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Near-surface wind speed and gust in ERA5 across Sweden: towards an improved gust parametrization

Lorenzo Minola, Fuqing Zhang, Cesar Azorin-Molina,
Amir A. Safaei Pirooz, Richard G. J. Flay, Hans Hersbach, Deliang Chen

lorenzo.minola@gu.se

INTRODUCTION

Ulbrich et al. (2013): In Europe windstorms and extreme wind events cause more than half of the economic losses associated with natural disasters

Ulbrich et al., 2013
Windstorms, the most costly natural hazard in Europe

Hannon Bradshaw (2017): Wind damages could seriously affect national economy in Sweden, where forests cover 56% of the land and 95% of those forests are used for the timber industry

Hannon Bradshaw, 2017
Sweden, forests & wind storms: developing a model to predict storm damage to forests in Kronoberg county

AIM

Focused on wind conditions across Sweden:

- Near-surface wind speed (WS) – *mean wind speed over the last 10 minutes*
- Near-surface wind gust (WG) – *maximum 3-seconds wind speed*

Objectives:

1) Compare the ERA5 and ERA-Interim reanalysis products with hourly observations of WS and WG across Sweden
2) Improve the gust parametrization adopted by ERA5 for Sweden
3) Evaluate if such formulation can be applied to Norway, where no observational data has been used in the calibration

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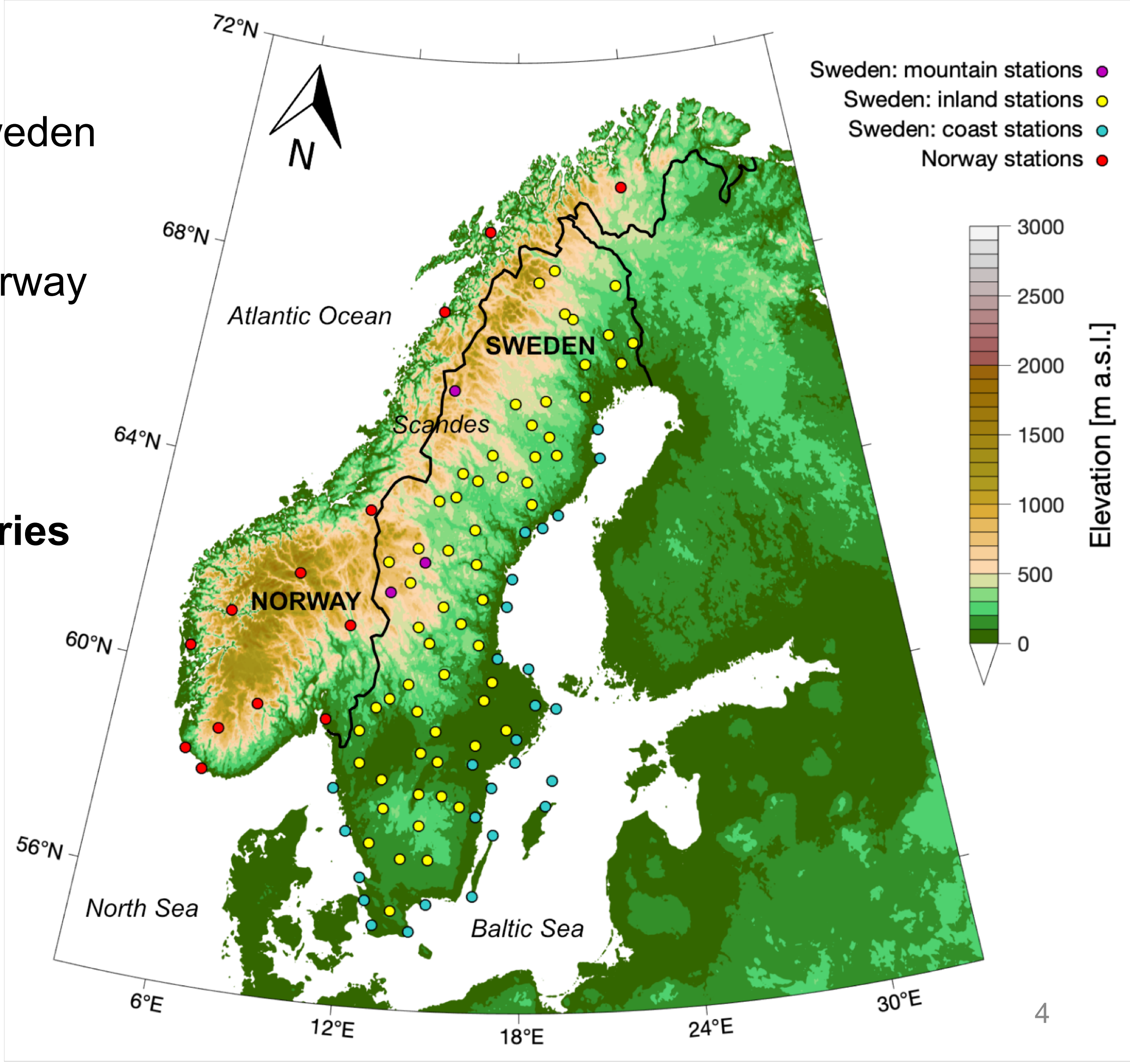
STATION-BASED OBSERVATIONS

- 90 stations across Sweden for 2013-2017
- 14 stations across Norway for 2015-2017

