The effect of the meridional atmospheric heat and moisture transport on the Arctic warming is estimated using the ERA-Interim reanalysis over 1979–2015. Major influx of sensible and latent heat into the Arctic occurs through the Atlantic sector 0°–80°E between the surface and the 750 hPa level. This influx explains more than 50% of the average temperature variability in the area 70°–90°N in winter with almost equal contribution of both fluxes. Calculations using MPI-ESM-MR Earth System model from the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble showed the similar effect of the meridional atmospheric heat and moisture transport and its increase by the end of the century. Mean summer transport in the low troposphere is directed from the Arctic and transfers out the moisture produced by summer melting of sea ice. The major drivers of summer warming are the radiation processes especially downwards longwave radiation.

1 | INTRODUCTION

Unusually warm winter conditions in the Arctic during the years of 2015–2016 attracted the attention of many researchers (Boisvert et al., 2016; Cullather et al., 2016; Woods and Caballero, 2016; Alexeev et al., 2017; Graham et al., 2017; Kim et al., 2017; Kim and Kim, 2017; Ricker et al., 2017) and stimulated investigation of the role of atmospheric heat and moisture transport to the Arctic. Anomalous warming and moisture transport were explained by the intrusion of the powerful cyclonic vortex from the North Atlantic, when the moist and warm air masses were contributing to an increase of downwards longwave radiation (DLR; Ghatak and Miller, 2013; Park et al., 2015; Boisvert et al., 2016; Cullather et al., 2016; Alexeev et al., 2017; Kim and Kim, 2017; Lee et al., 2017) and to a growth of the turbulent heat flux to the surface (Yim et al., 2016; Alexeev et al., 2017; Kim and Kim, 2017).

Intrusions of the cyclonic systems are believed to be the important source of water vapour for the Arctic (Woods et al., 2013; Woods and Caballero, 2016; Graham et al., 2017; Messori et al., 2018) affecting the increase in the DLR at the surface. Woods et al. (2013) found that from 1990 to 2010, 28% of the total transport of moisture through 70°N originated from the North Atlantic to the Barents and Kara Seas, and from the Pacific Ocean. Vázquez et al. (2016) used the Lagrangian diagnosis model FLEXPART to localize the main sources of moisture for the Arctic region in the subtropical and southern extratropical Pacific and Atlantic Oceans, North America, and Siberia.

Historical temperature records show (Graham et al., 2017) that winter warming has been observed on the greater part of the Arctic Ocean since the end of the 19th century. It was associated with the storm systems originating in the Atlantic and/or Pacific Oceans. Notably, they were twice as...
likely to occur in the Atlantic Ocean. Strong warming in the area of the North Pole was noted in the 1930s (Dzerdzevsky, 1943; Vittels, 1946). The influx of water vapour was considered as the main factor of DLR increase (Woods et al., 2013; Cullather et al., 2016; Woods and Caballero, 2016; Yim et al., 2016; Lee et al., 2017). In the papers (Ghatak and Miller, 2013; Park et al., 2015; Gong et al., 2017; Kim and Kim, 2017; Wang et al., 2017) it is also pointed to the contribution of an increase in air temperature to DLR, which corresponds to the empirical formula used in the calculations of DLR (Makshtas, 1991), having a general form:

\[ F_n = \varepsilon_s(n, T, \varepsilon)\sigma T^4, \]

where \( F \) is the power of DLR, \( \varepsilon_s \) is the effective longwave emissivity of the atmosphere, which is a function of cloudiness \( n \), temperature \( T \), and water vapour pressure \( \varepsilon \) at 2 m, \( \sigma \) is the Stefan–Boltzmann constant.

Kim and Kim (2017) calculated the transport of both latent (LH) and sensible (SH) heat from the ERA-Interim reanalysis data and found that in winter the average transport of moisture and sensible heat to the North European Arctic sector 0°–90°E, 70°–90°N is related to the average values of DLR in this sector with correlation coefficients 0.80 and 0.62, respectively. Thus, they confirmed the dependence of the DLR on the inflows of both moisture and heat transports. Earlier, Oort (1974) believed that, on average, over the course of a year, most of the energy necessary to balancing radiation-cooling in the polar cap came with atmospheric transport across the southern boundary. Consequently, transport of sensible heat predominates. But the follow-up calculations of atmospheric transport to the Arctic based on various data and global model results did not reveal unequivocally the heat influx impact, especially of sensible heat (Graversen, 2006; Hwang et al., 2011; Kay et al., 2012; Koenigk et al., 2013; Pithan and Mauritsen, 2014). The discrepancies in evaluation of vertical distribution of heat influx and the role of albedo feedbacks remained too (Winton, 2006; Screen and Simmonds, 2010; Screen et al., 2012; Graversen et al., 2014).

