RÉANALYSE CANADIENNE DE SURFACE (RCaS-CaSR) VERSION 3.1 D'ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA (ECCC)

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SYMPOSIUM OURANOS 2025

28-29 janvier 2025, Montréal

What is CaSR ?

Canadian Surface reanalysis (CaSR) is based on online and offline sub-systems – from existing ECCC operational systems
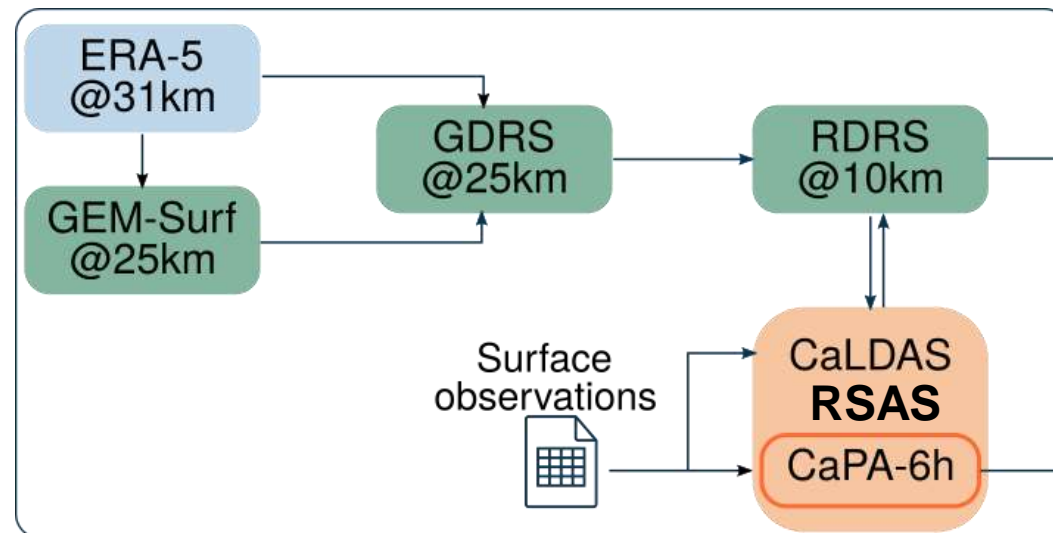
- **Online components**

    GDRS: Global Deterministic Reforecast System (25km) initialized by an existing atmospheric reanalysis (ERA5) and GEM-Surf open-loop forced by the same reanalysis at the surface

    RDRS: Regional Deterministic Reforecast System (10km) initialized as GDRS, piloted by GDRS and coupled with land data assimilation (**CaLDAS**) and 6-h precipitation analysis (**CaPA-6h**) systems (**RSAS**)
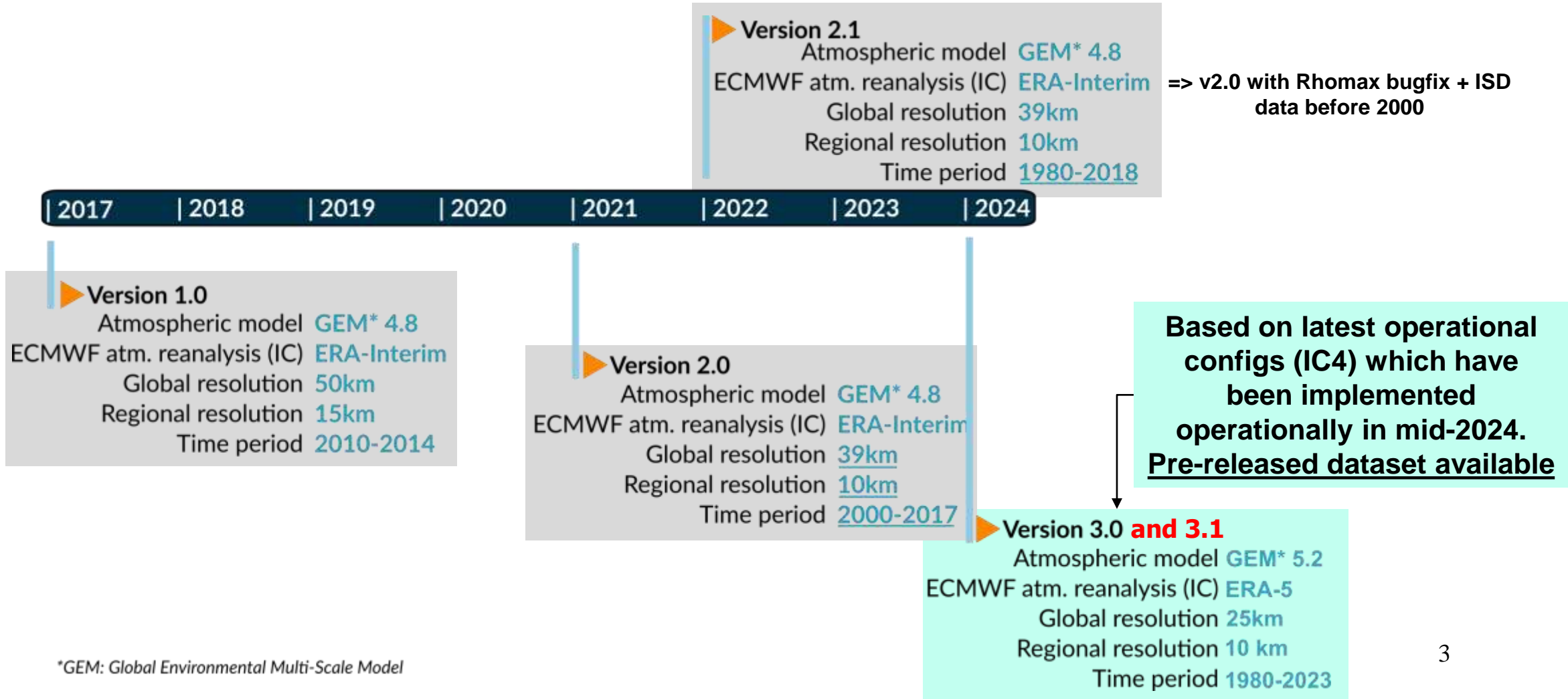
- **Offline component**

    - **RDPR (CaPA-24h):** Regional Deterministic Precipitation Reanalysis (24-hour precipitation analysis using RDRS background fields)

Versions of CaSR

So far - 3 versions of CaSR disseminated to the public

Version 2.1
Atmospheric model	GEM* 4.8
ECMWF atm. reanalysis (IC)	ERA-Interim
Global resolution	39km
Regional resolution	10km
Time period	1980-2018

=> v2.0 with Rhomax bugfix + ISD data before 2000

| 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |

Version 1.0
Atmospheric model	GEM* 4.8
ECMWF atm. reanalysis (IC)	ERA-Interim
Global resolution	50km
Regional resolution	15km
Time period	2010-2014

Version 2.0
Atmospheric model	GEM* 4.8
ECMWF atm. reanalysis (IC)	ERA-Interim
Global resolution	39km
Regional resolution	10km
Time period	2000-2017

Based on latest operational configs (IC4) which have been implemented operationally in mid-2024. Pre-released dataset available

Version 3.0 and 3.1
Atmospheric model	GEM* 5.2
ECMWF atm. reanalysis (IC)	ERA-5
Global resolution	25km
Regional resolution	10 km
Time period	1980-2023

*GEM: Global Environmental Multi-Scale Model

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CaSR applications and collaborators

- Active collaborations
  - Universities (10 Grants and contributions (G&Cs) handled under Flood Hazard Identification and Mapping Program (FHIMP))
  - PCIC (Pacific Climate Impact Consortium)
  - Ouranos

- Historical Flood Events database (HFE)
  - CaSR precip. populates HFE db at places where floods occurred in Canada instead of closest station ⇒ **better coverage in space and time**

- Analysis of past and extreme events
  - CaSR precipitations used to infer on return period of extremes at location without stations
  - Flood plain delimitations, hydraulic structure design

- CaSR as climate reference (e.g. operational Snow Water Equivalent anomaly product)
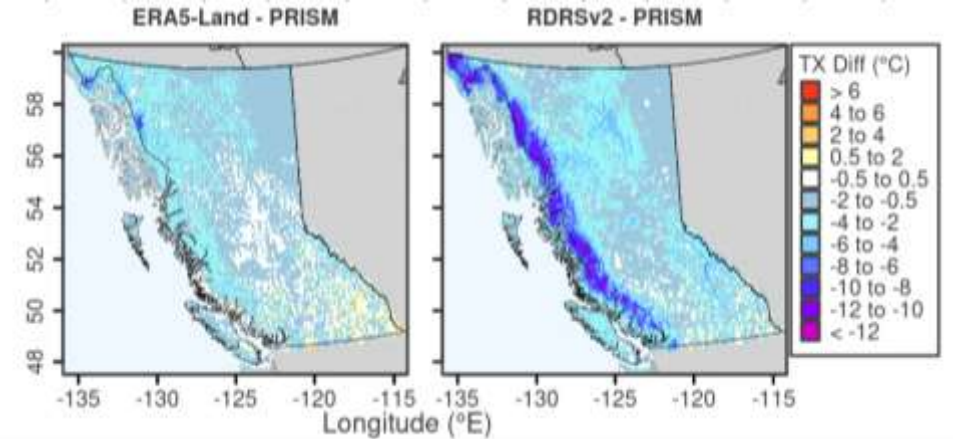
Figure courtesy of Francis Zwiers

