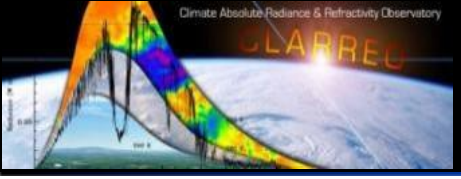

Climate Change Calibration Accuracy Requirements For Total Cloud and By Cloud Type

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[2]Science Systems and Applications

Two Updates: Requirements & ICF

1. Science-Driven Climate Change Accuracy Requirements
   - Quantify impact of instrument measurement uncertainty on detection time
   - For decadal-scale, global (climate-scale) trends how much does the instrument uncertainty delay trend detection times?
   1. Globally averaged, total cloud
   2. Globally averaged, by cloud type
2. Preliminary Results from Information Content Framework: OSSE Application

Climate observing system requirements

Climate Trend Uncertainty Factor

$$U_a = \frac{\sqrt{12(\Delta t)^{-3}(\sigma_{\mathrm{var}}^2 \kappa_{\mathrm{var}} + \sigma_{Vcal}^2 \kappa_{cal})}}{\sqrt{12(\Delta t)^{-3}(\sigma_{\mathrm{var}}^2 \kappa_{\mathrm{var}})}} = \sqrt{1 + \frac{\boxed{\sigma_{Vcal}^2} \kappa_{cal}}{\sigma_{\mathrm{var}}^2 \kappa_{\mathrm{var}}}}$$

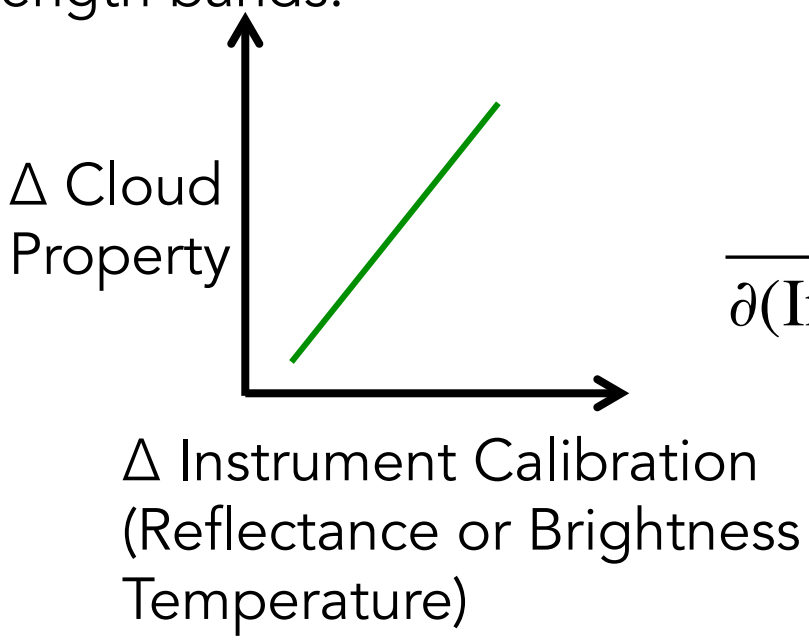
$U_a = 1.2$	For an instrument **20% from perfect**
Δt	Length of observed trend
σ_{var}	Standard deviation of variable time series anomalies
$\kappa_{\mathrm{var}} = \frac{1+\rho_1}{1-\rho_1}$	Natural variability autocorrelation constant: time between independent measurements - based on lag-1 autocorrelation (ρ_1)
κ_{cal} = 5 Years	Calibration autocorrelation time: estimated instrument lifetime used
σ_{Vcal} Unknown	Calibration uncertainty *as a function of the cloud property*

