The YOPP verification Task Team

http://www.polarprediction.net/yopp-activities/yopp-task-teams/verification/

Members: **Barbara Casati (ECCC), Thomas Haiden (ECMWF), Morten Køltzow (MetNo)**, Greg Smith (ECCC), Helge Goessling (AWI), Eugene Petrescu (NOAA), Zen Mariani (ECCC), Stella Melo (ECCC), Gunilla Svensson (U Stockholm), Taneil Uttal (NOAA, IASOA), Jonathan Day (ECMWF), Matthew Shupe (NOAA, MOSAIC), Qizhen Sun (NMEFC)

The YoPP verification task team was formed in order to help outlining a YoPP verification strategy and develop / support a YoPP verification effort.

We also aim to provide a framework and platform for exchange,
in order to connect YOPP ongoing verification activities,
to enhance collaboration, harmonize comparisons, avoid duplications.

YOPP verification Docs on the YOPP TT web-site

1. "**Verification of Environmental Prediction in Polar Regions: recommendations for the Year of Polar Prediction**", by Casati et al (2016) focus mainly on the verification methods (from CBS verification standards to conditional and spatial methods) and challenges (observation uncertainty).

2. "**YOPP verification goals, YOPP core-phase activities, and verification plans for the YOPP consolidation phase**" outlines the YOPP verification priorities and ongoing activities.

3. "Verification needs for planning the YOPP archive**"** are listed in a short presentation by Casati et al (Oslo, 10 Nov 2016).

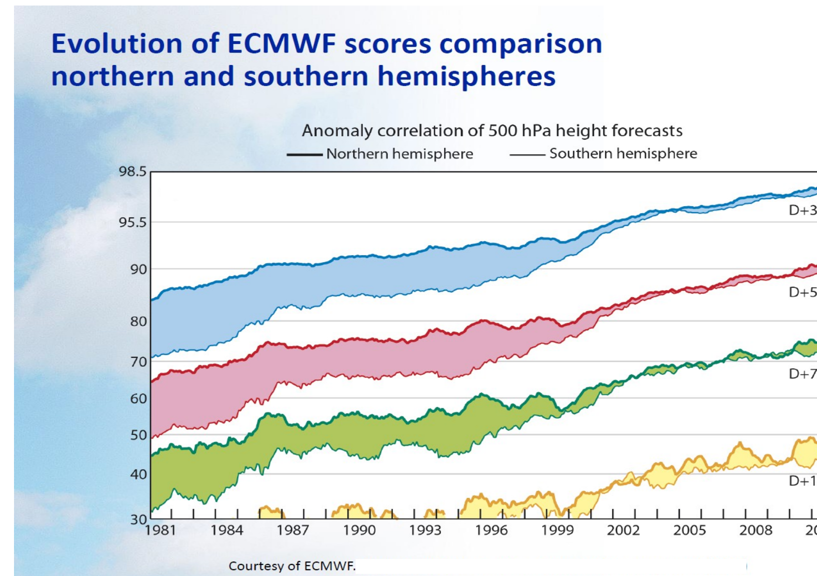
“Verification of Environmental Prediction in Polar Regions: recommendations for the Year of Polar Prediction” identify three classes of users / verification purposes:

1. Diagnostics for model developers: identify sources of error; compare different model schemes.

2. Summary verification scores for administrative / generic purposes (compare and monitor progresses).

3. Meaningful verification measures for selected end-users:

- e.g. focus on the **transport sector** (aviation, marine and land transport).
- address the verification of environ-mental variables such as **sea-ice**, snow, permafrost, ceiling and icing, fog and visibility.



Key variables and polar processes

Basic (surface and upper-air) atmospheric variables: temperature, dew-point temperature, precipitation, cloud cover, relative humidity, wind speed and direction, geopotential height, mean sea level pressure.

Environment surface variables: Sea-ice. Snow at the surface (snow cover, snow thickness). Permafrost (soil temperature).

