Soil moisture initialization for multilayer soil model of the global weather prediction system SL-AV.

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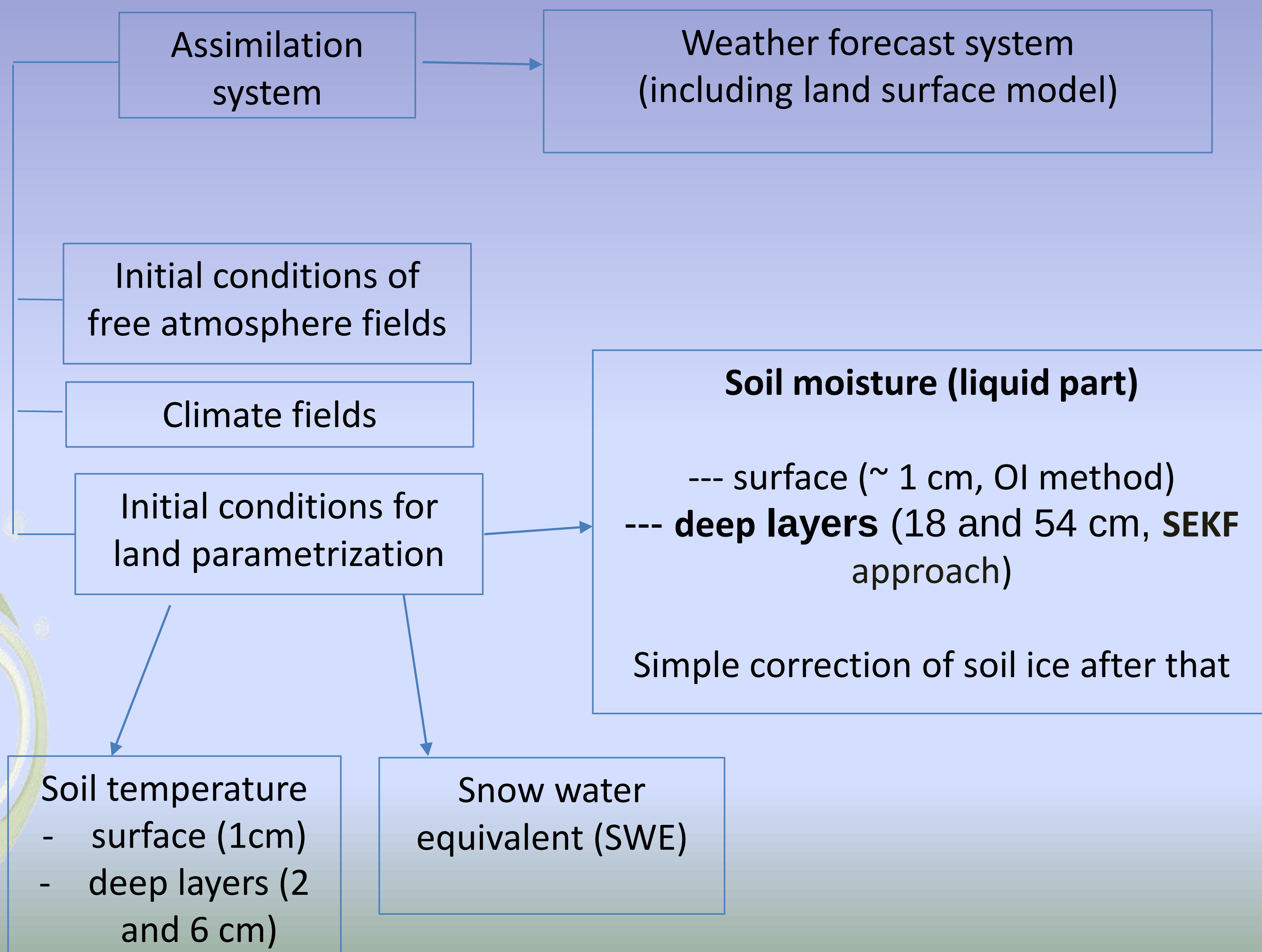
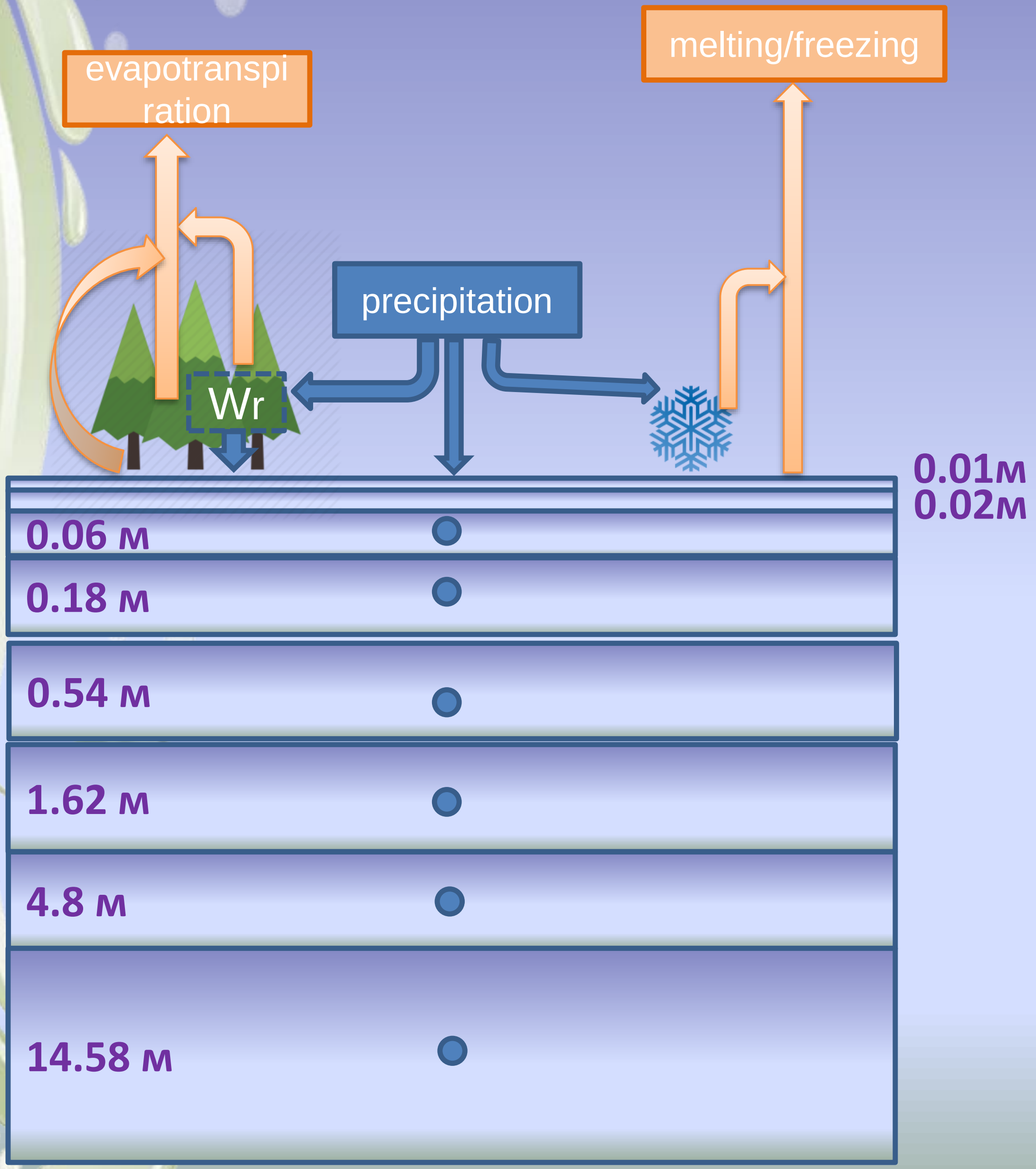
Scheme of the global weather prediction system SL-AV (L96 0,9°x0,72°)



