



Supplement of

Warm and moist air intrusions into the winter Arctic: a Lagrangian view on the near-surface energy budgets

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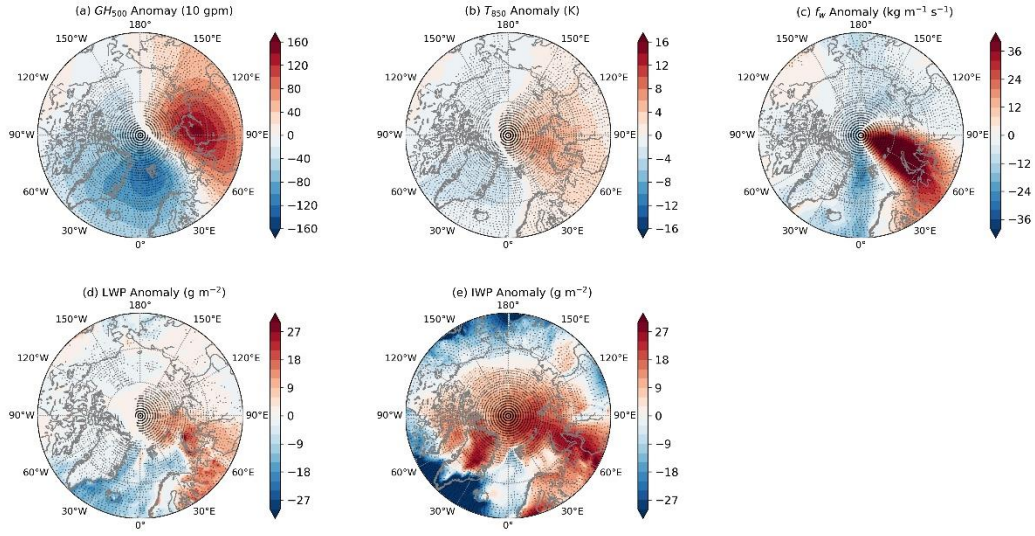


Figure S1. Composite ERA5 anomalies of (a) 500-hPa GH (10 gpm), (b) 850-hPa temperature (K), (c) northward water-vapor flux ($kgm^{-1}s^{-1}$), (d) liquid water path ($g m^{-2}$), and (e) ice water path for all EMIs over the Kara Sea, during 1979~2018 winters. The stippling indicates statistical significance at the $p < 0.01$ level from a Student's t test.

