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EVALUATING HORIZONTAL INHOMOGENEITIES WITH GROUND-BASED MICROWAVE RADIOMETER USING LARGE-EDDY SIMULATIONS

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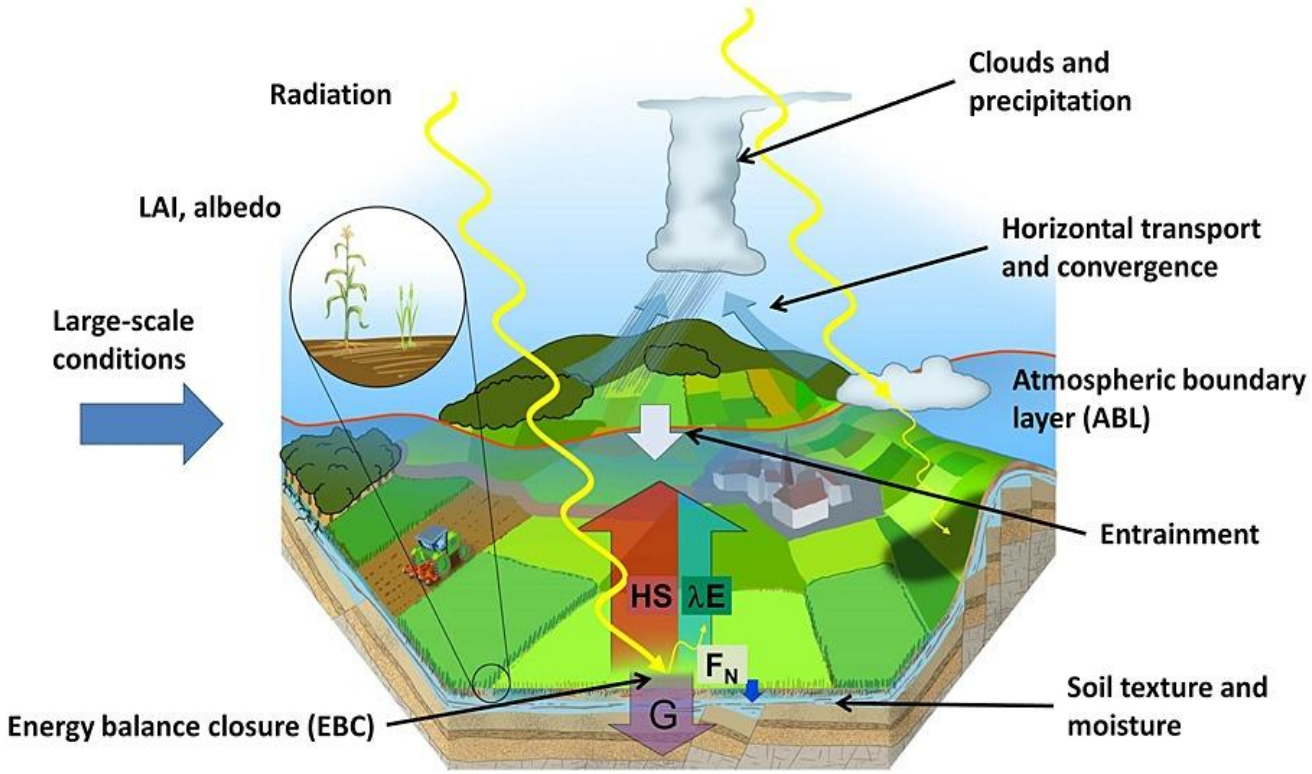
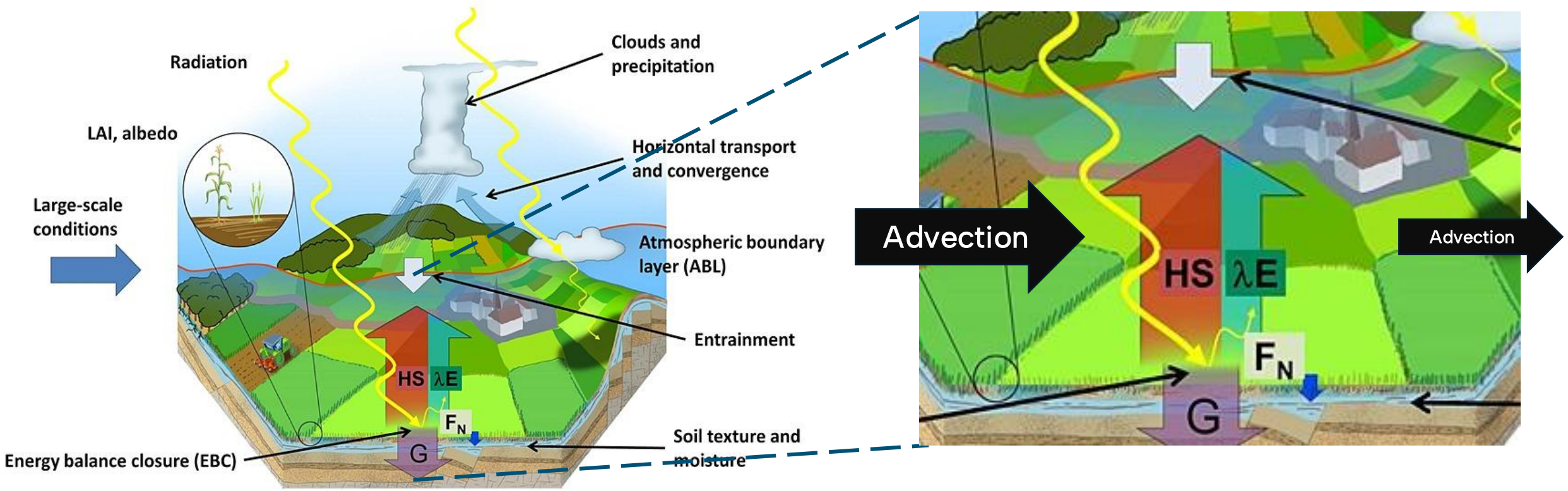
Motivation



Wulfmeyer et al. (2015)

Motivation



Wulfmeyer et al. (2015)

Water vapour variability in the atmospheric boundary layer is linked to local changes and advection

$$\frac{\partial \alpha}{\partial t} = \frac{D\alpha}{Dt} - \bar{V} \cdot \nabla \alpha$$

