A High-Resolution, Dynamically Downscaled ERA5 Reanalysis Dataset for Alaska

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1 Motivation & scope

- There is a need to create higher-resolution versions of coarse-resolution climate reanalysis (ERA5: 0.25°) and GCM data to capture features that are needed for local decision making
- Alaska has complex topography, so downscaling is necessary!

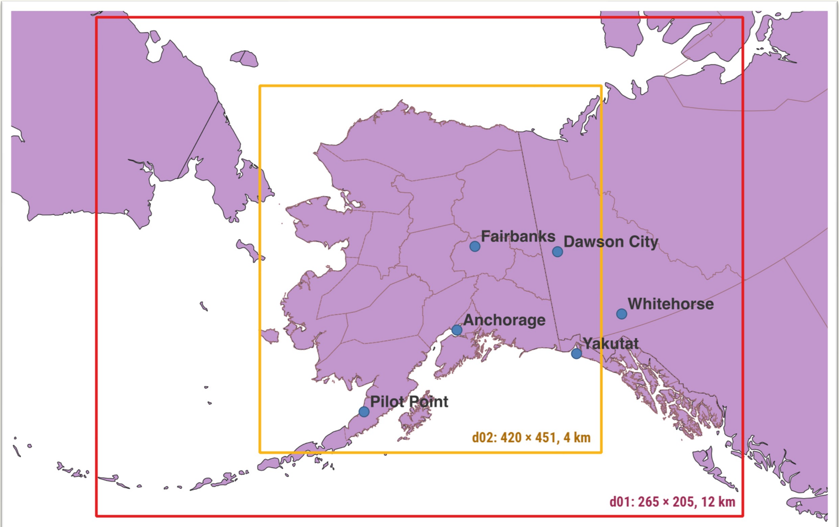


Fig 1) 3:1 nested domains for WRF . The outer 12 km domain is 265×205 grid cells in size, while the inner 4 km domain measures 420×451 grid cells.

The selected map projection is Polar Stereographic.

Output data is produced hourly.

- The 12-km domain covers Alaska (except outer Aleutians) and neighboring Canada (including Yukon Territory)
- The 4-km domain covers all of interior (boreal) and Arctic Alaska as well as the Anchorage area population center
- This creates products that are useful for fire management, snow analysis, natural resource management, and other applications

2 WRF parameterization and configuration

WRF configuration	
time_step = 60	60 s time step, except for rare failed runs (reduced to 30 s)
feedback = 1	Two-way nesting w/ feedback
num_metgrid_levels = 38	Metgrid levels
grid_fdda = 2	Spectral nudging **(outer 12 km domain only)**
physics	
mp_physics = 10, 10,	Morrison double-moment scheme
ra_lw_physics = 4, 4, ra_sw_physics = 4, 4,	RRTMG scheme longwave and shortwave
sf_sfclay_physics = 91, 91,	MM5 similarity
sf_surface_physics = 2, 2,	Noah Land Surface Model
bl_pbl_physics = 1, 1,	Yonsei University scheme (boundary layer)
cu_physics = 3, 0,	Grell-Freitas **(outer 12 km domain only)**
sf_lake_physics = 1, 1,	Lake physics w/ MODIS lakes and bathymetry
sst_update = 1	Sea surface temperature updates
fractional_seaice = 1	Sea ice fraction

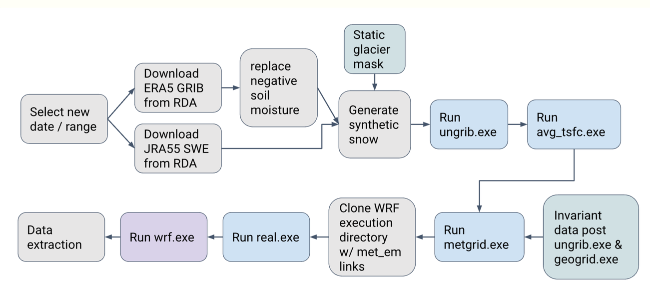


Fig. 2.1: Processing workflow

Table 2.1 : Selected WRF namelist options

Output Variables

Soil & surface variables	
ALBEDO	albedo
SMOIS SH2O	soil moisture soil liquid water content
SWDNB SWDNBC SWUPB SWUPBC	short-wave downwelling instantaneous heat flux at bottom ... clear sky ... upwelling ... clear sky
LWDNB LWDNBC LWUPB LWUPBC	long-wave downwelling instantaneous heat flux at bottom ... clear sky ... upwelling ... clear sky
SEAICE SST	sea ice (fraction) sea surface temperature
TSK TSLB	surface skin temp soil temperature
HFX LH	sensible heat flux latent heat flux

