Weather forecast on Mars

Why? and How?

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Why weather forecast on Mars?

- Expansion of human activities

  Mars would be the target of manned exploration

  next of Moon

  (NASA is targeting to realize in 2030s)

- Mars for the business use

  - Water and resource exploration

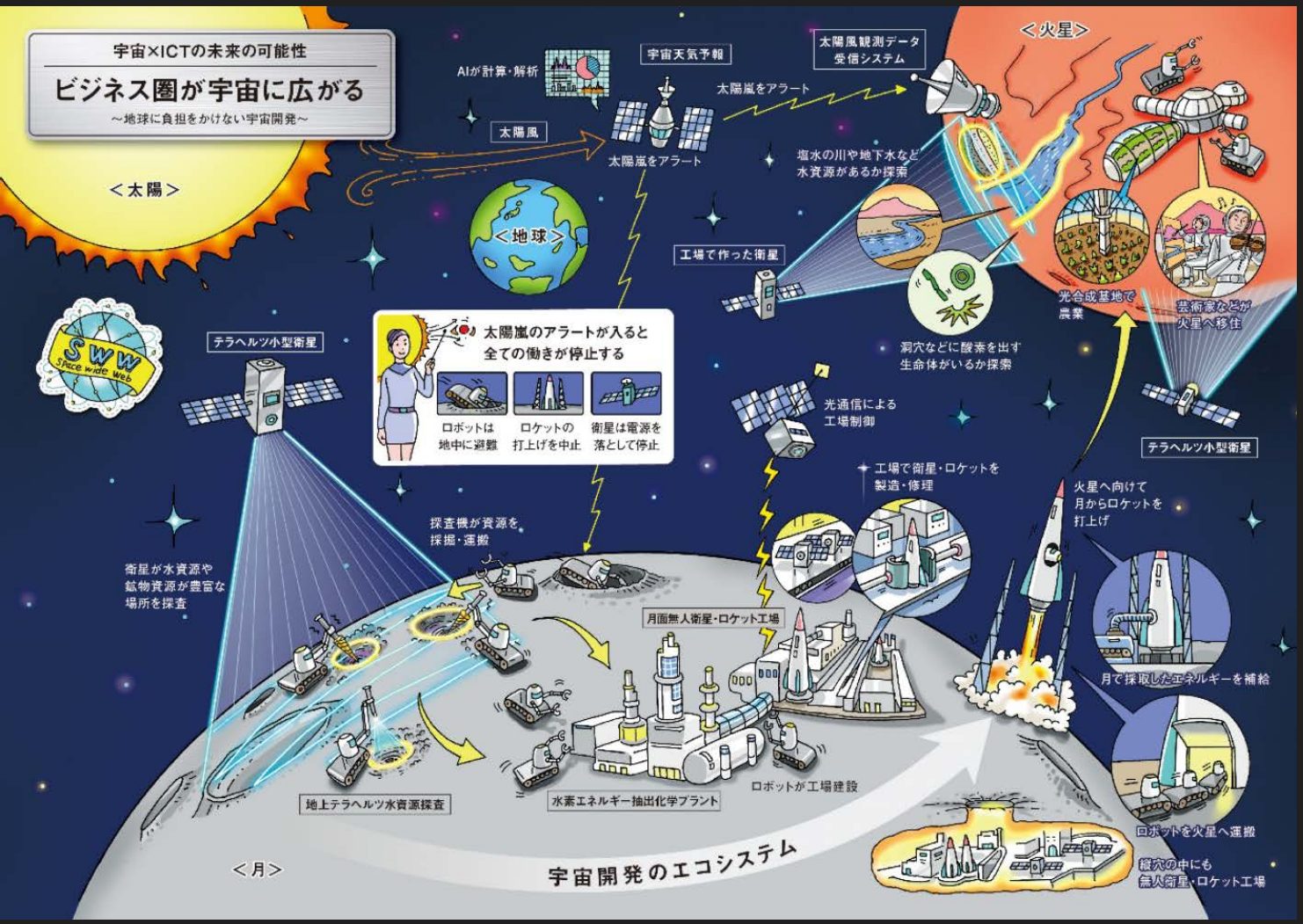
  - Immigration

  - Entertainment

  (Artists would be the first immigrants on Mars)