Modeling challenging processes / variables:

- coupling atmosphere - surface - ocean -cryosphere.
- surface-atmosphere exchanges (turbolence, energy and momentum fluxes, radiation budget).
- stable boundary layer representation (temperature verical profile).
- effects of steep orography.
- clouds, mixed phase clouds.

High Impact Weather: polar lows, low-level jets, topographically influenced flows such as katabatic winds and hydraulic shocks, extreme thermal contrasts, blizzards, freezing rain, fog → Collaboration and interplay with verification activities of the HIW project.

User-relevant variables: visibility, ceiling and icing (for aviation); sea-ice, fog and visibility (for navigation); ground conditions (e.g. snow, permafrost) for land transport → Collaboration and interplay with the SERA group activities

YOPP verification primary goals (1/2)

1. **Demonsterate the added value of enhanced observations** in:
   - **data assimilation** (data denial, x-validation, standard scores)
   - **prediction** (data denial, x-validation, standard scores, DA)
   - **verification practices** (thinning, spatial representativeness)

   1b) verification research opportunities: verif in data-sparse regions; obs uncertainty; verif against analysis; synergies with DA.

2. **Quantify the accuracy of current numerical models in polar regions:**
   - Compare **coupled versus uncoupled** systems.
   - Assess the **impact of dynamical sea-ice models**.
   - Identify model **systematic errors**.

     - verification of upperair and surface variables; verification of ocean variables; verification of the **raditation budget** in presence/absence of clouds; verification of **energy fluxes** over ocean/land in presence/absence of sea-ice/snow.

YOPP verification primary goals (2/2)

3. **Analyse the performance of dynamical sea-ice models for sea-ice concentration, thickness, drift, extent, edge, pressure.**

4. **Demonstrate advancements associated with the YOPP modeling effort**: **pre-YOPP versus post-YOPP**.

5. **Linkages**: **demonstrate that improvements in the forecast accuracy in polar regions transfer to improvements in the predictability at mid-latitudes.**

Second order priority:
- Representation of snow cover and depth;
- Representation of solid precipitation types; freezing rain.
- Fog / horizontal visibility; cloud ceiling / base height (user oriented).
- Representation of Low-level mixed phase clouds.
- Representationm of stable boundary layer.
- Effects of steep orography: orographically enhanced precipitation, katabatik winds, hydraulic shocks.

WMO score exchange, new CBS standard (WMO manual 485)

	Upper air	Surface
Variables	Mean sea-level pressure, geopotential height, temperature, wind (relative humidity)	2m temperature, 10m wind speed and direction, 24h precipitation (total cloud cover, 6h precipitation, 2m relative humidity, 2m dew-point)
Levels (hPa)	850, 500, 250 (100)	
Frequency	24 h (12 h)	6 h up to T+72h, 12 h afterwards (3 h up to T+72h, 6 h afterwards)
Scores	Mean error, root mean square error, anomaly correlation, S1 score for mslp (mean absolute error, rms forecast and analysis anomalies, standard deviation of forecast and analysis field)	Mean error, mean absolute error, root mean square error; wind vector rmse. contingency tables with thresholds: 10-m wind speed: 5, 10, 15 m s^{-1} 24-h precipitation: 1, 10, 50 mm 6-h precipitation: 1, 5, and 25 mm Total cloud cover: 2 okta, 7 okta
Interpolation	Nearest grid-point on native model grid for verification against station / radiosonde; interpolation to 1.5x1.5 deg grid for verification against analysis	

Table adapted from T. Haiden

YOPP core phase verification activities

1. NWP **process-based evaluation** against high frequency multivariate observations **at the YOPP super-sites**.

Research teams involved: Gunilla Svensson (U. Stockholm); Barbara Casati, Stella Melo, Zen Mariani (ECCC); Jonny Day, Linus Magnusson (ECMWF); Morten Køltzow (MetNo); Matthew Shupe (NOAA, Mosaic); Taneil Uttal (IASOA - NOAA).

