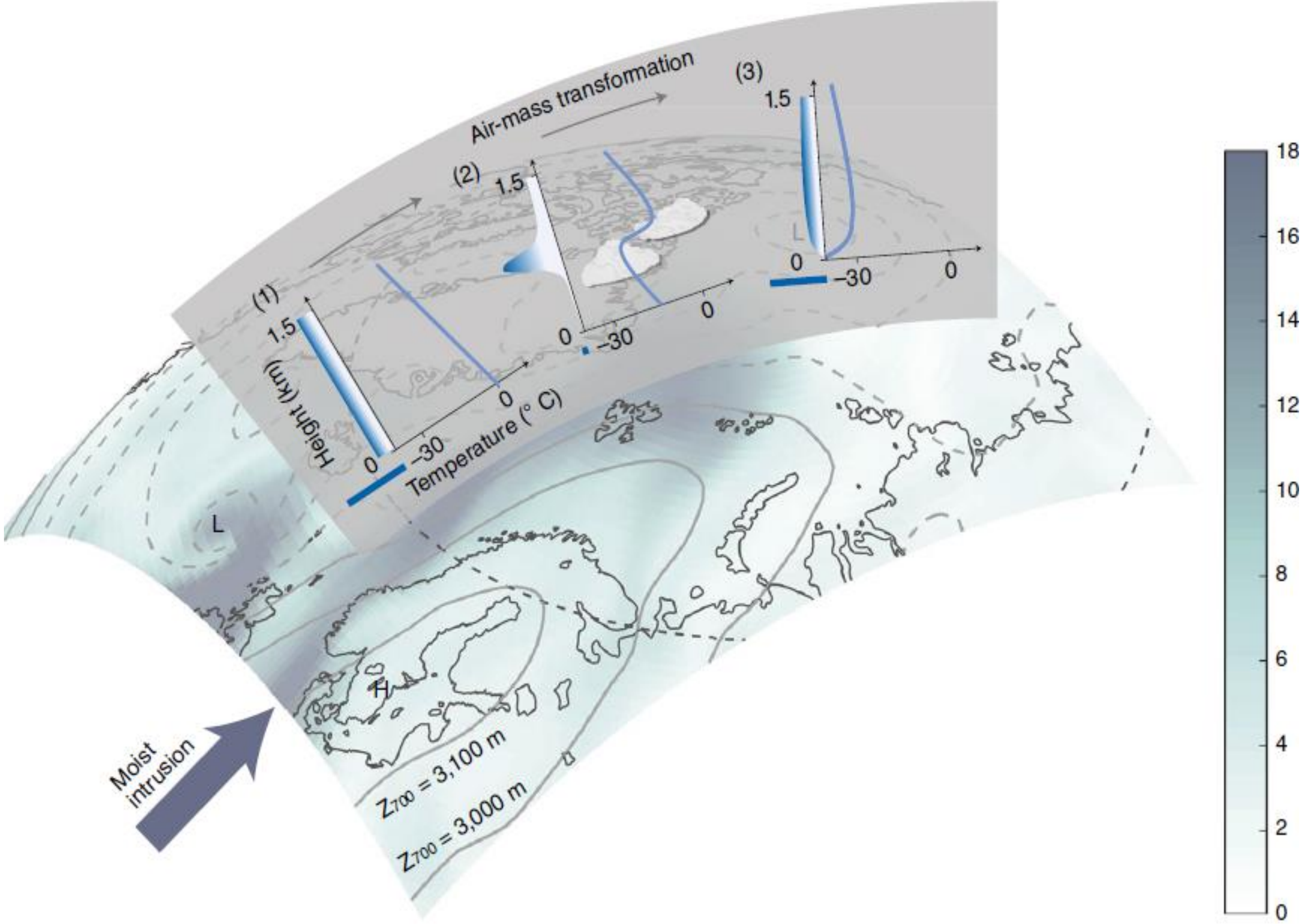
Summer

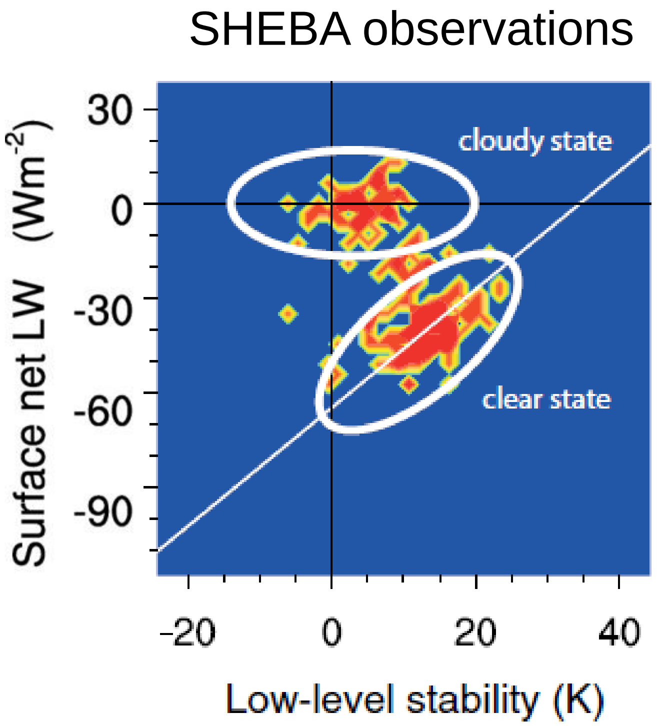
Challenges related to:

- physical processes, wide range of scales, coupling
- use of observations
- data assimilation techniques
- ensemble prediction

ECMWF

Modelling challenges – one example : Arctic air mass transformation

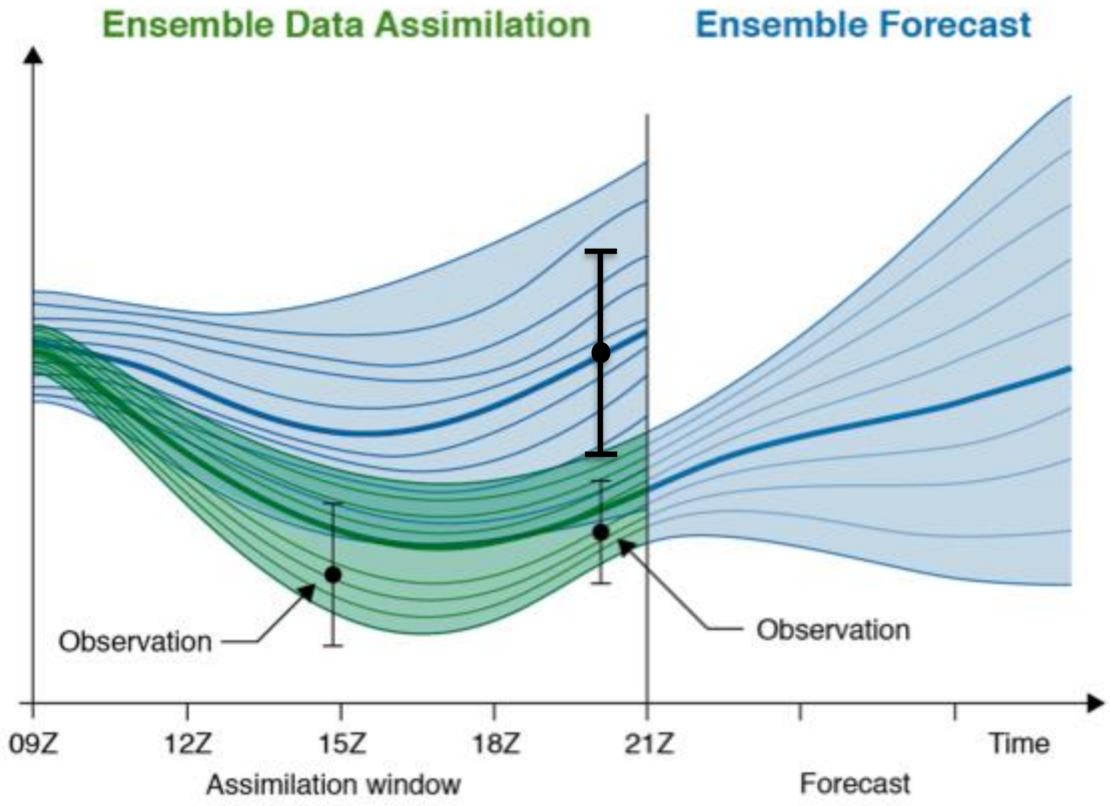




- Stable boundary layers
- Mixed phase clouds
- Atmosphere-sea ice coupling
- Sea ice
- Snow over sea-ice
- Wide range of scales

