Section 6

Developments in global forecast models, case studies, predictability investigations, global ensemble, monthly and seasonal forecasting

Comparison of soil moisture in the FSU climate model coupled to a land model CLM2 to soil moisture from NCEP/DOE Reanalysis 2.

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Soil moisture is a key component in controlling the exchange of water and heat energy between the land surface and the atmosphere. Given that the soil moisture is prescribed in the FSU climate model, the implementation of the CLM2 model as the land parameterization in the FSU climate model allows us to obtain an explicit treatment of soil moisture into ten layers.

Given that the soil moisture is difficult to measure accurately in both time and space, reanalysis is a good substitute to supply with global soil moisture data set on a long time series. We compare our soil moisture outputs to one of the most well known global reanalysis: NCEP/DOE Reanalysis 2 (R-2). In both coupled model and R-2, the soil moisture takes soil liquid water and soil ice into account.

In order to compare soil layers of similar thicknesses, we added the soil layers of the coupled model. Thus, the first layer is 0-10 cm for R-2 and 0-16.6 cm for the coupled model and the second layer is 10-200 cm for R-2 and 16.6-229 cm for the coupled model. The coupled model layers are thicker than these of R-2.

The global distribution of soil moisture for the coupled model, for R-2 and the difference between the coupled model and R-2 over 5 years (1992-1996) is shown in figure 1 for the first layer and figure 2 for the second layer.

The coupled model shows high values in regions with ice (Polar Regions, west Siberia …) compared to R-2 for both layers. This difference comes from the fact that the soil ice amount becomes an important component of soil moisture in the frozen regions for the coupled model. Indeed, over west Siberia (55º-65ºN), the mean percentage of soil ice is about 60% whereas the mean percentage of soil ice in the northern hemisphere (0º-60ºN) is only 20% for the first layer. For the Polar Regions (90º-60ºS and 60º-90ºN) the mean percentage of soil ice reaches about 78%. The effects of frozen soil on the hydrologic process can be very important. Frozen soil stores more soil liquid water through the winter which cannot be evaporated. Ice changes also the thermal properties of the soil. When water freezes it releases latent heat.

For the latitudes from 60ºS to 60ºN global wetness and dryness areas agree with expectations in both model and R-2: the driest places are Sahara Desert, Arabian Peninsula and Central Australia, whereas the wettest regions are typically at higher latitudes. Despite the fact that for the coupled model, the layers are thicker and the soil ice component is more important in the regions where the ground is frozen, the coupled model is drier (global mean soil moisture for the latitudes from 60ºS to 60ºN over 5 years is 0.21 m3/m3) than R-2 (0.26 m3/m3) in the first layer. In the second layer, the soil moisture content of the coupled model (0.231 m3/m3) is more similar to that of R-2 (0.235 m3/m3), but still drier in regions without ice and wetter in regions with ice.

To conclude, the coupled model compares well with R-2 in most regions but tends to give a dry bias under a dry climate (Australia, Sahara desert) and a wet bias when the soil is frozen (west Siberia, Polar Regions). The wet bias in frozen regions is due to the fact that the soil ice contribution to the soil moisture is more important in the coupled model than in R-2. This difference can have important consequences on the hydrologic process and the thermal properties of the soil.

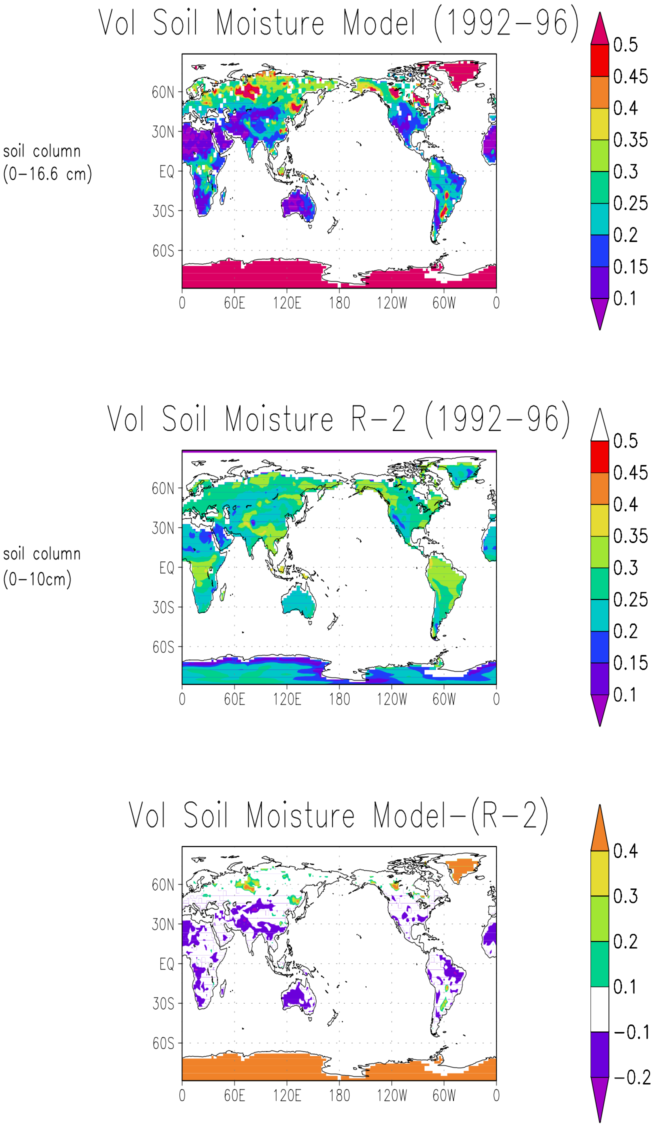

Figure 1: Global distribution of soil moisture for the coupled model (top), R-2 (middle) and model - (R-2) (bottom).

