

**Updating Key Metrics Regarding
Outdoor Water Use in Texas
Community Water Systems**

TWDB Contract Agreement 2500012883

Progress Report 3

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Project Goals

1. Characterize changes in outdoor water use during and after the 2011 – 2015 drought.
2. Develop key outdoor water use metrics that incorporate the most recently available data.
3. Evaluate the prospective relationship between outdoor water use and climate drivers.

Project Objectives

1. Analyze annual seasonal single-family (SF) residential water use for at least the 259 community water systems (CWS) evaluated in Technical Note 12-01.
2. Determine the annual percentage of outdoor water use for each CWS and by region.
3. Evaluate CWS monthly intake data and predict outdoor use by developing a seasonal use index.
4. Determine 2011 – 2015 drought and post-drought trends in CWS outdoor water use.
5. Identify and document methodological differences from Technical Note 12-01, if any, used to generate updated CWS outdoor water use data.
6. Assess any trends in CWS gallons per capita demand driven by changes in outdoor water use.
7. Evaluate the prospective relationship between outdoor water use and climate drivers.

PROJECT PROGRESS DISCUSSION

Summary

We have made significant advancements in the following areas since our last progress report:

- Improving data quality and consistency across annual and monthly datasets through systematic quality control and corrections, expanding coverage and improving comparability across systems.
- Implementing and evaluating additional methods for deriving monthly SF water use volumes, including comparisons to verify that each method preserves the seasonal structure required to defensibly estimate indoor baselines and outdoor use.
- Establishing a method selection decision framework to guide assignment of the most appropriate proxy method for deriving monthly SF distributions and outdoor use estimates across all CWS.

Across most CWS and years, the seasonal behavior of SF use is recoverable across proxy approaches, providing confidence that the indoor–outdoor framework remains structurally sound. Method differences are now better understood in the context of system size, data availability, particularly with respect to baseline identification for indoor use. This moves Subtask 2 from method development into method selection, establishing a path forward for estimating outdoor-use and subsequent climate analyses.

Subtask 1. Data Assessment and Collection

Status: Subtask 1 is essentially **complete**.

All primary water system datasets necessary to extend the original outdoor water use study have now been compiled and organized for analysis. This includes annual SF volumes, total metered volumes, monthly intake data, and retail sales data for ~230 CWS.

Statewide atmospheric datasets have been fully assembled and pre-processed, including precipitation, temperature, soil moisture, and evapotranspiration (ET). These datasets are ready to be incorporated into Subtask 3 to evaluate prospective relationships between outdoor water use and climate drivers.

Subtask 2. Methodology Development and Water Use Analysis

Status: Subtask 2 is progressing and **ongoing**.

Building upon the intake-based proxy (Intake) improved and validated in our previous project update, improving the quality and coverage of total metered volume data was critical because it is fundamental to the other two methods. Prior to now, we had identified only 105 systems with available total metered volumes (TMV) data. Through systematic QA/QC, available TMV coverage increased from 105 to 225 CWS. These additional methods were designed to address different data availability scenarios across CWS and to test whether alternative data sources could improve seasonal pattern accuracy.

Method 2: Monthly SF from Total Metered/Intake Ratio

This method (Metered) uses annual TMV to reconcile intake-based totals to the portion of water that is metered/billed. We compute an annual scaling factor:

$$z = \text{Annual Intake} / \text{TMV}$$

and apply it to monthly intake to produce a synthetic monthly metered volume:

$$\text{Monthly Metered} = z \times \text{Monthly Intake}$$

We then allocate the annual SF volume to months using a constant annual SF share:

$$y = \text{Annual SF} / \text{TMV}$$

$$\text{Therefore, Monthly SF} = y \times \text{Monthly Metered}$$

This method was designed for systems with total metered data but lacking monthly retail sales breakdowns. It uses the monthly intake ratio to derive a synthetic monthly metered volume and allocates annual SF proportionally, producing estimates functionally equivalent to Intake, which validated their consolidation into a single intake-based method.

Method 3: Monthly SF from Monthly Retail Sales

This method (Retail) uses actual monthly treated water retail sales data to derive SF consumption patterns. For systems reporting retail sales by customer category, the monthly distribution of SF retail sales is scaled to the annual SF volume:

$$\text{Monthly SF} = (\text{SF Annual Volume} / \text{TMV}) \times \text{Monthly Retail Sales}$$

Data Quality Assurance

Data Issues Identified

Misclassified volumes – In several cases, TMV was not reported in the designated total field but instead entered under individual customer categories such as “Other Volume”, leading to the assumption that TMV were unavailable or unreported for those years. This was predominantly the case for 85 CWS between 2004 and 2011, and sometimes later years.

Order of magnitude reporting errors – Some CWS exhibited reporting values that were off by a factor of ten (e.g., missing or added zeros), resulting in annual TMV values that were implausibly high or low relative to surrounding years.

Missing summations of customer categories – For many systems, individual customer category volumes (e.g., residential, commercial, industrial) were reported, but the total metered volume field was left blank or did not reflect the sum of those categories.

Correction Approach

Reported totals were first checked against annual intake to ensure physical plausibility ($\text{TMV} \leq \text{Intake}$). Where inconsistencies occurred, category-level fields were reviewed to identify misclassified totals or missing summations, and totals were reconstructed where appropriate. Magnitude anomalies (power-of-10 errors) were evaluated using year-to-year continuity to identify dominant reporting scale and correct isolated deviations. Adjustments were applied only where internal consistency clearly supported correction. Ambiguous values were left unchanged.

Comparative Analysis of Methods

To understand how the three methods capture seasonal variation, we compared normalized monthly SF volumes across CWS by size: top 10 largest, medium and smallest CWS, sorted by their average annual intake volumes. Because the Intake and Metered methods both use total monthly intake distribution as the proportioning key applied to the same annual SF volume, we only present one curve for intake-based methods.

Large Systems

Among the largest systems, El Paso, Arlington, Irving, and Laredo show the closest agreement between Intake and Retail SF estimates across most of the study years (**Figures 1-7**). In El Paso, both curves track a smooth, bell-shaped summer peak consistently across 2015–2023, with Intake and Retail arriving at nearly identical timing and amplitude in most years. SF/Intake ratio remain stable in the 0.45–0.47 range

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throughout the period, meaning SF demand accounts for nearly half of all production and the intake signal is strongly conditioned by residential outdoor use behavior. Arlington shows similarly close tracking in most years, with SF/Intake holding between 0.45 and 0.50, though 2018 and 2021 show intake slightly leading retail into the summer peak before converging by September. Laredo tracks well in timing across most years, though the retail curve tends to show a sharper, higher peak than intake in several years, including 2018 and 2023.

Austin also shows close method agreement across most examined years. Although SF accounts for approximately 35–38% of total metered volume, TMV/Intake ratio remains consistently near 0.9, meaning nearly all intake reaches metered customers and the non-SF metered demand does not carry a distinct seasonal pattern that would distort the intake signal. A notable exception is 2021, where January retail sales were unusually elevated at 9.4% of annual retail and a particularly low February together create a wide normalization range, amplifying the apparent seasonal peaks in the retail-based estimate relative to other years. Irving similarly shows close intake-retail tracking across all study years despite SF/TMV of around 0.32–0.34; again, TMV/Intake remaining consistently close to 0.90 across the period explains why the method works despite moderate SF customer share.

San Antonio, with SF accounting for approximately 41–58% of total metered volume across the study period, shows a temporal shift in method agreement across the years examined. In 2015 and 2017 (**Figures 1-2**), intake peaks earlier and higher than retail, with the gap most pronounced in 2017 where SF/Intake falls to 0.40, consistent with a larger non-SF component driving the aggregate intake signal. The system's customer mix includes significant reuse volumes which began in 2010 and grew considerably through the study period, as well as substantial industrial demand. If the seasonal distribution of reuse deliveries or industrial use differs from SF demand, this contributes to the earlier intake ramp observed in those years. By 2018–2020 the two curves align more closely in both timing and amplitude, and while some divergence persists into 2021 where SF/Intake drops to 0.39, the character of the mismatch shifts from timing-driven to amplitude-driven. In 2023 both methods show close agreement with nearly identical peak timing in August.

Fort Worth shows a similar but more persistent timing divergence across all study years, with intake rising earlier in summer and typically peaking in July, while retail reaches its maximum later in August or September, reflecting the aggregate seasonal behavior of its large commercial and industrial customer base.

Houston shows a related but more variable pattern. In 2015 intake peaks earlier than retail consistent with non-SF demand driving the early summer ramp. In 2018 both curves show a notably compressed summer signal. In 2019 intake follows a similar trajectory to retail through summer but falls short of the retail peak. All of these results are consistent with SF accounting for less than 10% of total intake, leaving the intake signal highly sensitive to the seasonal behavior of non-SF customers (**Figures 1, 3-4**).

The methods can also diverge for reasons unrelated to customer composition, as illustrated by Houston in 2021 and 2023 (**Figures 5, 7**). In both years, an unusually low January intake value sets a depressed normalization anchor, causing the entire Intake curve to appear elevated relative to retail for the remainder of the year, an effect absent from the Retail estimate since January retail sales remained normal in both years. The effect is more pronounced in 2023, where January intake represented only 4% of annual intake compared to a consistent 7.5 - 8.2% share in preceding years. In 2021 the January anchor was moderately low rather than extreme, producing a less dramatic but similar distortion. Hence, intake and retail sales can decouple when operational factors such as storage drawdown or supply transfers affect

monthly production independent of actual customer demand. In such cases the Retail estimate may more faithfully reflect true consumption patterns.

A structurally similar but more persistent pattern is observed in Corpus Christi, where the intake curve shows an erratic or inverted seasonal pattern in multiple years rather than a timing shift. With SF accounting for only 14–17% of annual intake, and 50–64% of intake reaching metered customers, a substantial fraction of intake exits through non-metered pathways who may carry their own seasonal signal. This produces active distortion across most study years rather than isolated year-specific anomalies.

Medium Systems

Among medium-sized systems, behavior varies considerably. Richmond shows close method agreement across most examined years, with Intake peaking earlier than Retail modestly in earlier years like 2015 and 2017 (**Figures 8-9**) before converging in later years. A shift consistent with SF's share of total annual intake growing from around 22% in 2015–2018 to 37–44% by 2021–2022 suggests either customer mix changes or improved reporting over time.

Brenham consistently shows Intake peaking earlier and higher than Retail across 2015, 2019, and 2021, converging more closely only in 2022 (**Figures 8, 11-12**). Its substantial Institutional use type demand (~150 - 230M gallons annually) may contribute to this pattern if that customer category follows a different seasonal schedule than SF residential.

Corinth shows close method agreement across examined years with both curves tracking a consistent summer peak and Highland Village similarly shows close agreement in most years examined, except in 2021.

Small Systems

Among the smallest systems, most CWS show close to perfect method agreement across years: Tioga, Bells, Gunter, and Wilson all produce nearly indistinguishable normalized curves (**Figures 15-21**). This suggests that for these systems, total intake proportionally mirrors retail sales and the choice of method has little practical consequence. These systems are predominantly SF-dominated, with SF accounting for roughly 60–85% of total metered volume and limited non-SF customer diversity.

Gordon stands apart, with Retail peaks ranging from 2.5 to 5x the minimum with variable timing across years while Intake remains comparatively stable at 1.4–2.0x with a consistent summer peak, a pattern that can be explained by TMV/Intake sitting at only 27 - 44%. This is compounded in recent years by the emergence of multi-family and industrial demand categories that were largely absent prior to 2020.

Hico shows a persistent but modest divergence with Retail peaks consistently higher than Intake across 2015–2021, with both methods broadly agreeing on peak timing in August–September, which is consistent with its relatively high SF fraction of 62–68%. Daisetta also shows similarly close method agreement in most years, though in some years the Retail-based estimate peaks outside the expected summer window, suggesting normalization anchor instability rather than a genuine seasonal pattern shift.

Seasonal Pattern of Monthly SF Volumes

Here, we evaluate how well monthly SF derived from the Intake method tracks the original study's monthly SF distributions across Phase 1 (2004–2008) and Phase 2 (2009–2011). For the largest systems where intake previously showed close agreement with retail (such as El Paso, Austin, Lubbock and Irving) the same close tracking with the original study is visible across both phases (**Figures 22-23, 28-29**). These are systems with relatively homogeneous or predictable customer mixes, and their aggregate intake signal appears to faithfully represent SF seasonal demand.

Where intake consistently diverges from retail in the current study, the same divergence is visible against the original. Houston's intake curve persistently sits below the original's summer peak across both phases, consistent with its low SF share of annual intake. Fort Worth similarly shows intake below the original peak in most Phase 1 and 2 years, reflecting the same timing divergence identified in the current study. These CWS's large non-SF customer bases dilute the SF summer peak in the aggregate intake signal. This has direct implications for the seasonal outdoor metrics: if intake systematically compresses the summer peak for these systems, the derived outdoor seasonal fractions may understate the proportion of use occurring in peak demand months. For example, Arlington shows close agreement with the original study in most years, except 2004 where an anomalously low March intake sets a depressed normalization anchor, causing the intake curve to appear dramatically elevated. This is consistent with the same mechanism observed in Houston in the current study period and suggests this is a recurring vulnerability of the Intake method.

Temporal patterns also shift meaningfully across the study period for several systems. San Antonio is the clearest example, where intake leads and peaks earlier than the original in Phase 1. This is consistent with the influence of reuse volumes and industrial demand on the aggregate intake signal. Then the curves begin converging by Phase 2 as those non-SF demand patterns apparently stabilize relative to SF seasonal behavior. A similar convergence is visible in some medium systems like Richmond, where intake leads modestly in earlier Phase 1 years before tracking more closely by 2008 and into Phase 2.

Taken together, the three proxy methods consistently reproduce the expected summer peak in SF residential water use across system sizes and years. The patterns observed in the current study hold across Phase 1 and Phase 2. Where the Intake method performs consistently in timing, amplitude, and stability across years, this is often associated with systems where SF constitutes a substantial share of total annual intake, most intake reaches metered customers, and non-SF demand does not carry a distinctly different seasonal pattern. Where performance is inconsistent, the sources of variability differ. Some systems show persistent structural divergence tied to customer mix while others show year-specific distortions driven by operational or reporting factors. These patterns are not exclusive to any particular system size. Retail-based estimates are less susceptible to operational distortions but are not available for all systems or time periods, which is itself a constraint on method selection. These observations form the basis for the method selection framework discussed below.

Method Selection Decision Framework

The seasonal proxy pattern analyses, Phase 1 and Phase 2 comparisons, and prior statistical assessments collectively inform a proposed framework for selecting between Intake and Retail methods for deriving monthly SF distributions. Because the derived seasonal fractions directly determine the proportion of SF use attributed to outdoor demand in each month, systematic method errors propagate directly into outdoor use estimates and any downstream analyses of seasonal indices, drought trends, or climate relationships. It is important to note that neither method yields directly observed SF volumes, both are derived estimates that depend on the quality and consistency of their respective input data.

Where SF accounts for a substantial share of total annual intake and most intake reaches metered customers, the Intake method reliably captures the expected seasonal pattern, as confirmed by strong Phase 1 and Phase 2 agreement and prior correlation analyses. In such systems, the intake curve is often stable and internally consistent across years. In some cases, Intake shows less year-to-year variability than Retail, which can be affected by operational factors or billing cycle irregularities. For homogeneous, SF-dominated systems, the choice between methods has limited practical consequence for derived outdoor fractions but Intake offers the practical advantage of broader statewide coverage.