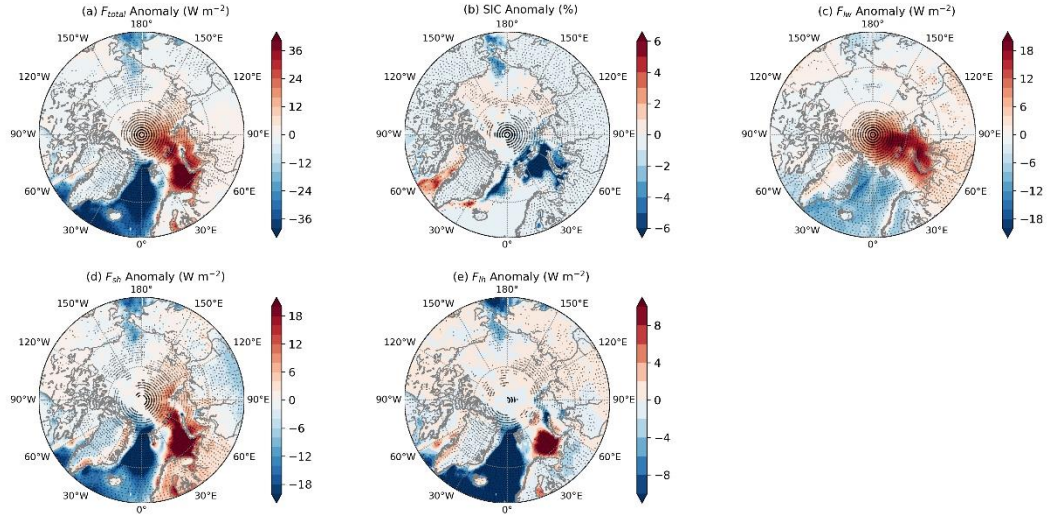


Figure S2. Composite ERA5 anomalies of (a) total surface energy ($W m^{-2}$), (b) sea ice concentration (%), (c) surface thermal net irradiance ($W m^{-2}$), (d) surface sensible heat flux ($W m^{-2}$) and (e) surface latent heat flux ($W m^{-2}$) for all EMIs over the Kara Sea, during 1979~2018 winter. The stippling indicates statistical significance at the $p < 0.01$ level from a Student's t test.

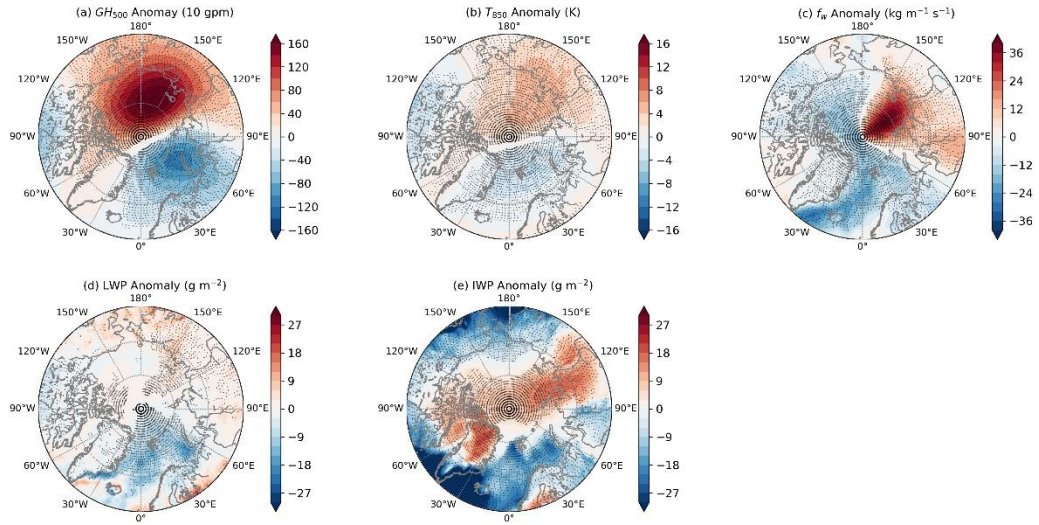


Figure S3. Same as figure S1 but for the Laptev Sea.

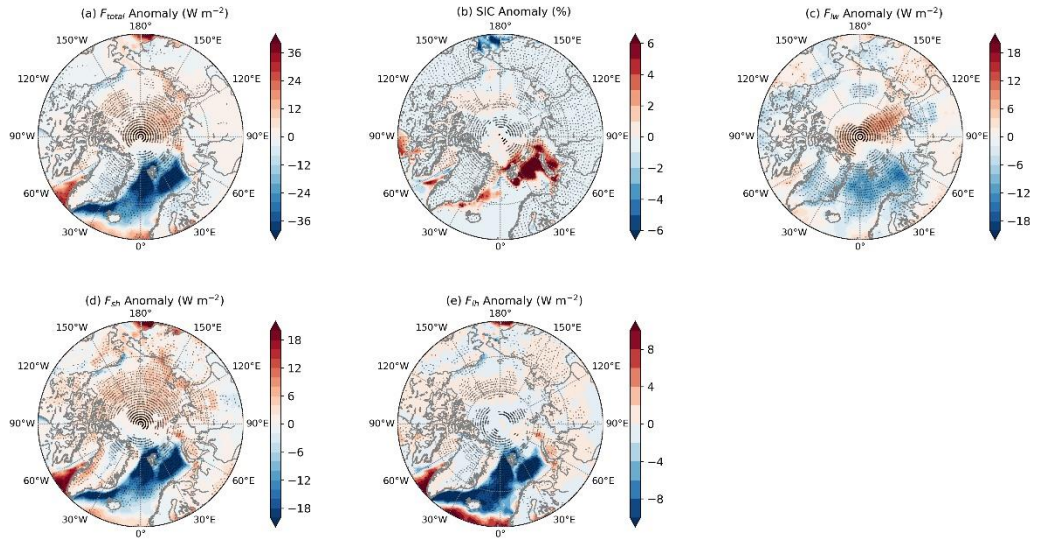


Figure S4. Same as figure S2 but for the Laptev Sea.

