Serendipitous detections of flying insects by EarthCARE CPR

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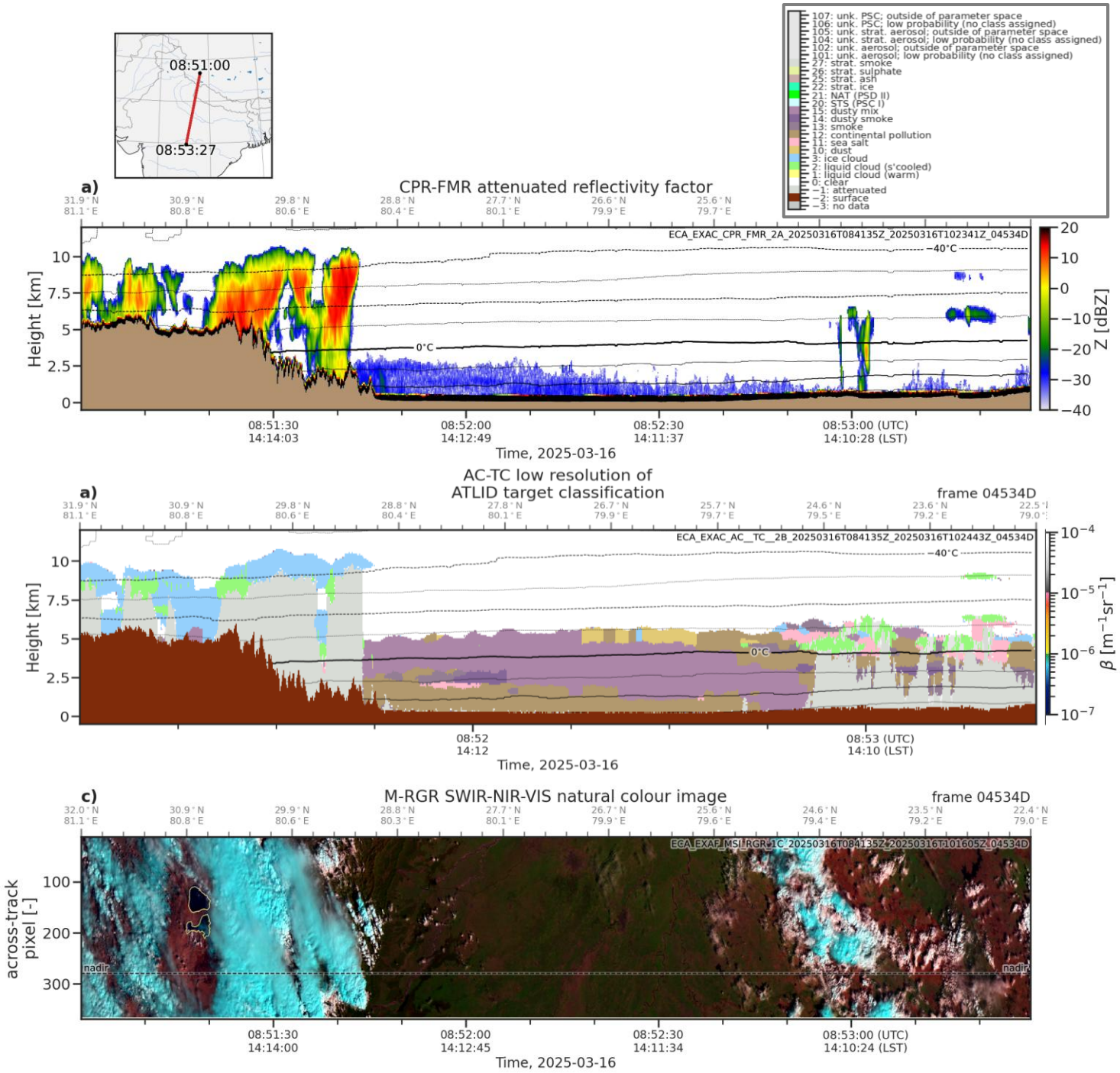
Overview

- First global detections of insects from space
- Selected case studies
- Verification with ground-based radars
- Insect detection statusvariable added to AC-TC
- First annual climatology of insects
- Next steps