Hourly WS and WG series



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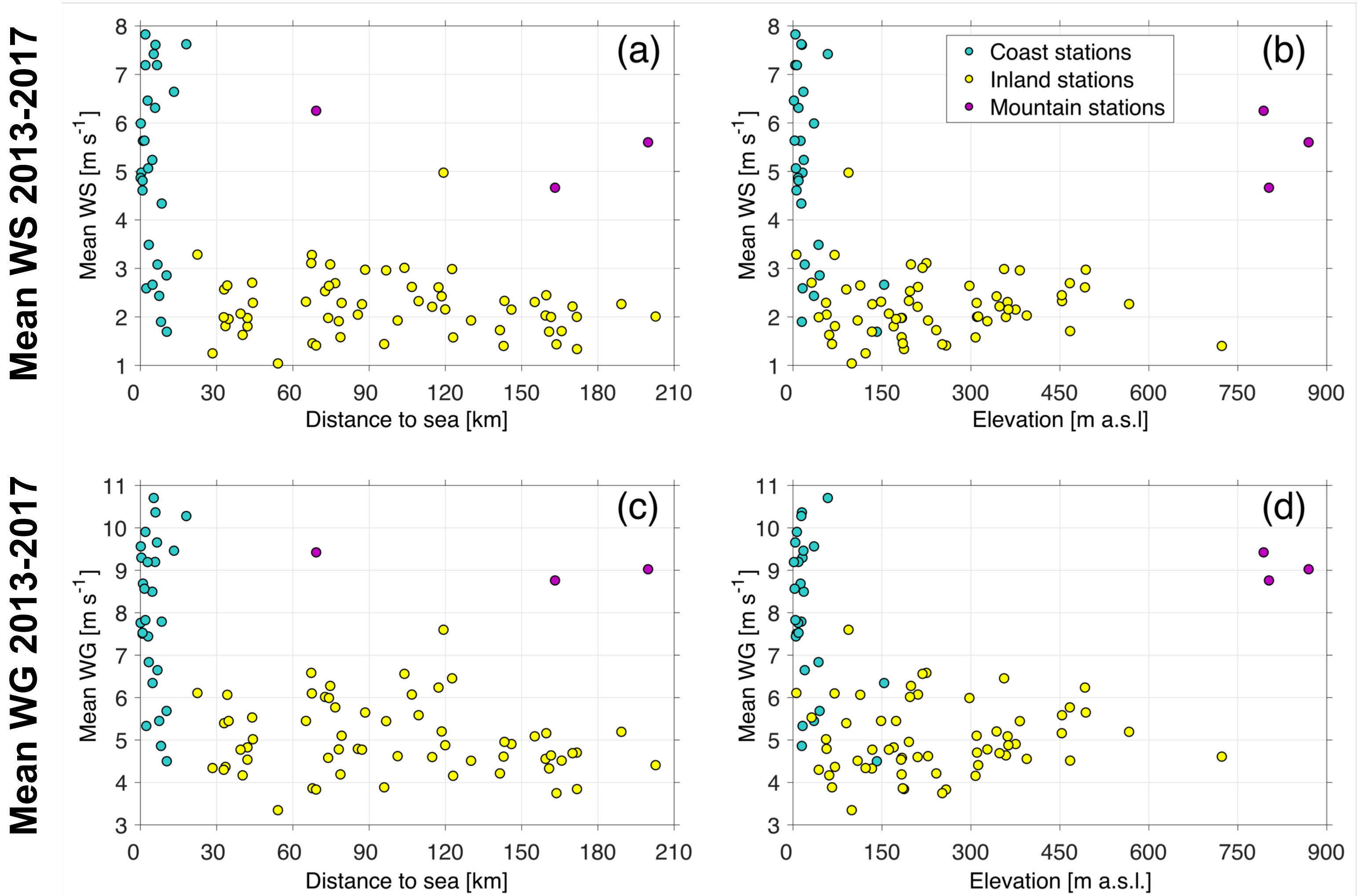
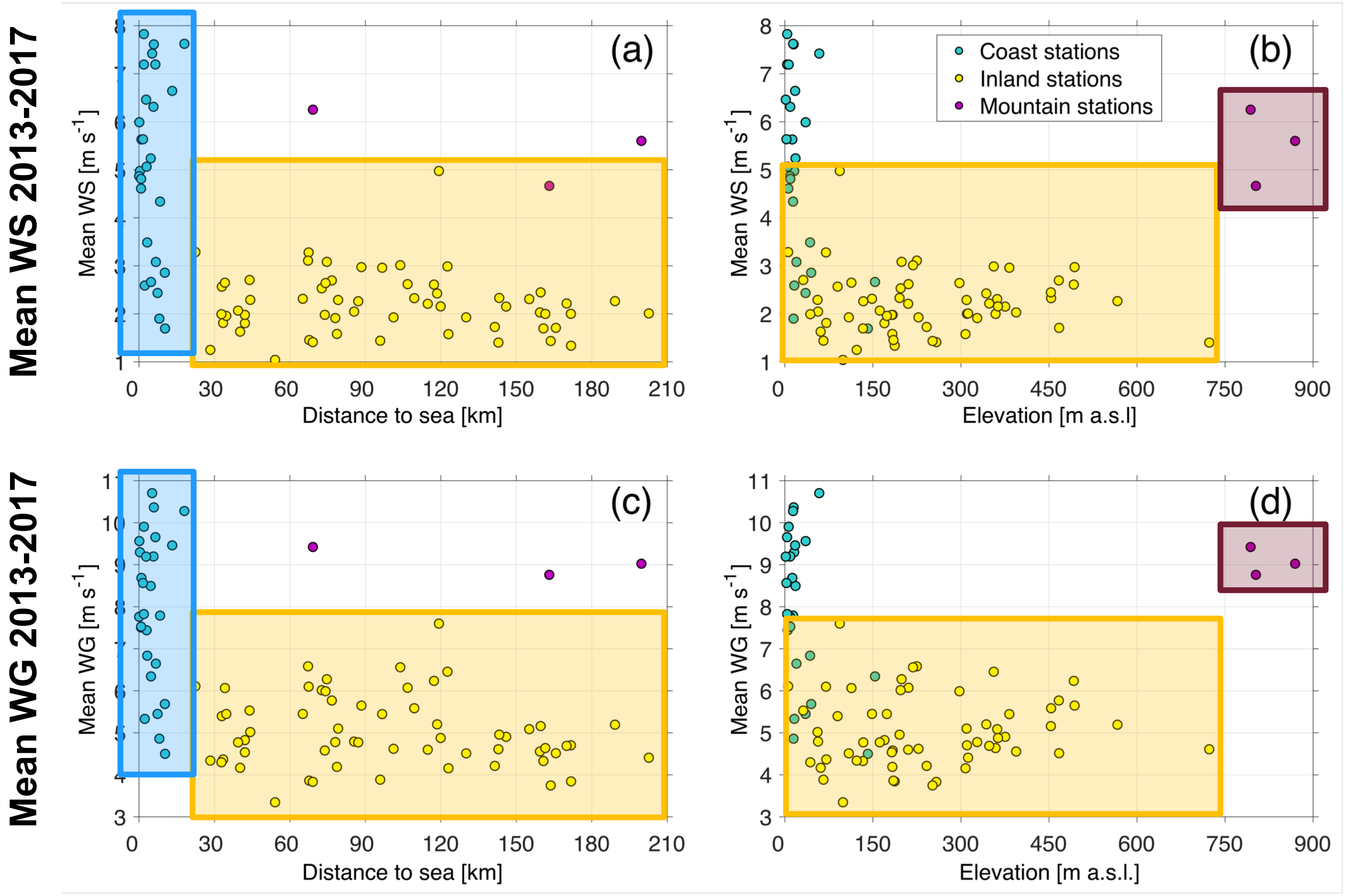
CLASSIFICATION OF MEASURING STATIONS



CLASSIFICATION OF MEASURING STATIONS



⟹ Identified 3 regions: **coast, inland, mountain**

ERA5 and ERA-Interim

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Reanalysis datasets from

ECMWF

ERA5

- Hourly WS and WG

ERA-Interim (hereafter, **ERAINT**)

- 3-hourly WS and WG

WG as:

- maximum gust during the last post-processing period (as ERAINT)
- instantaneous gust, i.e. gust calculated for a given time (each hour)

Observed wind series of a given measuring stations is compared with the wind series from the **closest** reanalysis grid point

