Development of Future Depth-Duration-Frequency Curves (DDF) for the SFWMD

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Joint Cooperative USGS-SFWMD Project in collaboration with the Sea Level Solutions Center at Florida International University.

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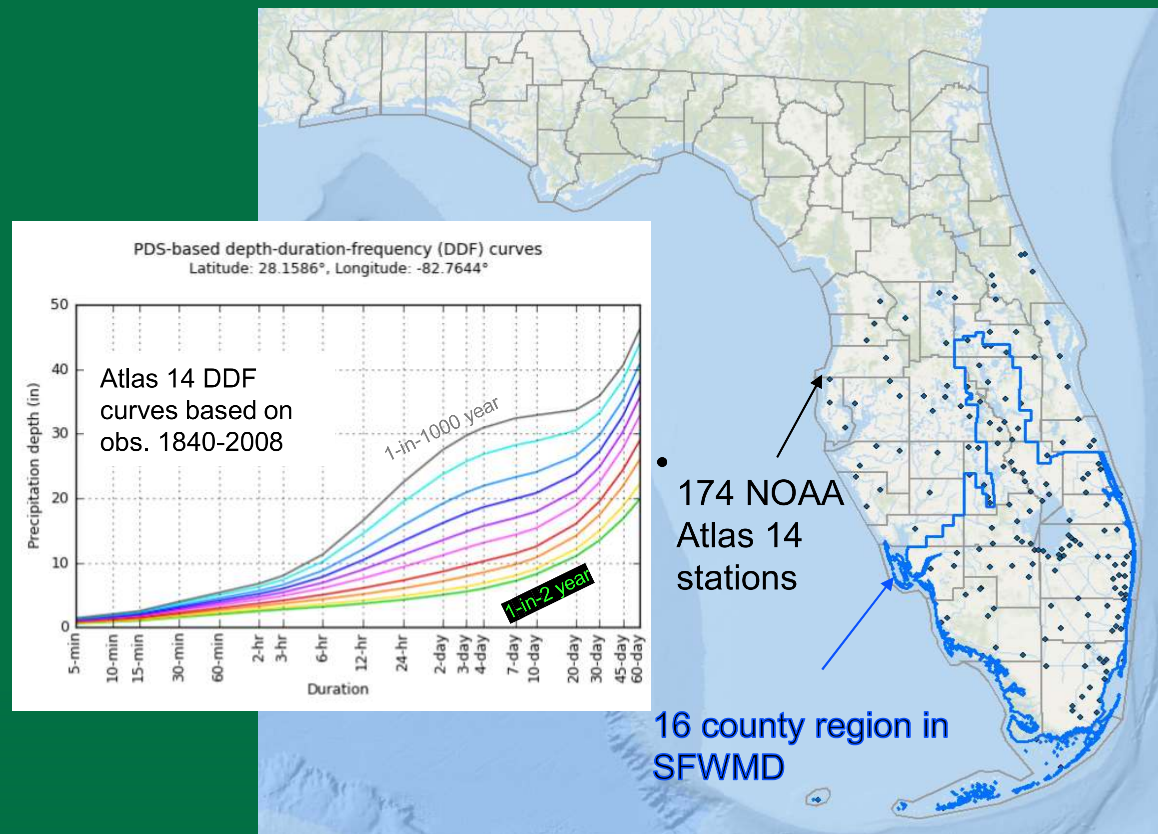
Project Description and Scope

- Ensemble of downscaled climate models used to determine median **change factors** of future (projected) rainfall depths at NOAA Atlas 14 stations located in SFWMD. To be used in evaluating flood protection level of service in SFWMD region.
  - 40-year hist. period: 1966-2005
  - 40-year future period: 2050-2089
  - Durations of rainfall event: 1, 3, and 7 days
  - Return periods (ave. # of years between events of the given rainfall depth): 5, 10, 25, 50, 100**, and 200** years



**Low confidence in long return periods

Change Factor

- Ratio of future (f) rainfall depth (D in inches) from model to historical (h) rainfall depth from model for a given duration (d in days) and return period (T in years).

$$\mathrm{CF} = D_f(d,T)\ /\ D_h(d,T)$$

Data from model grid cells for two 40-year periods

$$\text{Future DDF} = D_{Atlas14}(d,T) * \mathrm{CF}$$

Atlas 14 DDF curves use obs. 1840-2008

Downscaled Climate Datasets

- **Statistical methods** differ in observational datasets used; how many analog days** are considered, averaged, weighted; how bias-correction is done; how tail (extreme values) are bias-corrected; whether actual values or anomalies are used; whether trends in GCM data are preserved, etc.

**Analog days are days in an observational dataset that best match coarse-scale meteorological field(s) for the day that is being downscaled.

