A discriminant analysis of hyperspectral data in clear and cloudy atmospheres

How do clouds matter?

King-Fai Li and Yuk L Yung

Division of Geological and Planetary Sciences, Caltech

Duane E Waliser

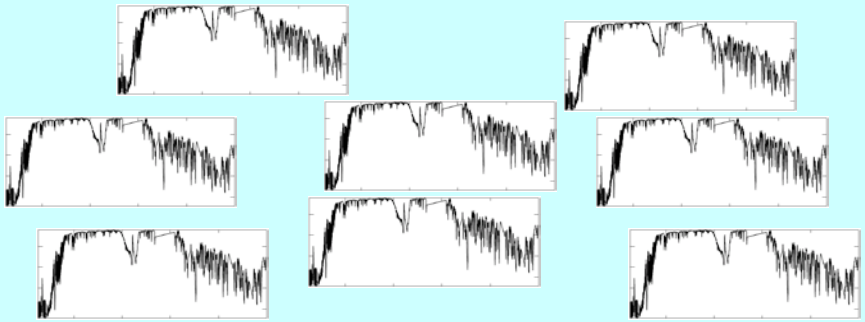
Science Division, Jet Propulsion Laboratory

L1B products

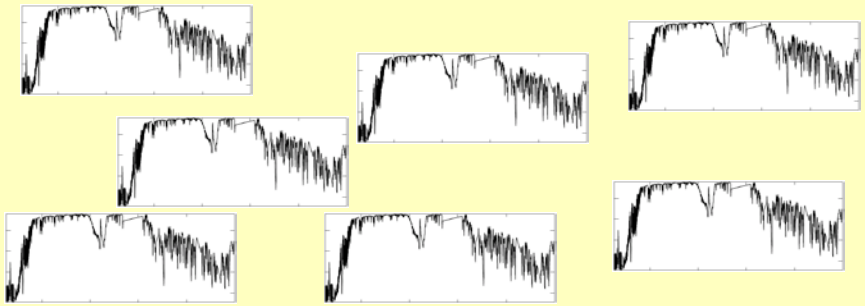
- They have signatures of both forcing (*e.g.*, changes of greenhouse gases) and the responses to the forcing (*e.g.*, temperature, water vapor, and clouds).

- Second-moment statistics are particularly important for testing model variability.

