Performing Arts Aerosol Study

Round one preliminary results

Clarinet, Flute, Horn, Soprano Singer, Trumpet

Study Chairs

James Weaver - NFHS Director of Performing Arts and Sports

Mark Spede – CBDNA President, Director of Bands, Clemson University

Lead Funders

NAMM Foundation®

NFHS
NATIONAL FEDERATION OF STATE HIGH SCHOOL ASSOCIATIONS

D'Addario Foundation

CBDNA College Band Directors National Association

Contributing Organizations

Alabama Music Educators Association
American Choral Directors Association
Arts Ed NJ – Many Partners. One Voice.
Athletes and the Arts
Association of Anglican Musicians
The Association of Concert Bands
Barbershop Harmony Society
California Youth Symphony
Canadian Band Association / Association Canadienne des Harmonies
C.M.P.A.
Church Music Publishers Association
CODA – College Orchestra Directors Association
CMA Foundation
Fargo-Moorhead Symphony Orchestra – Christopher Zimmerman, Music Director
fmea – Florida Music Education Association
CSFI – Au service de la musique depuis 1890
GALA Choruses
Indiana Choral Directors Association
Indiana State School Music Association
Indianapolis Children's Choir
International Double Reed Society
idrs
Building Better Bands For Kansas
KMEA – Kentucky Music Educators Association
LGBA – Music. Visibility. Pride.
MBA
MTNA – Music Teachers National Association
mpa
name – National Association for Music Education
nats – National Association of Teachers of Singing, Inc. – 1944
NCCO
National Speech & Debate Association – National Forensic League
New Horizons Music
NYSBDA – New York State Band Directors Association
New York State School Music Association
North Carolina Music Educators Association
Nova Scotia Band Association
Ohio Foundation for Music Education
OMEA
OA
Orcas Island Community Band
Orchestras Canada / Orchestres Canada
PAMA – Performing Arts Medicine Association
Phi Mu Alpha Sinfonia
Quadrant
Saskatchewan Band Association
Sing Mile High – Denver Colorado
Slate Valley Singers
South Dakota Bandmasters Association
SDMEA – South Dakota Music Education Association
Sweet Adelines International
TMEA – Tennessee Music Education Association
TBA
Texas Music Educators Association
The College Music Society
Main Street Singers – since '94
Phi Mu Alpha Sinfonia
The Voice Foundation
VASTA – Voice and Speech Trainers Association
Virginia Music Educators Association
WSMA
WBDI – Women Band Directors International
WASBE – World Association for Symphonic Bands and Ensembles
Young Voices of Colorado
OAKE – Organization of American Kodály Educators
Music Learning Band

Supporting Organizations

American School Band Directors Association (ASBDA)
American String Teachers Association (ASTA)
Arts Education in Maryland Schools (AEMS)
Association Européenne des Conservatoires/Académies de Musique et Musikhochschulen (AEC)
Buffet et Crampon
Bundesverband der deutschen Musikinstrumentenhersteller e.V
Chicago Children's Choir
Children's Chorus of Washington
Chorus America
Confederation of European Music Industries (CAFIM)
Drum Corps International (DCI)
Educational Theatre Association (EdTA)
European Choral Association - Europa Cantat
HBCU National Band Directors' Consortium
High School Directors National Association (HSBDNA)
International Conductors Guild
International Music Council
International Society for Music Education
League of American Orchestras
Louisiana Music Educators Association (LMEA)
MidWest Clinic
Minority Band Directors National Association
Music Industries Association
Musical America Worldwide
National Dance Education Organization (NDEO)
National Flute Association (NFA)
National Guild for Community Arts Education
National Music Council of the US
Percussive Arts Society (PAS)
Save the Music Foundation
WGI Sport of the Arts

Lead Researchers

Dr. Shelly Miller
University of Colorado Boulder

Dr. Jelena Srebric
University of Maryland

Lab Work

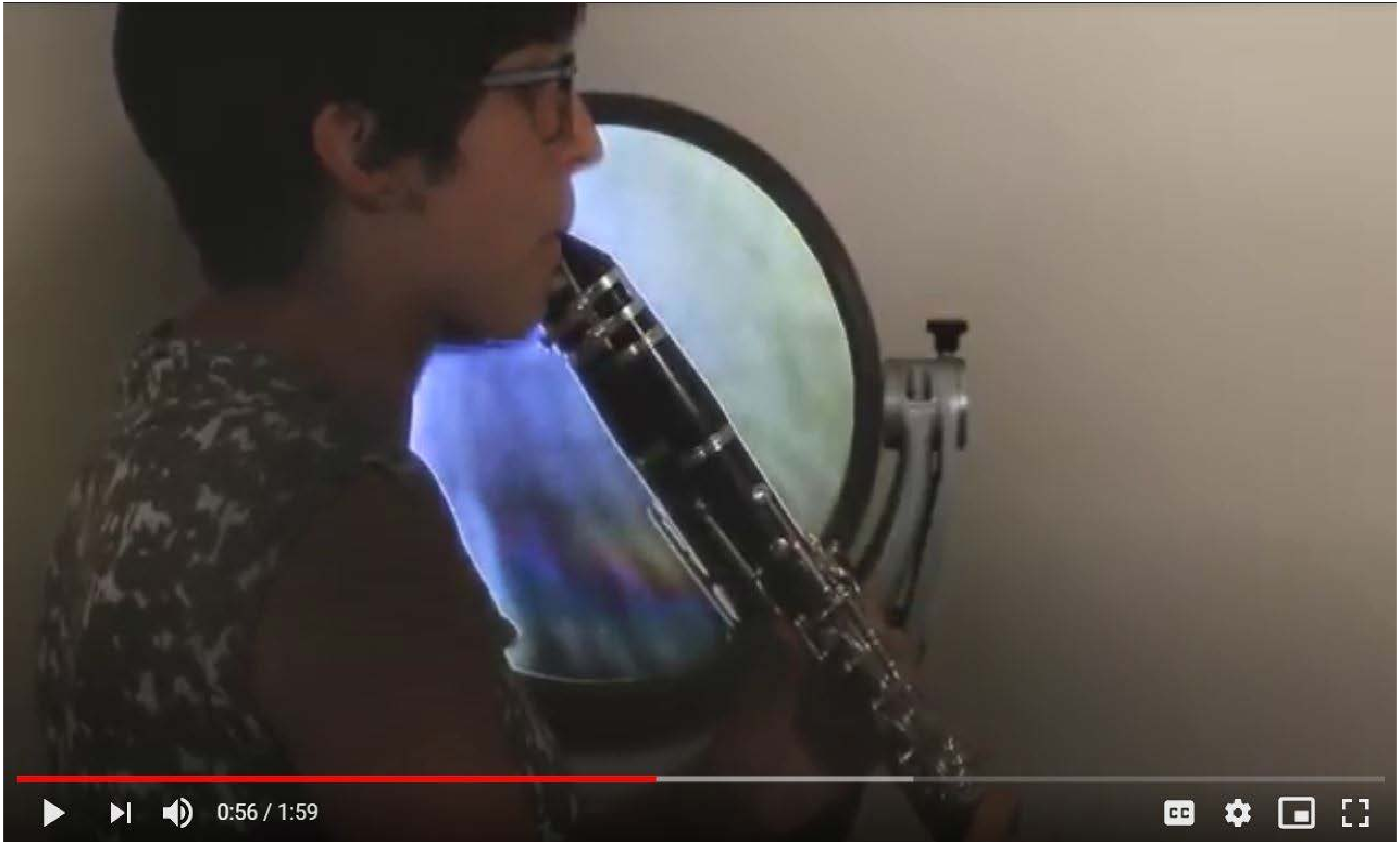
Exploratory measurements on some band instruments and singing completed

Tests conducted in controlled "clean room"

