Florida Water Climate Alliance Workshop

Future Conditions 100-Year Flood Elevation Map

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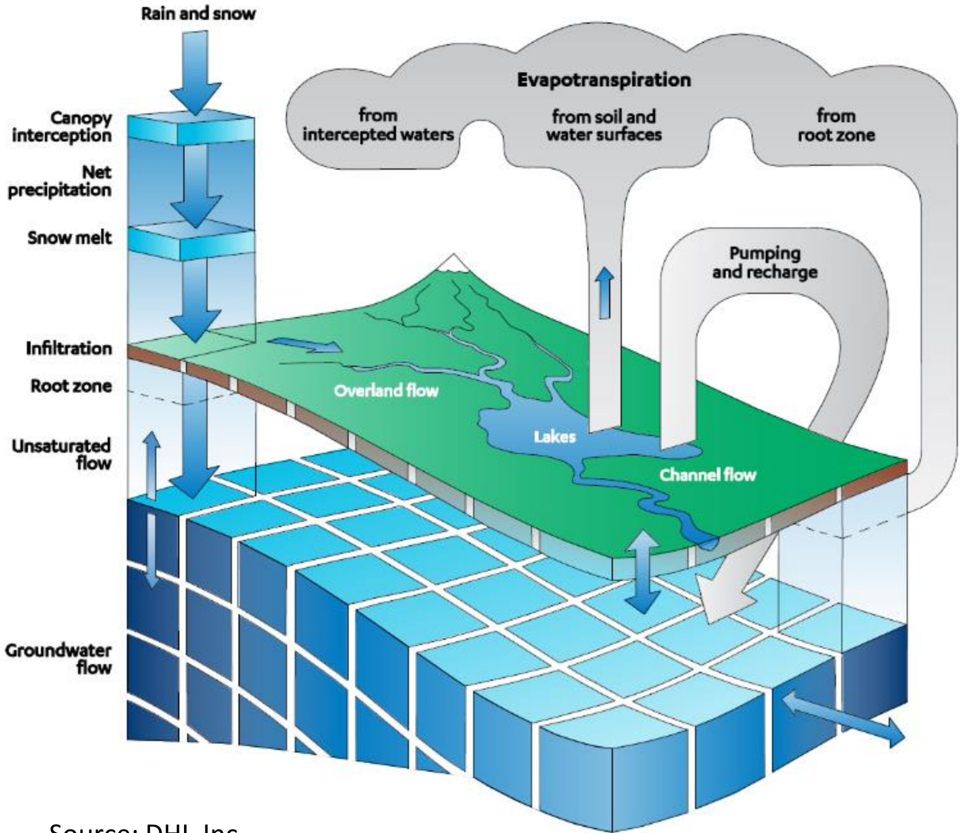
February 7, 2020

Project Team

- Broward County Leadership: Dr. Jennifer Jurado, P.E.
- Geosyntec: Prime Consultant
  - Data Collection and Compilation
  - Stakeholder Outreach
  - Rainfall Analysis (current and future conditions)
  - Model Tool Development
  - CRS Evaluation and Recommendations
- Taylor Engineering: Hydrologic & Hydraulic Modeling
  - Update Current Conditions Model
  - Future Conditions Model Development
  - Integration with Coastal Analysis
- CLIMsystems and Jupiter Intelligence: Future Rainfall Development
- Stoner & Associates: Surveying
- Adept Strategy and Public Relations
- Special Acknowledgement to Dr. Carolina Maran and Michael Zygnerski

Project Goals

- Mapping Future Flood Risk:
  - Increased rainfall due to warming climate
  - Year 2060-2069 sea level rise
  - Increased runoff due to higher water tables
  - Land use changes
  - Accomplished through integrated GW/SW modeling
- Will enhance infrastructure resilience:
  - Design standards
  - Finished floor elevations, streets, sanitary manholes, critical infrastructure, etc.

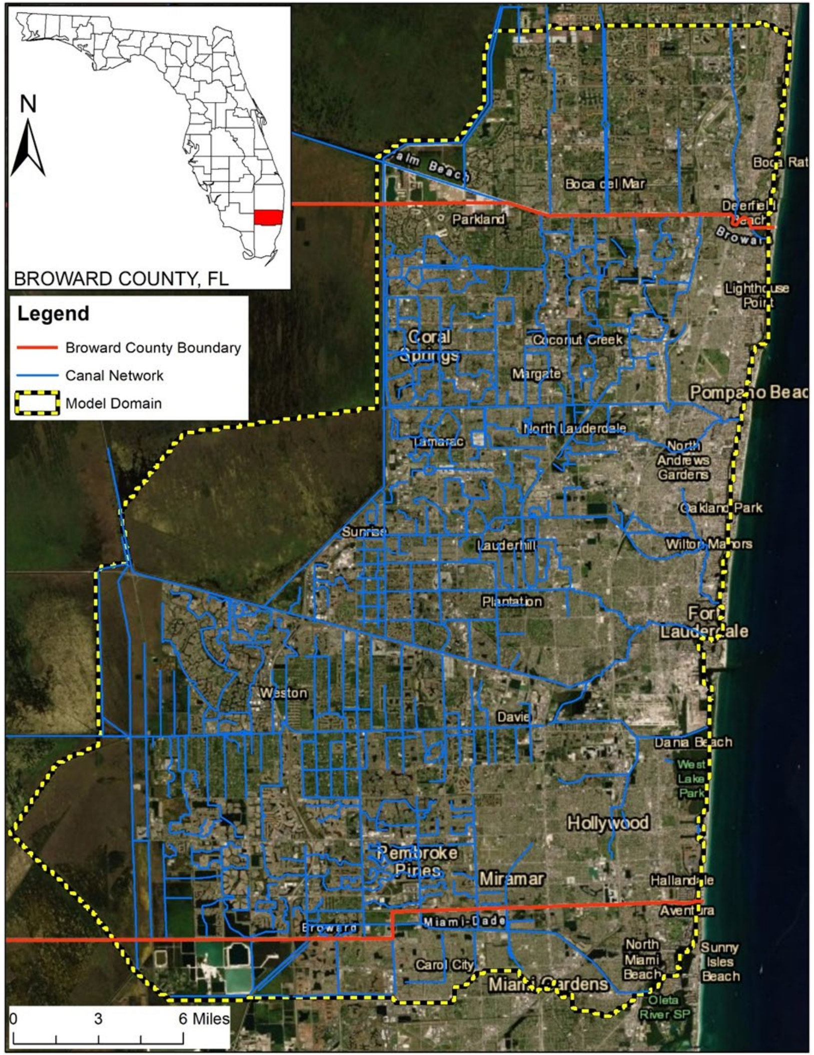


Source: DHI, Inc.

Current Conditions Modeling Updates and Results

Model Development

- Covers urban boundaries of Broward County and contributing areas to the north, west, and south.
- 1-D Surface Water Model
- 2-D Overland Flow Model
- Unsaturated Zone Module
- 3-D Groundwater Model
  - 5 layers representing stratified surficial aquifer
  - Includes high permeable zones of the Biscayne aquifer
- All Components fully integrated with each other



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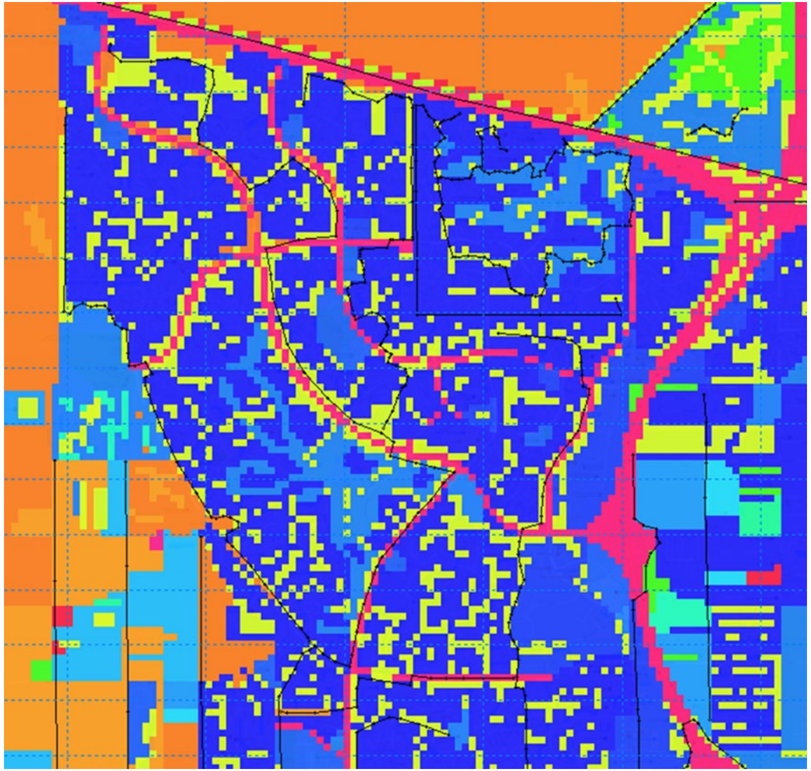
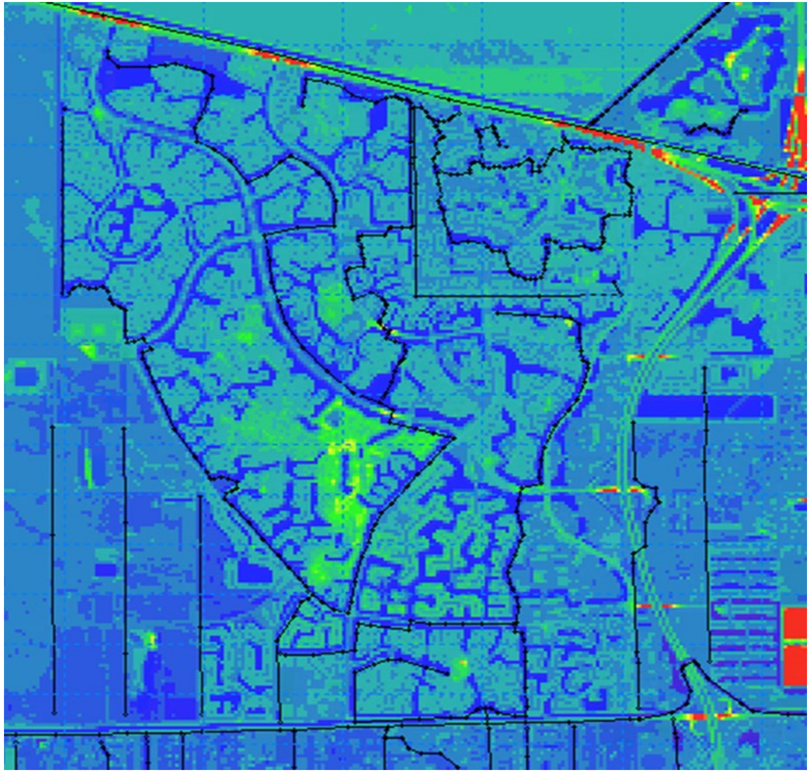
Model Development