Pithan et al. (2018, 2016)

Challenges in data assimilation techniques

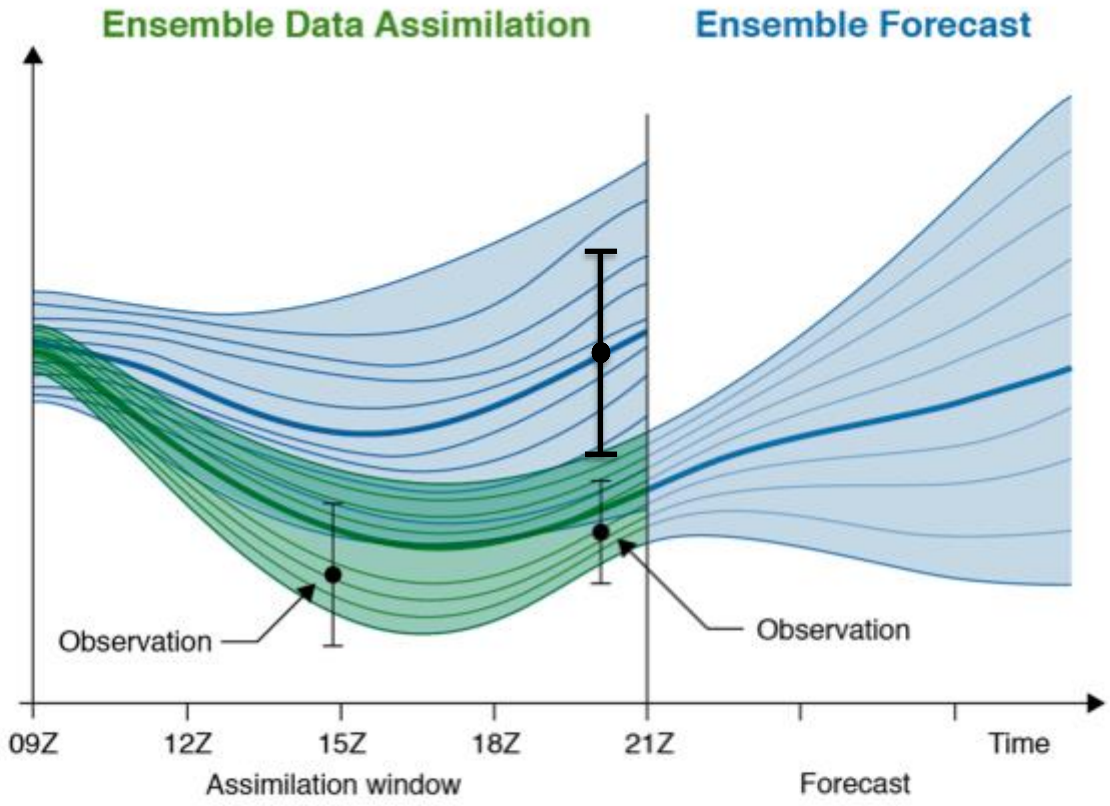


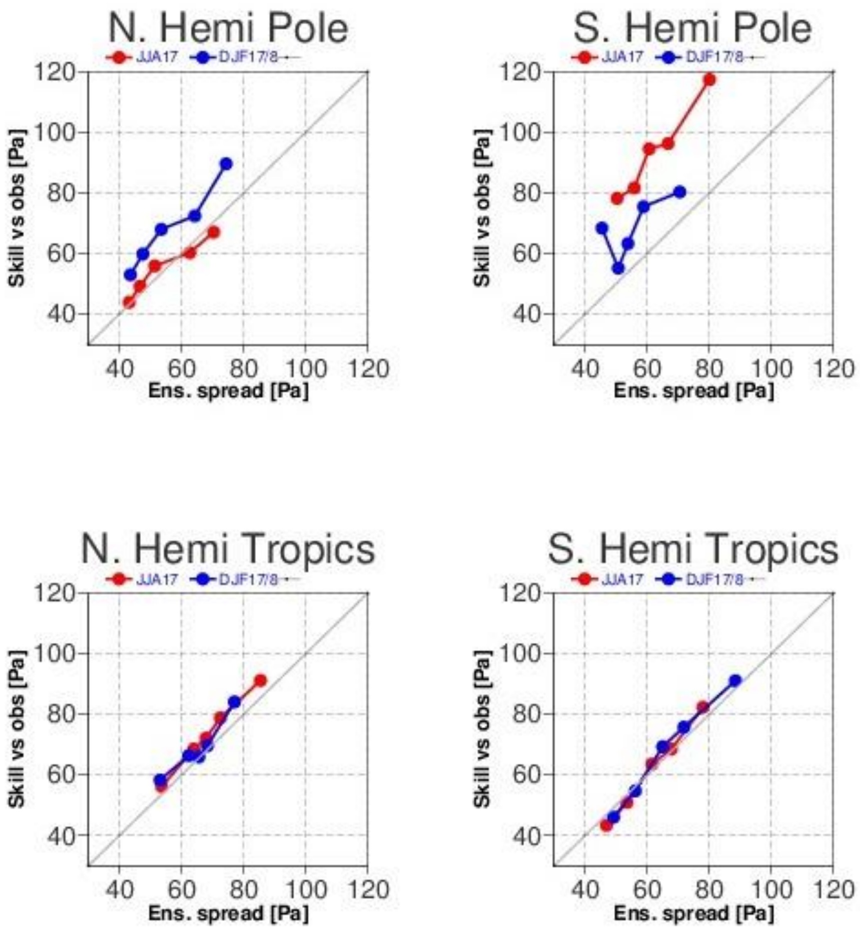
We know observations and models are not perfect:

1. As long as observations and background forecast uncertainty are properly specified, we should produce an optimal analysis
2. As long as initial condition and model uncertainty are properly specified, we should produce a reliable ensemble forecast

Challenges in data assimilation techniques

APPLICATE.eu
Advanced prediction in polar regions and beyond





JJA
DJF

ECMWF

In lower-troposphere & upper-stratosphere, the adjustments observations can make to the short-range forecasts in the Arctic during the assimilation are now limited

