Environment and Climate Change Canada | Environnement et Changement climatique Canada

LMD | SORBONNE UNIVERSITÉ

EarthCARE's Radiative Closure Assessment Programme

Howard Barker, Jason Cole, Zhipeng Qu, Mark Shephard
Environment and Climate Change Canada, Toronto, Canada

Najda Villefranque
Laboratoire de Météorologie Dynamique (LMD/IPSL), Paris, France

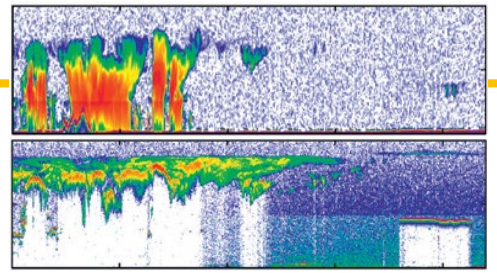
Canada

Living Planet Symposium, Bonn, 23-27 May 2022

1. Radiative Closure Assessment

L1 products (X-MET, etc.)

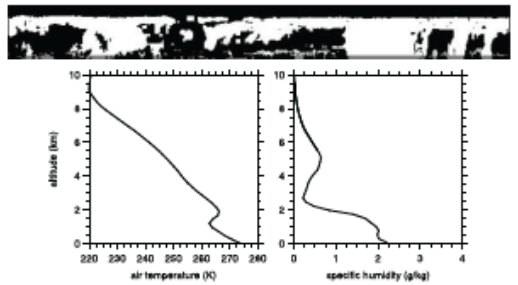
L2a products (CPR, ATLID, MSI)



RT^{-1}: Clouds & aerosols

RT closure assessment

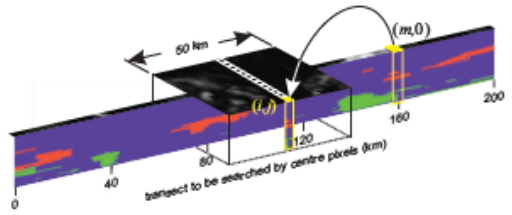
ACM-COM



Set-up of Atmosphere(s)

- Create **L2a composite** atmosphere & surface properties
- Prepare data for ACM-RT, including **ACM-CAP**

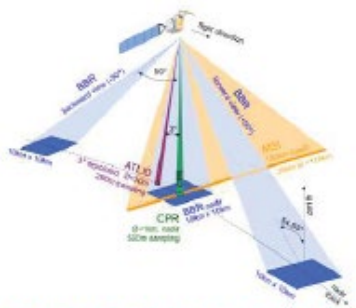
ACM-3D



3D Scene Construction
Assessment Domain Selection

- Construct 3D scenes (1D: ~5 x 21 km) for ACM-RT
- Screen and sample assessment domains

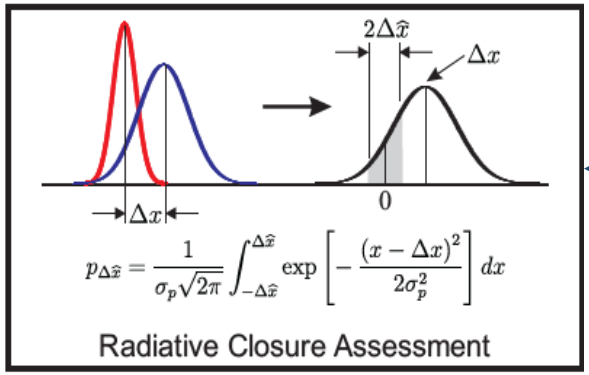
BM-RAD & BMA-FLX



TOA BB Radiances and Fluxes

BBR

ACMB-DF

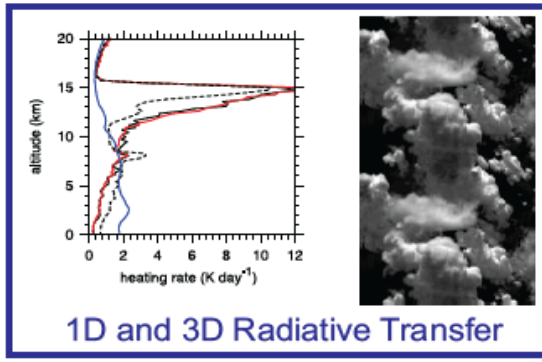


Radiative Closure Assessment

- Compare model radiances to BBR obs
- Compare model fluxes to BMA-FLX: $\Delta x < 10\ W\ m^{-2}$

BBR'

ACM-RT



1D and 3D Radiative Transfer

- Perform 1D and 3D RT calculations (HR profiles)
- TOA radiances and fluxes to be used in ACMB-DF

Agree?

