Rapid Transmittance Status

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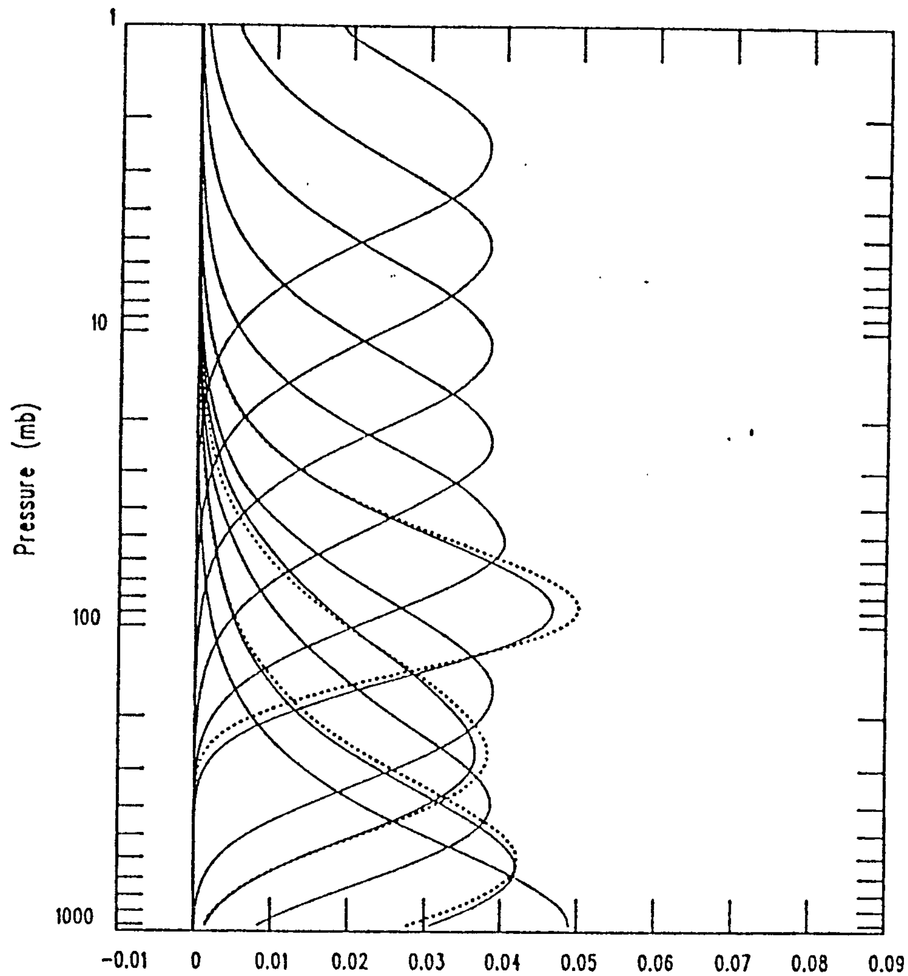
Atmospheric Weighting Functions



Transmittance level

- The level for the temperature measured by a given channel is determined by
  - the wavelength of the measurement
  - And the absorption spectra of the gases absorbing at that wavelength

Transmittance Definitions

- Monochromatic
  - Single wavelength on the absorption line
  - Transmittance calculations are easy
- Polychromatic
  - Wavelengths spread over a significant portion of the absorption line
  - Transmittance calculations are challenging
- Satellite measurements are polychromatic

