Циркуляция скрытого тепла в атмосфере Земли:
анализ 15 лет радиотепловых спутниковых измерений

Д.М. Ермаков, Е.А. Шарков, А.П. Чернушич

ФИРЭ им. В.А. Котельникова РАН

ИКИ РАН

ДЗЗ и моделирование климата

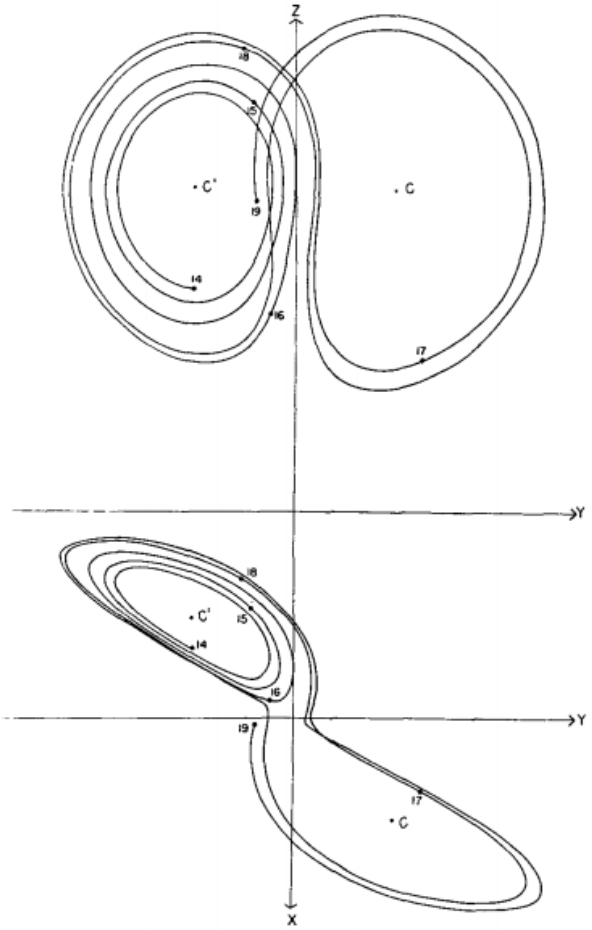


FIG. 2. Numerical solution of the convection equations. Projections on the X-Y-plane and the Y-Z-plane in phase space of the segment of the trajectory extending from iteration 1400 to iteration 1900. Numerals "14," "15," etc., denote positions at iterations 1400, 1500, etc. States of steady convection are denoted by C and C'.

E.N. Lorenz. Deterministic nonperiodic flow. J. of the Atmos. Sciences, 1963, 20, 130-141

Summary of why we care

Met Office

1. Access to information on mass and wind field is important.
2. AMVs provide global wind coverage and can be the only source of tropospheric wind data over some areas of ocean and at high latitude
3. Positive impact on forecast accuracy, but less so than some other observations e.g. ATOVS radiances
4. Can be important for improving tropical cyclone track forecasts

M. Forsyth. Atmospheric motion vectors: Past, present and future. ECMWF Annual Seminar, 2007

Водяной пар, атмосферные движения и энергообмен

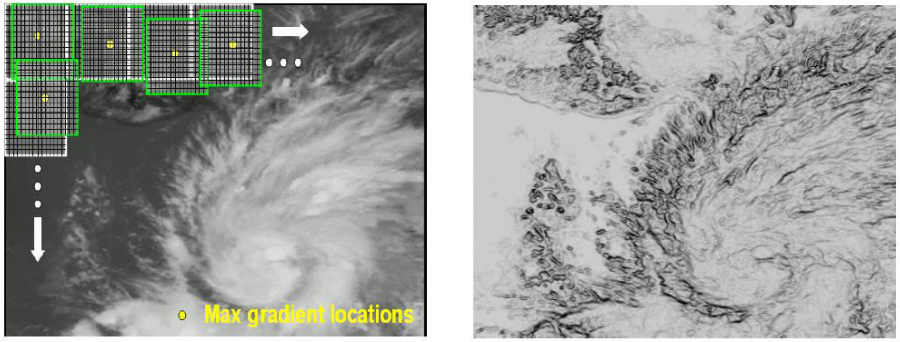


Figure 3. Image of 11um brightness temperature (left) and the 11um brightness temperature gradient (right) from the GOES-12 imager instrument. The white boxes show the target scenes at there original locations. The green boxes show the target scenes which have been repositioned at the pixel location containing the maximum brightness temperature gradient as indicated by the yellow dot.

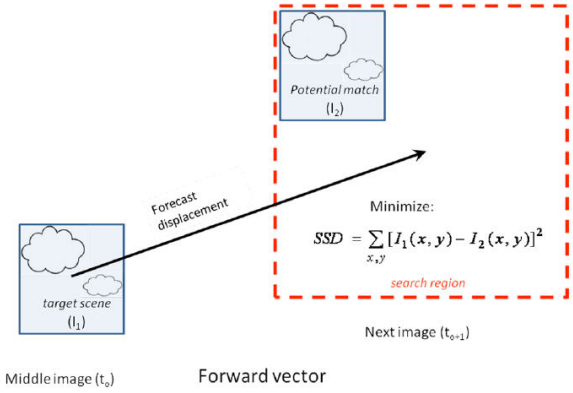


FIG. 6. Schematic showing the basic concepts associated with the feature tracking algorithm. Targets are selected from the middle image of a three-image loop and tracked forward and backward in time via the SSD method. The two displacements are averaged to produce a final motion estimate. Only the forward vector is shown in the figure.

Daniels J. et al. GOES-R Advanced Base Imager (ABI) Algorithm Theoretical Basis Document For Derived Motion Winds. NOAA, 2012

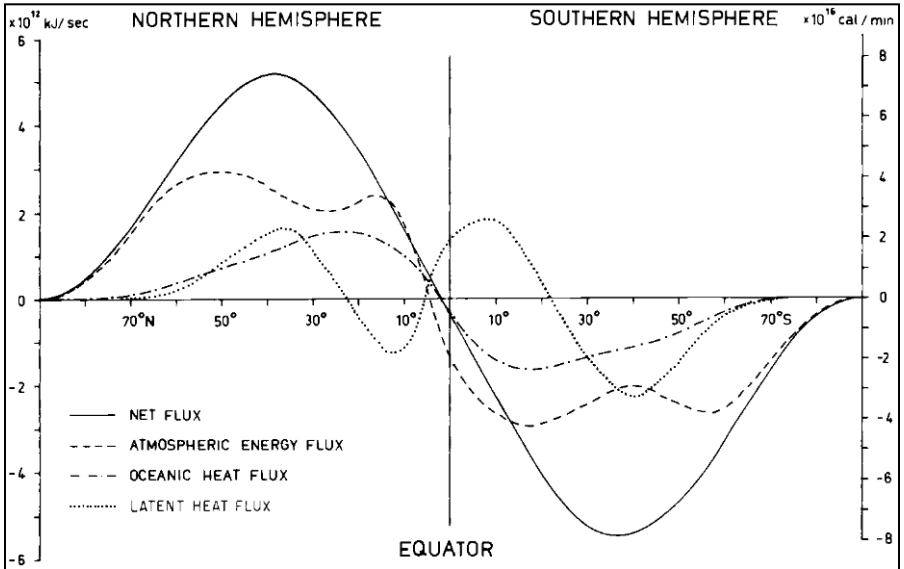
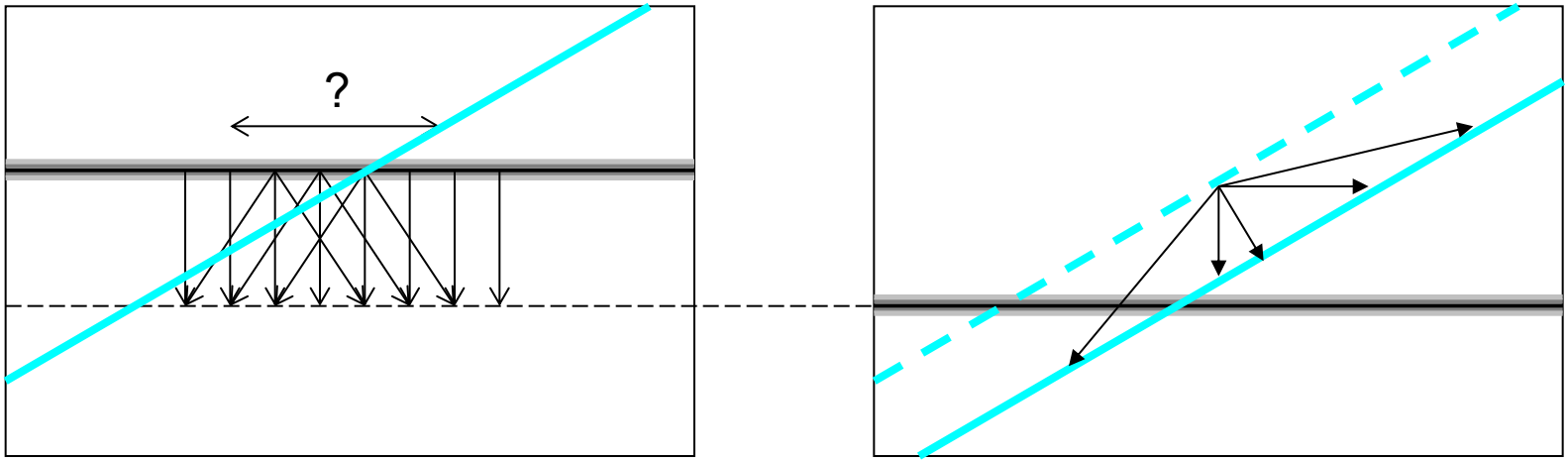


FIG. 2.4 Solid curves show the mean annual northward flux of net energy in the atmosphere-ocean system. Other curves show atmospheric flux of realized energy (enthalpy + potential energy), atmospheric flux of latent heat, and oceanic flux of heat. Units are (right scale) 10^{16} cal/min or (left scale) 10^{12} kJ/sec. (Reprinted, redrawn, from W. D. Sellers, *Physical Climatology*, by permission of The University of Chicago Press, copyright 1965 by The University of Chicago.)

Palmén E., Newton C.W. Atmospheric circulation systems: Their structure and physical interpretation. Academic Press, NY and London, 1969.

Нелокальность алгоритмов оценки движения



Приближение консервативных трассеров

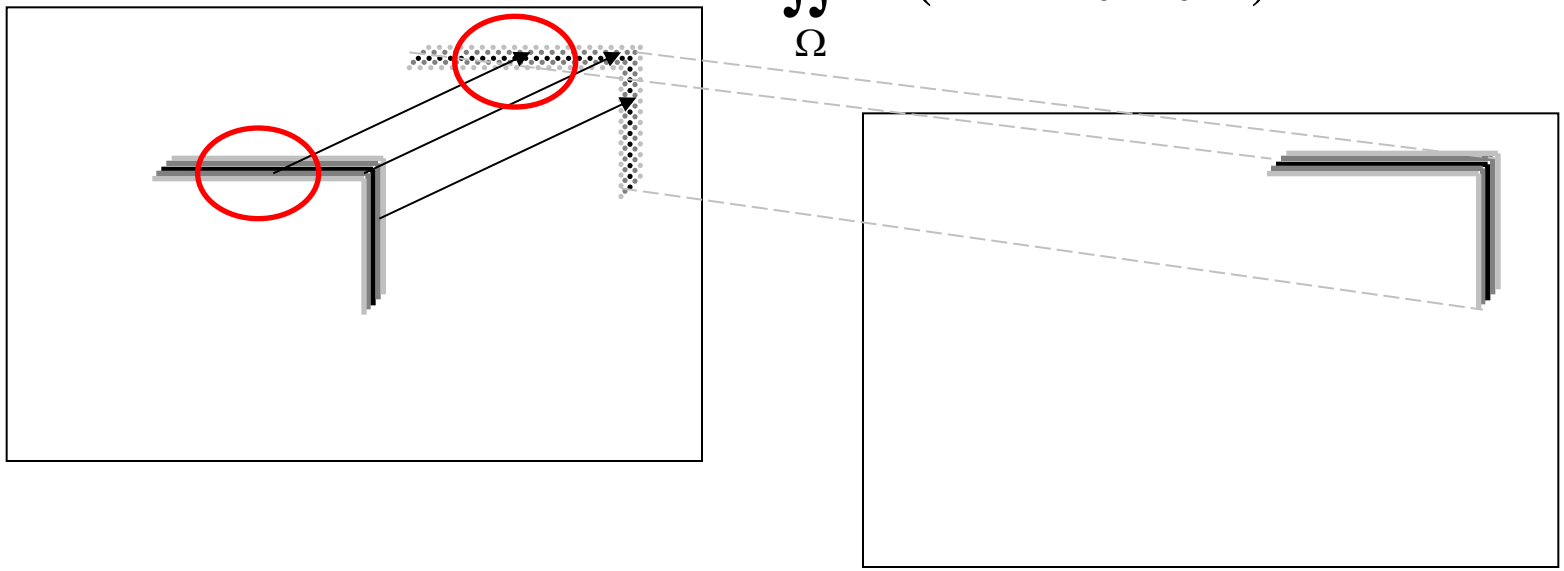
$$I\left(x,y,t\right)=I\left(x+u\cdot dt,y+v\cdot dt,t+dt\right)$$

Уравнение оптического потока

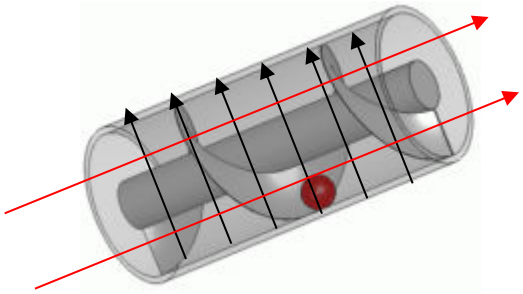
$$\frac{\partial I}{\partial x}\cdot u+\frac{\partial I}{\partial y}\cdot v=-\frac{\partial I}{\partial t}$$