Land Use



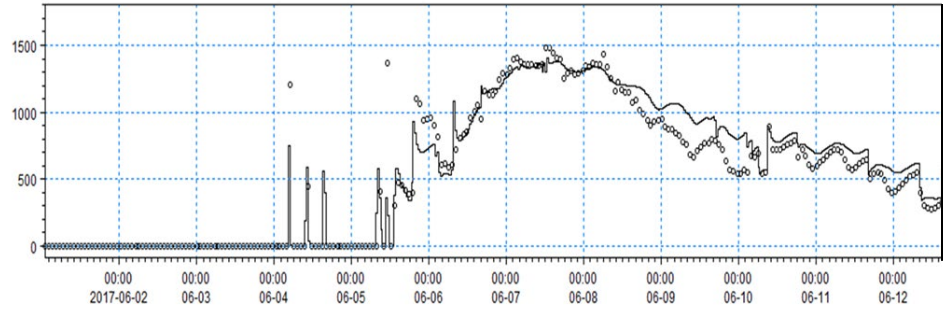
Topography

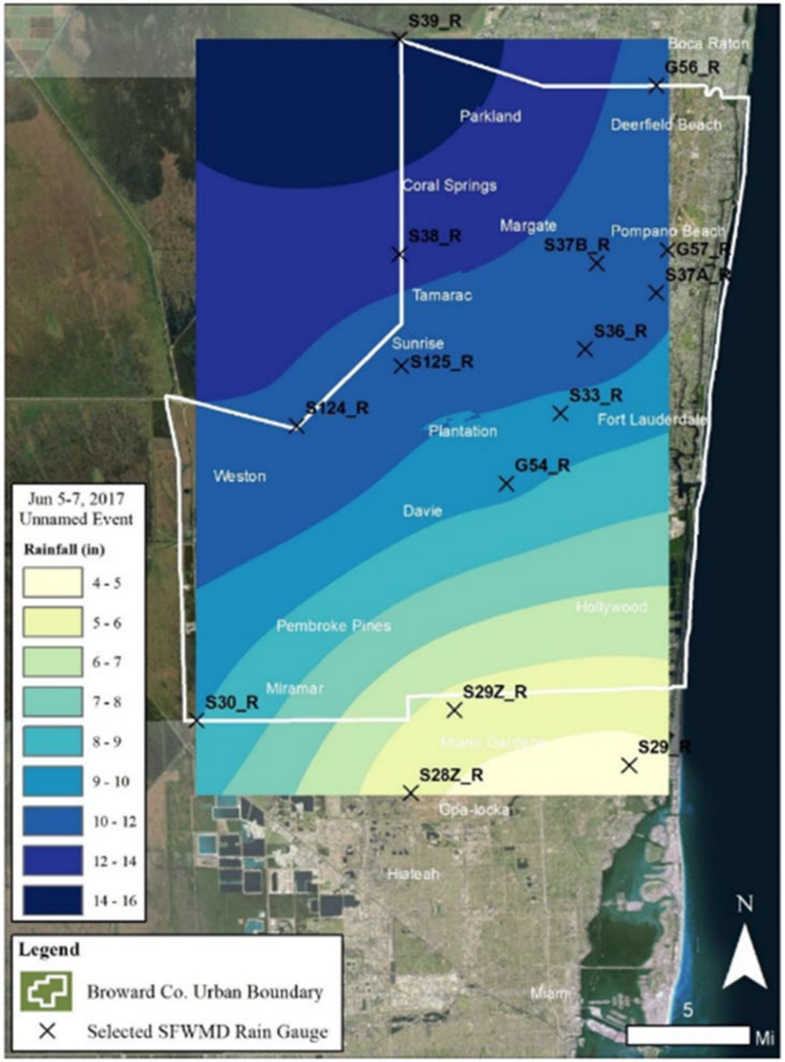


Model Validation

- June 2017 storm event
  - Up to 16" of rainfall in 72 hours
- Calibrated to multiple surface water and groundwater measurement sites

G-54 Discharge





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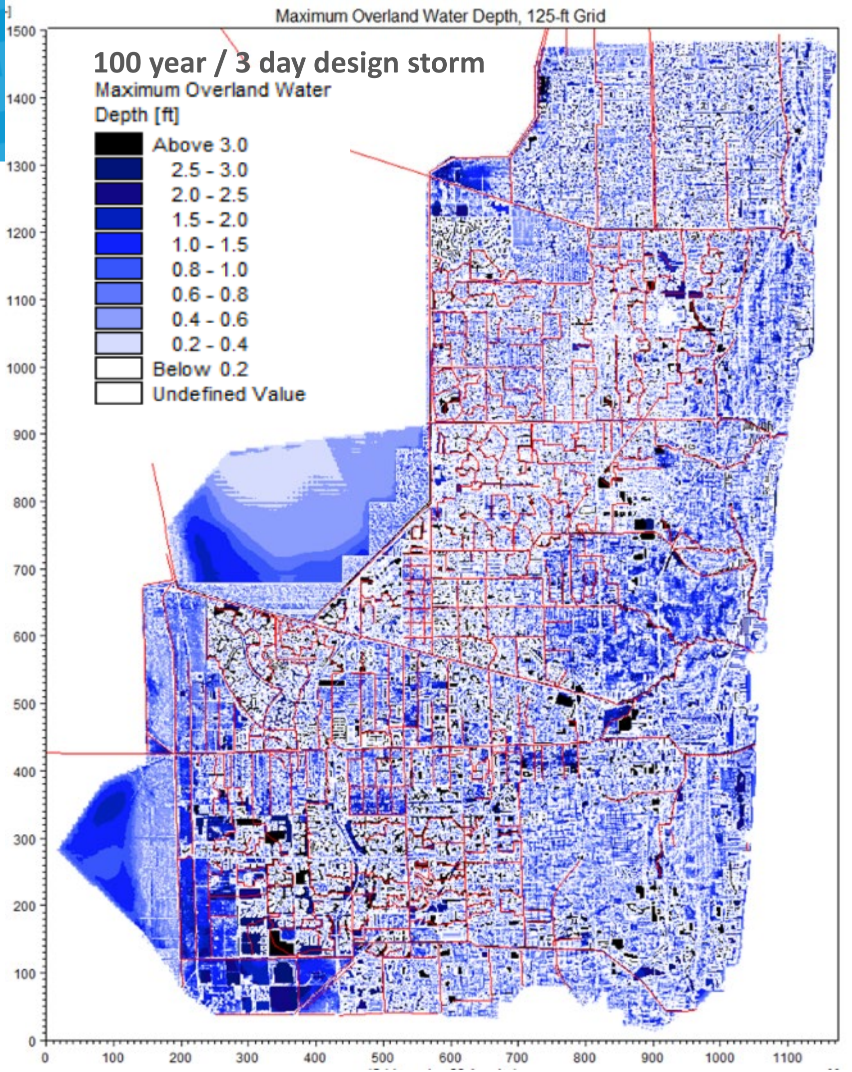
Design Storm Results

- 10, 25, 50, 100, and 500-year, 3-day rainfall events
- NOAA Atlas 14 for rainfall depths w/ SFWMD 3-day distribution
- Implemented rules-based operations for control structures and pumps
- Current conditions average wet season groundwater levels
- No storm surge



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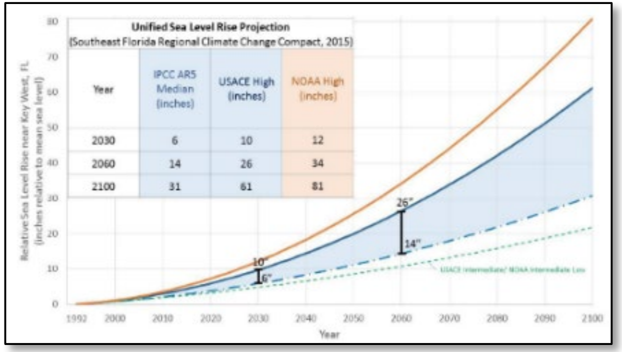
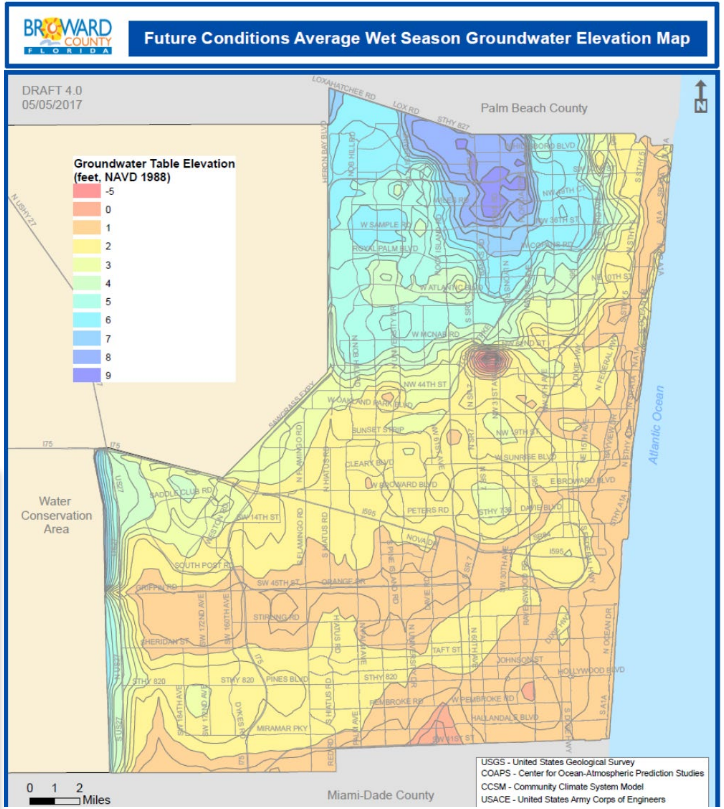
Future Conditions Modeling

Future Conditions Model Updates

- 26” Sea Level Rise (Climate Compact)
- Future Groundwater Conditions (Broward County GW Elev. Map)
- Future Rainfall
- Future Land Use



Year	IPCC AR5 Median (inches)	USACE High (inches)	NOAA High (inches)
2030	6	10	12
2060	14	26	34
2100	31	61	81



Future Conditions 100-Year Flood Elevation Map

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Future Land Use

- Undeveloped and agricultural parcels were assumed to be developed by 2060.
- Exceptions:
  - Wetlands
  - Parks/preserves
- Several golf courses assumed redeveloped to residential, per input from County Planning Dept.

