Improvement of SL-AV model climate and the impact on medium-range weather forecasts

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SL-AV global atmosphere model (1)

SL-AV: **S**emi-**L**agrangian, based on **A**bsolute **V**orticity equation

- **Finite-difference semi-implicit semi-Lagrangian** dynamical core of own development. Vorticity-divergence formulation, unstaggered grid (Z grid), 4th order finite differences, variable resolution in latitude, possibility to use **reduced lat-lon grid** (Tolstykh et.al., Geosci.Mod.Dev., 2017).
- The model can run at 9072 cores with 63 % efficiency (at 13608 cores with 52 % efficiency)**.**

SL-AV global atmosphere model

- Many parameterizations algorithms for subgrid-scale processes developed by ALADIN/ALARO consortium.
- Parameterizations for shortwave and longwave radiation: CLIRAD SW + RRTMG LW.
- INM RAS- SRCC MSU multilayer soil model (Volodin, Lykossov, Izv. RAN 1998).
- Marine stratocumulus parameterization

Current applications of SL-AV model:

- Operational medium-range weather prediction up to 10 days; probabilistic seasonal forecast at the Hydrometcentre of Russia.
- Weather prediction up to 3 days in Novosibirsk.
- 60-day weekly forecast (S2S Prediction project, WMO) – quite an old SL-AV version (1.4*1.1deg,L28)! Need of urgent update

Development of seamless prediction version of SL-AV model

- The necessity to use the model in subseasonal, seasonal, and potentially in decadal prediction => need for good model climate
- Lack of computational resources => a low horizontal resolution version (0.72˚x0.9˚ lat-lon) was used for model climate diagnosis
- The number of levels was increased from 28 to 85 and 100 as the stratosphere processes needed to be represented

Initial model diagnostics (2016)

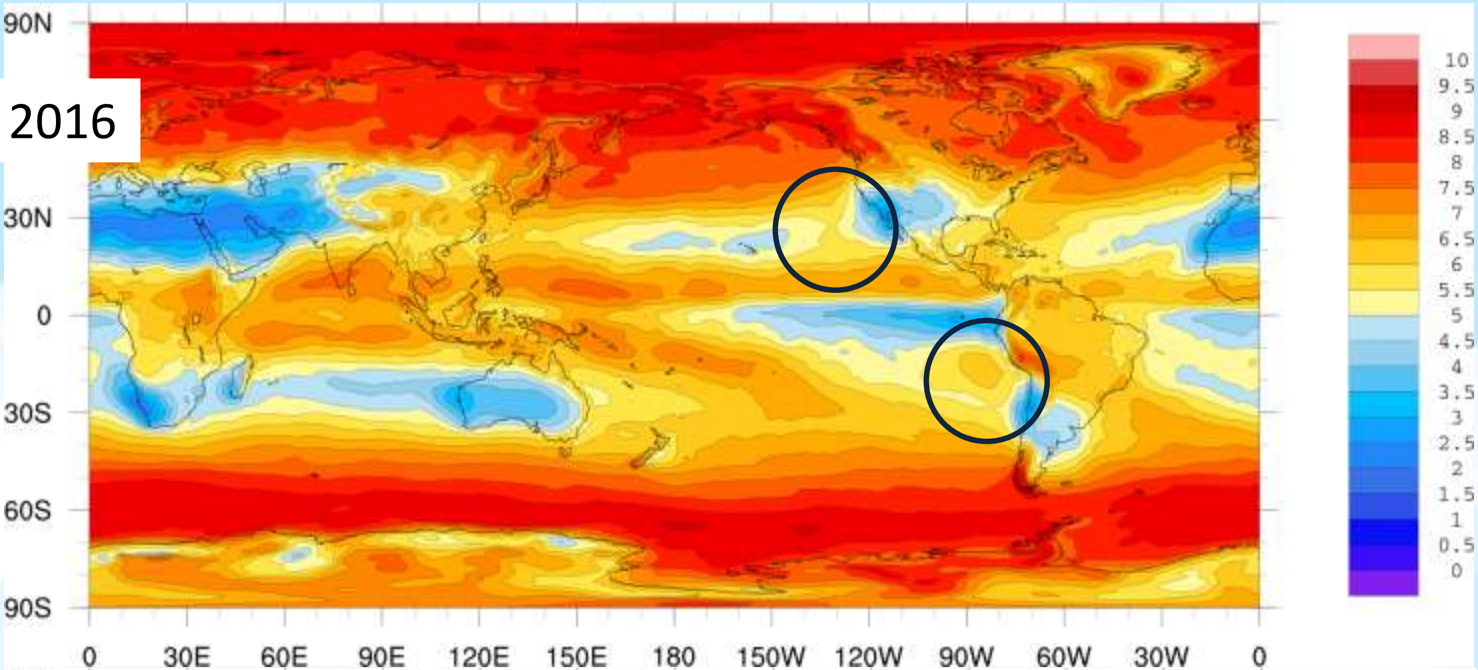
- Imbalance in surface net mean annual heat flux ~17 Wm^{-2}
- Doubled ITCZ, too much precipitation
- Lack of marine stratocumulus
- No stratosphere oscillations because of too low vertical resolution (28 levels)

Actions on model improvement (2016-2018)

- 85 then 100 vertical levels (top at 0.05 hPa), Hines (1997) parameterization of convective gravity wave drag
- New algorithm for shallow convection
- Improvements in deep convection (new locally conservative formula for humidity convergence, reduction of convection near the mountains)
- Parameterization of marine stratocumulus