Повышение размерности задачи

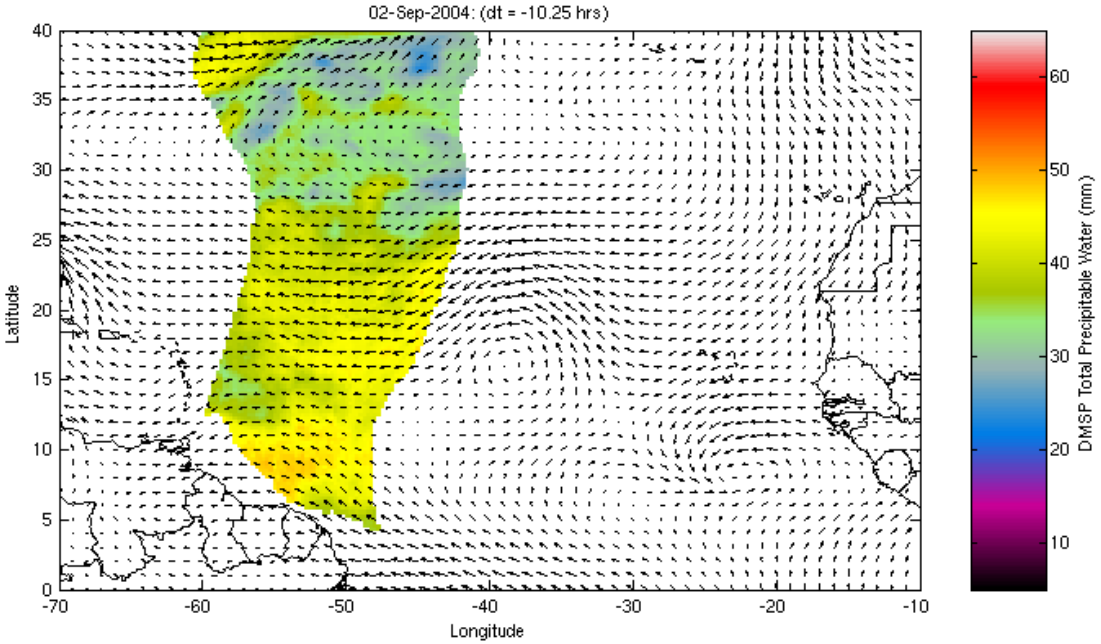
$$\iint_{\Omega} D(x, y, u_0, v_0, t)dxdy \to \min$$



Всегда ли адекватна двумерная постановка задачи?



Двумерная постановка задачи



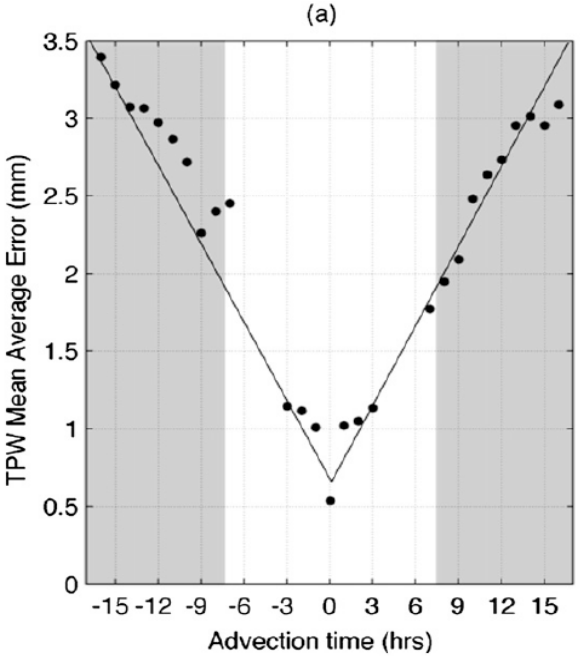
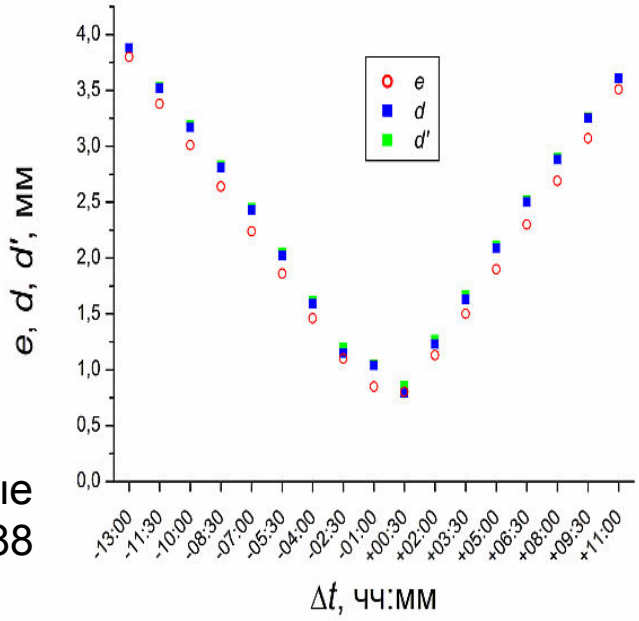


Table 2. Advecting wind profile weighting functions, by latitude.[a]

Height (hPa)	weight, ≤ 25°	weight, ≥ 50°
700	0.160	0.138
850	0.280	0.345
1000	0.560	0.517

[a] Valid for north and south latitude (always positive in this table). Weights between 25° and 50° latitude are calculated by linear interpolation.

Wimmers A.J., Velden C.S., *J. Appl. Meteor. Climatol.*, **50**, 1024 (2011)



Ермаков, Шарков, Чернушич, Современные проблемы…, 2015, 12, №2, 77–88

Исходные данные

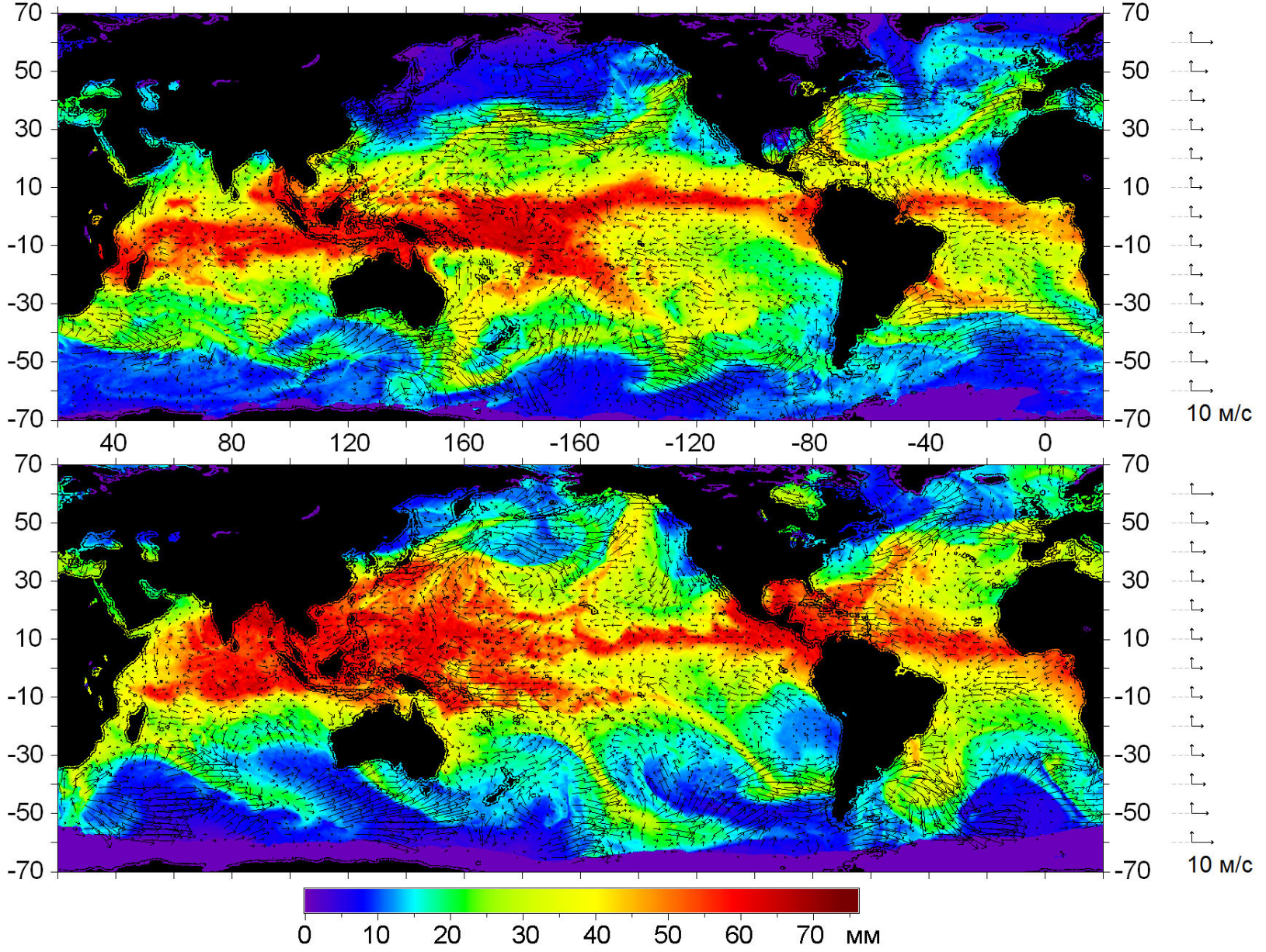
Электронный архив Remote Sensing Systems (www.remss.com)

Поля интегрального влагосодержания атмосферы на сетке 0,25°

DMSP F13 SSM/I	Январь 2003	--	Ноябрь 2009
DMSP F14 SSM/I	Январь 2003	--	Август 2008
DMSP F15 SSM/I	Январь 2003	--	Август 2006, далее фрагменты
DMSP F16 SSMIS	Октябрь 2003	--	Октябрь 2017
DMSP F17 SSMIS	Декабрь 2006	--	Октябрь 2017
DMSP F18 SSMIS	Январь 2017	--	Октябрь 2017
Coriolis WindSat	Февраль 2003	--	Октябрь 2017
Aqua AMSR-E	фрагментарно		
GCOM-W1 AMSR-2	фрагментарно		

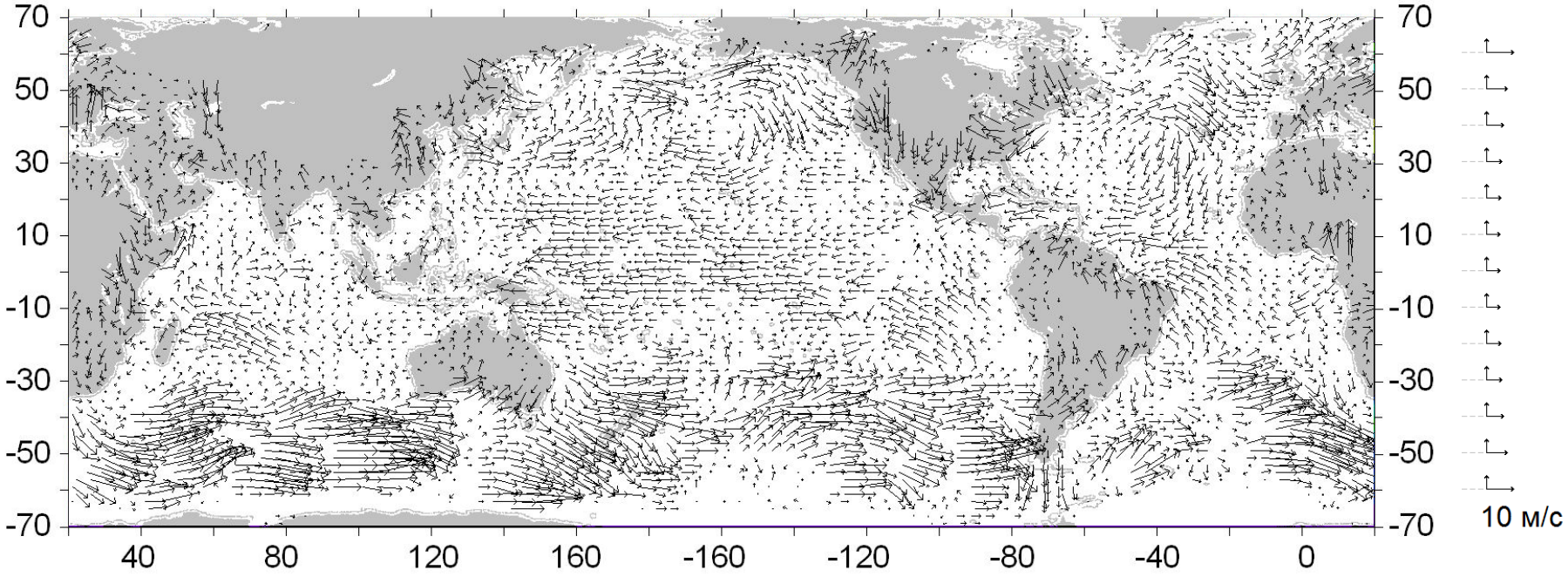
Динамика полей интегрального влагосодержания