Leroy et al., 2008; *Wielicki et al.*, 2013

Climate observing system requirements

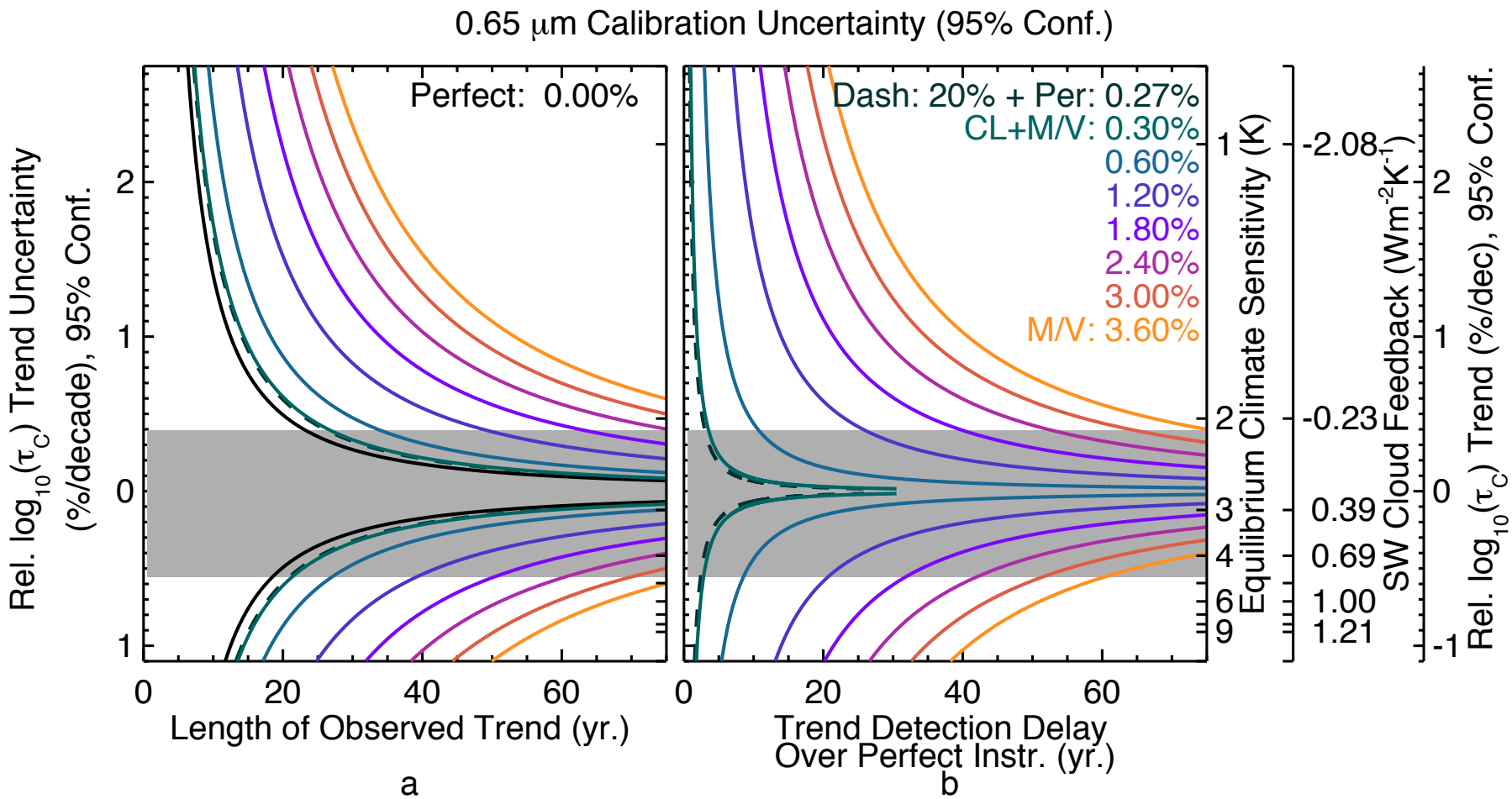
- σ_{Vcal}: Calibration uncertainty cloud property units.
- For influence on instrument design, this needs to be in instrument units - Reflectance (%) or Brightness Temperature (K)

- Therefore, we need the sensitivity of the retrieved cloud property to changes in instrument calibration in different wavelength bands.

