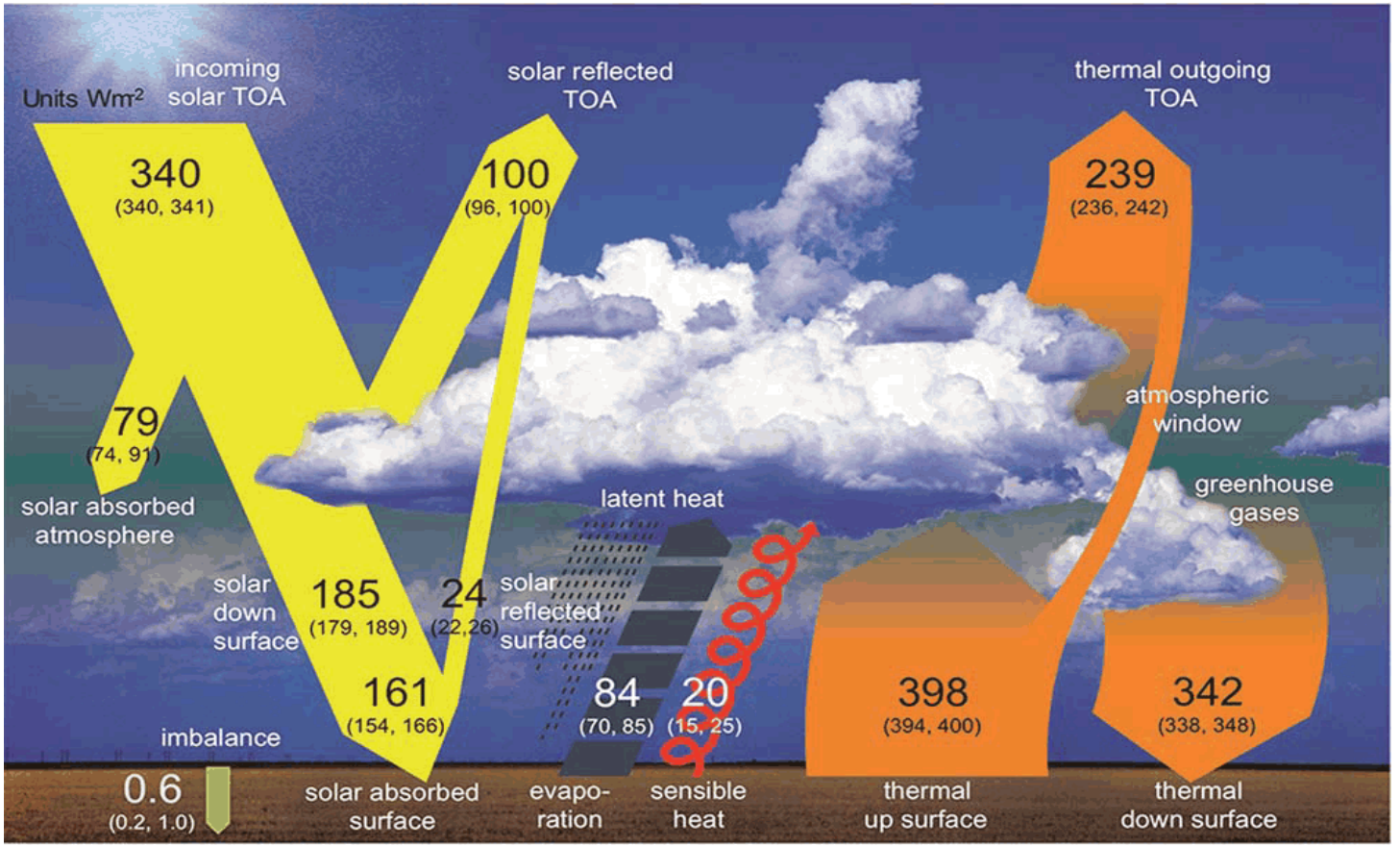
Valerio Lembo, Gabriele Messori, Rune Graversen, Valerio Lucarini

WAVE DECOMPOSITION OF MERIDIONAL ENERGY TRANSPORTS IN NORTHERN HEMISPHERE MIDLATITUDES

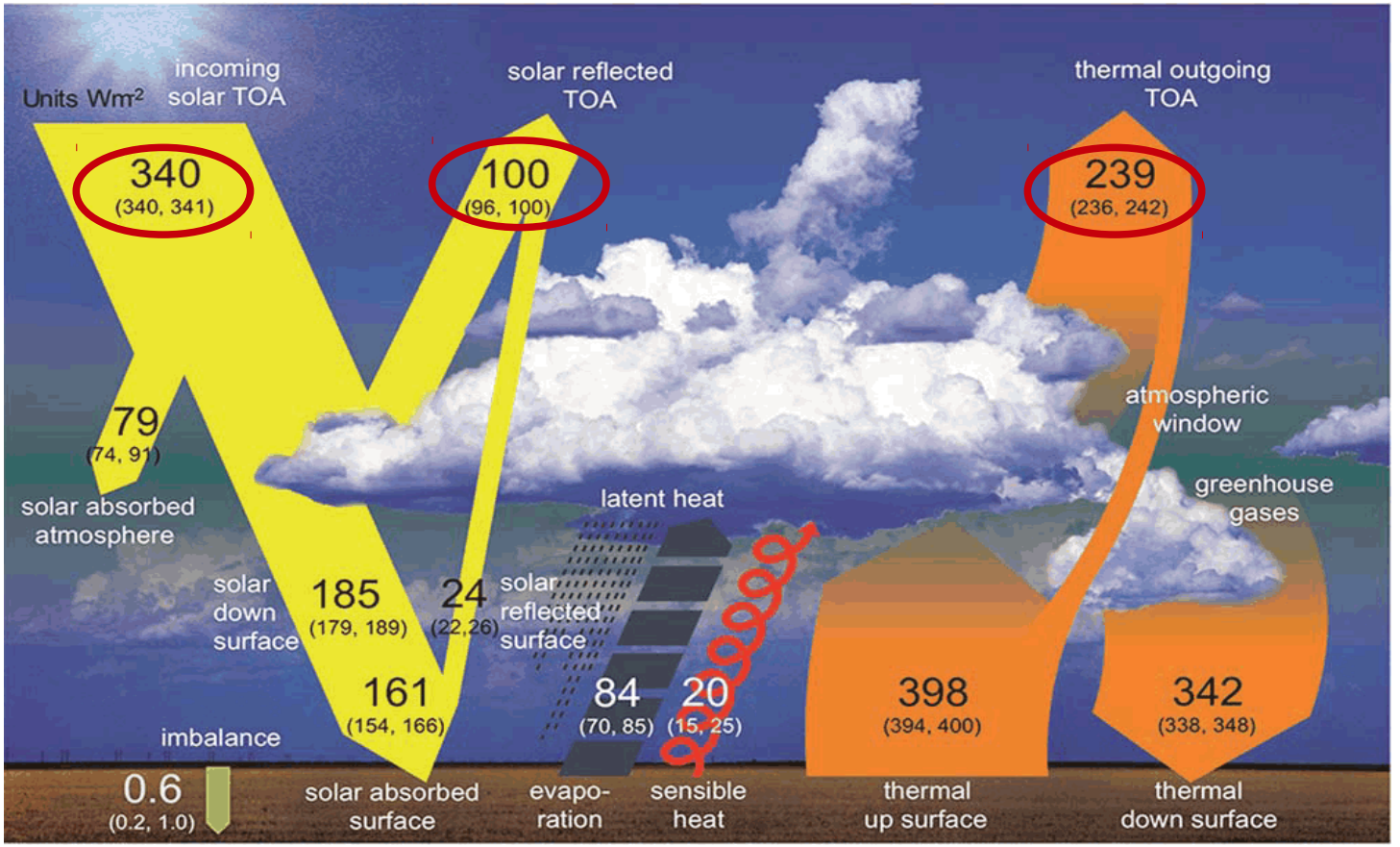
Hamburg, 05.04.2018

The radiative and heat budget



(Wild et al., 2013)

The radiative and heat budget



(Wild et al., 2013)