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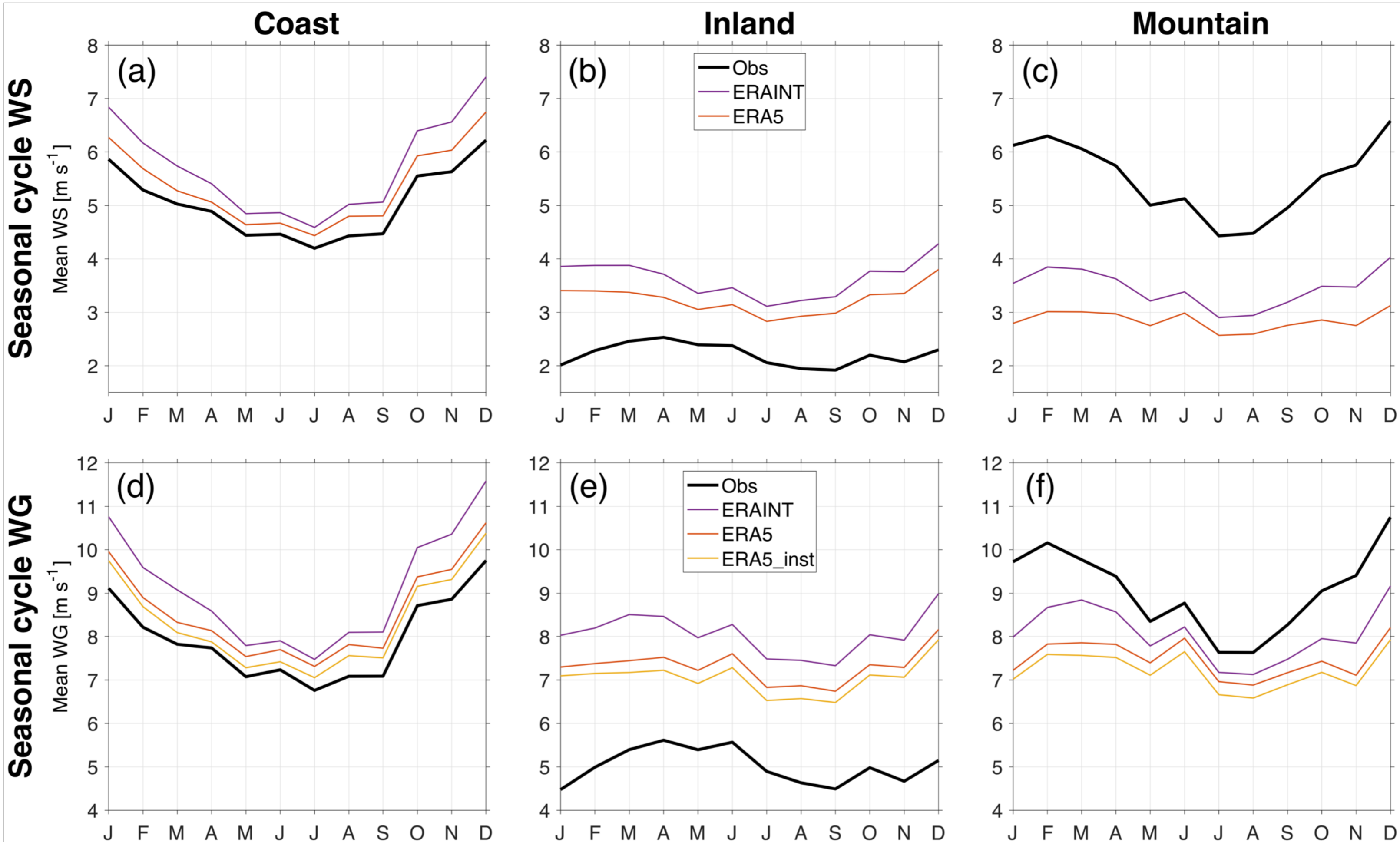
MEAN SEASONAL CYCLE

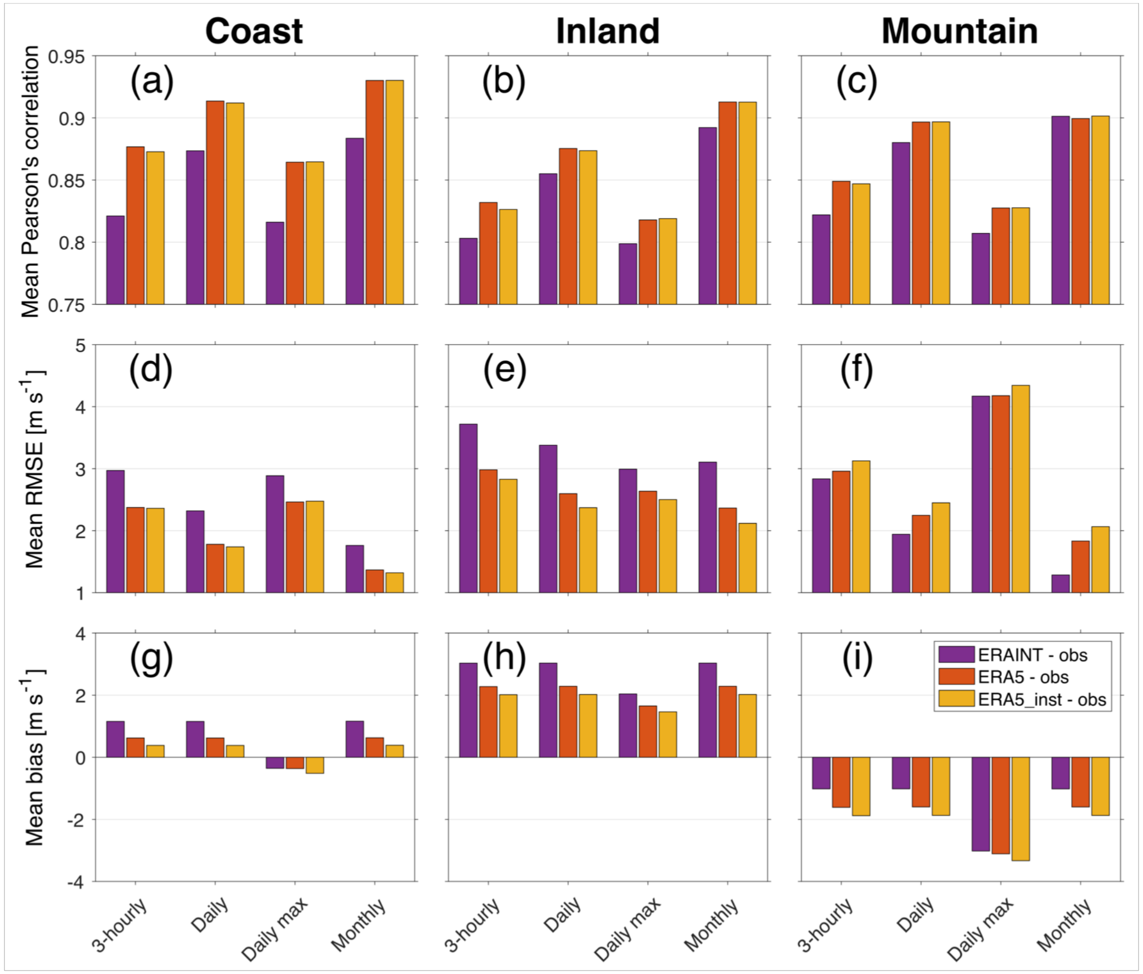
Observations vs ERA5 vs ERAINT

Mean WS and WG for 2013-2017



STATISTICS FOR COMPARISON

WG observations vs ERA5 vs ERAINT



⟹ <u>ERA5 shows better performance than ERAINT in representing both WS and WG</u>