No

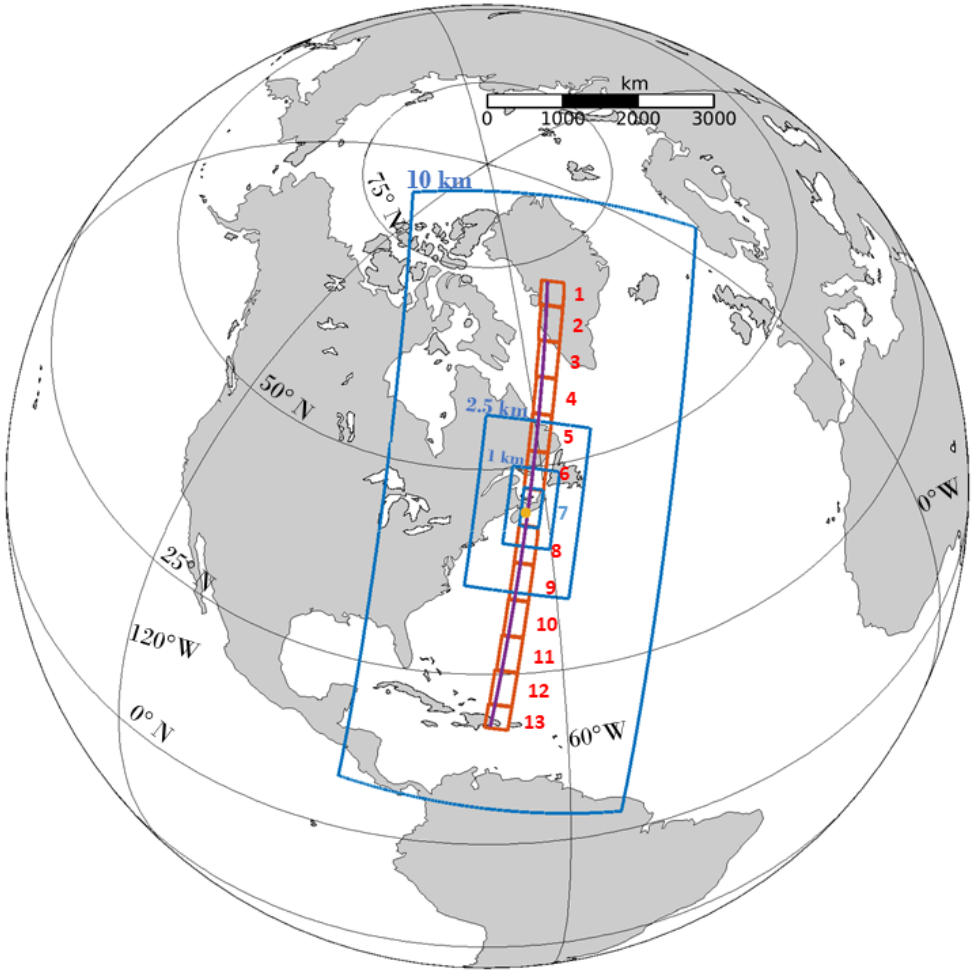
:-O

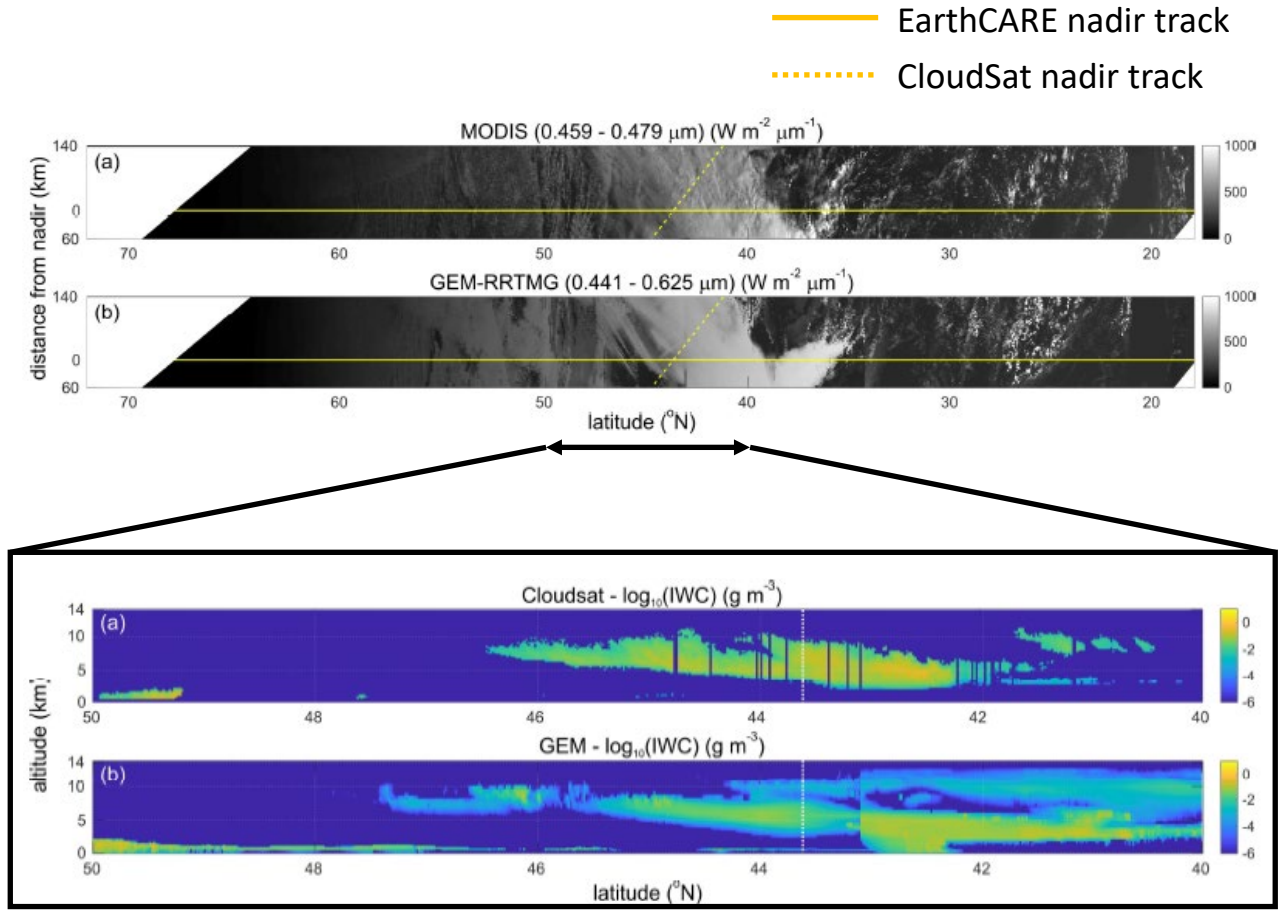
Yes

:-)

2. Test Scenes

Halifax scene (17:30 UTC 2014-12-07)





- ECCC Global Environmental Multiscale (GEM) model
- Δx = 250 m, 57 vertical layers, 200 x 6200 km frames
- Each frame is composed of 13 individual segments

Two other scenes:

- Baja scene: Canadian Arctic to Baja California, continental
- Hawaii scene: central Pacific, tropical MSC (see ACMB-DF)

