Staff Report

Progress Report on San Joaquin Valley Emissions Reductions for the 0.08 Parts Per Million 8-Hour Ozone Standard

October 18, 2019

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EXECUTIVE SUMMARY

This Progress Report on San Joaquin Valley Emissions Reductions for the 0.08 Parts Per Million 8-Hour Ozone Standard (Report) demonstrates that the California Air Resources Board (CARB) has met the Clean Air Act (Act) requirement to define control measures needed to achieve emissions reductions undefined in the 2007 Ozone Plan for the San Joaquin Valley (Valley). The Report fulfills the commitment CARB made in 2011 to revisit the 2007 Ozone Plan air quality modeling to reflect emission inventory improvements and any other new information for the 8-hour standard. The updated modeling results confirm that the 2023 attainment emission targets of 160 tons per day (tpd) of oxides of nitrogen (NOx) and 342 tpd of reactive organic gas (ROG) in the 2007 Ozone Plan are appropriate, and demonstrates that, with existing control measures and without reliance on emission reductions from Act section 182(e)(5) advanced technology measures, the Valley is on track to attain the 0.08 ppm 8-hour ozone standard in 2023. This report will be submitted to the United States Environmental Protection Agency (U.S. EPA) as a revision to the California State Implementation Plan (SIP).

BACKGROUND

2007 Ozone Plan and Clean Air Act Section 182(e)(5) Requirements

In 2007, CARB adopted the 2007 Ozone Plan[1] for the 8-hour ozone standard of 0.08 ppm for the Valley. The Valley is in Extreme nonattainment for this standard. The 2007 Ozone Plan identified the overall emissions reductions needed to meet the standard by 2023 and laid out the State and San Joaquin Valley Air Pollution Control District (District) control strategy necessary to achieve those reductions. Ongoing implementation of CARB's longstanding mobile source control programs for new passenger vehicles, trucks, buses, and off-road equipment provided the core portion of the needed emissions reductions, with additional reductions from in-use vehicles and equipment.

To demonstrate attainment in 2023, the 2007 Ozone Plan relied on 82 tpd of NOx emissions reductions coming from control measures that were undefined at the time, as permitted under the Act. Section 182(e)(5) of the Act allows Extreme ozone nonattainment areas like the Valley to include emissions reductions in their attainment strategy from anticipated development of new control techniques or improvement of existing control technologies. These advanced technology measures are generally undefined at the time the SIP is adopted and submitted to U.S. EPA. Areas with SIPs that rely on such provisions must submit a SIP revision three years prior to the attainment year[2] to demonstrate the area will achieve the reductions assigned to the undefined measures by the attainment date, or include additional adopted contingency measures. This report demonstrates that NOx emissions reductions needed for

[1] San Joaquin Valley Air Pollution Control District. *2007 Ozone Plan*. April 30, 2007. http://www.valleyair.org/Air_Quality_Plans/AQ_Final_Adopted_Ozone2007.htm

[2] Since the Valley must attain the 0.08 ppm 8-hour standard by 2023, measures must be in place by December 31, 2022, and must be defined by December 31, 2019.

attainment in 2023 can be met with defined CARB and District measures adopted since the 2007 Ozone Plan was submitted to U.S. EPA, eliminating the need to rely on advanced technology measures and to provide contingency measures under section 182(e)(5).[3]

2011 Emission Inventory Updates and Commitment to Remodel

The 2007 Ozone Plan reflected, at the time of adoption, the best available emissions inventory estimates, technical calculations, and air quality modeling used to meet federal air quality planning requirements. In 2011, CARB made emissions inventory improvements as an update to the PM2.5 and ozone SIPs for the Valley and the South Coast Air Basin. These emissions inventory updates reflected technical improvements as well as key CARB regulations to control mobile source emissions that were adopted after submittal of the 2007 Ozone Plan. These included U.S. EPA-approved regulations like CARB's diesel Truck and Bus Regulation, adopted in 2008 and amended in 2010, which phases in the replacement of older in-use trucks and buses with the cleanest models, and CARB's Off-Road Regulation, adopted in 2007 and amended in 2010 and 2011, which achieves emissions reductions from in-use off-road equipment used in construction, manufacturing, and other sectors.

In a separate 2011 SIP update,[4] CARB described that the emission estimates based on these and other CARB and District emissions inventory improvements resulted in a change in baseline emissions for 2002, the baseline for modeling in the 2007 Ozone Plan. At that time, it was not feasible in the near term to conduct new SIP modeling to assess whether the emissions inventory improvements would affect the attainment demonstration in the 2007 Ozone Plan, and a qualitative review was conducted. CARB committed, however, to update the 2007 Ozone Plan modeling to reflect emissions inventory improvements and any other new information, in order to remove the uncertainty regarding the amount of reductions needed to attain the standard in 2023.[5] U.S. EPA approved the 2011 updates to the 2007 Ozone Plan as well as CARB's commitment to remodel.[6] The updated modeling in this report fulfills that commitment.

Inventory Updates Since 2011

Since the updates in 2011, CARB and the District have continued improving the emissions inventory for the Valley. CARB submitted the 2012 emissions inventory developed for the 2016 ozone SIPs[7] to U.S. EPA in July 2014. This inventory included

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[3] CARB and the District recognize that attainment contingency to satisfy Act section 172(c)(9) is still required.

[4] CARB. *Proposed 8-Hour Ozone State Implementation Plan Revisions and Technical Revisions to the PM2.5 State Implementation Plan Transportation Conformity Budgets for the South Coast and San Joaquin Valley Air Basins. Appendix B: Current Estimates of Remaining Emissions, Documentation and Methodology*. (July 21, 2011) https://ww3.arb.ca.gov/planning/sip/2007sip/sjv8hr/final_proposed_ozone_sip_revisions.pdf

[5] CARB Resolution 11-22 (July 21, 2011) http://www.arb.ca.gov/planning/sip/2007sip/sjv8hr/Resolution_11-22.pdf

[6] 77 FR 12670 (March 1, 2012)

[7] CARB. *2012 State Implementation Plan (SIP) Emission Inventory Submittal for the 2008 Federal 8-Hour Ozone Standard*. (July 17, 2014) http://www.arb.ca.gov/planning/sip/2012iv/2012iv.htm

the update of CARB's on-road mobile source emissions model from EMFAC 2007, used for the 2007 Ozone Plan, to EMFAC 2011. Using this updated inventory, CARB conducted the modeling update for the 2007 Ozone Plan in 2014, as described in greater detail below. This updated attainment demonstration relies solely on defined U.S. EPA-approved CARB and District measures reflected in this inventory without requiring any section 182(e)(5) advanced technology measures.

UPDATED MODELING AND ATTAINMENT DEMONSTRATION

The photochemical modeling conducted in 2014 as part of this update follows U.S. EPA modeling guidance.[8] The grid-based Community Multiscale Air Quality Modeling System (CMAQ) was used to estimate the relative change in 8-hour ozone levels between the 2012 reference and 2023 future year due to changes in NOx and reactive organic gas (ROG) emissions. This relative change, referred to as the relative response factor (RRF) was estimated for each ozone monitoring site in the Valley. The RRF was then combined with observed ozone at the corresponding monitoring site to estimate the future year ozone level.

Meteorological fields for CMAQ simulations were developed with the Weather and Research Forecasting Model. Two modeling domains were used in CMAQ simulations. The larger statewide domain with a 12 kilometer (km) by 12 km horizontal grid resolution extends from the Pacific Ocean to Eastern Nevada and from the U.S.-Mexico border to the California-Oregon border. The smaller nested domain covers the Valley at a finer scale with 4 km by 4 km grids. All model simulations covered the entire May through September ozone season, thus providing a data set of simulated ozone concentrations large enough to result in stable RRF estimates. RRFs were based on the maximum simulated ozone level within a 15 km radius of a monitor (consistent with the 2007 U.S. EPA modeling guidance utilized in the original Plan).

Emissions inventory data used in the updated photochemical modeling were based on the 2012 emission inventory developed for the 2016 ozone SIPs submitted to U.S. EPA in July 2014. This 2012 inventory was forecasted to 2023 using current growth factors. 2012 was chosen as the baseline year for modeling and calculating future design values because 2012 represented recent measured ozone levels and the most complete and up-to-date emissions inventory at the time the modeling was conducted. The 2023 future year emissions inventory also accounts for emissions reductions from State and District control measures, including measures that were undefined in the 2007 Ozone Plan. Table 1 summarizes the updated summer 2012 and 2023 emissions in tons per day by major source category.

[8] U.S. EPA. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze. EPA-454/B-07-002. (April 2007) http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

Table 1. Summer 2012 and 2023 Emission Inventories (tons/day)

Source Category	2012 NOx	2012 ROG	2023 NOx	2023 ROG
Stationary	42.2	101.3	30.5	108.5
Area	4.8	158.2	5.0	176.8
On-Road Mobile	177.2	57.8	54.8	22.9
Other Mobile	109.9	47.3	74.2	31.9
Total	334.1	364.6	164.5	340.1

Note: Minor differences in the 2012 inventory in Table 1 and that submitted to U.S. EPA in July 2014 (reference 7 on Page 2) are due to updates in the following categories: off-road equipment, diesel motor coach buses, managed burning and disposal, wood and paper, and pesticides and fertilizers.

As shown in Table 2, the 2023 future year emissions estimate levels of NOx and ROG are very near the attainment targets identified in the 2007 Ozone Plan. This is as a result of the successful ongoing implementation of the overall control program. The attainment targets are the maximum allowable NOx and ROG emissions levels that the Valley can accommodate while still attaining the 8-hour ozone 0.08 ppm standard.

Table 2. Summer 2023 Attainment Targets (tons/day)

Emission Inventory	NOx	ROG
2014 Modeling Update	165	340
2007 Ozone Plan	160	342

Modeling the updated NOx and ROG emissions predicts that all sites in the Valley meet the standard in 2023. Table 3 lists the 2012 base year 8-hour ozone design values and 2023 modeled design values. Due to rounding conventions, design values—the measure used to determine compliance with the standard—which fall at or below 84 parts per billion (ppb) (equivalent to 0.084 parts per million) meet the standard. In all cases, the modeled 2023 attainment year design value based on the updated emissions inventory information is below the 84 ppb attainment threshold, demonstrating that in 2023 the standard will be attained throughout the Valley. In addition, twelve sites are predicted to also attain the more stringent 8-hour ozone standard of 0.075 ppm by 2023.

Table 3. 8-Hour Ozone Design Values (parts per billion, ppb)

Site	Average Base Year Design Value[1]	2023 Attainment Year Design Value
Clovis-N Villa	97.0	82
Fresno-Drummond	94.7	81
Sequoia-Kings Canyon	94.7	79
Fresno-Garland	93.0	80
Edison	91.7	75
Fresno-Skypark	91.7	79
Parlier	90.7	74
Arvin-Di Giorgio	90.0[2]	73
Hanford-Irwin	89.0	75
Bakersfield-California	87.7	76
Oildale-Manor	87.3	76
Turlock-S Minaret	87.0	78
Maricopa-Stanislaus	86.3	73
Visalia-N Church	85.0	71
Shafter-Walker	84.3	71
Merced-S Coffee	82.7	72
Sequoia-Kaweah	81.7	67
Madera-Road 28	79.3	68
Tracy-Airport	79.0	70
Modesto-14th Street	75.0	66
Stockton-Hazelton[3]	68.0	-

[1] This value represents the average of the 2011, 2012, and 2013 design values unless otherwise specified.

[2] This value represents the average of the 2012 and 2013 design values at Arvin-Di Giorgio. The site does not have a 2011 design value because the monitor became operational in 2010, and three years of data are required to calculate a valid design value; thus, 2012 is the first year for which a design value can be calculated for this site.

[3] There were not a sufficient number of modeled days that met the criteria for use in the RRF calculation, so Stockton-Hazelton does not have a 2023 design value.

The 2007 Ozone Plan listed the Arvin-Bear Mountain monitoring site located in southern Kern County as the 8-hour ozone design value site. Although the site shut down in 2011, the site needs to be considered in the modeling update. CARB estimated what the 2023 design value at Arvin-Bear Mountain would have been using the 2010 design value of 104 ppb as the base year design value—based on 2008 through 2010 ozone measurements at the regulatory monitor—and an RRF of 0.812, estimated from the 2012 and 2023 photochemical model simulations. Between 2004 and 2010, the 8-hour ozone design value at Arvin-Bear Mountain decreased consistently and this trend was expected to continue due to ongoing implementation of control measures. Thus, use of the 2010 8-hour ozone design value results in a conservative estimate of the 2023 design value at this monitoring site. Nonetheless, the resulting 2023 Arvin-Bear Mountain design value of 84 ppb also attains the 8-hour ozone standard.

FURTHER REDUCTIONS

Since the modeling was conducted for this update in 2014, the current emissions inventory projection has been further updated to reflect additional NOx emissions reductions from additional control measures adopted since the 2014 timeframe, as well as more recent estimates of fleet turnover. As shown in Table 4, the latest summer 2023 emissions inventory shows NOx emissions of 158 tpd, which is 7 tpd lower than the carrying capacity of 165 tpd modeled in 2014, and 2 tpd lower than the carrying capacity of 160 tpd modeled for the 2007 Ozone Plan. Thus, based on the best currently available information, NOx emissions are now projected to be even lower than the levels modeled in 2014, which already showed attainment of the standard in 2023.

Table 4. Comparison of Summer 2023 NOx Emissions Remaining and Attainment Targets (tons/day)

Emission Inventory	NOx
Current Inventory	158 (emissions remaining)
2014 Modeling Update	165 (attainment target)
2007 Ozone Plan	160 (attainment target)

Furthermore, the latest emissions inventory showing 158 tpd of NOx emissions remaining in 2023 does not reflect the control measures that will achieve additional NOx emissions reductions recently adopted by CARB and the District, which are needed to meet the newer more stringent ozone and PM2.5 standards. New CARB measures achieving 32 tpd NOx emissions reductions (on an annual basis) by 2024 are laid out in the *San Joaquin Valley Supplement to the 2016 State SIP Strategy*[9], adopted by CARB in 2018. In addition, new District measures achieving 1.88 tpd NOx emissions reductions (on an annual basis) in 2024 are laid out in the *2018 Plan for the 1997, 2006, and 2012 PM2.5 Standards* for the Valley, adopted by CARB in 2019.[10] A portion of these reductions will be achieved in 2023 due to implementation of the additional measures in advance of 2024. Thus, NOx emissions remaining in 2023 will be even lower than the 158 tpd in the current inventory.

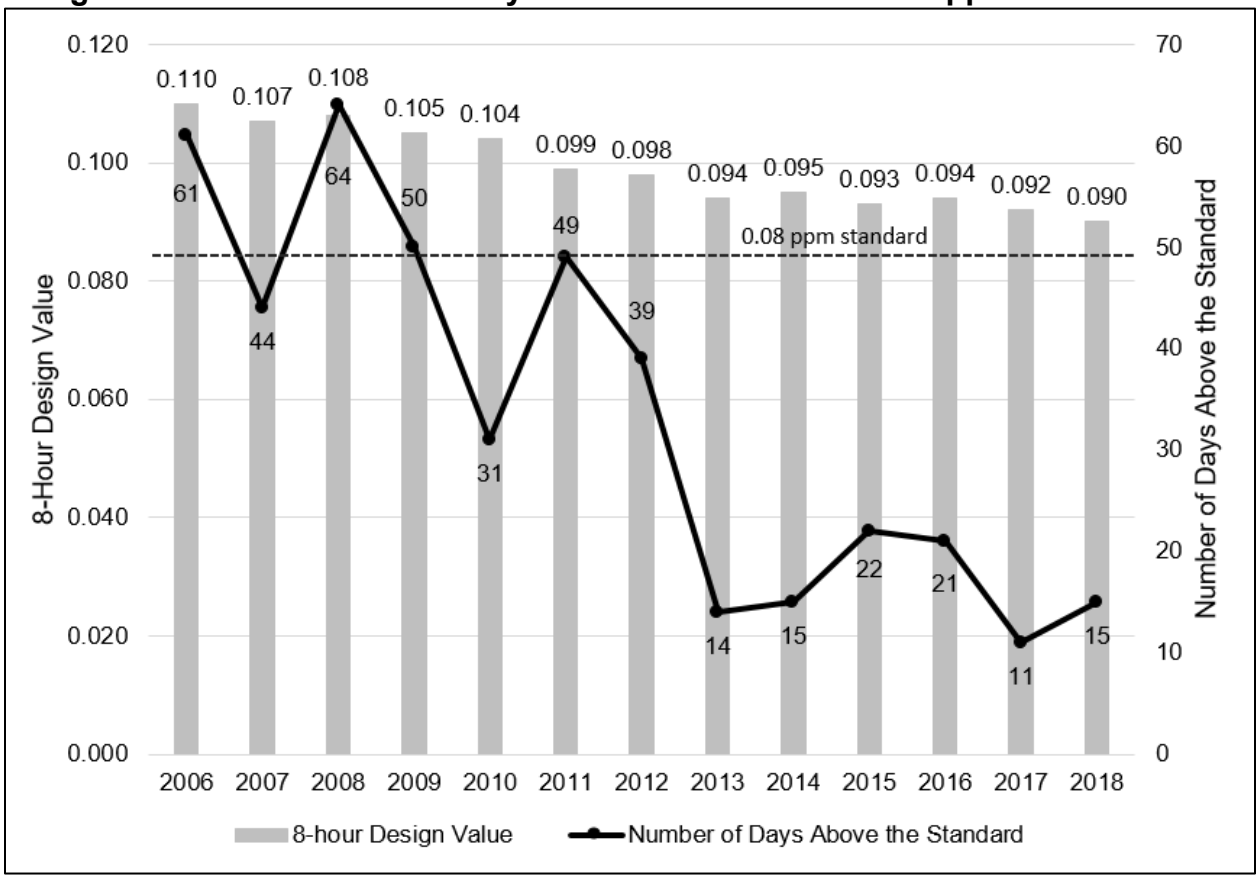
8-HOUR OZONE AIR QUALITY TRENDS

Emissions reductions achieved from CARB and District measures have resulted in continued ozone air quality progress in the Valley. As shown in Figure 1, between 2006 and 2018, the Valley 8-hour ozone design value (0.08 ppm standard) has decreased by 18 percent. On average, there are 78 percent fewer days that recorded 8-hour ozone concentrations over the standard.

[9] CARB. *San Joaquin Valley Supplement to the 2016 State SIP Strategy*. October 25, 2018. https://ww3.arb.ca.gov/planning/sip/2016sip/valleystrategy.pdf

[10] SJVAPCD. *2018 Plan for the 1997, 2006, and 2012 PM2.5 Standards.* See *Chapter 4: Attainment Strategy for PM2.5.* November 18, 2018. http://www.valleyair.org/pmplans/documents/2018/pm-plan-adopted/04.pdf

Figure 1. San Joaquin Valley Ozone Air Quality: 8-Hour Ozone 0.08 ppm Standard Design Values and Number of Days Above 8-Hour Ozone 0.08 ppm Standard



Thirteen sites in the Valley already attain the standard in 2018 and no sites are more than 0.006 ppm, or about 7 percent, above the standard. In addition, preliminary 2019 data show this year is one of the Valley's cleanest ozone years. As of October 2019, the preliminary 2019 design value is 0.088 ppm and preliminary data show no sites recording a fourth high value above the standard. CARB anticipates that these trends in ozone air quality improvement will continue and that the Valley will attain the 0.08 ppm 8-hour standard by 2023.

CONCLUSION AND STAFF RECOMMENDATION

This Report demonstrates that the Valley will meet the federal 0.08 ppm 8-hour ozone standard in 2023 without reliance on emission reductions from 182(e)(5) advanced technology measures. With this demonstration, the 182(e)(5)(B) requirement to submit contingency measures three years before attainment if "the anticipated technologies do not achieve planned reductions" no longer applies to the Valley for the 0.08 ppm 8-hour ozone NAAQS. Therefore, this Report fulfills the section 182(e)(5) requirements for the 0.08 ppm 8-hour ozone NAAQS.

CARB staff recommend the Board adopt this Report and direct the Executive Officer to submit it to U.S. EPA as a revision to the California SIP.

Appendix A

Updates to the Ozone Photochemical Modeling for the 2007 SJV 8-hour Ozone State Implementation Plan

1. INTRODUCTION

In 2007, the San Joaquin Valley Air Pollution Control District (SJVAPCD) adopted a State Implementation Plan (SIP) for the 1997 8-hour Ozone standard of 0.08 ppm. Attainment by the 2023 deadline was demonstrated through photochemical modeling (model attainment demonstration), which determined the emission targets required to meet the standard: 160 tons/day of oxides of nitrogen (NO_x) and 342 tons/day of reactive organic gases (ROG). In 2011, the California Air Resources Board (CARB) adopted revisions to the San Joaquin Valley (SJV) Ozone SIP that accounted for regulatory actions and impacts of the economic recession on emissions that occurred after the 2007 ozone SIP was adopted. As part of the 2011 SIP revision, CARB committed to update the model attainment demonstration from the 2007 8-hour ozone SIP using the latest emissions inventory. This document summarizes the findings from this updated modeling. The second section of this document describes the general approach utilized, while the remaining sections present the meteorological modeling (Section 3), a description of the emissions inventory (Section 4), the photochemical modeling and results (Section 5), and a comparison to the 2007 SJV Ozone SIP modeling (Section 6).

2. APPROACH

This section describes CARB's procedures, based on U.S. EPA guidance (U.S. EPA, 2007), for projecting ozone Design Values (DVs) to the future using model output and a Relative Response Factor (RRF) approach in order to show future attainment of the 0.08 ppm 8-hour ozone standard.

2.1. METHODOLOGY

The application of photochemical ozone models has a long history in California, for uses ranging from the preparation of SIPs, research activities, and regulatory development. One of the fundamental understandings that has come out of these activities in California and other states, as well as at the federal level is that photochemical models are best used in regulatory applications to estimate the relative change between modeling scenarios (e.g., base and future years), rather than for estimating absolute changes (e.g., Hogrefe et al., 2008; Pegues et al., 2012; Zhou et al., 2013).

Using the base and future years as an example, the photochemical model can be used to simulate the base and future year ozone, where both simulations utilize the same meteorology, chemical boundary conditions, and natural (biogenic) emissions, and only differ with respect to the anthropogenic emissions inventory. In this way, the impact of

specific changes in the anthropogenic inventory can be isolated within the model. Rather than calculating the absolute change in ozone (future year ozone minus base year ozone) a relative change is calculated (future year ozone divided by base year ozone) and this relative change is used to scale observed peak ozone levels for the base year (i.e., the Design Values discussed in Section 2.3) to the future year. The U.S. EPA guidance on the use of models in the attainment demonstration for 8-hour ozone (U.S. EPA, 2007) uses this relative change approach in the form of a Relative Response Factor (RRF; discussed in Section 2.5).

2.2. MODELING PERIOD

In consultation with District Staff, the year 2012 was chosen as the reference (or baseline) year for modeling and calculating the design values, because 2012 represents recent ozone levels, as well as the most complete and up to date emissions inventory. Rather than focusing on a few select modeling episodes, which can limit the number of modeled days used in the RRF calculation, the entire ozone season (May – September, 2012) was modeled. This resulted in a much larger subset of days with elevated ozone, covering a wide range of meteorological conditions, to include in RRF calculations. This ultimately resulted in a more stable RRF (i.e., the RRF becomes less sensitive to any single modeled day). The future year modeled was 2023, the designated year by which attainment of the .08 ppm 8-hour ozone standard must be demonstrated.

2.3. REFERENCE DESIGN VALUES

Specifying the reference design value is a key consideration in the model attainment test, since this value is projected forward and used to test for future attainment at each site. The design value for any given year represents a three-year average of the fourth highest daily maximum 8-hour ozone from the preceding three years, so the 2012 design value represents an average over 2010, 2011, and 2012. To maintain consistency with U.S. EPA guidance (U.S. EPA, 2007), the 8-hour ozone reference design value is calculated as the average of the three design value periods which straddle the reference year. Since the reference year in this work is 2012, the average reference design value would generally be calculated as the average of the design values from 2012, 2013, and 2014. However, at the time of this work (mid-2014) the 2014 design values were not available. Therefore, the average design value was instead calculated from the 2011, 2012, and 2013 design values (see Table A1).

Table A1. Year-specific design values for 2011, 2012, and 2013, and the average reference design value represented as the average of the three year-specific design values.

Site	8-hr ozone Design Value (ppb)			
	2011	2012	2013	Average
Arvin-Bear Mountain	100[1]	99[1]	97[1]	98.7[1]
Clovis-N Villa	99	98	94	97.0
Fresno-Drummond	95	95	94	94.7
Sequoia-Kings Canyon	96	95	93	94.7
Fresno-Garland	96	94	89	93.0
Edison	96	93	86	91.7
Fresno-Skypark	95	92	88	91.7
Parlier	88	92	92	90.7
Arvin-Di Giorgio	--	91	89	90.0[2]
Hanford-Irwin	93	90	84	89.0
Bakersfield-California	88	89	86	87.7
Oildale-Manor	89	89	84	87.3
Turlock-S Minaret	87	88	86	87.0
Maricopa-Stanislaus	88	87	84	86.3
Visalia-N Church	88	87	80	85.0
Shafter-Walker	85	86	82	84.3
Merced-S Coffee	84	83	81	82.7
Sequoia-Kaweah	79	81	85	81.7
Madera-Road 28	81	78	79	79.3
Tracy-Airport	78	80	79	79.0
Modesto-14th Street	75	75	75	75.0
Stockton-Hazelton	68	69	67	68.0

[1] Values are imputed and shown for reference only (See Larsen and Shah, 2015 for details on the imputation method)

[2] Average only includes 2012 and 2013 design values as it became operational in 2010

2.4. BASE, REFERENCE, AND FUTURE YEARS

The model attainment demonstration consisted of three primary model simulations: 1) the base year simulation used for determining model performance; 2) the reference year simulation used in calculating the site-specific RRF; 3) the future year simulation used in calculating the site-specific RRF (see Table A2). The base year simulation was chosen

to coincide with the reference year (2012) and used in evaluating the model performance to show that the model adequately represents the observed hour-to-hour and day-to-day variability in ozone across the modeling period. Consequently, the base year simulation incorporated as much day-specificity into the emissions inventory as feasible, including day-specific wildfires, agricultural and prescribed burning, biogenic, and mobile source emissions.