Goal was to identify flow and aerosol release pathways

Particle size and concentration measured near to the aerosol release

Next phase is to improve aerosol capture and estimate emission rates


0:56 / 1:59

Schlieren Test

Goal was to identify flow pathways, which would carry emitted particles


View Options

Video
Reciting Alphabet Schlieren Test

https://youtu.be/0UXn3Zke1qA

Video
Clarinet Schlieren Test

https://youtu.be/r0-aZ-PQ_hI

Bagged Clarinet

Video
Trombone Schlieren Test

https://youtu.be/0s5kAgBAhAk

Video
Soprano Schlieren Test

https://youtu.be/JCHZ_dKa59k

Preliminary Lab Results

CPC and APS Total Concentration Over Time

Preliminary Results Disclaimer

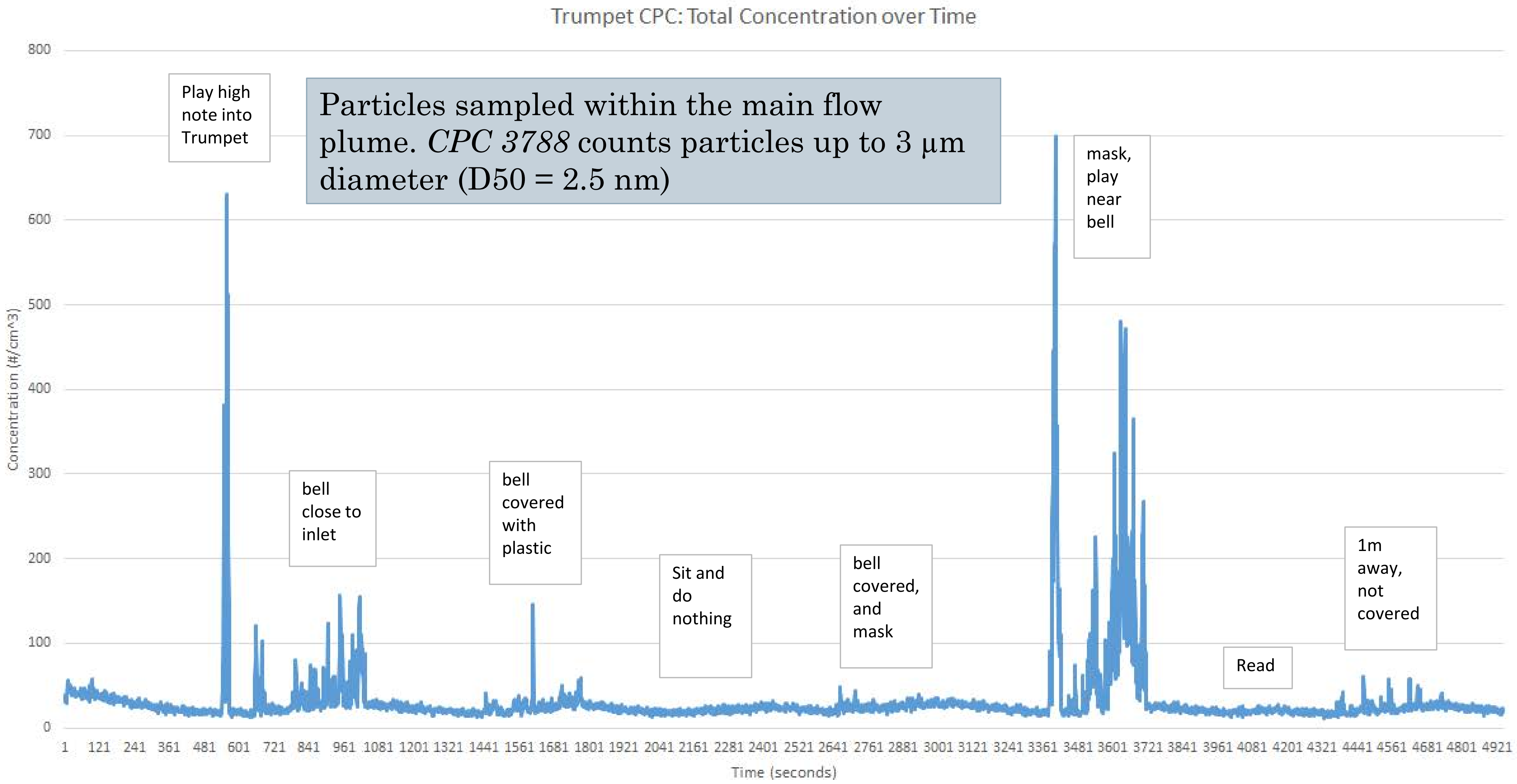
- These preliminary results are from our 1st week of exploratory testing. They will be further defined as the study continues. We are providing these preliminary results to assist in the safe return to classrooms. (Normally we do not release data until they have been quality assessed and peer reviewed).
- This study focuses strictly on the distribution of respiratory aerosols that are released while playing wind and brass instruments, singing, acting, speaking, dancing, and during a simulated aerobic activity.
- This study did not use a live virus or infected participants and therefore cannot be used to determine specific infection rates. This study was designed to (1) identify performing arts activities that generate respiratory aerosols including volume, direction, density, (2) estimate the emission rates of respiratory aerosol, (3) model the dispersion of these aerosols, and (4) investigate mitigation strategies.

Study Staggered Release

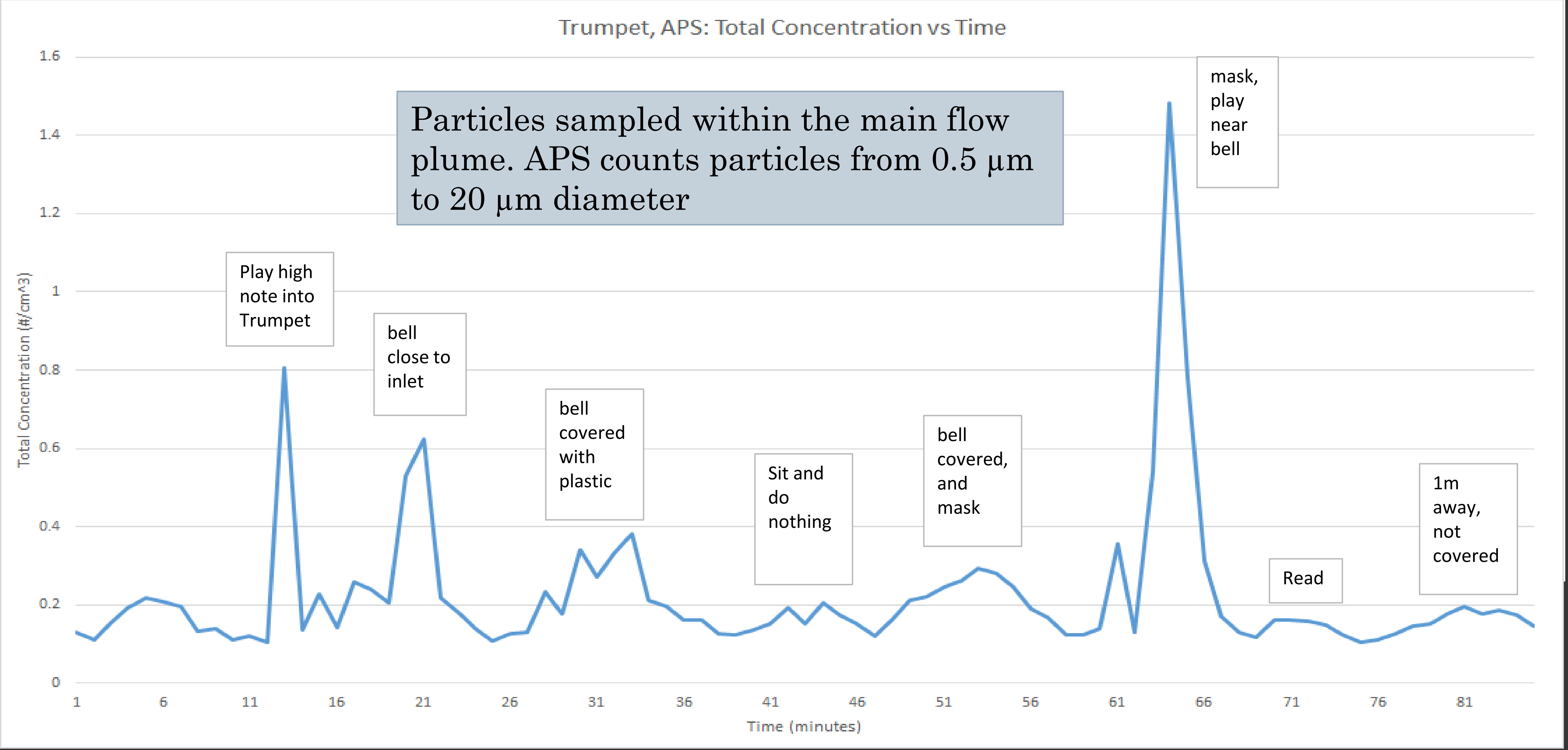
- Due to the size of this study the decision was made to explore winds and brass first as marching bands are currently rehearsing for the fall season.
- Additional information on vocal, theatrical, and aerobic tests will be ready by the end of July.
- The study will then enter another phase of deeper research and finalize results that will be added to the body of peer-reviewed science for our overall knowledge of respiratory safety in performing arts classrooms and performance venues.

