UNIVERSITE DE NANTES

UMR-CNRS 6112
PLANETOLOGIE & GEODYNAMIQUE

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

Derivation of local crustal magnetization using multiple altitude magnetic data

SWARM

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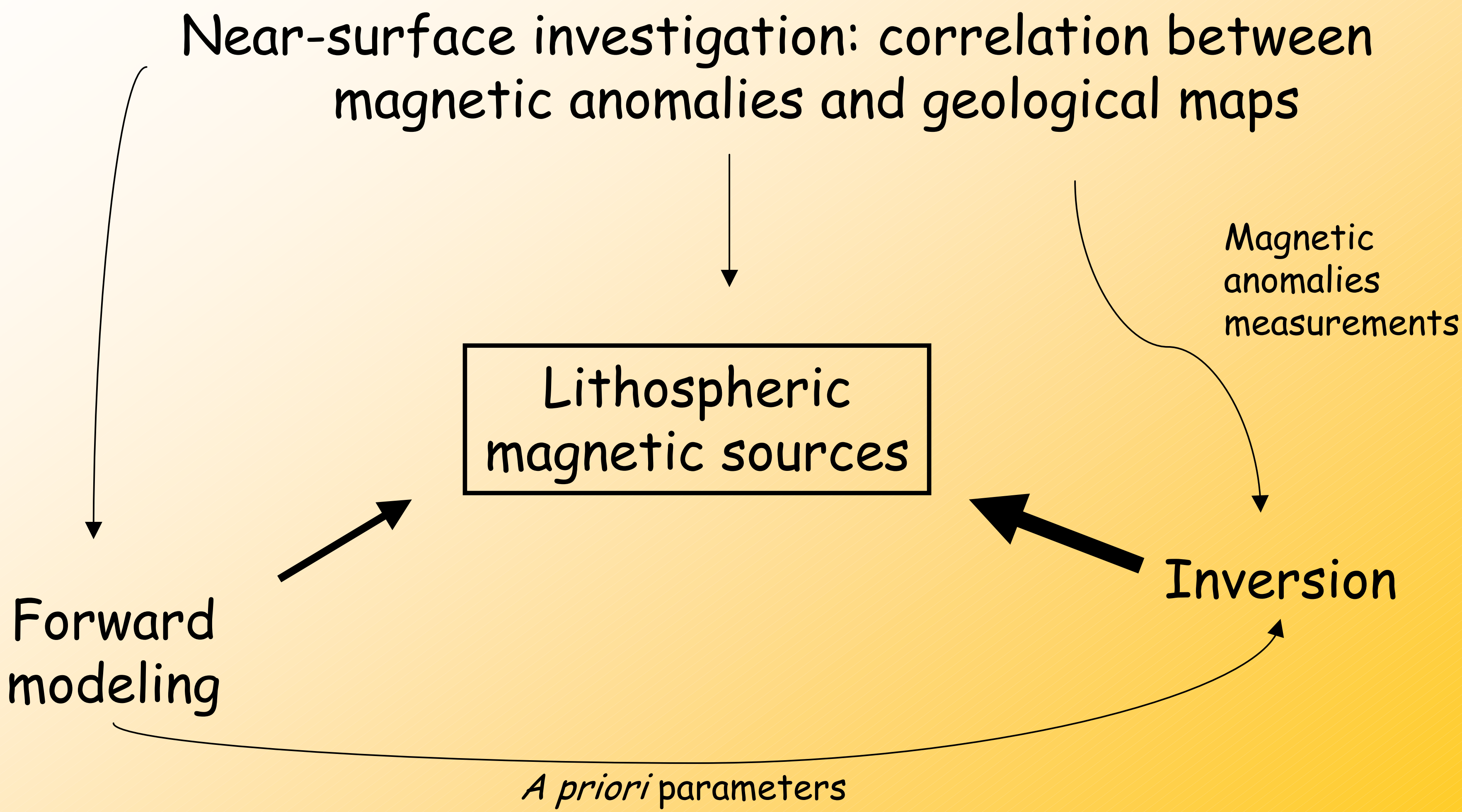
Outline

