Deformation forecasts from the SIDFEx database

V. Ludwig, H. Goessling and the SIDFEx team*

IICWG-DA workshop
Oslo
Mar 23, 2023

*Helge Goessling, Ed Blockley, Axel Schweiger, Valentin Ludwig, Ed Blanchard-Wrigglesworth, Thomas Krumpen, Marcel Nicolaus, Ignatius Rigor, Bob Grumbine, Frank Kauker, Simon Reifenberg, Wendy Ermold, François Massonnet, Quentin Dalaiden, Pam Posey, Joe Metzger, Michael Phelps, Rick Allard, Laurent Bertino, Malte Müller, Maxime Beauchamp, Amy Solomon, Janet Intrieri, Frédéric Dupont, Yukie Hata, Jean-François Lemieux, Nick Szapiro, Mario Hoppmann, Steffen Tietsche, Jennifer Hutchings, Thomas Rackow, Till Rasmussen, Cyril Palerme, Suman Singha, Antonia Jost

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

Best of SIDFEx applications, with a focus on deformation forecasts

V. Ludwig, H. Goessling and the SIDFEx team*

IICWG-DA workshop
Oslo
Mar 23, 2023

*Helge Goessling, Ed Blockley, Axel Schweiger, Valentin Ludwig, Ed Blanchard-Wrigglesworth, Thomas Krumpen, Marcel Nicolaus, Ignatius Rigor, Bob Grumbine, Frank Kauker, Simon Reifenberg, Wendy Ermold, François Massonnet, Quentin Dalaiden, Pam Posey, Joe Metzger, Michael Phelps, Rick Allard, Laurent Bertino, Malte Müller, Maxime Beauchamp, Amy Solomon, Janet Intrieri, Frédéric Dupont, Yukie Hata, Jean-François Lemieux, Nick Szapiro, Mario Hoppmann, Steffen Tietsche, Jennifer Hutchings, Thomas Rackow, Till Rasmussen, Cyril Palerme, Suman Singha, Antonia Jost

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

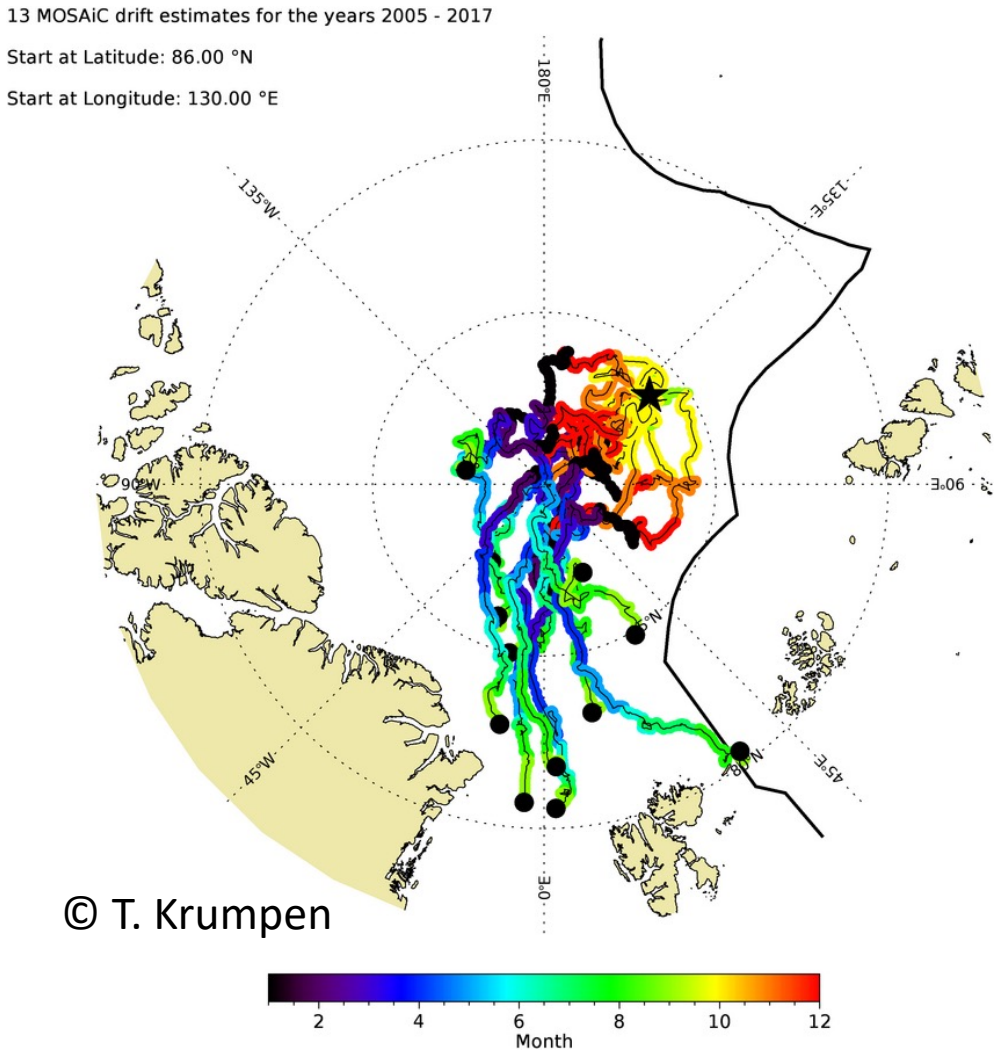
MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

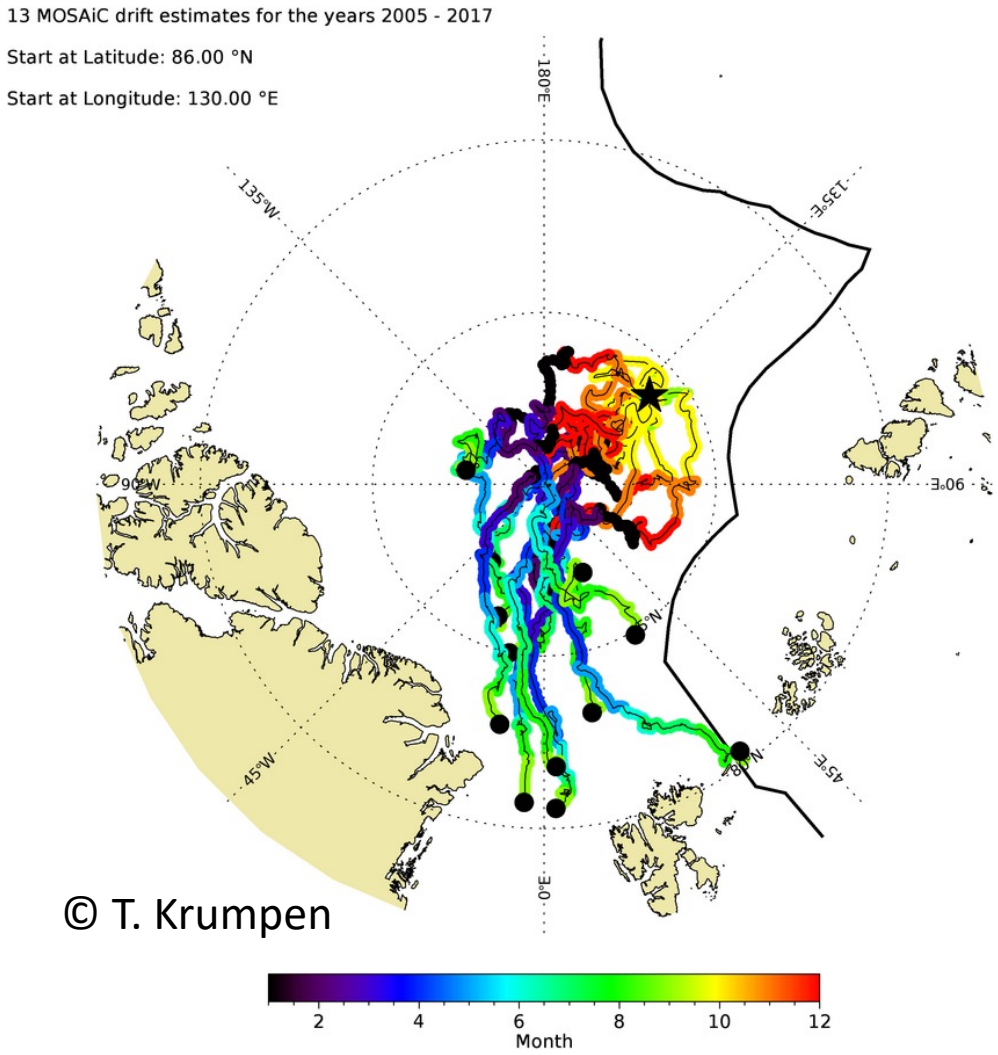
Bundesministerium für Bildung und Forschung

Where to start MOSAiC?



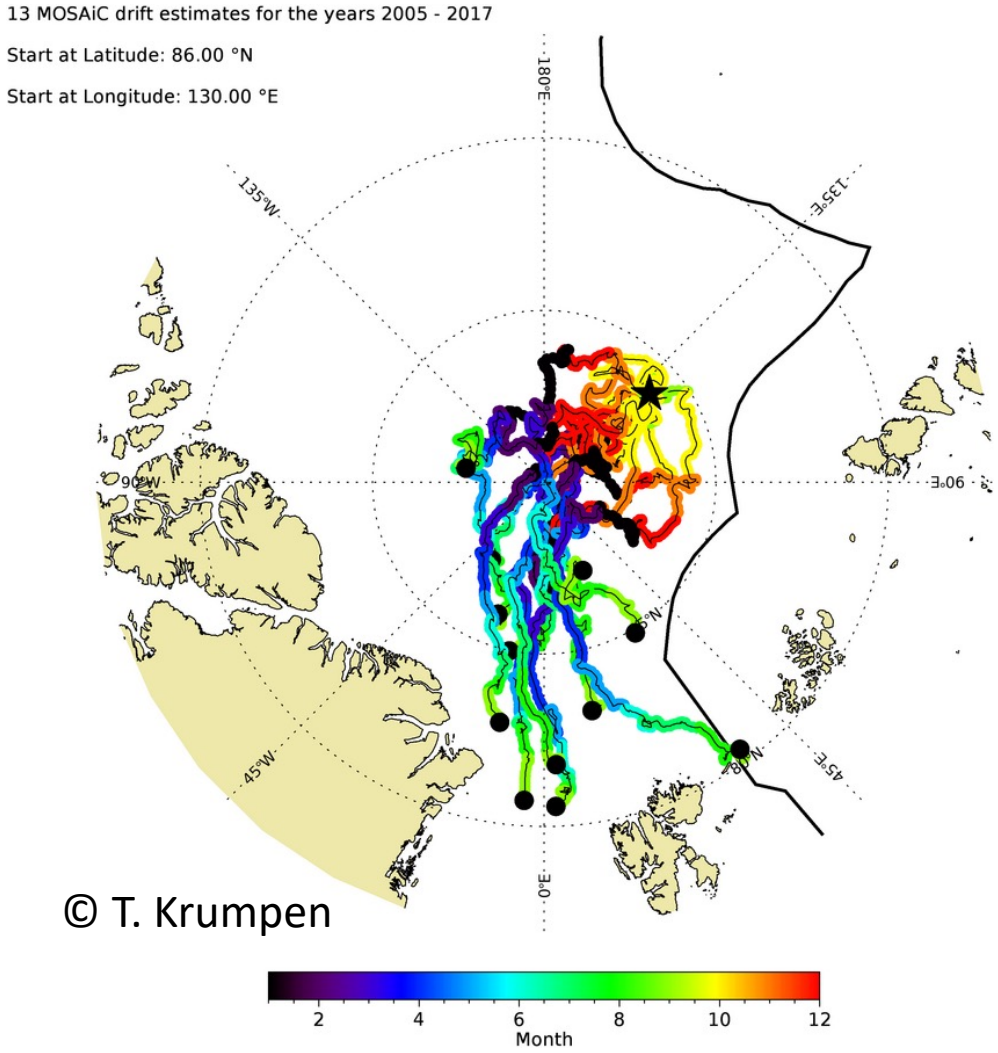
© T. Krumpen

Where to start MOSAiC?



© T. Krumpen

Where to start MOSAiC?



© T. Krumpen

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

The Sea Ice Drift Forecast Experiment

The Sea Ice Drift Forecast Experiment

ECMWF

AWI

Met Office

Meteorologisk institutt

NERSC

NOAA

Environment and Climate Change Canada

UCLouvain

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

The Sea Ice Drift Forecast Experiment

„SIDFEx is a community effort to collect and analyse Arctic sea-ice drift forecasts at lead times from days to a year. Forecasts are made with various methods for drifting sea-ice buoys and the trans-Arctic MOSAiC drift campaign.“

The Sea Ice Drift Forecast Experiment

„SIDFEx is a community effort to collect and analyse Arctic sea-ice drift forecasts at lead times from days to a year. Forecasts are made with various methods for drifting sea-ice buoys and the trans-Arctic MOSAiC drift campaign.“

HI...

The Sea Ice Drift Forecast Experiment

„SIDFEx is a community effort to collect and analyse Arctic sea-ice drift forecasts at lead times from days to a year. Forecasts are made with various methods for drifting sea-ice buoys and the trans-Arctic MOSAiC drift campaign.“

ChatGPT

HI… … or AI?

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

The Sea Ice Drift Forecast Experiment

„SIDFEx is a community effort to collect and analyse Arctic sea-ice drift forecasts at lead times from days to a year. Forecasts are made with various methods for drifting sea-ice buoys and the trans-Arctic MOSAiC drift campaign.“

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

Bundesministerium für Bildung und Forschung

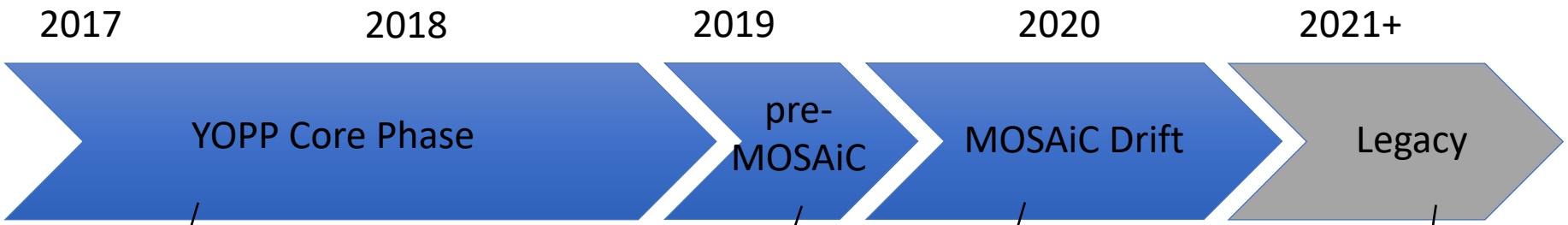
The Sea Ice Drift Forecast Experiment

„SIDFEx is a community effort to collect and analyse Arctic sea-ice drift forecasts at lead times from days to a year. Forecasts are made with various methods for drifting sea-ice buoys and the trans-Arctic MOSAiC drift campaign.“ (stolen from Helge‘s slide)

- **S**ea **I**ce **D**rift **F**orecast **Ex**periment
- 23 forecast systems, operated by groups in Europe, US and Canada
- Use cases:
  - MOSAiC starting position
  - Ordering of SAR images

    “Because of SIDFEx, our hitting rate was about 80 - 85%. Without SIDFEx my expectation was below 50%.” (S. Singha)
  - Operational support

The SIDFEx CV



Phase I)
Collect forecasts for 5⁺ selected IABP buoys, start 1st June 2017

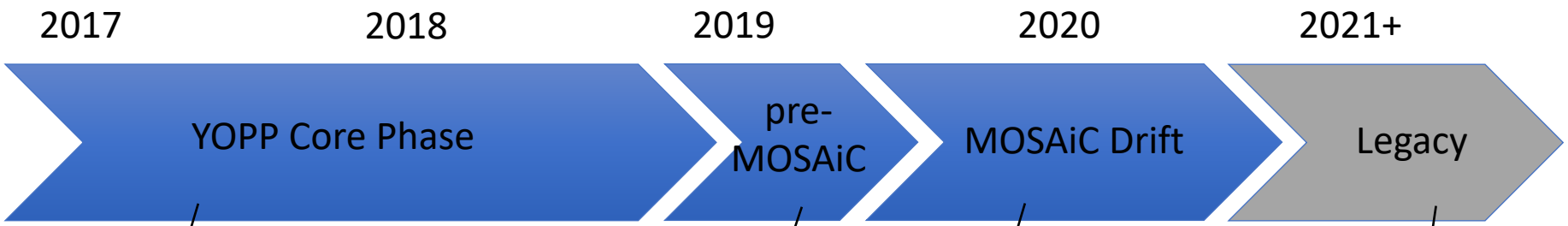
Phase II)
In addition, target points relevant for *Polarstern* drift start position

