Improving MWR LWP Retrievals at the NSA site with Multiple-sensor Measurements and Retrievals

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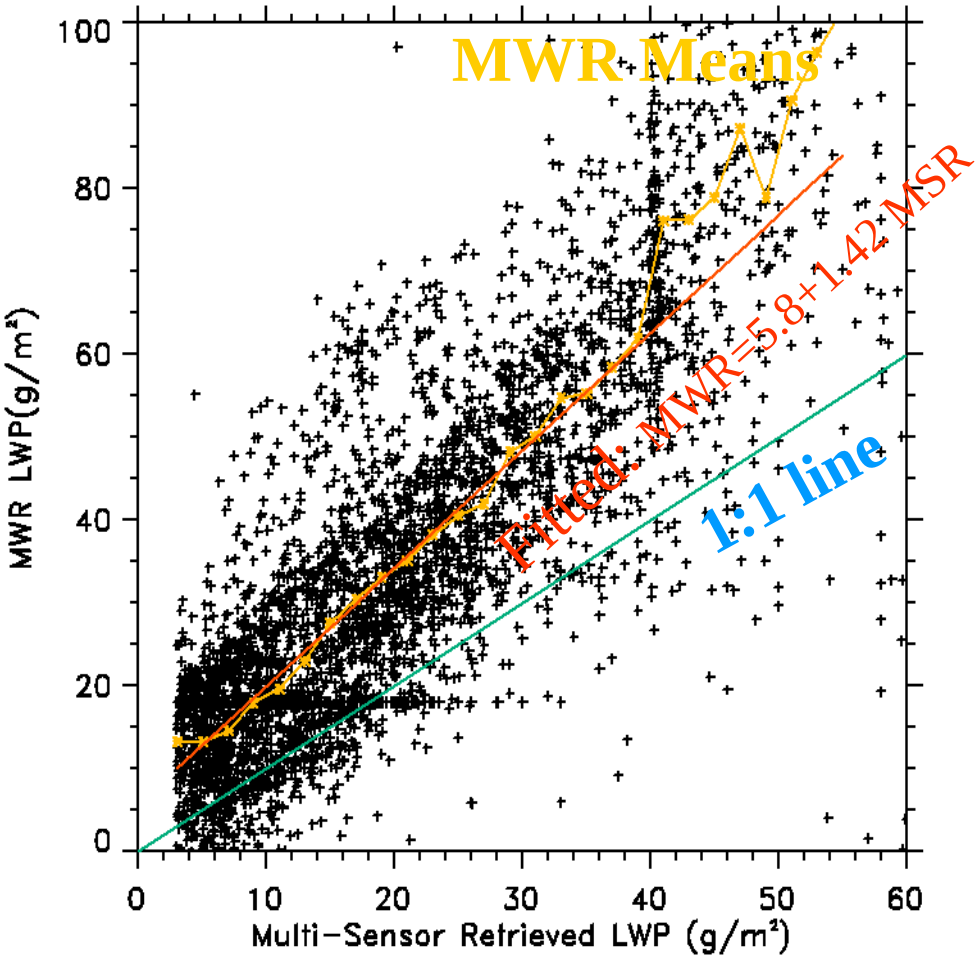
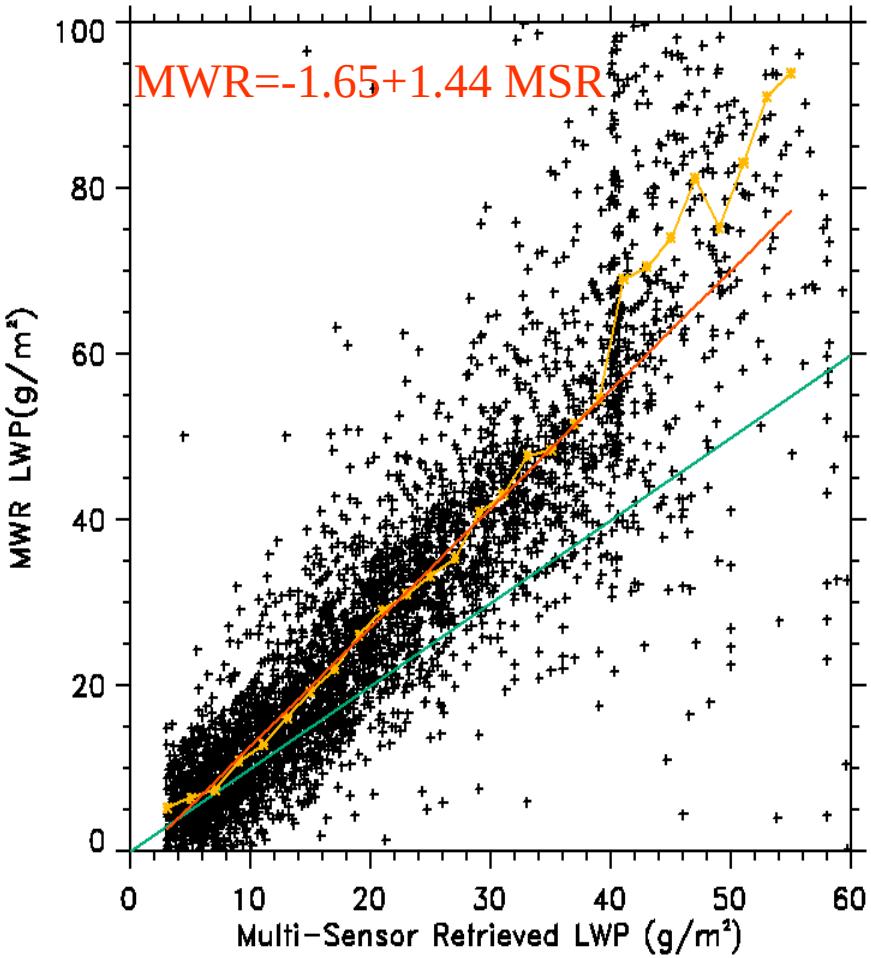
Statistical Comparison