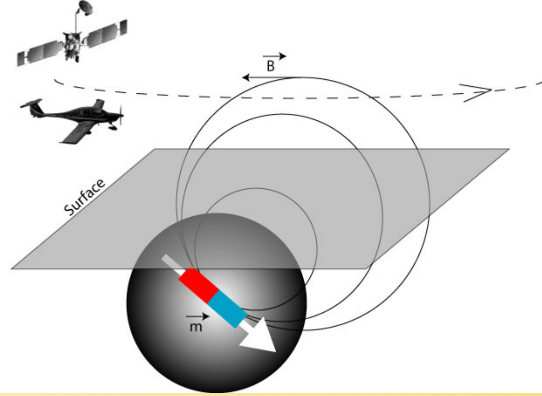
- Method
- Aeromagnetic case (synthetic and raw data)
- Satellite case (MGS martian data and Swarm simulated)
- Conclusions

Method



Near-surface investigation: correlation between magnetic anomalies and geological maps
Lithospheric magnetic sources
Magnetic anomalies measurements
Forward modeling
Inversion
A priori parameters

Method



Forward models: uniformly magnetized spheres, cylinders (Blakely, 1995) and prisms (Plouff, 1976; Talwani, 1965).

Generalized non-linear inversion (Tarantola and Valette, 1982)

Input: B_r, B_θ, B_φ or ΔB anomaly

Unknown parameters : moment (mx, my, mz or m) and location (x, y, z) of one or several dipoles

