

GSA-5859

SISTEMAS DE INFORMAÇÃO GEOGRÁFICA EM SOFTWARE LIVRE

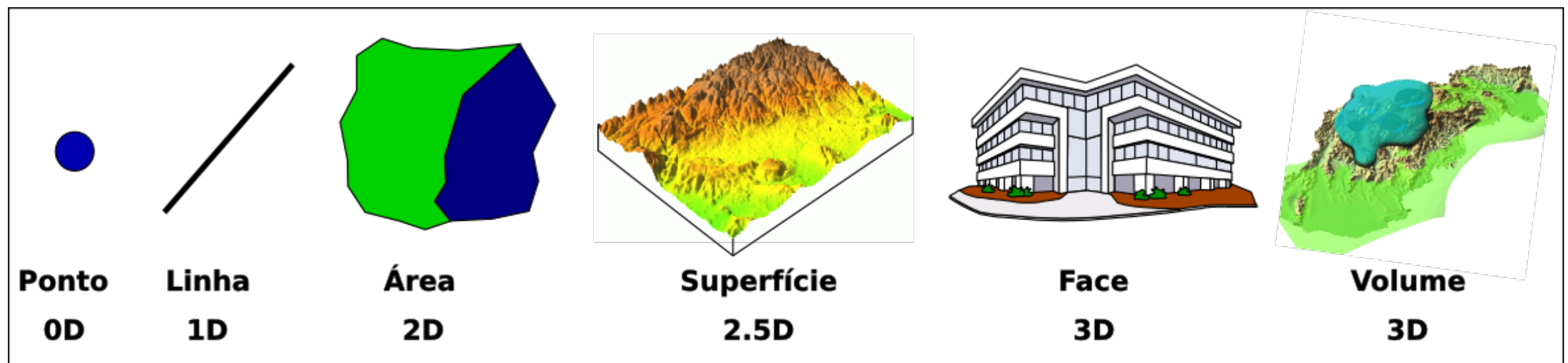
CARLOS HENRIQUE GROHMANN

INSTITUTO DE ENERGIA E AMBIENTE - USP

Modelos Digitais de Terreno

MDE/MDT

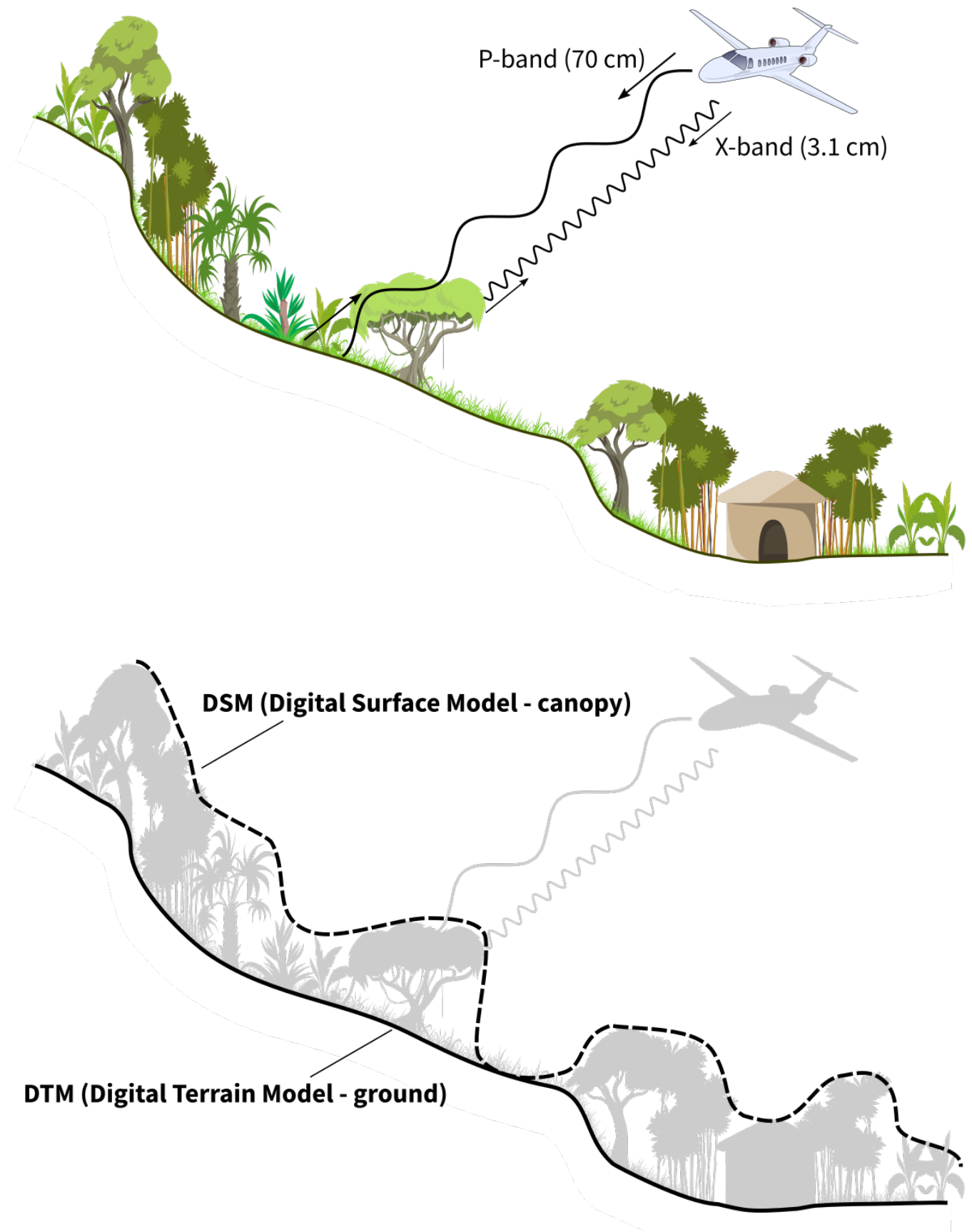
- ▶ Representação de uma superfície em SIG
 - ▶ Raster
 - ▶ Vetor (TIN)
- ▶ “2.5D”



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 ??

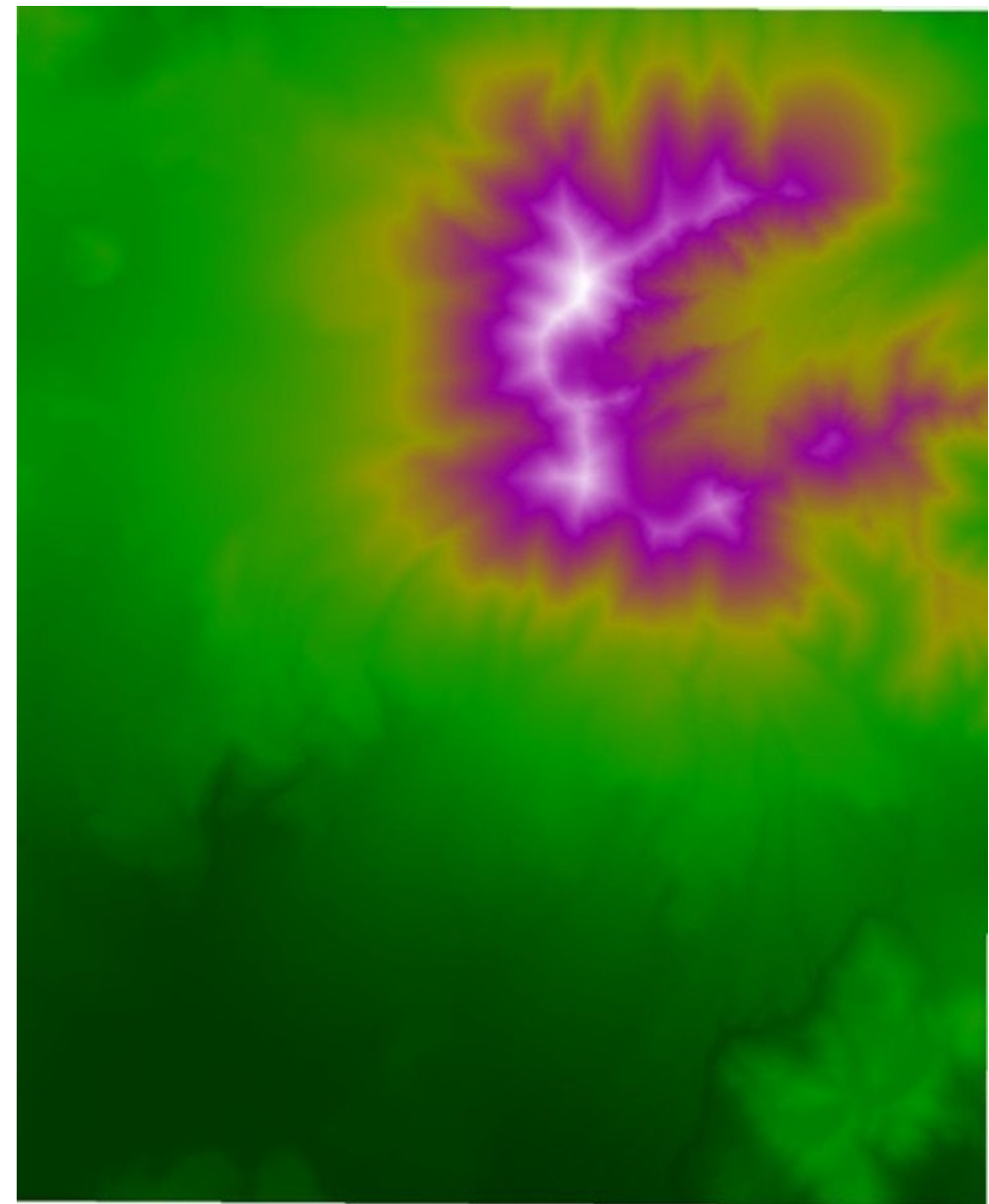
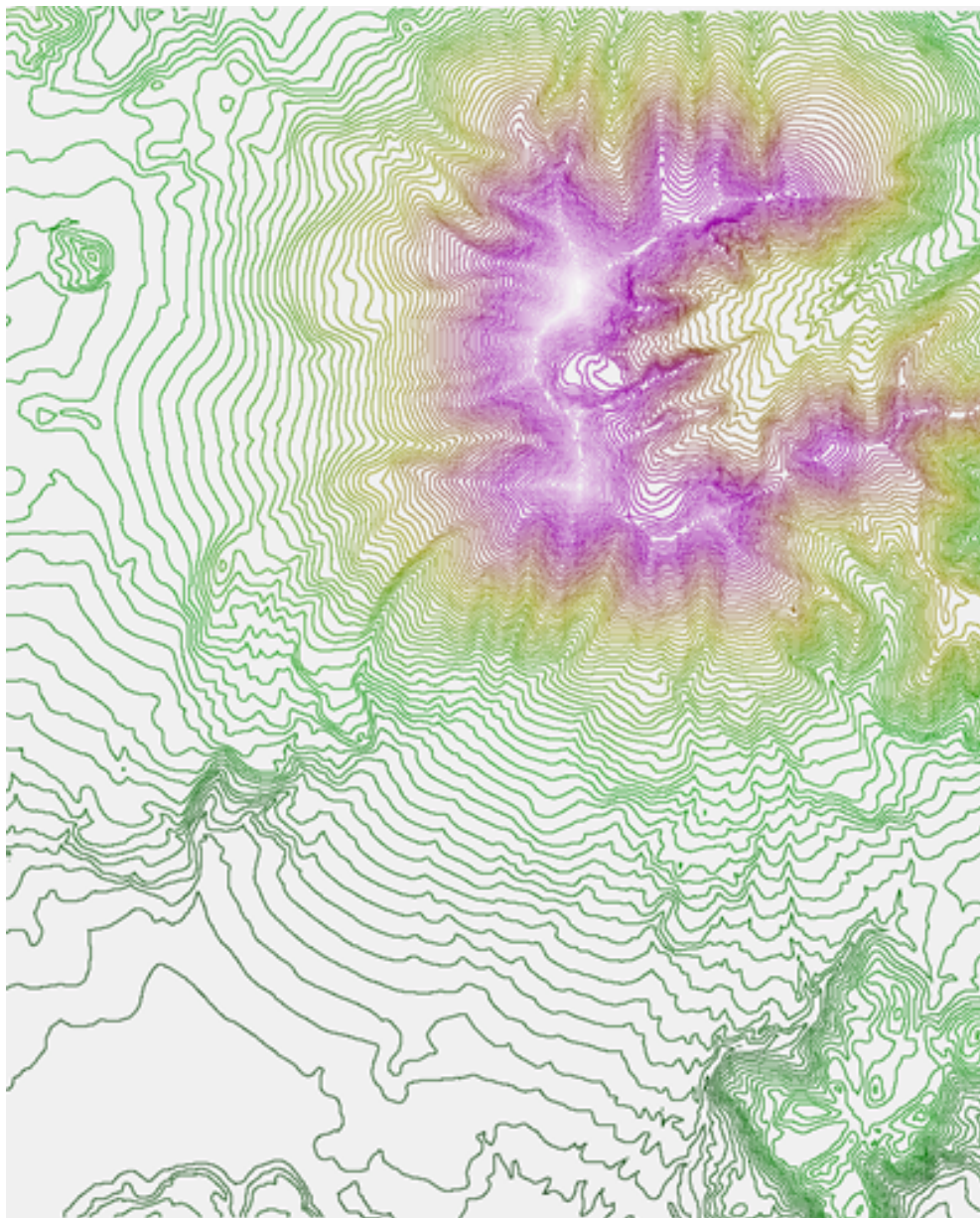