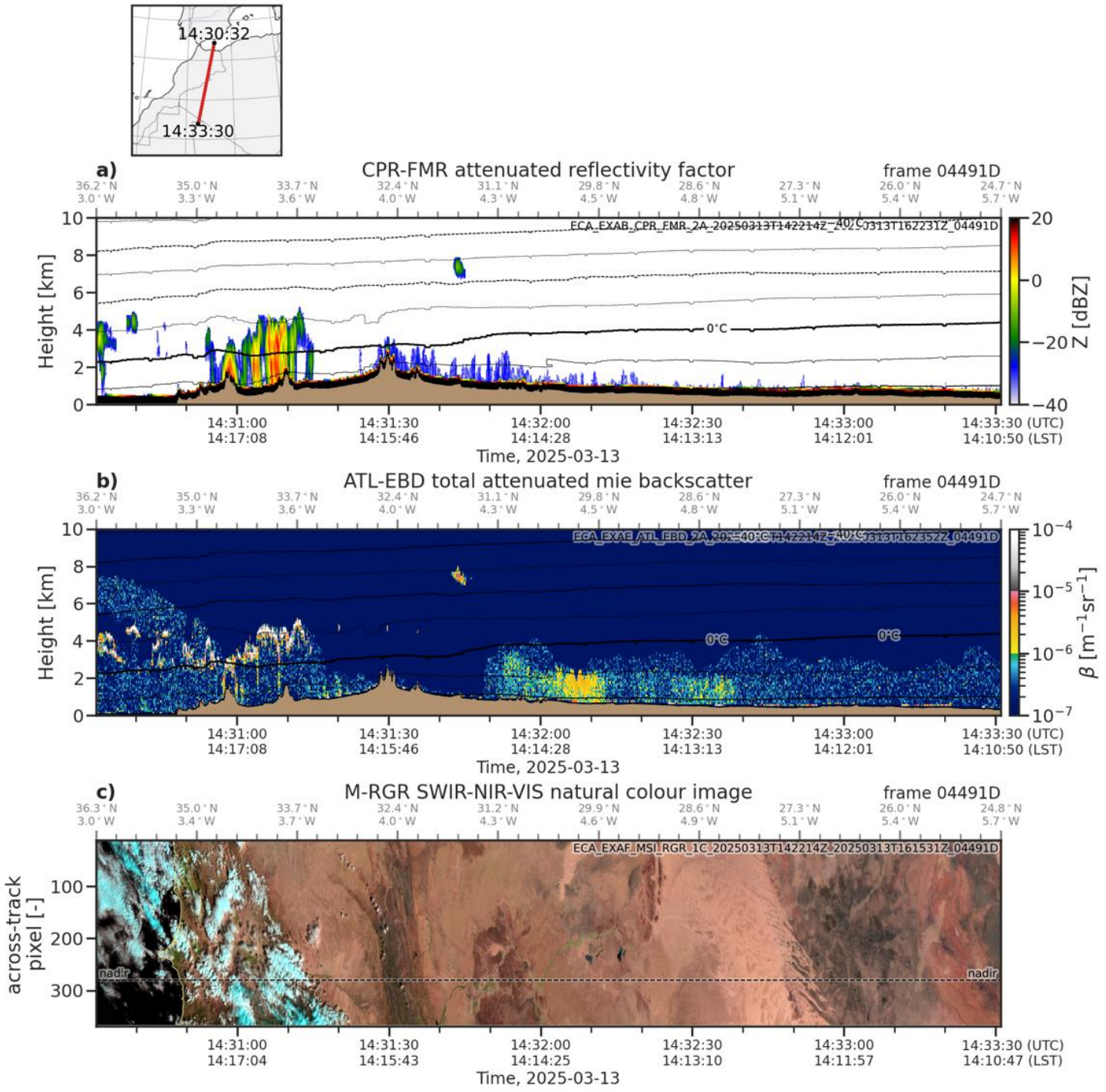
First detections

- 16 March 2025, northern India
- Synergistic detection & verification:
  - Large and widespread area of weak radar reflectivity signal (-35 < Z < -20 dBZ)
  - ATLID detects aerosols in the same layer
  - MSI confirms cloud-free
- Revealed an apparent inconsistency in AC-TC target classification
  - AC-TC “synergetic_target_classification” variable includes an “insects” class
  - AC-TC prioritizes aerosol detections from ATLID over insect detection by CPR: *because we retrieve aerosols*
- Rather than include insects + [any aerosol class], we’ll add a new variable



Case studies: deserts

- Frequently observed over deserts:
  - 18 January 2025, South Australia
  - 13 & 14 March 2025, north Africa
- Surprising results:
  - insects throughout the most arid and hot landscapes
  - lofted quite high or over mountains: at least as cold as 0°C
- Clear changes over different land-surface types



