Integral characteristics of Polar lows

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Baikal Young Scientists' International School on Fundamental Physics
"Physical processes in outer and near-earth space"

XV Young Scientists' Conference
«Interaction of fields and radiation with matter»

Irkutsk, 11 - 16 September 2017

Overview

- Motivation
- Object of research
- Helicity. Main equations for the Ekman flow
- Correlation between the integral helicity and the square of the geostrophic wind velocity components
- Diagnostic meaning of the helicity
- Selection criterion for the helicity estimation
- Analysis of the global helicity fields in the Atmospheric boundary layer according to the data from ECMWF and to the findings of the WRF model as in the case of March 2013
- Prognostic meaning of the helicity
- Summary and results

Motivation

- Harley D.G. 1960

Some publications in a recent 15 years:

- Rasmussen E. A. , Turner J., «Polar Lows», 2003
- G. Fu, T. Kato, H. Niino and R. Kimura, 2003
- James A. Renwick, 2004
- Condron A. and Grant R. Bigg, 2005
- Mokhov I.I. and Akperov M.G., 2003, 2006
- Claud C., Duchiron B., and Terray P., 2007
- Claud C., Carleton A.M., Duchiron B. , Terray P., 2008
- Zahn M., H. von Storch, 2008
- Thomas J. Bracegirdle and Suzanne L. Gray, 2008
- Blechschmidt A.-M., 2008
- Golicyn G.S., 2008, 2012
- Shkolnik I.M. and Efimov S.V., 2013
- Zappa G. and Shaffrey L., Hodges K. , 2014
- Shun-Ichi I. Watanabe and Hiroshi Niino, 2014
- Pegahfar N., Ghafarian P., 2015 ………

Similarity of the Polar Lows and Tropical Cyclones:

- Polar Lows 2003
- G. Fu, T. Kato, H. Niino and R. Kimura, 2003
- Golicyn G.S., 2008
- Shkolnik I.M. and Efimov S.V., 2013
- Akter F., Ishikawa H., 2014
- ………

Object of Research

Morphological characteristics, referred to in the definition of Polar Lows (Rasmussen and Turner, 2003):

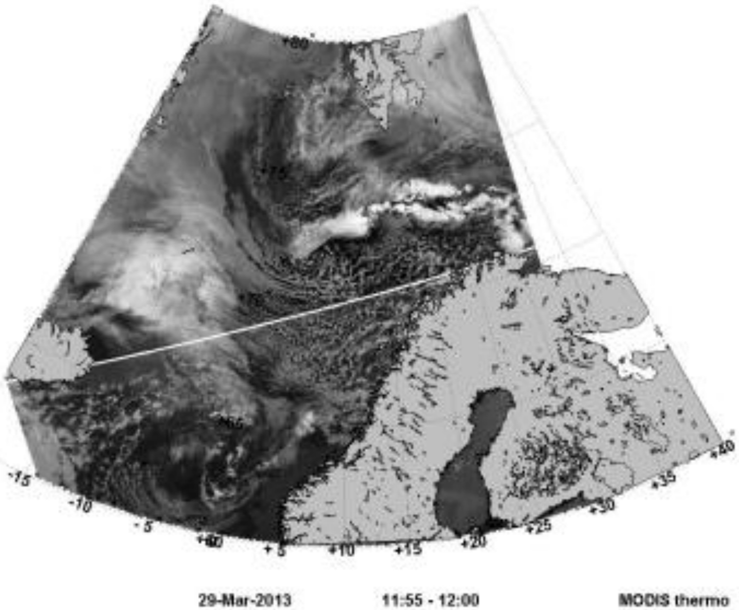
- approximate diameter is 150, 200 or 550 km (1000 km) (diameter of the external closed-loop pressure contour);
- created over ocean surface to northward of the main baroclinic zone (polar front);
- wind velocities in the area of the maximum ones ≥15 м/с

50 km/h, day

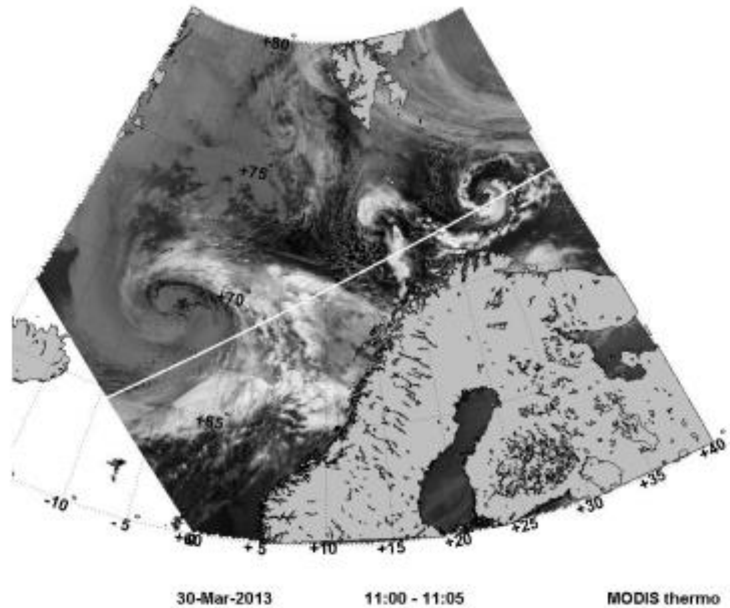
Object of research (Verezemskaya, 2014):

Mesocyclonic formations, that can be observed over Norwegian Sea and Barents Sea surfaces in the period between 27 and 31 March, 2013

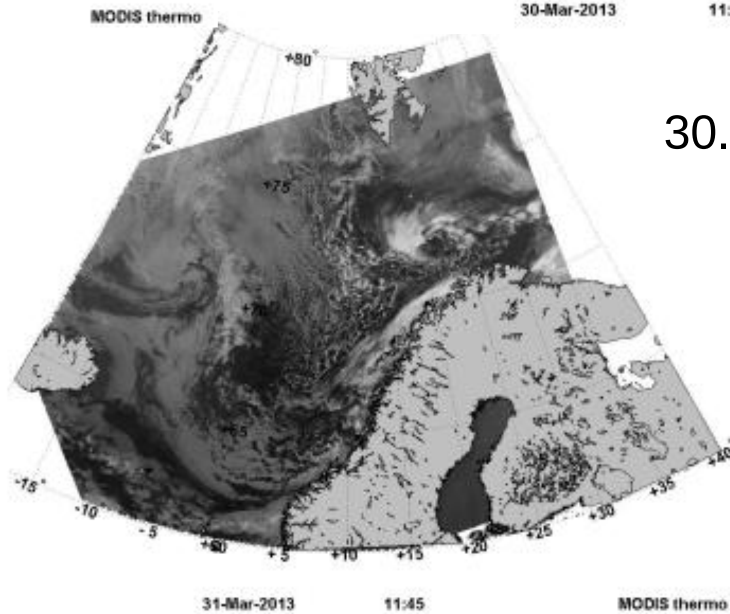
MODIS images for the object of research



29.03.13 12:00 UTC



30.03.13 11:00 UTC



31.03.13 12:00 UTC

Helicity. Main equations for the Ekman flow

The helicity is defined as the scalar product of velocity and vorticity–

$$\mathrm{H} = v \cdot rot(v).$$

The Ekman flow is:

$$U = U_G\left(1 - \exp\left(-\frac{z}{h}\right)\cos\frac{z}{h}\right) - V_G \exp\left(-\frac{z}{h}\right)\sin\frac{z}{h};$$

$$V = V_G\left(1 - \exp\left(-\frac{z}{h}\right)\cos\frac{z}{h}\right) + U_G \exp\left(-\frac{z}{h}\right)\sin\frac{z}{h}.$$

Here $h = \sqrt{\nu/_{\Omega}}$ - the Ekman scale,

V_G, U_G - the geostrophic wind velocity components in a free atmosphere. The vertical components of the vorticity in these cases can be neglected.

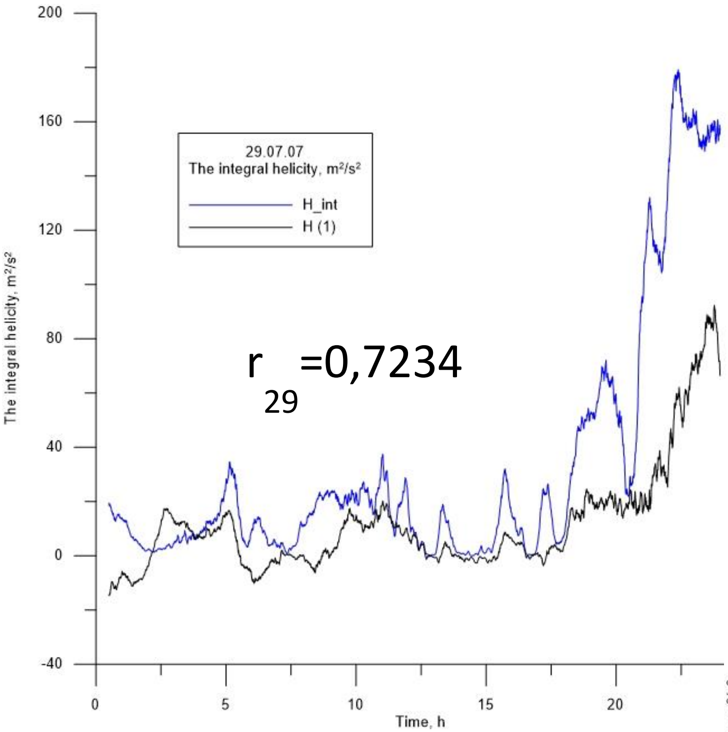
In that case the helicity (Ekman flow helicity (Hide, Kurgansky)) is:

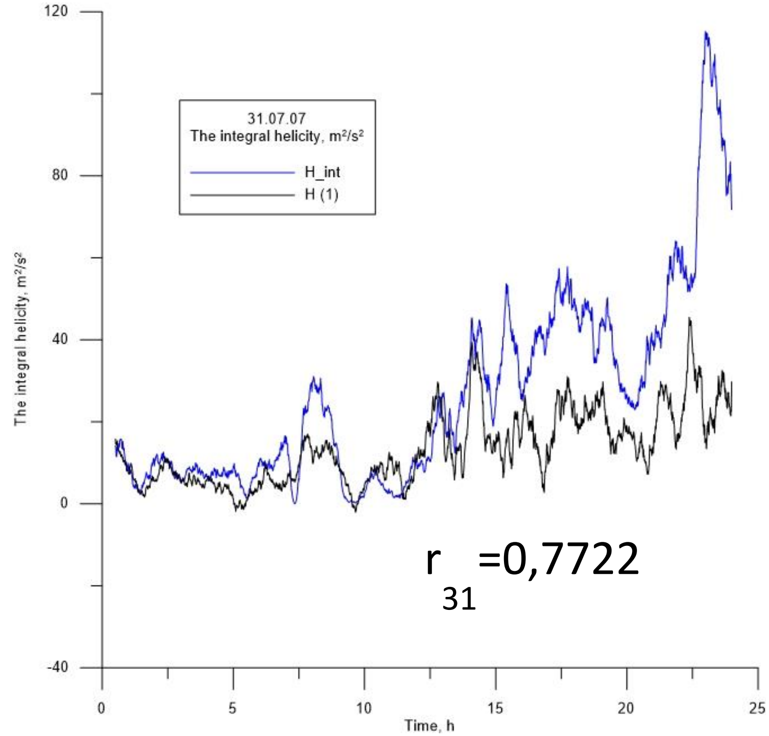
$$H = -U\frac{\partial V}{\partial z} + V\frac{\partial U}{\partial z}. \qquad (1)$$

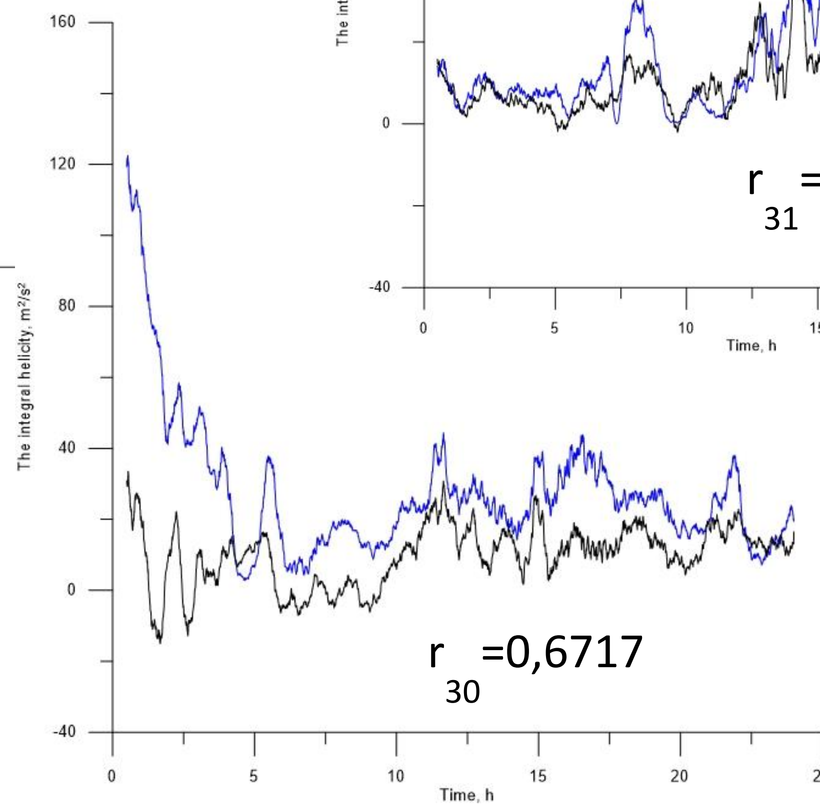
And the integral helicity (Kurgansky, 1989) is:

$$H_{int} = \int_0^{\infty} H dz = \frac{1}{2}\left({U_G}^2 + {V_G}^2\right). \qquad (2)$$

Correlation between the integral helicity and the square of the wind velocity components on the highest sounding levels







Kalmykia, 2007;
same results in
Tsimlyansk 2012

Publications

- Vazaeva N. V., Chkhetiani O.G., *Kouznetsov R.D., Kallistratova M.A., Kramar V.F., Lyulyukin V.S., Kouznetsov D.D.* The helicity estimation in the Atmospheric boundary layer according to acoustic sounding data. // Izvestiya RAS, Atm. and Oc. physics. – 2017. – V. 53. № 2. – P. 200-214.
- Vazaeva N. V. et al. On the helicity estimation in the atmospheric boundary layer // EGU General Assembly Conference Abstracts. – 2015. – T. 17. – C. 2203.
- Vazaeva N.V., Chkhetiani O.G., Maksimenkov L.O., Kurgansky M.V. Helicity estimations in the atmospheric boundary layer // «Nonlinear waves - 2016», Nizhny Novgorod, 27 February - 4 March 2016.
- Vazaeva N.V., Chkhetiani O.G., Maksimenkov L.O., Kurgansky M.V. Polar lows: helicity dynamics // «Climate, geography and environment of the Russian Arctic», Apatity, 4 - 10 September 2016.

- And others

Helicity in the atmosphere

- Etling D., 1985
- Hauf T., 1985
- Lilly D.K., 1986
- Kurgansky M.V., 1989
- Hide R., 1990
- Droegemeier K. K., Lazarus S. M., Davies-Jones R., 1993
- Markowski P.M., Straka J.M., Rasmussen E.N., Blanchard D.O., 1998
- Chkhetiani O.G, 2001
- Doswell C.A. and Schultz D.M., 2006
- Onderlinde M.J., Nolan D.S., 2014

Prognostic meaning?

- Pichler H., Schaffhauser A., 1997
- Tan Z., Wu R., 1994
- Glebova E.S., Levina G.V., Naumov A.D., Trosnikov I.V., 2009
- Lavrova A.A., Glebova E.S., Trosnikov I.V., Kaznacheeva V.D., 2010
- Levina G.V., Montgomery M.T., 2010
- Levina G.V., Montgomery M.T., 2011
- Pegahfar N., Ghafarian P., 2015

Diagnostic meaning of the helicity

Some being used parameters of the cyclone intensity

- Storm-relative environmental helicity (storm-relative helicity):

$$\mathrm{SRE}H = \int_0^h \left[(\vec{V} - \vec{C}) \cdot \left(\vec{k} \times \frac{\partial \vec{V}}{\partial z} \right) \right] dz \,,$$ (*Onderlinde, Nolan, 1990*);

Relative helicity:

$$H = (v - v_{mean}) \frac{\partial u}{\partial z} - (u - u_{mean}) \frac{\partial v}{\partial z},$$ (*Davies-Jones, 1990*);

$\vec{V}$- horizontal component of the wind velocity, $\vec{C}$- the velocity of the cyclone, h is chosen between 1 and 3 km, $\vec{k}$ - unit vector vertically, $\frac{\partial \vec{V}}{\partial z}$ - wind velocity shift; u, v – wind velocity components in the cyclone, u_{mean}, v_{mean} - velocity components of the cyclone center

- Helicity index:

$$S = \frac{8\pi}{3} \int_0^\infty V^3 dr,$$ (*Kurgansky, 2008*);

S – helicity index (m^4/s^3), V – tangens component of the wind velocity (m/s), r – radius (m)

Selection criterion for the estimation of helicity as the integral square characteristic, being referred to aggregate vortex formation

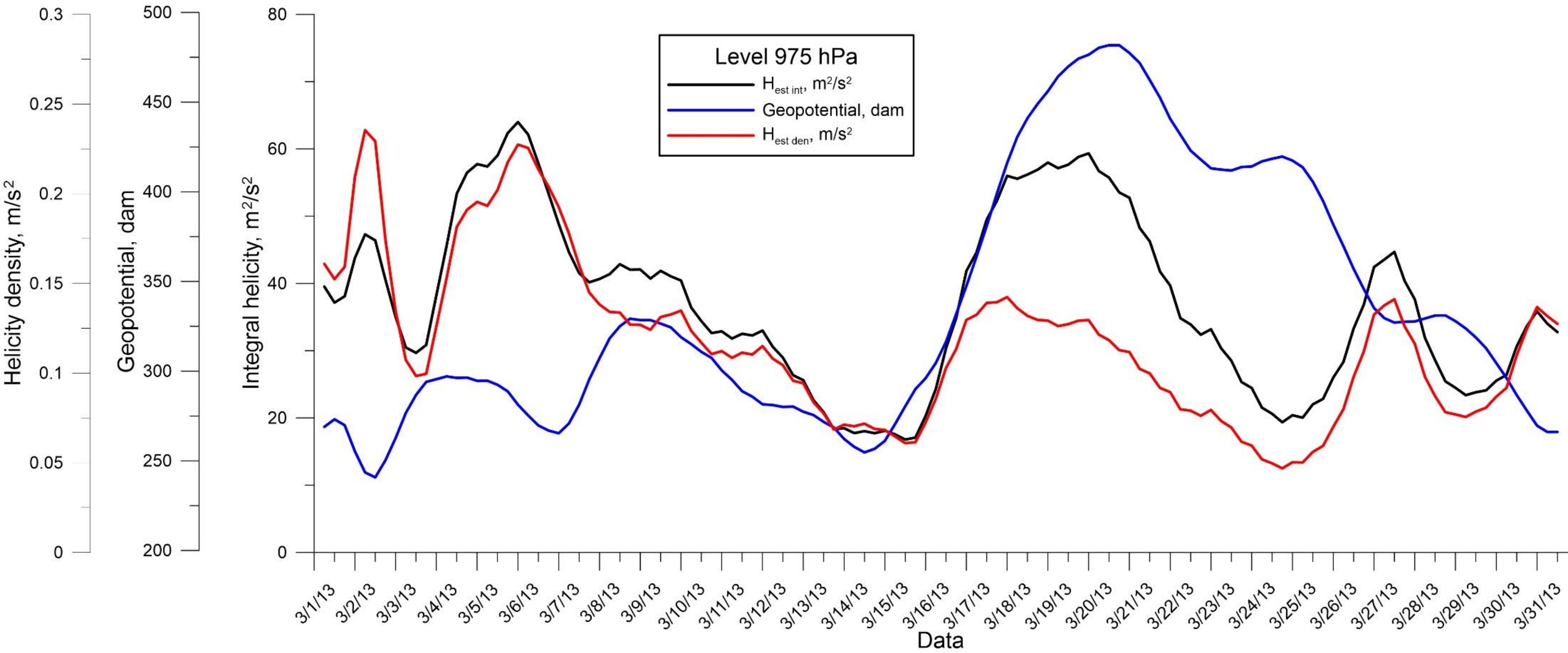
- h (U_G, V_G) - ? ⟶ Levels 975, 850, 700 hPa
- $H_{int}(x_i, y_i) = \frac{1}{2}\left({U_G}^2 + {V_G}^2\right).$
- $H_{den}(x_i, y_i) = \frac{1}{2HGT}\left({U_G}^2 + {V_G}^2\right).$

- $H_{est} = \overline{H}_S = \overline{\sum_{x_i, y_i \epsilon S} H\ (x_i, y_i)}$

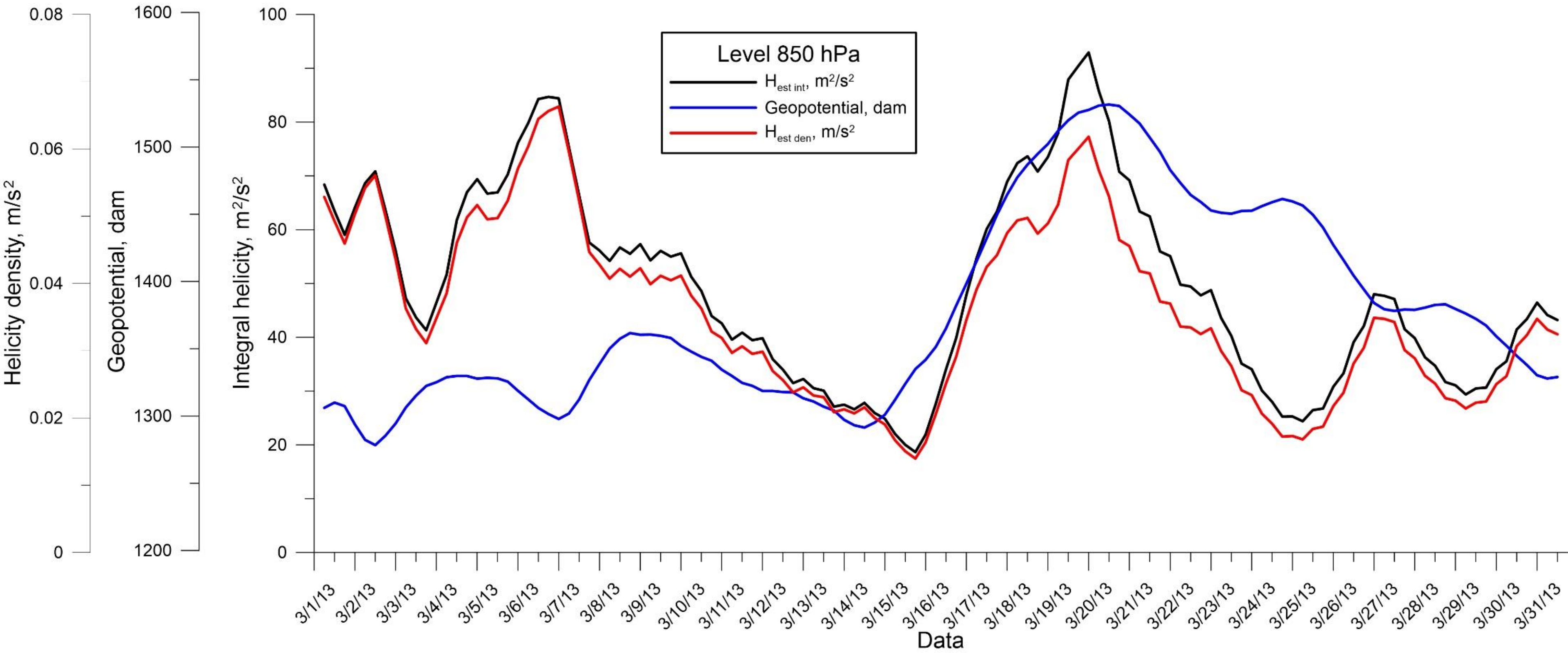
where S: square lon = 0-60°E; lat = 60-90°N

(For the moving with Polar Low square the result was qualitatively similar); $H\ (x_i, y_i)$ defined as (2).

