Using cloud radar to understand the vertical distribution of absorption in tropical clouds

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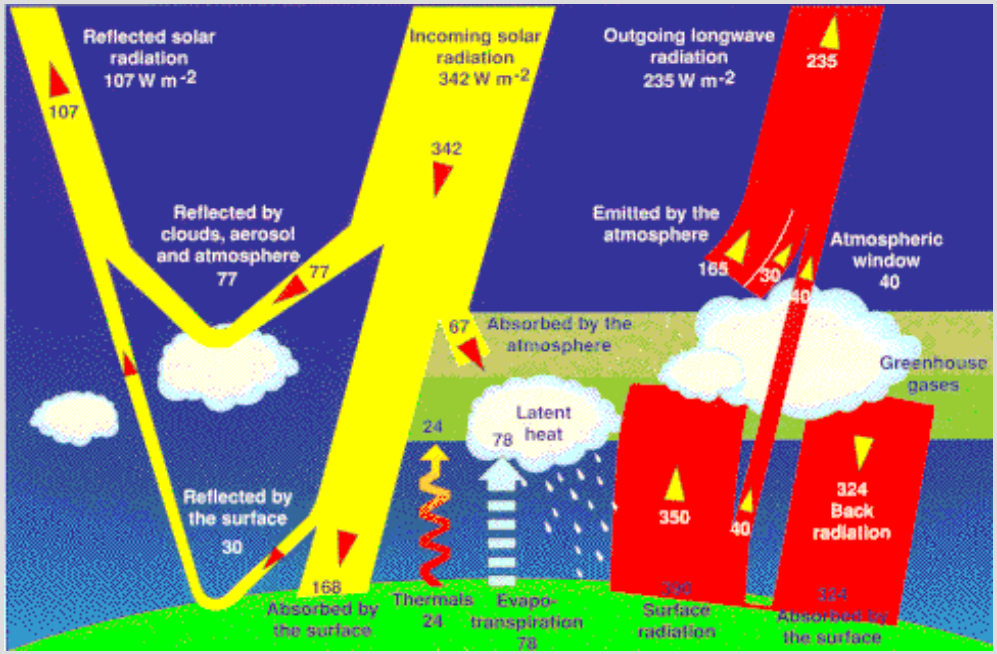
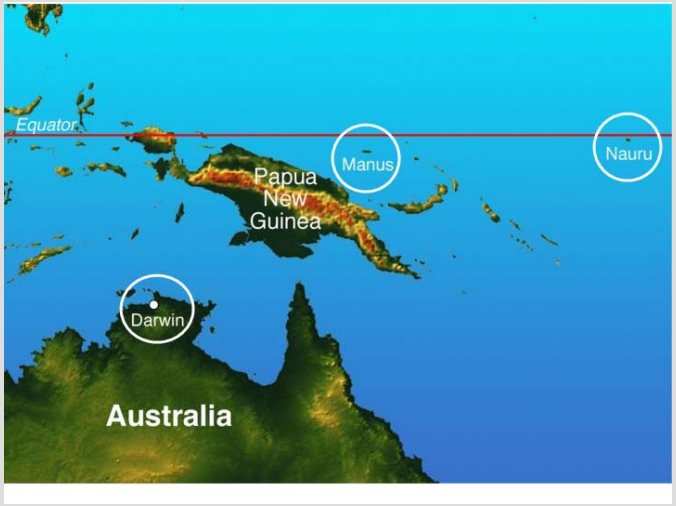
- Clouds reflect and absorb solar radiation
- Effect of clouds on energy balance usually examined at the TOA or surface; or combined for total column absorption
- Direct impact on dynamics is through absorption and redistribution of energy vertically in the atmosphere
- Knowledge of vertical distribution of SW absorption requires profiles of cloud properties

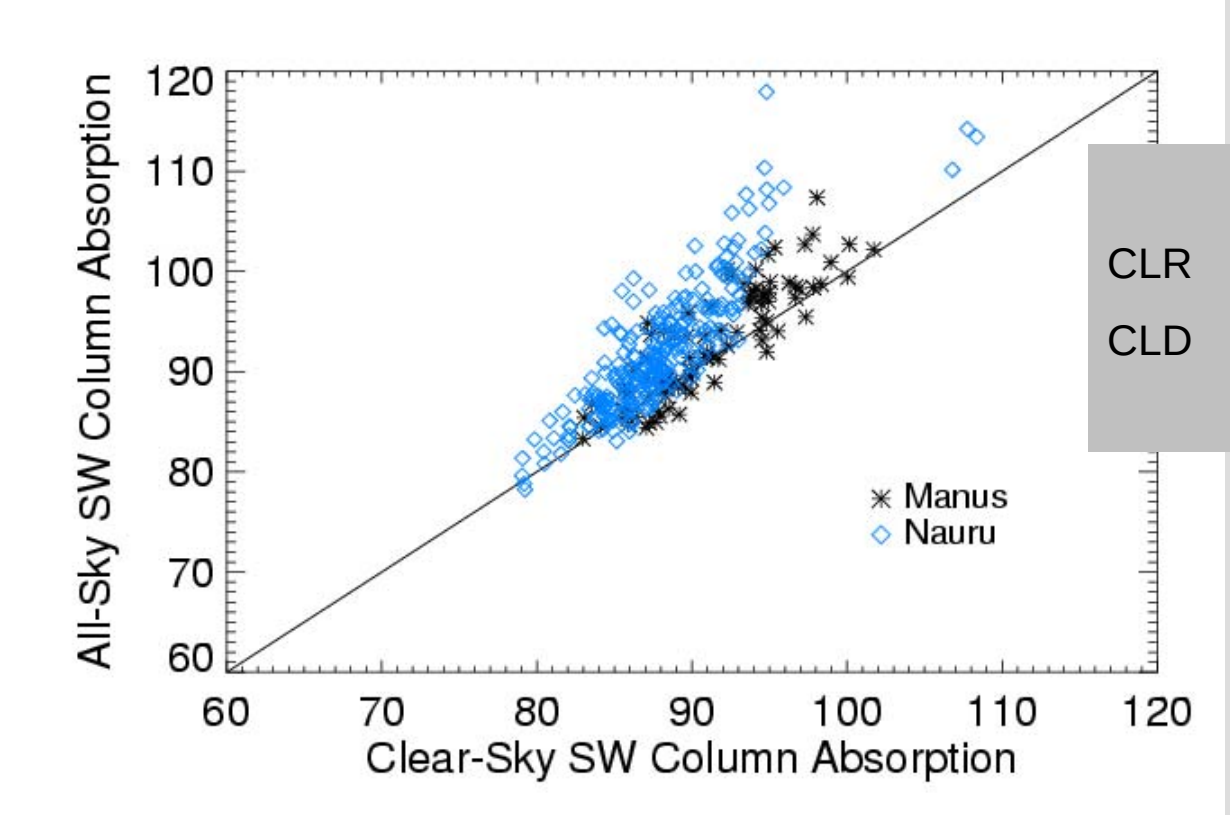


Data from ARM Tropical Sites



- **ARM Tropical Sites**
  - Manus: Feb-July 2000
    - Convectively Active Period
  - Nauru: Mar-Dec 1999
    - Convectively Suppressed
- MMCR - 35 GHz cloud radar
- Retrievals of ice water content, particle size
  - Simple regression equation relationships (Microbase)
- Calculations of SW flux profiles
  - Fu-Liou 1D radiation code
  - Updated gaseous absorption
  - Performed every 5 minutes on sampled cloud profiles