Land constants	
LU_INDEX LANDMASK VEGFRA HGT	land use category land mask vegetation fraction terrain height

Surface meteorology	
PMSL - SLP PSFC T2 Q2 RH2	pressure at mean sea level surface pressure 2m air temp water vapor mixing ratio at 2m 2m relative humidity
SNOW SNOWC SNOWH ACSNOW	snow liquid water equiv snow cover (flag 0/1) snow depth m snow accumulation (hourly)
RAINC RAINNC	convective/non-convective precipitation (hourly)
U10m V10m WSPD10 WDIR10	X-wind at 10m Y-wind at 10m wind speed at 10m wind direction at 10m
CTT	cloud top temperature

Dimensions	
t s_n w_e p s	time south_north west_east pressure level soil_layers

(4D) Variables at pressure levels (200, 300, 500, 700, 850, 900, 925, 950, 1000 hPa)	
T Z U V W RH TWB	temperature geopotential height X -wind component Y -wind component Z -wind component relative humidity wet bulb temperature
CLDFRA	cloud fraction
QVAPOR	water vapor mixing ratio

Data volume:
~1.6 GB / day

3 Snow data preprocessing

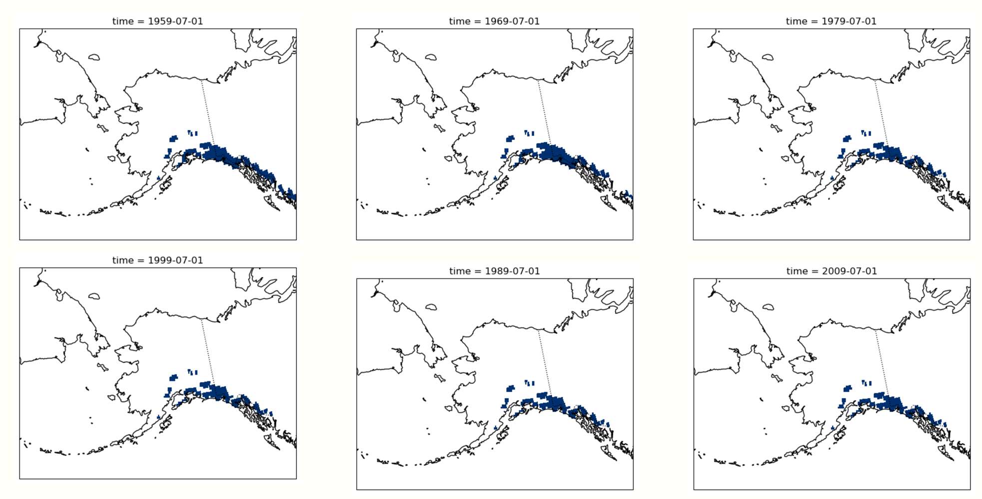


Fig 3.1) ERA5 July 1 SWE exceeding a threshold of 1 m. (any cell 1959–2021). ERA5 glacier masking varies in time and exhibits interpolation effects probably due to the model grid and the product grid not being identical.

- **The problem:** ERA5 snow depth (m of water equivalent) is set to 10 m over glaciated areas. This introduces a cold bias in near-surface air temperatures and causes instabilities in WRF
- **The solution:** We masked the glaciated and neighboring areas and inserted snow-water equivalent (SWE) the JRA55 reanalysis (available 1959-) to create a **synthetic snow dataset**

