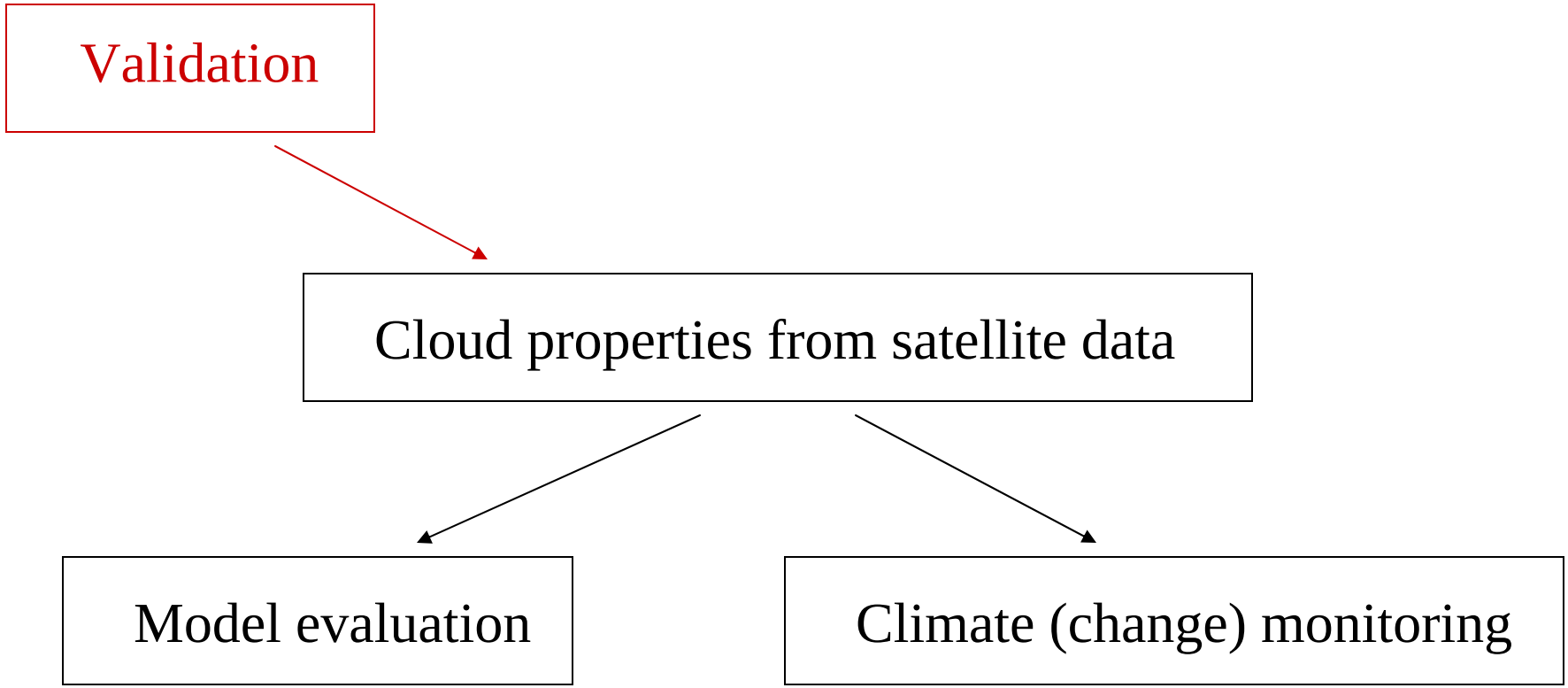
VALIDATION OF SATELLITE-DERIVED LIQUID WATER PATH

Improve method:

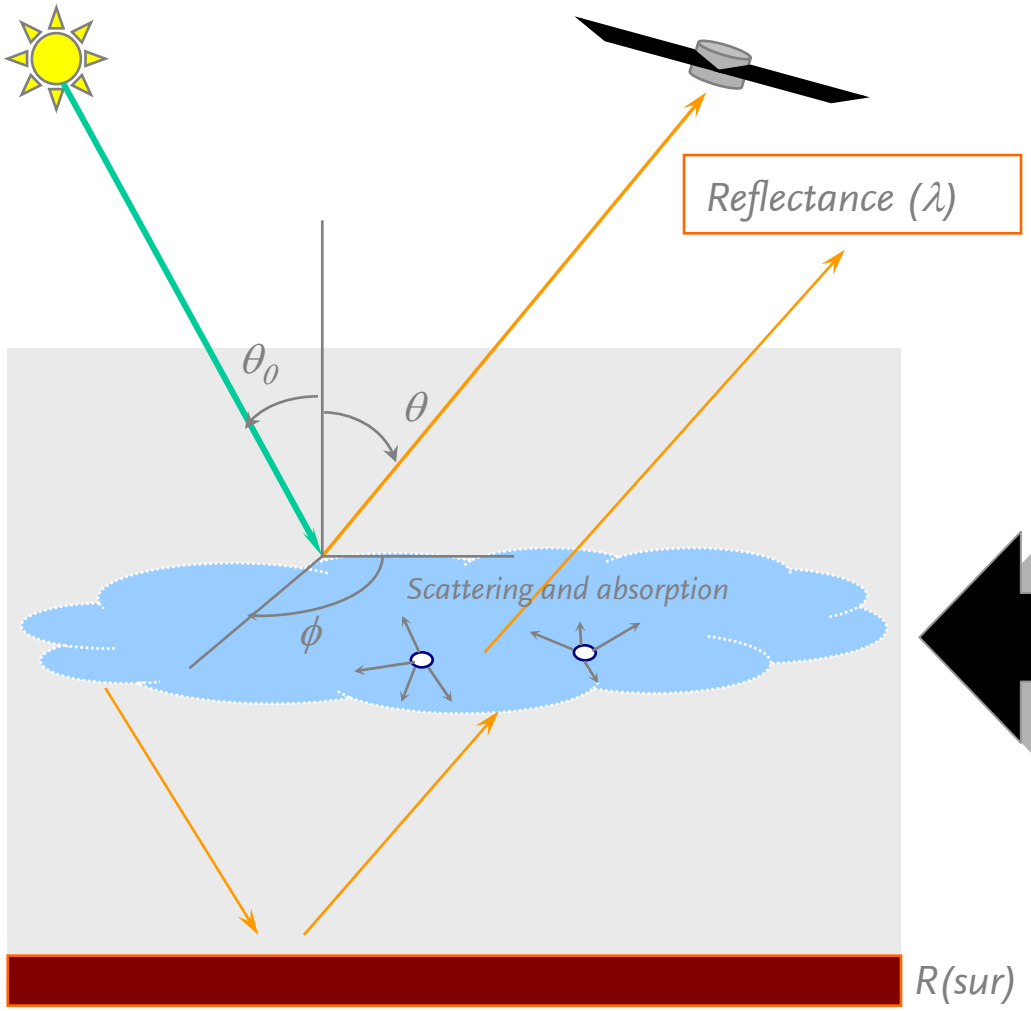
1) **length and time scale?**
2) **parallax?**
3) **variations in wind field?**

Satellite data: from SEVIRI (METEOSAT)
Ground data: CLOUDNET stations

WHY?