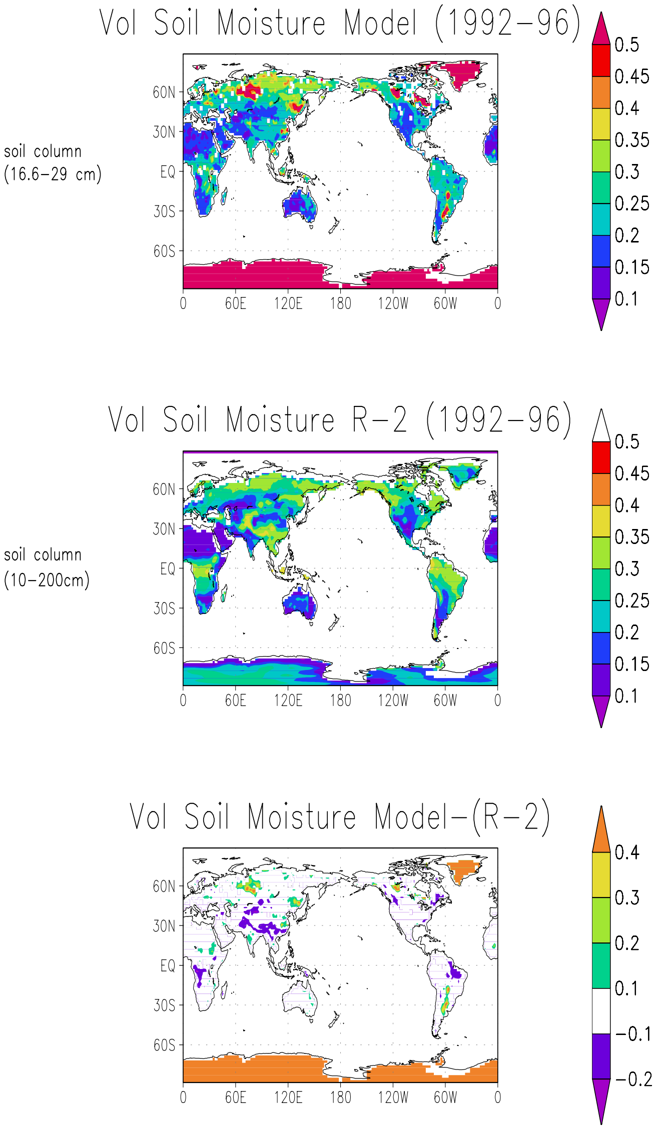

Figure 2: Same figure for the second layer.

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40 km/40 Layer Version of the Global Model GME of DWD

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On 27 September 2004 DWD put a new version of its global model GME (Majewski et al., 2002) in operation. The new version has higher horizontal and vertical resolution. The width of the hexagonal grid cells was reduced from 60 km to 40 km. This corresponds to a reduction of mean grid cell area from 3100 km^2 to 1384 km^2. The number of main levels of the model was increased from 31 to 40. As in the previous version the top level is at 10 hPa, however the lowest level is at a height of approximately 10 m above the surface.

In addition a muli-layer soil model (Schrodin and Heise, 2001) which solves the temperature and humidity equations for the soil is employed. It replaces the old 2-layer force-restore soil model of Jacobsen and Heise (1982). The layer boundaries are listed in Table 1. The temperature at the lowest depth of 21.87 m is constant in time and set to the climatological mean 2 m temperature. The new soil model allows for more realistic freezing and thawing of the soil.

The changes lead to an overall improvment of GME. The temperature and spread at 2 m predicted by the old and new GME are compared with observations in Figure 1. The root mean square error at 1281 stations in Europe from 1 September to 30 October 2004 is shown for the old GME (red) and the new GME (blue). The new GME has much smaller errors with a reduction of variance (SK) of 28 % for the spread, and 11 % for temperature.

For the old model the subgrid scale orographic drag was too strong. With higher horizontal resolution this drag is reduced, which diminishes the wind speed bias of the model. This is demonstrated in Figure 2 where model forecasts are compared with TEMP winds in the northern hemisphere. In the old version the bias increased with forecast time, whereas it is constant, and much smaller with the new version. Further tuning of the SSO scheme at the new model resolution will be performed in the near future.

The forecast range is extended mainly after 3 days. Figure 3 shows the anomaly correlation of the 500 hPa height, mean sea level pressure, and temperature at 850 hPa over the northern hemisphere for 31 forecasts at 12 UTC from 26 September to 26 October 2004. There is marked improvement for the sea level pressure and the temperature at 850 hPa.

The new model requires approximately 5 times as much computing power as the old model. A 178 hour forecast takes approximately 120 minutes on 450 Power III processors of an IBM RS/6000. It produces approximately 45 GB of data.

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Table 1: Depth of lower boundaries and thicknesses of the layers of the new soil model.

