State Hydrometeorological Service of the Ministry of Ukraine of Emergencies
Ukrainian Hydrometeorological Institute NASU
UHMI

LONG-RANGE FORECASTING METHOD DEVELOPED IN UKRAINIAN HYDROMETEOROLOGICAL INSTITUTE

Prof. V.F. Martazinova ,
Head of the Department of Climate Research and Long-Range Forecasting

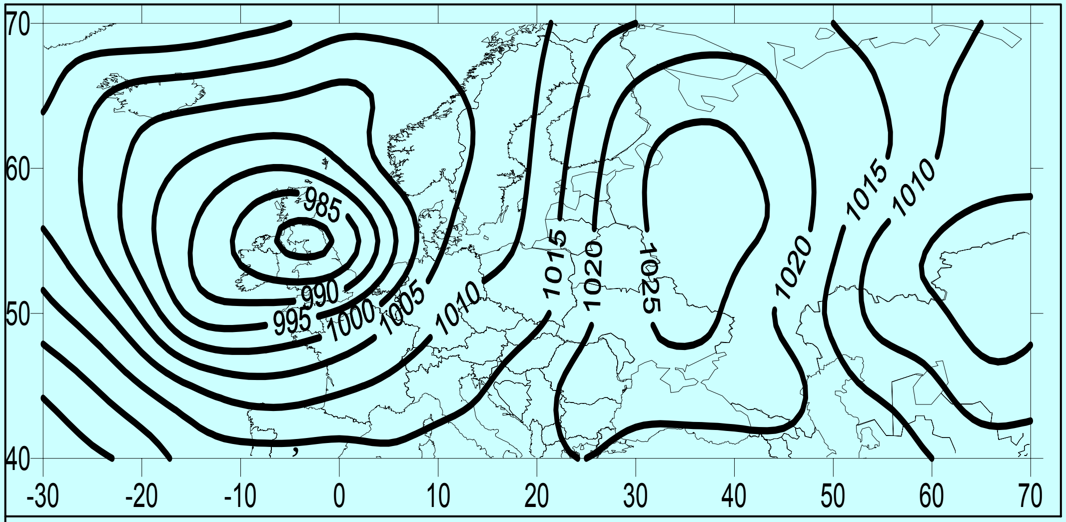
Vazira@gmail.com

NEACOF-5
2013

Key approaches used in the long-range forecasting system UHMI

- Floating analog method
- Two-month quasi-periodicity of atmospheric processes
- Etalon fields method

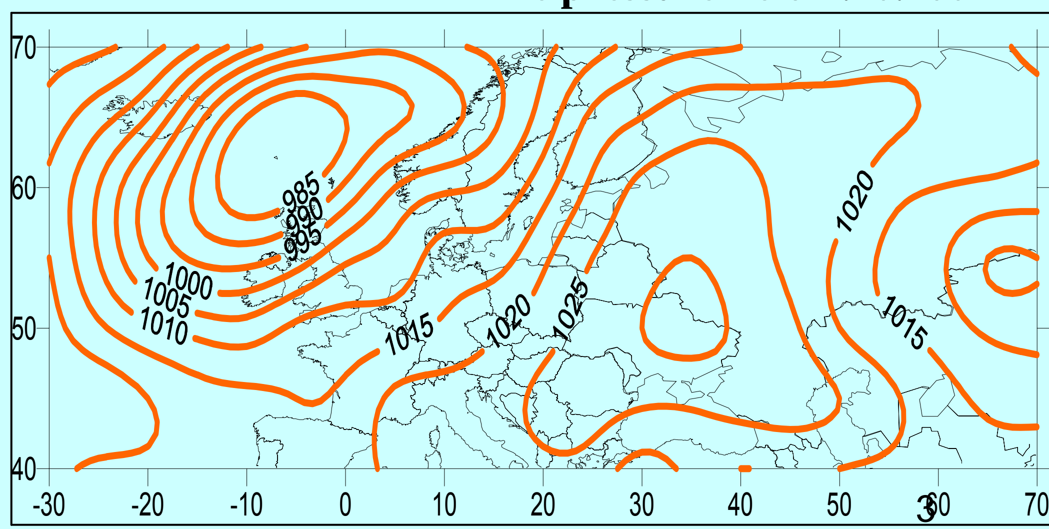
The traditional method of analogue (TAM)



The pressure field 5.10.2004

If synoptic process is observed at some region of Earth during some time with analogues , then current synoptic process by analogy will develop in past time in the same place and in the same calendar dates.

The pressure field 7.10.2001



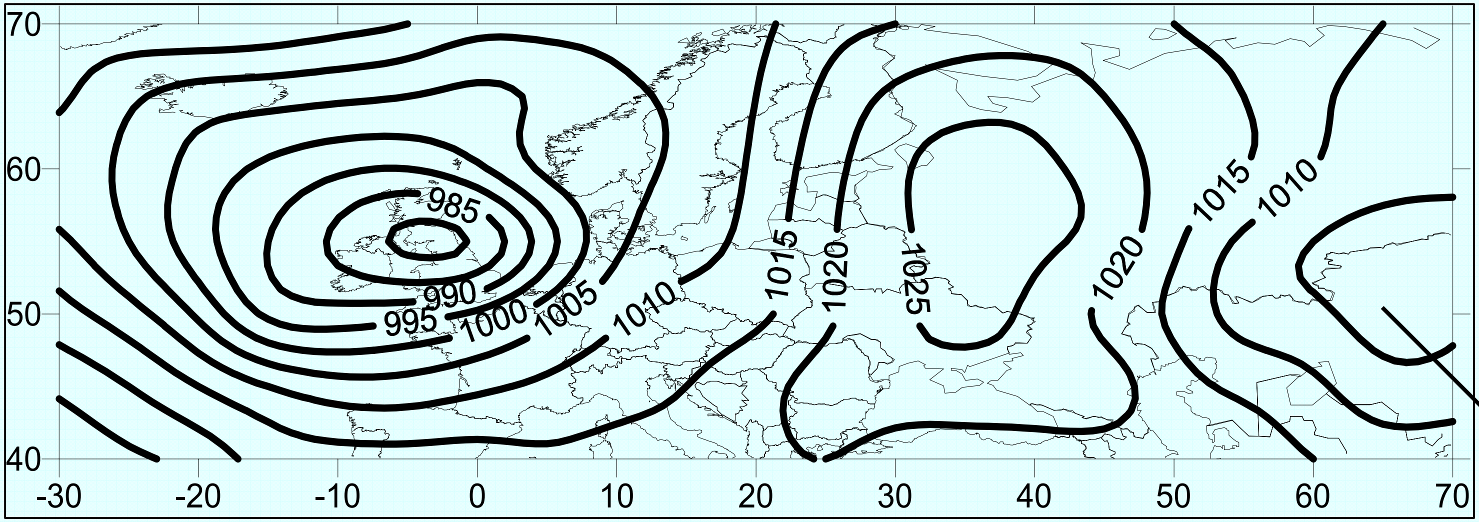
Criteria's of analogue: **Geometrically distinguish a sign of anomaly two fields**

$$\rho = \frac{n_+ - n_-}{n},$$ $1 \geq \rho \geq -1$

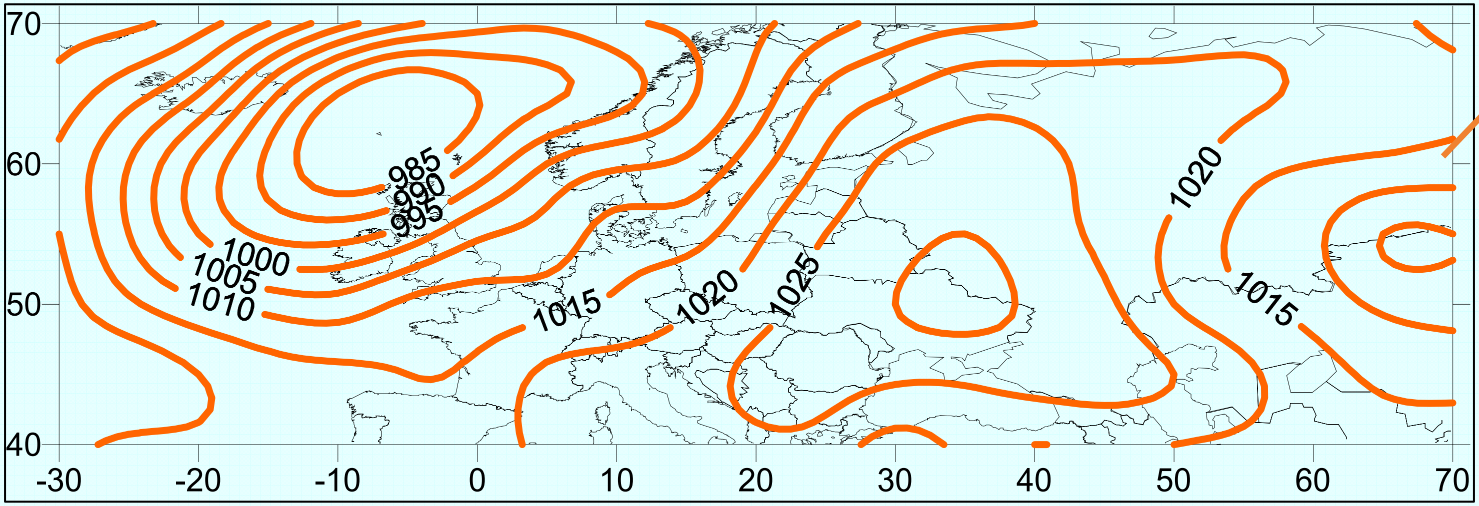
Criterion of mean square distance between two fields

