Characterizing Historical and Projected Future Droughts for South Florida

Michelle M. Irizarry-Ortiz, Hydrologist (mirizarry-ortiz@usgs.gov)

U.S. Geological Survey

Florida WCA Webinar
May 30, 2024

USGS science for a changing world

Acknowledgments

Carolina Maran, SFWMD

Tarana Solaiman, SFWMD

Jayantha Obeysekera, FIU

John F. Stamm, USGS

Brett Johnston, USGS

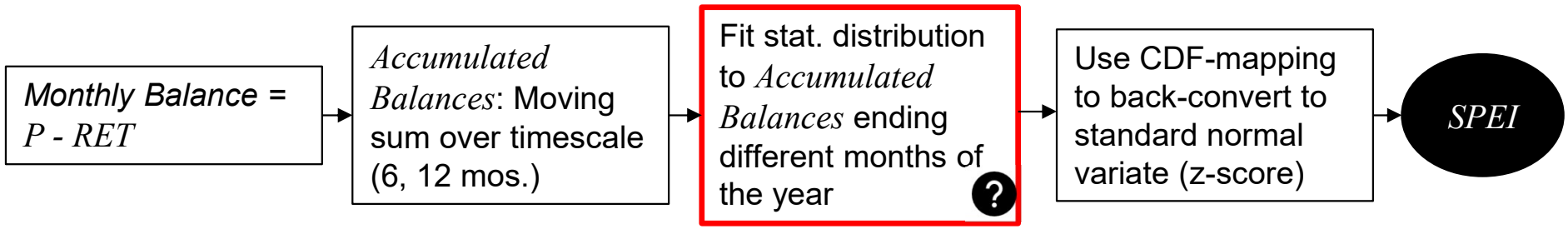
FIU

Objectives and Scope

- Collaborative project between USGS, SFWMD, and FIU
- Evaluate projections of future drought event characteristics from climate models
- Will inform water-supply planning vulnerability assessments at SFWMD to determine the capacity of local and regional water resources to meet future water needs.
- Ultimate Need:
  - Identify a small subset of climate models representing a plausible range of future drought conditions to drive hydrologic and groundwater models used in water-supply planning for 2075.

Characterizing Historical Droughts

- SPI and SPEI estimated from 2x2 mi SFWMD gridded *P* and *RET* from historical observations and reanalysis data (1948–2022)



P: monthly precipitation
RET: monthly reference evapotranspiration
SPEI: Standardized Precipitation Evapotranspiration Index

SPI: Standardized Precipitation Index (same steps as for SPEI but using just Precipitation instead of Balances)

Characterizing Historical Droughts

- SPI and SPEI estimated from 2x2 mi SFWMD gridded *P* and *RET* from historical observations and reanalysis data (1948–2022)

Table I. SPI categories

SPI	Category
2.00 and above	Extremely wet
1.50 to 1.99	Very wet
1.00 to 1.49	Moderately wet
−0.99 to 0.99	Near normal
−1.00 to −1.49	Moderately dry
−1.50 to −1.99	Severely dry
−2.00 and less	Extremely dry

McKee et al. (1993)

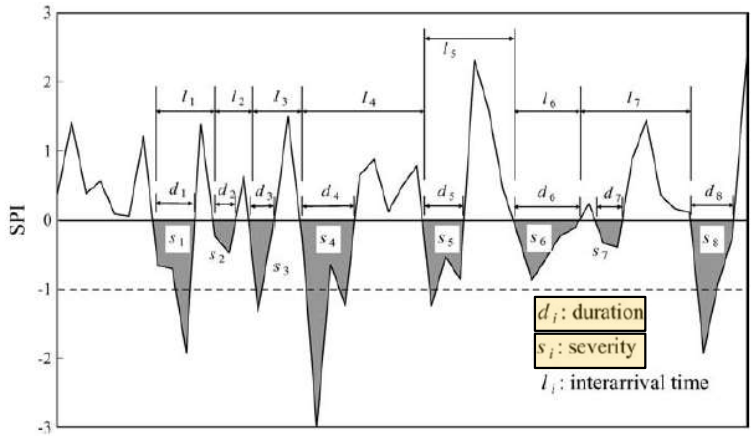
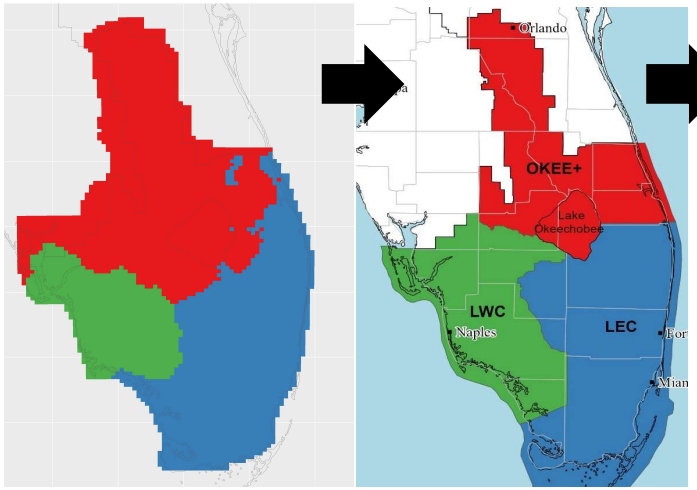


