Multiscale version of the global atmospheric SL-AV model

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The use of global atmospheric models

- Climate change modelling (*boundary value problem*).
- Numerical weather prediction (*initial value problem*):

-- Deterministic (2-10 days). Also providing boundary conditions.

-- Probabilistic (ensemble medium- and longe-range (month-season) forecasts).

Emerging: prediction for 1-10 years, a combination of boundary and initial value problem

Seamless prediction

- There is no artificial boundaries between the time scales (Shukla, 2006), (Hoskins QJ 2013).
- The model should be good in reproducing all time scales.
- UK Met Office – Unified Model since 198x
- Cost of model development and code maintenance

However:

- NWP and climate models have different error metrics.
- Different parameterizations can be used fro NWP and climate modeling.

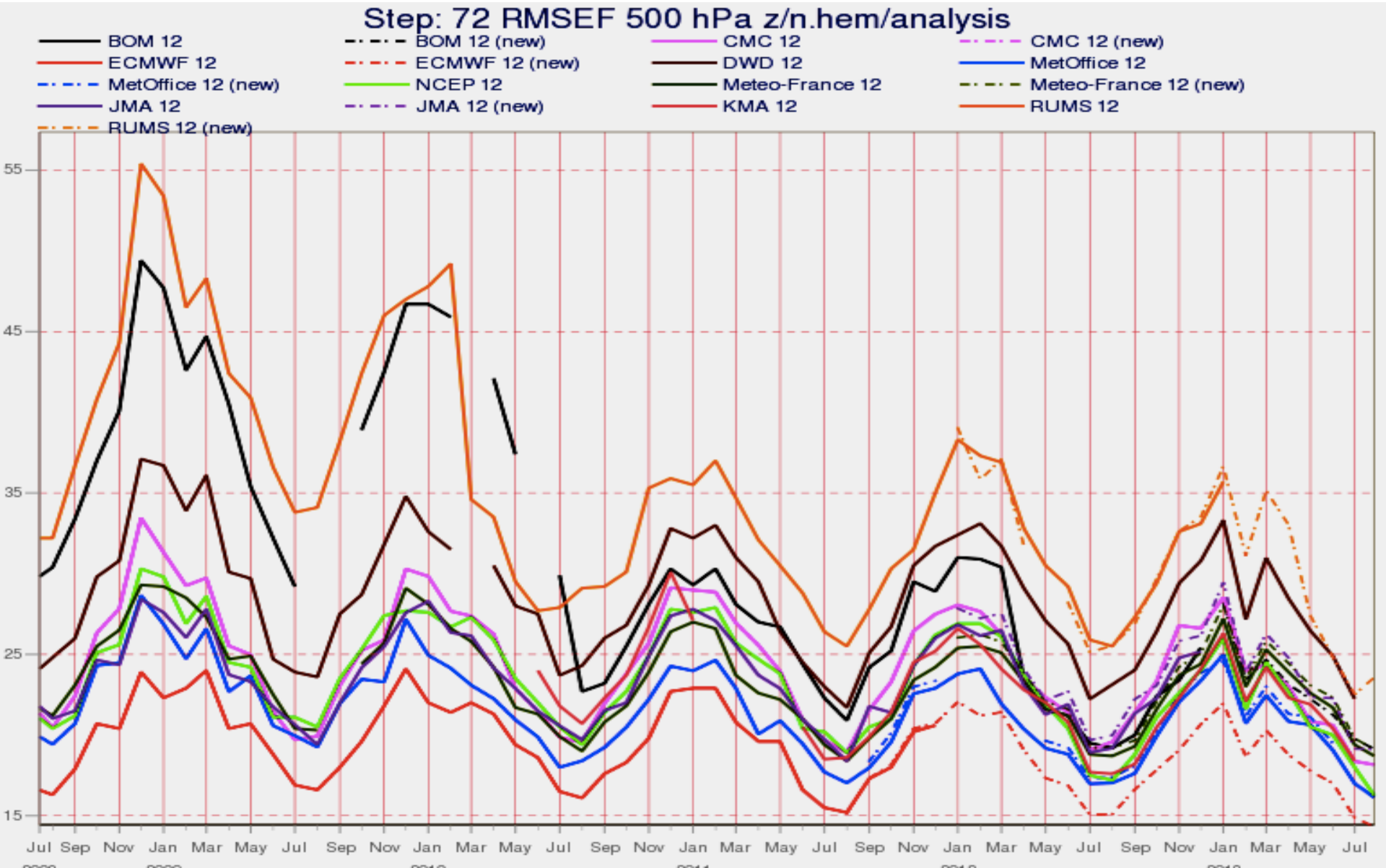
Forecast Centre (Country)	2015	2016	2017	2018	2019
ECMWF (Europe)	T_L1279L137	T_L2047 L137	T_L2047 L137	T_L2047 L137	
Met Office (UK)	17 km L70	17 km L70	Coupled O-A 12/25?km L120-200	Coupled O-A 12/25?km L120-200	Coupled O-A 12/25?km L120-200
Météo France (France)	T799c2.4 L70	T1198c2.2 L105	T1198c2.2 L105	tbd	tbd
DWD (Germany)	13 km L90 (6.5 km in Europe)	13 km L90 (6.5km in Europe)	13 km L90 (6.5km in Europe)	tbd	tbd
HMC Russia	0.72°x0.9° L28 T169 L31;	0.18˚x0.225˚L51 T339 L31;	0.18˚x0.225˚L51 T339 L63;	0.18˚x0.225˚L51 T339 L63;	tbd
NCEP (USA)	T878 L91 (7.5) T574 L91 (16)	T878 L91 (7.5) T574 L91 (16)			
CMC (Canada)	(0.35°x0.23°) L80 Ying-Yang (0.14°x0.14°) L80	Ying-Yang (0.09°x0.09°) L125	Ying-Yang (0.09°x0.09°) L165	Ying-Yang (0.09°x0.09°) L200	
CPTEC/INPE (Brazil)	20 km L96	20 km L96	10 km L96	10 km L128	
JMA (Japan)	T_L959 L60	T_L959 L100	T_L959 L100		
CMA (China)	T_L639 L60 GRAPES 50 km L31	GRAPES 25 km L70	GRAPES 0.25 L70	GRAPES 0.25 L90	
KMA (Korea)	25 km L70	17 km L70	17 km L70		
BoM (Australia)	ACCESS 25 km L70	17 km L85	17 km L85		