Top	[cm]	0	1	3	9	27	81	243	729
Bottom	[cm]	1	3	9	27	81	243	729	2187
Thickness	[cm]	1	2	6	18	54	162	486	1458

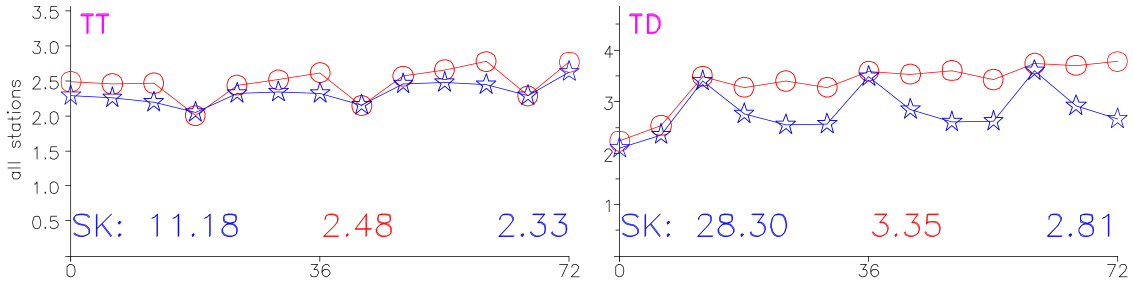

Figure 1: Root mean square error of temperature (TT) and spread (TD) at 2 m as a function of forecast time; old (red) and new (blue) GME. The mean value over 72 hours is written above the abscissa. To the left the skill (reduction of variance, SK) is written.

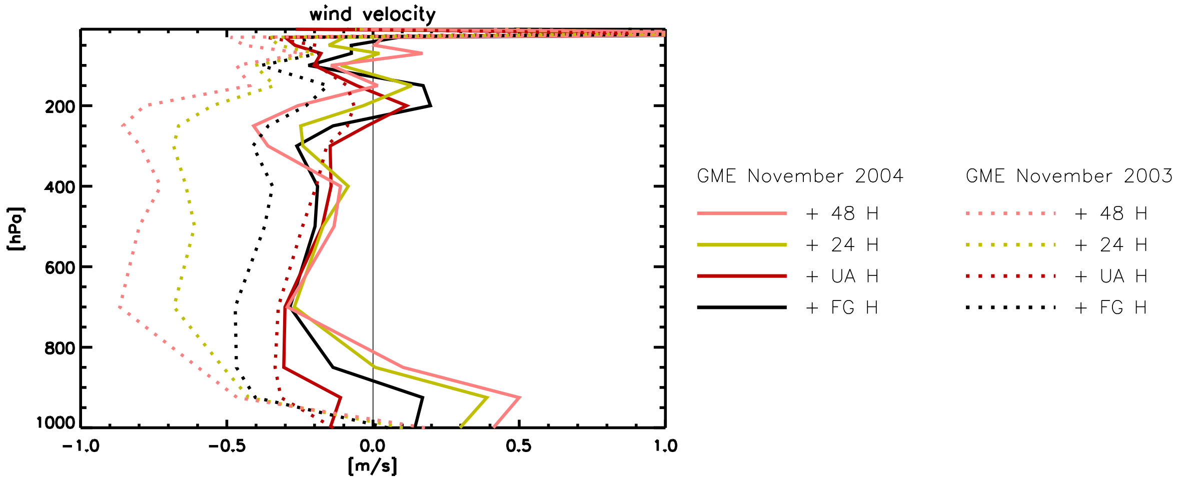

Figure 2: Wind bias of 00 UTC runs in November 2004 (solid, new GME) and November 2003 (dotted, old GME): uninitialized analysis (UA), first guess (FG), 24 h and 48 h forecasts. Comparison of forecasts and TEMP observations in the northern hemisphere.

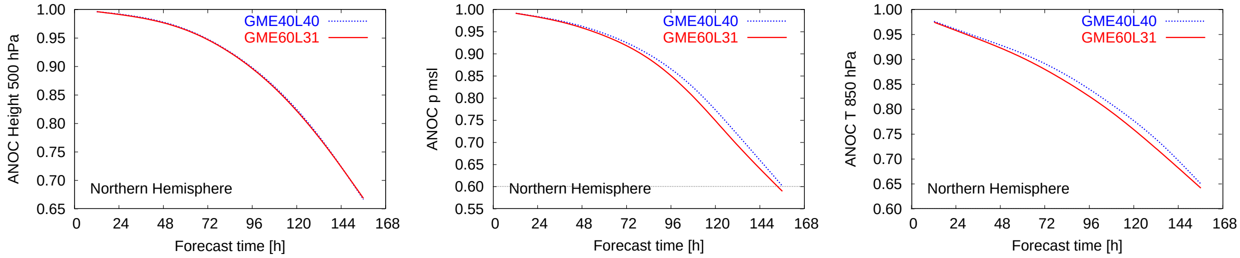

Figure 3: Anomaly correlation of 500 hPa height, mean sea level pressure, and temperature at 850 hPa in the northern hemisphere for 31 forecasts at 12 UTC in September and October 2004; old (red) and new (blue) GME (red).

Operational Implementation of a new semi-Lagrangian global NWP model at JMA

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1) Introduction

The global modeling group of NPD/JMA, and the Climate Research Department of MRI/JMA have been developing the JMA-MRI unified global model. The new global model will be used for climate research at MRI and the operational NWP at JMA. The new model adopts a semi-Lagrangian scheme and has been well optimized on various supercomputers such as Hitachi SR8000 and NEC SX-6 (Earth Simulator) (Katayama et al., 2004).

Data assimilation and forecast experiments with the new global model (TL319L40) have been conducted on the JMA operational NWP system. The forecast performance of the new model is as well as the JMA operational global NWP model (GSM-T213L40). The new global NWP model will be operational in the beginning of 2005.