CONSTRUÇÃO DE MDES

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

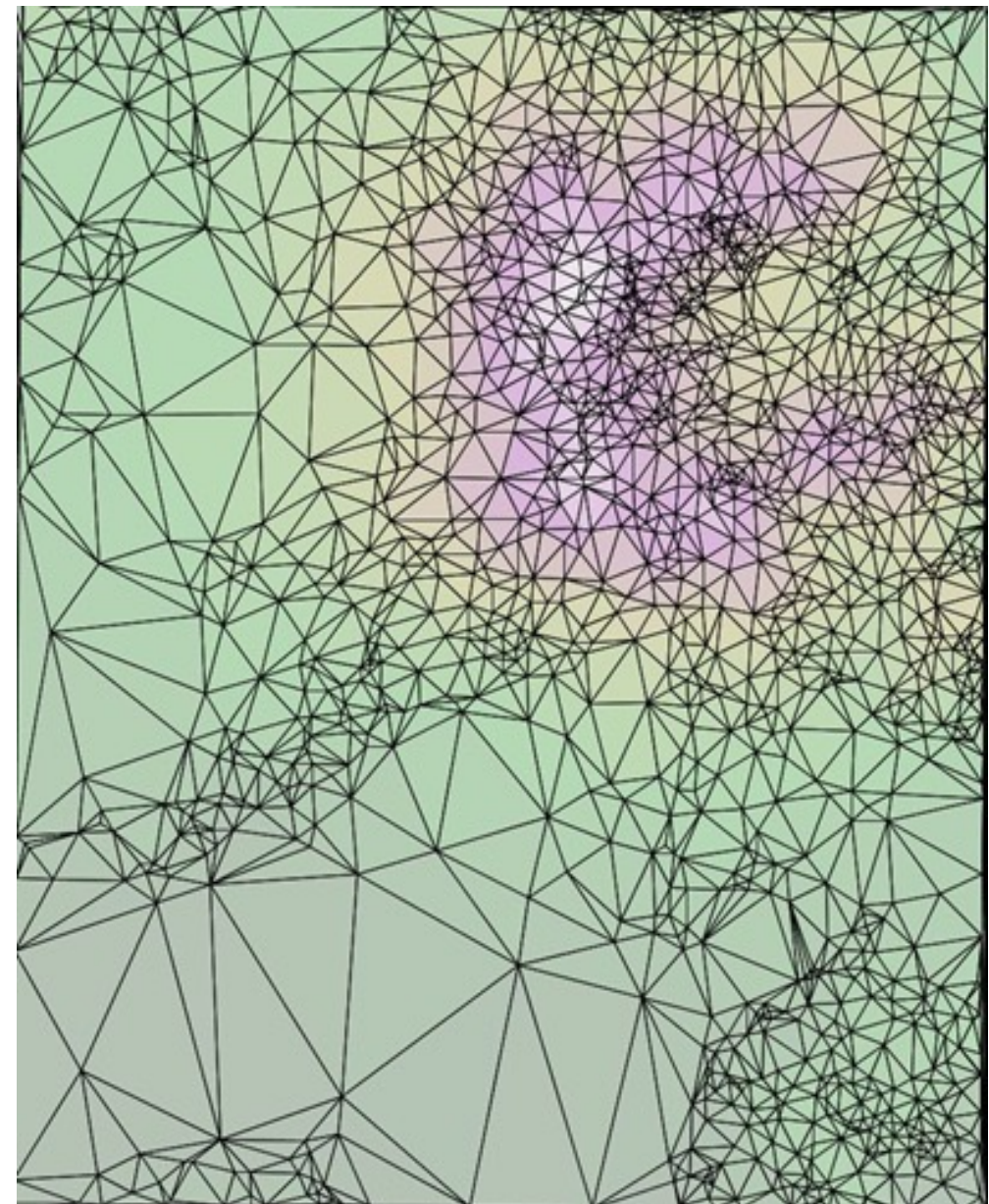
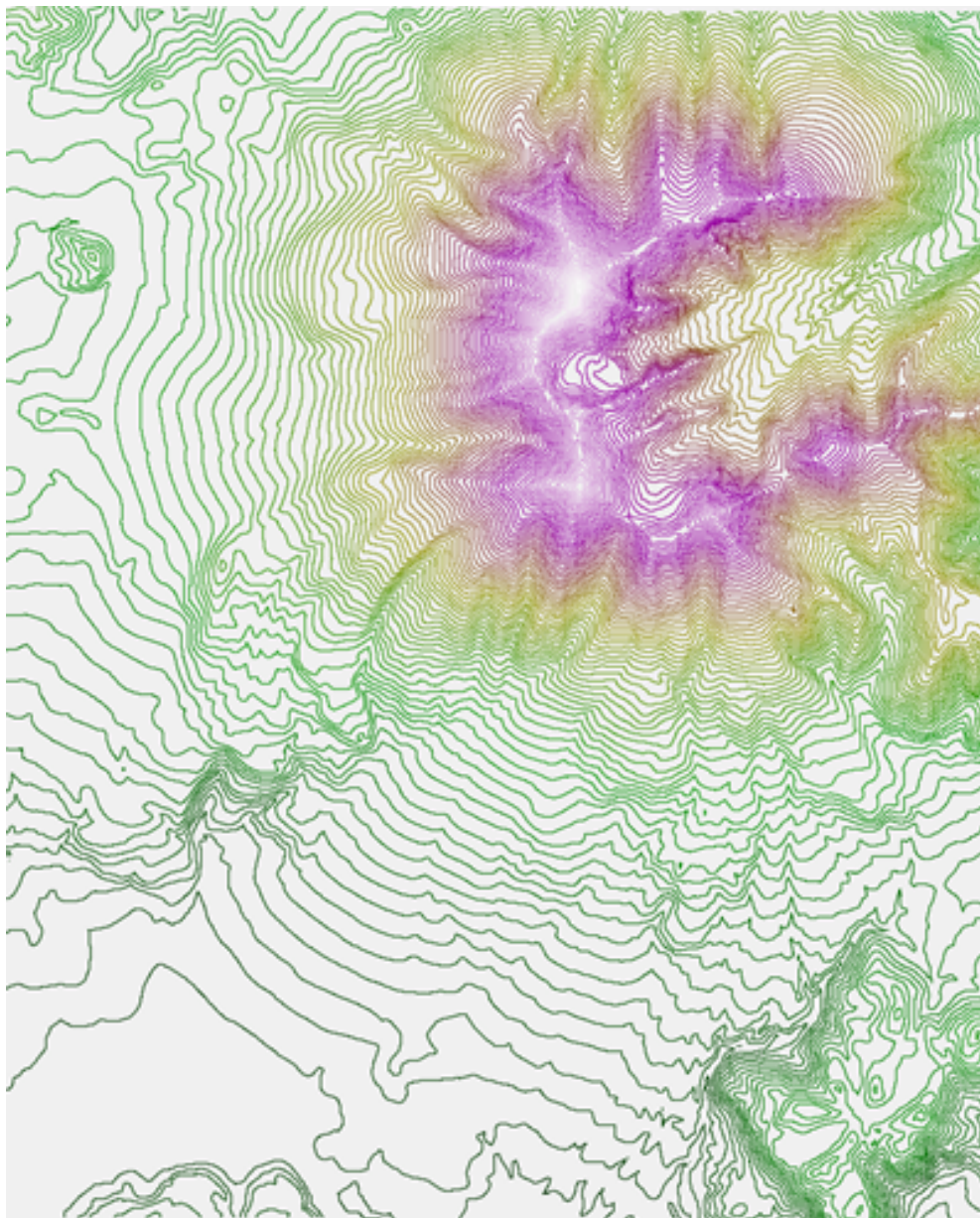
CONSTRUÇÃO DE MDES

- ▶ Interpolação de dados vetoriais



CONSTRUÇÃO DE MDES

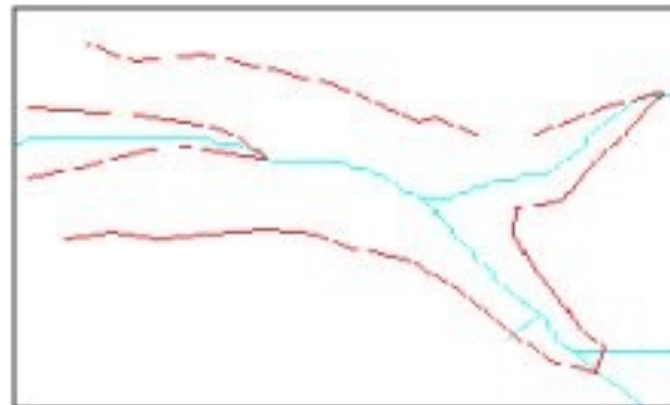
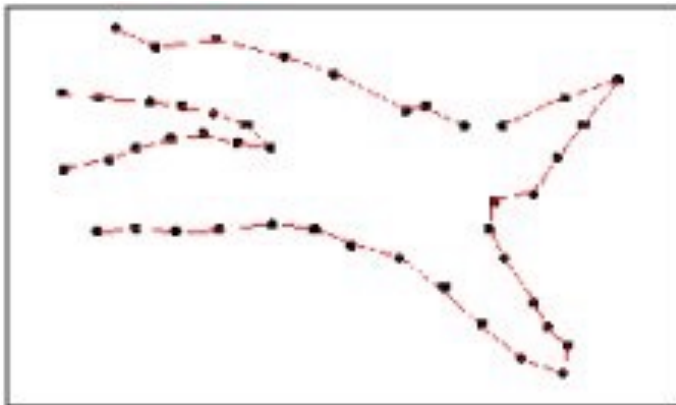
- ▶ Interpolação de dados vetoriais



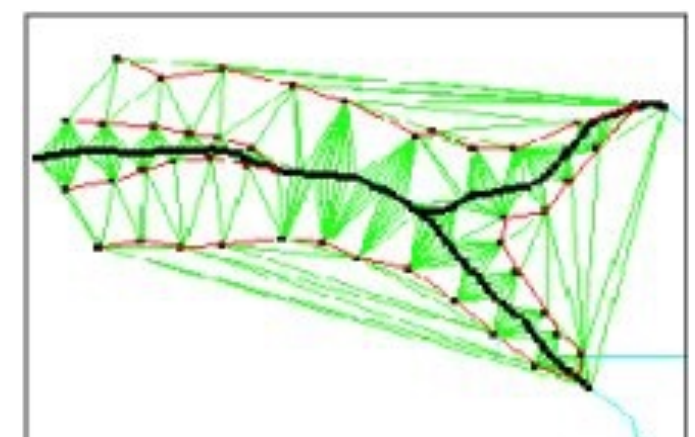
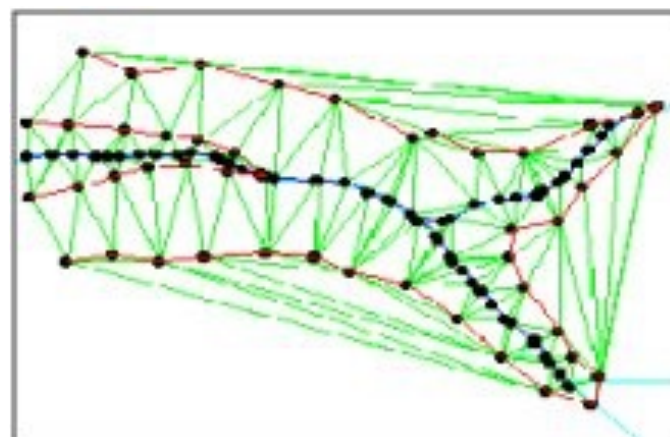
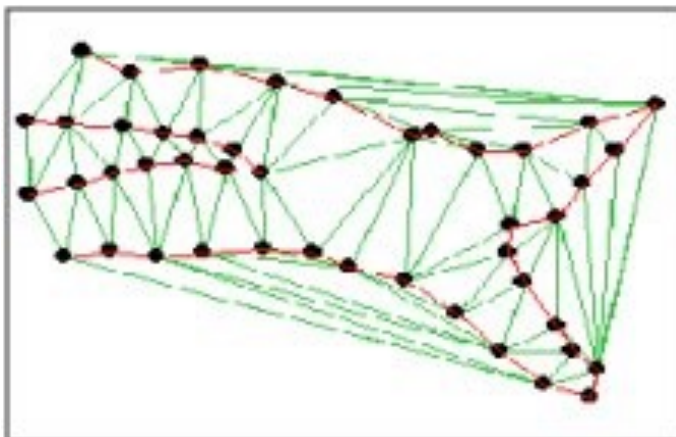
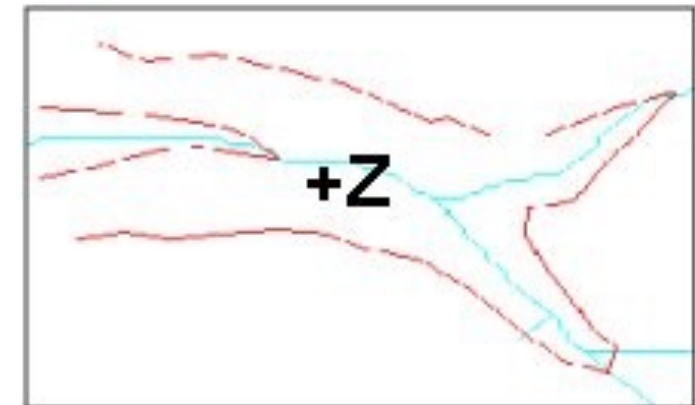
CONSTRUÇÃO DE MDES

► Breaklines

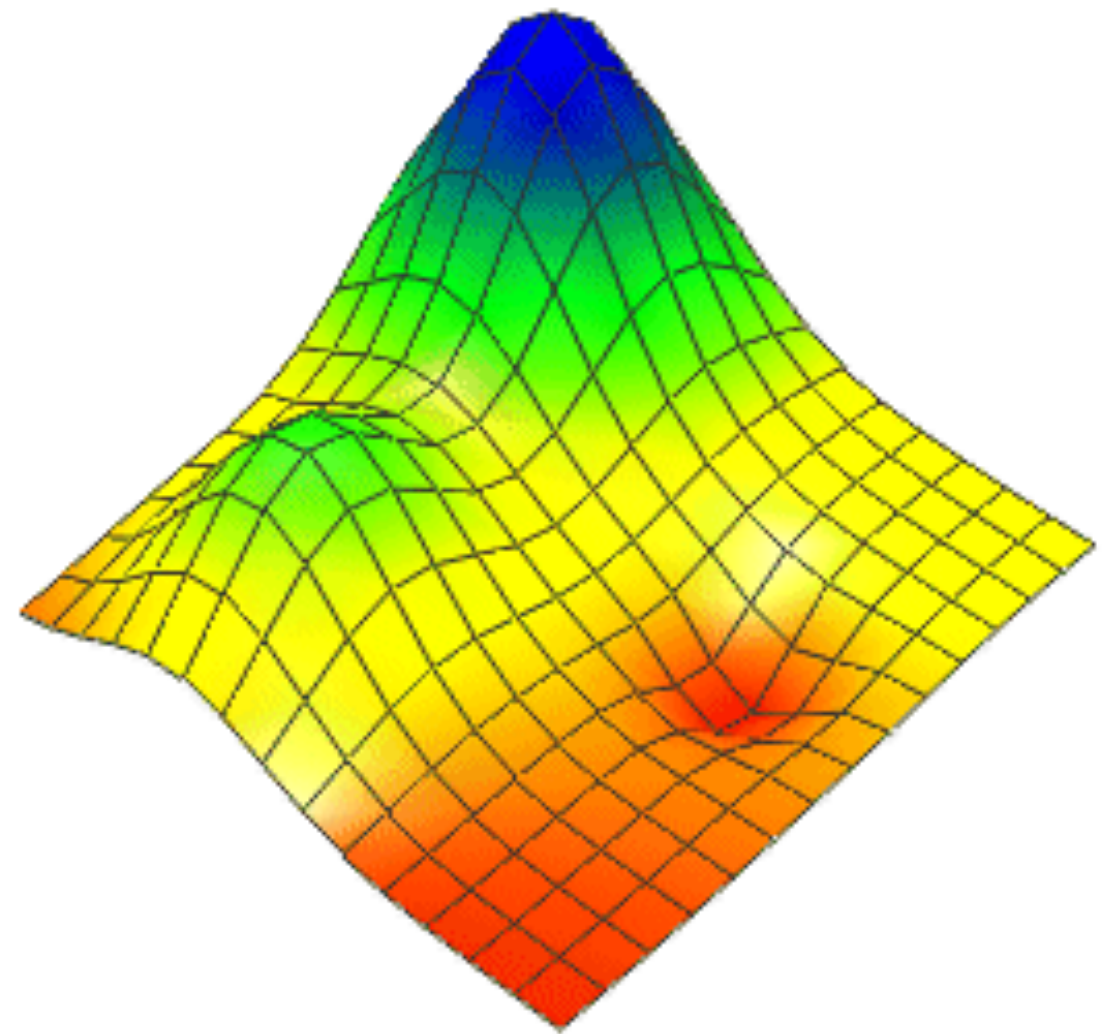
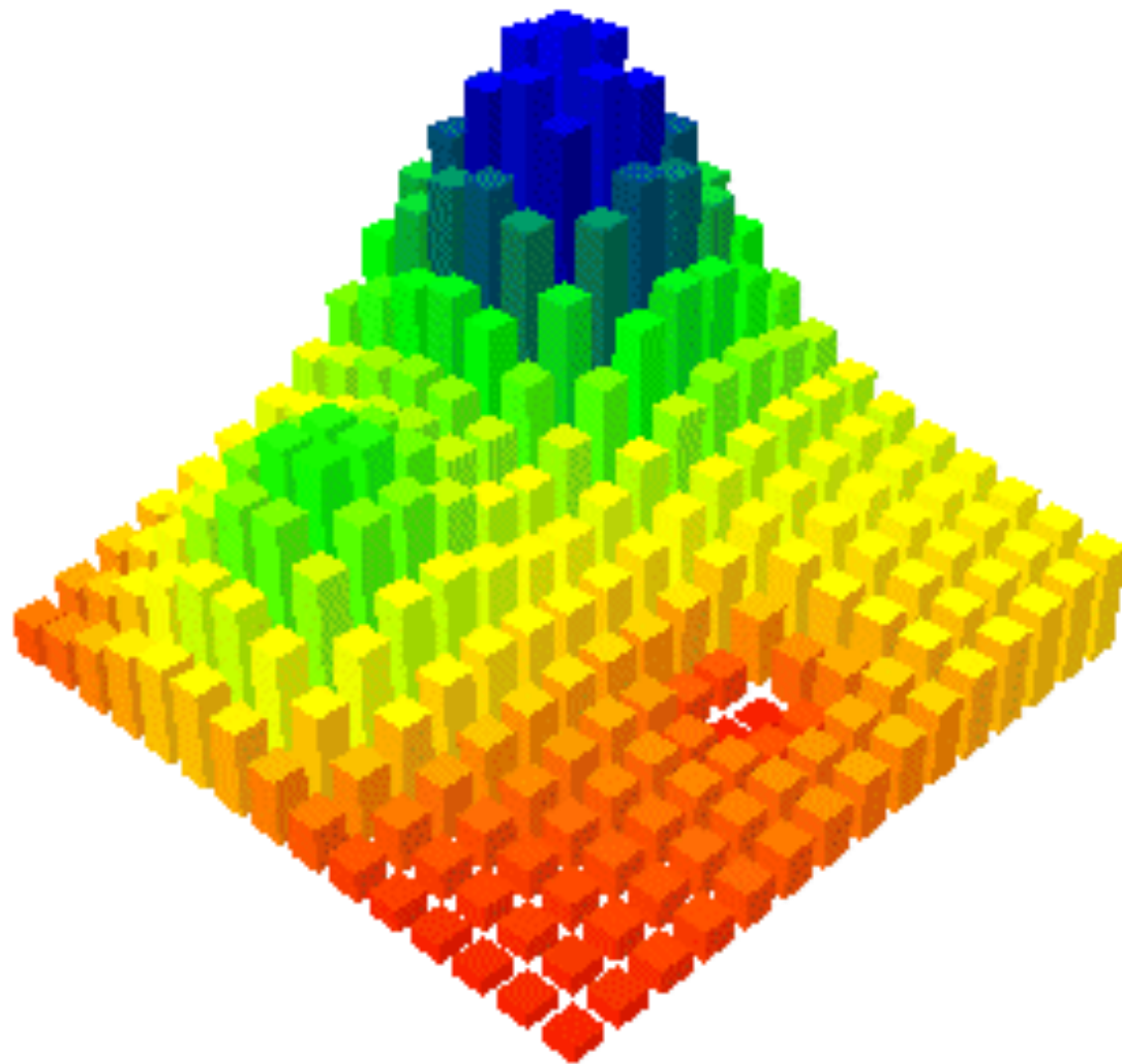
soft breaklines