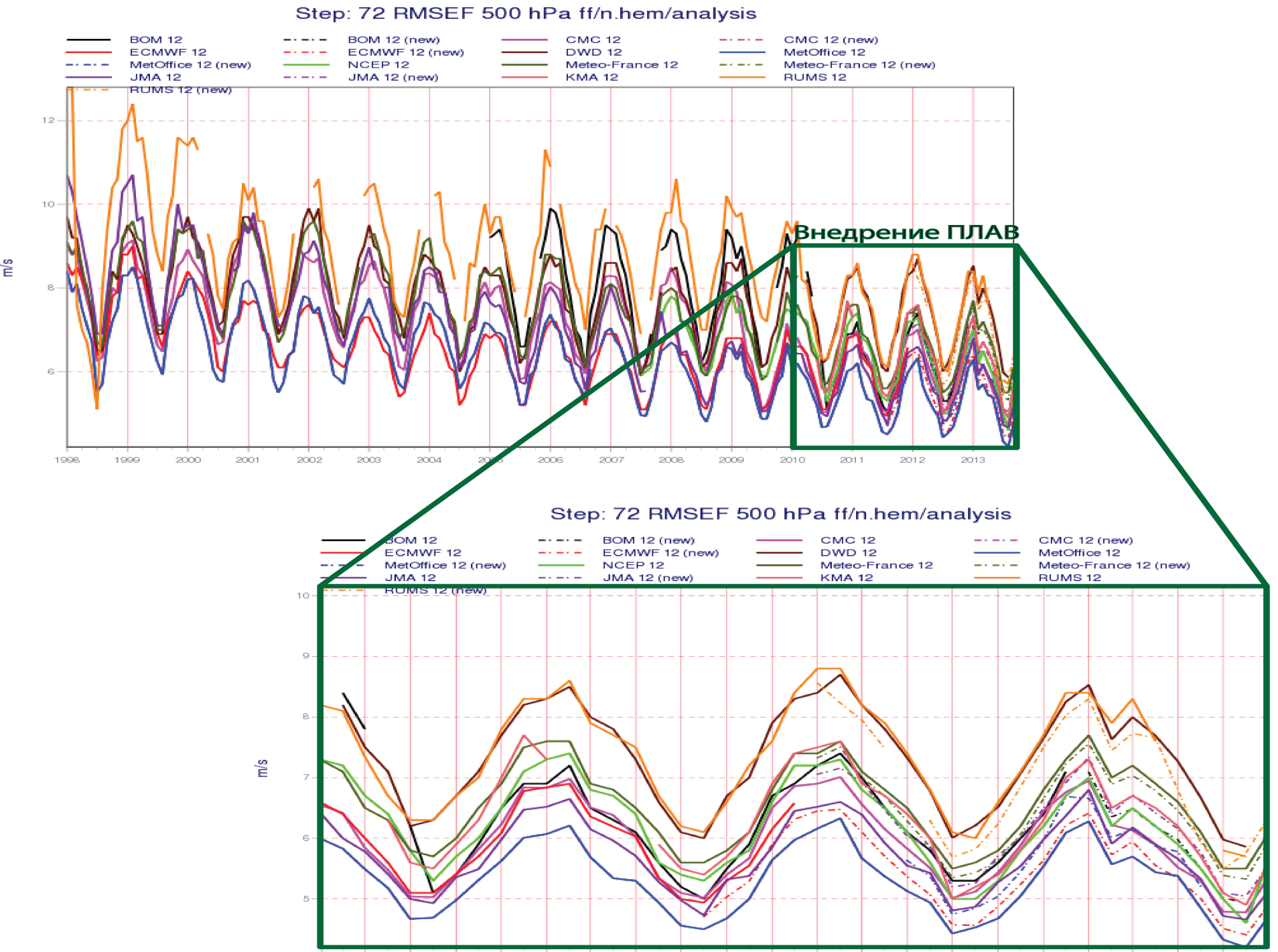
Global NWP models

- 15 in total (13 in the preceding slide + India and NRL (USA))
- 8 original (of own development)
- NCEP model is used in India, UKMO model is used in Australia and S. Korea, ECMWF model is used in China. ECMWF and Meteo-France model are of joint development with different parameterizations.
- Gradual reduction in number of spectral models. In 5 years, 3 spectral models disappeared models less (Australia, Brazil, S. Korea), China plans to switch to own non-spectral model soon.
- ECMWF declares transition to non-spectral model after 2020.
- 7 original models are semi-Lagrangian (recently NCEP)
- Typical horizontal resolution in 2015 - 20-30 km
- The leader is ECMWF with 15 km and 137 levels (planning 10 km this year)

Среднеквадратическая ошибка прогноза Н500 на 3 суток. Период: июль 2008 – август 2013.

Гидрометцентр: желтый. **Внедрение ПЛАВ**: февраль 2010; **внедрение 3ДВар**: апрель 2013.
Июнь-июль 2013: догнали DWD. Источник: http://apps.ecmwf.int/wmolcdnv/

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BOM 12
ECMWF 12
MetOffice 12 (new)
JMA 12
RUMS 12 (new)
BOM 12 (new)
ECMWF 12 (new)
NCEP 12
JMA 12 (new)
CMC 12
DWD 12
Meteo-France 12
KMA 12
CMC 12 (new)
MetOffice 12
Meteo-France 12 (new)
RUMS 12
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1998
1999
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2013
Внедрение ПЛАВ
Step: 72 RMSEF 500 hPa ff/n.hem/analysis
BOM 12
ECMWF 12
MetOffice 12 (new)
JMA 12
RUMS 12 (new)
BOM 12 (new)
ECMWF 12 (new)
NCEP 12
JMA 12 (new)
CMC 12
DWD 12
Meteo-France 12
KMA 12
CMC 12 (new)
MetOffice 12
Meteo-France 12 (new)
RUMS 12
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8
7
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5

From preceding 2 slides:

- Borrowed models (S. Korea, Australia) always worse than originals in terms of forecast errors. Some borrowed models do not report their errors
- Introduction of SL-AV model into RHMC operational practice at the beginning of 2010 allowed to reduce the gap in errors between Russia and leading centres by factor of 2.

Global semi-Lagrangian atmosphere model SL-AV

(Semi-Lagrangian based on Absolute Vorticity equation)

- Finite-difference semi-implicit semi-Lagrangian dynamical core of own development: vorticity-divergence formulation, 4th order finite-differences at the unstaggered grid (Tolstykh J Comput Phys 2002)
- + set of parameterizations for subgrid-scale processes developed by ALADIN/ALARO consortium. In new versions, some freeware parameterizations are used – SW and LW radiation (CLIRAD SW and RRTM LW)
- **Codevelopment of Institute of Numerical Mathematics Russian Academy of Sciences and Hydrometcentre of Russia**
- More coautors: + A.V.Shlyaeva, N.N. Bogoslovskii, A.Yu. Yurova

Model version	Resolution	SETTLS	Local mass-cons.	Radiation RRTM+ CLIRAD; aerosols	Microphysics	Parallel.	Daily update of Boundary fields	Output fields
Operational «Seasonal»	1.4˚x1.1˚ , 28 levels	-	-	-	-	OpenMP	+	CLIM
Operational «medium-range»	0.9°x 0.72°, 28 levels	+	-	-	-	OpenMP	-	OPER
Operational SibNIGHMI	0.5625˚ lon; from 28 to 80 km in latitude, 50 levels	+	-	-	-	MPI+ OpenMP	-	OPER
New «medium-range»	0.225˚ lon, from 27 km in South.Hem. to 18 km in North. Hem., 51 levels	+	+	+	+	MPI+ OpenMP	-	OPER
Unified	Arbitrary, choice from predefined	+	+	+	+	MPI+ OpenMP	+	CLIM or OPER

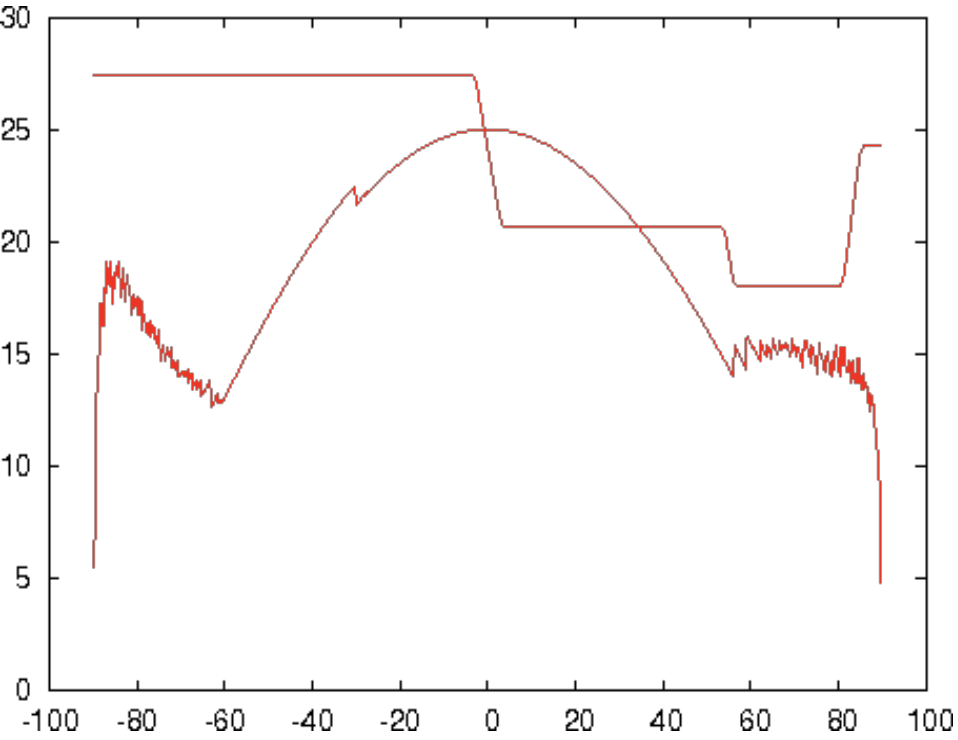
New NWP version of SL-AV model

* Resolution 0.225˚ in longitude, in latitude form 27 km (South. Hem.) to 18 km (North. Hem.). The grid is generated by R.Yu. Fadeev (Russ. Comp.Math. Math.Phys.2013).
* Orography is prepared at the reduced lat-lon grid.
- 51 vertical levels, 5 hPa top.
- **For the first time in Russia, the world medium level of horizontal resolution is achieved in Northern hemisphere.**
- Support of RFBR, RSCF, Mis. Of Educ. Grants.
- Time to calculate 24h forecast at RSC Tornado (Roshydromet): 24 min at 224 procs, 6 min at 864 procs.
- Accepted by Roshydromet comission 25/05/15.