Without Clear-sky Biases Correction



With Clear-sky Biases Correction



A Multi-sensor Based Mixed-phase Cloud Retrieval Algorithm

Wang et al., *J. Appl. Meteor.*, **43**, 449-460, 2004

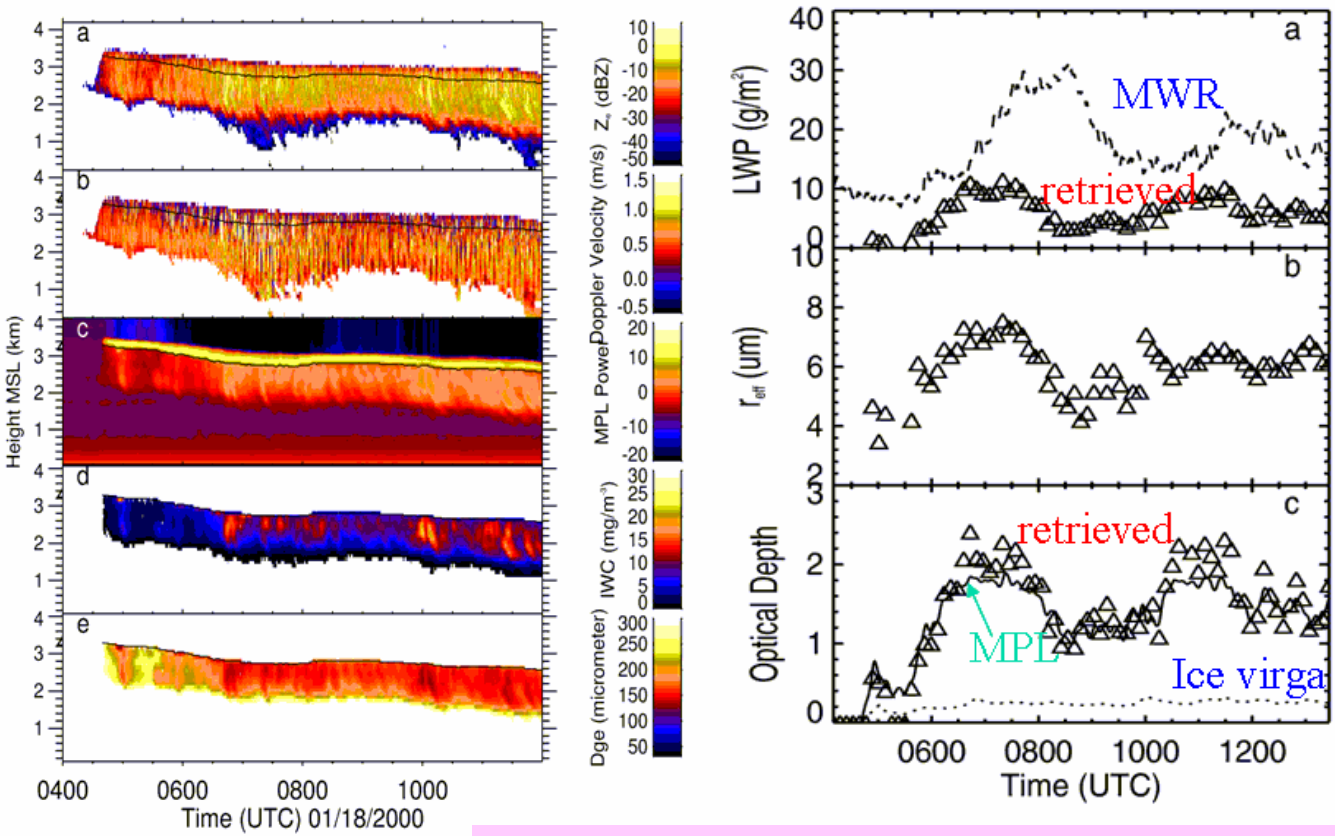
Observations:

MMCR, MPL, AERI, Radiosonde

A Case at the NSA Site

01/18/2000

-23°C



Lidar-only approach to retrieve optical depth.

Different Approaches to improve LWP Retrieval

- Radiometers with high frequency channels:
  - We have it at the NSA site
- Methods be able to use past ARM long-term MWR data.
  - Physical retrievals: many challenges, but with hopes.
  - Statistical based methods (Westwater, 1978; Hogg et al. 1983; Liliegren et al. 2001).
- Challenges:
  - MWR calibration draft and random noise
  - Atmospheric vertical structure changes
  - Liquid water and gases absorption coefficient uncertainties

Using Clear-Sky as a reference to improve LWP retrieval

- Reformulate the statistical retrieval method of Liliegren et al. (2001) by introducing clear sky MWR measurements as a reference.

$$\tau = \ln\left(\frac{T_{mr} - T_{bg}}{T_{mr} - T_{sky}}\right)$$

The frequency dependent τ includes contributions from dry air (τ_{dry}), form water vapor (τ_{vap}) and from liquid water clouds (τ_{liq}), i.e.,

$$\tau(\nu) = \underline{\tau_{dry}(\nu) + \tau_{vap}(\nu)} + \tau_{liq}(\nu) + \varepsilon(\nu)$$

Cloudy Measurements:

$$\tau_{CLD}(\nu) = \tau_{dry,CLD}(\nu) + \tau_{vap,CLD}(\nu) + \tau_{liq,CLD}(\nu) + \varepsilon_{CLD}(\nu)$$

Clear Sky Measurements:

$$\tau_{CLR}(\nu) = \tau_{dry,CLR}(\nu) + \tau_{vap,CLR}(\nu) + \tau_{liq,CLR}(\nu) + \varepsilon_{CLR}(\nu)$$

$$\Delta\tau(\nu) = \tau_{CLD}(\nu) - \tau_{CLR}(\nu)$$

$$= \Delta\tau_{dry}(\nu) + \Delta\tau_{vap}(\nu) + \Delta\tau_{liq}(\nu) + \Delta\varepsilon(\nu)$$

$$\approx \Delta\tau_{vap}(\nu) + \tau_{liq,CLD}(\nu) + \Delta\varepsilon(\nu)$$

$$\tau_{vap} = \kappa_{vap}\mathrm{PWV} \text{ and } \tau_{liq} = \kappa_{liq}\mathrm{LWP}$$

