Mingling with the Jetset - a senior weather forecaster's recollections

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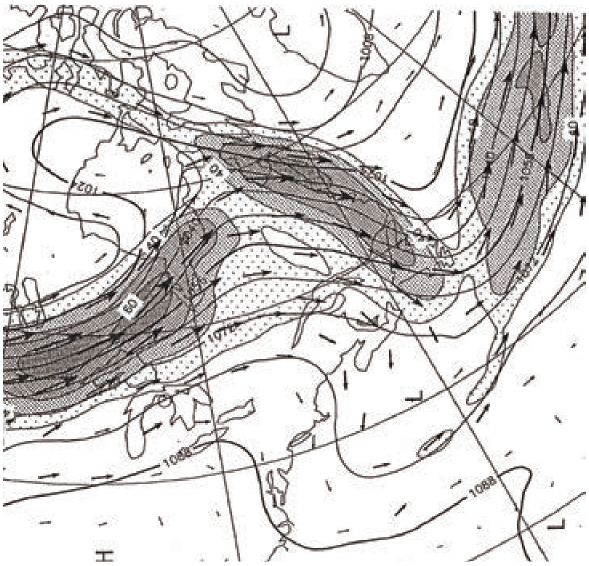
Introduction

In a previous article (Persson, 2019) I told how my Section Head at ECMWF, **Bernard Strauss**, asked me to come up with ideas about additional material to display in the map room. One such was the Hovmöller trough and ridge diagram (Persson, 2017). On the wall there were already on display maps with MSLP, 850 temperatures and 500 hPa geopotential and temperature, all to ten days ahead.

My suggestion was to set up 250 hPa jet stream charts, a compromise between 300 hPa suitable for mid-latitudes jets streams and 200 hPa suitable for the subtropical jet stream. Most jet stream charts are plotted with isohypses (isolines for geopotential heights) and isotachs (isolines for wind speeds). But I also wanted wind vectors, they did not add information concerning the wind speed but, of equal importance, about the wind direction.

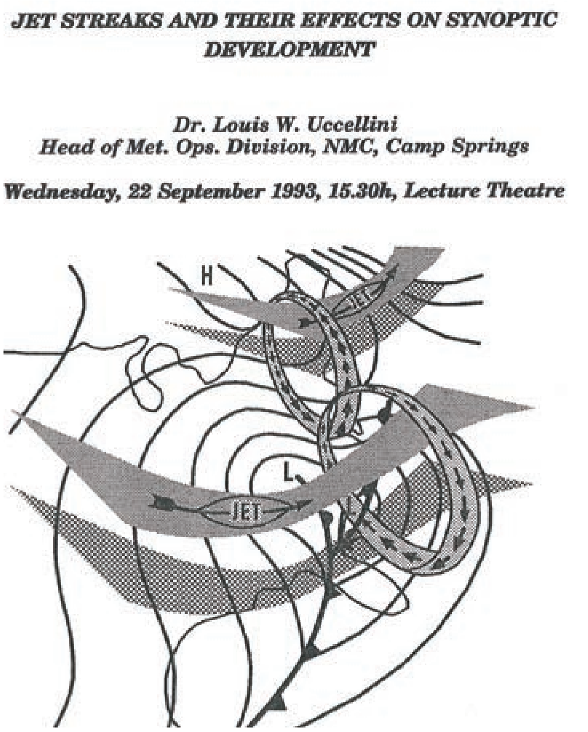


▲ *Figure 1: 250 hPa jet stream chart 14 September 1992 as presented in the ECMWF map room (detail).*

