Towards Improved Radiative Transfer Simulations of Hyperspectral Measurements for Cloudy Atmospheres

AGU FALL MEETING
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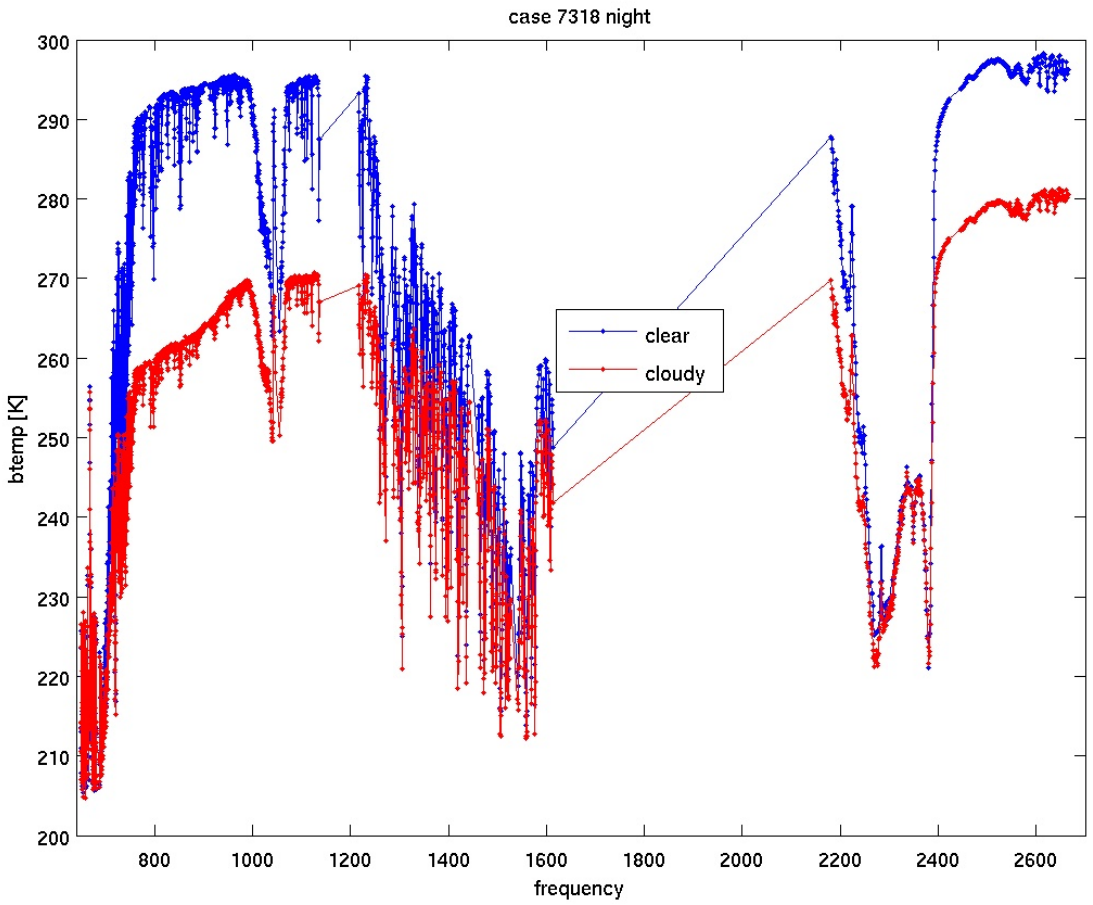
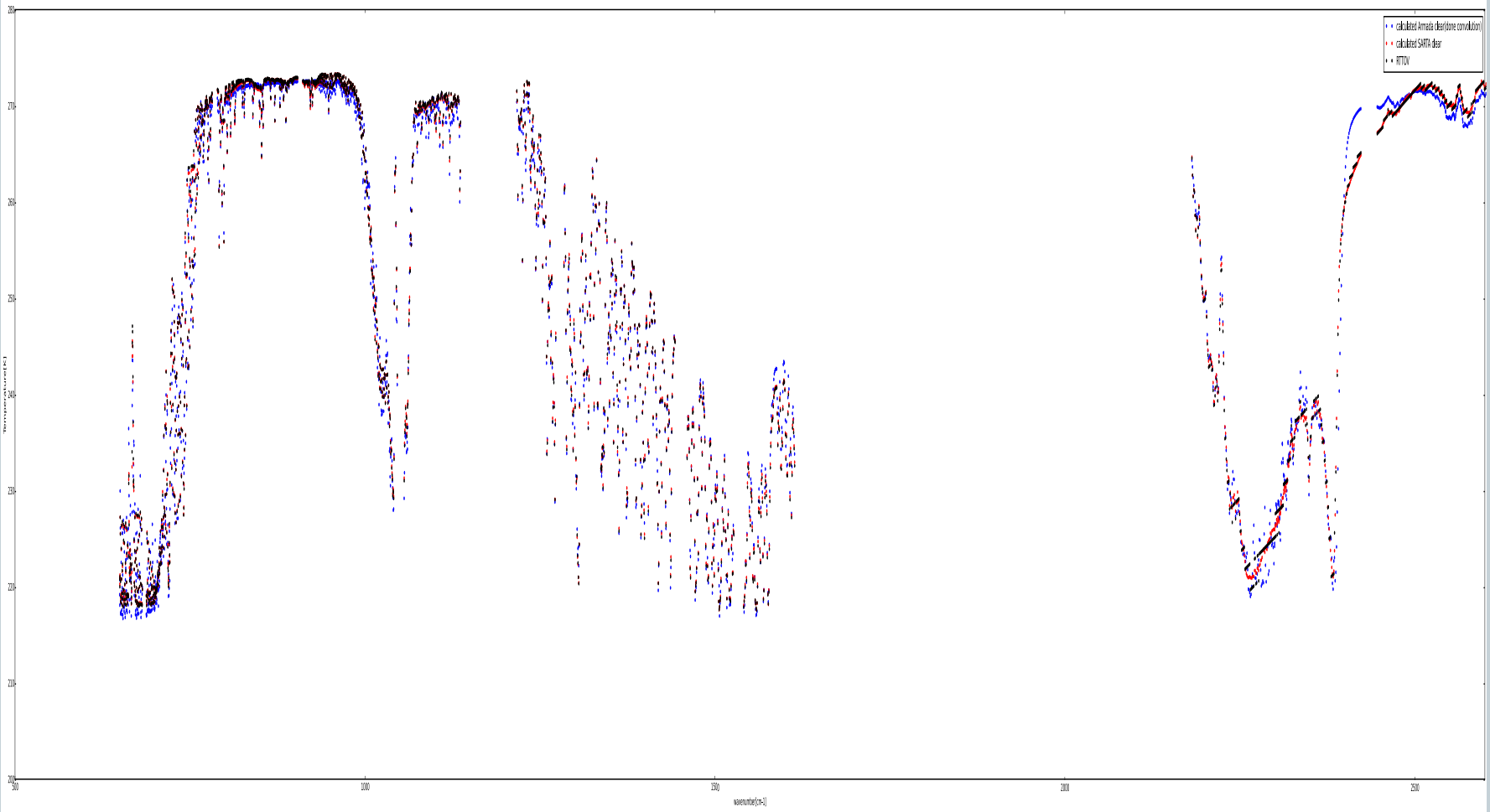
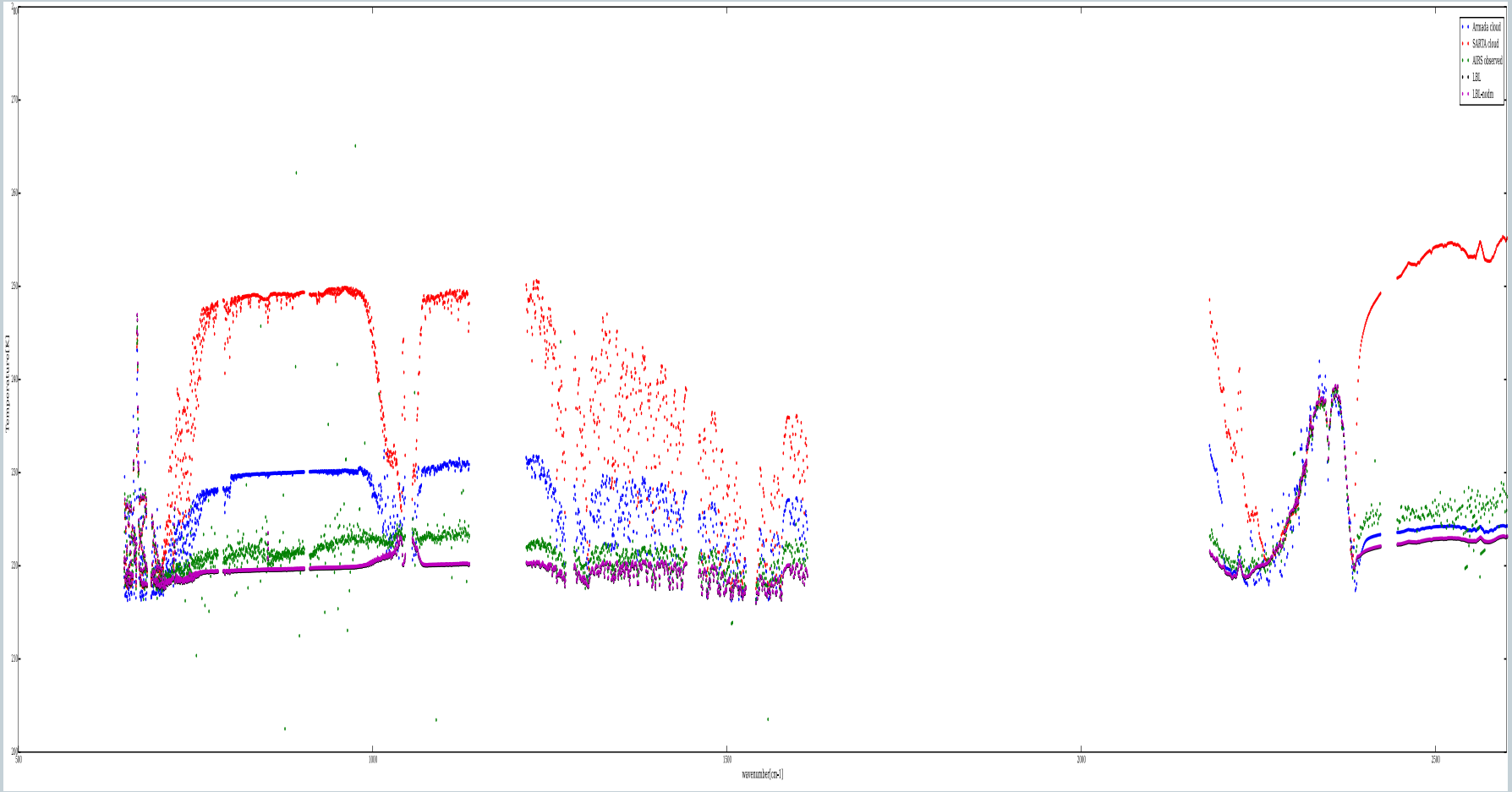
AIRS Clear and Cloudy Spectra