GUST PARAMETRIZATION IN ERA5

$$WG = WS + \Delta WG_{\text{turbulent}} + \Delta WG_{\text{convective}}$$

Total gust is parametrized as the sum of:

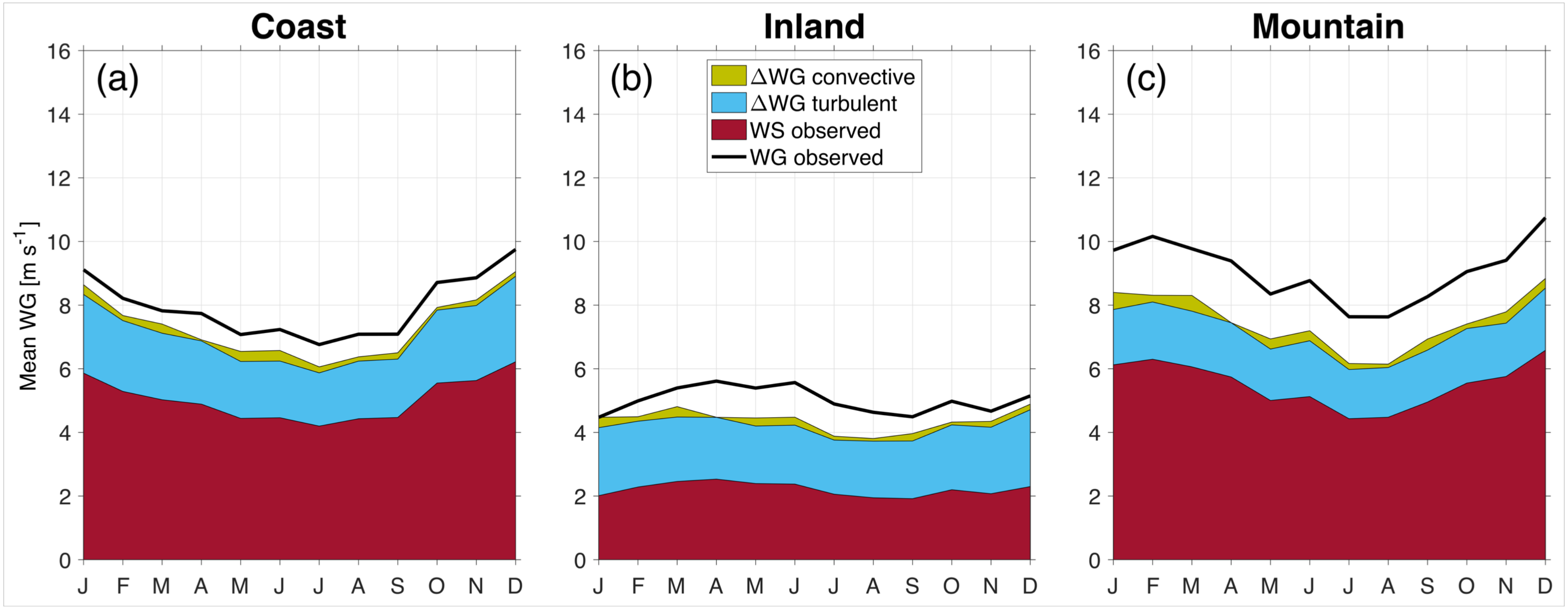
(A) WS — to express mean wind speed conditions

(B) $\Delta WG_{\text{turbulent}}$ — to express gustiness driven by shear-stress (~ friction velocity) and the boundary layer stability (~ Monin Obukhov length)

(C) $\Delta WG_{\text{convective}}$ — to represents gusts generated in deep convective situations (~ low-level wind shear)

MEAN WG SEASONAL CYCLE

Decomposition of parametrized gust



⟹ Discrepancies across inland, and especially in mountain areas

⟹ ΔWG $_{convective}$ contribution ≠ seasonality of deep-convective situations & mesoscale convective systems

LIMITATIONS OF CURRENT WG FORMULATION

1) $\Delta WG_{turbulent}$ is derived by field experiments of Panofsky et al. (1977) *over uniform surfaces*

$\Longrightarrow$ Over land grids, conditions of homogeneity cannot be guaranteed

Panofsky et al., 1977
The characteristics of turbulent velocity components in the surface layer under convective conditions

2) $\Delta WG_{convective}$ is proportional to low-level wind shear through a *tunable* convective parameter (Bechtold & Bidlot, 2009)

$\Longrightarrow$ Convective parameter may not be tuned to Swedish wind climate

Bechtold & Bidlot, 2009
Parametrization of convective gusts

HOW TO BETTER PARAMETRIZE WG?

Improve WG parametrization by:

1) Implementing an elevation-dependency in $\Delta WG_{turbulent}$
2) Tuning $\Delta WG_{convective}$ to observed climate of Sweden

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Test different WG parametrization

		$\Delta WG_{turbulent}$	$\Delta WG_{convective}$
a)	**Standard**	-	-
b)	**Turbulent function**	*Elevation-dependency*	-
c)	**Convection tuned**	-	*Tuned*
d)	**Turbulent function + Convection tuned**	*Elevation-dependency*	*Tuned*

