Universität Bremen

Dust Devils and Dust Storms on Planet Mars

Simulation and Animation of Natural Phenomena

Bachelor report from Anna-Lena Kramer

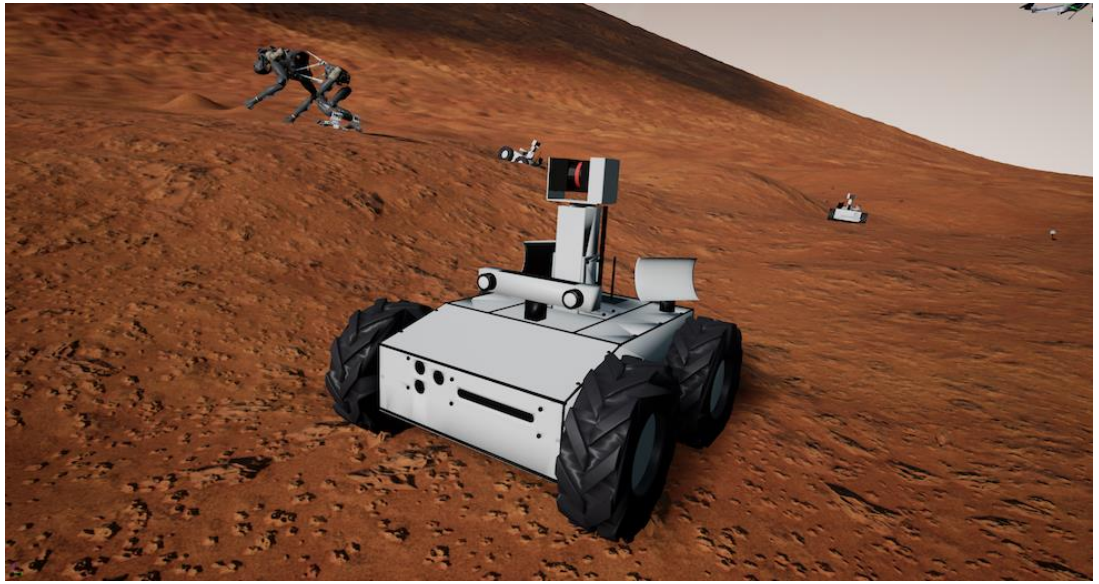
Anna-Lena Kramer
Digital Media B.Sc., Faculty 3 – Mathematics and Computer Science,
University of Bremen

First Examiner: Prof. Dr. Gabriel Zachmann
Second Examiner: Dr. Tim Laue
Supervisor: M.Sc. Philipp Dittmann

Agenda

- Goals
- Information about Natural Phenomena
- Details Implementation
  - Dust Devils
  - Dust Storms
  - Atmosphere
- User Study
  - Structure & Goals
  - Results
- Conclusion
- Future Work

