

# Gravity-driven differences in fluvial sediment transport on Mars and Earth

Lisanne Braat, PhD

Elliot Sefton-Nash  
Michael Lamb  
Muriel Brückner  
Anne Baar

Research Fellow at ESTEC | ESA

✉ [lisannebraat@gmail.com](mailto:lisannebraat@gmail.com) / [lisanne.braat@esa.int](mailto:lisanne.braat@esa.int)



end ESA fellowship  
end of April



Veni grant



Utrecht  
University

Lisanne.braat@esa.int

L.Braat@uu.nl  
lisannebraat@gmail.com

# Gravity-driven differences in fluvial sediment transport on Mars and Earth

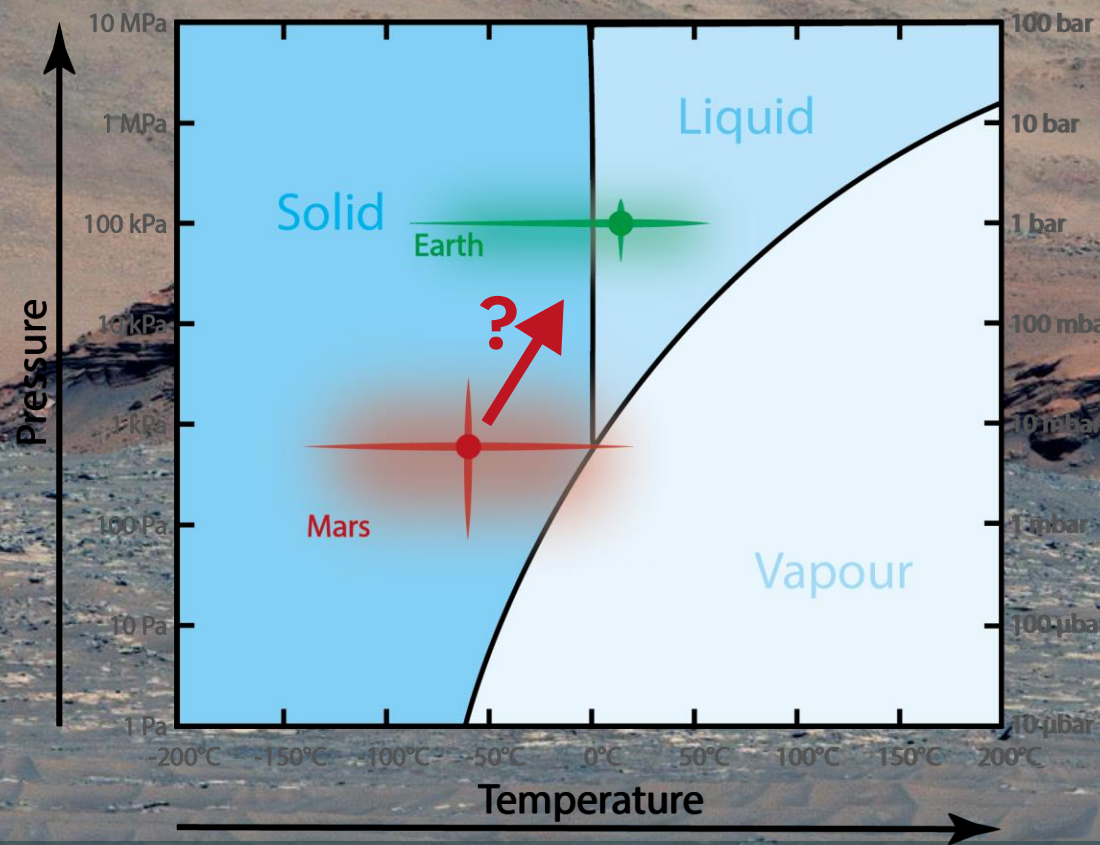
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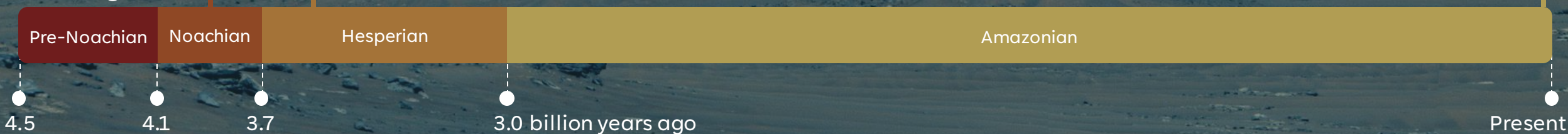
✉ [lisannebraat@gmail.com](mailto:lisannebraat@gmail.com) / [lisanne.braat@esa.int](mailto:lisanne.braat@esa.int)

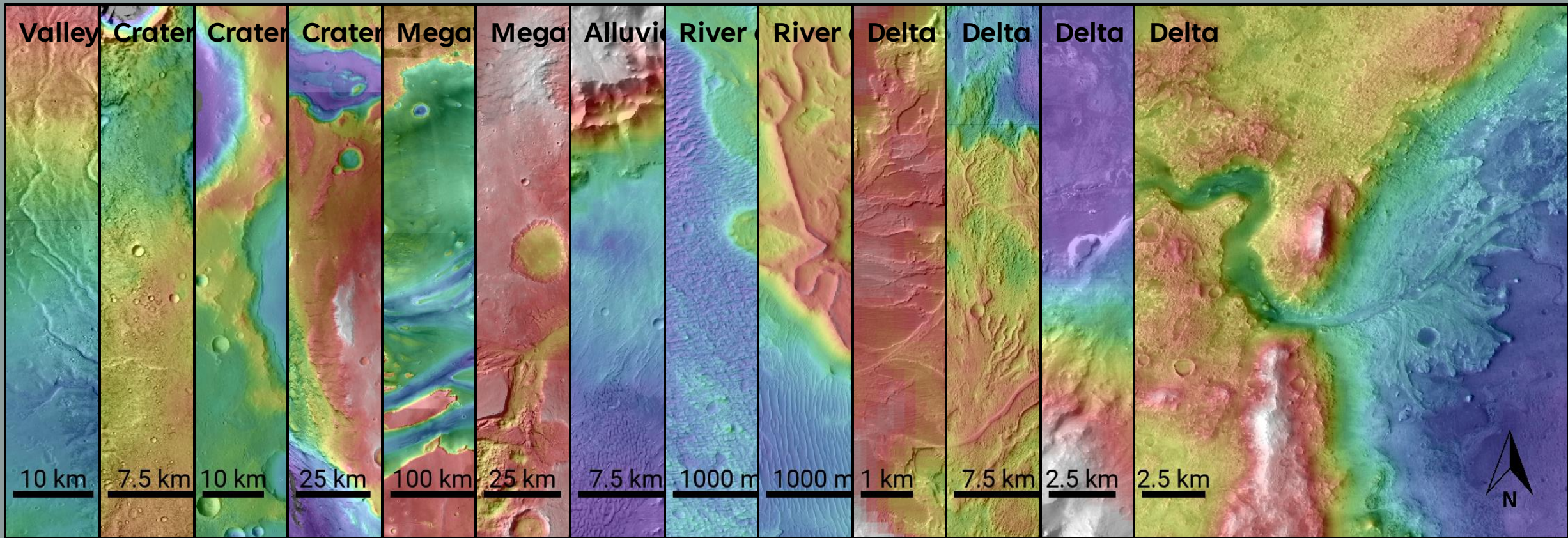
# Early Mars



Perseverance rover  
Mastcam-Z panorama  
NASA/JPL-Caltech/ASU/MSSS

## Geological timeline Mars





VIS + Elevation  
Sources: HiRISE, CTX, HRSC, MOLA

# Fluvial landforms

## Geological timeline Mars



Landforms created  
or altered by  
flowing water

Ancient **fluvial geomorphology** can be used to  
determine past **conditions** on **Mars**

Hydrological  
Environmental  
Climate



case,  
action,  
begin situation,  
initial and  
boundary conditions

Induction

Deduction

Abduction

effects,  
outcome,  
end situation,  
consequences

rules,  
processes,  
laws of nature,  
generalisations



# Earth

# Mars

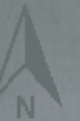
Wax lake delta

2 km

Jezero delta

**Is it a fair comparison?**

5 km





# Differences **Earth** and **Mars**

## Examples

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- Ice and permafrost
- Sediment density differences
- No organisms
- Minimal tides
- **Gravity**
  - Modelling only option

A composite image showing the Earth on the left and Mars on the right, both in space. The Earth is larger and shows blue oceans, white clouds, and brown landmasses. Mars is smaller and has a reddish-brown surface with some darker spots.