hard breaklines

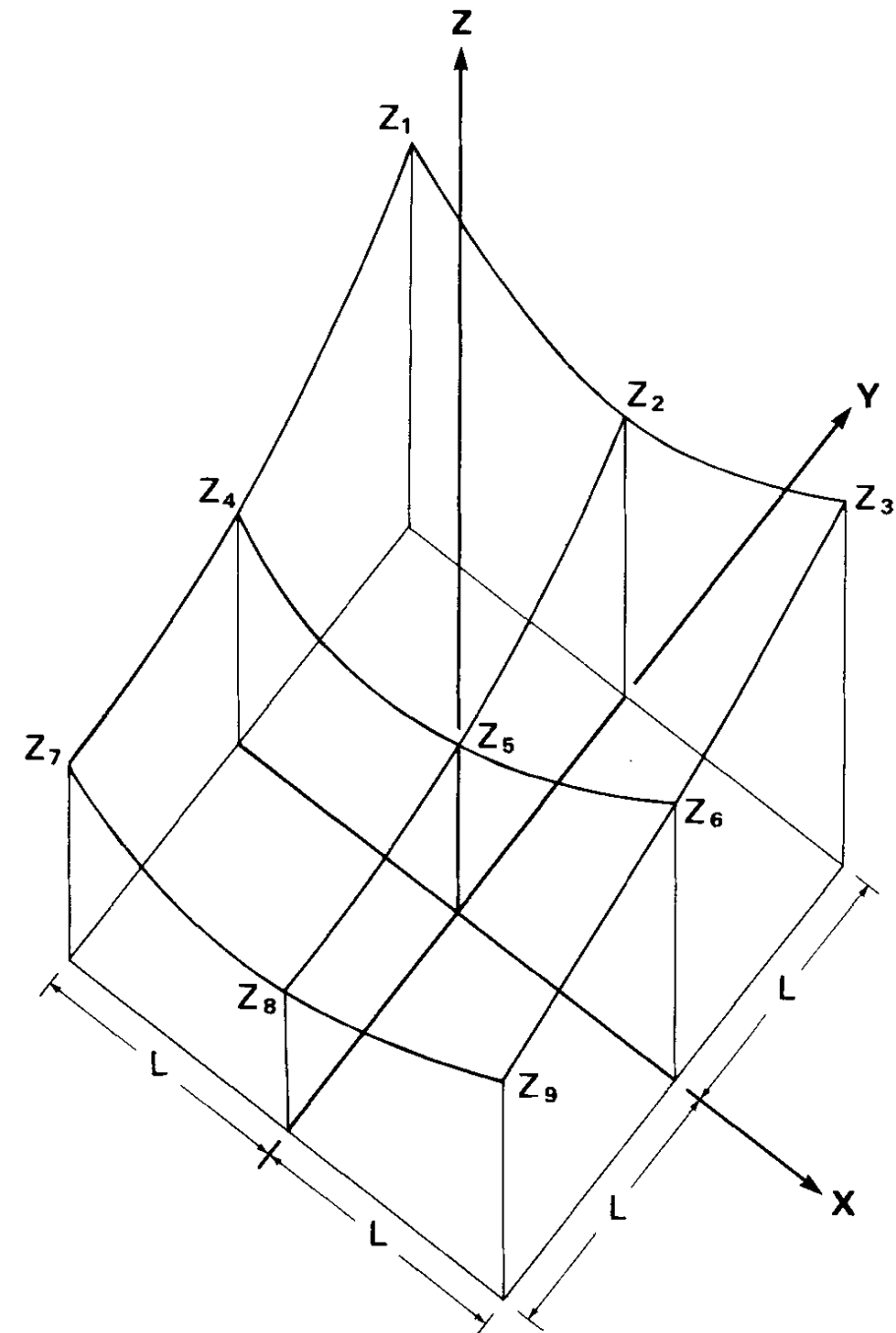


REPRESENTAÇÕES DISCRETAS X CONTÍNUAS

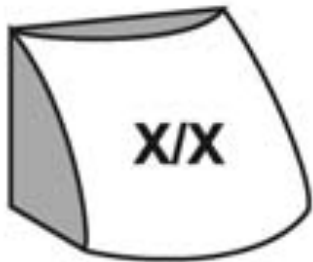
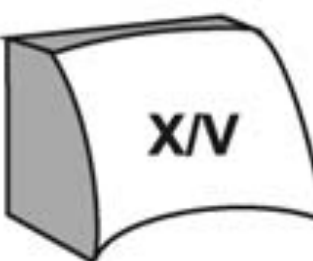


DERIVADAS DA SUPERFÍCIE

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



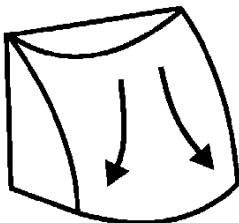
CURVATURAS

		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

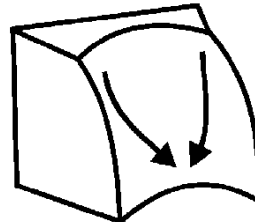
CURVATURAS

Contour

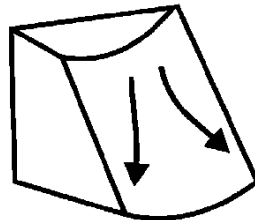
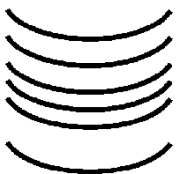
Block



