CO₂ Slicing Method for IASI

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IASI algorithms ← recommended methods from ISSWG
- Cloud detection within IFOV → profile retrievals
- CTP retrieval ← CO₂ slicing method (Smith and Frey, 1990)

Prototyping Processing Facility for IASI L2 products (MET division)
- Implement methods, optimise algorithms & coefficients

- Input:
  - ECMWF (or ATOVS) co-located profiles & $T_{\text{skin}}$
  - IASI L1 radiance, surface emissivity, RTIASI-4, auxiliary file (list of channels)

- Output:
  - CTP and CFR → iterative profile retrieval
Algorithm

\[ X_{k,n} = \frac{R^\text{clear}_k}{R^\text{clear}_\text{ref}} - \frac{R^\text{cloudy}_k}{R^\text{cloudy}_\text{ref}} - \frac{R^B_k(p_n)}{R^\text{clear}_\text{ref}} - \frac{R^B_k(p_n)}{R^\text{clear}_\text{ref}} \]

\[ P_k = P(\min(|x_{k,n}|)) \]

\[ P_c = \sum_{k=1}^{M} w_k^2 P_k \]

CO₂ channel selection
Algorithm implementation

**Non noisy radiance**

\[
\begin{align*}
(R_{\text{cloudy}} - R_{\text{w}}^B(p_{\text{suf}})) & \geq RN_{\text{ref}} \cdot SNR \cdot NE\delta E_{\text{ref}} & \text{with} & \quad SNR = 3 \\
(R_{\text{clear}} - R_{\text{cloudy}}) & \geq SNR \cdot \sqrt{2} NE\delta E_{\text{ref}} & \text{and} & \quad (R_k - R_{\text{cloudy}}) & \geq SNR \cdot \sqrt{2} NE\delta E_k
\end{align*}
\]

- Search profile for inversions below 500 hPa (flag levels \( p_i \))
- Flag levels \( p_n \) with noisy cloud signal \( R_{\text{ref}}(p_n) \) → skip levels \( p_n, p_i \)

- Retrieve cloud top pressure \( P_k \) with a single CO\(_2\) channel
  Calculate effective \( C_{fk} \) using the window channel → exclude channel \( k \) if \( C_{fk} \) outside \((0,1]\)

- CTP histogram from single channel retrievals
  - Retrieved \( P_c \) as in Smith and Frey ↔ \( P_k \) in most populated class
    - If inversion exists and \( P_c > 600 \text{ hPa} \) → use \( P_k \) below inversion basis only
  - Effective cloud fraction \( C_f \) ↔ \( P_c \) and window channel
    - \( P_c \) and \( C_f \) delivered if \( C_f > 10\% \)

(Other results for quality control: \( P_k \) rms, \( \Delta P_k \), \( \delta P_c \) from NE\(\delta R \) and T error, Number of channels used)
window: 990.50 cm$^{-1}$ (11.10494 μm)  reference: 796.75 cm$^{-1}$ (12.55099 μm)

Retrievals of 53980 scenarios (RTIASI) $\rightarrow$ 41 CO$_2$ channels (707.50 – 756.00 cm$^{-1}$)

- Two global data sets (all cloud fractions, surface types, day/night, seasons)
  - (A) single level black clouds and (B) multilevel, water/ice clouds, 6 types

![CTP of highest cloud (data set B)]
Retrievals with single channel $k \leftarrow 545$ IASI frequencies (645.0 to 781.0 cm$^{-1}$)

Significance of channel $k$: Q% scenarios \{k NOT used OR error $\geq$ critical E\}

Given a critical error $E_n$ identify (among 545 channels) the set $M_{ni}$ of channels with a pre-defined $Q_i$ and find the set $S_{ni}$ of scenarios left with no channels

\{\text{En} < 100 \text{ hPa}, \text{Sn} \leq 1\%\} \iff Q_i = 10\% \Rightarrow \text{exclude 498 (A) [264 (B) channels]}
Statistics of retrievals (data set B) using 41 or 281 CO₂ channels

| Layer (100, 400] hPa | 41 chs: 34383 | 20780 | 12.5 | 61.8 |
| Layer (400, 800] hPa | 281 chs: 35848 | 21101 | 19.6 | 68.9 |

- Layer (100, 400] hPa:
  - 41 channels: 34383 retrievals
  - 20780 retrievals, bias = 12.5, RMSE = 61.8
  - 21101 retrievals, bias = 19.6, RMSE = 68.9

- Layer (400, 800] hPa:
  - 281 channels: 35848 retrievals
  - 9128 retrievals, bias = -0.4, RMSE = 67.6
  - 9496 retrievals, bias = 8.8, RMSE = 94.3

Algorithm: CO₂ channel selection

Validation: EUMETSAT
Frequency (%) of retrievals vs. cloud cover of highest cloud
(data set with multilevel water/ice clouds, six types)

34383 retrievals
41 CO$_2$ channels

35848 retrievals
281 CO$_2$ channels
Consistency with AVHRR images: frontal system & post frontal convection (north Atlantic)
**Algorithm**

**CO$_2$ channel selection**

**Validation (1b)**

**Consistency with AVHRR images:** frontal system (western south Pacific)
Consistency with AVHRR images:
post frontal squall-line and cumulus clouds organised as open cells (western north Atlantic)
**Metop sounding campaign**
Lindenberg Observatory (near Berlin)
Jun-Aug (+Sep) 2007

180 overpasses (~9 AM, ~8 PM) with IASI data
Co-located ECMWF forecasts (profiles, $T_{\text{skin}}$)
Co-located surface emissivity (as in PPF)

**Cloud data:** type & CFR (overpass time) + CTP
Observer (Jun-Aug) and AVHRR images
Cloud radar (1 min-integrated) reflectivity + Sounding

CTP from radar measurements (zenith):
CTP = mode of radar samples
within a sampling time interval
(200-400 hPa wind) / 7 km (~ IFOV radius)

**Algorithm**  
CO$_2$ channel selection

Validation
Mean of retrieved CTP (and CFR) within IASI IFOVS up to
7 km of Lindenberg 50 km of Lindenberg if CTP in \([P_R-100, P_R+100]\)
All 82 cases: bias = 29.4 hPa  std = 49.2 hPa
72 cases (CFR > 40%): 25.1  45.9

Lindenberg (< 7 km, triangles) or neighbourhood mean (< 50 km, squares)

Cloud layer: single (.) or multiple (+)

Corr. coeff. = 0.978
F-test = 1746.766
F(0.01,1,80) = 6.963

Validation (4)
66 cases (Jun-Aug): CFR bias = -6.2%  CFR std = 22.4%
(with respect to cloud cover reported by the observer)
Relative frequency (%) of retrievals (10 layers)
Relative frequency (%) of non-retrieved cases
Cloud fraction: cyan[0–0.2], pink[0.2–0.4], blue[0.4–0.6], green[0.6–0.8], red[0.8–1]