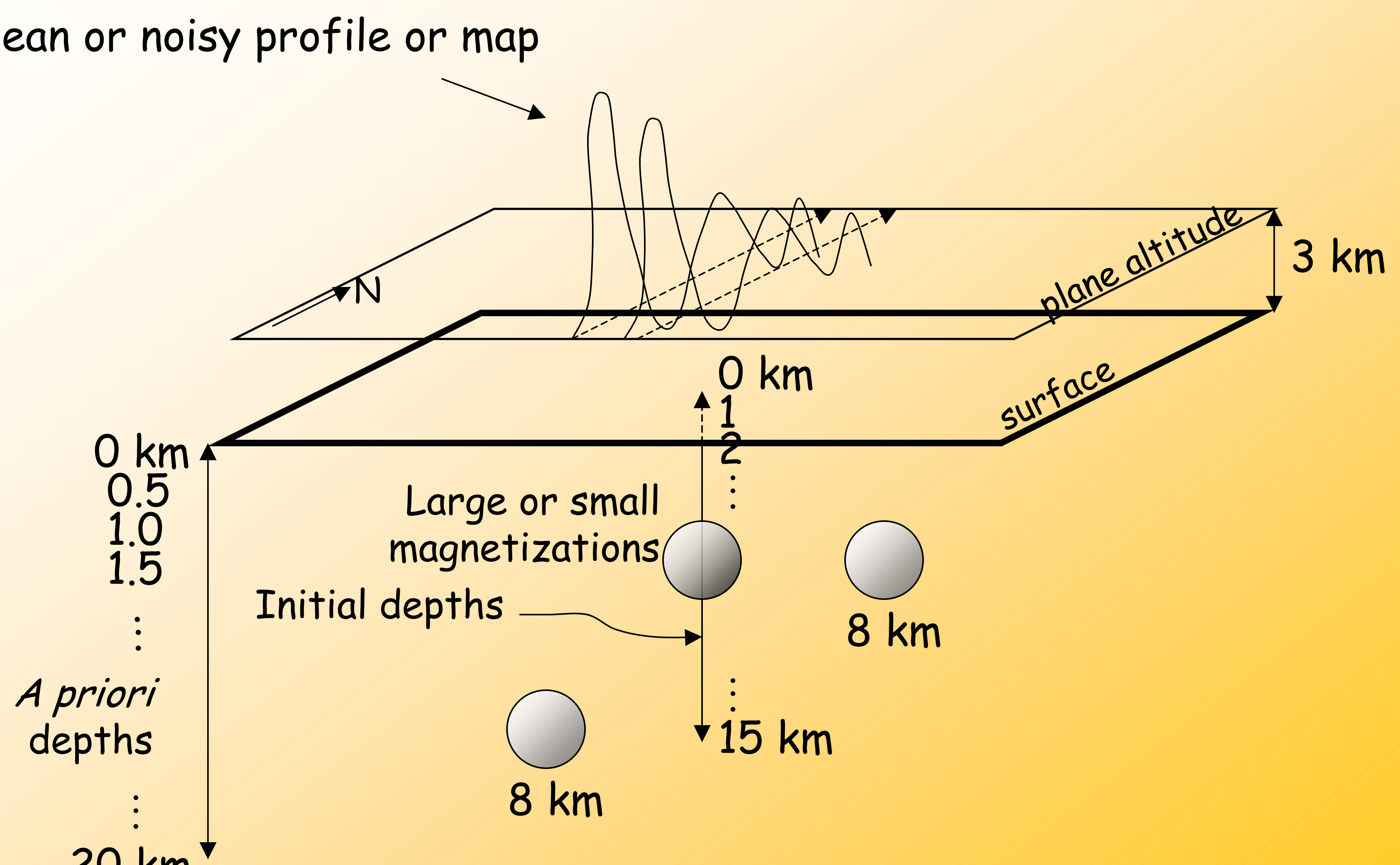
Non-linear system

Process: generalized non-linear inversion (Tarantola et Valette, 1982) $\rightarrow$ *a priori* parameters and associated Standard Deviations (SD)

Criterion: convergence and smallest χ^2

A posteriori tests: rms residuals, gaussian distribution

Synthetic aeromagnetic data



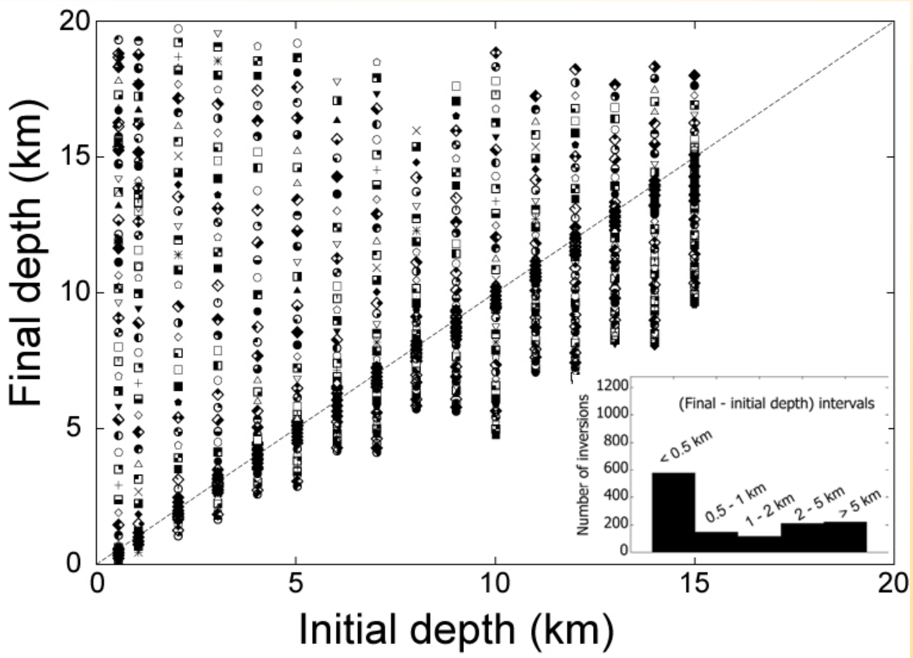
Dipole 1 *a priori* depth SDs: 0.1, 1 or 10 km