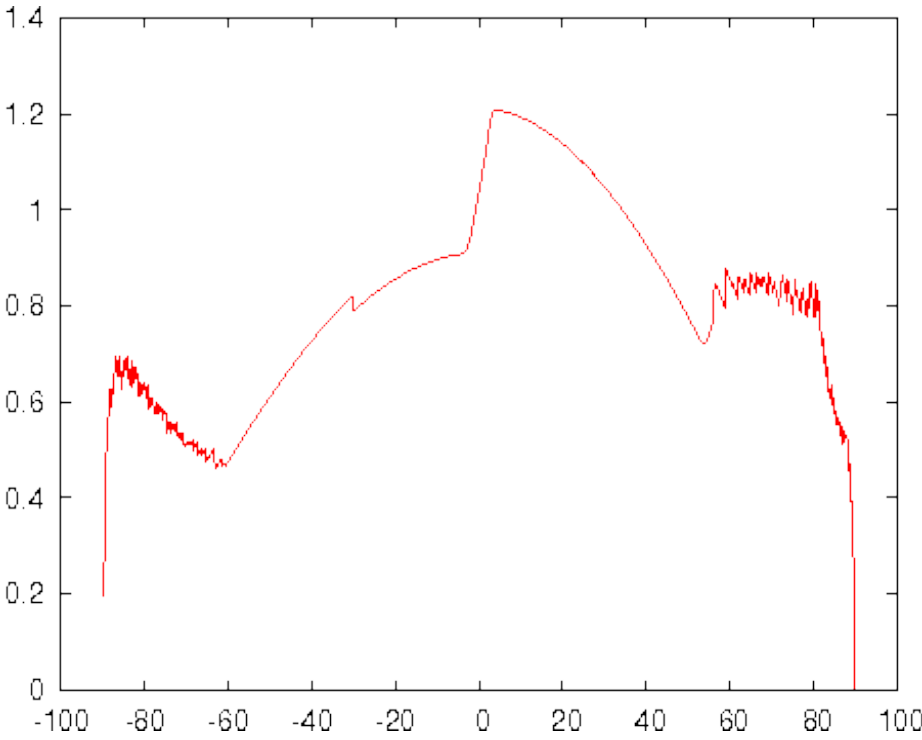
Changes in new SL-AV model

- Locally-conservative approximations for gradient and divergence; accuracy near the poles is increased
- Parameterization of shortwave radiation CLIRAD SW (freeware).
- Parameterization of longwave radiation RRTM LW (freeware).
- 3D Ozone monthly mean climatology (ERA Interim).
- Sea salt, sand dust aerosol GISS climatology.
- Microphysics in non-convective clouds (ALARO).
- Vertical resolution is taken into account in clouds parameterization (ALARO).

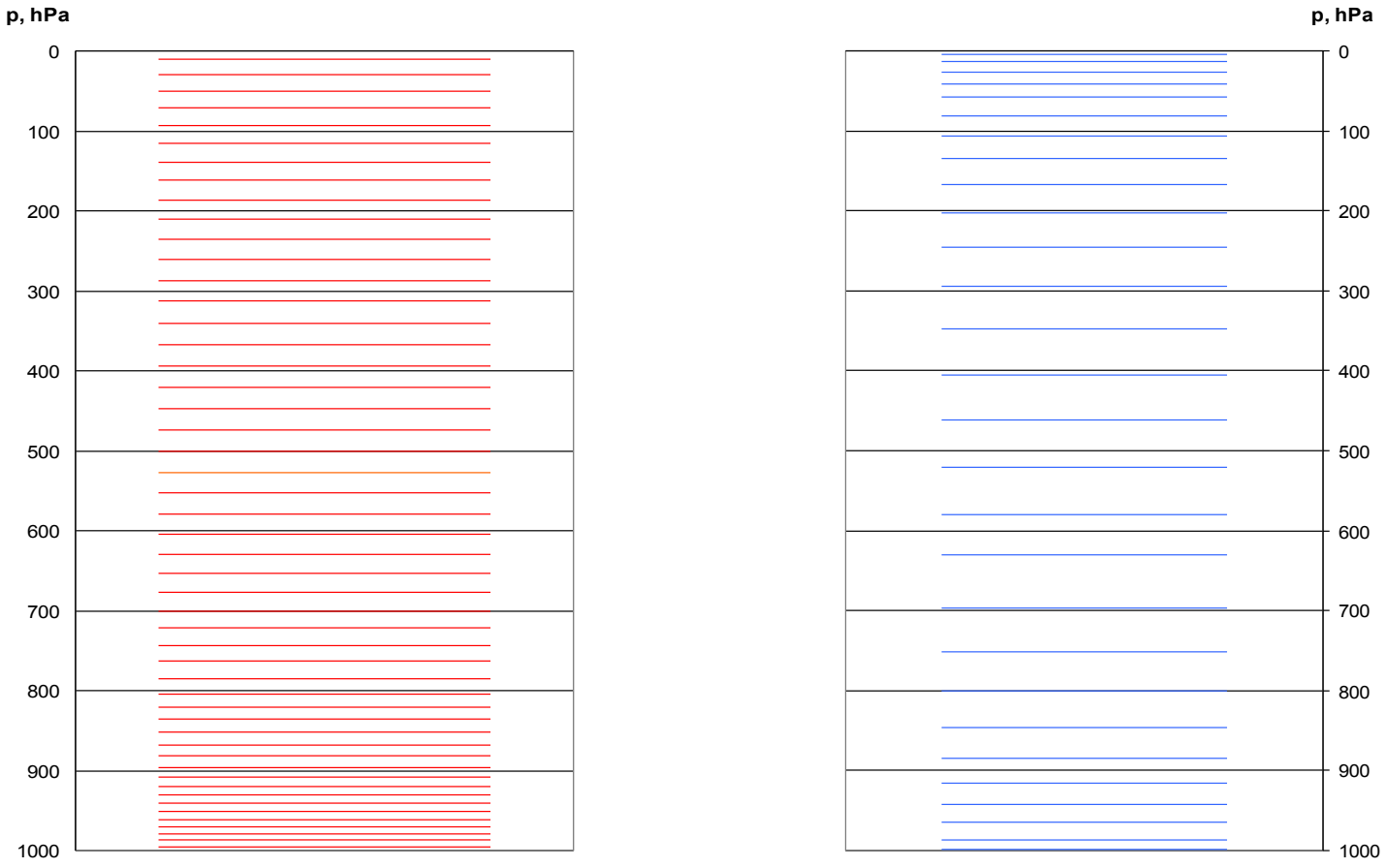
Grid step in latitude (upper curve) and longitude (lower curve), in km



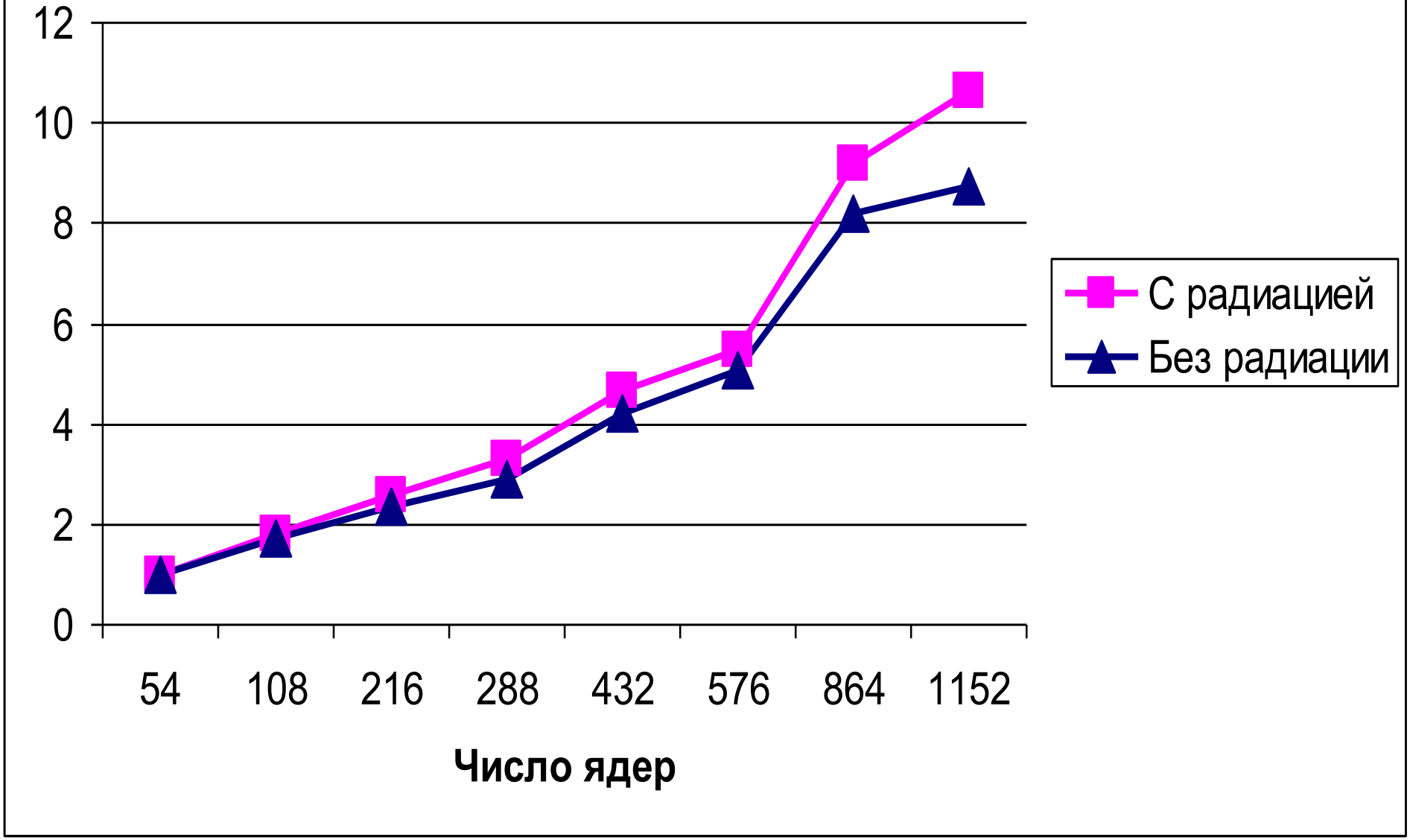
Proportion of ‘physical’ grid steps Max(dx/dy, dy/dx)