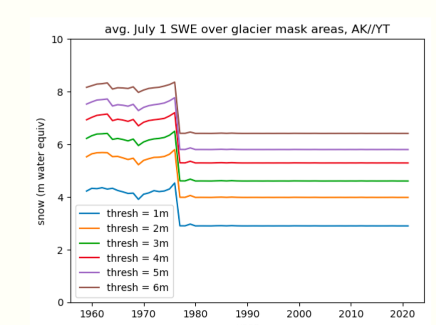
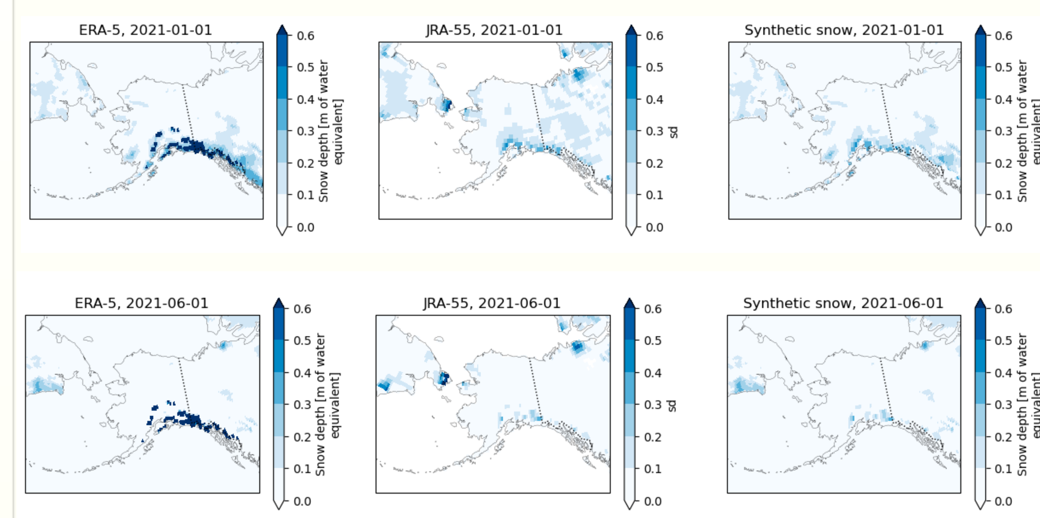


Fig 3.2) Illustration of the temporal inconsistency of ERA5 glacier masking for various SWE thresholds over time (AK & YT)

Fig 3.3) Example data for synthetic snow dataset (January 1 and June 1 2021). The dataset is identical with ERA5 snow outside the glacier mask areas



