Seasonal variations of gravity and continental water storage

Speaker: Yi-Xiu Lai

References

- Boy, J.P., Hinderer, J., (2006) Study of the seasonal gravity signal in superconducting gravimeter data. Journal of Geodynamics 41, 227–233

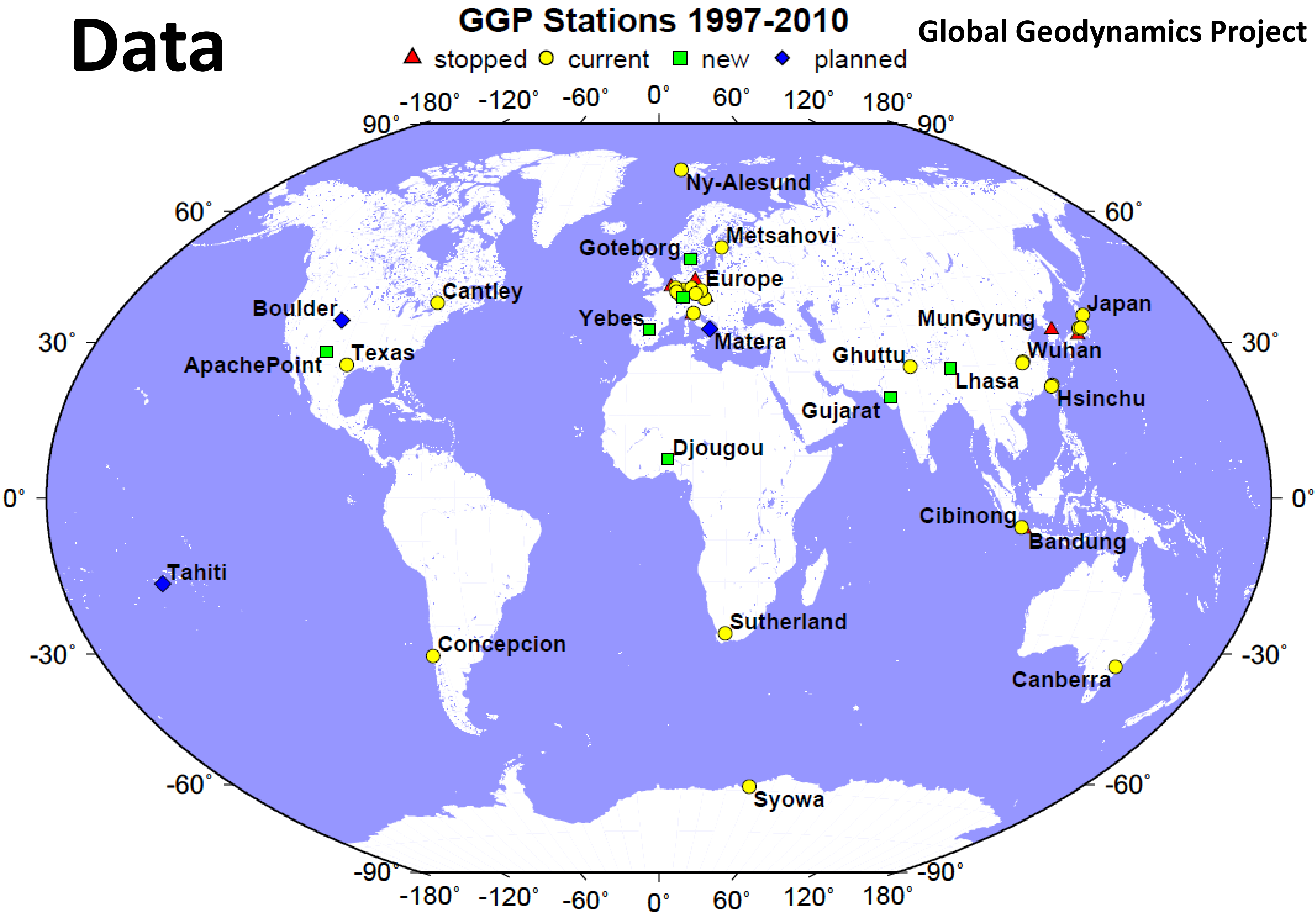
- Memina, A., Rogister, Y., Hinderer, J., Llubes, M., Berthier, E. Boy, J.P., (2009) Ground deformation and gravity variations modelled from present-day ice thinning in the vicinity of glaciers. Journal of Geodynamics 48, 195–203

Introduction

- Most geodetic observations show large annual or seasonal variations which are most likely due to changes of continental water storage.
- Computing the gravity changes due to continental water storage using hydrology model, to compare it with SG observations.
- Taking glaciers in the Mont Blanc area for an example, shows that the influence of gravity variations and ground deformation from ice thinning.

