Yesterday's cloud, tomorrow's rain

Quantifying cloud and precipitation re-evaporation with a Lagrangian diagnostic

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What is the effect of internal moisture recycling on the atmospheric water budget and downstream dynamics?

Evaporation of clouds and precipitation affects the atmospheric water cycle and can be understood as internal moisture recycling. Observations of stable water isotopes have shown that in the tropics, **20–50% of precipitation can re-evaporate** (Worden et al. 2007), and in the extratropics, this proportion can even rise to **60% during cold front passages** (Aemisegger et al. 2015). While these studies highlight the importance of precipitation evaporation, there is still **little information available on the role that cloud evaporation** plays in the atmospheric water cycle. Furthermore, there are currently **no tools available to systematically and efficiently investigate internal moisture recycling**. By extending an existing Lagrangian tool, we aim to contribute to a better understanding of internal moisture recycling and its effects on the atmospheric water budget.

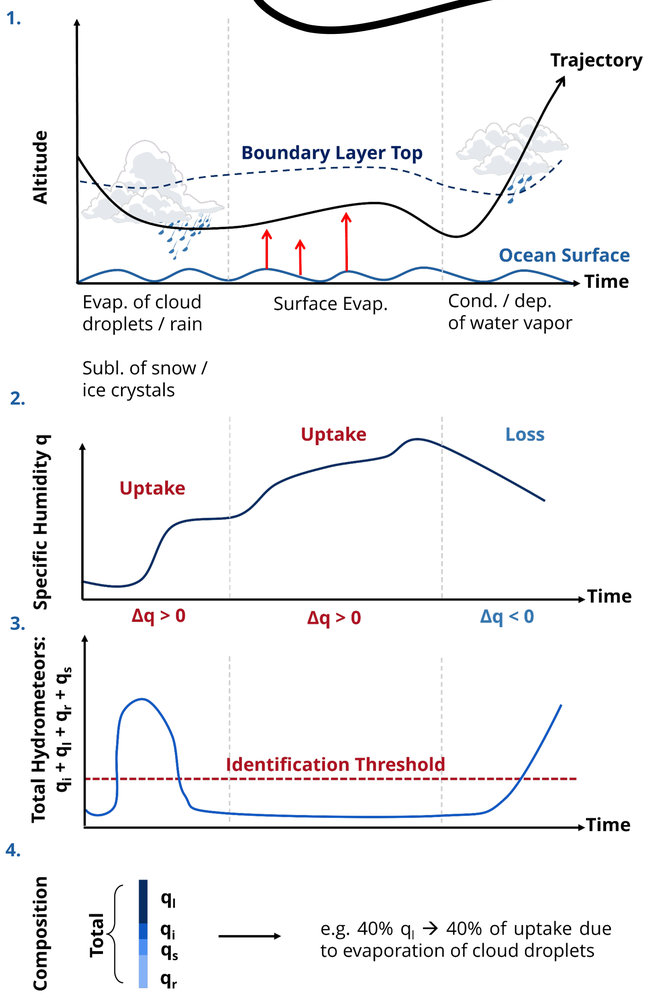


Fig. 1: Schematic description of the moisture source diagnostic (Steps 1-2; Sodemann et al. 2008) and the extended version of it to identify moisture uptake processes (Steps 3-4; LEMUR).

How does the Lagrangian identification of moisture uptake processes (LEMUR) work?

The **L**agrangian id**E**ntification of **M**oisture **U**ptake p**R**ocesses (LEMUR) is depicted in Fig.1 and can be described as follows:

1. **and 2.** Identify moisture uptake along backward trajectories computed with LAGRANTO (Sprenger and Wernli, 2015) and the moisture source diagnostic developed by Sodemann et al. (2008).

3. Identification of moisture uptake processes within (BL) and above (ABL) the boundary layer:

Given **uptake at t:**

At t-1: $q_i + q_l + q_s + q_r$ > threshold

yes / **no**

Uptake identified as:
- Microphysics
  (rain or cloud droplet evaporation, snow or ice crystal sublimation)

Uptake identified as:
- Surface Evaporation (BL)
- Mixing (above BL)

4. Distribute moisture uptake based on hydrometeor content prior to the uptake

How is LEMUR evaluated?

Trajectories used in this study are based on a special ECMWF IFS simulation (cycle 43R1) covering a 13-day period in Jan-Feb. 2018. In addition to the standard IFS output, the dataset also includes tendency (TEND) outputs for specific humidity (q) and diabatic heating rates for the parameterized processes large-scale microphysics, convection and turbulence (Spreitzer et al. 2019). LEMUR is evaluated by **comparing moisture sources** identified along trajectories with the **IFS q-TEND values.**

Do LEMUR and IFS q-TEND agree?

