

**PCA-5017**

**INTRODUÇÃO AOS SISTEMAS DE  
INFORMAÇÃO GEOGRÁFICA EM SOFTWARE  
LIVRE**

CARLOS HENRIQUE GROHMANN

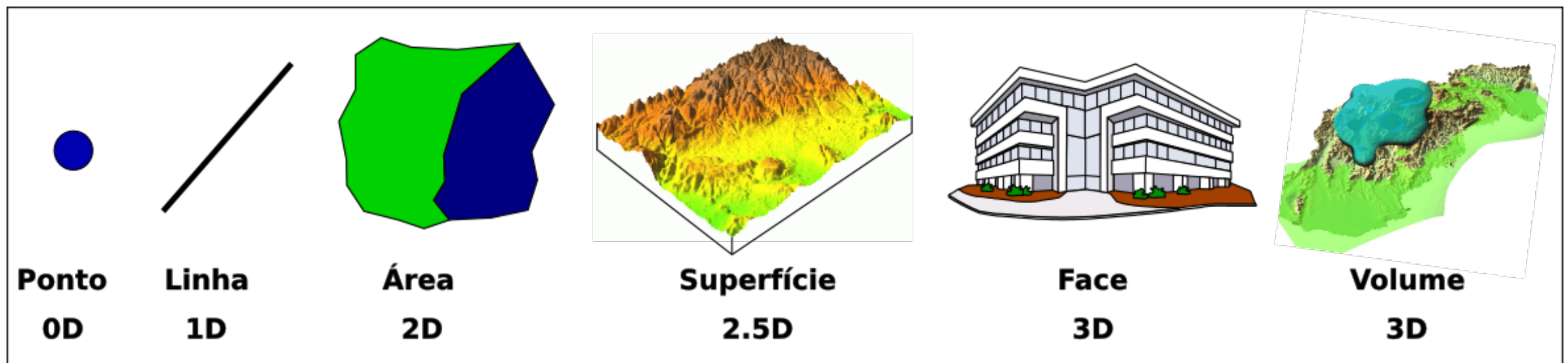
INSTITUTO DE ENERGIA E AMBIENTE - USP

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**Modelos Digitais de Terreno**

## MDE/MDT

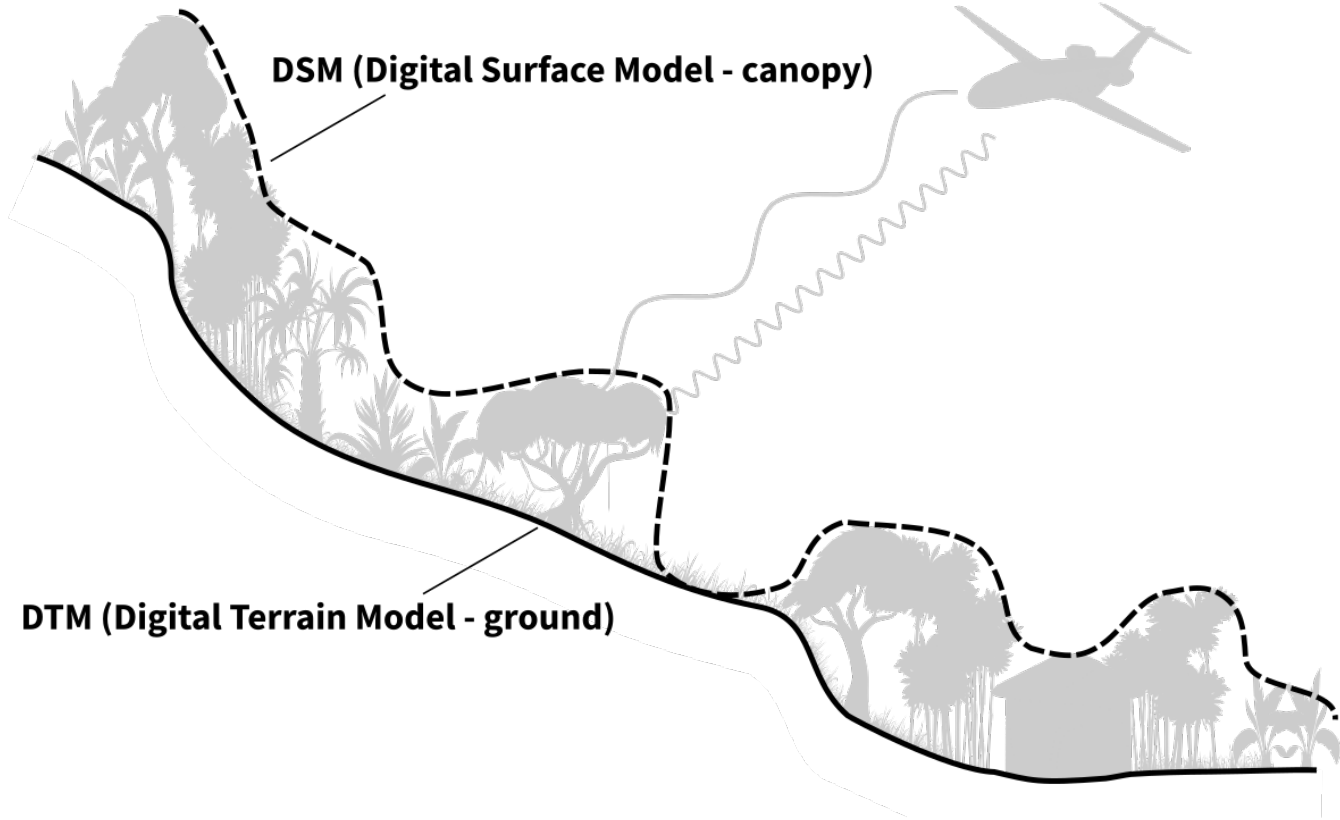
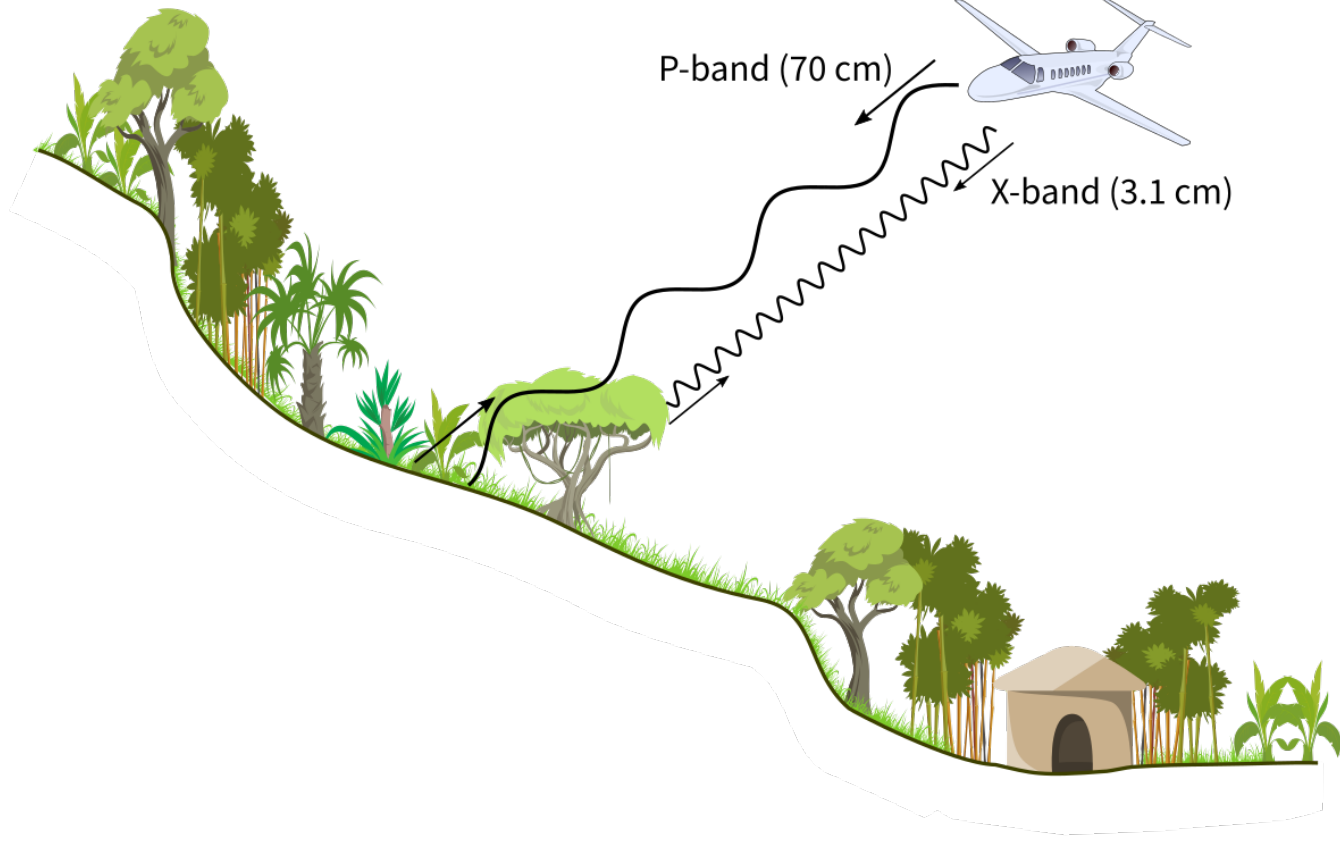
- ▶ Representação de uma superfície em SIG
  - ▶ Raster
  - ▶ Vetor (TIN)
  
- ▶ “2.5D”



## MDE/MDT/MDS ??

- ▶ MDS – Modelo Digital de **Superfície**
  - ▶ termo mais genérico
- ▶ MDT, MNT, DTM – Modelo Digital de **Terreno**
  - ▶ representa o relevo real
- ▶ MDE, DEM – Modelo Digital de **Elevação**
  - ▶ não necessariamente representa o relevo real, mas às vezes é usado com esse sentido

# MDE/MDT/MDS ??



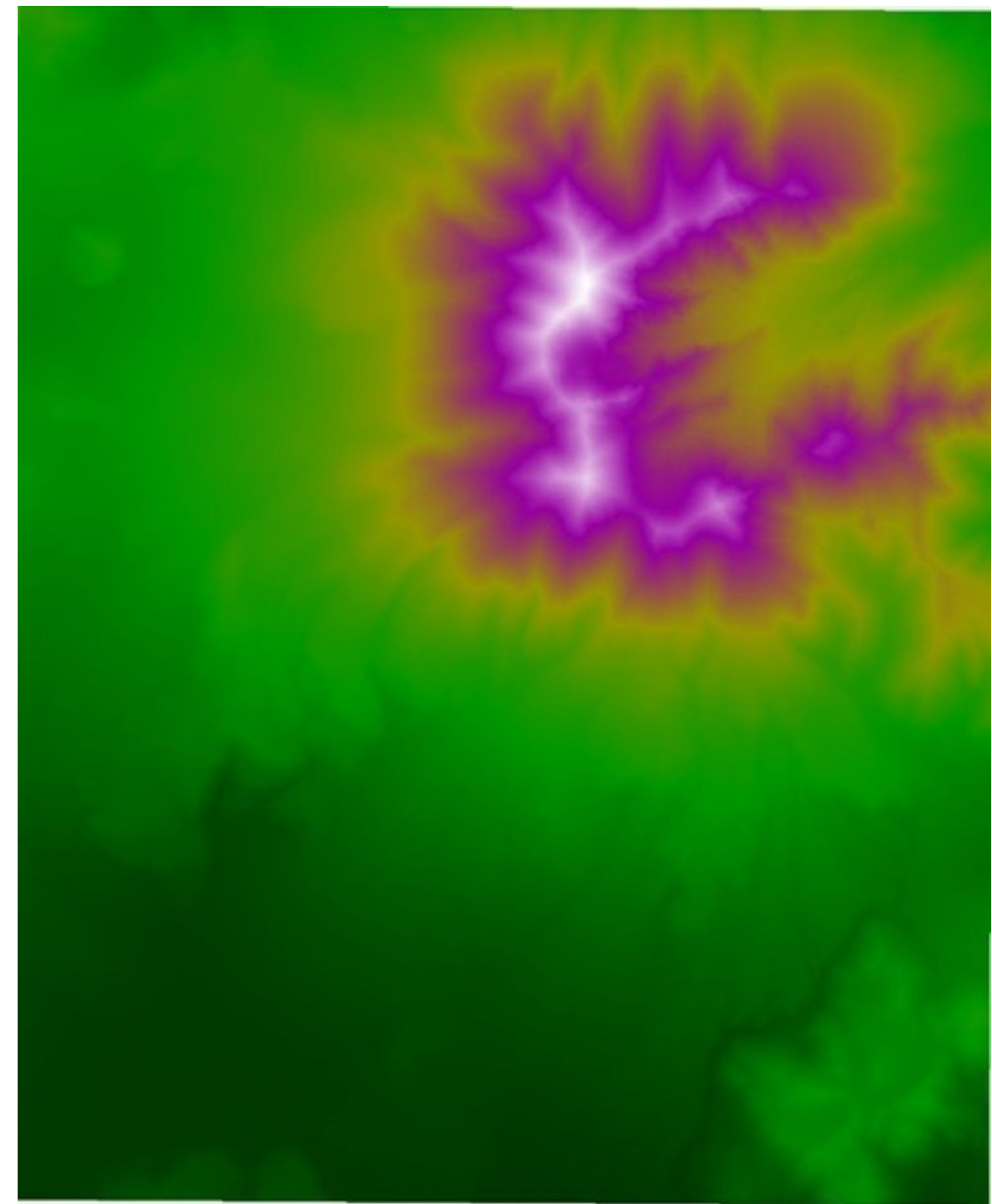
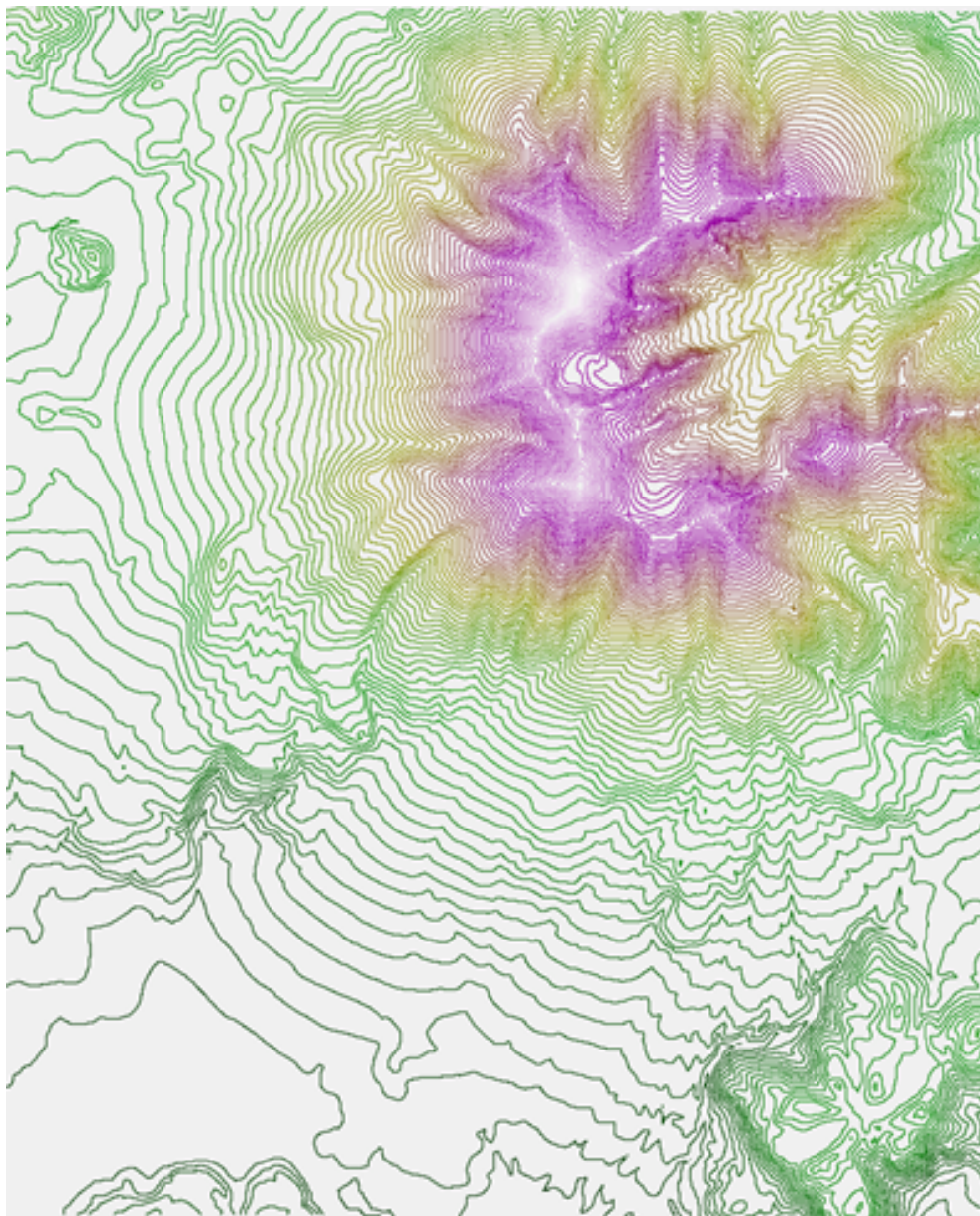