Validation
Cloud properties from satellite data
Model evaluation
Climate (change) monitoring

RETRIEVE CLOUD PROPERTIES FROM SATELLITE MEASUREMENTS

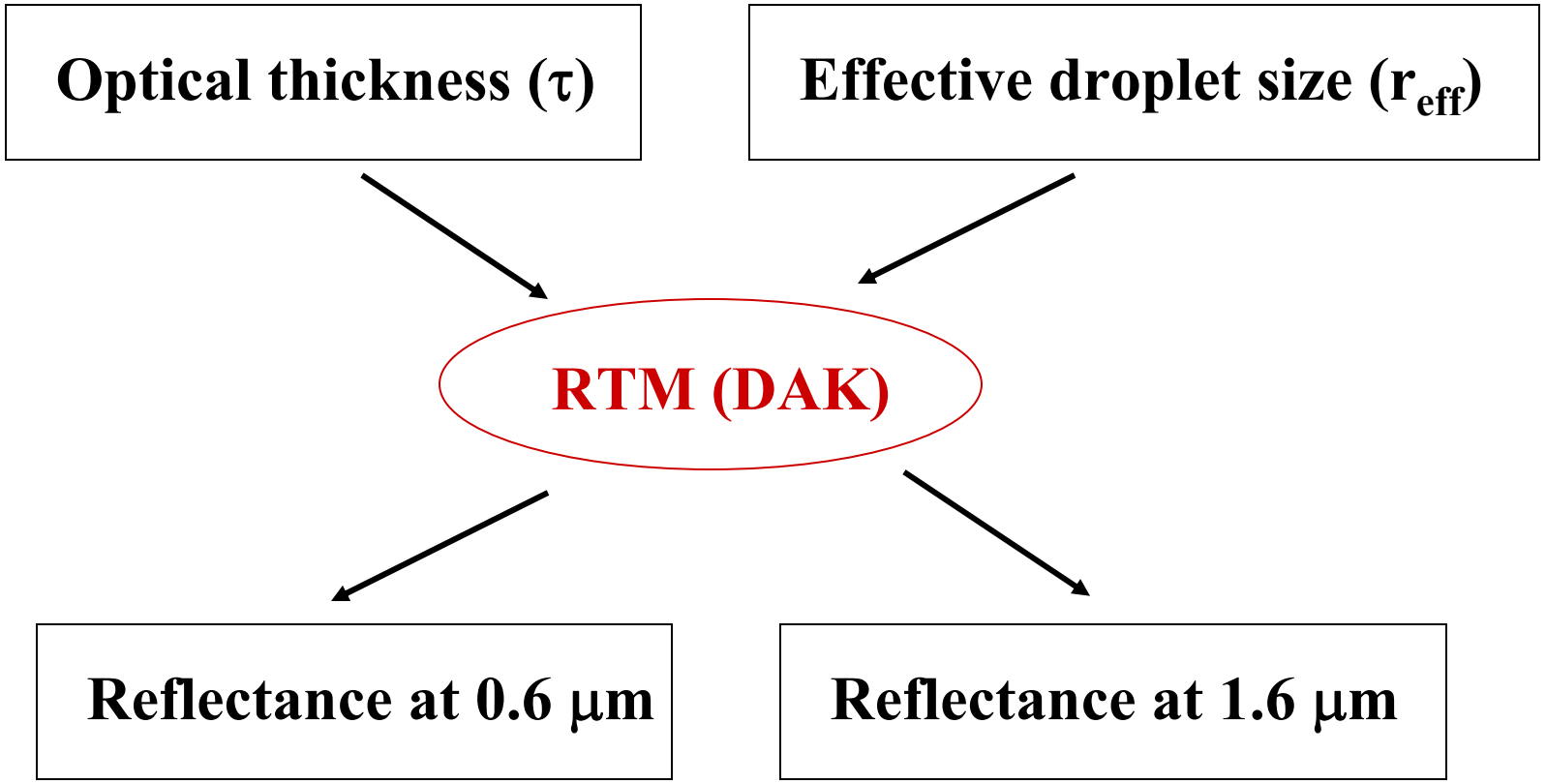


Cloud properties

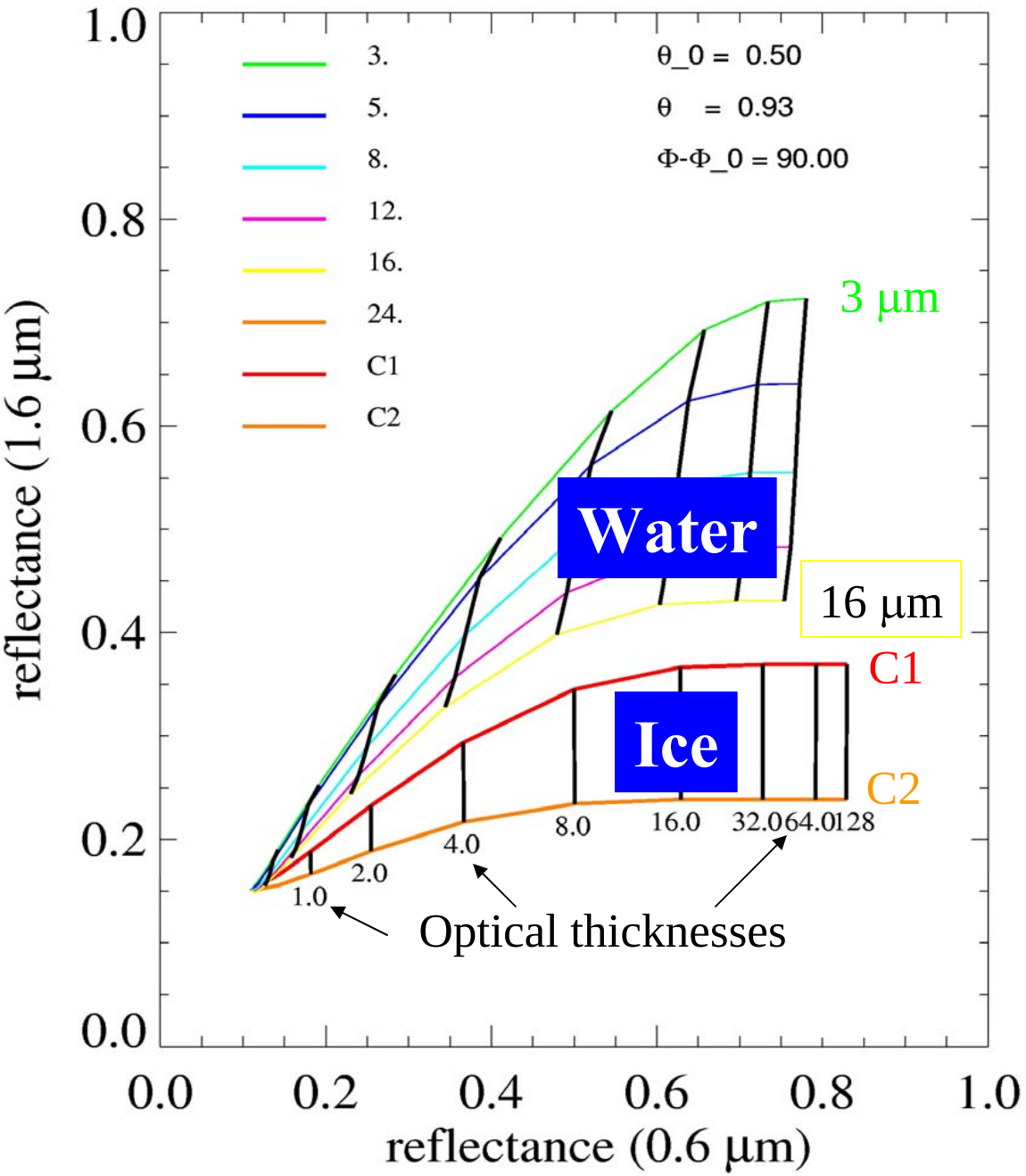
- Geometric thickness
- Thermodynamic phase
- Optical thickness
- Effective radius
- Droplet distribution

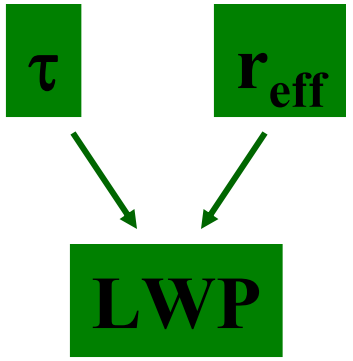
LOOK-UP-TABLE

produced by forward modelling



INVERSION





Errors due to

- inadequacies RTM model
- RTM assumptions
- Phase attribution
- Mixed clouds
- 3D effects
- Satellite sensor calibration