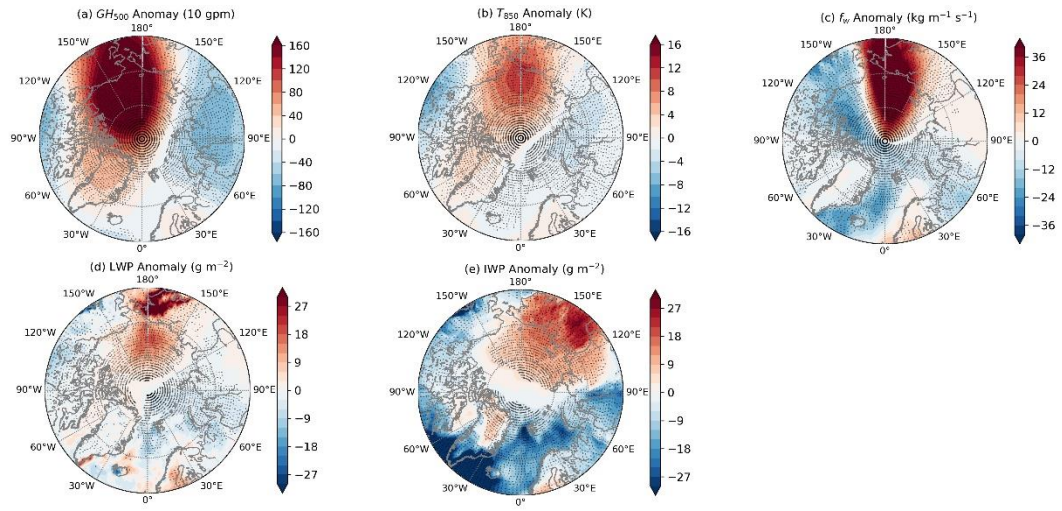


Figure S5. Same as figure S1 but for the East Siberian Sea.

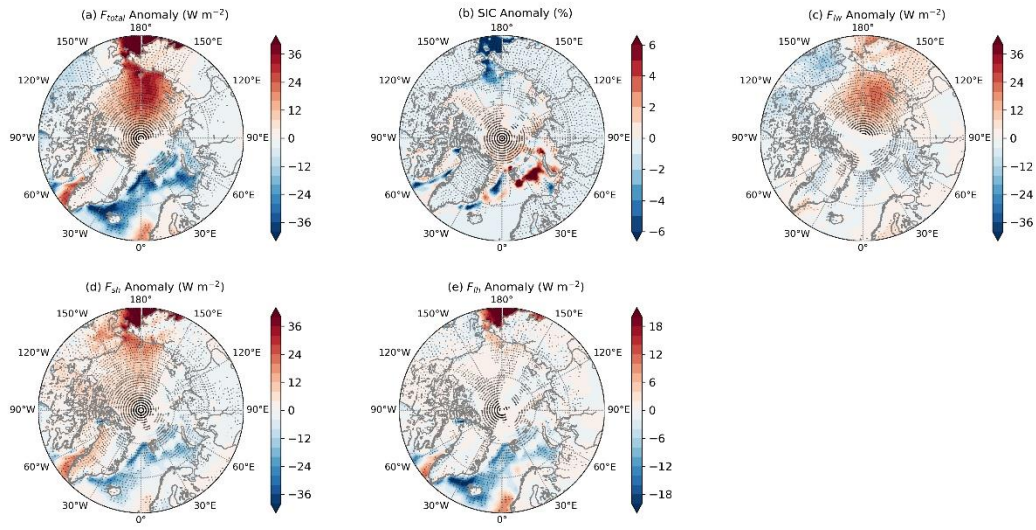


Figure S6. Same as figure S2 but for the East Siberian Sea.

