Site-assessment and icing impact using ERA5 assimilation data

WinterWind 2018
February 6th-7th

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windPROSPER

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3.C Comparison to sites

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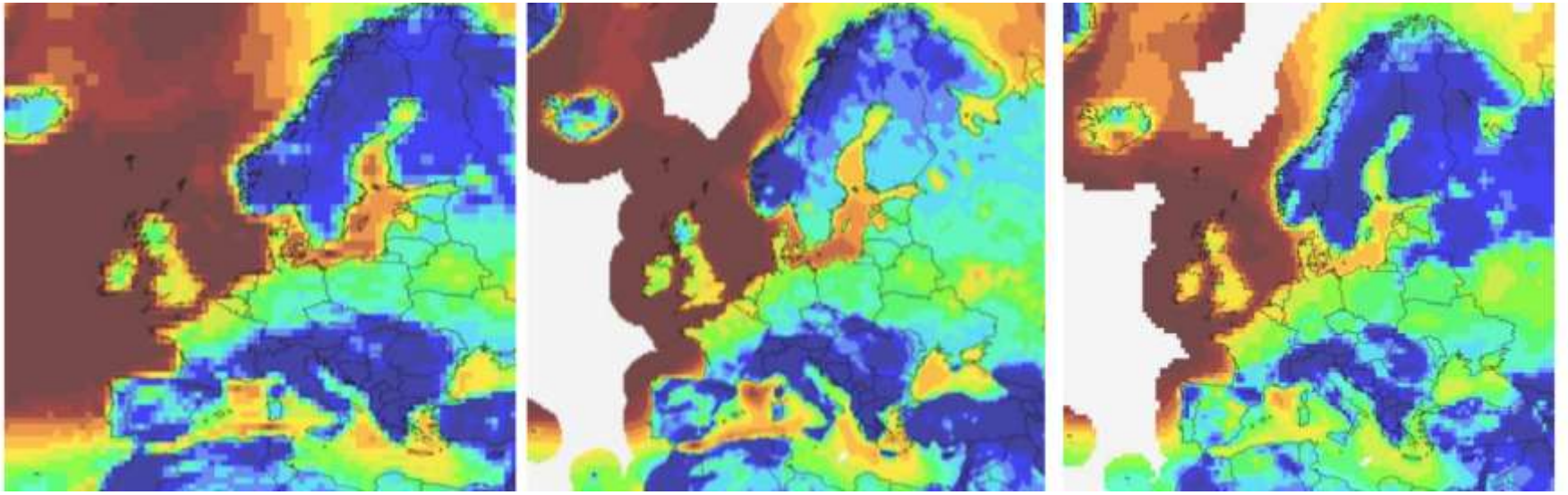
ERA-Interim *ERA5* *MERRA-2*



1. What is ERA5? - Overview

- ECMWF most recent reanalysis dataset (5th generation)
- Higher temporal and spatial resolution that ERA-Interim
- New parameters available – such as 100m winds

Released so far

- 7 years have been released as first segment (2010-2016)
- Continious updating (December 2017)
- Full coverage 2017 (February 2018)

Still under development

Item	Old Plan (Last Thursday)	New Plan (Last Friday)
ERA5T (short delay product)	~~2017-Q4~~	2018
Access to observations	~~2017-Q4~~	2018
Years 1979-2009 released	~~2018-Q2~~	Late 2018
Years 1950-1978 released	2019-Q1	2019

Public release plan @ http://climate.copernicus.eu/products/climate-reanalysis

1. What is ERA5? – Comparison

Parameter \ Dataset	ERA5	ERA-Interim	MERRA2	CFSR / CFSv2
Vertical levels	137	60	72	64
Horizontal resolution	~31 km	~80 km	~50 km	~38km/~25km
Upper modelling level	0.01hPa (~80 km)	0.1hPa (~60 km)	0.01hPa (~80 km)	0.26 hPa (~55 km)
Temporal resolution	1-hourly	6-hourly	1-hourly	1-hourly
Release schedule	Monthly*	Monthly	Monthly	Daily
Assimilation model	IFS Cycle 41r2	IFS Cycle 31r2	GEOS 5.12.4	Grid-Point Statistical Interpolation, GSI
Spatial grid type	Reduced Gaussian	Reduced Gaussian	Cubed sphere	Varies
Period available (now)	2010-2016	1979-present	1980-present	CFSR: 1979-2010 CFSv2: 2011-present
Period available (at completion)	1950-present	1979-present	1980-present	CFSR: 1979-2010 CFSv2: 2011-present
Delay in data delivery	3 months *)	3 months	1-2 months	1 day

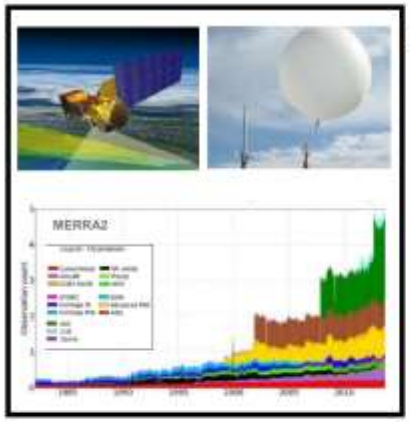
*) A preliminary version 'ERA5T' with 1 week delay will be available

