Environmental controls on new particle formation over a forested region in the southeastern U.S.A. during one year

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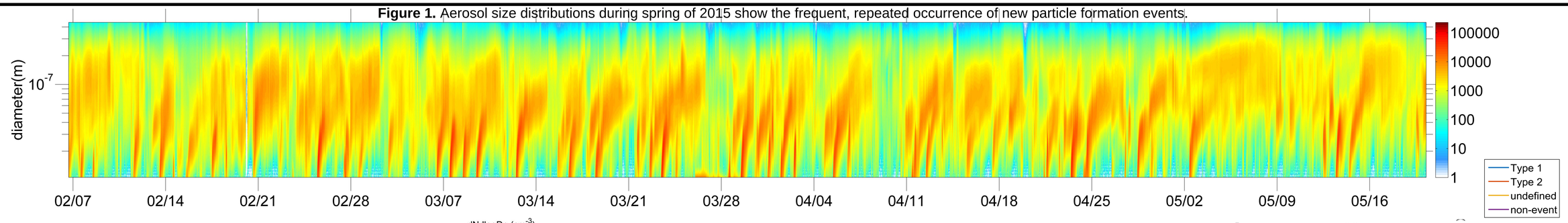
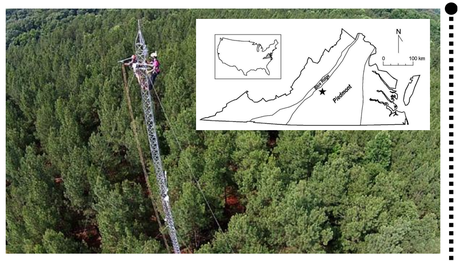
Figure 1. Aerosol size distributions during spring of 2015 show the frequent, repeated occurrence of new particle formation events.



Introduction

Figure 1. The Sweet Briar College Land-Atmosphere Research Station is situated in central Virginia in a loblolly pine plantation at the foothills of the Blue Ridge Mountains. SBC-LARS is a registered AmeriFlux site and a PhenoCam core site.



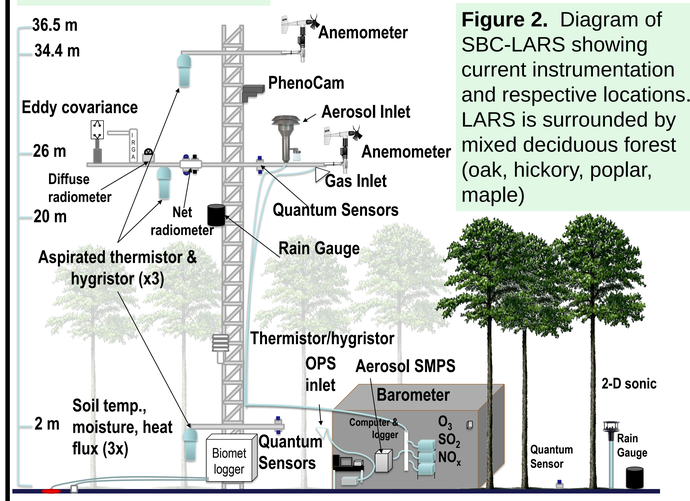


Figure 2. Diagram of SBC-LARS showing current instrumentation and respective locations. LARS is surrounded by mixed deciduous forest (oak, hickory, poplar, maple)

Methods

- Continuous data collection since August 2014
- Precursor gas mixing ratios measured from above the canopy using Thermo Scientific models 42i (NO_x), 43i (SO_2), and 49i (O_3).
- Aerosol size distributions (10 nm<diameter<10 µm) measured from above the canopy using a scanning mobility particle sizer (TSI 3034) and optical particle sizer (TSI 3330).
- NPF events classified based on Dal Maso et al., 2005
- 48-hour HYSPLIT back trajectories of air mass source regions
- Isoprene emissions modeled using MEGAN (Guenther et al., 2006)