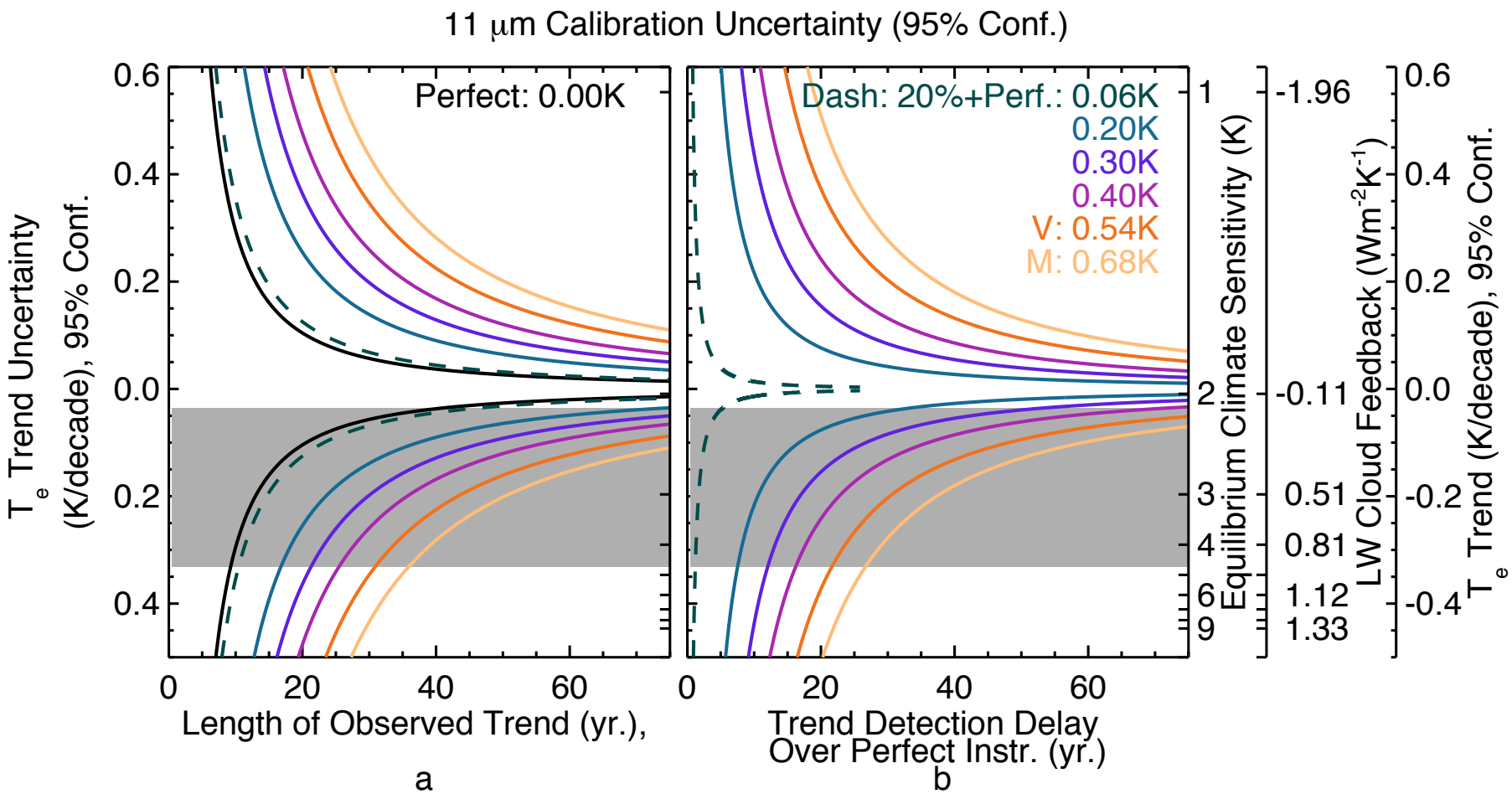


$$\frac{\partial(\text{Cloud Property})}{\partial(\text{Instrument Calibration}_{\lambda})}$$

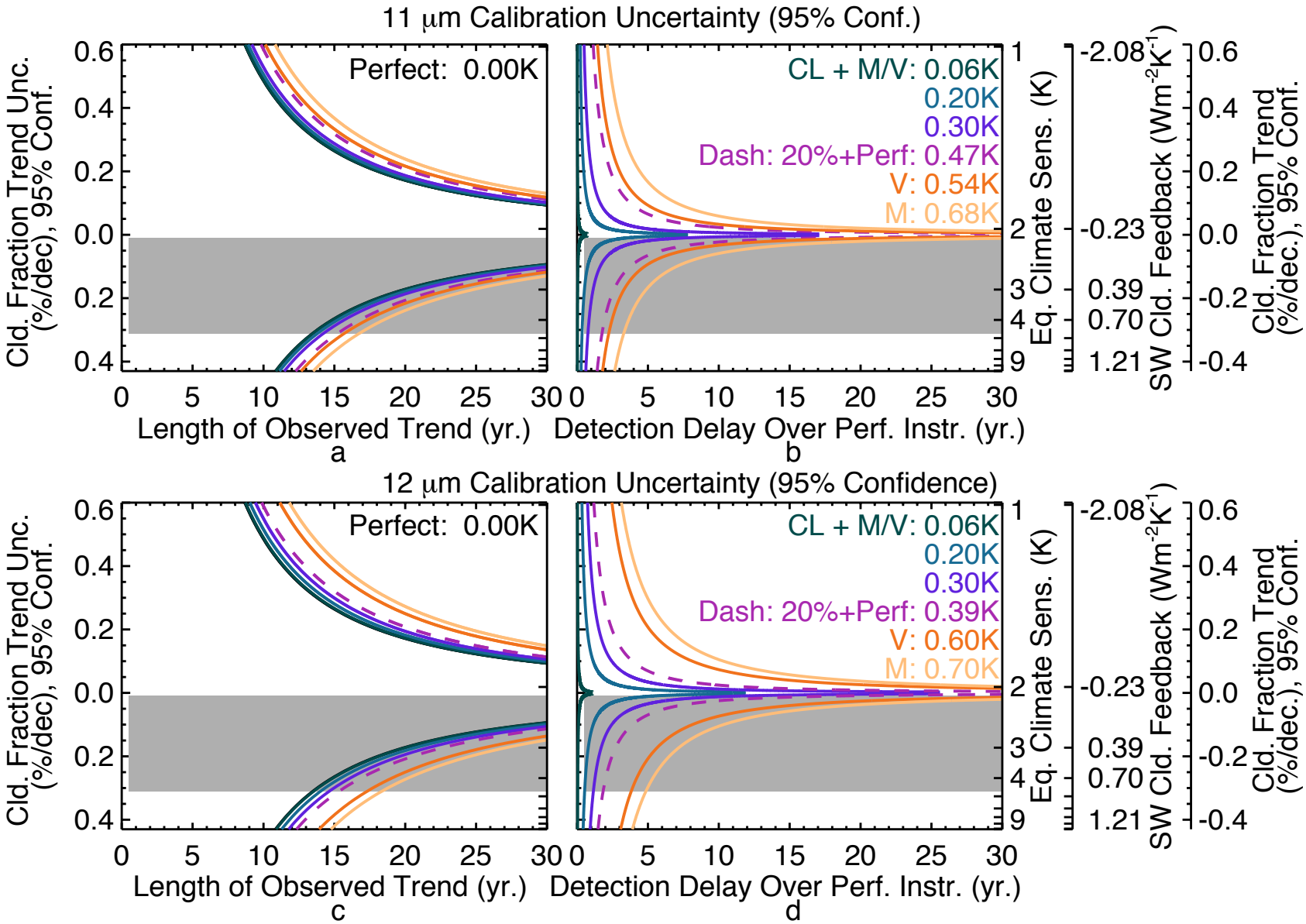
Placing Cloud Optical Depth Requirement into CMIP5 Context