Goals

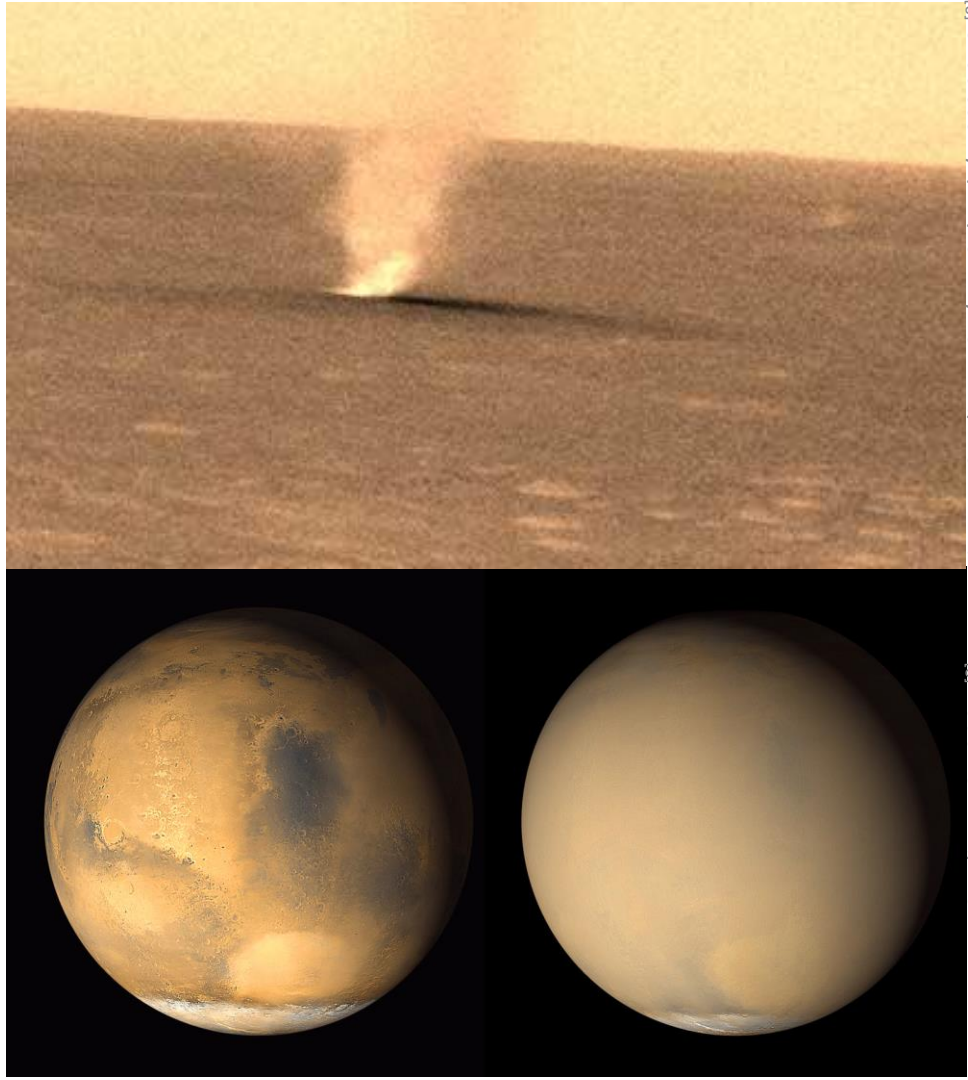


UGV on Mars Terrain, Credit: CGVR University of Bremen - VaMEx-VTB (2020) [12]

- Extension of the virtual Mars environment of the VaMEx-VTB
  - Dust Devils
  - Dust Storms
  - Atmosphere
- Wider range of realistic test scenarios for the autonomous, heterogenous swarm behavior

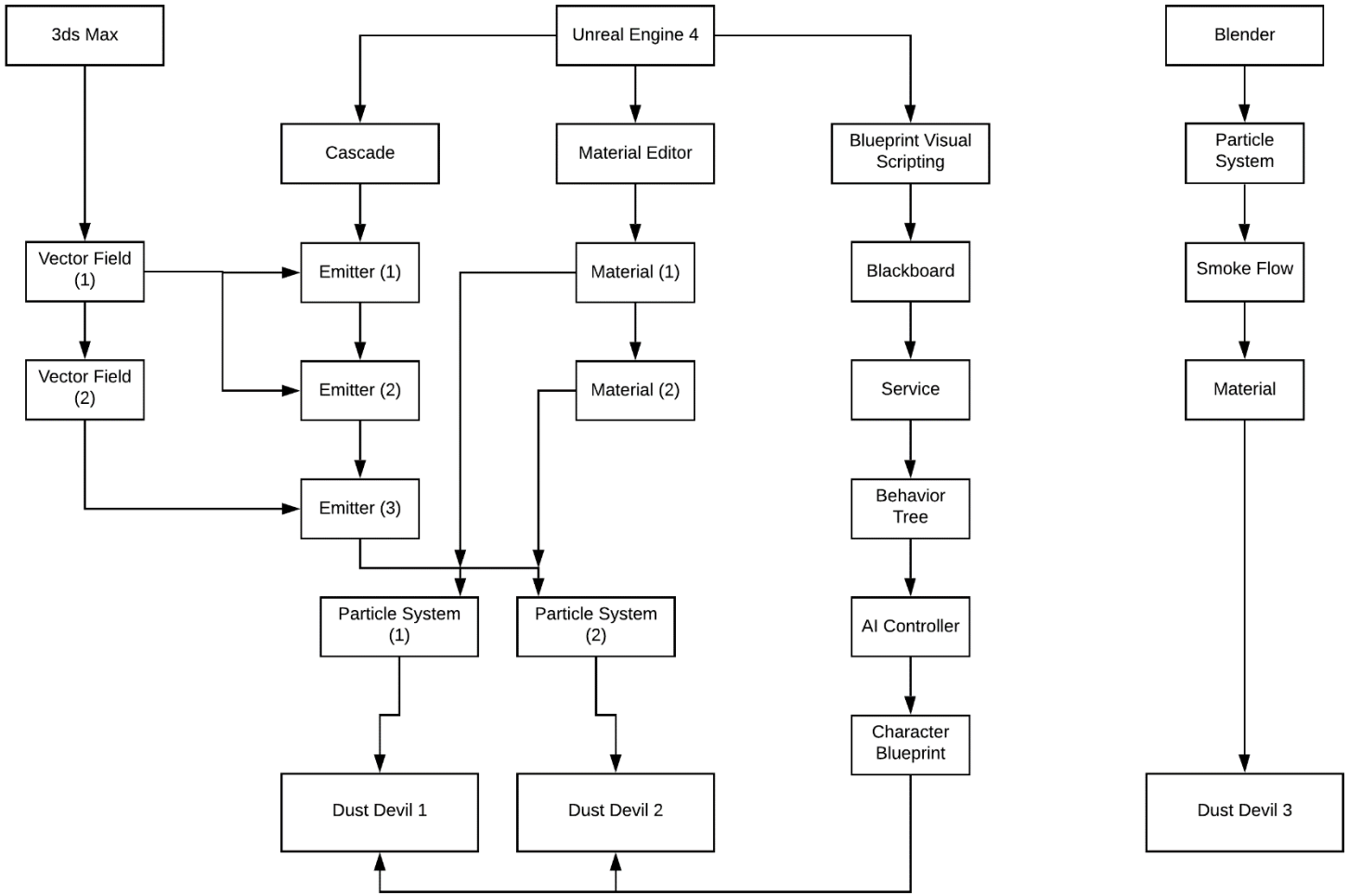
Information about natural phenomena on planet Mars

