Hydrologic Loading in the Lower Mississippi Alluvial Valley

ZACK LOKEN

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Background

Significant groundwater pumping in the LMAV during duck hunting season

- Flooded rice, timber, and moist soil habitat
- Mid-November through January

Question: How does flooding the landscape with groundwater influence the velocity and position of GNSS stations in this region?

Importance: Assessing hydrologic loading can help evaluate changes in groundwater resources

- Improves knowledge of the local hydrological cycle

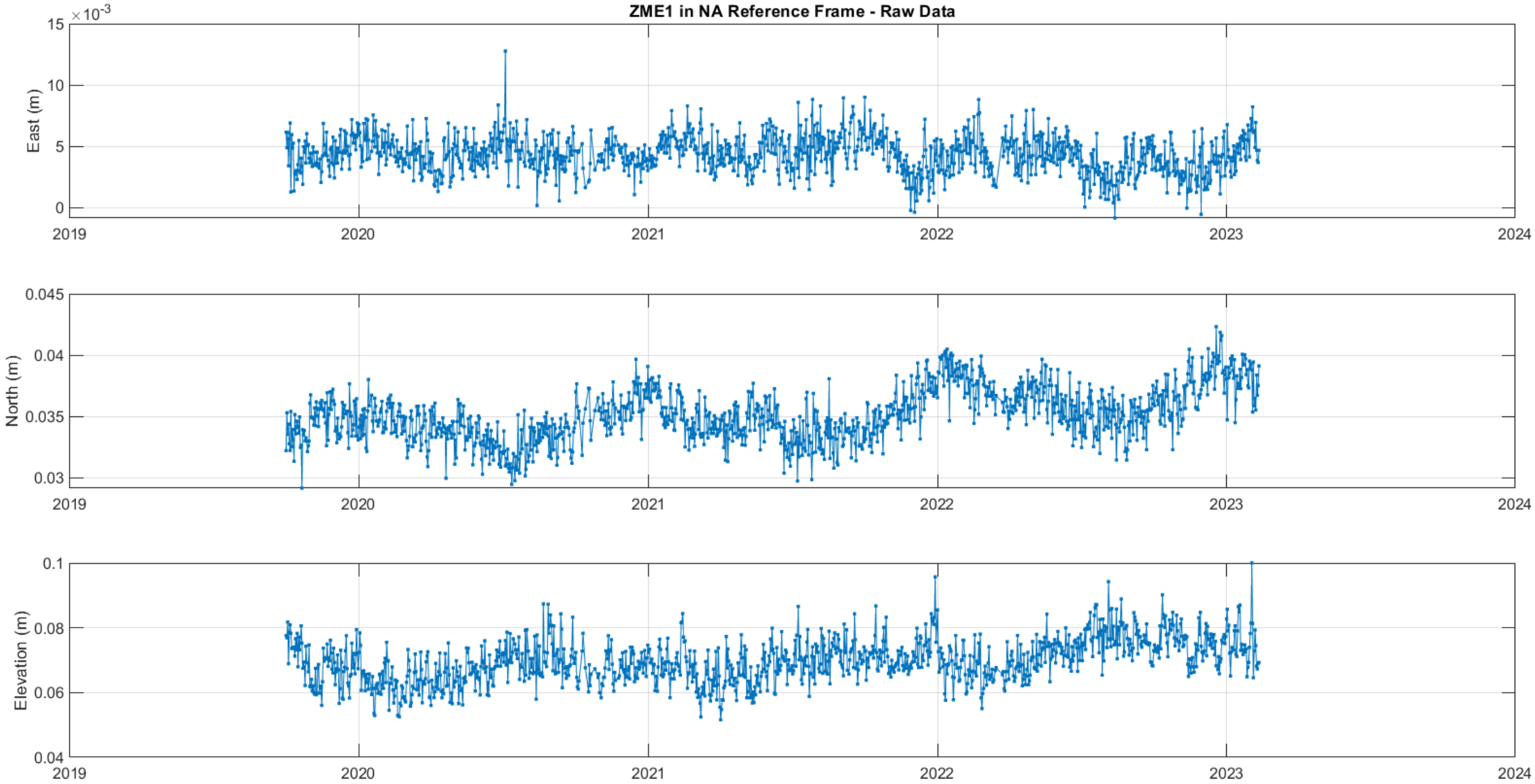
Methods - Preprocessing

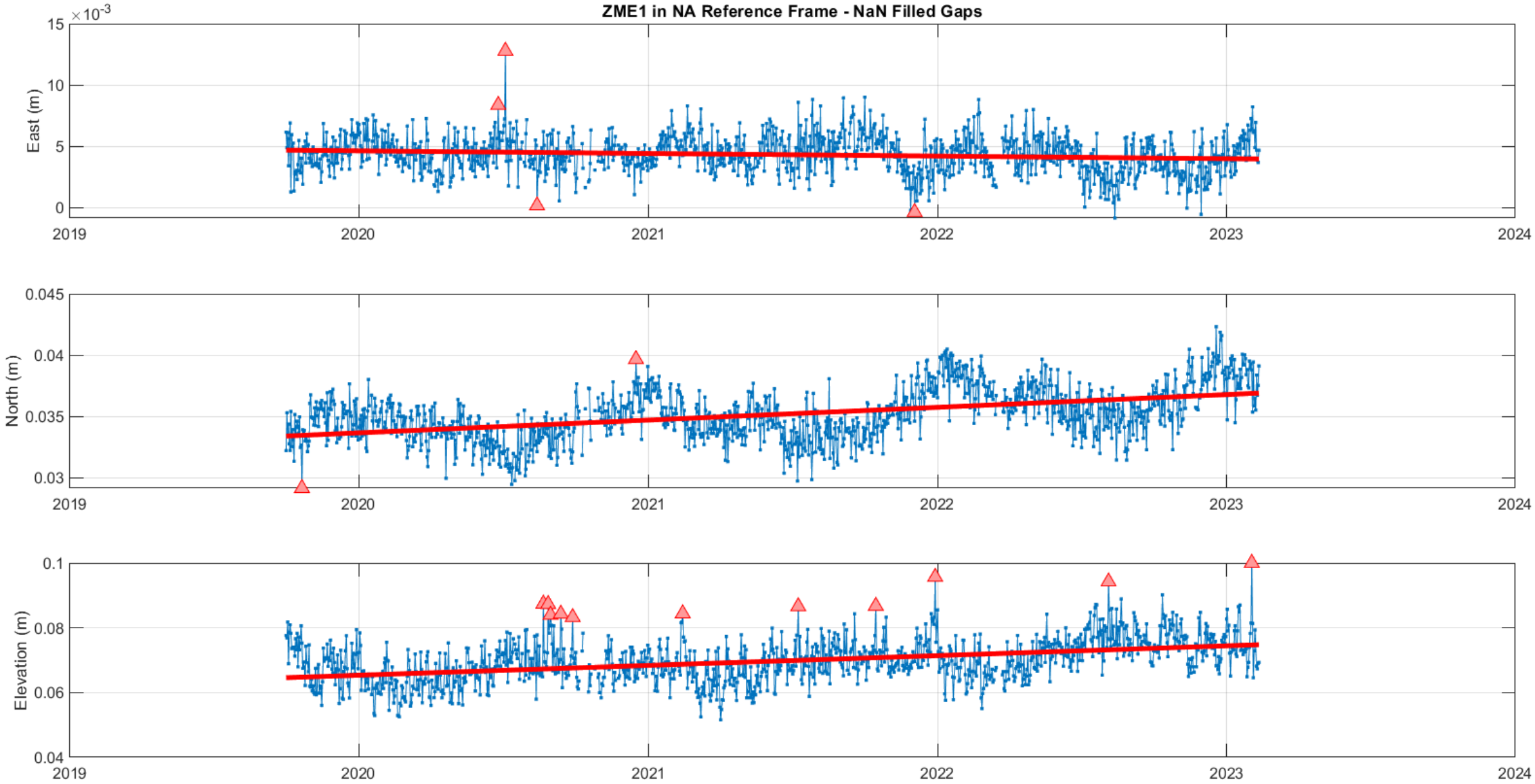
Download the NGL station data

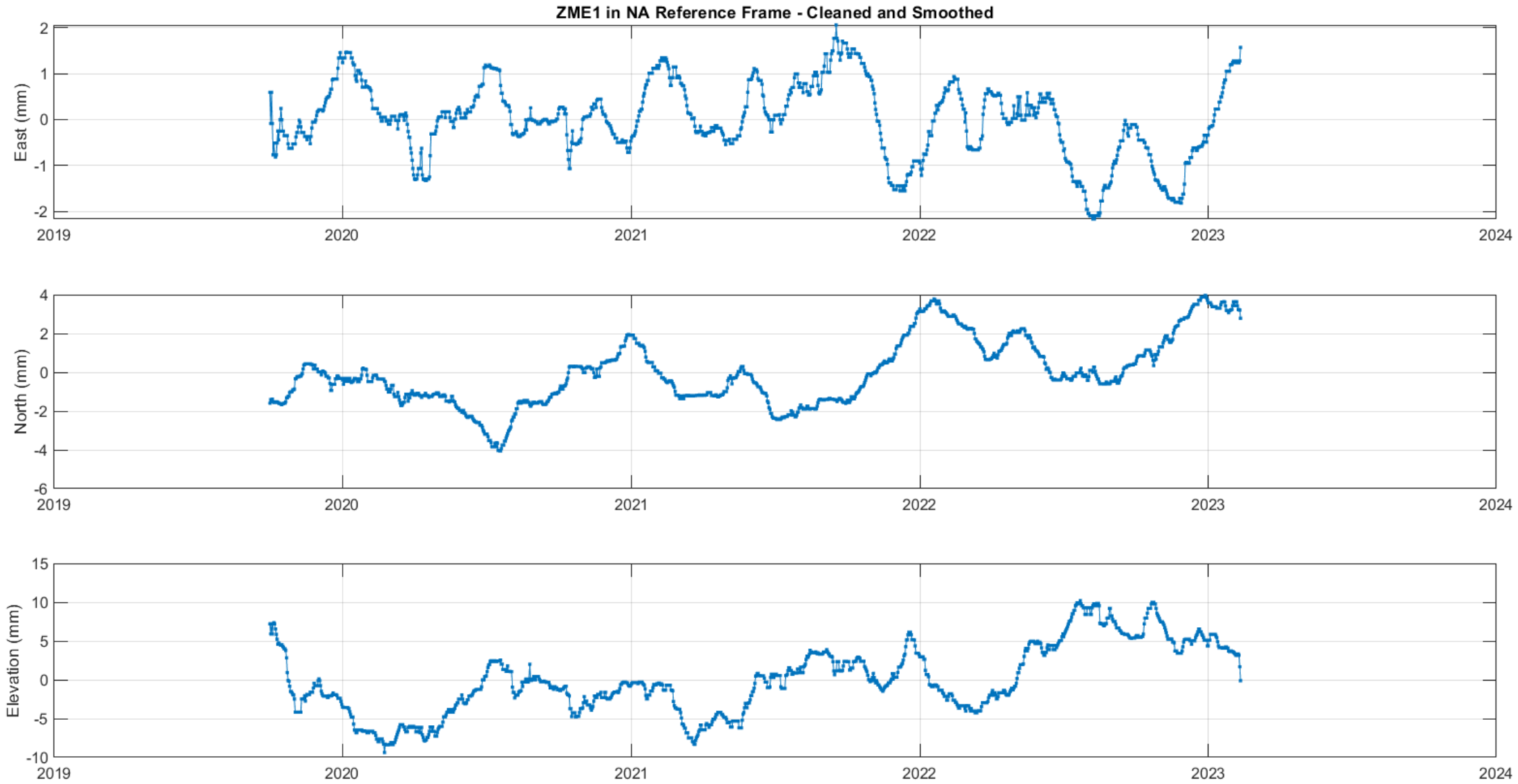
- 24-hour final solution / NA Plate
- 11 stations in AR, LA, MS, and TN

Clean and Isolate relevant variables

- T, E, N, V, Lat, and Long
- Remove observations before October 1, 2019
- Fill gaps in data with NaNs – continuous time series
- Remove outliers using median absolute deviation on 365-day median
- Calculate and plot the annual velocity for each station [E, N]
- Make the first value in time-series zero
- Smooth the filtered data using a moving median with 30-day window


ZME1 in NA Reference Frame - Raw Data
×10-3
East (m)
North (m)
Elevation (m)
2019
2020
2021
2022
2023
2024


ZME1 in NA Reference Frame - NaN Filled Gaps
East (m)
×10-3
15
10
5
0
North (m)
0.045
0.04
0.035
0.03
Elevation (m)
0.1
0.08
0.06
0.04
2019
2020
