Science Prototyping

Visualization and Validation Toolkit

Retrieval

- **Inversion Scheme**
  - Level 1 radiances --> Level 2 products.
  - Optimal estimation (Rodgers, 1976, 1990)
    - Requires a priori and measurement covariances
  - Prototype retrieval algorithm
  - Examine appropriate combinations of radiance channels to retrieve:
    - Temperature/pressure, aerosols, constituent gases
  - Examine multiplex retrievals using the HIRDLS viewing geometry:
    - Initially : profile-by-profile independent retrievals
    - More advanced : along track/across track/whole orbit batch retrievals
- **Operational retrieval algorithm**
  - Computational considerations
  - 8000 profiles x 10 products per day
  - Approximations : trade-off accuracy vs speed

Retrieval Sequence

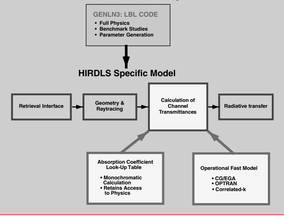
	Target	Contaminants					Channels				
1	T,p	CO_2,	H_2O	N_2O	CO_2,	O_3	Aerosol	2	3	4	5
2	Aerosol	H_2O	N_2O	CO_2,	O_3	HNO_3,	CH_4	1	6	13	19
3	O_3	CO_2,	H_2O	N_2O	CFC12	Aerosol		10	11	12	
4	H_2O	CH_4	H_2O	O_3	CO_2	Aerosol		18	20		
5	NO_2	H_2O	ClOn,	O_3		Aerosol		21			
6	HNO_3, CFC11 CFC12	H_2O	CO_2	O_3		Aerosol		8 7 9			
7	N_2O_5 N_2O ClONO$_2$, CH_4	H_2O	CO_2	HNO_3,	CF_4	Aerosol		14 15 16 17			

- **General Requirements**
  - initial guess profile(s) for species being retrieved :
    - climatology (interpolated)
    - or "nearest" profile at previous retrieval stage
    - or co-located profile at previous retrieval stage
  - contaminant profiles for gases contributing to emission but not being retrieved at same retrieval step :
    - as listed for initial guess profile
    - or co-located data at current retrieval stage
  - retrieval order
    - retrieve those species which contaminate other channels first
  - retrieval grouping
    - joint retrievals for channels with cross-contamination

Radiative Transfer Models

- **Forward Model**
  - Simulation of calibrated Level 1 radiances.
  - Spectroscopic, atmospheric, instrument parameters.
  - Hierarchy of models (validated against GENLN2).
    - LBL --> Tabulated Coefficients --> Fast Parameterized

Forward Model Hierarchy

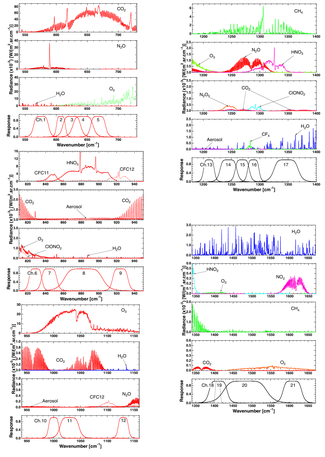


Spectral Channels

Gas	Channel / Target Gas																				
	Aerosol	Temper	CO_2	H_2O	H_2O	Aerosol	O_3	HNO_3,	CFC12	O_3	O_3	Aerosol	N_2O_5	N_2O	ClONO$_2$,	CH_4	CF_4	Aerosol	H_2O	NO_2
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CO_2	■	■	■	■	■																
Aerosol	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
O_3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
H_2O	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
NO_2																					■
CFC11								■	■												
HNO_3								■	■					■							
CFC12														■							
N_2O_5	■	■												■	■	■	■				
N_2O														■	■	■	■				
ClONO$_2$															■	■	■				
CH_4																■	■				
CF_4																	■				
O_2																			■		

Limb Radiance Spectra

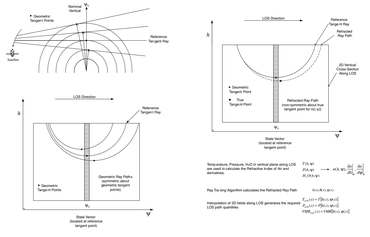
- **Typical atmospheric limb-radiance spectra calculated for a tangent height of 25 km at mid-latitude**
  - HIRDLS Channel band pass filters are represented schematically