SWE anomaly
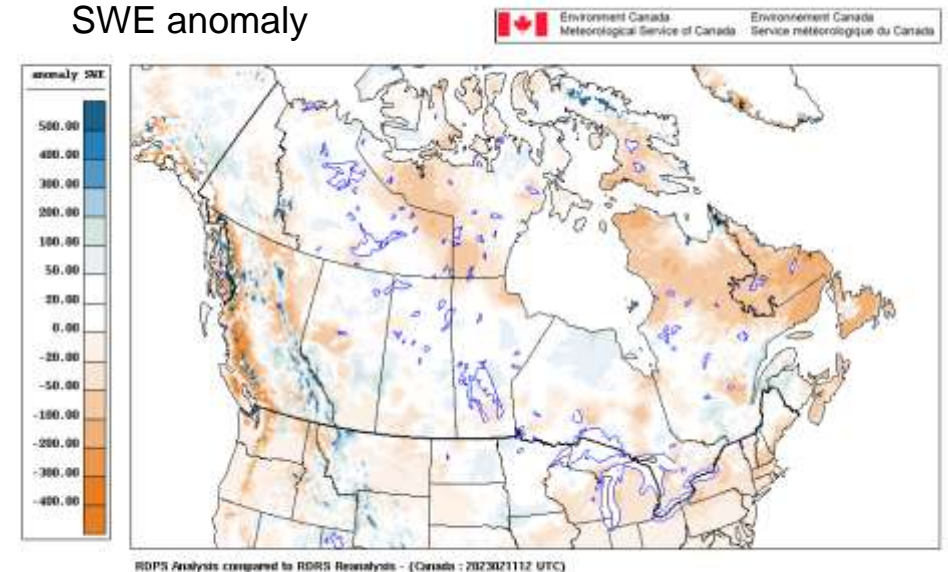
Global/Regional Reforecast Configuration (v3)

Global: GDRS (updated IC4)

- GEPS control member config.
- GEM 5.2.1, Global Yin-Yang grid, 25-km **(new)**
- 12-h cycle/48-h reforecast

Regional: RDRS (updated IC4)

- Modified RDPS config. (cover Arctic Ocean)
- GEM 5.2.1, LAM, 10-km **(new)**
  - **New orography**
  - **Modified ISBA for snow cover and melt/refreeze**
- 12-h cycle/48-h reforecast
- **Coupled with CaLDAS/CaPA (RSAS)**

RDRS domain
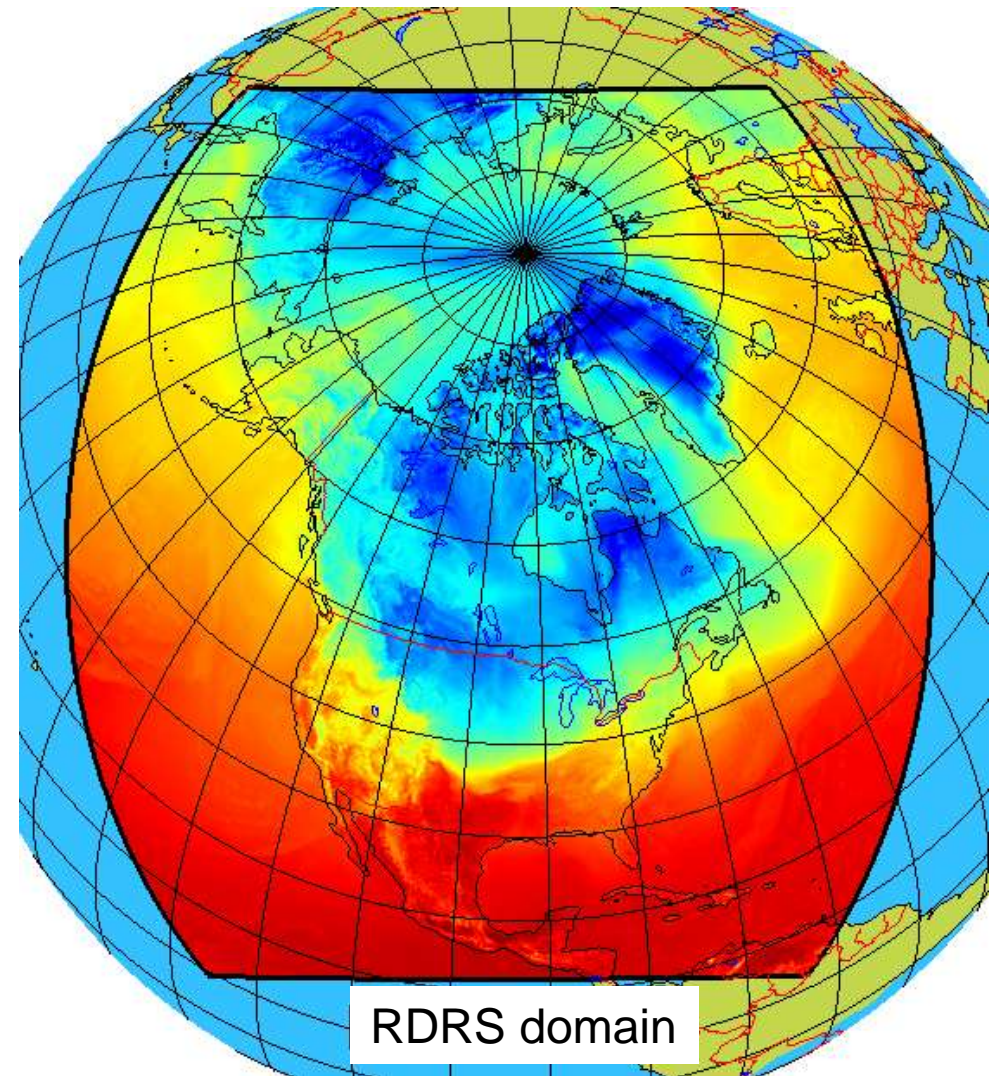
CaLDAS/CaPA Configuration (v3)

Online pcp and surface analysis: RSAS (updated IC4)

- North-America, 10-km, 1-h

- CaLDAS-Screen/OI **(new)**
  - **New diagnostic of precipitation phase**
  - **Modified ISBA for snow cover and melt/refreeze: cold bias**

- CaPA-6h pcp analysis

- 06-18h RDRS forcings

Offline 24-h pcp analysis: CaPA-24h (updated IC4)

Observations assimilated:

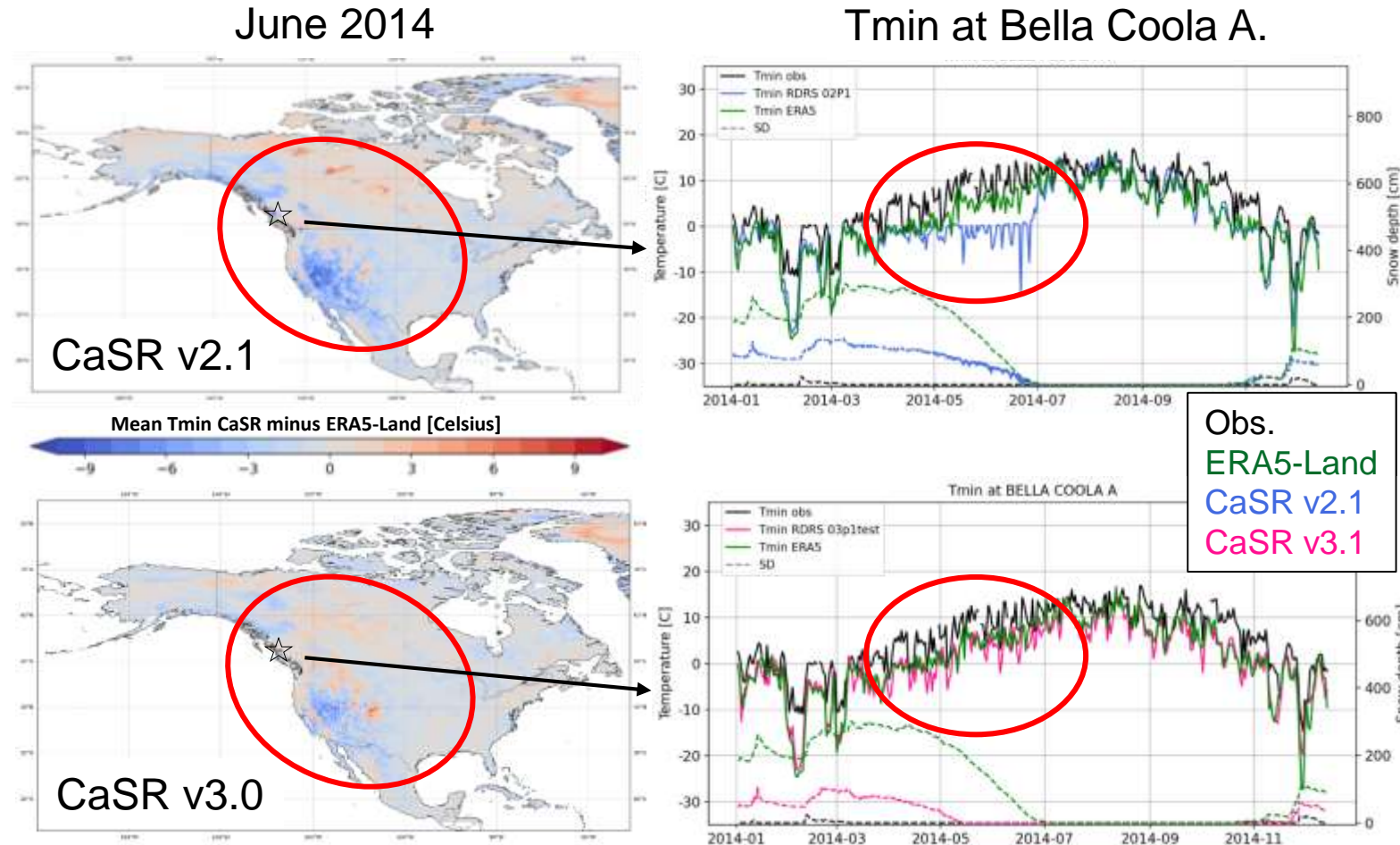**Temperature, Dew point, Precipitation and Snow depth**

- ECCC Operational/Climate archive (ADE, **after 2000**)

- ISD (NCEI, Smith et al. 2011; **before 2000**) **(updated, bugfix)**

- AdjDlyRS (**CaPA-24h**, Wang et al. 2017) **(updated)**

- AdjHlyRS (**CaPA-24h**, Smith et al. 2022) **(new)**

- CHDSD (Brown et Braaten 1998) **(new)**
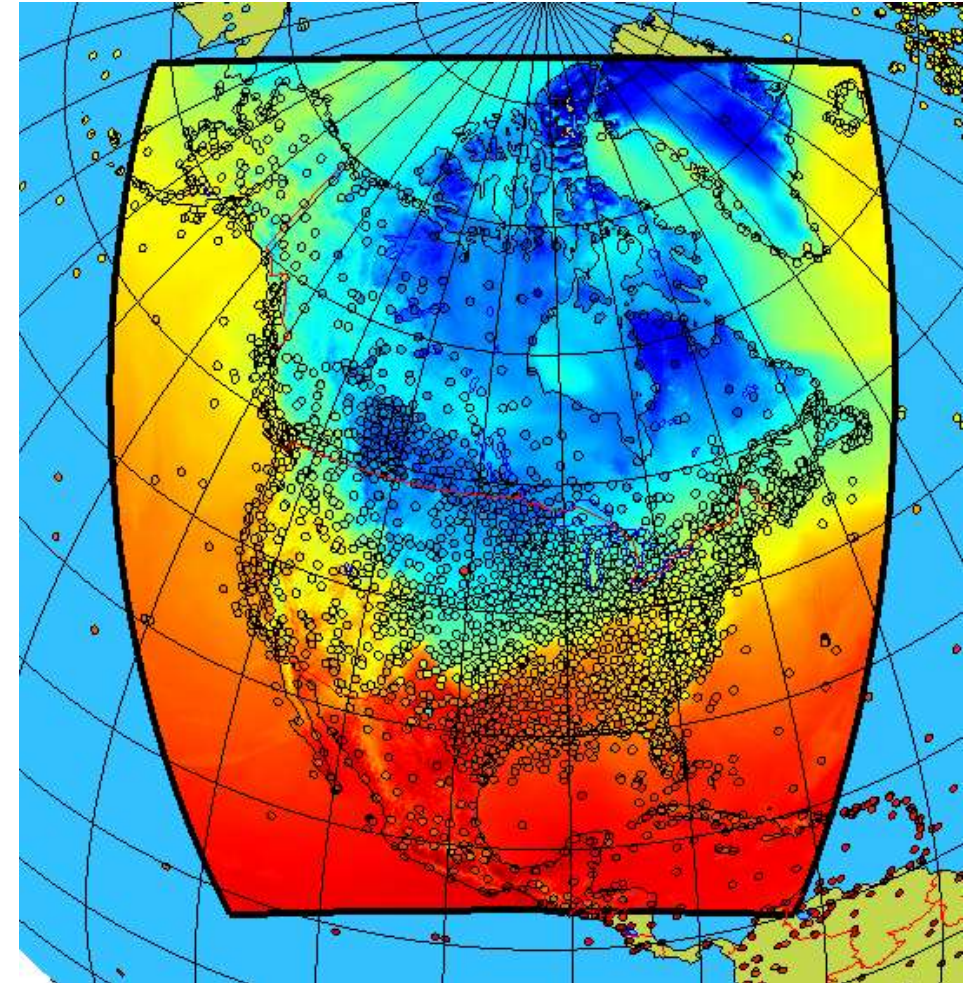
RSAS domain with observations

One of the major problem in v2.1: cold spring bias

- CaSR v2.1 extensively used by several G&C (Grants and Contributions) recipients funded by the FHIMP (Flood Hazard Identification and Mapping Program) (as CaSR itself)

- Quality of CaSR v2.1 assessed by recipients using different verification approaches

- PCIC (Pacific Climate Impact Consortium) developed bias correction methods for climate models using CaSR v2.1 and raised a major issue

June 2014

Tmin at Bella Coola A.

CaSR v2.1

Mean Tmin CaSR minus ERA5-Land [Celsius]

CaSR v3.0

Obs.
ERA5-Land
CaSR v2.1
CaSR v3.1

Clear warming in spring in v3.1 – scores against obs. show a clear improvement!

How CaSR v3.1 compares to v2.1: against surface observations

Temperatures — Seasons — Regions

Wind — Seasons

Surface pressure — Seasons

CaSR v2.1 better
CaSR v3.1 better

Significant improvements (Bias, STDE) of all surface and atmospheric variables for all domains and seasons

24h precipitation analysis: CaSR v3.1 vs v2.1 (CaPA 24h: 2012-2014)