MICROWAVE RADIOMETER

Frequencies:
20 –30 GHz

Retrieval of:
- LWP
- IWV

Limitations:
- not sensitive to ice
- not when rain

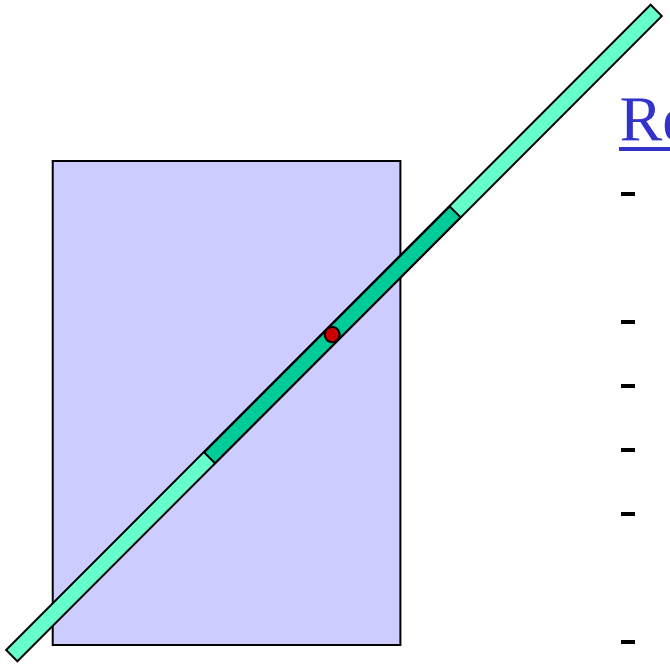
Errors due to:
- instrumental drift and noise
- errors in RTM (absorption properties)
- Fluctuations in atmospheric profiles of T and humidity

PROBLEM 1: SCALE DIFFERENCE

SEVIRI pixel: 6 * 3 km^2

MWR: beamwidth = 2.5º

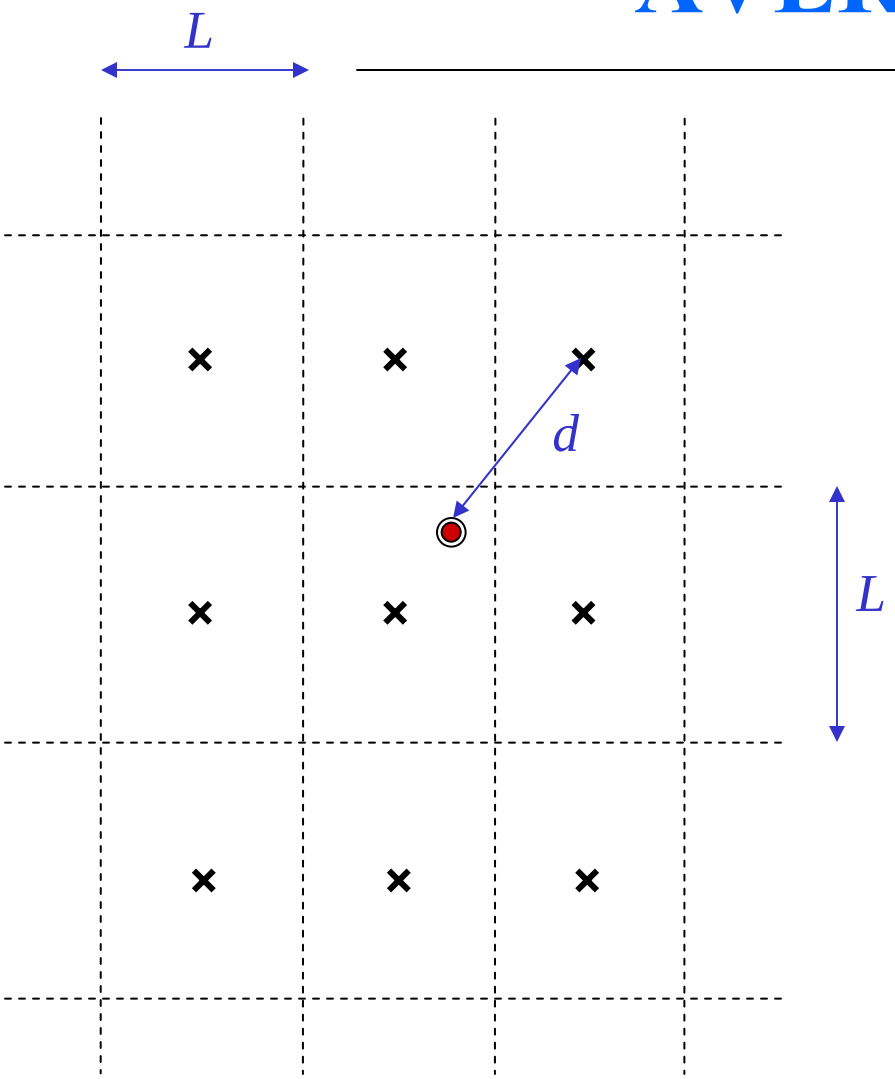
1 measurement: 220 * 220 m^2 at 5 km; ~0.25% of pixel



Remedy:

- assumption: LWP pattern moves across station without change
- average ground data in time (T = Ldx/v)
- larger fraction of pixel is measured
- average over time: 220 * 3-6 km2; ~5% of pixel
- preciser assumption: no change (stationarity) in local variability of LWP
- Sample over interval longer than T ?

AVERAGING IN SPACE



Best estimation of satellite LWP at station location

Weight function (w) for Gaussian mean:

$$w(d) = \exp\left(\frac{-2d^2}{L^2}\right)$$

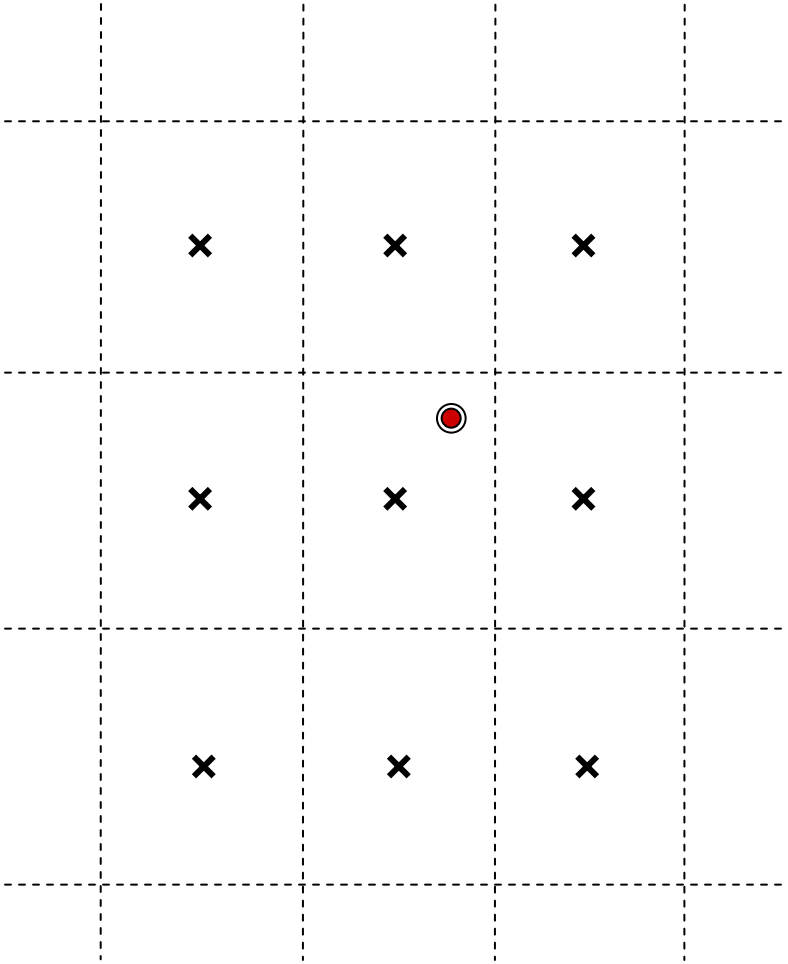
d: distance station to grid point

L: length scale

Units: grid size

L is free parameter

AVERAGING IN SPACE



Best estimation of satellite LWP in area (size L) surrounding the station

Weight function (w) for Gaussian mean:

$$w(d) = \exp\left(\frac{-2d^2}{L^2}\right)$$

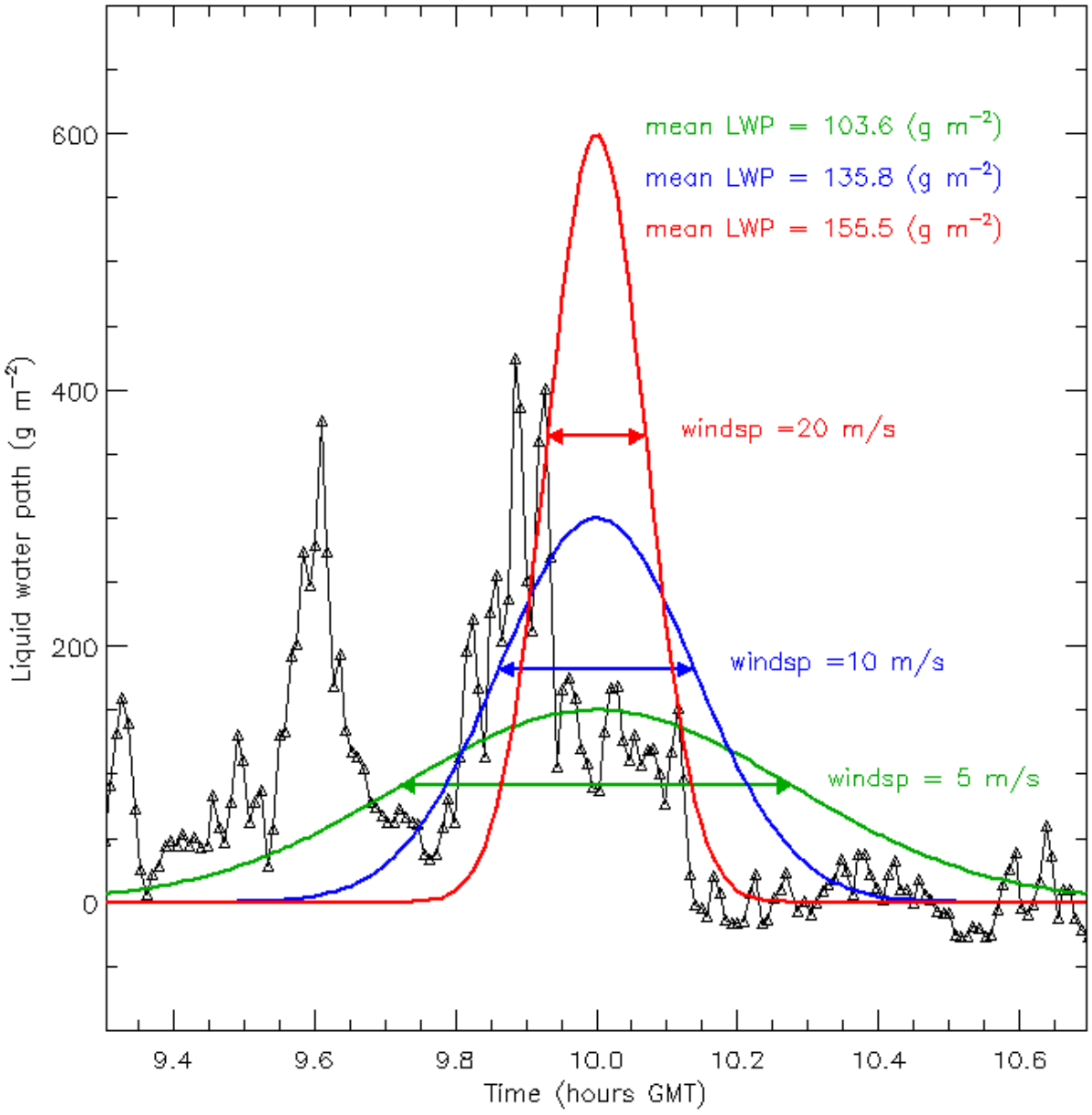
d: distance station to grid point

L: length scale

Units: grid size

L is free

AVERAGING IN TIME



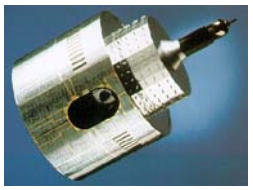
$$w_{gr} = \exp\left(\frac{-2(t-t_c)^2}{T^2}\right)$$

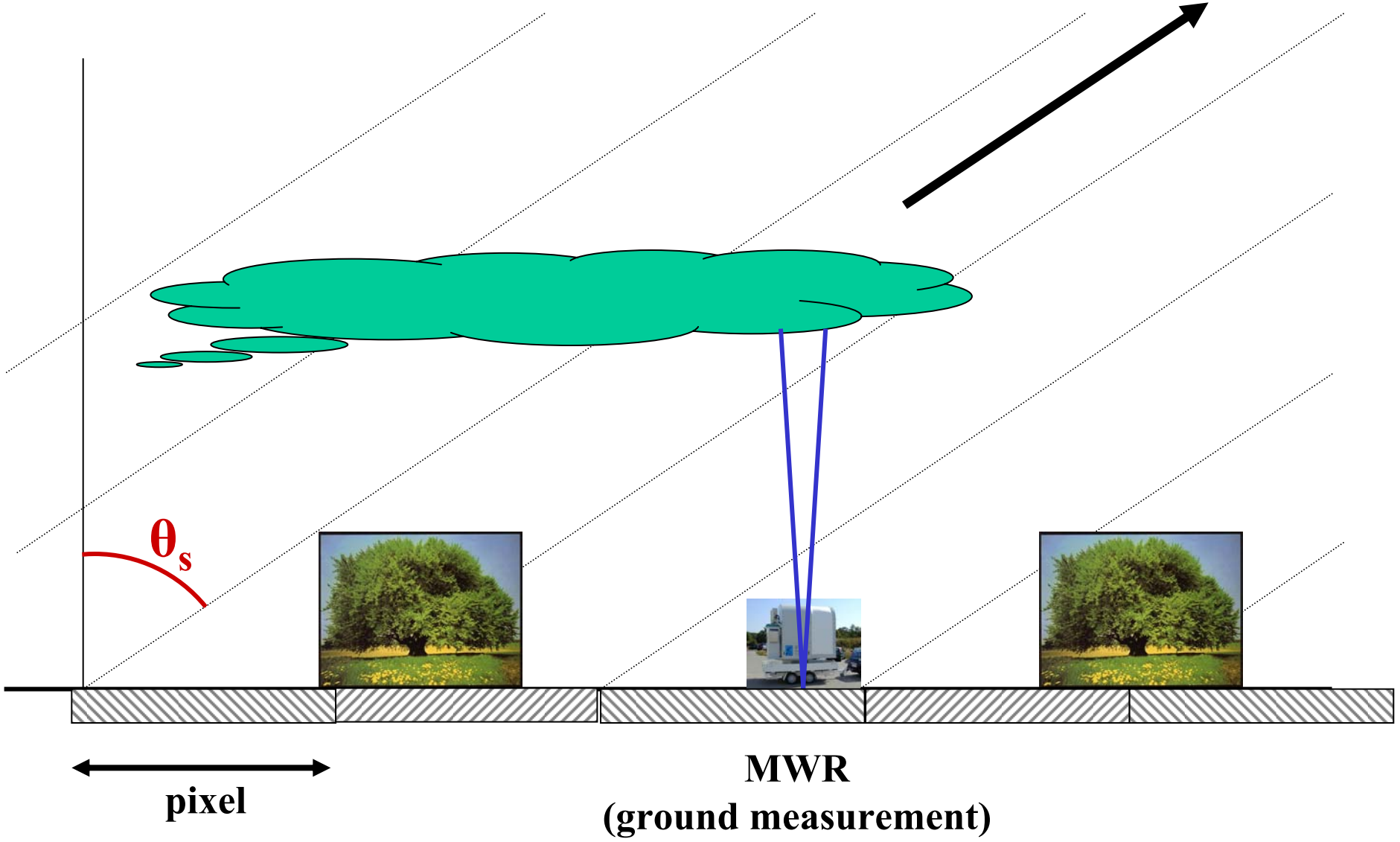
Option:
multiply time window with factor f_t (free parameter)

$$T = f_t \frac{L\,dx}{u_{cltop}}$$

dx: pixel size (m)