Phase III)
During drift, provide forecasts for operational planning support

Phase IV)
Analyses, publications, continuation, legacy

© H. Goessling

The SIDFEx CV



Phase I)
Collect forecasts for 5⁺ selected IABP buoys, start 1st June 2017

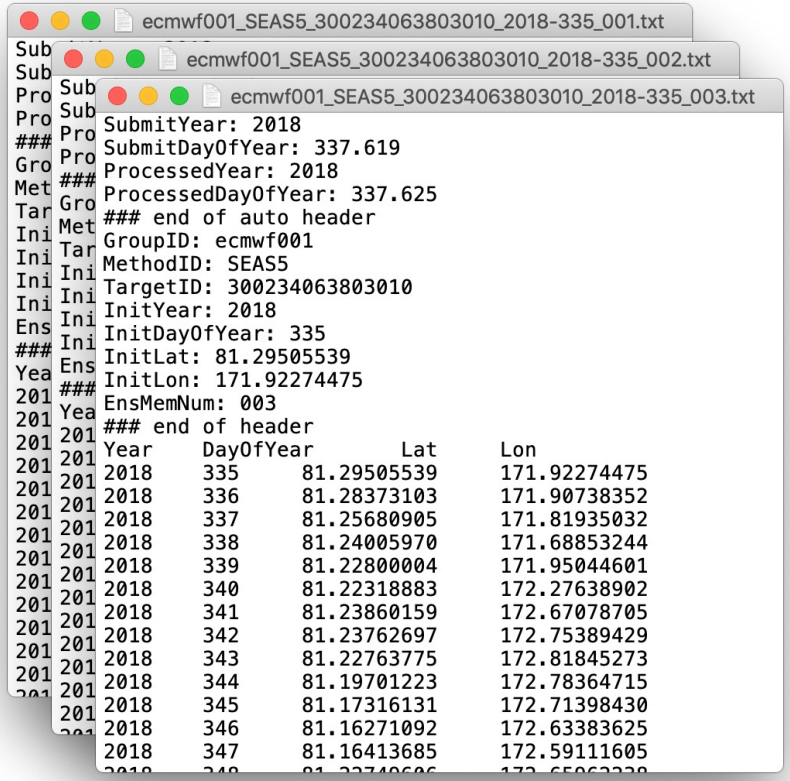
Phase II)
In addition, target points relevant for *Polarstern* drift start position

Phase III)
During drift, provide forecasts for operational planning support

Phase IV)
Analyses, publications, continuation, legacy

© H. Goessling

SIDFEx is growing up



© H. Goessling

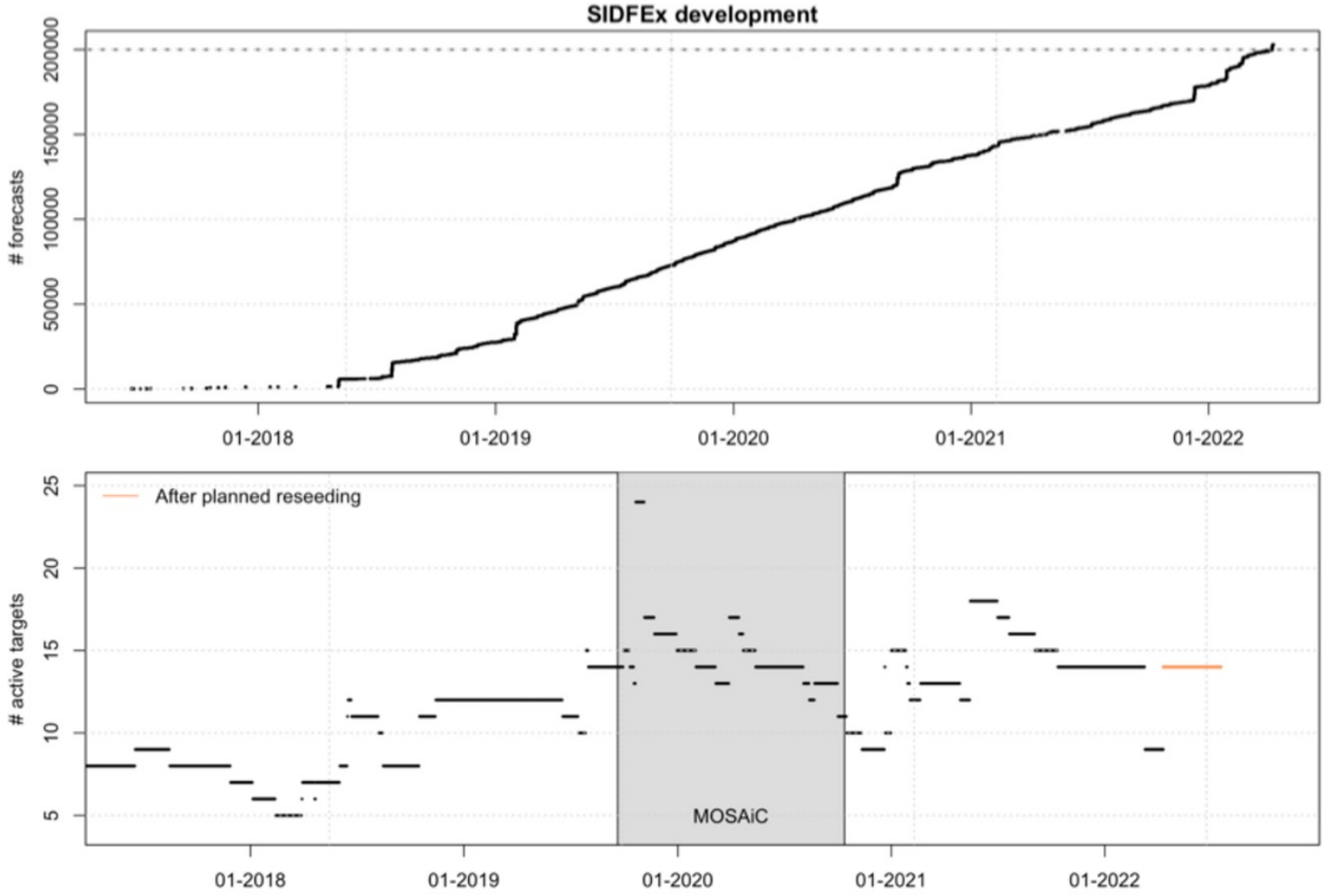
SIDFEx is growing up

ecmwf001_SEAS5_300234063803010_2018-335_001.txt

ecmwf001_SEAS5_300234063803010_2018-335_002.txt

ecmwf001_SEAS5_300234063803010_2018-335_003.txt

```
SubmitYear: 2018
SubmitDayOfYear: 337.619
ProcessedYear: 2018
ProcessedDayOfYear: 337.625
### end of auto header
GroupID: ecmwf001
MethodID: SEAS5
TargetID: 300234063803010
InitYear: 2018
InitDayOfYear: 335
InitLat: 81.29505539
InitLon: 171.92274475
EnsMemNum: 003
### end of header
Year    DayOfYear       Lat     Lon
2018    335     81.29505539     171.92274475
2018    336     81.28373103     171.90738352
2018    337     81.25680905     171.81935032
2018    338     81.24005970     171.68853244
2018    339     81.22800004     171.95044601
2018    340     81.22318883     172.27638902
2018    341     81.23860159     172.67078705
2018    342     81.23762697     172.75389429
2018    343     81.22763775     172.81845273
2018    344     81.19701223     172.78364715
2018    345     81.17316131     172.71398430
2018    346     81.16271092     172.63383625
2018    347     81.16413685     172.59111605
```



© H. Goessling

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

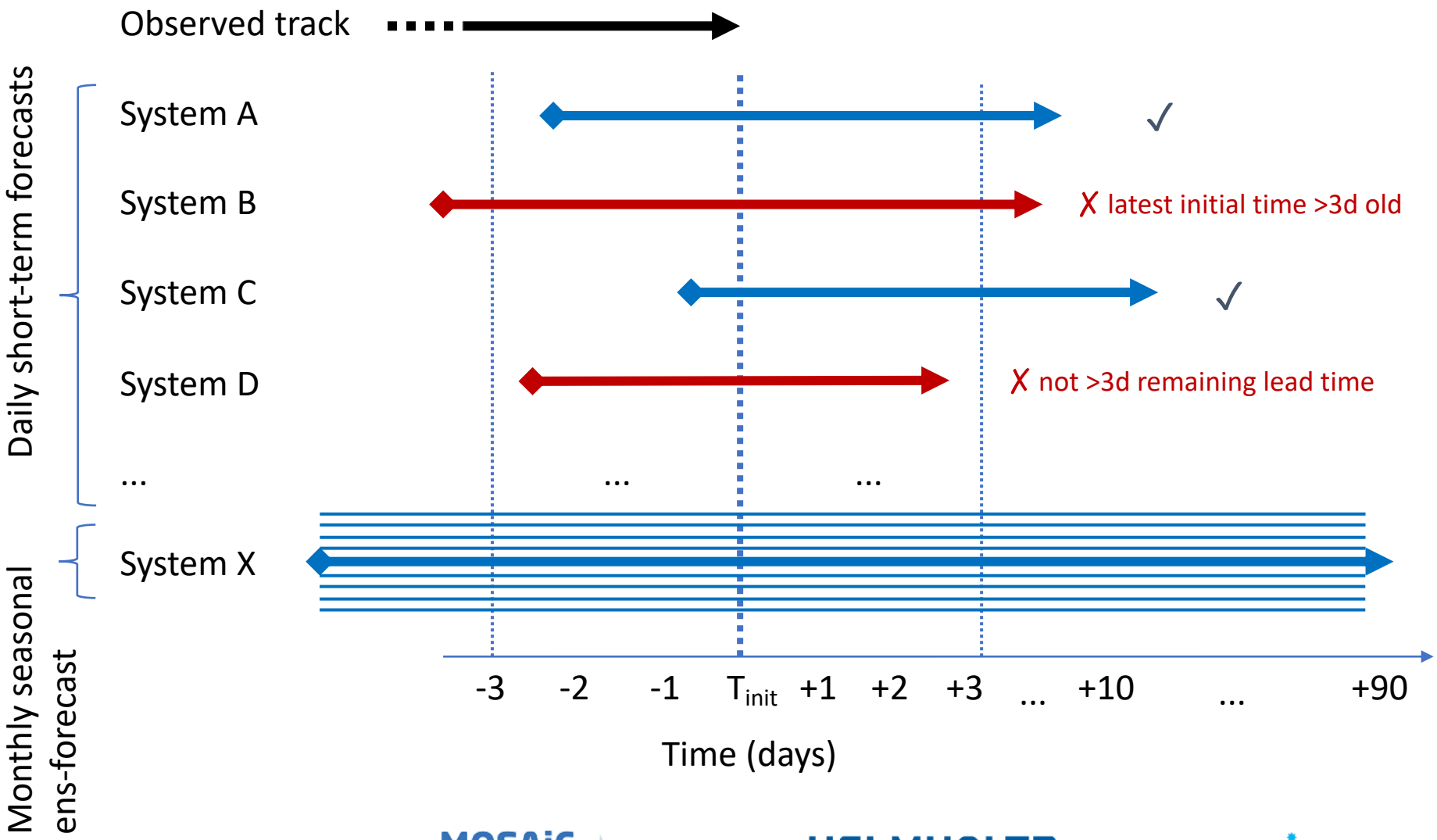
MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF POLAR PREDICTION

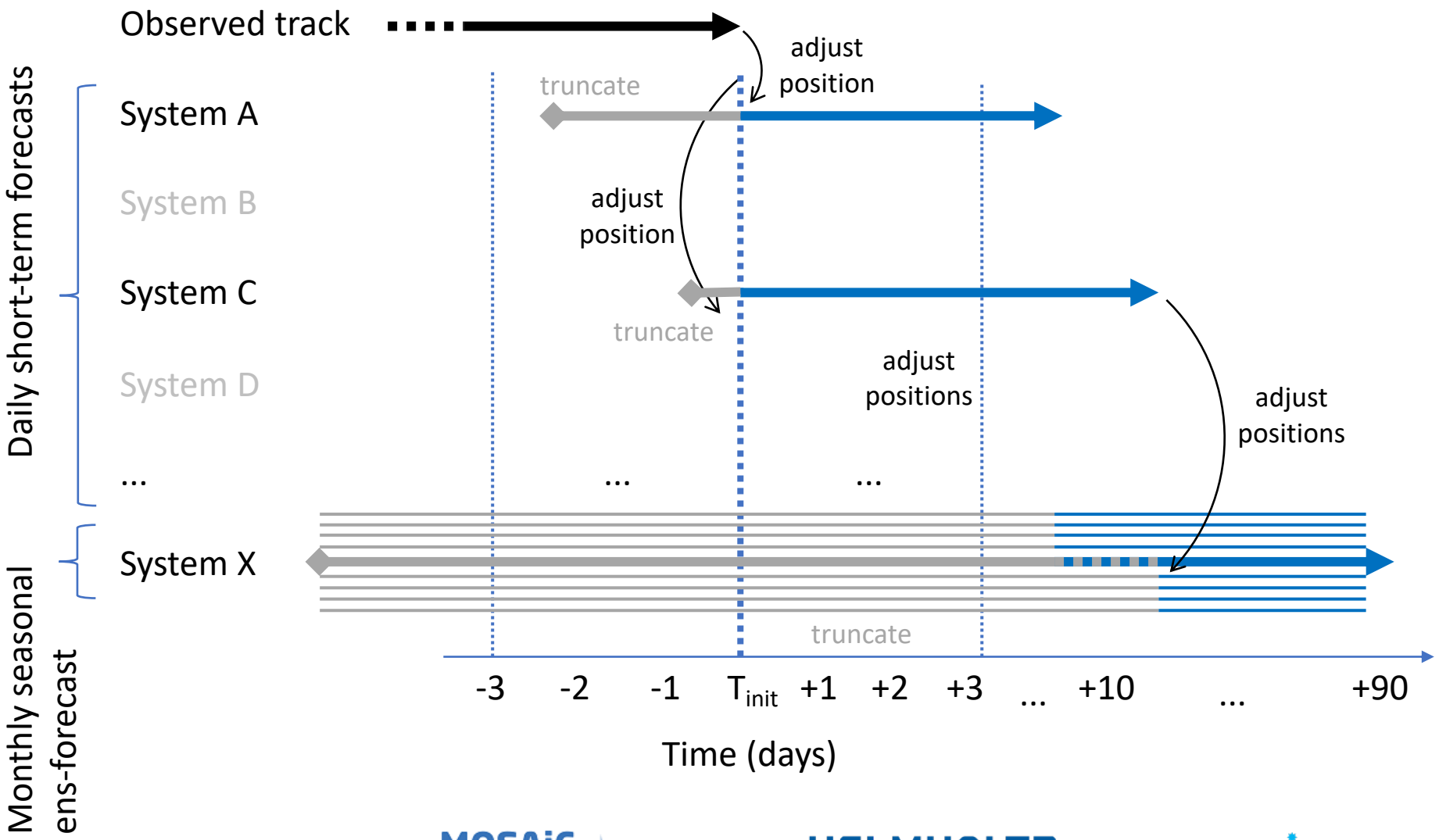
Bundesministerium für Bildung und Forschung

SIDFEx consensus forecast



© H. Goessling

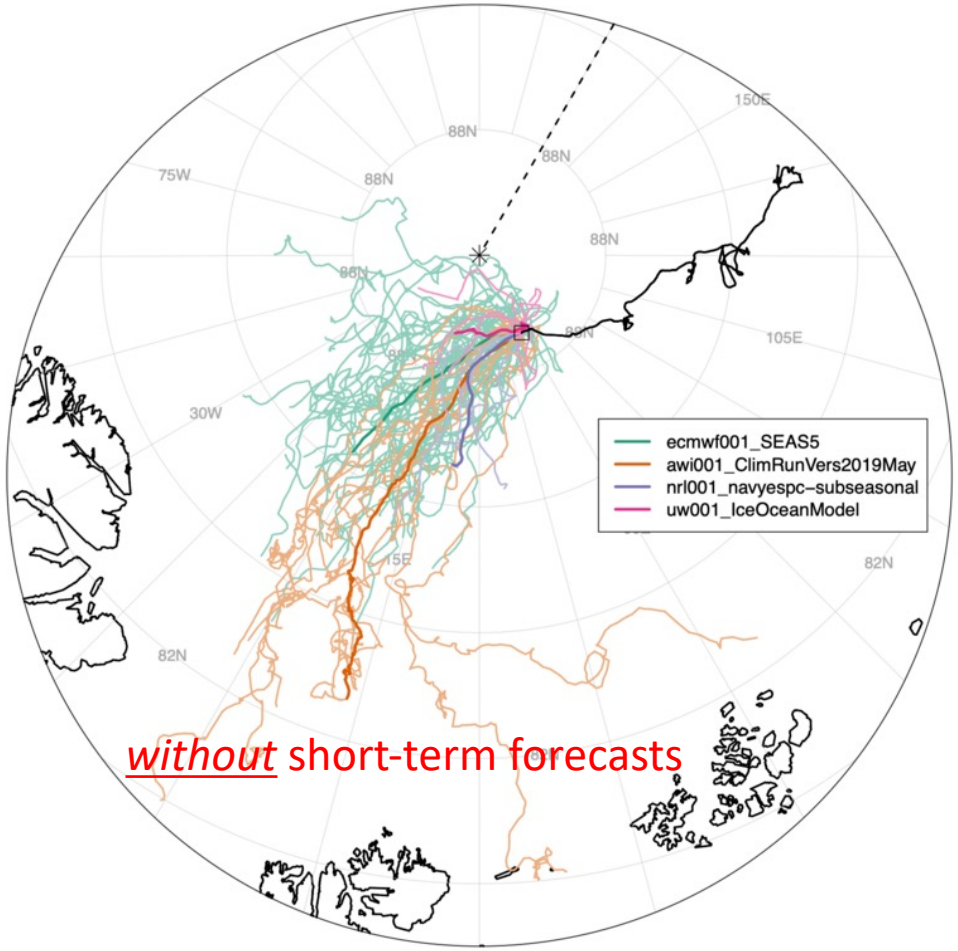
SIDFEx consensus forecast



© H. Goessling

How close to the North Pole will Polarstern drift?