1 .What is the performance?
R^2 – Correlation –windspeed at 107 masts

	Parameter / Dataset ->	ERA5	ERA-Interim	MERRA2	CFSR / CFSv2
Hourly	Mean Value	0.67	0.64	0.61	0.61
	Standard Deviation	0.12	0.12	0.13	0.12
	Minimum	0.34	0.32	0.33	0.32
	Maximum	0.88	0.84	0.83	0.83
Daily	Parameter / Dataset ->	ERA5	ERA-Interim	MERRA2	CFSR / CFSv2
	Mean Value	0.86	0.83	0.81	0.81
	Standard Deviation	0.08	0.09	0.10	0.09
	Minimum	0.51	0.49	0.45	0.45
	Maximum	0.96	0.95	0.95	0.95
Monthly	Parameter / Dataset ->	ERA5	ERA-Interim	MERRA2	CFSR / CFSv2
	Mean Value	0.89	0.87	0.86	0.84
	Standard Deviation	0.12	0.13	0.14	0.14
	Minimum	0.25	0.27	0.24	0.28
	Maximum	0.99	0.99	0.99	0.99

1. Modelling Chain

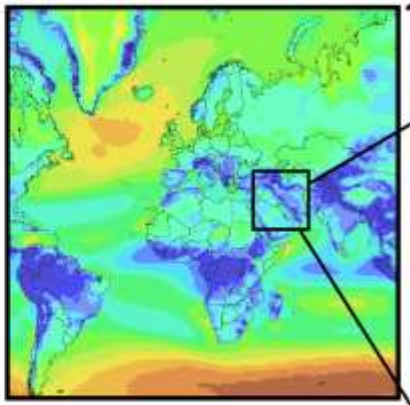
OBSERVATIONS



DATA: IN-SITU AND REMOTE OBSERVATIONS

ERA-5 RAW DATA

DATA ASSIMILATION / REANALYSIS



DATA: GLOBAL / SYNOPTIC SCALE:

Reanalysis Data: ECMWF ERA5
Spatial Resolution: ~35km

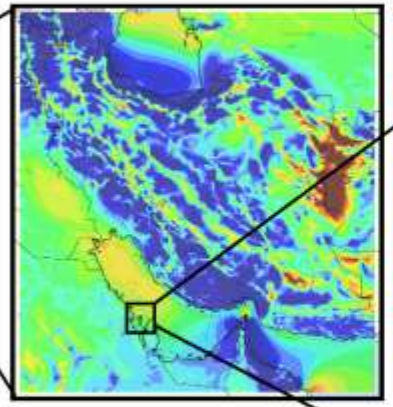
Typical model scales: ~100 km's
Time-series data, 1 hourly resolution

EMD-WRF OD

EMD-WRF MESOSCALE MODELLING

Data Input:
- ERA5 Boundary Data
- Globcover Terrain

Model Execution:
- Standard EMD-WRF setup
- Spatial resolution ~ 3 km



DATA: MESOSCALE:

Time series, wind speed and direction
Spatial Resolution: ~3 km
Temporal resolution: 1 hour

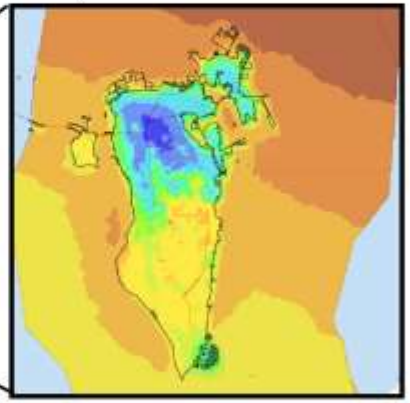
Typical model scales: ~10 km's

DOWNSCALING

EMD-MESO/MICRO DOWNSCALE MODELLING

Data Input:
- Mesoscale time series and terrain
- Detailed, high-resolution microscale terrain

