Computation of Irradiance Profile in CERES

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Method (CRS)

- Shortwave and Longwave irradiances are computed with 32+ layers for every CERES footprints and output 5 levels (TOA, Sfc, 70 hPa, 200 hPa, and 500 hPa).
- MODIS-derived cloud properties (Minnis et al. 2002) with empirically derived cloud base height .
- MODIS-derived aerosol optical thickness (MOD04, Kaufman et al. 1997).
- GEOS4 temperature and water vapor profile.
- Ozone profile from NCEP.

From Charlock et al. 2006

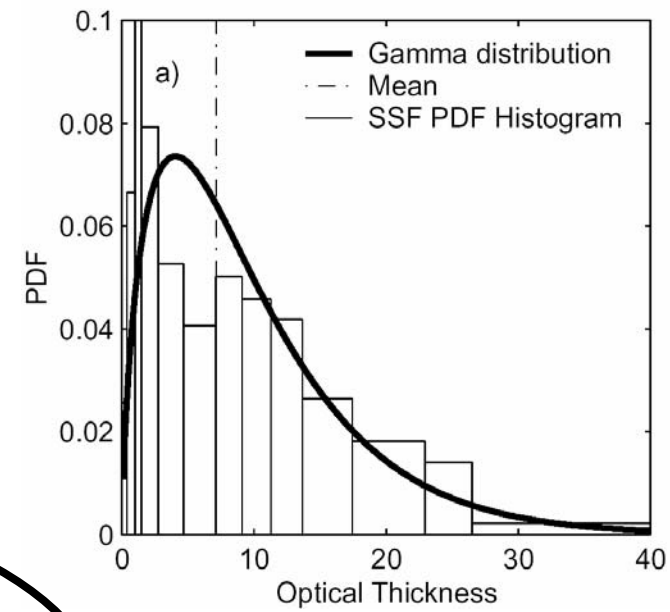
CRS Method (cont.)

- CERES derived clear-sky sfc albedo(Land)
  - Theoretical spectral ocean and snow surface albedo (Jin et al. 2004).
- H2O, CO2, O3, and O2 in shortwave (Kato et al. 1999).
- H2O, CO2, O3, CH4, and N2O in longwave (Kratz and Rose 1999).
- A model with the gamma-weighted two-stream approximation (SW, Kato et al. 2005)
- A two/four -stream model (LW, Fu et al. 1997).
- MATCH (Collins et al. 2001) derived aerosol optical thickness when MODIS-derived optical thickness not retrieved
- 7 aerosol types from MATCH and properties from OPAC Hess et al. (1998) & Dust Tegen and Lacis (1996)
- Water cloud properties from Hu and Stamnes (1993) and ice cloud properties from Fu (1996).

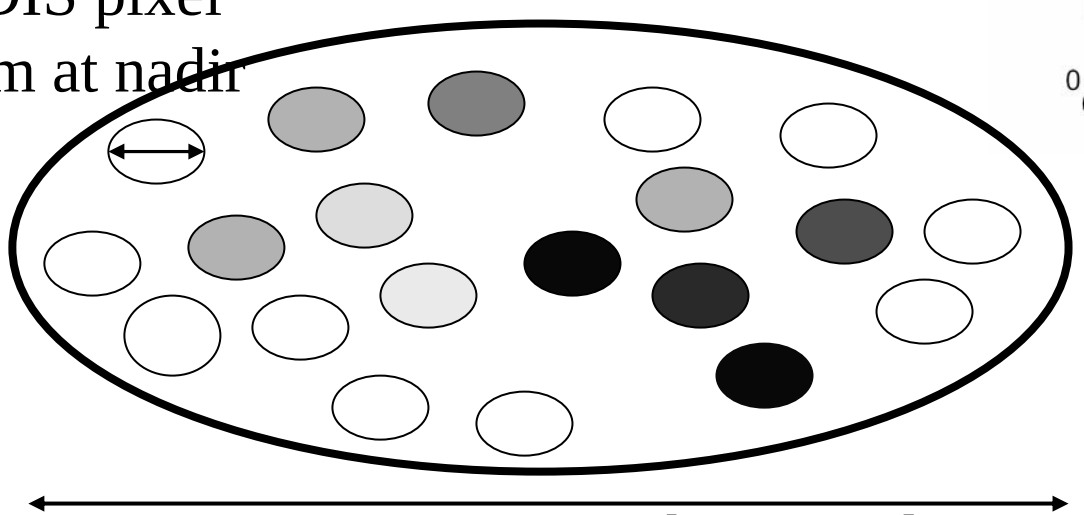
From Charlock et al. 2006

Clouds in a CERES footprint Inhomogeniety Treatment

- Up to 2 levels
- A gamma distribution of the optical thickness is assumed
- No overlap at present
- Clear part is computed separately



MODIS pixel
~1 km at nadir



CERES FOV ~20 km at nadir

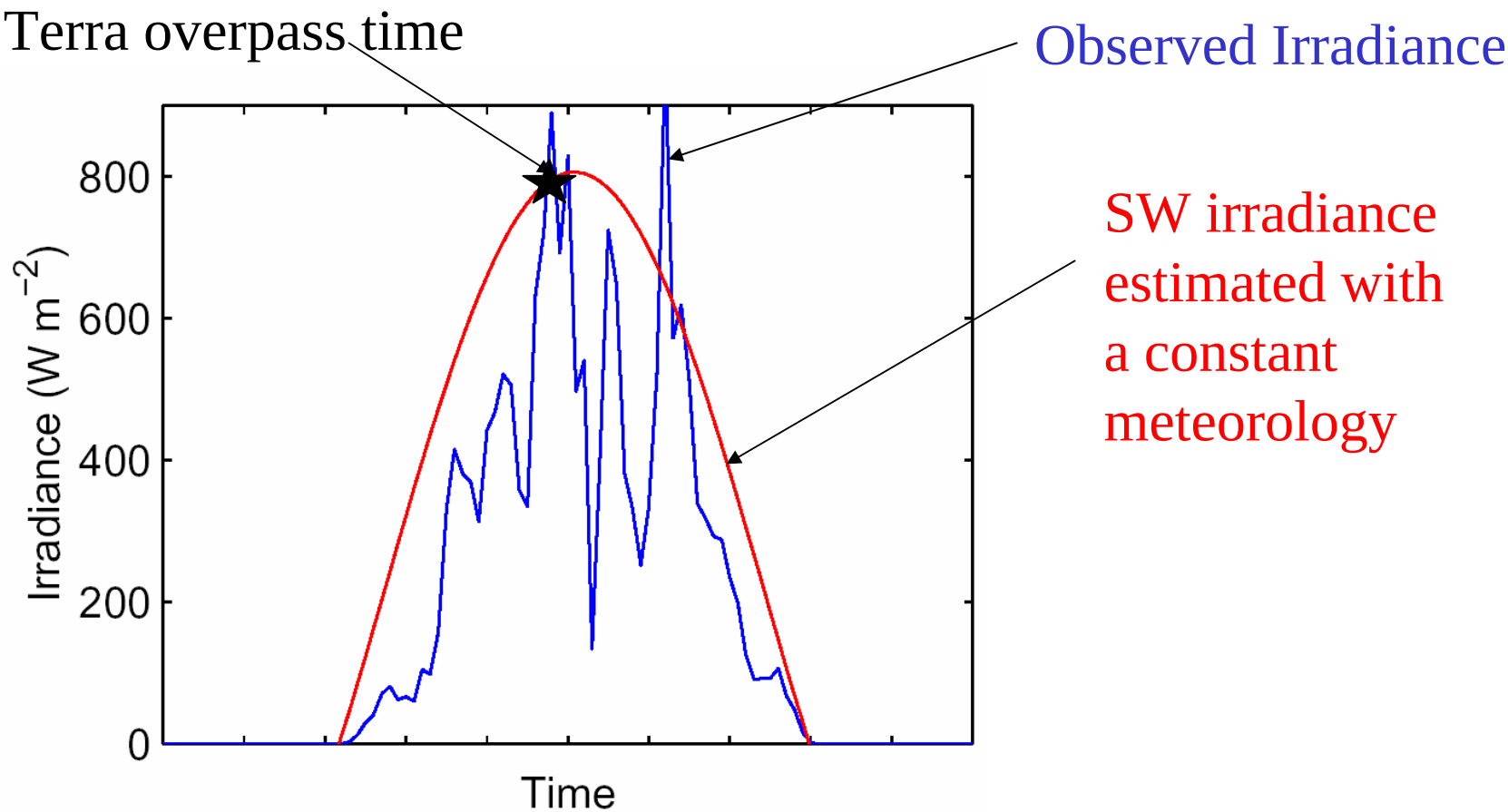
CERES Terra Surface and Atmosphere Radiation Budget (SARB) Ed2B FOVs (day ~1030 L, nite ~2230L) nearest SGP E13 (Mar 00 - Feb 03)

	Observed (Wm-2)	Bias (Wm-2)
SW down TOA	999.6	0
SW up TOA	289.2	0.4
SW down SFC	591.4	3.6
SW up SFC	117.6	-17.4
LW up TOA	241.3	1.1
LW down SFC	337.0	-10.8
LW up SFC	403.0	-2.3
Net Atmosphere (TOA-SFC)		
SW	236.6	-21.4
LW	-175.3	7.4
SW Clear sky	*202.8*	*-13.7*
LW Clear sky	*-181.0*	*10.0*