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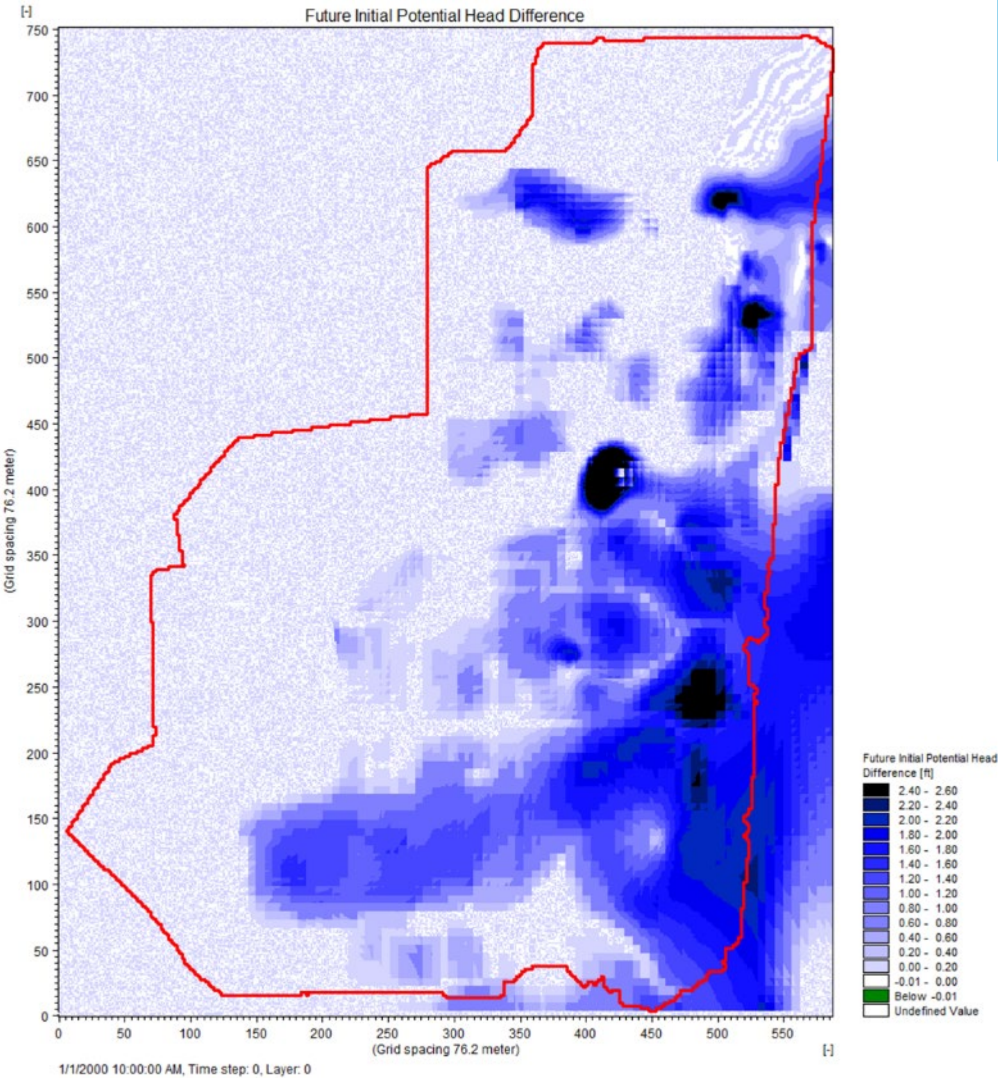
Future Groundwater

- Started with USGS MODFLOW Inundation Model results
- Subtracted Current Conditions map from Future Conditions to create difference map
- Zeroed out negative values and modeling artifacts



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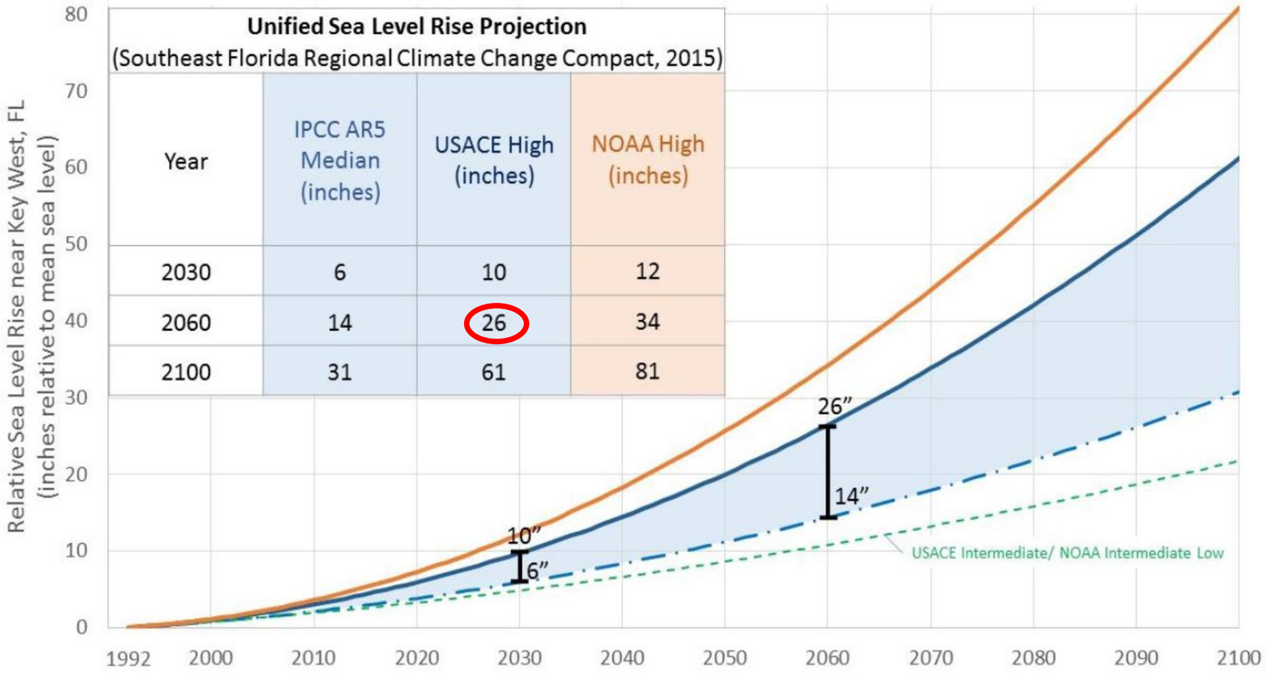
Future Tidal Outfalls and Boundaries

Tidal boundaries increased from current conditions by 26” for:

- 1-D channels
- 2-D Overland
- Groundwater



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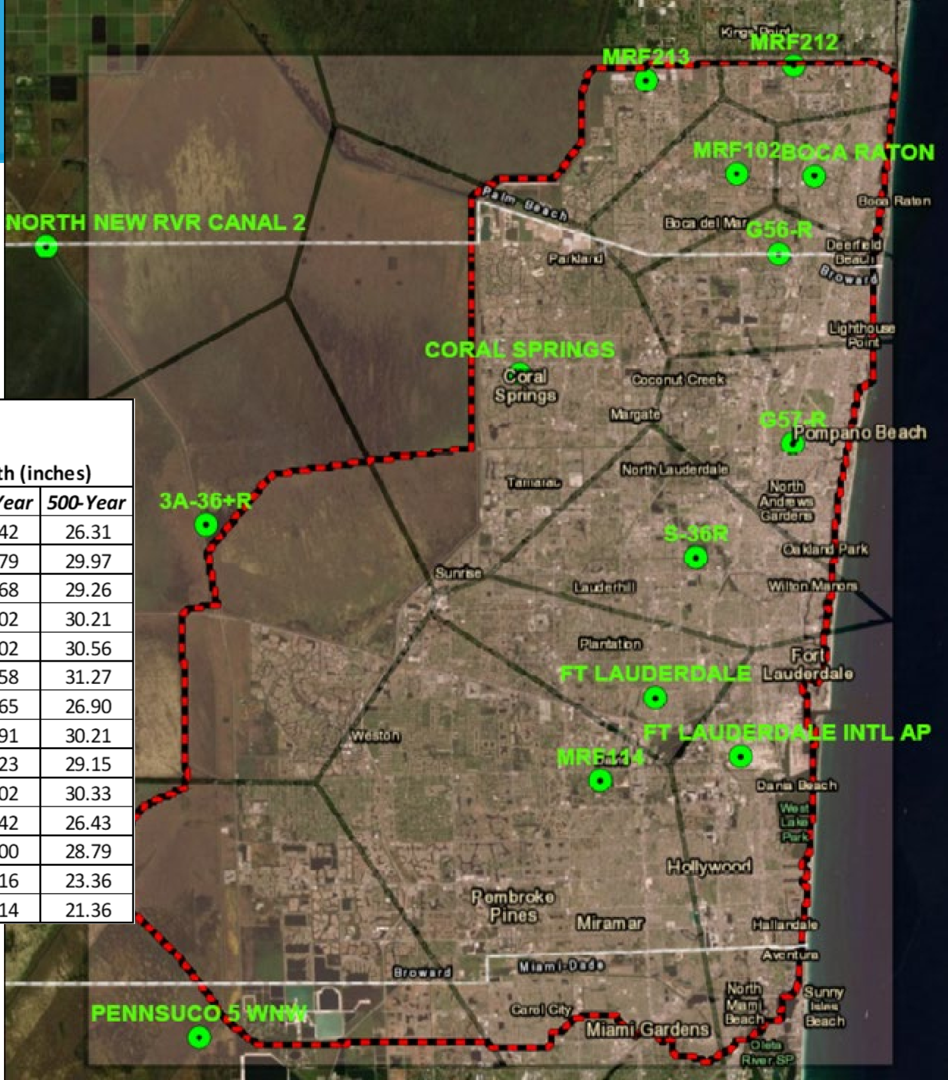
Future Rainfall