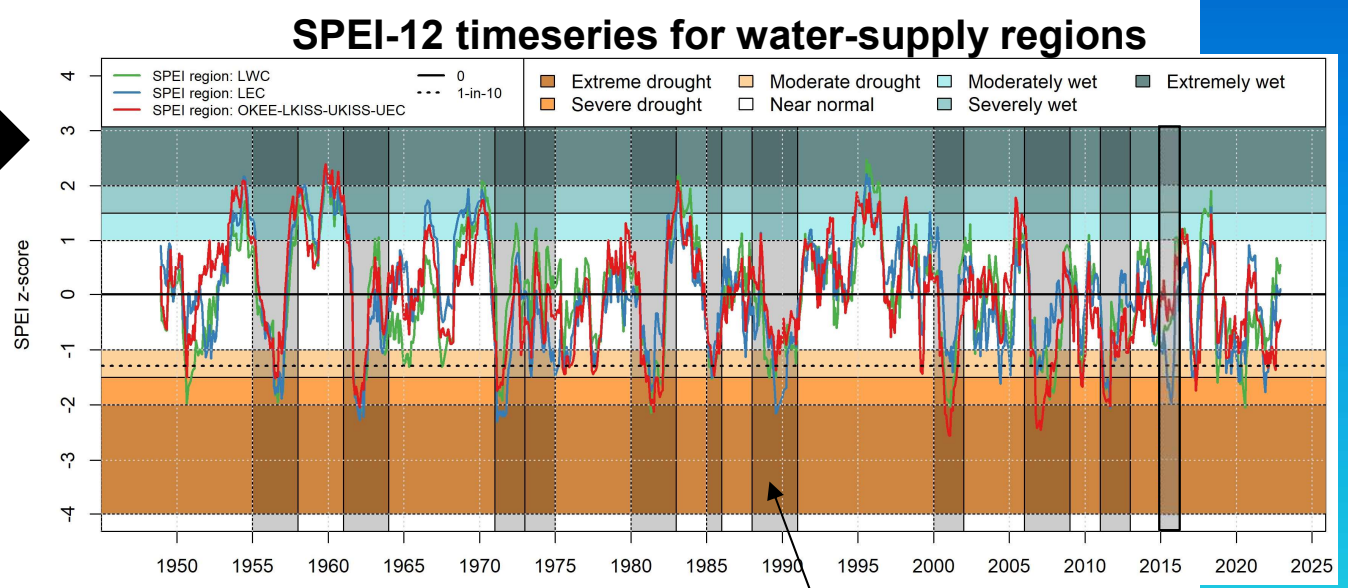
Figure 1. Definition sketch of drought events.

$i_i: intensity = severity/duration$

Shiau (2006)

SPI and SPEI Regionalization via PCA





LWC: Lower West Coast, LEC: Lower East Coast,
OKEE+: Lower & Upper Kissimmee, Upper East Coast, plus Lake Okeechobee

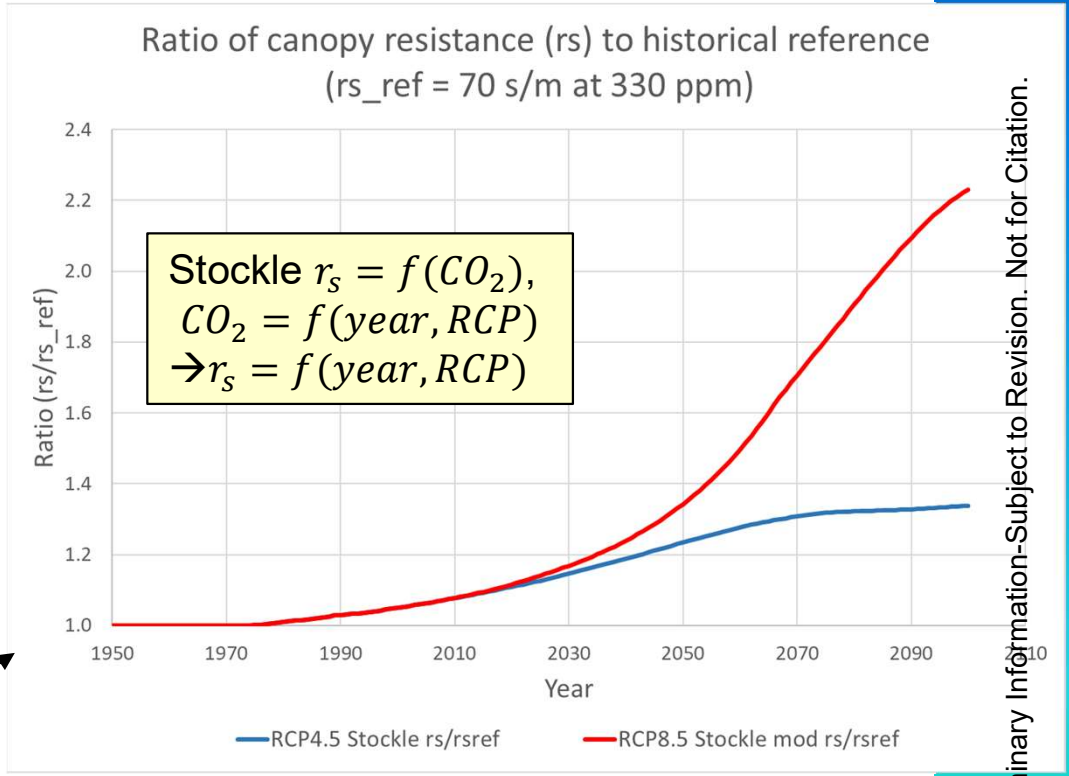
Historical droughts of significance

Region	SPEI Timescale (months)	Months of the year	Sen-Theil Trend (SPEI index value/mo. per yr.)
LWC	1	Aug.	+0.0102*
LWC	1	Oct.	-0.0122*
LEC	1	Oct.	-0.0147*
OKEE+	1	Oct.	-0.0127
OKEE+	12	Jan.-Dec.	-0.0114