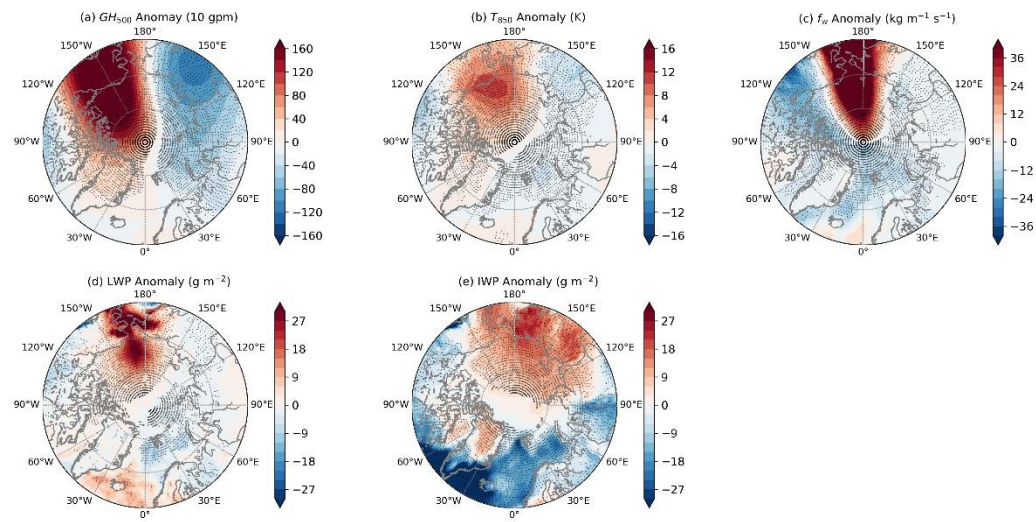


Figure S7. Same as figure S1 but for the Chukchi Sea.

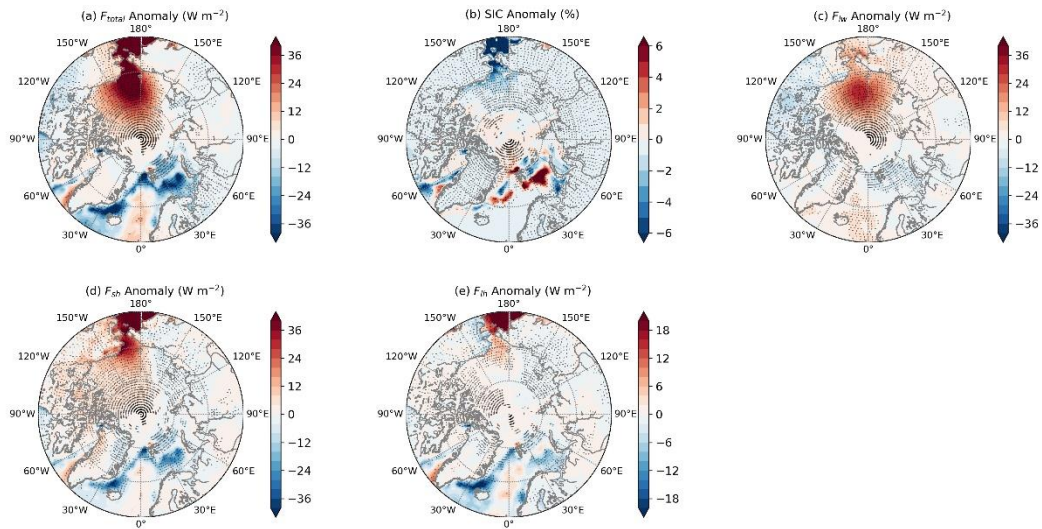


Figure S8. Same as figure S2 but for the Chukchi Sea.

