The life cycle of anvil clouds from SEVIRI

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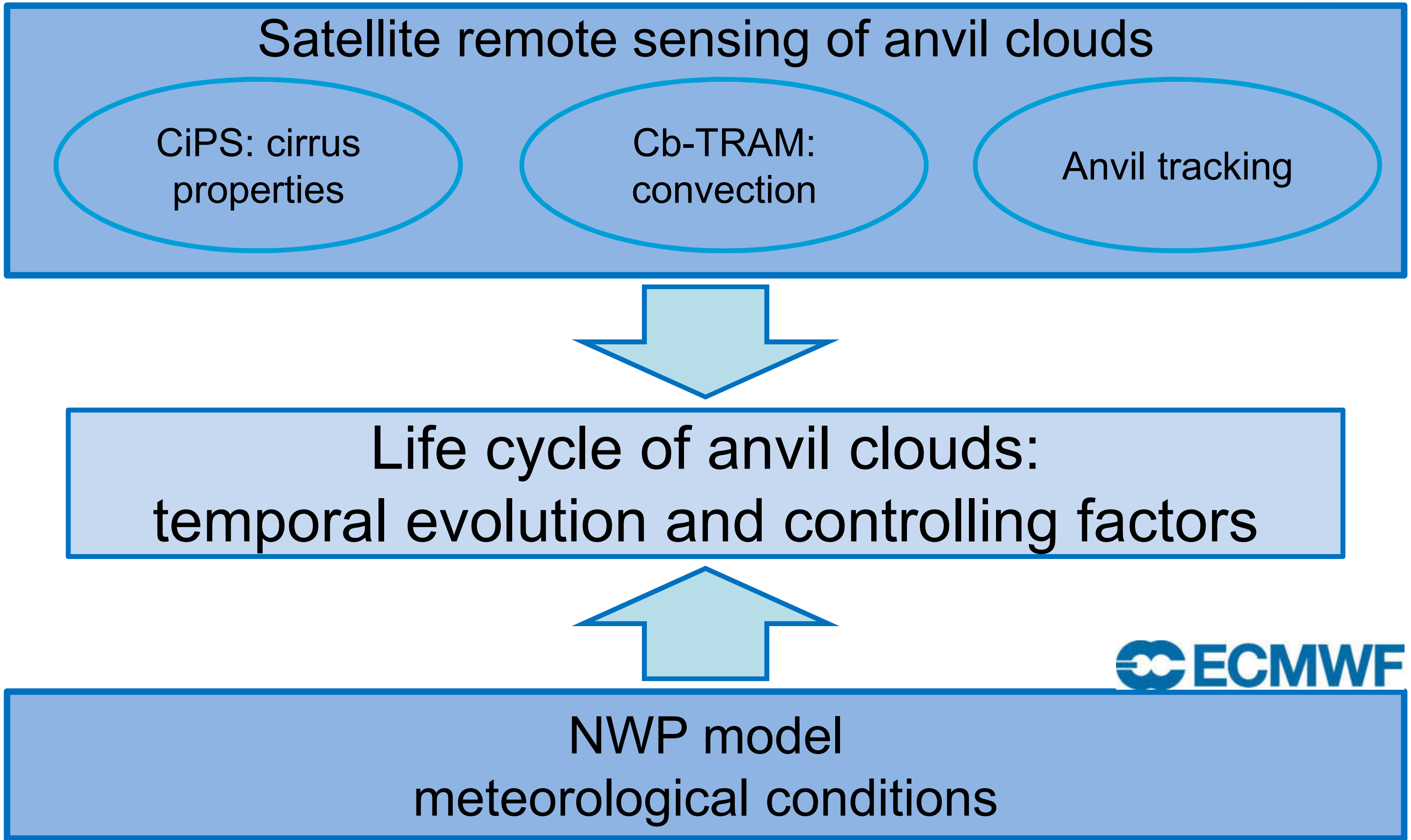
Goal


Satellite remote sensing of anvil clouds
CiPS: cirrus properties
Cb-TRAM: convection
Anvil tracking
Life cycle of anvil clouds:
temporal evolution and controlling factors
ECMWF
NWP model
meteorological conditions

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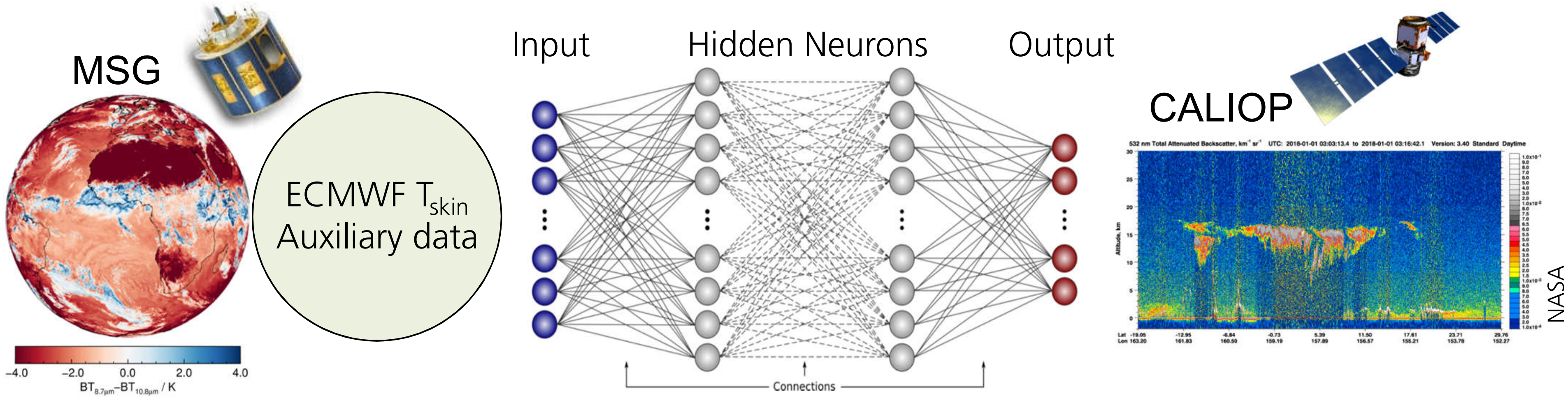
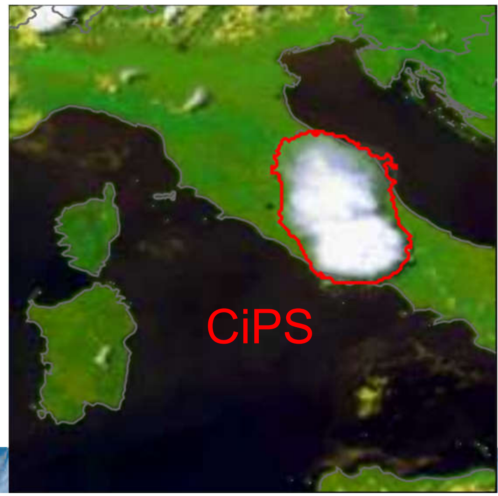
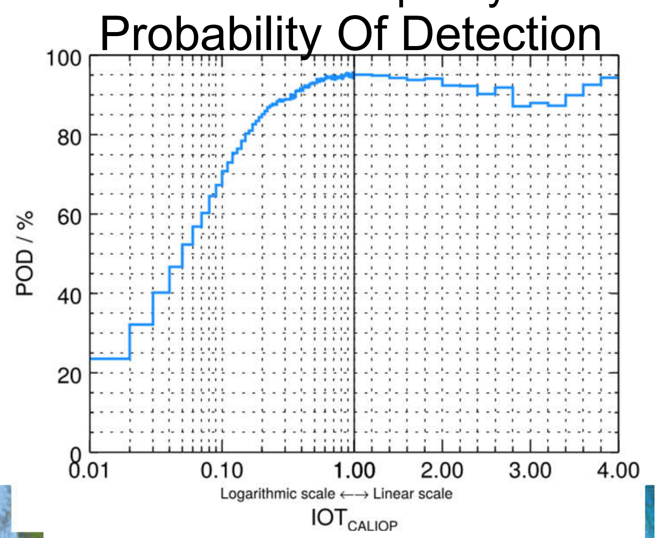
CiPS: anvil cirrus detection and properties