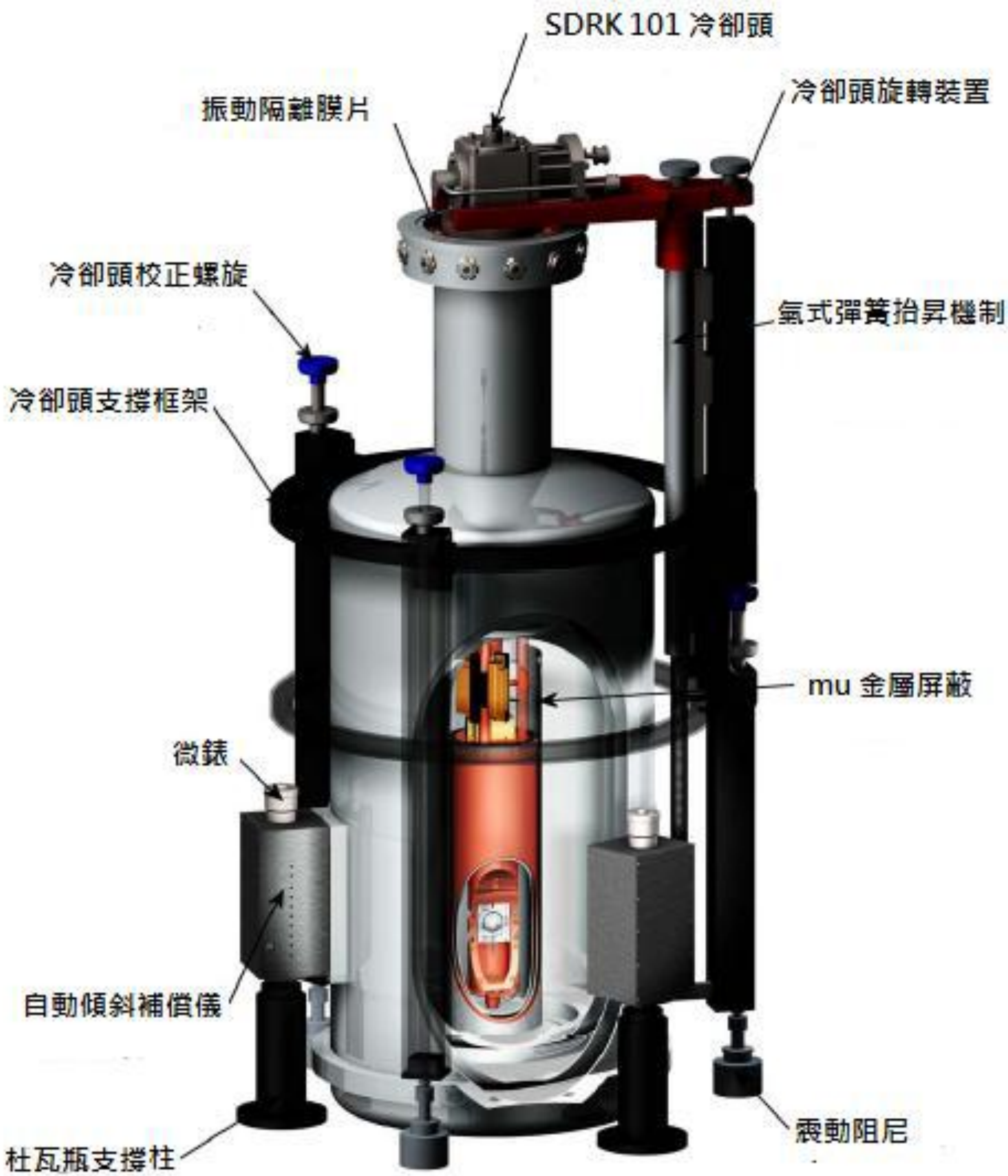
Data

Global Geodynamics Project



Superconducting gravimeter

- 原理：設法在超導線圈內產生一個永久性的穩定閉合電流。之後，在超導線圈所產生的一次磁場中放置一個同樣由超導材料製成的球形體。由於超導體完全抗磁，磁場不能穿入球體內部。小球表面感應電流所產生的二次磁場與線圈永久電流所產生的一次磁場互斥，使小球浮起，當小球受到的浮力與其重量互相平衡時，小球便會浮在線圈上方的一定高度。重力的變化將引起小球平衡位置的改變。準確測出小球位置的變化，就可以求出重力的變化。

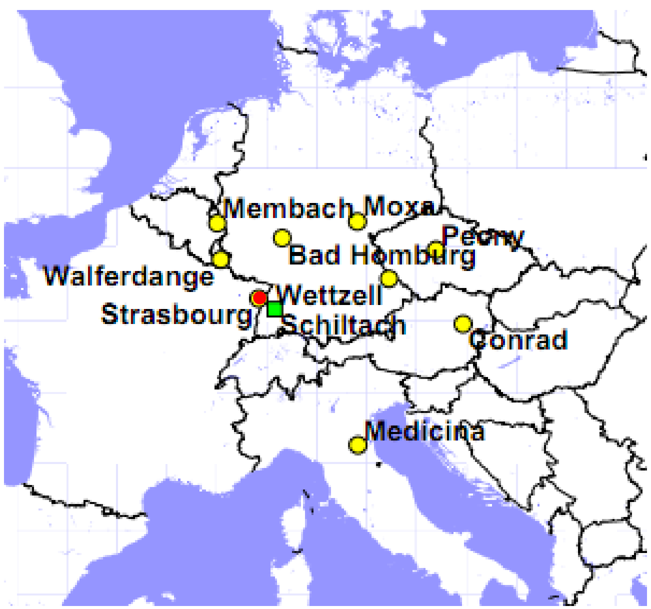

SDRK 101 冷卻頭
振動隔離膜片
冷卻頭旋轉裝置
冷卻頭校正螺旋
氣式彈簧抬昇機制
冷卻頭支撐框架
mu 金屬屏蔽
微錶
自動傾斜補償儀
震動阻尼
杜瓦瓶支撐柱

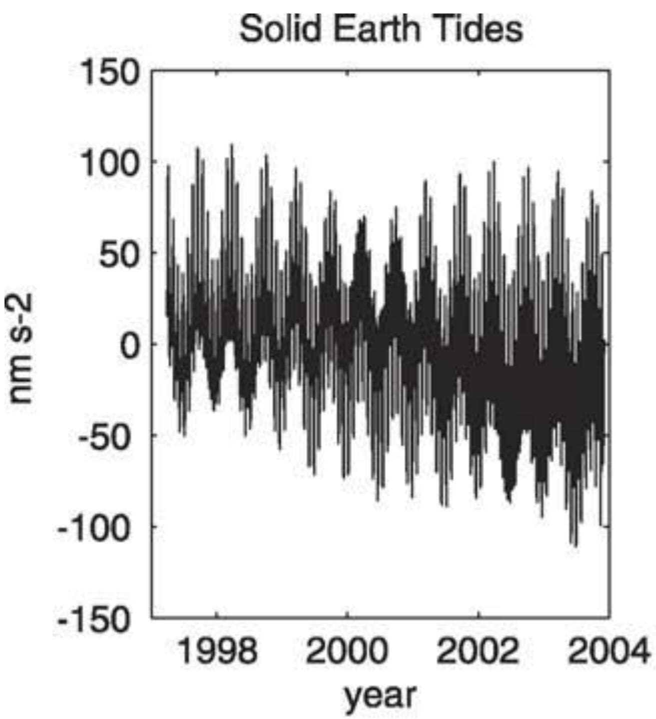
Modeling seasonal gravity changes

- Low pass filter 0.33 cycle/day
- Other contributions
  1. solid Earth tides
  2. ocean tidal loading
  3. pole tide
  4. atmospheric loading
  5. non-tidal ocean loading
  6. Continental water storage loading