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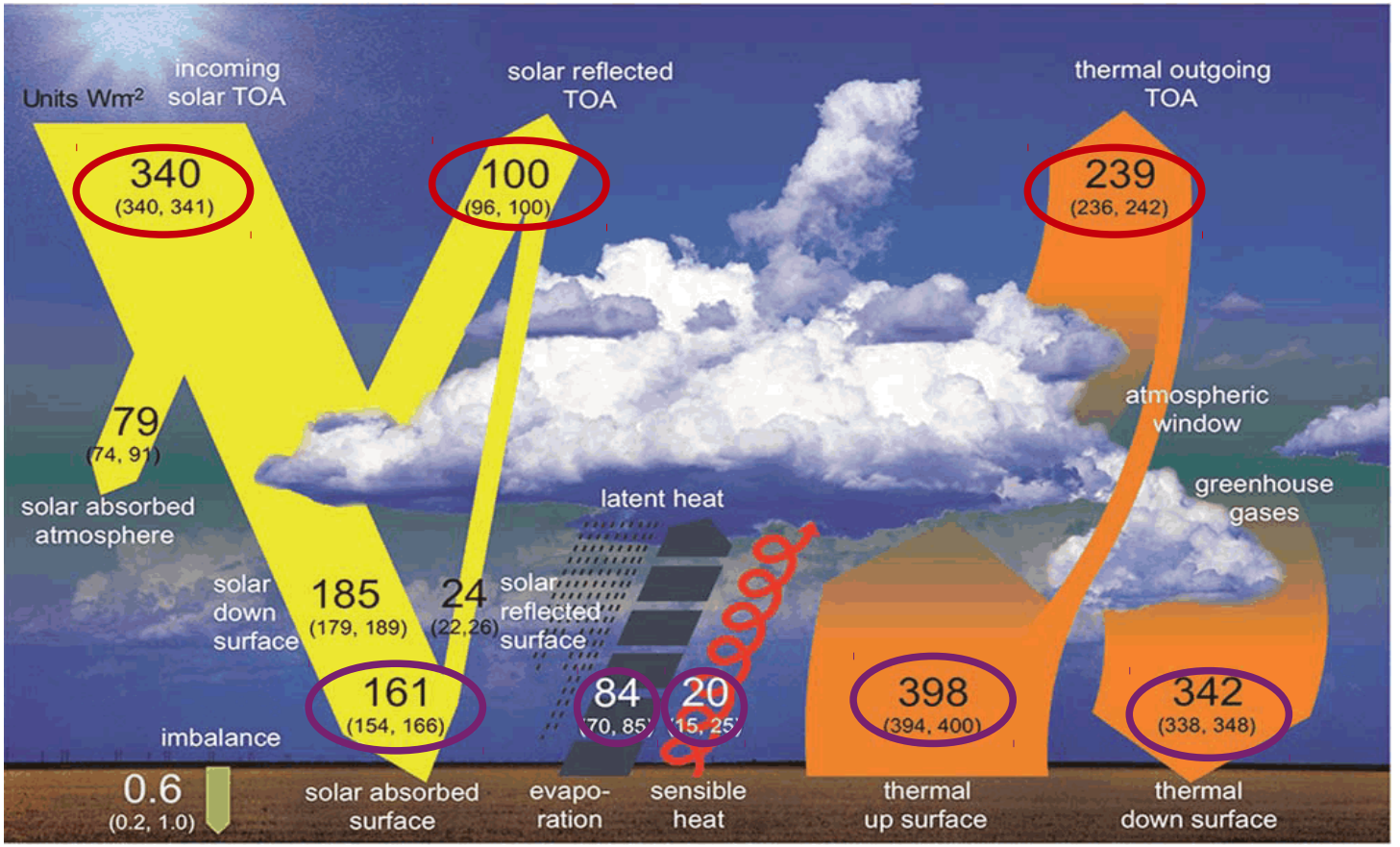
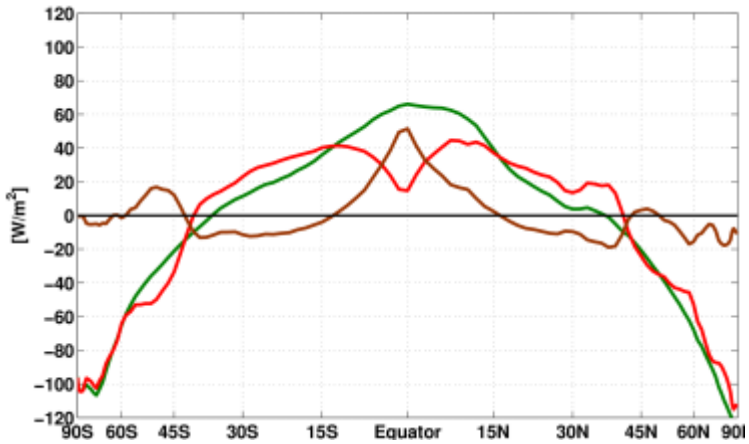


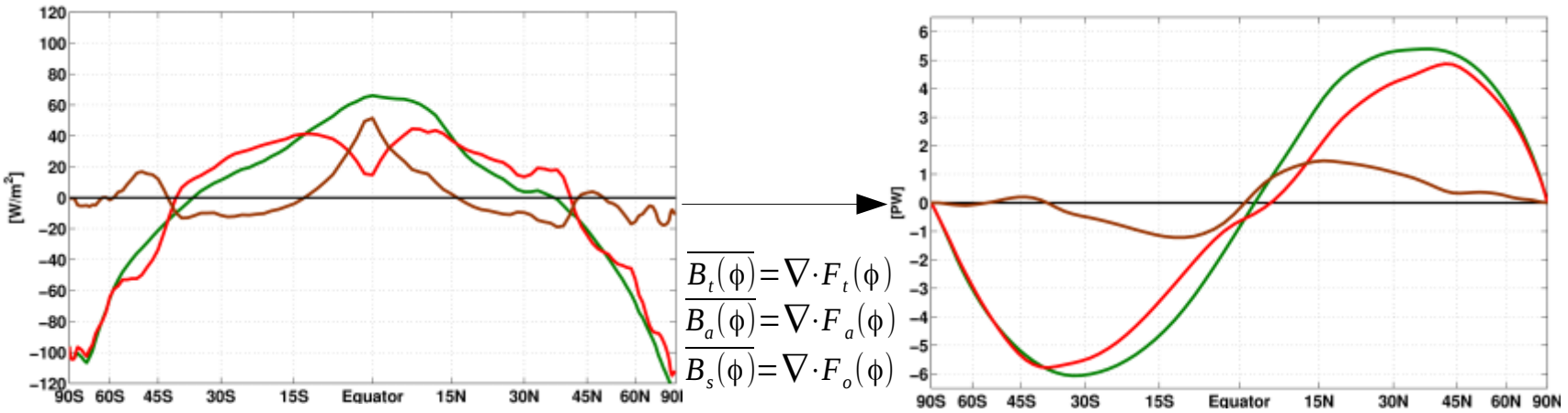
(Wild et al., 2013)

Differential heating...



(Lembo et al., 2016)

Differential heating... and meridional heat transports

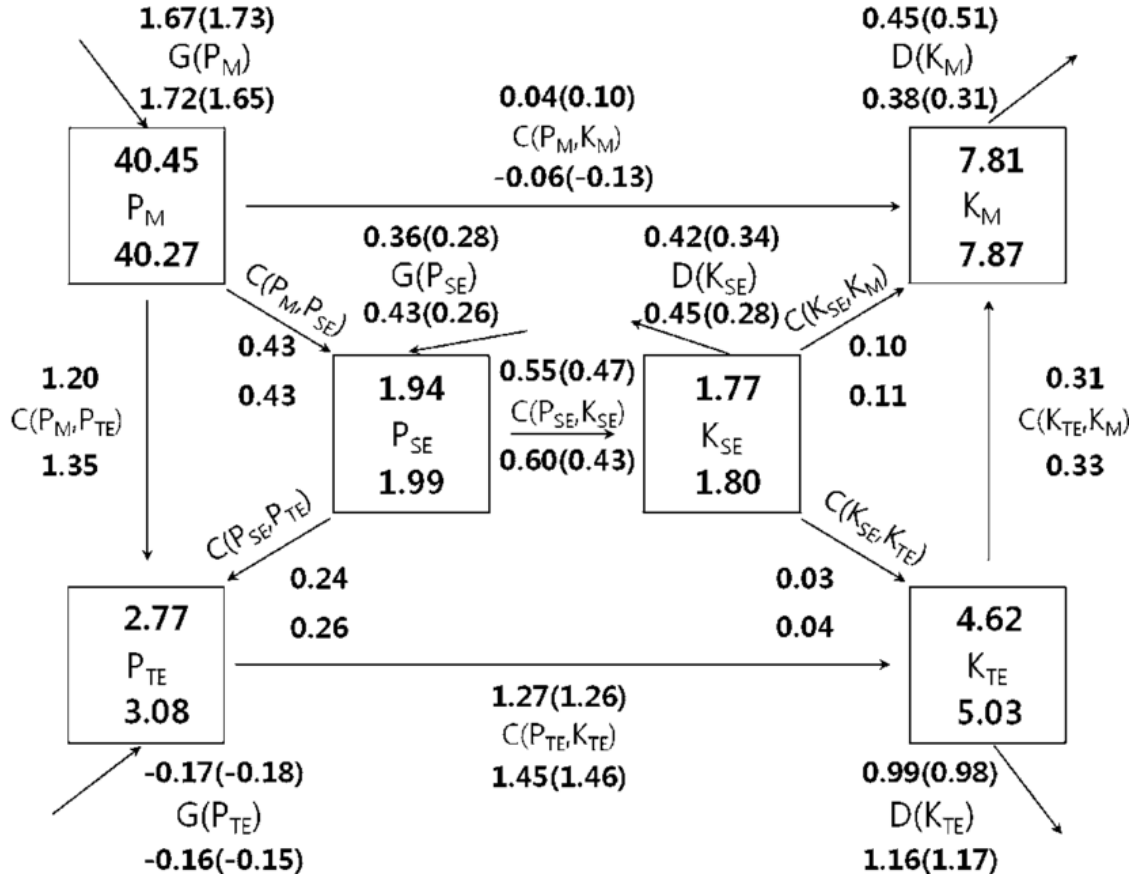


(Lembo et al., 2016)

	Tot. (NH)	Tot. (SH)	Atm. (NH)	Atm. (SH)	Oc. (NH)	Oc. (SH)
Intensity (PW)	5.9 +/-0.3	5.9+/-0.5	5.1+/-0.5	4.9+/-0.2	1.7+/-0.3	1.2+/-0.5
Location (φ)	35	-35	41	-41	15	-11

(Fasullo and Trenberth, 2008)

The Lorenz Energy Cycle



(Ulbrich and Speth, 1991; Kim and Kim, 2013)

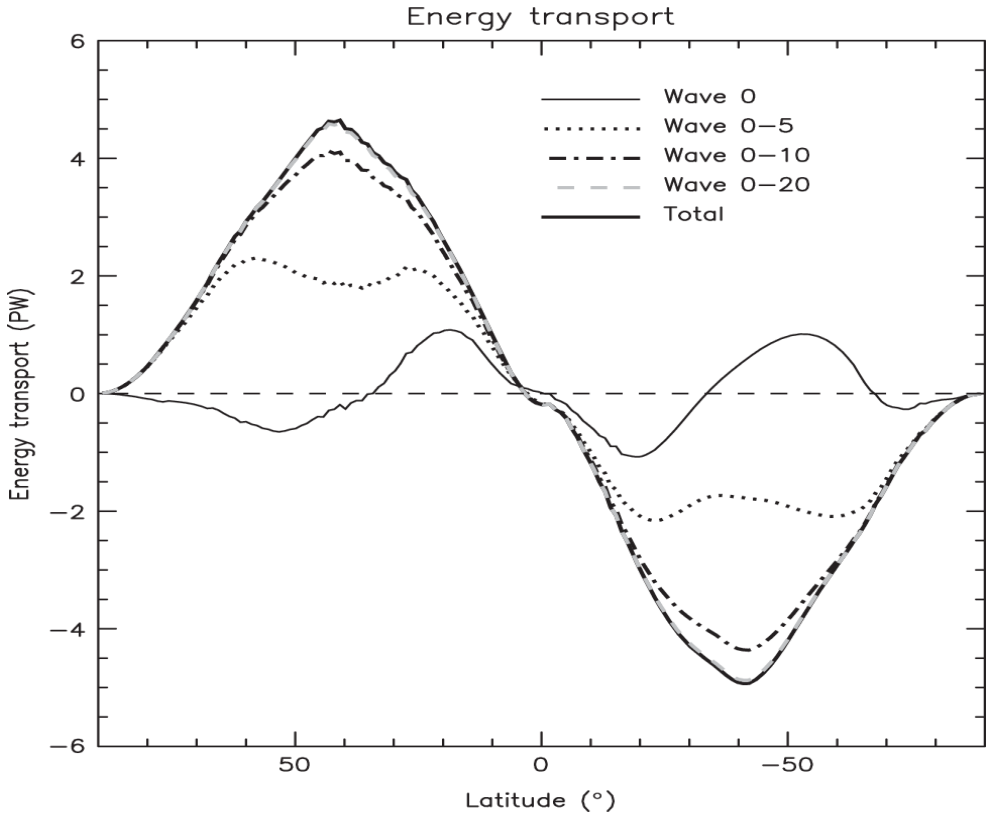
If we consider:

$$E(\Omega)=P(\Omega)+K(\Omega)$$

In the long-term mean the climate is a non-equilibrium dissipative steady-state system, i.e.:

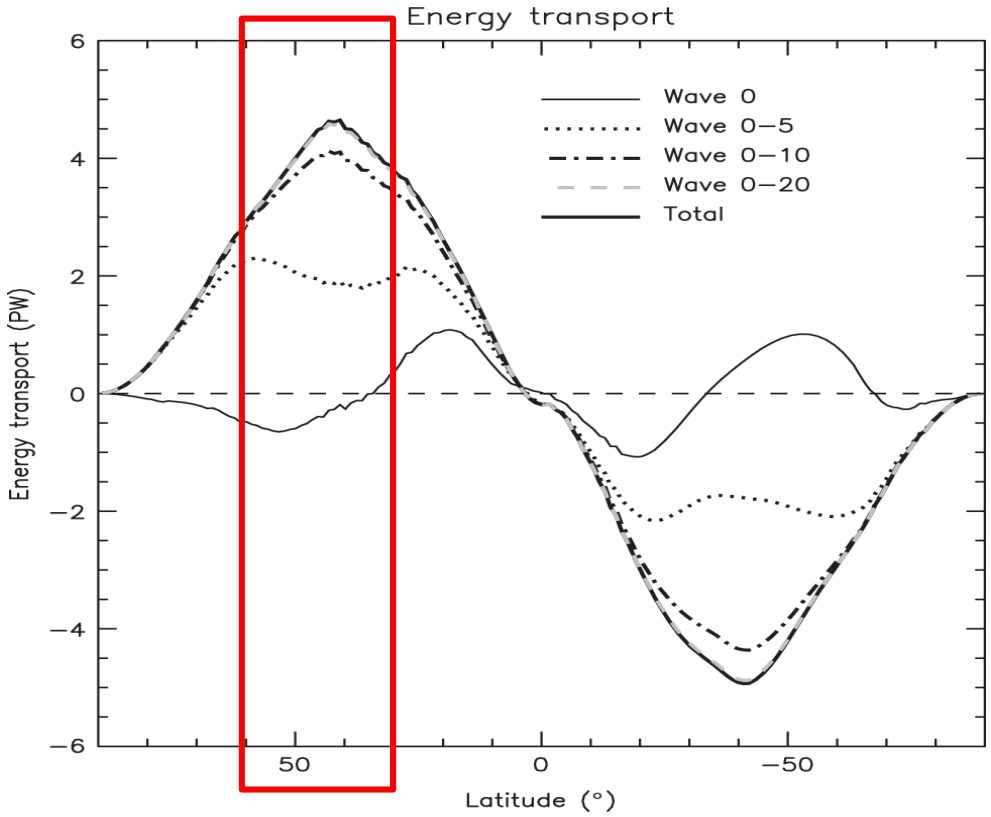
$$\overline{\dot{E}}=\overline{\dot{P}}=\overline{\dot{K}}=0$$

Decomposition of the atmospheric heat transport



(Graversen et al., 2016)

Decomposition of the atmospheric heat transport



(Graversen et al., 2016)

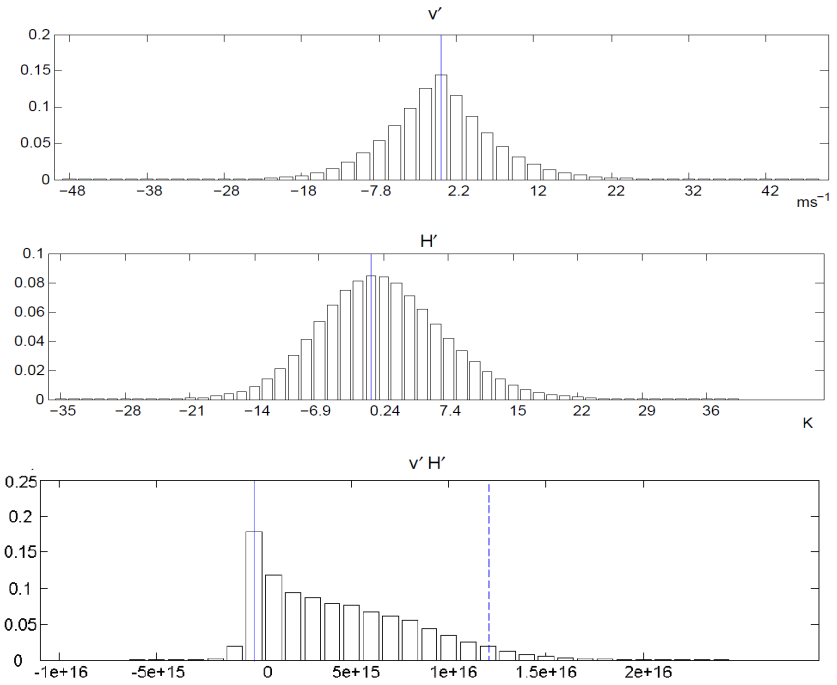
In the NH mid-latitudes (30-60) the first 10 wavenumbers contribute to nearly all the transport:

- Wave 0 (zonal mean): slightly negative

- Waves 1-5 (planetary waves): contributes nearly half of the transport;

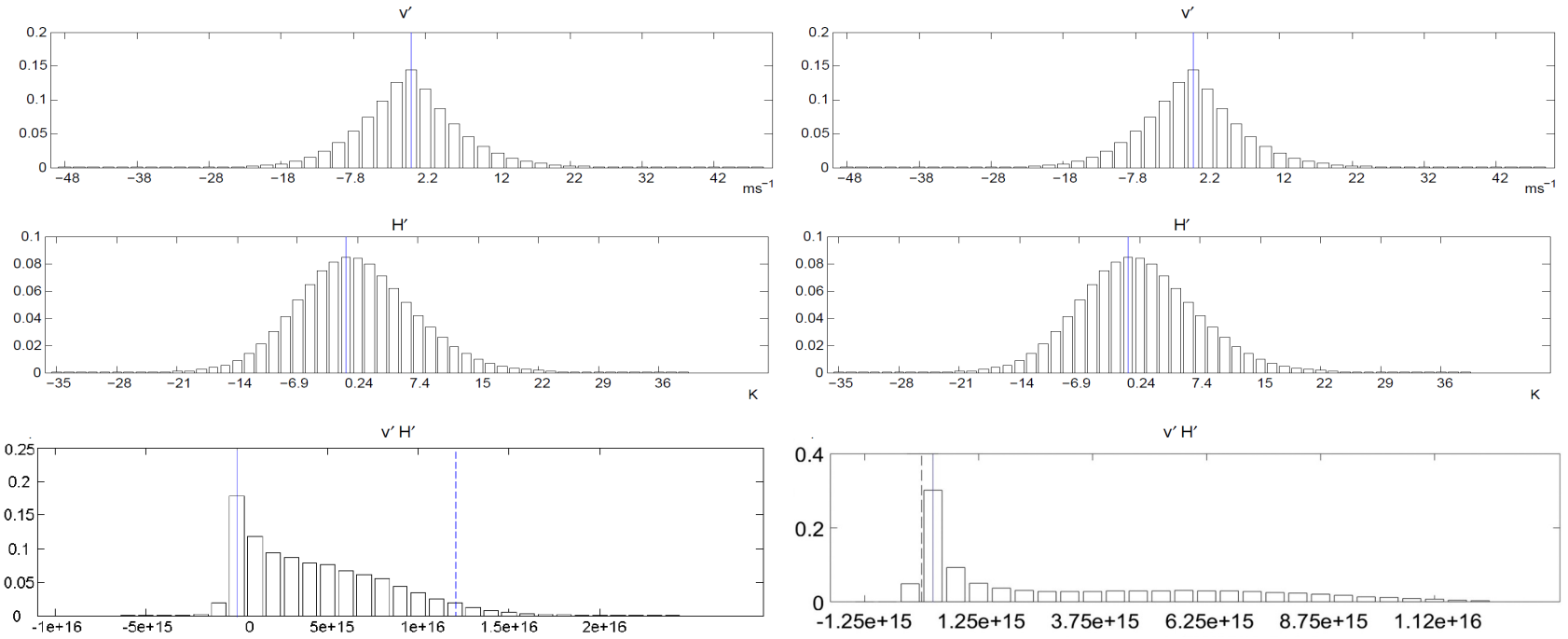
- Waves 6-10 (synoptic waves): set the peak of the transport;