Vertical levels distribution: 50 levels (left), 28 levels (right).



Parallel acceleration of the SL-AV model with the resolution (0.16-0.24)˚x0.225˚, 51 levels (w.r.t. time at 54 procs). RSC Tornado

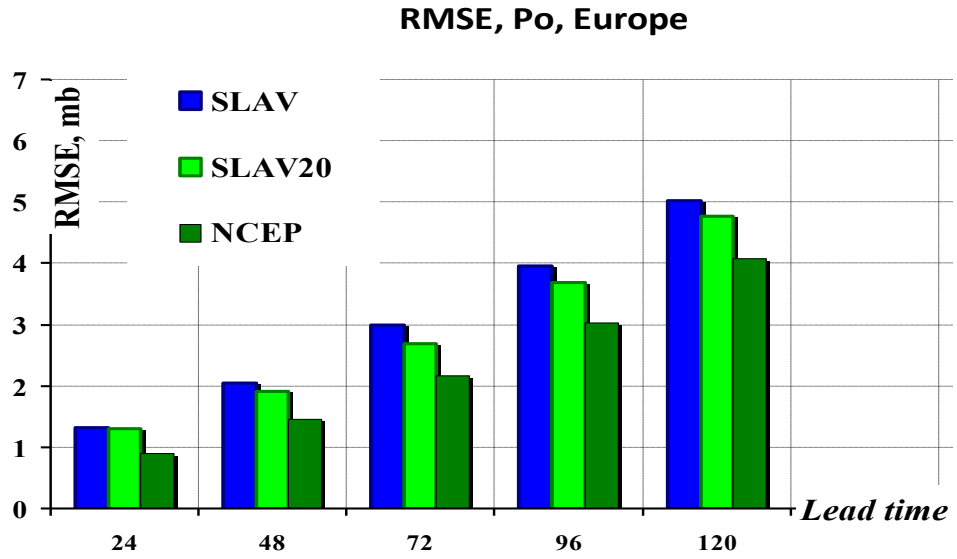


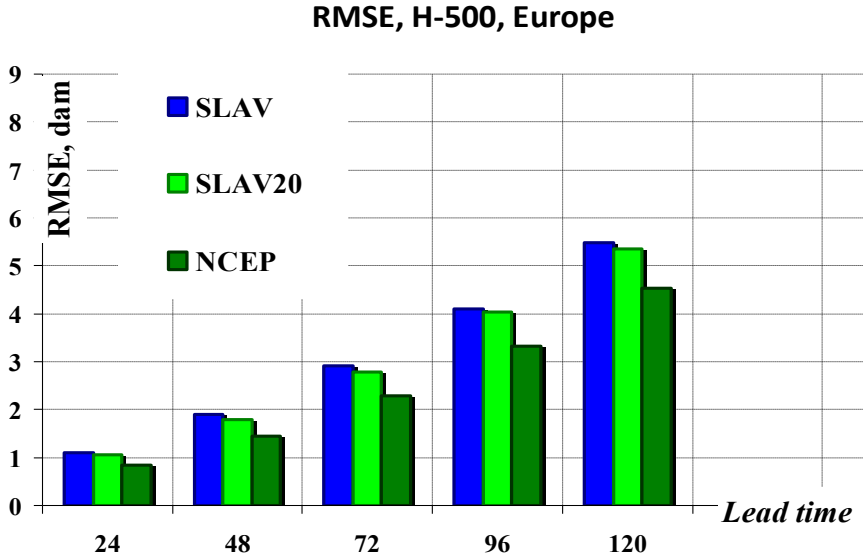
Developing multiscale version

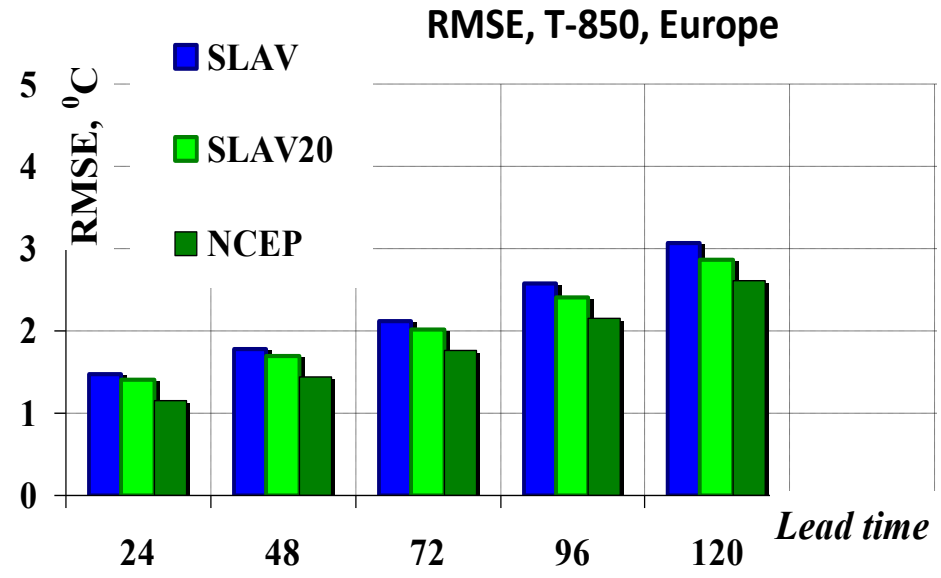
- Merging different options and resolutions into a single code.
- Unified multiscale version has parameterization set from the new NWP version
- Two input/output options, for NWP and for climate changes modelling.
- Verification on medium range NWP- OK.
- First runs according to AMIP2 protocol.