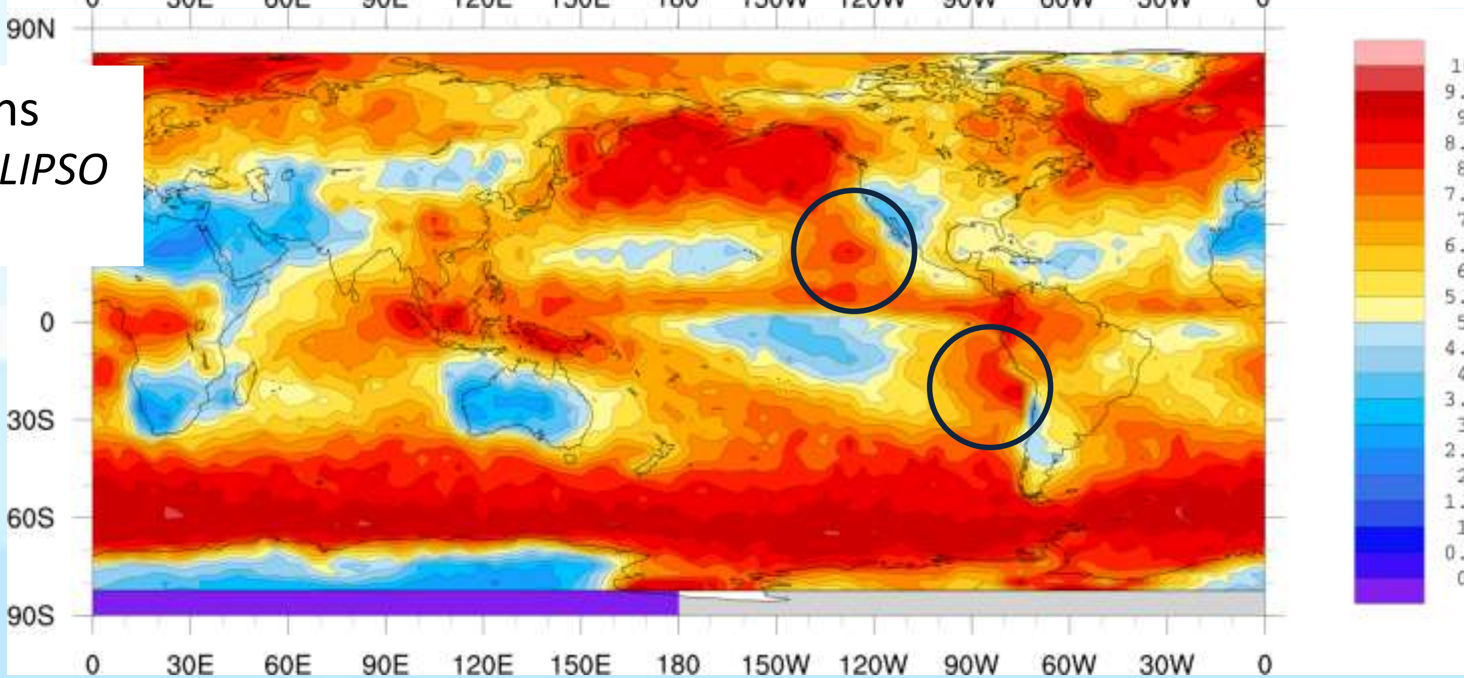
Annual mean cloudiness

Slav, 28 lev, 2016



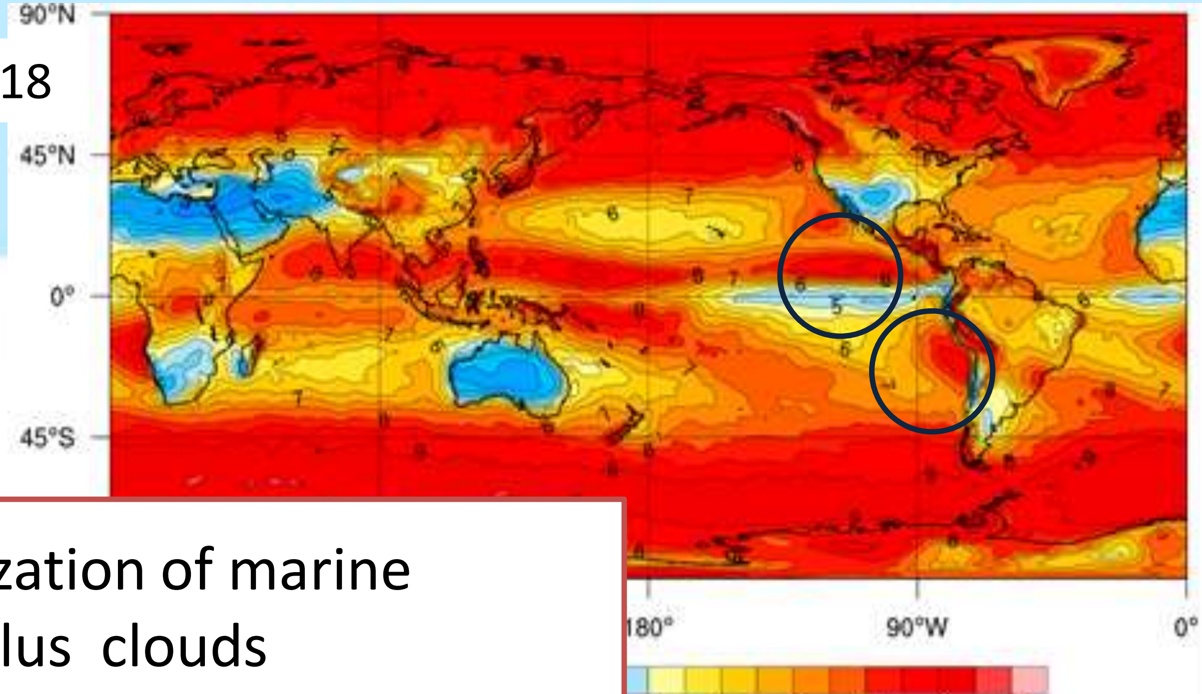
Observations

CloudSat/CALIPSO Data



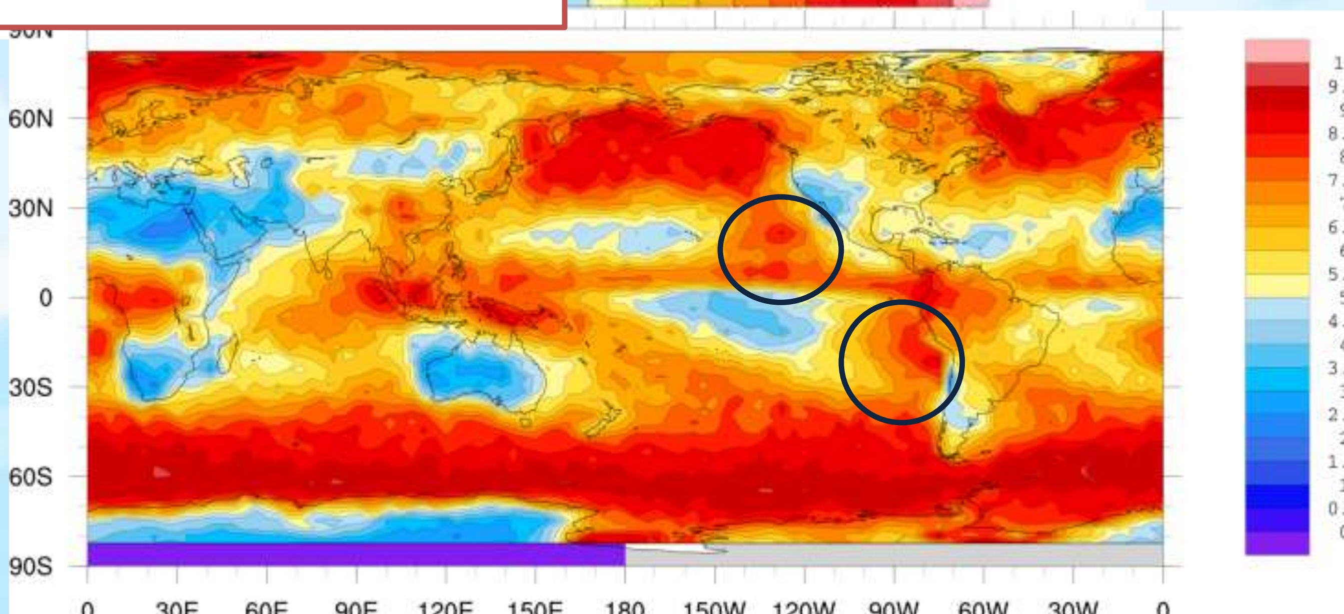
Annual mean cloudiness

SLAV, 85 lev, 2018



Parameterization of marine stratocumulus clouds

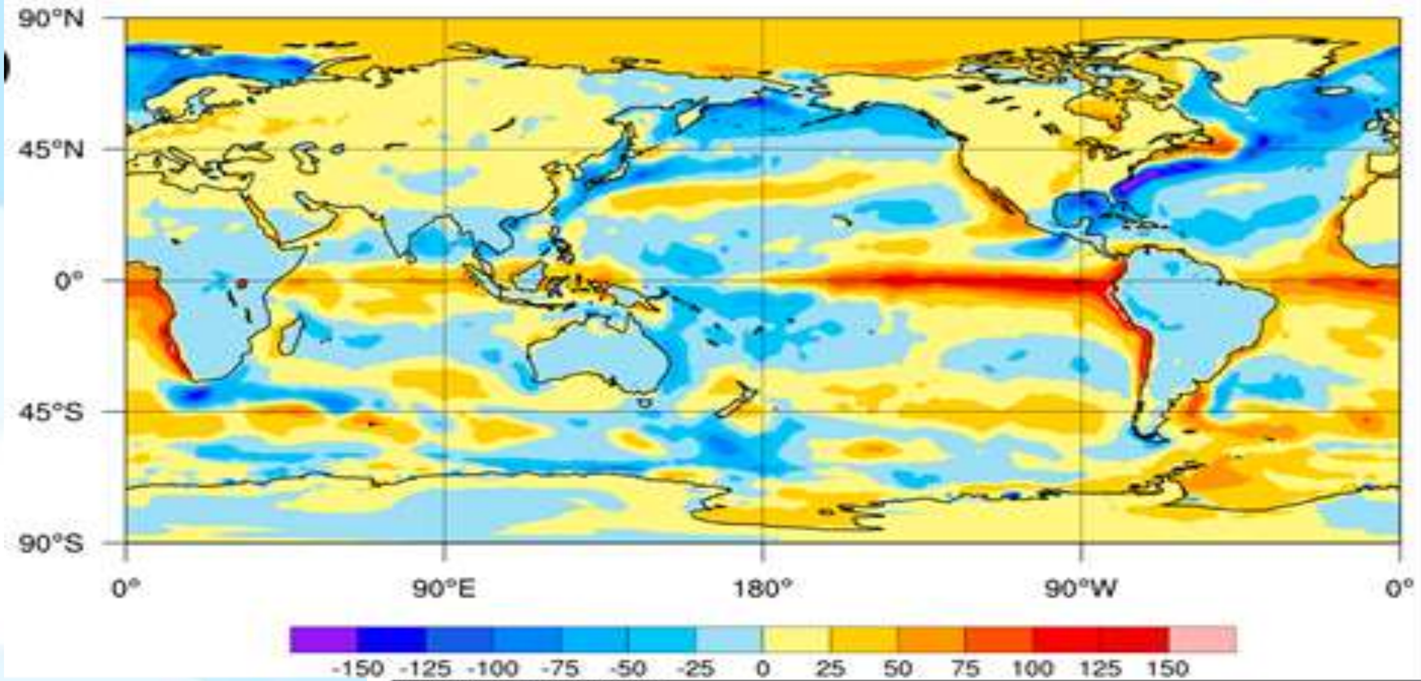
Observations
CloudSat/CALIPSO Data



Global mean energy budget

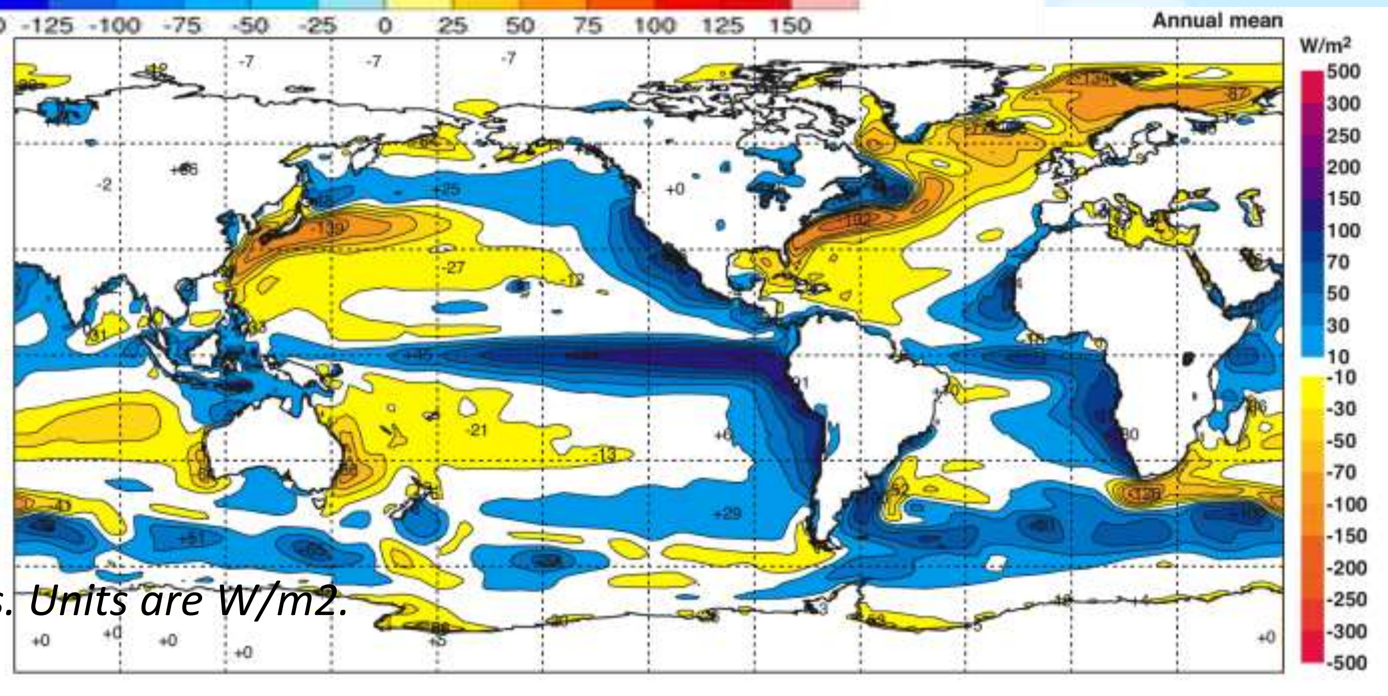
item	IPCC data (range, absolute values), W/m^2	IPCC data (recommended values), W/m^2	SL-AV in AMIP2, W/m^2
Top incoming short-wave radiation	340-:-341	341.3	341.6
Top outgoing short-wave radiation	96-:-100	100	97.6
Top outgoing long-wave radiation	-(236-:-242)	-239	-243.1
Surface downward solar radiation	154-:-166	161	161.2
Surface long-wave radiation balance	-(54-:-58)	-56	-54.6
Surface sensible heat flux	-(15-:-25)	-20	-14.7
Surface latent heat flux	-(70-:-85)	-84	-91.1
Imbalance	**-**	**1**	**0.8**