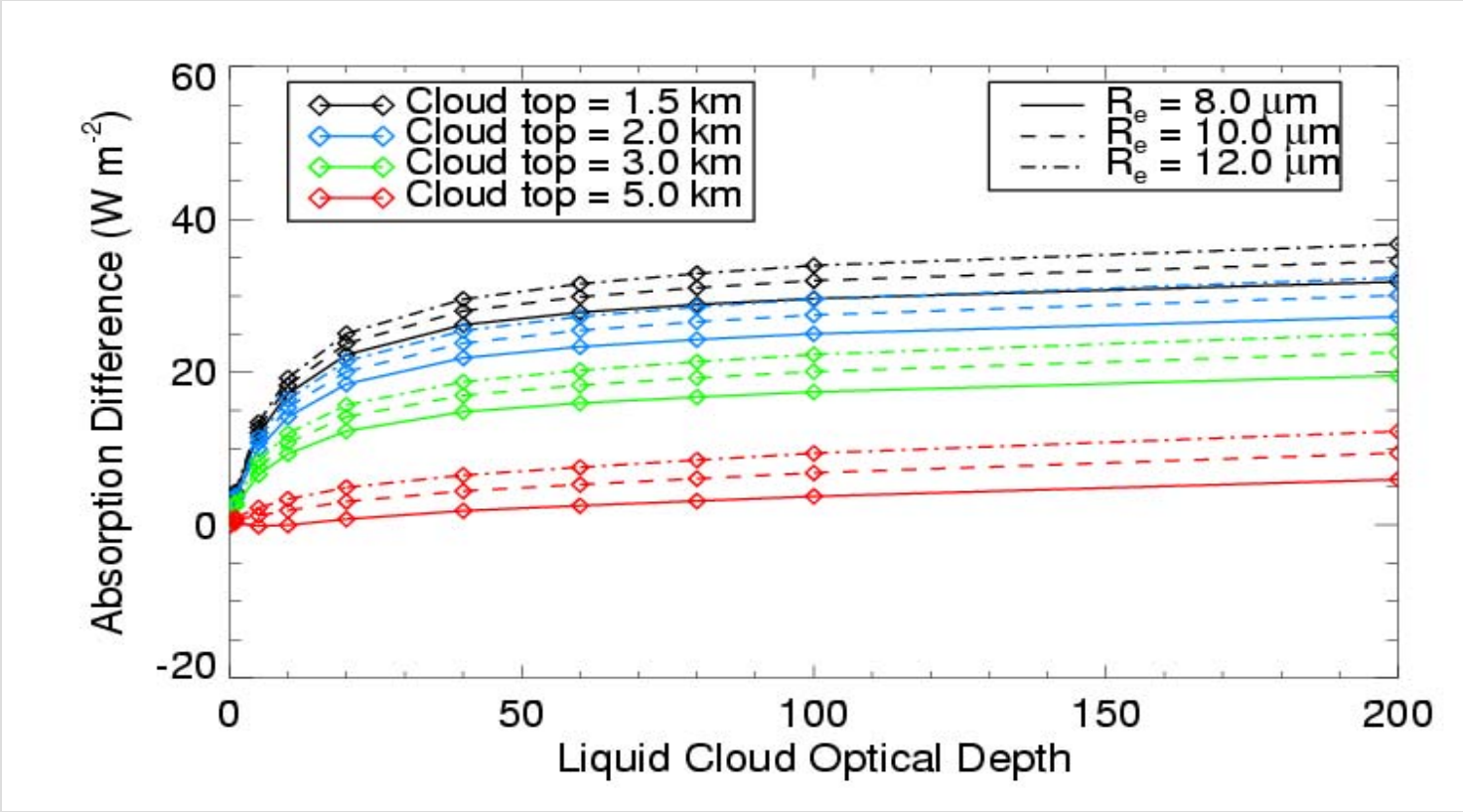
Daily-Averaged (24-hour) Column SW Absorption



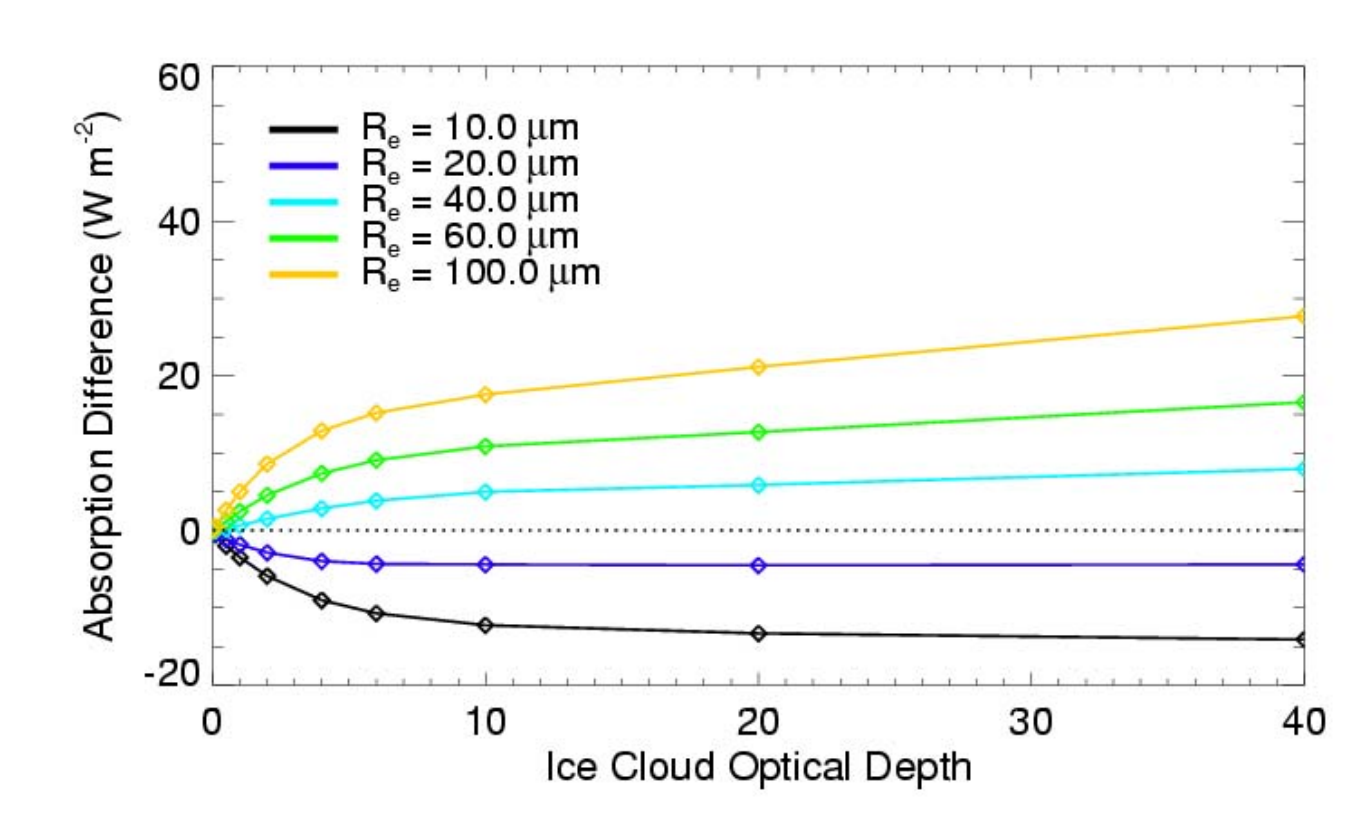
	Manus	Nauru
CLR	91.5 W/m^2	87.2 W/m^2
CLD	93.3 W/m^2	91.3 W/m^2