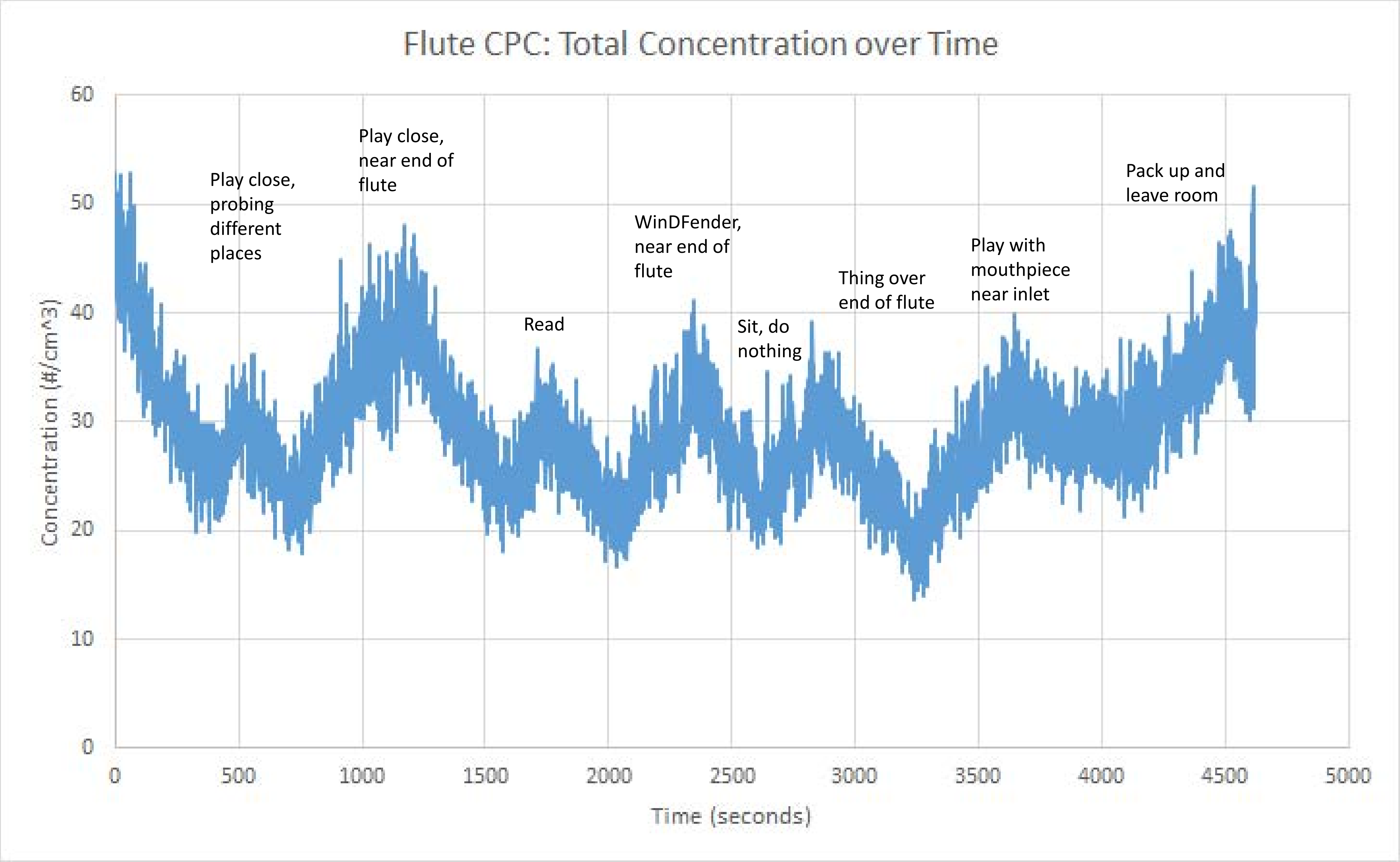
Definitions

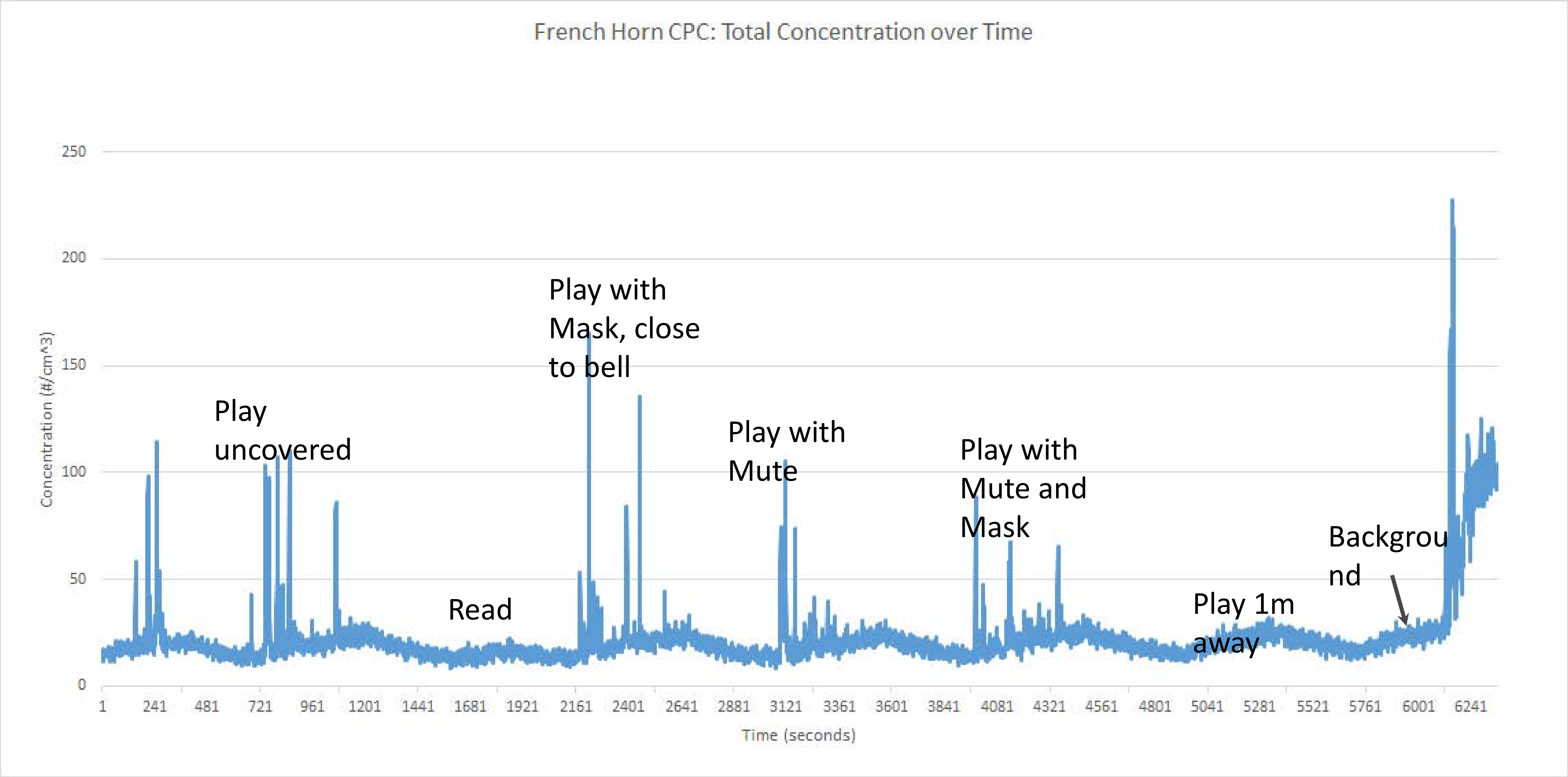
- Condensation particle counters **(CPC)** measure number concentration of airborne particles < 3 µm (microns).
- The Aerodynamic Particle Sizer spectrometer (**APS)** is based on the acceleration of **airborne** particles immersed in an air flow through a nozzle (measures 0.5-20 µm particles).