Other dipoles *a priori* depth SDs: 0.01 or 1 km

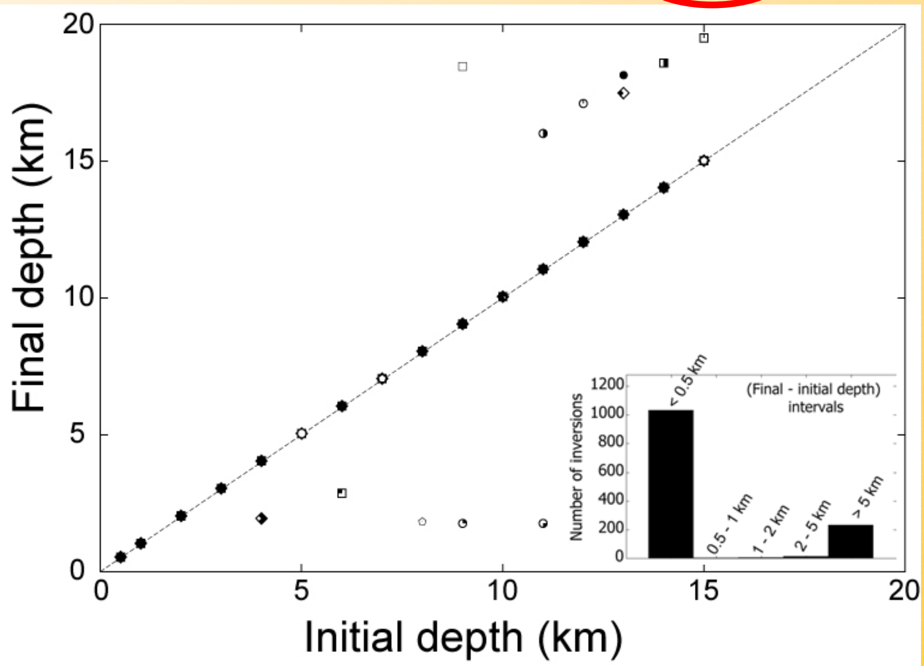
Synthetic aeromagnetic data

Inversion of synthetic 1 dipole profile

A priori depth SD = 0.1 km



A priori depth SD = 1 km



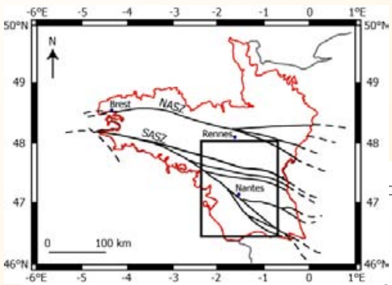
Other results:

→ *A priori* data SD must be proportional to the measurement noise

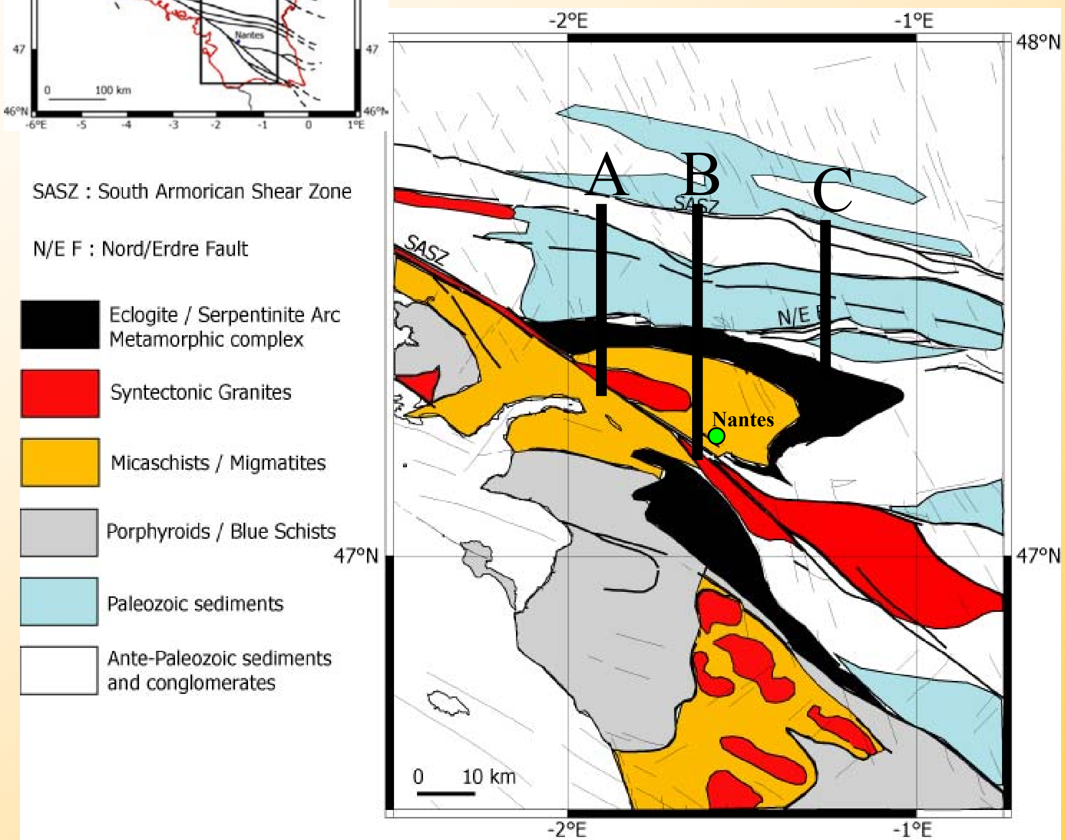
→ Other *a priori* parameters SDs need to be large enough