Cartoons of space use in 2030s

Space services including Moon and Mars



- Space weather alert system
- Space stations on Moon
- Search and use of resources on Moon and Mars: to ease the terrestrial resource obligation
- Search of life on Mars

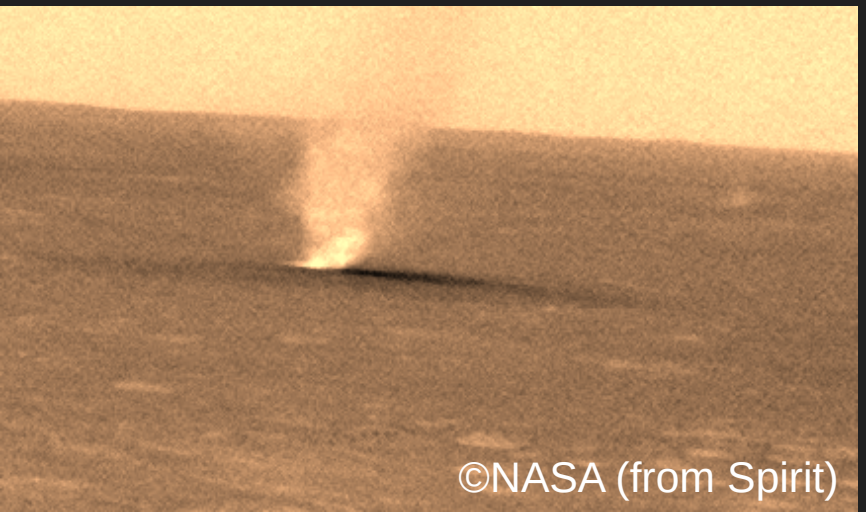
Cartoons of space use in 2030s

Space entertainments

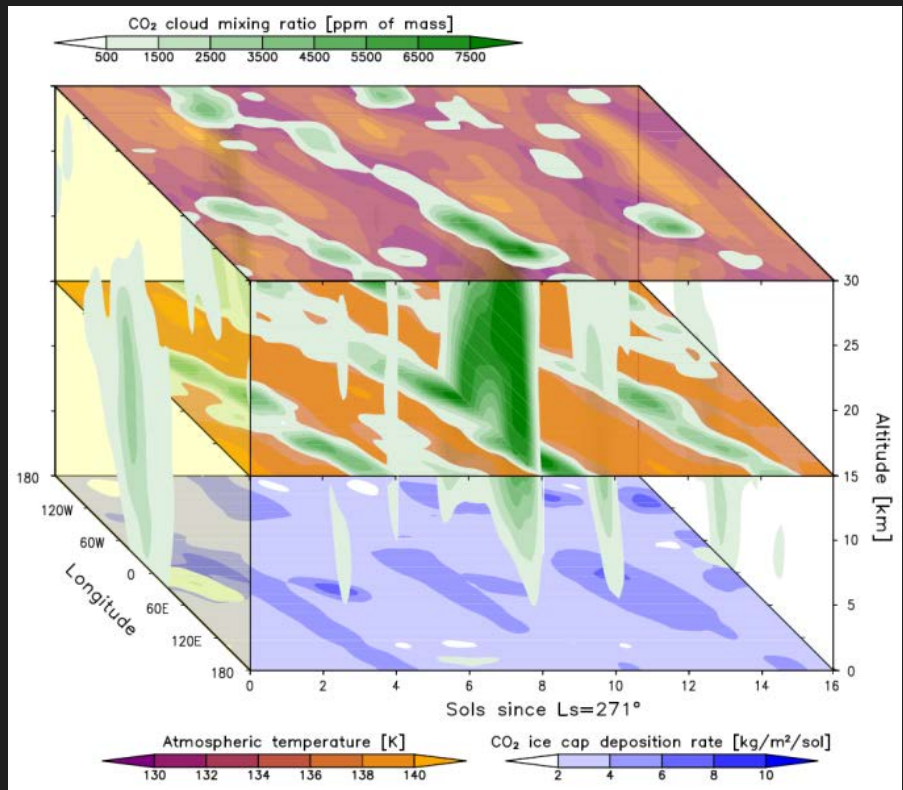
- Amusement park
- Trail running on Mars (with the use of avatars)
- Android idols on Mars
- Virtual sightseeing

Weather parameters to forecast

- For the practical activities on Mars
  - Temperature
  - Wind
  - Dust storms
  - Snowfalls (CO_2 and water)

