Monitoring of the Atmosphere on the International Space Station with the Air Quality Monitor

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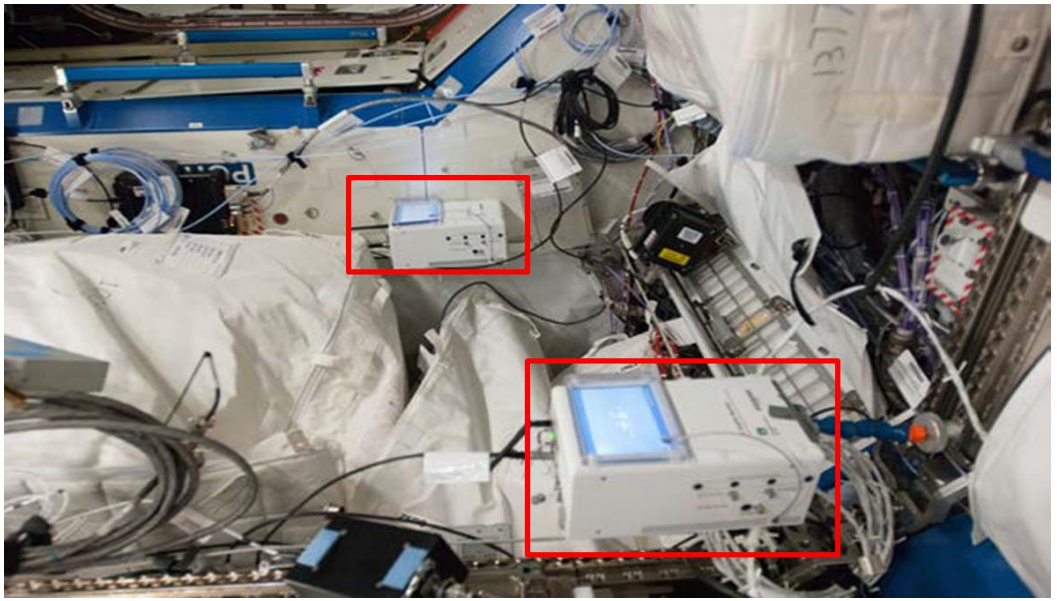
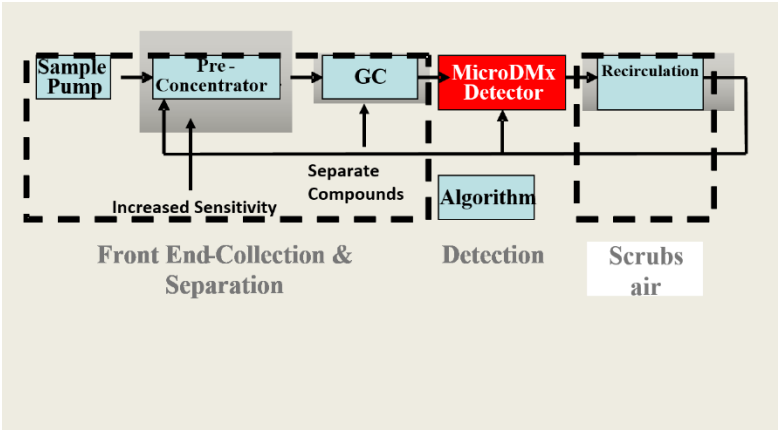
Background

- **Need: Assessment of the trace VOCs in spacecraft atmosphere to protect crew and system health**
  - Archival samples used exclusively until ISS (1-2 week missions)
  - Longer duration missions require more real-time information
  - Volatile Organic Analyzer (VOA) delivered to ISS in Sept. 2001.
    - GC/IMS
    - Operated for 8 years
    - Mass/volume not acceptable for future missions
    - Reduce crew time and reliance on spacecraft resources

Air Quality Monitor (AQM)



- AQM combines gas chromatography with differential mobility spectrometry
- GC carrier gas and detector make-up gases are recirculated air
- 3 kg, 25.4 cm x 15.2 cm x 13.2 cm
- 2 units used simultaneously on ISS; different GC columns (DB5 / VF624)
- First 2 units delivered March 2013; one operational through 1/15 and one through 1/16
- Second 2 units delivered 12/15; one began operation in 2/16 and one in 3/16



Background

- **The AQM monitors trace concentrations of 23 targeted volatile organic compounds in the ISS atmosphere (Non-target detection capability)**
  - Years of archival data from spacecraft was used to select the target compounds
  - Compounds on the target list had one or more of the following characteristics
    - **Compounds frequently detected in spacecraft atmosphere (ethanol, acetone, xylenes, and 2-butanone)**
    - **Compounds with significant toxicity at low concentrations, even though they are detected infrequently on spacecraft (benzene)**
    - **Compounds that can affect an ECLS system (siloxanes and 2-propanol)**
    - **The target list is fluid, dictated by experience and changes in materials of construction or ECLS systems**

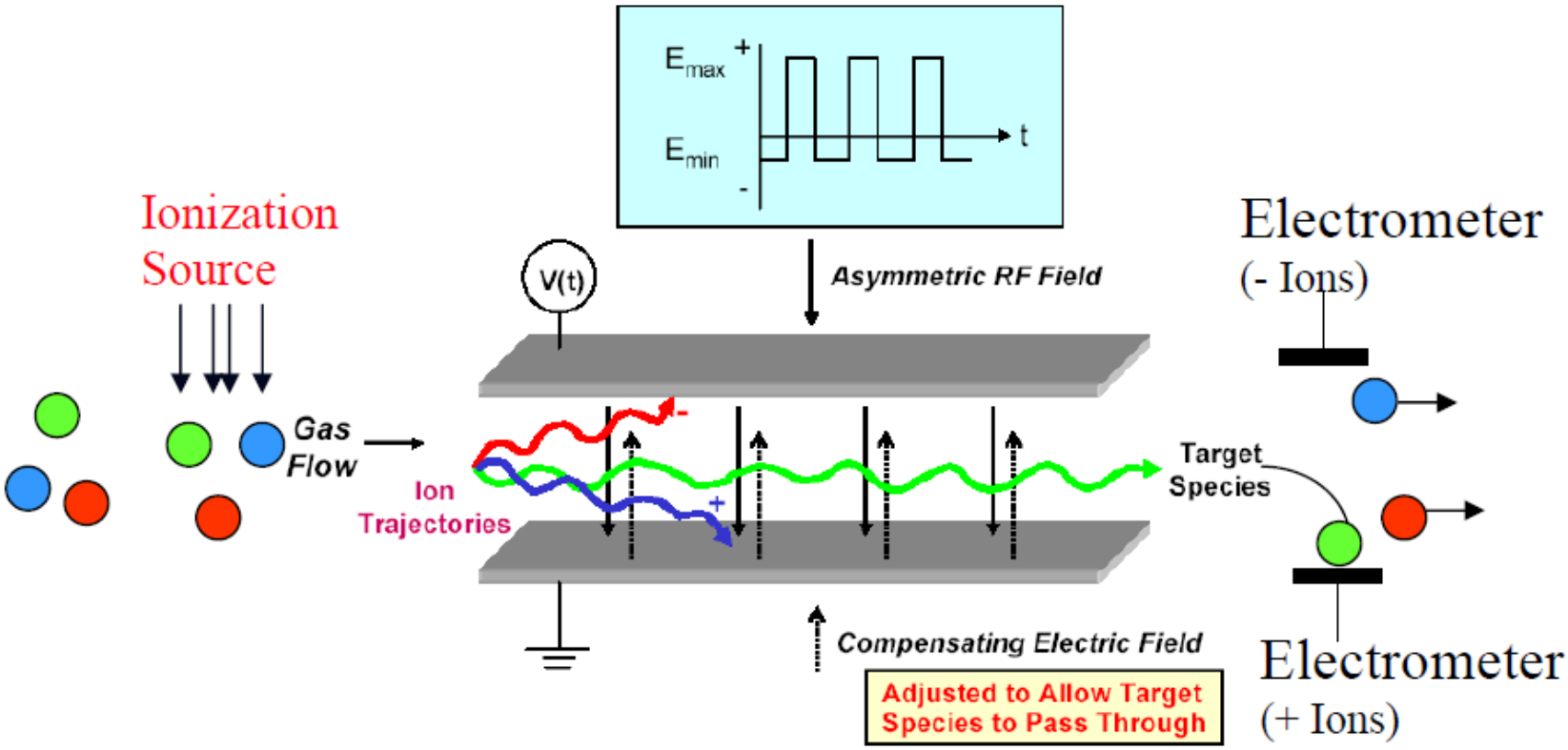
Required Target List

Compound	Concentration Range (mg/m^3)		Potential Effects
	Low	High	
Acetaldehyde	0.1	2	Mucosal irritation
Methanol	0.1	3	Visual disturbance
Ethanol	0.5	7	Liver toxicity, mucosal irritation
Acetone	0.1	4	CNS depression
2-Propanol	0.1	4	CNS depression, mucosal irritation
1-Butanol	0.1	3	Mucosal irritation, Visual disturbance
Ethyl Acetate	0.1	4	
Dichloromethane	0.1	4	Liver toxicity
Toluene	0.1	4	Dizziness, CNS depression
Xylenes (m,p)	0.1	2	CNS depression
Xylene (o)	0.1	1	CNS depression
2-Butanone	0.1	4	Mucosal irritation, Visual disturbance
Hexane	0.5	8	Neurotoxicity
Benzene	0.1	4	Immunotoxicity
Hexamethylcyclotrisiloxane	0.2	6	
Octamethylcyclotetrasiloxane	0.2	6	CNS depression
Decamethylcyclopentasiloxane	0.2	6	
Trimethysilanol	0.2	6	
Hexanal	0.1	3	
Propenal	0.03	1	Pulmonary irritation, Visual disturbance
1,2- Dichloroethane	0.1	2	
Ammonia	Trending Only	Trending Only	