$$\eta^2 = \frac{1}{n}\sum_{j=1}^{n}(x_{ij} - x_{kj})^2, \quad \eta > 0$$

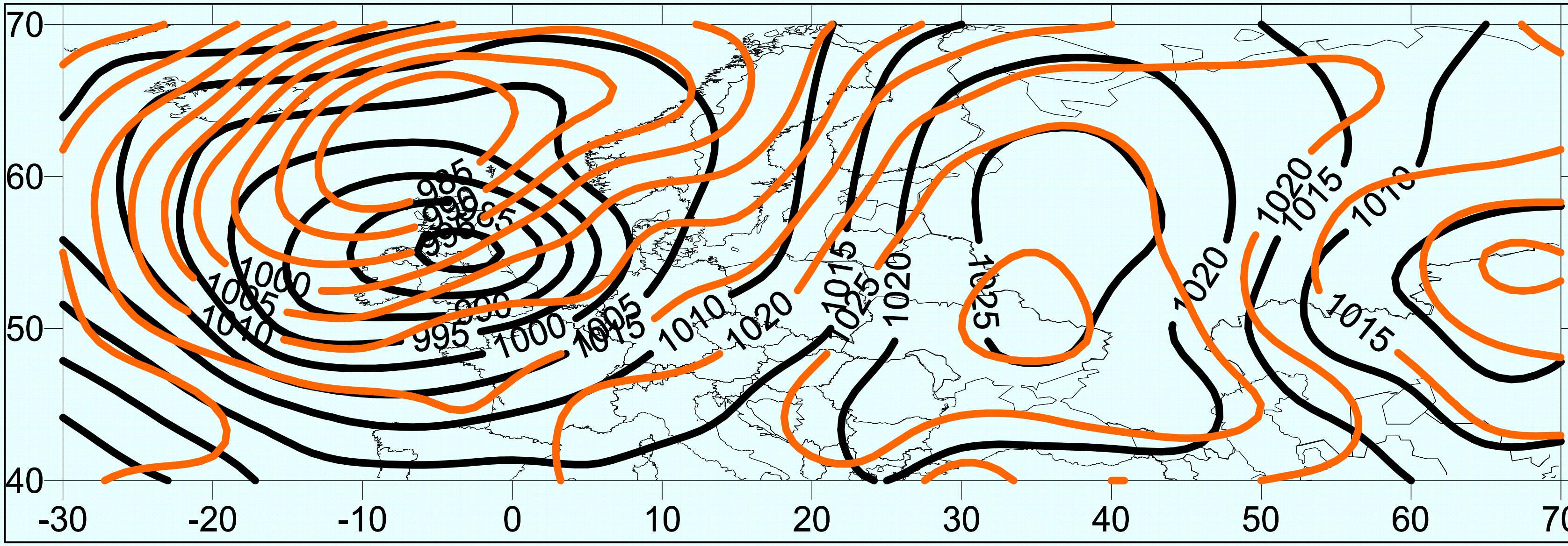
The pressure field 5.10.2004



The pressure field 7.10.2001

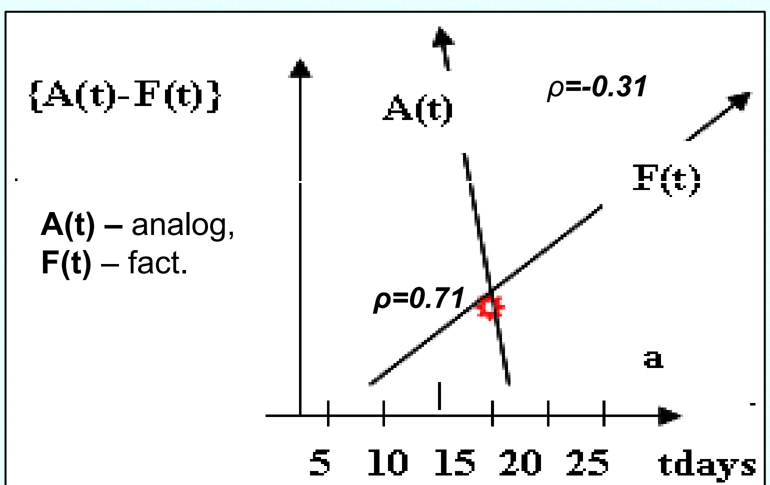


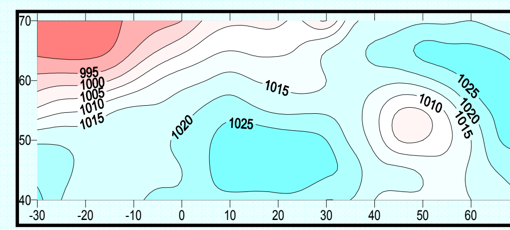
ρ=0.71

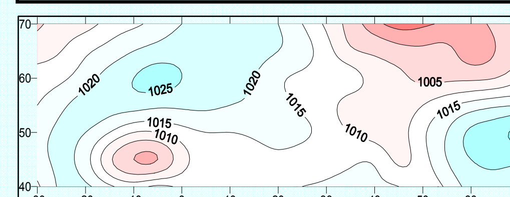


The pressure field 5.10.2004 **The pressure field 7.10.2001**

Scheme of variation in time TAM

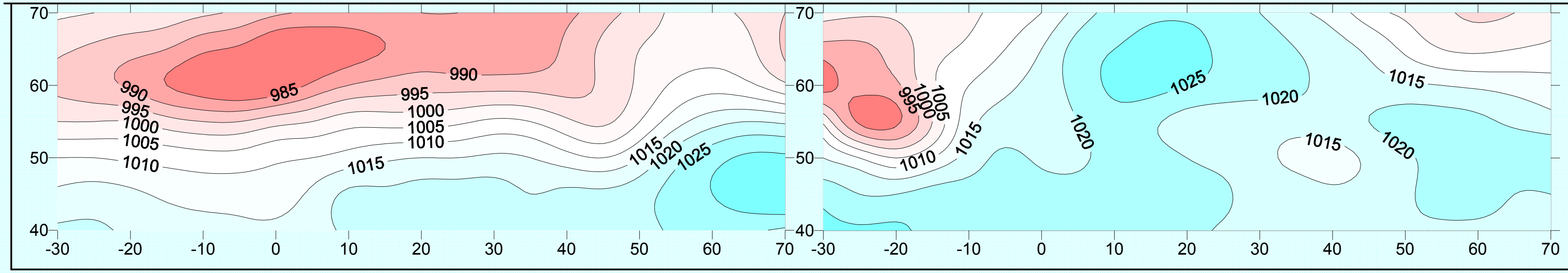






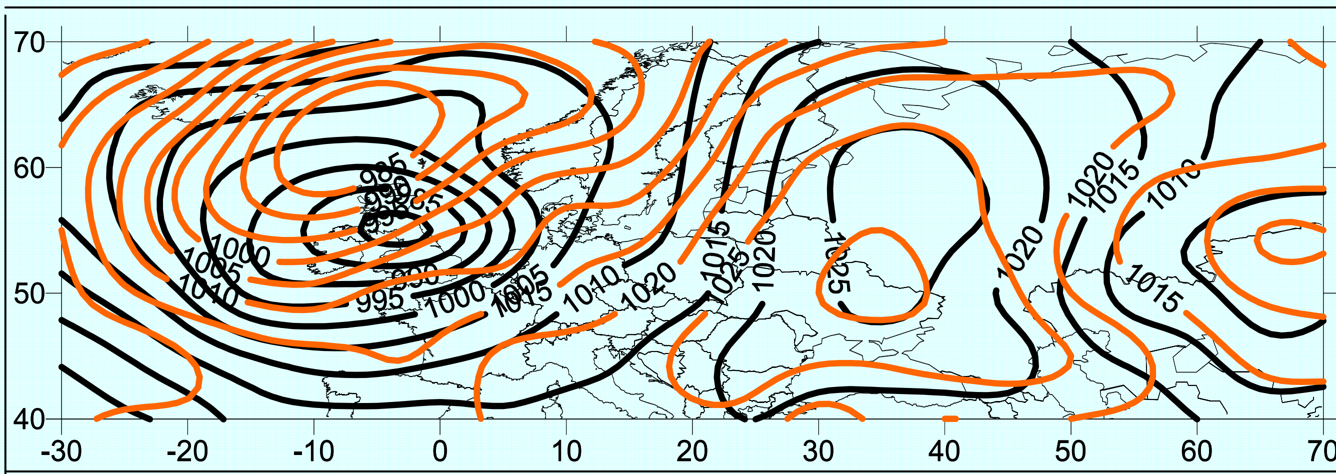
The pressure field
10.10.2004 ≈ 12.10.01
ρ=-0.31

TRADITIONAL ANALOG METOD



1.10.2004 **3.10.2001**

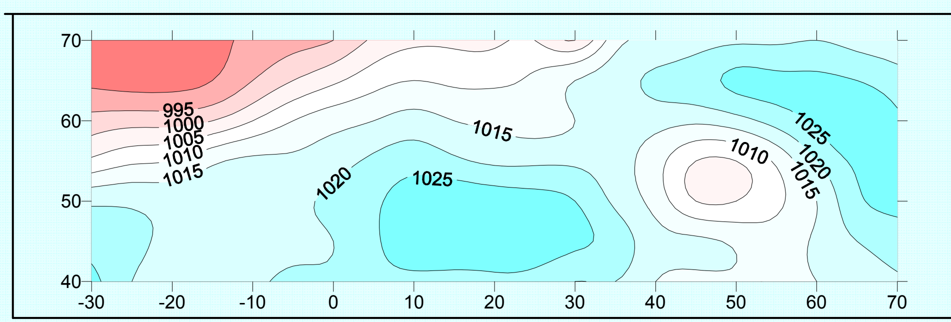
***ρ*=0.25**



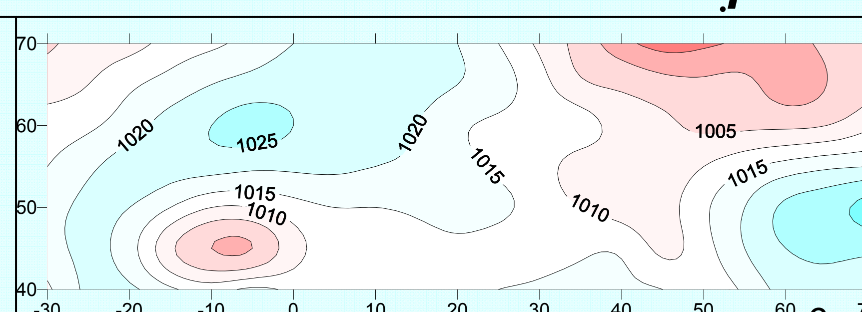
The pressure fields 5.10.2004(—) and 7.10.2001(—)

***ρ*=0.71**

***ρ*= -0.31**



The pressure field 10.10.2004



The pressure field 12.10.2001

Conclusion:

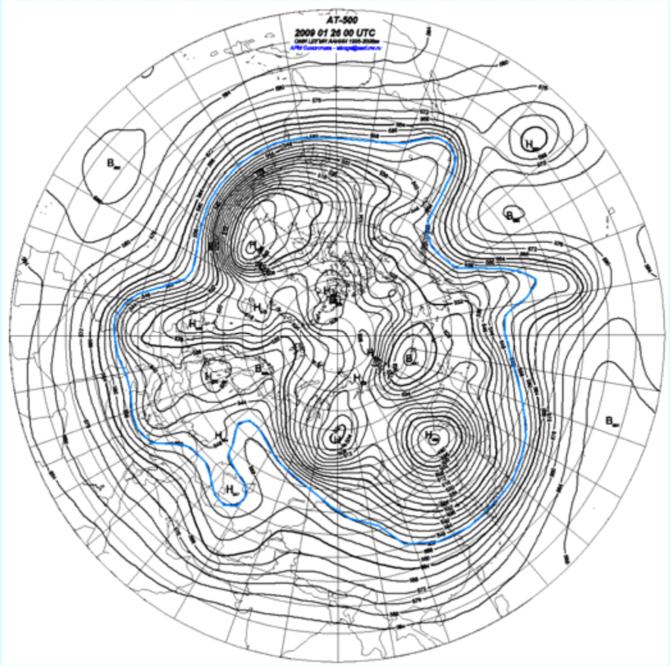
- Traditional method of analog (TAM) does not work well and gives the random result in practice of long-range forecast .

The floating analogue method (FAM)

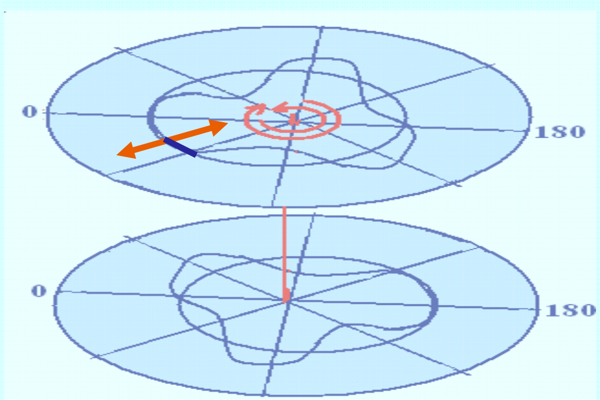
Martazinova V.,1986

The method of “floating analogue” (FAM)

Martazinova V.,1986



The planetary high-level frontal zone 28.01.09



It requires only geometrical similarity of the planetary high-level frontal zone and pressure at surface of the Earth in the Northern Hemisphere. As result the limiting conditions of the coincidence in time and space are lifted.

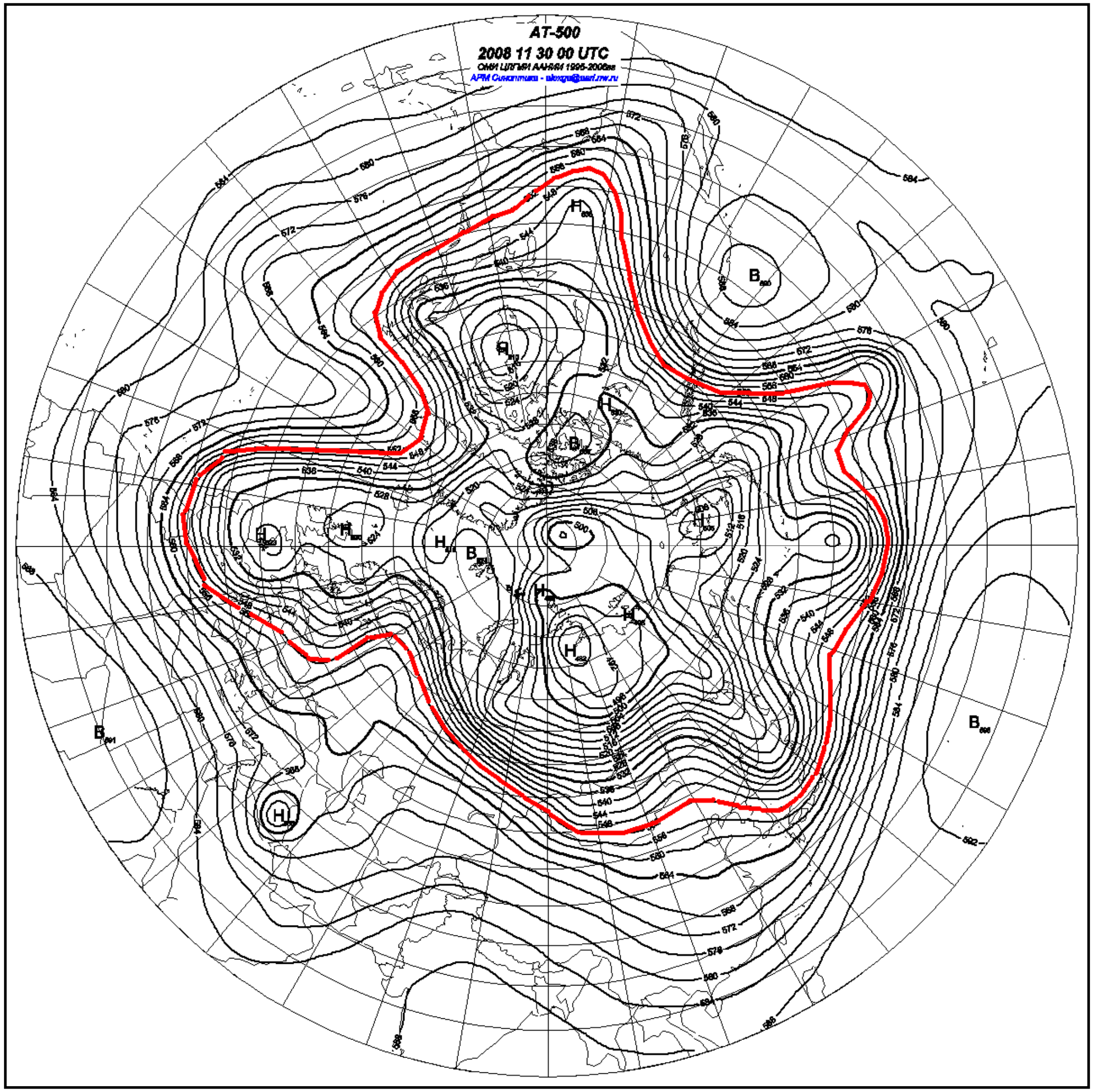
Criteria’s of analog:

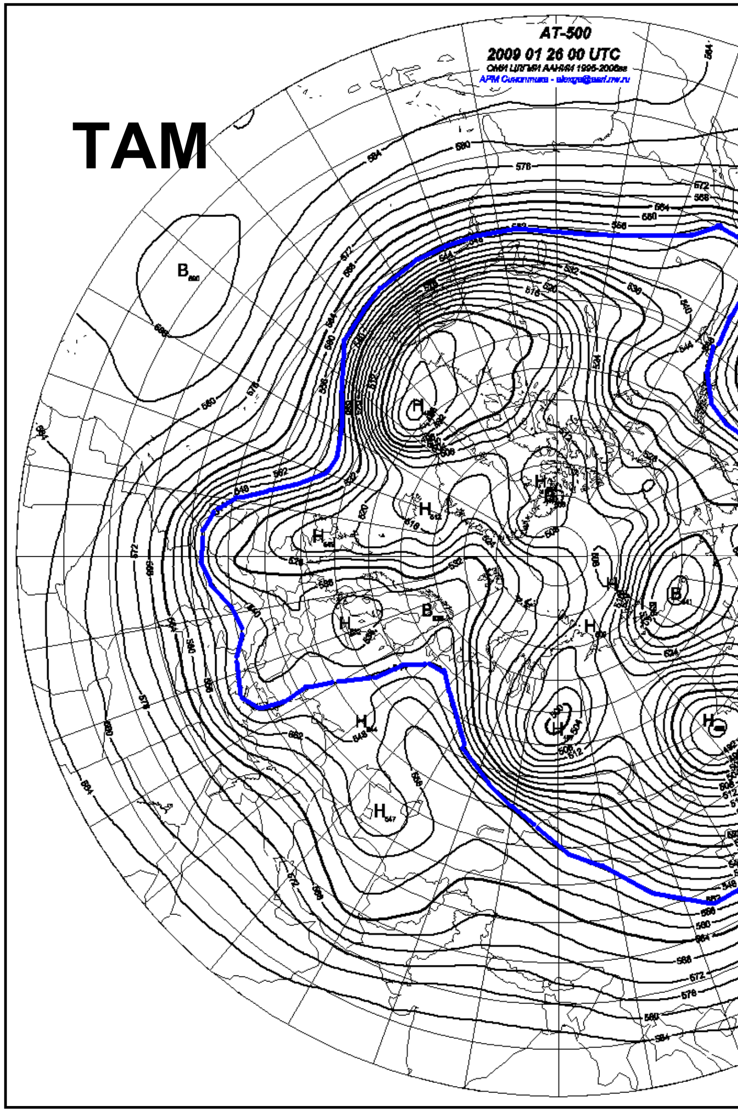
Geometrically distinguish two fields

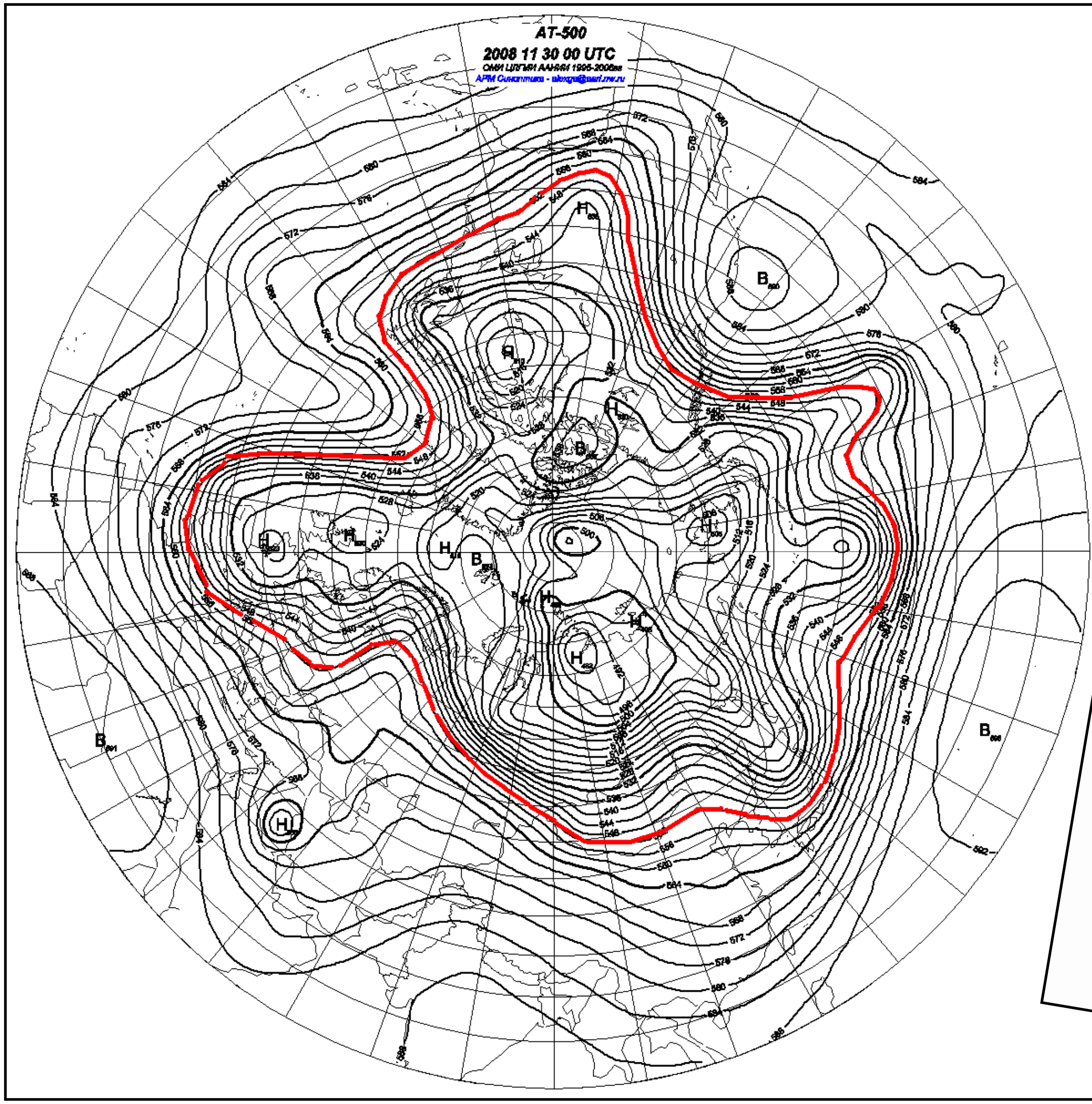
$$\rho = \frac{n_+ - n_-}{n} \qquad 1 \geq \rho \geq -1$$

Criterion of mean square distance between two fields

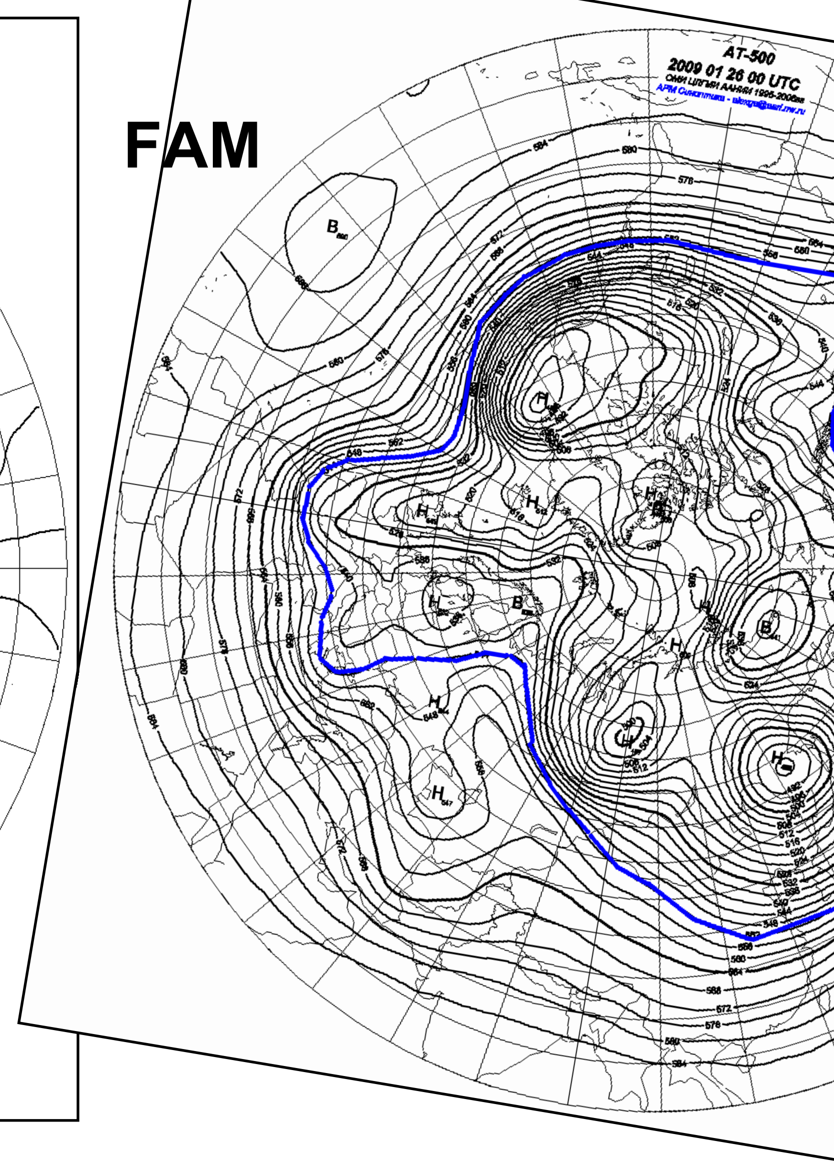
$$\eta^2 = \frac{1}{n}\sum_{j=1}^{n}(x_{ij} - x_{kj})^2 \qquad \eta > 0$$


AT-500
2008 11 30 00 UTC


TAM
AT-500
2009 01 26 00 UTC

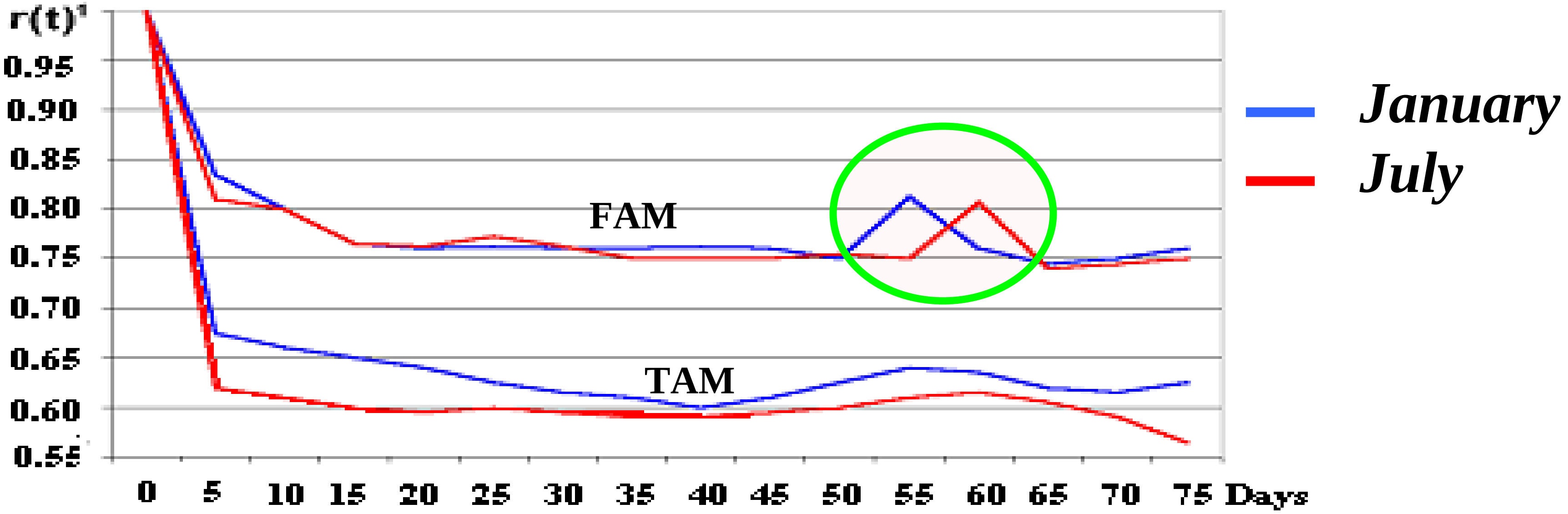


FAM



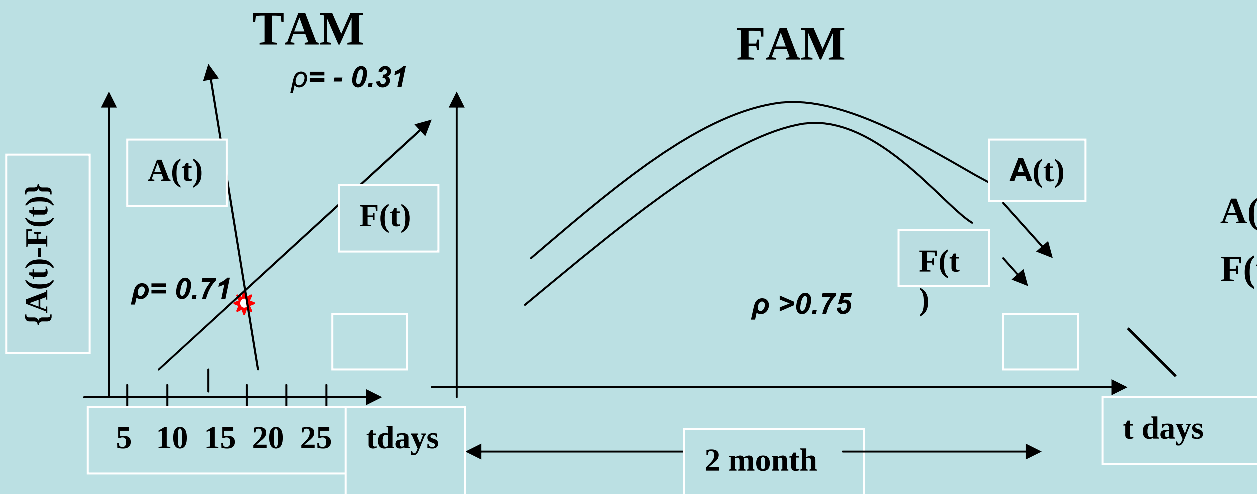
Two-month quasi-periodicity of atmospheric processes

Two-month quasi-periodicity of atmospheric processes in the troposphere of the Northern Hemisphere.



Autocorrelation function of the geopotential field on the mean level of the Northern Hemisphere calculated by TAM and FAM.

Scheme of the behavior in time of the traditional (TAM) and floating (FAM) analogues.



A(t)- similar synoptically process,

F(t) – actual synoptically process .

Seasonal shift of the two-month quasi-periodicity of atmospheric circulation in the Northern Hemisphere

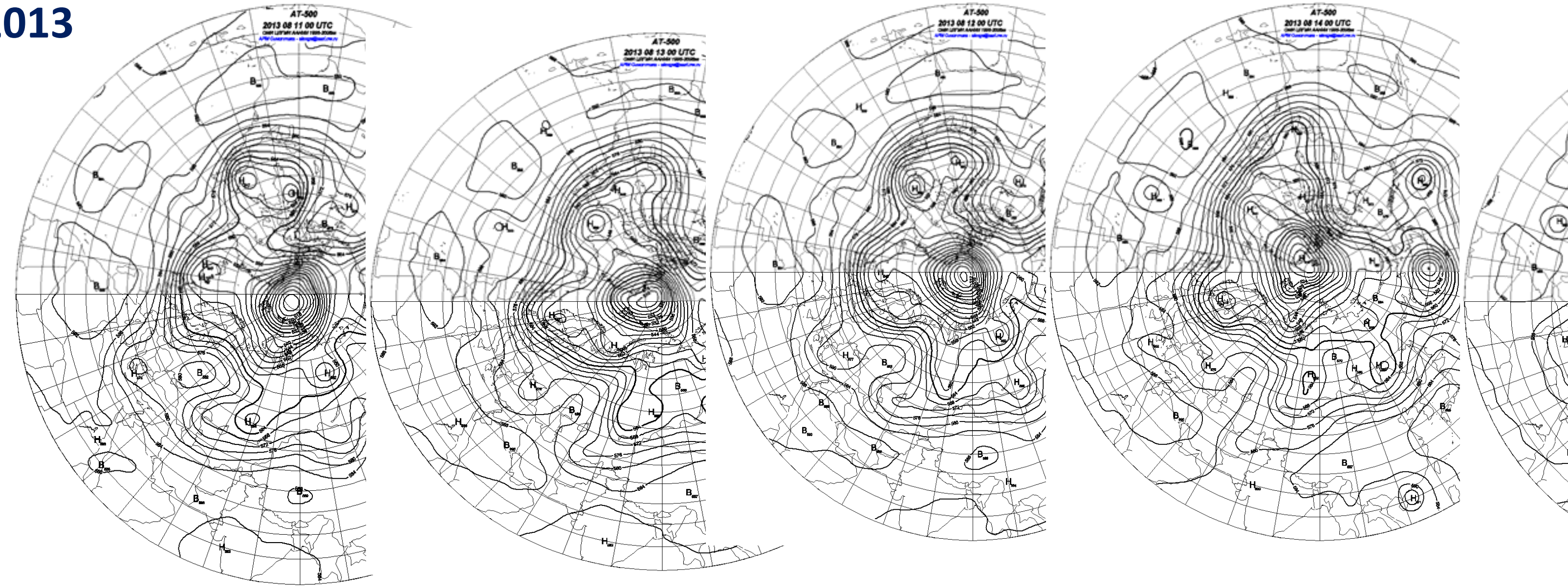
Month	Month - analog	Position of analog Δλ	Δ φ	Month	Month - analog	Position of analog Δλ	Δ φ
January	November	−5°	5°	July	May	5°	0°
February	December	−10°	5°	August	June	10°	0°
March	January	−5°	−5°	September	July	5°	5°
April	February	−5°	−10°	October	August	0°	10°
May	March	−5°	−5°	November	September	0°	5°
June	April	0°	−5°	December	October	−5°	5°