As customer diversity increases and SF's share of total annual intake declines, the intake signal becomes progressively more influenced by the seasonal behavior of non-SF customers, reuse volumes, and unmetered water use. The seasonal comparisons show that this dilution effect is systematic and persistent by consistently compressing or shifting the summer peak relative to the Retail estimate, with direct implications for outdoor use fractions. In these cases, the Retail method is proposed as the preferred option where data are available and internally consistent, as it more directly reflects SF billing patterns and is less susceptible to structural dilution. Prior statistical analyses support this, showing Retail maintaining stronger seasonal agreement with the original study benchmark across a broader range of customer-diverse systems. However, this preference is conditional; where retail data show their own instabilities the performance advantage over Intake may diminish.

Operational factors introduce an additional layer of uncertainty that applies to both methods. Single-month anomalies in intake, documented across multiple systems and time periods, can produce normalization effects that distort the seasonal curve independently of customer composition. The same applies to Retail where billing irregularities may affect the anchor month. These cases are identifiable in the data and can inform method assignment. Thus, where one method shows anchor month instability, the more stable method is proposed for that CWS. Where both methods show weak or unstable seasonal signal, assignment is based on relative performance, with elevated uncertainty noted for derived outdoor fractions.

A particular concern for drought and post-drought outdoor use estimation is that each method responds to the behavioral and operational changes that characterize drought years. The Phase 2 comparison provides direct validation of the Intake method against ground truth through 2011. However, the 2014–2015 drought falls outside this validated period, meaning method performance must be inferred from patterns established in the 2011 drought period. In 2011, intake tracks the broadly elevated summer peaks reasonably well for SF-dominated systems but diverges for customer-diverse systems where non-SF drought response conflates with the SF signal. Both methods are additionally sensitive to drought-induced shifts in the normalization anchor where suppressed winter demand lowers the anchor and inflates apparent summer amplitude. Post-drought demand rebounds raise the anchor and may compress apparent peaks, making amplitude shifts across the drought and post-drought transition difficult to attribute solely to changes in true outdoor use behavior. Anchor month stability will be evaluated explicitly as part of method assignment for drought and post-drought years.

Next Steps:

- Finalize and apply method assignments using the method selection framework across all CWS.
- Compute outdoor use metrics for each CWS, including annual outdoor use volumes, seasonal indices, and per capita demand contributions.

Subtask 3. Climate Driver Assessment

Status: This subtask is dependent on the completion of Subtask 2 and has therefore not yet commenced.

Description of Figures

Figures 1 – 21: Line subplots of monthly SF for the Intake and Retail methods for select systems and years to illustrate the seasonal distribution of monthly SF across methods. CWS-years where retail data is lacking are shown as “no data”. Each system's monthly SF volumes are normalized by dividing by the minimum month, setting the lowest month to 1 to isolate seasonal shape independent of absolute magnitude.

Figures 22 – 29: Line subplots of monthly SF for Intake method compared against the original study phase 1 and phase 2 years. CWS with no intake-derived SF data for certain years are shown as “no data”.

Figure 1

Normalized SF Monthly Volumes: Largest Systems (2015)

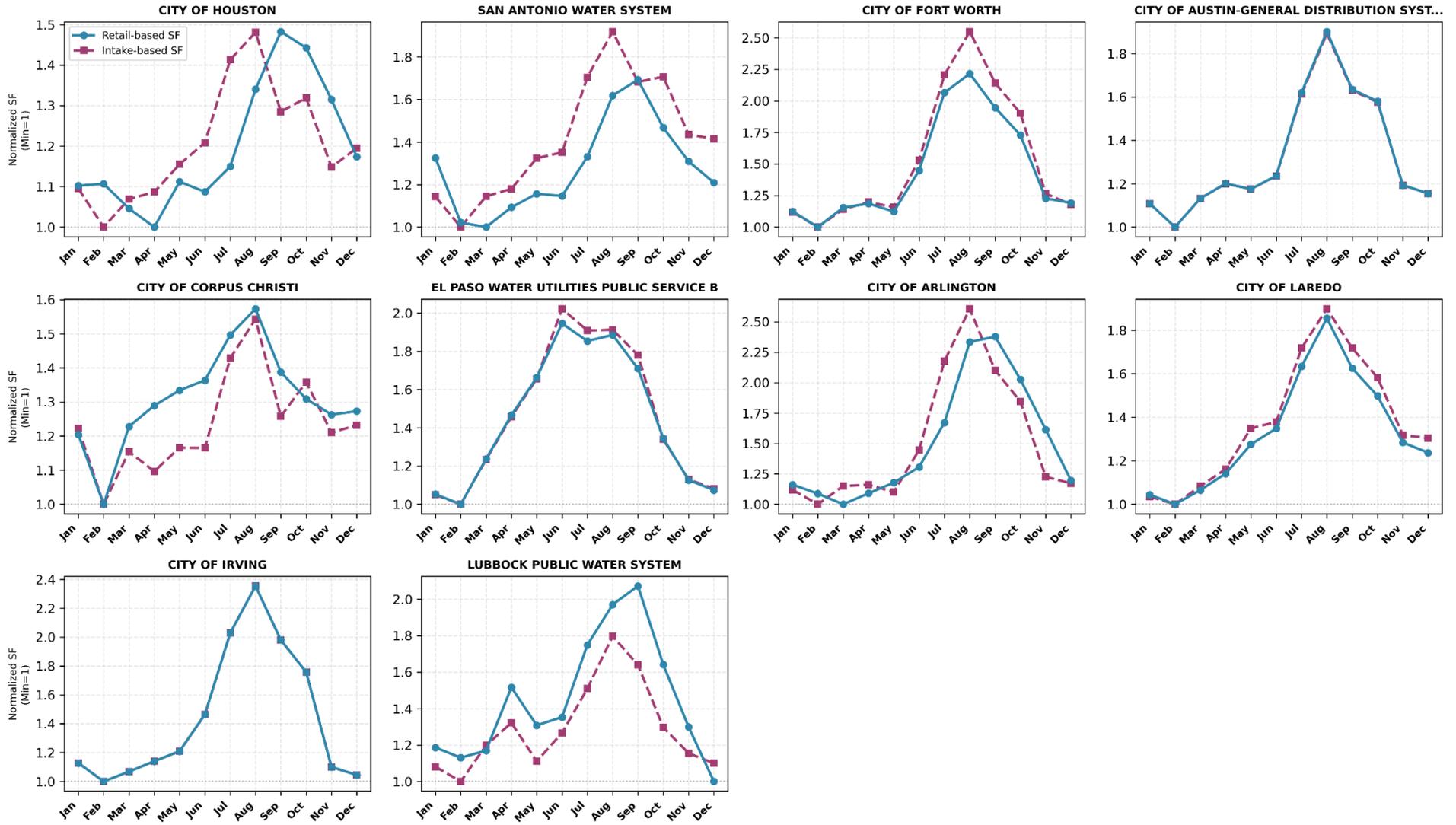


Figure 2

Normalized SF Monthly Volumes: Largest Systems (2017)

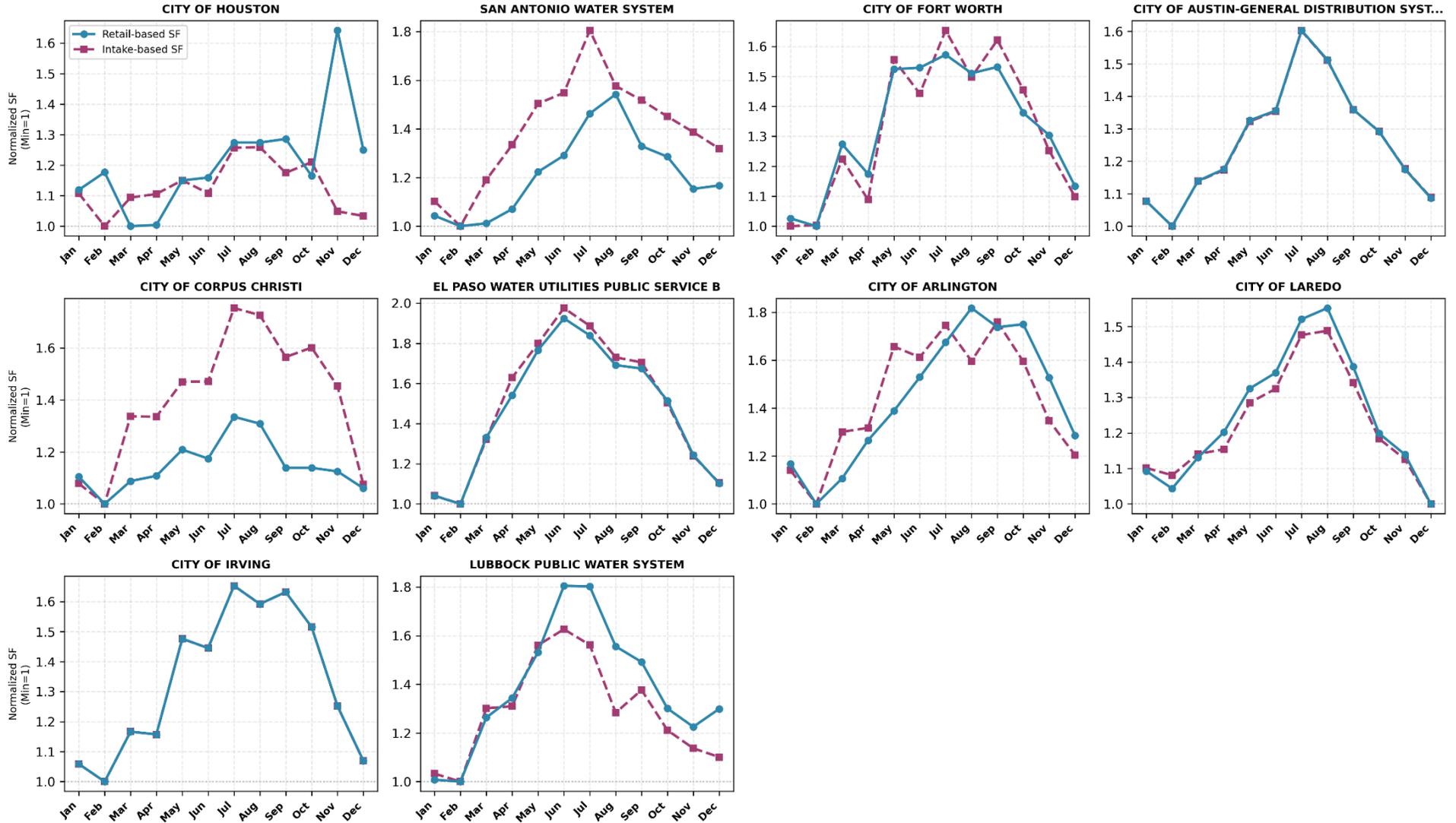


Figure 3

Normalized SF Monthly Volumes: Largest Systems (2018)

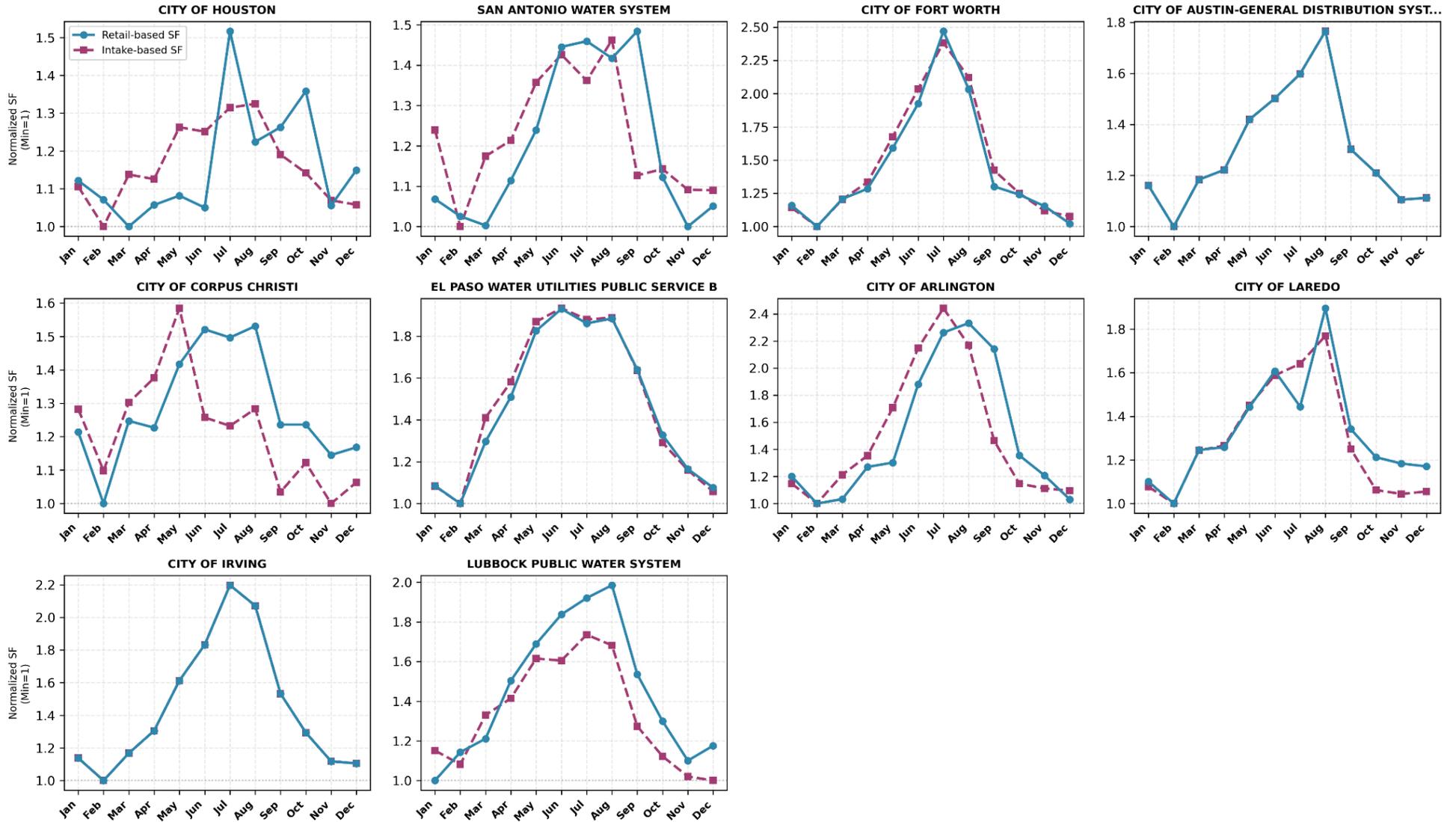


Figure 4

Normalized SF Monthly Volumes: Largest Systems (2019)