Here we propose to evaluate the heat and moisture transport to the Arctic across 70°N, its spatial–temporal distribution and contribution to variability of the average air temperature in the 70°–90°N area in winter and summer. In addition to the ERA-Interim reanalysis data, we also use results of experiments with the global climate model MPI-ESM-MR from the CMIP5 ensemble to assess its ability to reproduce results obtained from the reanalysis.

2 | DATA AND METHODS

We used ERA-Interim reanalysis data (Dee et al., 2011) for the period 1979–2015, which included high-resolution thermodynamic parameters of global atmosphere, as well as vertical integrals of northwards heat and moisture fluxes from ERA-Interim data (Dee et al., 2011), also for the period 1979–2015. Monthly mean data from the area between 60°N and 90°N was used, including air temperature, water vapour content, and a wind meridional component on the regular 1 × 1° grid and on the isobaric surfaces from 1,000 to 100 hPa with a 50 hPa resolution, as well as components of longwave radiation balance (LRB) on the surface. The similar data of recent global climate experiment with MPI-ESM-MR model for 1980–2100 taken from the CMIP5 ensemble were also used. Integral transports of SH and LH through 70°N were calculated, averaged over the entire latitude circle and along its separate parts for comparison with the average air temperature in the 70°–90°N area. Similar calculations of integral transports were carried out from the reanalysis data in papers (Graversen, 2006; Kim and Kim, 2017). In order to take into account the vertical inhomogeneity of transport, values of SH (\( J_T, \text{W/m}^2 \)) and LH (\( J_Q, \text{W/m}^2 \)) were calculated at each isobaric level with 50 hPa spacing at points on 70°N latitude through 1° of longitude as

\[
\langle J_T \rangle_{lpgm} = (C_p \rho TV)_{lpgm}, \tag{1}
\]

\[
\langle J_Q \rangle_{lpgm} = (LpQV)_{lpgm}, \tag{2}
\]

where \( C_p = 1,005 \text{ J (kgK)}^{-1} \); \( L = 2.50 \times 106 \text{ Jkg}^{-1} \); \( \rho \) is the air density, kgm\(^{-3}\); \( T \) is monthly mean air temperature, K; \( Q \) is the monthly mean water vapour content (kg\(^{-1}\)); \( V \) is the monthly mean meridional component of wind speed, m/s; \( l \) is the longitude; \( p \) is the isobaric surface, g is the year, \( m \) is the month. Obtained values were used to calculate monthly average transport at each isobaric level in every grid point across 70°N and then across its separate sectors for winter (December–February) and summer (June–August) seasons.

3 | RESULTS

3.1 | Atlantic and Pacific gates for heat influx into the Arctic

Generally, the correlation between mean values of the vertically integrated transport of SH across 70°N and the average surface air temperature (SAT) in the region of 70°–90°N for each month for 1979–2015 is insignificant. For LH transport significant correlation \( (r > 0.32) \) was found from November to April, excluding December. At the same time, there is a significant correlation between LH and SH transports for the winter months, with a correlation maximum of 0.74 in January.

During the cold part of the year (October–April), the deviations of multiyear average values of SAT and water vapour content in the area of 60°–90°N from their zonal averages show positive anomalies in the regions adjacent to the North Atlantic and Pacific Ocean (Figure 1). These regions have been noted earlier (Overland and Turet, 1994; Graversen, 2006; Serreze et al., 2011; Woods et al., 2013;...
Graham et al., 2017; Kim and Kim, 2017). The distribution of the meridional component of wind along 70°N allowed to separate out sectors 0°–80°E and 200°–230°E which were identified as the Atlantic and Pacific gates, respectively. During the winter, the average vertically integrated fluxes of SH and LH through the Atlantic gate affect the average temperature in the region of 70°–90°N. This influence was estimated by the correlation with coefficients 0.41 and 0.50, respectively. Correlation between fluxes through the Pacific gate and the average air temperature in the Arctic is insignificant. Thus, the vertically integrated transport of SH and LH through the Atlantic gate affects the SAT variations in the high-latitude Arctic, but accounts for less than 20% of its variability.