## Construção de MDEs

- ▶ Interpolação de dados vetoriais
  - ▶ curvas de nível
  - ▶ pontos cotados
  - ▶ curvas + pontos
  - ▶ soft breaklines, hard breaklines
- ▶ Sensoriamento remoto
  - ▶ fotogrametria
  - ▶ interferometria de radar
  - ▶ LiDAR

## Construção de MDEs

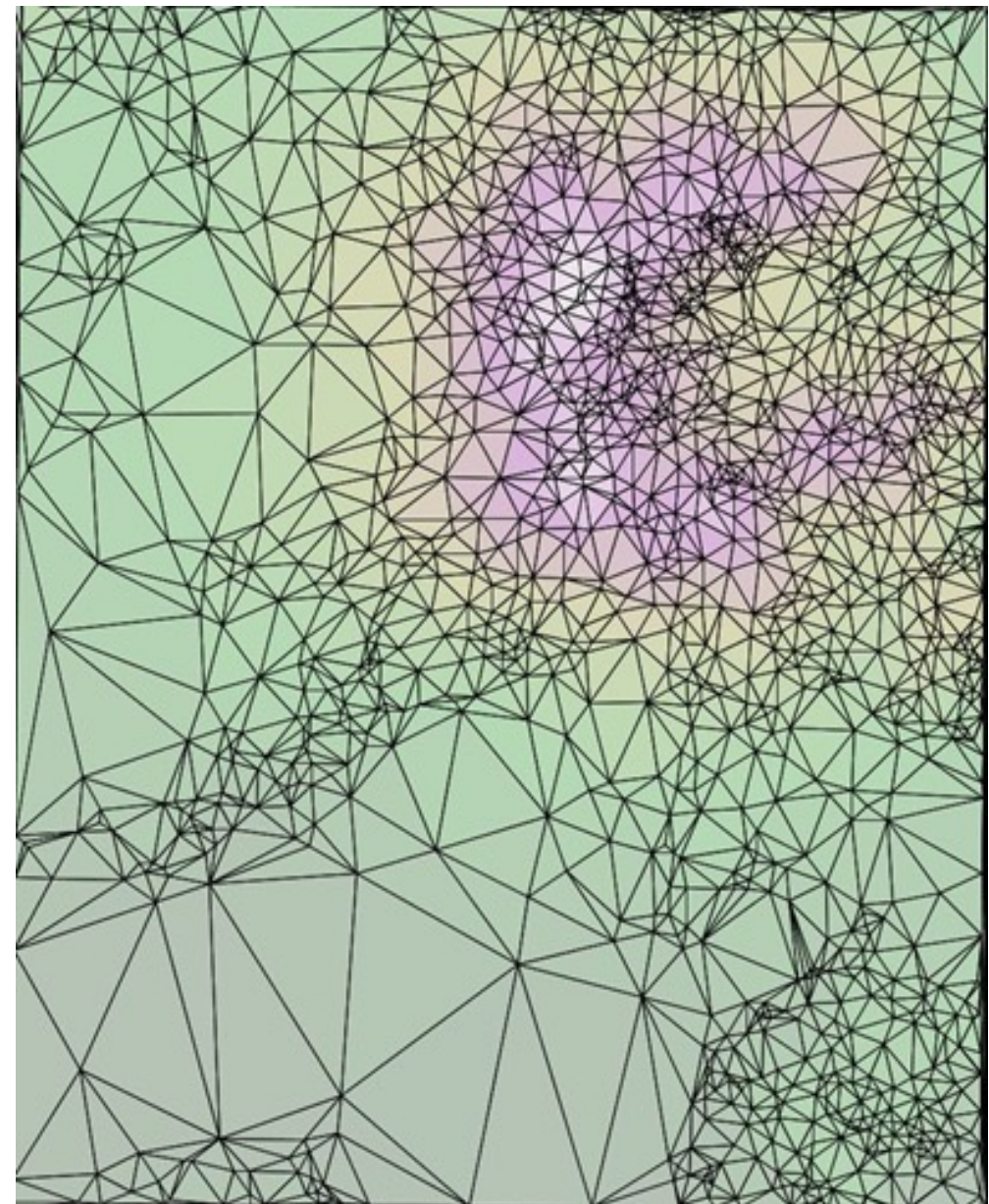
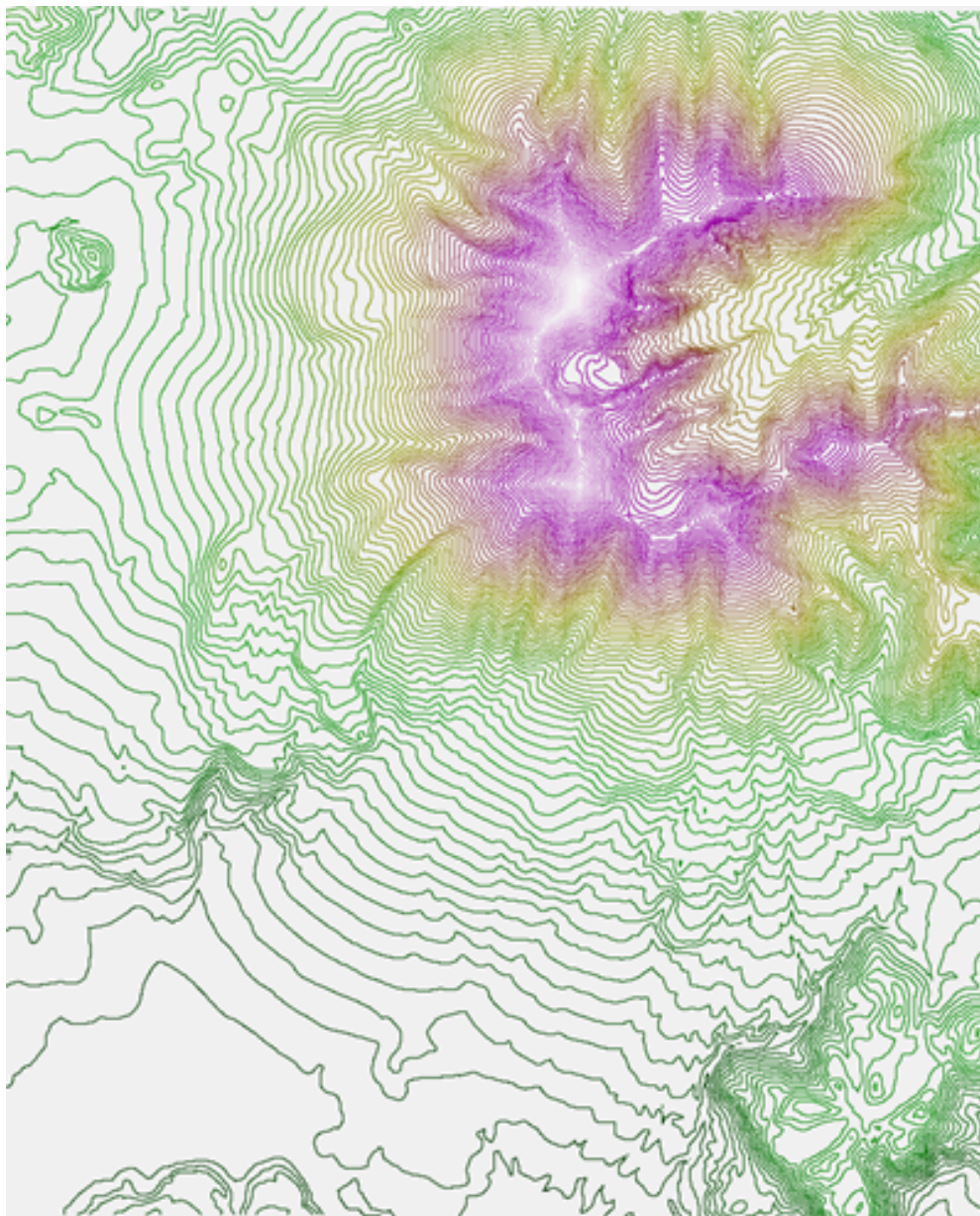
- ▶ Interpolação de dados vetoriais





## Construção de MDEs

- ▶ Interpolação de dados vetoriais



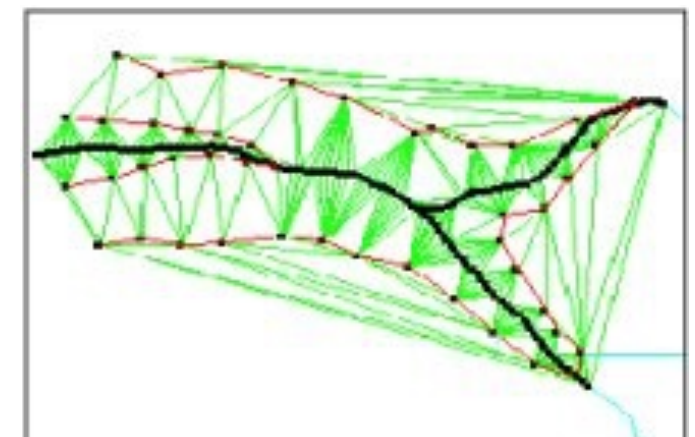
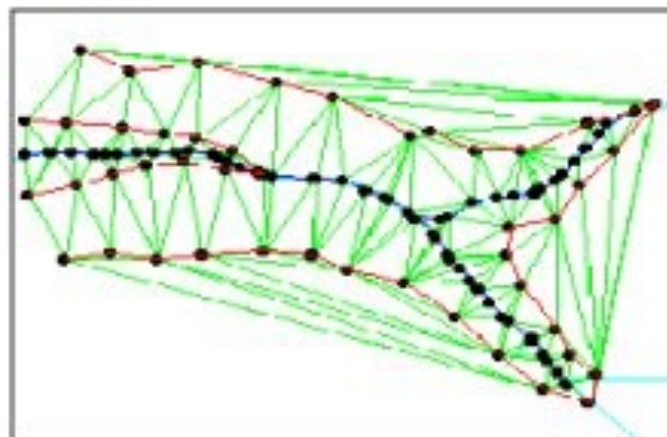
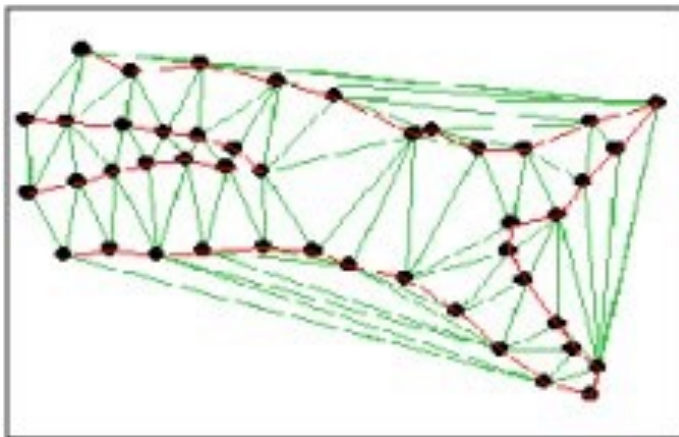
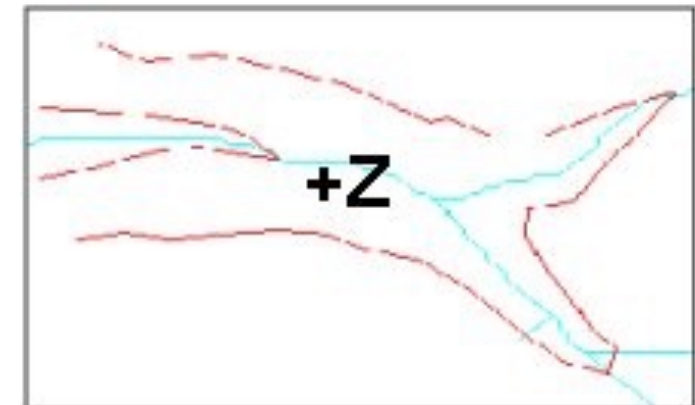
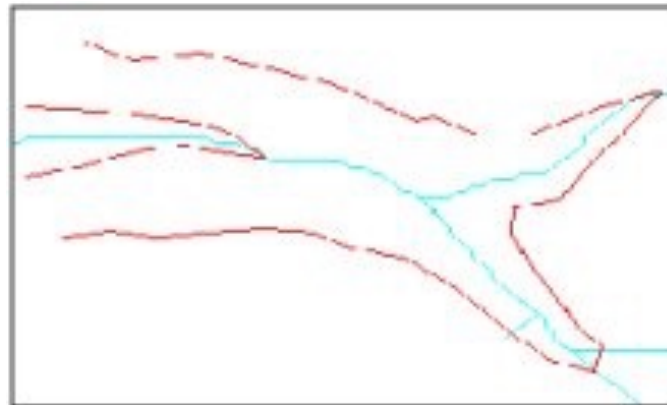


## Construção de MDEs

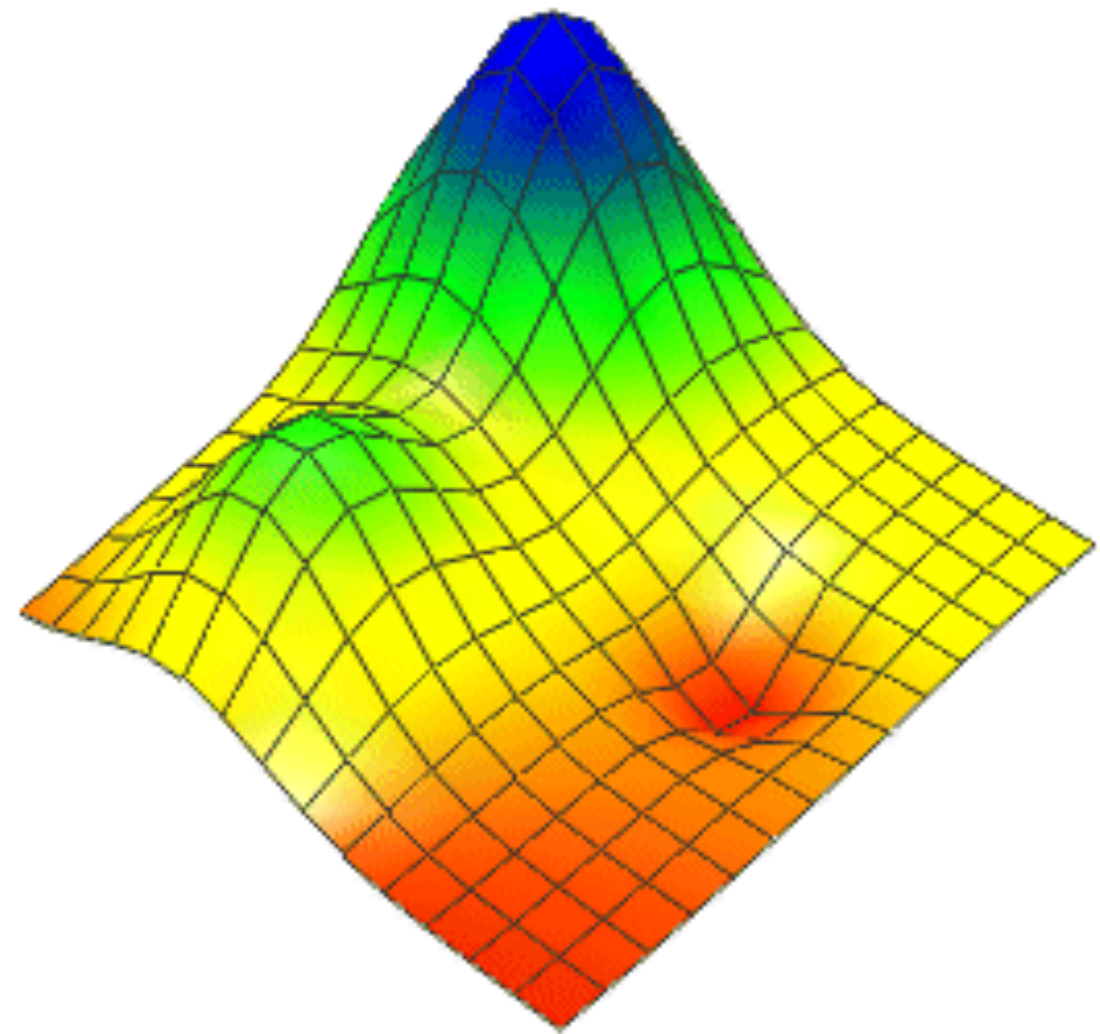
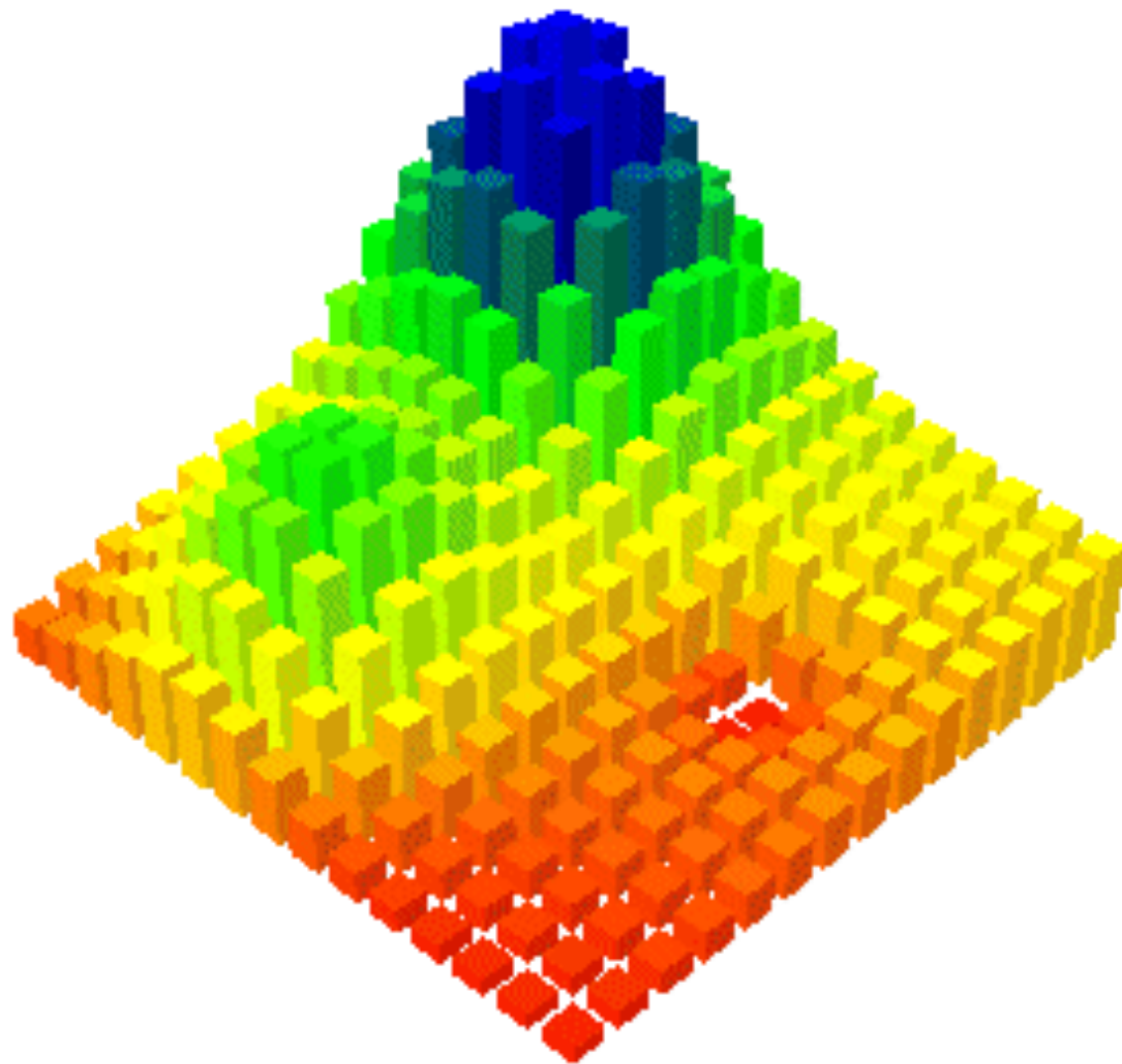
### ► Breaklines