How close to the North Pole will Polarstern drift?

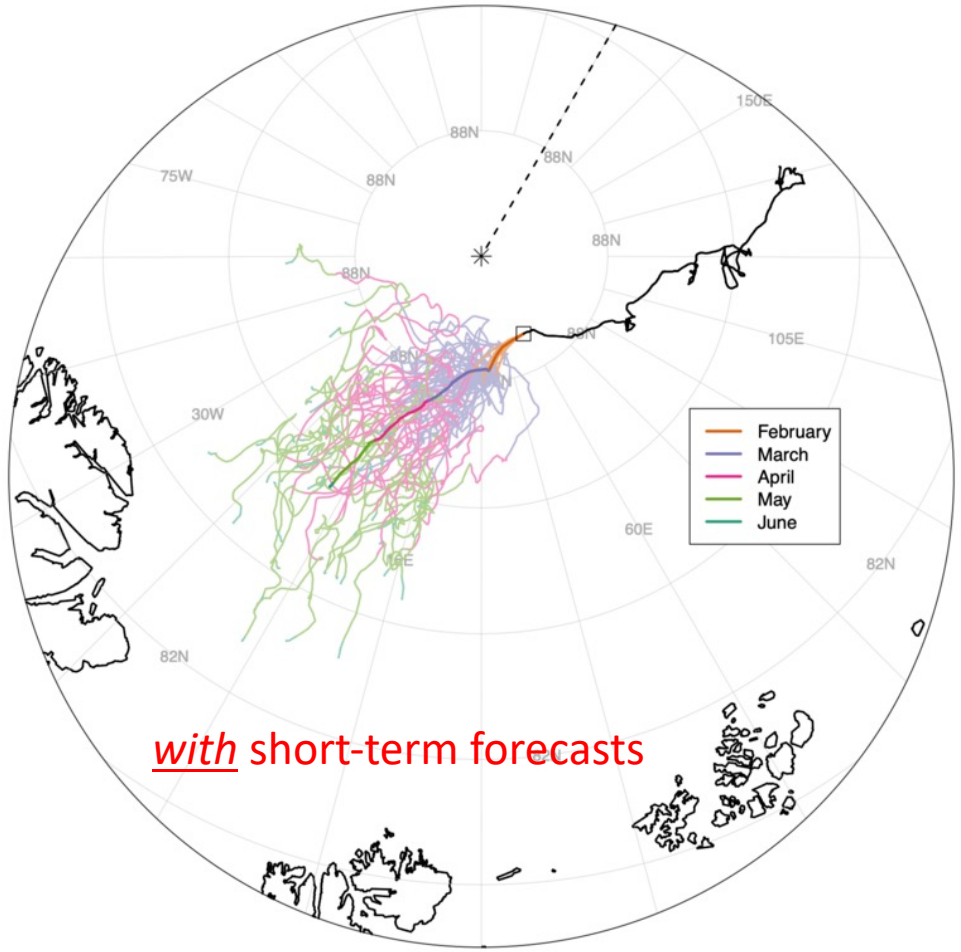


without short-term forecasts

© H. Goessling

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
MOSAiC
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN
YOPP YEAR OF POLAR PREDICTION
Bundesministerium für Bildung und Forschung

How close to the North Pole will Polarstern drift?



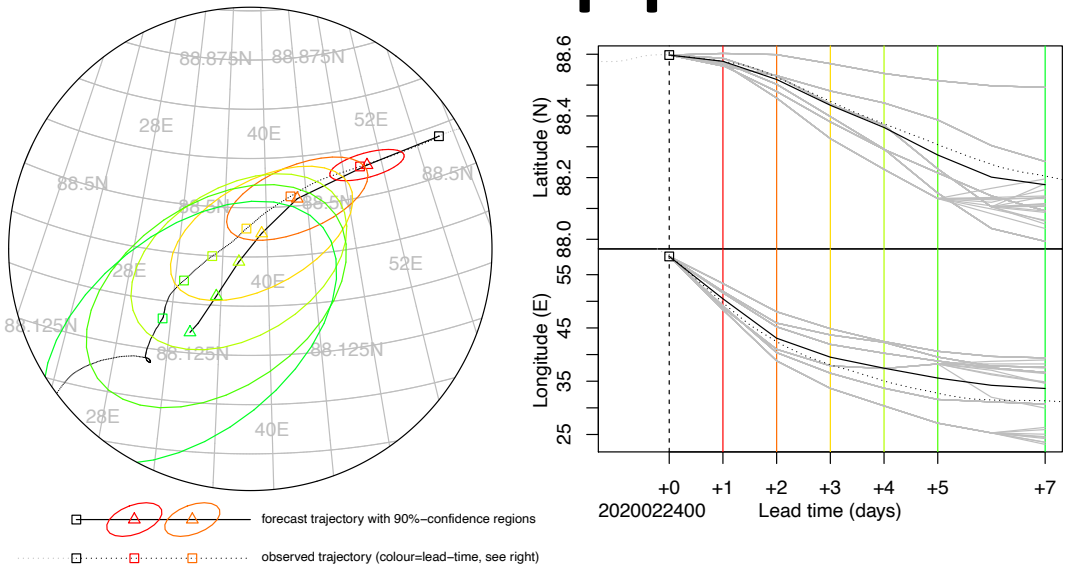
with short-term forecasts

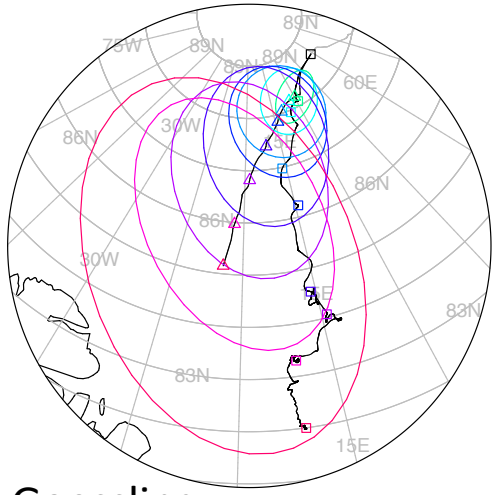
© H. Goessling

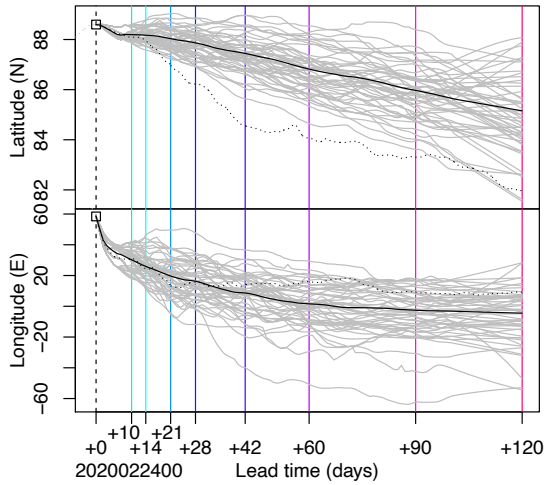
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
MOSAiC
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN
YOPP YEAR OF POLAR PREDICTION
Bundesministerium für Bildung und Forschung

Support for research cruises

Support for research cruises







© H. Goessling

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

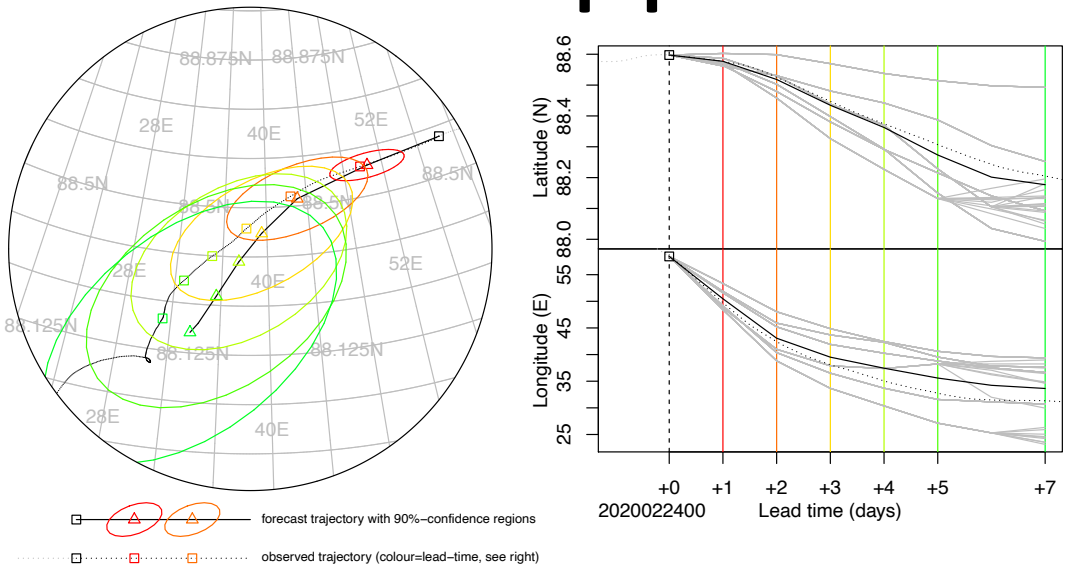
MOSAiC

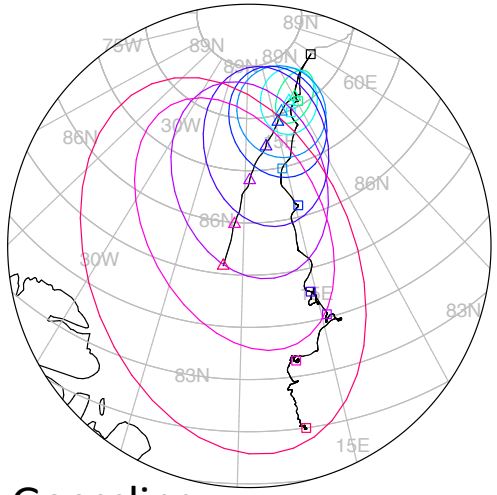
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

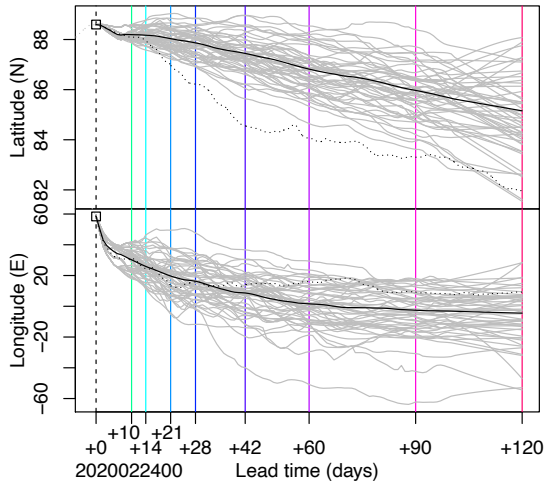
YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

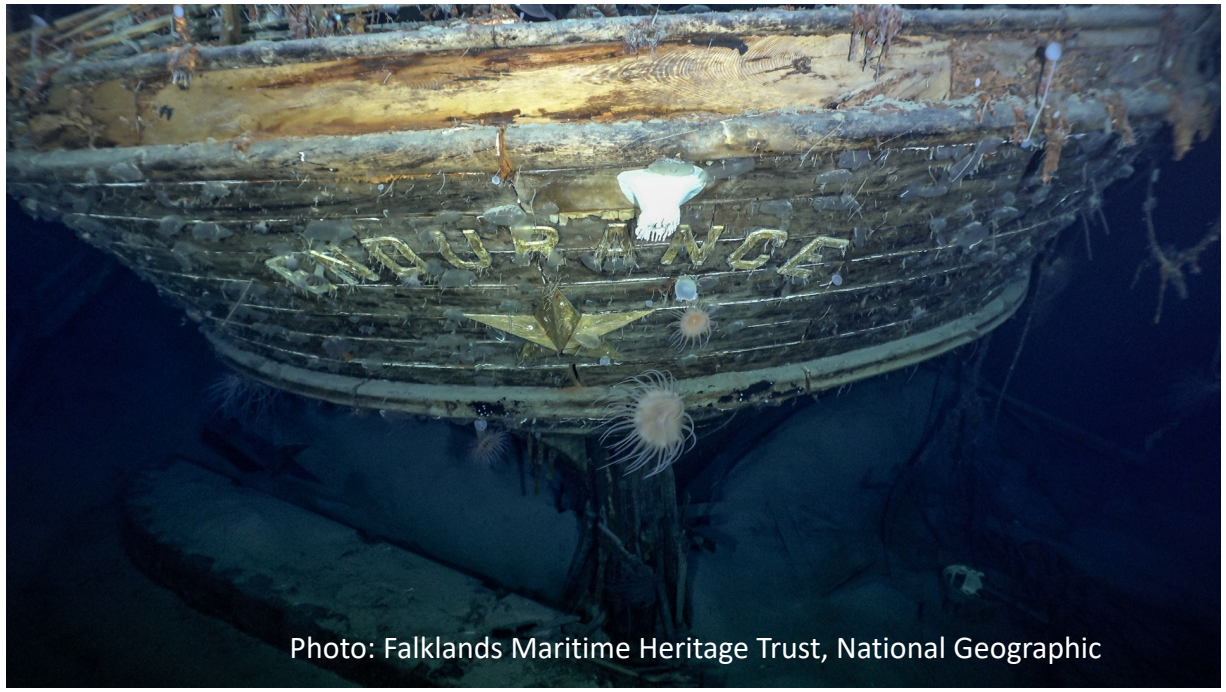
Support for research cruises







ENDURANCE22



© H. Goessling

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

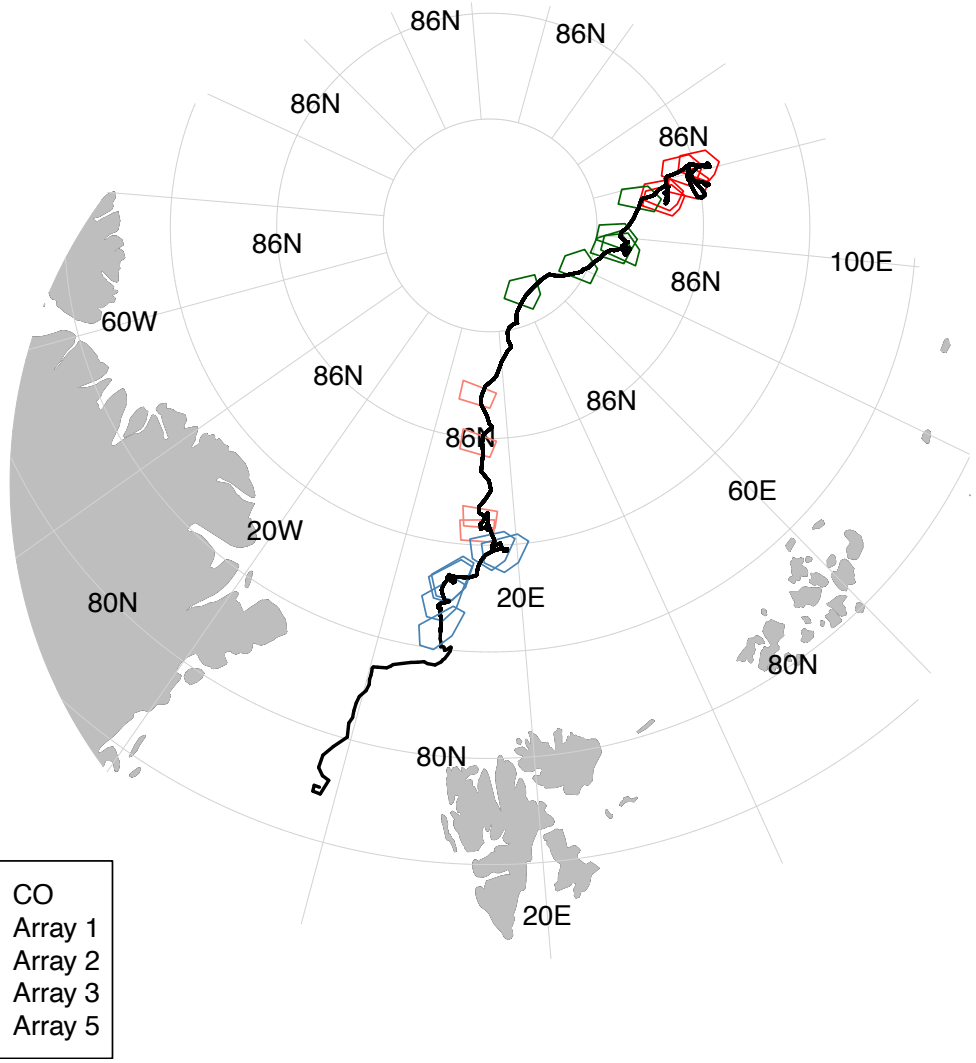
MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