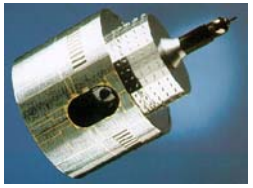
PROBLEM 2: PARALLAX

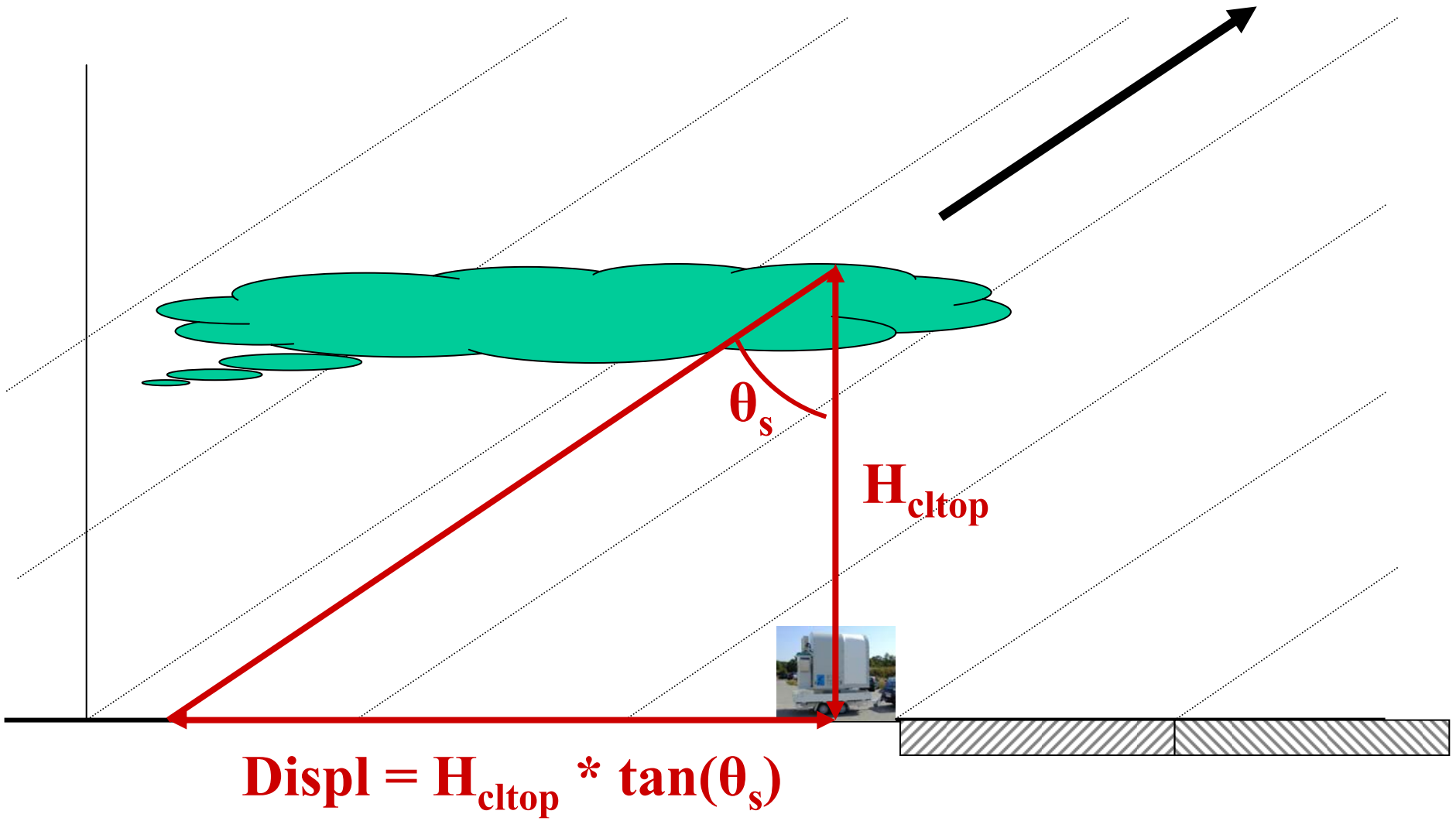




REMOVE PARALLAX

Sat.





$$Displ = H_{cltop} * \tan(\theta_s)$$

DETERMINE CLOUD TOP HEIGHT

a) **from ground data**
radar and lidar

b) **from satellite data**
cloud top temperature and ECMWF temperature profile

cloud top height

ECMWF data

wind field

QUESTIONS

1) Should parallax be taken into account?
2) Should we consider variations in the wind field for computing T (the averaging time interval)?
3) What are the optimum length (L) and time scales (f_t) for validating LWP?

DATA SELECTION

Satellite data: from SEVIRI (METEOSAT)
Ground data: CLOUDNET stations

4 summers (May-August), 4 images per hour: n = 47232

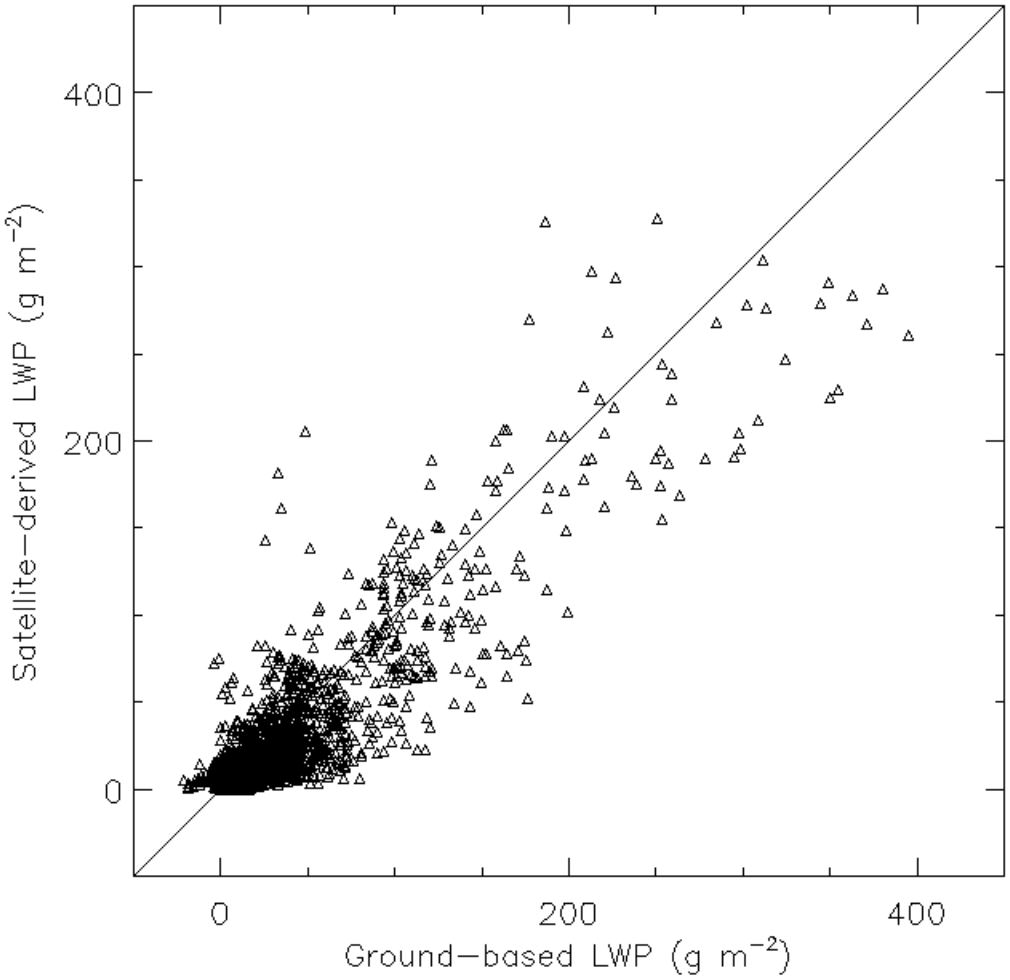
Criteria:

- solar zenith angle < 72°
- data available
- water clouds according to ground measurements (>95%)
- water clouds according to sat. retrieval
- no rain acc. To ground measurements
- LWP < 400 g/m^2 acc. To ground measurements
- no offset during clear sky in ground measurements