Increased Current Conditions 3-Day Depths by these multipliers:

- 10 Yr: 1.09
- 25 Yr: 1.12
- 50 Yr: 1.12
- 100 Yr: 1.13
- 500 Yr: 1.18

NOAA Station	Future 3-Day Storm Rainfall Depth (inches)				
	10-Year	*25-Year*	*50-Year*	*100-Year*	*500-Year*
PENNSUCO 5 WNW	10.53	13.55	15.79	18.42	26.31
MRF114	11.66	15.12	17.70	20.79	29.97
FT LAUDERDALE INTL AP	11.77	15.12	17.70	20.68	29.26
FT LAUDERDALE	11.77	15.23	17.92	21.02	30.21
S-36R	11.77	15.23	17.92	21.02	30.56
G57-R	11.99	15.57	18.37	21.58	31.27
CORAL SPRINGS	10.56	13.55	15.90	18.65	26.90
G56-R	11.66	15.12	17.81	20.91	30.21
MRF102	11.45	14.67	17.25	20.23	29.15
BOCA RATON	11.77	15.12	17.81	21.02	30.33
MRF213	10.54	13.44	15.79	18.42	26.43
MRF212	11.23	14.56	17.02	20.00	28.79
3A-36+R	9.16	11.76	13.78	16.16	23.36
NORTH NEW RVR CANAL 2	8.88	11.19	12.99	15.14	21.36



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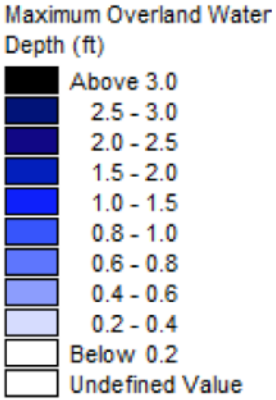
Future Conditions Results

Future 100-year / 3 day storm flood depth results



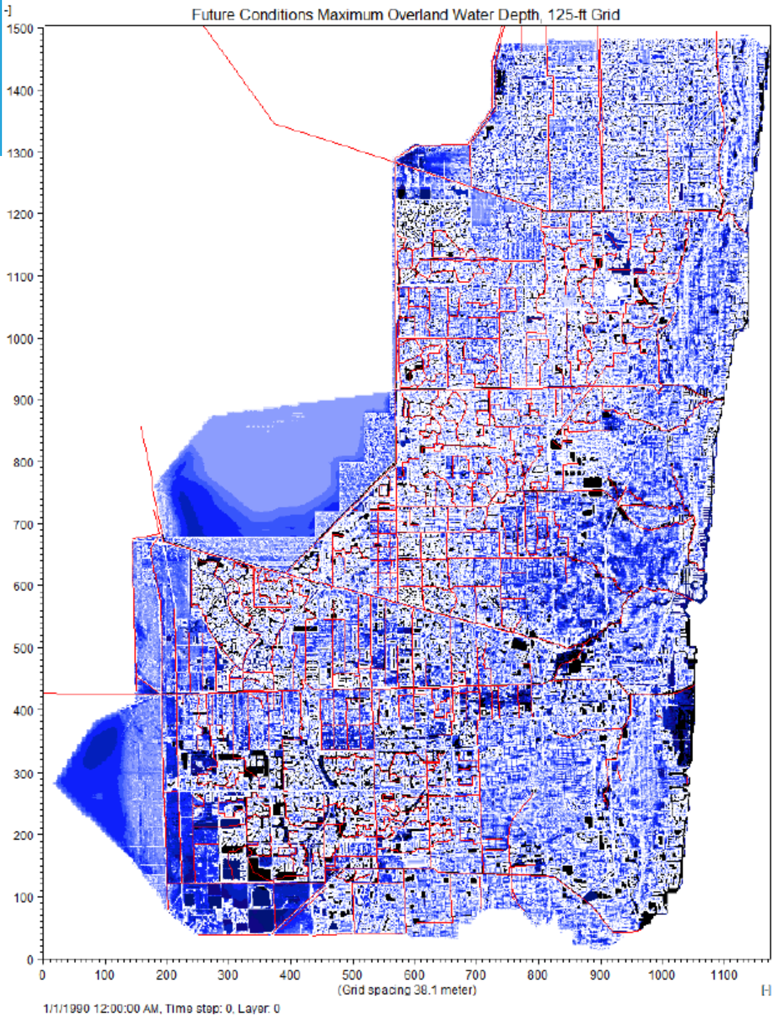


Figure 41: 100-Year Design Storm Maximum Overland Water Depth

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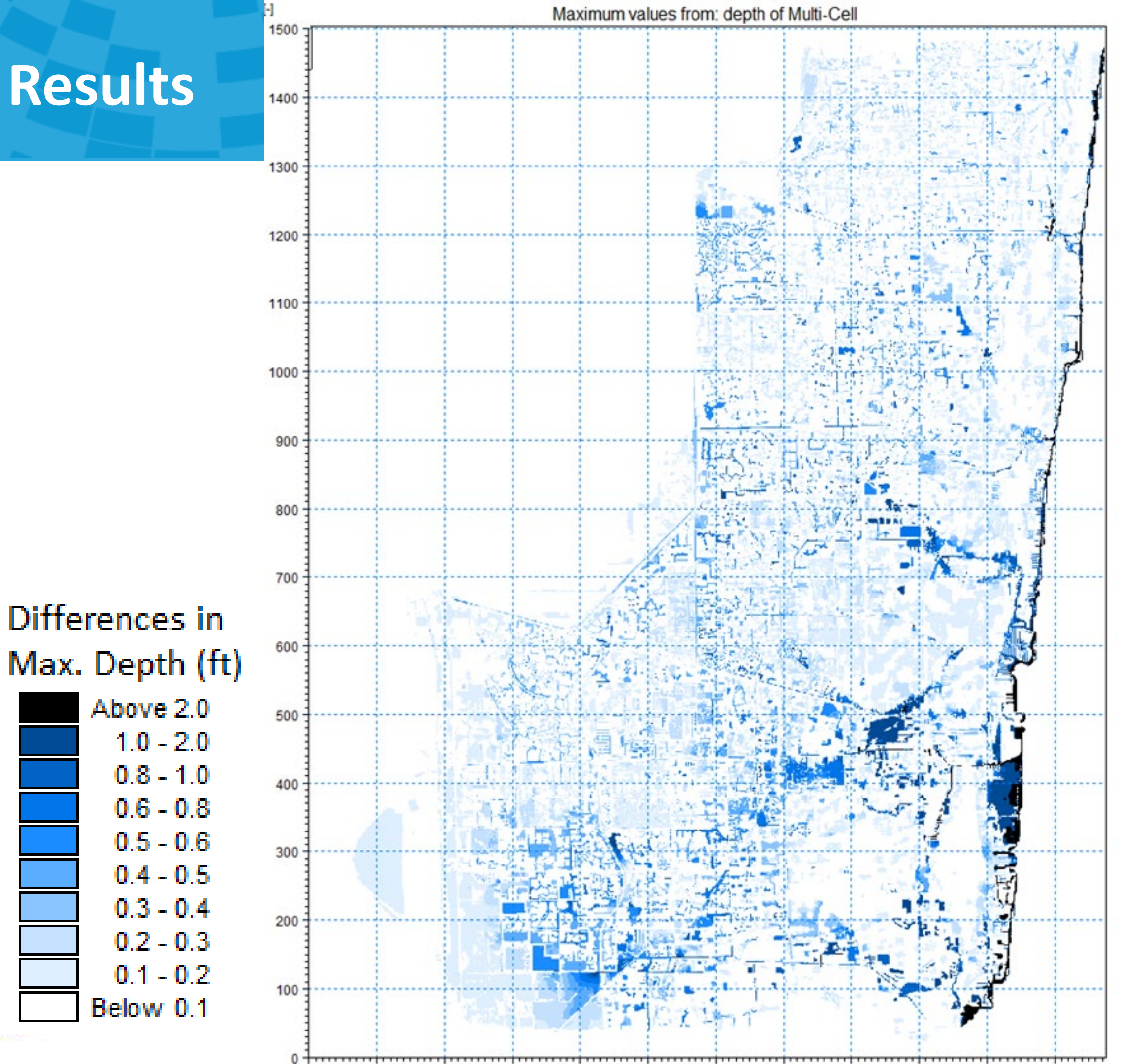
Future Conditions Results