- **Dynamically-downscaled** datasets (25-50 km) are “physically-based” in terms of solving equations of hydrodynamics and thermodynamics; however, convection is parameterized based on empirical equations. **To actually simulate convection in momentum equation requires model resolution < 2-km.** Sea-breeze, lake-breeze, coastal curvature enhanced convection not adequately captured at coarse RCM resolutions.

- Both methods depend on regional climate, tropical storms, and remote **teleconnection patterns** that drive precipitation in south Florida being adequately captured in the parent GCM.

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Downscaled Climate Datasets

- **LOCA**: Statistical. Localized Constructed Analogues product by University of California at San Diego.
  - 1/16th degree, ~6 km
  - 30 historical runs, 30 RCP4.5, 30 RCP8.5
- **MACA**: Statistical. Multivariate Adaptive Constructed Analogs.
  - Livneh training data: 1/16th degree, ~6 km
  - gridMET training data: 1/24th degree, ~3 km
  - 20 GCMs for each training dataset in historical period, RCP4.5 and RCP8.5.
- **CORDEX**: Dynamical. North American Coordinated Regional Downscaling Experiment
  - 0.22 to 0.44 degree, ~25 to ~50 km (parameterized convection)
  - bias corrected by DayMet and gridMET
  - 54 historical runs, 14 RCP4.5, 54 RCP8.5.
- **JupiterWRF**: Hybrid
  - Dynamical model: **W**eather **R**esearch and **F**orecasting (WRF) model developed by Jupiter Intelligence.
    - 4 km resolution.
  - Hybrid approach: intensity scaling x analog resampling
  - Based on CMIP5 and CMIP6 GCM output (7 GCM/RCP_SSP combinations).
  - Model datasets developed by Jupiter Intelligence, coordinated by FIU.
  - Only extreme events of 1-day duration can be evaluated.

RCP4.5: Medium-low emission scenario with 4.5 W/m^2 increase in radiative forcing by 2100 with respect to pre-industrial era
RCP8.5: High emission scenario with 8.5 W/m^2 increase in radiative forcing by 2100 with respect to pre-industrial era