01.01.2003



01.10.2017

Динамика полей интегрального влагосодержания

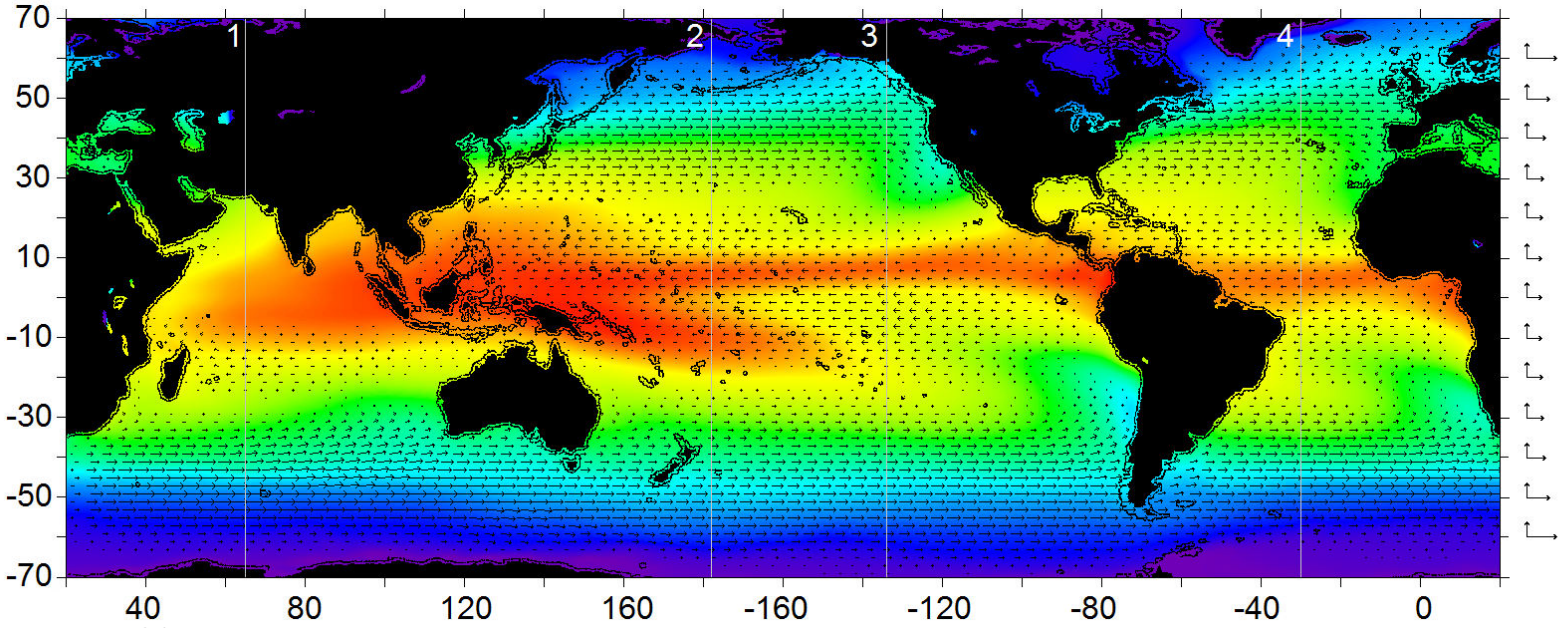


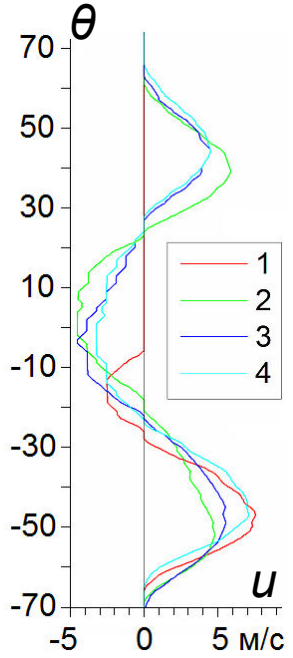
1440 x 720 элементов x 4 пары в сутки

x 365.25 суток в год x ~15 лет

22000 пар полей

Средняя картина циркуляции 2003 – 2016 гг.





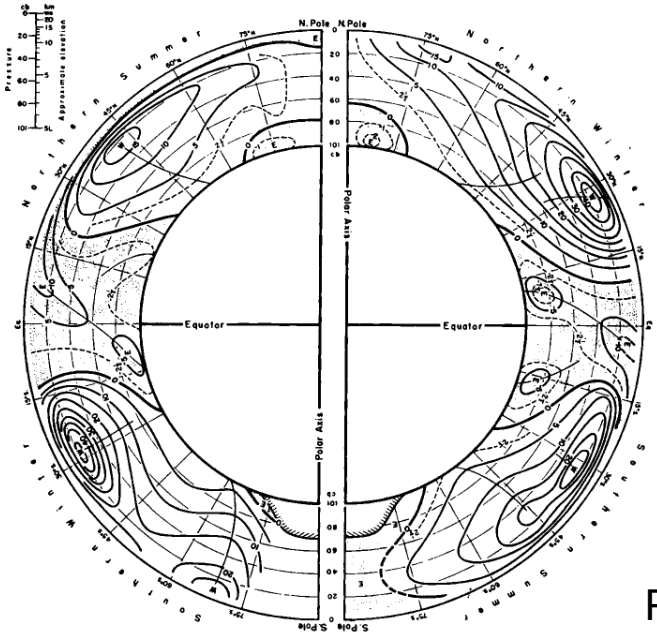


FIG. 1.2 Mean zonal wind (m/sec) averaged over all longitudes, in summer and winter. Negative values denote mean easterly wind. (After Mintz, 1954.)

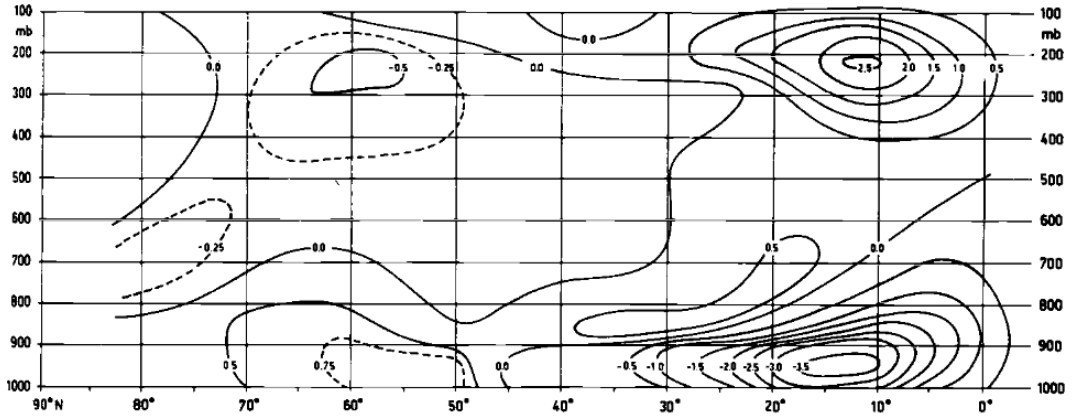
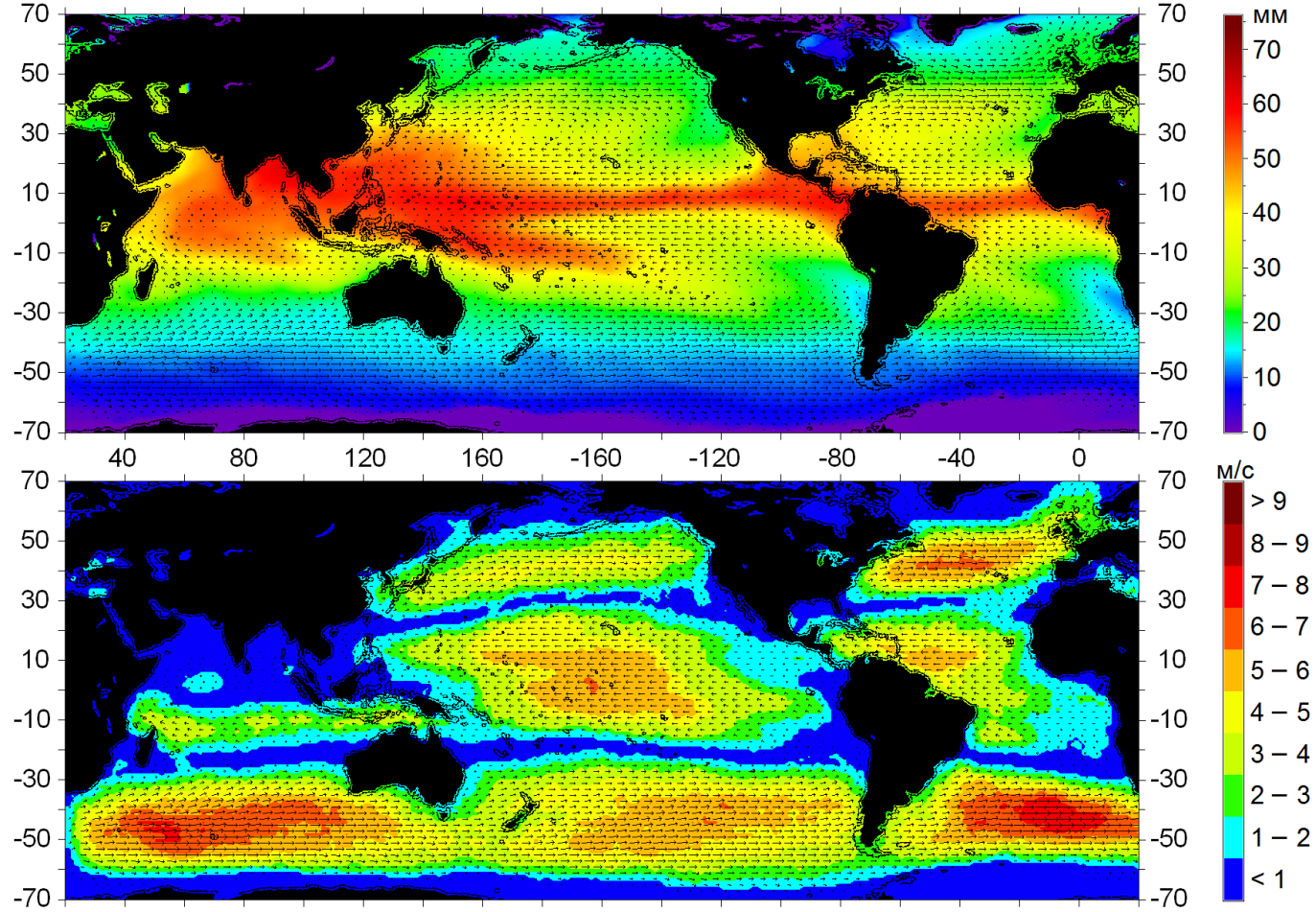


FIG. 1.3 Mean meridional wind components (m/sec, positive for south wind) in the Northern Hemisphere during the winter season, December-February. (After Palmén and Vuorela, 1963.)

Palmén, Newton. Atmospheric circulation systems

Средняя картина летней циркуляции 2003 – 2017 гг.

Вверху: цветной фон – поле ИВС



Внизу: цветной фон – диапазоны скоростей адвекции

Palmén, Newton

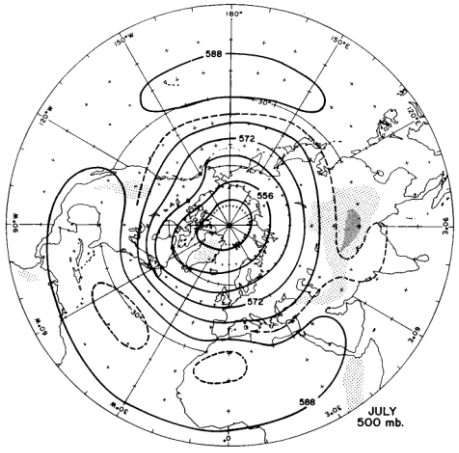


FIG. 3.2 Mean 500-mb contours in July (summer), Northern Hemisphere. (Redrawn, from I. Jacobs, 1958.)