2021
2022
2023
2024


ZME1 in NA Reference Frame - Cleaned and Smoothed
East (mm)
North (mm)
Elevation (mm)
2019
2020
2021
2022
2023
2024

Methods - Analysis

Principal Component Analysis (PCA)

- Clustering method focused on dimensionality reduction
- Looks for a source set that minimizes the correlation
  - i.e., covariance matrix = identity matrix
- n – 1 components (n = # of stations)
  - Ten components for this analysis

Reconstruction Independent Component Analysis (rICA)

- Components are statistically independent
- Look for a source set that maximizes independence
- Analyst chooses the number of components
  - Four components for this study

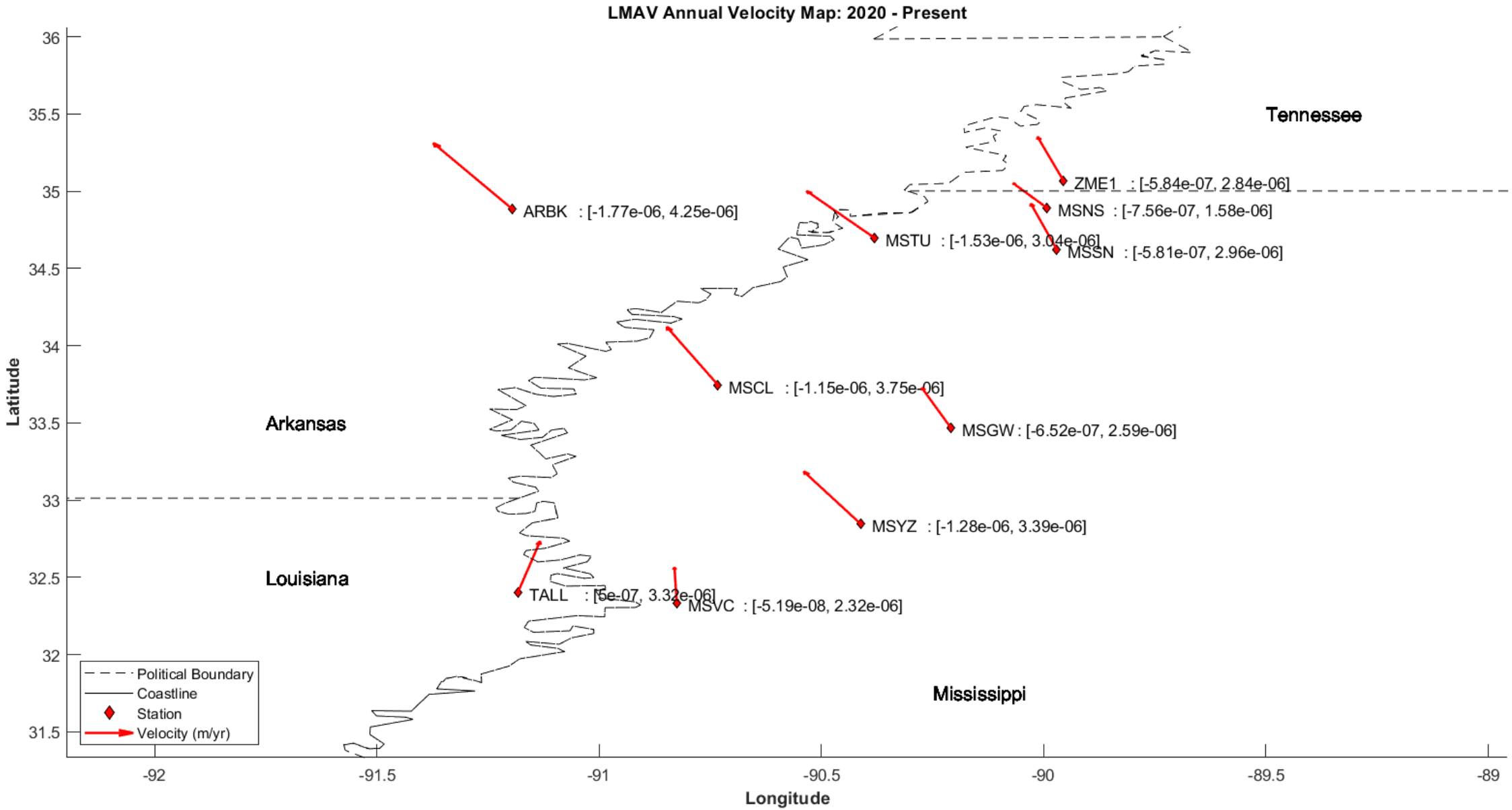
Results - Velocity

Absolute min velocity: [5.19E-08 E, 1.58E-06 N] meters/year

Absolute max velocity: [1.77E-06 E, 4.25E-06 N] meters/year

Absolute mean velocity: [8.85E-07 E, 3.00E-06 N] meters/year

General trend 2019 – present: moving northwest


LMAV Annual Velocity Map: 2020 - Present
Latitude
Longitude
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
-92
-91.5
-91
-90.5
-90
-89.5
-89
Tennessee
Arkansas
Louisiana
Mississippi
ARBK : [-1.77e-06, 4.25e-06]
MSTU : [-1.53e-06, 3.04e-06]
ZME1 : [-5.84e-07, 2.84e-06]
MSNS : [-7.56e-07, 1.58e-06]
MSSN : [-5.81e-07, 2.96e-06]
MSCL : [-1.15e-06, 3.75e-06]
MSGW : [-6.52e-07, 2.59e-06]
MSYZ : [-1.28e-06, 3.39e-06]
TALL : [5e-07, 3.32e-06]
MSVC : [-5.19e-08, 2.32e-06]
Political Boundary
Coastline
Station
Velocity (m/yr)