2. **Operational summary verification** scores:

- Pre-YOPP NWP system performance
- Operational verification practices in the Polar Regions
- Objective verification exchange during the SOPs

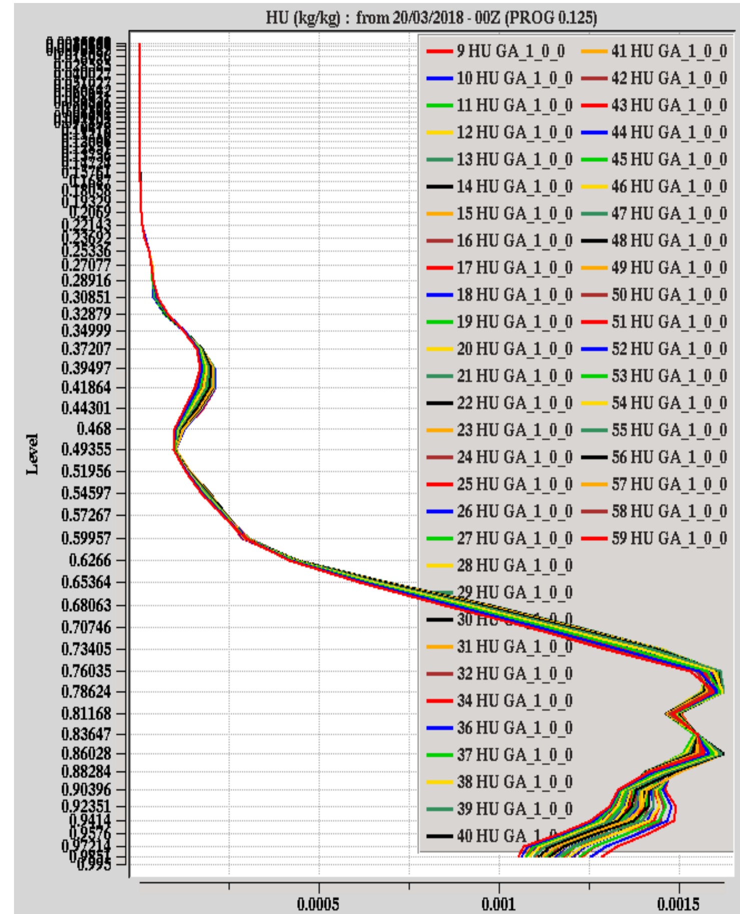
Tom Robinson, Barbara Casati, Gabrielle Gascon (ECCC); Thomas Haiden, Martin Janousek (ECMWF); Morten Køltzow, Teresa Valkonen (Met Norway); Eric Bazile (MetFrance).

3. Verification of **sea-ice** prediction during YOPP

Barbara Casati, JF Lemieaux, Ji Lei, Greg Smith (ECCC); Pam Posey, Julie Crout, Rick Allard (NRL); Bob Grumbine (NOAA); Malte Müller, Arne Melsom (MET Norway); Helge Goessling, Lorenzo Zampieri (AWI); Bill Merryfield et al (ECCC); Steffen Tietsche, Sarah Keeley, Jonny Day (ECMWF).

YOPP ongoing projects: NWP process-based evaluation against high frequency multivariate observations at the YOPP super-sites.

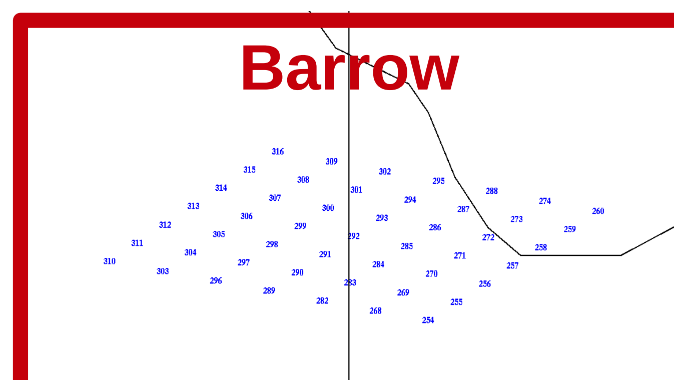
Jonny Day and Linus Magnusson (ECMWF) Process Based Verification of EC-HIRES forecasts for Sodankyla (and other YOPP supersites): investigation of IFS winter warm bias; evaluation of vertical profiles of wind, temperature, humidity; coupled diagnostics (radiation, turbulent fluxes etc.) to evaluate multi-level snow scheme.