J. Farnan

Challenges in the use of observations

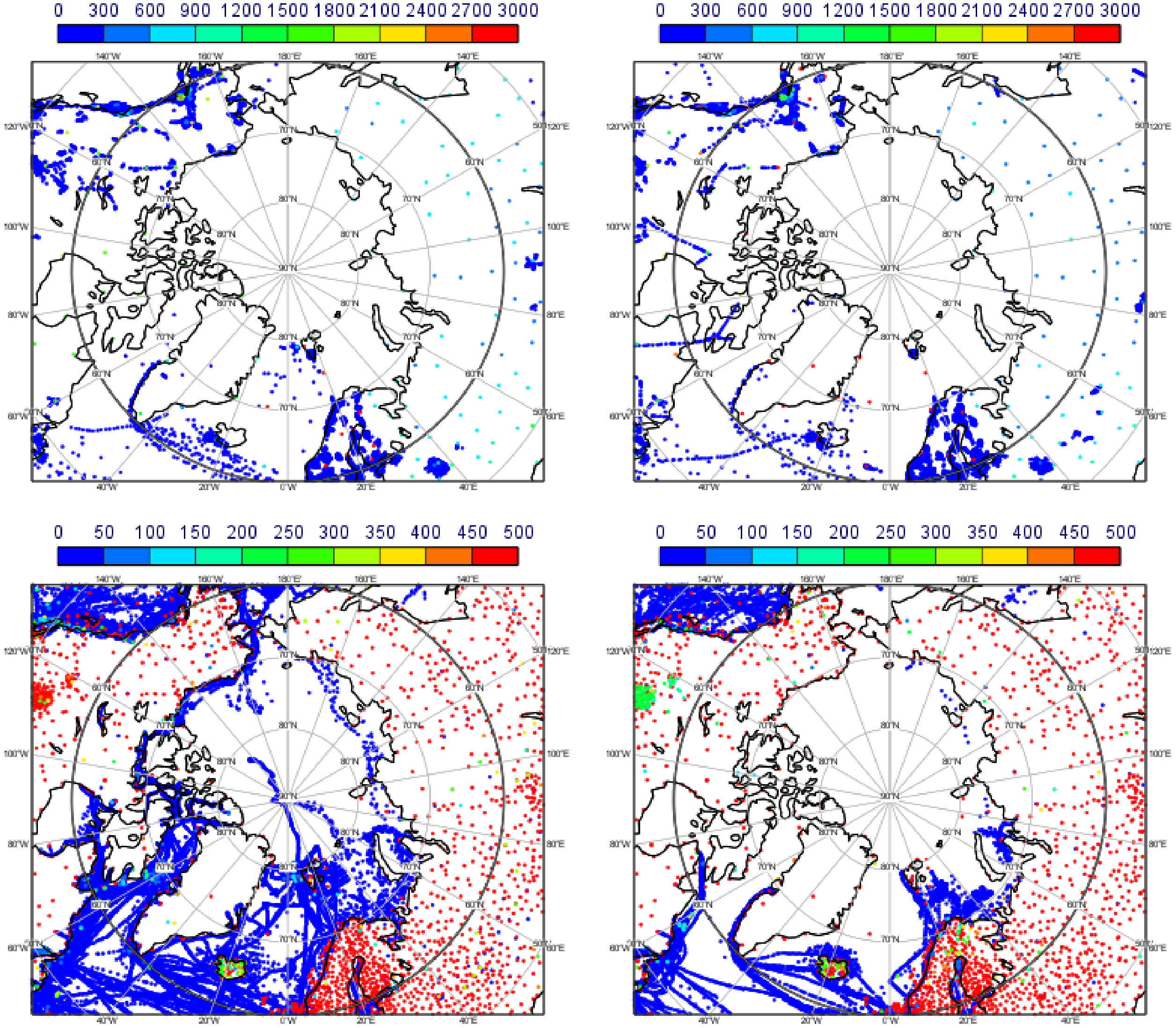
APPLICATE.eu
Advanced prediction in polar regions and beyond

Summer 2016

Winter 2017/2018

Nb radiosondes

Nb surface pressure



Less conventional data above 70N than Northern mid-latitudes

Also larger model errors & too much confidence in the model in the lower-troposphere

ECMWF

H. Lawrence

Challenges in the use of observations

APPLICATE.eu
Advanced prediction in polar regions and beyond

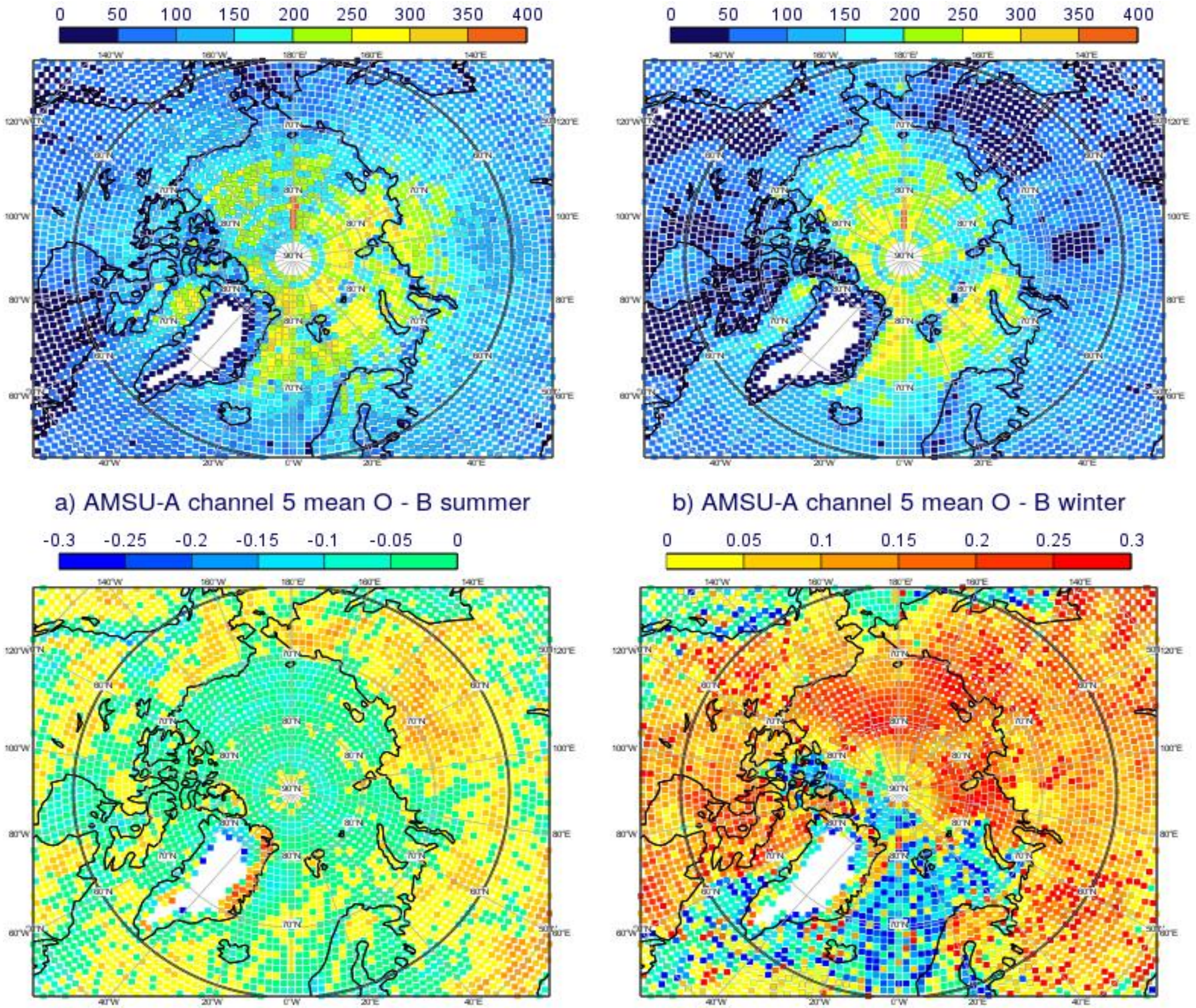
Summer 2016

Winter 2017/2018

Nb obs

NOAA-15
AMSU-A channel 5
(peaks 500-700hPa)

Obs - fc



- better coverage from polar orbiting satellites than anywhere else
- more challenges witn their use (model errors, radiative transfer modelling)
- more data rejected for tropospheric channels in winter

ECMWF

H. Lawrence

YOPP Modelling Plan - Components

Reference datasets	Experimental datasets	Model Evaluation	Outcomes
Core datasets	Modelling and process studies	Verification research	Model output
Datasets of opportunity	Predictability studies	Model diagnostics	Plans for consolidation phase
	Teleconnections and linkages		Workshops and meetings
	Observing system design		

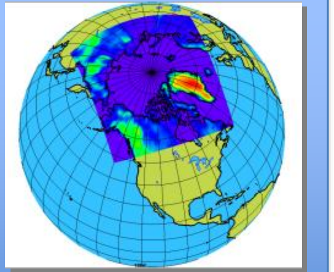
Swinbank et al. (2017)