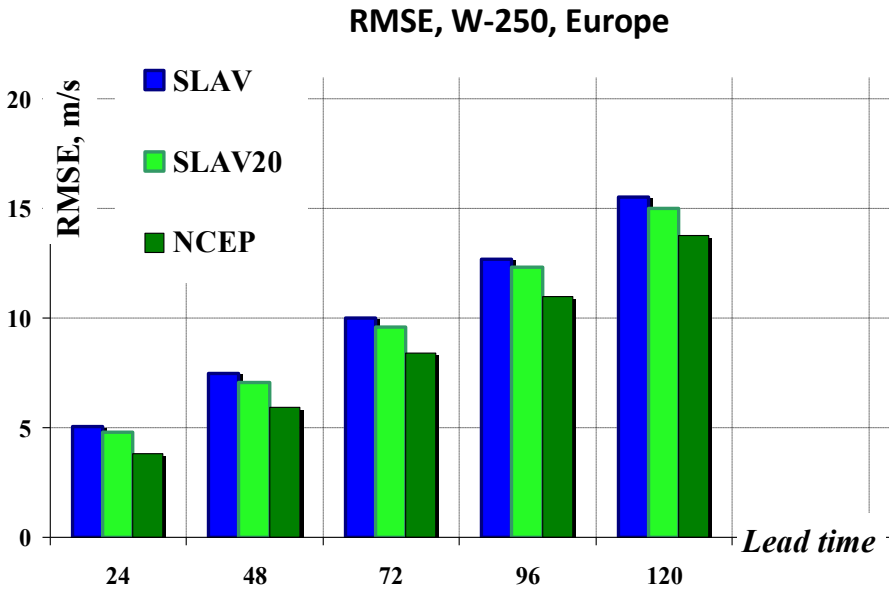
RMS forecast errors for 11.04.2014-14.06.2015 with respect to analysis . Region: Europe, 12 UTC

(SLAV – operational version, SLAV20 – new version)

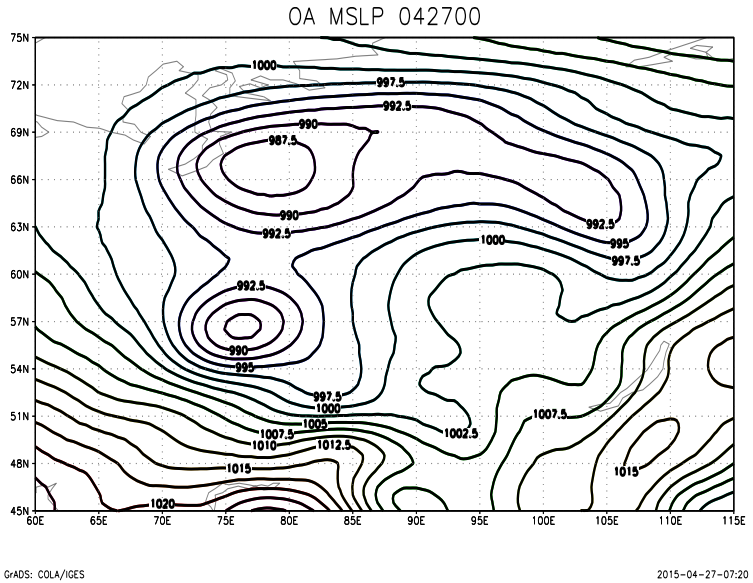




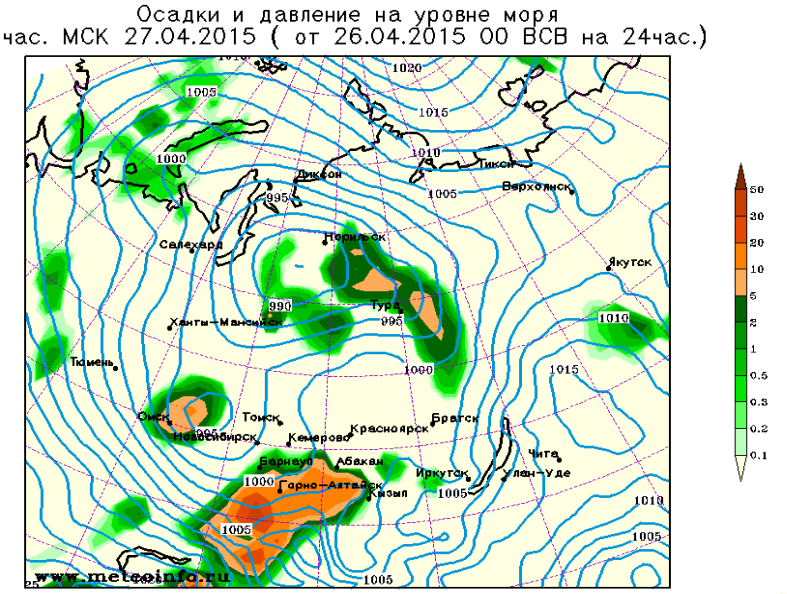




Analysis at 27.04.2015 00UTC and 24-h forecasts from 26.04.2015 00UTC



OA



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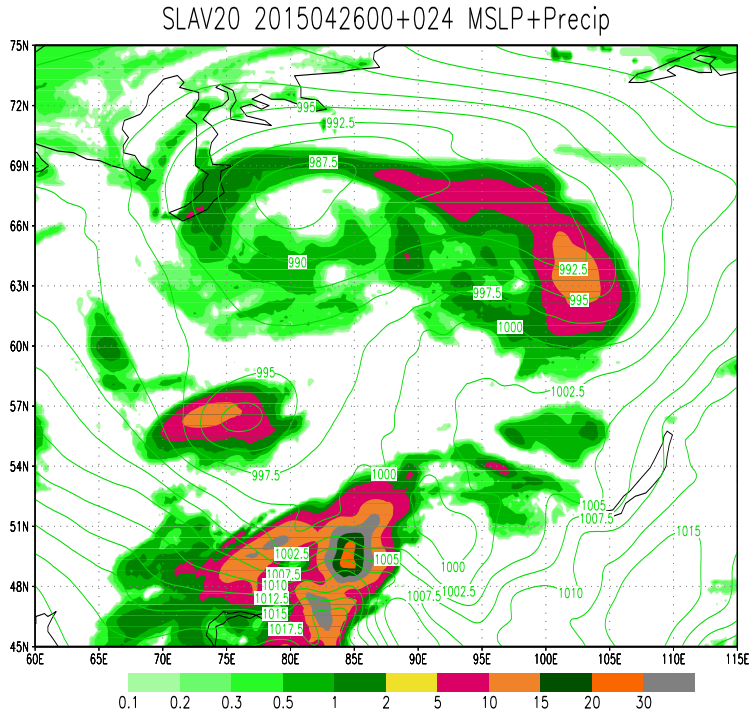
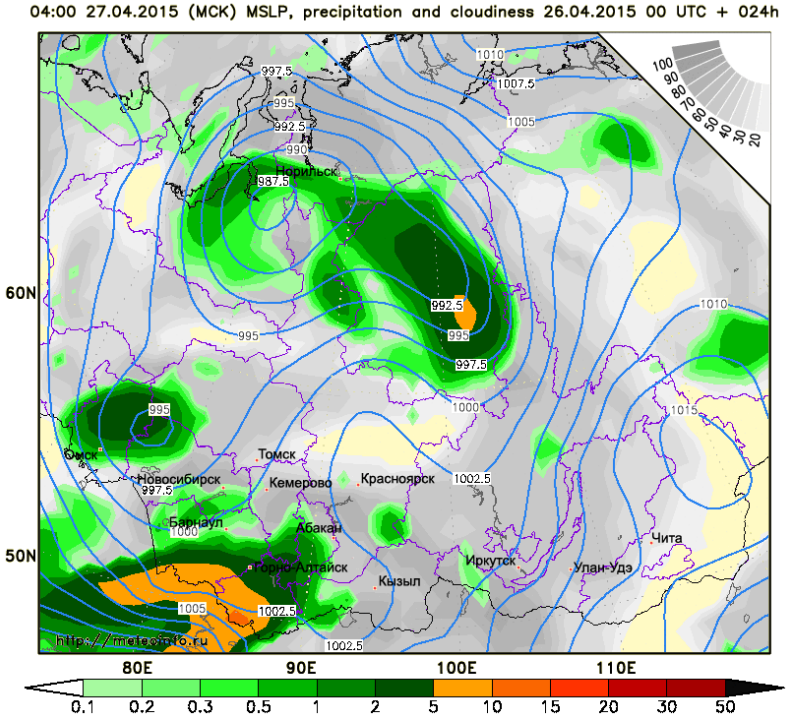