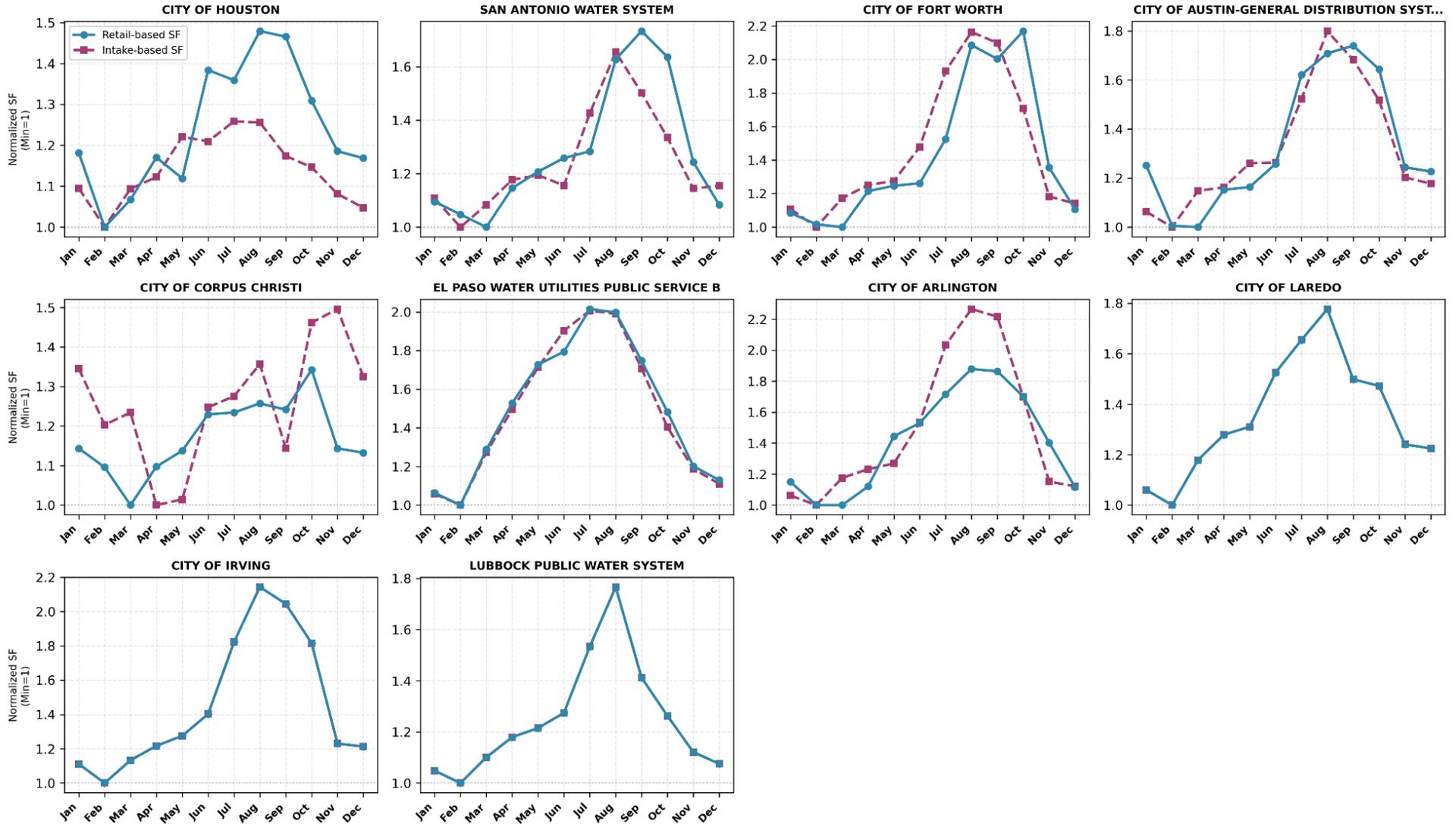


Figure 5

Normalized SF Monthly Volumes: Largest Systems (2021)

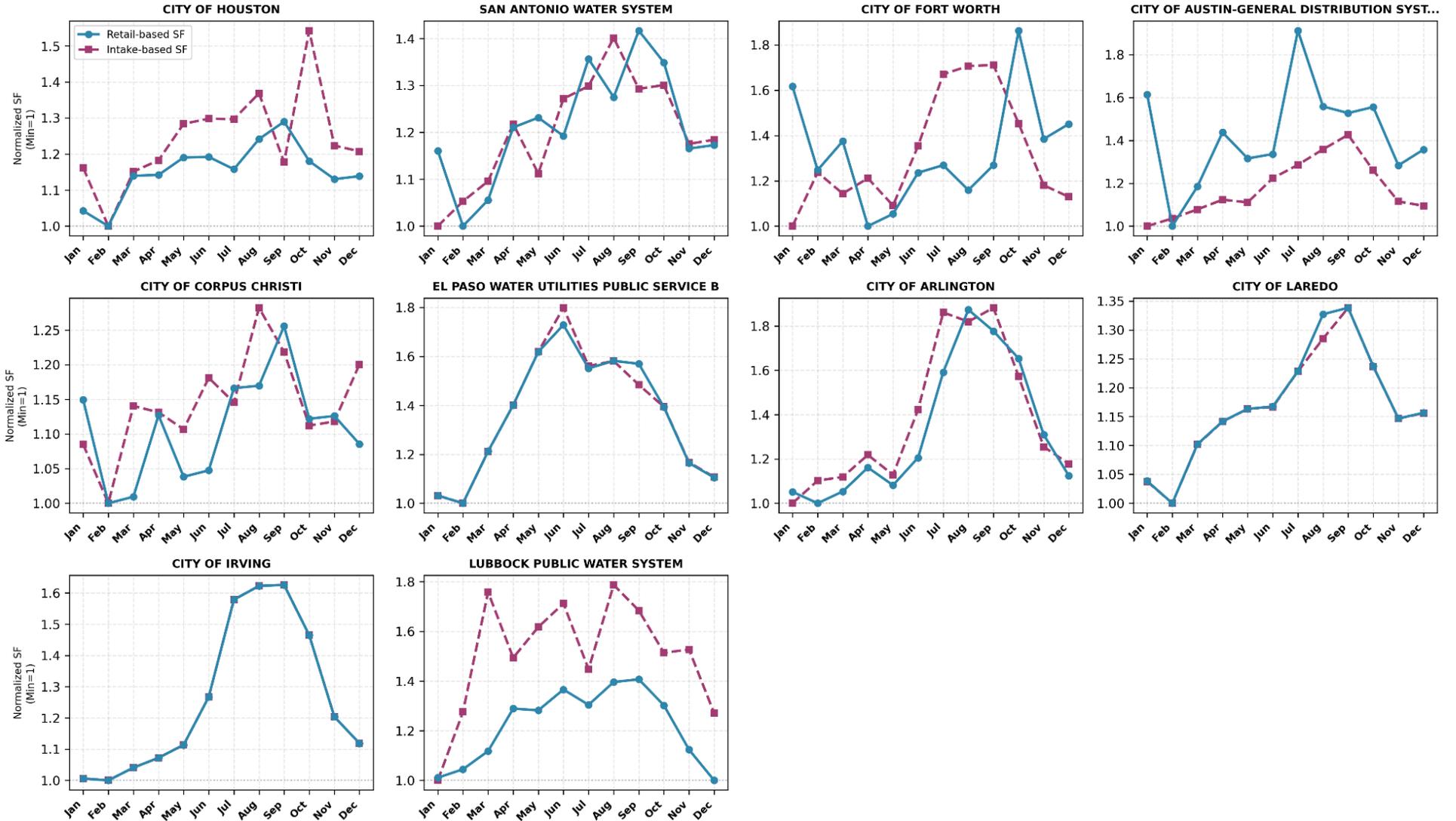


Figure 6

Normalized SF Monthly Volumes: Largest Systems (2022)

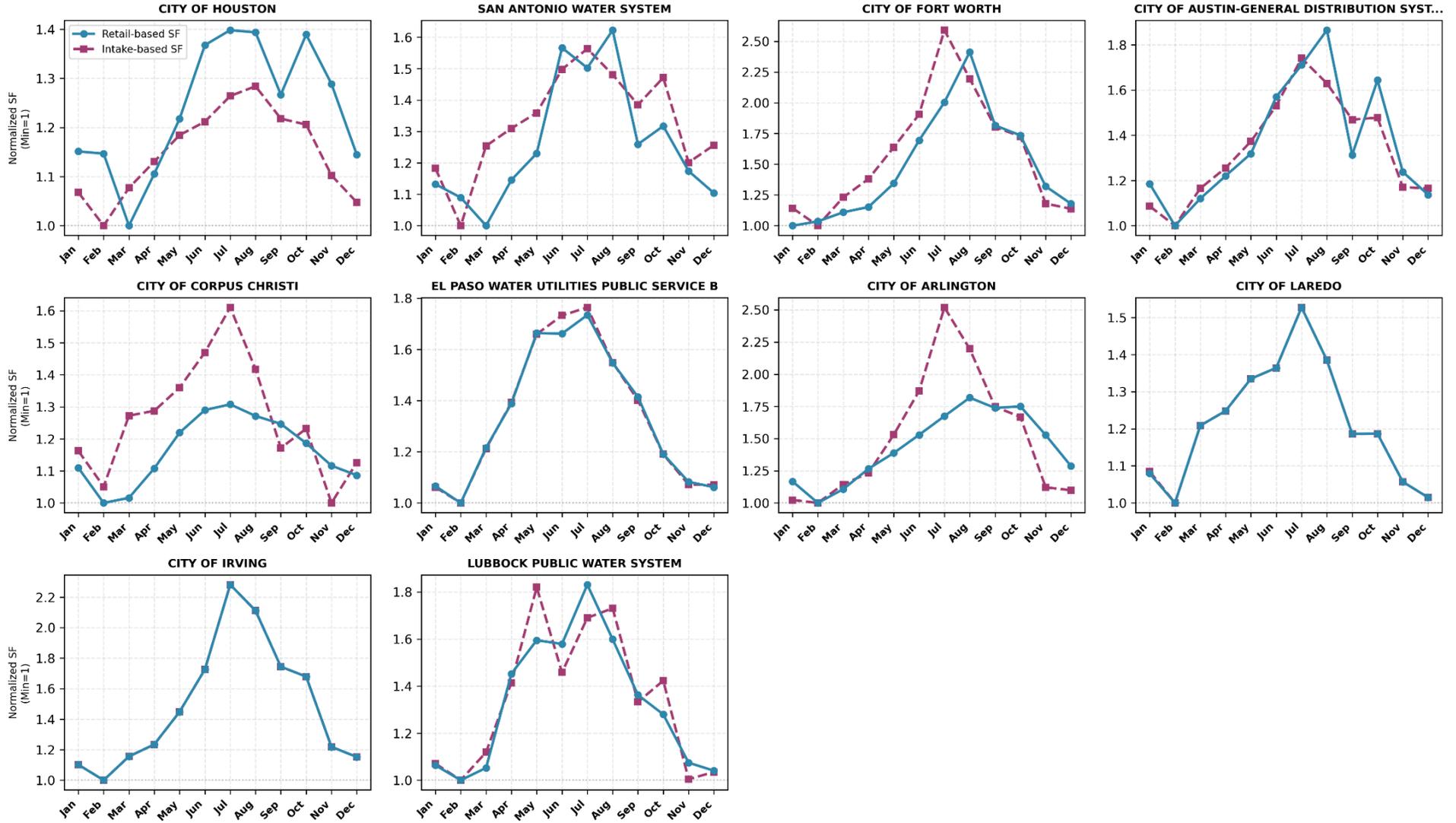


Figure 7

Normalized SF Monthly Volumes: Largest Systems (2023)

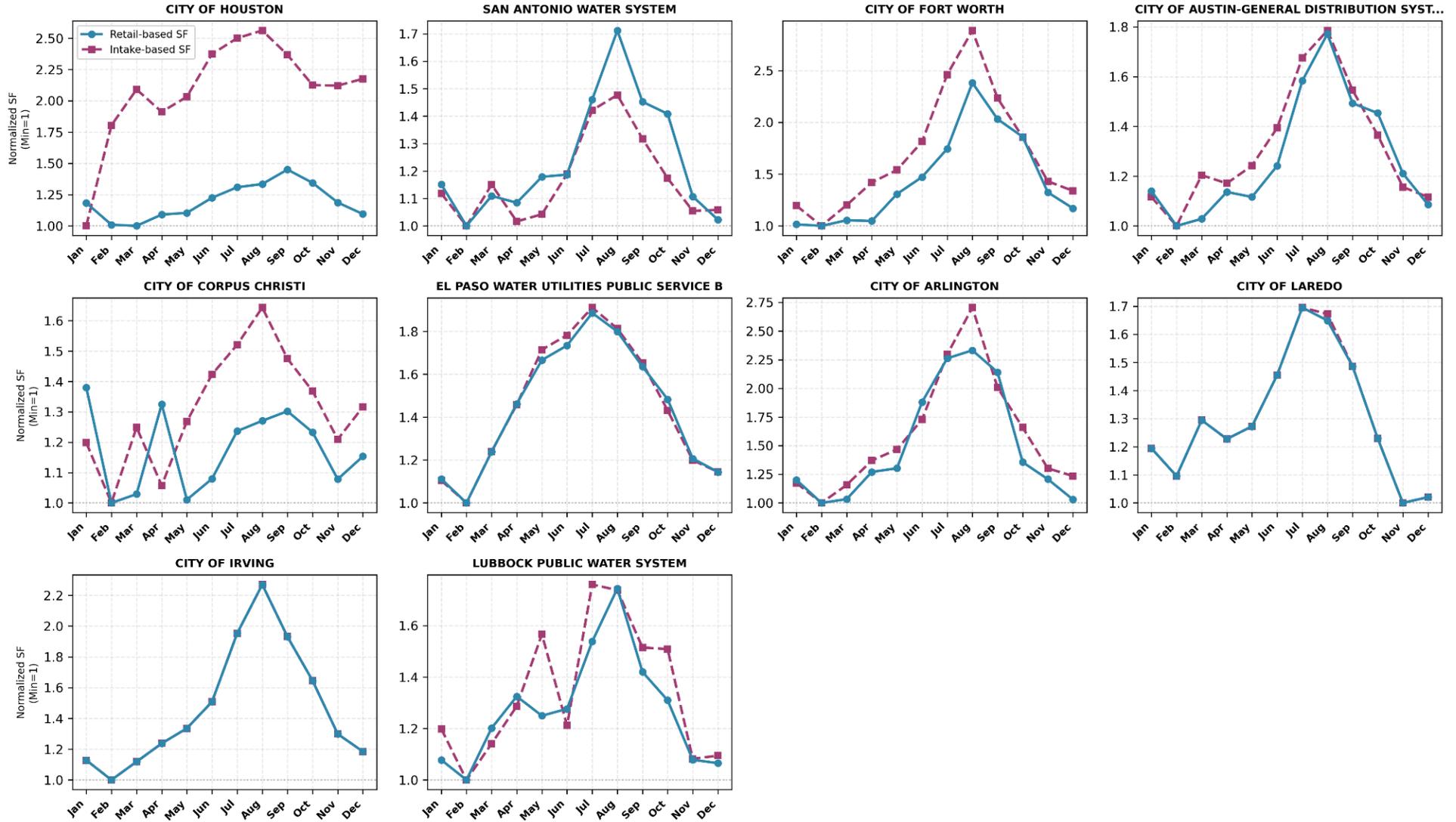


Figure 8

Normalized SF Monthly Volumes: Medium Systems (2015)