*similar trends found for SPI

Future Drought Projections

- MACA (CMIP5) Statistically Downscaled Climate Dataset. 20 GCMs, 2 bias-correction datasets, 2 scenarios: RCP4.5 and RCP8.5.
  - Monthly *P* and meteorological data for *RET* estimation. *RET* bias-corrected to USGS *RET* for 1995–2005.
  - Due to global warming, *RET* will increase into the future. May be mitigated at least partially by potential increases in plant **stomatal resistance (r_s)** due to increased CO_2 concentrations. **What r_s to assume into the future?**



Challenges with SPEI Projections

- Distributions fit to 6- and 12-mo. *Accumulated balances* (*P* – *RET*) in the historical reference period 1950–2005 only (12 fits, one per month). Then we **also** use those historically fitted probability distributions to determine future SPEI values for 2006–2100, i.e., future SPEI is *with respect to the historical reference period.*
- Problems when distributions are fit to *Accumulated balances* in the "worst-case" scenario assuming that the current stomatal resistance holds into the future (GW increases *RET* unimpeded):
  - Distributions that best capture lower tail tend to result in **many +/- infinity SPEI values in the future for some models**. Major non-stationarity into the future.
- What do we do then?

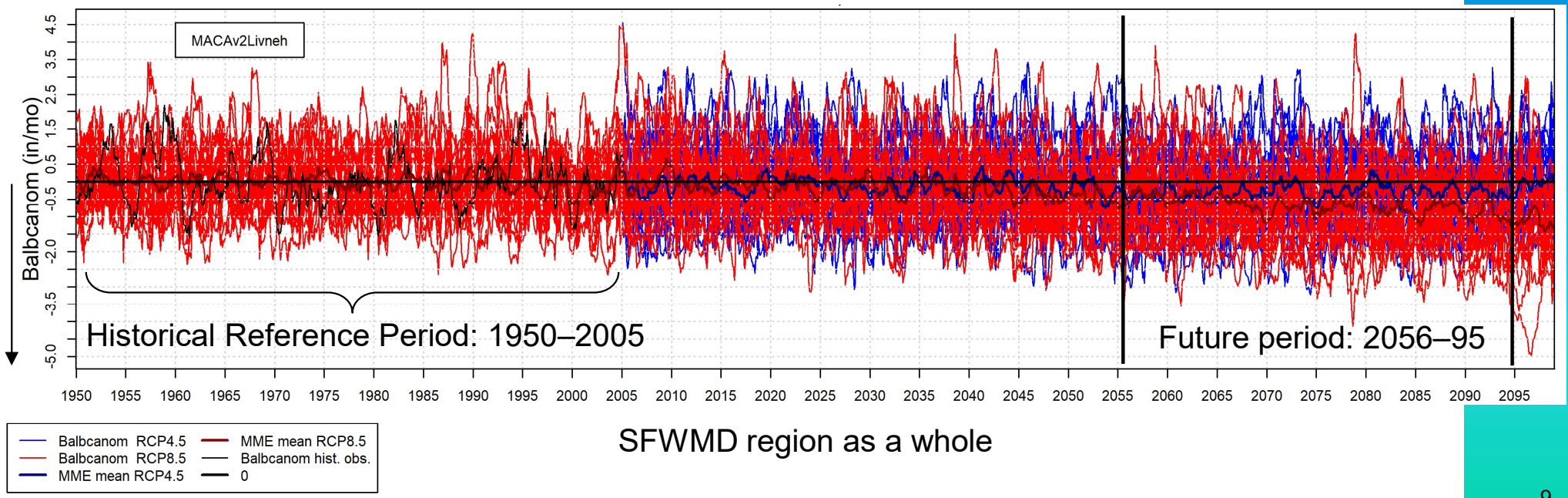
Alternative: Timescale-Averaged Balance Anomalies

Monthly Balance = *P - RET*

→ Subtract mean historical *balance* for month of the year to get *Balance Anomalies*