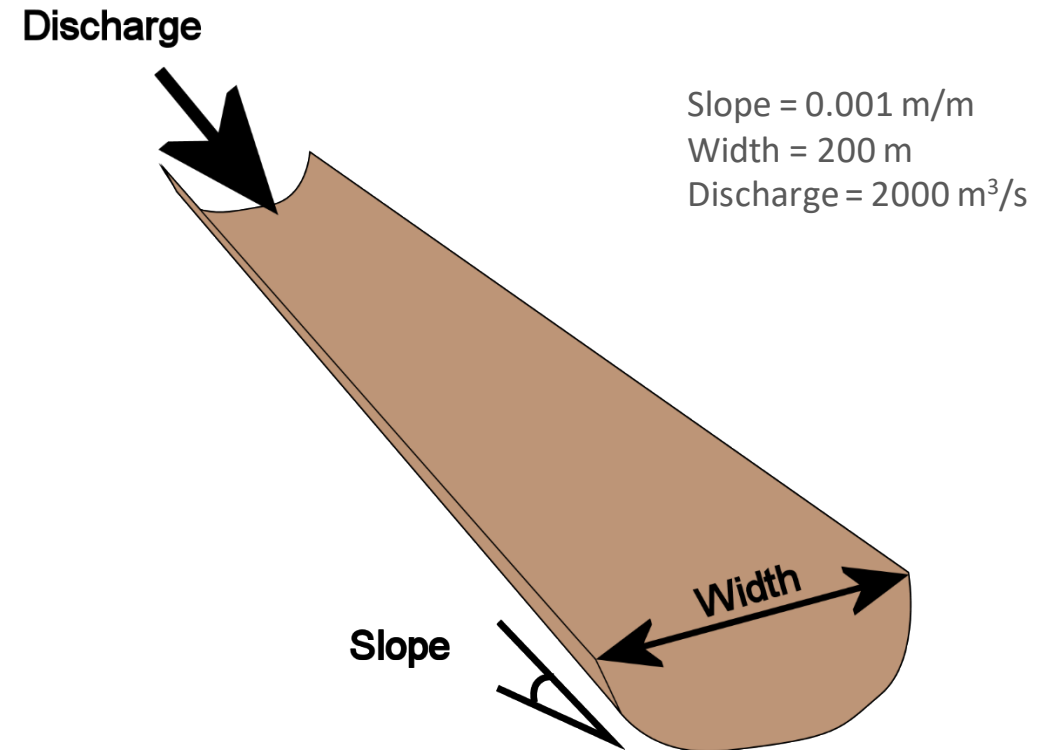
# Effect of gravity on fluvial sediment transport

A large, detailed image of the planet Mars, showing its reddish-brown surface with various craters and geological features, set against a dark blue space background with stars.

# Methodology

# Methodology

- Analytical equations (static 1D model)
- Run same scenario for **Earth** and **Mars** gravity
- Equal channel shape
  - width
  - slope
- Comparing equal water discharge

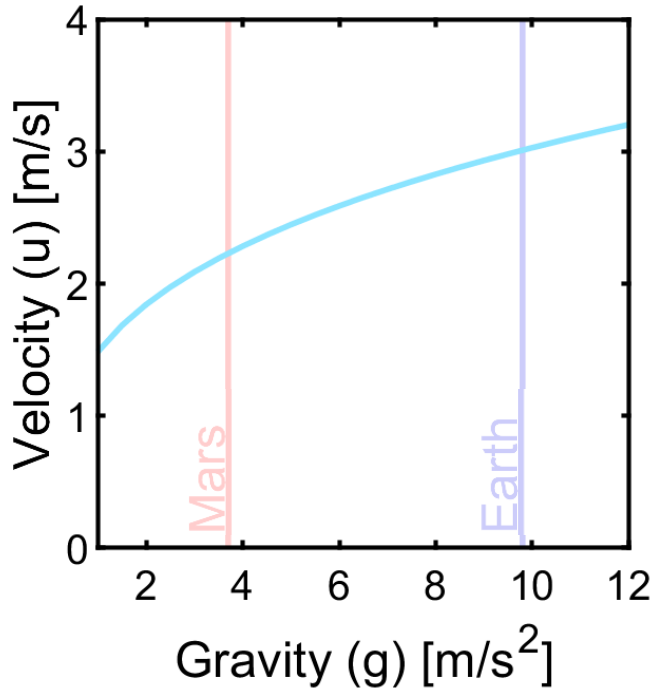


A large background image showing the Earth on the left and Mars on the right, both in space. The Earth is a vibrant blue and white, while Mars is a reddish-brown sphere. A thin yellow rectangular border frames the central text.

# Comparing flow conditions

# Comparing flow conditions

For the same discharge (Q) and geometry



Input:  
 Q = 2000 m<sup>3</sup>/s  
 Slope = 0.001 m/m  
 Width = 200 m

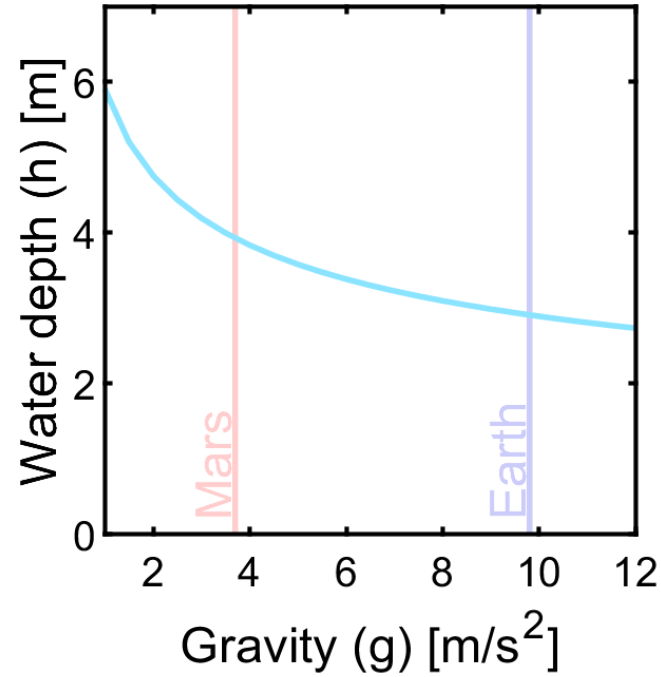
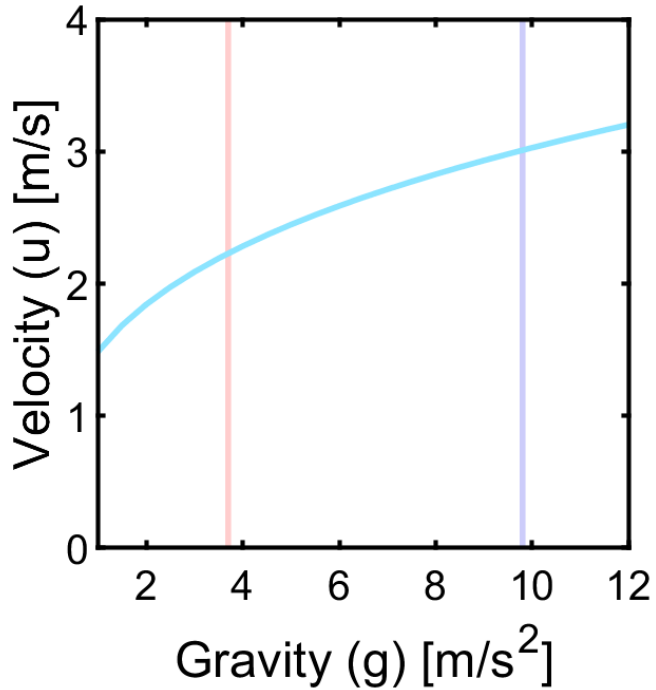
Constants:  
 $g_{\text{Earth}} = 9.8 \text{ m/s}^2$   
 $g_{\text{Mars}} = 3.7 \text{ m/s}^2$   
 Roughness = 0.01 m  
 density = 1000 kg/m<sup>3</sup>

$$u = C \sqrt{R_w S} \quad (\text{Chézy})$$

velocity = roughness ·  $\sqrt{\text{hydraulic radius} \cdot \text{slope}}$

# Comparing flow conditions

For the same discharge (Q) and geometry



Input:

Q = 2000 m<sup>3</sup>/s

Slope = 0.001 m/m

Width = 200 m

$$h = \frac{Q}{W \cdot u}$$

depth = discharge / (width · velocity)

Constants:

