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Mesoscale organization and structure of orographic precipitation producing flash floods in southern Switzerland

Luca Panziera[1,3], **Curtis James[2]**, Urs Germann[1]

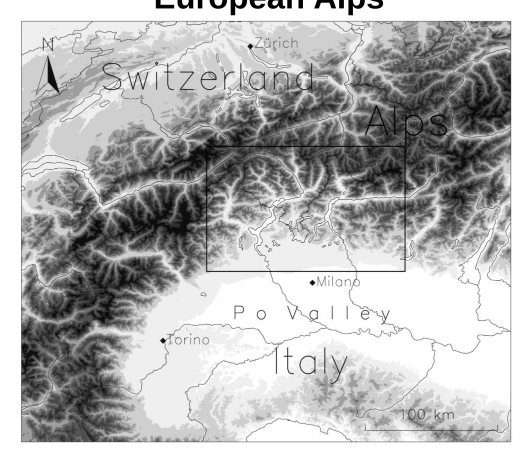
(1) **MeteoSwiss, Locarno Monti, Switzerland** (2) **Embry-Riddle Aeronautical University, Prescott, Arizona** (3) **University of Trento, Italy**

luca.panziera@unitn.it

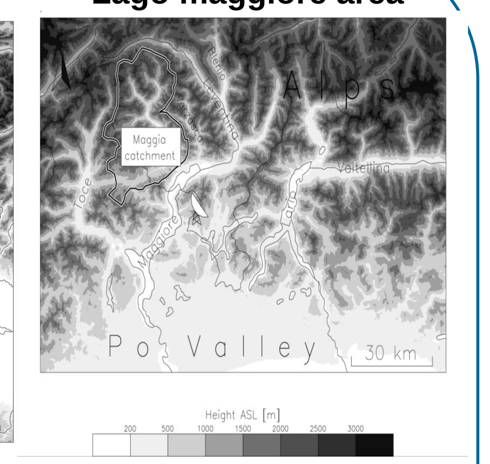
Motivation

- **The Maggia River catchment, located in the Lago Maggiore area in the southern European Alps, is prone to flash floods. In some floods, the river discharge rate can increase by as much as 1400 m³/s in less than 3 hours!**
- **There is a strong need for short-term quantitative precipitation forecasts for mountainous catchments such as the Maggia Valley which have short response times (1-3 hours).**
- **Orographic precipitation models and numerical models have serious difficulty predicting convective orographic rainfall, which is characterized by a high degree of non-linearity and strong spatial and temporal gradients.**
- **Nowcasting based on *analogues* can be successfull, as long as mesoscale quantities that have a strong correlation with rainfall are taken as *predictors* (NORA approach, *Panziera et al., 2011, QJRMS).***
- **From the detailed study of the structure of the most intense storms which have occurred in the Maggia Valley, we expect to find important predictors that can be included in nowcasting schemes.**