Spatial difference comparison 100-year storm results

Future conditions maximum depths minus current conditions maximum depths



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Future Conditions Results

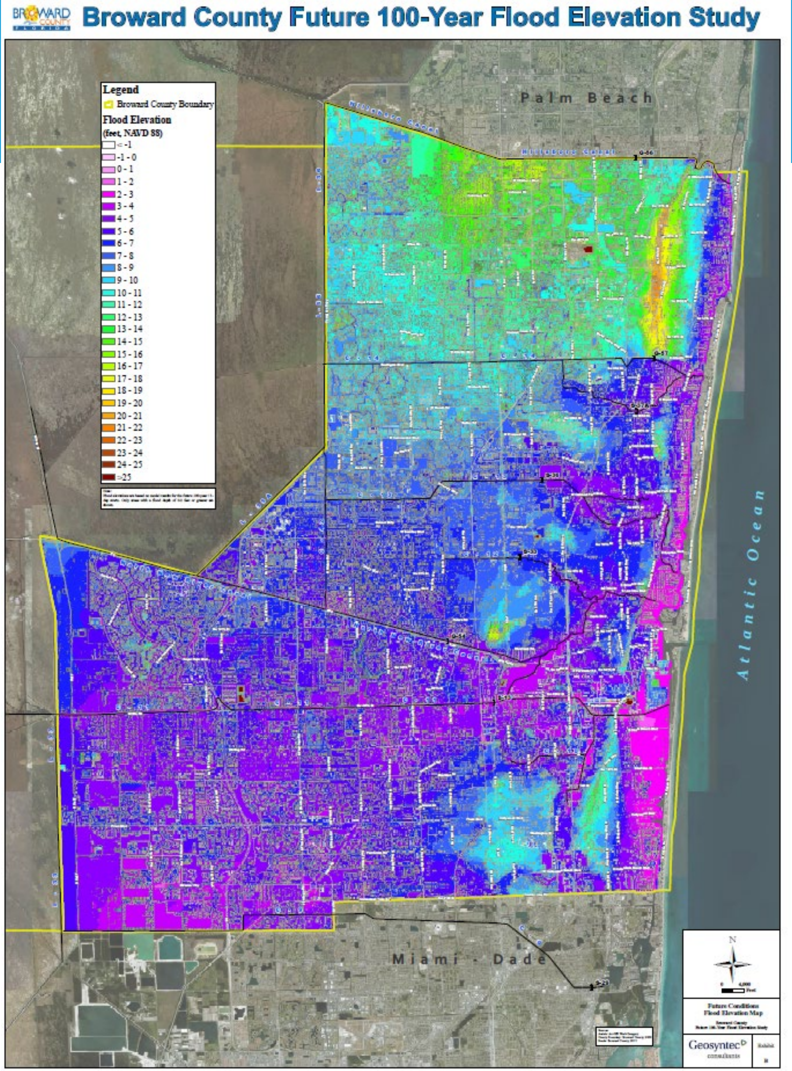
- Preliminary Future 100-year / 3 day storm flood elevations (FT NAVD 1988)

Legend

Broward County Boundary

Flood Elevation (feet, NAVD 88)

- < -1
- -1 - 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12
- 12 - 13
- 13 - 14
- 14 - 15
- 15 - 16
- 16 - 17
- 17 - 18
- 18 - 19
- 19 - 20
- 20 - 21
- 21 - 22
- 22 - 23
- 23 - 24
- 24 - 25
- >25



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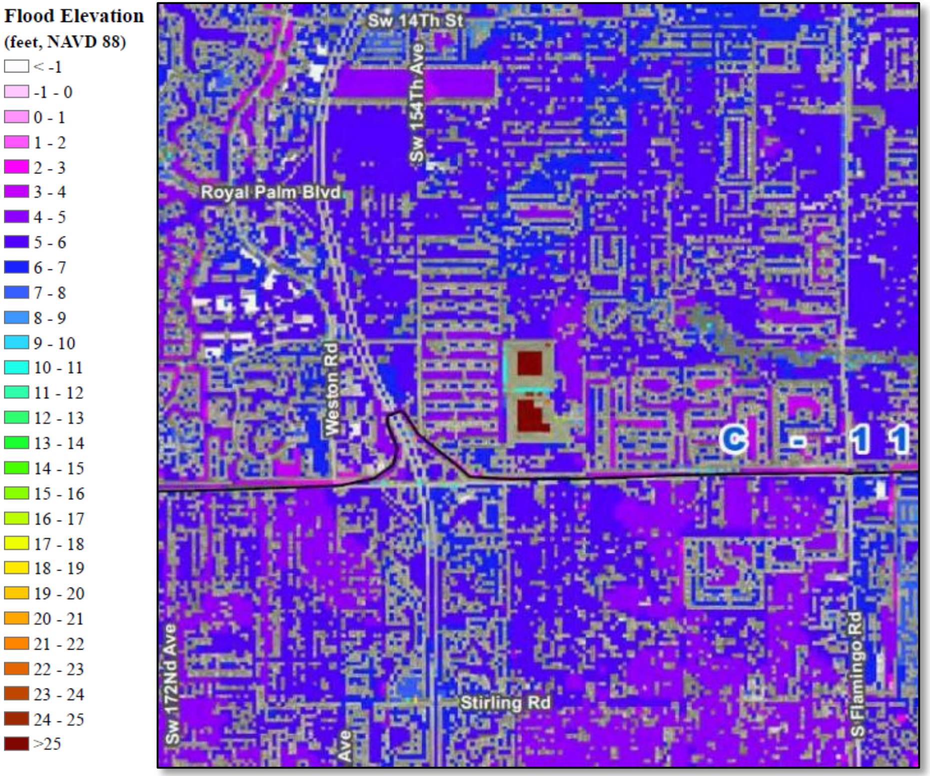
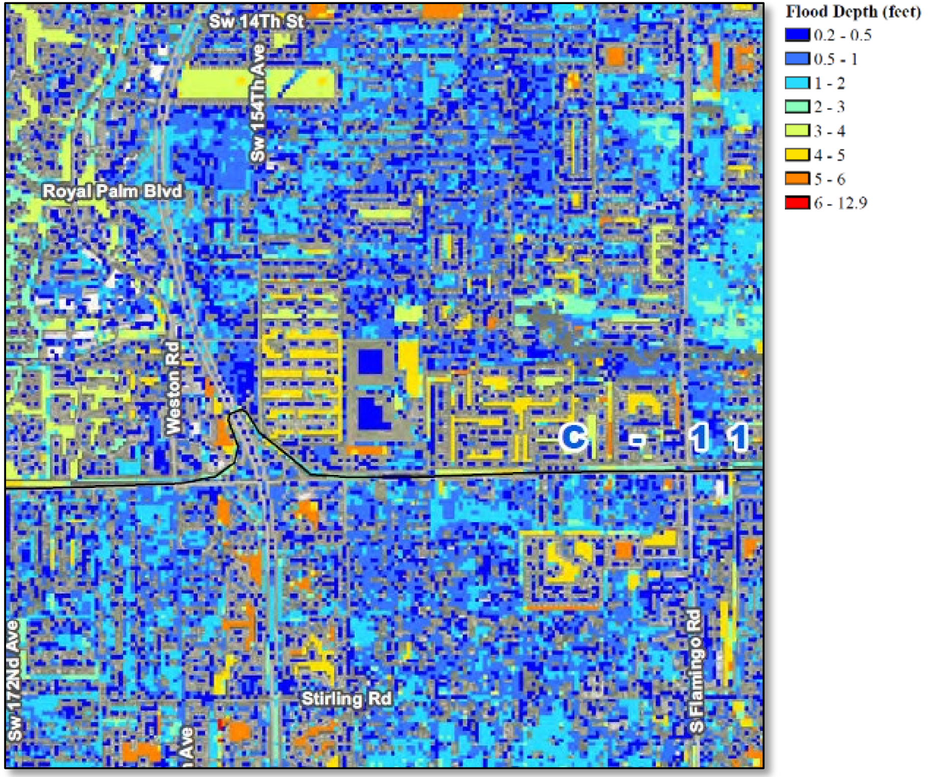
Future Conditions Results - Detail

Flood Elevation



Flood Depth



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Future Conditions 100-Year Flood Elevation Map

Future Rainfall Projections

Future Rainfall Analysis – Proposed Steps

Obtain Rainfall Observations Dataset	Obtain Global Climate Models / Downscaled Datasets	Fitting Probab. Distribution Curve to both Observations and Downscaled Data	Compare Extreme Observations vs. Downscaled Data (historical period)	Calculate Change Factors (ratio future to historic) (Bias correction)	Estimate and Distribute Future Rainfall Projections

Available Data / Approaches:

- NOAA Atlas 14
- CPC Merged Analysis over CONUS
- SFWMD GARR (Baxter)
- NEXRAD
- SFWMD Regular Gauges

- BCCA – Statically (Reclamation)
- LOCA (UCSD) – Stat.
- CORDEX (WCRP) – Dynami...
- COAPS (FCI / FSU) – Dynamically
- ...ESM (...eric) – Dynamically
- BCSA (UF)
- WRF – Jupiter
- Raw GCMs - SimClim

- Annual Maxima
- Partial Duration Series
- GEV and other ...stribution types ...earson III, Pare...
- Shape/Location/Scale Parameters: L-Mom x MLE
- Regional Frequency vs. At site Frequency distributions

- Correlation metrics (RMSE, IVSS, Taylor Diagram)
- Bias calculation

- Quantile Mapping x Quantile Delta Mapping
- Multiplicative x Additive Quantile Delta Mapping
- ...Model Res... x ensemble approach
- Super ensemble vs. subset of best performing models
- Fit IDF Curves to selected durations and frequencies

- Add calculated deltas individually to each station x regional average
- Deterministic vs. perform stochastic simulation on ranges of calculated deltas
- Hourly distribution approaches (Santa Barbara, SFWMD, NOAA Atlas 14)

General Goals / Considerations:

- Represent extreme rainfall precipitation
- Sub daily datasets preferable
- Appropriate Broward coverage
- Length of time series (min 25-30 years)

- Daily Rainfall Data ...sub daily?)
- IPCC AR5 (CMIP5)
- Regional Models
- RCP 8.5 and others?
- 2060 Horizon projection
- Min. 20 years of historical simulation
- Spatial Resolution (less than 30km)

- Duration ...ties of Interest (independently versus joint)
- Rolling window for annual maxima
- NOAA scaling factors (constrained x non-constrained)
- Bias Correction Steps applied previously?