Zen Mariani and Barbara Casati (ECCC): Process-based evaluation at Iqaluit (and other YOPP super-sites): evaluation of vertical profiles of wind, temperature, humidity; surface fluxes, radiation, clouds + hydrometeors micro-physics.

Morten Køltzow (MET Norway)
Verification of AROME Arctic (2,5 km) and IFS HRES at Bjørnøya (74.5167N; 19.0050E).

Taneil Uttal et al (IASOA – NOAA) The SOP Merged Observatory Data Files (MODF): unified file format, with standardized quality controls a data processing, which includes all measurements at the IASOA observatories.



One page Summary: NWP process-based evaluation against high frequency multivariate observations at the YOPP super-sites

- **Arctic and Antarctic observatories**, furnished by suites of instruments that provide detailed measurements characterizing the vertical column of the atmosphere as well as the surface conditions and energy fluxes.
  - ➔ IASOA merged observatory data files

- Modelling centres (ECMWF, ECCC, Meteo France, …) are providing **NWP model output** at high frequency (on the order of model time-step) on model levels to enable comparison with the multitude of available measurements at the YOPP supersites.

- This unique dataset of paired model output and multi-variate high-frequency observations enables detailed **process-based diagnostics**.
  - ➔ Open access via the YOPP data portal: https://yopp.met.no/

- **Target processes** include the representation of cloud micro- and macro-physics; aerosols and hydro-meteors micro-physics; radiation, turbulence and energy budgets; energy and momentum fluxes.

- Wish to get involved? barbara.casati@canada.ca, gunilla@misu.su.se

YOPP ongoing projects: Operational summary verification scores (1/2)

- **Pre-YOPP NWP system performance**
- **Operational verification practices in the Polar Regions**
- Objective verification exchange during the SOPs

Gabrielle Gascon and Barbara Casati (ECCC): Pre-YOPP performance of the Canadian NWP systems: surface and upper-air variables, 2016-2017, Canadian Arctic.

Linus Magnusson et al. (ECMWF) Summarizing operational verification at ECMWF for the Arctic: upper-air and surface variables. This work is part of the deliverable of APPLICATE on current status of NWP in Arctic.

Morten Køltzow (MET Norway) ScoreAtlas: summary verification scores for AROME Arctic (2,5 km) and IFS HRES, upper-air and surface variables, 2016-2018. Temperature, humidity, 1h and 24h precipitation, wind, cloudiness against synop. Standard continuous and categorical scores by lead time, as time series, and station by station. Note: precipitation obs corrected for under catchment due to wind, investigate spatial and temporal representativeness of site observations. This work is also part of a deliverable of APPLICATE on current status of NWP in Arctic (with ECMWF and Meteo France).

Teresa Valkonen and Morten Køltzow (MET Norway) Wind verification over ocean by ASCAT: Verification of wind from AROME Arctic (2,5 km) and IFS HRES over ocean, period YOPP SOPs Sep 2017 - Sep 2018. Scores; standard continuous and categorical scores.

YOPP ongoing projects: Operational summary verification scores (2/2)

- Pre-YOPP NWP system performance
- Operational verification practices in the Polar Regions
- **Objective verification exchange during the SOPs**

Tom Robinson and Barbara Casati (ECCC): Objective verification of the Canadian NWP systems during the YOPP Special Observing Periods: surface and upper-air variables, Fennoscandia, Canadian Arctic and North Pole (lat>60N). Highlights: inhomogeneity of observation network: thinning versus weighting; precipitation obs corrected for under catchment due to wind; conditional verification (temperature | clouds).
Sebastien Chouinard and Allan Rahill (ECCC): Subjective evaluation of the Canadian NWP systems during the YOPP SOPs.