$g_{\text{Earth}} = 9.8 \text{ m/s}^2$

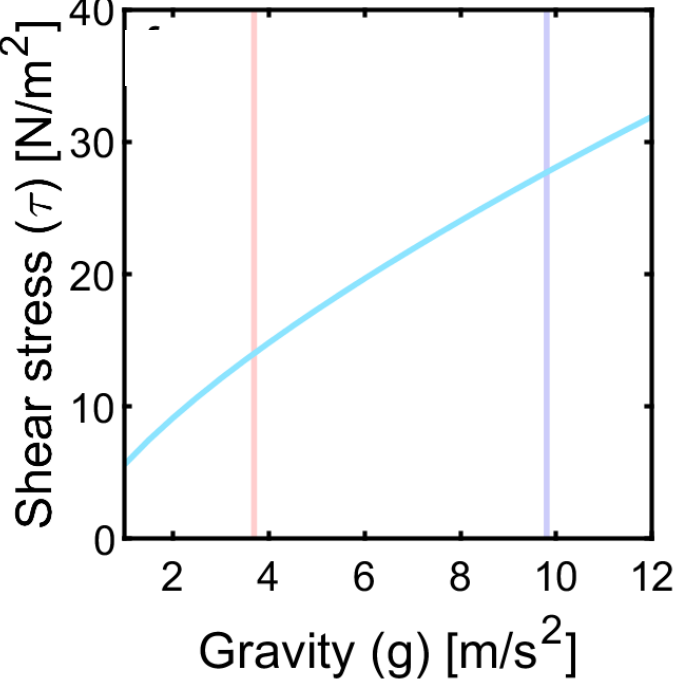
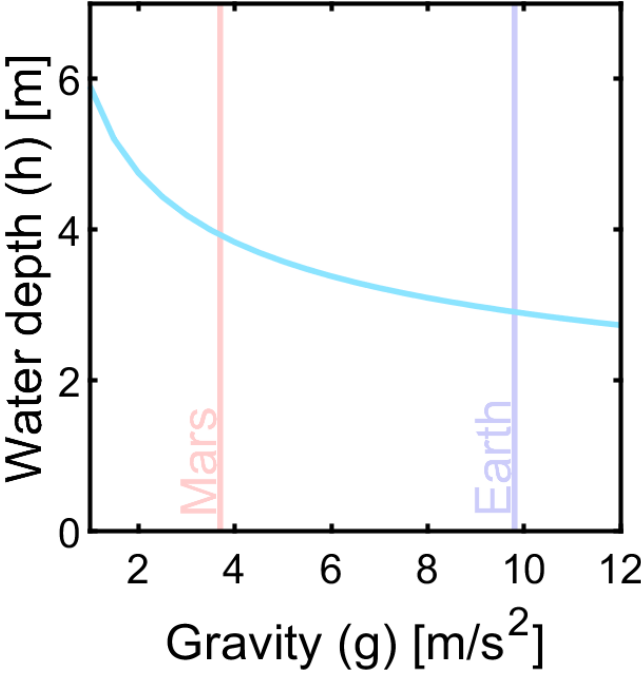
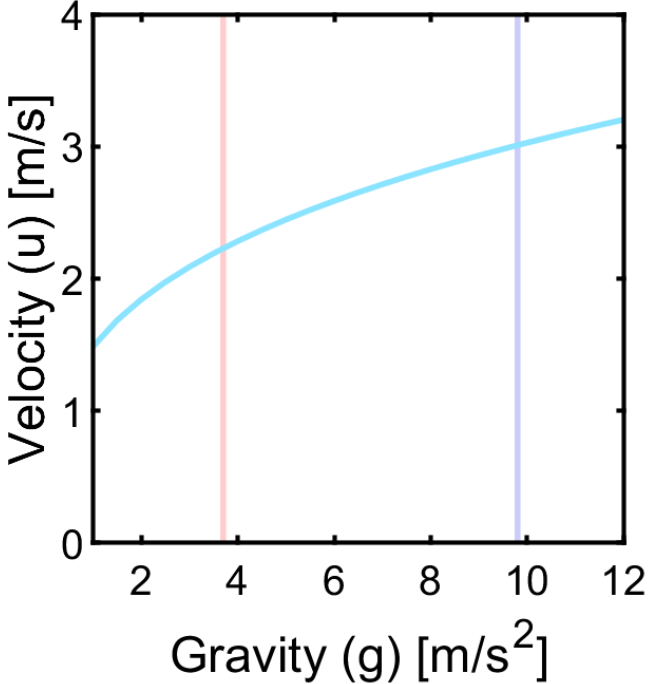
$g_{\text{Mars}} = 3.7 \text{ m/s}^2$

Roughness = 0.01 m

density = 1000 kg/m<sup>3</sup>

# Comparing flow conditions

For the same discharge (Q) and geometry



Input:  
 Q = 2000 m<sup>3</sup>/s  
 Slope = 0.001 m/m  
 Width = 200 m

$$\tau = \rho \cdot g \cdot R_w \cdot S$$

Shear stress = density · gravity acceleration · hydraulic roughness · slope

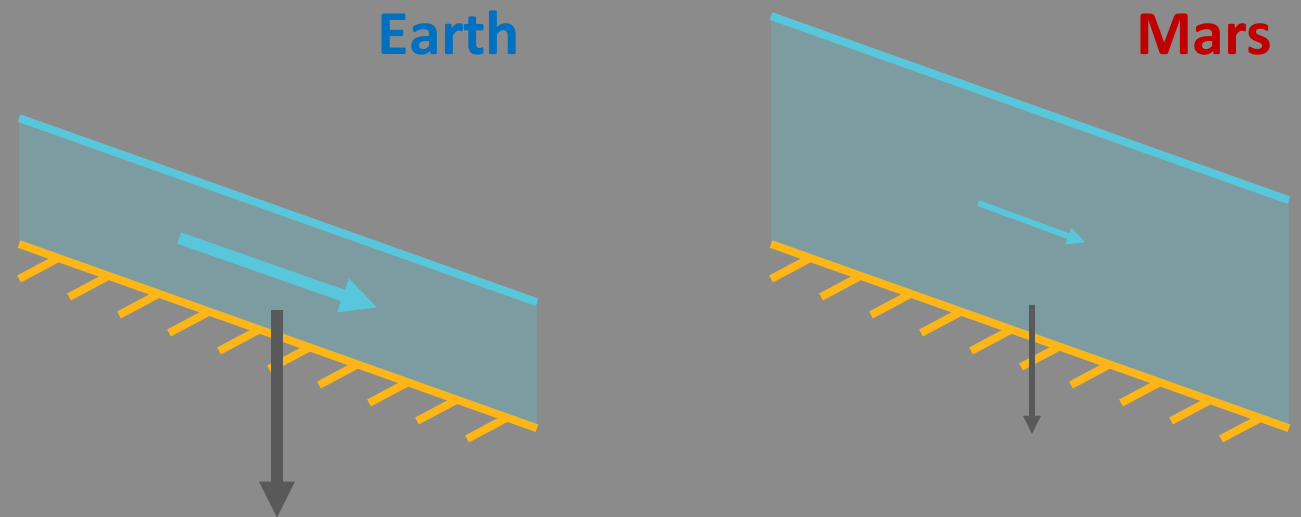
Constants:  
 $g_{\text{Earth}} = 9.8 \text{ m/s}^2$   
 $g_{\text{Mars}} = 3.7 \text{ m/s}^2$   
 Roughness = 0.01 m  
 density = 1000 kg/m<sup>3</sup>



# Conclusions for Mars

Differences in flow (for equal discharge and morphology)

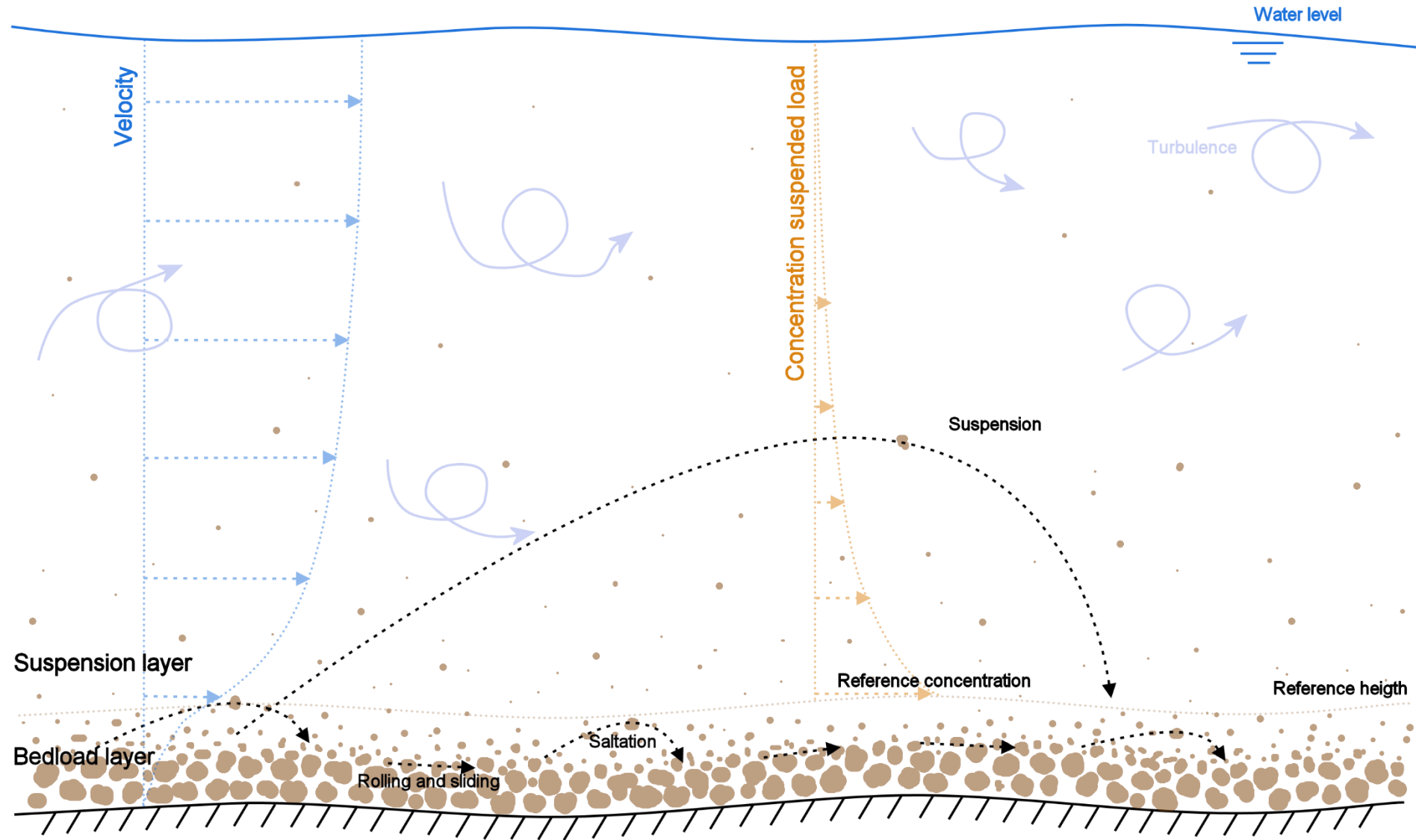
- Less force pulling water downslope
- Lower velocity
- Higher water depth
- Lower stresses