Line of Sight (LOS) Gradients

- **Limb-radiance is dependent on horizontal thermal and constituent mixing ratio gradients**
  - sensitivity to thermal gradients increases with decreasing wavelength (Planck function dependence) for same opacity
  - optically thin channels are less sensitive to gradients
  - typical errors of 2-3 K in temperature for gradient of 1K/100km
- **Two-Pass Approach**
  - first pass
    - assume horizontal homogeneity
    - retrieve and grid products
  - second pass
    - calculate horizontal gradients from gridded data (local or global grid)
    - retrieve applying LOS correction
- **Limb-View Geometry Approach**
  - requires significant overlap of LOS paths for successive profiles
    - not applicable for standard HIRDLS global mode observations (5°x5°)
    - could be applied to observation modes with finer along-track spacing

2D LOS Geometry

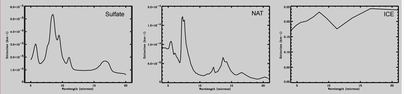


Aerosols

- **Aerosol Channels**
  - HIRDLS has 4 "designated" aerosol channels in which the contaminants are gases retrieved in other channels.

Channel	Wavelength	Contaminants
01	17.38 μm	CO_2, H_2O, N_2O
06	12.07 μm	CO_2, O_3, H_2O
13	8.26 μm	CO_2, O_3, HNO_3, N_2O, CH_4
19	7.10 μm	H_2O

- **Sulfate Aerosols**
  - spherical liquid drops, Mie theory appropriate
  - recent measurements of low temperature refractive indices
  - under background conditions we may assume that scattering is negligible
  - under severe volcanic conditions the single scatter albedo in the HIRDLS wavelength range may approach a few percent
- **Polar Stratospheric Clouds / Cirrus**
  - Scattering becomes significant problem for large particles
  - Non-sphericity of particles
  - Include scattering in HIRDLS forward model (correlated-k?)
  - All channels will show large effects in presence of PSC / cirrus
- **Spectral signatures of PSCs/cirrus/sulfate**
  - Difficult to correct gas channels adequately (e.g. refractive indices for PSCs are not well known)



- **Cloud detection**
  - each vertical column of detector focal plane array has an aerosol channel

Climatology Data

- **Climatological data are required for each contaminant species in the HIRDLS channels**
  - Gridded data on standard pressure surfaces
  - Temporal and spatial resolution depends on the species

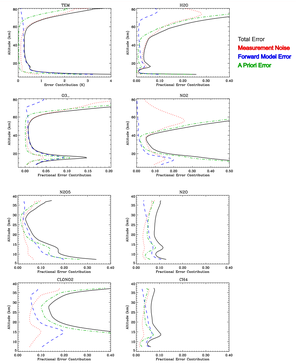
Field	Temporal	Spatial
CO_2	Fixed	1-D Profile
O_3	Monthly	2-D Zonal Mean
H_2O	Monthly	2-D Zonal Mean
NO_2	Monthly, Diurnal	2-D Zonal Mean
CFC11	Monthly	2-D Zonal Mean
HNO_3	Monthly	2-D Zonal Mean
CFC12	Monthly	2-D Zonal Mean
N_2O_5	Monthly, Diurnal	2-D Zonal Mean
N_2O	Monthly	2-D Zonal Mean
ClONO$_2$	Monthly, Diurnal	2-D Zonal Mean
CH_4	Monthly	2-D Zonal Mean
CF_4	Monthly	2-D Zonal Mean
O_2	Fixed	1-D Profile
Aerosol	Background to Volca nic	2-D Zonal Mean
Temperature	Monthly	2-D Zonal Mean
Height	Monthly	2-D Zonal Mean