1. solid Earth tides

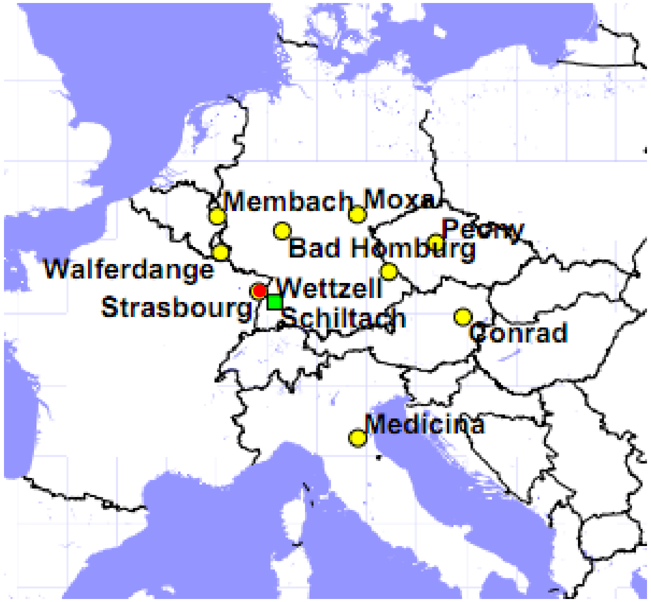
- Using Dehant et al. (1999) Love numbers and Hartmann and Wenzel (1995) tidal potential.

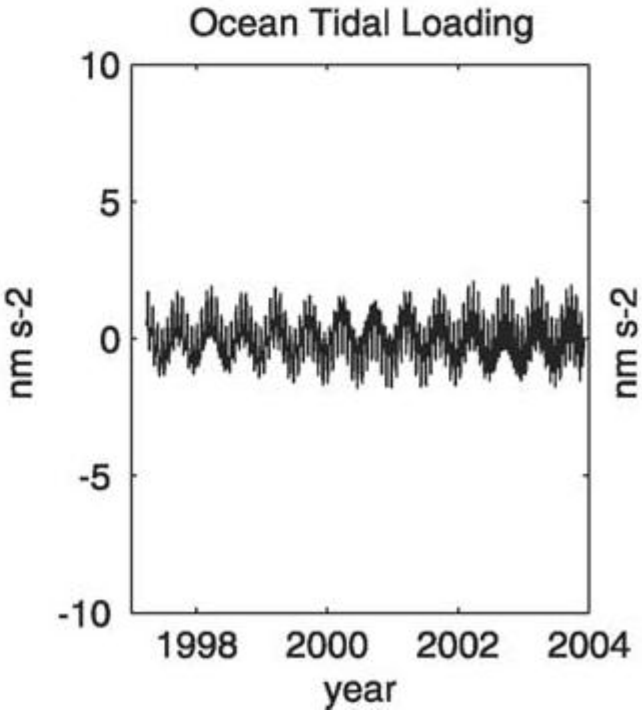




2. ocean tidal loading

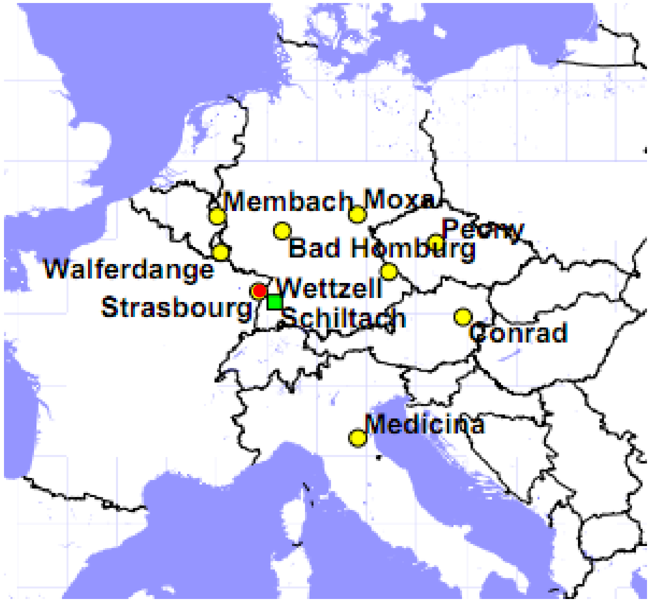
- Computing from NAO99b tide model.
  (Matsumoto et al., 2000)