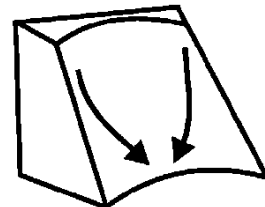
Divergent Shoulder



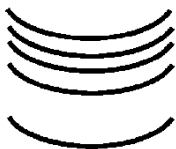
Convergent Shoulder



Divergent Backslope



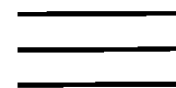
Convergent Backslope



Divergent Footslope

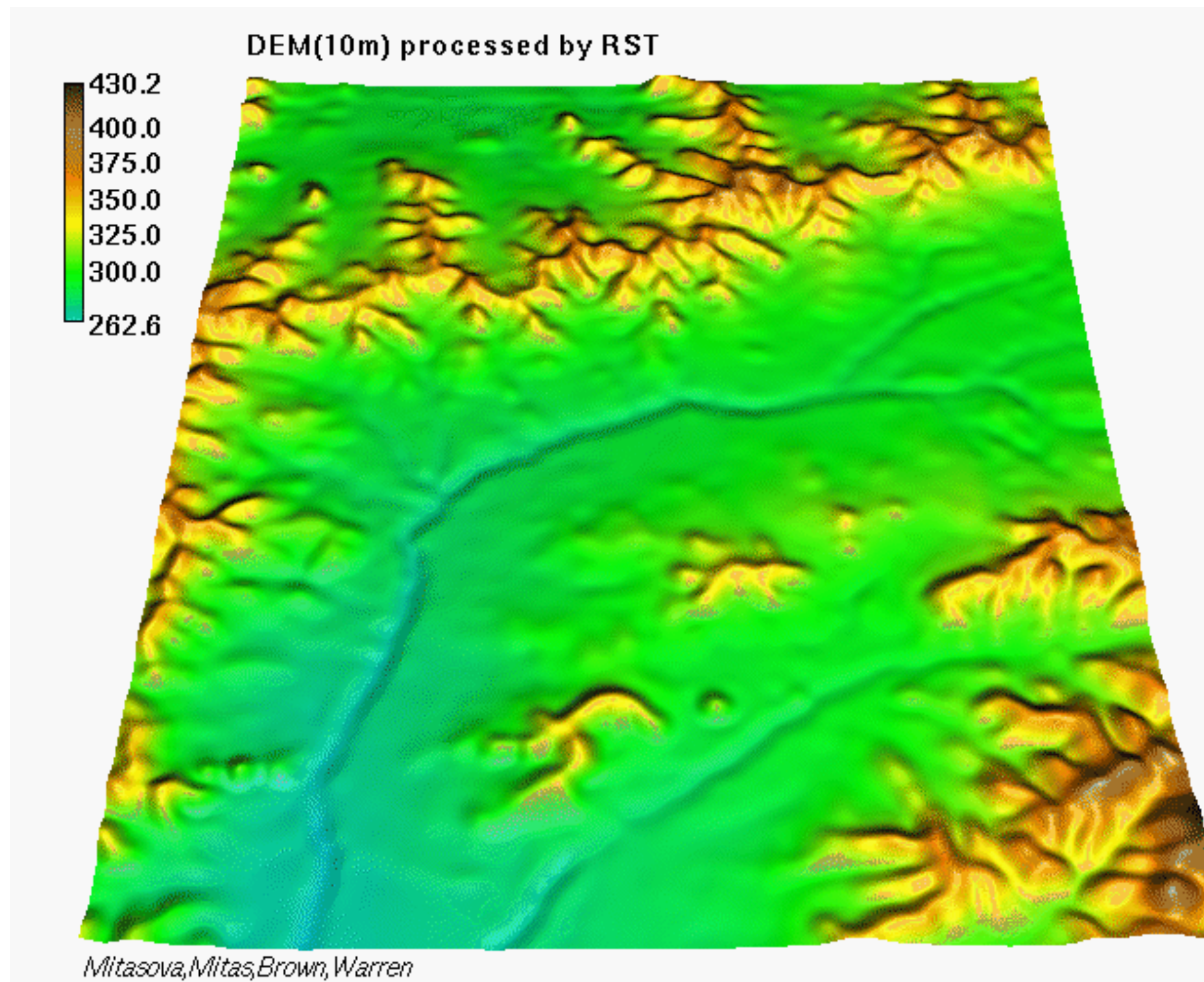


Convergent Footslope

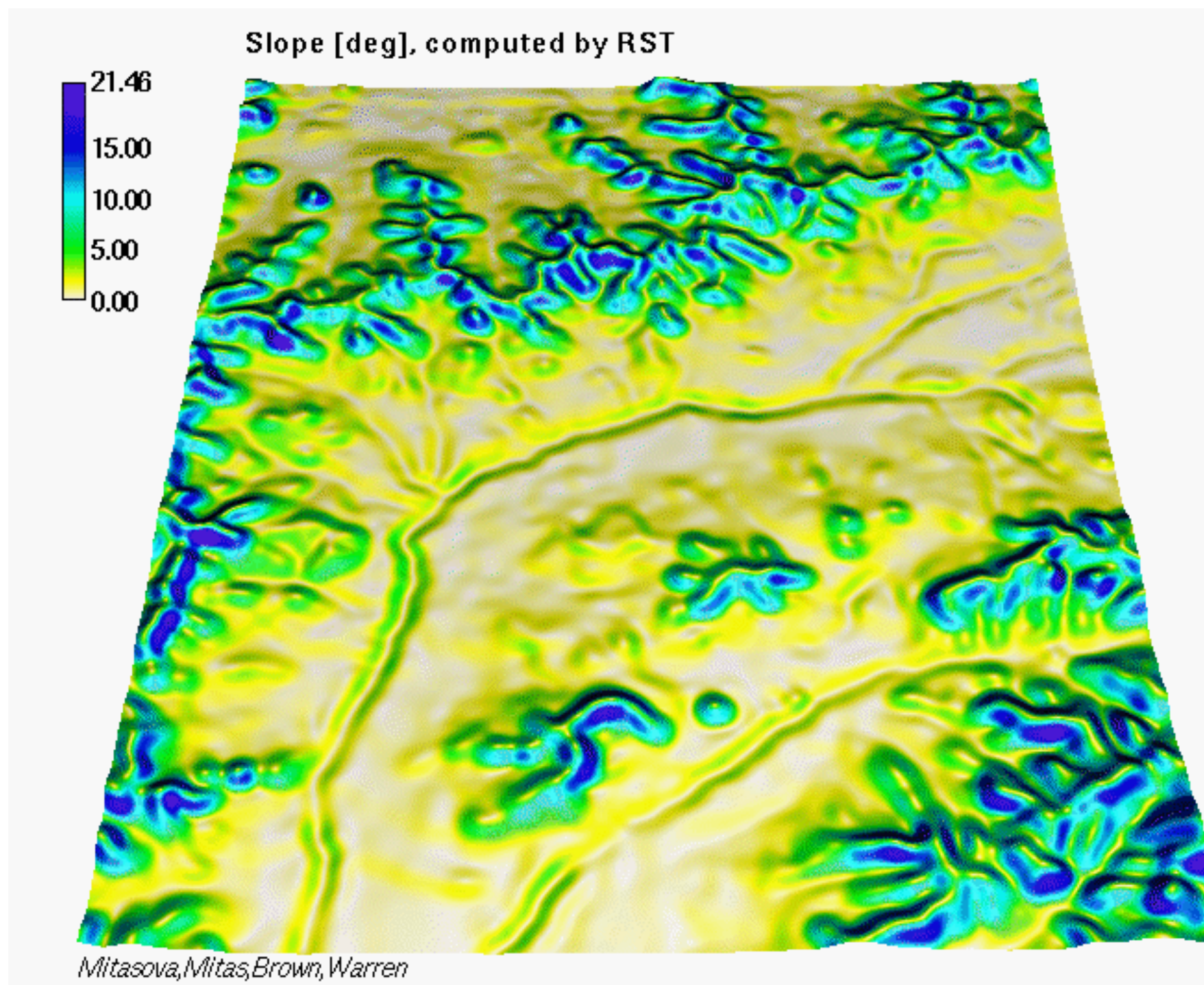


Level

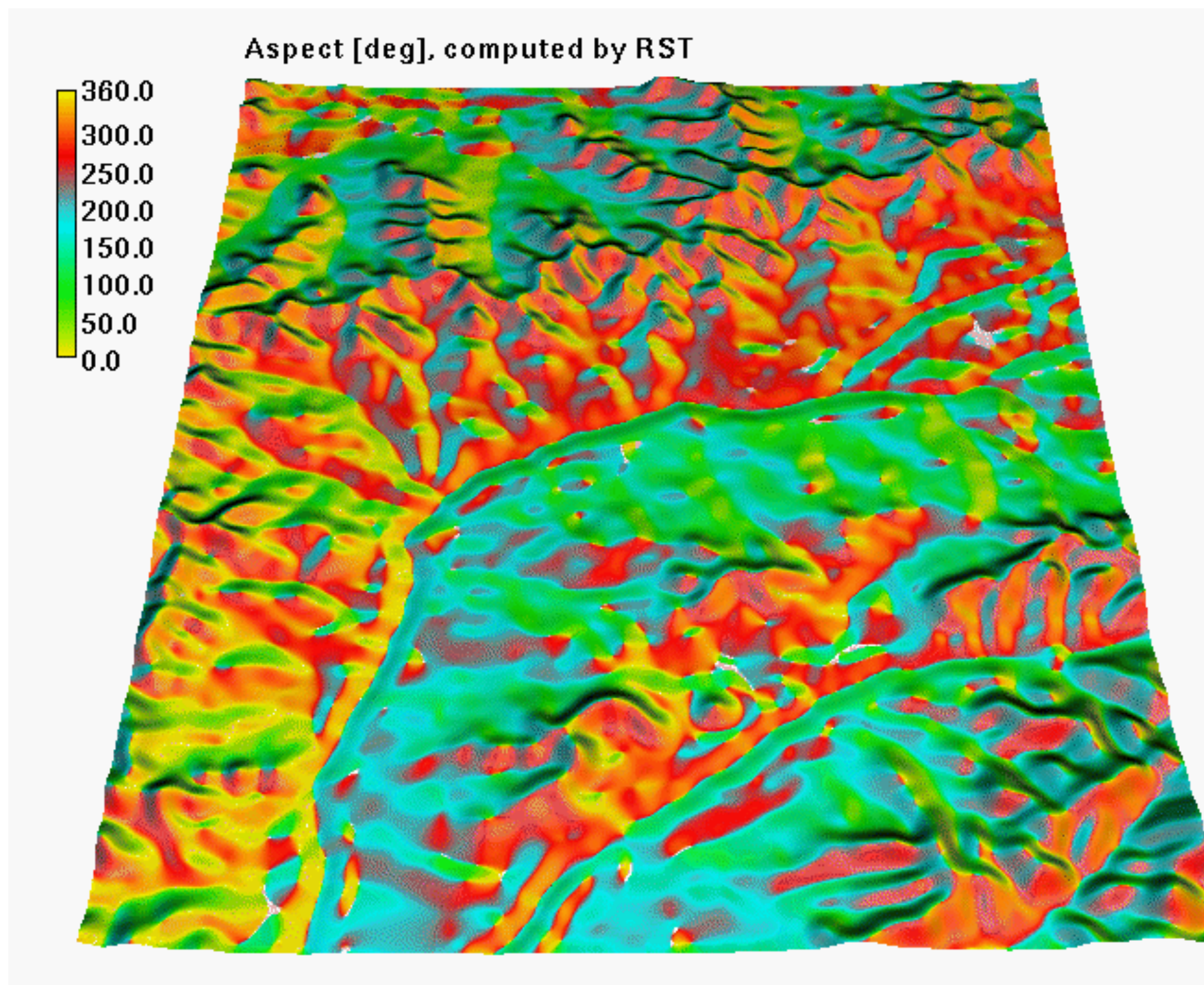
DEM



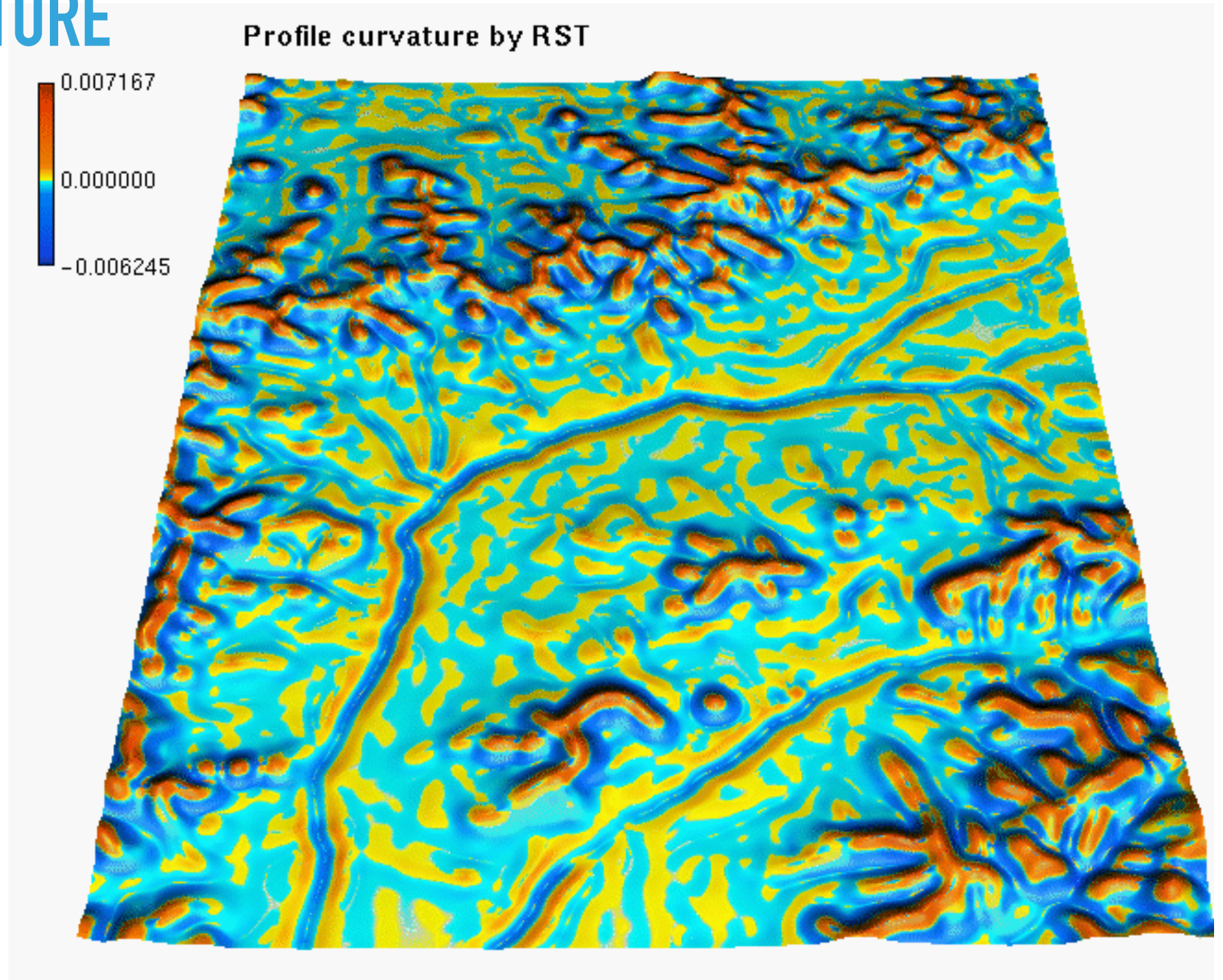
SLOPE



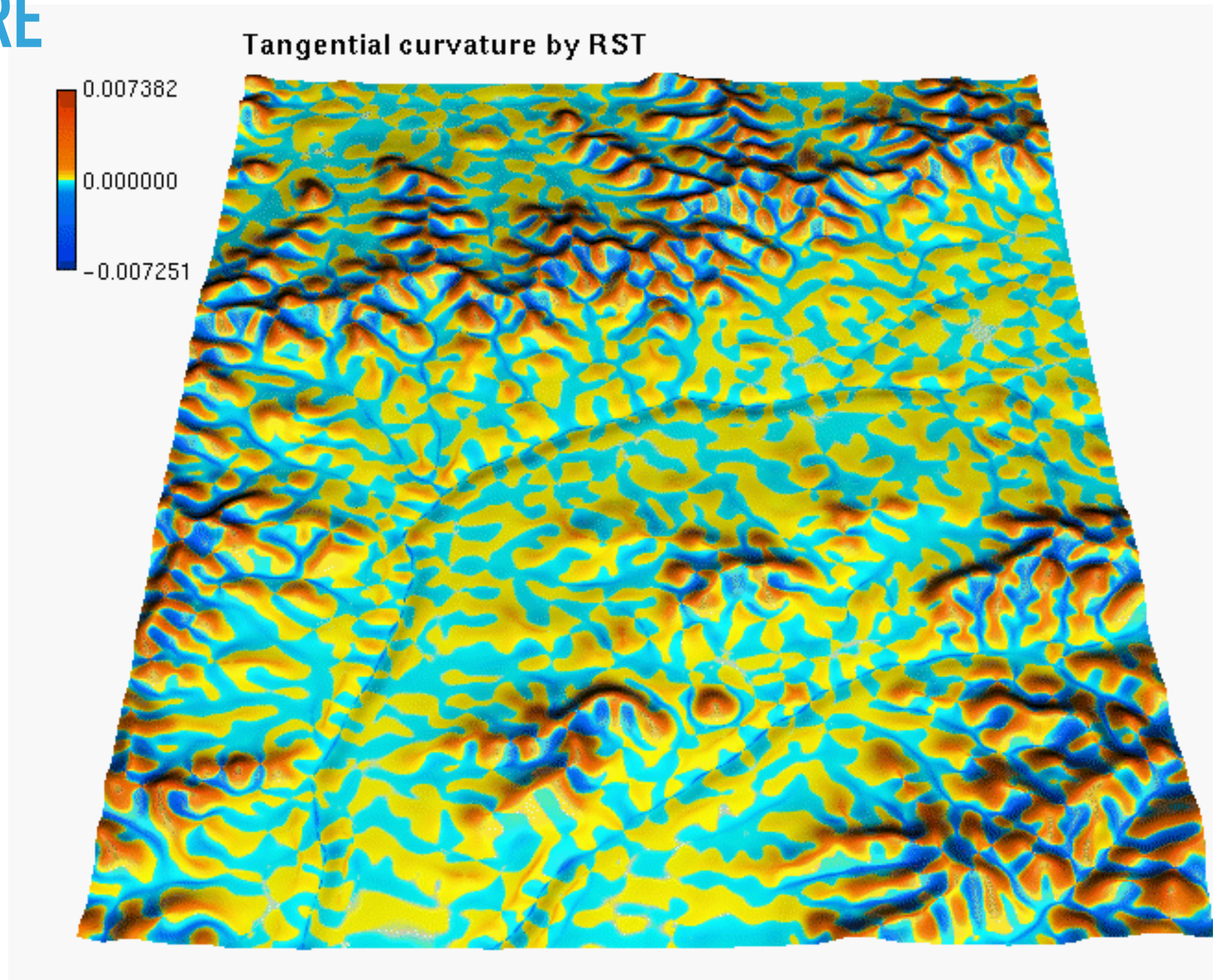
ASPECT



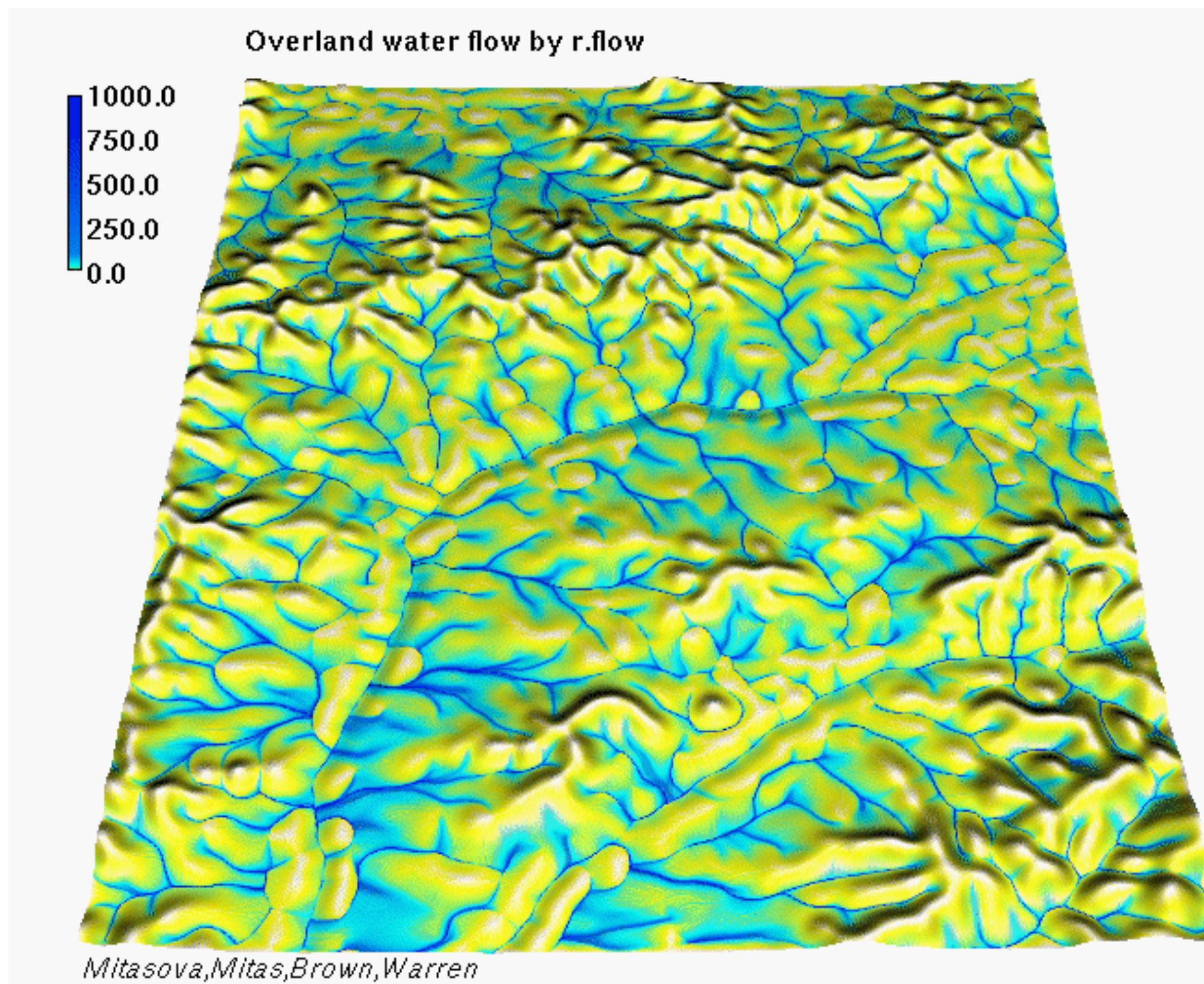