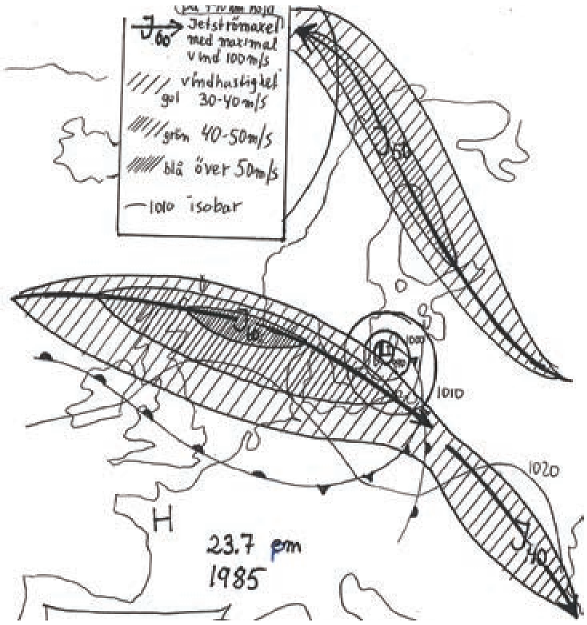
It is true that the isohypses give the approximate wind directions above the boundary layer where the wind is geostrophic or almost geostrophic. But at the jet levels of 200-300 hPa the wind direction, in particular where the air is sucked into the jet (the "entrance") or is leaving the jet (the "exit"), it may deviate strongly from the geostrophic directions by 20°- 30°. For a 30 m/s wind speed, a 20° deviation from the geostrophic direction, could mean an ageostrophic wind component of in the order of 10 m/s.

Jet streaks

My interest in the ageostrophic flow in jet streams had been kindled by a seminar at ECMWF in autumn 1987 by **Louis Uccellini** (then at NASA Goddard Space Flight Center in Maryland, now Head of US National Weather Service). In 1979, he was more widely known from a paper, with his professor **Donald R. Johnson** at the University of Wisconsin,



▶ *Figure 2: In 1993 Louis Uccellini visited the ECMWF and had a seminar about jet streams and their dynamics. The poster showed one of his favourite cases: the collaboration between the right entrance of a jet stream in a northerly position and the left exit of a jet stream in a more southerly position.*



◀ *Figure 3: Tentative sketch of the 300 hPa jet streams in connection with the 23 July 1985 storm over the Baltic Sea, just "hit" by the left exit of the jet streak drifting eastward from the North Sea. The sketch was drawn after Karl Göran Karlssons instructions.*

about jet streaks (Uccelini and Johnson, 1979). When I came back to SMHI I held a seminar about what I had picked up at ECMWF, most notably Uccellini's views on jet stream dynamics. I was particularly intrigued by his illustration of "collaborating jet streams". Later, when I had started at ECMWF, I used his illustration on a poster.

While I was still at SMHI during the late 1980's one of my forecast colleagues, **Karl Göran Karlsson**, had become interested in the copies I had brought home from the WGCEF. When looking more deeply into jet streak dynamics, an interesting discovery was made. One of Uccellini's ideas could explain a mysterious storm that had struck the southern Baltic Sea in July 1985. A weakening low, arriving from Britain over the North Sea and Denmark, had suddenly deepened explosively and produced 20-25 m/s winds. This had not been forecast and we were lucky that none of the crews in the sailing ships had perished.

Downstream development

Karl Göran now showed how the jet stream coupled to the next upstream cyclone (over the British Isles) had "escaped" from its "mother cyclone" and, as it appeared on the maps, drifted downstream and "hit" the weakening Baltic Sea system. Not just "hit" it but it's left exit region, where cyclones generally develop in relation to jet streams (the other development region being the right entrance), had landed a perfect shot.

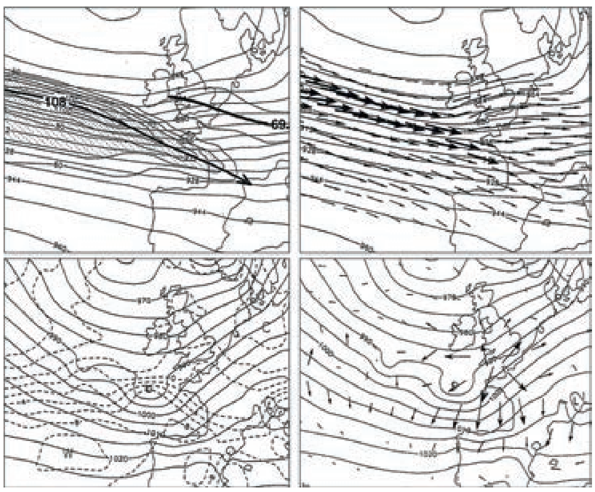
When we went back in the archives we found more cases where sudden cyclogenesis had occurred when a jet stream had "loosened" and "drifted" into the next downstream system, often intensifying it.

The ECMWF forecast system was quite skilful picking up such events several days in advance, although it was at that time less skilful predicting if it would be the "left" or "right" exit that would "hit" the downstream system. In the latter case the downstream system might completely disappear.