Table A2. Description of CMAQ model simulations. All simulations included modeling for both the 12-km statewide domain and the 4-km Northern California sub-domain and covered the entire ozone season (May – September; See Figure A4 for a definition of the two CMAQ modeling domains).

Simulation	Anthropogenic Emissions	Biogenic Emissions	Meteorology	Chemical Boundary Conditions
Base year	2012 w/ wildfires	2012 MEGAN	2012 WRF	2012 MOZART
Reference year	2012 w/o wildfires	2012 MEGAN	2012 WRF	2012 MOZART
Future year	2023 w/o wildfires	2012 MEGAN	2012 WRF	2012 MOZART

The reference year differs from the base year in that some large episodic emission categories, which are either not expected to reoccur in the future or are difficult to predict, are excluded from the emission inventory. For the 2012 reference year modeling there are two categories/emissions sources that were excluded: 1) wildfires, which are difficult to predict in the future and can influence the model response to anthropogenic emissions reductions in regions with large fires, and 2) the Chevron refinery fire in the Bay Area, which occurred over 6 days from August 19-24, 2012.

The future year was chosen to coincide with the year by which attainment must be demonstrated (2023 for the 0.08 ppm 8-hour ozone standard). The future year simulation was driven with the same 2012 meteorology as the reference year, utilized the same boundary conditions derived from MOZART global model output, as well as the same biogenic emissions, such that the only difference between the reference and future year simulations was in the anthropogenic emissions inventory.

2.5. RELATIVE RESPONSE FACTORS

The Relative Response Factor (RRF) is a monitor-specific value that is calculated based on the ratio of modeled future year average daily maximum 8-hour ozone (DM8hrO3) to modeled reference year average DM8hrO3 (Equation 1), where the DM8hrO3 values are based on the maximum simulated ozone within a 15-km radius of a monitor (for a 4-km grid resolution this is equivalent to a 7x7 matrix of grid cells

surrounding a monitor). The days used to calculate the average DM8hrO3 for the reference and future years are inherently consistent, since the same meteorology is used to drive both simulations.

$$RRF = \frac{\text{average DM8hrO3}_{future}}{\text{average DM8hrO3}_{reference}} \quad (1)$$

Not all modeled days are included in the RRF calculation. Since ozone response to emission reductions is less variable at ozone levels at or above the NAAQS and there is a decrease in ozone responsiveness at lower ozone levels, the U.S. EPA suggests beginning with all days in which the simulated reference DM8hrO3 is above a threshold value set at the NAAQS standard (in this case 0.08 ppm or for simplification 85 ppb). This 85 ppb threshold level ensures that the RRFs are sufficiently robust and adequately represent high ozone days. If there are 10 or more days with simulated DM8hrO3 > 85 ppb, then those days are used in the RRF calculation. If there are fewer than 10 days, then the threshold is lowered in 1 ppb increments until 10 days are above the threshold or the threshold is reduced to 70 ppb. If the threshold has been reduced to 70 ppb and there are fewer than 10 days with DM8hrO3 > 70 ppb then all days > 70 ppb are used in the RRF calculation, as long as there are at least 5 days used in the calculation. If there are fewer than 5 days > 70 ppb, an RRF is not calculated. For additional information regarding the RRF calculation, see U.S. EPA (2007). To ensure that only modeled days which are consistent with the observed ozone levels are used in the RRF calculation, we further restricted the days used in the RRF calculation by only including days with reference DM8hrO3 within +/- 20% of the observed value at the monitor location.

2.6. FUTURE YEAR DESIGN VALUE CALCULATION

Future year design values for each site are calculated by multiplying the corresponding reference design value (Table A1) by the site-specific RRF (Equation 2).

$$DV_F = DV_R \times RRF \quad (2)$$

where,

DV_F = the future year design value,
DV_R = the reference year design value (from Table A1), and
RRF = the site specific RRF from Equation 1

Future year design values from the model attainment demonstration are discussed in Section 5.3.

3. METEOROLOGICAL MODELING

California's proximity to the ocean, complex terrain, and diverse climate represent a unique challenge for developing meteorological fields that adequately represent the synoptic and mesoscale features of the regional meteorology. In the past, CARB has utilized both prognostic and diagnostic meteorological models, as well as hybrid approaches in an effort to develop meteorological fields for use in air quality modeling that most accurately represent the meteorological processes that are important to air quality. In this work, we applied the state-of-the-science Weather and Research Forecasting (WRF) prognostic model (Skamarock et al., 2005) version 3.4.1 to develop the meteorological fields used in the subsequent photochemical model simulations. Recent versions of WRF have been successfully applied to California to simulate meteorology for use in air quality modeling studies by CARB (Kulkarni et al., 2014), U.S. EPA (Baker et al., 2013; Kelly et al., 2014), and others (e.g., Hu et al., 2012; Pfister et al., 2011; Fast et al., 2012; Fast et al., 2014; Fuelberg et al., 2010; Angevine et al., 2013; Angevine et al., 2012).

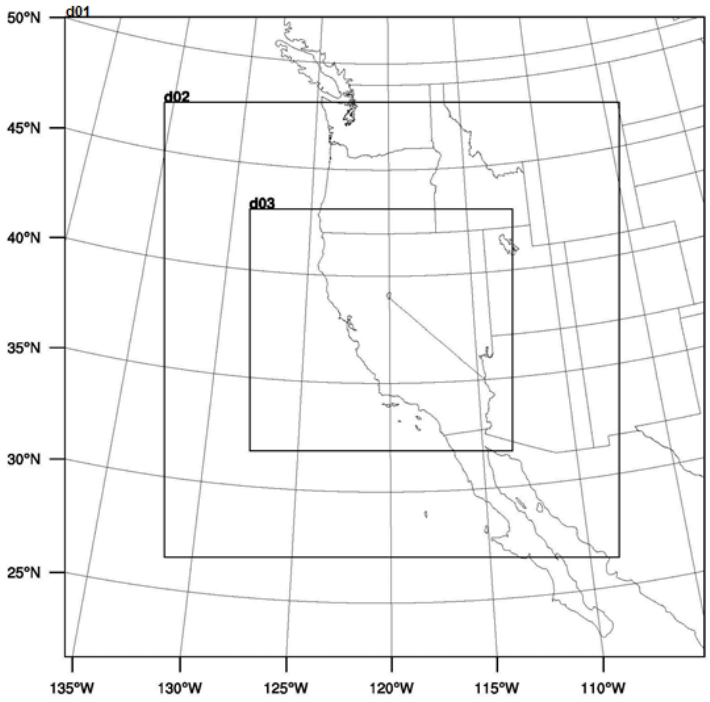


Figure A1. WRF modelling domains for 36-km (d01), 12-km (d02), and 4-km (d03).

3.1. WRF MODEL SETUP

The WRF meteorological modeling domain consisted of three one-way nested grids of 36-km, 12-km, and 4-km horizontal resolution (Figure A1). The outermost domain (d01) was nudged towards the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) fields (http://www.esrl.noaa.gov/psd/data/gridded/data.narr.html), using Four Dimensional Data Assimilation (FDDA) analysis nudging, to provide synoptic-scale conditions to the two inner domains. No nudging was used on the two inner domains. Initial conditions for all three domains were developed from the NCEP reanalysis fields and were further refined using surface and upper air observations from the NCEP. The WRF vertical layer structure is shown in Table A3 and the physics options used in the WRF modeling are summarized in Table A4.

Table A3. WRF Vertical Layer Structure.

Layer Number	Height (m)	Layer Thickness (m)	Layer Number	Height (m)	Layer Thickness (m)
30	15674	998	14	1900	339
29	14676	982	13	1561	285
28	13694	976	12	1276	238
27	12718	970	11	1038	199
26	11748	972	10	839	166
25	10776	973	9	673	139
24	9803	979	8	534	115
23	8824	983	7	419	97
22	7841	994	6	322	81
21	6847	1002	5	241	67
20	5845	972	4	174	56
19	4873	818	3	118	47
18	4055	687	2	71	39
17	3368	577	1	32	32
16	2791	484	0	0	0
15	2307	407			

Note: Shaded layers denote the subset of vertical layers used in the CMAQ photochemical model simulations. Further details on the CMAQ model configuration and settings can be found in section 5.

Table A4. WRF Physics Options.

Physics Option	Scheme Used
Microphysics	WSM 6-class graupel (Hong and Lim, 2006)
Surface Layer	MM5 Monin-Obukhov (Paulson, 1970)
Land Surface Model	Pleim-Xiu (Pleim and Xiu, 1995)
Planetary Boundary Layer Scheme	YSU (Hong et al., 2006)
Cumulus	Kain-Fritsch (new Eta)[1] (Kain, 2004)
Longwave Radiation Scheme	RRTM (Mlawer et al., 1997)
Shortwave Radiation Scheme	Dudhia (Dudhia, 1989)
Topographic surface wind correction	Yes[2] (Jimenez and Dudhia, 2012)

[1] d01 (36-km) and d02 (12-km) domains only. No cumulus scheme on d03 (4-km) domain.
[2] d03 (4-km) only. No topographic wind correction on domains d01 (36-km) and d02 (12-km).

3.2. WRF MODEL RESULTS AND EVALUATION

Simulated surface wind speed, temperature, and relative humidity from the 4-km domain were validated against hourly observational data for 17 surface stations in the SJV. Data for the surface stations were obtained from the CARB air quality and meteorological database (http://www.arb.ca.gov/aqmis2/aqmis2.php; see Table A5 for the list and location of surface sites). Considering the large size of the SJV, it is useful to divide the valley into three distinct regions for evaluating model performance: Northern SJV (NSJV), Central SJV (CSJV), and Southern SJV (SSJV). Several quantitative performance metrics were used to compare hourly surface observations and modeled estimates: mean bias, mean error and correlation coefficients (R) (Simon et al., 2012). A summary of calculated statistics by performance region is shown in Table A6 and scatter plots for wind speed, temperature, and relative humidity are shown in Figure A2.

Table A5: Surface meteorological station names by model performance region.

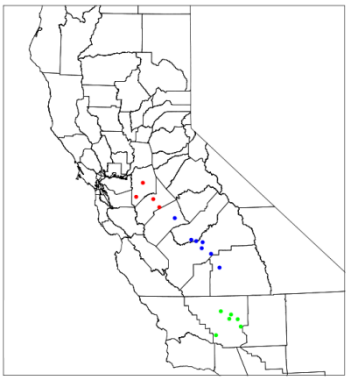
Region	Site Name	Site Location
Northern San Joaquin Valley (NSJV)	Modesto-14th Street Stockton-Hazelton Street Tracy-Airport Turlock-S Minaret Street	 Northern SJV Central SJV Southern SJV
Central San Joaquin Valley (CSJV)	Clovis-N Villa Avenue Fresno-Drummond Street Fresno-Sierra Skypark Madera-Pump Yard Merced-S Coffee Avenue Parlier Visalia-N Church Street	
Southern San Joaquin Valley (SSJV)	Arvin-Di Giorgio Edison Bakersfield-5558 California Avenue Maricopa-Stanislaus Street Oildale-3311 Manor Street Shafter-Walker Street	

Table A6. Hourly surface wind speed, temperature, and relative humidity statistics by region for May-September 2012.

Region	Observed Mean	Modeled Mean	Mean Bias	Mean Error	Correlation Coefficient
			Wind Speed (m/s)		
SSJV	1.87	1.97	0.10	0.84	0.439
CSJV	1.88	3.10	1.22	1.43	0.540
NSJV	2.38	3.13	0.75	1.45	0.446
			Temperature (K)		
SSJV	299.77	299.73	-0.04	2.18	0.907
CSJV	298.03	299.38	1.35	2.12	0.940
NSJV	296.53	296.52	-0.02	1.89	0.929
			Relative Humidity (%)		
SSJV	36.56	29.43	-7.13	11.92	0.561
CSJV	44.11	29.85	-14.26	15.63	0.714
NSJV	49.73	41.65	-8.08	10.28	0.855

Wind Speed biases are all positive, with the smallest bias occurring in SSJV (0.1 m/s) and the largest bias occurring in the CSJV (1.22 m/s). Temperature bias is relatively small in the SSJV and NSJV, -0.04 and -0.02 K, respectively, and higher in CSJV (1.35 K). Temperature also shows a strong correlation between the observations and simulation in all regions due to the strong diurnal pattern associated with temperature.

Similarly, the correlation with relative humidity is generally high due to its dependence on the diurnally varying temperatures. Relative humidity biases are all negative, with the largest bias occurring in the CSJV. These results are comparable to other recent WRF modeling efforts in California investigating ozone formation in Central California (Hu et al., 2012) and modeling analysis for the CalNex and CARES field studies (Fast et al., 2014; Baker et al., 2013; Kelly et al., 2014; Angevine et al., 2012). Detailed hourly time-series of temperature, relative humidity, wind speed, and wind direction for each sub-region can be found in the Appendix B (Figures B1 - B20).

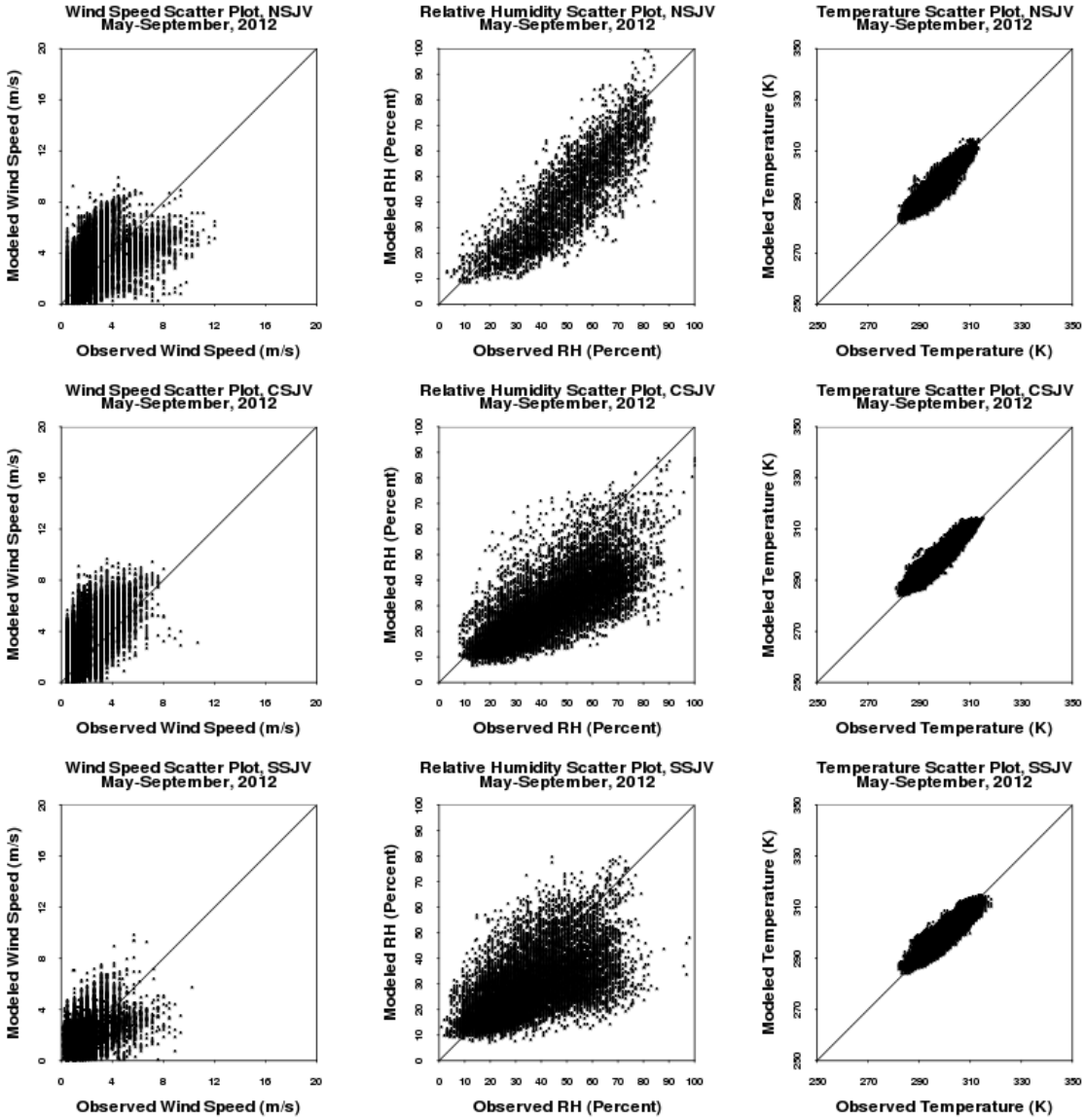


Figure A2. Comparison of modeled and observed hourly wind speed (left column; m/s), relative humidity (middle column; %), and 2-meter temperature (right column; K). Results for the Northern SJV are shown in the top row, Central SJV in the middle row, and Southern SJV in the bottom row.

4. EMISSIONS

The emissions inventory used in this modeling was based on the most recent inventory submitted to the U.S. EPA for the 8-hour ozone SIP for the 2008 standard (0.075 ppm), with base year 2012 (http://www.arb.ca.gov/planning/sip/2012iv/2012iv.htm). The following sections describe how this latest emissions inventory was updated and processed from the planning inventory to a gridded inventory for modeling.

4.1. ON-ROAD MOTOR VEHICLE EMISSIONS

The on-road mobile emissions were processed using the same methodology described in the modeling protocol for creating on-road motor vehicle inventories for the 2012 SJV 24-hour $PM_{2.5}$ SIP (http://www.valleyair.org/Air_Quality_Plans/PM25Plans2012.htm). The gridded inventory was produced using CARB's EMFAC 2011 and then scaled (using EIC, county, pollutant specific ratios) to reflect draft updates to EMFAC, which is consistent with the recent 2012 inventory submittal to the U.S. EPA.

4.2. DAY-SPECIFIC EMISSIONS

A considerable number of source types were replaced with day-specific emissions. These are: 1) wildfires and prescribed burns, 2) agricultural burns in Feather River, Imperial, Sacramento, San Joaquin Valley, Ventura and Yolo-Solano, 3) the August 2012 fire at the Chevron Richmond refinery and 4) ocean-going vessels. Additionally, facilities that have closed since 2012 were removed from future year modeling inventories.

4.3. EMISSIONS INVENTORY PROCESSING

CARB and local district staffs conducted a thorough review of growth and control data. The latest data available were used, from such sources as local regional transportation planning agencies, economic activity forecasts and demographic data from the California Department of Finance. CARB and local district staff have updated control data to reflect all State and Federal regulations as well as local district rules that have been adopted.

4.3.1. Gridded emissions inventory

The Sparse Matrix Operator Kernel Emissions (SMOKE) version 3.1 (www.cmascenter.org/smoke/) was used to process the annual average emissions for point and area sources. The emission inventories for ozone modeling were developed from the 2012 annual average CEIDARS database for total organic gas (TOG), NO_x, sulphur oxides (SO_x), carbon monoxide (CO), particulate matter (PM), and ammonia (NH_3). Point sources were allocated to a grid cell using the latitude/longitude coordinates, while each area source category was assigned a spatial surrogate that was used to allocate emissions to a grid cell. Examples of surrogates include population,

land use, and other data with known geographic distributions for allocating emissions to grid cells.

4.3.1.1. Updates to temporal profiles

The planning emissions inventory, which represents a summer average emission rate (tons/day), is translated to an hourly inventory for modeling using monthly, day-of-week, and hourly temporal profiles for each emission category. No updates to temporal profiles have been implemented since the most recent SJV SIP submitted to U.S. EPA (24-hour $PM_{2.5}$ SIP; http://www.valleyair.org/Air_Quality_Plans/PM25Plans2012.htm).

4.3.1.2. Updates to spatial surrogates

Sonoma Technology Inc. (STI) developed spatial allocation factors (SAF) or spatial surrogates which are used to assign county level area and non-road mobile source emissions to individual grid cells within the statewide modeling domain. These statewide spatial allocation factors were developed for a 2000 base year and three future years (2005, 2010 and 2020) in support of CRPAQS and CCOS (Funk and Chinkin. 2001). The underlying spatial data and spatial surrogate cross-reference files were later updated to account for new emission source categories (Reid et al., 2006). Finally, STI updated spatial allocation factors for CARB's statewide modeling domain for a base year of 2000 and future years of 2010, 2015, and 2020 (Reid et al., 2008)
Since the work from STI to develop the spatial surrogates, CARB and district staffs have updated surrogates for auto body shops, dry cleaners, gas stations, gas wells, oil wells, landfills, restaurants, secondary paved roads, wineries, lakes/coastline, forest land, non-urban land, and high/low density urban land. Recently, Sierra Research under a CCOS contract, developed data to create updated spatial surrogates for pesticides, agricultural crop land, pasture land, harvesting, land preparation, farm road VMT, livestock and silage (Wilkinson and Carlson, 2012).

4.3.1.3. Updates to speciation profiles

Many organic speciation profiles have been added or updated since the inventory for the 2012 SJV 24-hour $PM_{2.5}$ SIP was developed. The profiles are related to E6 and E10 gasoline, consumer products, silage and aircraft exhaust. The specific profiles that were updated are shown in Appendix C (Table C1). The updated profiles can be found in the CARB's speciation database (http://www.arb.ca.gov/ei/speciate/speciate.htm).

4.5 ANTHROPOGENIC EMISSION SUMMARIES

Table A7 summarizes the 2012 and 2023 SJV emissions used in this work.

Table A7. SJV Summer Planning Emissions for 2012 and 2023 (tons/day).

Source Category	NO_x [tons/day] 2012	ROG [tons/day] 2012	NO_x [tons/day] 2023	ROG [tons/day] 2023
Stationary	42.2	101.3	30.5	108.5
Area	4.8	158.2	5.0	176.8
On-Road Mobile	177.2	57.8	54.8	22.9
Other Mobile	109.9	47.3	74.2	31.9
Total	334.1	364.6	164.5	340.1

Note: Minor differences in the 2012 inventory in Table A7 and that submitted to U.S. EPA in July 2014 (reference 7 on Page 2) are due to updates in the following categories: off-road equipment, diesel motor coach buses, managed burning and disposal, wood and paper, and pesticides and fertilizers.

4.6. BIOGENIC SOURCES

Biogenic emissions were estimated using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) version 2.04 (Guenther et al., 2006). MEGAN estimates biogenic emissions as a function of normalized emission rates (i.e., emission rates at standard conditions), which are adjusted to reflect variations in temperature, light, leaf area index (LAI), and leaf age (estimated from changes in LAI). The default MEGAN input databases for emission factors (EFs), plant functional types (PFTs), and LAI are not used in the application of MEGAN in California. Instead, California-specific emission factor and PFT databases were translated from those used in the Biogenic Emission Inventory GIS (BEIGIS) system (Scott and Benjamin, 2003) to improve emission estimates and to maintain consistency with previous California biogenic emission inventories. LAI data was derived from the MODIS 8-day LAI satellite product. Hourly surface temperatures were from observations gridded with the CALMET meteorological model and insolation data was provided by the WRF meteorological fields. Emissions of isoprene, monoterpenes, and methylbutenol were estimated from California-specific gridded emission factor data, while emissions of sesquiterpenes, methanol, and other volatile organic compounds were estimated from California-specific PFT data and PFT derived emission rates.

MEGAN emissions estimates for California were evaluated during the California Airborne BVOC Emission Research in Natural Ecosystems Transects (CABERNET) field campaign in 2011 (Karl et al., 2013; Misztal et al., 2014a) and were shown to agree to within +/-20% of the measured fluxes (Misztal et al., 2014b), which is well within the stated model uncertainty of 50%. Monthly average biogenic ROG emissions for 2012 in California and in the SJV Air Basin are shown in Figure A3.

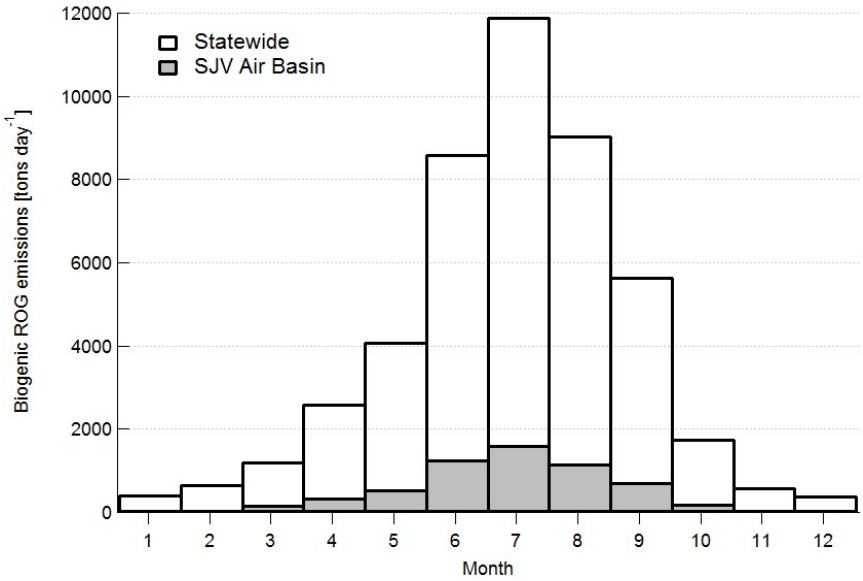


Figure A3. Monthly average biogenic ROG emissions for 2012.

