Various methods for the definition of reference pressure

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1. The importance of reference pressure

Reference pressure is important for the following calculations:

- Atmospheric pressure loading (Petrov & Boy, 2004)
- Atmospheric gravity (Flechtner, 1997)
- Reference frames (Plag et al., 2007)
- Total atmospheric mass (Gruber, 2004)
- The center of atmospheric mass (Chen et al., 1999)
- Seasonal variations in the atmosphere (Hoinka, 1998)
- …. etc

2. Recommendations for the definition of reference pressure

- **Previous recommendations (Böhm et al., 2008)**

  - **A reference pressure** field should be accompanied by information about its **corresponding height**
  - The model for the reference pressure should be as **simple as possible but accurate**
  - The same reference pressure should be **unambiguously determinable now and any time** in the future
  - The reference pressure should cause **no (or only small) biases** of previous results

- **Some implications from the recommendations**

  - Surface topography model should be clearly defined (orography model or real topography ?, sea level height or ellipsoidal height?)

3. Requirements for ref. pressure to obtain 1mm of station bias

- **Atmospheric pressure loading correction (unit in mm)**

$$APL = r\left(P - P_{ref}\right) \approx 0.5\left(P - P_{ref}\right)$$

$$\sigma_{P_{ref}} = 2 \text{ hpa} \qquad \sigma_{H_{ref}} = 20 \text{ m}$$

In order to obtain the 1-mm level of station bias:

- The reference pressure P_{ref} has to be known with an error of 2 hpa

- The corresponding height H_{ref} has to be known with an error of 20 m

For other purposes, the requirements are different

4. Methods for the definition of reference pressure

- **Various possible methods**

  - **Empirical pressure model**

    + Berg model (Berg, 1948)

    + Global Pressure and Temperature (GPT) model (Böhm et al., 2007)

  - **Pressure data from Numerical Weather Models (NWM)**

    + Global average of the surface pressure data

    + Reduced reference pressure at the 5’ x 5’ topographic height (Plag et al., 2007)

    + Reduced reference pressure at the mean height of a cell with pre-defined size

4. Methods : Empirical pressure model (1)

- **Berg model (Berg, 1948)**

  - Required input: Height

$$p = p_o \left(1 - 0.0000226\, H\right)^{5.225}$$

p_o = the reference pressure (~ 1013.25 hPa), H = the height above MSL

- **GPT model (Böhm et al., 2007)**

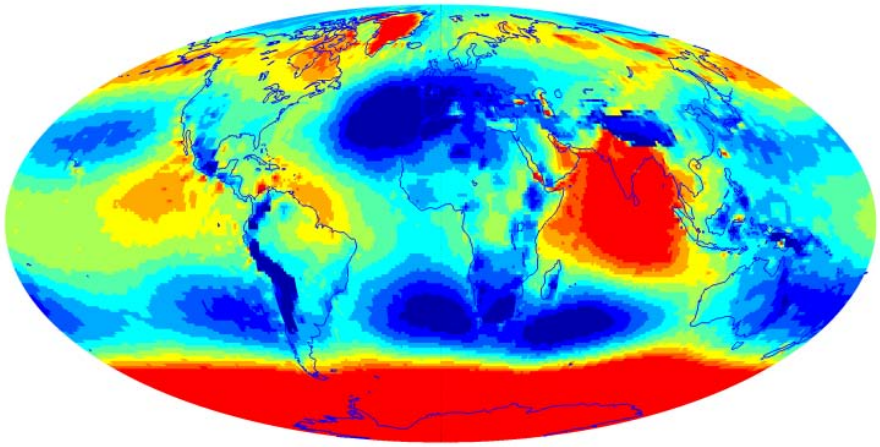
  - Required inputs: Latitude, Longitude, Height