example

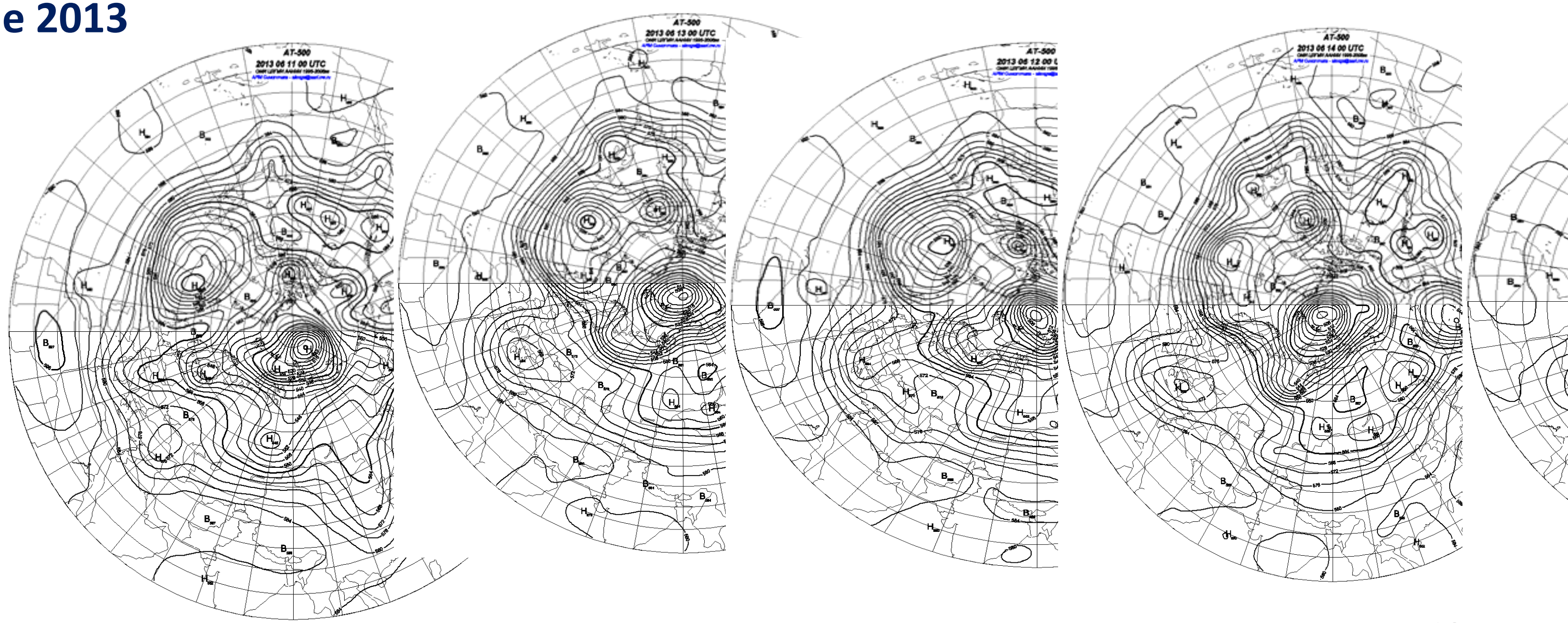
Two-month quasi-periodicity of atmospheric processes for August 2013

Analogs of June for consistent days of August 2013 (TAM)

11-15 August 2013

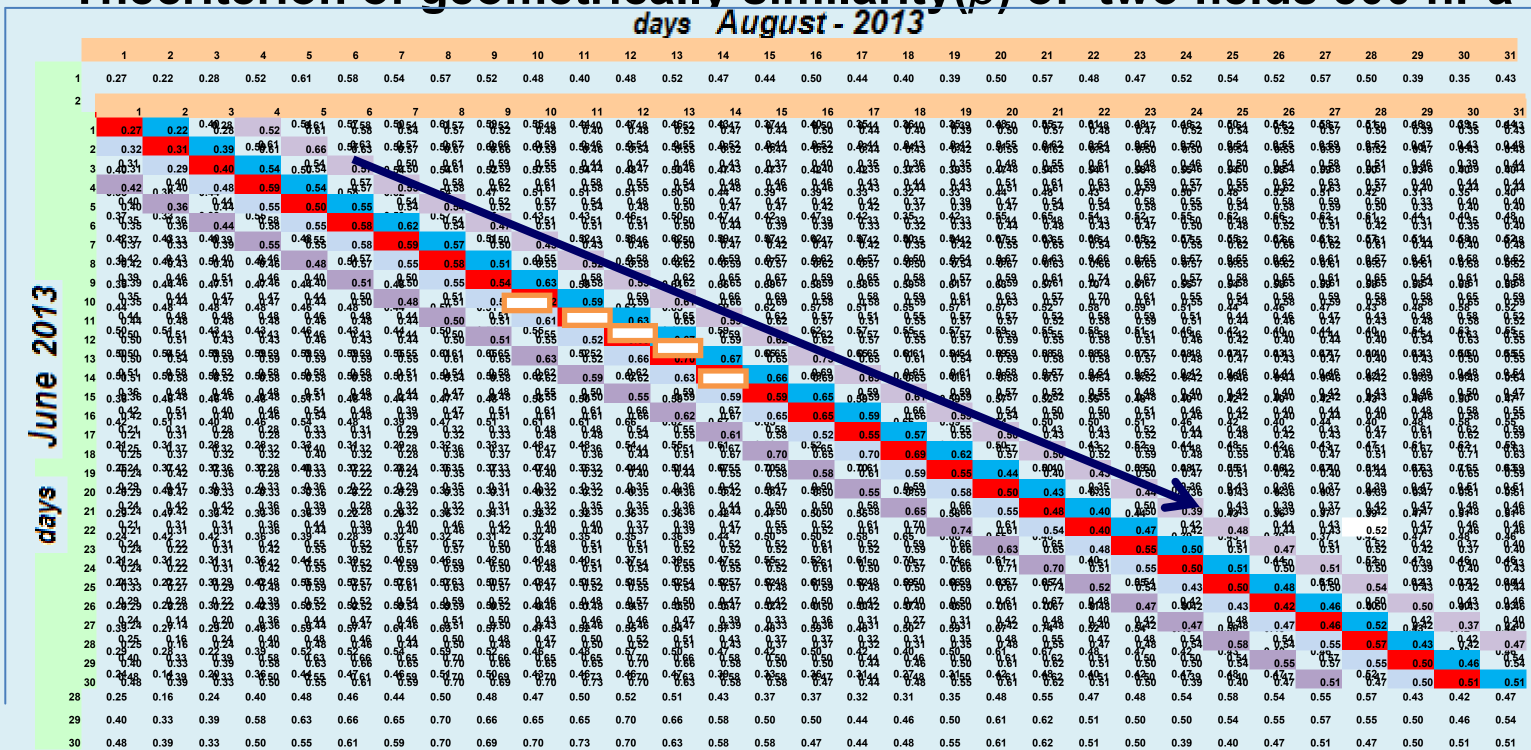


11-15 June 2013



THE TWO-MONTH QUASI-PERIODICITY THE ATMOSPHERIC CIRCULATION OVER NORTH HEMISPHERE FOR AUGUST 2013

Thecriterion of geometrically similarity(ρ) of two fields 500 hPa



•**This matrix** criteria ρ of geometric similarity between fields of the June and August on the same territory (no shift in latitude and longitude) reveals the similarity.

• **The diagonal elements** of the matrix are high and indicate the existence of the two-month periodicity for the daily fields of atmospheric circulation in August 2013 over the Northern Hemisphere.

•**For a more accuracy** definition of similarity to be used "Floating analog“

Calculation of position of analog with the two-month quasi-periodicity at level 500 mb for August 2013

	11.06.2013	12.06.2013	13.06.2013	14.06.2013	15.06.2013
12.08 2013	ρ(4, 1) = 0.714 ρ (4, 7) = 0.633 ρ (4, 2) = 0.607	ρ (4, 6) = 0.729 ρ (4, 7) = 0.660 ρ (4, 5) = 0.654	ρ (4, 7) = 0.633 ρ (4, 9) = 0.624 ρ (4, 8) = 0.614	ρ (5, 1) = 0.711 ρ (4, 1) = 0.657 ρ (4, 9) = 0.654	ρ (4, 2) = 0.607 ρ (4, 3) = 0.597 ρ (4, 1) = 0.581
13.08 2013	ρ (4, 1) = 0.771 ρ (4, 7) = 0.646 ρ (4,10) =0.635	ρ (4, 7) = 0.673 ρ (4,10) = 0.651 ρ (4, 9) = 0.639	ρ (4, 7) = 0.701 ρ (4, 6) = 0.686 ρ (4,10) = 0.667	ρ (5, 2) = 0.750 ρ (5, 2) = 0.688 ρ (4, 8) = 0.671	ρ (4, 8) = 0.629 ρ (4, 3) = 0.613 ρ (4, 7) = 0.592
14.08 2013	ρ (4, 1) = 0.752 ρ (4, 2) = 0.714 ρ (4,12) =0.661	ρ (4,11) = 0.714 ρ (4,12) = 0.643 ρ (3,12) = 0.625	ρ (3,11) = 0.686 ρ (3,10) = 0.685 ρ (4, 7) = 0.673	ρ (4, 6) = 0.750 ρ (4, 7) = 0.687 ρ (3,10)=0.685	ρ (4, 8) = 0.686 ρ (5, 2) = 0.667 ρ (4, 3) = 0.647

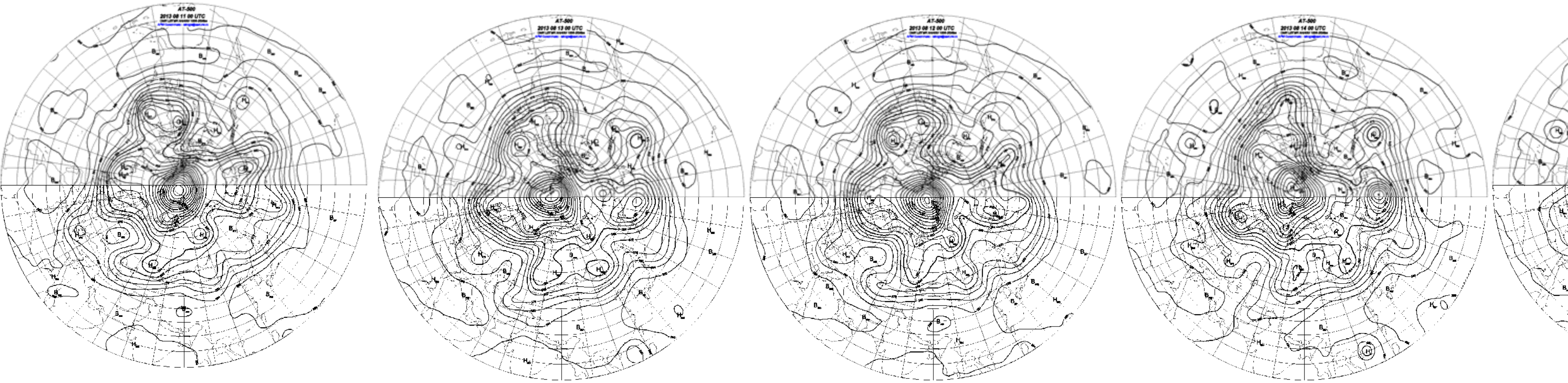
where ρ(Δλ,Δφ)-the geometrically criterion of similarity of two fields
Δλ –analog shift of latitude, Δφ -analog shift of longitude

Δλ,
1 SHIFT TO 15^0 S
2 SHIFT TO 10^0 S
3 SHIFT TO 5^0 S
4 SHIFT TO 0^0
5 SHIFT TO 5^0 N
6 SHIFT TO 10^0 N
7 SHIFT TO 15^0 N

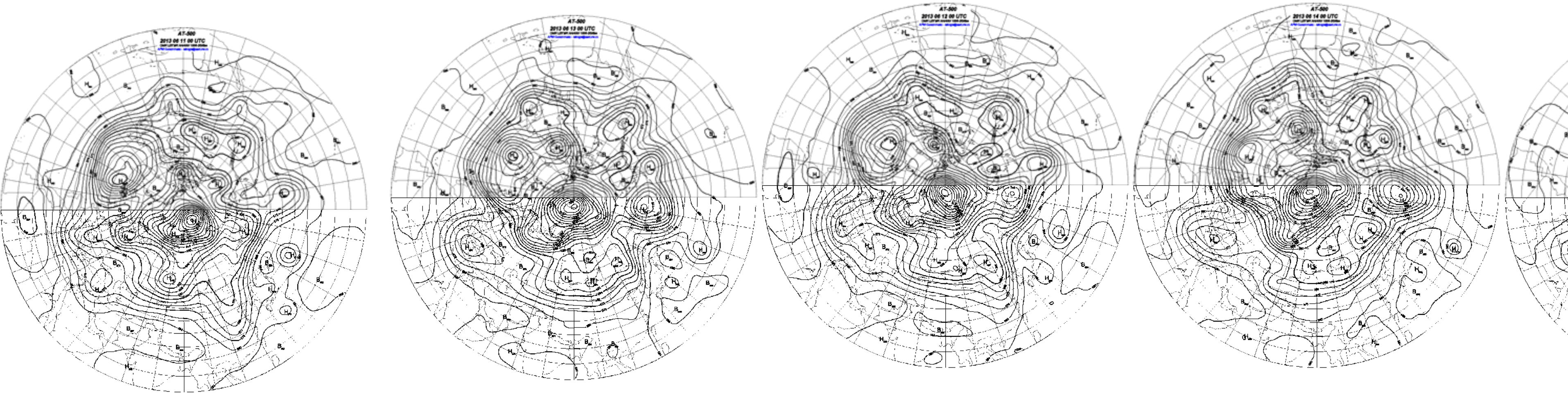
Δφ
1 SHIFT TO 30^0 E
2 SHIFT TO 25^0 E
3 SHIFT TO 20^0 E
4 SHIFT TO 15^0 E
5 SHIFT TO 10^0 E
6 SHIFT TO 5^0 E
7 SHIFT TO 0^0
8 SHIFT TO 5^0 W
9 SHIFT TO 10^0 W
10 SHIFT TO 15^0 W
11 SHIFT TO 20^0 W
12 SHIFT TO 25^0 W
13 SHIFT TO 30^0 W