5. OZONE MODELING

5.1. CMAQ MODEL SETUP

Figure A4 shows the modeling domains used by CARB for this work. The larger domain covering all of California has a horizontal grid size resolution of 12-km with 107x97 lateral grid cells for each vertical layer and extends from the Pacific Ocean in the west to Eastern Nevada in the east and runs from the U.S.-Mexico border in the south to the California-Oregon border in the north. The smaller nested domain covering the SJV region has a finer scale 4-km grid resolution and includes 192x192 lateral grid cells. The 12-km and 4-km domains are based on a Lambert Conformal Conic projection with reference longitude at -120.5°W, reference latitude at 37°N, and two standard parallels at 30°N and 60°N, which is consistent with WRF domain settings. The 31 vertical layers (30 vertical levels) from WRF were mapped onto 19 vertical layers (18 vertical levels) for CMAQ extending from the surface to 100 mb such that the majority of the vertical layers fall within the planetary boundary layer. This vertical layer structure is based on the WRF sigma-pressure coordinates and the exact layer structure used can be found in Table A3.

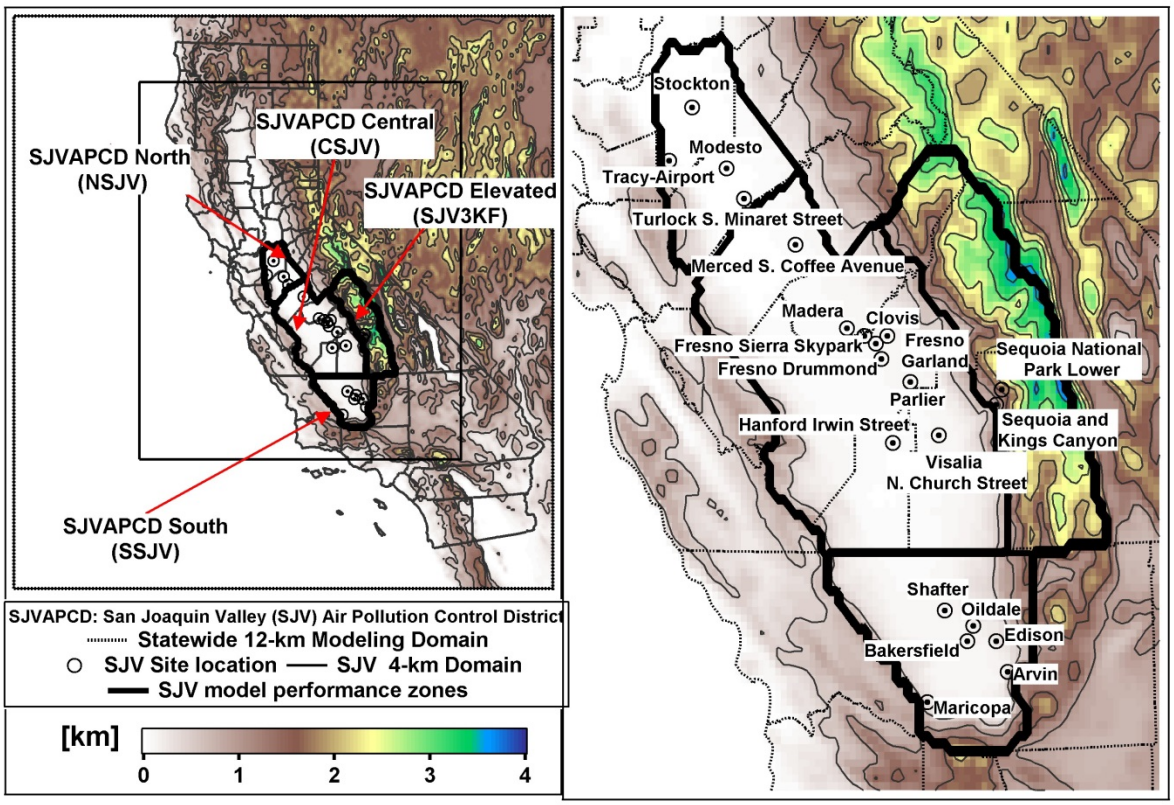


Figure A4: The ozone monitoring stations in the San Joaquin Valley (SJV) region of California. SJVAPCD stands for the San Joaquin Valley Air Pollution Control District. The outer box of the left panel is the California statewide 12-km modeling domain, while the inner box shows the 4-km modeling domain covering Central California. The gray shaded and black line contours denote the gradients in topography (km), while the thick black lines show the boundaries of the SJV sub regions used in model performance analysis for ozone. The insert on the right shows the zoomed-in view of the site locations that were used for ozone model performance evaluation. (Figure adapted from Kulkarni et al., 2014)

The photochemical modeling for this work used the latest and most updated version of CMAQ (v5.0.2) released by the U.S. EPA (https://www.cmascenter.org/cmaq/). The SAPRC07 mechanism was selected as the photochemical mechanism for the CMAQ simulations. Further details of the CMAQ configuration used in this work are summarized in Table A8.

Table A8. CMAQ v5.0.2 configuration/settings.

Process	Scheme
Horizontal advection	Yamo (Yamartino scheme for mass-conserving advection)
Vertical advection	WRF-based scheme for mass-conserving advection
Horizontal diffusion	Multi-scale
Vertical diffusion	ACM2 (Asymmetric Convective Model version 2)
Gas-phase chemical mechanism	SAPRC-07 gas-phase mechanism with version "C" toluene updates
Chemical solver	EBI (Euler Backward Iterative solver)
Aerosol module	Aero6 (the sixth-generation CMAQ aerosol mechanism with extensions for sea salt emissions and thermodynamics; includes a new formulation for secondary organic aerosol yields)
Cloud module	ACM_AE6 (ACM cloud processor that uses the ACM methodology to compute convective mixing with heterogeneous chemistry for AERO6)
Photolysis rate	phot_inline (calculate photolysis rates in-line using simulated aerosols and ozone concentrations)

Chemical boundary conditions for the outer 12-km domain were extracted from the global chemical transport Model for Ozone and Related chemical Tracers, version 4 (MOZART-4; Emmons et al., 2010). The MOZART-4 data for 2012 was obtained from the National Center for Atmospheric Research (NCAR; http://www.acd.ucar.edu/wrf-chem/mozart.shtml) for the simulations driven by meteorological fields from the NASA GMAO GEOS-5 model. The MOZART-4 simulations utilized a horizontal resolution of 1.9˚ x 2.5˚ with 56 vertical levels and were conducted using anthropogenic emissions based on the ARCTAS inventory (http://bio.cgrer.uiowa.edu/arctas/emission.html) and fire emissions from the FINN-v1 (Wiedinmyer et al., 2011). Model output was available at 6-hour intervals for the entire 2012 modeling period, which were interpolated to a 1-

hour resolution to provide dynamic hourly boundary conditions for the CMAQ simulations.

The larger 12-km statewide domain was run on a monthly basis with a one week spin up for each monthly simulation consistent with the “ramp-up” period for photochemical model simulations as recommended by the U.S. EPA modeling guidance (U.S. EPA, 2007). The SJV region fine scale 4-km simulations used initial and boundary conditions derived from the corresponding statewide 12-km domain runs.

5.2. CMAQ MODEL EVALUATION

The CMAQ model framework used in this work is evaluated for ozone by comparing the simulated values against observations from the representative sites in the SJV region (shown in Figure A4) using simulated data from the 4-km modeling domain. The evaluation of model performance is presented for the entire SJV region and also disaggregated for the four sub regions shown in Figure A4. The northern region (NSJV) covers San Joaquin and Stanislaus Counties, while the central region (CSJV) includes Merced, Mariposa, Fresno, Madera and King Counties below an elevation of 3000 feet. The region above 3000 feet represents the elevated sites (that are likely impacted by long range transport) and labeled as SJVAPCD Elevated (SJV3KF). The southern sub-region (SSJV) represents the western portion of Kern County within the jurisdiction of the SJVAPCD. Performance statistics are reported separately for different ozone metrics including 8-hour daily maximum ozone using all data and only data above 60 ppb, 1-hour daily maximum ozone, and hourly ozone (all hours of the day).

Performance statistics for daily maximum 8-hour ozone (all days and only days above 60 ppb) are shown in Table A9 (similar statistics for hourly ozone and daily maximum 1-hour ozone can be found in Appendix D, Tables D1 and D2, respectively). Overall, the model shows a slight negative bias in 8-hour daily maximum ozone in all regions, with the smallest bias occurring in the region above 3000 feet (-2 ppb) and the largest bias occurring in the Central SJV (-4.3 ppb). When days with modeled and observed daily maximum 8-hour ozone less than 60 ppb are excluded from the analysis, the bias grows slightly to -2.4 ppb in the region above 3000 feet to -5.5 ppb in the Northern SJV. Mean error shows the opposite trend with the error getting smaller when only days with observed and modeled ozone greater than 60 ppb are considered.

Model performance statistics within the range of values shown in Table A9 and Tables D1 and D2 are consistent with previous studies in the SJV and studies elsewhere in the U.S. Hu et al. (2012), simulated an ozone episode in the SJV (July 27 – August 2, 2000) using different chemical mechanisms and found that modeled bias ranged from -0.5 to -12.6 ppb for daily maximum 8-hour ozone (compared to -3.6 for the entire SJV in

this work) and -0.2 to -15.3 ppb for daily maximum 1-hour ozone in the SJV (compared to -4.8 in this work). Similarly, Shearer et al. (2012) compared model performance in Central California during two episodes in 2000 (July 24 – 26 and July 31 – August 2) for two different chemical mechanisms and found that normalized bias for daily maximum 8-hour ozone ranged from -7% to -14% with hourly peak ozone showing a slightly larger range from -7% to -18%. These are also consistent with the statistics found in this work, which were calculated as -4.9% (8-hour) and -6% (1-hour). Jin et al. (2010) conducted a longer term simulation over Central California (summer 2000) and found a RMSE for daily maximum 8-hour ozone of 13 ppb, which is greater than the 8.7 ppb found in this work, but Jin et al. (2010) showed a smaller overall bias of -1 ppb, compared to -3.6 ppb in this work. Simon et al. (2012) conducted a review of photochemical model performance statistics published between 2006 and 2012 for North America (from 69 peer-reviewed articles) and found that mean bias for daily maximum 8-hour ozone ranged from approximately -7 ppb to 13 ppb, while mean error ranged from around 4 ppb to 22 ppb, and RMSE ranged from approximately 8 ppb to 23 ppb; all of which are similar in magnitude to the statistics presented in Table A9. Time series of the 8-hour daily maximum ozone data used to generate Table A9 can be found in Appendix D.

Table A9. Daily maximum 8-hour ozone performance statistics by modeling subregions and entire SJV region for May-September 2012.

Daily Maximum 8-hour ozone (all days)

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	576	1344	306	899	3125
Mean obs (ppb)	57.4	65.6	71.6	68	65.4
Standard Deviation obs (ppb)	13.4	12.5	11.9	11.1	12.9
Mean Bias (ppb)	-3.1	-4.3	-2	-3.6	-3.6
Mean Error (ppb)	8.2	7.5	8.1	7.1	7.6
RMSE (ppb)	10.7	9.9	10.2	9	9.8
Normalized Mean Bias (%)	-5.4	-6.5	-2.9	-5.2	-5.6
Normalized Mean Error (%)	14.3	11.4	11.3	10.4	11.6
R-squared	0.44	0.5	0.36	0.53	0.52
Index of Agreement	0.79	0.8	0.77	0.83	0.83

Daily Maximum 8-hour ozone (above 60 ppb)

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	139	651	232	550	1572
Mean obs (ppb)	72.6	73.7	75.9	73.9	74
Standard Deviation obs (ppb)	9	9.1	8.7	7.6	8.6
Mean Bias (ppb)	-5.5	-4.4	-2.4	-2.7	-3.6
Mean Error (ppb)	7.9	6.7	7.6	6	6.7
RMSE (ppb)	10.3	8.8	9.6	7.6	8.7
Normalized Mean Bias (%)	-7.6	-6	-3.1	-3.7	-4.9
Normalized Mean Error (%)	10.9	9.1	10	8.1	9
R-squared	0.13	0.31	0.13	0.3	0.25
Index of Agreement	0.55	0.68	0.61	0.72	0.68

Note: The statistical metrics used in this table are defined in Simon et. al., (2012)

5.3. RELATIVE RESPONSE FACTORS AND FUTURE YEAR DESIGN VALUES

The RRFs (Section 2.5) and the future design values (Section 2.6) for the representative sites in the SJV region were calculated using the procedures outlined in those sections, respectively, and are summarized in Table A10.

Table A10. Summary of key parameters related to the RRF calculation along with future year design values projected from the average reference year design value represented as average of the 2011, 2012, and 2013 design values.

Site	Average Reference Design Value (ppb)	RRF	Projected Average Future Year Design Value (ppb)
Arvin-Bear Mountain	98.7	0.812	80
Clovis-N Villa	97.0	0.849	82
Fresno-Drummond	94.7	0.857	81
Sequoia-Kings Canyon	94.7	0.834	79
Fresno-Garland	93.0	0.867	80
Edison	91.7	0.818	75
Fresno-Skypark	91.7	0.864	79
Parlier	90.7	0.826	74
Arvin-Di Giorgio	90.0[2]	0.814	73
Hanford-Irwin	89.0	0.85	75
Bakersfield-California	87.7	0.877	76
Oildale-Manor	87.3	0.874	76
Turlock-S Minaret	87.0	0.901	78
Maricopa-Stanislaus	86.3	0.846	73
Visalia-N Church	85.0	0.835	71
Shafter-Walker	84.3	0.844	71
Merced-S Coffee	82.7	0.875	72
Sequoia-Kaweah	81.7	0.828	67
Madera-Road 28	79.3	0.866	68
Tracy-Airport	79.0	0.898	70
Modesto-14th Street	75.0	0.888	66
Stockton-Hazelton	68.0	-	-

Note: No RRF or Future Year Design Value was calculated for Stockton-Hazelton, because there were not a sufficient number of modeled days that met the criteria for use in the RRF calculation.

[2] Average only includes 2012 and 2013 design values.

6. COMPARISON TO THE 2007 SJV 8-HOUR O_3 SIP

Since the original model attainment demonstration for the 2007 SJV 8-hour Ozone Plan, the science and computational constraints of regulatory photochemical modeling have changed substantially. Whereas computational constraints required the 2007 Plan to focus on a few multi-day ozone episodes, current computing power allows the modeling of an entire ozone season, which is more consistent with U.S. EPA modeling guidance (U.S. EPA, 2007) and allows for more stable and robust modeling results.

Table A11. Comparison of the modeling approach for the 2007 SJV 8-hour Ozone Plan and the current modeling presented in this document.

	2007 SJV 8-hour Ozone SIP Modeling	Updated Modeling
Base year (model performance)	CCOS episodes: July 9-13, 1999 and July 29-August 2, 2000 (10 days total)	Ozone season 2012: May-September (153 days total)
Reference year	2002 emissions w/ CCOS meteorology	2012 emissions w/ 2012 meteorology
Future year	2023 emissions w/ CCOS meteorology	2023 emissions w/ 2012 meteorology
Days used in RRF calculation	Hourly & DM8hr O_3 threshold, bias, error, DM8hr O_3 within +/- 20% (results in few days used in the RRF calculation)	DM8hr O_3 threshold, DM8hr O_3 within +/- 20% (results in many days used in the RRF calculation and is consistent with EPA guidance)
Meteorological Model	MM5 v3.7.2	WRF v3.4.1
Photochemical Model	CAMx v4.10	CMAQ v5.0.2
Chemical Mechanism	SAPRC99	SAPRC07
Boundary Conditions	Fixed	Dynamic: MOZART-4/GEOS5
Domain	4-km Northern CA	12-km Statewide and 4-km Northern CA

Table A11 summarizes the differences between the modeling for the original 2007 SJV 8-hour Ozone Plan and the current modeling. Recent work has shown that different modeling platforms (e.g., photochemical model: CMAQ vs. CAMx or chemical mechanism: SAPRC vs. CB) generally produce a consistent ozone response to emission reductions (Hogrefe et al., 2008), which suggests that the differences in models and chemical mechanisms illustrated in Table A11 would not be expected to

cause a significant change in the model response. Potentially larger impacts might be expected from the differences in episodes simulated, and in particular the number of simulation days used in the RRF calculation, as well as boundary conditions feeding into the modeling. However, despite these differences the original modeling and the current modeling predict consistent emission targets needed to meet the 0.08 ppm 8-hour O_3 NAAQS. In particular, the updated modeling shows attainment of the standard in 2023 at NO_x and VOC target emission levels of 165 tons/day and 340 tons/day, respectively, compared to 160 tons/day and 342 tons/day from the 2007 Ozone Plan.

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Appendix B

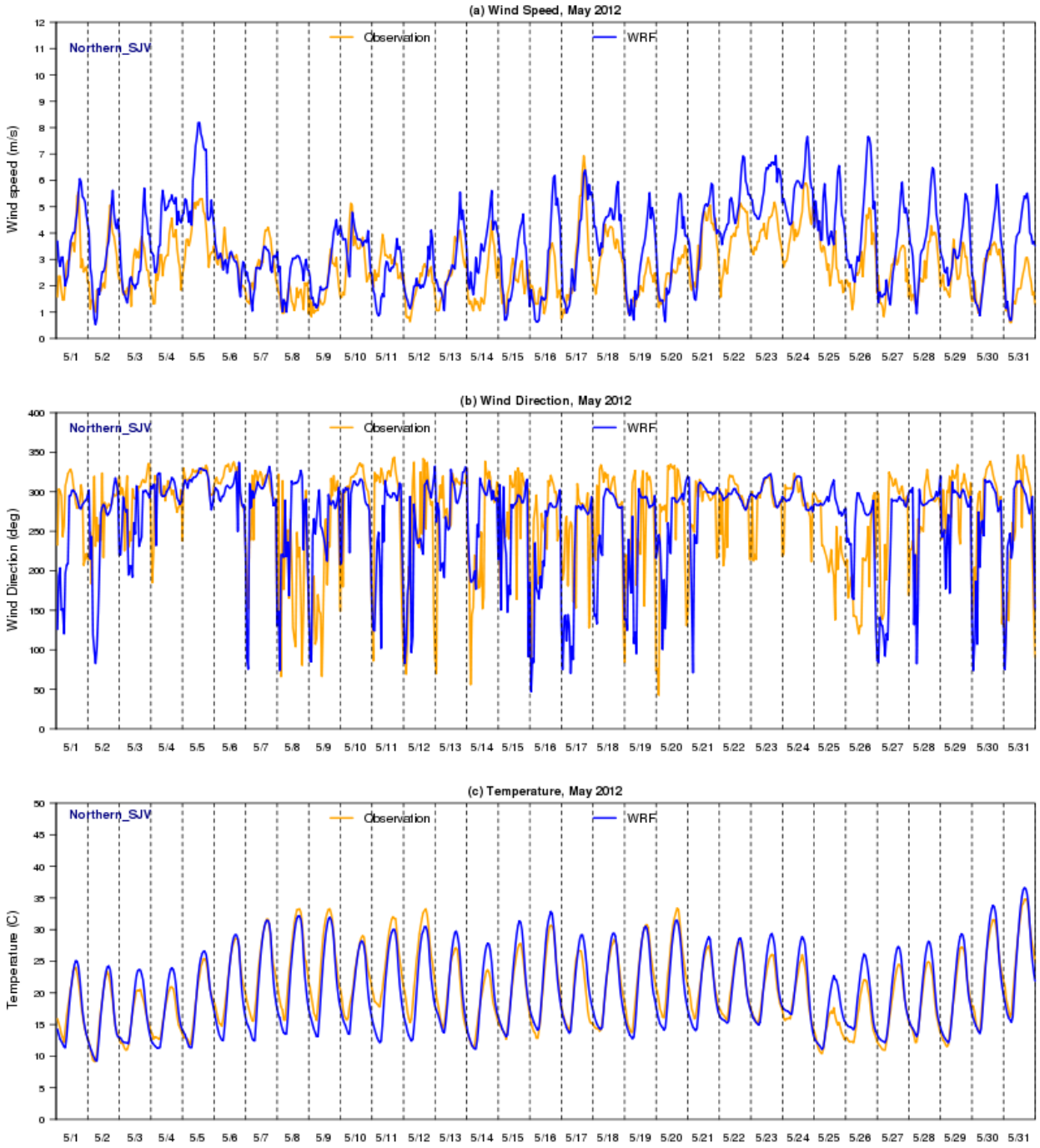
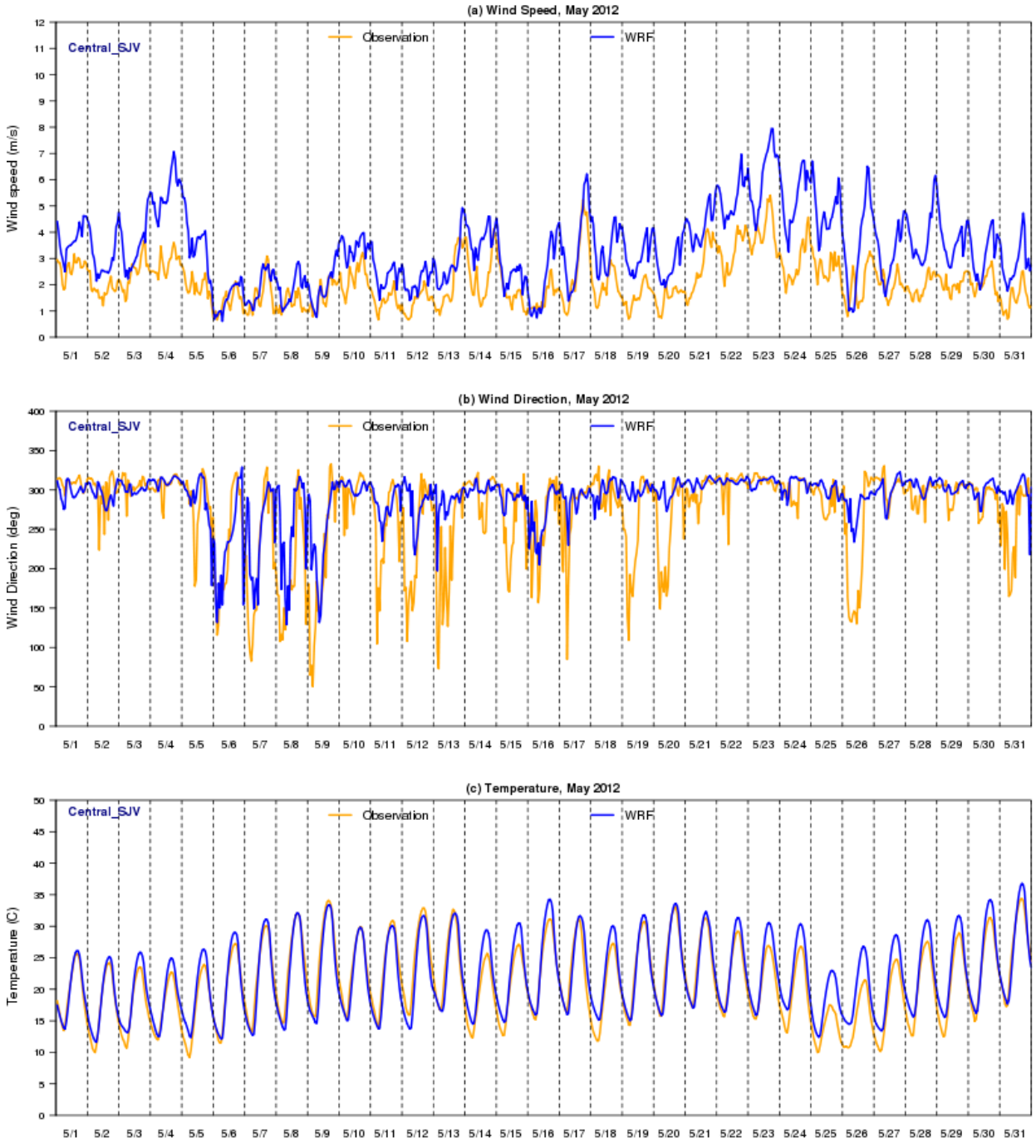


Figure B1. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley in May 2012.