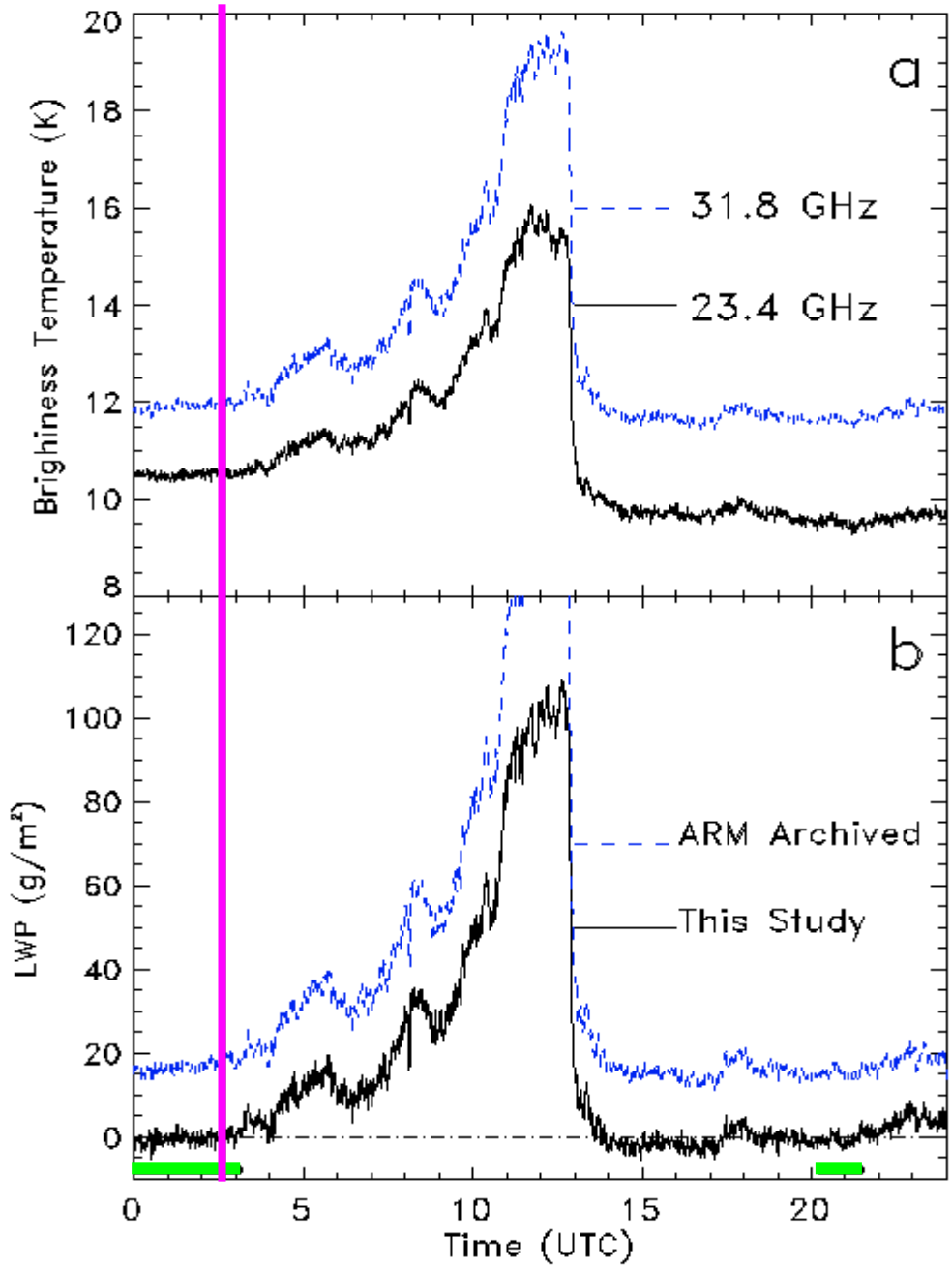
$$\Delta\tau(\nu) \approx \Delta PWV\, \kappa_{vap}(\nu) + \kappa_{liq}(\nu,T)\,\mathrm{LWP} + \Delta\varepsilon(\nu)$$

$$\Delta PWV << PWV;\ \Delta\varepsilon(\nu) << \varepsilon(\nu)$$

An Example

Clear sky measurements used as a reference.