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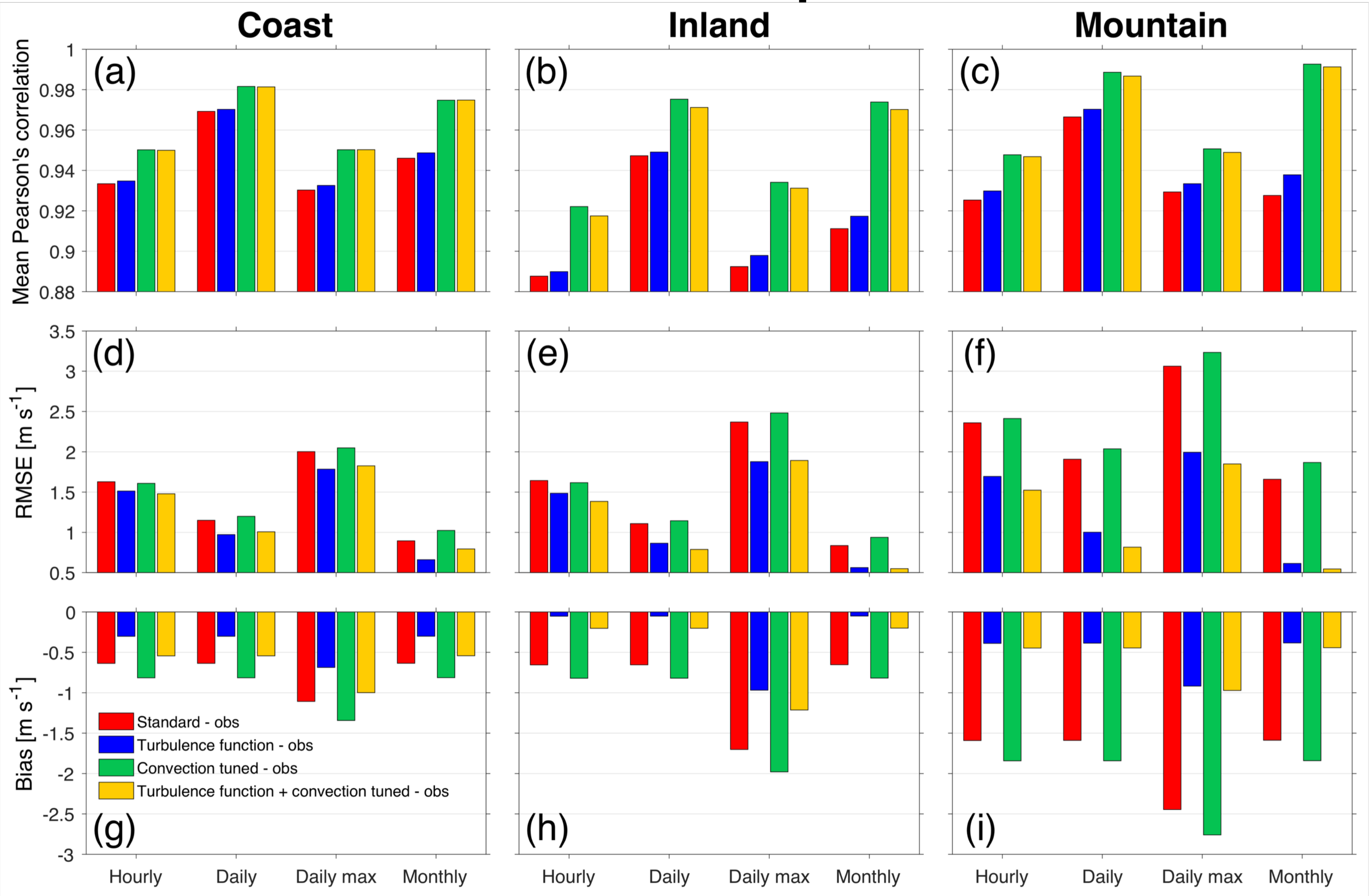
STATISTICS FOR COMPARISON

Observations vs different parametrizations



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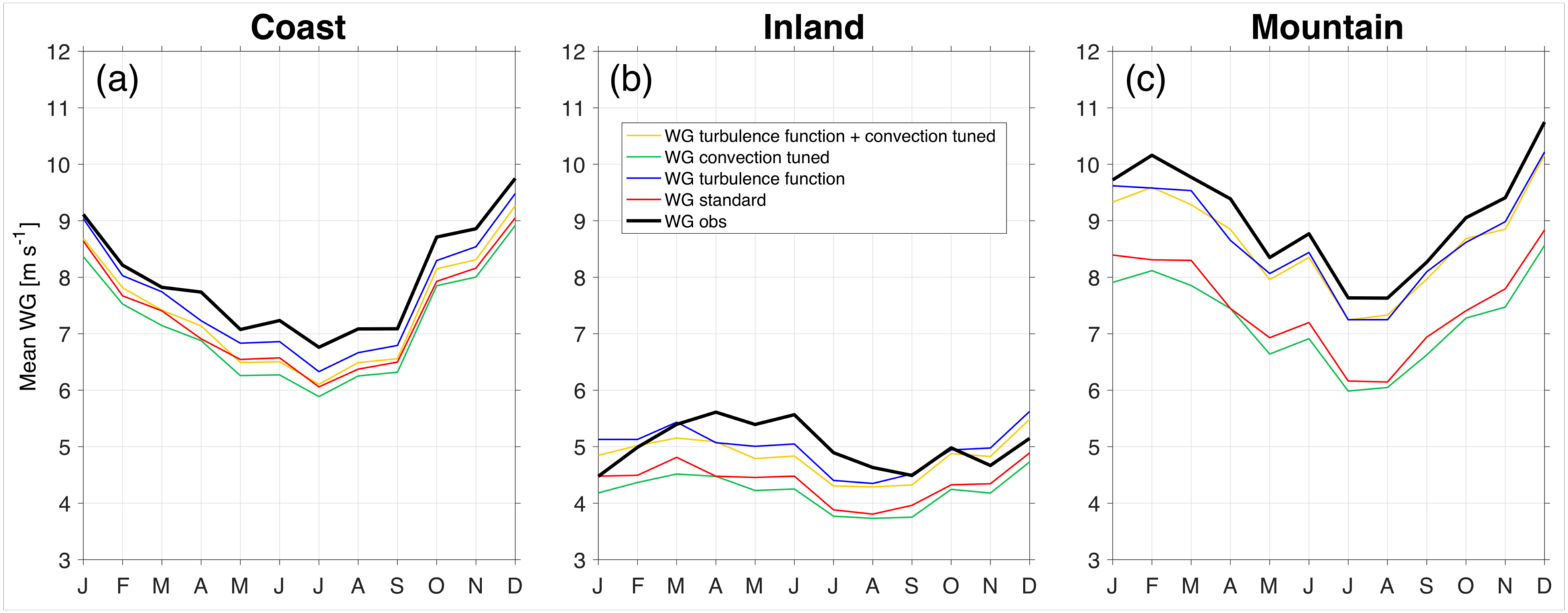
MEAN WG SEASONAL CYCLE