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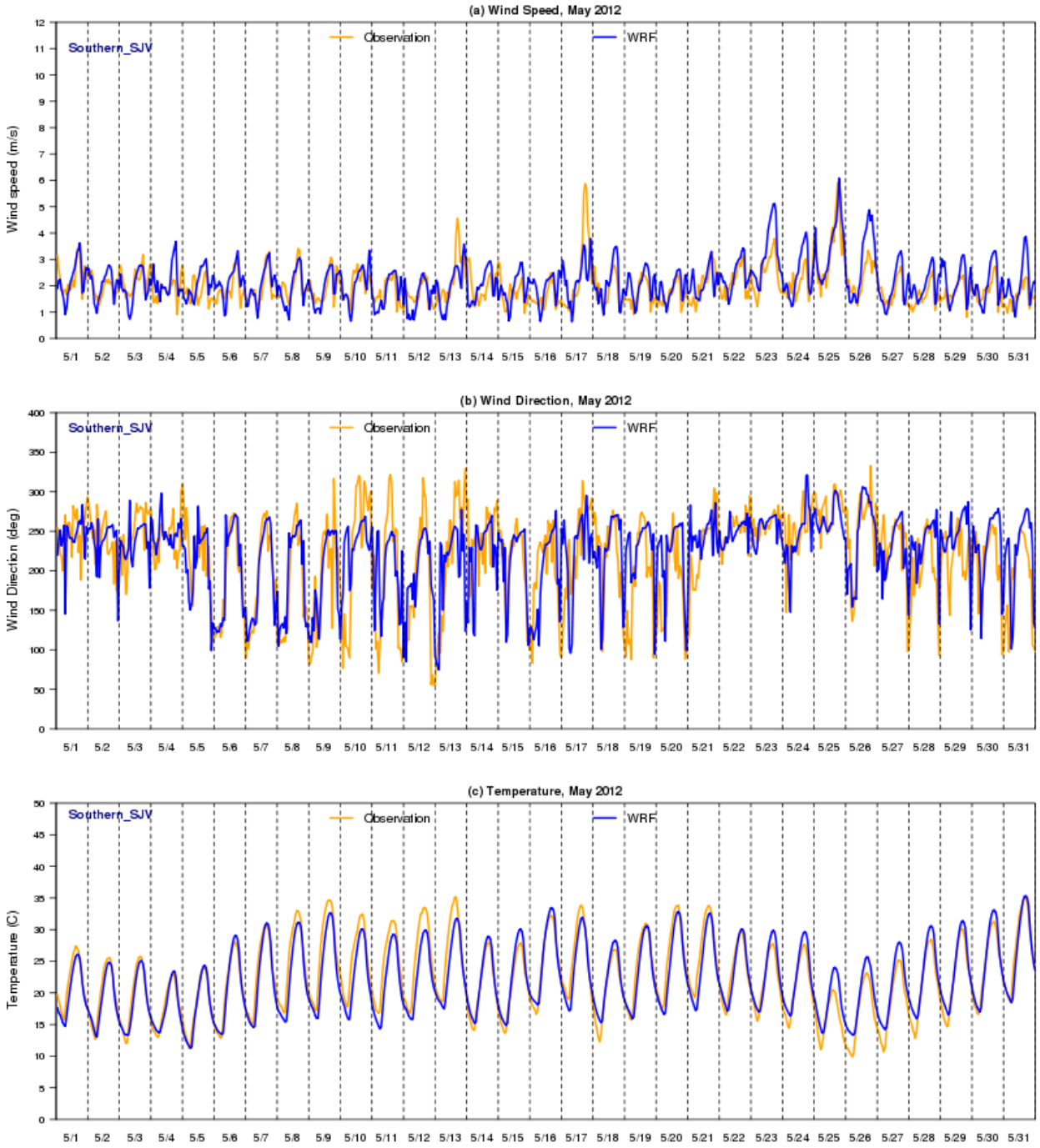

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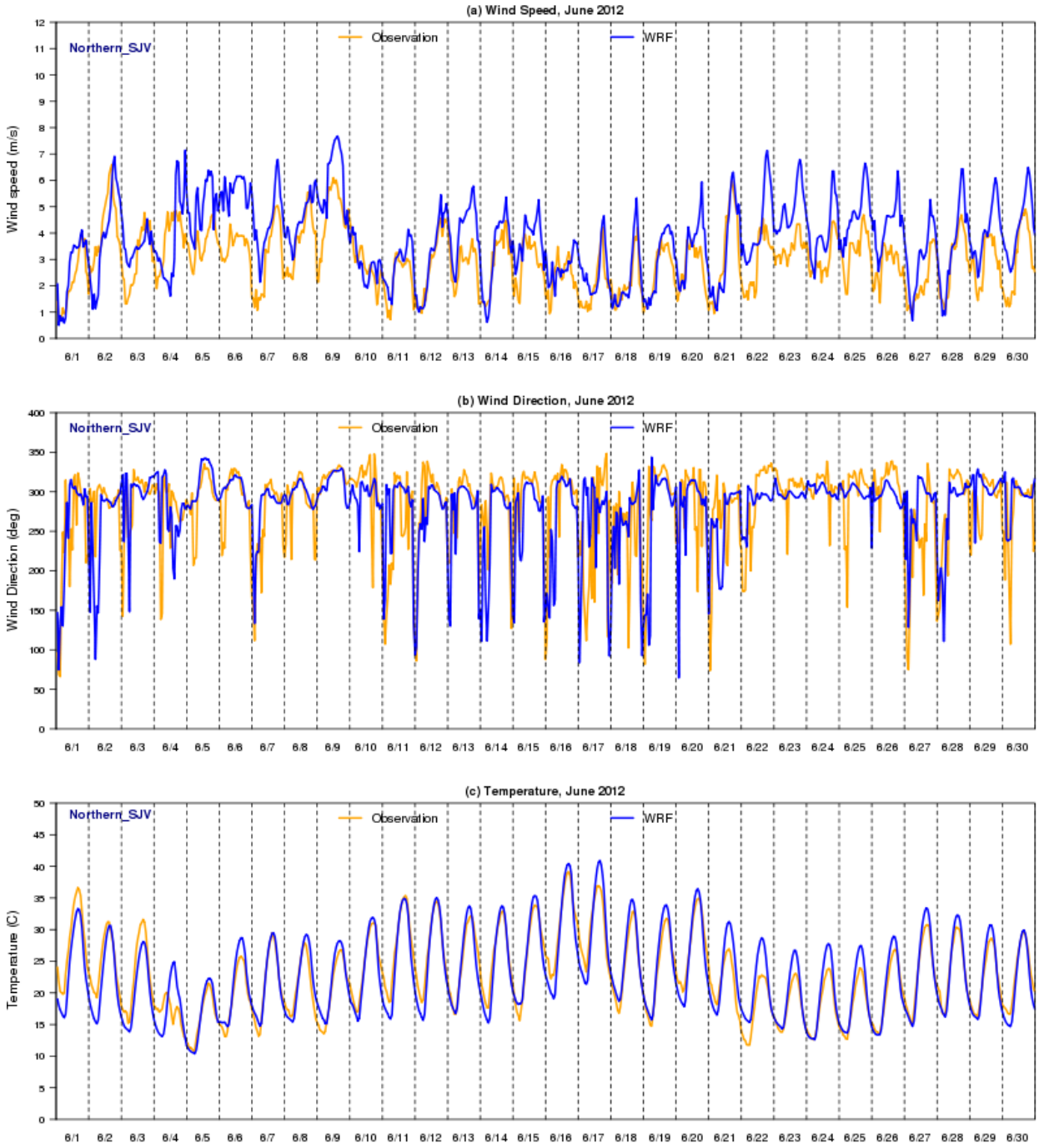

Figure B4. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley in June 2012.

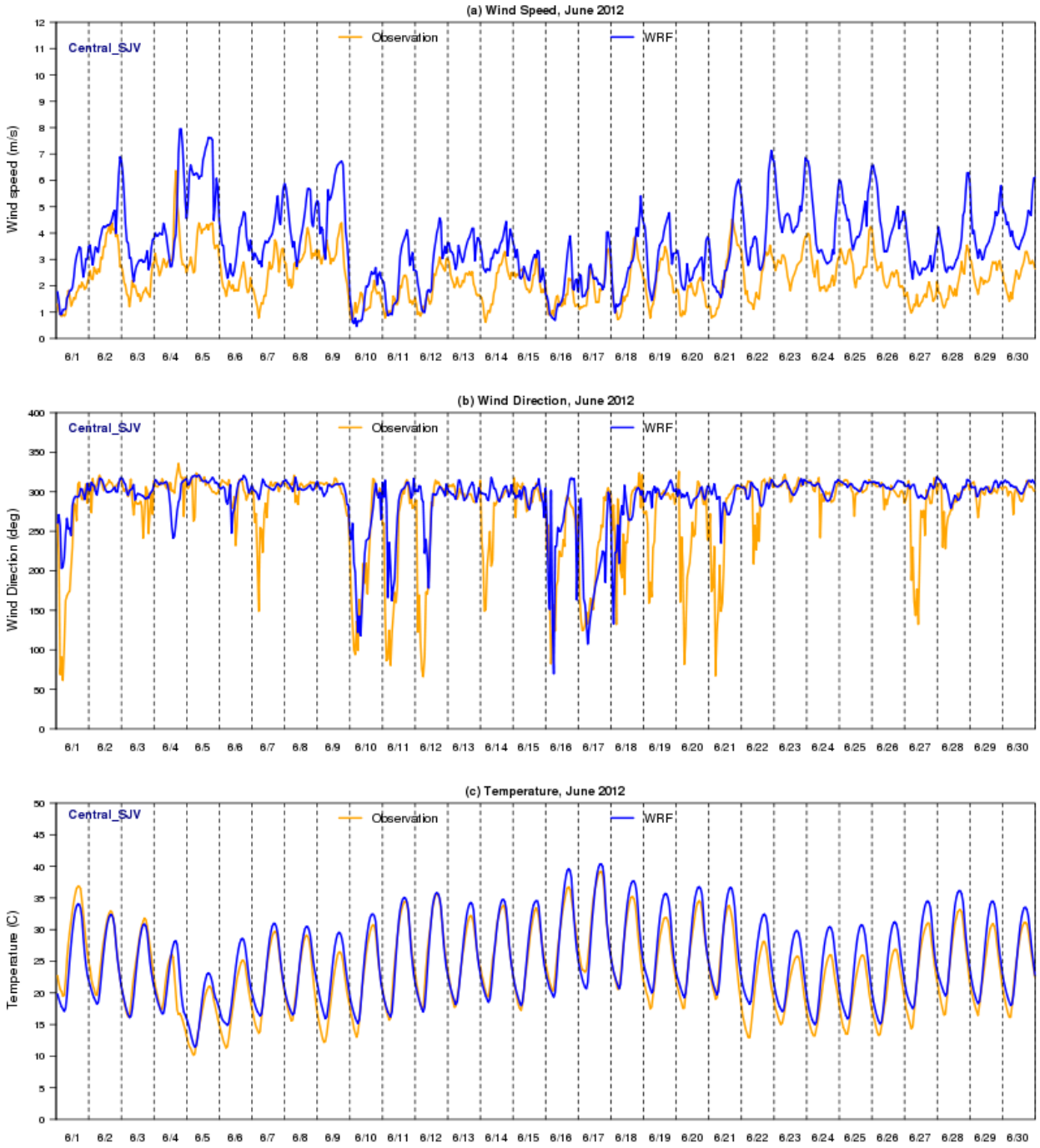

Figure B5. Time series of wind speed, direction, and temperature for the Central San Joaquin Valley in June 2012.

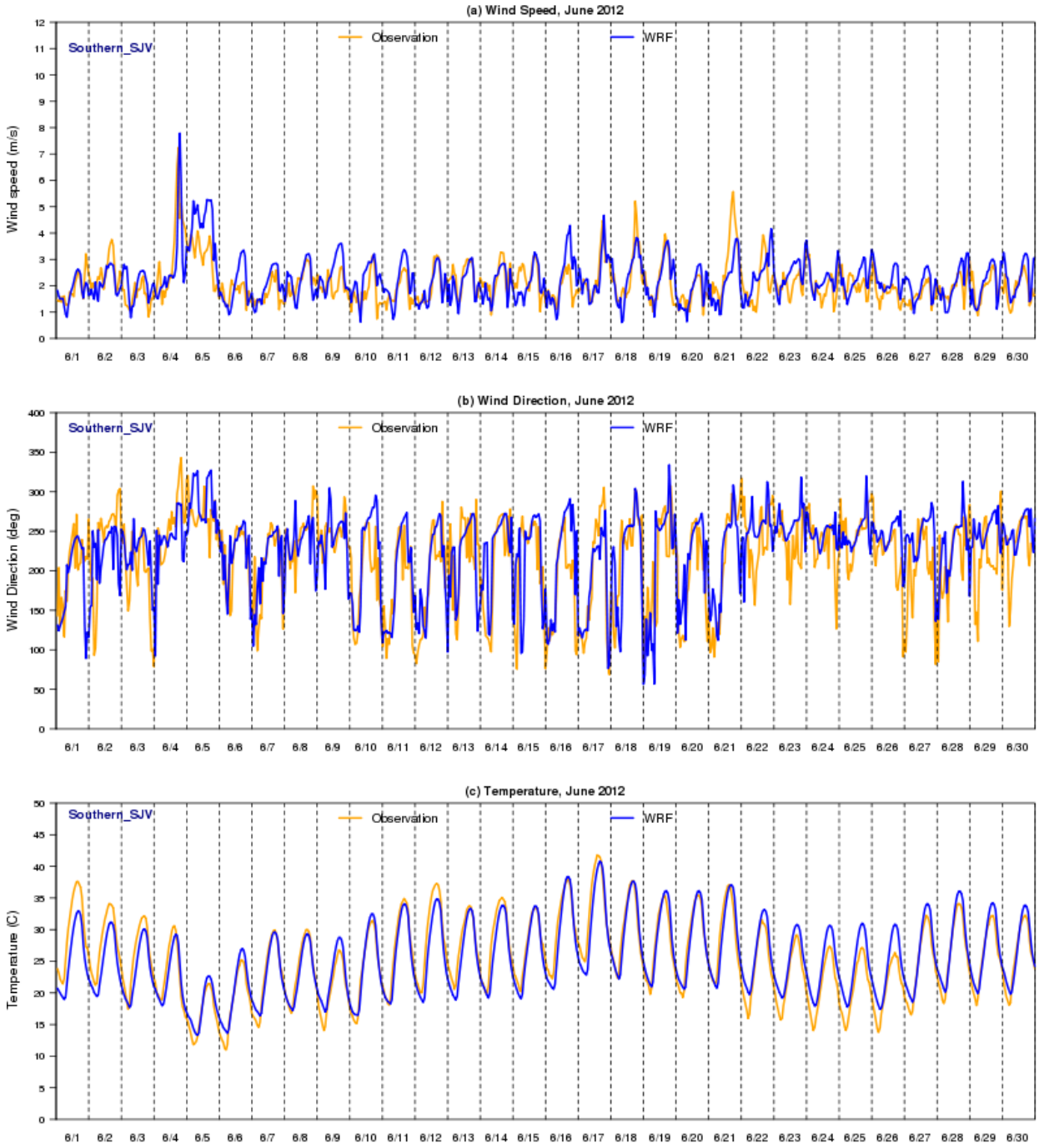

Figure B6. Time series of wind speed, direction, and temperature for the Southern San Joaquin Valley in June 2012.

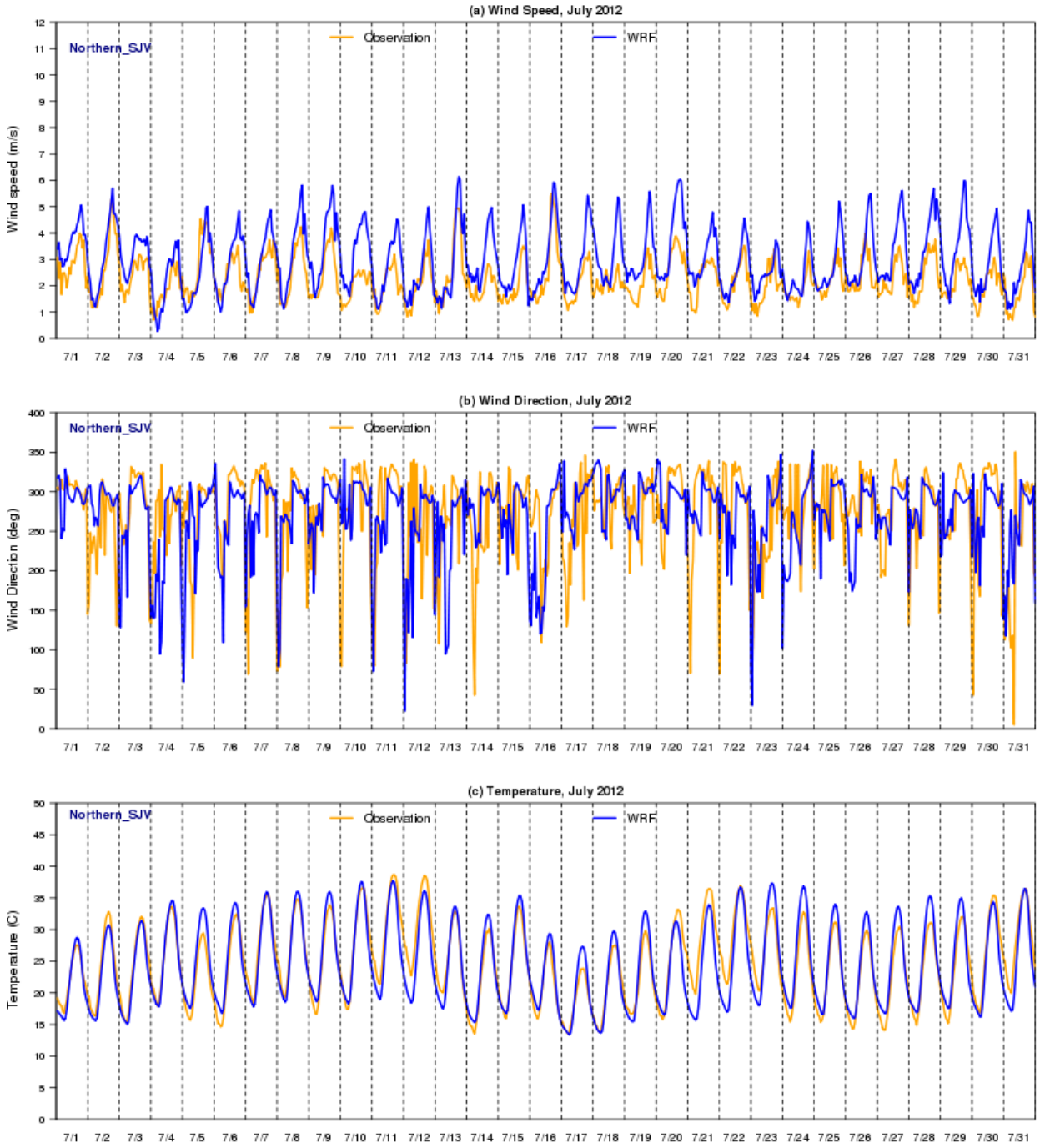

Figure B7. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley in July 2012.

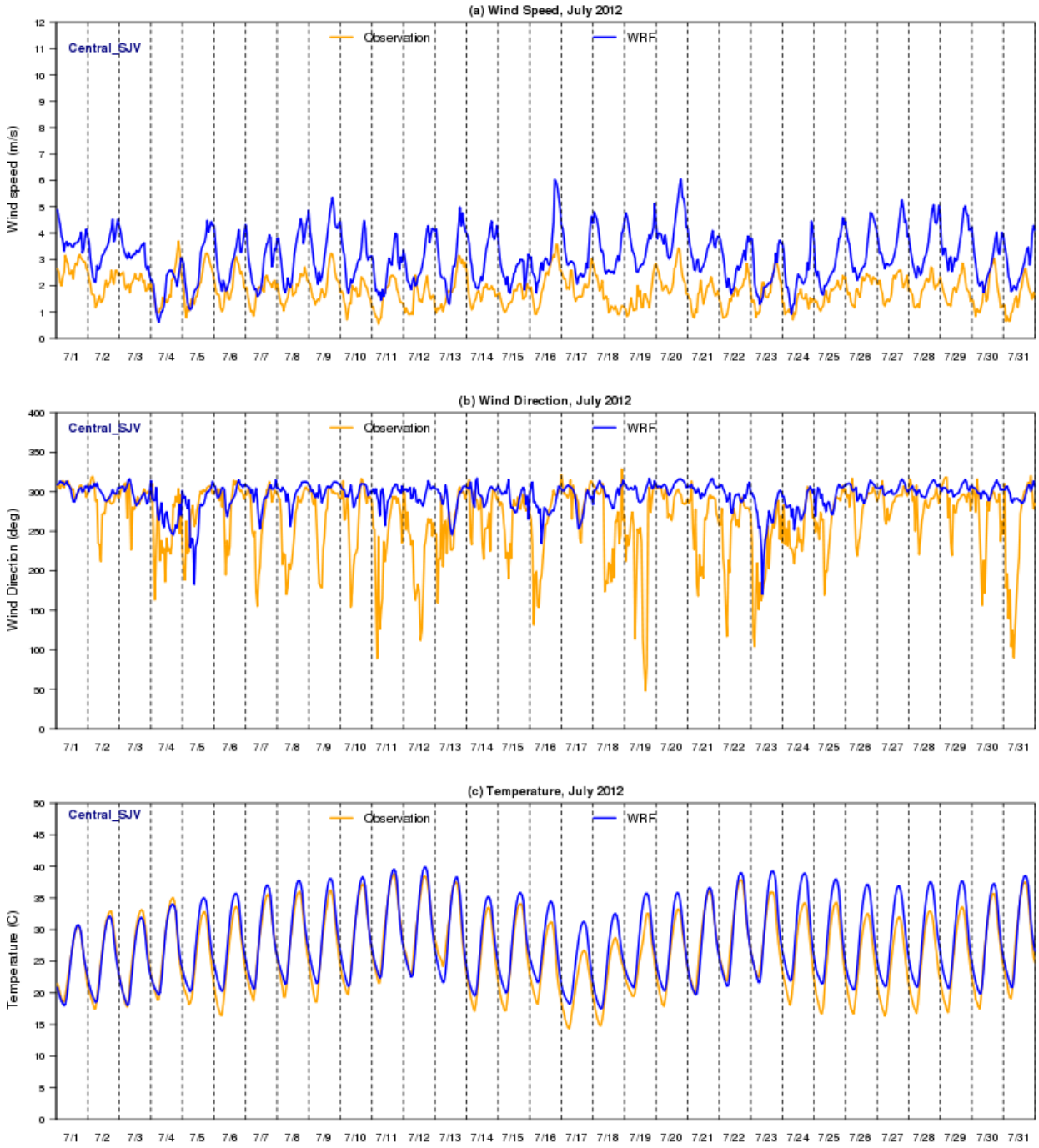

Figure B8. Time series of wind speed, direction, and temperature for the Central San Joaquin Valley in July 2012.

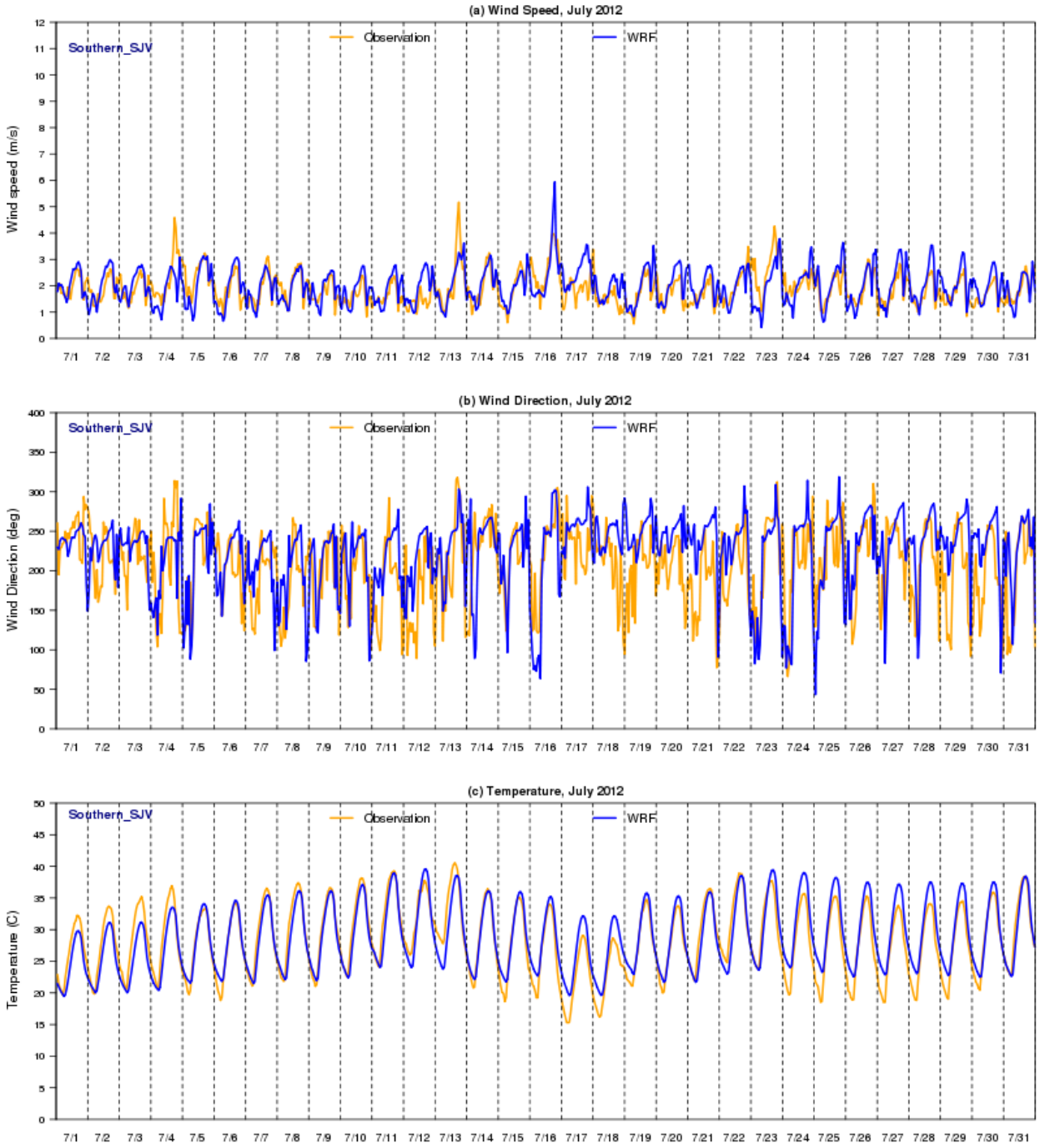

Figure B9. Time series of wind speed, direction, and temperature for the Southern San Joaquin Valley in July 2012.