Clear Sky Period

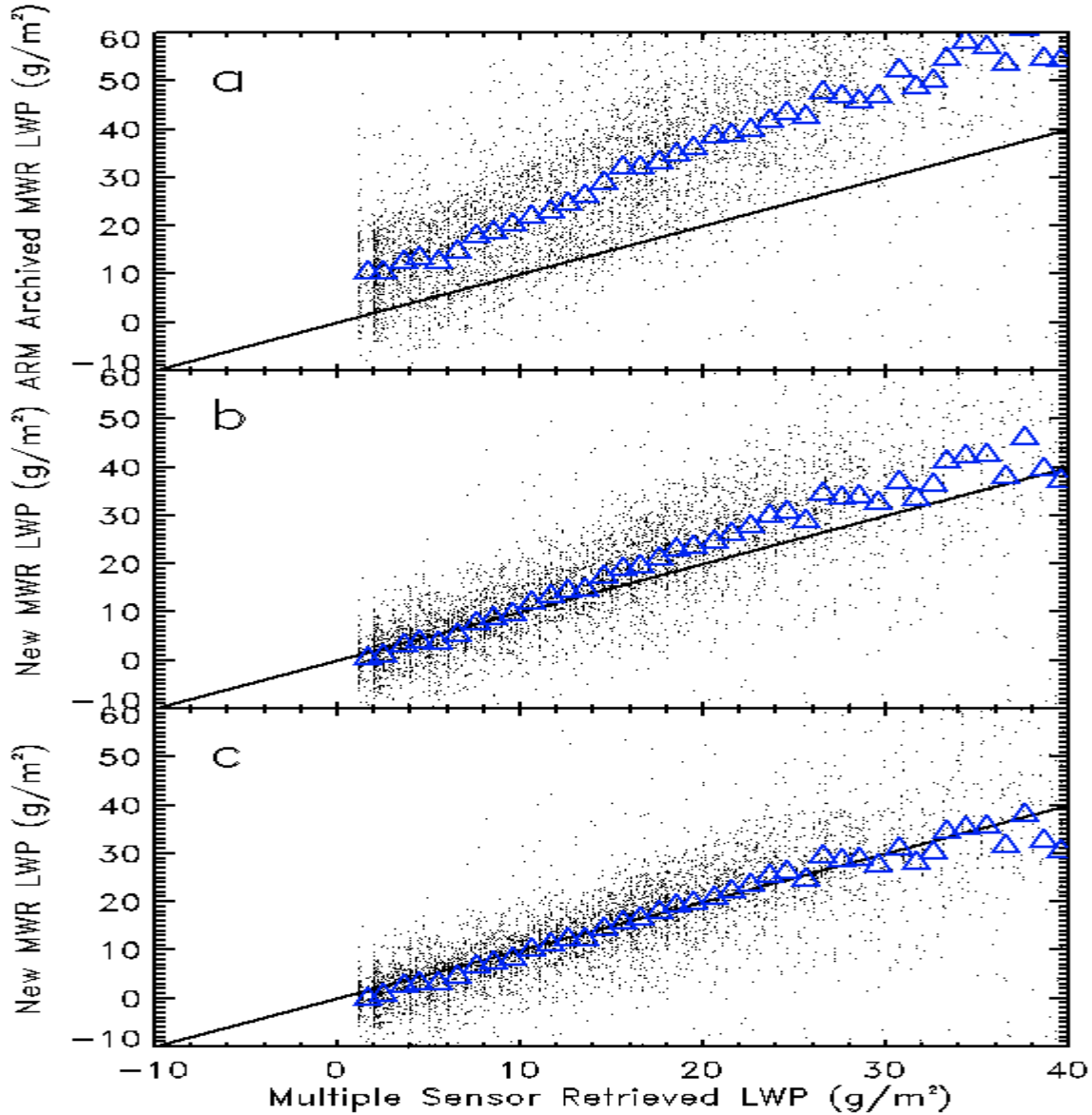


MWR and multiple sensor comparison

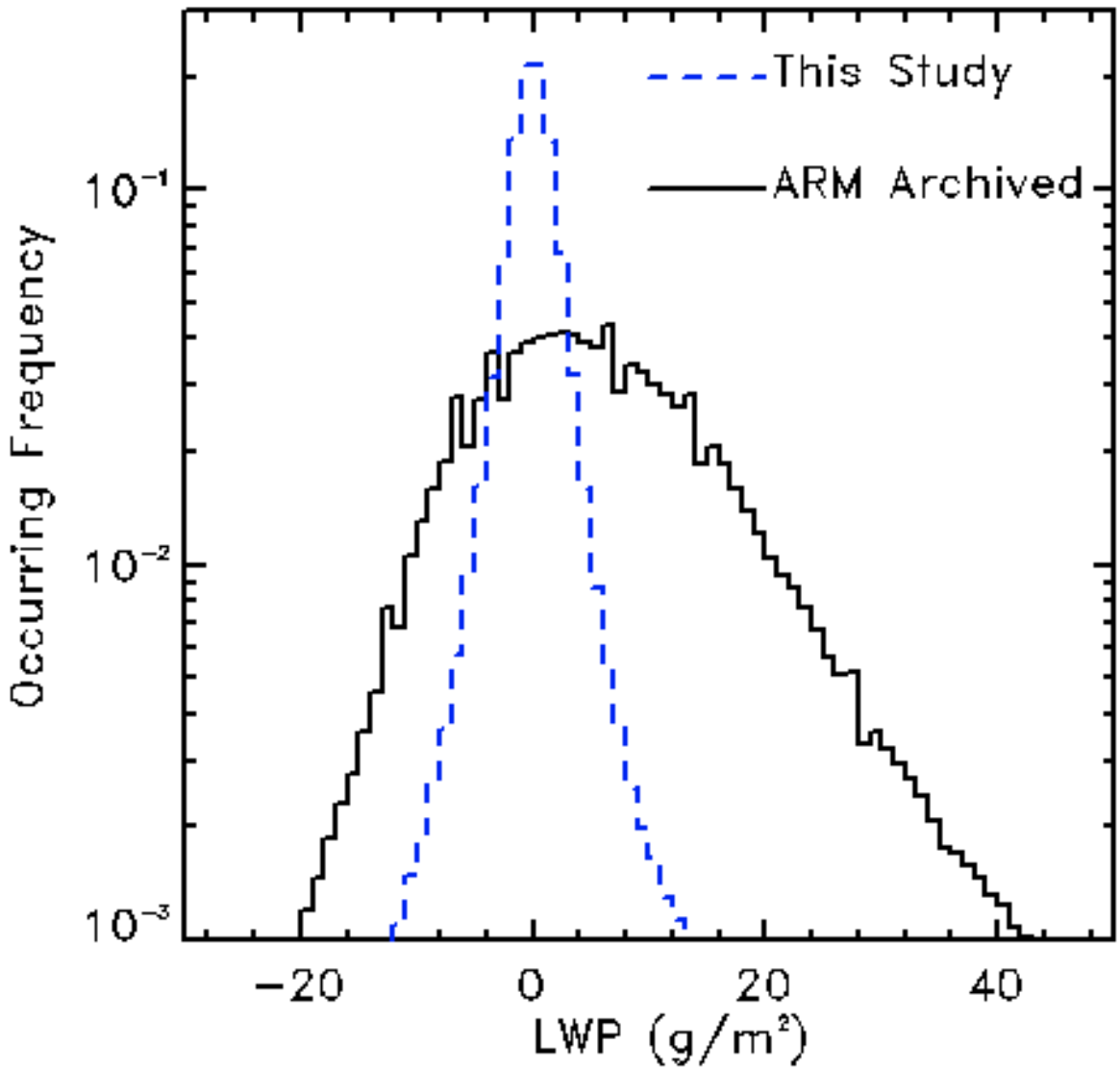
ARM Archived

Clear Sky Reference
and Liliegren et al. 2001

Clear Sky Reference
and Temperature
dependency of liquid
absorption coefficient of
Liebe et al. (1991).