11-15 August 2013

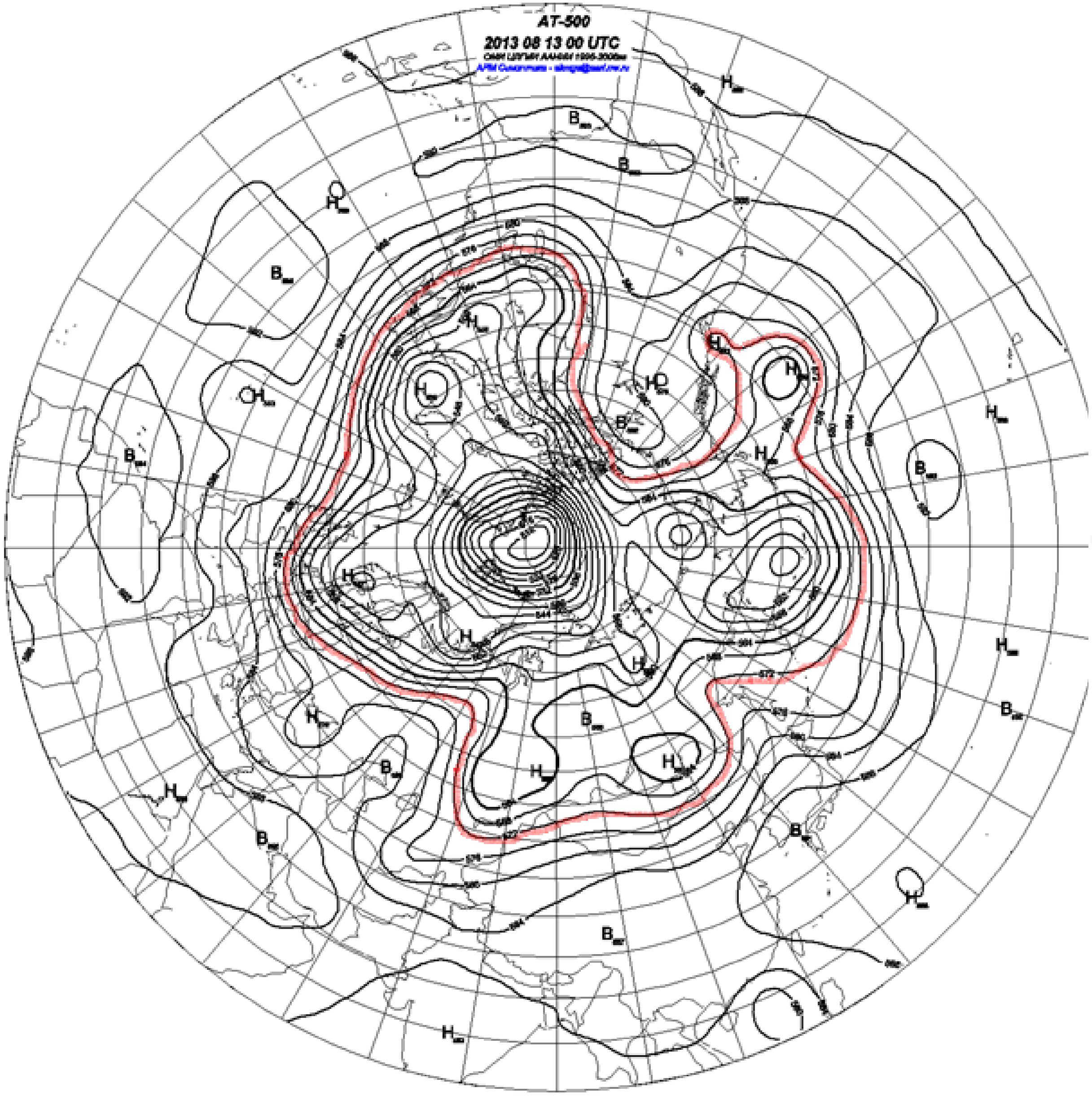
Analogs of June for consistent days of August 2013 (FAM)

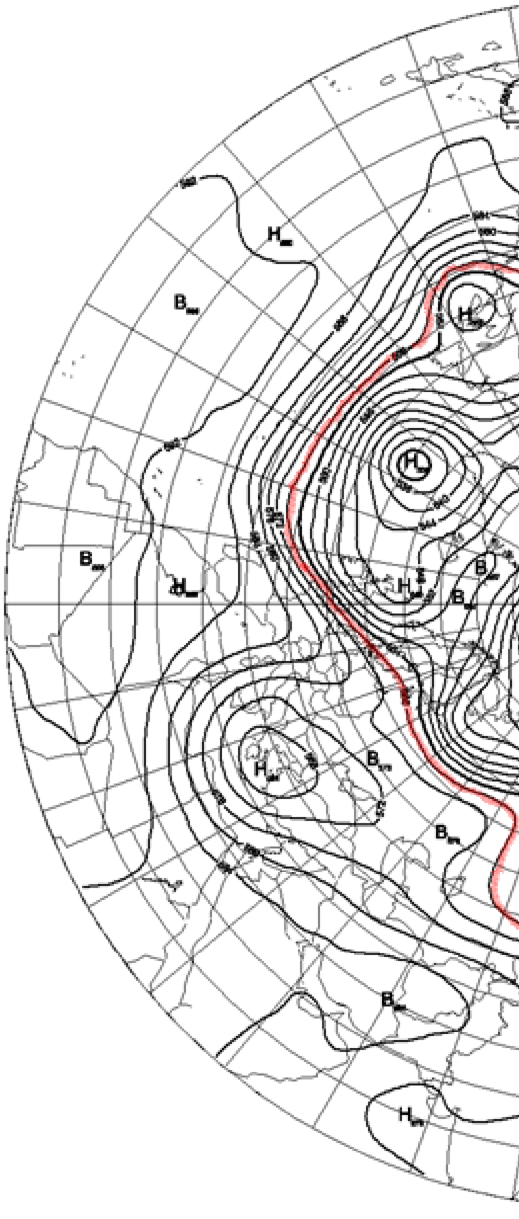


11-15 June 2013

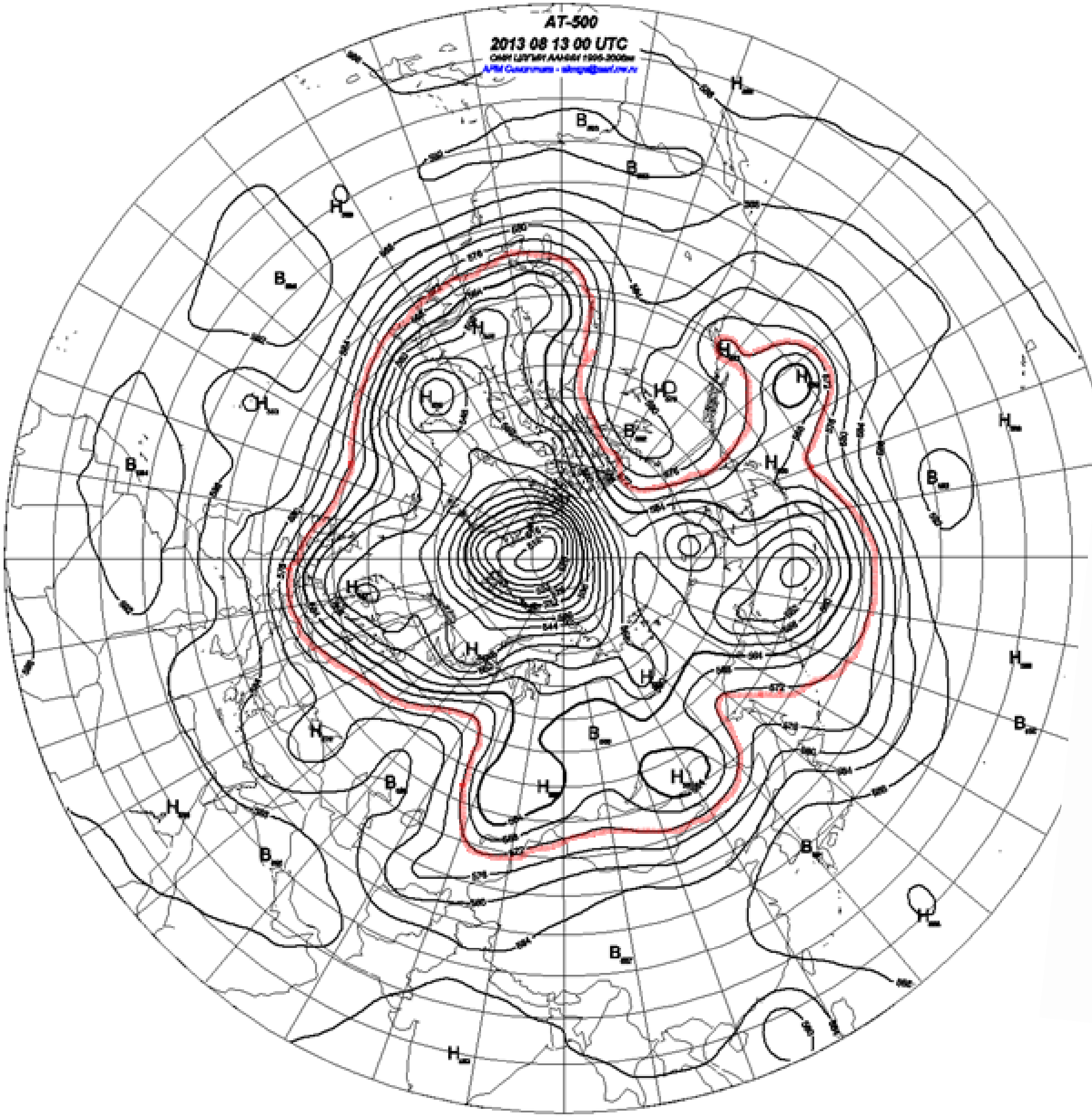


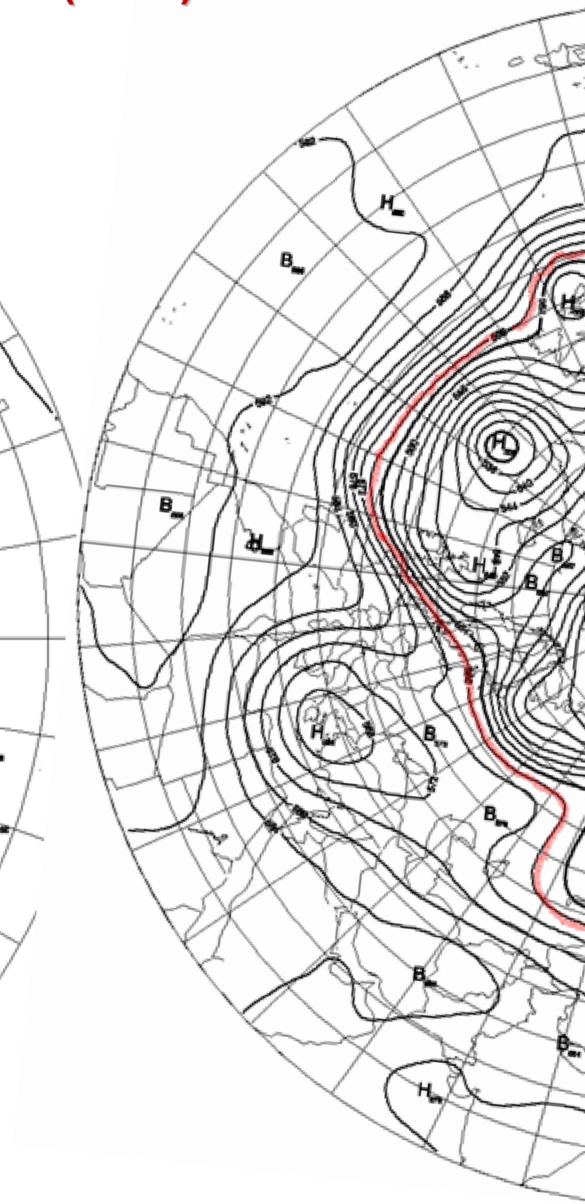
Analogs of 13 June for 13 August 2013 (TAM)





Analogs of 13 June for 13 August 2013 (FAM)



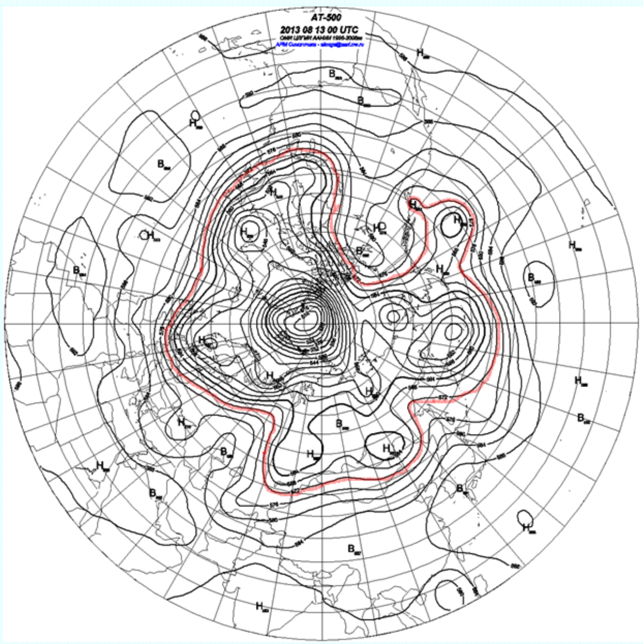


If the pressure fields is written as a matrix P with elements which correspond to values of pressure in the point ***j*** and ***i*** of a regular grid of field of our archive for every decade :

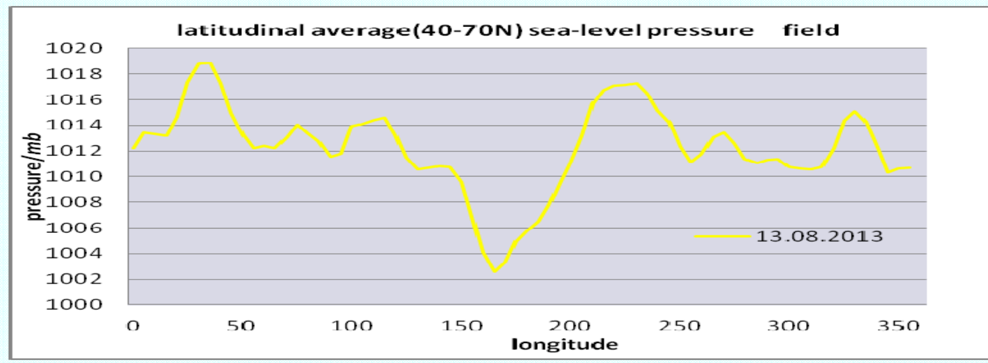
$$P=\begin{Vmatrix} p_{11} & p_{12} & \cdots & p_{1j} & \cdots & p_{1n\text{-}1} & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2j} & \cdots & p_{1n\text{-}1} & p_{1n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ p_{N1} & p_{N2} & \cdots & p_{Nj} & \cdots & p_{Nn\text{-}1} & p_{Nn} \end{Vmatrix}$$

, if $\overline{p_j} = \frac{1}{n}\sum_{i=1}^{N} p_{ij}$

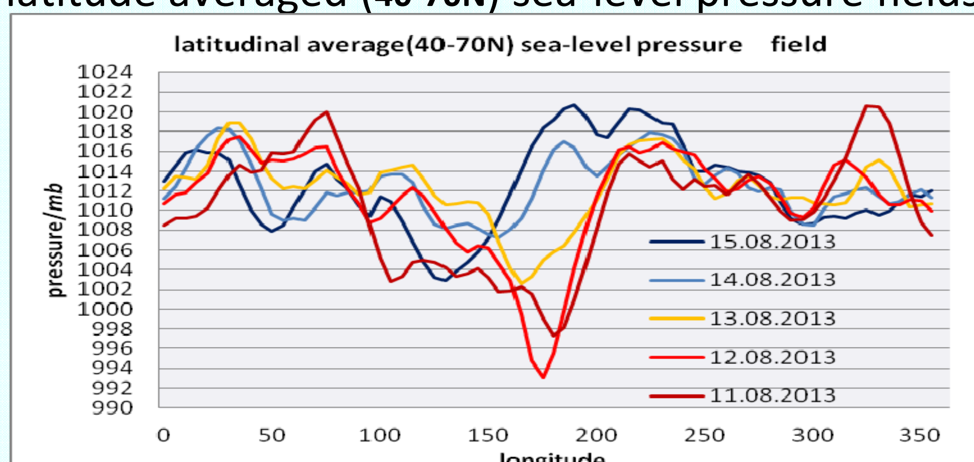
then $\overline{P}=\left(\overline{p}_1 \quad \overline{p}_2 \quad \cdots \quad \overline{p}_j \quad \cdots \quad \overline{p}_{n\text{-}1} \quad \overline{p}_n\right)$ is latitude averaged sea-level pressure field.