Model Execution:
- WAsP version 11+
- windPRO version 3.1+

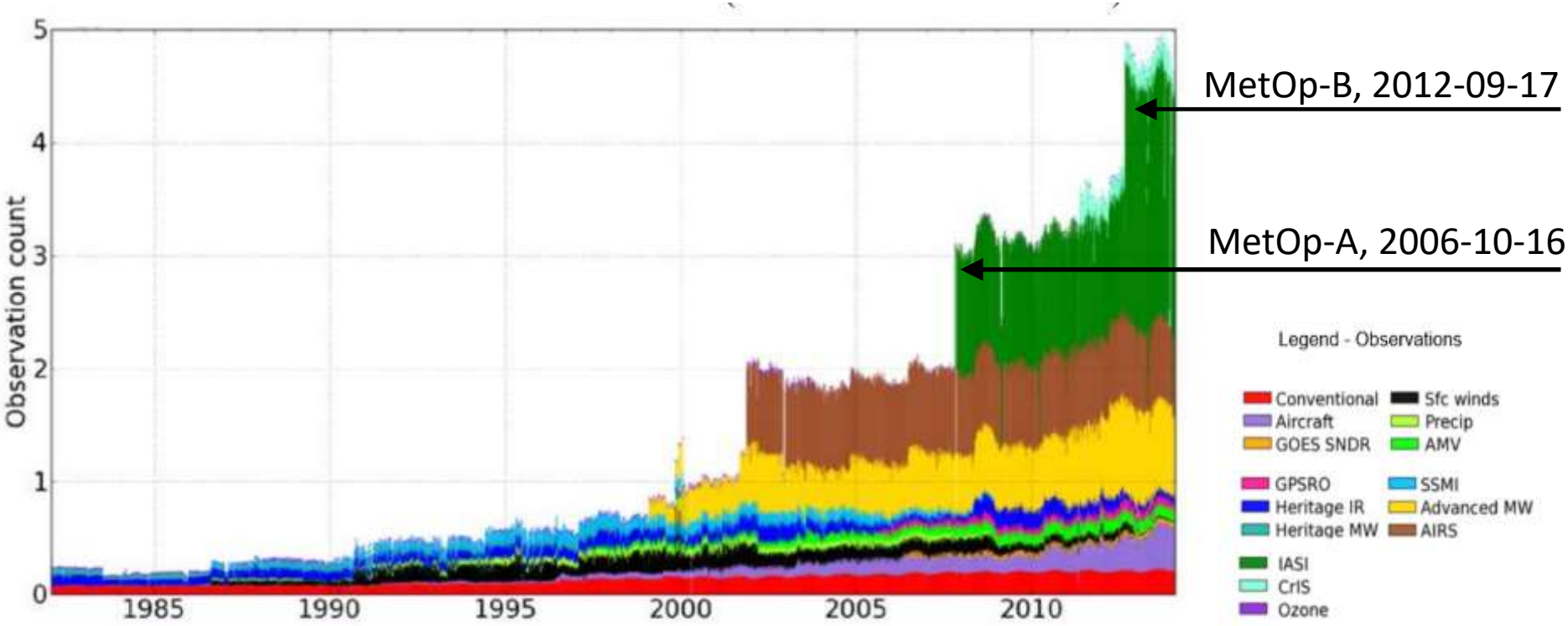


DATA: MICROSCALE:

Time series & statistical data, wind speed and direction
Spatial Resolution: ~250m
Temporal resolution: 1 hour

Typical model scales: ~10 m's

1.Why also observations?



Credit:
Observations assimilated in the MERRA2 datasets for the period 01.1980 until 12.2014. Units are millions per 6 hours. From Bosilovich et al: 'MERRA-2: Initial Evaluation of the Climate - Technical Report Serieson Global Modeling and Data Assimilation – Volume 43'

1. Expectations before this study?

Could ERA5 in the modelling chain bring improved accuracy for icing (temperature, winds, clouds...) – as has been seen for winds?

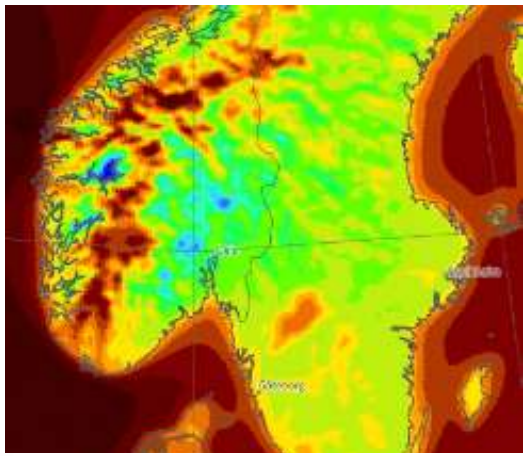
Observations:

- Much better model resolution (spatial and temporal)
- Improved assimilation model
- More data-sources being assimilated in recent years

Method:

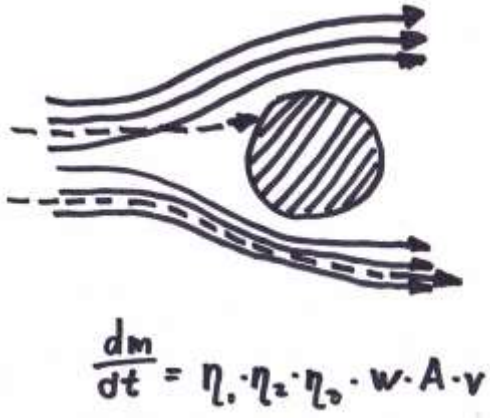
- Run different 'ensembles'
- Try to quantify any differences (possibly improvements) by looking at simple metrics such as icing-hours

WRF Model Setup for This Study



WRF Model Setup
- Resolution (1): 3 km
- Resolution (2): 1.5 km
- Time Span: 1993-present (ERA5: 2010-2017)
- Land Use: Globcover (300m)

WRF Parameterization Schemes
- Microphysics (1): Ferrier
- Microphysics (2): Thompson
- Surface layer: Janjic
- Planetary boundary layer: Mellor-Yamada-Janjic
- Land-surface model: Noah
- Radiation: GFDL



Global Boundary Data
- ERA5 (1)
- ERA-Interim (2)
- MERRA2 (3)
- CFSR (4)

Icing Model

Makkonen / ISO 12494
In cloud icing on standard cylinder
driven by (downscaled) WRF model parameters
Pressure, temperature, cloud water,
wind speeds. dm/dt > 10g/h

Current Study – In Three Steps

A. Sensitivity to boundary data

WRF-Setup: Microphysics Ferrier (1) and Thompson (2)
1 winter of modelling – 2 sites (DK and SE)

- ERA5 (1)
- ERA-Interim (2)
- MERRA2 (3)
- CFSR (4)