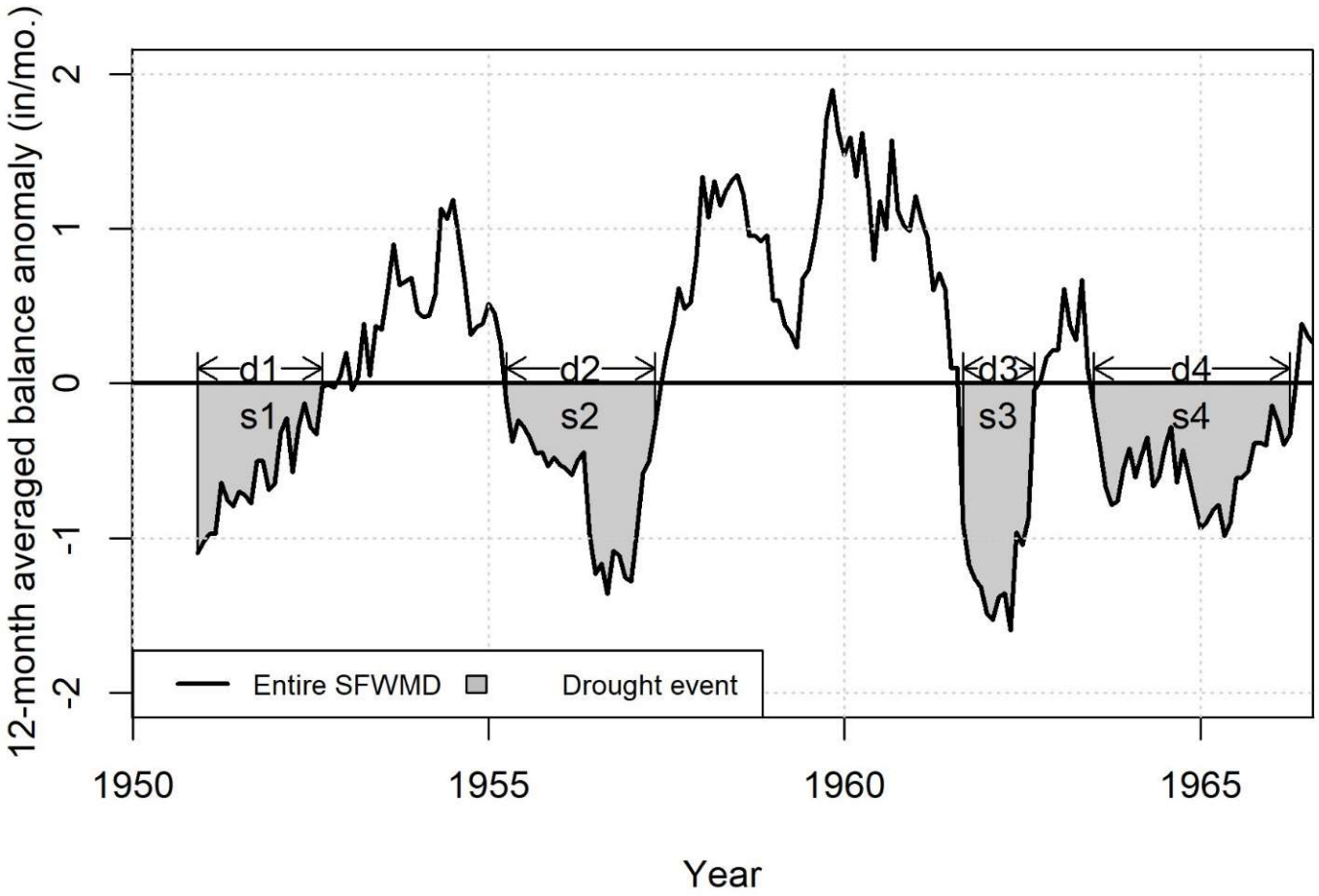
→ Moving average of *Balance Anomalies* over timescale (6, 12 mos.)