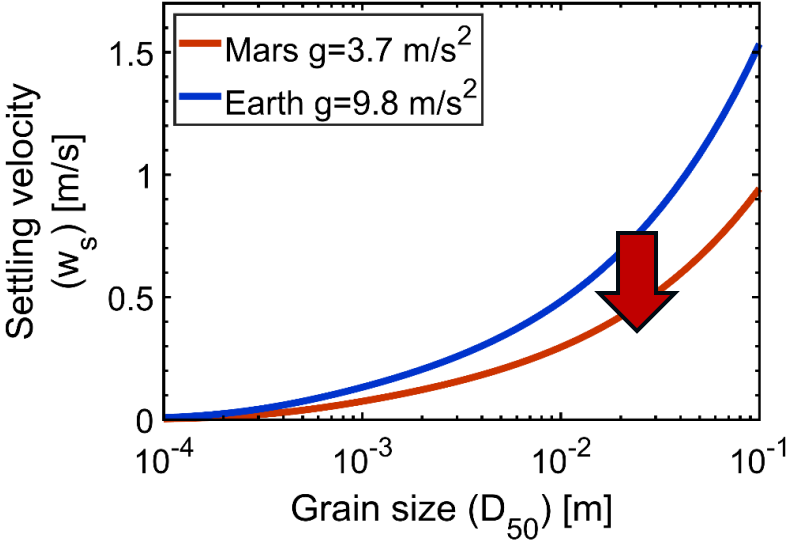


# Comparing sediment transport

# Transport modes



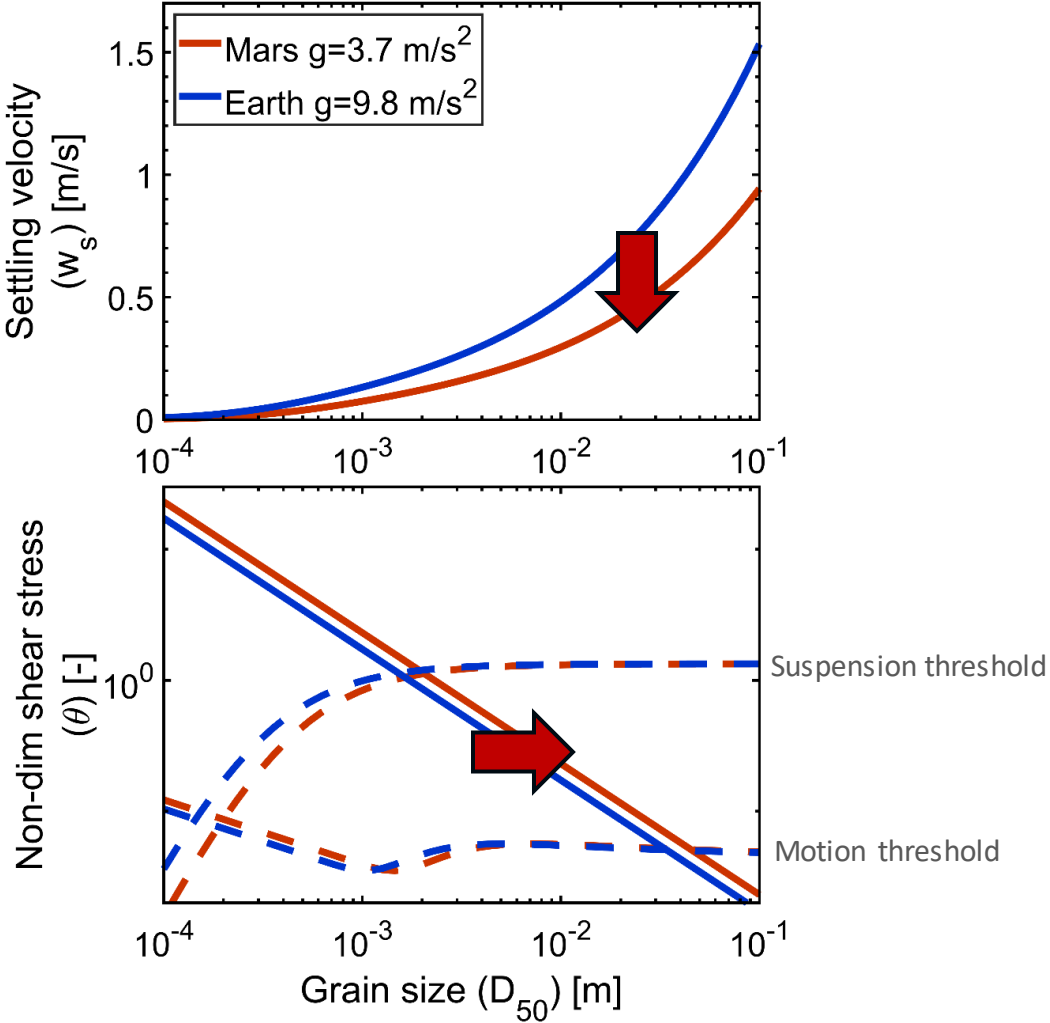
# Comparing sediment transport



$$w_s = \frac{RgD^2}{C_1\nu + \sqrt{0.75C_2RgD^3}}$$

Komar, 1980  
 Burr et al., 2006  
 Grotzinger et al., 2013  
 Amy and Dorrell, 2021

# Comparing sediment transport

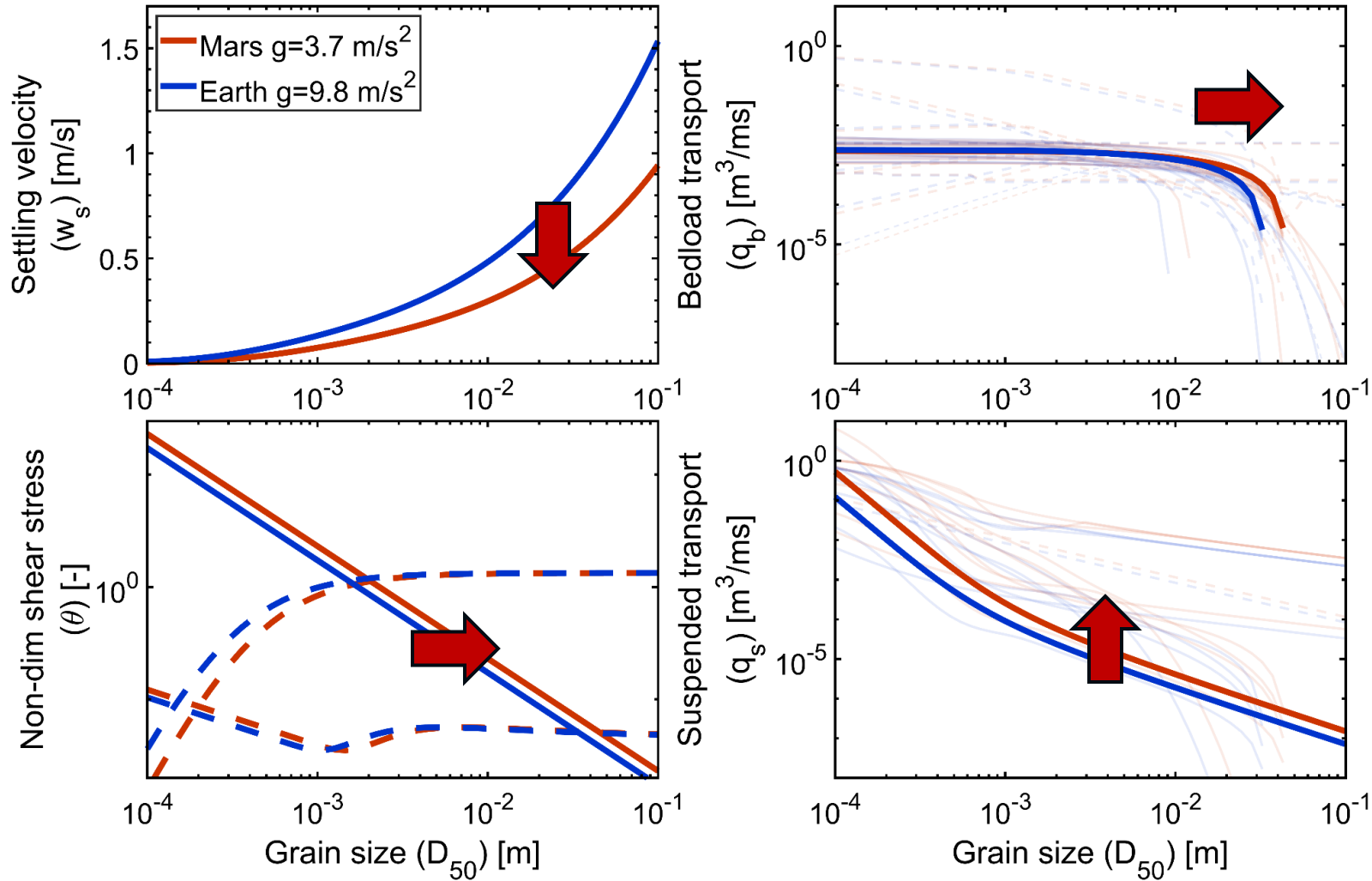


$$w_s = \frac{RgD^2}{C_1\nu + \sqrt{0.75C_2RgD^3}}$$

$$\theta = \frac{\tau}{(\rho_s - \rho)gD_{50}}$$

Komar, 1980  
 Burr et al., 2006  
 Grotzinger et al., 2013  
 Amy and Dorrell, 2021