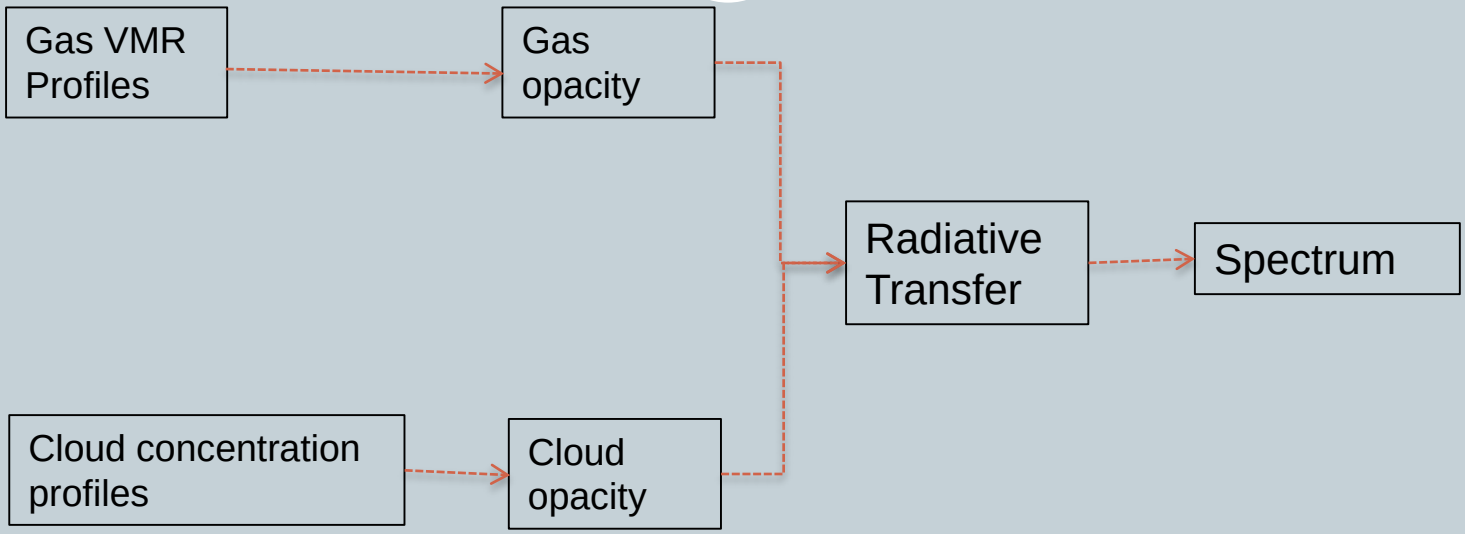
Code Comparison: Clear Spectrum



Code Comparison: Cloudy Spectrum



RT Flowchart

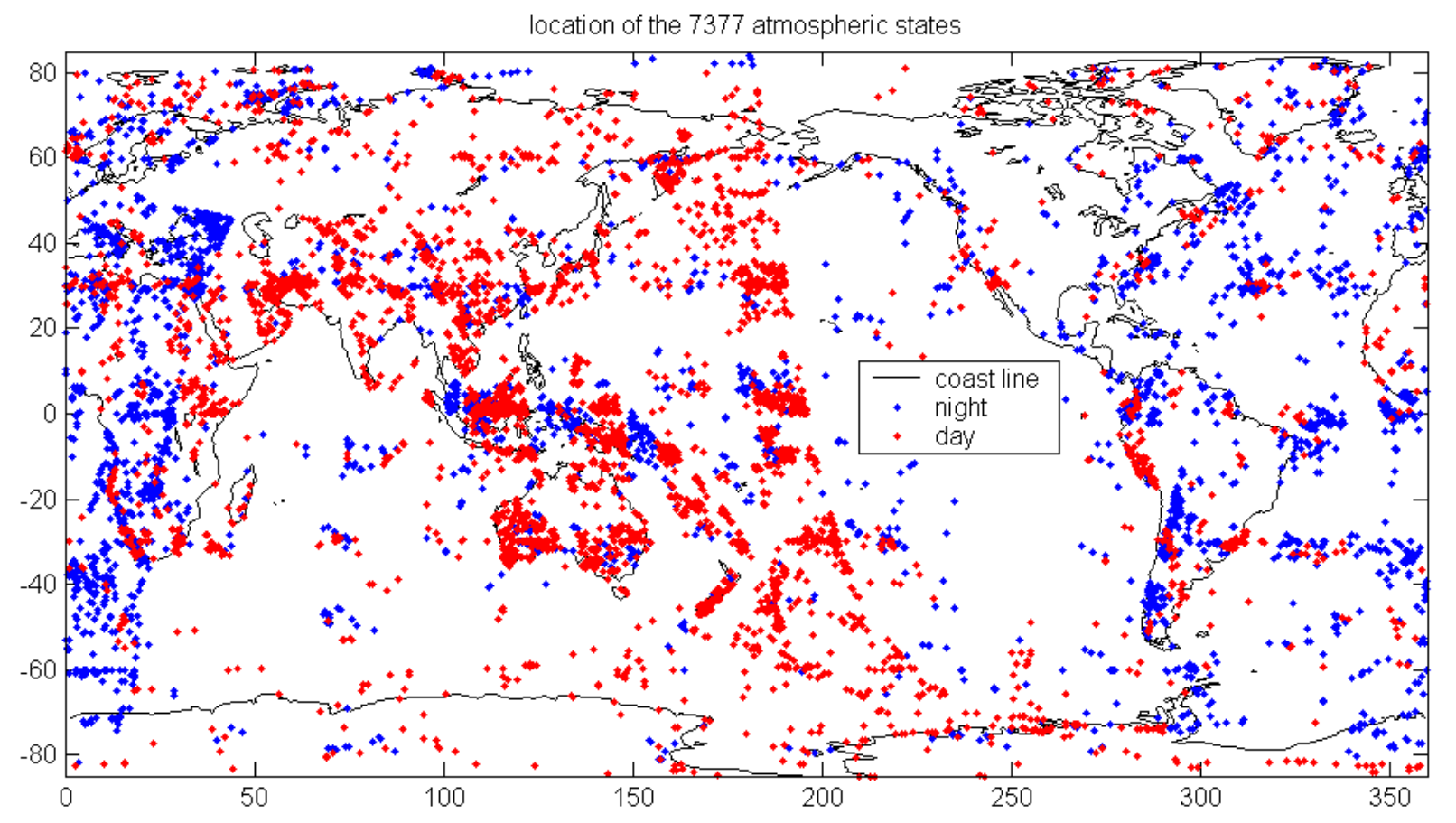


Gas opacity: continuum absorption, CIA, line mixing, non-LTE

Cloud opacity: cloud particle radius, liquid/ice water path parameterization

Radiative transfer: scattering, sphericity, angular (number of streams)/spectral (fineness of wavelength grid)/vertical (number of layers) fidelity

Locations of Test Data



RT Model

Start: Create complete set of all optical properties.

Binned set of optical properties: $[\mathbf{G}]_{ni} = \{\ln \Delta_{ni}, \ln \omega_{ni}\}$

Mean-removed correlation: $\mathbf{Y} = [\mathbf{G} - \langle \mathbf{G} \rangle]^{\mathrm{T}} \cdot [\mathbf{G} - \langle \mathbf{G} \rangle]$

PCA on $\mathbf{Y}$ → EOFs & Principal Components $\{\mathbf{W}_k, \mathbf{P}_k\}, k = 1, \ldots K_P$

PCA

MS computations by LIDORT/2S for PCA-derived optical states $\{\mathbf{F}_0, \mathbf{F}_k^{\pm}\}, k = 1, \ldots K_P$. Total $2K_P + 1$ simulations.