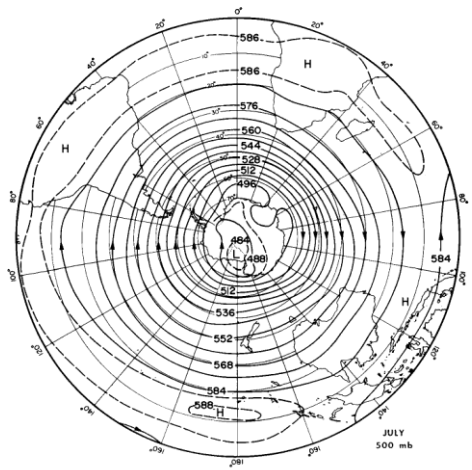
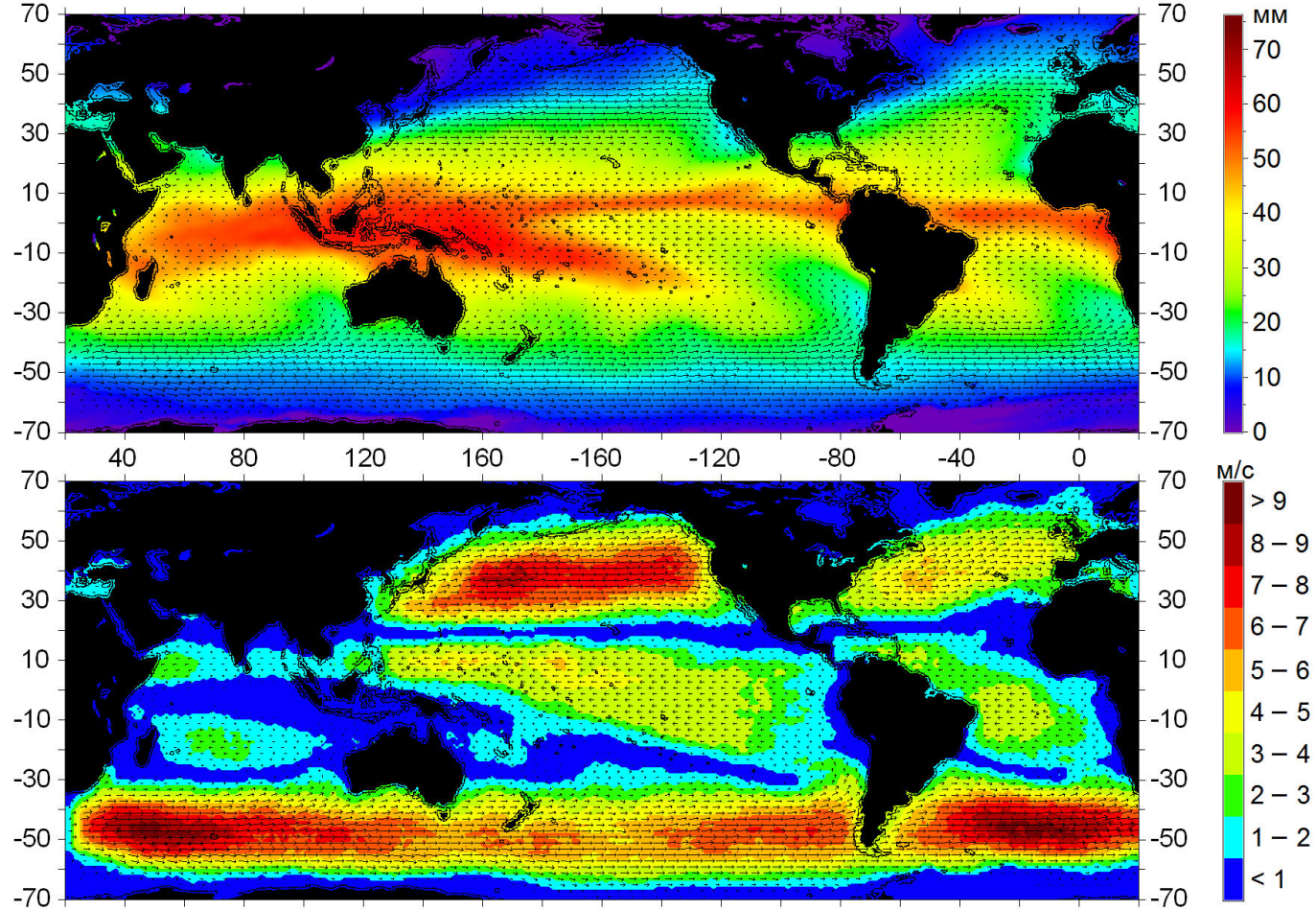


FIG. 3.4 Mean 500-mb contours in July (winter), Southern Hemisphere. (After Taljaard *et al.*, 1969.)

Средняя картина зимней циркуляции 2004 – 2017 гг.

Вверху: цветной фон – поле ИВС



Внизу: цветной фон – диапазоны скоростей адвекции

Palmén, Newton

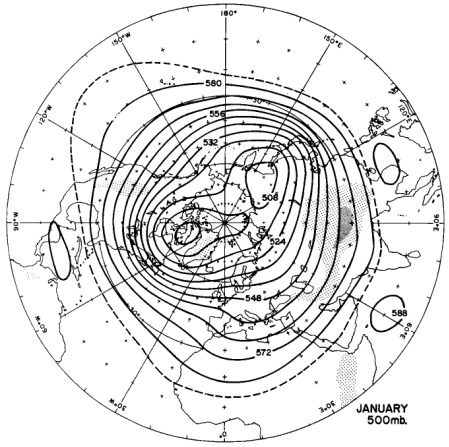


FIG. 3.1 Mean 500-mb contours in January (winter), Northern Hemisphere. Redrawn at 80-m intervals from I. Jacobs (1958). Light and heavier stippling show regions where elevations are above 1.5 km and 5 km (smoothed over 5° latitude-longitude tessera),

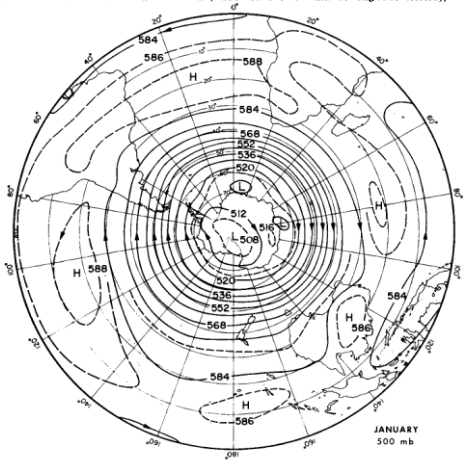
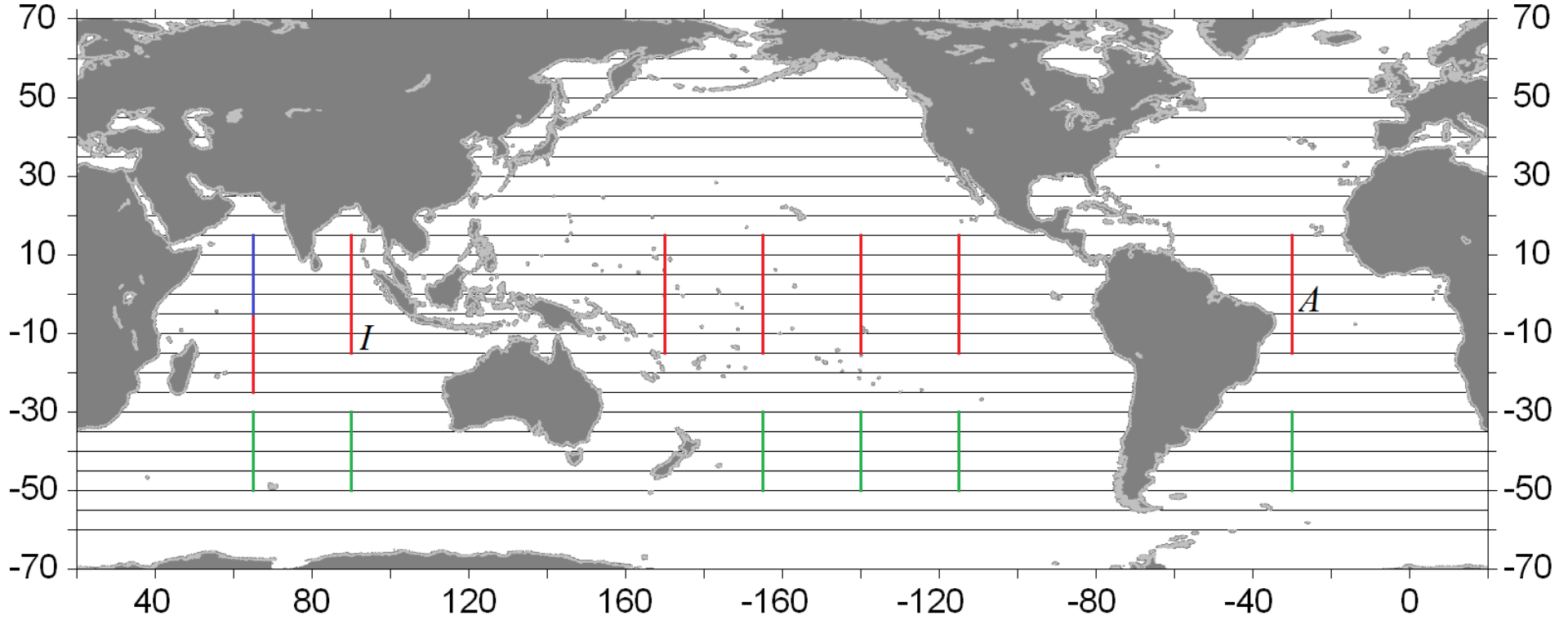


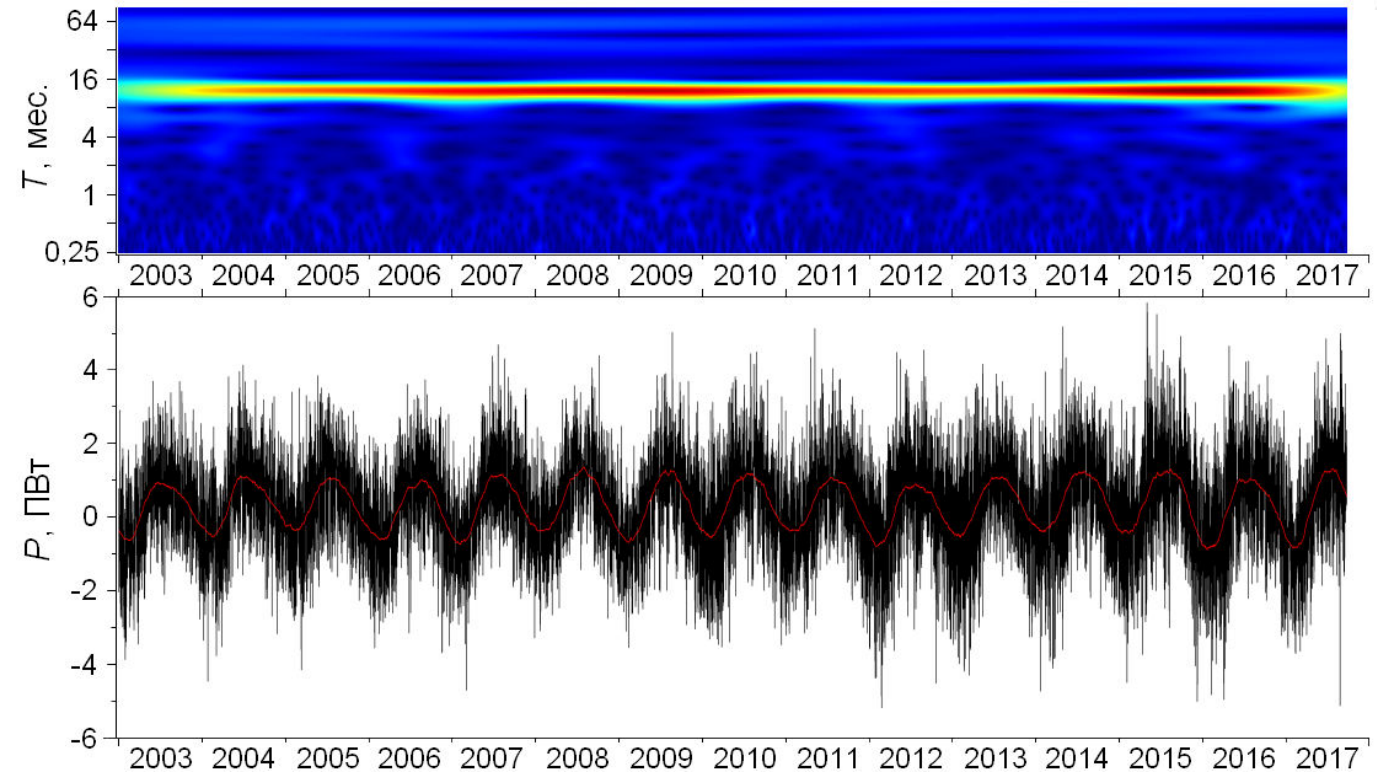
FIG. 3.3 Mean 500-mb contours (80-m interval) in January (summer), Southern Hemisphere. (After Taljaard *et al.*, 1969.)

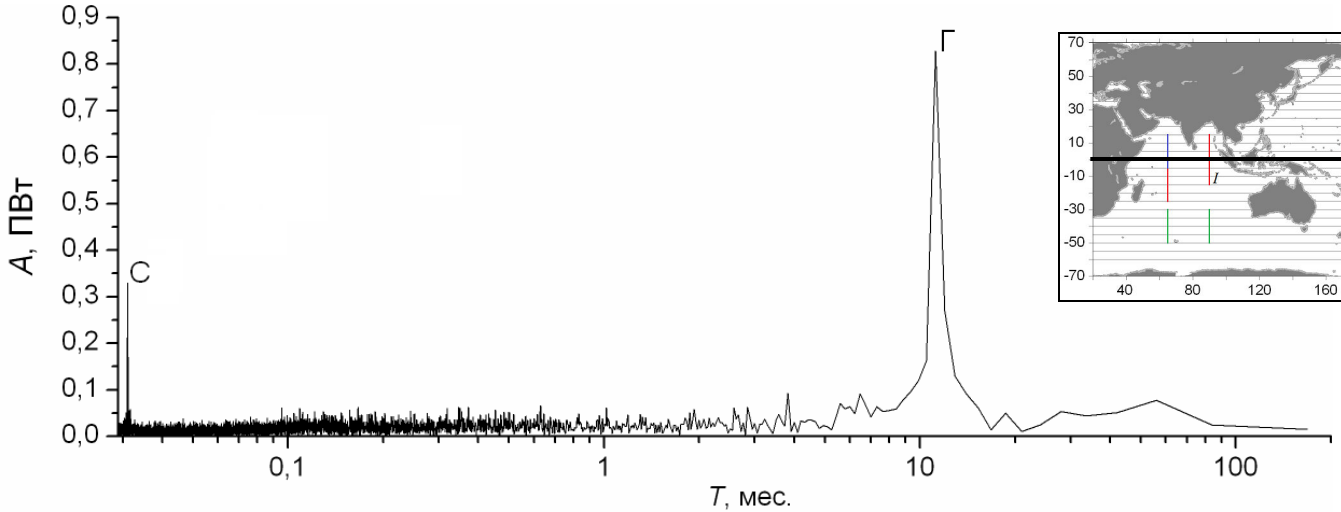
Расчет потоков скрытого тепла

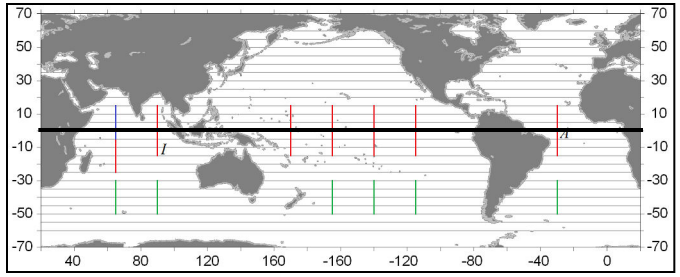


Наличие синхронных полей интегрального влагосодержания атмосферы *W* и эффективных (интегральных по высоте) скоростей адвекции водяного пара ***v*** позволяет провести расчет мощностей потоков скрытого тепла $Q \sim q\mathbf{v}W$ через произвольно задаваемые границы