Cloud Altitude Requirements in CMIP5 Context

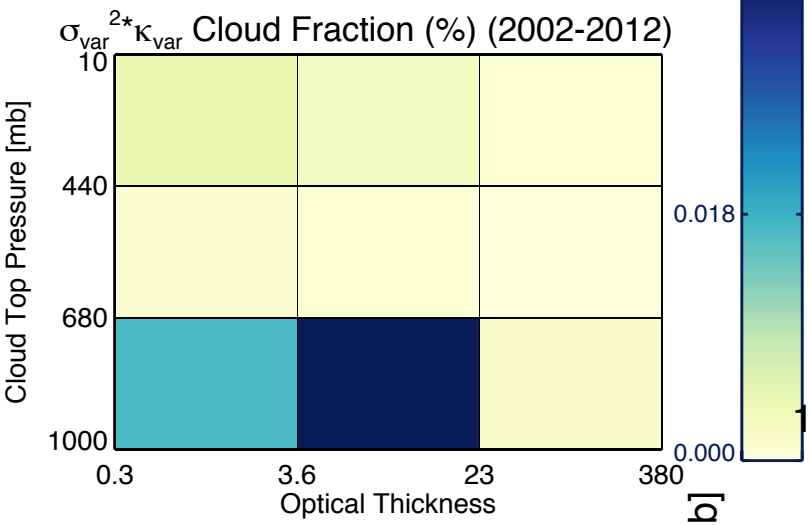


Cloud Fraction Requirements in CMIP5 Context

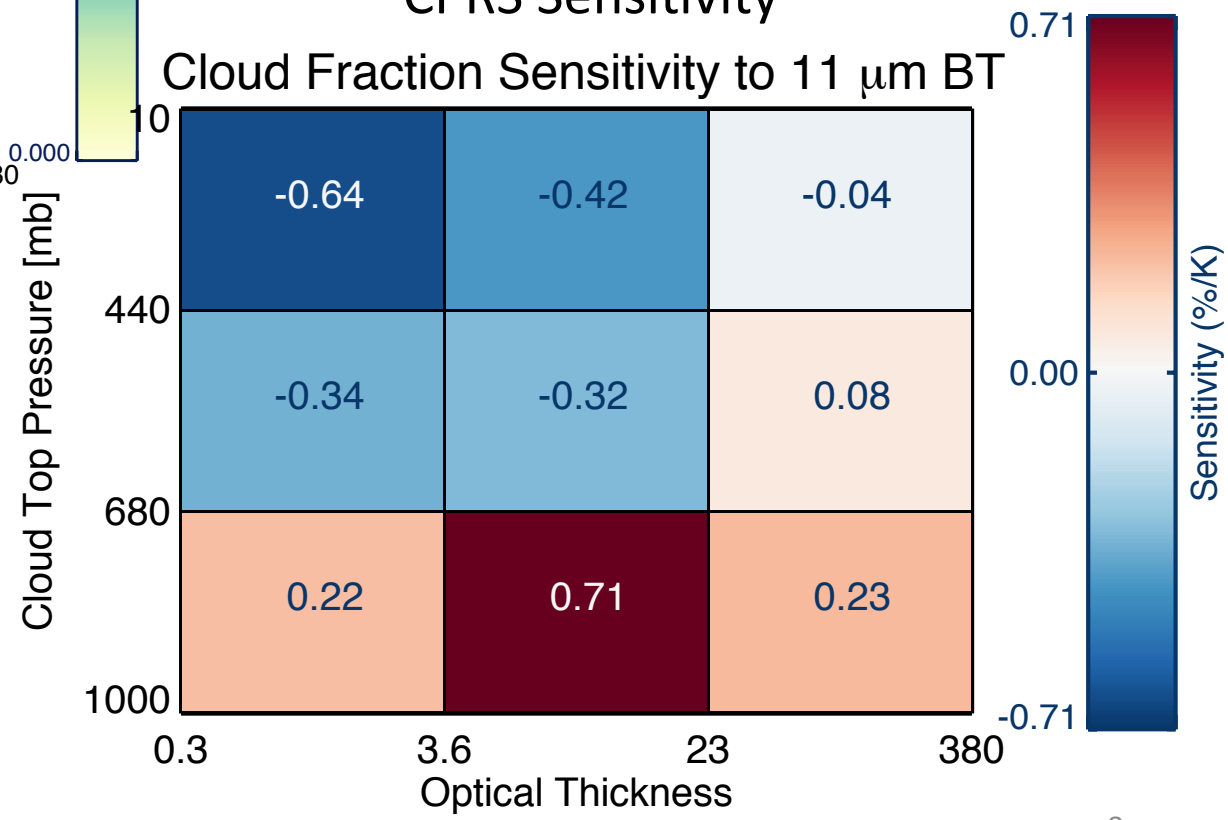


Cloud Fraction Requirement by Cloud Type (11um)

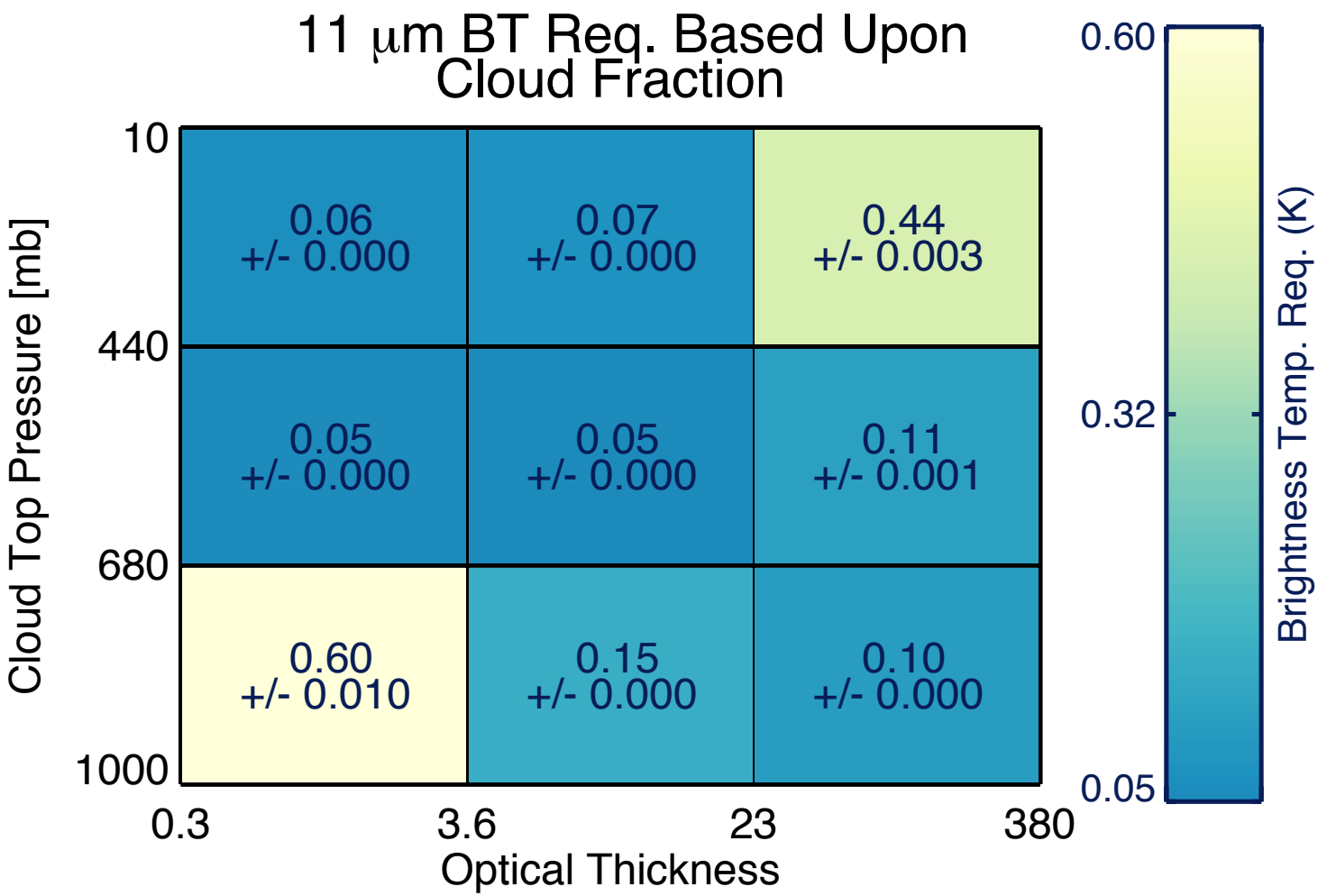
Natural Variability



CPRS Sensitivity



Cloud Fraction Requirement by Cloud Type (11um)



Next Steps

- Paper on total cloud studies close to submission-ready – Submitting to Journal of Climate
- Continue Cloud Type studies: Evaluating requirements by cloud type
- Follow-on Studies: Evaluate total and cloud type results by region
- Results shown here are independent of calibration changes in other bands
  - Follow-on study: Evaluating accuracy requirements considering changes in multiple bands simultaneously.