Clear Sky LWP Distributions



Summary

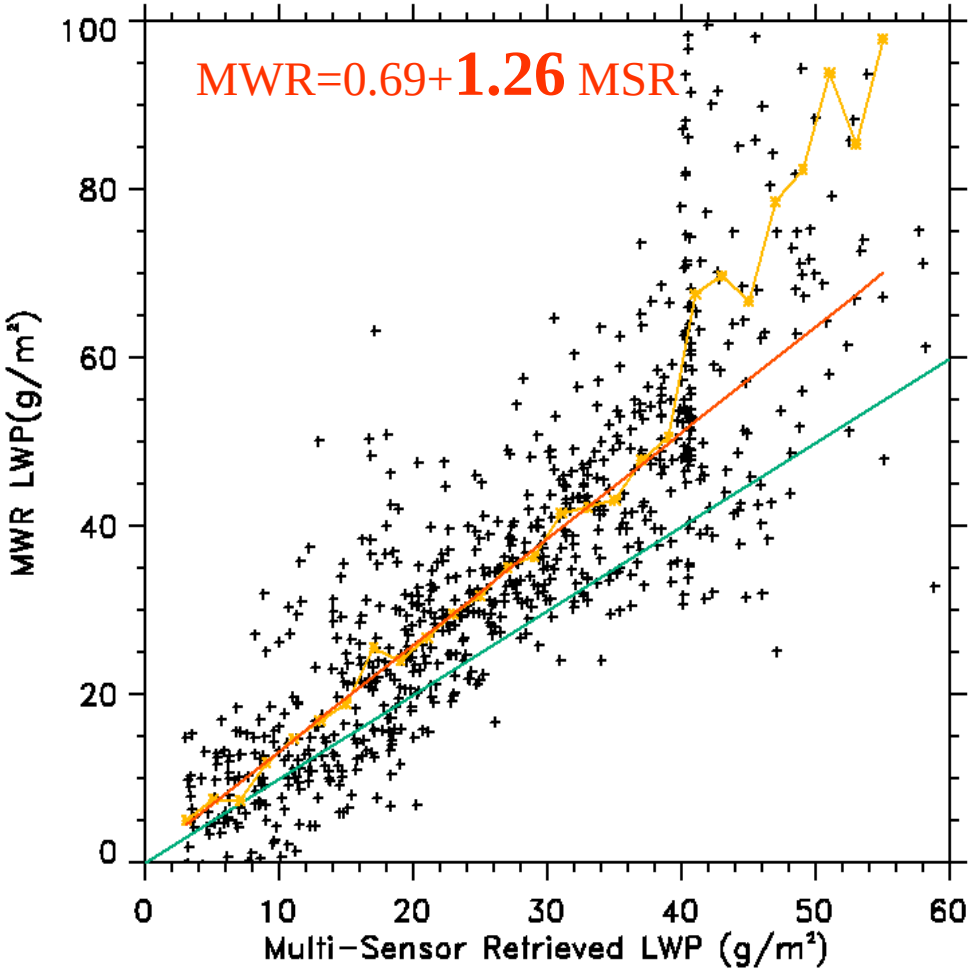
- Using clear sky measurements as references can improve MWR LWP retrieval accuracy at the NSA site.
  - *Easy to implement !!*

- Will do similar exercises for MWR measurements at the SGP and TWP sites.