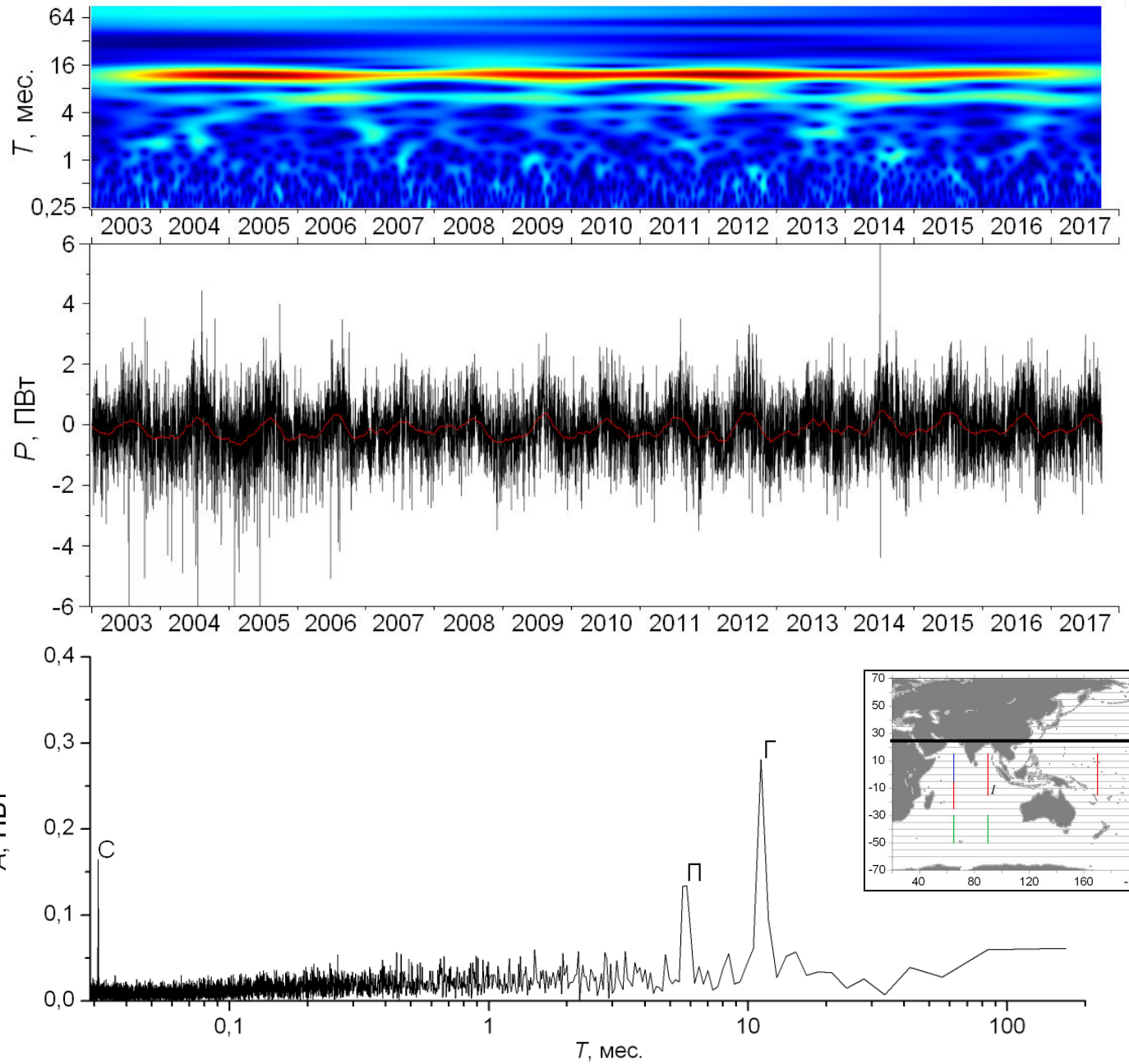
Меридиональный поток через экватор

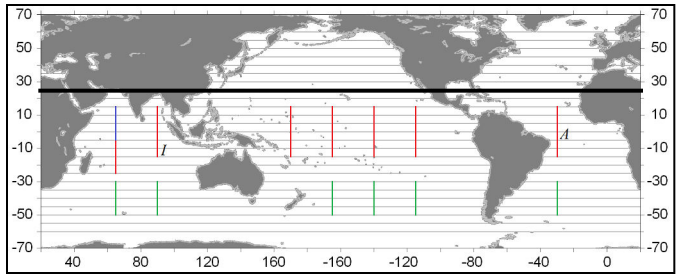






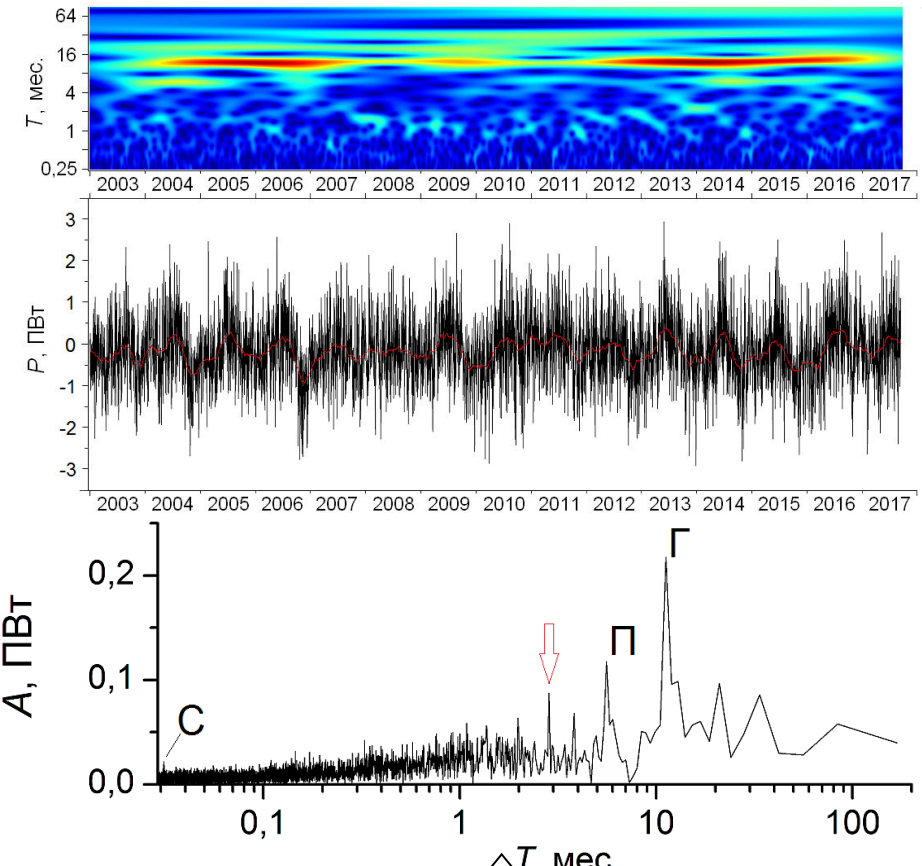
Меридиональный поток через 25° с.ш.