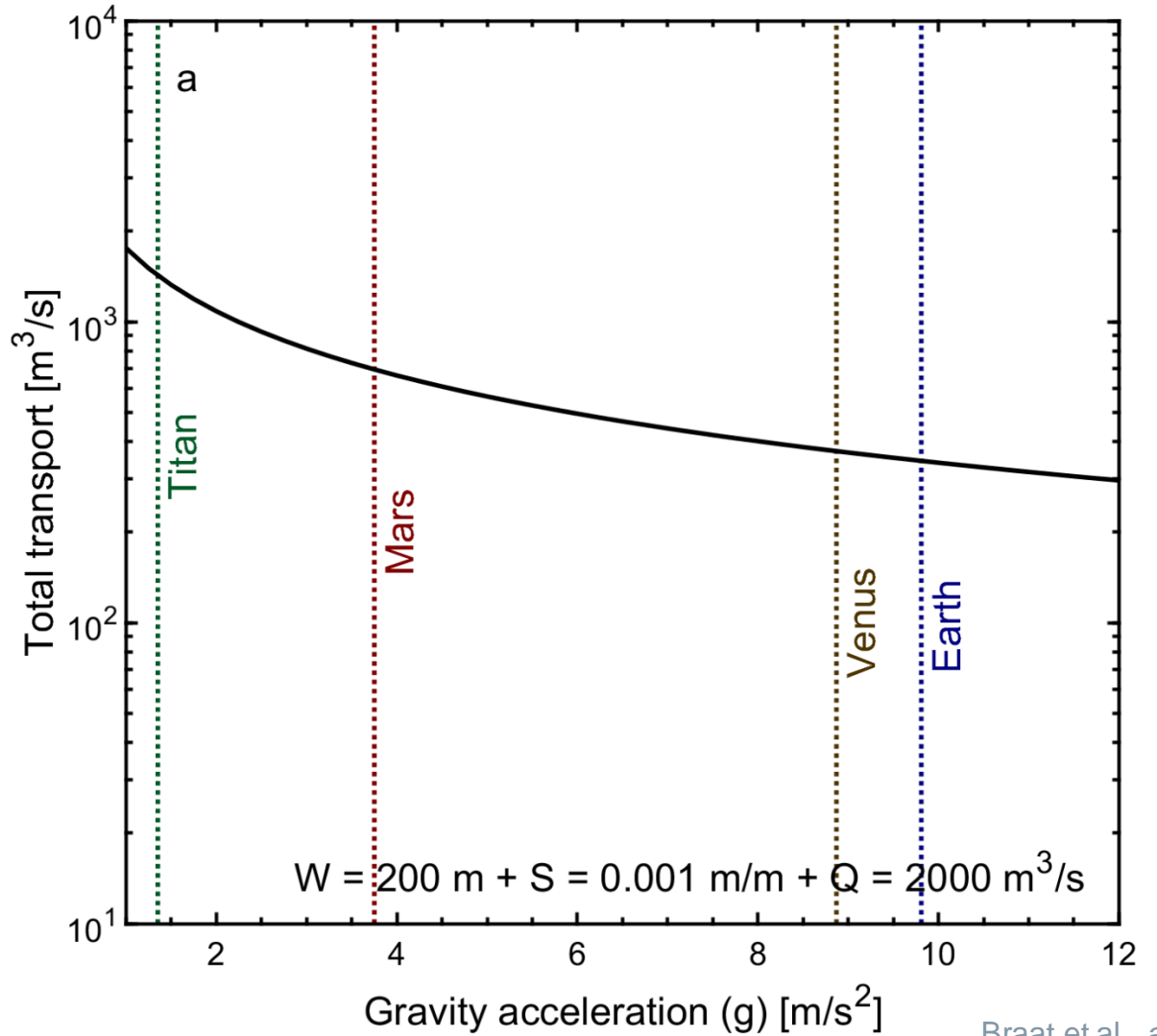
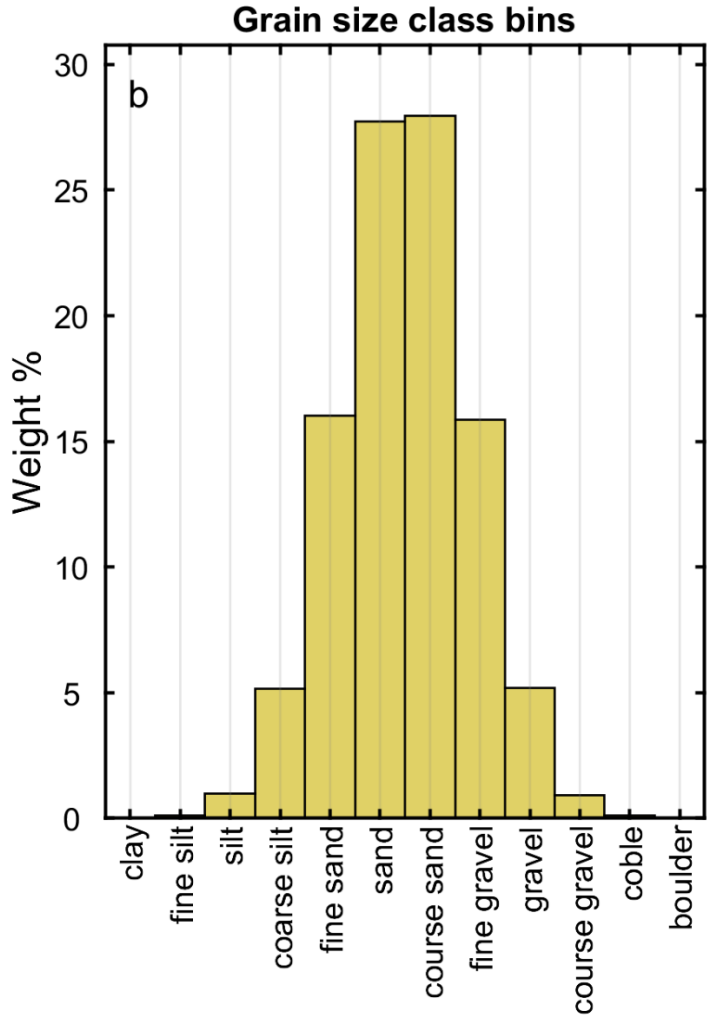
# Comparing sediment transport



Komar, 1980  
 Burr et al., 2006  
 Grotzinger et al., 2013  
 Amy and Dorrell, 2021

Braat et al., *accepted*

# Total sediment transport



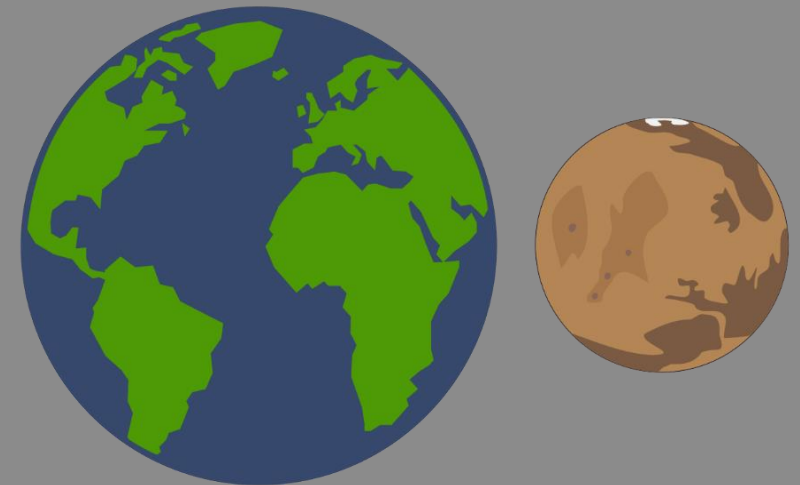
Braat et al., *accepted*

# Conclusions for Mars

## Differences in sediment transport (for equal discharge)

- Sediment easier mobilised
- Higher sediment transport rates
- More suspended transport (relative and absolute)
- Effect of gravity varies with grain size

➤ Effect on morphology expected





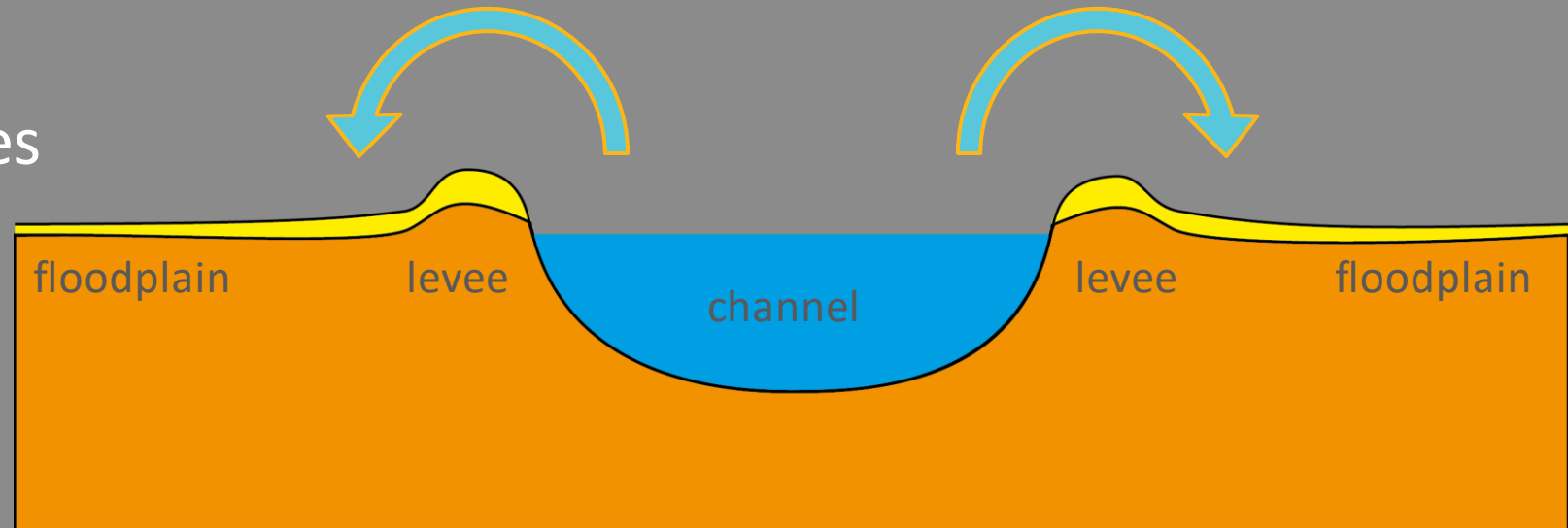
A composite image showing the Earth on the left and Mars on the right, both in space. The Earth is larger and shows blue oceans, white clouds, and brown landmasses. Mars is smaller and has a reddish-brown, cratered surface. A yellow rectangular box is overlaid on the center of the image, containing the text.