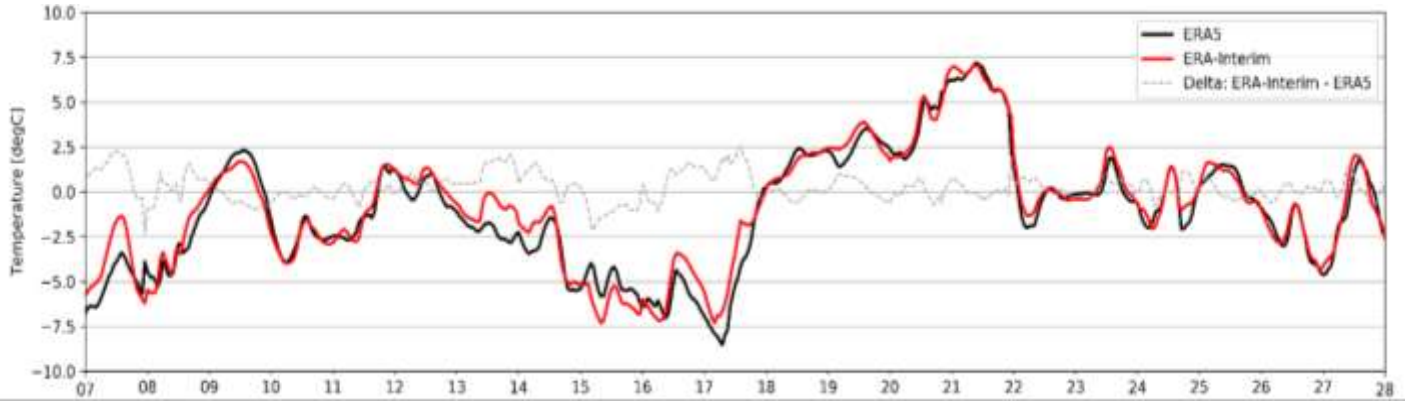
B. Sensitivity to model resolution

- Boundary data: ERA5 and ERA Interim
- Resolution: 3 km & 1.5 km

C. Comparison to local masts

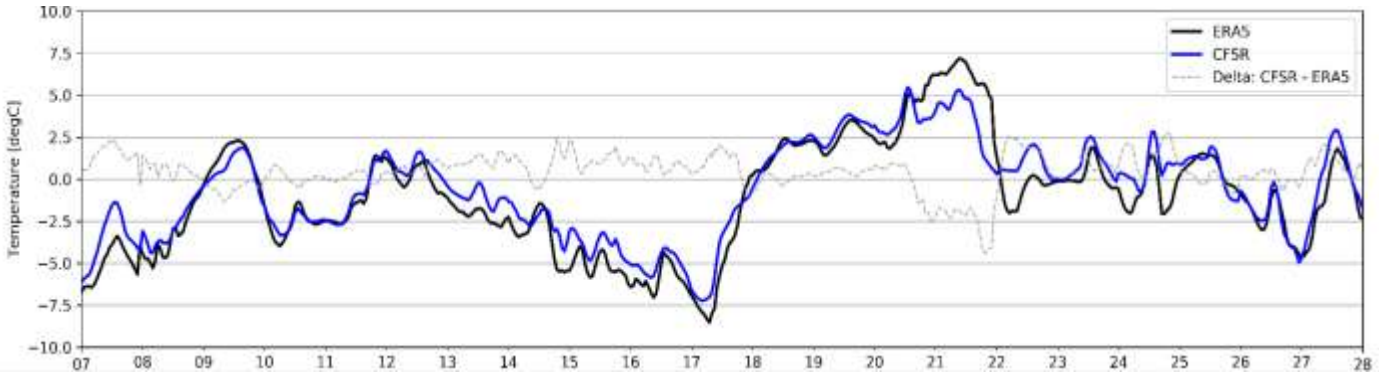
- Boundary data: ERA5 and ERA Interim
- Resolution 3 km
- 10 cases
- Microphysics: Thompson
- Period: Mast Period (typically ~1 year)

