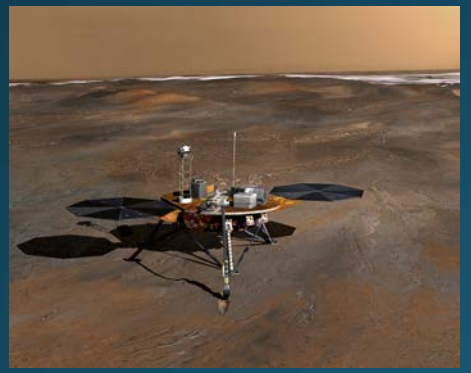
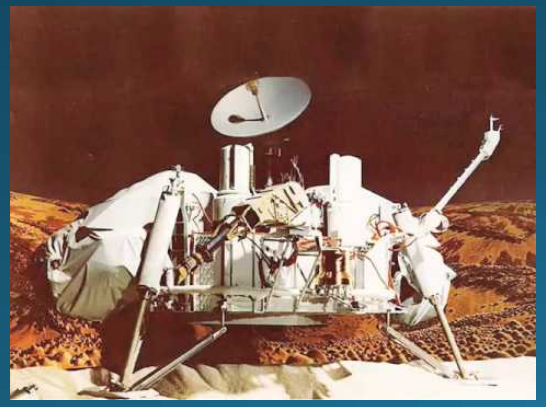
Atmospheric Transport of Contaminants and Microbes on Mars





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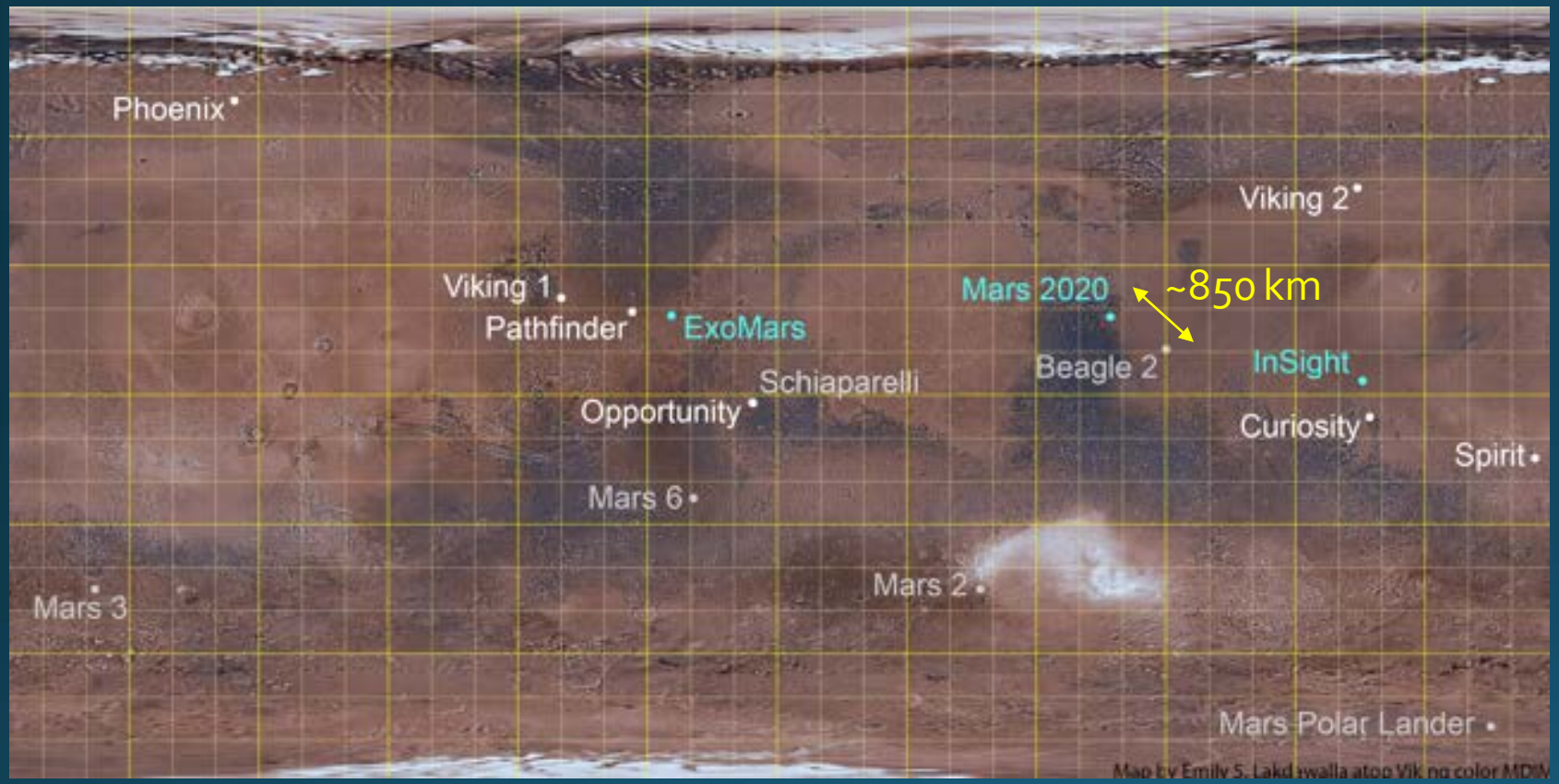
Over a Dozen Forward Contamination Events



