

# Chicxulub and Popigai

after 15 years\*

double or multiple impact craters?

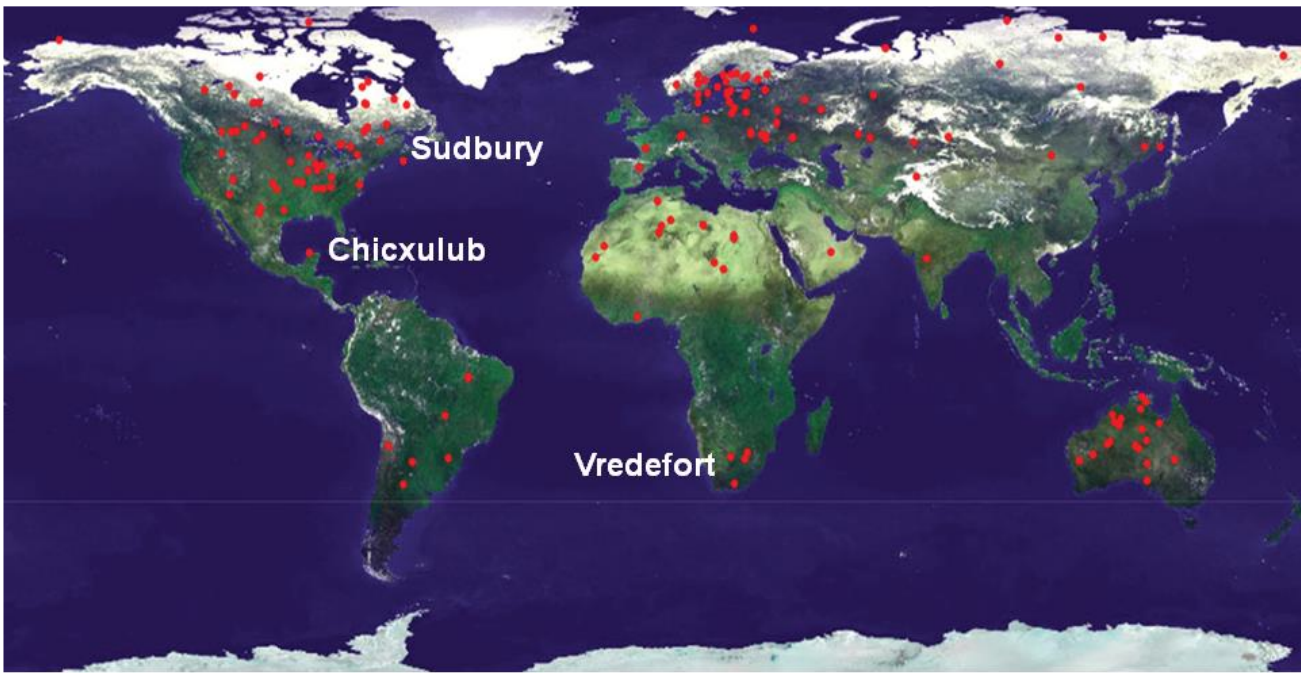
\* Klokočník J., Kostecký J., Pešek I., Novák P., Wagner C.A., Sebera J. 2010. Candidates for multiple impact craters?: Popigai and Chicxulub as seen by the global high resolution gravitational field model EGM08, *Solid Earth EGU* **1**, 71-83; DOI: 10.5194/se-1-71-2010. See also: Is Chicxulub a double impact crater? *6th EGU A. von Humboldt Internatl. Conf. on Climate Change, Natural Hazards, and Societies*, Mérida, México, Section: The Cretaceous/Tertiary Boundary and the Chicxulub Impact Crater, paper AvH6-5, 15 March 2010.



**Astronomical  
Institute**  
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of Sciences

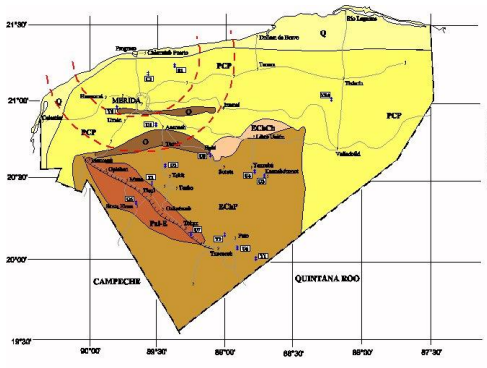


## **Supplement 4 Chicxulub**

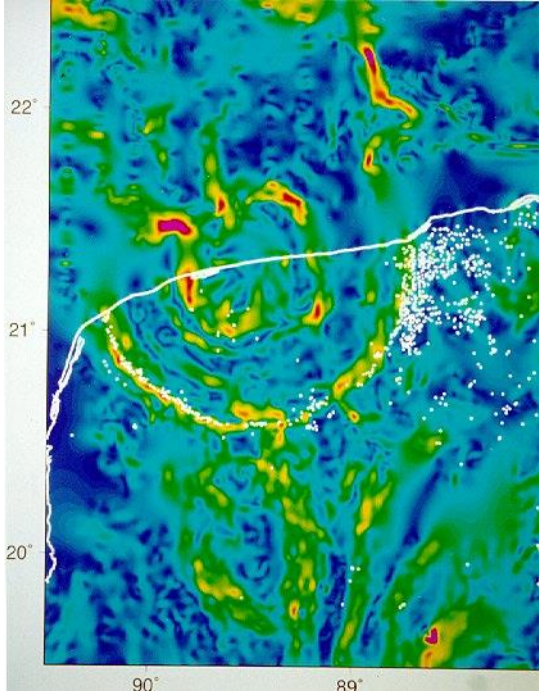


# Chicxulub

Three Large Complex Multiring Structures



LEGEND		
AGE	LITHOLOGY	
PERMIAN	Q	Quaternary and recent (Quaternary alluvium)
CRETACEOUS	PCP	Proterozoic basement and igneous (Cretaceous)
CRETACEOUS	Q	Mainly calcareous and (Cretaceous)
CRETACEOUS	ECHM	Chicxulub impactite (Chicxulub Crater)
CRETACEOUS	ECHC	Chicxulub impactite (Chicxulub Crater)
CRETACEOUS	Pa-B	Chicxulub impactite (Chicxulub Crater)

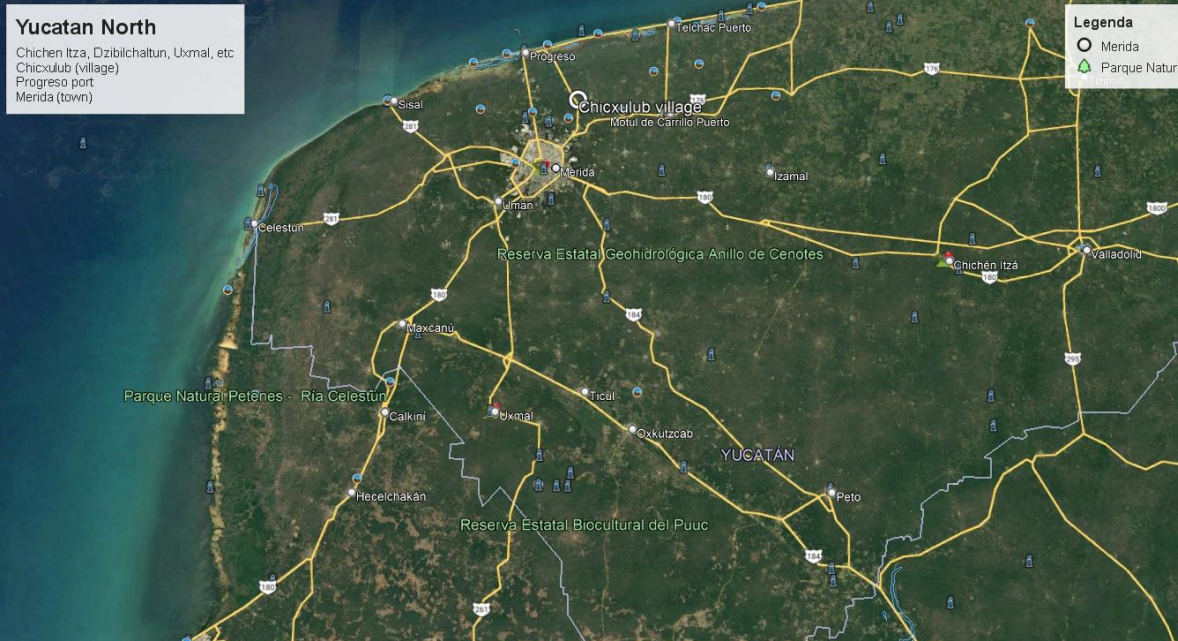


Alvarez, L.W., Alvarez, W., Asaro, F. & Michel, H.V. 1980. Extraterrestrial cause for the Cretaceous–Tertiary extinction. *Science*, v.208, pp.1095–1108.

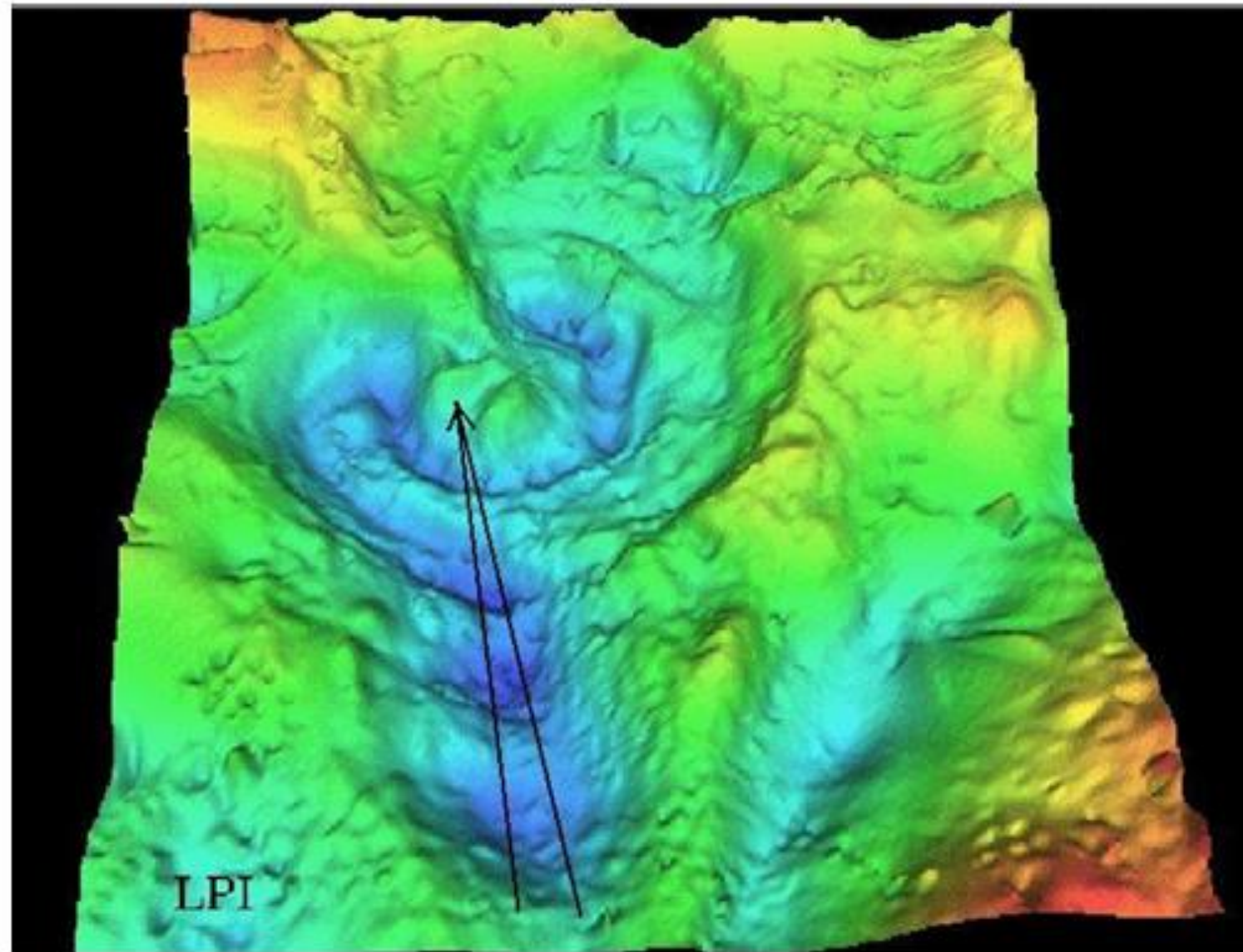
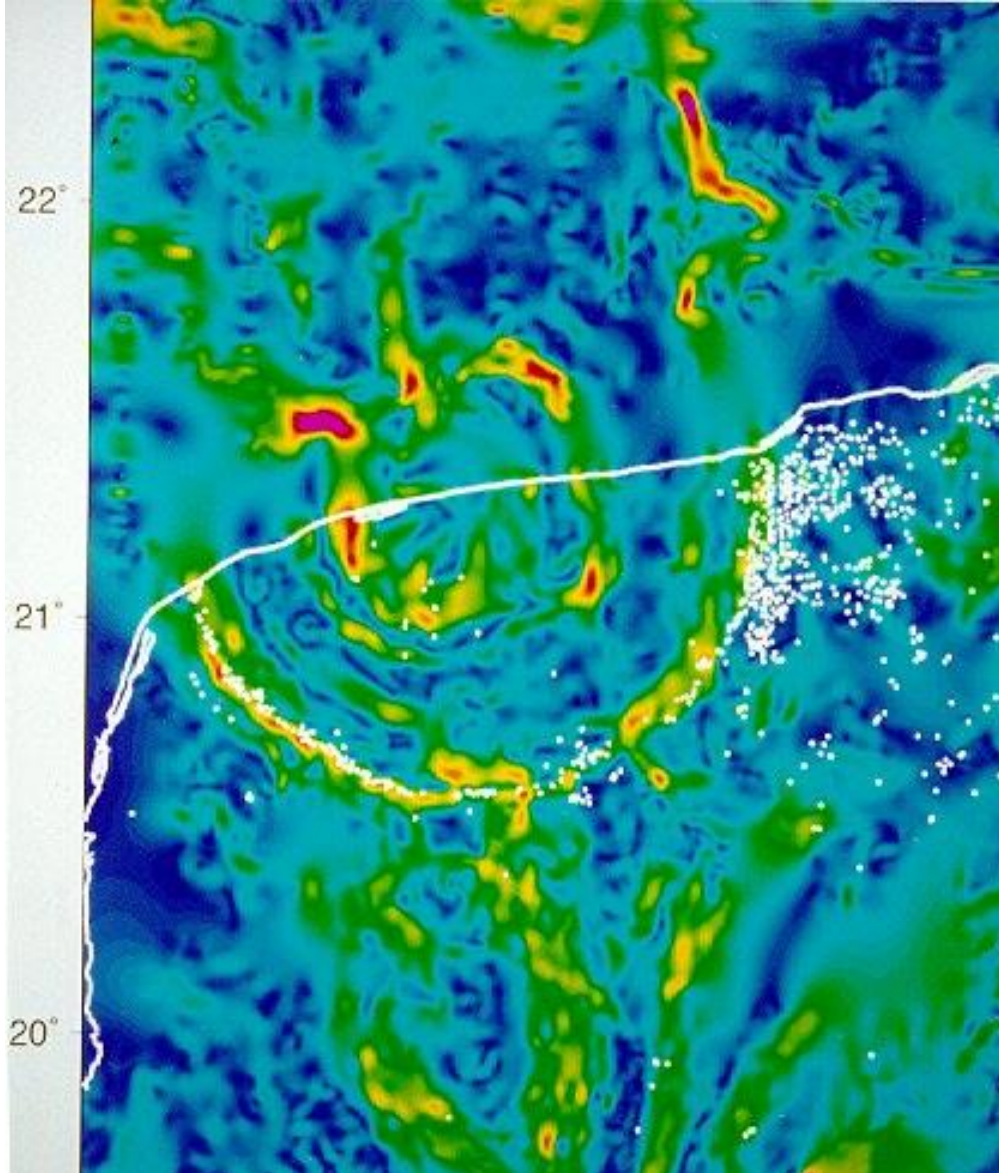


# Yucatan North

- Chichen Itza, Dzibilchaltun, Uxmal, etc
- Chicxulub (village)
- Progreso port
- Merida (town)







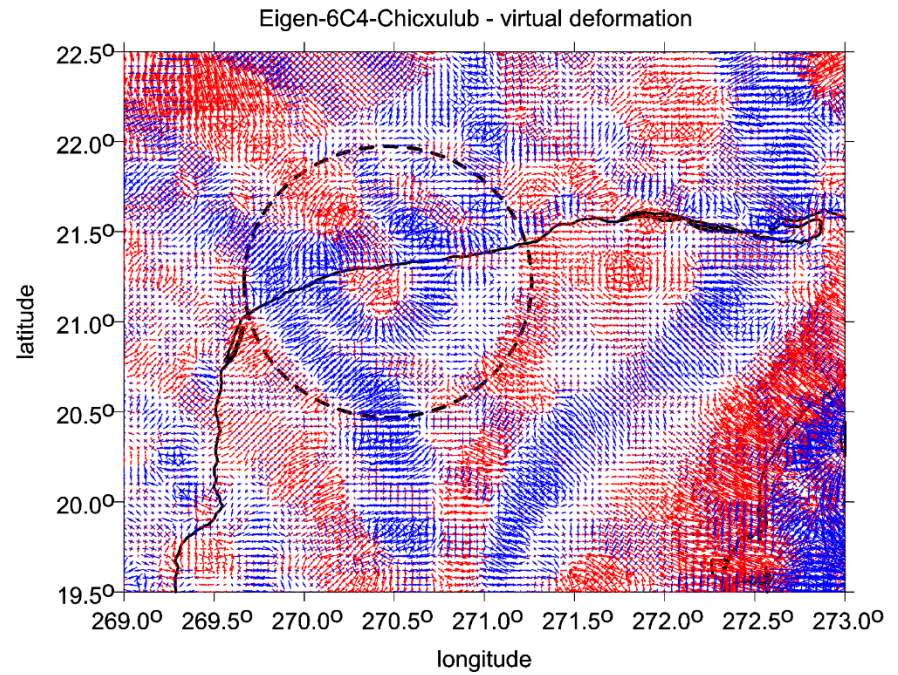
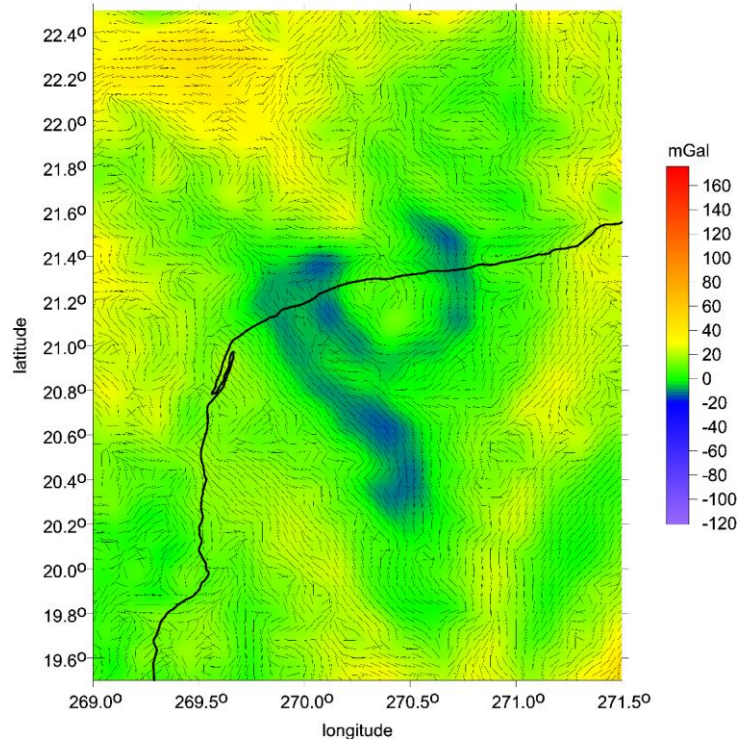
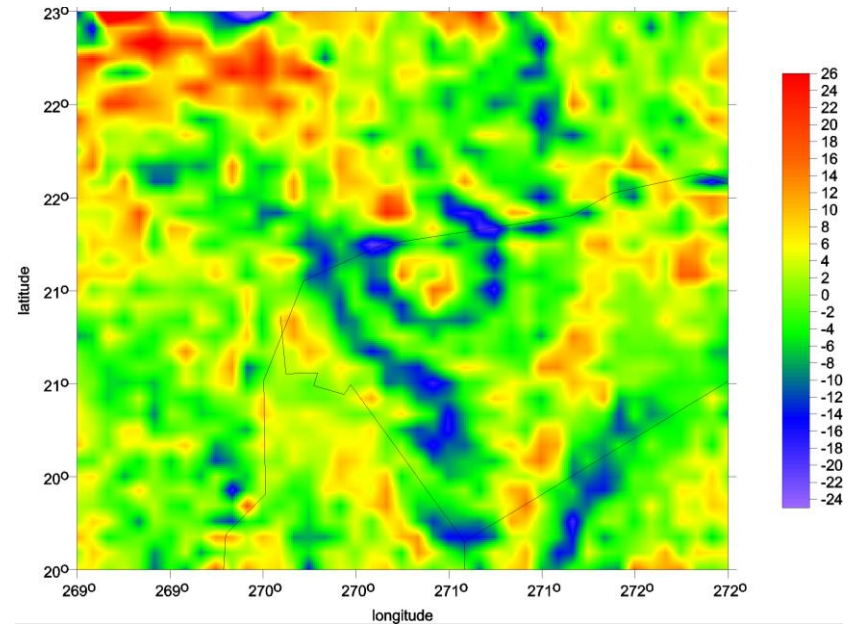
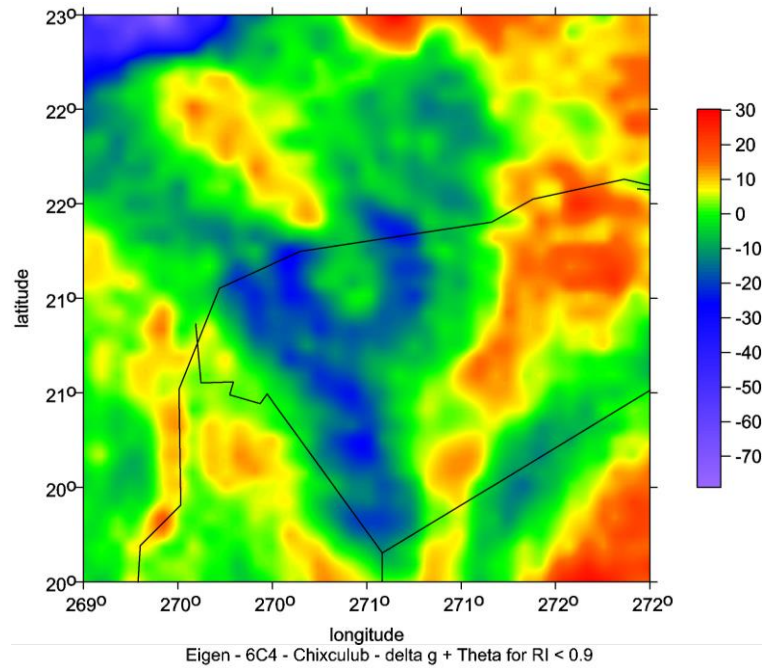
**Chicxulub** historical material **a**

traditional terrestrial  
gravity anomalies [mGal] measured  
by PEMEX for oil prospection, white dots: cenotes (singholes)