- CiPS is a set of four artificial neural networks using thermal SEVIRI observations
- CiPS detects ice clouds
- CiPS determines ice optical thickness, IWP, cloud top height, effective radius and opacity



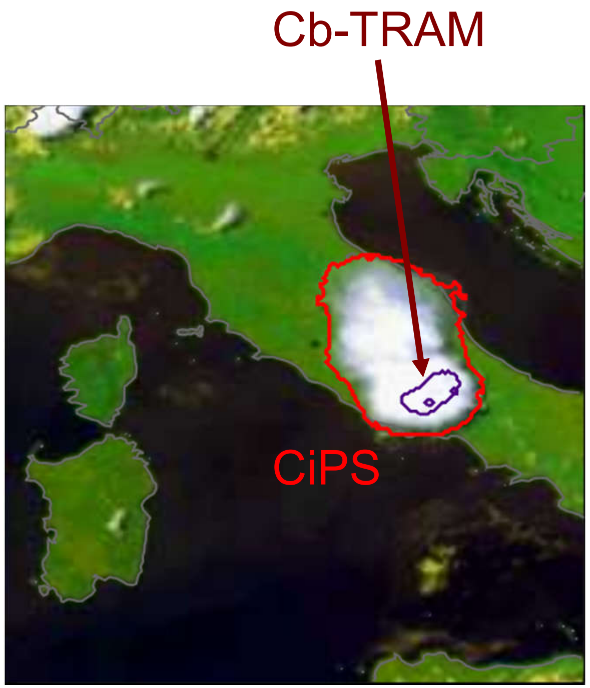


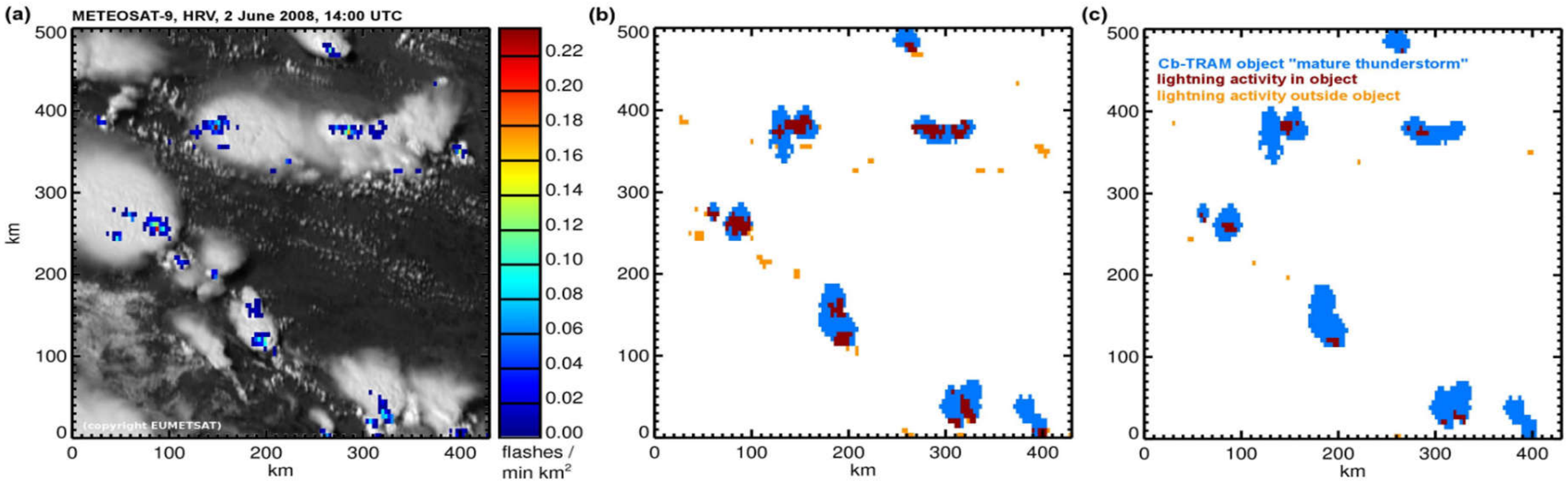
CiPS: Cirrus Properties from SEVIRI

Strandgren et al. 2017a, 2017b

Cb-TRAM: detection of convection

- Stage 1: strong local development of low convective clouds.
- Stage 2 (rapid growth of severe convective cells): rapid cooling of high cloud tops in consecutive WV images.
- Stage 3 (mature convective cells / active cell cores with cirrus anvil): WV temperature close to or smaller than the temperature of the current tropopause + large local spatial inhomogeneity of High Resolution Visible (HRV) reflectivity.