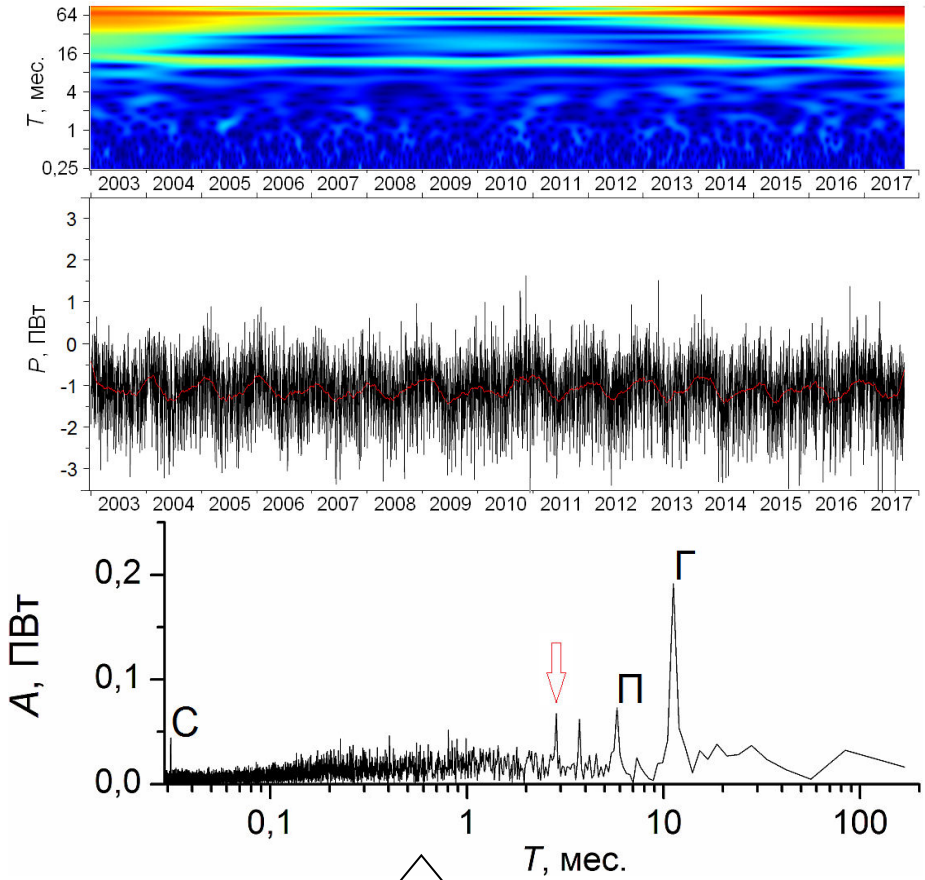


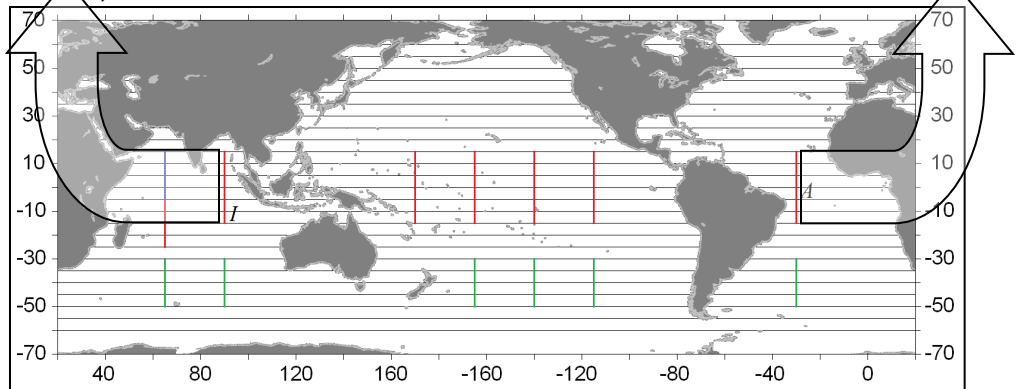
Зональные потоки

Индийский океан



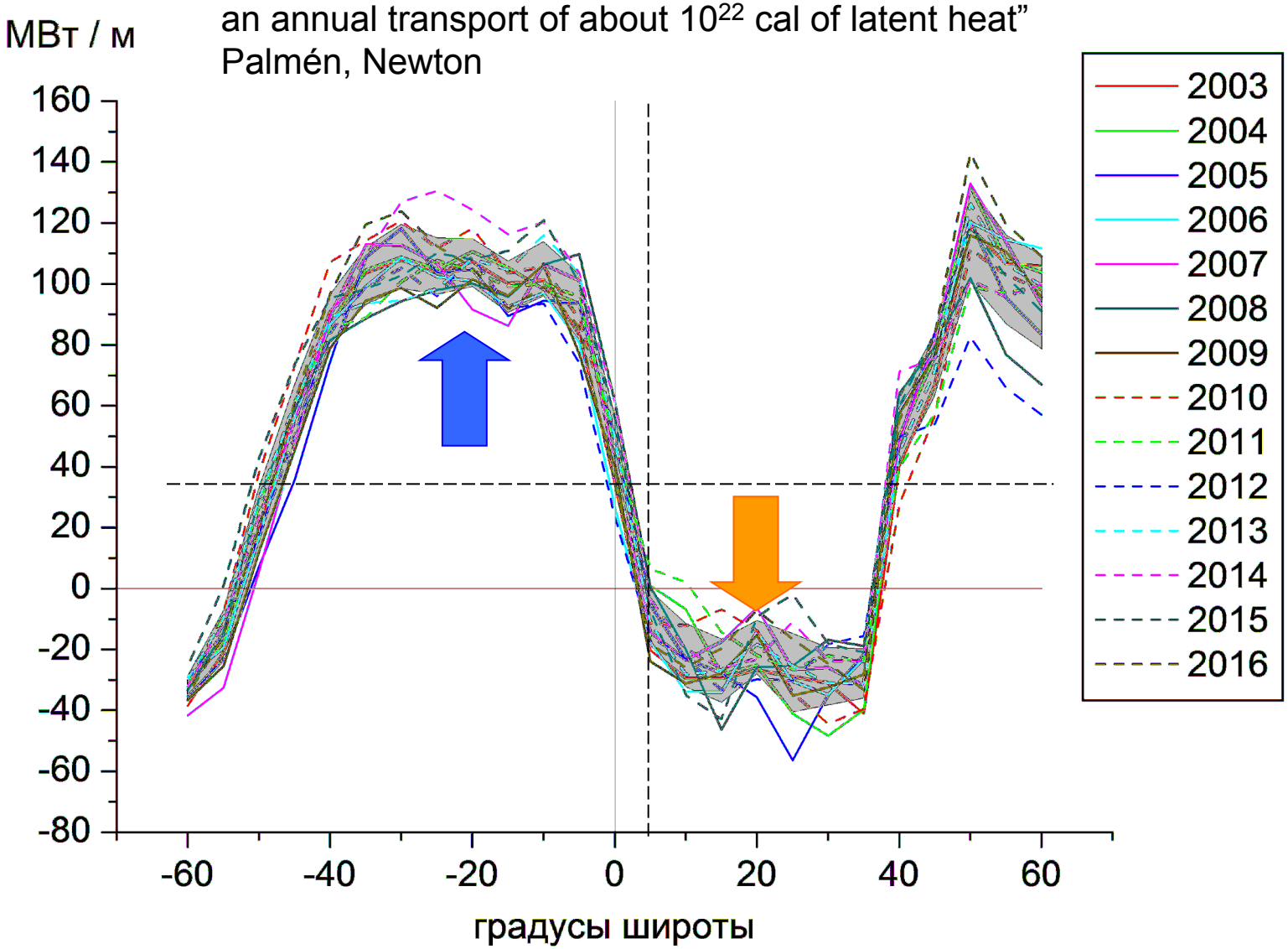
Атлантический океан



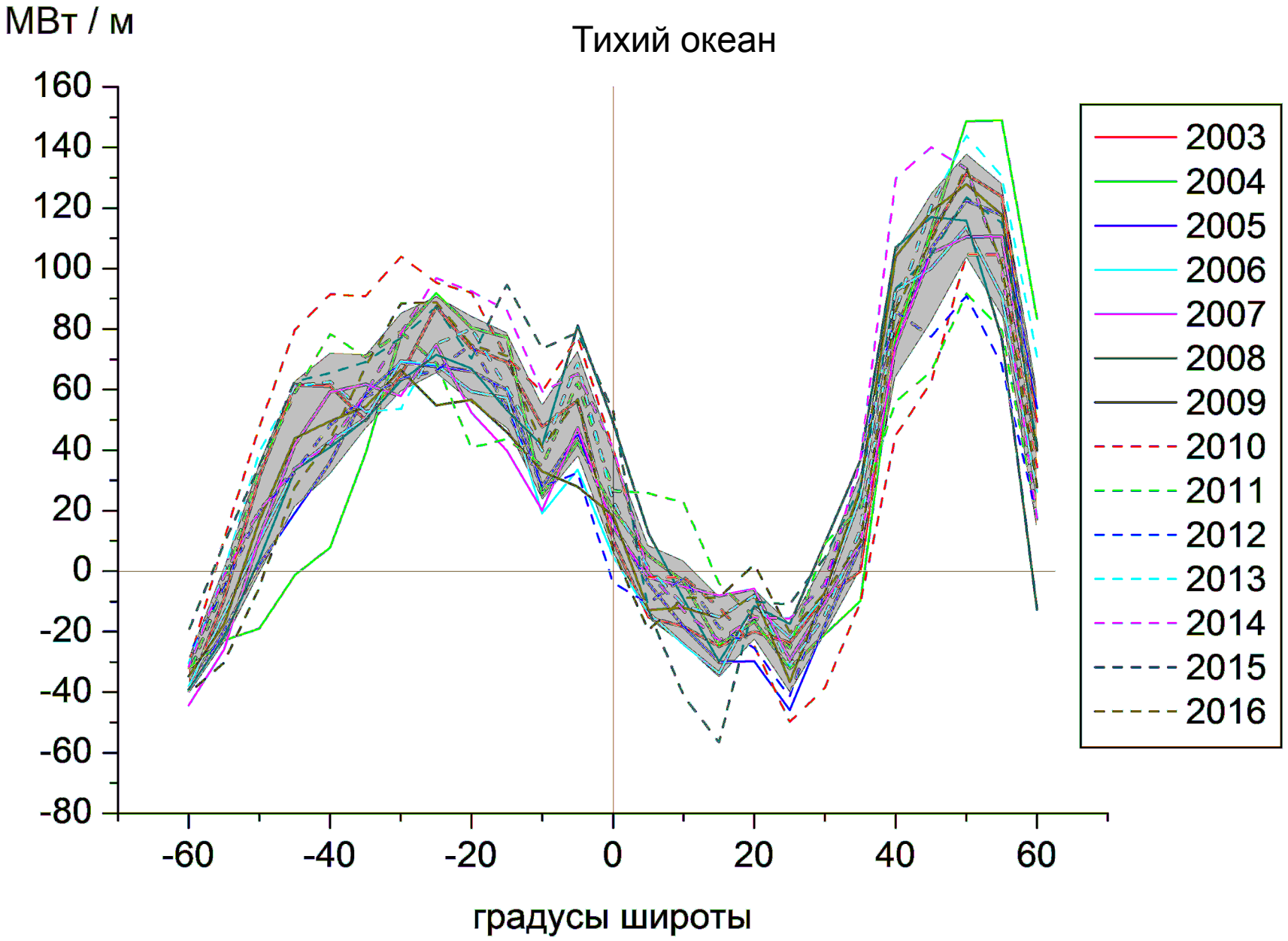


Широтное распределение среднегодовых потоков

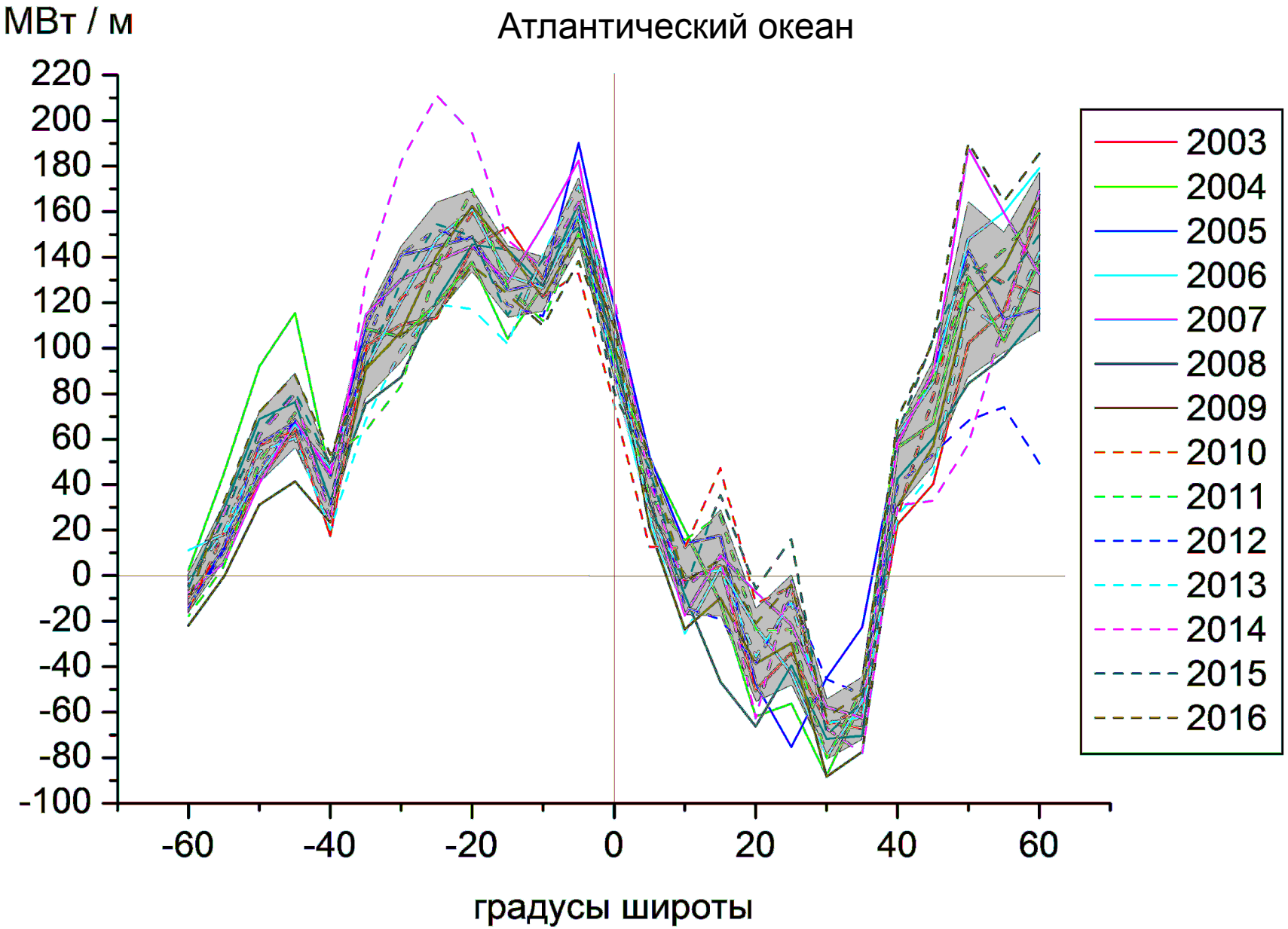
"On the whole (*P*–*E*) is positive in the Northern Hemisphere and negative in the Southern Hemisphere. To achieve balance, 1647 x 10^{13} kg/year of water vapor must hence be transported northward across the Equator. This corresponds to an annual transport of about 10^{22} cal of latent heat"
Palmén, Newton



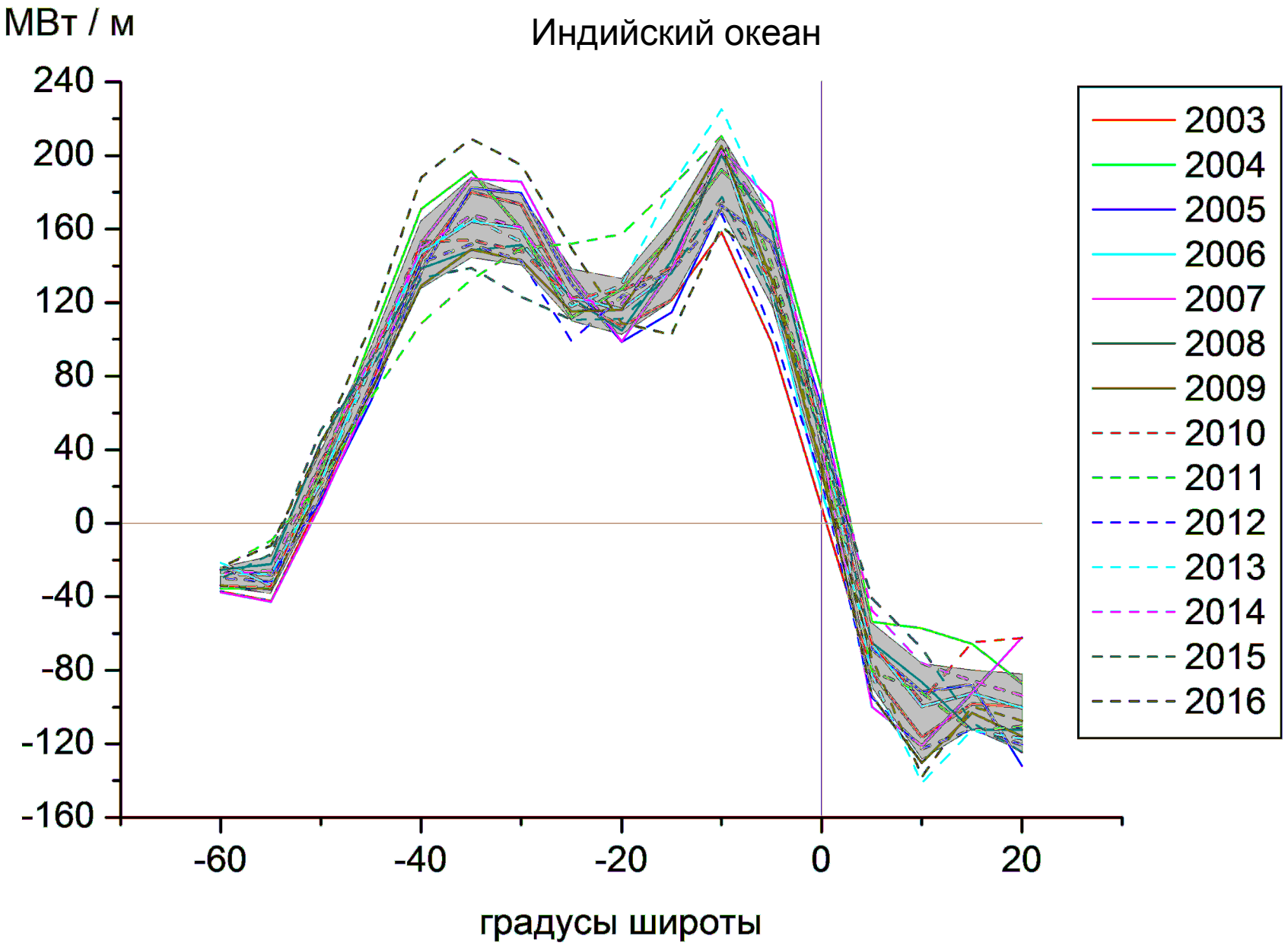
Широтное распределение среднегодовых потоков