Thought Experiment: Toss a handful of very fine dust into the atmosphere from the steps of the Lincoln Memorial, Washington D.C. What is the probability that a single particle would land in a small area on the Rockefeller Plaza ice rink in NYC and that you would find it after a few random samples ?

What is the potential for contamination transport from one location to another?

Transport Considerations

- Source Function
  - Total contaminant reservoir
  - Viable reservoir fraction
  - Mobilization processes and transport vector
- Transport
  - Wind
  - Turbulence
  - Sedimentation
  - Aerosol and microphysical interactions
- Sinks/Destruction Mechanisms
  - Ionizing radiation
  - UV spectrum
  - Chemistry
  - Temperature
  - Humidity/Water activity
  - Electrodynamics
  - Others?

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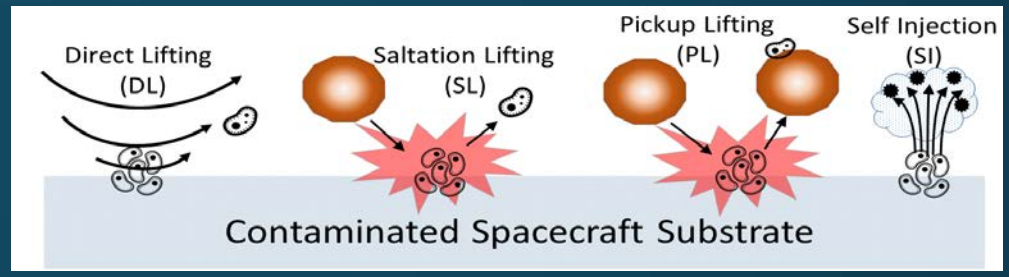

Rafkin, PPRP proposal, 2018

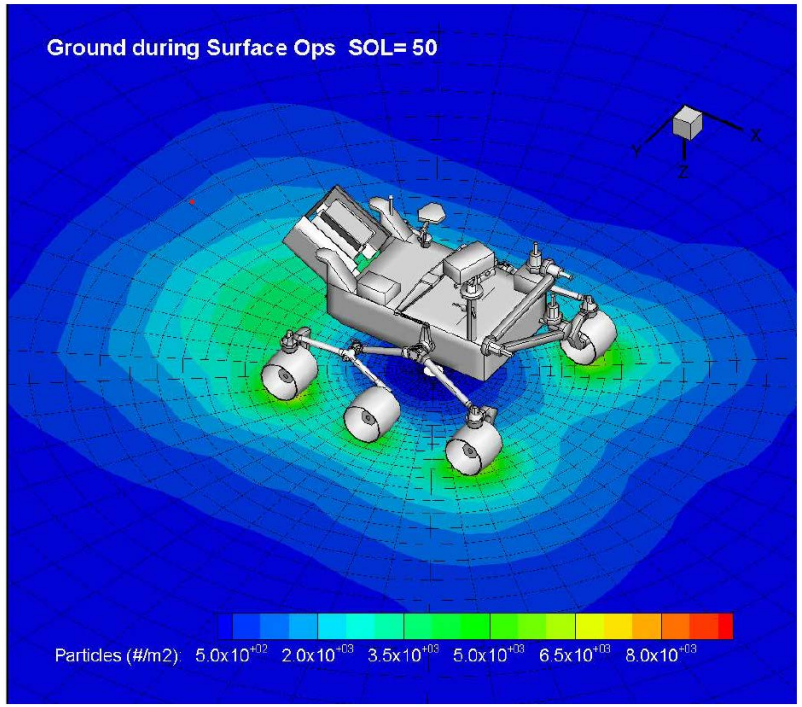

Fig. 4. Illustration of particle resuspension and transport for the Mars 2020 rover on the surface of Mars