3. Set-up of Surface-Atmosphere System (ACM-COM)

Purpose: Prepare EarthCARE's L2 products for computation of broadband RT calculation

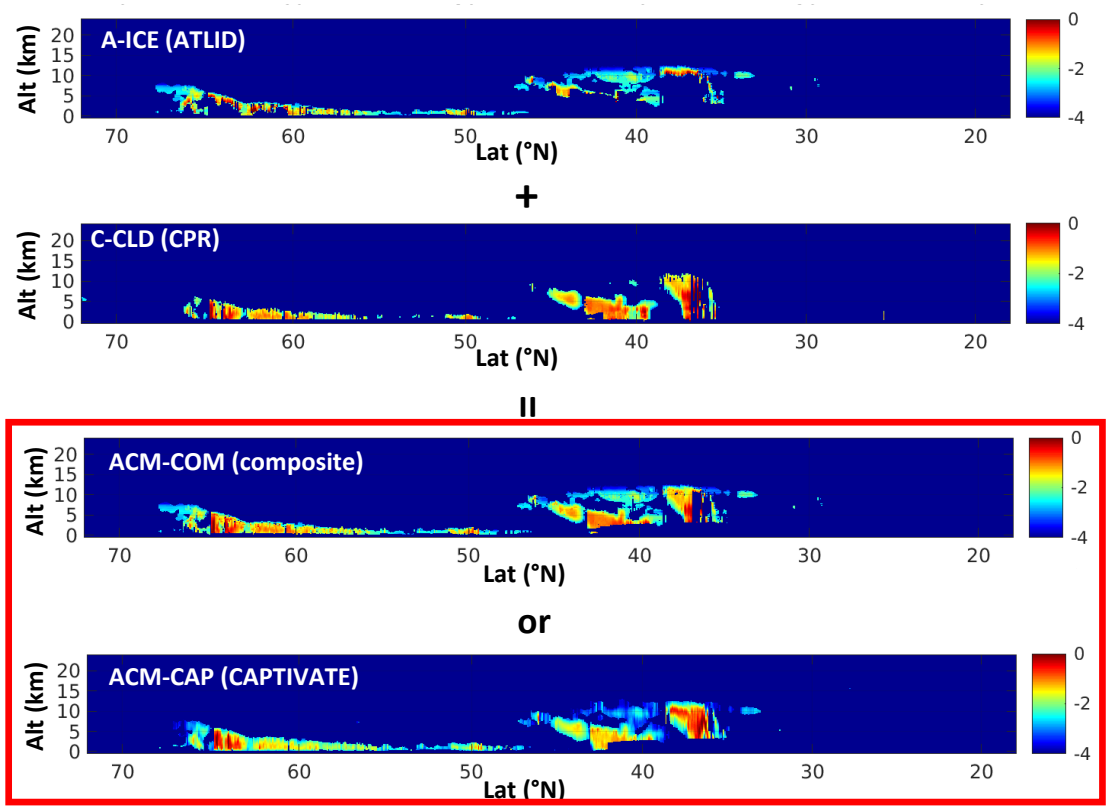
1. **Create an L2a composite atmosphere (in addition to ACM-CAP)**
   - similar to NASA's C3M merged product (Kato et al. 2010)
   - a fall-back "best-estimate" **if and when *CAPTIVATE* fails**

2. **Direct use of L2b synergistic products (ACM-CAP... *CAPTIVATE*)**
   - Hogan, Mason et al.