Problems: 1 input air temperature bias 2 mismatch in surface albedo

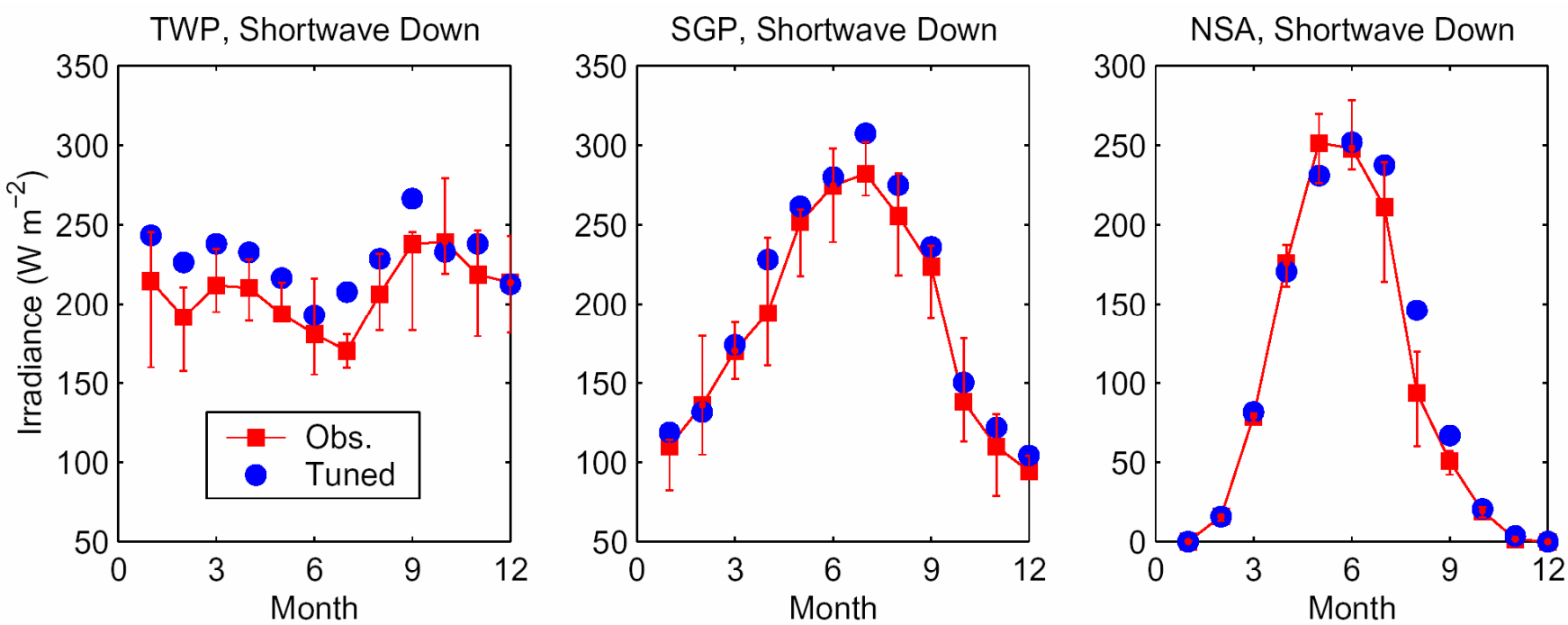
Google "CERES CAVE" and seek the CAVE homepage for CERES CRS Ed2B

Daily Mean SW Irradiance Estimate (Kato) Using Instantaneous CERES CRS



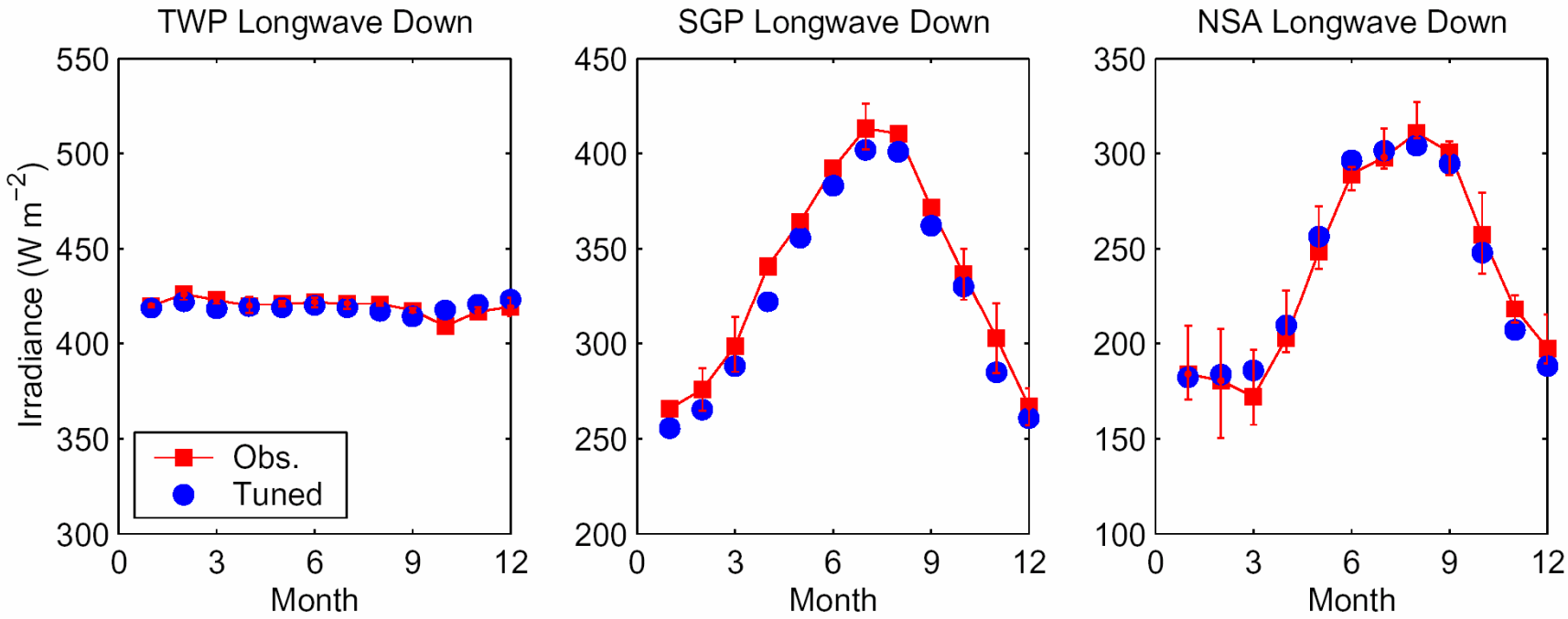
The red line is estimated from downward shortwave at different latitudes.
The longwave daily mean is the average of day and night values.
An official CERES product (SYNI) includes diurnal variations by merging GEO data

Comparison at ARM sites (SW)



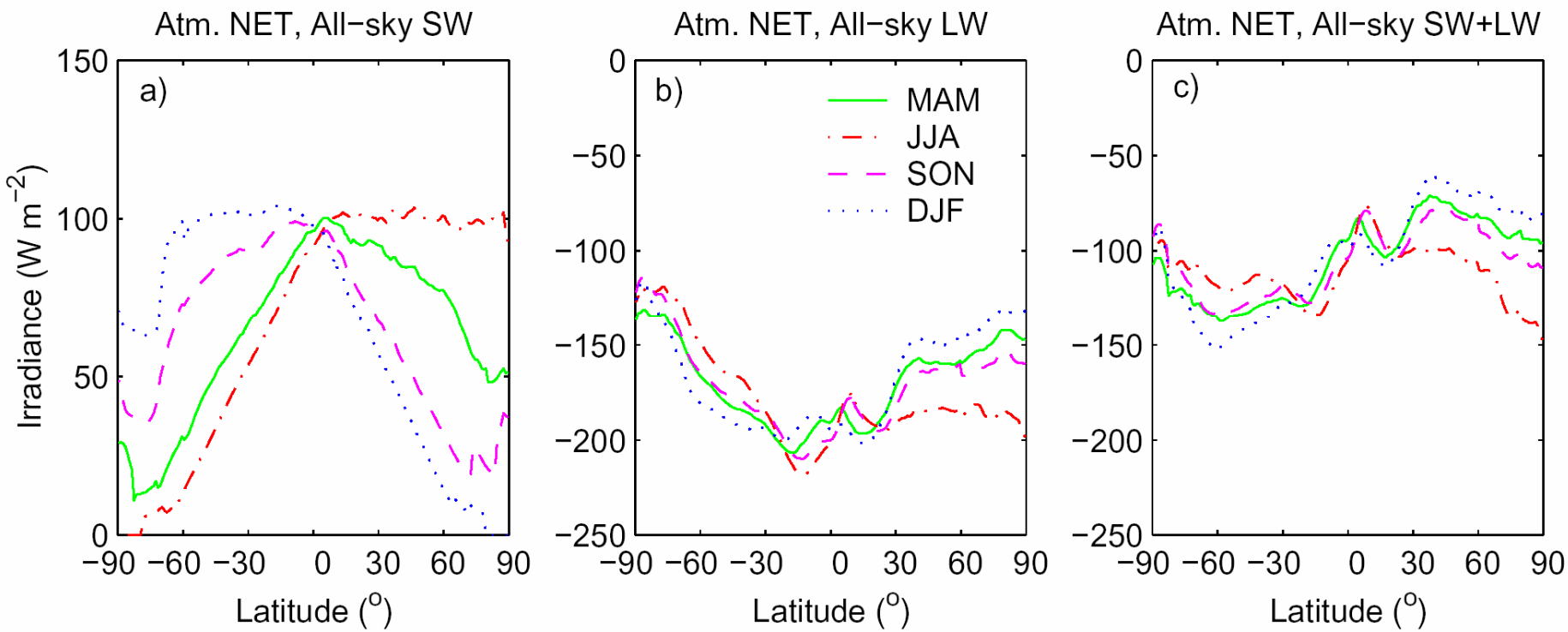
Data from March 2000 through Feb. 2003
Vertical bars indicate min. and max. within 3 years

Comparison at ARM sites (LW)