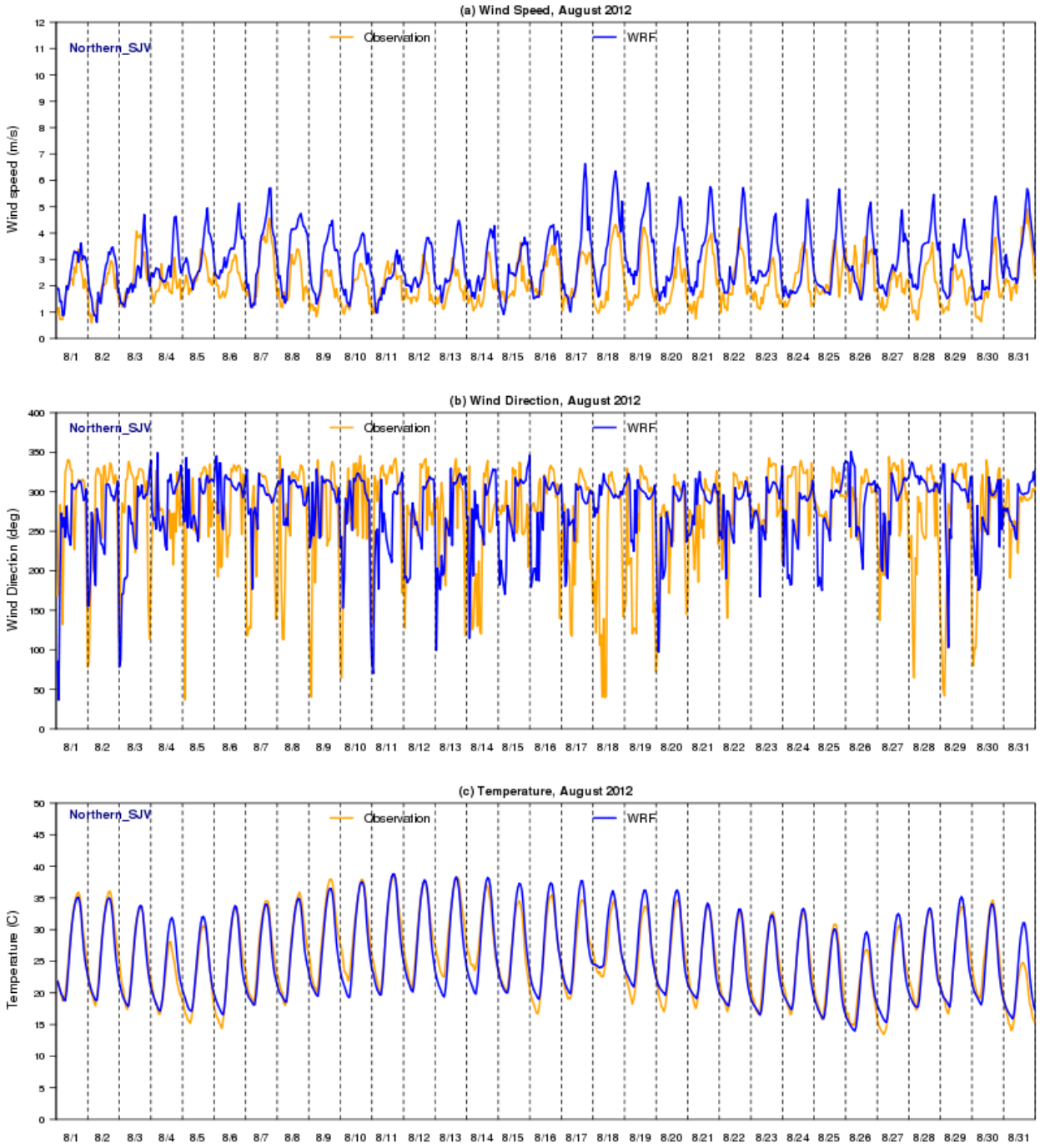

Figure B10. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley in August 2012.

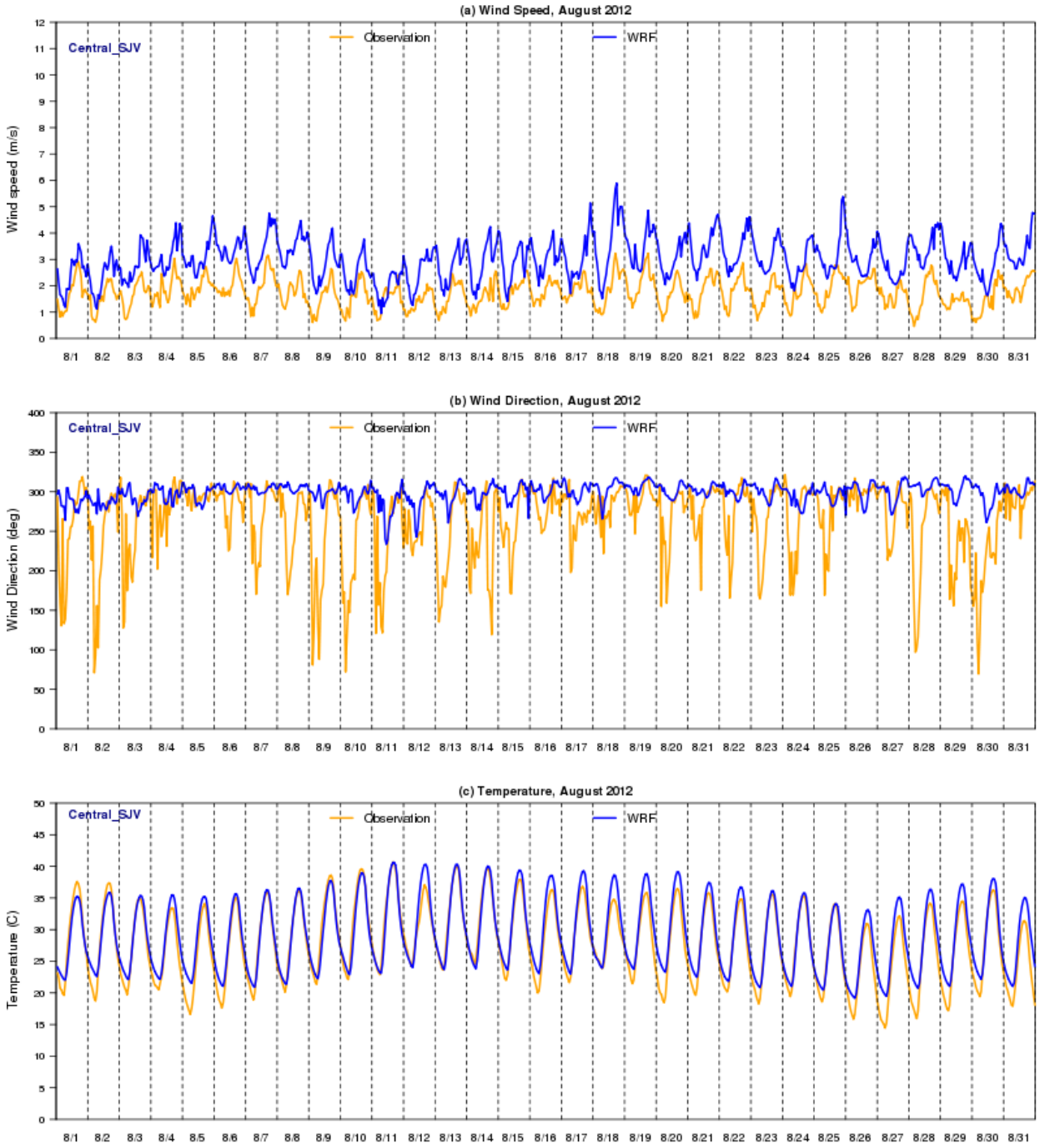

Figure B11. Time series of wind speed, direction, and temperature for the Central San Joaquin Valley in August 2012.

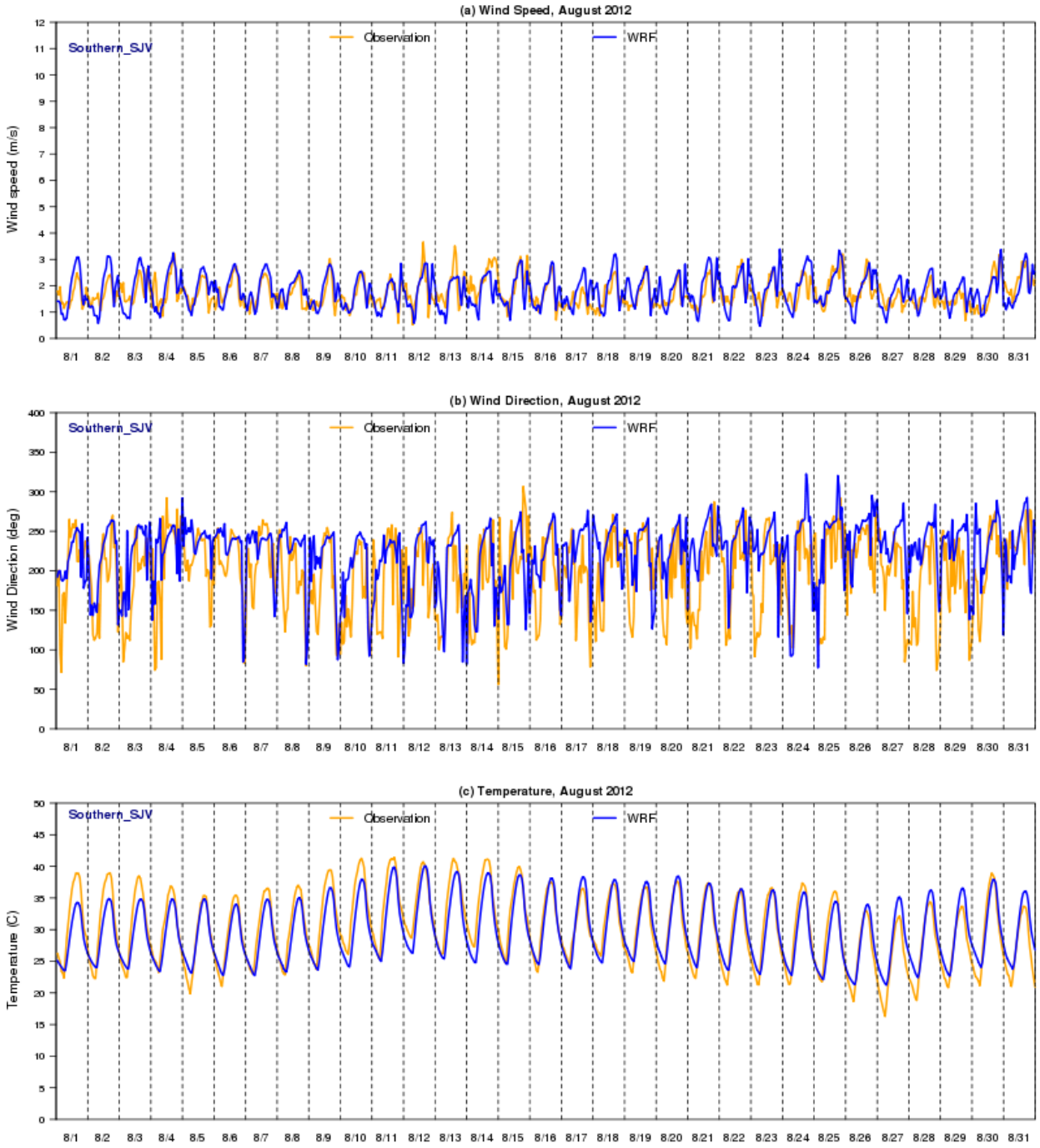

Figure B12. Time series of wind speed, direction, and temperature for the Southern San Joaquin Valley in August 2012.

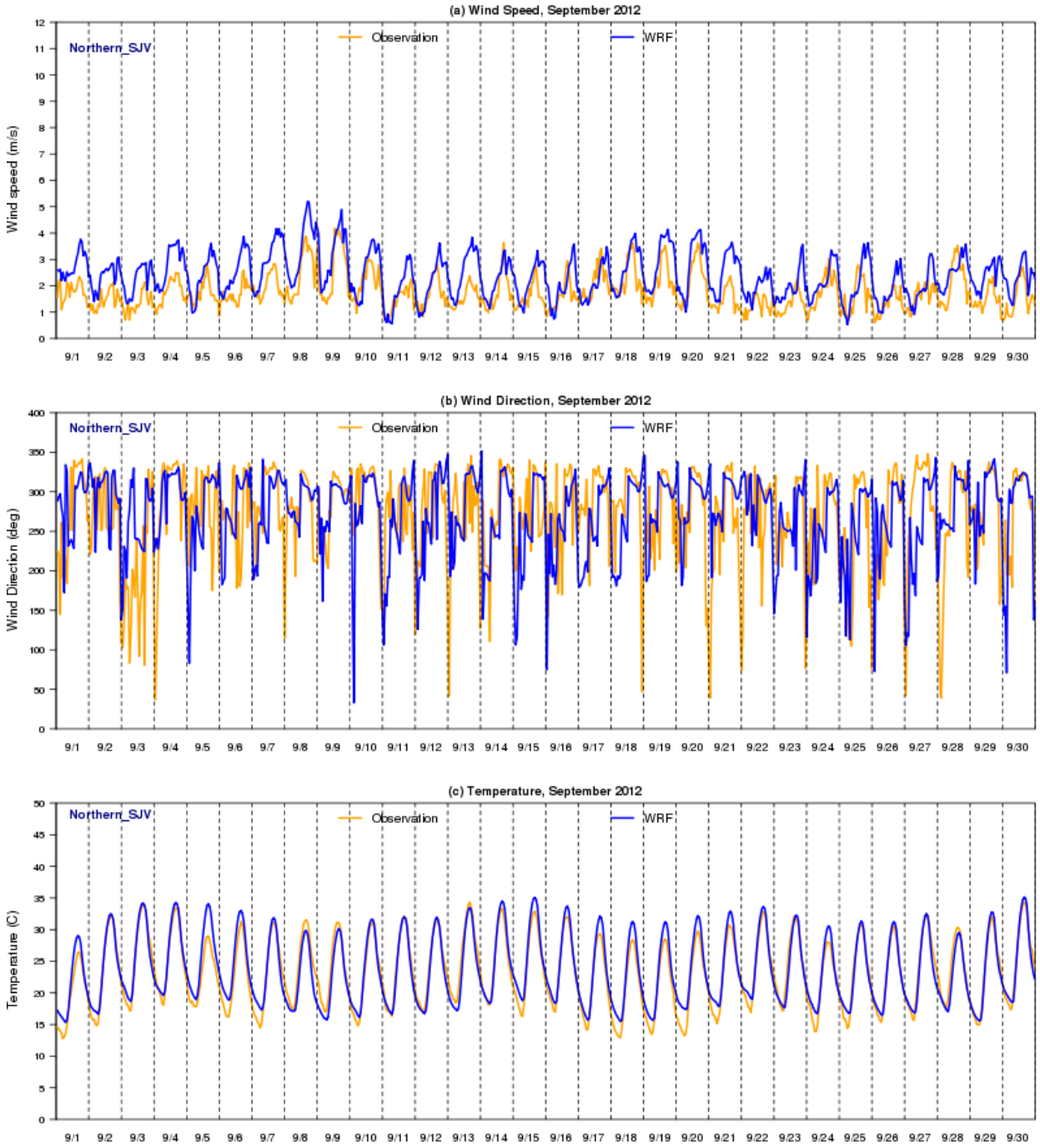

Figure B13. Time series of wind speed, direction, and temperature for the Northern San Joaquin Valley in September 2012.

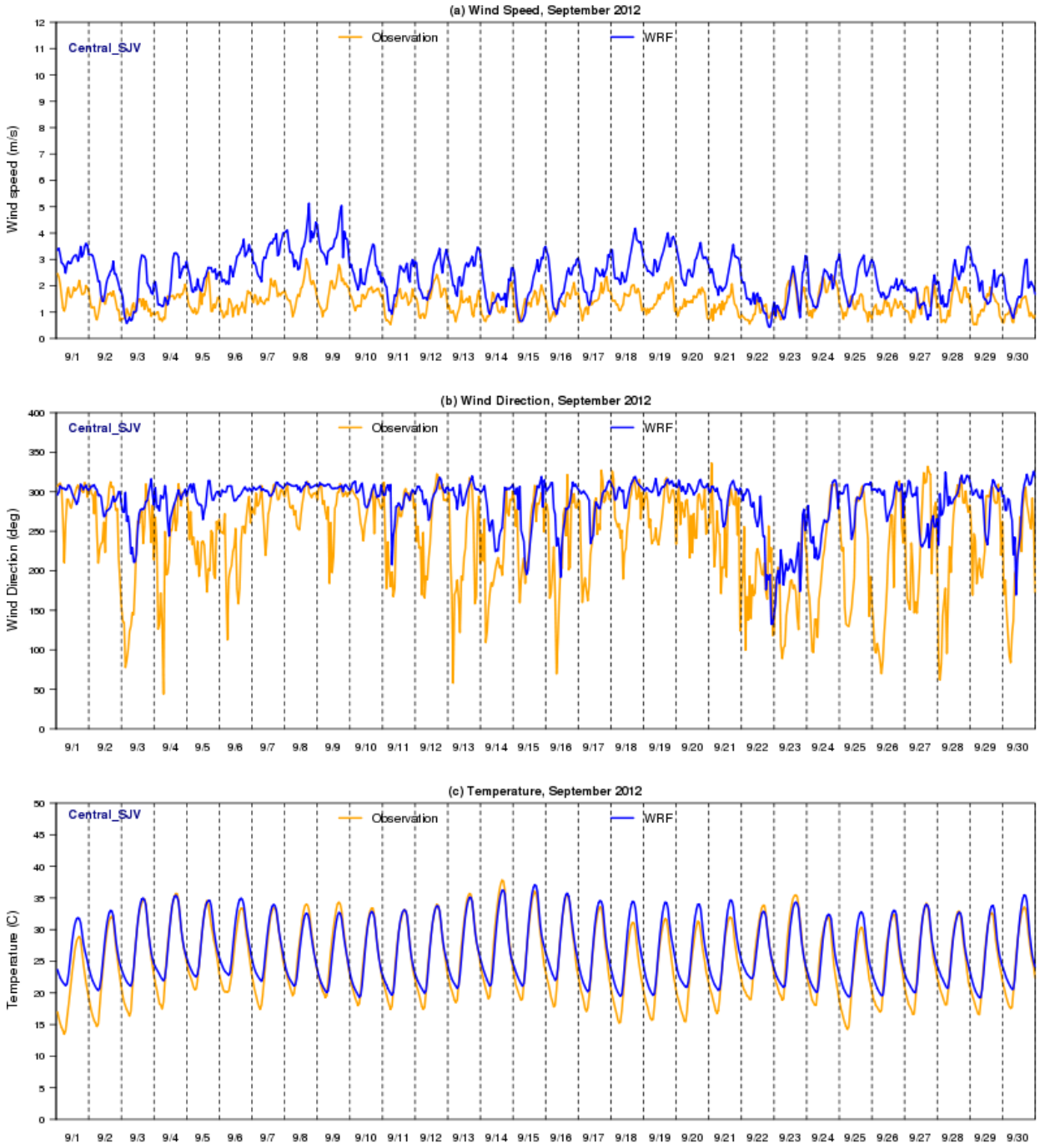

Figure B14. Time series of wind speed, direction, and temperature for the Central San Joaquin Valley in September 2012.

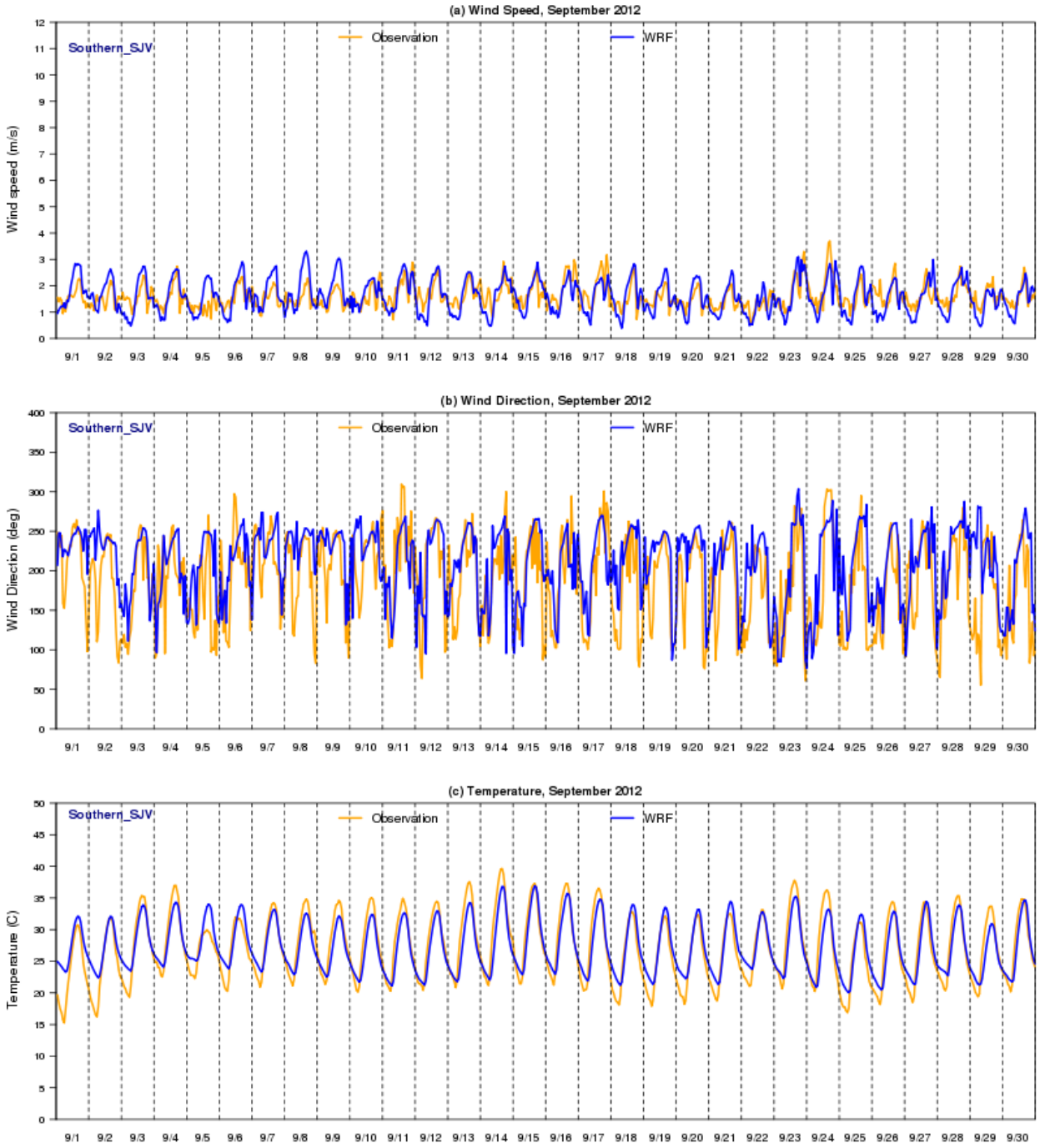

Figure B15. Time series of wind speed, direction, and temperature for the Southern San Joaquin Valley in September 2012.

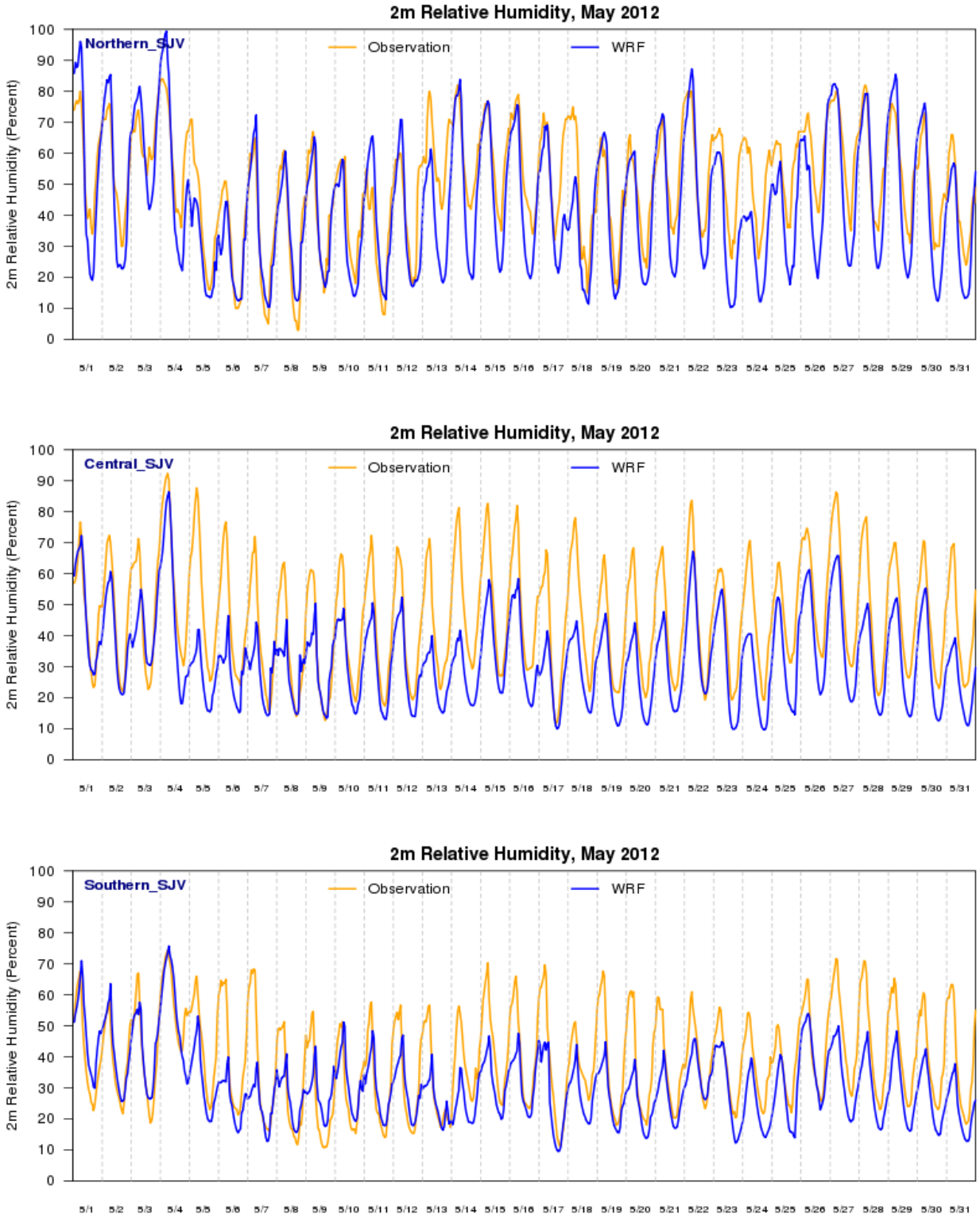

Figure B16. Time series of relative humidity for the (top) Northern SJV, (middle) Central SJV, and (bottom) Southern SJV in May 2012.