- Statistical parameters (RMSE, S...) quality metrics
- Visualization of data – heat maps

- Stationarity x non-stationarity bias calculation
- Average biases? Models? Spatially?
- Select best performing methods or combine them all together?

- Representing Uncertainties (stochastic approach)
- Spatial differences among changing factors

Large associated uncertainties

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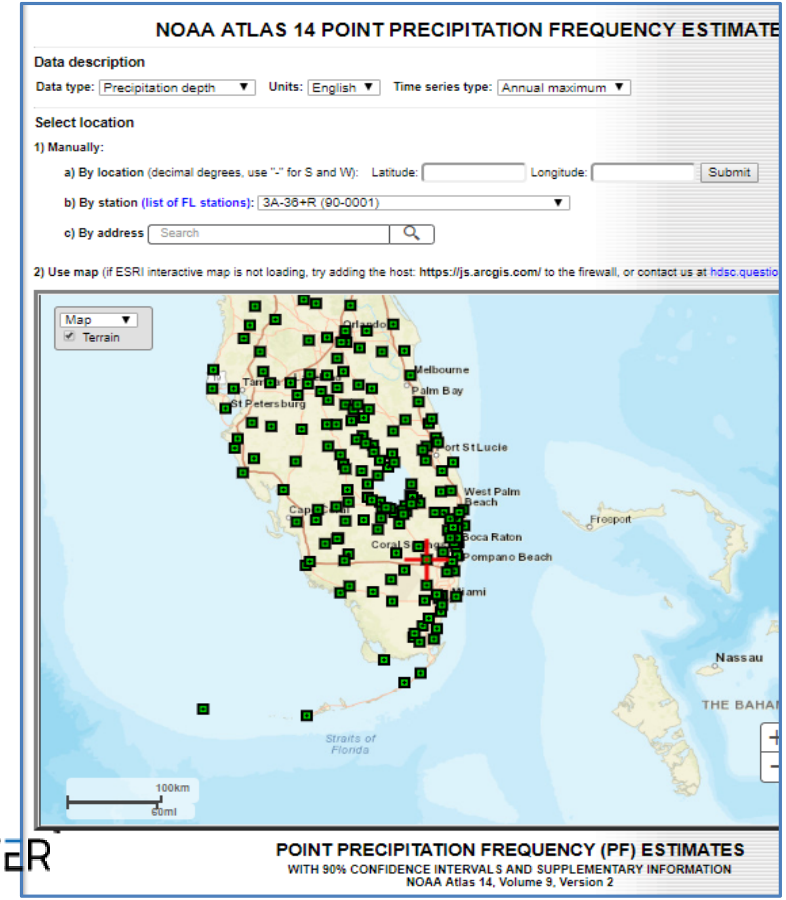
Future Rainfall Analysis Datasets

- Evaluated Datasets
  - CLIMsystems
    - BC
    - Hyperion
    - FSU COAPS
    - CORDEX
    - Raw GCMs
  - Jupiter Intelligence
    - LOCA
    - Jupiter WRF
- Leverage Atlas 14 Rainfall Stations
- Target Future Year 2060

All best currently available global model data



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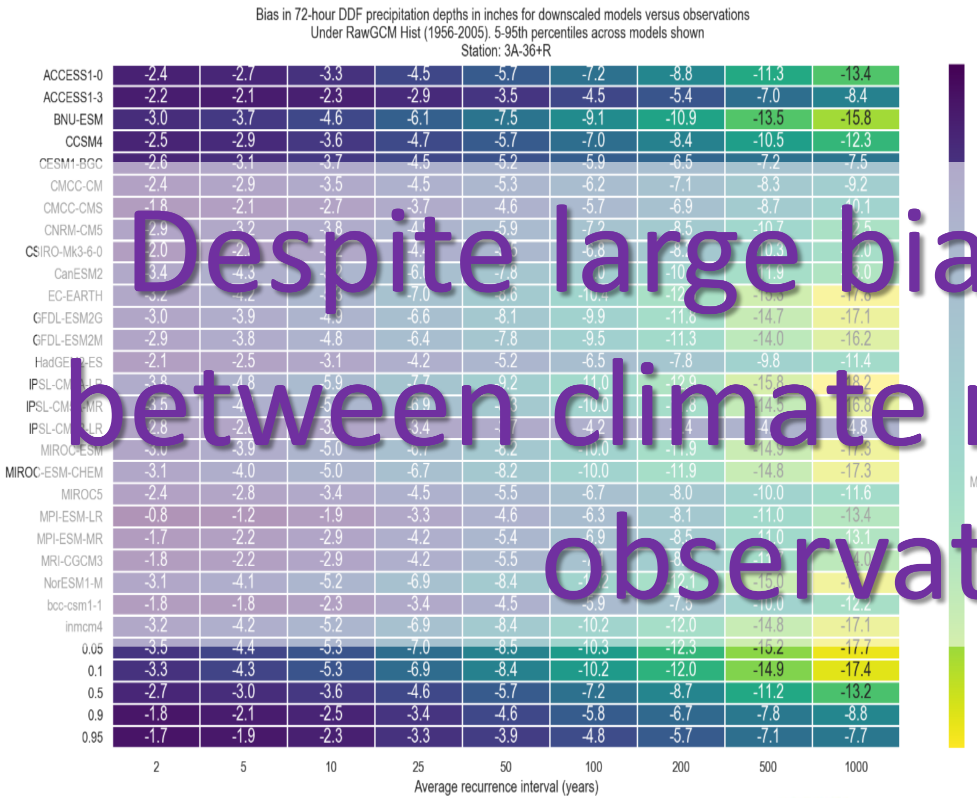
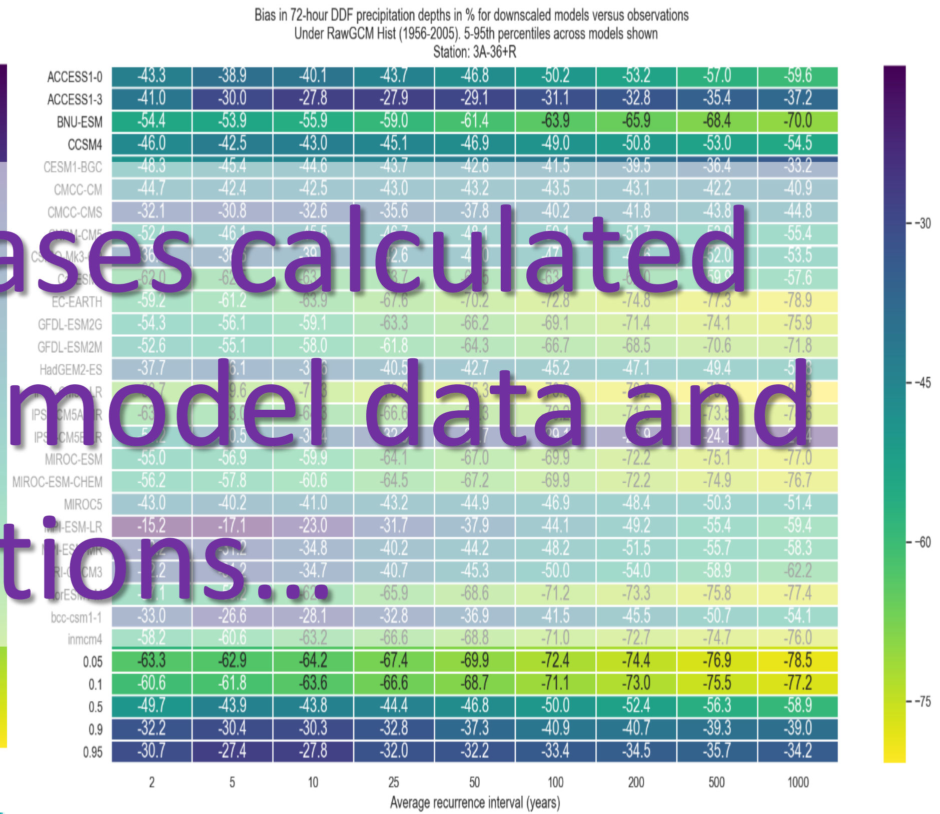
Bias estimation