Remaining number of samples: 2628

VALIDATION

with parallax correction; with variations in wind field
L = 2 pixels, f_t = 6



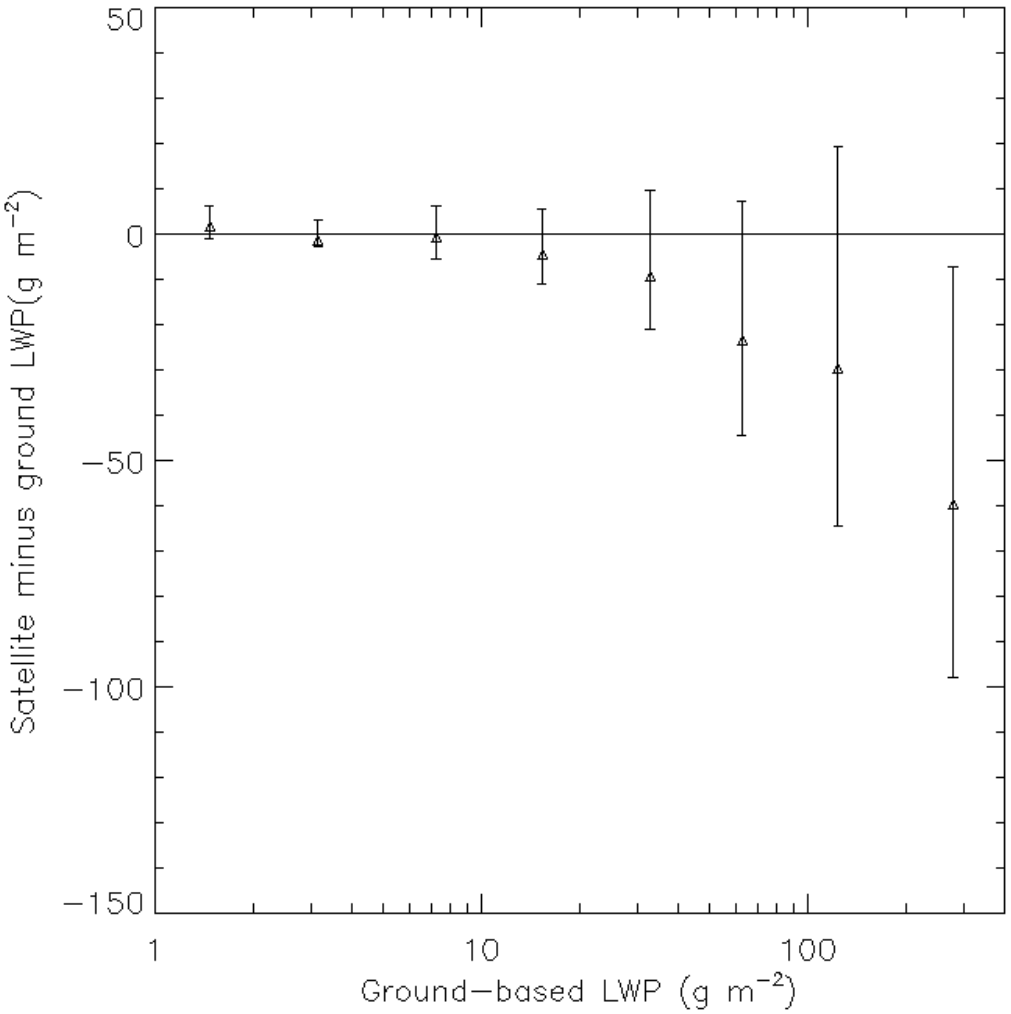
n = 2628
Ground mean = 26.4 g/m²
Sat mean = 22.6 g/m²

Explained variance = 80.5%

<u>Differences:</u>
median: -0.1 g/m²
66.7 % within:
-14.9 to +6.2 g/m²
Q67 = 21.1 g/m²