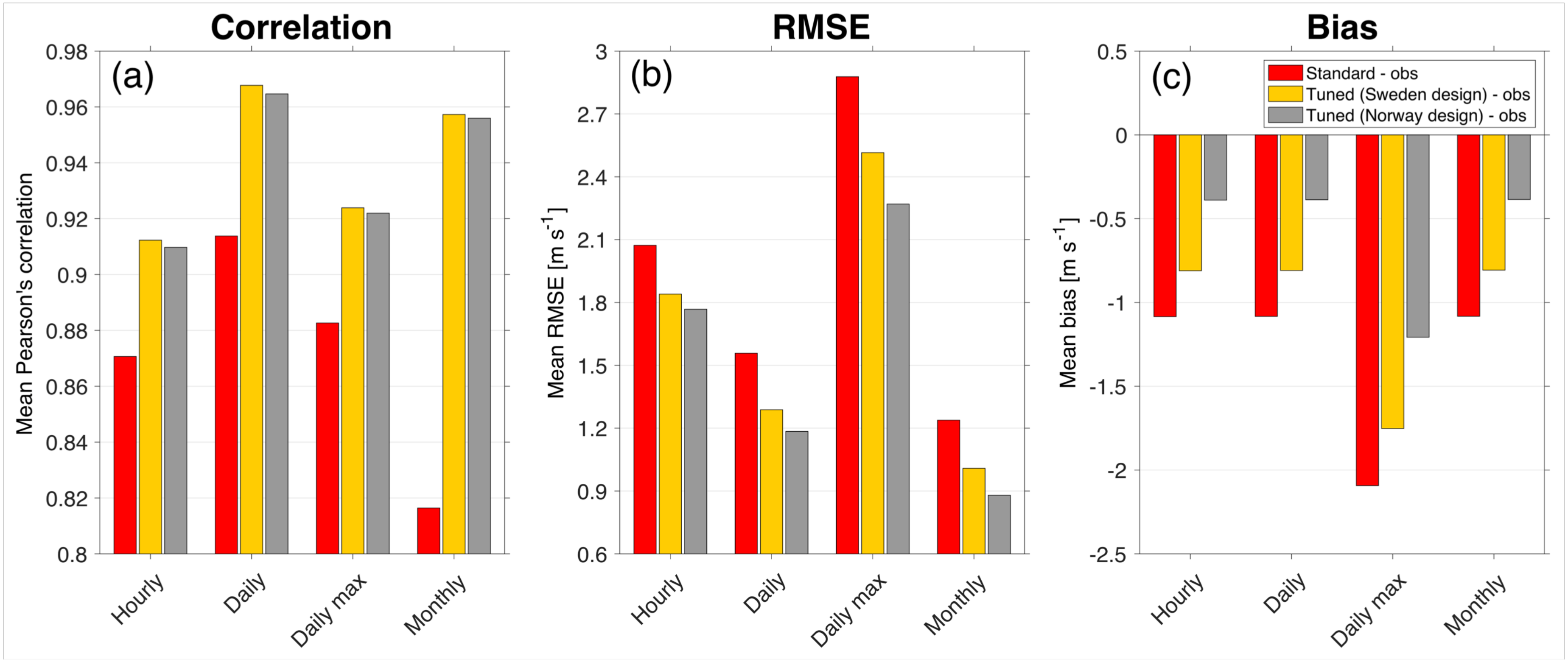
Comparison different parametrizations



- Elevation-dependency in $\Delta WG_{\text{turbulent}}$ $\longrightarrow$ Negative bias reduced
- Tuning of $\Delta WG_{\text{convective}}$ $\longrightarrow$ Higher correlation

$\Longrightarrow$ Better performance with **turbulent function + convection tuned**

TEST FOR NORWAY



Wind gusts across Norway are better estimated, but a small negative bias still exists

SUMMARY

1) ERA5 agrees better than the previous ERAINT dataset with both WS and WG measurements, although significant discrepancies are still found for inland and mountain regions.

2) Wind gust is better simulated through parametrization by:
   - implementing an elevation-dependency in the turbulent contribution
   - tuning the convective gust contribution to the Swedish climate conditions

3) With the new designed gust parametrization, wind gusts are better simulated across Norway, but negative biased.

lorenzo.minola@gu.se

Thank you!

For more info:

Minola et al., 2020 (under revision)
Near-surface mean and gust wind speeds in ERA5 across Sweden: towards an improved gust parametrization. *Climate Dynamics*

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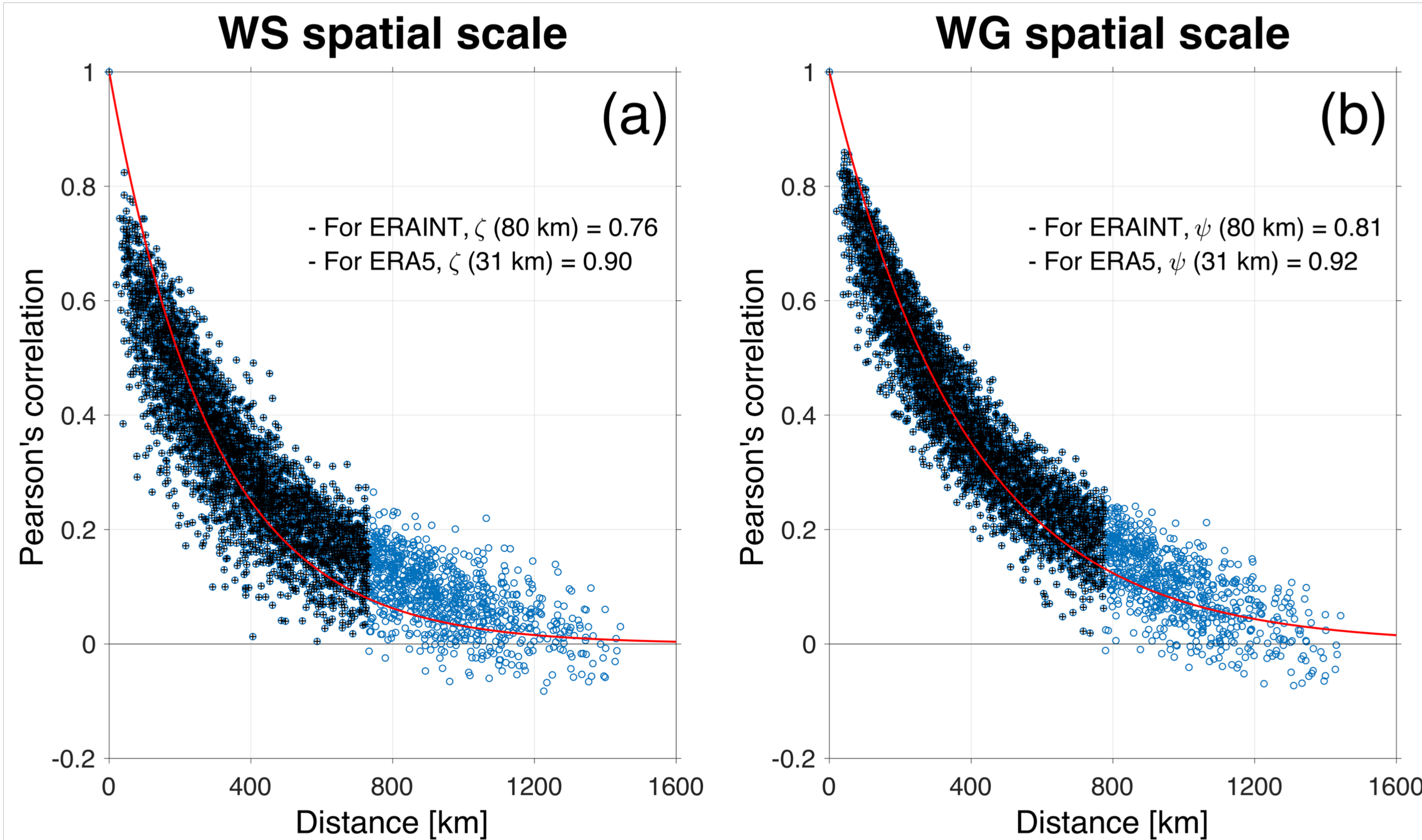
This study contributes to the strategic research areas of Modelling the Regional and Global Earth system (MERGE) and Biodiversity and Ecosystem services in a Changing Climate (BECC). This study is partly funded by: (i) Swedish Research Council, "Detection and attribution of changes in extreme wind gusts over land" (2017-03780); (ii) Spanish Ministry of Science, Innovation and Universities, "Evaluación y atribución de la variabilidad de la velocidad media y las rachas máximas de viento: causas del fenómeno "stilling" (RTI2018-095749-A-I00 MCIU/AEI/FEDER, UE); and (iii) Ramon y Cajal fellowship (RYC-2017-22830).