Effect of Clouds on SW Absorption

- Cloud particles absorb SW radiation
  - Depends on composition (liquid/ice)
  - Larger particles absorb more
- Clouds reflect SW radiation
  - Low clouds: increase water vapor absorption because photons travel through troposphere twice
  - High clouds: decrease water vapor absorption because photons don’t reach lower troposphere (where majority of water vapor exists)
- Multiple scattering within a cloud increases effective water vapor path length (smaller effect)

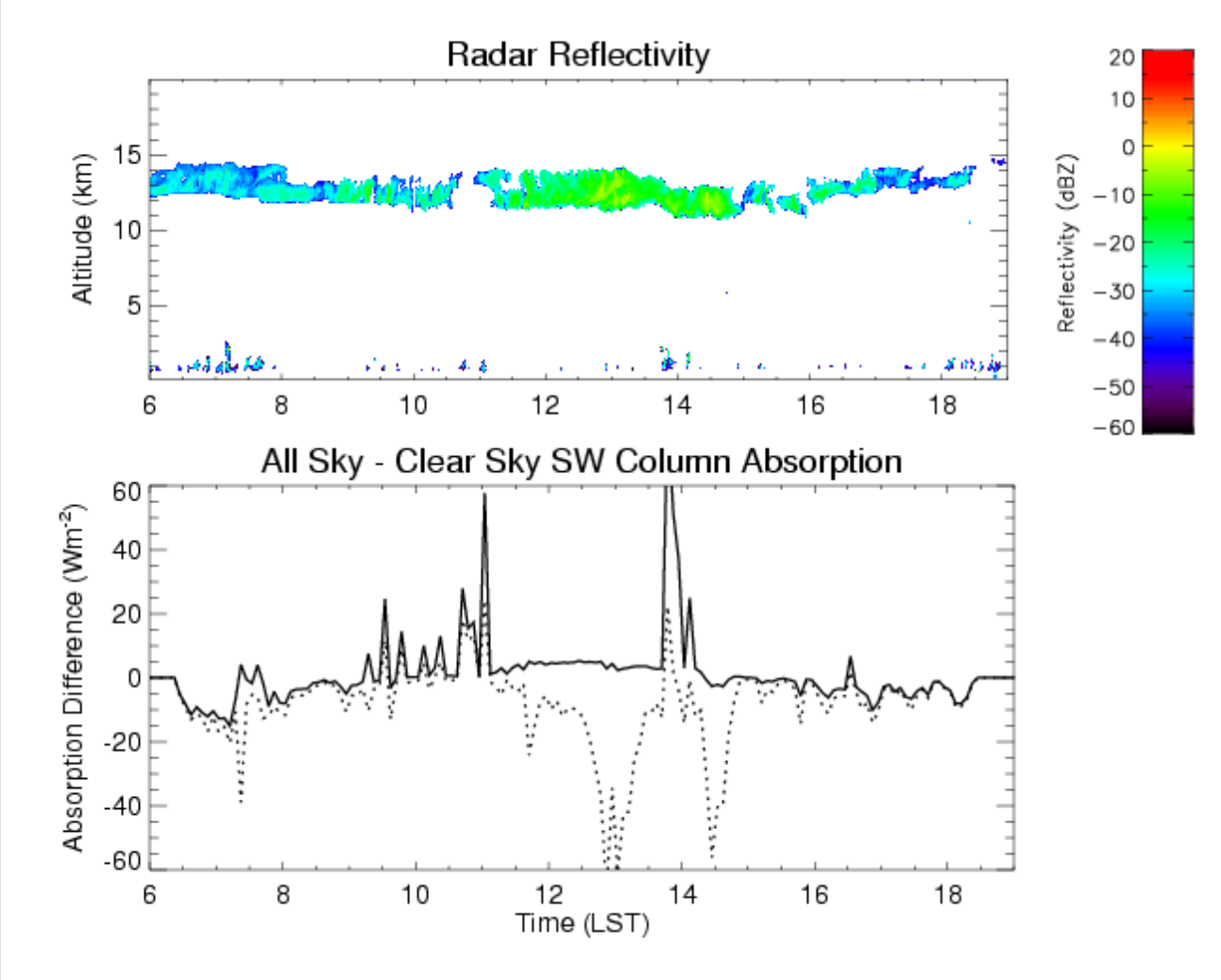


- Low-level liquid clouds increase SW column absorption
- As cloud top height increases; effect on column absorption decreases