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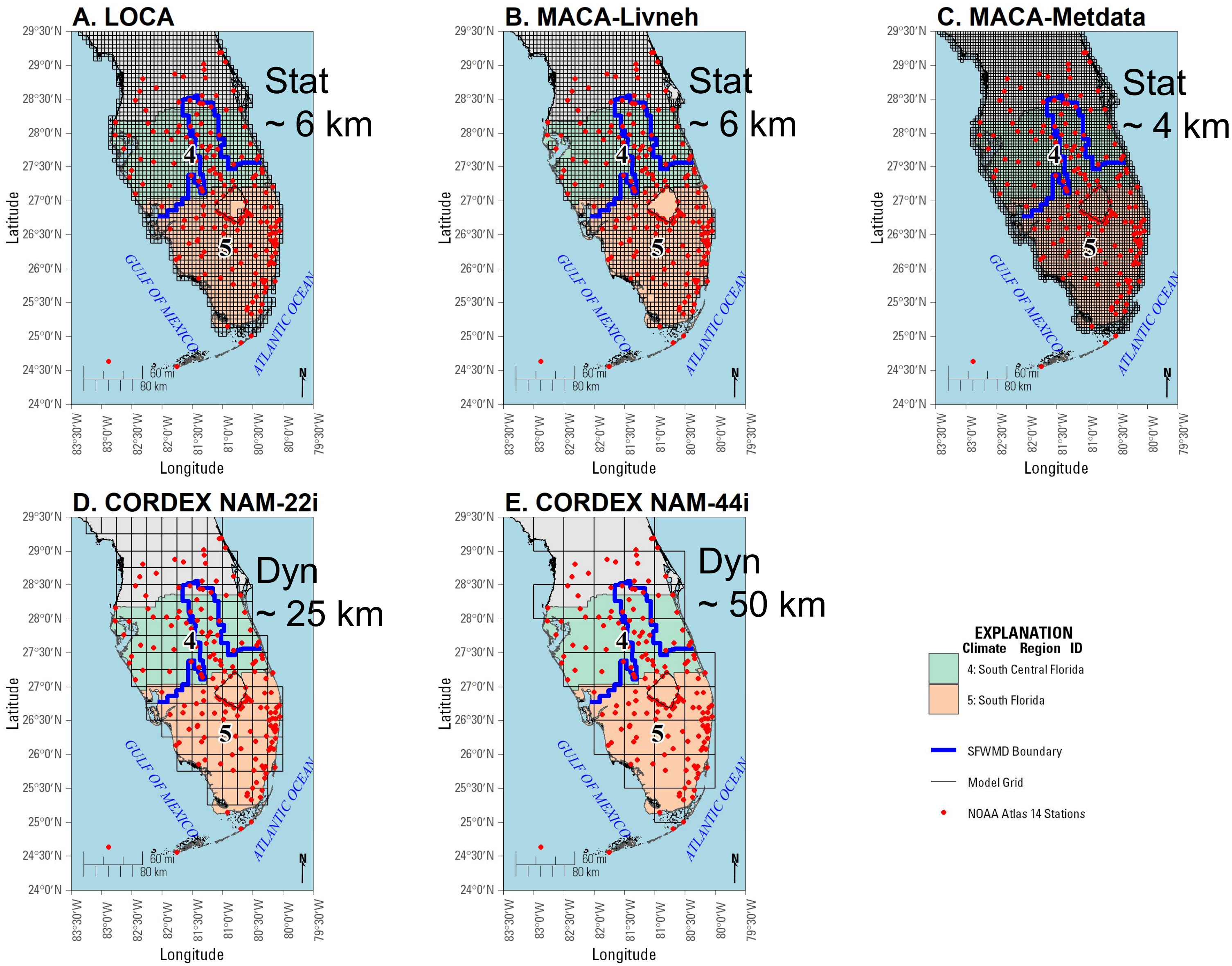
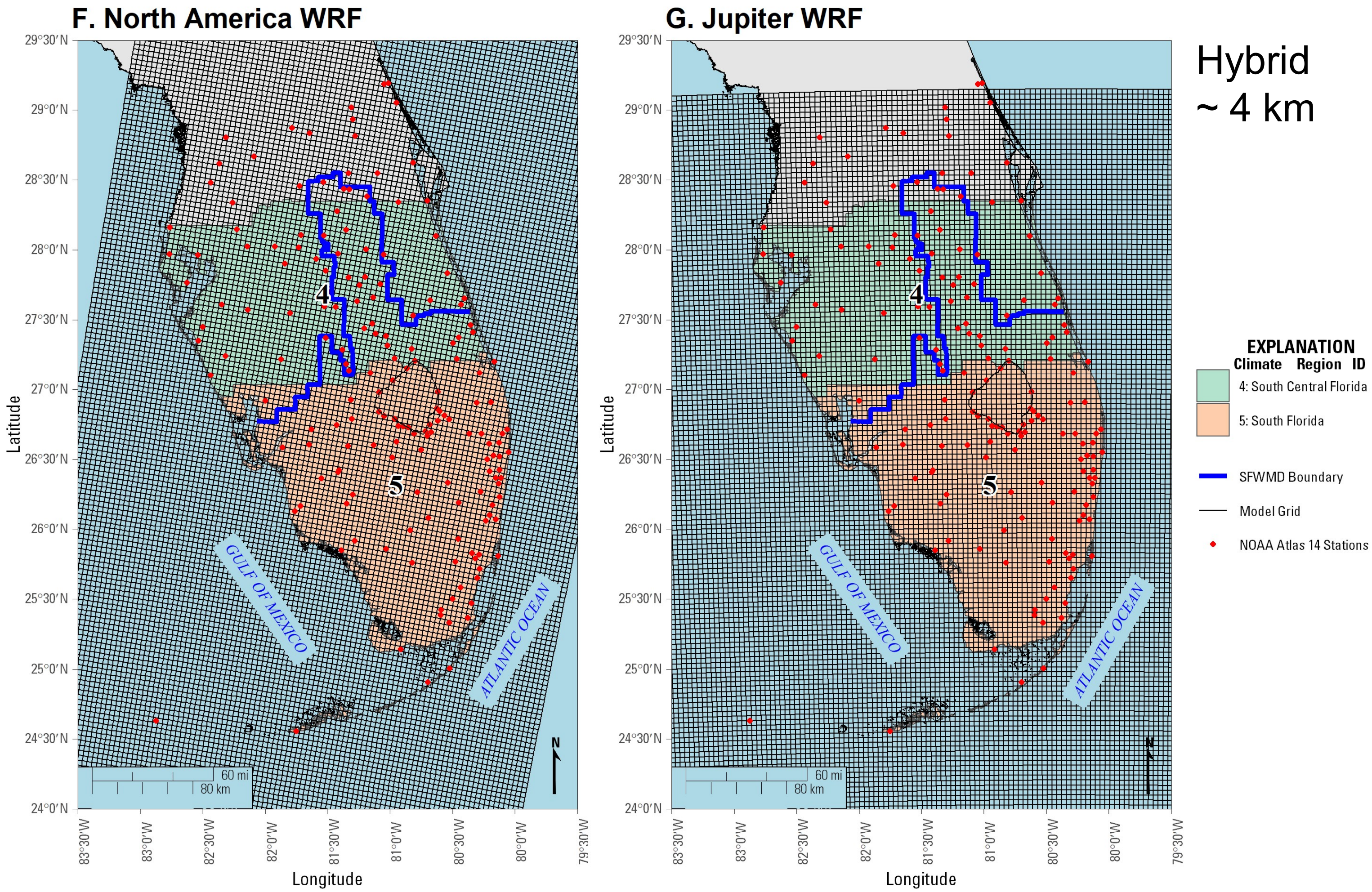