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Scope of the paper

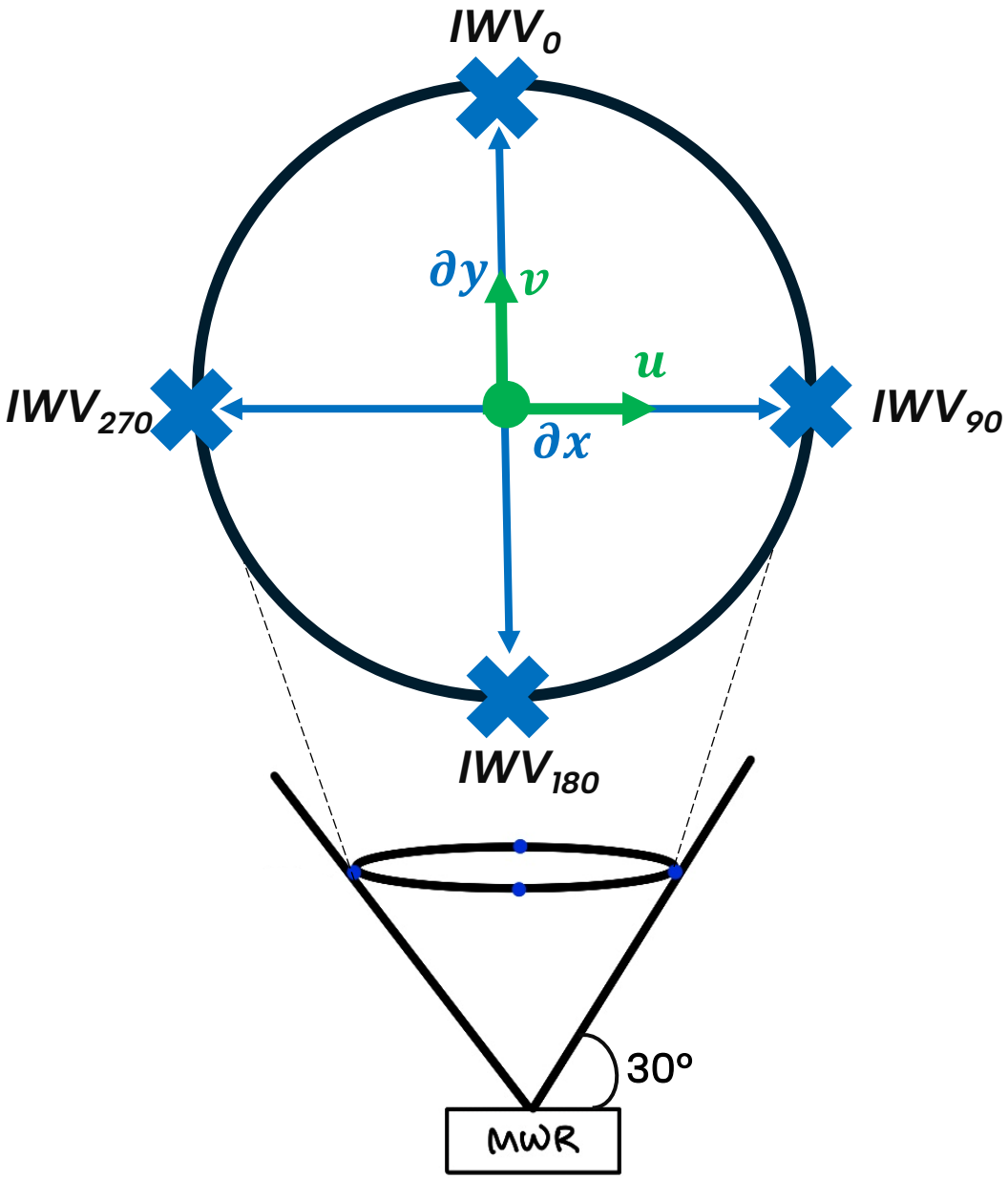
$$-\bar{V} \cdot \nabla\alpha = -\left(u\frac{\partial\alpha}{\partial x} + v\frac{\partial\alpha}{\partial y}\right)$$

Using 3D spatial scans from microwave radiometer (MWR), we present a method to derive integrated water vapour (IWV) gradient.

$$\frac{\partial IWV}{\partial x} = \frac{IWV_{90} - IWV_{270}}{\partial x}$$

$$\frac{\partial IWV}{\partial y} = \frac{IWV_{0} - IWV_{180}}{\partial y}$$

u, v are derived from scanning lidar



Scope of the paper

We don't have ground truth for the slant path profiles

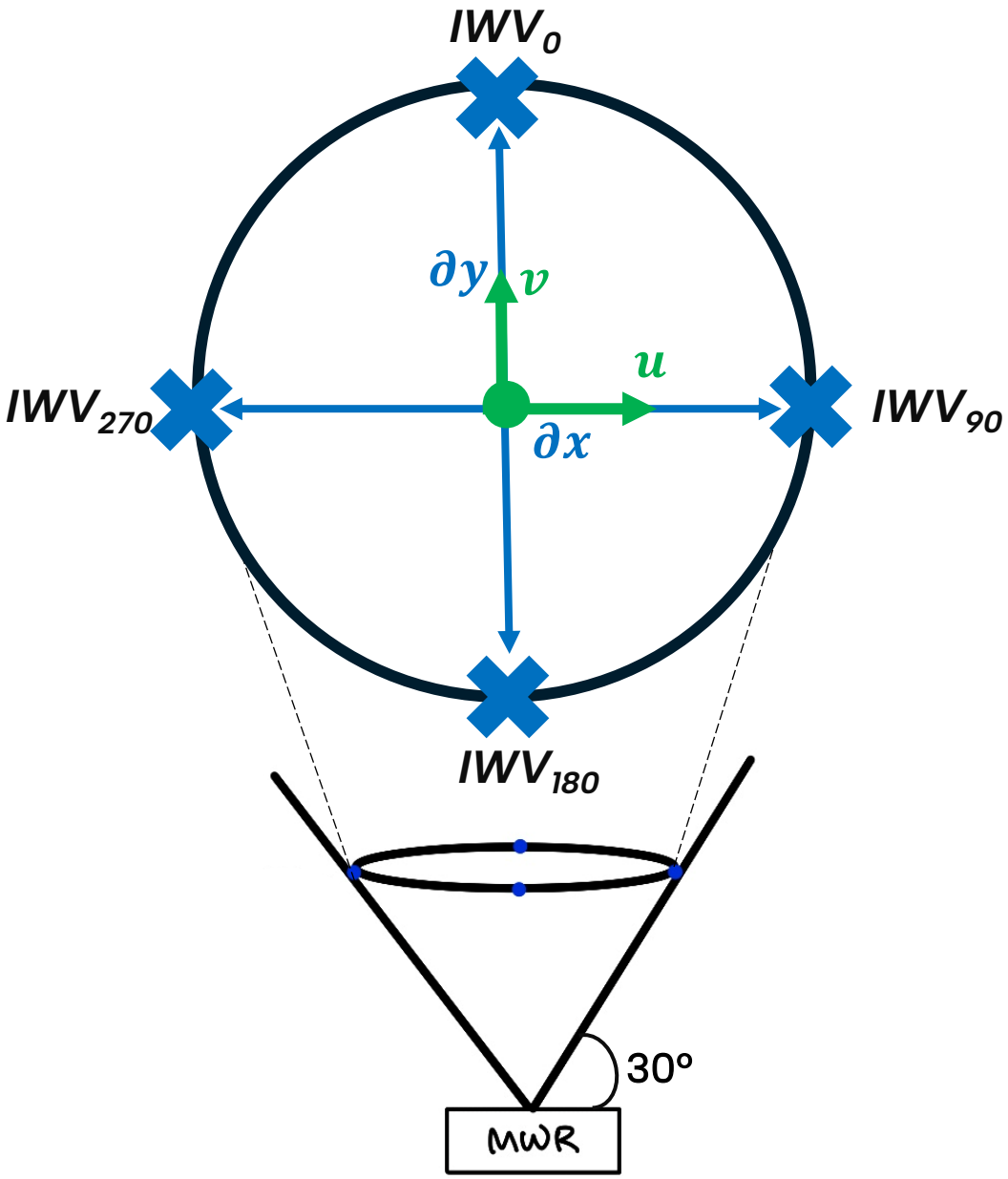
- … we turn to high resolution models for proxy
- … we simulate observations from the virtual truth

Now we ask ourselves:

I. How good do the gradients from simulated MWR agree with the truth?

II. What are the uncertainties associated with the gradients?

III. What is the impact of the uncertainties on advection estimation?



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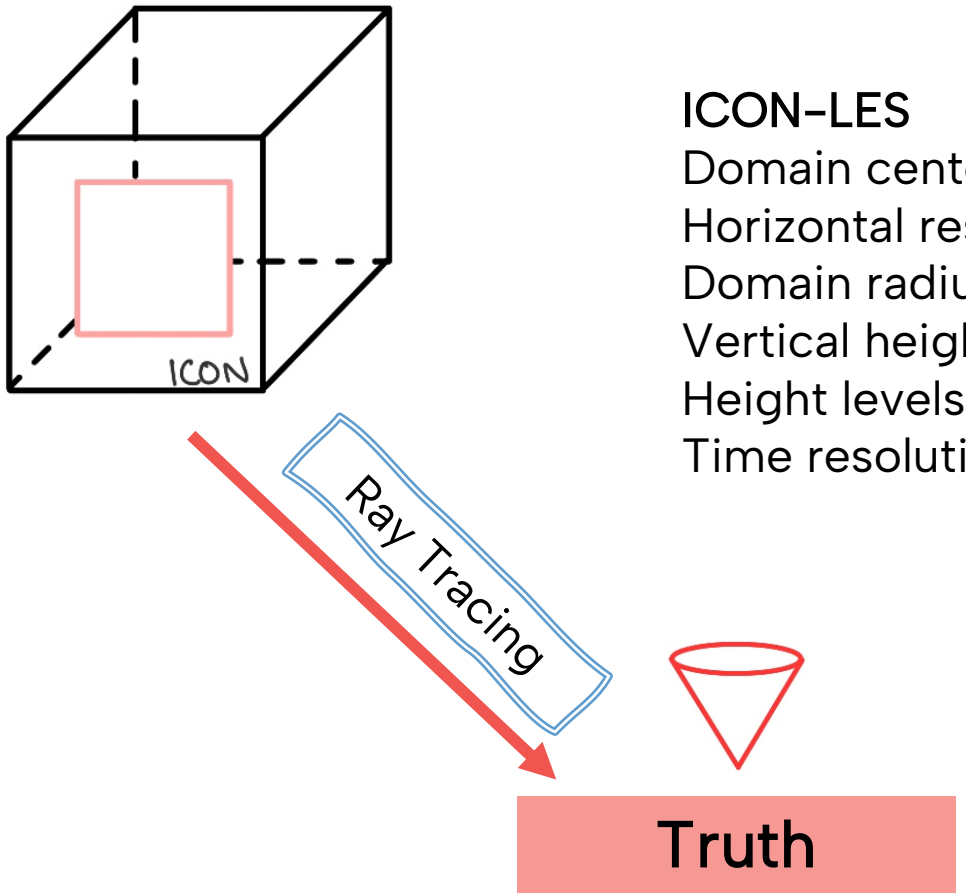
Deriving slant path profiles of humidity

3D model reality

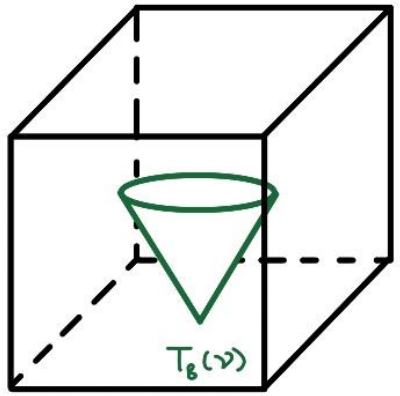


ICON-LES
Domain center: JOYCE (6°24′ 46.8″, 50°54′ 28.8″)
Horizontal resolution: 78m
Domain radius: 25km
Vertical height: 22km
Height levels: 150
Time resolution: 15 mins

Deriving slant path profiles of humidity

3D model reality

Simulated MWR measurements



$$T_b(\nu) = T_{B_{cos}}\, e^{-\tau(z)} + \int_0^\infty \beta_\nu(z)\, e^{-\tau(z)} dz$$

Ray Tracing

Radiative Transfer

Truth

Microwave Radiometer
Brightness temperatures along 14 channels:
K-band: 22.24 – 31.4 GHz
V-band: 51.0 – 58.0 GHz

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Deriving slant path profiles of humidity

3D model reality

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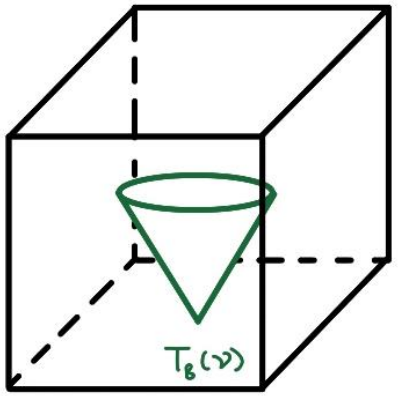
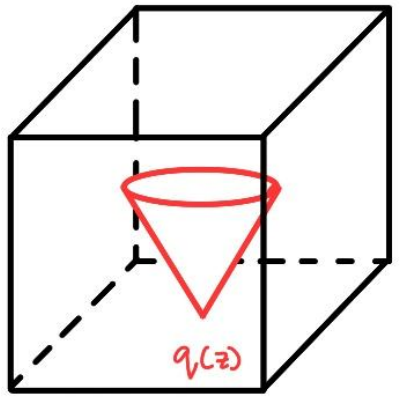
Simulated MWR measurements



$$q(z) = c_0(z) + \sum_{\nu} c_1(z,\nu) \cdot T_b(\nu) + \sum_{\nu} c_2(z,\nu) \cdot T_b(\nu)^2$$