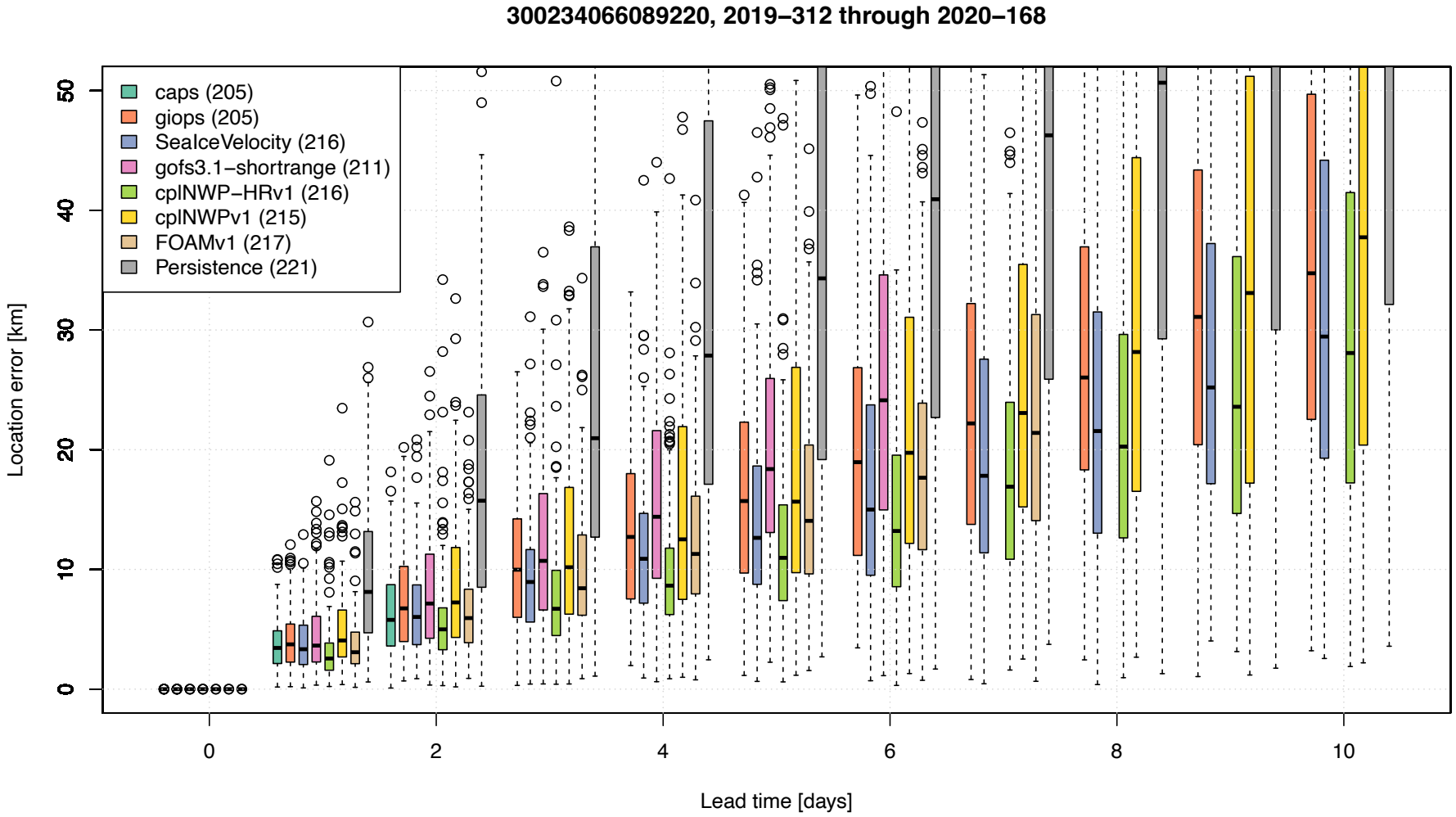
Bundesministerium für Bildung und Forschung

Tracking the DN



- Varying buoy constellations
- Tracking outer ring of DN
- Buoy spacing approx. 35 km
- Time: November 2019 – June 2020
- Endgame: derive deformation of buoy array

Forecast evaluation



- Forecasts for one buoy between November 2019 and June 2020
- Distance as function of lead time
- All systems beat persistence
- Inter-system spread increases after 3 days
- Skillful forecast for drift of single buoys, so…

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

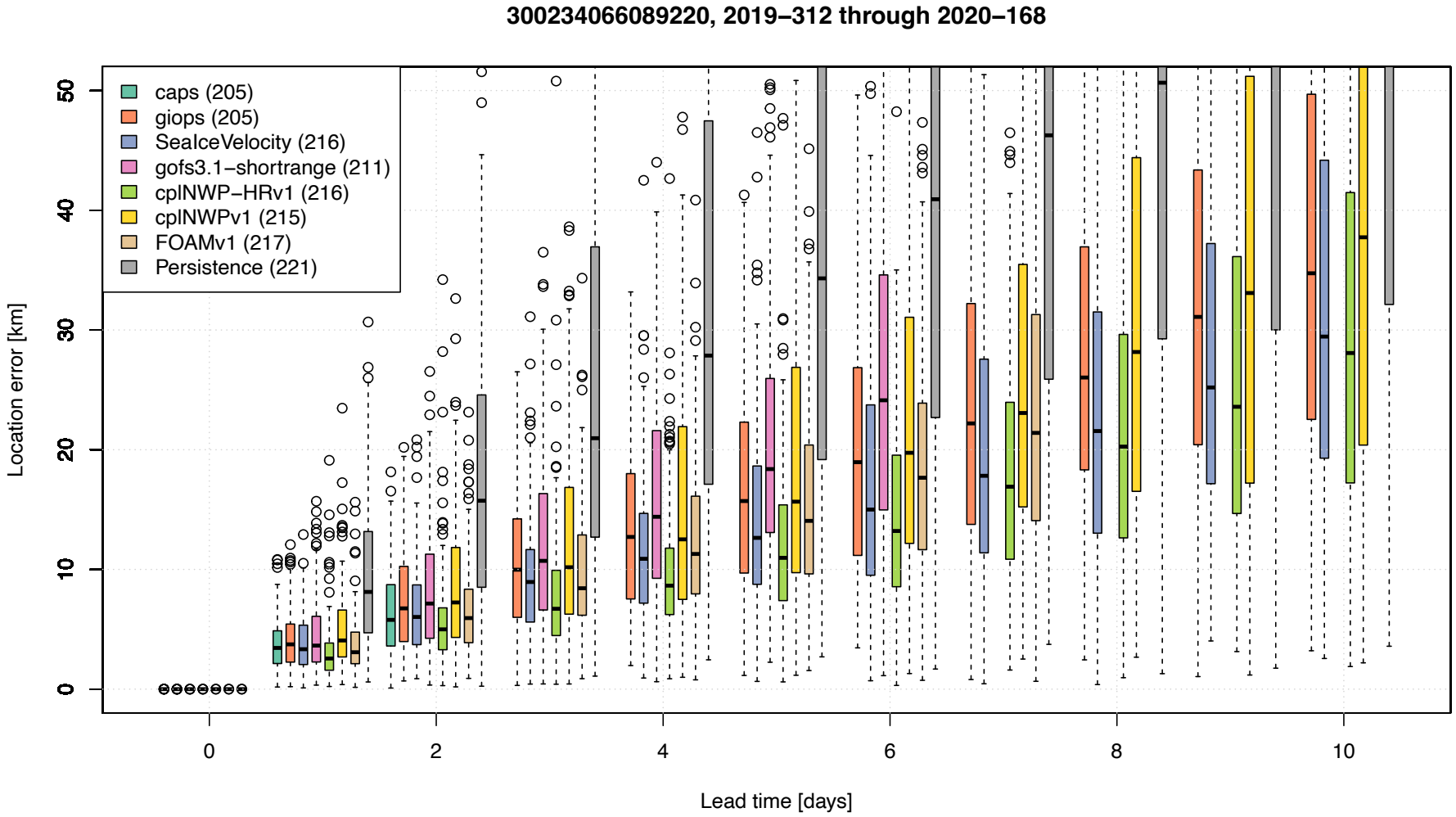
MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

Forecast evaluation



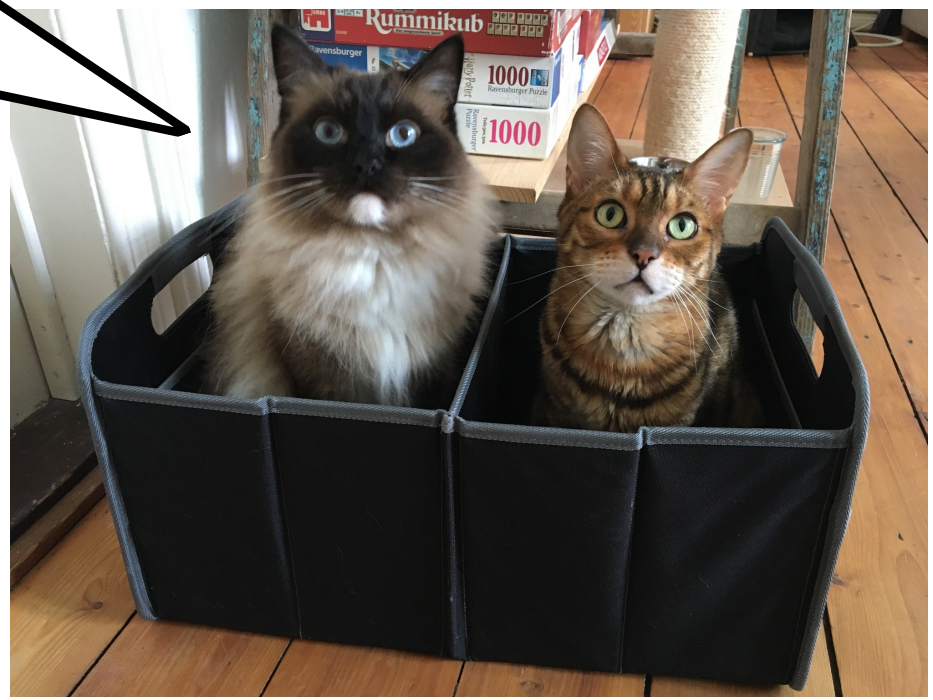
- Forecasts for one buoy between November 2019 and June 2020
- Distance as function of lead time
- All systems beat persistence
- Inter-system spread increases after 3 days
- Skillful forecast for drift of single buoys, so…

…how about all buoys together and relative to each other?

Research questions

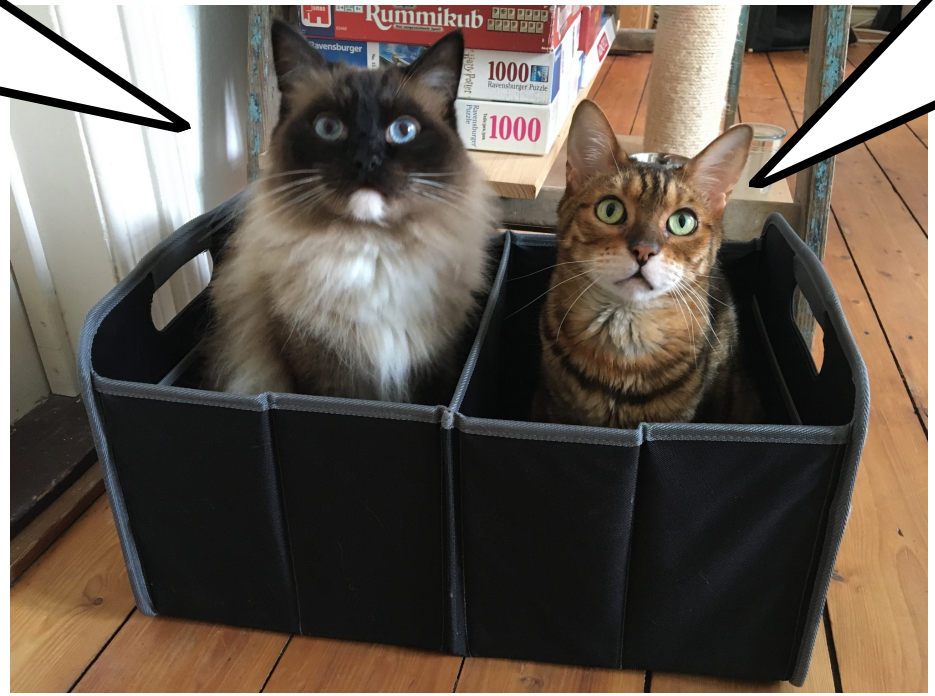
Research questions

Can we use a numerical weather prediction model to forecast sea-ice deformation…



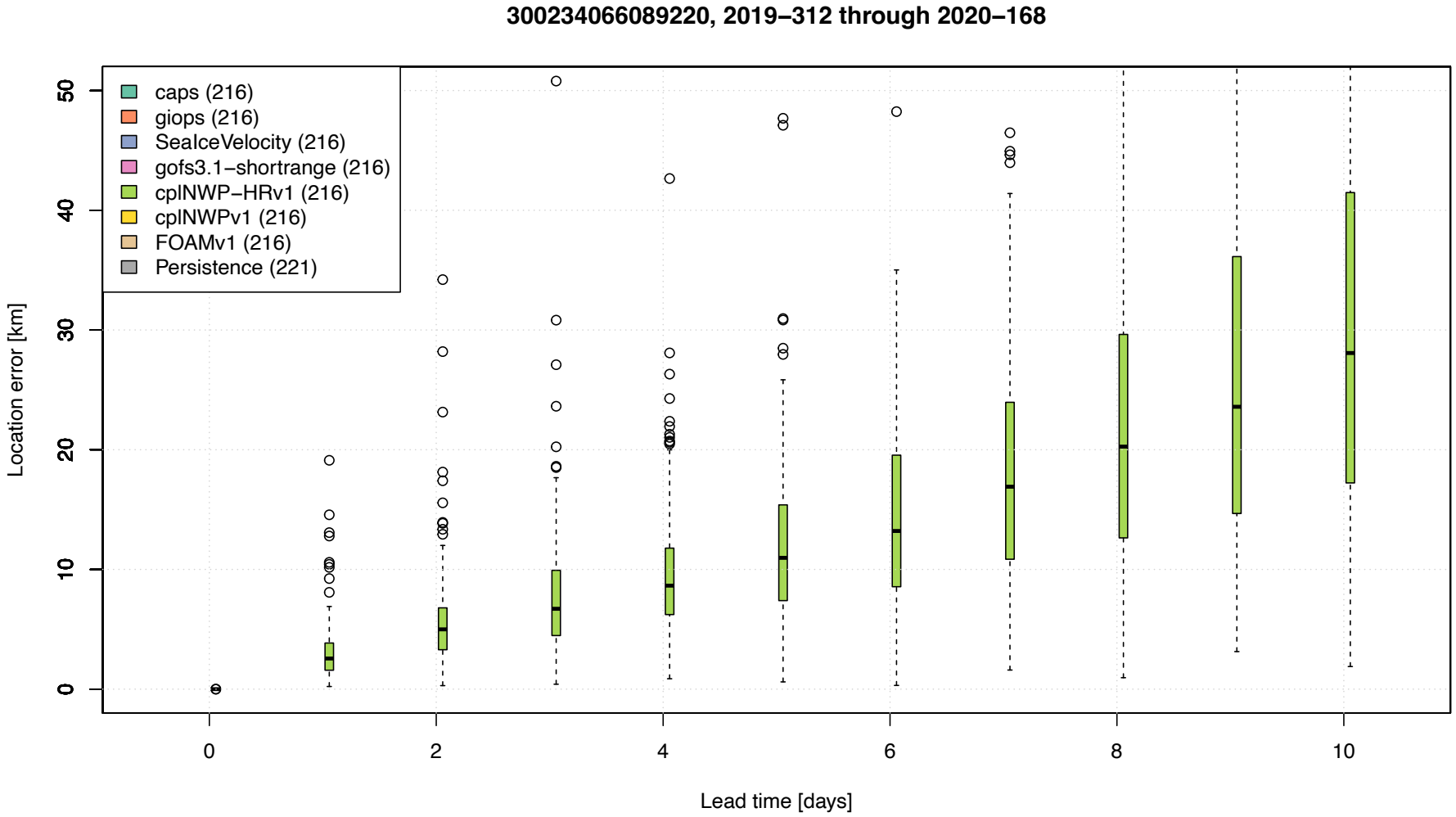
Research questions

Can we use a numerical weather prediction model to forecast sea-ice deformation…



…and does the skill depend on the spatial scale?

