Cloud Radiative Effects over the Atlantic from Satellite and Ship Based Observations

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Meridional Ocean Radiation Experiment
MORE

Development of Autonomous Measurement Platforms for Energy and Mass Exchange at the Ocean Surface
OCEANET

IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

Atmosphere: remote sensing

Ocean:

Primary production

Atmosphere/ocean

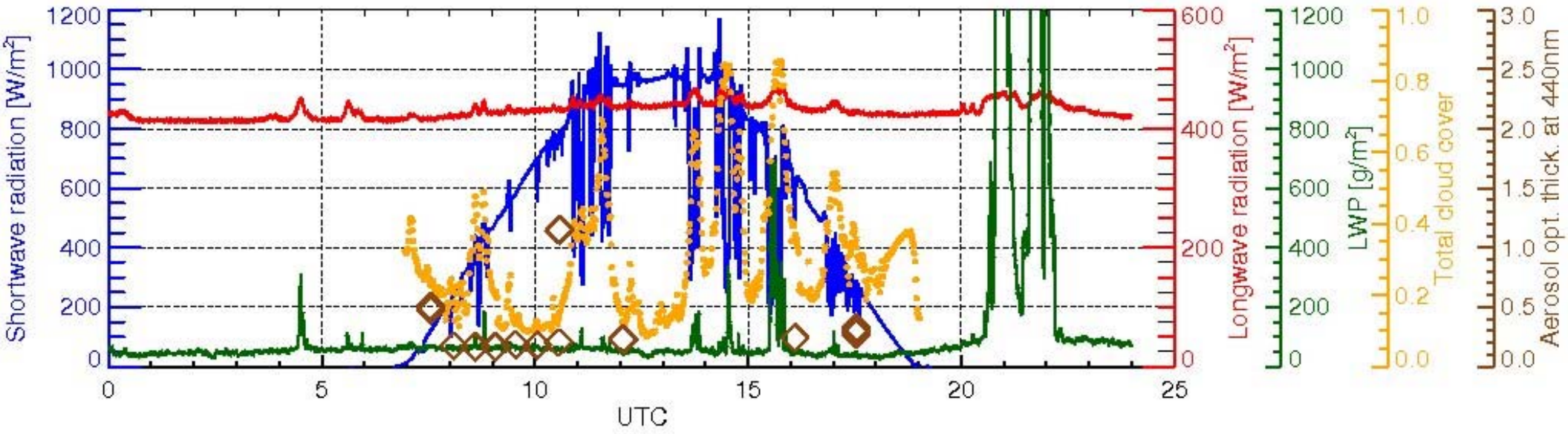
Energy budget

GKSS FORSCHUNGSZENTRUM in der HELMHOLTZ GEMEINSCHAFT e.V.

Atmosphere/Ocean: CO_2-budget

AWI

April 21, 2007: cloud & radiation data



Broadband downward solar radiative flux at the sea surface

Broadband downward thermal radiative flux at the sea surface

Cloud cover

Liquid water path

Aerosol optical thickness

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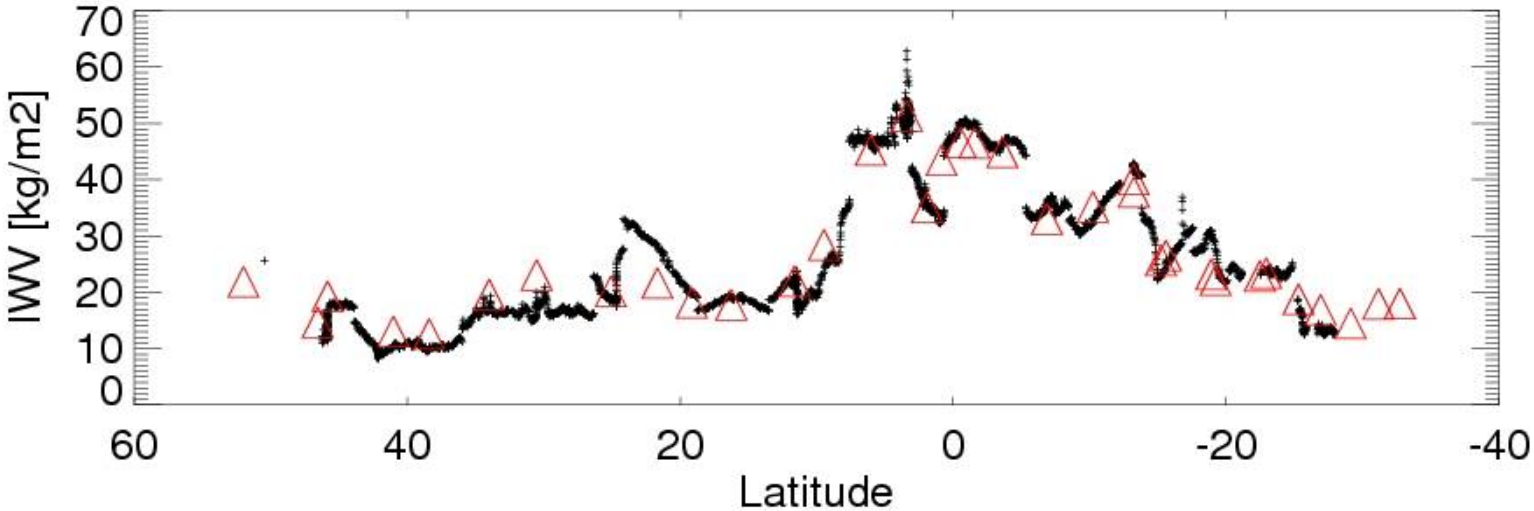
Meridional Ocean Radiation Experiment (**MORE**) Cruises

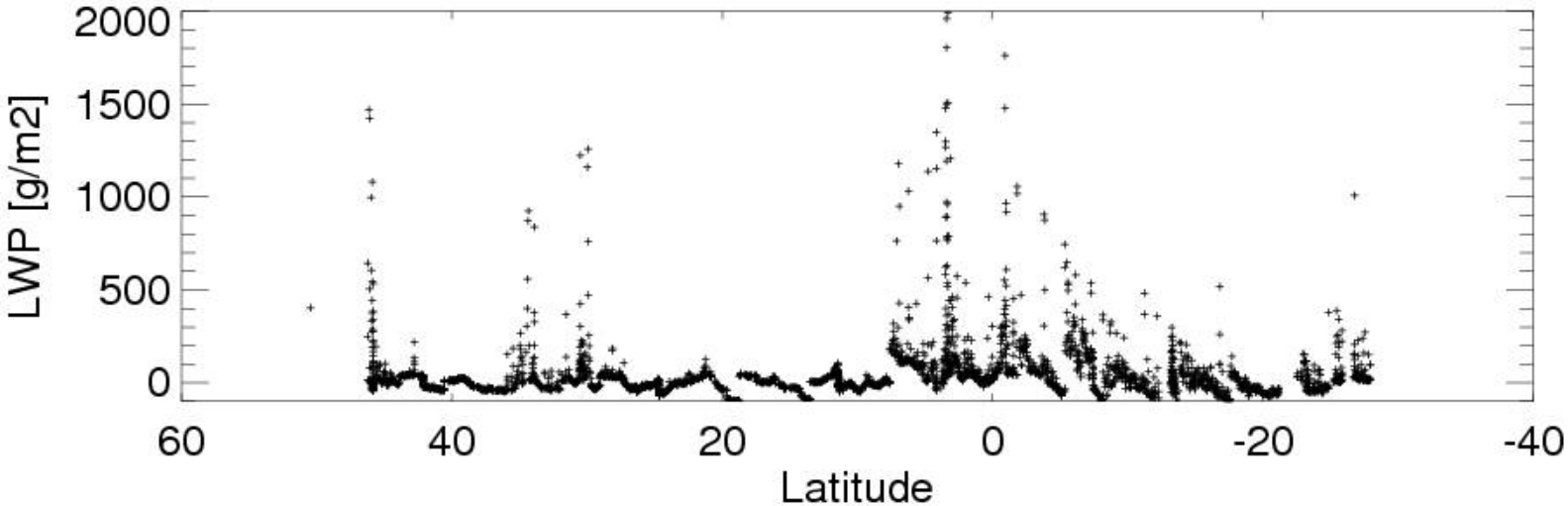
- Oct/Nov 2004: Bremerhaven – Cape Town, Vavilov
- Sept/Oct 2005: Bremerhaven – Cape Town, Vavilov
- Sep-Nov 2005: Bremerhaven – Ushuaia, Ioffe
- Ma/Apr 2006: Montevideo – Kiel, Ioffe
- Oct 2006: Bremerhaven – Montevideo/Cape Town
- **April 2007: Bremerhaven – Cape Town, Polarstern**
- **Oct/Nov 2007: Cape Town, Bremerhaven, Polarstern**

OCEANET Cruises

- **April/May 2008: Punta Arenas – Bremerhaven, Polarstern**
- Nov-Dec 2008: Bremerhaven – Cape Town, Polarstern
- **April/May 2009: Punta Arenas – Bremerhaven, Polarstern**
- **Nov-Dec 2009: Bremerhaven – Punta Arenas, Polarstern**
- 2010 : tbd

ANT-XXIV/1 – Fall 2007





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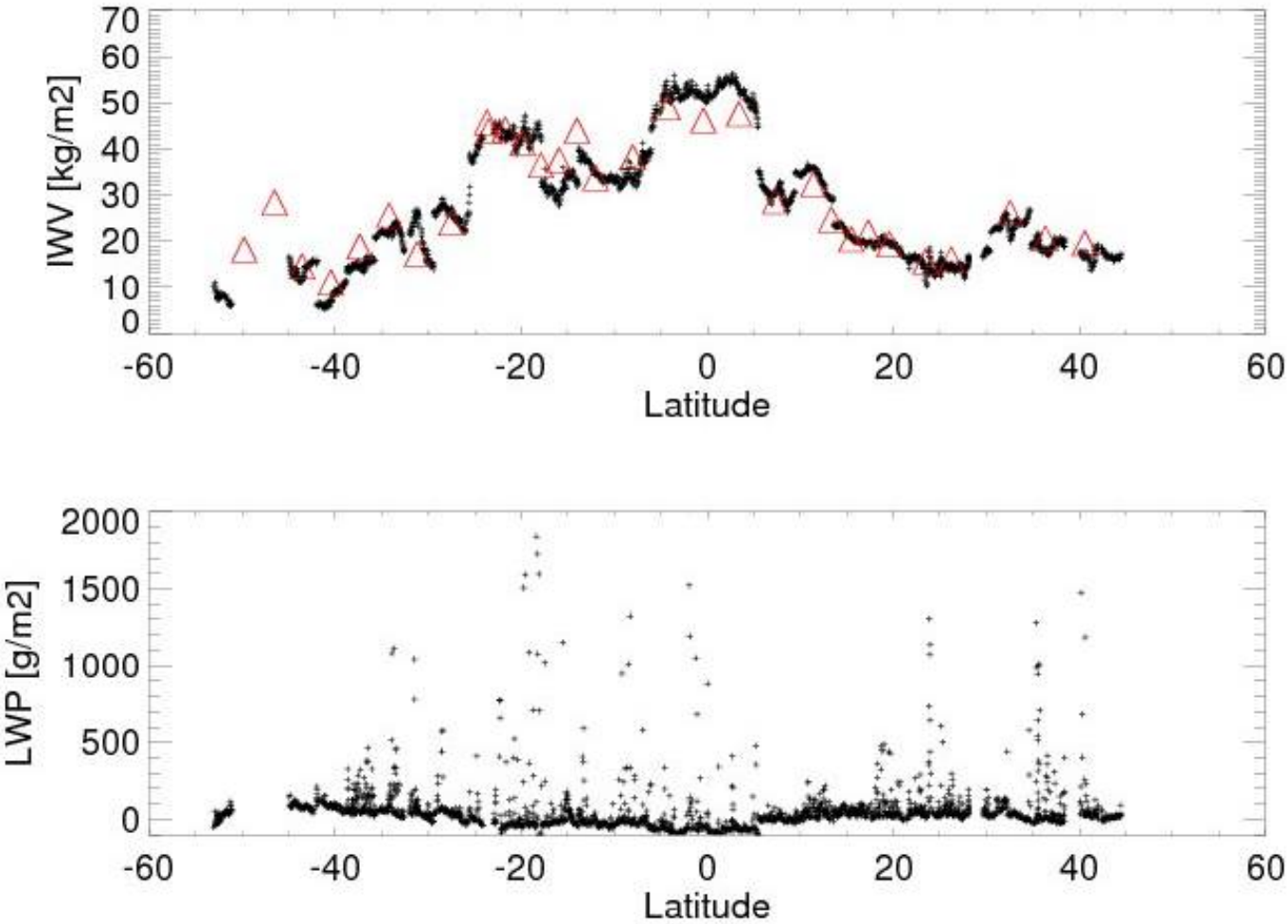