Table S1. Launch time and longitude of WaMAIs trajectories with boundary layer energy budget pattern of category RAD (radiation-dominated), TBL (turbulence-dominated), and TCD (turbulence-dominated with cold dome) over the Barents Sea.

Category RAD:

Time	Longitude
1984-02-01T00:00	3.0
1984-12-18T12:00	4.5
1985-01-01T00:00	3.0
1990-02-06T00:00	33.0
1995-12-03T06:00	9.75
2001-01-31T00:00	8.25
2005-01-29T00:00	4.5
2006-01-24T00:00	31.5
2018-02-25T12:00	1.5

Category TBL:

Time	Longitude	Time	Longitude	Time	Longitude
1979-12-20T06:00	6.0	1999-12-28T06:00	9.75	2008-02-07T06:00	3.0
1980-01-12T00:00	9.75	2001-02-13T12:00	30.75	2008-12-24T18:00	6.75
1981-02-17T18:00	3.75	2002-01-04T18:00	36.0	2009-01-29T06:00	9.75
1984-02-01T00:00	3.0	2002-01-06T12:00	4.5	2009-01-31T12:00	30.75
1984-02-11T18:00	30.75	2002-12-26T12:00	0.75	2009-12-12T18:00	1.5
1989-12-27T06:00	30.75	2004-12-06T06:00	9.75	2011-02-27T00:00	31.5
1990-01-07T12:00	3.0	2004-12-30T00:00	30.75	2012-01-27T12:00	6.75
1990-01-22T00:00	1.5	2005-01-25T18:00	31.5	2013-01-06T06:00	7.5
1990-12-24T06:00	9.75	2005-12-21T12:00	0.75	2013-12-19T12:00	9.75
1994-02-13T00:00	9.75	2005-12-26T12:00	9.75	2014-02-12T12:00	9.75
1996-01-19T06:00	9.75	2006-01-04T12:00	9.75	2015-12-29T12:00	3.0
1996-02-21T18:00	8.25	2006-01-08T12:00	9.75	2016-01-03T06:00	9.75
1997-02-18T12:00	9.0	2006-01-11T06:00	30.75	2016-02-15T18:00	9.75
1997-12-13T18:00	6.75	2006-01-18T18:00	2.25	2016-12-17T18:00	4.5
1997-12-14T18:00	48.0	2007-02-19T06:00	0.75	2017-01-16T12:00	5.25

Category TCD:

Time	Longitude	Time	Longitude	Time	Longitude
1982-12-31T06:00	30.75	1996-02-04T18:00	3.0	2008-01-02T06:00	9.75
1984-01-22T12:00	0.75	1999-01-29T18:00	9.0	2008-12-10T12:00	9.0
1984-12-30T06:00	9.75	2001-01-13T00:00	31.5	2009-02-18T00:00	9.75
1985-01-12T06:00	30.75	2001-01-23T06:00	9.75	2012-02-08T18:00	30.75
1986-12-13T06:00	0.75	2002-12-03T12:00	30.75	2012-12-30T18:00	8.25
1988-01-18T18:00	39.75	2003-02-17T18:00	4.5	2015-01-21T18:00	3.75
1988-02-17T06:00	5.25	2005-02-15T12:00	30.75	2015-02-04T18:00	6.75
1990-01-02T06:00	6.75	2005-12-06T06:00	6.0	2016-01-24T12:00	5.25
1991-12-07T18:00	9.75	2005-12-29T18:00	5.25	2016-12-14T12:00	4.5
1992-01-20T12:00	35.25	2006-01-16T06:00	9.75	2017-02-04T00:00	30.75
1994-12-17T06:00	9.75	2006-12-26T06:00	35.25	2017-12-18T06:00	30.75

Table S2. Launch time and longitude of WaMAIs trajectories over the land-locked Sea sectors (red for Beaufort Sea sector, black for East Siberian Sea sector, Green for Laptev Sea sector and purple for the Chukchi Sea sector).