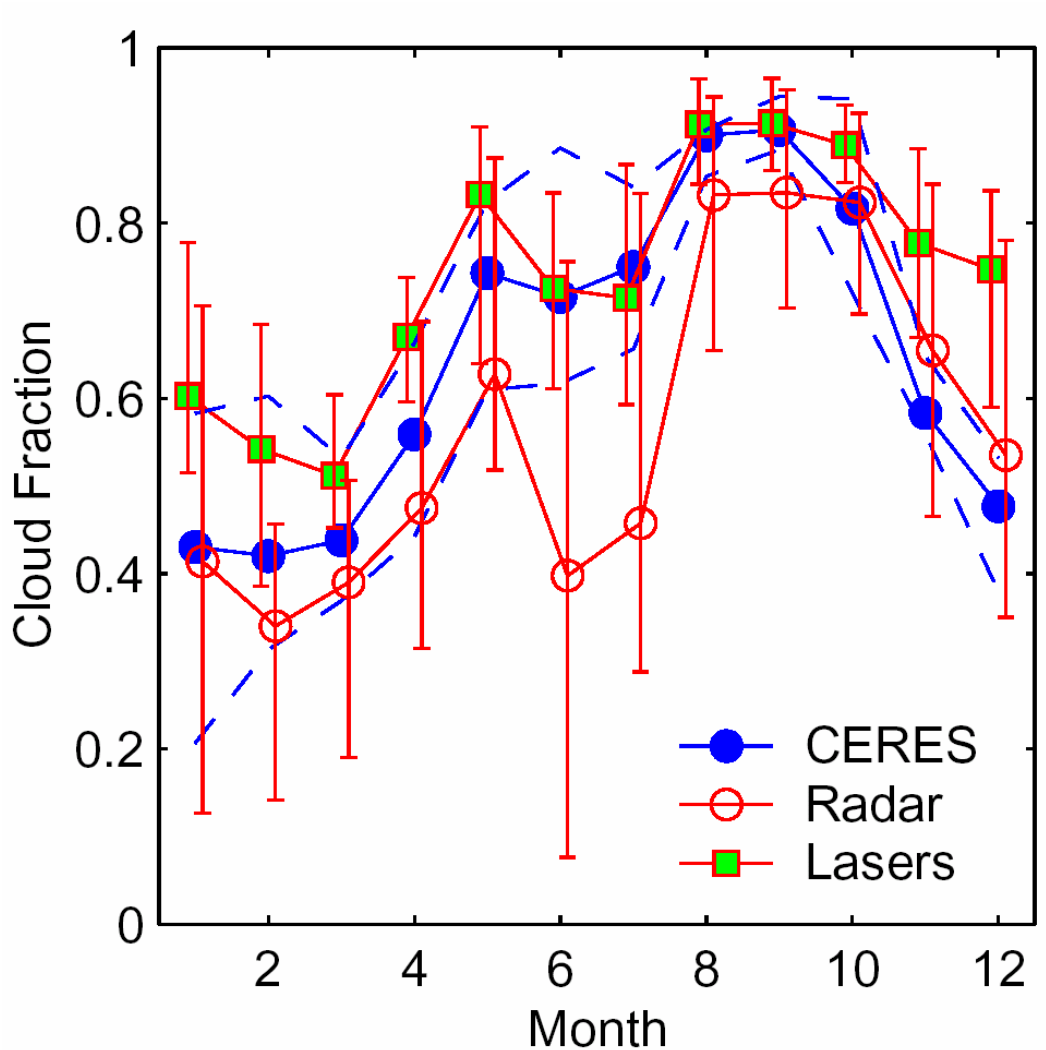


Data from March 2000 through Feb. 2003
Vertical bars indicate min. and max. within 3 years

Seasonal and Zonal Atmospheric Net Irradiance (Daily mean values)



Comparison with Cloud Occurrence Derived from Ground-based Active Sensors



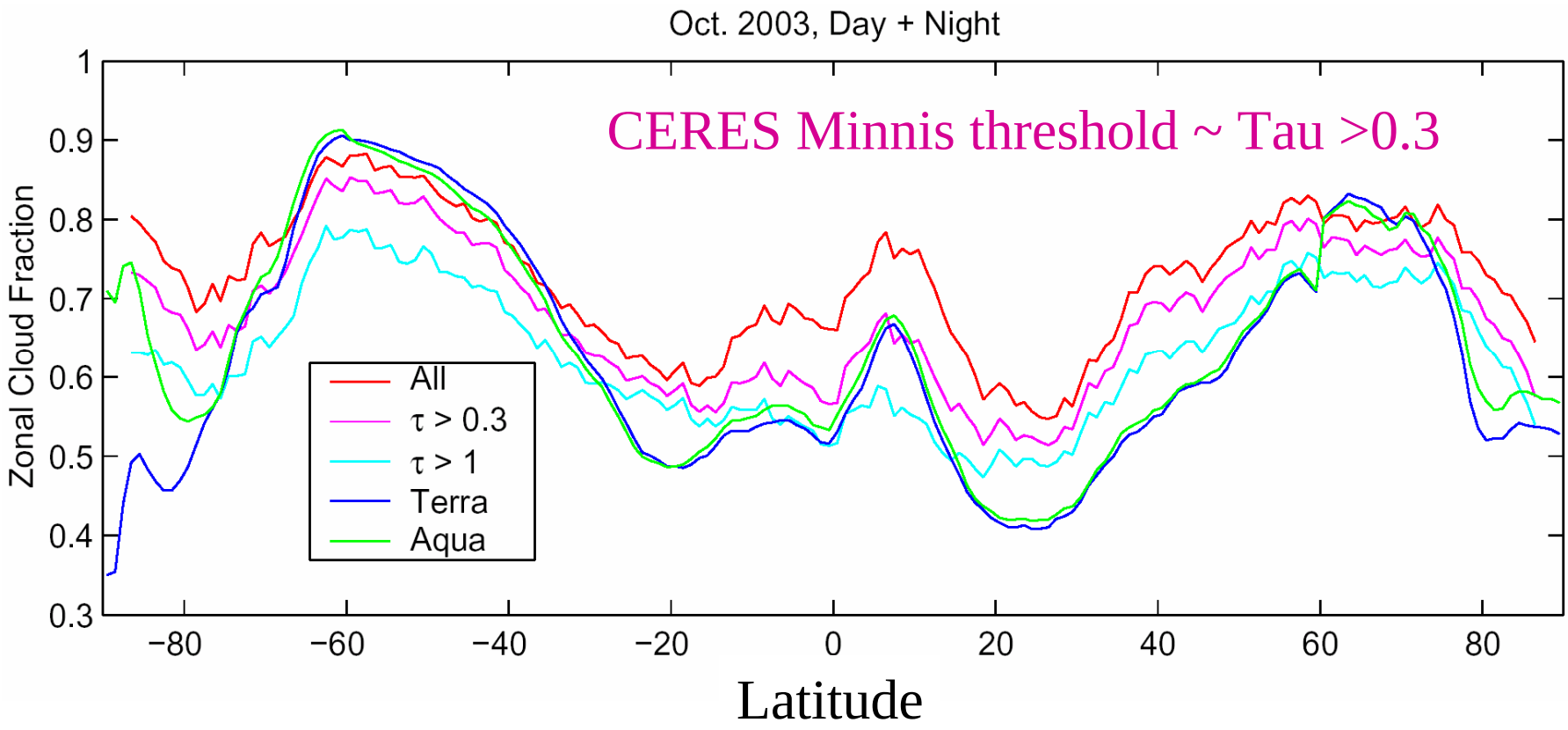
Day + Night clouds
Barrow, AK
Mar.2000 – Feb. 2004

CERES: CERES Minnis cloud algorithm

Radar: Millimeter Cloud Radar

Lasers: micro-pulse lidar
Vaisala celometer

Zonal Cloud Fraction Comparison (IceSat)



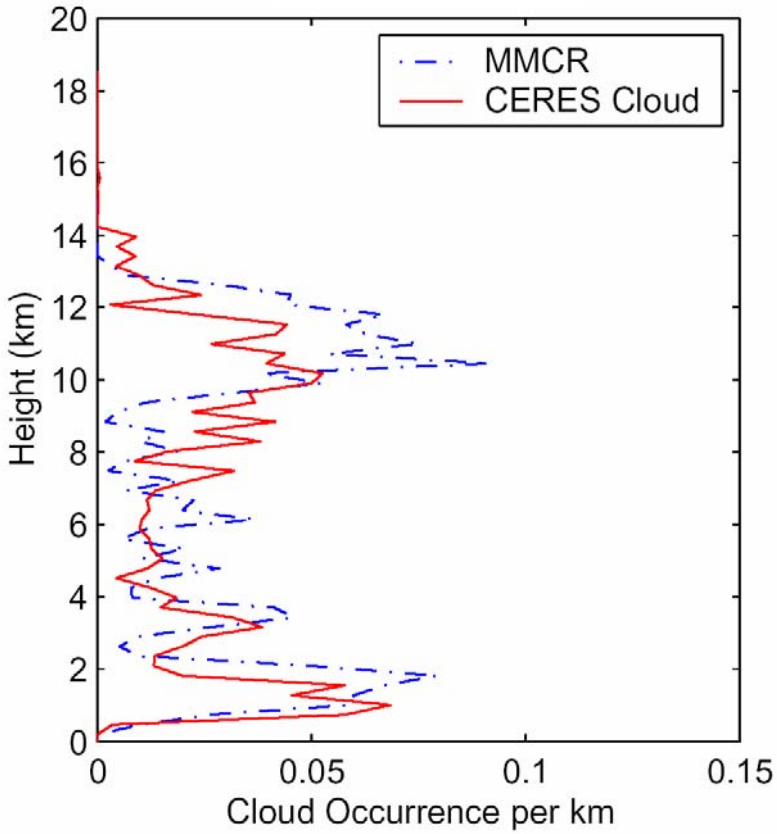
Modis Vs Radar
Cloud Profiles at SGP

- Radar: ARM millimeter cloud radar
  - +/- 1hr of satellite overpass
  - Sensitive to larger particles

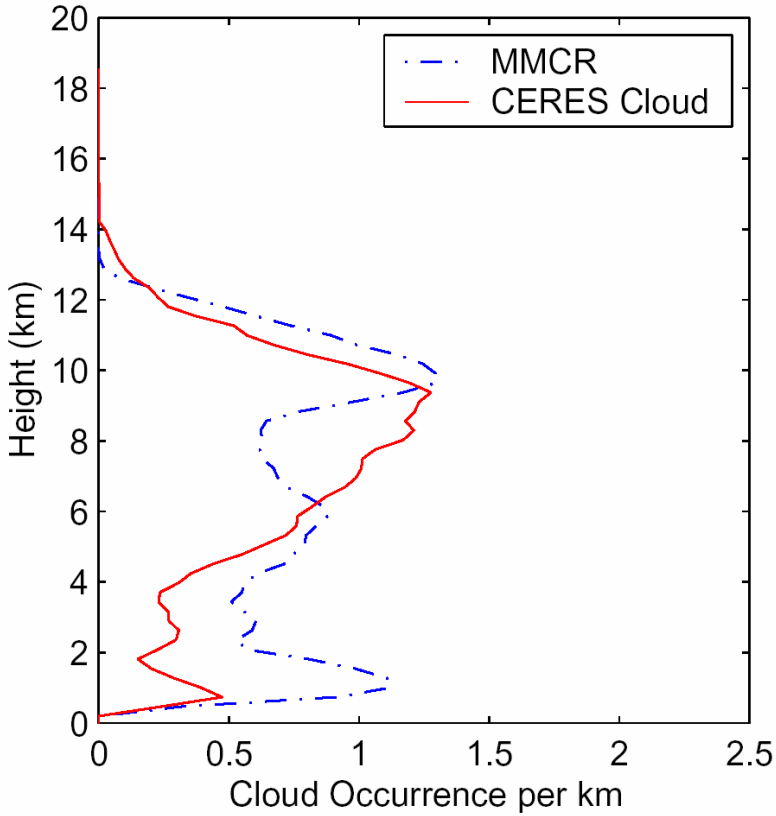
- Modis: Ceres (Minnis) retrievals
  - Empirical cloud base f(tau, temperature)
  - Ceres Fovs within 25km of site
  - View Zeinth angle influences
    - -FOV Area
    - -Cloud fraction & cloud tau