YOPP Modelling & Forecasting Datasets

ECMWF YOPP dataset

- EPS control coupled forecasts 15 days (18 km)
- Process tendencies provided
- http://apps.ecmwf.int/datasets/data/yopp/

ECCC YOPP datasets



- CAPS-RIOPS (A:3 km, IO: 3-8 km, 2 days)
- GDPS-GIOPS (A: 25km, IO: 1/4º, 10 days)
- GIOPS ensemble (32 days, 20 members)
- Seasonal predictions (1º, 20 members)
- Available through World Mapping Service (WMS)

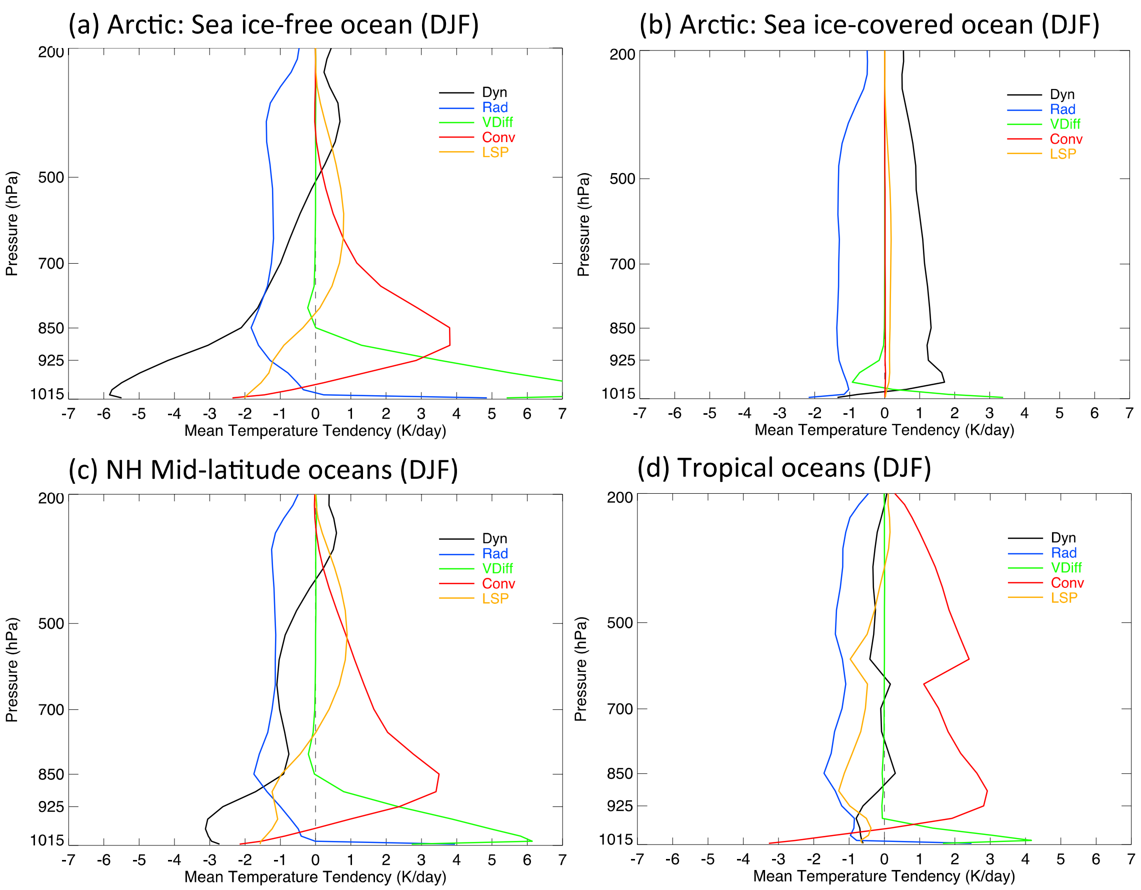
ECMWF

Data availability and further information
http://polarprediction.net

YOPP Modelling & Forecasting Datasets

APPLICATE.eu
Advanced prediction in polar regions and beyond

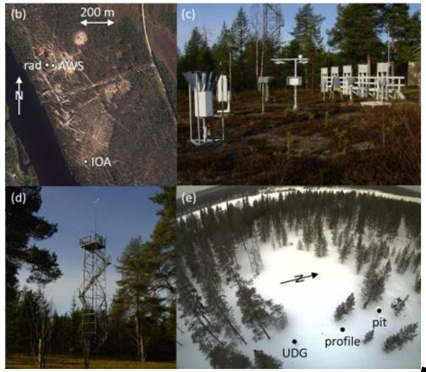
Example application:
Contrasting mean tendencies in different regions



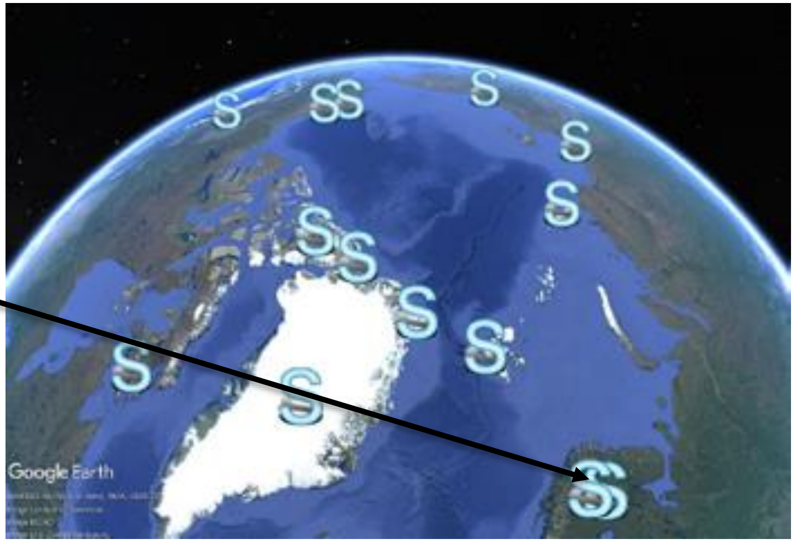
ECMWF

Jung et al. (2016)