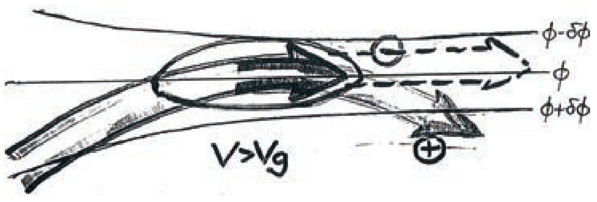
This introduced an element of randomness in the forecasts, a concrete example of how "butterflies" manifest themselves in the atmosphere. With the advent of the ensemble system (ENS) we would be more able to tell the probabilities in such cases.

The jet stream "snaps"

The jet streak ideas could be extended to jet systems that stayed with their "mother cyclone". Among my rare possessions is a sketch by the eminent German synoptician **Manfred Kurz** from a meeting in Paris in February 2000. It was in the wake of the two devastating storms "*Lothar*" and "*Martin*" in December 1999.



▲ *Figure 4: The synoptic situation on 25 December 1999 18 UTC. Clockwise from upper left: 300 hPa jet winds as isotachs and wind vectors, MSLP with 850 hPa temperature and with ageostrophic 300 hPa winds from my ECMWF Memorandum 13 November 2000 after the conference in Toulouse 17-18 October 2000.*



▲ *Figure 5: Manfred Kurz's schematic sketch at the Paris meeting of the super geostrophic jet streak that was deflected to the right and created a sudden and strong upper air divergence at the left exit of the jet in the evening of 25 December 1999.*

Within a jet stream there seems to be kernels of stronger winds, which move within the jet. Kurz's idea was that one such "kernel" of strong winds moved downstream and entered areas where the geostrophic value of the jet wind was much weaker. The winds in the "kernel", now became highly super-geostrophic and would rapidly deflect to the right, they would make the jet "snap".

Exporting air from a region would decrease the pressure, the weight of all air above, and cause a sudden deepening closer to the surface.

Diabatic heating

The focus on the ageostrophic components also helped to understand how heating from convective systems (release of latent heat) could strengthen a jet stream. I learnt this from another American and a co-worker to Uccellini at NASA, Dr **Ralph Petersen**, whom I met at a WMO Training Course in Seoul in October 1986.

Below is a copy of the transparency (as this was before the age of Power Point) where we, the students, summarised how a decaying typhoon (or tropical storm) coming from China could energize a mid-latitude baroclinic system over Korea.

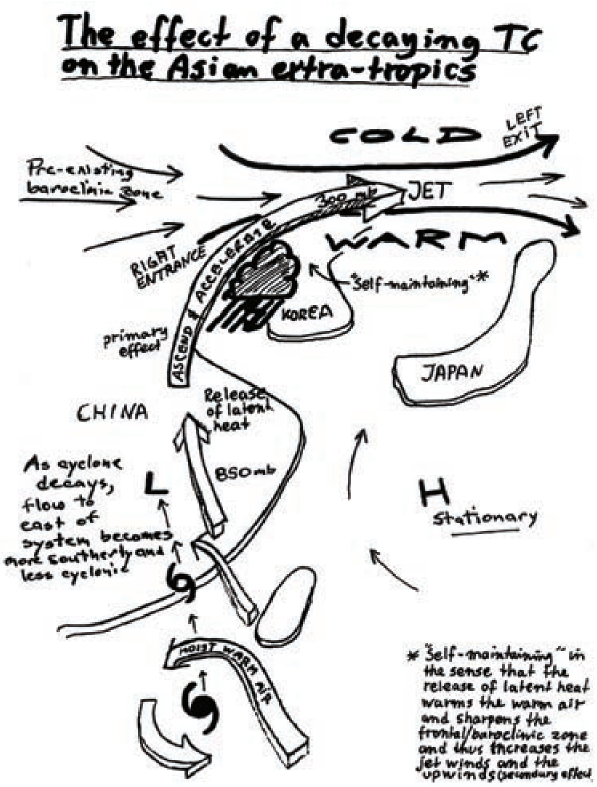
This diabatic heating of the jet stream becomes particularly important when the source is an ex-tropical cyclone which has entered the mid-latitudes and started to interact with the cyclones there. Even a decaying TC is quite powerful and has a lot of energy to give away, energy that is not necessarily identified by the analysis system. A downstream cyclone can receive both more, or less, energy than predicted by the model and the cyclone will of course behave accordingly.