SUPPLEMENTARY MATERIAL

SPATIAL SCALE



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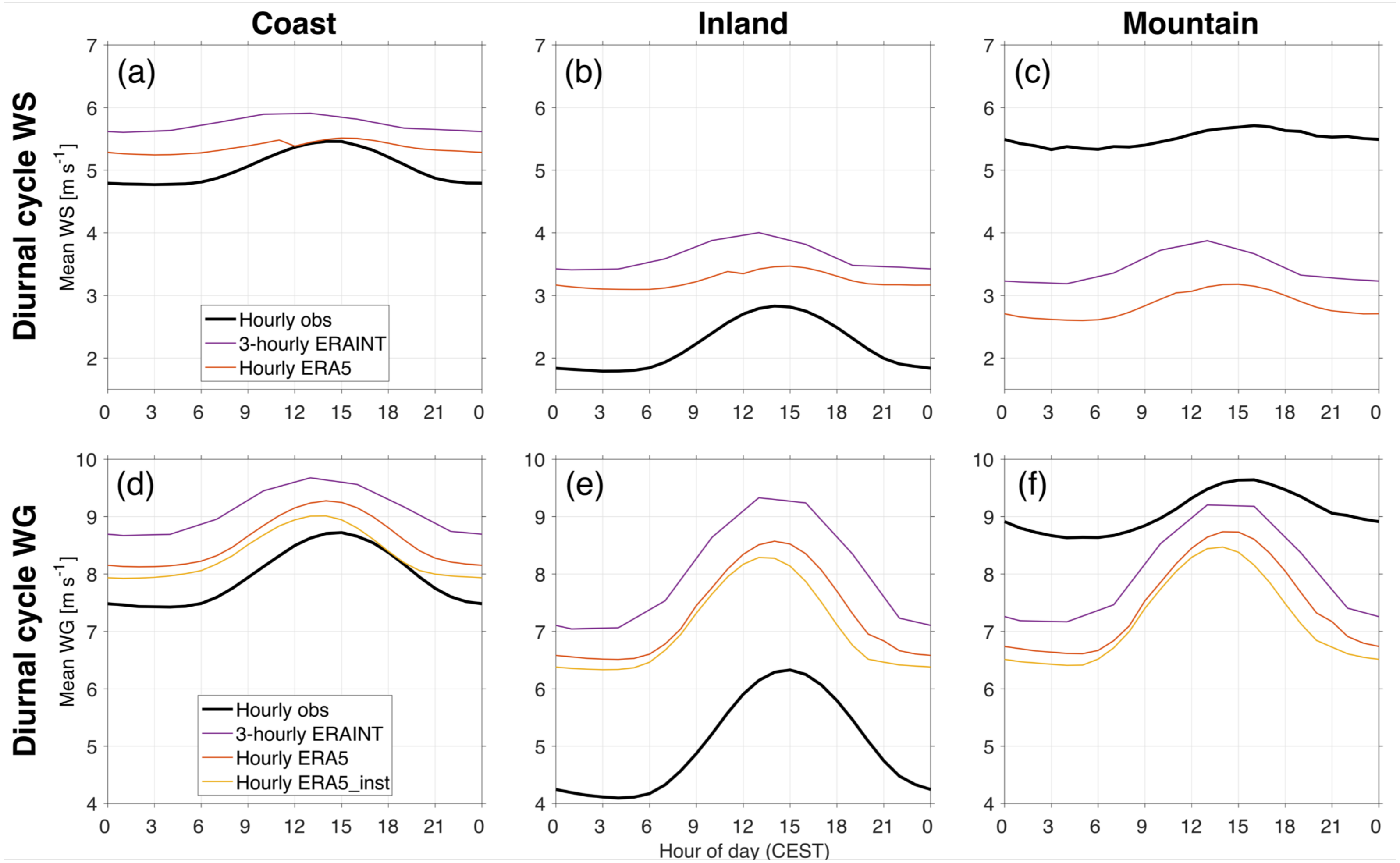
MEAN DIURNAL CYCLE