  - Spherical harmonic expansion up to degree and order 9

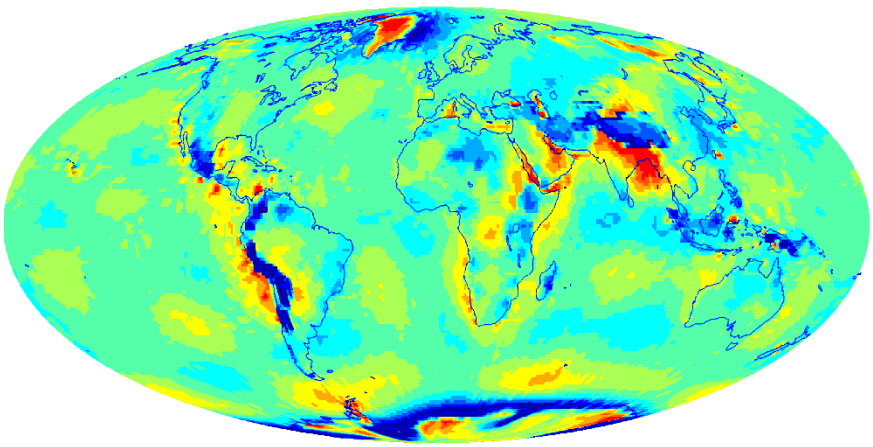
4. Methods : Empirical pressure model (2)

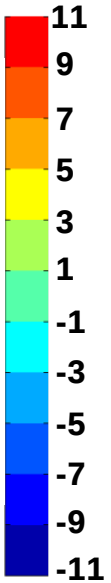
- **Model error wrt the reference pressure derived from the ECMWF (1994-2007)**

Pressure errors (hPa) of the Berg model



Pressure errors (hPa) of GPT





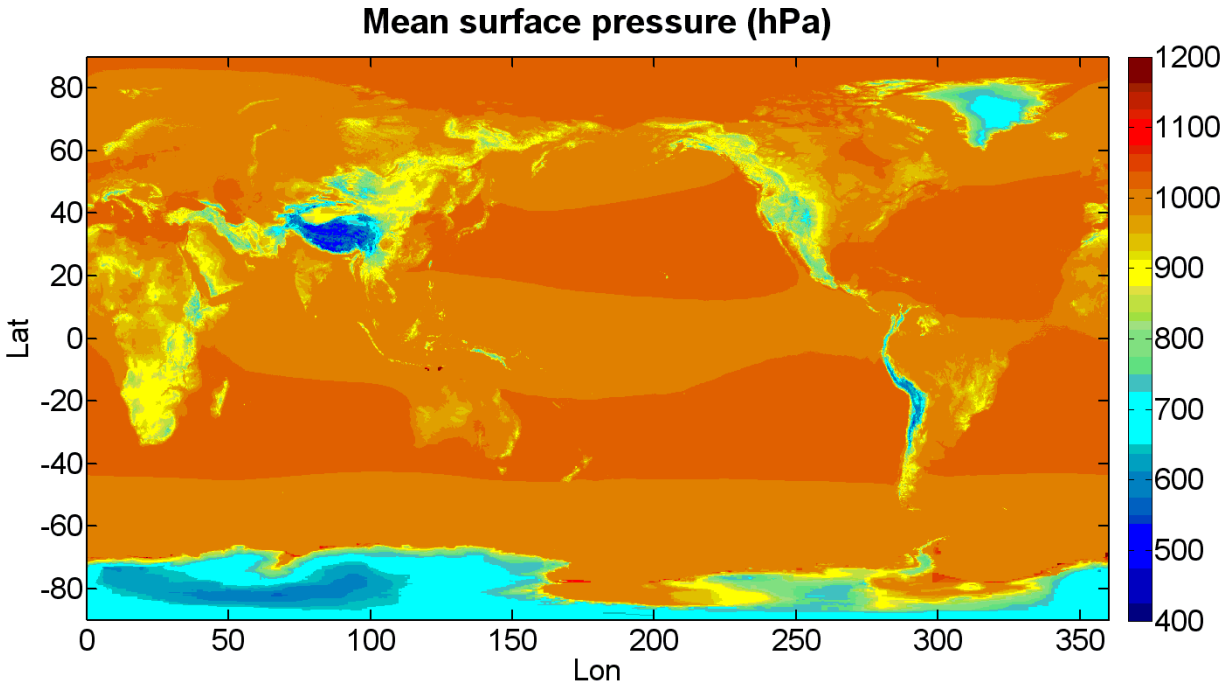
Percentage (%) of the area with pressure error below a certain threshold