A few days later, on my return to England, I had a bumpy landing at Heathrow Airport. The plane landed in the midst of an Atlantic baroclinic system that had been energized by an upstream decaying tropical storm "*Lili*". It was of course very inspiring to have confirmation of theory so fast and it resulted in an ECMWF Memorandum some weeks later with a detailed analysis of the event.

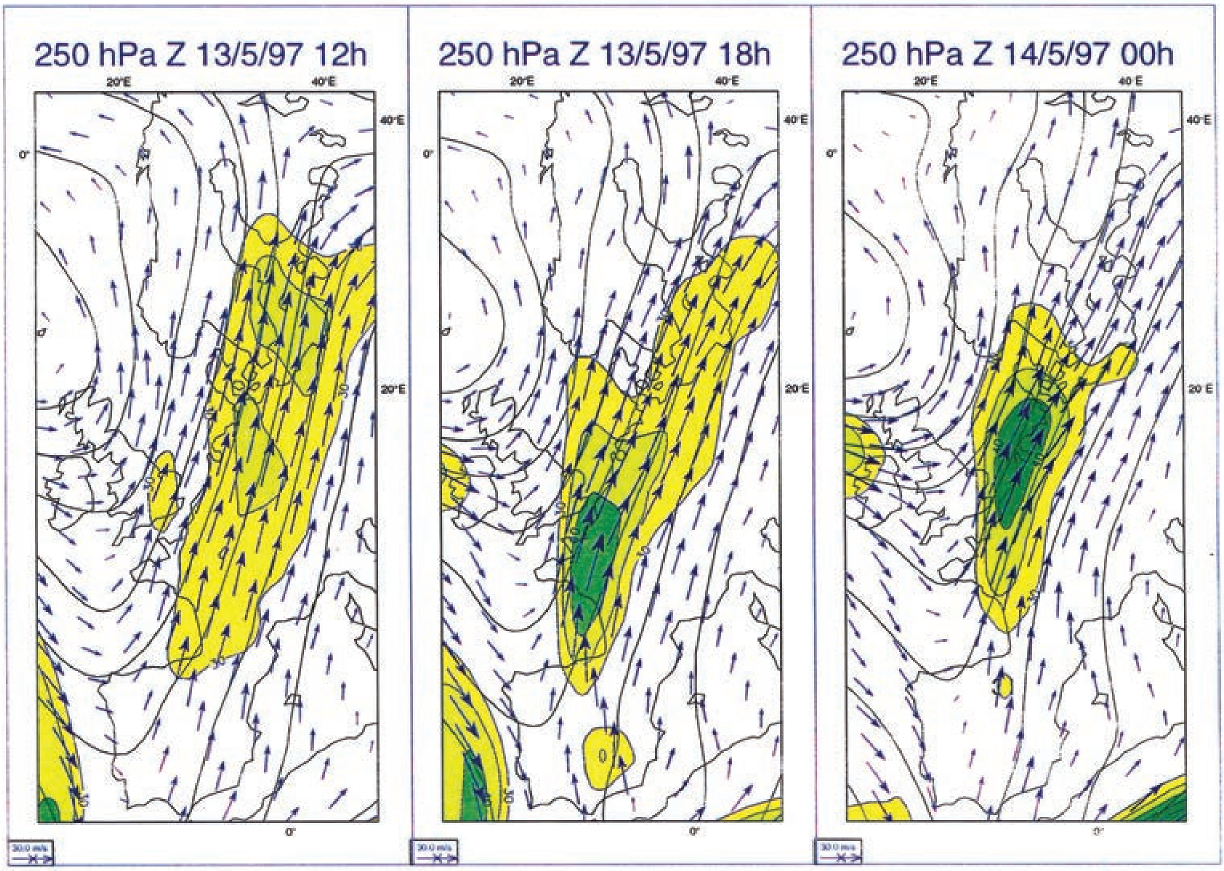
Frustrated Dutch forecasters

I would soon benefit from what I had learnt from Ralph. At the ECMWF Training Course, the following spring (May 1997), the Dutch participants arrived grey faced, red eyed and frustrated. They had battled with unreliable numerical forecasts the week before. The numerical models had consistently predicted the end of a rainfall - that kept going!