A. LOCA
Stat
~ 6 km
B. MACA-Livneh
Stat
~ 6 km
C. MACA-Metdata
Stat
~ 4 km
D. CORDEX NAM-22i
Dyn
~ 25 km
E. CORDEX NAM-44i
Dyn
~ 50 km
GULF OF MEXICO
ATLANTIC OCEAN
Latitude
Longitude
29°30′N
29°0′N
28°30′N
28°0′N
27°30′N
27°0′N
26°30′N
26°0′N
25°30′N
25°0′N
24°30′N
24°0′N
83°30′W
83°0′W
82°30′W
82°0′W
81°30′W
81°0′W
80°30′W
80°0′W
79°30′W
60 mi
80 km
N
4
5
EXPLANATION
Climate Region ID
4: South Central Florida
5: South Florida
SFWMD Boundary
Model Grid
NOAA Atlas 14 Stations

Hybrid
~ 4 km



F. North America WRF
G. Jupiter WRF
29°30′N
29°0′N
28°30′N
28°0′N
27°30′N
27°0′N
26°30′N
26°0′N
25°30′N
25°0′N
24°30′N
24°0′N
Latitude
83°30′W
83°0′W
82°30′W
82°0′W
81°30′W
81°0′W
80°30′W
80°0′W
79°30′W
Longitude
4
5
GULF OF MEXICO
ATLANTIC OCEAN
60 mi
80 km
N
EXPLANATION
Climate Region ID
4: South Central Florida
5: South Florida
SFWMD Boundary
Model Grid
NOAA Atlas 14 Stations

Technical Approach

- Peak over threshold (POT): Model exceedances above a sufficiently high threshold. Uses more data in the tail of the distribution than classical annual maxima approach.

- Grid cell values represent areal averages. Fitting DDF curves at each model grid cell at its native resolution and applying areal reduction factors for conversion to station values
  - Allows comparison of station-scale DDF curves fit for historical period against NOAA Atlas 14 PDS-based official DDF curves.
  - Assumption constancy of area reduction factors from current to future. The ARF would cancel out in the computation of change factors.

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Summarizing Change Factors

- Median and model spread in change factors at 174 NOAA Atlas 14 stations in south and central Florida for durations and return periods of interest.

- Model selection criteria – performance metrics based on precipitation climate extremes indices from Expert Team on Climate Change Detection Indices (ETCCDI).
  - Two observational datasets: **PRISM** and SFWMD Super-grid for the period 1981-2005.
  - 4 indices for annual maxima of various durations (1, 3, 5, 7 days) used in model culling for central FL and south FL regions. 11 additional indices used to inform overall dataset performance.
  - Evaluated based on how well the models reproduce the observed climatology and interannual variability of climate extreme indices.