	Berg	GPT	Berg	GPT
	< 2 hPa		< 10 hPa	
Land+Ocean	27	71	83	98
Land	28	56	85	96

(Böhm et al., 2008)

4. Methods : Global average

- **Global pressure average derived from the ECMWF or other numerical weather models**



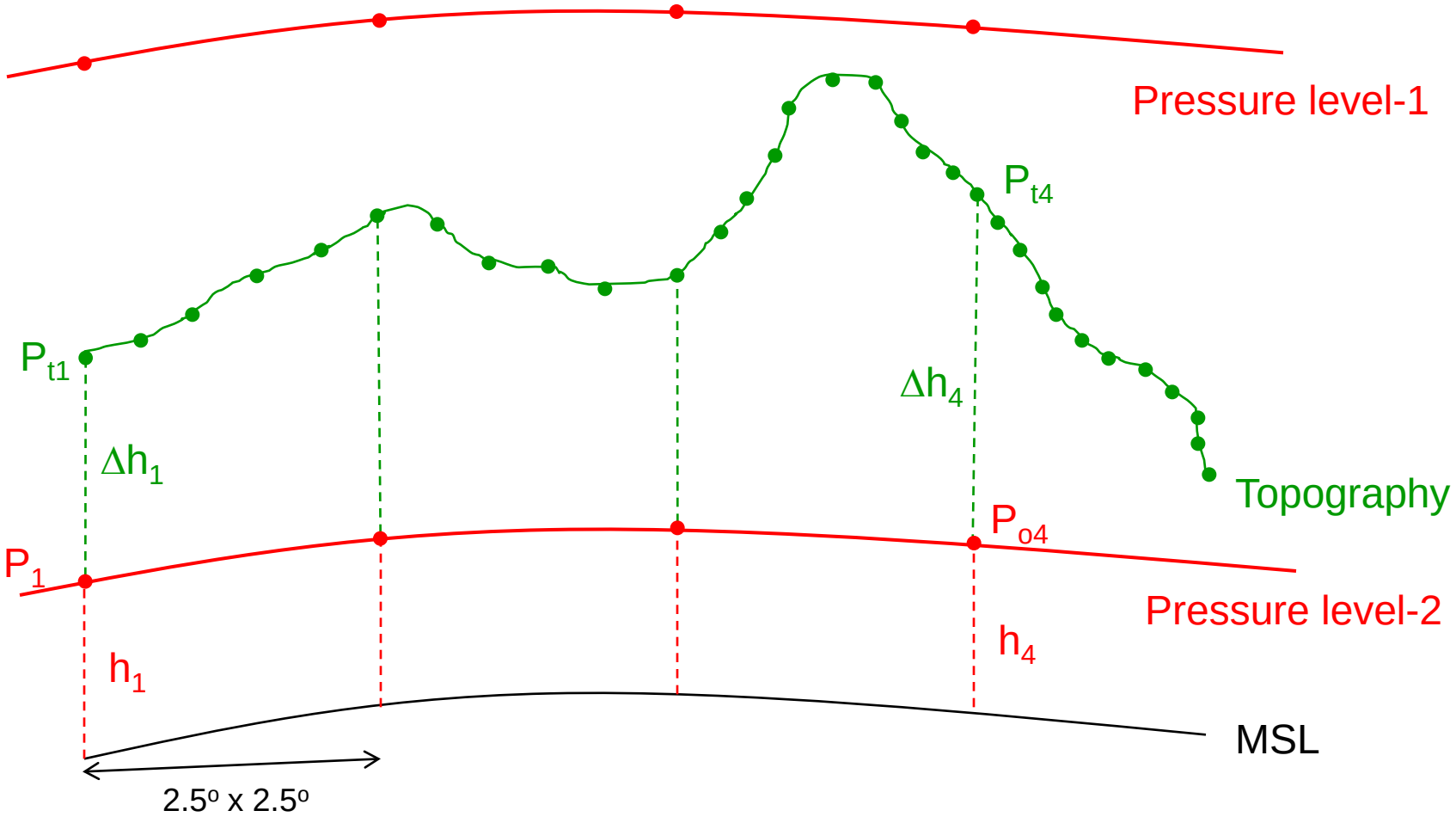
(Plag et al., 2007)

