B03 Moist convection and tracer transport into and out of the Asian Summer Monsoon Anticyclone

TP CHANGE

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Motivation

- ❖ Deep boundary layers over elevated terrain drives ABL–UTLS exchange.
- ❖ Deep convection during the South Asian Summer Monsoon transports moisture to the UTLS.
- ❖ ASMA strongly influences both regional climate and global circulation patterns.
- ❖ Accurate representation of ASMA at convection-permitting scales is critical for improving model performance.

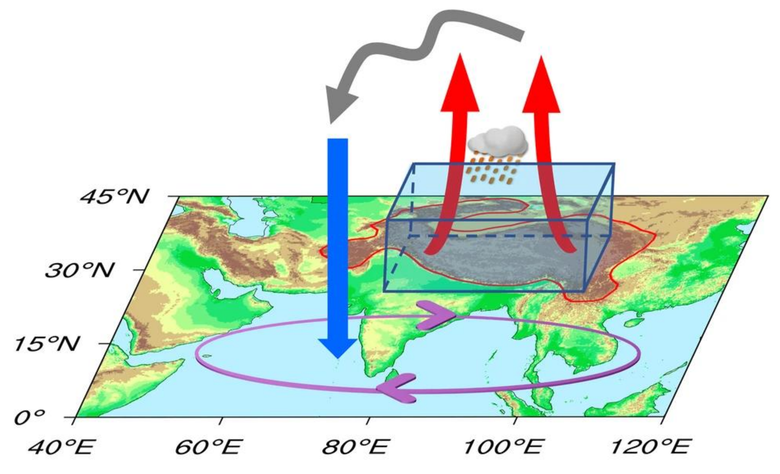
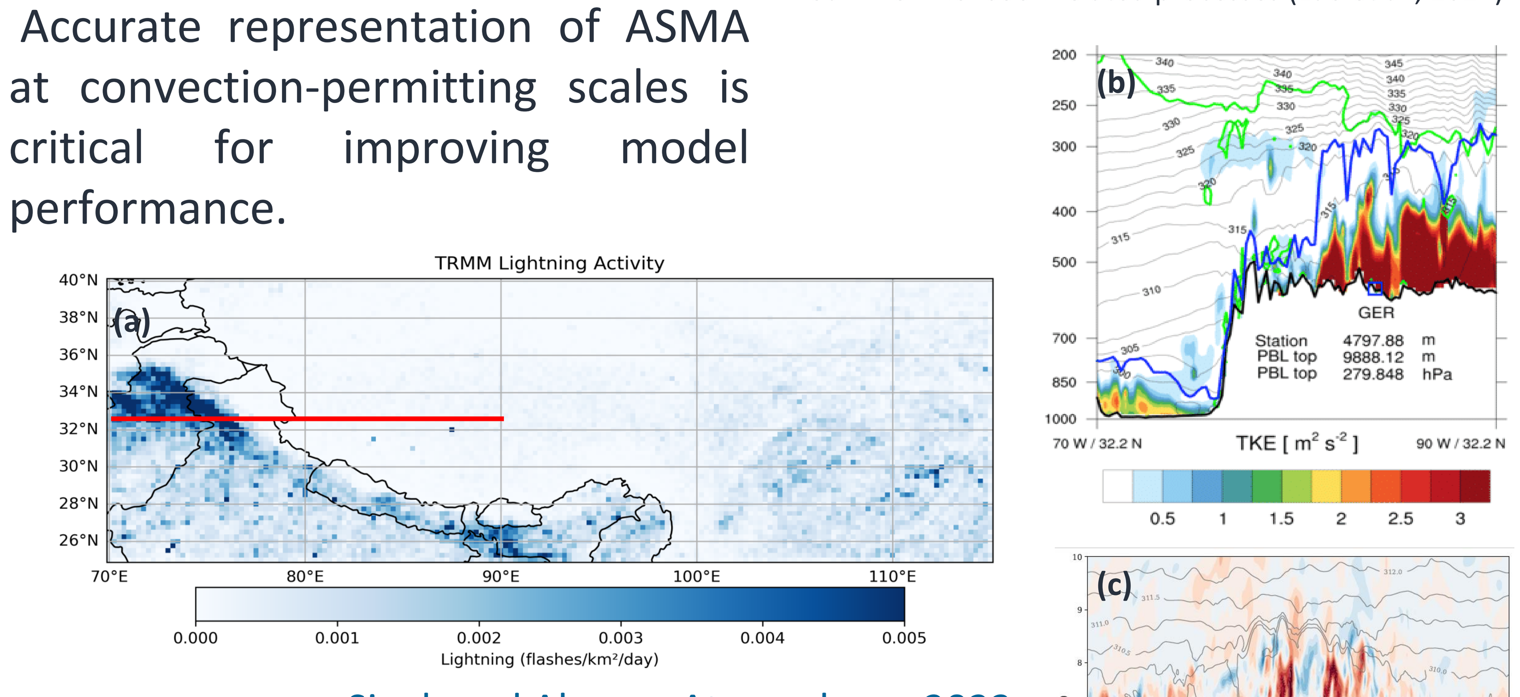
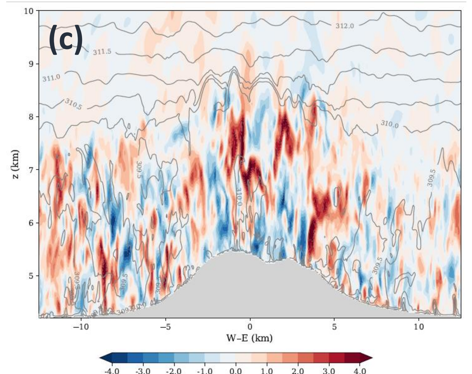