- Definition Dust Devil:[1],[6],[10]
  - Whirlwinds, made visible through whirled up dust and sand
  - Development through the spiral rising of warmed up air
- Definition Dust Storm:[2],[3],[4],[13],[14]
  - Moving dust cloud
  - Development through the whirling up of loose surface material into the atmosphere
- Definition Atmosphere:[3],[7],[11]
  - Shows a high amount of dust (‘red planet‘)



Upper image, Credit: NASA 2005 [8] – Lower image, Credit: NASA/JPL-Caltech/MSSS 2018 [9]

Details of the Implementation: Dust Devils

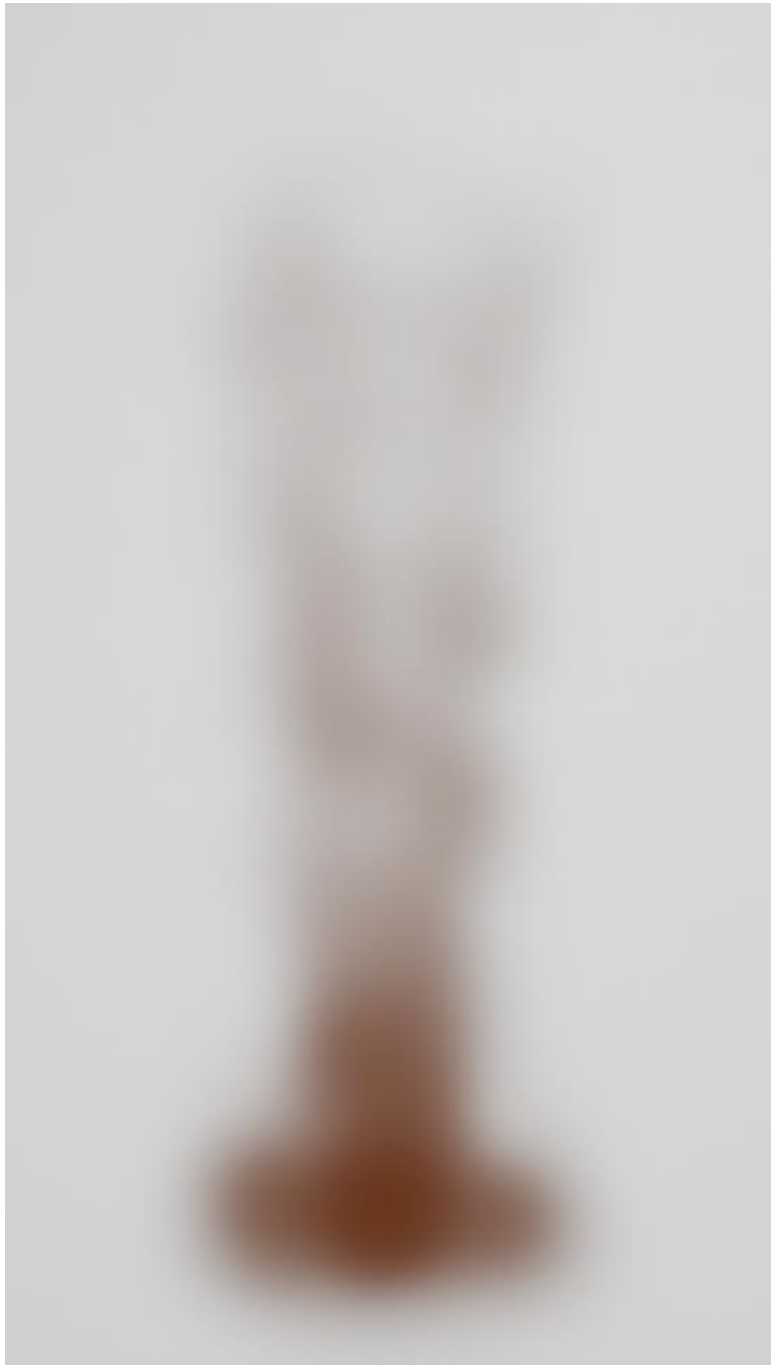


Details of the Implementation: Dust Devil No. 1

- Used Software:
  3ds Max & Unreal Engine 4
- Consists of:
  - 2 Vector Fields
  - 1 Material, called ‘Surface Material‘
  - 1 Particle System, consisting of
    3 Emitters
  - AI Movement, based on
    1 Blackboard, 1 Behavior Tree,
    1 Costum Service, 1 AI Controller
    & 1 Character Blueprint