Background

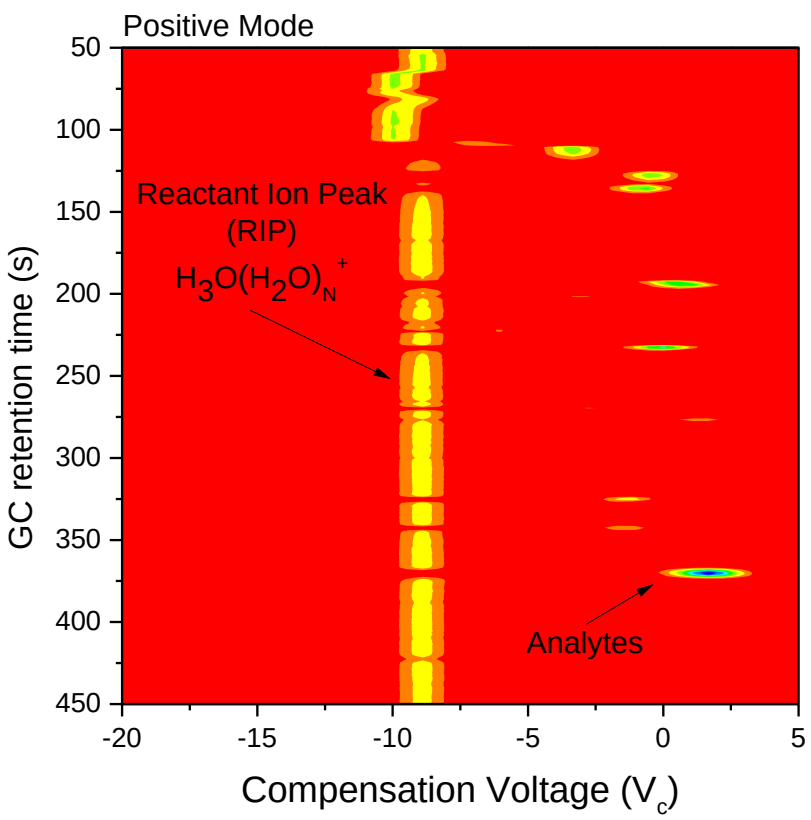
- The data from the AQM is used by the NASA Toxicologist to assess the air quality aboard the ISS
- Some archival sampling continues
- The AQM can also provide data for ECLS troubleshooting
- In case of contingency, the AQM can help to monitor clean up efforts

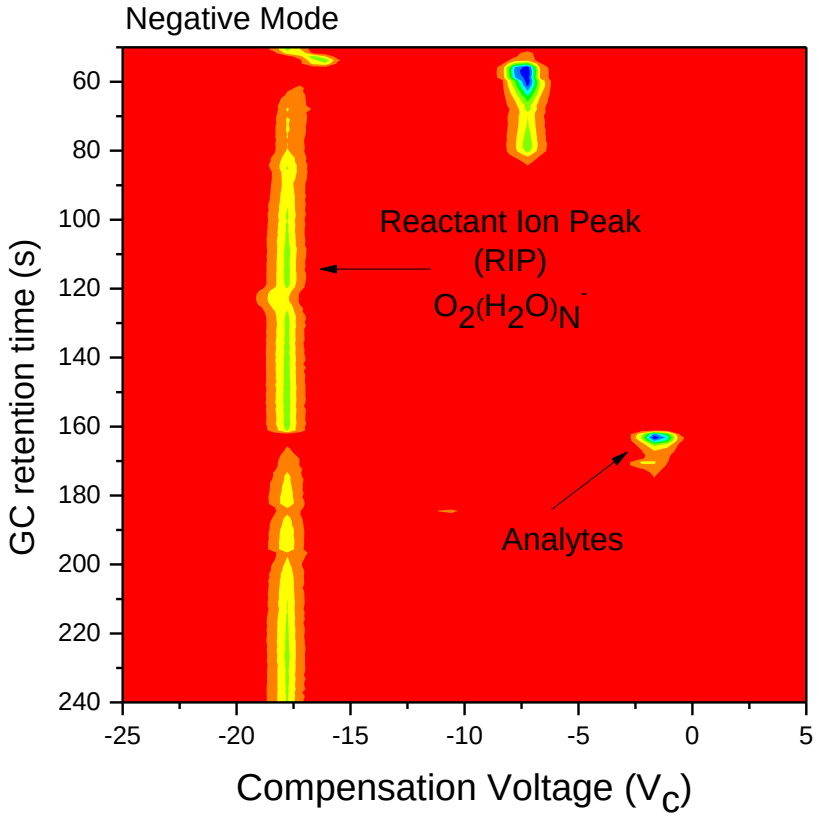
What is Differential Mobility Spectrometry?