soft breaklines

hard breaklines

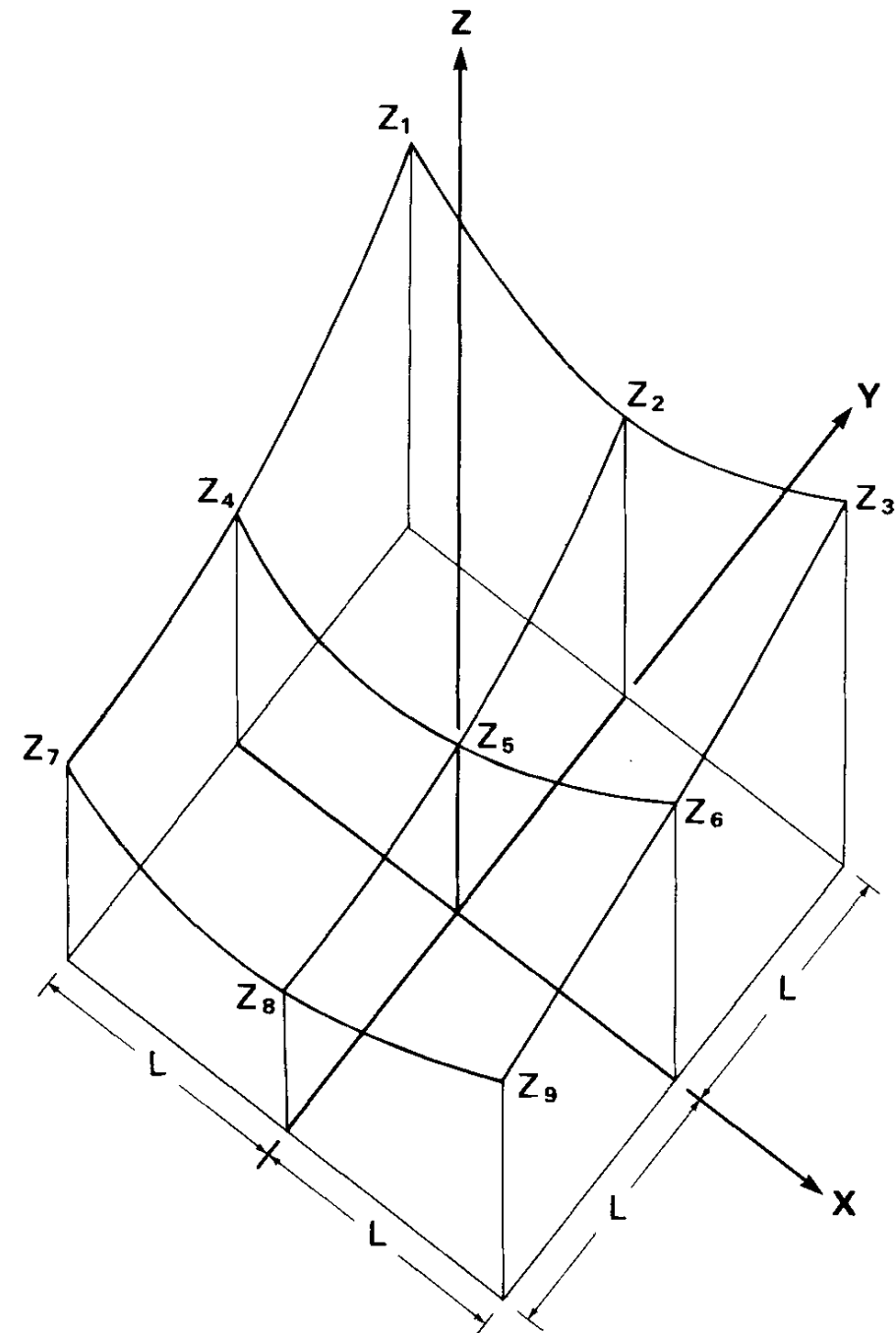


## Representações Discretas x contínuas

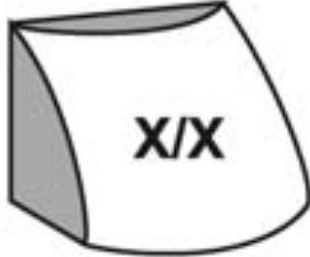


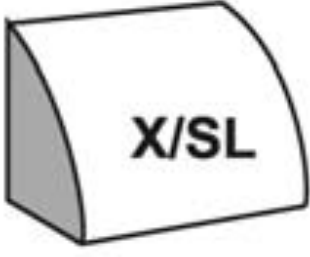


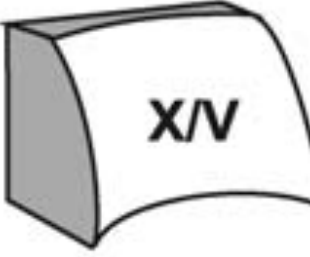




## Derivadas da superfície

- ▶ Declividade (slope)
  - ▶ 1a. derivada vertical
- ▶ Orient. de vertentes (aspect)
  - ▶ 1a. derivada horizontal
- ▶ Curvatura de perfil
  - ▶ 2a. derivada vertical
- ▶ Curvatura tangencial
  - ▶ 2a. derivada horizontal



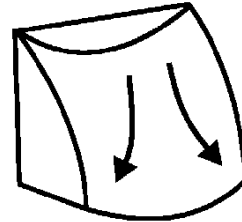
# Curvaturas

		profile curvature		
		convex	profile-straight	concave
tangential curvature	convex	 X/X	 SF/X	 V/X
	tangential-straight	 X/SL	 SF/SL	 V/SL
	concave	 X/V	 SF/V	 V/V

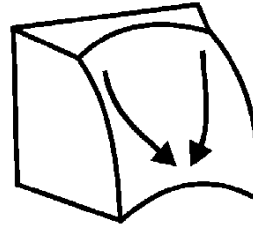
## Curvaturas

Contour

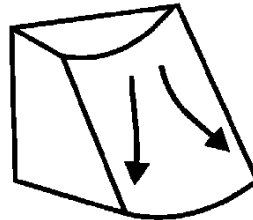
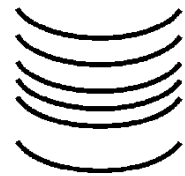
Block



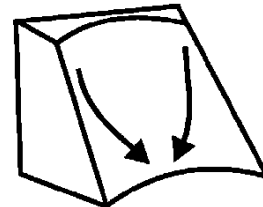
Divergent Shoulder



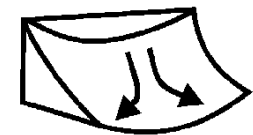
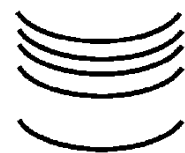
Convergent Shoulder