Clear Scenes



Cloudy Scenes

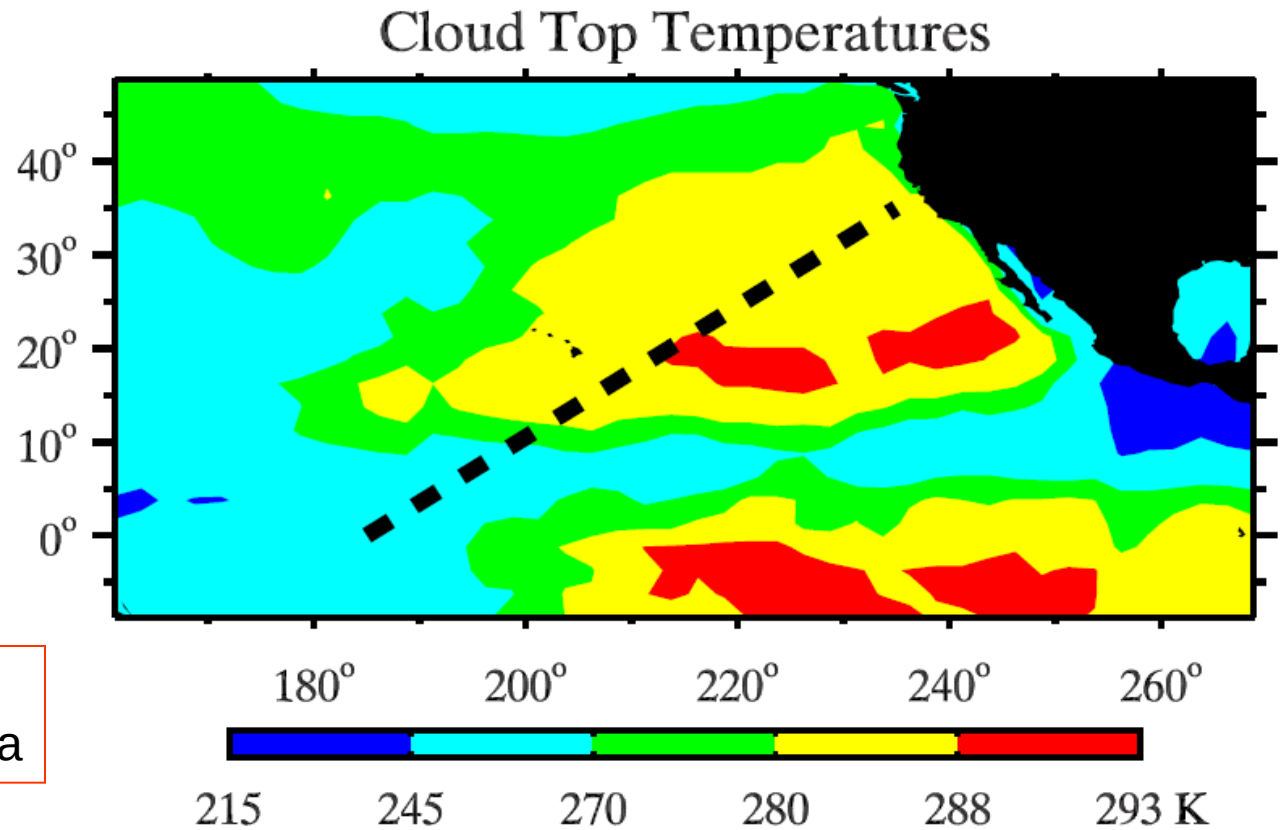


How to distinguish spectra belonging to these groups? → Reflectivity

How different are the spectra in these groups? → Difference in Spectral Mean

How different do they vary in these groups? → Spectral PCs