Observations vs ERA5 vs ERAINT

Mean WS and WG for 2013-2017



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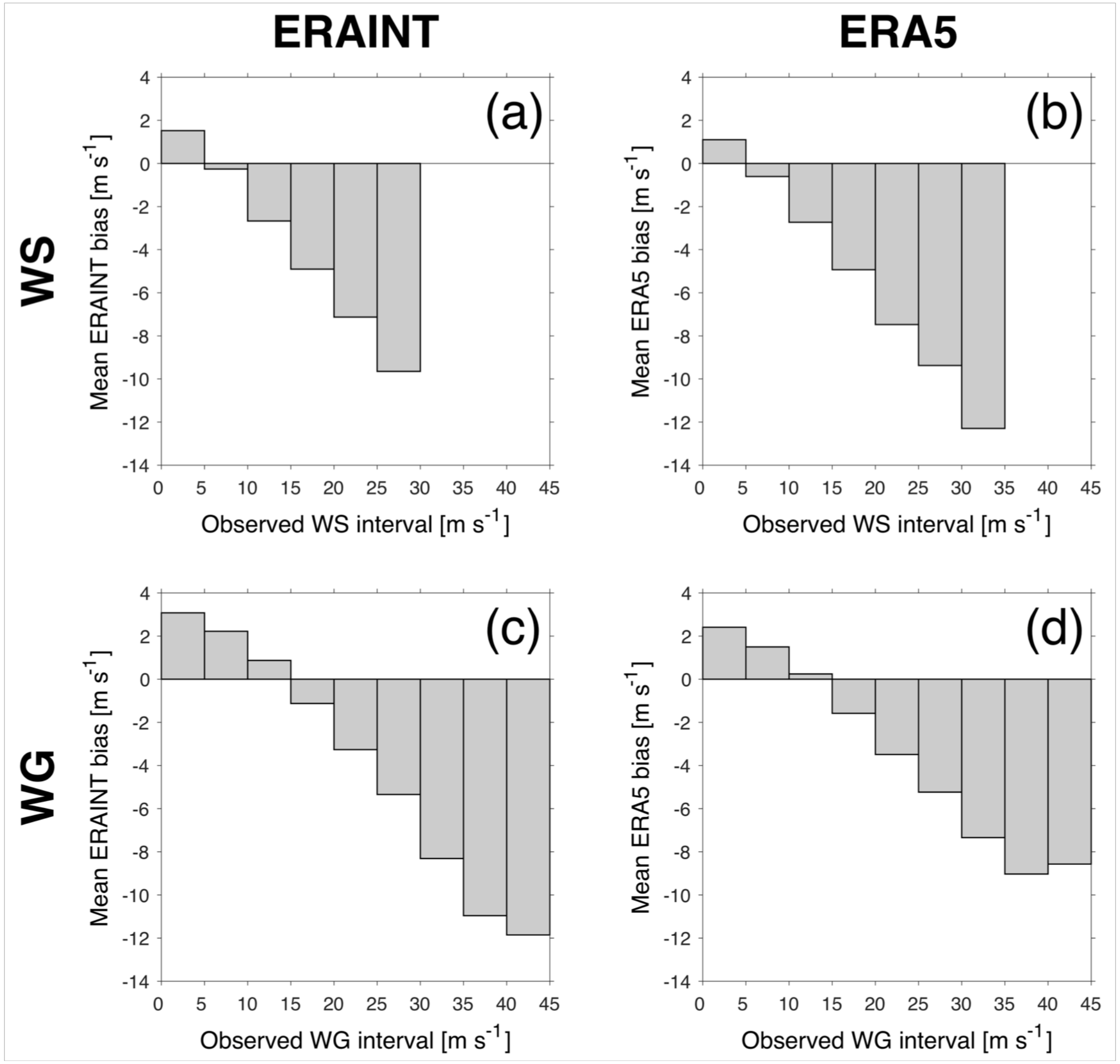
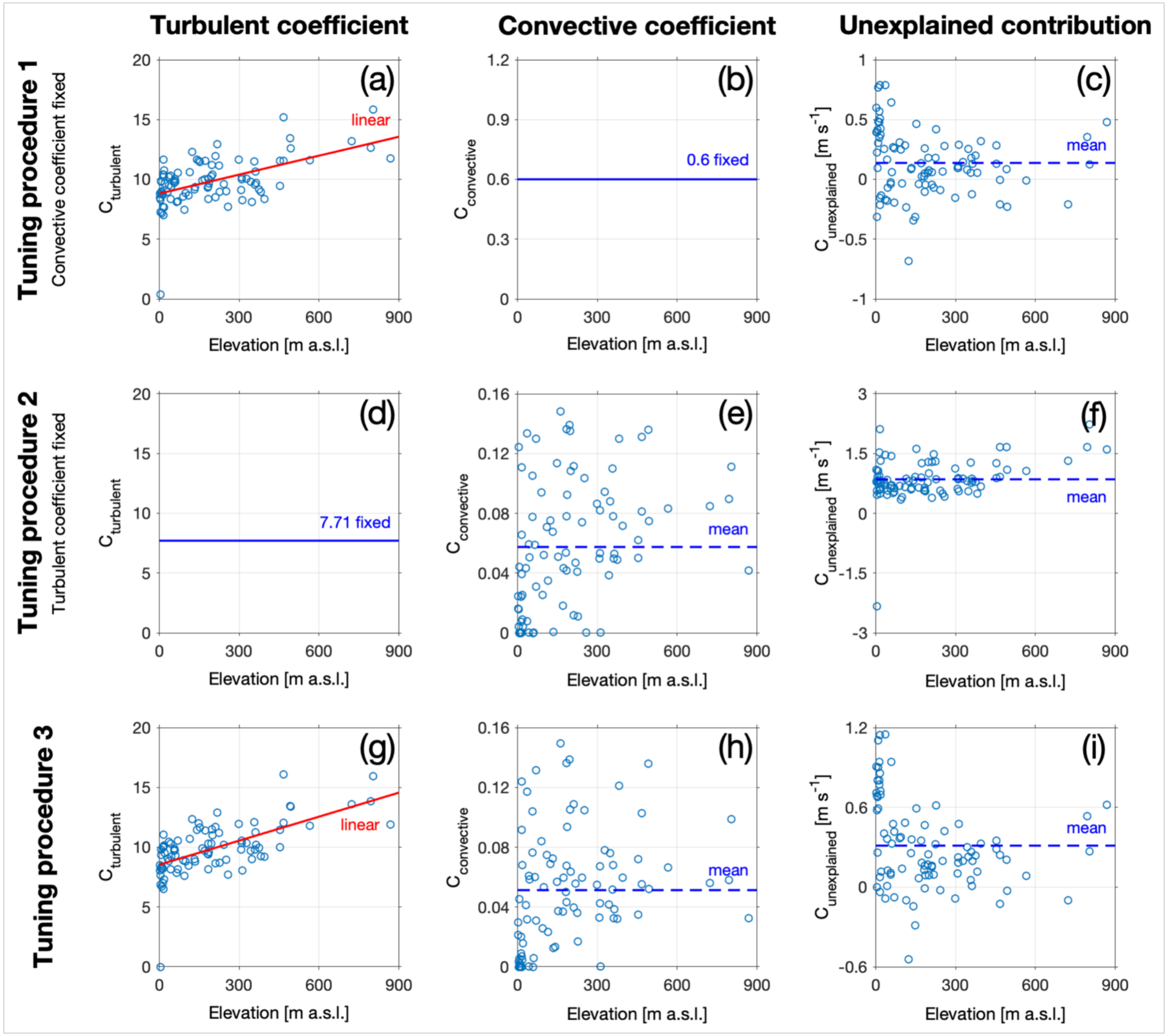
MEAN MODEL BIASS vs OBSERVED WIND INTERVALS



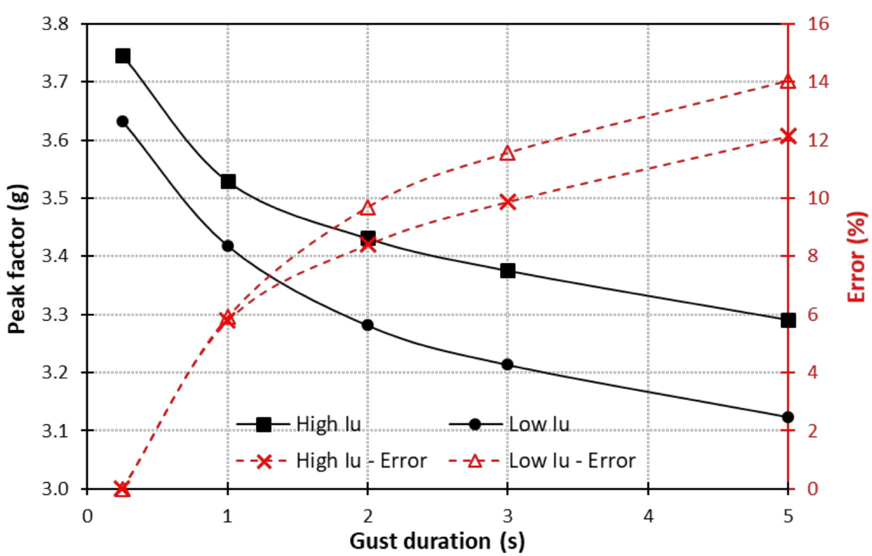
DESIGN OF THE TESTED WG PARAMETRIZATIONS



EFFECT OF GUST DURATION ON MEASURED GUST

Safaey Pirooz et al. (2020): Lower gust wind speeds are recorded when employing a 3-seconds gust duration compared to a 2-seconds one

Safaey Pirooz AA, et al, 2020 (under revision)
Effects of gust duration configuration on maximum wind speed measurements



⟹ <u>Gust duration differences could explain a positive bias</u>

Negative bias across Norway must be due to other reasons such as the more complex topography or by the design and/or calibration of the elevation-dependent function