Research questions

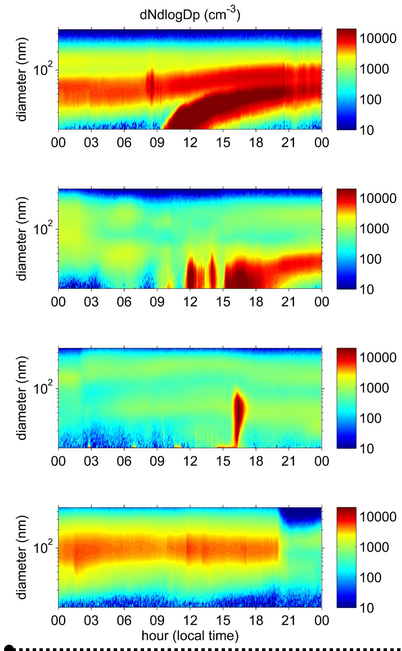
What are the environmental controls on the occurrence and strength of new particle formation events, specifically:

How does observed in situ variation in meteorological variables and concentrations of NO_x, SO_2, O_3 and modeled isoprene emission affect:

N_{25} – number of nucleation mode (diameter<25 nm) particles

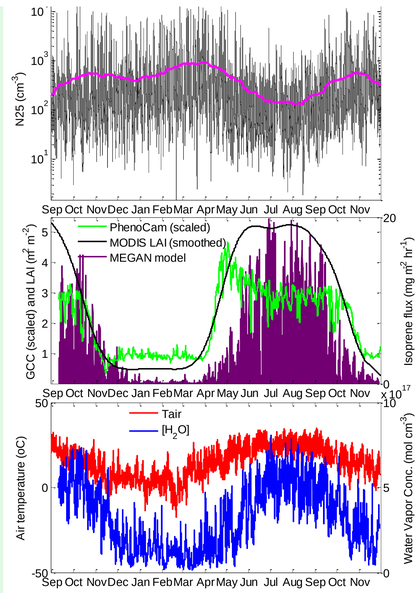
dDp/dt – modal diameter growth rate of nucleation mode

$Jnucl_{10}$ – calculated nucleation rate based on 10nm (Jnucl = dN_{10}/dt + Fcoag)



←Figure 3 Time series of aerosol size distributions exemplifying the four new particle event classifications (Dal Maso et al., 2005). (from top to bottom) type 1 event, type 2 event, undefined, and non-event.

Figure 4→ Time series of nucleation mode aerosol concentration (N25) shows semiannual maxima in spring and fall, and minimum in summer, when LAI, canopy greenness (GCC), humidity, and modeled isoprene emissions are maximum.



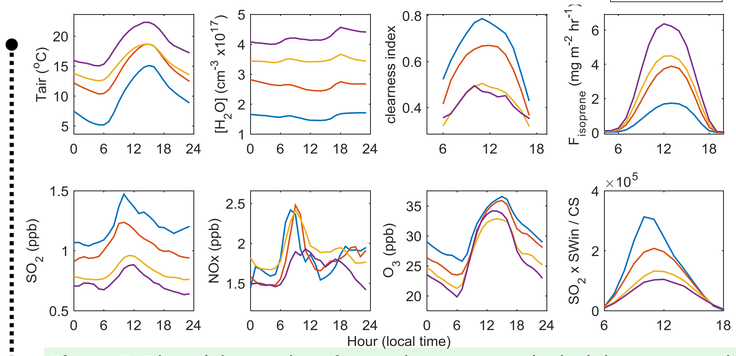
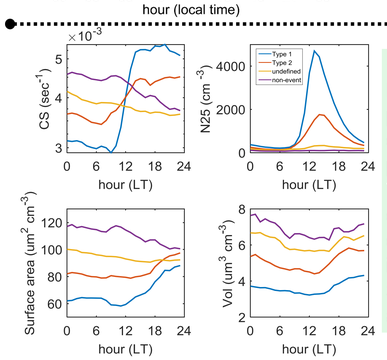


Figure 7. Diurnal time series of one-minute meteorological data averaged by new particle formation event type. Tests for significant differences between selected event types are shown in Table 1. Isoprene emissions were modeled using observations of PAR, Tair, RH, and wind speed from the tower, and LAI from MODIS (Figure 4).



←Figure 5 Diurnal cycle of aerosol properties averaged over the four new particle event classes. The strongest (Type 1) events occur when the condensation sink (CS) is low in the morning. Surface area converges as the day progresses.