# Effects on fluvial geomorphology?

# Hypotheses for Mars

## Effects of sediment transport differences on morphology

- Faster development of landforms
- More overbank sedimentation
  - Levee building
  - Reduced migration
  - More avulsions
- Lower depositional slopes



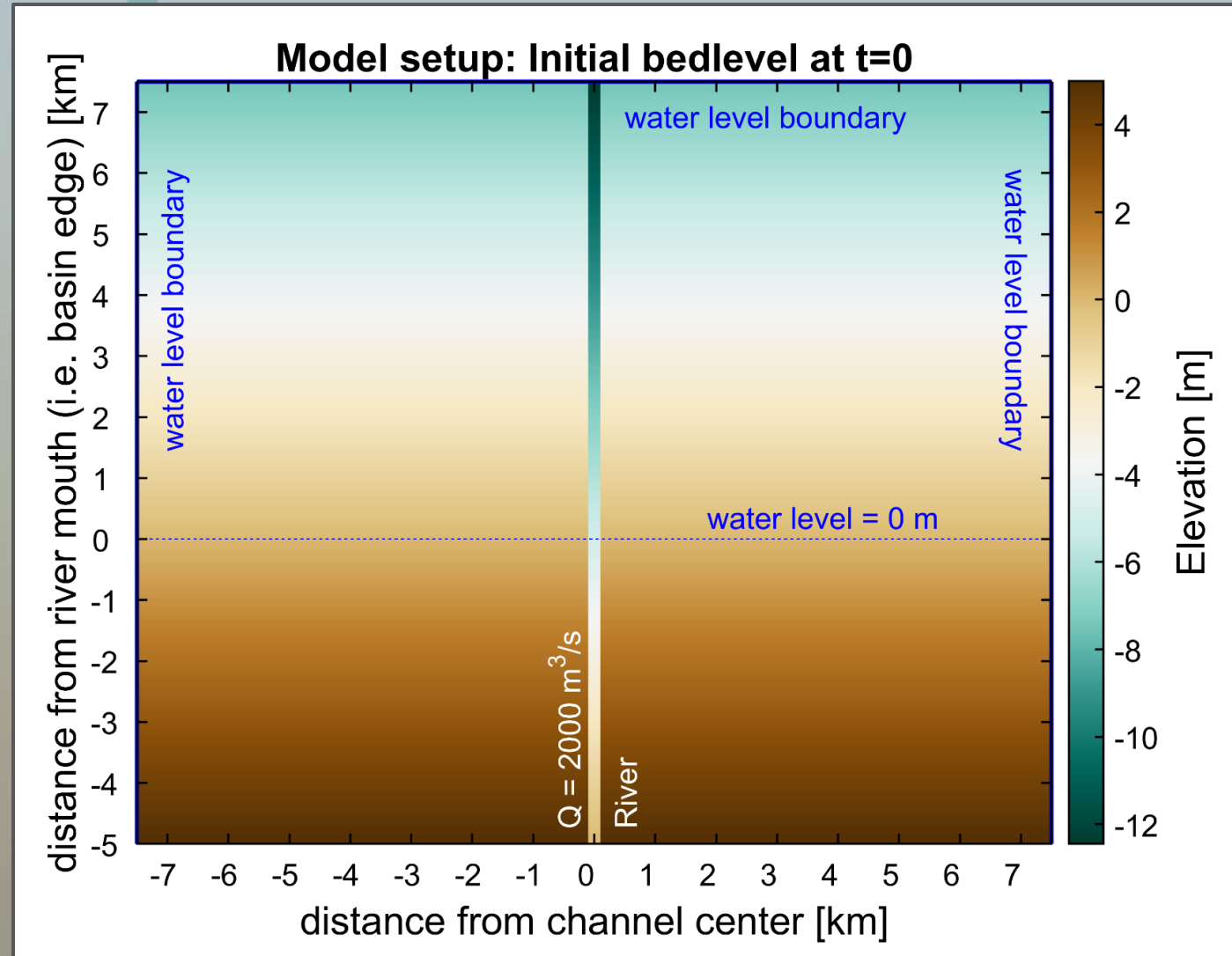
Thank you

A composite image showing the Earth on the left and Mars on the right, both in a similar perspective from space. The Earth shows blue oceans, white clouds, and brown/green landmasses. Mars is a reddish-brown sphere with some darker spots.

# Comparing delta morphology

# Hydro-morphodynamic delta model

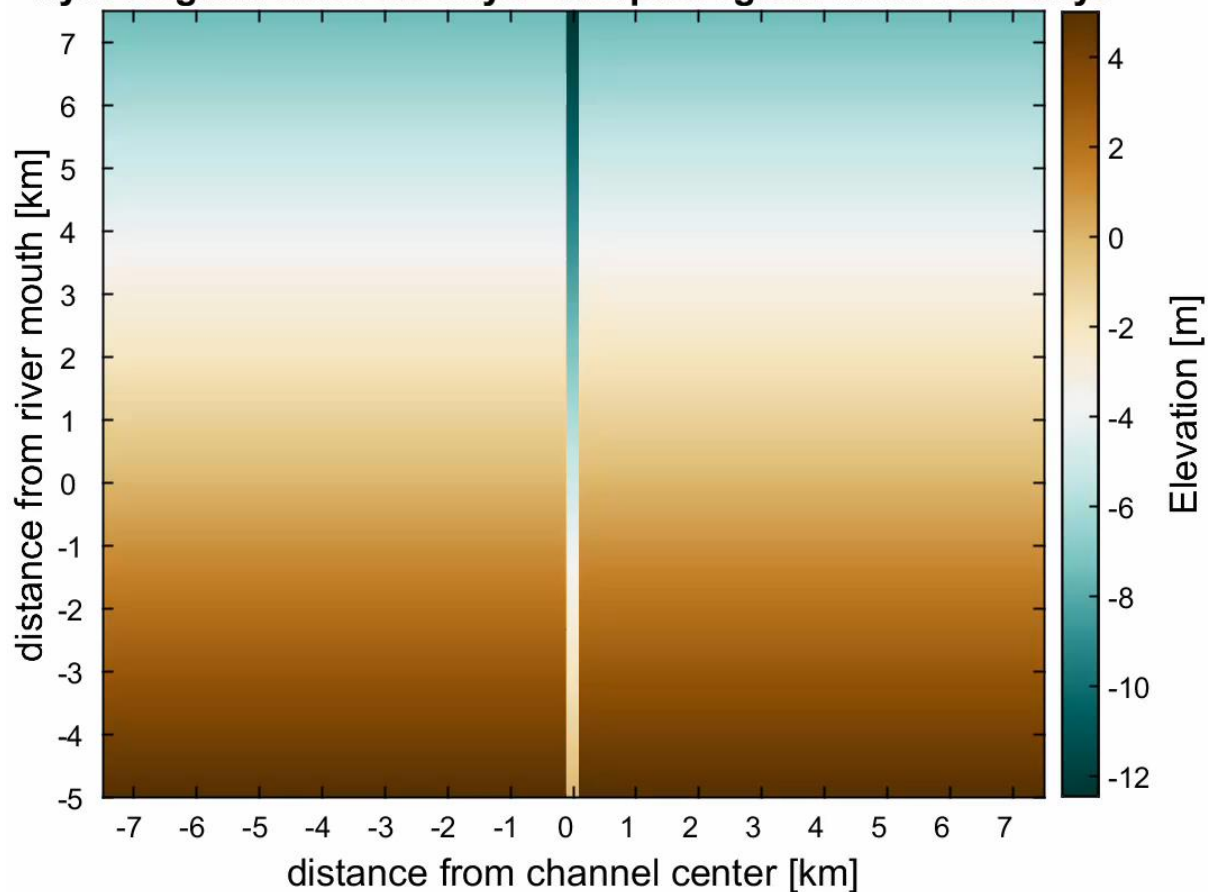
- River flowing into a basin
- Sloping plane = 0.001 m/m
- Channel = 200 m wide, 5 m deep
- Grain size = 2 mm
- Transport predictor = van Rijn 2004
- Delft3D Flexible Mesh