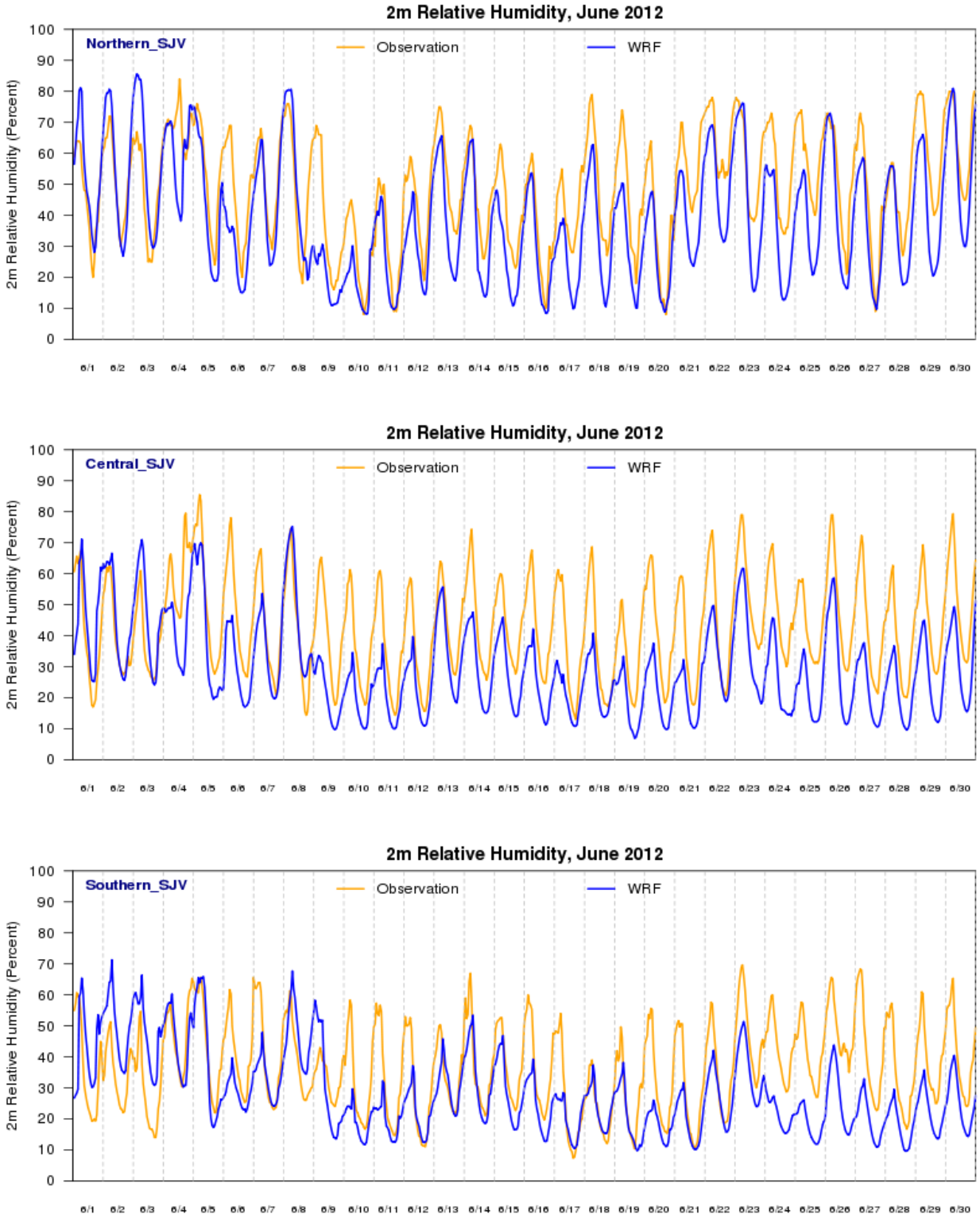

Figure B17. Time series of relative humidity for the (top) Northern SJV, (middle) Central SJV, and (bottom) Southern SJV in June 2012.

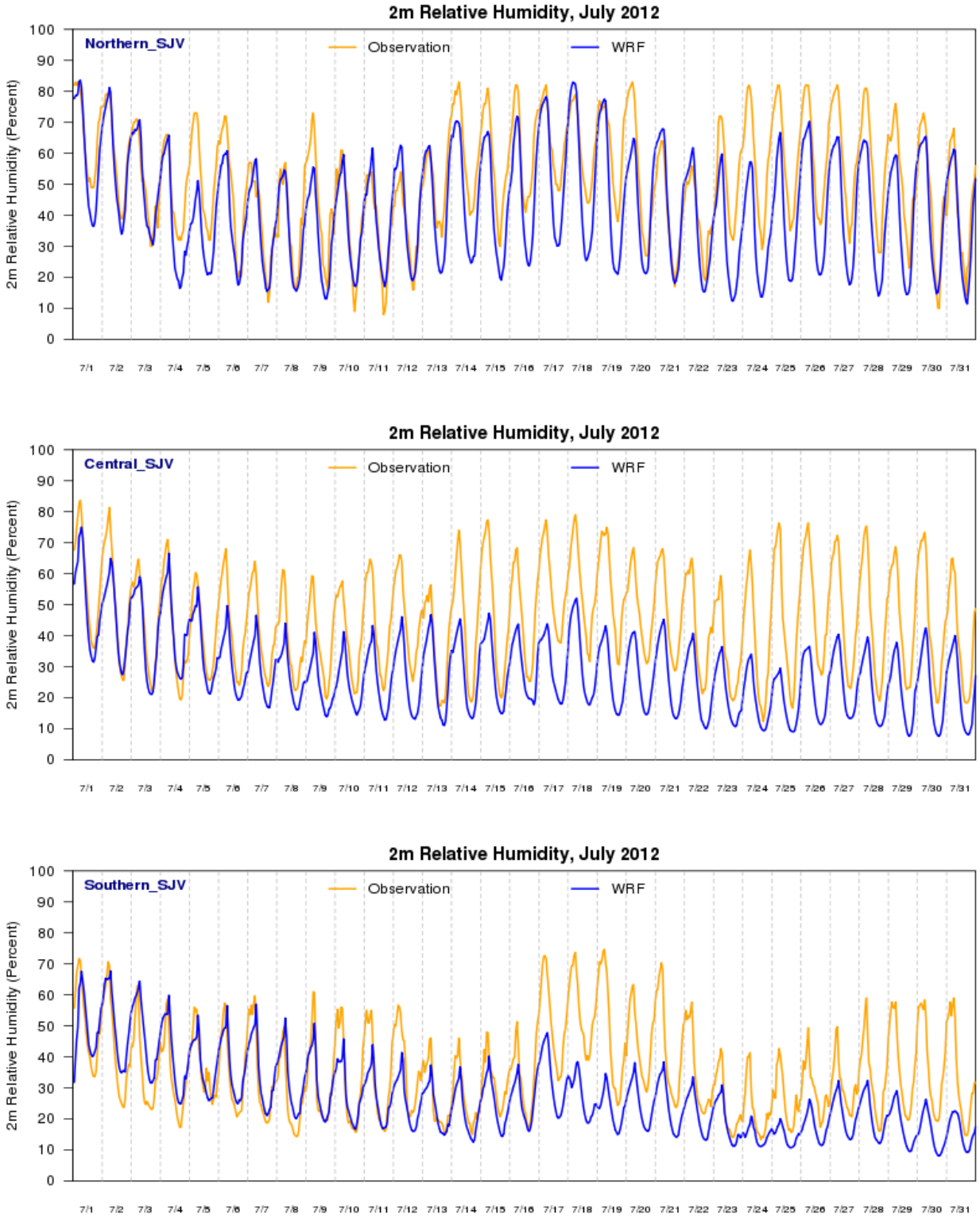

Figure B18. Time series of relative humidity for the (top) Northern SJV, (middle) Central SJV, and (bottom) Southern SJV in July 2012.

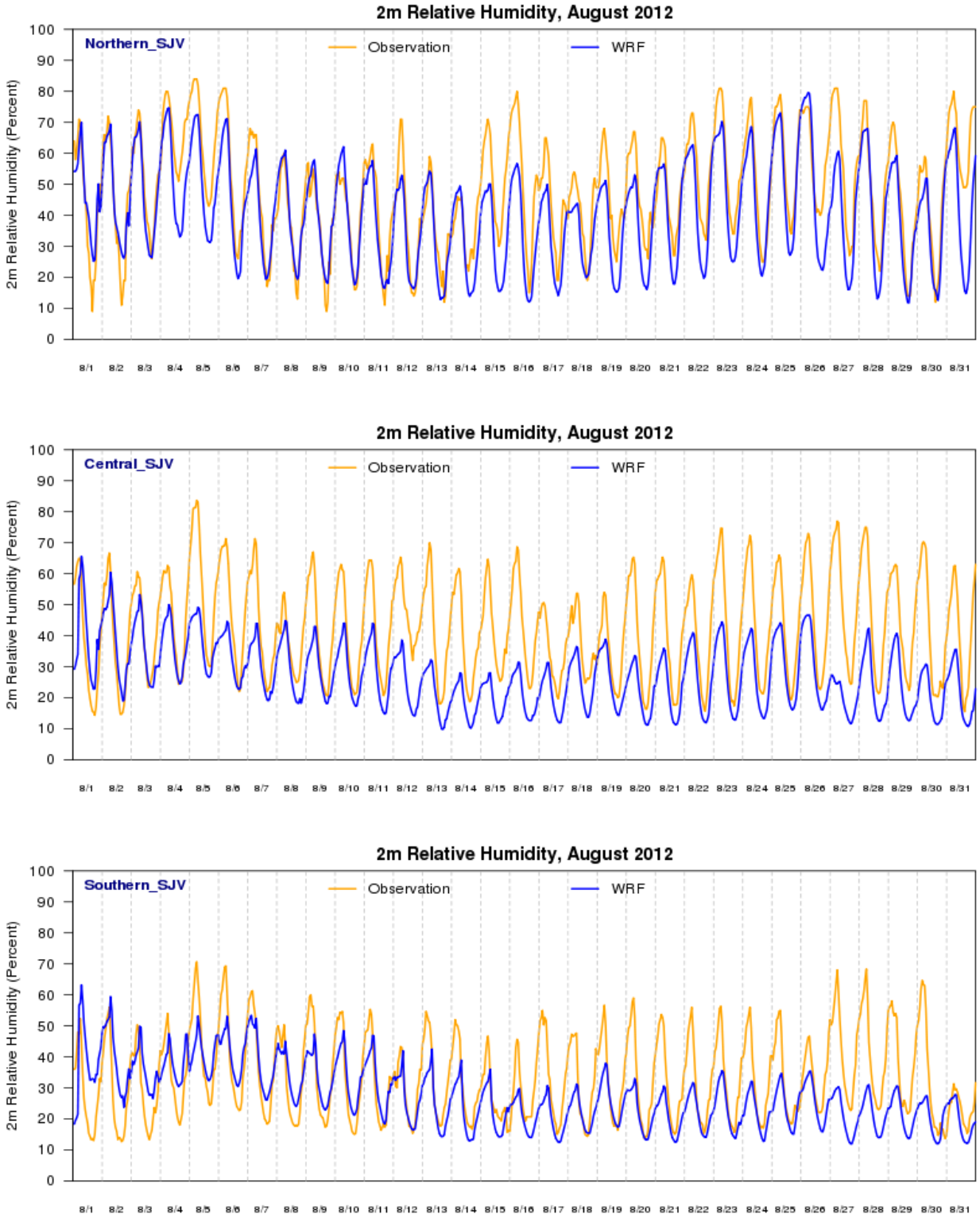

Figure B19. Time series of relative humidity for the (top) Northern SJV, (middle) Central SJV, and (bottom) Southern SJV in August 2012.

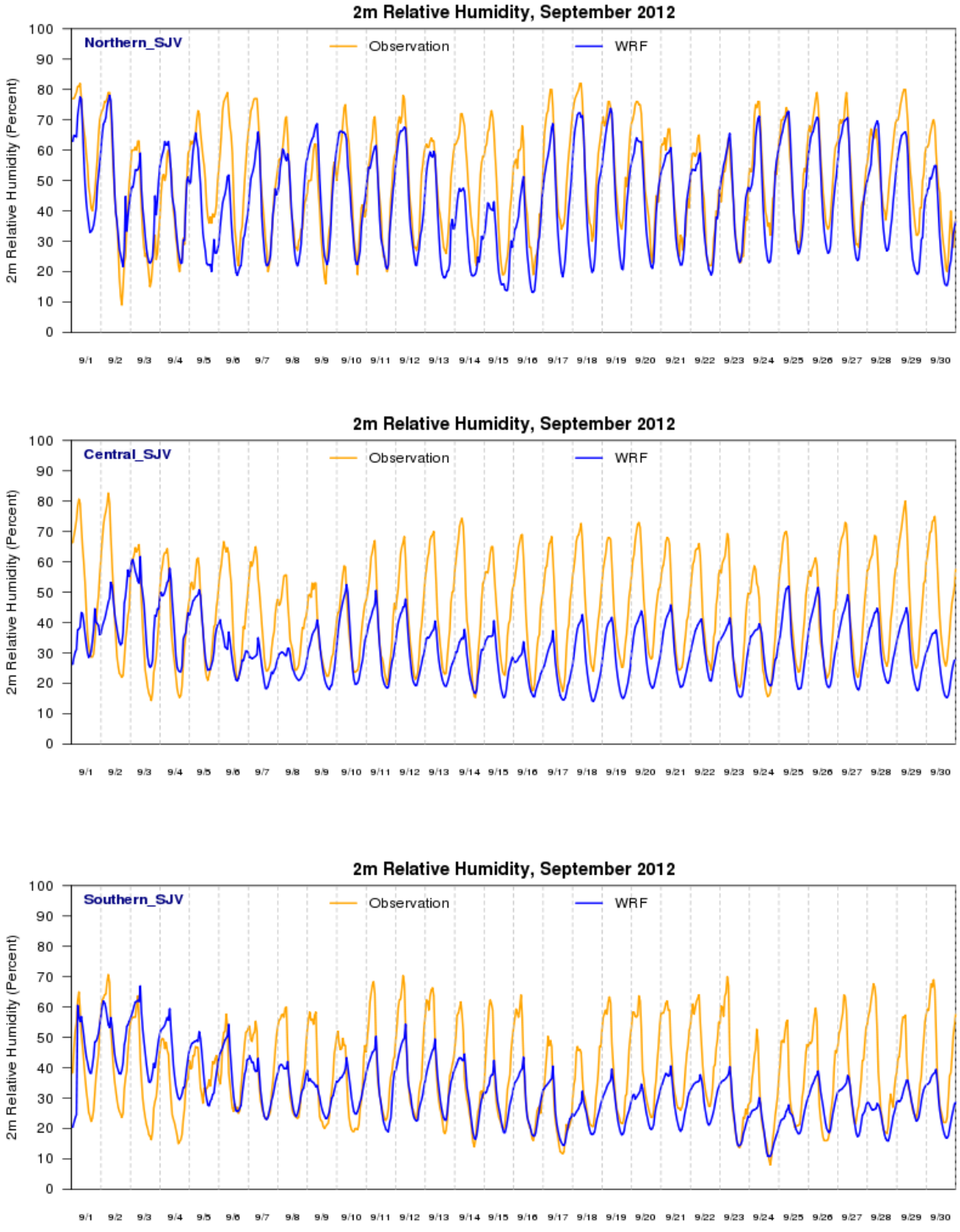

Figure B20. Time series of relative humidity for the (top) Northern SJV, (middle) Central SJV, and (bottom) Southern SJV in September 2012.

Appendix C

Table C1. Speciation profiles updated since the 2012 SJV 24-hour $PM_{2.5}$ SIP

Organic Gas Profile Number	Profile Description
204	Silage (ROG)
681	Liquid gasoline E6 summer fuel
682	Liquid gasoline E6 winter fuel
683	Headspace vapors E6 summer gasoline fuel
684	Headspace vapors E6 winter gasoline fuel
690	Liquid gasoline E10 summer fuel (2012 update)
691	Headspace vapors E10 summer gasoline fuel
692	Liquid gasoline E10 summer fuel (2013 update)
2301	Gasoline - catalyst - Bag1-3 start - E6 summer (ARB VSP17)
2302	Gasoline - catalyst - Bag1-3 start - E6 winter (ARB VSP17)
2303	Gasoline - catalyst - stabilized exhaust - E6 summer (ARB VSP17)
2304	Gasoline - catalyst - stabilized exhaust - E6 winter (ARB VSP17)
3001	CONS PRD- CONSTRUCTION, PANEL, OR FLOOR COVERING ADHESIVE (2010 UPDATE)
3002	CONS PRD- GENERAL PURPOSE ADHESIVE (2010 UPDATE)
3003	CONS PRD- AEROSOL ADHESIVE (INCLUDING INDSTRIAL) (2010 UPDATE)
3004	CONS PRD- PIPE CEMENT AND PRIMER (2010 UPDATE)
3005	CONS PRD- SEALANT AND CAULKING COMPOUND (2010 UPDATE)
3006	CONS PRD- BUG AND TAR REMOVER (2010 UPDATE)
3007	CONS PRD- AUTO HARD PASTE WAX (2010 UPDATE)
3008	CONS PRD- AUTOMOTIVE INSTANT DETAILER (2010 UPDATE)
3009	CONS PRD- AUTOMOTIVE POLISH,SEALANT,WAX,GLAZE (2010 UPDATE)
3010	CONS PRD- AUTOMOTIVE RUBBING OR POLISHING COMPOUND (2010 UPDATE)
3011	CONS PRD- TIRE CLEANER AND WHEEL CLEANER (2010 UPDATE)
3012	CONS PRD- AUTOMOTIVE BRAKE CLEANER (2010 UPDATE)
3013	CONS PRD- CARBURETOR OR FUEL-INJECTION AIR INTAKE CLEANER (2010 UPDATE)
3014	CONS PRD- ENGINE DEGREASER (2010 UPDATE)
3015	CONS PRD- TIRE SEALANTS AND INFLATOR (2010 UPDATE)
3016	CONS PRD- AUTOMOTIVE UNDERCOATINGS - AEROSOL (2010 UPDATE)
3017	CONS PRD- AUTOMOTIVE WINDSHIELD WASHER FLUID - NON TYPE A AREAS (2010 UPDATE)
3018	CONS PRD- PAINT REMOVER OR STRIPPER (2010 UPDATE)
3019	CONS PRD- MULTI-PURPOSE SOLVENT AND PAINT THINNER (2010 UPDATE)
3020	CONS PRD- DISINFECTANTS (ALL FORMS) (2010 UPDATE)
3021	CONS PRD- SANITIZER (2010 UPDATE)
3022	CONS PRD- NON-SELECTIVE TERRESTRIAL HERBICIDE (2010 UPDATE)
3023	CONS PRD- FLEA AND TICK INSECTICIDE (2010 UPDATE)
3024	CONS PRD- FLYING BUG INSECTICIDE - AEROSOL (2010 UPDATE)
3025	CONS PRD- FLYING BUG INSECTICIDE - NON-AEROSOL (2010 UPDATE)
3026	CONS PRD- WASP OR HORNET INSECTICIDE (2010 UPDATE)
3027	CONS PRD- LAWN AND GARDEN INSECTICIDE (2010 UPDATE)
3028	CONS PRD- CRAWLING BUG INSECTICIDE - AEROSOL (2010 UPDATE)
3029	CONS PRD- CRAWLING BUG INSECTICIDE - NON-AEROSOL (2010 UPDATE)
3030	CONS PRD- INSECTICIDE FOGGER - AEROSOL (2010 UPDATE)
3031	CONS PRD- INSECT REPELLENT - AEROSOL (2010 UPDATE)
3032	CONS PRD- INSECT REPELLENT - NON-AEROSOL (2010 UPDATE)

Organic Gas Profile Number	Profile Description
3033	CONS PRD- CARPET AND UPHOLSTERY CLEANER - AEROSOL (2010 UPDATE)
3034	CONS PRD- CARPET AND UPHOLSTERY CLEANER - NON-AEROSOL (2010 UPDATE)
3035	CONS PRD- SPOT REMOVER - AEROSOL (2010 UPDATE)
3036	CONS PRD- SPOT REMOVER - NON-AEROSOL (2010 UPDATE)
3037	CONS PRD- FABRIC PROTECTANT - AEROSOL (2010 UPDATE)
3038	CONS PRD- FLOOR WAX STRIPPER (2010 UPDATE)
3039	CONS PRD- GENERAL PURPOSE CLEANER - AEROSOL (2010 UPDATE)
3040	CONS PRD- GENERAL PURPOSE CLEANER - NON-AEROSOL (2010 UPDATE)
3041	CONS PRD- GENERAL PURPOSE DEGREASER - AEROSOL (2010 UPDATE)
3042	CONS PRD- GENERAL PURPOSE DEGREASER - NON-AEROSOL (2010 UPDATE)
3043	CONS PRD- GLASS CLEANER - AEROSOL (2010 UPDATE)
3044	CONS PRD- GLASS CLEANER - NON-AEROSOL (2010 UPDATE)
3045	CONS PRD- METAL POLISH OR CLEANSER (2010 UPDATE)
3046	CONS PRD- OVEN CLEANER - AEROSOL (2010 UPDATE)
3047	CONS PRD- OVEN CLEANER - NON-AEROSOL (2010 UPDATE)
3048	CONS PRD- BATHROOM AND TILE CLEANER - AEROSOL (2010 UPDATE)
3049	CONS PRD- BATHROOM AND TILE CLEANER - NON-AEROSOL (2010 UPDATE)
3050	CONS PRD- LAUNDRY PREWASH (2010 UPDATE)
3051	CONS PRD- LAUNDRY STARCH OR SIZING (2010 UPDATE)
3052	CONS PRD- DUSTING AID - AEROSOL (2010 UPDATE)
3053	CONS PRD- DUSTING AID - NON-AEROSOL (2010 UPDATE)
3054	CONS PRD- FLOOR POLISH OR WAX - RESILIENT AND NONRESILIENT (2010 UPDATE)
3055	CONS PRD- FLOOR POLISH OR WAX - WOOD (2010 UPDATE)
3056	CONS PRD- FURNITURE MAINTENANCE PRODUCT - AEROSOL (2010 UPDATE)
3057	CONS PRD- FURNITURE MAINTENANCE PRODUCT - NON-AEROSOL (2010 UPDATE)
3058	CONS PRD- MULTIPURPOSE LUBRICANT (2010 UPDATE)
3059	CONS PRD- SILICONE BASED MULTI-PURPOSE LUBRICANT (2010 UPDATE)
3060	CONS PRD- PENETRANT (2010 UPDATE)
3061	CONS PRD- SPECIAL PURPOSE LUBRICANT (2010 UPDATE)
3062	CONS PRD- SINGLE PHASE AEROSOL AIR FRESHENER (2010 UPDATE)
3063	CONS PRD- DOUBLE PHASE AEROSOL AIR FRESHENER (2010 UPDATE)
3065	CONS PRD- LIQUID OR PUMP AIR FRESHENER (2010 UPDATE)
3066	CONS PRD- CHARCOAL LIGHTER MATERIAL (2010 UPDATE)
3067	CONS PRD- AEROSOL COOKING SPRAY (2010 UPDATE)
3068	CONS PRD- ANTIPERSPIRANT (2010 UPDATE)
3069	CONS PRD- UNDERARM DEODORANT (2010 UPDATE)
3070	CONS PRD- ASTRINGENTS AND TONER (2010 UPDATE)
3071	CONS PRD- PERSONAL FRAGRANCE PRODUCT (FRAGRANCE <= 20%) (2010 UPDATE)
3072	CONS PRD- PERSONAL FRAGRANCE PRODUCT (FRAGRANCE > 20%) (2010 UPDATE)
3073	CONS PRD- HAIR SPRAY (2010 UPDATE)
3074	CONS PRD- HAIR SHINE (2010 UPDATE)
3075	CONS PRD- NAIL COATING (2010 UPDATE)
3076	CONS PRD- RUBBING ALCOHOL (2010 UPDATE)
3077	CONS PRD- HEAVY-DUTY HAND CLEANSER OR SOAP (2010 UPDATE)
3078	CONS PRD- DEODORANT BODY SPRAY (2010 UPDATE)
3079	CONS PRD- DRYER SHEET (2010 UPDATE)

Organic Gas Profile Number	Profile Description
3080	CONS PRD- ODOR REMOVER OR ELIMINATOR (2010 UPDATE)
3081	CONS PRD- WINDSHIELD WATER REPELLENT (2010 UPDATE)
3082	CONS PRD- FLOOR MAINTENANCE PRODUCT (2010 UPDATE)
3083	CONS PRD- TEMPORARY HAIR COLOR - AEROSOL (2010 UPDATE)
3084	CONS PRD- INSULATING AND SEALING FOAM (2010 UPDATE)
3085	CONS PRD- HAND SANITIZER (2010 UPDATE)
3086	CONS PRD- PERSONAL CARE WIPES (2010 UPDATE)
3087	CONS PRD- FABRIC PROTECTANT - NON-AEROSOL (2010 UPDATE)
3088	CONS PRD- SUN SCREEN AND TANNING PRODUCT (2010 UPDATE)
3089	CONS PRD- FABRIC SOFTENER (2010 UPDATE)
3090	CONS PRD- MOTHBALLS (2010 UPDATE)
3091	CONS PRD- BRUSH CLEANER (2010 UPDATE)
3092	CONS PRD- AUTOMOTIVE WINDSHIELD WASHER FLUID - TYPE A AREAS (2010 UPDATE)
3093	CONS PRD- PRESSURIZED GAS DUSTER (2010 UPDATE)
3094	CONS PRD- WITCH HAZEL (2010 UPDATE)
3095	CONS PRD- MOTOR VEHICLE WASH AND CLEANER (2010 UPDATE)
3096	CONS PRD- ALL OTHER ADHESIVES (2010 UPDATE)
3097	CONS PRD- OTHER SEALANTS (2010 UPDATE)
3098	CONS PRD- OTHER CLEANERS AND DEGREASERS (2010 UPDATE)
3099	CONS PRD- OTHER FUELS (2010 UPDATE)
3100	CONS PRD- OTHER LAUNDRY (2010 UPDATE)
3101	CONS PRD- OTHER MISC HOUSEHOLD PRODUCTS (2010 UPDATE)
3102	CONS PRD- OTHER PERSONAL CARE PRODUCTS (2010 UPDATE)
3103	CONS PRD- OTHER PESTICIDES AND INSECTICIDES (2010 UPDATE)
3104	CONS PRD- OTHER VEHICLE MAINTENANCE PRODUCTS (2010 UPDATE)
3105	CONS PRD- MISC ART AND OFFICE PRODUCTS (2010 UPDATE)
3106	CONS PRD- OTHER LAWN AND GARDEN PRODUCTS (2010 UPDATE)
3107	CONS PRD- OTHER AIR FRESHENERS (2010 UPDATE)
5861	Aircraft exhaust - jet fuel

Appendix D

Table D1. Hourly ozone performance statistics by modeling subregions and the entire SJV region for May-September 2012.