Annual mean surface heat flux



SL-AV2018

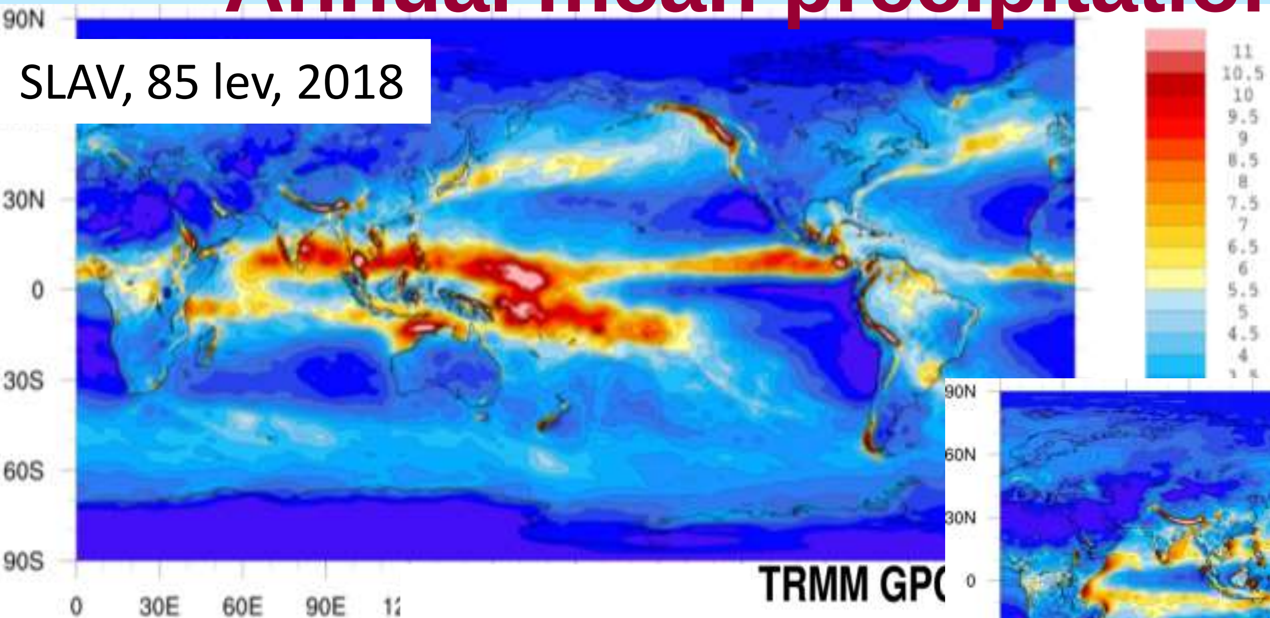
85 levs



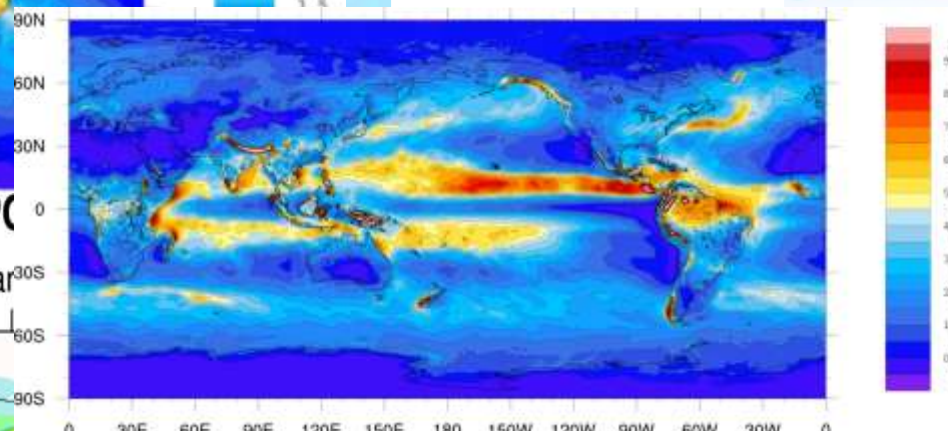
ECMWF 40-year reanalysis. Units are W/m2.
Kallberg et al 2005.

Annual mean precipitation (mm/day)