Fig. 1: Schematic representation of future South Asian Summer Monsoon related processes (Luo et al., 2024)





Singh and Ahrens, Atmosphere, 2023

Fig. 2: (a) Deep convection over the Third Pole characterized using long term TRMM-Lightning observations; Deep boundary layer over the Third Pole on 04 March 2016: (b) real-case COSMO simulation (Chen et al., 2016), (c) semi-idealized large-eddy simulation (Basic et al., ACP, 8888)

Jadhav et al., IJGI, 2025; Basic et al., ACP, 2025 (submitted)

Approach

- ❖ ICON-CLM climate scale simulations at horizontal resolutions from 1 km to 13 km
- ❖ Evaluate turbulence (TKE & 2TE) and microphysics schemes (SM and DM)
- ❖ Satellite observations and ERA5/6 reanalysis for intercomparison
- ❖ Source quantification and evolution of UTLS WV via Lagrangian tracking

Collaborations within TPChange

A02 A02 contributes satellite data, B03 model simulations

B06 2TE scheme and ICON km-scale simulations

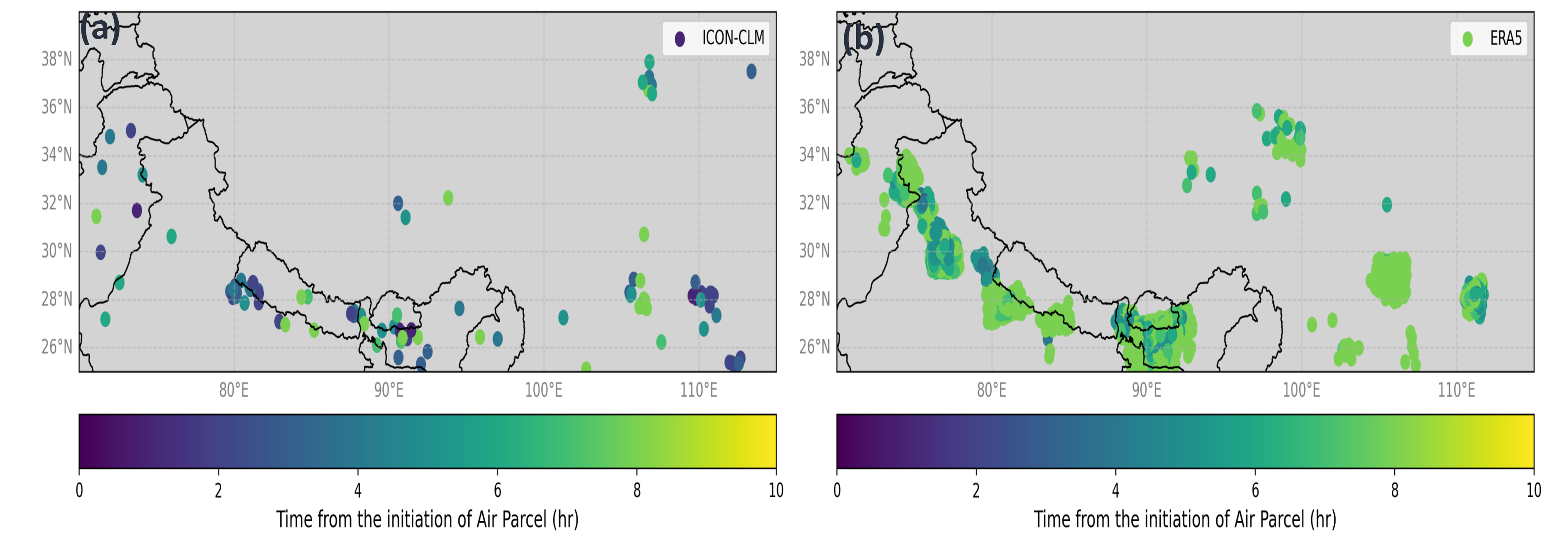
B08 Integrate online quantification of air mass transport