Time	Longitude	Time	Longitude	Time	Longitude
1980-02-13T00	-146.25	1988-02-04T00	159.0	1980-12-02T00	-165.0
1980-02-15T06	-145.5	1991-01-01T12	152.25	1981-02-01T00	-158.25
1980-12-02T00	-147.0	1992-12-28T12	176.25	1981-12-09T00	-162.0
1981-01-27T18	-132.0	1993-02-05T12	165.0	1982-01-07T12	180.0
1982-01-21T12	-156.75	1993-02-13T12	171.75	1982-01-20T18	-176.25
1982-02-04T00	-144.75	1994-01-08T18	149.25	1983-12-21T18	-168.0
1983-12-20T12	-156.0	1994-02-02T00	175.5	1988-01-03T06	-164.25
1985-01-05T06	-137.25	1994-02-22T12	177.0	1988-01-06T00	-168.0
1987-12-03T12	-127.5	1995-01-07T12	180.0	1989-01-06T18	-165.0
1988-01-03T00	-155.25	1995-02-10T12	179.25	1989-02-08T12	-162.0
1989-01-06T18	-156.75	1995-02-14T06	149.25	1989-02-15T06	-156.75
1989-02-15T06	-156.0	1996-12-22T12	175.5	1989-02-20T00	-156.75
1989-02-20T00	-156.0	1997-01-26T12	160.5	1993-02-09T12	-156.75
1993-01-11T18	-150.75	1998-12-27T18	165.0	1994-02-02T06	-169.5
1993-02-09T18	-150.0	2000-12-14T18	168.0	1996-12-22T12	180.0
1994-02-03T00	-156.0	2002-01-18T18	180.0	2002-01-18T18	-174.0
1998-12-19T00	-147.0	2003-01-19T06	178.5	2003-01-11T18	-158.25
1999-01-25T00	-138.75	2003-01-26T00	171.75	2003-01-19T00	-179.25
2001-12-28T12	-127.5	2004-01-08T12	158.25	2004-01-01T18	-164.25
2003-01-11T18	-156.75	2004-01-26T12	180.0	2005-01-04T00	-156.75
2005-01-03T18	-143.25	2007-02-03T18	176.25	2006-02-16T18	-156.75
2006-02-16T18	-141.0	2007-02-08T12	180.0	2007-02-03T12	-177.0
2007-02-09T18	-152.25	2007-12-02T00	180.0	2007-12-01T12	-166.5
2008-12-18T12	-154.5	2008-12-19T06	180.0	2008-12-18T12	-156.75
2009-02-24T06	-152.25	2011-01-12T00	173.25	2009-02-23T18	-172.5
2010-01-26T06	-131.25	2013-12-11T06	160.5	2010-12-08T12	-175.5
2010-12-20T12	-127.5	2014-02-03T06	180.0	2014-02-02T12	-174.75
2011-01-05T00	-147.0	2014-02-07T06	163.5	2015-01-04T06	-171.75
2015-01-09T18	-156.75	2014-02-09T06	165.75	2016-01-06T18	-156.75

2016-01-06T18	-149.25	2015-01-04T12	177.75	2016-12-07T12	-178.5
2017-01-03T12	-129.75	2015-01-08T12	178.5	2017-01-08T12	-170.25
2017-01-29T18	-153.75	2016-02-02T18	174.0	2017-01-29T18	-156.75
2017-12-26T00	-152.25	2016-12-06T06	171.75	2017-12-24T12	-168.75
2019-02-11T12	-138.75	2016-12-09T12	178.5	2019-02-10T06	-160.5
1980-12-19T06	174.0	2017-01-08T12	178.5	2019-02-27T18	-161.25
1982-01-07T12	179.25	2017-12-24T12	180.0		
1982-01-20T12	178.5	2018-01-31T00	172.5		
1983-12-02T06	180.0	1984-12-31T00	138.75		
1983-12-08T06	180.0	1995-02-14T18	139.5		
1983-12-19T18	178.5	2000-12-10T12	139.5		
1983-12-25T06	171.75	2009-01-05T00	120.75		
1984-12-29T18	153.75	2014-12-05T12	115.5		
1988-01-11T00	180.0	1980-02-13T00	-156.75		