All hourly data

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	13478	30170	7284	20721	71653
Mean obs (ppb)	38.8	44.6	59.7	47.6	45.9
Standard Deviation obs (ppb)	19.8	21.6	15	21.6	21.4
Mean Bias (ppb)	-4	-3.6	-3.1	-2.3	-3.3
Mean Error (ppb)	8.9	9.4	9	11.2	9.8
RMSE (ppb)	11.8	12.3	11.5	14.2	12.7
Normalized Mean Bias (%)	-10.3	-8.2	-5.1	-4.9	-7.1
Normalized Mean Error (%)	23	21.2	15.1	23.4	21.3
R-squared	0.69	0.71	0.47	0.58	0.67
Index of Agreement	0.89	0.89	0.8	0.86	0.89

Hourly data above 60 ppb

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	835	3979	2141	3489	10444
Mean obs (ppb)	75.6	76.6	75.4	76.1	76.1
Standard Deviation obs (ppb)	10.3	10.9	9.8	9.1	10.1
Mean Bias (ppb)	-7.8	-8.6	-5.7	-6.8	-7.4
Mean Error (ppb)	9.7	10	8.5	8.8	9.2
RMSE (ppb)	12.8	13.1	10.7	11.1	12
Normalized Mean Bias (%)	-10.3	-11.3	-7.6	-9	-9.7
Normalized Mean Error (%)	12.9	13	11.2	11.6	12.2
R-squared	0.1	0.19	0.22	0.22	0.18
Index of Agreement	0.53	0.55	0.63	0.62	0.58

Note: The statistical metrics used in this table are defined in Simon et. al., (2012)

Table D2. Daily maximum 1-hour ozone performance statistics by modeling subregions and entire SJV region for May-September 2012.

Daily Maximum 1-hour ozone (all days)

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	558	1278	302	891	3029
Mean obs (ppb)	65.4	73.3	79.1	75.8	73.2
Standard Deviation obs (ppb)	15.1	15.4	13.5	12.9	15.1
Mean Bias (ppb)	-3	-5.8	-4.6	-4.5	-4.8
Mean Error (ppb)	9.2	9.3	10	8.7	9.2
RMSE (ppb)	12	12.6	12.5	11.1	12
Normalized Mean Bias (%)	-4.6	-7.9	-5.8	-6	-6.5
Normalized Mean Error (%)	14.1	12.7	12.6	11.5	12.6
R-squared	0.44	0.49	0.34	0.52	0.49
Index of Agreement	0.79	0.78	0.74	0.82	0.81

Daily Maximum 1-hour ozone (above 60 ppb)

Parameter	NSJV	CSJV	SJV3KF	SSJV	Entire SJV
Number of data points	270	883	259	677	2089
Mean obs (ppb)	76.1	79.2	82.3	80.1	79.5
Standard Deviation obs (ppb)	11.5	13.2	11.2	10.4	12
Mean Bias (ppb)	-4	-6	-4.7	-3.5	-4.8
Mean Error (ppb)	8.9	9.2	10	8.1	8.9
RMSE (ppb)	11.7	12.4	12.5	10.5	11.7
Normalized Mean Bias (%)	-5.2	-7.6	-5.8	-4.4	-6
Normalized Mean Error (%)	11.7	11.6	12.1	10	11.2
R-squared	0.16	0.34	0.15	0.35	0.29
Index of Agreement	0.61	0.69	0.62	0.75	0.7

Note: The statistical metrics used in this table are defined in Simon et. al., (2012)

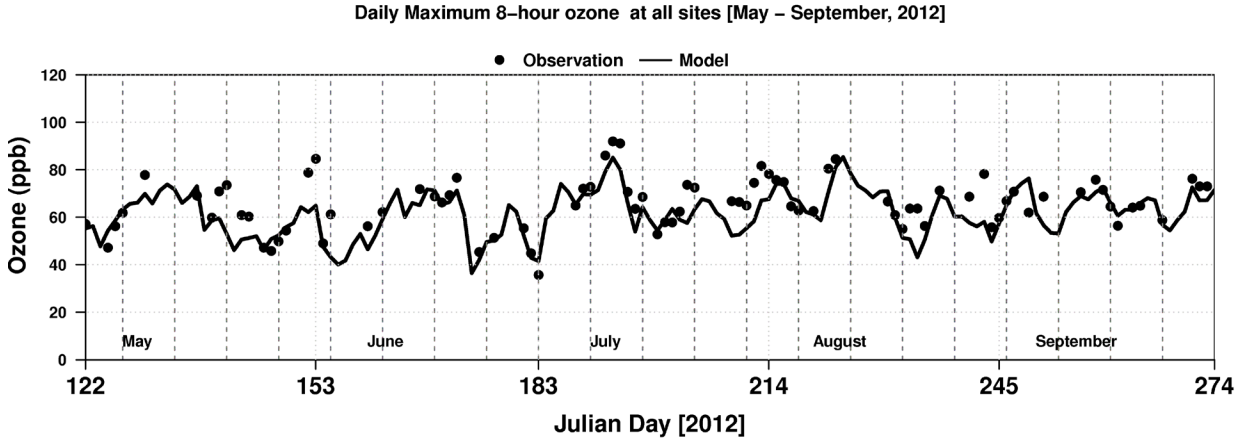

Figure D1. Time-series of daily maximum 8-hour ozone averaged over all sites in the SJV.

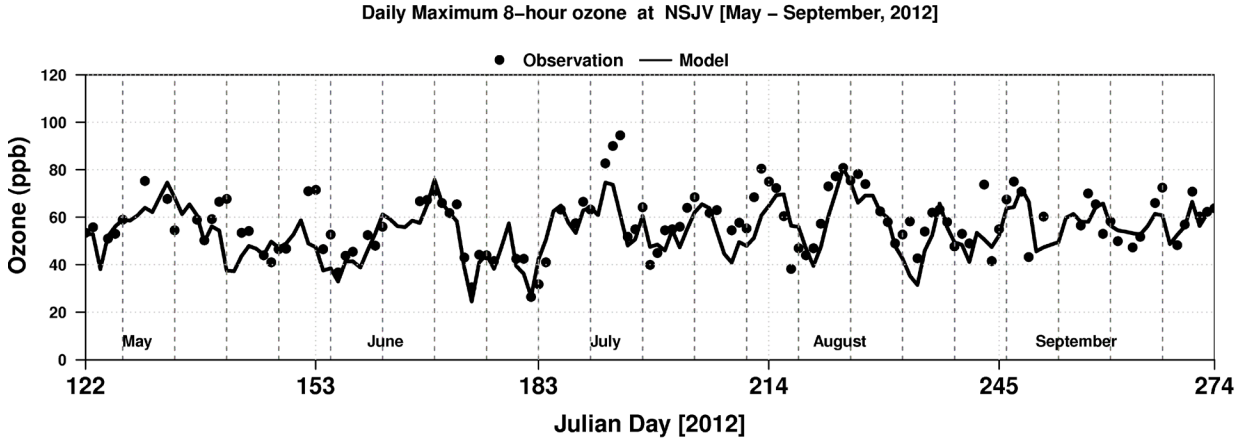

Figure D2. Time-series of daily maximum 8-hour ozone averaged over all sites in the Northern SJV.

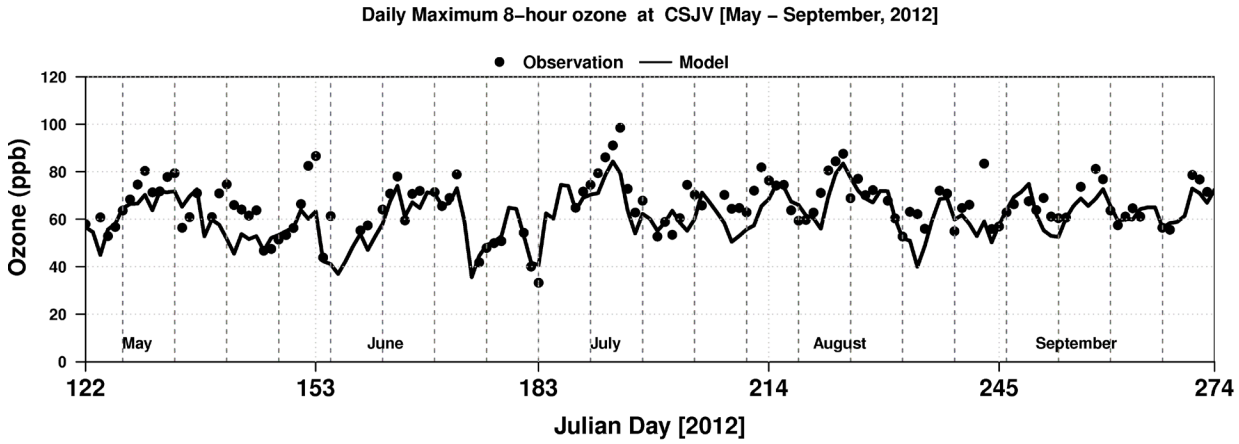

Figure D3. Time-series of daily maximum 8-hour ozone averaged over all sites in the Central SJV.

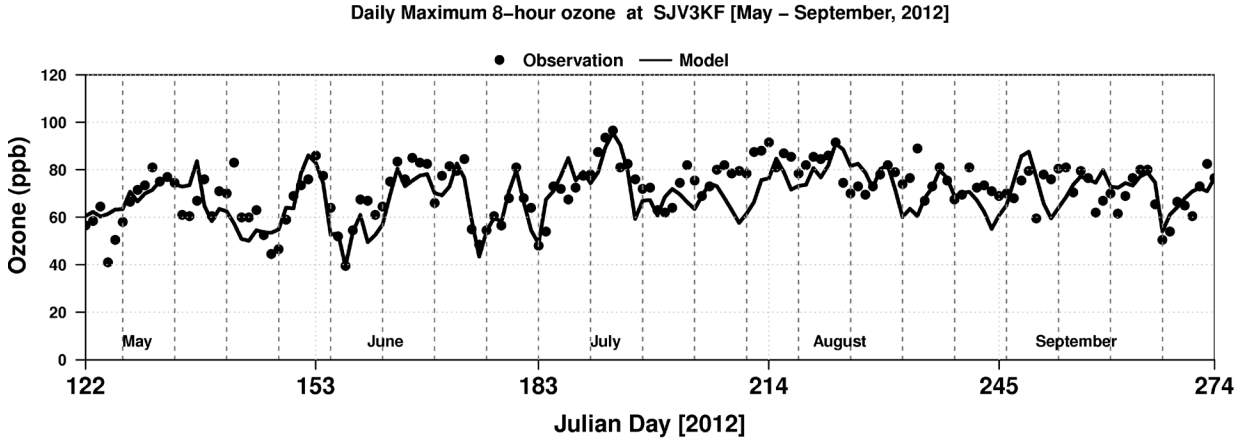

Figure D4. Time-series of daily maximum 8-hour ozone averaged over all sites in the in the SJV above 3000 feet in elevation.

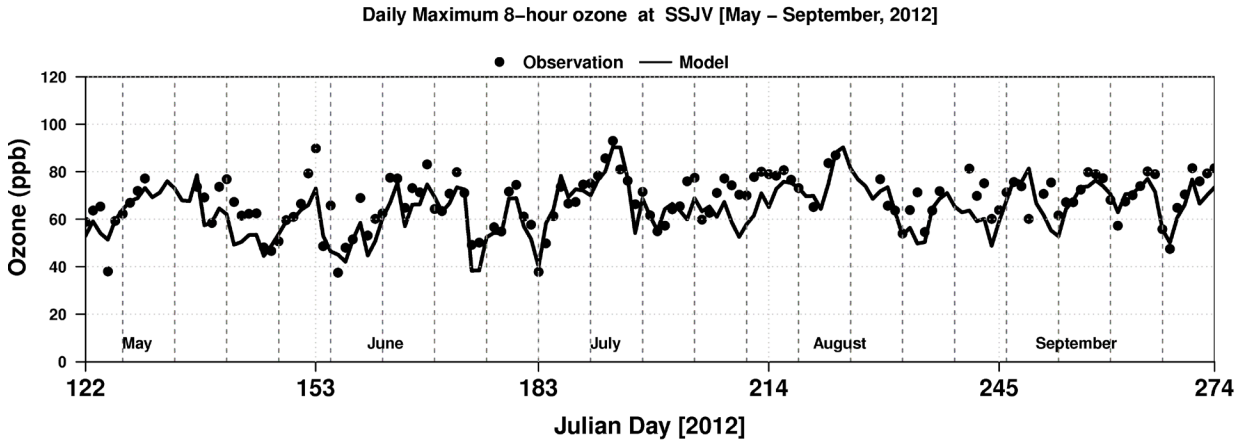

Figure D5. Time-series of daily maximum 8-hour ozone averaged over all sites in the Southern SJV.

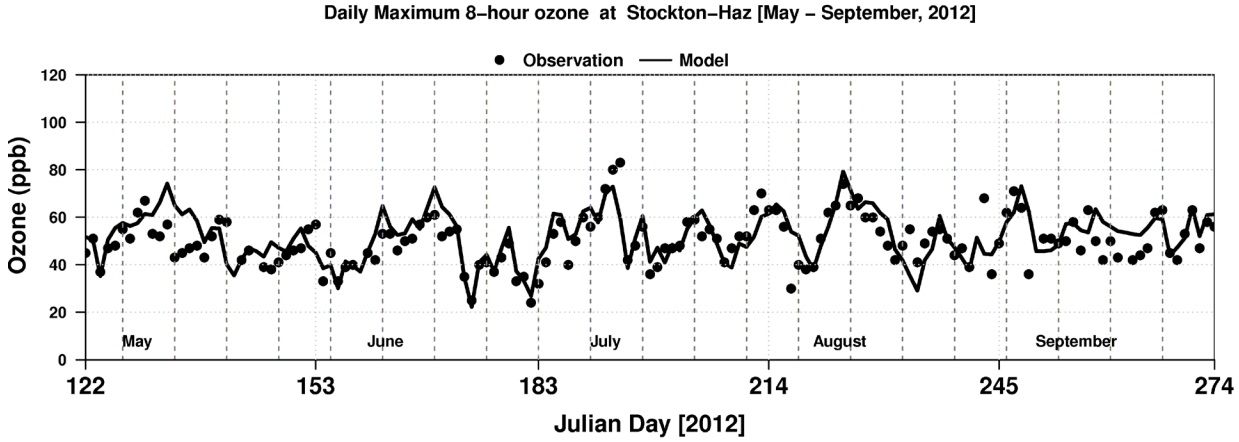

Figure D6. Time-series of daily maximum 8-hour ozone at Stockton-Hazelton.

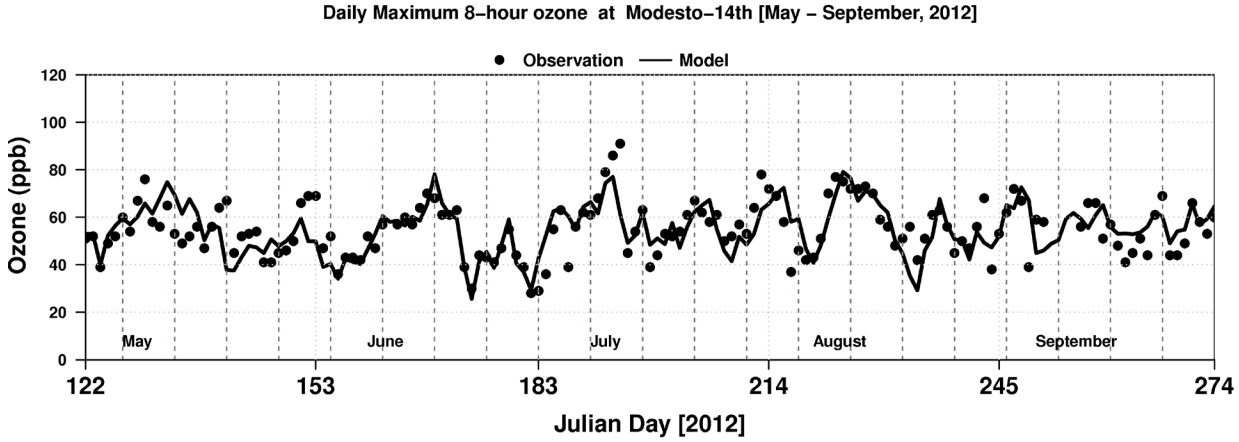

Figure D7. Time-series of daily maximum 8-hour ozone at Modesto-14th Street.

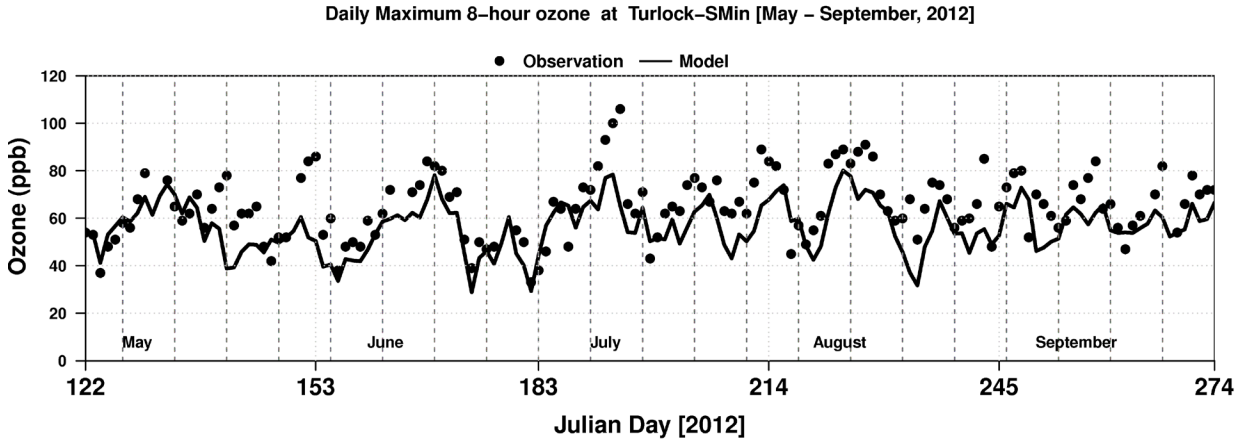

Figure D8. Time-series of daily maximum 8-hour ozone at Turlock-S Minaret.

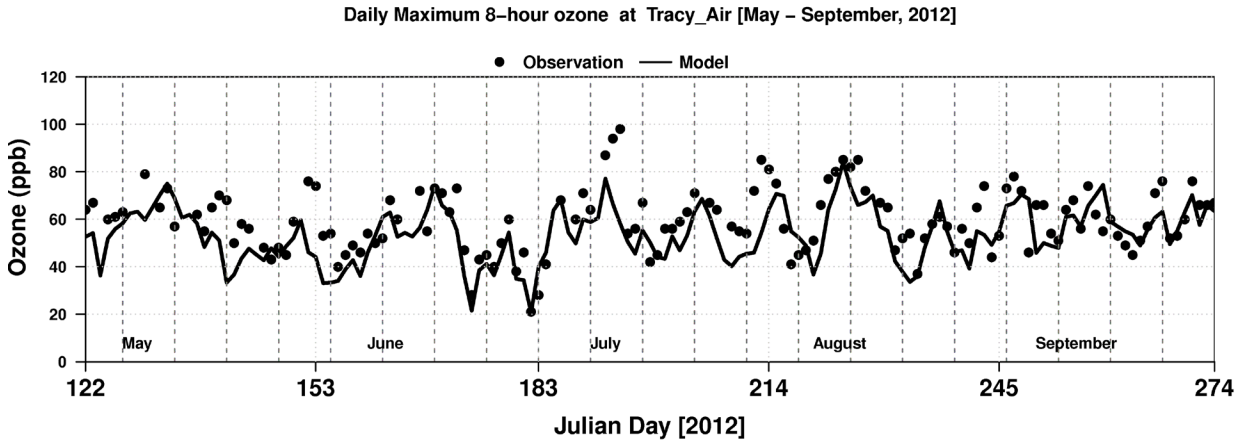

Figure D9. Time-series of daily maximum 8-hour ozone at Tracy-Airport.

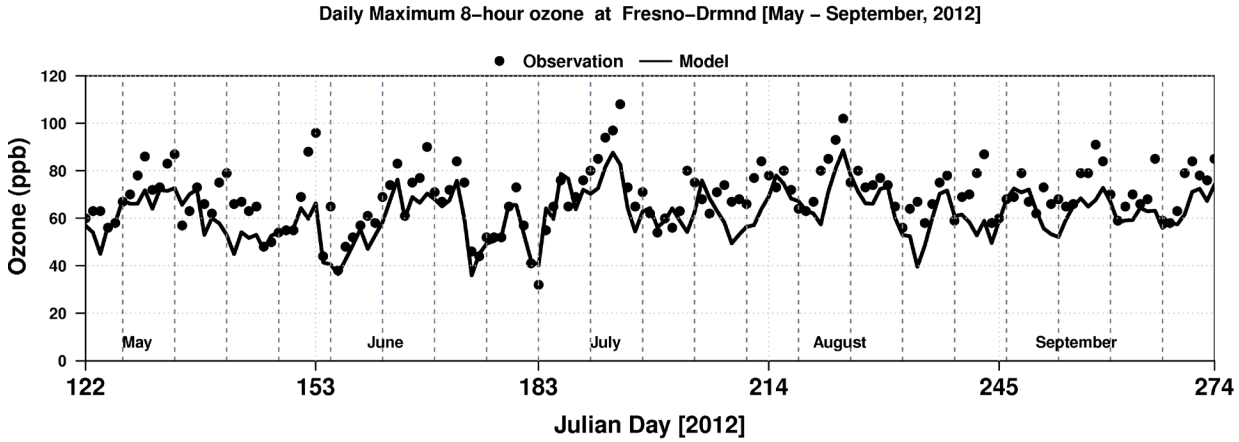

Figure D10. Time-series of daily maximum 8-hour ozone at Fresno-Drummond.

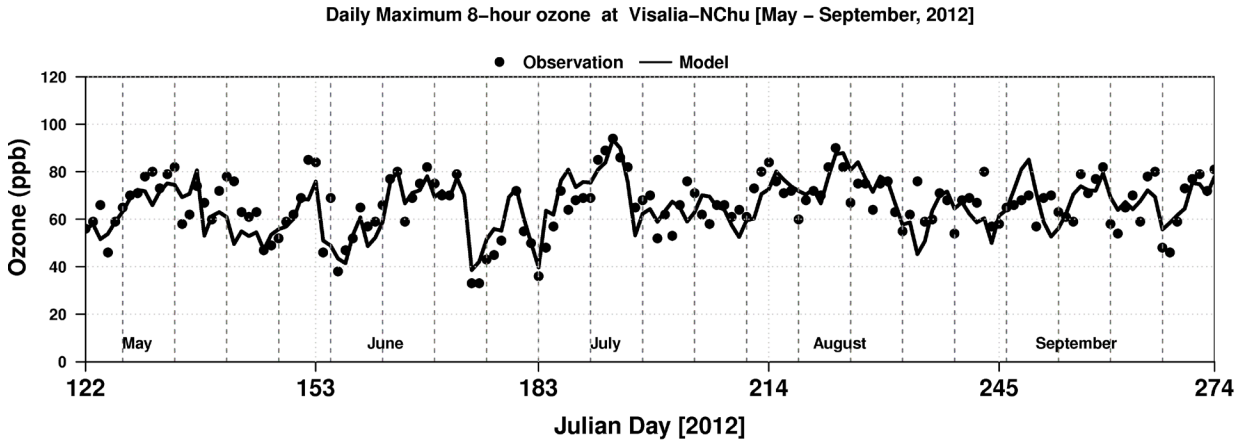

Figure D11. Time-series of daily maximum 8-hour ozone at Visalia-N Church.

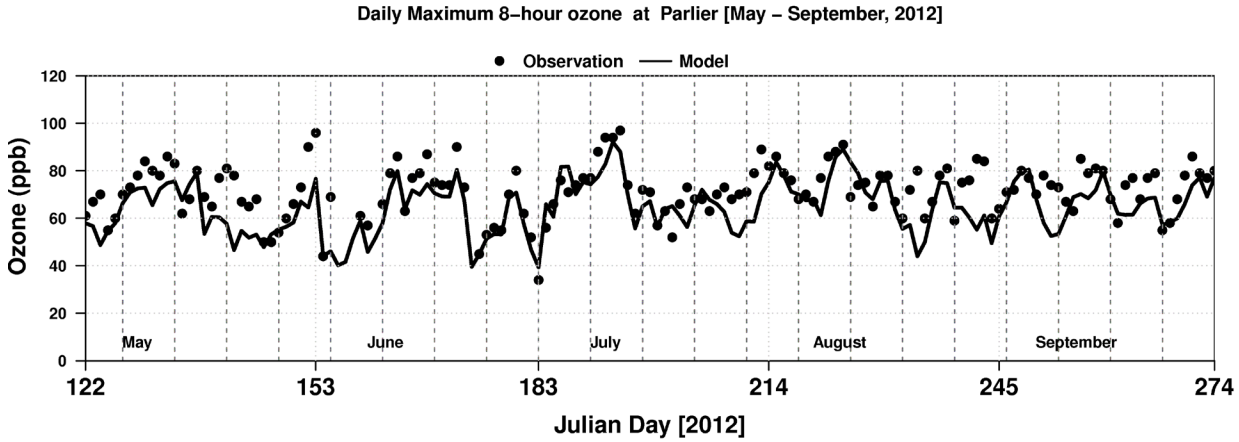

Figure D12. Time-series of daily maximum 8-hour ozone at Parlier.