Soares et al., 68th IAC, 2017

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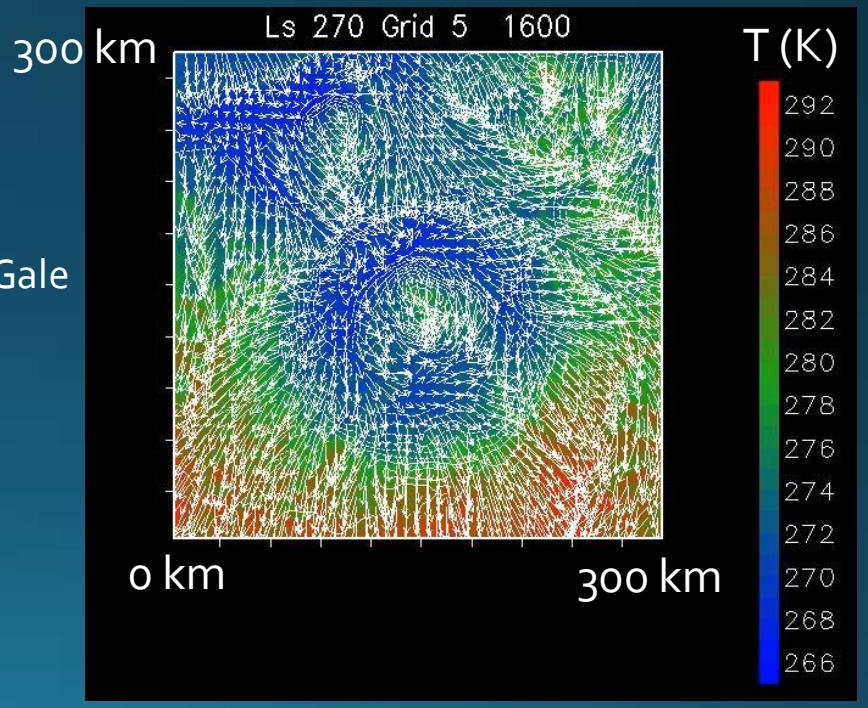
Large Eddy Simulation of Afternoon Turbulence



Near-Surface Winds in the Gale Crater Area. (Rafkin et al., Icarus, 2016)

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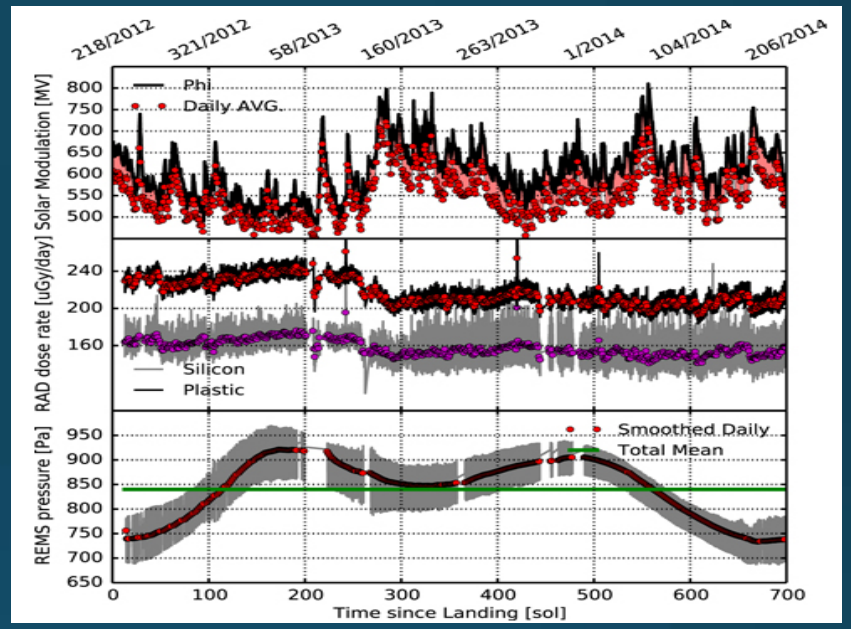
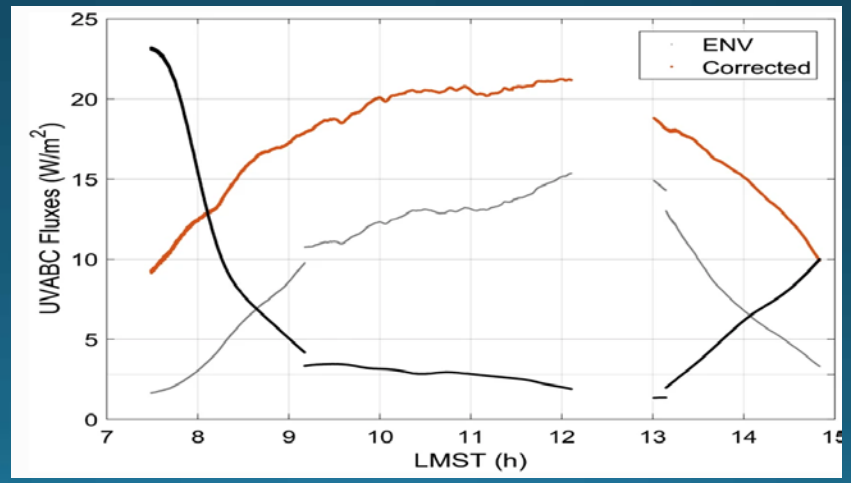