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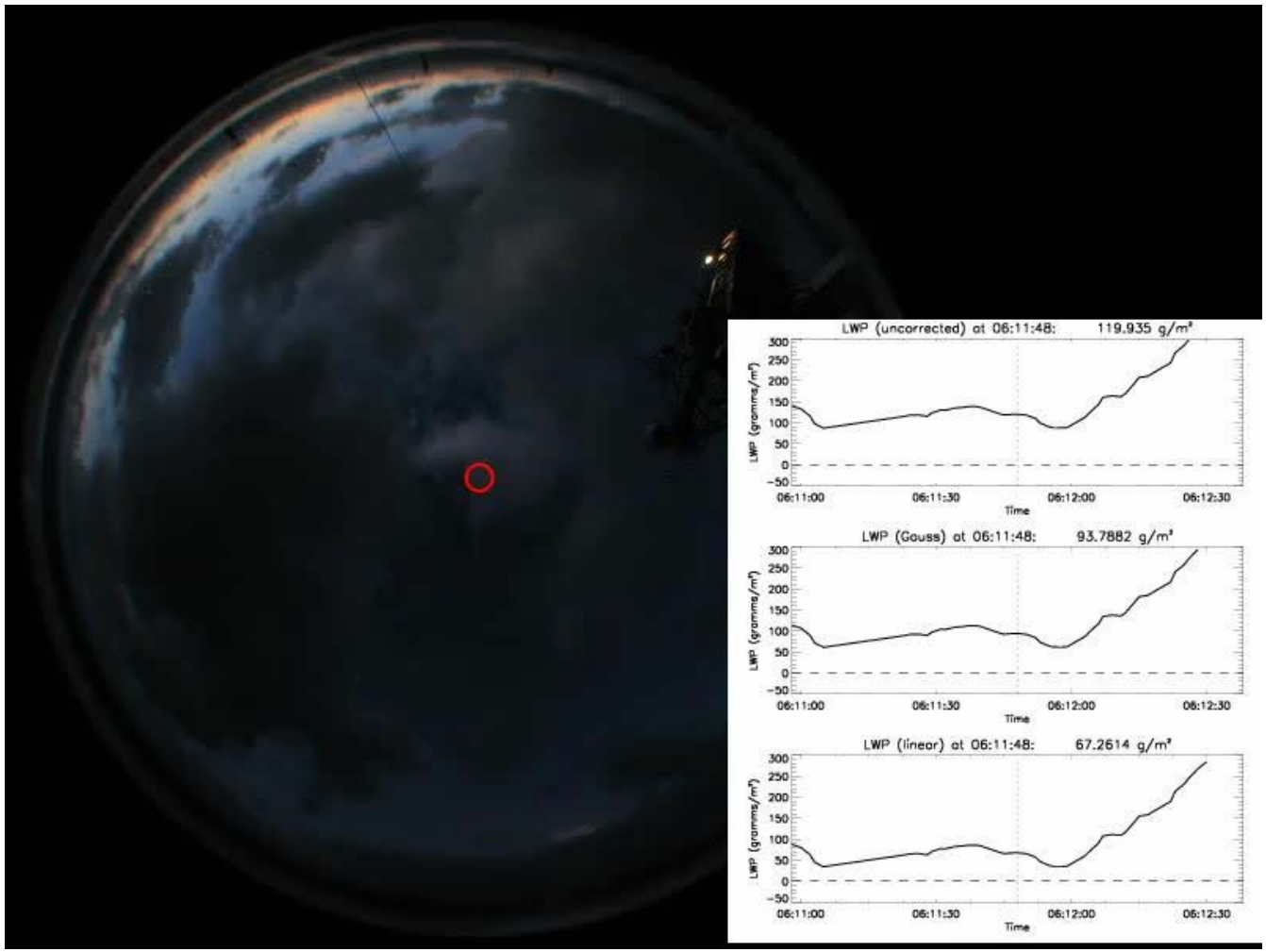
Liquid Water Path from Microwave Remote Sensing (HATPRO)



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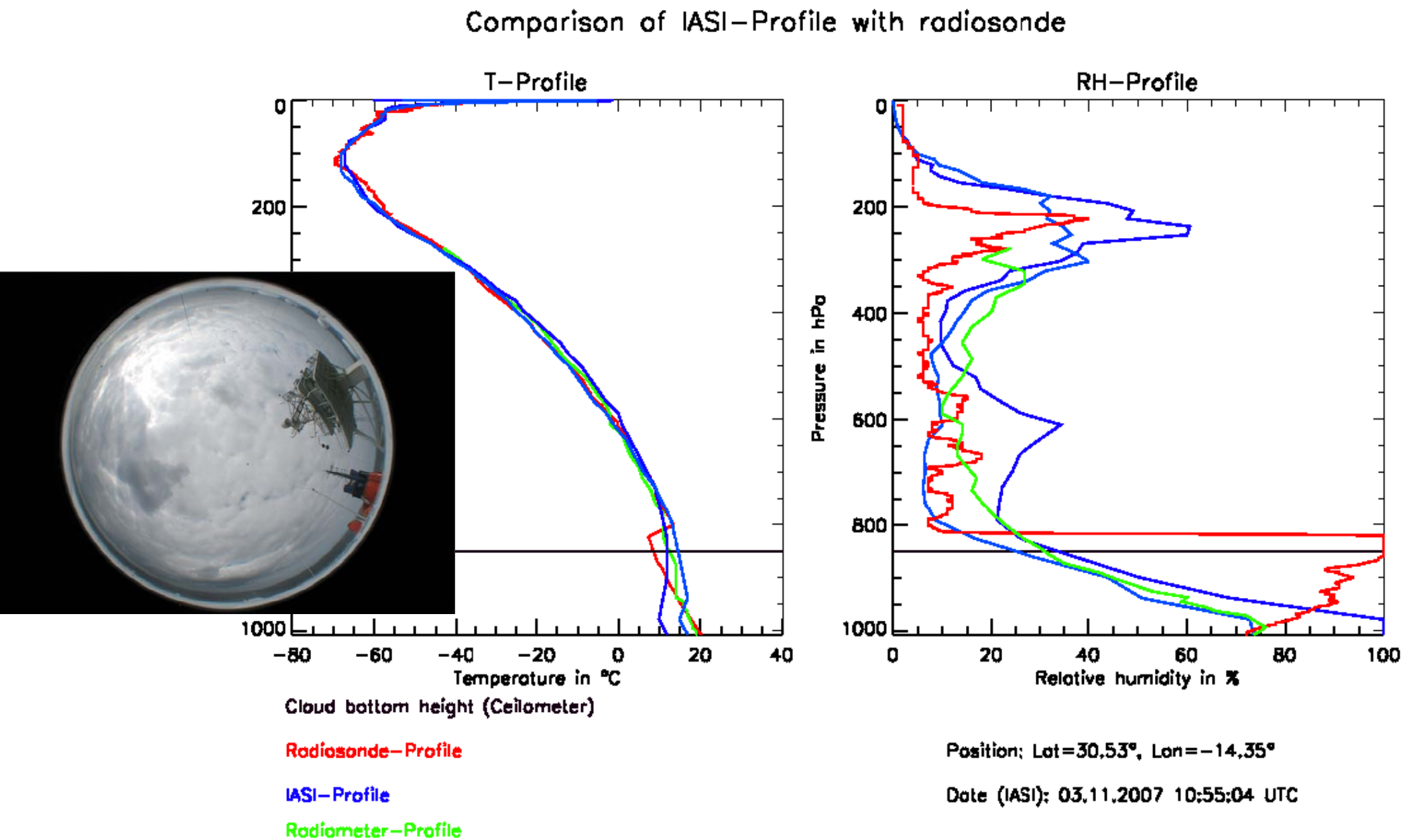
Comparison of IASI-Profile with radiosonde
T-Profile
RH-Profile
Pressure in hPa
Temperature in °C
Relative humidity in %
Cloud bottom height (Ceilometer)
Radiosonde-Profile
IASI-Profile
Radiometer-Profile
Position: Lat=30.53°, Lon=-14.35°
Date (IASI): 03.11.2007 10:55:04 UTC

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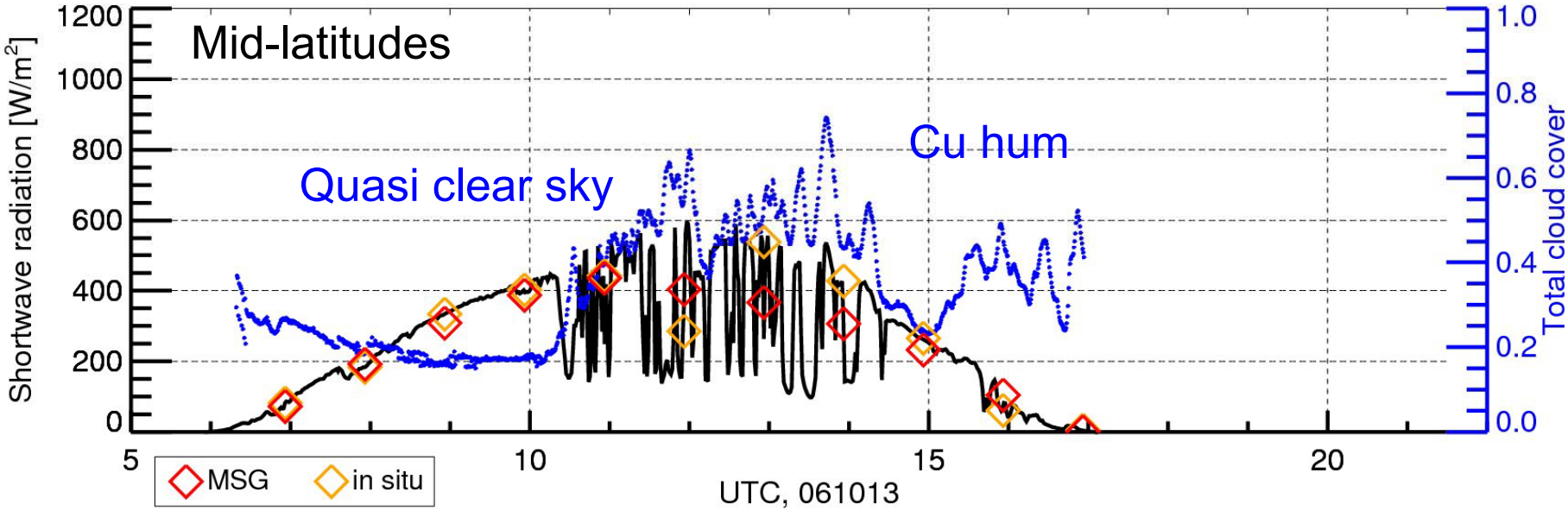
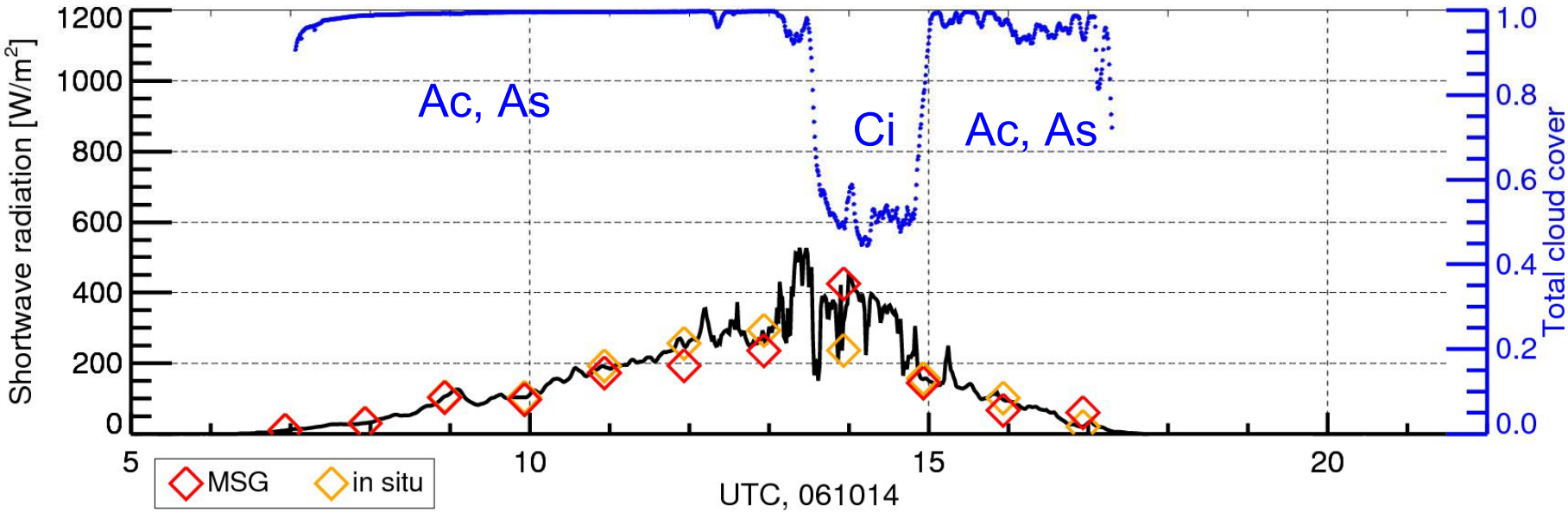
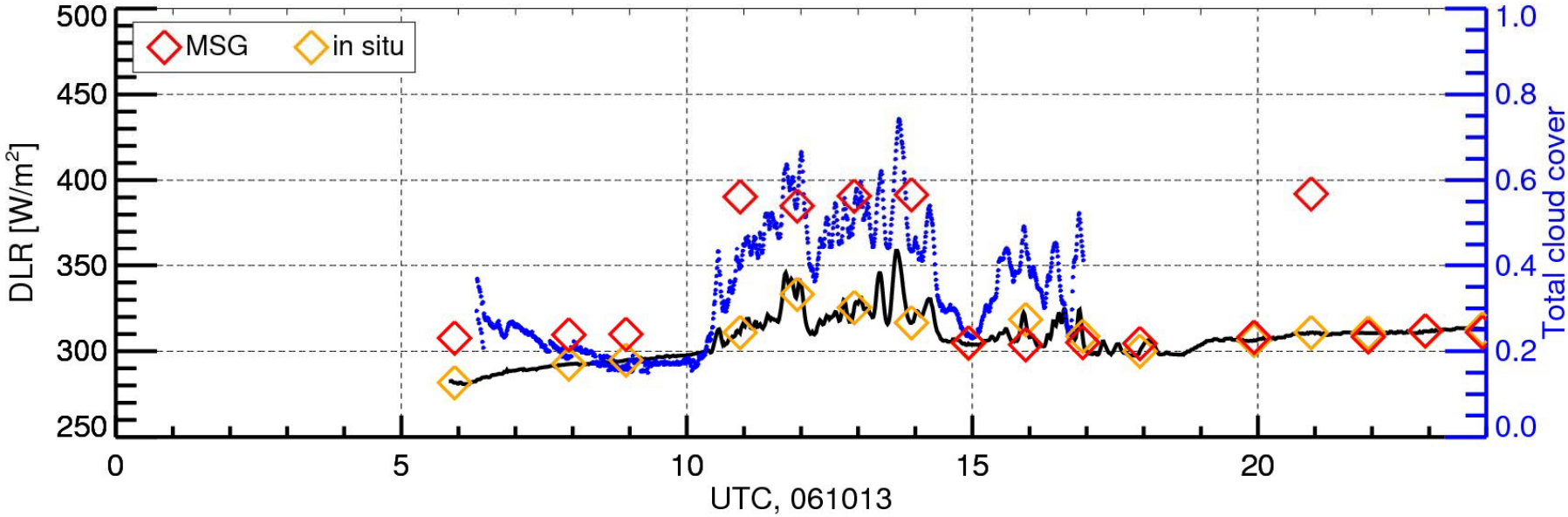
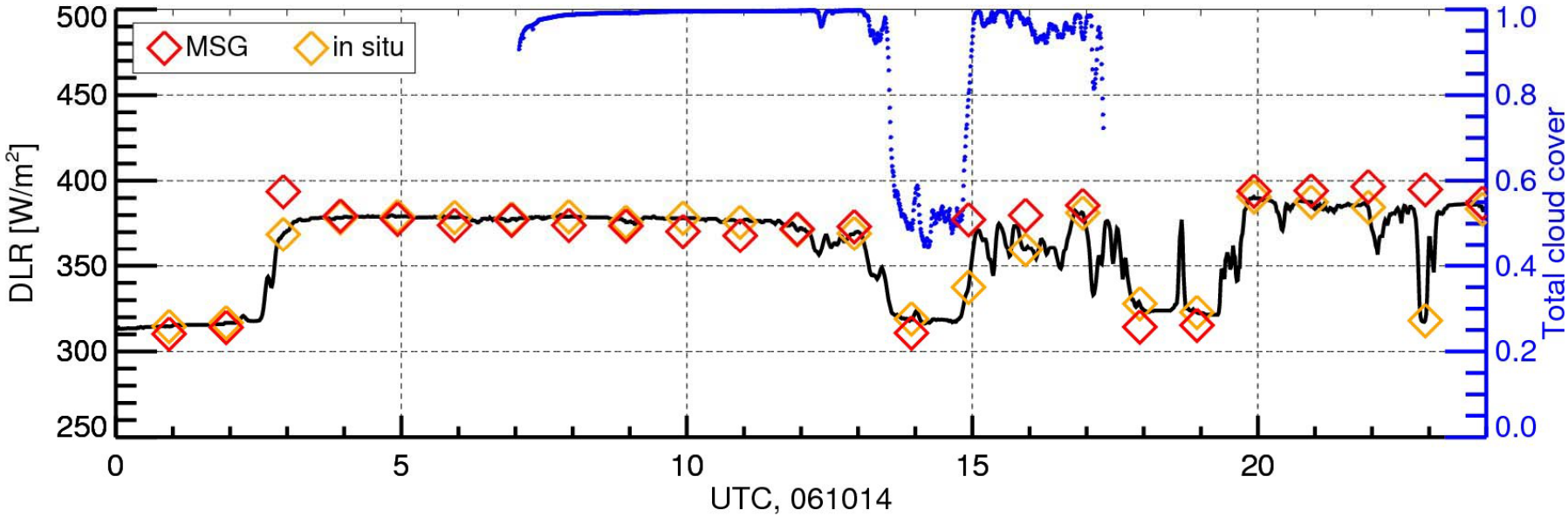
Downwelling Shortwave Radiation DSR