The gravity anomalies with a well-expressed gravitational trace of the Chicxulub crater, D=180 km, age  $65.2 \pm 4$  Ma:  
– according to Sharpton, LPI. (<http://www.solarviews.com/cap/earth/chicxulb.htm>)



# Chicxulub





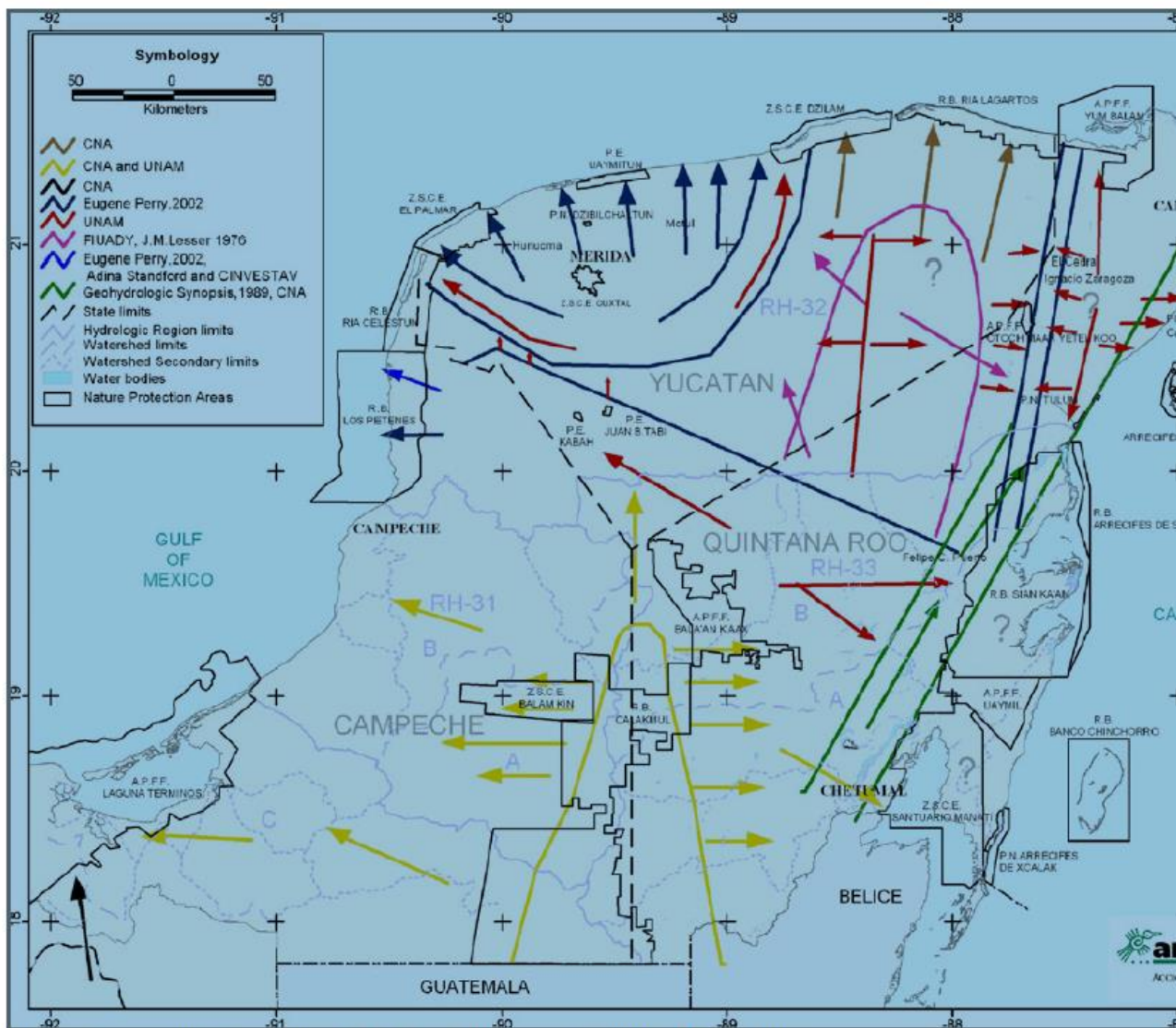
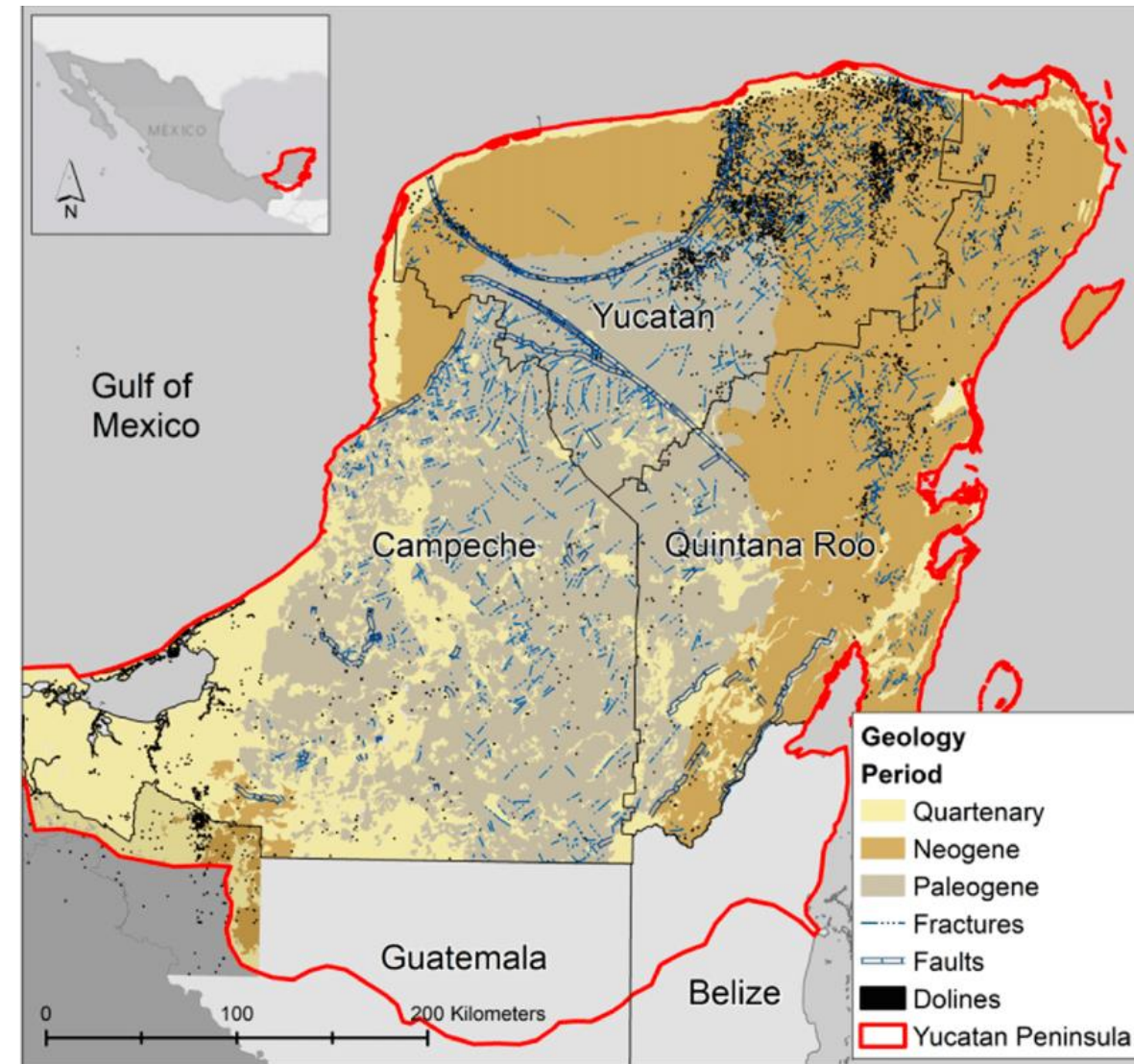


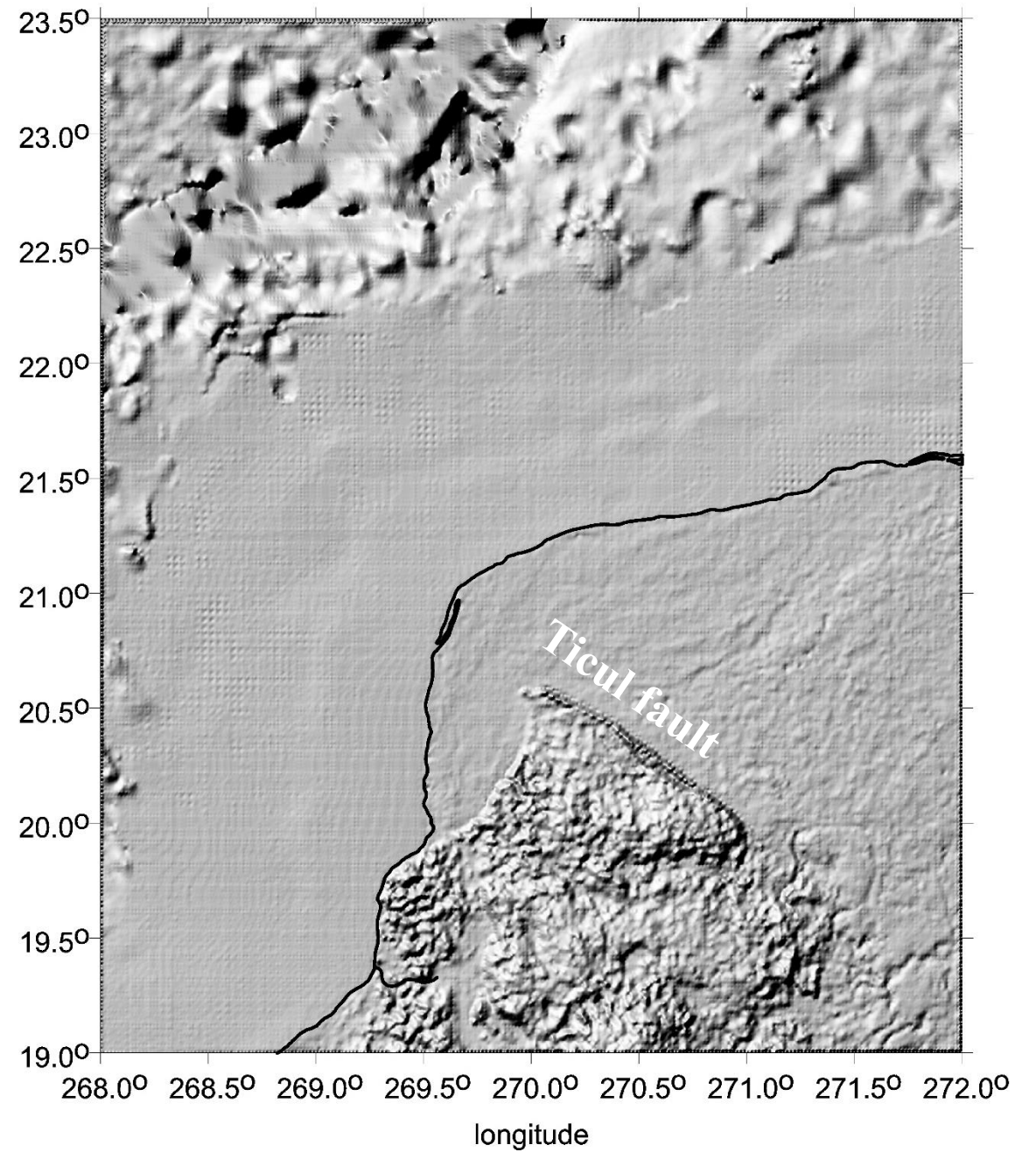
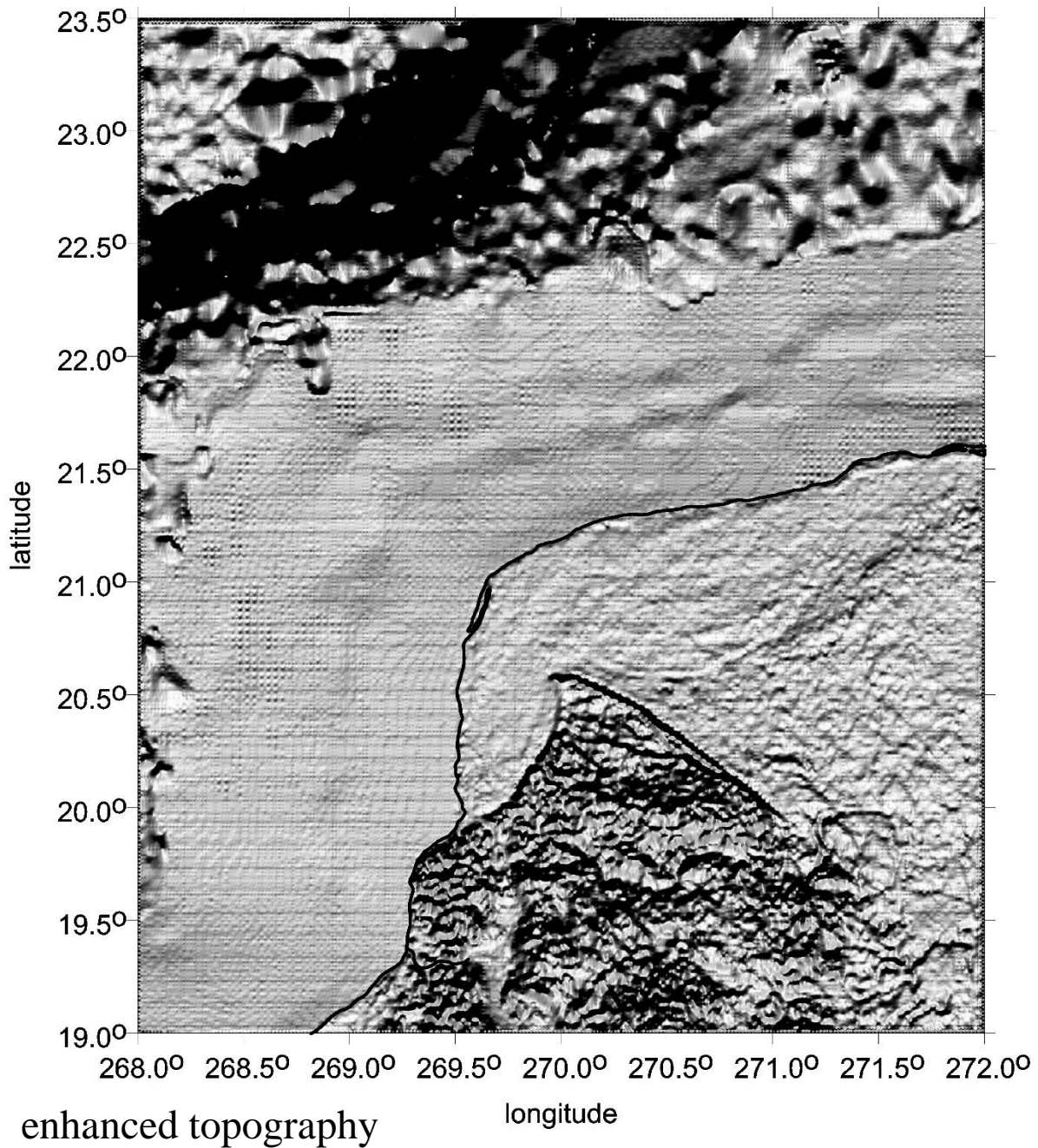
Fig. 7 Consensus map of regional-scale groundwater flow (ASK 2003, with perm groundwater flow directions according to the respective reference. Details of refe communication, 2003; UNAM Universidad Nacional Autónoma de México, persona Perry et al. (2002). FIUADY Universidad Autónoma de Yucatán, personal comunic Adina Stanford and CINVESTAV refers to Centro de Investigación y de Estudios A communication, 2003; Geohydrologic Synopsis, 1989, CNA refers to Comisión Nac



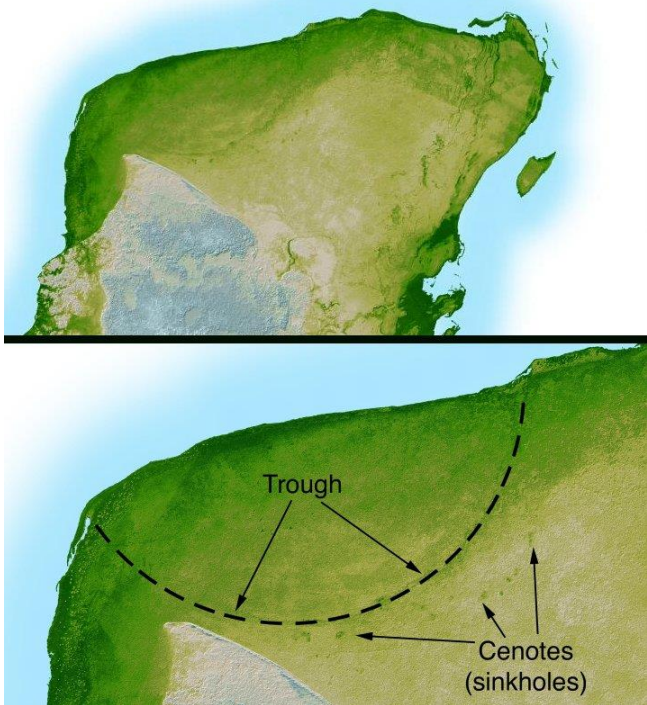
Ramos, E.L. (1975). Geological Summary of the Yucatan Peninsula. In: Nairn, A.E.M., Stehli, F.G. (eds): The Gulf of Mexico and the Caribbean. Springer, Boston, MA. [https://doi.org/10.1007/978-1-4684-8535-6\\_7](https://doi.org/10.1007/978-1-4684-8535-6_7)



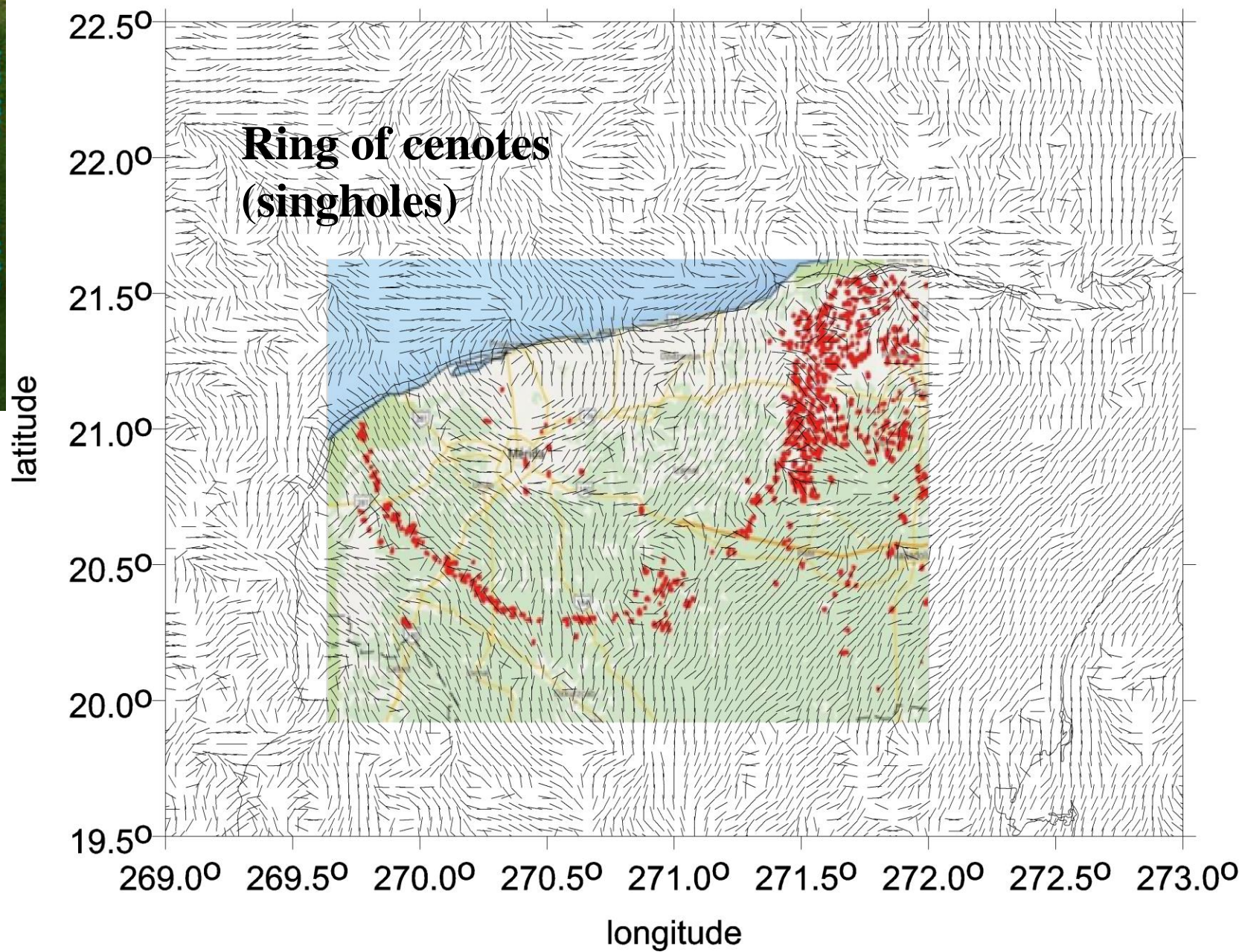
# Chicxulub ETOPO 1 3D topography (sunshine from South)