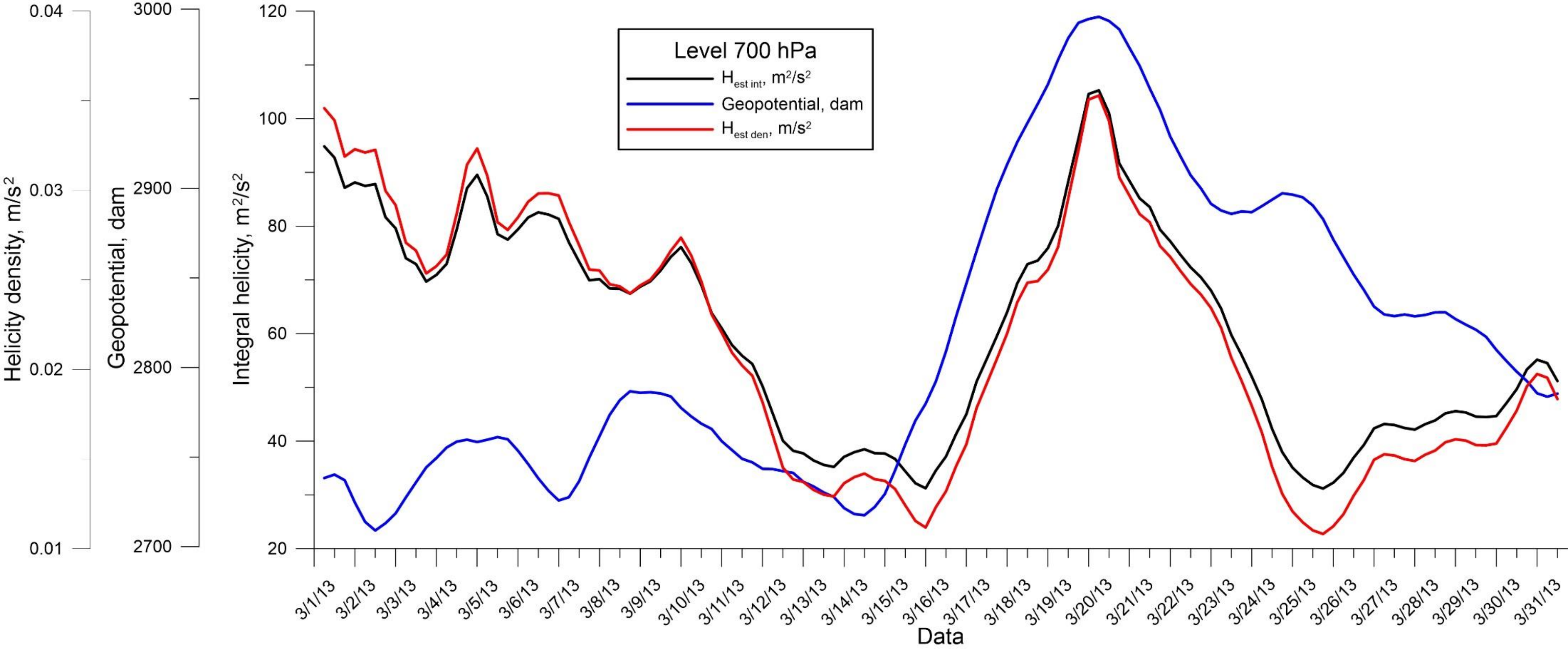
The comparison of the time behavior of the square average integral helicity and helicity density estimation according to the data from ECMWF for the period 01.03.13 – 31.03.13. Level 975 hPa



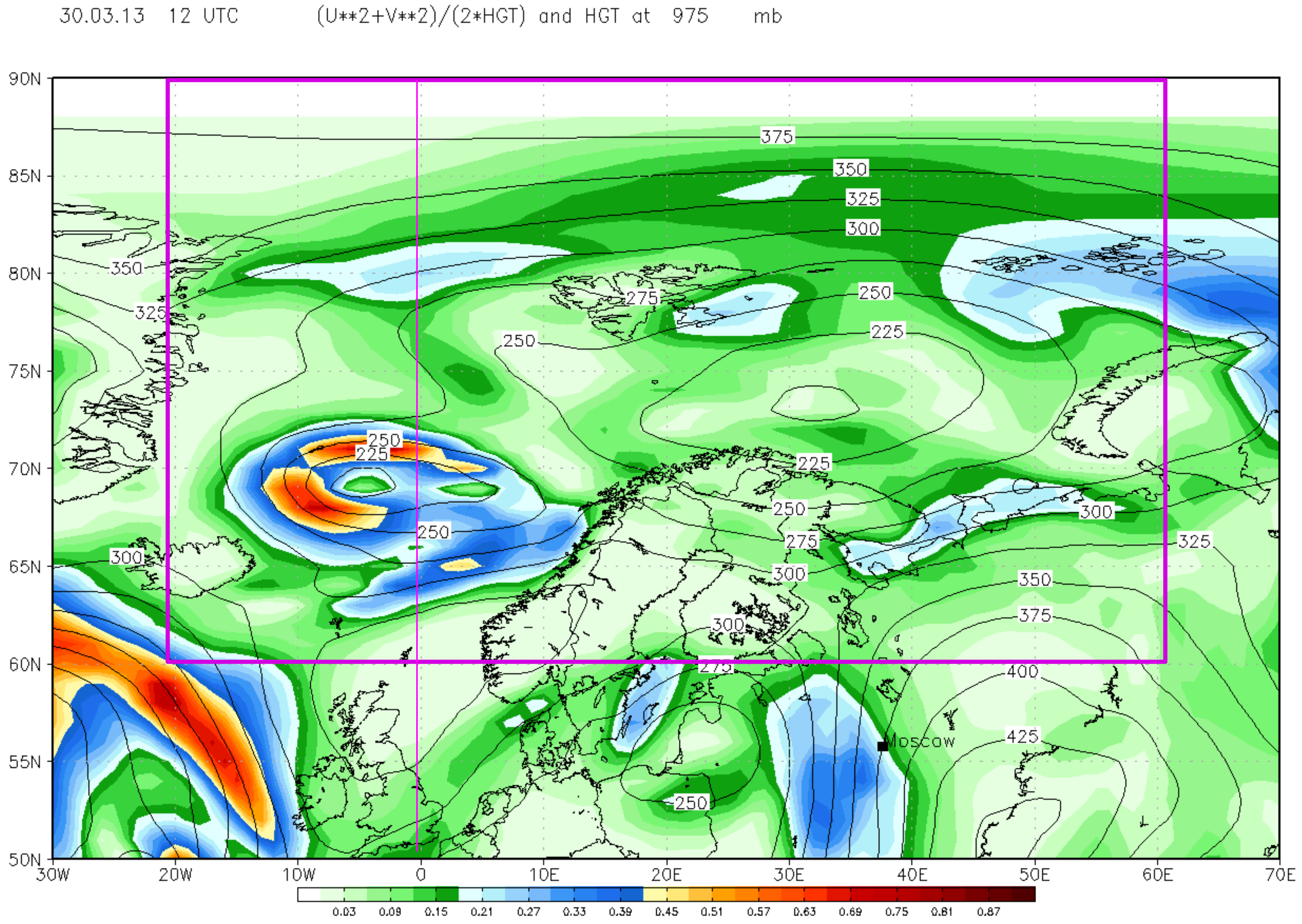
The comparison of the time behavior of the square average integral helicity and helicity density estimation according to the data from ECMWF for the period 01.03.13 – 31.03.13. Level 850 hPa



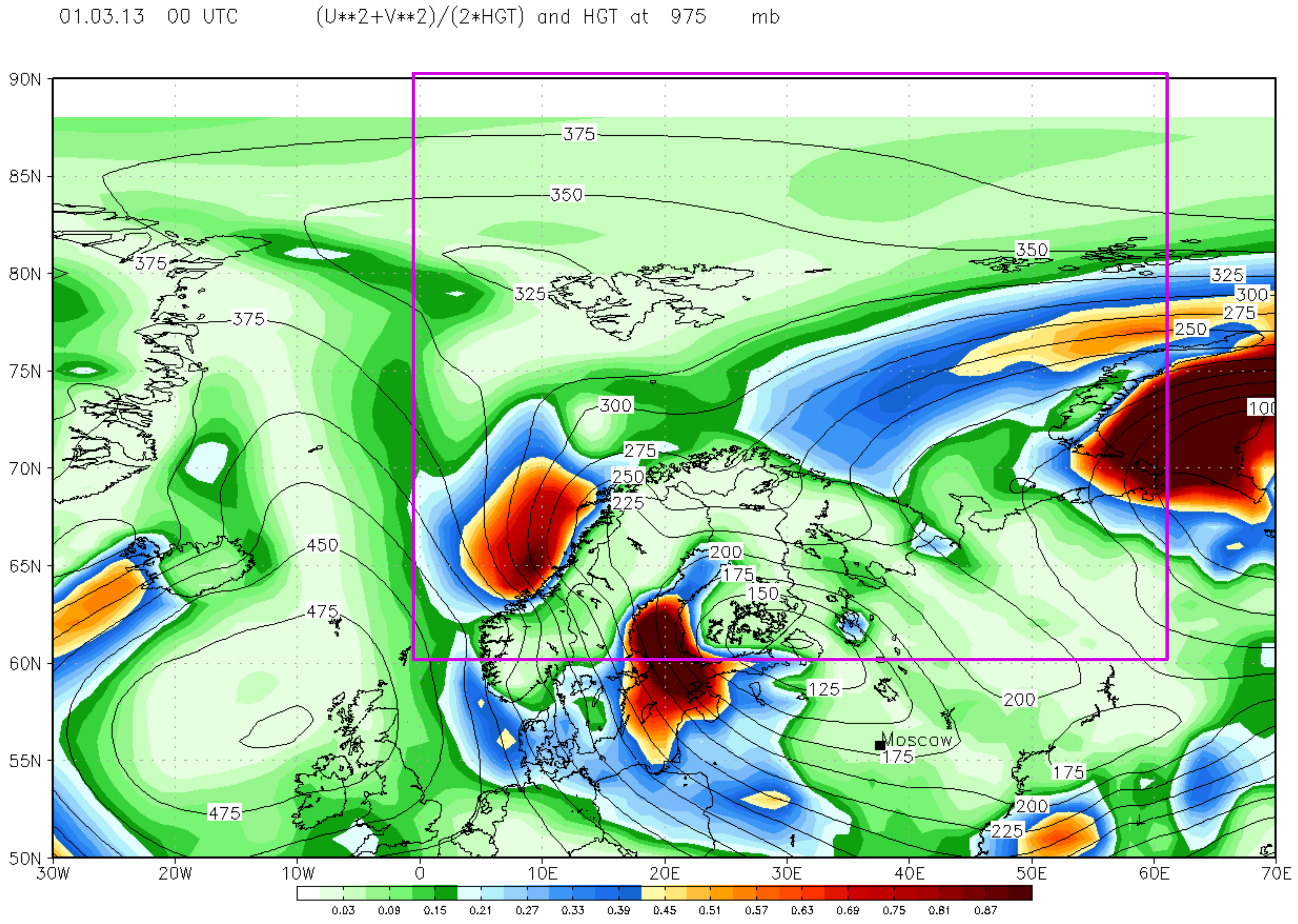
The comparison of the time behavior of the square average integral helicity and helicity density estimation according to the data from ECMWF for the period 01.03.13 – 31.03.13. Level 700 hPa



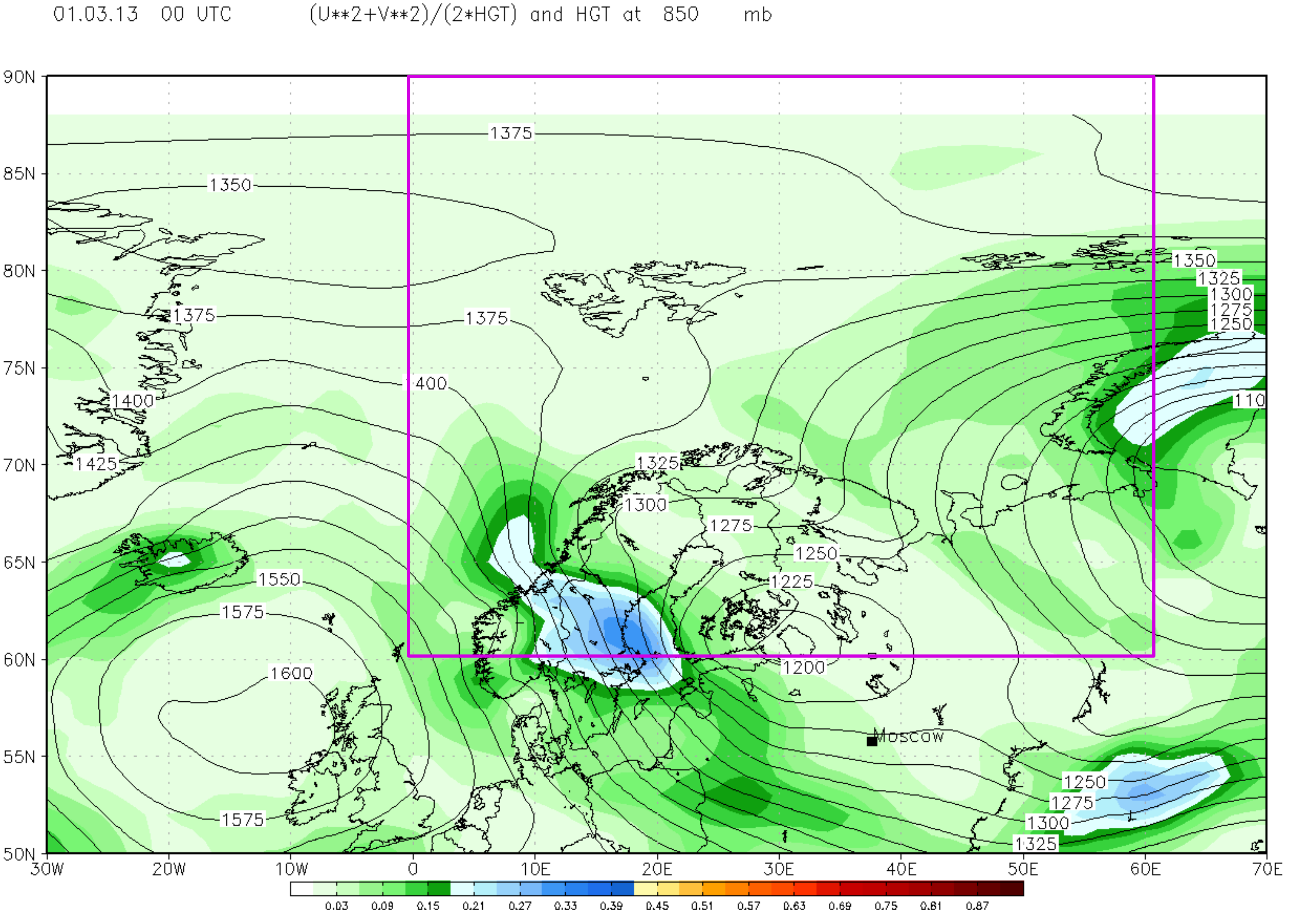
Computational domain for the square average of the integral helicity and geopotential for the period 01.03.13 – 31.03.13



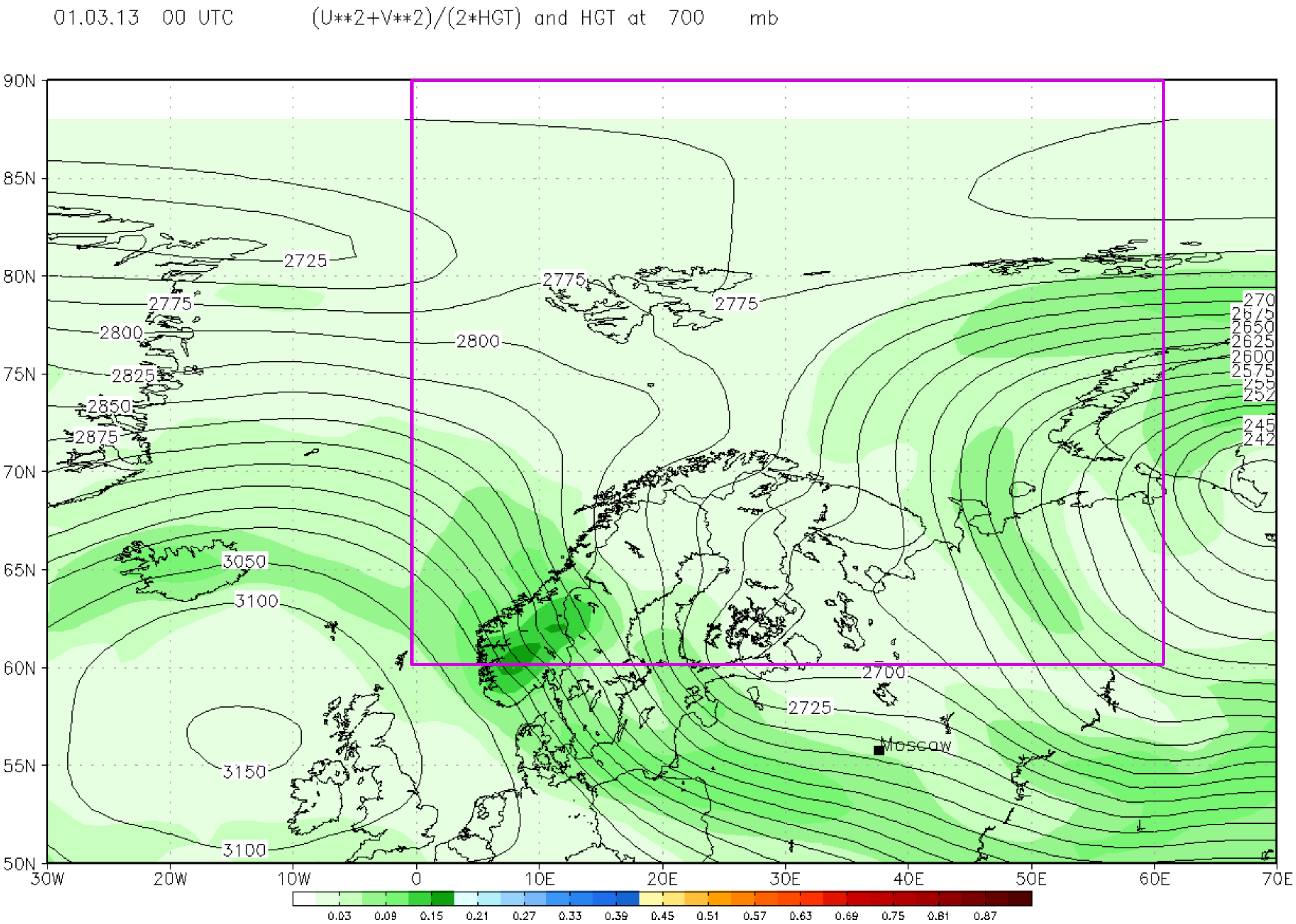
Integral helicity and geopotential according to the data from ECMWF over the surfaces of the Norwegian Sea and Barents Sea, 01.03.13 – 31.03.13. Level 975 hPa



Integral helicity and geopotential according to the data from ECMWF over the surfaces of the Norwegian Sea and Barents Sea, 01.03.13 – 31.03.13. Level 850 hPa

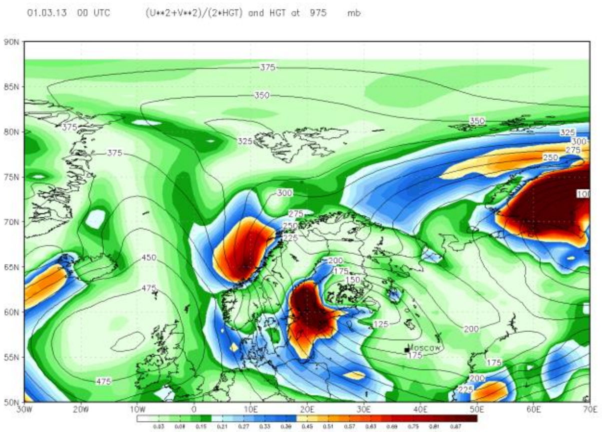


Integral helicity and geopotential according to the data from ECMWF over the surfaces of the Norwegian Sea and Barents Sea, 01.03.13 – 31.03.13. Level 700 hPa