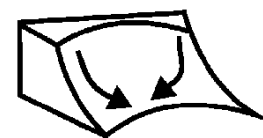
Divergent Backslope



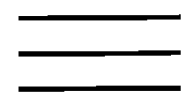
Convergent Backslope



Divergent Footslope



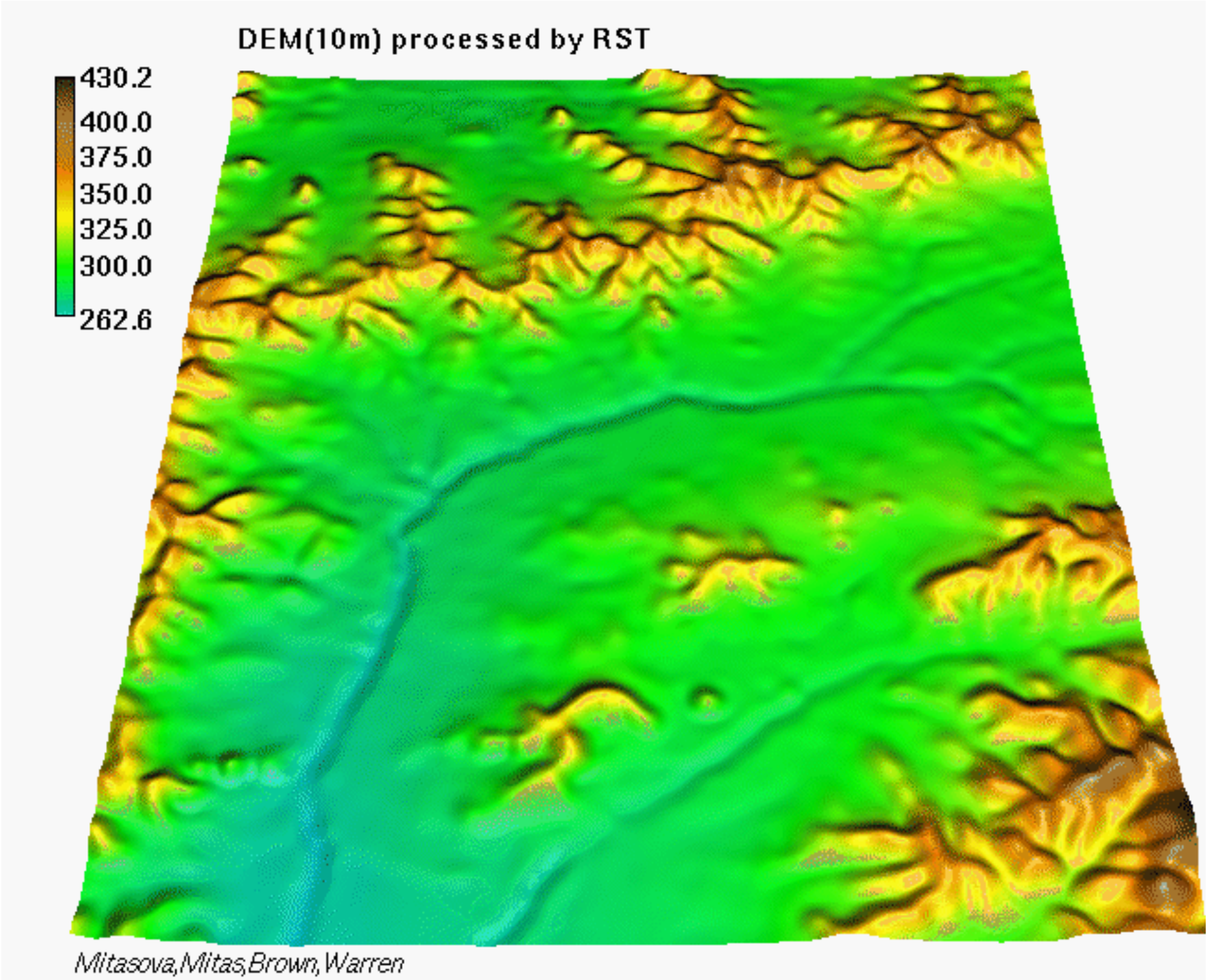
Convergent Footslope



Level

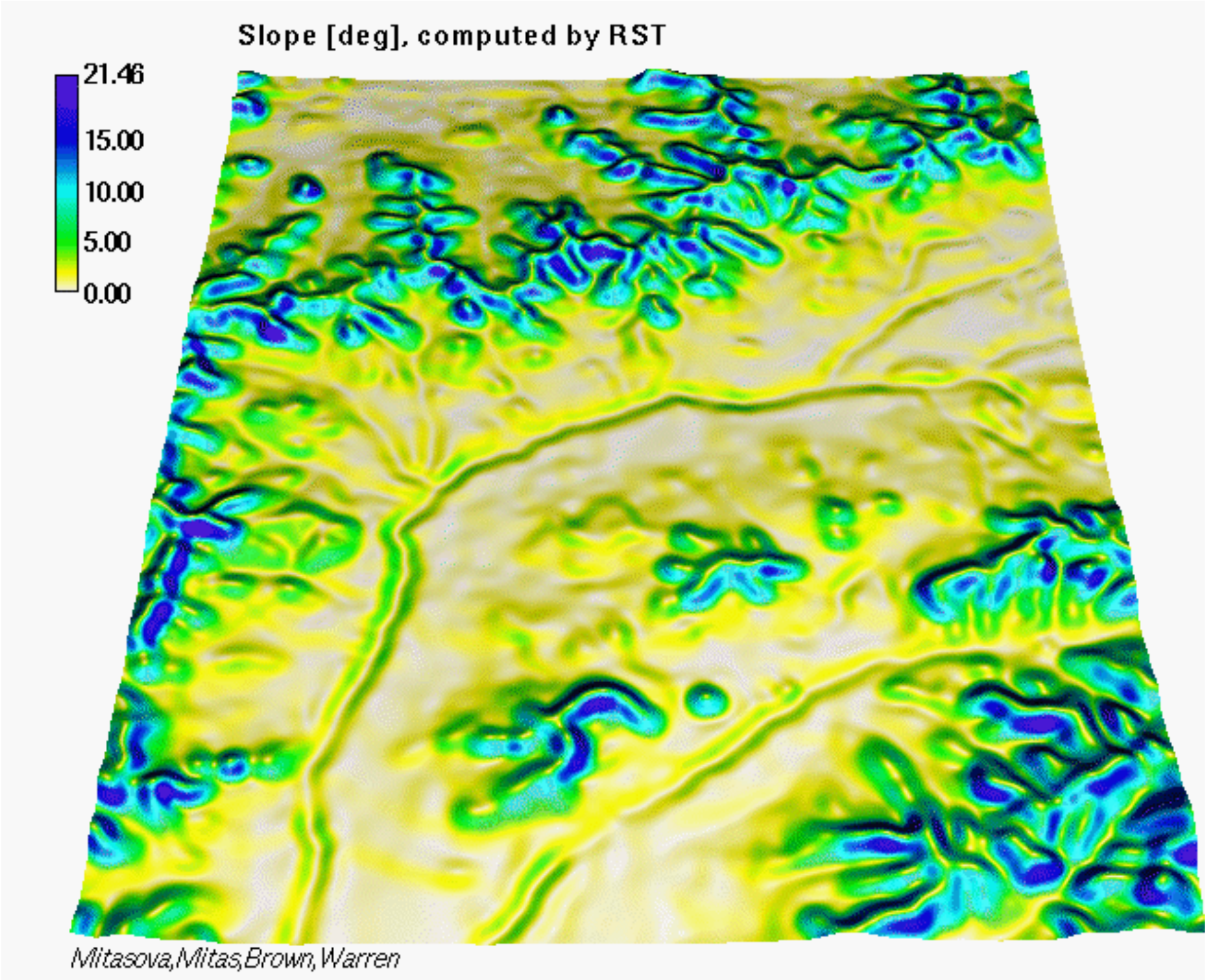


DEM



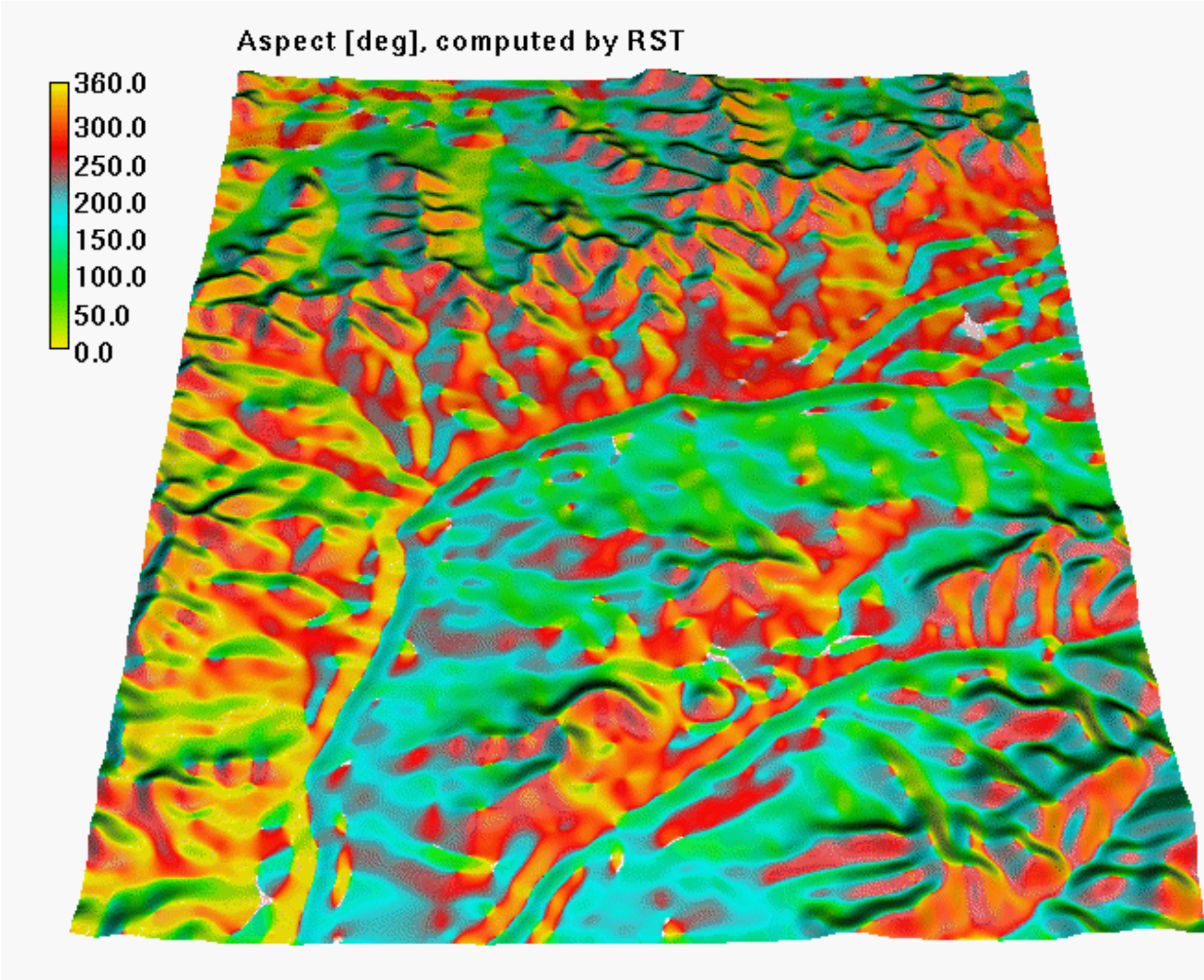


# Slope



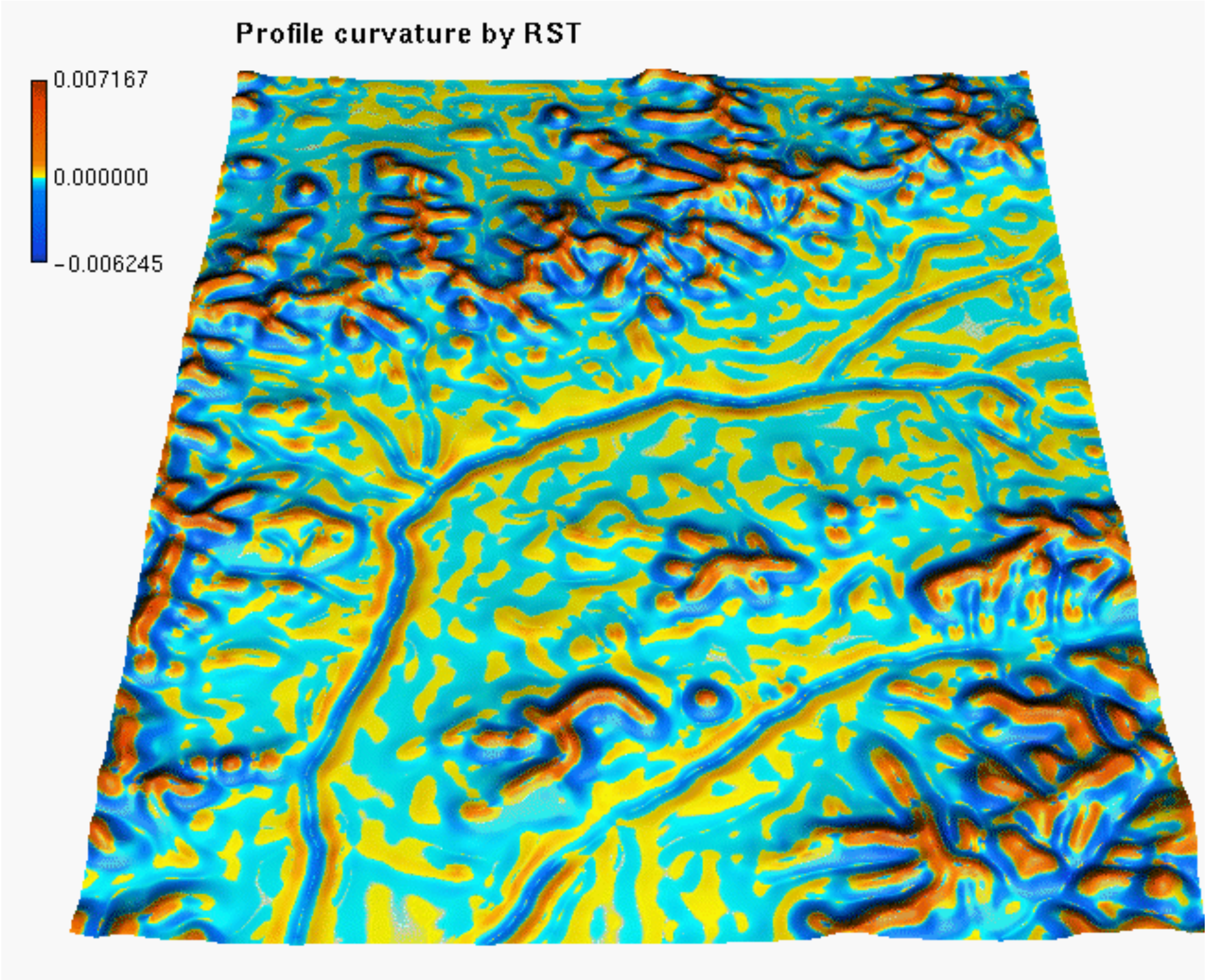


# Aspect



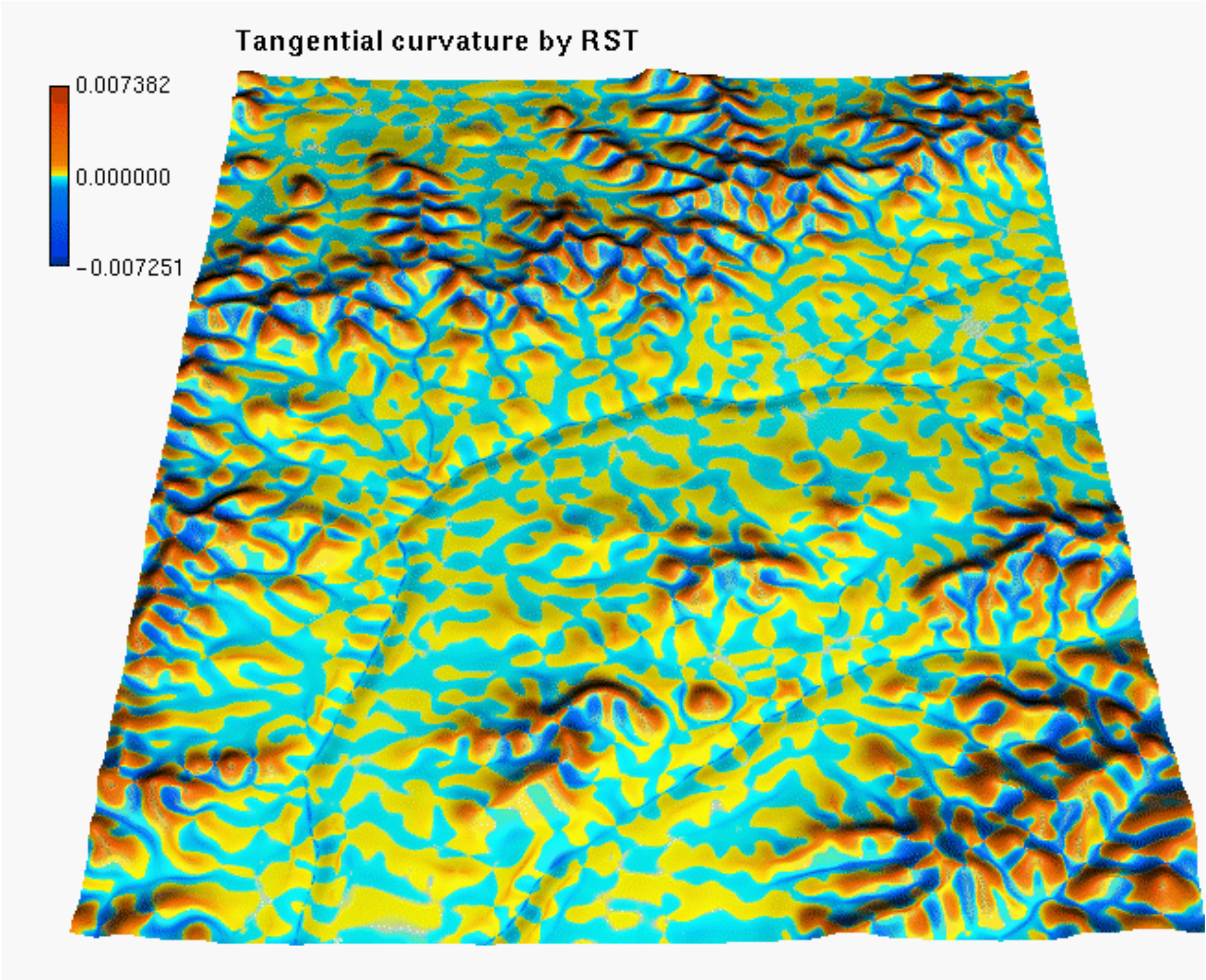


profile curvature



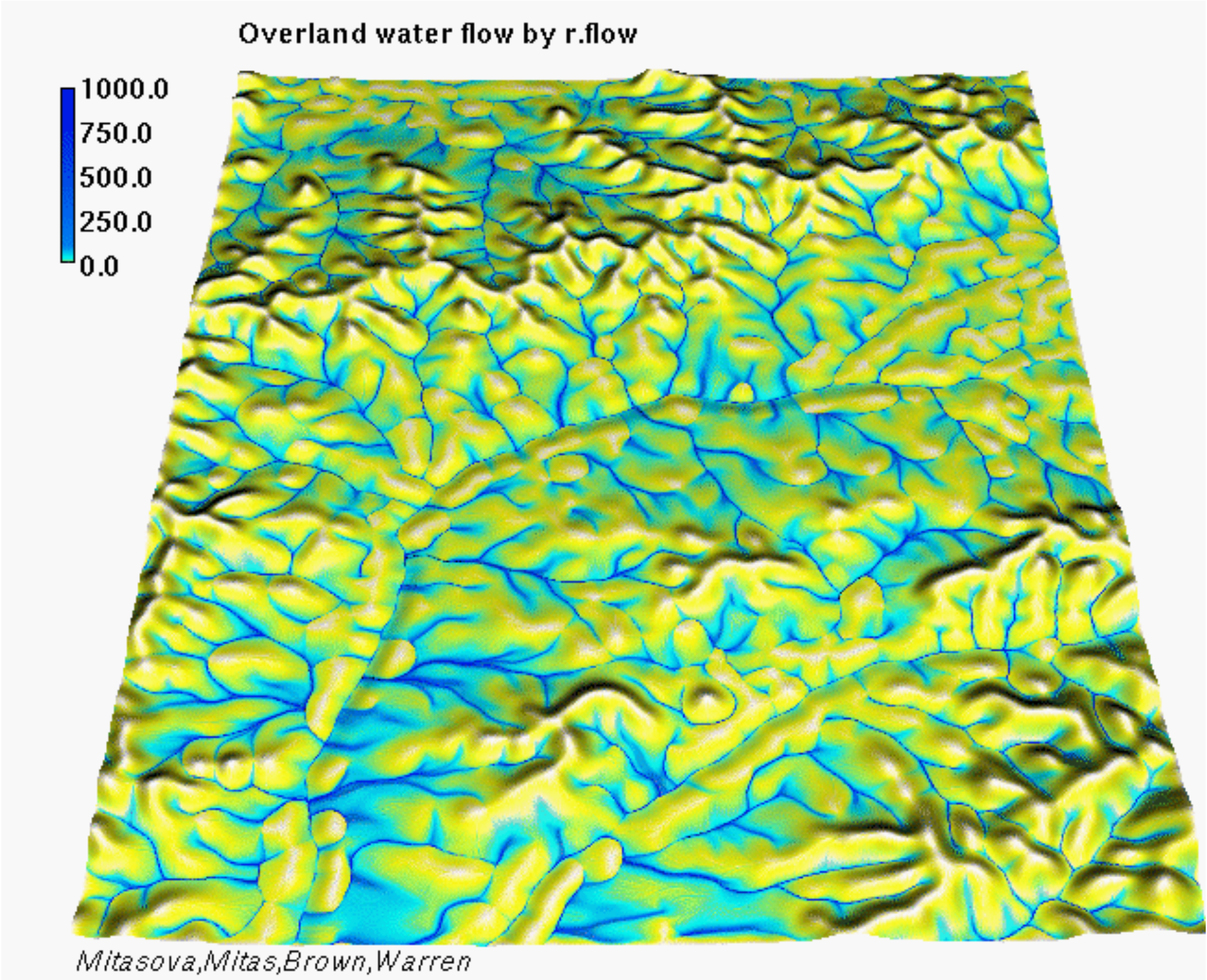


**tang. curvature**



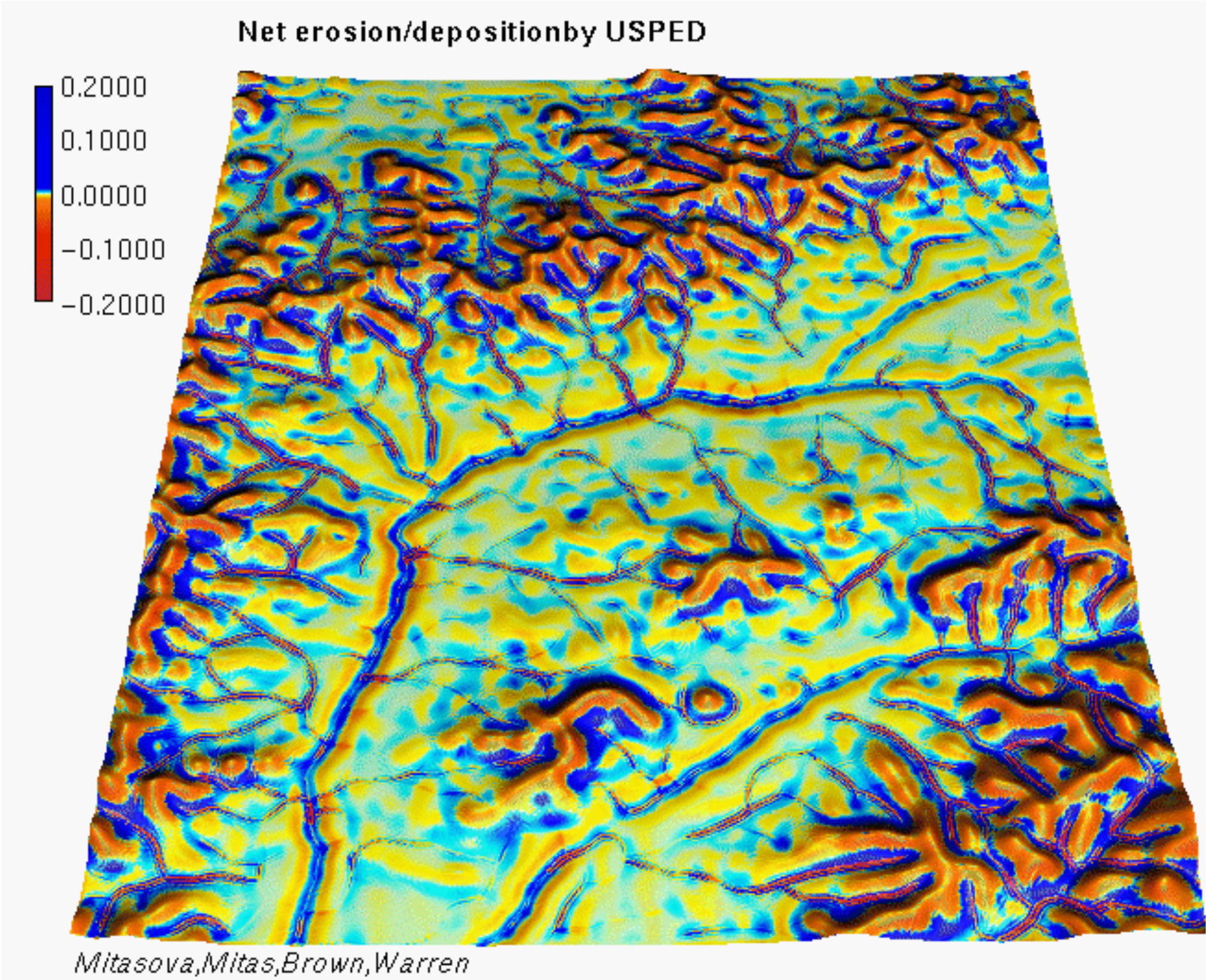


flow





erosion



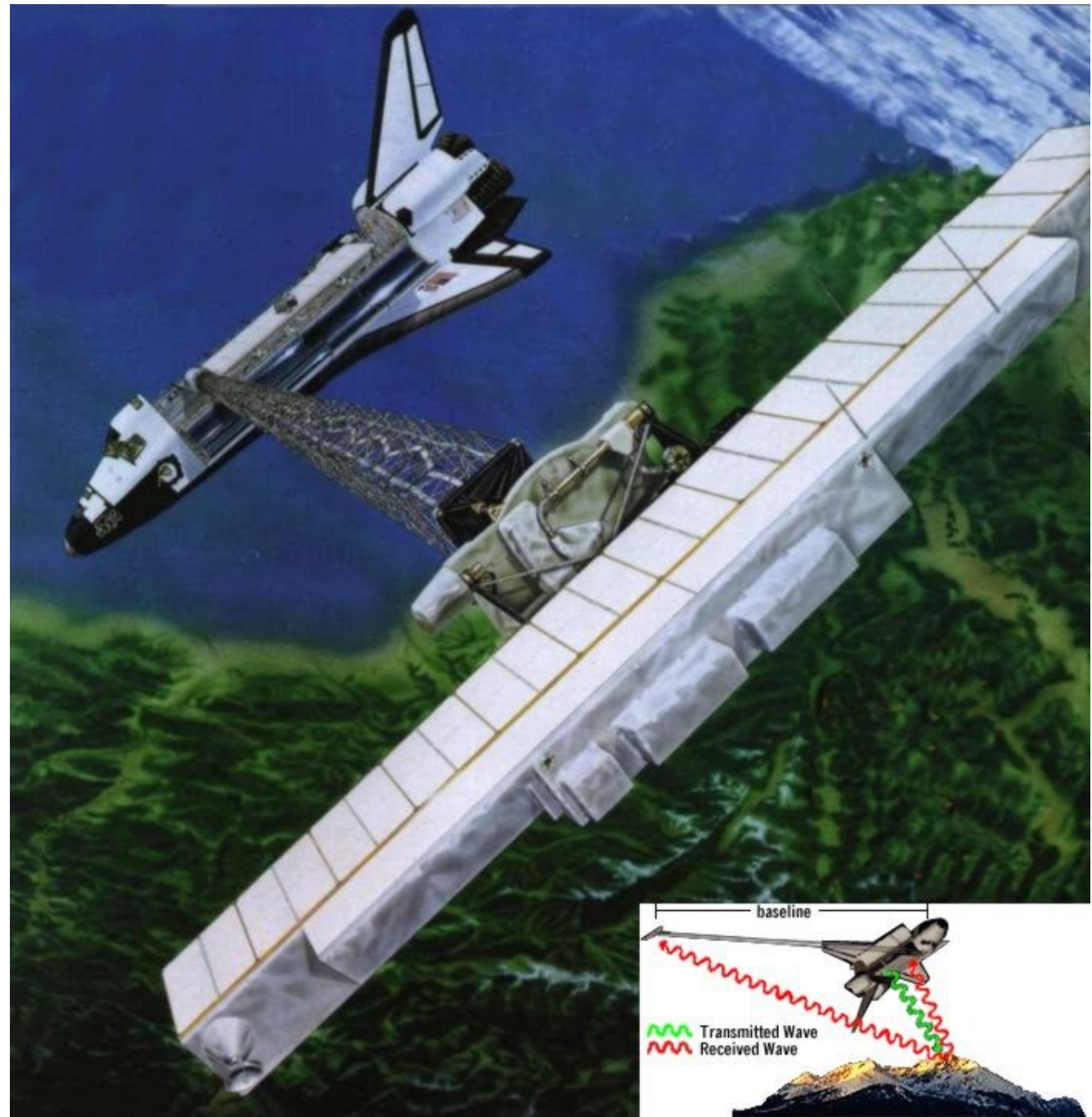
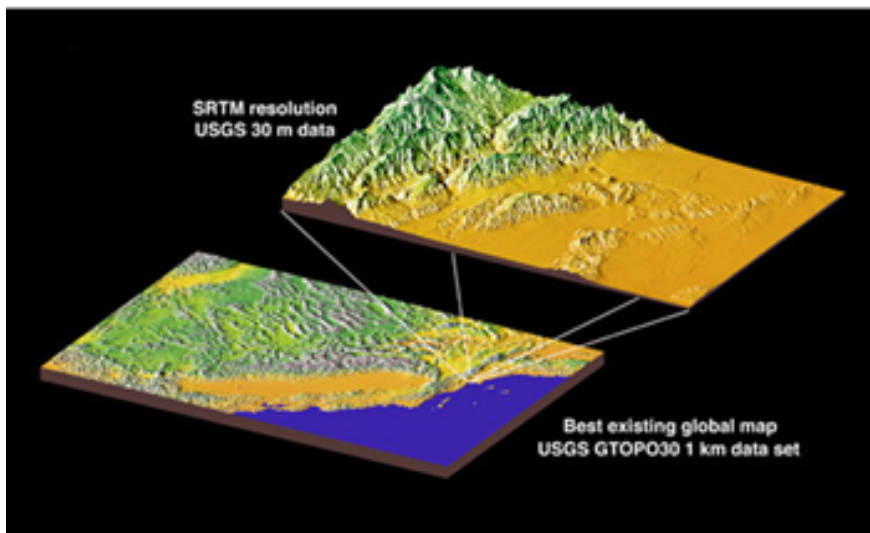
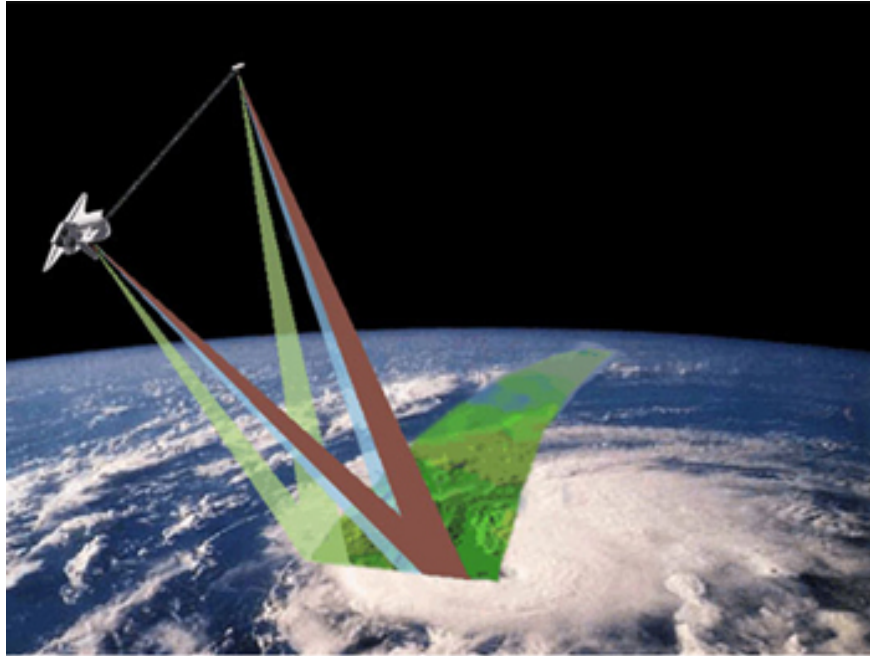
## SRTM

### ▶ Shuttle Radar Topography Mission

- ▶ MDEs gerados por interferometria de radar, com abrangência de 80% da superfície terrestre