Measurements for the Mars Science Laboratory RAD and REMS Investigation (Guo et al., 2015)



UVABC flux from MSL REMS (Vicente-Retortillo et al.,Space Sci. Rev., 2020)

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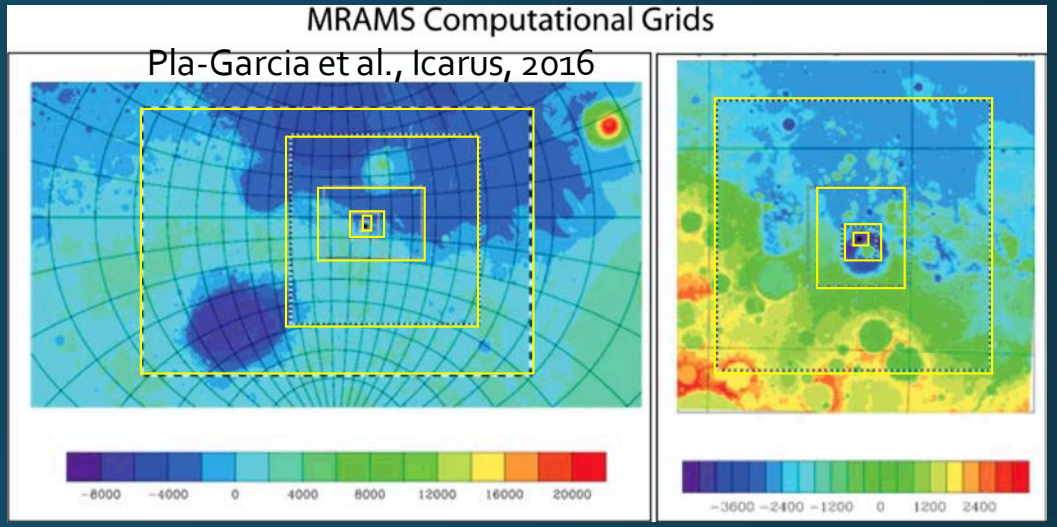
- This is a highly interdisciplinary problem.
- Many of the elements are poorly understood, poorly constrained, or highly uncertain.
- Parametric studies and simplifications can bound the problem.
- This study:
  - Ignore source function.
  - Ignore sedimentation and microphysics.
  - Ignore destruction.
- Future Work will incrementally add complexity to encompass additional source, transport, and destruction mechanisms.

Modeling Transport at MSL: Tracers and Trajectories in the Mars Regional Atmospheric Modeling System

The Mars Regional Atmospheric Modeling System (MRAMS)

- A dynamic atmospheric model that calculates the time-varying atmospheric properties (Rafkin et al., 2013, 2020).
- Includes topography and realistic surface properties.
- Nestable: high-resolution coverage over limited domains and coarser resolution over larger domains.