Draper Labs, microAnalyzer V2.0 Series Product Family Manual

Technical Overview





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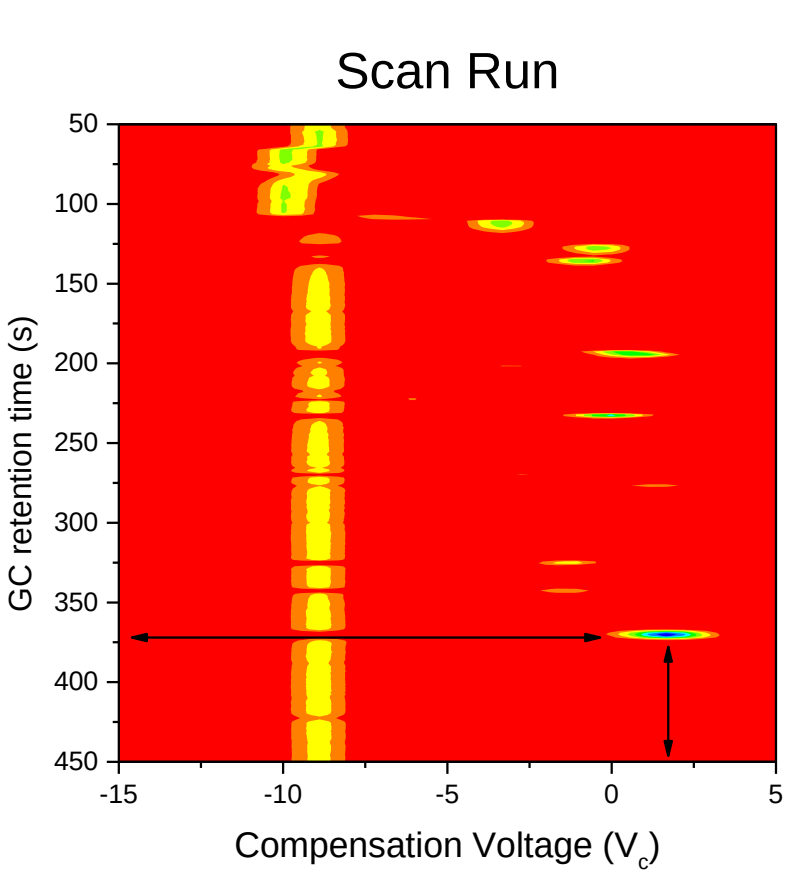
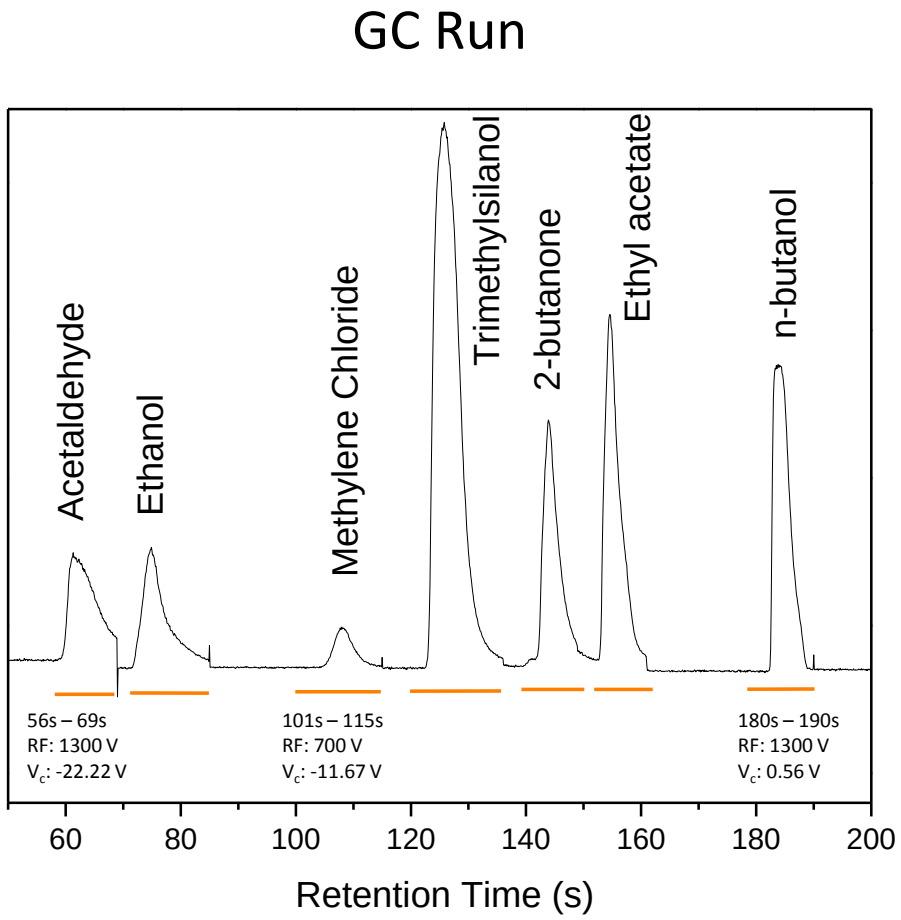
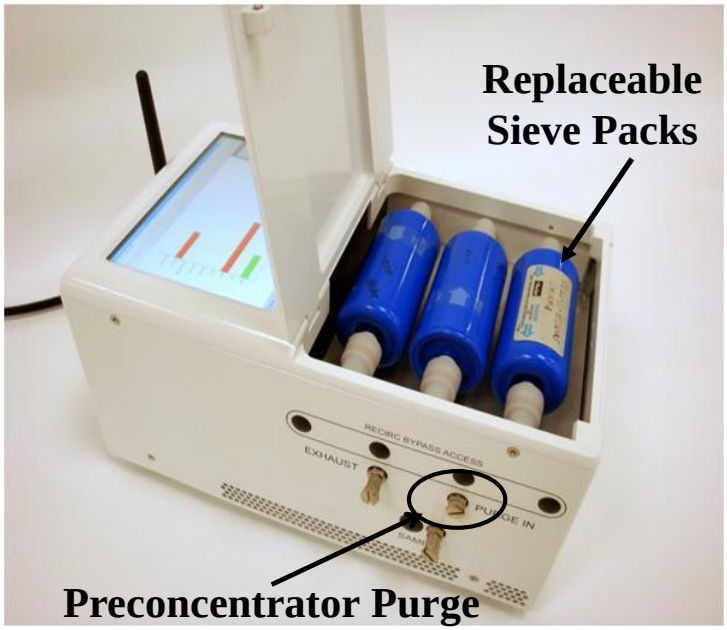
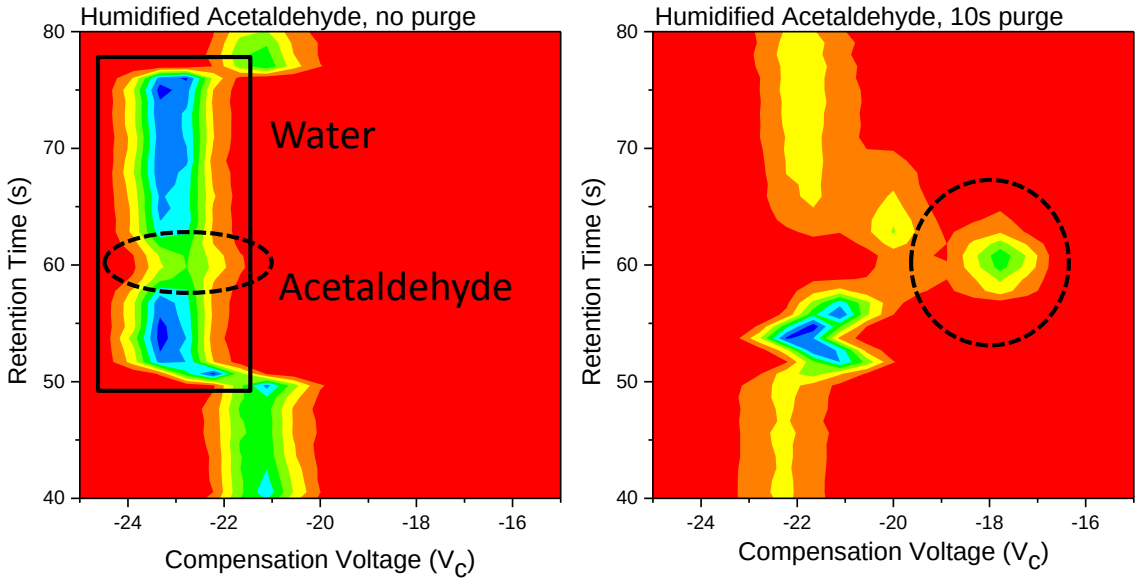




- Use scan runs to determine detection parameters (GC retention time, RF voltage, polarity, and compensation voltage) for each compound
- Parameters are used to establish GC and V_c windows at specific RF and polarity
- GC method table developed, which directs the software where to find the peaks

AQM Details



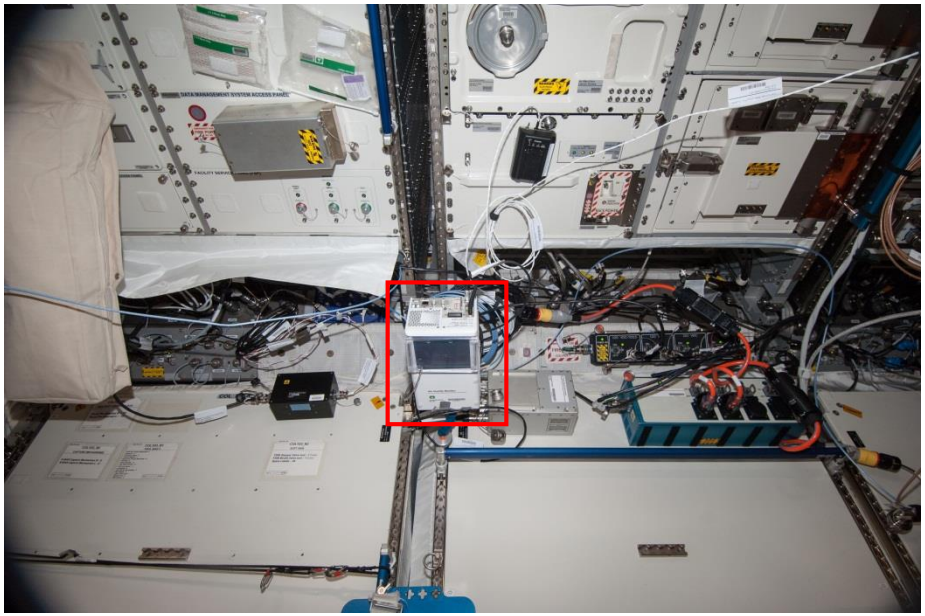


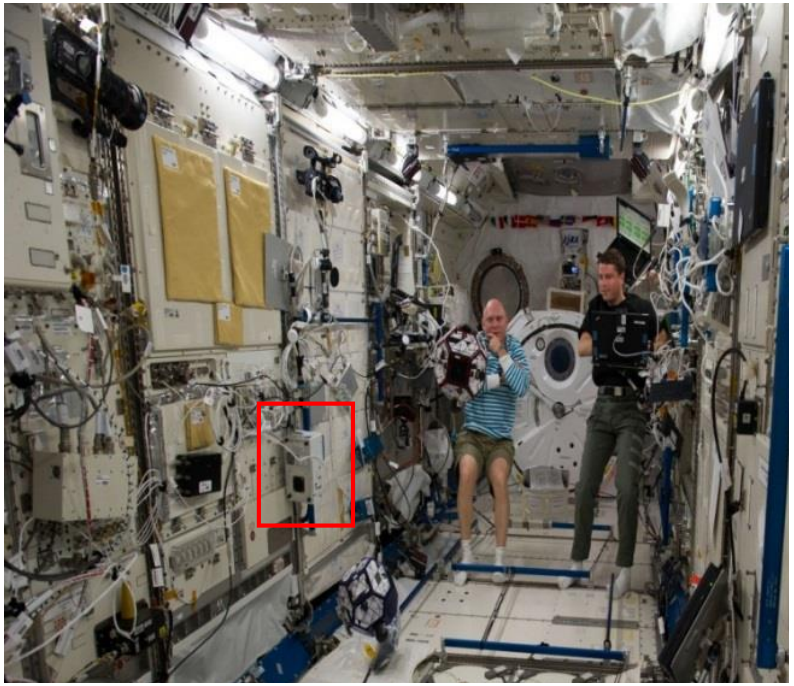
Improvements in current AQM over previous on-board air analyzers