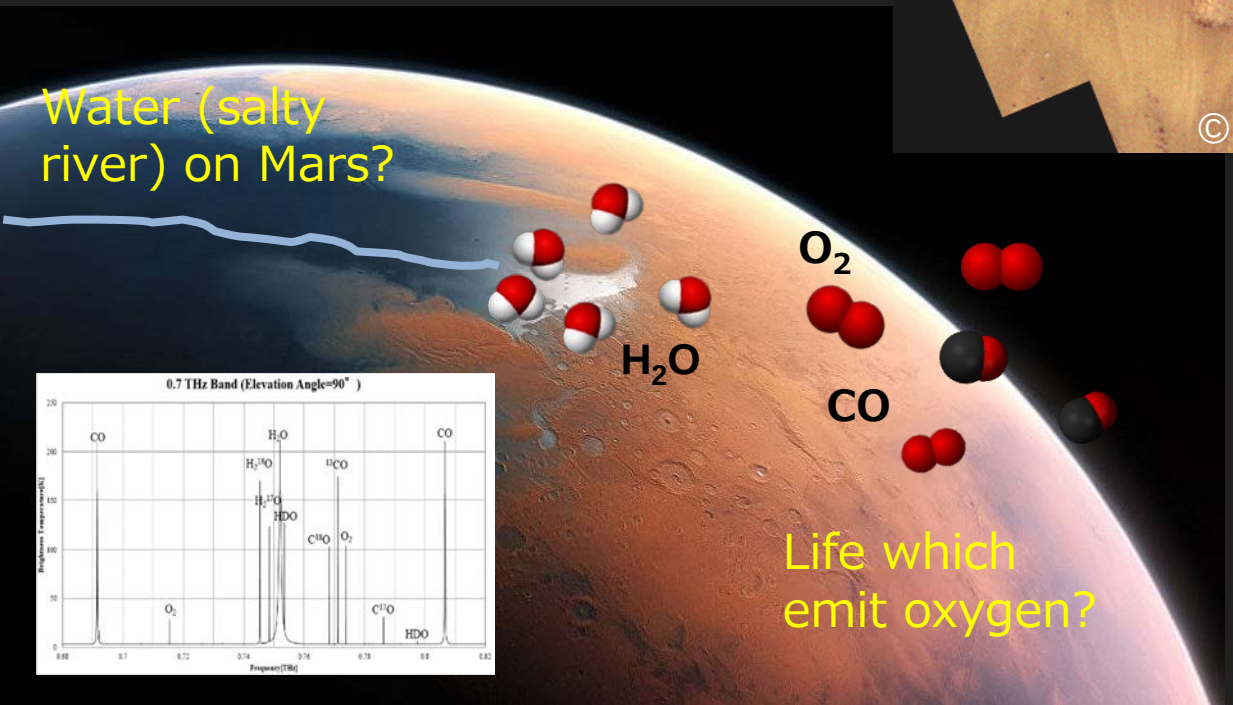


First indication of forecasting CO_2 snowfalls [Kuroda et al., GRL, 2013]



Weather parameters to forecast

- For the searches of resource and life
  - Water vapor
  - Other minor species (CH_4, O_2, O_3, H_2O_2, …)



How weather forecast on Mars?

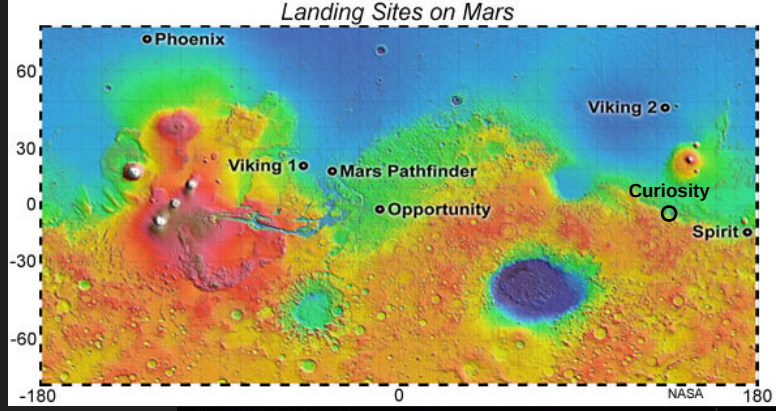
- Prediction of dust storms must be the key challenge

  Dust storms affect everything (temperature, stability, cloud formation, composition, …)

- How can we forecast the dust storms?