→ ***Timescale-Averaged Balance Anomaly***



SFWMD region as a whole

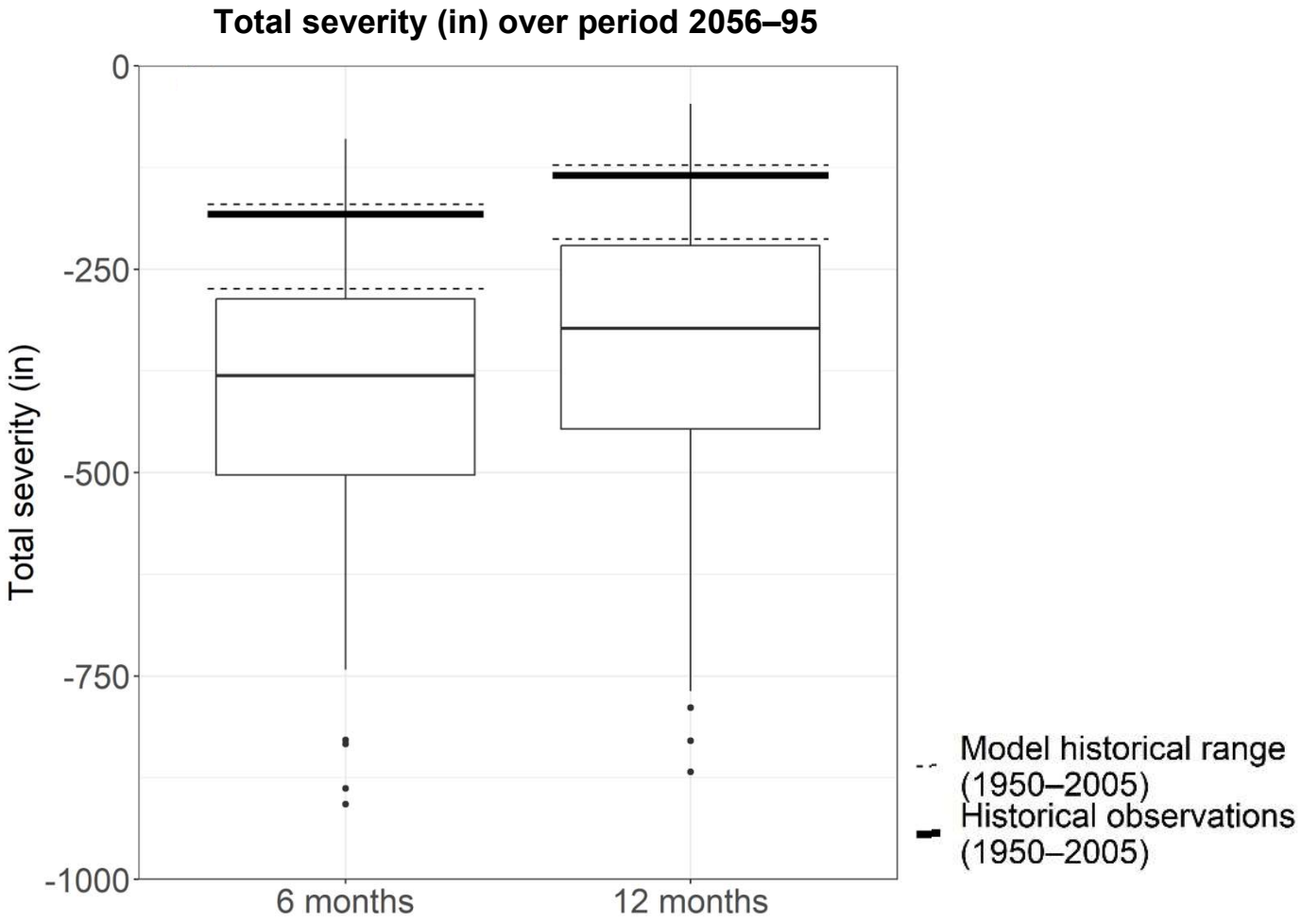
Drought-Event Characterization

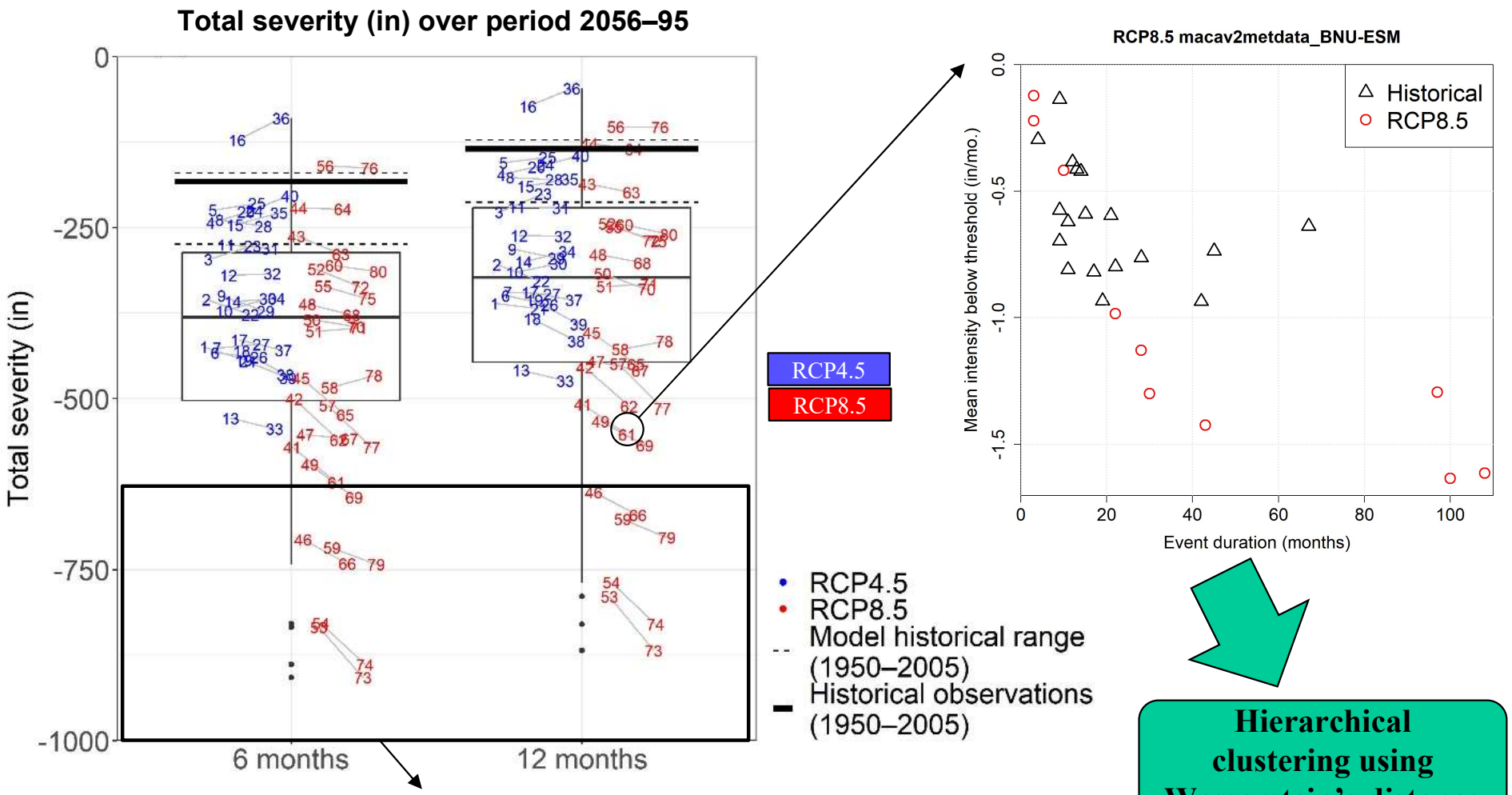


s_k: severity for event *k*
d_k: duration for event *k*
i_k: intensity for event *k*