Thomas Haiden and Martin Janousek (ECMWF) Global model inter-comparison of upper-air scores in the Arctic (lat>60N) and Antarctic (lat<60S): comparison of standard CBS upper-air scores (areal means) against both analysis and observations. Available models: ECMWF, CMC, UKMO, JMA, NCEP, M-F, KMA. Skill as a function of lead time is compared to corresponding results for mid-latitudes.

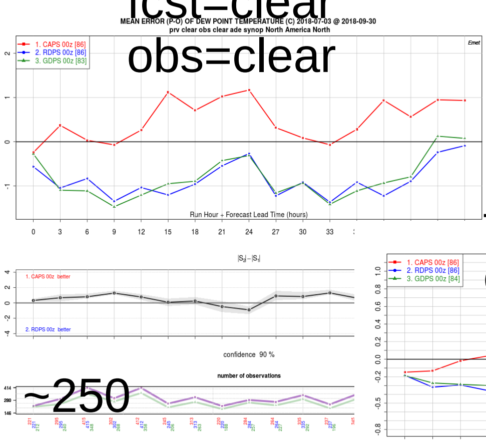
Morten Køltzow (MET Norway) YOPP Limited Area Model intercomparison: summary verification scores for AROME Arctic (MetNo. MeteoFrance), IFS HRES (ECMWF), CAPS (ECCC), surface variables. Highlights: station representativeness; precipitation obs corrected for under catchment due to wind; conditional verification (temperature | clouds). Objective verification **accompanied by forecasters subjective synoptic analysis**.

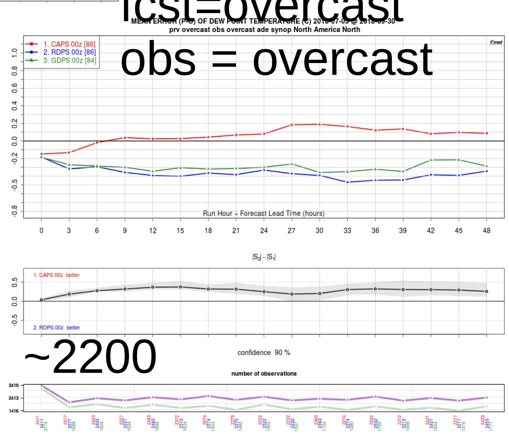
One Page Summary of the Findings: Operational summary verification scores

- Pre-YOPP NWP system performance
- Operational verification practices in the Polar Regions
- Objective verification exchange during the SOPs

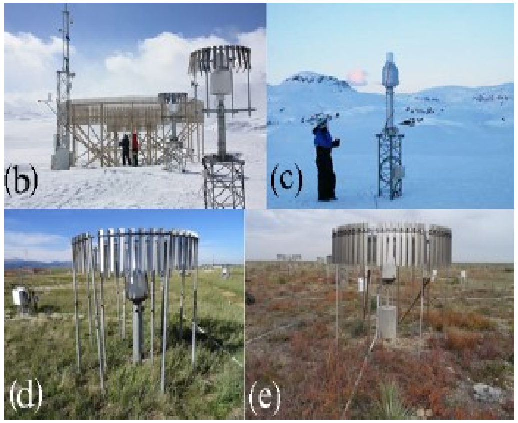
YOPP is providing the framework for analyzing current verification practices in the Polar Regions, propose novel approaches, reveal issues and investigate solutions