INM RAS multilayer soil model



Atmospheric forcing:

- precipitation
- radiation
- low level model temperature and specific humidity
- low level model horizontal components of the wind speed

Prognostic variables:

- soil moisture (7 layers)
- ice soil (7 layers)
- water vapor (7 layers)
- soil temperature (7 layers)
- snow water equivalent

Root fraction:
[0.0412, 0.0437, 0.14, 0.28, 0.31, 0.16, 0.0196]

Volodin E.M., Lykosov V.N. Izvestiya, Atmospheric and Oceanic Physics, 1998

Simplified extended Kalman filter (SEKF)

(Balsamo J.-P. 2004, Mahfouf J.-F. 2009)

Forecast step

$$\mathbf{w}_t^b = M_{t-1}(\mathbf{w}_{t-1}^a)$$

$\mathbf{w}_t^b$ - forecast vector of deep soil moisture [w_1, w_2]

$\mathbf{w}_{t-1}^a$ - previous analysis vector [w_1, w_2]

M_{t-1} - forecast model components

Analysis step

$$\mathbf{w}_{t-1}^a = \mathbf{w}_{t-1}^b + \mathbf{K}_{t-1}\left[\mathbf{y}_{t-1}^o - H\left(\mathbf{w}_{t-1}^b\right)\right]$$

$\mathbf{y}_{t-1}^o$ - observation vector at moment t-1 (screen-level temperature and relative humidity at grid point);

$H\left(\mathbf{w}_{t-1}^b\right)$ - fist guess of screen-level temperature and relative humidity

H - non-linear observation operator;

$\mathbf{K}_{t-1}$- Kalman gain matix at moment t-1, [i x n] ;

i –number of analysis soil layers;

n – number of observations;

$$\mathbf{K}_{t-1} = \mathbf{BH}^T\left(\mathbf{HBH}^T + \mathbf{R}\right)^{-1}$$

Simplified extended Kalman filter (SEKF)

$$\mathbf{K}_{t-1} = \mathbf{B}\mathbf{H}^T\left(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}\right)^{-1}$$

Linear estimation of operator observation $\mathbf{H}$

$$H(w + \delta w) = H(w) + \mathbf{H}\delta w$$

$$\mathbf{H} = \frac{H(w + \delta w) - H(w)}{\delta w}$$

$$\mathbf{H} = \begin{bmatrix} \frac{\partial T_{2m_1}}{\partial w_1} & \frac{\partial RH_{2m_1}}{\partial w_1} \\ \frac{\partial T_{2m_2}}{\partial w_2} & \frac{\partial RH_{2m_2}}{\partial w_2} \end{bmatrix} \qquad \mathbf{H} = \frac{\mathbf{H}^+ + \mathbf{H}^-}{2}$$

δw_i - perturbation of i-th soil layer;

$$\delta w_i = [0.003 \cdot SWI_i, 0.007 \cdot SWI_i]$$

$$SWI_i = \frac{w_i - w_{wilt_i}}{w_{fc_i} - w_{wilt_i}}$$

$$\frac{\partial T_{2m_1}}{\partial w_1} = \frac{T_{2m}^{\pm} - T_{2m}}{\pm \delta w_1}$$

$\mathbf{R}$ - observation error covariance matrix;