Longwave Transmittance

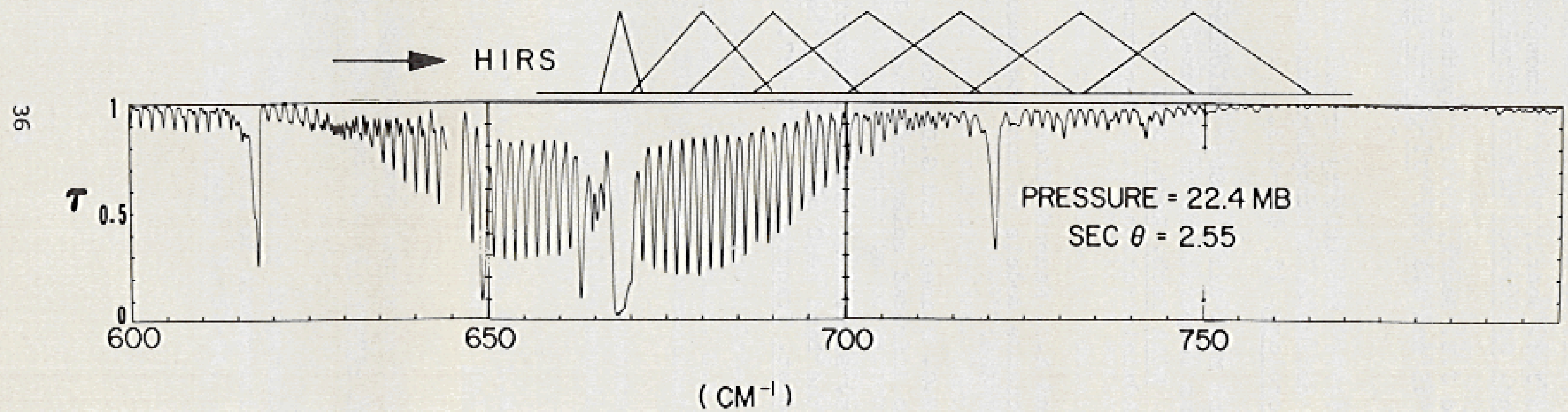


Figure 1.--Locations of idealized spectral intervals of HIRS channels 1-7 with atmospheric spectrum (Murcray et al. 1971) measured from balloon at altitude of 22.4 mb. Ordinate is in units of transmittance.

The Need For Rapid Transmittance Calculations

- Satellite measurements are compared to an model state
  - The atmospheric parameters for the guess state are known
  - The measure radiances are known
- Need to relate the model state vectors to measured radiances
  - Calculate radiances from the model state vectors
  - Analytic Jacobian is more accurate and faster than a brute force Jacobian

Transmittance calculations

- Line-by-line
  - All conditions and frequencies
  - Slow
  - Difficult to get the cases required for rapid transmittance models
- Intermediate models
  - All conditions and frequencies
  - Close to line-by-line accuracy
  - Fast enough to run cases required for rapid models
- Rapid model
  - parameterize a single channel
  - fast
- Models require rapid calculations

Current Status

- PFAAST/PLOD
  - Jacobians not done – may be difficult
  - Coefficient generation requires tuning
  - Uses OPTRAN for water vapor
    - Uses OPTRAN with optical depth, not absorption coefficient
- OPTRAN
  - Analytic Jacobians done
  - Coefficient generation is automatic
- RTTOVS
  - Analytic Jacobians
  - Performance on intermediate levels not known
  - Water vapor accuracy is not as good as OPTRAN

Requirements Rapid model Applications

- Numerical prediction centers
  - Need to analytic derivatives (adjoint, tangent linear, and Jacobian)
  - Speed is essential
- AIRS
  - Accuracy to check forward calculations

Two Versions of OPTRAN

- General
  - Predictors are level quantities
  - Predictors are interpolated to absorber space
  - Transmittances are interpolated to the profile space
- EMC
  - Predictors are model layer averages
  - Coefficients are interpolated to the model space
  - Highly optimized for (integrated into) the EMC model

Interpolation Issues

- Interpolation is essential for for rapid transmittance calculations
  - Model levels change with conditions (Sigma levels)
  - Interpolation is an integral part of intercomparisons
    - What levels do you use for comparisons?
    - Are the results typical of conditions in actual use?
  - Interpolation plays a key role in rapid transmittance models
    - Transmittances are calculated at fixed locations in some space
      - Absorber amount
      - pressure
  - Resources prevent a full evaluation of this effect
    - LBL calculations too slow to provide all the cases desired

Ideal Test

- Calculate the predictor profiles at the desired levels
- Calculate test profiles on a separate set of levels
- Reality – The predictor profiles are used in the evaluation
  - Note LBL runs take several months on a standard workstation
- We need an intermediate model such as kCARTA to provide flexibility to calculate the needed cases
  - Provides essentially LBL accuracy
  - Speed is much faster

Future

- We need an intermediate model such as kCARTA to provide flexibility
  - Provides essentially LBL accuracy
  - Speed is much faster

Comparison Results

- Comparison of OPTRAN and PLOD
  - OPTRAN was implemented as optical depth in this comparison
  - Current version uses absorption coefficient
  - Showed PLOD more accurate for the fixed gases
- Comparisons with RTTOVS
  - RTTOVS coefficients are calculated at the model levels
  - Comparisons are made at the same model levels
  - Showed constant pressure is more accurate for the fixed gases
- Our results
  - Small interpolation error
  - For fixed gases, OPTRAN and PLOD produce similar results
  - We believe the differences in results are the result of the differences in the test conditions (optical depth and no interpolation)