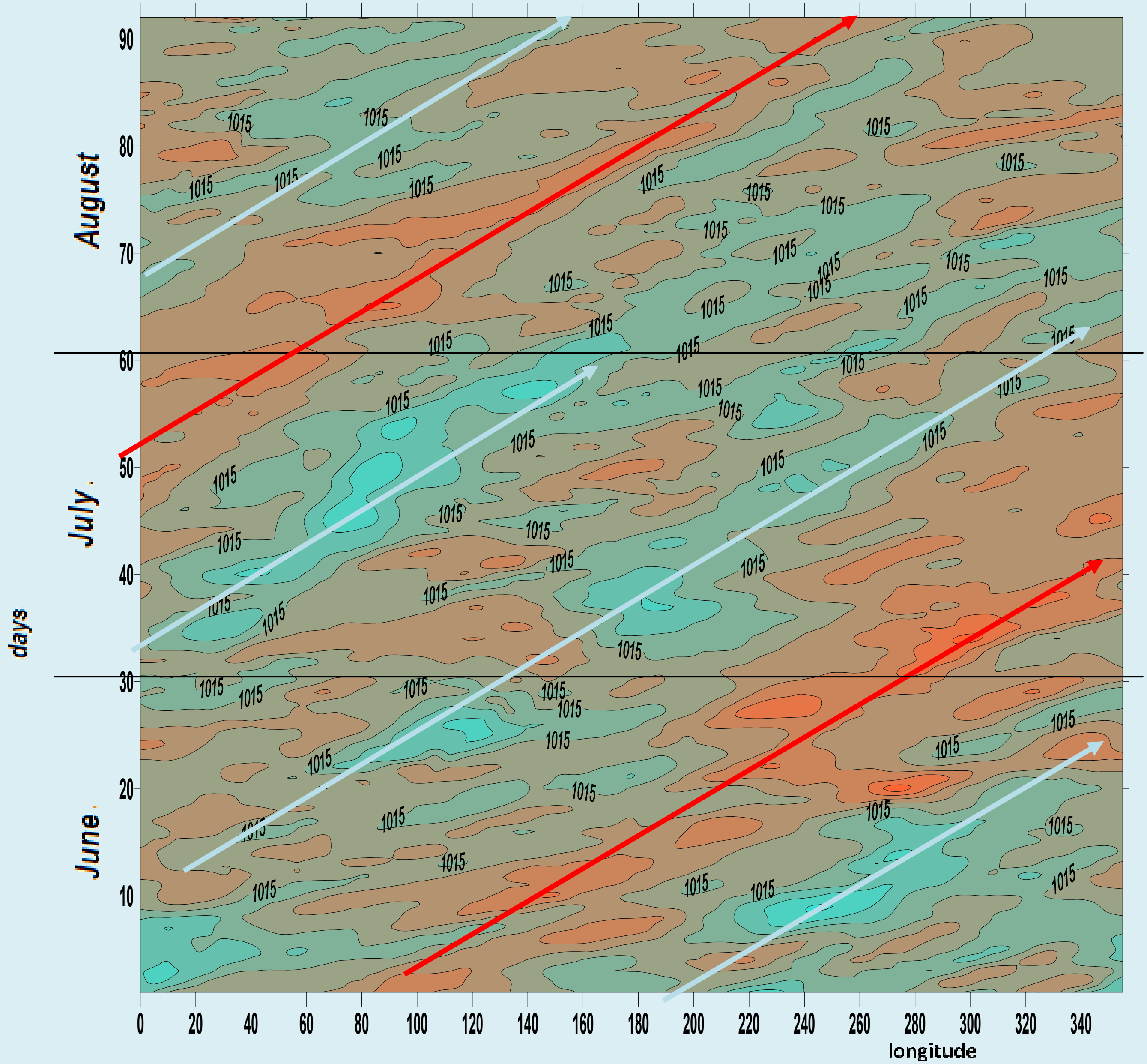
The field of pressure ($\overline{P}_{13}$) 13.08.2013



The latitude averaged (**40-70N**) sea-level pressure fields $\overline{P}$



Hovmöller diagram of the latitude averaged (40-70N) sea-level pressure fields $\overline{P}$
1.06-31.08.2013



- Integral characteristics of large-scale atmospheric processes from day to day shift to the east.
- The large-scale cyclonic and anticyclonic formation weaken, when they come in the climate zone with another sign. When they come into the zone of the same sign , these formations appear again .
- The displacement of large-scale structures in the mid-latitude is the average of about 6 degrees to the east for a day.
- After about two months, all the formations are returned to about initial position.
- Seasonal changes in the temperature gradient Pole- Equator and the Land - Ocean after two months define them new geographical location in around initial position.

Model of forecast of pressure and temperature fields for Northern hemisphere on 40-60 days using expansion in spherical harmonics

$$H_l(\theta,\lambda) = H_l^{'}(\theta,\lambda) + H_l^{''}(\theta+\Delta\theta,\lambda+\Delta\lambda),$$

when

$H_l^{'}(\theta,\lambda)$ - the seasonal component of forecast from year-analog.

$H_l^{''}(\theta+\Delta\theta,\lambda+\Delta\lambda)$ -the weather component of forecast from the two-month quasi-periodicity of atmospheric processes, $\Delta\theta$ and $\Delta\lambda$ define its seasonal geographical position.

The general equation for forecast in point (θ,λ) of the grid is

$$\begin{aligned}
H_l(\theta,\lambda) = {} & [a_0^0 + (a_2^0 \cos m\lambda + b_2^0 \sin m\lambda) P_2^0 \cos(\theta) + (a_4^0 \cos(m\lambda+\Delta\lambda) + b_4^0 \sin(m\lambda+\Delta\lambda)) P_4^0 \cos(\theta+\Delta\theta) + \\
& + (a_6^0 \cos(m\lambda+\Delta\lambda) + b_6^0 \sin(m\lambda+\Delta\lambda)) P_6^0 \cos(\theta+\Delta\theta)] + [(a_1^1 \cos m\lambda) + b_1^1 \sin m\lambda) P_1^1 \cos(\theta) + \\
& + (a_3^1 \cos(m\lambda+\Delta\lambda) + b_3^1 \sin(m\lambda+\Delta\lambda)) P_3^1 \cos(\theta+\Delta\theta) + (a_5^1 \cos(m\lambda+\Delta\lambda) + \\
& + b_5^1 \sin(m\lambda+\Delta\lambda)) P_5^1 \cos(\theta) + + (a_7^1 \cos(m\lambda+\Delta\lambda) + b_7^1 \sin(m\lambda+\Delta\lambda)) P_7^1 \cos(\theta+\Delta\theta)] + \\
& + \sum_{n=2}^{10} \sum_{m=2}^{n} (a_n^m \cos(m\lambda+\Delta\lambda) + b_n^m \sin(m\lambda+\Delta\lambda)) P_n^m \cos(\theta)
\end{aligned}$$

(V.Martazinova, 2002)

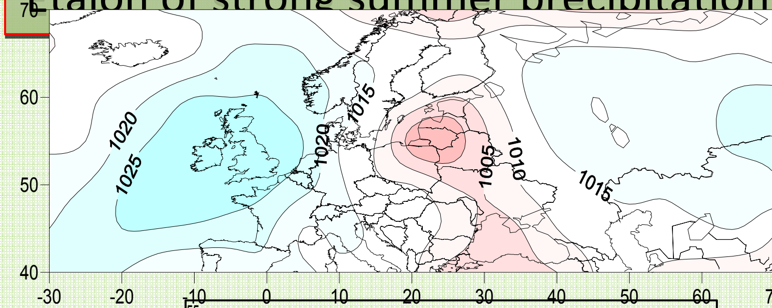
Etalon-fields method

(Martazinova, 1993)

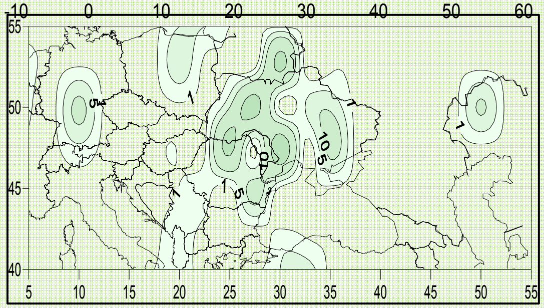
- The synoptic situation of any dangerous meteorological event corresponds to the ensemble of fields of pressure. It is necessary to classify these fields.
- Each class will have has the probability. In each class the field of the pressure at sea-level exists which has best similarity with the rest fields of ensemble.
- The field with best similarity from set of class has the complete information about a class and it is called the field -Etalon of a class.
- Field-Etalon the most informative field on synoptic situation relating dangerous meteorological events from class. It can be used for recognition of the dangerous events in forecast
- Field-etalon determines class of the fields of pressure by method of analogs