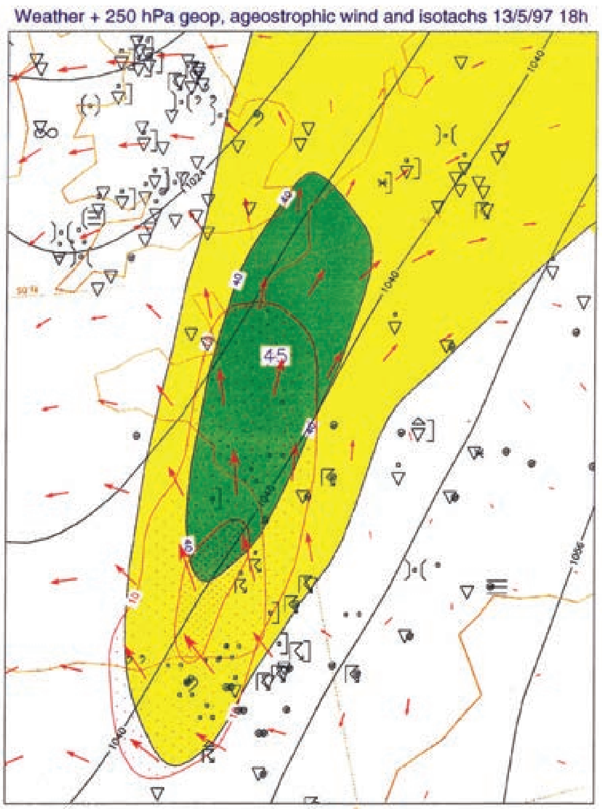
We took a look at it together. The rain was, broadly speaking, coupled to the left exit region of a north-south oriented jet stream from southern France to the Netherlands. There again the theory was confirmed, on the afternoon of the 13th of May, widespread and intense thunderstorm cells provided energy to the jet and prevented it from weakening.



◀ *Figure 6: Mine and Ralph Petersen's schematic sketch from the WMO Training Course in Seoul in October 1996. A decaying typhoon moving over mainland China is drawn into the right entrance of a baroclinic system over Korea.*



▲ *Figure 7: The 250 hPa chart on 13-14 May 1997. In only six hours, the 30-35 m/s jet stream from France to southern Scandinavia intensified with winds up to 45 m/s.*



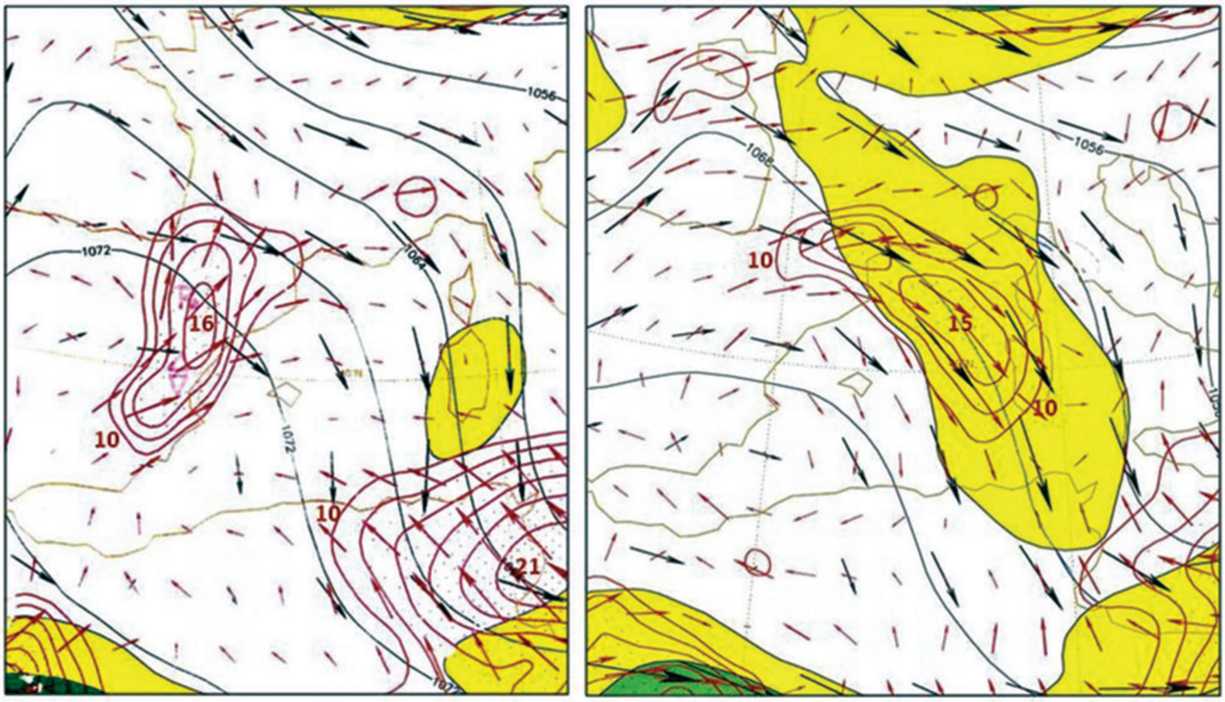
▲ *Figure 8: The 13 May 1997 18 UTC, 250 hPa jet chart with ageostropic winds (red isolines) up to 15 m/s due to diabatic forcing of extensive thunderstorms over southern France.*