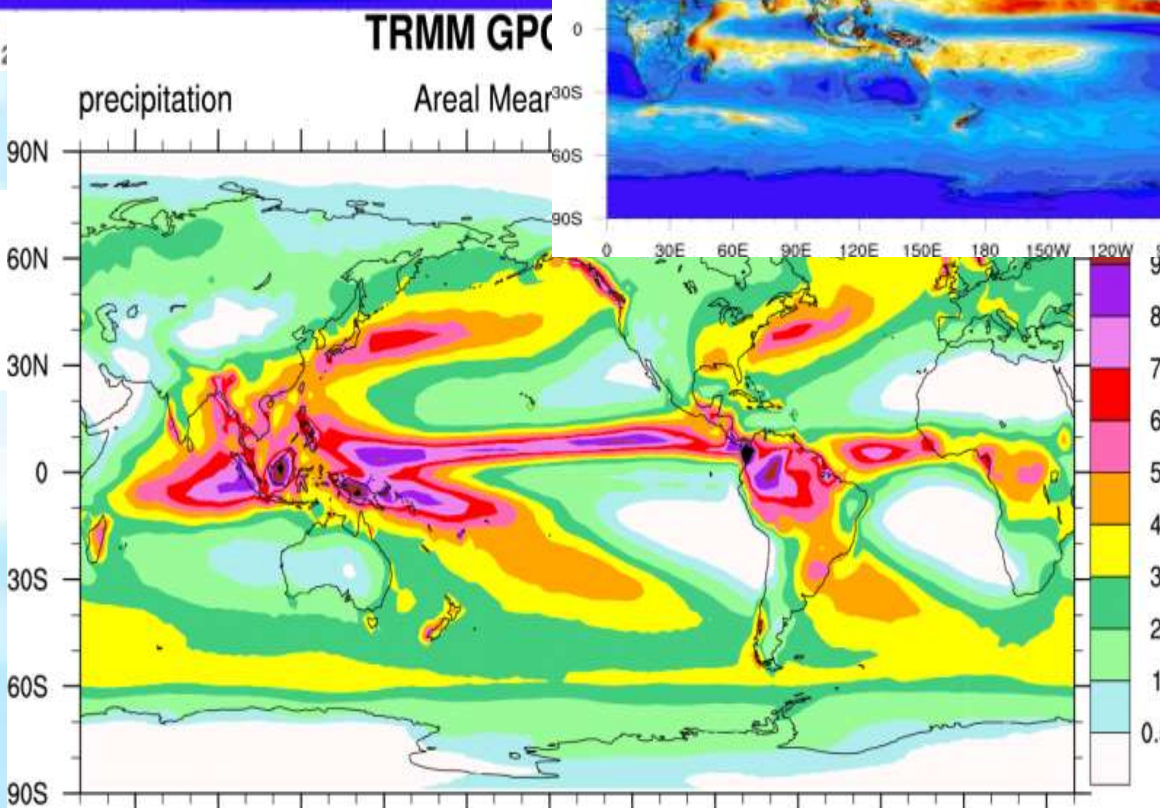
SLAV, 85 lev, 2018



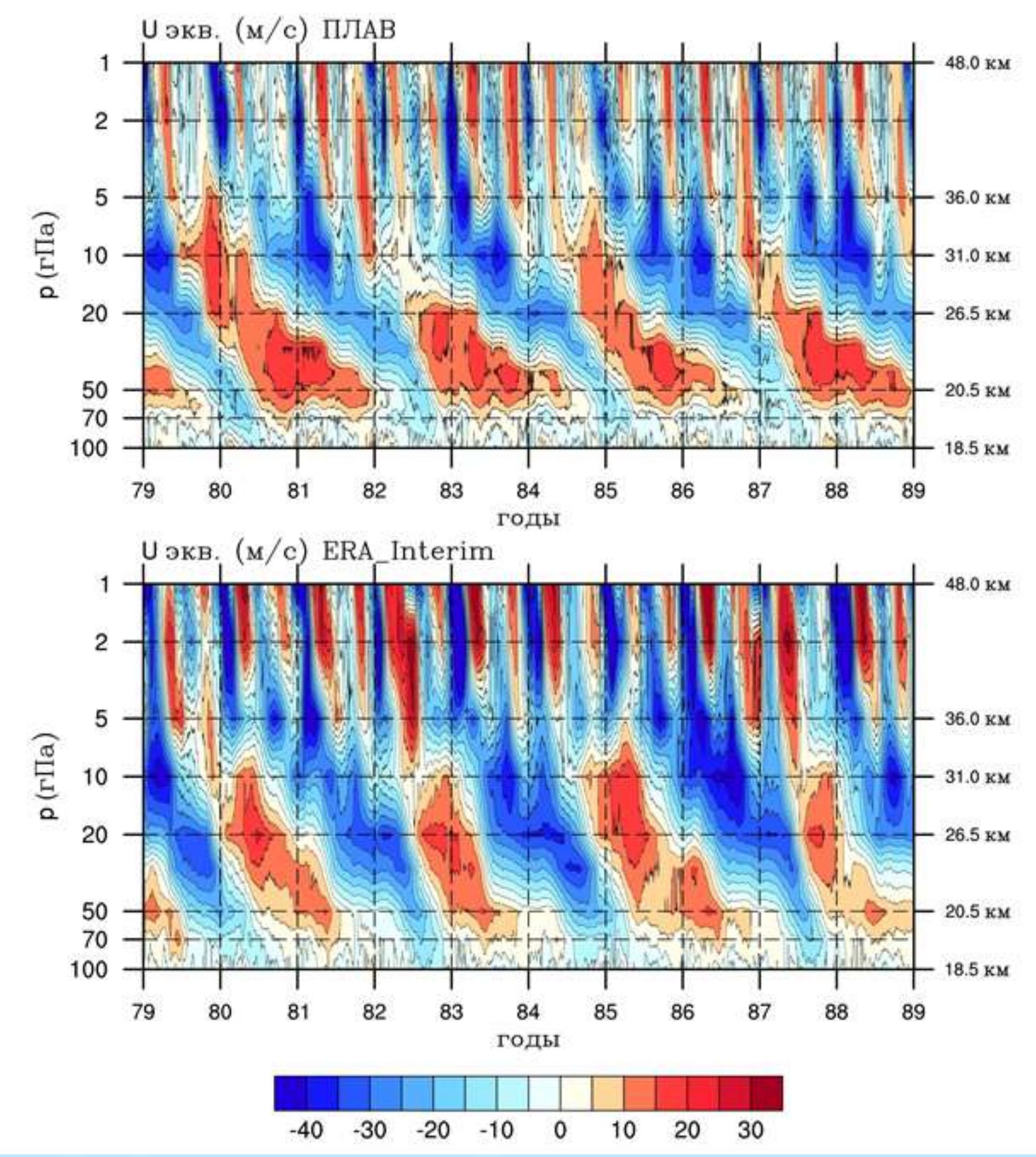