Some crucial issues:

- **Different meteorological sources use different orography models**
- **An optimum time period for the averaging: 1, 5 or 10 years ?**
- **Which time period ?**
- **What to do in case of trends ?**

4. Methods : Reference pressure at the topographic height (1)

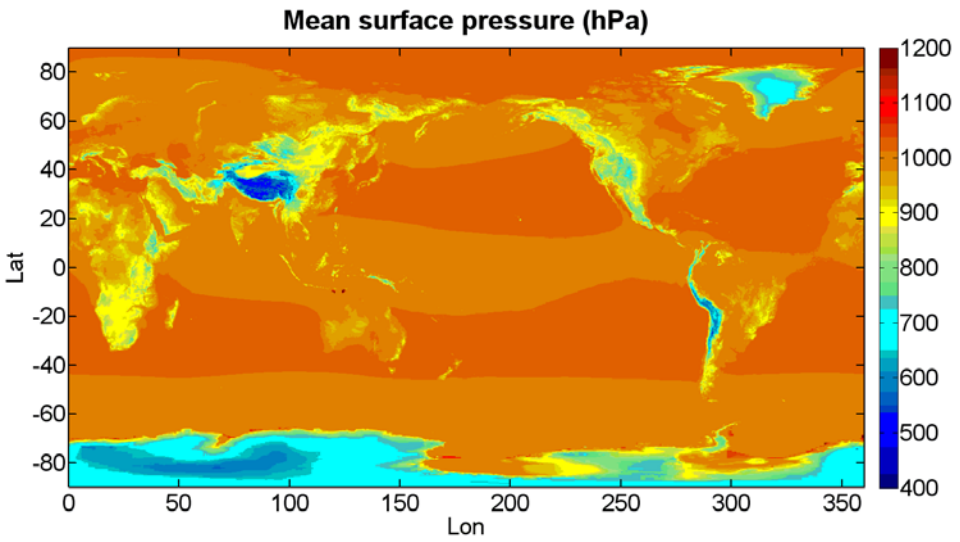
- **Reduction from pressure level to the topography**

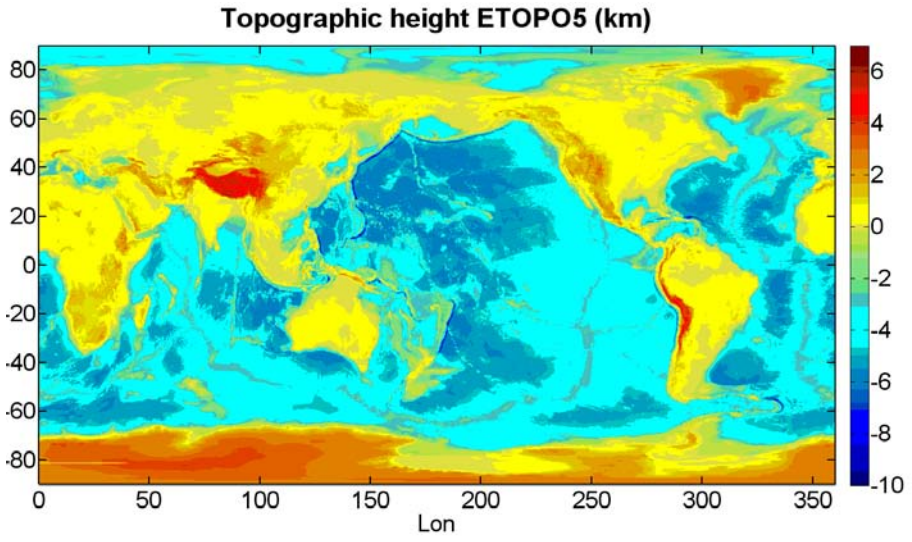


(Plag et al., 2007)