$$i_k = {}^{s_k}/_{d_k}$$

Convention for droughts:
$s_k < 0$ and $i_k < 0$



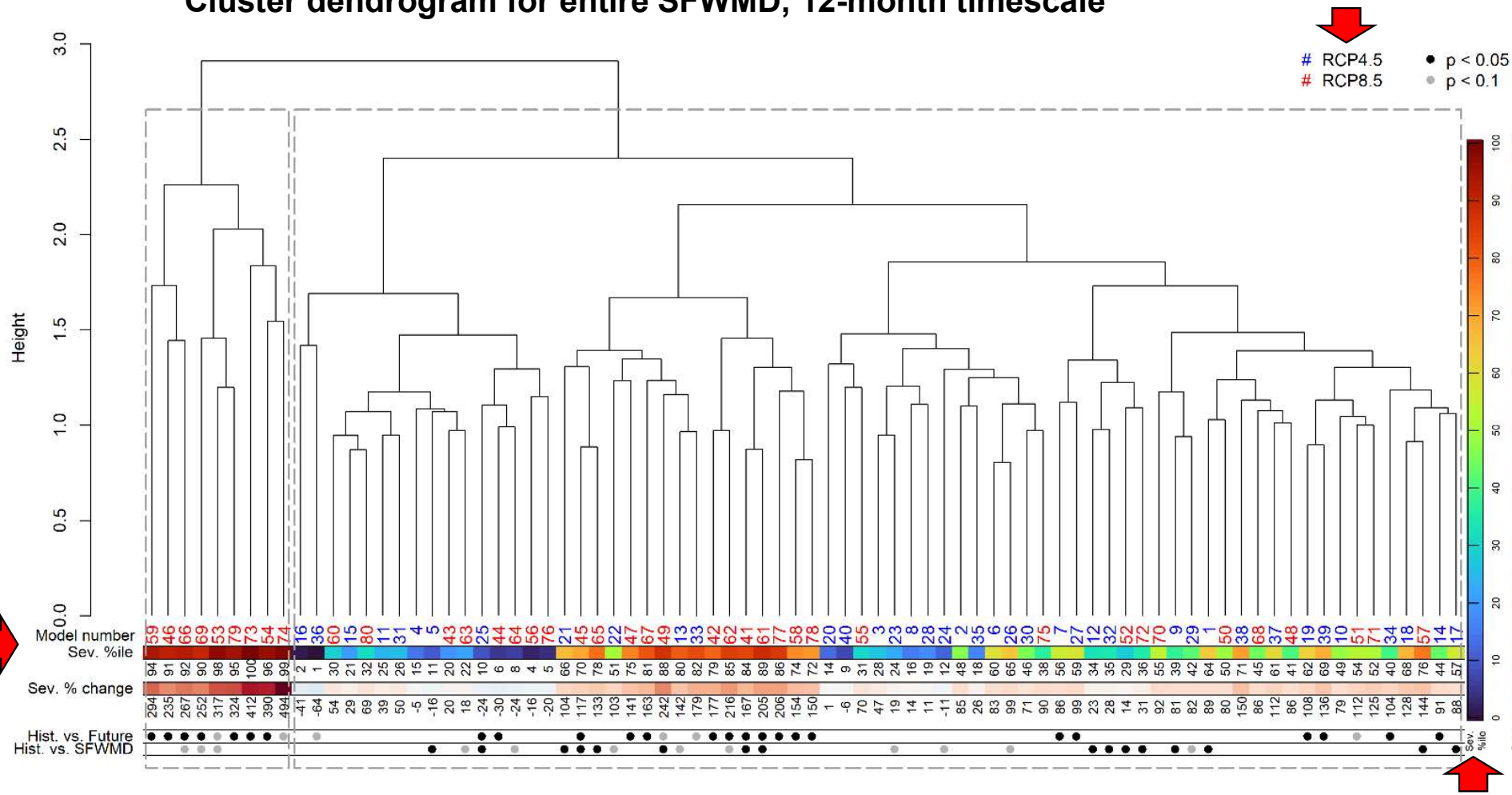


RCP8.5 Models 46, 66, 53, 73, 54, 74, 59, 79 are outliers.