YOPPsiteMIP - YOPP supersite Model Inter-comparison Project



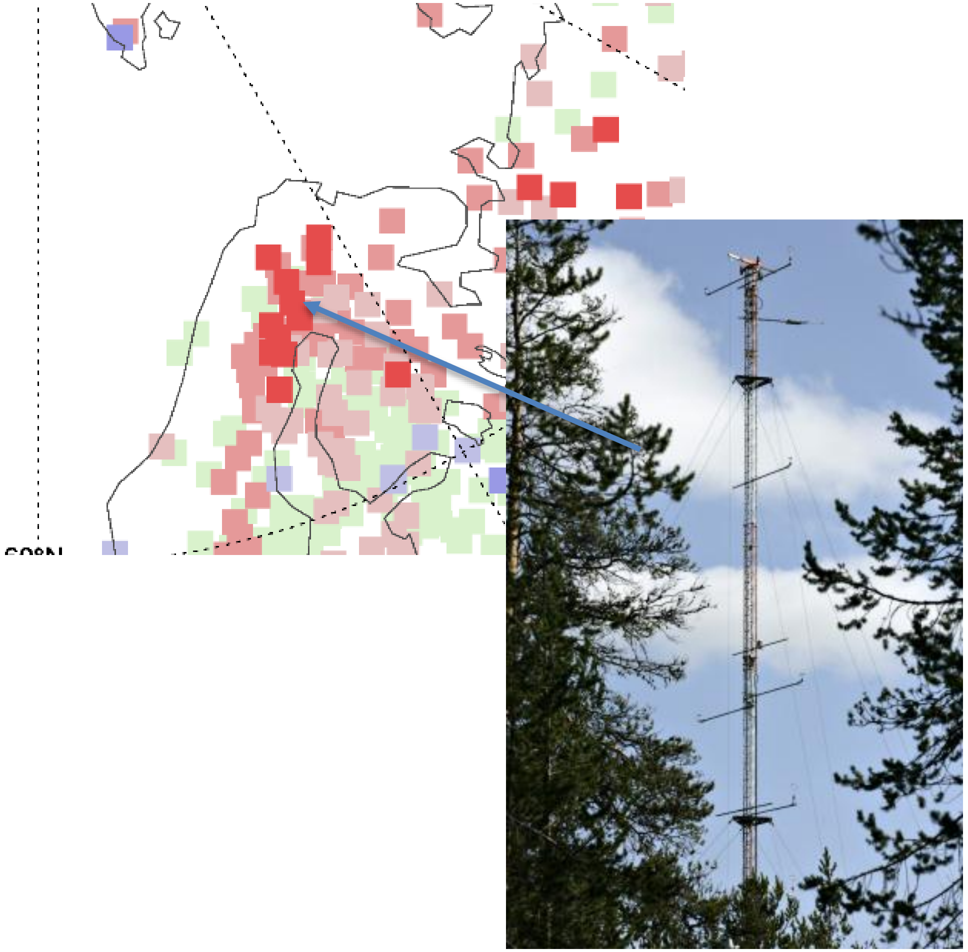
Sodankyla

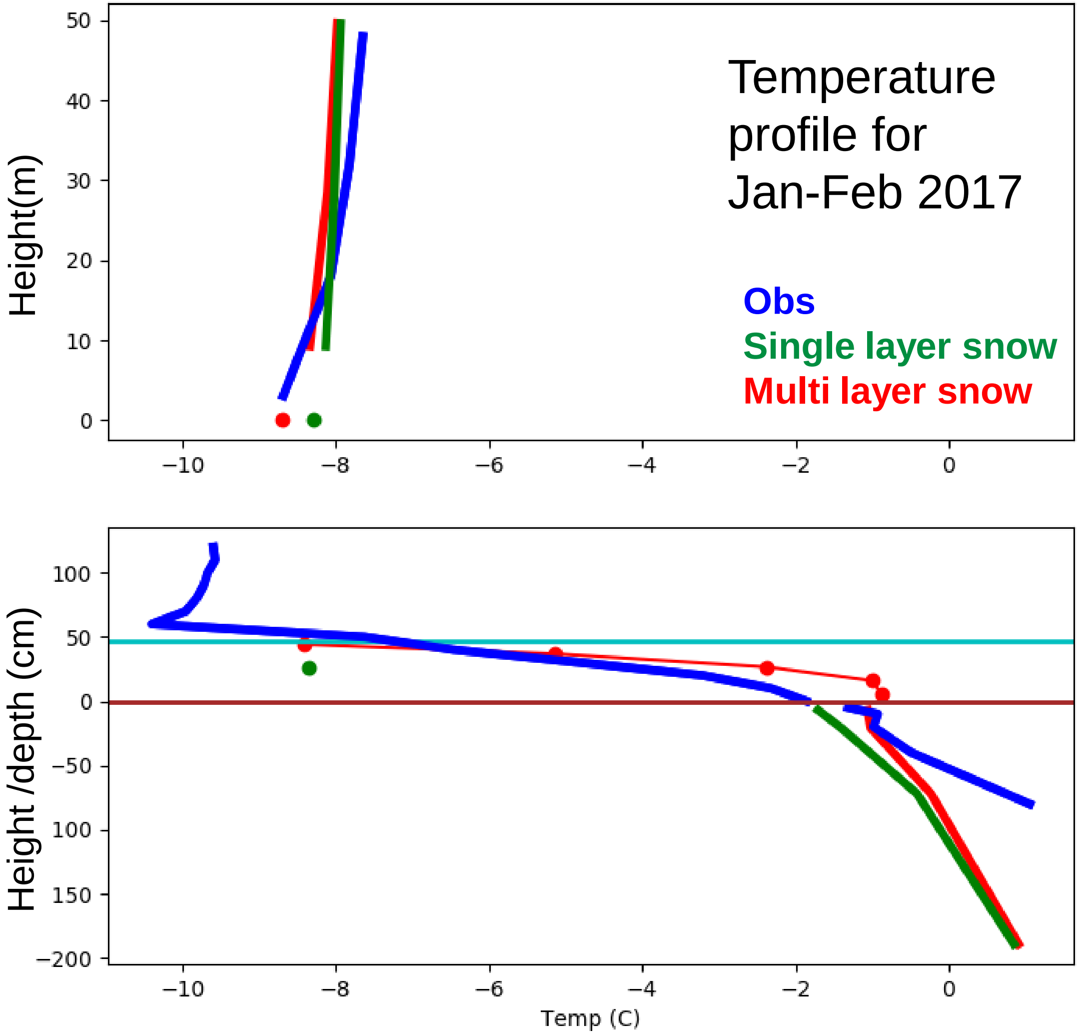


- **Process based forecast evaluation** at YOPP supersites: fixed and floating, range of surface & climate types
- IASOA/NOAA producing Merged Observatory Data Files (MODFs) for YOPP SOPs, hosted by MetNo
- Modelling contributions from ECMWF, UK Met Office, Russian Hydromet, ECCC, Met No., Univ. Stockholm.

ECMWF

Example of diagnostic analysis at the Sodankyla supersite (Finland)