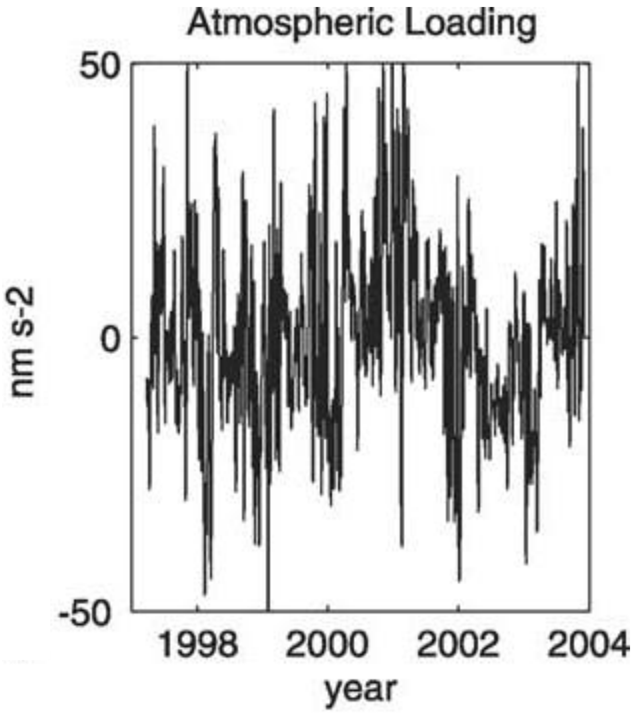




3. atmospheric loading

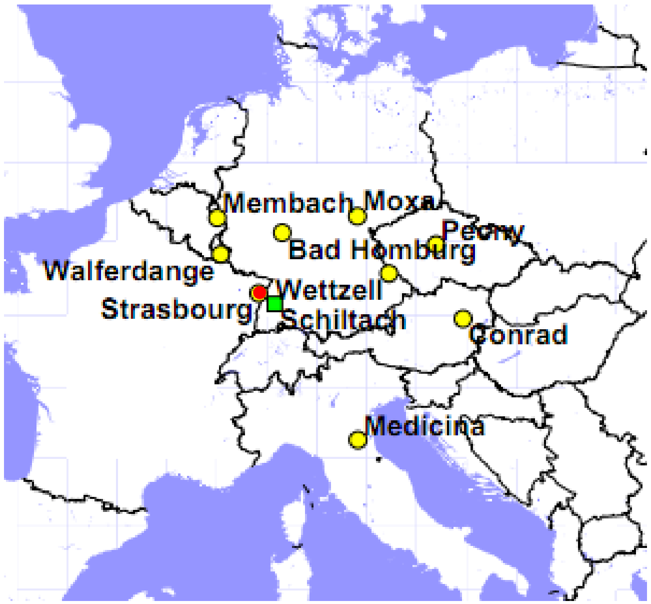
- Using NCEP (National Centers for Environmental Prediction) Reanalysis surface pressure fields, following Boy et al. (2002).

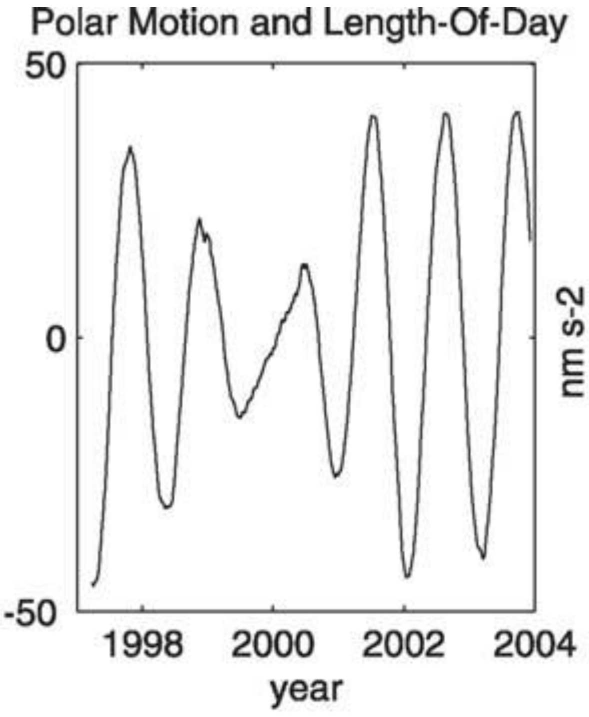




4. pole tide

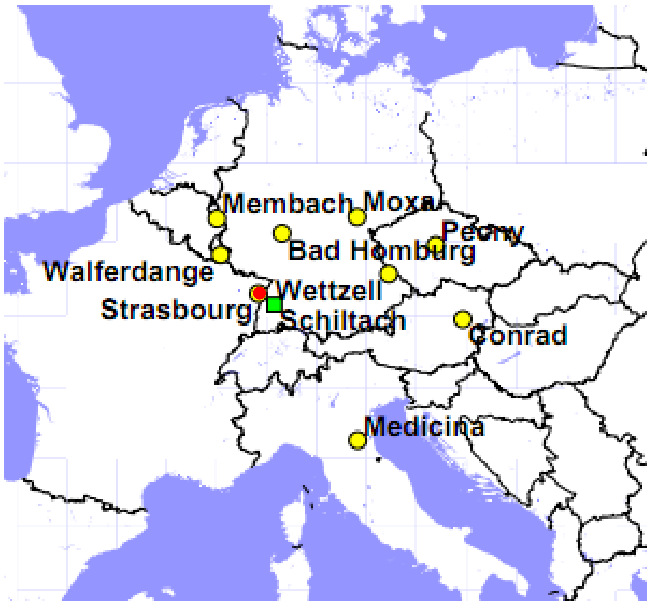
- Using daily Earth orientation parameters provided by the IERS (International Earth Rotation Service).

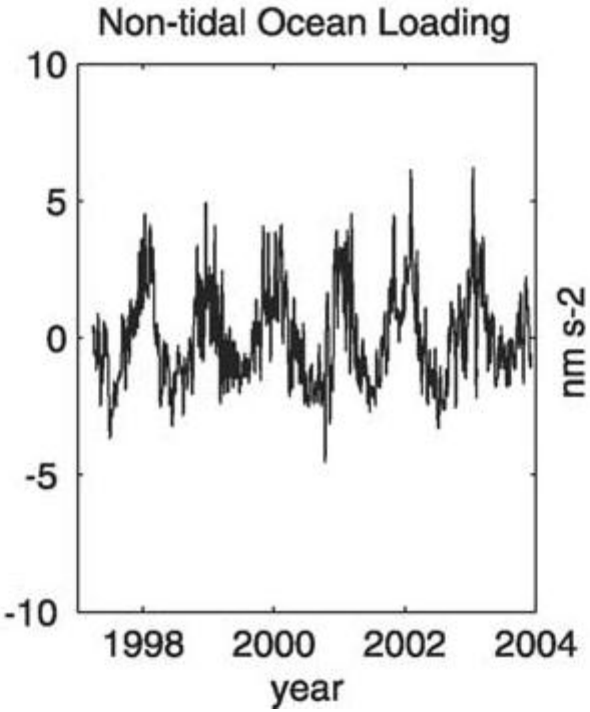




5. non-tidal ocean loading

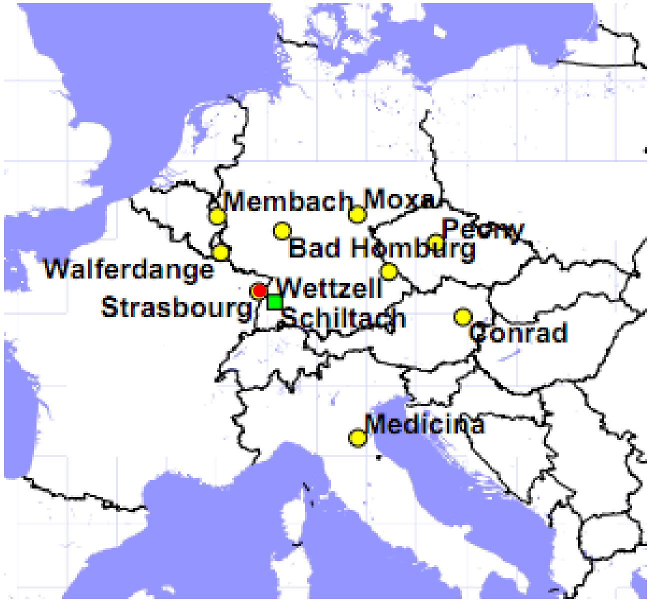
- Using bottom pressure outputs from the ECCO (Estimating the Circulation and the Climate of the Ocean) general circulation model.