Information Content Framework

- Applying ICF to OSSE SW reflectance CMIP3 output for one year
  - Modifying 1) spectral resolution; 2) spatial resolution; 3) absolute spectral accuracy
- ICF to be applied to SCIAMACHY data over process-level and climate scale relevant time/space scales
- Daniel Goldin, Susan Kizer, and Xu Liu working on new PCRTM reflectance data set simulated using MODIS L2/L3 and ECMWF data products – one year only
  - The ICF will be applied to this data set as well

ICF Equations/Explanation

$$I(x_n) = \log_2\left(\frac{1}{p(x_n)}\right) = -\log_2(p(x_n))$$

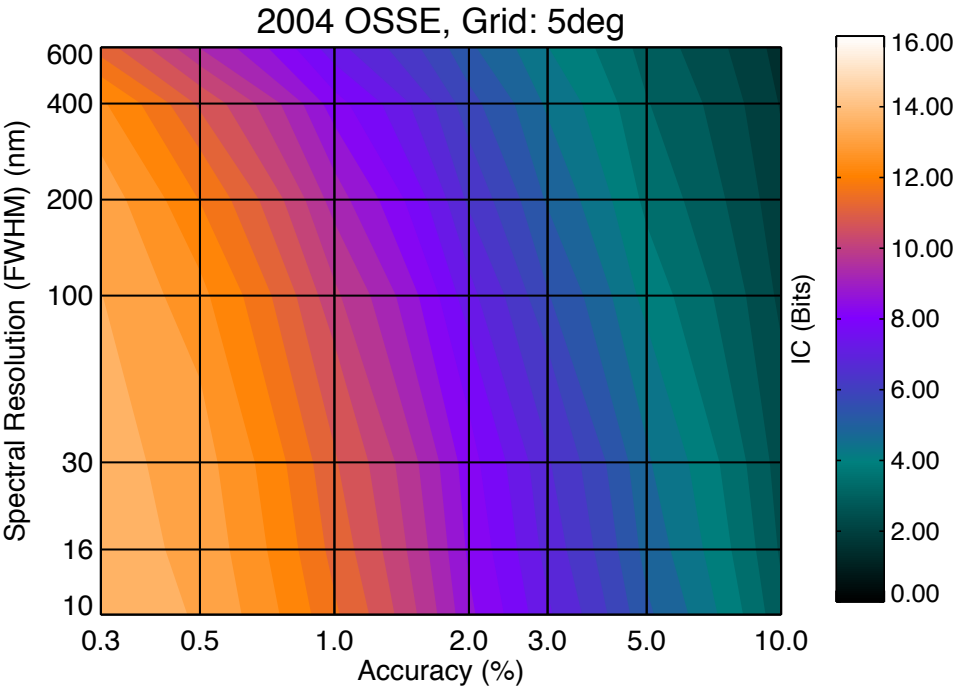
Self-Information for one spectrum out of *N* total spectra.

$$I(X) = E[-\log_2(p(x_n))] = \frac{-\sum_{n=1}^{N} p(x_n)\log_2(p(x_n))}{\sum_{n=1}^{N} p(x_n)}$$

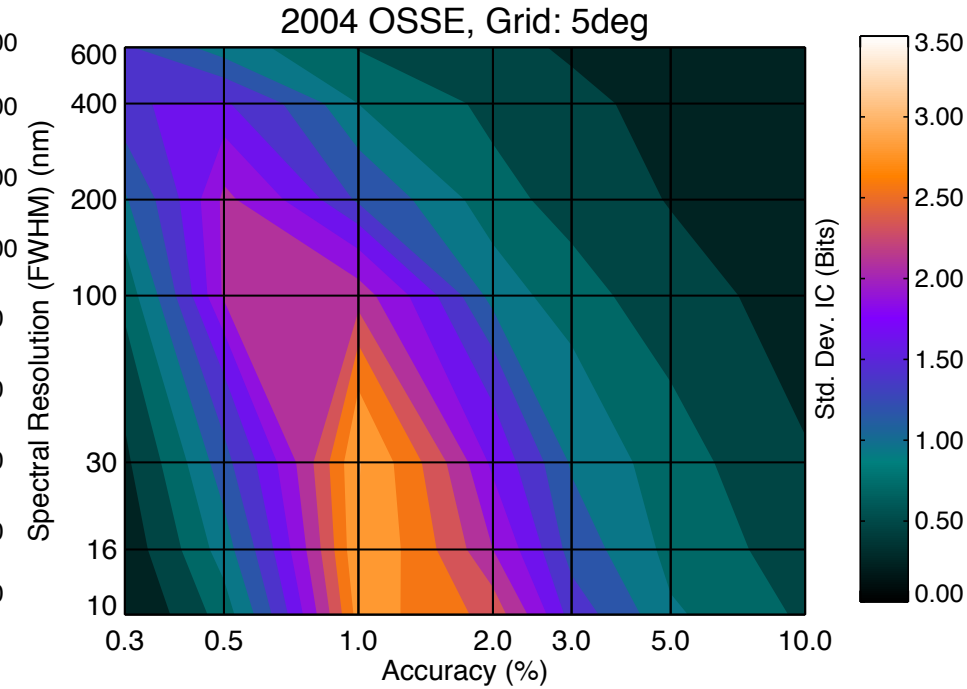
Generalized Formula: Self-Information for an entire data set composed of *N* spectra.