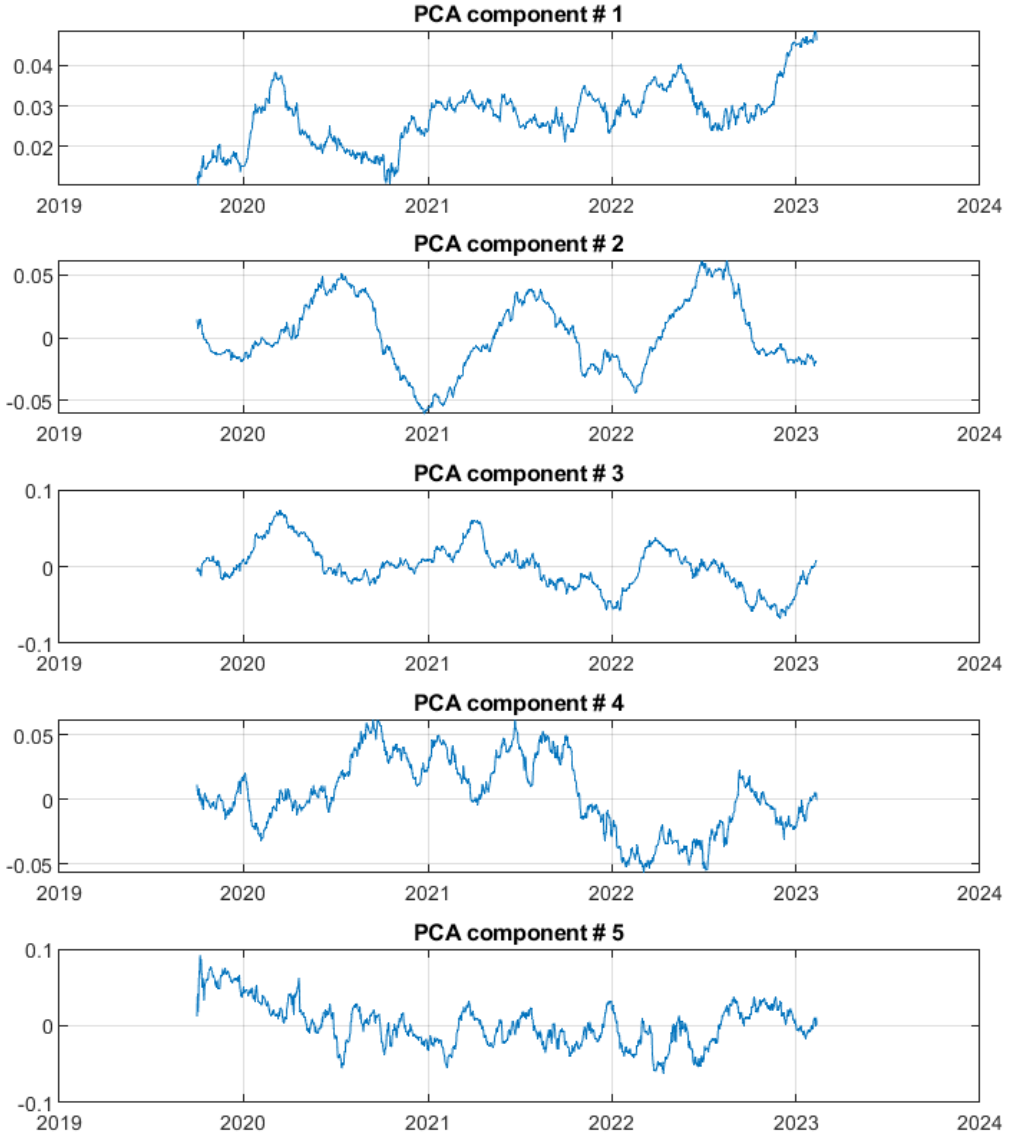
Results - PCA

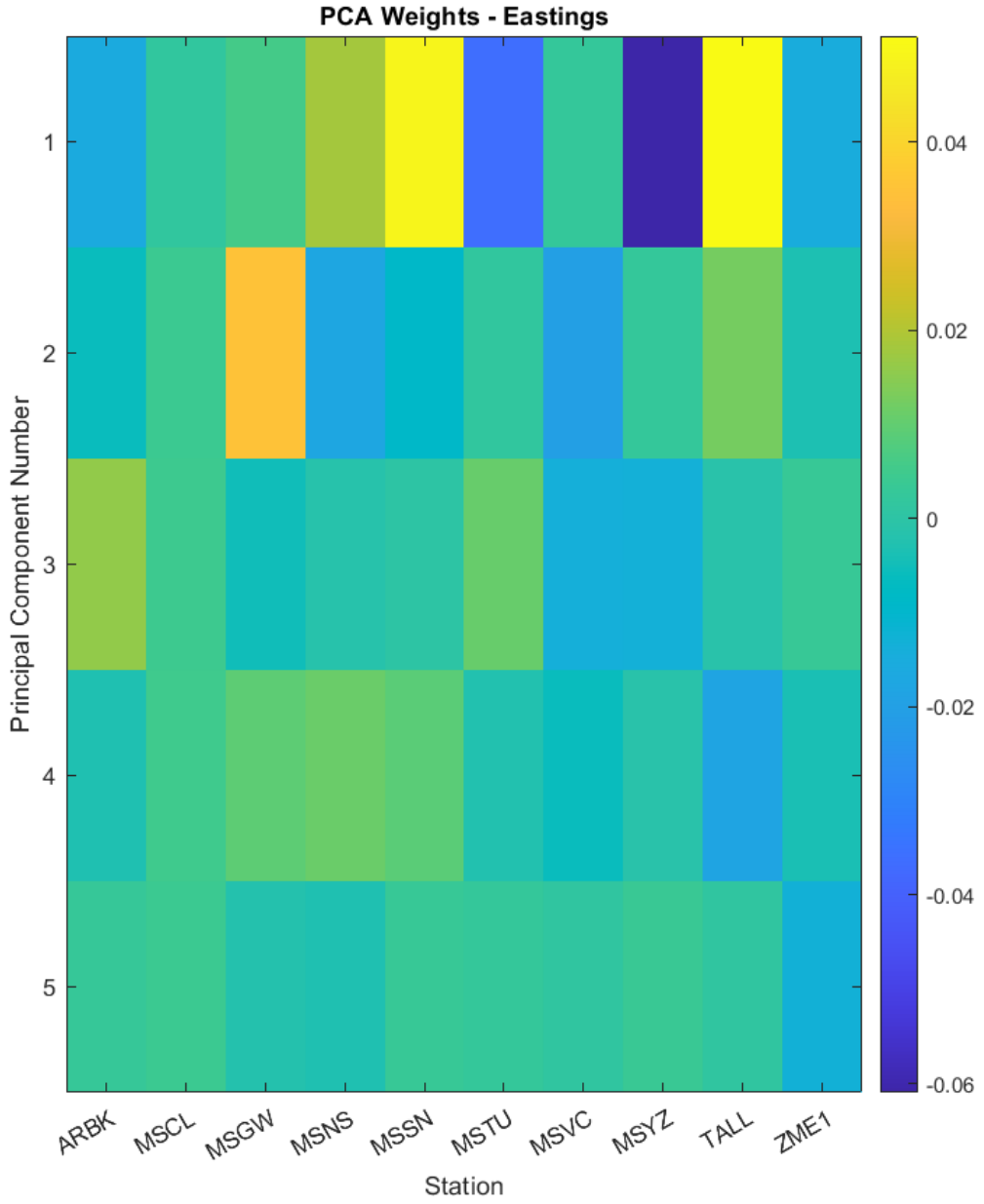
Eastings:

Component 1—Total water on landscape / getting wetter

Component 2—Seasonality / groundwater depletion during duck hunting season

Component 3—Long-term velocity / trending west


PCA component # 1
0.04
0.03
0.02
2019
2020
2021
2022
2023
2024
PCA component # 2
0.05
0
-0.05
PCA component # 3
0.1
0
-0.1
PCA component # 4
PCA component # 5


PCA Weights - Eastings
Principal Component Number
1
2
3
4
5
0.04
0.02
0
-0.02
-0.04
-0.06
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1
Station

Results - PCA

Eastings:

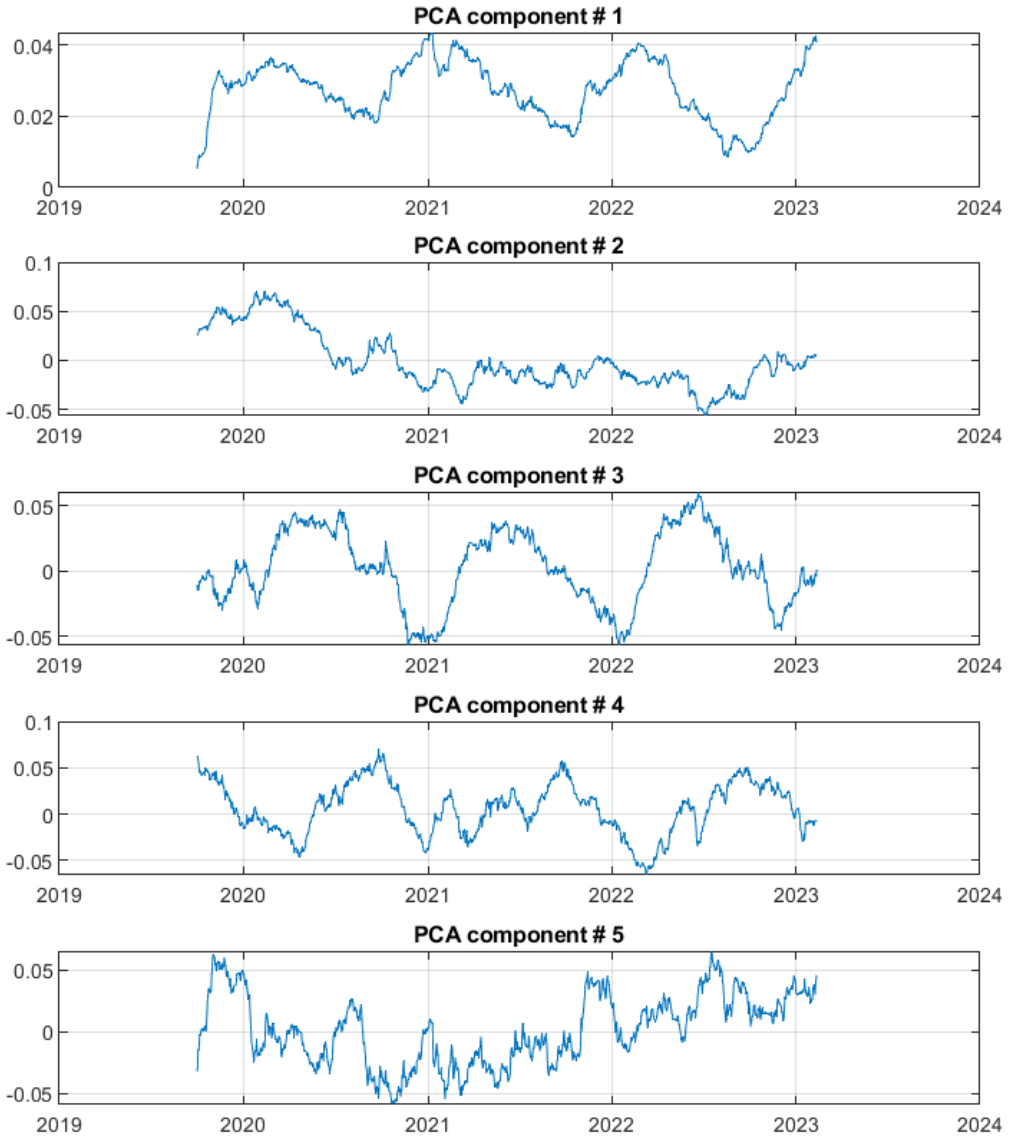
Component 1—Total water on landscape / getting wetter

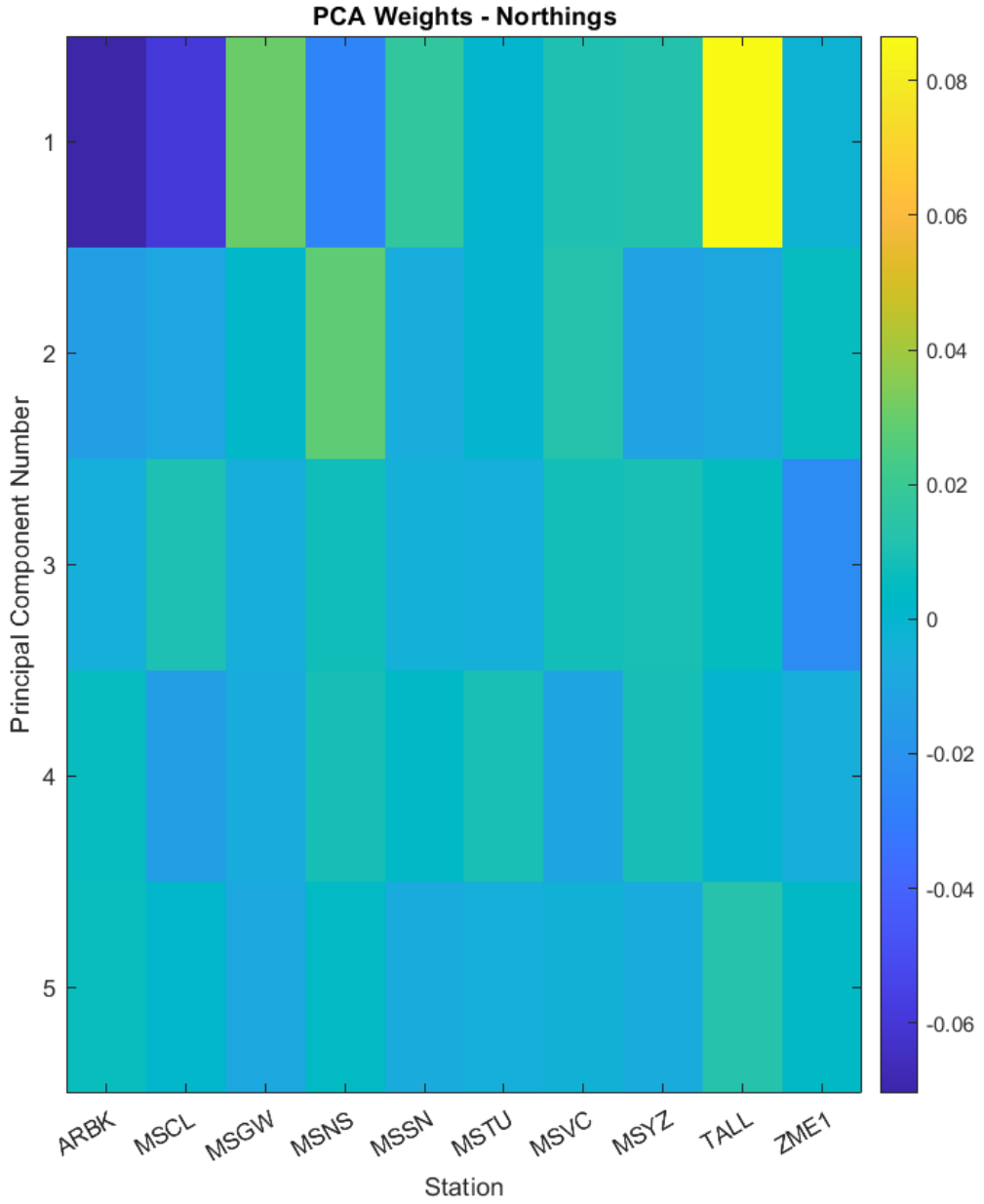
Component 2—Seasonality / groundwater depletion during duck hunting season

Component 3—Long-term velocity / trending west

Northings:

- Component 1—Total water on landscape / getting wetter
- Component 2—Not velocity / unsure
- Component 3—Seasonality / groundwater depletion during duck hunting season


PCA component # 1
PCA component # 2
PCA component # 3
PCA component # 4
PCA component # 5
2019
2020
2021
2022
2023
2024


PCA Weights - Northings
Principal Component Number
Station
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1

Results - PCA

Eastings:

Component 1—Total water on landscape / getting wetter

Component 2—Seasonality

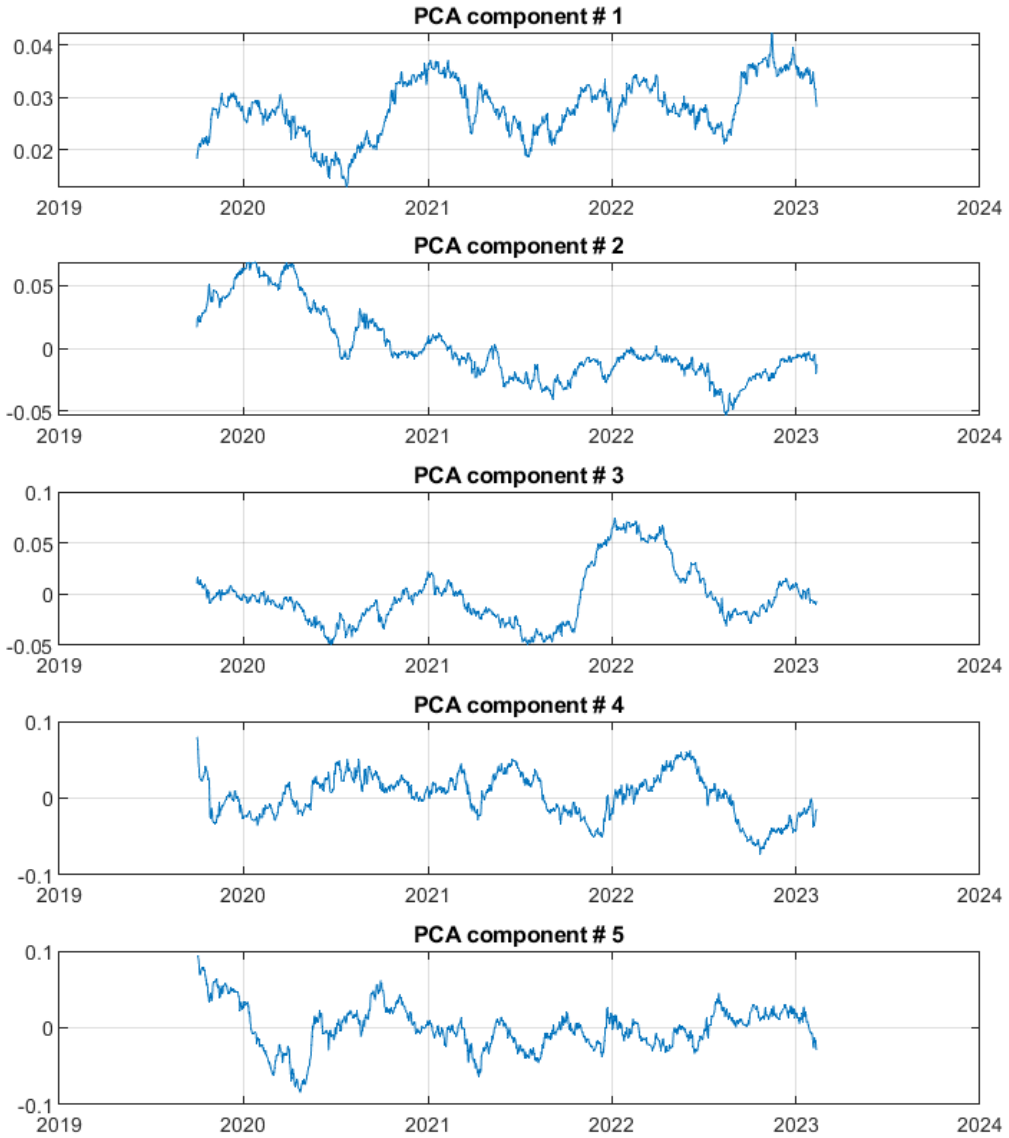
Component 3—Long-term velocity / trending west

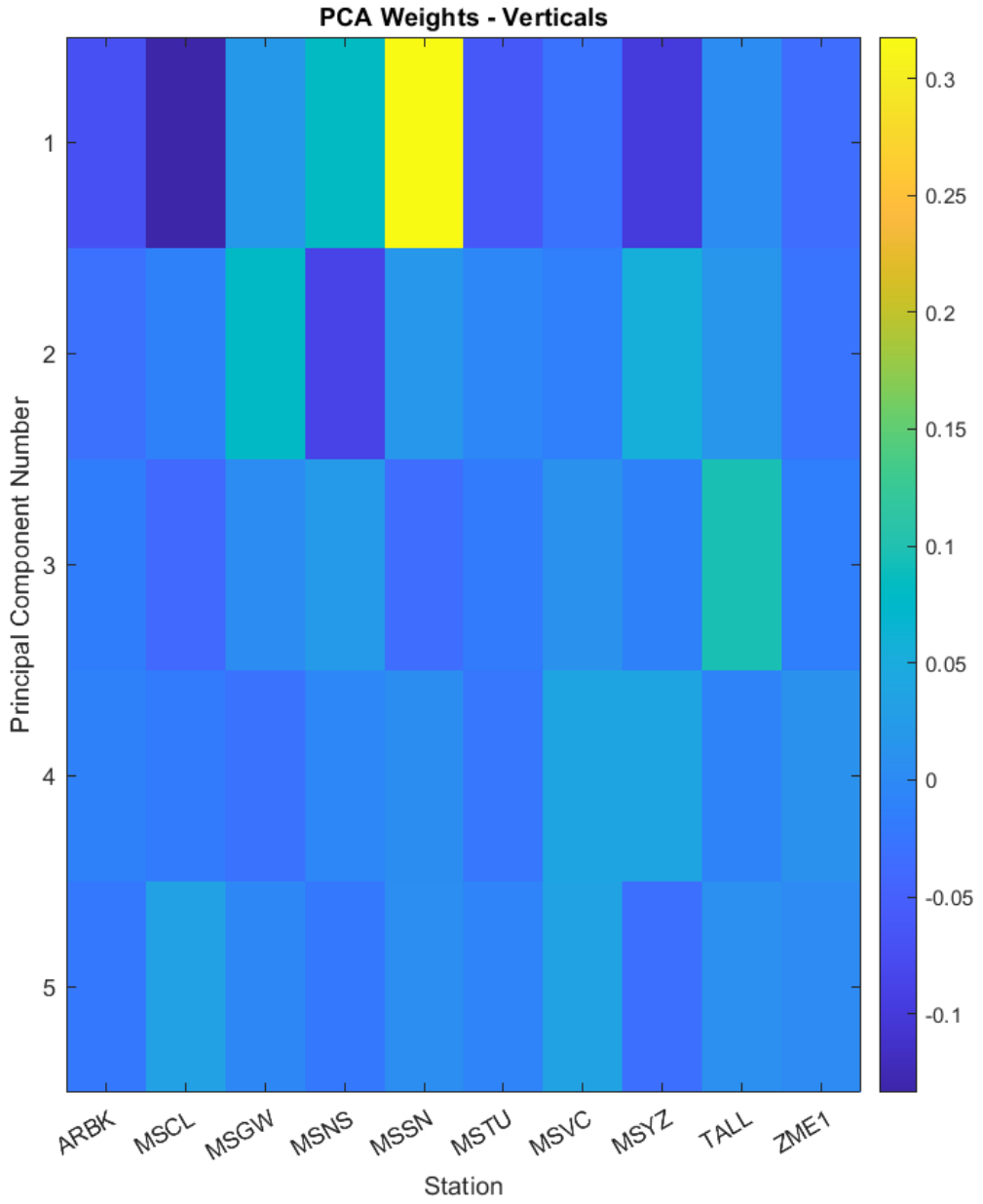
Northings:

- Component 1—Total water on landscape / getting wetter
- Component 2—Not velocity / unsure
- Component 3—Seasonality

Verticals:

- Component 1—Total water on landscape / getting wetter
- Component 2—Long-term velocity
- Component 3—Hydrologic loading / groundwater depletion during duck hunting season


PCA component # 1
0.04
0.03
0.02
2019
2020
2021
2022
2023
2024
PCA component # 2
0.05
0
-0.05
PCA component # 3
0.1
PCA component # 4
-0.1
PCA component # 5


PCA Weights - Verticals
Principal Component Number
1
2
3
4
5
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1
Station
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1

Results - ICA

Eastings:

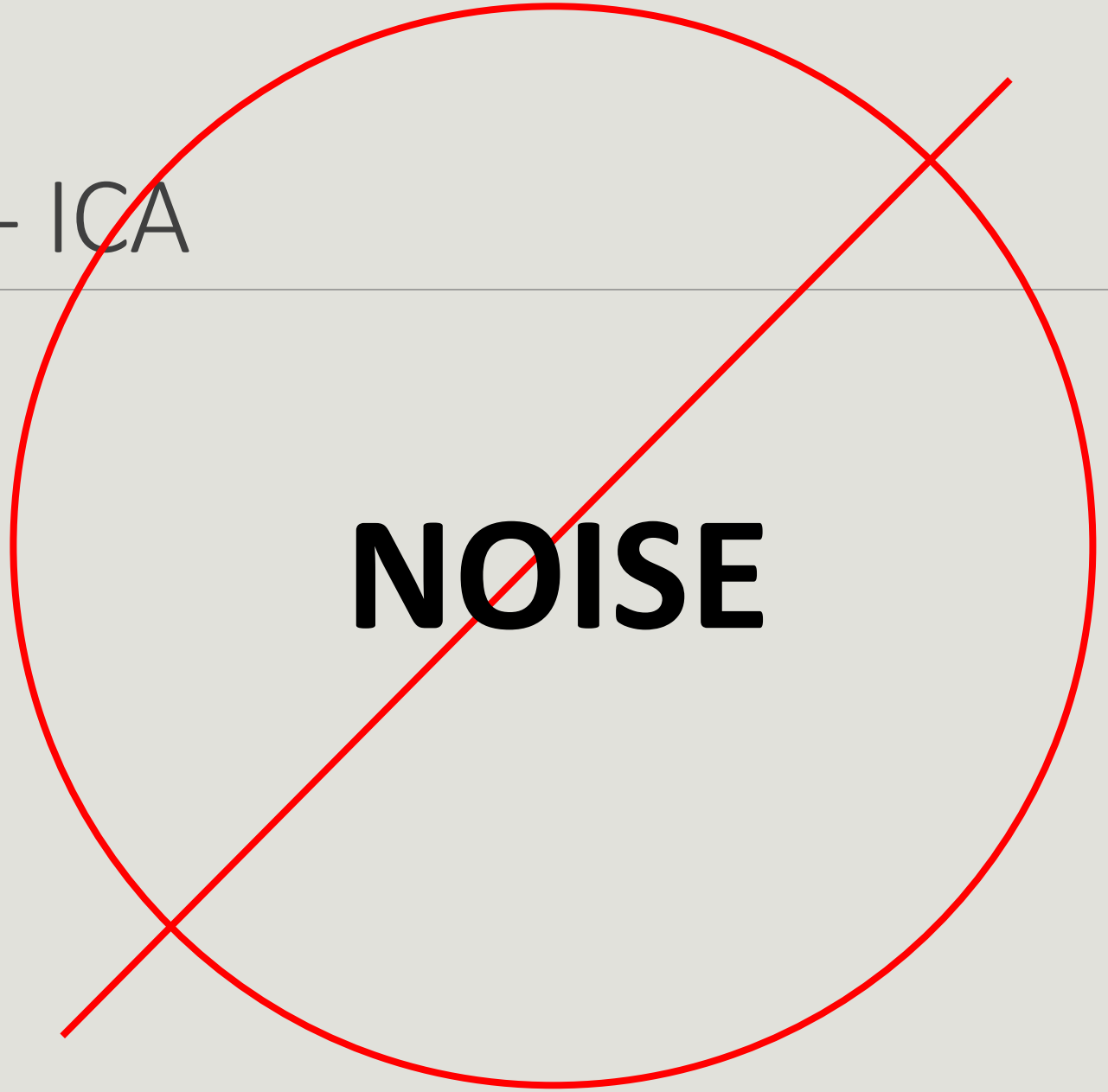
- Component 1–
- Component 2—
- Component 3—

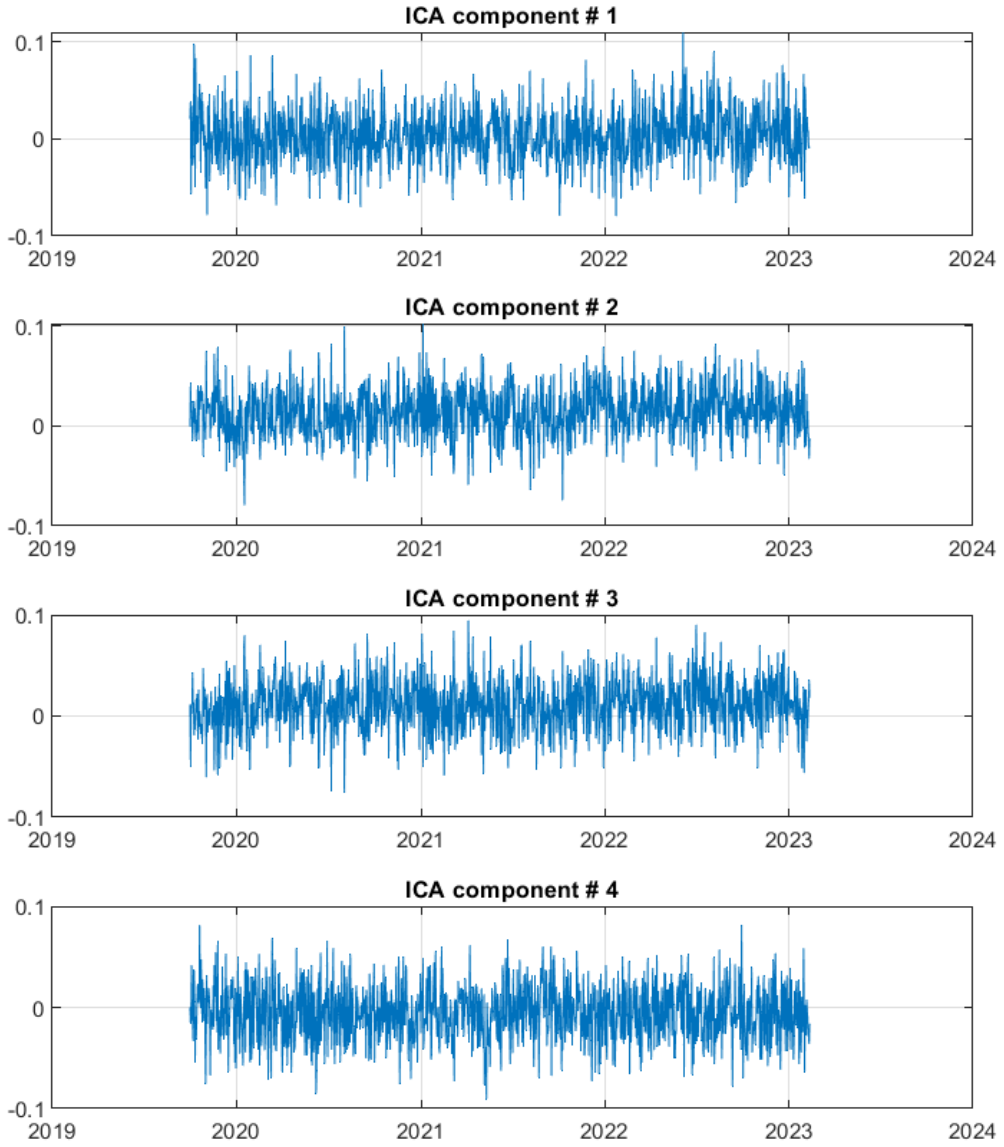
Northings:

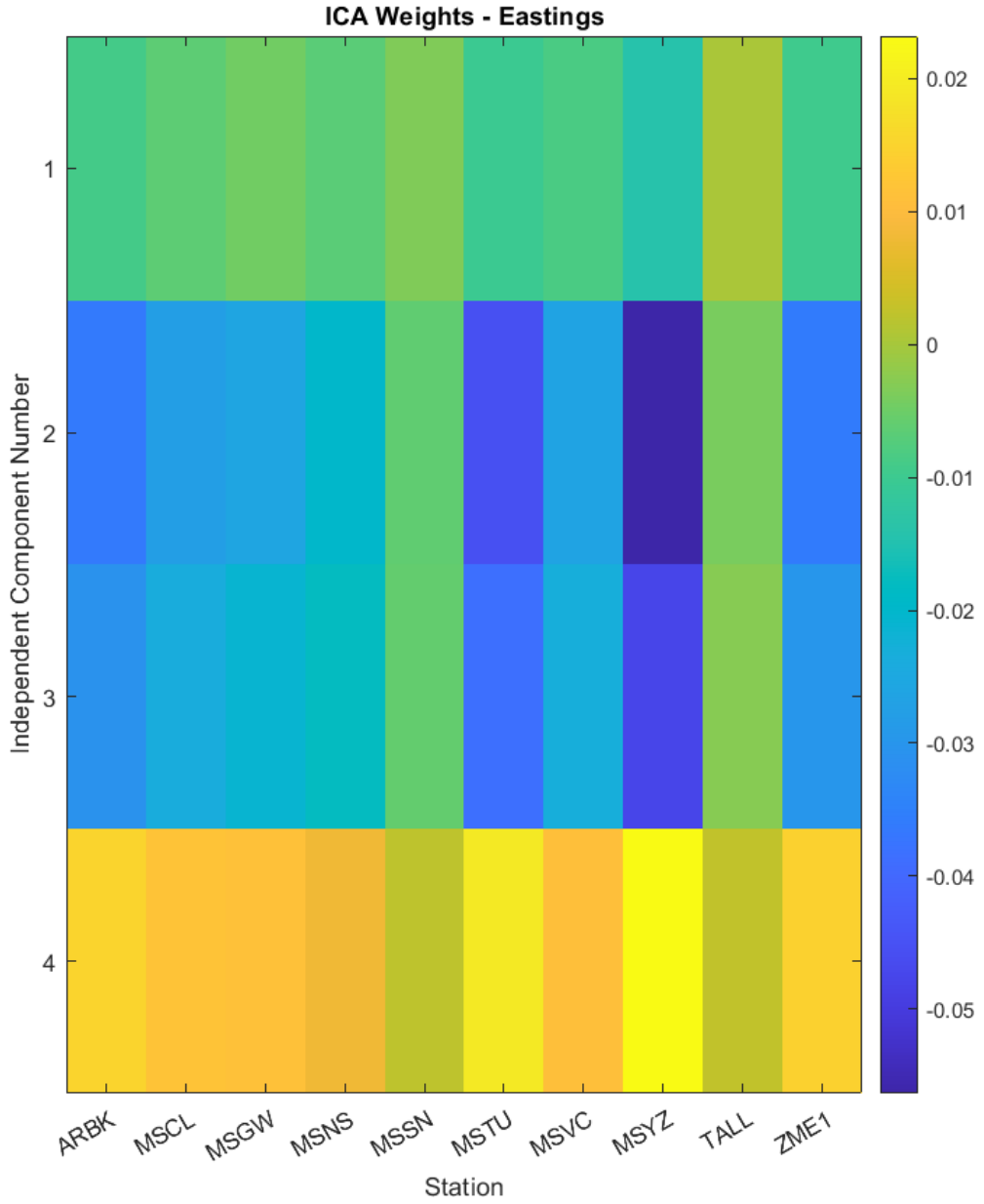
- Component 1—
- Component 2—
- Component 3—