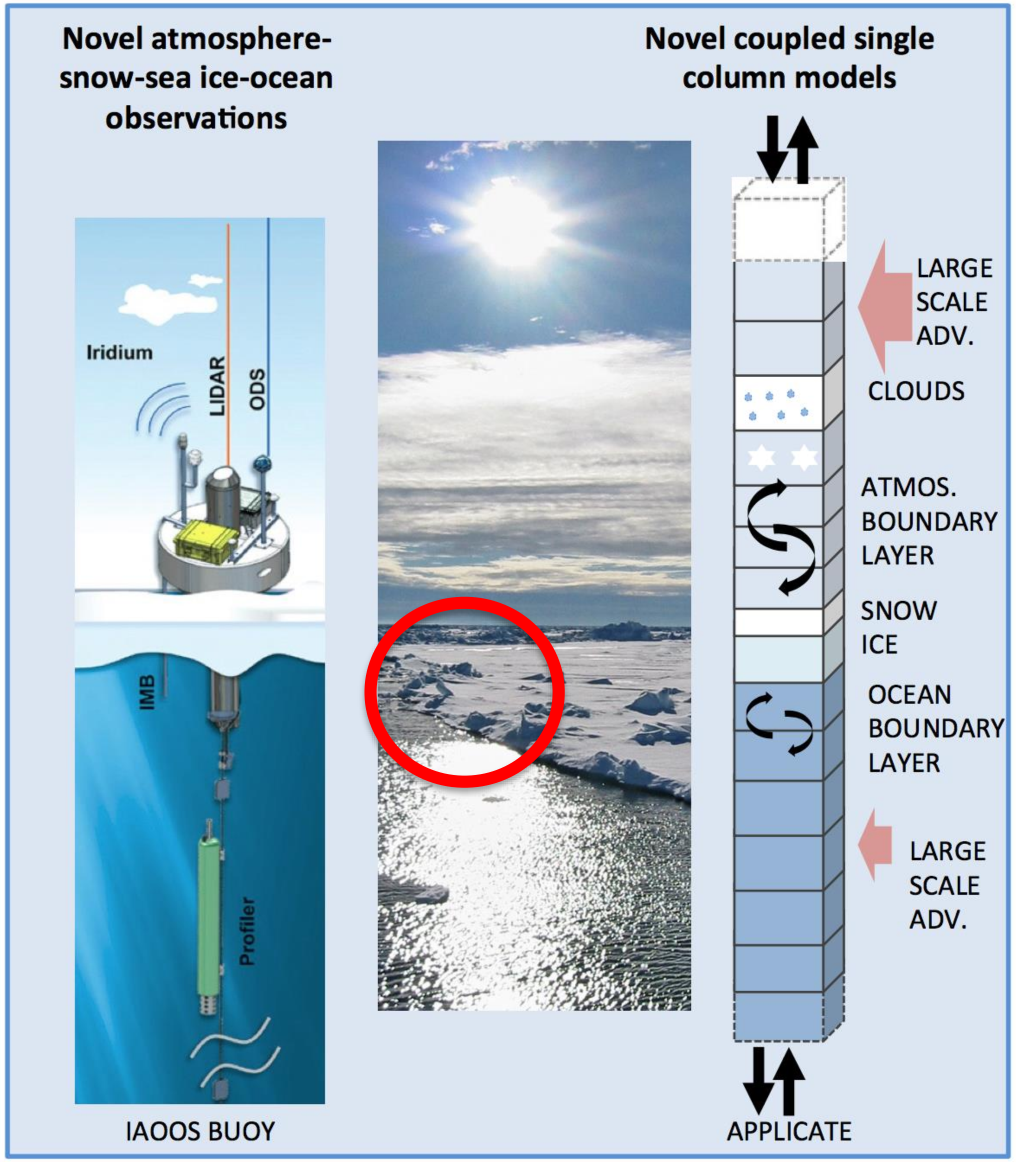




Targeted diagnostics & model evaluation inform model development

J. Day & G. Arduini

Coupled (atm/ocean/sea-ice) modelling and process understanding



Hartung et al. (2018)

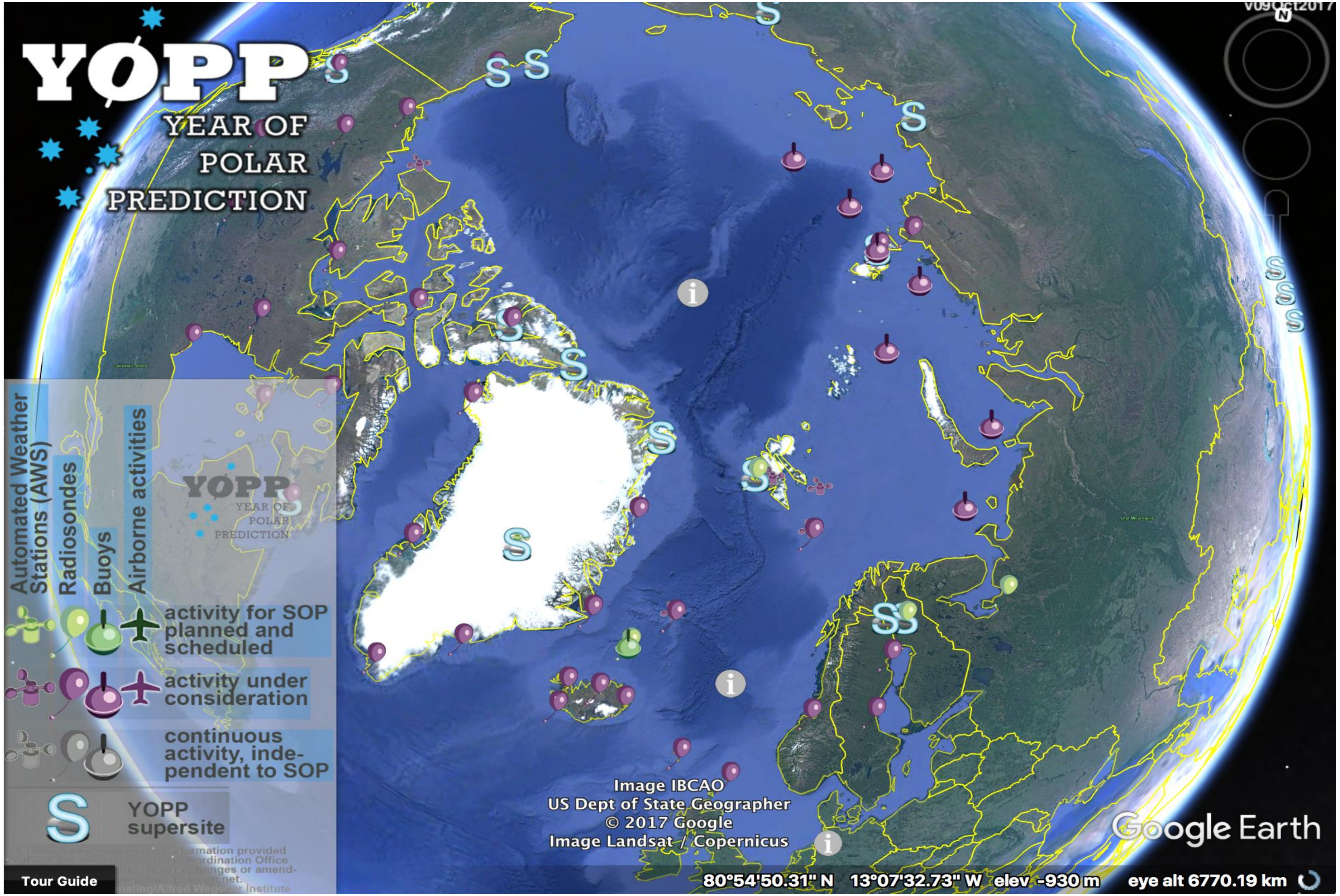
Specific dynamic & thermodynamics coupling challenges in NWP

- Initialization
- Temporal and spatial scales

Arctic Winter SOP Extra Observations

YOPP
YEAR OF
POLAR
PREDICTION

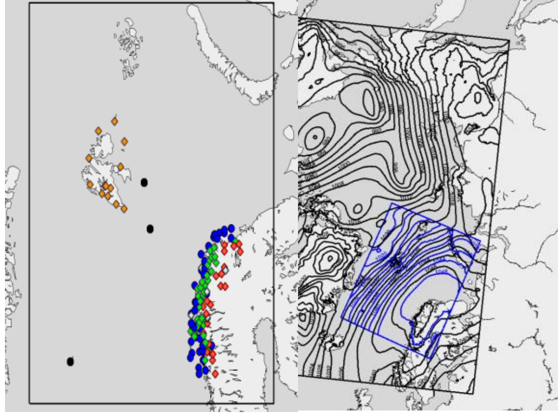
WORLD
METEOROLOGICAL
ORGANIZATION



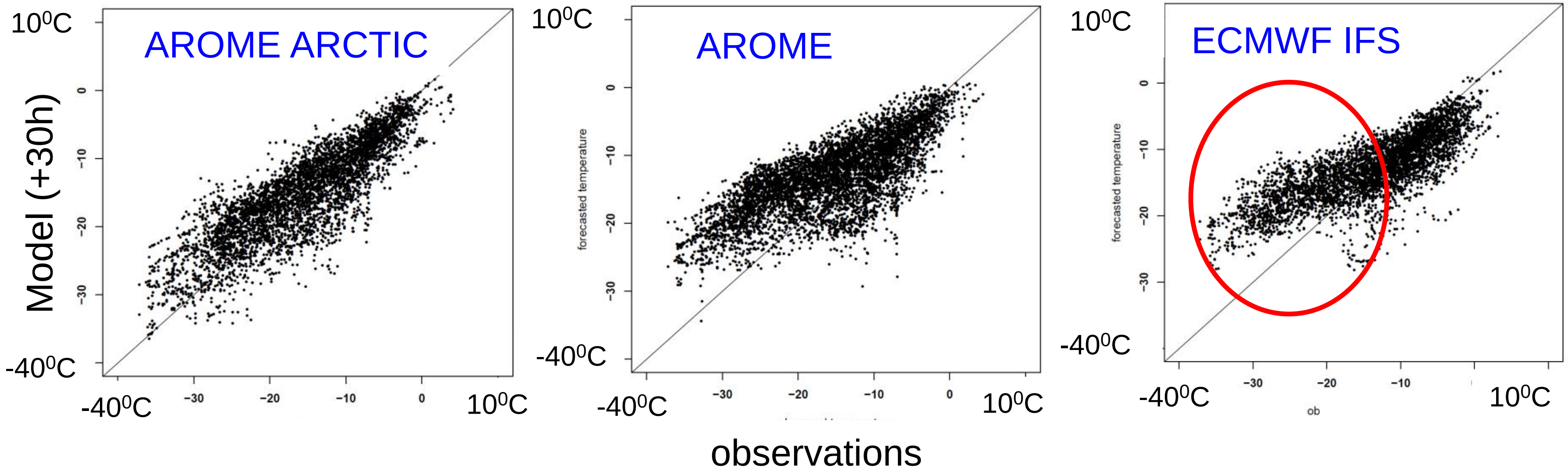
http://www.polarprediction.net/yopp-activities/yopp-observations-layer/