3A: Sensitivity to Boundary Data



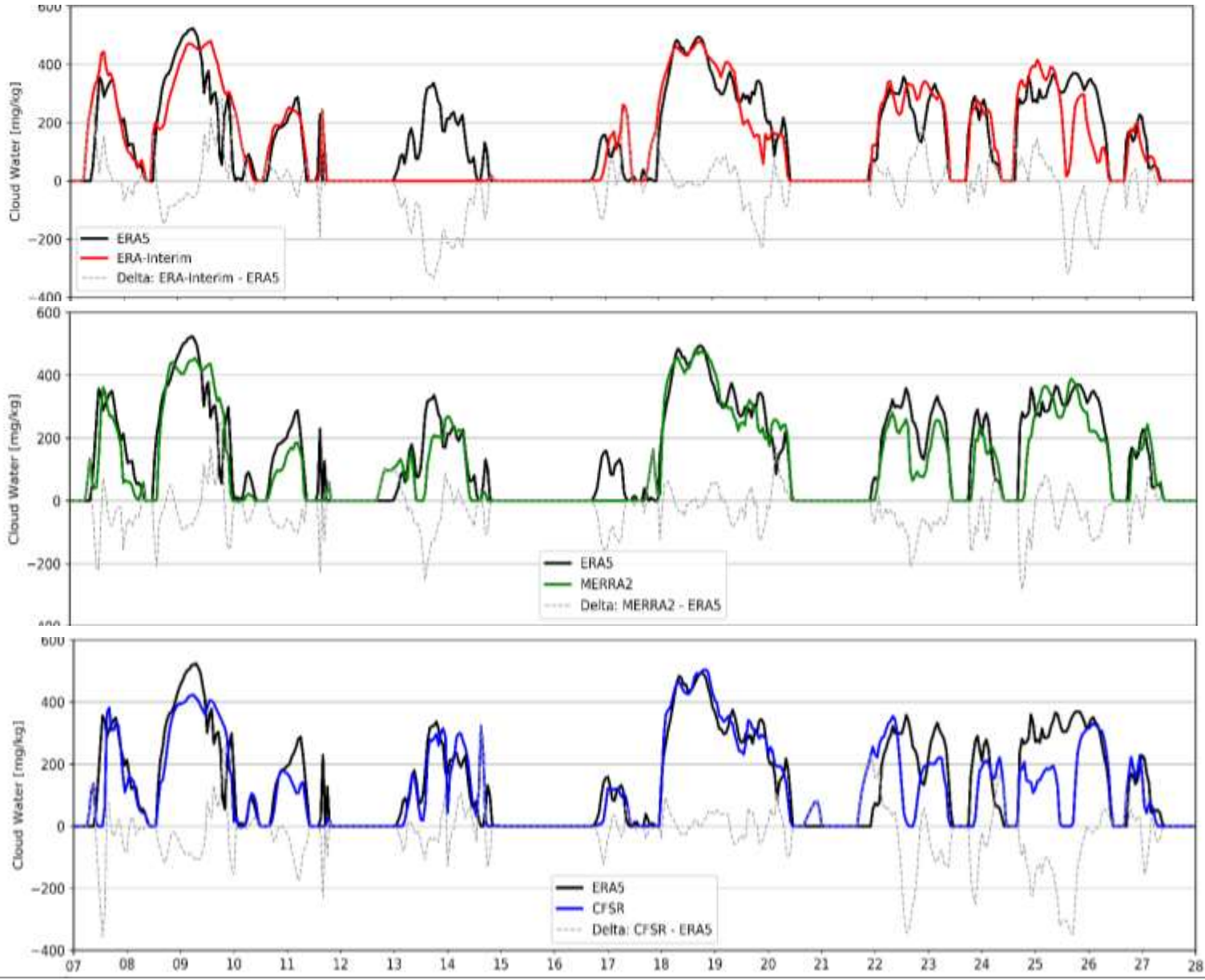
ERA5 vs ERA-Interim

ERA5 vs MERRA2



ERA5 vs CFS / CFSR

3A: Sensitivity to Boundary Data

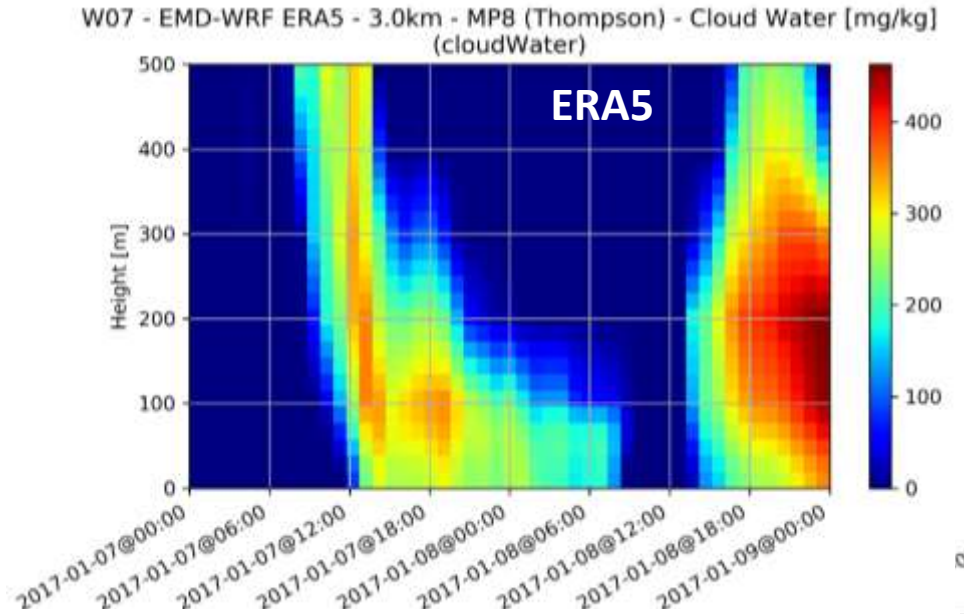


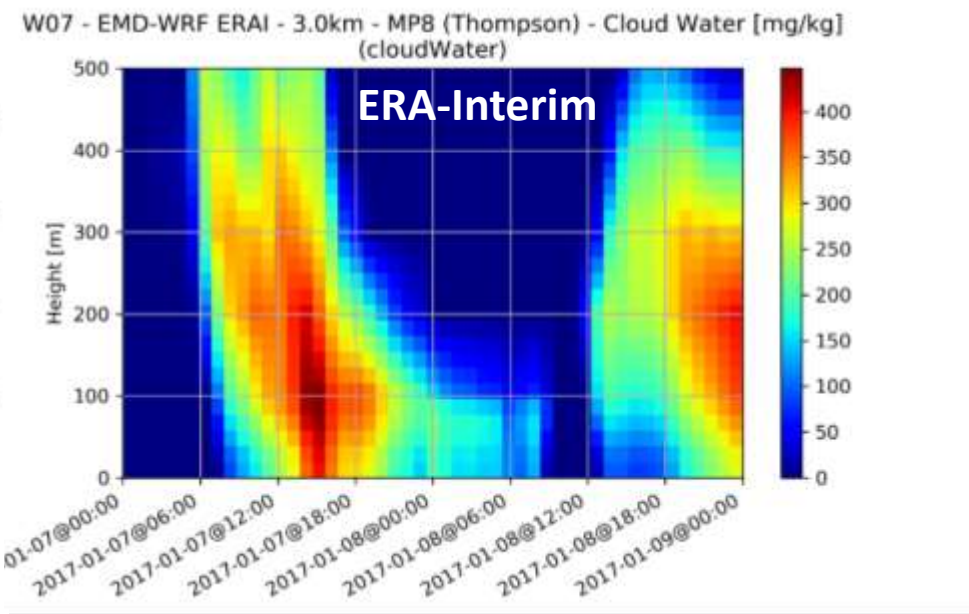
ERA5 vs ERA-Interim

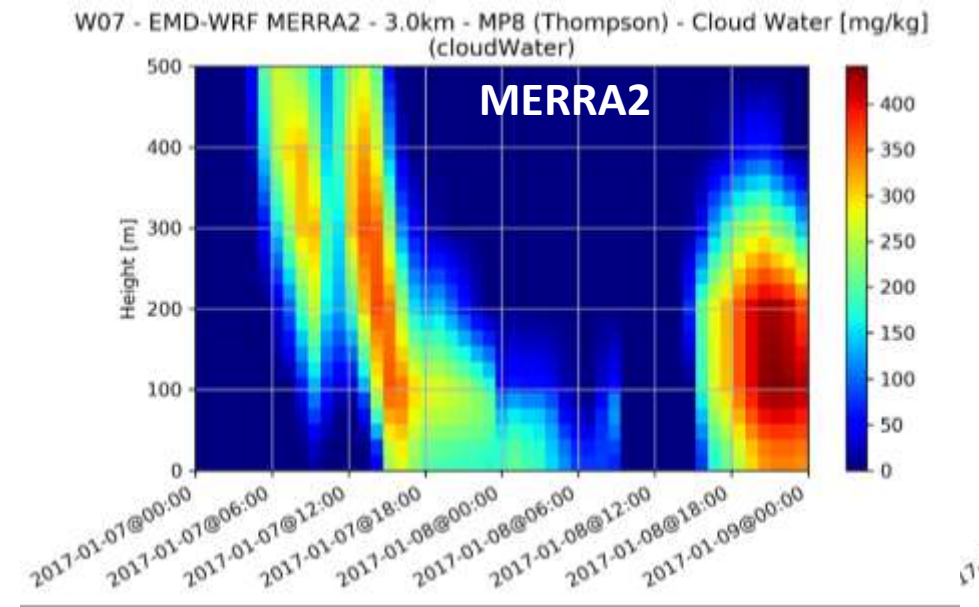
ERA5 vs MERRA2

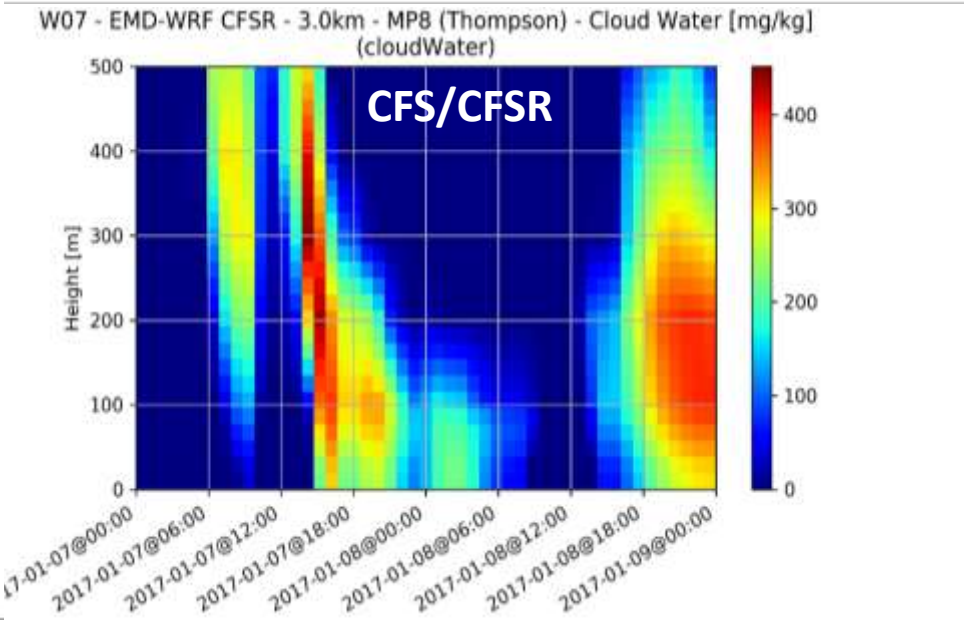
ERA5 vs CFS / CFSR

3A: Sensitivity to Boundary Data









3A: Sensitivity to Boundary Data

Site: W12 - Danish Site @ 100m
Period: 2011.10-2012.03

Boundary	Microphysics	Active Icing Events [#]	Active Icing Icing [h]	Active Icing PowerRatio [%]	Passive Icing Events [#]	Passive Icing Icing [h]	Passive Icing PowerRatio [%]
ERA 5	Thompson	7	21	0.06%	5	179	2.20%
ERA Interim	Thompson	9	45	0.18%	7	196	1.96%
MERRA 2	Thompson	27	104	0.73%	16	806	9.70%
CFS / CFSR	Thompson	3	14	0.03%	3	128	1.44%
Average		11.5	46	0.25%	8	327	3.82%
Min		3	14	0.03%	3	128	1.44%
Max		27	104	0.73%	16	806	9.70%