FORECAST

Etalon of strong summer precipitation

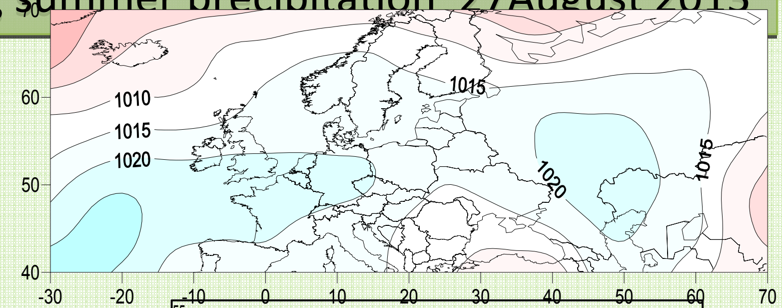


3 class

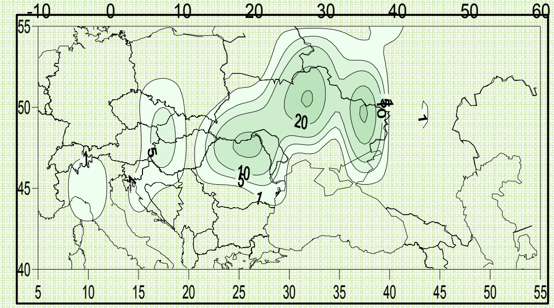


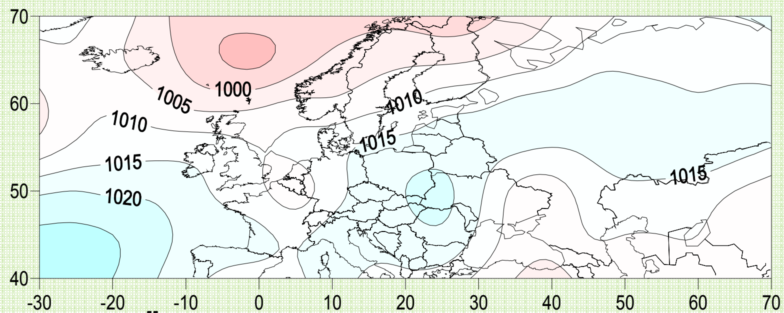
FACT

Strong summer precipitation 27August 2013

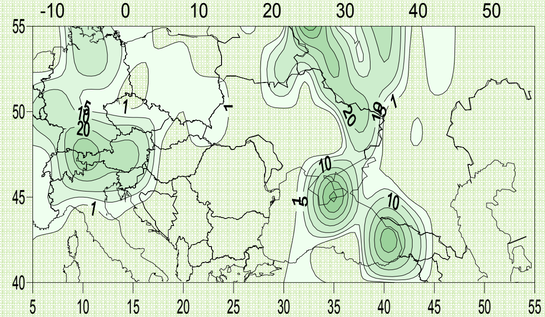


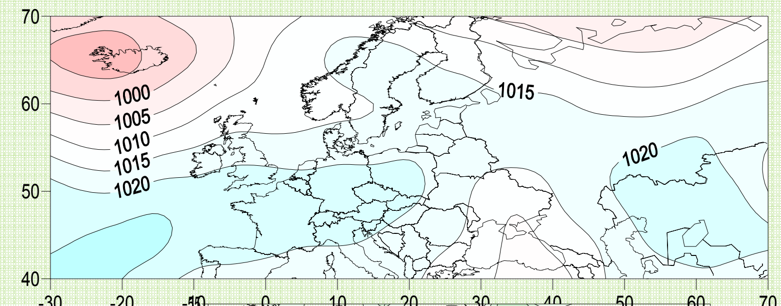
27August 2013



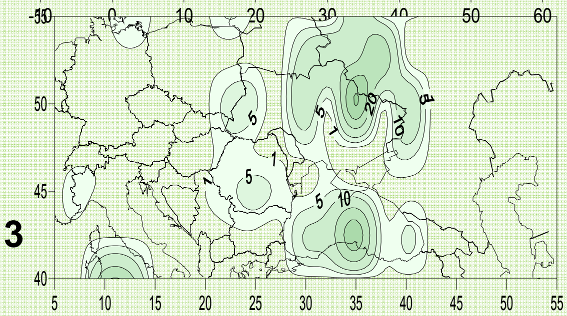


4 class



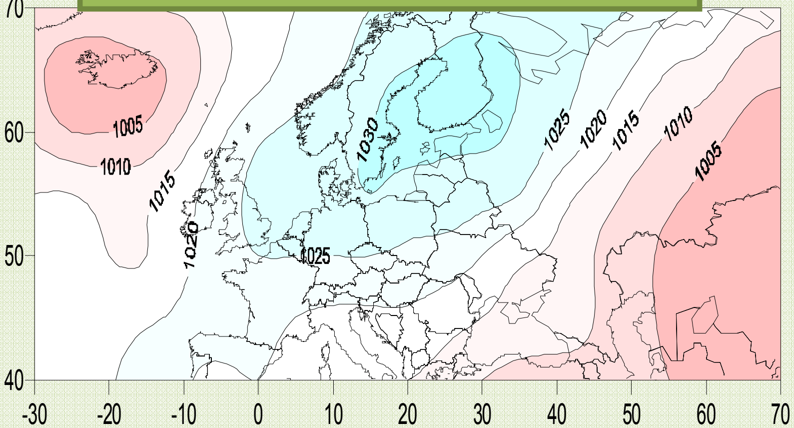


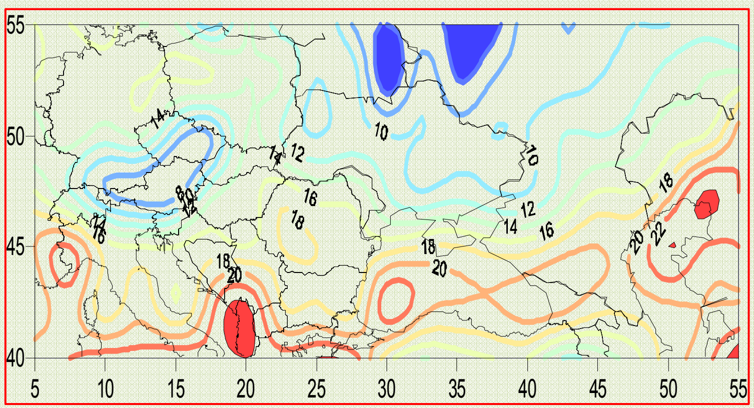
30 August 2013



FORECAST

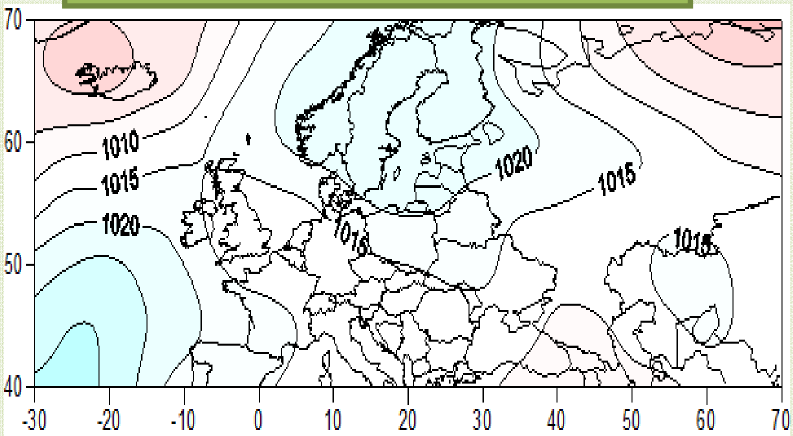
Etalon of strong summer cold

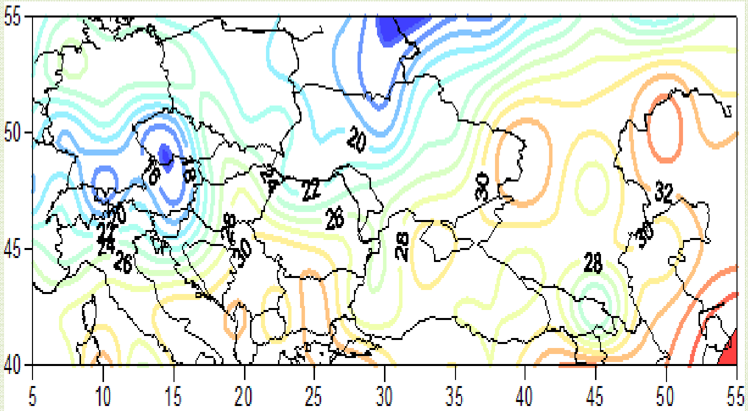




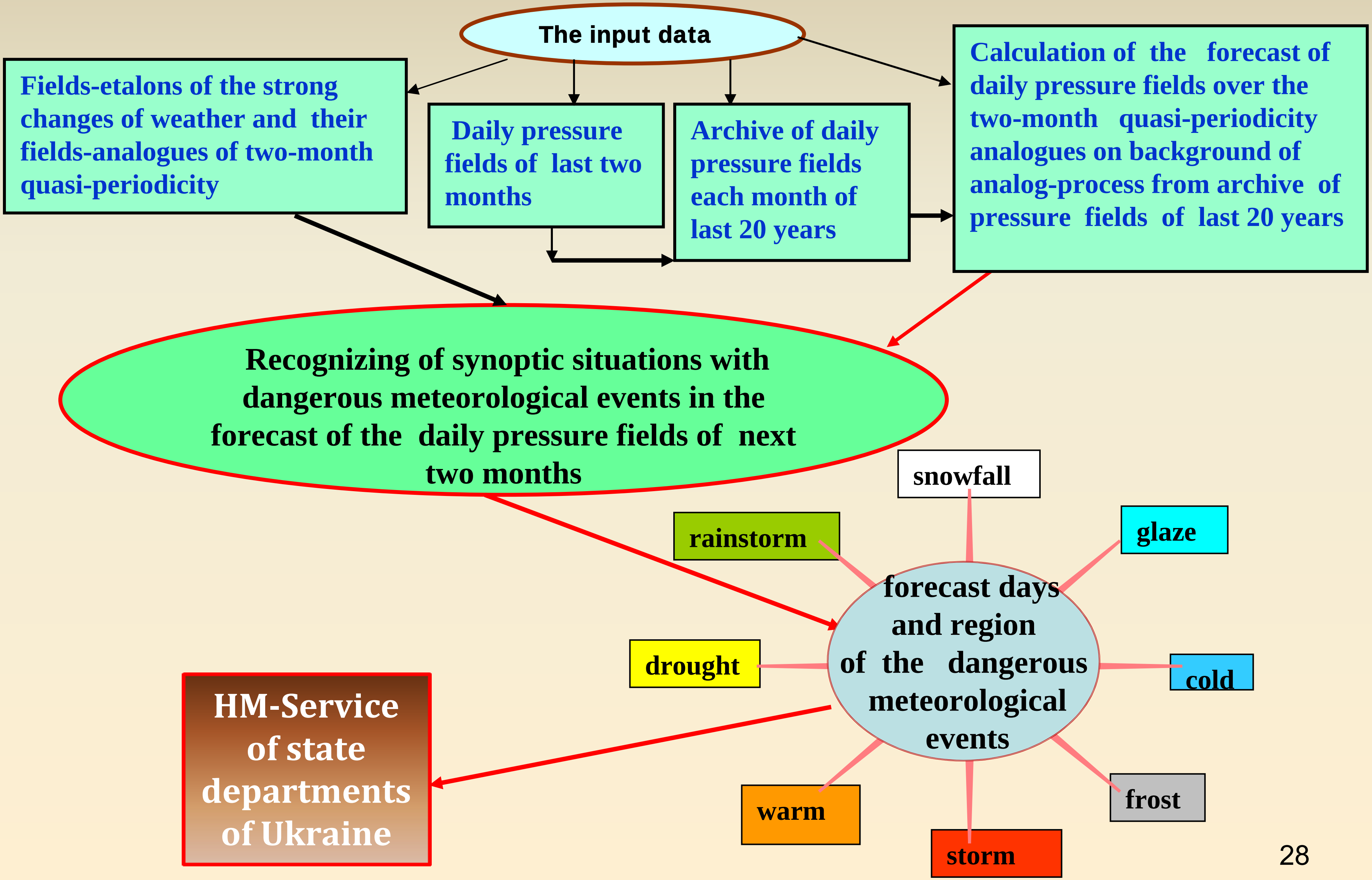
FACT

Strong cold in 25 August 2013





LONG-RANGE WEATHER FORECASTING SYSTEM UHMI



Conclusions

This report showed :

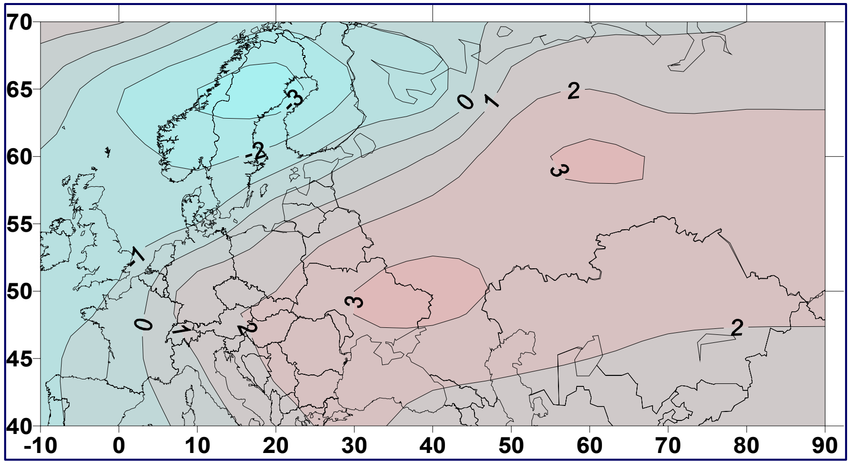
- Floating analog method (Martazinova,1986);
- Two-month quasi-periodicity of atmospheric processes (Martazinova,1986);
- Etalon fields method(Martazinova,1998).
- Two-month quasi-periodicity of atmospheric processes defines skill of the long-range forecast ($\rho > 0.75$).
- Error of the long-range detailed forecast into month is +/- 2 day.

The forecast of the anomaly of the mean month temperature

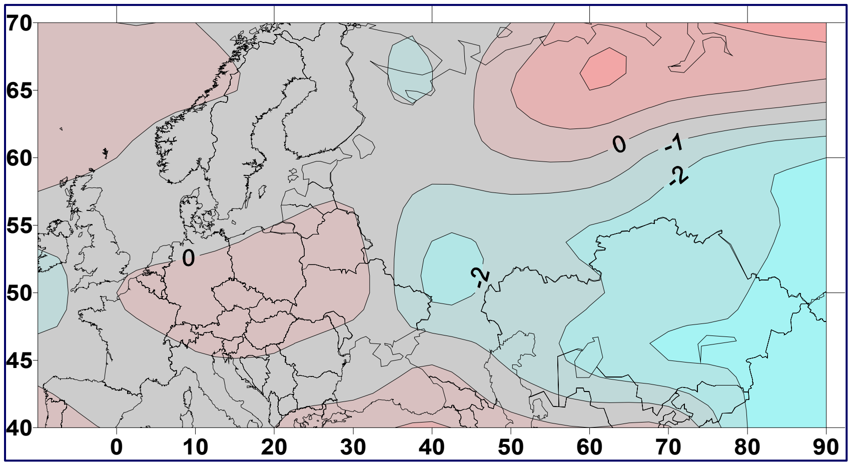
Department of climate research and long-range weather forecast of Ukrainian Hydrometeorological Institute
of National Academy of Sciences of Ukraine , State Hydrometeorological Service of the Ministry of Ukraine of Emergencies

21.10.13

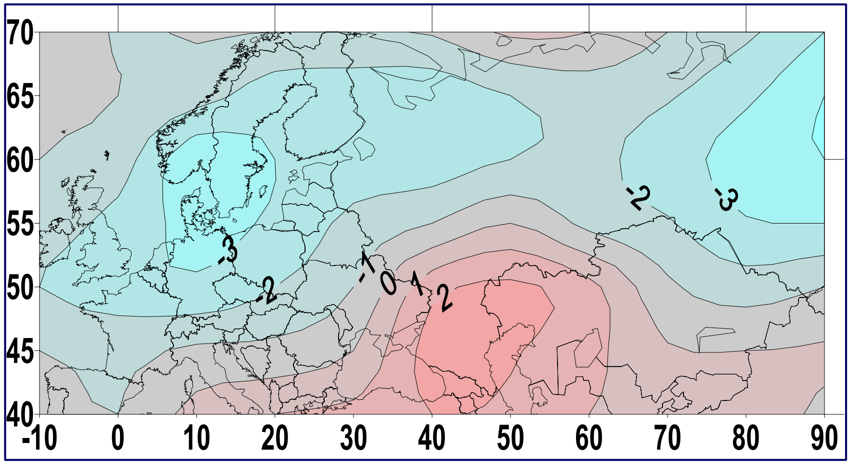
November 2013



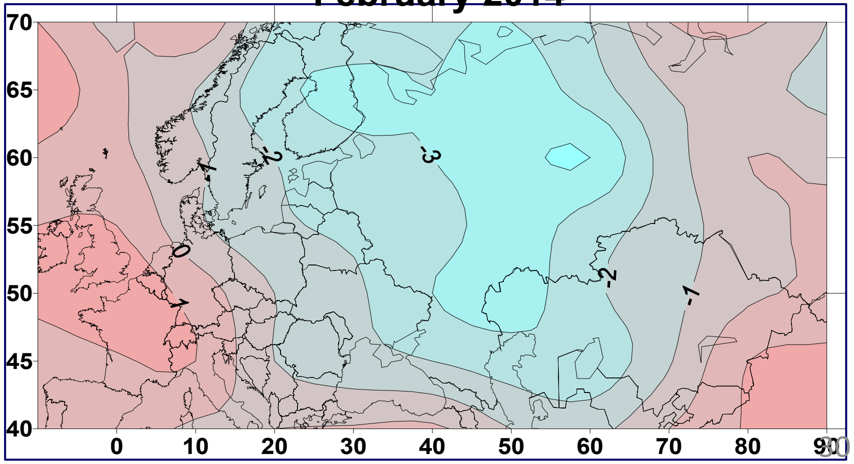
January 2014



December 2013



February 2014



PUBLICATIONS

1.Мартазинова В.Ф. Метод плавающего аналога и двухмесячная квазиперио-дичность атмосферных процессов в долгосрочном прогнозировании. Сб."Проблемы и достижения долгосрочного метеорологического прогнозирования" - К.: Ника-Центр, 2012.

2. Мартазинова В.Ф., Сологуб Т.А. Определение квазипериодичности атмосферных процессов на Северном полушарии с помощью метода плавающий аналог // Труды УкрНИГМИ. - 1986. -вып.219. -С. 42-46.

3. Мартазинова В.Ф. К вопросу об использовании аналоговых полей метеоэлементов для прогноза // Труды УкрНИГМИ. - 1986. -вып.219.- С.37-42.

4. Martazinova V. Extended range forecasting in Ukraine // 2-nd European Conference on Applications of Meteorology. -Paris. - 1995. - P. 216-219.

5. Martazinova V.F. Progress report on long-range weather forecasting in the Ukraine. // Long-range forecasting progress report for 1997/1998. WMO/TD .-1999. - No.967. -P.79-82.

6. Martazinova V.F., Ivanova E.K., Sologub T.A. Long-range weather forecasting in the Ukraine January 2001 to December 2001 // Long-range forecasting progress report for 2001. WMO/TD -2002. -No.1150. -P.77-79.

7. V. Martazinova The Classification of Synoptic Patterns by Method of Analogs.//J. Environ. Sci. Eng. -2005. -7, -P.61-65.

8. Martazinova V. The method of the floating analog, two-month quasi-periodicity of the atmospheric processes and long-range weather forecasting. // APCC Seminar Reports. -2006. http://www.apcc21.net/common/download.php?filename=sem/CLIMATe%20CHANGE.pdf

9. Мартазинова В.Ф., Бахмутов В.Г., Чайка Д.Ю. Влияние глобального потепления на изменение крупномасштабной атмосферной циркуляции и формирование аномальных погодных условий в Украине //Доклады НАН Украины. - 2006. -№2. С.105-110.

10. В.Ф.Мартазинова, Е.К. Иванова, Д.Ю. Чайка Изменение крупномасштабной циркуляции атмосферы на протяжении XX века и ее влияние на погодные условия и региональную циркуляцию воздуха в Украине // Геофизический журнал. -2006. -№1. -Т.28. -С.51-60.