$$\sigma_{T_{2M}} = 1K, \quad \sigma_{RH_{2M}} = 10\%$$

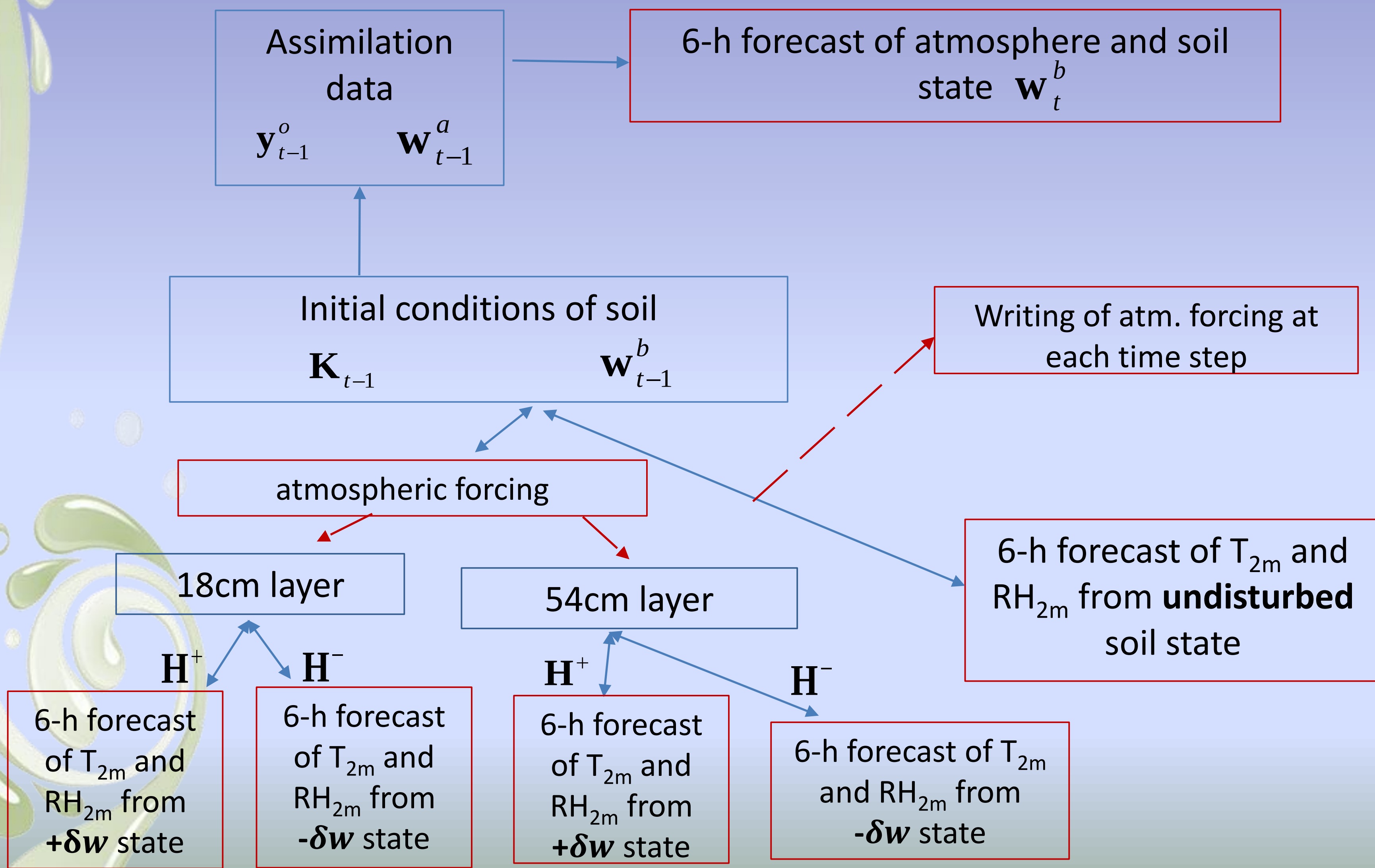
$$\mathbf{R} = \begin{pmatrix} \sigma^2_{T_{2M}} & 0 \\ 0 & \sigma^2_{RH_{2M}} \end{pmatrix}$$

$\mathbf{B}$ - background error covariance matrix;