Analysis LOO categorical scores
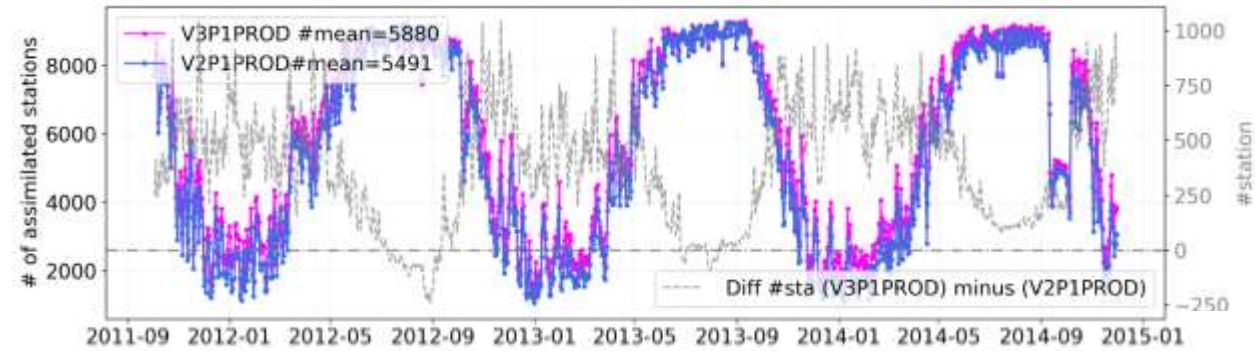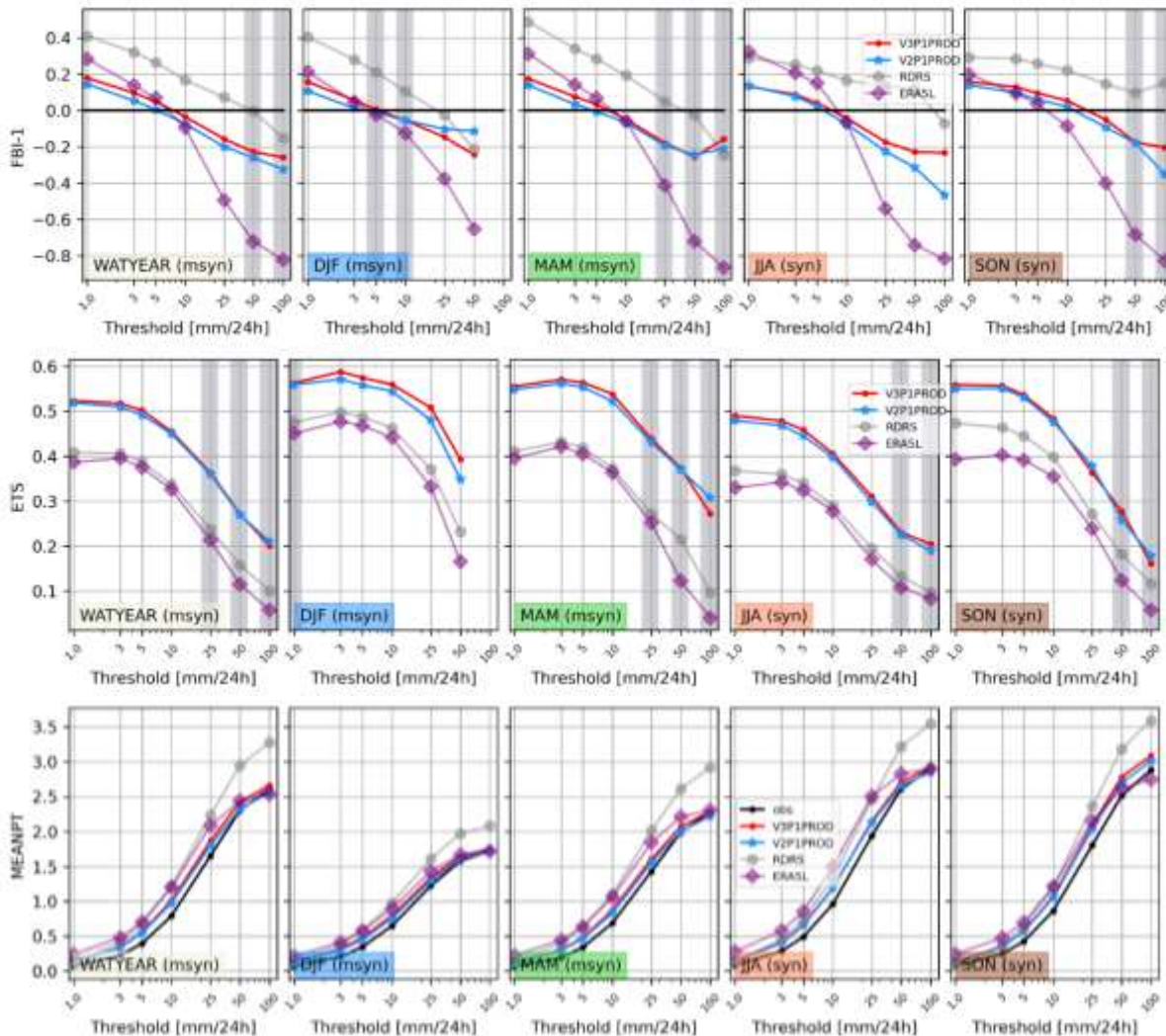
- CaPA 24h scores for CaSRv3.1 show **neutral to slightly improved results** w.r.t. ETS and a very small degradation in terms of FBI for small quantities (<10mm) in comparison to CaSRv2.1 for the years after 2000

- Update of Adjusted Dataset brings **up to 1000 additional observations per analysis notably in winter above Canada**

- **CaPA 24h scores from CaSR are significantly better than ERA5-Land**

How CaSRv3.1 compare to current ECCC operational systems ?

Regional Deterministic Prevision System (RDPS)

RDPS/HRDPS better
CaSR v3.1 better

High Resolution Deterministic Prevision System (HRDPS)

- **Significant improvements against RDPS** (Bias, STDE) of surface temperatures for most domains and seasons (same 10-km resolution and GEM config).
- **Results are mitigated against HRDPS** (2.5-km resolution but same surface analysis methodology).

RDPS table:

stdev RDRS3P0PROD / G0FC900V2FS22		20210930 / 20211130 00z	20210930 / 20211130 12z	20211101 / 20220228 00z				
Arctic All CLIM	TD	6.47%	6.73%	-1.19%				
	TT	7.52%	7.93%	-0.08%				
Arctic plus CLIM	TD	10.43%	11.09%	-0.15%				
	TT	10.41%	11.05%	0.17%				
Boreal CLIM	TD	4.47%	5.57%	2.08%				
	TT	2.51%	3.88%	1.83%				
Central CLIM	TD	7.40%	7.18%	2.71%				
	TT	5.54%	6.30%	4.92%				
Desert CLIM	TD	8.41%	7.56%	9.06%				
	TT	11.09%	11.06%	8.21%				
East CLIM	TD	5.36%	4.93%	1.84%				
	TT	4.02%	5.70%	4.27%				
Great Lakes CLIM	TD	4.89%	4.94%	3.90%				
	TT	2.97%	3.56%	5.46%				
Mt West CLIM	TD	9.01%	9.30%	3.78%			-1.27%	-0.16%
	TT	8.07%	9.50%	4.88%	6.98%		-0.47%	0.81%
Pacific North West CLIM	TD	5.14%	4.33%	1.33%	1.64%	1.41%	1.84%	2.26%	1.80%
	TT	7.50%	7.60%	5.90%	7.00%	3.65%	5.01%	6.35%	8.05%
Pacific South West CLIM	TD	-10.63%	-8.89%	-4.61%	-3.01%	2.07%	0.67%	4.30%	3.93%
	TT	1.45%	2.58%	2.49%	3.28%	4.75%	4.49%	1.49%	0.81%
South CLIM	TD	14.16%	15.04%	10.60%	11.13%	7.43%	5.21%	3.96%	3.38%
	TT	3.75%	5.52%	3.70%	6.36%	2.12%	3.90%	1.23%	0.28%

HRDPS table:

stdev		20210930 / 20211130 12z	20211101 / 20220228 00z	20220301 / 20220531 12z	20220601 / 20220831 00z	12z
Arctic All CLIM	TD	1.15%	5.27%	6.44%	1.63%	1.89%
	TT	-1.37%	0.58%	3.54%	1.04%	1.59%
	TD	0.15%	5.83%	6.70%	1.23%	1.75%
	TT	-2.82%	0.57%	3.21%	-2.14%	-0.97%
	TD	1.07%	2.46%	0.04%	0.78%	1.35%
	TT	1.76%	5.19%	3.78%	0.61%	0.67%
	TD	1.87%	-0.10%	0.22%	-0.50%	0.10%
	TT	2.43%	-0.24%	-0.29%	-1.08%	0.63%
	TD	-7.66%	-4.02%	-4.22%	1.75%	3.13%
	TT	-5.51%	-1.07%	-1.21%	0.97%	1.96%
	TD	-5.93%	-2.14%	-2.76%	0.85%	1.13%
	TT	-9.88%	-4.63%	-7.55%	-3.28%	-1.50%
Mt West CLIM	TD	-2.97%	-1.61%	4.54%	5.38%	-0.41%	0.46%	1.54%	0.27%
	TT	0.15%	1.43%	2.44%	2.93%	-2.14%	-1.06%	4.90%	5.93%
Pacific North West CLIM	TD	-1.13%	-0.91%	-0.62%	0.42%	-2.56%	-3.03%	-3.91%	-5.84%
	TT	-0.70%	-1.10%	-0.50%	1.14%	-0.64%	0.18%	4.77%	6.41%
South CLIM	TD	-4.47%	-2.33%	-0.54%	2.45%	-12.11%	-9.36%	-2.85%	-2.84%
	TT	0.00%	4.94%	2.10%	7.47%	-1.23%	0.00%	-1.96%	-6.18%

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How CaSRv3.1 compare to current ECCC operational systems ?