ПЛАВ20

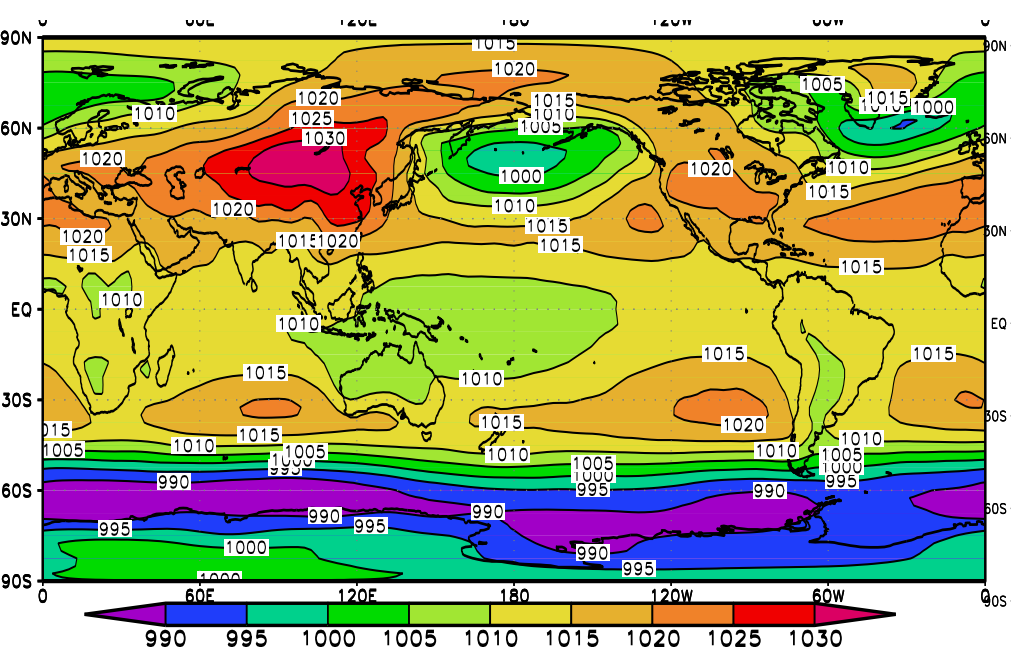


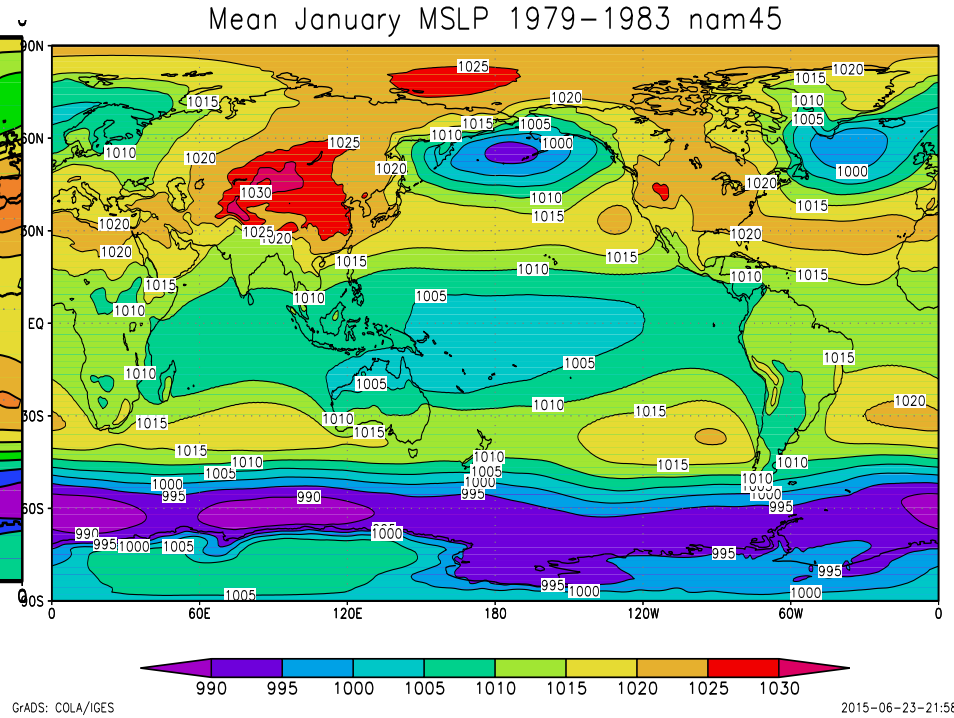
ПЛАВ 2008

Current (intermediary) results of climate modelling

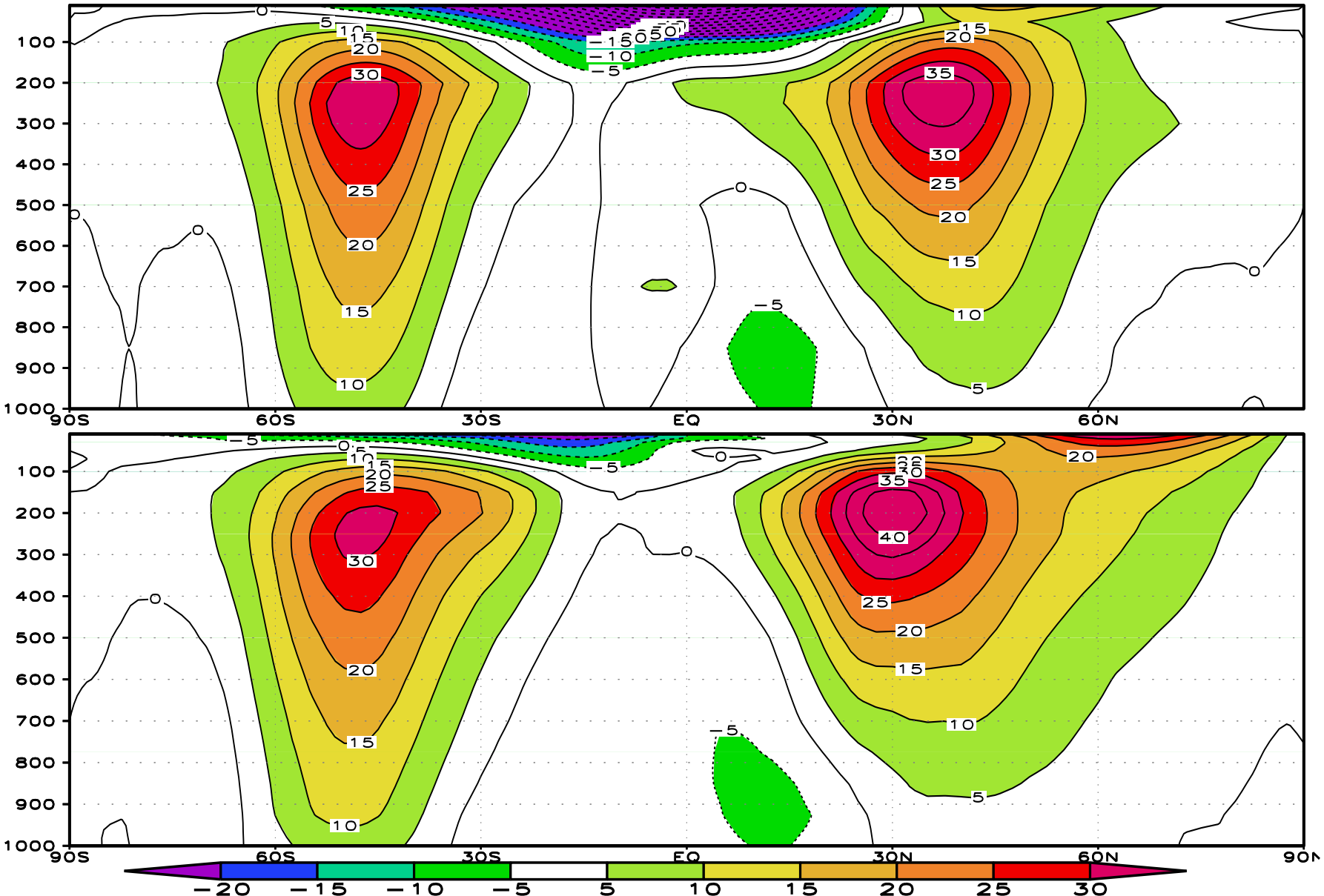
- Resolution 0.9x0.72 degrees lon-lat, 28 levels
- AMIP2 protocol (SST and sea-ice fields prescribed, changing in time).
- Initial conditions for 01.01.1979 (ERA Interim).
- 5 years calculated so far.