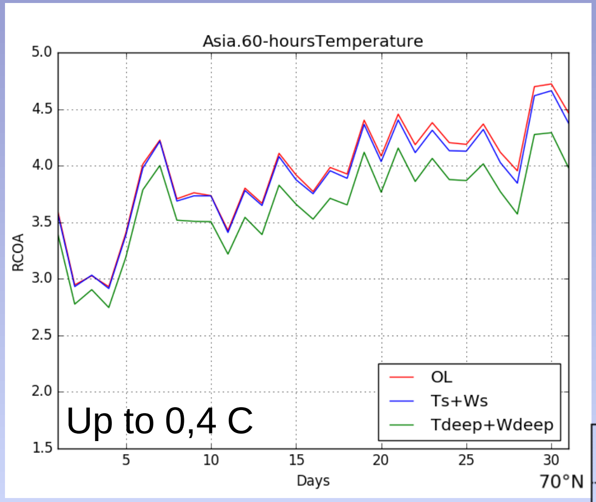
$$\sigma_{w_{b_i}} = 0.1(w_{fc_i} - w_{wilt_i})$$

$$\mathbf{B} = \begin{pmatrix} \sigma^2_{w_{b_1}} & \sigma_{w_{b_1}}\sigma_{w_{b_2}} \\ \sigma_{w_{b_2}}\sigma_{w_{b_1}} & \sigma^2_{w_{b_2}} \end{pmatrix}$$

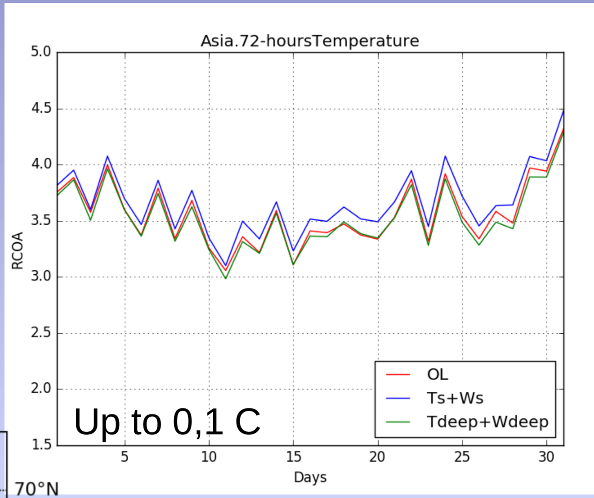
The stand-alone scheme of soil moisture fields initialization

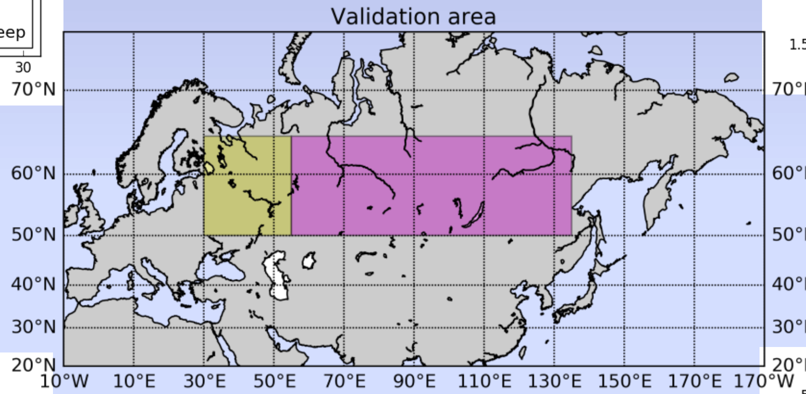


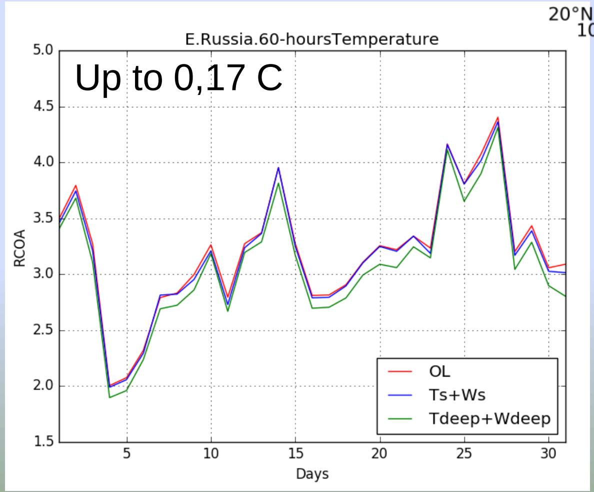
Verification of screen-level forecasts SL-AV(L96 0,9°x0,72°) with soil initialization system. July 2017. Mean abs error.