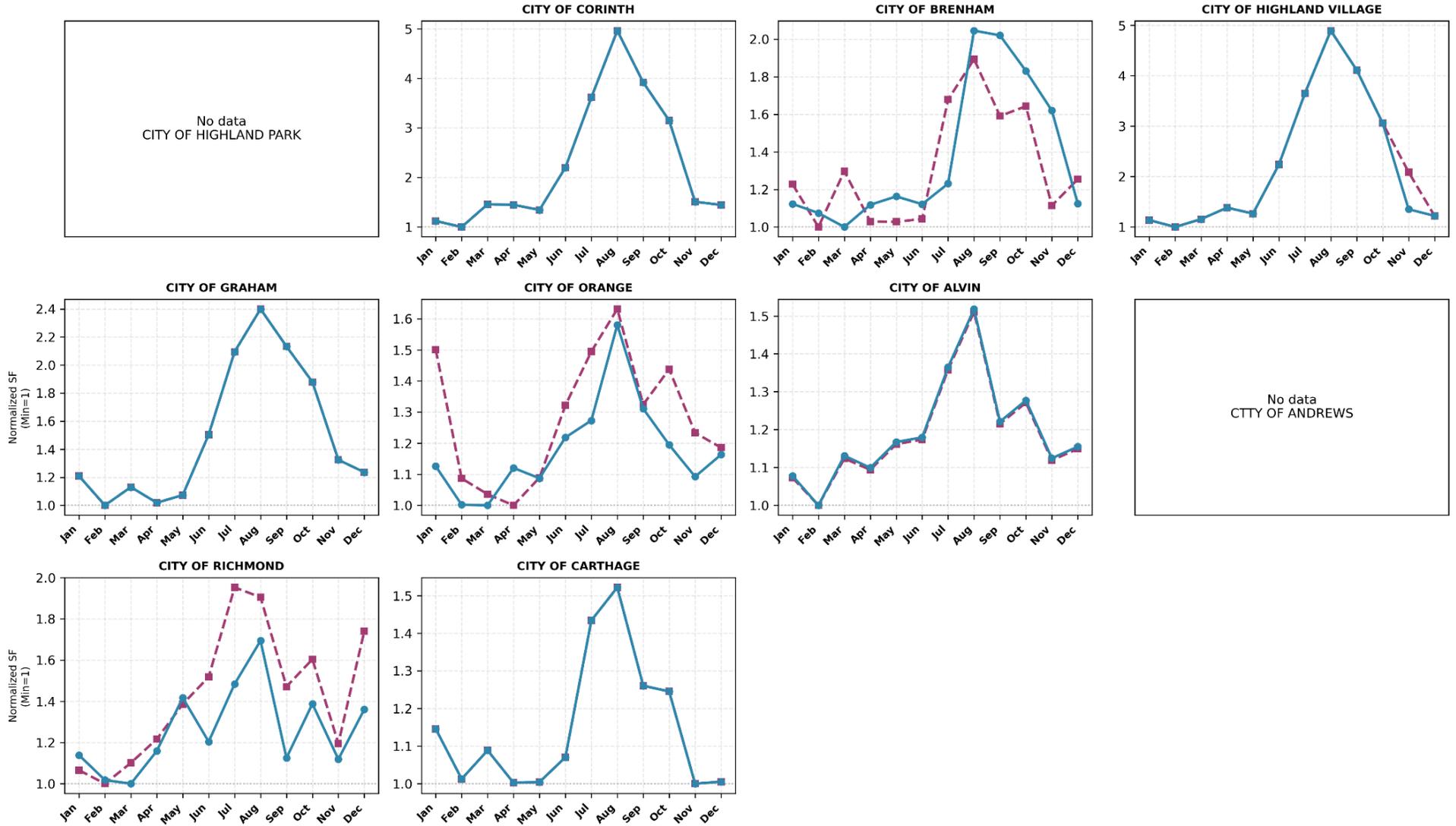


Figure 9

Normalized SF Monthly Volumes: Medium Systems (2017)

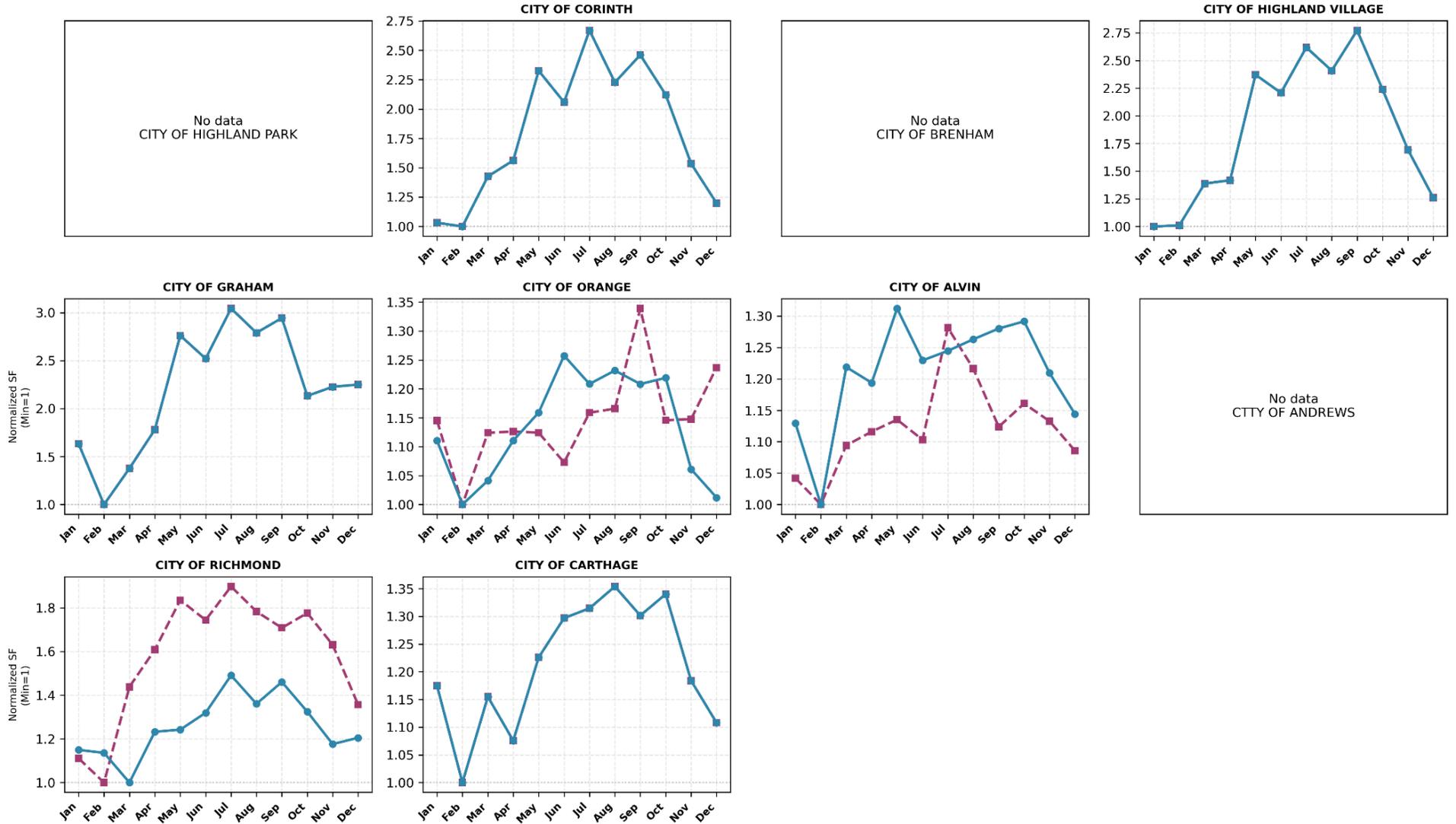


Figure 10

Normalized SF Monthly Volumes: Medium Systems (2018)

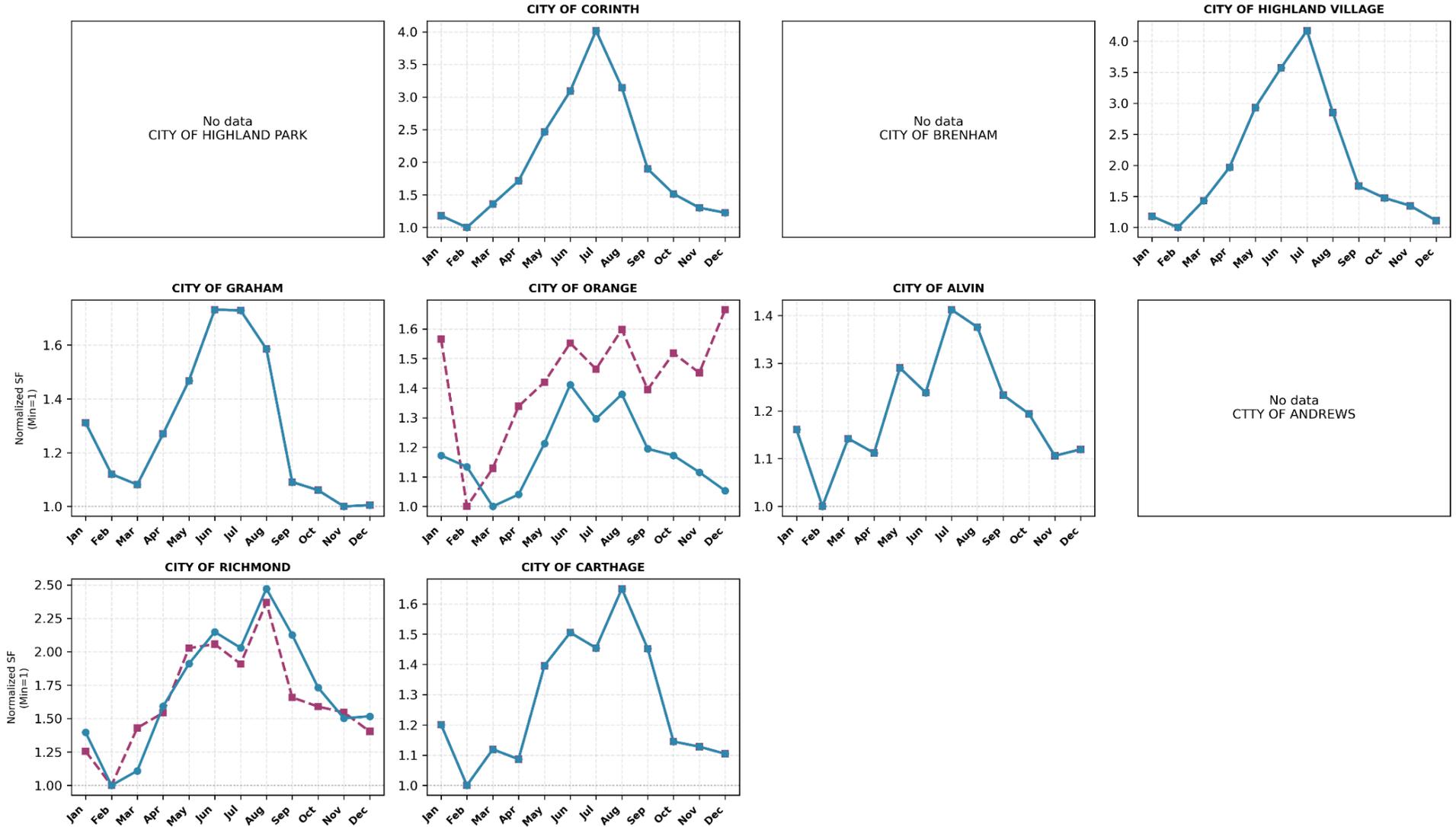


Figure 11

Normalized SF Monthly Volumes: Medium Systems (2019)

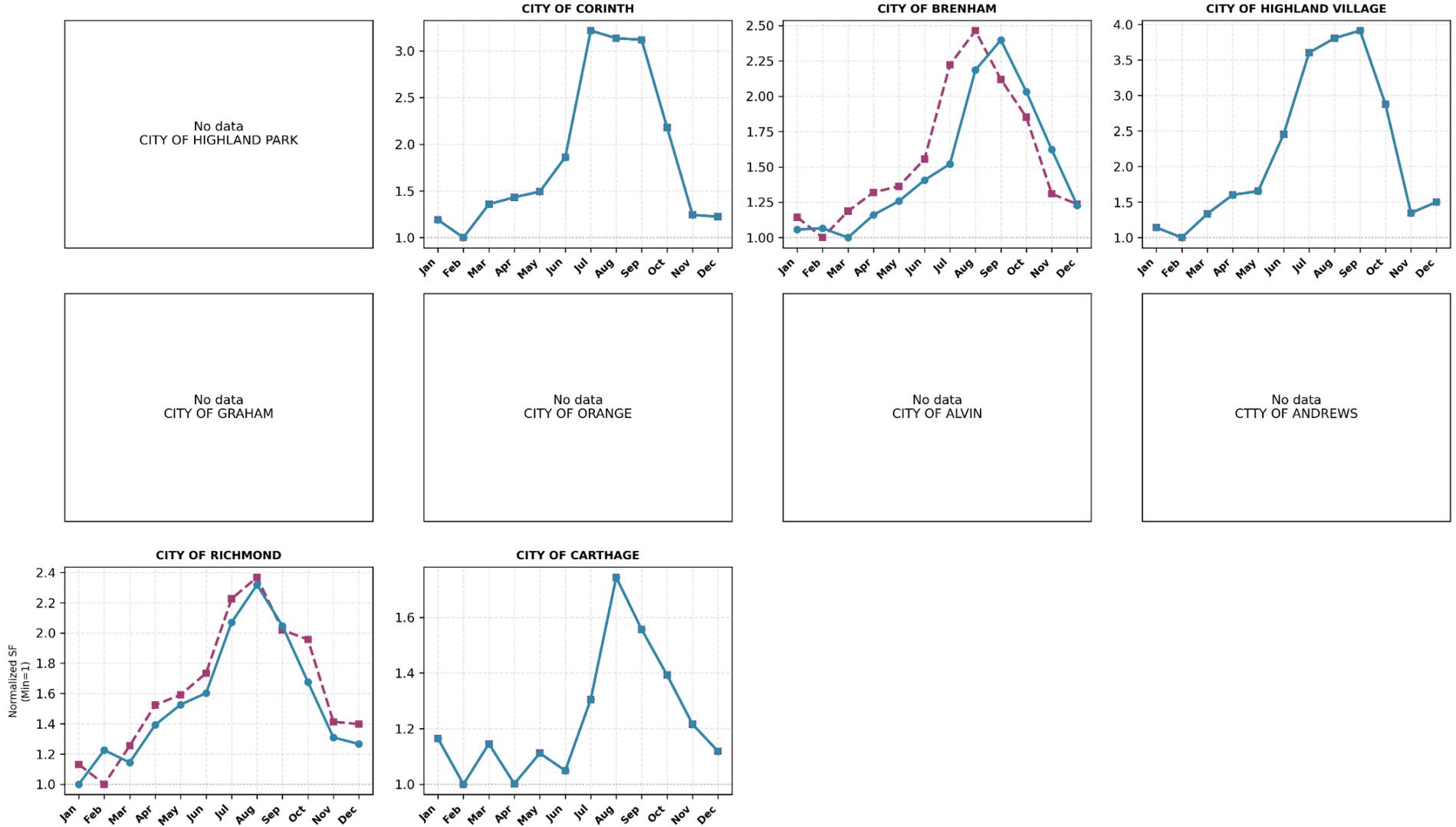


Figure 12

Normalized SF Monthly Volumes: Medium Systems (2021)