The NH mid-latitudinal heat transports and its extremes



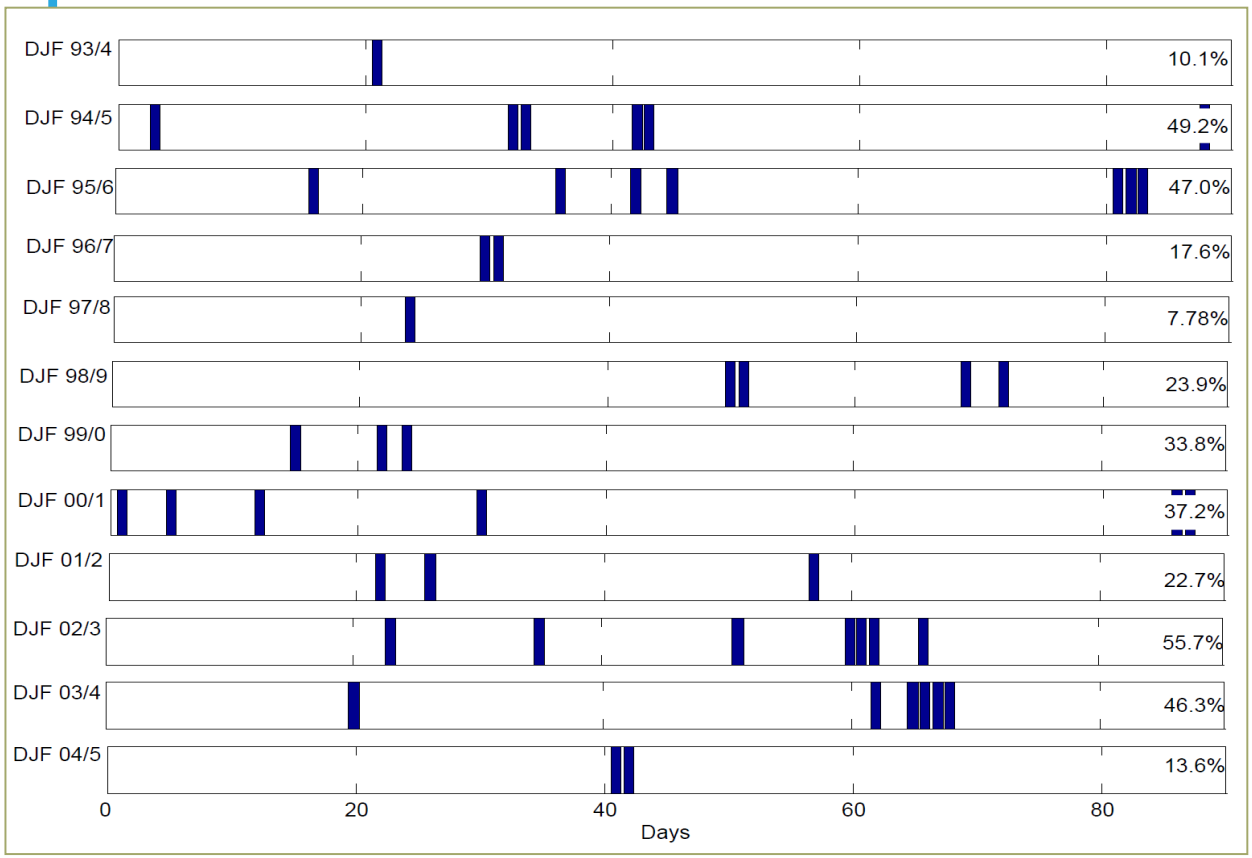
(Messori and Czaja, 2013; Messori and Czaja, 2015)

The NH mid-latitudinal heat transports and its extremes



(Messori and Czaja, 2013; Messori and Czaja, 2015)

Occurrence of top 5% percentile values at specific gridpoint



(Messori and Czaja, 2013)

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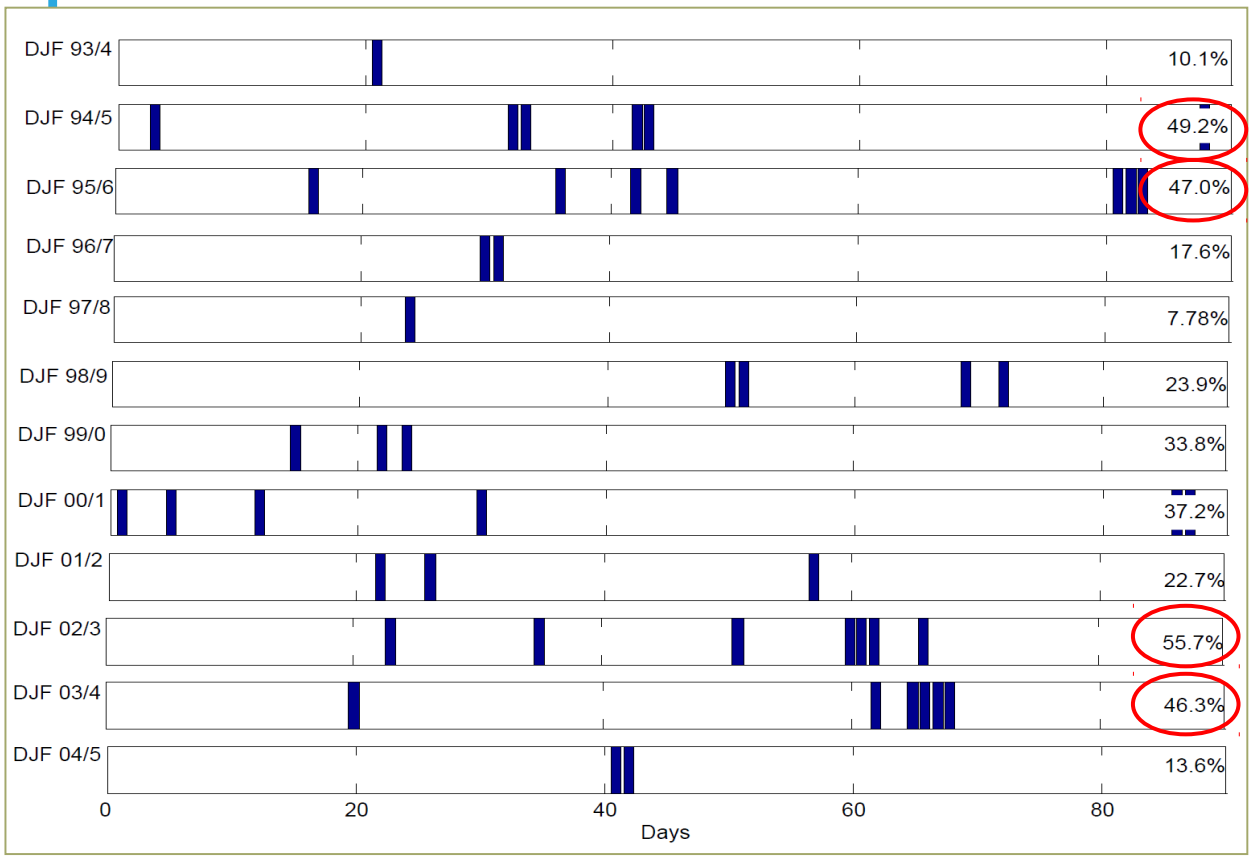


(Messori and Czaja, 2013)

Key questions

- Which wavenumbers are most relevant for the overall transport?

- What are the statistical properties of meridional heat transports across scales?
  - How do northward and southward extremes vary as a function of wavenumber?
  - Are statistical properties to some extent invariant?

- What is the seasonal variability of such transports and related properties?

Data

- ERA-Interim Reanalyses (1979-2012):
  - T255 horizontal resolution (approx. 0.5°);
  - 60 hybrid levels;
  - 6-hr time resolution;
  - Barotropic correction for mass-flux inconsistencies due to data assimilation;

Methods

- The computation of atmospheric energy results from the combination of a dry static, moist and kinetic component:

$$E = c_p T + gz + Lq + \frac{1}{2}\mathbf{v}^2$$

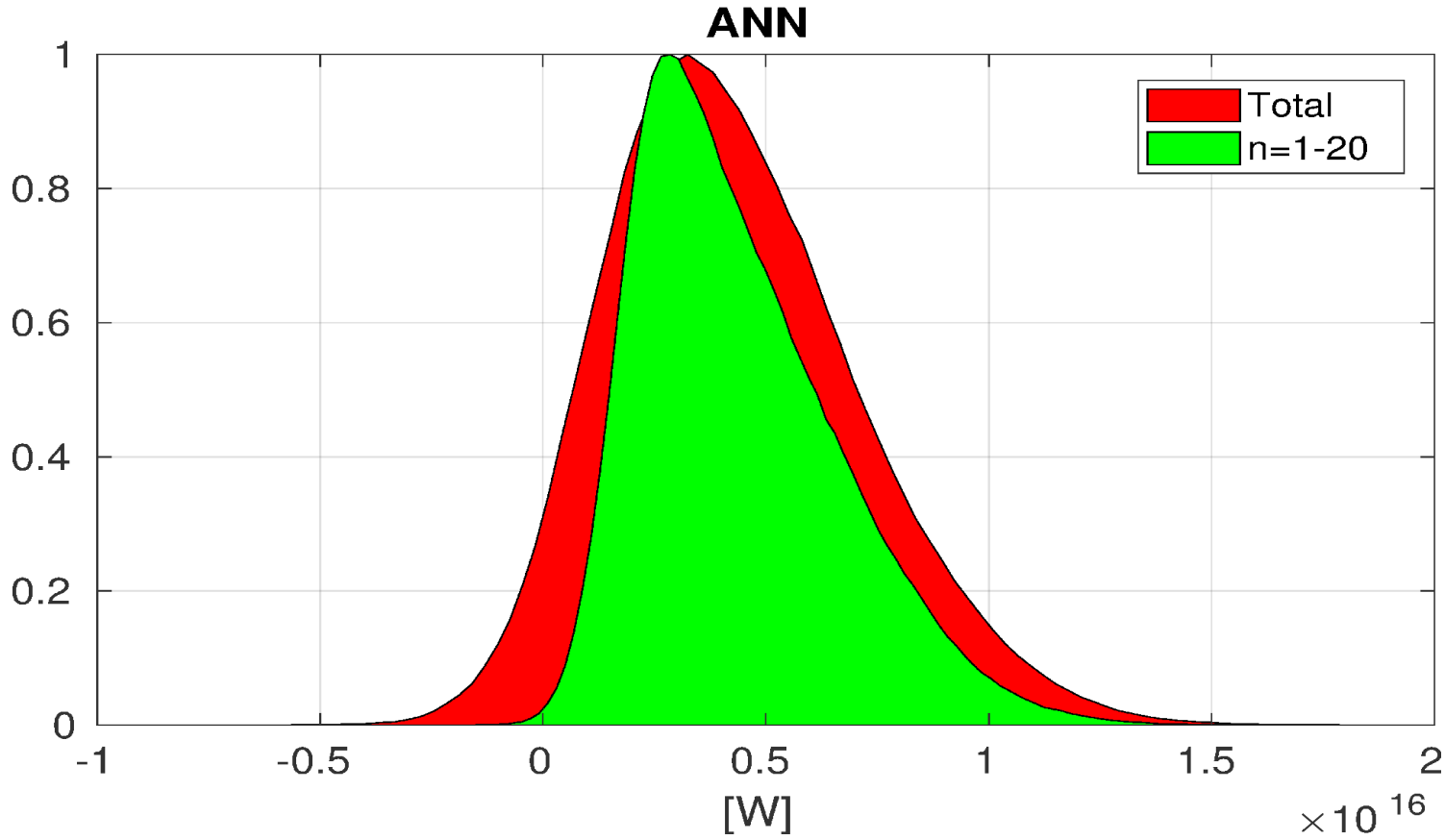
- The zonal integrated total meridional energy transport is thus:

$$vE(\varphi) = \oint \int_0^{p_s} vE \frac{dp}{g} dx$$

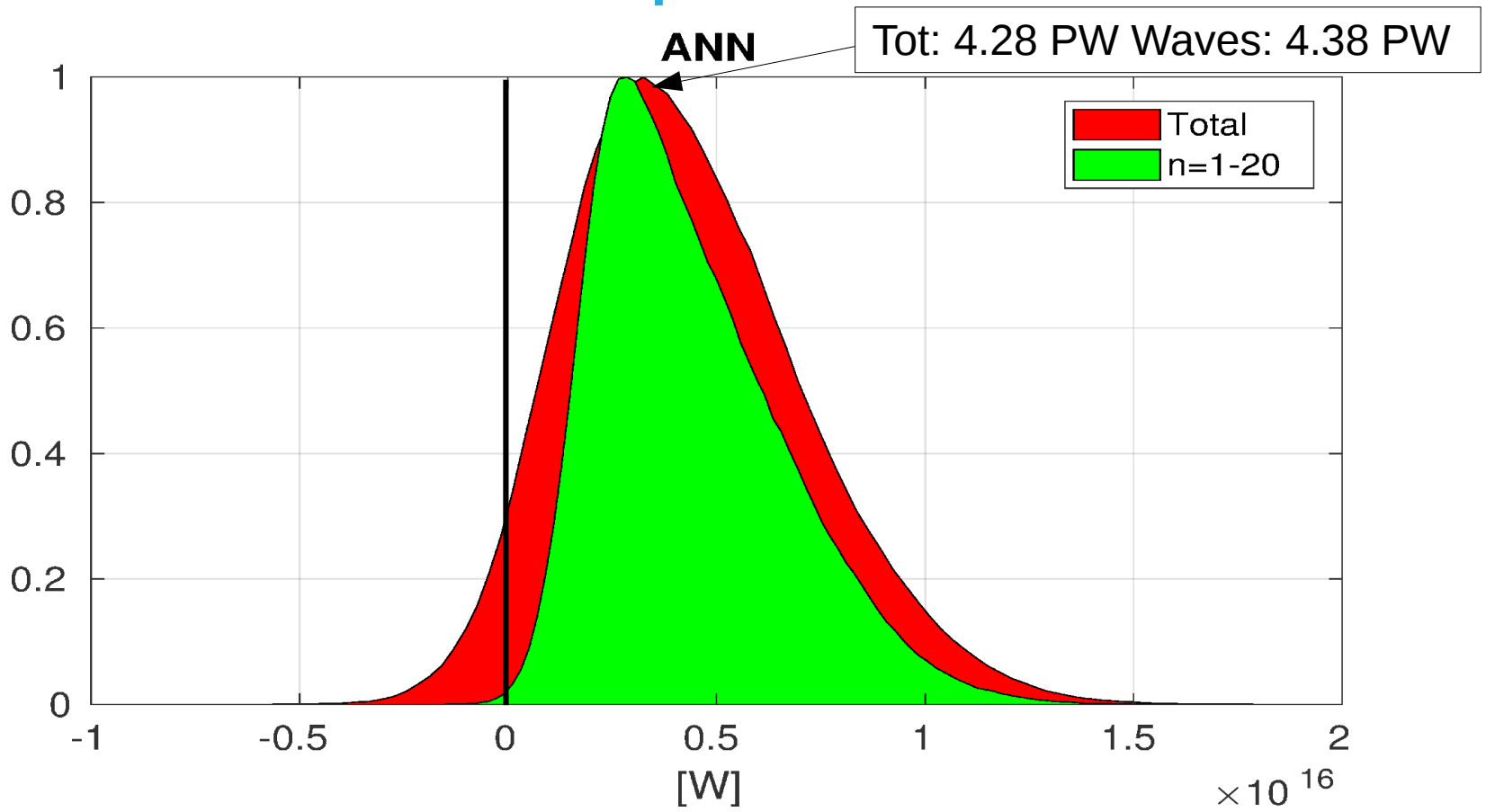
- The Fourier coefficients (a_n, b_n) are separately computed for meridional velocity and energy at every level, thus the energy transport for wavenumber n is retrieved as:

$$vE_n(\varphi) = d \sum_n \left\{ \int_0^{p_s} \frac{1}{2} \left(a_n^v a_n^E + b_n^v b_n^E \right) \frac{dp}{g} \right\}$$

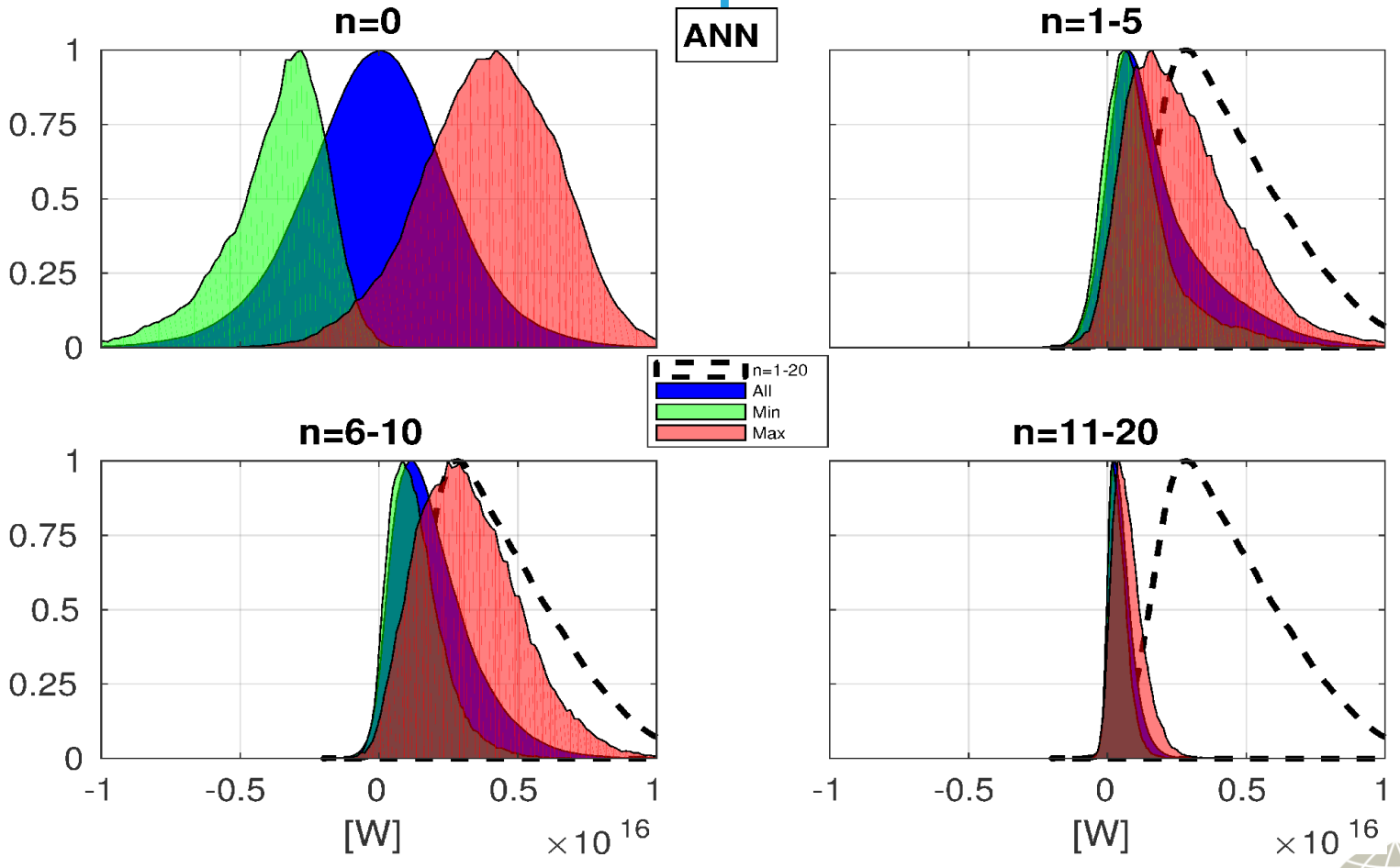
The PDF of the total transport vs. wavenumbers 1-20