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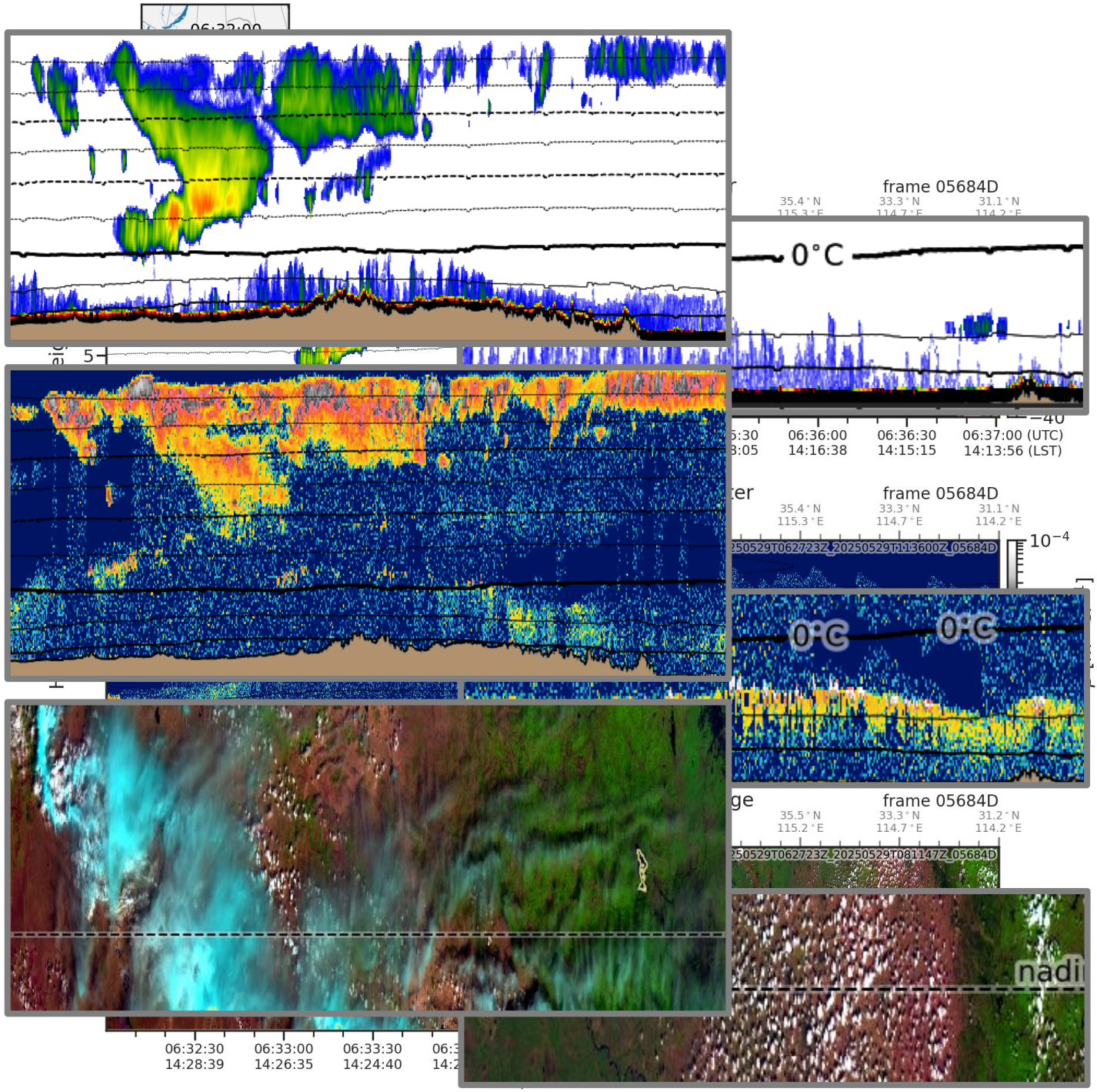
Case studies: China

- 29 May 2025, Eastern China
  - Continuous insect signals over +2000km
- Daytime cases show distinct convective features: small insects lofted high into the atmosphere
  - The deepest convective features are topped with cumulus clouds: insect signals reveals structure of small-scale convection in clear skies.
- Frequently see insect-like signals from CPR below clouds, where ATLID and MSI cannot be used to verify the profiles are cloud-free
- In nighttime cases insects tend to form shallower and more stratiform layers:
  - Larger migratory insects such as moths and locusts