SLAV, 28 lev, 2016



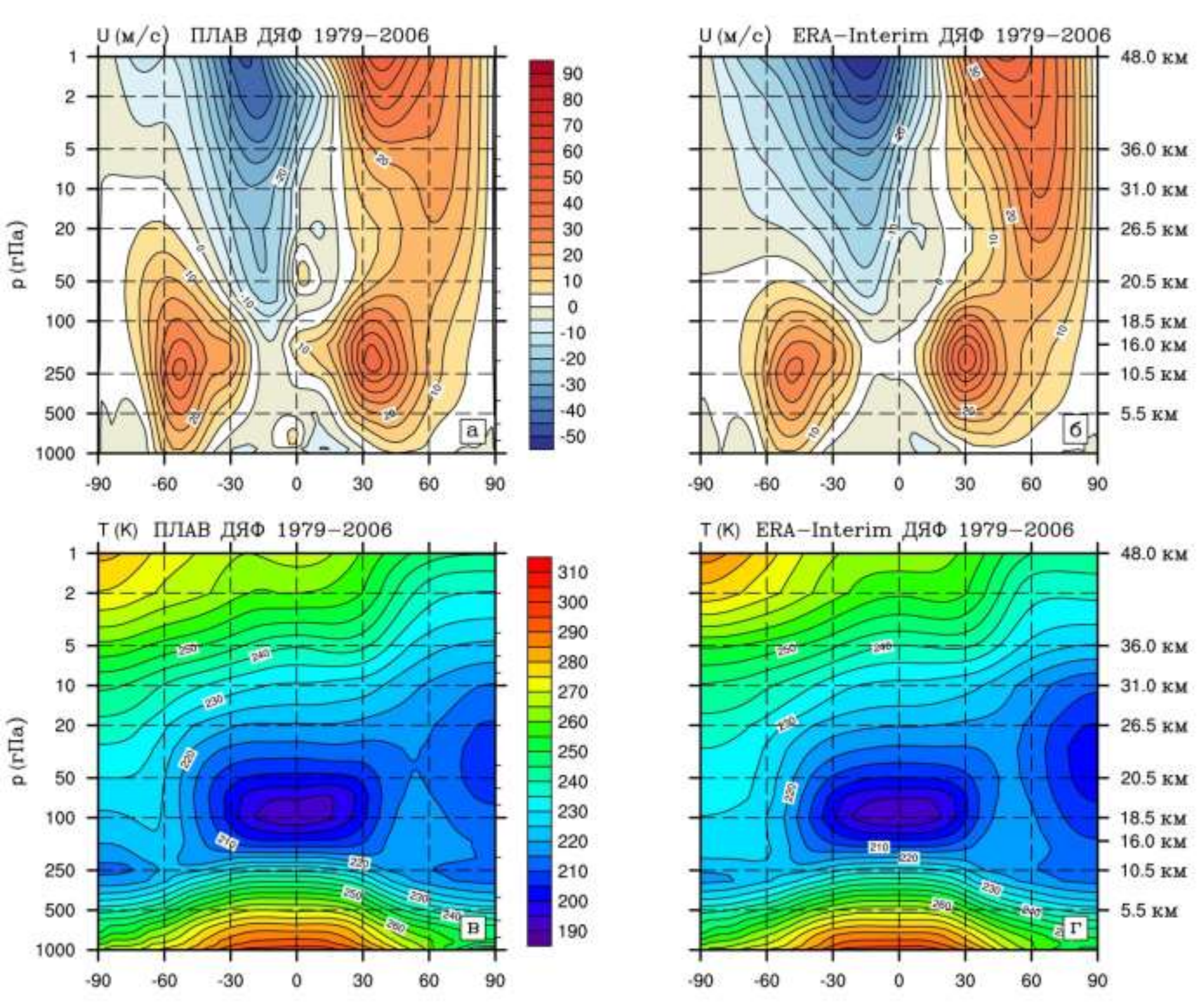
Obs GPCP
TRMM
(1979-2010)