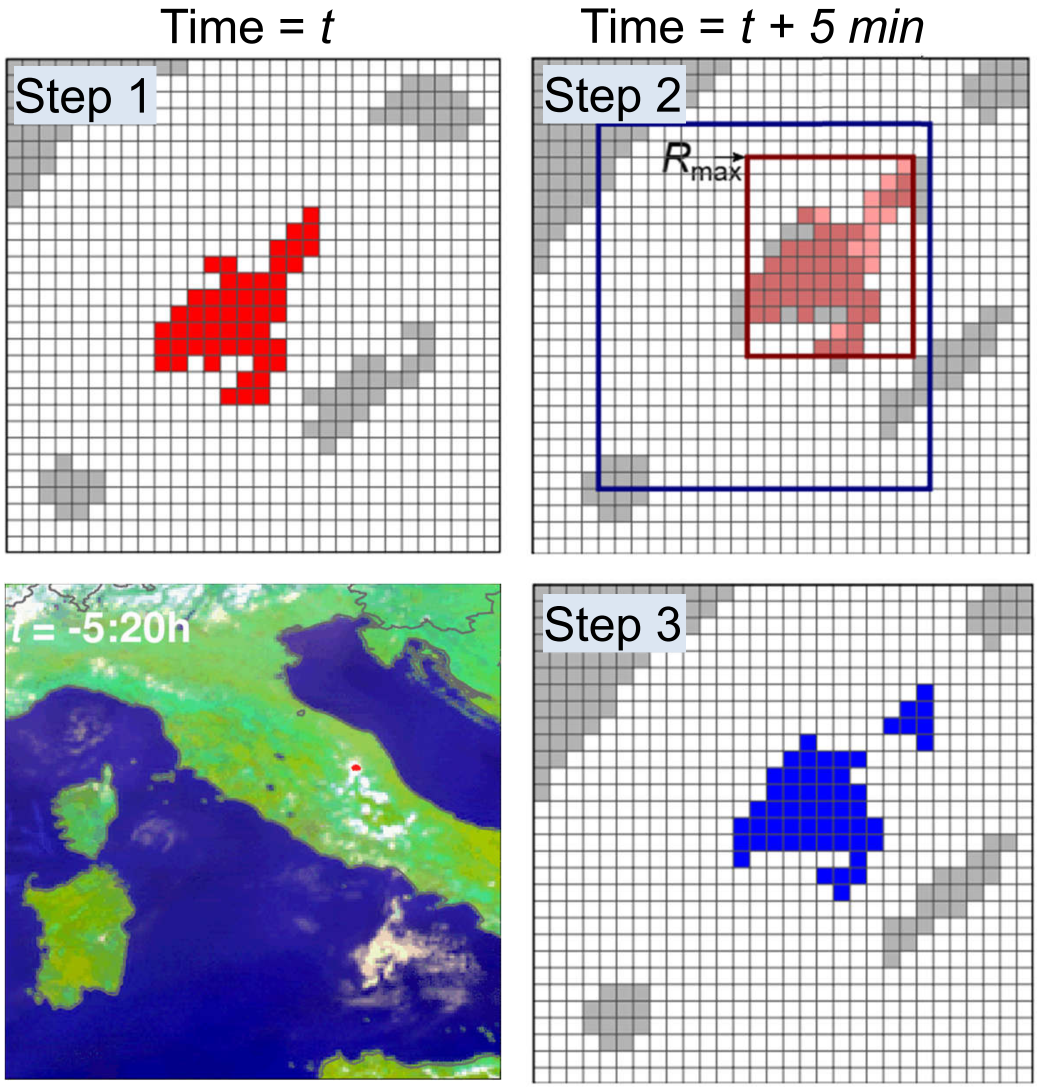




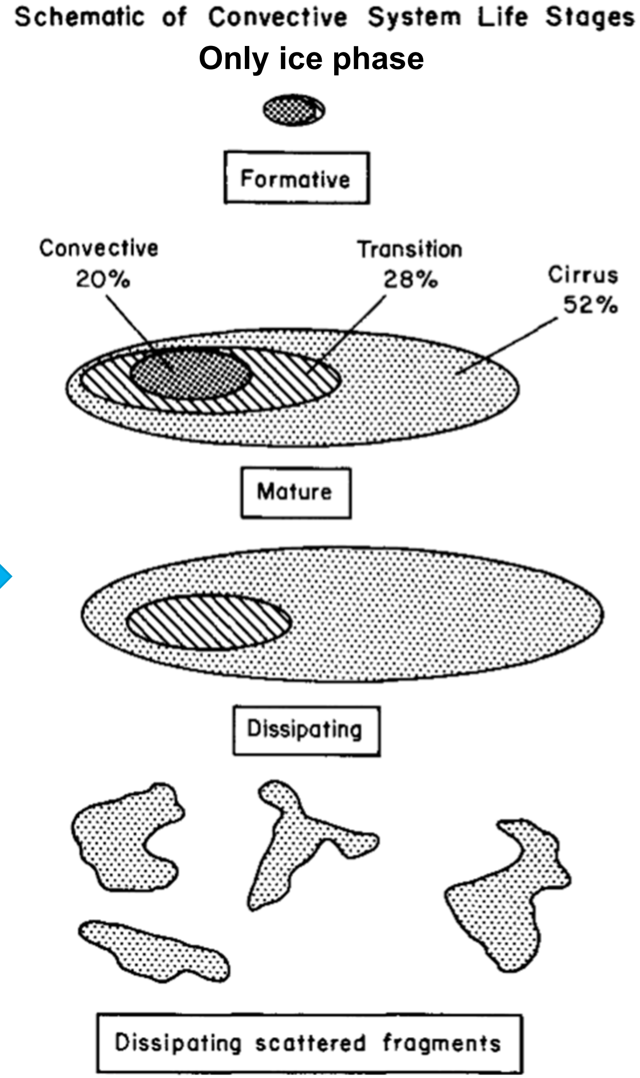
Cb-TRAM: Cb Tracking and Monitoring

Zinner et al. 2008, 2013, Merk and Zinner 2013

Anvil tracking: an overlap technique



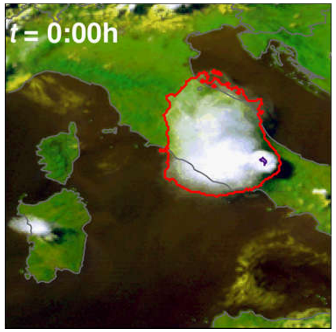
Inspired by Bolliger et al. 2003

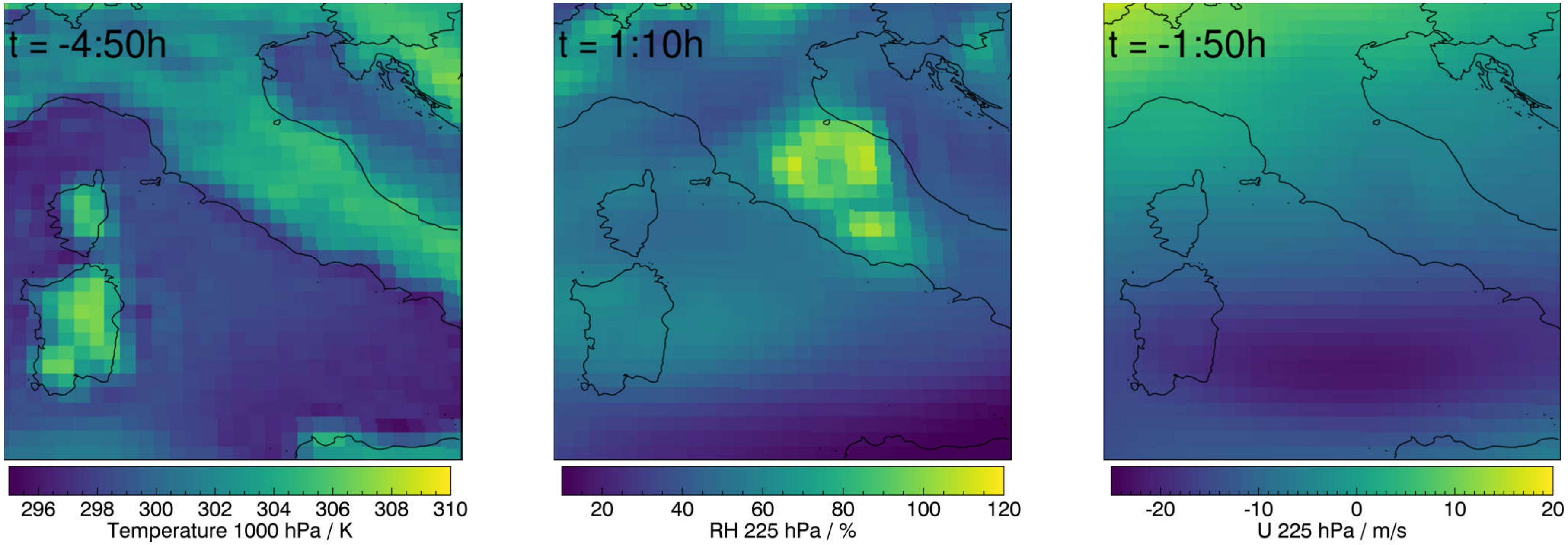


Machado and Rossow 1993