SGP Cloud Vertical Profile Comparison: Summer, Day

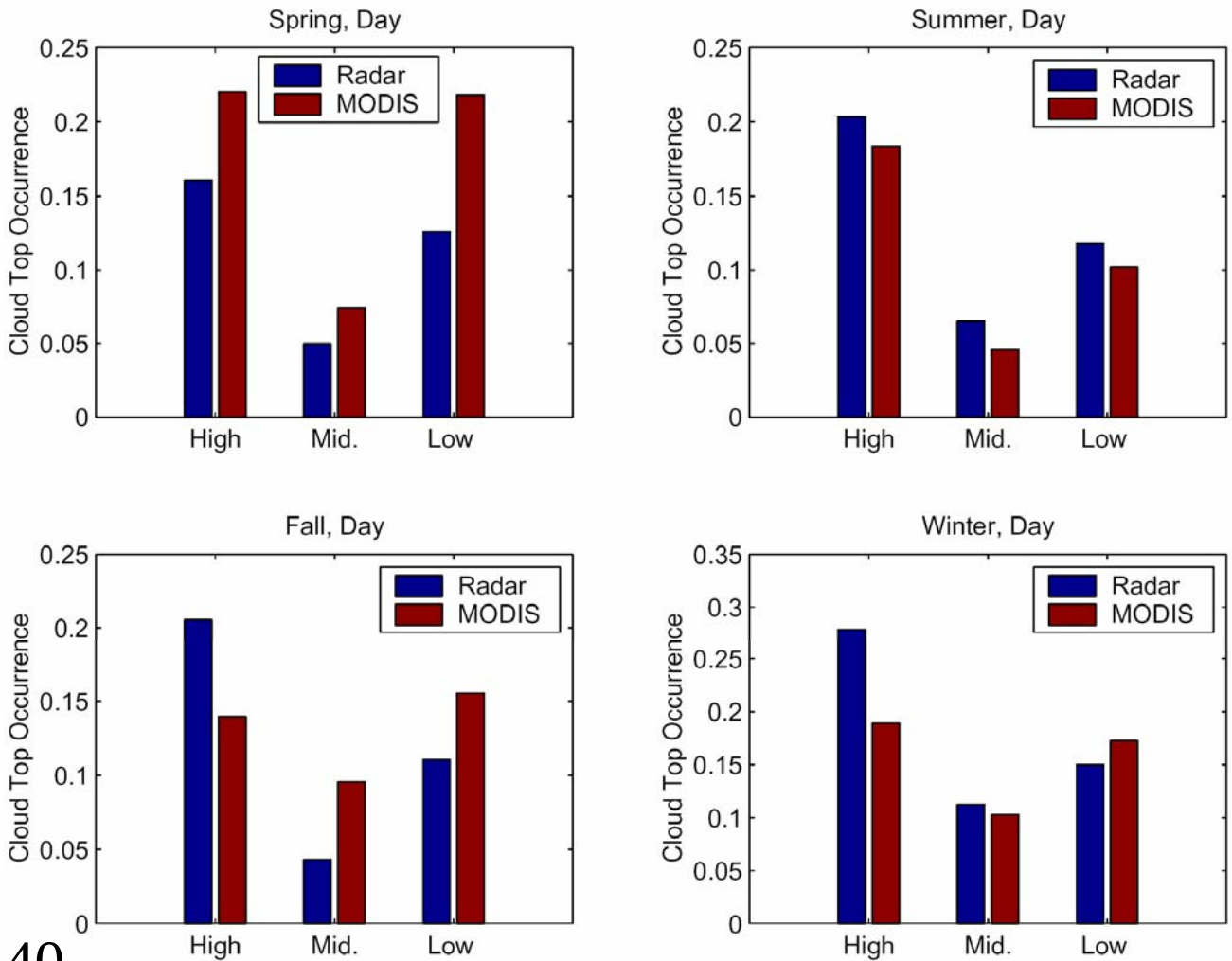
Cloud Top



Cloud Volume (Top:Bot)



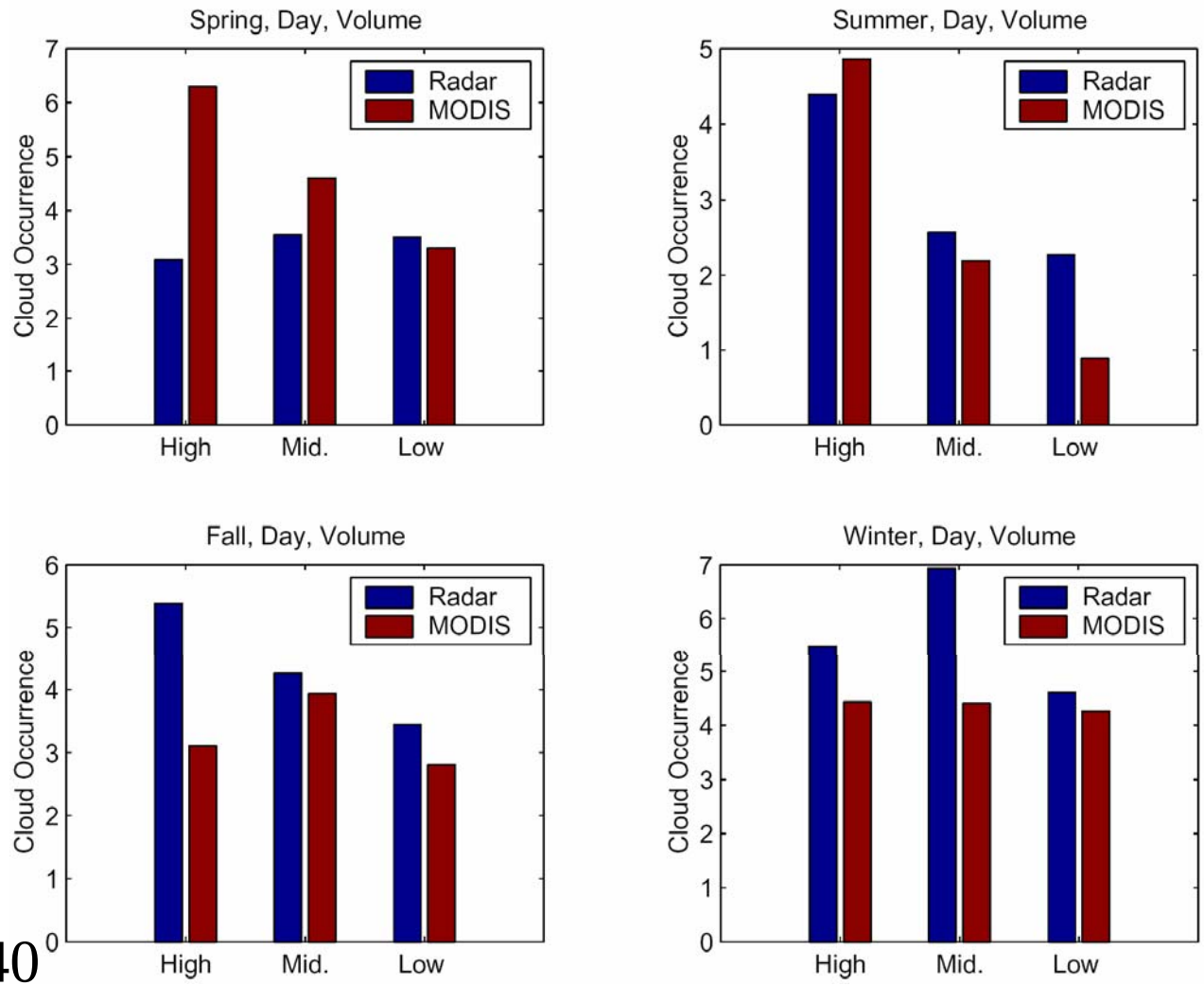
Cloud TOP Comparison Summary



High: Top < 440
Mid: 680>Top>440
Low: Top>680

Radar : +/- 1 Hr :: Modis Inst. ~30km radius

Cloud VOLUME Comparison Summary



High: Top < 440

Mid: 680>Top>440

Low: Top>680

Cloud Overlap Conditional Probability at SGP Using Radar

Conditional Probability	Spring	Summer	Fall	Winter
Mid.-low level (partially included)	26%	24%	25%	34%
High-low level (not included)	16%	8%	14%	21%
High-mid. Level (partially included)	30%	18%	35%	38%

Current CERES Cloud Retrievals do not retrieve overlapped clouds

Edition3 retrieval will include passive overlap retrieval method (Fu-Lung Chang)

Flux Comparison over ARM sites (summary) Model(Tuned[c]) – Observations

	TWP (Manus) (W m^{-2}) (%diff.)	SGP (W m^{-2}) (%diff.)	NSA (Barrow) (W m^{-2}) (%diff.)
Inst All-sky SWdn	7 (1%)	6 (1%)	7 (3%)
Inst.All-sky LWdn	-2 (0.5%)	-10 (3%)	1 (0.4%)
Daily SW dn[a]	21 (11%)	12 (7%)	6 (7%)
Daily LW dn[a]	-2 (0.4%)	-11 (3%)	1 (0.2%)
Daily ATM net SW	[b]-22 (13%)	-15 (16%)	-8 (15%)
Daily ATM net LW	8 (5%)	15 (8%)	-1 (0.6%)

[a] **Daily values are estimated with constant meteorology**.
[b] Modeled surface upward irradiance is used for the observation.
[C] TOA irradiances are tuned to match CERES-derived irradiances
Based on data from March 2000 through Feb. 2003

Global Radiation Budget (Annual mean)

	S. Kato integration of CERES (CRS)[1]	Kiehl & Trenberth (1997)
Solar Const.	342	342
TOA SW	97	107
SW Sfc. Net	170	168
SW Atm. Abs.	73	67
OLR	238	235
LW Sfc down	341	342
LW Sfc. up	399	390
LW Atm. Net	-181	-169
TOA SW+LW Net	6	0
Sfc. SW+LW Net	112	102
Atm. SW+LW Net	-111	-102

