Methane and Carbon Monoxide Concentration Dynamics of the International Space Station's Cabin Atmosphere

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Introduction

Methane and carbon monoxide:

- Common gaseous contaminants
- Generation sources: human metabolism and equipment offgassing

Overview of:

- Generation source magnitudes
- Active control methods
- Concentration dynamics over 19 years of ISS operations

Evaluate:

- Perceived interactions between octafluoropropane leak events and methane and carbon monoxide concentration dynamics

Conclusions

Methane Sources

Human metabolism

- Between 30% and 60% of the human population
- ISS crew complements indicate 37% average production incidence

Source rates from breath (20%) and intestinal gases (80%)

- 4.8 mg/h average, 3.62 mg/h SD from breath
- 15.9 mg/h average, 3.4 mg/h SD from intestinal gases
- 0.22 mg/h via skin emissions

Very minor equipment offgassing source

- Offgassing from 10500 kg of equipment equivalent to 1% of a single person metabolic load

Carbon Monoxide Sources

Human metabolism

- Hemoglobin oxidation associated with the heme catabolism process

Source rate

- 0.77 mg/h average, 0.2 mg/h SD

Significant equipment offgassing source

- Offgassing from 9070 kg of equipment equivalent to a single person metabolic load
- Accounts for an estimated 31 mg/h aboard the ISS

Active Control Methods

Catalytic oxidation processes

- Platinum group metals supported on various substrates
- Methane requires high temperature
- Carbon monoxide can oxidize at ambient temperature
- Processes are susceptible to poisoning

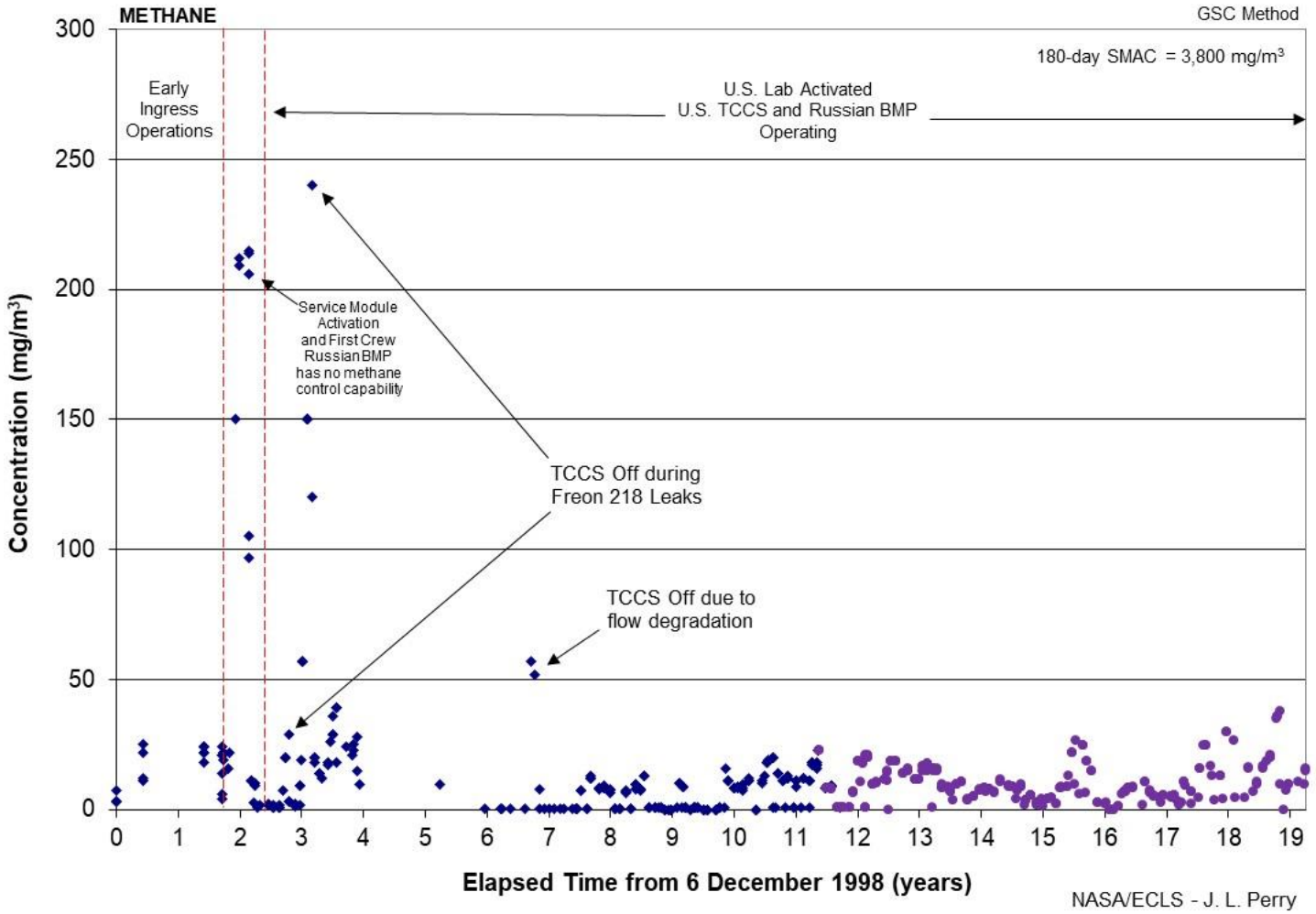
Observations from methane thermal catalytic oxidation poisoning investigations