Raw aeromagnetic data

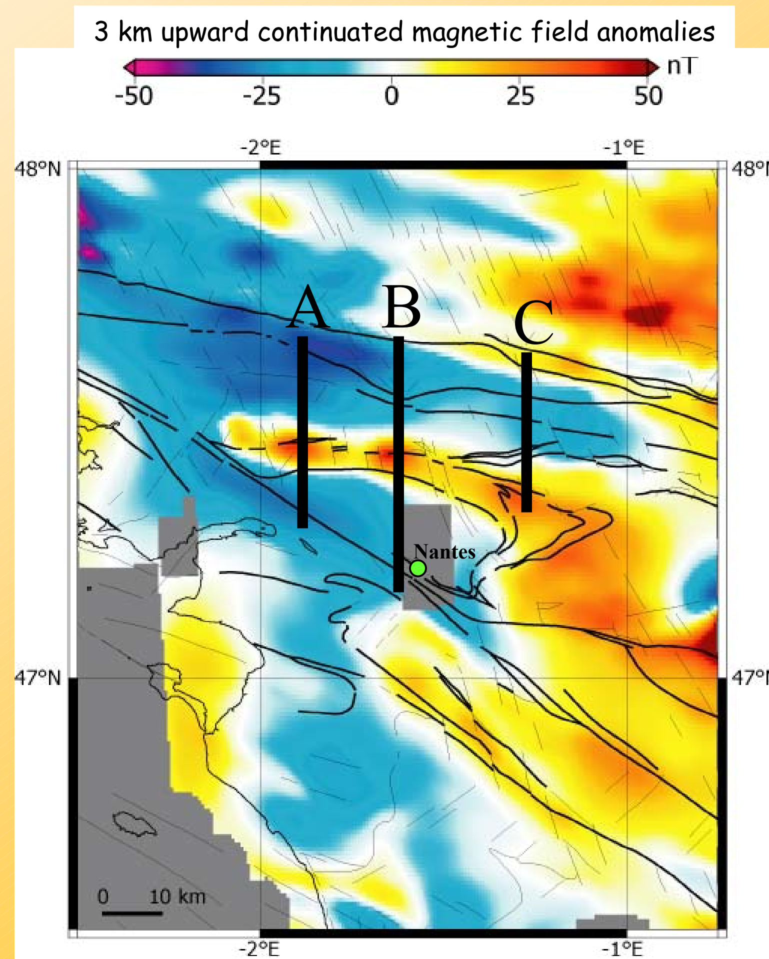
Area: metamorphic complex of Champtoceaux (Armorican Massif, Western France)
Data: total-field 120 m magnetic measurements (summer 1998, BRGM, GéoFrance3D Armor2 program)



