Re-evaluation of IR Cloud Detection in NWP:

Comparing Infrared Cloud Detection Algorithms to Improve the Current National Weather Prediction Infrared Cloud Detection Algorithm

Brianne Andersen with James Jung, Paul Menzel, and Sharon Nebuda

Acronyms Used

BT: Brightness Temperature | COT: Cloud Optical Thickness | CrIS: Cross-track Infrared Sounder | CRTM: Community Radiative Transfer Model | CTP: Cloud Top Pressure | DR: Dual Regression
ECMWF-CADS: European Centre for Medium-Range Weather Forecasts Cloud and Aerosol Detection Algorithm | FOV: Fields of View | HIRS: High-Resolution Infrared Radiation Sounder | HSRTV: HyperSpectral ReTrieVal
IR: Infrared | JPSS: Joint Polar Satellite System | NCEP: National Center for Environmental Prediction | PBL: Planetary Boundary Layer | VIIRS: Visible Infrared Imaging Radiometer Suite

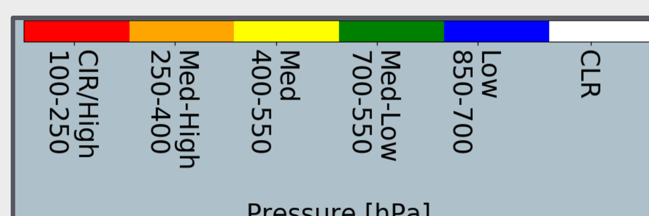
Foundational Concept

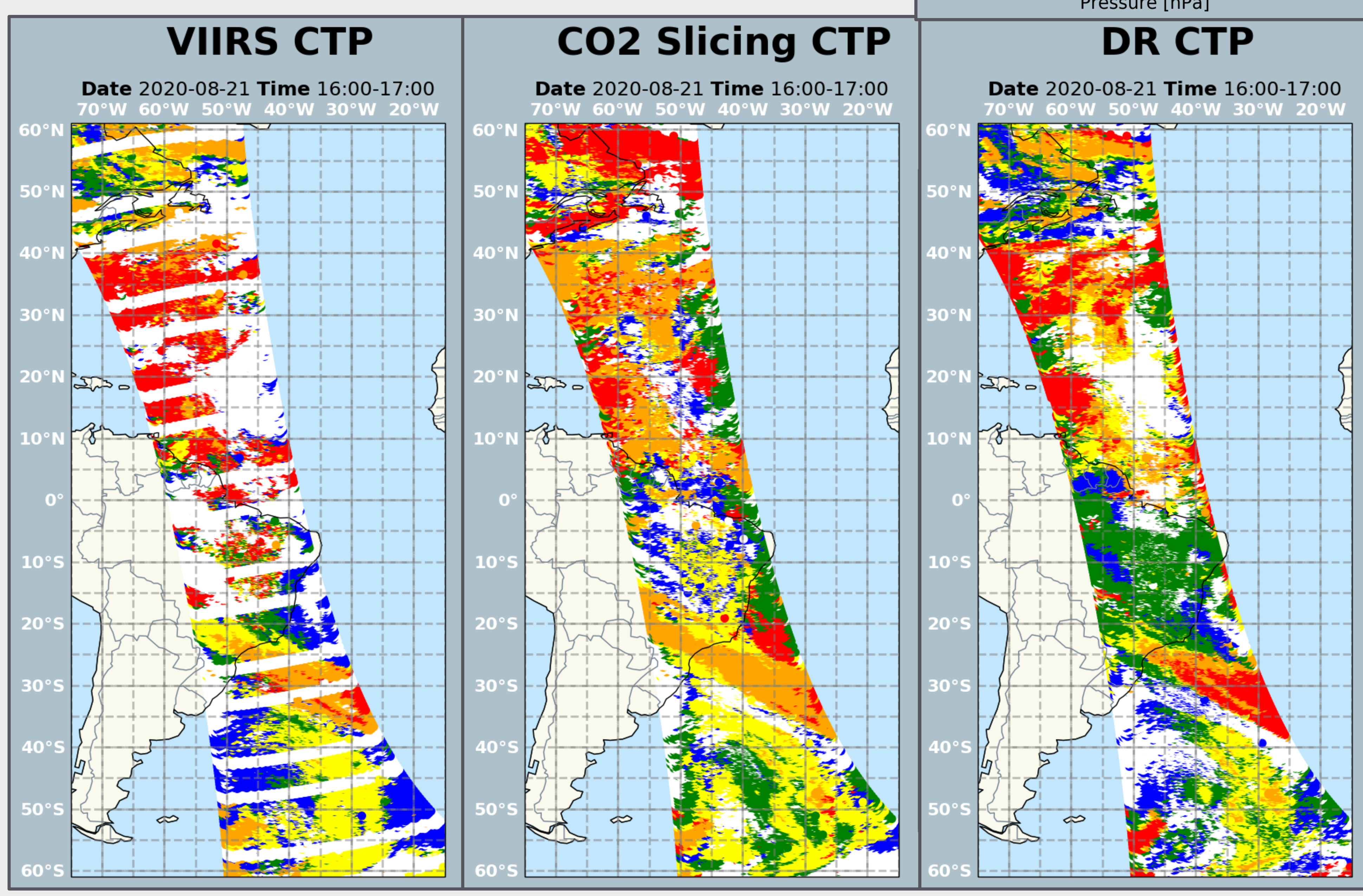
The current NCEP high spectral IR cloud detection algorithm dates back to Rossow and Garder 1993, and utilized data from HIRS. HIRS has since been outdated by CrIS, which has significantly higher spectral resolution and smaller channel bandwidth. However, the current algorithm has yet to update, and does not utilize the full capabilities CrIS offers. The purpose of this study is to bring the NCEP's algorithm into the modern age by comparing other methods which take advantage of CrIS and its high spectral resolution potential. The two main objectives include:

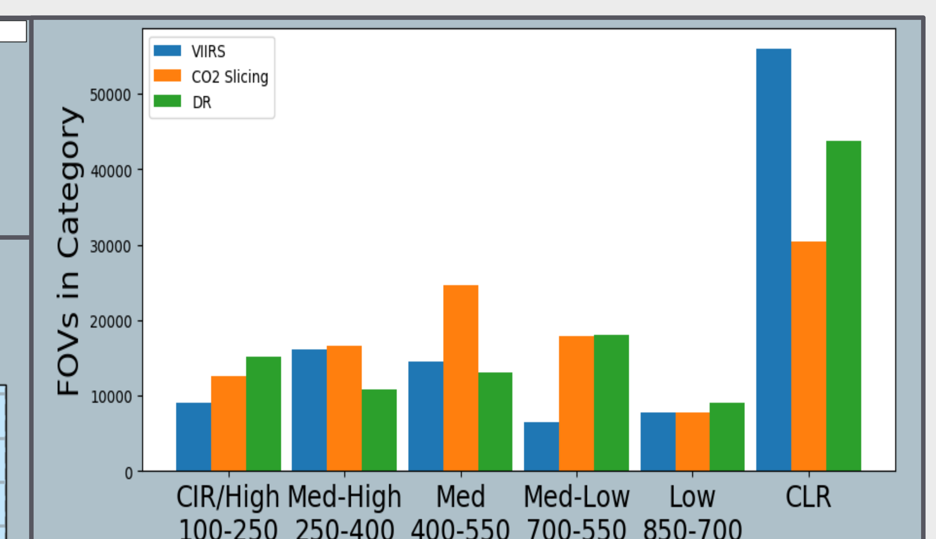
1) Suggest possible implementable changes to the current algorithm by what has worked for other methods/algorithms
2) Propose channels which could improve the NCEP clear sky scheme by removing cloud contaminations

This poster is designed to explain the encompassing ideas of the initial research.