2) Configuration of data assimilation and forecast experiments

(a) Dynamical core : Vertically conservative semi-Lagrangian scheme (Yoshimura and Matsumura 2003)
(b) Physical Processes : Same as the JMA operational global NWP model
(c) Resolution : TL319L40 (640x320x40 grids)
(d) Time steps : 900 sec (9 days forecast) and 450 sec (data assimilation cycle)
(e) Initialization : Vertical normal mode incremental initialization (Murakami and Matsumura 2004)
(f) Target period : January and August 2004

3) Results

(a) January 2004

Figure 1 shows the root mean square error (RMSE) of 500 hPa height field. RMSE is almost same as the control-run (operational model) in both the Northern Hemisphere and the Southern Hemisphere. Figure 2 shows the mean error (ME) of 500 hPa height field. ME of the new model in the Southern Hemisphere is smaller than the control-run.

(b) August 2004

RMSE is almost same as the control-run until 5 days forecast and slightly larger after 6 days forecast (Figure 3) in both the Northern Hemisphere and the Southern Hemisphere. ME is much smaller than the control-run in both the Northern Hemisphere and the Southern Hemisphere (Figure 4). Figure 5 shows the mean track error of Typhoon forecast for 9 Typhoons. The Typhoon track forecast with the new global model is better than the operational model.

(c) Computational time

The computational time for 9 days forecast with the new model is 30-50 % shorter than the current operational Eulerian model.

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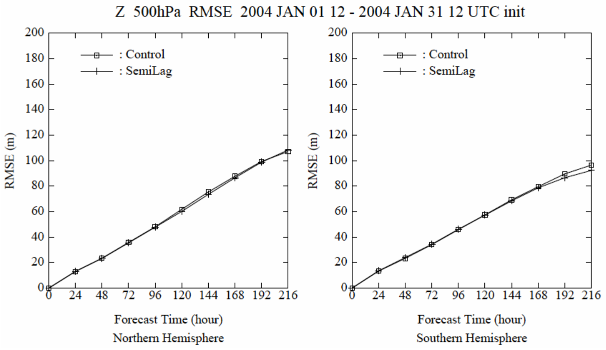

Fig.1 Result of the experiment in Jan 2004. Root mean square error of 500 hPa height. Northern hemisphere (left) and Southern hemisphere (right). Control-run (□) and new semi-Lagrangian model (+).

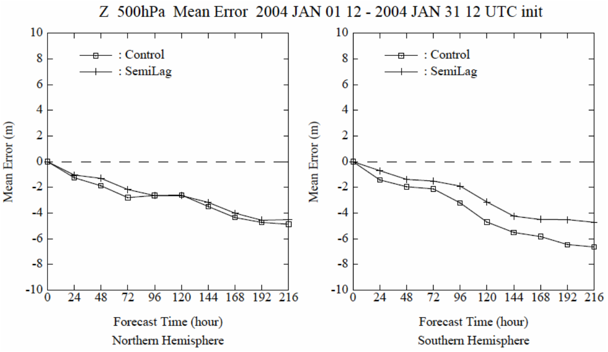

Fig.2 Result of the experiment in Jan 2004. Mean error of 500 hPa height.

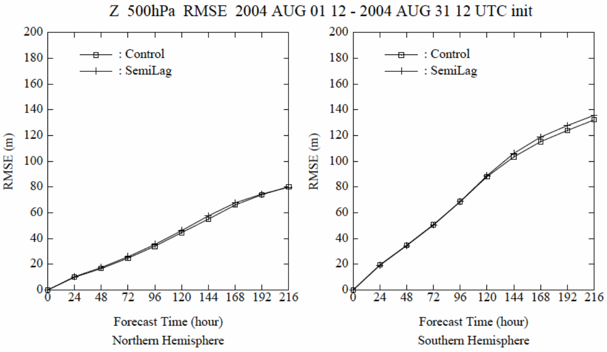

Fig.3 Same as Fig.1, but for Aug 2004.

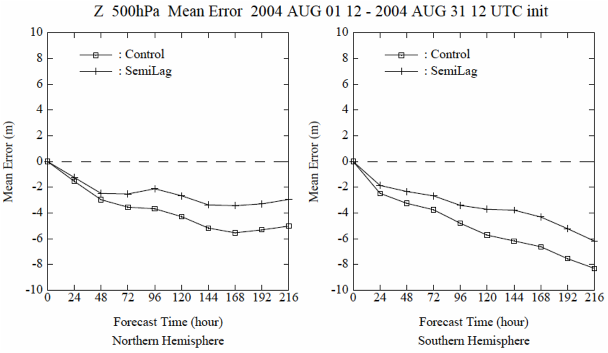

Fig.4 Same as Fig.2, but for Aug 2004.

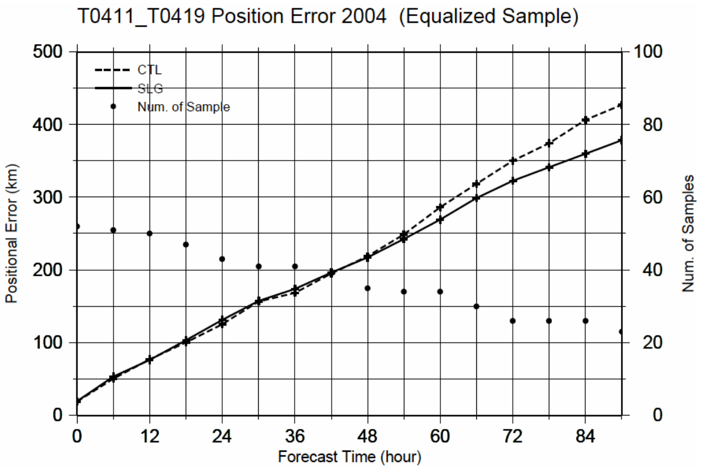

Fig.5 Mean Typhoon track error. Control-run (broken line) and new semi-Lagrangian model (solid line).