Snow depth and SWE from **CaSRv3.1** against **RDPS**, **HRDPS** and **ERA5-Land**

Regional Deterministic Precipitation Analysis (**RDPA**) (version with no radar and no satellites)
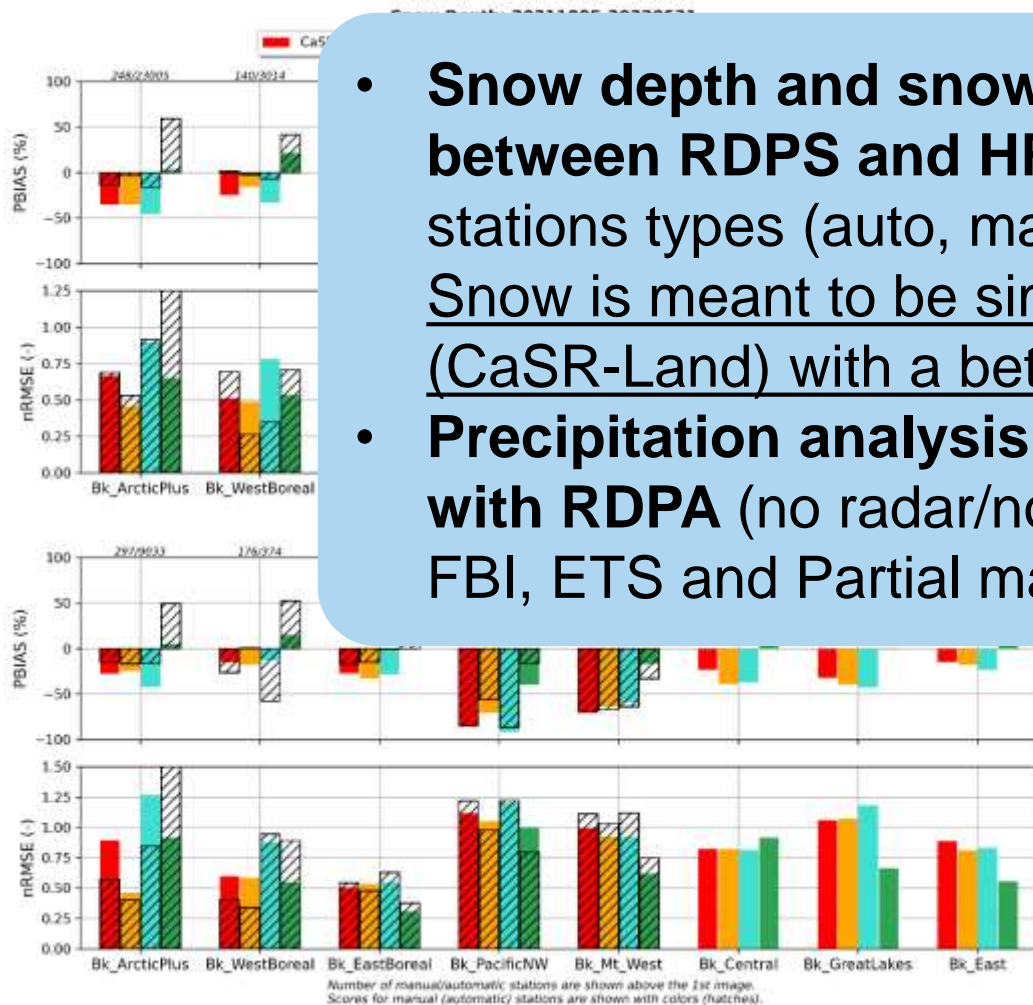
- **Snow depth and snow water equivalent fall in between RDPS and HRDPS** depending on the domain, stations types (auto, manual) and metrics (Bias, RMSE). Snow is meant to be simulated by an offline reanalysis (CaSR-Land) with a better snow scheme.

- **Precipitation analysis are in very good agreement with RDPA** (no radar/no satellites version) in terms of FBI, ETS and Partial mass.
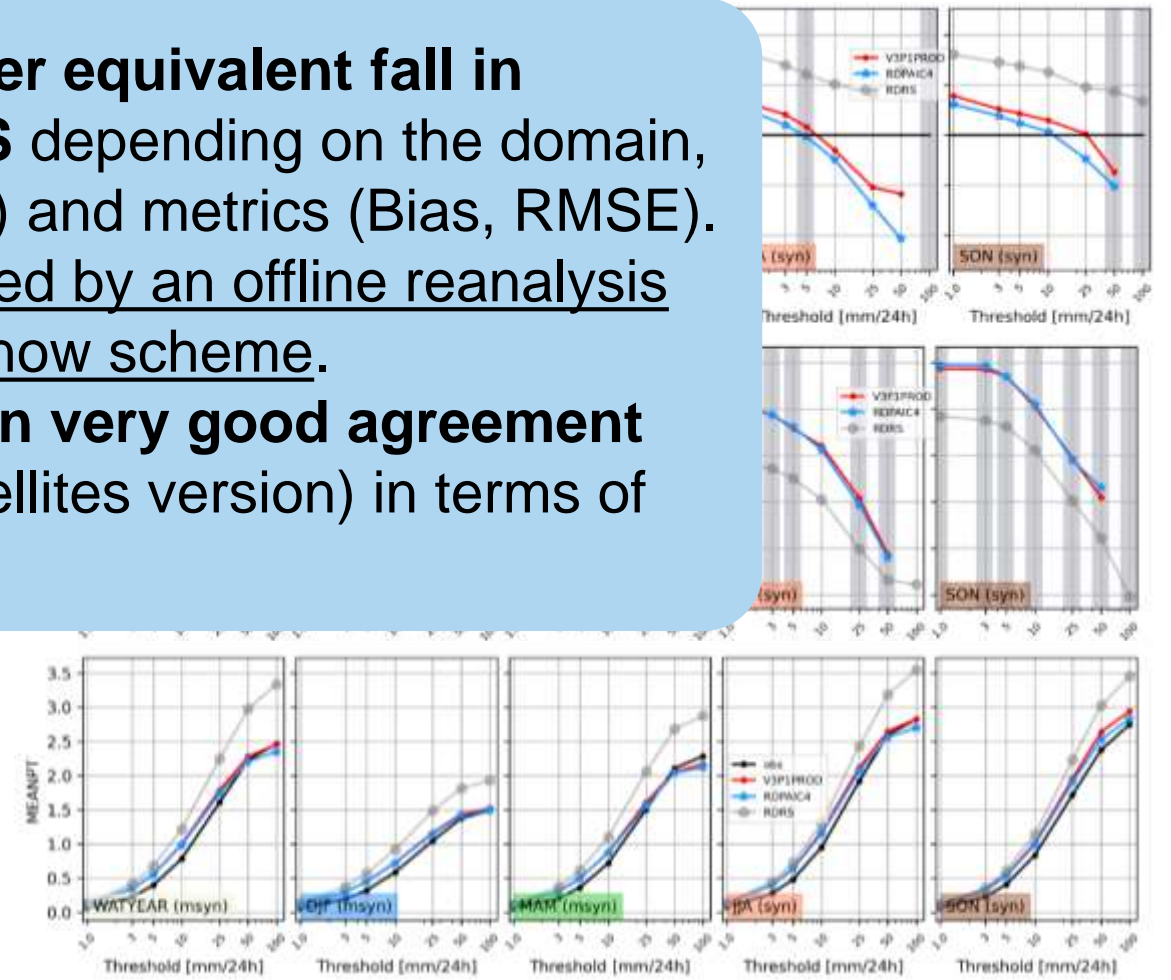
CaSR data dissemination

- CaSR data dissemination so far (v2.1 and before)

  - CaSPAr: http://www.caspar-data.ca North America (1-h/10km), 1980-2018

  - Ouranos-PAVICS https://pavics.ouranos.ca (only identified statistics for selected variables)

- CaSR v3.1 will be made available on:

  - CaSPAr (similar to v2.1)

  - Ouranos-PAVICS (only identified statistics for selected variables)

  - GPSC-C: ECCC "collaborative cluster" https://hpfx.collab.science.gc.ca/~scar700/rcas-casr/ (Sample available - Full dataset sliced by days soon available ~ 11TB)

- **Additional variables in CaSRv3.1**: 24h precipitation analysis and confidence index, precipitation types, 2m temperature and dew point analysis

- The long-term plan is to disseminate CaSR on the Canadian Weather Services usual channels: **DATAMART/GeoMet-Climat**

Conclusion and next/final steps

- **CaSR v3.1 planed to be released early 2025 (production now completed, preliminay sample publicly available)**

    - Important improvements compared to CaSR v2.1

    - Lot of work was done to refine surface-atmosphere interaction in order to mitigate the spring cold bias and spurious temperature trends issues => also improve performances elsewhere (but snow)

- **CaSR v3.1 back extension before 1980** could be produced once the main production is completed

- Two additional products to CaSR have been developed (**CaSR-Land** and **CaSR-River**) and forced by CaSR v2.1 (v3.1 is the next step) – see presentation : *A description of the Canadian Surface Reanalysis - Land (CaSR-Land) and Rivers (CaSR-Rivers), Ouranos Symposium, 2025 (Session 3 – Modélisation hydrologique)*