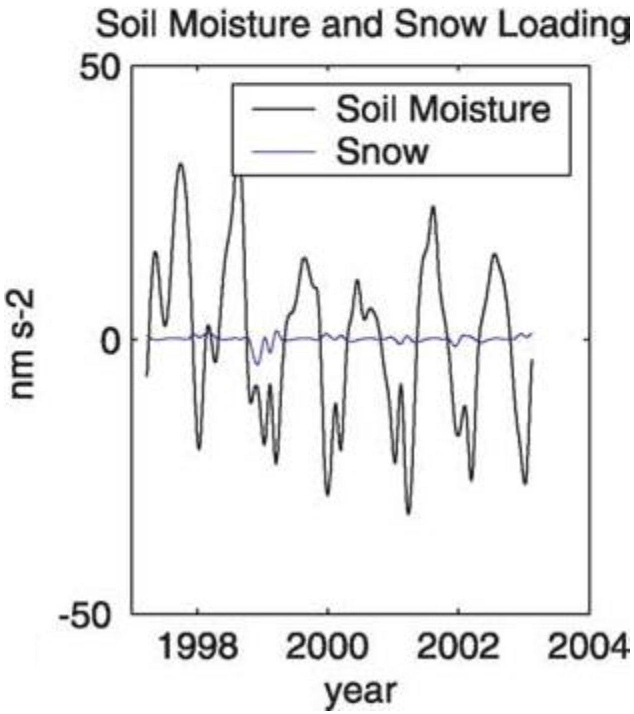


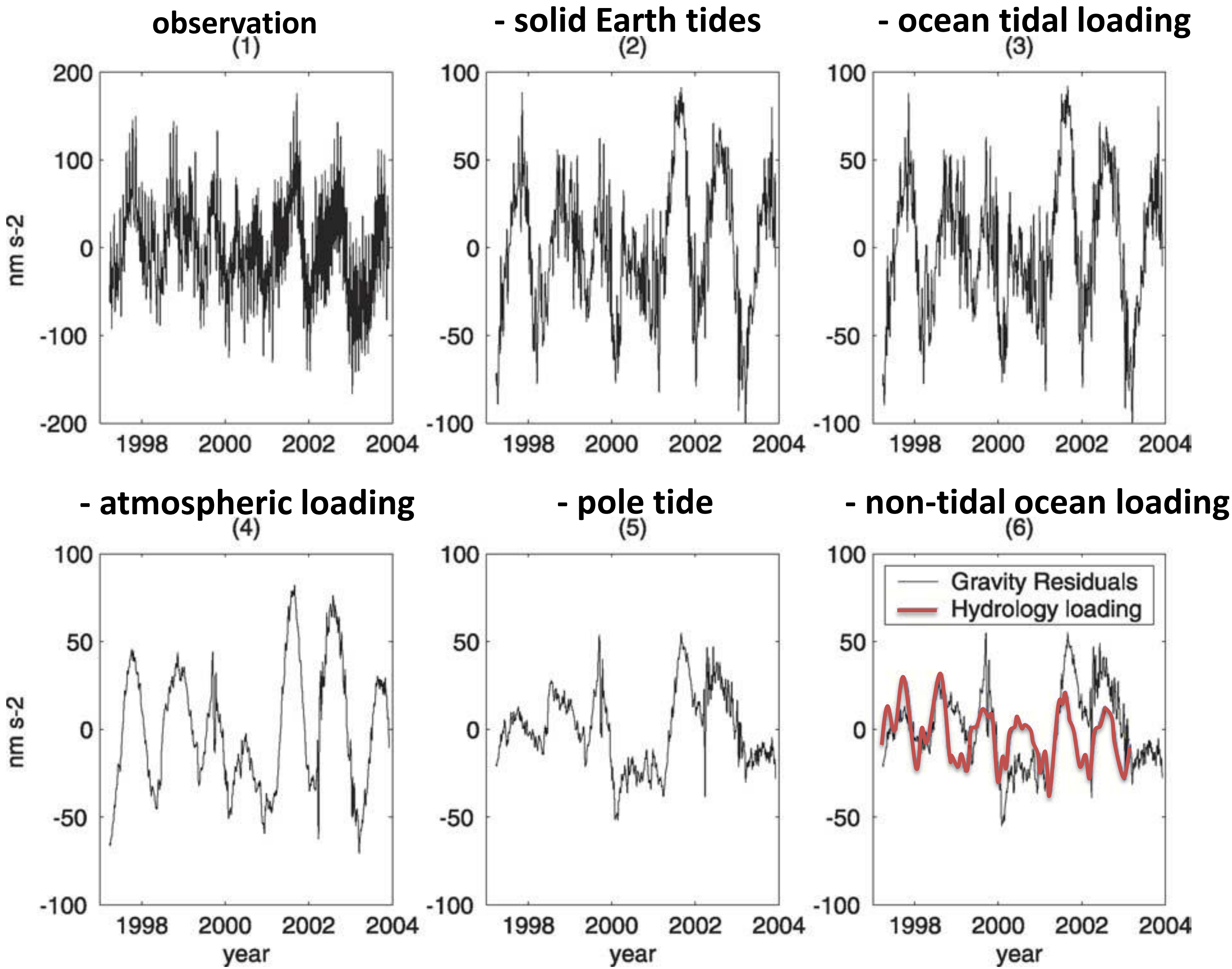


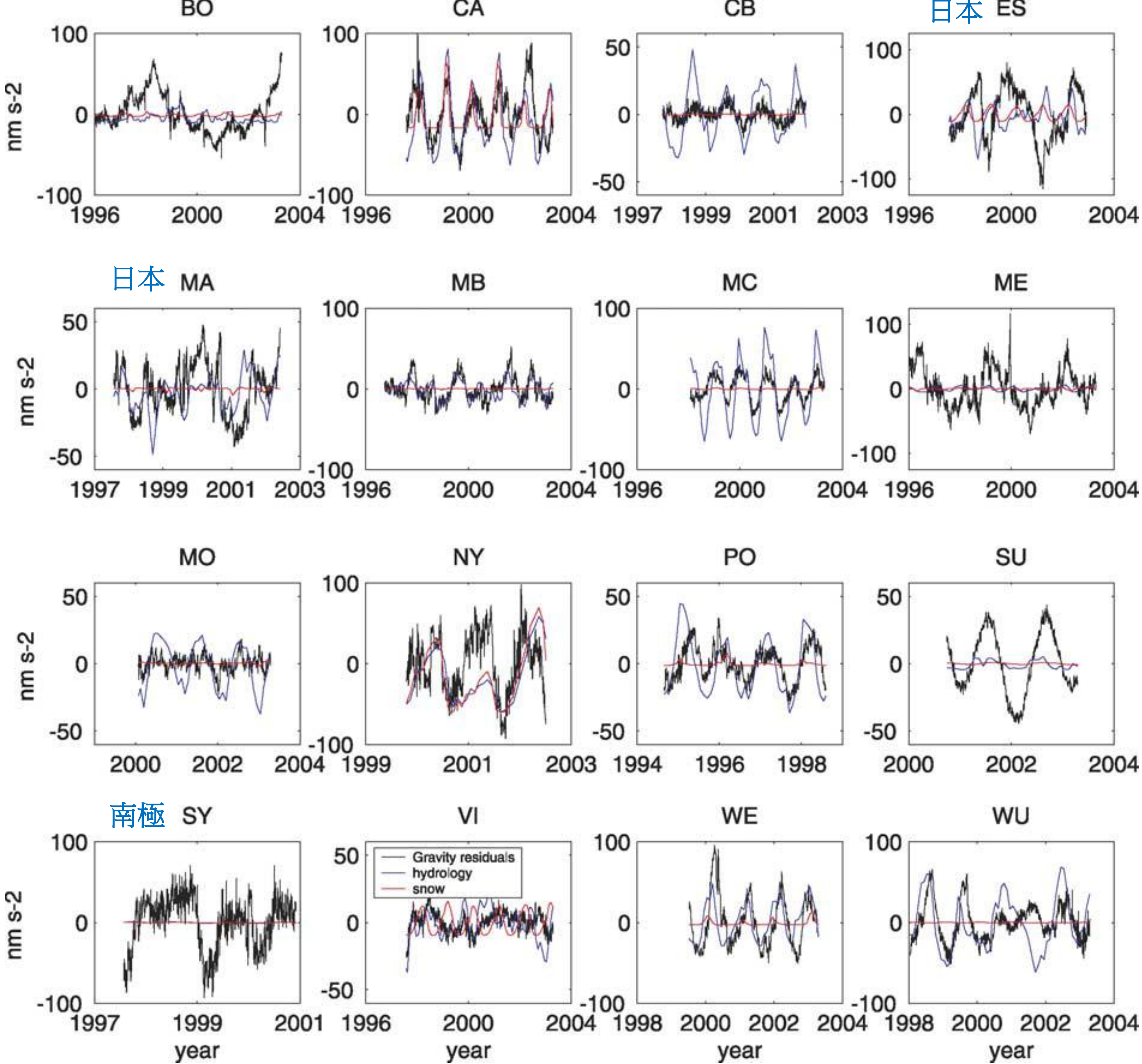
6. Continental water storage loading

- LaD (Land Dynamics)model Milly and Shmakin (2002)
- Spatial：1^{o} / temporal：1 month






observation
(1)
- solid Earth tides
(2)
- ocean tidal loading
(3)
- atmospheric loading
(4)
- pole tide
(5)
- non-tidal ocean loading
(6)
Gravity Residuals
Hydrology loading
nm s-2
year
200
100
50
0
-50
-100
-200
1998
2000
2002
2004