PROFILE CURVATURE

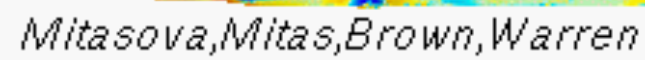


TANG. CURVATURE



FLOW



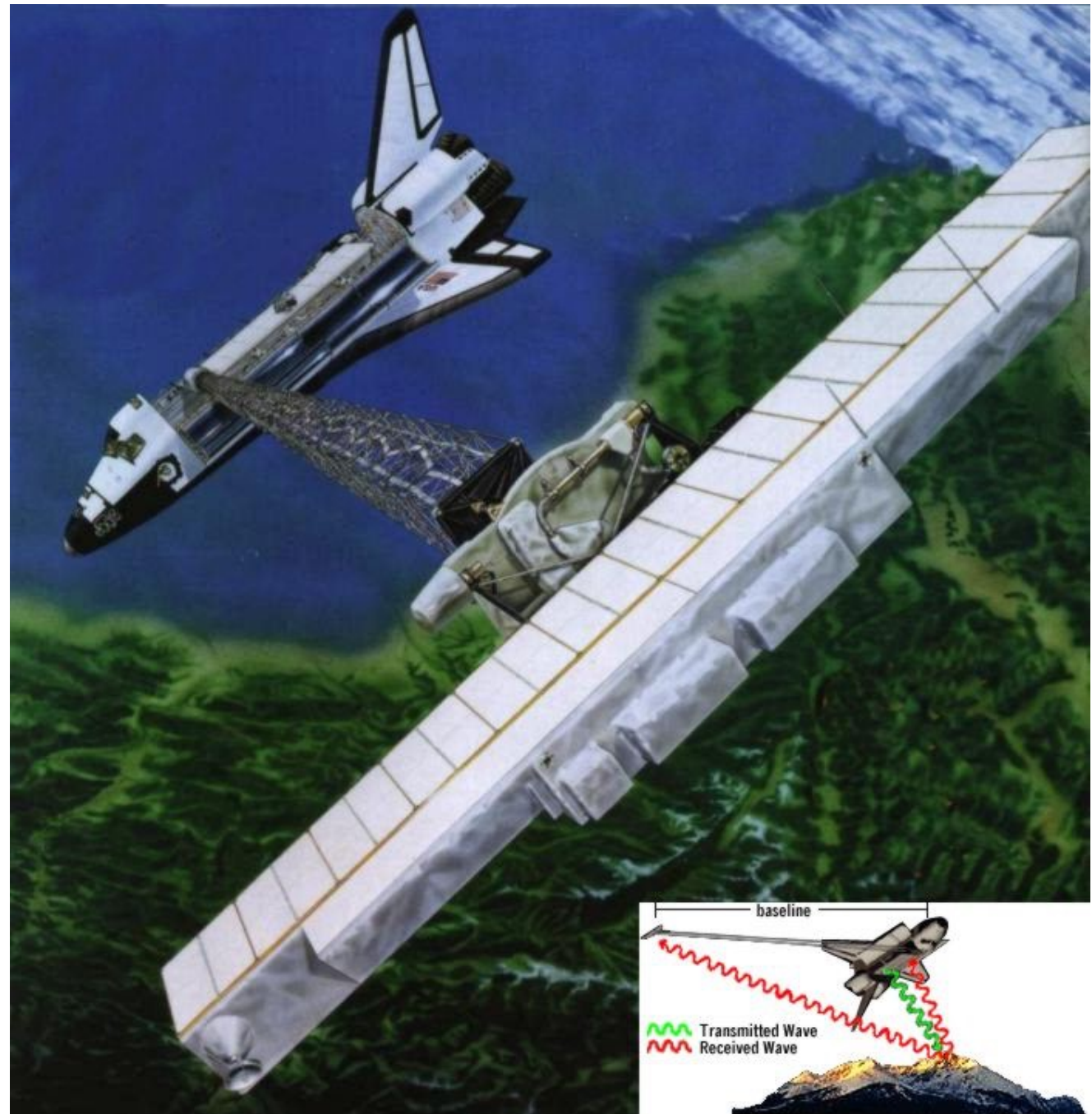
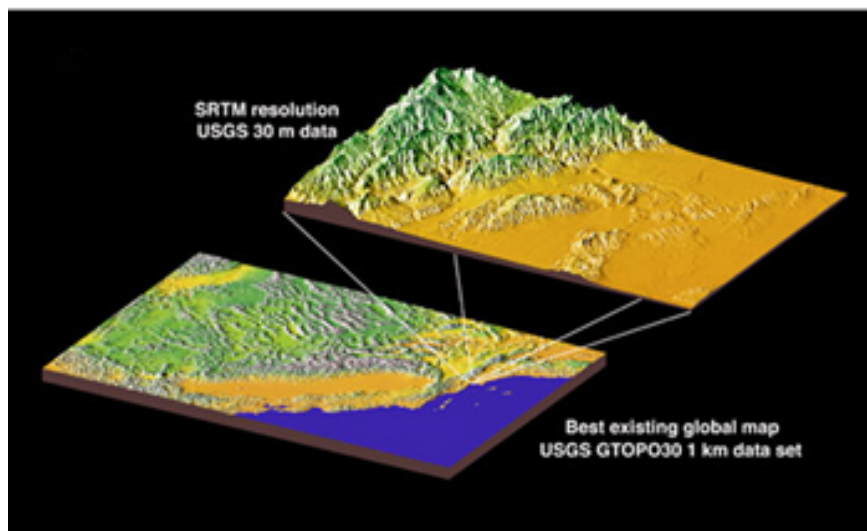
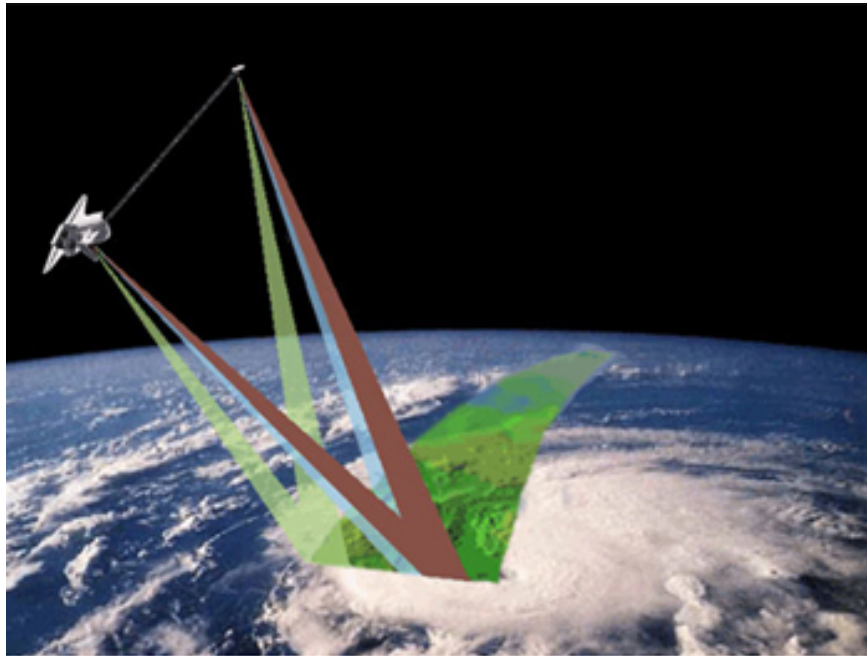


SRTM

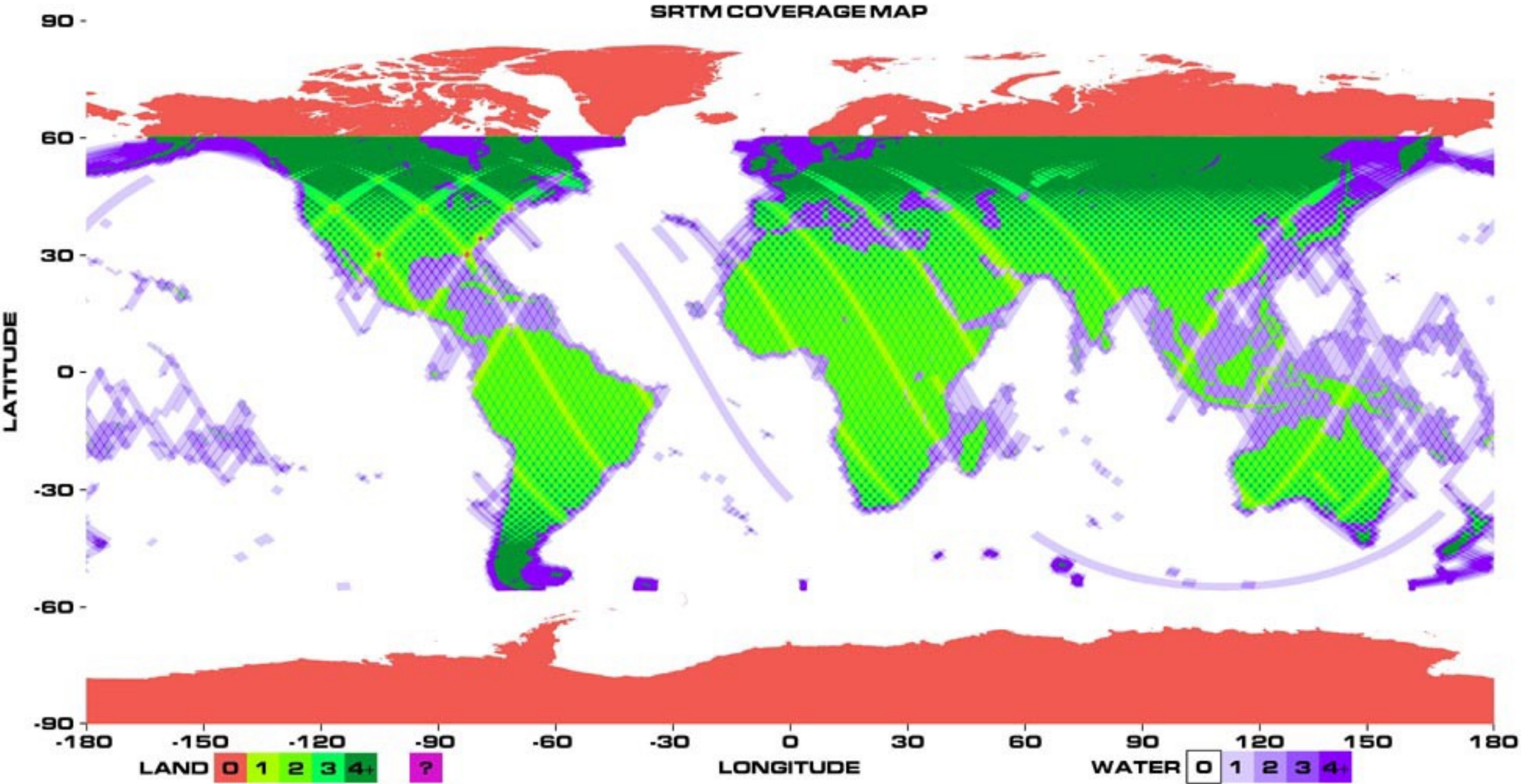
▶ Shuttle Radar Topography Mission

- ▶ 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

Dados SRTM originais (1 arcsec $\approx$ 30m)

760	770	785	815	815
770	780	790	810	820
780	790	795	820	825
790	805	810	820	830
800	790	800	820	830