First RT Step

Correction factors $C(\lambda_i)$ at all points λ_i using Step-1 RT simulations and 2nd-order central-differencing with Principal Components $\mathbf{P}_k$

Point-by-point Fast 2S/FO Simulations: $I_{2S}(\lambda_i), I_{FO}(\lambda_i)$

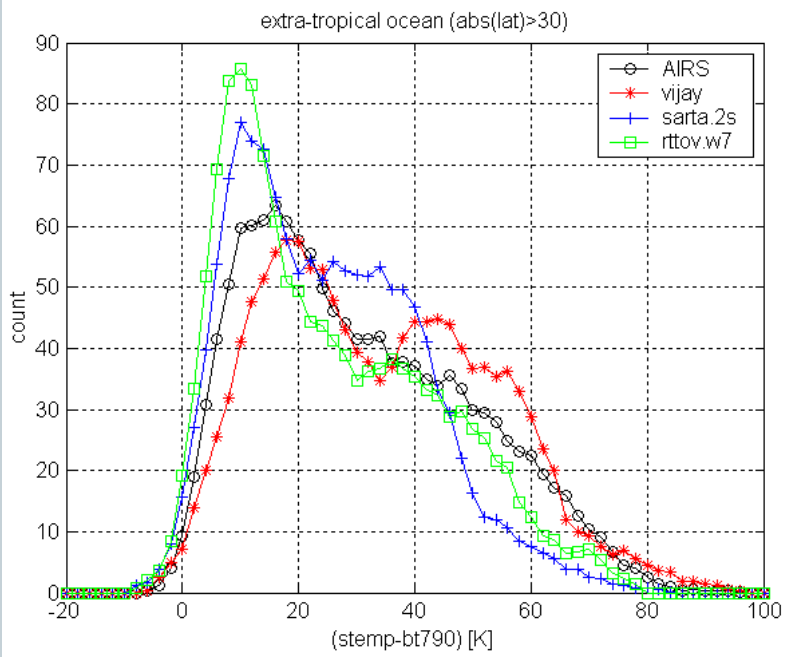
Second RT Step

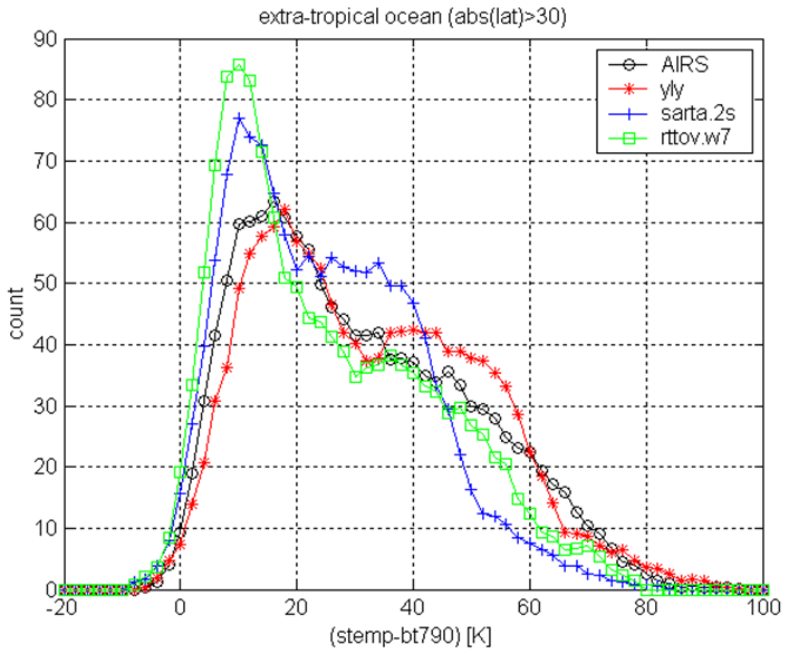
Finish: Final results: $I_{PCA}(\lambda_i) = [I_{2S}(\lambda_i)]C(\lambda_i) + I_{FO}(\lambda_i)$

RT Details

- Water cloud effective diameter: 20 microns
- Ice cloud effective diameter: 80/120 microns
- No vertical variation of water and ice cloud properties
- Cloud single scattering properties computed using Fu-Liou method
- LBLRTM v12.4, MT-CKD v2.8
- LIDORT: 8 streams
- RT calculations at 0.0025 cm^{-1} resolution (samples every pixel in AIRS SRF)
- 92 (ECMWF) level atmosphere