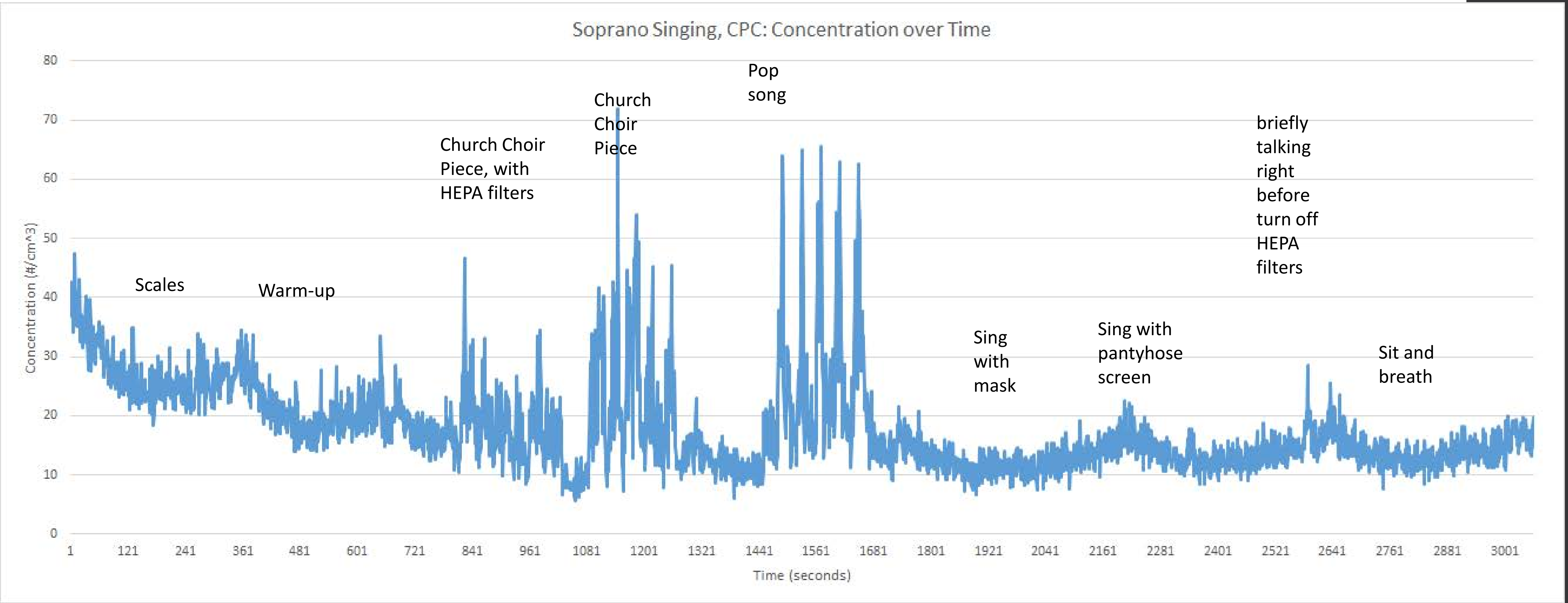


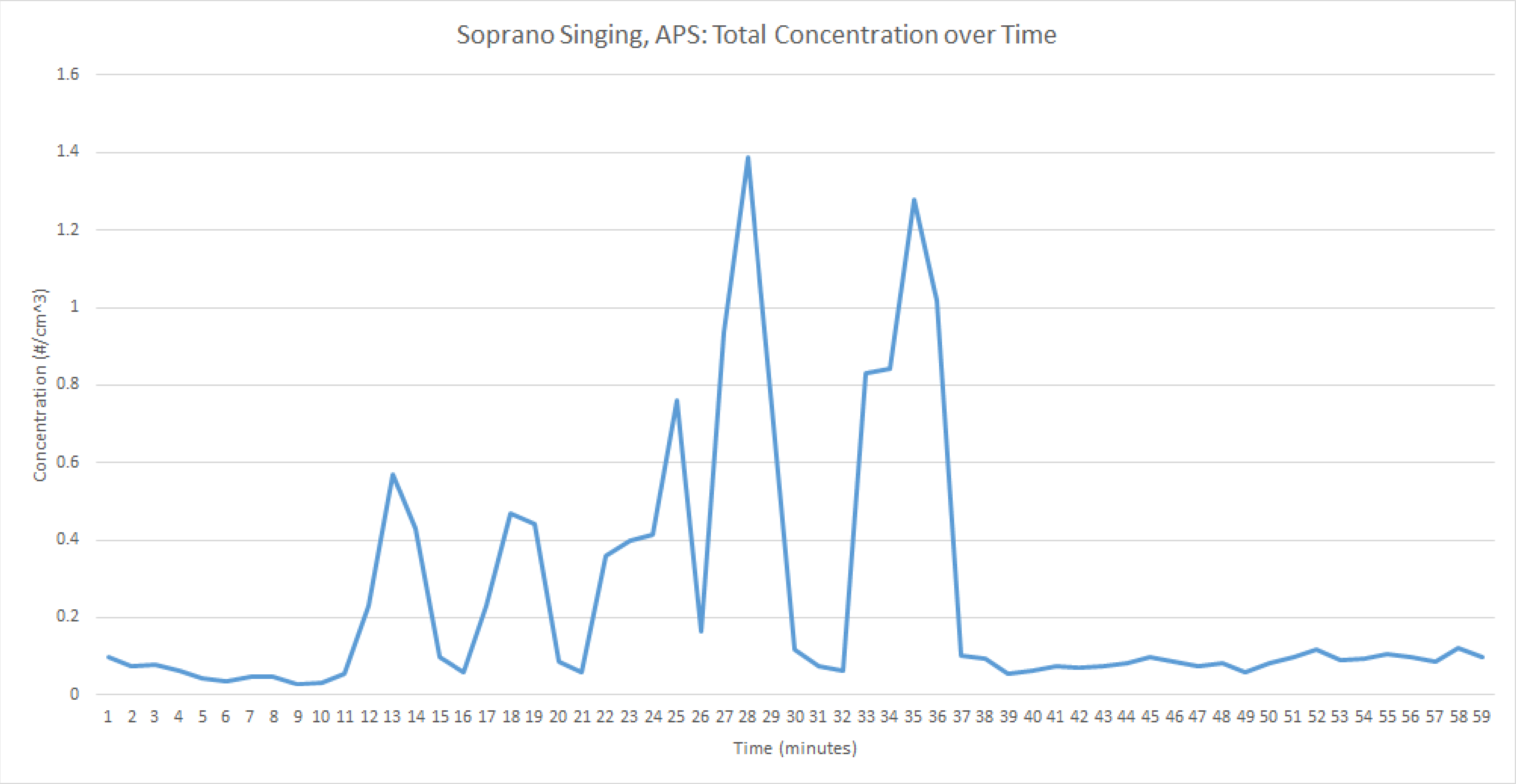
Trumpet CPC: Total Concentration over Time
Particles sampled within the main flow plume. *CPC 3788* counts particles up to 3 µm diameter (D50 = 2.5 nm)
Play high note into Trumpet
bell close to inlet
bell covered with plastic
Sit and do nothing
bell covered, and mask
mask, play near bell
Read
1m away, not covered
Concentration (#/cm^3)
0
100
200
300
400
500
600
700
800
Time (seconds)
1 121 241 361 481 601 721 841 961 1081 1201 1321 1441 1561 1681 1801 1921 2041 2161 2281 2401 2521 2641 2761 2881 3001 3121 3241 3361 3481 3601 3721 3841 3961 4081 4201 4321 4441 4561 4681 4801 4921

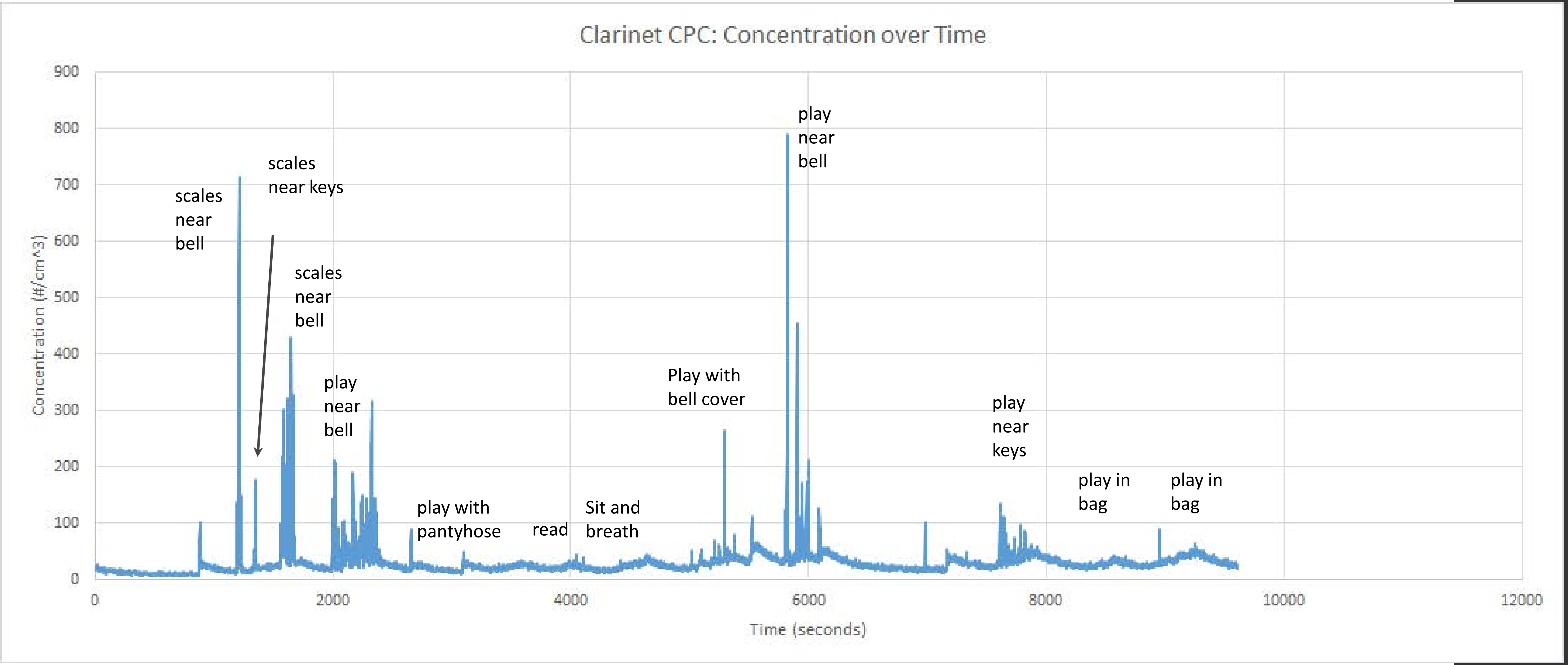

Trumpet, APS: Total Concentration vs Time
Particles sampled within the main flow plume. APS counts particles from 0.5 µm to 20 µm diameter
Total Concentration (#/cm^3)
Time (minutes)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
Play high note into Trumpet
bell close to inlet
bell covered with plastic
Sit and do nothing
bell covered, and mask
mask, play near bell
Read
1m away, not covered


Flute CPC: Total Concentration over Time
Concentration (#/cm^3)
Time (seconds)
0
10
20
30
40
50
60
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Play close, probing different places
Play close, near end of flute
Read
WinDFender, near end of flute
Sit, do nothing
Thing over end of flute
Play with mouthpiece near inlet
Pack up and leave room