- ▶ Inicialmente:
  - ▶ Estados Unidos – resolução de 1" (aprox. 30m)
  - ▶ O resto do Mundo – resolução de 3" (aprox. 90m)
- ▶ Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., Seal, D., Shaffer, S., Shimada, J., Umland, J., Werner, M., Oskin, M., Burbank, D., & Alsdorf, D., 2007. The Shuttle Radar Topography Mission. *Review of Geophysics*, 45:RG2004.

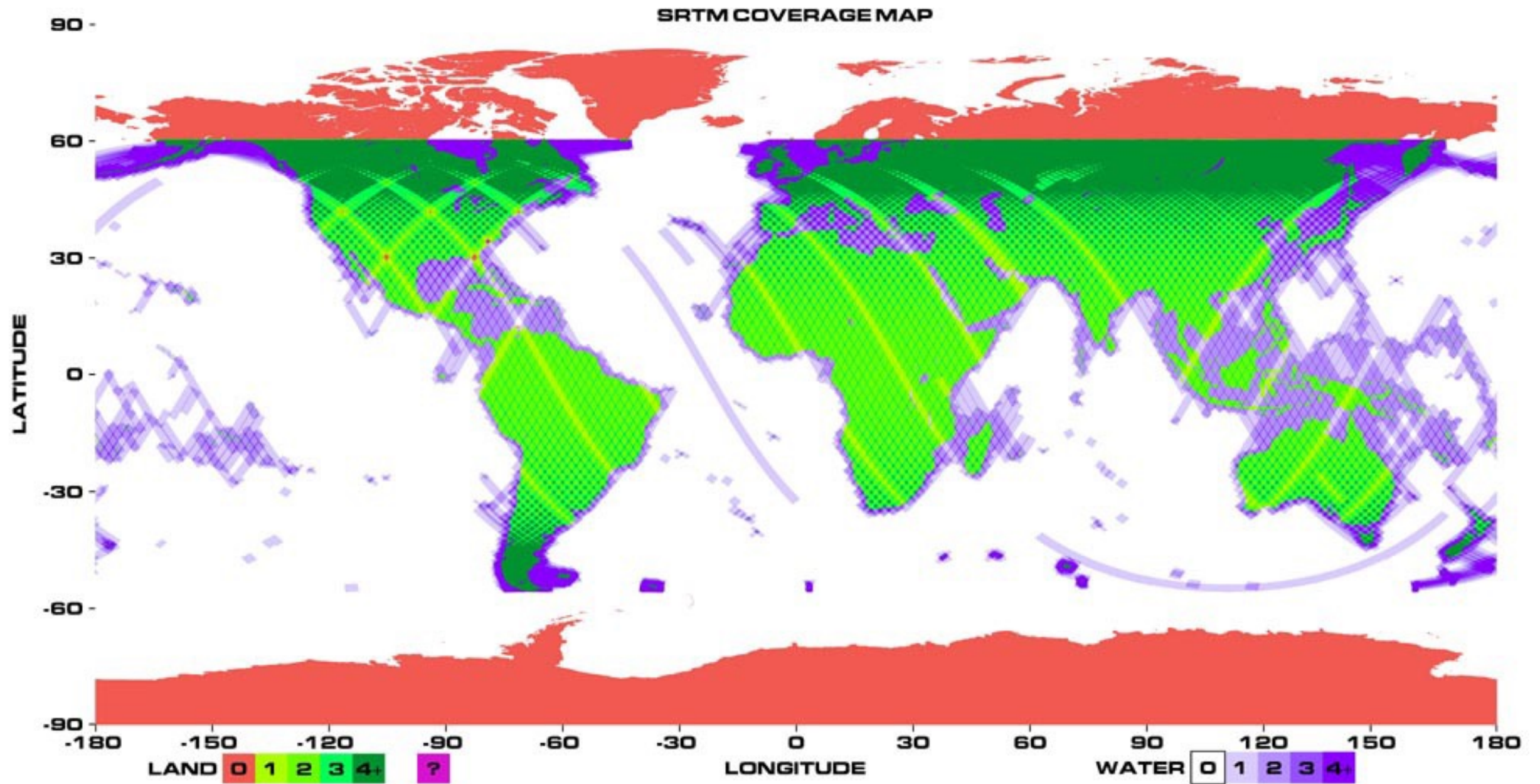


# SRTM





# SRTM



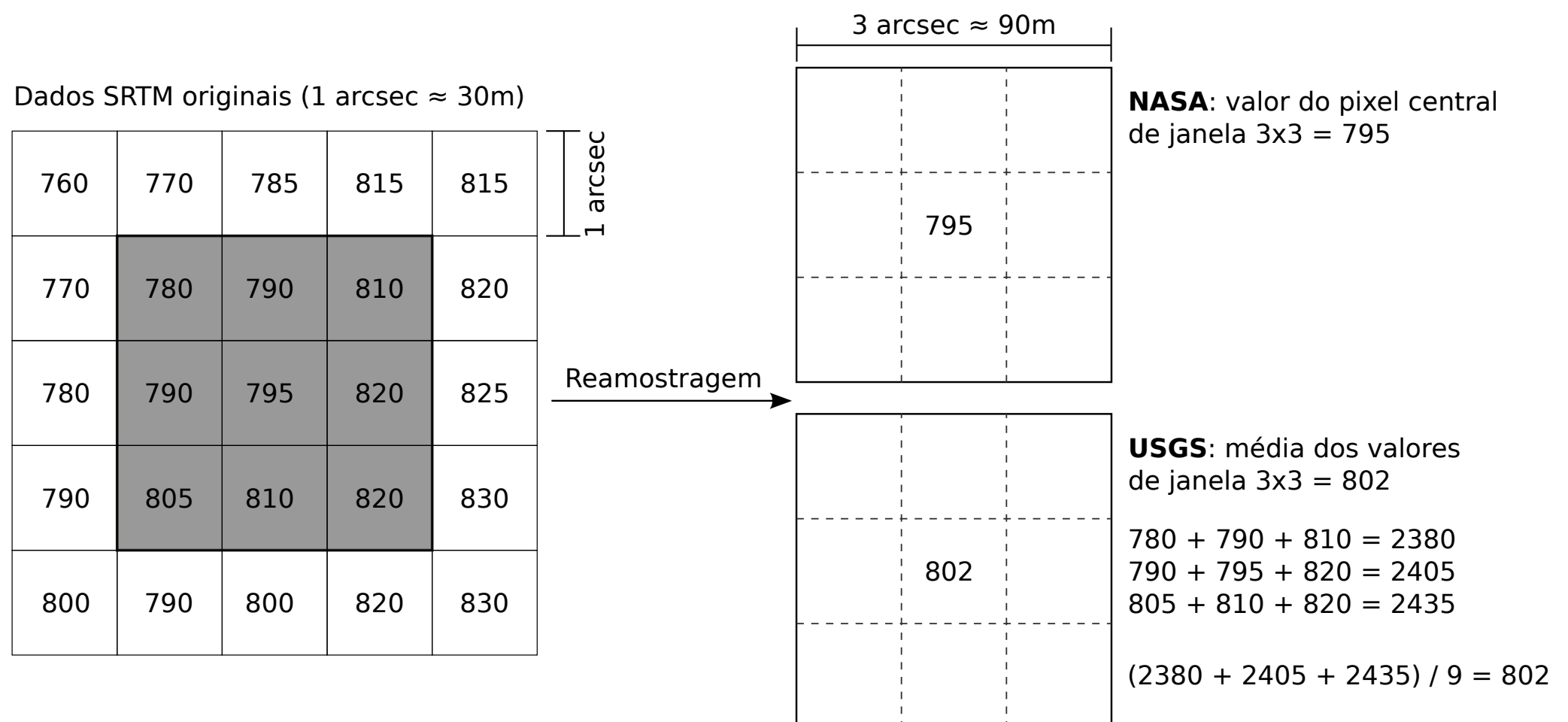
## SRTM

### ▶ Versões dos dados SRTM

- ▶ NASA SRTM V1 - 2003
- ▶ NASA SRTM V2 e V2.1 - "*Finished version*" (2005)
  - ▶ SRTM Water Body Data - SWBD
  - ▶ Embrapa - Brasil em Relevo (2005)
- ▶ NASA SRTM V3 - 2013/2014 (01" para mundo todo)
- ▶ CGIAR-CSI SRTM V4.1 - 2008
- ▶ DLR SRTM X-SAR - 30m - 2010