Towards a High Resolution Global Model for Data Assimilation and Medium-Range Weather Forecasting in Canada

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1. Introduction

Operational forecasting and data assimilation both at regional and global scales have been performed at the Canadian Meteorological Centre in the context of a unified model strategy, the Global Environmental Multi-scale (GEM) model (Côté et al. 1998a and Côté et al. 1998b). The global model configuration of the system has remained stable in the past few years while the data assimilation was being significantly upgraded, going from optimal interpolation to three dimensional variational data assimilation (3DVAR) (Gauthier et al. 1999) and now to four dimensional variational data assimilation (Stephane Laroche, personal communication). The next step is now to improve the modeling aspect of the system.

2. An improved global model

The objective of this work is to improve upon the model's behaviour by a significant increase in horizontal and vertical resolution and by replacing many of the physical parameterizations used in the model by schemes more adapted to high resolution. From the assimilation point of view, the shorter time step together with the sharpness of this new meso-scale version of the model should take full advantage of the capacity of the 4DVAR to assimilate data at the correct time of observation while imposing a temporal constraint on the model's trajectory. From the forecasting point of view, the physical realism of the simulated weather is greatly improved. The changes to the dynamical configuration with respect to the operational one are shown in table 1. The comparison of the new and old physics package is shown in table 2.

3. Discussion

There is an increase in resolution by a factor of three of the global model together with a significant improvement to the physical parameterizations. This leads, among other things to a much better representation of the global characteristics of the precipitation patterns while at the same time improving the behaviour of the weather systems down to the meso-scale. To illustrate this point an analysis of the global distribution of precipitation is used and objective scores are performed at the regional scale.

Figure 1 shows the zonally averaged precipitation for the winter season for the new and operational model as compared to the analysis from the Global Precipitation Climatology Project (GPCP). The latitudinal distribution of the precipitation maxima and minima is better represented in the new version of the model.

Objective precipitation scores against the SHEF observation network over the United States for the winter season are shown in figure 2. Again, the new version of the model shows a significant improvement over the operational model.

	New version	Operational version
No. of points	800 x 600 x L58	400 x 200 x L28
Grid	Non-rotated Lat/Lon grid	Rotated Lat/Lon grid
Resolution	33 km at 49 deg.	100 km at the computational equator
Time step	900 sec.	2700 sec.
Orography	USGS	US NAVY

Table 1. Comparison of the dynamics characteristics of the new and operational versions of the GEM model.

	New version	Operational version
Thermodynamic Roughness over water	Constant in the Tropics	Charnock formulation everywhere
Mixing length for the vertical diffusion	Bougeault-Lacarrere	Blackadar 1962
Overshooting cumulus clouds	Yes	No
Deep convection	Kain-Fritsch	Kuo
Grid-scale condensation	Modified Sundqvist scheme	Sundqvist scheme

Table 2. Comparison of the physics characteristics of the new and operational versions of the GEM model.

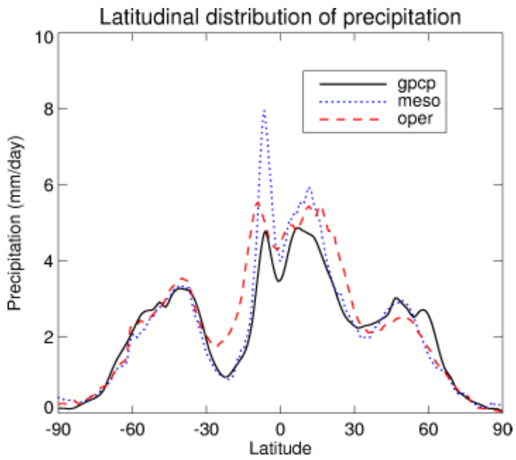

Fig. 1. Zonally averaged mean precipitation rate for December/January/February for the GPCP analysis (full), operational model (dashed) and new meso-global model (dotted)

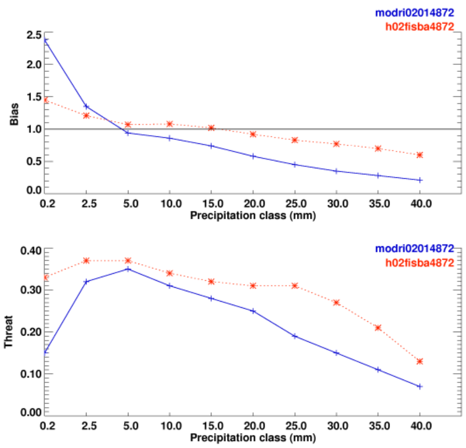

Fig. 2. Bias (top) and threat (bottom) scores for the 48 to 72 hour accumulation of precipitation over the United States for the SHEF network for January and February 2002 for the operational (full) and new meso-global (dotted) models

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The Role of the CLM2 in the Surface Air Temperature and Precipitation of the FSU Climate Model

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The current Florida State University (FSU) climate model is upgraded by coupling the National Center for Atmospheric Research community land model (NCAR CLM2) as its land component in order to make a better simulation of surface air temperature and precipitation on seasonal time scale which are critical information for a crop model application. Climatological and seasonal simulations with the FSU climate model coupled to the CLM (hereafter, FSUCLM) are compared to those of the control (the FSU model with the original simple land surface treatment). The current version of the FSU model is known to have a cold bias in the temperature field and a wet bias in precipitation. The implementation of FSUCLM has reduced or eliminated this bias greatly due to reduced latent heat and increased sensible heat flux. The role of land model in seasonal simulations is shown to be more important during summer time than winter time. An assimilation experiment with atmospheric forcings (FSUCLMa) helps produce a better land model initial condition, which in turn, makes the biases become further smaller. The impact of various deep convective parameterizations is examined as well to further assess model performance.