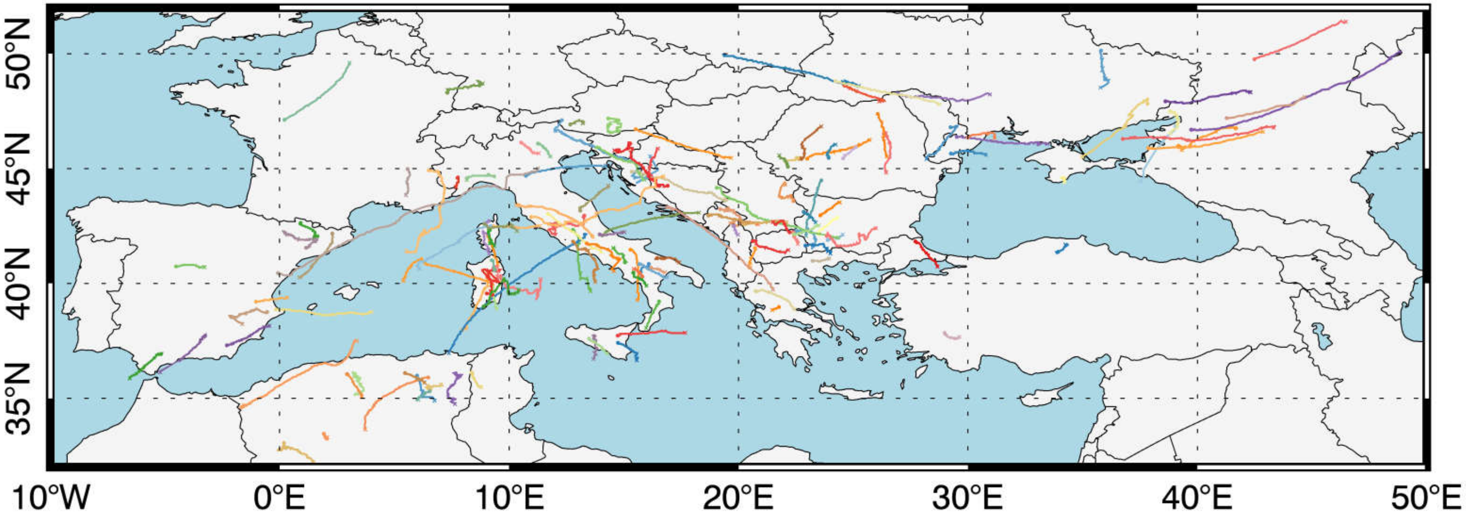
Model data: ERA5

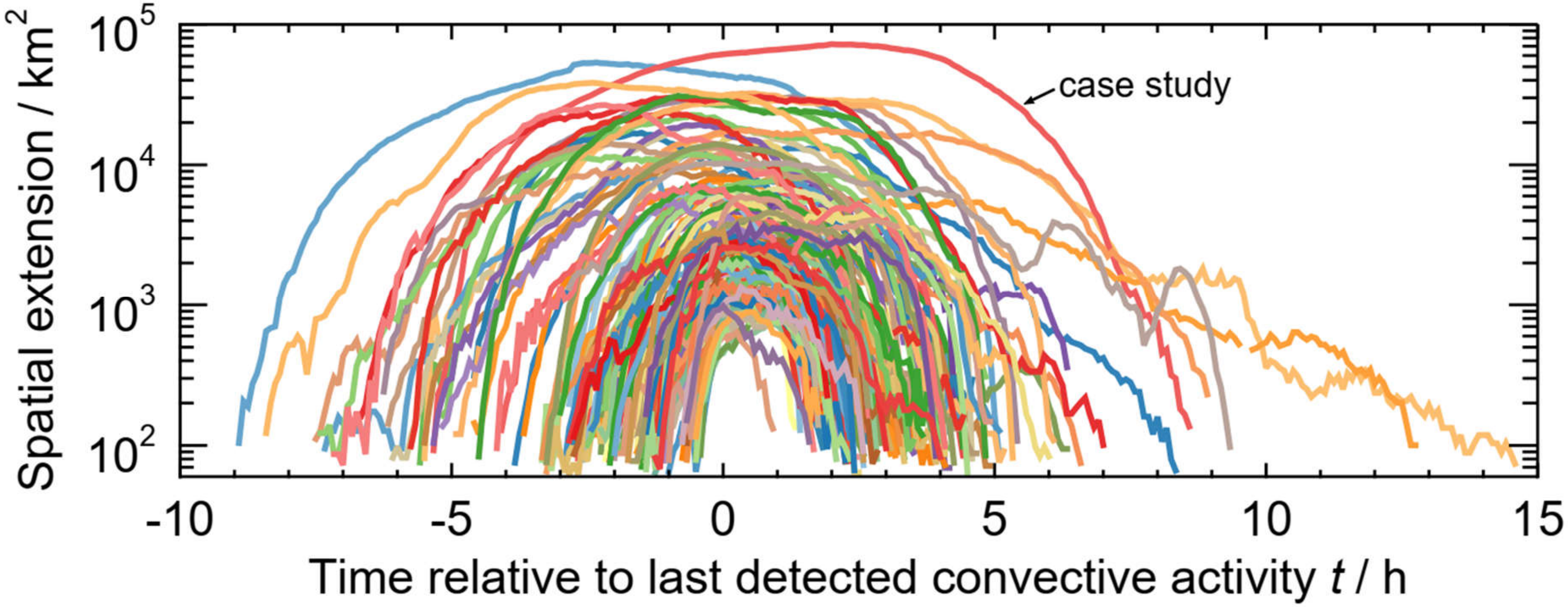
- Air temperature, relative humidity (RH), convective available potential energy (CAPE) and horizontal wind analysis data are used to characterise the **meteorological conditions** in which convective cumulonimbus clouds and anvil cirrus form.
- Resolutions: 31 km, 1 h