The contribution of the sensible heat influx cannot be detected if the inflow is calculated through the 70°N latitude as a whole. The reason is that in this case large contribution to the overall influx is made by the arrival of cold air from Eurasia through 70°N between 80° and 150°E. But this inflow does not have a noticeable effect on the average air temperature in the area of 70°–90°N due to the flux of heat from the coastal polynyas and the Great Siberian polynya to the north of the fast ice in the Laptev and East Siberian Seas in winter. Influxes of heat from polynya in the Arctic reach 700–1,000 W/m² (Maykut, 1978; Makshtas, 1991; Gultepe et al., 2003).

3.2 Effect of heat and moisture transport through the gates at the different isobaric levels

The statement of the sufficiency of using vertically integrated transports under the assumption of their strong vertical coherence (Woods et al., 2013) is not confirmed in the studies of Overland and Turet (1994). Woods’s speculation is not confirmed by the data in his article, but the distribution of the average meridional flows is illustrated in the articles mentioned. Serreze et al. (1995) and Jakobson and Vihma (2010), in which transports maxima were observed at 850 hPa, and also at 930 hPa in winter and at 970–990 hPa in other seasons. In our study, SH and LH transports were calculated at each isobaric level with 50 hPa spacing at points along 70°N through 1° of longitude using formulas 2 and 3 and averaged over the period 1980–2015. Calculated values were additionally averaged separately over the 70°N, Atlantic and the Pacific. They are presented in Figure 2 together with the profile of the meridional wind. Vertical profiles show that the average SH and LH influxes into the Arctic through the 70°N, as well as Atlantic and Pacific gates are concentrated in the lower layers of the atmosphere (up to 750 hPa). The main heat transport passes into the Arctic through the Atlantic gates. The transports maximum is located near 1,000 hPa, whereas above 750 hPa, the average transport through the Atlantic gates is directed outside the Arctic.

Effect of winter (December–February) heat transports to the Arctic through the Atlantic gate at 1,000 hPa on the variability of the Arctic mean SAT in January–February (Figure 3) is significant with the correlation coefficients of 0.70 and 0.75 for SH and LH fluxes correspondingly (multiple correlation is 0.75). The coefficient of multiple correlation \( R \) is equal to the square root of the coefficient of determination \( D \) of the dependence between SAT SH, LH in the form SAT = \( \alpha \text{SH} + \beta \text{LH} \): \( R = (D)^{1/2} \). This corresponds to their joint contribution to the SAT variability of more than 50%, and into the temperature trend of 34% from sensible and 40% from latent heat transport. At the same time, estimates indicate an increase in the effect of transports on the temperature with a delay of 1 month. This means a contribution to the trend dispersion.
The altitude-time diagram of heat transports through the Atlantic gate (Figure 4) confirms the location of their maxima in the lower troposphere and shows their significant inter-annual fluctuations in the form of alternating maxima and minima with a 5–7-year cycle and gradual growth during the considered period.

The spatial distribution of the influence of heat influxes through the Atlantic gate on the Arctic winter air temperature is illustrated in Figure 5, where are shown correlation coefficients between changes in SH, LH transports and SAT. The area of the greatest influence of influxes on the Arctic winter temperature expands from the Norwegian Sea to the East Siberian Sea and to the North Pole. A similar distribution of heat influx effect was observed in the winter anomaly of 2015–2016 (Cullather et al., 2016; Kim et al., 2017), as well as under generalizing the effect of cyclonic intrusions (Woods et al., 2013; Woods and Caballero, 2016) and in the calculations using reanalysis data (Overland and Turet, 1994; Graversen, 2006; Serreze et al., 2011; Kim and Kim, 2017).

3.3 Impact of heat transports in experiments with the MPI-ESM-MR model

Heat and moisture transports to the Arctic via the Atlantic gate at the 70° N were calculated also from the results of the control and RCP8.5 scenario experiments with the global climate model MPI-ESM-MR from the CMIP5 ensemble. This model reproduces the main features of the observed
atmospheric circulation with sufficient accuracy (Schneck et al., 2015). Calculations showed the distribution of the transports effect on the SAT (Figure 6) similar to that received using reanalysis data (see Figure 5).

The model experiment under the RCP8.5 scenario indicated an increase in the heat transports to the Arctic until 2100 (Figure 7) in accordance with the projected temperature increase in the Arctic. Vertical profiles of model heat transports to the Arctic are also maximal in the lower troposphere.