QBO. U at equator, 1979-1989: SL-AV model (top), ERA Interim (bottom)



Zonal mean U and T (DJF, 1979-2006), SL-AV (left), ERA-Interim (right)



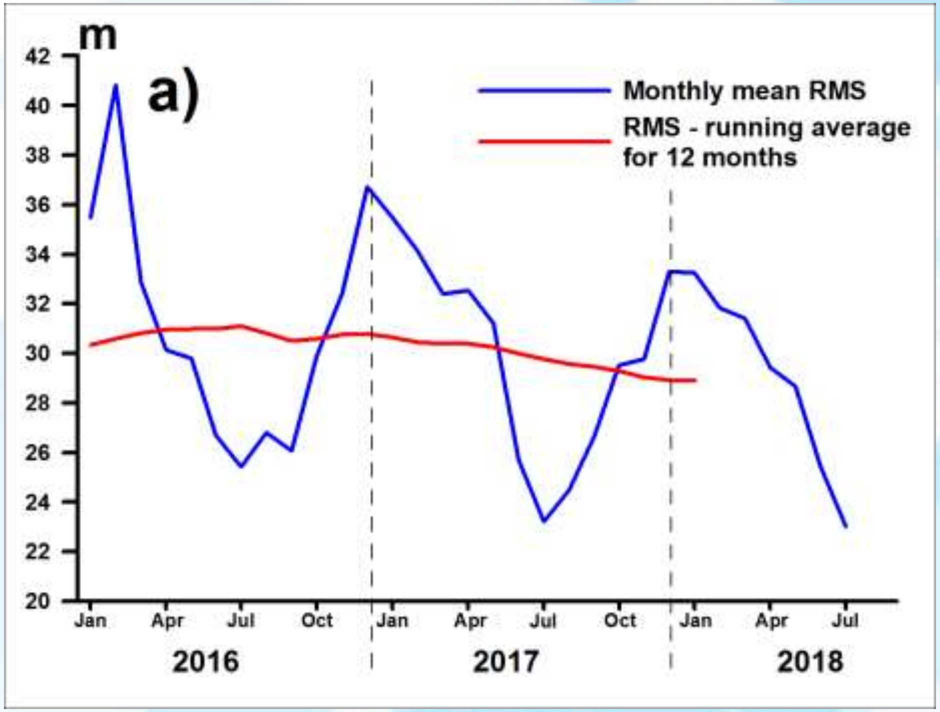
These improvements in model climate (tested at low horizontal resolution) **resulted in a reduction of the operational medium-range forecast errors**

Operational version of the model: resolution in longitude 0,225°, in latitude from 0,16° in NH to 0,245° in SH, 51 vertical levels

