Analysis of the 18 July 2005 Tornadic Supercell over the Lake Geneva Region

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Introduction:

While supercell thunderstorms tend to be most prevalent in North America east of the Rockies over predominately flat terrain, many other countries around the world experience them as well, albeit on a less frequent basis. Switzerland is no exception. On the afternoon of 18 July 2005, a particularly intense supercell struck the Lake Geneva region. The storm initiated just southwest of Lyon, France and tracked over 250 km towards the northeast before losing ist supercell characteristics in the central Alpine foothills around the town of Interlaken. During its 3-hr lifespan, the storm's forward translation averaged 60-80 km/h. At the height of ist severity, this supercell was responsible for **hail the size of golf balls, wind gusts up to 160 km/h and two confirmed tornadoes**. Miraculously, **nobody was killed nor seriously injured**. However, material losses were considerable including ravaged vineyards, damage to buildings and vehicles and sections of forests completely destroyed. **Total costs for hail damage alone surpassed 70 millions Euros.**

The storm underwent a splitting process very early in its lifetime as it passed over Lyon, France

Damage map highlighting the locations of the two confirmed tornadoes, the microburst and the numerous reports of large hail and strong winds

Forward-flank gustfront as it approached Vevey on Lake Geneva's east shore.

Forward-flank gustfront battering down on Montreux with 80-120 km/h winds

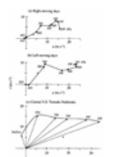
Forest damage in Veigy, France near Geneva after EF1 tornado passage

Local authorities shoveling knee-deep hail while many buildings in Montreux had their windows shattered by wind-driven golfball-sized hail

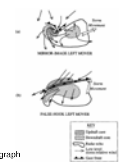
Microburst damage to a forest near Le Bouveret with a recorded windgust of 161 km/h

Background:

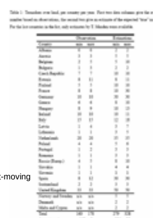
Several papers have already been published concerning convective mode in Switzerland and on tornado frequency in Europe in general. Houze et al., 1993 found based on 8 yrs worth of data that **Swiss hailstorms were equally divided between right and left moving storms** and that this balance was most likely attributable to the orographic nature of the terrain. Schiesser et al., 1995 studied 82 Swiss mesoscale convective systems (MCSs) over a 5 yr period and were able to classify them into general categories of organization, similar to Houze et al. 1990 who examined the mesoscale structure of major springtime rainstorms in Oklahoma. With regards to tornado production, Dotzek, 2003 has recently found that contrary to Alfred Wegener's 1917 estimate of at least 100 tornadoes per year over the European continent, that the number is closer to 170 based on observations and that the **true number is most likely closer to 300 due to significant underreporting**. Out of 107 significant tornado events over France reported between 1680-1988, Dessens and Snow, 1993 identified several regions where tornadic thunderstorms tended to cluster, among which **a sector along the Swiss-French border in the Jura mountains considered to be a local tornado alley**. These observations and others, suggest that **low-level wind flow modified through channeling by the mountains may provide a locally favorable wind shear environment for tornadogenesis**, given the appropriate large-scale dynamics are in place and that sufficient thermodynamic support is available.



Houze et al. 1993 : Typical hodograph profiles of over the Swiss Plain as compared to the Central US



Houze et al. 1993 : Some left-moving storms exhibited a false hook



Dotzek, 2003: number of observed and estimated tornadoes per European country

Type	Observation (25)	Estimations (25)	Estimations (28)
Tornadoes	169 ± 9	295 ± 25	304 ± 25
Waterspouts	160 ± 3	382 ± 11	393 ± 11
All	329 ± 12	677 ± 36	697 ± 36

Dotzek, 2003: total annual number of observed and estimated tornadoes in Europe

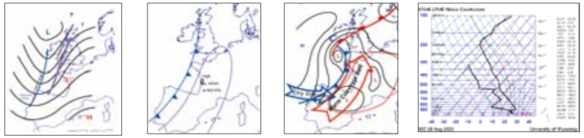
Case Study : 18 July 2005 Tornadic Supercell

Careful examination of forecasted model fields up to 48 hrs prior to the event and meticulous scrutiny of the observations on the morning of this case highlighted conditions that are typically associated with organized severe convection. As the event unfolded, various observational platforms such as satellite/radar imagery and automated surface stations captured several distinctive signatures typically associated with supercell thunderstorms. **Features such as the V-notch, Weak Echo Region (WER), Bounded Weak Echo Region (BWER), thunderstorm longevity, deviant motion, storm splitting and mesocyclone signatures were all discernable**. Less evident, was the probability that tornadoes could ensue from the convection given the meteorological information available and the complex topography within which the storm evolved.

Pre-storm Environment :

The pre-storm environment was caracterized by the presence of a typical **Spanish Plume synoptic configuration** (see conceptual model below) where a sharp trough located over the Iberian Peninsula advects an elevated mixed layer from the Spanish Plateau northeastwards over a warm and humid airmass drawn northwards from the Mediterranean Sea. As the trough slowly lifted northeastwards along with the **embedded double jet streak structure**, large scale quasi-geostrophic ascent associated with the ageostrophic circulations helped destabilize the mid and upper levels of the atmosphere. This aided in eroding the cap (CIN) and facilitated the liberation of the accumulated instability (CAPE).