C06 Offline Lagrangian tracking

C07 Validation of the global ICON-MESSy with ICON-CLM and observations

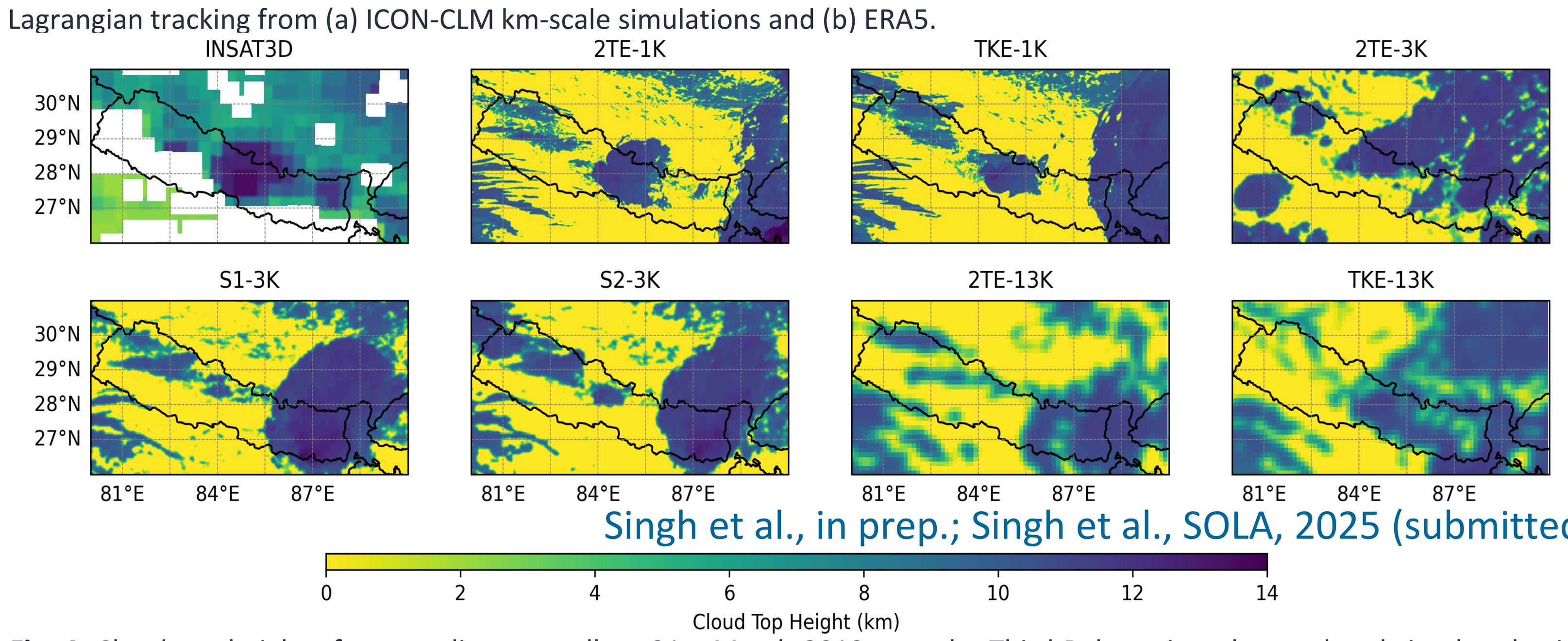
Z03 Evaluation of newly developed 2TE turbulence scheme over complex terrain: Third Pole and European Alps.
Conducted 10-year-long high-resolution (3 km) ICON-CLM simulations over the Third pole/ASMA region.