- Replaceable sieve cartridges for scrubbing carrier gas
  - Extends life of instrument
- Preconcentrator purge
  - Removes excess water from preconcentrator; simplifies spectra
- Wireless communication
  - Reduces need for crew time; MCC can interface remotely
- Battery operation

ISS Data and Module Survey

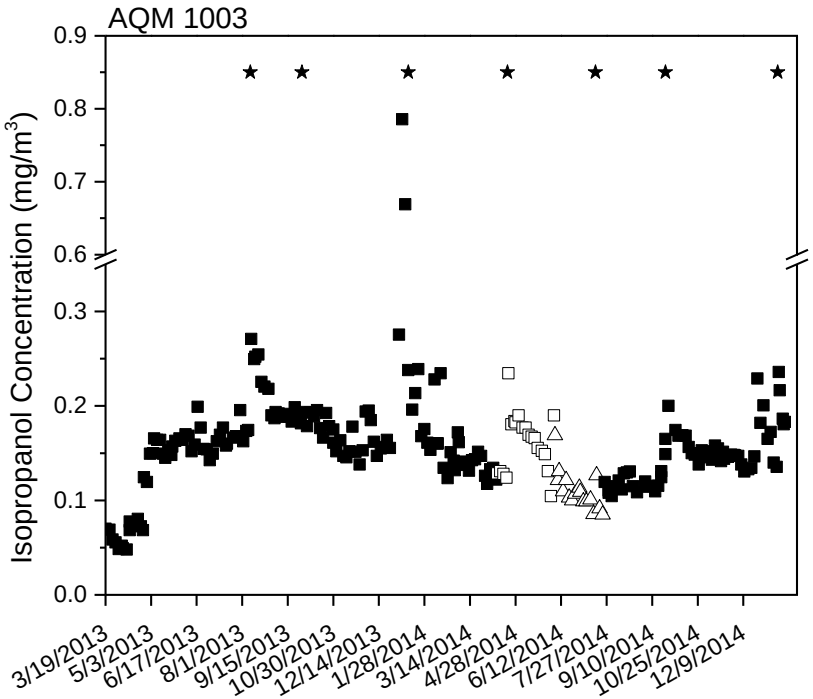
- AQMs generally located in U.S. Lab
- After validation, survey begun to assess potential differences in contaminants for LAB, Columbus, and JEM
- One unit stayed in LAB while other moved to other modules
- AQM 1 (unit 1003) survey began on 4/10/14 in Columbus
- AQM 1 moved from Columbus to JPM on 6/6/14
- Survey completed on 7/23/14 when unit returned to LAB
- AQM 2 (unit 1004) survey began on 9/19/14 in Columbus
- AQM 2 moved from Columbus to JPM on 11/20/14
- Survey completed on 1/19/15

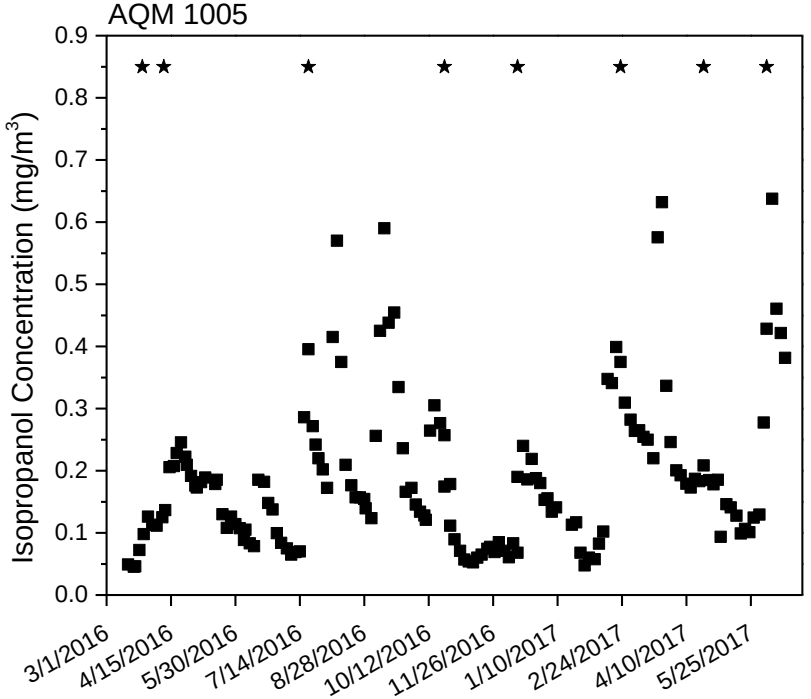




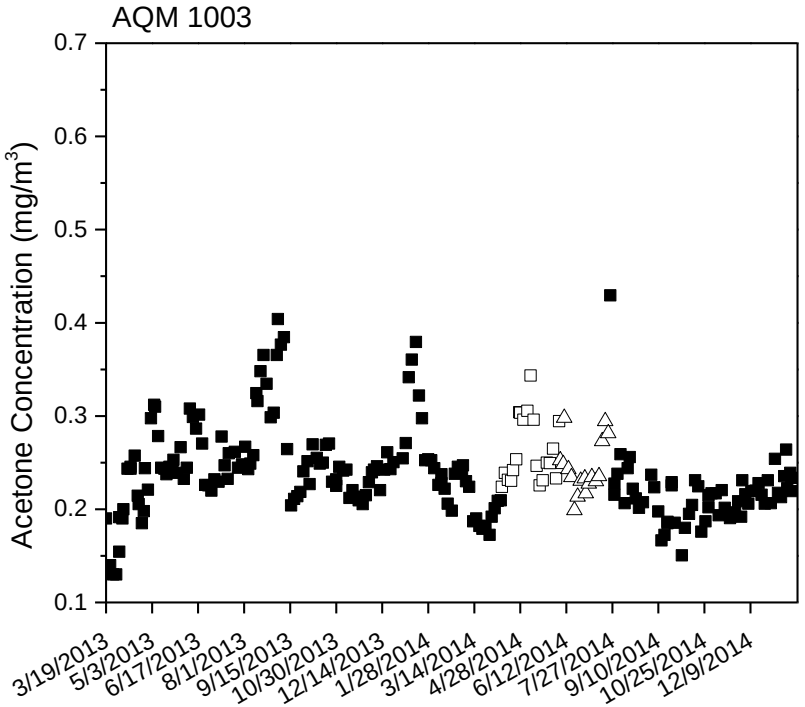
ISS Data - Isopropanol

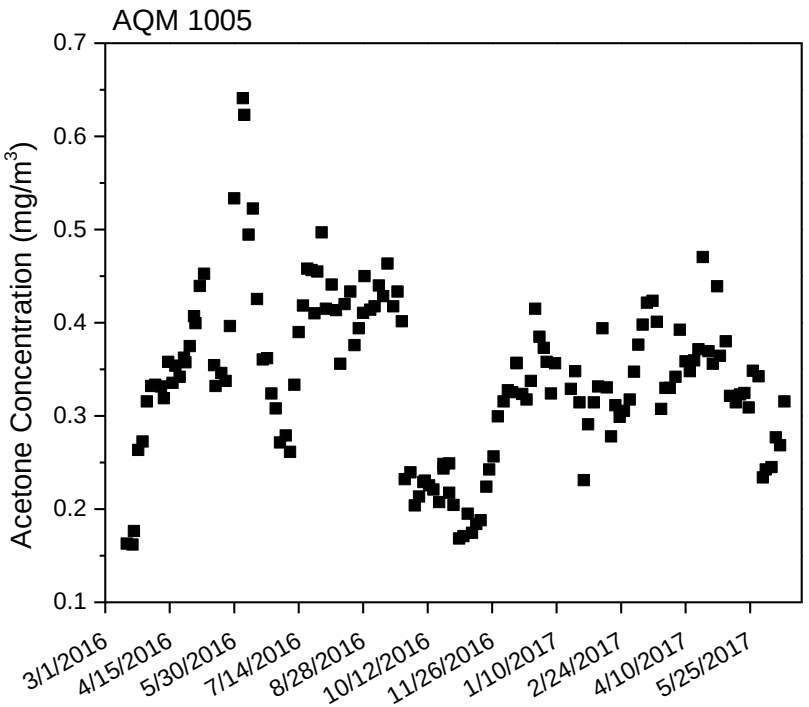
- Isopropanol concentrations often spike with USOS vehicle dockings
  - AQMs started ≤ 1 hour prior to *scheduled* hatch opening
  - Open squares – AQM 1 located in Columbus module
  - Open triangles – AQM 1 located in Japanese Pressurized Module