1: From March 2000 through February 2001

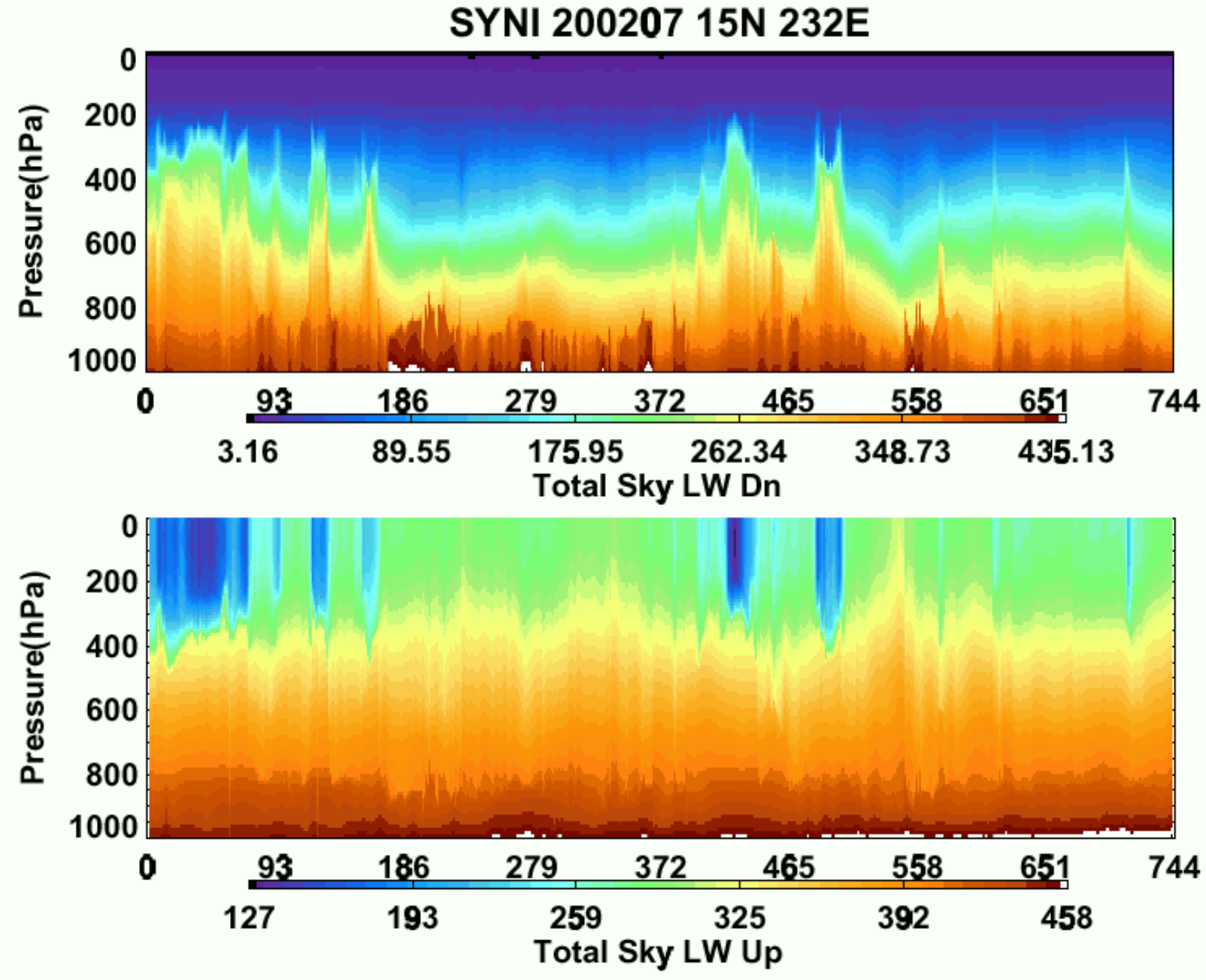
Red: difference is greater than 5%

Required Accuracy for Climate Analyses

Variables	Accuracy	Stability (per decade)
Downward surface longwave Irradiance	1 W m^{-2}	0.2 W m^{-2}
Downward surface shortwave irradiance	1 W m^{-2}	0.3 W m^{-2}
Cloud Top height	150 m	30 m
Cloud base height	0.5 km	0.1 km
Cloud Cover	0.01	0.003

From Ohring et al, 2005, BAMS

SYNI Example Time Height Profile Longwave Flux



Critical Input Variables to Reduce Heating Profile Uncertainties

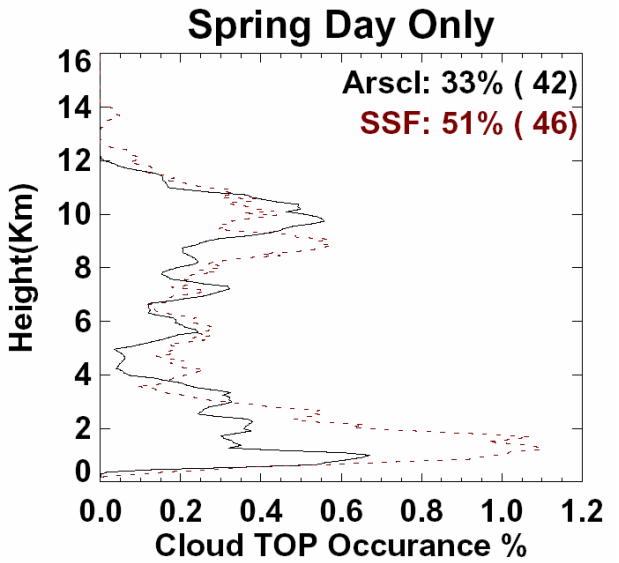
- Water Vapor & Temperature profile
- Clouds
  - Fraction
  - Cloud Top & Base
  - Overlap
  - Particle size & LWP/IWP profile
- Aerosols
  - (Optical properties, vertical profile)
- Snow/sea ice detection
  - (consistency with cloud retrieval)

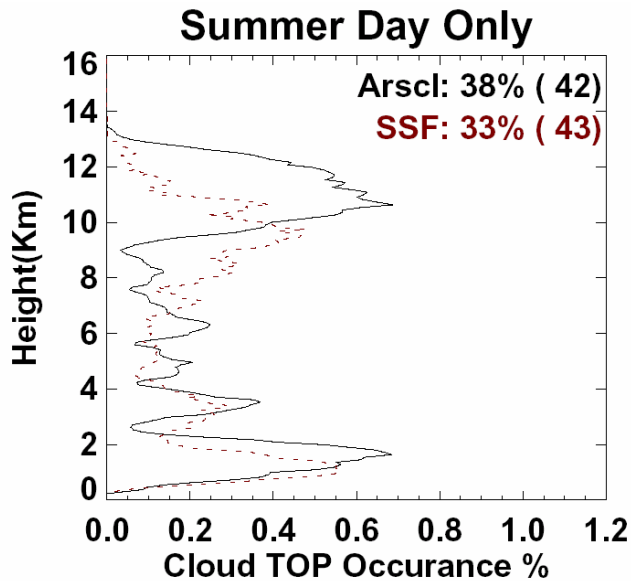
Summary and Conclusions

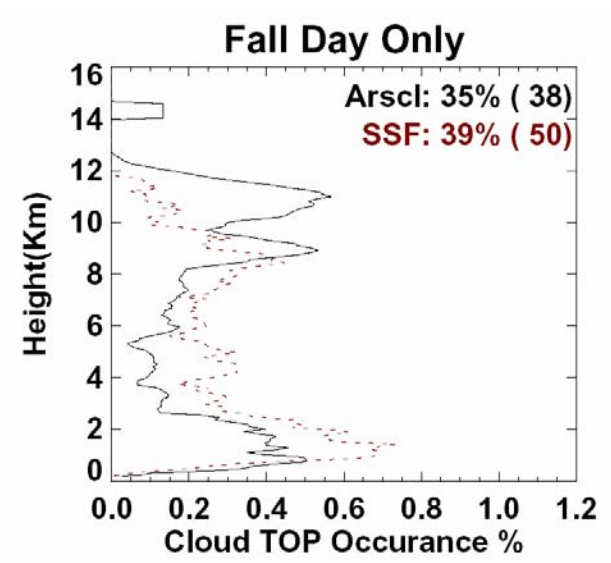
- CERES provides SW and LW irradiance at 5 levels (TOA, Sfc, 70 hPa, 200 hPa, and 500hPa) by CRS(instantaneous), FSW(gridded instantaneous), and SYNI (gridded monthly including diurnal variations).
- The relative difference between modeled and observed **instantaneous** downward irradiance averaged over three ARM sites is **1.6% for shortwave** and **1.3% for longwave**.
- **Daily mean** downward irradiance relative differences increase to **8.3% for shortwave** and **1.2% for longwave**
- **Daily mean** net atmospheric irradiance relative difference is **14.7% shortwave** and **4.5% longwave**. The part of this difference is caused by the diurnal integration, which will be explicitly handled in the CERES product (SYNI).