Notes:
PowerRatio = Yield for 2MW turbine for iced vs. all time-stamps

3A: Sensitivity to Boundary Data

Site: W12 - Danish Site @ 100m
Period: 2011.10-2012.03

Boundary	Microphysics	Active Icing Events [#]	Active Icing Icing [h]	Active Icing PowerRatio [%]	Passive Icing Events [#]	Passive Icing Icing [h]	Passive Icing PowerRatio [%]	Avg. Temp [degC]
ERA 5	Thompson	7	21	0.06%	5	179	2.20%	4.7
ERA Interim	Thompson	9	45	0.18%	7	196	1.96%	4.6
MERRA 2	Thompson	27	104	0.73%	16	806	9.70%	3.7
CFS / CFSR	Thompson	3	14	0.03%	3	128	1.44%	5.0
Average		11.5	46	0.25%	8	327	3.82%	4.5
Min		3	14	0.03%	3	128	1.44%	3.7
Max		27	104	0.73%	16	806	9.70%	5.0

Notes:
PowerRatio = Yield for 2MW turbine for iced vs. all time-stamps

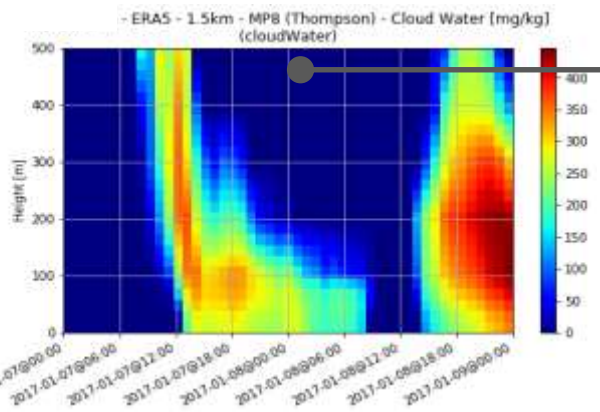
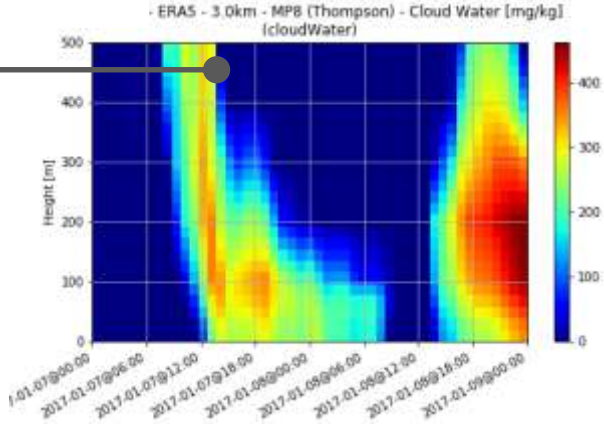
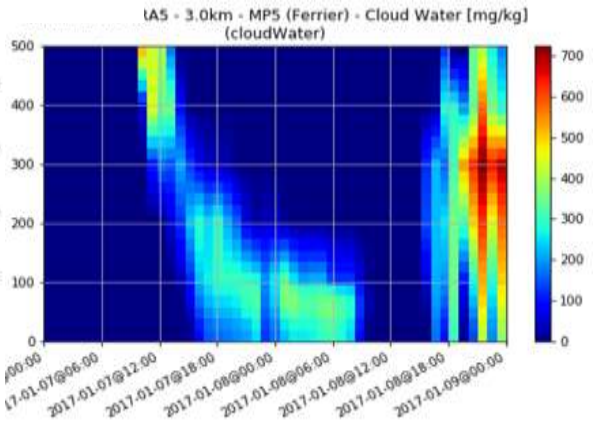
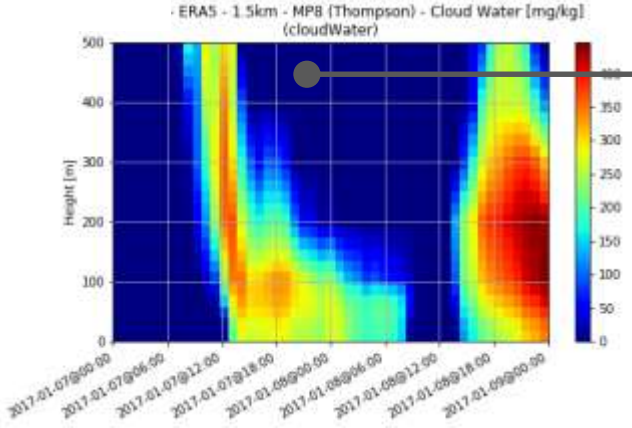
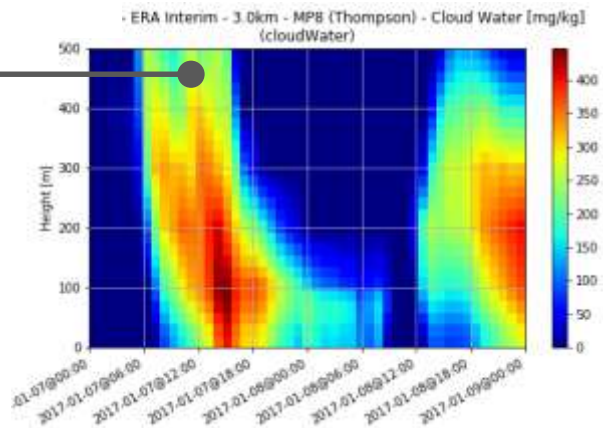
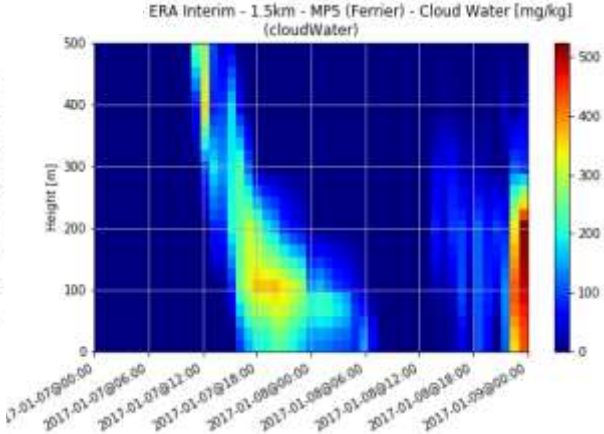
3A: Sensitivity to Boundary Data