Details of the Implementation: Dust Devil No. 2

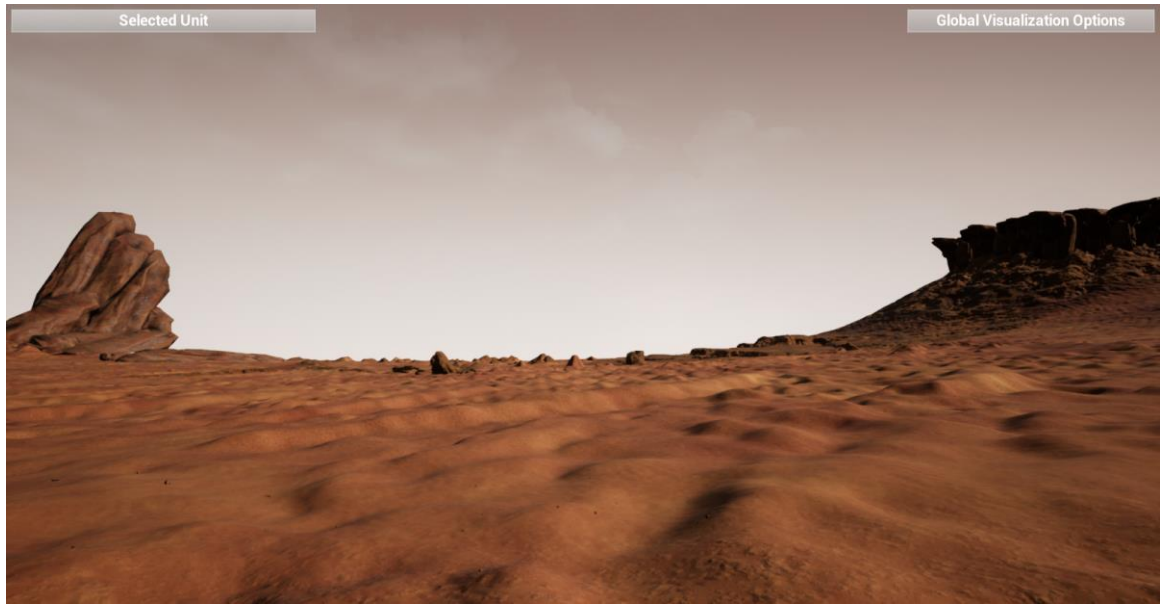
- Dust devil no. 1 and dust devil no. 2 are mostly identical, except for the used material and some settings
- Used Software:
  3ds Max & Unreal Engine 4
- Consists of:
  - 2 Vector Fields
  - 1 Material, called ‘Volume Material‘
  - 1 Particle System, consisting of 3 Emitters
  - AI Movement, based on 1 Blackboard, 1 Behavior Tree, 1 Costum Service, 1 AI Controller & 1 Character Blueprint

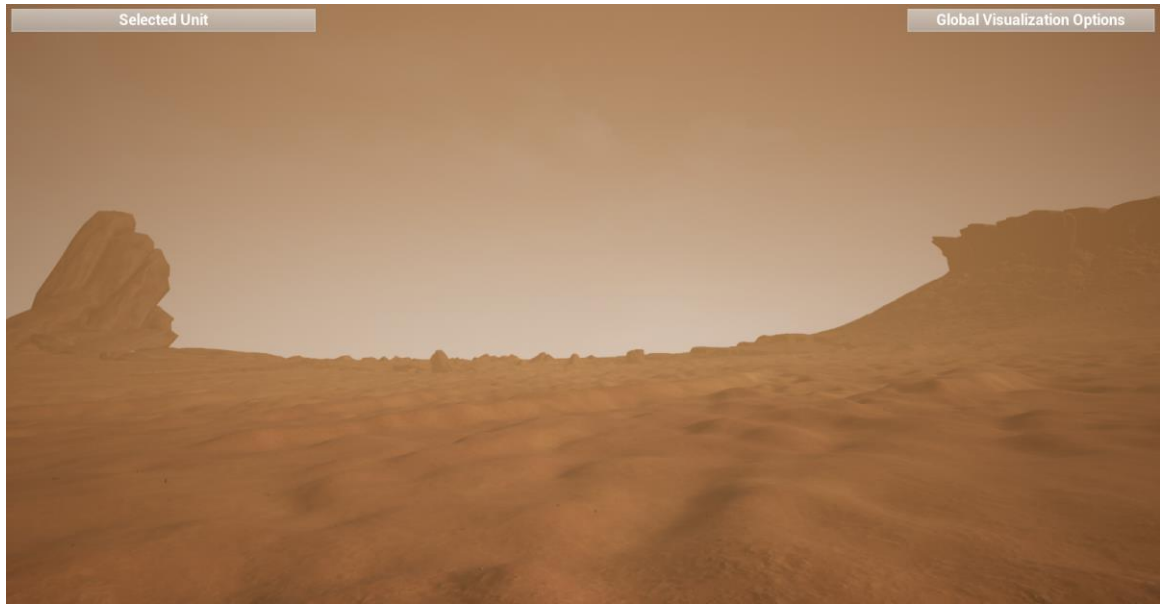


Details of the Implementation: Dust Devil No. 3

- Used Software: Blender
- Consists of:
  - 1 Particle System with 1 Emitter
  - 3 Force Fields
  - 1 Animation
  - Fluid Simulation (Smoke Simulation)
  - 1 Material