Forecast evaluation



- Forecasts for one buoy between November 2019 and June 2020
- Distance as function of lead time
- All systems beat persistence
- Inter-system spread increases after 3 days
- Choose high-res coupled NWP from UKMO
- ~10km for the atmosphere and ~12km for the ocean

Bending the ice

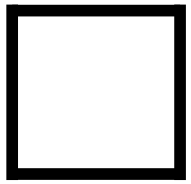
Divergence

Pure shear

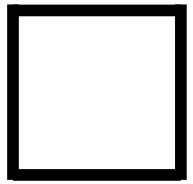
Normal shear

Bending the ice

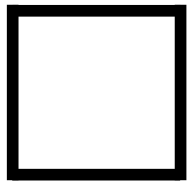
Divergence



Pure shear

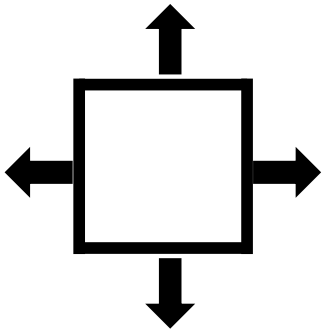


Normal shear

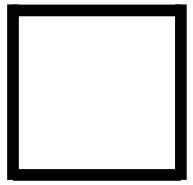


Bending the ice

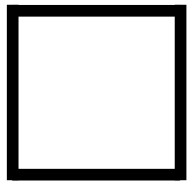
Divergence



Pure shear

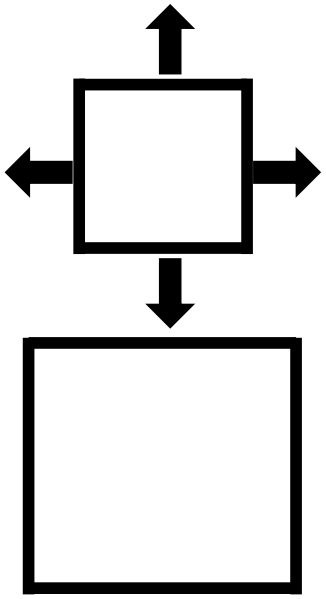


Normal shear

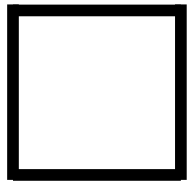


Bending the ice

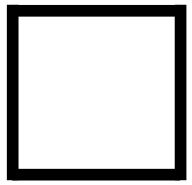
Divergence



Pure shear

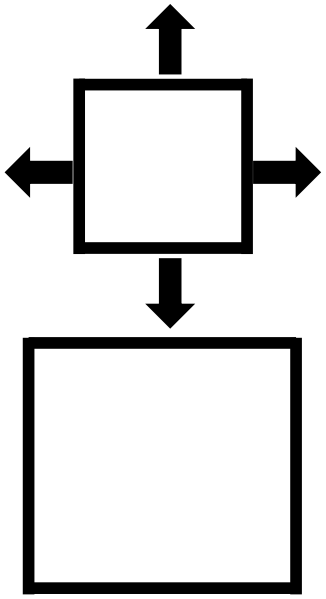


Normal shear

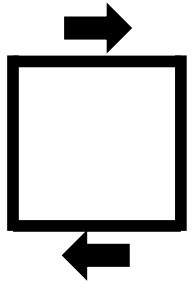


Bending the ice

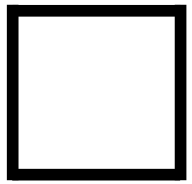
Divergence



Pure shear

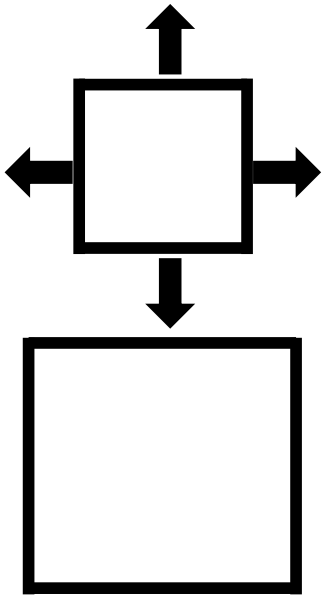


Normal shear

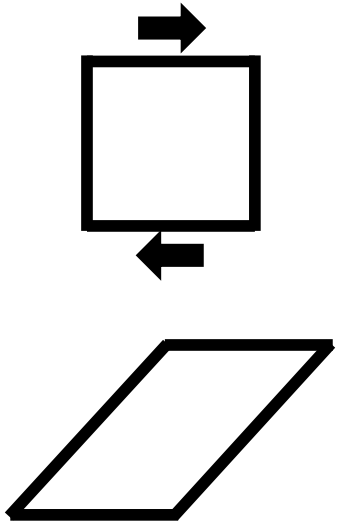


Bending the ice

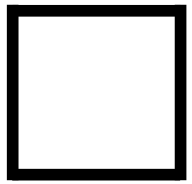
Divergence



Pure shear

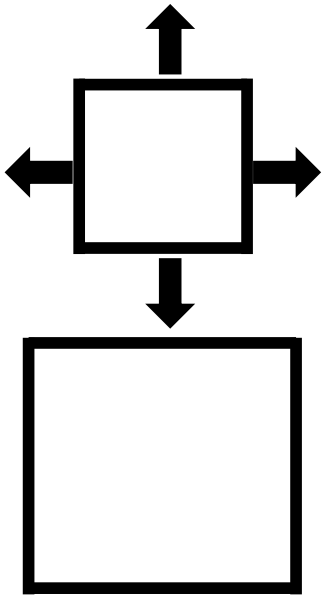


Normal shear

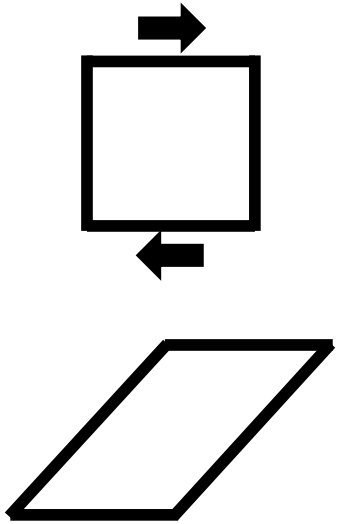


Bending the ice

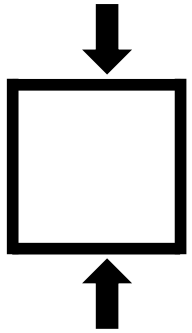
Divergence



Pure shear

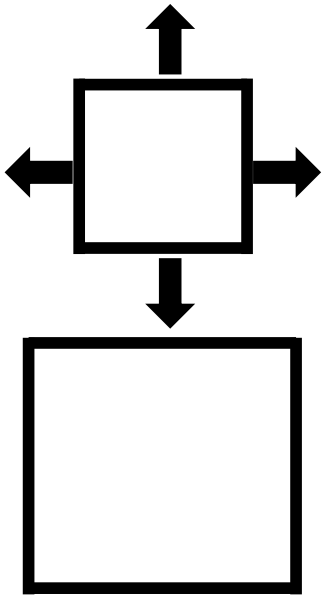


Normal shear

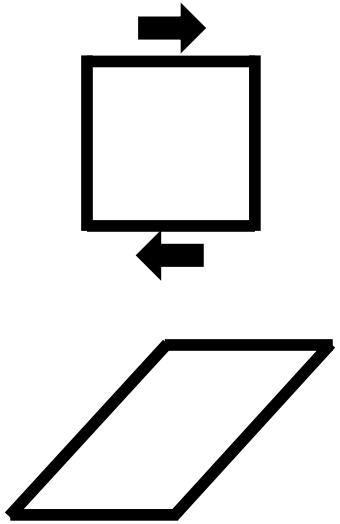


Bending the ice

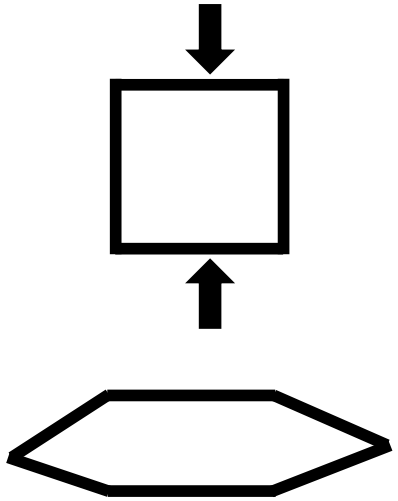
Divergence



Pure shear

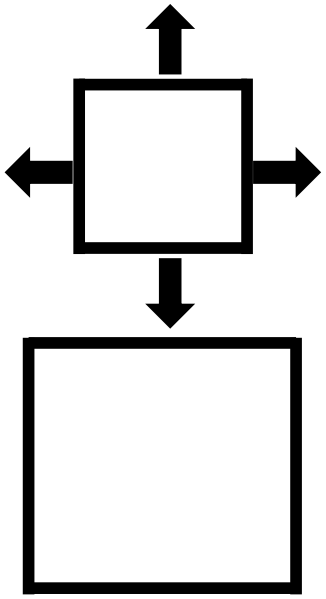


Normal shear



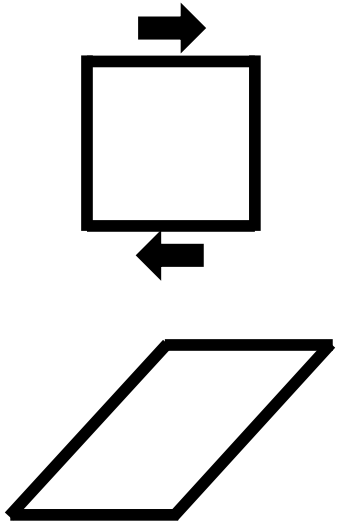
Bending the ice

Divergence



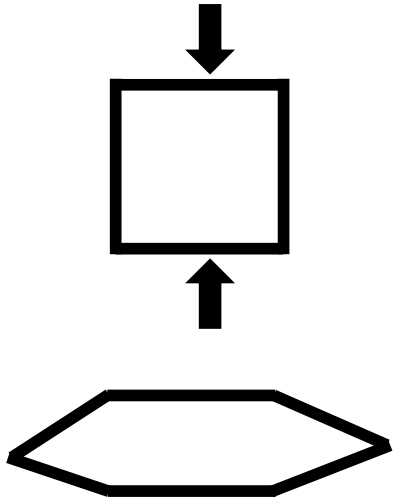
$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Pure shear



$$S = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Normal shear



$$N = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

Bending the ice

Divergence

$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Pure shear

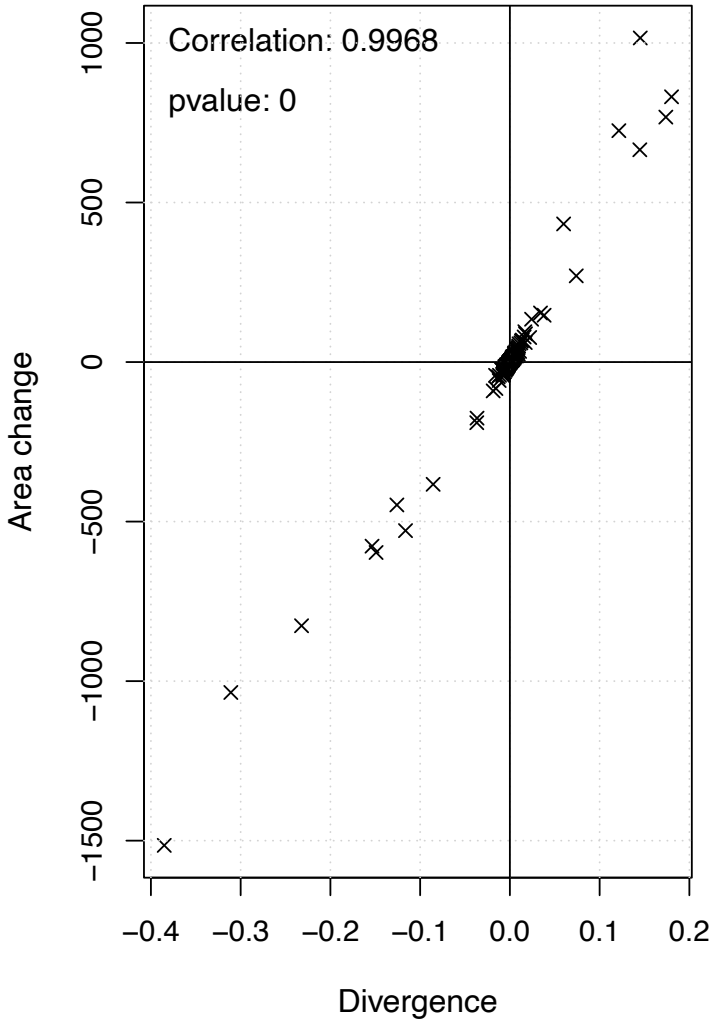
$$S = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

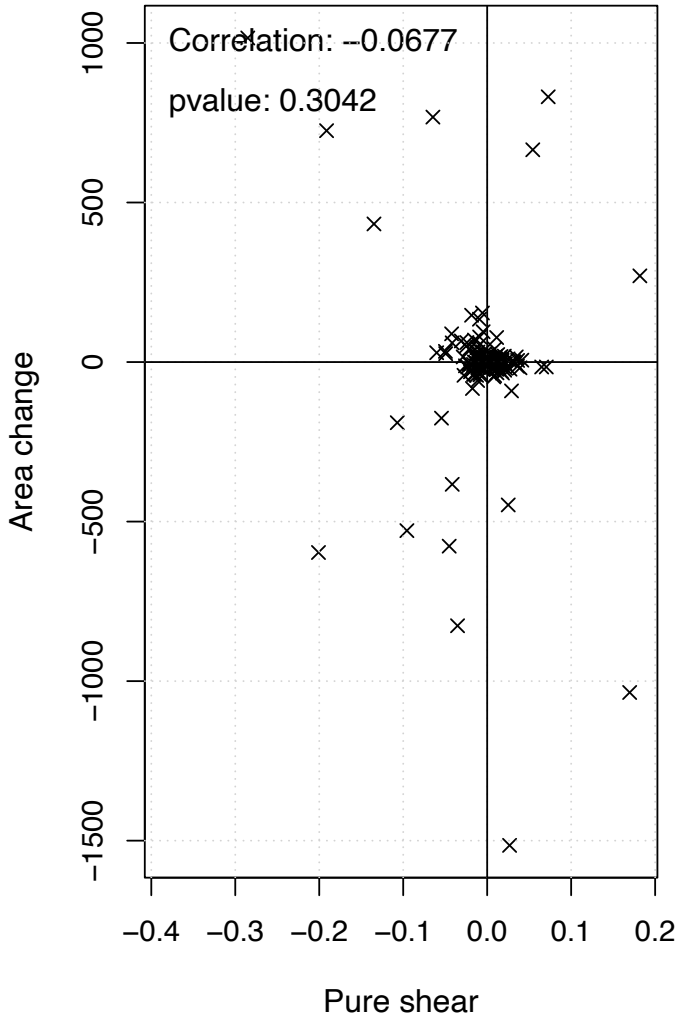
Normal shear

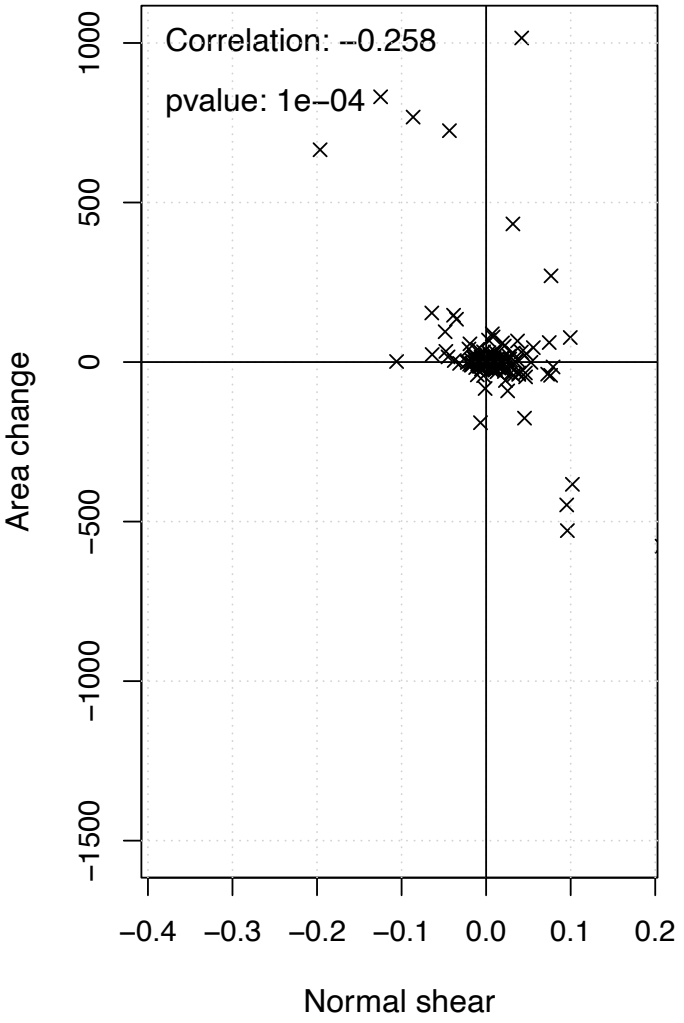
$$N = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