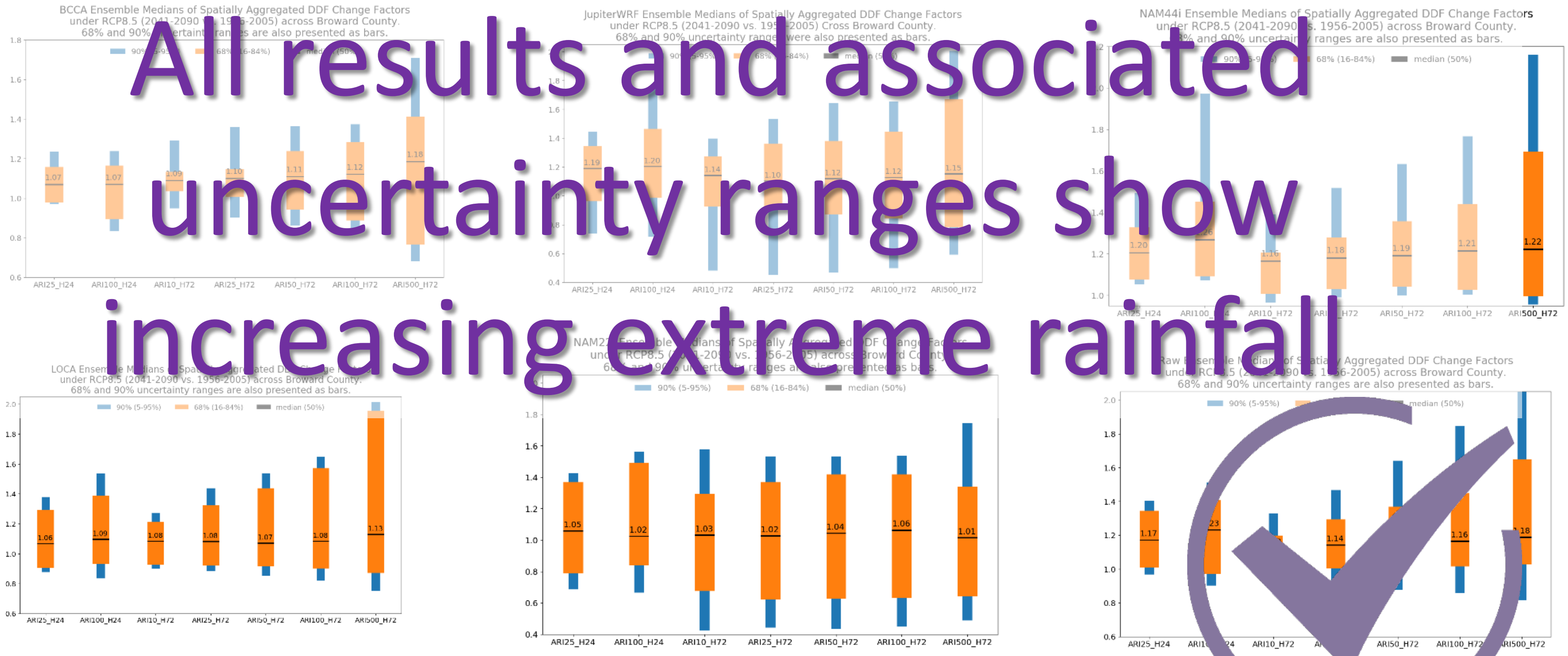




Despite large biases calculated between climate model data and observations…

Changing Factors

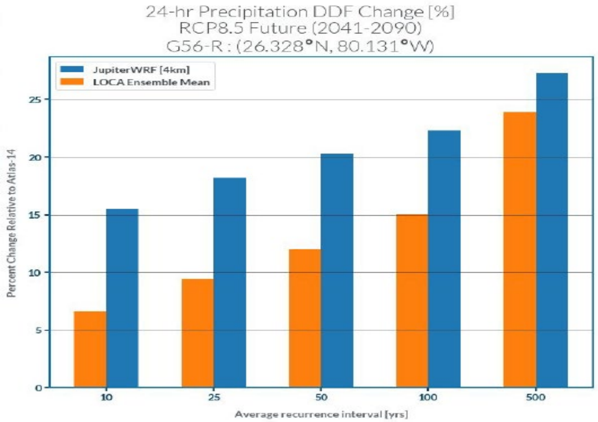
All results and associated uncertainty ranges show increasing extreme rainfall

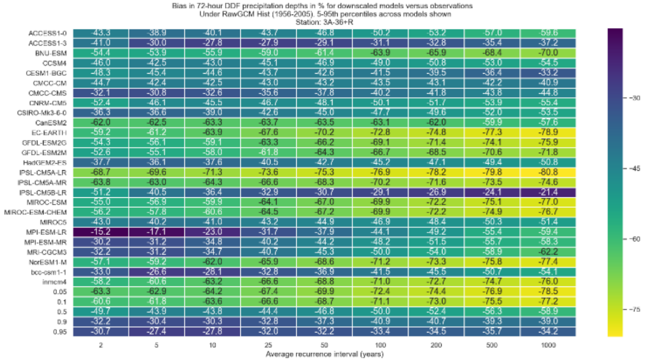


Future Rainfall – Experts Panel

- Workshop on September 17
  - Representatives from:
    - Broward County
    - SFMD
    - FIU
    - USGS
    - Consultant Team
    - Other interested parties
  - Consensus on strategy for moving forward:

Super-Ensemble approach





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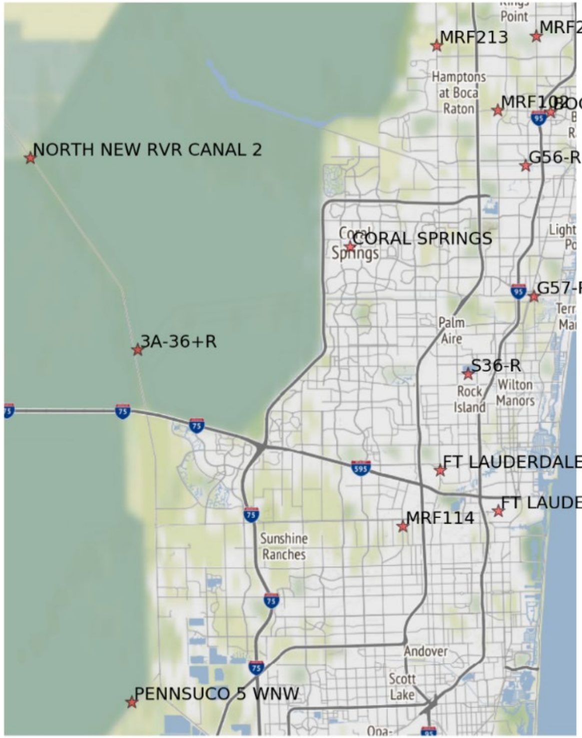
Combining Results for Broward

- Best available approach
- No significant difference for the calculated CF among stations; small spatial variability:



ADOPT SINGLE AVERAGE FACTOR (%) FOR THE ENTIRE URBAN AREA

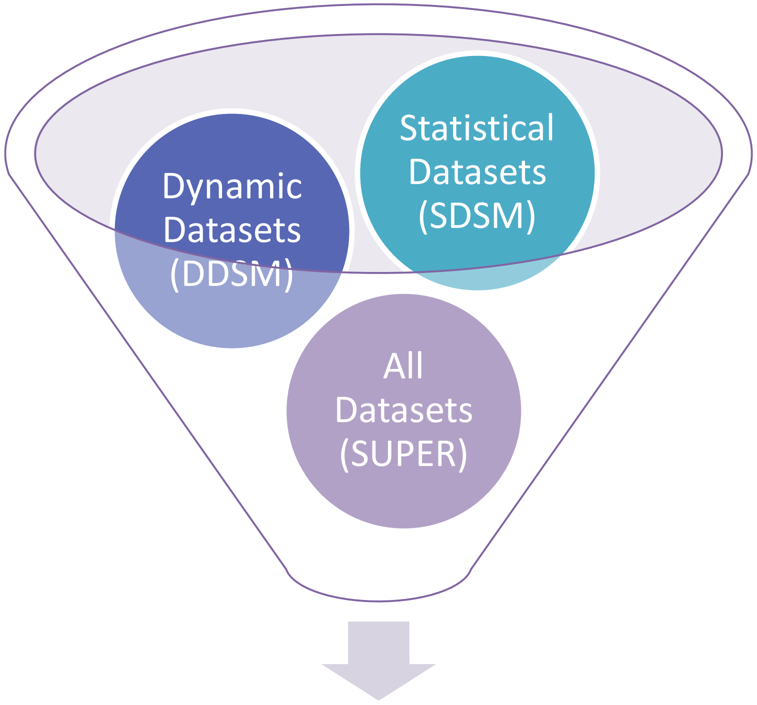
IPCC Recommendations

- Evaluating Results from Multiple Models
- Measure of Model Skills (model performance): yet to be identified
- Importance of characterizing uncertainty:
  - More than one dataset to represent observations
  - Multi-model calculations out-perform individual models
  - Multiple sources (Raw GCMs, Regional Models statistical & dynamical downscaled data)
  - Weighting or Subsets Approaches: need to determine statistical significance of the difference between models – given metric
  - ***Super Ensemble Approach,*** plus documentation of all individual results
  - Sample uncertainty space

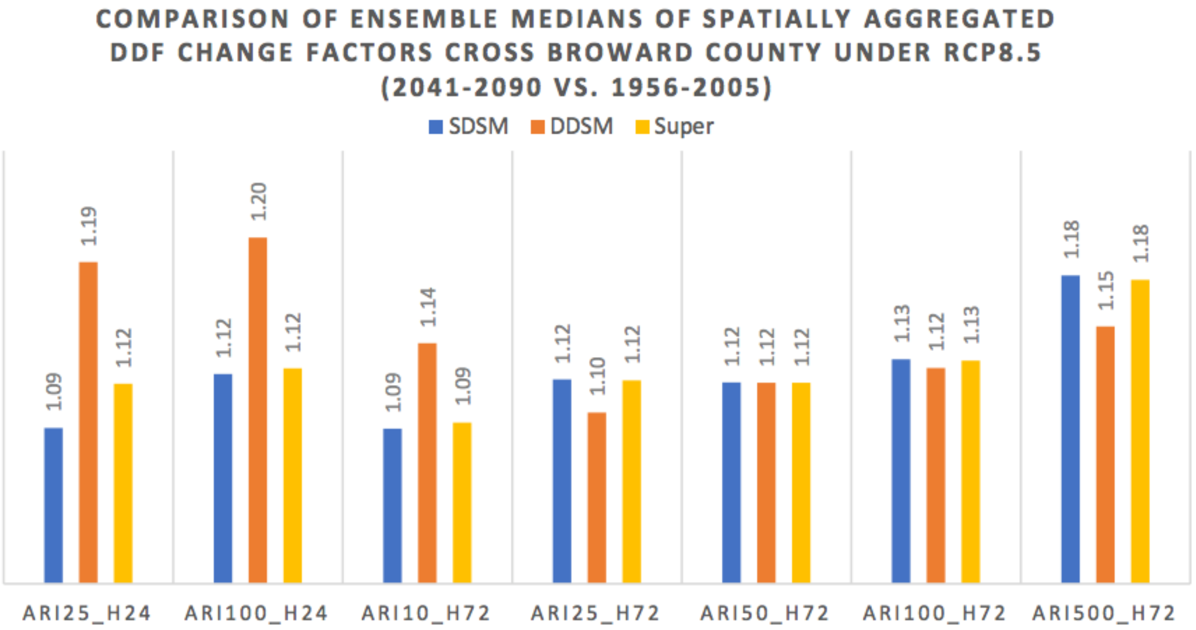
Aligned with all IPCC Recommendations

Super Ensemble

- Super-ensemble Approach:
  - Different subsets of all the individual model projections from the different datasets are chosen and fittings are calculated from each of these subsets (prob. analysis)
  - This approach more explicitly calculates the uncertainty in the median change factors, and reduce the generalization error of the predictions.
  - This approach converges on providing a single model domain-wide scaling value to use for storm events