4. Methods : Reference pressure at the topographic height (2)

- **Data bases for the mean pressure and topographic height in 5’ x 5’ grid**





Data source for the mean pressure:

- Hans-Peter Plag’s website

http://cheryl.nbmg.unr.edu/hanspeterplag/tools/air_pressure_refs/

- Averaging interval: 1992 to 2000

- Original data source: ECMWF with 2.5º x 2.5º

Data source for ETOPO5:

- National Geophysical Data Center (NGDC)

http://www.ngdc.noaa.gov/mgg/global/etopo5.HTML

- Original grid size: 5’ x 5’

4. Methods : Reference pressure at the mean height (1)

- **Reduction to the mean height of a defined cell (block-mean)**

Results consistent with those provided by Plag et al. (2007)

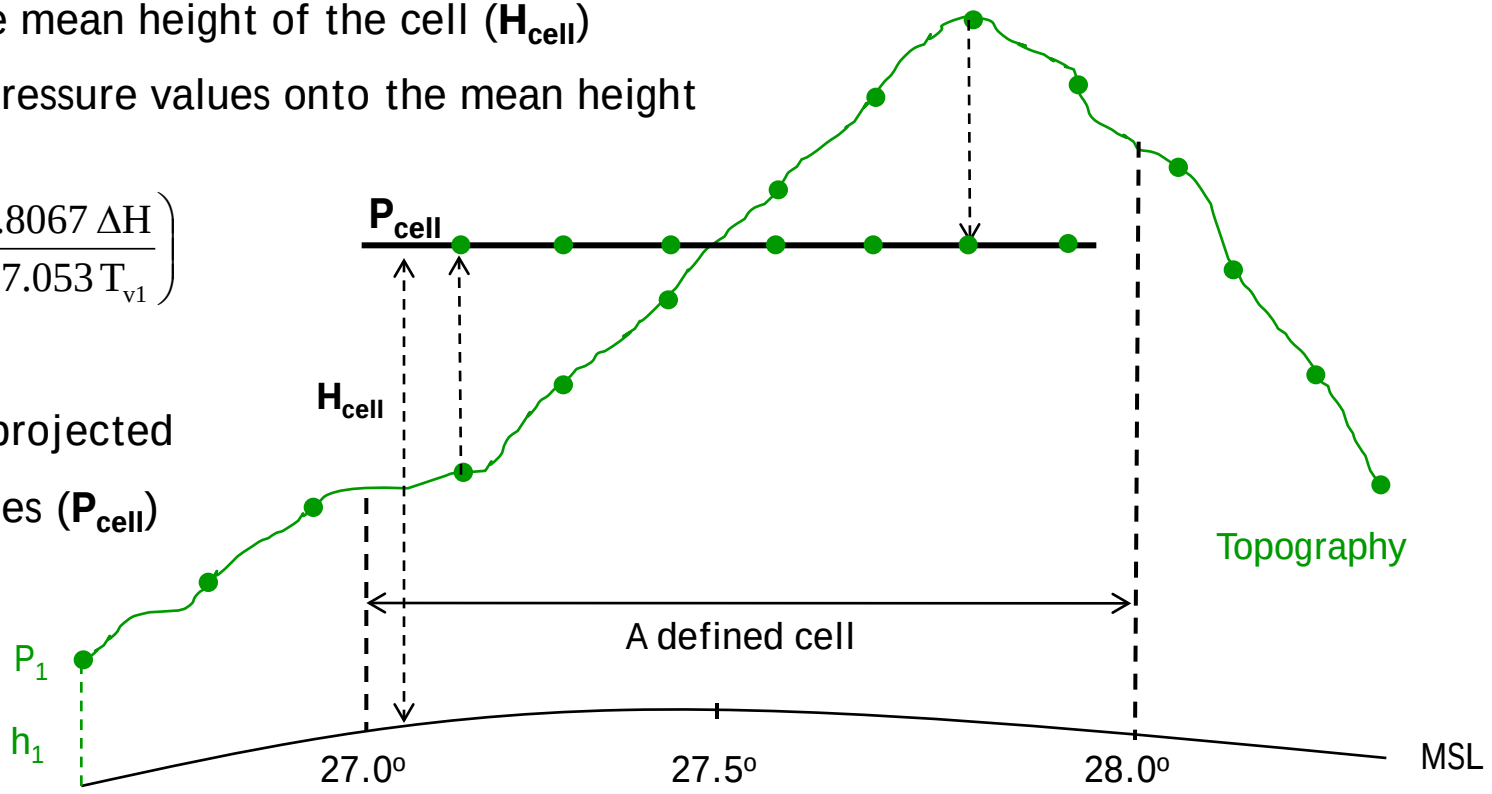
a. Define a cell with standard size (0.5° x 0.5°, **1.0° x 1.0°**, 2.5° x 2.5°)