The PDF of the total transport vs. wavenumbers 1-20



The PDF of the total transport vs. wavenumbers 1-20



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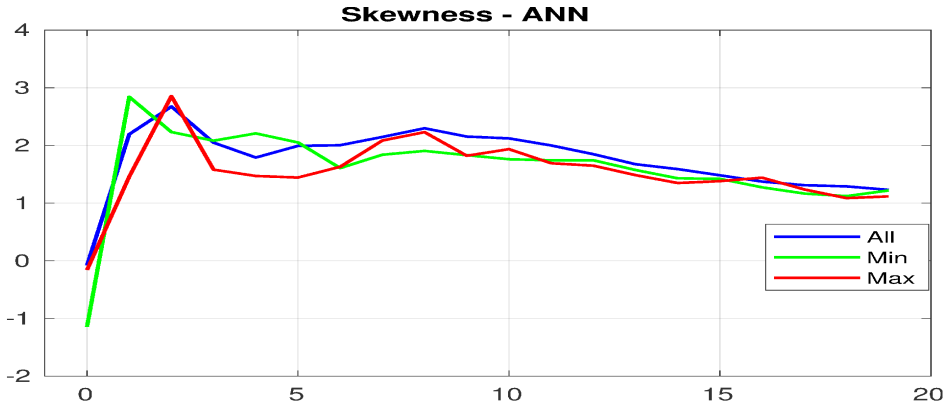
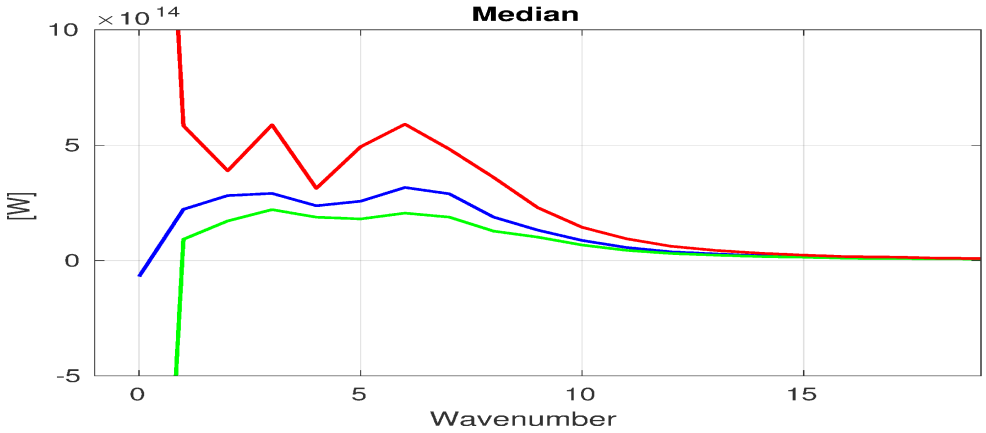
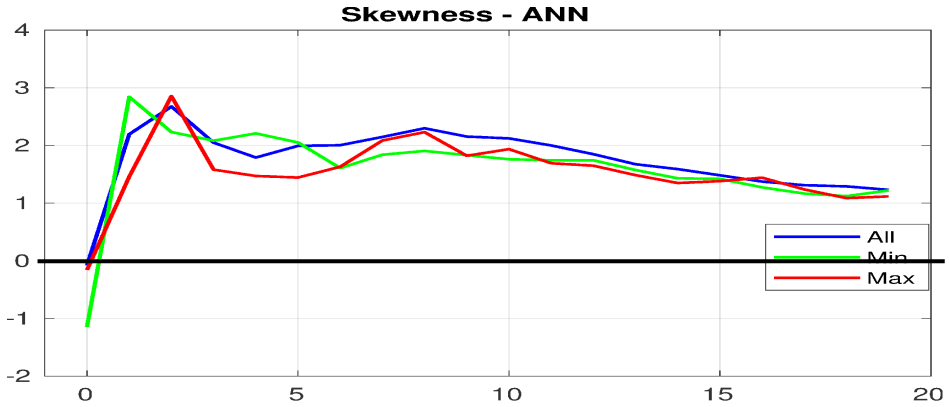
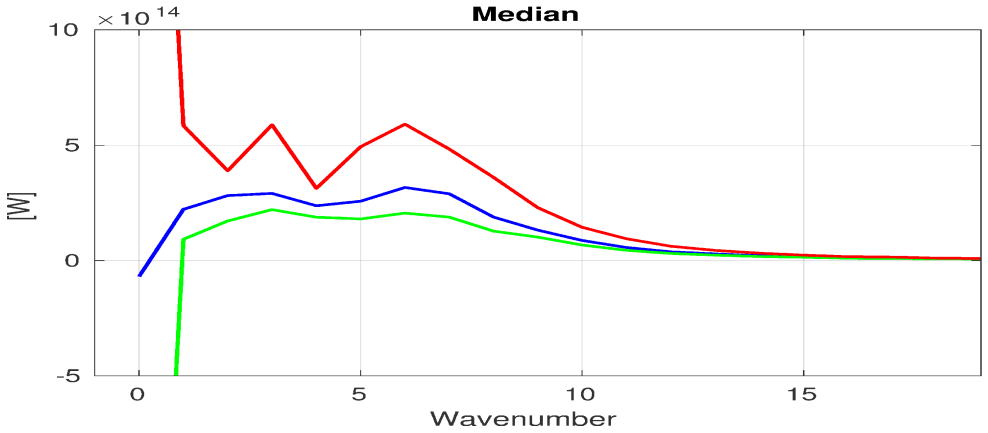




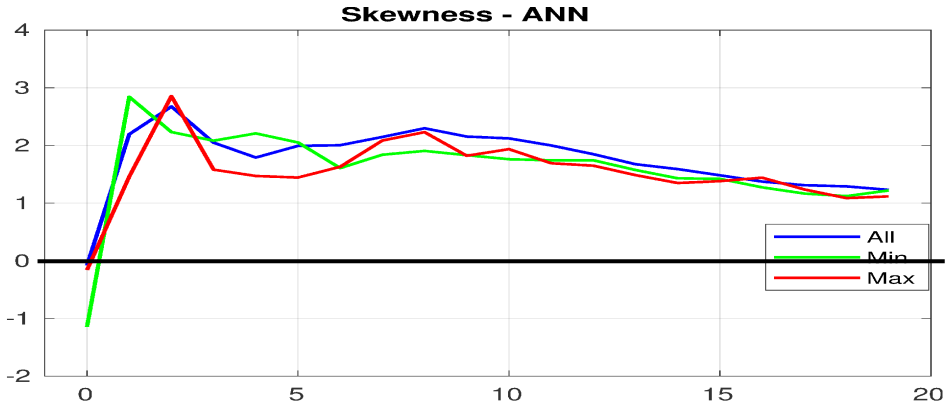
The PDF of the total transport vs. wavenumbers 1-20



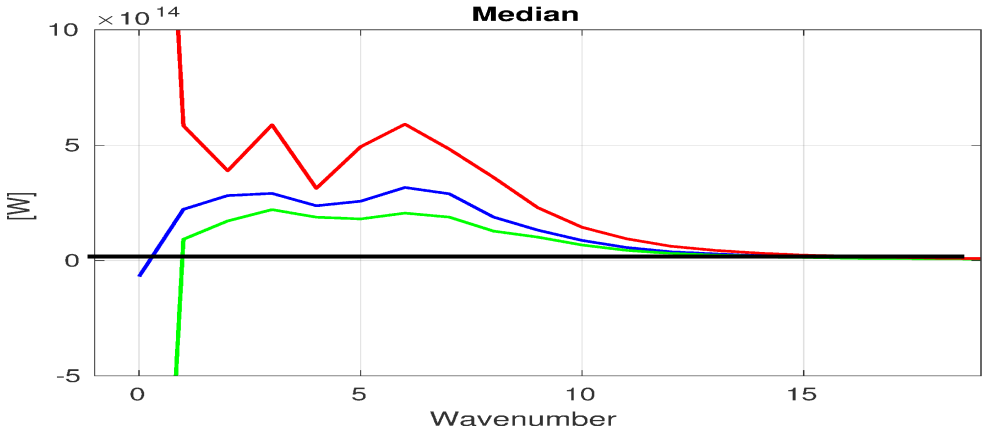
Skewness above 0 at every wavenumber, peaking at n=2-3: northward extremes are dominant at all scales except the planetary ones;



The PDF of the total transport vs. wavenumbers 1-20



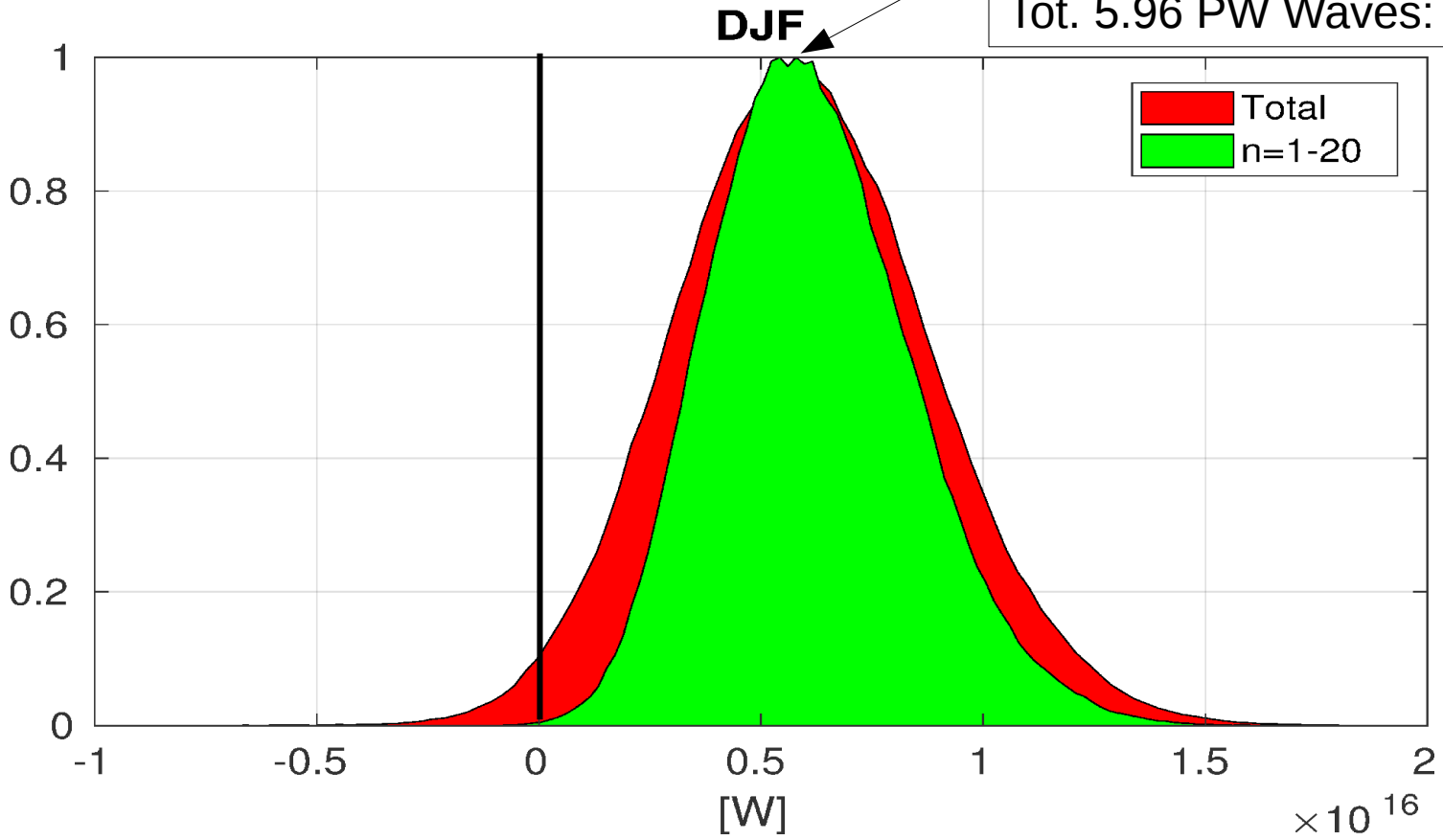
Skewness above 0 at every wavenumber, peaking at n=2-3: northward extremes are dominant at most of planetary scales