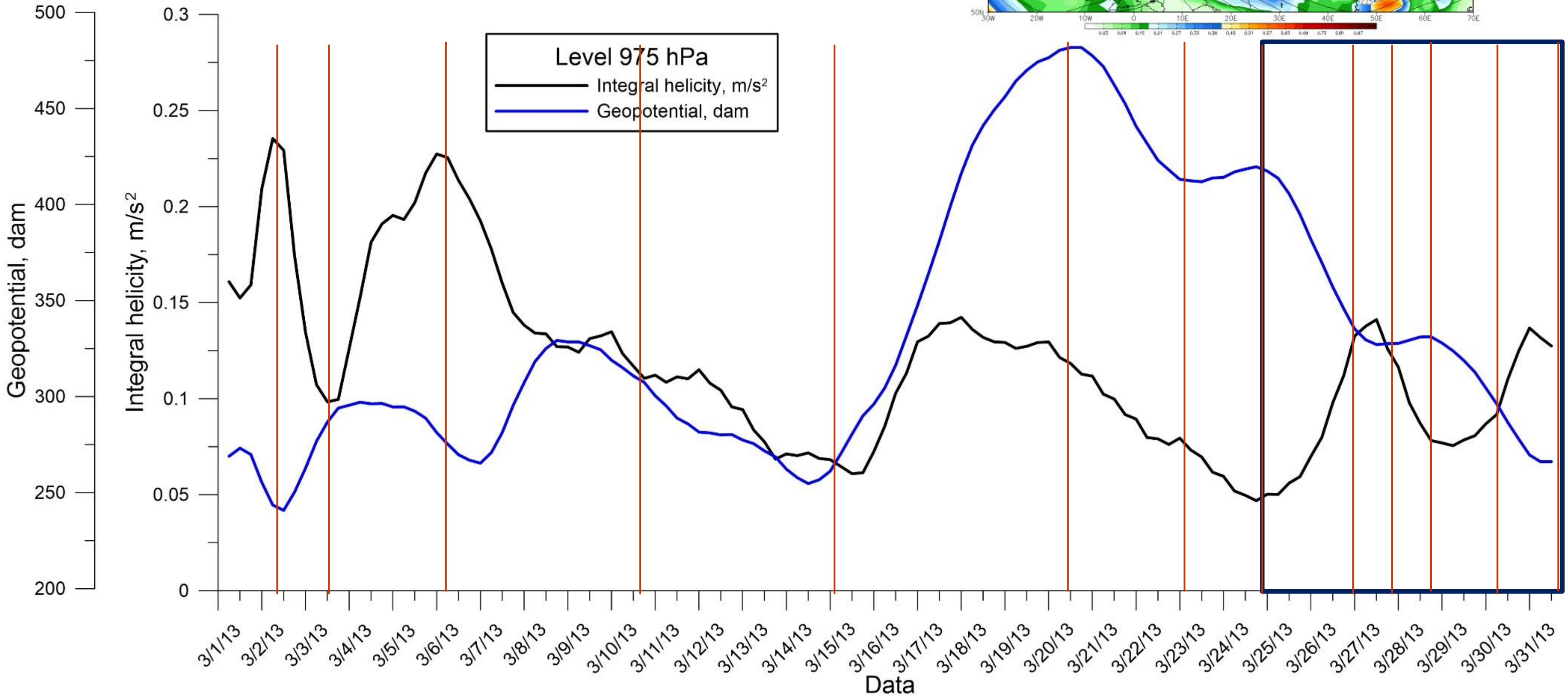


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

01.03.13 – 31.03.13

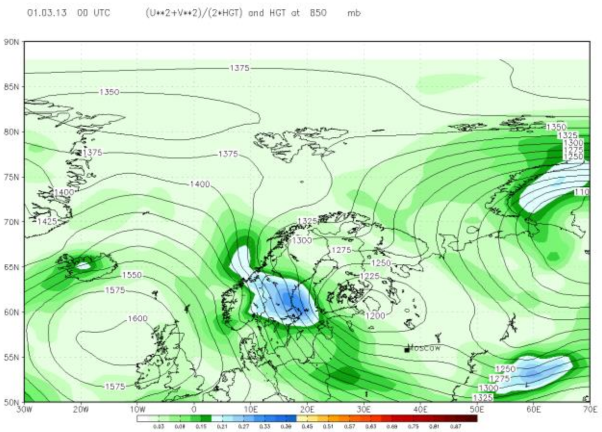


27.03.13 – 31.03.13

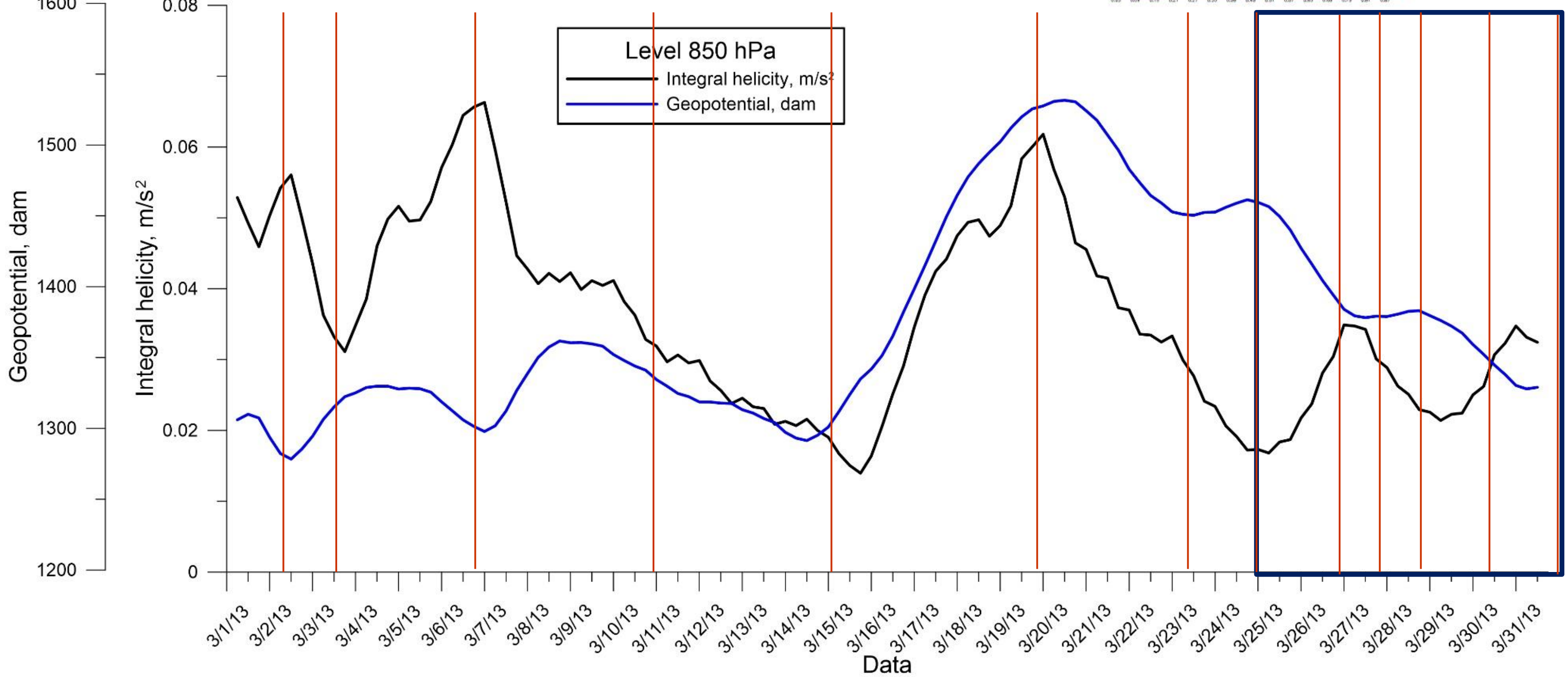


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

01.03.13 – 31.03.13



27.03.13 – 31.03.13

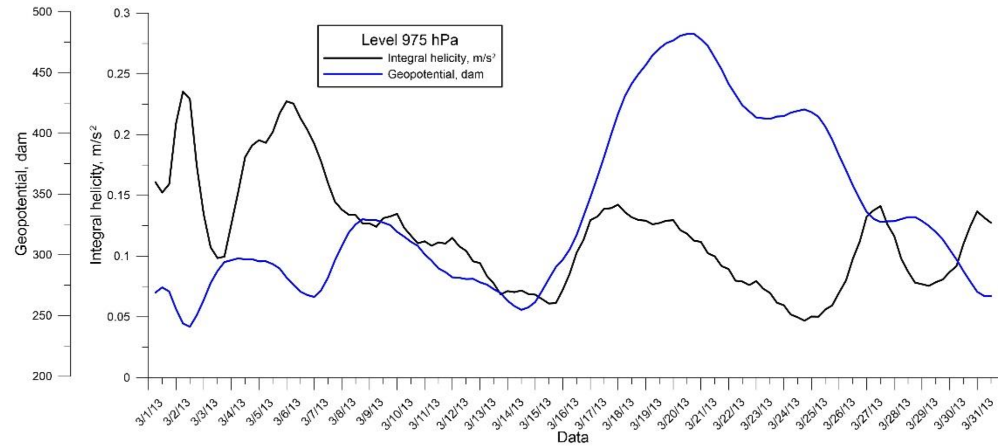


WRF-ARW model grid and parameterizations

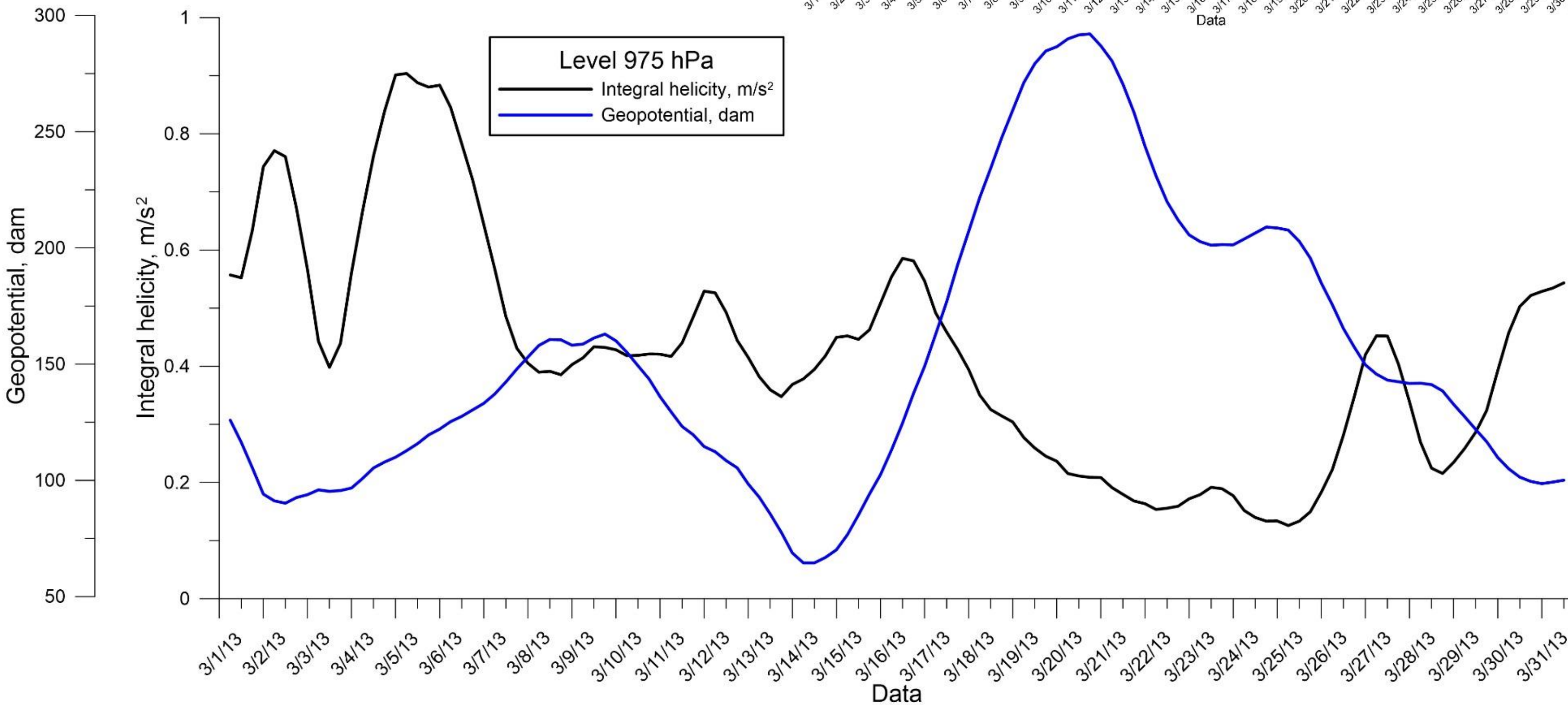
Run time	01.03.2013 00 UTC-31.03.2013 18 UTC
Number of domains	2
Simulation Domains (parent/nest)	50°N – 90°N, 30°W – 70°E / 60°N – 90°N, 0°E – 60° E
Map projection	Polar
Grid distance	10 000 м (10 км)/3333 m (3,333 km)
Full south-north dimension	327/109
Full east-west dimension	270/90
Full vertical dimension	50
Time step	60 sec
Longwave Radiation	CAM/CAM (Community atmosphere model, W. D. Collins et al., 2004)
Surface Layer	Monin-Obukhov (Zilitinkevitch)
Land Surface Model	Noah, (Chen et al., 2001)
Planetary Boundary Layer	Схема Меллора-Ямады и Янича (Janjic, 1994, MWR)

Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, WRF. Level 975 hPa

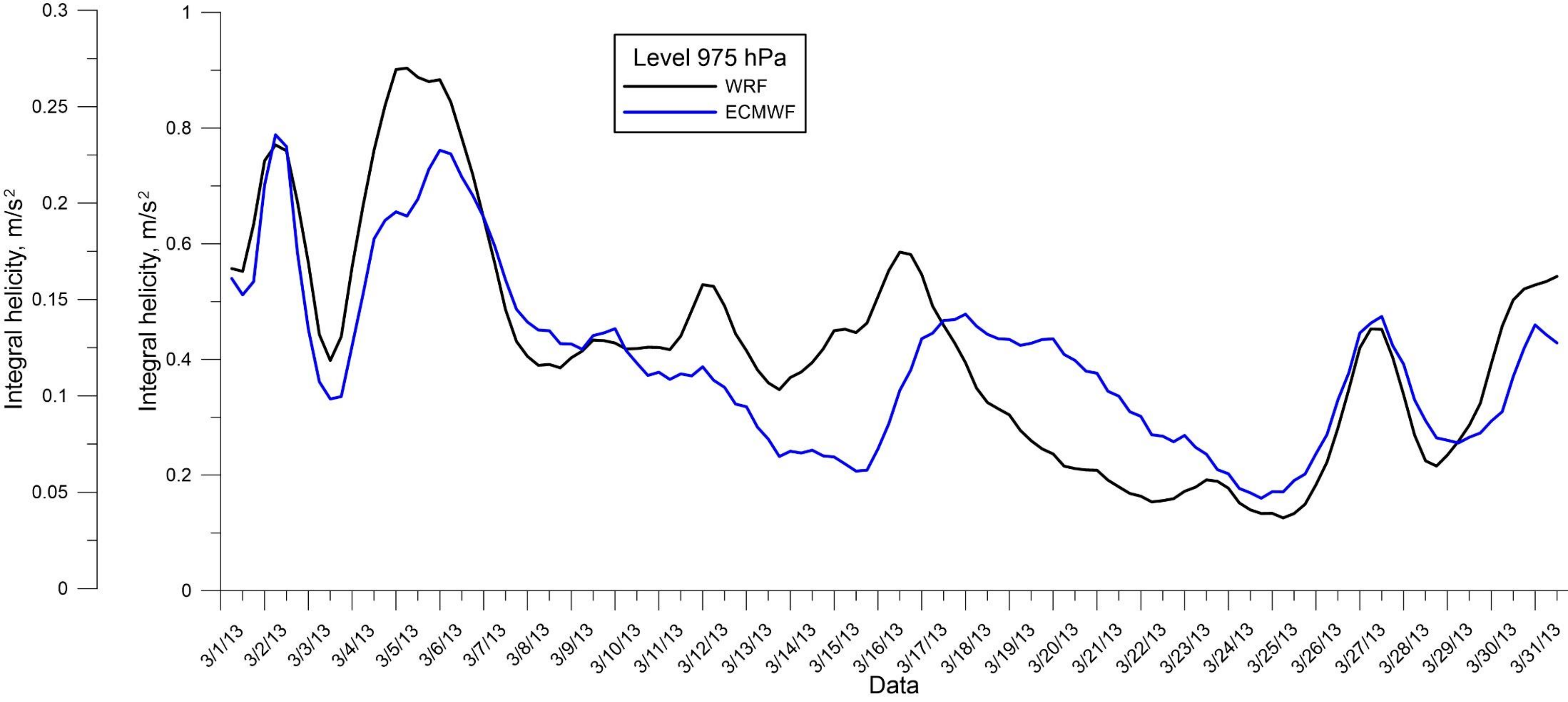
ECMWF



WRF

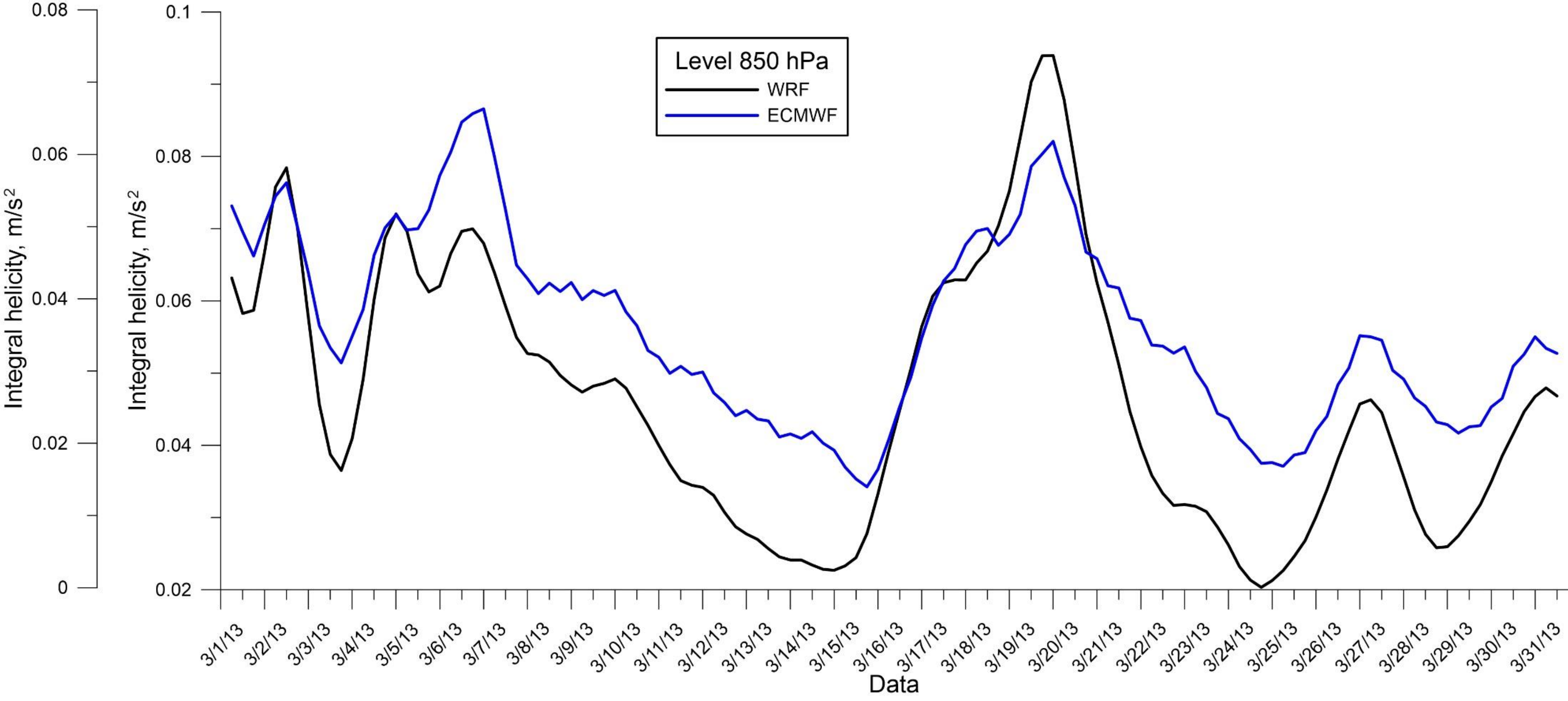


The comparison for the integral helicity according to the data of WRF and ECMWF as in the case of Polar Lows in the period between 27-31 March, 2013. Level 975 hPa



01.03.13 – 31.03.13

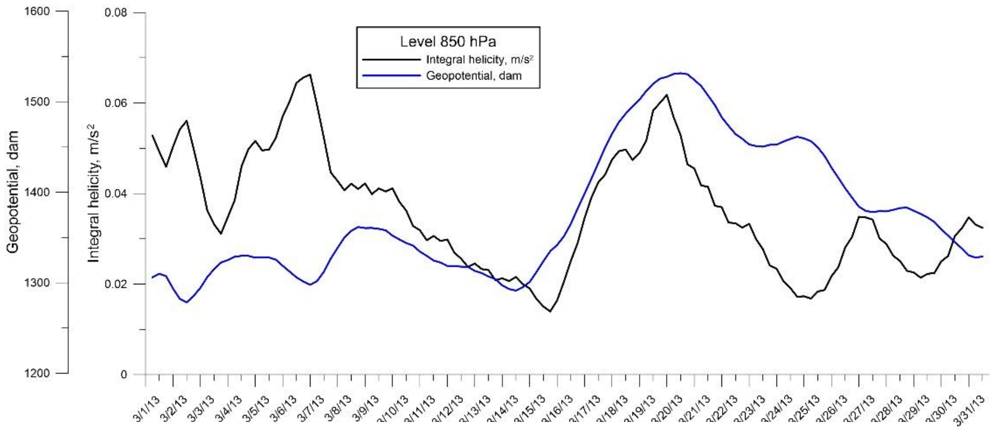
The comparison for the integral helicity according to the data of WRF and ECMWF as in the case of Polar Lows in the period between 27-31 March, 2013. Level 850 hPa



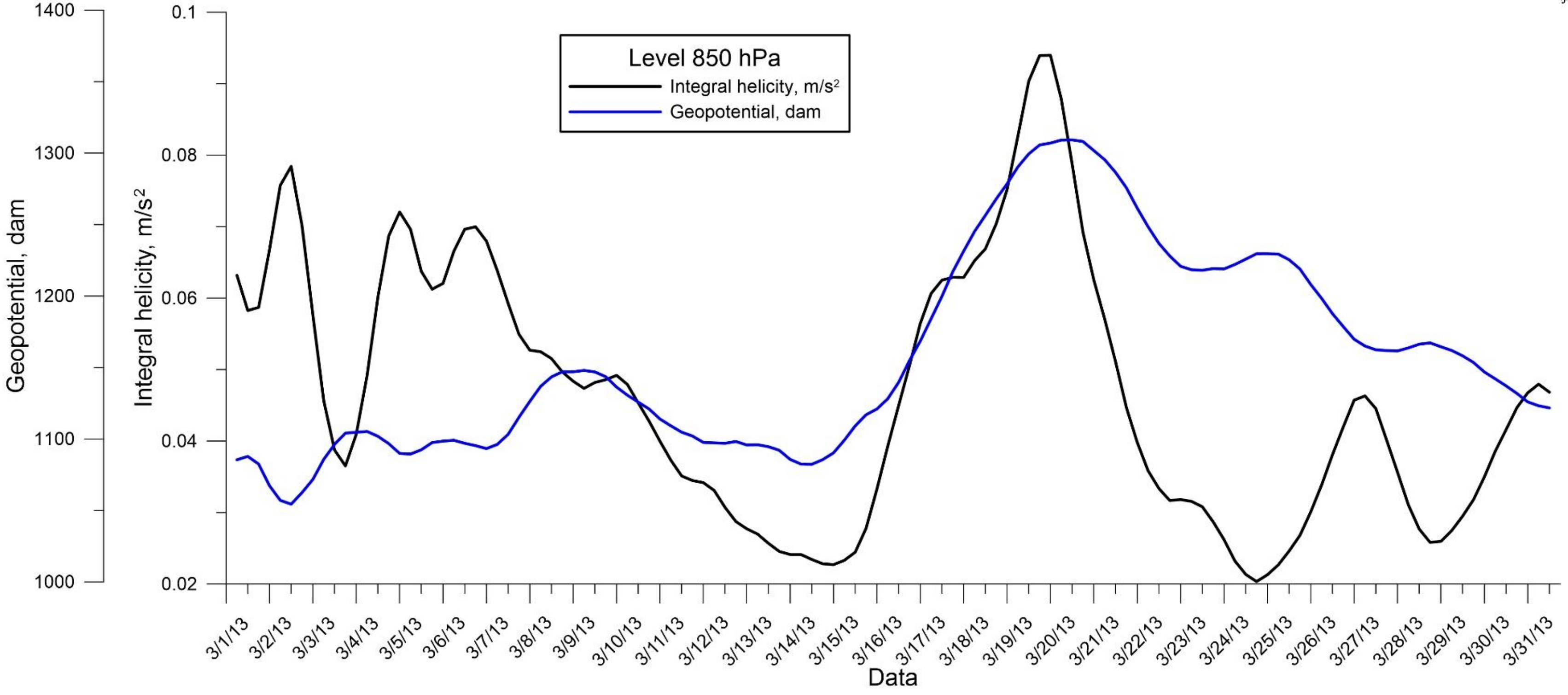
01.03.13 – 31.03.13

Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, WRF. Level 850 hPa

ECMWF



WRF



Summary and Conclusions

- There is a good correlation between the integral helicity and the square of the wind velocity on the higher sounding levels (400-800 m) in slightly unstable or neutral stratification conditions. This fact allows to use the geostrophic wind data to build the regional and global helicity fields.
- The analysis of the global helicity fields in the Atmospheric boundary layer according to the data from ECMWF for the polar latitudes of the Nothern Hemisphere per 2013 year was made
- The comparison between ECMWF data and WRF-ARW findings for the global helicity fields in the Atmospheric boundary layer for the polar latitudes of the Nothern Hemisphere per 2013 year was carried out
- The local variations of the helicity neighbor with the front of the cyclone
- It was demonstrated that as the criterion for the estimation of helicity as the integral square characteristic, being referred to aggregate vortex formation we can $H_{den}(x_i, y_i) = \frac{1}{2HGT}\left({U_G}^2 + {V_G}^2\right)$.

Summary and Conclusions

- At a time of Polar Lows activity, from 27.03.2013 to 31.03.2013, the local minimums of the integral helicity estimation align with the local maximums of the geopotential
- In the period of the generation Polar Lows the integral helicity estimation increases
- In the Polar Lows occlusion, as per 29-30.03.2013, the helicity estimation decrease, due to the slowing of the rotating motion during the boundaries expansion of the Polar Lows
- The helicity may have diagnostic meaning as a useful additional physics/hydrodynamics characteristic of the atmospheric motions
- The farther investigation on the utilizing the helicity as the integral square characteristic, being referred to aggregate vortex formation is required; in particular the research of other case studies for the Polar Lows or the Tropical Hurricanes, the participation of more processed data; the investigation of the possibility for the selection of other estimation criteria

Thank you for your attention!