Retrieval Algorithm



Retrieved

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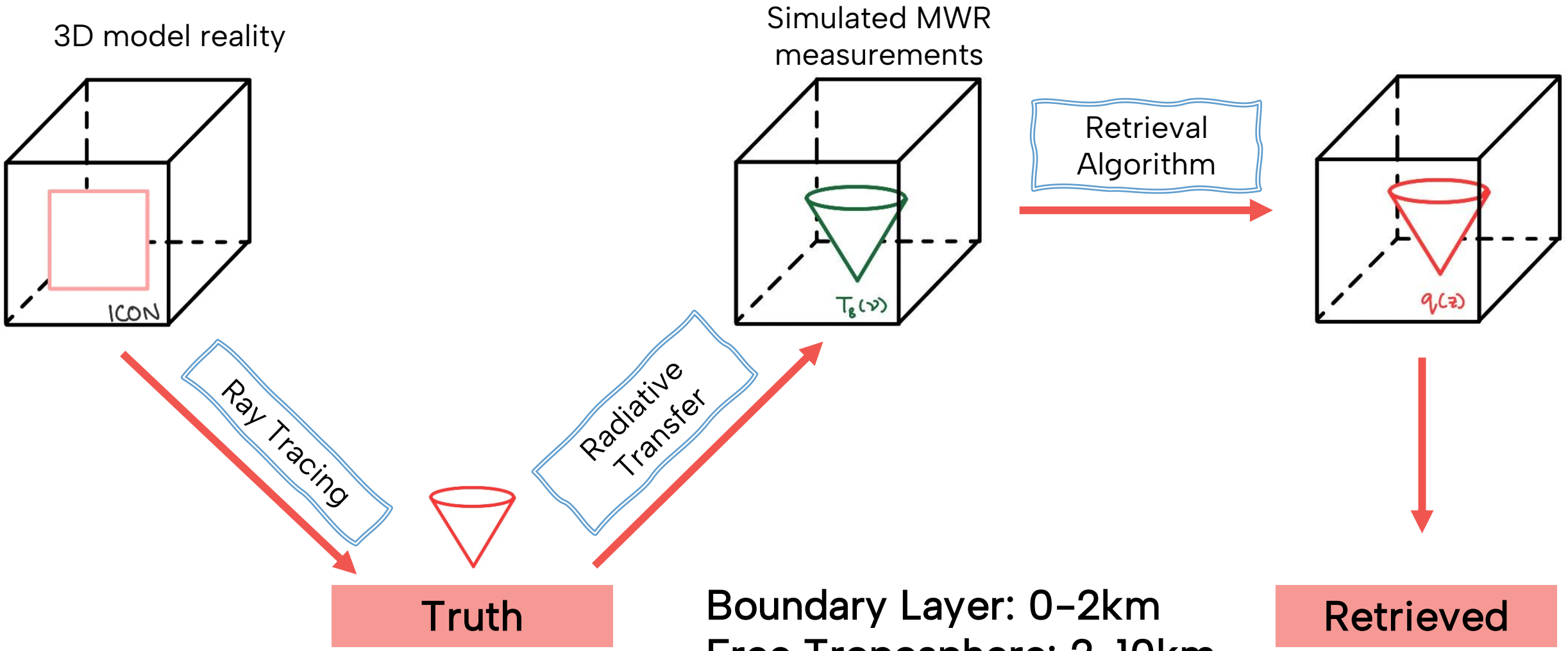
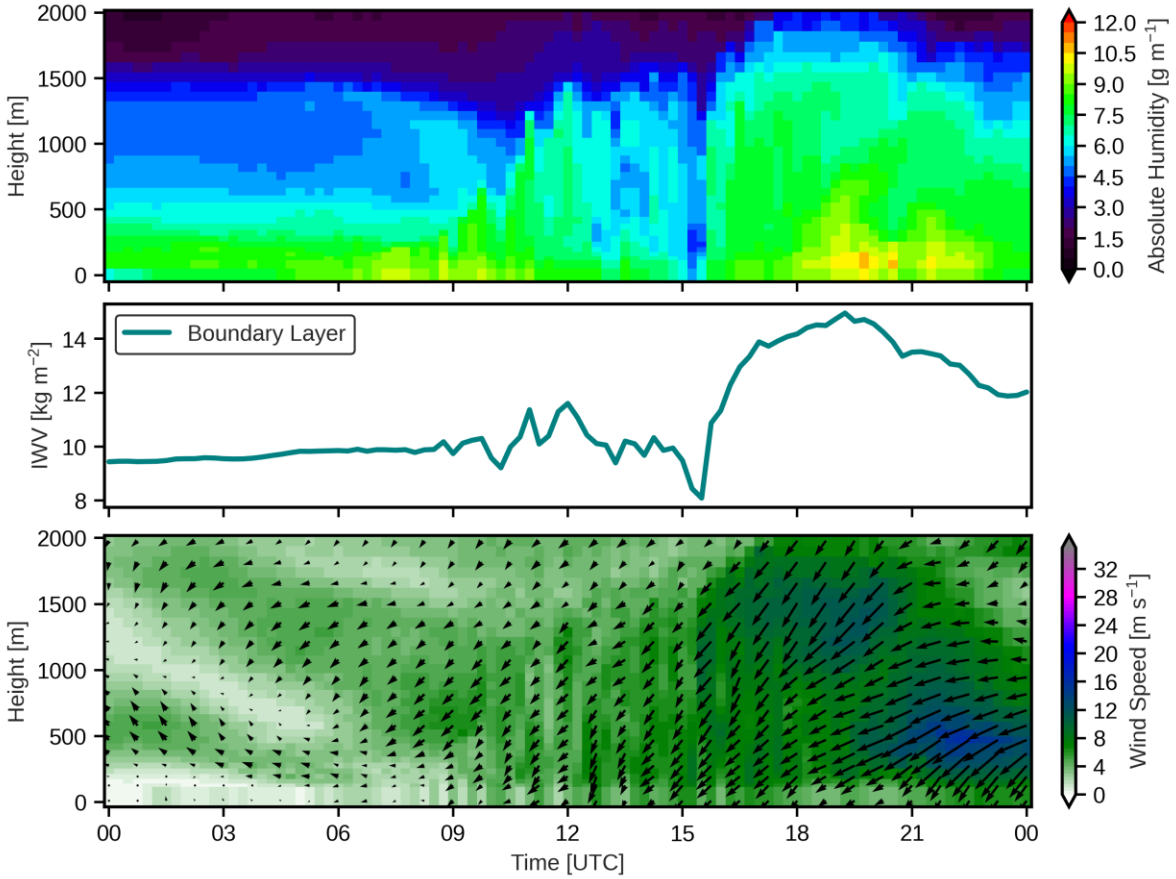
Deriving slant path profiles of humidity



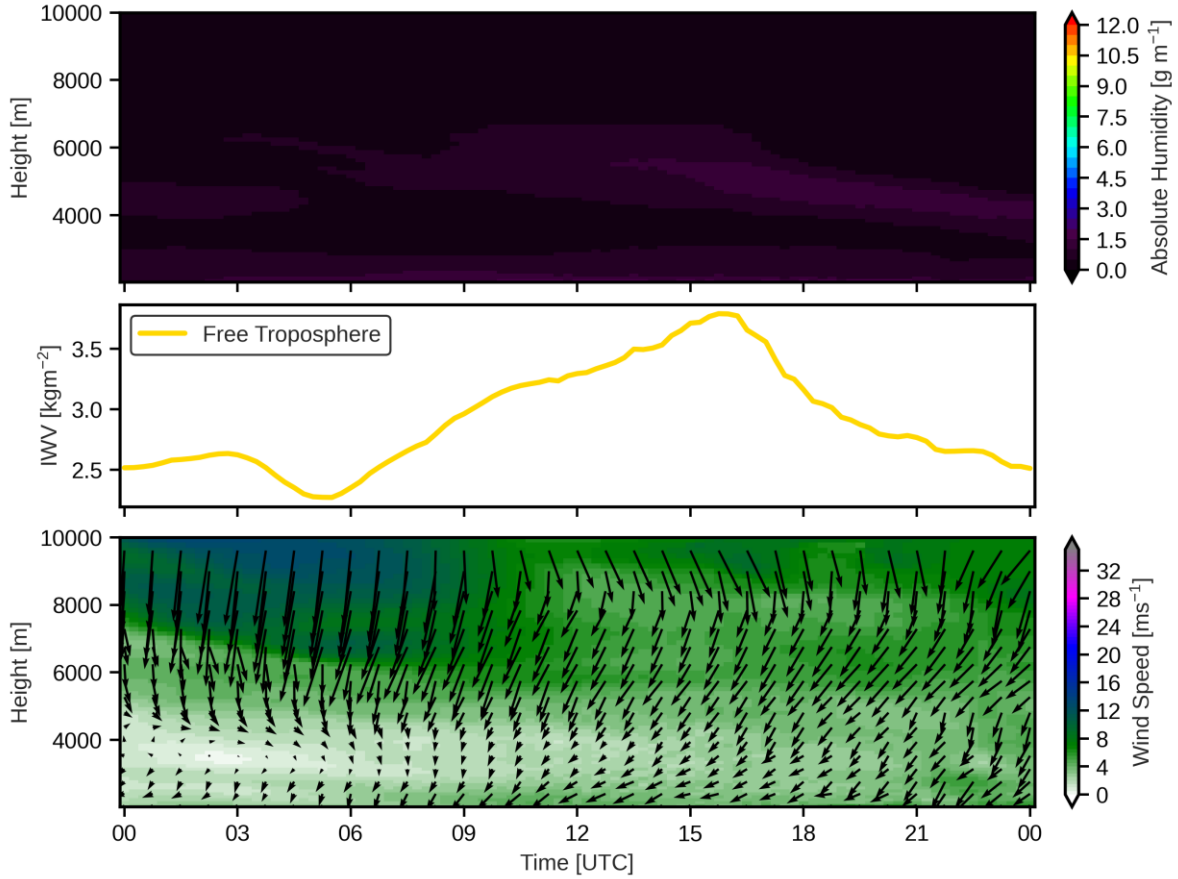
Case Study Results

Atmospheric column over Jue on 28.05.2023

Boundary Layer (0-2km)