3.4 Heat and moisture transport in summer

The meridional transports of heat and moisture, their interannual variability and effect on the air temperature and water vapour content in the Arctic atmosphere are significantly different in winter and summer. In summer, the average wind meridional component is directed from the Arctic in the lower layer of the troposphere up to 700 hPa (Figure 8a). The higher-level transport has the opposite direction—to the Arctic. Accordingly, the average transport of SH and LH (Figure 8) are directed from the Arctic in the lower layer of the troposphere up to 700 hPa, on average throughout the latitude circle and Atlantic gate. Through the Pacific gate, the meridional component of the wind is directed to the Arctic actually in the entire troposphere, with the exception for the near-surface layer below 925 hPa.

The average vertical distribution of transport through the Atlantic gate in the MPI-ESM-MR model in the control run (for 1980–2011) and under the RCP8.5 scenario (for 2060–2090) showed the similar opposite direction of transport in the lower troposphere up to 600 hPa in the control run and up to 800 hPa in the RCP8.5 experiment (Figure 9).

Correlation between SH and LH transfers and the average air temperature at the different tropospheric levels in summer showed no significant effect of sensible heat transport on the summer temperature almost in the entire troposphere in the area 70°–90°N. The latent heat (water vapour) transport and average air temperature are significantly negatively correlated at the lower levels (Figure 10a). This is caused by the increase in air temperature and water vapour content in the 70°–90°N area and growth of meridional
component of the wind from the Arctic through the Atlantic gate (Figures 10b and 11).

Integral influx of water vapour through the “wall” at 70°N latitude to the area of 70°–90°N significantly affects the content of water vapour and air temperature in this area only in the cold part of the year (Figure 3h,i).

At the same time, the integral water vapour transfer through 70°N and the water vapour content are largest in summer. This means that in summer there is an additional influx of water vapour from the melting snow and ice and from increasing area of open water. As a result, the water vapour content in the Arctic in summer grows in the lower layer of the troposphere. The latter is consistent with the model results (Vavrus et al., 2011) on the increase in the lower cloudiness due to more intense evaporation during summer sea ice reduction, while at the medium and high levels cloudiness increases as a result of enhanced meridional moisture transfer from the lower latitudes. But the inflow of water vapour in the upper layers of the troposphere, where water vapour is converted to frozen water, does not affect the integral content of water vapour and the near-SAT. We note that the multiyear changes in the integral transport of water vapour in summer do not show a positive trend, in contrast to its integral content.

3.5 | Heat and moisture transport and longwave radiation at the surface

The DLR in winter is the main way of delivering advective heat to the snow and ice surface (Ghatak and Miller, 2013;
Park et al., 2015; Boisvert et al., 2016; Cullather et al., 2016; Alexeev et al., 2017; Gong et al., 2017; Kim and Kim, 2017; Lee et al., 2017). Fluctuations in the average DLR in winter are largely determined by the inflow of SH and LH in the lower troposphere through the Atlantic gate. The correlation coefficient between the average DLR in the 70°/C14–90°/C14 N area and the heat inflows through the Atlantic gate at 1,000 hPa is 0.67 for SH and 0.74 for LH, which is close to the values of 0.62 and 0.80 found in the work (Kim and Kim, 2017) for the sector 0°–90°E; 70°–90°N when calculating with the vertically integrated transport. In winter 1980–2015, the average for the area of 70°–90°N, DLR and upwards longwave radiation (ULR) matches in with trends of 0.333 and −0.332 W m⁻² year⁻¹, respectively, with a zero trend of LRB. All trends are at the 99% level and are of significance, according to the Fisher test.

In summer, the integral influence of advective heat and moisture inflows on DLR in the Arctic is not revealed: the
correlation (Table 1) between DLR averaged over the area of 70°-C14–90°C14 N and transport through latitude 70°C14 N in 1979–2015 is weak and negative.

Negative correlation between mean DLR and advective heat and moisture inflows is consistent with the above-established negative correlation between influxes and air temperature and with increase of water vapour content in the lower troposphere due to summer melting. The correlation coefficient between DLR and SAT, both averaged over the area of 70°-C14–90°C14 N, is 0.84 (in winter 0.97), and between the mean ULR and SAT −0.93 (in winter −0.99). In summer, the average DLR in the considered area is increasing (trend 0.222 W m⁻² year⁻¹), but more slowly than in winter (0.333 W m⁻² year⁻¹), and balance of longwave radiation decreases (trend 0.156 W m⁻² year⁻¹) due to weaker summer SAT growth (trend 0.0229 K/year) compared to the winter SAT growth (trend 0.0897 K/year). All trends are at the 99% level and are of significance, according to the Fisher test.