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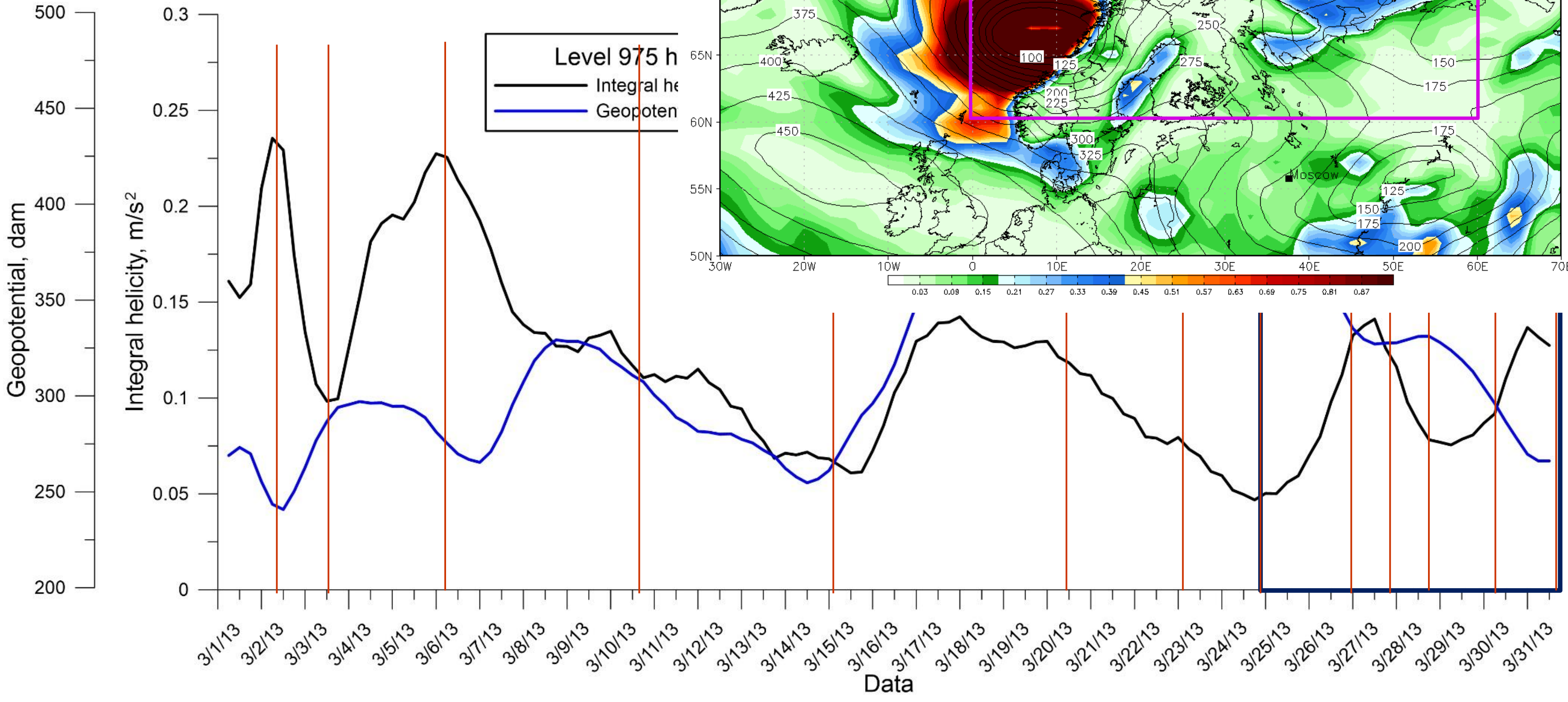
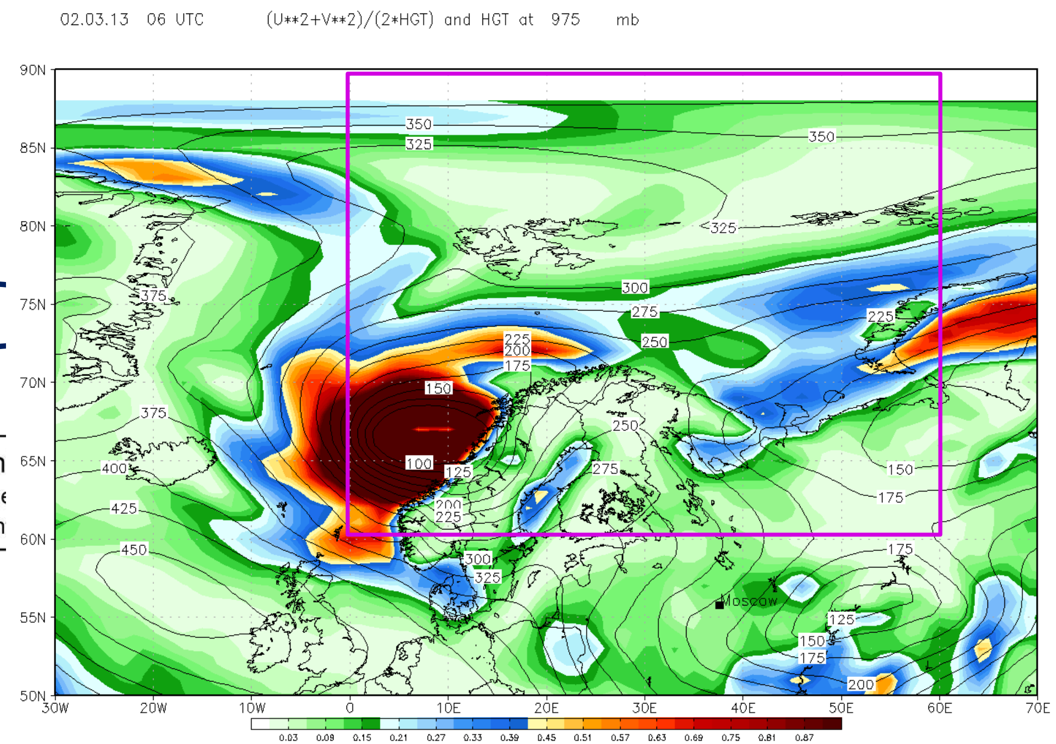
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