Downwelling Longwave Radiation DLR





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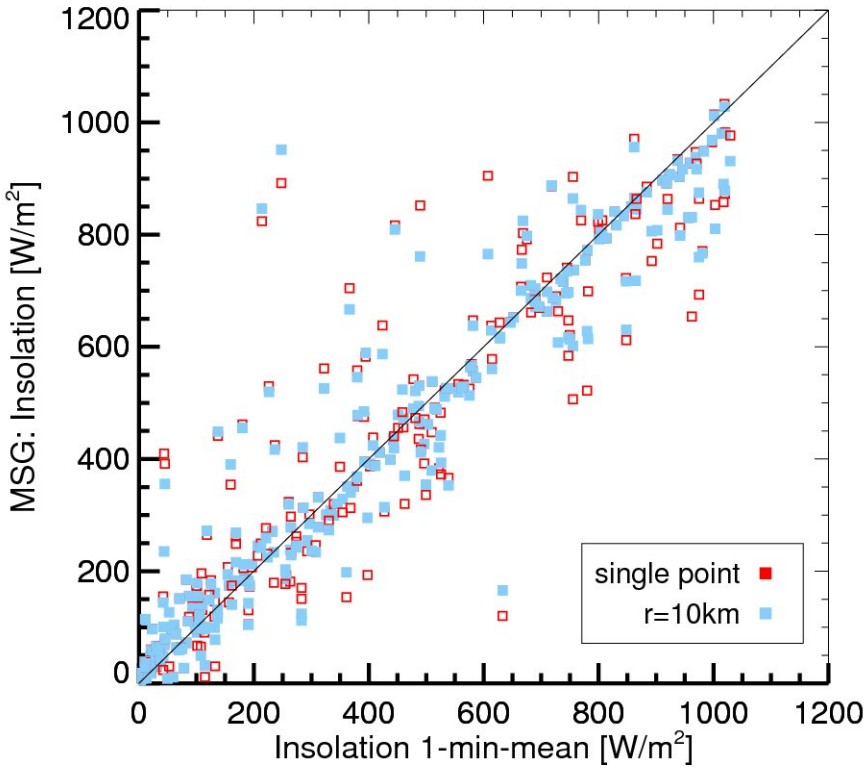
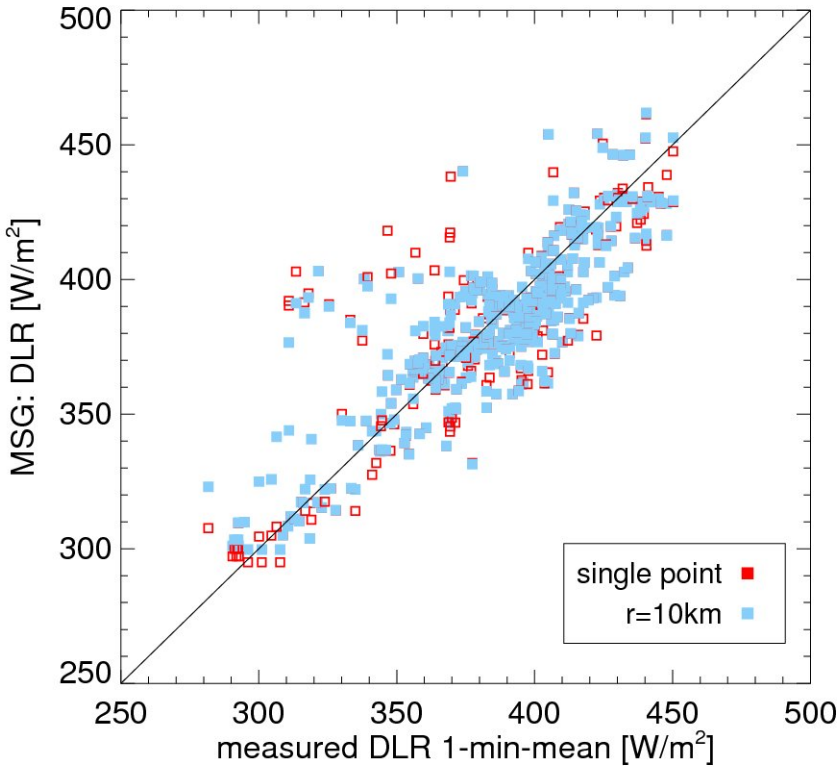
Correlations
MSG versus ship measurements





solar **thermal**

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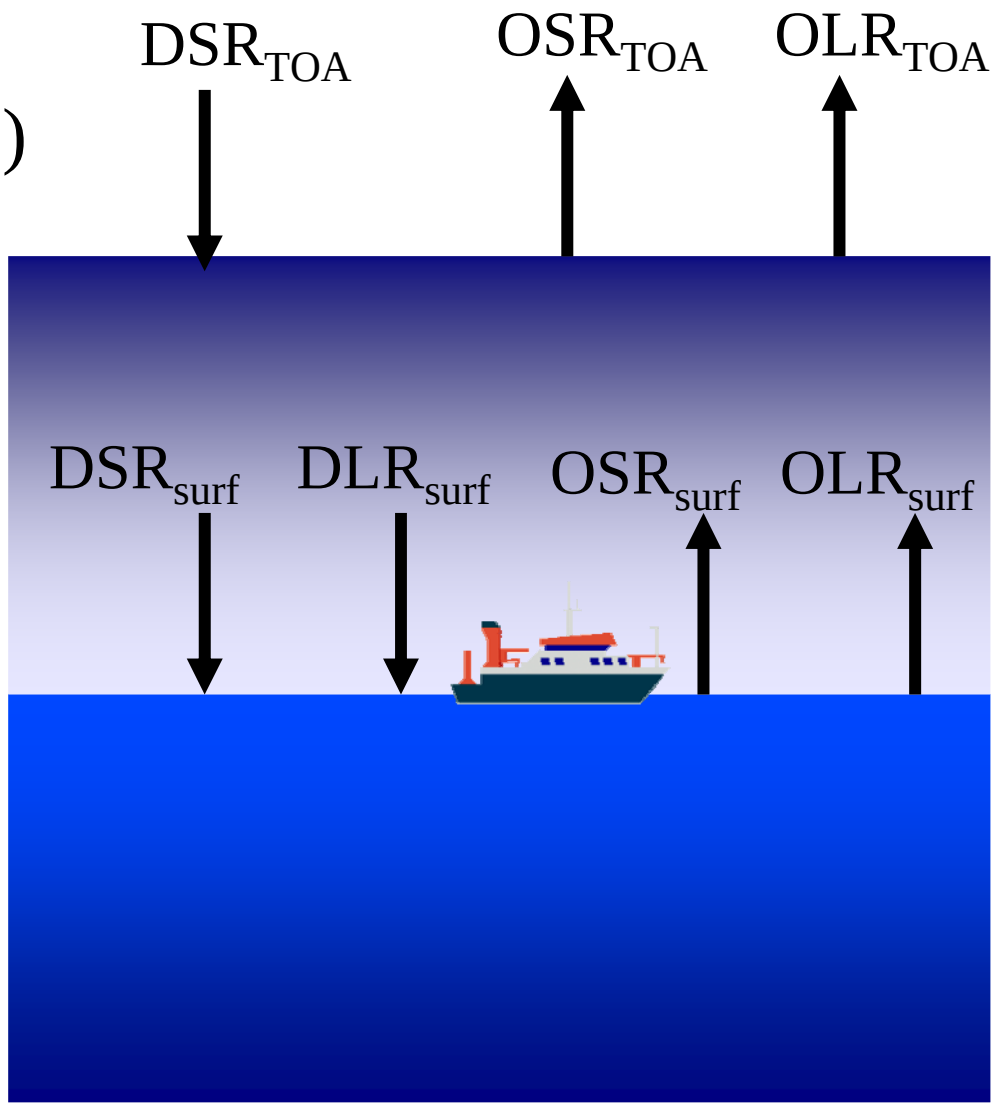
Cloud Radiative Effects

- DSR: Downwelling Shortwave Radiation
- OSR: Outgoing Shortwave Radiation
- DLR: Downwelling Longwave Radiation
- OLR: Outgoing Longwave Radiation

Cloud Radiative Effects: **Radiation** Parameter

- Top Of Atmosphere (MSG)
  - $DSR_{TOA} = S_0 \cos \theta_0$
  - $DLR_{TOA} = 0$
  - OSR_{TOA}
  - OLR_{TOA}
- Surface (Polarstern)
  - $DSR_{surface}$
  - $DLR_{surface}$
  - $OSR_{surface} = f(\theta_0, v)$
  - $OLR_{surface} = \sigma T^4$



Cloud Radiative Effects: **Cloud** Parameter

- Surface (Polarstern)
  - Cloud Cover
  - Cloud Type
  - Cloud Bottom Height & Temperature
  - Liquid Water Path (warm nonprecip. clouds)
- Top Of Atmosphere (MSG)
  - CM-SAF Products

Cloud Radiative Effects: **Cloud** Parameter

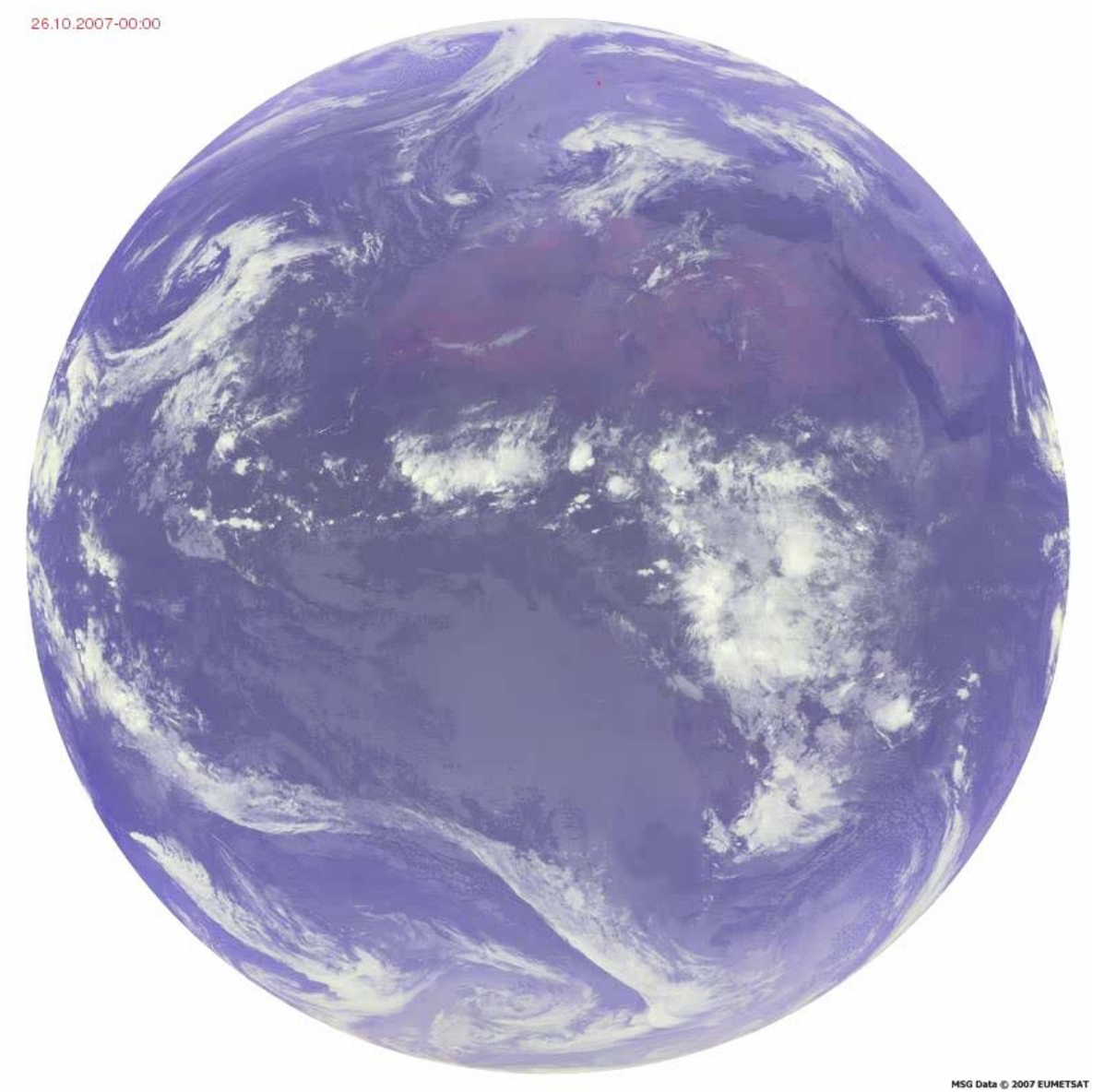
- Surface (Polarstern)
  - Cloud Cover
  - Cloud Type
  - Cloud Bottom Height & Temperature
  - Liquid Water Path (warm nonprecip. clouds)
- Top Of Atmosphere (MSG)
  - CM-SAF Products