We use temperature, downwards and upwards longwave radiation, water vapour content values averaged over the region of 70°–90°N, which at certain points can be nonlinearly interconnected, and find significant connections

TABLE 1 Correlation between sensible heat (SH) and latent heat (LH) transport through 70° N latitude and average DLR on the surface in the area 70°–90° N in summer for 1979–2015 (significant coefficients are bolded). Winter correlations are indicated by slashes.

| Flux        | Through | Correlation coefficient |
|-------------|---------|-------------------------|
| SH          | 70°N wall | −0.01/0.29              |
| LH          | 70°N wall | −0.36/0.68              |
| SH          | 0–80°E sector at 70°N wall | −0.26/0.59              |
| LH          | 0–80°E sector at 70°N wall | −0.22/0.50              |
| Transport at 1,000 hPa |         |                         |
| SH          | 70°N wall | −0.09/0.67              |
| LH          | 70°N wall | −0.39/0.63              |
| SH          | 0–80°E sector at 70°N | −0.32/0.68              |
| LH          | 0–80°E sector at 70°N | −0.38/0.74              |
TABLE 2  Trends of the integral content (WVC, kg m\(^{-2}\) year\(^{-1}\)), transport (WVT, kg m\(^{-1}\) s\(^{-1}\) year\(^{-1}\)) of water vapour to the area of 70\(^{\circ}\)–90\(^{\circ}\)N, and SIE in the Arctic Ocean (SIE, 10\(^{3}\) km\(^{2}\)/year) for 1979–2014. Significant trends are highlighted in bold

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|
| WVC   | 0.011 | 0.005 | 0.004 | 0.014 | 0.018 | 0.027 | 0.028 | 0.037 | 0.022 | 0.016 | 0.014 | 0.013 |
| WVT   | 0.022 | −0.013 | 0.004 | 0.020 | 0.012 | 0.007 | −0.016 | −0.001 | −0.010 | −0.002 | 0.046 | 0.021 |
| SIE   | −25.4 | −23.45 | −18.58 | −17.84 | −21.07 | −39.34 | −64.3 | −71.89 | −84.87 | −75.05 | −42.46 | −30.29 |

TABLE 3  Correlation between SIE in the Arctic Ocean, the integral content of water vapour (WVC), and DLR at the surface in the 70\(^{\circ}\)–90\(^{\circ}\)N area in different months for 1979–2014

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|-------|---|---|---|---|---|---|---|---|---|----|----|----|
| WVC   | −0.60 | −0.53 | −0.28 | −0.53 | −0.47 | −0.66 | −0.69 | −0.63 | −0.59 | −0.50 | −0.49 | −0.68 |
| DLR   | −0.65 | −0.59 | −0.44 | −0.62 | −0.53 | −0.57 | −0.82 | −0.73 | −0.82 | −0.75 | −0.71 | −0.72 |

TABLE 4  Correlation between the integral content of water vapour and DLR on the surface both averaged over the region of 70\(^{\circ}\)–90\(^{\circ}\)N

| Month | 6 | 7 | 8 | 9 |
|-------|---|---|---|---|
| Coeff. | 0.88 | 0.77 | 0.94 | 0.89 |

between them. To confirm the acceptability of this approach, the ratio between the average temperatures in the region in summer and winter, which are found in the average ULR is compared with the ratio between the average temperatures in the region in summer and winter. From the ratio of ULR average values in summer and winter ULR\(_s\)/ULR\(_w\) = \((\sigma T^4)\)_s/\((\sigma T^4)\)_w, the ratio between \(T_s/T_w = 1.0973\) follows, which practically coincides with the ratio between the average summer and winter SAT in this area, which is 1.1014. This coincidence confirms the acceptability of comparisons between the region-averaged characteristics of longwave radiation on the surface, advective inflows and SAT.

3.6 Amplification of summer SIE shrinking

Long-term changes in the total water vapour content in the arctic atmosphere show an increase in all months of the year with a maximum trend in August, while the integral transport of water vapour through 70°N in the summer months does not increase (Table 2). Earlier this was noted in the paper (Dufour et al., 2016) for the whole year. Recently Gimeno-Sotelo et al. (2018) found a general decrease in moisture transport in summer and enhanced moisture transport in autumn and early winter, with different contributions depending on the moisture source and ocean subregion.

In the summer months, there is an accelerated reduction in SIE (Table 2), which affects the increase in the water vapour content in the summer months and, as a consequence, the DLR (Table 3).