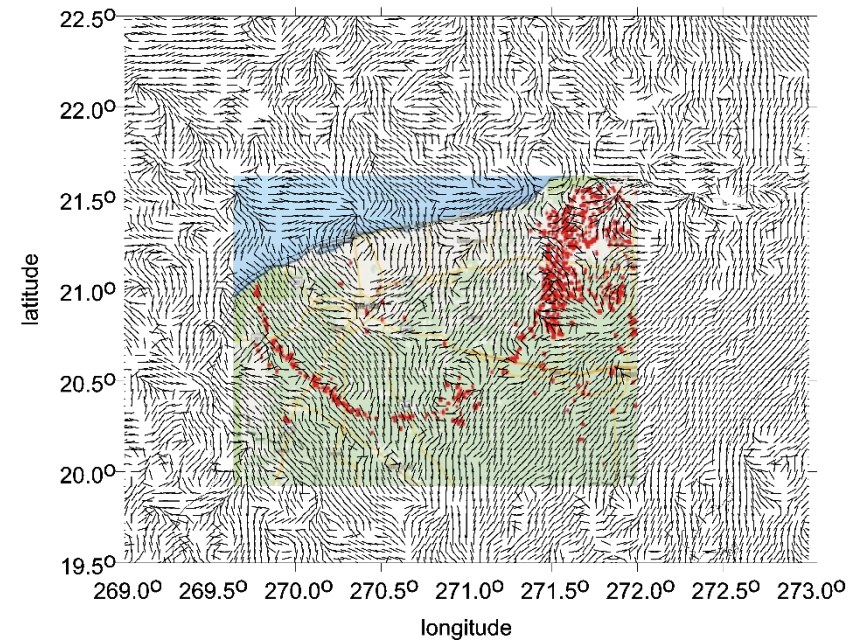


Eigen-6C4 - Chicxulub - cenotes + Theta for RI < 0.9

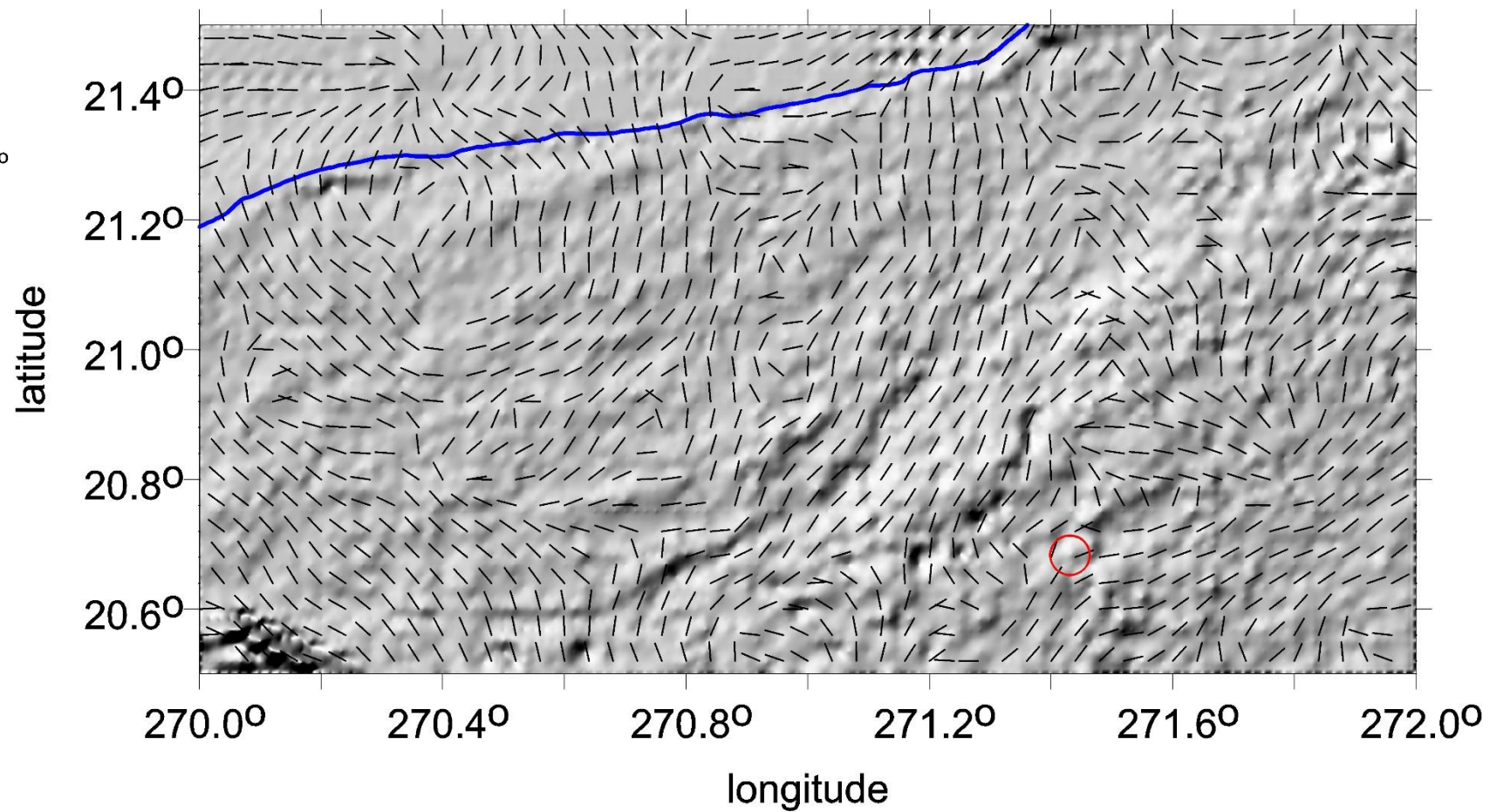




Eigen-6C4 - Chicxculub - cenotes + Theta for RI < 0.9



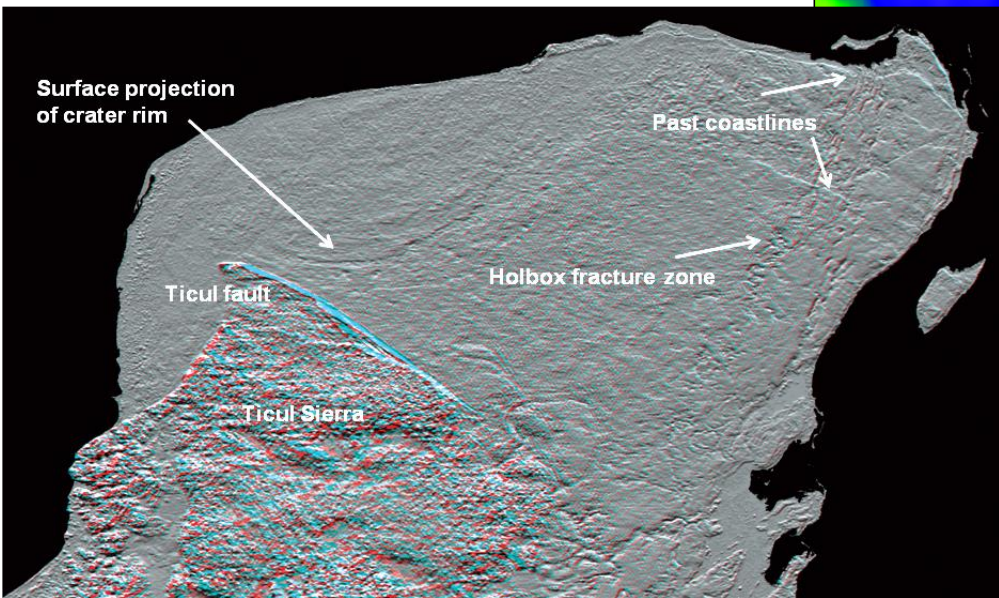
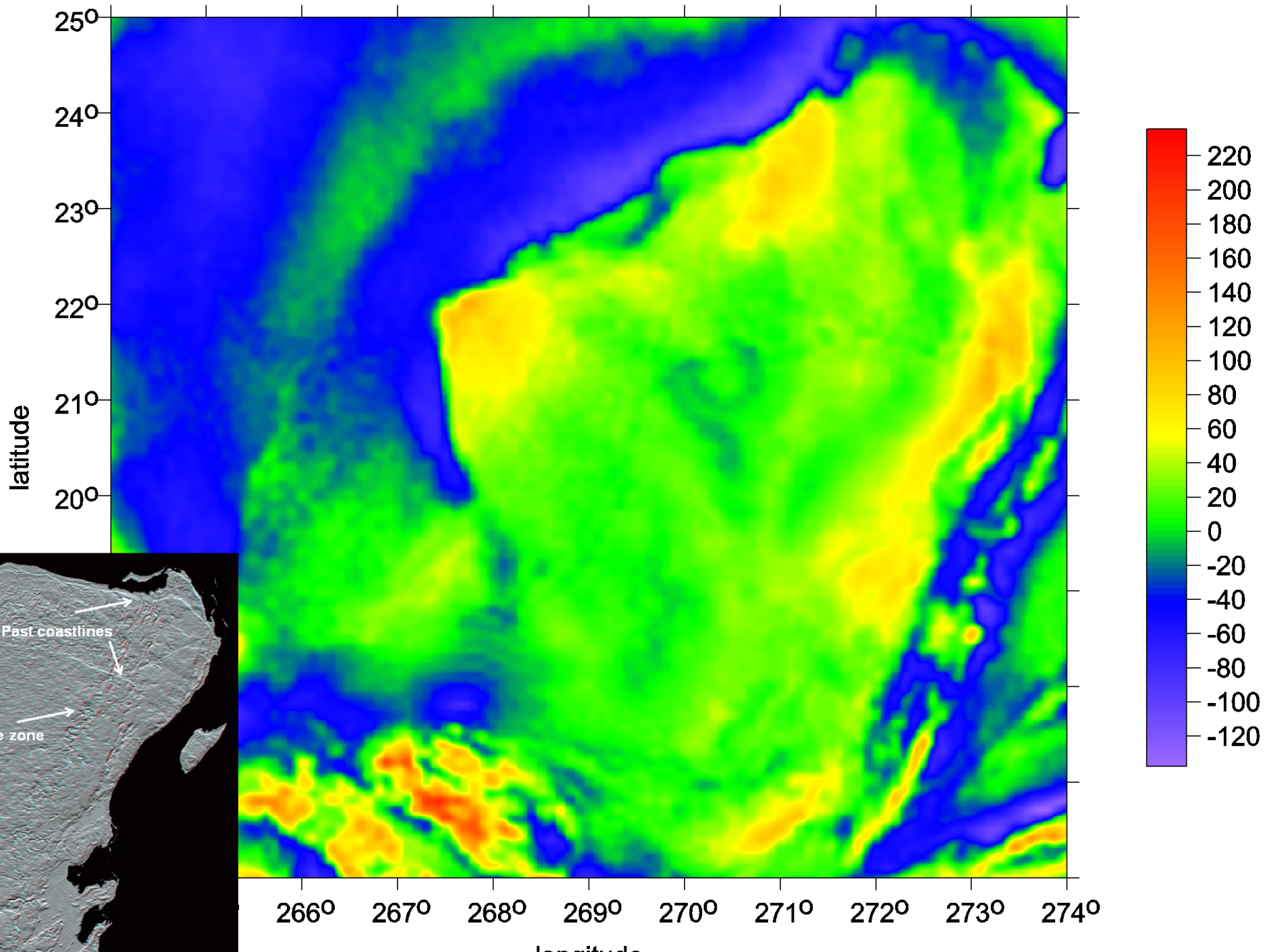
Eigen 6C4 - Chicxculub - topo + theta for RI < 0.9





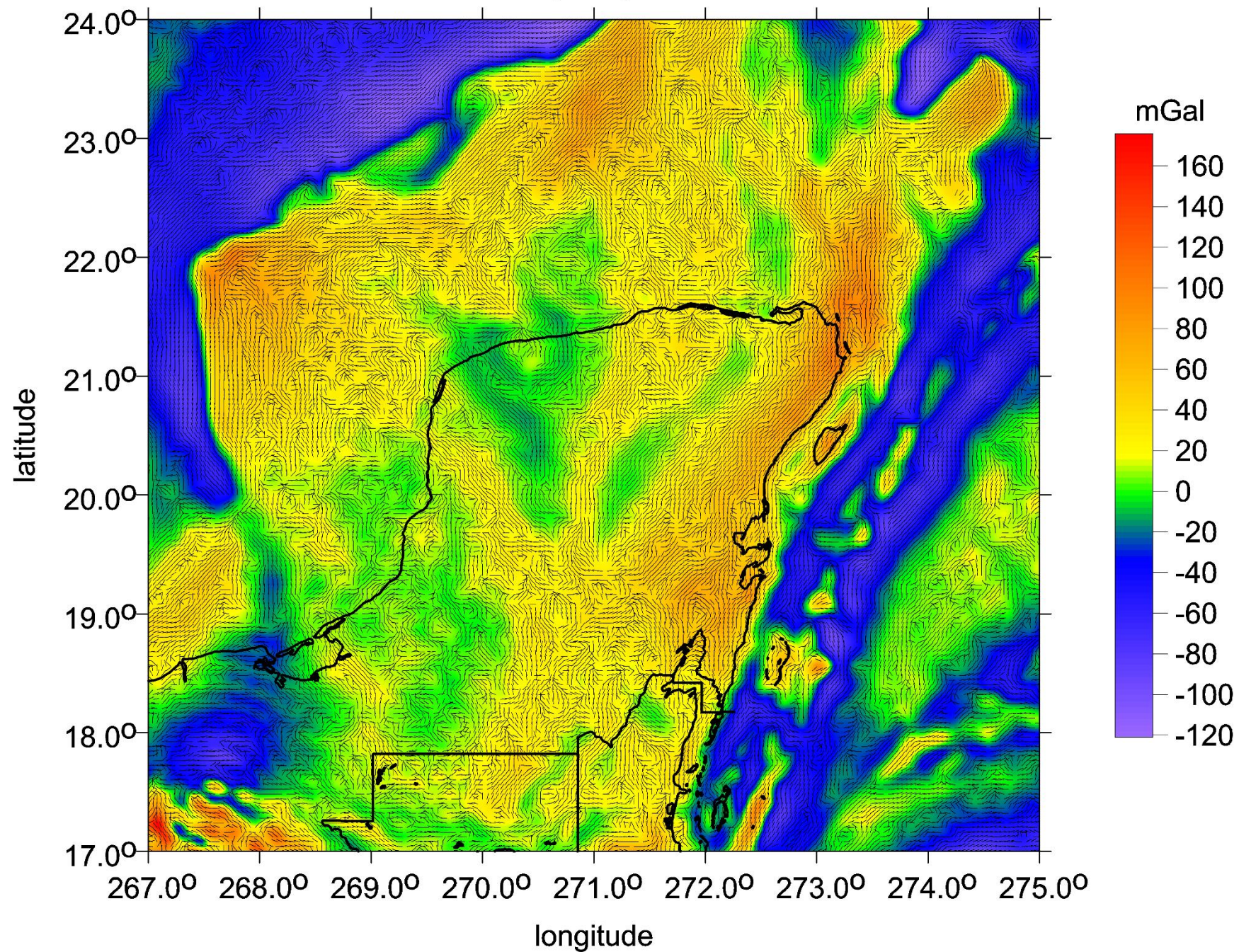
# Chicxulub Yucatan

model EIGEN6C4 series  
of the gravity aspects

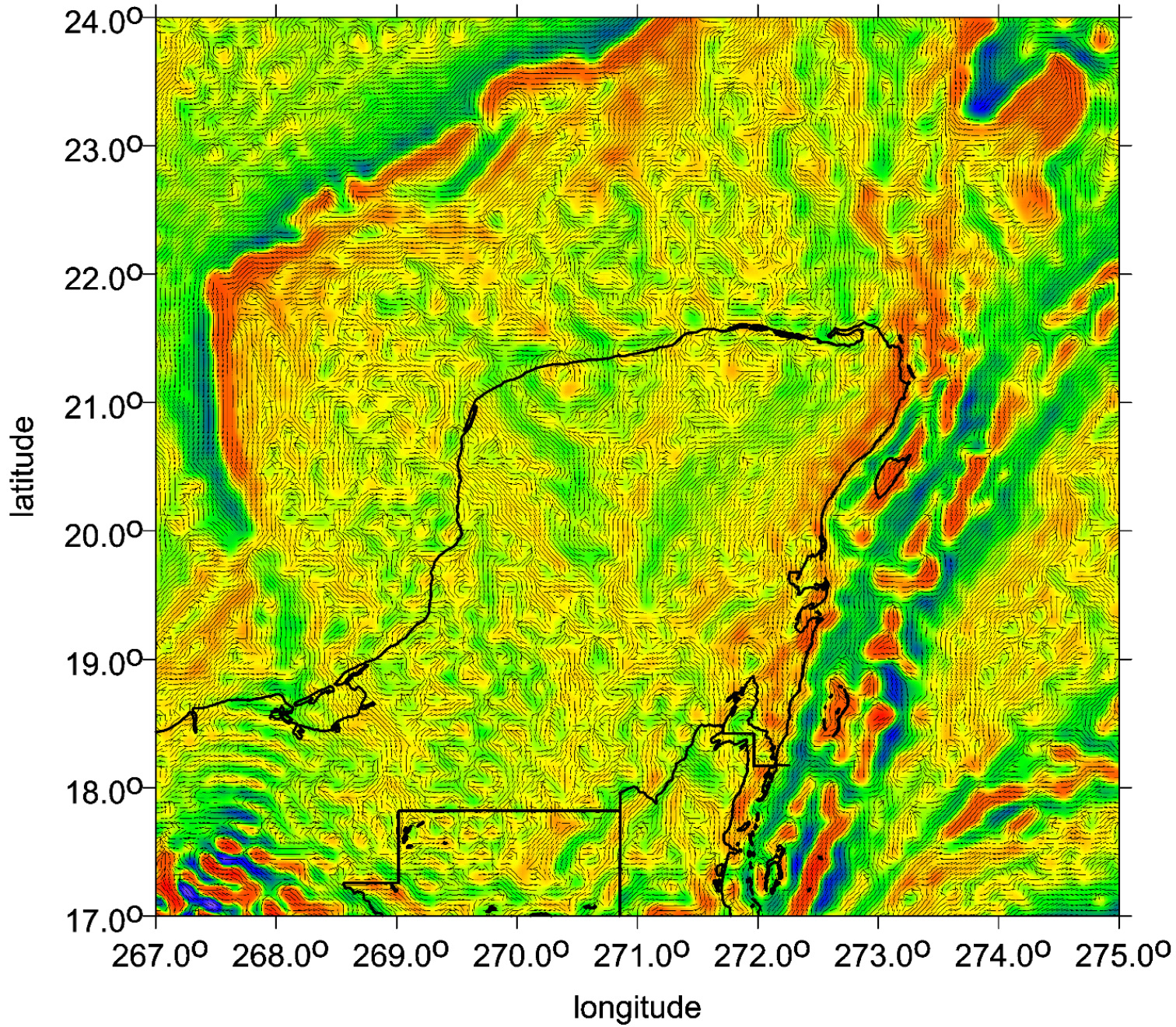




Eigen-6C4 - Chicxculub - delta g + Theta for RI < 0.9  
(4 km)