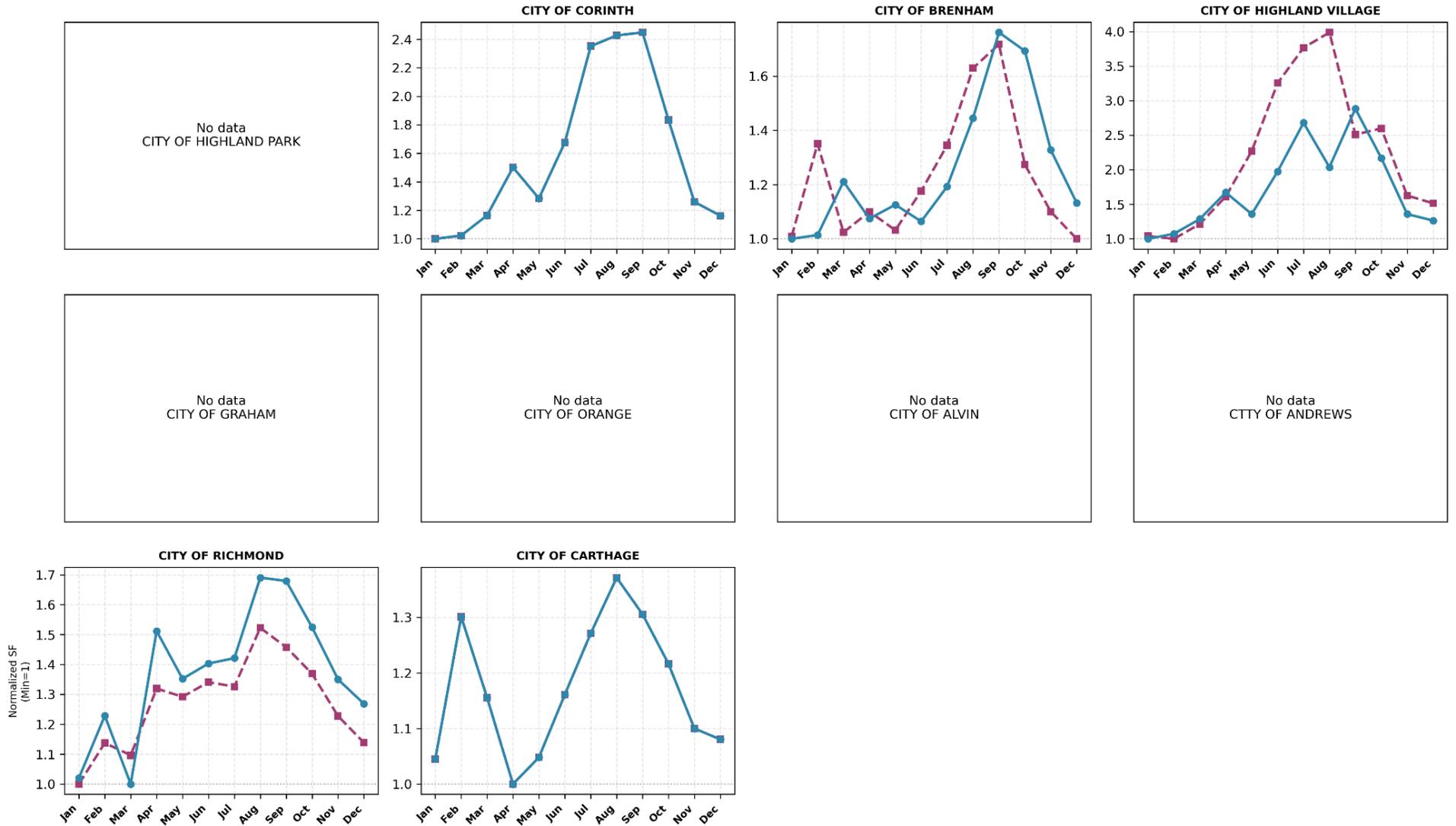


Figure 13

Normalized SF Monthly Volumes: Medium Systems (2022)

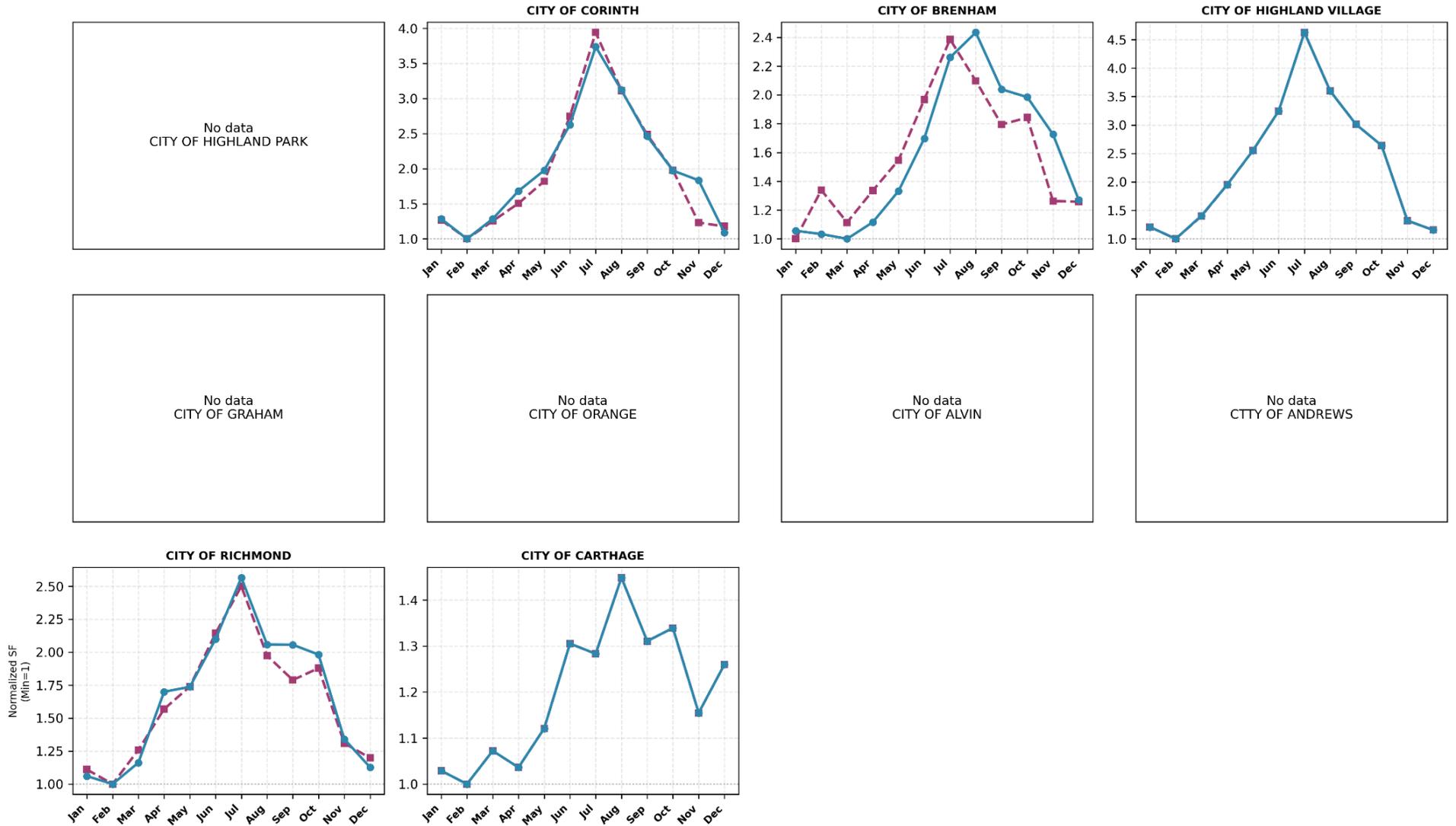


Figure 14

Normalized SF Monthly Volumes: Medium Systems (2023)

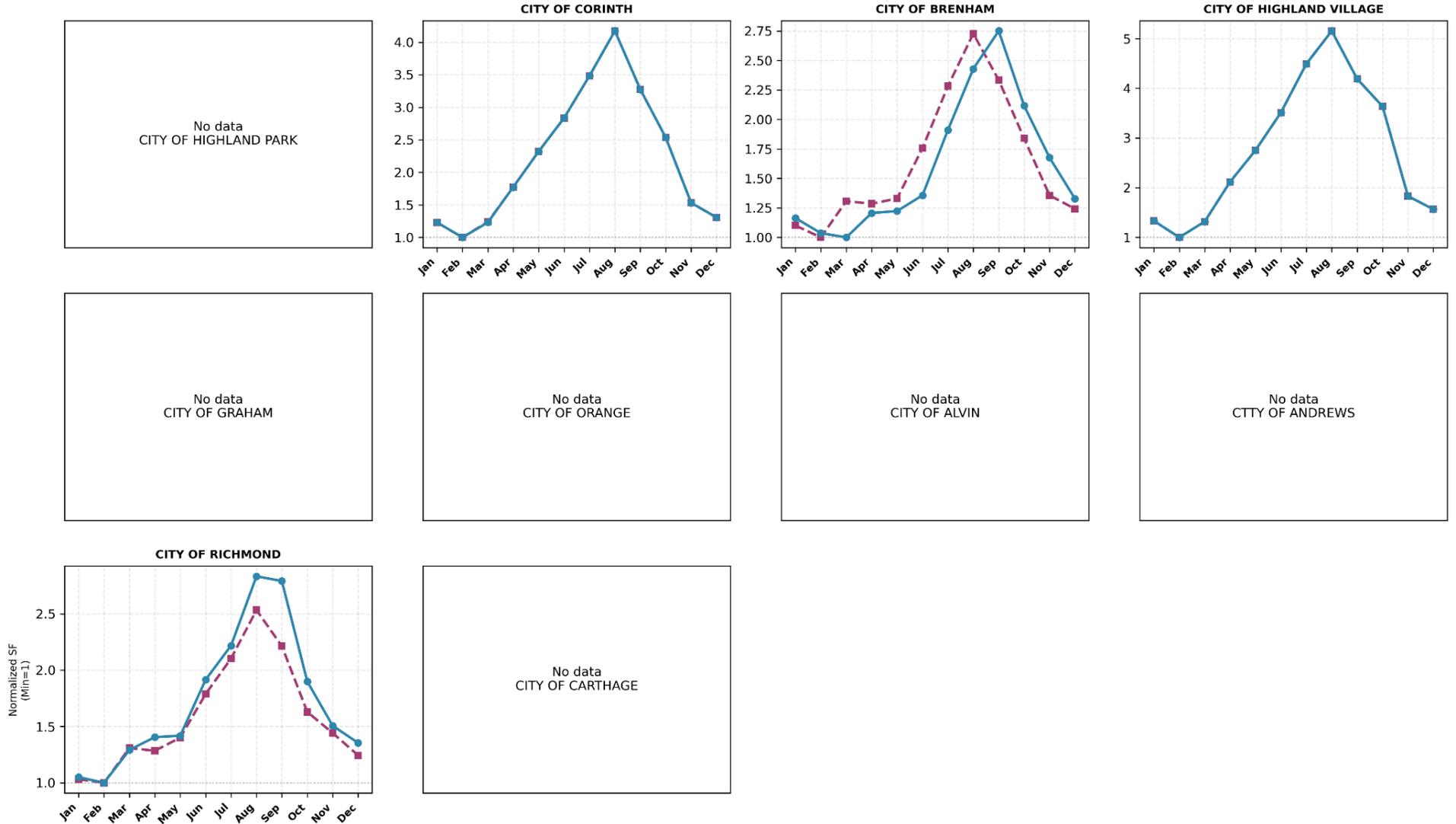


Figure 15

Normalized SF Monthly Volumes: Smallest Systems (2015)

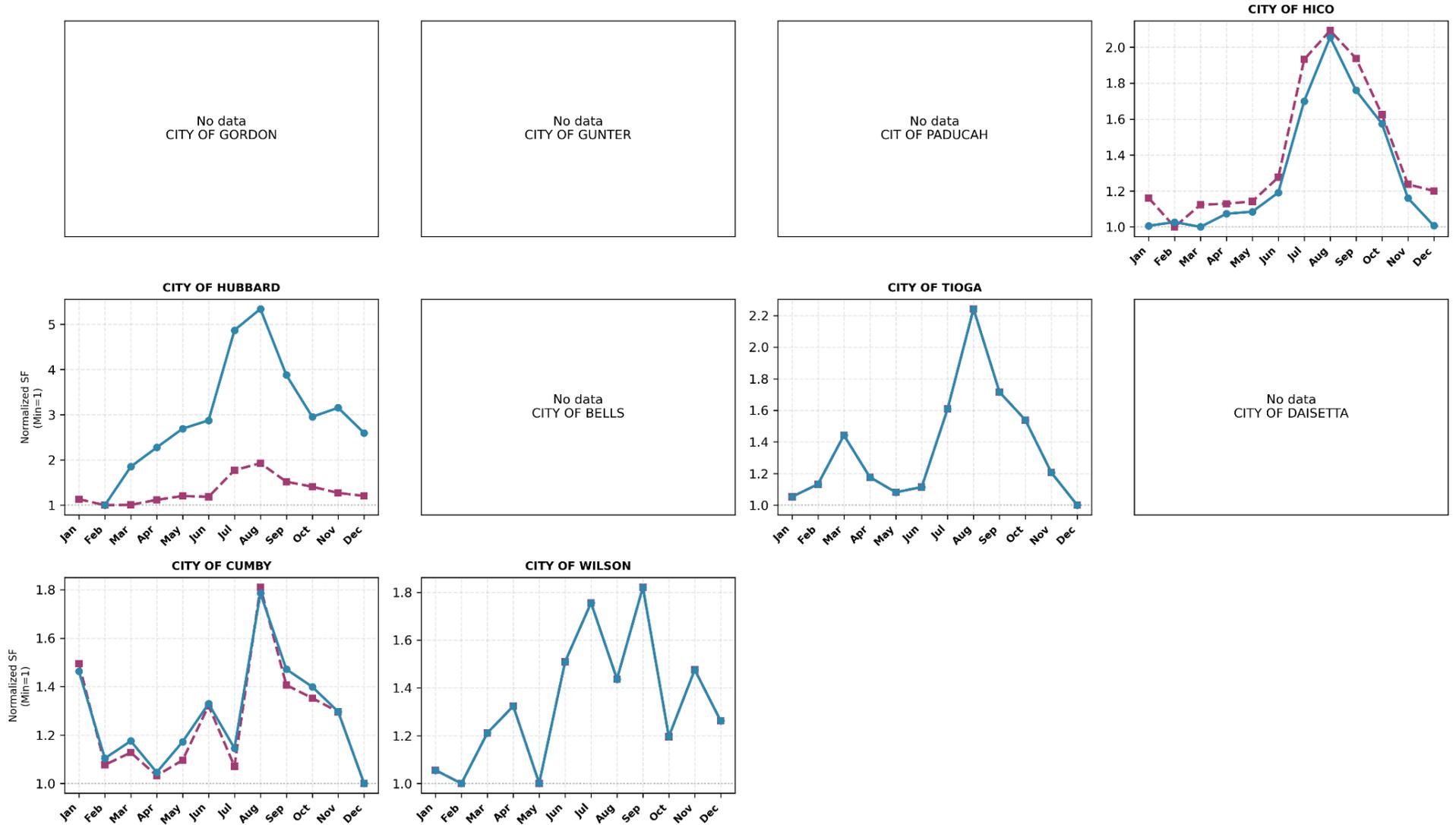


Figure 16

Normalized SF Monthly Volumes: Smallest Systems (2017)