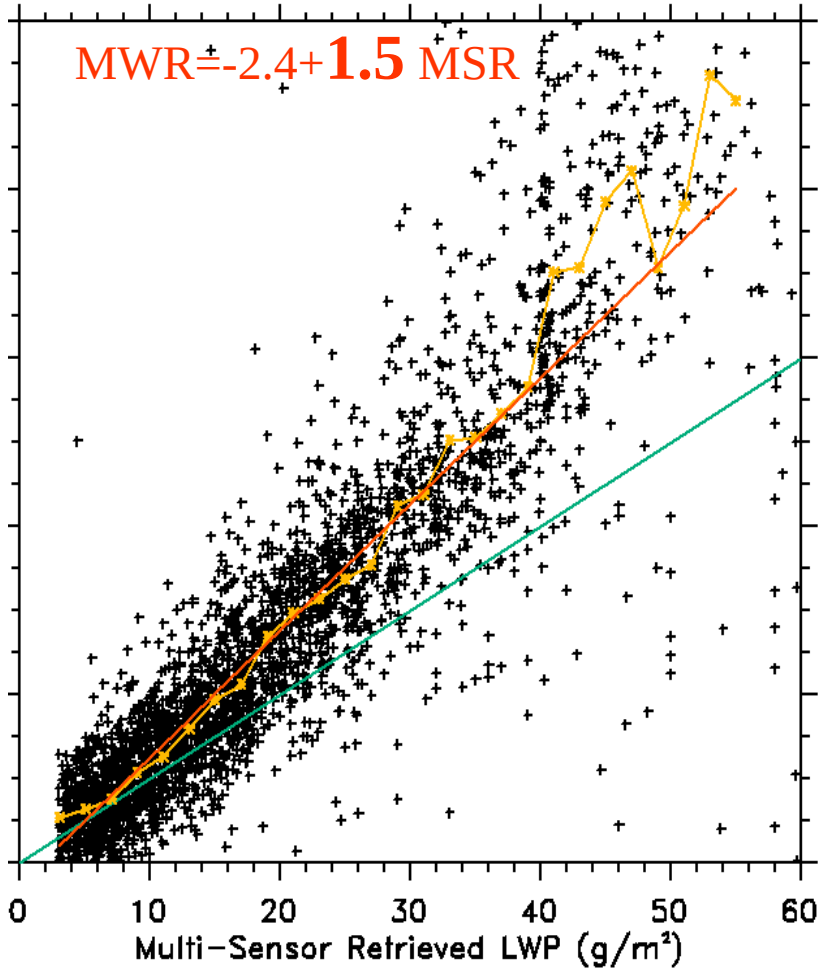
- **Will use the new MWR LWP retrievals for arctic mixed-phase cloud study.**