As noted above, water vapour transport through 70°N in summer, practically does not act the water vapour content and, consequently, the DLR, which is closely related to the water vapour content (Table 4).

Since the summer reduction in SIE leads to an increase in the content of water vapour and DLR, it is possible to estimate the inverse effect of this process on increasing the reduction in SIE from the formula obtained in the linear approximation of the dependencies between \(S, R,\) and \(Q\).

\[
\Delta S_R = \Delta S \rho_{SR} \frac{\sigma_S}{\sigma_R} \rho_{RQ} \frac{\sigma_R}{\sigma_Q} \rho_{SQ} \frac{\sigma_Q}{\sigma_S} \Delta S,
\]

whence we obtain

\[
\Delta S_R = \rho_{SR} \rho_{RQ} \rho_{SQ},
\]

where \(\rho\) are the correlation coefficients between the ice area \(S\), the DLR at the surface \(R\) averaged over the 70°–90°N, the integral content of water vapour in the atmospheric column \(Q\) averaged over the 70°–90°N area. The values of the coefficients \(\rho\) are given in Tables 3 and 4.

The results of calculations by the formula are given in Table 5.

The data of the table show that the reduction in SIE in the summer is substantially accelerated due to the growth of the water vapour content and DLR.

4 Conclusion

Winter atmospheric transport of sensible and latent heat is equally important for the variability of the mean SAT in the Arctic north of 70°N if one takes into account that the main transport passes through the Atlantic gate between 0° and 80°E and that the inflow occurs at the lower levels up to 700 hPa. Atmospheric transport from the North Pacific through the Pacific gate has an incomparably lower influence on the average air temperature in the area of 70°–90°N in winter.

The contribution of the sensible heat influx cannot be detected if the inflow is calculated through the 70°N as a whole. The reason is that in this case large contribution to
the overall influx is made by the arrival of cold air from Eurasia through 70°N between 80° and 150°E. But this inflow does not have a noticeable effect on the average air temperature in the area of 70°–90°N due to the flux of heat from the coastal polynyas and the Great Siberian polynya to the north of the fast ice in the Laptev and East Siberian seas in winter. Influxes of heat from polynya in the Arctic reach 700–1,000 W/m² (Maykut, 1978; Makashtas, 1991; Gultepe et al., 2003).

Calculations of transports from control and RCP8.5 scenario experiments with the global climate model MPI-ESM-MR from CMIP5 ensemble also showed the largest in winter transport to the Arctic in the lower troposphere through the Atlantic gate and the distribution of the effect of transports on the air temperature similar those established with the use of ERA-Interim data.

In summer, the direction of the average heat transport through the 70°N and Atlantic gate is opposite to direction of the winter transport. In this case, summer transport does not affect SAT in the Arctic, although the summer integral inflow of moisture through the 70°N to the Arctic is much larger than the winter one. However, this inflow has not increased during the period 1979–2015, in contrast to the total moisture content in the atmosphere, which increases due to evaporation from the surface of melting snow and ice and increasing open water area. The inflow of water vapour in the upper layers of the troposphere, where water vapour turns into frozen water, does not affect the integral content of water vapour and SAT in the Arctic.

In the lower troposphere, the outflow of moisture from the Arctic increases, especially through the Atlantic gate, and this is balanced by an influx in the upper layers. Such a change in the direction of transports was also shown by the data from experiments with the global climate model MPI-ESM-MR.

The main way of delivering advective heat to the surface of snow and ice in winter is DLR on the surface. Here it was found that the averaged over the whole area 70°–90°N DLR at the surface is largely determined by the transport of SH and LH in the lower troposphere through the Atlantic gate and is closely related (correlation coefficient 0.97) with fluctuations in the mean SAT during 1980–2015 in winter.

In summer, the influence of mean advective heat and moisture inflows on DLR is not revealed: the correlation between DLR (averaged over the area 70°–90°N) and integral transport through 70°N latitude for 1979–2015 is weak and negative. This correlation is consistent with negative correlation between influxes and SAT and with increasing water vapour content in the lower troposphere due to summer melting.

It is found that the relative part of the anomaly of SIE in the Arctic Ocean due to the feedback “reduction in SIE–increase in water vapour content—an increase in DLR–reduction of SIE” in the summer months (June–September) is up to 40%. These estimates are consistent with the obtained (Francis et al., 2005), the conclusion that up to 40% of the interannual variability of the summer SIE in the Arctic seas is due to the effect of anomalies of DLR.

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