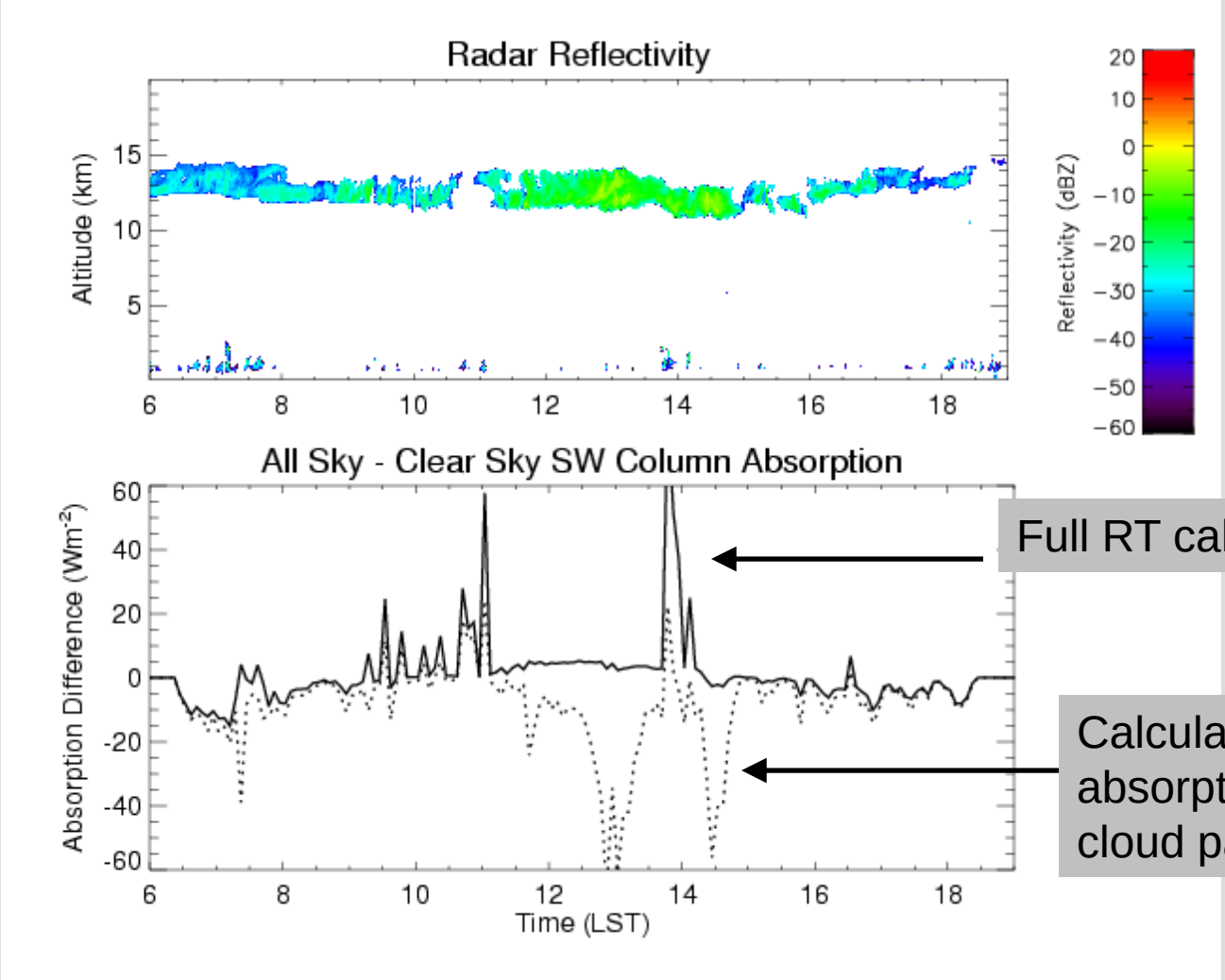


- Ice clouds with small (large) particles decrease (increase) SW column absorption
- For smaller particles, absorption by cloud particles does not offset decreased water vapor path

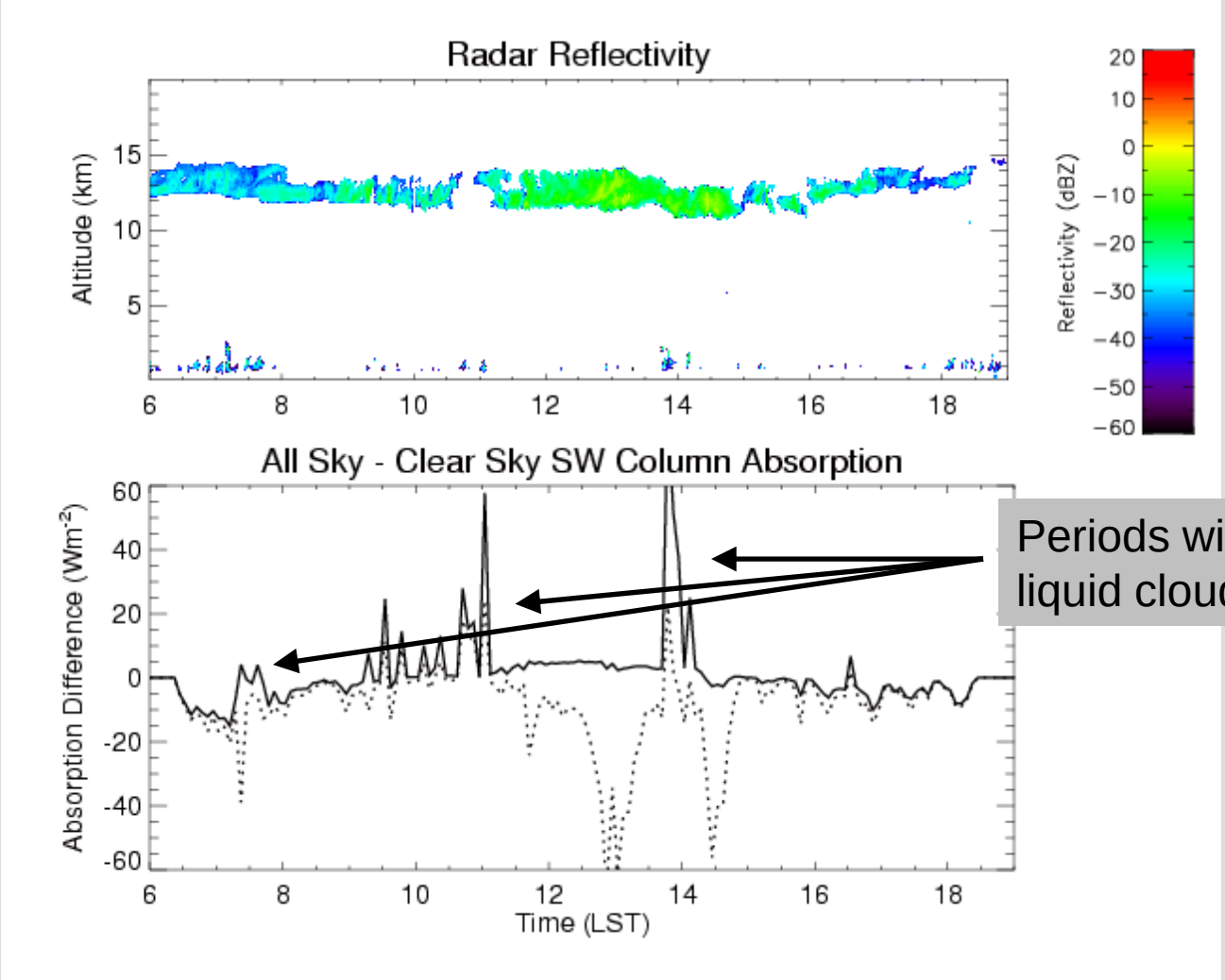
Case Study (Manus; 3/1/2000)