4 Case studies: hazards & extreme weather events

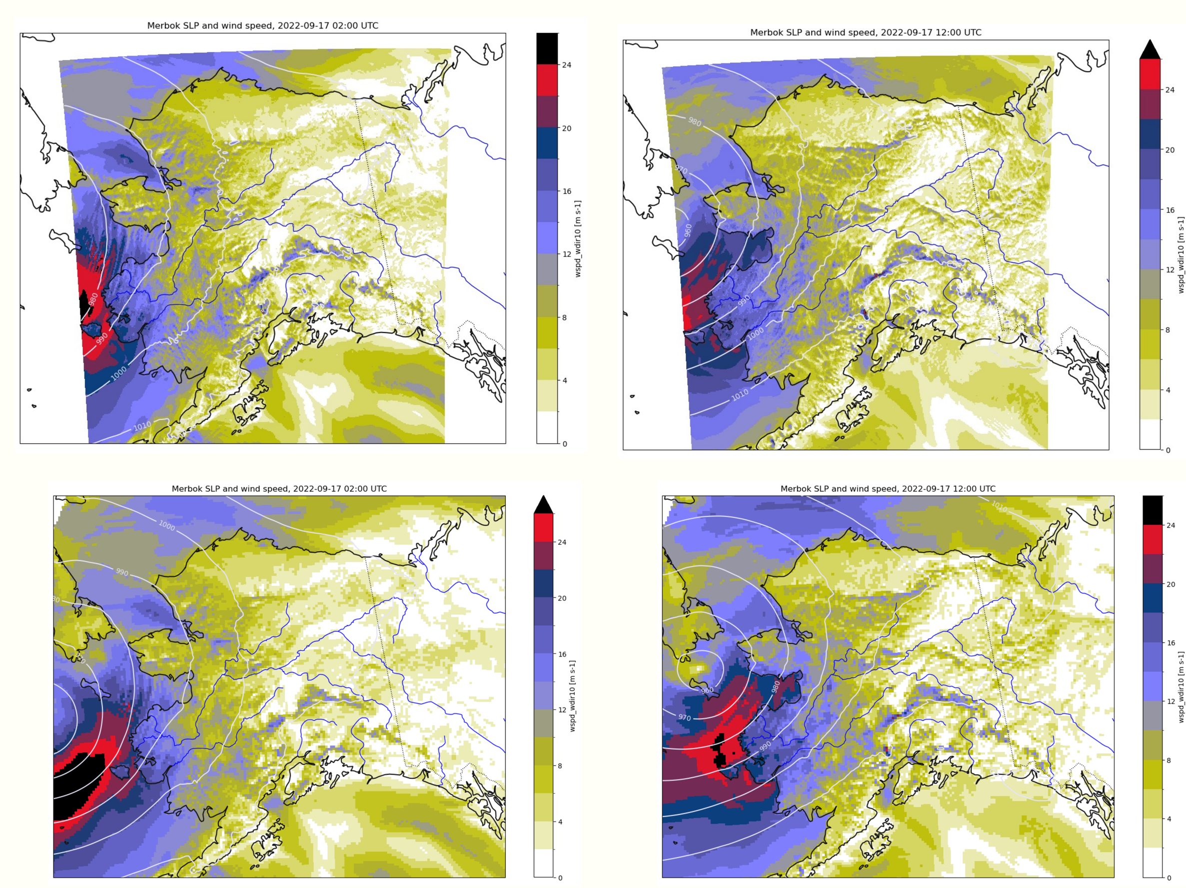


Fig 4a) **Sep 2022 ex-typhoon Merbok** caused severe flooding along the SW Alaska coastline from Kuskokwim Bay to the Bering Strait. This led to a major disaster declaration

- Snapshots of the simulation of sea level pressure and 10 m wind speed at 4 km (top) and 12 km (bottom) on September 17, 2022
- Eye of the storm entering the Bering Sea can be tracked
- Locations of high wind along the coast and in the mountain ranges are visible. (Major rivers added for context.)

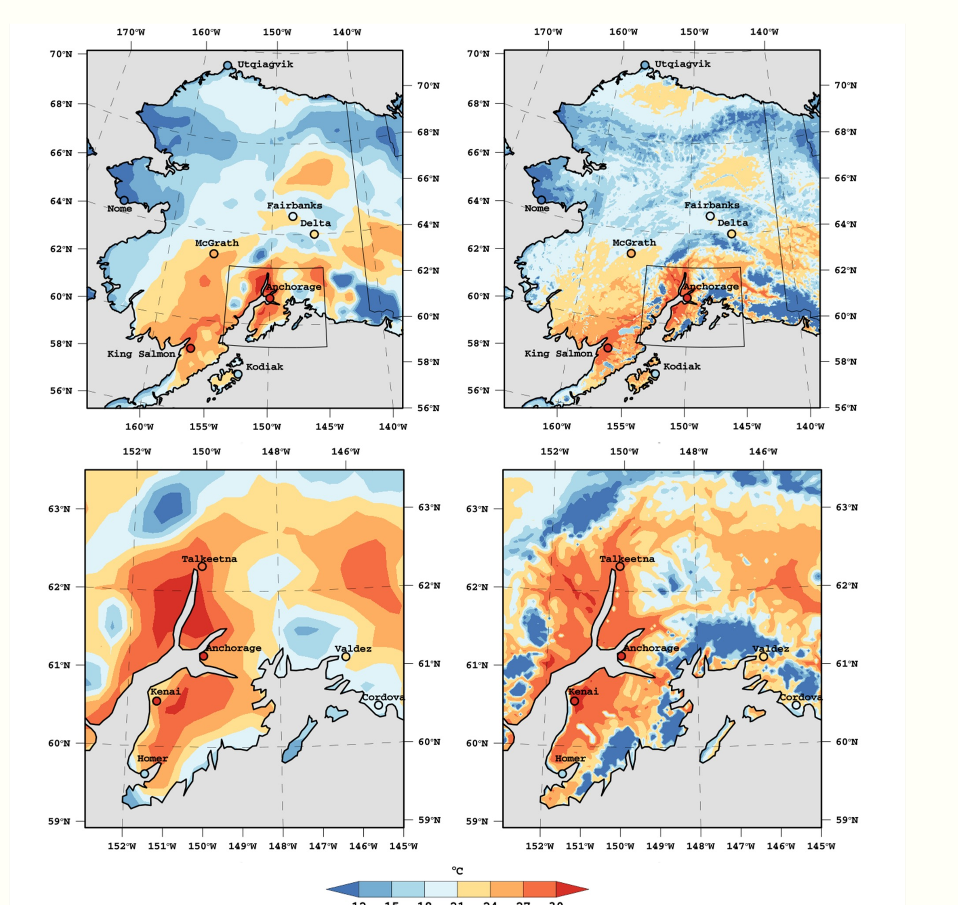


Fig 4b) **July 4, 2019 extreme heat event. Anchorage Airport recorded 90 °F / 32.2 °C for the first time ever.**