1. Conditional Verification

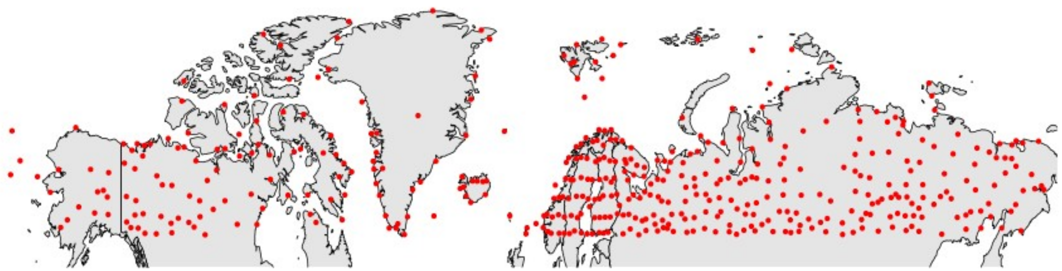




3. Solid precipitation undercatchment



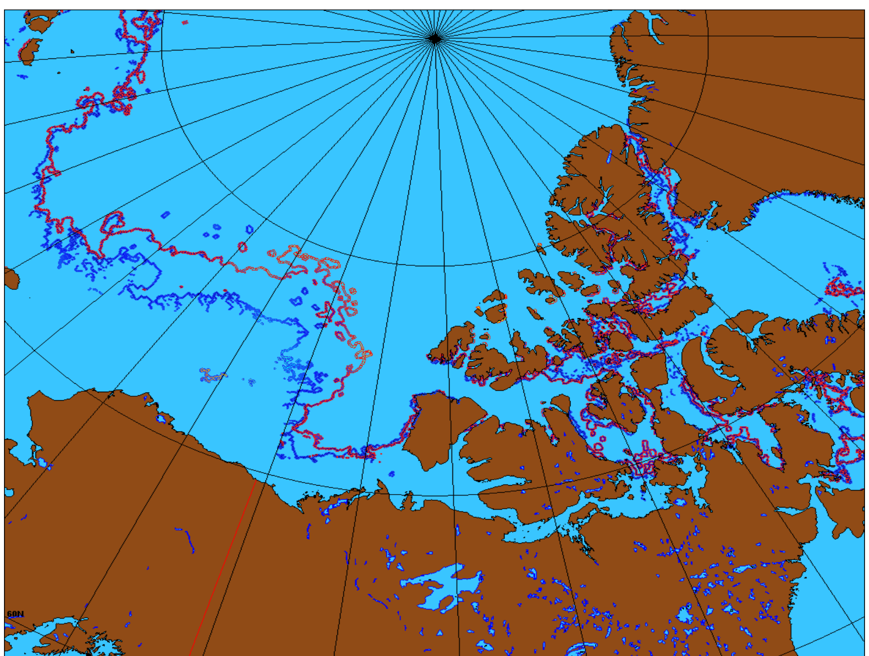
2. network inhomogeneity



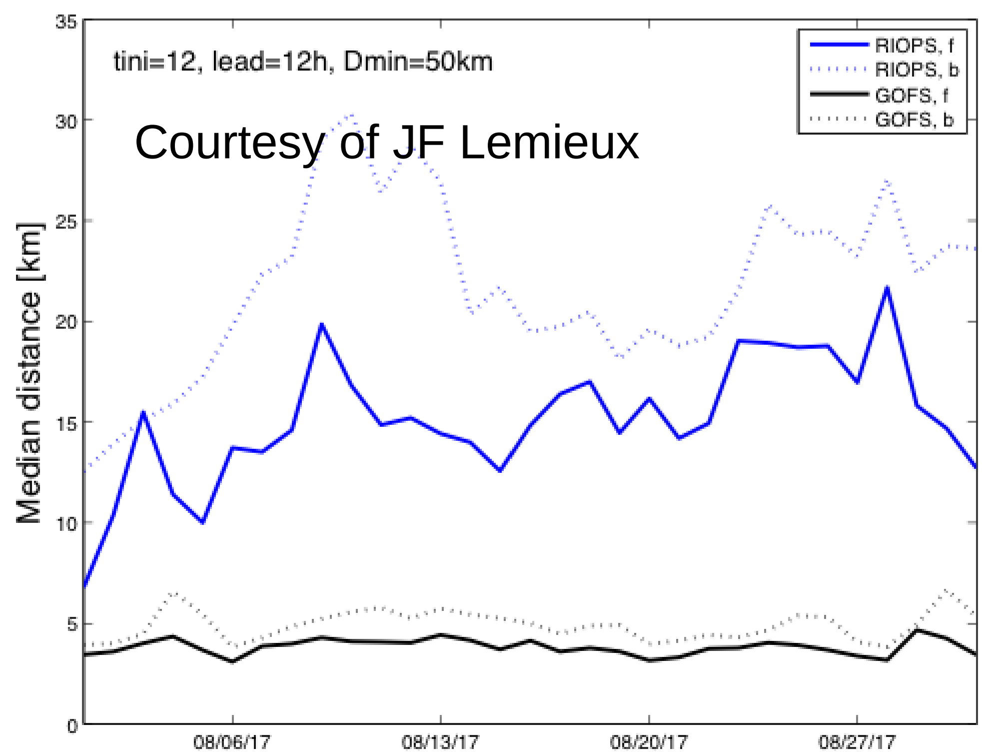
Verification of sea-ice prediction (1/2)