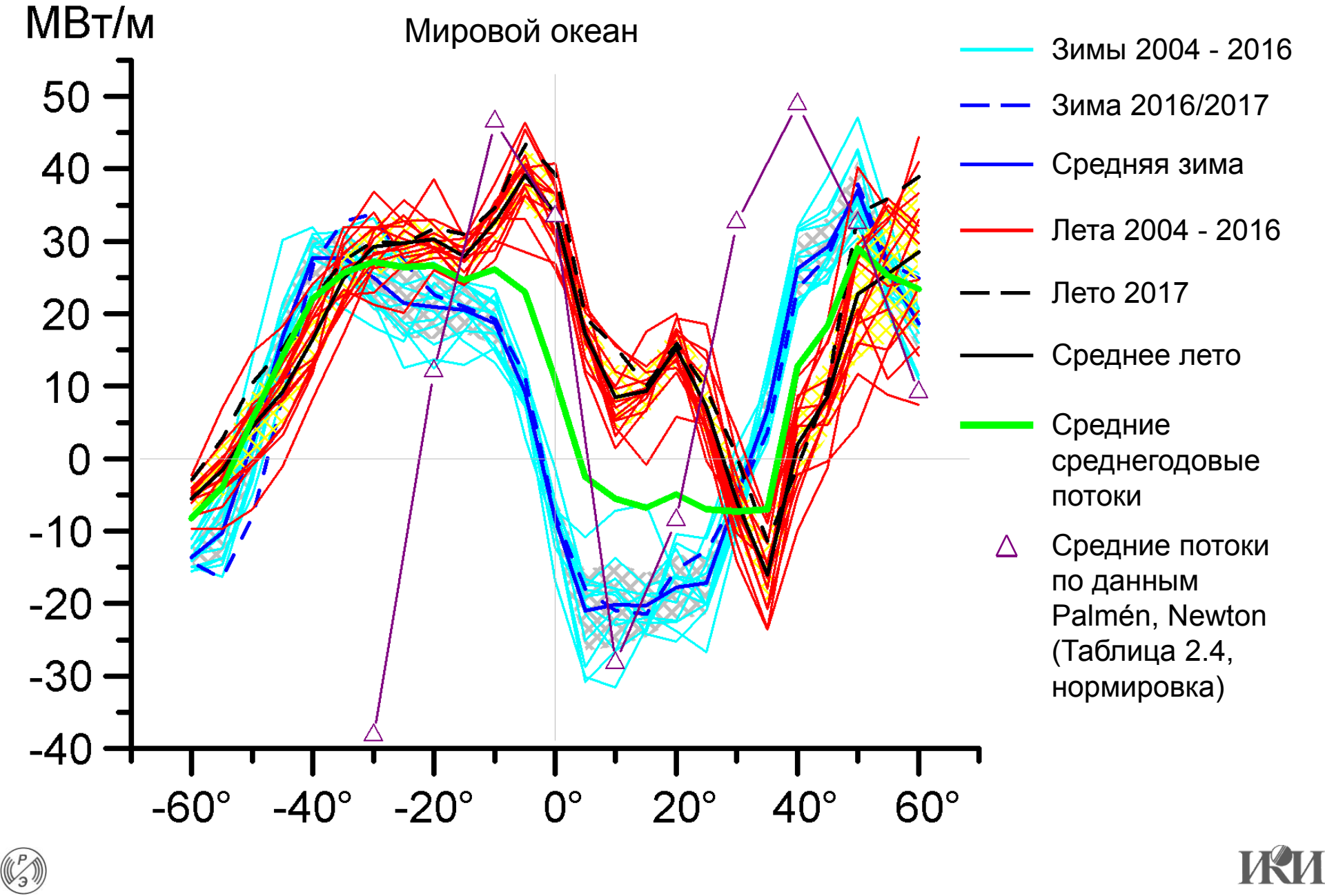
Широтное распределение среднегодовых потоков



Широтное распределение среднегодовых потоков



Широтное распределение средних сезонных потоков



Циркуляция скрытого тепла по Palmén, Newton

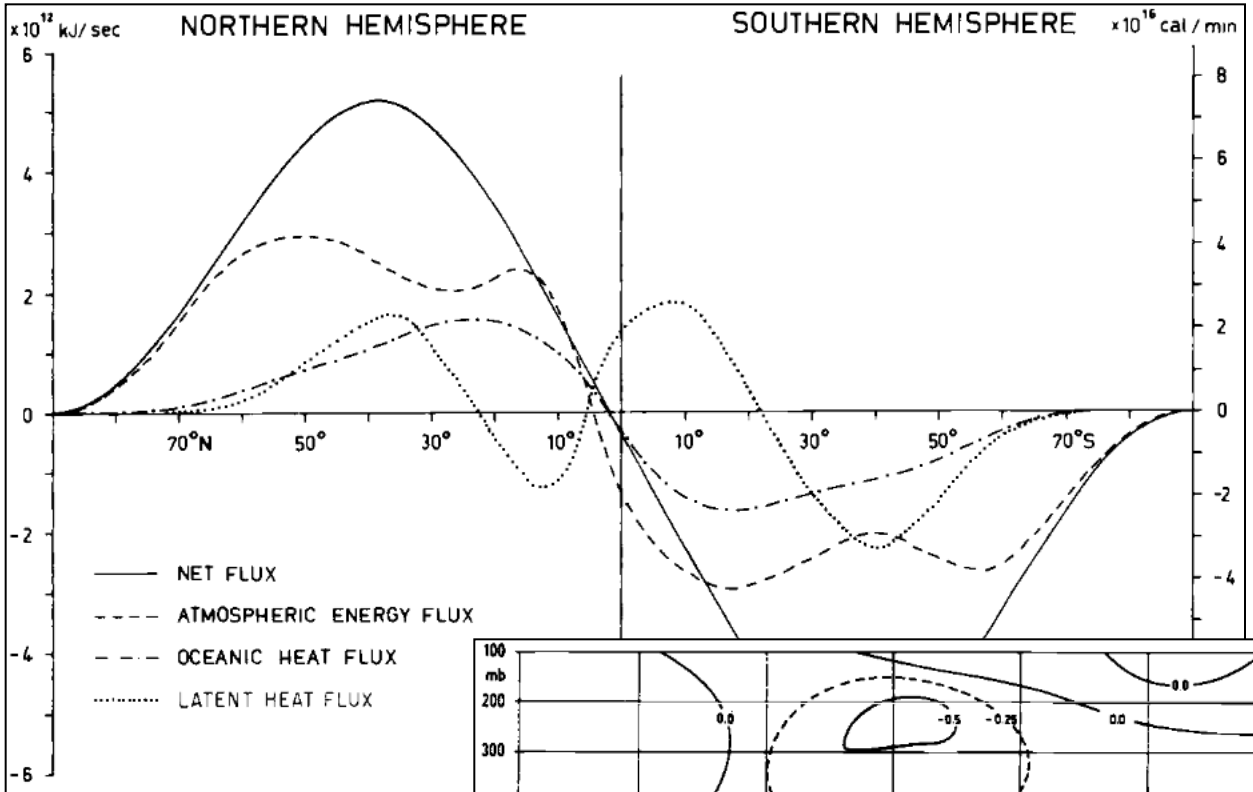


FIG. 2.4 Solid curves show th
atmosphere-ocean system. Other
thalpy + potential energy), atmo
Units are (right scale) 10^{16} cal/mi
W. D. Sellers, *Physical Climatolo*
copyright 1965 by The University

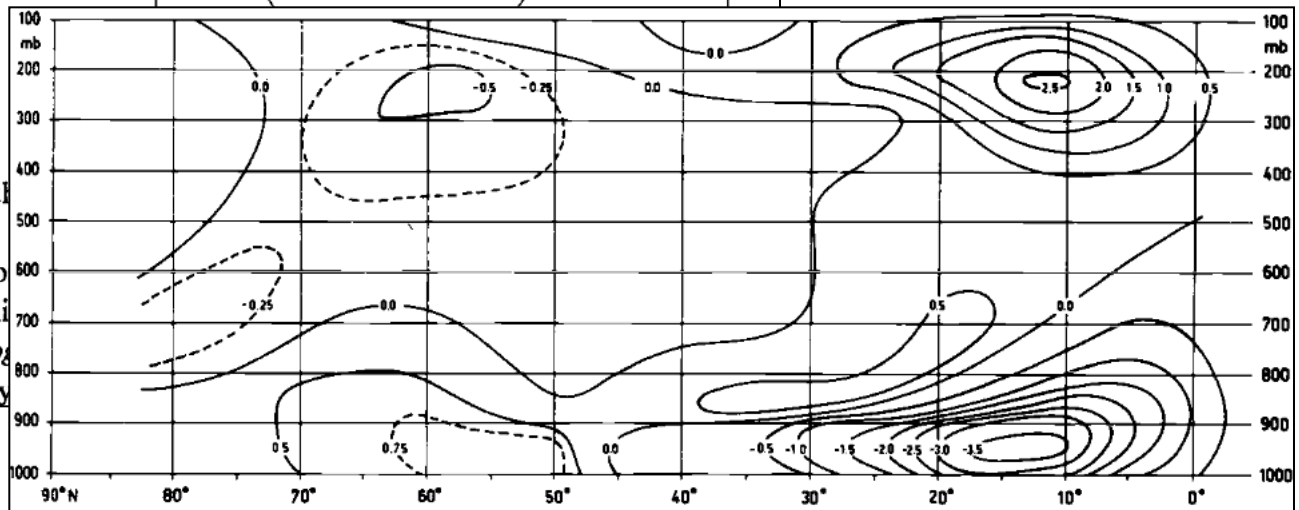
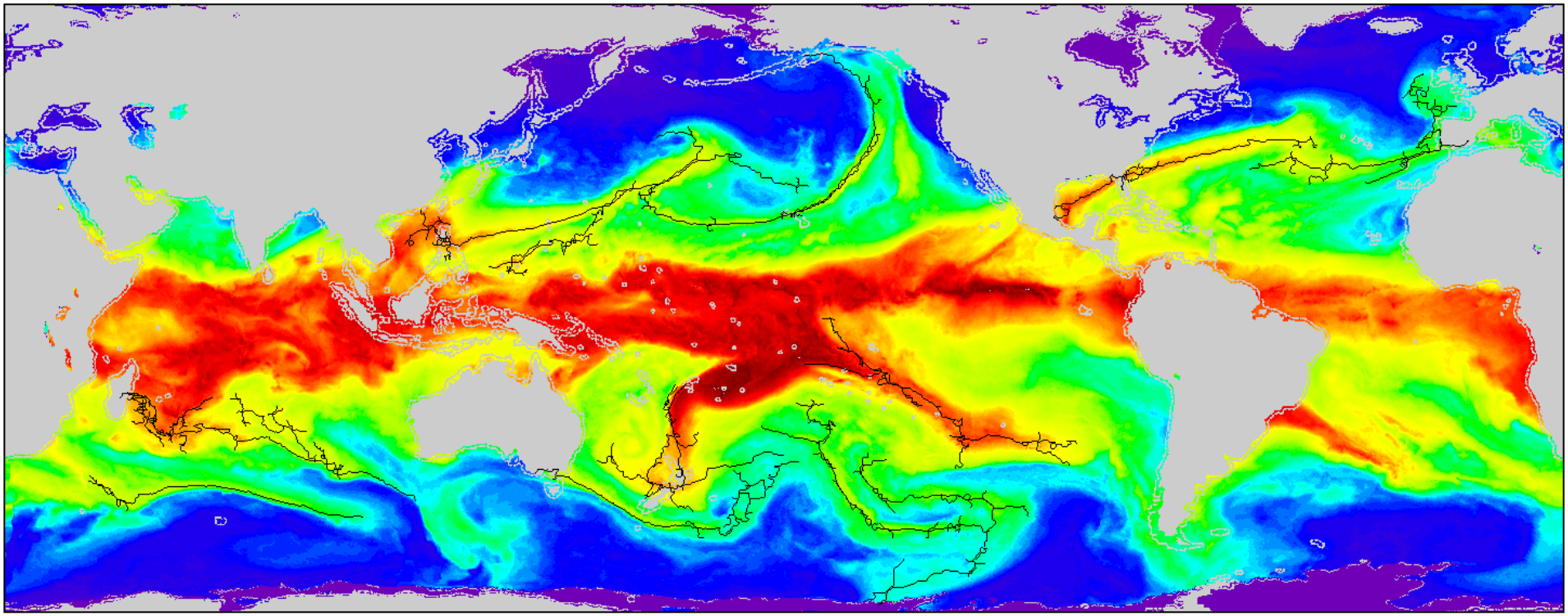
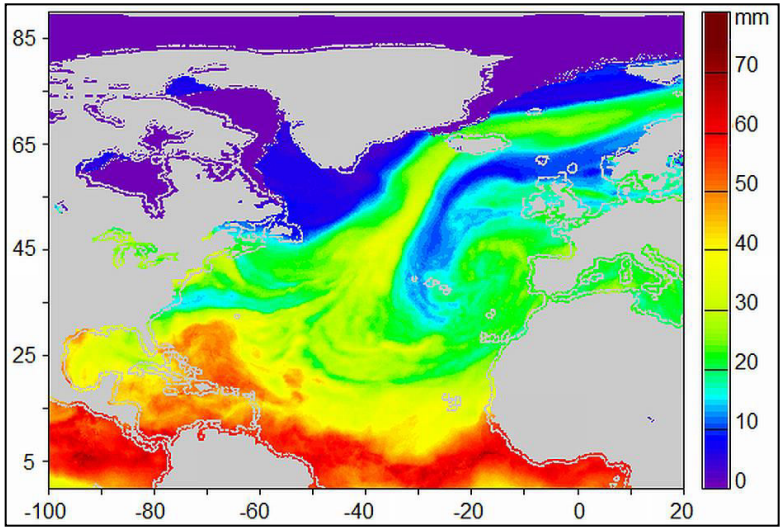
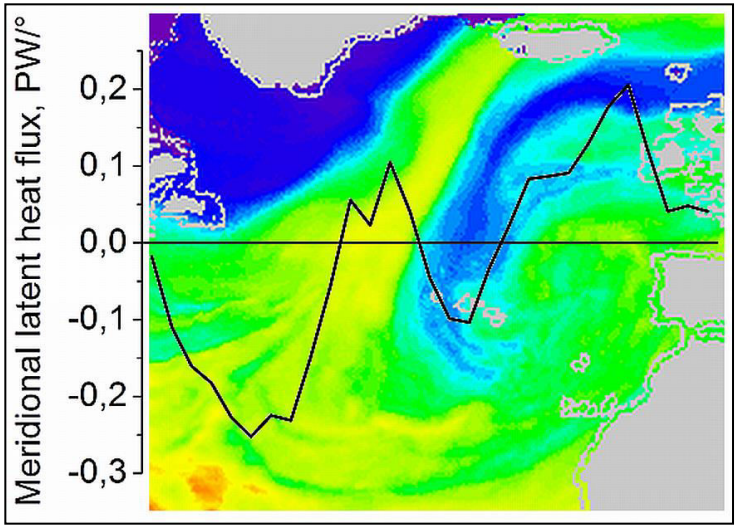


FIG. 1.3 Mean meridional wind components (m/sec, positive for south wind) in the Northern Hemisphere during the winter season, December-February. (After Palmén and Vuorela, 1963.)