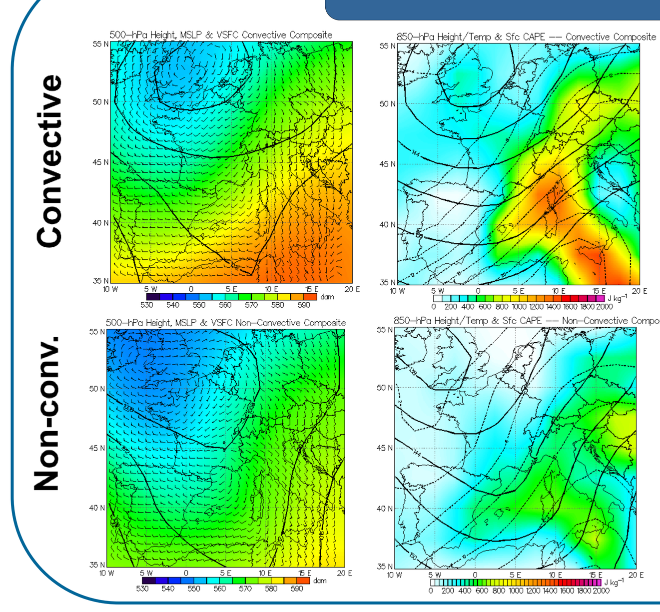
European Alps



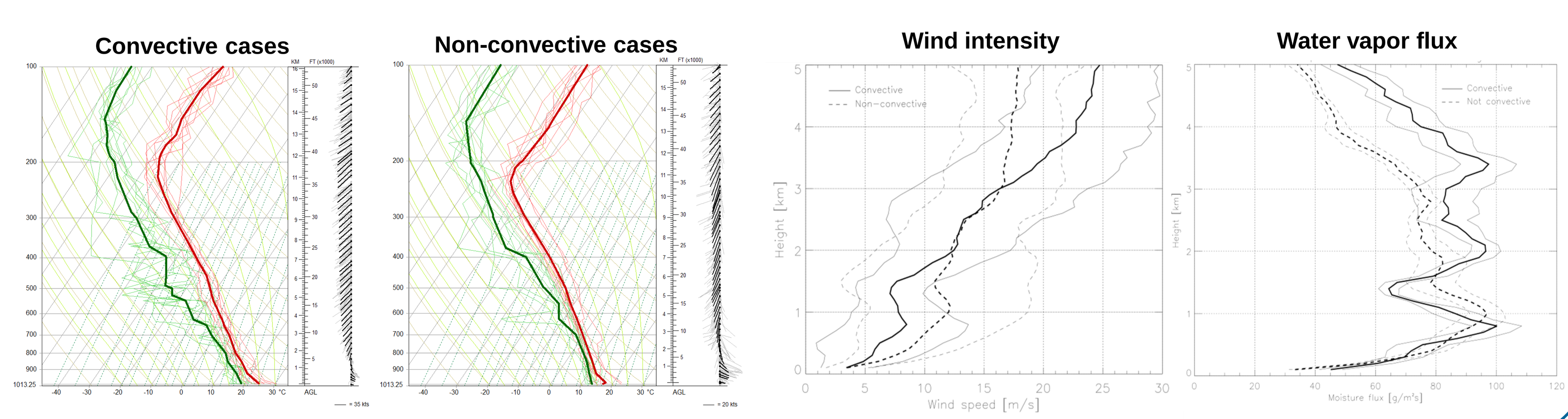
Lago maggiore area



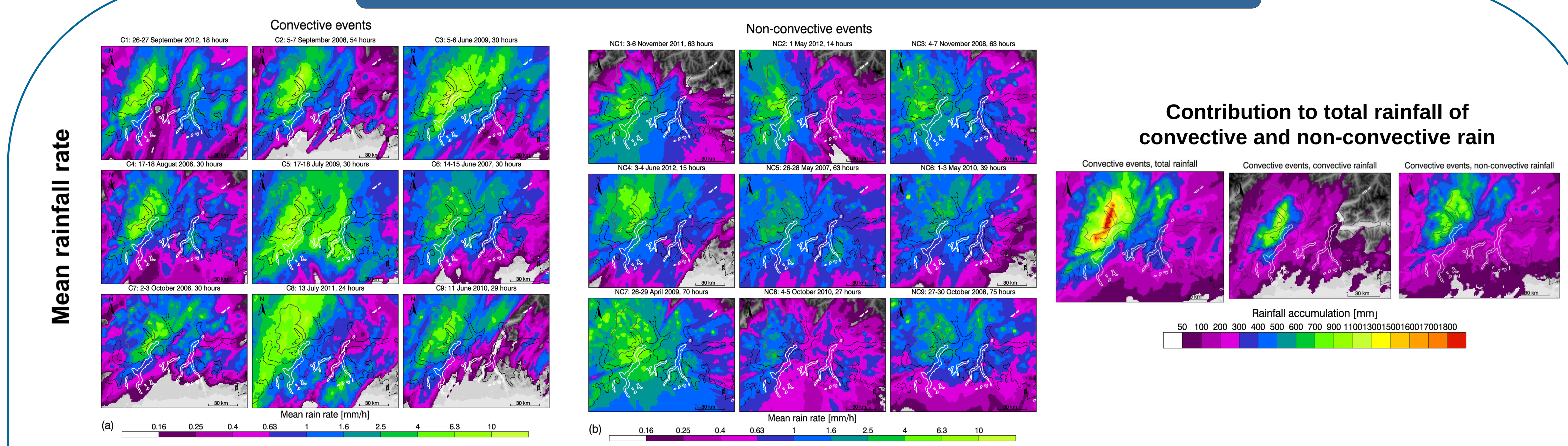
Synoptic and mesoscale features



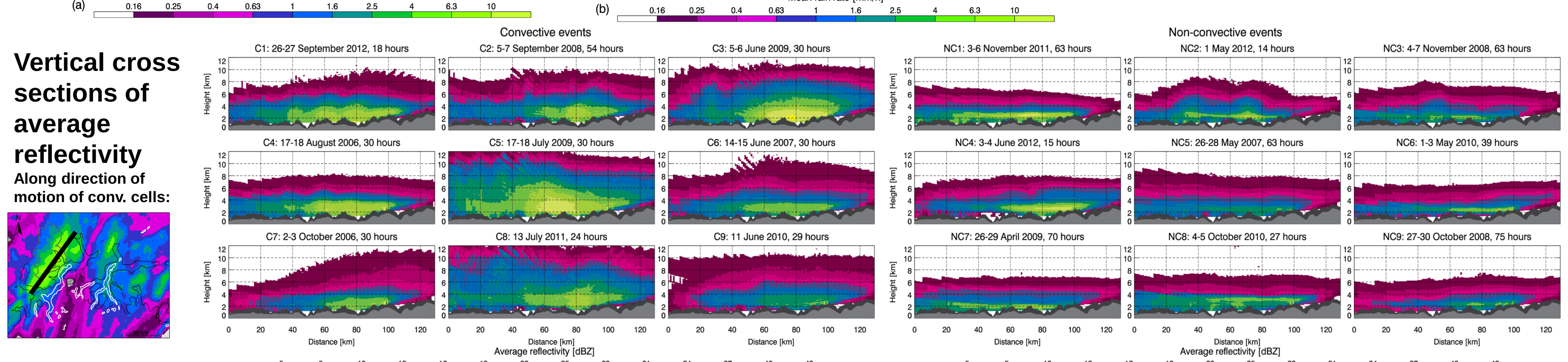