Simulations of 10-yr length (1987-1996) were performed with each land model and four convective schemes (NCEP/SAS: moisture flux, only one cloud type, NCAR/ZM: similar to the AS but three significant assumptions, NRL/RAS: handing of detrainment, MIT/EMANUEL: buoyancy-sorting hypothesis, mixing hypothesis, and a stochastic coalescence model) coupled to the FSU climate model at a resolution of T63 (~ 1.86^o) with 17 vertical levels. The integrations commence on 1 January, 1987. Only the last 5 yr of the simulations (i.e., 1992-1996) were analyzed to allow a 5-yr spinup of soil water and temperature for the FSUCLM run.

In the near future, the coupled model (FSUCLM) will be used in our on-going project, downscaling for crop models. Since the current simulations were carried out using the FSU global climate model at a very low resolution (~200km), downscaling the parameters for a particular station may result in inaccurate results. In this connection, the CLM2 has to be coupled to the FSU regional climate model to allow more accurate representation of the station data. The regional model will be place over the southeast US and run at 20km resolution, roughly resolving the county level. To be precise, an attempt will be made to integrate outputs from the FSU regional model with agricultural models to forecast maize yield in southeast US using the CERES-maize (Crop Environment Resource Synthesis) crop model.

Computations were performed on the IBM SP4 at the FSU. COAPS receives its base support from the Applied Research Center, funded by NOAA Office of Global Programs awarded to Dr. James J. O'Brien.

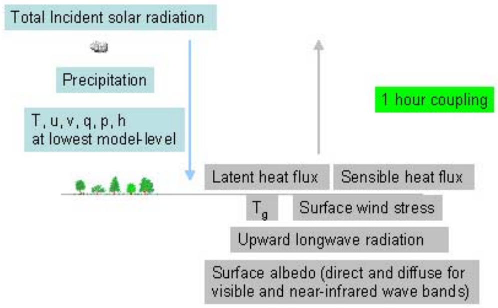

Fig. 1: Coupling Strategy

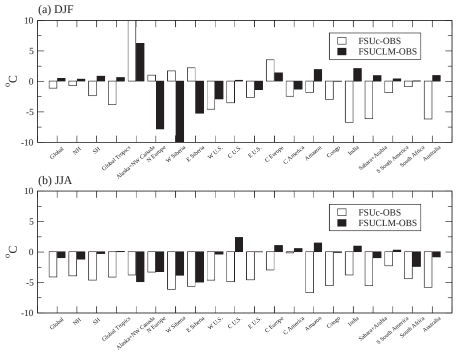

Fig.2: Surface (2m) air temperature bias over different geophysical locations for (a) DJF and (b) JJA.

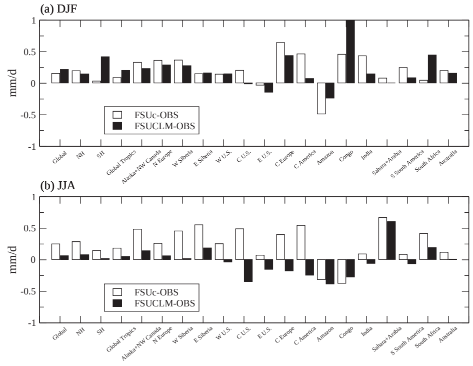

Fig.3: Same as Fig. 2 but for precipitation.

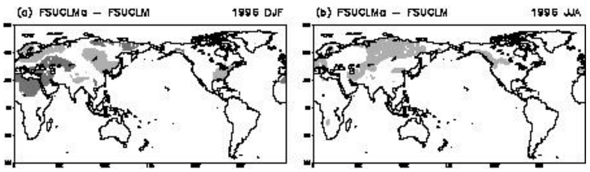

Fig.5: Seasonal surface (2m) air temperature difference between FSUCLMa and FSUCLM for (a) DJF and (b) JJA, 1996. Values greater than 2K are shaded light. Values smaller than -2K are shaded dark.

Table 1: Surface (2m) air temperature RMSE.

	DJF		JJA	
	FSUc	FSUCLM	FSUc	FSUCLM
NCEP	6.16	**4.08**	6.28	4.33
NCAR	5.98	4.12	6.12	**4.27**
NRL	5.70	4.34	5.93	4.51
MIT	5.38	4.77	5.59	4.73

Table 2: ETS (45N-45S over land) for 5-yr average (1992-1996) precipitation

		DJF		JJA	
		FSUc	FSUCLM	FSUc	FSUCLM
>0.25 mm/d	NCEP	0.246	**0.417**	0.051	0.251
	NCAR	0.258	0.397	0.030	0.271
	NRL	0.317	0.410	0.042	0.347
	MIT	0.196	0.356	0.035	0.221
> 2.5 mm/d	NCEP	0.495	0.528	0.364	0.464
	NCAR	0.494	**0.547**	0.368	0.501
	NRL	0.476	0.491	0.413	**0.545**
	MIT	0.402	0.430	0.423	0.527