Geology



Magnetism



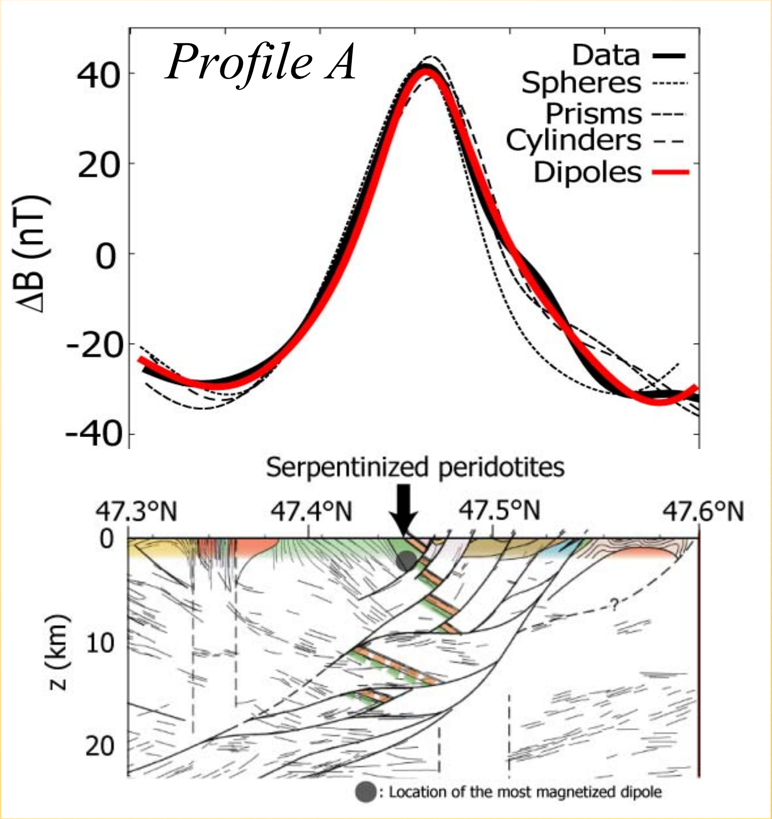
Raw aeromagnetic data

Comparison between forward and inverse models for profile A

	Lat. (°N)	Lon. (°E)	z (km)	M* (A/m)	Fit
Spheres	47.47	-1.91	3.8	5.8	82 %
	47.38	-1.92	9.8	-1.5	
	47.60	-1.89	9.8	-1.5	
Prisms	47.46 / 47.48	-1.91 / -1.89	1.8 / 4.0	8.0	83 %
	47.30 / 47.38	-1.95 / -1.85	8.0 / 12.0	-2.0	
	47.57 / 47.67	-1.95 / -1.85	8.0 / 11.6	-2.0	
Cylinders	47.47	-1.90	4.0	3.0	84 %
	47.35	-1.90	10.0	-1.5	
	47.63	-1.90	10.0	-1.5	
Dipoles	47.45	-1.91	3.4	4.4*	95 %
	47.38	-1.92	10.8	-1.8*	
	47.60	-1.89	8.9	-1.3*	

* : magnetizations if the 3 dipoles correspond with the 3 spheres (r1=1.5 km, r2=r3=4 km).

Comparison between measured and predicted magnetic anomaly field.



Interpretation of a seismic cross-section (Bitri et al., 2003)

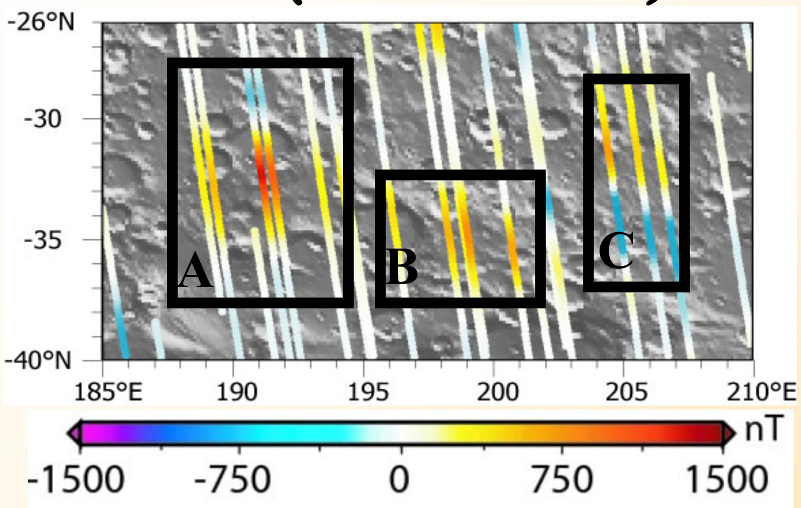
Other results:

→ 4 to 8 A/m and 3.4 to 6.5 km from East to West → same results as previous studies (Bitri et al., 2003 ; Gumiaux et al., 2003)

