Climate Hyperspectral InfraRed Product (CHIRP) Combining AIRS, CrIS, and IASI

AIRS Science Team Meeting

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Motivation: Combine AIRS + CrIS + IASI for Long Time Series

- Produce Level 1b CHIRP radiances for retrievals
- Produce Level 3 climate-level gridded CHIRP radiance products
- Goals
    - Minimize sensitivity to a-priori estimates, etc.
    - Remove artificial sampling biases
    - Perform as much analysis in radiance space for error traceability
- Geophysical Products
    - Level 3 T/Q anomalies and trends (and surface T?)

This approach is in principle very simple and quick. Allows frequency re-processing.

What's Hard:

- Dealing with clouds
- AIRS radiometric stability estimates (ie. how good?)

CHIRP Overview

Motivation

- Level 1 radiances for the basis

(1) Multi-Instrument Hyperspectral Radiance Climate Time Series

- 1:30 Orbit: AIRS + CrIS, 9:30 Orbit: IASI
- Convert to common ILS to facilitate inter-instrument radiance calibration
- Produce time/space grids of radiance time series and anomalies for climate analysis

(2) Level 3 Geophysical Products

- Generate geophysical (T/Q, etc.) "Level 3" anomaly time series
- Trends will be a science product, not a DIS product

Validation/Comparisons

- AIRS/CrIS/IASI inter-comparisons
- Reanalysis: ERA+, MERRA-2
- Microwave
- Surface and SST climatologies
- GPS-RO (Leroy)

Time Series Length Nearing Climate Scales

CLARREO Schematic: Our Uncertainty?

./Figso/Pdf/clarreo.pdf

AIRS, CrIS, IASI are *all* very stable
CLARREO has removed us from this figure!

AIRS 14-Year global trends

./Figso/Pdf/1231and1566cm-1_dbt

These are 2-σ B(T) statistical uncertainties due to inter-annual variability.

Some channels, some latitudes not gaussian

CHIRB Processing Flow

./Figs/Pdf/airs2cris_stm_talk2_landscape.pdf

Anomaly and Trend Approach: (Result Shown Previously)

Linear solution for trends with a-priori state = 0 given by,

$$\frac{dx}{dt} = \left(K^T S_\epsilon^{-1} K + R^{-1}\right)^{-1} \left(K^T S_\epsilon^{-1} \frac{dBT}{dt}\right)$$

- x is the atmospheric state
- K are the B(T) Jacobians
- S_ϵ is the observation error covariance matrix.
- R combines empirical regularization (Tikonov L1-type) and the *a-priori* covariance-based terms

S_ϵ covariances represent inter-annual variability and instrument stability. They introduce significant constraints compared to L3 time derivatives, *still implementing*.

Jacobian state from standard all-sky retrievals or from re-analysis; high accuracy not needed.

This Talk

- Concentrate on 16 (or 15) year radiance trends
- AIRS Stability
- Cloud variability on 15 years, how to minmize

Cocentrate on global, zonal trends to emphasize instrument issues

Data Sets

- Start with a ~1% random, area-weighted subset (for quick processing)
- Produce 40 area weighted zonal bins (all channels) for 5475 days
- Proudce 48 x 90 deg. area-weighted gridded trends (1 channel)
- All data is L1c (frequency calibrated)

Stability: Clear Ocean Trends

./Figs/Pdf/clear_desc_pm50lat_with_witho_nucal_era

- This is AIRS 16-year clear ocean BT trend

Stability: AIRS 1231 cm^{-1} Trends vs ERA SST Trends

./Figs/Png/final_sst_vs_1231_vs_lat.png

- ERA SST modification due to water vapor absorption

Stability: OEM Retrieval of Clear Ocean CO_2 Trends vs MLO

./Figs/Pdf/co2_clear_results.pdf

- OEM retrieval off due to co-linearity of CO_2 and T

Climate Quality AIRS Channels

OEM retrieval fitting residual for clear-ocean trends

All L1c with A/B=0

./Figs/Pdf/clear_ocean_desc_rate_fits_resid_all_ab0.pdf

Further Trimming of A/B=0

./Figs/Pdf/clear_ocean_desc_rat

About 1000 L1c channels good for trending

Global B(T) Trends: Descending Node

All L1c Channels:

./Figs/Pdf/rand_desc_global_trends_l1c_abfixed_ab0.pd

Global B(T) Trends: Descending Node

Now only A/B Fixed Channels:

./Figs/Pdf/rand_desc_global_trends_abfixed_ab0.pdf

Global B(T) Trends: Descending Node

Now only A/B = 0 Channels (equally weighted)

./Figs/Pdf/rand_desc_global_trends_ab0.pdf

Global B(T) Trends w/ 2-σ Unc: CO_2 Removed using MLO

./Figs/Png/desc_dbt_obs_global.png

- CH_4 dominates MW (follows ESRL trends)
- H_2O B(T) trends smaller than T channel trends

Compare T-channel to WV-channel Trends (vs Latitude)

./Figs/Png/wv_dbt_vs_trop_dbt.png

- Color is latitude: note "lime green"
- If relative humidity is constant, Δ BT = 0 for water channels

How Does the T vs H_2O Trend Vary with Latitude?

./Figs/Pdf/drying_in_convective_regions_v2.pdf

- Plotting latitude variability relative to the global mean ratio of

Radiance Gridding: Minimize Cloud Variability

- Radiance gridding combines clear + cloudy scenes
- Clouds change slowly, but regional variability seen after 16 years
- Want simple approaches to evaluating gridded radiances trends
- Possible approach (suggested several years ago)
    - Grid not ony mean radiance but:
    - Grid by rough measure of "clear"
- Nominal approach
    - Generate radiane anomaly
    - Separate 10% hottest scenes in anomaly radiance, from colder (more cloudy) scenes.
    - Minimized cloud interferene for surface trending
- Crude test done here
    - Forget anomaly
    - Just trend 10% hottest scenes in yearly gridded bins
    - Just one channel, 917 cm^{-1}

15-Year Global Trends: 10% of Hottest Scenes (Desc node)

AIRS Trends (K/year)

./Figs/Png/desc_airs_hot_trend.png

AIRS Global trend: 0.019K/year
AIRS Global std: 0.043K/year

ERA Surface Trends for *these* Scenes

./Figs/Png/desc_era_hot_trend

ERA Global trend: 0.019K/year
ERA Global std: 0.049K/year

- Quite similar, no cloud patterns?
- High cancellation of trends, but not to zero

Compare Trends to Full ERA Sampling

AIRS Trends (K/year)

./Figs/Png/desc_airs_hot_trend.png

ERA Surface Trends for *these* Scenes

./Figs/Png/desc_era_hot_trend

Cloud Forcing Patterns (K)

ERA Surface Trends (full Sampling)

Global Variability for This 10% Hot Subset

AIRS Std (over time, in K)

./Figs/Png/desc_airs_hot_std.png

ERA Std (over time, in K)

./Figs/Png/desc_era_hot_std.png

- Quite similar!
- No obvious cloud patterns?
- High North polar variability
- Just an example of what can be done without retrievals!

Global Trend in 902 cm^{-1} Channel: All Scenes

./Figs/Pdf/bt902_global_trend_vs_time.pdf

- Global average time series of 902 cm^{-1} channel with 2-year smoothing

Conclusions

- Good progress in defining "good" channels for CHIRP
- CHIRP radiometric stablility evaluation on-going
  - Need to examine time-dependence more carefully
- CHIRP "L1c" product nearly ready for implementation (need AIRS L1c)
- CHIRP gridded "L3" product being assessed
  - Very valuable to have all scenes paired with re-analysis
  - Several type of gridding seem worthwhile (all sky, gridded by nominal % clear)
- OEM retrievals of T/Q zonal trends will continue with an emphasis on observation error co-variances and better all-sky cloudy jacobians