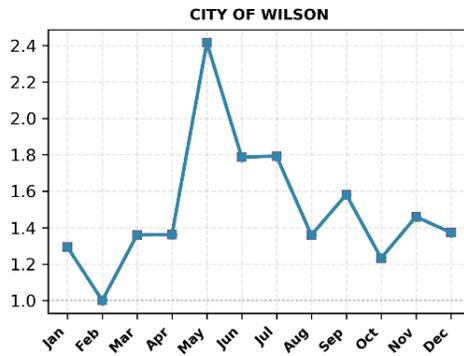
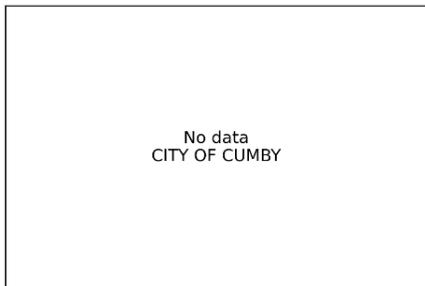
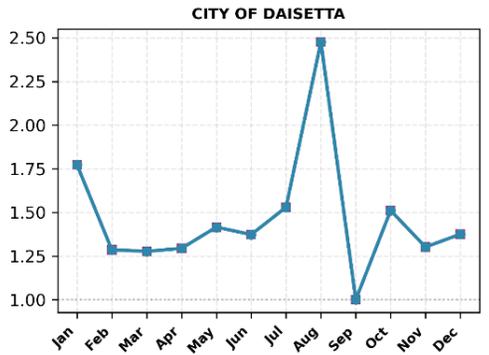
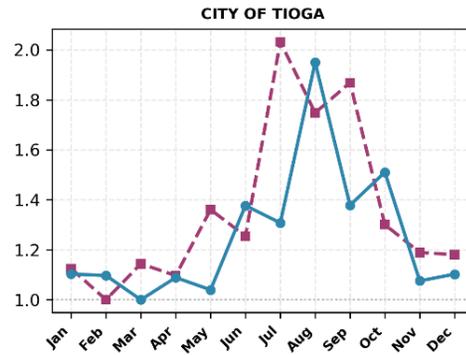
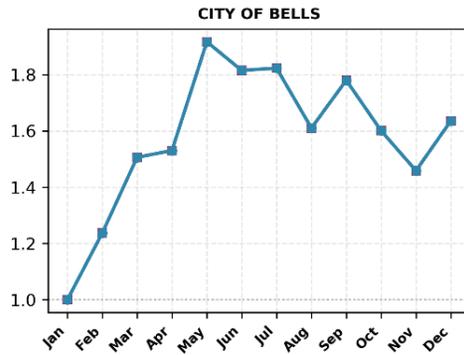
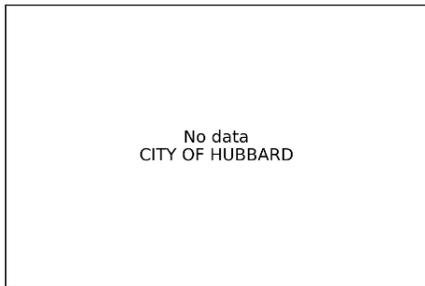
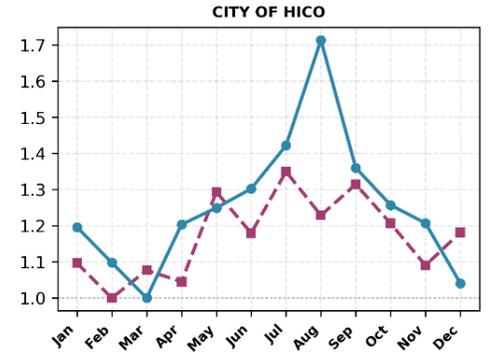
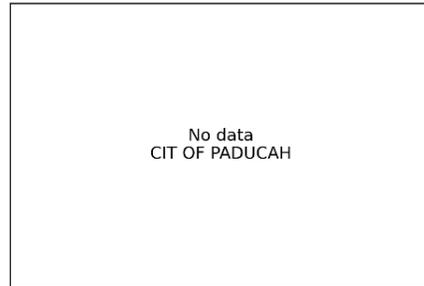


Figure 17

Normalized SF Monthly Volumes: Smallest Systems (2018)

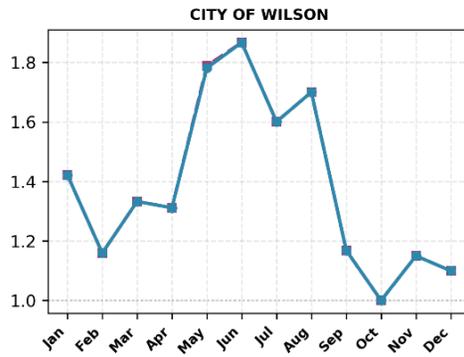
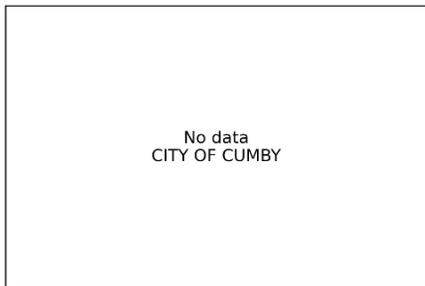
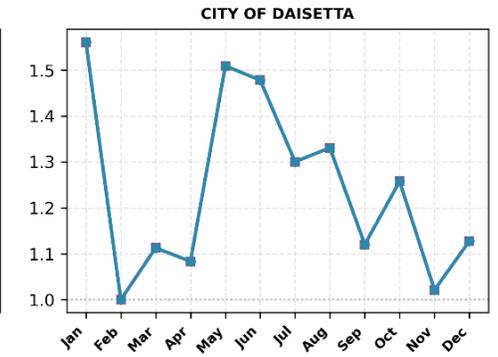
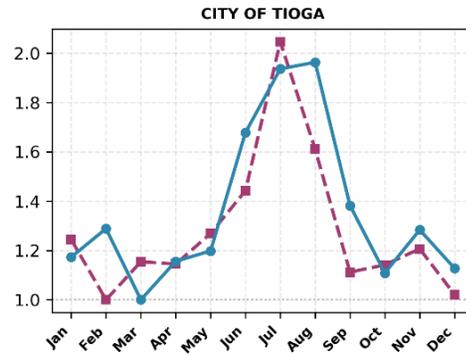
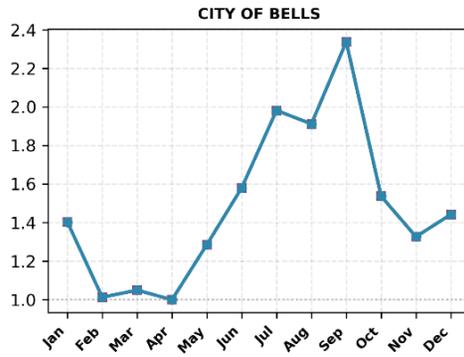
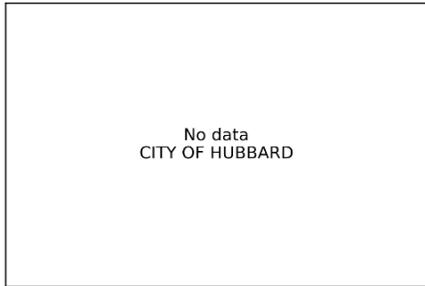
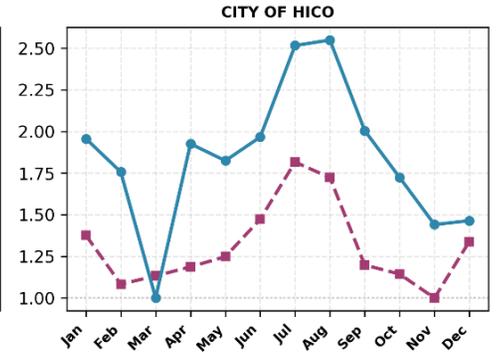
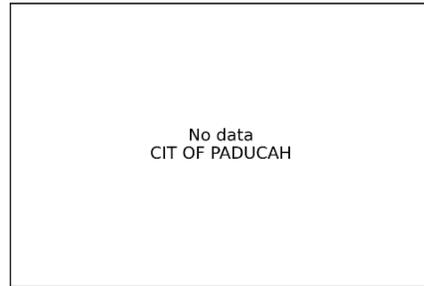
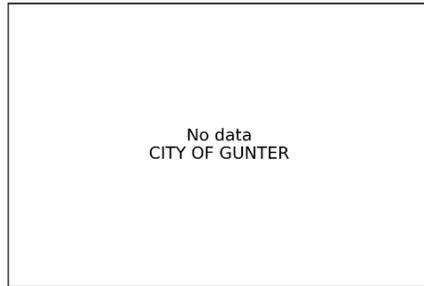
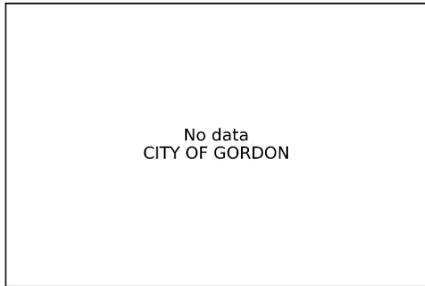
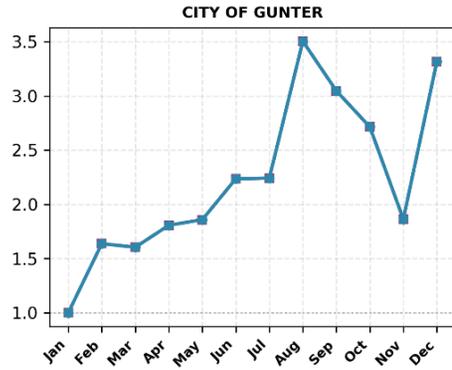
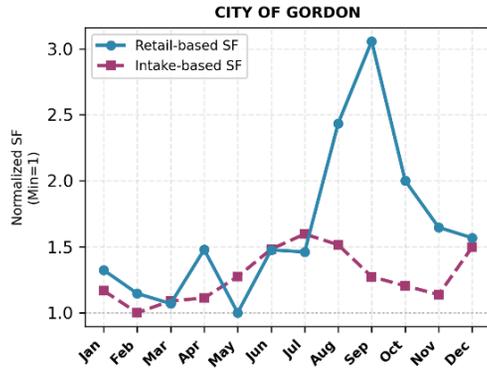
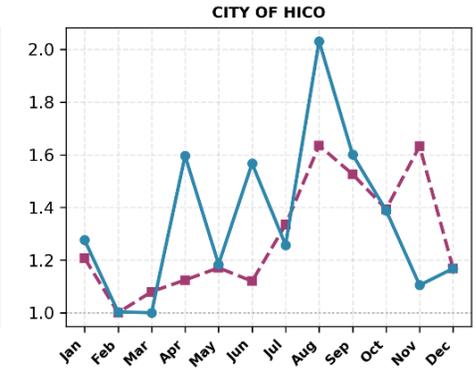


Figure 18

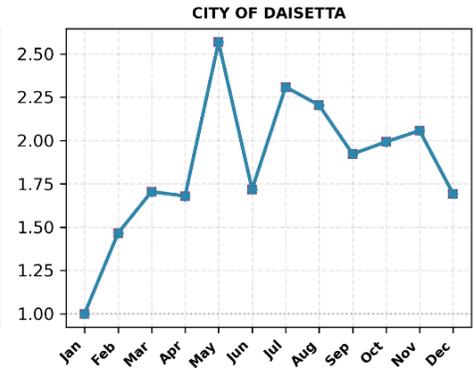
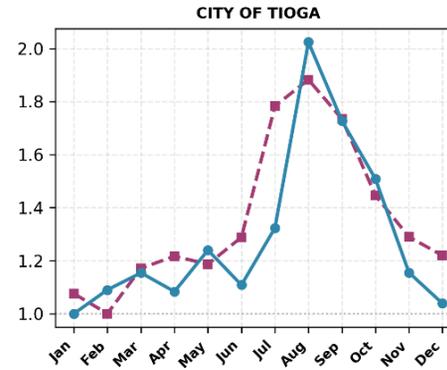
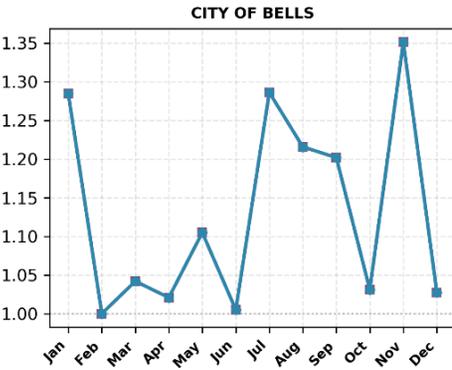
Normalized SF Monthly Volumes: Smallest Systems (2019)



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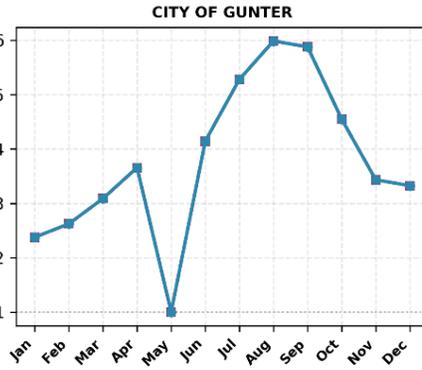
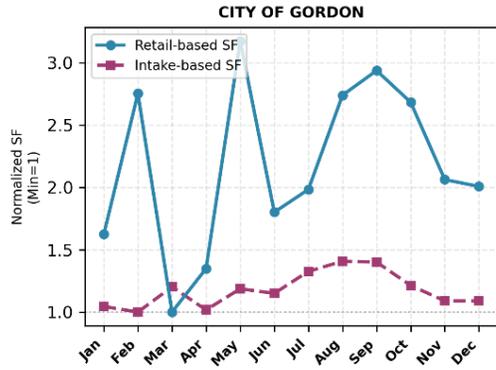


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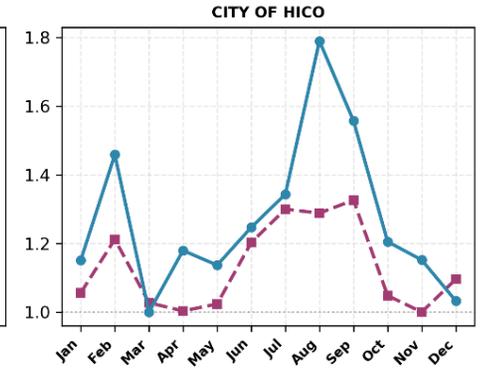
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Figure 19

Normalized SF Monthly Volumes: Smallest Systems (2021)