2.03.2013 UTC 06

27.03.13 – 31.03.13

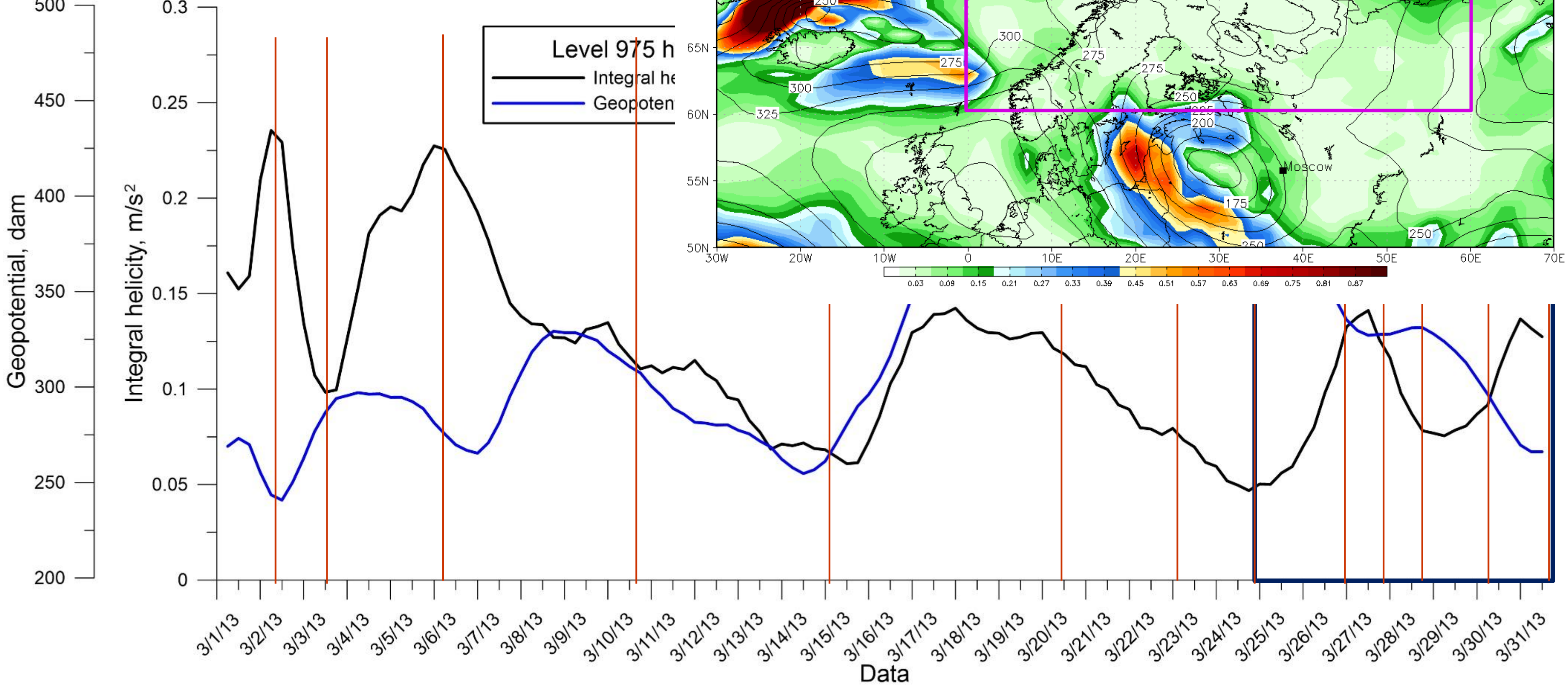


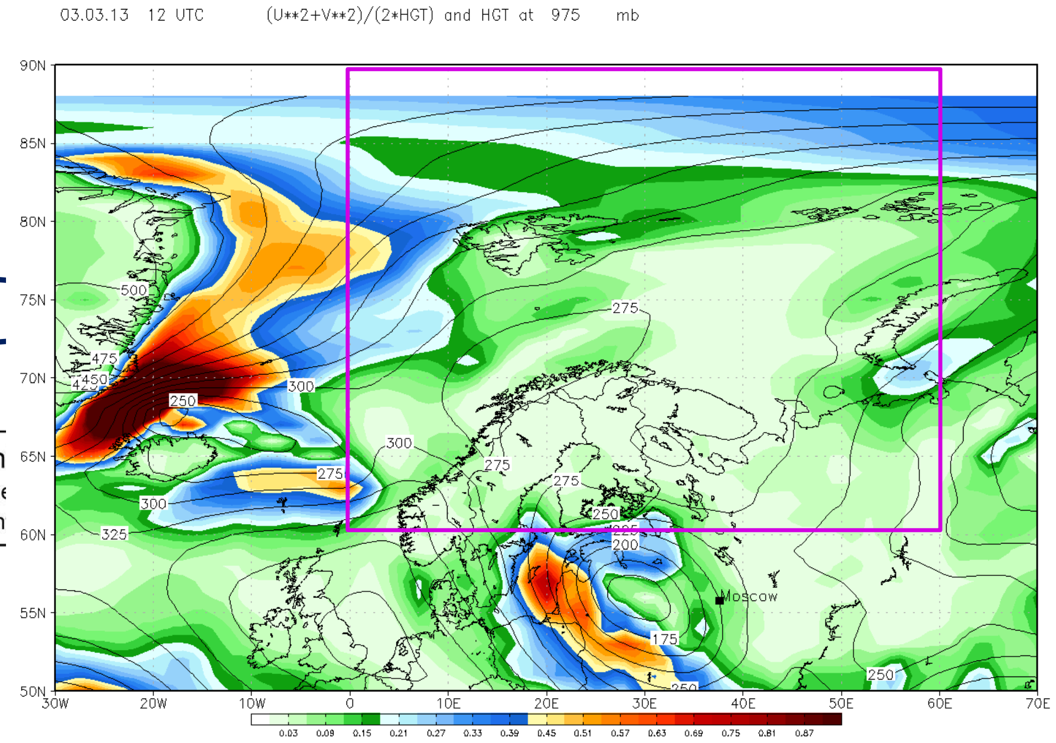


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

3.03.2013 UTC 12

27.03.13 – 31.03.13

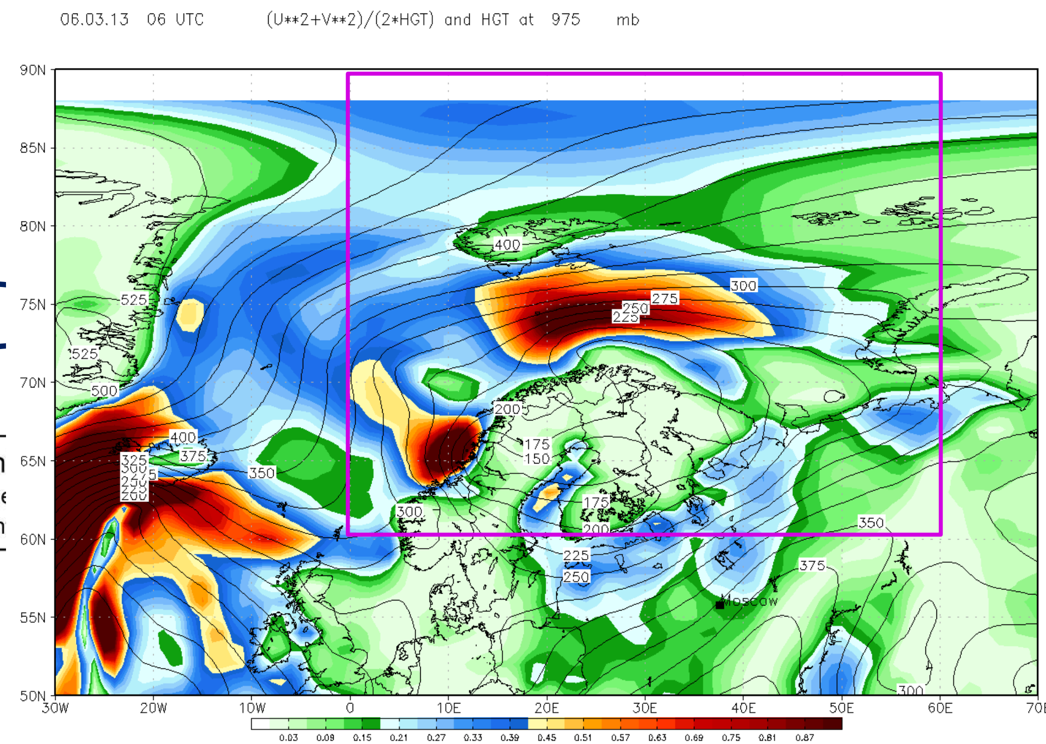


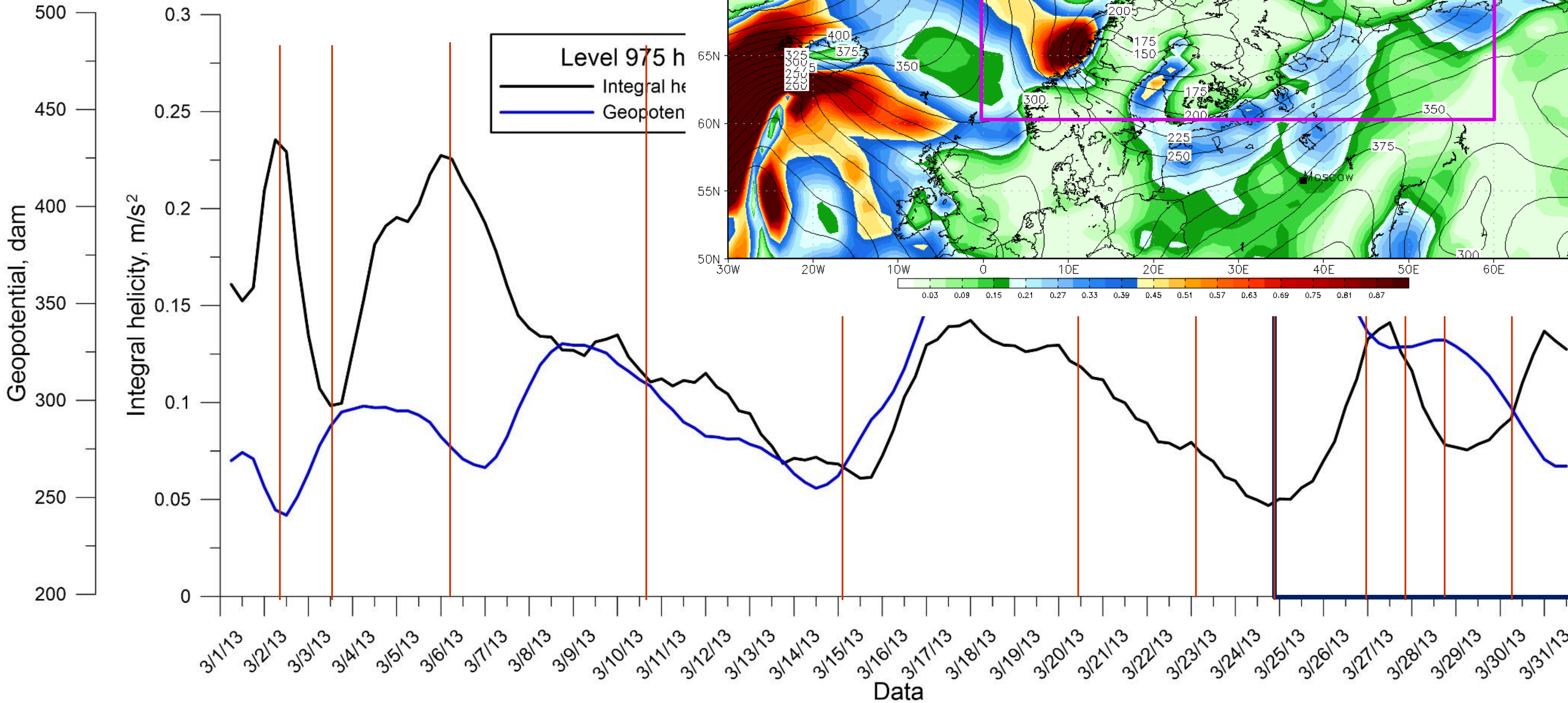


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

6.03.2013 UTC 00

27.03.13 – 31.03.13

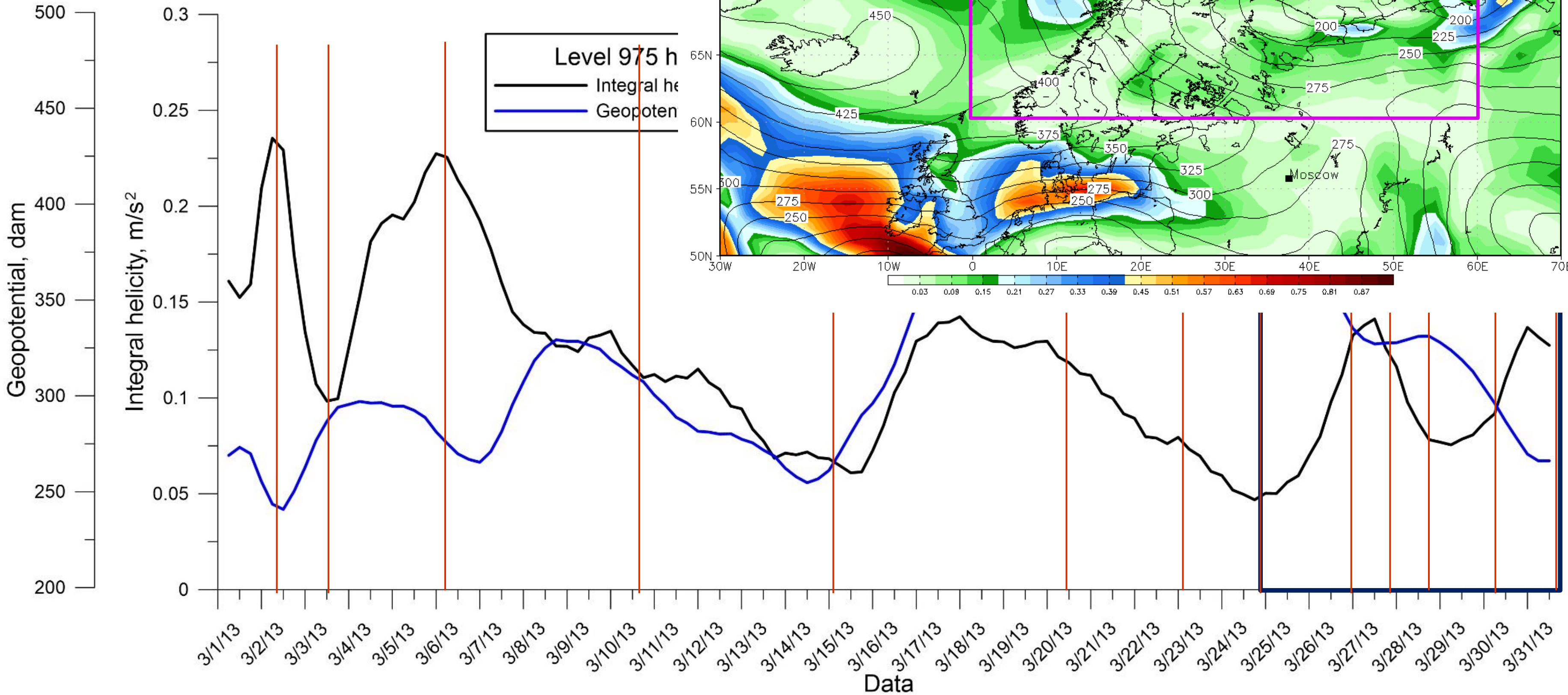


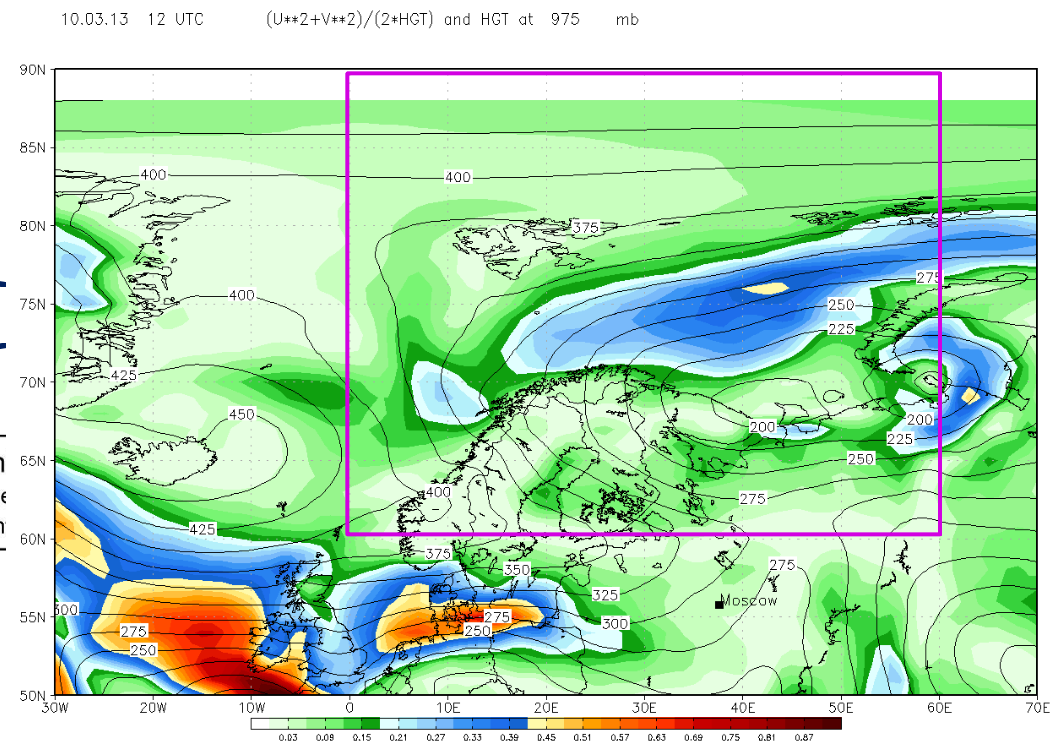


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

10.03.2013 UTC 12

27.03.13 – 31.03.13

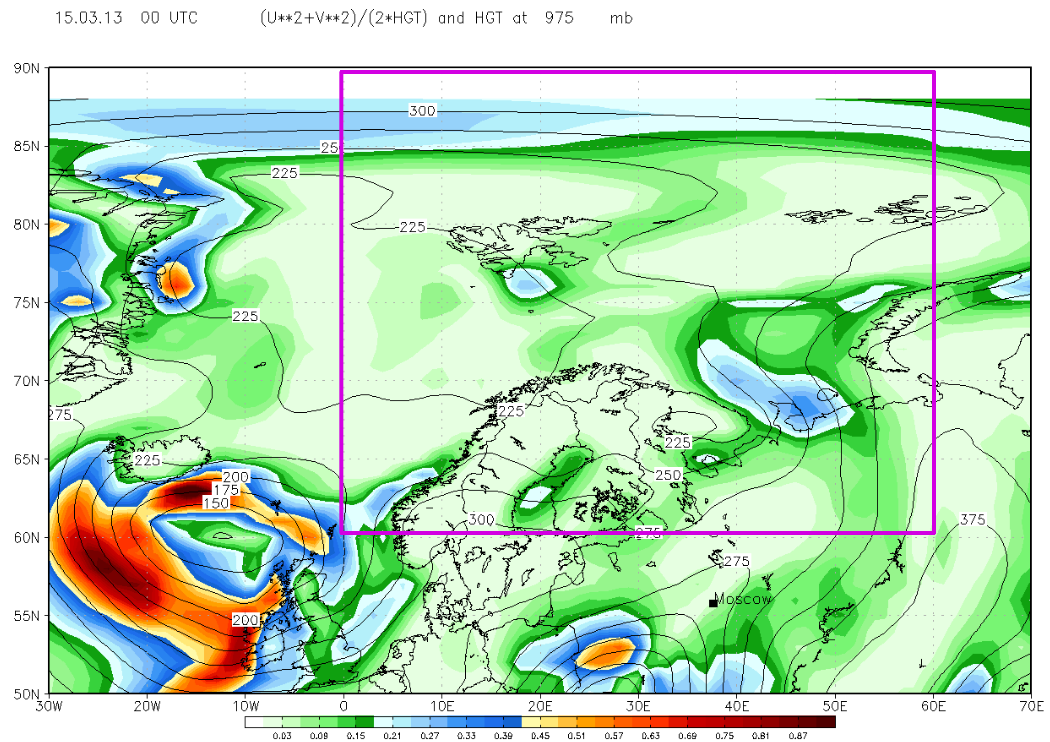


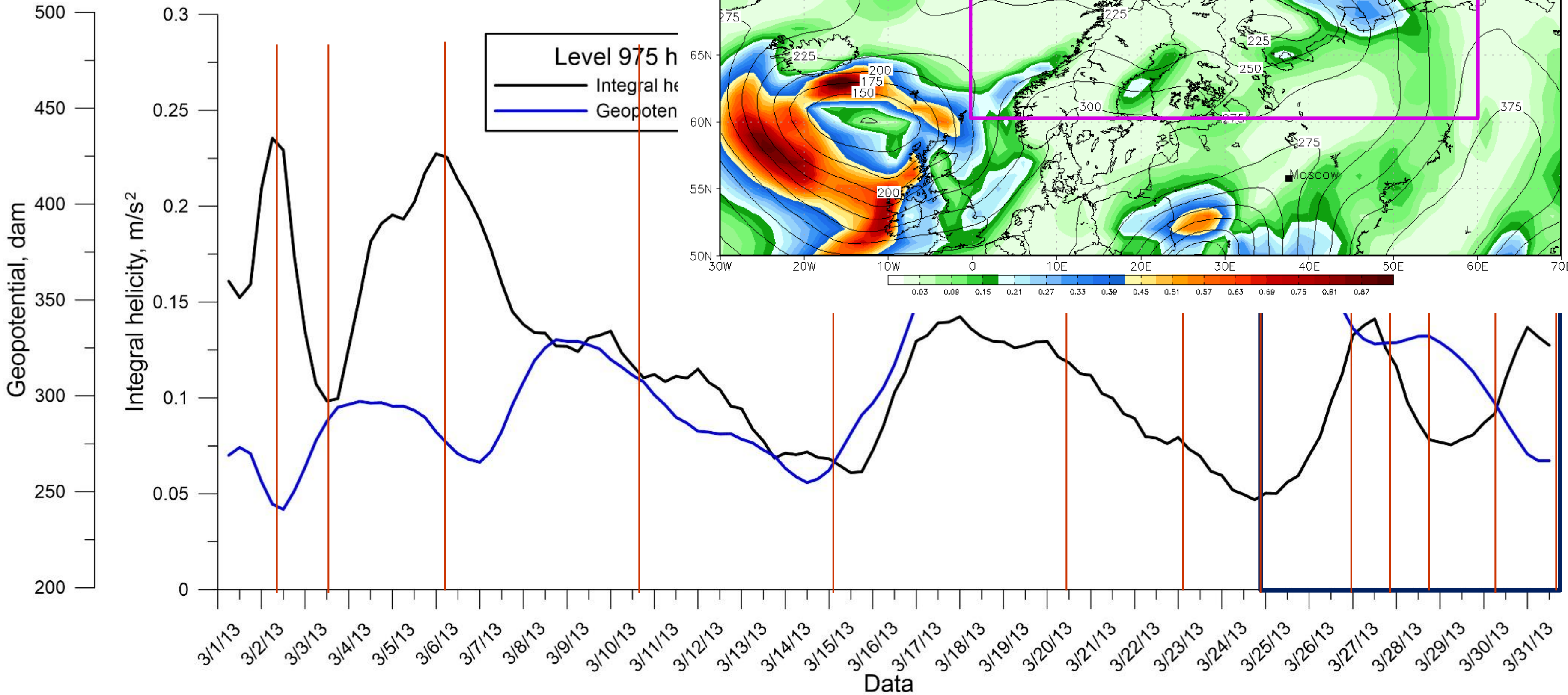


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

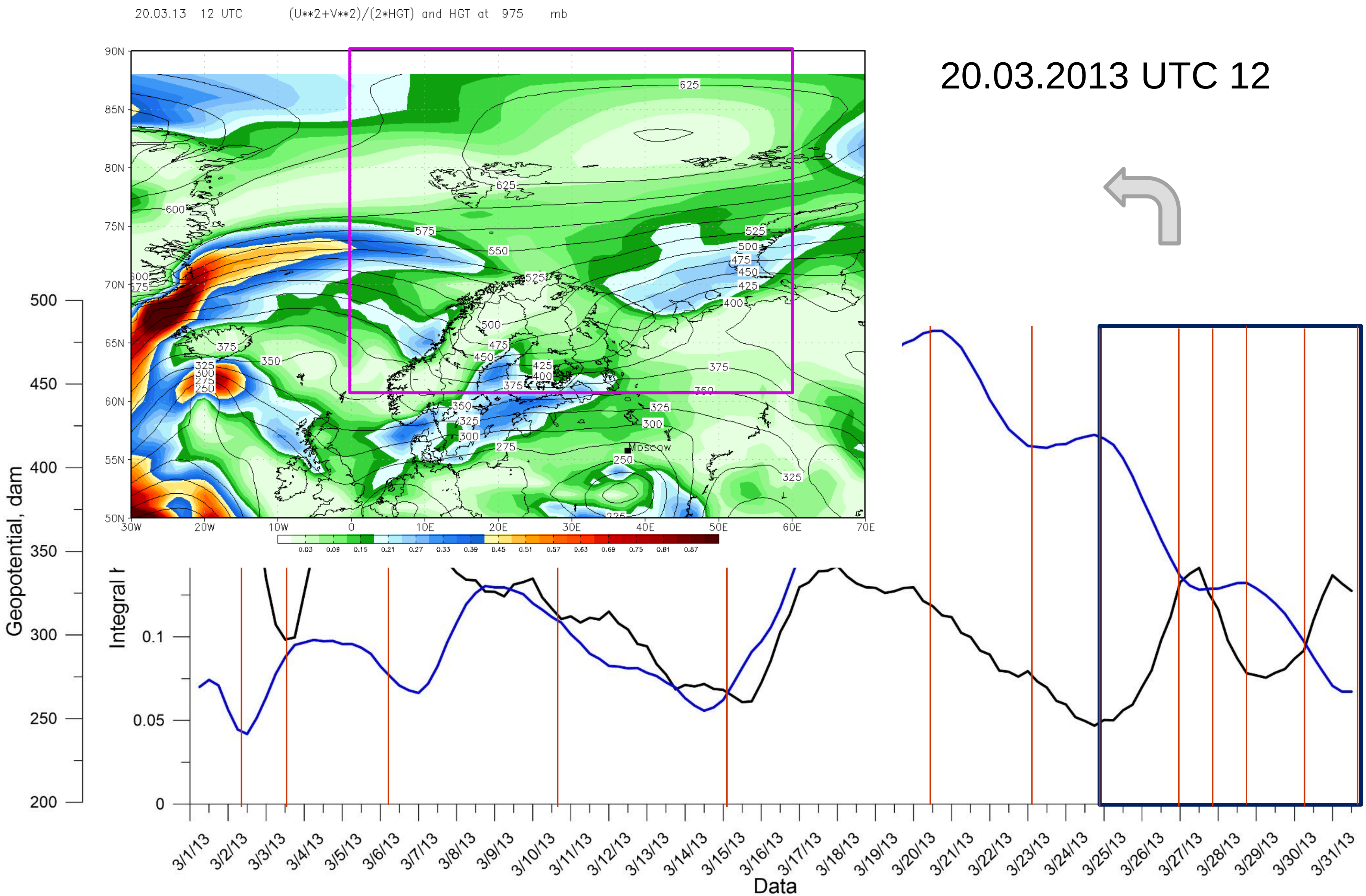
15.03.2013 UTC 00

27.03.13 – 31.03.13



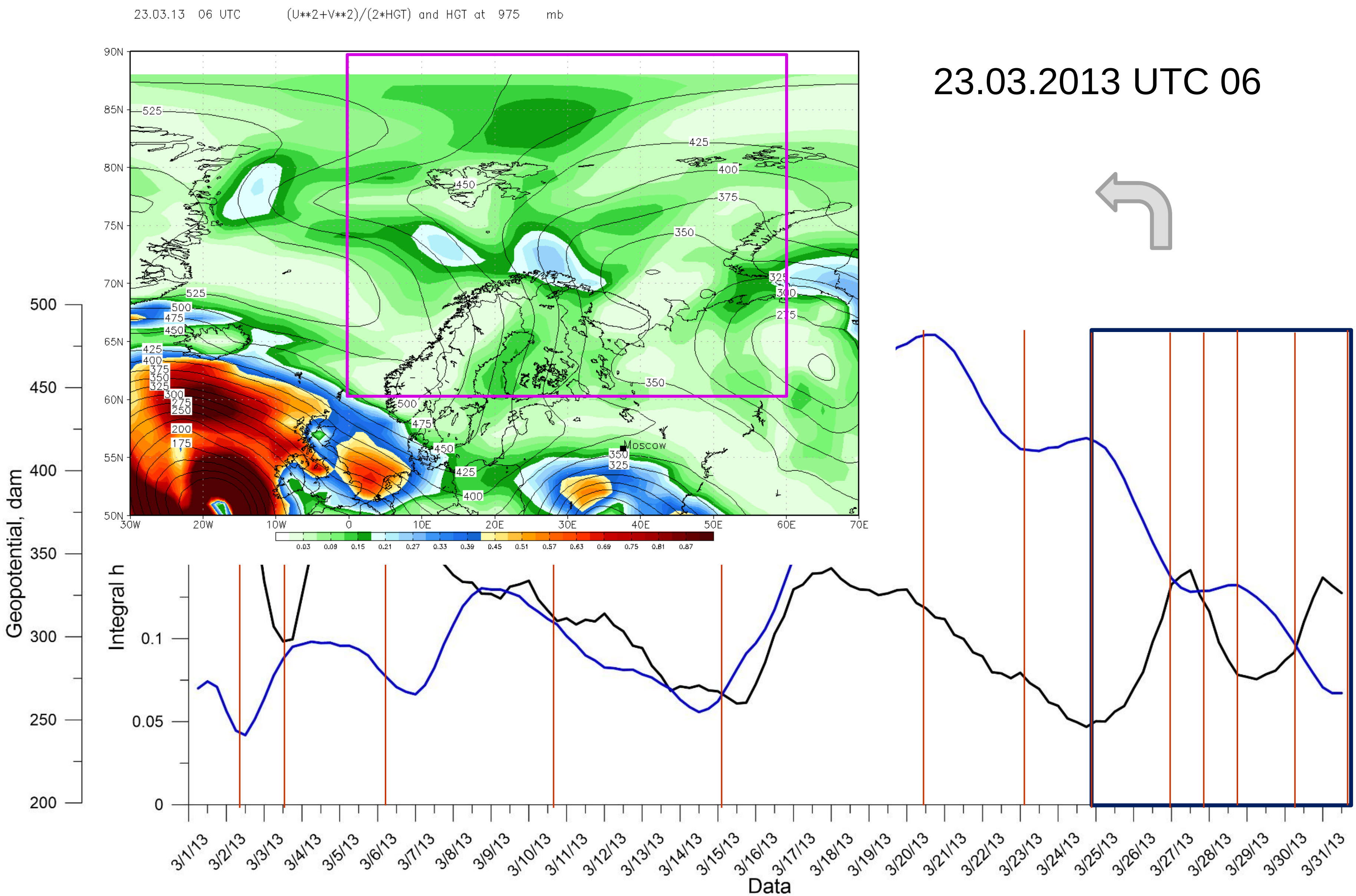


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

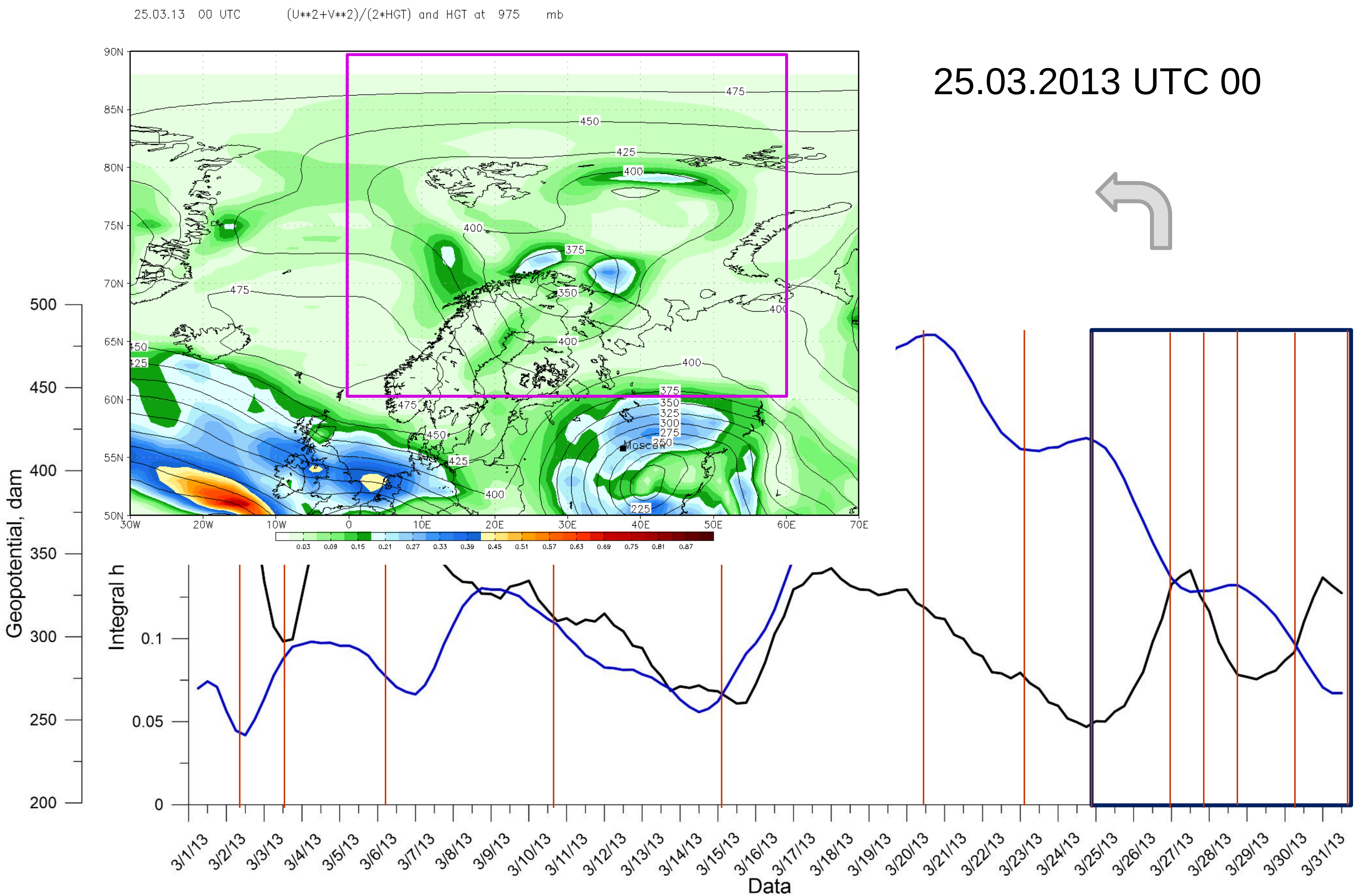


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

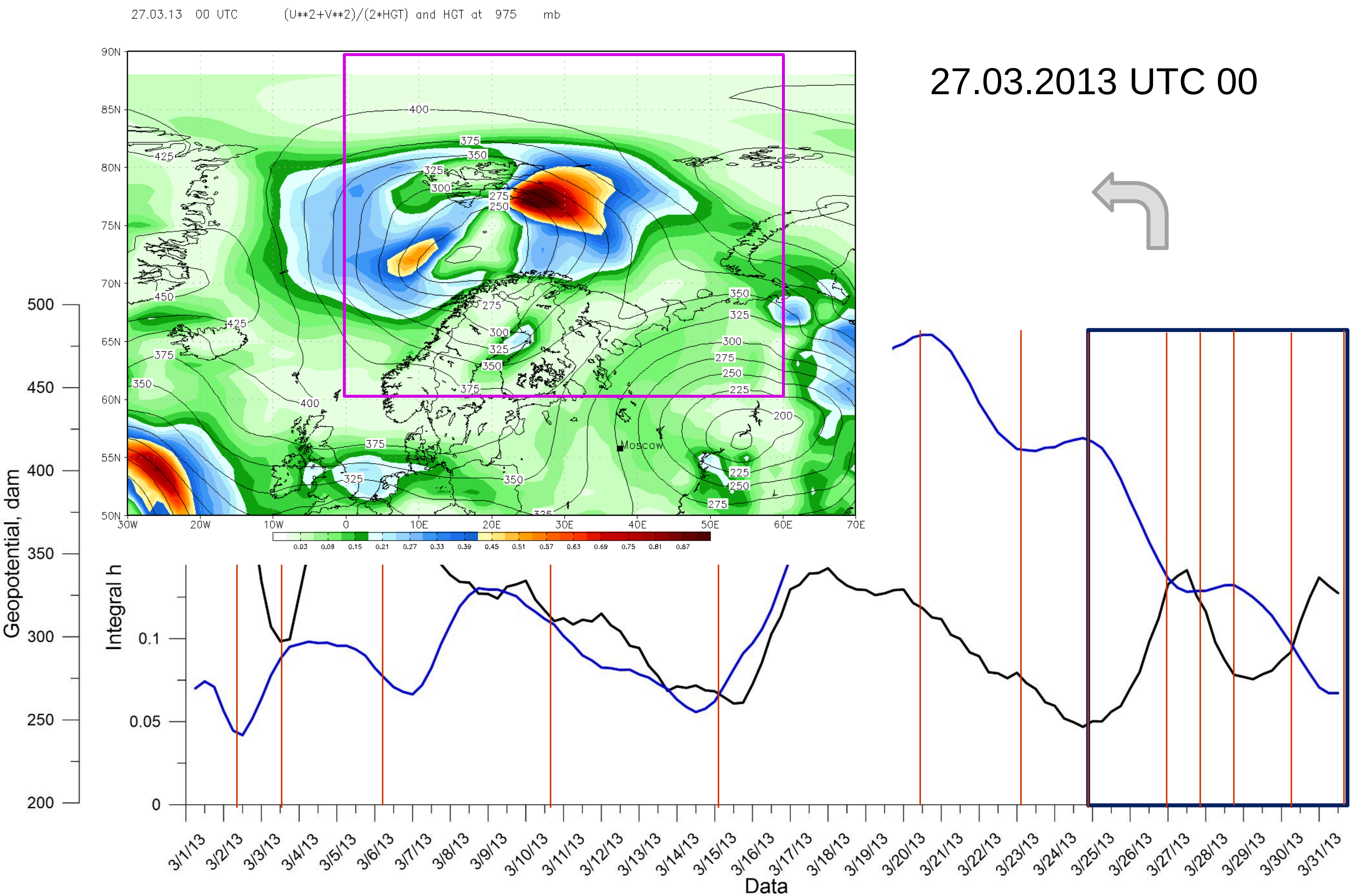
23.03.2013 UTC 06



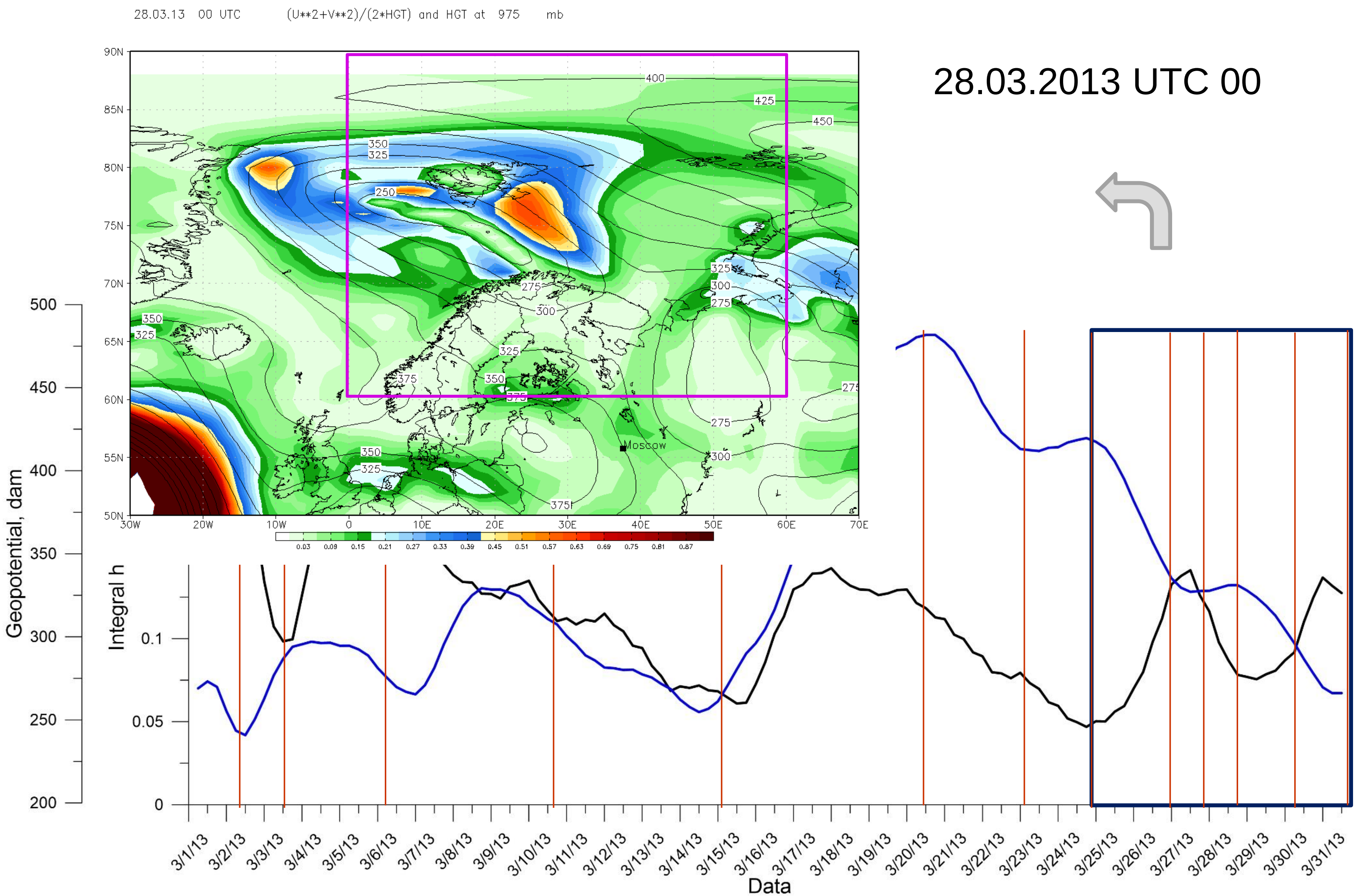
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa



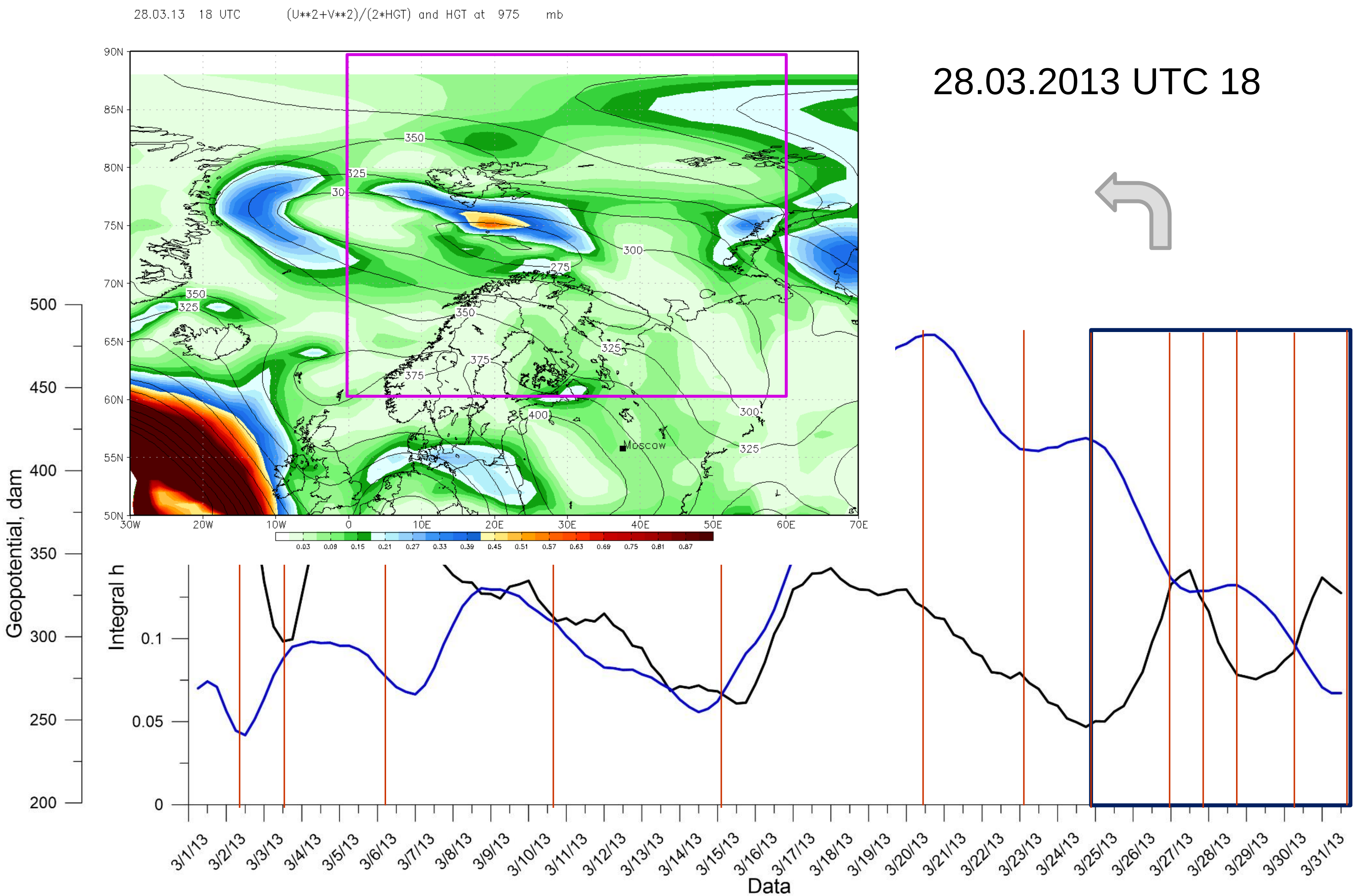
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa



Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

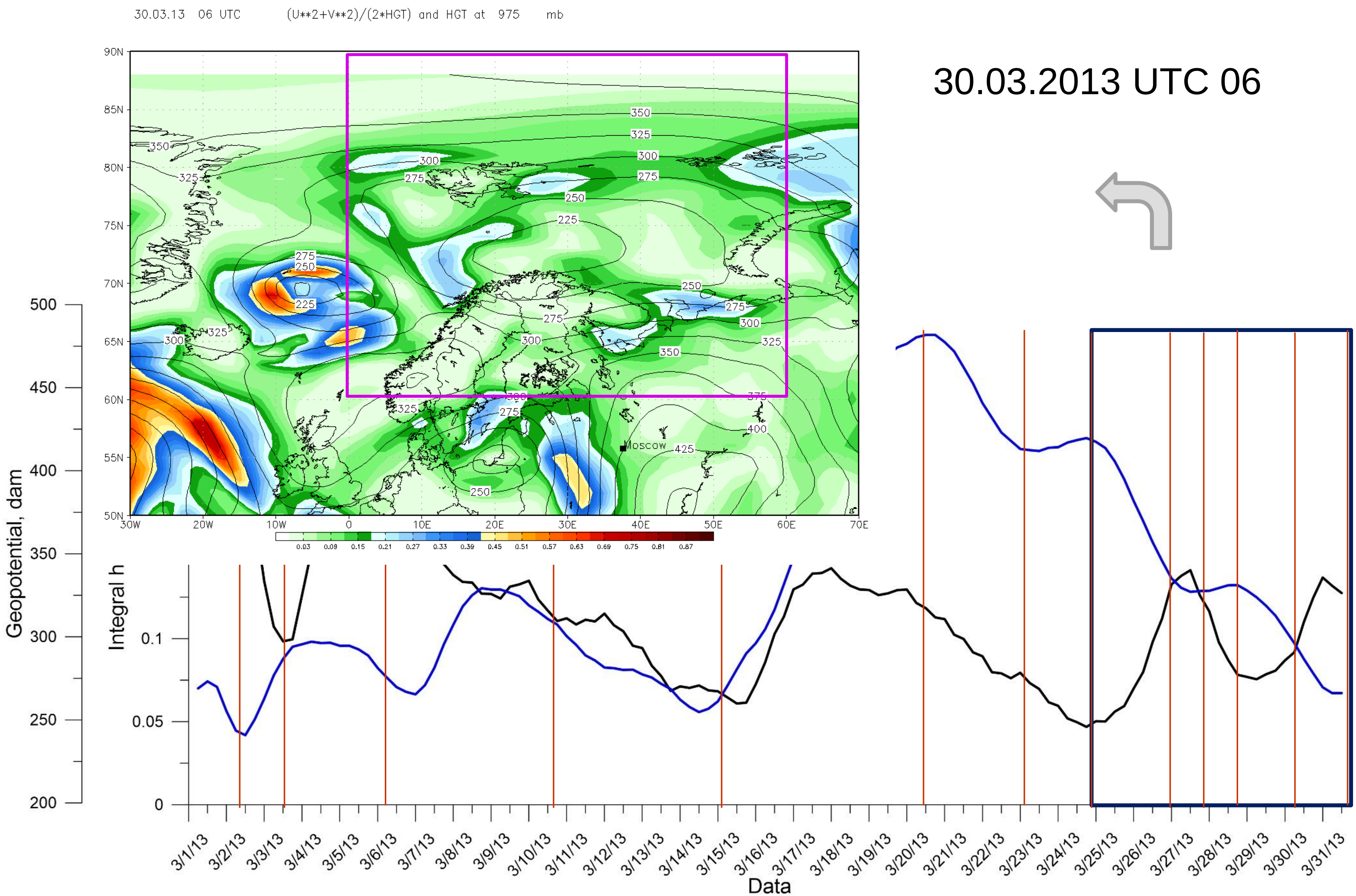


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa



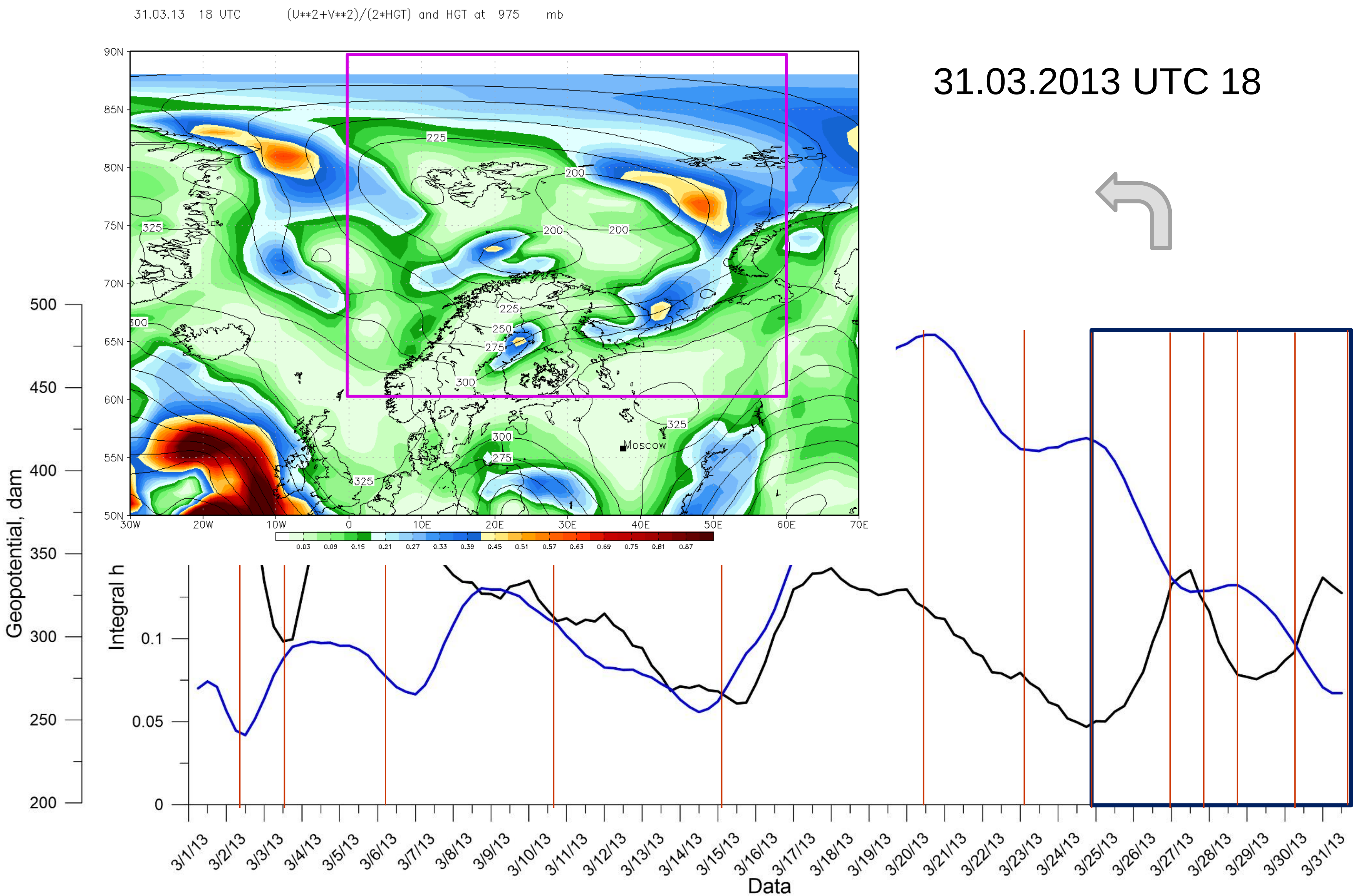
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