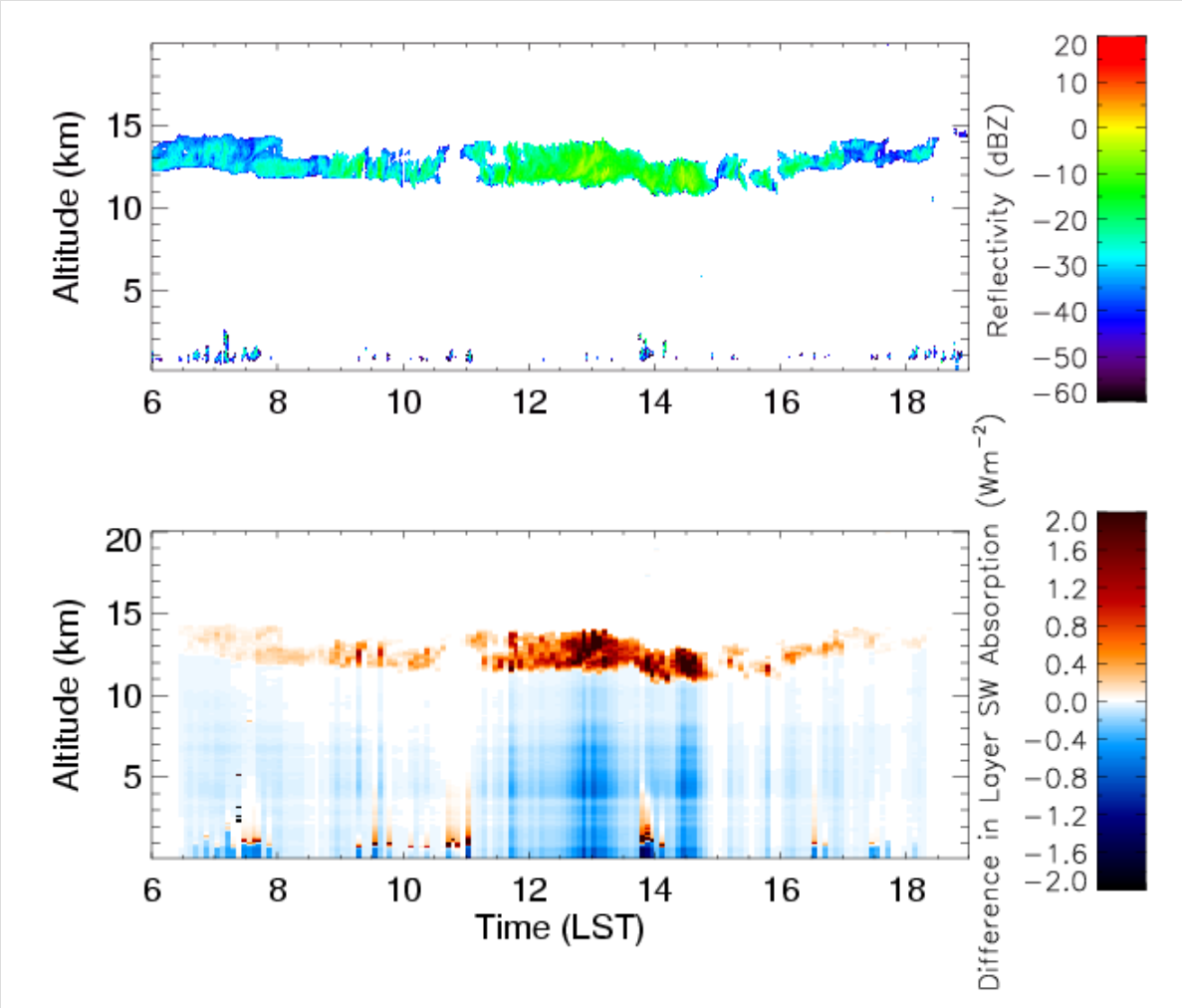
Case Study


Radar Reflectivity
Altitude (km)
15
10
5
6
8
10
12
14
16
18
Reflectivity (dBZ)
20
10
0
−10
−20
−30
−40
−50
−60
All Sky - Clear Sky SW Column Absorption
Absorption Difference (Wm^{-2})
60
40
20
0
-20
-40
-60
Time (LST)
Full RT calculation
Calculation w/o absorption by cloud particles