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Verification against ground-based radars

- 15 June 2025, Central Europe
  - Continuous detection of insects from Poland to Italy
- Verification against CloudNet
  - CloudNet synergistic target classification has always had an “insects” class, with detections often collocated with aerosols in the boundary layer
  - Many CloudNet overpasses available for European cases
  - Enhanced detection with Ka-band radar; linear depolarization ratio distinguishes insect signal from hydrometeors
  - Diurnal cycle shows a clear deepening of the insect layer around sunrise
    EarthCARE overpasses at ~02:00 and 14:00 local time

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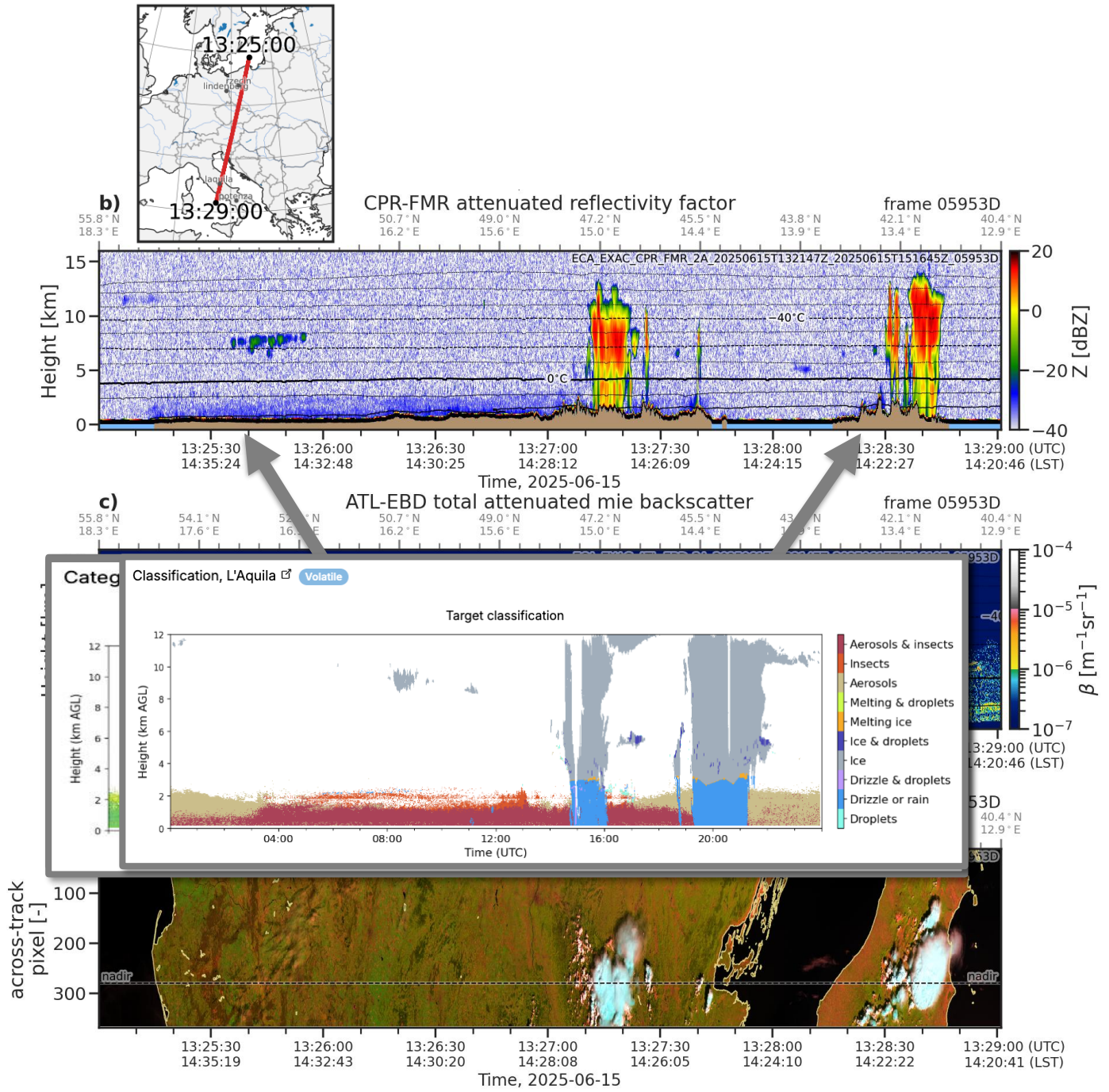
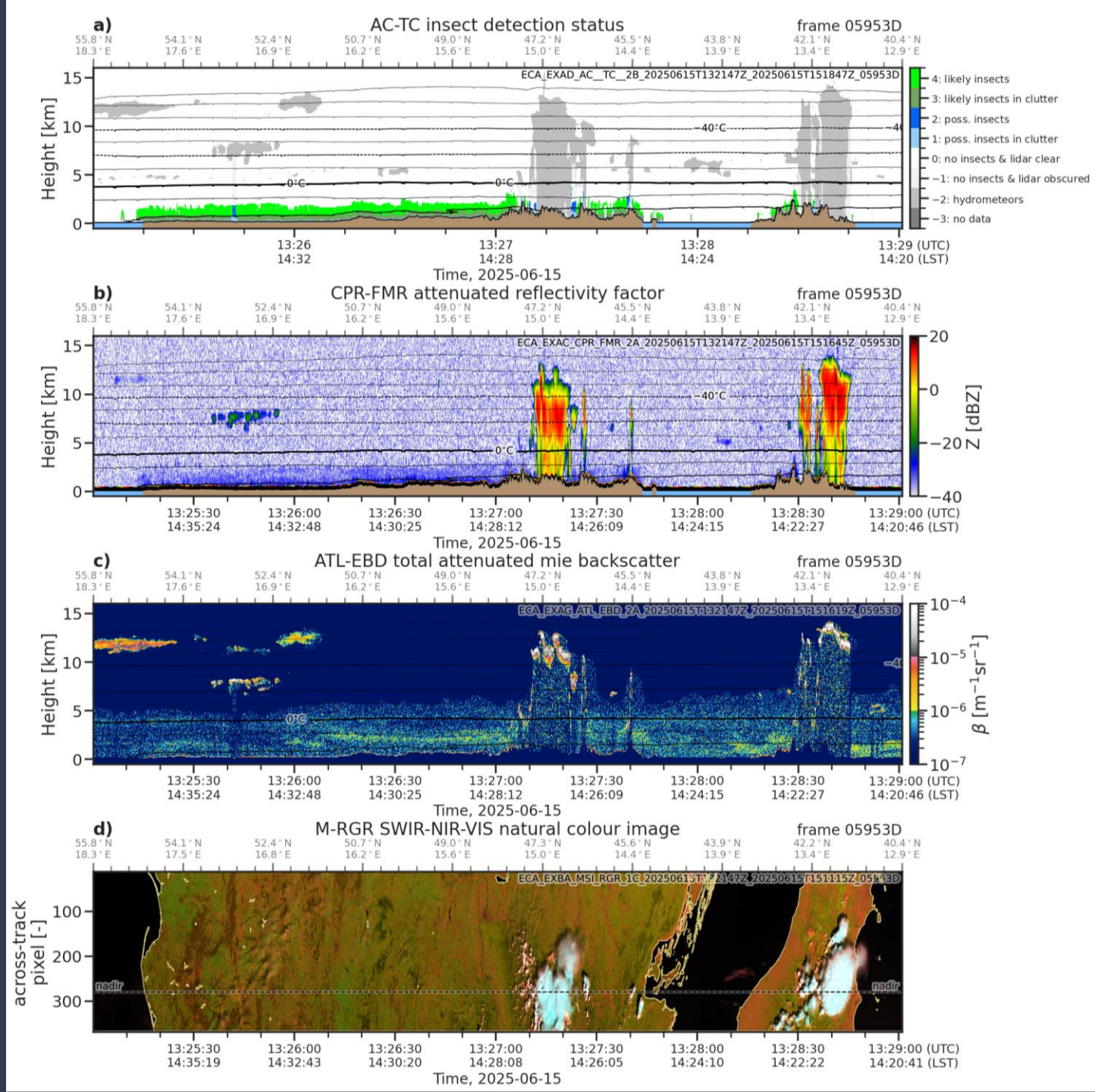


Insect detections added to AC-TC

- As of baseline BC:
  - **insect_detection_status (along_track, JSG_height)**
  - "**likely**" where ATLID is available to verify cloud-free pixels, "**possible**" where ATLID is extinguished
  - Also tracks "clear" and "obscured" pixels to facilitate correctly-weighted frequencies
- Other relevant meteorological data available from X-MET: temperature, wind, humidity, etc.
- Available in AC-TC from November 2025; will have to await the next reprocessing for a longer-term dataset (or contact me for data processed offline)