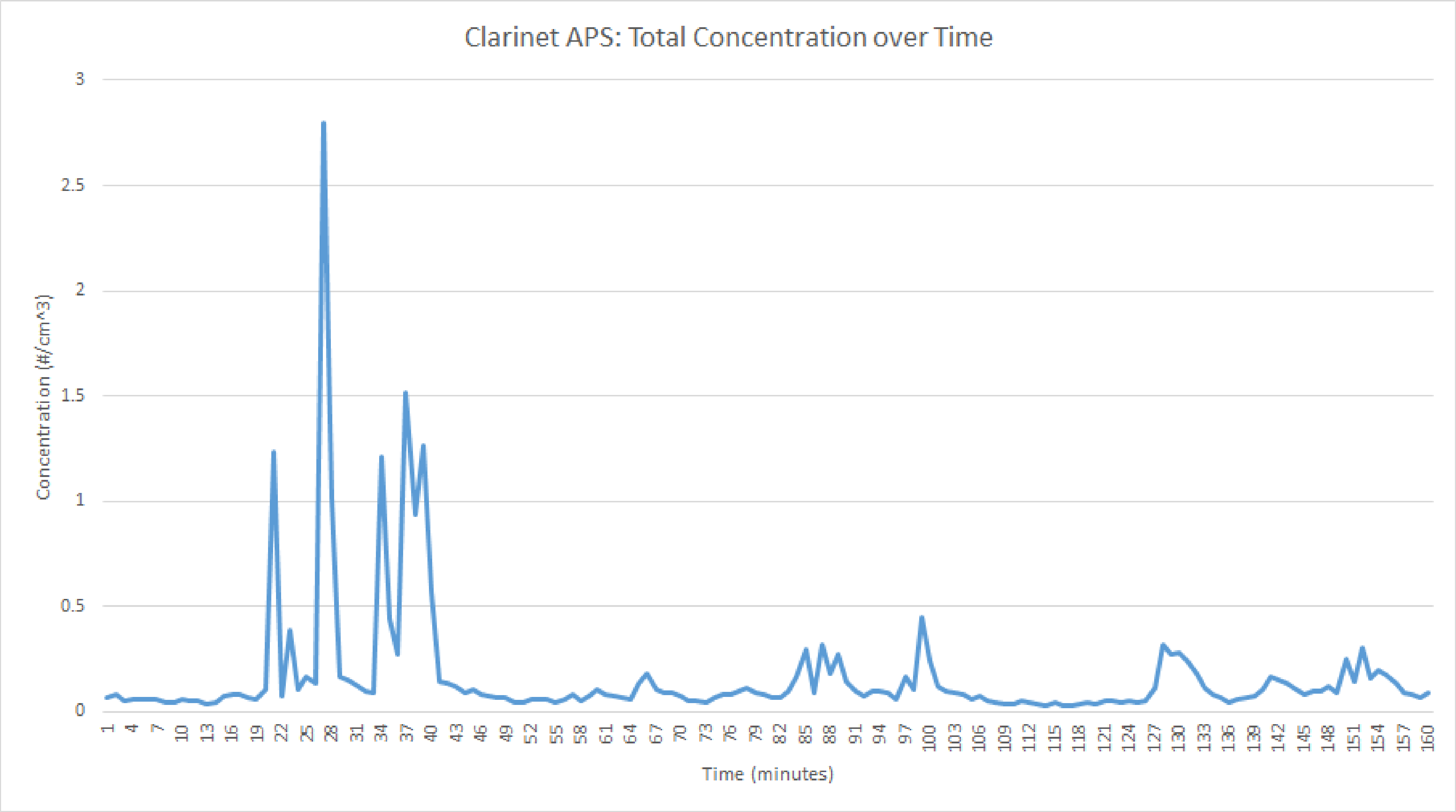

French Horn CPC: Total Concentration over Time
Concentration (#/cm^3)
Time (seconds)
250
200
150
100
50
0
1
241
481
721
961
1201
1441
1681
1921
2161
2401
2641
2881
3121
3361
3601
3841
4081
4321
4561
4801
5041
5281
5521
5761
6001
6241
Play uncovered
Read
Play with Mask, close to bell
Play with Mute
Play with Mute and Mask
Play 1m away
Background


Soprano Singing, CPC: Concentration over Time
Concentration (#/cm^3)
Time (seconds)
Scales
Warm-up
Church Choir Piece, with HEPA filters
Church Choir Piece
Pop song
Sing with mask
Sing with pantyhose screen
briefly talking right before turn off HEPA filters
Sit and breath
0
10
20
30
40
50
60
70
80
1
121
241
361
481
601
721
841
961
1081
1201
1321
1441
1561
1681
1801
1921
2041
2161
2281
2401
2521
2641
2761
2881
3001


Soprano Singing, APS: Total Concentration over Time
Concentration (#/cm^3)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59
Time (minutes)



Clarinet CPC: Concentration over Time
Concentration (#/cm^3)
900
800
700
600
500
400
300
200
100
0
0
2000
4000
6000
8000
10000
12000
Time (seconds)
scales near bell
scales near keys
scales near bell
play near bell
play with pantyhose
read
Sit and breath
Play with bell cover
play near bell
play near keys
play in bag
play in bag



Clarinet APS: Total Concentration over Time
Concentration (#/cm^3)
Time (minutes)

Remarks based on Initial Exploratory Testing

- Exploratory results indicate the need to contain the aerosol emissions in a smaller sampling volume
- Sizing measurements show particles are typically < 10 μm
- Concentrations were relatively higher for instruments that had straight shapes from mouthpiece to bell (trumpet, clarinet)
- Masks, nylon bell coverings all reduced particle concentrations

Initial CFD Results of Aerosol Spread form a Singer without a Mask

Shengwei Zhu and Jelena Srebric

Center for Sustainability in the Built Environment (***City@UMD***)

University of Maryland

July 11, 2020

CFD (Computational Fluid Dynamics) Modeling

Using computational fluid dynamics and the Wells-Riley equation, the City@UMD team has analyzed the concentration of airborne COVID-19 particles in **one outdoor and two indoor case studies**.

The **outdoor case study** represents a musician in a light wind field of 1m/s (2.2 mph) at 10 m (33ft) above ground, being roughly 0.2 m/s (0.5 mph) at a person's height. A simulation represents a single wind direction, so considering that a wind often changes its direction, the presented Covid-19 concentrations and infection risk will likely occur in a radius around a musician, rather than just behind a musician.

The **indoor case studies** represent a typical small rehearsal hall with a single musician. **Indoor Case 1** has both the supply and exhaust at the ceiling level, a typical ventilation system design. **Indoor Case 2** has the supply at the ceiling and the exhaust at the floor. Both cases are simulated with a musician breathing out Covid-19 in the center of the room. The two indoor cases differ solely in the placement of the space's HVAC supply and exhaust diffusers.

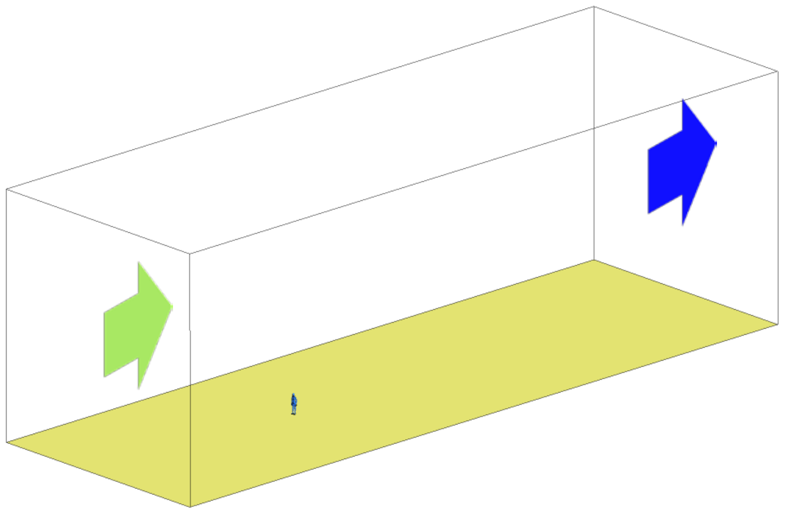
Animations of Indoor cases can be found here:

https://city.umd.edu/covid-19

CFD Case Study Setups

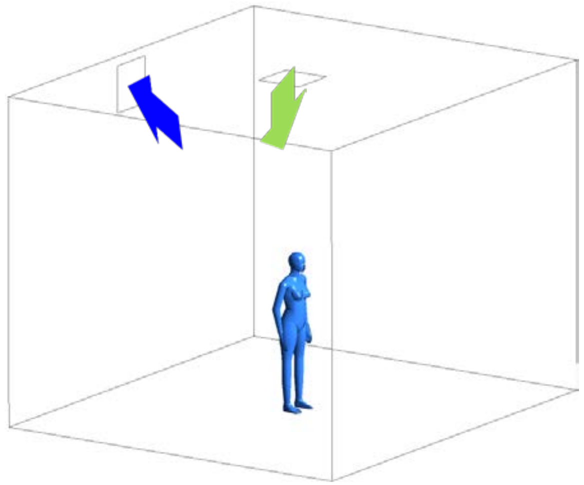
Outdoor Case (20 m × 60 m × 20 m)

Inlet (green arrow):
Vel.: 1 m/s at elevation of 10 m
Temp.: 22^{o}C at elevation of 1.5 m

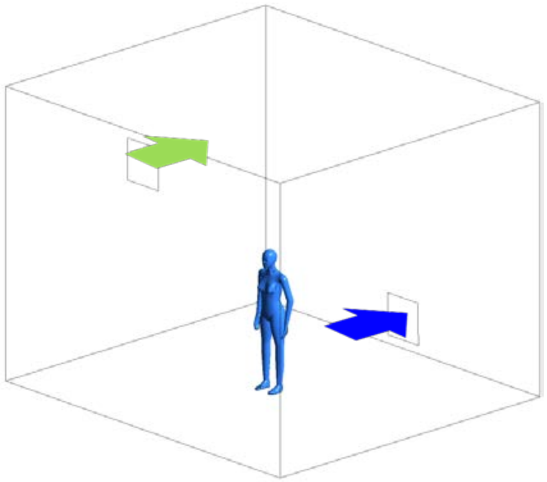


Indoor Cases (4.5 m × 4.0 m × 3.5 m)