30.03.2013 UTC 06



Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 975 hPa

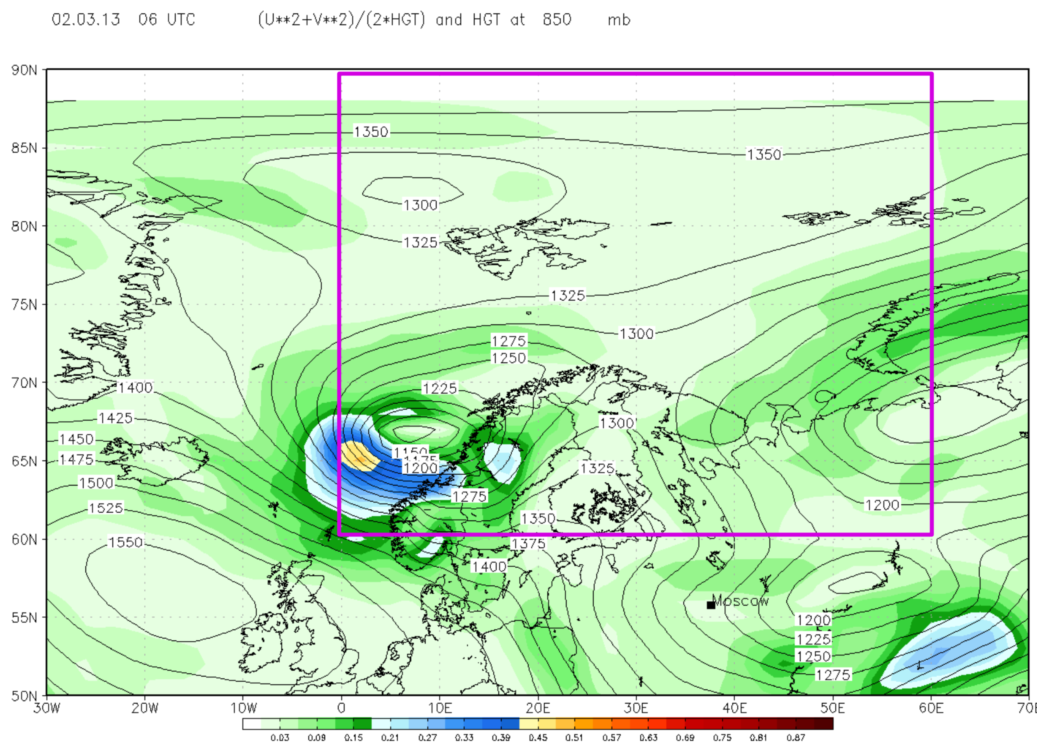
31.03.2013 UTC 18

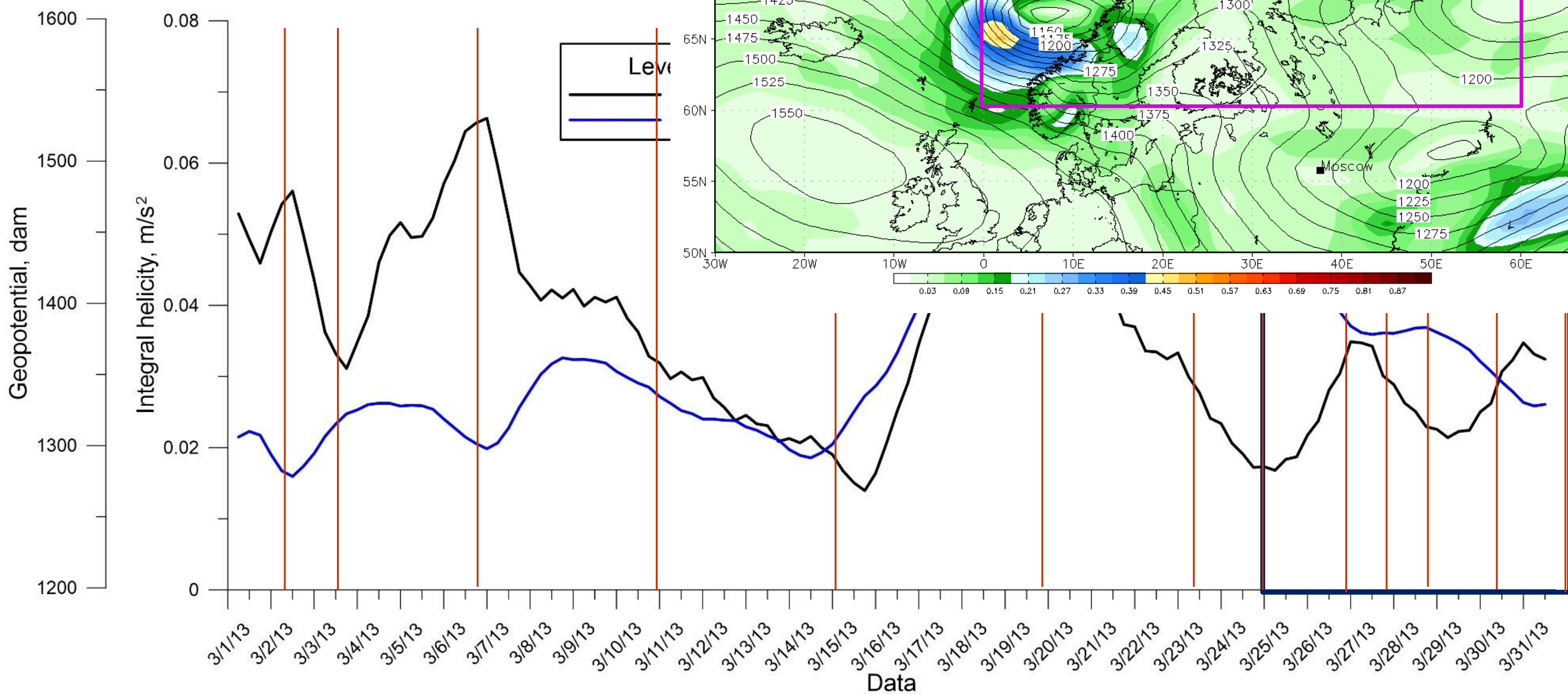


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

2.03.2013 UTC 06

27.03.13 – 31.03.13

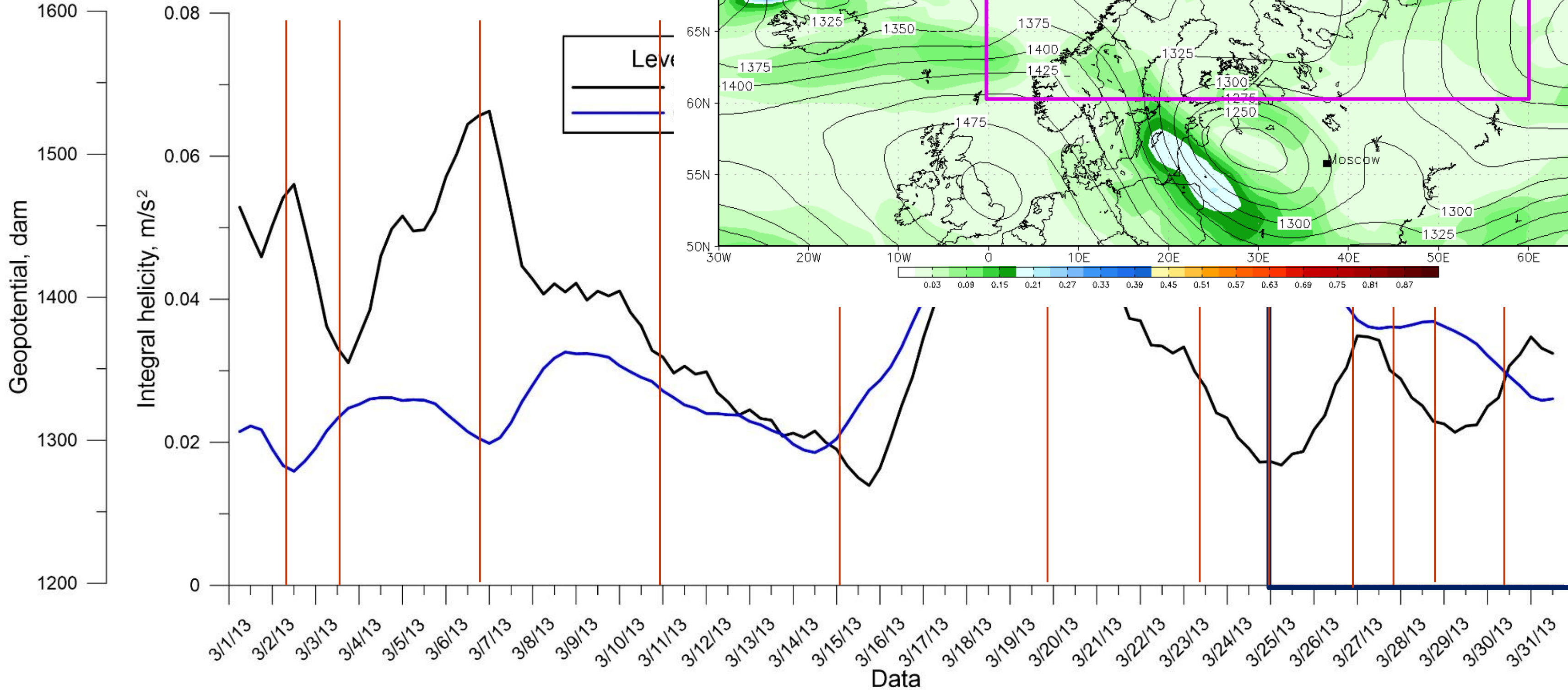


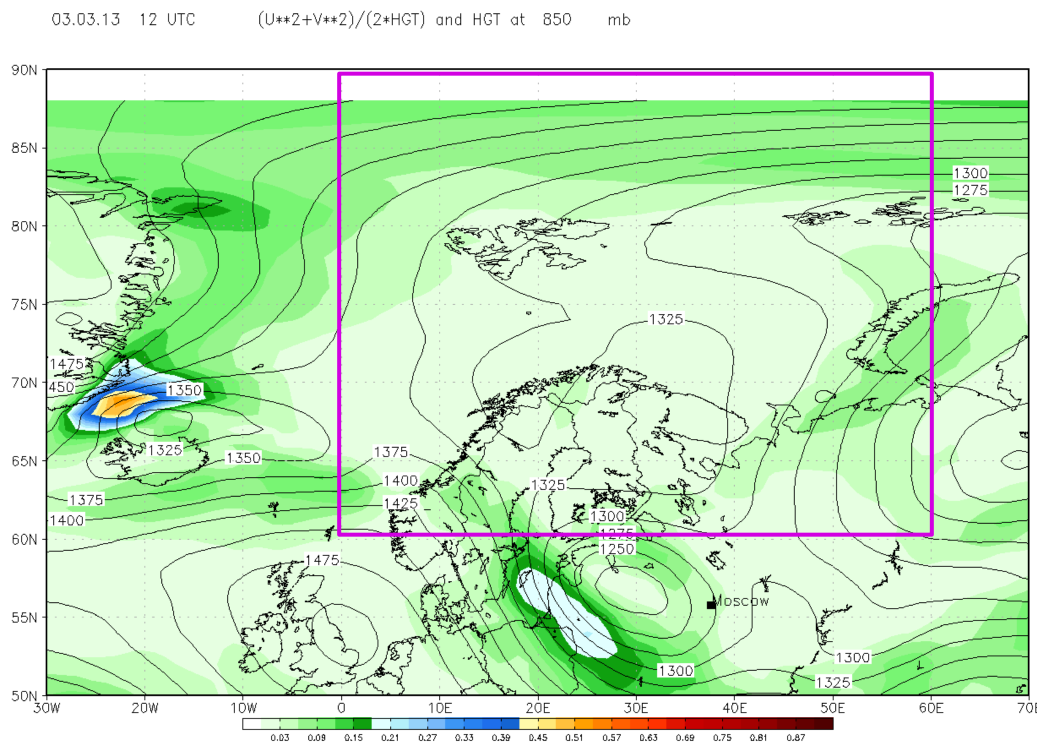


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

3.03.2013 UTC 12

27.03.13 – 31.03.13

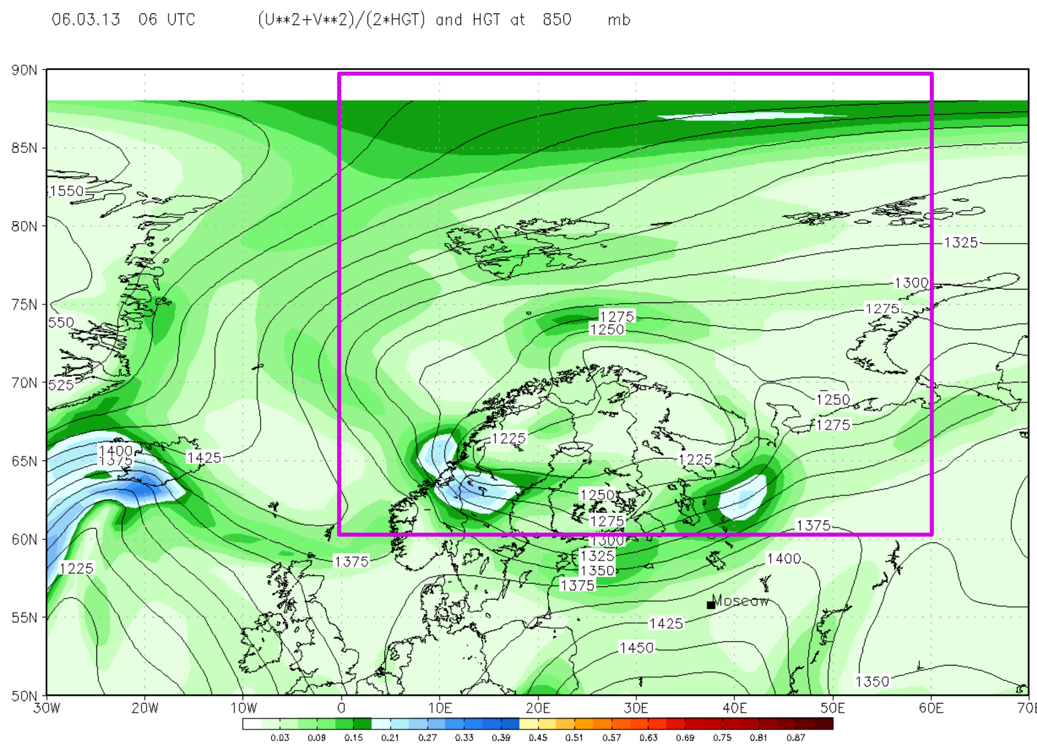


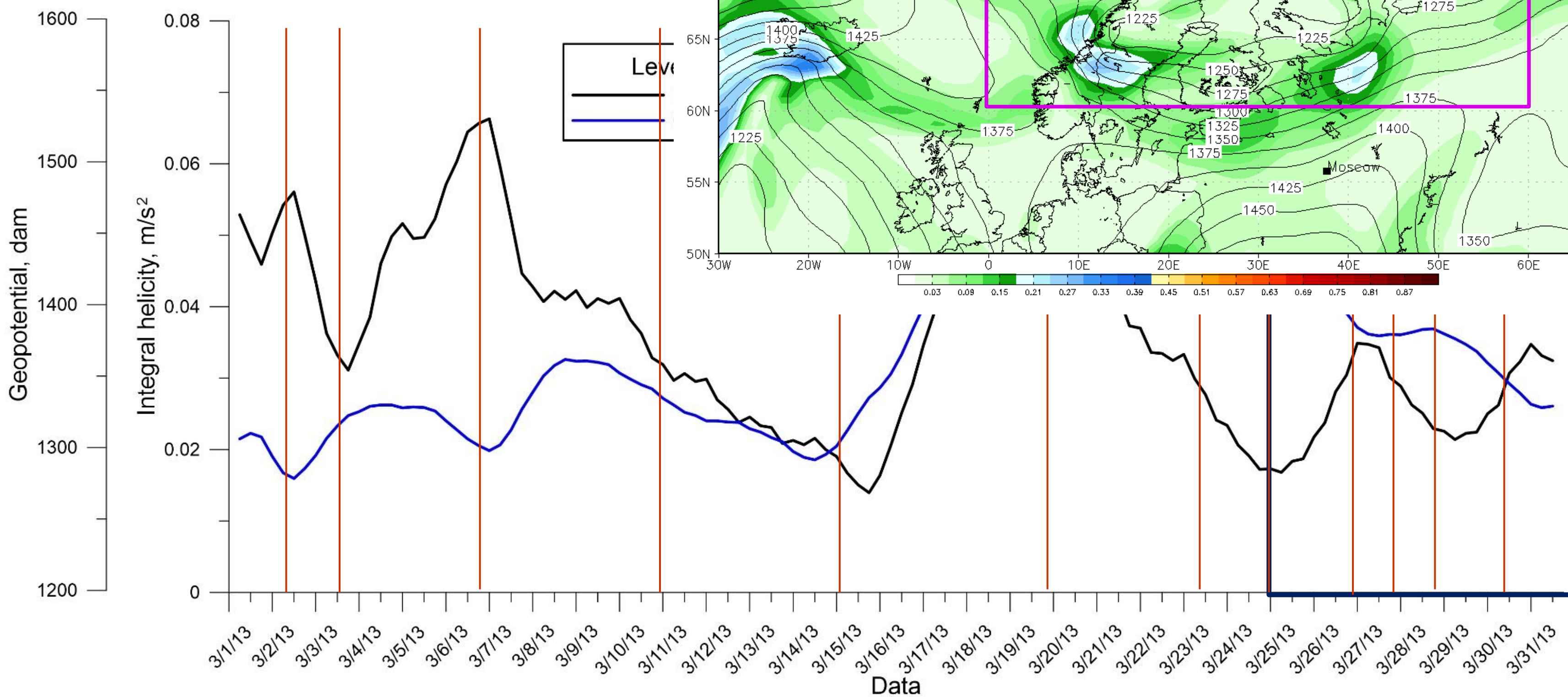


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

6.03.2013 UTC 06

27.03.13 – 31.03.13

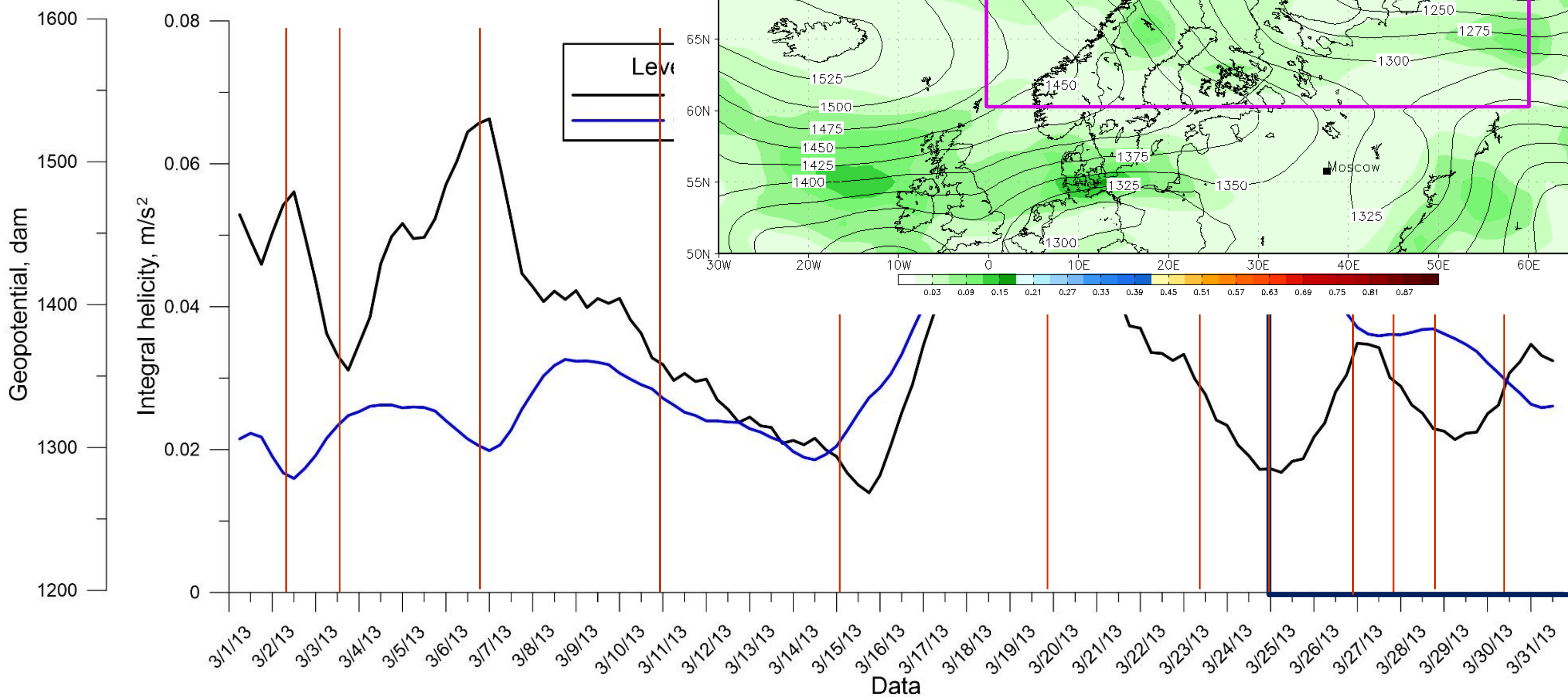


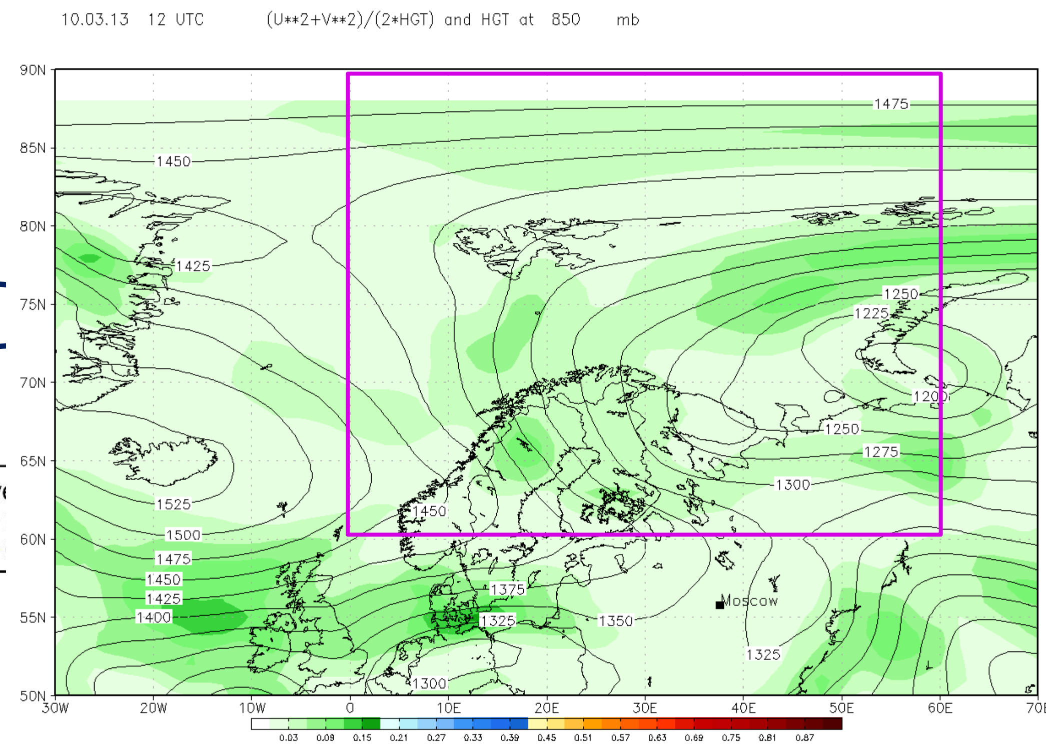


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

10.03.2013 UTC 12

27.03.13 – 31.03.13

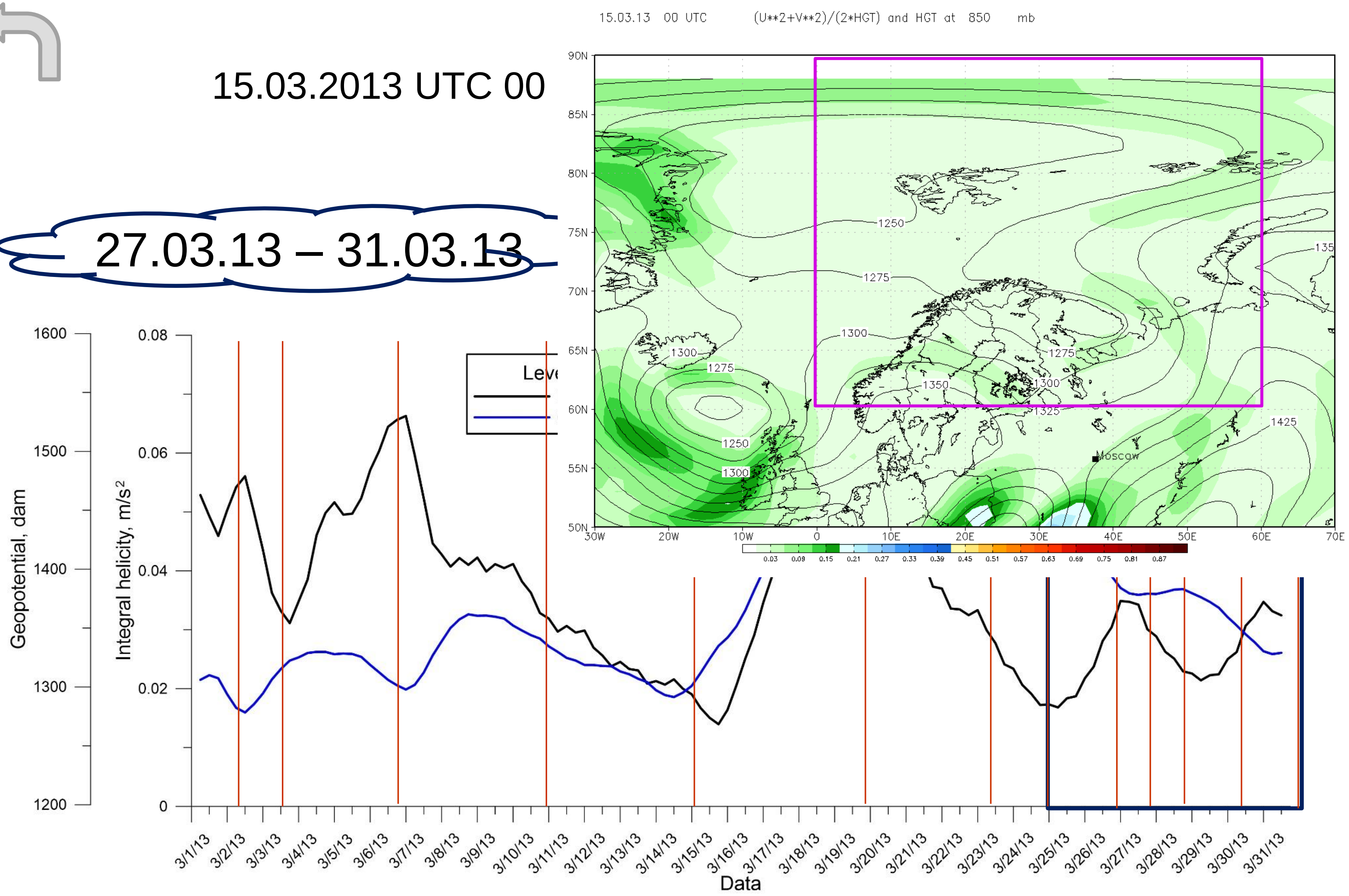




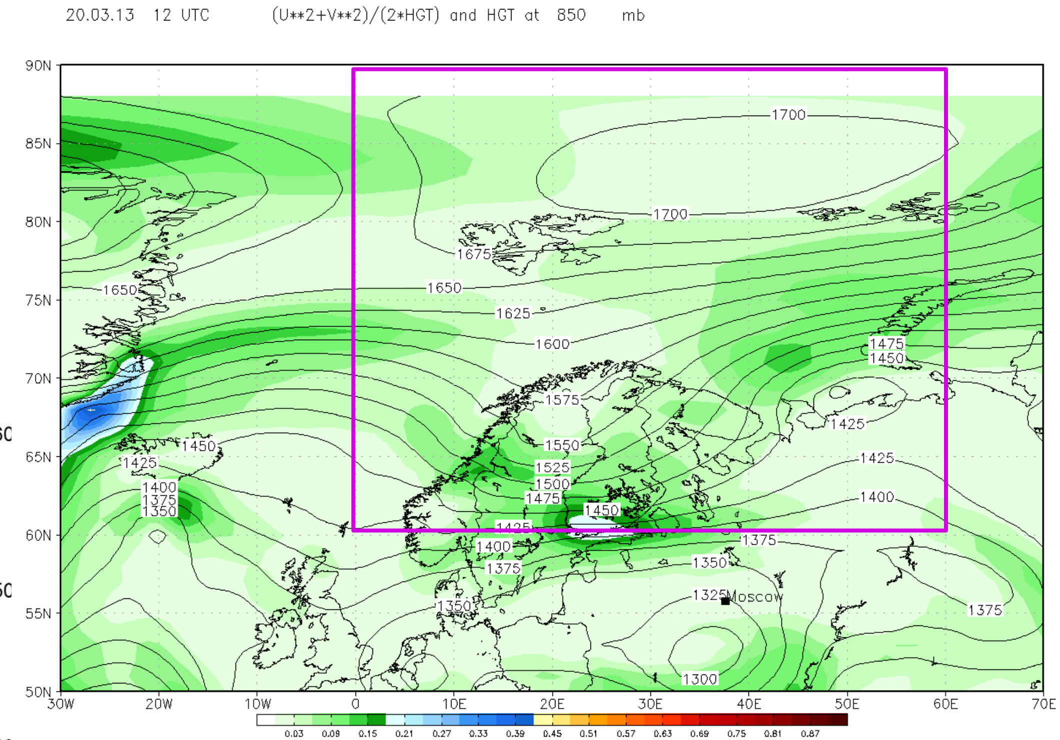
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

15.03.2013 UTC 00

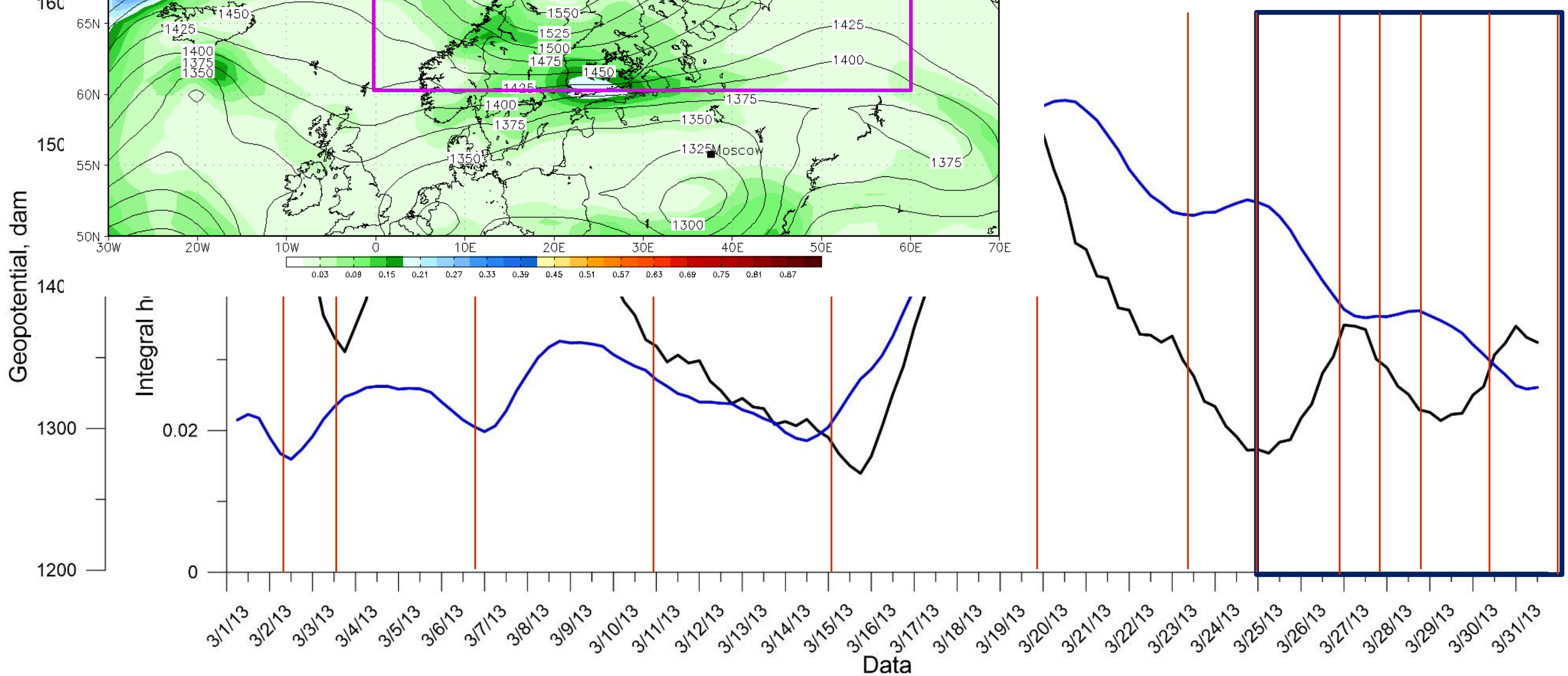
27.03.13 – 31.03.13



Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

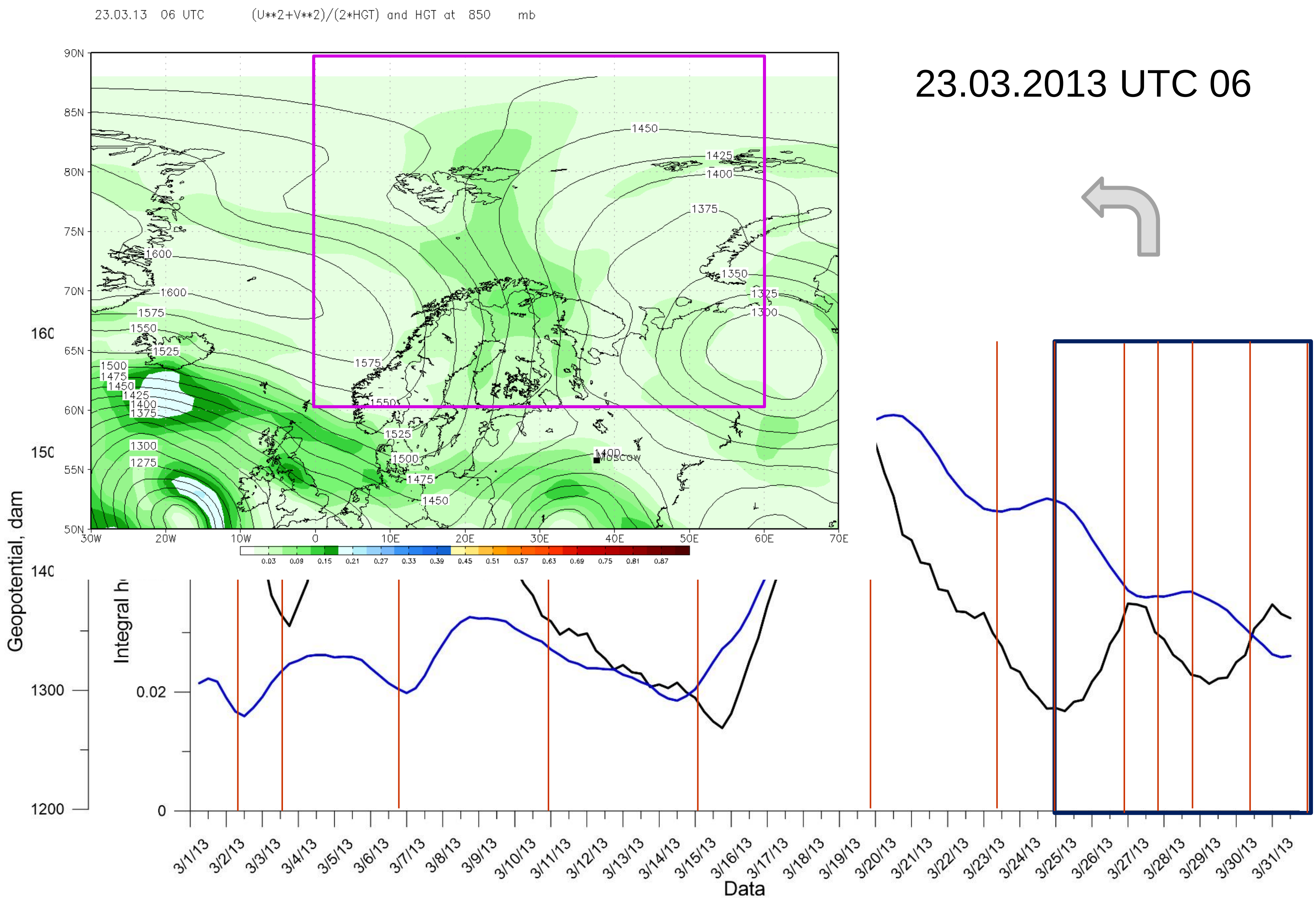


20.03.2013 UTC 12



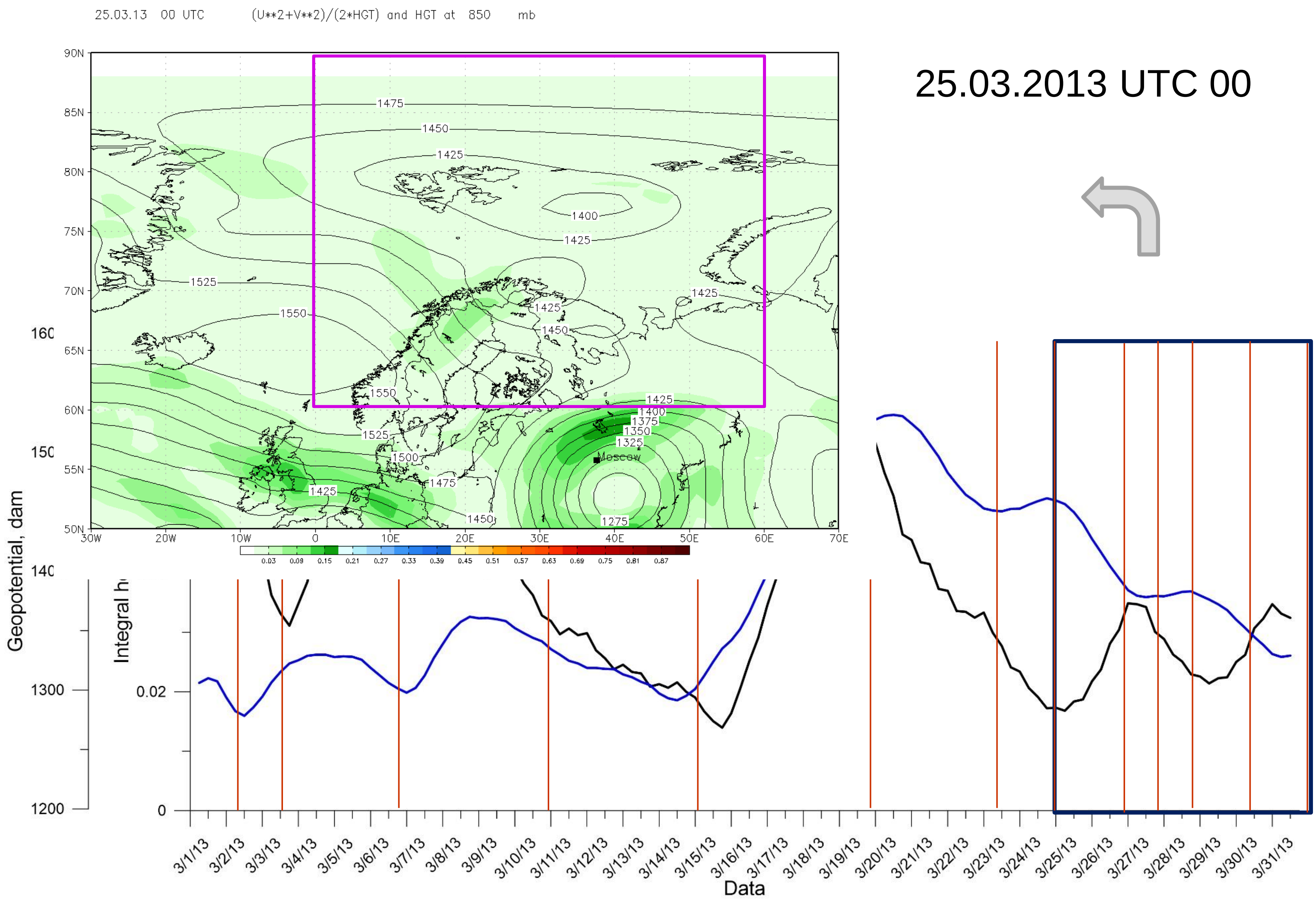
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