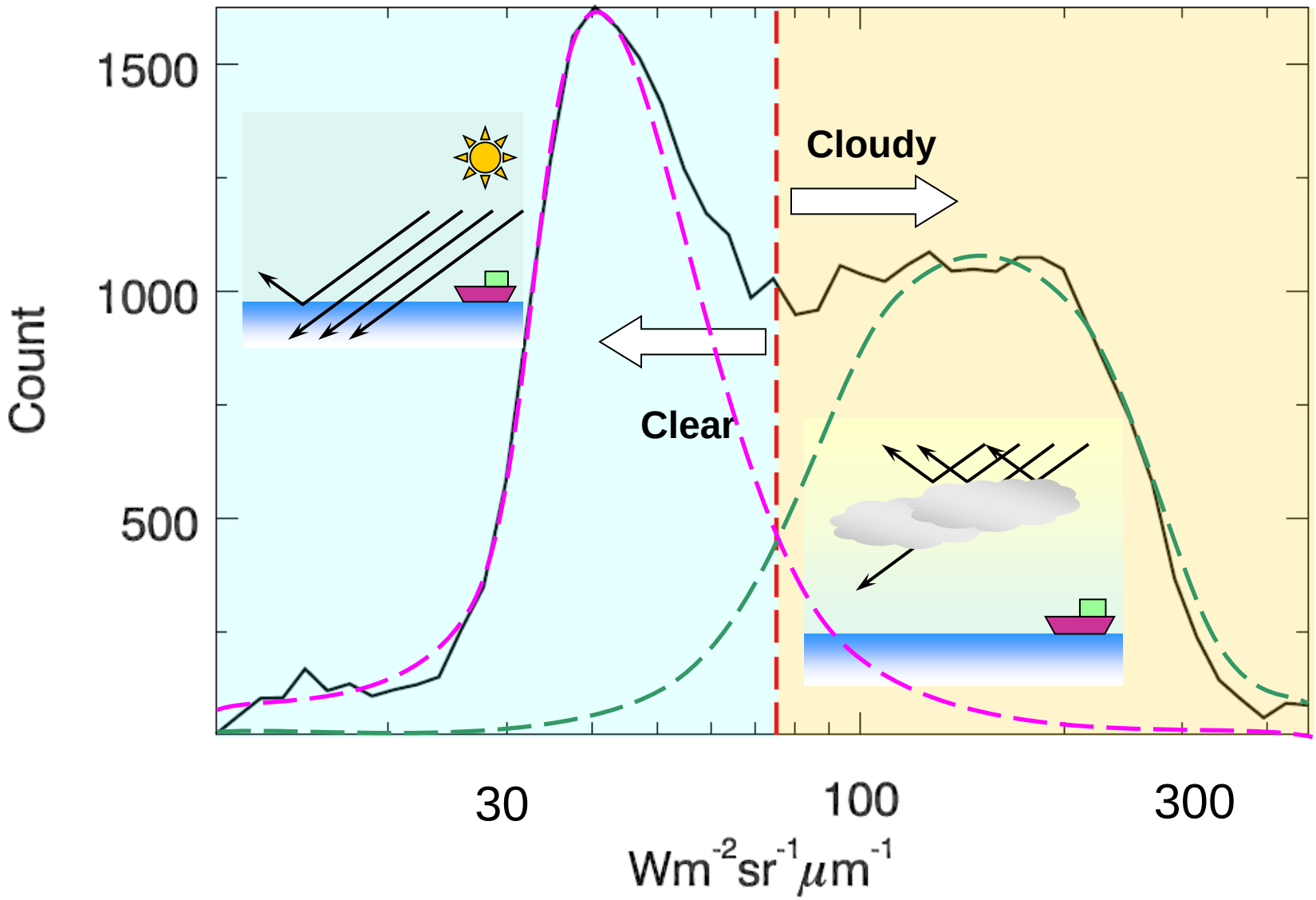
Pacific Cross Section



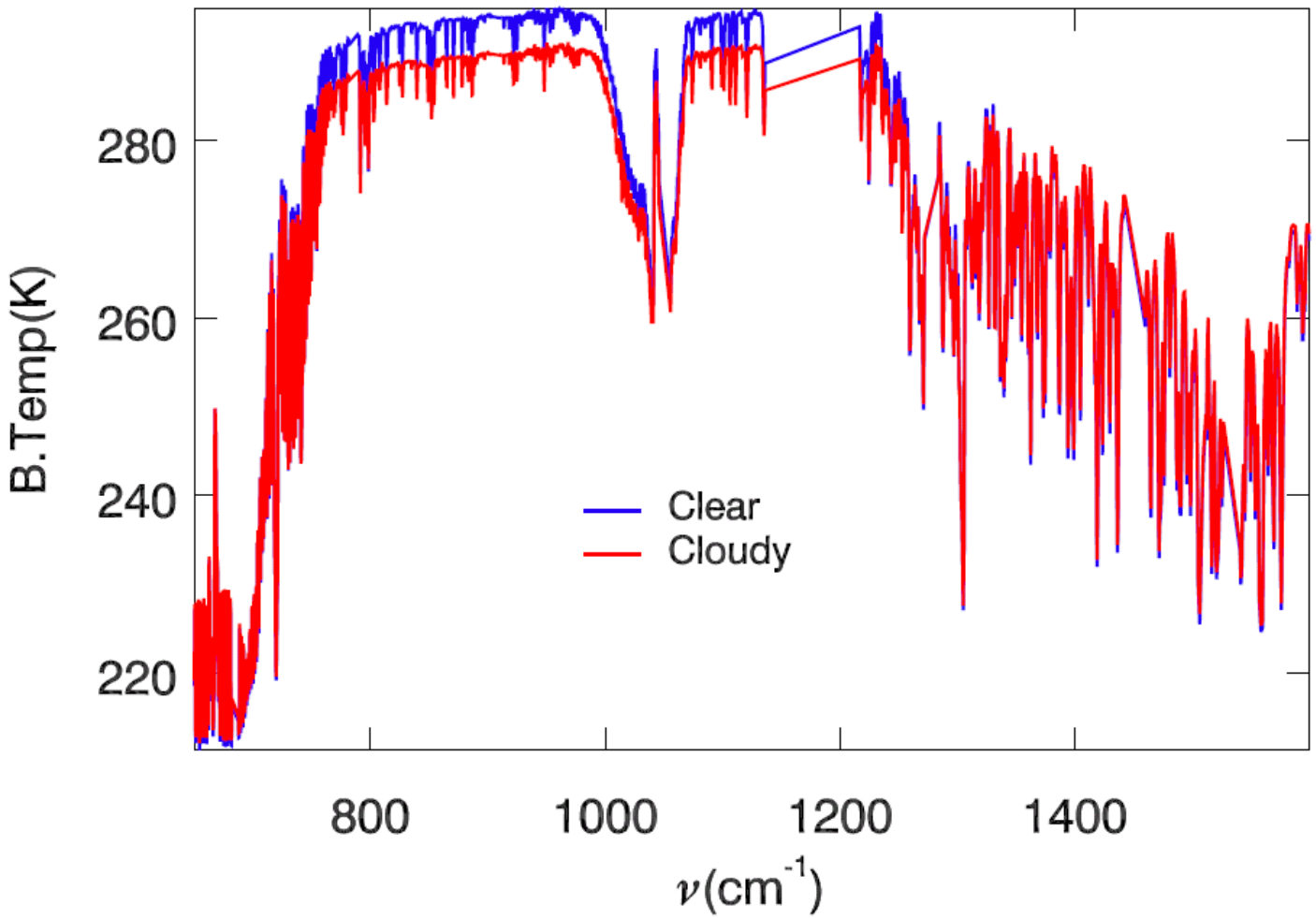
July, 2005
~20,000 AIRS spectra

Ideal place for testing GCMs:
From stratocumulus regions off the coast of California, across the shallow cumulus