3. **Prepare other inputs for ACM-RT**
   - Atmospheric conditions (T, Q, etc.)
   - Surface properties (albedo, emissivity, etc.)
   - Extension of atmospheric profiles up to 80 km

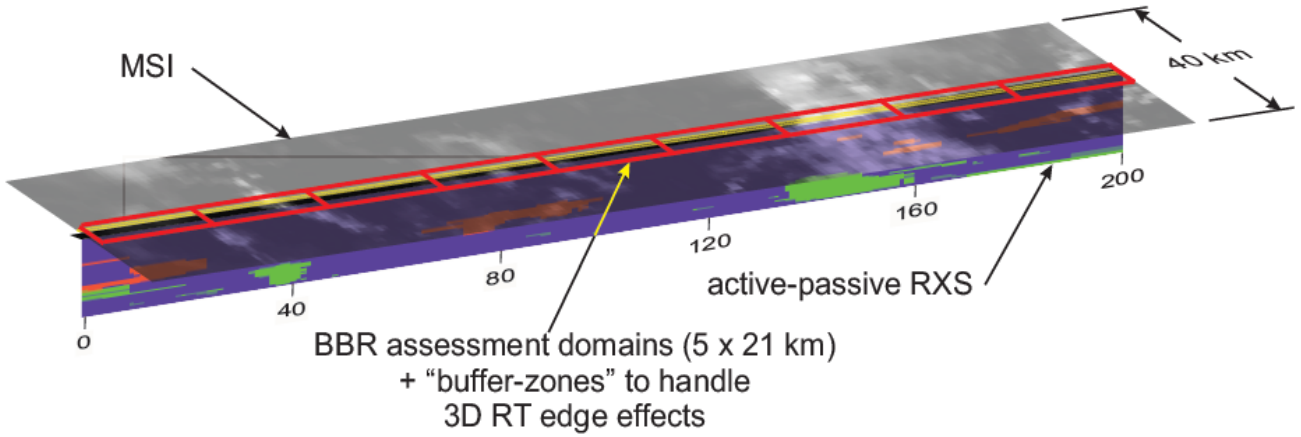
ACM-3D & ACM-RT

Ice water content (g m^{-3}), Halifax scene

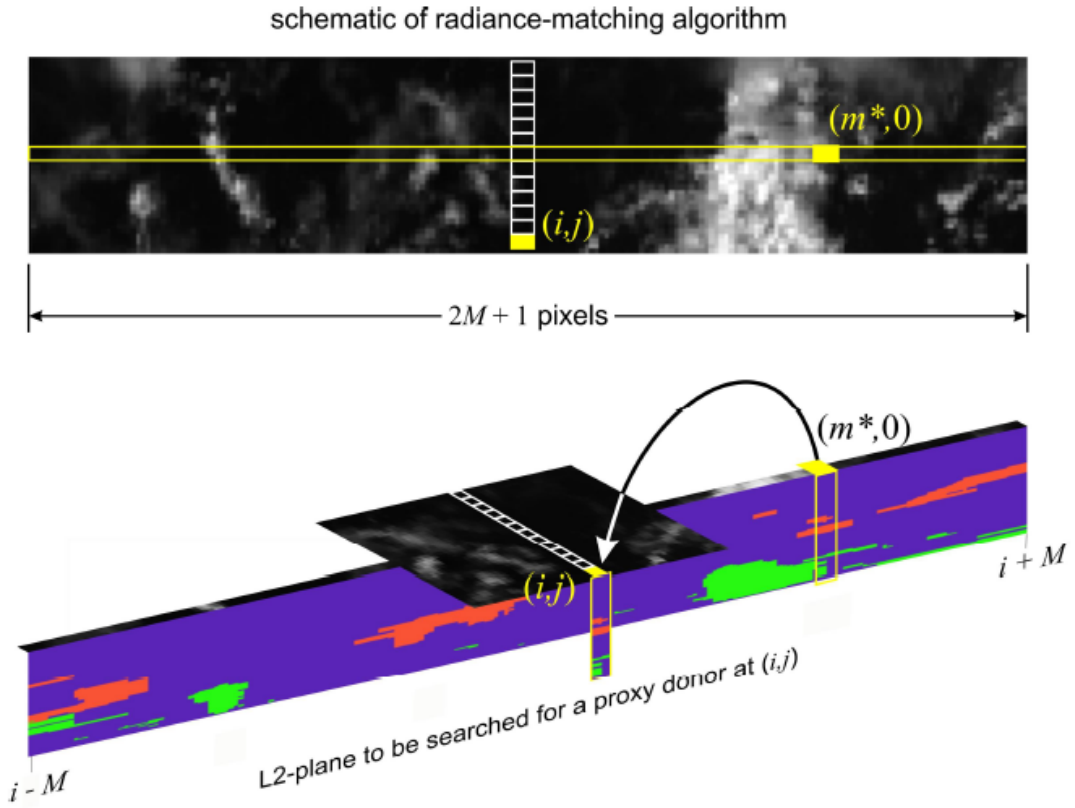


4. ACM-3D (3D scene construction)

- **Closure assessment:** compare modelled-to-measured BB radiances/fluxes
- But the active-passive RXS (ACM-COM) is only ~1 km wide
- Horizontal transport of BB radiation in and out of the RXS: 3D RT models be applied to atmosphere-surface systems of width > 1 km
- BBR performs better as its FOV increases