  Currently the parameterizations of surface wind stress and dust devils have been adopted into the atmospheric models, but far from the realistic forecasting with a lot of unknowns…

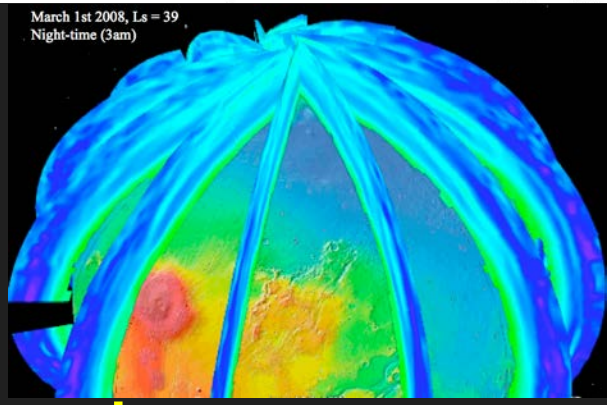
Possible solutions



- More observations

  Currently only 7 successful landers/rovers and several orbiters (mostly with fixed localtime)

  -> Only dots and lines!



MRO-MCS observational feature

- Improvement of parameterizations

  -> Should be after the increase of observations

- Others

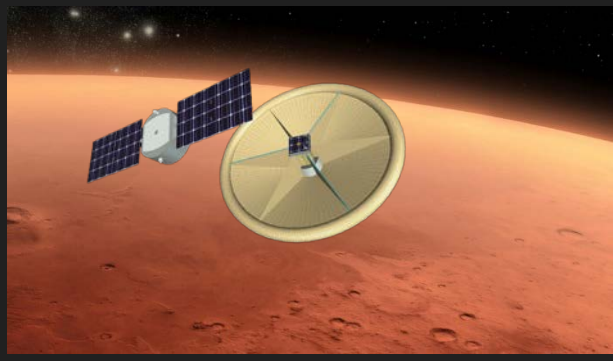
  New way(s) based on the observations corresponding to the current ‘big data’ era…

Desired ‘more observations’

- Much more ‘dots’ (landers)

  Microsatellite missions would help!

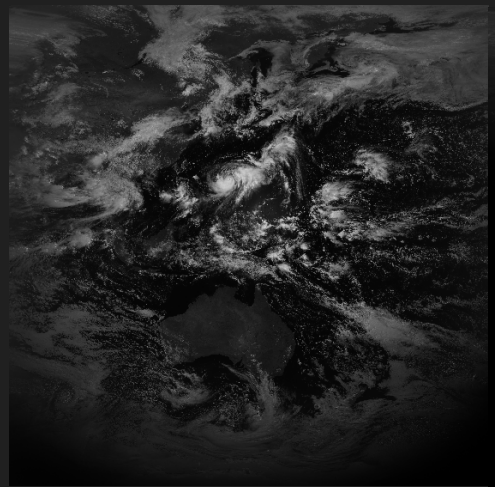
  (details later)



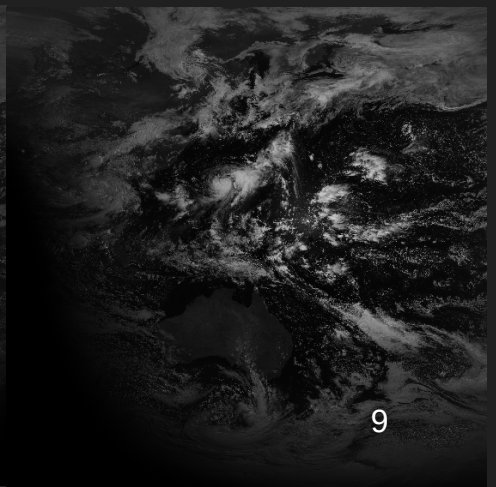
- ‘Plane’-style observations

  Geostationary(-like) observations would strongly help to catch the hourly-scale dust activities in a broad area

Every 1 day



Every 2 hours



Animations of terrestrial clouds using Himawari pictures [Imamura and Ogohara, SGEPSS 2012]

Upcoming ‘Plane’ observations (possibly)