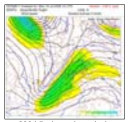
SPANISH PLUME CONCEPTUAL MODEL :



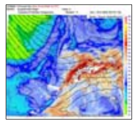
Typical upper-level flow — Typical low-level flow — Typical surface flow — Typical Spanish Plume sounding

Spanish Plume airmass origins

COSMO7 MODEL ANALYSIS FIELDS ON 18 JULY 2005 :

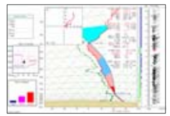


300 hPa isotach analysis at 12utc on 18 July 2005

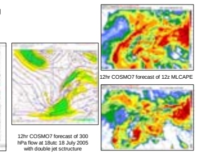


850 hPa analyzed height field and Theta-e at 12utc

Analyzed surface pressure and fronts at 12utc on 18 July 2005



12UTC Payerne sounding with modified low-level T & Td



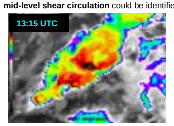
12hr COSMO7 forecast of 300 hPa flow at 18utc 18 July 2005 with double jet sctructure

12hr COSMO7 forecast of 12z MLCAPE

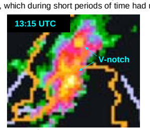
COSMO7 analysis of 12z MLCAPE

Satellite & Radar Observations :

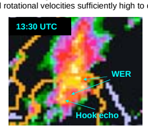
Visible and enhanced infrared Meteosat Second Generation (MSG-8) satellite imagery nicely captured the supercell's **overshooting top and enhanced V signature** as the storm traversed Lake Geneva. The volumetric reflectivity radar data from the " La Dôle" C-band Doppler radar helped identify several **Weak Echo Regions (WER)** at the lower elevation CAPPI scans as well as several probable **Bounded Weak Echo Regions (BWER)** on the higher elevation slices. **V-notches** and possible **owl horn signatures** were also observed. On the volumetric radial velocity PPI scans, a **60min long, 2-4km deep mid-level shear circulation** could be identified, which during short periods of time had rotational velocities sufficiently high to qualify as a **weak to moderate mesocyclone**.



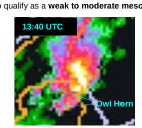
Enhanced IR MSG image with overshooting top and enhanced V signature



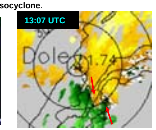
La Dôle 2km CAPPI reflectivity image with V-notch



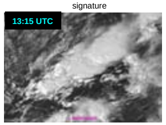
La Dôle 3km CAPPI reflectivity image with hook-like appendage and WER



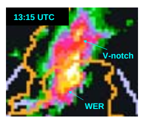
La Dôle 5km CAPPI reflectivity image with possible owl-horn signature



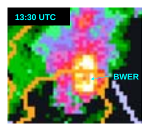
La Dôle 3.5° base velocity PPI image with mid-level shear signature (green = towards, yellow = away)



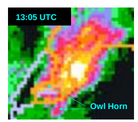
Visible MSG image : overshooting top and anvil canopy



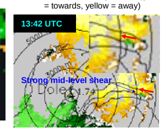
La Dôle 4km CAPPI reflectivity image with WER and V-notch



La Dôle 7km CAPPI reflectivity image with probable BWER hole



La Dôle max reflectivity image with possible owl-horn signature

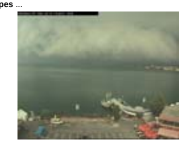


La Dôle 3.5° base velocity PPI image with strong mid-level shear signature (probable mesocyclone)

Visual Observations and Damages :

As the supercell approached the east end of Lake Geneva, it attained its maximum intensity. A **potent forward-flank downdraft** created a very impressive gustfront which terrassed the town of Montreux with **80-120 km/h wind driven hail**. Further south a **tornadic waterspout formed over the lake and struck the town of Le Bouveret** a few minutes later. A **damage survey** conducted by the lead author (Geneva NWSFO forecaster), points to several probable origins to the damages analyzed/encountered. It appears that **both a microburst and a tornado** ravaged Le Bouveret as **2 separate damage paths** were found **with 2 distinct signature types** ...