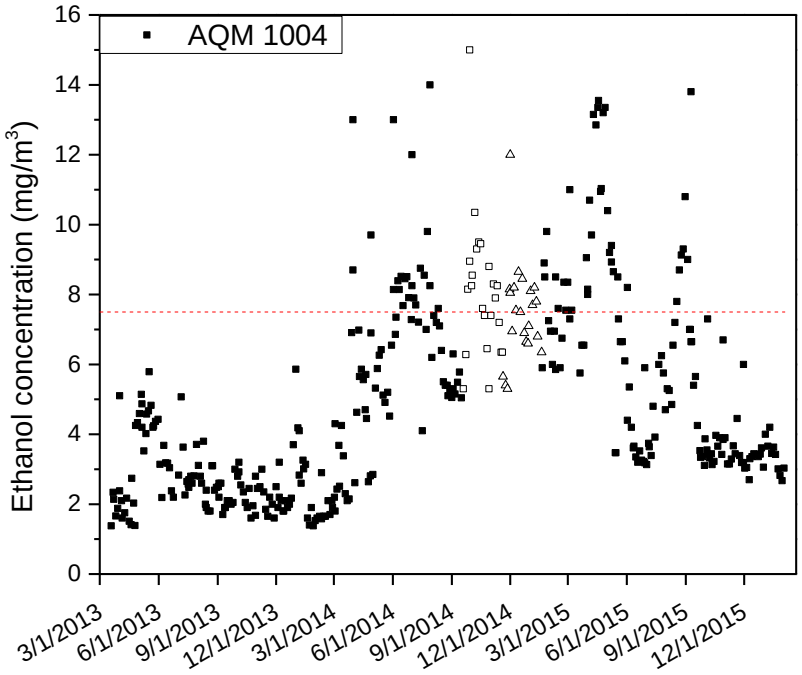
ISS Data - Acetone

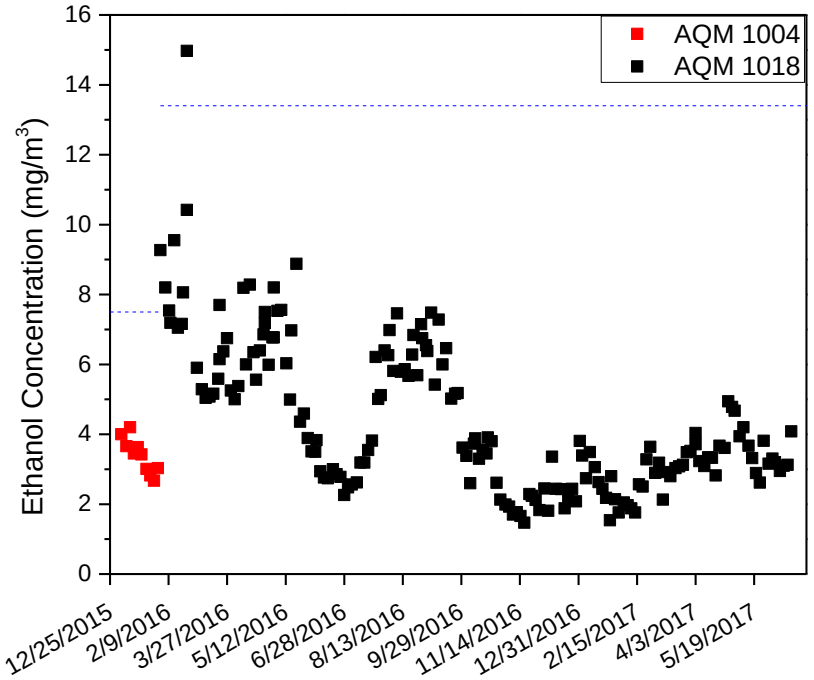




ISS Data - Ethanol

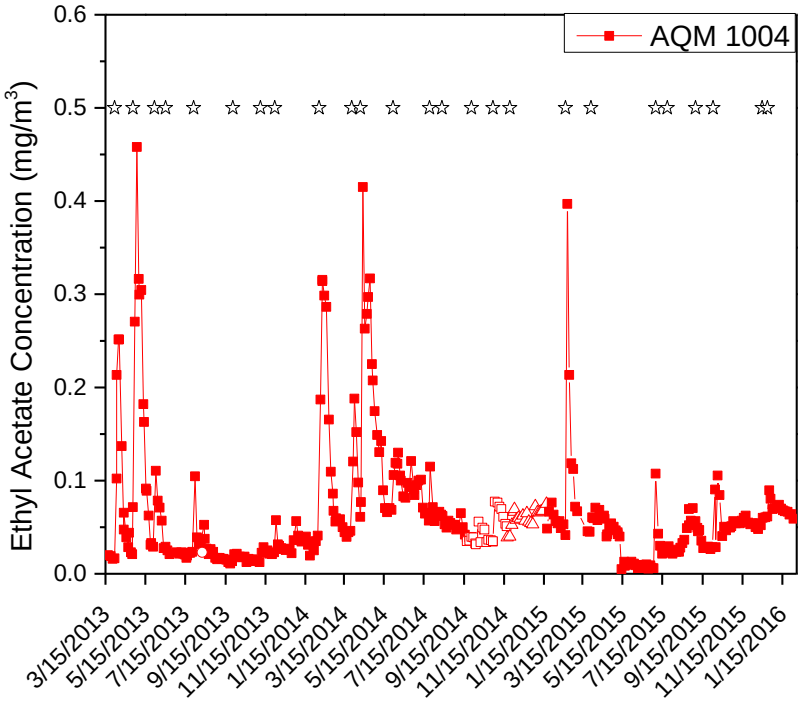
- Science requirements for ethanol: 0.5 mg/m^3 – 7 mg/m^3 (SMAC – 2000 mg/m^3)
- Calibration range sufficient based on historical concentrations
- Ethanol increases in 2014 and 2015; above calibration range; required manual analysis for estimated concentrations
- For second delivery, secondary ethanol calibration prepared (~ 6 mg/m^3 – 13.5 mg/m^3); smaller sample size used to prevent saturation