areas, to the deep convection regions of the ITCZ.

Reflectivity Index: AIRS Visible Channel (0.63 μm)

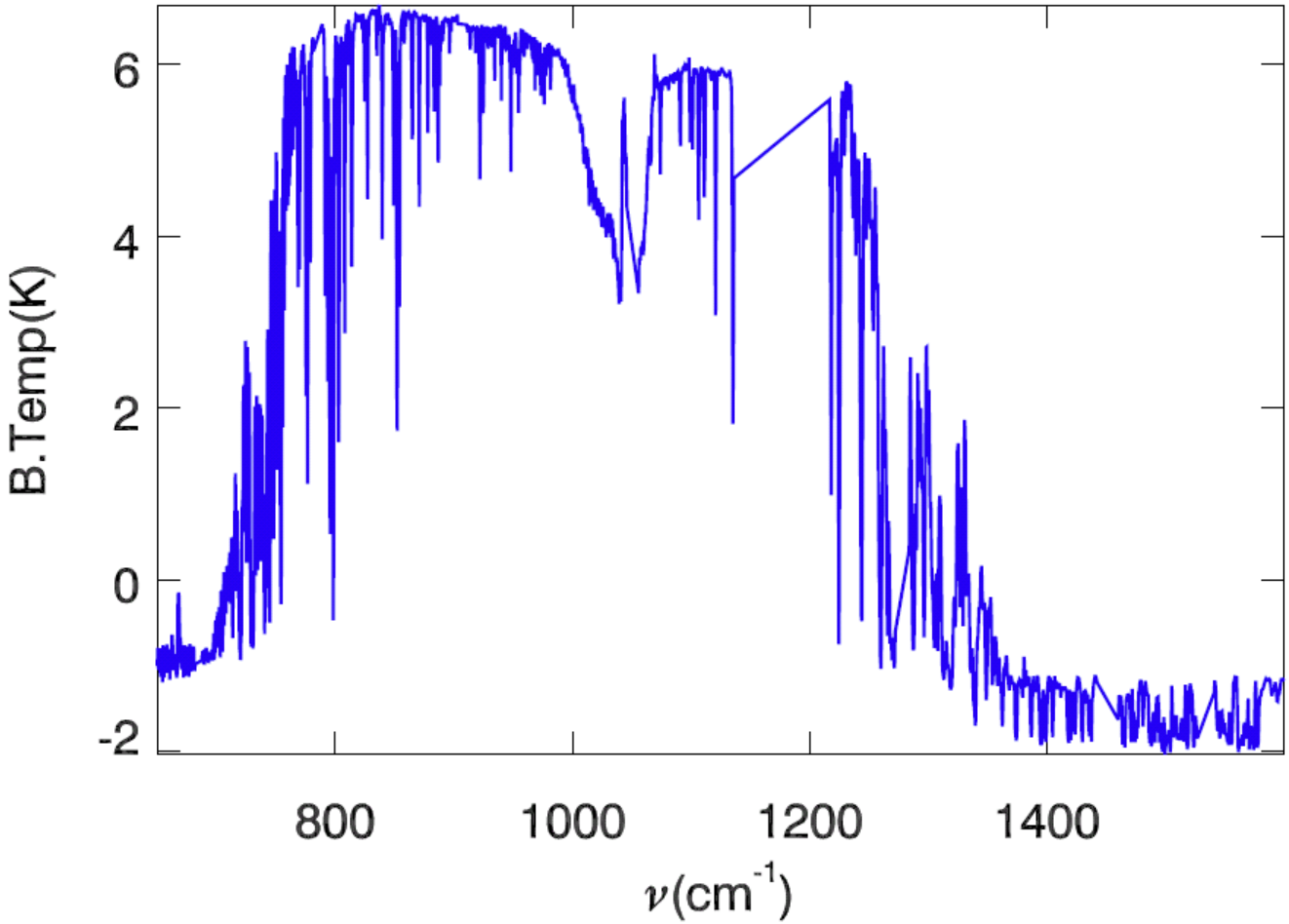


Group Means



Mean Difference

- Difference mainly in the window region
- Regions higher up are also affected?