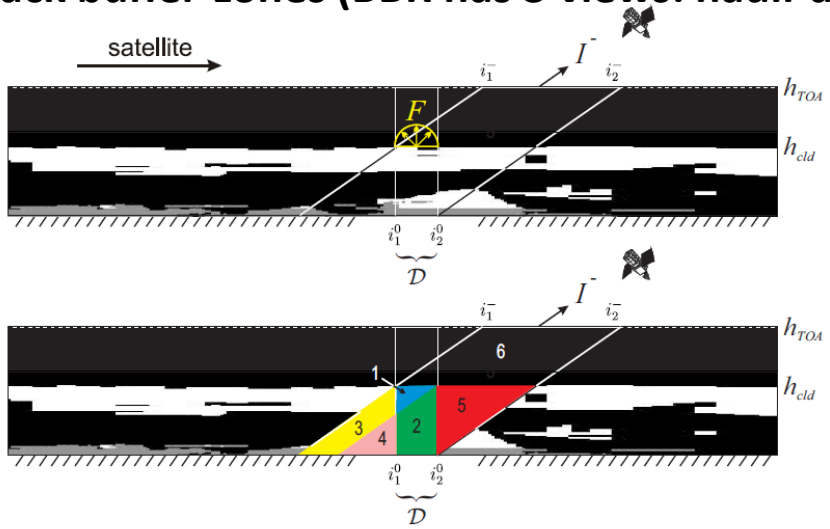
- Find best match between MSI radiances for off-nadir and RXS-aligned pixels
- Replicate matched RXS profiles at the off-nadir pixel
- Repeat until entire MSI swath is filled



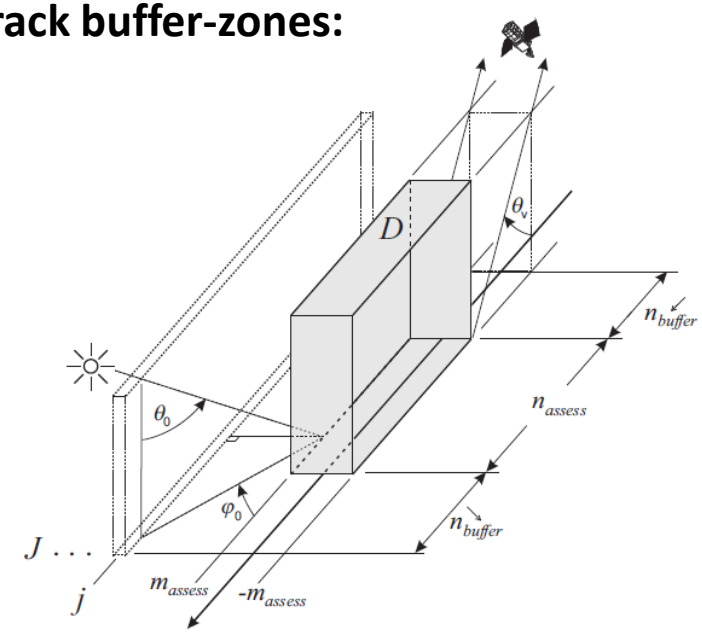
4. ACM-3D (Buffer zone & assessment domain screening/sampling)

Buffer zone calculation

Along-track buffer-zones (BBR has 3 views: nadir and ±53º VZA):



Cross-track buffer-zones:



Screening & Sampling

Screening of Assessment Domains

- Corrupt, missing data or failed retrievals
- SZA, land/surface type, elevation, etc.
- poor quality of radiance matching.
- likely to be problematic for closure

Sampling of Assessment Domain:

- CPU limits
- 3D RT is expensive... proportionally sample assessment domains with regard to natural appearance frequency w.r.t. cloud type based on MODIS data

5. ACM-RT (Radiative transfer simulation)

1D RT (cf. CloudSat 2B-FLX-HR)

- RRTMG for 1D SW and LW RT codes
- Possibly 2 all-sky atmospheres (COM and CAP) + clear-sky + pristine
- Flux profiles for all columns (up to ~5 x 6,000 = 30,000 / frame; 200+ layers)
- All assessment domains with successful screening in ACM-3D