- **New platform to share and document CaSR on ECCC collaborative server (GPSC-C)**

    https://hpfx.collab.science.gc.ca/~scar700/rcas-casr/

THANKS FOR YOUR ATTENTION

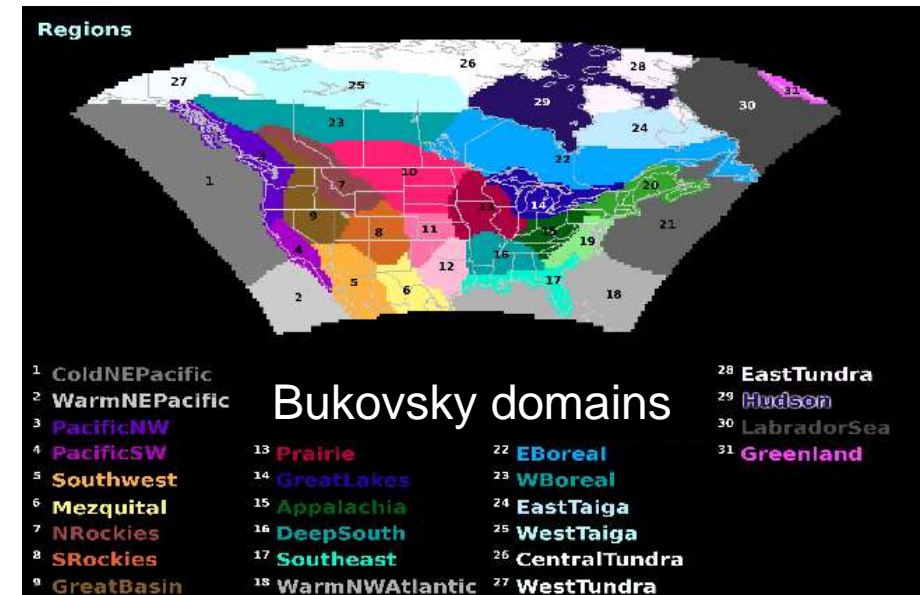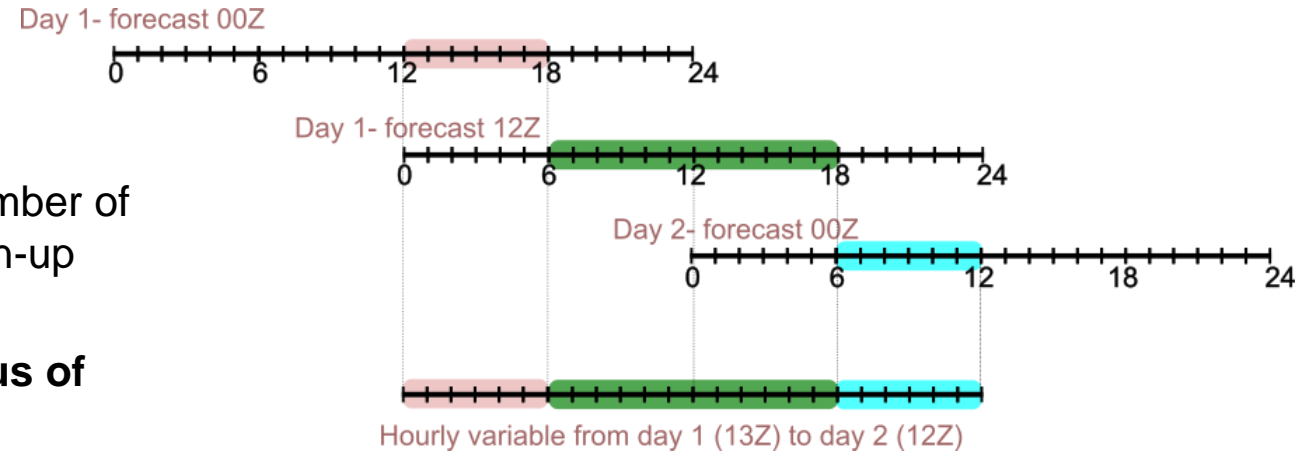Questions and/or comments?

EXTRA SLIDES

Further details on CaSR v3.1
evaluation method and tools

CaSR development and evaluation strategy

- Simulations extend over **one year**:
  - Same methodology as production runs:
    - Spin-up: 1-month offline RSAS spin-up (September of the previous year) + 3-month RDRS/RSAS spin-up (October to December of the previous year)
    - Actual data: +one-year of RDRS/RSAS ← **focus of evaluation**

- Two distinct one-year sample evaluated,
  - One year **before** 2000 → Integrated Surface Database (ISD) observation database
  - One year **after** 2000 → ADE observation database

- Evaluation of analysis, short-term forecasts (6 to 18-h) as well as full forecasts (0 to 48-h)

Day 1- forecast 00Z

Day 1- forecast 12Z

Day 2- forecast 00Z

Hourly variable from day 1 (13Z) to day 2 (12Z)

Regions

Bukovsky domains

1 ColdNEPacific
2 WarmNEPacific
3 PacificNW
4 PacificSW
5 Southwest
6 Mezquital
7 NRockies
8 SRockies
9 GreatBasin
13 Prairie
14 GreatLakes
15 Appalachia
16 DeepSouth
17 Southeast
18 WarmNWAtlantic
22 EBoreal
23 WBoreal
24 EastTaiga
25 WestTaiga
26 CentralTundra
27 WestTundra
28 EastTundra
29 Hudson
30 LabradorSea
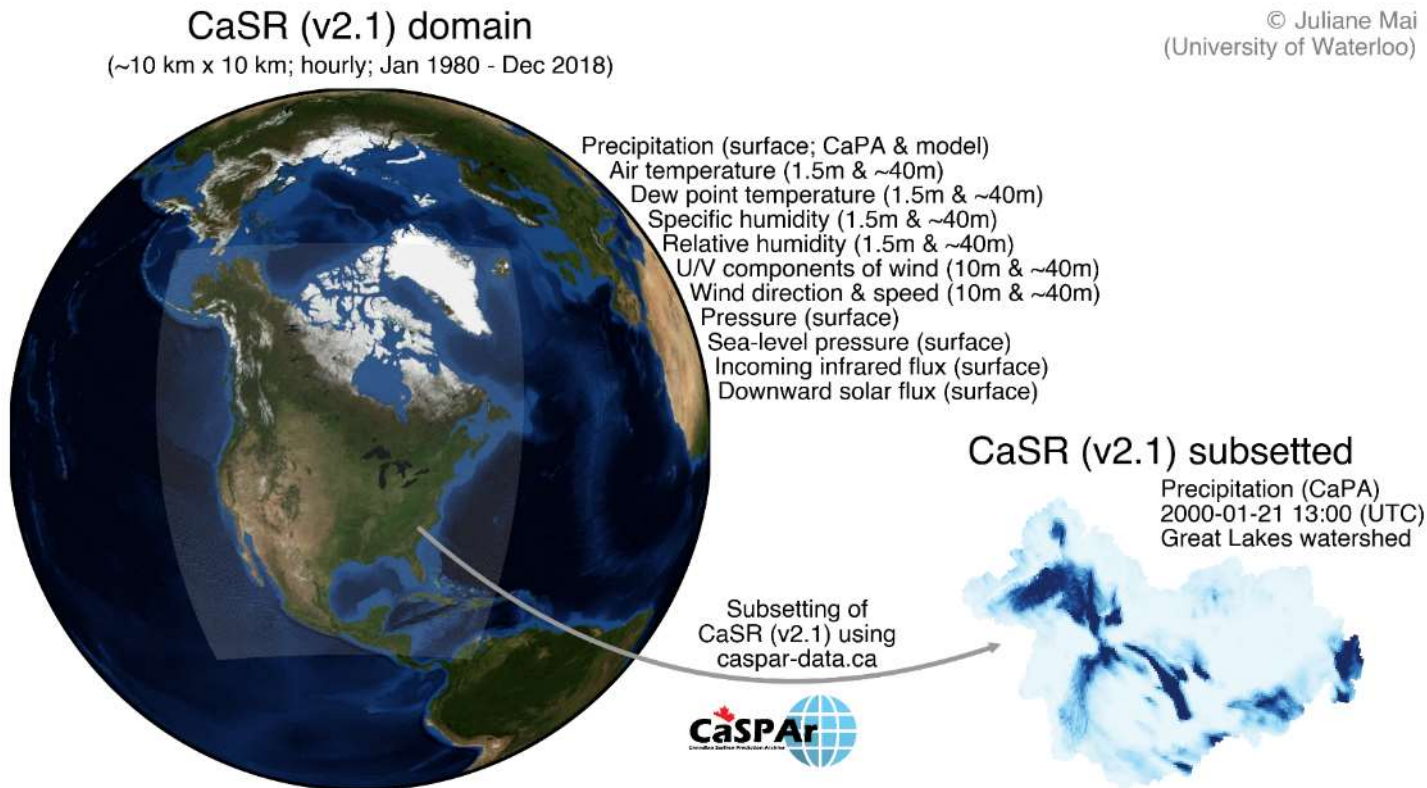31 Greenland

Evaluation tools

Classical CMC tools

- **EMET**: against surface observations (TT, TD, UV, PR, P0) with altdiffmax=100m

- **ARCAD:** against radiosonde obs. at several levels in the atmosphere

- **SnowEval:** against automatic and manual stations for snow depth (SD) and snow water equivalent (SWE) with altdiffmax=100m