Principal Component Analysis

- Series expansion of multivariate functions:

Data (zero mean)

$$D(\vec{x},\nu)=\sum_n f_n(\vec{x})\,g_n(\nu)$$

Space and time

wavenumber

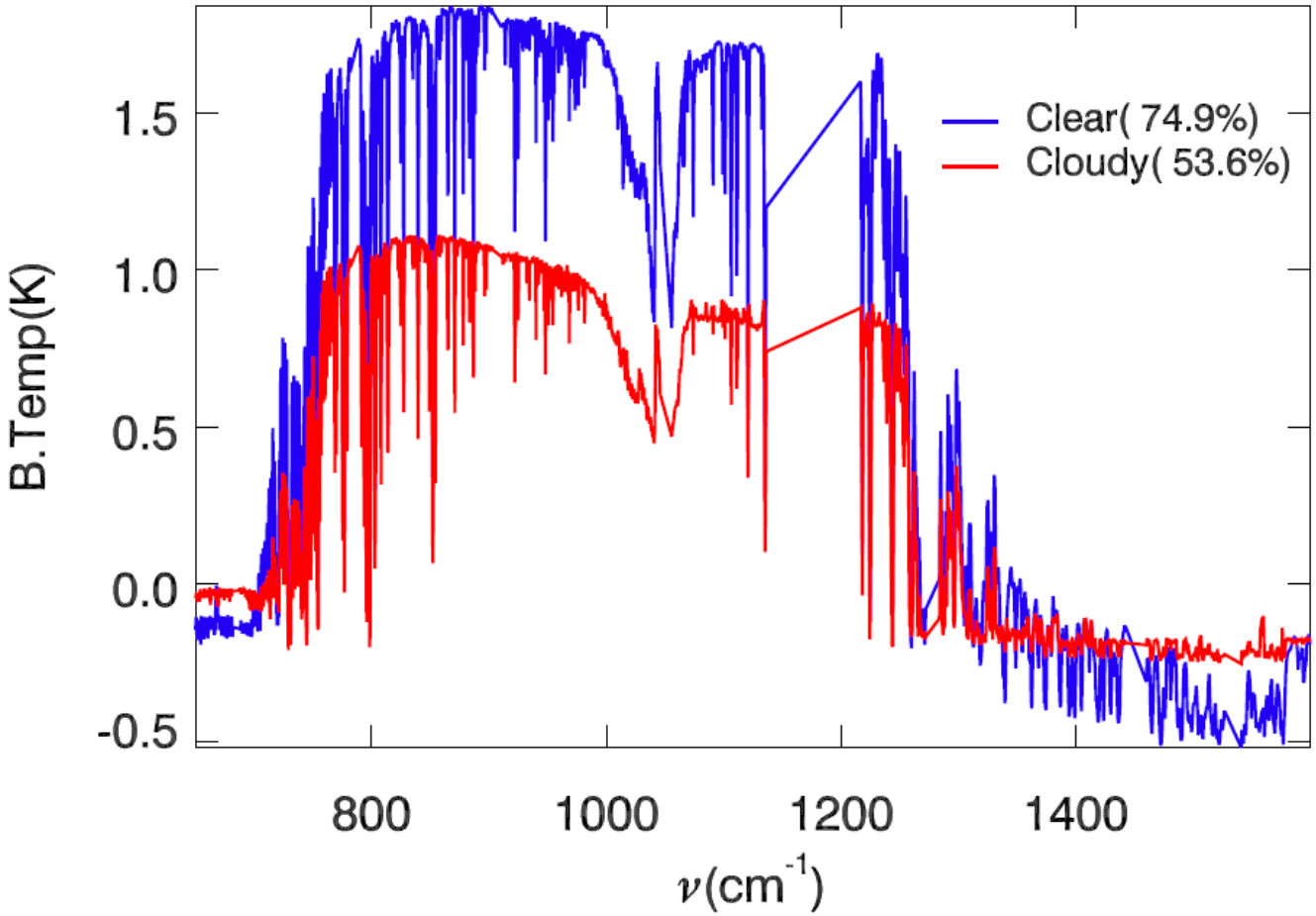
Principal components

where $g_n(\nu)$ are the eigenfunctions of the covariance matrix $D(\vec{x},\nu)^T D(\vec{x},\nu)$