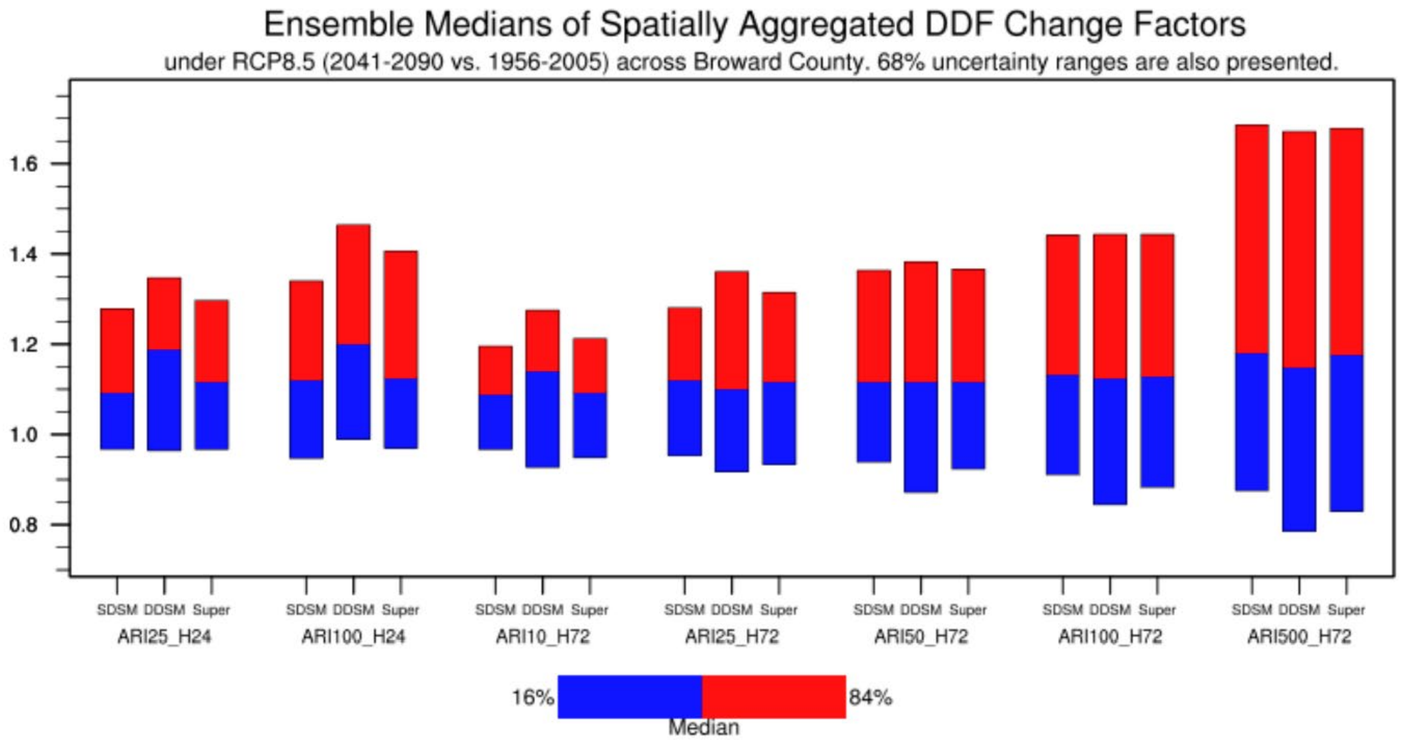


Ensemble Results



Note: (1) SDSM=Raw + BCCA + LOCA, DDSM=NAM22i + NAM44i + JupiterWRF, Super=SDSM + DDSM; (2) JupiterWRF only contributed to H24 in DDSM and Super.

Ensemble Results

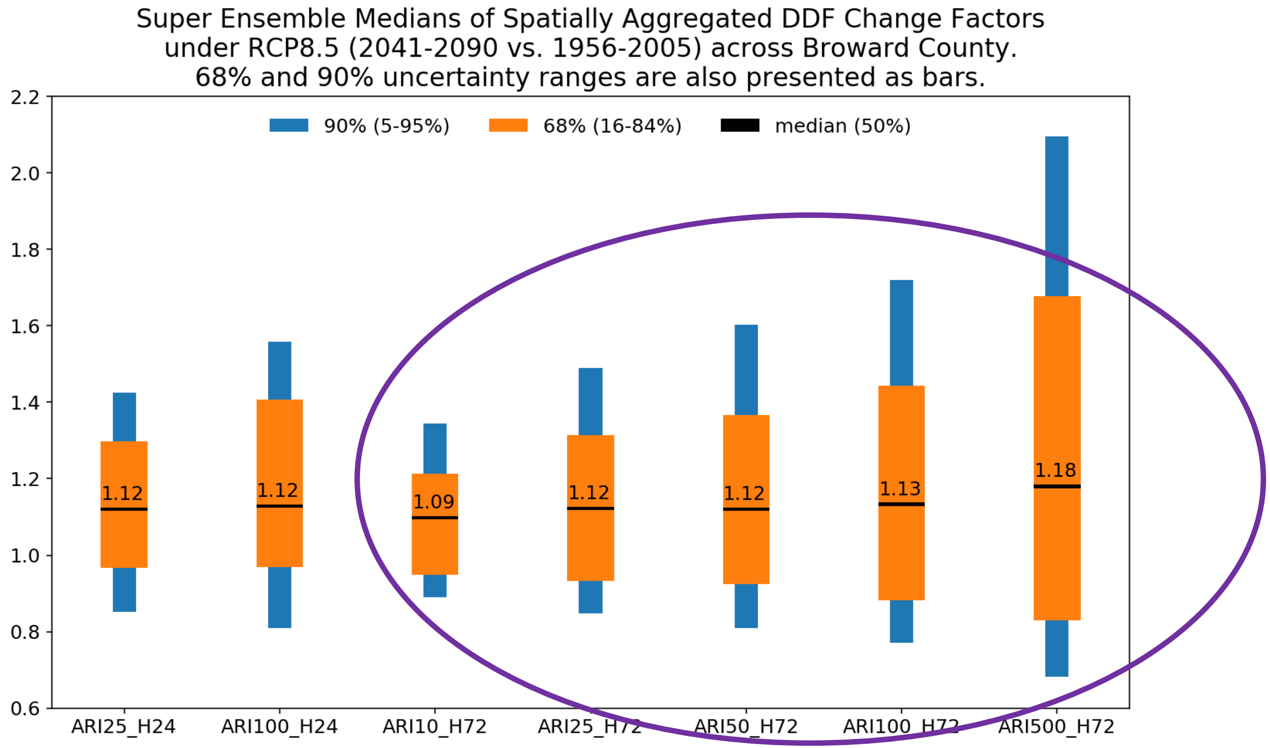


Super-ensemble Results for Design Storms (Longer Durations - 3 days)

Single model domain-wide scaling values for design storm events

- 10 year/3 day = 9% increase*
- 25 year/3 day = 12% increase*
- 50 year/3 day = 12% increase*
- **100 year/3 day = 13% increase***
- 500 year/3 day = 18% increase*

**To be applied over NOAA Atlas 14 precipitation frequency estimates*



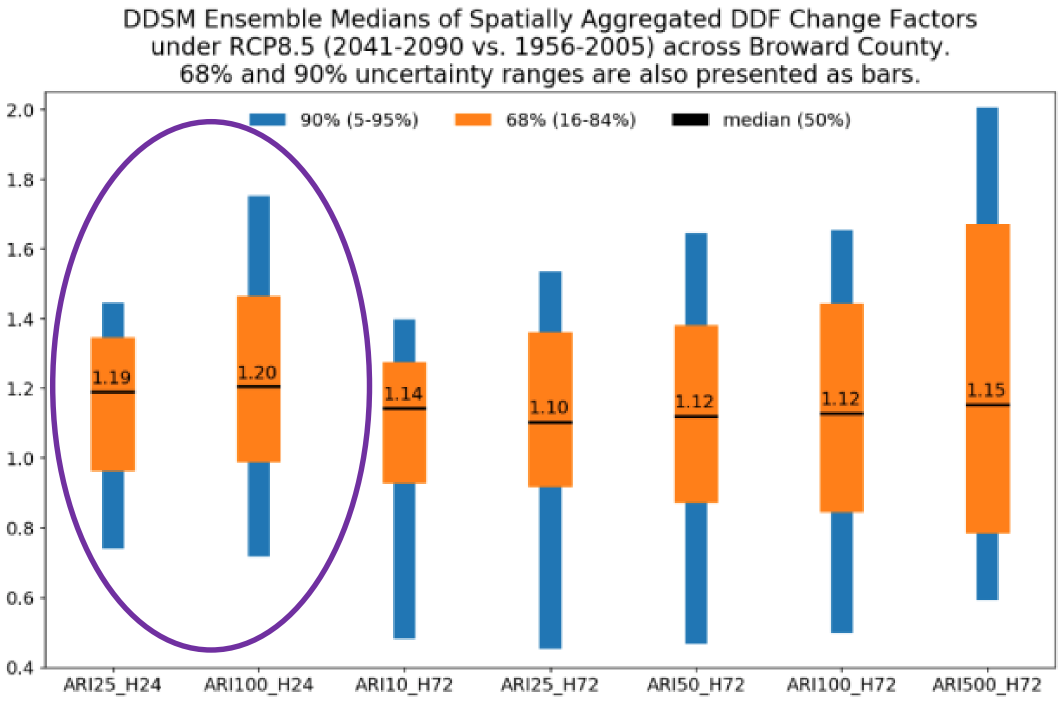
Whisker diagram of SUPER ensemble medians of spatially aggregated DDF change factors with uncertainty ranges.

Super-ensemble Results for Design Storms (Shorter Durations – 24 hours)

Single model domain-wide scaling values for design storm events

- 25 year/1 day = 19% increase*
- 100 year/1 day = 20% increase*

**To be applied over NOAA Atlas 14 precipitation frequency estimates*



Whisker diagram of DDSM ensemble medians of spatially aggregated DDF change factors with uncertainty ranges.

Thank you

Questions?

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