Not used yet

Cloud Radiative Effects: Definitions

- Shortwave Radiation Budget: DSR - OSR
- Longwave Radiation Budget: DLR - OLR
- Net Radiation Bugdet : SW Bugdet + LW Budget
- Atmosphere Budget: TOA Budget – Surface Budget
- Cloud Effect: Budget (all sky) – Budget (clear sky)
- Clear sky budget from
  - Parameterizations (surface)
  - Nearest clear sky pixel (MSG)

Polarstern Cruise ANT-24-1



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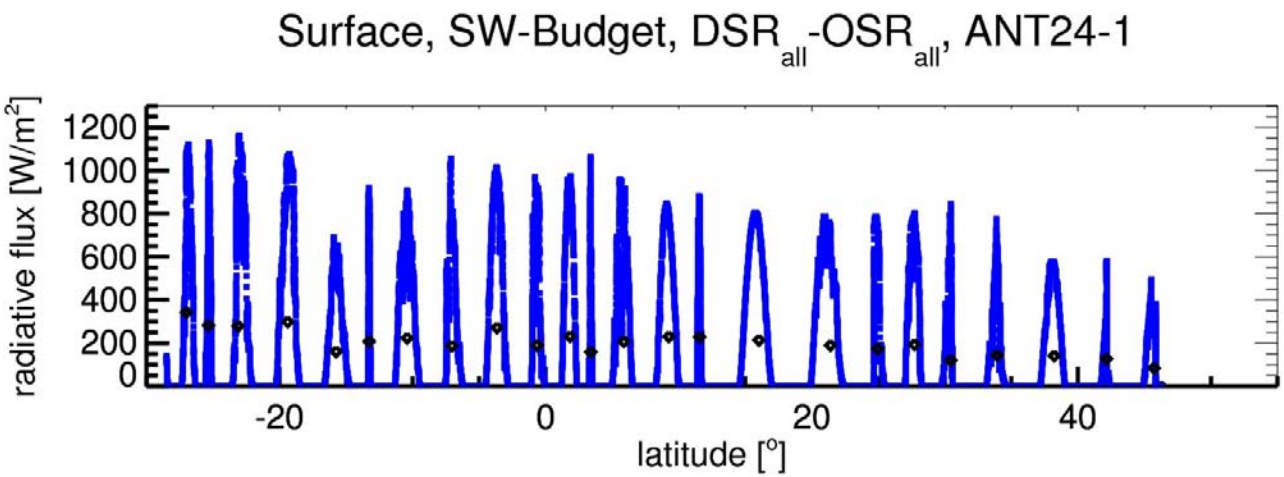
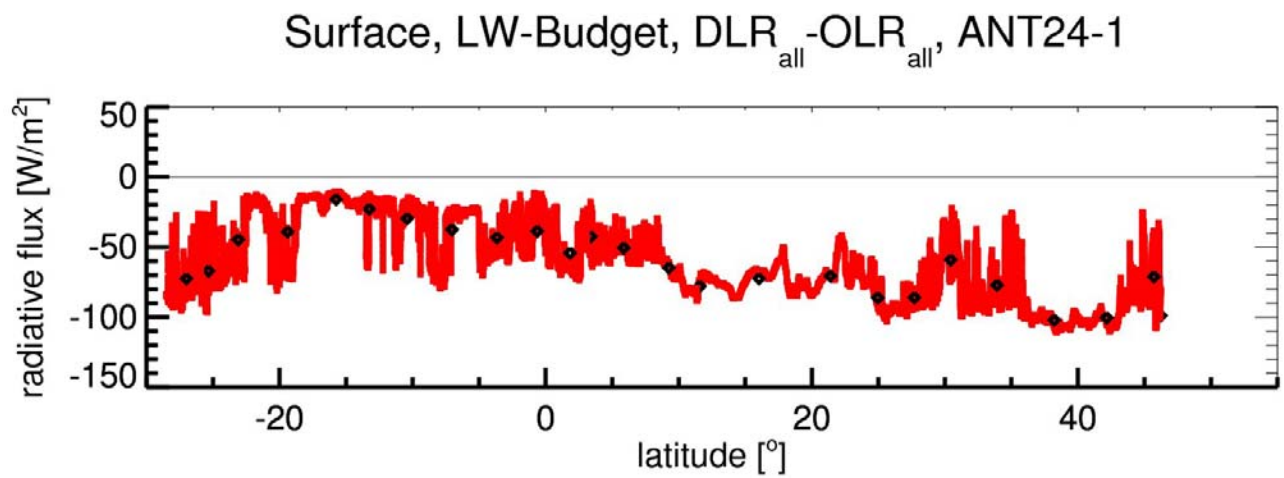

Surface, SW-Budget, DSR all -OSR all, ANT24-1
radiative flux [W/m2]
1200
1000
800
600
400
200
0
-20
0
20
40
latitude [o]


Surface, LW-Budget, DLR all -OLR all, ANT24-1
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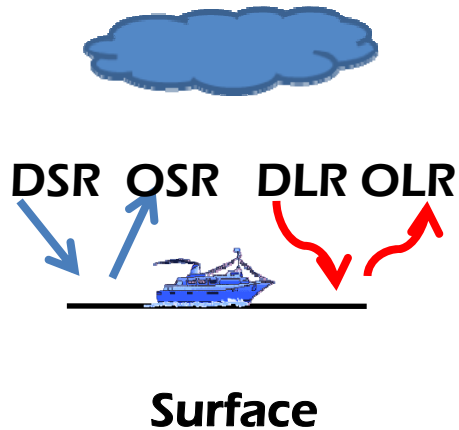
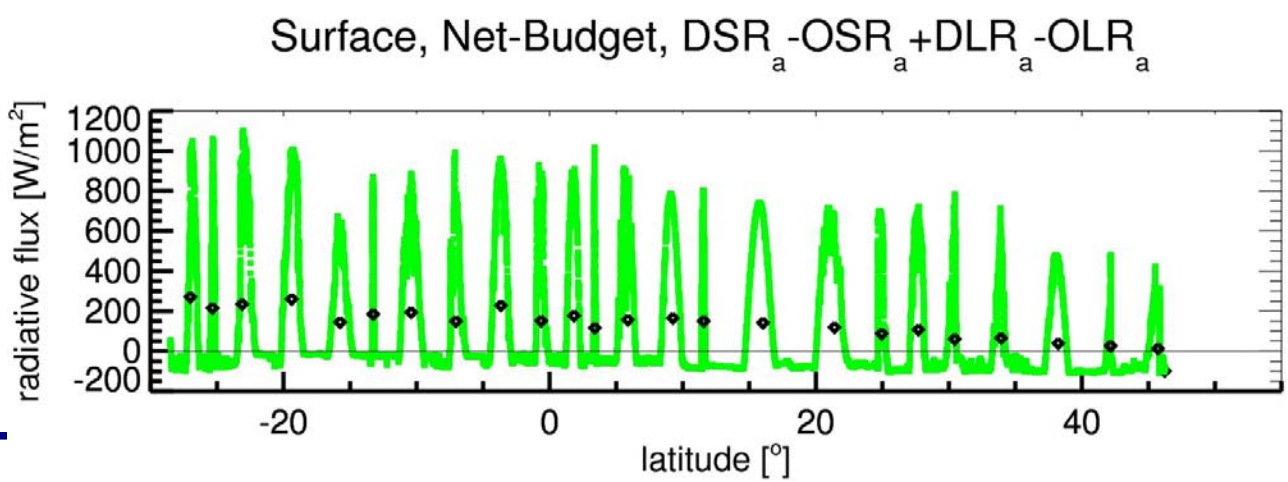
50
0
-50
-100
-150
-20
0
20
40
latitude [o]


DSR OSR DLR OLR
Surface


Surface, Net-Budget, DSR a -OSR a +DLR a -OLR a
radiative flux [W/m2]
1200
1000
800
600
400
200
0
-200
-20
0
20
40
latitude [o]

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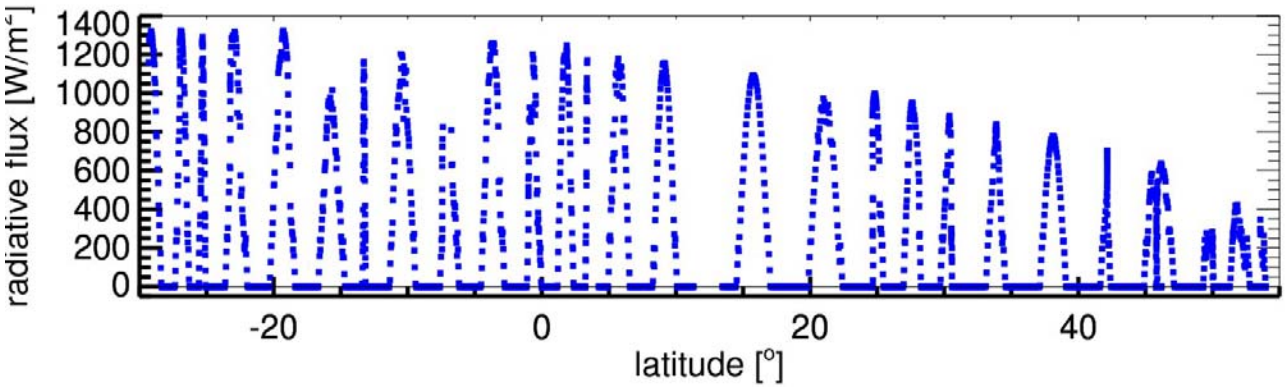
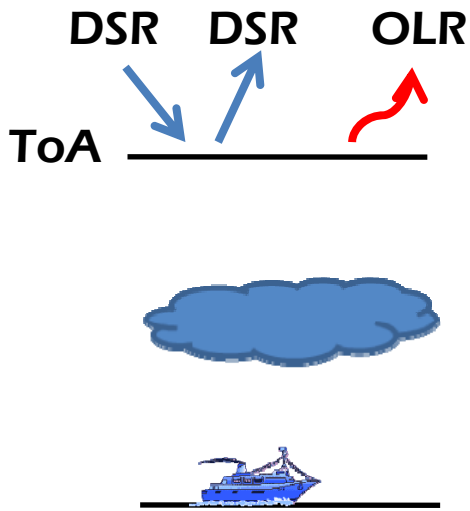
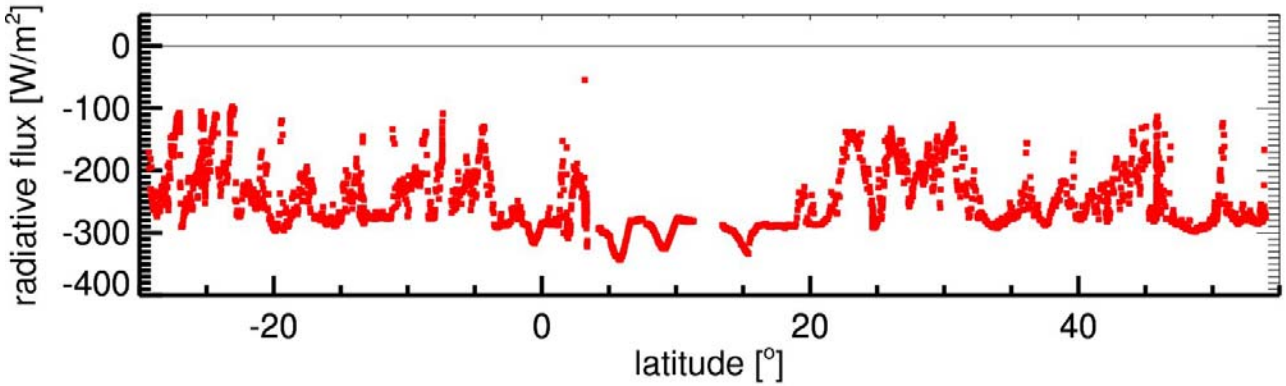
ToA, SW Energy Budget [DSR - OSR] ANT24-1

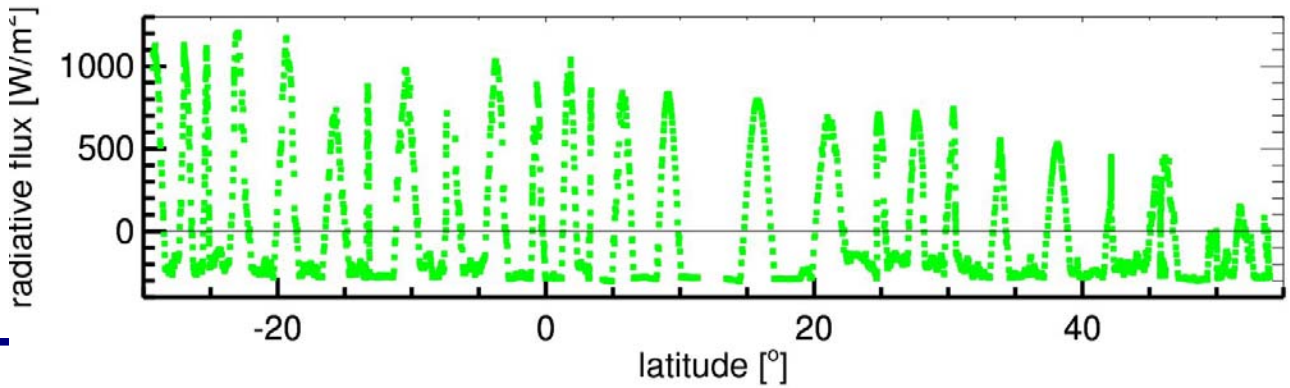




ToA, LW Energy Budget [DLR - OLR] ANT24-1



ToA, Net Energy Budget [DSR + DLR - OSR - OLR] ANT24-1



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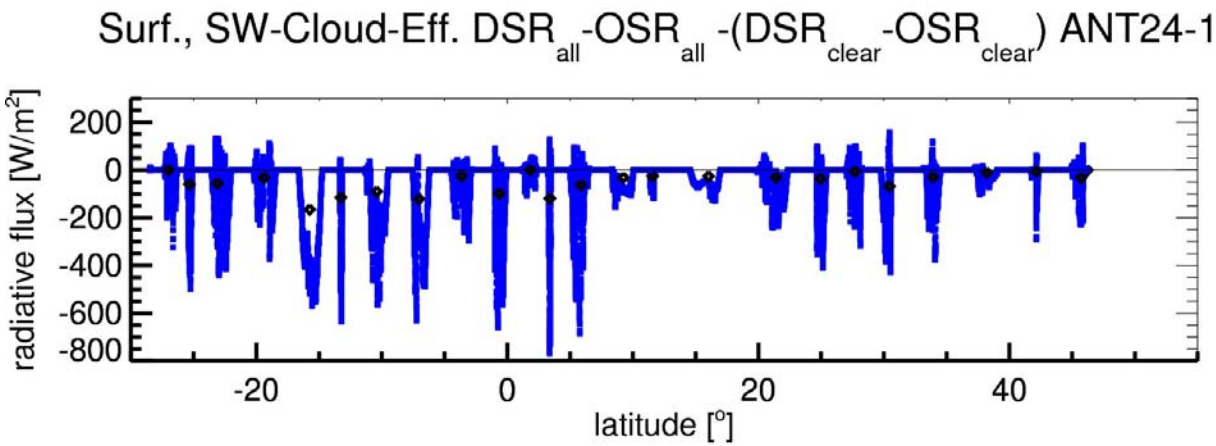
Cloud Radiation Effect at the Surface