- Percentages of variance given from the eigenvalues of $g_n(\nu)$

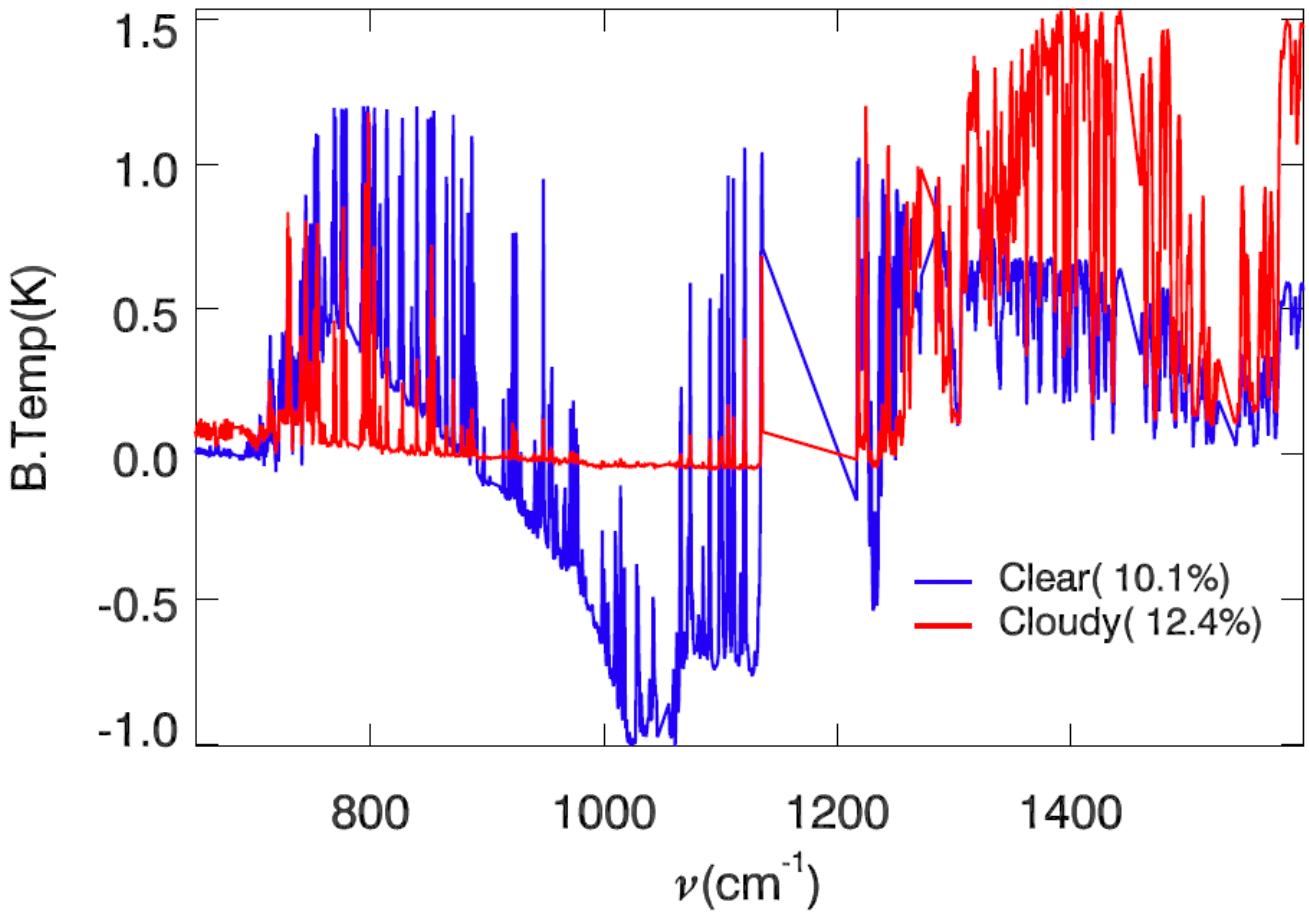
Principal Component #1

- Sea surface temperature dominates in clear group
- Cloud top temperature dominates in cloudy group



Principal Component #2

- Water vapor continuum dominates in clear group
- Upper atmospheric humidity dominates in cloudy group
- **These components best discriminate the groups.**



Summary

- The bimodal distribution of the visible channel serves as a training index to define clear and cloudy groups
- Mean spectra and principal components have been studied. Water vapor continuum is an important discriminant for the clear and cloudy groups.