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First global climatology of insects

- November 2024 to October 2025
- At monthly scales, distributions are still noisy
- Seasonal fluctuations in frequency of occurrence:
  - Sahel (DJF) to southern Africa (JJA)
  - South & East Asia (DJF) to Eurasian steppe (JJA)
  - More consistent signals over Europe, Australia & South America
- Other quantities and statistics:
  - Physical depth of cloud layers: day/night difference
  - Column-integrated CPR reflectivity: size/species information?
- Drastically different characteristics overnight

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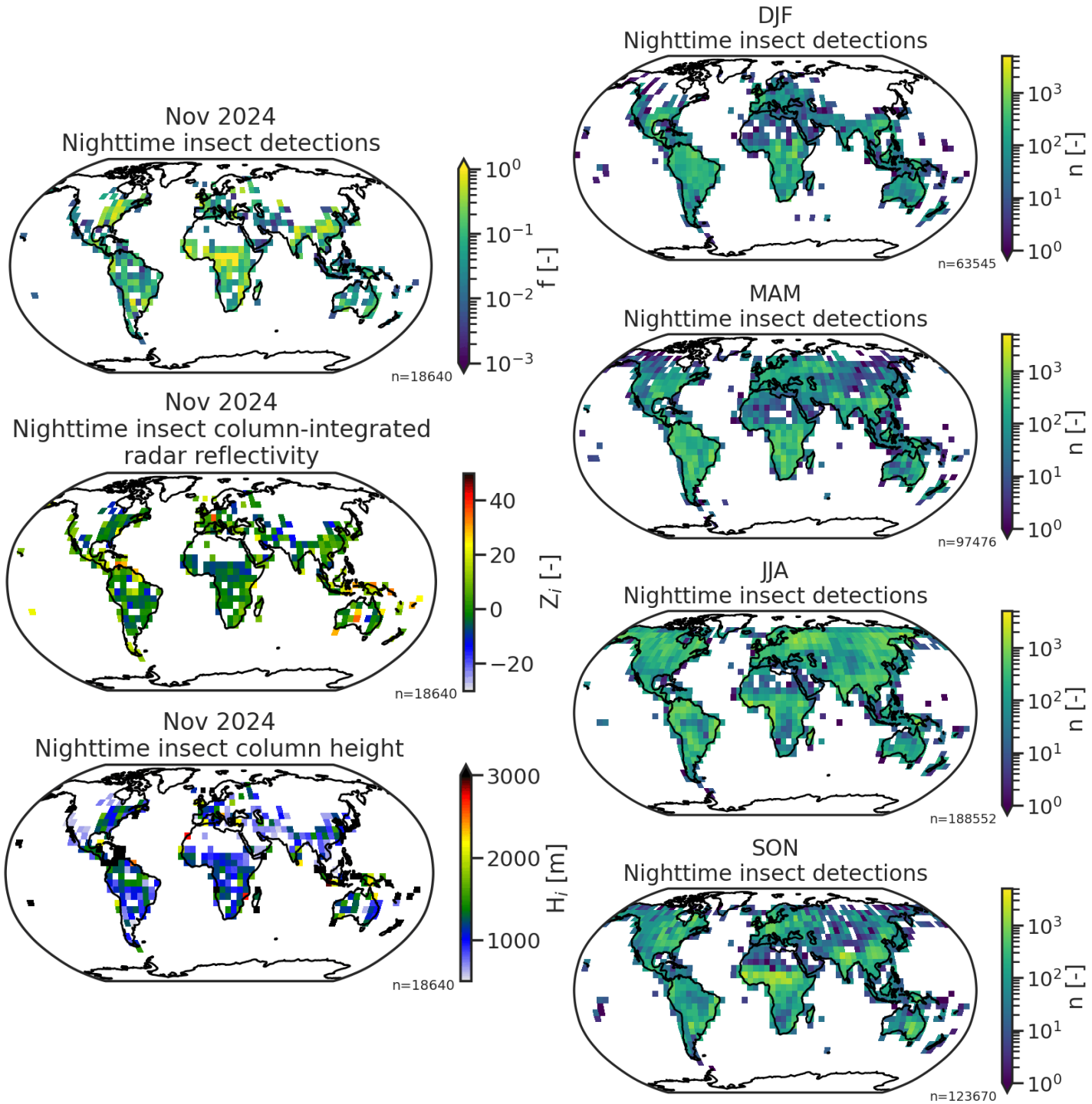

Further questions…

- Can we tease more signal out of CPR?
  - ~30km along-track averaging could tease out around 5 dBZ more signal
  - Could be applied to CloudSat to tease out insects signal
- Can we use the characteristic texture and structure of insect signals to improve confidence of detection when ATLID is obscured?
- In-insect wind speed and direction, humidity, temperature, etc.: can we determine conditions for insect take-off, migration events, etc.
- Can we rule out (or discriminate) insects from other bio-signals like bats and birds? Are the bats and birds eating the insects? If not, why not?