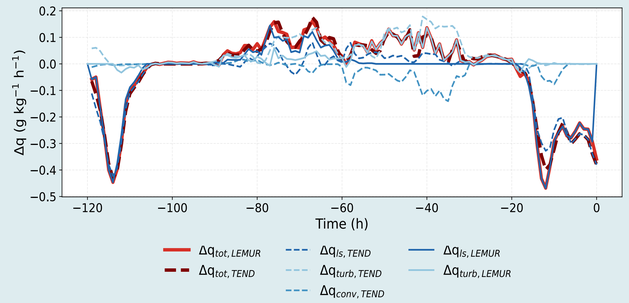


Fig. 4: Temporal evolution of hourly changes in q, averaged over all trajectories, for moisture uptakes identified with LEMUR and the IFS q-TEND output. Shown components are TOT = total, LS = large-scale microphysics, turb = turbulent, and conv = convection. Pearson correlation coefficients between LEMUR and TEND are 0.95 for TOT, 0.82 for LS, and 0.44 for turb.

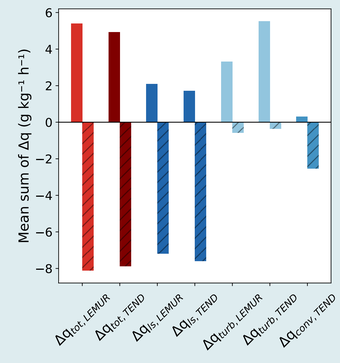


Fig. 5: Sum of positive and negative hourly changes in q averaged over all trajectories, for moisture uptakes identified with LEMUR and the IFS q-TEND output. Shown components are TOT = total, LS = large-scale microphysics, turb = turbulent, and conv = convection.

- LEMUR microphysical uptakes agree well with q-TEND (Fig. 4)
- Turbulent-process uptakes show weaker agreement (Fig. 4)
  → including surface fluxes as constraints could improve results
- Uncertainty of the convection parameterization
- Total uptakes and losses along trajectories are similar between LEMUR and q-TEND (Fig. 5)

Which trajectories were used to test LEMUR?

Coherent airstream identified as a subset of 5-day backward trajectories initialized on 6 February 2018 at 12 UTC within a 200 km radius around Reykjavik, Iceland.

The airstream (Fig. 2) is characterized by segments of:
- Ascent and descent → formation or dissipation of clouds
- Positive cold air outbreak index (CAO; Fig. 3) → strong surface evap. and cloud formation (Fletcher et al. 2016; Papritz and Spengler 2017)

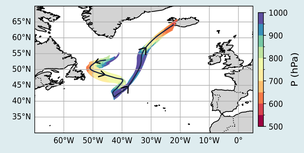


Fig. 2: Selected airstream trajectories arriving near Reykjavik, Iceland on 06-02-2018 12 UTC colored by pressure.

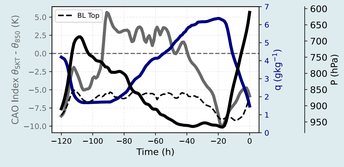


Fig. 3: Temporal evolution of CAO index, specific humidity q, pressure p and boundary layer top averaged over all trajectories within the selected airstream.

Are moisture uptakes from cloud and precipitation evaporation important?

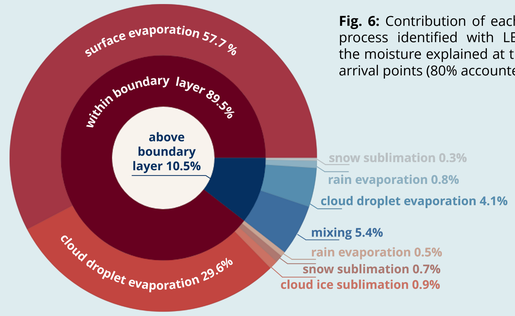


Fig. 6: Contribution of each uptake process identified with LEMUR to the moisture explained at trajectory arrival points (80% accounted for).

Where is the moisture taken up?

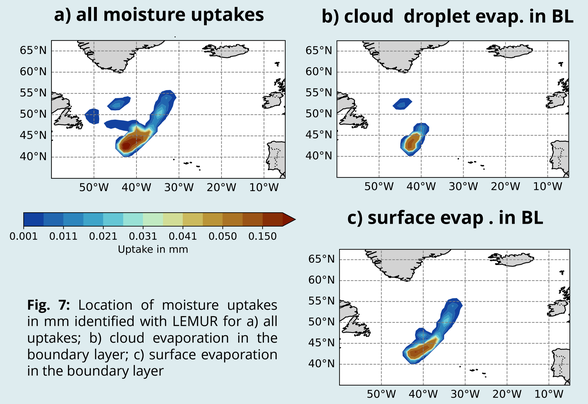


Fig. 7: Location of moisture uptakes in mm identified with LEMUR for a) all uptakes; b) cloud evaporation in the boundary layer; c) surface evaporation in the boundary layer

- Cloud evaporation is an important moisture source (Fig. 6), especially in BL entrance region, with shallow cumulus clouds due to CAO (Fig. 7)
- Surface evaporation hotspot where air parcels are within the CAO and/or close to the ocean surface (Fig. 7)

Internal moisture recycling can be quantified by adapting an existing moisture source diagnostic tool

- LEMUR moisture uptake processes agree well with IFS q-TEND
- Cloud droplet evaporation is an important moisture source

Outlook:
- Incorporation of surface fluxes
- Process-based evaluation with stable water isotope observations (NAWDIC)
- Investigate different atmospheric features (dry intrusions, extreme precipitation events in dry regions)

Want to know more?

SCAN ME

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