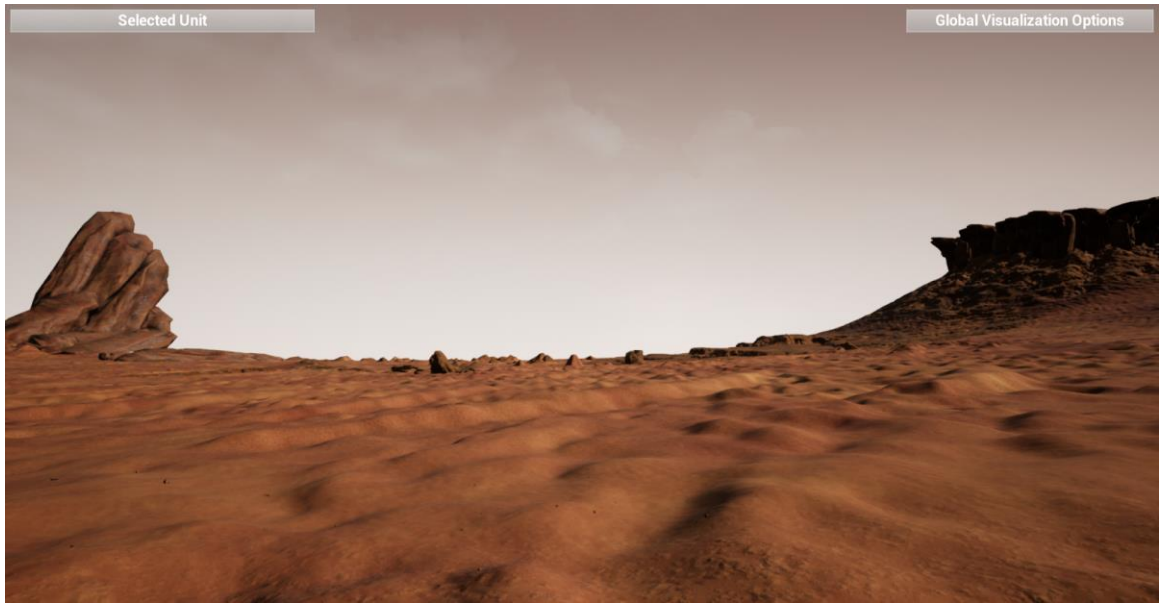
Details of the Implementation: large regional & global dust storms





- Used Software:
  Unreal Engine 4
- Exponential Height Fog &
  Volumetric Fog

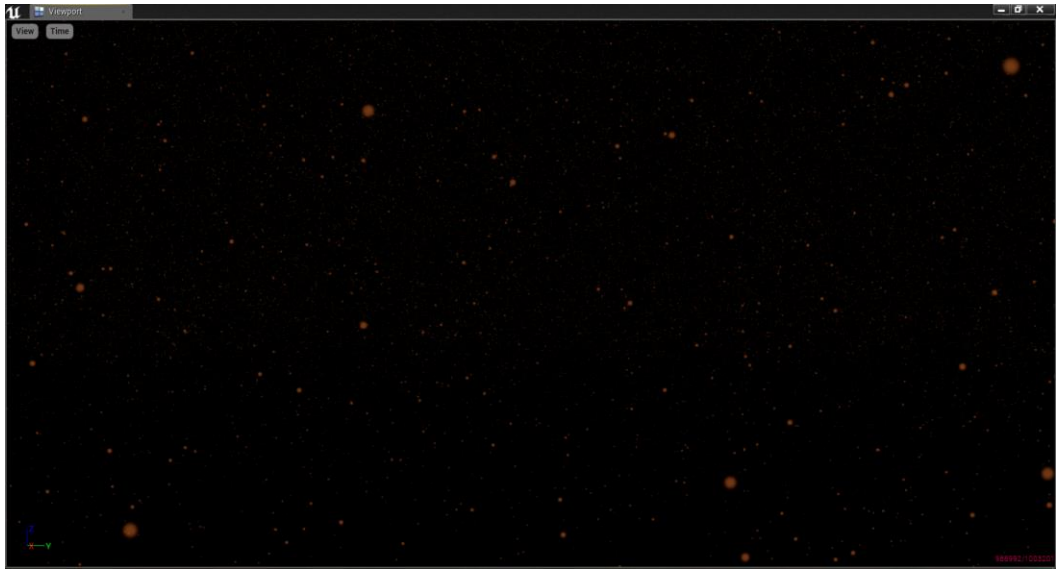
Details of the Implementation: local & small regional dust storms