Other tools for evaluation and diagnose problems

- **Time series** of Tmin and snow depth at stations

- Comparisons against **gridded datasets** and derivate statistics against (PCIC-PRISM, Ouranos, MERRA2, ERA5-Land)

- Number of stations assimilated in CaLDAS

CaSR disseminated variables

Data dissemination guidelines → only disseminate evaluated surface variables meant to drive hydrologic and land-surface models

CaSR (v2.1) domain
(~10 km x 10 km; hourly; Jan 1980 - Dec 2018)

© Juliane Mai
(University of Waterloo)

Precipitation (surface; CaPA & model)
Air temperature (1.5m & ~40m)
Dew point temperature (1.5m & ~40m)
Specific humidity (1.5m & ~40m)
Relative humidity (1.5m & ~40m)
U/V components of wind (10m & ~40m)
Wind direction & speed (10m & ~40m)
Pressure (surface)
Sea-level pressure (surface)
Incoming infrared flux (surface)
Downward solar flux (surface)

CaSR (v2.1) subsetted

Precipitation (CaPA)
2000-01-21 13:00 (UTC)
Great Lakes watershed

Subsetting of
CaSR (v2.1) using
caspar-data.ca

CaSPAr

- Surface variables and/or lowest atmospheric level for given variables
- **CaSPAr**: official website for version 1.0 to 3.1
- **Version 3.0 and 3.1:**
    - **ECCC GPSC-C**
    - **ECCC official data server**
    - **PAVICS**

Additional variables in CaSRv3.1:
24h precipitation analysis and confidence index, precipitation types, 2m temperature and dew point analysis

Snow evaluation: CaSR v3.1 and v2.1

Snow depth and Snow water equivalent → Slight degraded to neutral in CaSRv3.1 compared to CaSRv2.1. Western mountanious regions show high variability of performances especially in the US. Theses scores are however in good agreement with parent operational systems (HRDPS/RDPS).
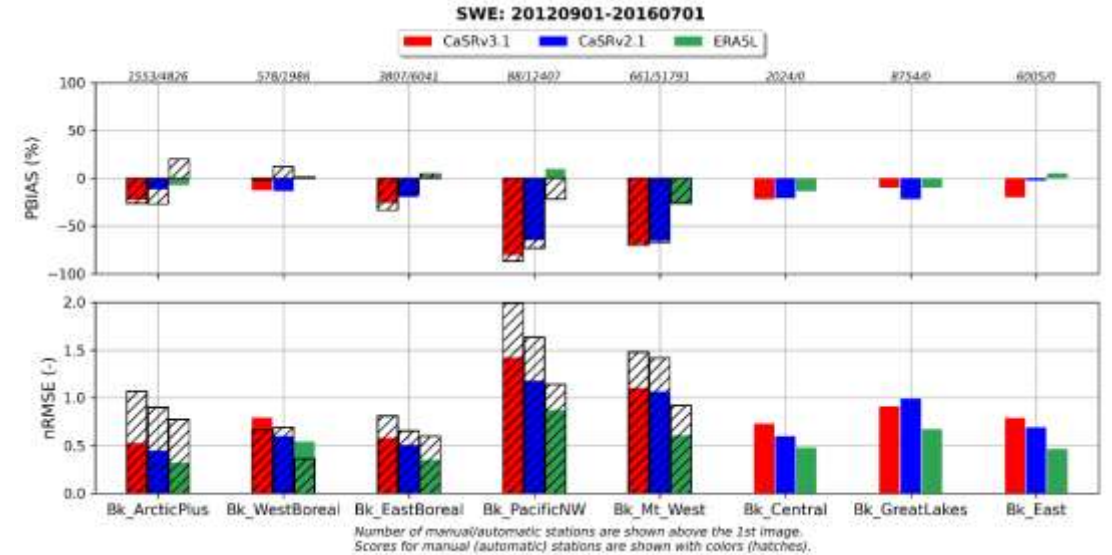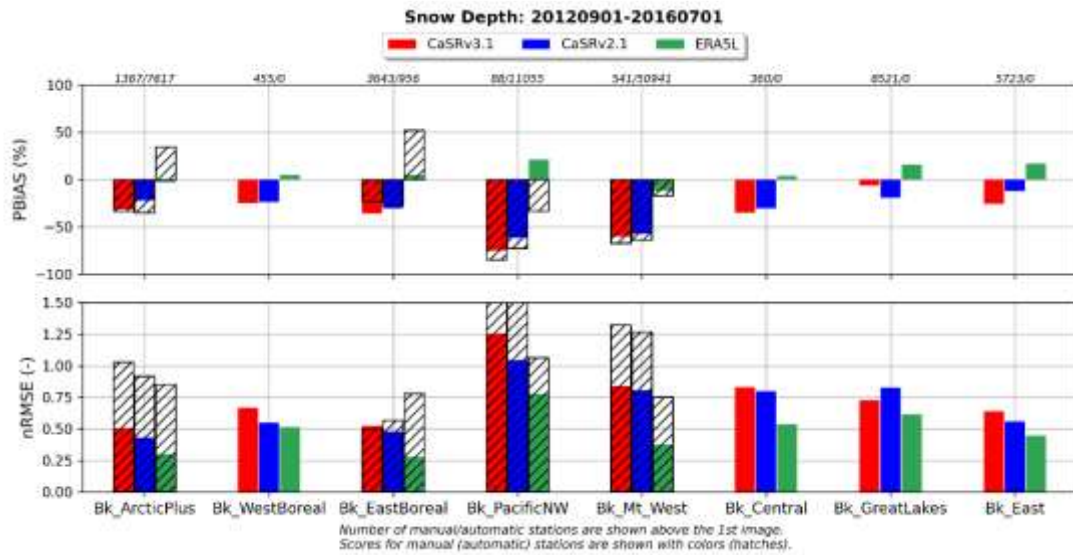
Despite important work w.r.t. snow depth in CaSR v3.1 compared with CaSR with vanilla IC4 systems → slightly degraded compared to CaSR v2.1 but not in all regions:
→ **SD is meant to be simulated by an offline reanalysis (CaSR-Land) with a better snow scheme**