- Sulfur compounds are strong, irreversible poisons
- Halocarbons are moderate, reversible poisons with concentration dependence
- Most catalyst poisons are present at levels that are expected to produce <10% methane oxidation efficiency losses

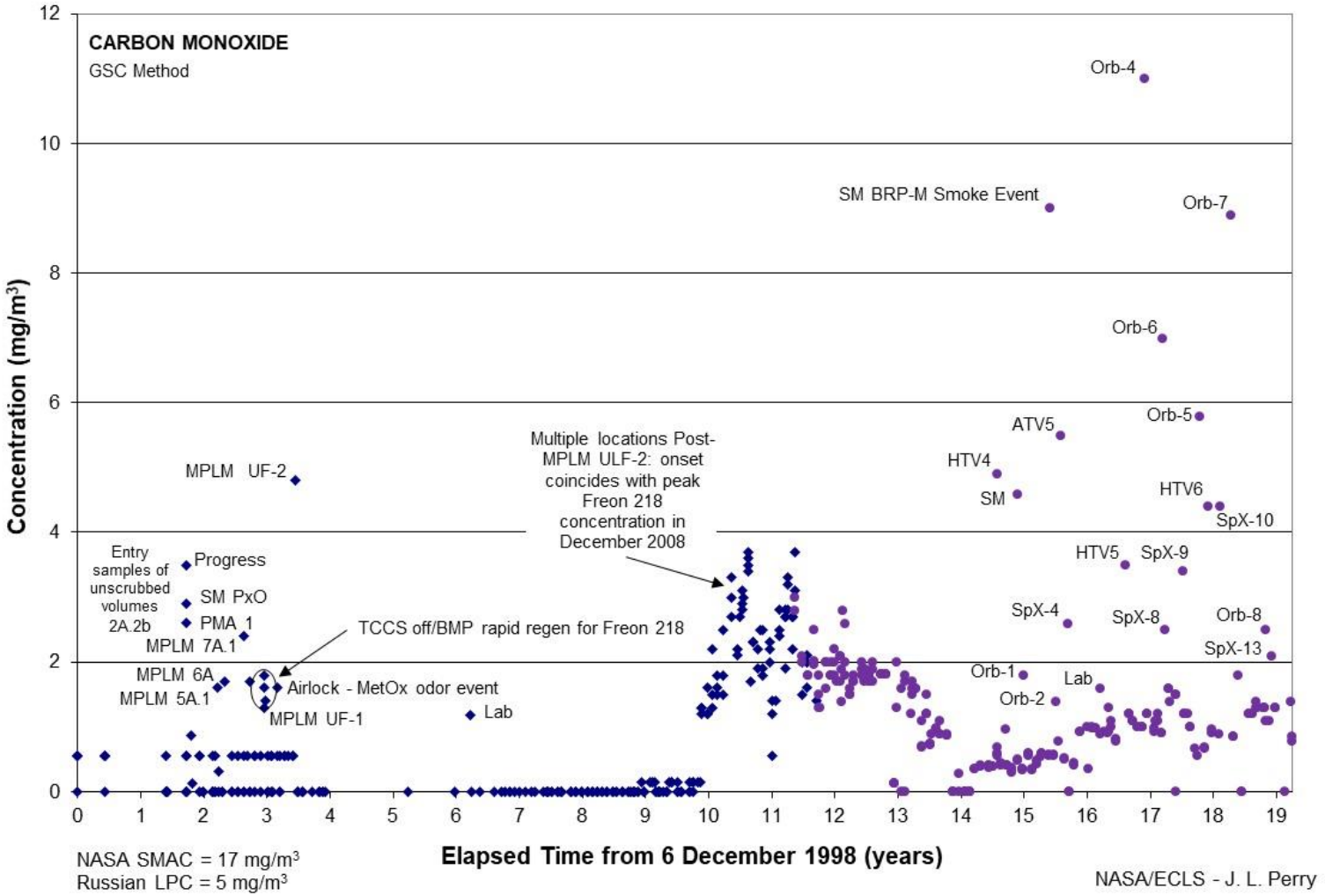
Observations on ambient temperature carbon monoxide oxidation poisoning investigations