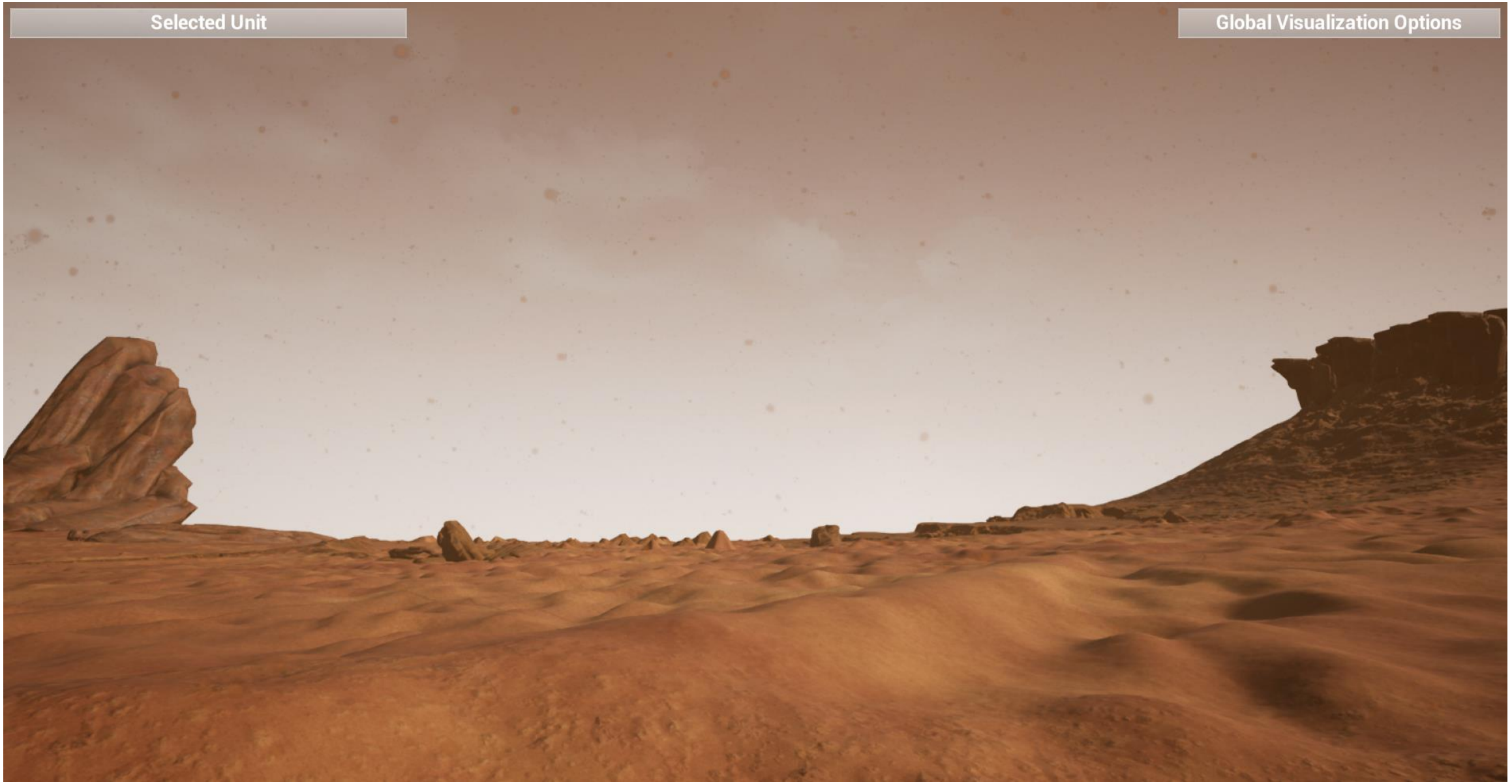


- Used Software: Unreal Engine 4
- Consists of:
  - Exponential Height Fog & Volumetric Fog
  - 1 ‘Volume‘ Material
  - 1 Particle System with 1 Emitter
  - AI Movement, based on 1 Blackboard,
    1 Behavior Tree, 1 Costum Service,
    1 AI Controller & 1 Character Blueprint

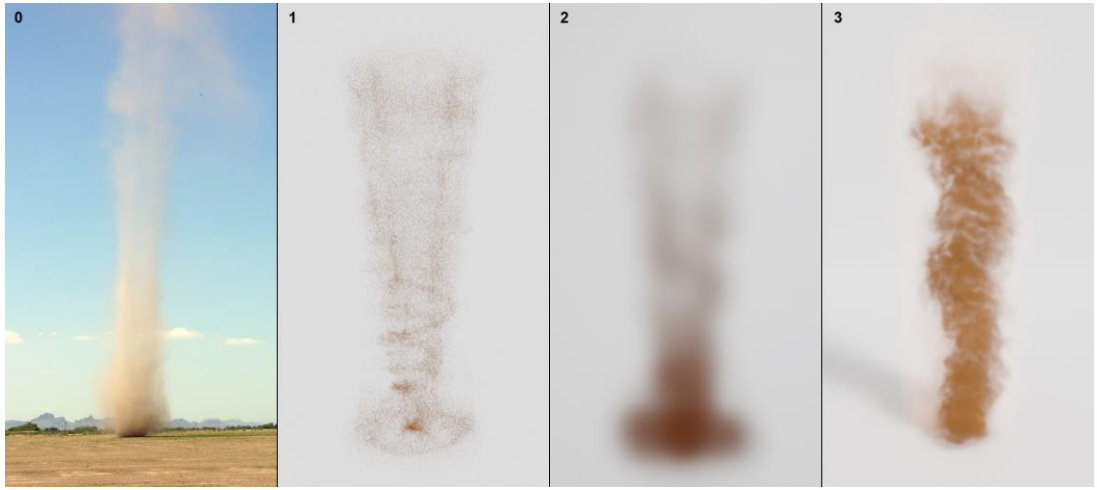
Details of the Implementation: Atmosphere

- Used Software:
  Unreal Engine 4
- Generation of atmospheric dust to simulate the atmosphere
- Consists of:
  - 1 ‘Surface‘ Material
  - 1 Particle System with 1 Emitter