# CaPA 24h: CaSR v3.1 vs v2.1 (1996-1997)

Analysis LOO Categorical scores (1996-1997)
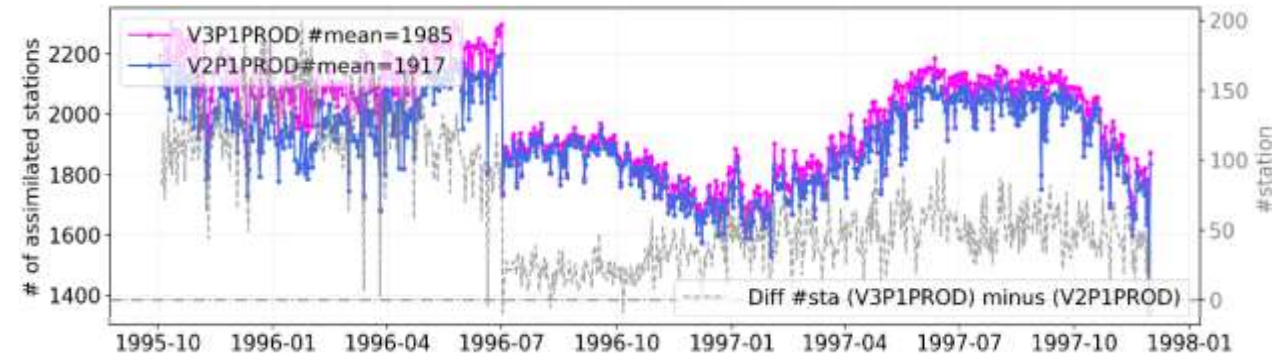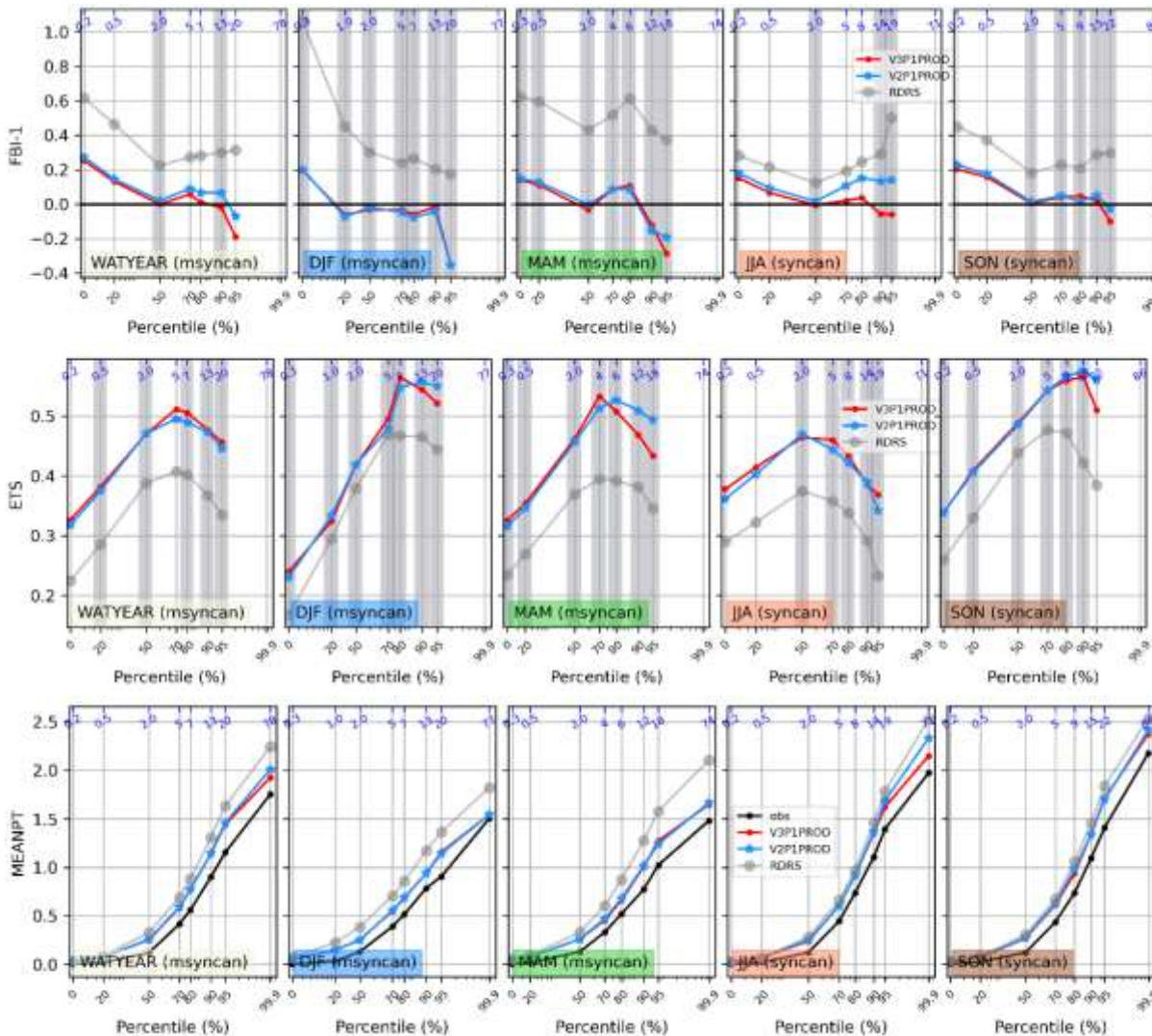
- CaPA 24h scores for CaSRv3.1 show **neutral to slightly improved results** (w.r.t. FBI) in comparison to CaSRv2.1 for the years before 2000
- Update of ISD and Ajusted Dataset brings **~50-100 additional observations per analysis**

CaSR v3.0 Back Extension Before 1980

Funded by the IJC, run a research CaSR version 3 over the 1972-1973 period as a proof of concept of the viability of CaSR before 1980
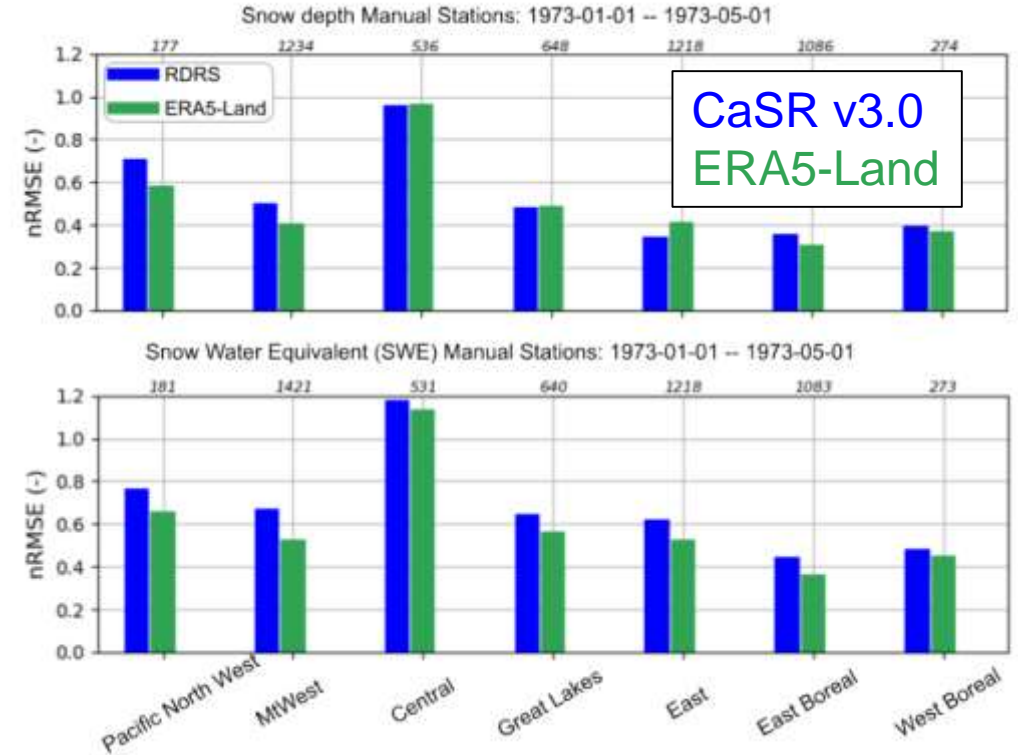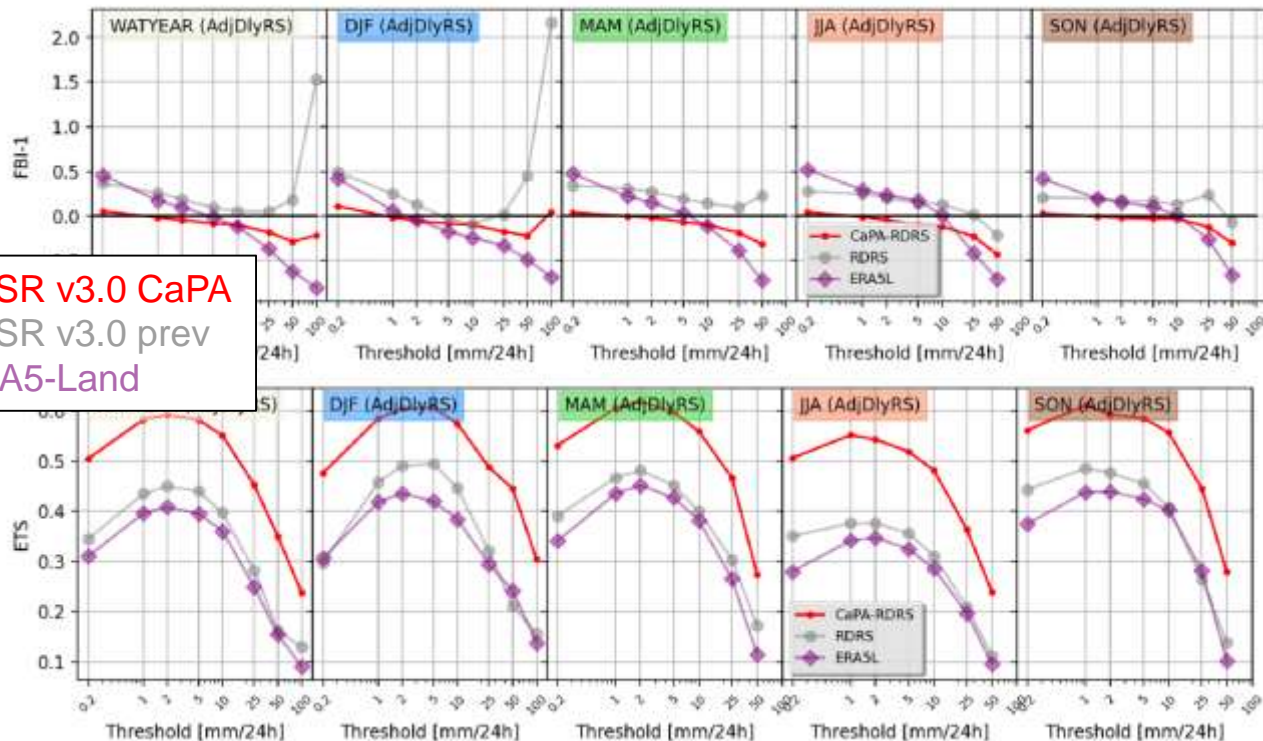
Pre-1980 planned to be produced and disseminated once CaSR version 3 is completed