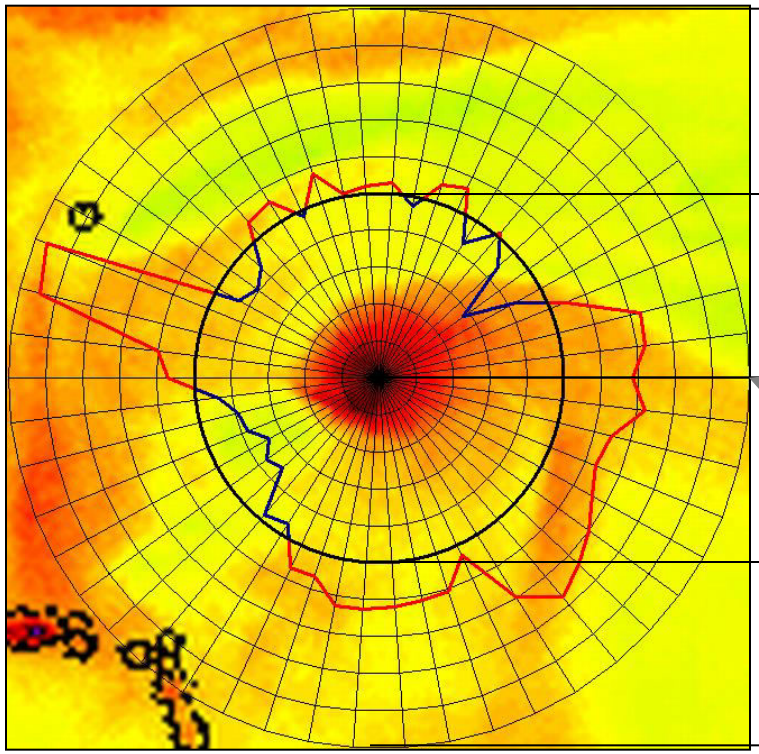
Климатологическая база данных атмосферных рек

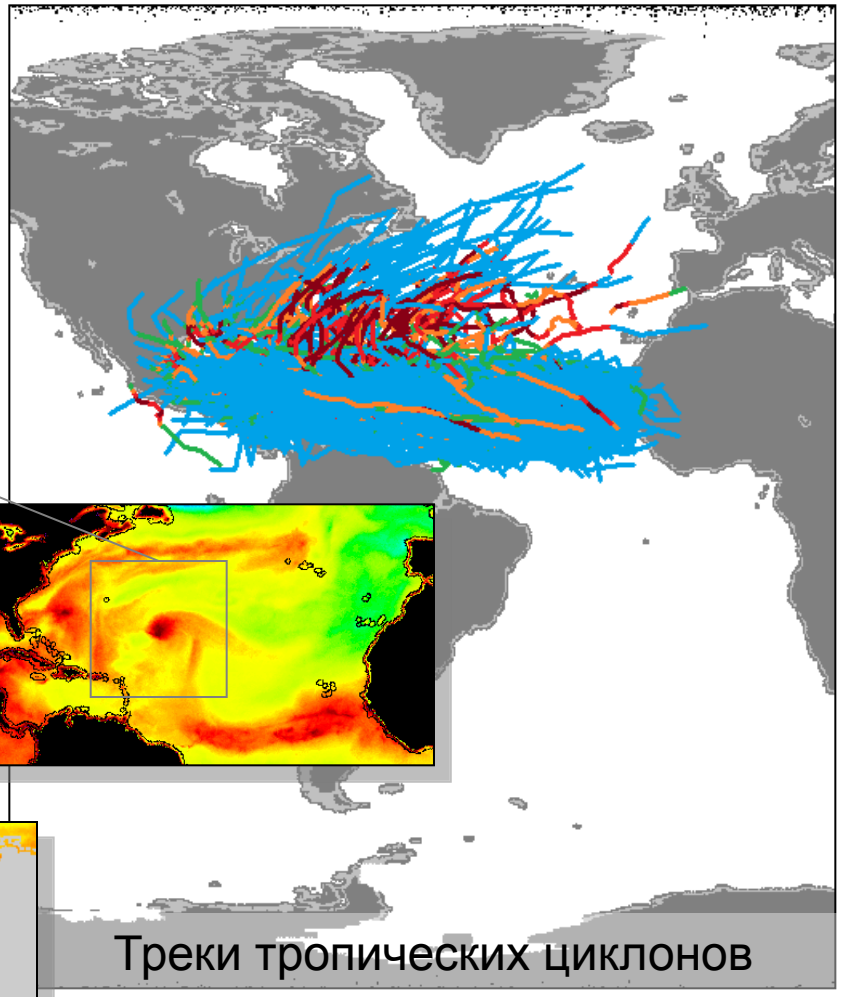






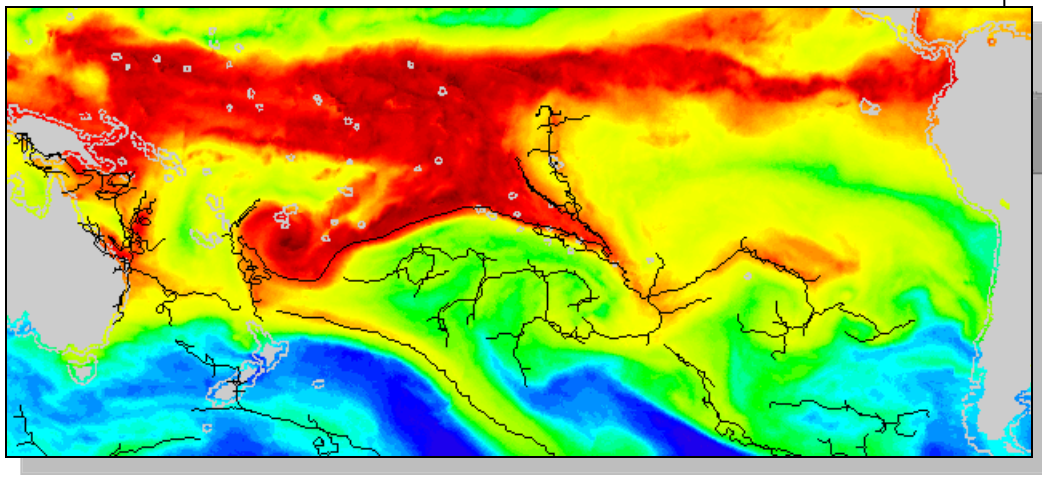
Глобальный тропический циклогенез



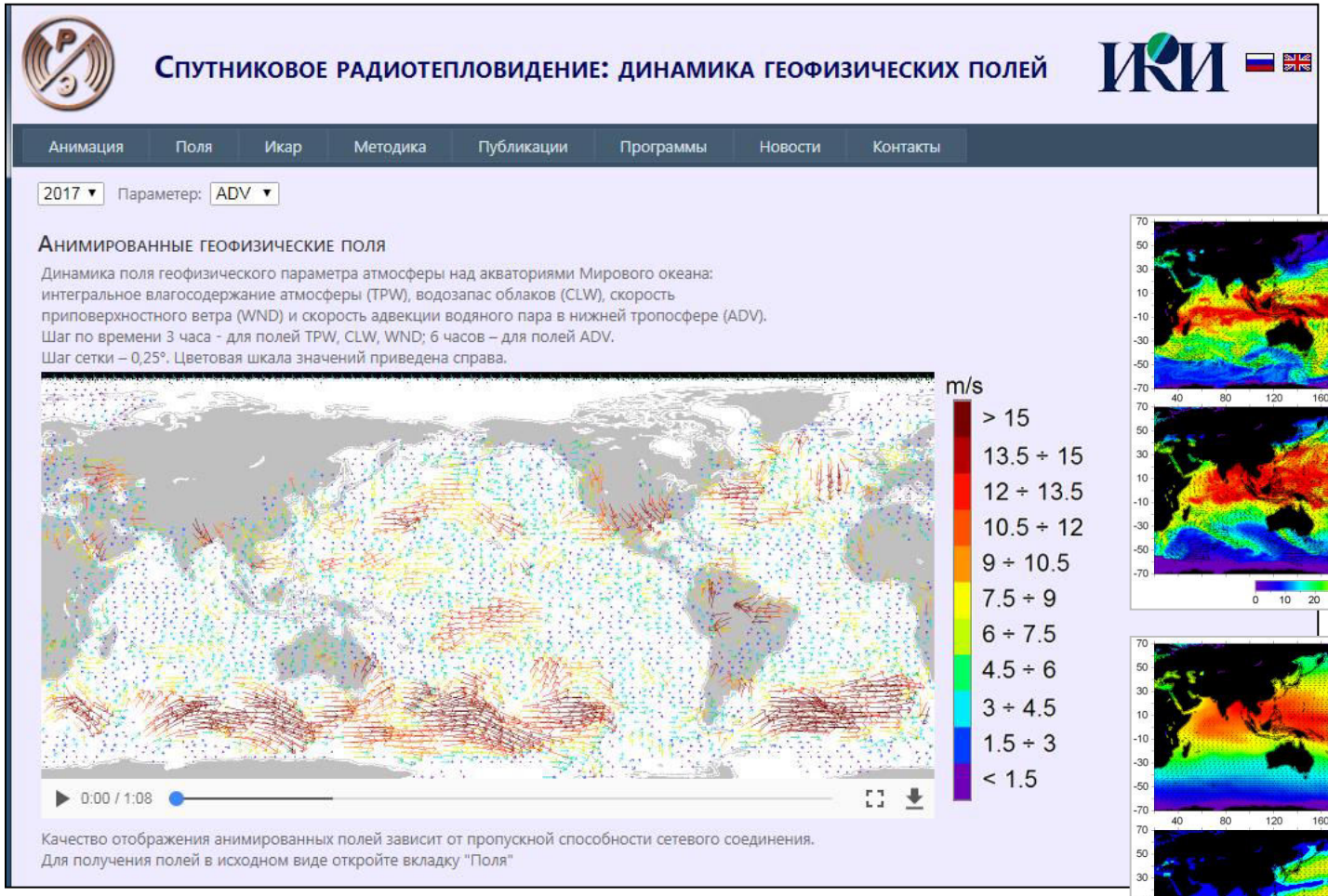


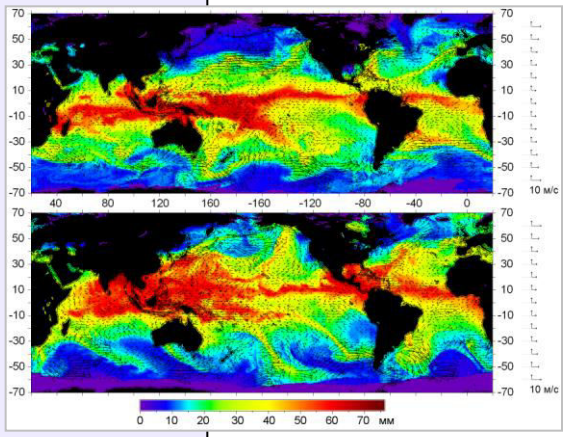
Треки тропических циклонов

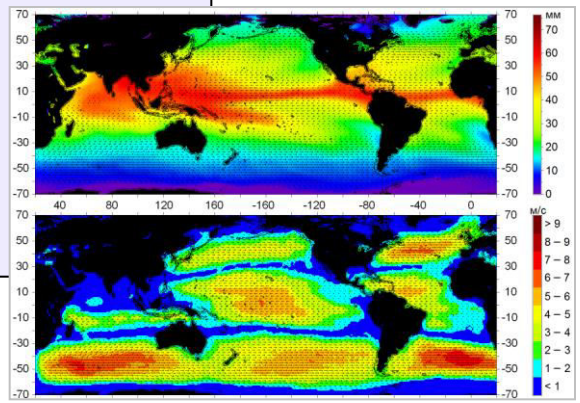
Тонкая структура потоков



Геопортал спутникового радиотепловидения







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