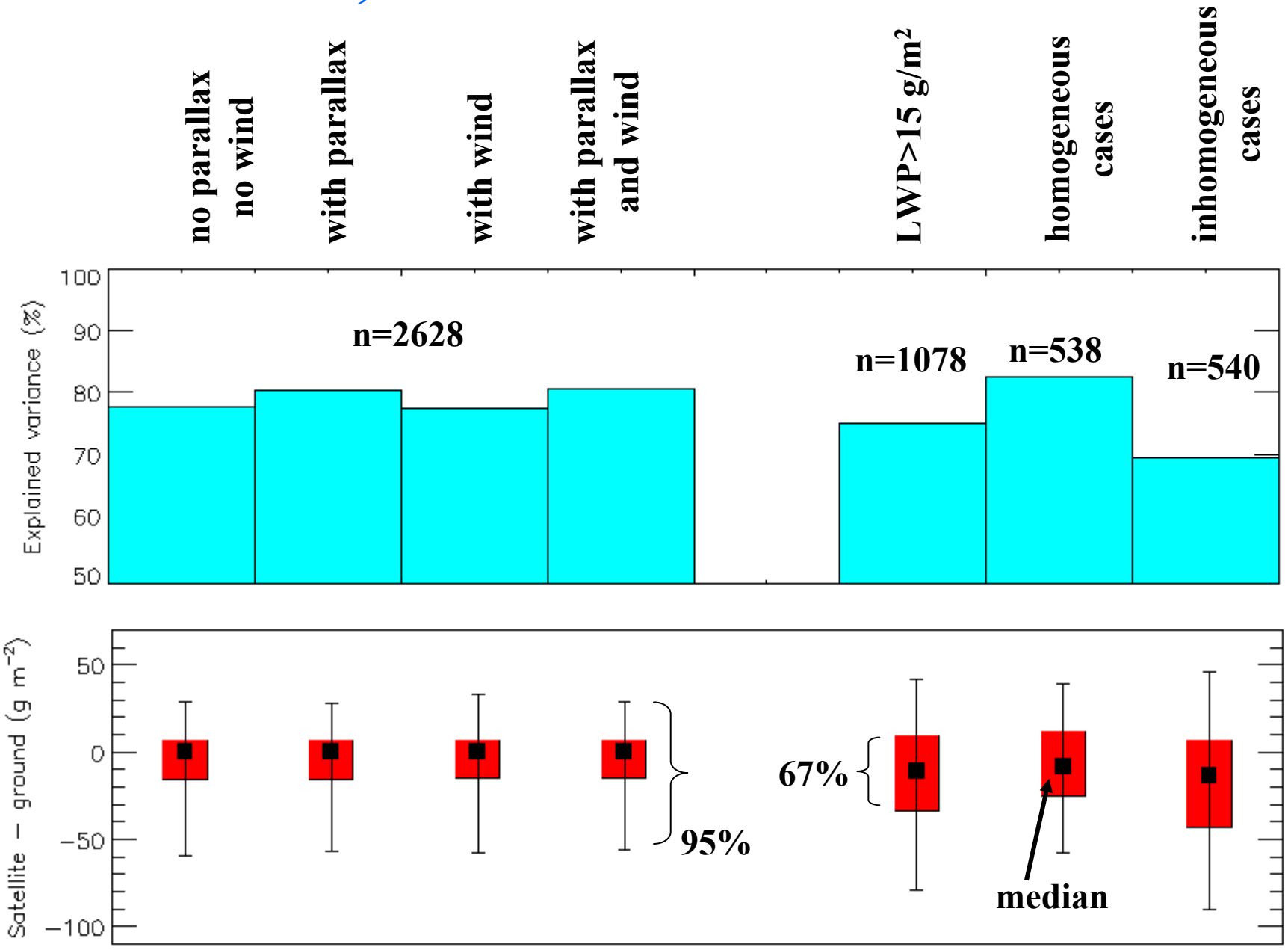
DIFFERENCES: SAT - GROUND

with parallax correction; with variations in wind field

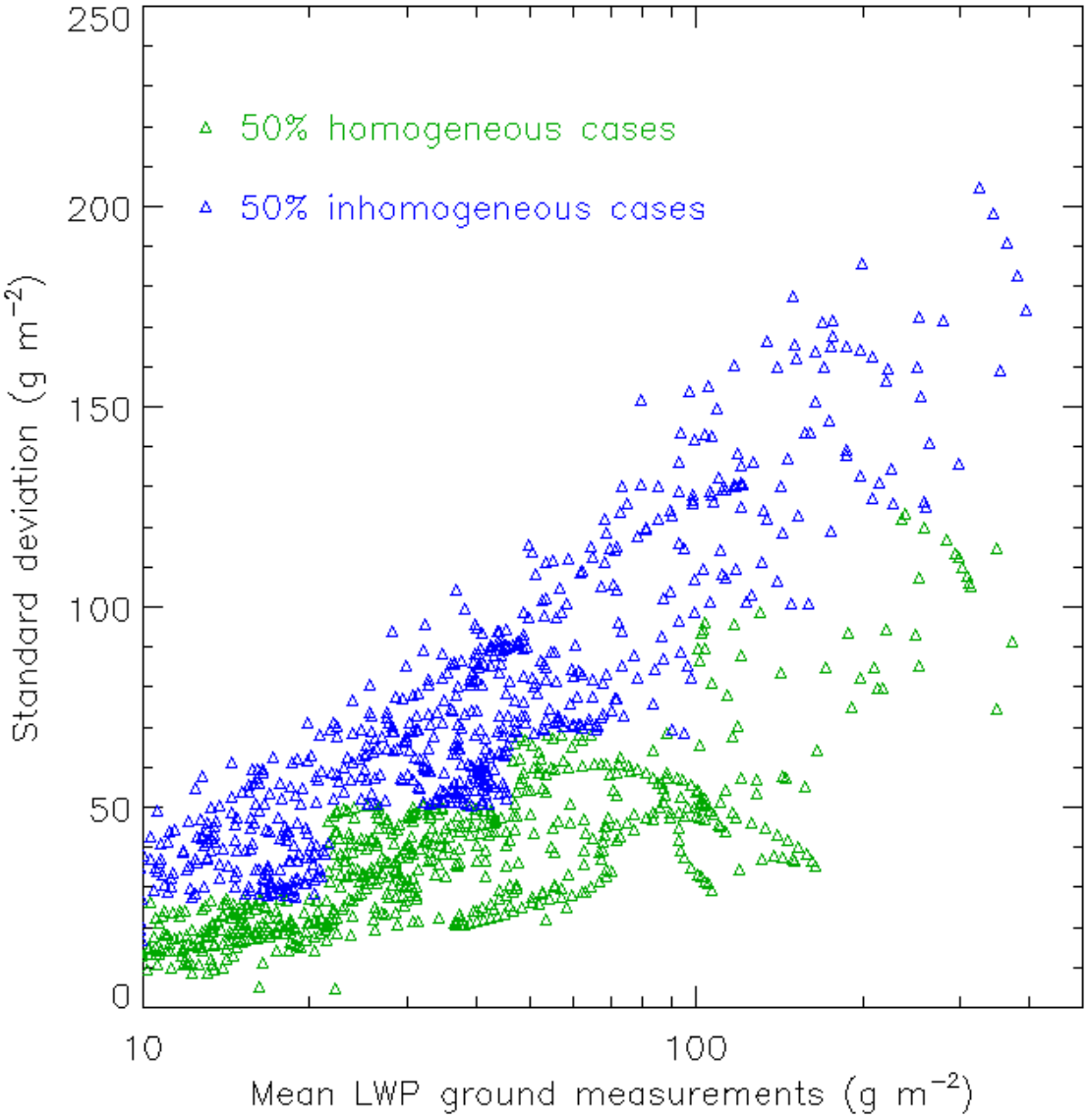


SEV = -0.1 + 0.862 * GRND

PARALLAX, WIND AND HOMOGENEITY

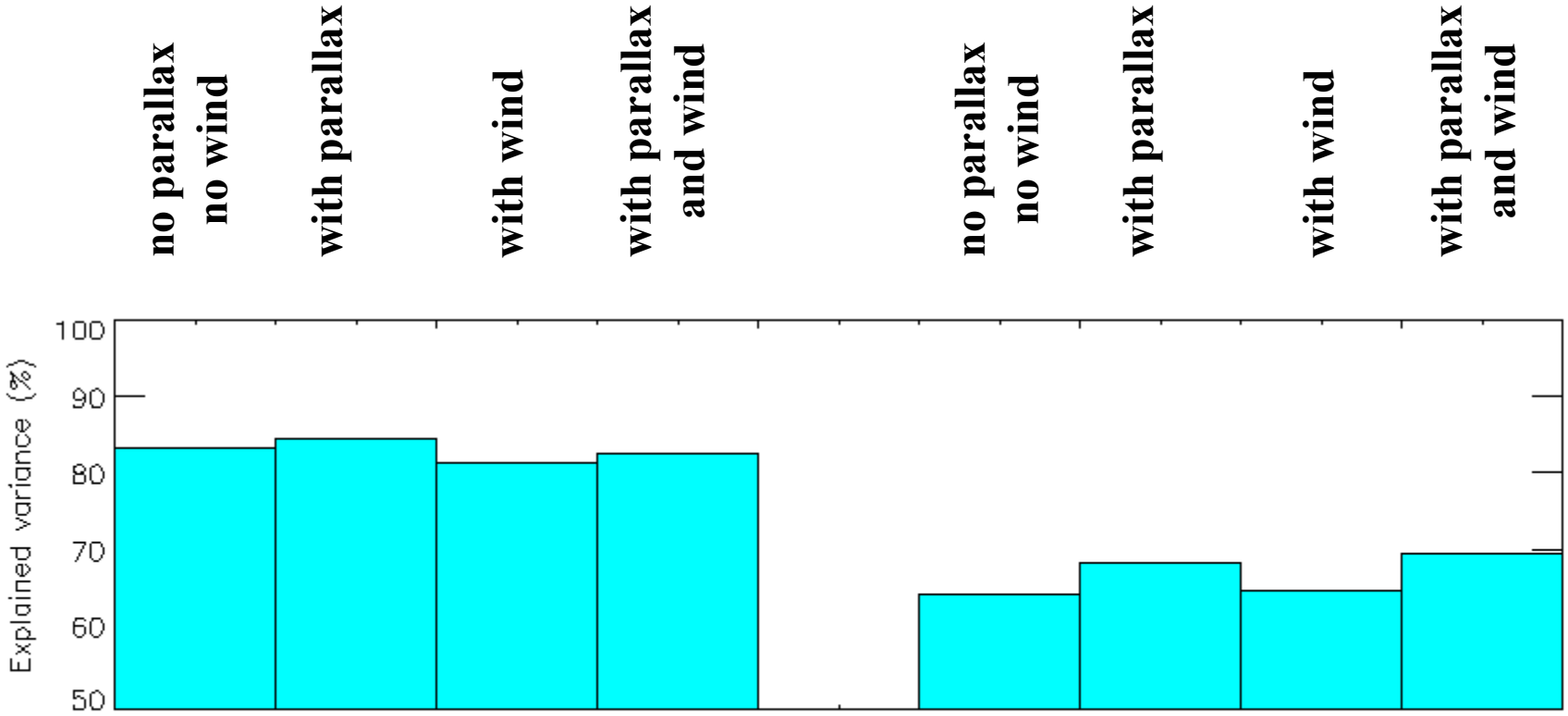


SELECT (IN)HOMOGENEOUS CASES



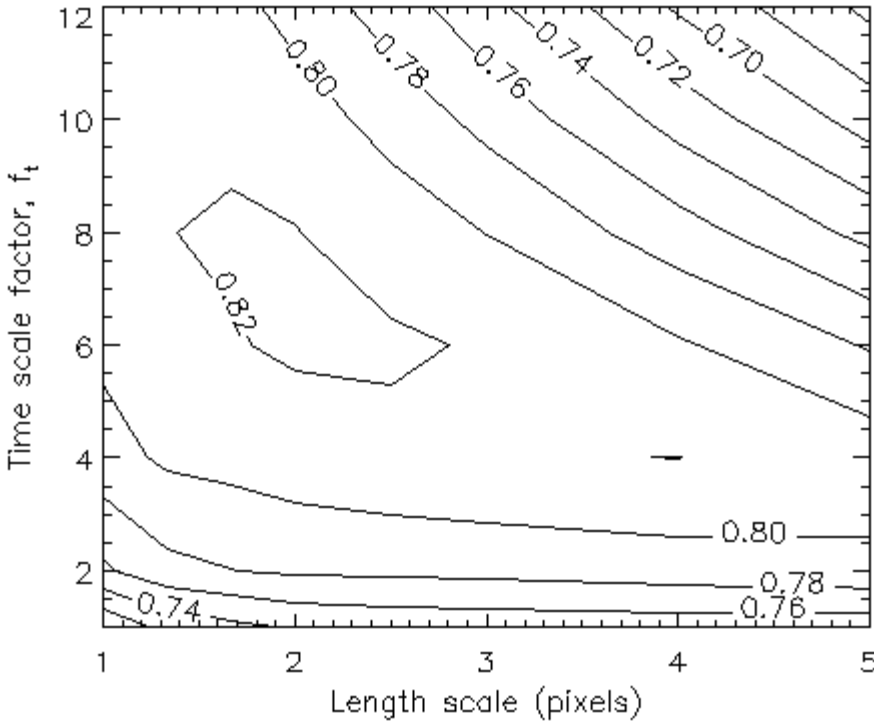
STATISTICS FOR (IN)HOMOGENEOUS CASES

homogeneous cases (n=538) **inhomogeneous cases (n=540)**

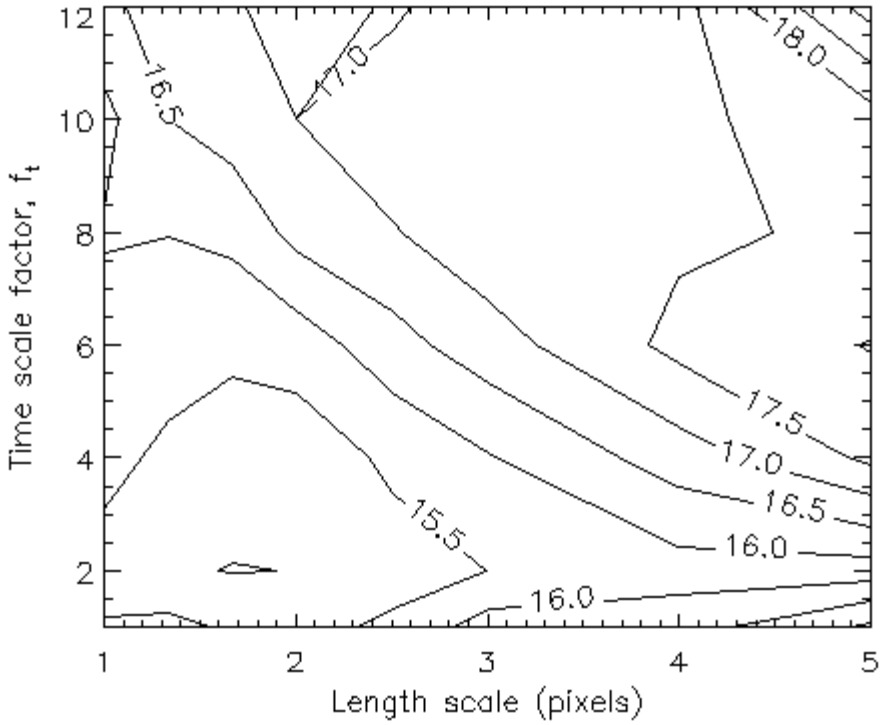


OPTIMUM LENGTH AND TIME SCALE

explained variance



Q67



CONCLUSIONS

If one is interested in validating whether satellite-retrieved variations in LWP are correct, the most appropriate scales for comparison with ground data are L=2 pixels and f_t=7

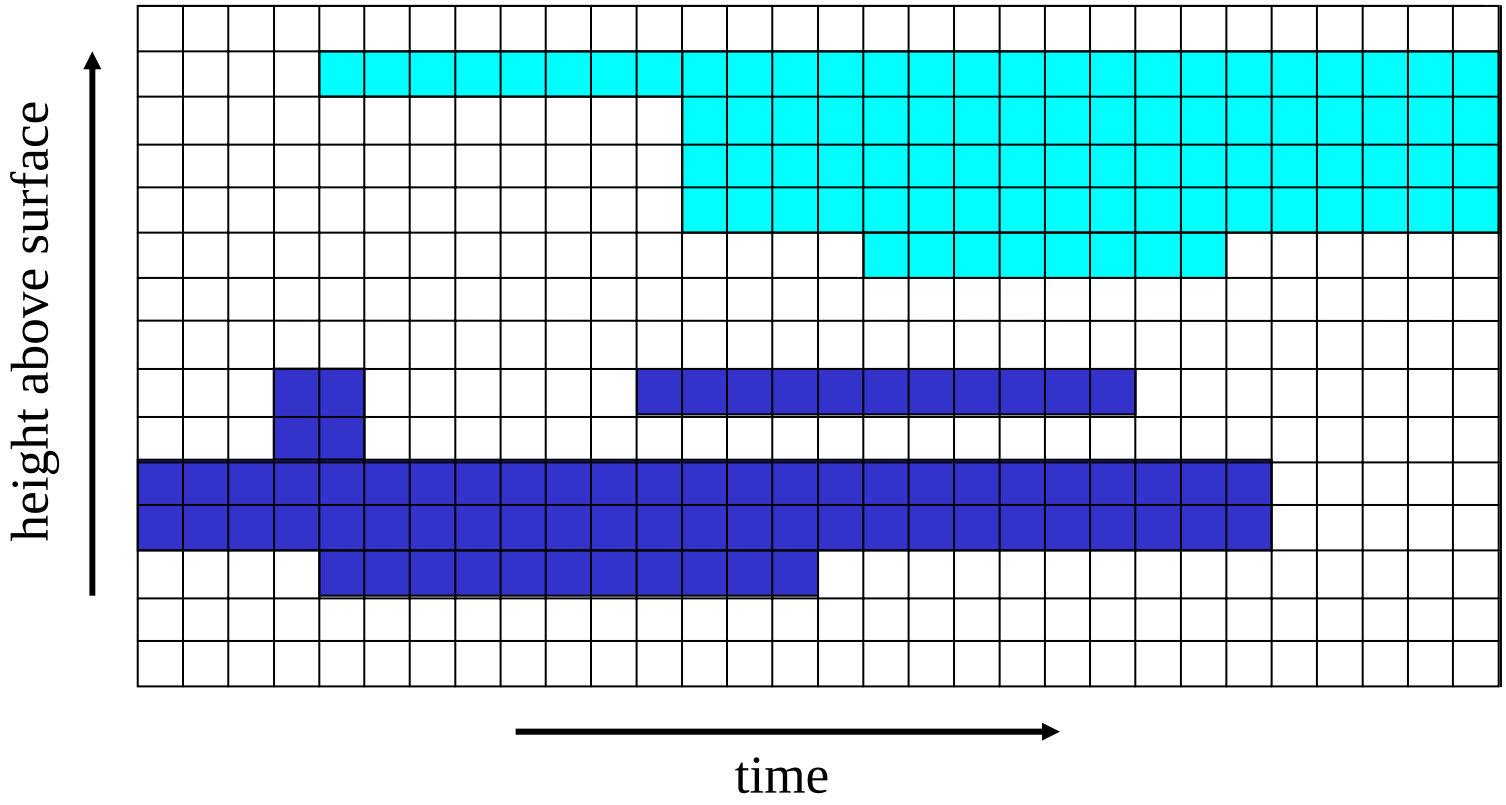
If we want to judge the quality of a retrieval by looking at the explained variance, the most appropriate scales are ..

If one is interested in validating that, in a statistical sense, satellite-retrieved values of LWP are correct (accepting a bias), the most appropriate scales for comparison with ground data are L=2 pixels and f_t=2

CONCLUSIONS

1) optimum length scale ~ 2 pixels
2) optimum time scale ($f_t > 1$) depends on application
3) correction for parallax improves results significantly
4) consideration of variations in the wind field brings no improvement
5) satellite and ground values match much better for homogeneous cases than for inhomogeneous cases
6) parallax correction does not affect the homogeneous samples
7) Findings also valid for other cloud-related variables (τ, surface incoming radiation)?
8) For other satellites?

CLOUD PHASE FROM GROUND DATA



water cloud points: 76
ice cloud points: 88

no clear sky
46% water cloud

water cloud

ice cloud

CLOUD PHASE VALIDATION