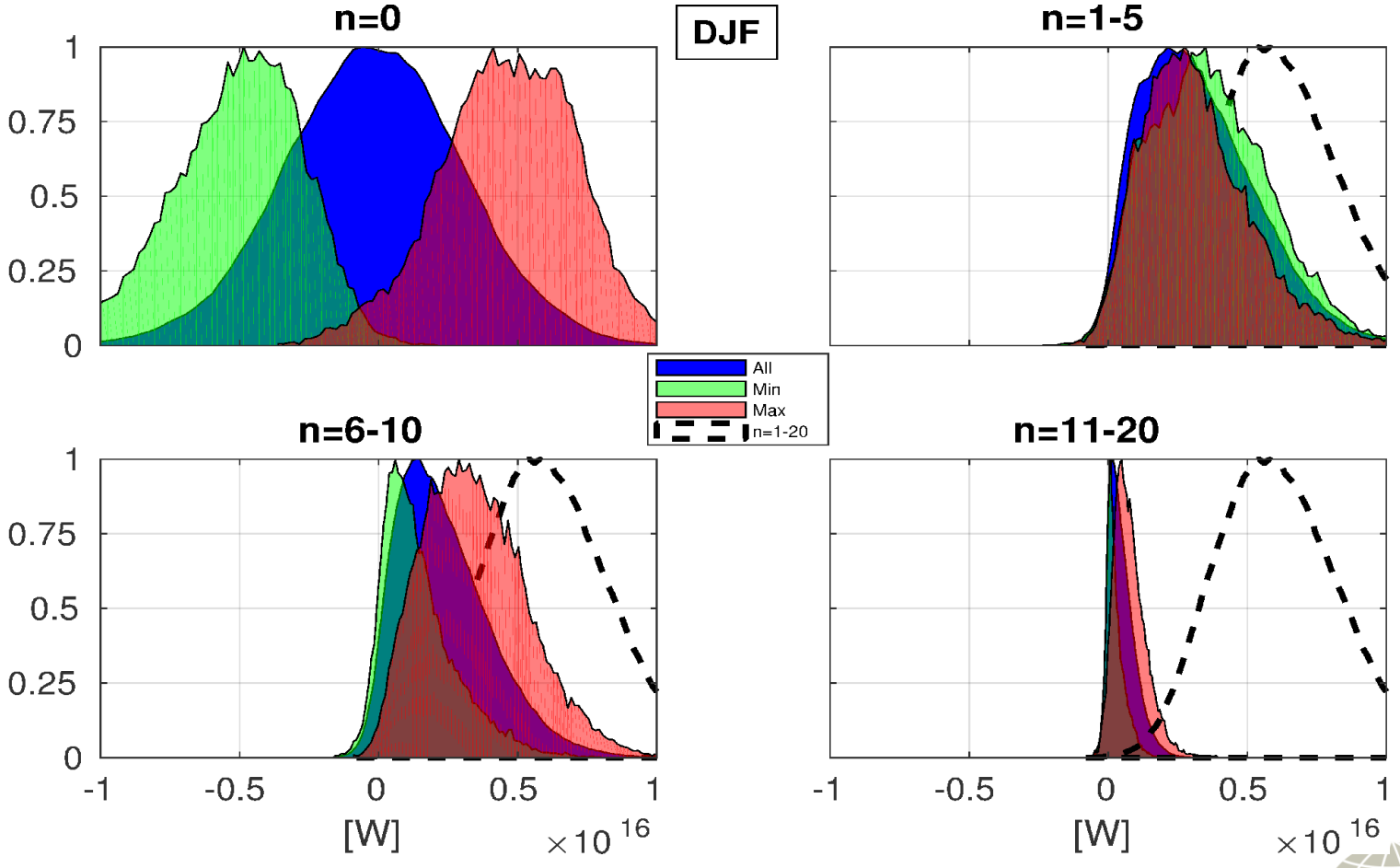
Median at n=0 marginal with respect to largest medians for planetary and synoptic waves; northward extremes have larger medians than southward extremes everywhere;

Focus on DJF...

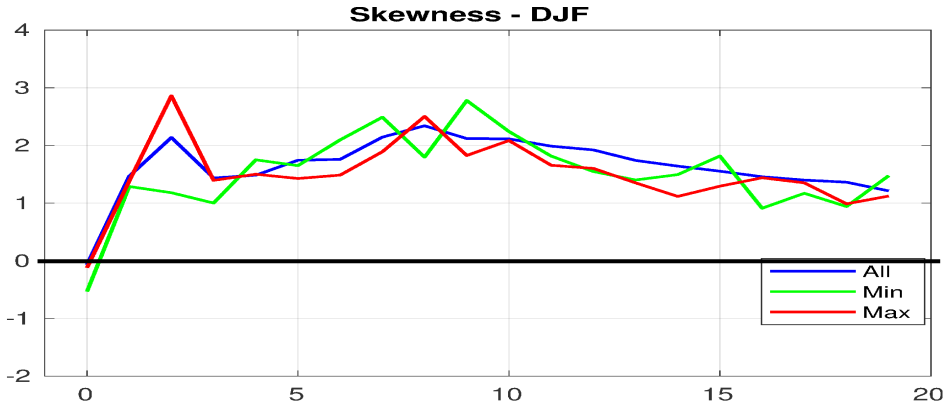
Maximum values are much larger than in ANN:
Tot. 5.96 PW Waves: 6.14 PW



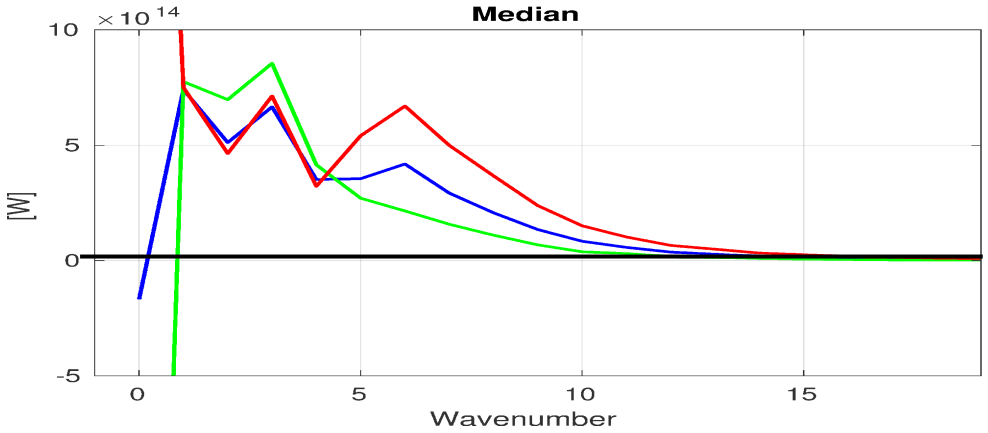
Focus on DJF...


DJF
n=0
n=1-5
n=6-10
n=11-20
All
Min
Max
n=1-20
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1
[W]
×10 16

Focus on DJF...