E  
mGal

200  
150  
100  
50  
0  
-50  
-100  
-150  
-200

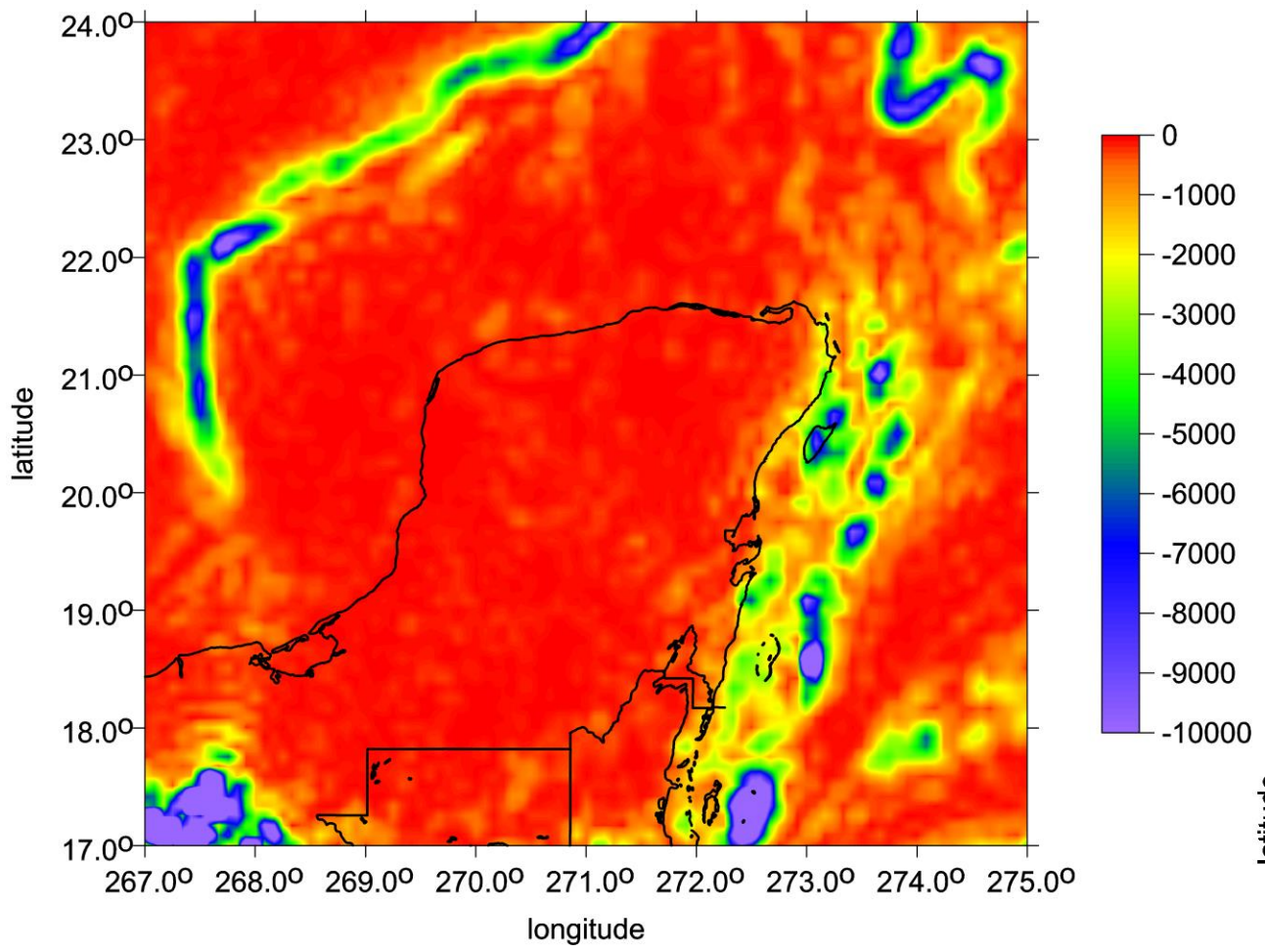
**Chicxulub,  
Yucatan  
Mexico**

**Strike angles  $\theta$  and  $T_{zz}$**

**Strike angles [deg],  $I < 0.9$ , with  $T_{zz}$  [E]**

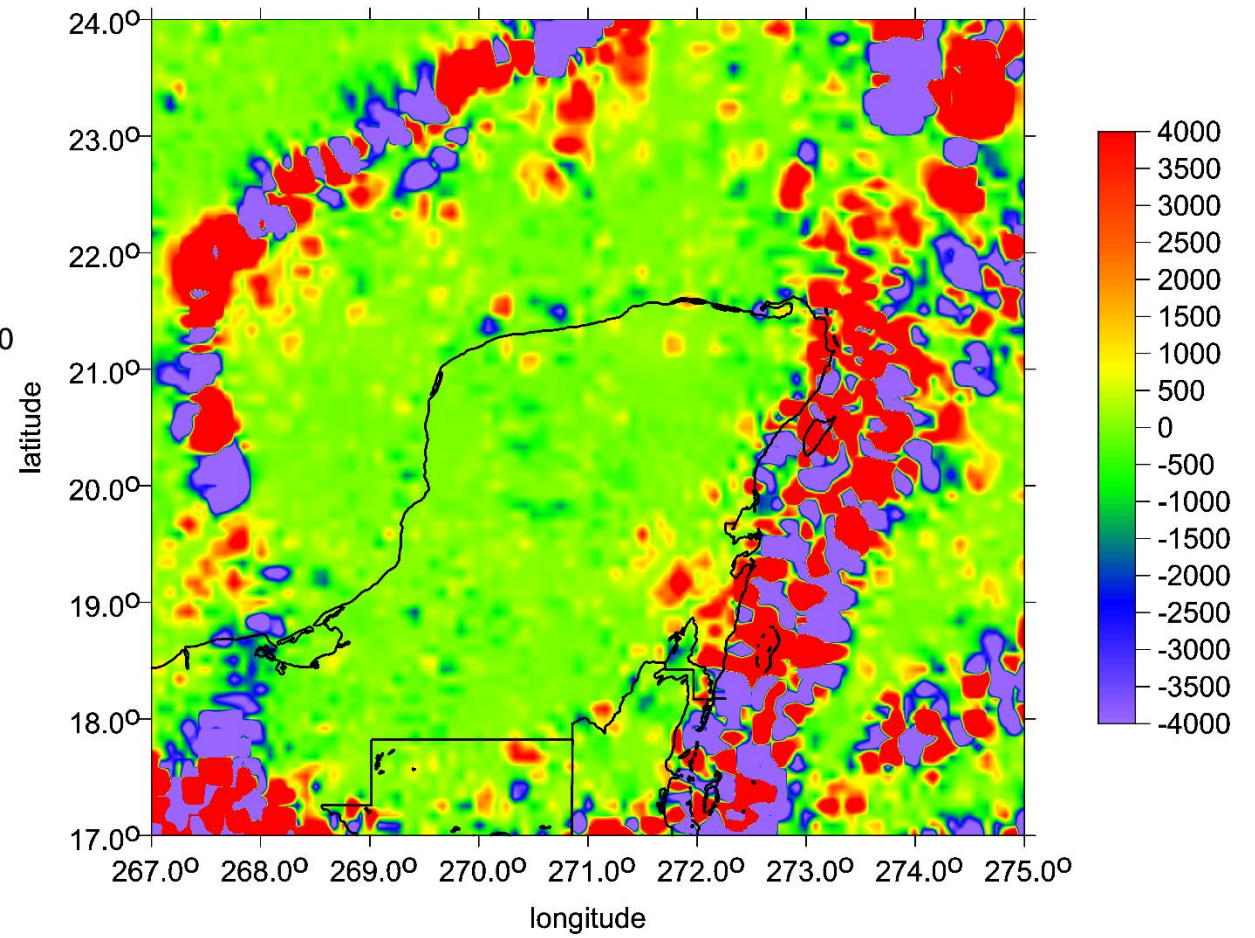


Eigen-6C4 - Chicxculub - RI2



# Chicxulub, Yucatan Mexico

Eigen-6C4 - Chicxculub - RI3

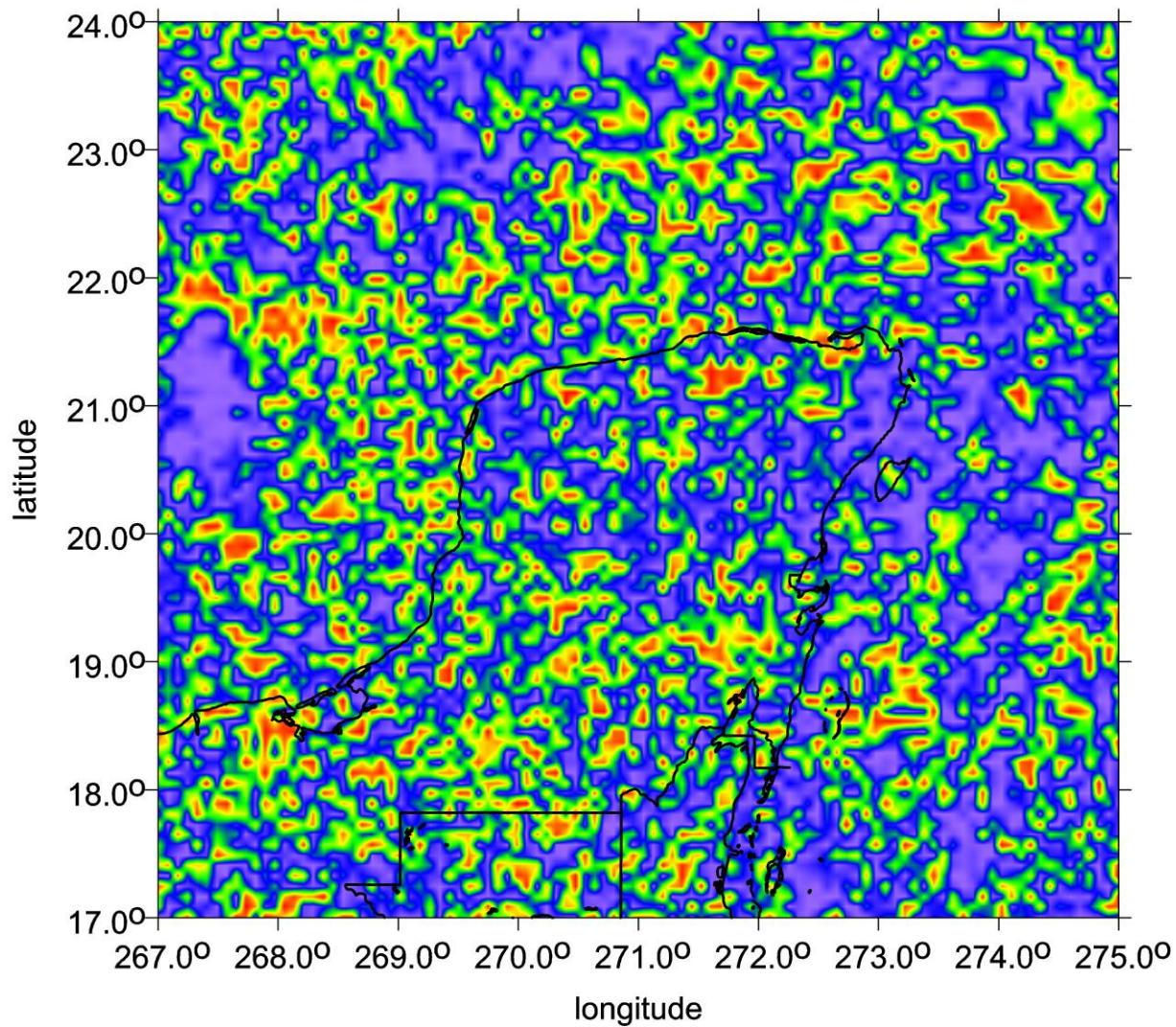




**Chicxulub,  
Yucatan  
Mexico**

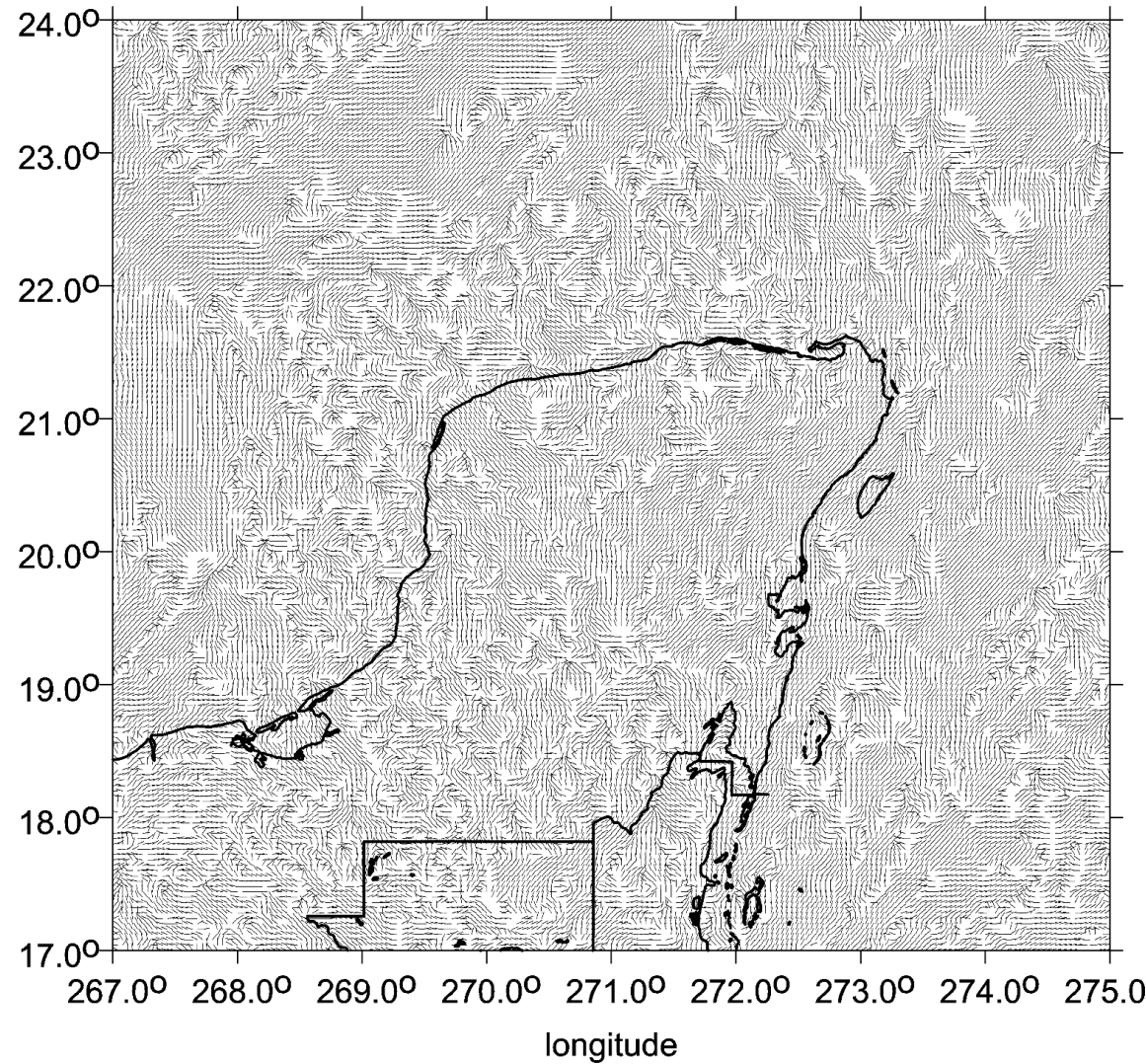
**Ratio  $I$  of the invariants**

Eigen-6C4 - Chicxculub - RI



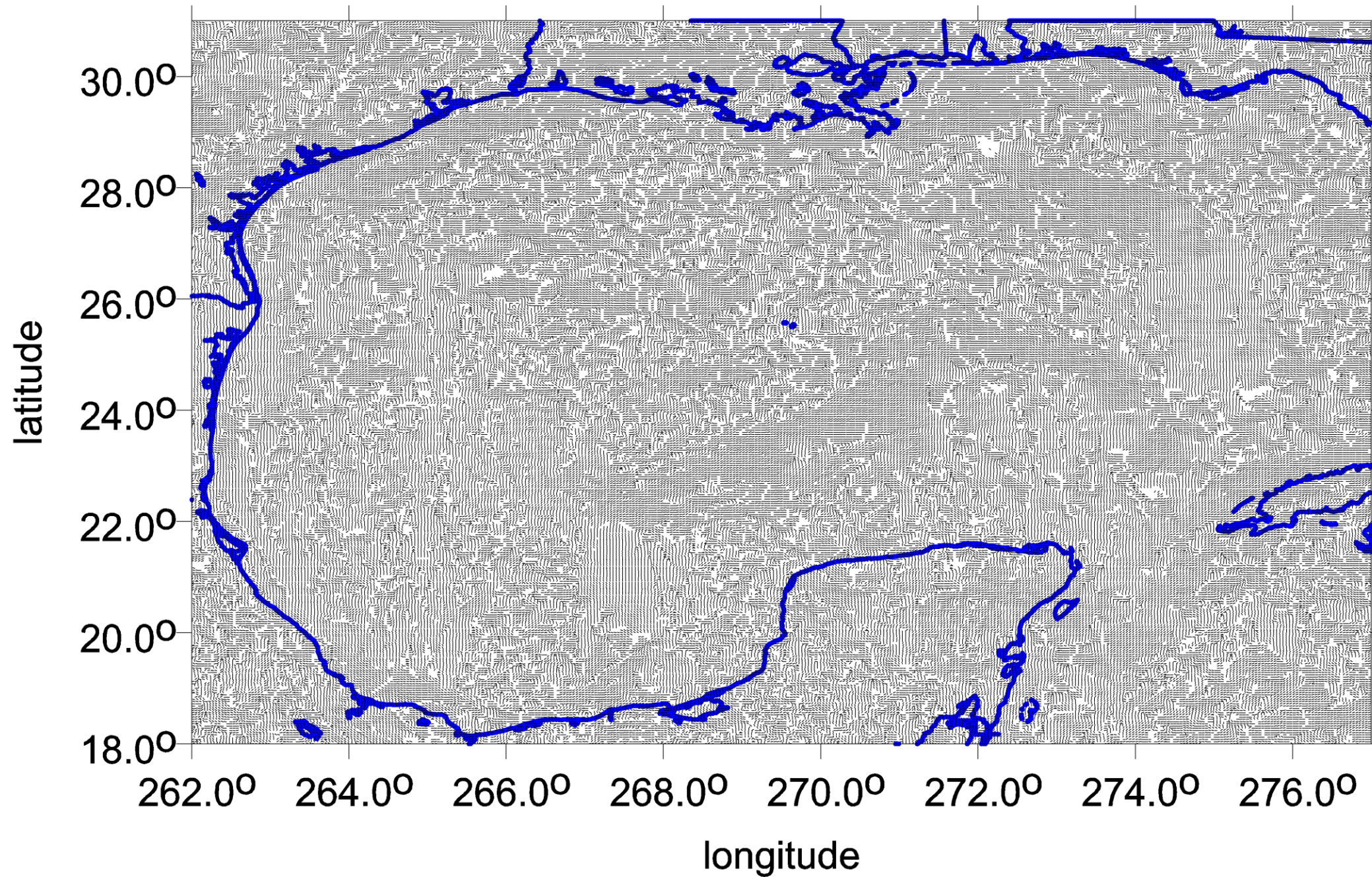
**Strike angles  $\theta$  [deg]**

Eigen-6C4 - Chicxculub - Theta for RI < 0.9  
(4 km)





Eigen-6C4 - Mexican Gulf Theta for RI < 0.9





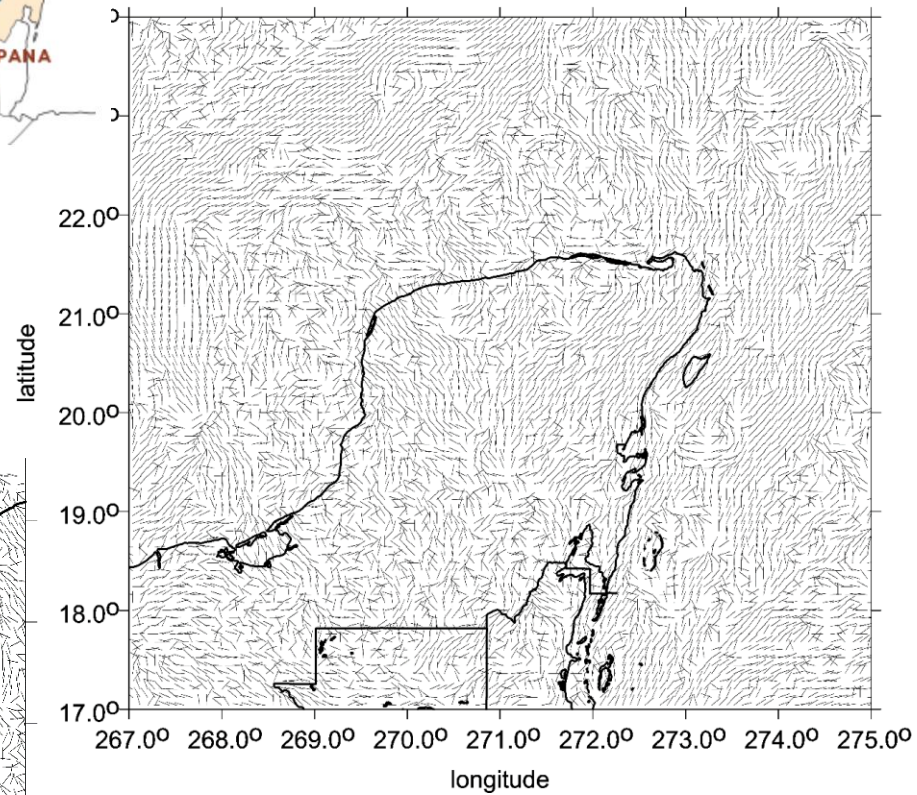


Source: *Southwest Economy*, Federal Reserve Bank of Dallas, Second Quarter 2014

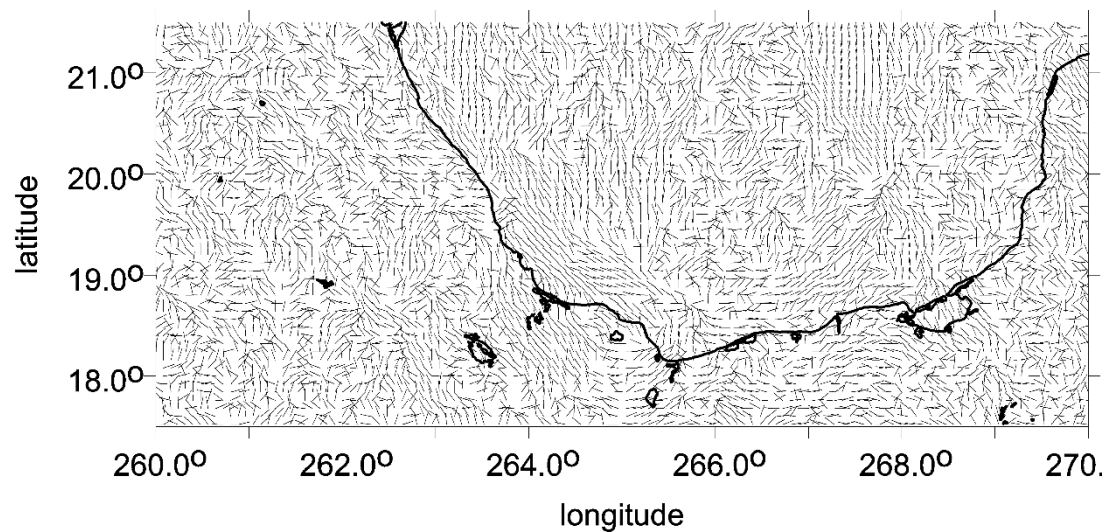
# Mexico

## Villahermosa, Veracruz

Eigen-6C4 - Chicxculub - Theta for RI < 0.9



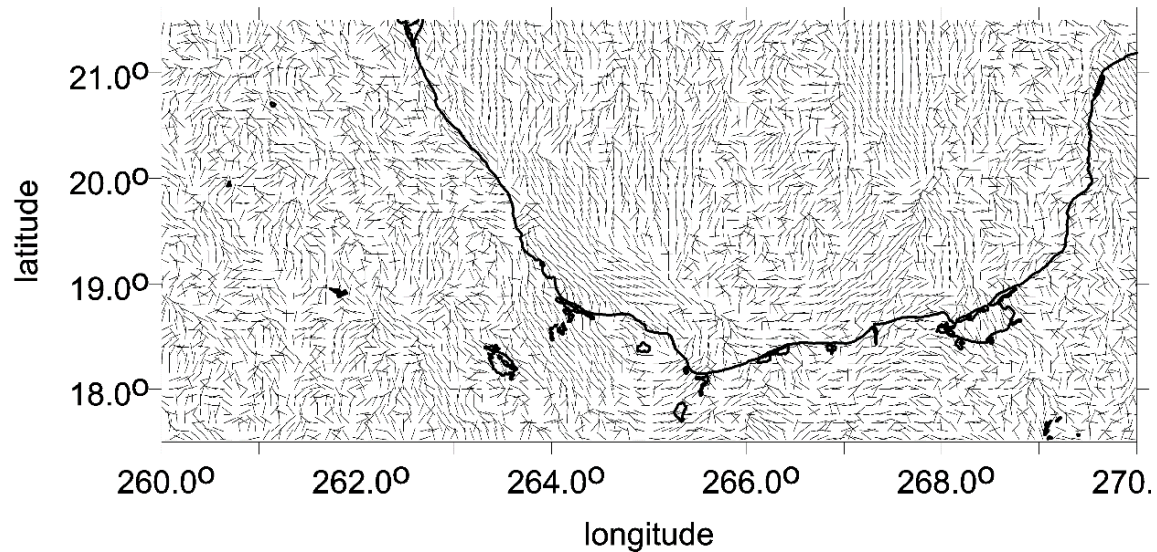
Eigen-6C4 Villahermosa - Theta for RI < 0.9