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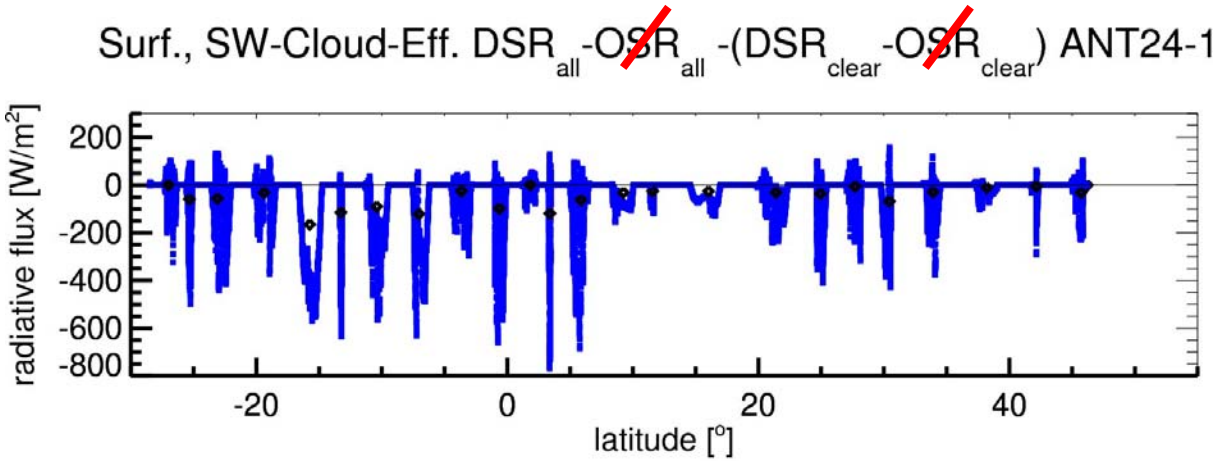
Cloud Radiation Effect at the Surface



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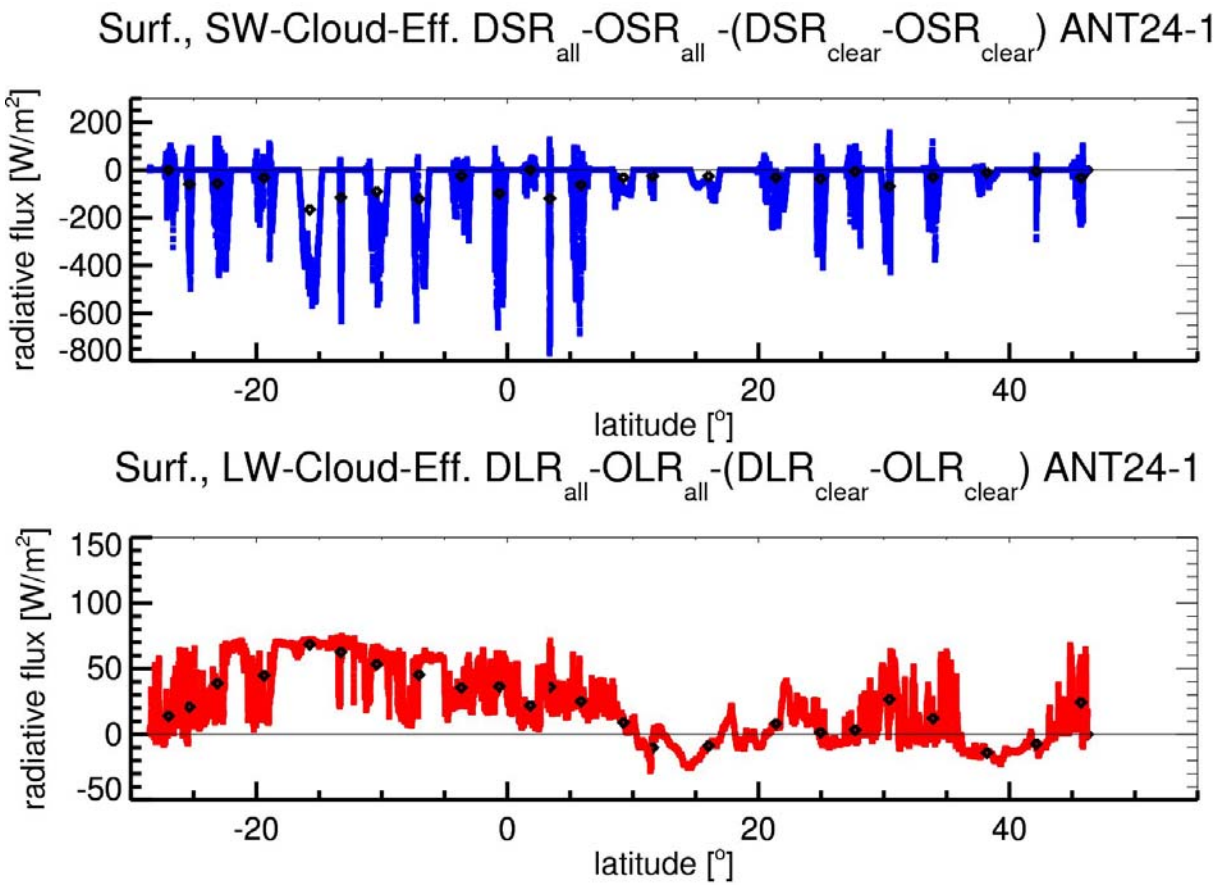
Cloud Radiation Effect at the Surface



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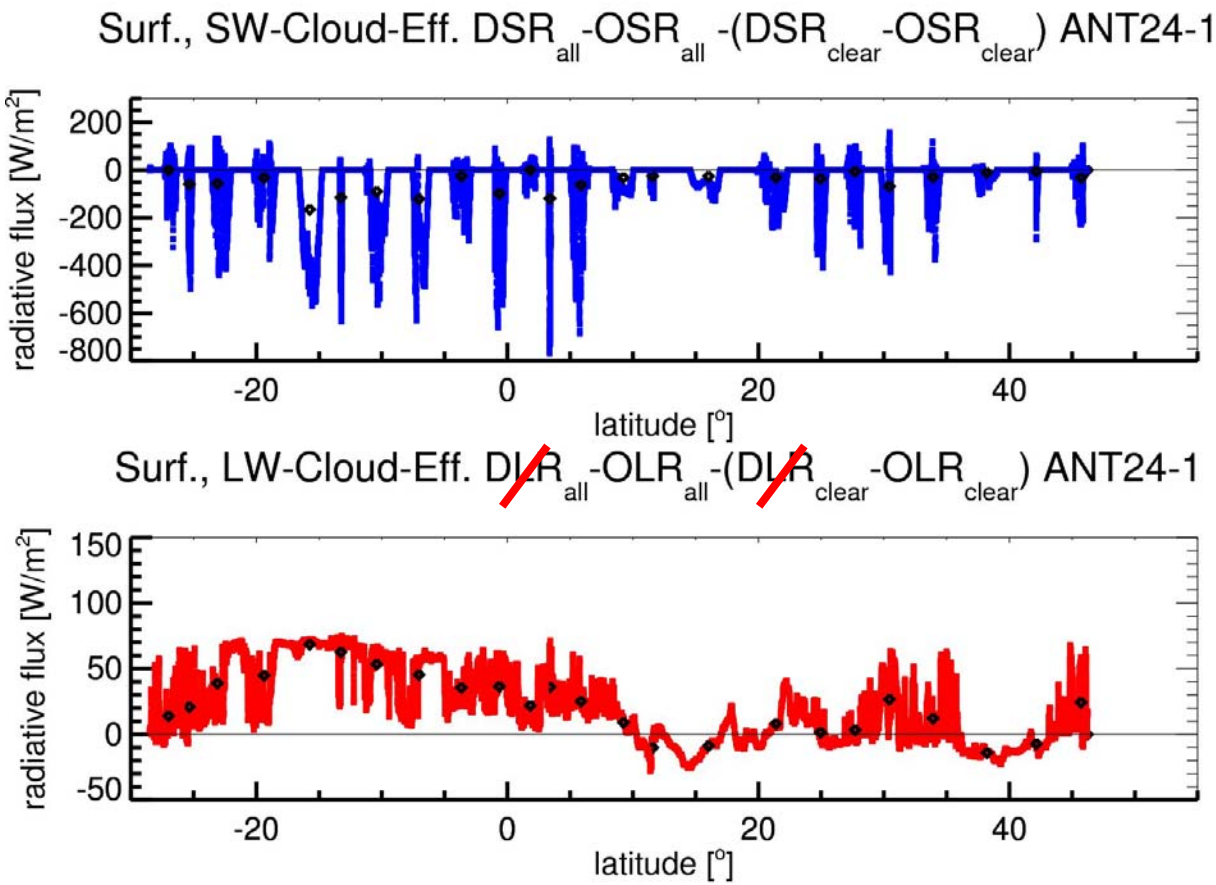
Cloud Radiation Effect at the Surface



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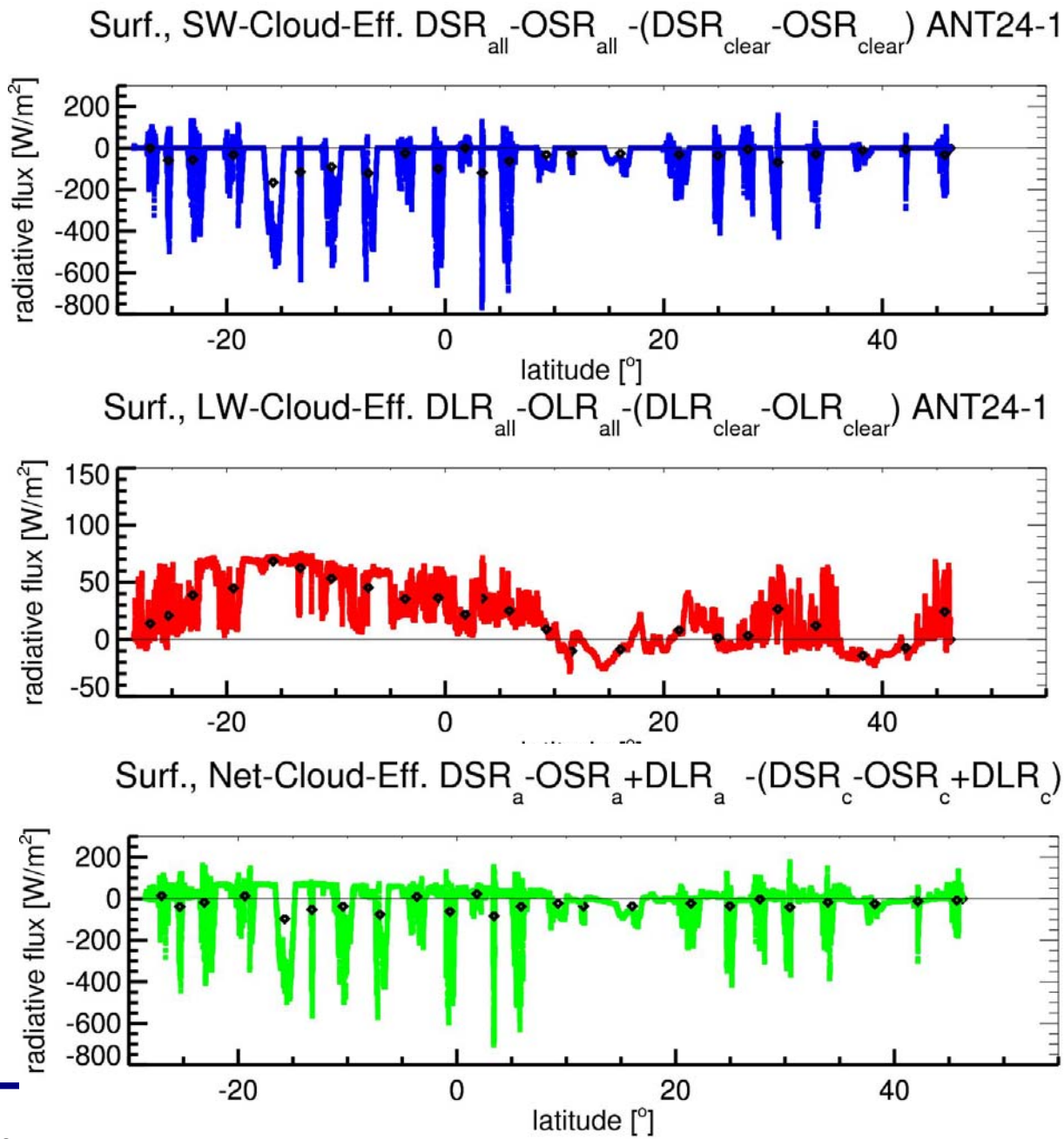
Cloud Radiation Effect at the Surface