b. Calculate the mean height of the cell ($\mathbf{H_{cell}}$)

c. Project the pressure values onto the mean height

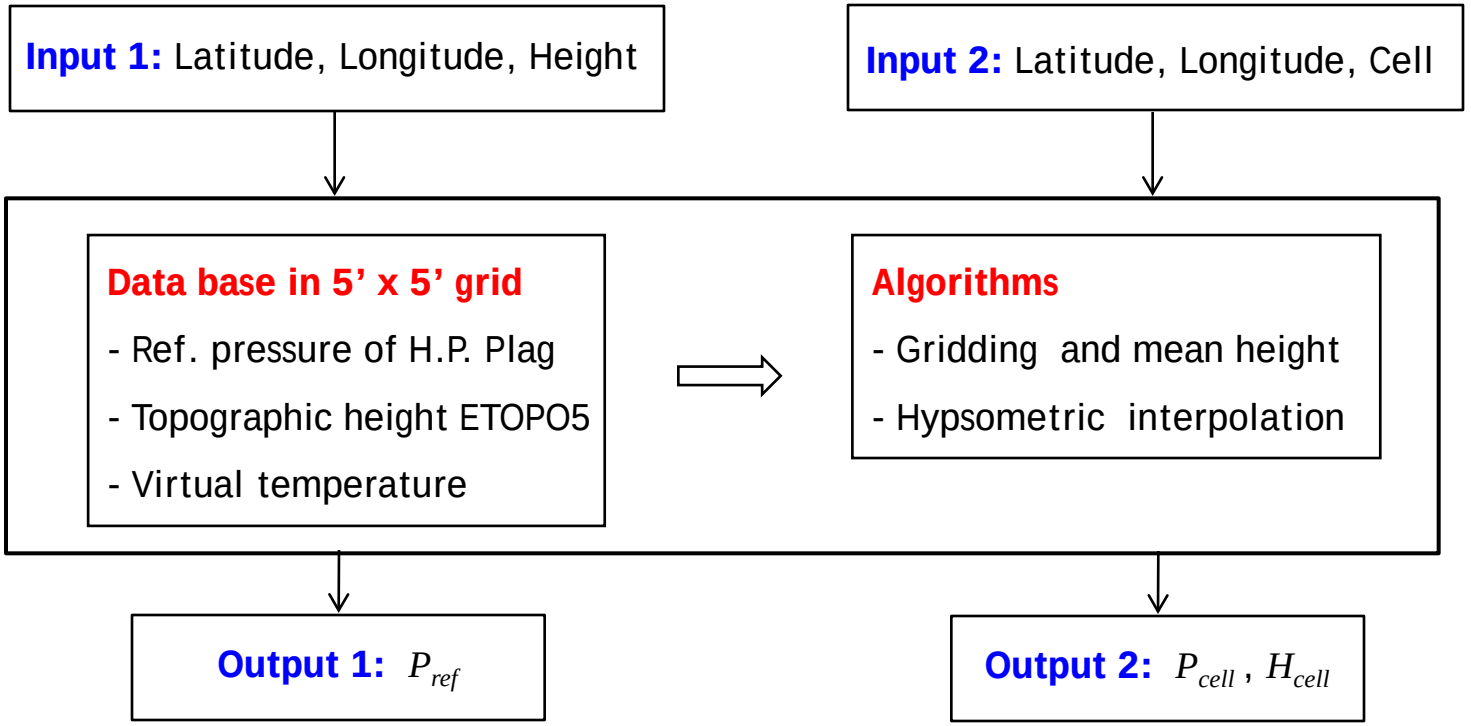
$$P_2 = P_1.\exp\left(\frac{-9.8067\,\Delta H}{287.053\,T_{v1}}\right)$$

d. Average the projected pressure values ($\mathbf{P_{cell}}$)



