National Aeronautics and Space Administration

Establishing an Effective Sensor Distribution for Localizing Methane Sources on the Martian Surface

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Objectives:
- To demonstrate the ability of multiple surface detectors, operating simultaneously, to localize a regional source or sources of methane from the martian surface.
- Establish the optimum configuration of multiple detectors in and around Gale crater to find source of methane observed by Curiosity.

Approach and Results

Localization of methane signals

- We use the Stochastic Time-Inverted Lagrangian Transport (STILT) model and the MarsWRF general circulation model to simulate methane plume transport and dispersion.
- STILT generates 'footprints' of virtual air particles that indicate the source locations of air that reach a specific detector at a specific time.
- *Example with a single detector*: From these footprints, we can generate a map showing the mass of methane required to produce a signal of some abundance (we choose 5 ppbv) at a single detector (Figure 1, black dot) from any arbitrary location.

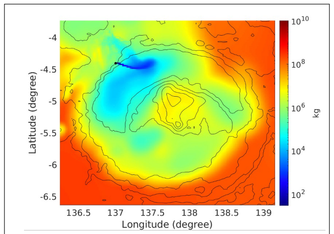

Figure 1. A mass footprint map, which shows the necessary amount of methane released steadily over 10 days from an emission site such that the detector (black dot) detects a signal of 5 ppbv.

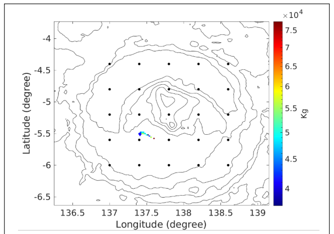

Figure 2. Black dots indicate the position of the 25 sensors. Blue diamond represents the prescribed location of the methane source. Colored region shows possible source locations that produce same detection pattern.

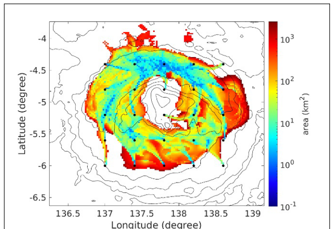

Figure 3. Area of possible source locations as a function of actual source location. White=methane source region could not be detected by any surface detectors. Colors=level of localization.

- *Example with multiple detectors*: Now, assume 25 detectors as arrayed in Figure 2 (black dots). Each detector will have its own map similar to Figure 1. If we place an arbitrary methane source somewhere in this region (e.g., at the blue diamond), some of the 25 detectors will sense a signal >5 ppbv, some will not.

BUT…

- There may be other potential source locations in the region that result in the same detection pattern (small, colored region in Figure 2). This tells us how good our chosen detector distribution is at localizing a source at that arbitrary location.
  - Few matching locations → detector array can highly localize the source (e.g., Figure 2).
  - Many matching locations → source can't be well localized using this detector distribution.
- For a fixed emission abundance and sensor distribution, we can create a regional map showing how well a signal from *any* potential source location in the region can be localized (Figure 3).

Background:
- The origin of methane in the Martian atmosphere has implications for the geology, geochemistry and astrobiology of the planet.
- The Tunable Laser Spectrometer (TLS) onboard Curiosity has detected several spikes in methane abundance, but their source and emission time have not been well constrained.
- Previously, we have applied back trajectory modeling of atmospheric circulation in Gale crater to better constrain the source location of the TLS observations.
- A network of small surface sensors can be used to further constrain source locations, and provide wider coverage across a specific region (like Gale crater), than a single sensor, alone.

Number of detectors

- Fraction of Gale crater having 'good' localization (<10 km radius) is ~45% for sensing a 5 ppbv signal with 25 detectors, assuming a ~10^5 kg source emission (Figure 4, orange curve).
- Tests show that more detectors enhance localization (Figure 5), but with diminishing returns
- ~20-25 detectors provides the best 'bang for the buck' for this scenario.

Detecting multiple methane spikes

- Two signals, from two different seasons with different circulation patterns, can increase the surface coverage having 'good' localization (<10 km radius) to nearly 70% (Figure 6).

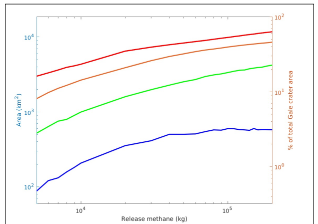

Figure 4. Sizes of four localization area categories (1, 3, 10, 30 km radius; blue, green, orange, red, respectively) as a function of the mass of methane released from a potential source. Up to 45% of Gale crater would have 'good' localization (<10 km radius) for a ~10^5 kg source.

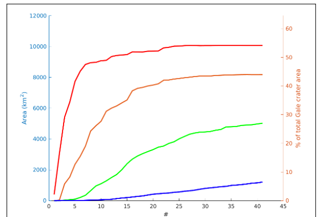

Figure 5. Sizes of the four localization area categories as a function of the number of detectors, from 1 to 41. Orange curve levels off between 20-25 detectors. Higher levels of localization (green, blue curves) can benefit from additional sensors.

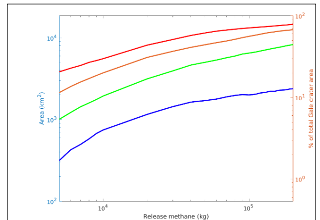

Figure 6. Same as Figure 4, but for two distinct detections from the same source in different seasons, with different atmospheric circulation patterns. Up to 70% of Gale crater would now have 'good' localization (<10 km radius) with these two separate ~10^5 kg emissions events.

Significance/Benefits to JPL and NASA:
- This work illustrates the number and scale of sensor distribution required to effectively localize these signals such that they could be approached by a future rover mission.
- Network could be delivered/dispersed on low-cost entry vehicle such as SHIELD
- Can leverage of new JPL technology such as mini-TLS instrumentation.
- Investigating Mars methane, is identified as a priority of MEPAG (Goal II, Subobjective A3) and noted in the Planetary Science Decadal Survey.

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