Follow ups

- By what mechanisms does the water vapor continuum affect the spectra? Cirrus clouds?
- How can we make use of these results to decouple different types of clouds?

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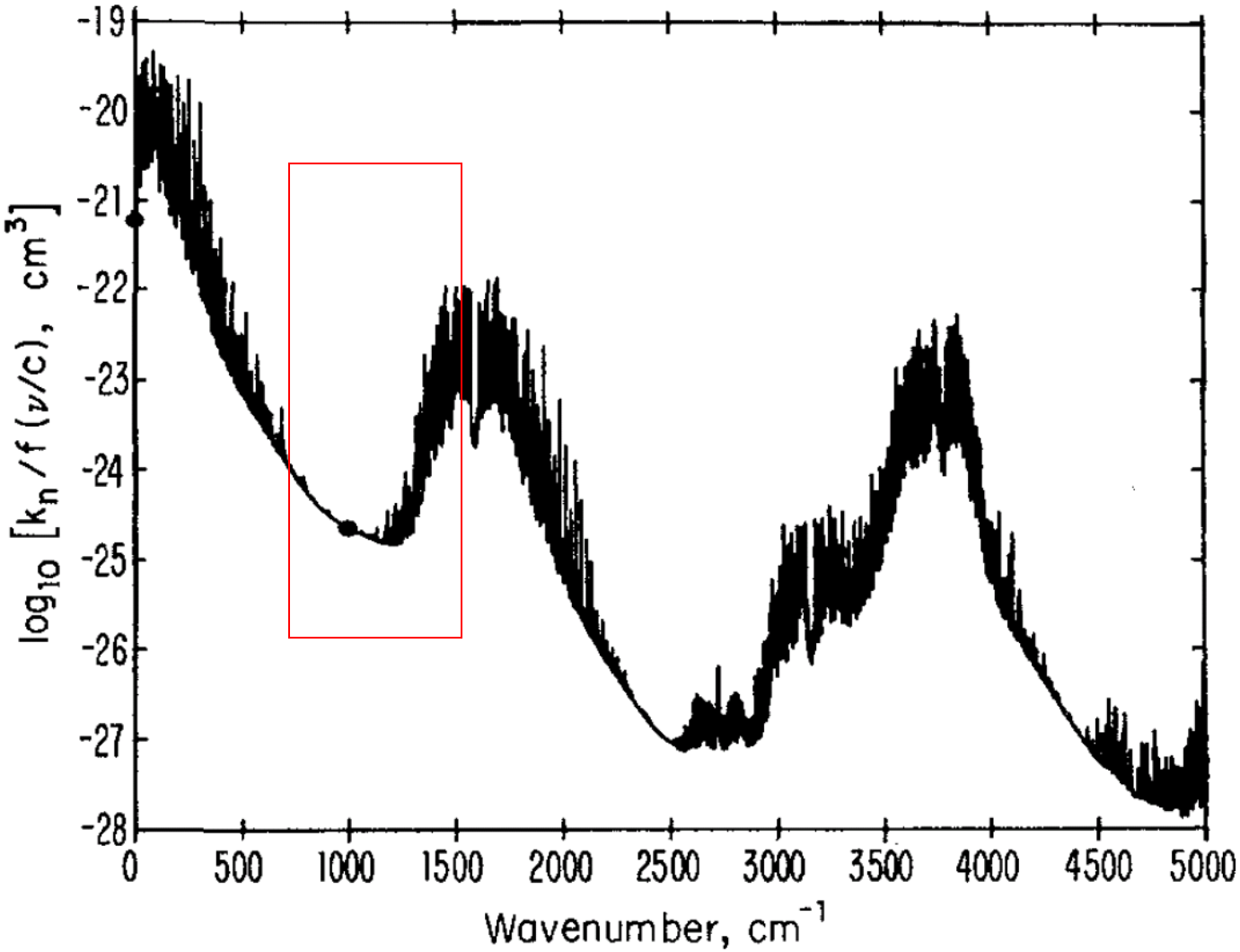
Water vapor continuum