B Casati, JF Lemieux, G Smith, J Lei, F Dupont (ECCC):
Evaluation of GIOPS (33km), RIOPS (4km) sea-ice concentration (categorical scores + distance metrics evaluated for the ice-pack and for the ice edge) and ice drift prediction (bias in speed magnitude, angle error during displacement, RMS error on the vector error)

Pam Posey, Julia Crout, Rick Allard (NRL); Bob Grumbine (NOAA)
Evaluation of NRL-GOFS and NOAA-GOFS sea-ice concentration.
Note: **There is an ongoing monthly exchange of scores between ECCC and NRL** (categorical + distance metrics). Bob Grumbine expressed interest in joining.



RIOPS vs IMS ice-edge, 15 Aug 2017

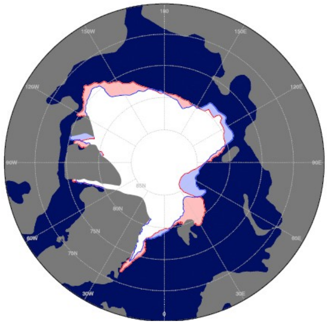


Verification of sea-ice prediction (2/2)

Malte Müller, Arne Melsom (MET Norway)
Copernicus Arctic Marine Forecasting Center (ARCMFC)
Sea-ice verification of ARCMFC analysis and forecasts (10 member ensemble sea-ice forecasts, with a 10-day lead-time). Verification parameters: sea-ice thickness, concentration, drift and type (example: http://cmems.met.no/ARC-MFC/V2Validation/index.html). Interested in model collaboration and inter-comparison with other centers.

Steffen Tietsche, Sarah Keeley, Jonny Day (ECMWF)
Verification of the IFS sea ice prediction (50 members coupled ensemble with interactive sea ice, runs twice a day up to day 15, with an extension to day 46 on Mondays and Thursdays). 20Y re-forecasts available for extended-range. Interested in monthly score exchange and in comparing medium range forecast to 1) persistence, 2) drift model.

H. Goessling, Lorenzo Zampieri (AWI)
Monitor the sea-ice prediction of S2S forecasting systems
Verification of sub-seasonal to seasonal sea-ice prediction using the IIEE and SPS scores.



Bill Merryfield (ECCC) and others:
Forecasting Regional Arctic Sea Ice from a Month to Season (FRAMS). Verification of sub-seasonal and seasonal sea-ice prediction. Parameters: sea ice concentration (extent, advance and retreat dates), thickness, velocity; compressive strength, normal stress, ridge ice thickness and area fraction, sea ice age. Participating centres: MSC (CanCM3/4, ensGIOPS), NOAA, Meteo-France, UK MetOffice, maybe ECMWF (SEAS5)

Summary: ongoing YOPP verification activities

1. NWP **process-based evaluation** against high frequency multivariate observations **at the YOPP super-sites**.

- A unique dataset of paired NWP model output and multivariate high frequency obs which enables detailed process-based diagnostics.
- Target processes: clouds and hydro-meteors micro-physics; radiation, turbulence and energy budgets; energy and momentum fluxes.