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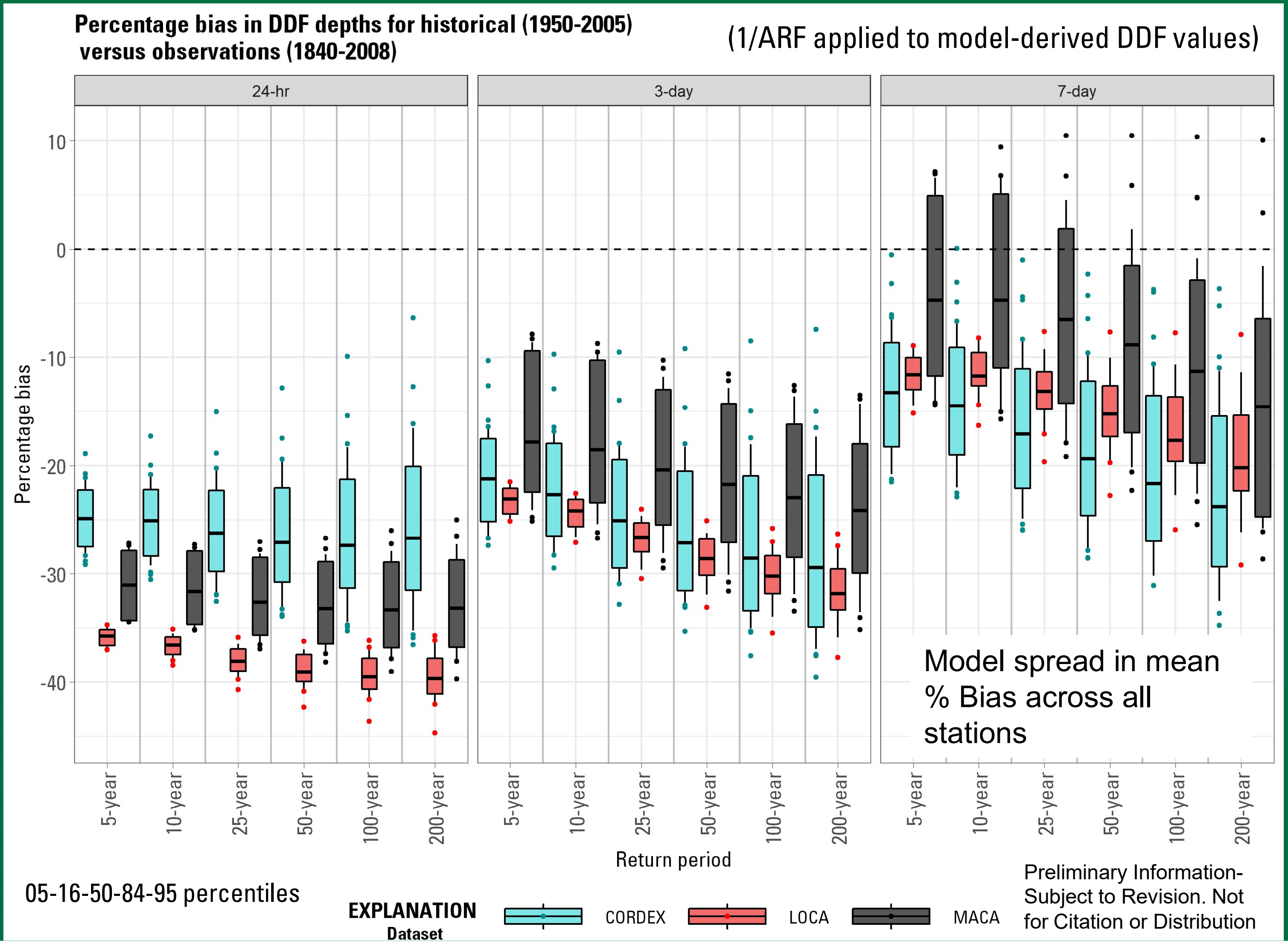
Bias Results