**strike angles**



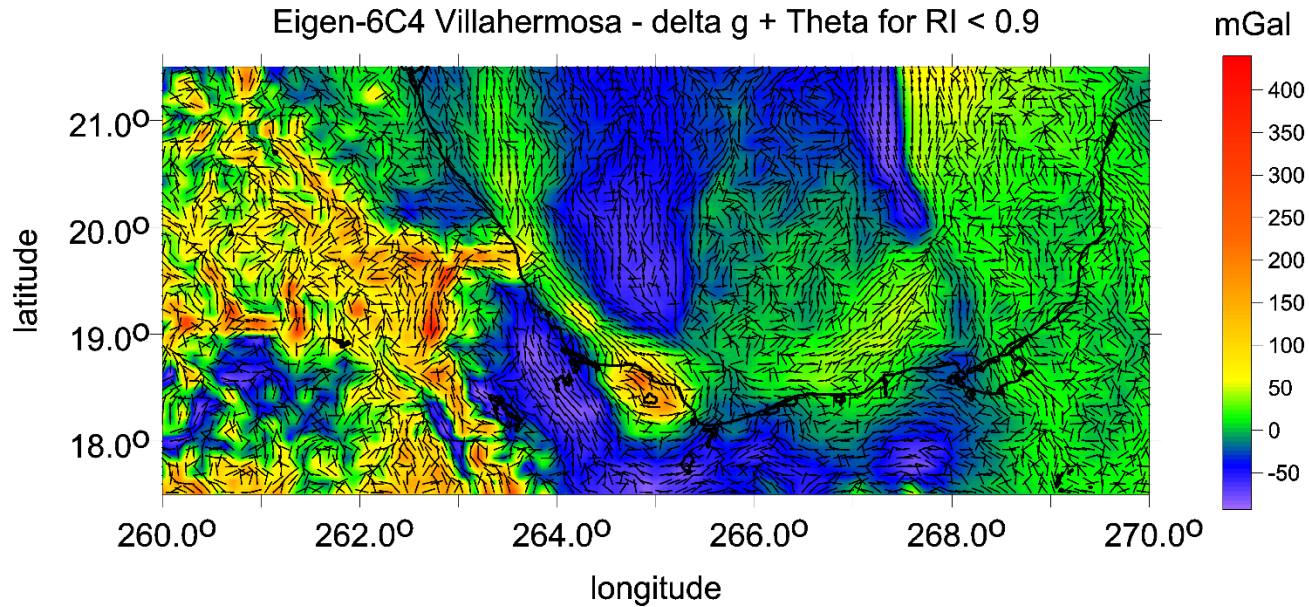
Eigen-6C4 Villahermosa - Theta for RI < 0.9



## Olmecs locality

Strike angles  
and  
Strike angles together with  $\Delta g$

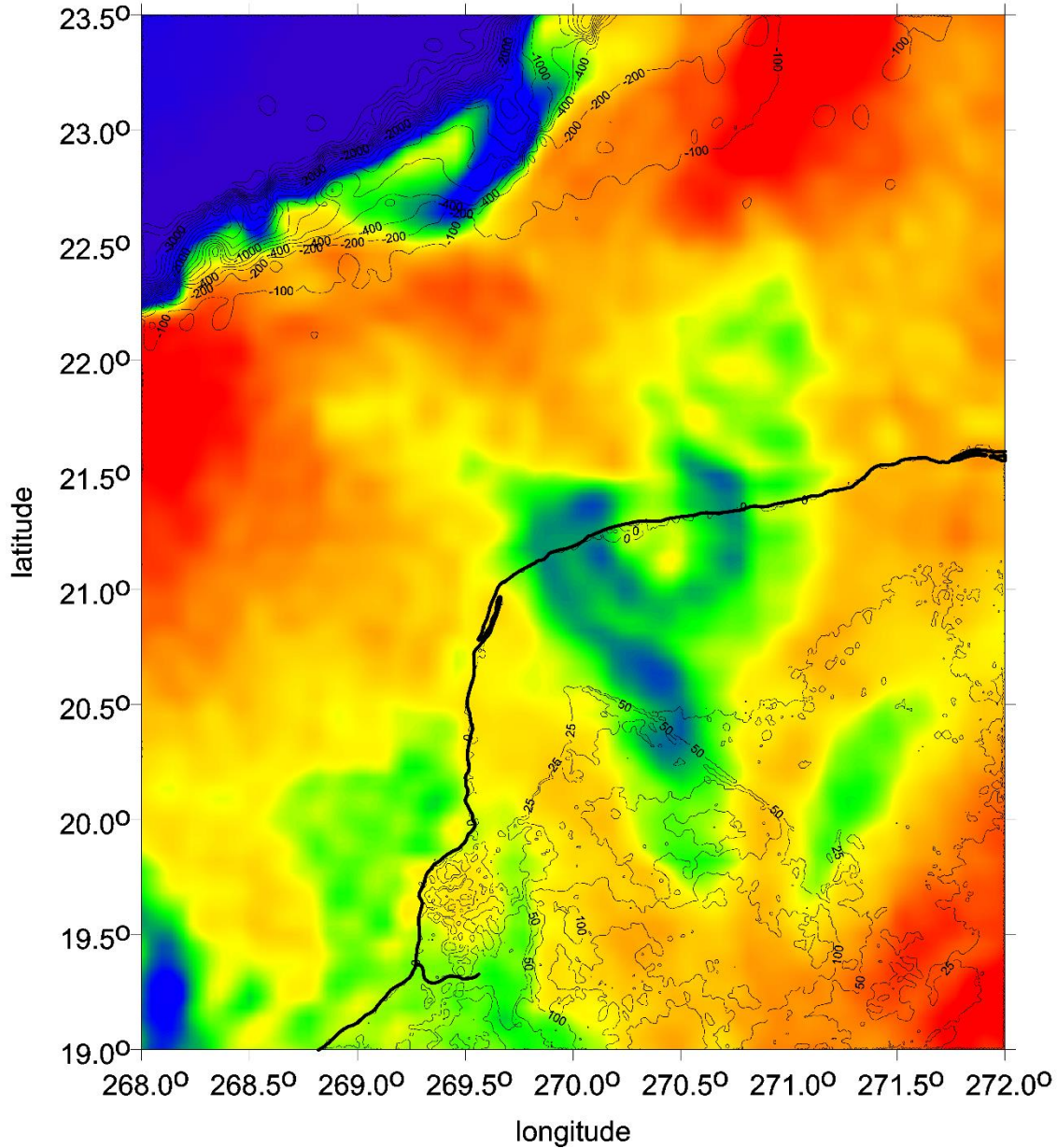
Eigen-6C4 Villahermosa - delta g + Theta for RI < 0.9



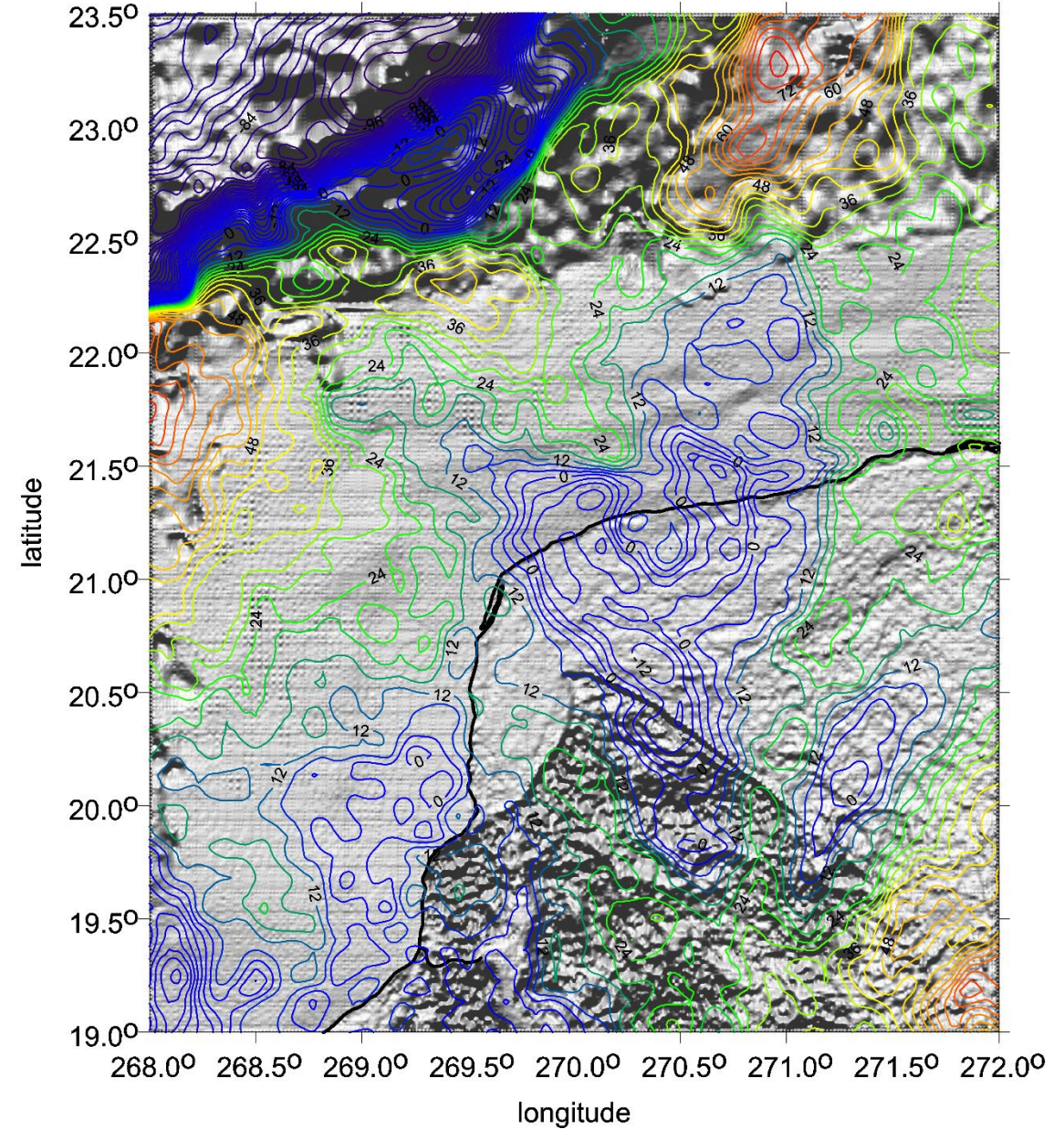


# Chicxulub, traditional and alternative view on gravity anomalies Yucatan Mexico

Eigen 6C4 - Chicxulub - topo + delta g

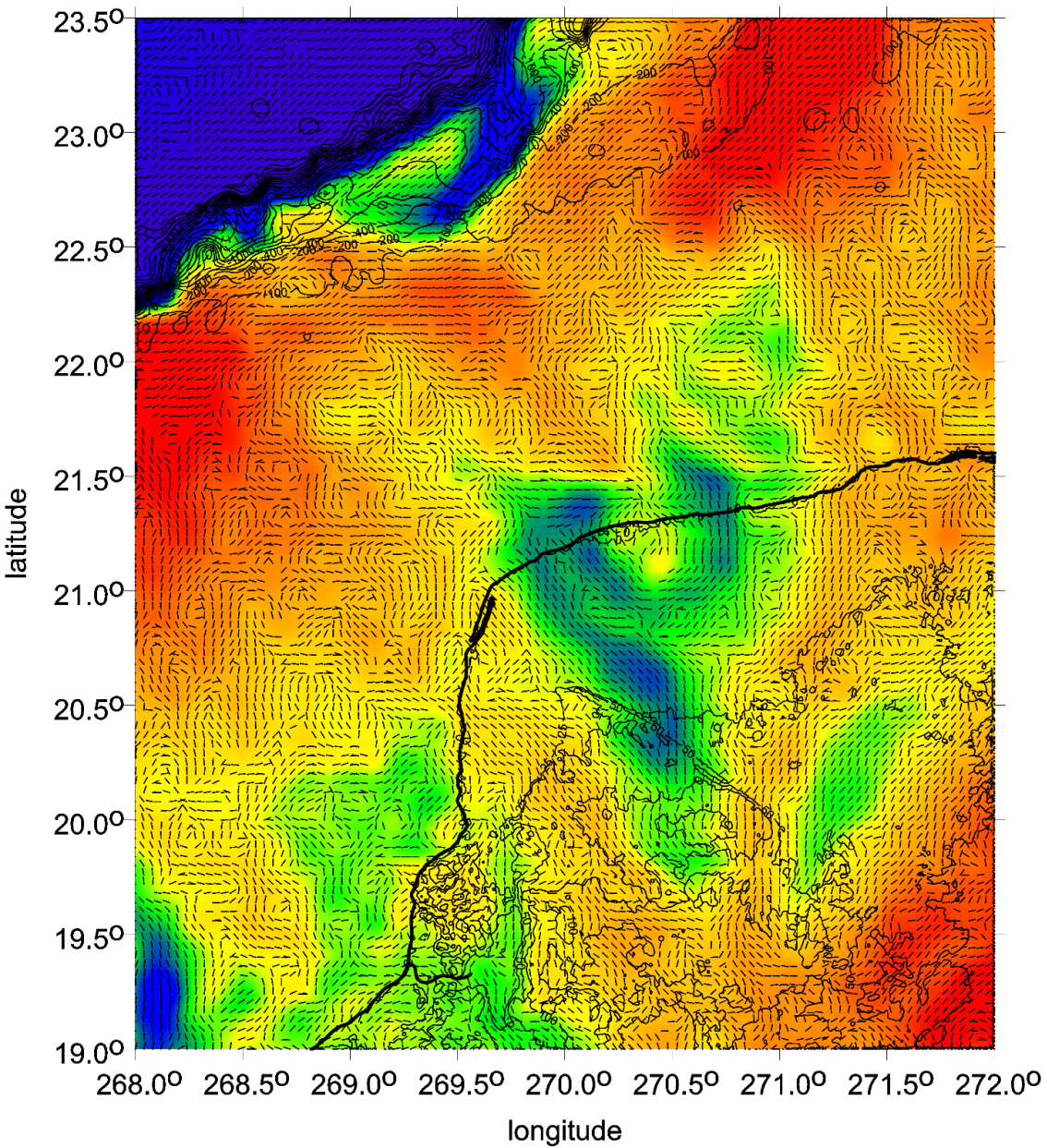


Eigen 6C4 - Chicxulub - topo + contours delta g

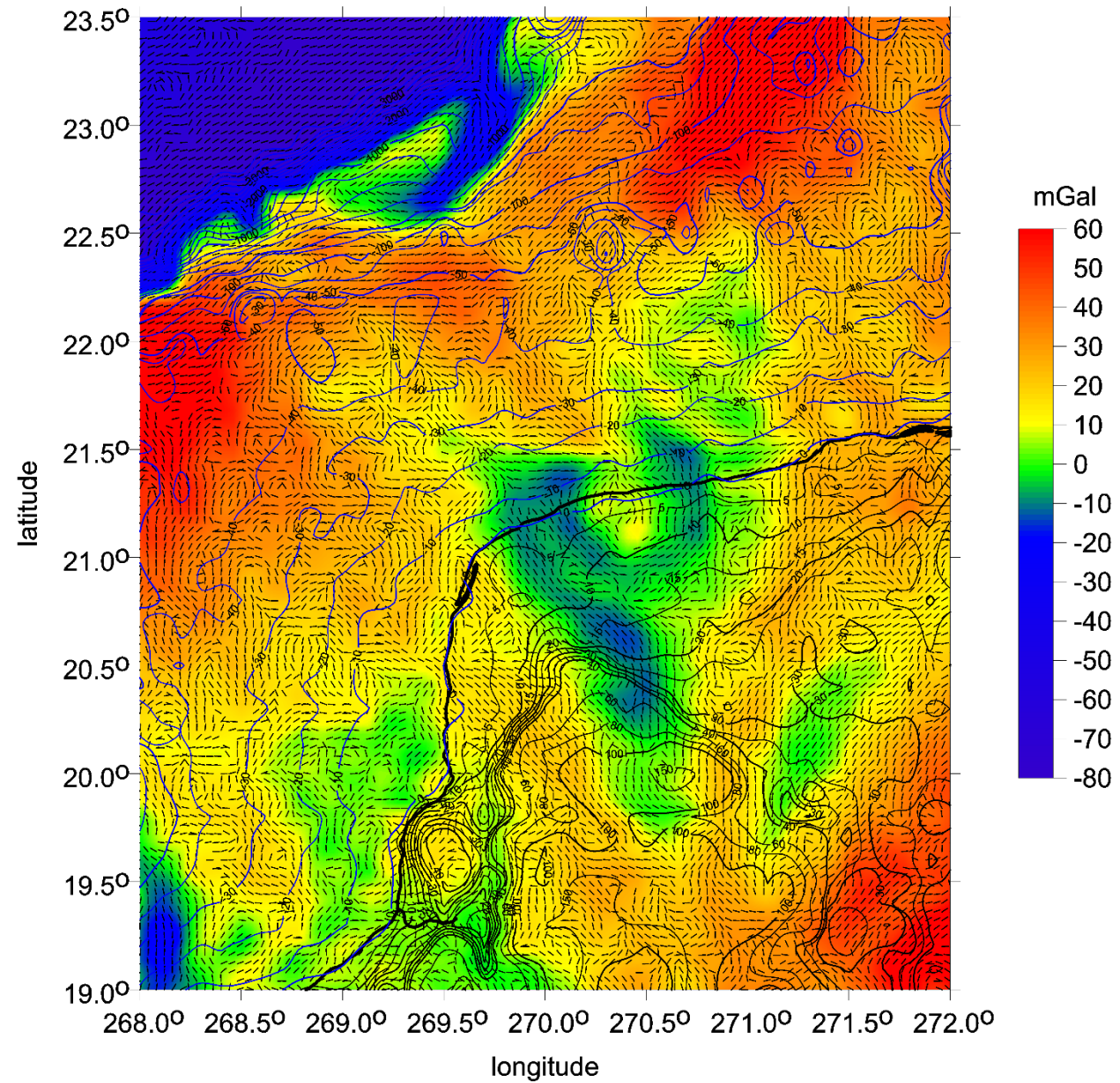




Eigen 6C4 - Chicxculub - topo + delta g + theta for RI < 0.9



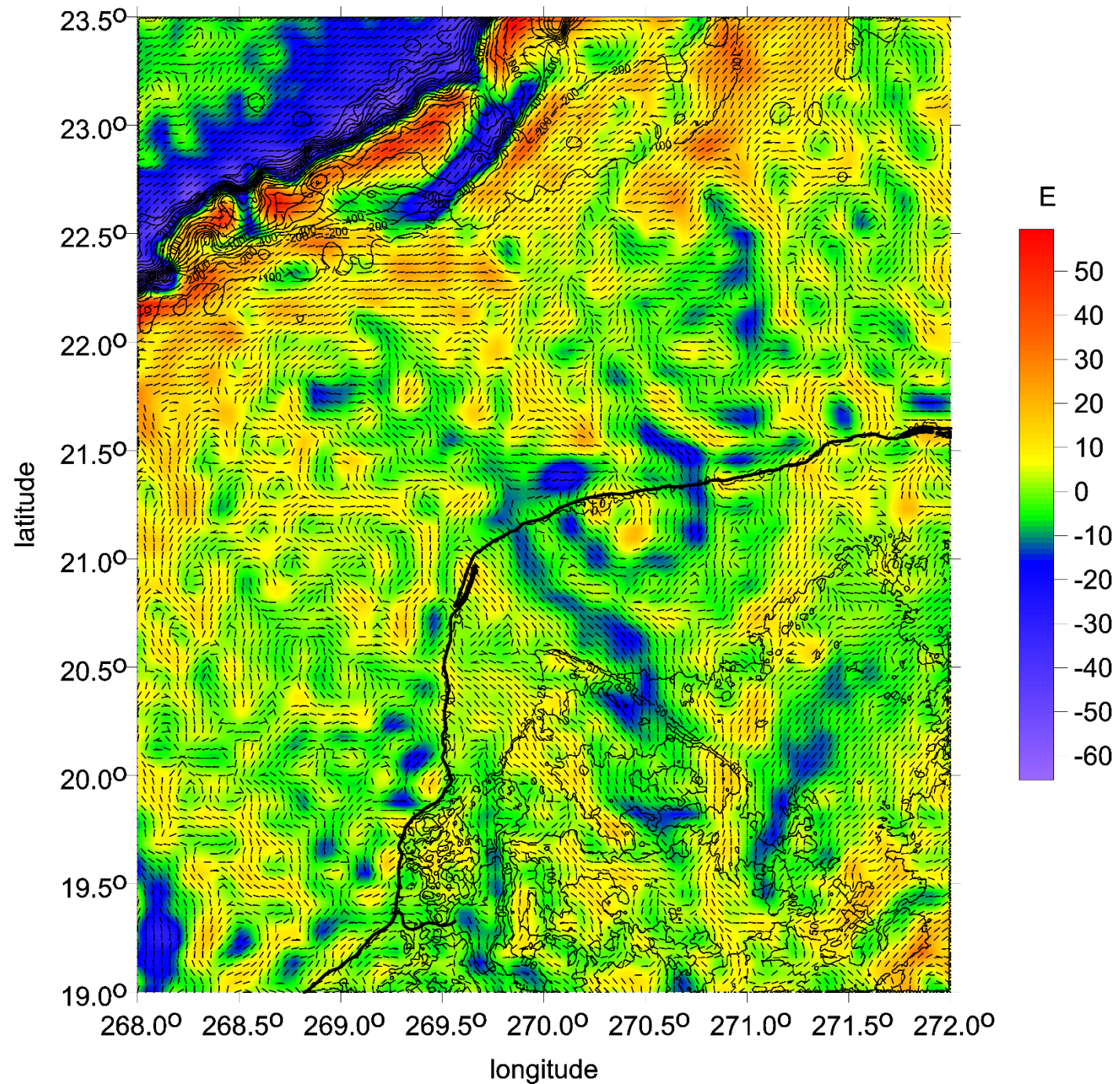
Eigen 6C4 - Chicxculub - topo + delta g + theta for RI < 0.9