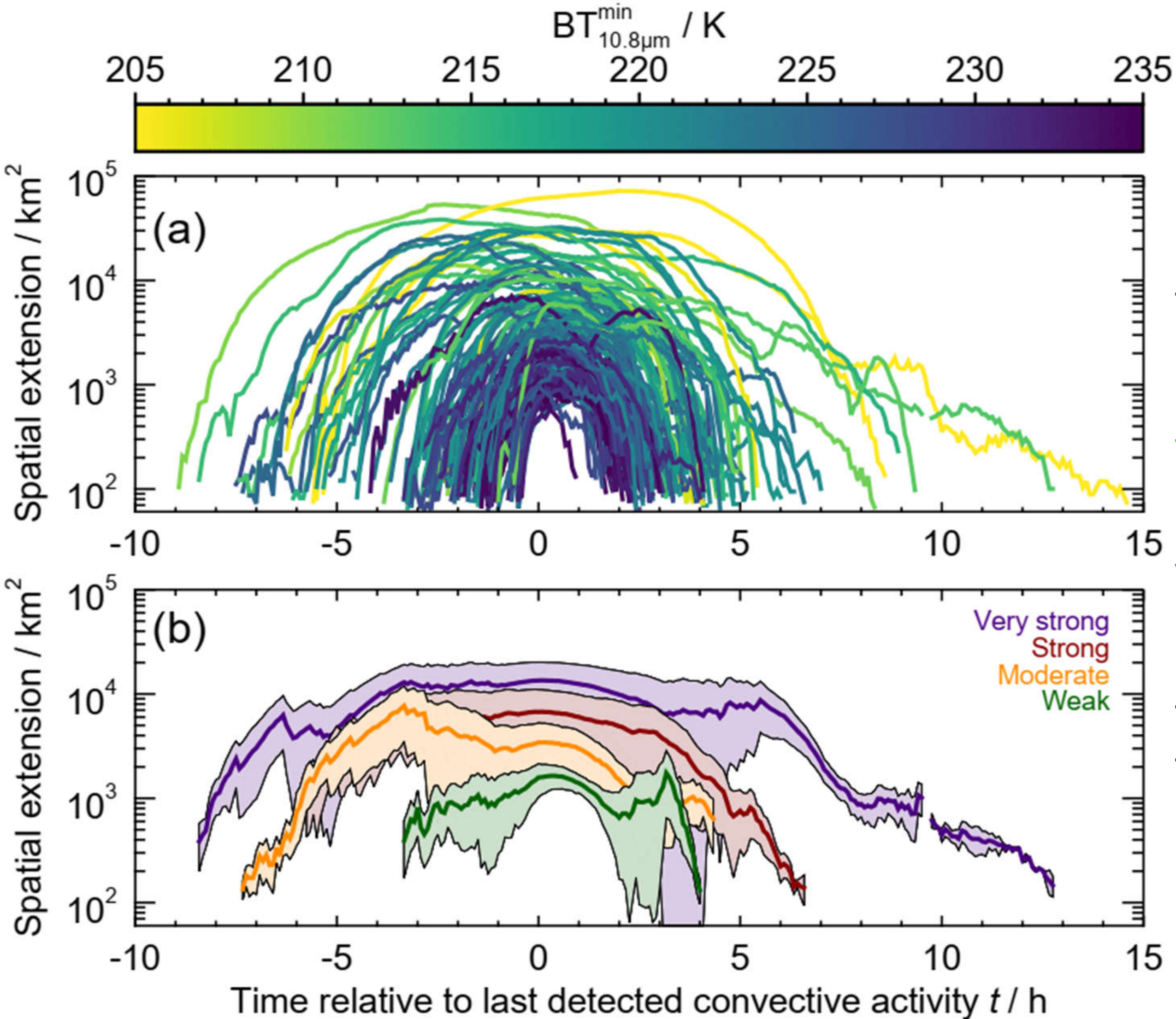


Life cycle of 132 isolated mid-latitude anvils in July 2015





Temporal evolution: spatial extension and life time



Four equally large convective strength (CS: minimum brightness temperature at 10.8 µm) classes:

Weak: $BT^{min} \geq 229$ K
Moderate: 229 K > $BT^{min} \geq 224$ K
Strong: 224 K > $BT^{min} \geq 219$ K
Very strong: 219 K > BT^{min}

Convective strength strives to represent the strength in the *vertical* development.

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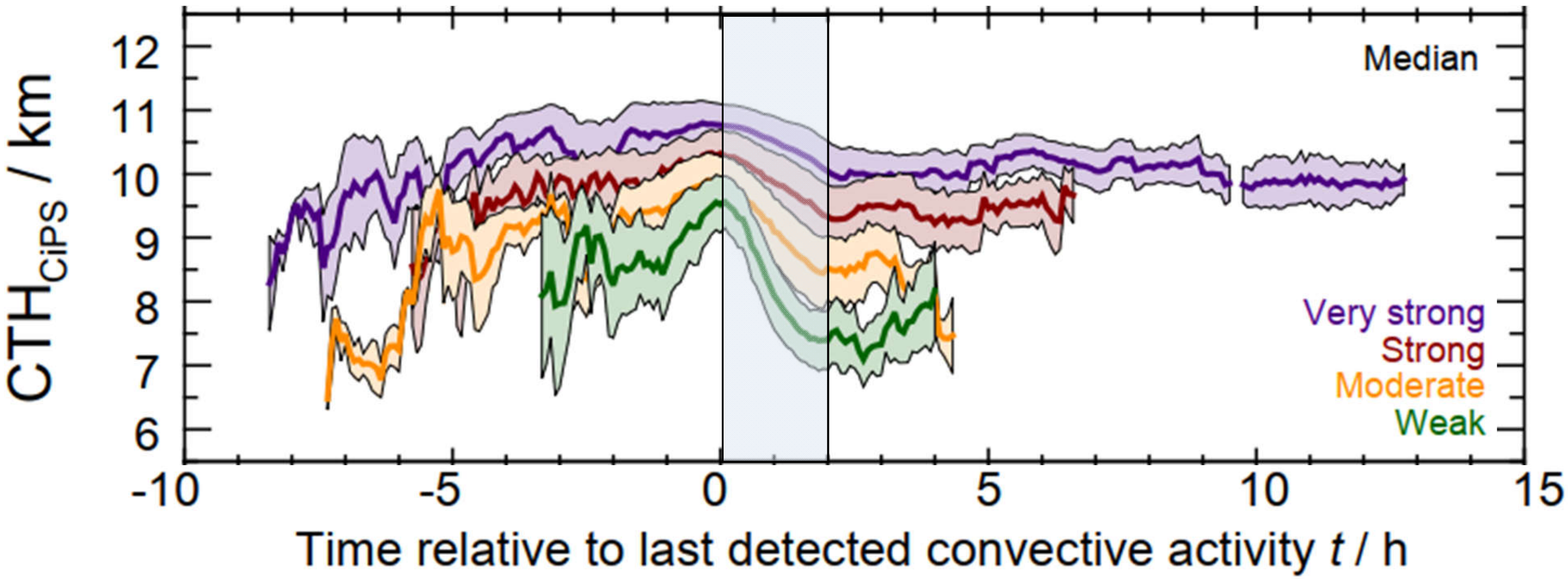
Temporal evolution: Cloud Top Height (CTH)