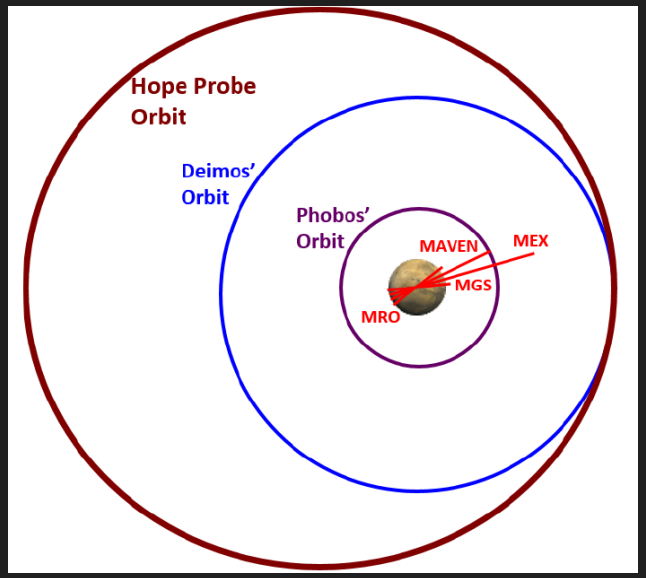
- Emirates Mars Mission

  Launching in 2020 and arriving at Mars in 2021, continuing global-scale-view observations