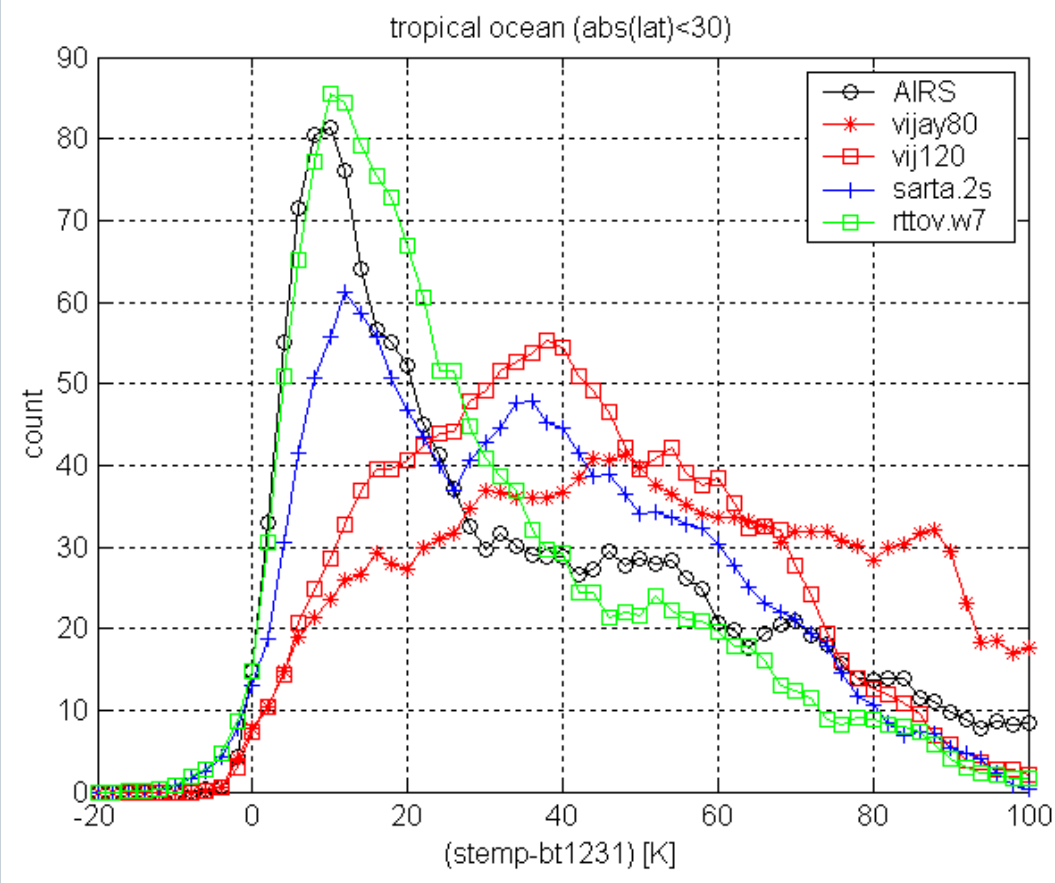
STEMP-BT1231: Extra-tropical Oceans



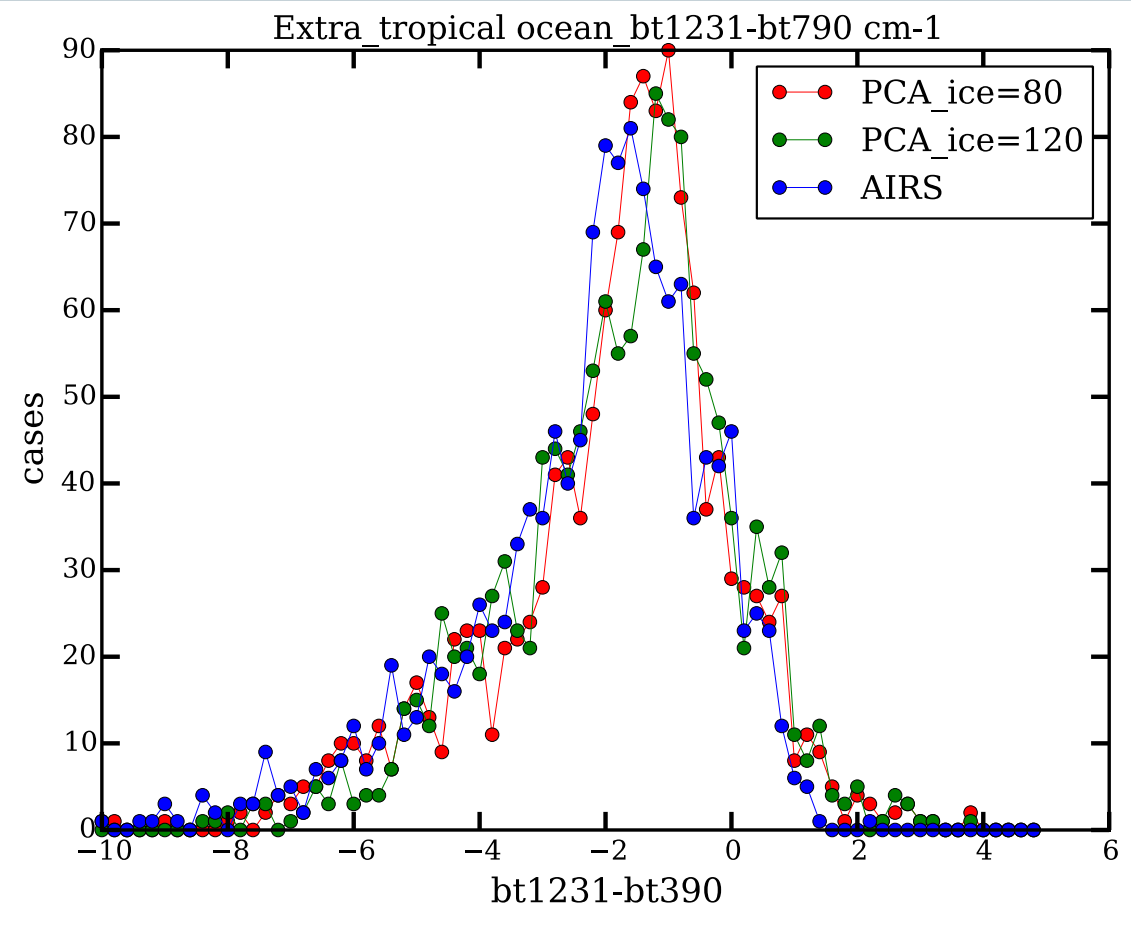


80 micron ice particle diameter

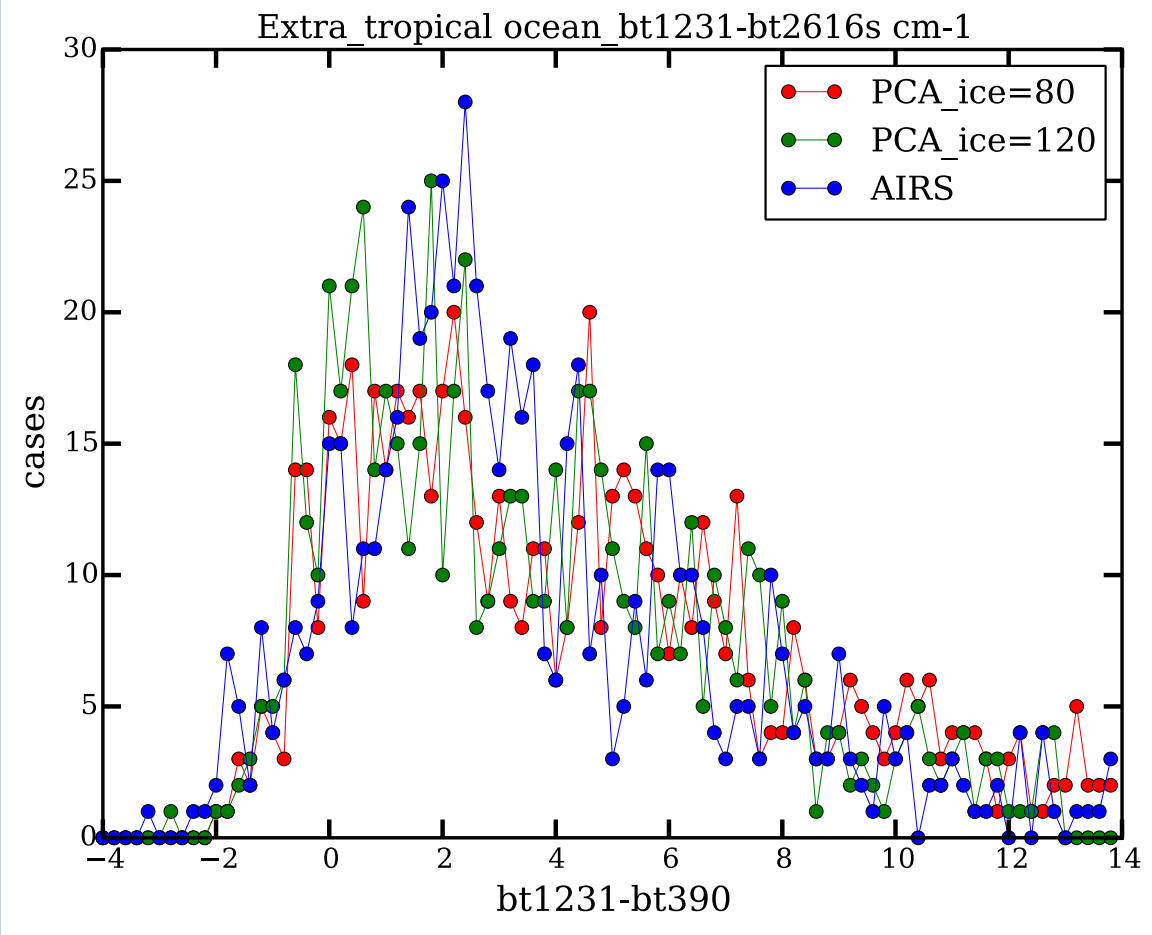
STEMP-BT1231: Tropical Oceans



BT1231-BT790



BT1231-BT2616

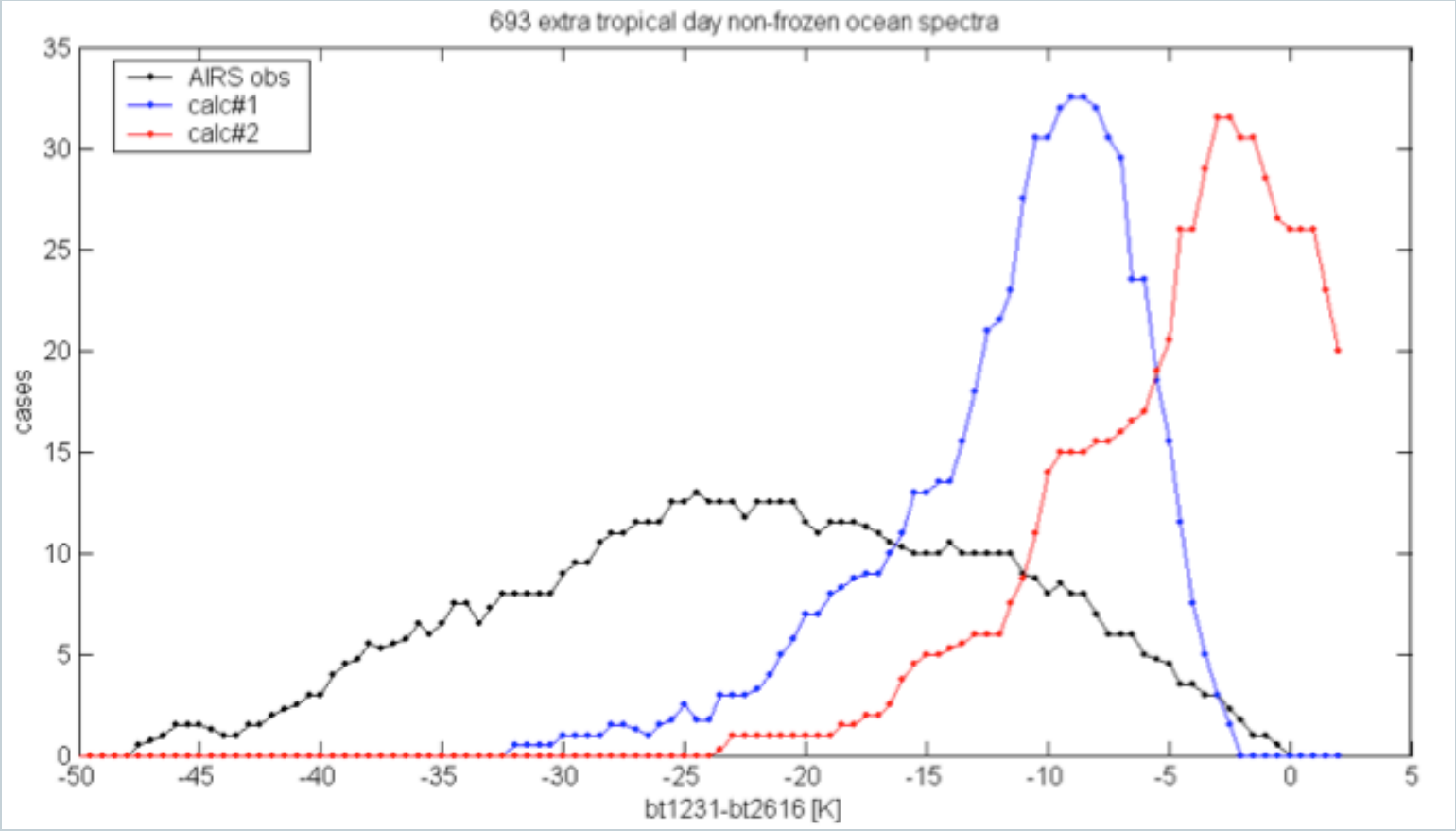


Timing Considerations

- PCA RT Timings (per channel/profile): 4s, 6s, 15s (for 790, 1231 and 2616 cm^{-1})
- LIDORT Timings: 185s, 292s, 606s
- ARMADA Timings: 965s, 1095s, 3480s
- Speed of PCA RT ~ speed of 2-stream RT
- Linear increase in speed with decrease in number of layers and/or decrease in spectral resolution
- Code is parallelized and very scalable with number of computational nodes
- Accuracy/speed trade-off application dependent

Final Thoughts

- Agreement better in extra-tropics -> mostly low (water) clouds
- Spectra very sensitive to ice cloud diameter
- How accurate are ECMWF estimates of clouds?
- Really a retrieval problem
- Need inter-comparison exercise to establish benchmarks
- “Best” computational algorithm dependent on application

Backup Slides

BT1231-BT2616: Daytime