Example of VIIRS, CO2 Slicing and DR CTP Capabilities





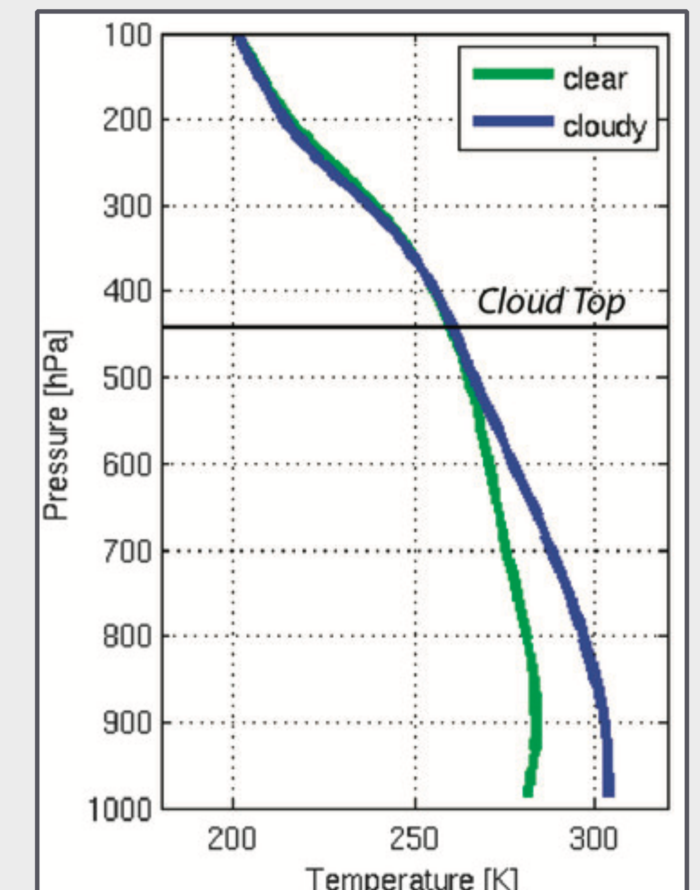


Demonstration of how CO2 Slicing works well at encompassing both what DR and VIIRS indicates. On the left is the map view, showing a part of the 16Z S-NPP pass on 2020-08-21, and on the top is the histogram view for the full path. CIR stands for cirrus clouds, which optically thin cirrus are particularly hard to detect, but CO2 Slicing shows promise.

Instruments

The main instrument used was CrIS. It's a sounder on the newest JPSS system (S-NPP and NOAA-20), and has 2211 spectral channel from 650 cm^{-1} to 2550 cm^{-1}. Co-located VIIRS, also on NOAA-20 and S-NPP, was used as observation truth, along with DR and geostationary satellites.

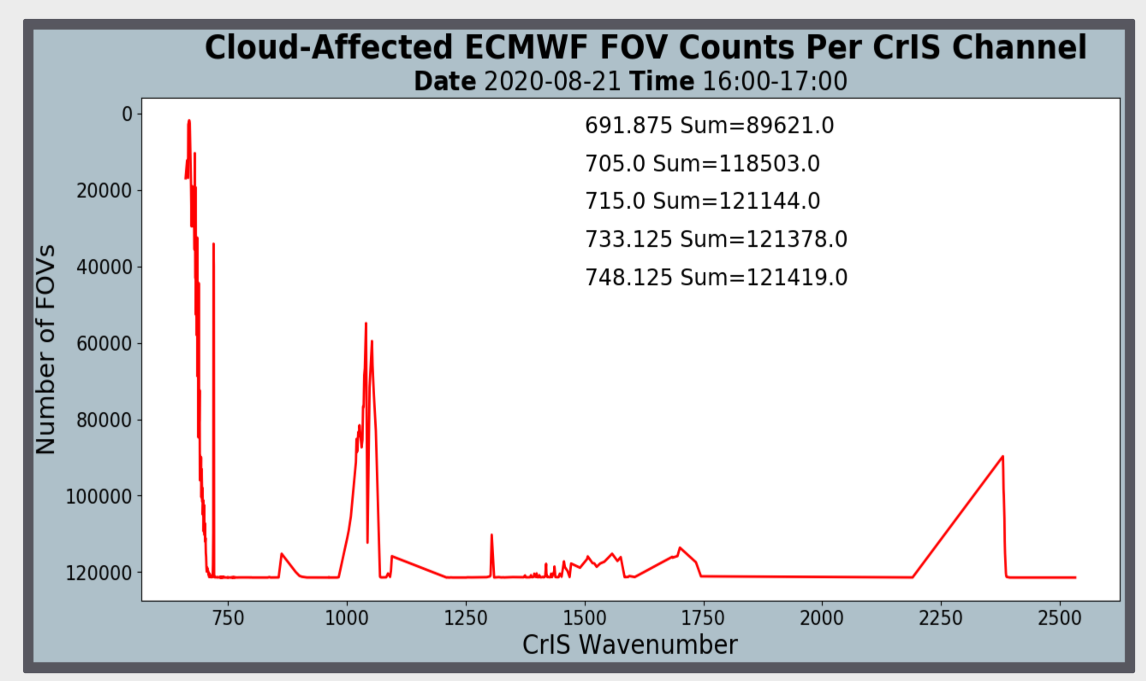
What is DR?