2. **Operational summary verification** scores:

- YOPP is providing the framework for analyzing current verification practices in the Polar Regions, propose novel approaches, reveal issues and investigate solutions

3. Verification of **sea-ice** prediction during YOPP

- User-informative distance metrics alongside traditional scores

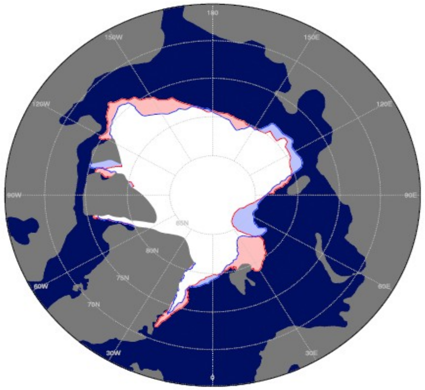


Figure 1. The sea ice edges (15% ice concentration contours) for two members of an AWI-CM idealized forecast ensemble on 15 September (initialized on 1 July of the same arbitrary year). Interpreting the blue contour as forecast and the red contour as truth (observations), the IIEE is the sum of all light blue (ice extent overestimated; *O*) and light red (ice extent underestimated; *U*) areas, compare equations (1)–(3). The depicted land-sea distribution corresponds to the AWI-CM ocean grid.

Verification plans for the YOPP consolidation phase

The major contribution of the YOPP verification task team in the YOPP consolidation phase is in “**Consolidating and synthesizing YOPP research**”, while completing the YOPP core-phase verification activities.

Moreover, the YOPP verification activities revealed issues and provided feedback for improved operational verification practices, which possibly will be part of revised CBS verification standards.

Consolidating and synthesizing YOPP research : Verification – summary scores

1. Operational summary verification scores:
Complete Arctic SOP verification activities (e.g. global models); participate to SH Antarctic SOP verification activities.

2. Synthesis and publishing major results: summary verification studies characterizing the overall performance of prediction systems during YOPP; comparison of the Pre-YOPP versus post-YOPP performance (coupled versus coupled models; effect of dynamic sea-ice models on weather prediction).

3. Assist OSE and linkages group in the assessment of the added value of the assimilated additional Polar observation for the initialization of prediction systems for an enhanced predictability in mid-latitudes (e.g. statistical significance, casuality).

→to be pursued in collaboration with the Task Team on Numerical Experimentation, lead by Irina Sandu

Consolidating and synthesizing YOPP research : Verification - process-based

4. (in alignment with WGNE) Collaborate with the modeling community in the development of process-based diagnostics (e.g.involving multiple variables -collaboration with Thomas Haiden); design specific diagnostic for exploiting the YOPPsiteMIP and MOSAIC datasets (multi-variate profile time-series)
→ to be pursued in collaboration / within the process Task Team, lead by Gunilla Svensson.

5. In the verification context for model development: promote aggregation (or other statistical approaches) to infer model behaviour from single case studies to a generalized result on process representation. Promote more strongly inference / statistical significance, in all verification studies.

Consolidating and synthesizing YOPP research : Verification - sea-ice

6. Sea-ice verification:

Currently: focus on **ice concentration, ice edge, ice drift**
Desiderata: **thickness, pressure, stage of development, MIZ**
Challenge: ought to exploit / improve **satellite products**
Analyse Canadian Archipelago (not only main ice pack).

Aim: model intercomparison
Challenge: prediction systems span all time scales (48h, medium- long- and extended-range, sub-seasonal and seasonal), and encompass deterministic and ensembles. Several ongoing parallel model intercomparison (GODAE, FRAMS, ...).

Currently: evaluation by using traditional categorical scores (correct ice, correct water) + **user-informative distance metrics**

→ Sea-ice verification will be pursued within the Sea-Ice Prediction Task Team, lead by Helge Goessling and Greg Smith.

Research to Operation and Services:
provide feedback to NWP weather centres and CBS standards for improved operational verification practices (e.g. apply the SPICE adjustment for the undercatchment of solid precipitation; weight verification results wrt the spatial density of the surface observation networks; identify representativeness of individual stations and match most suitable model output).

Future WMO projects:
Address station representativeness issue (CBS+JWGFVR, activities are already ongoing, lead by B.Casati, T. Haiden, M.Mittermaier).