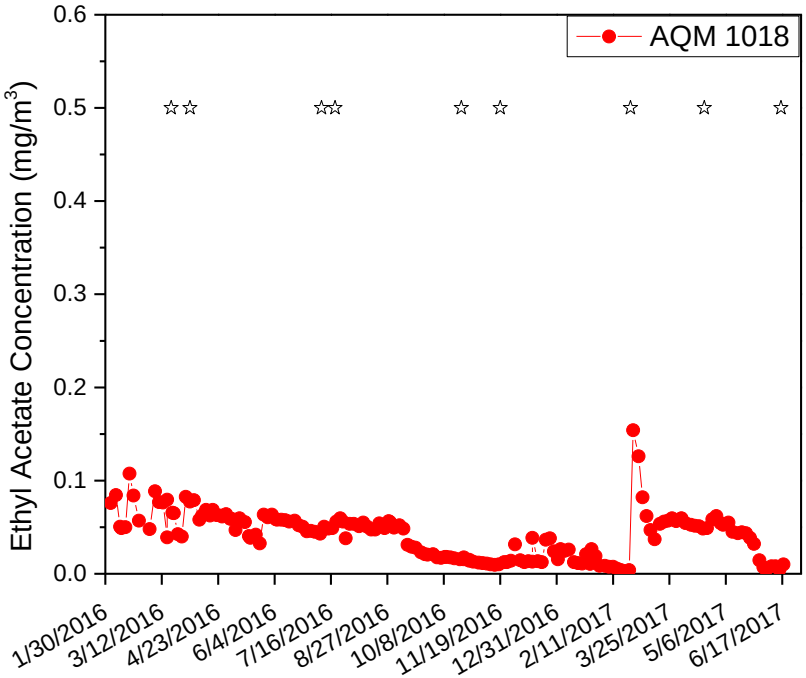




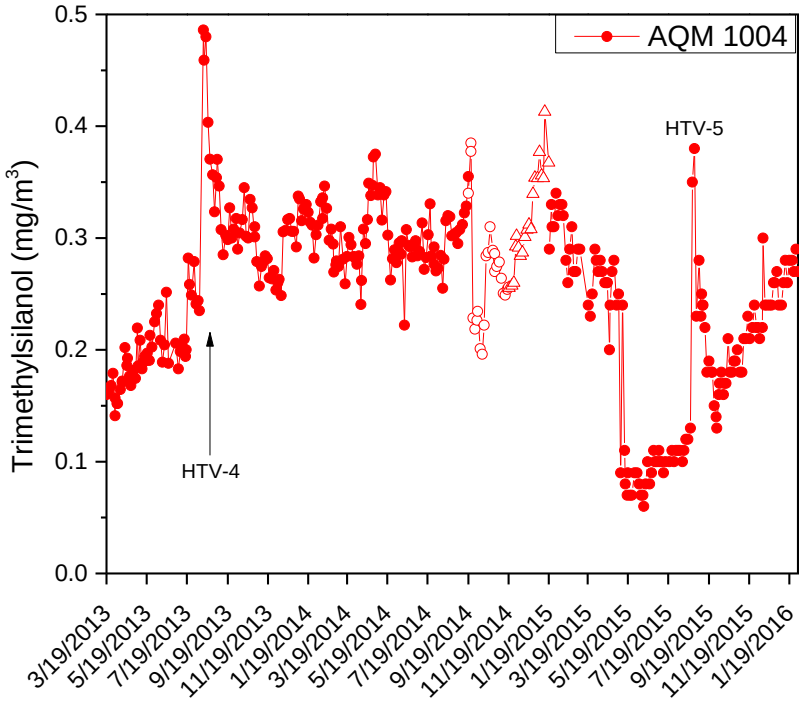
ISS Data – Ethyl Acetate

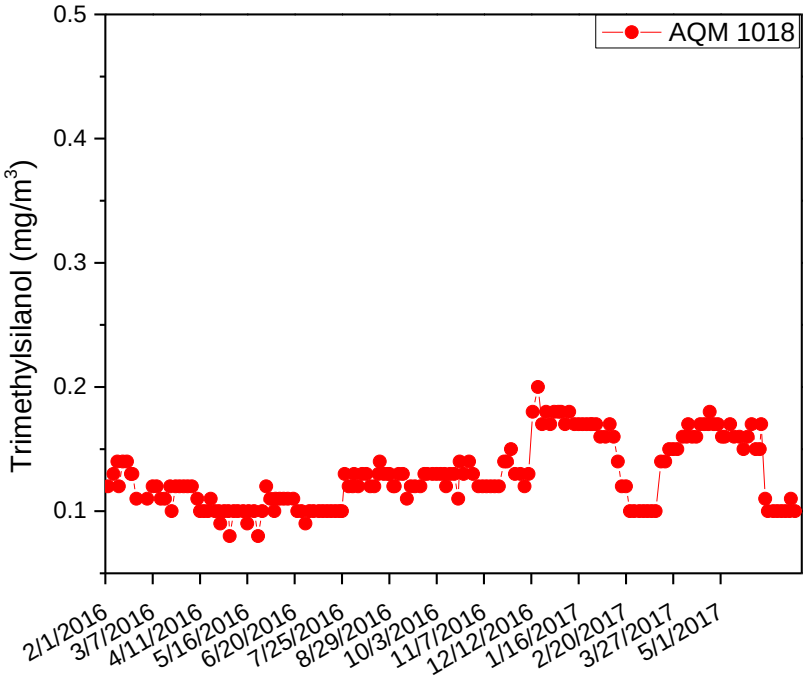
- Ethyl acetate concentrations often spike with Russian vehicle dockings
  - AQMs started ≤ 1 hour prior to *scheduled* hatch opening
  - Open squares – AQM 1 located in Columbus module
  - Open triangles – AQM 1 located in Japanese Pressurized Module





ISS Data – Trimethylsilanol

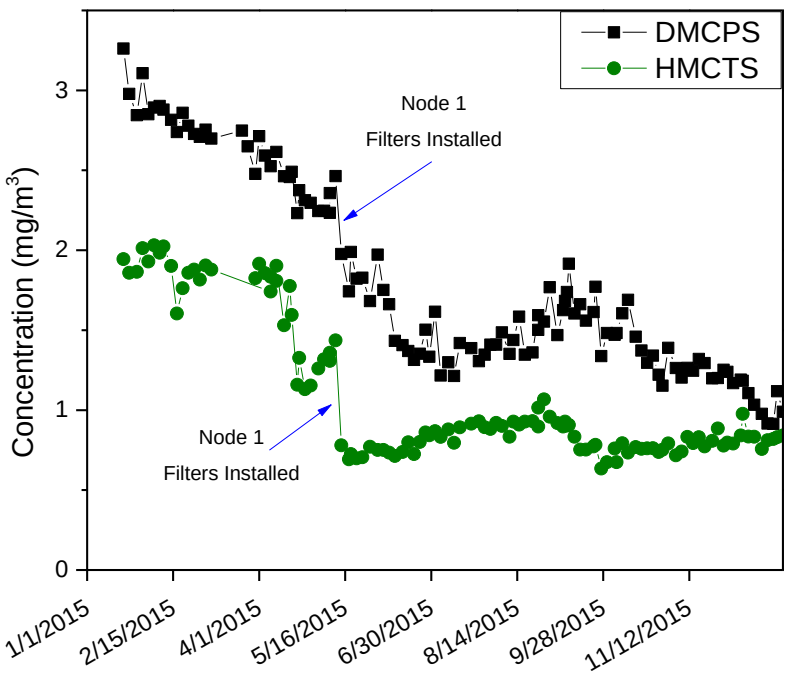


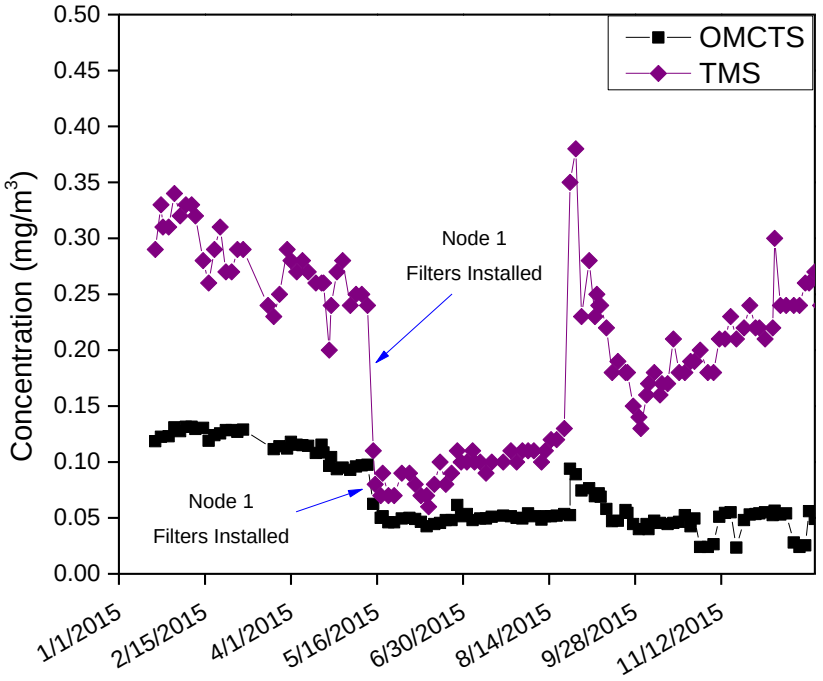


Troubleshooting, Contingencies, and Continuing Issues

ECLSS Effects

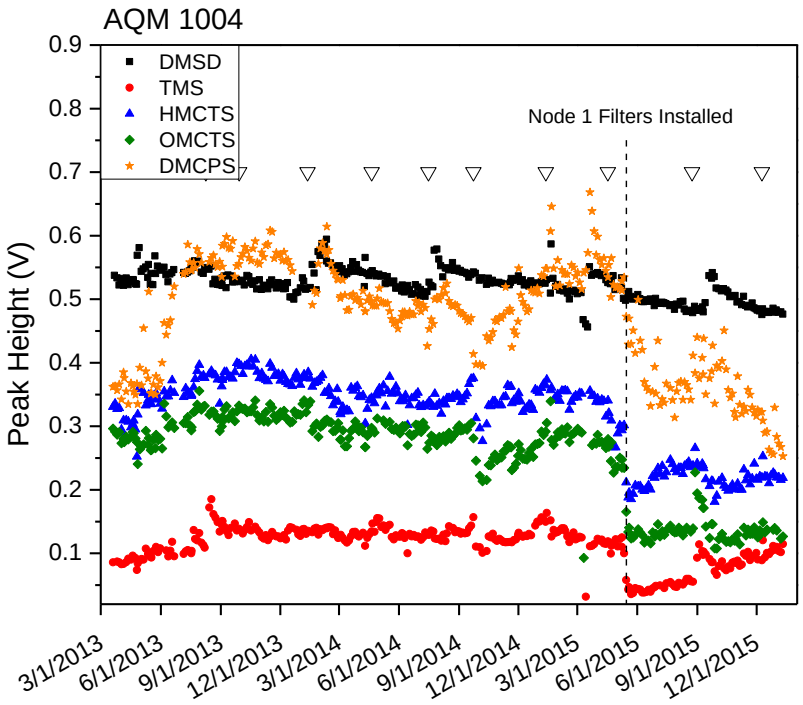
- mid-May 2015: activated carbon filters placed in Node 1 to reduce atmospheric siloxanes leading to DMSD in U.S. condensate