ICF OSSE Results for 2004: 5deg Grid

Information Content (Bits)



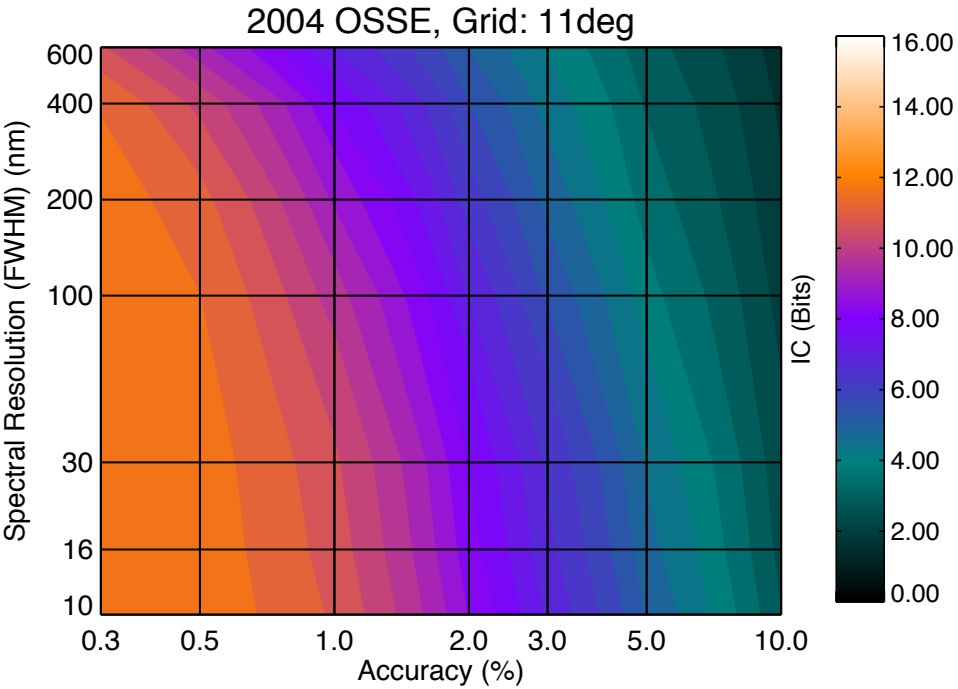
Standard Deviation ICF (Bits)



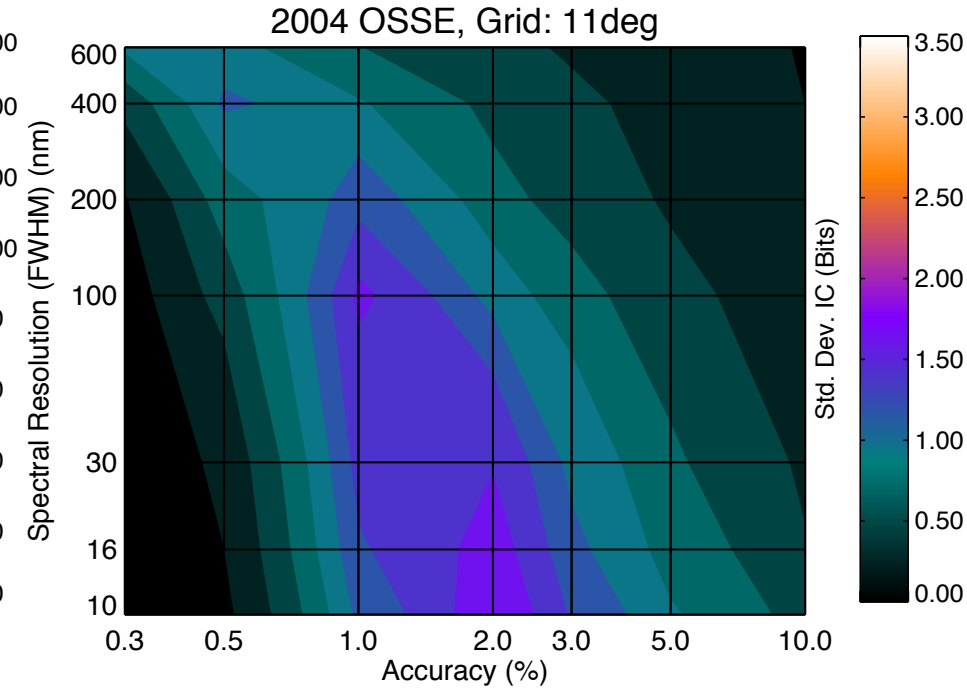
Both axes are on a log scale.