Summer and Winter Slope Difference

Summer

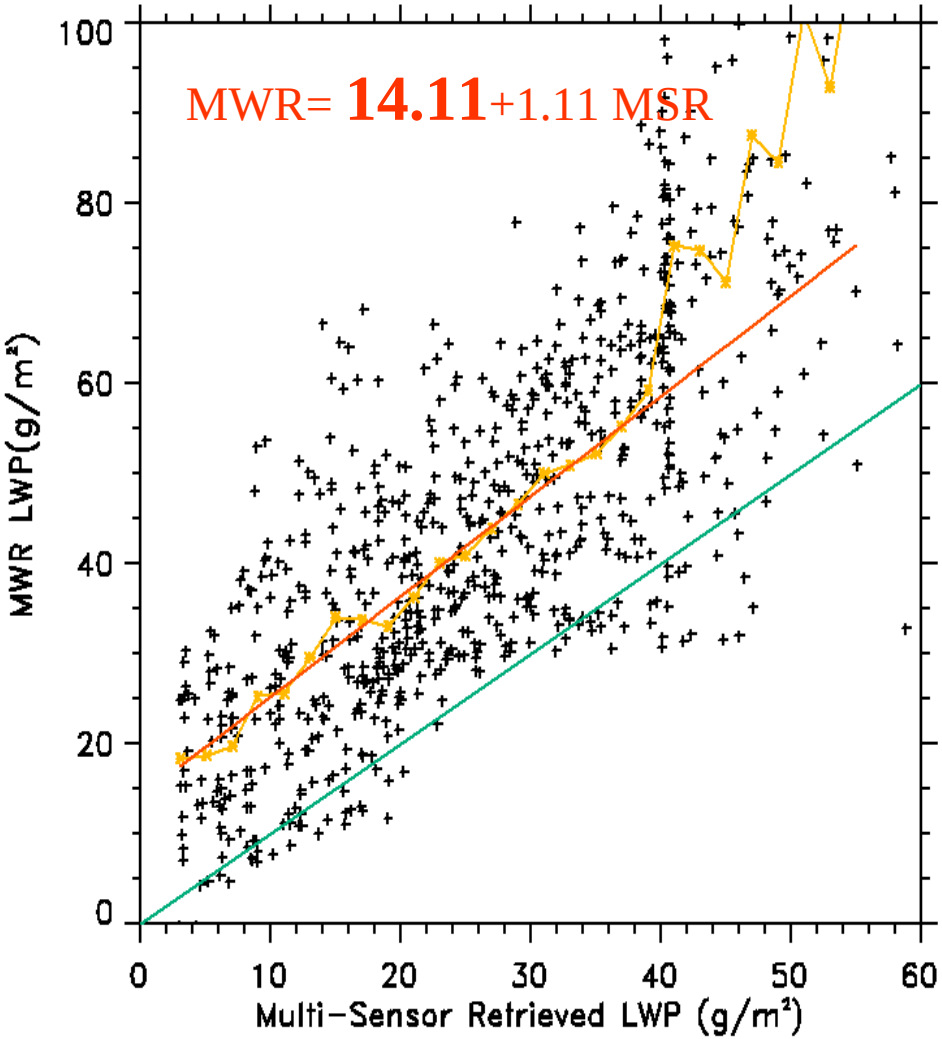
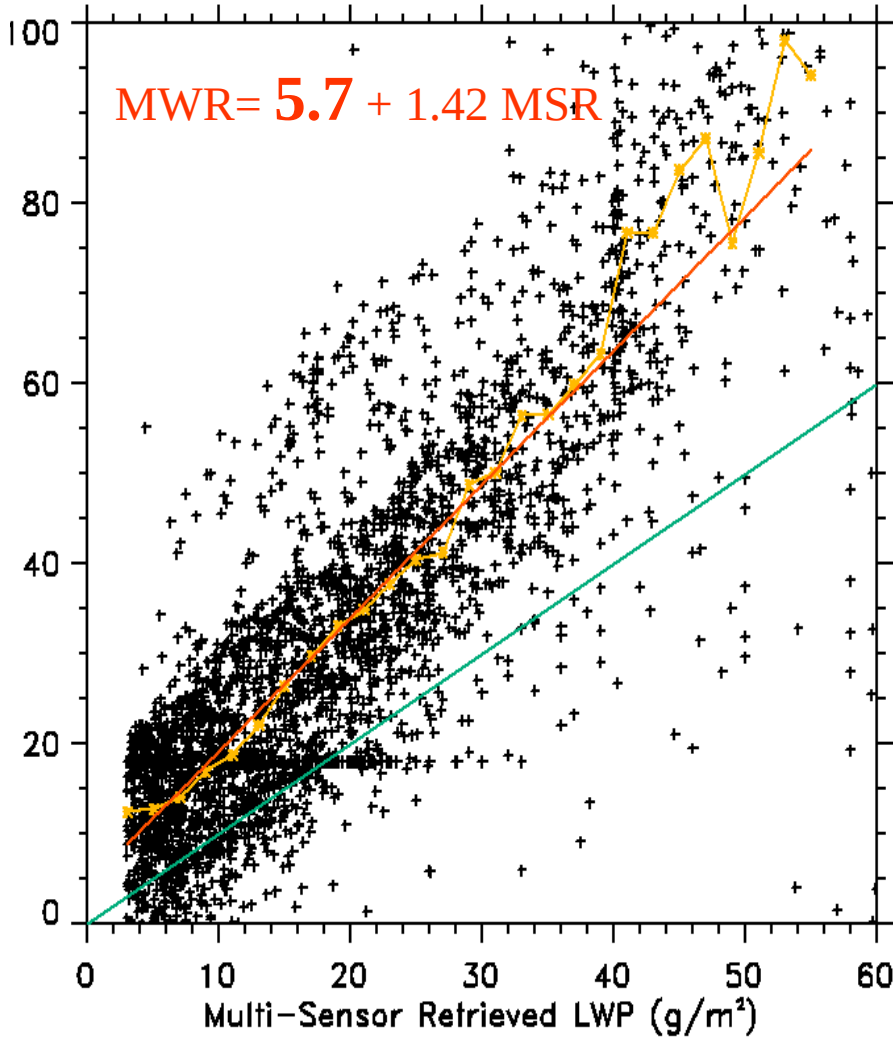


Winter



Summer and Winter Clear-sky Bias Difference

Summer



Winter