Hierarchical clustering using Wasserstein's distance

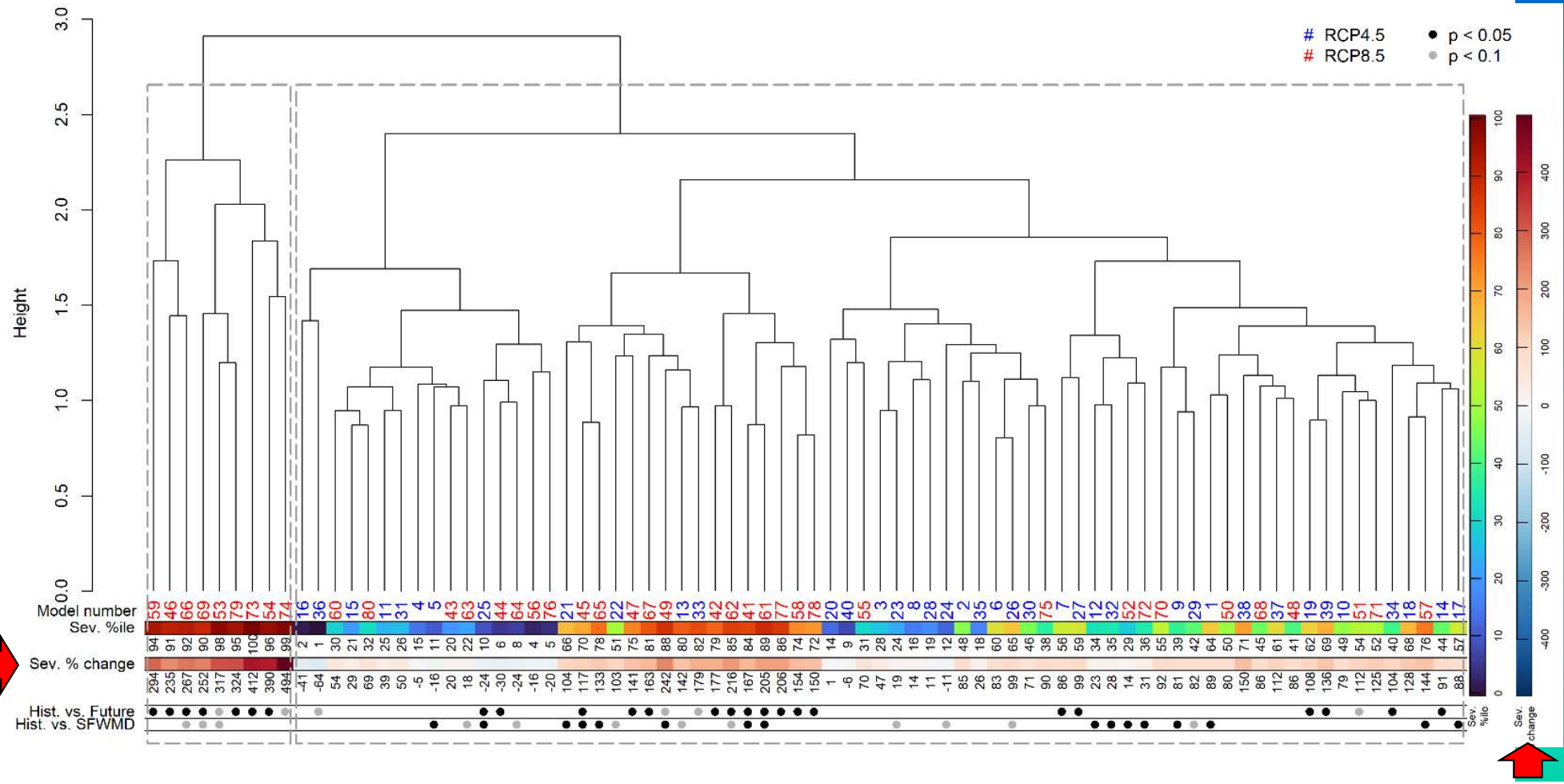
USGS science for a changing world

Cluster dendrogram for entire SFWMD, 12-month timescale



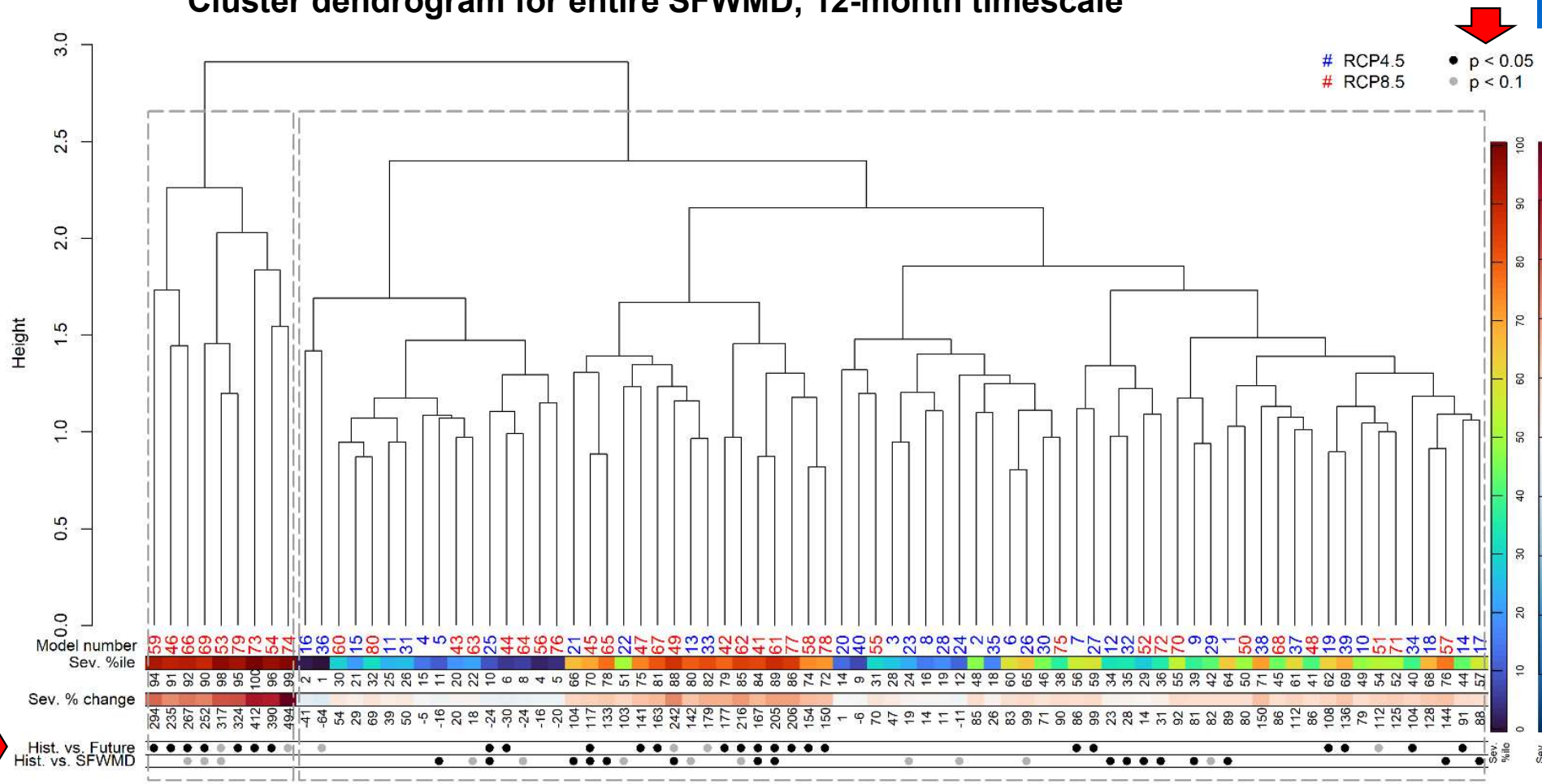
USGS science for a changing world

Cluster dendrogram for entire SFWMD, 12-month timescale



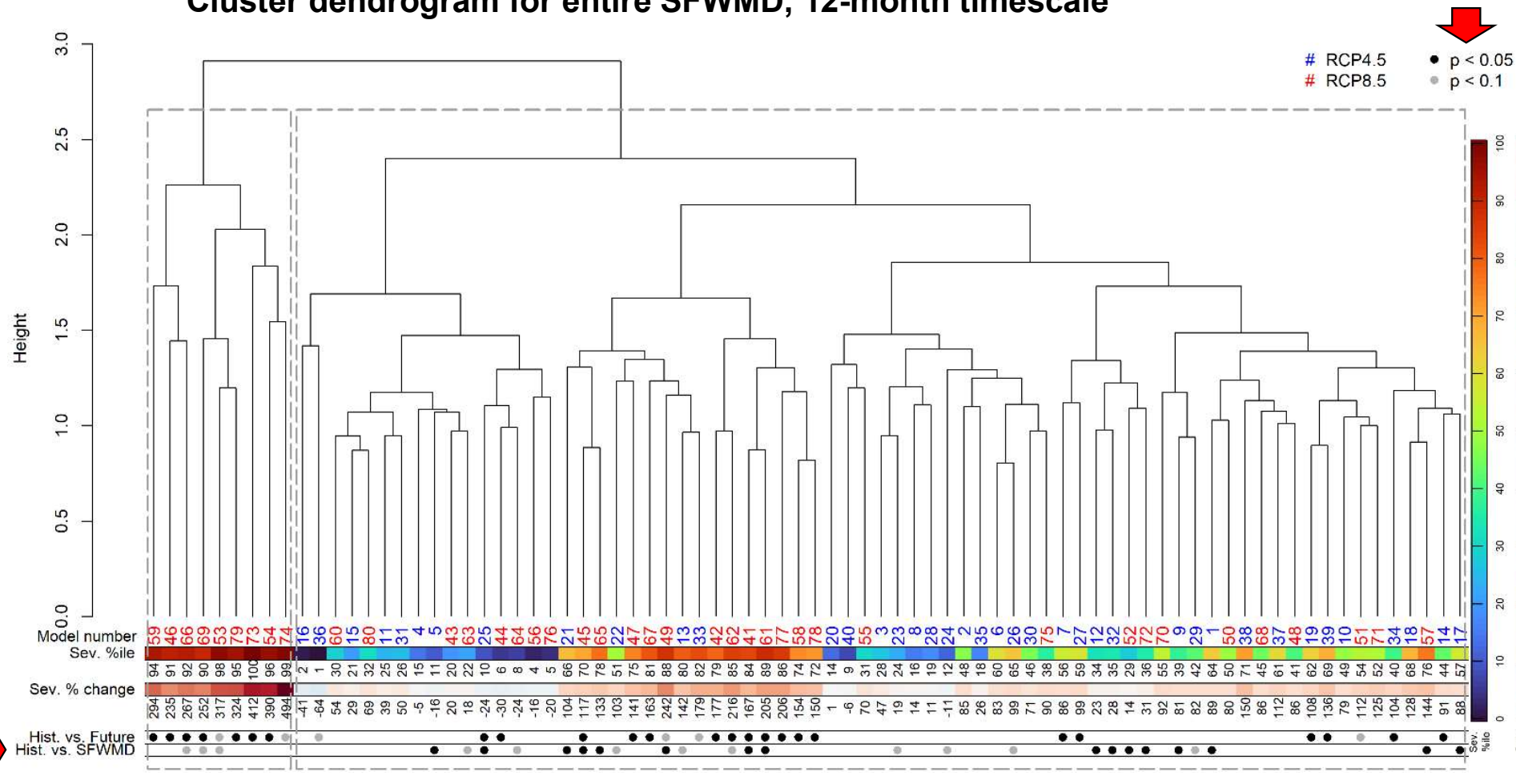
USGS science for a changing world

Cluster dendrogram for entire SFWMD, 12-month timescale



USGS science for a changing world

Cluster dendrogram for entire SFWMD, 12-month timescale



Next Steps

- Working on a USGS data release with key files and results from the future drought evaluation analyses.
- Writing journal article: “Characterizing Projected Future Droughts for South Florida”

Thank you!

Email: mirizarry-ortiz@usgs.gov