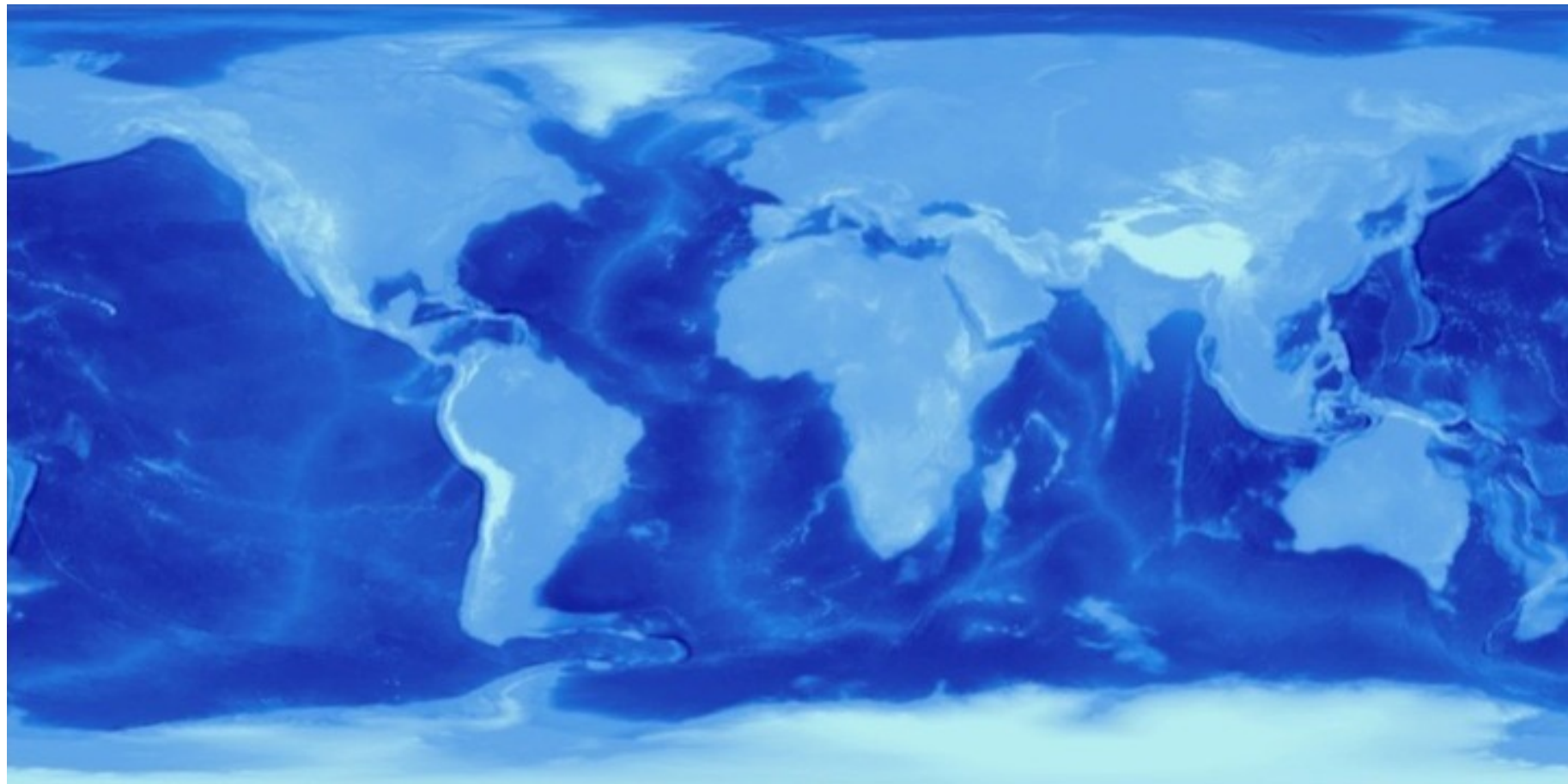
## SRTM - reamostragem

- ▶ NASA SRTM V3
  - ▶ SRTMGL3 - média de janela 3x3
  - ▶ SRTMGL3S - sub-sampled



## SRTM30\_PLUS

- ▶ Resolução de 30" (aprox. 1km)
- ▶ SRTM30 (30") + GLOBE (altas latitudes) + batimetria por satélite + batimetria por navios



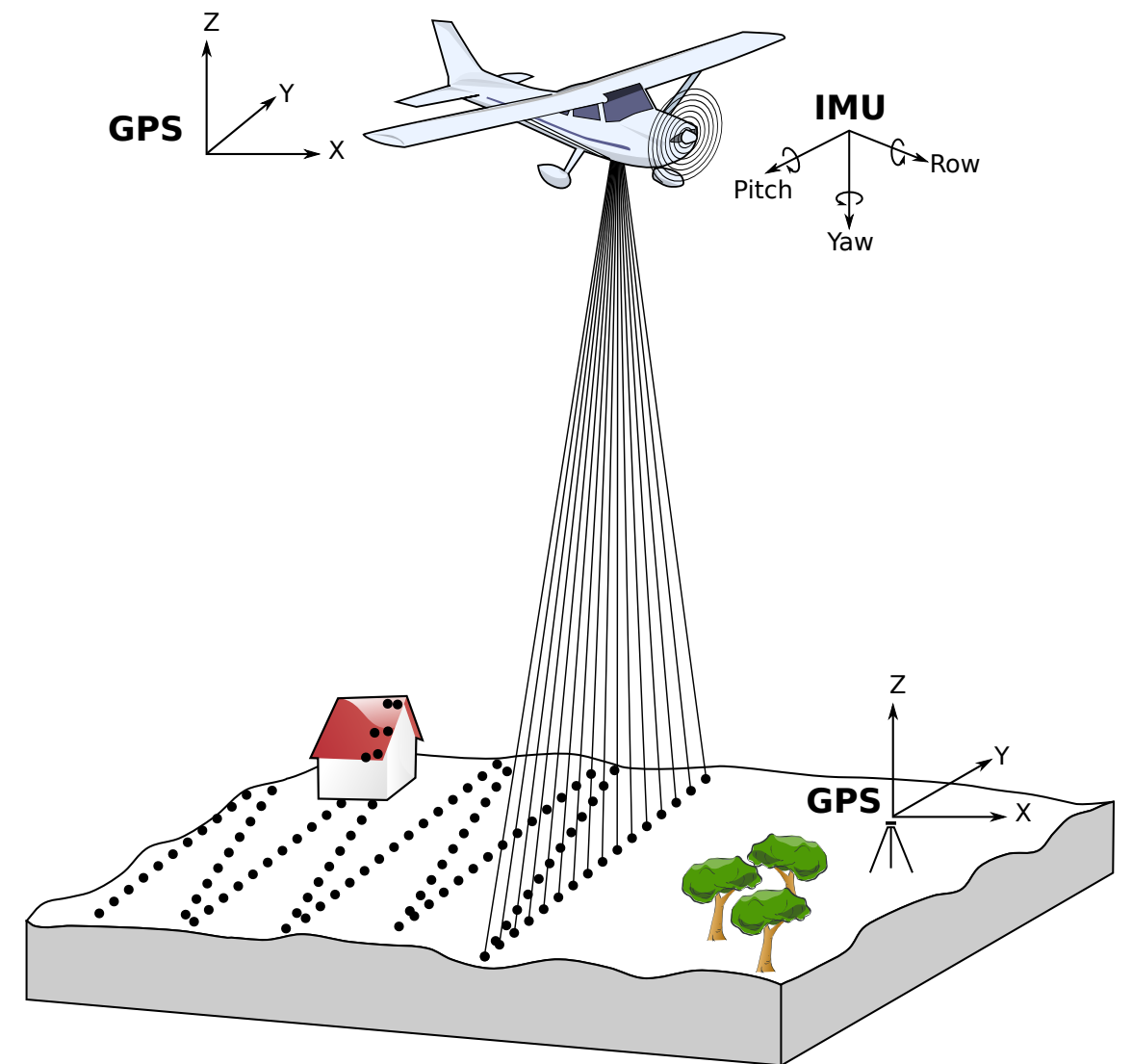
## Dados SRTM

- ▶ SRTM v1 - <http://dds.cr.usgs.gov/srtm/version1/>
- ▶ SRTM v2.1 - [http://dds.cr.usgs.gov/srtm/version2\\_1/](http://dds.cr.usgs.gov/srtm/version2_1/)
  - ▶ Os diretórios SRTM1, SRTM3 e SRTM30 representam dados com resolução espacial de 1 segundo, 3 segundos e 30 segundos de arco, respectivamente.
- ▶ SRTM v3:
  - ▶ OpenTopography - <http://www.opentopography.org/id/OTSRTM.042013.4326.1>
  - ▶ NASA Reverb - <https://reverb.echo.nasa.gov/reverb>
  - ▶ USGS LPDAAC Data Pool - [https://lpdaac.usgs.gov/data\\_access/data\\_pool/](https://lpdaac.usgs.gov/data_access/data_pool/)
- ▶ SRTM V3 01'' - <http://e4ftl01.cr.usgs.gov/SRTM/SRTMGL1.003/2000.02.11/>
- ▶ SRTM v4.1 CGIAR-CSI - <http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp>



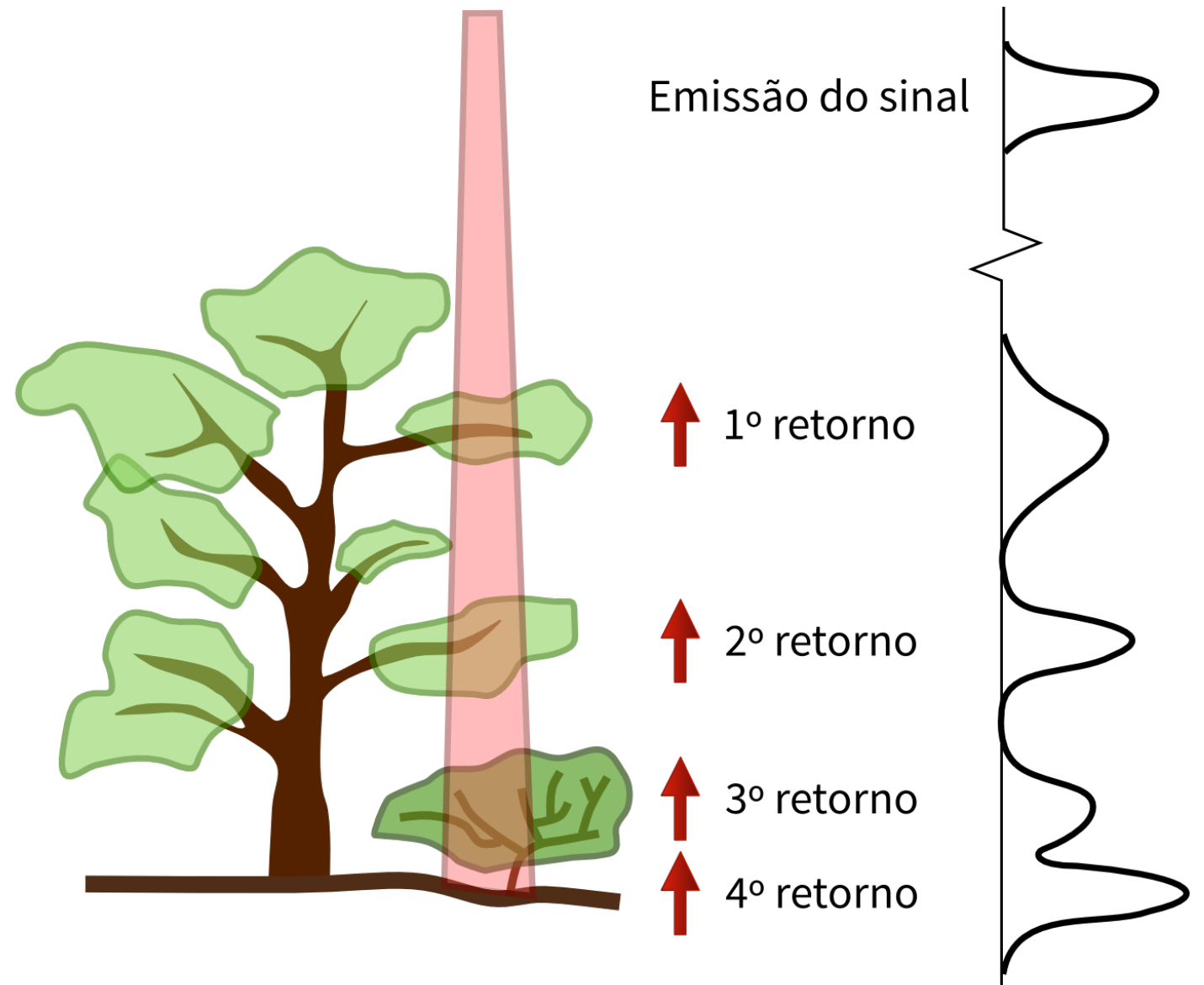
## LIDAR

- ▶ LiDAR – *Light Detection and Ranging*
- ▶ Aeroportado ou Terrestre (TLS)
- ▶ Densidade de pontos absurda
- ▶ DGPS + IMU + Laser
- ▶ Múltiplos retornos
  - ▶ múltiplas superfícies