OPTRAN Features

- Transmittance coefficients are calculated at fixed intervals of absorber amount
- One model works for all gases
- Changes in transmittance at a given absorber amount are small
- Small changes are easier to predict accurately
- One Jacobian model is needed
- Coefficient generation is automatic

OPTRAN Equations

1. Gives the absorption coefficient calculation
2. Gives the absorption coefficient prediction
3. Gives the transmittance

Interpolation Choices

- Predict Transmittances
- Predict Optical Depths
- Predict Absorption Coefficients
  - OPTRAN
  - Rapid OPTRAN
    - Interpolate the prediction coefficients to the prediction model levels
    - Use the model layer values as predictors
  - OPTRAN on constant pressure for fixed gases
    - Combines the accuracy of the
    - Fixed level approach with the speed of the
      - Predicts optical paths
    - Fixed absorber approach – OPTRAN
      - Predicts absorption coefficients at fixed pressures
      - Angle replaces pressure as a predictor

Rapid Transmittance Calculations

- Steps required to generate a fast model
  - Select a set of dependent profiles that covers the range of atmospheric states
    - ~50
  - Select the levels at which the line-by-line transmittances are to be generated
  - Select the gases to be included
    - Currently 3
  - Select the angles to be used
    - 6
  - Perform the line-by-line calculations on the selected profiles
  - Generate prediction coefficients
  - Generate the Jacobian for the rapid transmittance model
  - Apply the rapid forward and Jacobian models

OPTRAN at EMC

- Steps to use OPTRAN
  - calculate the predictors at the profile levels
  - interpolate the regression coefficients for the absorption coefficient from the fixed amounts to the profile levels
  - calculate the absorption coefficients at the profile levels
  - convert the absorption coefficients to optical depths and calculate the transmittances, all at the profile levels

Speed Counts

- Important steps for speed
  - note that the average pressure and temperature need to be calculated only once per profile (not for every channel)
  - Rapid Jacobian calculations require channel independent calculations be pulled out of the channel loop and not calculated repeatedly
- OPTRAN with Jacobian takes 3.75 times the forward calculation alone
- We expect to get 2.5 after optimization

Transmittance Calculation Summary

- Line-by-line transmittance models
  - Can cover all conditions and frequencies
  - Calculations are slow
- Rapid transmittance model
  - Each channel has its own parameterization
  - Calculations are fast
- Models require rapid calculations
  - Line-line calculations take days for a few profiles
- Intermediate Models
  - kCARTA - needs friendly user interface

Completed Investigation at NESDIS

- Use OPTRAN formulation on pressure for fixed gases
  - predict average absorption coefficients (k) at average layer pressures
  - multiply by layer thickness to get optical depth
  - get transmittance
- Above can be accomplished in OPTRAN by
  - Replacing the absorber amount with pressure as the interpolation variable
  - Replacing pressure with the secant of the angle as a predictor
- Equivalent results were obtained