1 arcsec

Reamostragem

3 arcsec $\approx$ 90m

	795	

NASA: valor do pixel central de janela 3x3 = 795

	802	

USGS: média dos valores de janela 3x3 = 802

$$780 + 790 + 810 = 2380$$

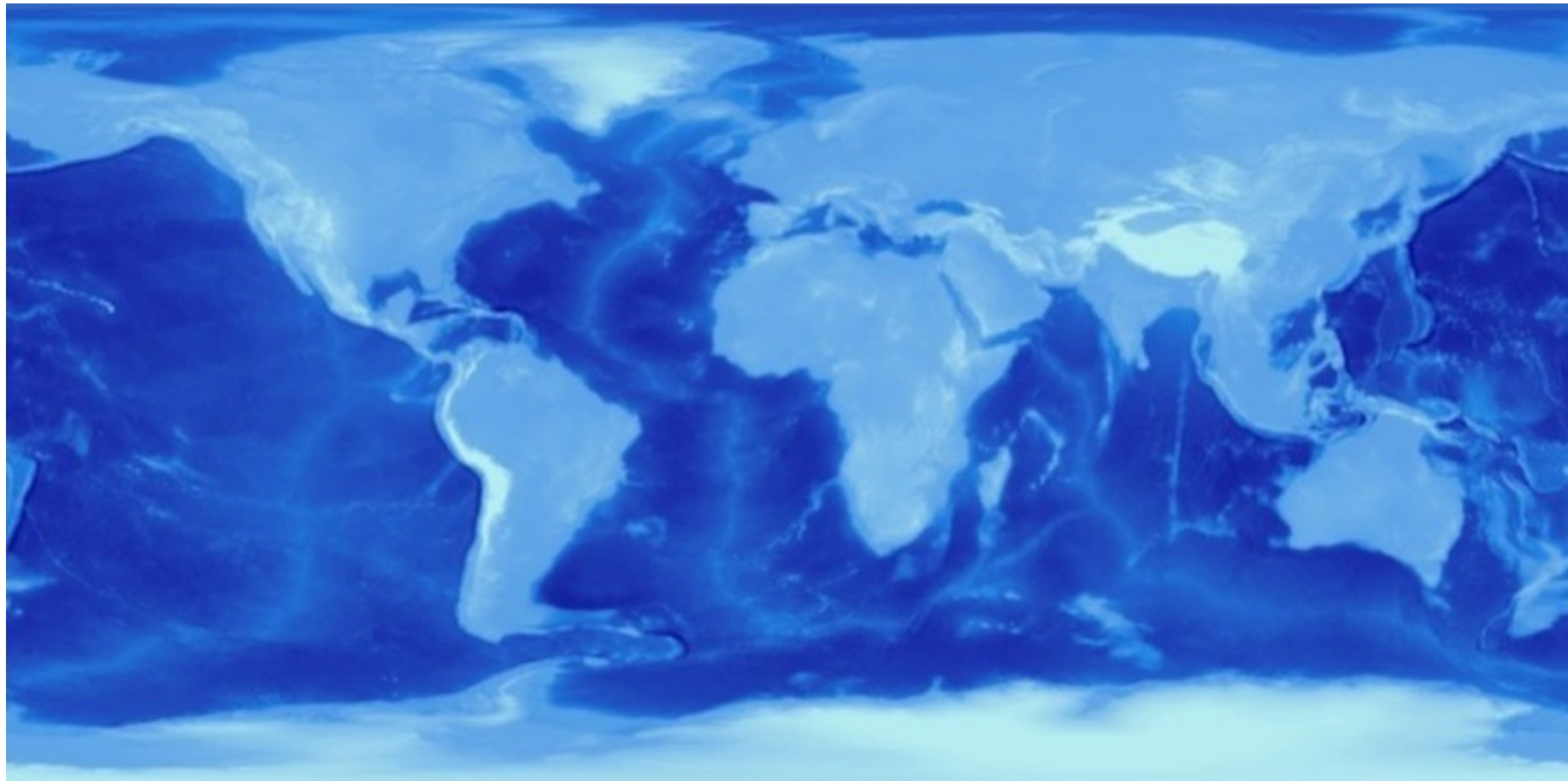
$$790 + 795 + 820 = 2405$$

$$805 + 810 + 820 = 2435$$

$$(2380 + 2405 + 2435) / 9 = 802$$

SRTM30_PLUS

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



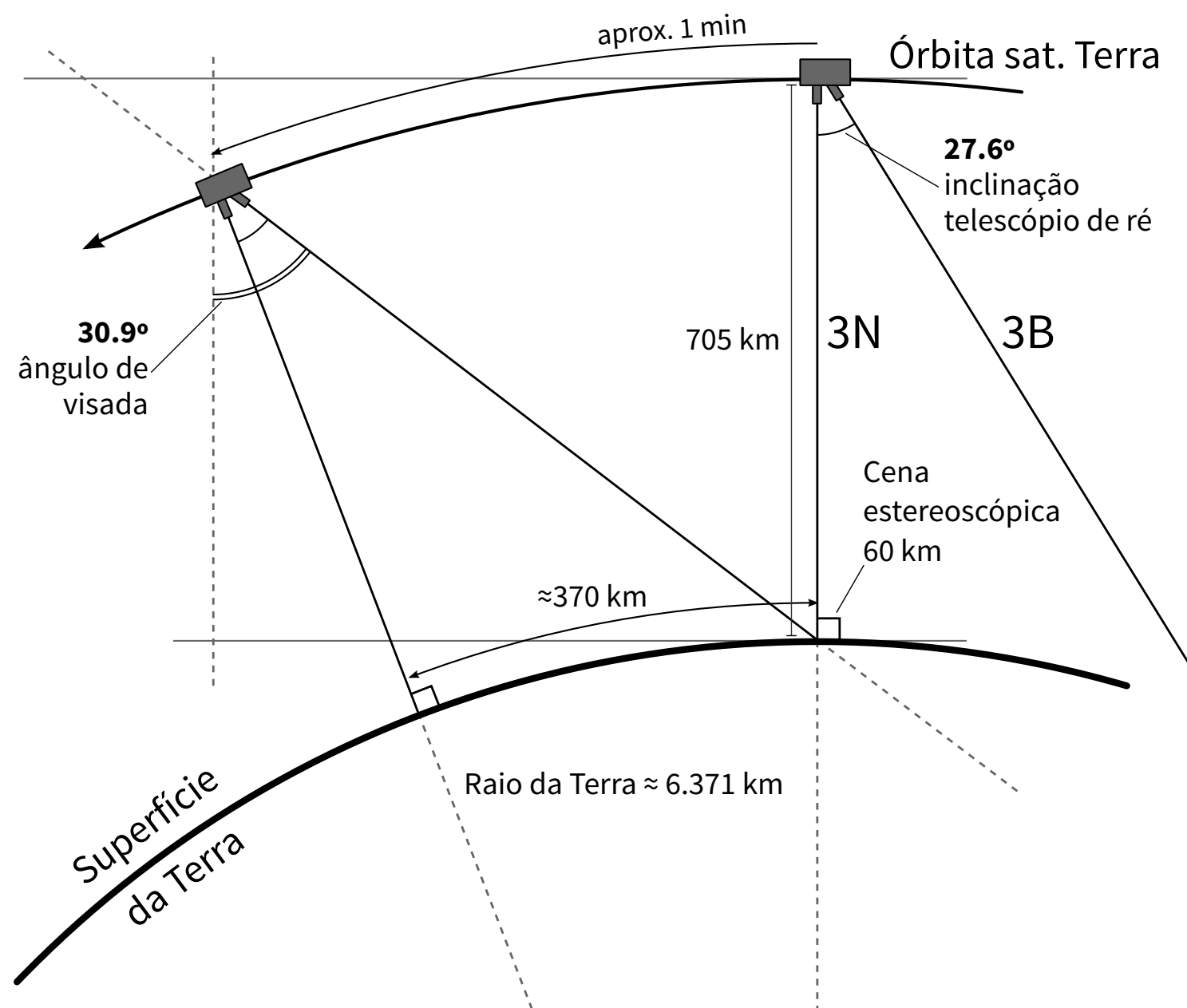
DADOS SRTM

- ▶ SRTM v1 - <http://dds.cr.usgs.gov/srtm/version1/>
- ▶ SRTM v2.1 - http://dds.cr.usgs.gov/srtm/version2_1/
 - ▶ 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/
- ▶ 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>