- CTH increases until convection ceases.
- Anvils sink faster as convection ceases if the convective strength is weaker.
- For the strongest 25%, the median CTH decreases by 0.8 km in 2 h as convection ceases, for the weakest 25%, the decrease in height is 2 km.

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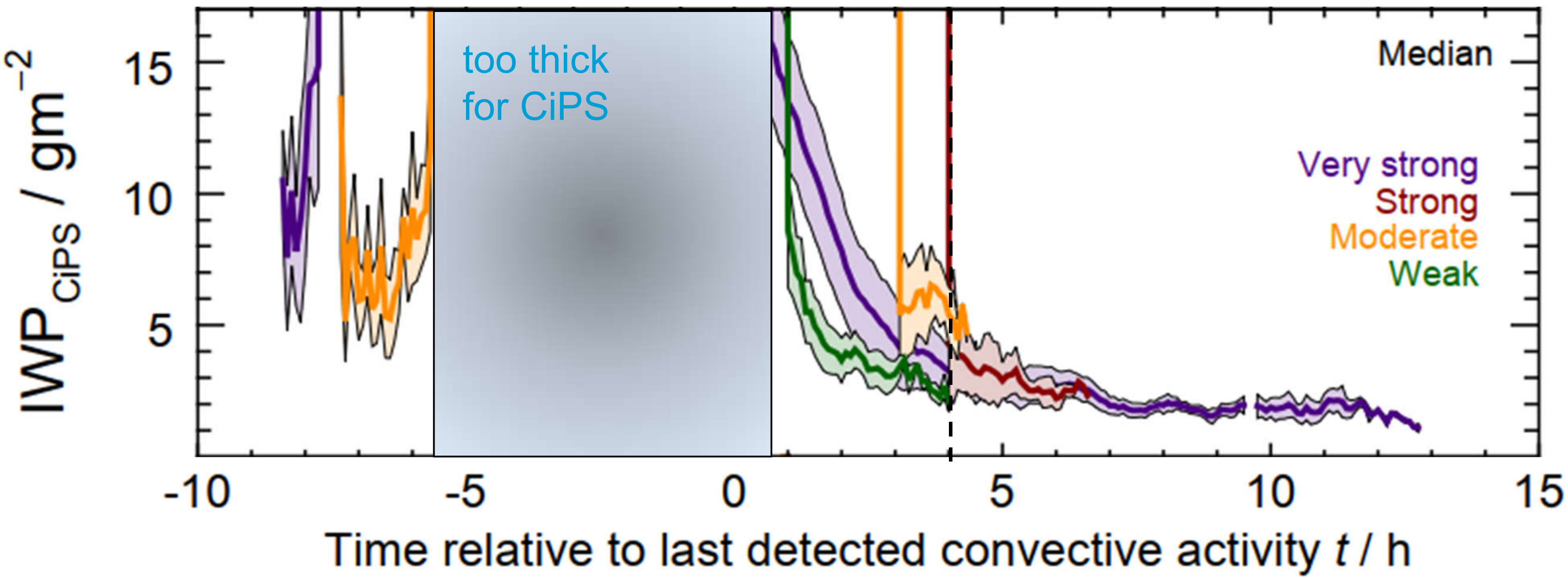
Temporal evolution: Ice Water Path (IWP)



- Anvils thin out fast after convection has ceased.
- There is no clear relationship between CS and IWP.
- IWP values are very similar starting approx. 4 h after convection : only the weakest 25% reach lower values.
- Approx. 4 h after convection IWP is not controlled by convection. Is ice supersaturation the main controlling factor?

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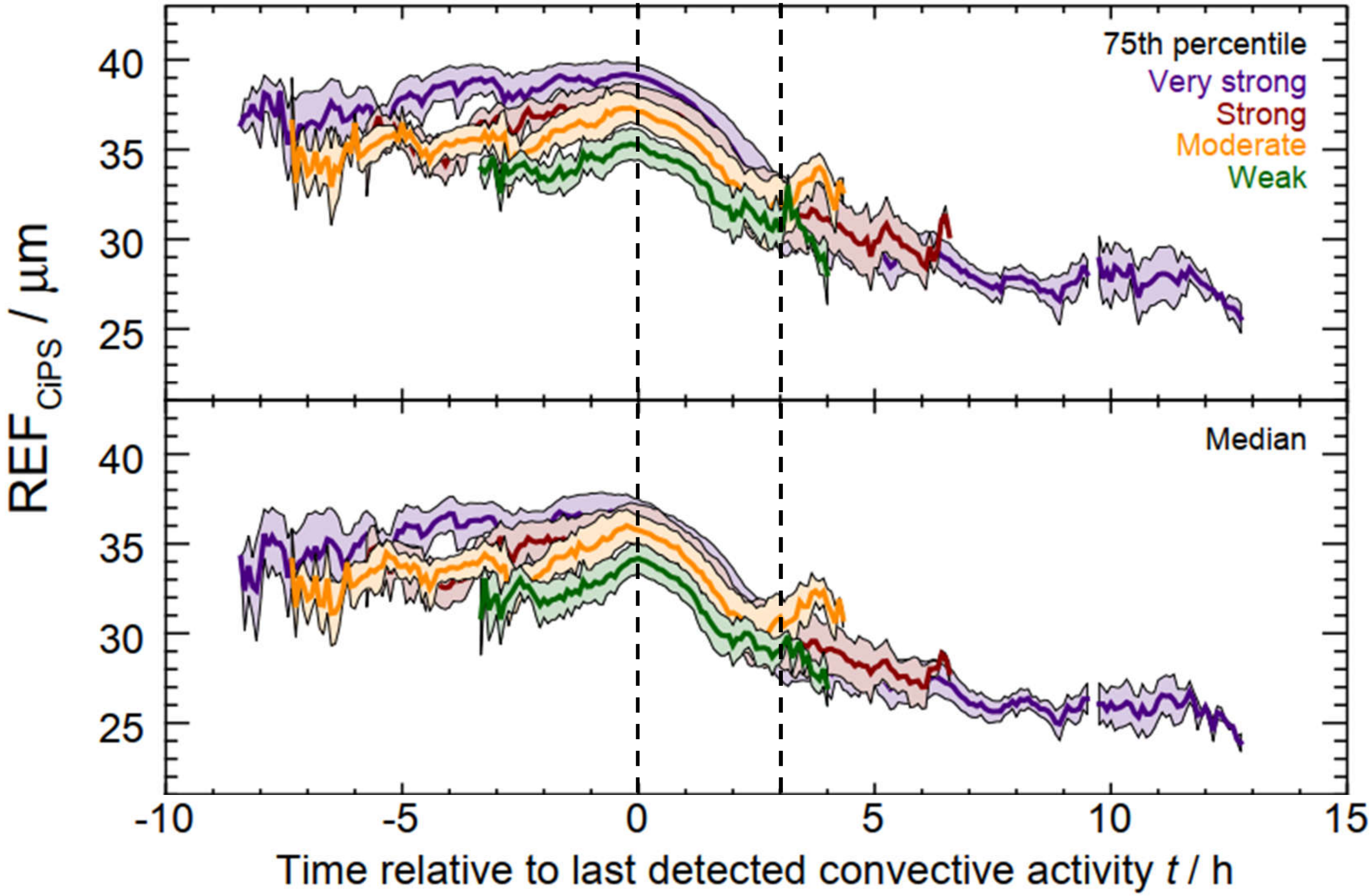
Temporal evolution: Effective Radius (REF)