Perhaps the numerical models are better at this today. Still, it might be useful to know about the mechanisms and interactions between the meso-scale and the synoptic scale.

Jet streams generated by thunderstorms

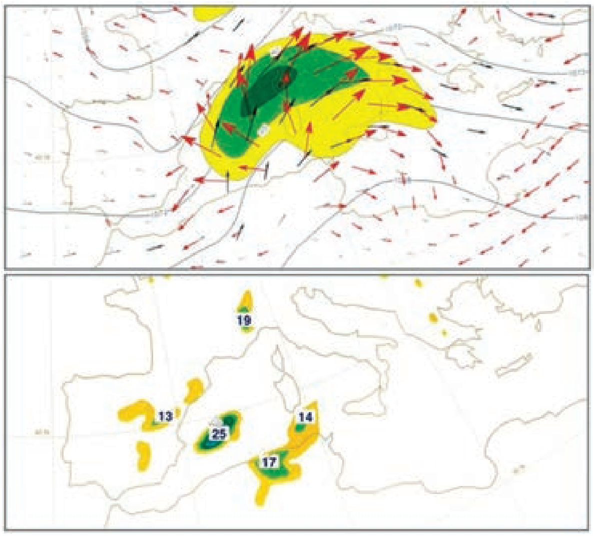
At the time **Federico Grazzini** worked at ECMWF. He made me aware of a mysterious storm that had caused serious problems in Italy a year earlier, in June 1996. When we looked at the weather maps and jet wind charts, there were some jet streaks that seemed to appear from "nowhere". Once created they then drifted with the large-scale flow into Italy. When plotting maps with the ageostrophic winds at 250 hPa it turned out that these jet streams had been produced *in situ* in connection with strong thunderstorms over north eastern Spain.

ECMWF forecast system of the late 90's seemed to be quite capable of simulating the diabatic forcing of upper tropospheric jet streams.



▲ *Figure 9: 250 hPa jet stream charts 18 June 1996, 12 and 18 UTC (black lines are 250 hPa isohypses, black arrows are 250 hPa winds and red arrows are the ageostrophic components). Extensive thunderstorms over north eastern Spain generated their own upper tropospheric jet stream that then propagated eastward over the Mediterranean.*

There are different ways to teach and understand dynamic meteorology. They all have advantages and disadvantages. What I found during my time at ECMWF was that plotting upper air vector winds and, if possible, their ageostrophic wind components, gave new and often surprising new insights. It may be true that the models nowadays manage these situations better than 23 years ago, but even so, as a forecaster I have always wanted to have a feeling of understanding about what is "going on" in the atmosphere.



▲ *Figure 10: Above: The 250 hPa jet stream and ageostrophic winds in the ECMWF forecast 8 June 1999 +36 hours, below the 24-hour accumulated rainfall (from the same forecast) in the +24 to +48 hour interval. The ECMWF forecast system of the late 90's seemed to be quite capable of simulating the diabatic forcing of upper tropospheric jet streams.*

Literature:

Persson, A: (2017): The story of the Hovmöller diagram: An (almost) eyewitness account. *Bulletin of the American Meteorological Society*. 98 (5): 949–57.

Persson, A: (2019): When forecasters were ahead of the theoreticians - the case of "downstream development", *The European Forecaster*, September 2019, 46-53.

Uccellini, L.W. and Johnson, D.R., (1979): The coupling of upper and lower tropospheric jet streaks and implications for the development of severe convective storms. *Monthly Weather Review*, 107, 682-703.