Inlet (green arrow):
Size: 0.5 m × 0.5 m
Vel: 0.21 m/s (3 ACH)
Temp.: 22^{o}C



Indoor Case 1



Indoor Case 2

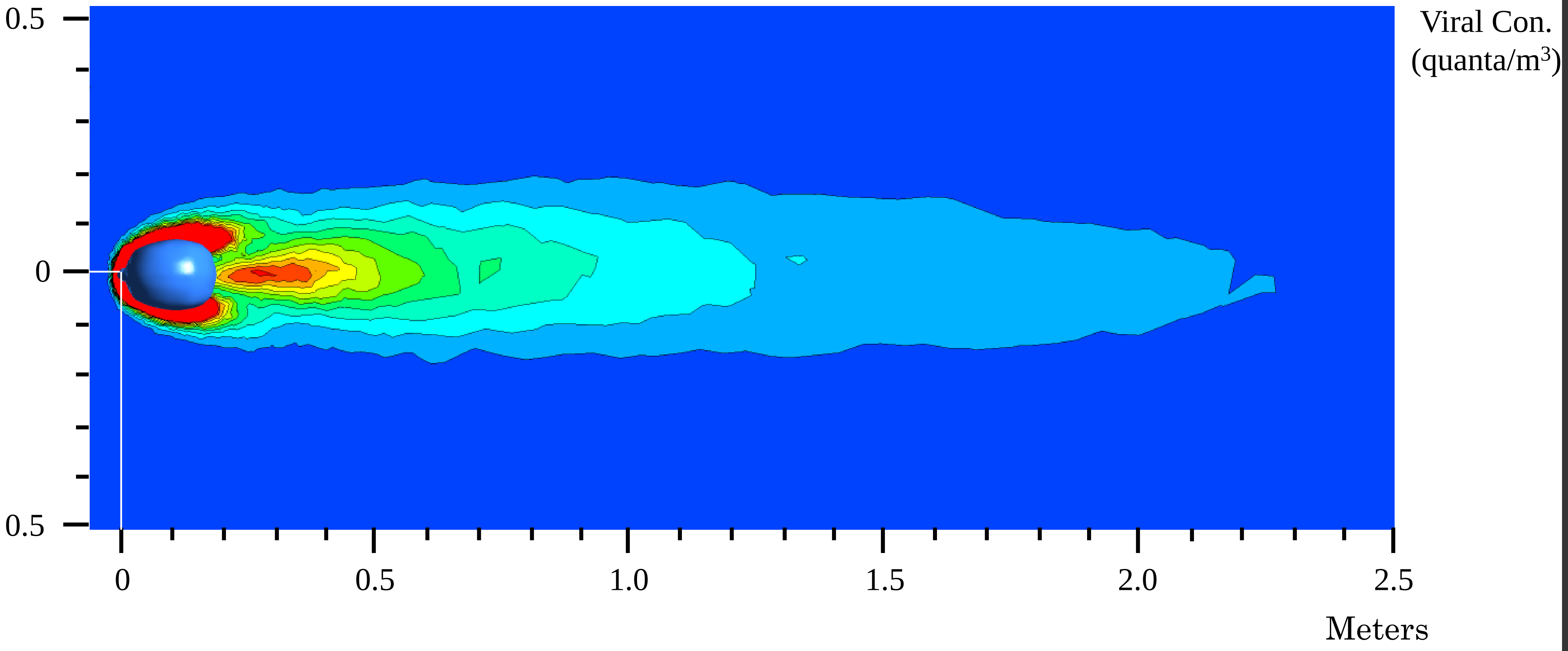
Human Body: Area of 1.47 m^2 and Heat flux of 23 W/m^2

Mouth Opening: Area of 3.8 cm^2, Velocity of 0.56 m/s, Temp. 32^{o}C, and NO mask

Covid-19 generation rate: 48 quant/hr

Outdoor Case: Virus Distribution after Roughly 90 Minutes

At the height of mouth opening

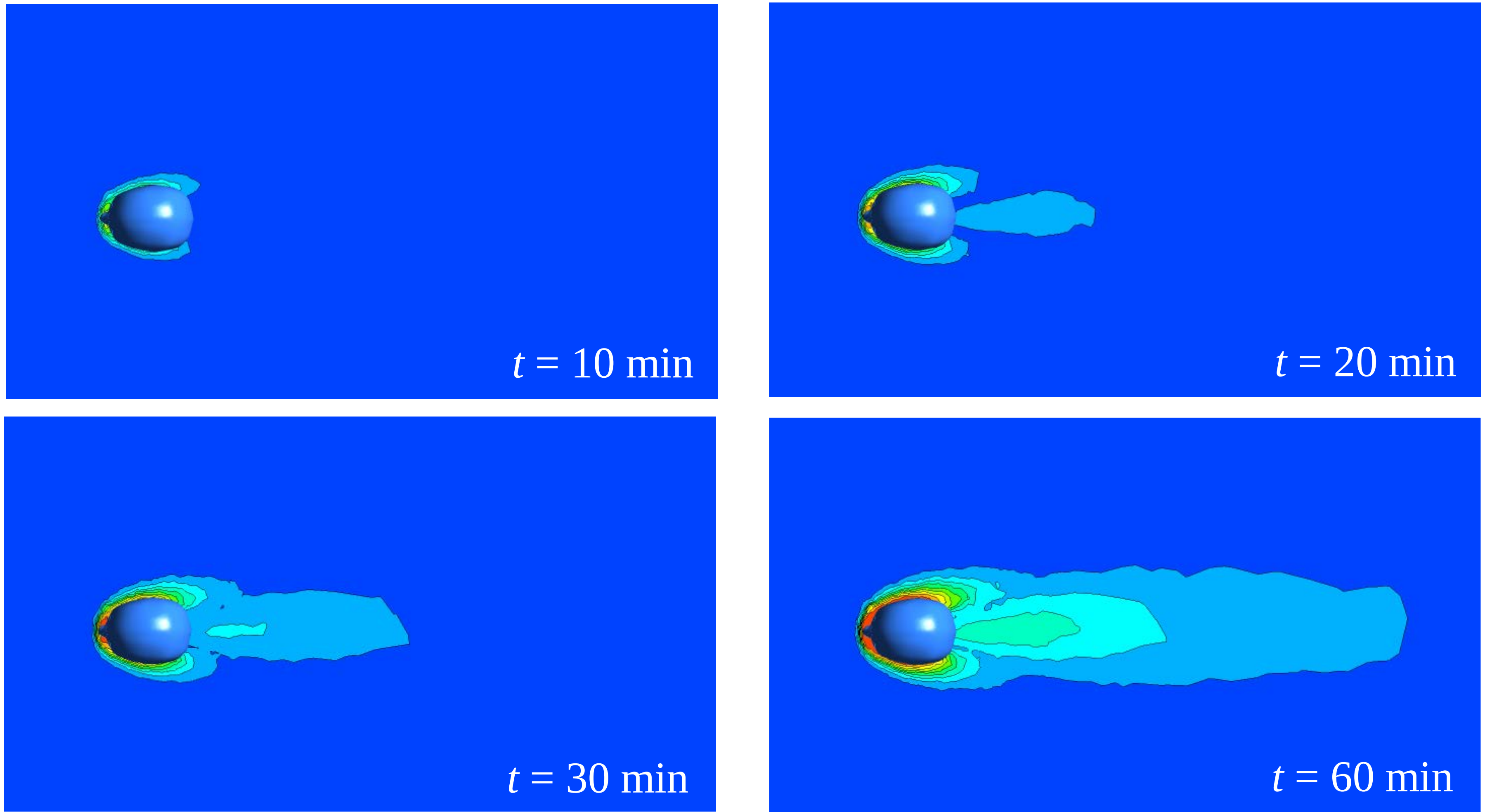


Outdoor Case: Infection Risk at the Horizontal Cross Section

Infection risk *r* by the Wells-Riley equation:

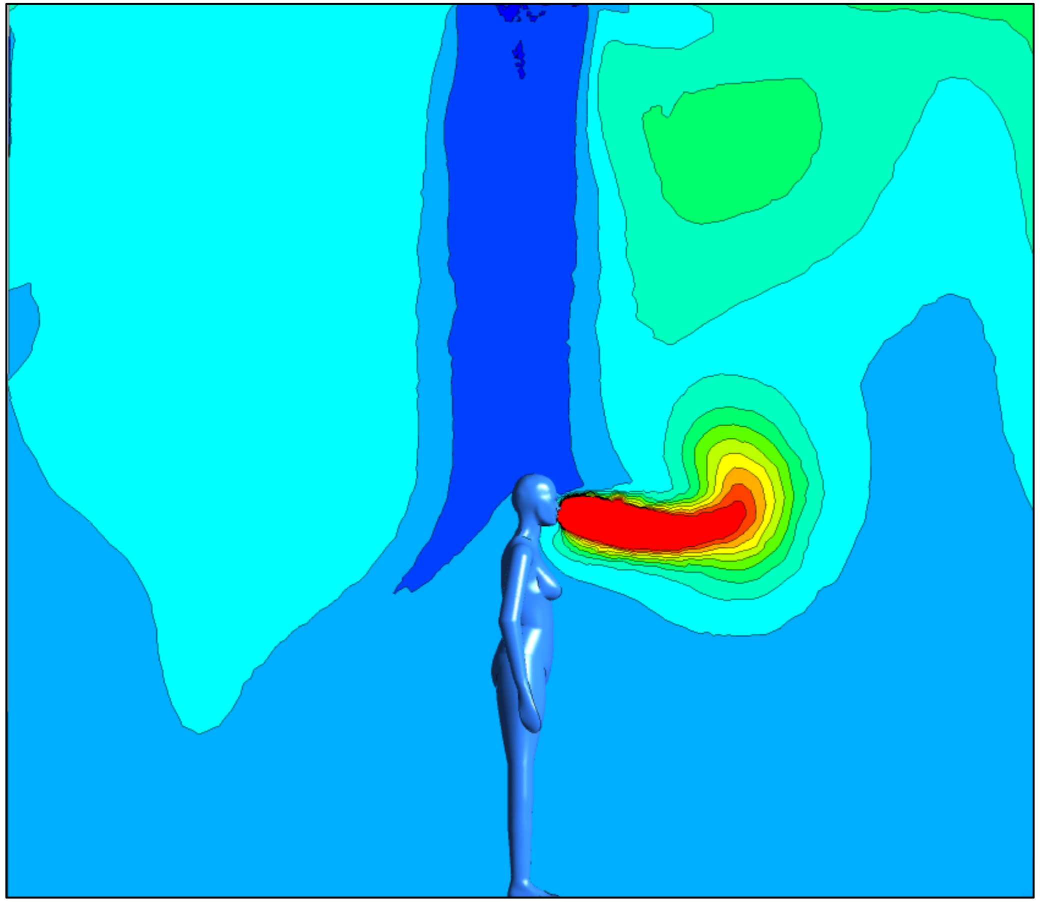
At the height of mouth opening

r

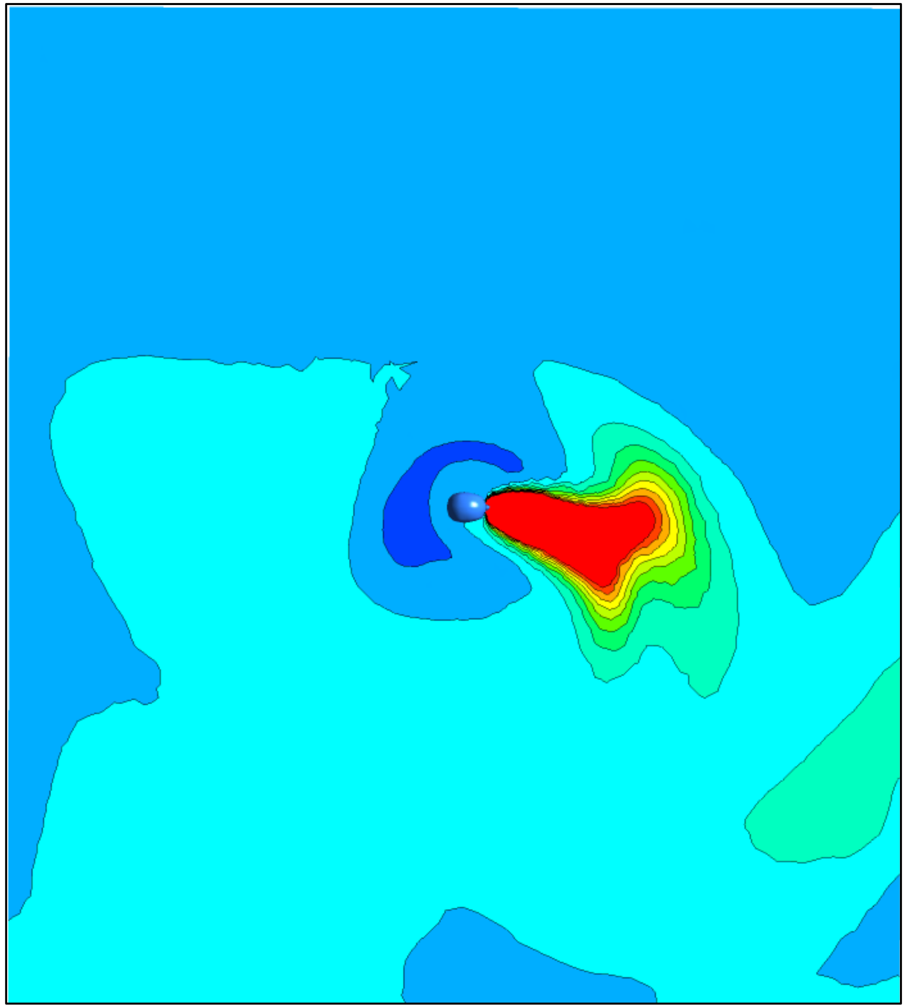


Indoor Case 1: Virus Concentrations after Roughly 60 Minutes

Viral Con. (quanta/m³)



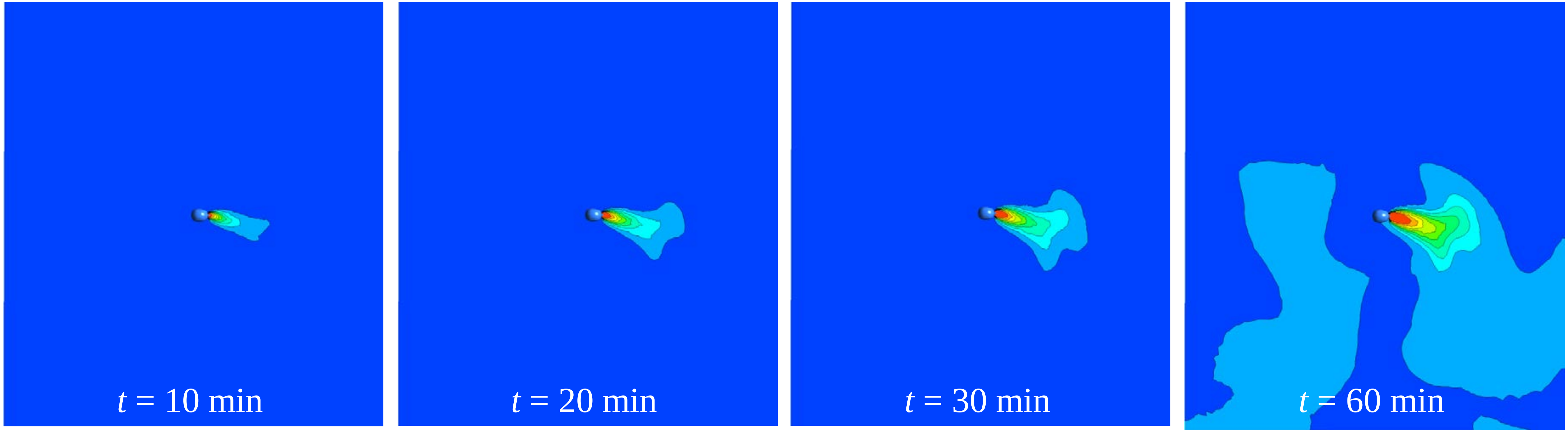
Vertical section
cross the middle of human body



Horizontal section
at the height of mouth opening

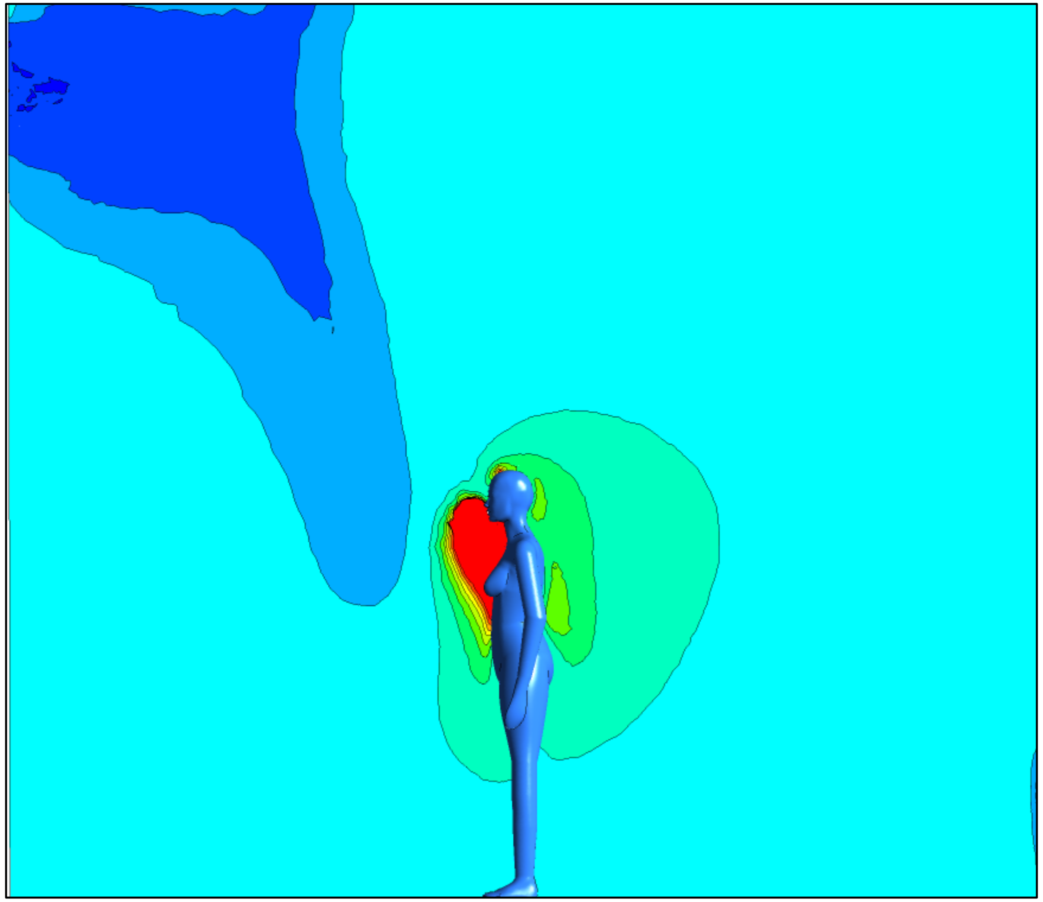
Indoor Case 1: Infection Risk at the Horizontal Cross Section

Infection risk ***r*** at the height of mouth opening by the Wells-Riley equation:

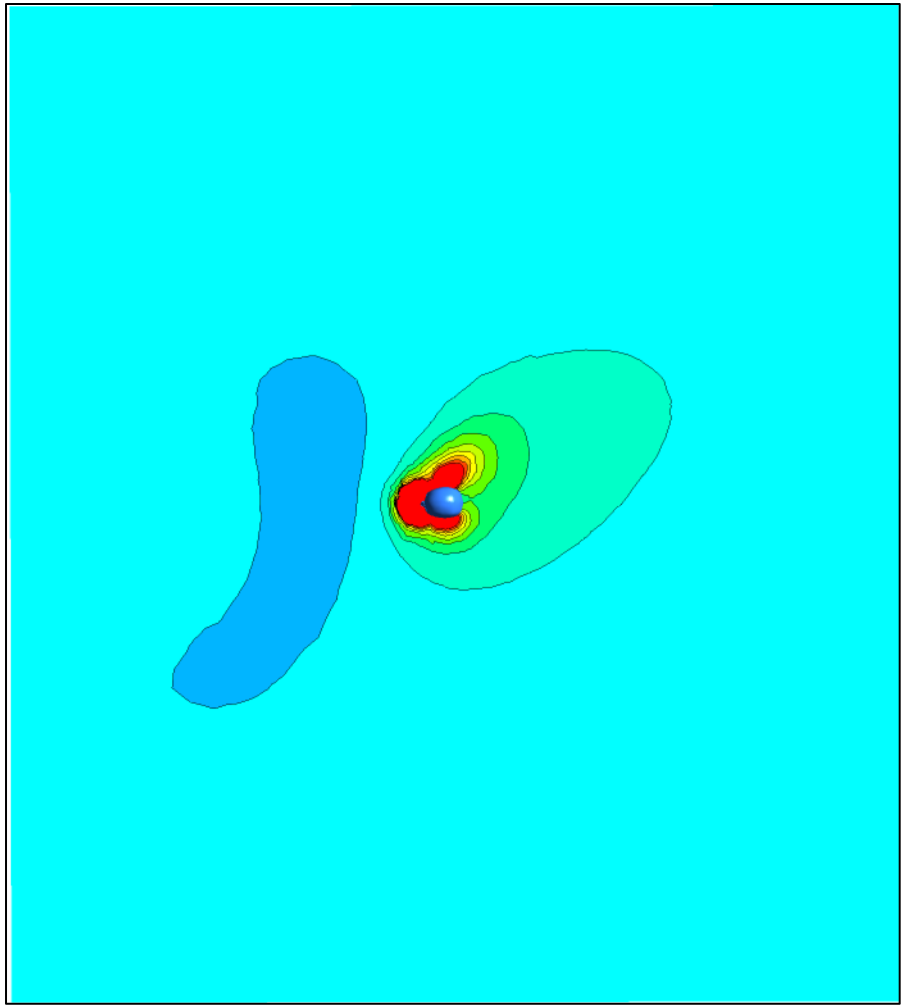


Indoor Case 2: Virus Concentrations after Roughly 60 Minutes

Viral Con. (quanta/m^3)



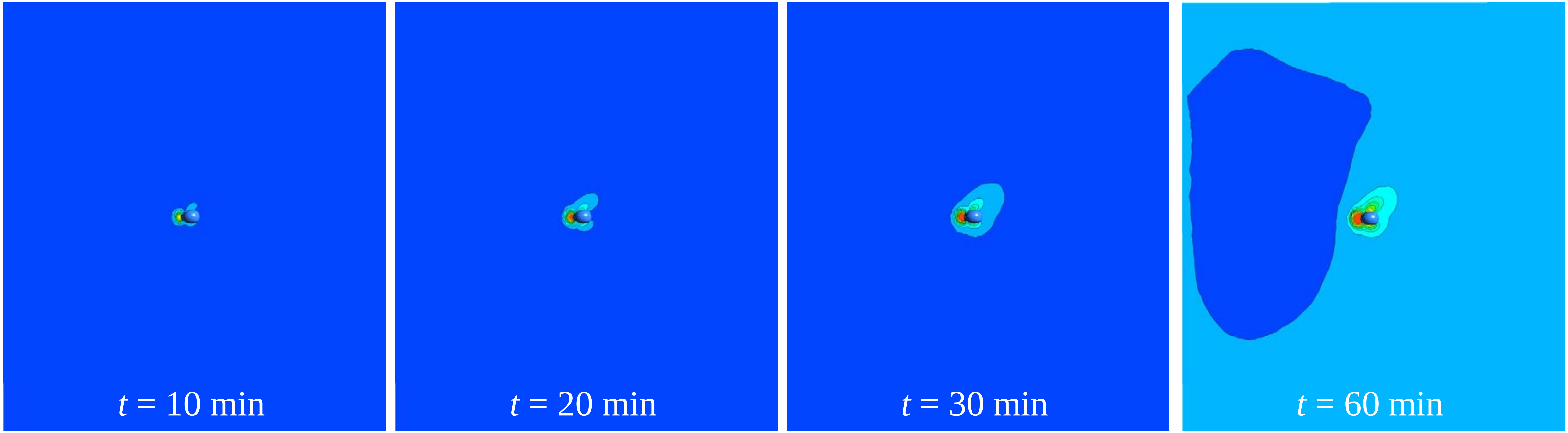
Vertical section
cross the middle of human body



Horizontal section
at the height of mouth opening

Indoor Case 2: Infection Risk at the Horizontal Cross Section

Infection risk ***r*** at the height of mouth opening by the Wells-Riley equation:



Remarks based on Initial CFD Simulations

Initial CFD findings confirm the effectiveness of social distancing directives to keep **2m/6ft** apart as this is the boundary of the region around an infected person in which the risk of infection begins to rise steeply, especially with an **exposure duration greater than 30 minutes**.

The simulations also show the variations in airborne particulate mixing due to different HVAC setups for the two indoor case studies. Indoor Case 1, a more **common layout of supply and exhaust air** in commercial buildings, is **less effective at removing COVID-19** particles yielding a larger and more persistent region of high COVID-19 infection risk.

Additional simulations will allow for multiple singers, multiple and varied instruments, and multiple infection risk mitigation strategies. All of these new cases will include measured data for the particle sources generated by musicians. City@UMD team will open for discussion future case studies as we have limited time to **answer most pressing questions** raised by our sponsors and colleagues.

General Considerations

General Considerations

- Masks should be worn by all students and staff prior to entering the performing arts room. Masks should continue to be worn until all students are seated and ready for instruction (example, long rests, sectional work, moving around the room, etc.)

- No talking should occur in the room without a mask being properly worn.

- When possible a mask with a small slit for mouthpiece access should be worn while playing.

- In instrument groups where a mask cannot physically be worn the mask should be worn over the chin and replaced during periods where the student is not playing. No talking without a mask.

General Considerations

- Social distancing should occur as suggested by the CDC. Currently that distance is a 6x6 foot space around each student with the student sitting in the center. This may reduce the number of students that can fit in a performing arts classroom. Straight lines should be used as curved setups can affect the aerosol movement in a room.
- Students should sit all facing the same direction, back to front to minimize potential exposure.
- Trombones should have an additional three feet of distancing making their space 9x6. The player should be seated three feet in front of the back line, leaving an additional six feet in front of them due to the extended nature of the instrument and slide that can be in extended position.

General Considerations

- Spit valves should not be emptied on the floor. Recommend using a puppy pad (or similar) to catch the contents of the spit valve and discard.
- Storage areas should be managed to limit the number of students at a time in the room. Anyone who enters the room should bring a 70% alcohol wipe to wipe all surfaces before and after touching. The wipe should be discarded properly upon leaving the storage area.
- Teachers should consider using a portable amplifier to keep their voices at a low conversational volume. Students should also ask questions in a low conversational volume with a mask.
- Teachers are assumed to talk the most and as a result should wear the most efficient mask possible that is readily available, which are surgical masks. (N95s are not recommended at this time due to supply chain issues.)

General Considerations

- Existing HVAC systems should be fitted with HEPA filters if possible.
- There are HEPA air purifiers on the market to provide additional filtration appropriate to the size of the rehearsal space which will increase the air change rate from standard HVAC systems.
- Air change rate accounts for volume of the room.
- Air refresh rate per room to “clean” the room:
  - Air changes per hour (ACH),
  - (1/ACH) x 60 min/h x 3
  - 3 ACH = (1/3)x60x3 = 60 minutes
- If volumetric flow rate (L/min) is available
  - divide by room volume to find the air change rate

Outdoor, Open-sided Tents

- An option to indoor, poorly ventilated space might be an open-sided tent. This does not allow sunlight or vertical mixing effects but does reduce sun exposure to students.

Marching Band

- See previous NFHS "Guidance for a Return to High School Marching Band"
- https://www.nfhs.org/media/3812337/2020-nfhs-guidance-for-returning-to-high-school-marching-band-activities.pdf
- Additionally, bell covers are highly recommended as "masks" for the instruments. Bell covers can be made of multi-layered high denier nylon material and provide a barrier for aerosols.
- Outdoor rehearsals are considered best practice; indoor rehearsals using CDC guidelines plus bell covers may be considered.

Risk Estimator Tool

- The University of Colorado-Boulder has developed a risk assessment tool: https://tinyurl.com/covid-estimator
- NFHS is developing a web-based tool specifically for music applications. Projected roll-out of the tool to occur by the end of July.
- Data needed for tool:
  - Room volume (length x width x height)
  - HVAC outside air turnover rate, expressed by air "changes per hour" or "liters per second."
  - Add additional HEPA air purifier units to reach higher "changes per hour" or "liters per second."