Preliminary Information-Subject to Revision. Not for Citation or Distribution

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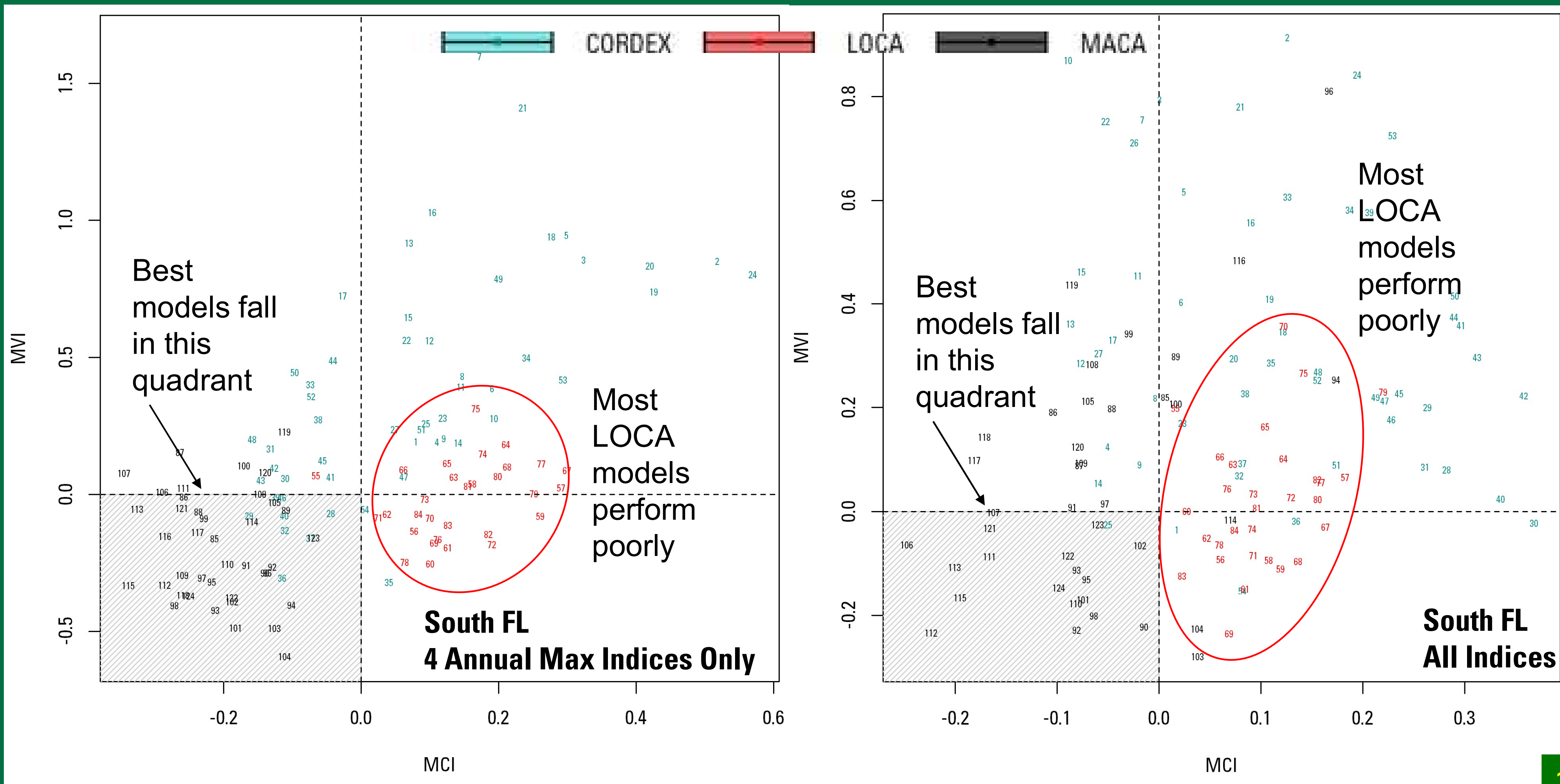
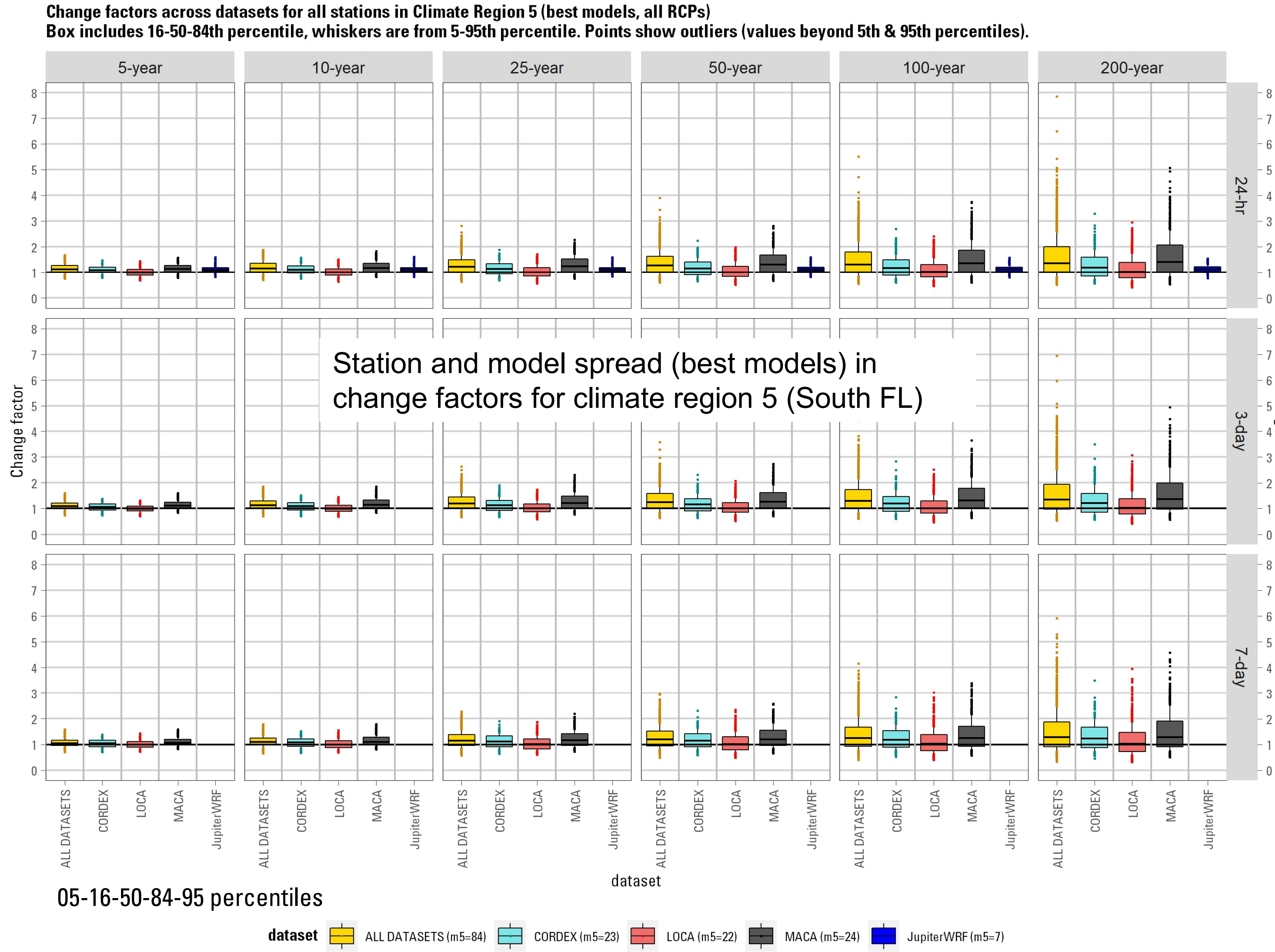
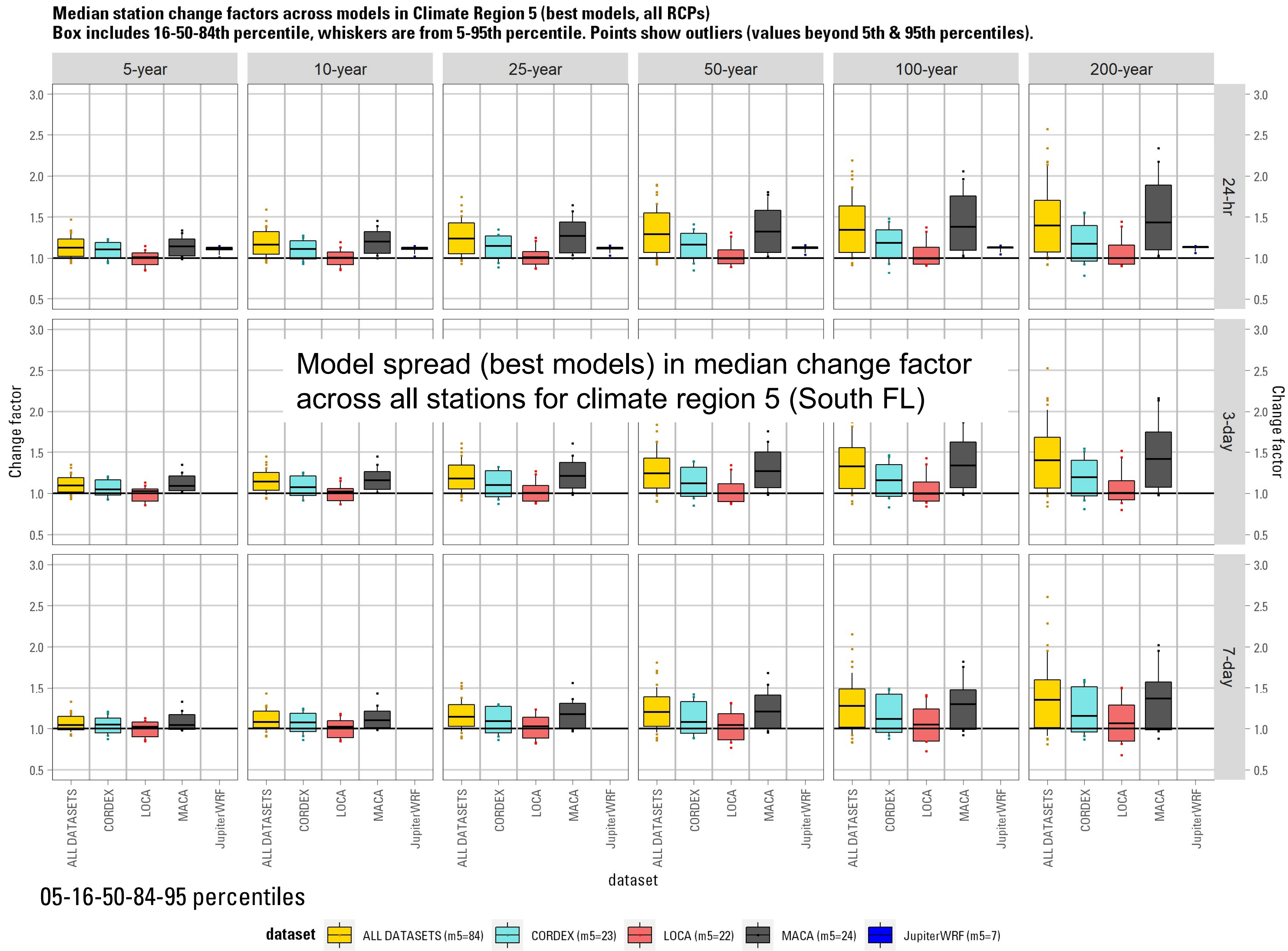
“Best” Models