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Evaluation of AVN NCAR model surface temperature data errors in cold Siberian region seasons

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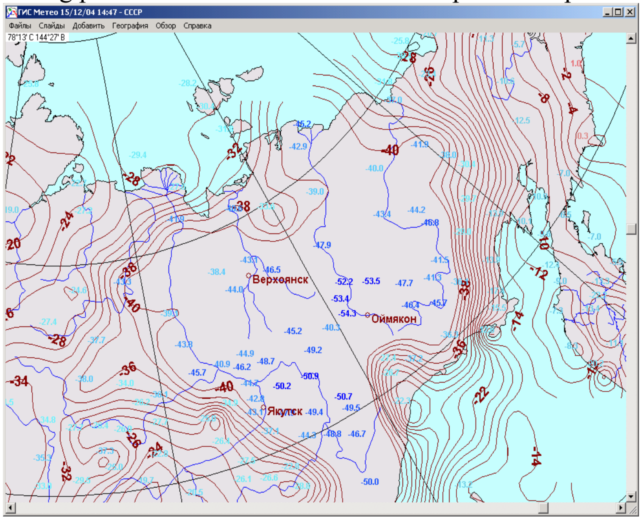
There is vast region in East Siberia where cold temperature –40°C and below lasts during several months. Evaluation of surface temperature fields received from INTERNET FTP server NCAR Washington (ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/avn/prod/ and ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/) during period of 2002-2004 shows unacceptable temperatures in such regions.

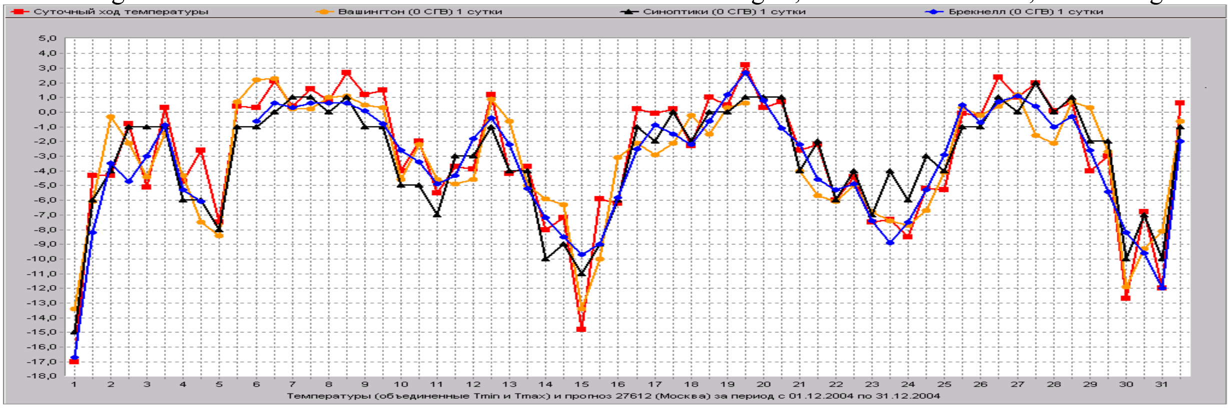


Vast area without isoterms on the surface temperature chart (Synop FM-12 data for 00 GMT 29 december 2004) shows such sample. Blue values are observed **T** data in °C. In this area differences between AVN data and observed T data are near 10-20°.

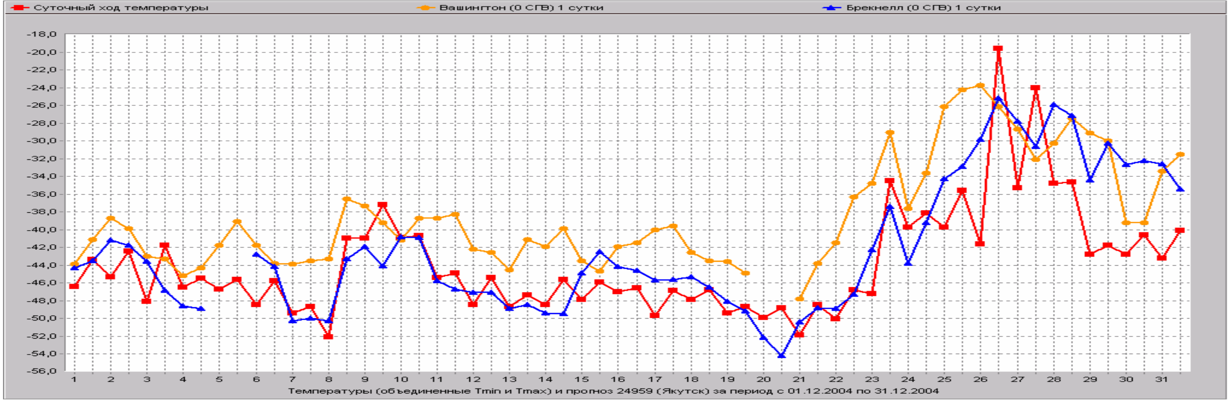
Cold weather periods in west Siberia in oil/gas fields region (from Yamal to Niznevartovsk) lasts so long too.

Numerical evaluation of surface temperature errors of AVN NCAR model data is shown below.

Graph below shows December 2004 day/night extreme temperature in Moscow (SYNOP FM-12 data from station 27612, red line) and corresponding 24/36 hours forecasts data. AVN NCAR data are in yellow color, London data (GTS WMO GRIB HTIE98 EGRR / HTIG98 EGRR from 00 GMT)are in blue, Moscow meteorological office data are in black. AVN model data are in 1°*1° grid, London data are in 1,25°*1.25° grid.