**Gravity anomalies and strike angles, with 3D topography or contour lines for topography (ETOPO1)**

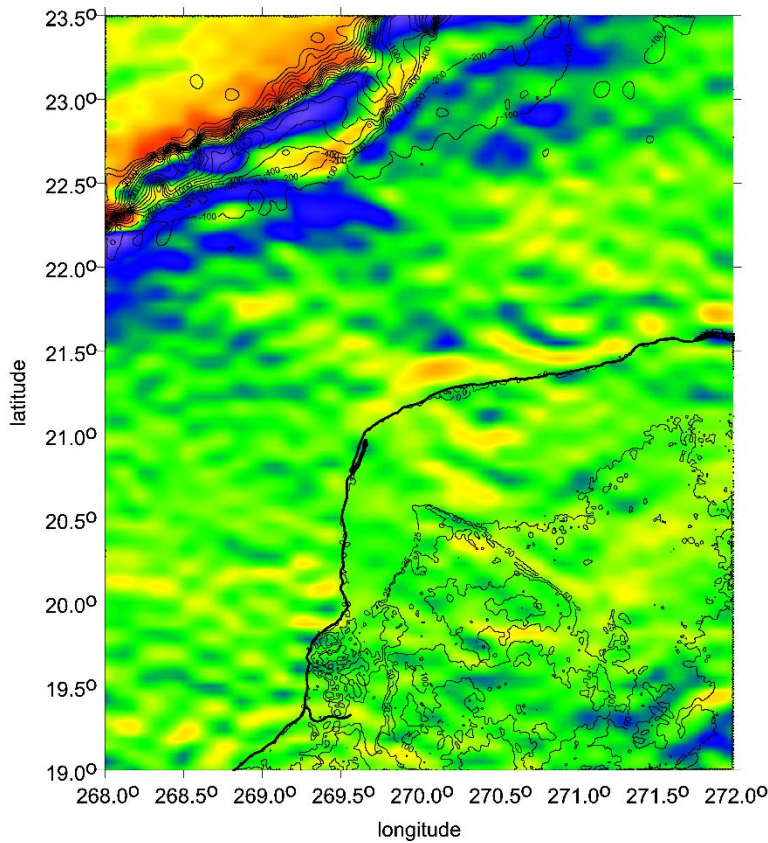


Eigen 6C4 - Chicxculub - topo + Tzz + theta for RI < 0.9

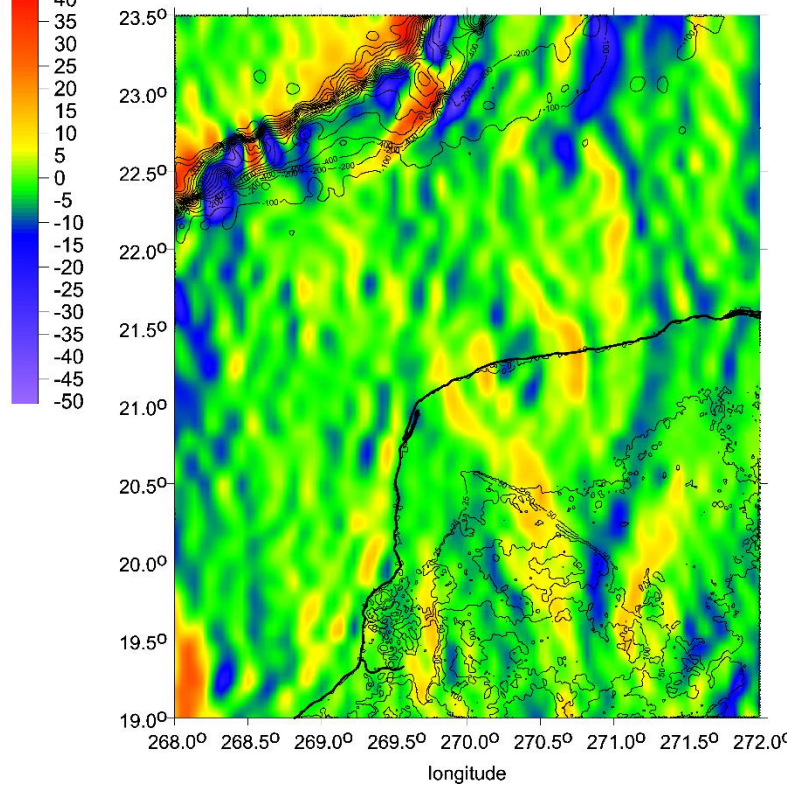




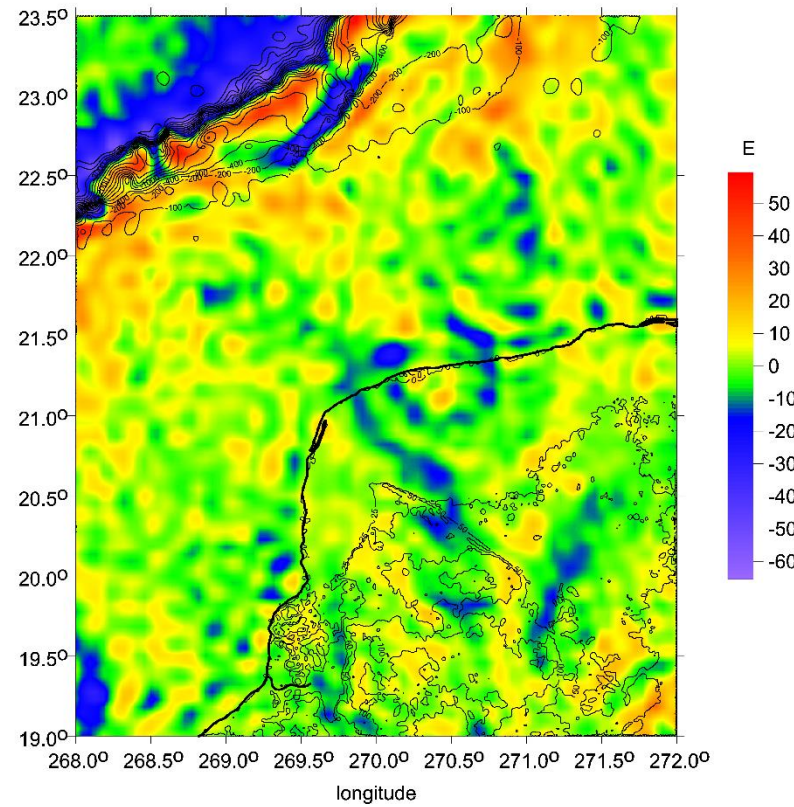
Eigen 6C4 - Chicxculub - topo + Txx



Eigen 6C4 - Chicxculub - topo + Tyy



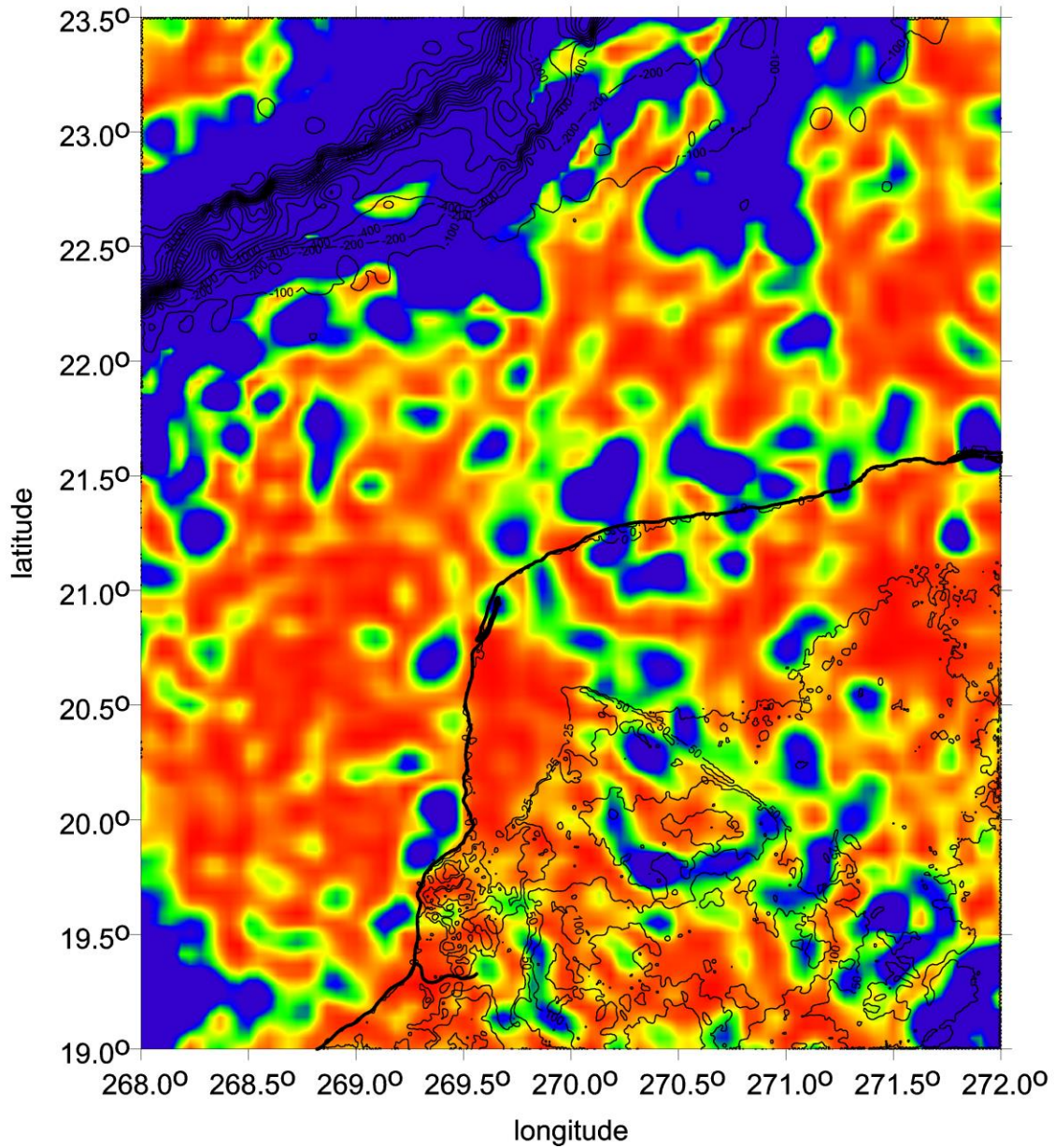
Eigen 6C4 - Chicxculub - topo + Tzz



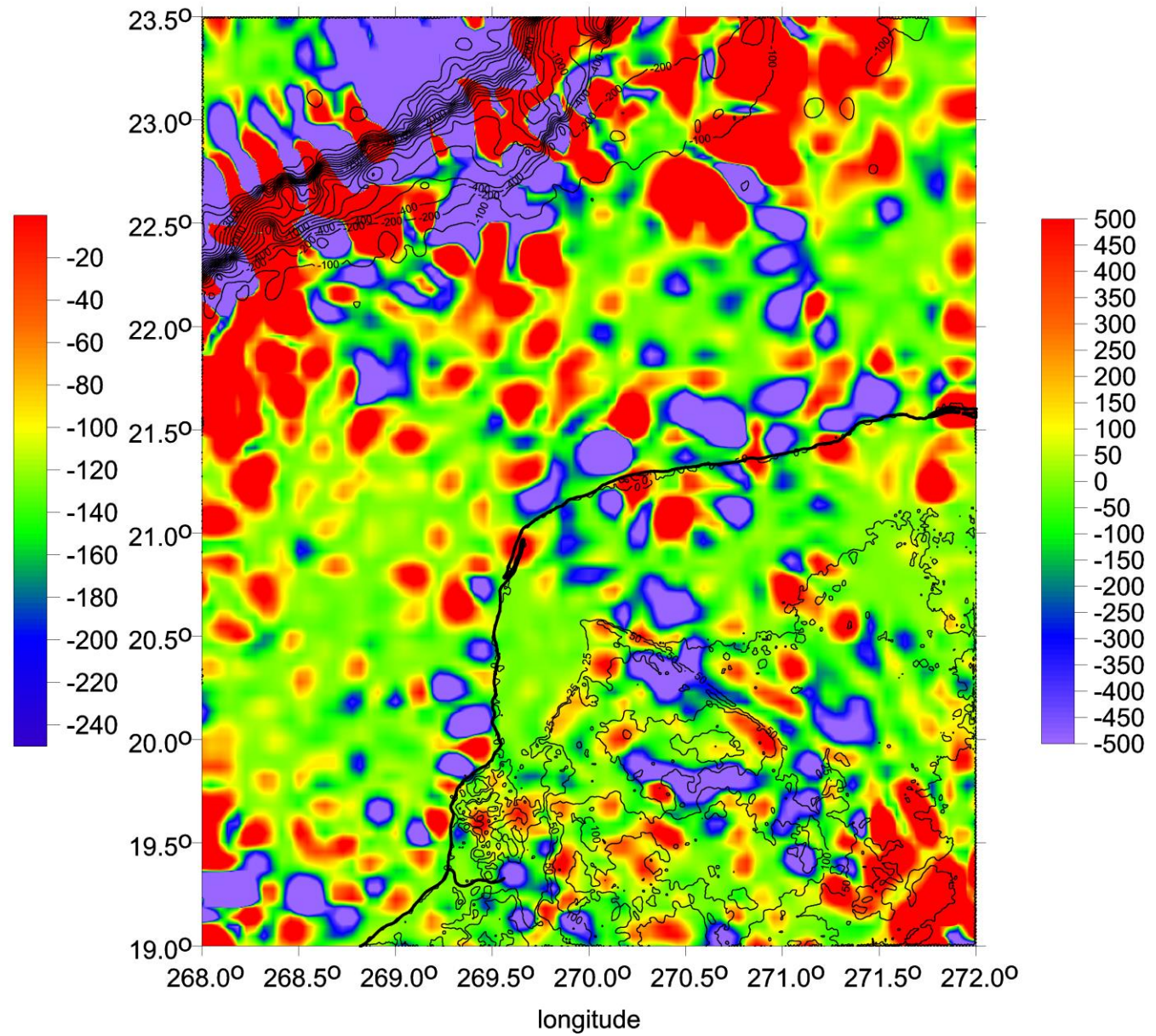
**Marussi tensor**  
the main diagonal  
xx, yy, zz components  
[E]