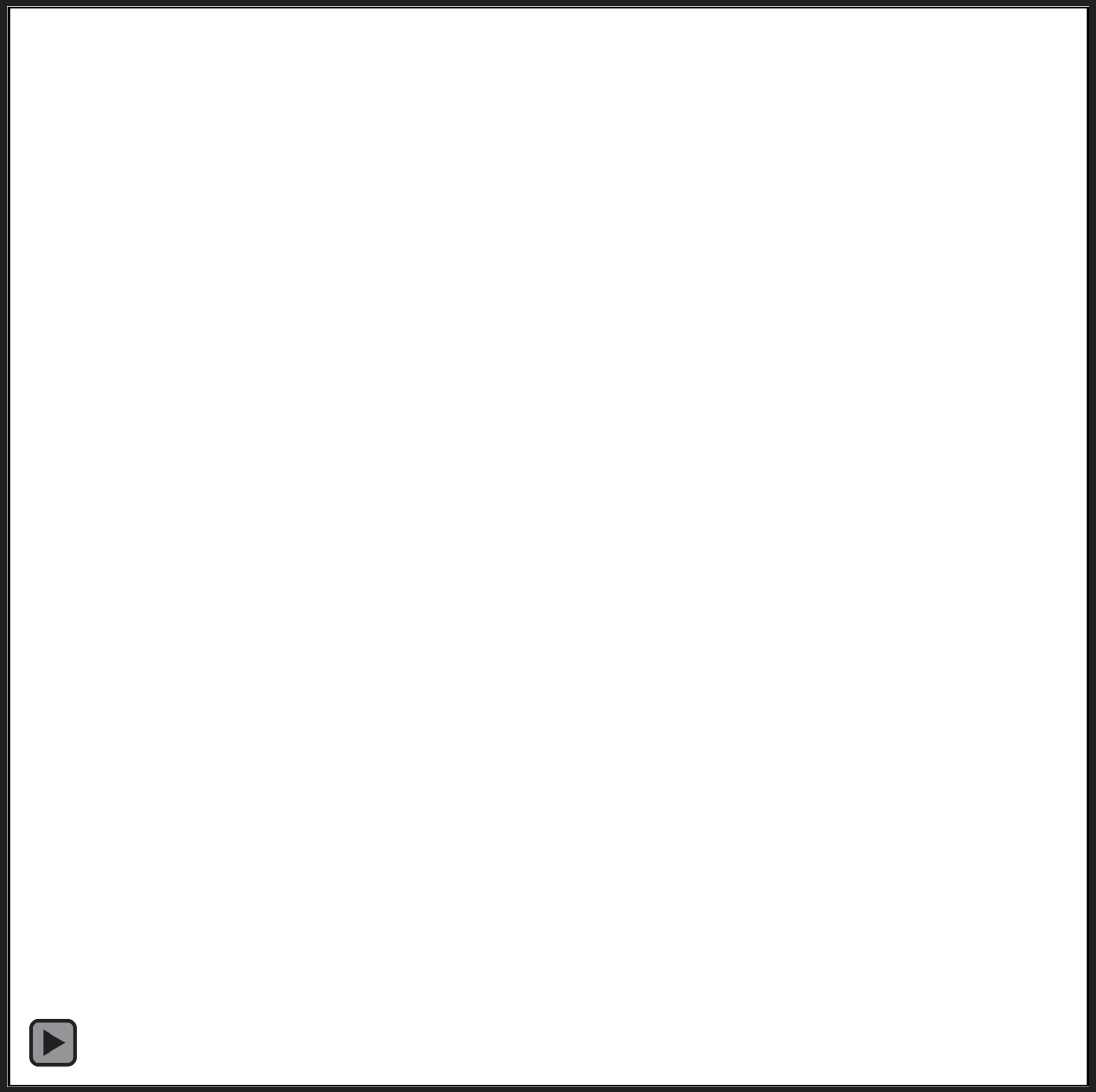
- MMX by JAXA

  (Martian Moons eXploration)
  Launching in 2024 and arriving at Mars in 2025, from the quasi-satellite orbit of Phobos

Orbit of Emirates Mars Mission
[Sharaf et al., MAMO 2017]



Aerosol assimilation on Earth



[Kuroda et al., COSPAR 2018]

Model:
NICAM-SPRINTARS
(non-hydrostatic icosahedral global model with aerosol transport scheme) with horizontal resolution of ~56 km

Observation:
Himawari 8
(taking aerosol opacity and angstrom parameter covering the East Asia) with high resolutions for both time (10 minutes) and space (~5 km)

Same approach may be performed on Mars!

Machine learning approach

AUTOMATIC MARTIAN DUST STORM DETECTION VIA DECISION LEVEL FUSION BASED ON DEEP EXTREME LEARNING MACHINE

Keisuke Maeda, Takahiro Ogawa and Miki Haseyama [IEEE ICIP 2017]

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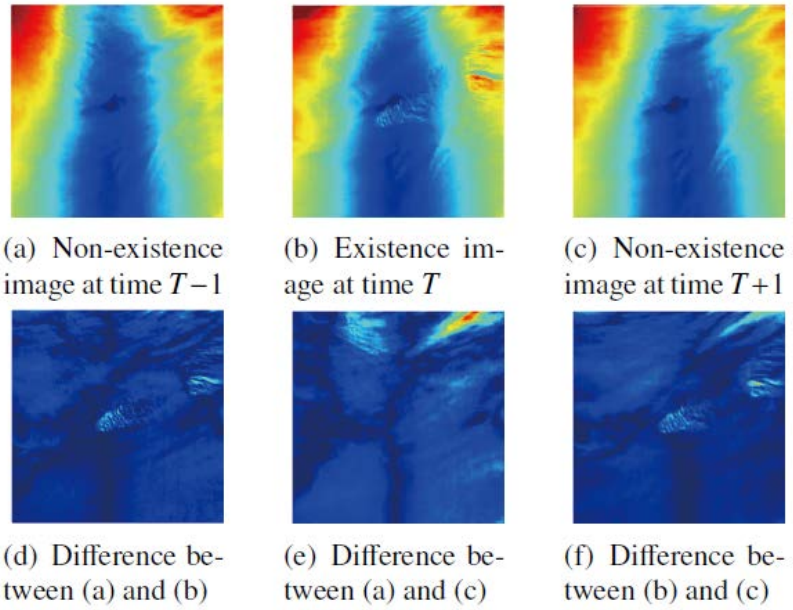
ABSTRACT

This paper presents an automatic Martian dust storm detection via decision level fusion (DLF) based on deep extreme learning machine (DELM). Since Martian images are taken in multi-wavelength bands, DLF techniques which output a final classification result by integrating multiple classification results are necessary. Furthermore, since the number of Martian images taken by satellites is different for each region, the number of the classification results to be integrated is different. Thus, we present a new DLF framework based on confidence values of the classification results. Specifically, we generate multiple extreme learning machines with kernel classifiers to obtain their classification results. Moreover, we monitor the classification results as confidence values and select the same number of the classification results with high confidence for each region. Finally, these selected results can be integrated by using a DLF based on DELM, which is a multilayered ELM. This integration framework is the biggest contribution of our method. Experimental results show the effectiveness of the DLF based on DELM.