Free Troposphere (2-10km)



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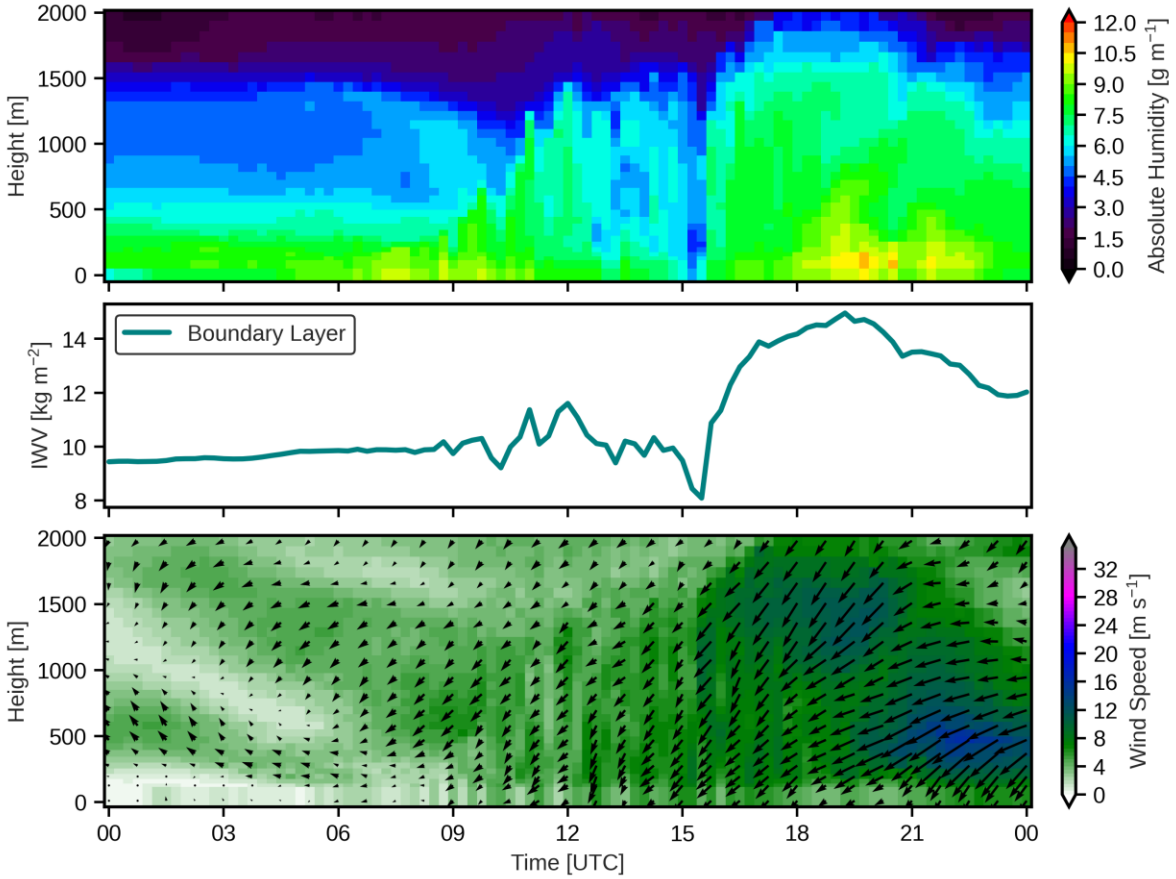
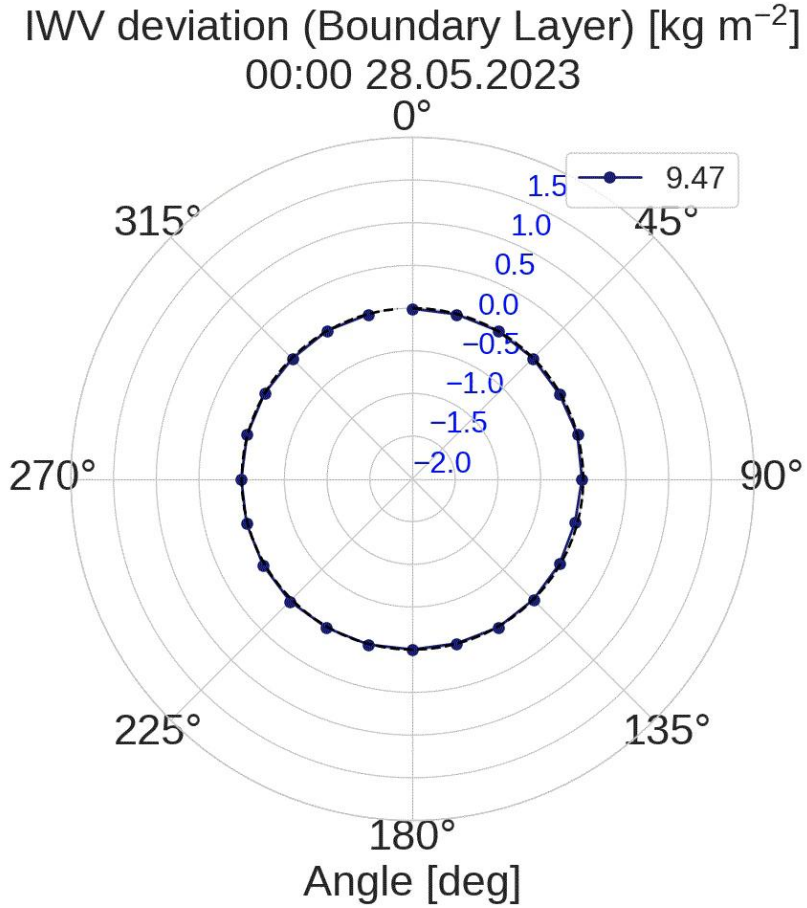
Atmospheric column over Jue on 28.05.2023

Boundary Layer (0-2km)