Mean January 1979-1983 MSLP field

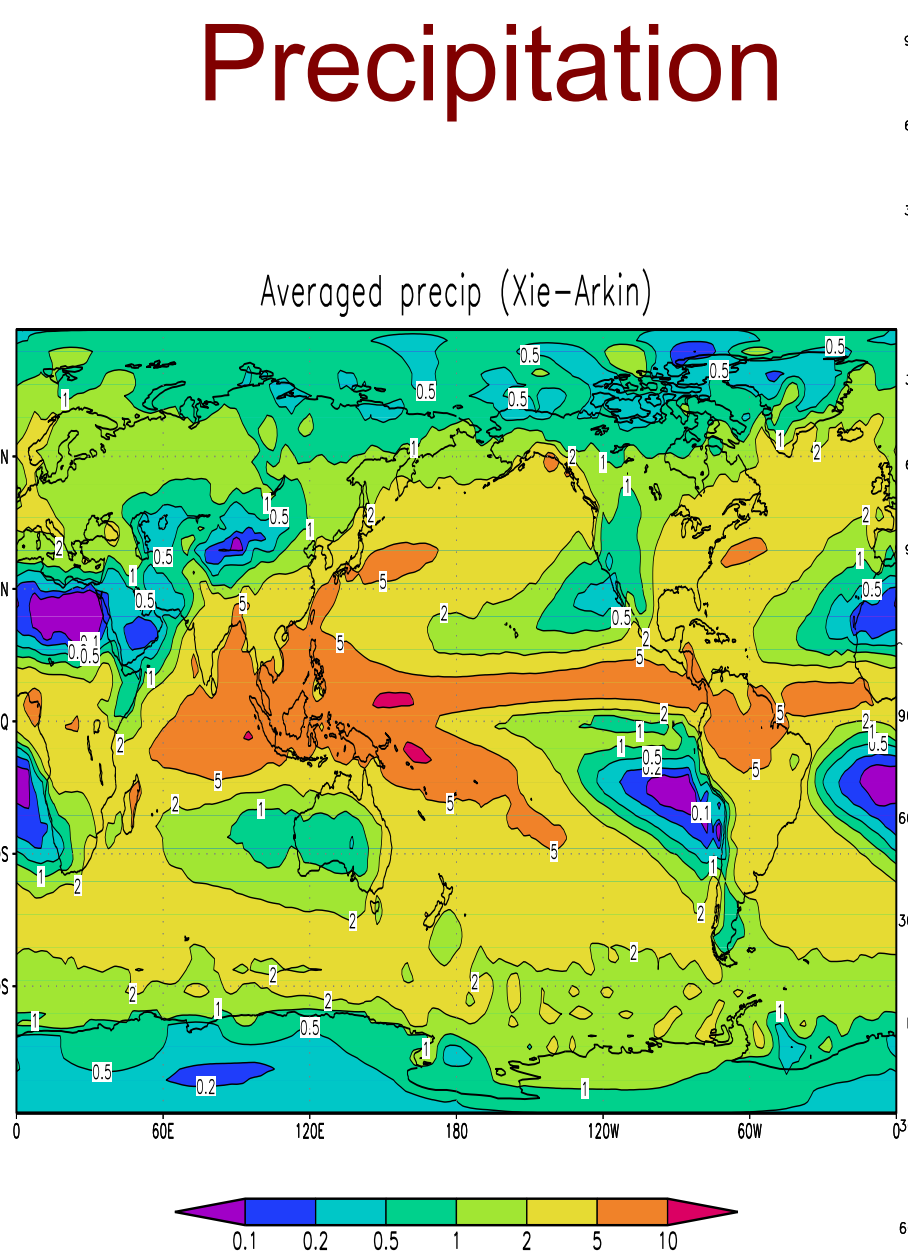


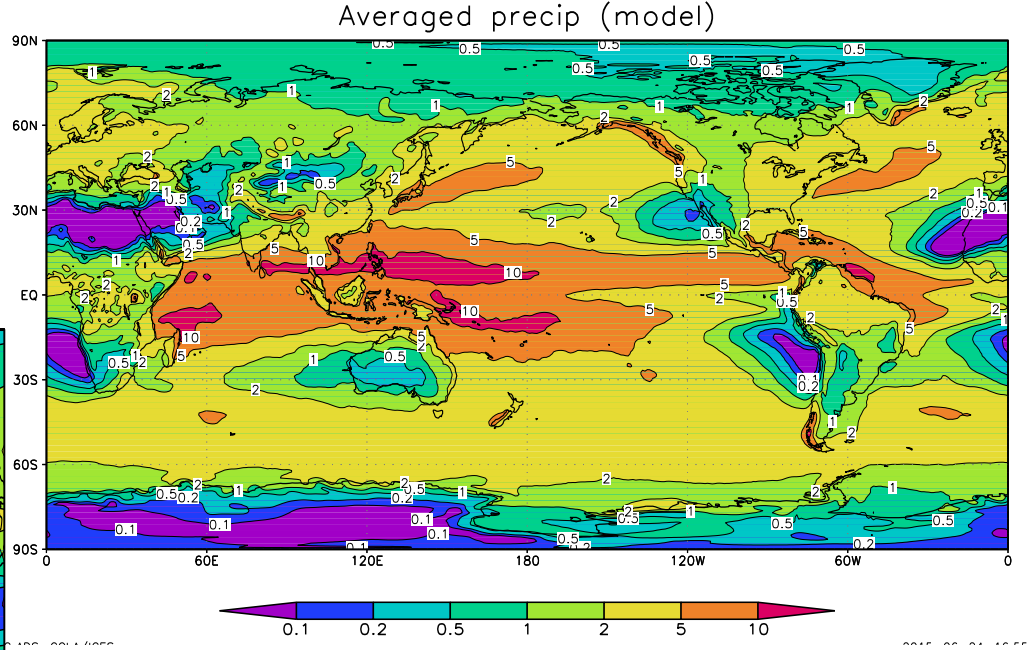


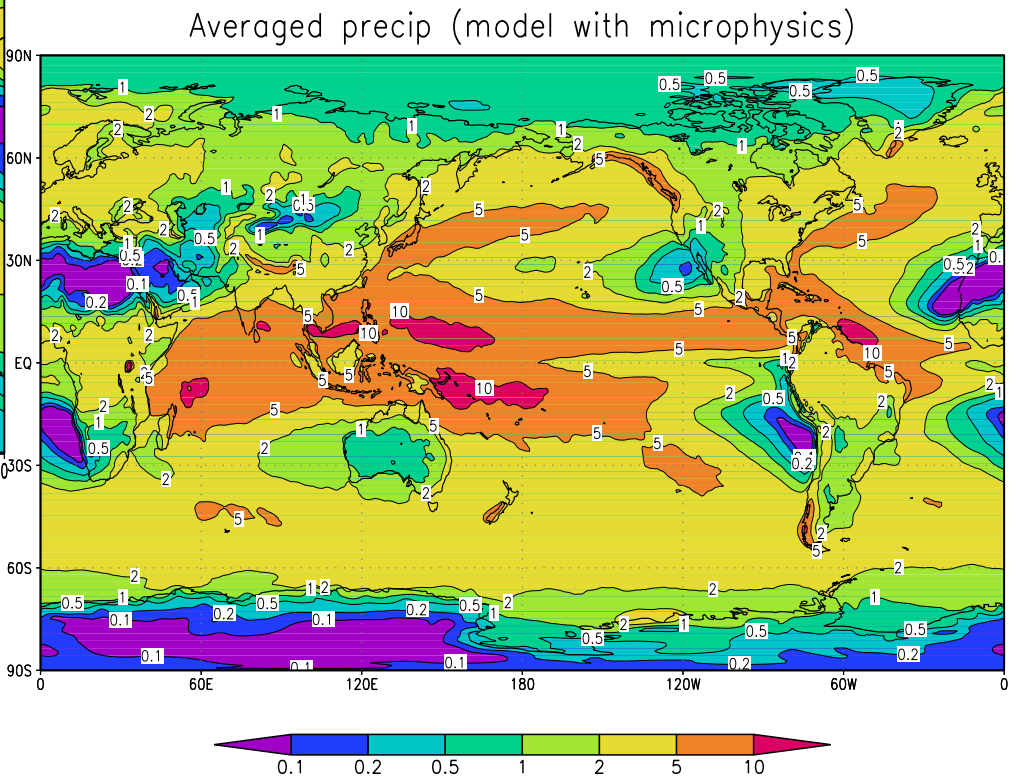
Mean January zonal wind: model (top), ERA (bottom)