4. Methods : Reference pressure at the mean height (2)

- **Flowchart for the calculation of the reference pressure**



Outputs:

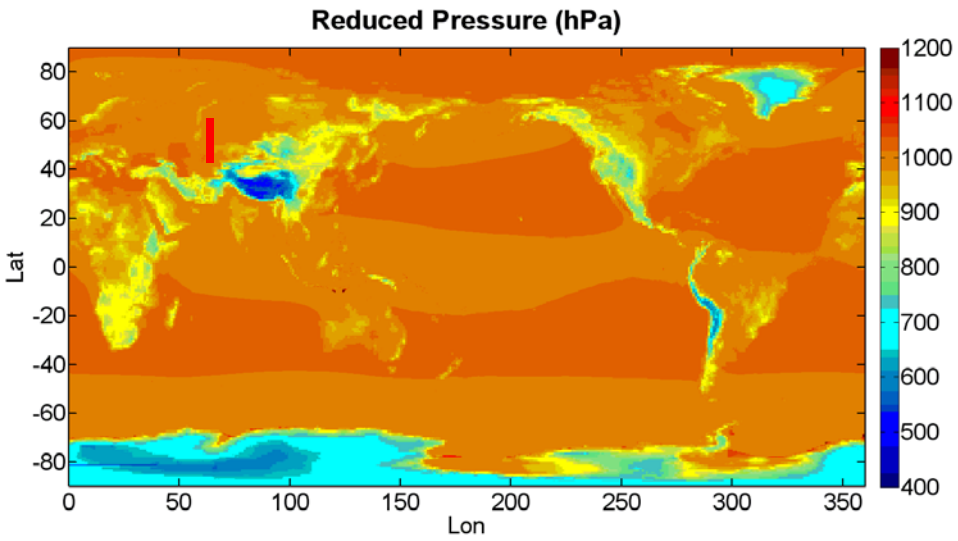
P_{ref} : reference pressure at a defined site

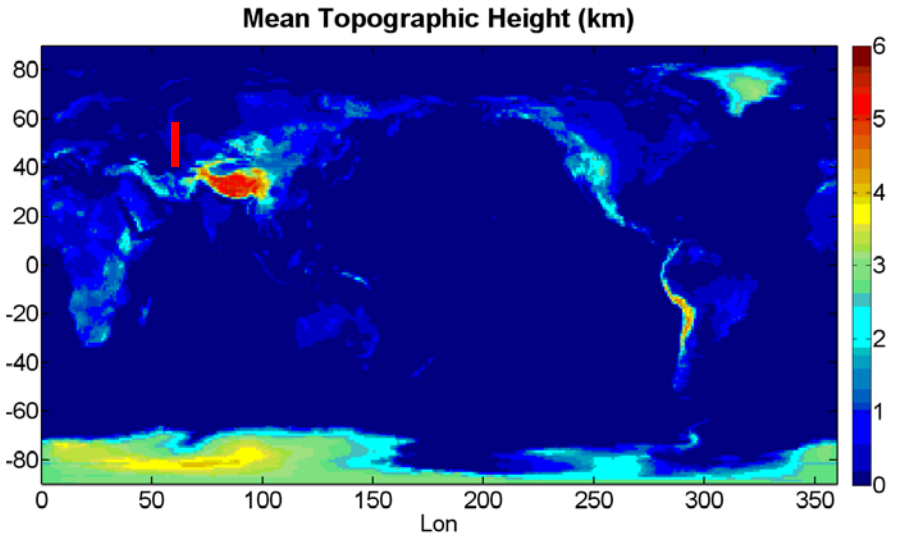
P_{cell} : reference pressure at a mean height of a defined cell size