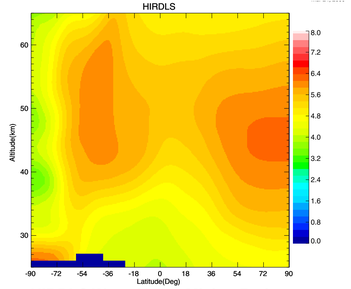
A Priori Data

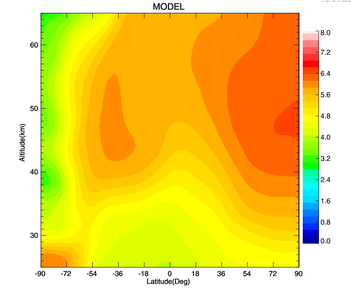
- **Consider a priori constraints to be "virtual measurements"**
  - represents priori knowledge of the atmospheric state and variability
  - combine with the direct measurements
- **Statistical constraint**
  - regard the a priori profile and covariance (determined from climatology) as an additional measurement and its uncertainty
  - retrieved state is a weighted mean of the true and a priori states plus a noise contribution
    $$\hat{\mathbf{x}} = \mathbf{A}\mathbf{x} + (\mathbf{I} - \mathbf{A})\mathbf{x}_a + \text{noise terms}$$
  - covariance is chosen to limit the bias introduced in the retrieved state
- **Matrix Inversion**
  - ensures non-singular matrices
- **Diagnostics**
  - retrieval formalism allows the influence of the a priori on the retrieved product to be quantified

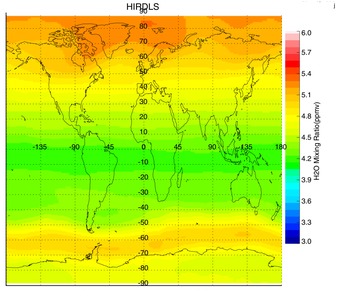
Error Characterization

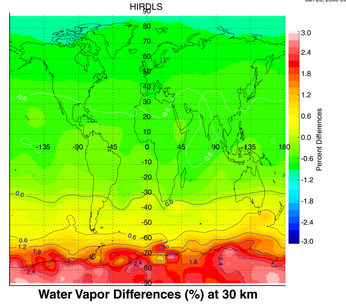
- **Error analyses performed using the AFGL tropical atmospheric model**
  - Temperature (4 channels, 02, 03, 04, 05)
  - Ozone (3 channels, 10 11,12)
  - Water vapor (2 channels, 18, 20)
  - Nitrogen dioxide (1 channel, 21)
  - CH_4, N_2O, $ClONO_2$, N_2O_5 (4 channels, 14, 15, 16, 17)
- Measurement error (channel noise only, pointing jitter not included).
- A priori error (temperature 20K, constituents 75% VMR off diagonal elements calculated using a correlation scale length of 10km)
- Forward model error (0.3% rms of radiance)
- Temperature error not included for constituent analyses



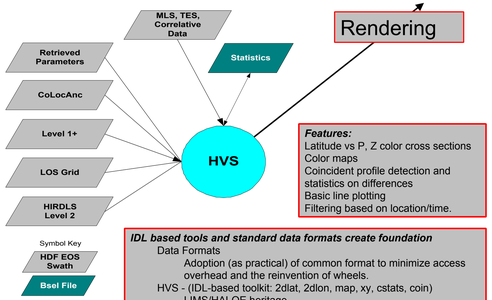






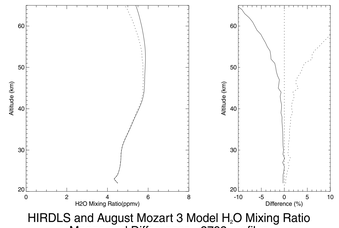


Validation and Visualization



Features:
Latitude vs P, Z color cross sections
Color maps
Coincident profile detection and statistics on differences
Basic line plotting
Filtering based on location/time.

IDL based tools and standard data formats create foundation
Data Formats
Adoption (as practical) of common format to minimize access overhead and the reinvention of wheels.
HVS - (IDL-based toolkit: 2dlat, 2dlon, map, xy, cstats, coin)
LIMS/HALOE heritage.
Collection of comparison, statistics, plotting & contouring routines with a simple command line interface.
Reads internal format (bsel) and HIRDLS HDF-EOS Swath.



HIRDLS and August Mozart 3 Model H_2O Mixing Ratio Means and Differences - 3792 profiles