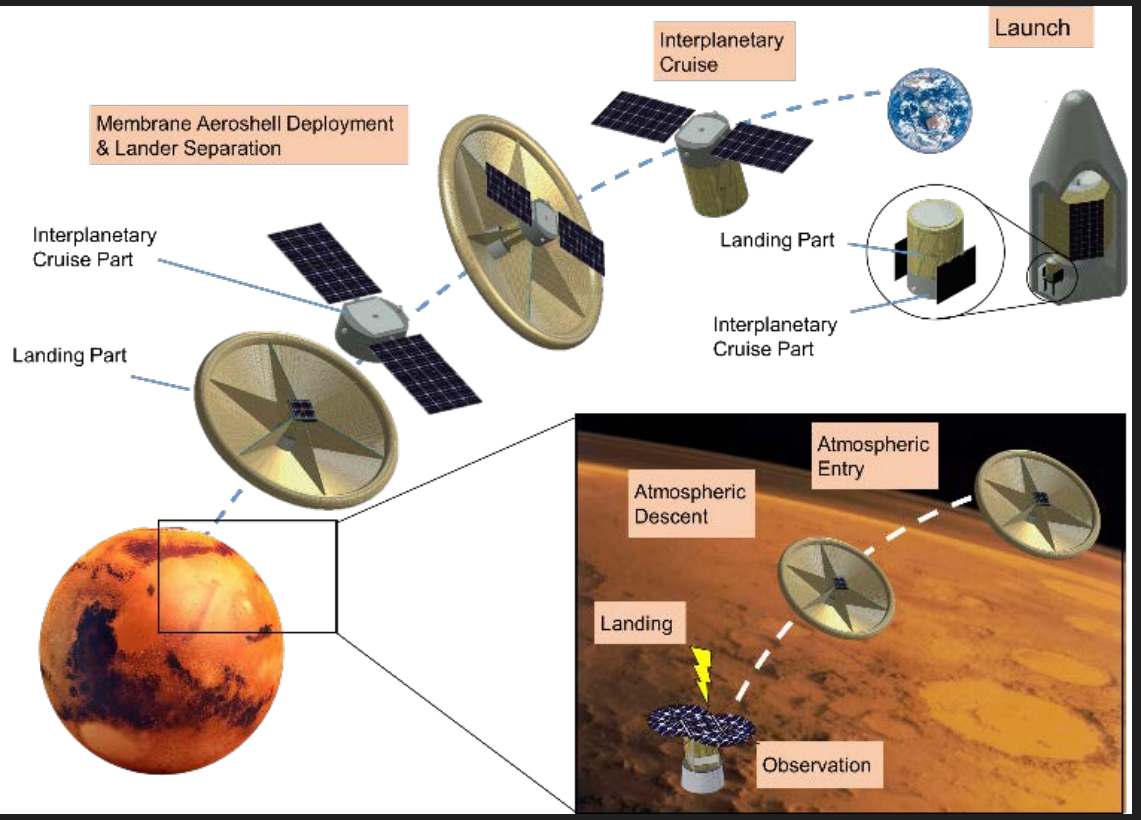
(a) Non-existence image at time $T-1$ (b) Existence image at time T (c) Non-existence image at time $T+1$

(d) Difference between (a) and (b) (e) Difference between (a) and (c) (f) Difference between (b) and (c)

Should be helpful for the dust storm predictions

-> More and more data!

TEREX (TERahertz EXplorer): Mission series with micro-satellites



- Collaborative mission by NICT, Univ. of Tokyo and Osaka Pref. Univ. (independent from JAXA)
- First TEREX Mars lander (TEREX-1) is planned to be launched in early 2020s
- TEREX-1 is targeting to observe O_2, H_2O, etc. for the search of surface water environment and hints of life
- Also we are developing TEREX-2 as an Mars orbiter
- One TEREX payload will cost 10-20M US$, less than 1/10 of previous Mars missions

Get frequent opportunities to send spacecrafts to Mars!

Summary

- Weather forecast on Mars would be the key challenge in the next decade, for the expansion of human activities and business use of Mars such as resource exploration, immigration and entertainment.
- Prediction of dust storms would be the key approach, and the adoption of machine learning may be considered with much observational data.
- Sending more and more spacecraft to Mars to get more and more data is the most important, and the applications of micro-satellites would help that.

Let’s be motivated!