Tracers

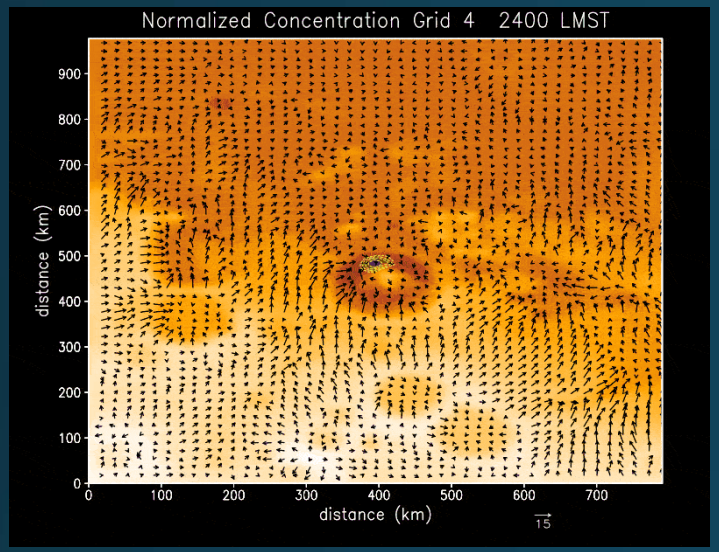
- Initialize a passive tracer at MSL.
- At t=0, tracer fills lowest level model grid box (3 km x 3 km x 14 m).
- Model winds and parameterized turbulence transport and mix tracer.
- Better suited to a gas that can be diluted, but instructional for particles.
- Provides some quantitative measure of dispersion and contamination probability.

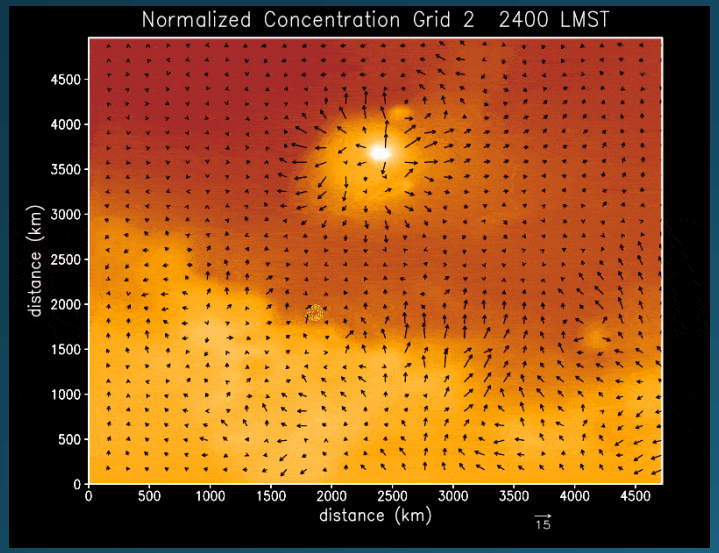
Trajectory

- Calculate the transport of a single particle by the model wind.
- Provides quantitative information on actual particle trajectories and histories.
- Can determine environmental properties along trajectory.
- Ensemble/Monte Carlo simulations quantify atmospheric transport chaos and chaotic attractors.