# Comparing delta evolution

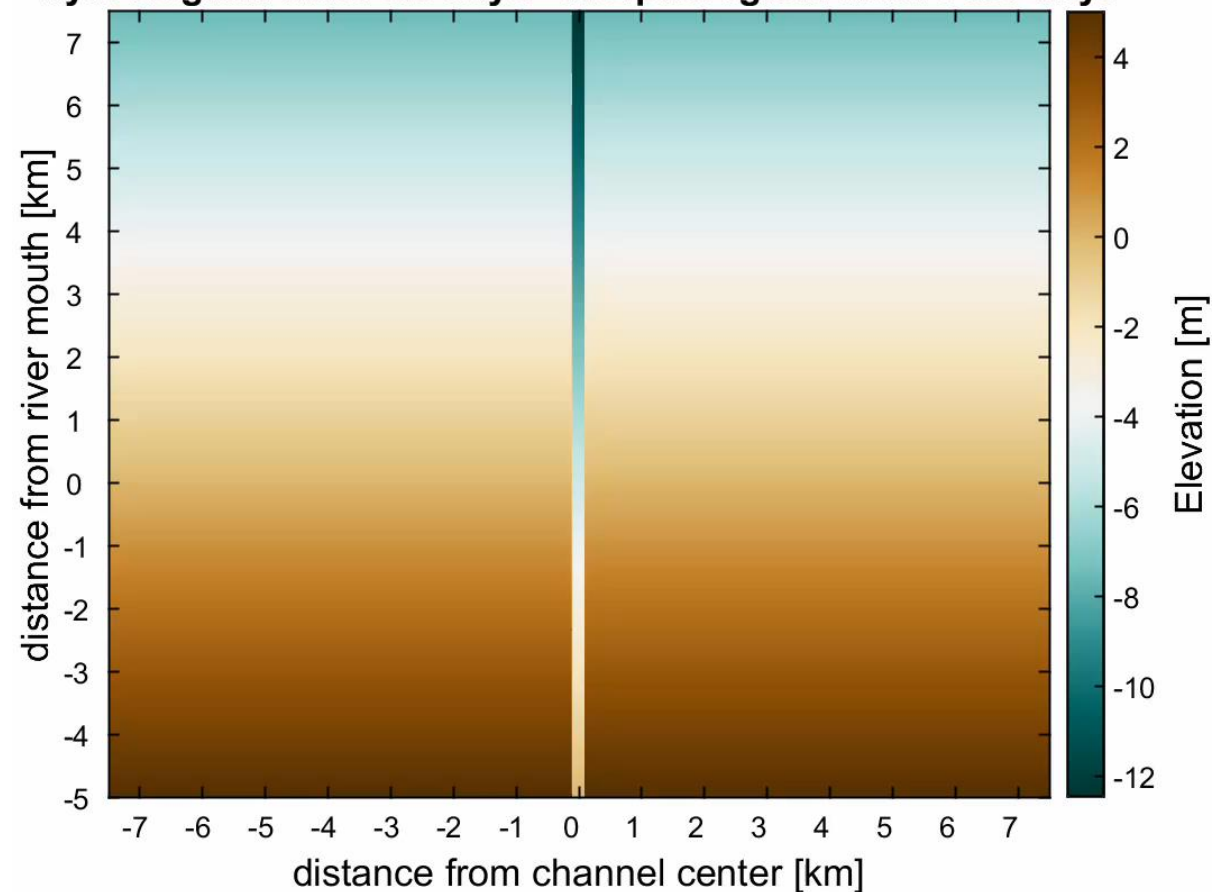
## Earth

Hydrological time: 0.0 days - Morphological time: 0000 days

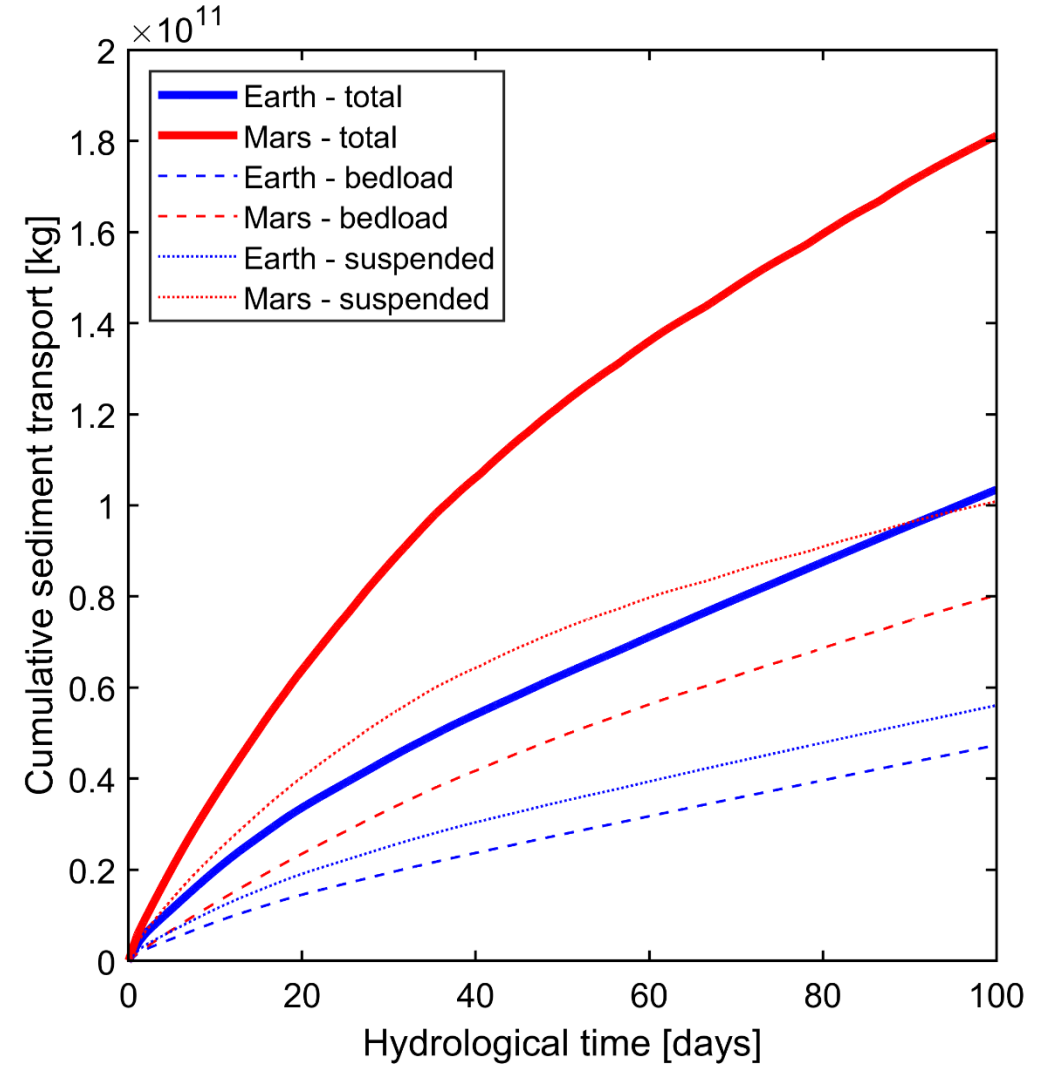
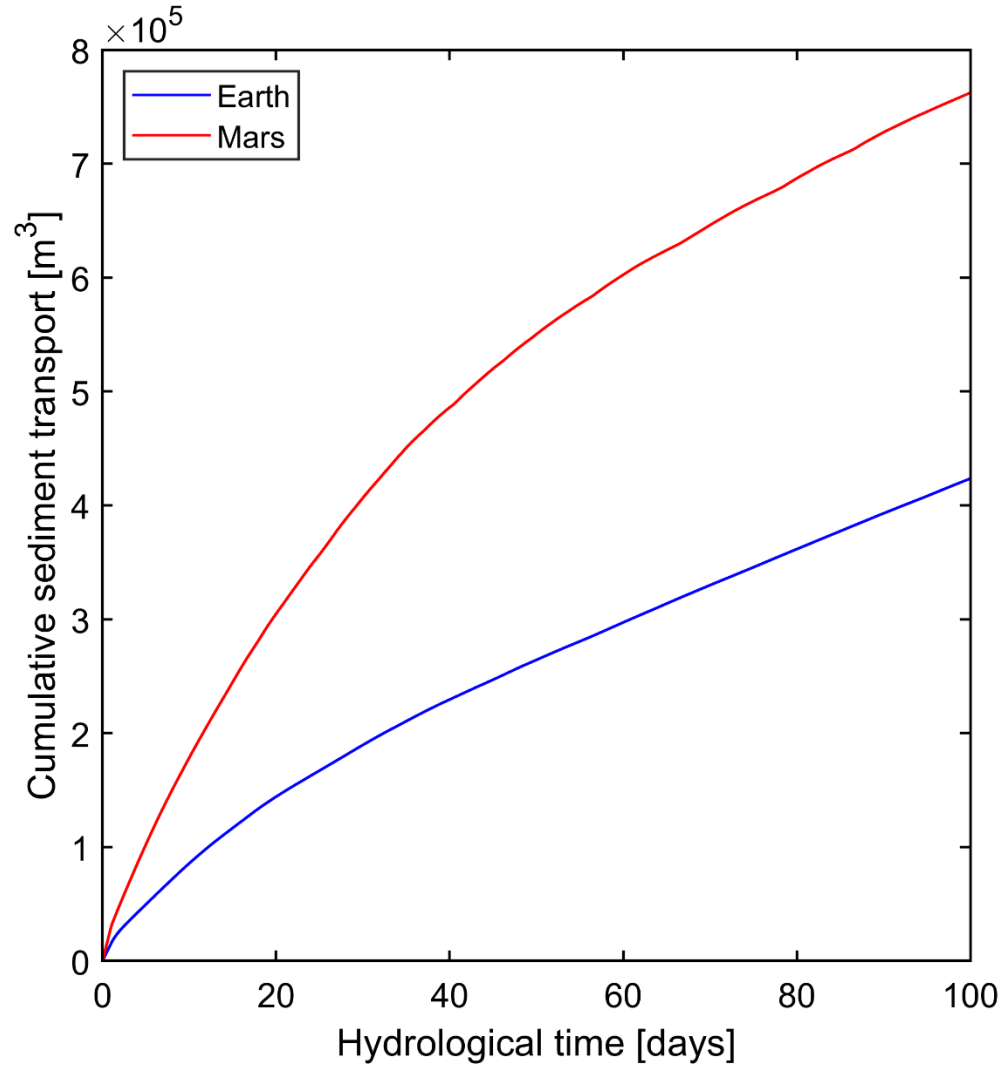