Eigen 6C4 - Chicxculub - topo + RI2

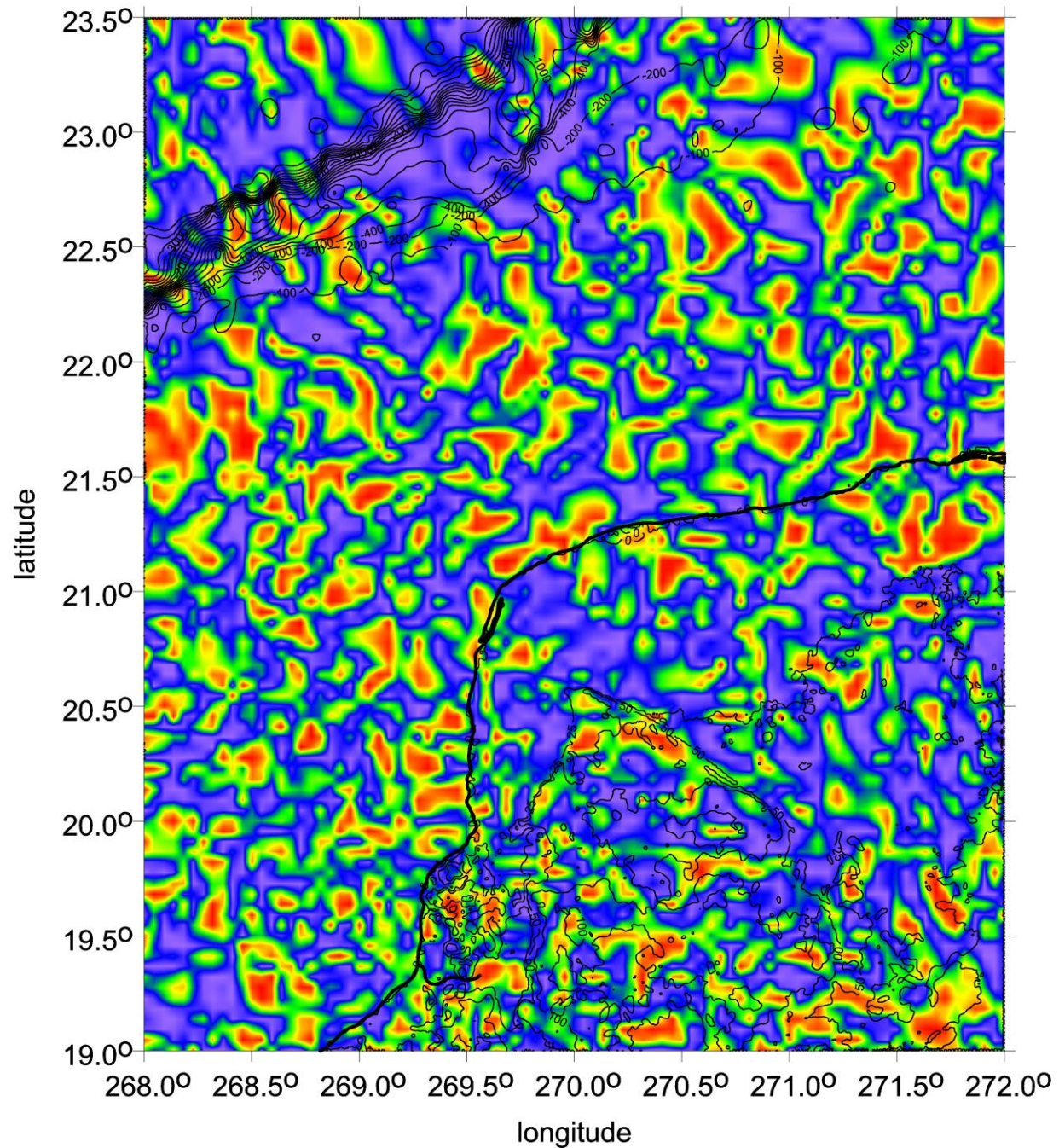


Eigen 6C4 - Chicxculub - topo + RI3

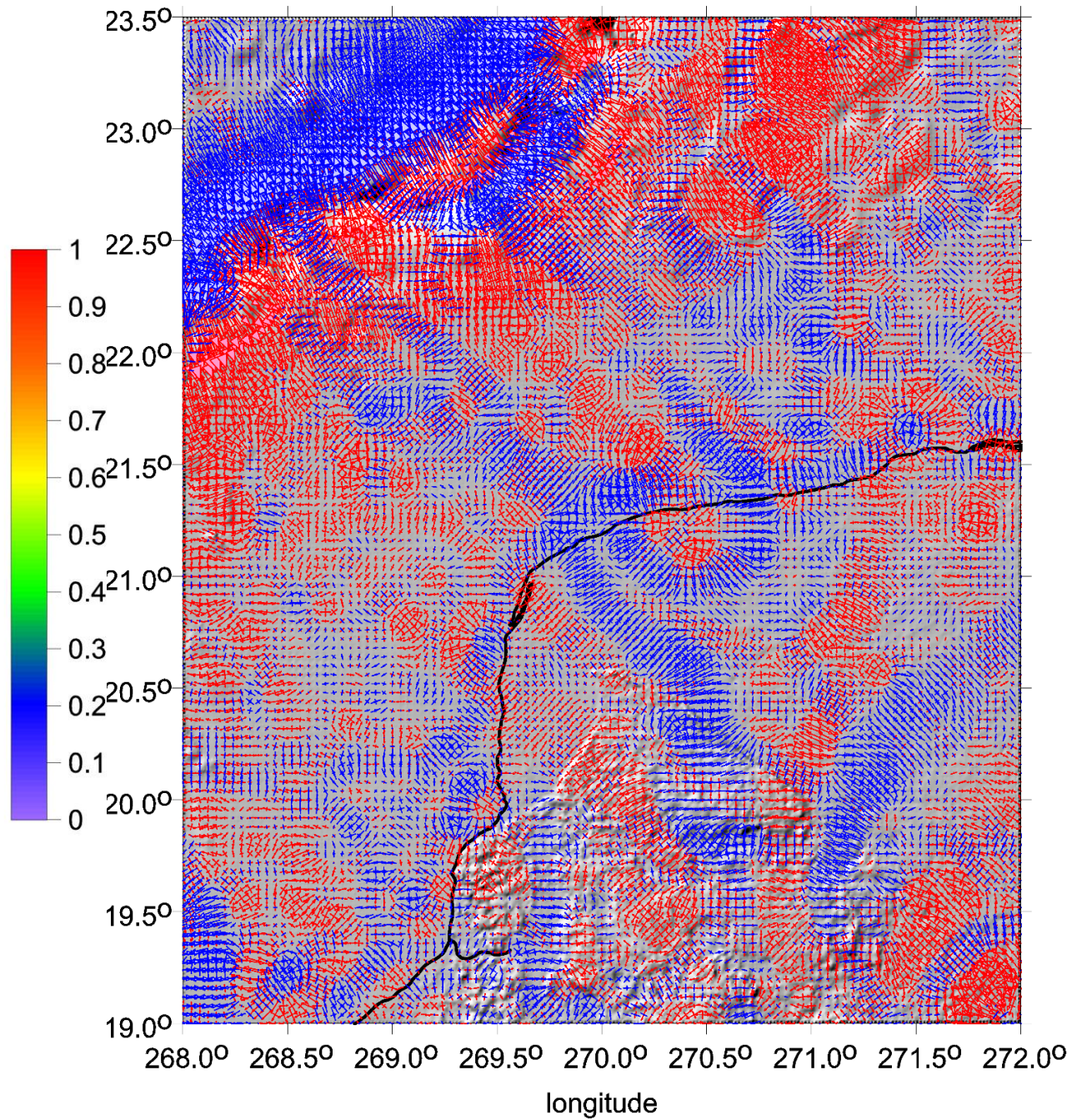




Eigen 6C4 - Chicxculub - topo + RI

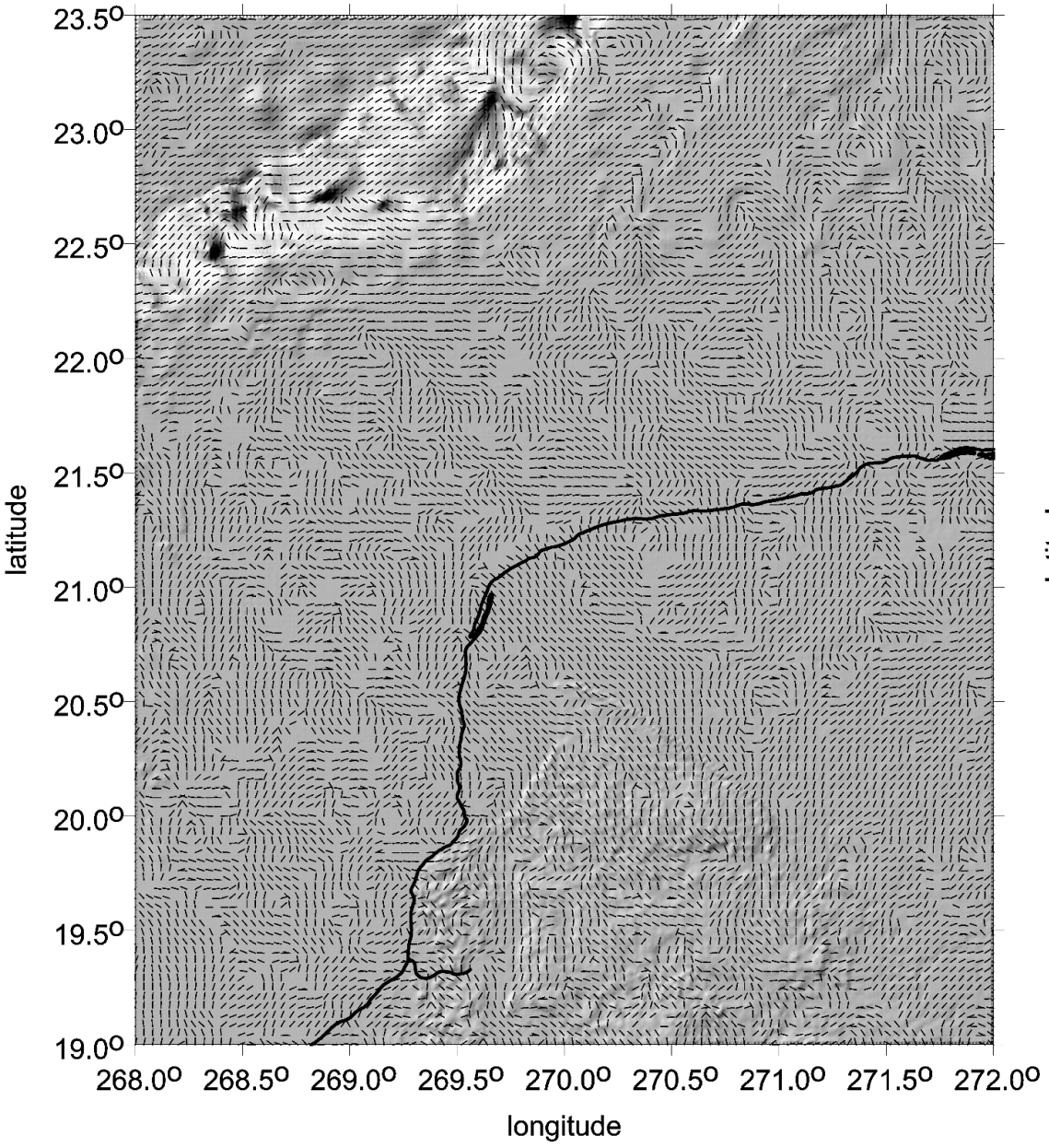


Eigen 6C4 - Chicxculub - topo + vd

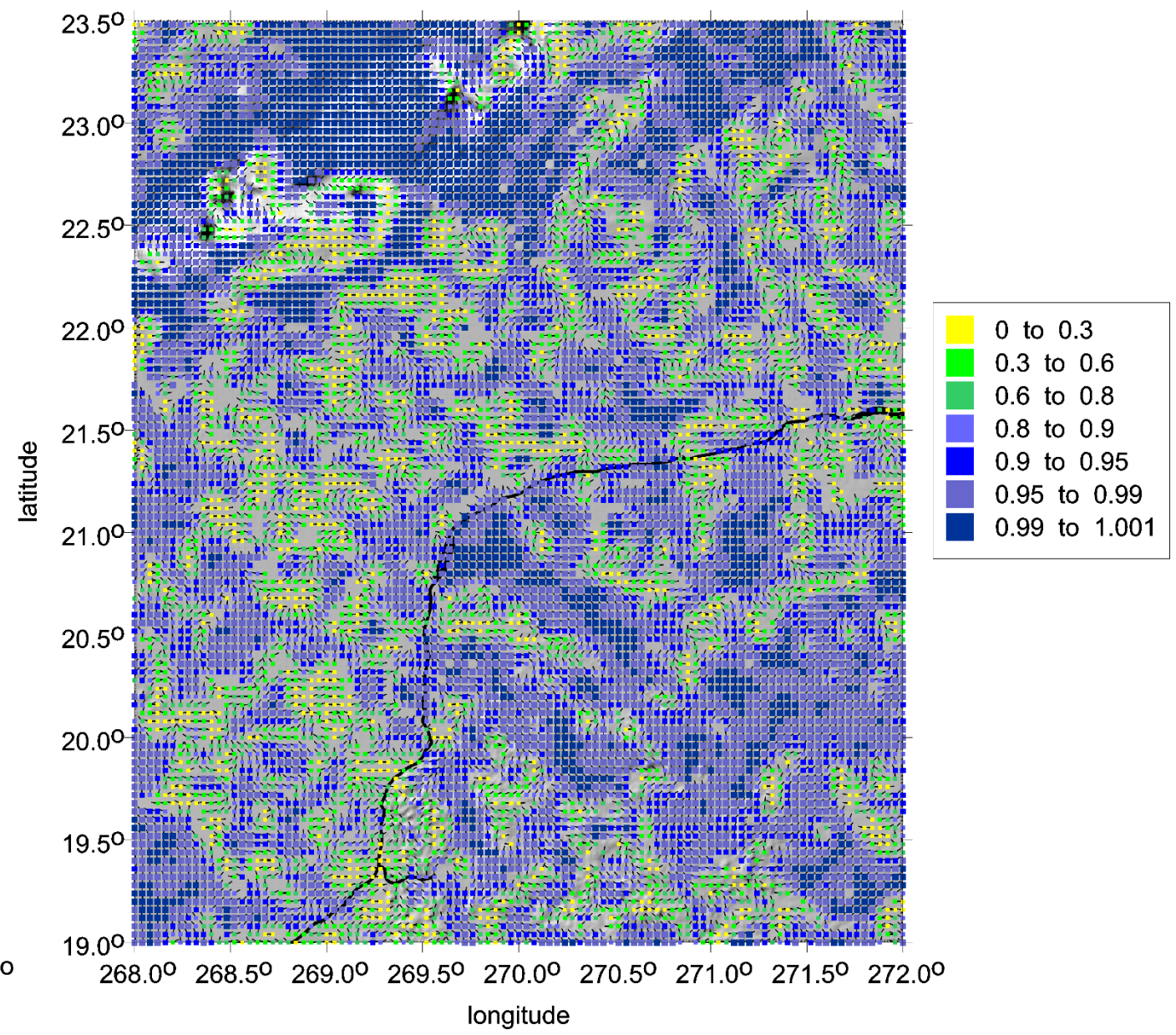




Eigen 6C4 - Chicxculub - topo + theta for RI < 0.9

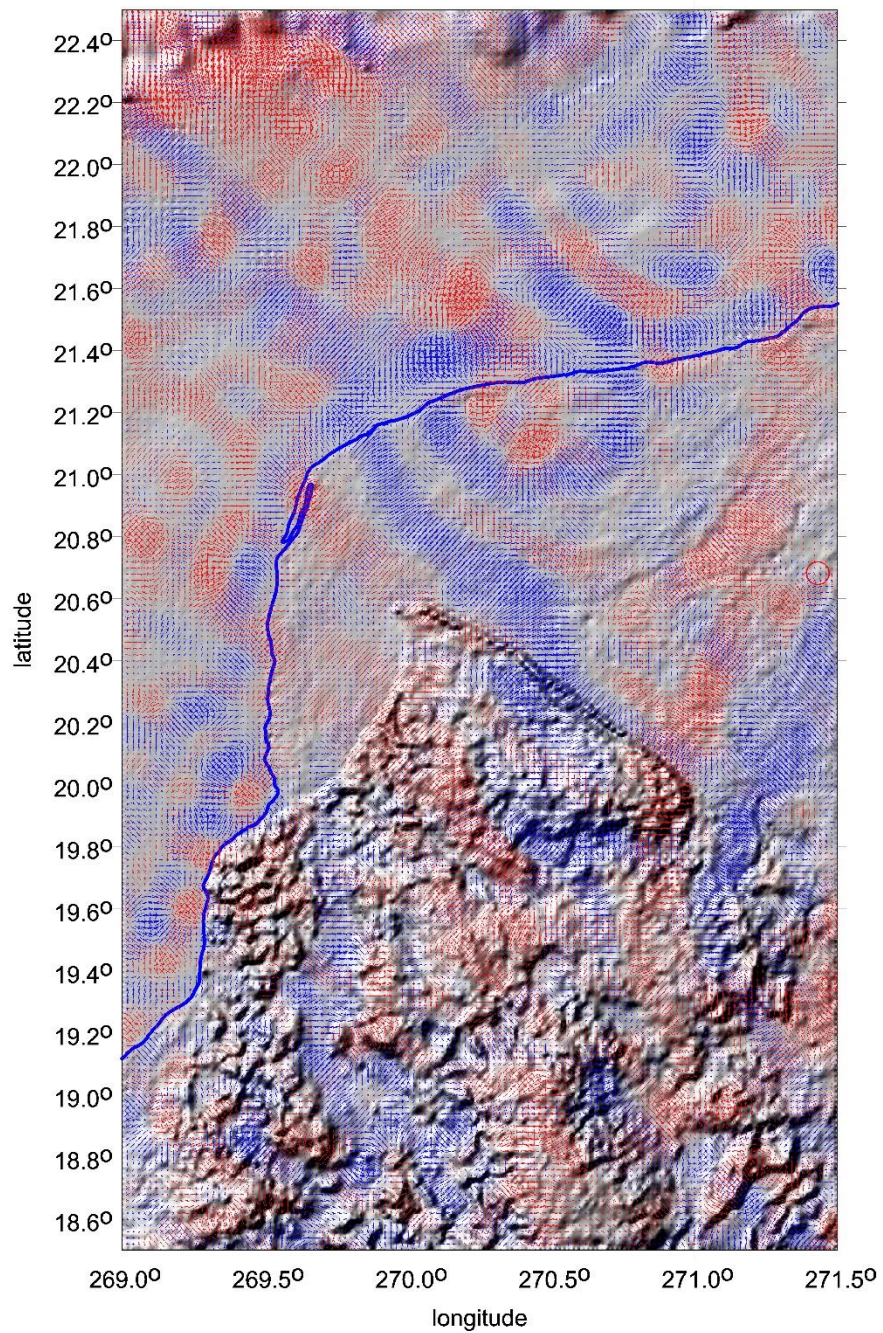


Eigen 6C4 - Chicxculub - topo + theta for RI < 0.9 + COMB

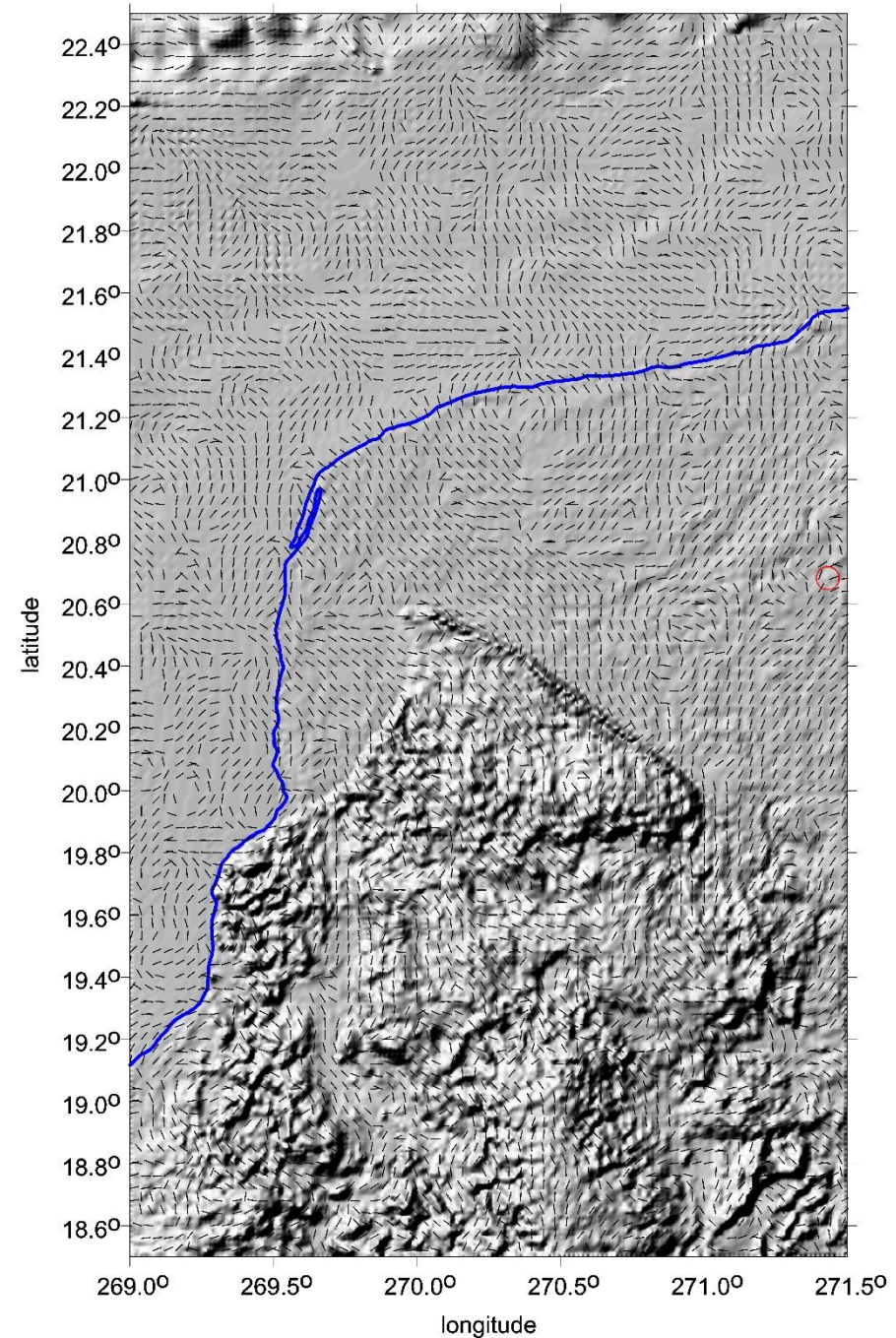




Eigen-6c4 - Chicxculub - topo + vd

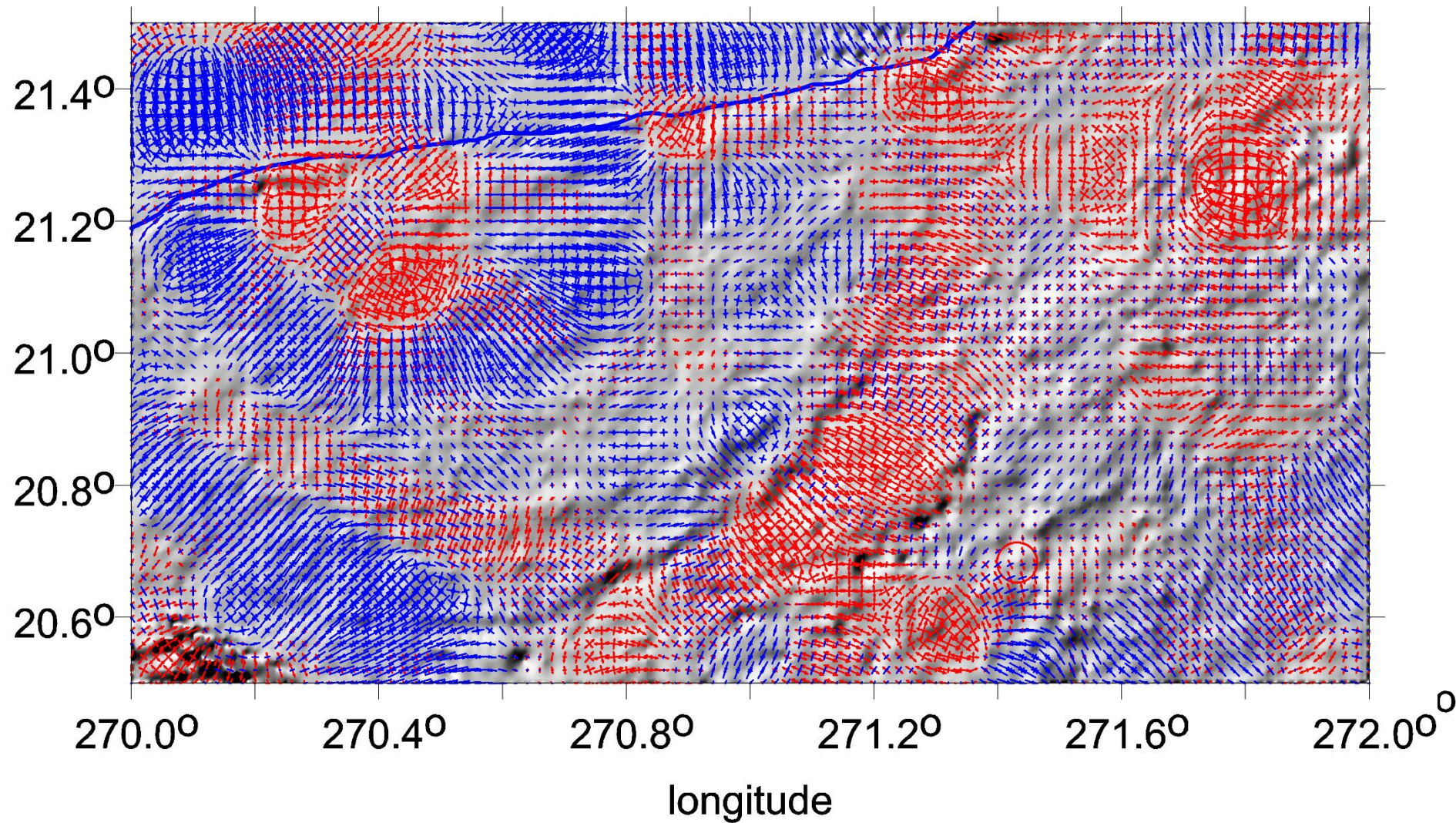
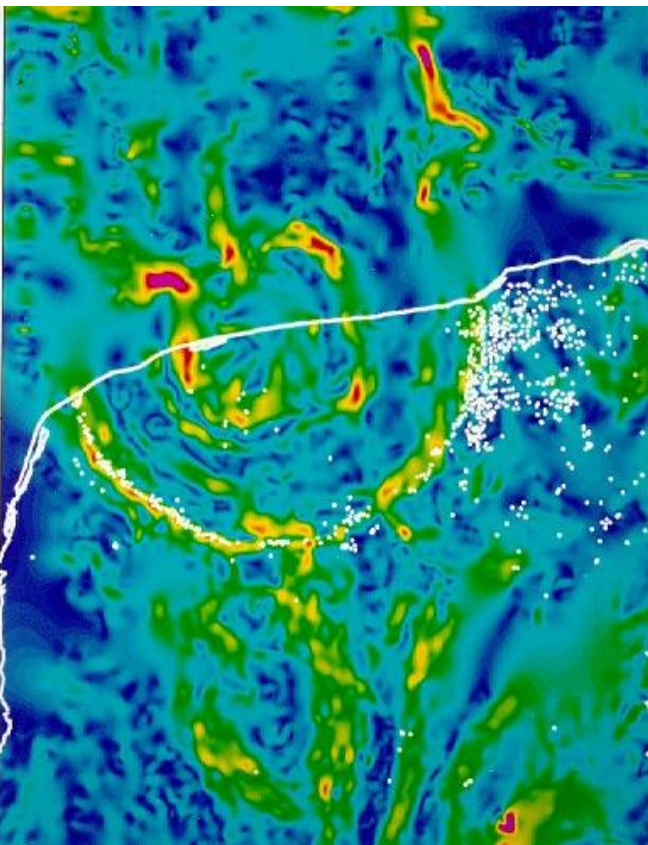


Eigen-6c4 - Chicxculub - topo + theta for RI < 0.9



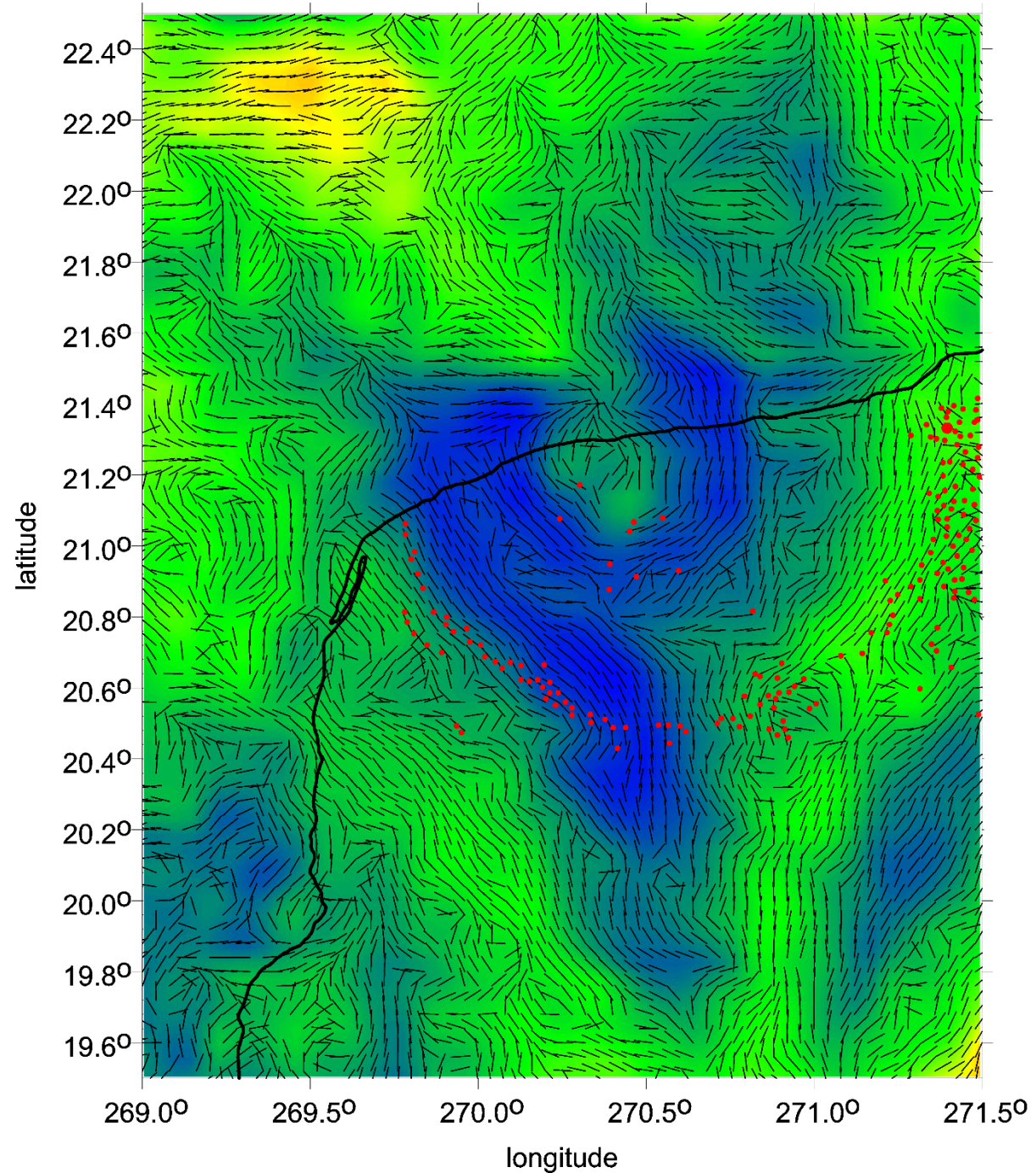


Eigen 6C4 - Chicxculub - topo + vd





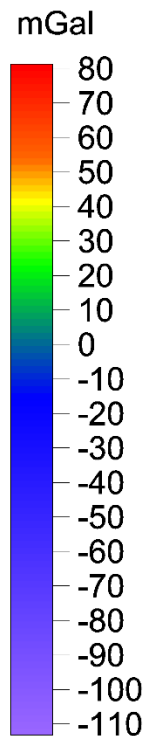
Eigen - 6C4 - Chixculub - cenotes + Theta for RI < 0.9 + delta g