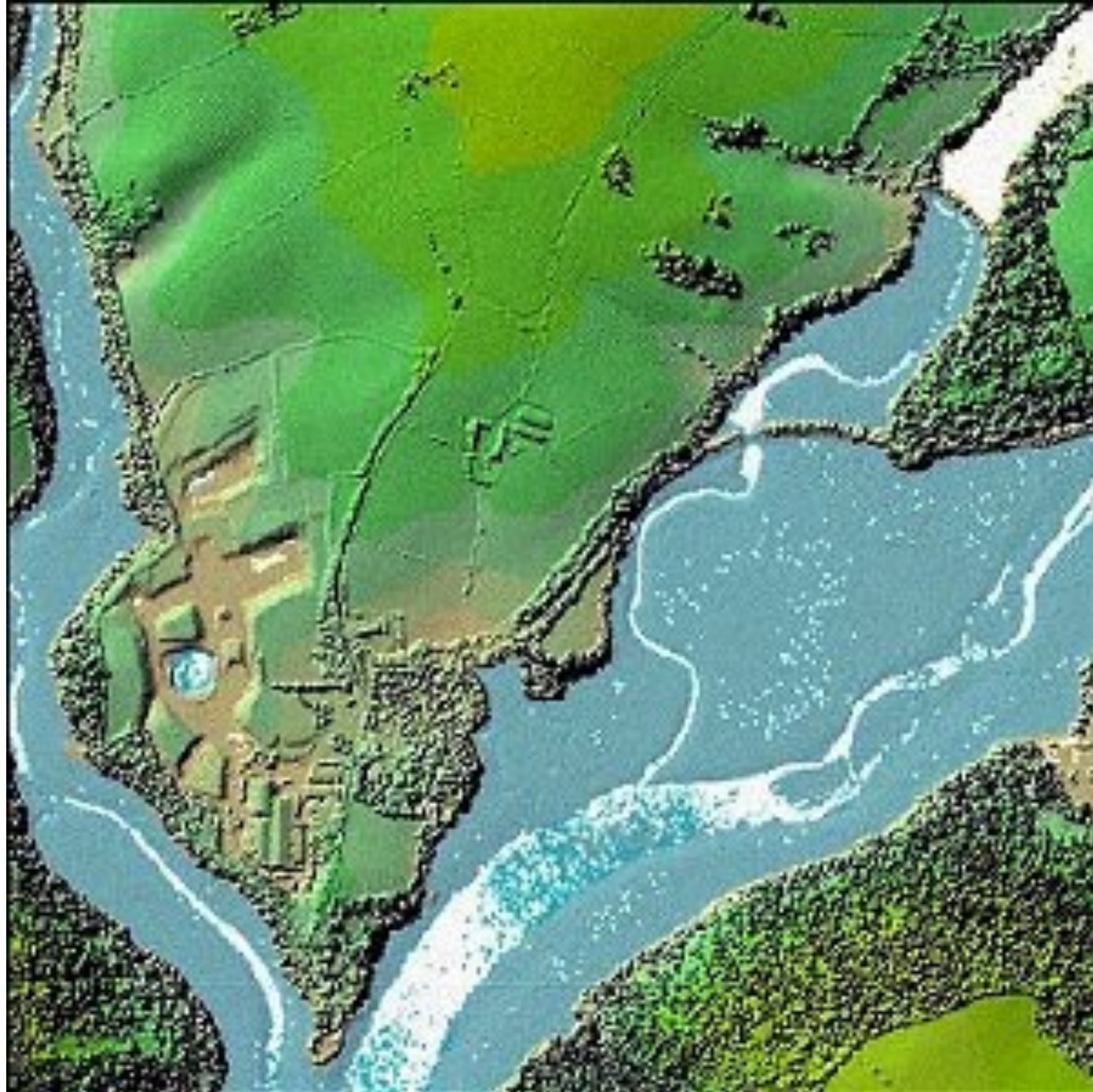
## LIDAR

- ▶ Múltiplos retornos
  - ▶ múltiplas superfícies
  - ▶ full waveform



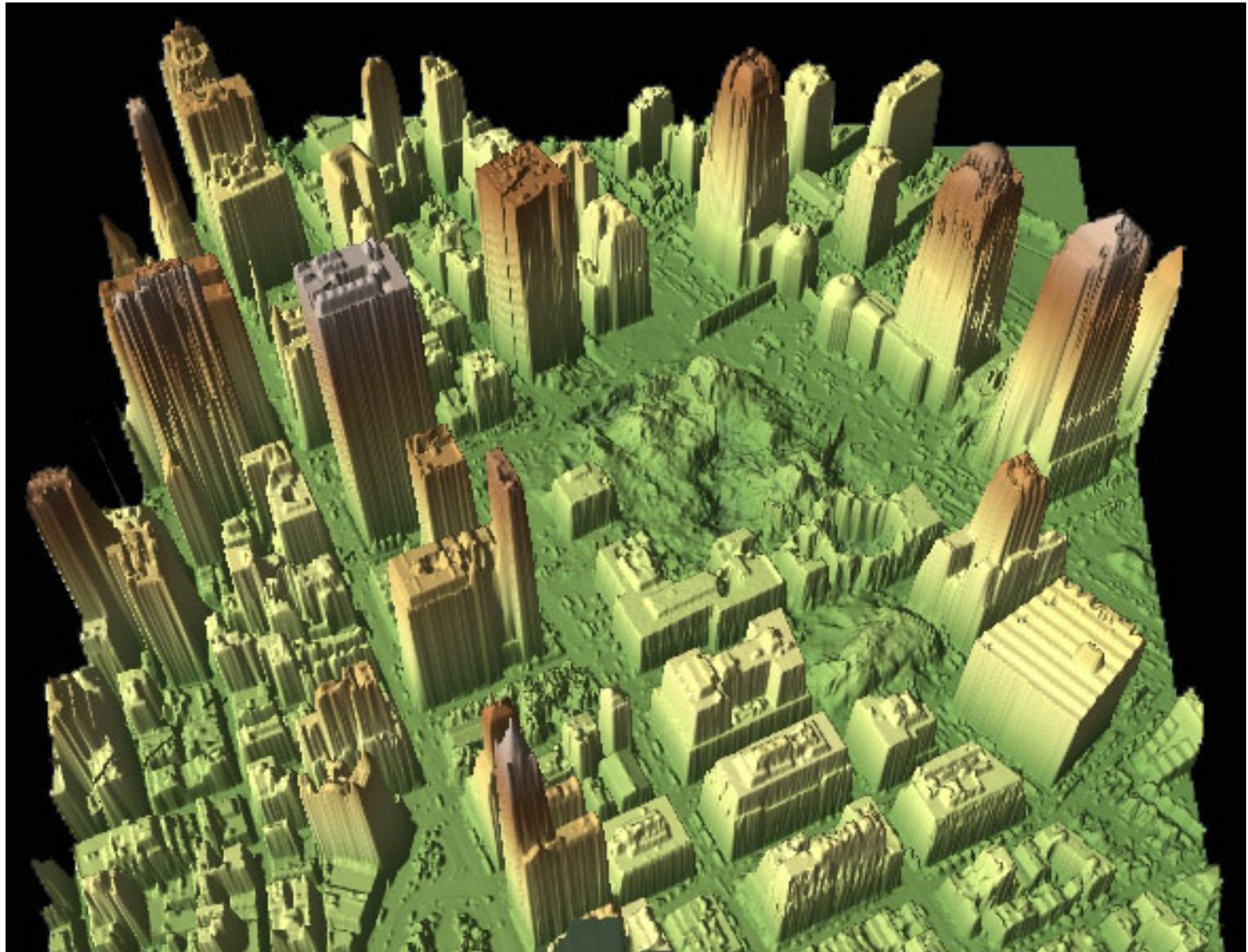


## LIDAR



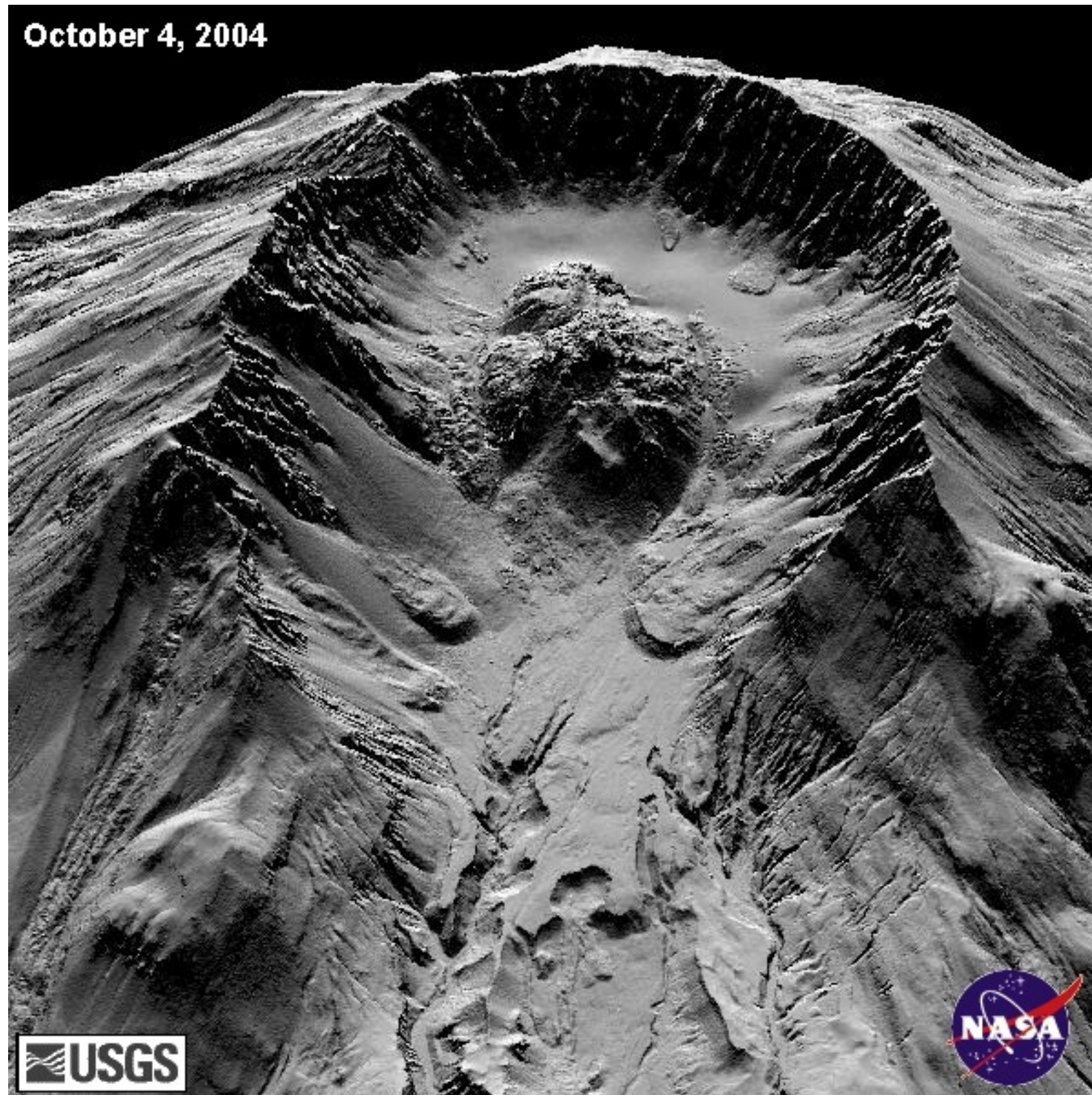


## LIDAR





# LIDAR



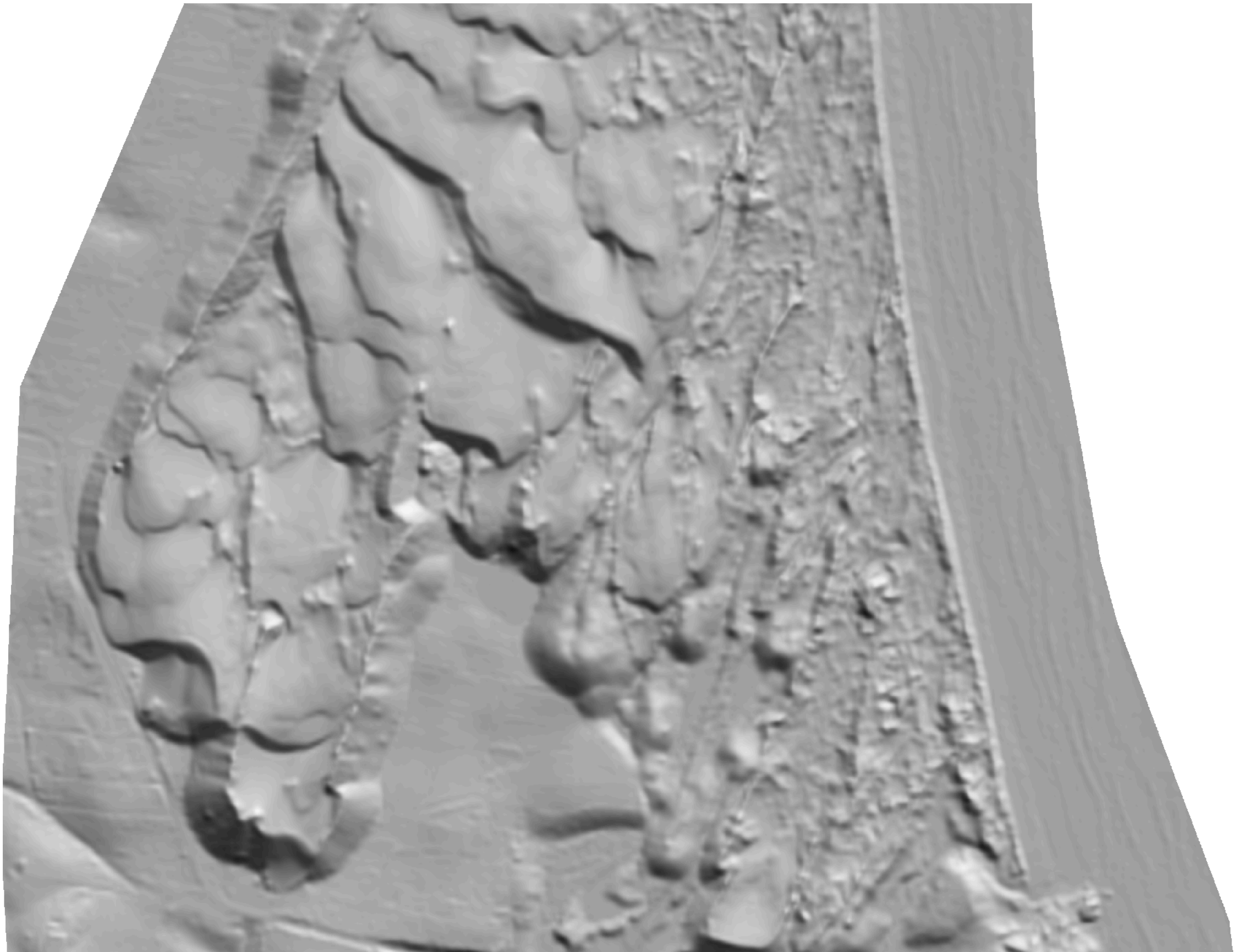


LIDAR





## LIDAR

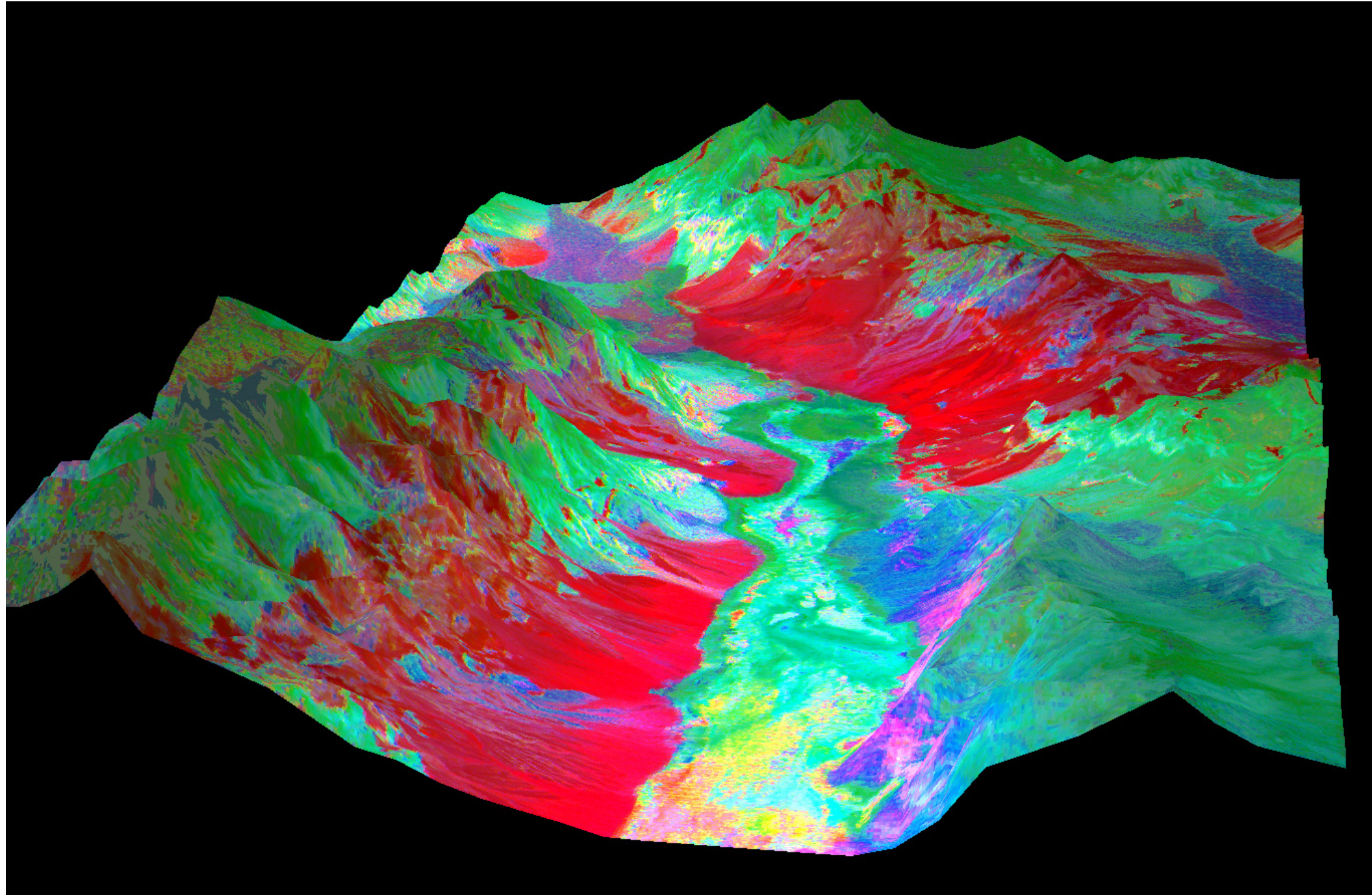


## Fotogrametria

- ▶ Alguns satélites possuem sensores duplicados para formar pares estereoscópicos
  - ▶ A partir dos pares, gera-se um MDE
  - ▶ Com sensores com capacidade de apontamento, pode-se fazer o mesmo em órbitas diferentes
- ▶ Fotogrametria a curta distância
  - ▶ Structure-from-Motion (SfM)
  - ▶ drones