Spatial Variability



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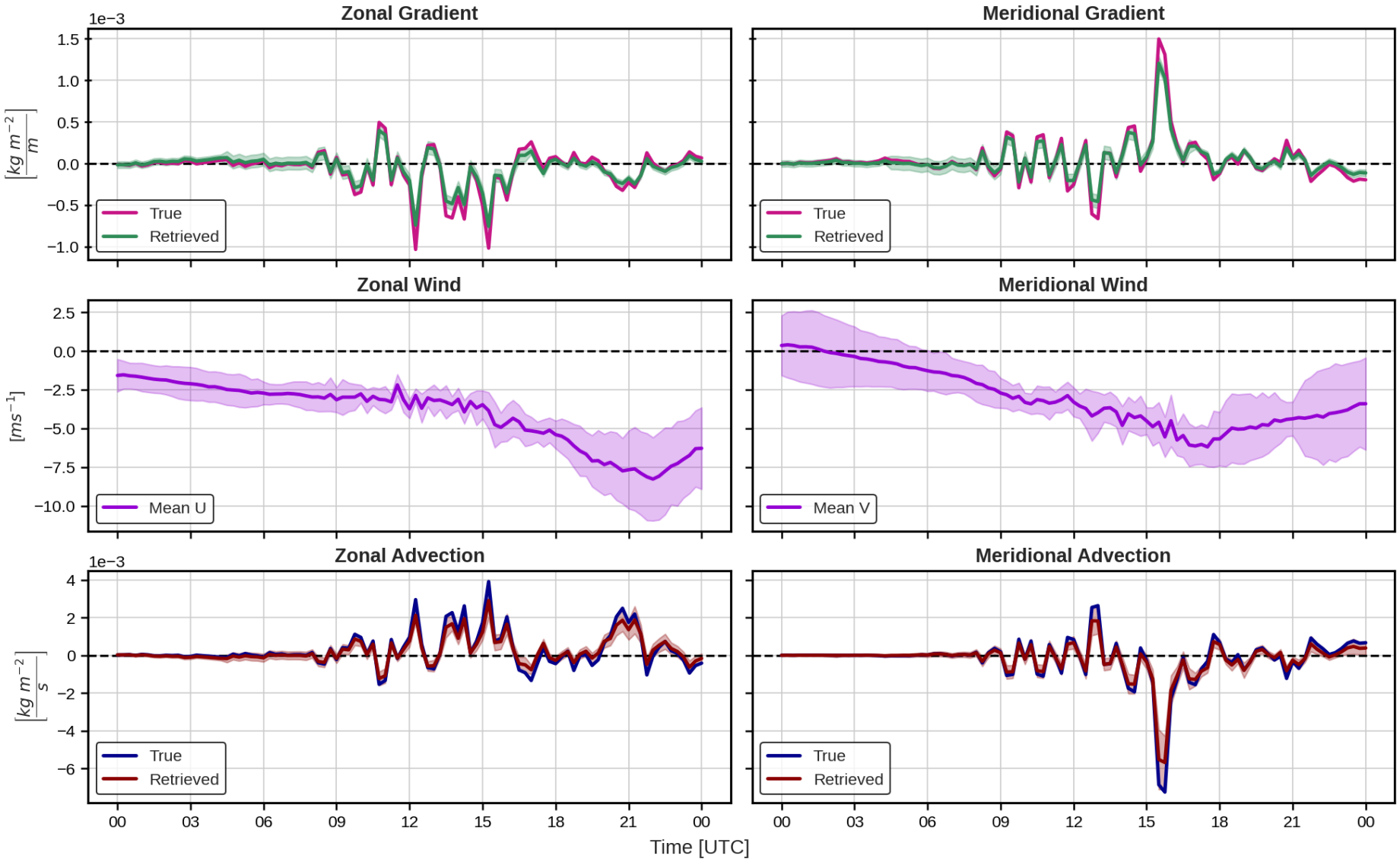
28.05.2025: Boundary Layer

$\frac{\partial IWV}{\partial x}$



$\frac{\partial IWV}{\partial y}$

u

v

$u\frac{\partial IWV}{\partial x}$

$v\frac{\partial IWV}{\partial y}$

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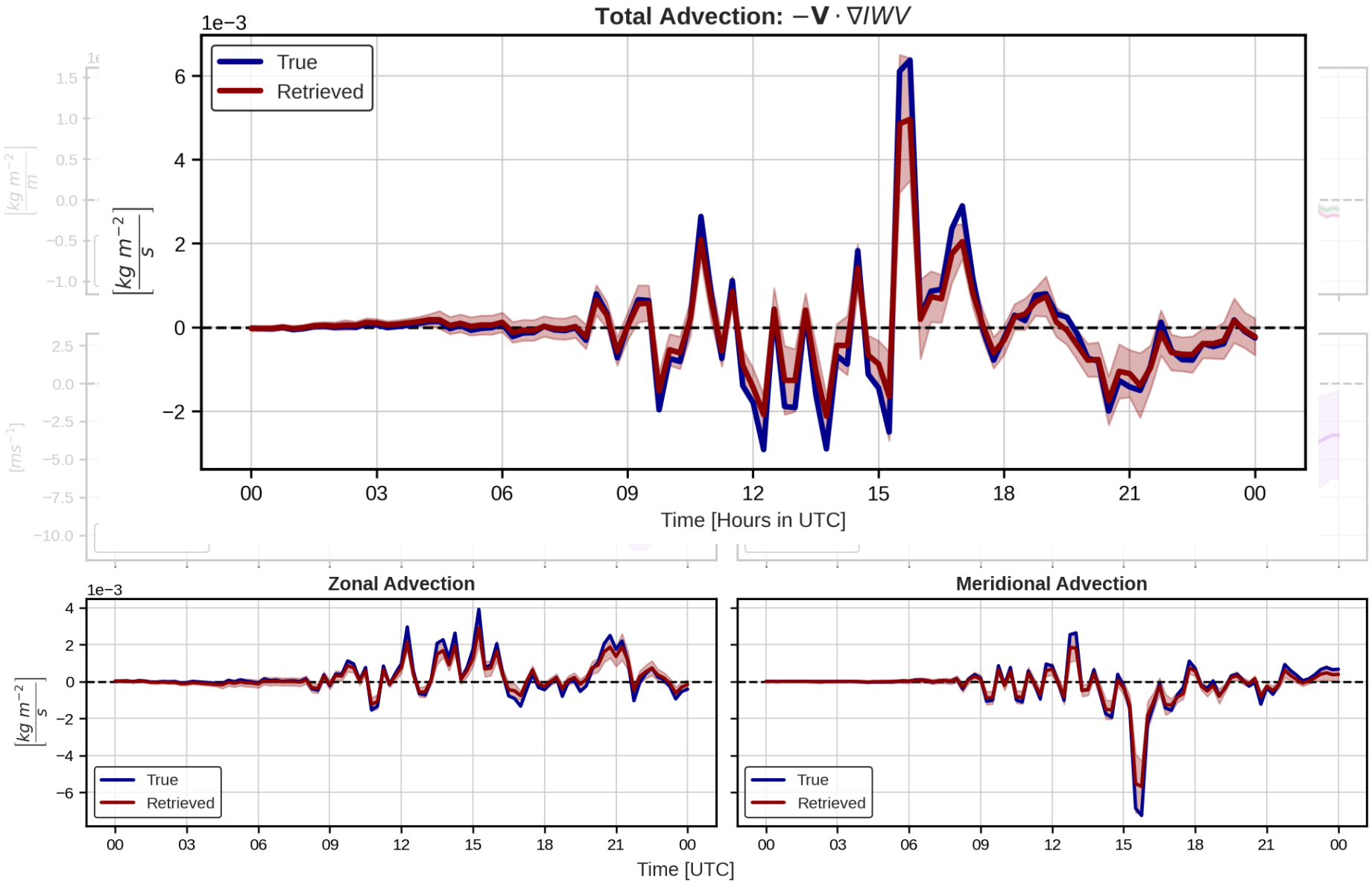
28.05.2025: Boundary Layer