Example Tracer Experiment

Ls 90



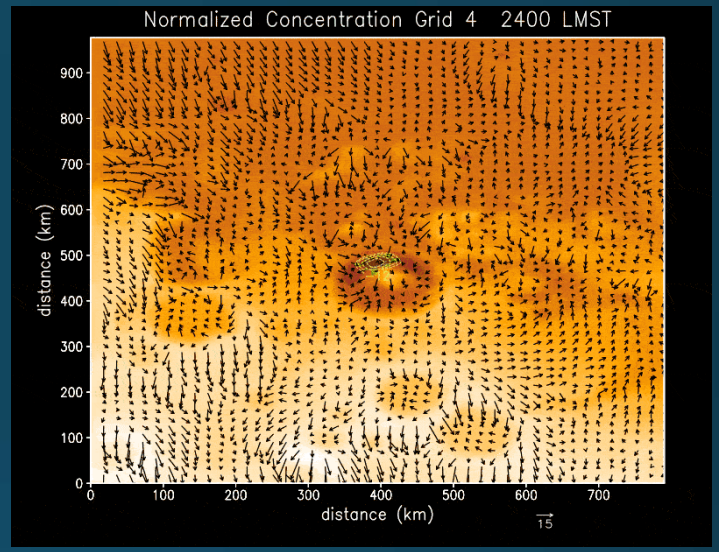


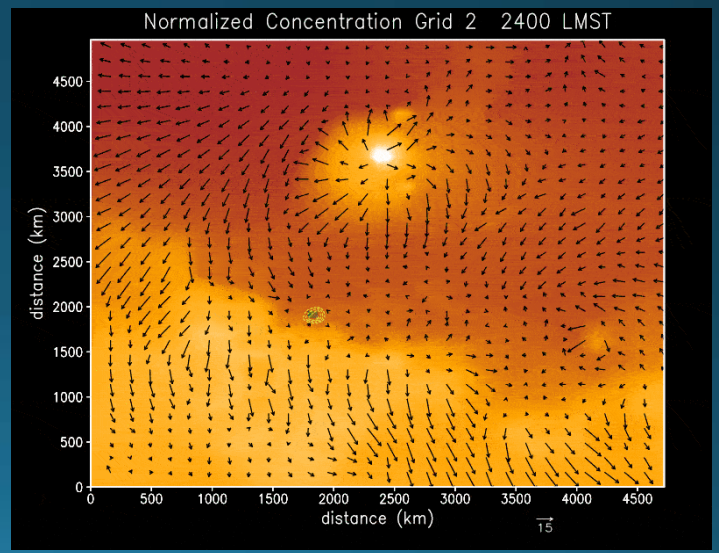
Log10(concentration)
Starting concentration = 1 .0 at MSL in Gale Crater

Grid 4: 8.8 km grid spacing

Grid 2: 80 km grid spacing

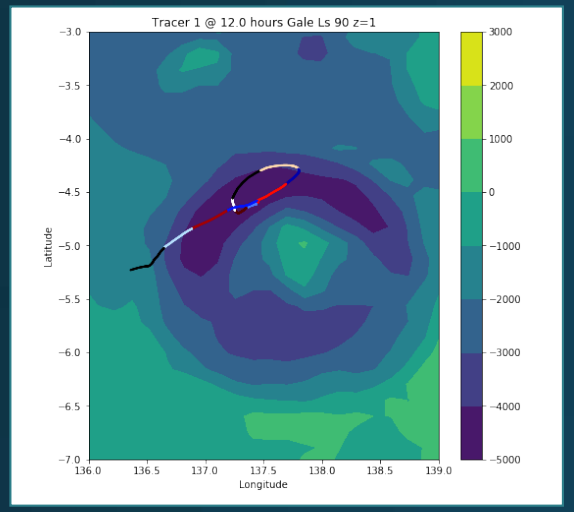
Ls 270





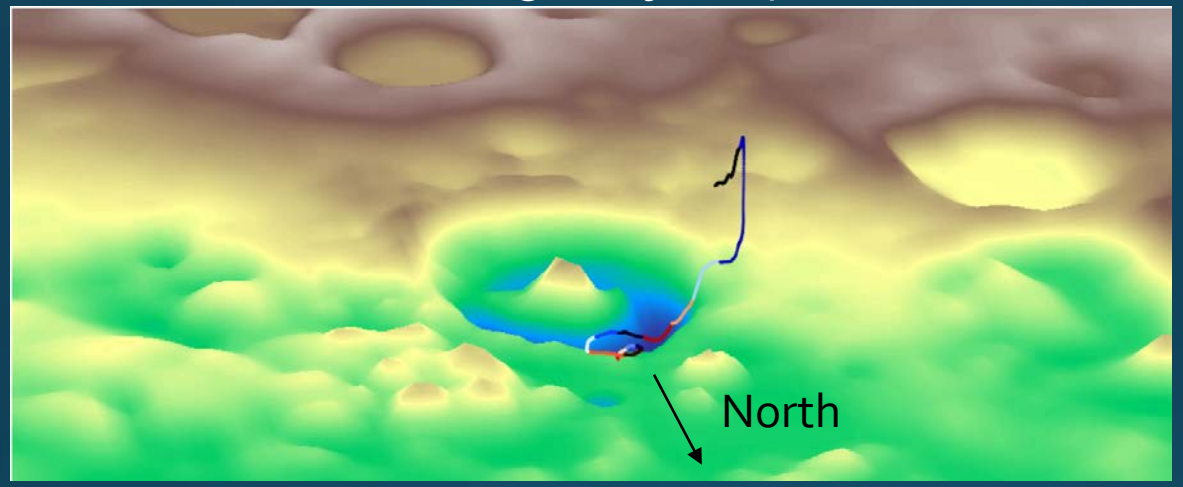
Example Trajectory Experiments Ls 90 with 12 Hour Integration