Selected Unit
Global Visualization Options

User Study: Structure and Goals



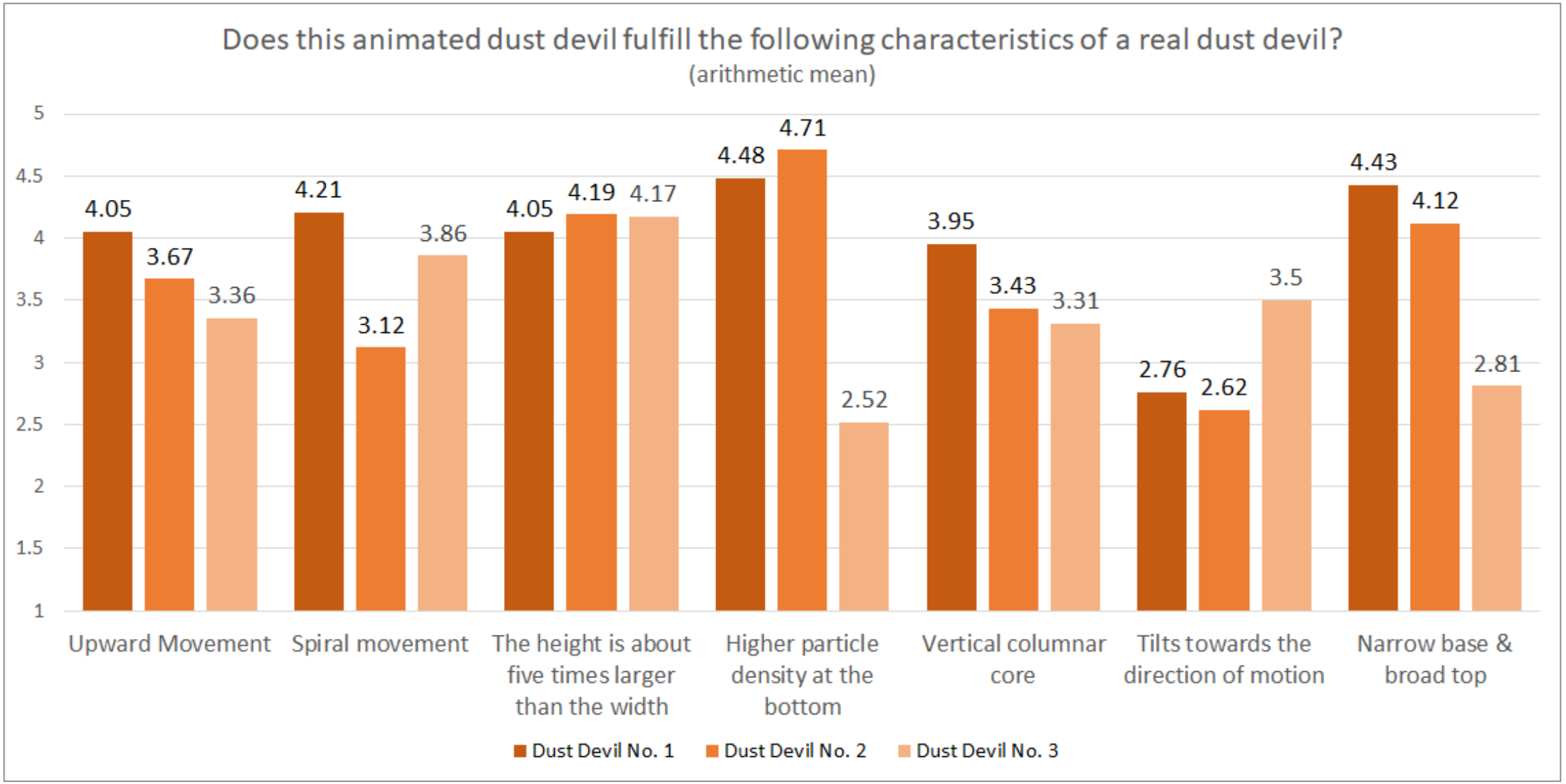
Left: picture of a real dust devil, Credit: NASA, 2005 [8]

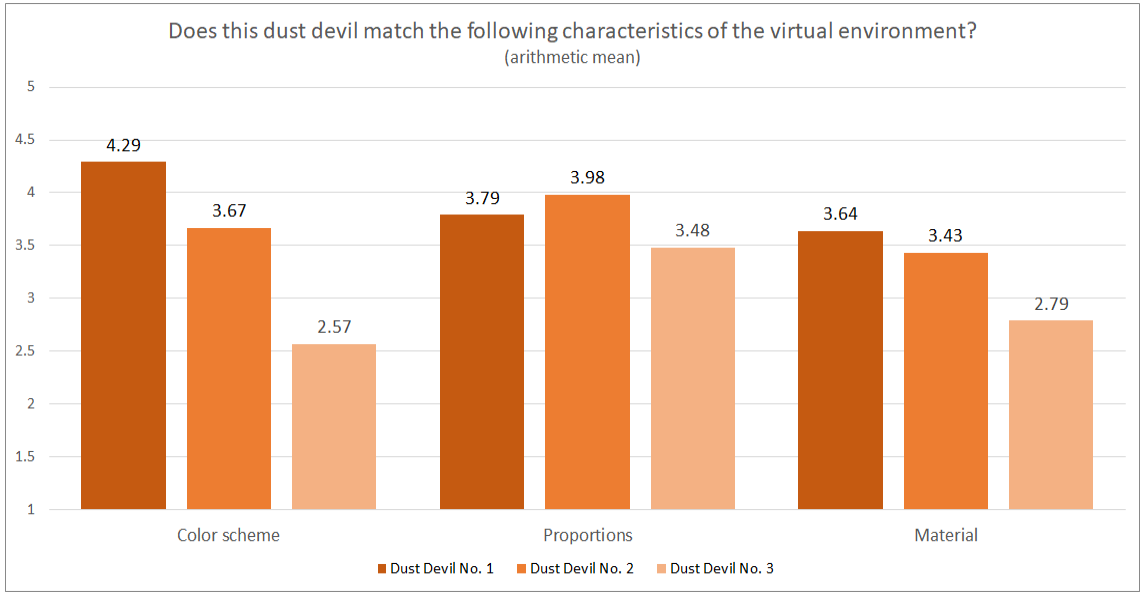
- Goals: Evaluation of the three implemented dust devils
- Structure:
  - Introduction (title, privacy statement, first content question set, information about the study topic)
  - First part (second content question set, control question)
  - Second part (third content question, control question)
  - Third part (feedback)
  - Farewell