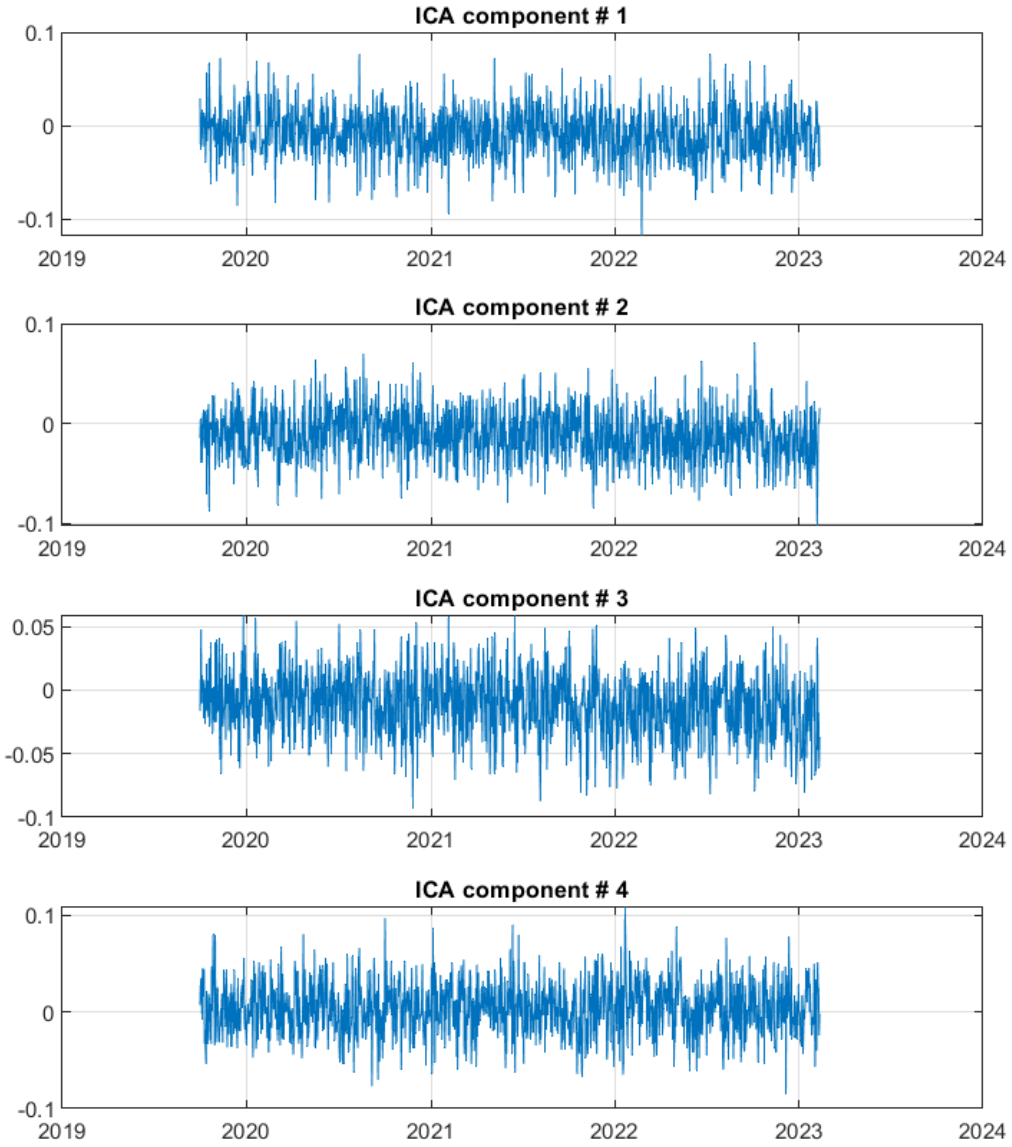
Verticals:

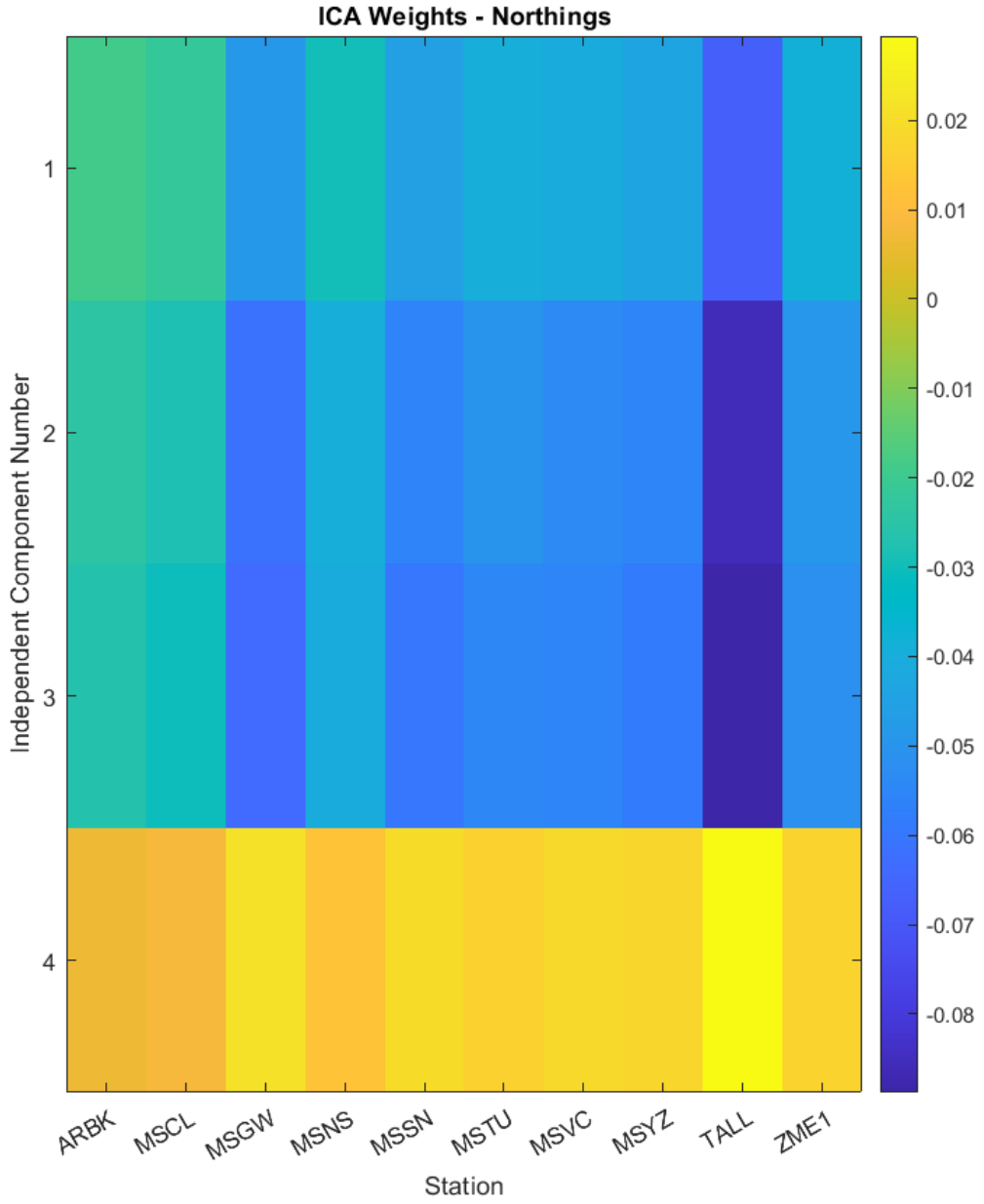
- Component 1—
- Component 2—
- Component 3—