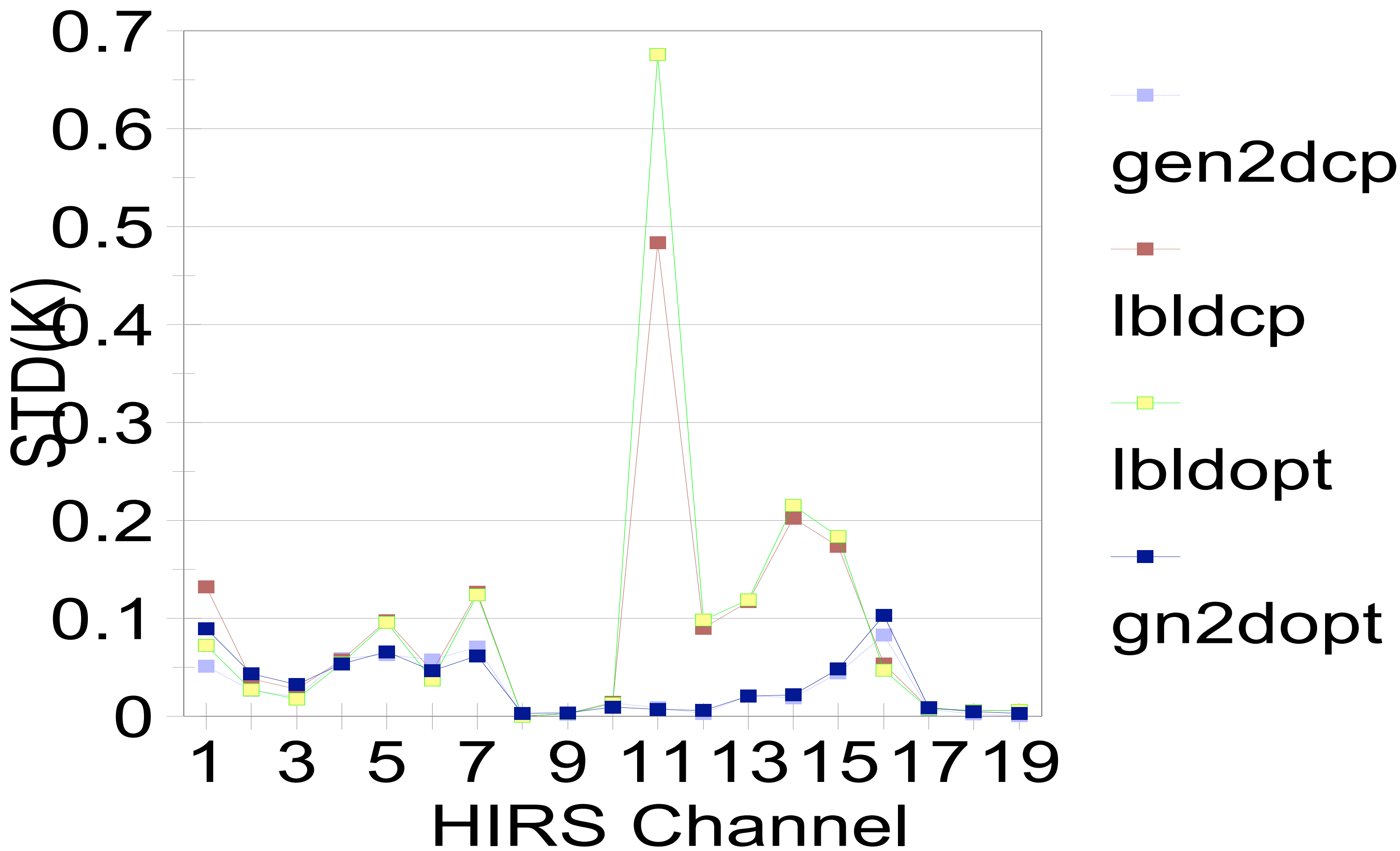
Current status of OPTRAN

- OPTRAN on pressure and OPTRAN on absorber amounts give similar results for fixed gases
- OPTRAN gives the most accurate results for water vapor
- OPTRAN formulation uses only 1 interpolation for varying pressures and absorber amounts - fixed pressure formulations require 2 (1 for the state variables and 1 for the transmittances)