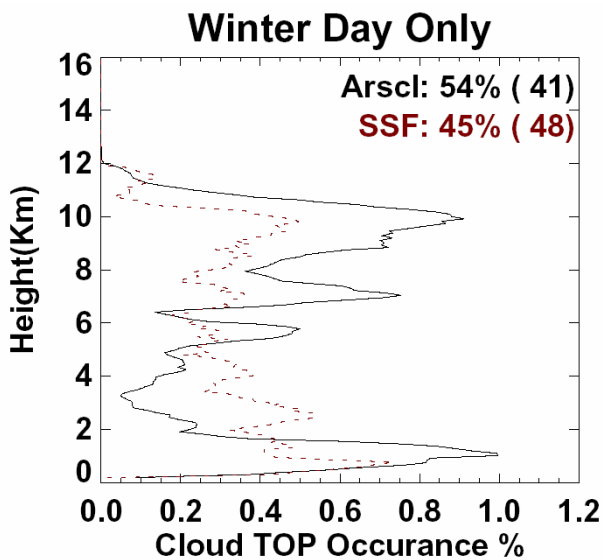
Back-up Slides

Cloud Vertical Profile

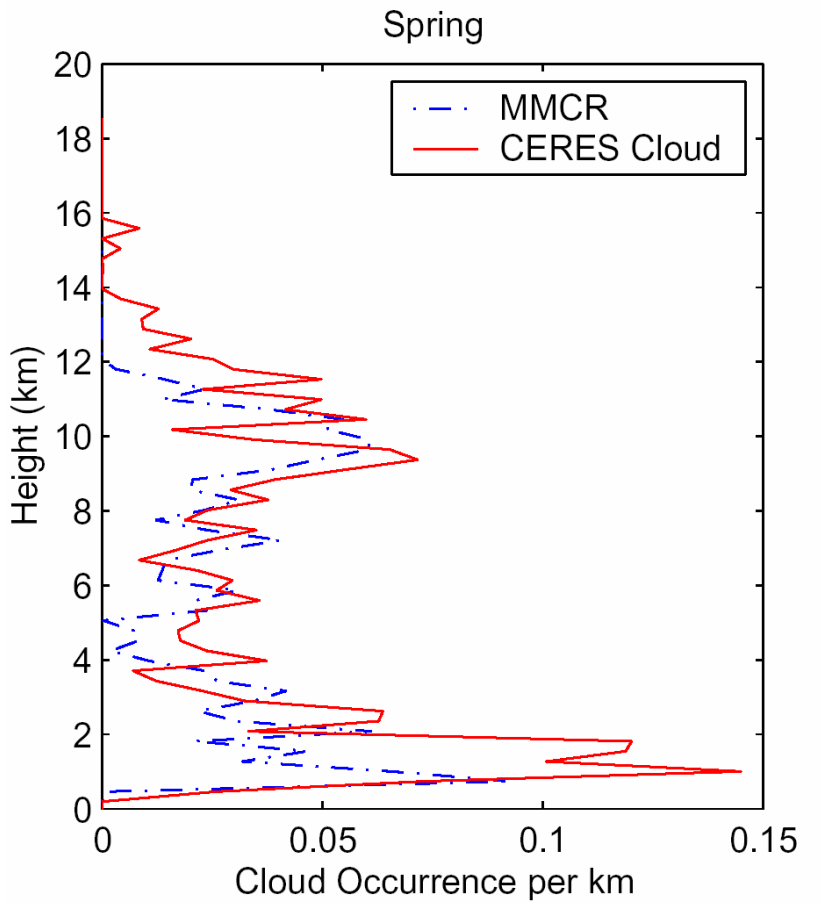


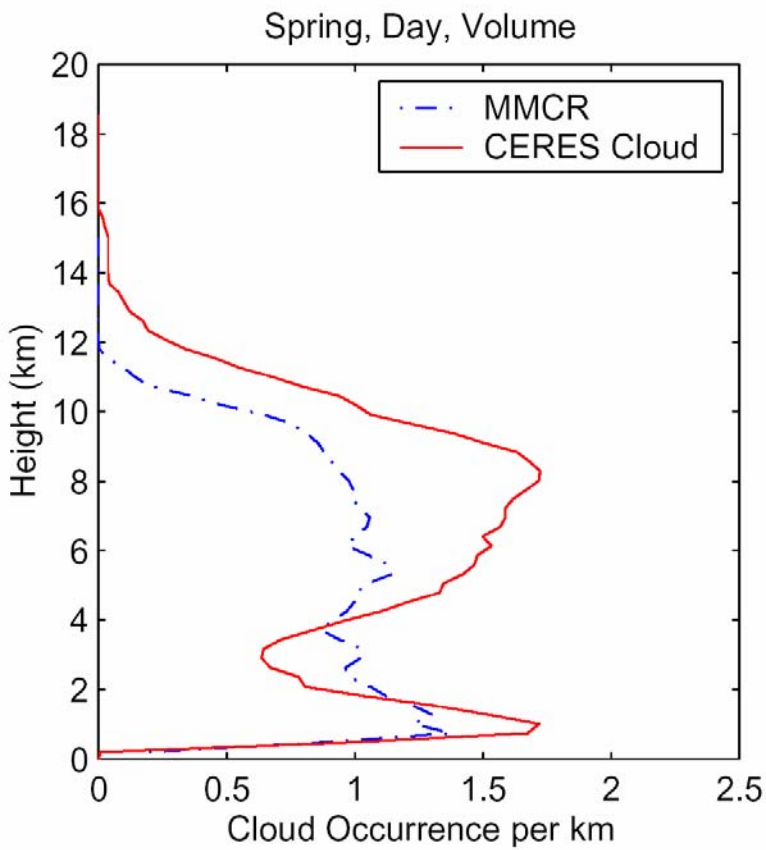




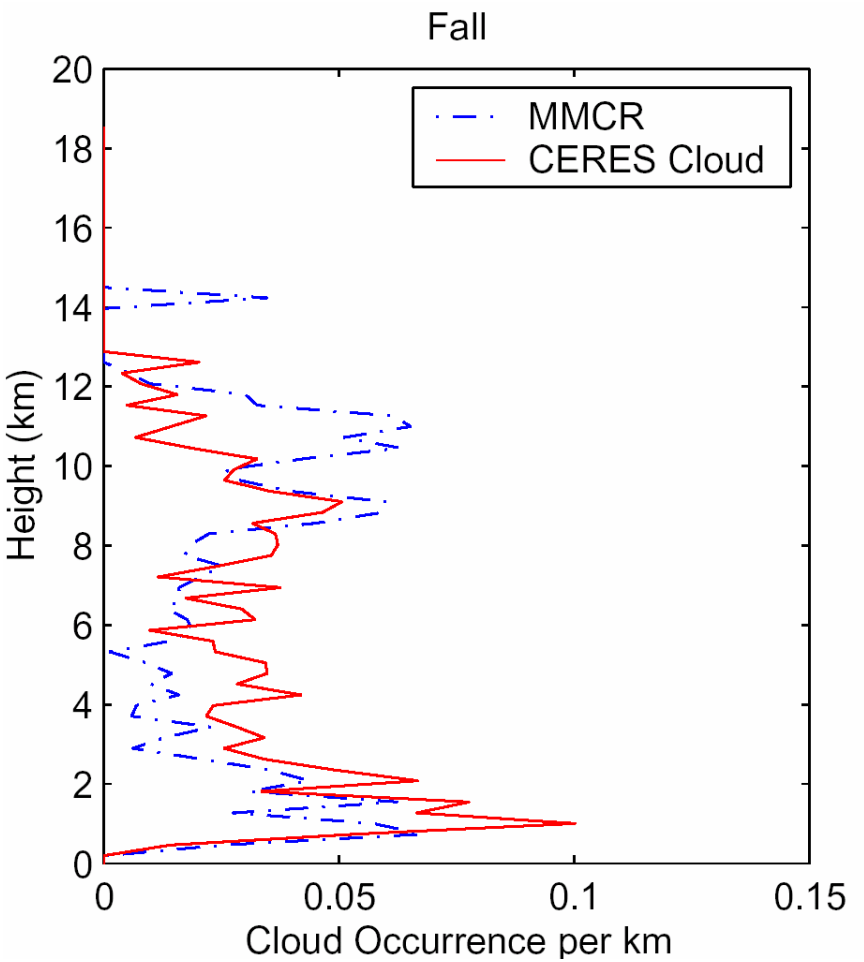


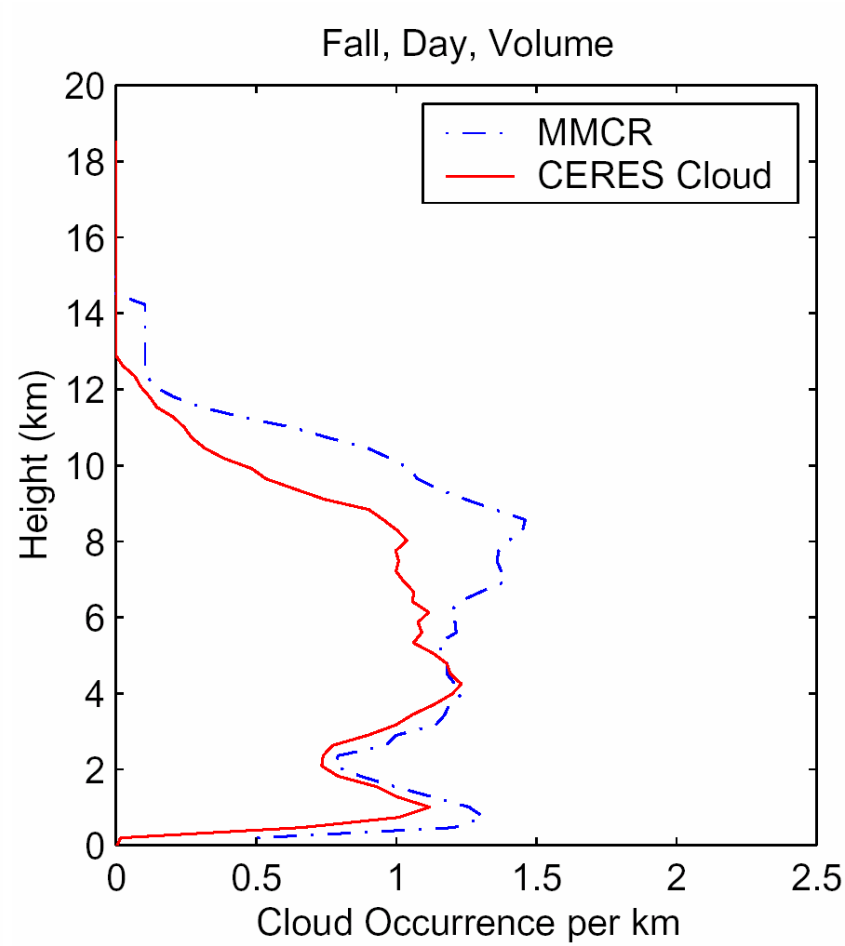
Cloud Vertical Profile Comparison (SGP) Spring