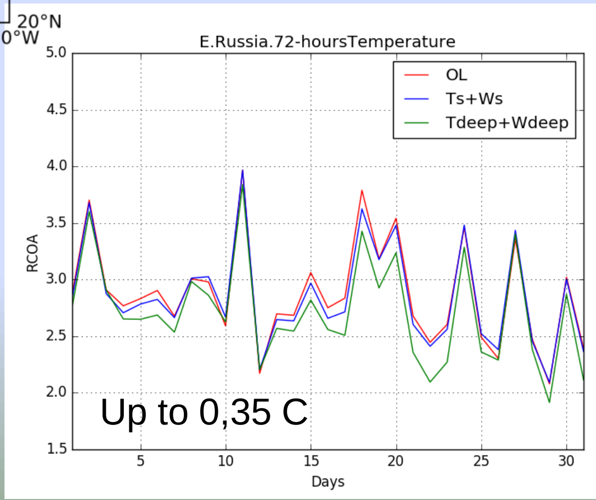


Forecast starts in 12 UTC:
60-h is 00 UTC
72-h is 12 UTC

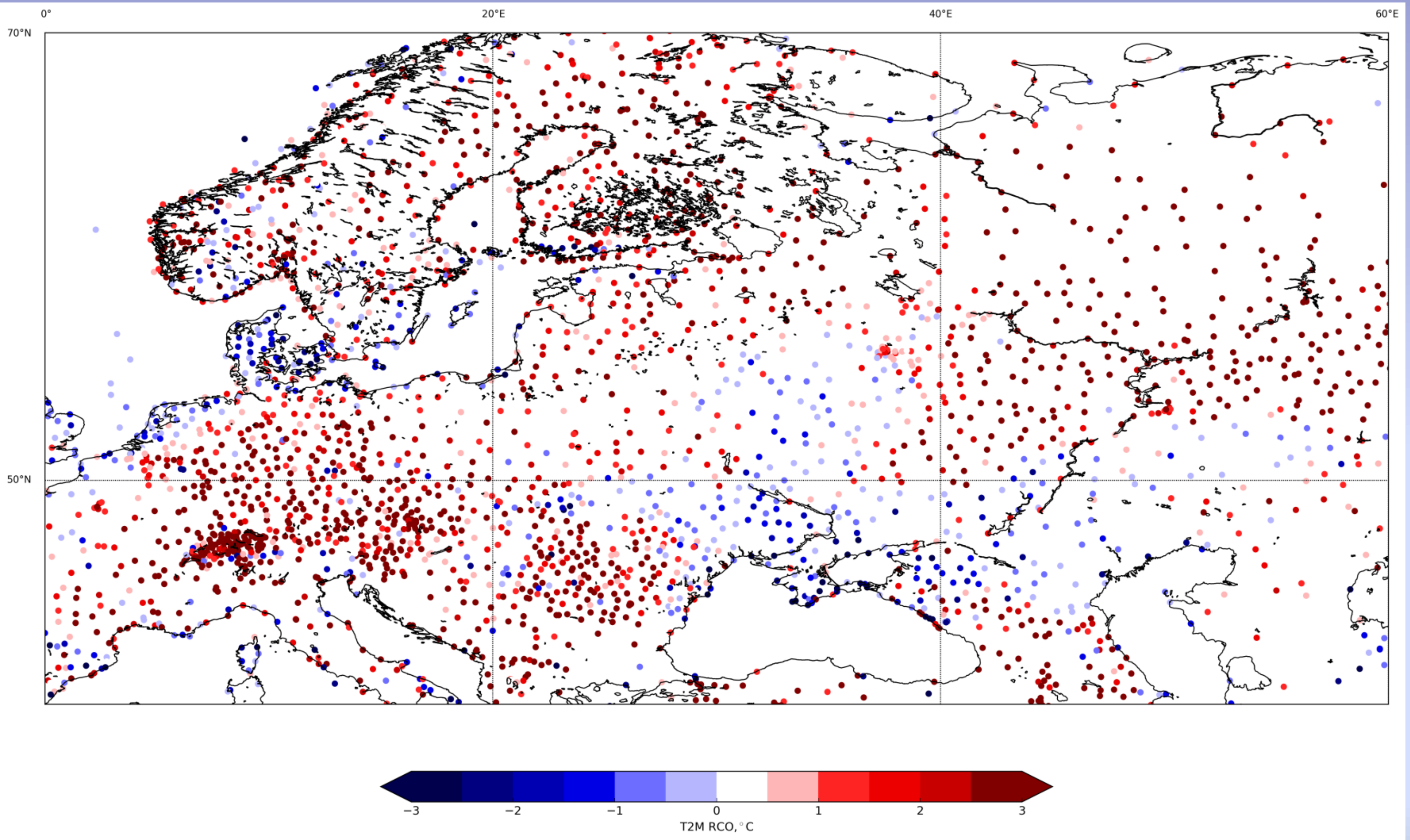








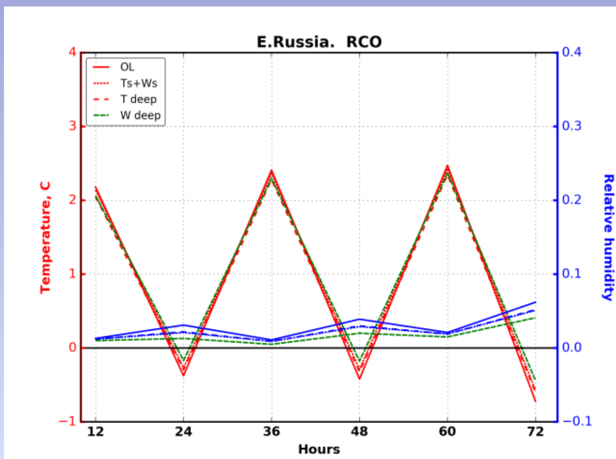
Verification of screen-level forecasts SL-AV(L96 0,9°x0,72°) with soil initialization system. July 2017. Bias. 60-hours (00 UTC)



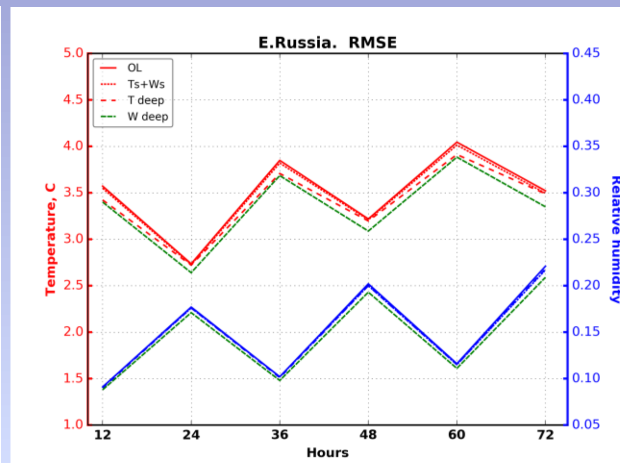
Assimilation parameters: Ts + Ws + (T+ W)deep

Verification of screen-level forecasts SL-AV(L96 0,9˚x0,72˚) with soil initialization system. July 2017.