User Study: Results

- Dust devil no. 2 shows the best results
- Dust devil no. 1 owns the second place in the overall rating
- Dust devil no. 3 has the worst overall rating

- The dust devil scene with integrated exponential height fog seems more realistic than the scene without exponential height fog, according to the participants


Does this animated dust devil fulfill the following characteristics of a real dust devil?
(arithmetic mean)
5
4.5
4
3.5
3
2.5
2
1.5
1
4.05
3.67
3.36
4.21
3.12
3.86
4.05
4.19
4.17
4.48
4.71
2.52
3.95
3.43
3.31
2.76
2.62
3.5
4.43
4.12
2.81
Upward Movement
Spiral movement
The height is about five times larger than the width
Higher particle density at the bottom
Vertical columnar core
Tilts towards the direction of motion
Narrow base & broad top
Dust Devil No. 1
Dust Devil No. 2
Dust Devil No. 3


Does this dust devil match the following characteristics of the virtual environment?
(arithmetic mean)
5
4.5
4
3.5
3
2.5
2
1.5
1
4.29
3.67
2.57
3.79
3.98
3.48
3.64
3.43
2.79
Color scheme
Proportions
Material
Dust Devil No. 1
Dust Devil No. 2
Dust Devil No. 3

Conclusion

- Dust devils, dust storms and an atmosphere extend the virtual Mars environment of the VaMEx-VTB
- The implemented natural phenomena build a base for new and adjusted test scenarios
- Dust devil no. 2 represents the most promising approach for the integration of the dust devils regarding the realistic implementation and harmonic overall impression

Future Work

- Implementation of the influences of the natural phenomena on the swarm behavior
- Variation in shape and look of the dust devils
- Dust devil tracks
- Landslides

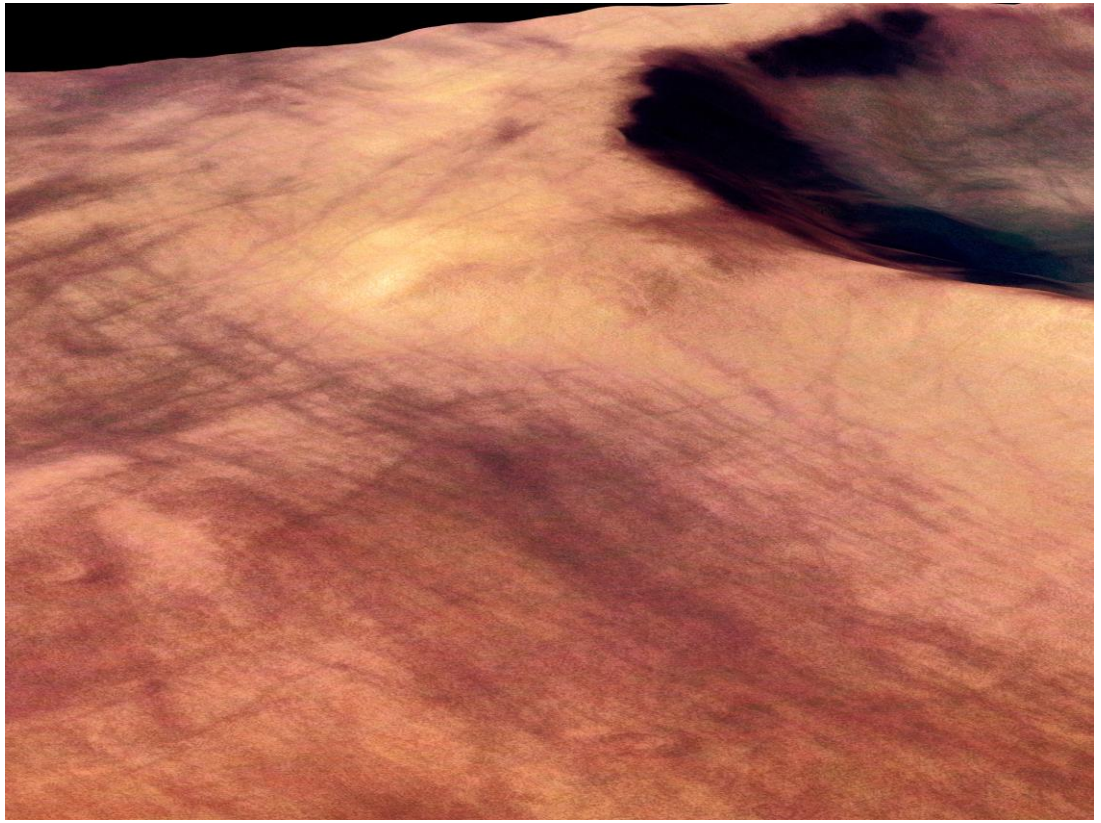


Image of dust devil tracks – Credit: ESA/DLR/FU Berlin (G. Neukum) (2004) [5]

Thank you for your attention!

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