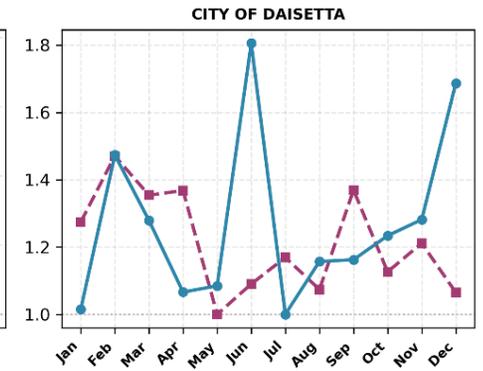
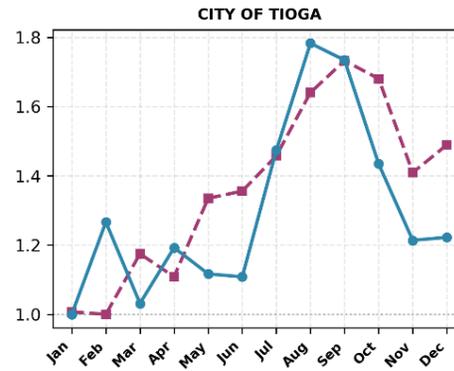


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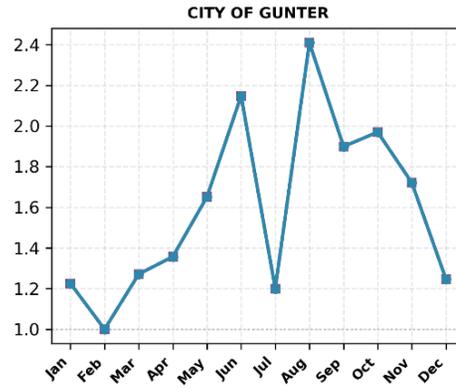
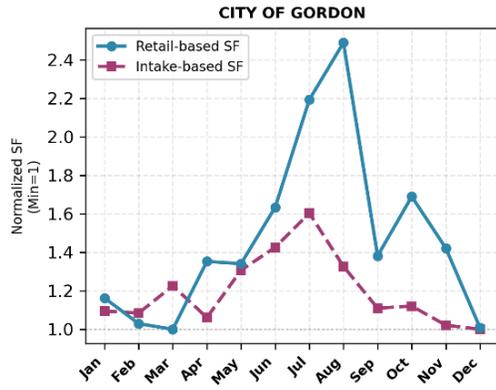


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Figure 20

Normalized SF Monthly Volumes: Smallest Systems (2022)



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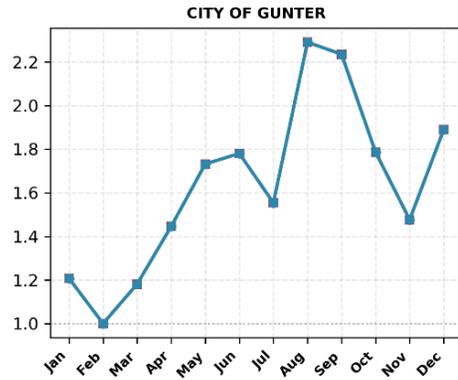
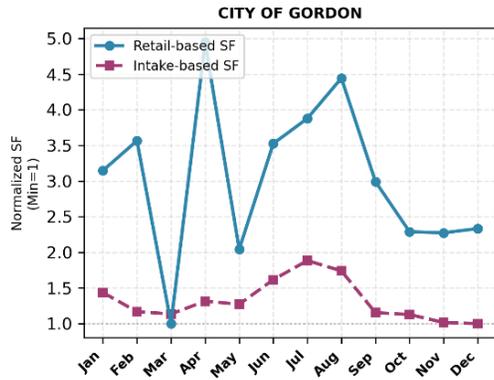
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Figure 21

Normalized SF Monthly Volumes: Smallest Systems (2023)



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Figure 22

Seasonal comparison between Phase 1 monthly sf and current study: Largest systems

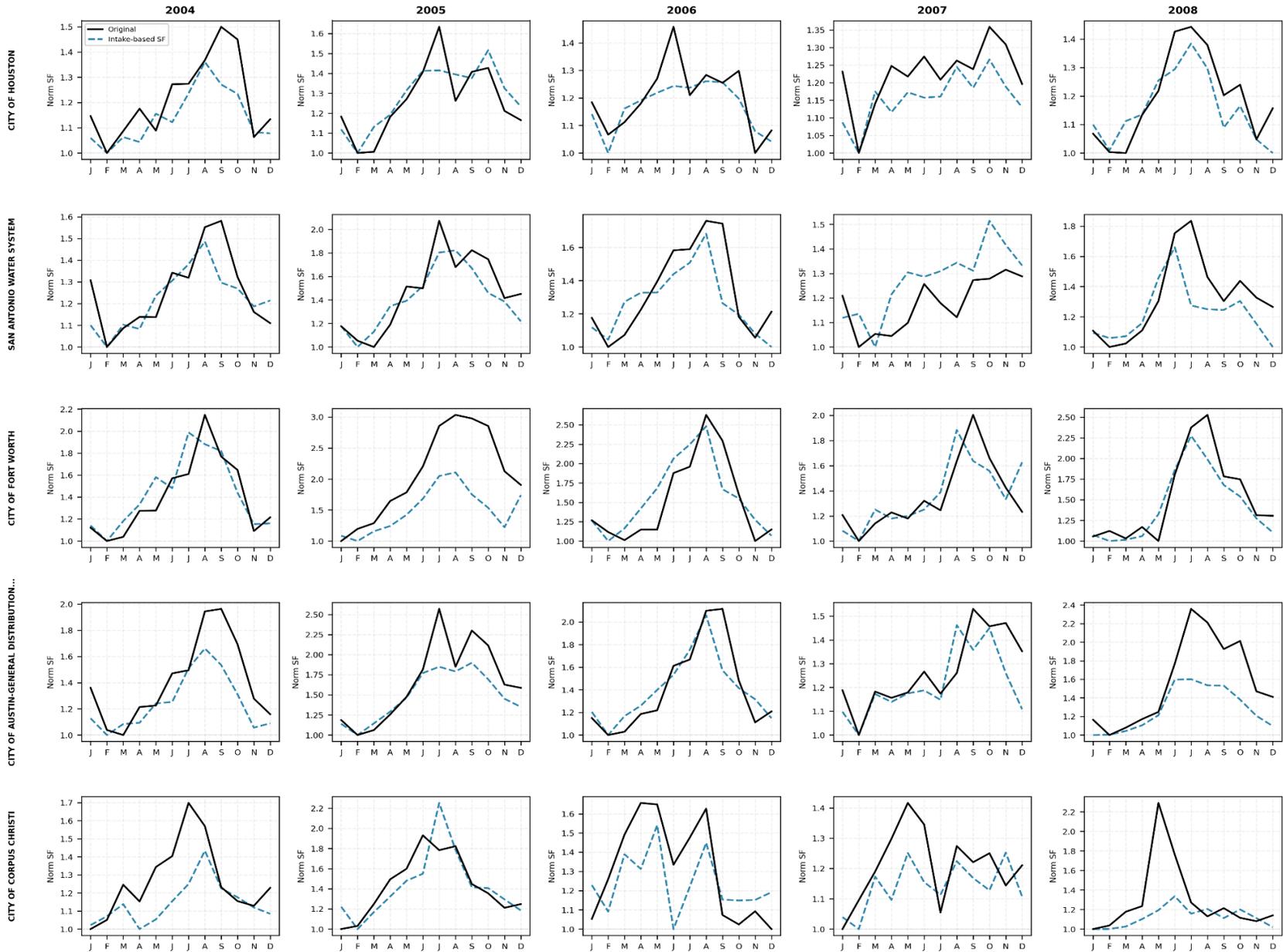


Figure 23

Seasonal comparison between Phase 1 monthly sf and current study: Largest systems