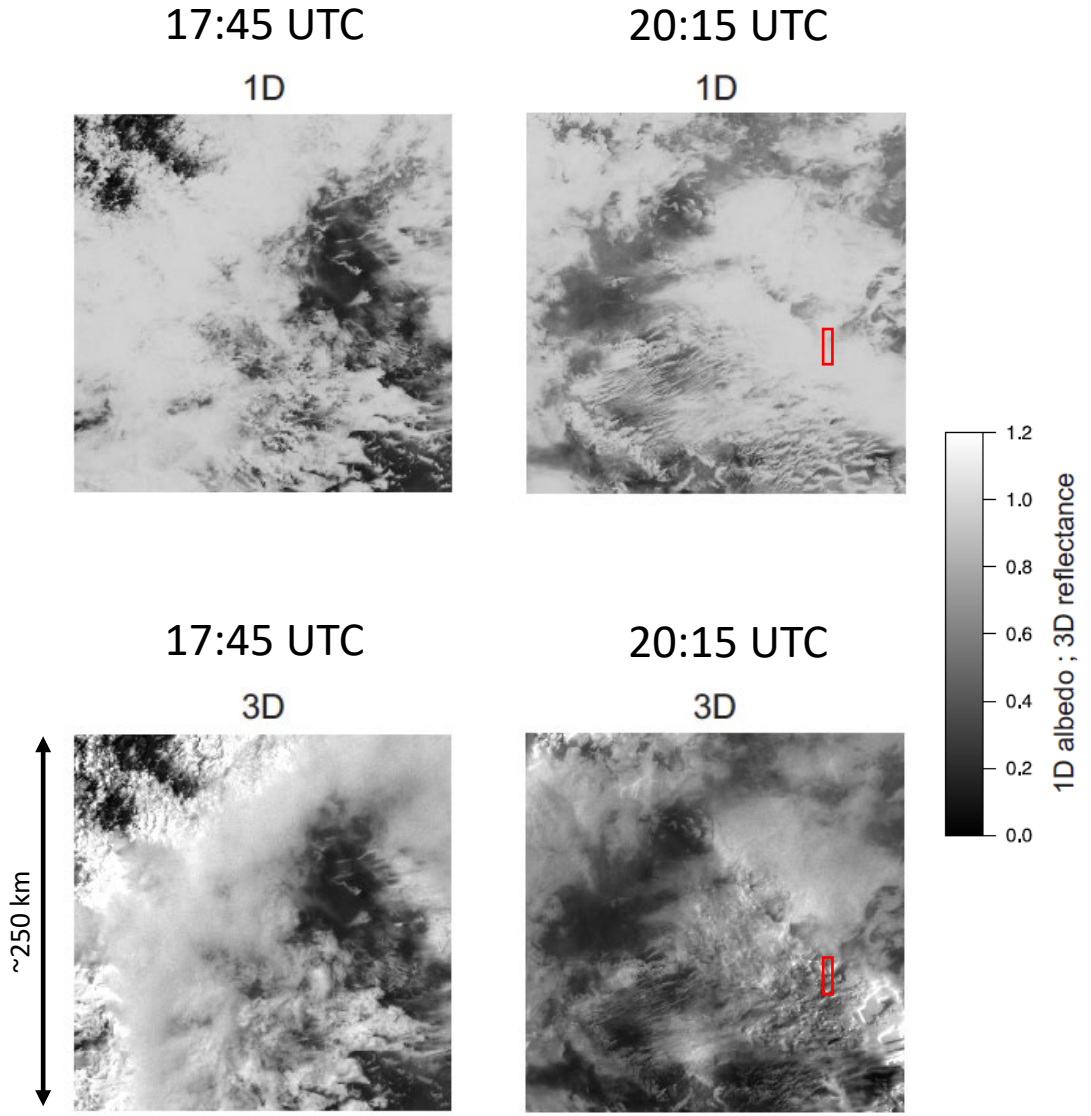
3D RT

- EarthCARE represents the first “operational” application of 3D RT models...

SW: - forward Monte Carlo (RRTMG + local estimation)
- domain-averge flux and HR profiles + 3 BBR radiances

LW: - backward Monte Carlo (RRTMG)
- domain-averge 3 BBR radiances (no fluxes)

CPU and time limits: only ~10 assessment domains per frame for 3D RT



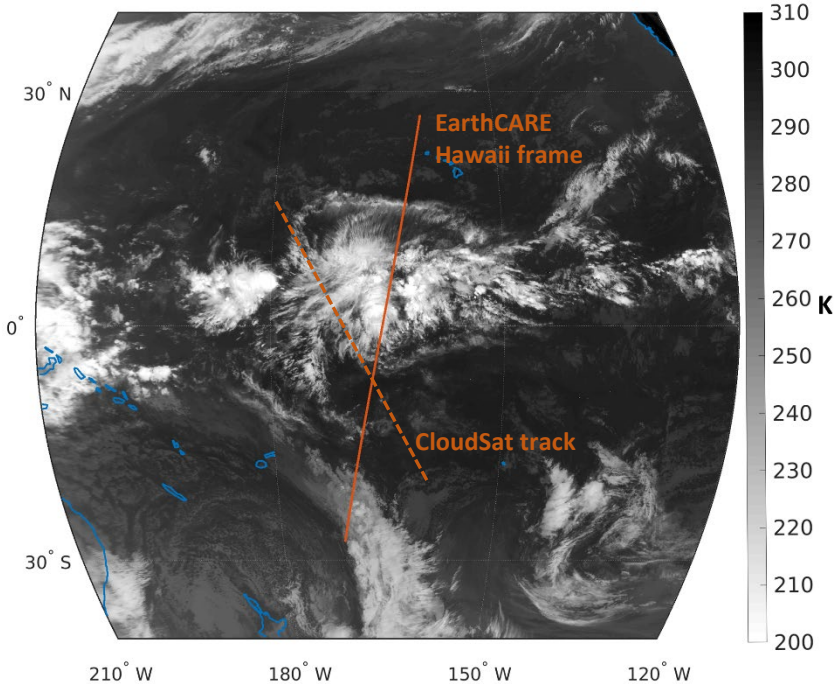
Reflectance/albedo simulated with 1D & 3D RT
Based on 250 m GEM simulation
2015-05-16 French Guiana