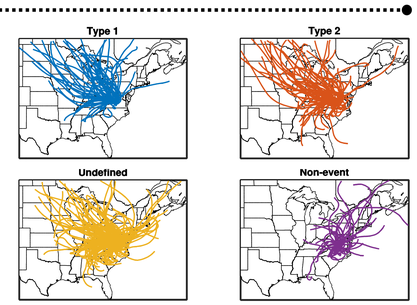


Figure 6 . HYSPLIT 48-hr back trajectories

Variable	1 vs. NE AM	1 vs. NE PM	2 vs. NE AM	2 vs. NE PM	1 vs. 2 AM	1 vs. 2 PM
NO	0.0574	0.7188	0.0977	0.9521	0.6764	0.7787
NO_2	0.1555	0.3136	0.0557	0.0678	0.578	0.4051
NO_x	0.7126	0.4454	0.1198	0.0874	0.2726	0.453
O_3	**4.88E-05**	0.1178	**0.0217**	0.3585	0.056	0.4627
SO_2	**2.27E-04**	**1.42E-07**	**0.0015**	**5.04E-06**	0.1733	**0.0485**
Wind Speed	**1.25E-04**	**0.0027**	**0.0012**	**0.0015**	0.1872	0.962
Tair	**1.50E-10**	**7.54E-08**	**1.06E-04**	**3.99E-04**	**2.67E-04**	**0.0022**
Tdew	**2.94E-14**	**3.30E-16**	**5.10E-07**	**3.18E-10**	**1.37E-05**	**4.28E-05**
RH	**3.32E-12**	**5.25E-16**	**2.73E-06**	**7.82E-11**	**5.06E-04**	**1.93E-05**
VPD	**1.12E-04**	0.8751	**0.0025**	0.3934	0.4333	0.2495
H_2O Conc.	**2.40E-14**	**2.26E-16**	**4.21E-07**	**2.51E-10**	**1.46E-05**	**3.41E-05**
Pressure	0.3032	**0.0121**	0.1723	0.5627	**0.0238**	**0.0076**
K_{in}	***	**0.0202**	***	**0.0464**	***	0.3976
Clearness Index	***	**8.78E-15**	***	**2.36E-08**	***	**3.56E-05**
Isoprene	**2.62E-07**	**1.84E-04**	**0.0021**	**0.0223**	**0.0040**	**0.0101**

←Table 1. p-values resulting from Wilcoxon rank-sum test for differences in one-minute mean values for the continuous distributions during two time periods: midnight – 7:00 AM LT (AM), and 7:00 AM – 5:00 PM LT (PM). Tests are between Type 1, Type 2 and non-events (NE).The bolded values represent statistical significance with α = 0.05, and indicate that the null hypothesis of the two distributions having equal medians can be rejected.

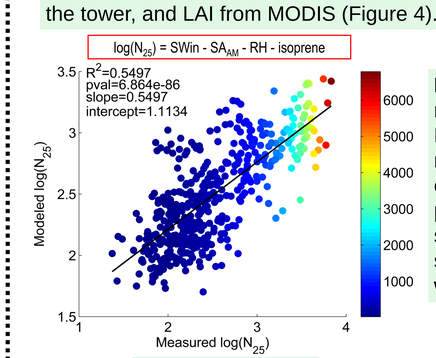
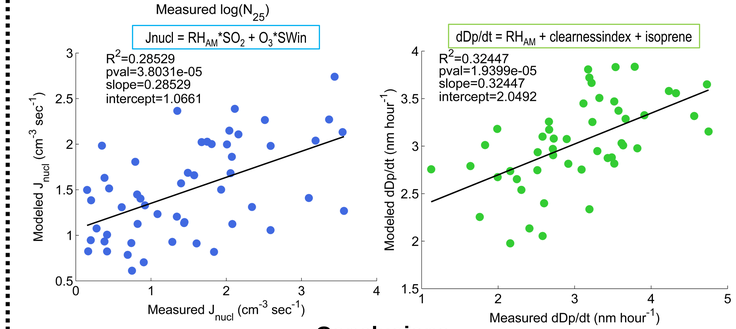


Figure 8. Multiple linear regression models between NPF metrics and meteorological and gas concentrations. The most parsimonious models were selected using BIC and only significant terms (α= 0.05) were included.



Conclusions

N_{25} – enhanced by sunlight; inhibited by RH, preexisting surface area, modeled isoprene emission

dDp/dt – enhanced by RH & isoprene, and inhibited by clouds (clearness index)

$Jnucl_{10}$ – enhanced by interactions: RH x SO_2, and O_3 x sunlight

Acknowledgements

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