The only known photo of the EF2 tornadic waterspout/tornado approaching Le Bouveret



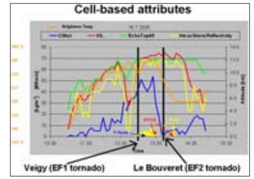
Striking image of the forward flank gustfront as it approached Montreux

Broad area of uni-directional forest damage near Le Bouveret most likely a result of a rear-flank downdraft induced microburst…

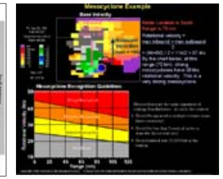
Narrow damage swath with strewn trees in various orientations along EF2 tornado path near Le Bouveret

Results :

Analyzing the supercell's internal characteristics, the **Thunderstorm Radar Tracking (TRT) algorithm**'s plot of cell-based attributes highlights the **drastic drop in cloud-to-ground lightning frequency just prior to the Le Bouveret tornado** as well as the **warming cloud top**. Concerning the storm's rotating updraft, a **mid-level base velocity shear circulation** was visible approximately **60 minutes over a depth of between 2 to 4 km**. At specific times, the shear circulation qualified as a mesocyclone based on its rotational velocity and seems to have reached moderate intensity just prior to tornadogenesis in Le Bouveret. Closer scrutiny of the surface winds in Le Bouveret 10 minutes prior to the supercell's arrival, shows the presence of a **10 kt SSE wind inflow**. **Wind channeling in the north-south oriented Rhône Valley** just south of the lake most likely aided in amplifying the **low-level directional windshear** thereby augmenting **storm-relative helicity** values on the east end of the lake. It is the author's hypothesis that this mechanism along with tilting of the horizontal vorticity created by the intense forward-flank and rear-flank gustfronts most likely favored tornadogenesis in this location...



Especially evident in this plot is the drastic drop in CG lightning frequency prior to the Le Bouveret tornado and the warming brightness temperatures indicating the collapse of the overshooting top and updraft weakening

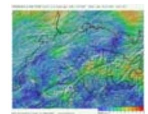


Mesocyclone recognition guidelines as set forth by the National Severe Storms Laboratory in Oklahoma

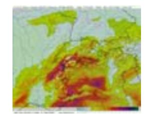
Elevation	Veigy (13:07 UTC) 22 km (14miles) from radar	Le Bouveret (13:42 UTC) 60 km (38 miles) from radar
3.5°	(15 + 10) / 2 = 12.5 m/s 25 kts Minimal mesocyclone	(20 + (15?)) / 2 = 17.5 m/s 35 kts Moderate mesocyclone
5.5°	(15 + 8) / 2 = 11.5 m/s 23 kts Minimal mesocyclone	(13 + 10) / 2 = 11.5 m/s 23 kts Minimal mesocyclone
7.5°	15 + 7 / 2 = 11 m/s 22 kts Minimal mesocyclone	---

Rotational velocities calculated at the times coincident with tornadogenesis in Veigy and Le Bouveret. The circulations were discernable through a depth of 2-4 km.

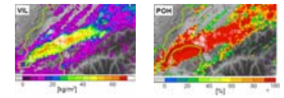
Google Earth 3-D depiction of the north-south oriented Rhône Valley just south of the eastern portion of Lake Geneva



2km NMM 33hr forecast of surface streamlines valid at 12z 18 July 2005



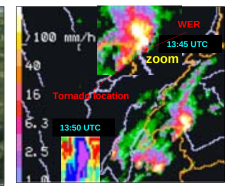
2km NMM 33hr forecast of 0-3km storm-relative helicity valid at 12z 18 July 2005



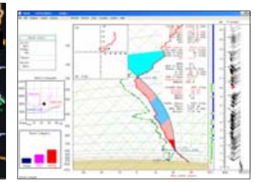
Vertically Integrated Liquid (VIL) values for 18 July 2005 supercell

Probability of Hail (POH) isoareas for 18 July 2005 supercell

Conceptual model of hypothesized flow structure as the tornadic supercell approached the east end of Lake Geneva



La Dôle 5km CAPPI reflectivity image at time of Le Bouveret tornado (13:45 UTC) and inset of RHI BWER at 13:50 UTC



Modified Payerne 12z sounding incorporating the 10-15kt SSE Rhône Valley low-level inflow into the storm

Conclusions :

- The pre-storm environment on 18 July 2005 was characterized on the synoptic scale by a Spanish Plume configuration with an embedded double jet structure. Both dynamic and thermodynamic conditions on the synoptic and meso-scales were of the type typically associated with severe convection, including supercells.

- Various observational platforms such as satellite/radar, surface observations, and cell-based attributes derived using developed algorithms all showed distinctive signatures typically associated with supercells, such as the enhanced V, cell splitting, (weak and bounded weak) echo regions, V-notch, owl-horn signature and base velocity shear signatures.

- Doppler radar base velocity images allowed the calculation of the rotational velocity of the shear circulation associated with the storm through a height of 2-4 km and time frame of about 60 minutes, helping establish the presence of a prolonged weak mesocyclone as well as the presence of a short-lived mesocyclone of moderate intensity.

-Modifying the 12z Payerne proximity sounding winds at low-levels using observed valley-channeled inflow winds 5 to 10 minutes prior to the supercell's arrival in Le Bouveret, resulted in increased directional shear and larger storm-relative helicity values. It is hypothesized that this may have been an important factor favoring tornadogenesis in Le Bouveret, along with the vertical tilting of the horizontal vorticity associated with both the very strong forward-flank and rear-flank gustfronts.

- Following the damage survey conducted shortly after the event and based on an aerial photo, it appears that a microburst was responsable for the damages to a section of forest southwest of the tornado track. It appears probable that this microburst was induced by the rear-flank downdraft.

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