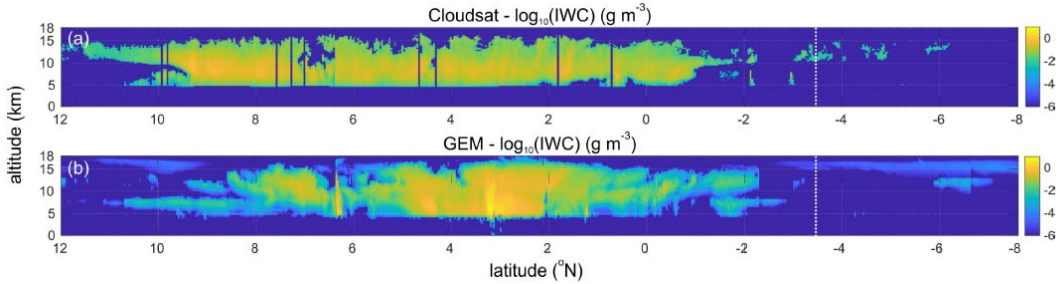
6. ACMB-DF (Radiative closure assessment)

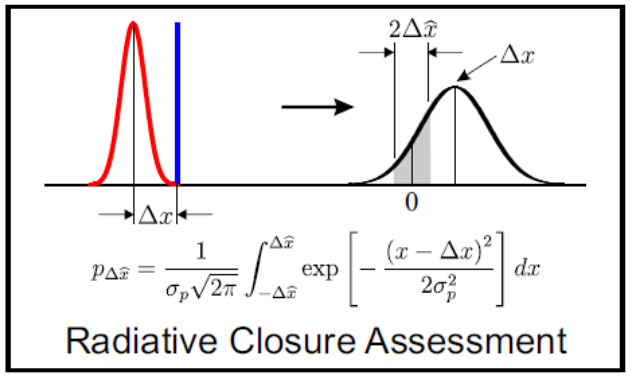
Radiative Closure Assessment using BMA-FLX

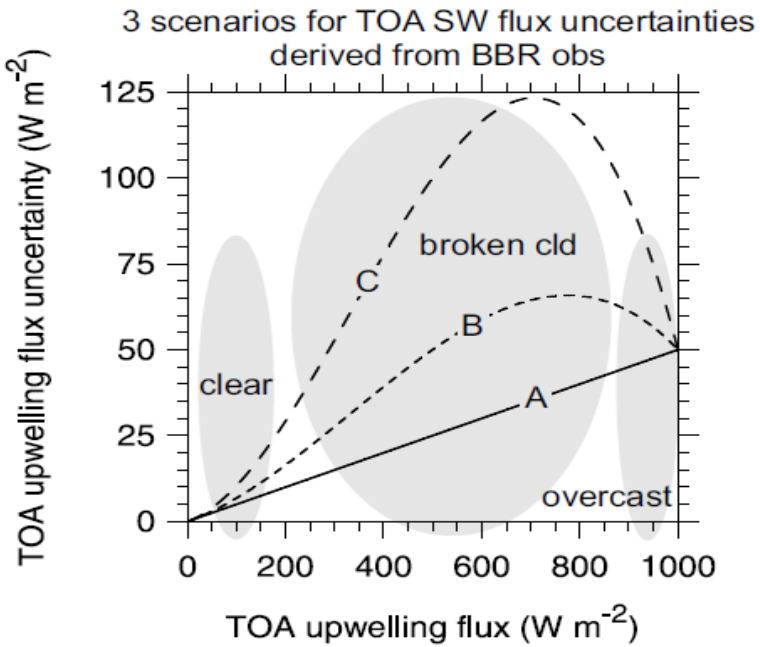
- centre of *Hawaii Frame* -

(00:00 UTC 2015-06-24)