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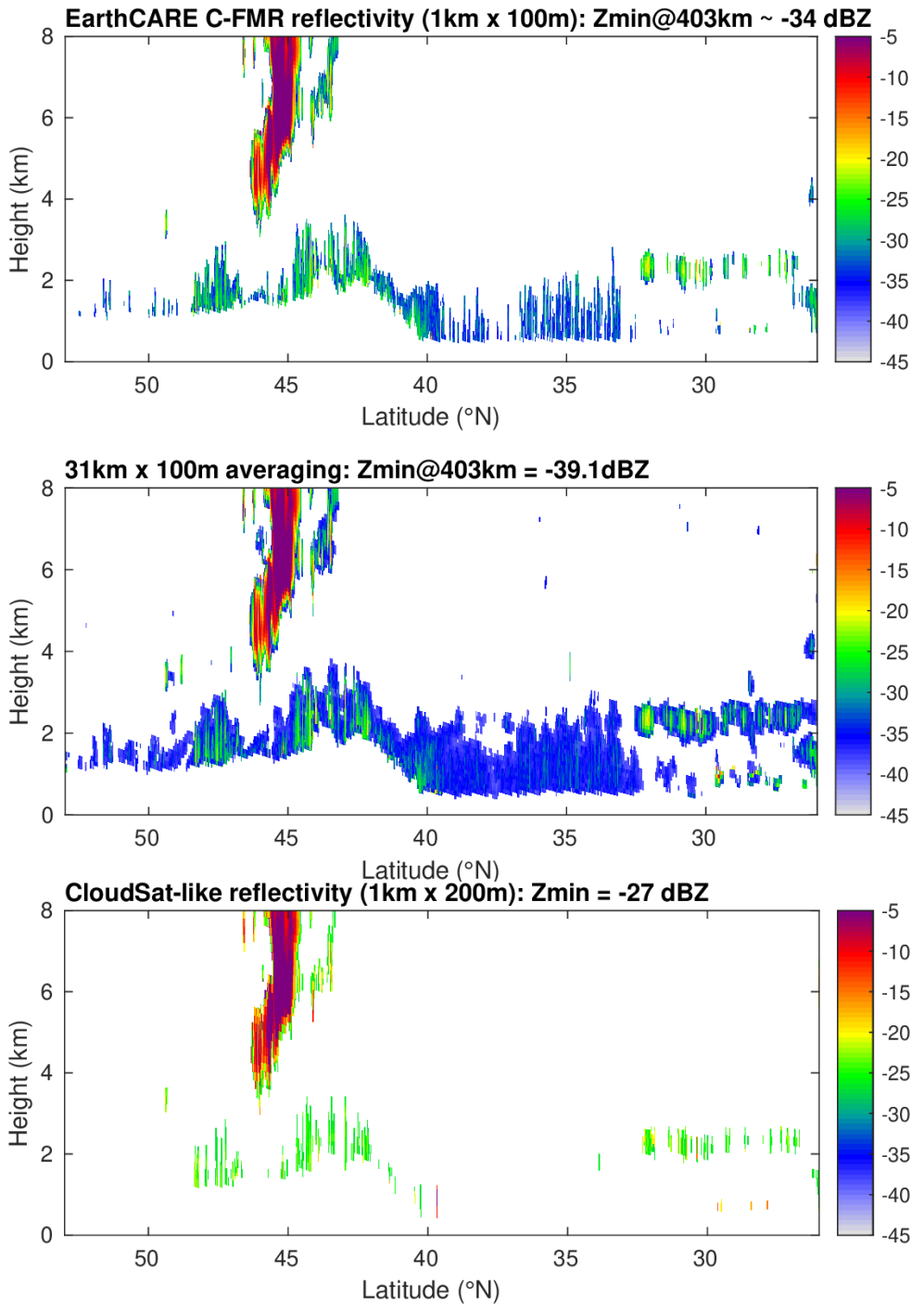
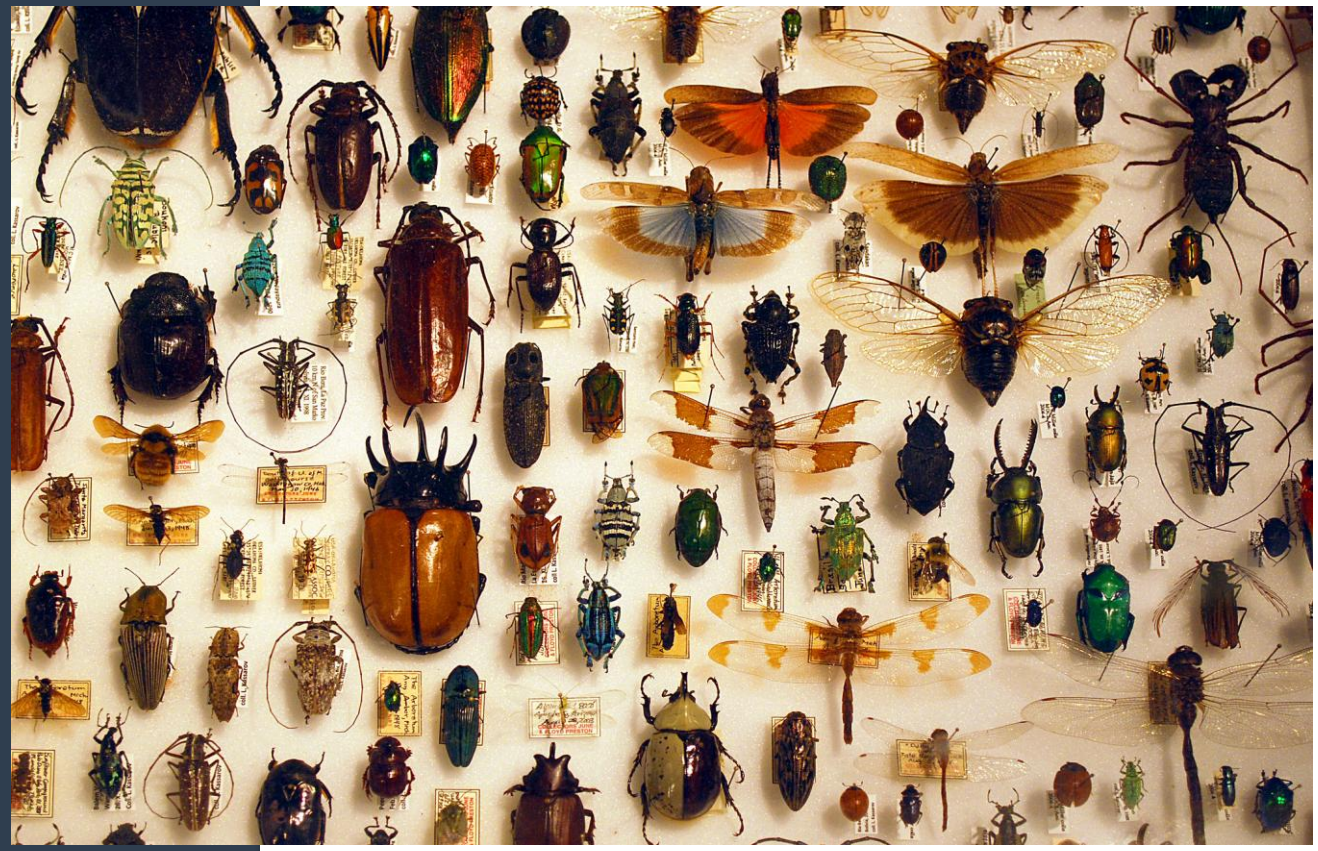


What do we do with all these insects?

- Working with radar entomologists for further verification and links with regional studies:
  - Expanding upon existing regional and seasonal studies based on ground-based remote-sensing and in-situ sampling.
  - Detailed verification of EarthCARE overpasses with dedicated entomological radars (Jason Chapman & Xu Shi at Nanjing), and meteorological radars (Ryan Neely at Leeds)
- Over the (decadal) lifetime of EarthCARE:
  - Longer-term trends:
    Can we quantify and track pollinator population decline or monitor agricultural pests?
  - Continuity with A-Train: CloudSat does make insect detections, especially with advanced noise & clutter removal (Jay Mace, personal communication)



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