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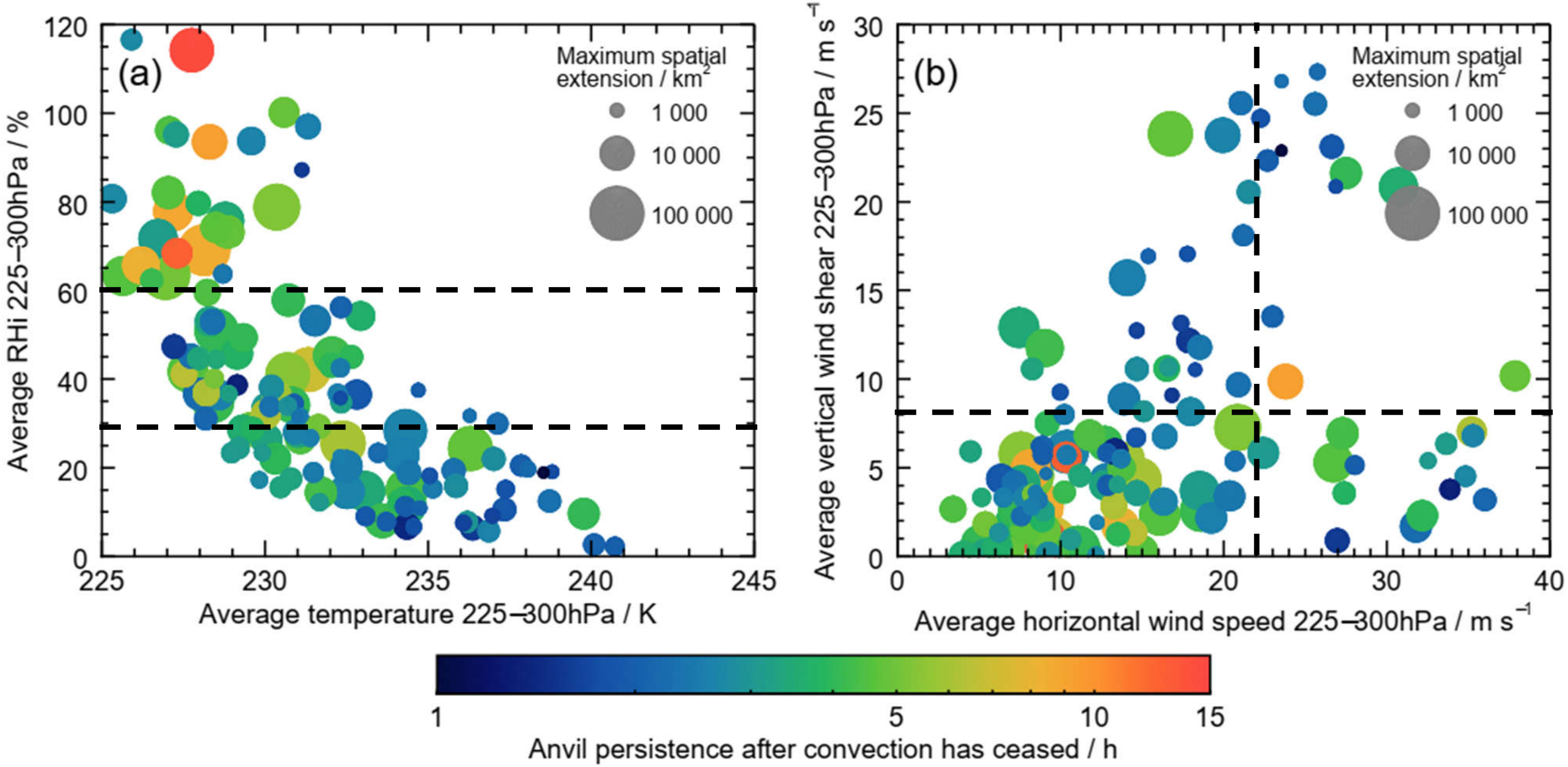
- Stronger convection produces larger ice crystals.
- After convection the decrease in REF is faster for strong systems.
- 3 h after convection: only small differences among CS classes, REF is no longer controlled by convection. Large ice crystals have sedimented out, water vapour deposition (or nucleation of new particles) controls persistence?

Factors controlling spatial extension and persistence



- Lower RHi (< 30%) generally leads to small and short-lived anvils.
- Higher RHi (> 60%) govern larger and more long-lived anvils.
- Most of the large long-lived anvils tend to have moderate horizontal wind speeds (< 22 m/s) and/or small vertical wind shear (< 8 m/s).