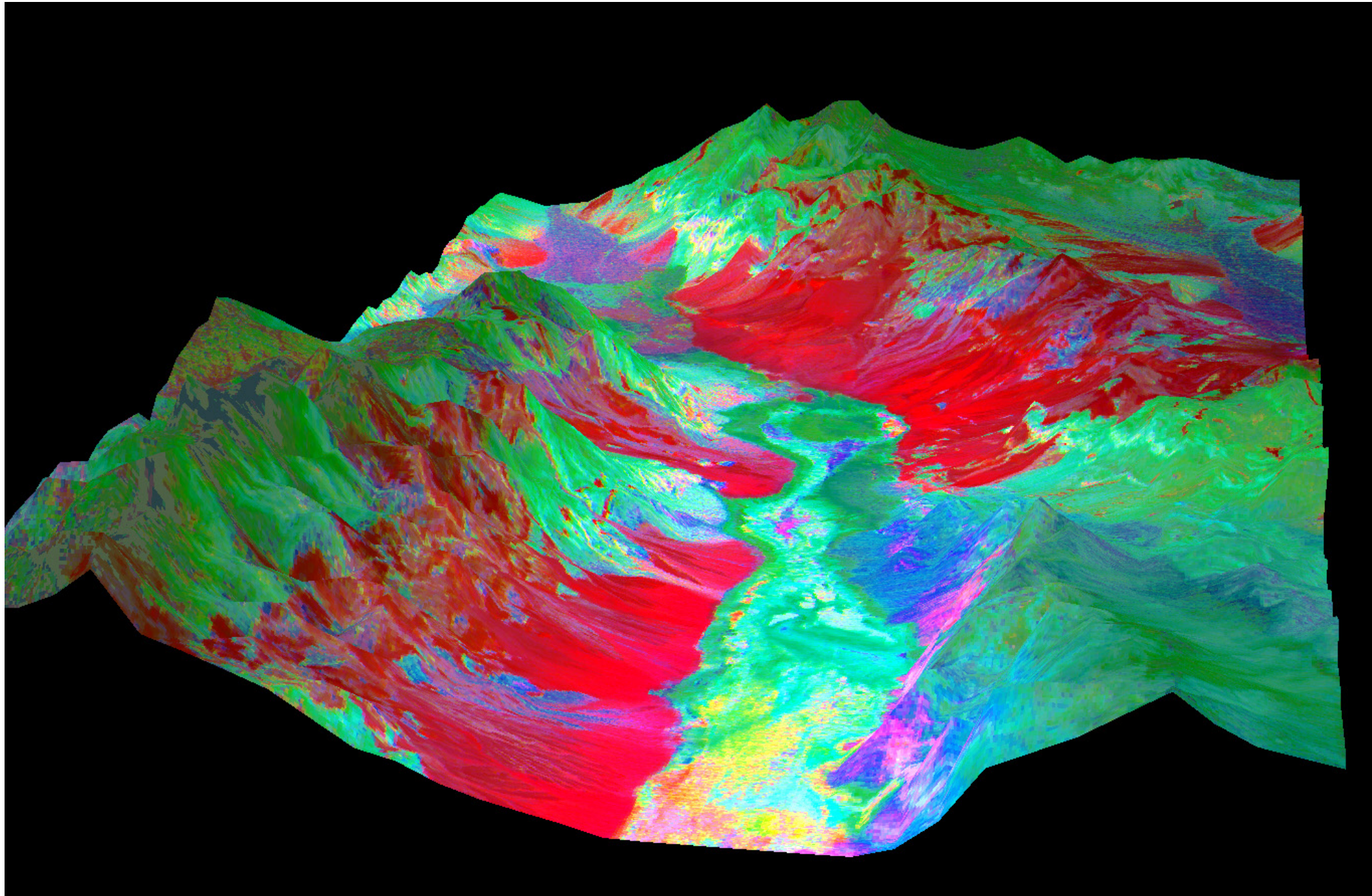
FOTOGRAMETRIA

- ▶ 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

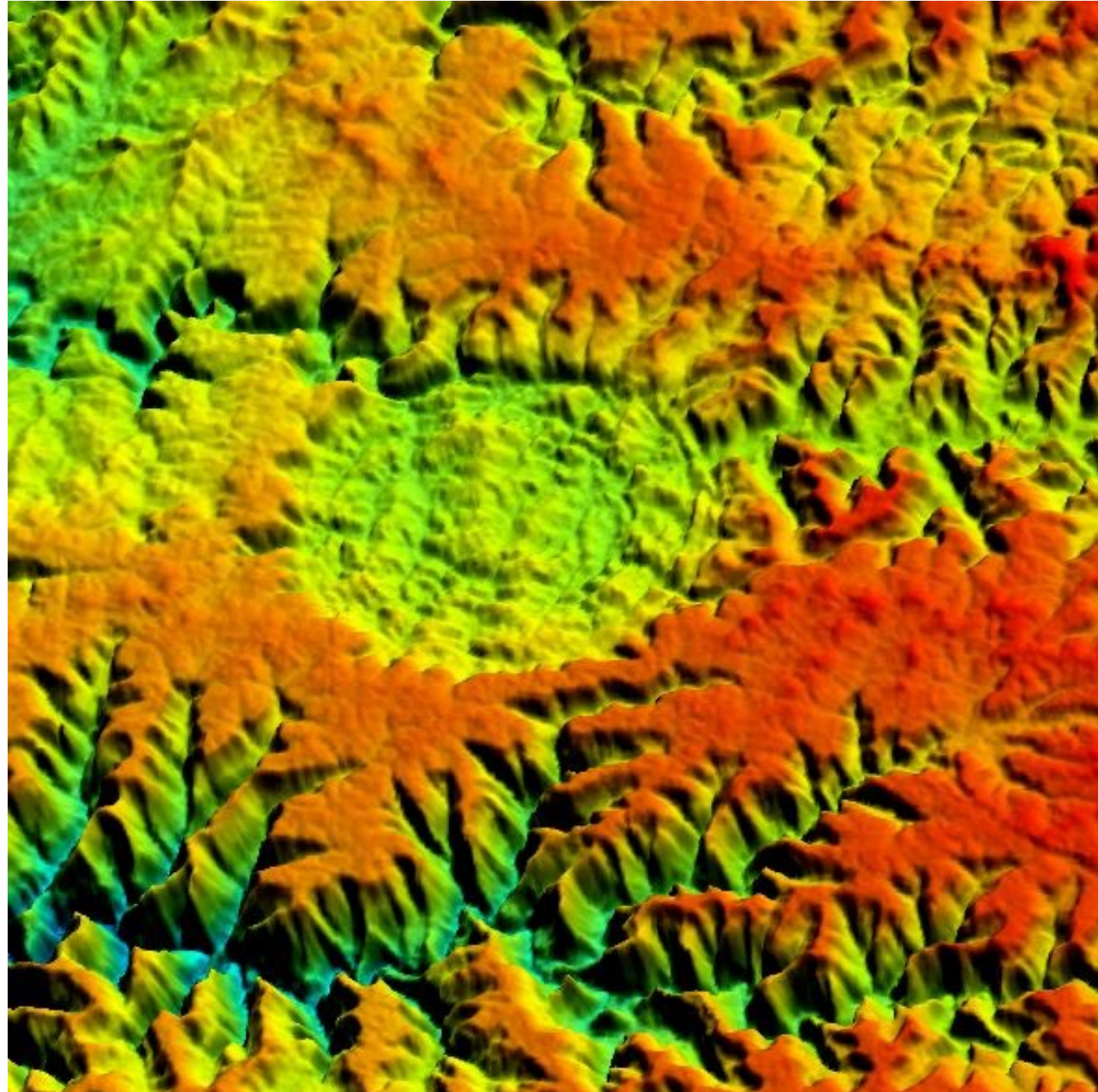
FOTOGRAMETRIA – ASTER 3N+3B



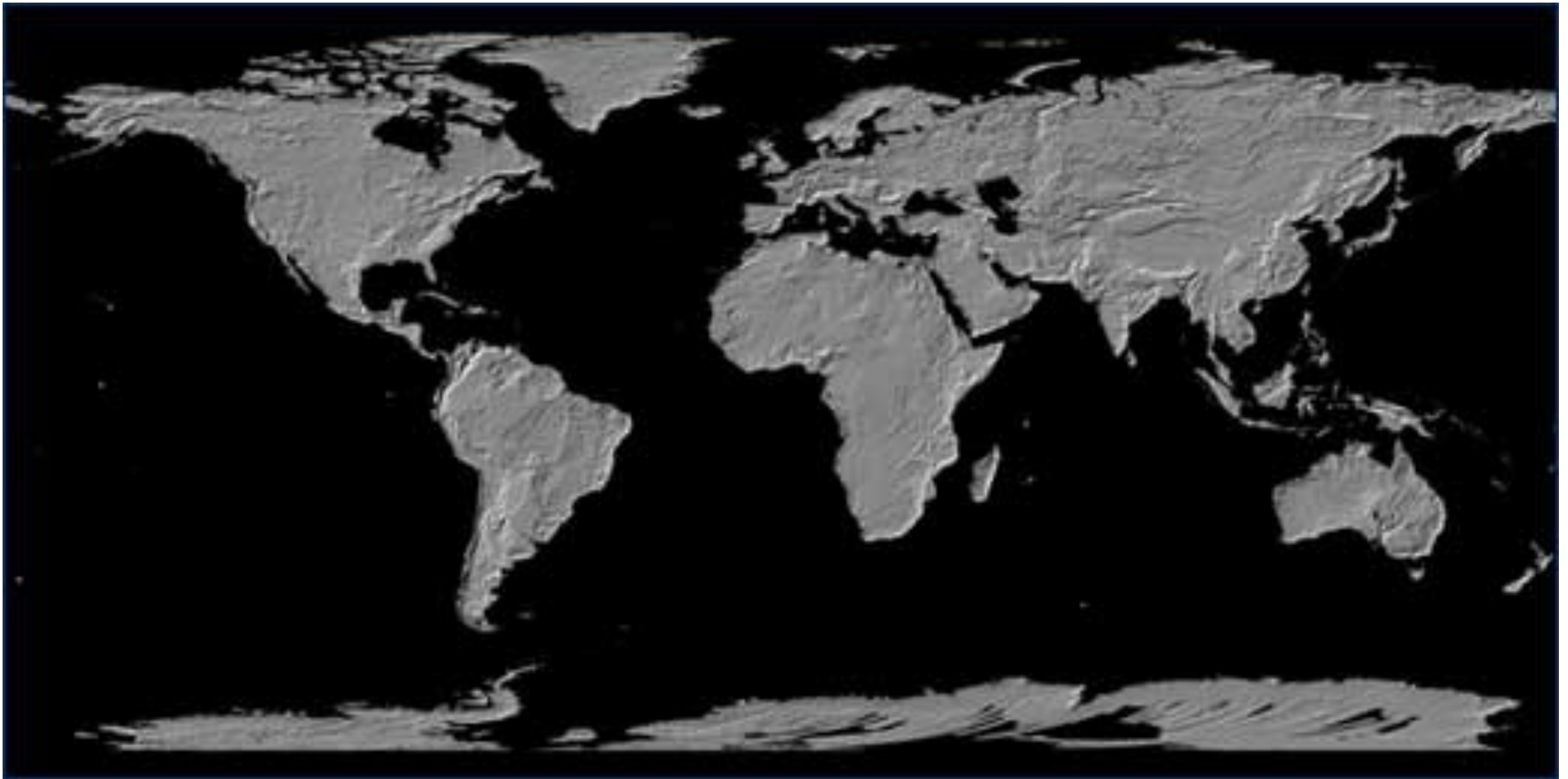
FOTOGRAMETRIA – ASTER 3N+3B



FOTOGRAMETRIA – ASTER 3N+3B



FOTOGRAMETRIA – ASTER GDEM

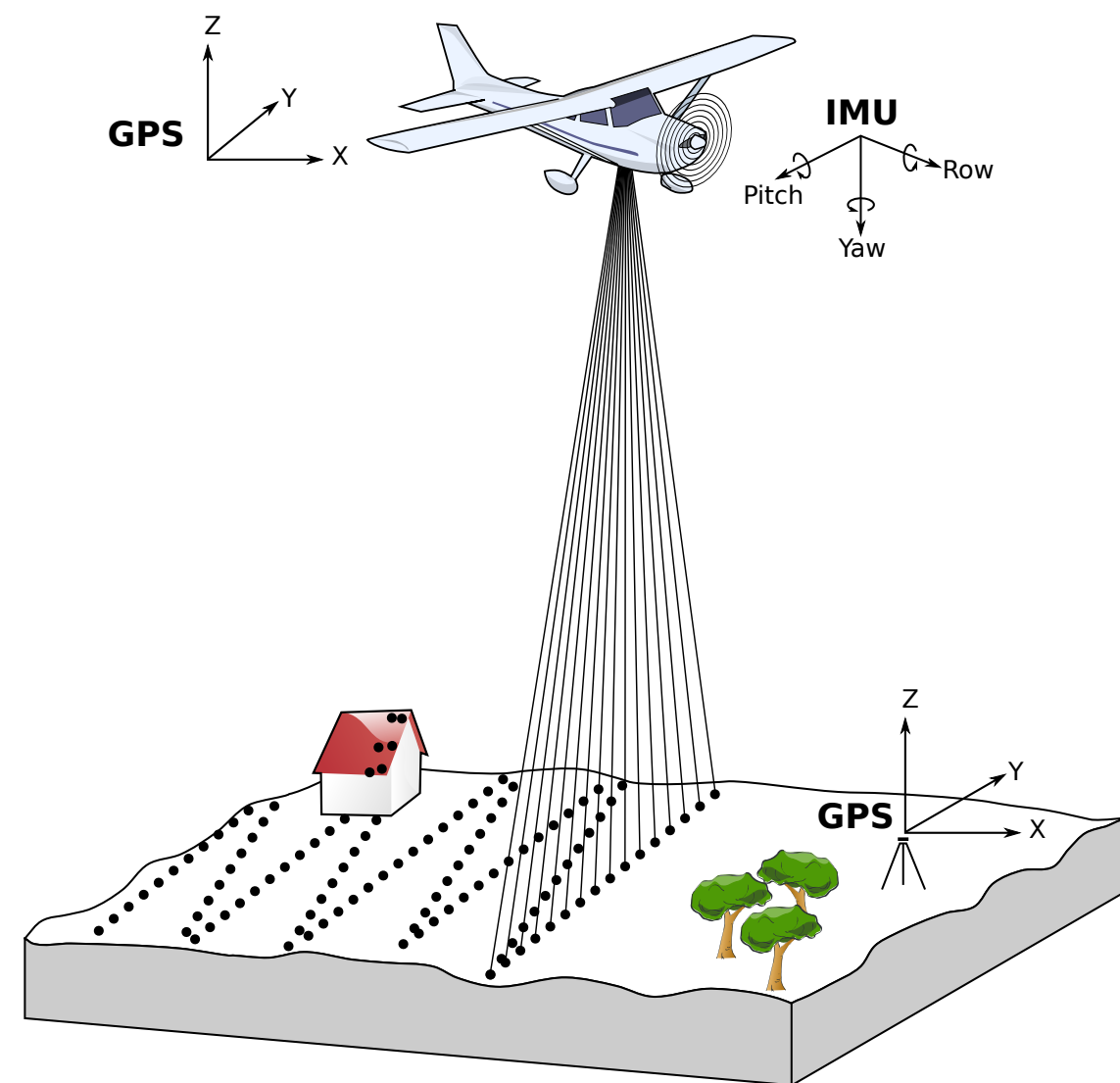


FOTOGRAMETRIA – ASTER GDEM

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

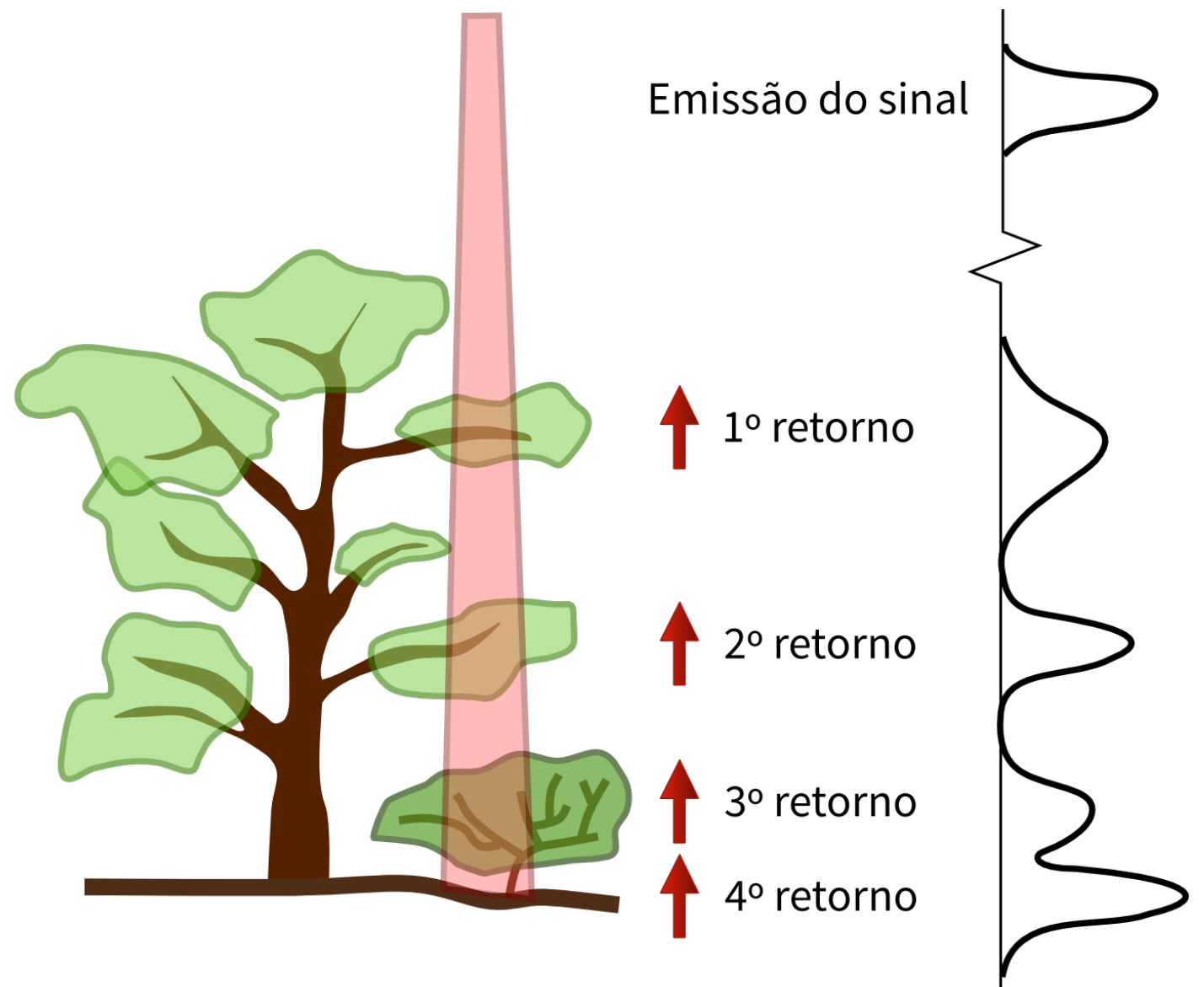
LIDAR

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

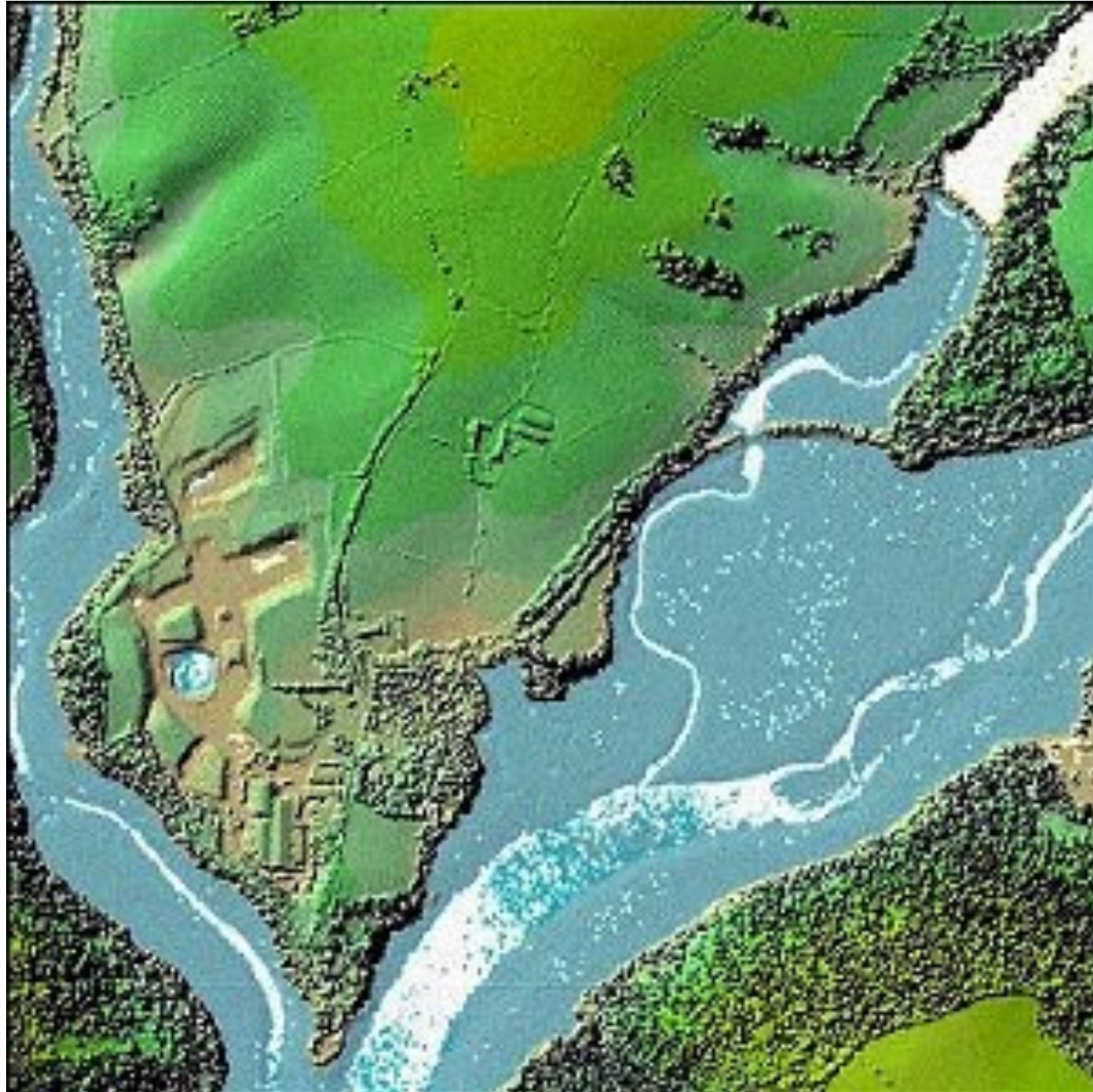


LIDAR

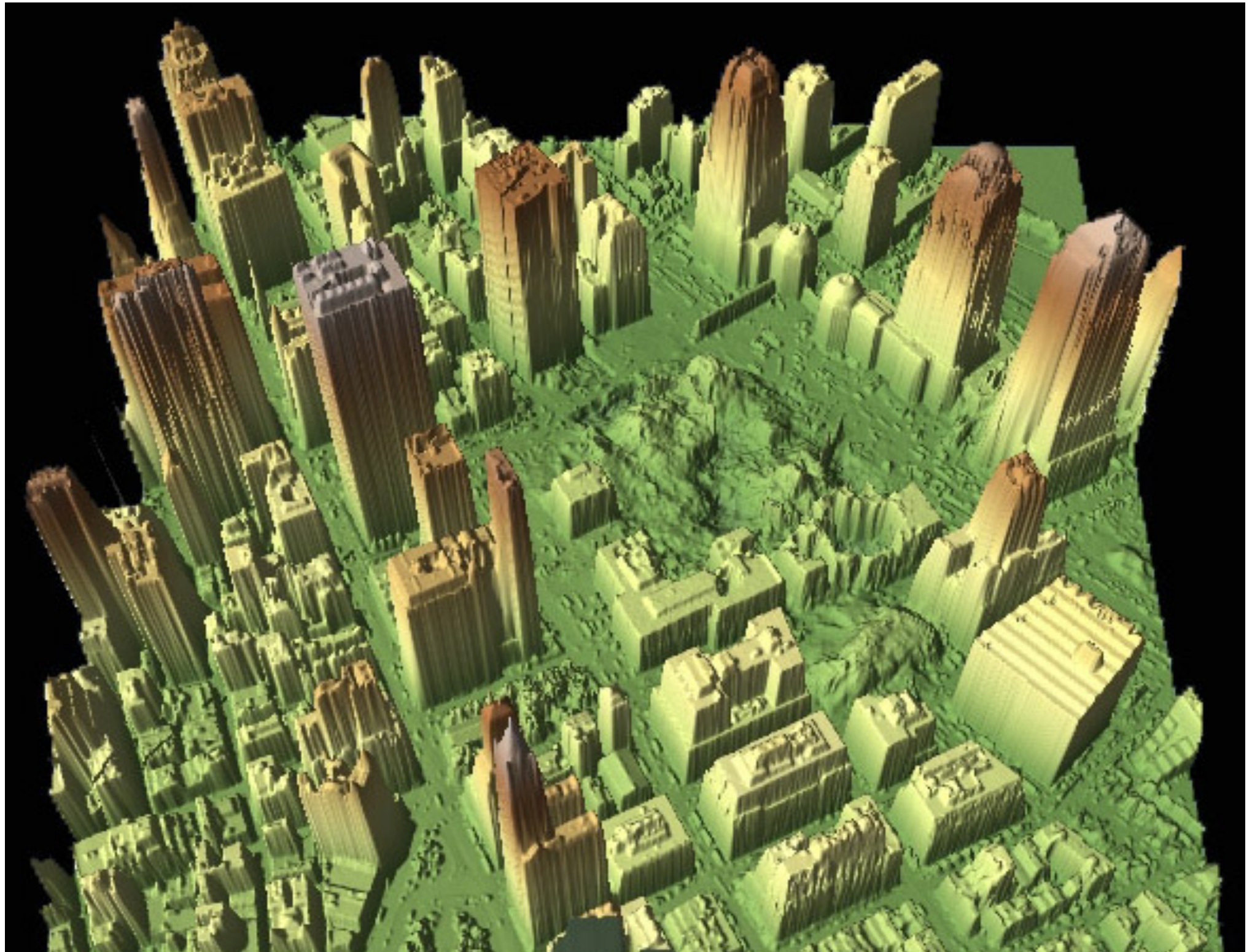
- ▶ Múltiplos retornos
 - ▶ múltiplas superfícies
 - ▶ full waveform