$$T = \sqrt{D^2 + S^2 + N^2}$$

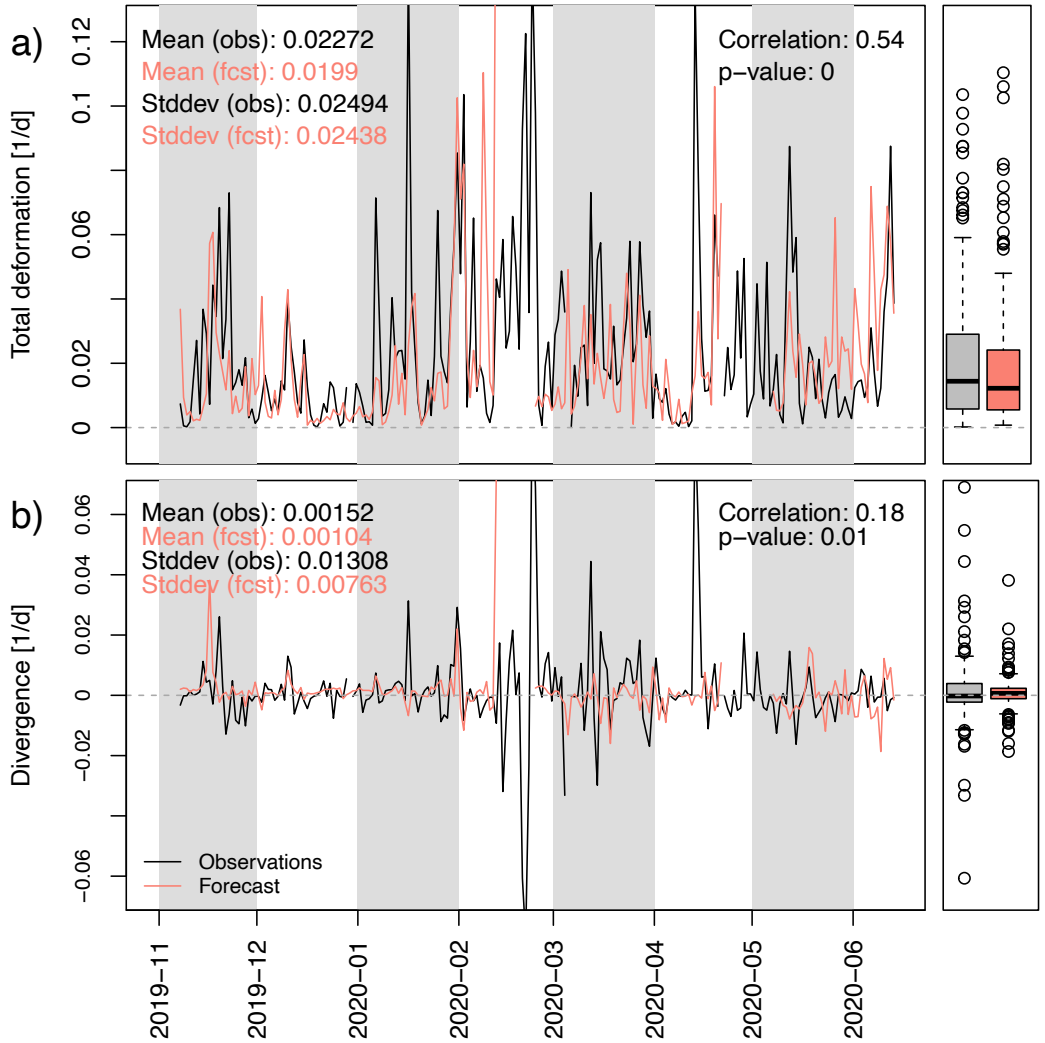
Sanity check





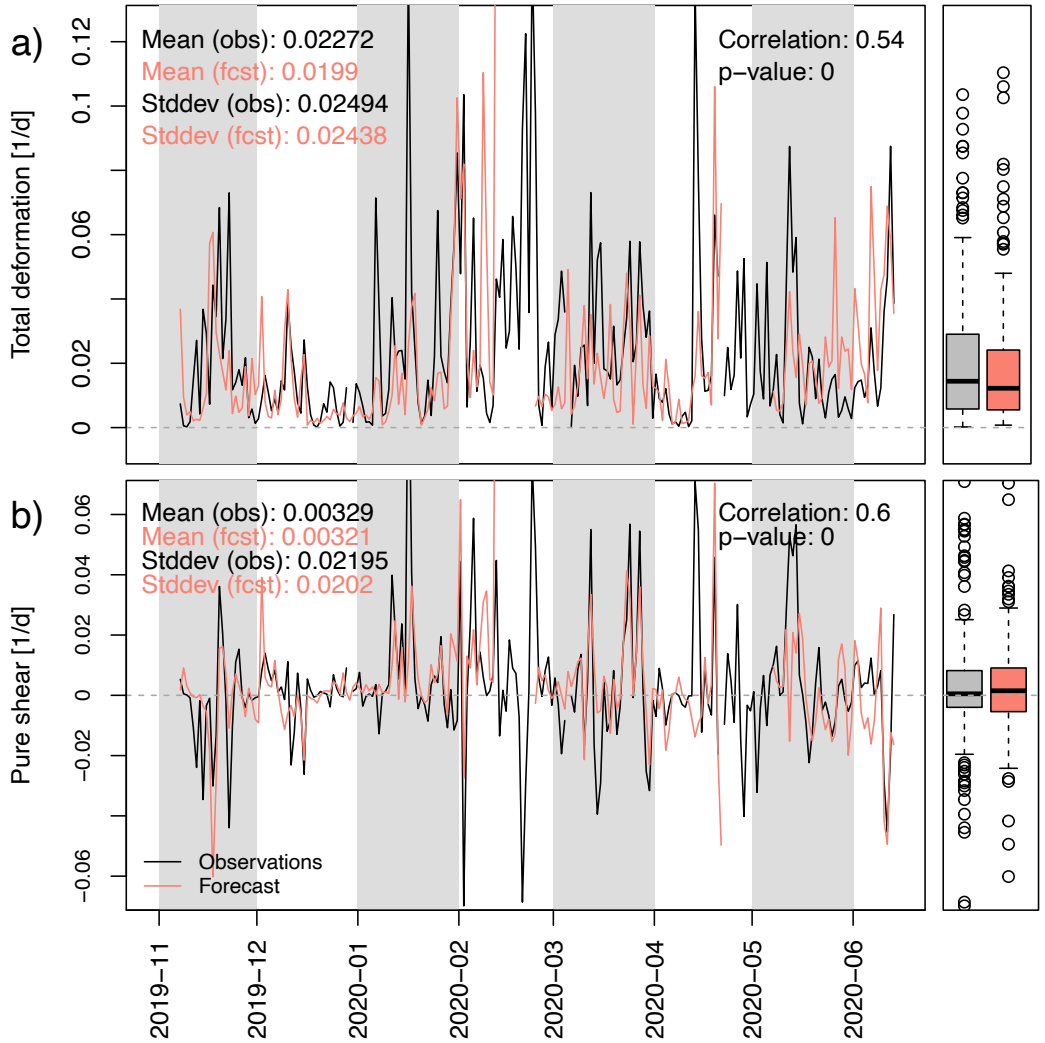


Forecast evaluation



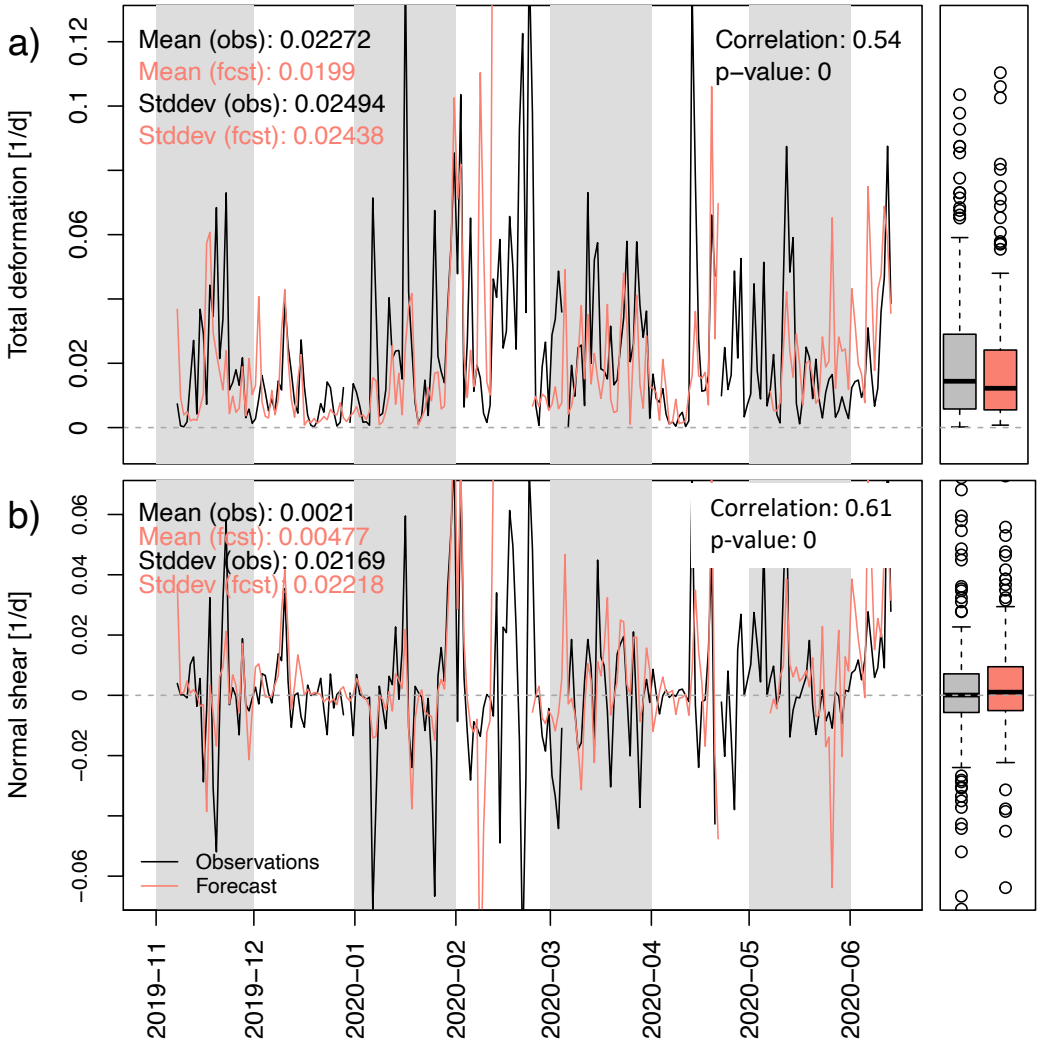
- Area roughly 4000km
- Compare forecast and observations at 1d lead time
- Total deformation: Means agree within 10%, variability is captured
- Divergence: correlation lower, distribution too narrow

Forecast evaluation



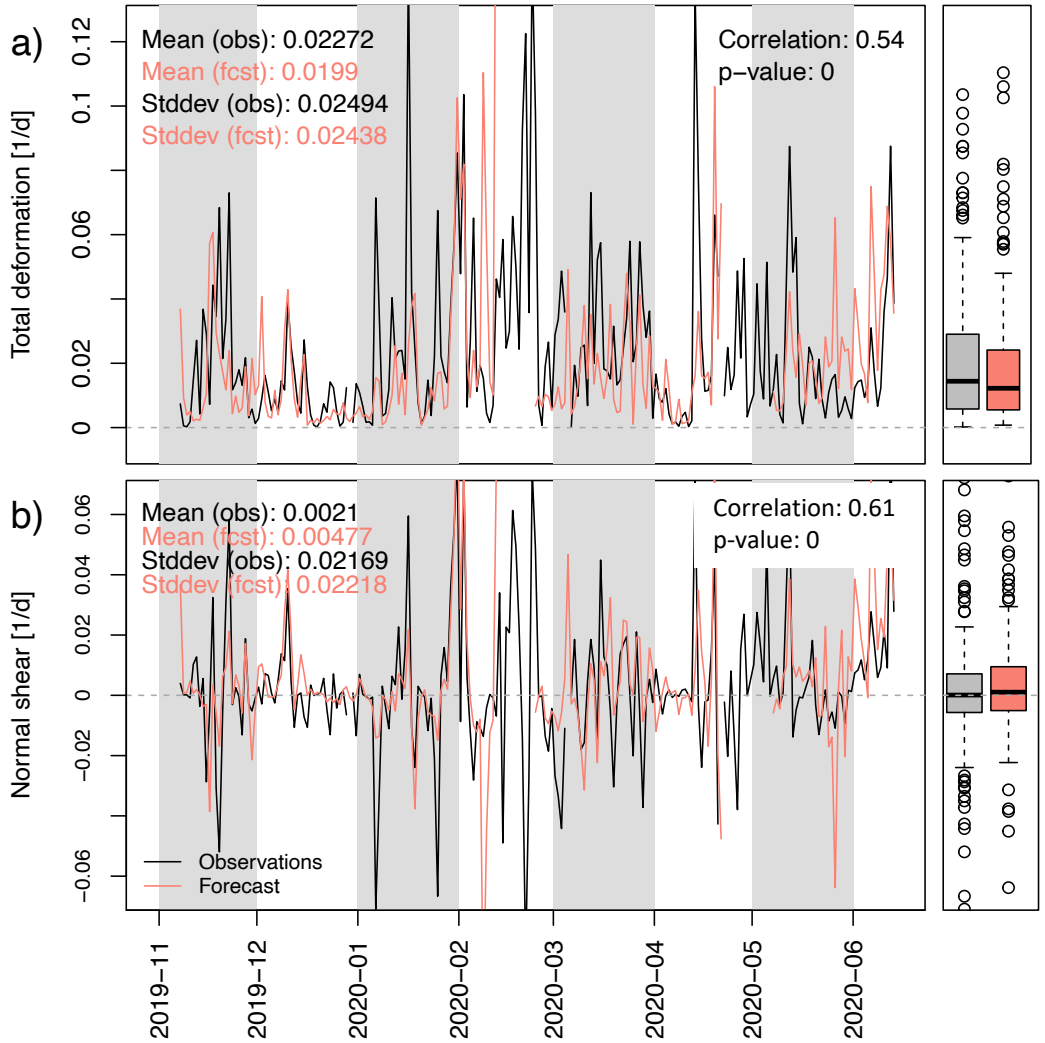
- Area roughly 4000km
- Compare forecast and observations at 1d lead time
- Total deformation: Means agree within 10%, variability is captured
- Divergence: correlation lower, distribution too narrow
- Pure and normal shear with higher correlations

Forecast evaluation



- Area roughly 4000km
- Compare forecast and observations at 1d lead time
- Total deformation: Means agree within 10%, variability is captured
- Divergence: correlation lower, distribution too narrow
- Pure and normal shear with higher correlations
- Models designed for larger scales/representation of mean states
- Still, there is skill even at small scales