23.03.2013 UTC 06



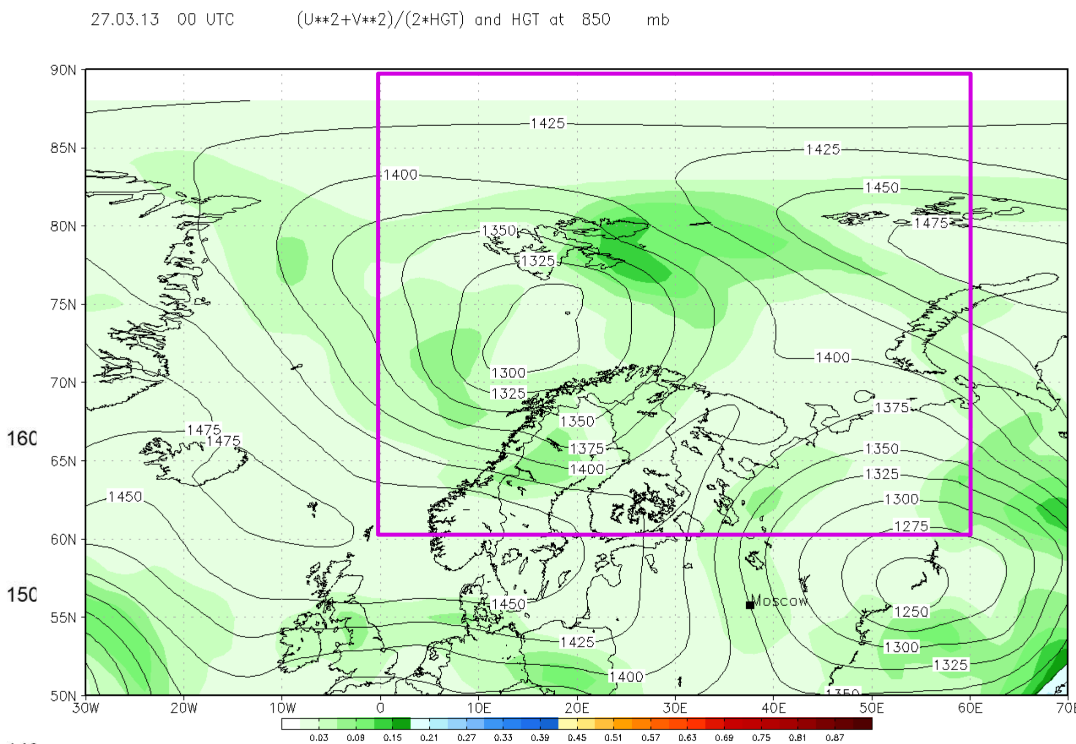
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

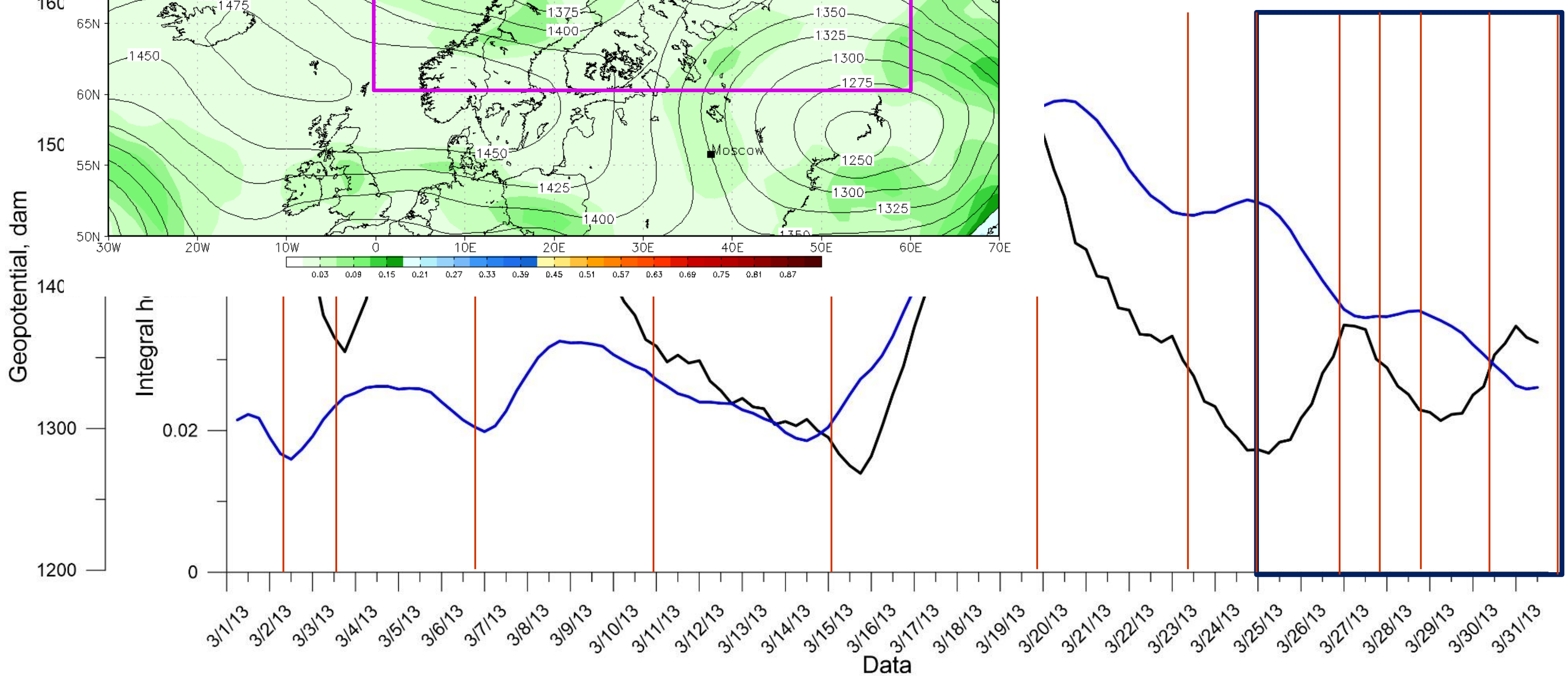
25.03.2013 UTC 00



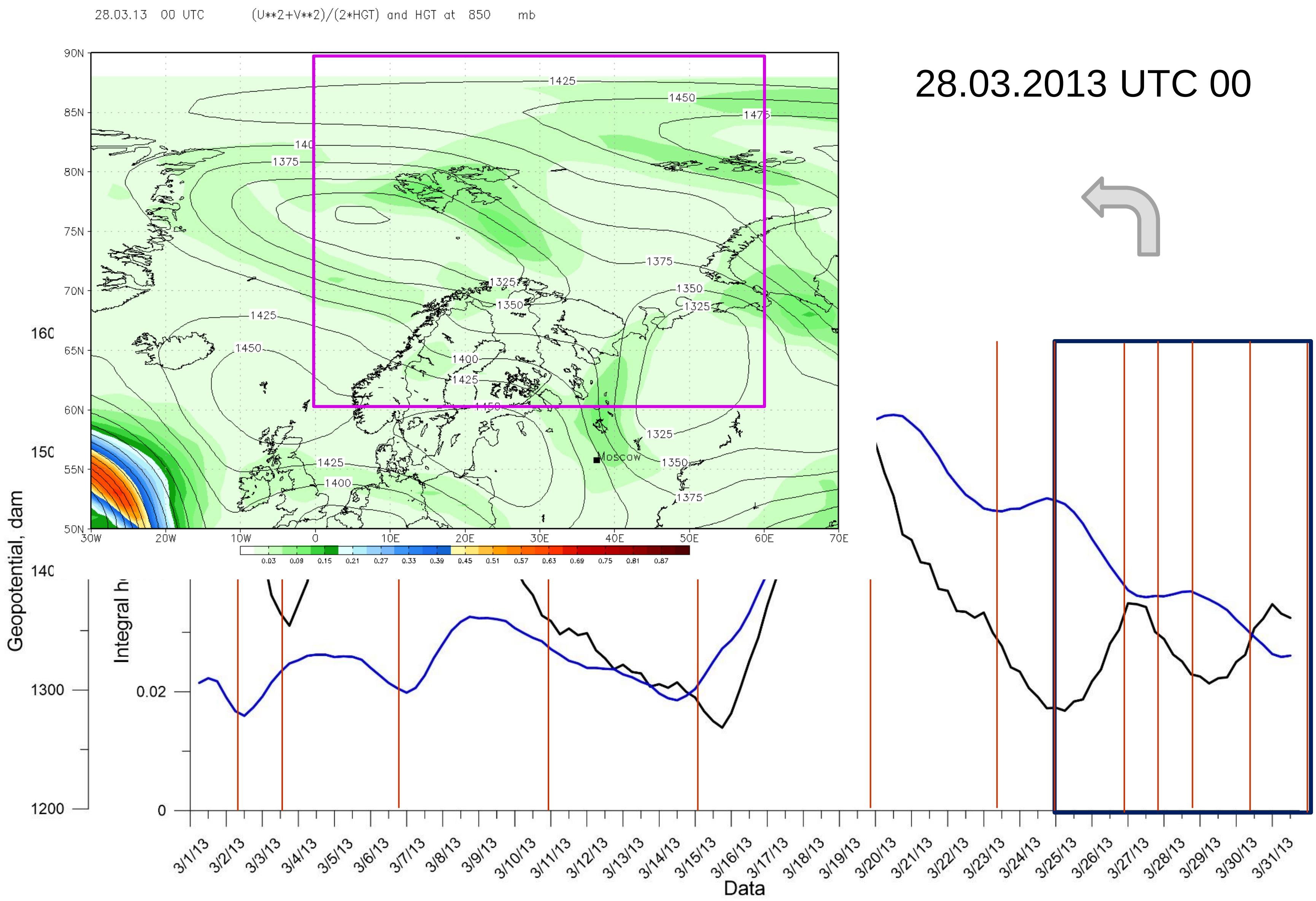
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

27.03.2013 UTC 00



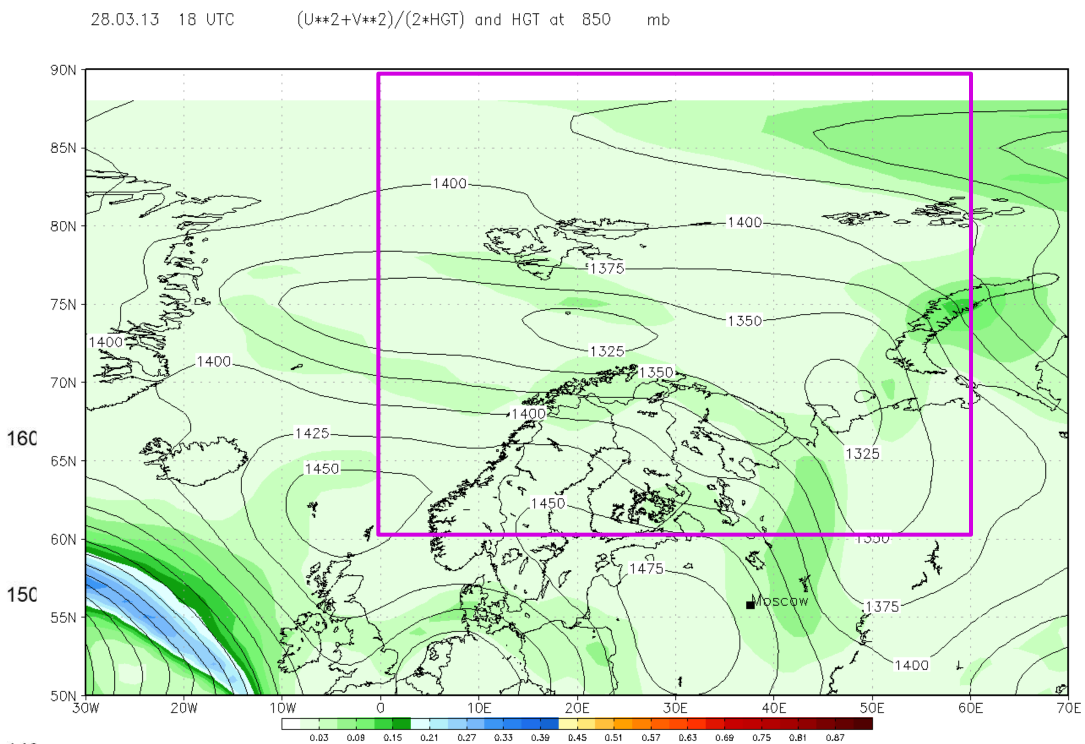


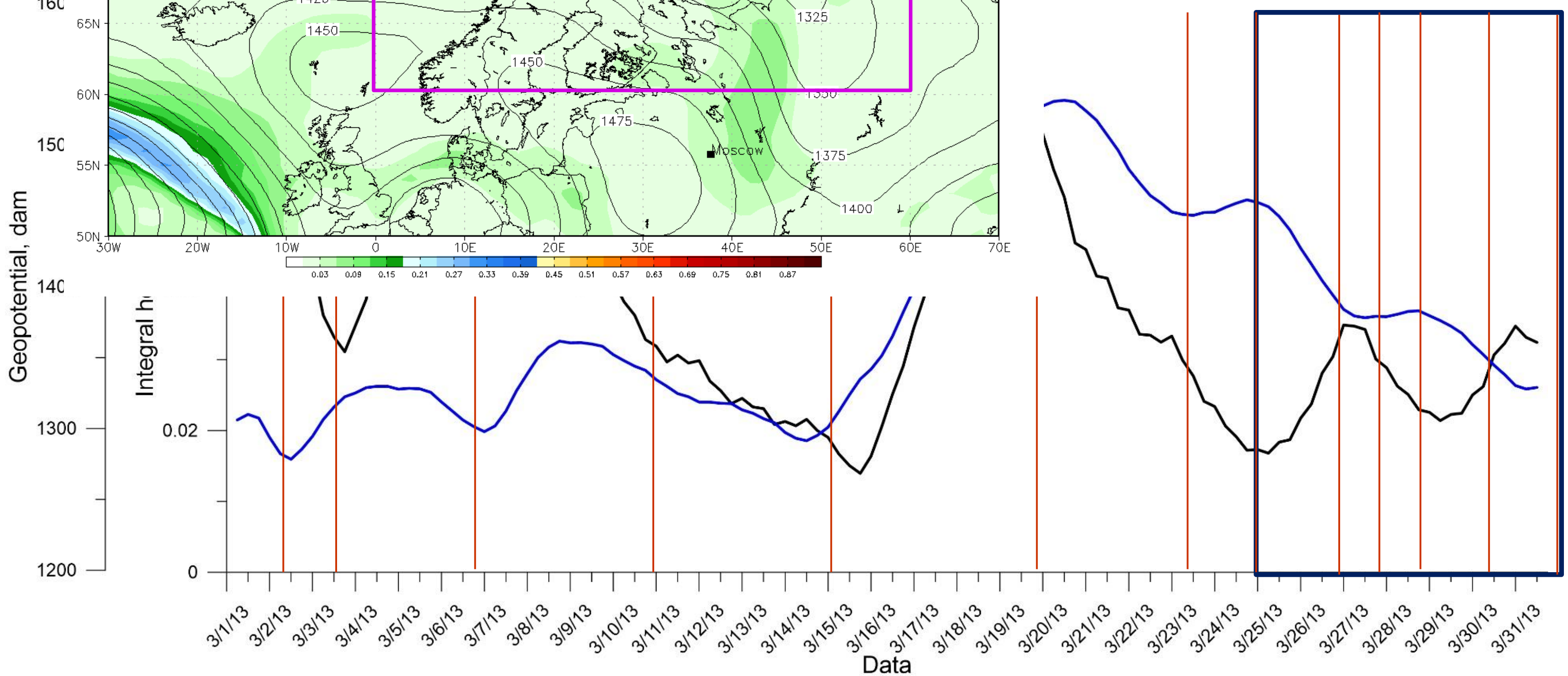
Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa



Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

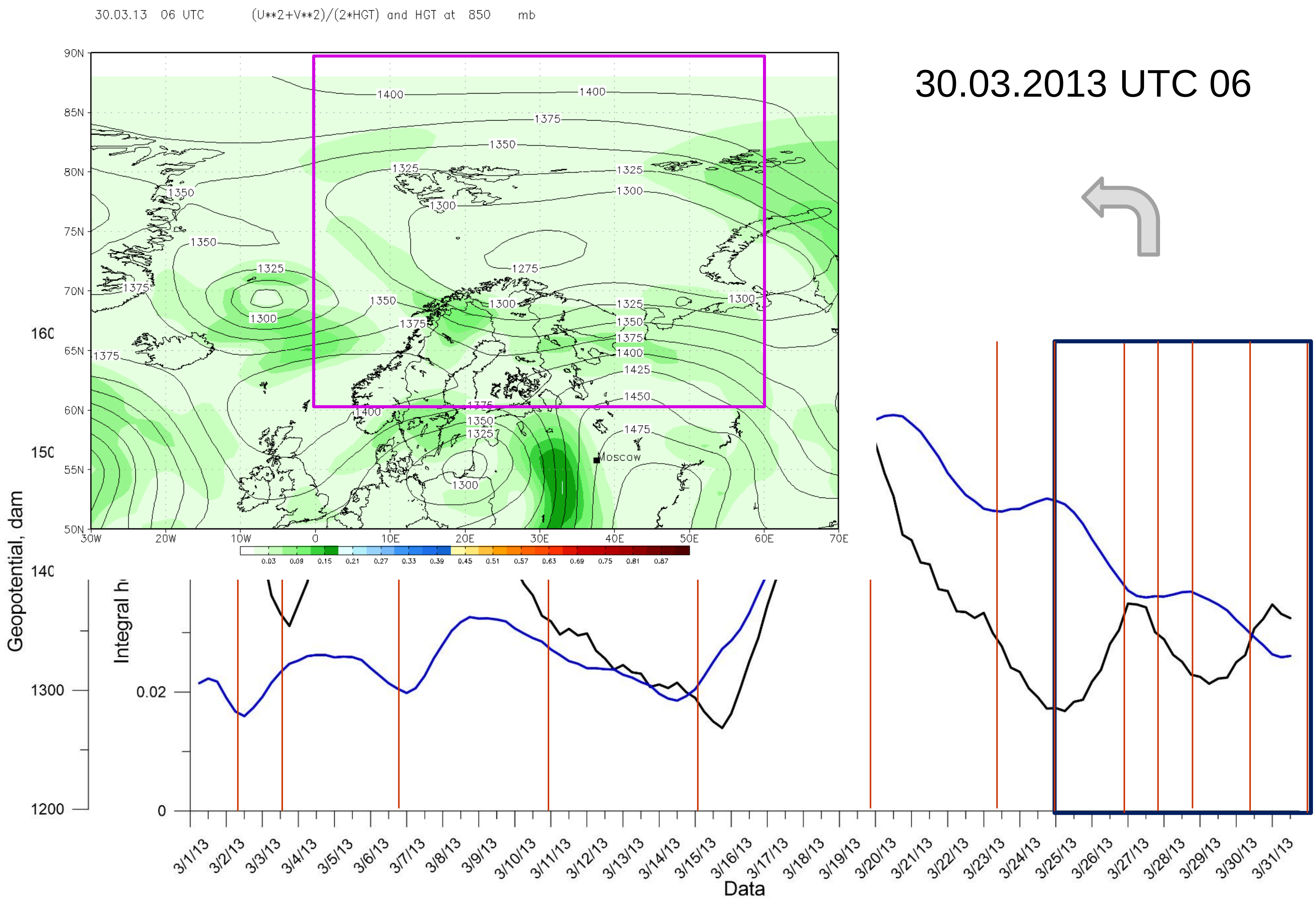
28.03.2013 UTC 18



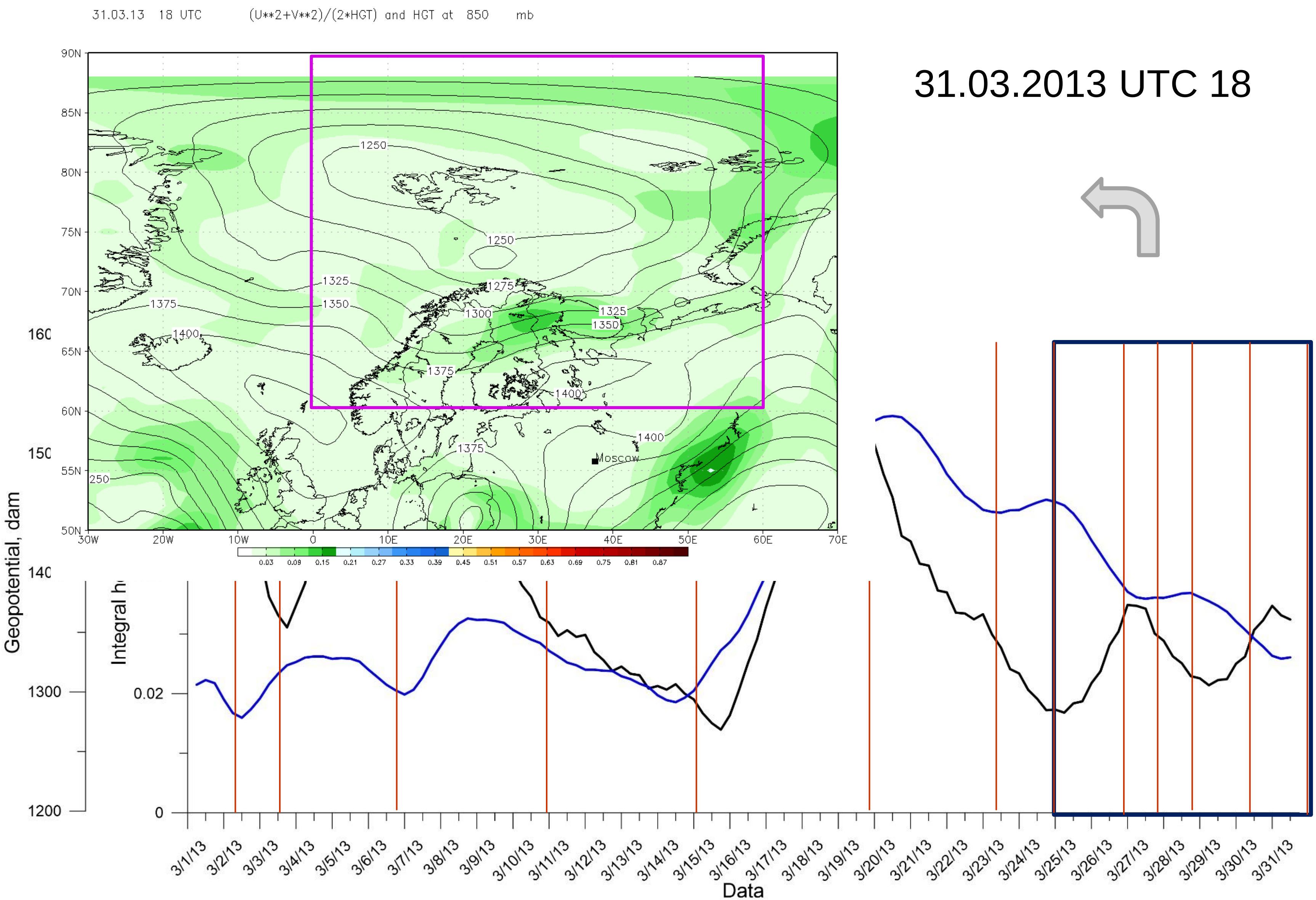


Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa

30.03.2013 UTC 06



Prognostic/diagnostic meaning of the integral helicity, Polar Lows 27-31 March 2013, ECMWF. Level 850 hPa



31.03.2013 UTC 18

Integral characteristics of Polar lows

*Vazaeva N.V., Chkhetiani O.G., Maksimenkov L.O.,
Kurgansky M.V.*

A.M. Obukhov Institute of Atmospheric Physics,
Russian Academy of Science

Baikal Young Scientists' International School on Fundamental Physics
"Physical processes in outer and near-earth space"

XV Young Scientists' Conference
«Interaction of fields and radiation with matter»

Irkutsk, 11 - 16 September 2017

Диагностический смысл интегральной спиральности на примере блокирующего антициклона 2010 года по данным ECMWF. Уровень 900 гПа

Эпизоды регенерации

Episodes of regeneration	
15.07-19.07	polar (from N-W) entry from Norwegian Sea
19.07-23.07	western entry from Baltic Sea
24.07-28.07	polar (from N-W) entry from Norwegian Sea
29.07-01.08	lowgradient field
02.08-08.08	ultrapolar (from N-E & E) entry from Barents Sea
09.08-10.08	lowgradient field
11.08-15.08	polar (from N-W) entry from Norwegian Sea

01.02.10 – 1.09.10