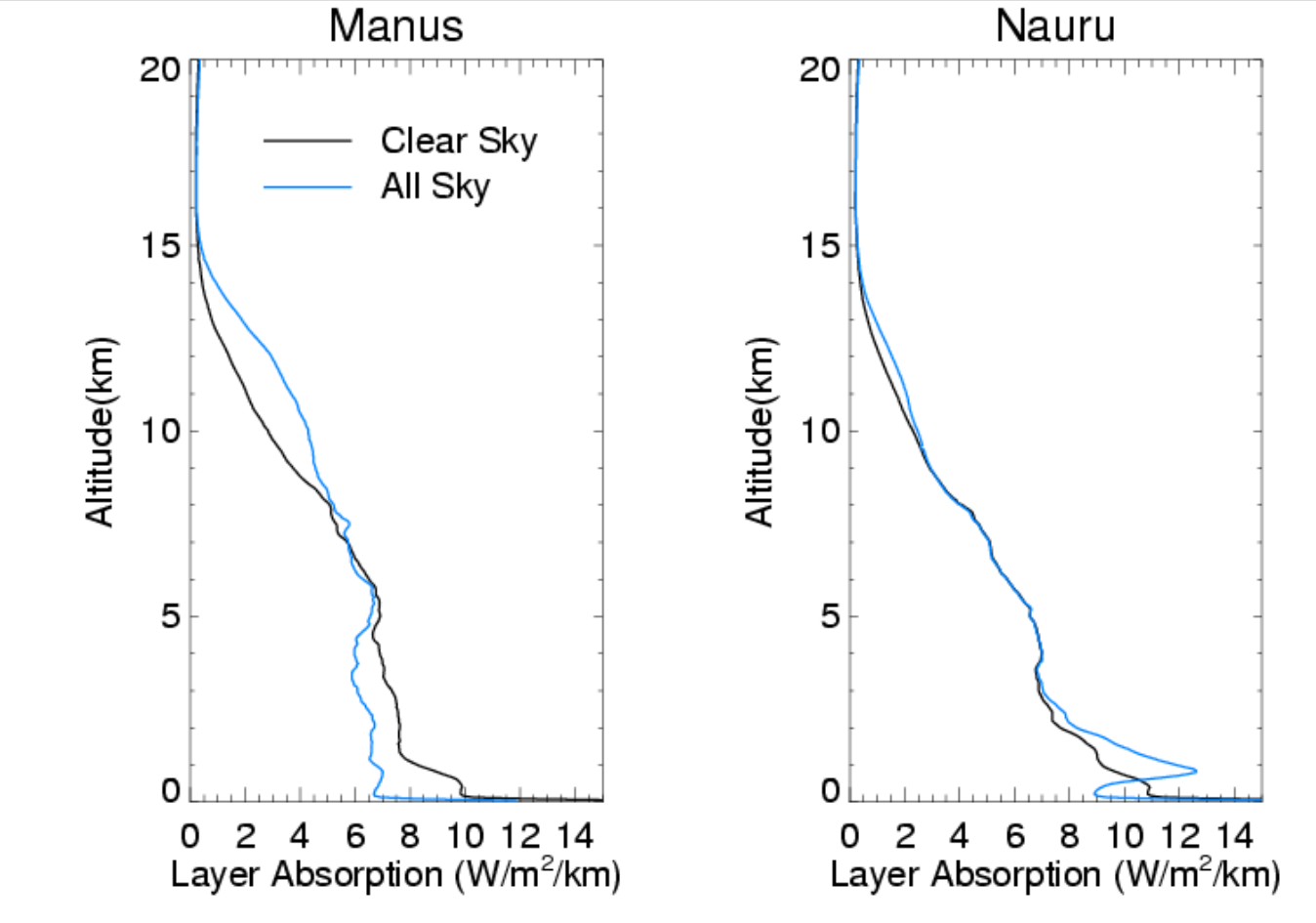
Case Study


Radar Reflectivity
Altitude (km)
15
10
5
6
8
10
12
14
16
18
Reflectivity (dBZ)
20
10
0
−10
−20
−30
−40
−50
−60
All Sky - Clear Sky SW Column Absorption
Absorption Difference (Wm^{-2})
60
40
20
0
-20
-40
-60
Time (LST)
Periods with thicker liquid clouds

Case Study

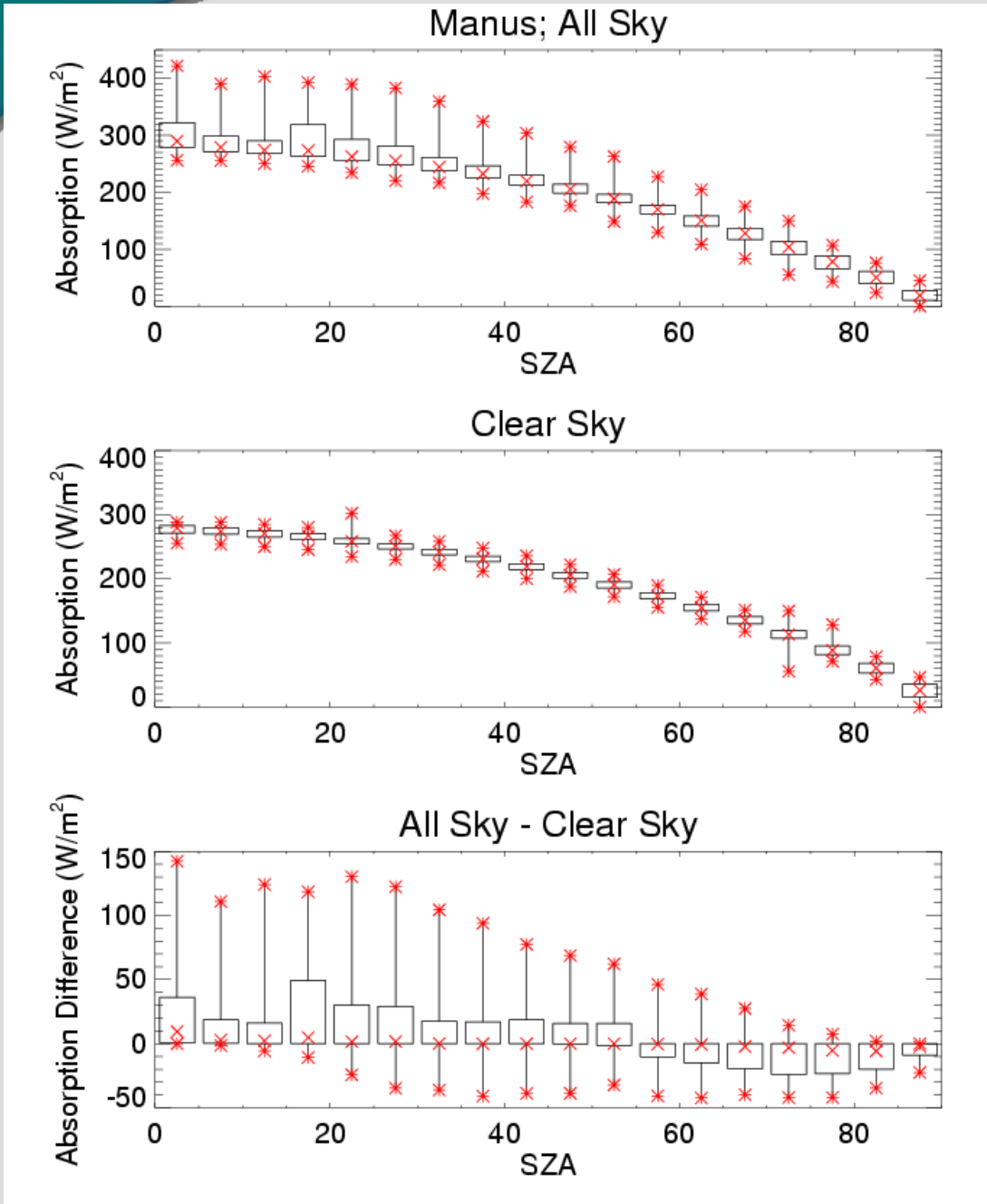

Altitude (km)
15
10
5
6
8
10
12
14
16
18
Reflectivity (dBZ)
20
10
0
−10
−20
−30
−40
−50
−60
Altitude (km)
20
15
10
5
Time (LST)
Difference in Layer SW Absorption (Wm^{-2})
2.0
1.6
1.2
0.8
0.4
0.0
−0.4
−0.8
−1.2
−1.6
−2.0