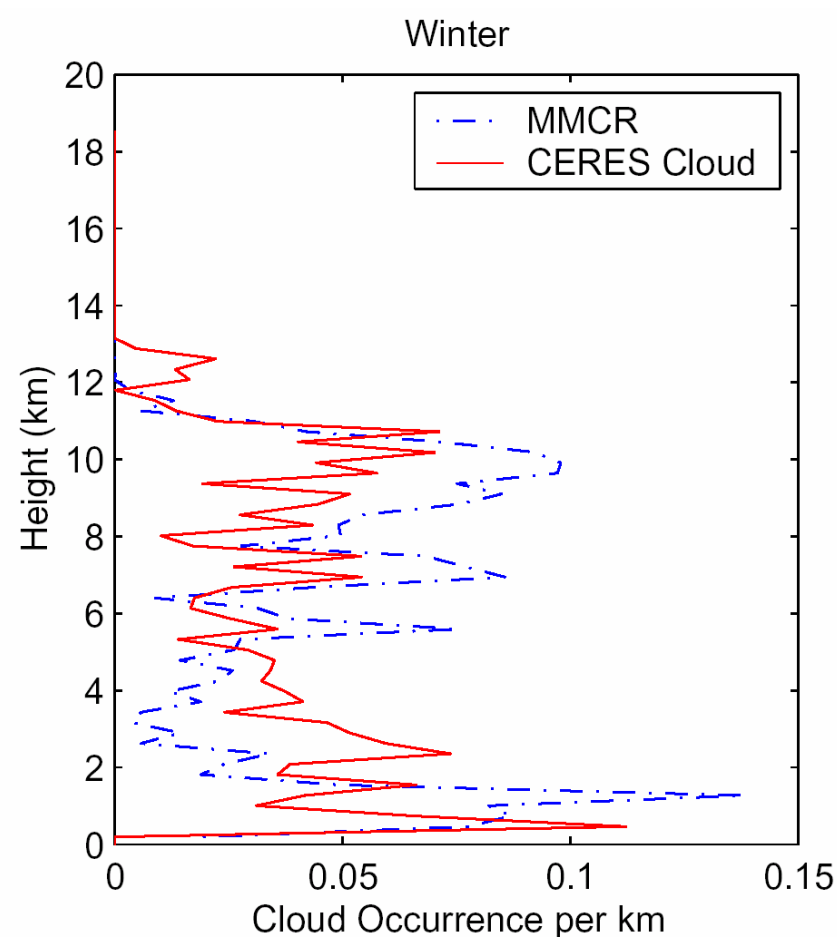


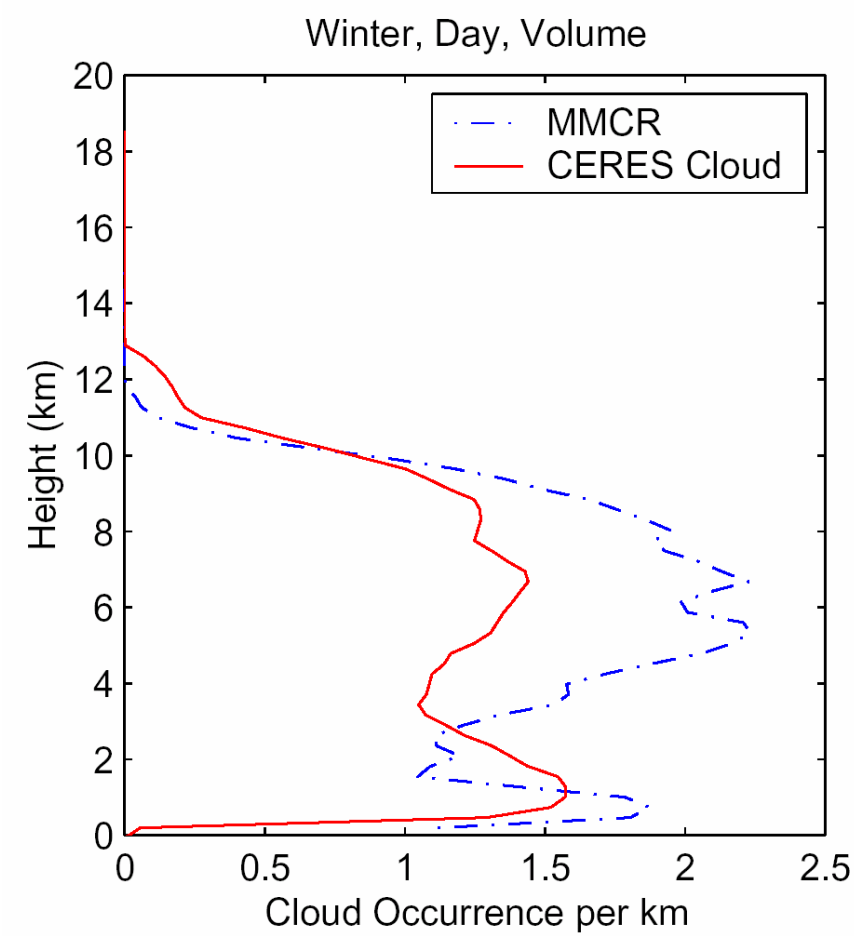
Cloud Vertical Profile Comparison: Fall



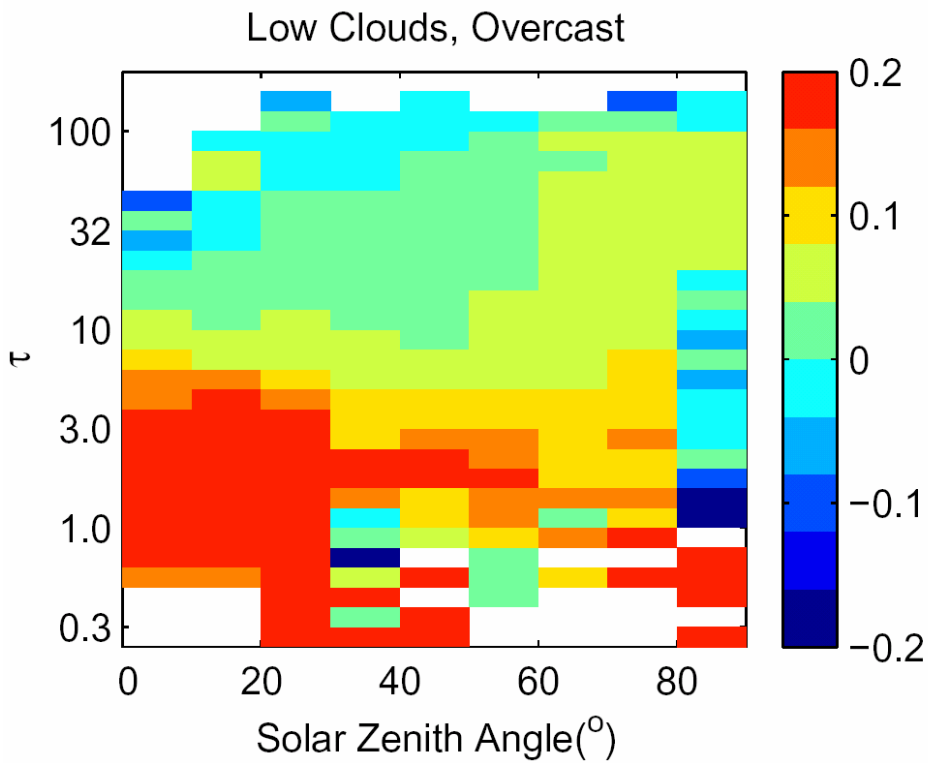


Cloud Vertical Profile Comparison: Winter



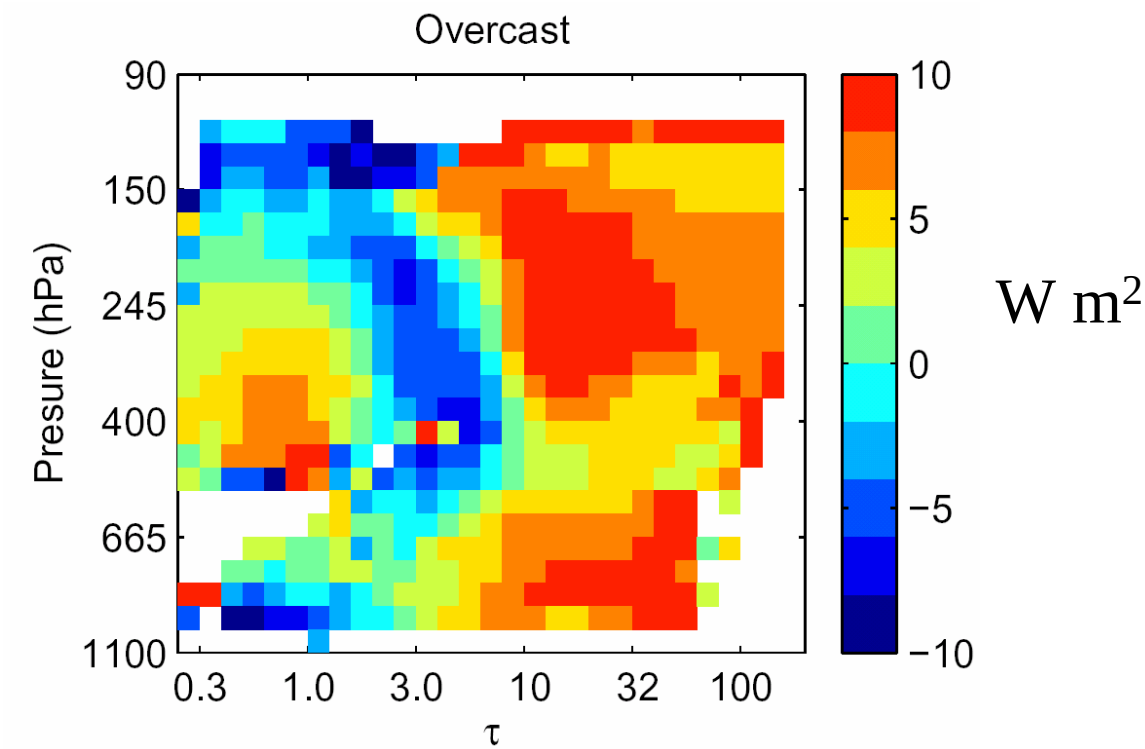


TOA Albedo Comparison with CERES



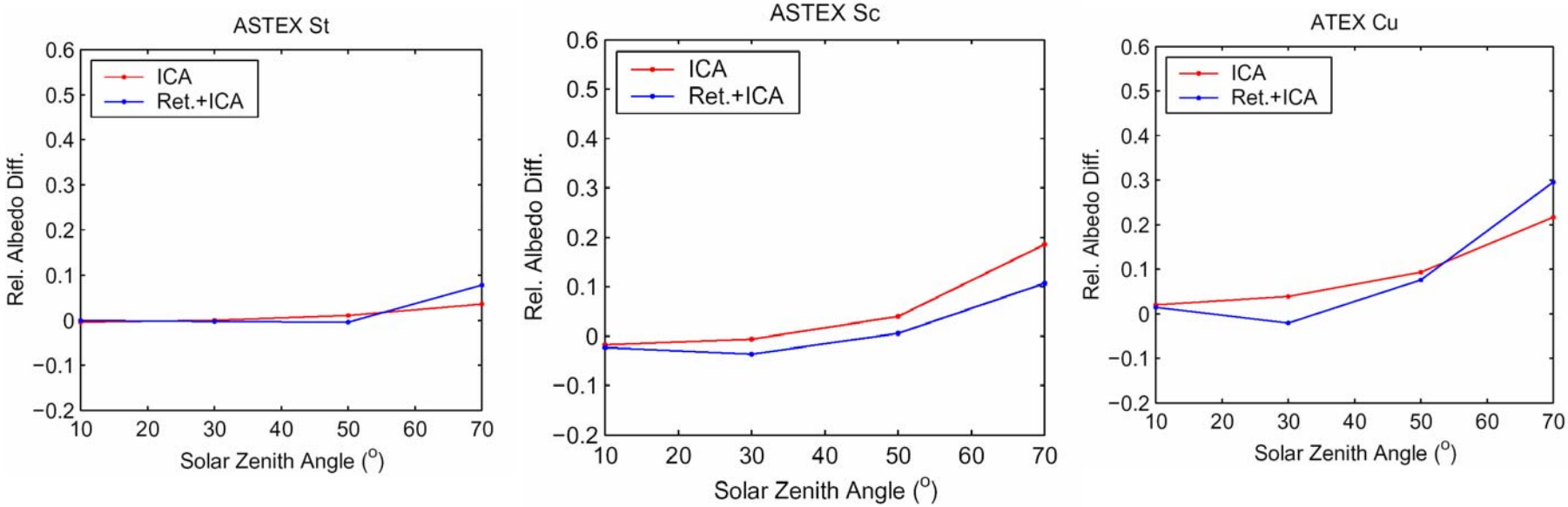
Overcast over oceans
uniform (nu > 7) clouds