- Ammonia and sulfur compounds are strong poisons
- Halocarbons produce up to 30% oxidation efficiency loss

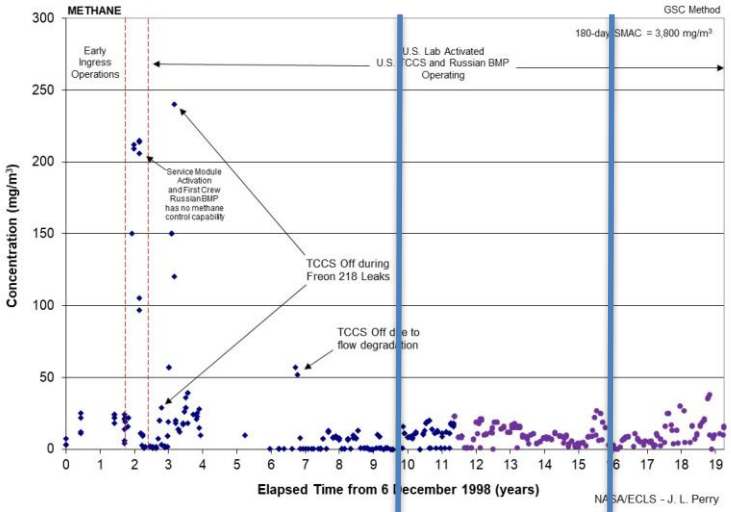
Methane Aboard ISS

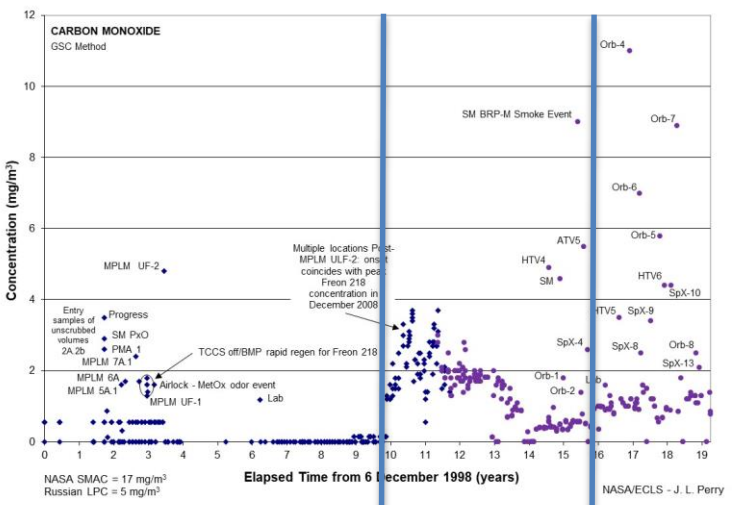


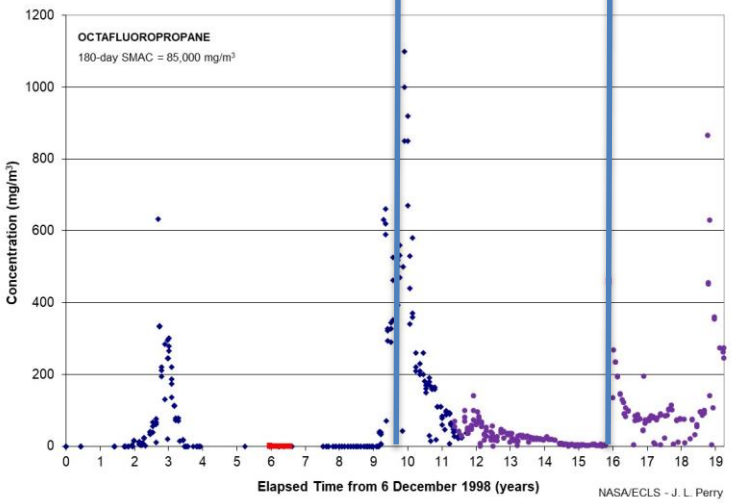
Carbon Monoxide Aboard ISS

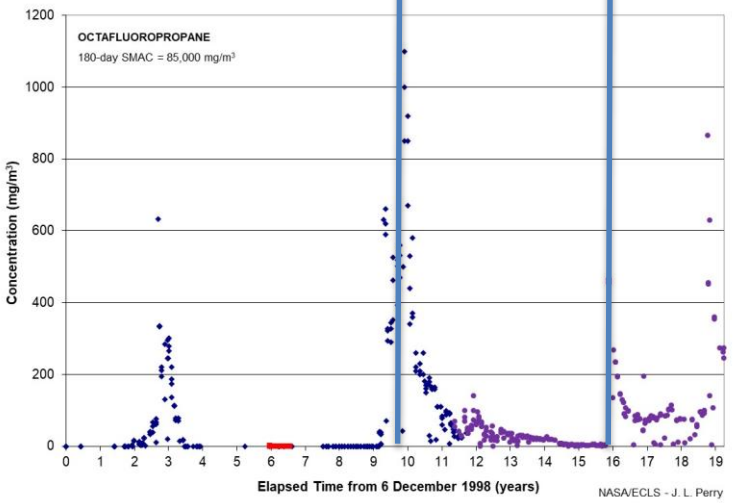


Octafluoropropane Effects (1)