Average Layer Absorption



Low cloud frequency: 41.3%
Cirrus frequency: 57.7%

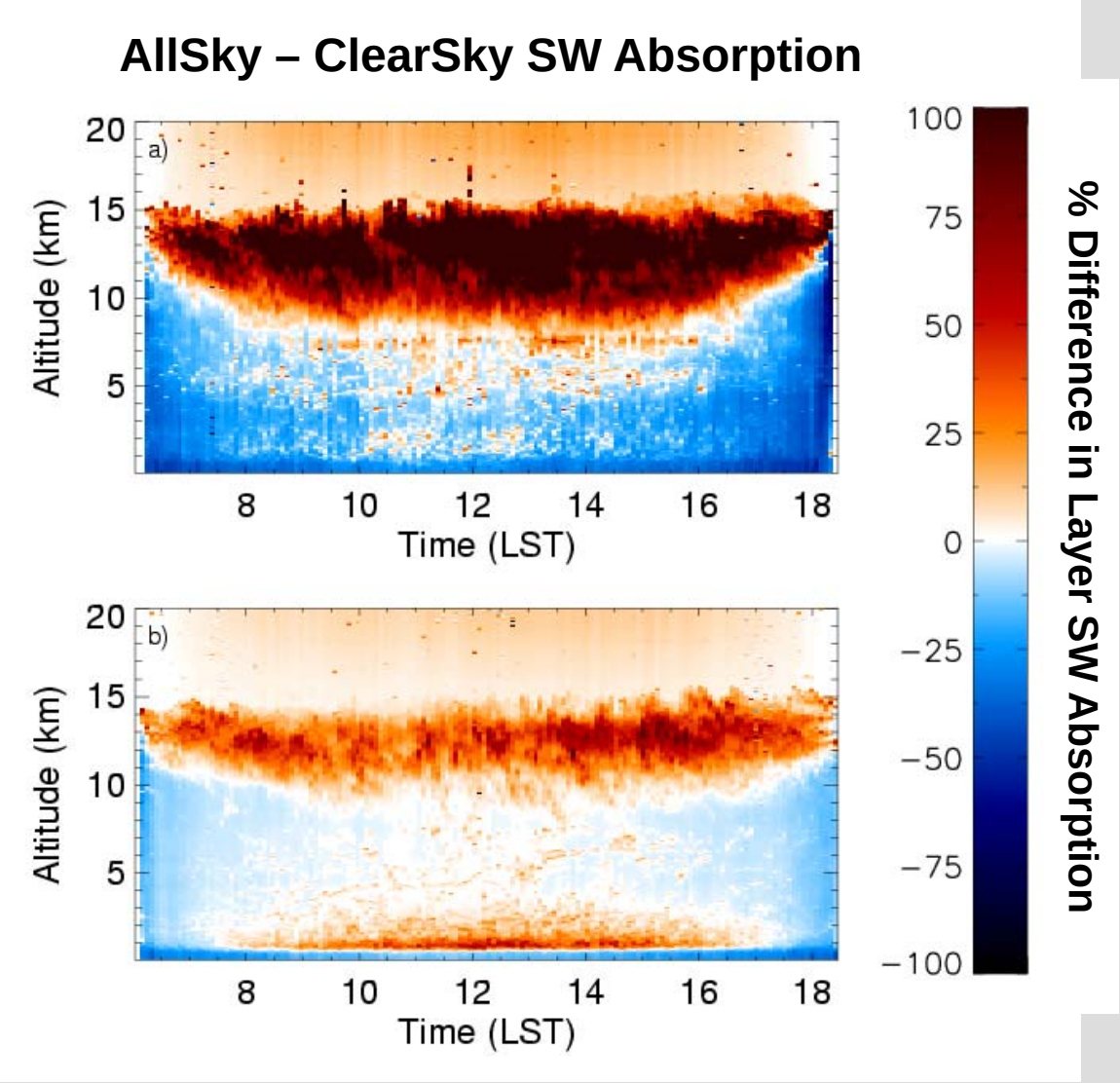
Low cloud frequency: 33.6%
Cirrus frequency: 24.9%



Diurnal variability in effect of clouds on column absorption

- high sun angles – clouds increase absorption
- low sun angles – clouds decrease column absorption
- medium sun angles – can do either, depending on details of cloud field

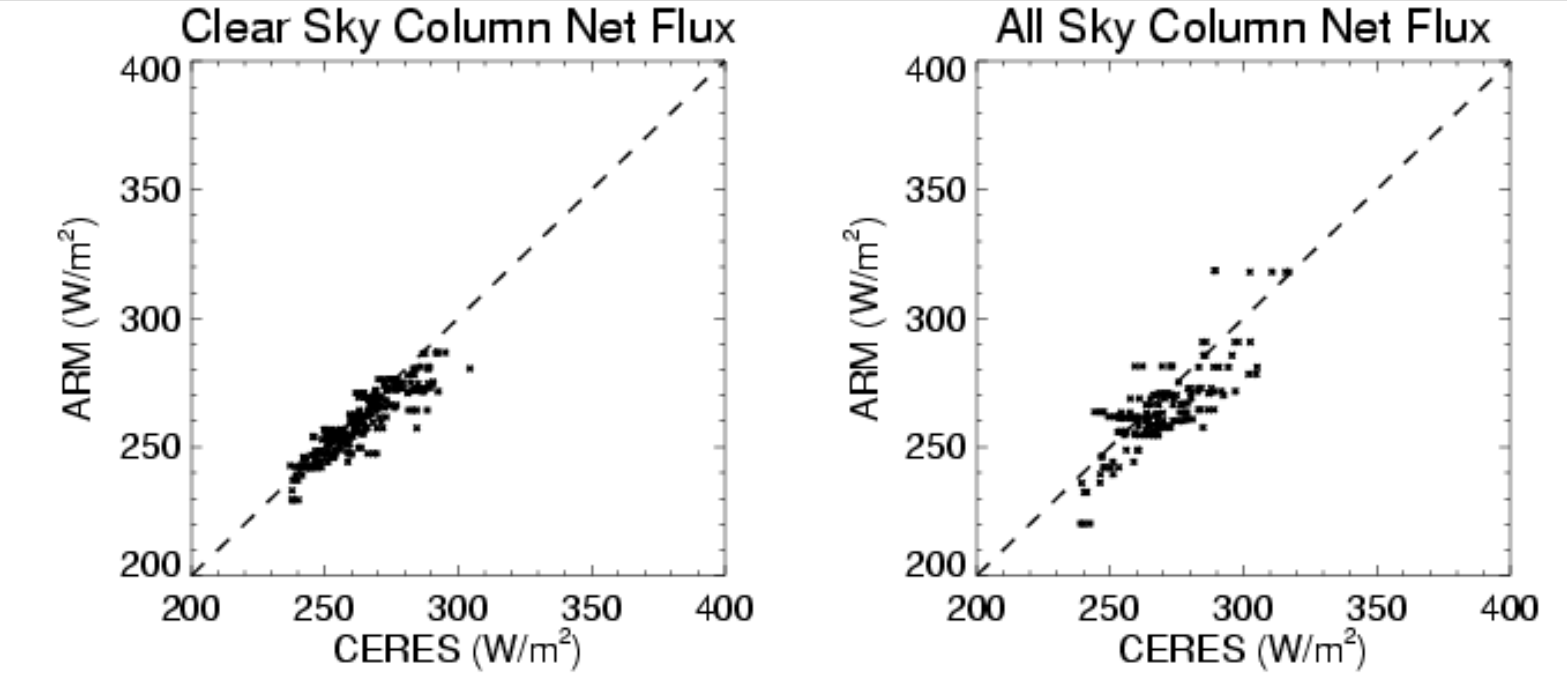
Composite of Diurnal Cloud Effect



Manus

Nauru

Satellite Comparisons (CERES)