OLR Comparison with CERES

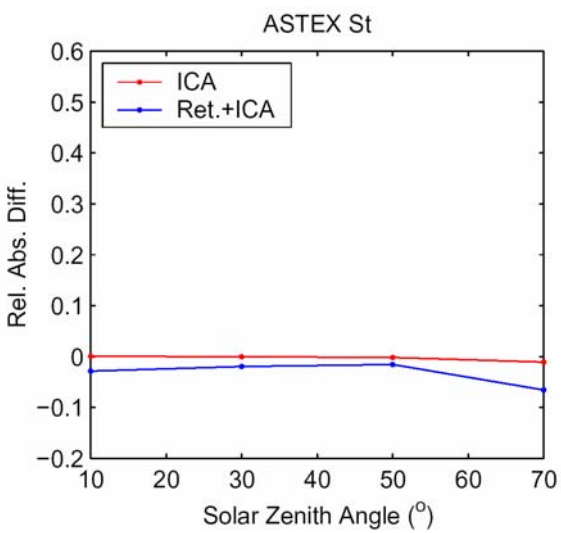


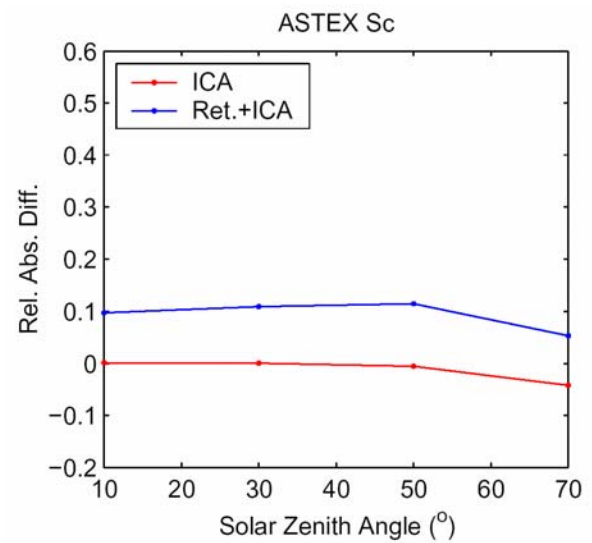
Tropics

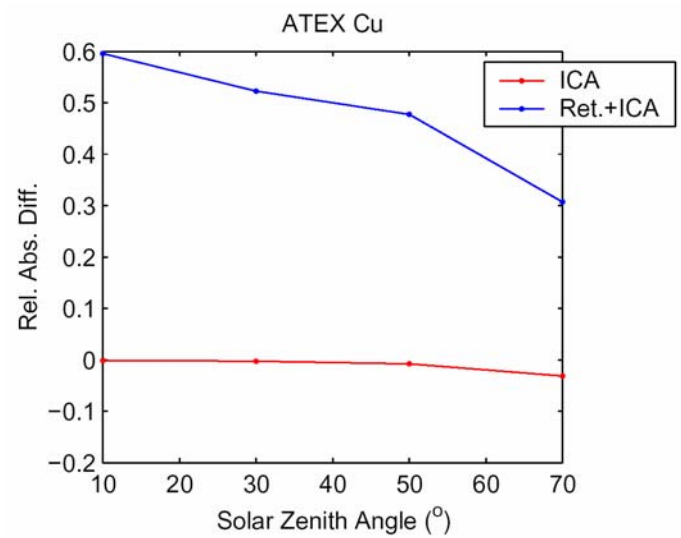
Estimating Error Neglecting 3D Albedo Error



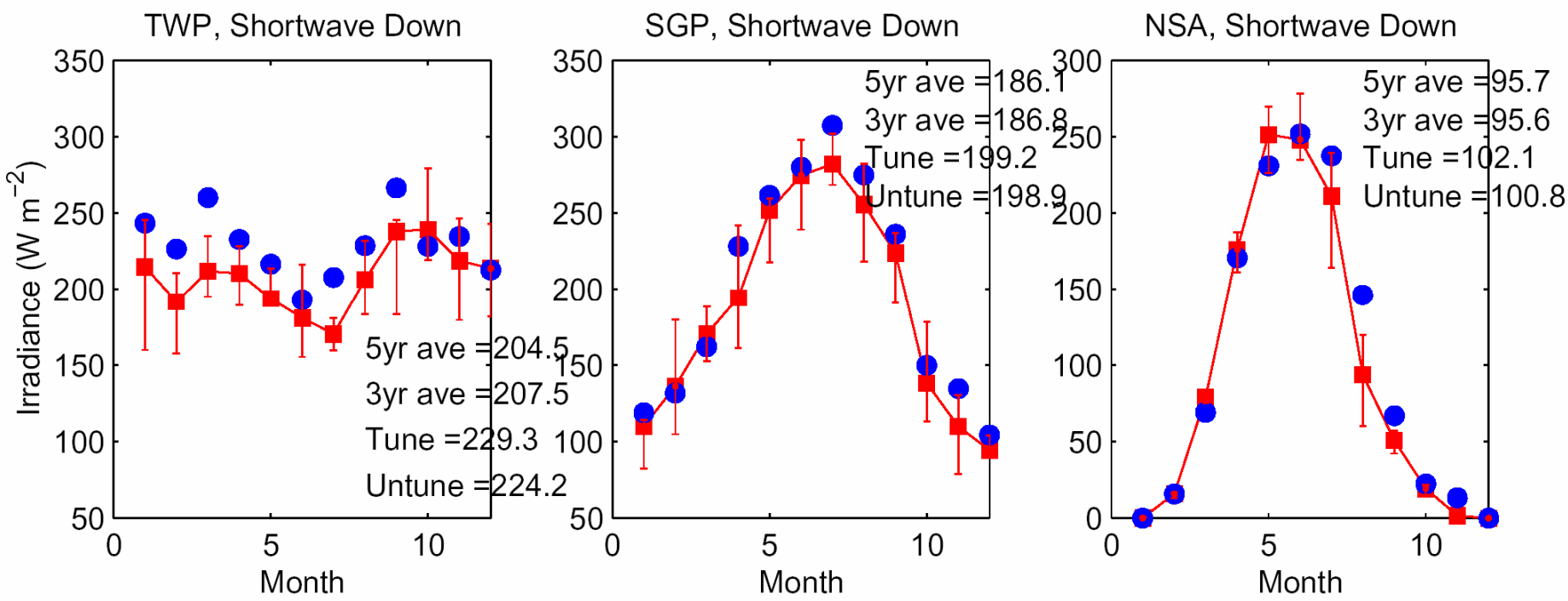
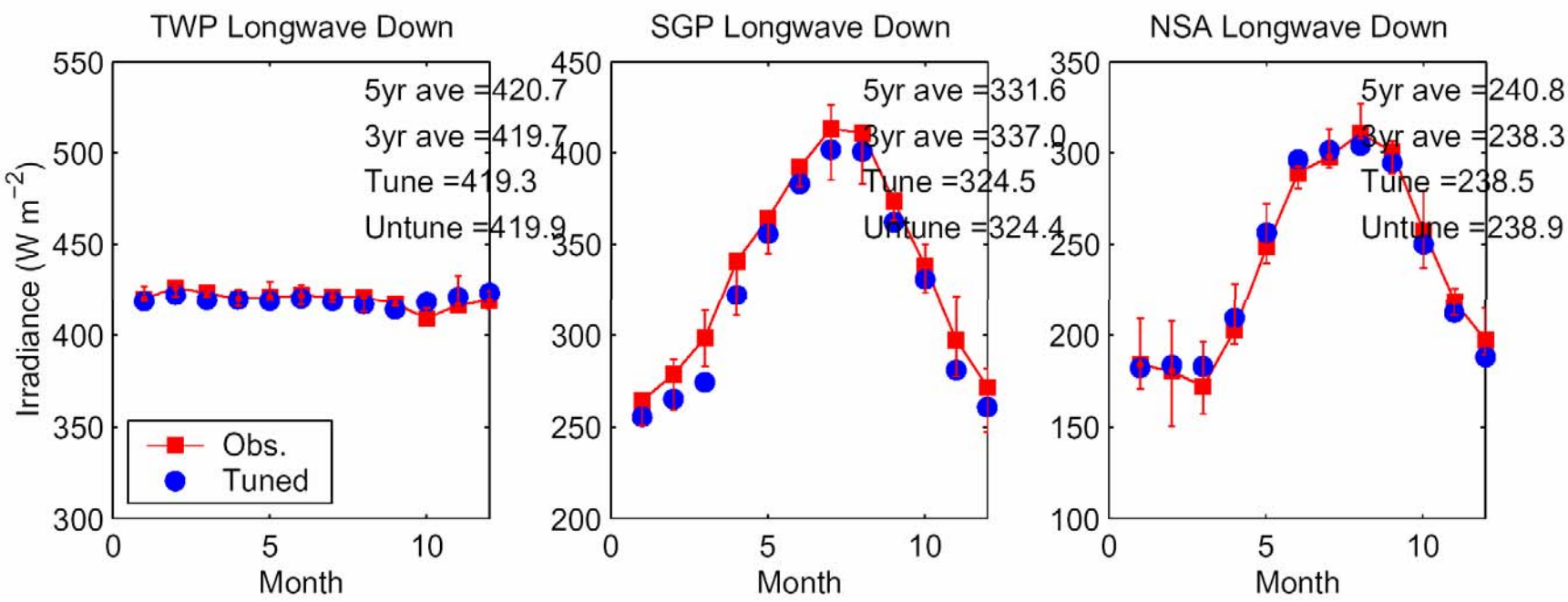
Absorptance Error due to 3D







Comparison at ARM sites (SW)



Comparison at ARM sites (LW)