Results from phase I



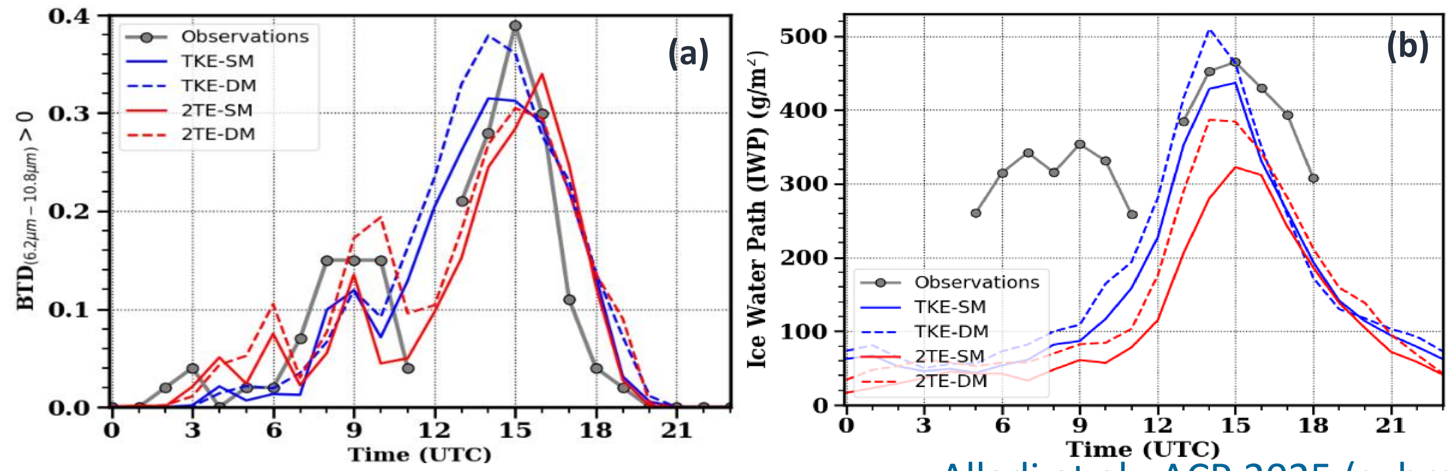
Singh and Ahrens, EGUsphere, 2025

Fig.3: Vertical transport time to the UTLS during deep convection events over the Third Pole region (2019-2020) using Lagrangian tracking from (a) ICON-CLM km-scale simulations and (b) ERA5.



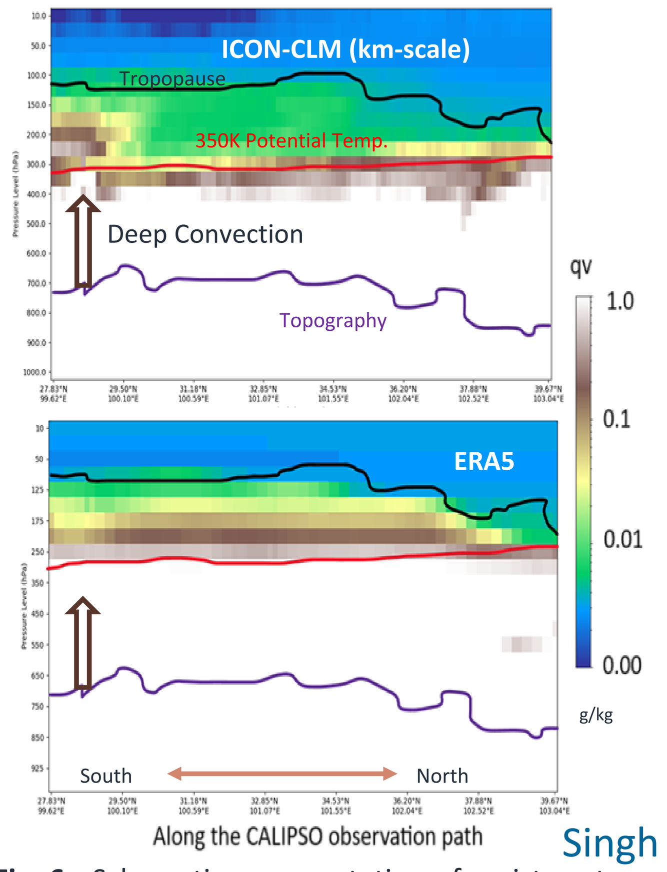
Singh et al., in prep.; Singh et al., SOLA, 2025 (submitted)

Fig. 4: Cloud top height of a tornadic supercell on 31st March 2019 over the Third Pole region observed and simulated using 2TE and TKE turbulence schemes at different horizontal resolutions (1 km, 3 km, and 13 km).