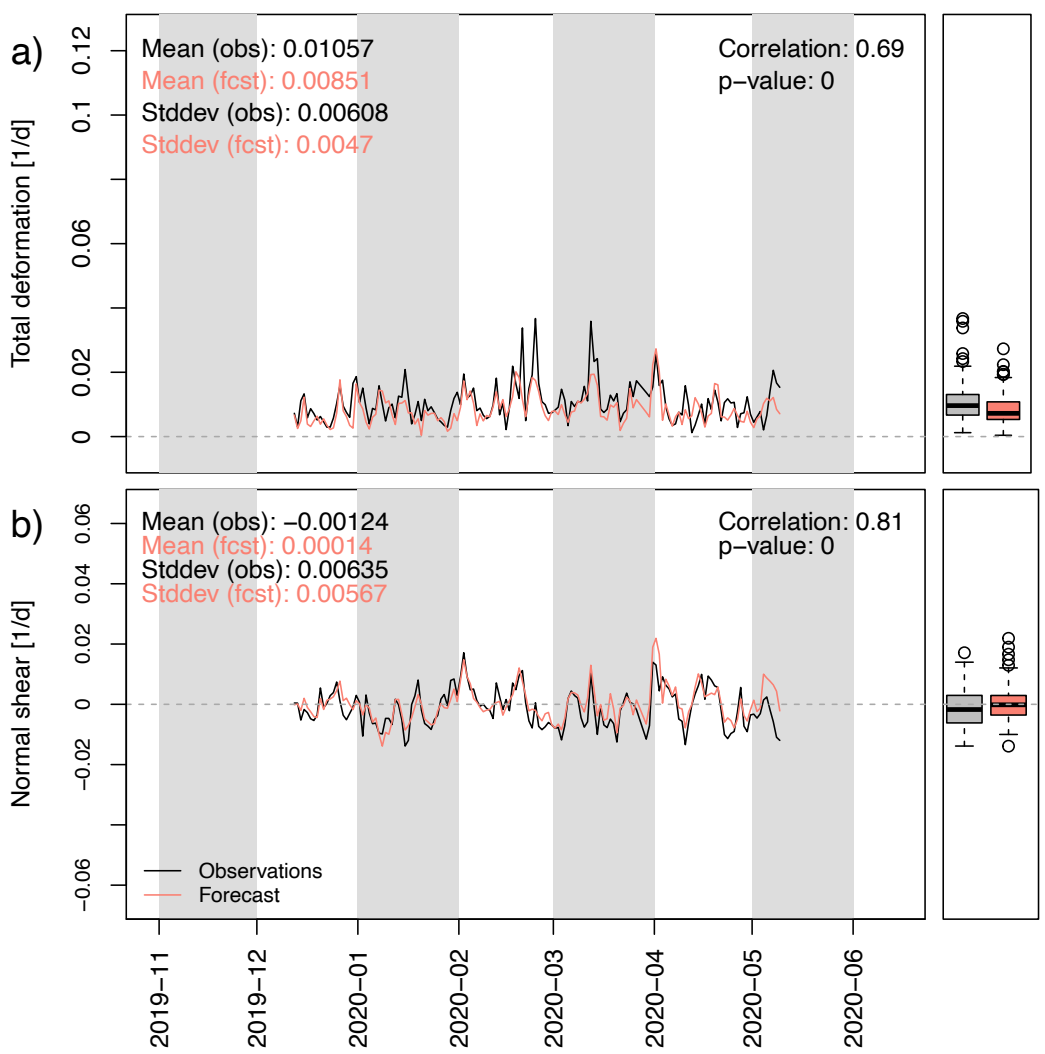
Forecast evaluation

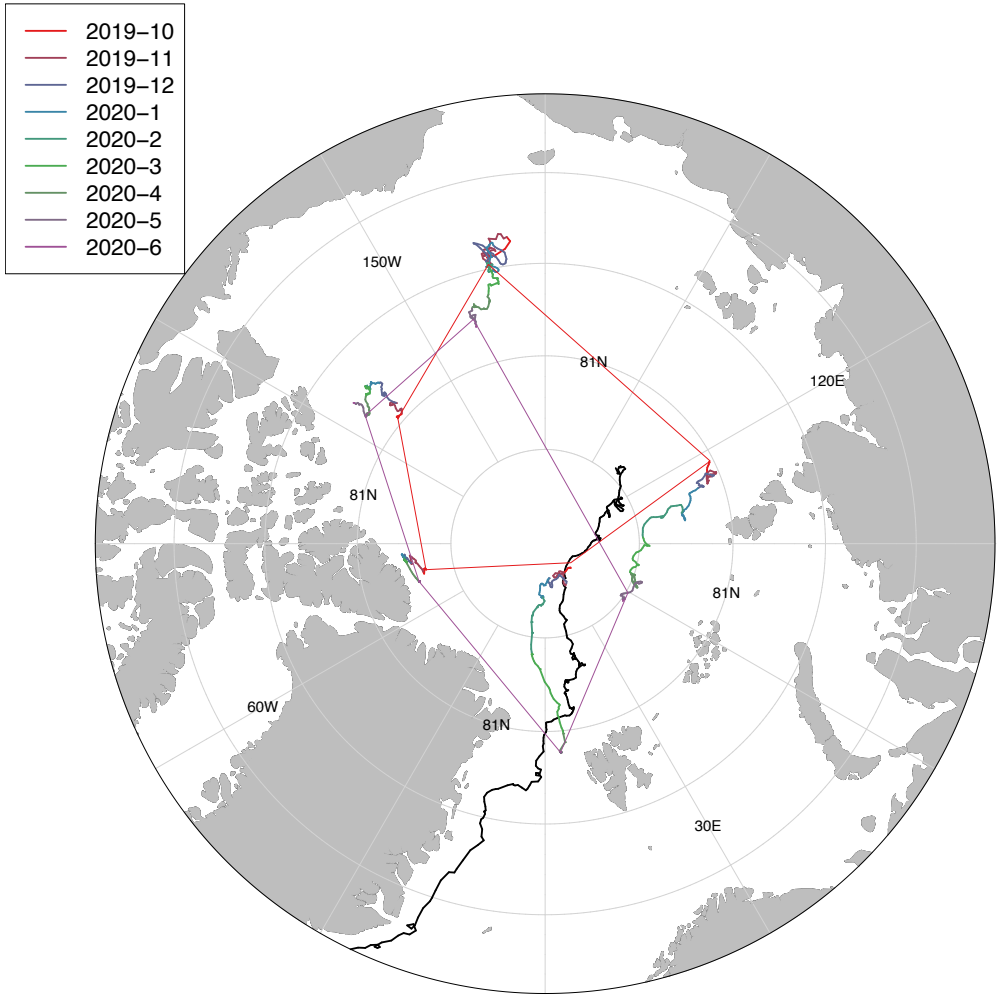


- Area roughly 4000km
- Compare forecast and observations at 1d lead time
- Total deformation: Means agree within 10%, variability is captured
- Divergence: correlation lower, distribution too narrow
- Pure and normal shear with higher correlations
- Models designed for larger scales/representation of mean states
- Still, there is skill even at small scales

Let’s go large!

Going for the large scale





ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

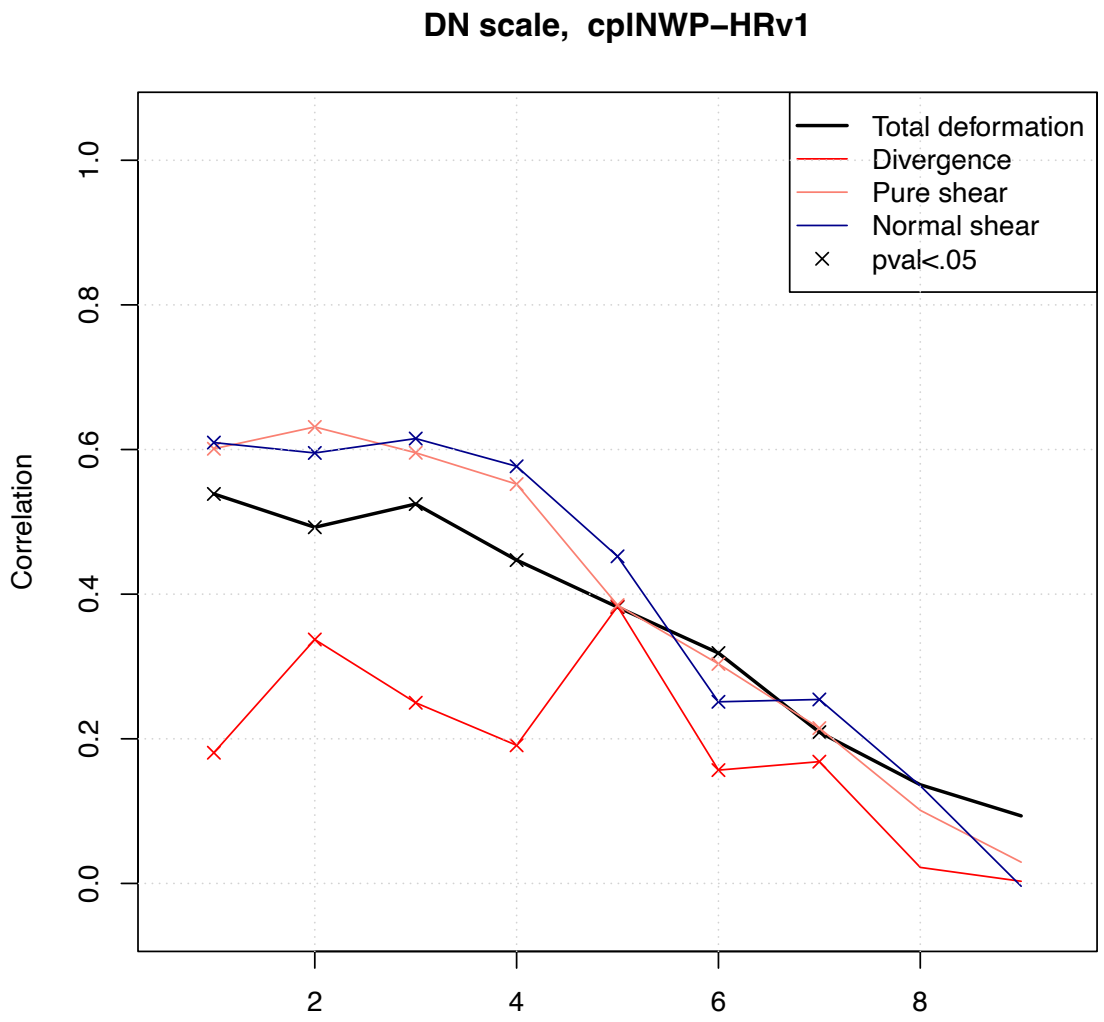
MOSAiC

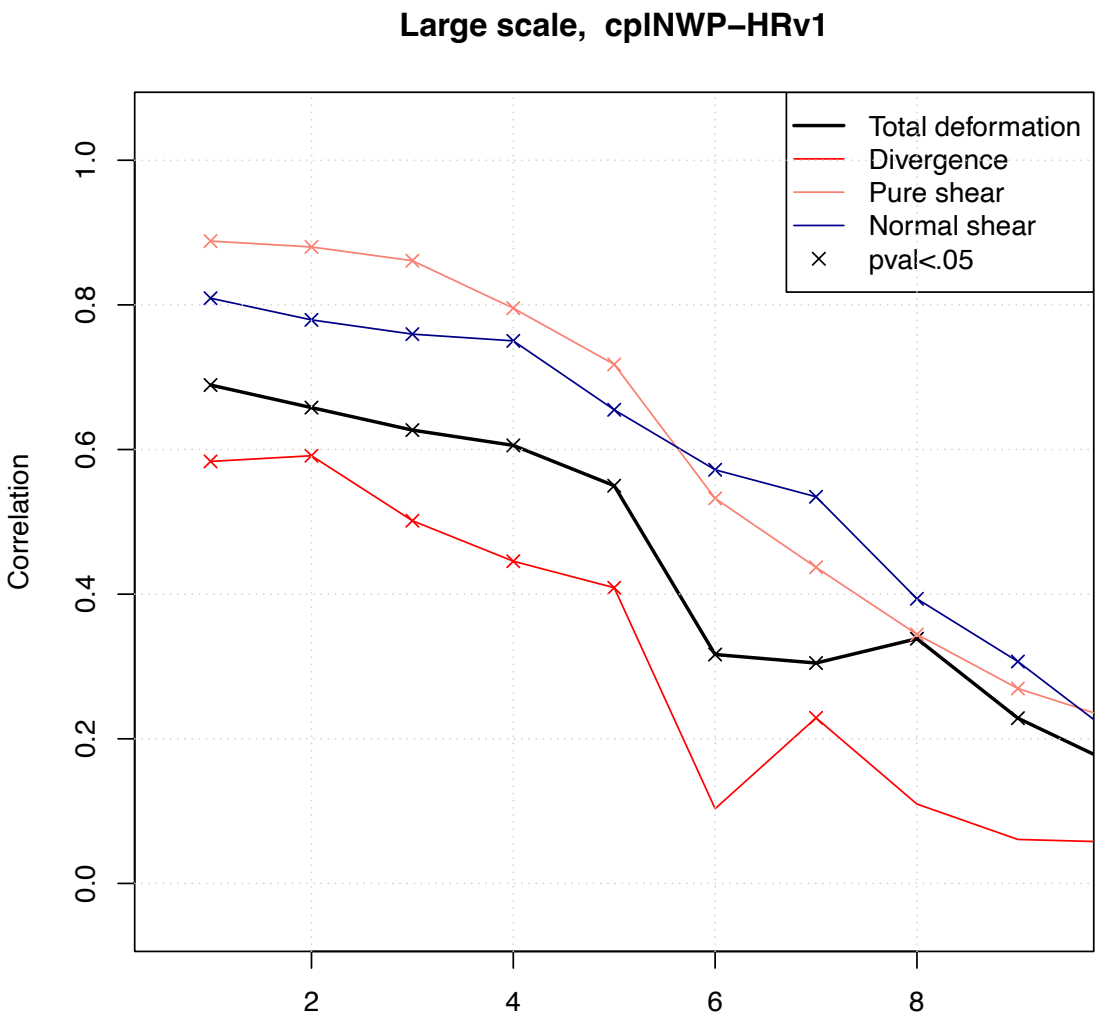
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