**Chicxulub**

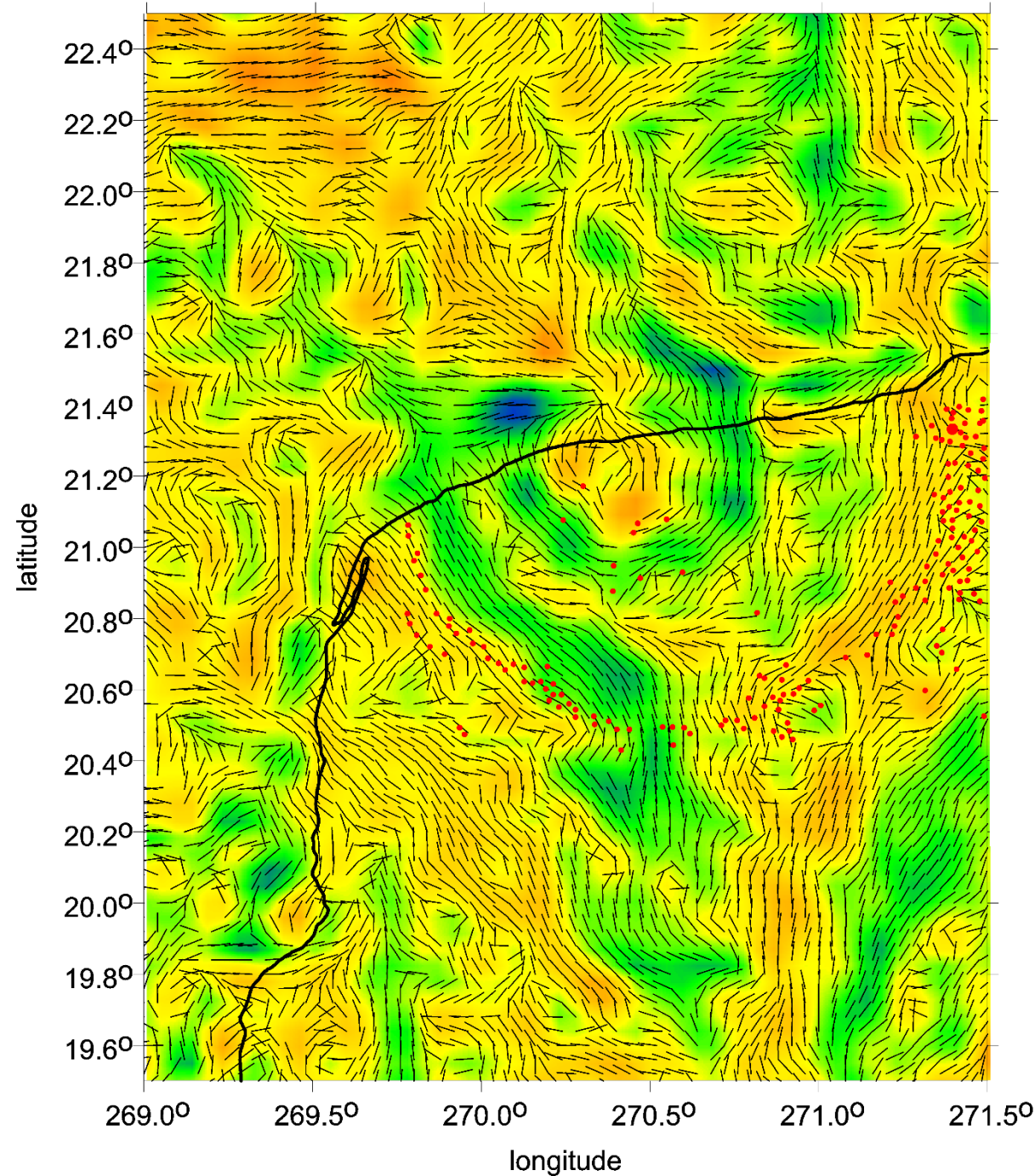
zoom  
gravity anomalies  
and strike angles

ring of cenotes as  
red dots





Eigen - 6C4 - Chixculub - cenotes + Theta for RI < 0.9 + Tzz



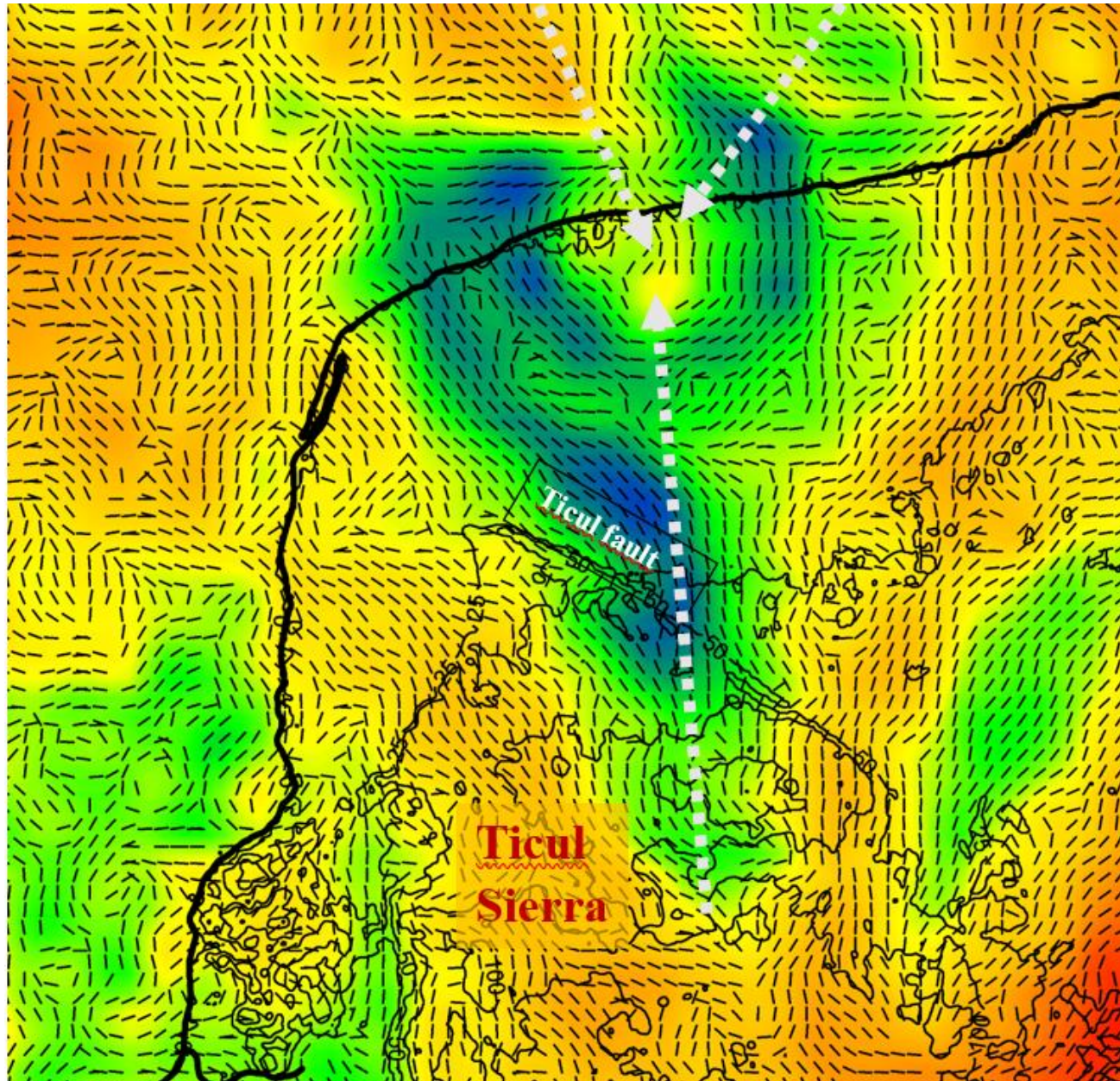
## Chicxulub

zoom

gravity anomalies  
and strike angles

ring of cenotes as  
red dots





## Chicxulub

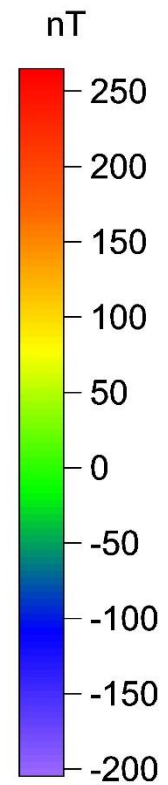
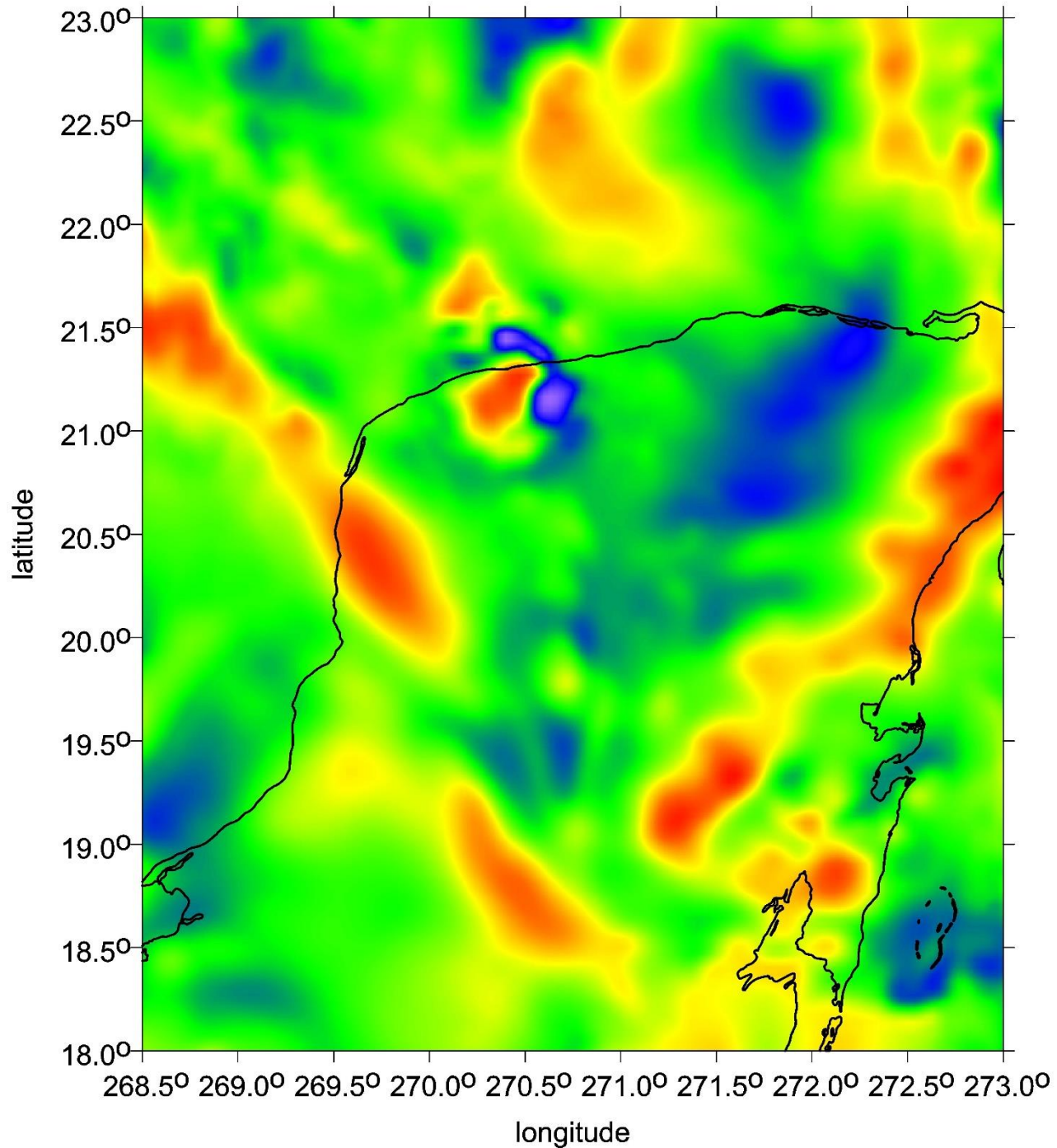
gravity anomalies and strike angles

ETOPO 1 topography  
Ticul Fault, Ticul Sierra  
coastal line

to discussion about the  
Southern anomaly (tail)



EMAG2\_V2 - Chicxulub - magnetic anomaly



**Magnetic field intensities**  
according to EMAG2\_V2 model  
[nanotesla, nT]





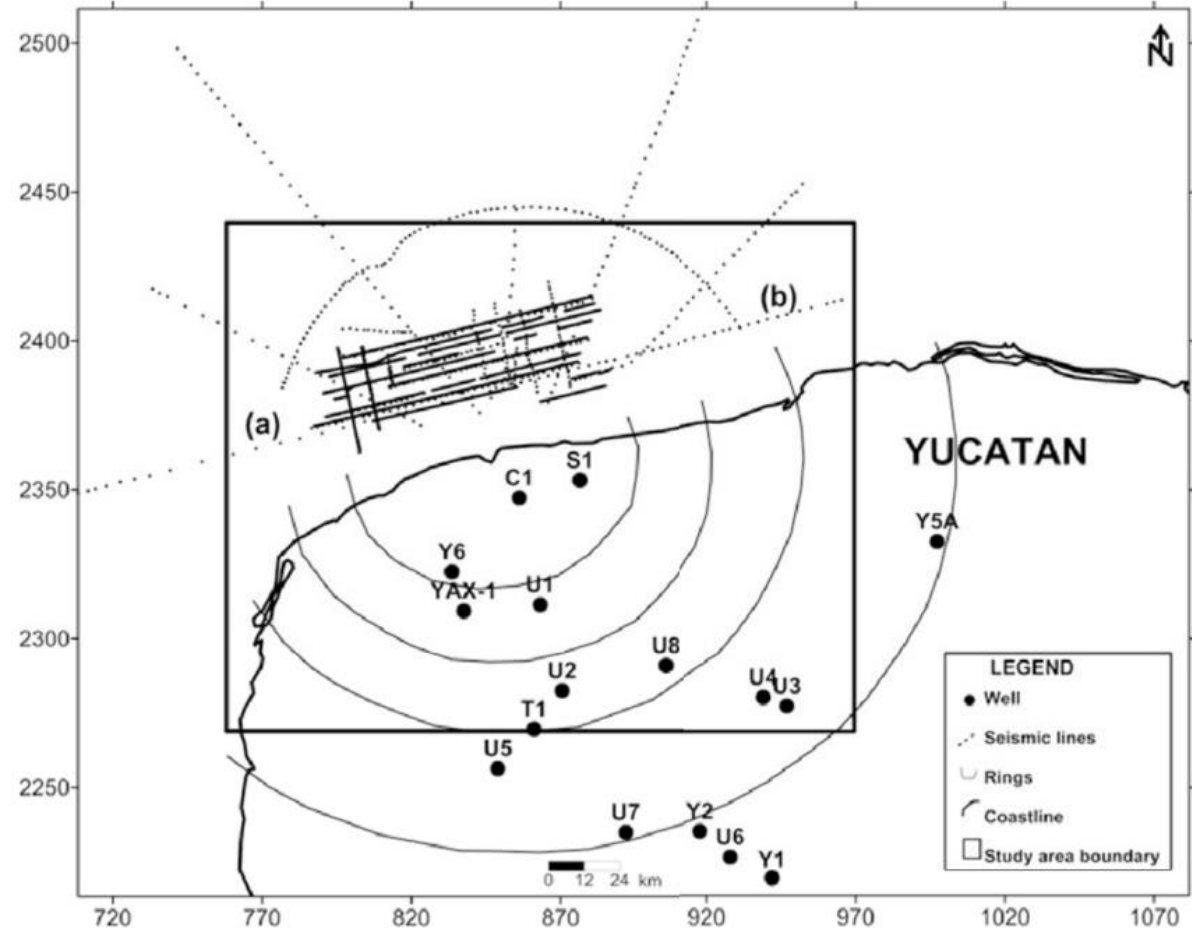
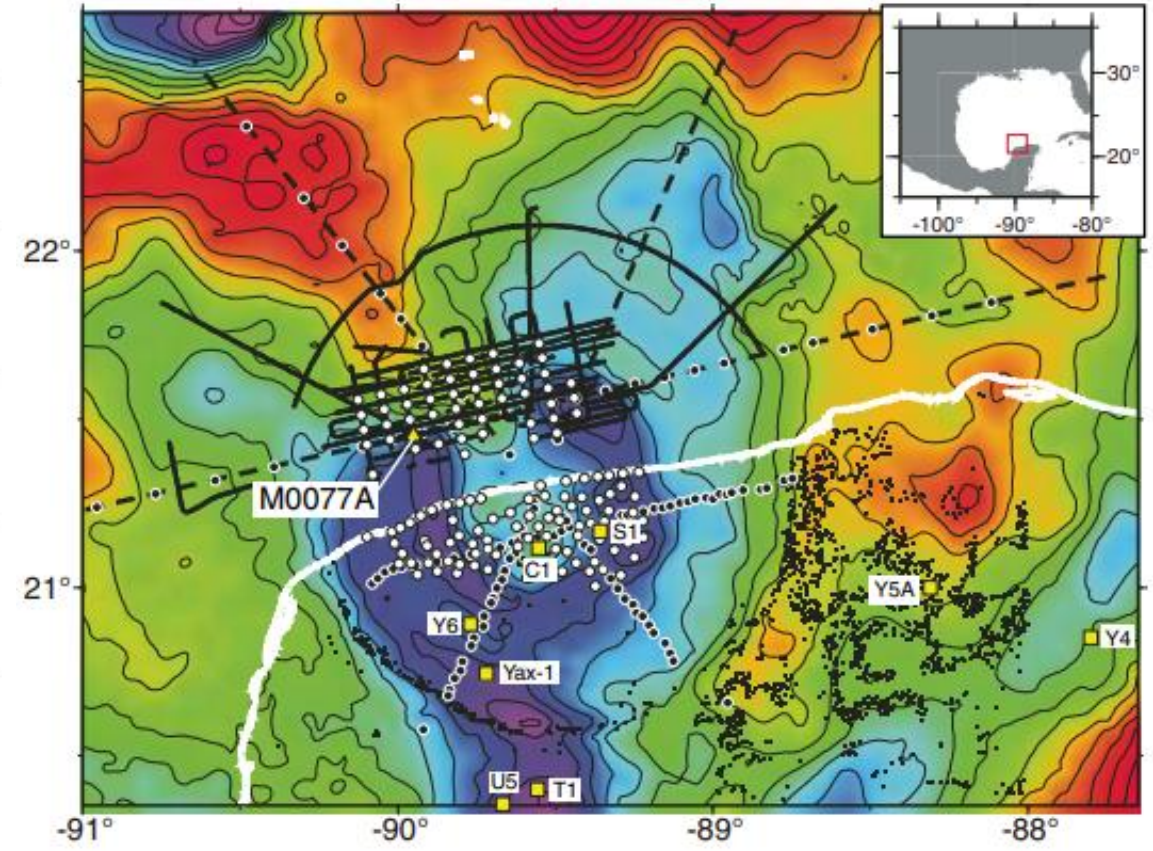


Fig. 1. Inner box shows the study area. Irregular line indicates the Yucatan coastline. Dotted lines point out the seismic lines locations. Thick dots are land borehole. Circular lines are rings obtained from the first horizontal derivate of the gravity field.

Batista-Rodriguez et al 2013, *Earth Planets Space*, 65, 973–983, Three-dimensional gravity modeling of Chicxulub Crater structure, constrained with marine seismic data and land boreholes

**right** International Ocean Discovery Program Expedition 364 Preliminary Report Chicxulub: drilling the K-Pg impact crater In collaboration with the International Continental Scientific Drilling Program Platform operations; Gulick et al 2016 and the Expedition 364 Scientist

### Seismic profiles cross Chicxulub



Seismic reflection data along Chicx-A. At about 20–30 km outboard of the crater rim at Chicxulub, the relatively undisturbed, flat-lying, pre-impact stratigraphy is abruptly offset vertically by 400–500 m (outer ring). The outer ring faults are observed out to radial distances of 90–120 km, giving a crater diameter of ~195–210 km (Morgan et al., 1997; Gulick et al., 2008). Modified from Gulick et al. (2008); from *Nature Geoscience*



[www.asu.cas.cz/~jklokocn](http://www.asu.cas.cz/~jklokocn)  
[jklokocn@asu.cas.cz](mailto:jklokocn@asu.cas.cz)



*The End of S4*