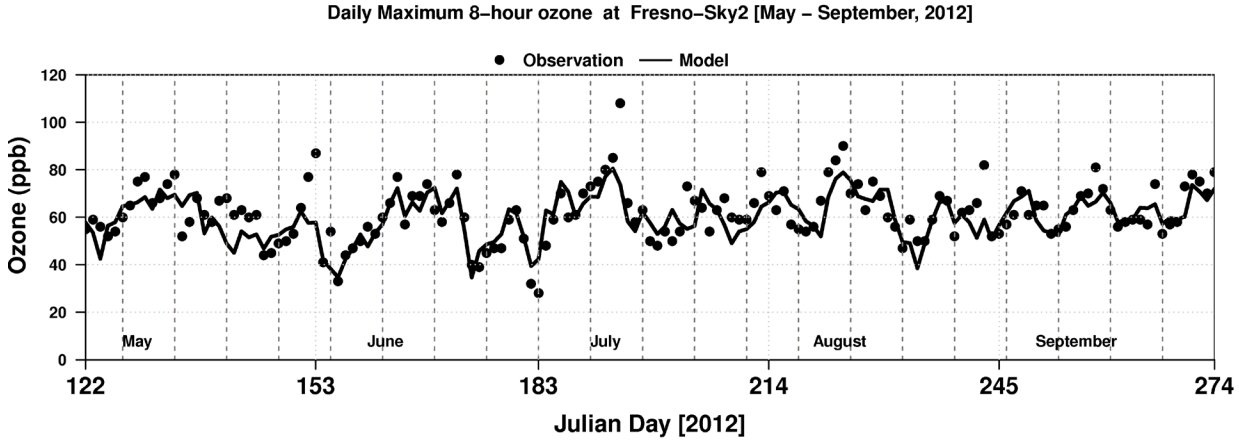

Figure D13. Time-series of daily maximum 8-hour ozone at Fresno-Skypark.

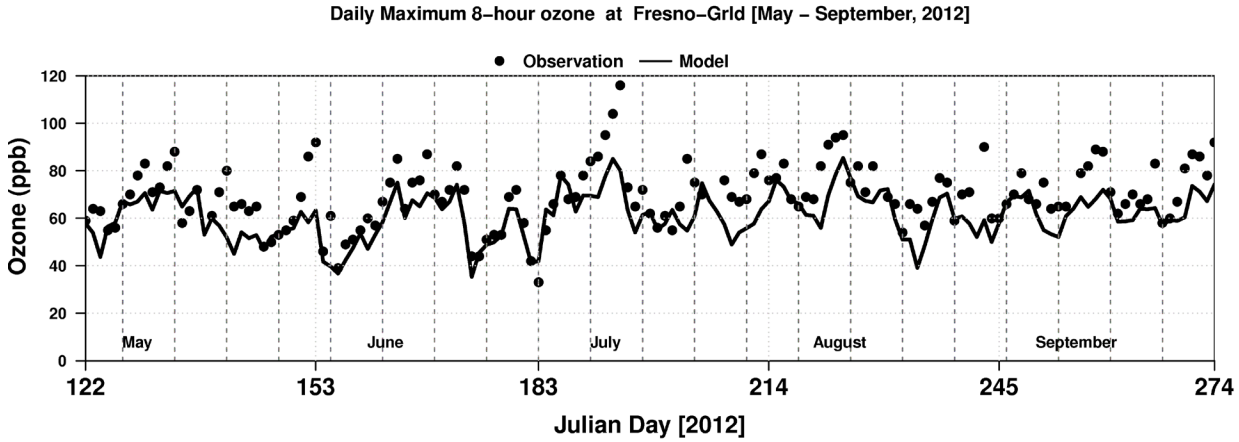

Figure D14. Time-series of daily maximum 8-hour ozone at Fresno-Garland.

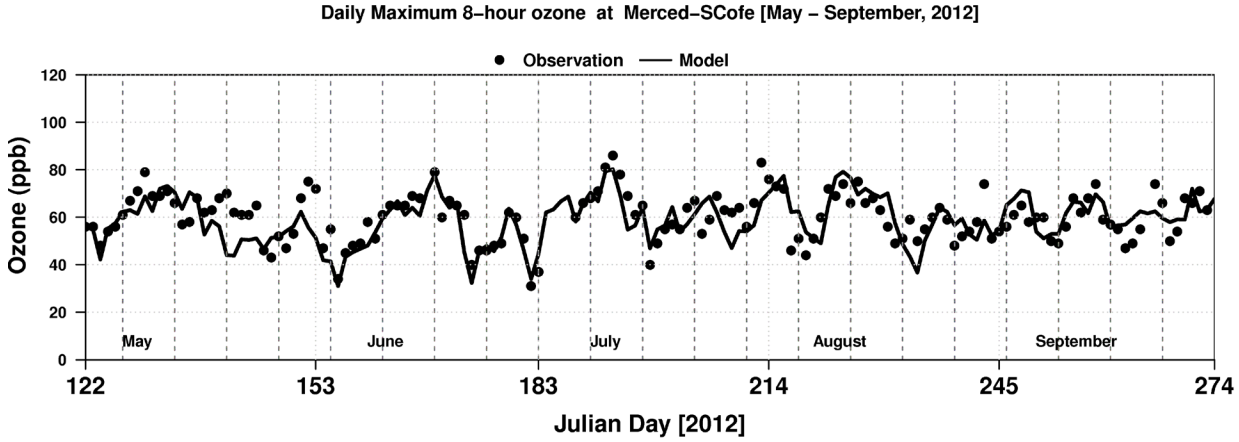

Figure D15. Time-series of daily maximum 8-hour ozone at Merced-S Coffee.

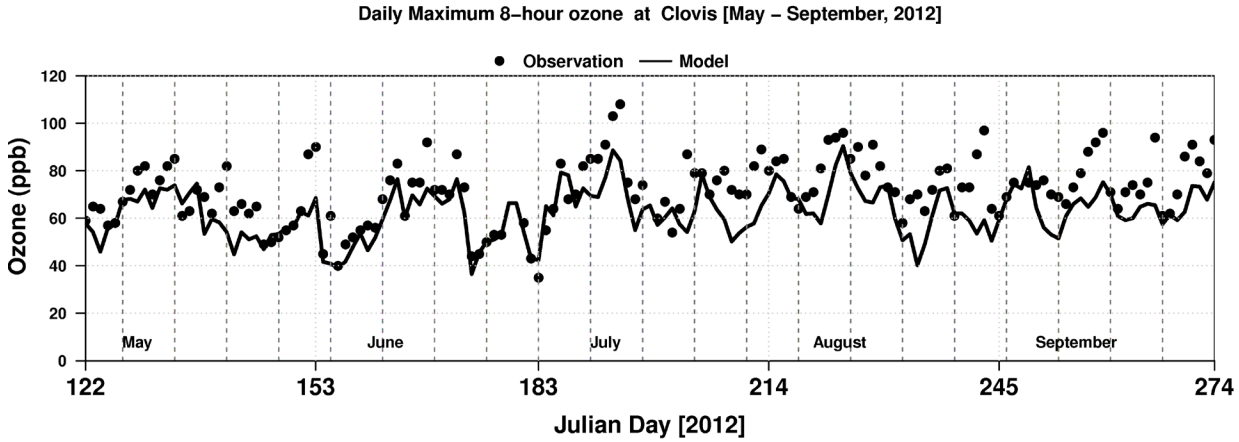

Figure D16. Time-series of daily maximum 8-hour ozone at Clovis.

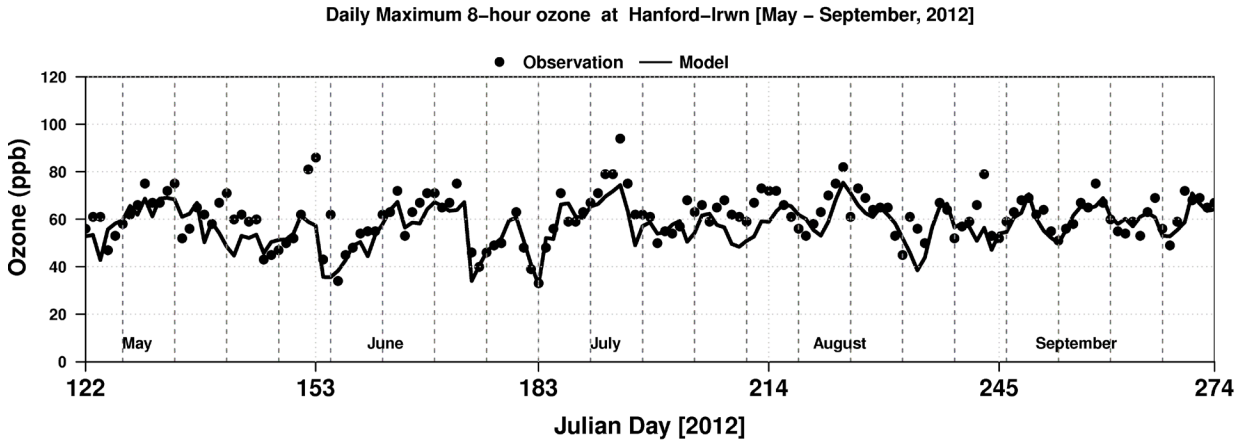

Figure D17. Time-series of daily maximum 8-hour ozone at Hanford-Irwin.

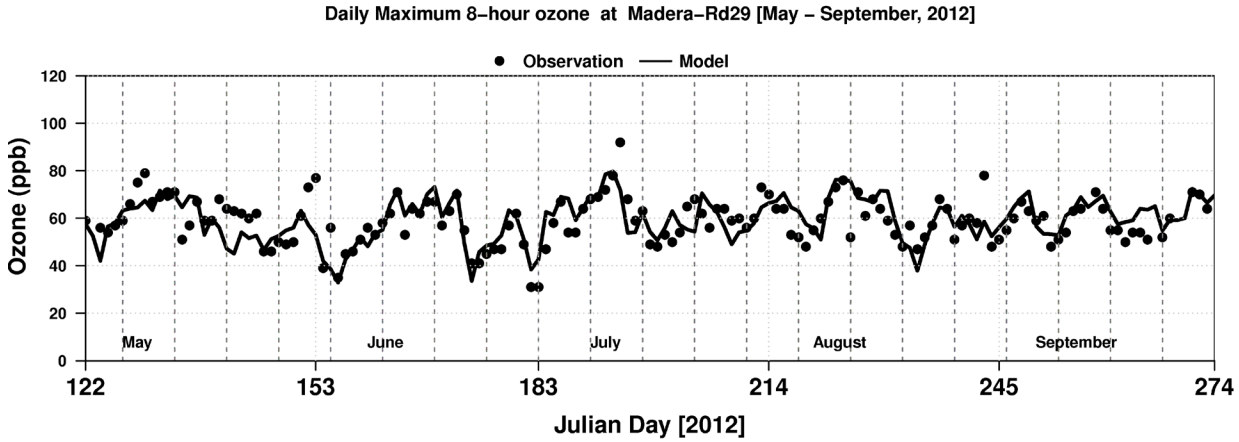

Figure D18. Time-series of daily maximum 8-hour ozone at Madera-Road 28.

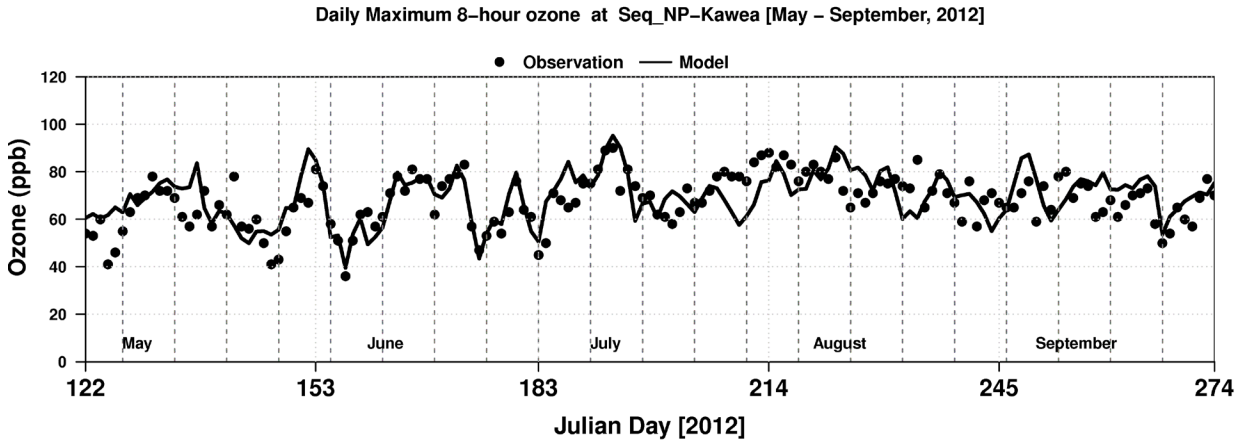

Figure D19. Time-series of daily maximum 8-hour ozone at Sequoia-Kaweah.

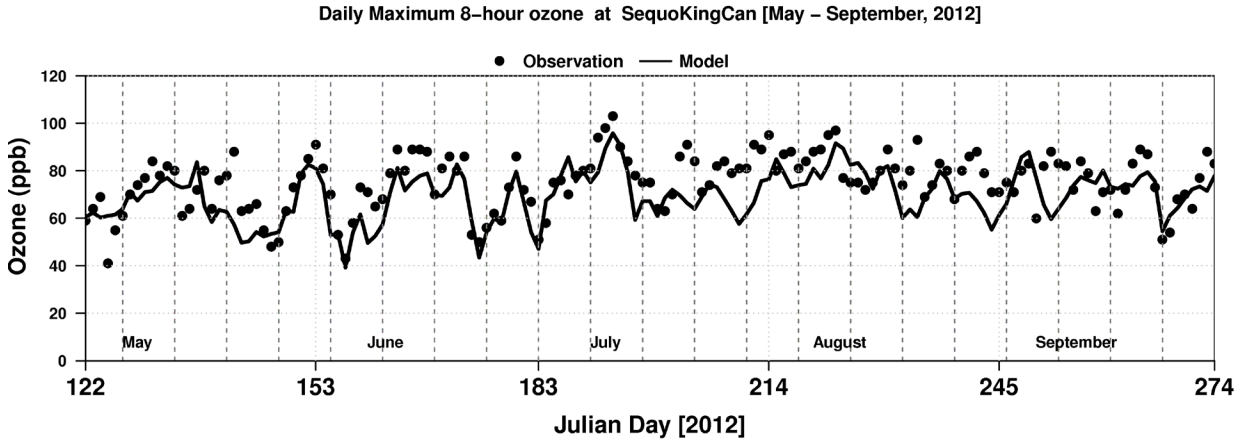

Figure D20. Time-series of daily maximum 8-hour ozone at Sequoia-Kings Canyon.

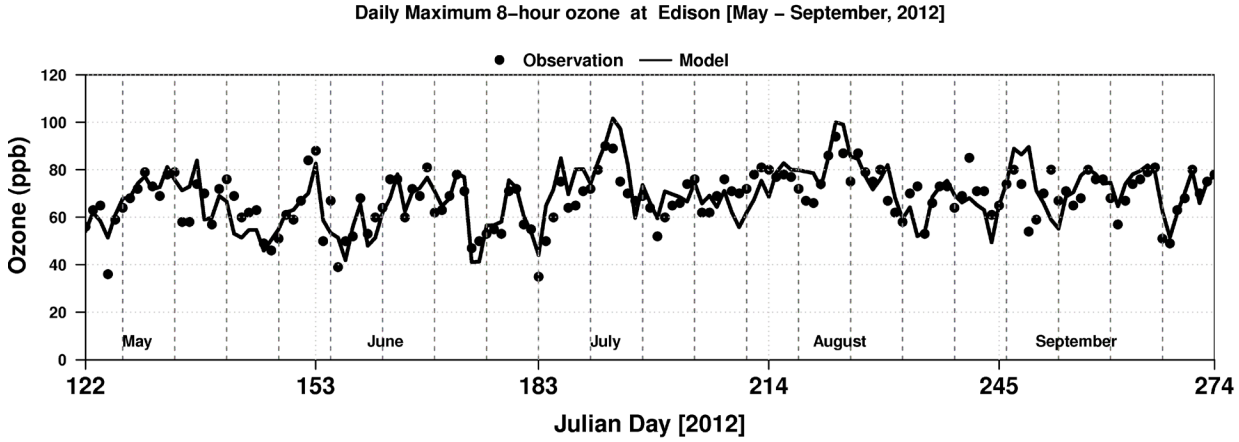

Figure D21. Time-series of daily maximum 8-hour ozone at Edison.

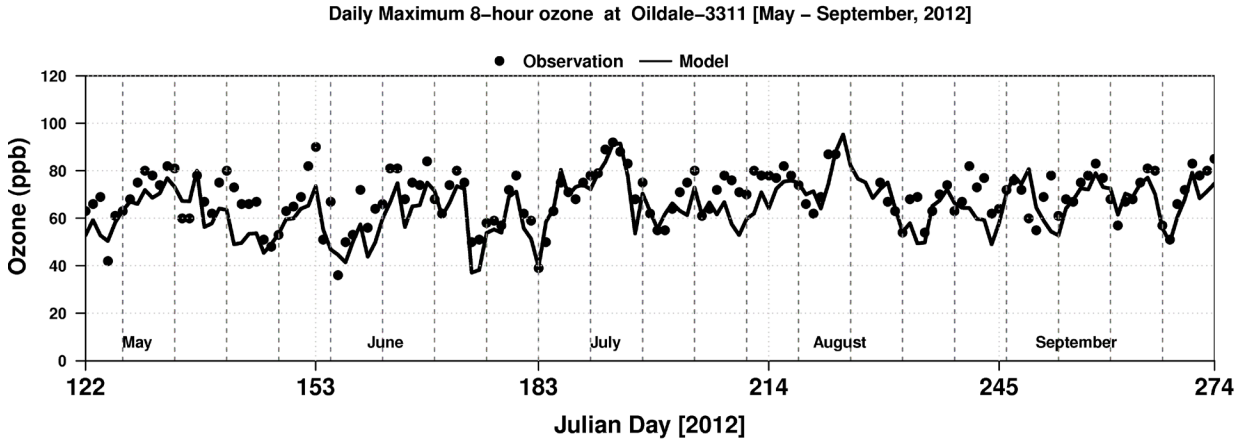

Figure D22. Time-series of daily maximum 8-hour ozone at Oildale-Manor.

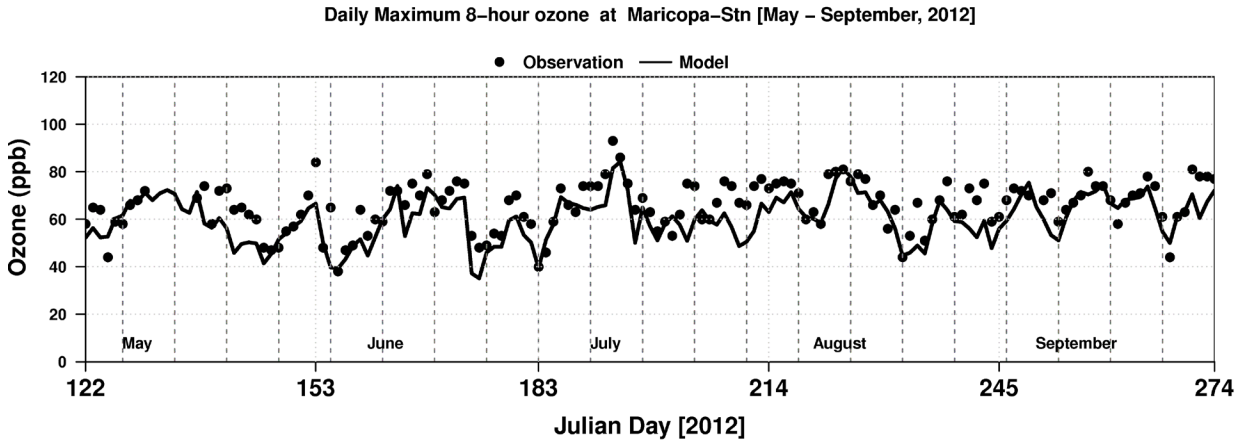

Figure D23. Time-series of daily maximum 8-hour ozone at Maricopa-Stanislaus.

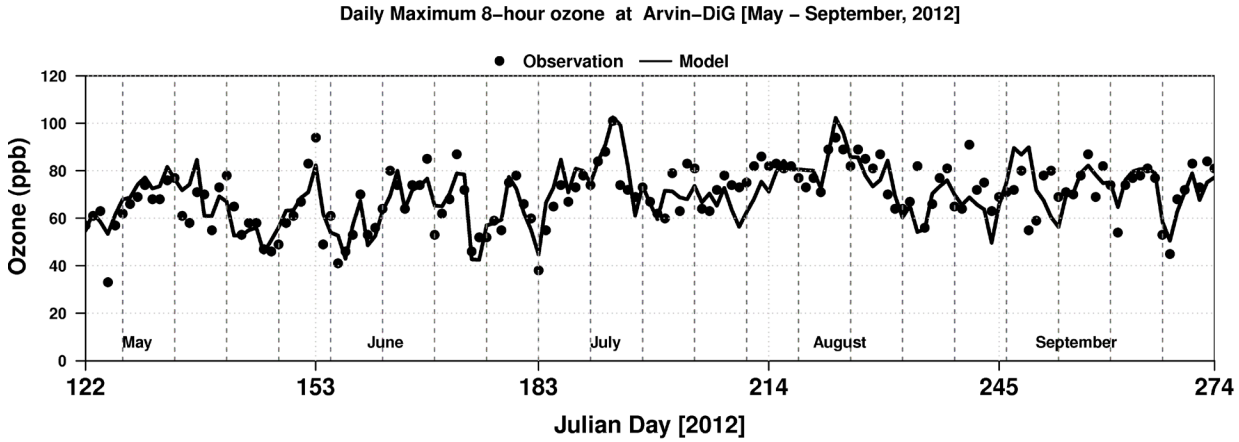

Figure D24. Time-series of daily maximum 8-hour ozone at Arvin-Di Giorgio.

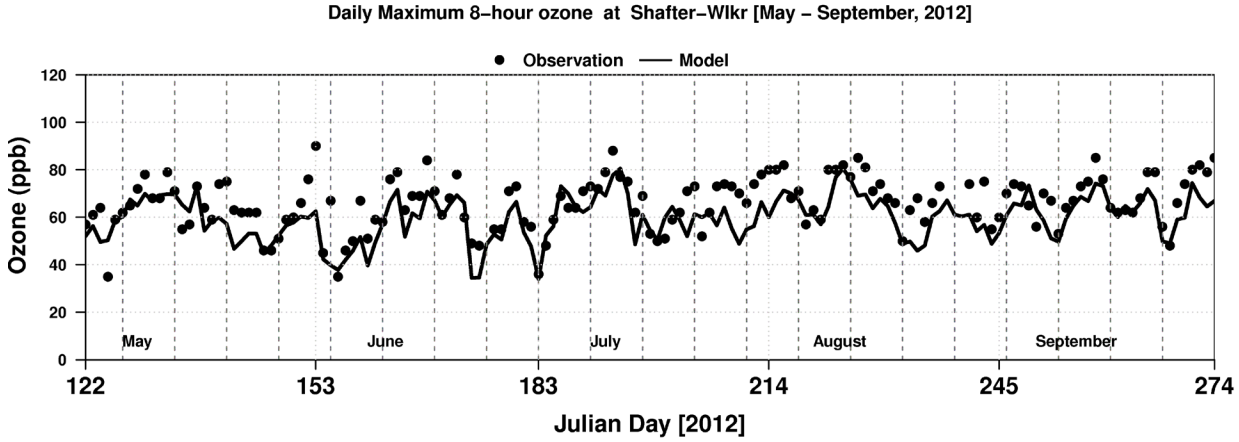

Figure D25. Time-series of daily maximum 8-hour ozone at Shafter-Walker.

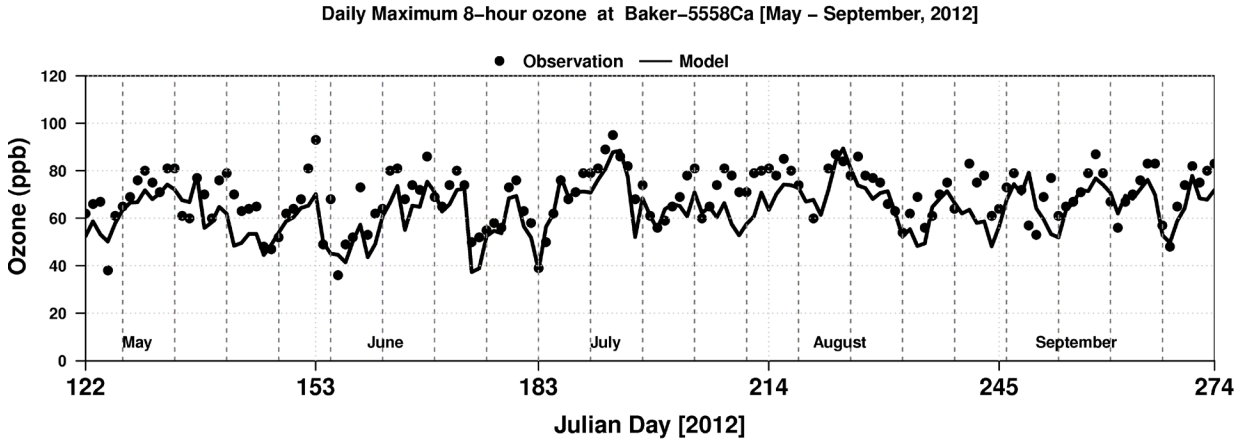

Figure D26. Time-series of daily maximum 8-hour ozone at Bakersfield-California.