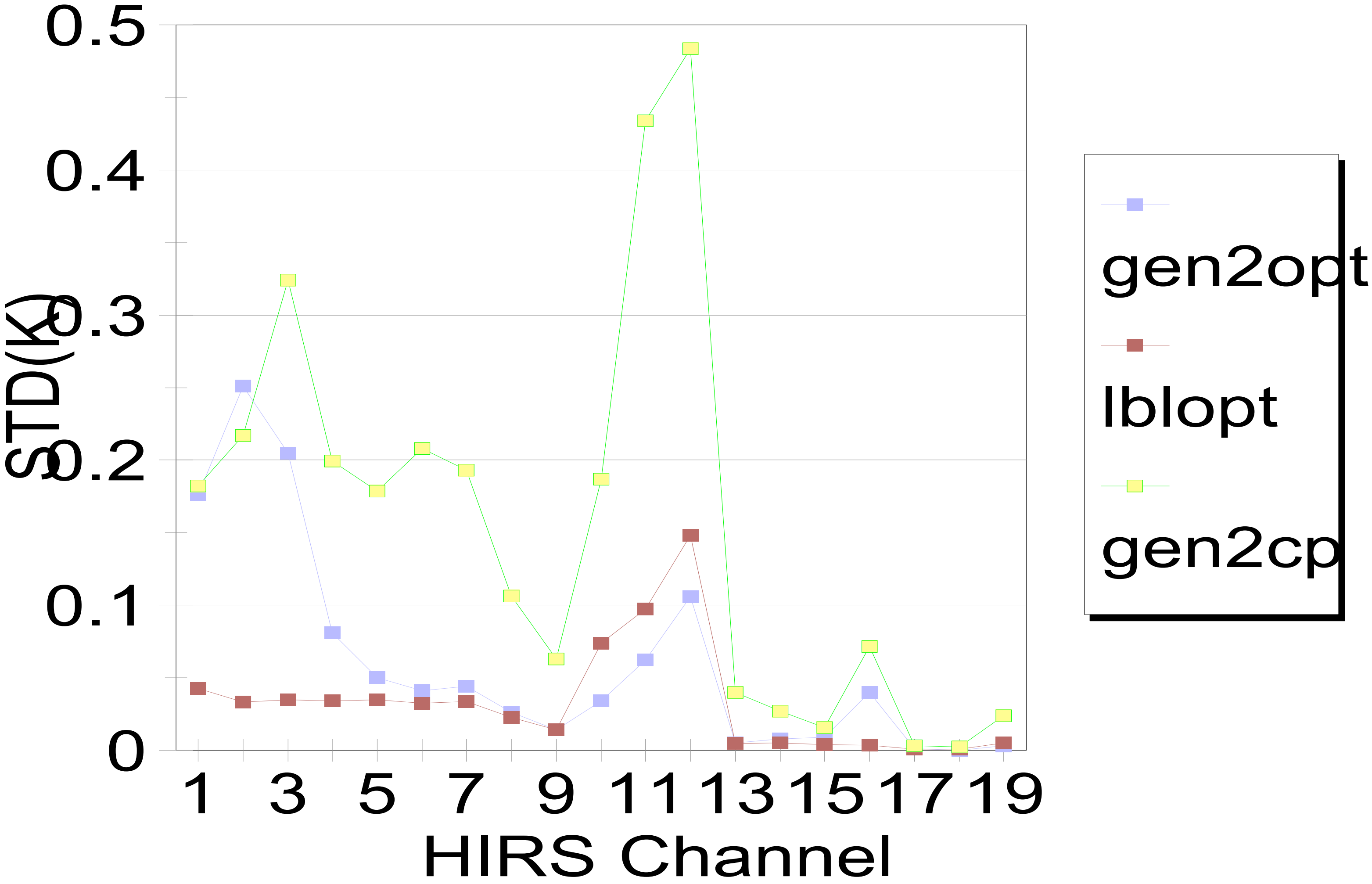
LBL source comparisons

- The next 3 slides compare the effects of the LBL sources on both absorber spacing (OPTRAN) and a constant pressure spacing
- LBLRTM
  - 32 atmospheres
  - But only 6 independent ozone profiles
  - 45 pressure levels - levels are added to the top
- GENLN2
  - 43 profiles for dry gases
  - 34 separate profiles for ozone
  - 43 pressure levels