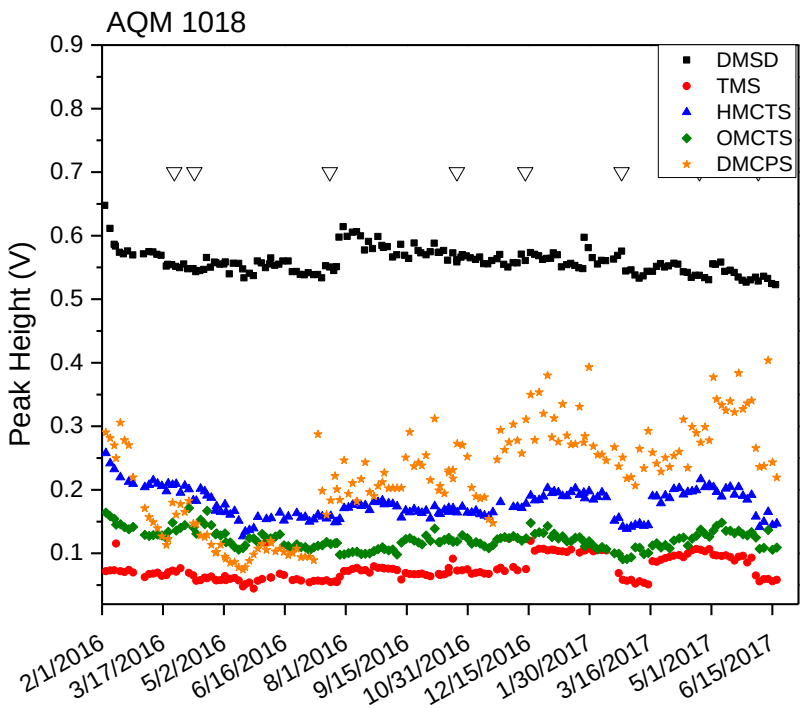




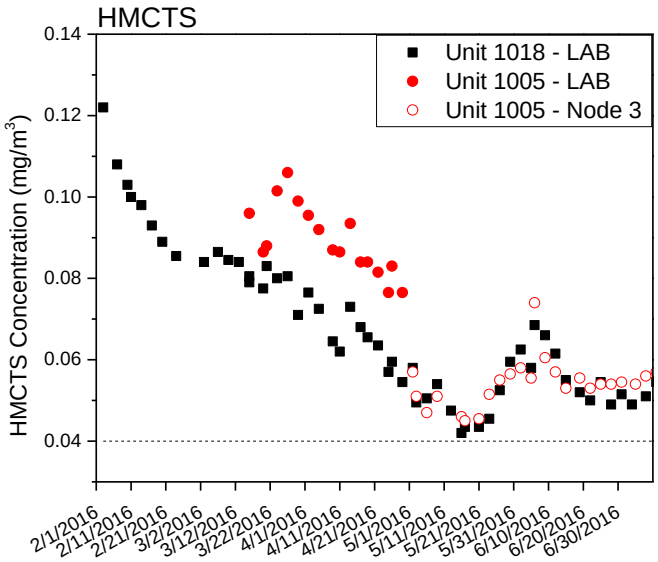
ECLSS Effects

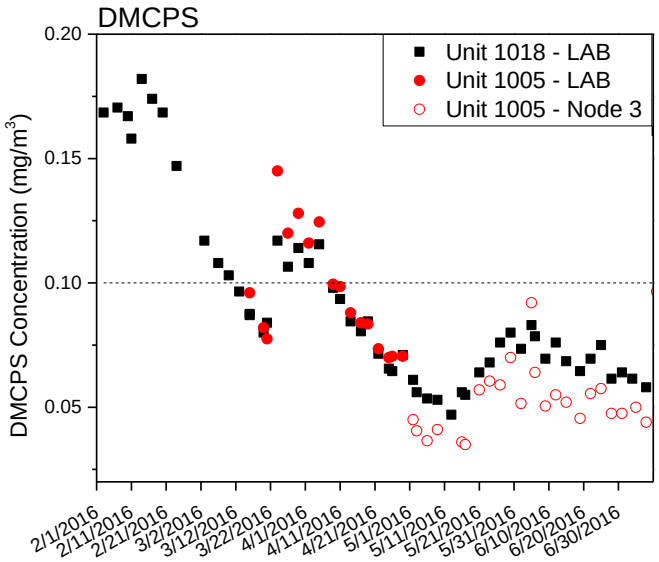
- AQM not calibrated for DMSD
  - Low vapor pressure makes preparation of air standards difficult/impossible
- Peak position discovered during testing of water inlet
- Intensity of DMSD peak in ISS air does not correspond with decreased siloxane intensity