Alladi et al., ACP,2025 (submitted)

Fig.5: (a) Time series of Brightness Temperature Difference (BTD>0) for observations and ICON simulated over Alps on 2021-07-08 (b) Ice Water Path (IWP). (SM-Single Moment; DM-Double Moment)



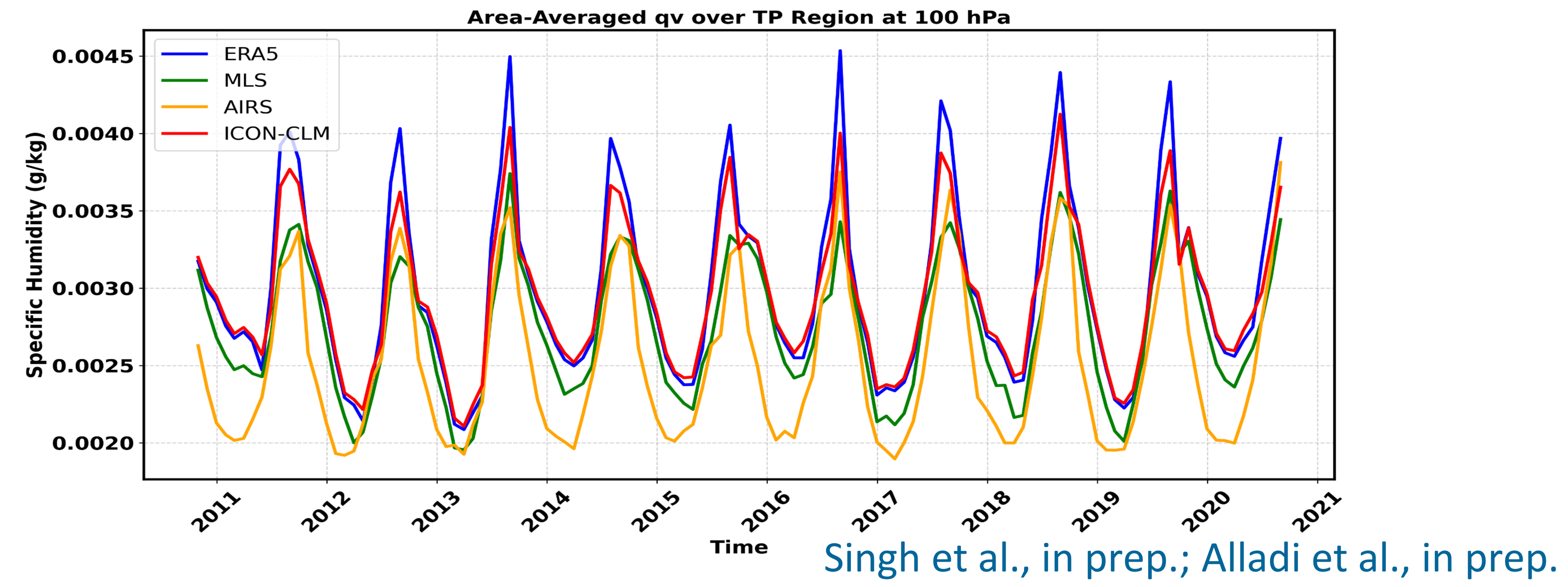
- ❖ km-scale ICON-CLM simulations show faster WV transport to the UTLS than ERA5/ICON-CLM-13km
- ❖ ERA5 shows higher frequency of air parcels reaching the upper troposphere.
- ❖ The newly developed turbulence scheme (2TE), at 1 km horizontal resolution, performs better than TKE over the Third Pole region.
- ❖ High-resolution ICON simulations over the European Alps suggest that the microphysics scheme has a larger impact on hydrometeor distribution than the turbulence scheme.
- ❖ ICON-CLM effectively represents deep convective moisture transport to UTLS than ERA5/ICON-CLM-13 km.

Singh and Ahrens, AR, 2025 (submitted)

Fig. 6: Schematic representation of moisture transport to the UTLS in (a) ICON-CLM km-scale simulation and (b) ERA5 along the observed deep convection (CALIPSO)

Research plan phase II

Main goal: Better understanding transport into and out of ASMA targeting better process representation in km-scale and CMIP-like climate models



Singh et al., in prep.; Alladi et al., in prep.