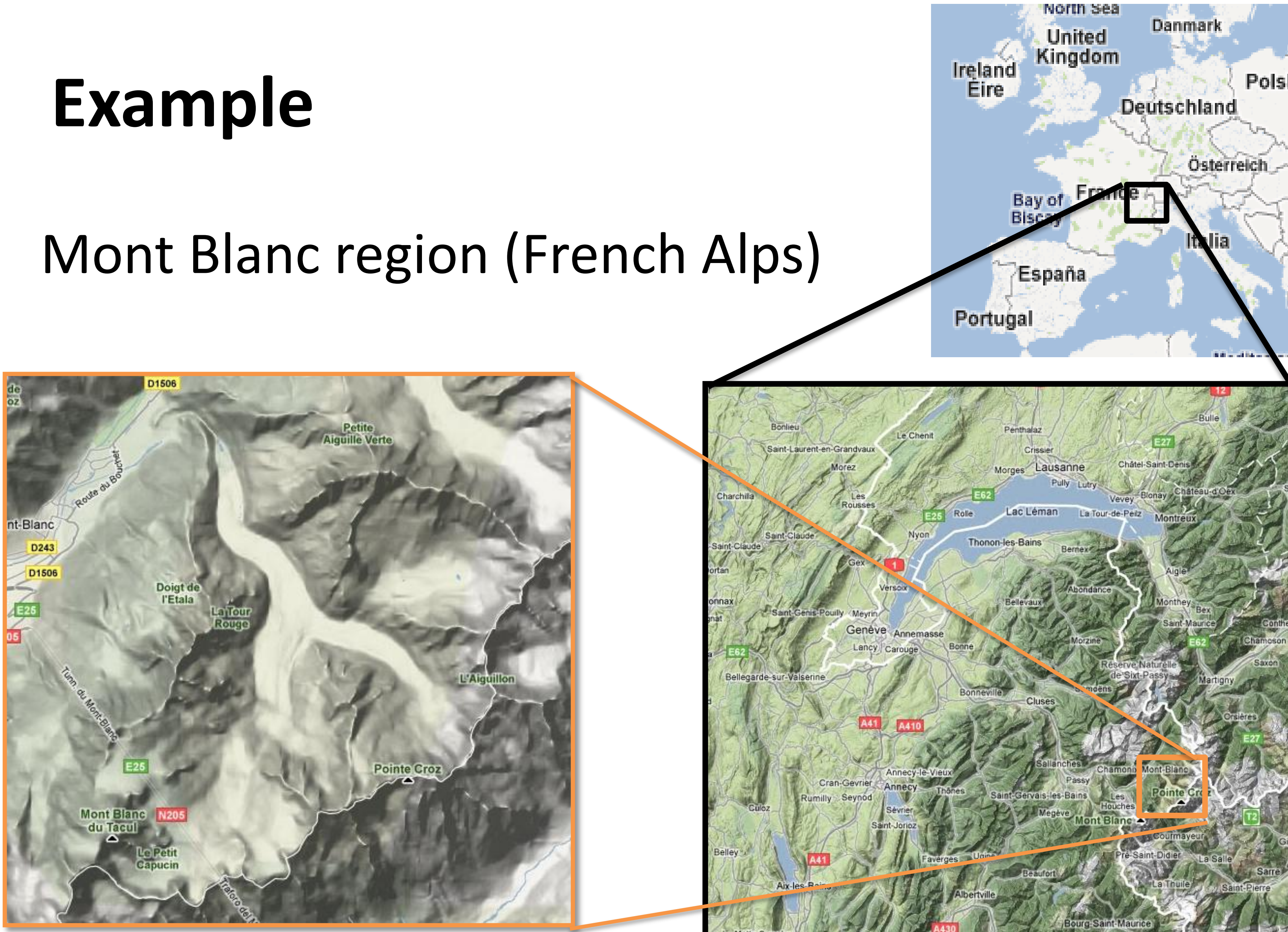
BO
CA
CB
日本 ES
日本 MA
MB
MC
ME
MO
NY
PO
SU
南極 SY
VI
WE
WU
nm s-2
year
Gravity residuals
hydrology
snow

Summary

- May be due to some local effects or the poor spatial resolution (1°) for islands like Japan.
- The contribution of the continental water storage changes (soil-moisture and snow) to gravity variations is one of the largest on seasonal timescales.

Example

Mont Blanc region (French Alps)



Ice thinning data

- 1979–1994: 1 ± 0.4m/yr
- 1994–2000: 2.9 ± 1.1m/yr
- 2000–2003: 4.1 ± 1.7m/yr Berthier et al. (2004)
- On the average over 24 years, it is approximately 2m/yr.

Modeling

- Half-space model：

Density (kg/m3)	Vp (m/s)	Vs (m/s)
2600	5800	3200

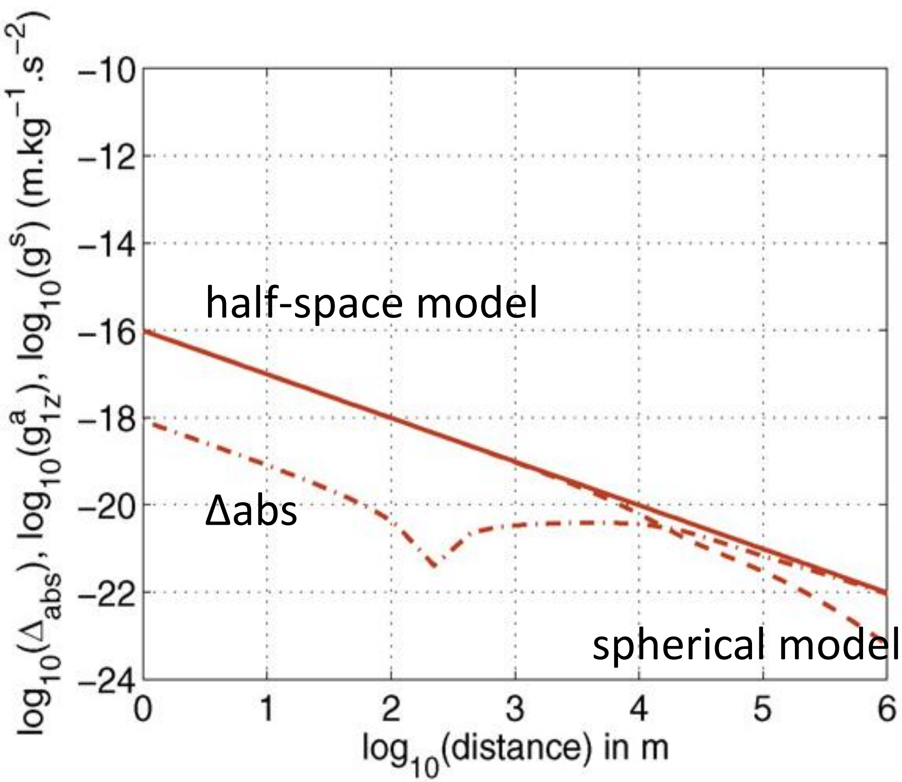
Farrell (1972)