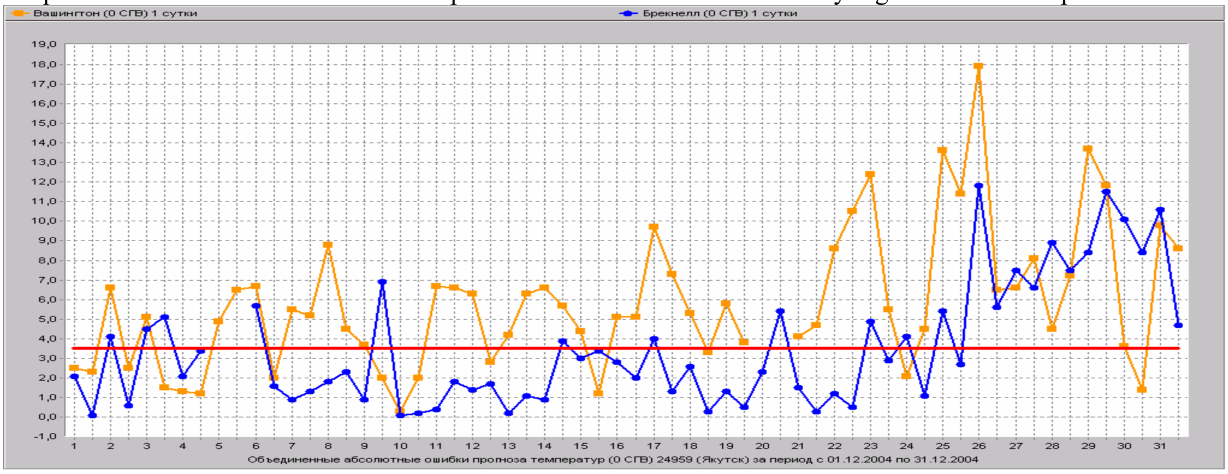


The same graph is done below for Yakutsk (meteostation Jakutsk 24959, GTS WMO GRIB EGRR HTJE98 и HTJG98).



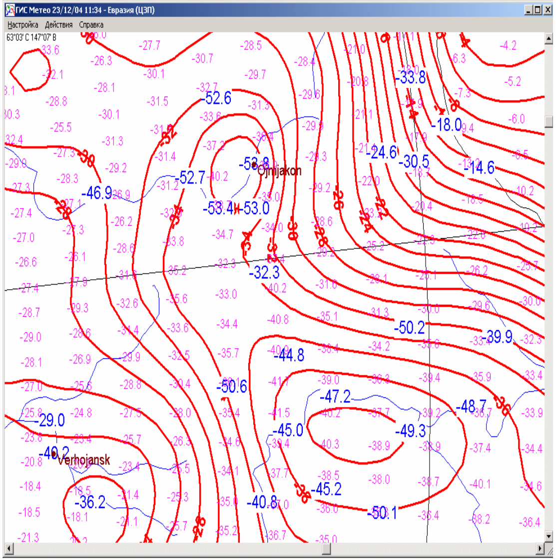
GRIB forecasts values for meteostations are prepared by interpolation. Its quality evaluates isoterms showed in maps below. Such interpolations are made automatically each day for more than 500 russian cities last 6 years. In this report we examine 24/36 forecast data from observing time 00 GMT only.
The graphs above demonstrates high quality AVN NCAR forecast for Moscow region and unacceptable one for Yakutsk.

Graph below shows absolute value of temperature forecasts errors for each day/night for the same period.

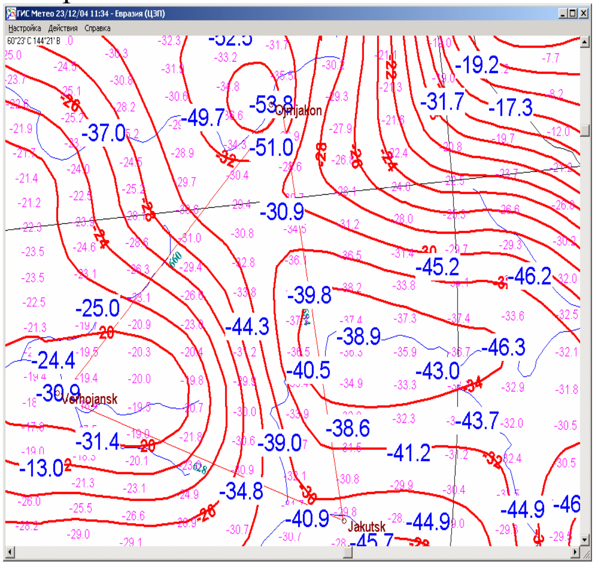


Red 3,5° line shows acceptable threshold for temperature forecast.

Some part of The cold region (Yakutsk – Verhoyansk - Ojmiakon) showed on surface T maps below. Magenta values and red isoterms are calculated for AVN NCAR data (see interpolation accuracy above), blue values are SYNOP air T data. Both kind of data relate toward same observing time, i.e. forecast with zero prediction time.



23 december 2004, obs. Time 00 GMT



23 december 2004, obs. Time 12 GMT

Triangle on the map to the right shows distances in km (pale blue). Meteostations are situated above sea level with the following heights: Yakutsk-110 m, Verhoyansk-138 m, Ojmiakon- 741 m.