H_{cell} : mean height of a defined cell size

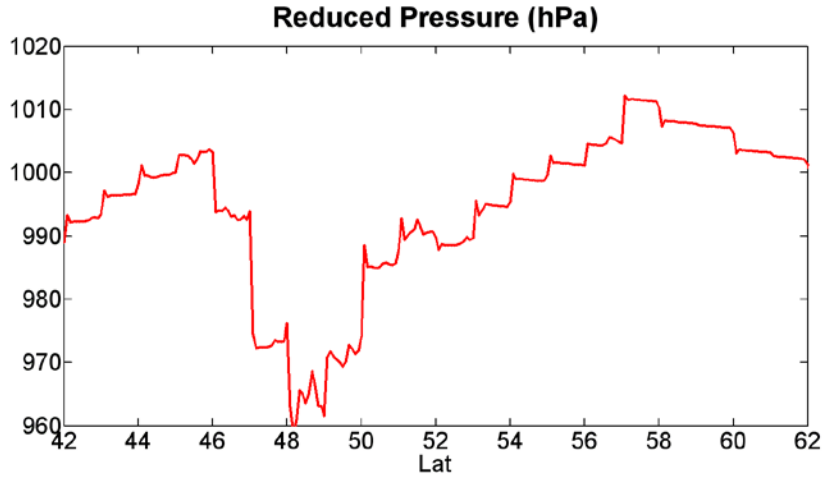
4. Methods : Reference pressure at the mean height (3)

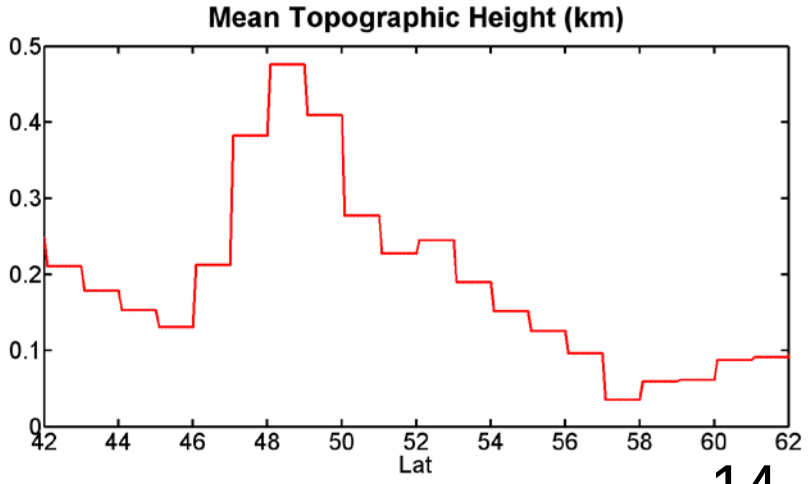
- **Numerical results: Cell size of 1º x 1º**





Profile at Lon=67º





5. Remarks, summary & recommendations (1)

- **Comparison of all methods**

	Empirical model		Pressure data from NWM		
	Berg	GPT	Global mean	Reduced to topography	Reduced to mean height
Accuracy	No	Yes*	Yes	Yes	Yes
Height-Relation	Yes	Yes	Yes*	Yes	Yes
Easy calculation	Yes	Yes	No	No	Yes
Unambiguous determination	Yes	Yes	No	No	No
Block-mean	No	No	No	No	Yes

*** with exception of rapid altitude variation**

5. Remarks, summary & recommendations (2)

- **Summary**

  - Various methods for the definition of reference pressure have been shown
  - The method should be simple and produce accurate reference pressure
  - Height information should be provided for the reference pressure
  - The reference pressure should be unambiguously determinable now and any time in the future
  - The reference pressure should cause no (or small) biases of previous results

- **Practical recommendation**

  - The reference pressure data with a standard grid size (0.5^o, 1.0^o, 2.0^o, 2.5^o) or the software to calculate the reference pressure should be put at a common place, which could be easily accessed by the user