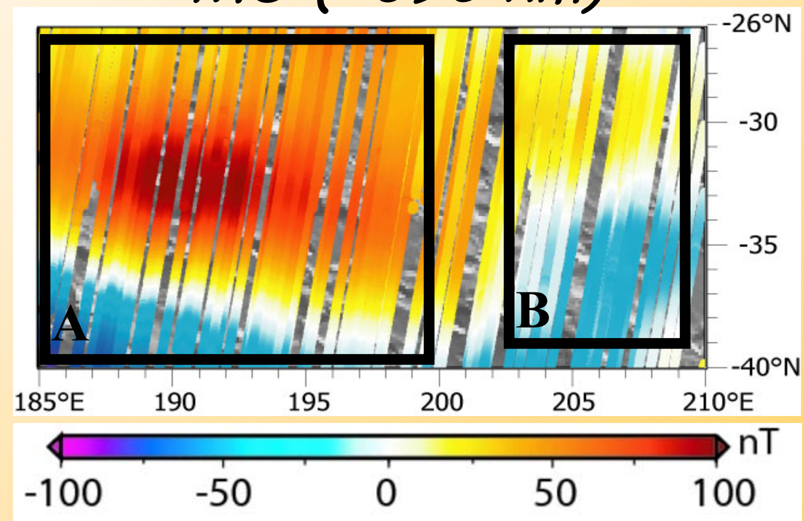
→ mainly induced magnetization

Martian satellite data

AB (100-250 km) *MO (~390 km)*



B_r



Rms observations compared to rms residuals of each model

		rms measurements (nT)	rms residuals (nT)				
			AB forward models	Inversion			
				AB-A subset	MO-A subset	AB-A + MO-A subsets	All AB and MO subsets
AB	br	353	98	90	223	125	123
	bt	278	112	99	181	108	112
	bp	96	77	85	61	80	78
MO	br	54	37	38	16	20	23
	bt	37	33	36	14	24	27
	bp	36	30	31	17	18	19

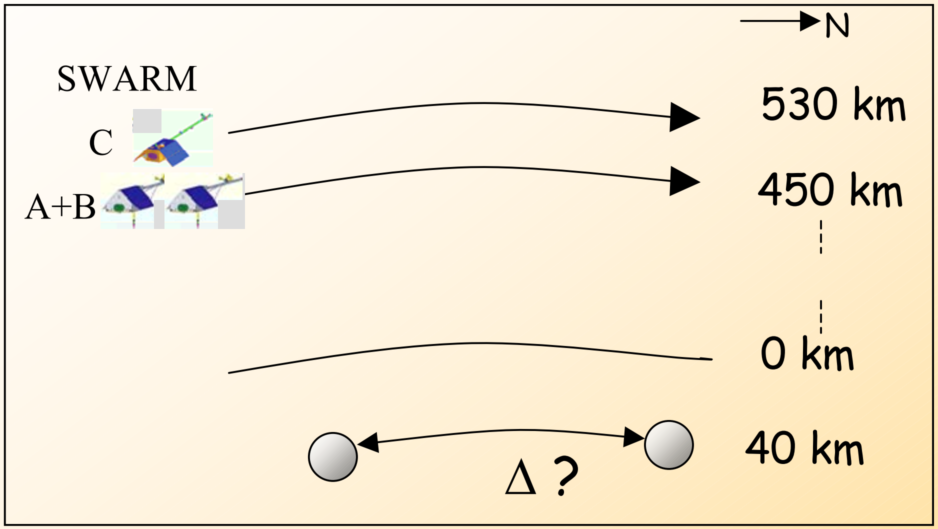
→ combined AB+MO data inversion gives the best fit to the AB and MO signals