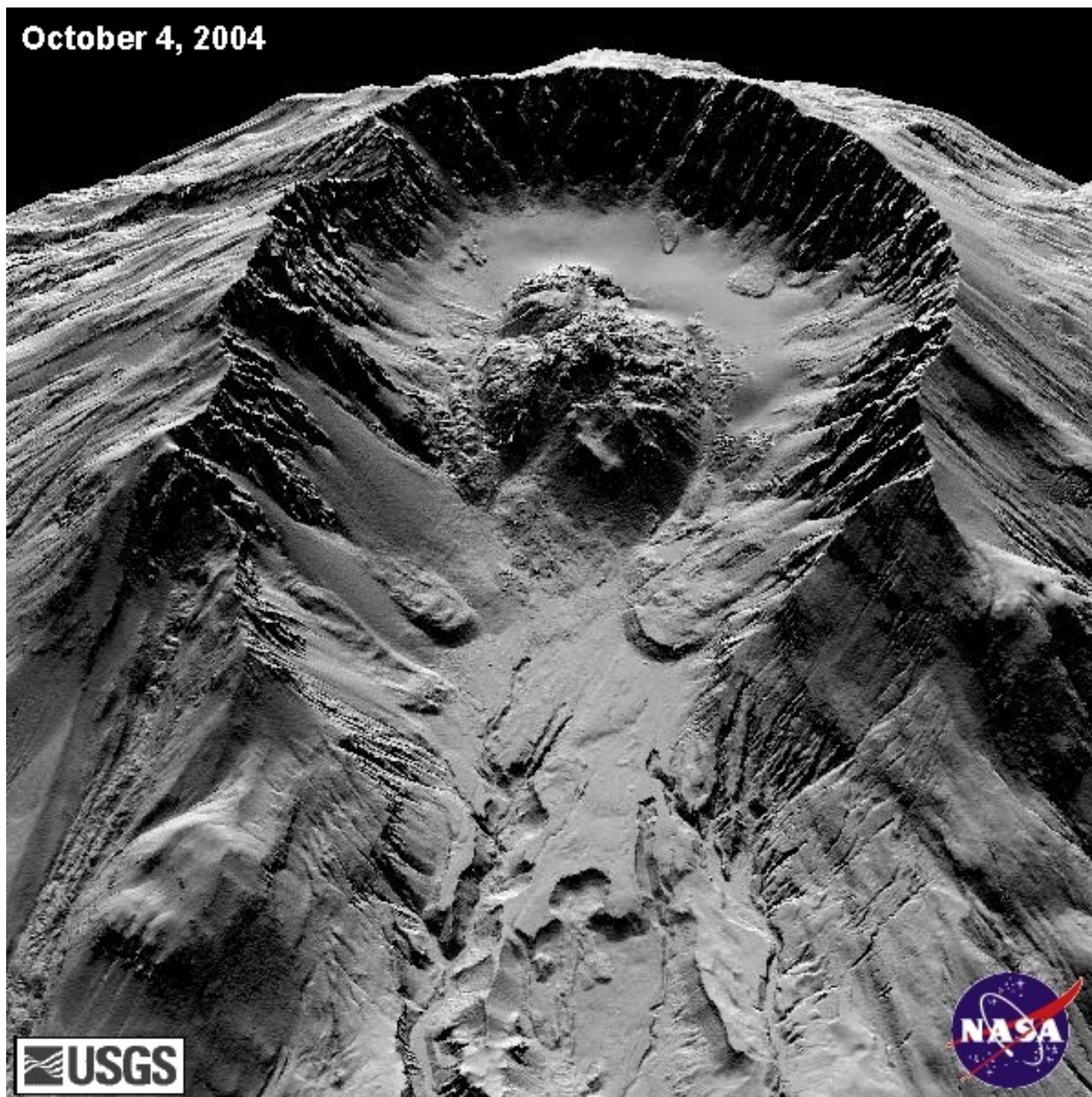
LIDAR



LIDAR

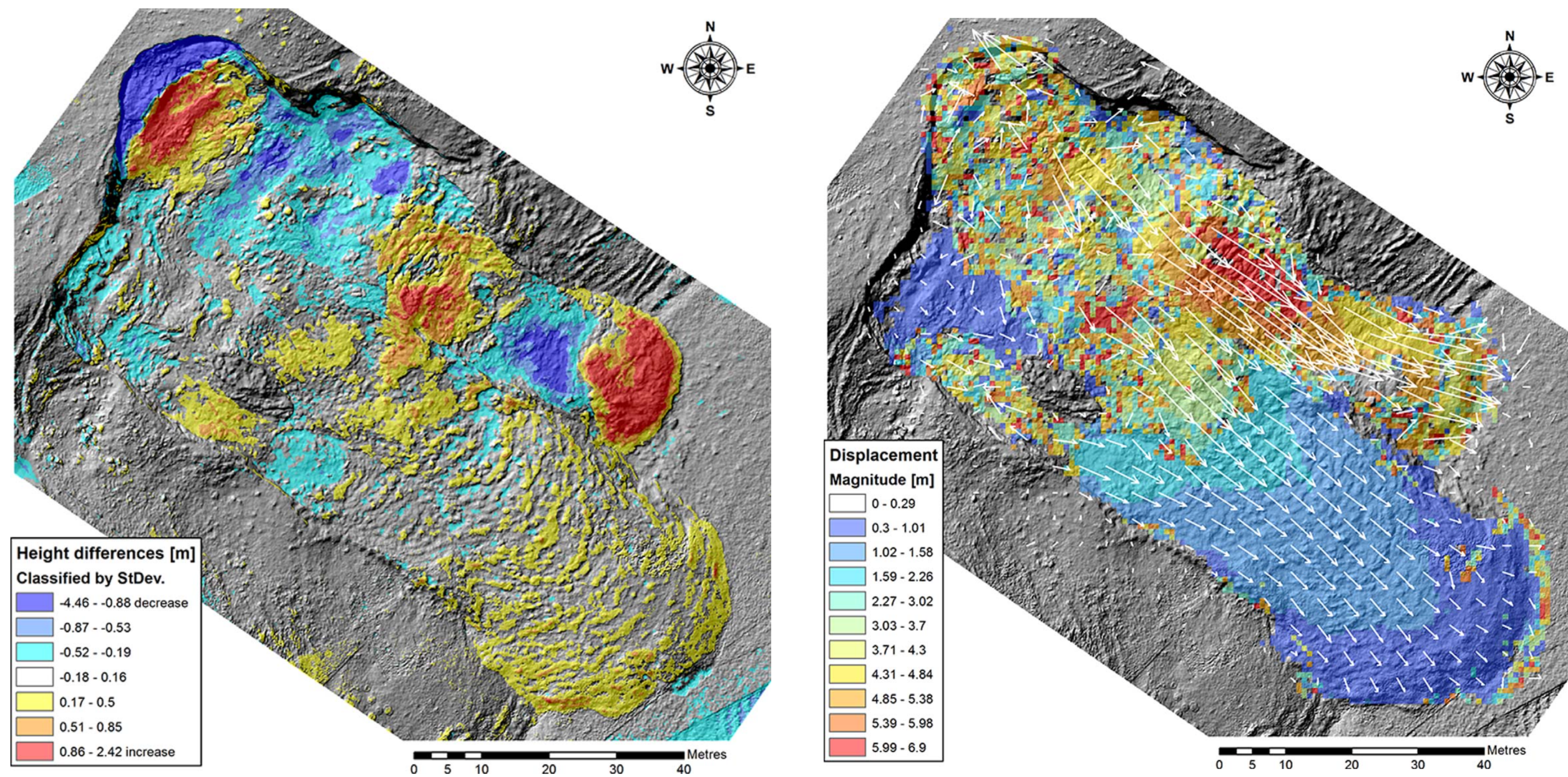


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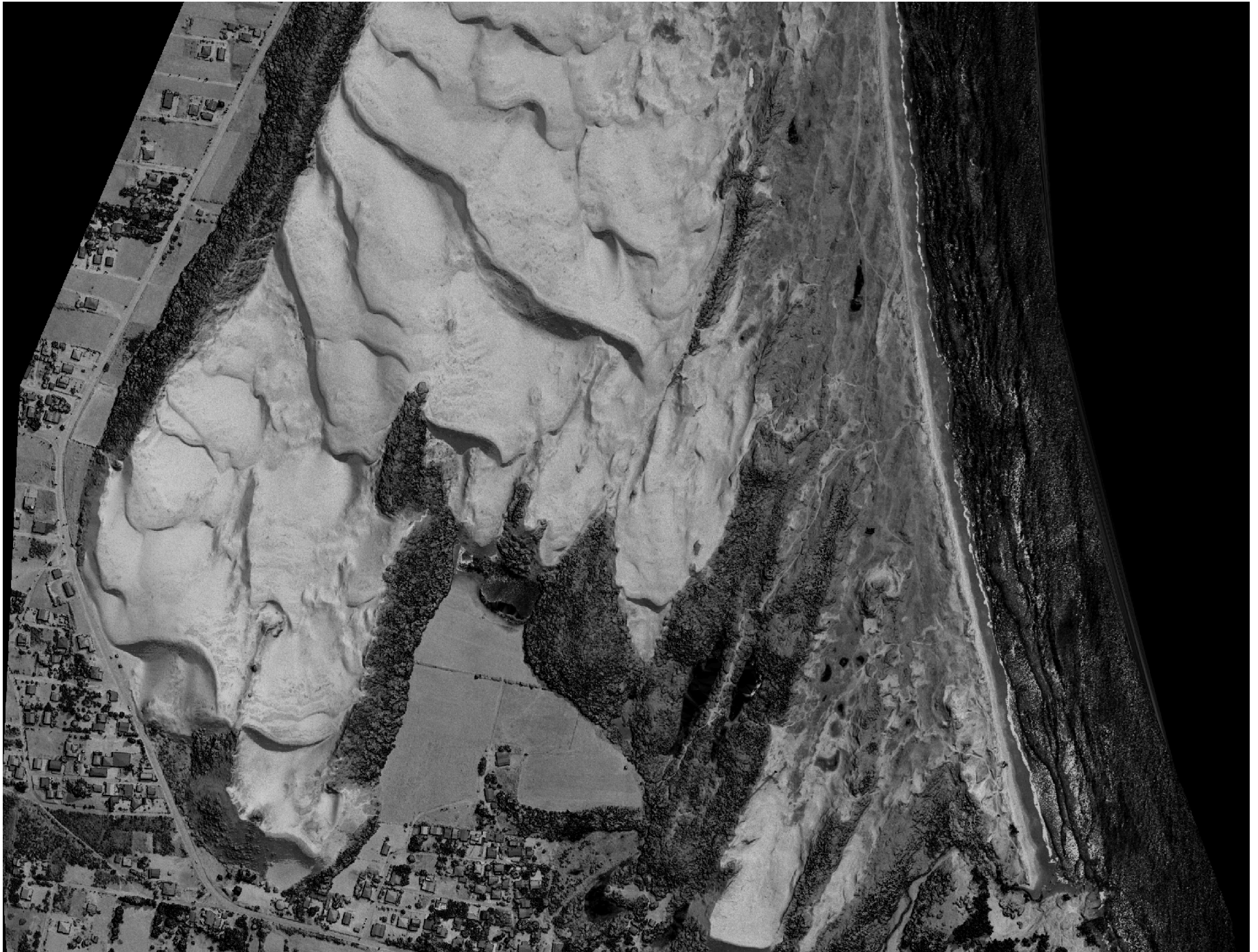


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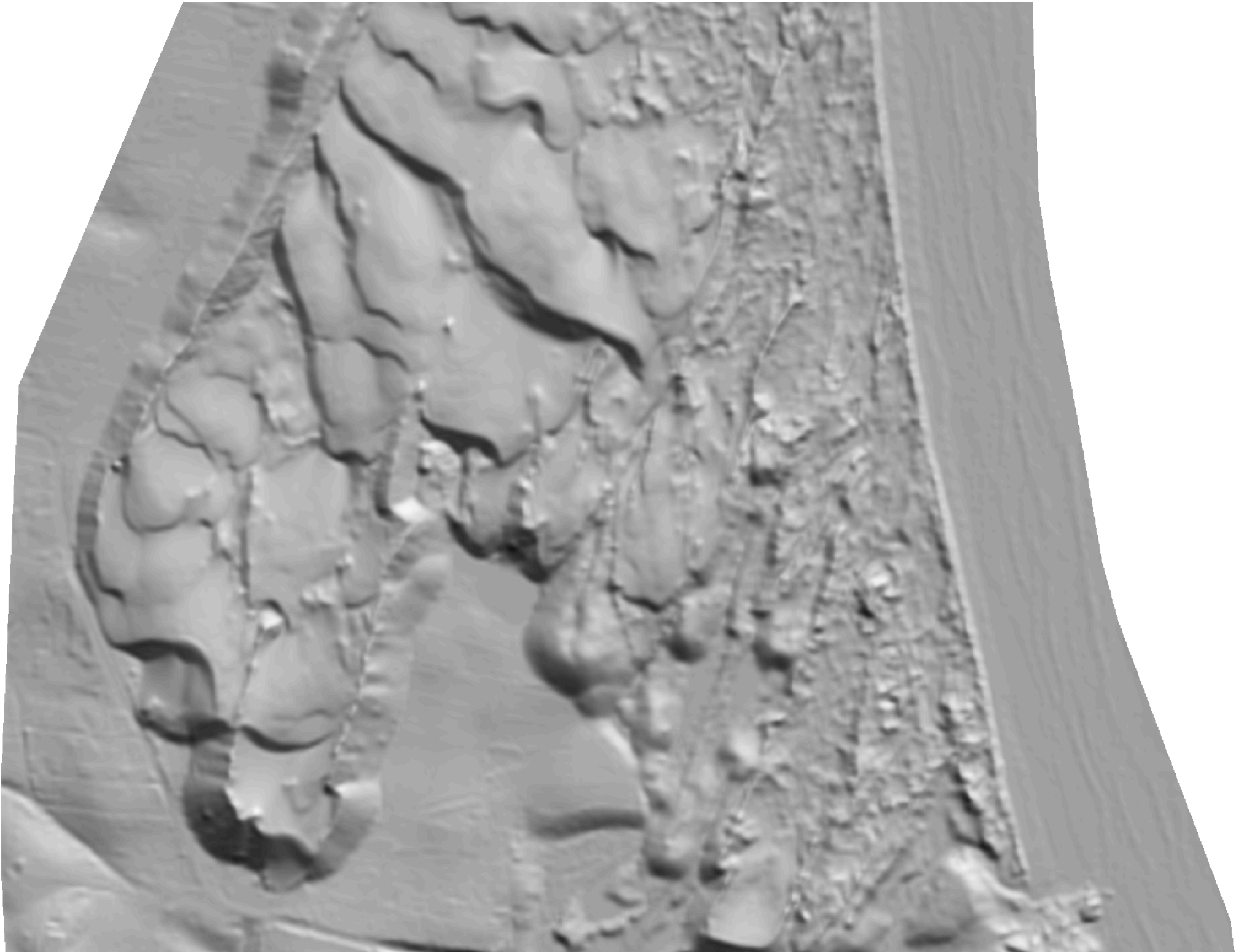
Multi-temporal analysis - displacement



LIDAR



LIDAR



STRUCTURE FROM MOTION – SfM