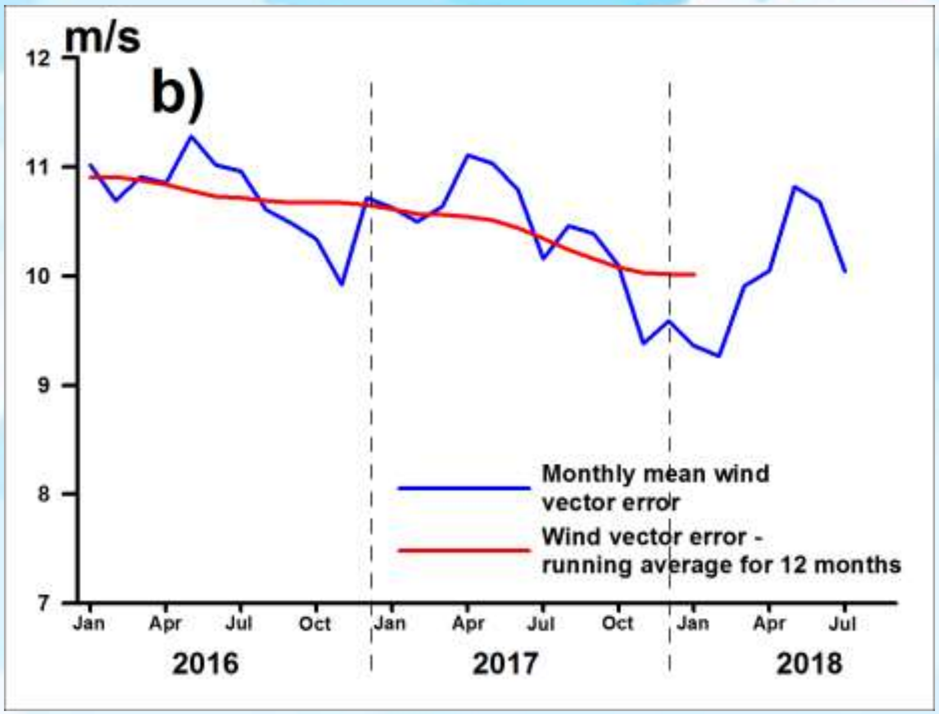
https://apps.ecmwf.int/wmolcdnv/

Reduction of SL-AV RMS forecast error for H500 and W250 72-hour forecasts (01.2016-07.2018).

H500



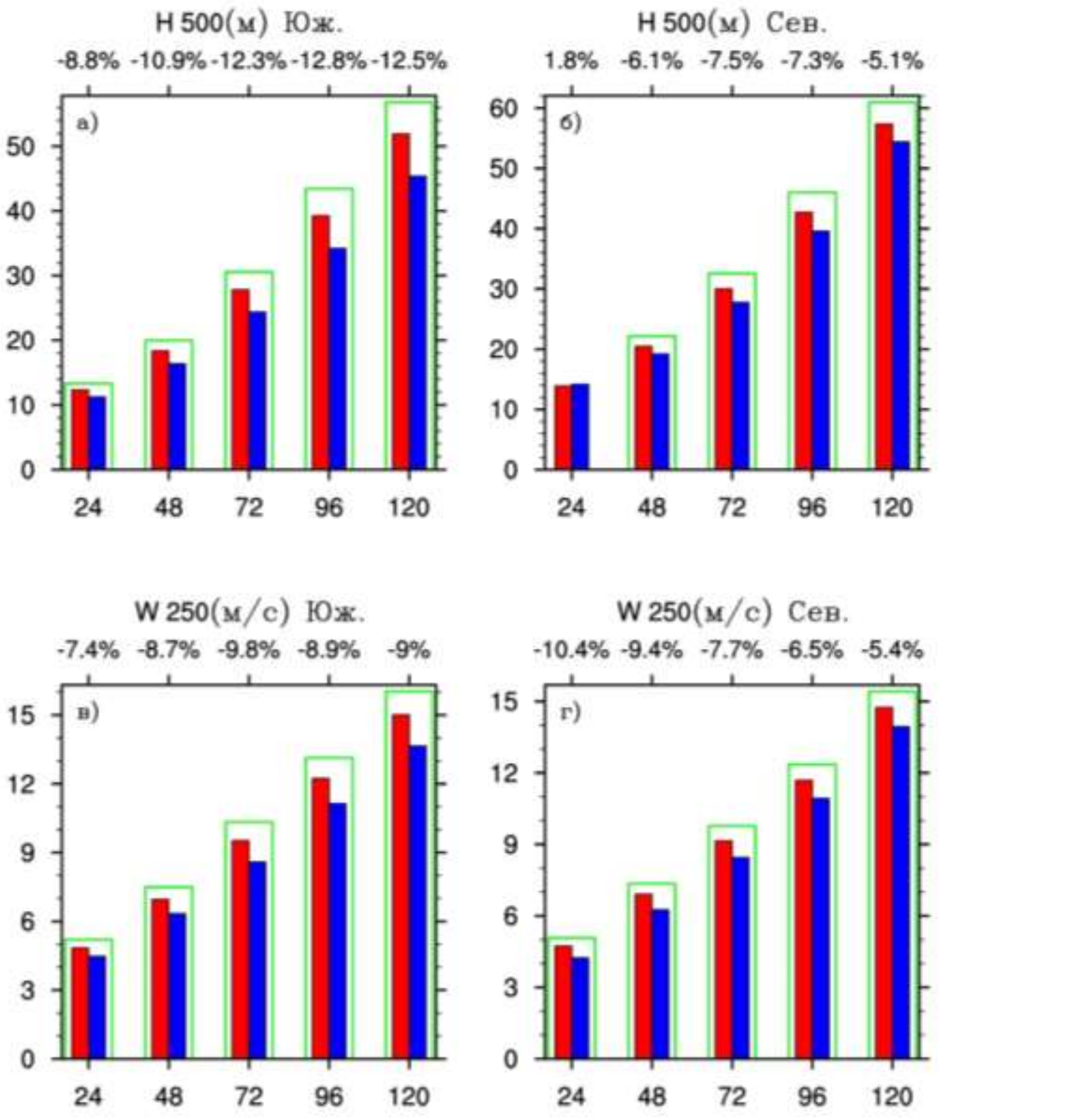
W250



Reduction in H500 RMS error: ~2,3 m (24hrs), 2,5m (72hrs), W250 RMS error: ~0,6 m/s (24hrs), 0.8 m/s (72 hrs). Lag between SL-AV and main group: ~1.2 m/s in W250 at 72 hrs, ~4,5 m in H500 at 72hrs

Improvements in RMS forecast error while using ECMWF upper-air initial data

31 fcst for Jan 2018. Southern extratropics - left, Northern ones – right; top - H500 , bottom- W250.



Reduction in 72 hrs forecast error: geopotential – 2-4 m, wind ~ 0.8 m/s.

Conclusions

- A new version of SL-AV model reproduces main characteristics of modern climate, including stratosphere oscillations.

- Improvements in model climate helped to reduce medium-range forecasts errors.

Thank you for attention!

http://nwplab.inm.ras.ru