DOI: 10.1175.JAMC-D-11-0173.1

DR is a method described by Weisz et al. 2012, and supported on HSRTV Software. DR determines if there is a cloud via two trained soundings, one clear scheme and one cloudy scheme, for each FOV. Via a foreword model, cloudy radiances at 8 heights and clear radiances are calculated, then run through respective clear and cloudy empirical orthogonal functions, developing two profiles. If there is no divergence of the profiles throughout the full depth of the atmosphere (from 100-1000 hPa), then the FOV is classified as cloud free. However, if there is divergence, then the height of bifurcation is the calculated CTP height. For the purposes of this study, DR was used as confirmation of the true observation, as DR does better at detecting lower level CTP than VIIRS.

What is ECMWF-CADS?



ECMWF-CADS was develop with and by McNally and Watts. ECMWF-CADS works by comparing BT changes [$\delta = BT_{obs} - BT_{calc}$] at ranked CrIS channels. Some assumptions are made to accomplish this, such as:

- Lower CrIS channel numbers are associated with higher level CTP
- CTP fall between the tropopause and the top of the PBL
- Model first guess data is converted to clear sky BT using a radiative transfer model such as CRTM or RTTOV

The end result is a binary cloud-affected or clear classification for each FOV at every CrIS channel. CrIS channels with relatively few FOVs that are cloud contaminated are assume to be clear sky channels. Clear sky channels are particularly important to NCEP as cloud contamination greatly affect clear radiance schemes.

Bibliography and Acknowledgments

This project was graciously funded, supported, and hosted by NOAA-NESDIS-JPSS and UW-Madison AOS

- Eresmaa, R (2020) Cloud and Aerosol Detection Software V3 User Guide
- Eyre, J and Menzel, P (1989) J. Appl. Meteor. Climatol., 28, 267–275, DOI:10.1175/152
- JPSS (2018) STAR JPSS - Instruments-CrIS, www.star.nesdis.noaa.gov
- McNally, A and Watts, P (2003) Q. J. R. Meteor. Soc., 129, 3411–3423, DOI:10.1256/qj.02.208
- Menzel et al. (2008) J Appl. Meteor. Climatol., 47, 1175-1198, DOI:10.1175/2007JAMC1705.1
- Menzel, P (2009) Remote Sens. Appl. with Meteor. Satell.
- Rossow, W and Garder, L (1993) J. Climate, 6, 2341-2369, DOI:10.1175.1520
- Weisz, E et al. (2013) J. Geol. Res. Atmos., 118, 6433–6443, DOI:10.1002/jgrd.50521

What is CO2 Slicing?

CO2 slicing is described in Menzel et al. 2008. Similar to the ECMWF-CADS method, CO2 slicing compares differences of observed and clear radiances calculated from CRTM (specifically the radiative transfer model), but limits to CrIS channels that absorb CO2. The following equation is used to calculate CTP, by finding the first pressure, where this equation is true:

$$\frac{R_{obs}(\nu_1)-R_{calc}(\nu_1)}{R_{obs}(\nu_2)-R_{calc}(\nu_2)} = \frac{\left(\left(\frac{R_{obs}(\nu_1)-R_{calc}(\nu_1)}{B(\nu_1,T(P_c))-R_{calc}(\nu_1)}\right)\int_{P_{sfc}}^{P_c}\left[\tau(\nu_1,P)\frac{dB(\nu_1,T(P))}{dp}dp\right]\right)}{\left(\left(\frac{R_{obs}(\nu_2)-R_{calc}(\nu_2)}{B(\nu_2,T(P_c))-R_{calc}(\nu_2)}\right)\int_{P_{sfc}}^{P_c}\left[\tau(\nu_2,P)\frac{dB(\nu_2,T(P))}{dp}dp\right]\right)}$$

$R = radiance, \quad B = BT, \quad P_c = CTP, \quad P_{sfc} = Surface\ Pressure, \quad \tau = transmittance, \quad \nu = wavelength$

Channel pairs are used to detect changes in radiances, signaling a cloud, and the pairs used were selected with the assistance of ECMWF-CADS. The first pair of wavenumbers, [690.625 and 705] is first input as ν_1 and ν_2, respectively, into the equation above. If no pressure level makes the equation true, then the second pair [705 and 715] is input, then [715 and 733.125], finally [733.125 and 748.125]. If no pressure level satisfies the equation, then the FOV is marked clear.