## Mars

Hydrological time: 0.0 days - Morphological time: 0000 days



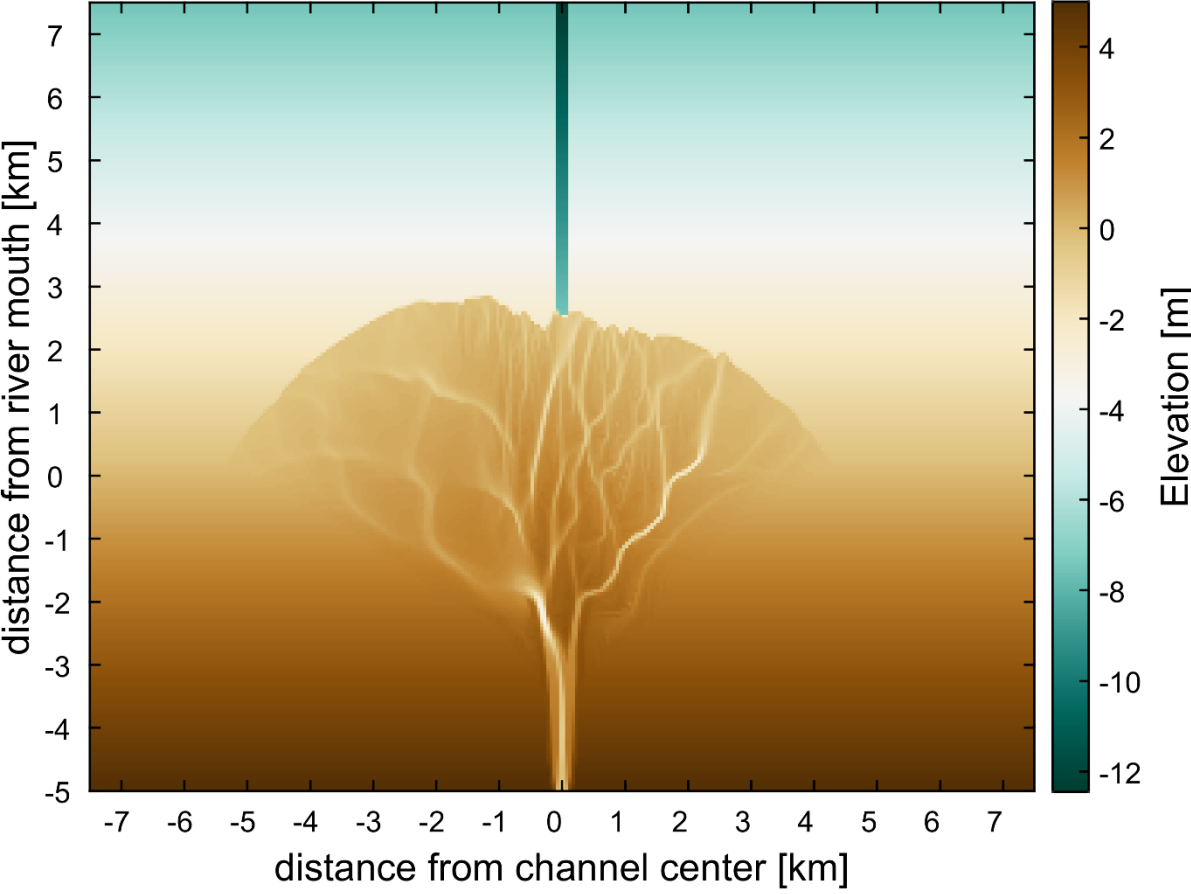
# Delta volume



# Multiple sediment fractions

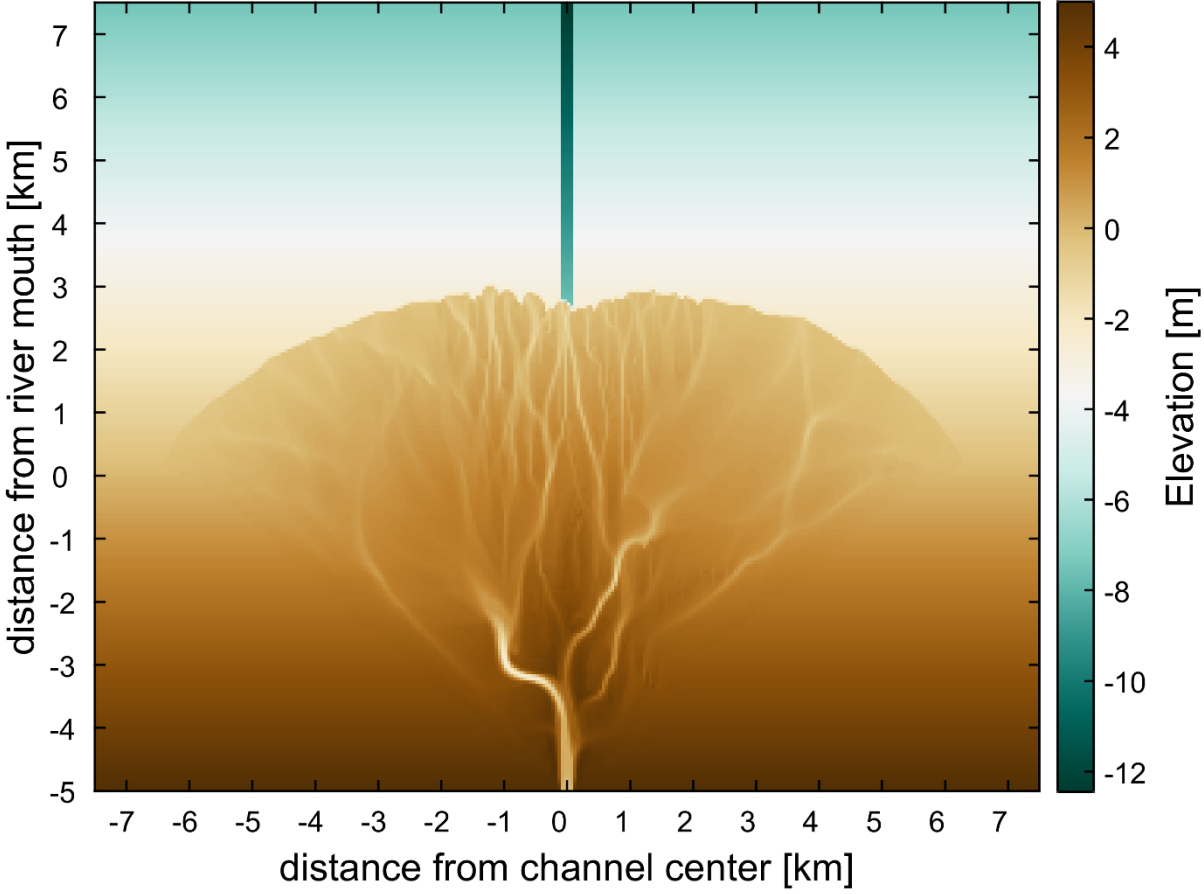
## Earth

Hydrological time: 24.5 days - Morphological time: 1175 days



## Mars

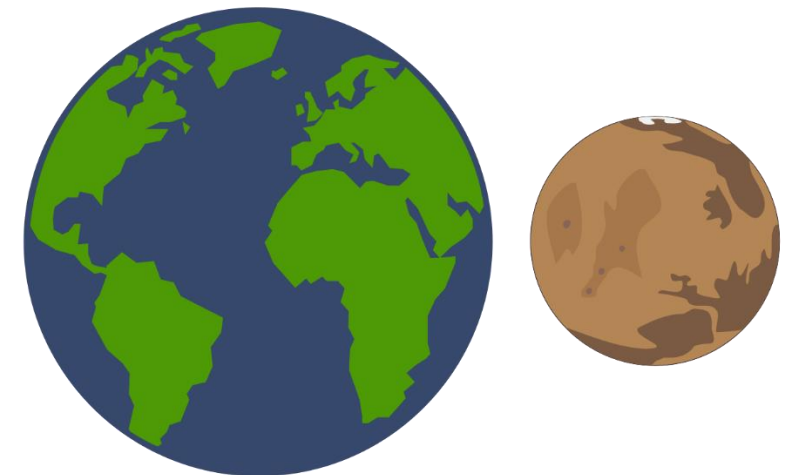
Hydrological time: 24.5 days - Morphological time: 1175 days



# Conclusions for Mars

## Effects of lower gravity in Deltas

- Deltas (and other fluvial landforms) develop more rapidly on Mars (for the same river discharge)
- Higher suspended transport rates
- Martian deltas have fewer active channels
- Less dynamic
- No conclusions yet on levees and slopes



Thank you for your attention! Questions?