Upstream Milano soundings



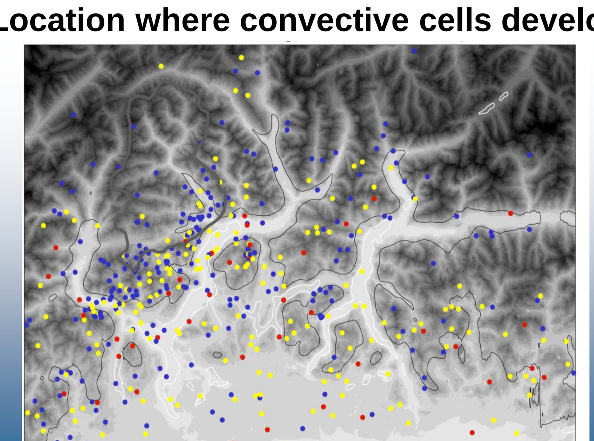
Structure of storms



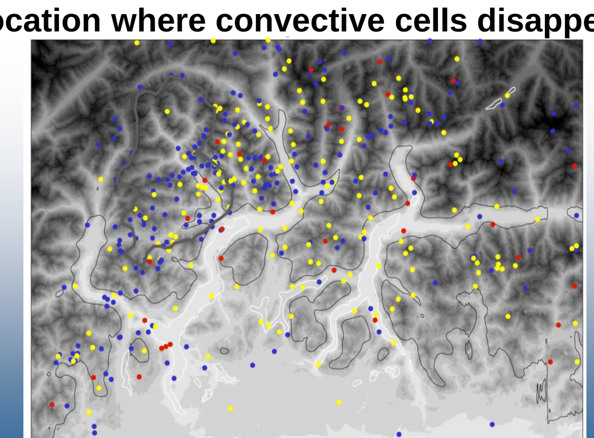
Vertical cross sections of average reflectivity
Along direction of motion of conv. cells:



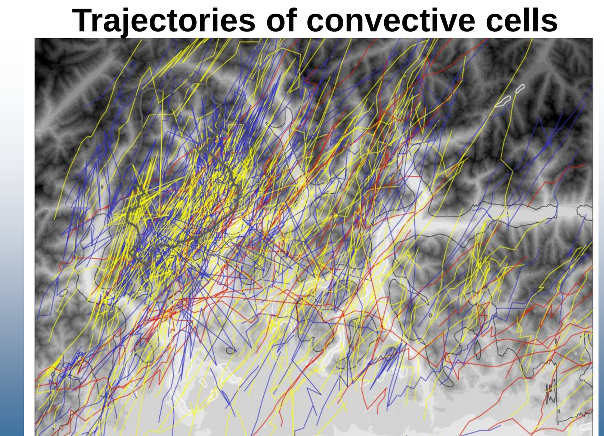
Location where convective cells develop



Location where convective cells disappear



Trajectories of convective cells

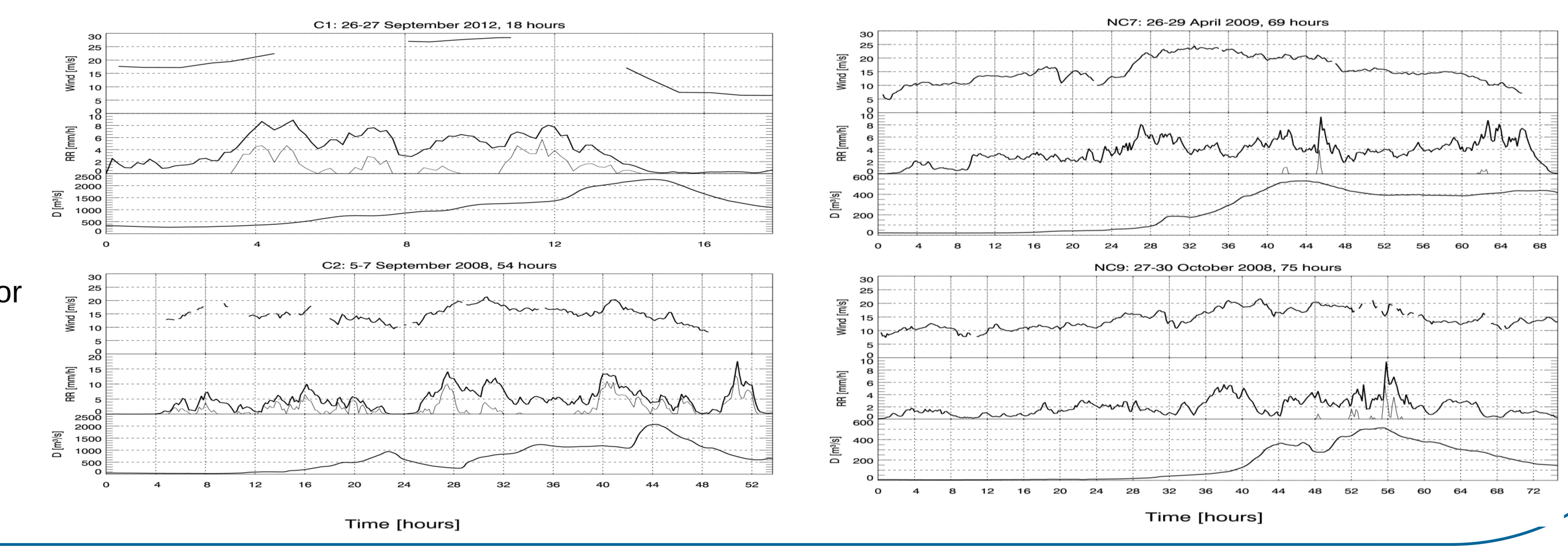


The events

The storms that produced the highest peak discharge rates at the outlet of the Maggia river from 2005 to 2012 are studied. The 9 most intense cases exhibit clear convective features.

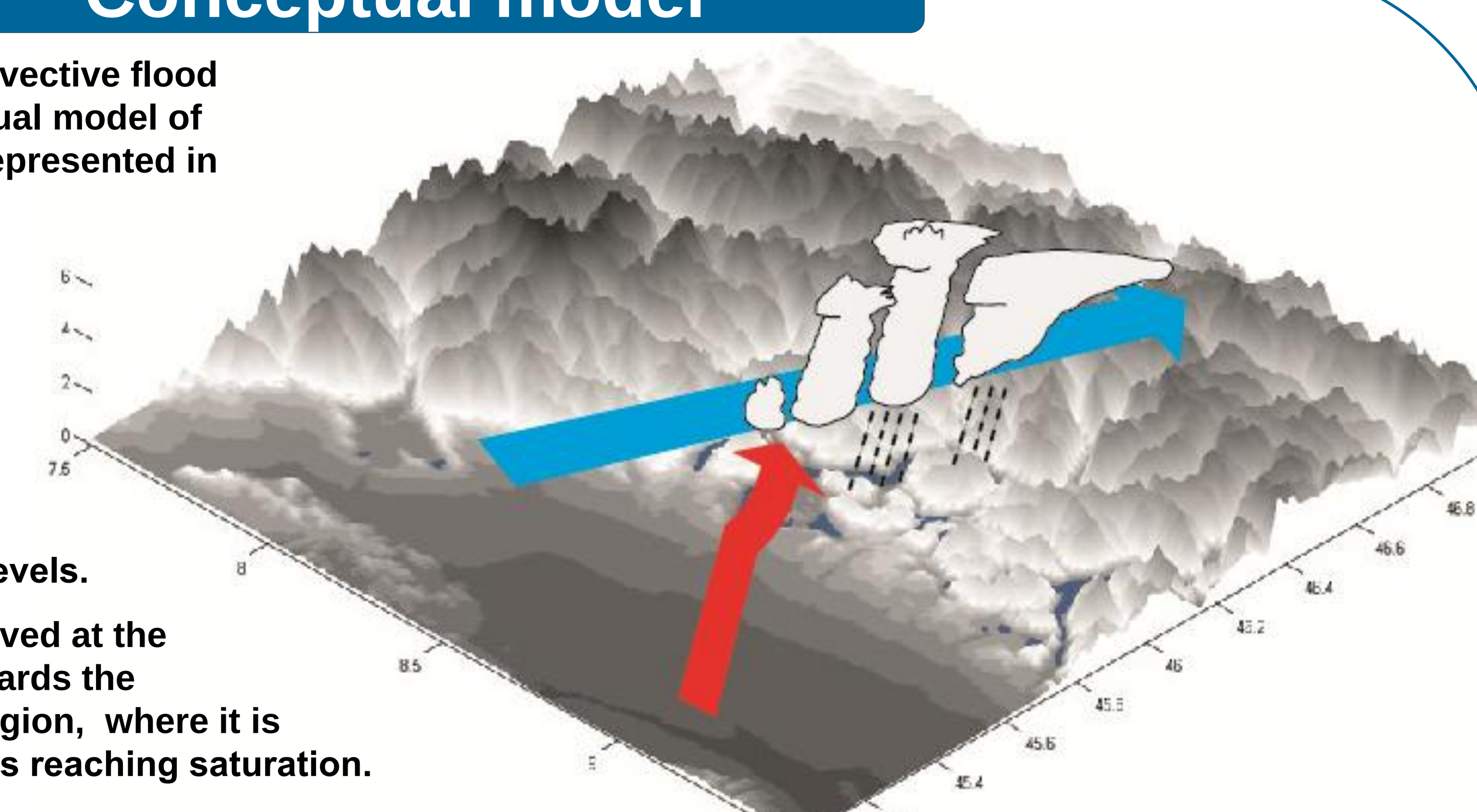
	Name	River peak discharge [m³/s]	Day of peak	Duration [hours]	Mean rain rate [mm/h]	Frequency convective cells [cells/hour]	Contrib. to tot rain of cells [%]	Height echoes [km]
Convective cases	C1	*2258*	09.27.2012	18	3.8	7	24	5.4
	C2	2079	09.07.2008	54	4.4	10	41	5.4
	C3	1592	06.06.2009	30	4.4	6	44	6.8
	C4	1579	08.18.2006	30	3.3	9	24	4.8
	C5	1216	07.18.2009	30	4.3	9	46	7.4
	C6	1203	06.15.2007	30	2.8	5	13	4.8
	C7	1045	10.03.2006	30	1.7	2	16	4.6
	C8	997	07.13.2011	24	6.3	9	58	8.4
	C9	978	06.12.2010	29	3.4	8	44	7.2
Non-Convective cases	NC1	775	11.05.2011	63	2.3	0	0	4.0
	NC2	750	05.01.2012	14	2.9	2	5	5.0
	NC3	708	11.05.2008	63	2.6	1	3	4.4
	NC4	684	06.04.2012	15	3.7	1	2	5.0
	NC5	605	05.28.2007	63	2.0	1	4	4.6
	NC6	544	05.02.2010	39	1.7	0	0	4.6
	NC7	533	04.27.2009	70	3.6	0	1	4.2
	NC8	516	10.05.2010	27	1.3	0	0	4.0
	NC9	516	10.30.2008	75	1.9	1	3	4.0