Thank you for the attention

Спасибо за внимание

Регіональна розрахункова схема прогнозу поля тиску до 40-60 днів за допомогою поліномів Чебишева

$$P_l(x_i,y_j) = [A_{00} + A_{10}\psi_1(x)\psi_0(y) + A_{01}\psi_0(x)\psi_1(y)] + [A_{30}\psi_3(x)\psi_0(y) + \ldots + A_{66}\psi_6(x)\psi_6(y)] = P_l^{'}(x_i,y_j) + P_l^{''}(x_i+\Delta\varphi, y_j+\Delta\lambda) \qquad (7)$$

где

$$P_l^{'}(x_i,y_j) = \sum_{k=0}^{1}\sum_{s=0}^{1} A_{ks}^{l}\psi_k(x_i)\psi_s(y_j); \qquad (8)$$

-сезонная составляющая прогноза- полиномы Чебышева порядка 0-1 поля давления года-аналога;

$$P_l^{''}(x_i,y_j) = P_l^{''}(x_i+\Delta\varphi, y_j+\Delta\lambda) = \sum_{s=0}^{3} A_{3s}^{l}\psi_3(x_i)\psi_s(y_j) + \sum_{k=0}^{2} A_{k3}^{l}\psi_k(x_i)\psi_3(y_j) +$$

$$+ \sum_{s=0}^{4} A_{4s}^{l}\psi_4(x_i)\psi_s(y_j) + \sum_{k=0}^{3} A_{k4}^{l}\psi_k(x_i)\psi_4(y_j) + \sum_{s=0}^{5} A_{5s}^{l}\psi_5(x_i)\psi_s(y_j) + \qquad (9)$$

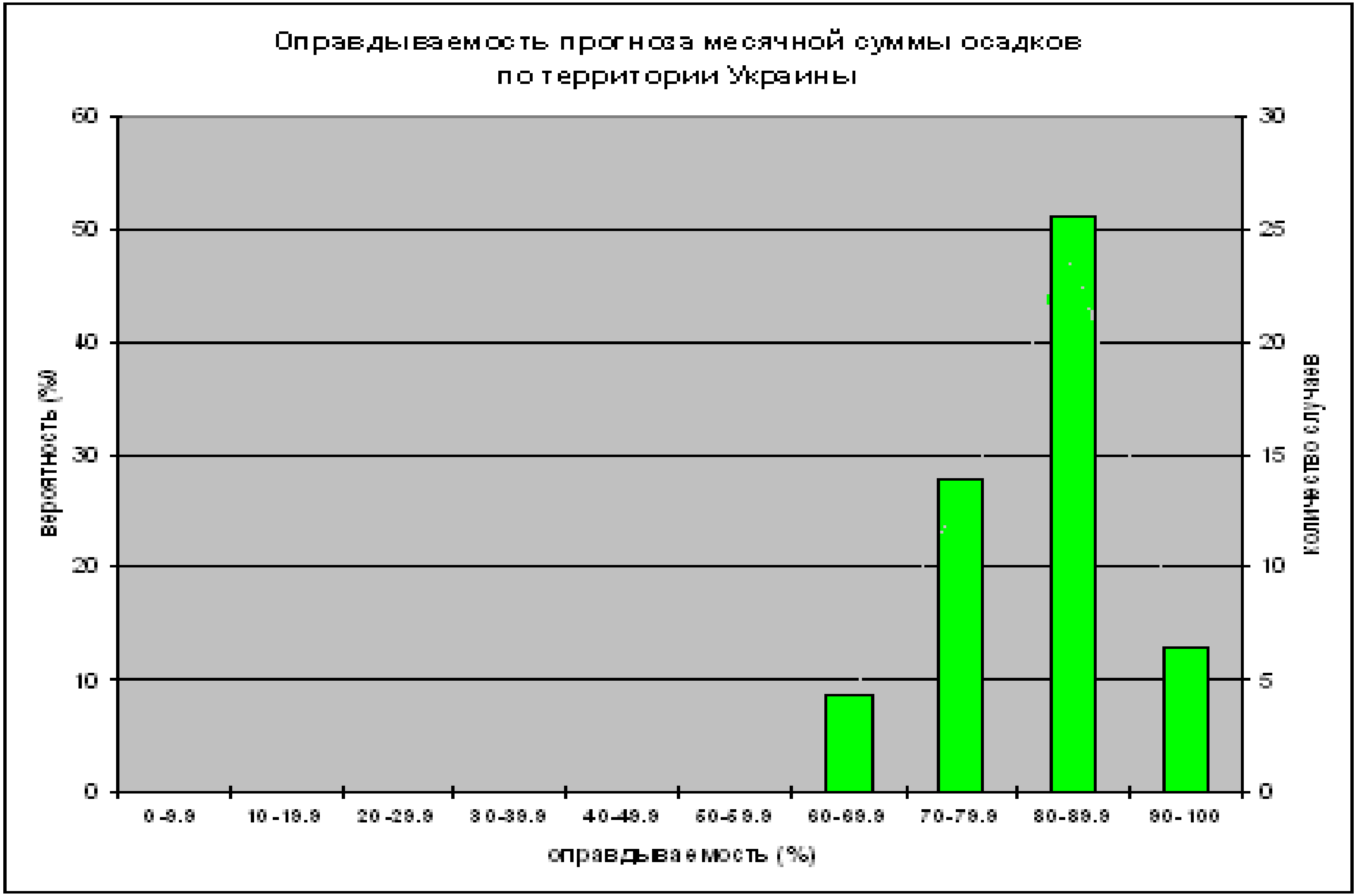
$$+ \sum_{k=0}^{4} A_{k5}^{l}\psi_k(x_i)\psi_5(y_j) + \sum_{s=0}^{6} A_{6s}^{l}\psi_6(x_i)\psi_s(y_j) + \sum_{k=0}^{5} A_{k6}^{l}\psi_k(x_i)\psi_6(y_j)$$

-погодная составляющая прогноза - полиномы Чебышева порядка 3-6 поля давл двухмесячной квазипериодичности , $\Delta\varphi$ и $\Delta\lambda$ определяют сезонное смещ географического положения двухмесячной квазипериодичности атмосферных проце

(V.Martazinova,E.Ivanova, 2008)

Оправдываемость прогноза средней месячной температуры воздуха и месячной суммы осадков по территории Украины за период 2006-2009*

*47 прогнозов



Результаты прогноза осадков для Нидерландов за период 2009 года (12 месяцев), 2010 (12 месяцев), январь-февраль 2011 года, то есть 26 случаев.

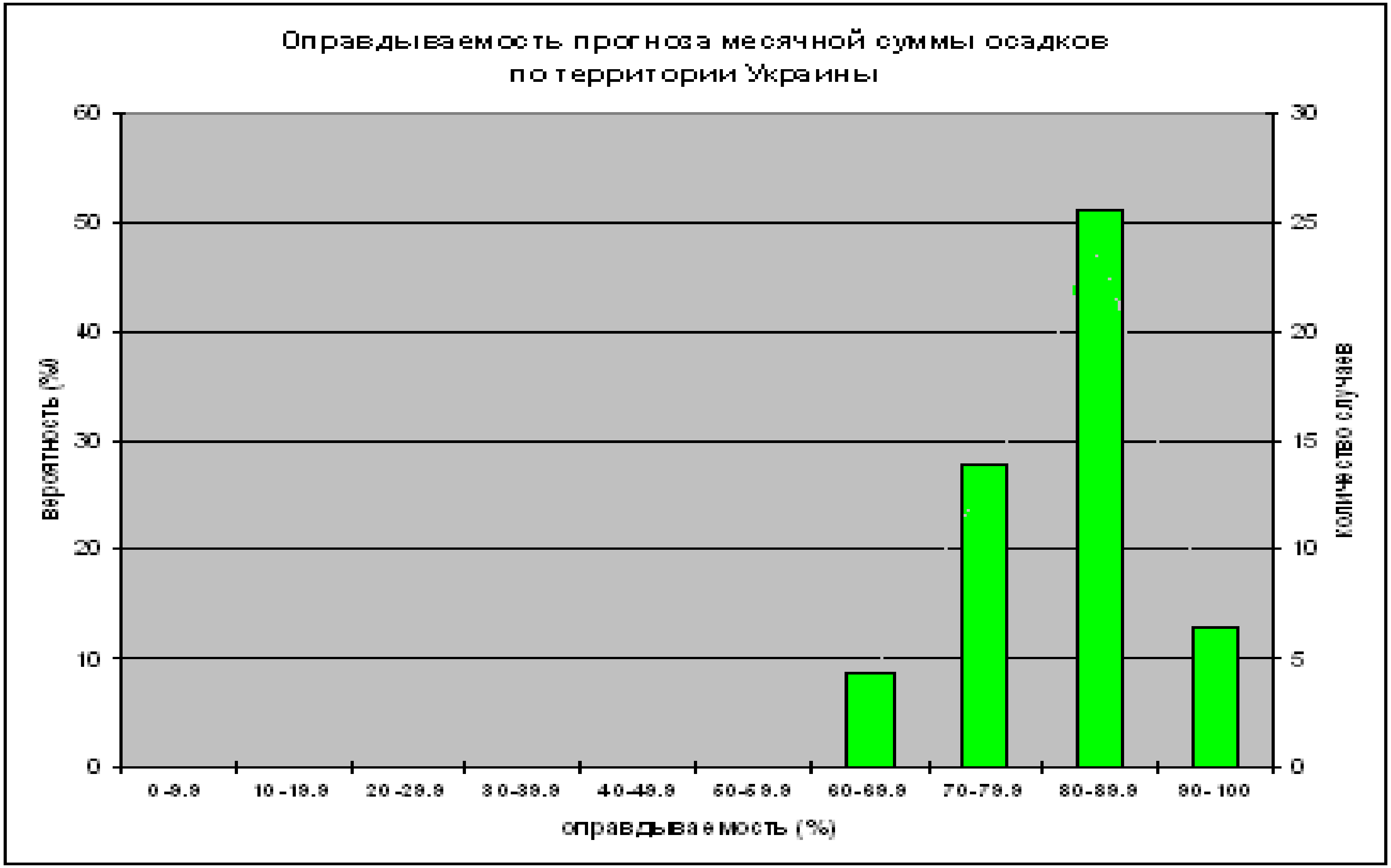
в 26 случаях было 13 экстремальных осадков,
из которых :
9 событий - отличный прогноз (100%) = 69,2%
2 события - соседний класс (50%*2) = 15,4%
2 события - с негативным прогнозом (-100% * 2) = 15,4%.

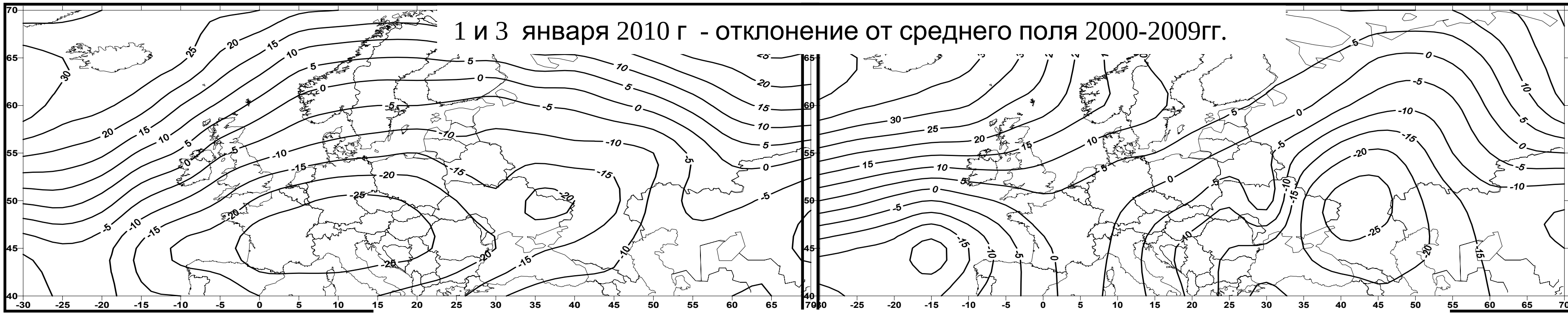
Всего из 26 прогнозов осадков для Нидерландов :
15 прогнозов 100% = 57,7%
9 близлежащий класс 50% = 34,6% **92.3%**
2 прогноза по -100% = 7,7%

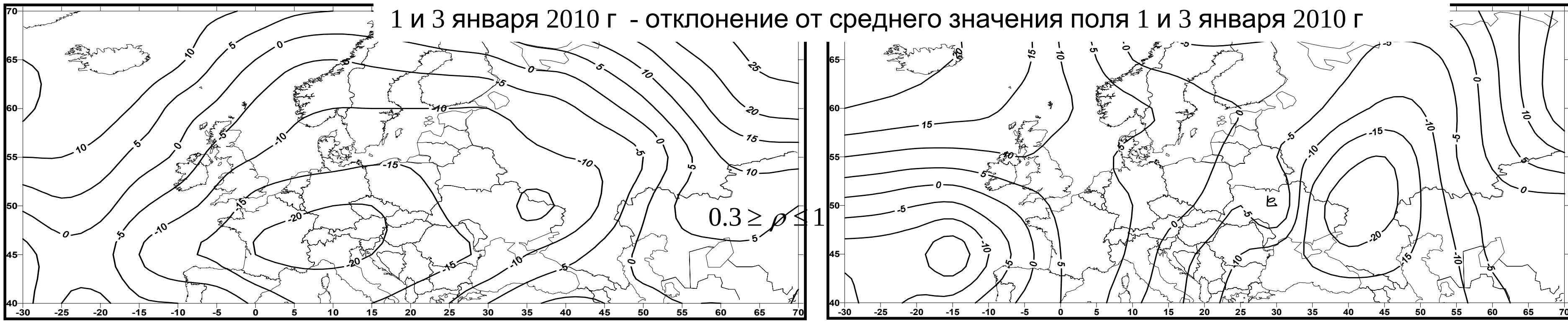
15	9	2
100%	50%	-100%

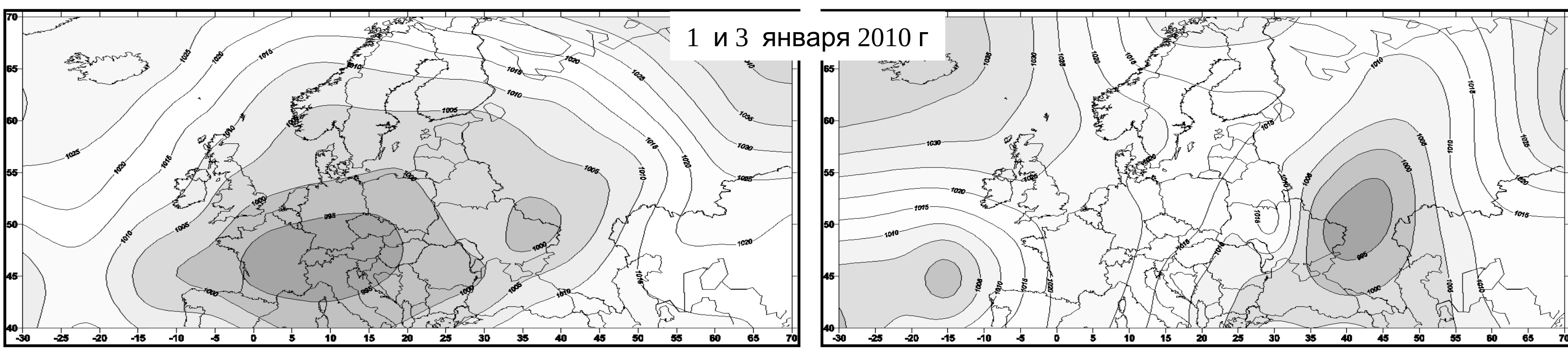
Справджуваність прогнозу середньої місячної температури повітря та місячної суми опадів по території України за період 2006-2009

*47 прогнозів









Criteria for search analogs: **Geometrically similarity by a sign of anomaly two fields**

$$\rho = \frac{n_+ - n_-}{n}$$