- Near-surface air temperature (°C) at 1600 LST, July 4th, 2019 from ERA5 at 0.25° (~31 km) resolution (left column) and downscaled ERA5 to 4 km (right column).
- Colored dots: observations. Downscaling better represents the topography and more precisely matches station data

(Figure: Rick Lader)

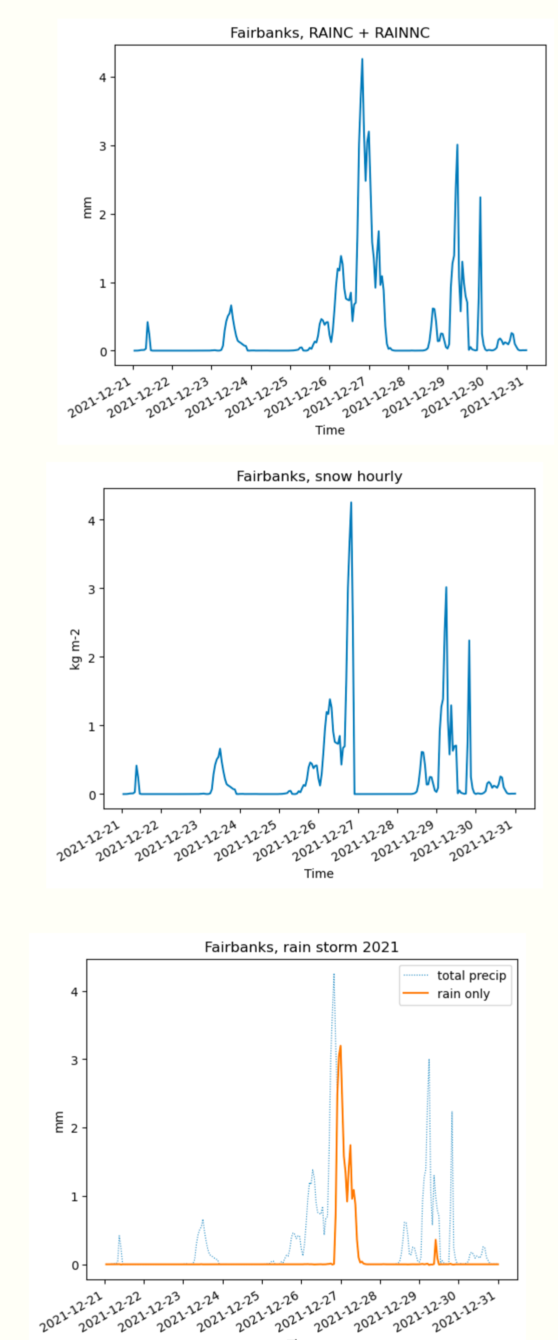


Fig 4c) **2021 Severe winter storm in interior Alaska (including Fairbanks).** The event consisted in a series of winter storms with snow, freezing rain and high winds. The freezing rain created persistent hazardous road conditions.

- The variables RAINC and RAINNC represent total convective and non-convective precipitation
- The variable ACSNOW represents hourly snow accumulation (in mm water equivalent)
- By subtracting hourly snow from hourly total precipitation we recover hourly rain
- Measured rain (weather station) in Fairbanks peaked at 2.7 mm

→ A new 4 km downscaled ERA5 dataset over Alaska is being generated and will be available during 2024

→ It will enable actionable modeling of climate driven events, specifically hazards and extreme weather

5 References and acknowledgements

- Bieniek, P. A et al. (2016). Dynamical Downscaling of ERA-Interim Temperature and Precipitation for Alaska. J. of Appl. Meteorology and Climatology, 55(3), 635–654. https://doi.org/10.1175/JAMC-D-15-0153.1
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- Lader, R. et al. (2020). Anticipated changes to the snow season in Alaska: Elevation dependency, timing and extremes. Int. J. of Climatology, 40(1), 169–187. https://doi.org/10.1002/joc.6201

Data sources: ERA5 (ECMWF) and JRA55 (JMA) data were downloaded from the NCAR Research Data Archive. Downscaling on UAF GI's Chinook HPC cluster.

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