Model comparison for the first YOPP SOP

(Feb-March 2018)



Temperature when forecasts and observed calm winds (< 2m/s)



APPLICATE.eu
Advanced prediction in polar regions and beyond

Norwegian Meteorological Institute

ECMWF IFS overestimates very cold temperatures in calm wind conditions, AROME(s) better

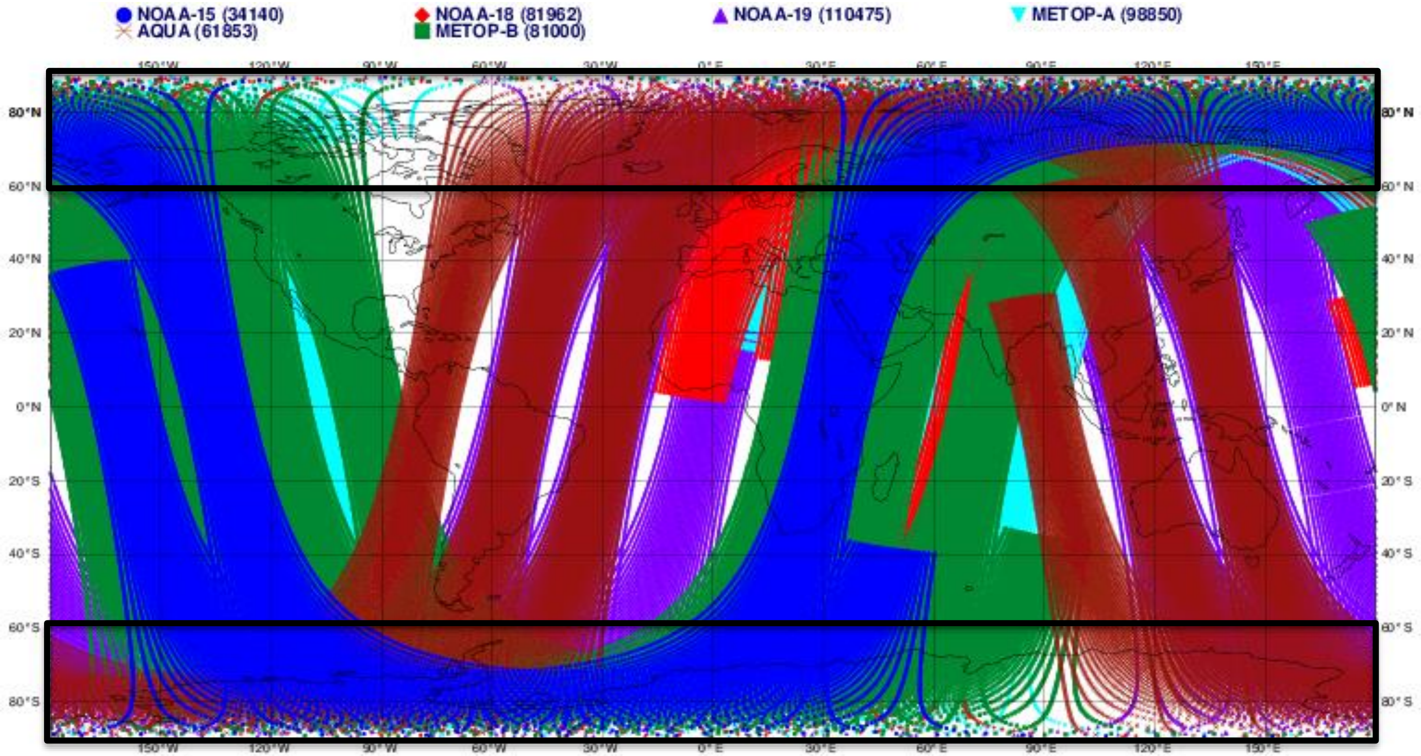
ECMWF

Morten Koltzow (MetNo)

Observing System Experiments (OSEs)

APPLICATE.eu
Advanced prediction in polar regions and beyond

Remove (satellite and conventional) observations at lat>60N and lat<-60N:



3 months winter (including YOPP 1st SOP)

3 months summer

Analyse the increase in forecast error when observations are removed from the Arctic

ECMWF

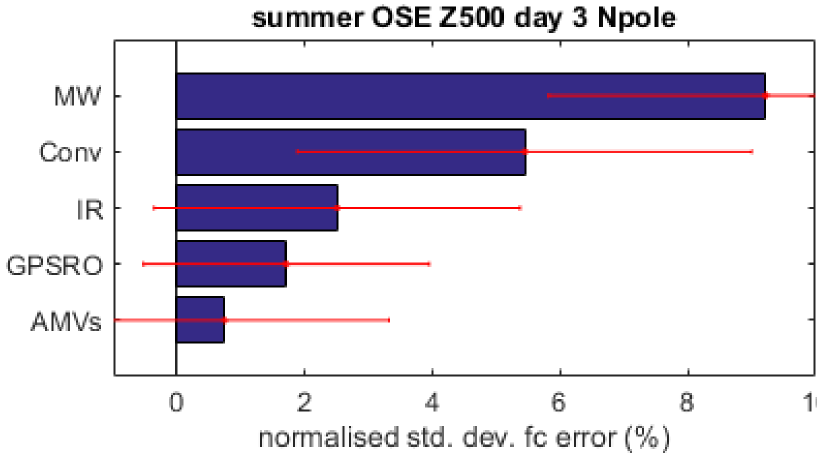
H. Lawrence et al., in preparation

Degraded forecast skill in the North Pole and Northern Mid-latitudes

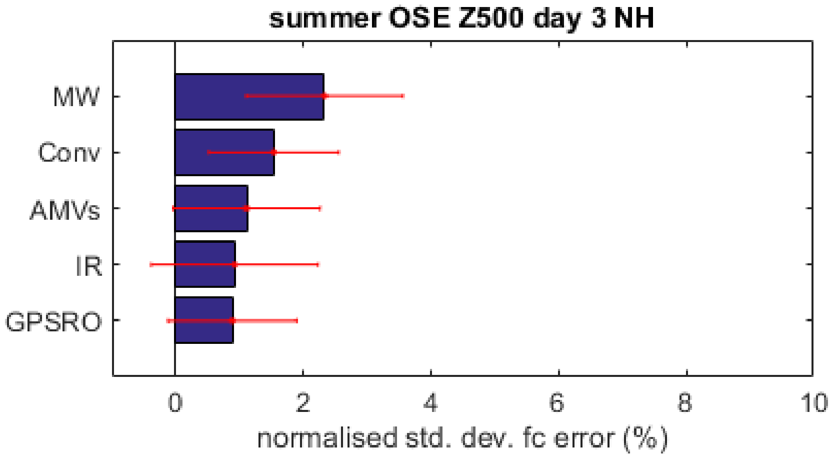
APPLICATE.eu
Advanced prediction in polar regions and beyond