Single Trajectory

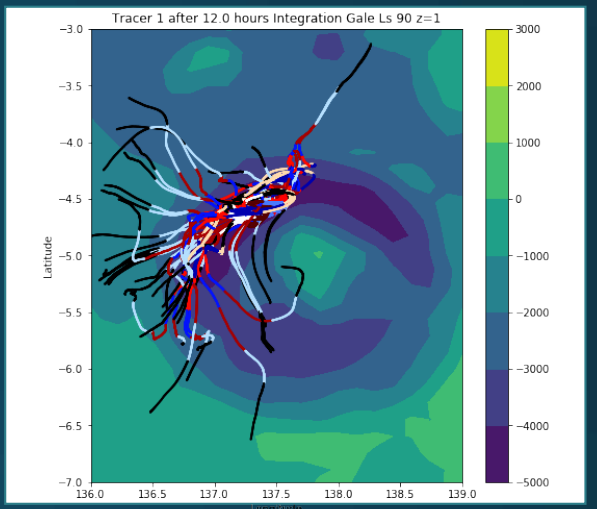


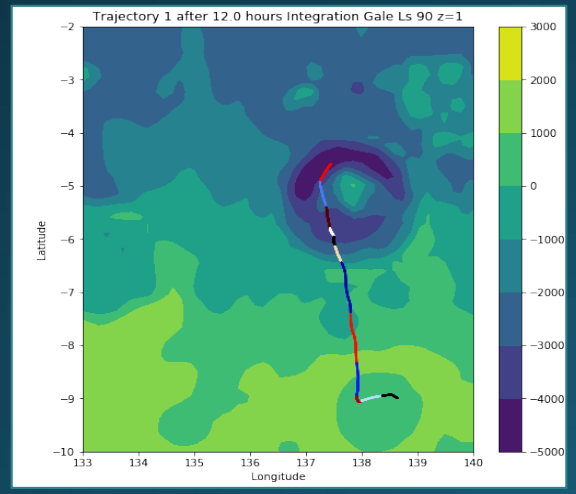
Morning Release

3-D Single Trajectory

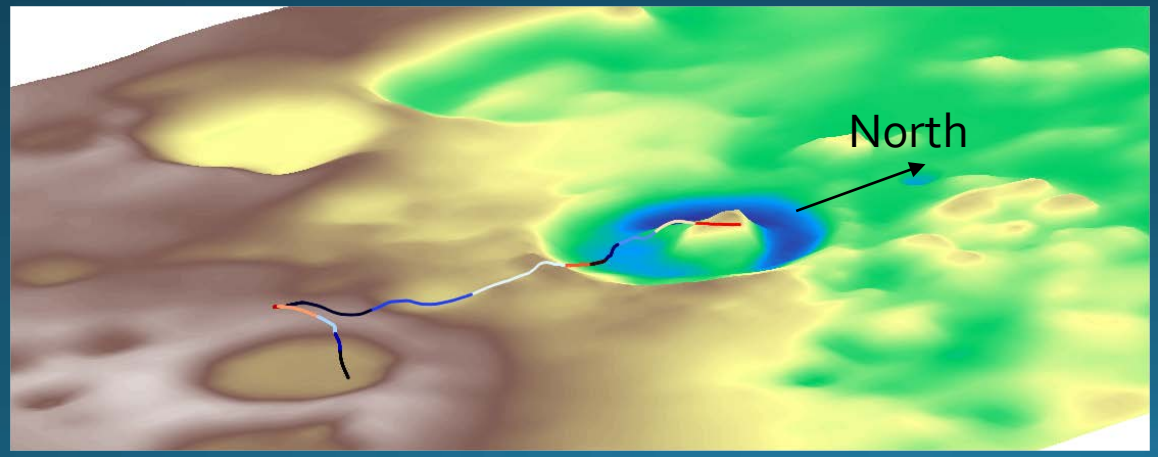


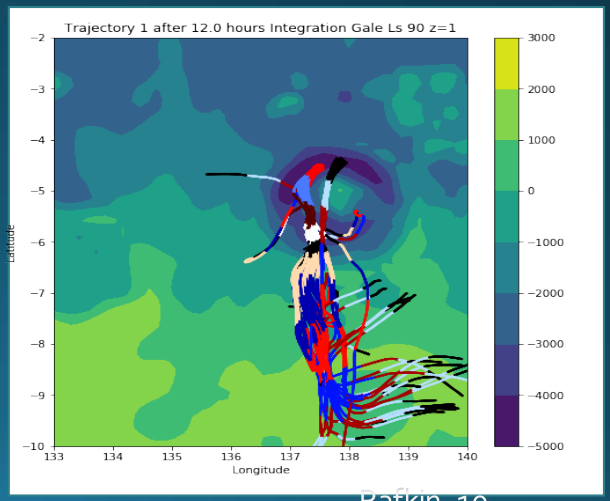
Ensemble of 48





Afternoon Release



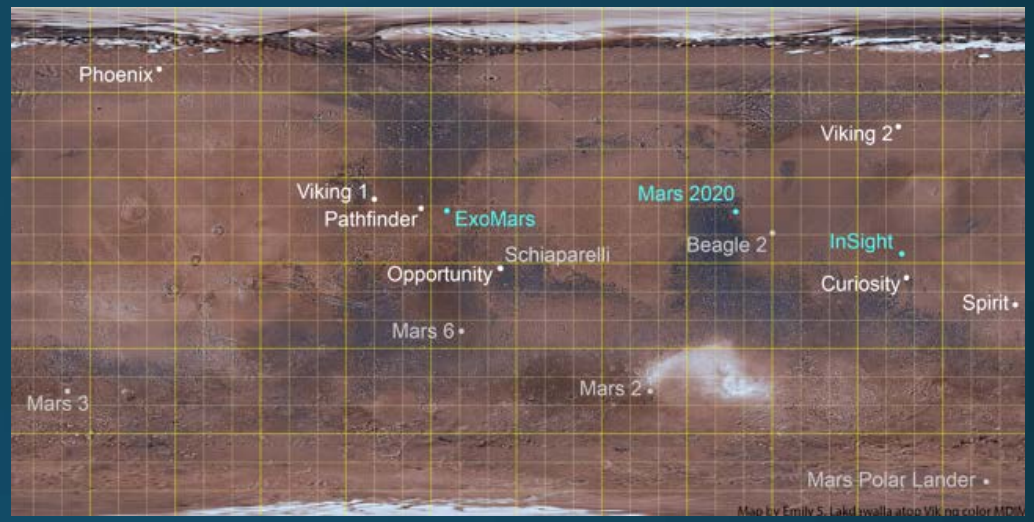


Rough Calculations (1/2)

- Assume source of 1 particle per m^3 in a model box (3 km x 3 km x 14 m).
  - A spacecraft of 6 m^2 surface area fluxing 100 particles per meter squared per sec fills this volume in ~2.5 sols.
- Our tracer experiments indicate a dilution of at least 9 orders of magnitude a few hundred km away.
  - Yields 1 particle per 10^9 m^3 in the lowest 14 m
  - 1 particle per $7x10^7$ m^2 (Note: Mars surface area = $1.4x10^{14}$ m^2)
- Assume that all particles in this box fall to the ground => add 1 particle to an area of 70 km^2 every 2.5 sols.
- In 100 Mars years ~27,000 particles would accumulate in that area.
  - 27,000 particles per $7x10^7$ m^2 after 100 years.
  - Two particles per football field after 100 years.

Rough Calculations (2/2)

- M2020 surface sample size is order 0.01 m x 0.01 m = $1x10^{-4}$ m^2.
- Probability of collecting this particle is: 10^{-4} m^2 ÷ $2.7x10^3$ m^2/particle= 3.7×10^{-8}.
  - Probability of royal flush: $1.5x10^{-6}$.
  - Probability of getting struck by lightning (in U.S.) in a lifetime: $6.5x10^{-5}$.
  - Probability of getting killed by meteorite (est.): $4x10^{-6}$.
  - Hence, probability is very, very low.
- Rough calculations, backed by preliminary model results, *generally* indicate contamination is only a local/regional issue.
- Our rough calculations will be refined with ongoing modeling, including back trajectory calculations, time varying source functions, and sink processes.



- Closest contamination site to M2020 is Beagle 2 @ ~800 km.
- 17 years ago, not 100 years.
- Likely not continuously fluxing 100 particles/m^2/sec for 100 years.
- Beagle not continuously upwind of M2020.
- Degradation of organics not factored in.
- Not all particles in lowest layer will settle to surface.

Top 5 Lessons from MRAMS Transport Experiments

5. Transport circulations are complex and vary strongly in space and time (minutes to seasonal).

4. Transport is location specific.

3. Mars transport *tends* to be highly dispersive.

2. Contamination *typically* drops by many orders of magnitude (e.g., 10^{12}) outside of immediate source region and continues to fall with distance.

1. The probability of transporting a single particle into a small sampling area hundreds of km away is excruciatingly small.