ICF OSSE Results for 2004: 11deg Grid

Information Content (Bits)



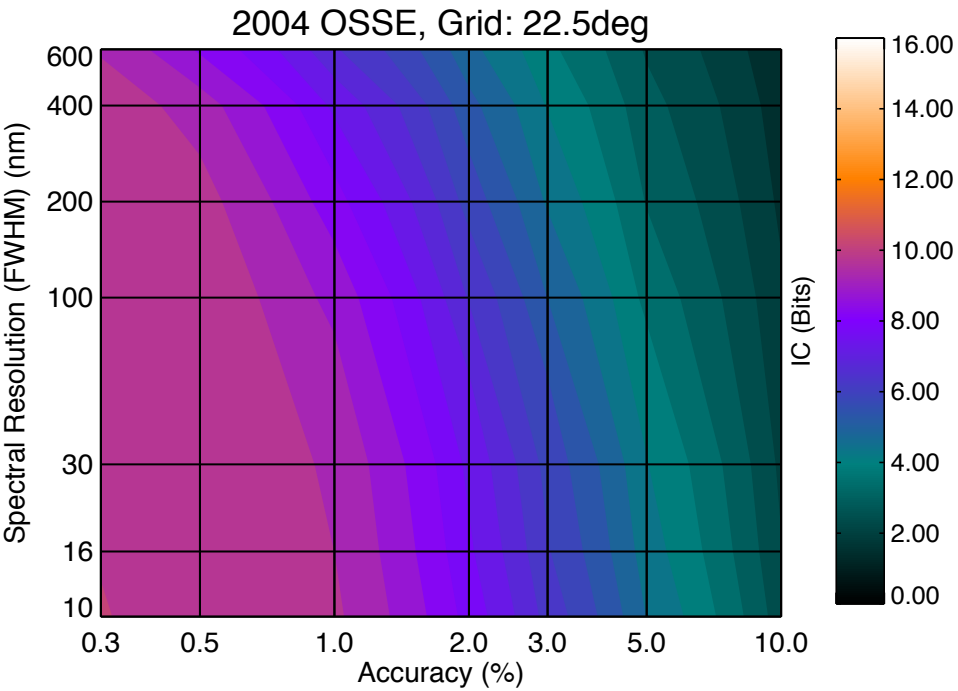
Standard Deviation ICF (Bits)



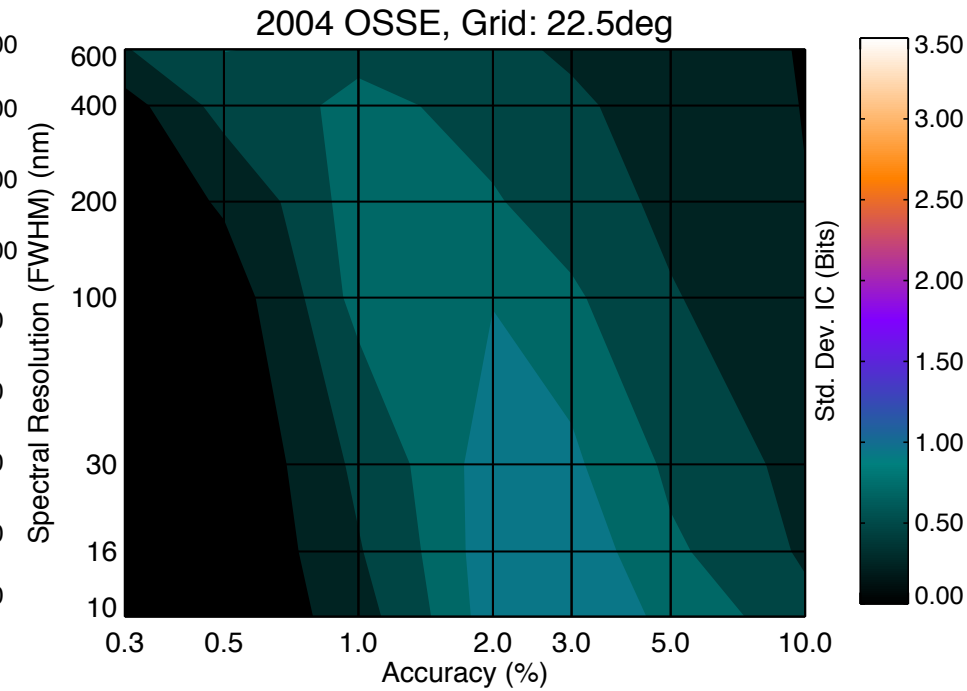
Both axes are on a log scale.

ICF OSSE Results for 2004: 22deg Grid

Information Content (Bits)



Standard Deviation ICF (Bits)



Both axes are on a log scale.

Next Steps: Information Content Framework

- Applying ICF to SCIAMACHY Data on weather & climate-relevant scales
- Continue developing PCRTM reflectance over one year using MODIS L2/L3 input
- Compute ICF for specific scene types – cloudy, clear, polar regions, etc