Right: wind at 1.5 km (top panel), mean rain rate over Maggia Valley (middle panel, thick line), mean convective rain rate over Maggia Valley (middle panel, thin line) and river discharge rate (bottom panel) for 4 selected flood events.



Conceptual model

The results of the analysis of the nine convective flood events can be generalized by the conceptual model of orographic convection in sheared flows represented in the figure to the right.



- **The red streamline indicates the south-southeasterly low-level flow observed over the Po Valley, which is frequently associated with a low-level jet.**
- **The blue streamline represents the south-westerly flow observed at mid and upper levels.**
- **The potentially unstable air which is observed at the low levels in the Po Valley is advected towards the north-northwest into the Lago Maggiore region, where it is forced to ascend over the first Alpine peaks reaching saturation.**
- **The sufficient instability and strong upslope orographic lifting create efficient convective cell development over the terrain just southwest of the Maggia watershed.**
- **The convective cells are transported towards the northeast by the upper-level southwesterly wind, reaching maturity over the Maggia catchment and then disappearing over the interior of the Alps northeast of the watershed.**
- **The vertical development of the storms is directly related to the magnitude of the low-level flow impinging on the Alps and to the instability of the lower atmospheric layers upstream. The number and the intensity of convective cells are also proportional with the low level flow speed.**
- **This conceptual model represents a process by which mountains can trigger and maintain moist convection over the same region, and it is likely to be observed over other mountain ranges of the world.**
- **This process is due to the advection of warm, moist potentially unstable air towards the barrier at low levels, and to the different directions of the lower and upper level wind, with the steering flow being parallel to the barrier.**
- **This study shows how flash flooding over complex terrain may occur in the presence of strong upper-level flow, in contrast with case studies of weak upper-level flow, such as the famous Big Thompson and Black Hills floods.**