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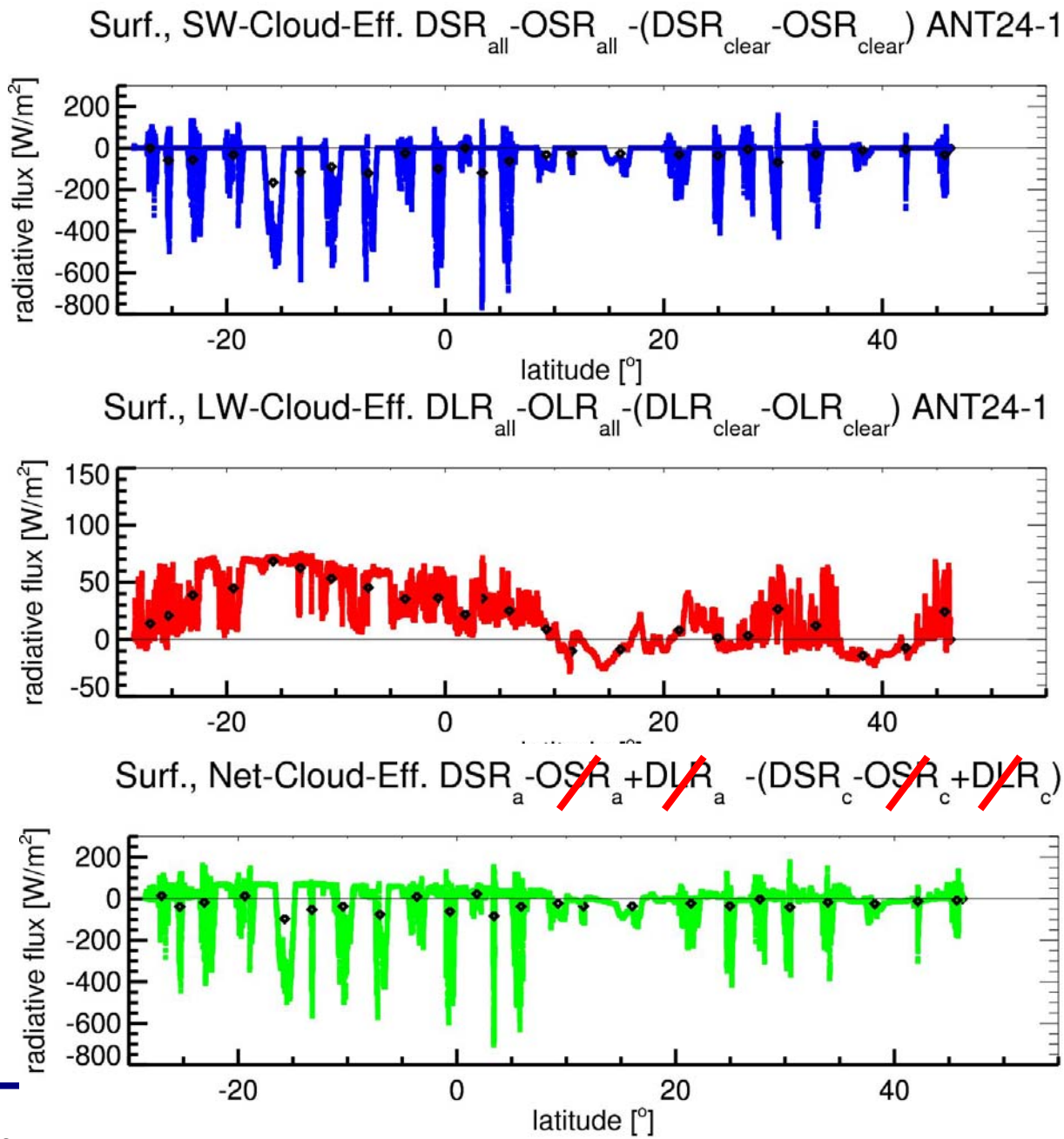
Cloud Radiation Effect at the Surface



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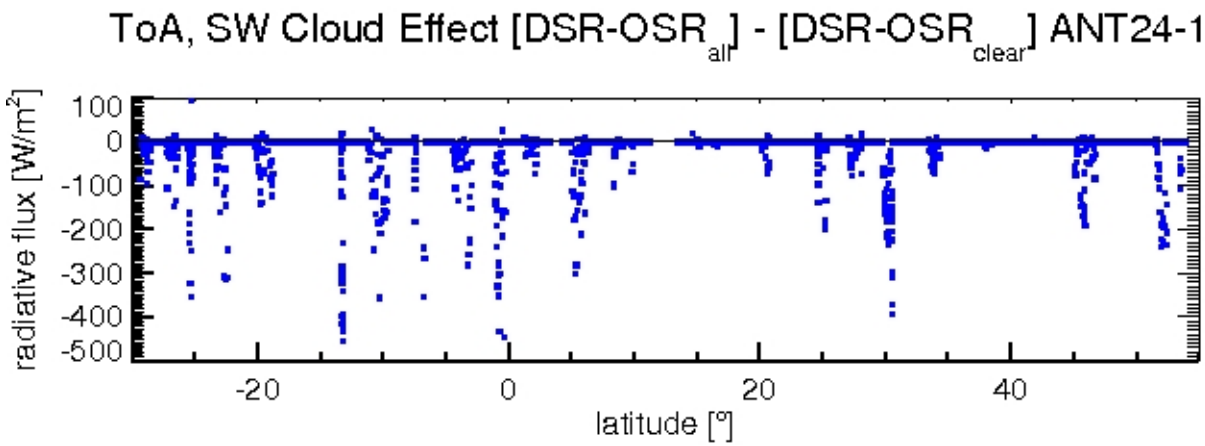
Cloud Radiation Effect at the TOA



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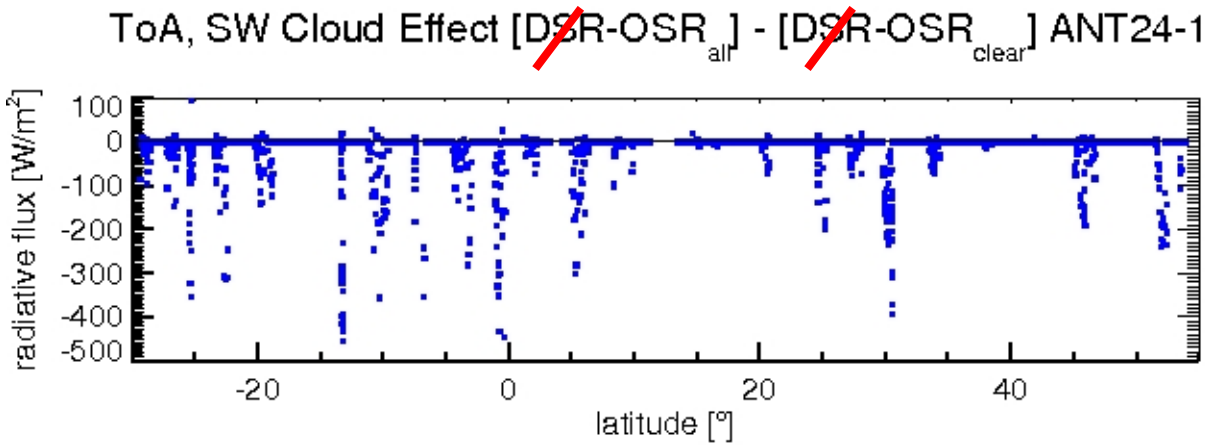
Cloud Radiation Effect at the TOA



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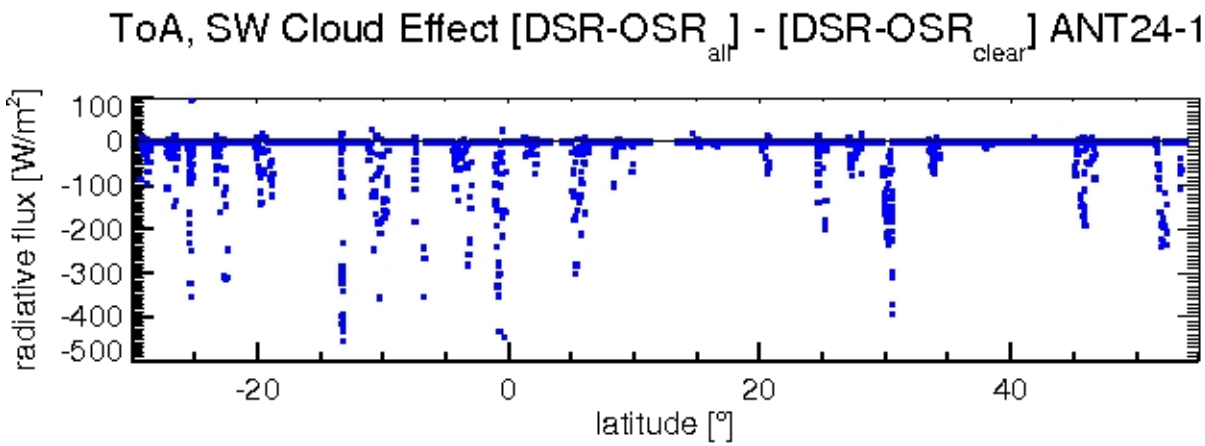
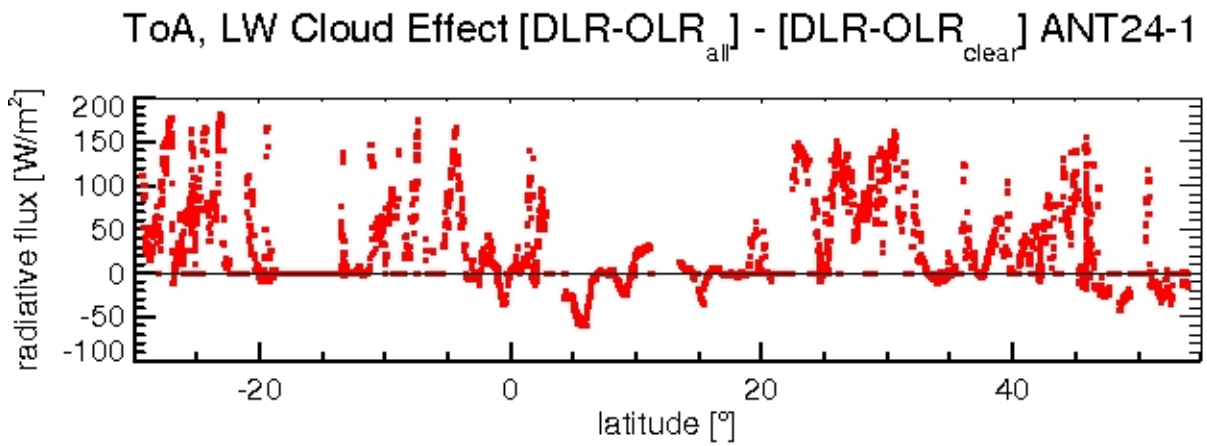
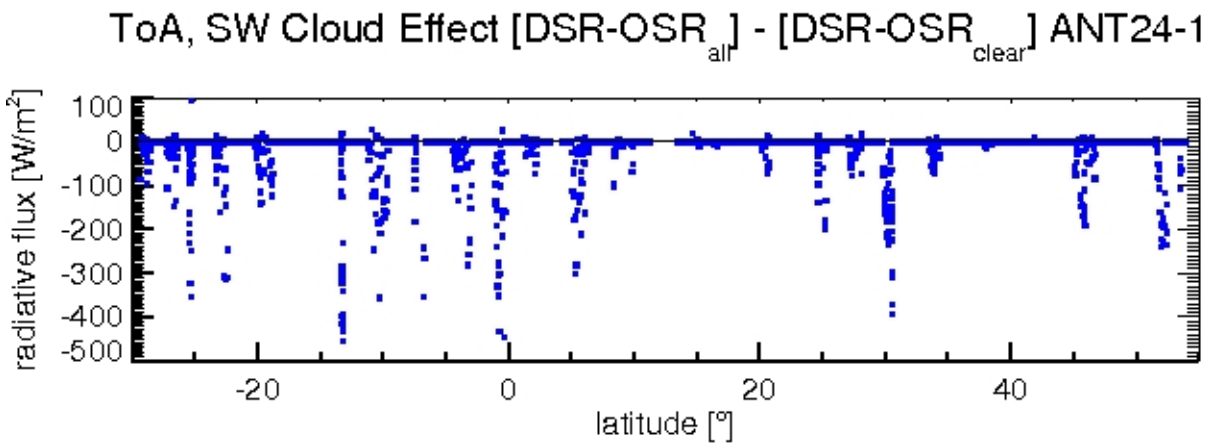
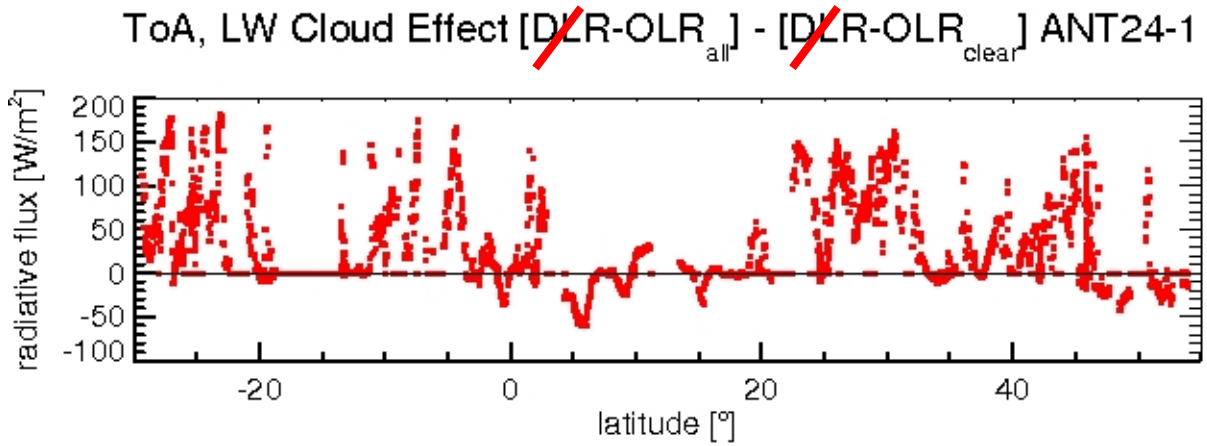
Cloud Radiation Effect at the TOA