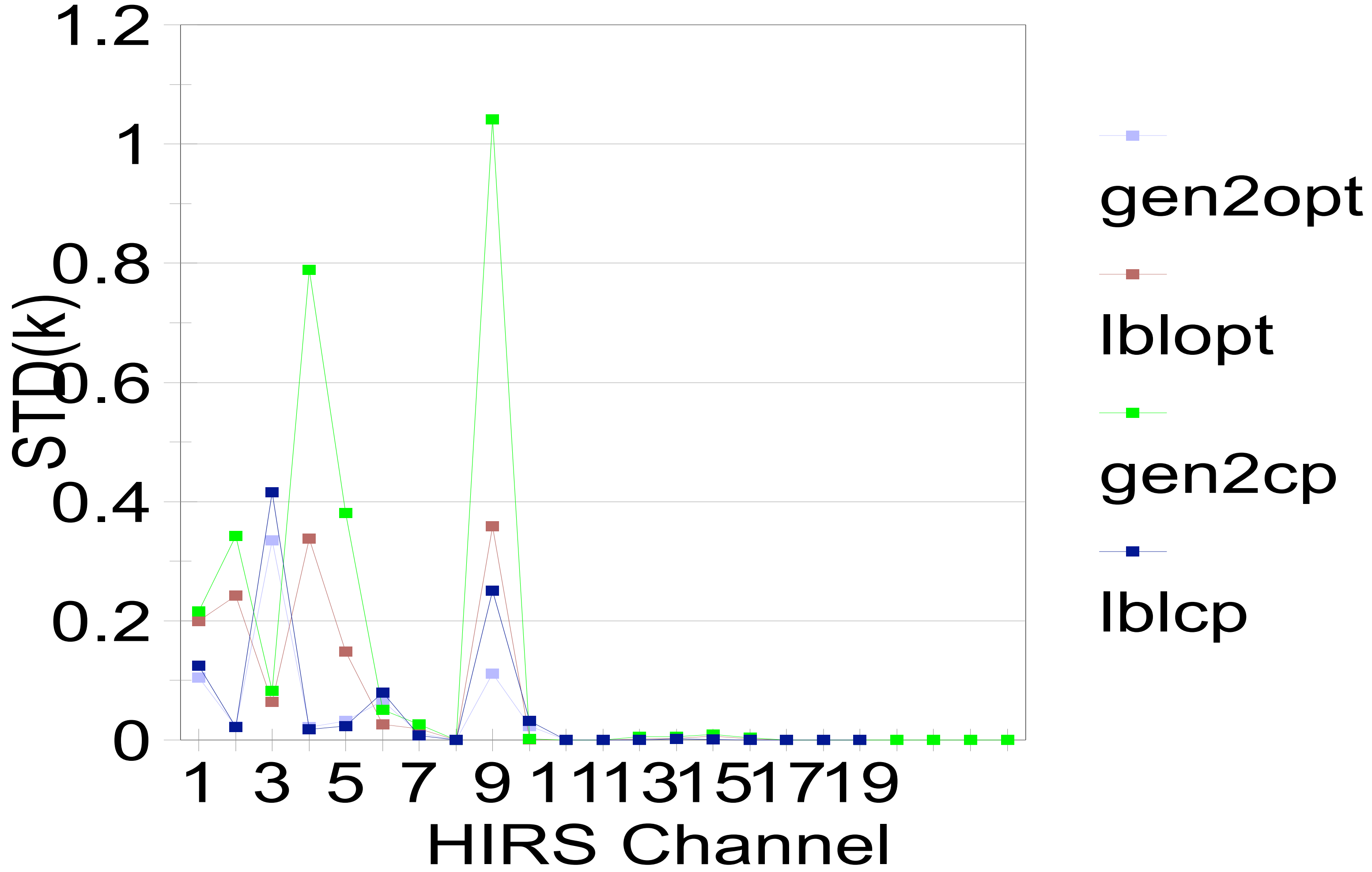
Dry Gas Comparis



Water Vapor


0.5
0.4
0.3
0.2
0.1
0
STD(K)
1 3 5 7 9 11 13 15 17 19
HIRS Channel
gen2opt
lblopt
gen2cp

Ozone Compariso



Comparison Results

- OPTRAN on pressure and OPTRAN on absorber amounts give similar results for the dry gases
- OPTRAN gives the most accurate results for water vapor
- OPTRAN gives the most accurate results for ozone
- LBLRTM has problems for the dry gas calculation for channel 11
- Ozone results for LBLRTM are questionable because only 6 actual profiles are used.

Use Effective Transmittance for Multiple Gases to Include Foreign Gas Effects

Changes Since the Last Publication

- Interpolate the coefficients directly
- Constant pressure formulation

NOAA LBL Concerns

- A fast transmittance program needs timely access to accurate LBL transmittance calculations
- Need to get support and a facility to calculate new LBL terms
- Need to agree on needs at the present
  - Need all combinations of gases (ie. 7 runs for 3 gases, not just 3 or 4)
    - Required for accurate calculations of mixed gases
    - The best order depends on the wavelengths region - one order does not work for all cases
  - Need to agree on a comprehensive set of profiles
  - Need to supply the true LBL profile along with the input profile and the transmittances
  - Need more layers at high altitudes for high resolution instruments

Plans

- Generate a user friendly version of KCARTA
  - Any reasonable data LBL data base can be calculated
  - Can run all combinations of gases
- Add layers at the top of the atmosphere
- Speed up the Jacobian calculation
- Generate coefficients and Plank functions for super channels
- Calculate coefficients for AIRS and IASI
- Stabilize the regression coefficients at the top of the atmosphere
- Add a single line-mixing gas
- Add scattering
- Add reflection terms
  - Includes surface emissivity

Conclusions

- Rapid transmittance models are:
  - fast
  - accurate
- Potential Improvements:
  - include trace gases
  - variable pressure layers
  - allow the concentrations of “fixed” gases such as carbon dioxide to vary
  - speed up the Jacobian calculation
  - Include high resolution instruments
  - Rapid line-by-line calculations
    - kCARTA
      - needs independent verification of accuracy
      - needs to be easy for relatively inexperienced user to use