$\frac{\partial IWV}{\partial x}$

u

$u\frac{\partial IWV}{\partial x}$



$\frac{\partial IWV}{\partial y}$

v

$v\frac{\partial IWV}{\partial y}$

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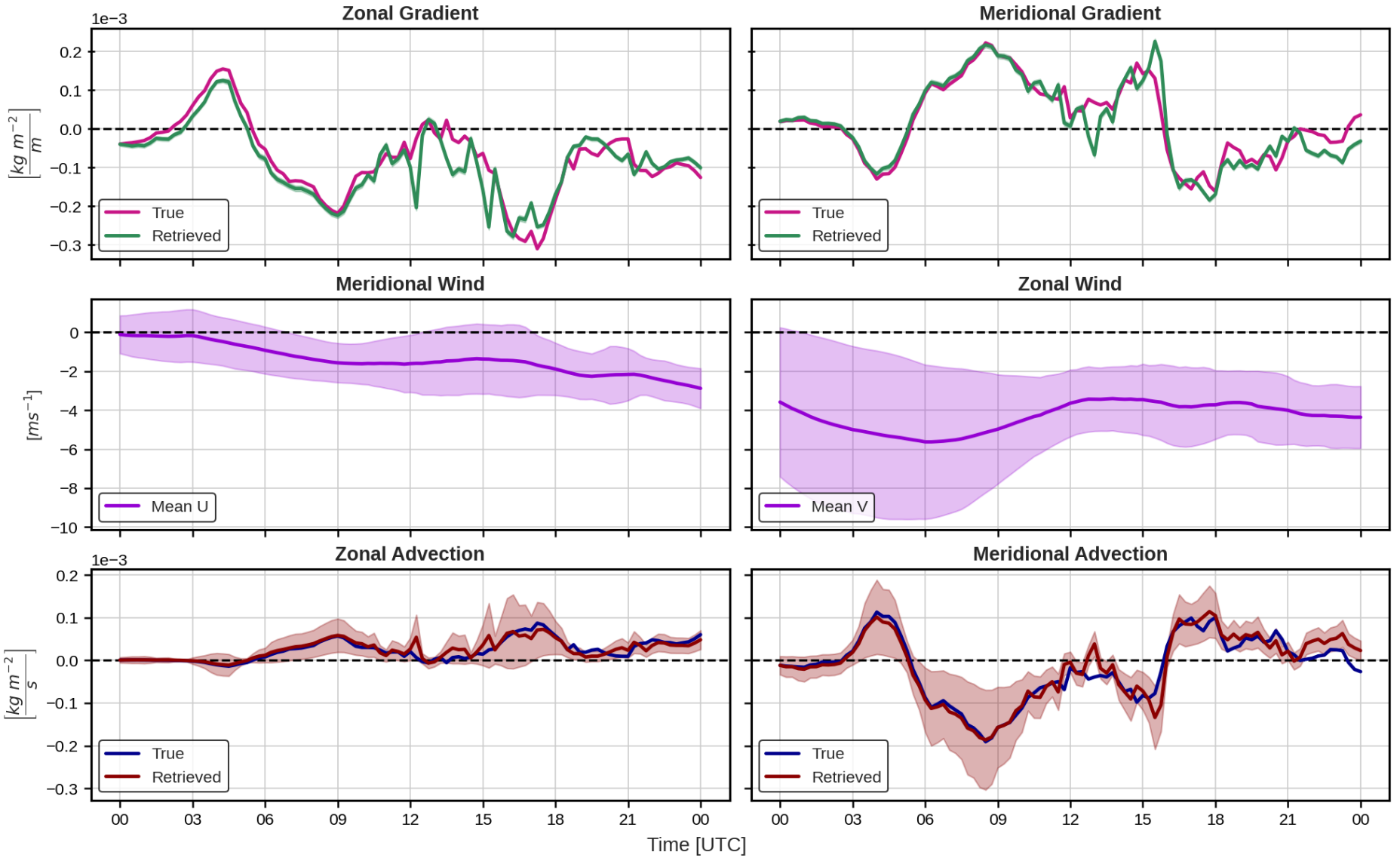
28.05.2025: Free Troposphere

$\frac{\partial IWV}{\partial x}$



$\frac{\partial IWV}{\partial y}$

u

v

$u\frac{\partial IWV}{\partial x}$

$v\frac{\partial IWV}{\partial y}$

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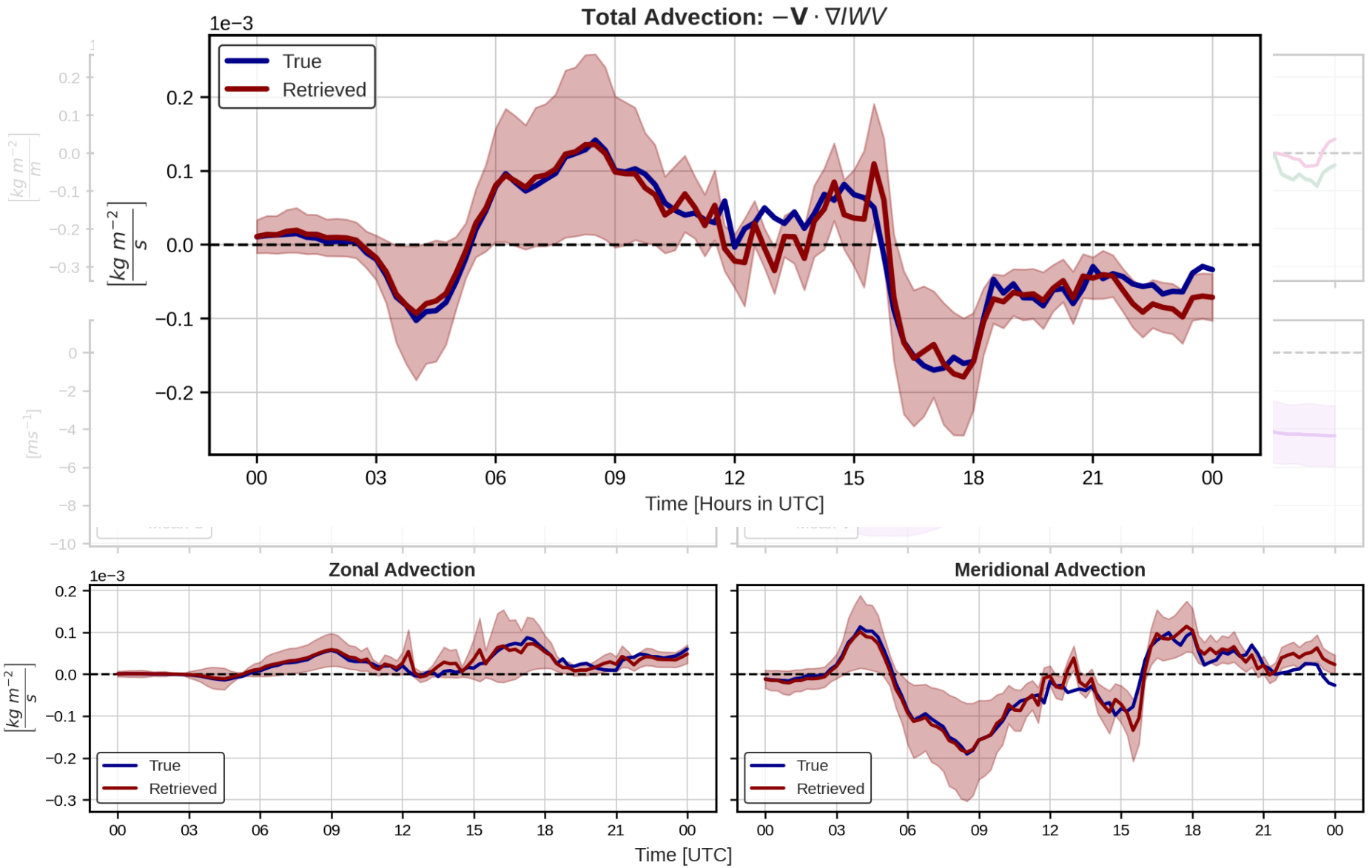
28.05.2025: Free Troposphere