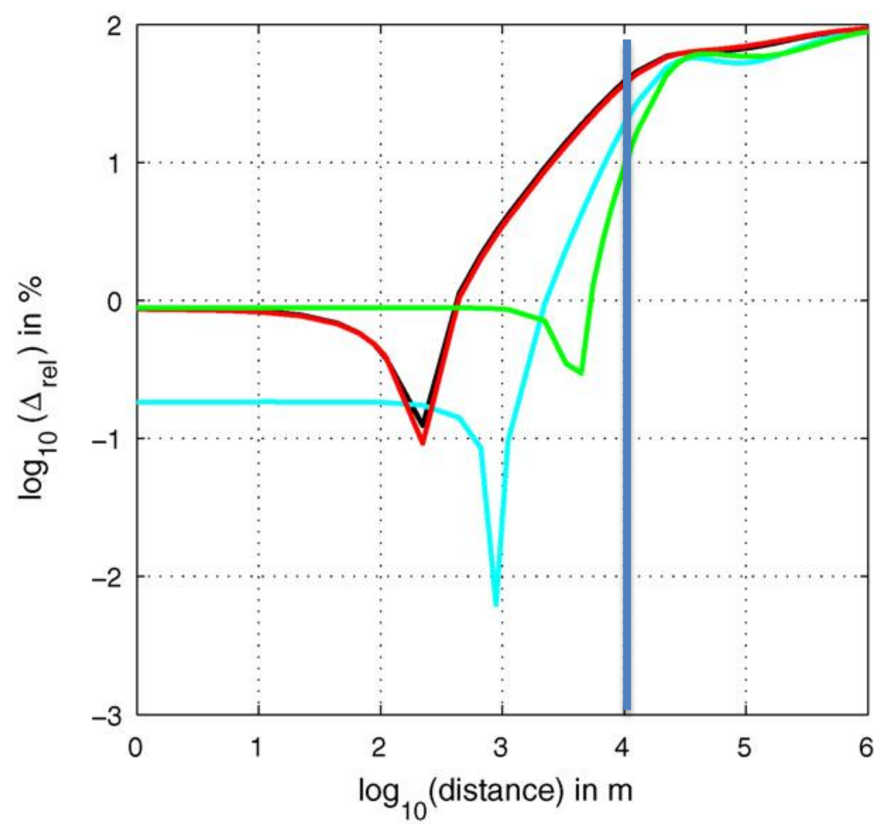
- Spherical model：
  spherically symmetric, non-rotating, and elastically isotropic (SNREI) Earth model

Dziewonski and Anderson (1981)

Half-space model / Spherical model

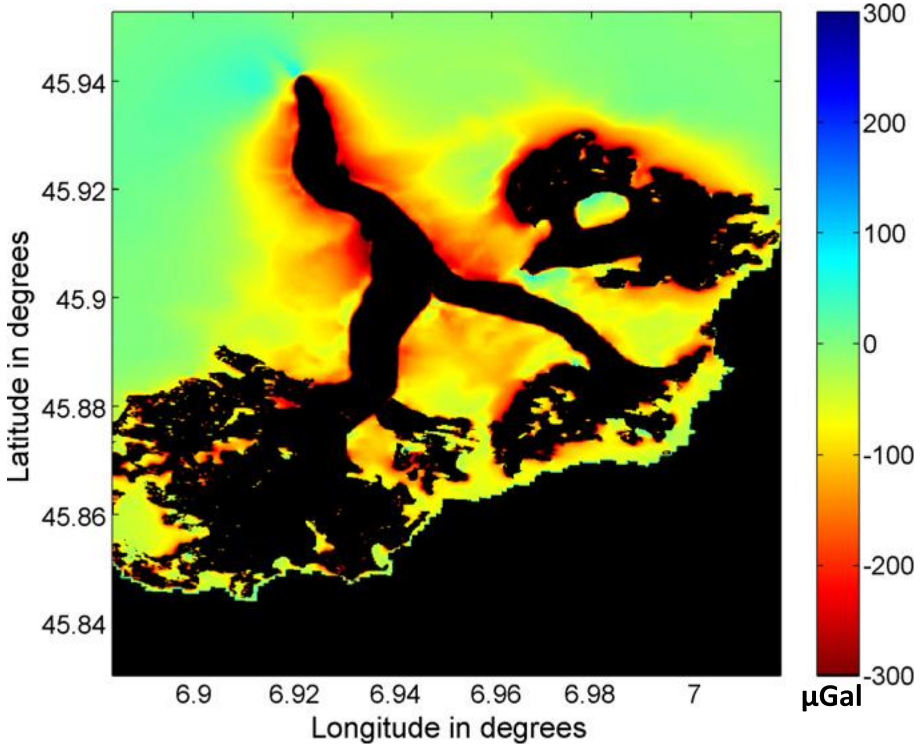
- Δabs(R, 0) = Ga – Gs
- Δrel(R, 0) = Δ abs/Ga



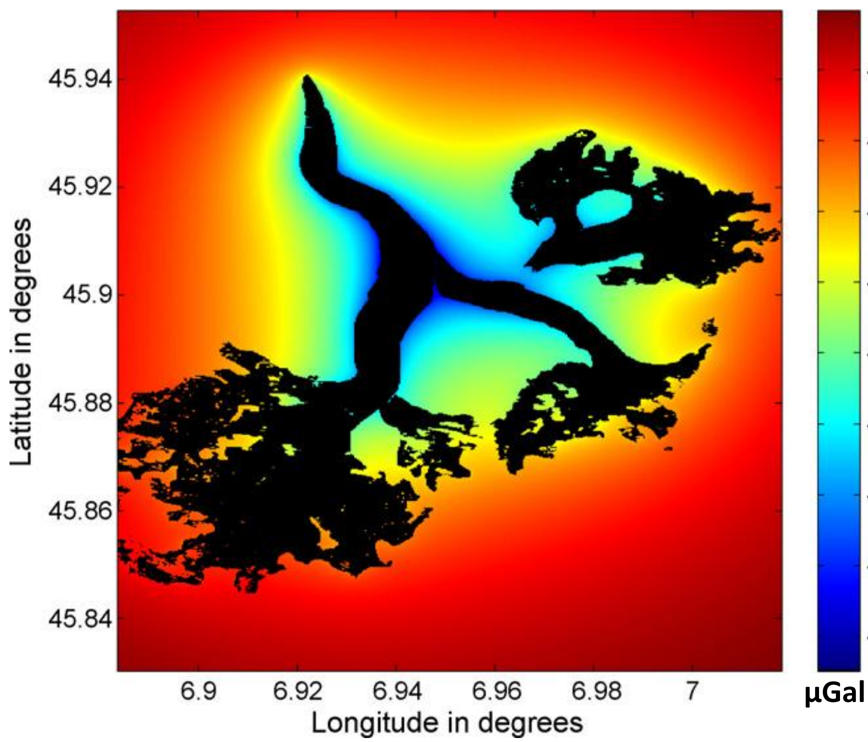


result

Newtonian part of the gravity effects



Elastic part of the gravity effects



Conclusions

- Half-space approximation is sufficient to model the Earth deformation on the local scale.
- Taking into account the topography of both the surrounding ice-free regions and glaciers is necessary to estimate the magnitude of the gravity variations.