60 – 90 N

summer

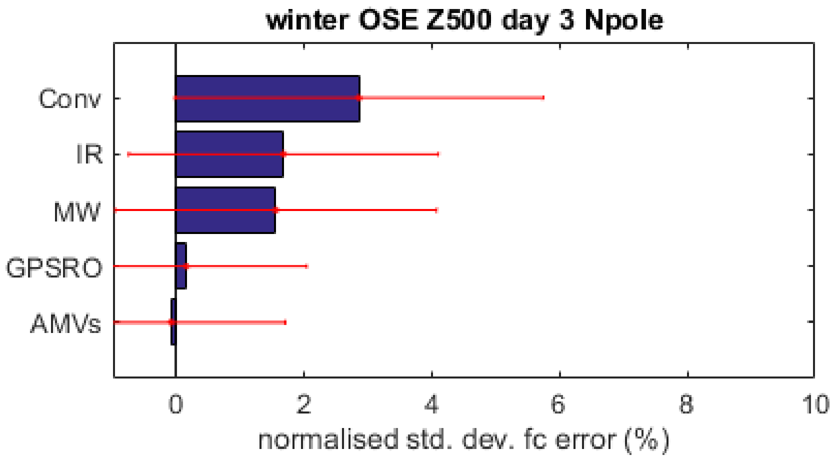


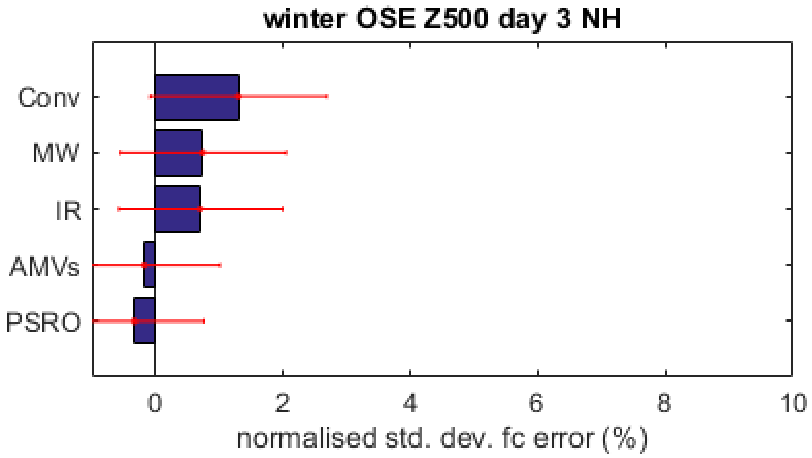
20 – 60 N



Summer:
- Microwave
- Conventional
- Infrared
- GPSRO, AMVs

winter





Winter:
- Conventional
- Less impact overall from each observation type

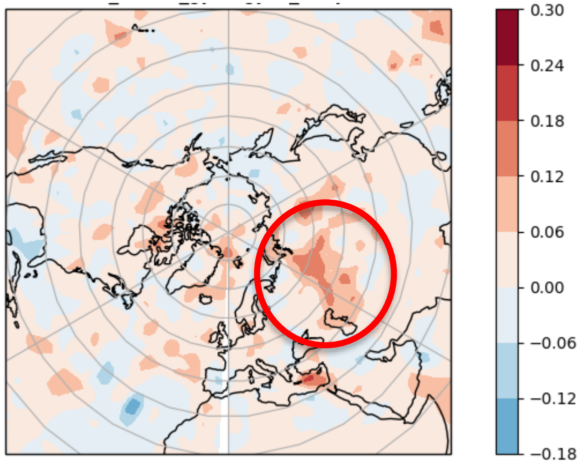
ECMWF

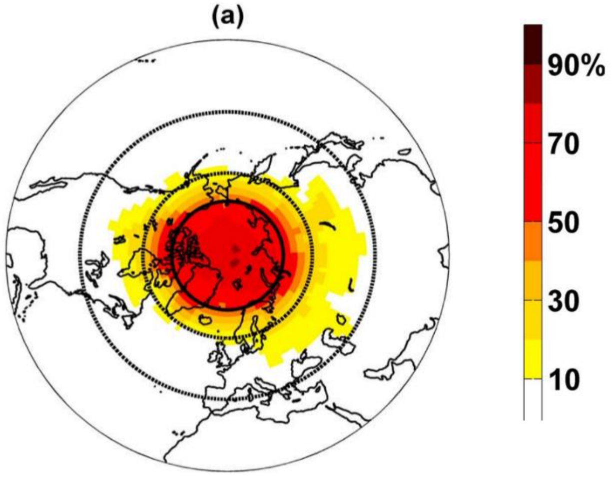
H. Lawrence et al., in preparation

Impact on the midlatitudes & Arctic – midlatitude linkages

APPLICATE.eu
Advanced prediction in polar regions and beyond

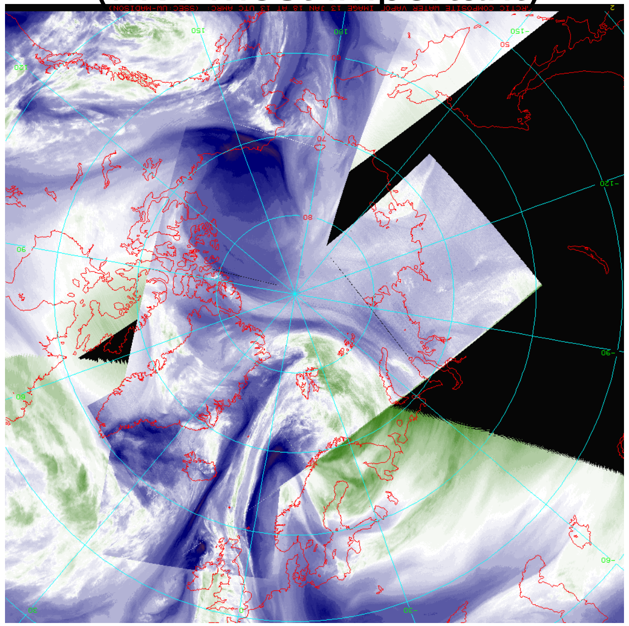
Day 4



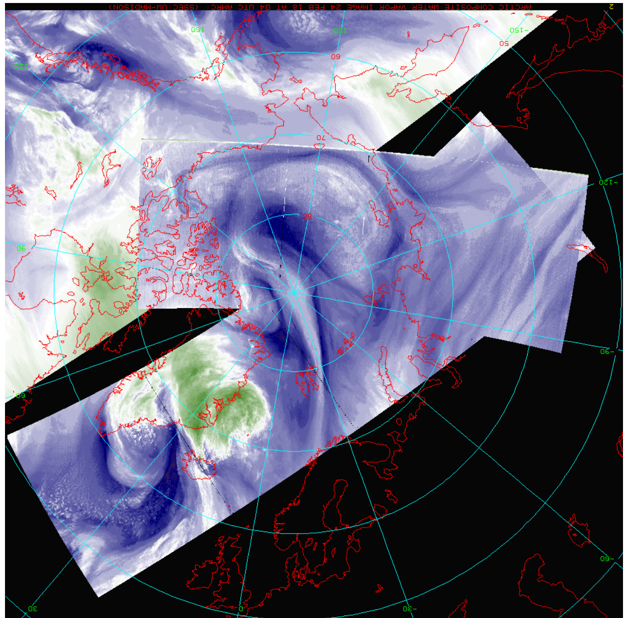


Jung et al, 2014

13-01-2018
(MW most important)



24-02-2018
(Conventional most important)



ECMWF

J. Day et al, in preparation

Specific challenges in the Arctic:

- Coupled model errors are large & the range of scales to cover is wide;
- The Arctic is sparse in term of conventional observations but very rich in terms of satellite observations;
- Satellite observations are more difficult to use (i.e. radiative transfer modelling);
- Background error representation in data assimilation systems.

Concerted effort in YOPP in:

- enhanced coupled modelling;
- data assimilation methods (including initialization of new components & coupled data assimilation) ;
- effective use of observations in the numerical weather prediction systems.
- Artic-mid-latitude linkages

ECMWF

YOPP YEAR OF POLAR PREDICTION

WORLD METEOROLOGICAL ORGANIZATION

APPLICATE.eu Advanced prediction in polar regions and beyond