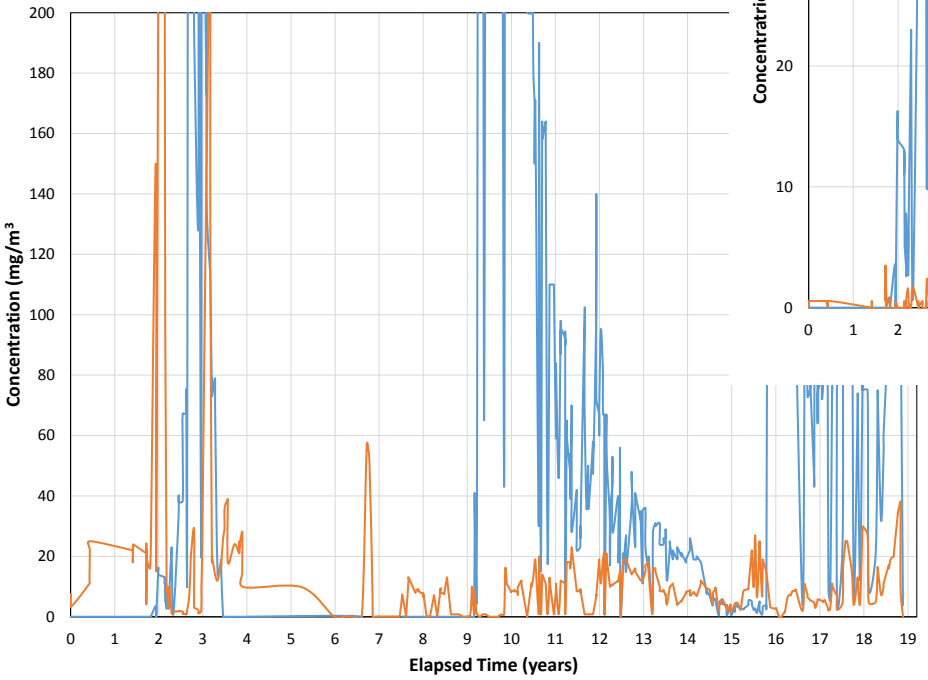


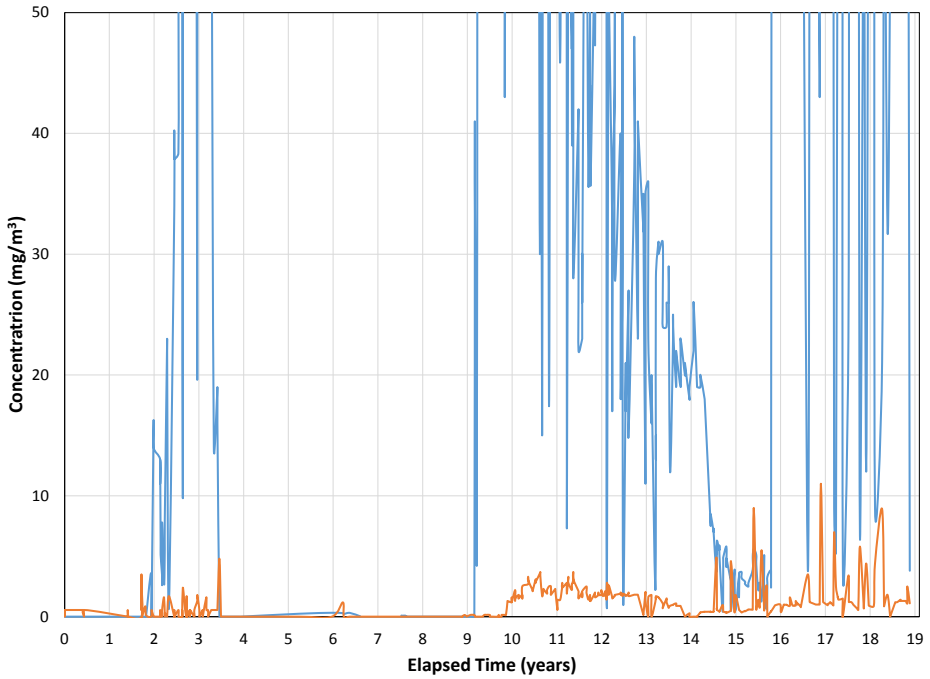




Octafluoropropane Effects (2)

Methane





Carbon Monoxide

Correlation with Octafluoropropane

Methane

- Weak correlation – correlation coefficients 0.3 to 0.4
- Indicates slight octafluoropropane effect on methane oxidation efficiency
- Variation more consistent with metabolic source variation

Carbon monoxide

- Very weak correlation with first and third leakage events – correlation coefficients 0.04 to 0.2
- Weak correlation with the second leakage event – correlation coefficient 0.4
- Variation indicates 41% reduction in removal capability
  - Consistent with some ambient temperature catalyst poisoning test observations
  - Additional testing needed for confirmation

Upstream activated carbon capacity for octafluoropropane can attenuate effects and confound correlation

Conclusion

- Methane and carbon monoxide have human metabolic and equipment offgassing sources:
    - 671 mg methane/day-person (>99% of the total sources)
    - 18.4 mg carbon monoxide/day-person (13% for 6 crew)
    - Carbon monoxide offgassing source is 744 mg/day (87% for 6 crew)
- Methane and carbon monoxide have been well controlled:
    - Methane typically <20 mg/m^3 versus 3800 mg/m^3 maximum allowable.
        - Methane concentration variation is consistent with human metabolic source variability.
    - Carbon monoxide typically <2 mg/m^3 versus 17 mg/m^3 maximum allowable.
        - Offgassing accumulation in cargo vehicles accounts for higher concentrations.
- Weak indication that control is inhibited by high octafluoropropane concentrations:
    - Weak correlation between methane concentration and octafluoropropane leak events.
    - Weak correlation between carbon monoxide concentration and one octafluoropropane leak event.
    - Similar effect magnitude on control performance is indicated by past oxidation catalyst tests.
    - More investigation is needed to confirm the observed weak correlation.
    - Varying activated carbon capacity for components upstream of the catalytic oxidizer stages can attenuate poisoning effects and confound correlation.