Cloud Radiation Effect at the TOA





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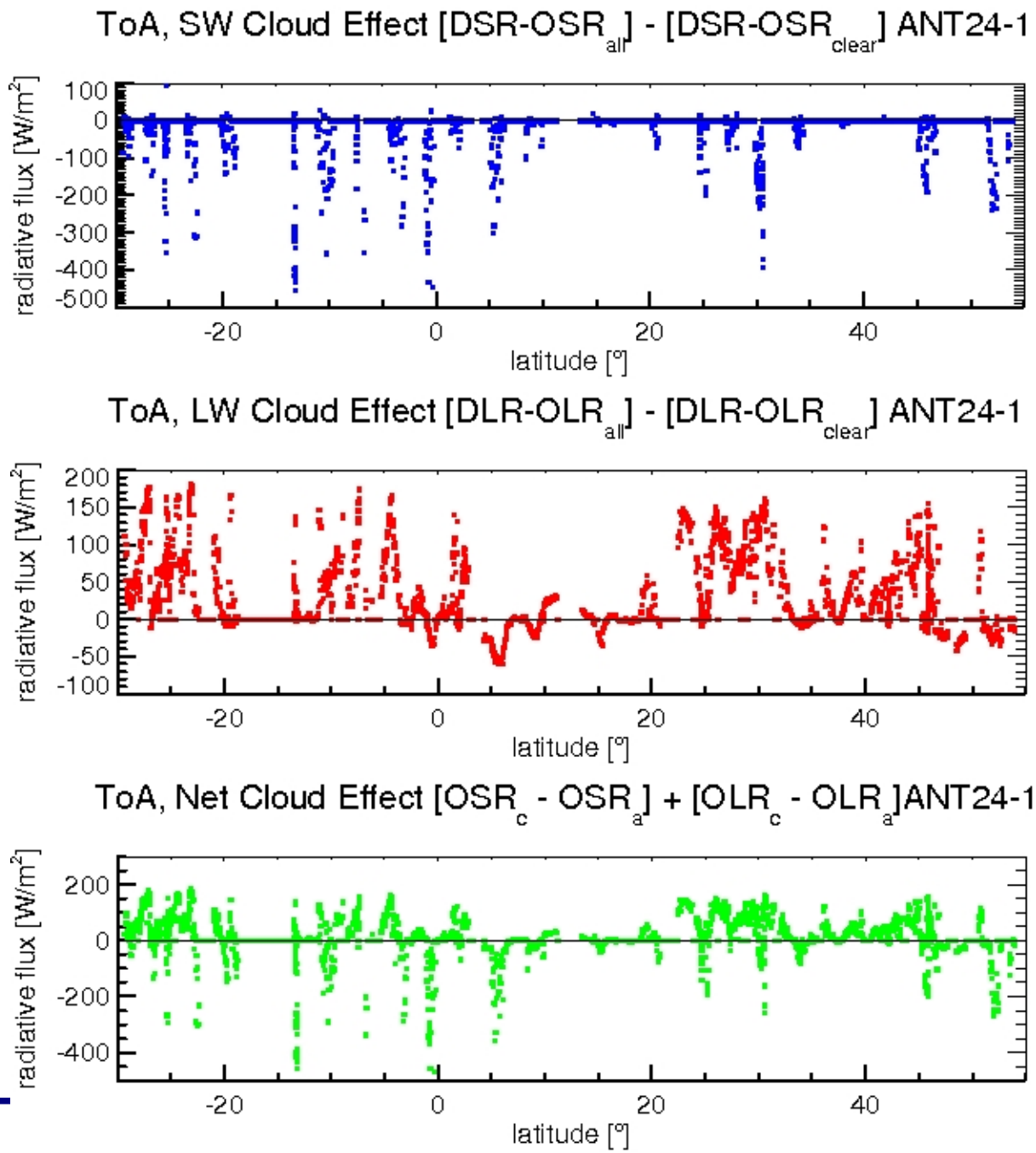
Cloud Radiation Effect at the TOA



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Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)

Atmospheric budget for **cloudy** skies = atm. **cloud** effect (ACE), scale analysis
X_t = flux at top, X_s = flux at surface

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

Atmospheric budget for **cloudy** skies = atm. **cloud** effect (ACE), scale analysis
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

ACRE_night = -OLR_t - DLR_s + OLR_s

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACRE_day: assume OLR_t, DSR_s small (problematic)

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

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Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACE_day: assume OLR_t, DSR_s small (problematic)
-> ACE_day ~= DSR_t - OSR_t - DSR_s + OLR_s

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
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ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACE_day: assume OLR_t, DSR_s small (problematic)
-> ACE_day ~= DSR_t - OSR_t - DSR_s + OLR_s
Almost no absorption in the solar part: DSR_t ~= OSR_t + DSR_s
-> **ACRE_day ~= OLR_s > 0**

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACE_day: assume OLR_t, DSR_s small (problematic)
-> ACE_day ~= DSR_t - OSR_t - DSR_s + OLR_s
Almost no absorption in the solar part: DSR_t ~= OSR_t + DSR_s
-> **ACRE_day ~= OLR_s > 0**

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACE_day: assume OLR_t, DSR_s small (problematic)
-> ACE_day ~= DSR_t - OSR_t - DSR_s + OLR_s
Almost no absorption in the solar part: DSR_t ~= OSR_t + DSR_s
-> **ACRE_day ~= OLR_s > 0**

ACRE_total = ACE_night + ACE_day -> **2*OLR_s - DLR_s > 0**

Atmospheric budget for **cloudy** skies = atm. **cloud** radiation effect (ACRE)
X_t = flux at top, X_s = flux at surface

ACRE = DSR_t - OSR_t - OLR_t - (DSR_s + DLR_s - OSR_s - OLR_s)

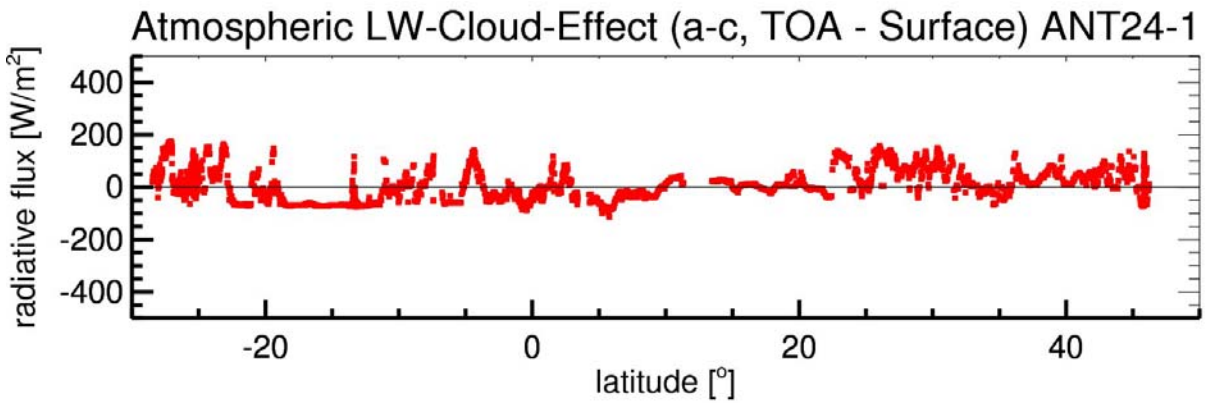
ACRE_night = -OLR_t - DLR_s + OLR_s
Cloud: OLR_t << OLR_s -> **ACRE_night ~= -DLR_s + OLR_s > 0**

ACE_day: assume OLR_t, DSR_s small (problematic)
-> ACE_day ~= DSR_t - OSR_t - DSR_s + OLR_s
Almost no absorption in the solar part: DSR_t ~= OSR_t + DSR_s
-> **ACRE_day ~= OLR_s > 0**

ACRE_total = ACE_night + ACE_day -> **2*OLR_s - DLR_s > 0**

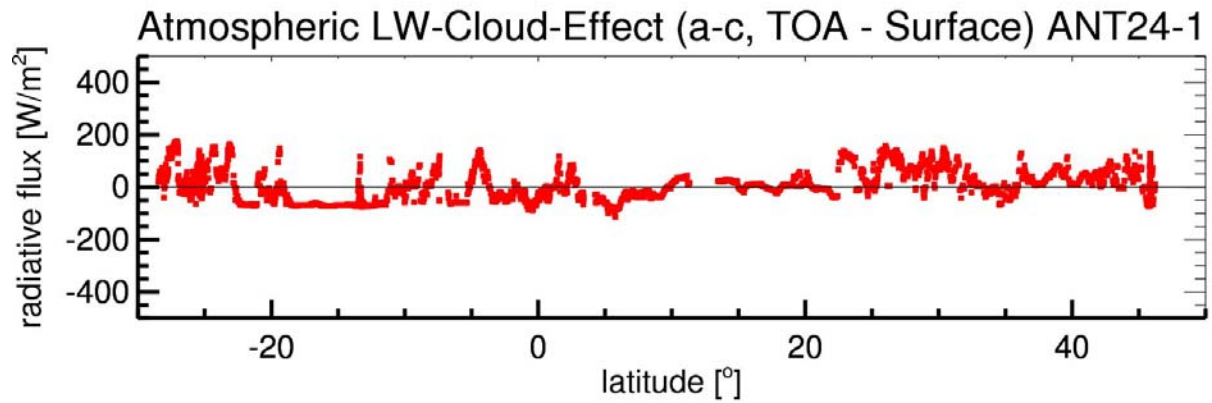
-> The approximate effects of clouds on the atmosphere radiation budget is positive (heating) and is dominated by the longwave radiation fluxes.