Preliminary Information-Subject to Revision. Not for Citation or Distribution



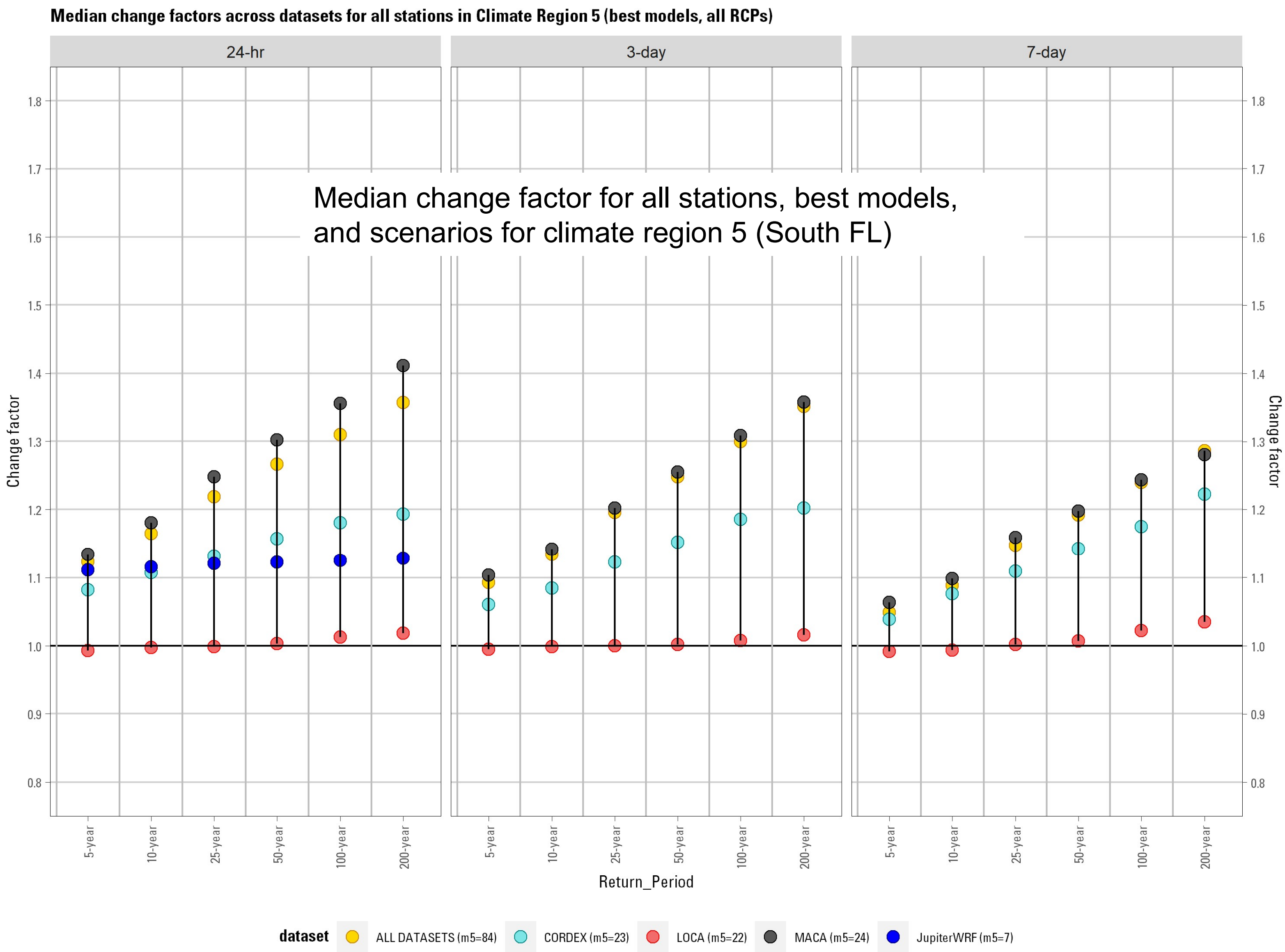


Station and model spread (best models) in change factors for climate region 5 (South FL)



Model spread (best models) in median change factor across all stations for climate region 5 (South FL)

05-16-50-84-95 percentiles



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Summary

- Uncertain CFs with no consensus across datasets (except most agree with CFs > 1; that is, an increase in precipitation extremes in the future). Selection of CFs should be based on risk-based approach. Median CFs of 1-1.6 may be adequate for low-risk situations, but CF values of 2-3 or even higher may be desirable in designing critical infrastructure.
- Highest and lowest CFs obtained from statistical downscaling datasets (MACA and LOCA, respectively).
- Lowest CFs from LOCA yet LOCA performs the worst in terms of reproducing historical climate extreme indices. Low daily CFs obtained from Jupiter WRF hybrid dataset. Intermediate CFs from CORDEX.
- To reduce some of the uncertainties in downscaling, a high-resolution regional climate model that can simulate convection in momentum equation (< 2-km) should be developed for the state of Florida.

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