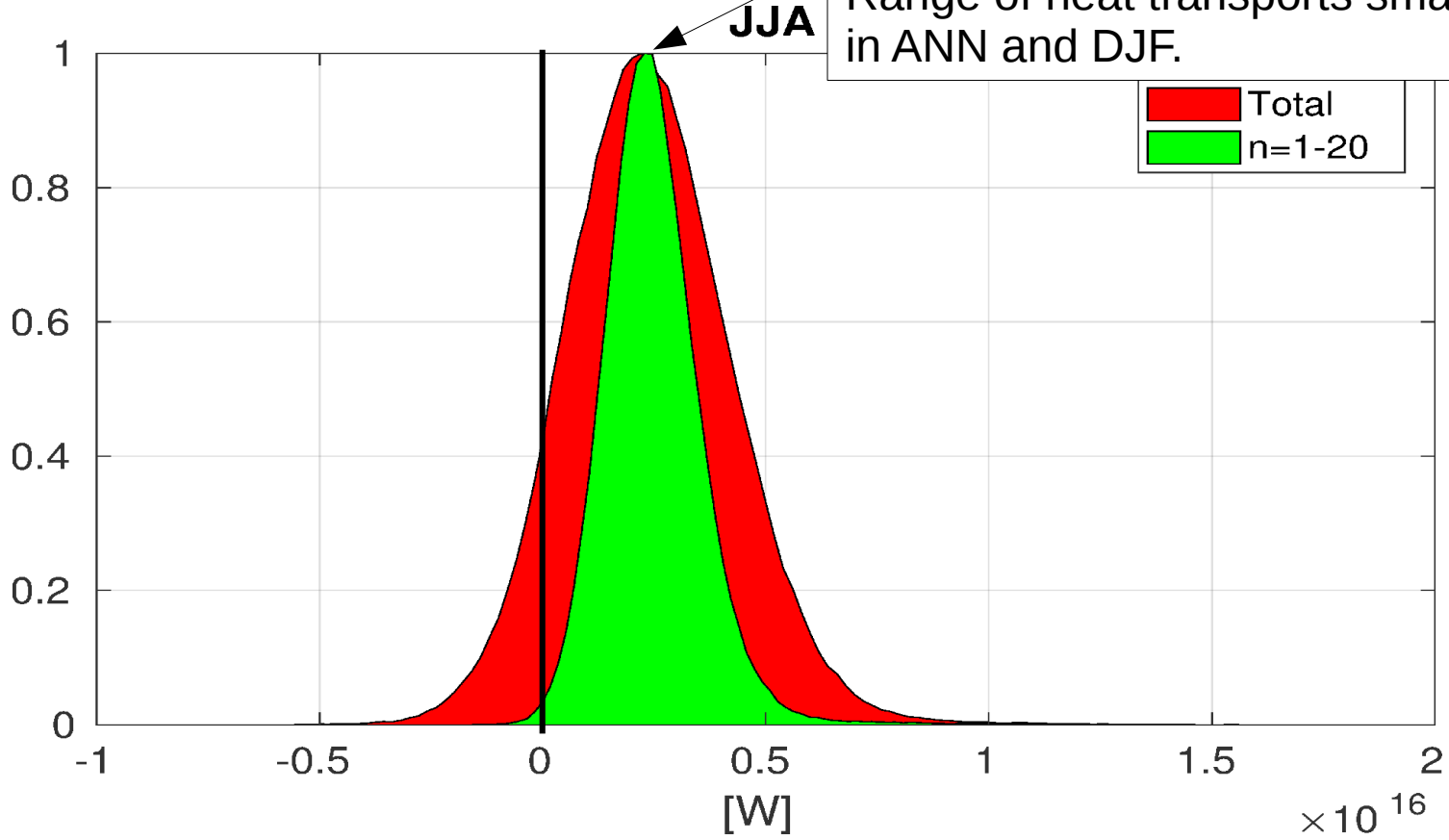
Skewness above 0 at every wavenumber. approximately stationary across all scales;



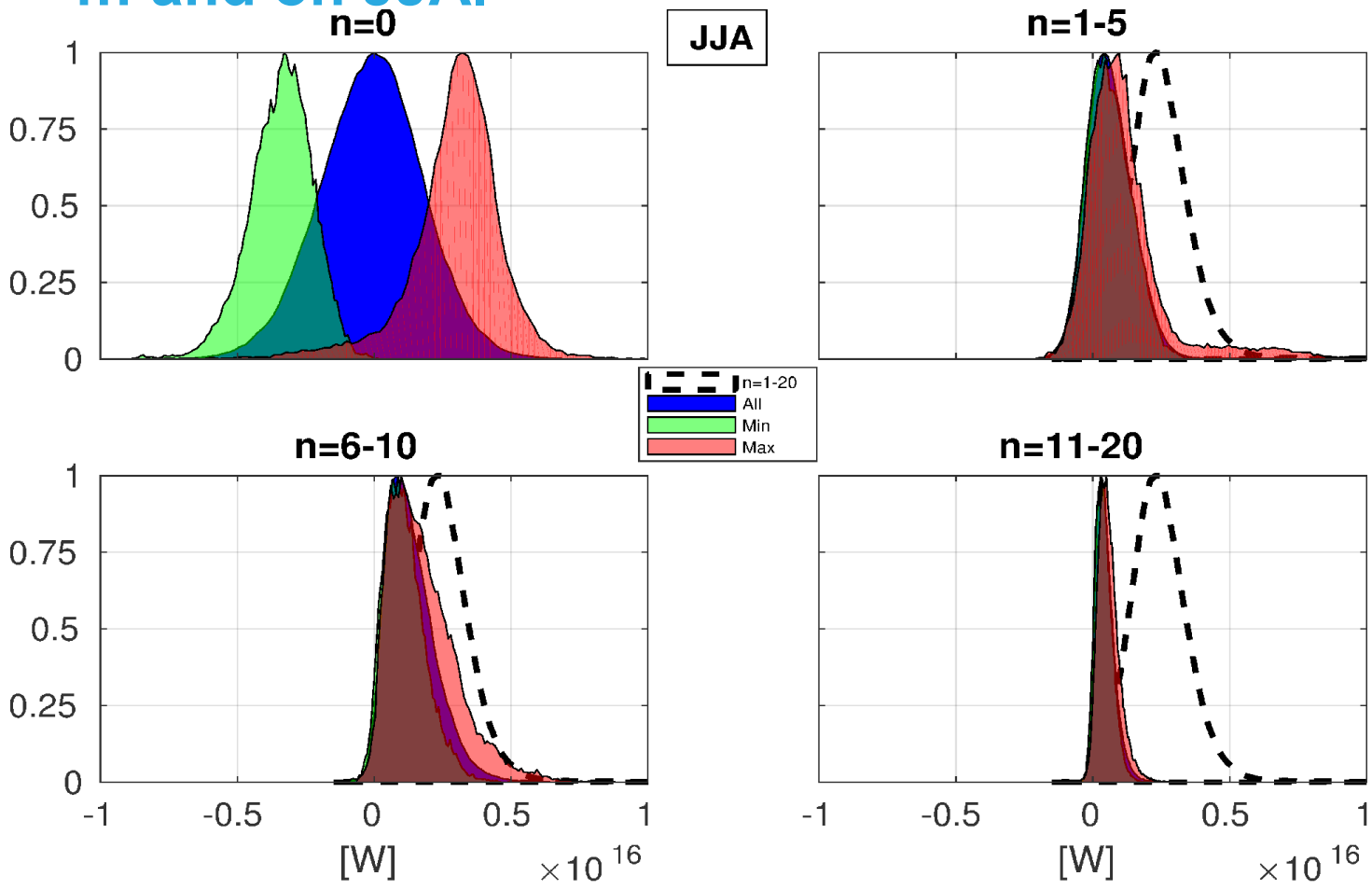
Median at n=0 slightly negative;
Southward extremes have larger values than northward extremes for planetary waves;

… and on JJA.

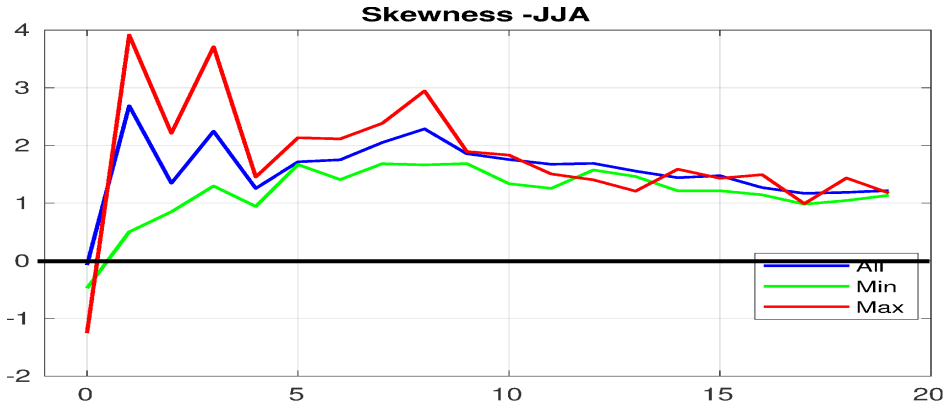
Maximum values are closer to zero:
Tot. 2.38 PW Waves: 2.48 PW
Range of heat transports smaller than in ANN and DJF.



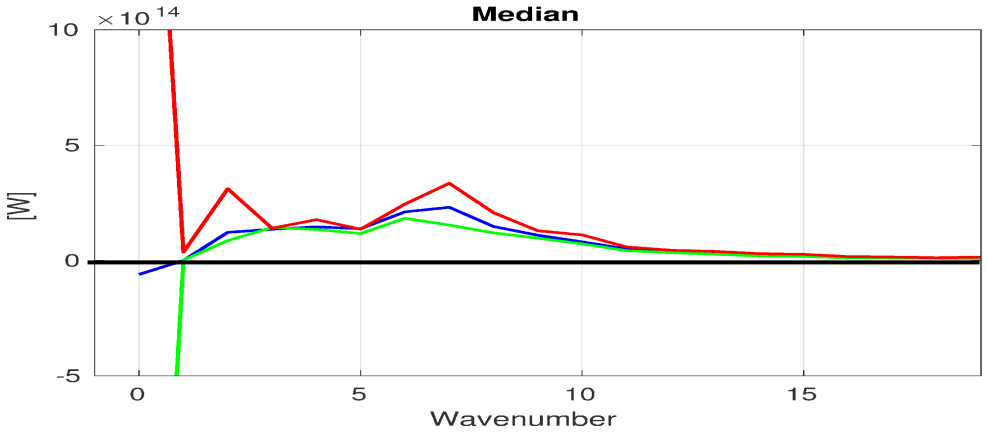
… and on JJA.


JJA
n=0
n=1-5
n=6-10
n=11-20
n=1-20
All
Min
Max
1
0.75
0.5
0.25
0
-1
-0.5
0
0.5
1
[W]
×10 16

… and on JJA.



Skewness above 0 at every wavenumber: larger skewness at planetary waves for northward extremes, at synoptic scales for southward extremes;



Median at n=0 still marginal;
Values for northward extremes always larger than for southward extremes;

Summary and Conclusions

- The transient and stationary waves account for the most part of meridional heat transports in mid-latitudes;
- Transports exhibit a strong seasonality, being more intense in DJF than in JJA;
- Stationary waves are more relevant in DJF, in JJA baroclinic and stationary are similarly relevant,;
- Total northward extremes in ANN, DJF and JJA correspond to northward extremes in synoptic waves;
- Total southward extremes correspond to northward extremes in planetary waves in DJF (southward in ANN and JJA);
- Larger skewness values in JJA (especially at planetary wavenumbers) suggest a more relevant role of extremes;

Open Issues

- Extending the wavenumber decomposition to higher frequencies, through the usage of higher-resolution models;
- Investigating extremes in the time frequency domain, in addition to the zonal wavenumber domain;

Thank you very much for the attention!

Questions?

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