$\frac{\partial IWV}{\partial x}$

u

$u\frac{\partial IWV}{\partial x}$



$\frac{\partial IWV}{\partial y}$

v

$v\frac{\partial IWV}{\partial y}$

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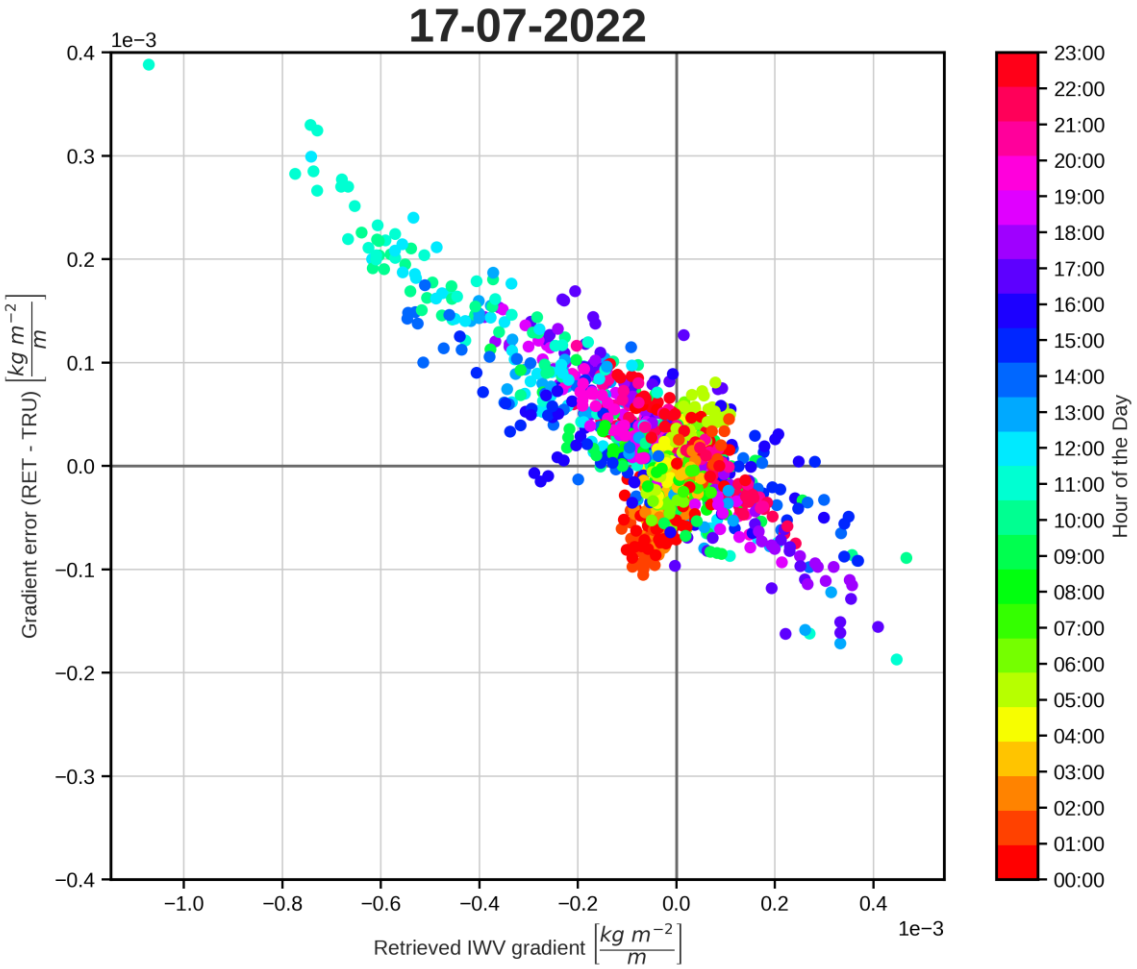
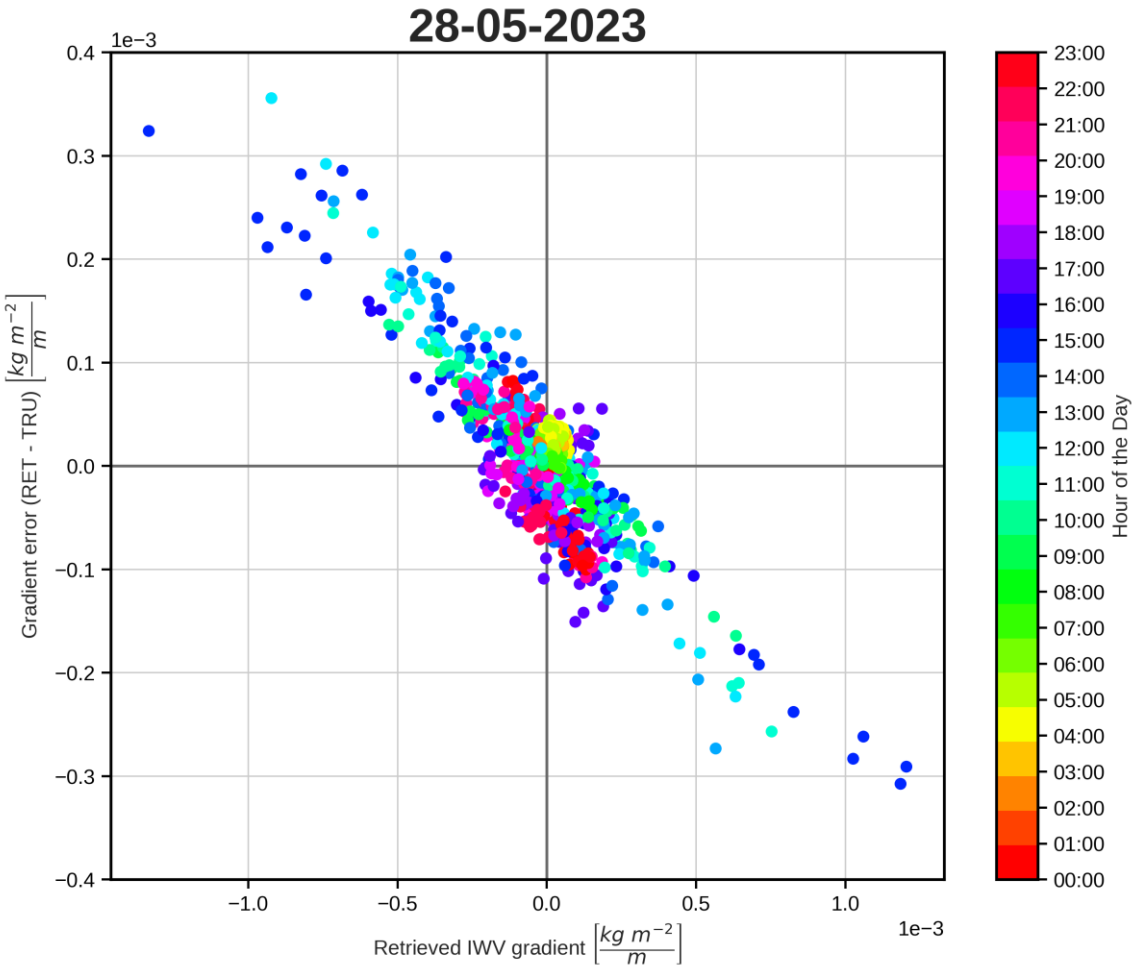
IWV gradient error analysis





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Summary & Outlook

I. Method to derive horizontal IWV gradients from MWR

II. Fairly good agreement between true and retrieved gradients in the BL

III. Errors tend to be higher when magnitude of gradients are higher

- … look at more events, frontal passages, heat wave events etc..
- … close moisture budget through Mixing Diagram approach
- … extend the method to see if height dependant advection can be estimated

Case	Retrieved cumulative advection in BL in kg m^{-2} (Truth)	Retrieved cumulative advection in FT in kg m^{-2} (Truth)
17.07.2022	-2.101 (-0.891)	1.005 (0.579)
28.05.2023	5.894 (5.190)	-0.628 (-0.347)

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