Fig. 7: Specific humidity simulated from ICON-CLM km-scale simulation with ERA5, and satellite observations (AIRS, MLS) at 100 hPa over the Third Pole region.

The Asian Summer Monsoon Anticyclone (ASMA), present during the monsoon, can confine water vapour in the upper troposphere (UT), from where it may slowly escape into the lower stratosphere (LS). We aim to deepen our understanding of these processes through four key research objectives.

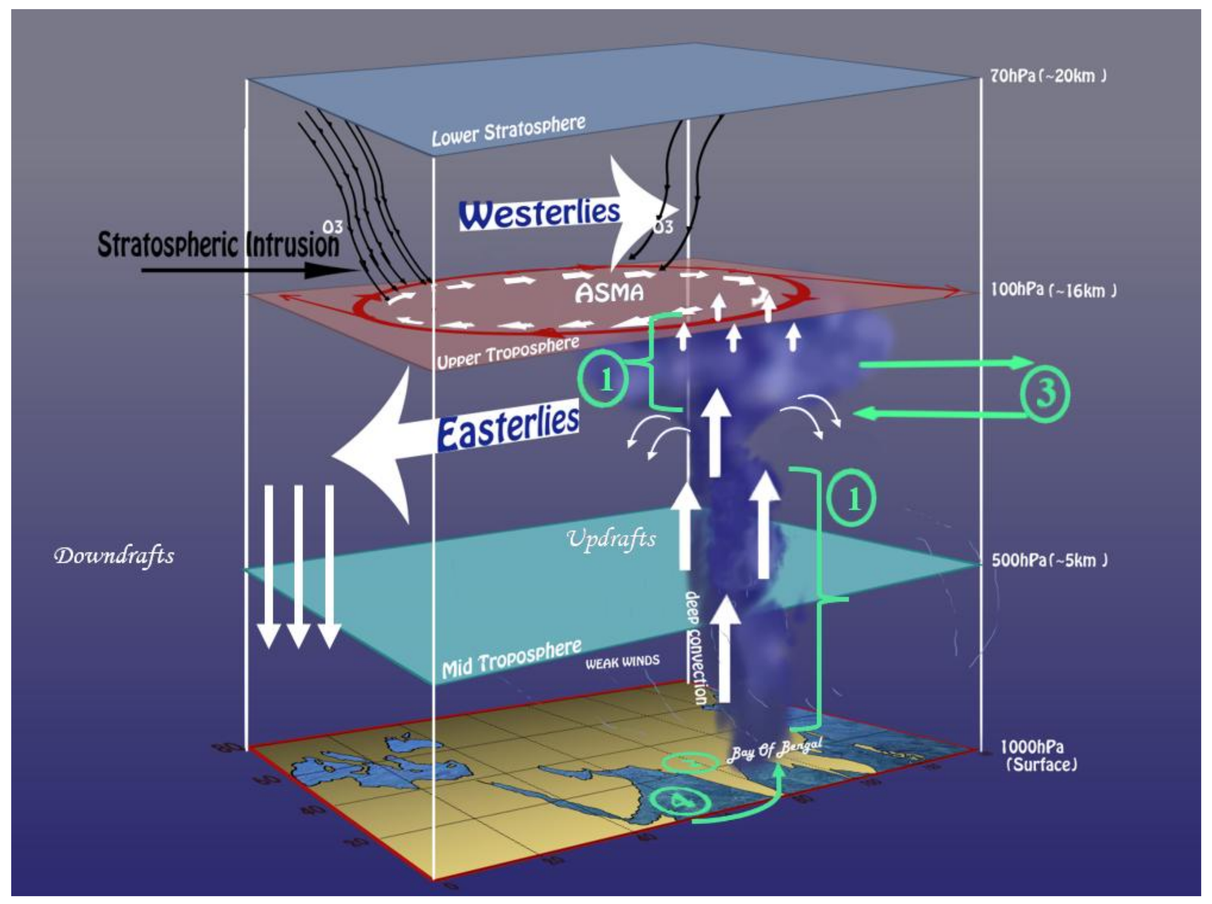


Fig. 8: Schematic representation of the proposed objectives. ASMA figure adapted from Alladi et al. 2022.

Objectives

1. Evaluate and investigate the water vapour transport in weather and climate models into and within ASMA.
2. Identifying hotspot regions and dominant transport pathways responsible for moistening the ASMA.
3. Examining transport from the ASMA into the extratropical lower stratosphere.
4. Quantifying seasonal and interannual variations in water vapour transport into and out of the ASMA.