Going for longer lead times





ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

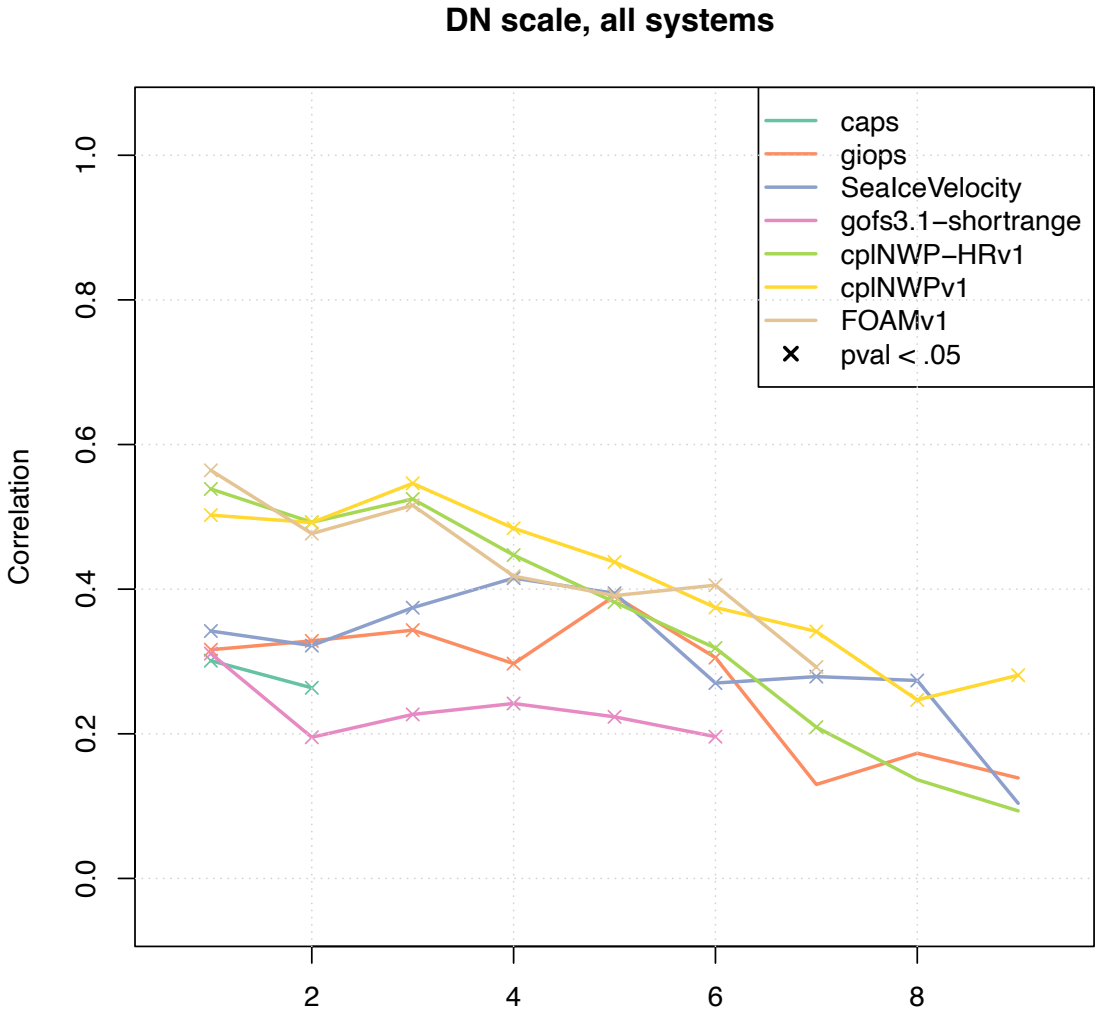
MOSAiC

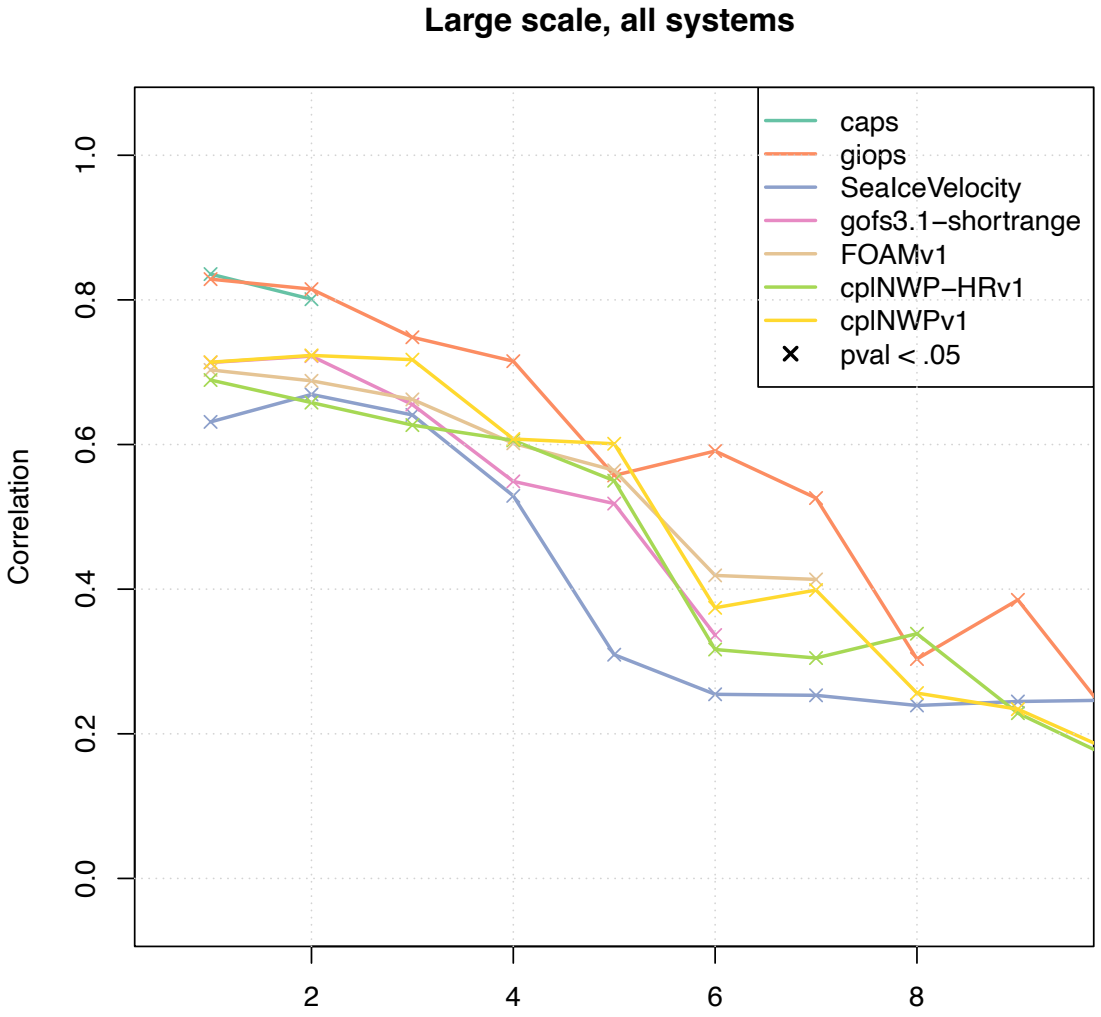
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

Going for multiple systems





ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung

In a nutshell

MOSAiC

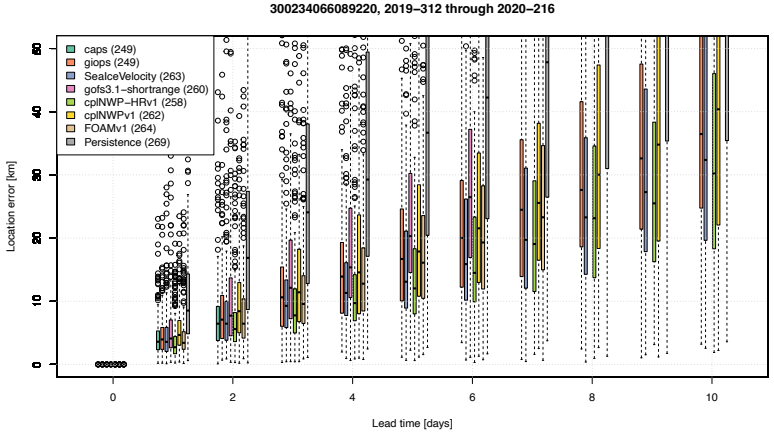
HELMHOLTZ
SPITZENFORSCHUNG FÜR
GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF
POLAR
PREDICTION

Bundesministerium
für Bildung
und Forschung

In a nutshell

We provide skillful drift forecasts



MOSAiC

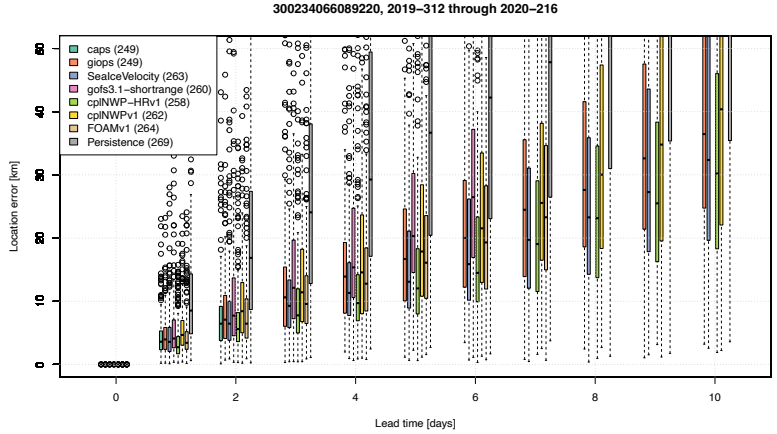
HELMHOLTZ
SPITZENFORSCHUNG FÜR
GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF
POLAR
PREDICTION

Bundesministerium
für Bildung
und Forschung

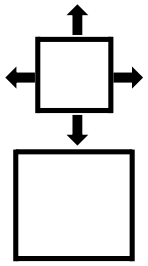
In a nutshell

We provide skillful drift forecasts



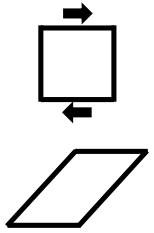
We look at sea-ice deformation

Divergence



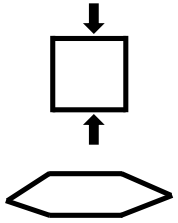
$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Pure shear



$$S = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Normal shear



$$N = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

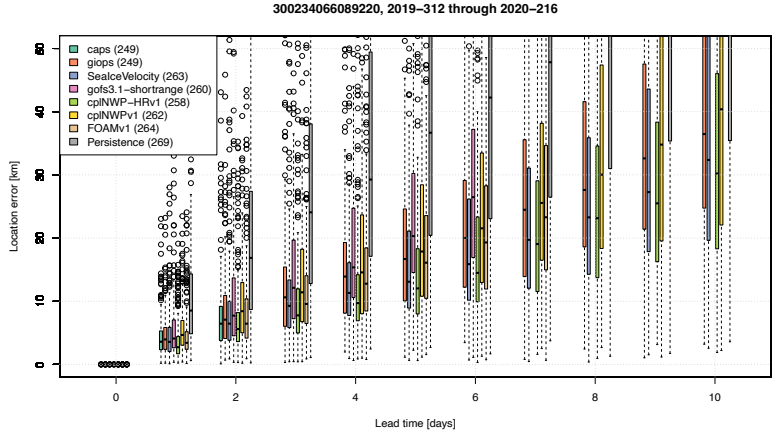
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

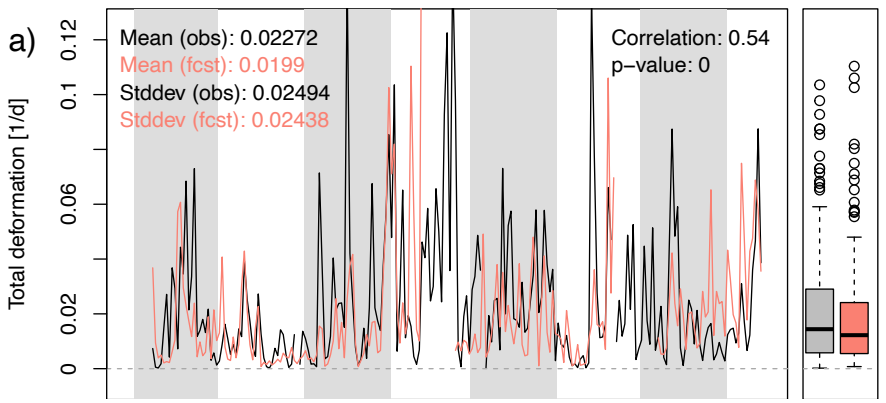
Bundesministerium für Bildung und Forschung

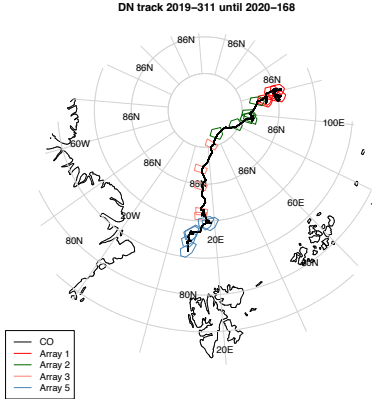
In a nutshell

We provide skillful drift forecasts



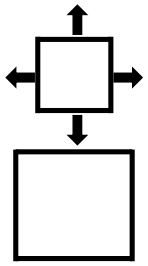
It works ok at DN scales





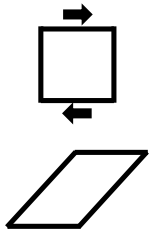
We look at sea-ice deformation

Divergence



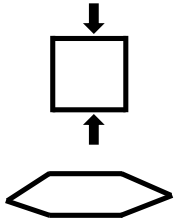
$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Pure shear



$$S = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Normal shear



$$N = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

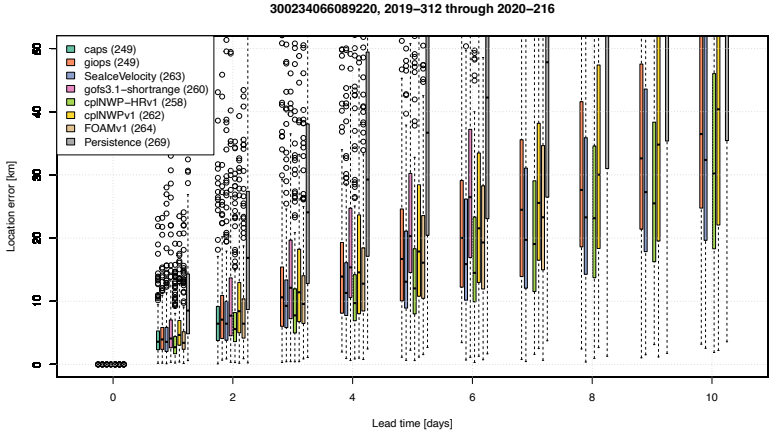
HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP
YEAR OF POLAR PREDICTION

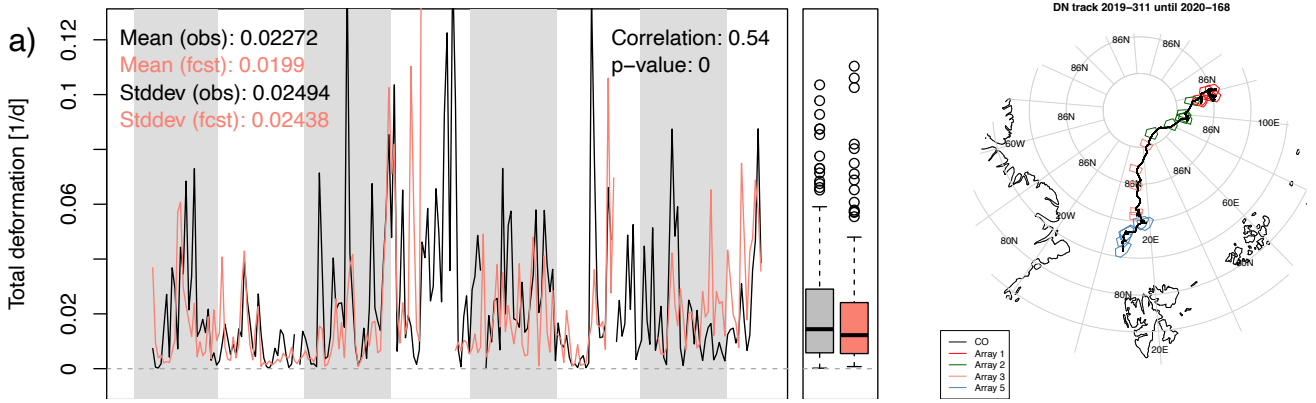
Bundesministerium für Bildung und Forschung

In a nutshell

We provide skillful drift forecasts

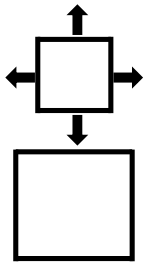


It works ok at DN scales



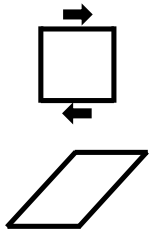
We look at sea-ice deformation

Divergence



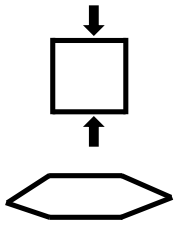
$$D = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

Pure shear



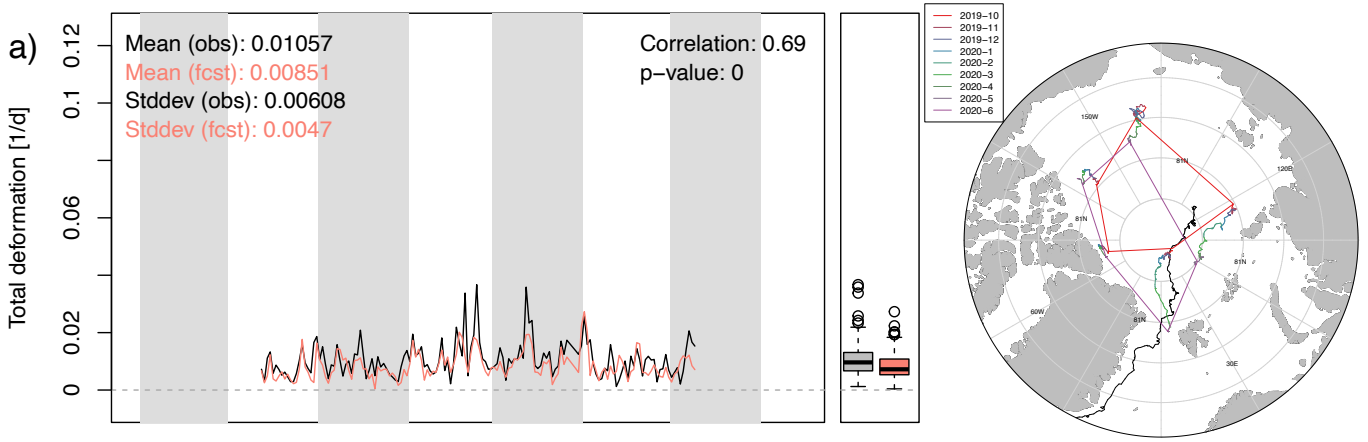
$$S = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Normal shear



$$N = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}$$

It works even better at pan-Arctic scales



ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

MOSAiC

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

YOPP YEAR OF POLAR PREDICTION

Bundesministerium für Bildung und Forschung