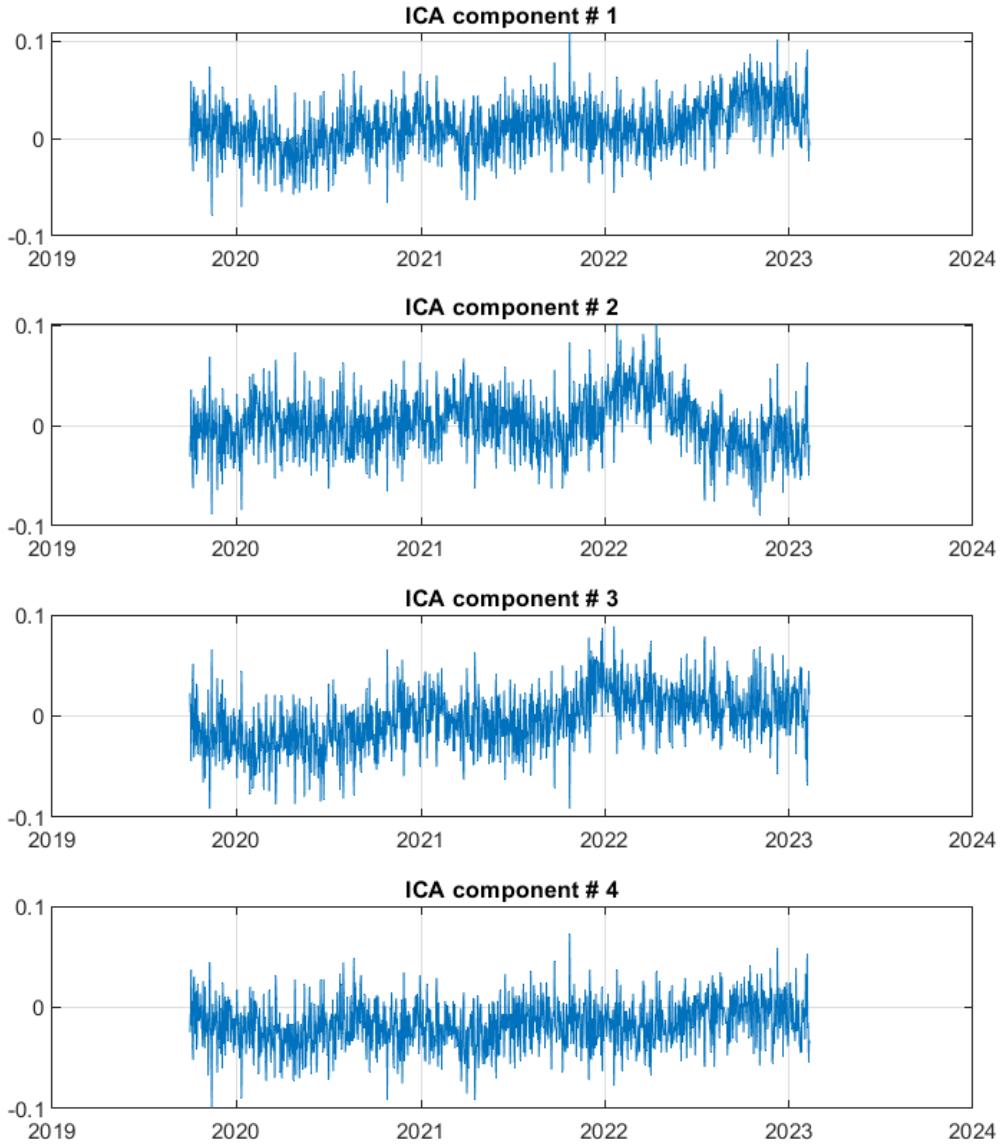


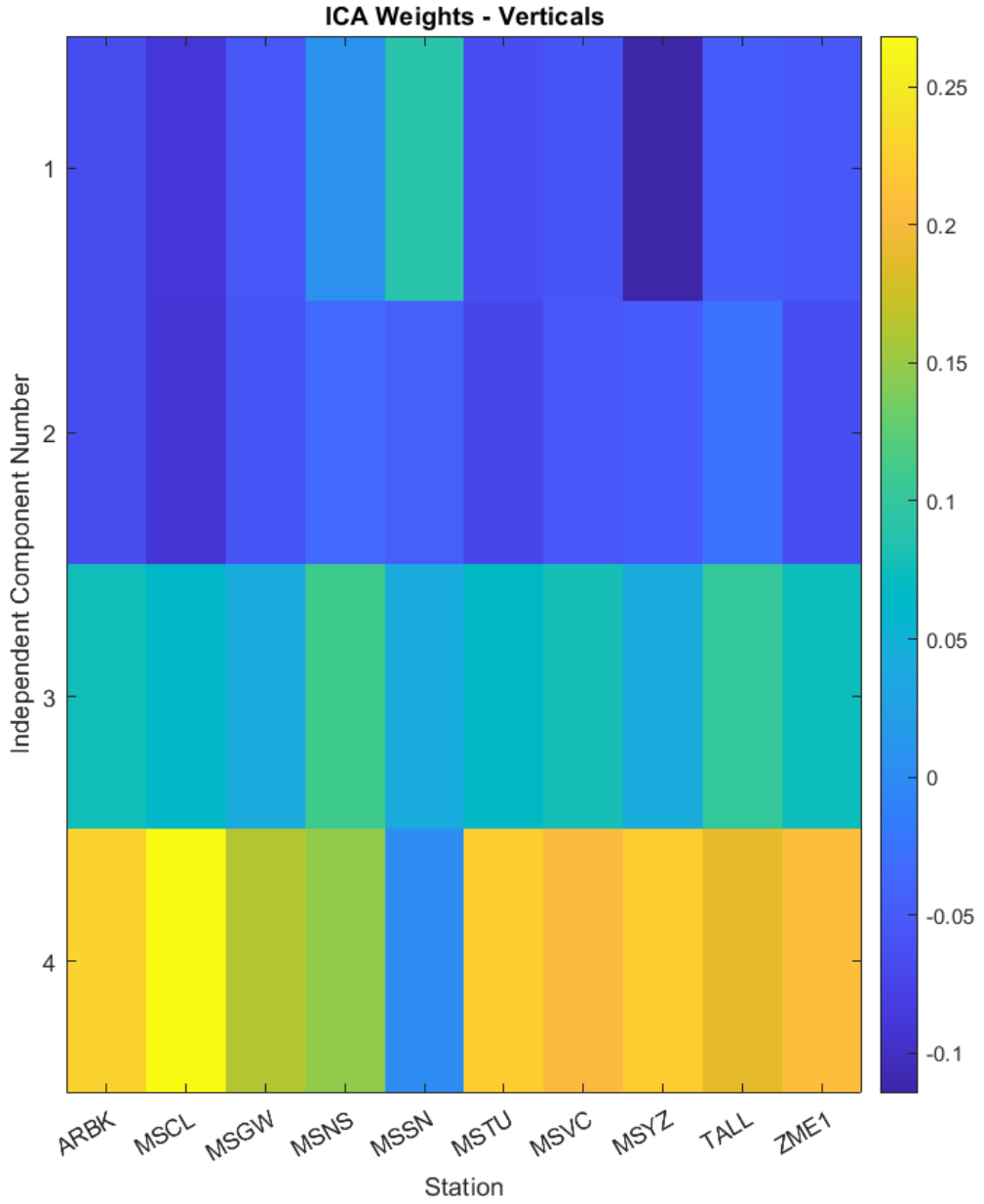

ICA component # 1
ICA component # 2
ICA component # 3
ICA component # 4
0.1
0
-0.1
2019
2020
2021
2022
2023
2024


ICA Weights - Eastings
Independent Component Number
1
2
3
4
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1
Station
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05


ICA component # 1
ICA component # 2
ICA component # 3
ICA component # 4
2019
2020
2021
2022
2023
2024


ICA Weights - Northings
Independent Component Number
Station
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1


ICA component # 1
ICA component # 2
ICA component # 3
ICA component # 4
0.1
0
-0.1
2019
2020
2021
2022
2023
2024


ICA Weights - Verticals
Independent Component Number
1
2
3
4
ARBK
MSCL
MSGW
MSNS
MSSN
MSTU
MSVC
MSYZ
TALL
ZME1
Station
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1

Argus et al. 2014

1. Determined seasonal vertical oscillation of all GPS sites in CA and NV
    1. Fit a position, velocity, and sinusoid with a period of 1-year to the GPS position as a function of time
2. Identified and omitted GPS sites on top of aquifers.
3. Fit a continuous, curved surface to the GPS observations of the seasonal vertical oscillations
    1. Due to the loading of water and snow
4. Inverted season vertical oscillations observed with GPS to infer change in total surface water
5. Compared the change in total surface water inferred from GPS to that observed with GRACE
    1. Also compared with three hydrology models
6. Evaluated the impact of seasonal oscillations on the weight of the atmosphere.