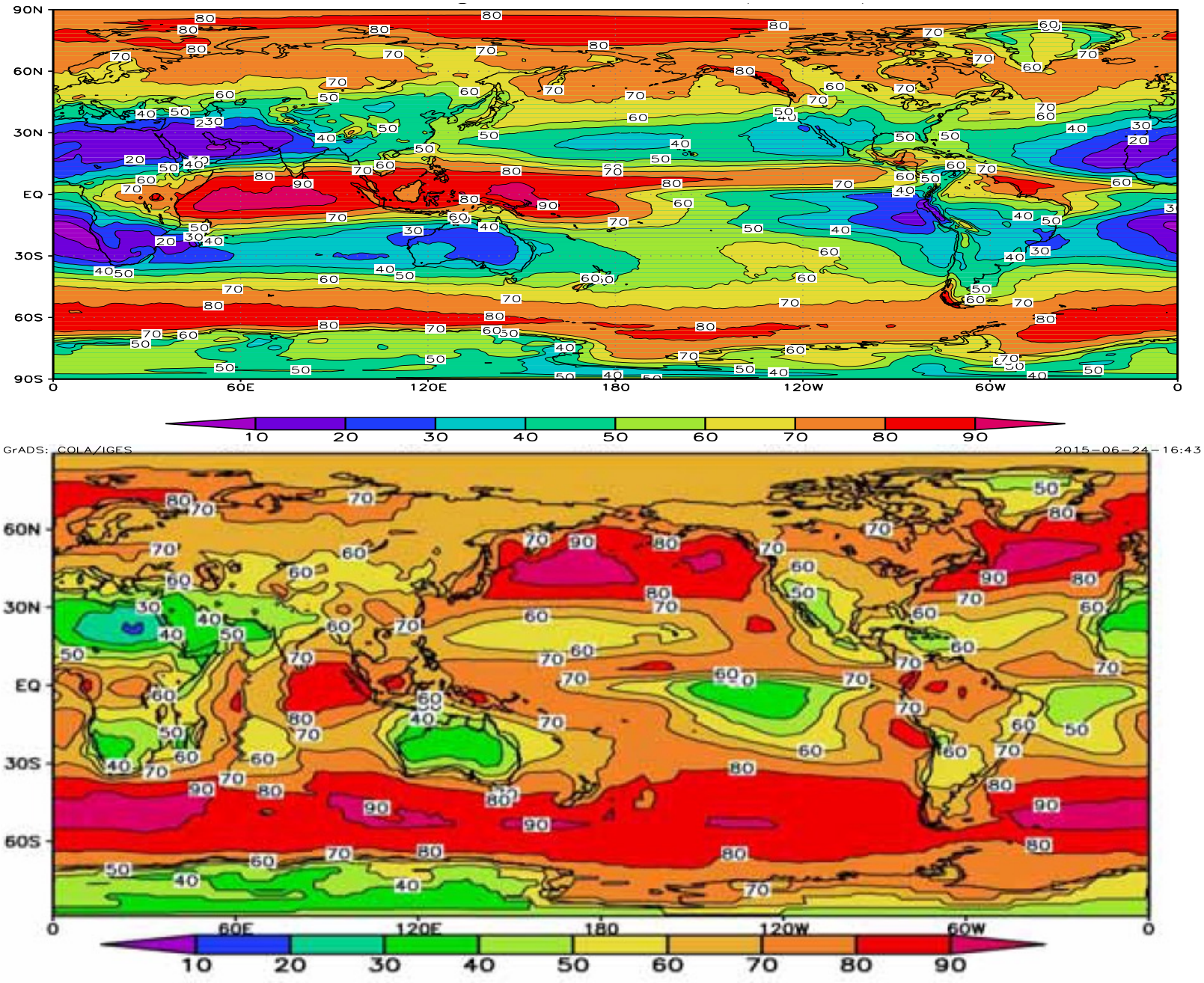
Precipitation



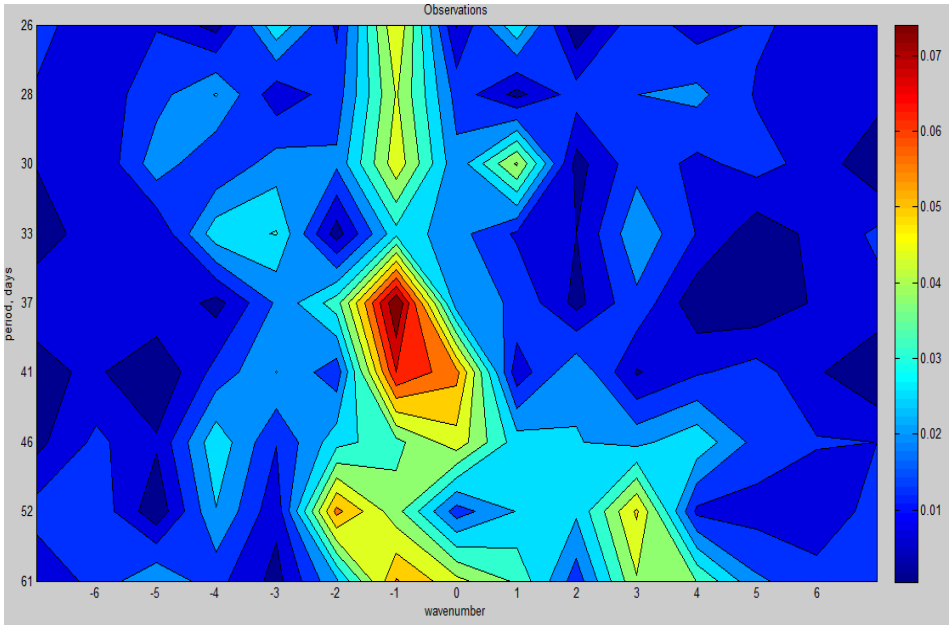


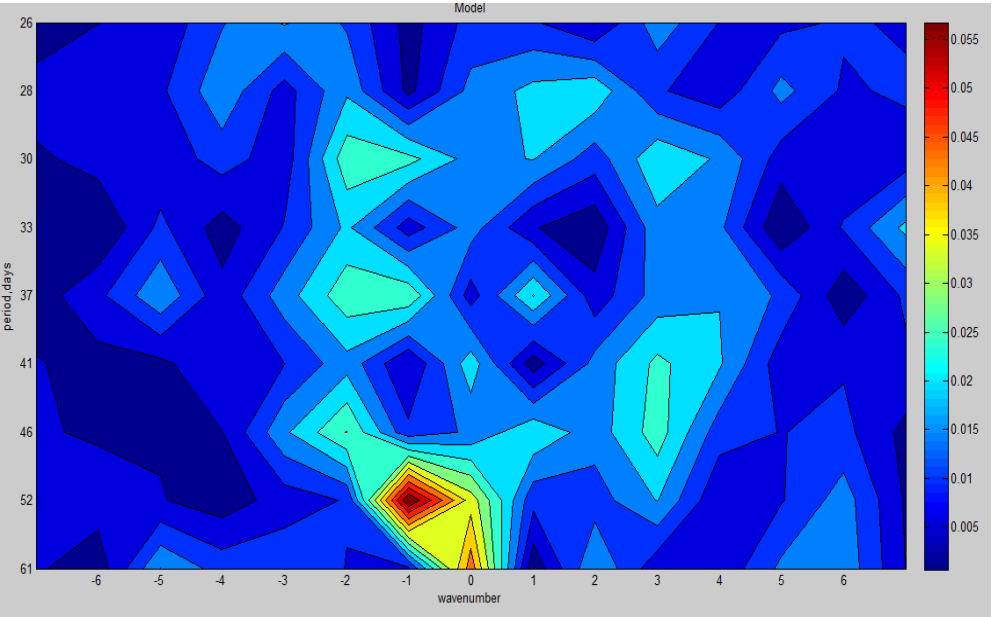


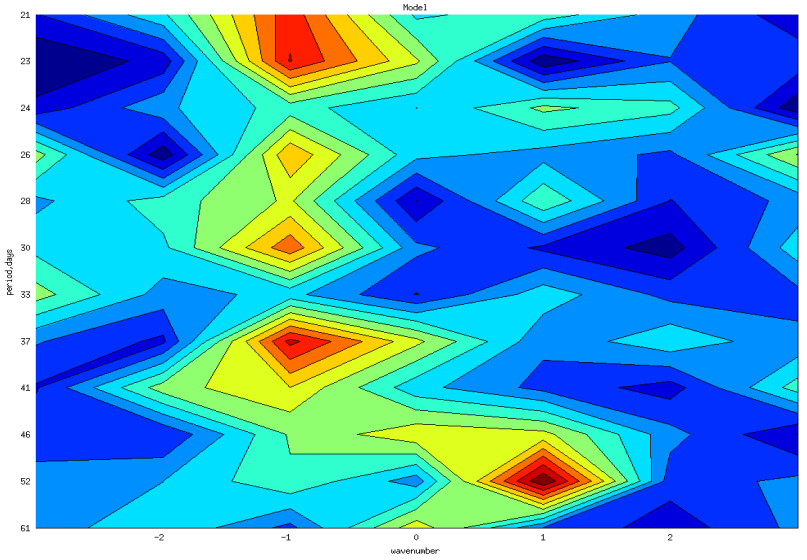
Mean cloudiness: model (top), reanalysis (bottom)



MJO spectra: observations (top), INM climate model (bottom left), SL-AV model (bottom right)







Further plans

- Hybrid vertical coordinate, higher model top (up to 0.5 hPa)
- Cloud parameterization for climate changes modelling mode.

- Coupling to the INM global ocean models

Conclusions

- Multiscale (unified) version of the global atmosphere model SL-AV has been developed.
- NWP mode works reasonably well
- Further improvements are needed for climate changes modelling.

Thank you for attention!

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