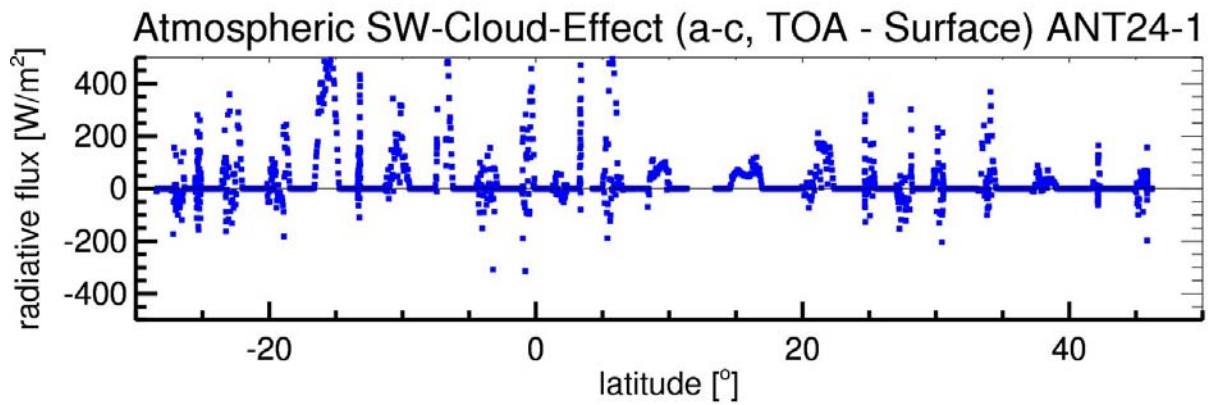
Atmosphere Cloud Radiation Effect



IFM-GEOMAR

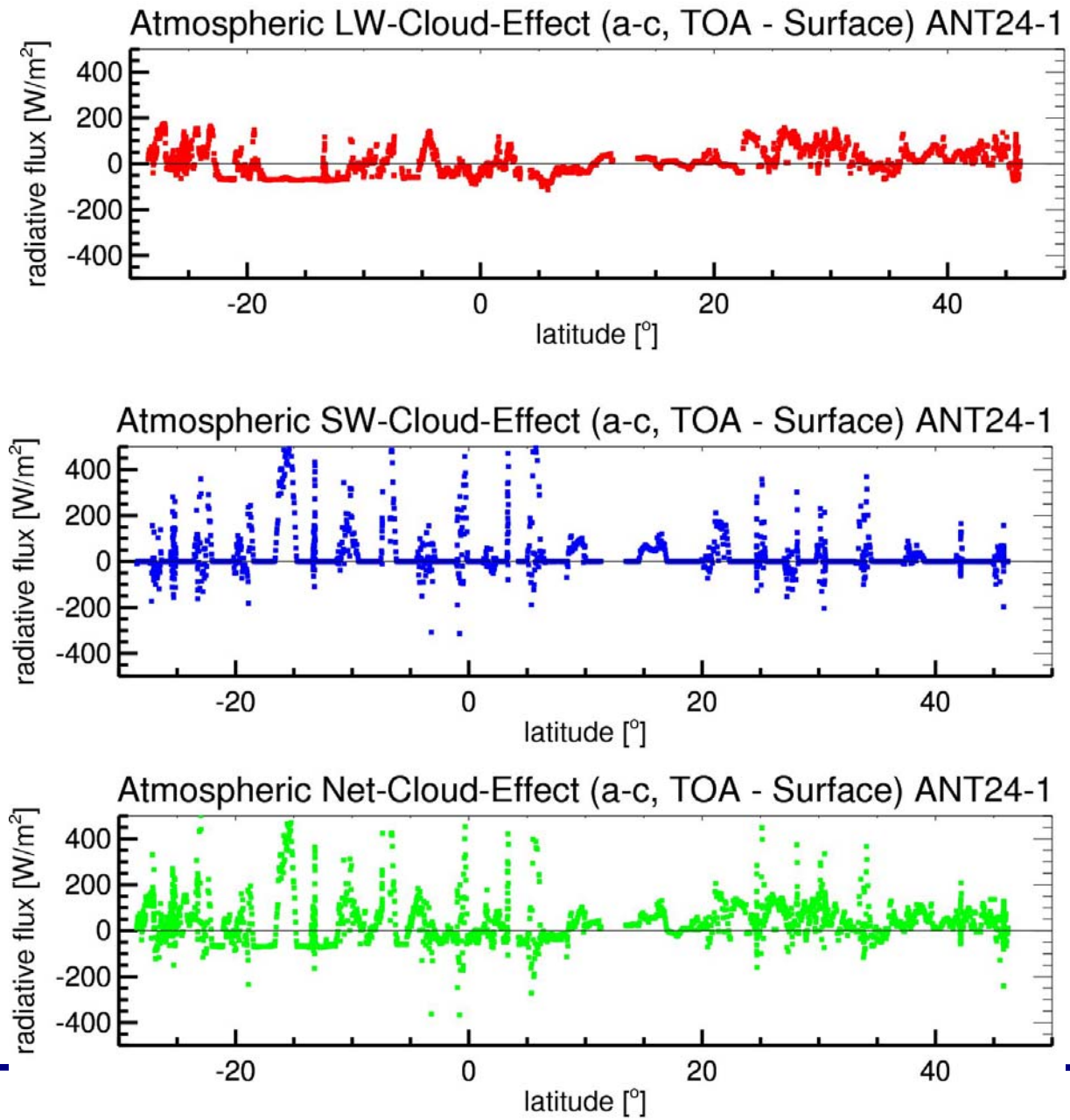
Atmosphere Cloud Radiation Effect

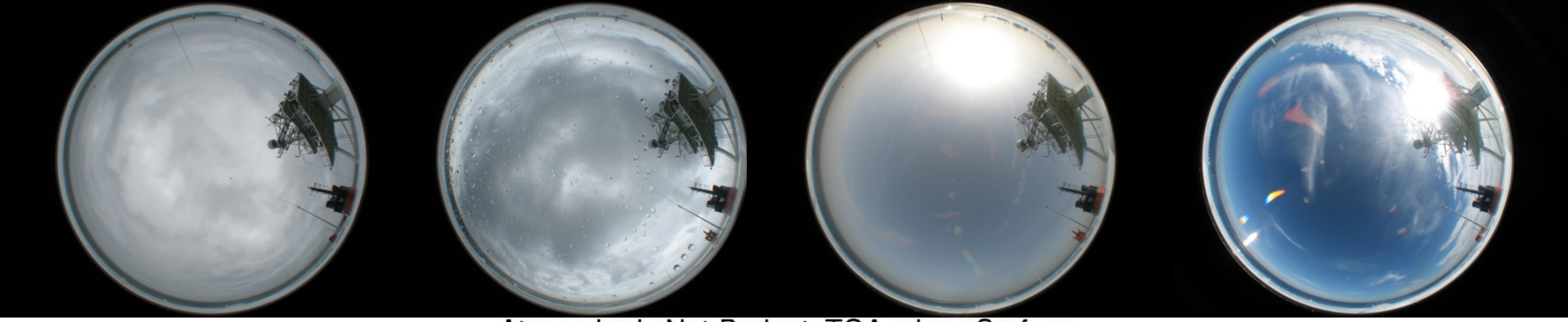


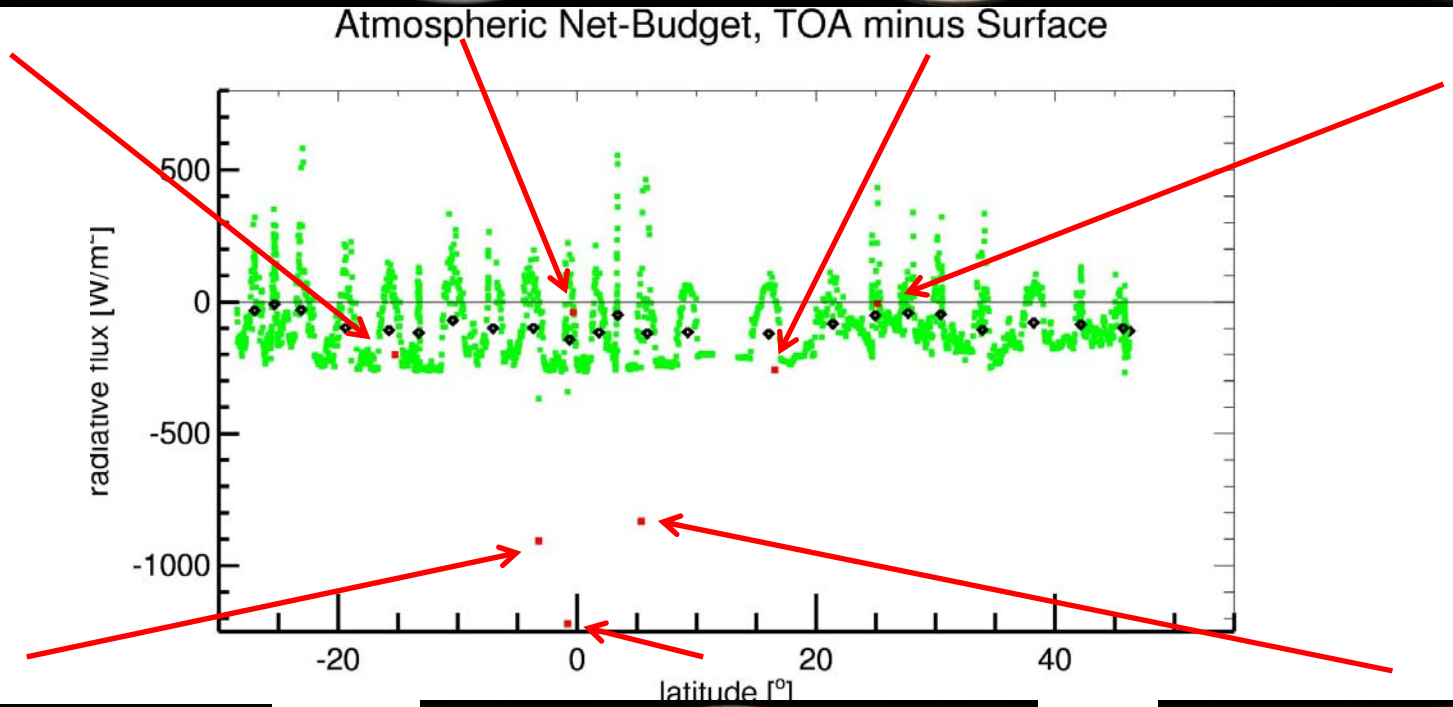


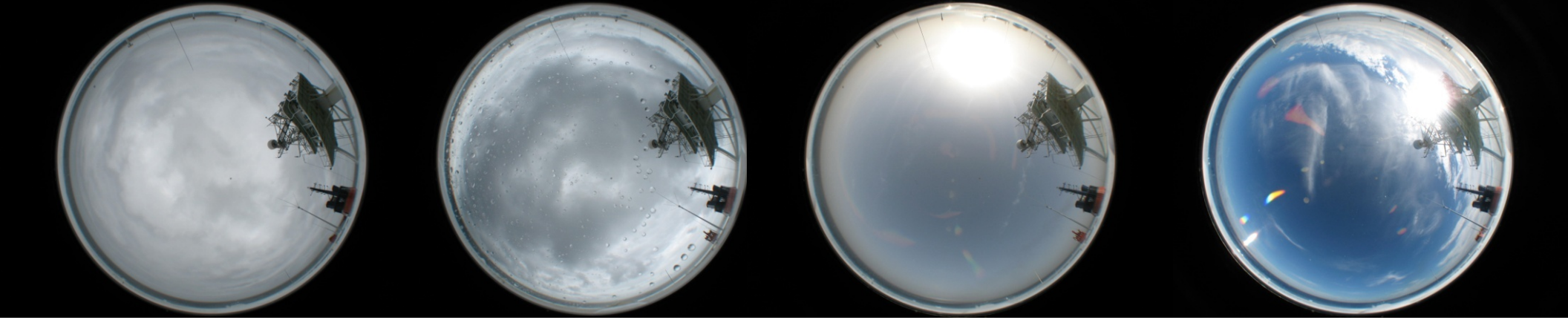
IFM-GEOMAR

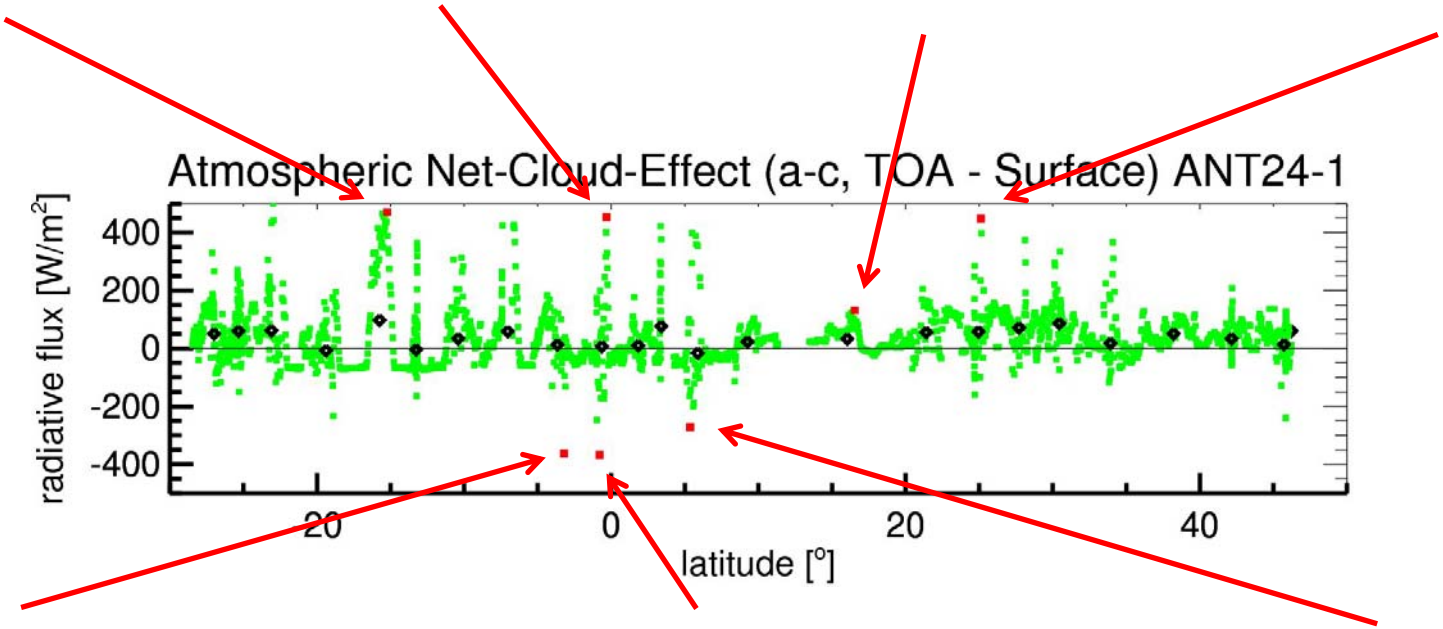
Atmosphere Cloud Radiation Effect

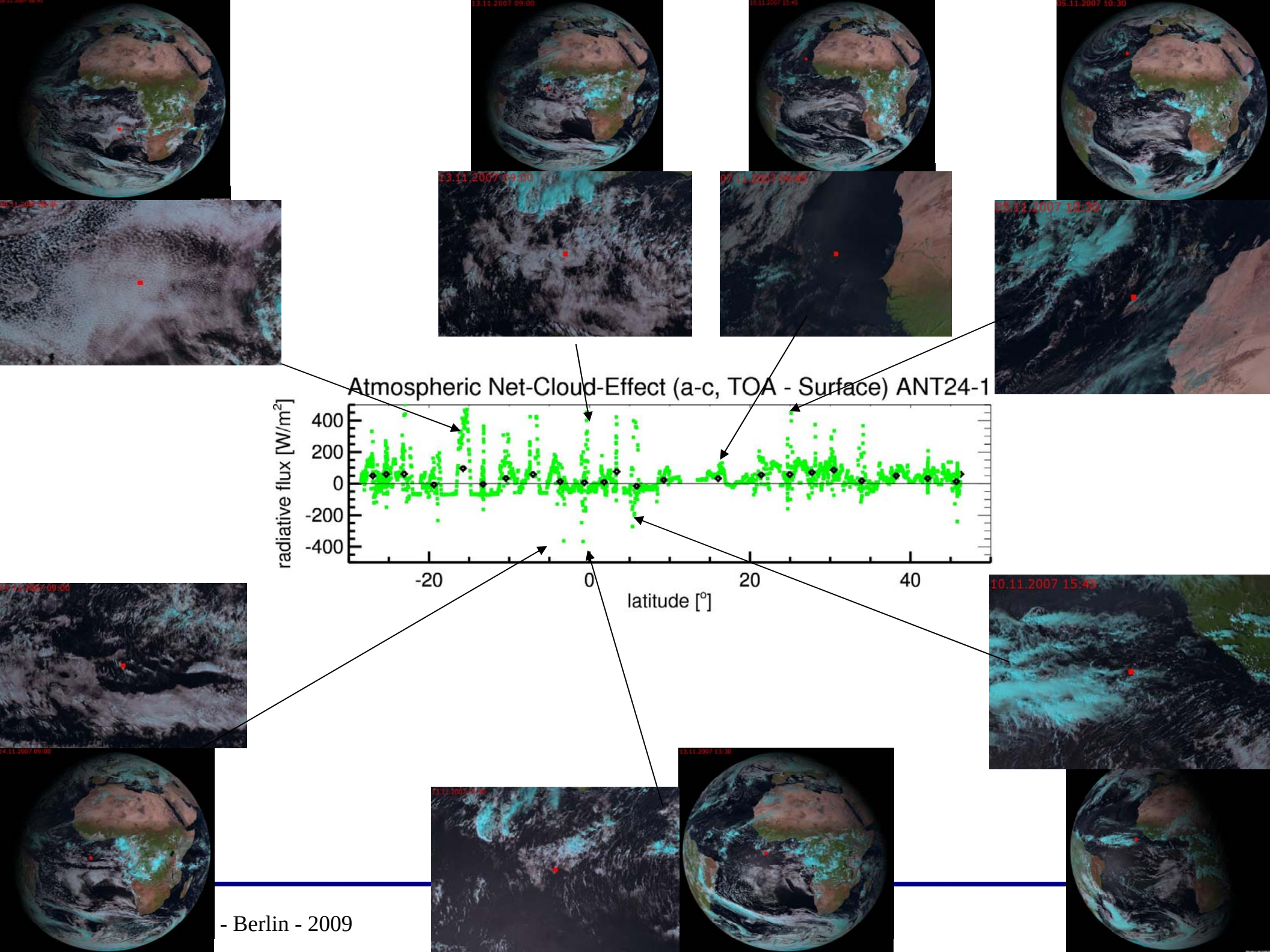





Atmospheric Net-Budget, TOA minus Surface
radiative flux [W/m²]
500
0
-500
-1000
-20
0
20
40
latitude [°]




Atmospheric Net-Cloud-Effect (a-c, TOA - Surface) ANT24-1
radiative flux [W/m²]
400
200
0
-200
-400
20
0
20
40
latitude [°]


Atmospheric Net-Cloud-Effect (a-c, TOA - Surface) ANT24-1
radiative flux [W/m²]
400
200
0
-200
-400
-20
0
20
40
latitude [°]
13.11.2007 09:00
10.11.2007 15:45
05.11.2007 10:30
14.11.2007 09:00
13.11.2007 13:30

Problems

- Clear sky reference fluxes
- Error analysis
- Sampling
- …

Outlook

- Cloud Radiative Effects as Function of Cloud Properties
- Comparison with Climate Models
- Observations in Polar Regions
- More Instruments for Cloud Observations
  - Ground based remote sensing
  - In situ

Addressing the workshop questions

- To ESA: keep on the good work with Meteosat