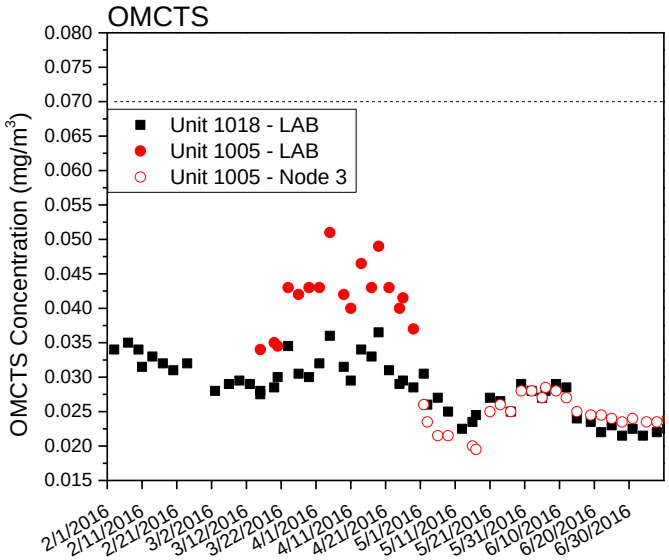




Use of AQM for Troubleshooting

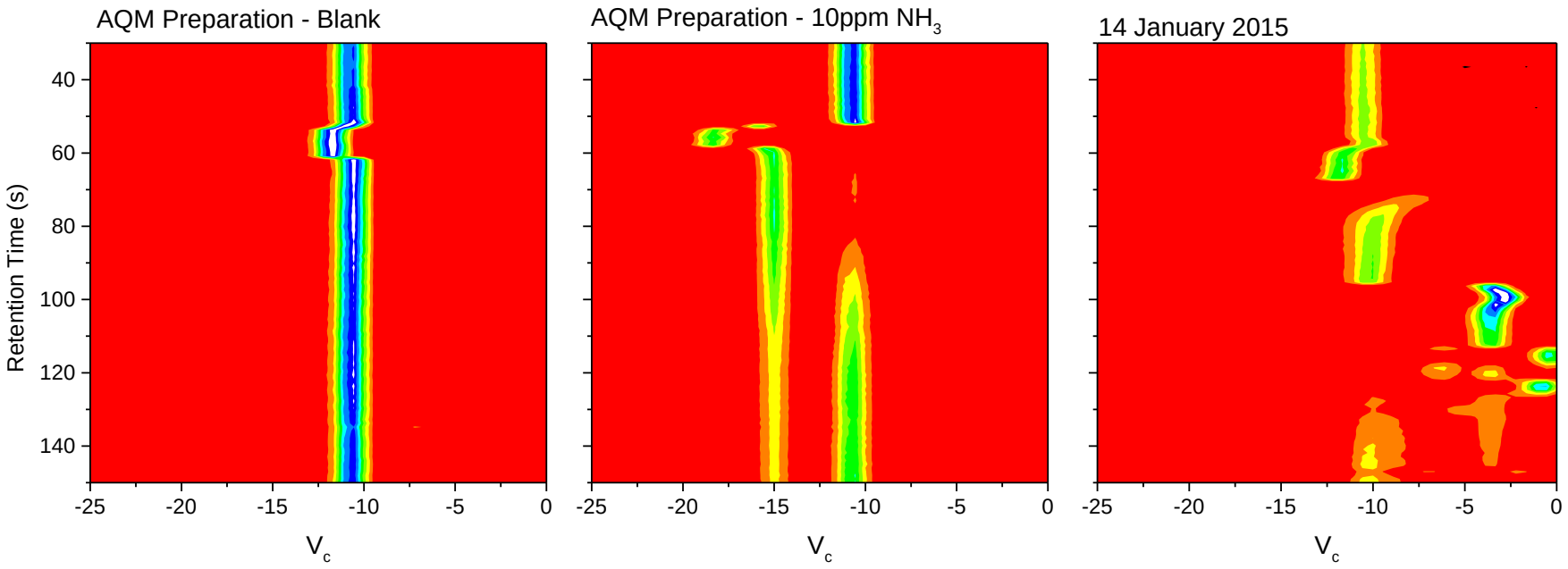






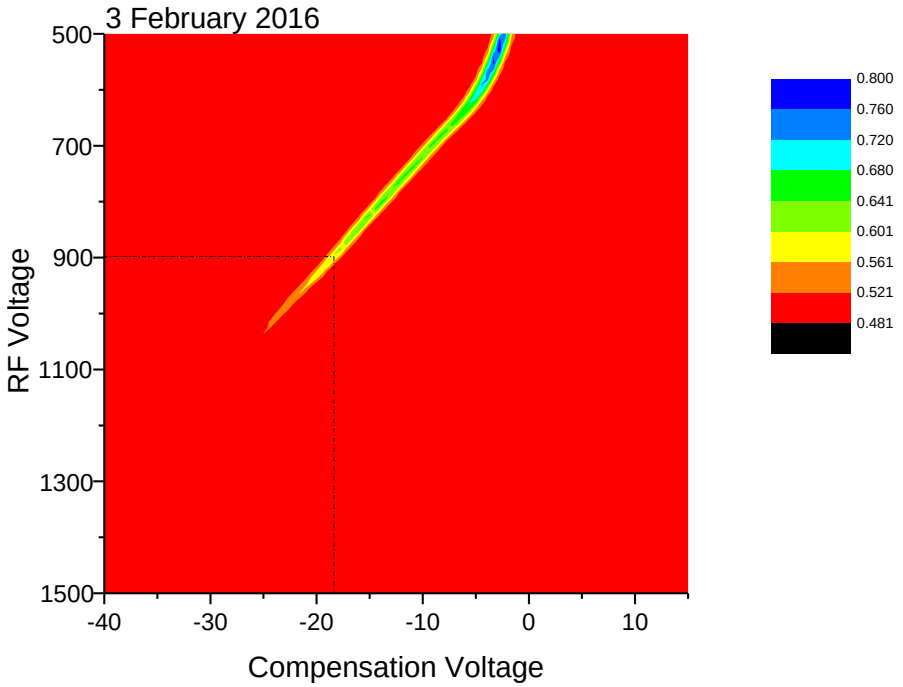
- Installation of Node 1 charcoal filters - decrease in LAB siloxanes but no decrease in condensate DMSD
- Suspicion that transient higher siloxane levels present in Node 3 near CHX
- AQM 1005 moved to Node 3 to monitor siloxane levels during condensate collection following routine 30-day dry-out of CHX

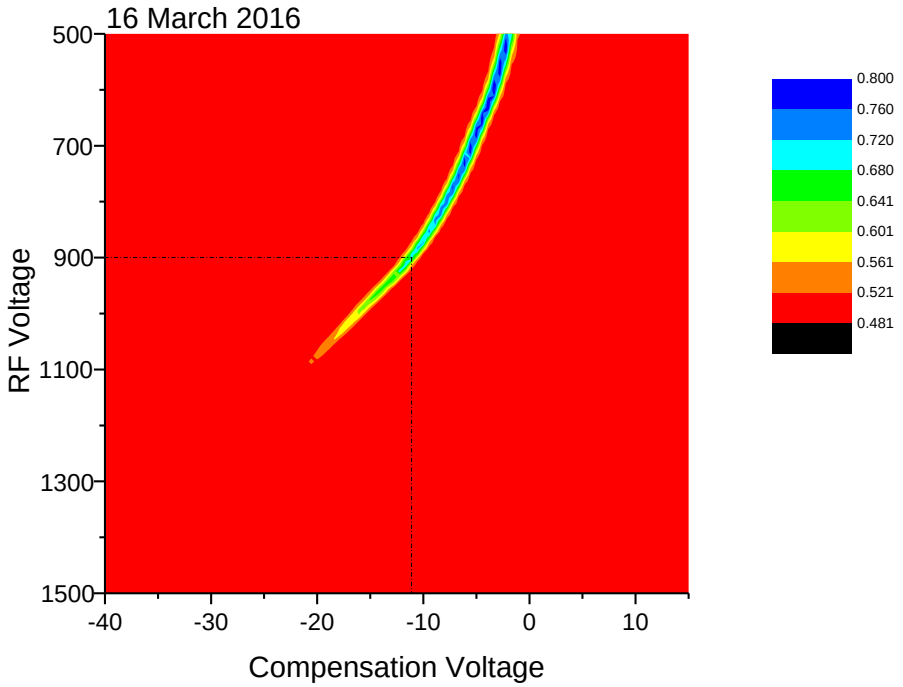
Use of AQM for Contingencies



- January 14, 2015 AM: Ammonia release alarm on ISS
- Crew donned masks, evacuated to RS, and closed hatches
- Operated remotely, AQM one of several real-time instruments used to confirm no ammonia present (official confirmation via Dräger tubes)

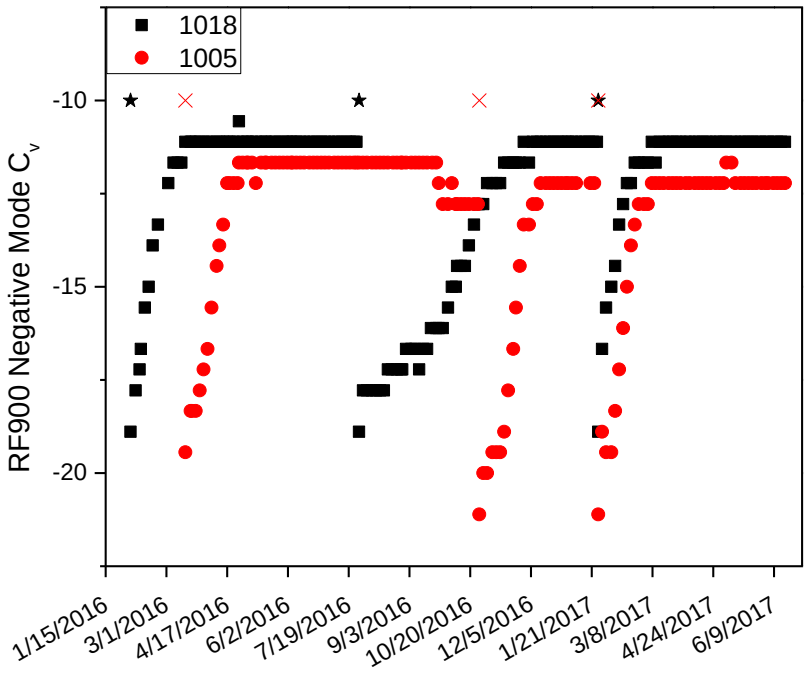
Change in Negative Mode RIP

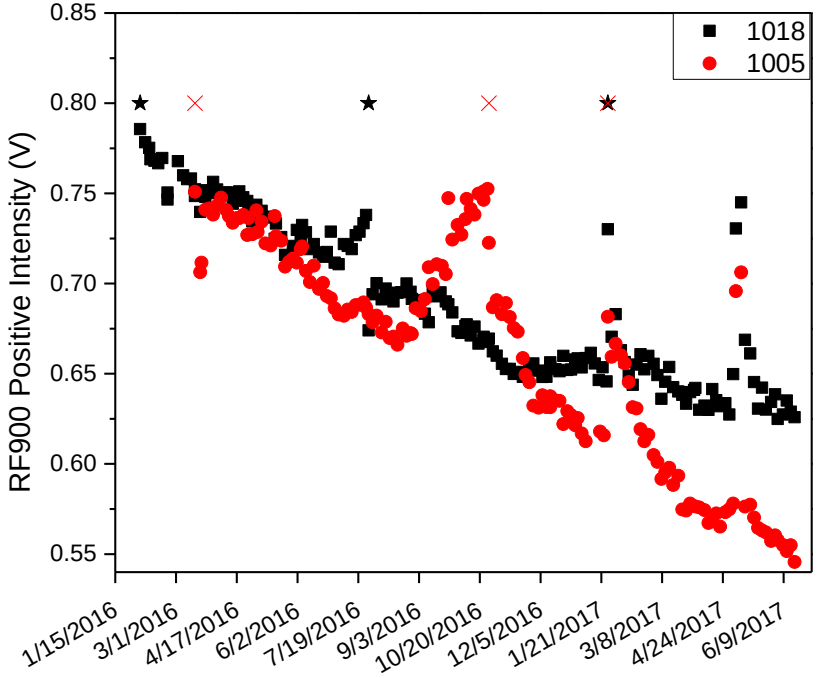




- When fresh sieve packs present, negative mode RIP is hydrated superoxide, $O_2(H_2O)_N^-$
- As CO_2 enters the system, RIP becomes $O_2 \cdot CO_2(H_2O)_N^-$
- Change in composition affects ionization chemistry and sensitivity towards compounds detected in negative mode; requires manual analysis of negative mode analytes
- Use of alternative sorbent materials in sieve packs could help to reduce CO_2 effects

Changes in RIP





- Change in negative mode RIP is reproducible after sieve pack change out
- Decrease in positive mode intensity shows that system is becoming dirtier
  - Increase in DMS temperature could potentially improve cleanliness

Summary

- AQMs have been successfully operating on ISS for 4.5 years
- Usage has been shown in nominal, contingency, and investigative situations
- Some lessons learned during initial deployment (expanded ethanol calibration, sieve cartridge changes, etc.)
- Introduction of CO_2 into system continues to be problematic

Acknowledgements

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