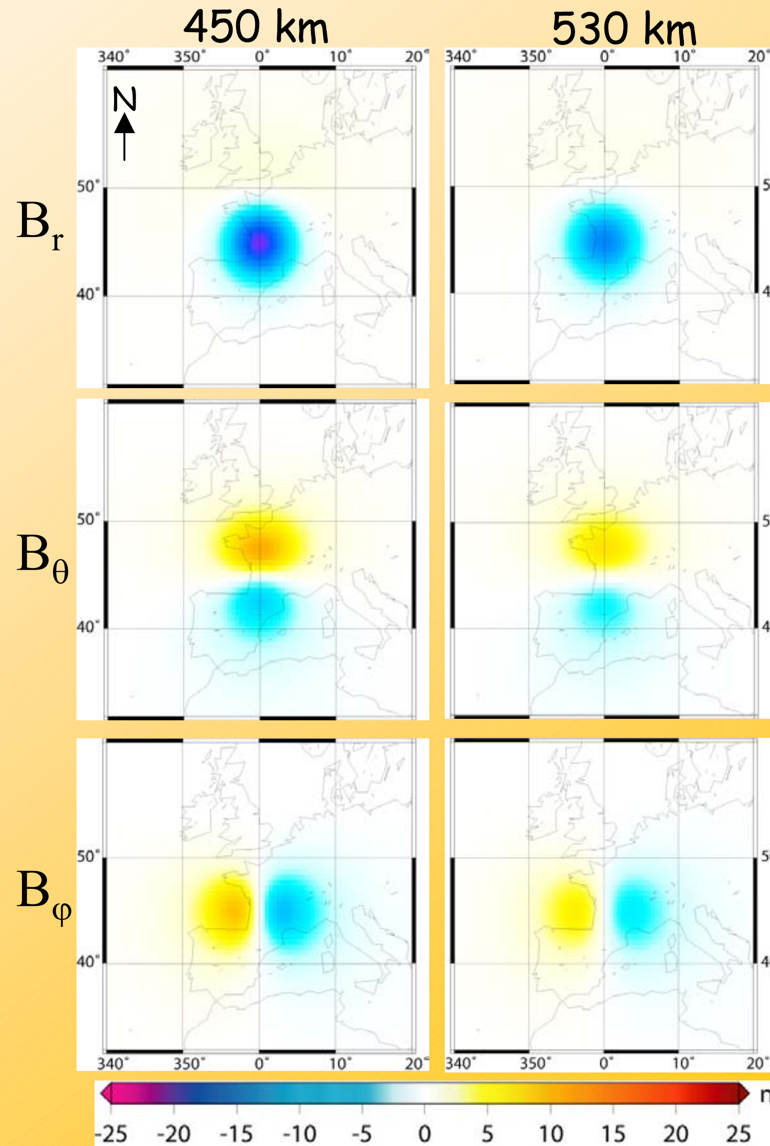
Quesnel et al., 2006, PSS

→ Other results: large magnetization (~50 A/m) and depth (~55 km) of investigated magnetized sources

Synthetic Swarm data

Minimum space interval to distinguish 2 adjacent lithospheric magnetized sources?





Initial sources parameters:

Lat. (°N)	Lon. (°E)	z (km)	r (km)	M (A/m)	I (°)	D (°)
45.0	0.0	40.0	35.0	40.0	63.4	0.0
46 ± 1	0.0	40.0	35.0	40.0	64 ± 2	0.0

$\text{tg } I = 2 \text{ tg } \lambda$

Synthetic Swarm data

Inversion parametrization:

- input data = B_r, B_θ and B_φ anomaly components
- 1 nT *a priori* data SD (= gaussian noise)

$\lambda_1 = 45°N \quad \lambda_2 = 47.7°N \rightarrow \Delta \sim 300$ km

	Lat. (°N)	Lon. (°E)	z (km)	r (km)	M (A/m)	I (°)	D (°)
Initial model	45.0	0.0	40.0	35.0	40.0	63.4	0.0
	47.7	0.0	40.0	35.0	40.0	66.5	0.0
Swarm-C	45.2	-1.4	35.7	35.0	-259.0	58.0	0.0
	45.2	-1.2	47.0	35.0	325.0	65.0	0.0
Swarm-A or B	44.9	1.2	38.7	35.0	31.2	62.0	-0.1
	47.2	-0.2	41.2	35.0	39.0	73.0	0.1
Swarm-A (or B) + C	44.9	1.2	37.8	35.0	33.4	63.0	0.0
	47.4	-0.4	41.0	35.0	37.3	74.7	0.0

Inversion results

Synthetic Swarm data

Inversion parametrization:

- input data = B_r, B_θ and B_φ anomaly components
- 1 nT *a priori* data SD (= gaussian noise)

$\lambda_1 = 45°N \quad \lambda_2 = 46.5°N \rightarrow \Delta \sim 170$ km

	Lat. (°N)	Lon. (°E)	z (km)	r (km)	M (A/m)	I (°)	D (°)
Initial model	45.0	0.0	40.0	35.0	40.0	63.4	0.0
	46.5	0.0	40.0	35.0	40.0	64.6	0.0
Swarm-C	44.9	-0.8	45.6	35.0	295.1	63.9	0.1
	44.8	-1.2	35.5	35.0	230.5	60.4	-0.1
Swarm-A or B	44.7	-1.0	35.9	35.0	-301.2	60.1	-0.1
	44.8	-0.8	45.6	35.0	365.3	63.4	0.1
Swarm-A (or B) + C	46.5	-0.6	39.0	35.0	35.6	69.2	0.0
	44.7	1.3	37.9	35.0	34.5	64.2	0.0

Inversion results

Conclusions

- the method works for aeromagnetic and/or satellite altitude magnetic measurements
- needs for realistic *a priori* parameters and SDs
- it can be used with Swarm measurements to detect sources as close as ~ 170 km

Future work...

- perform more tests to confirm these preliminary results
- application to real Orsted, CHAMP or Magsat measurements