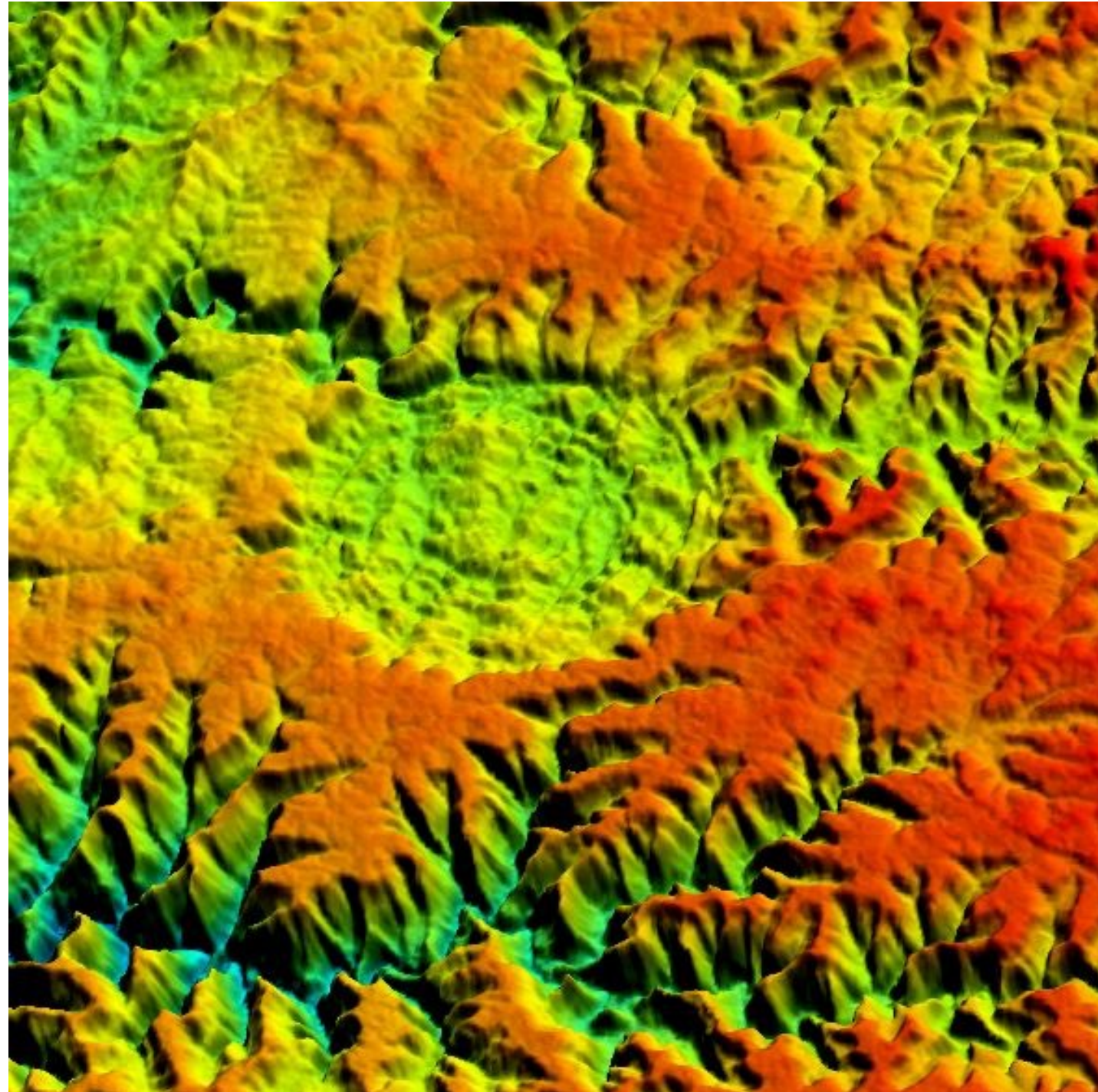


## Fotogrametria - ASTER 3N+3B



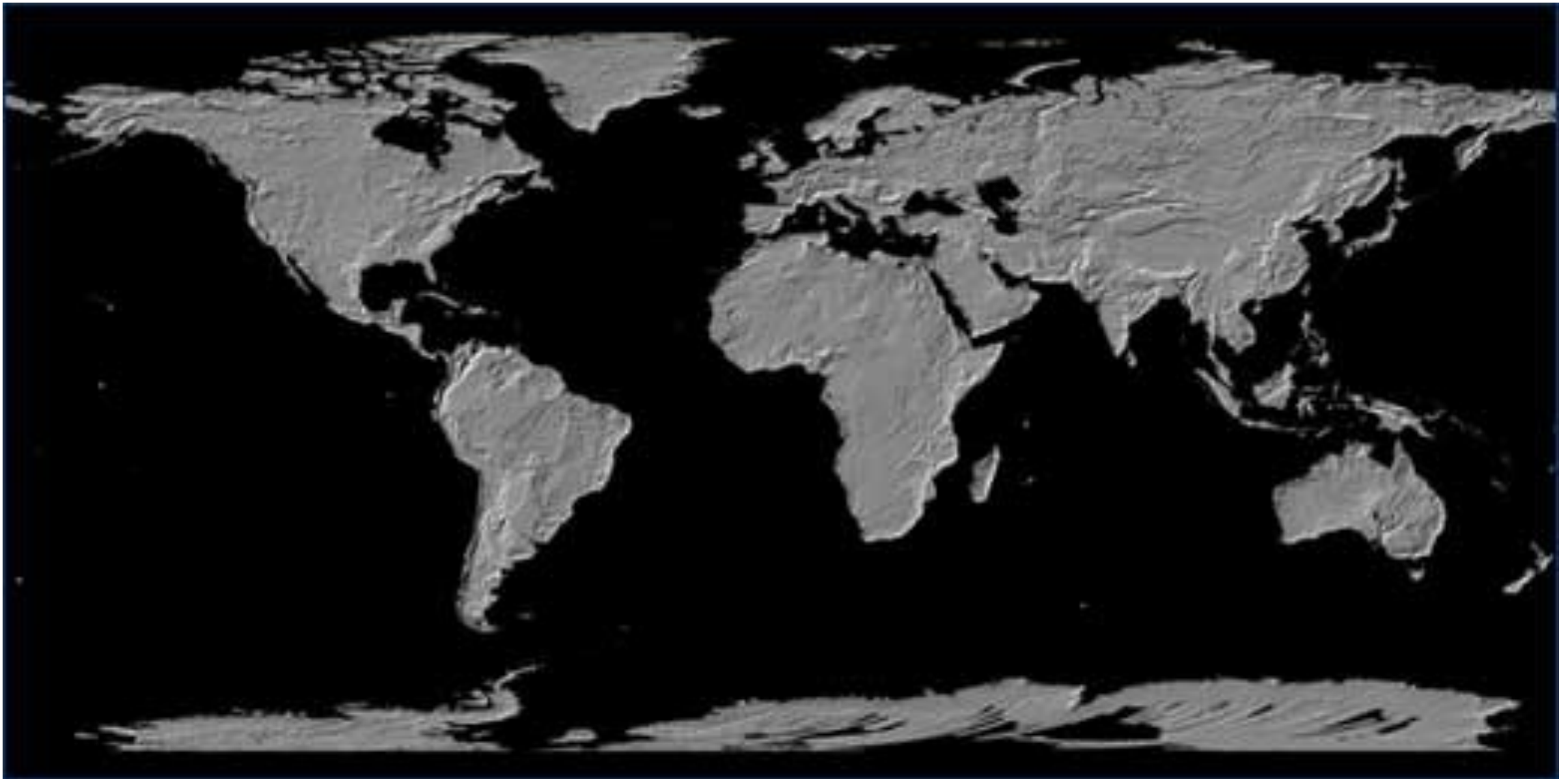


## Fotogrametria - ASTER 3N+3B





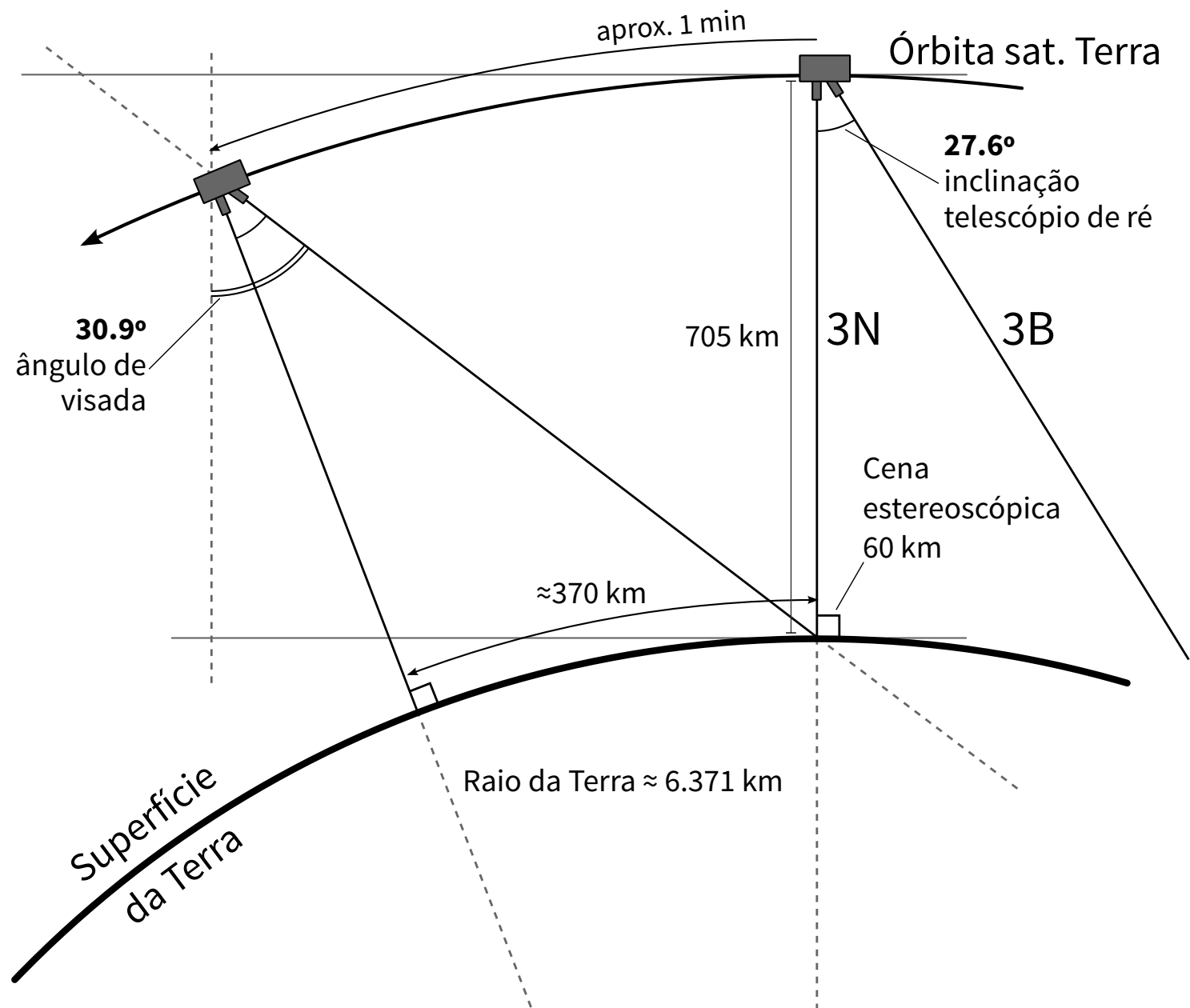
## Fotogrametria - ASTER GDEM



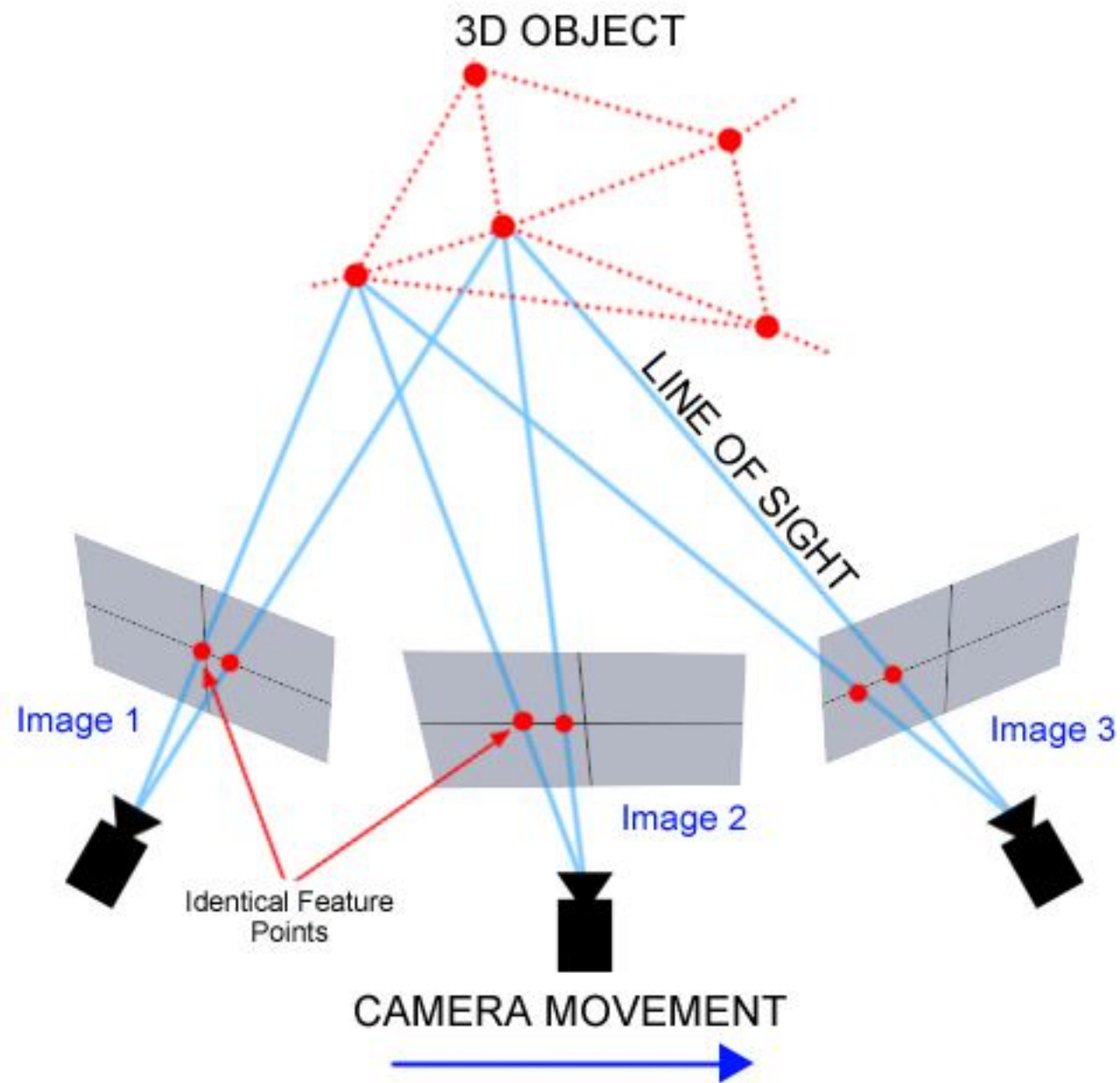
## Fotogrametria - ASTER GDEM

- ▶ ASTER GDEM v.1 - 2009
- ▶ ASTER GDEM v.2 - 2011
  - ▶ 30m (teóricos)
  - ▶ DSM
  - ▶ Global

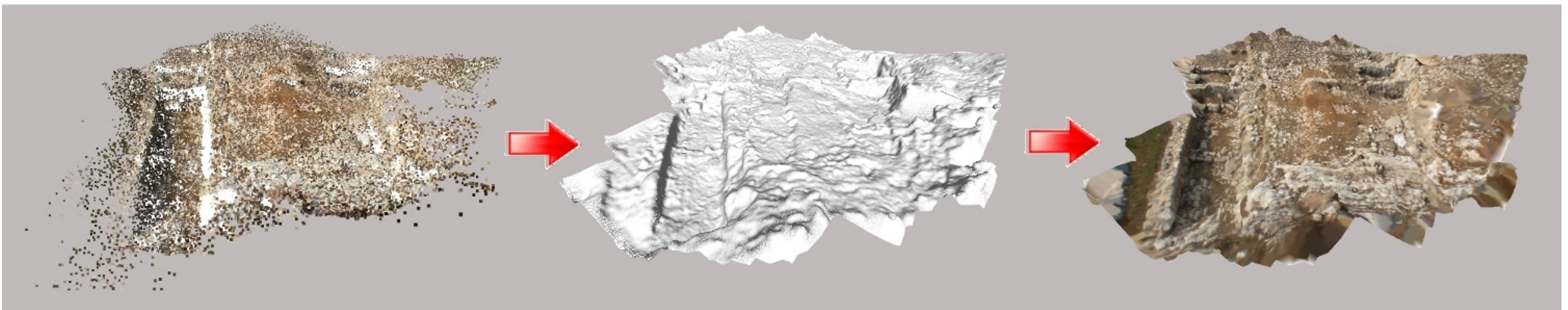
## Fotogrametria - ASTER 3N+3B



# Fotogrametria - SfM



## Fotogrametria - SfM





## Fotogrametria - SfM