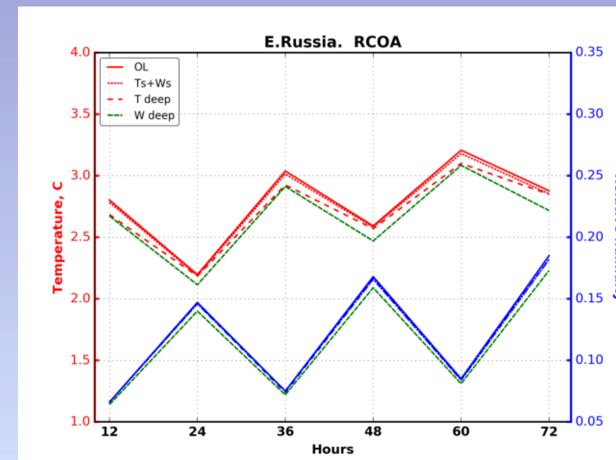
Up to 0,13 C (5%)

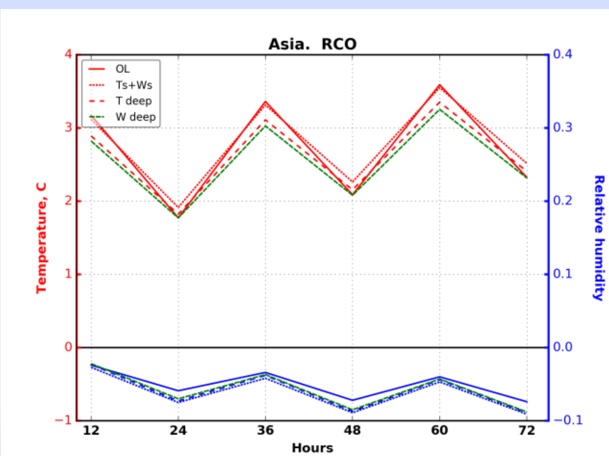


Up to 0,12 C (4%)

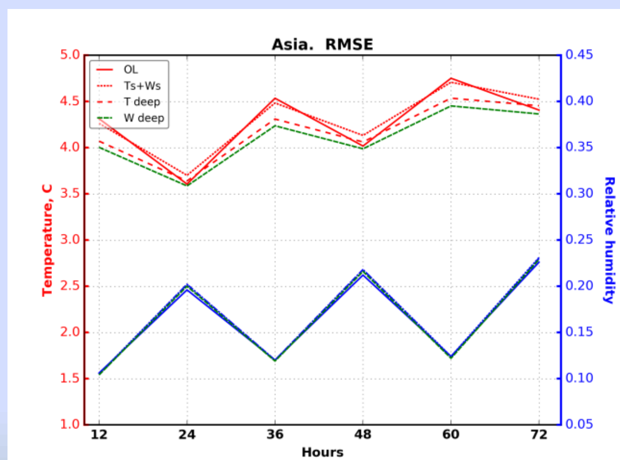


Up to 0,1 C (4%)

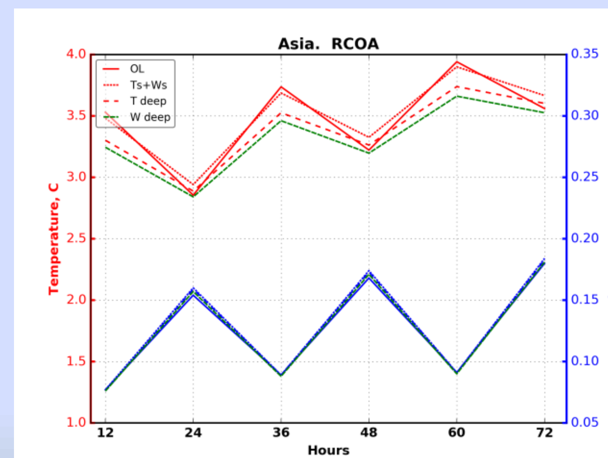




Up to 0,33 C (13%)



Up to 0,28 C (7%)



Up to 0,3 C (4%)

Results

- Soil moisture assimilation system was developed for multilayer soil model INM RAS. The algorithm for analysis of deep soil temperature fields was corrected.
- The first author’s experiments with this assimilation system were provided. It was shown that this block allows to reduce screen-level temperature by 0.3C in Asia region (~ 13% of bias and ~ 7% RMSE) and by 0.1 C in European part of Russia (~ 5% of bias and RMSE).
- Tuning of assimilation system is in progress.

Thanks for attention!