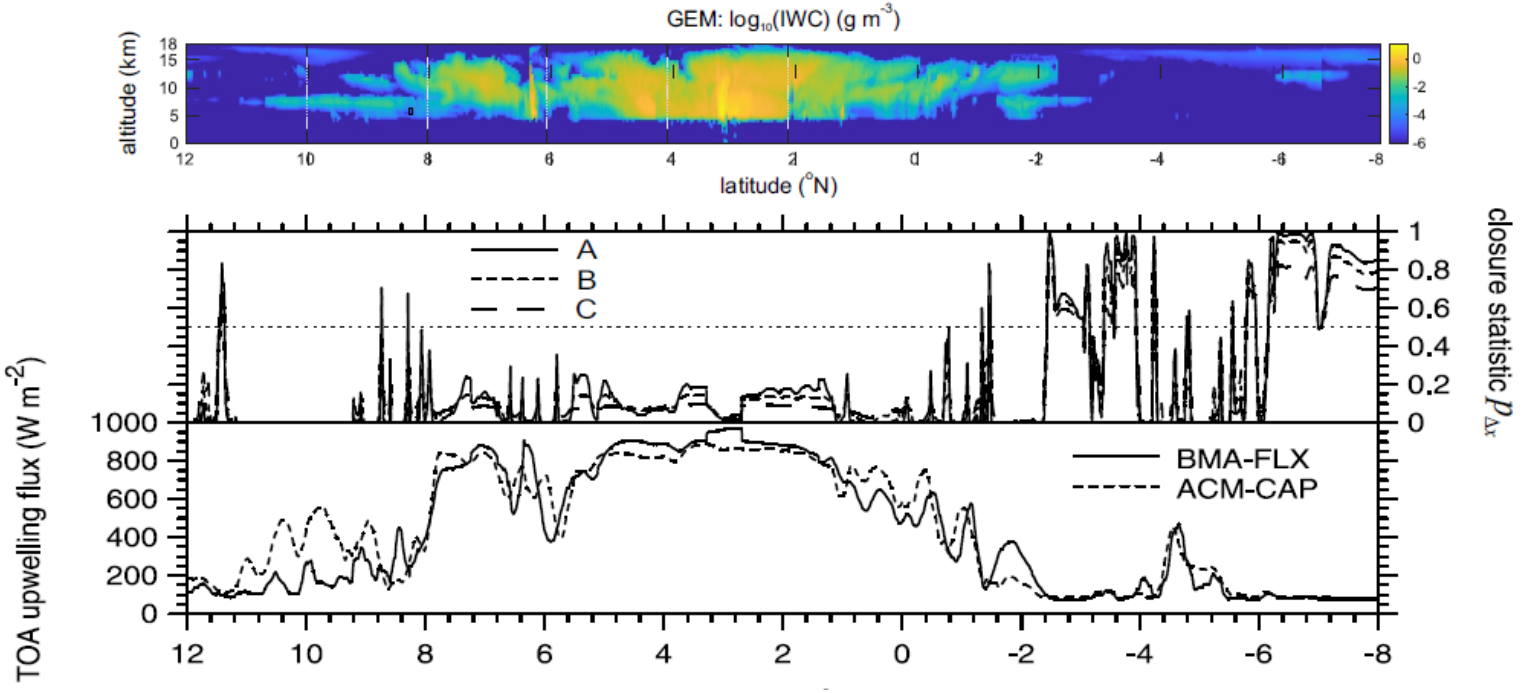


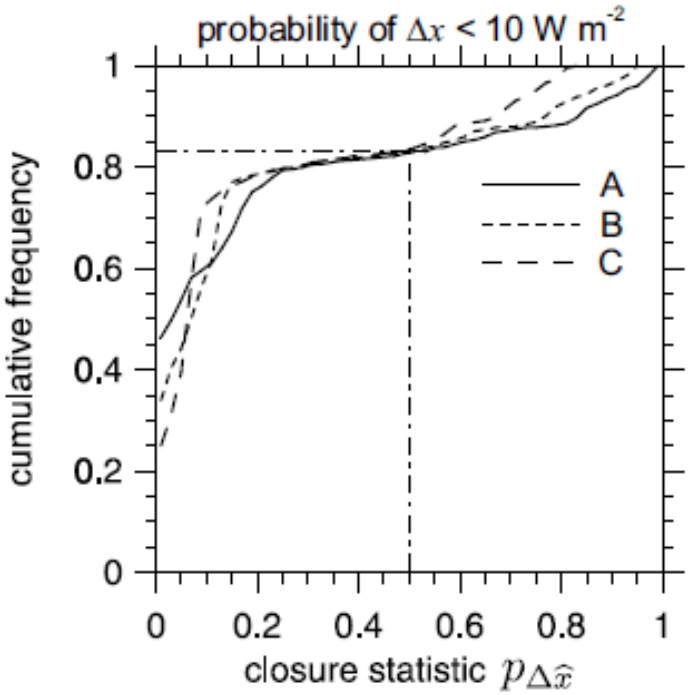




- 5 x 21 km assessment domains (ACM-3D)
- TOA upwelling SW fluxes derived by ADM using BBR observed radiances, three scenarios (A, B, C) for flux uncertainties (spread)
- 1D RT modelled values use ACM-CAP retrievals, no uncertainties (spread)
- find probabilities (ACMB-DF) that differences between ADM (BMA-FLX) and modelled fluxes are less than $\Delta\hat{x}$=10 W m^{-2}

6. ACMB-DF (Radiative closure assessment)





- 17% have $P_{\Delta \hat{x}} > 0.5$ for $\Delta \hat{x} < 10\ W\ m^{-2}$, success?
- Smaller than Illingworth et al. (2015)... retrievals are used
- Will improve when radiances, rather then fluxes, are used
- But likely to decrease when 3D RT is applied to ACM-CAP

7. Summary

primary scientific goal: retrieve cloud and aerosol properties such that TOA radiative fluxes can be modelled to within ~10 W m^{-2} for ~100 km^2 regions;

Goal verification: TOA radiative closure assessment

- apply 1D and ***3D RT*** models to retrieved cloud and aerosol properties
- compare modelled radiances (fluxes) to BBR radiances (ADM-derived fluxes) that are ***not used for retrievals***;
- *goal achievement* as a probability (uncertainties)
- CPU-limited... just mean values for ***a few*** ~100 km^2 domains / frame for 3D RT
- *CAPTIVATE*: active-passive synergy is crucial (Friday morning, A1.10.1, Shannon Mason)

Pre-launch end-to-end (algorithms + chaining + ground segment)

- wide sampling using 3 full-frame, hi-res NWP simulations
- 3D RT simulation of MSI and BBR radiances