Site: W07 - Swedish Site @ 100m
Period: 2016.06-2017.05

Boundary	Microphysics	Active Icing Events [#]	Active Icing Icing [h]	Active Icing PowerRatio [%]	Passive Icing Events [#]	Passive Icing Icing [h]	Passive Icing PowerRatio [%]	Avg. Temp [degC]
ERA 5	Thompson	56	434	3.1%	25	1256	12.3%	6.7
ERA Interim	Thompson	52	380	3.0%	26	1150	12.4%	6.7
MERRA 2	Thompson	54	377	2.9%	26	1336	14.1%	6.8
CFS / CFSR	Thompson	37	248	1.6%	16	907	8.3%	6.9
Average		50	360	2.7%	23	1162	11.8%	6.8
Min		37	248	1.6%	16	907	8.3%	6.7
Max		56	434	3.1%	26	1336	14.1%	6.9

Notes:
PowerRatio = Yield for 2MW turbine for iced vs. all time-stamps
Mast: 7.7% instrumental ice = 670h

3B: Sensitivity to Resolution and Microphysics

	1.5km - Thompson	3.0km - Thompson	1.5km - Ferrier
ERA5			
ERA-Interim			

3B: Sensitivity to Resolution and Microphysics

Site: W07 - Swedish Site @ 100m
Period: 2016.06-2017.05

Boundary	Resolution	Microphysics	Active Icing Events [#]	Active Icing Icing [h]	Active Icing PowerRatio [%]	Passive Icing Events [#]	Passive Icing Icing [h]	Passive Icing PowerRatio [%]	Avg. Temp [degC]
ERA 5	1.5 km	Thompson	60	460	3.5%	25	1397	15.0%	6.6
ERA 5	3.0 km	Thompson	56	434	3.1%	25	1256	12.3%	6.7
ERA 5	3.0 km	Ferrier	42	251	1.3%	20	1041	10.3%	6.7
ERA-Interim	1.5 km	Ferrier	37	202	1.3%	22	1077	11.7%	6.7
ERA-Interim	3.0 km	Ferrier	43	210	1.2%	20	1043	10.7%	6.7
ERA-Interim	3.0 km	Thompson	53	380	3.0%	27	1150	12.4%	6.7

Notes:
PowerRatio = Yield for 2MW turbine for iced vs. all time-stamps
Mast: 7.7% instrumental ice = 670h

3C: Evaluation on Local Sites

Instrumental Icing vs Meteorological Icing on Swedish Sites

MastID	Period	Mast Instr. Ice. [%]	Active Icing ERA 5 [%]	Active Icing ERA-Interim [%]	Avg. Temperature ERA 5 [degC]	Avg. Temperature ERA-Interim [degC]
Ma01	2011-2012	5.6%	3.1%	4.7%	5.87	5.72
Ma02	2010-2011	0.6%	5.9%	7.7%	5.90	5.85
Ma03	2010-2011	4.0%	2.0%	5.1%	5.88	5.50
Ma04	2010-2011	7.4%	4.5%	5.6%	5.59	5.62
Ma05	2011-2012	3.0%	0.6%	2.0%	7.69	7.66
Ma06	2012-2013	10.0%	3.0%	7.5%	5.31	5.14
Ma07	2011-2012	5.0%	3.4%	5.7%	7.09	6.77
Ma08	2012-2013	11.0%	5.3%	8.1%	4.82	4.72
Ma09	2010-2011	5.5%	2.4%	3.8%	5.59	5.44
Ma10	2016-2017	7.7%	5.0%	4.3%	6.72	6.74
				Average	6.05	5.92

ERA5 = WRF with ERA5 and Thompson microphysics, 3km resolution
ERA-Interim = WRF with ERA-Interim and Thompson microphysics, 3km resolution

4. Findings / Conclusions!

General Conclusion on ERA5:

- **ERA5 as input to WRF - or on its own- is a significant improvement**
  - over previous reanalysis datasets (at least when looking on winds
- **ERA-Interim is still the preferred choice for long-term wind and icing**
  - until a longer period of ERA5 data become available (Late 2018)

This Icing Study:

- **Comparison directly against instrumental icing is very uncertain**
  - no clear trend is (yet) identified
- **In average, ERA5 data results in less hours of active icing than ERA-I**
  - in our case in 9 out of 10 sites
- **Local temperature bias correction is needed**
- **Cloud microphysics scheme seem more important than reanalysis source**
- **More recent (higher) quality validation data and analysis are needed**
  - before any firm conclusion can be drawn of ERA5 data and icing

Thank you!

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