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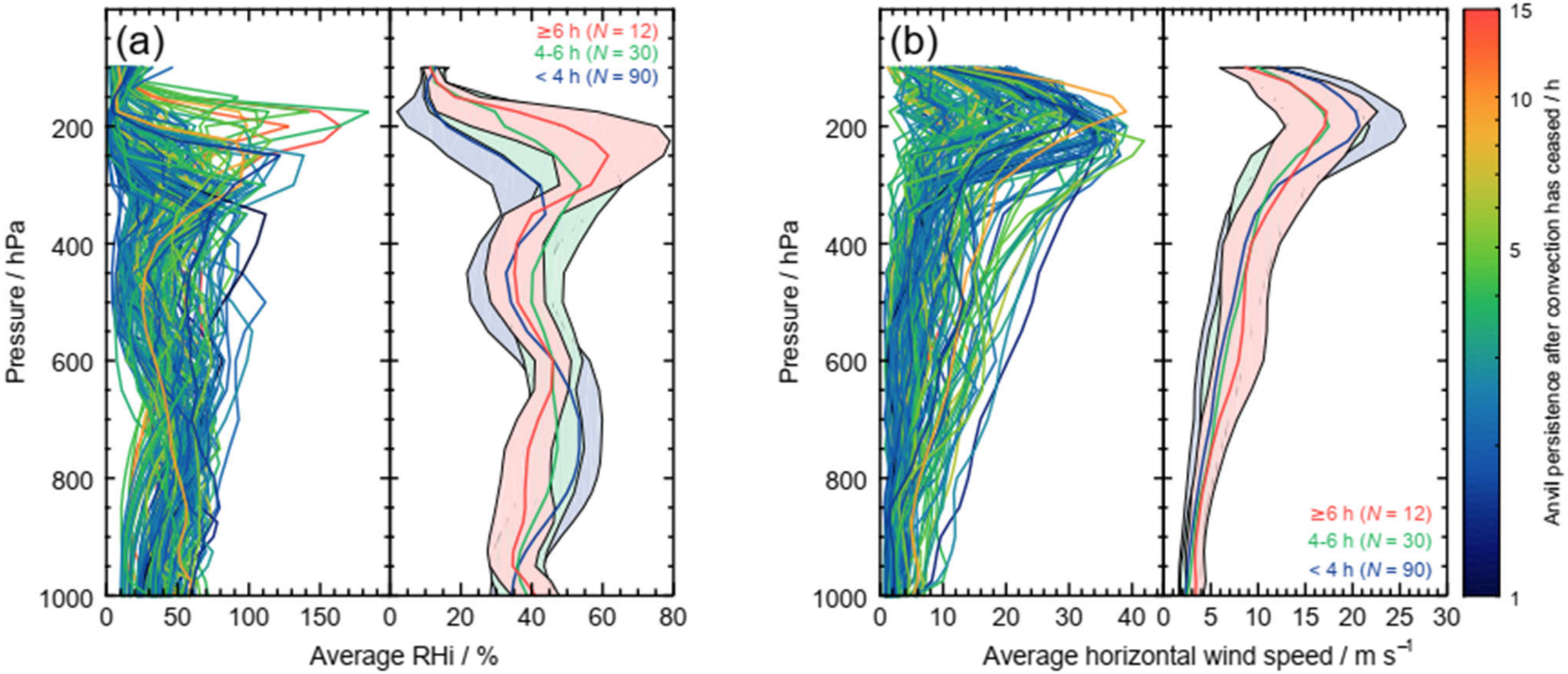
Factors controlling persistence



- More long-lived anvils are associated with higher RHi in the upper troposphere.
- Higher wind speeds in the upper troposphere tend to reduce anvil persistence after convection has ceased.

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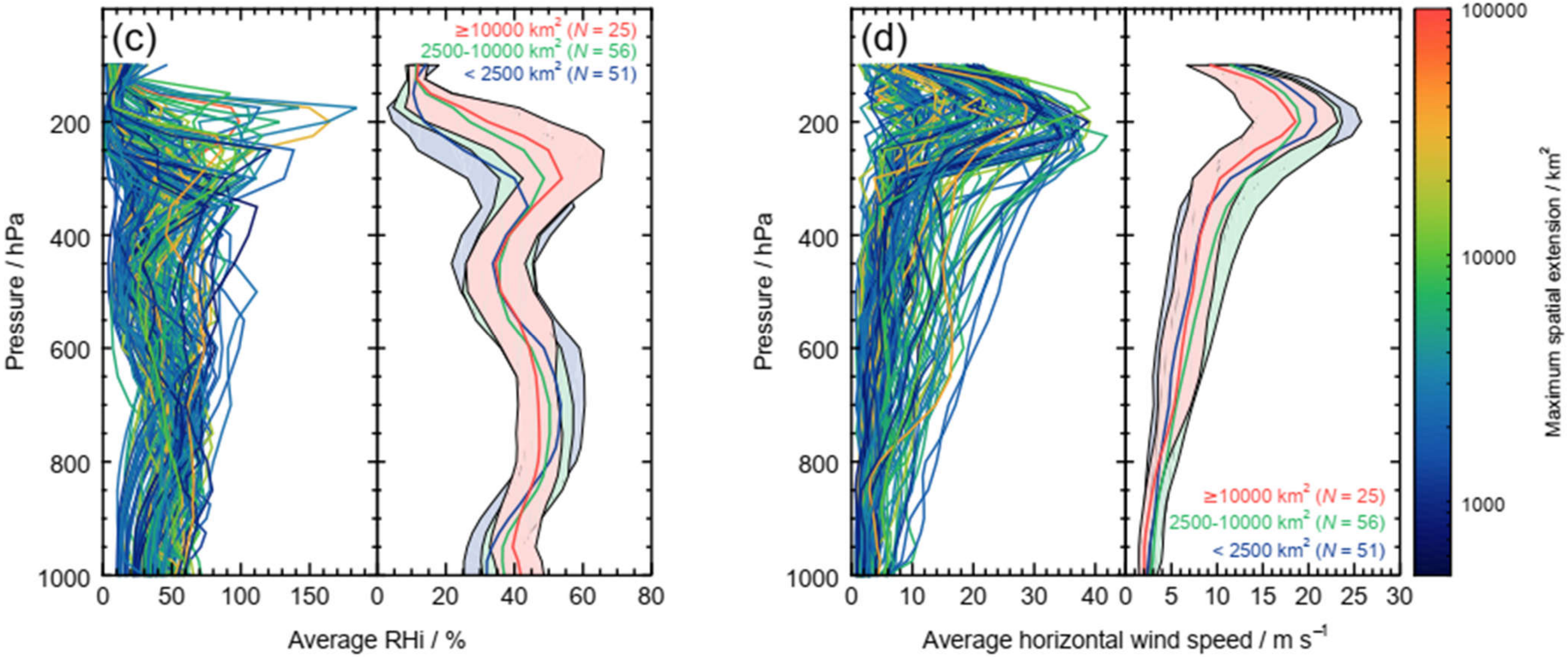
Factors controlling spatial extension



- Higher RHi in the upper troposphere is associated with larger anvils.
- Higher wind speeds in the upper troposphere tend to reduce anvil spatial extension.

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Conclusions

132 isolated anvil clouds have been tracked in July 2015 with MSG/SEVIRI.

Large variability of observed spatial extension and life time.

During convection large particles are produced, with strong systems producing larger particles.

As convection has ceased the anvils sink and thin out fast. After 2-3 h smaller ice particles remain that can live for many hours if ambient conditions (especially RHi) are favourable.

Convective strength appears to have no impact on the ice crystal size and IWP of ageing anvils.

High horizontal wind speeds in the upper troposphere tend to reduce the anvil cirrus lifetime and spatial extension.