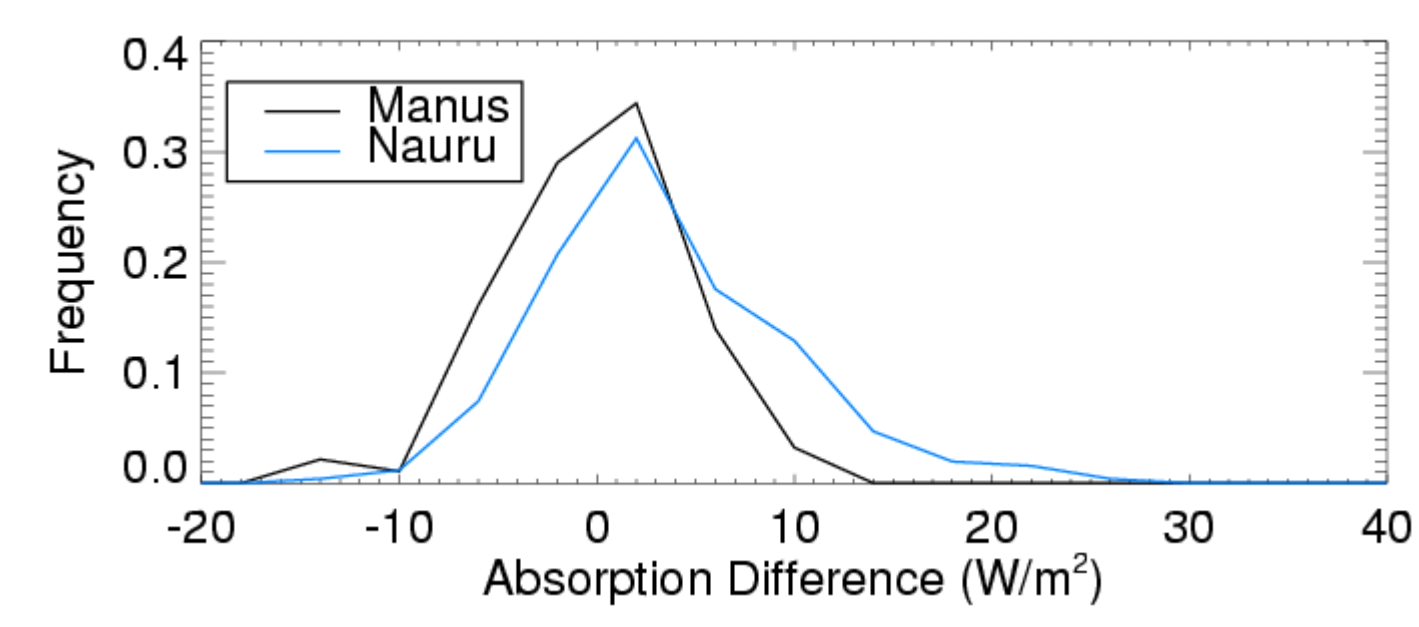
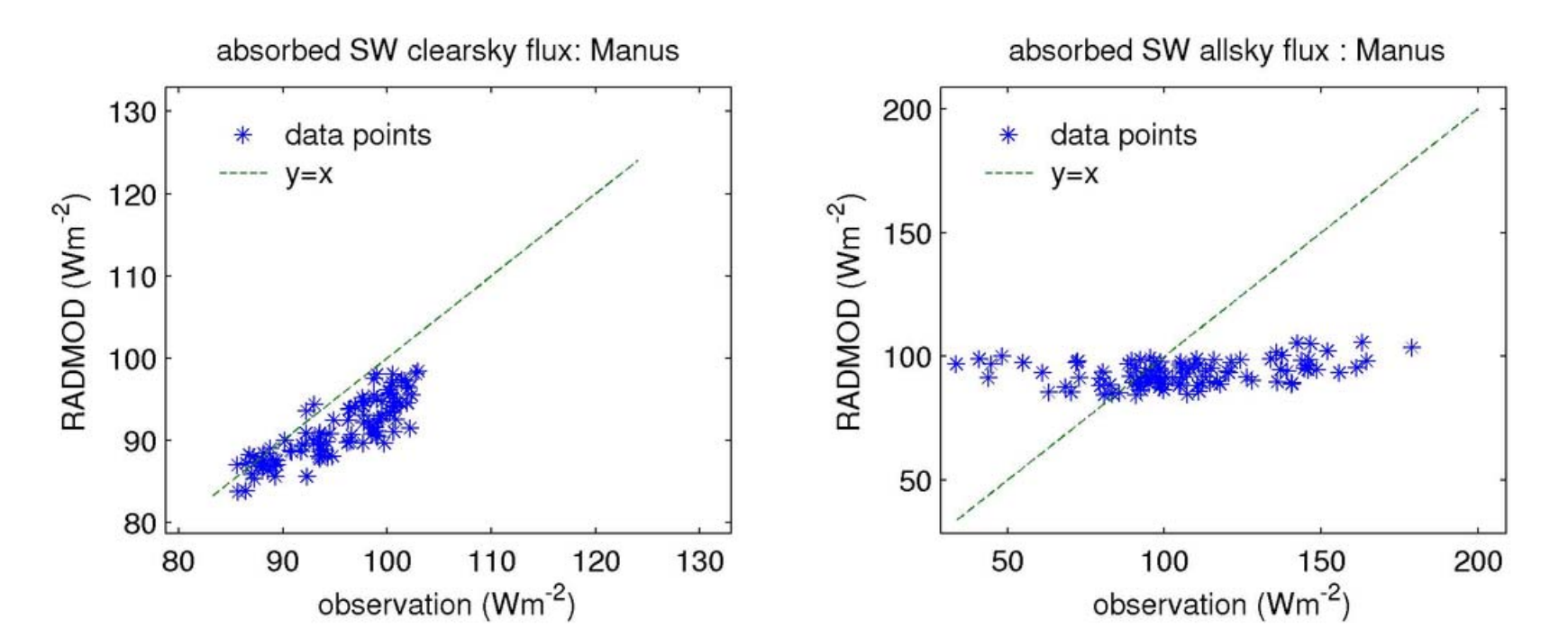
1-hour average of ARM observations around Terra overpass (10:30 am LST) for Manus 2000 period

Conclusions/Future Work

- Cloud radar allows high-vertical resolution estimates of SW absorption in the atmosphere:
  - In long-term average, clouds have relatively little impact on total column absorption at Manus/Nauru
  - Clouds significantly alter the vertical distribution of SW absorption
  - Details of vertical distribution depend on cloud vertical structure; vary with cloud-type frequency
- Initial comparisons with satellite data (CERES SARB product) show reasonable agreement
- CloudSAT will allow global evaluation of the role of cloud vertical structure on radiative heating
- Model studies required to understand:
  - Vertical resolution needed to capture important structures
  - Impact of cloud vertical structure on dynamics

Extra Slides

Daily-Averaged (24-hour) Column SW Absorption



Satellite Comparisons (GMS + SRB) Daily (24-hour) Average Absorption