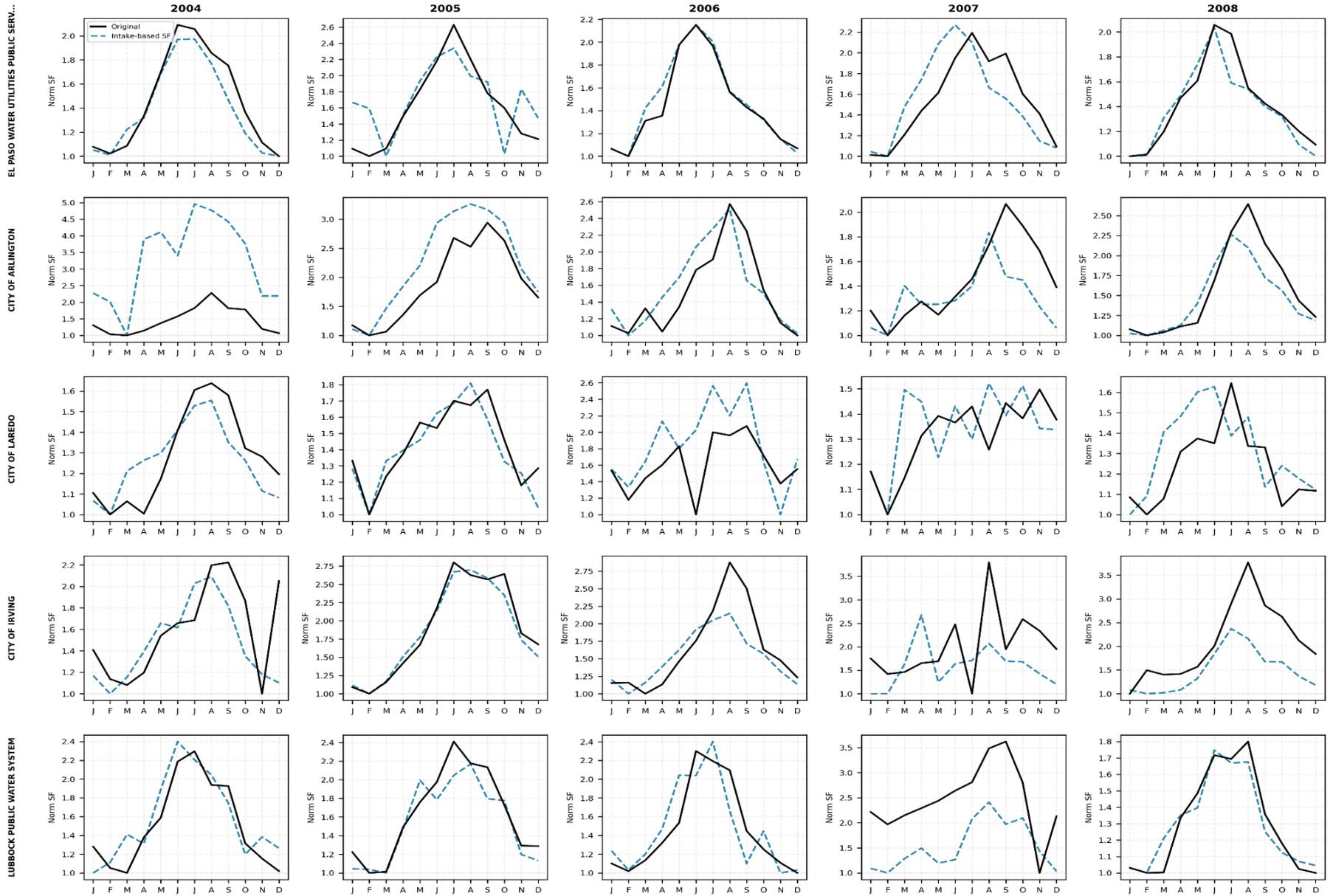


Figure 24

Seasonal comparison between Phase 1 monthly sf and current study: Medium systems

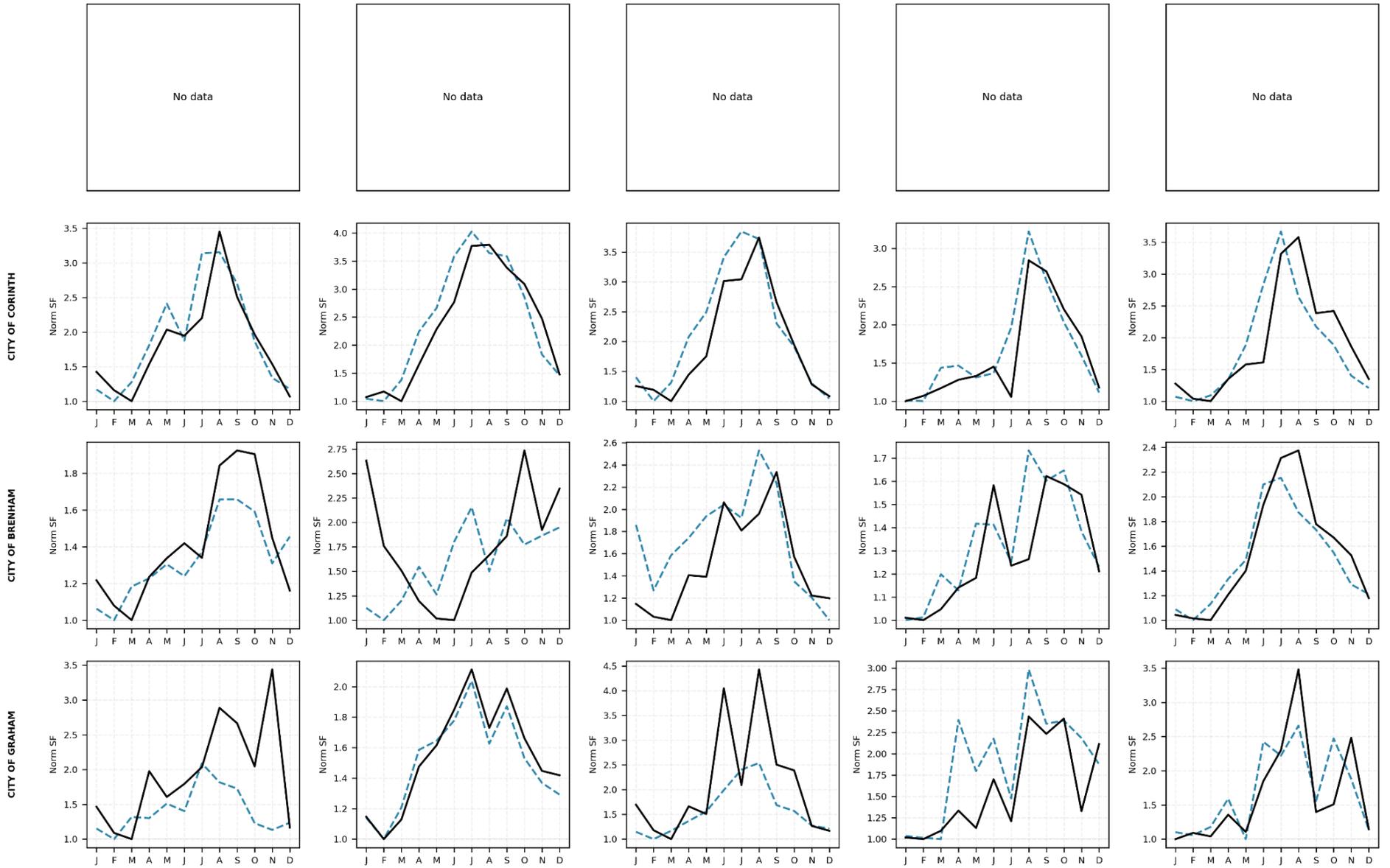


Figure 25

Seasonal comparison between Phase 1 monthly sf and current study: Medium systems

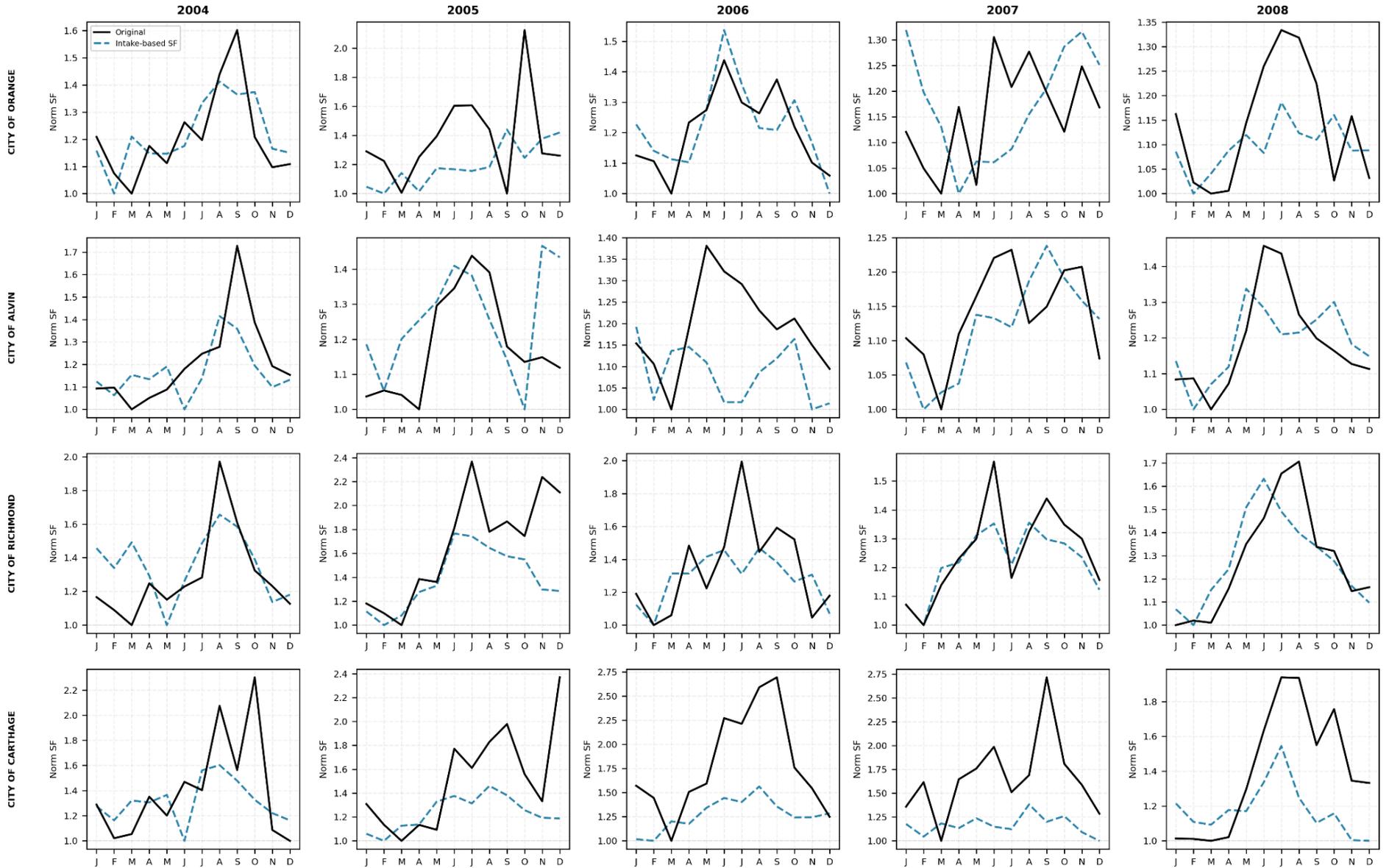


Figure 26

Seasonal comparison between Phase 1 monthly sf and current study: Smallest systems

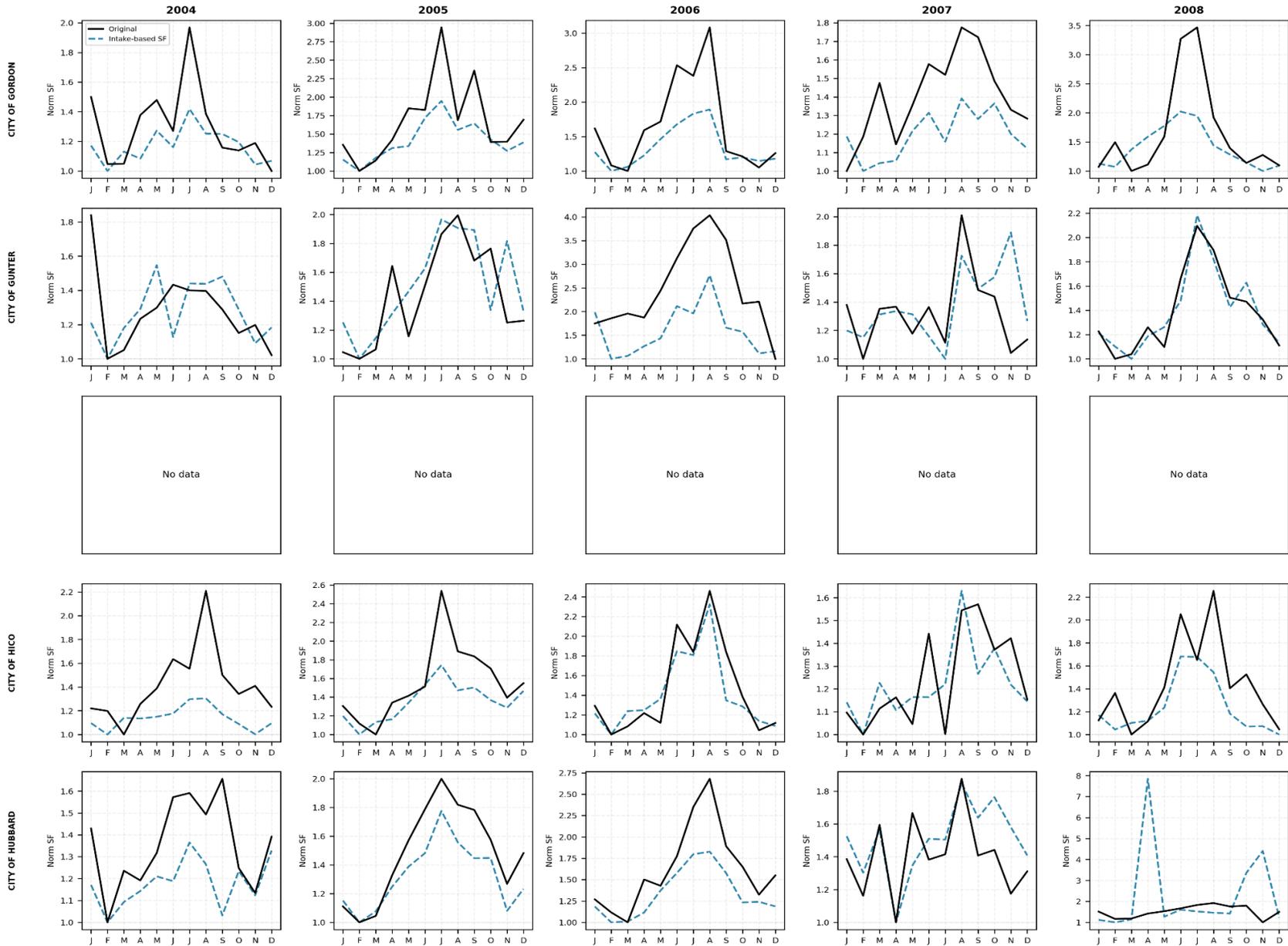


Figure 27

Seasonal comparison between Phase 1 monthly sf and current study: Smallest systems

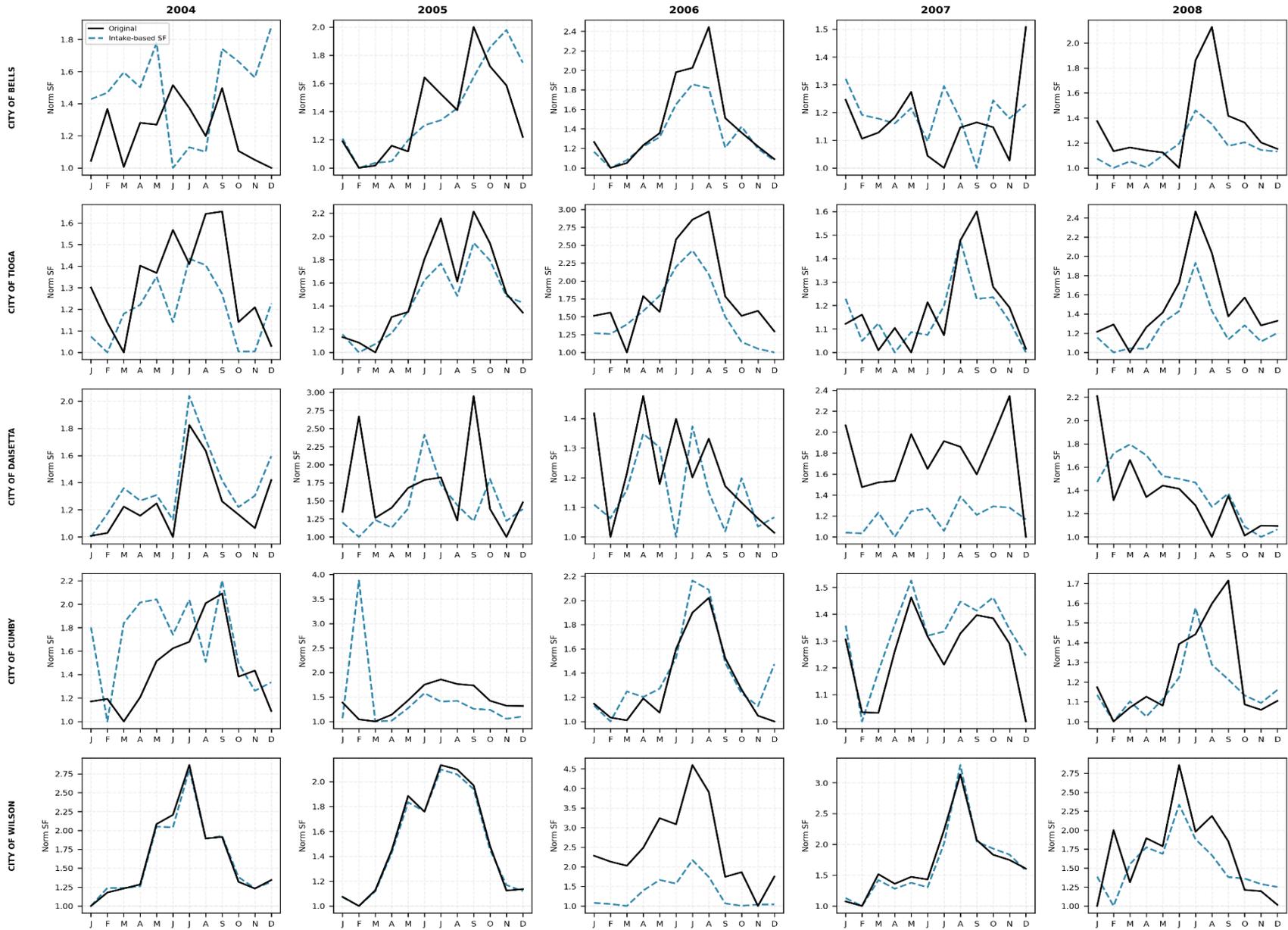


Figure 28

Seasonal comparison between Phase 2 monthly sf and current study

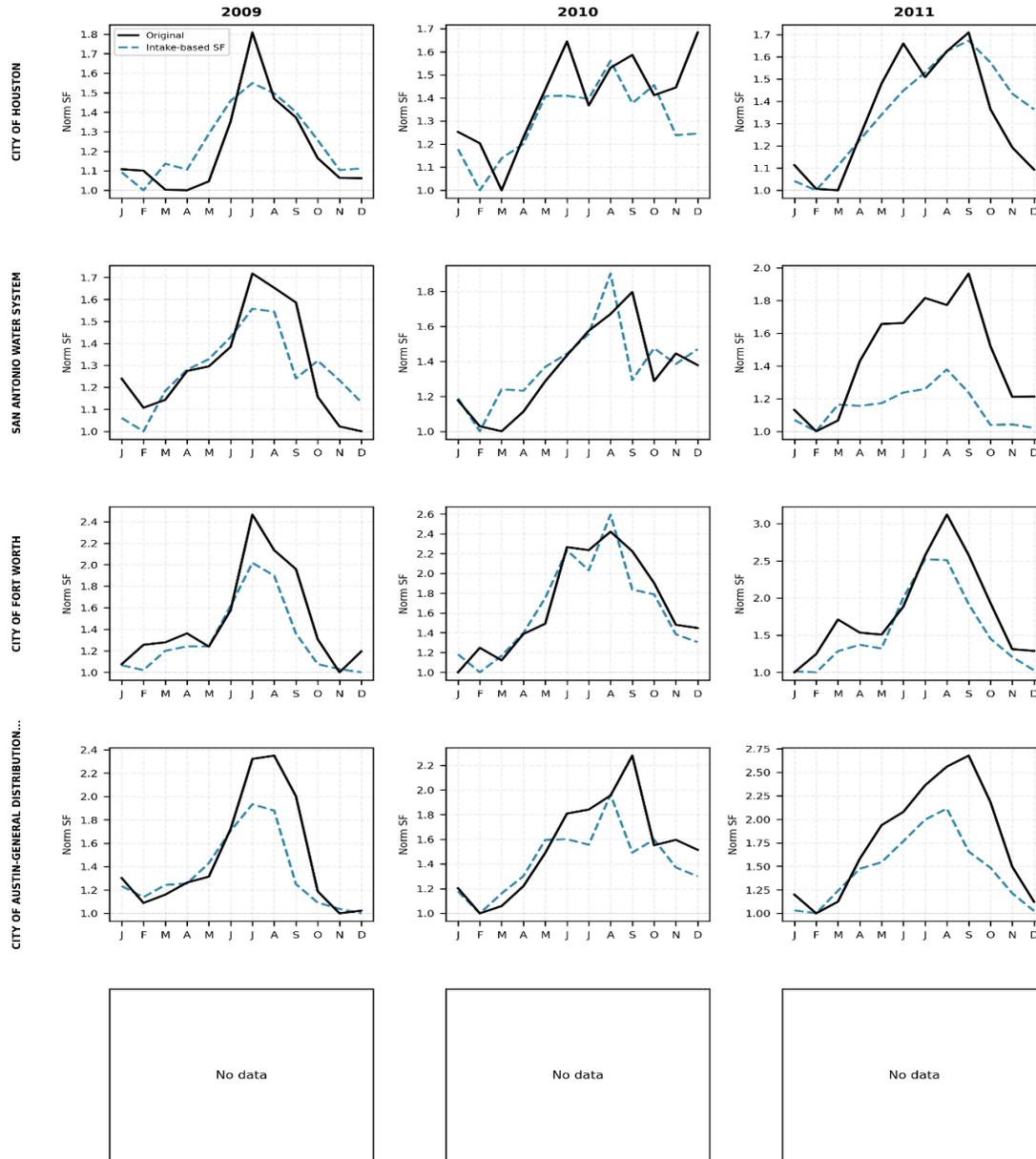


Figure 29

Progress Report 3

Seasonal comparison between Phase 2 monthly sf and current study

