Development of RT Models Based on the Optimal Spectral Sampling (OSS) Method

Jean-Luc Moncet and Gennady Uymin

AER, Inc.

presenter: Alan Lipton

Topics

- OSS S/W Transition to JCSDA
- Generalized training
- Land validation
- Application to cloudy atmospheres
- Summary

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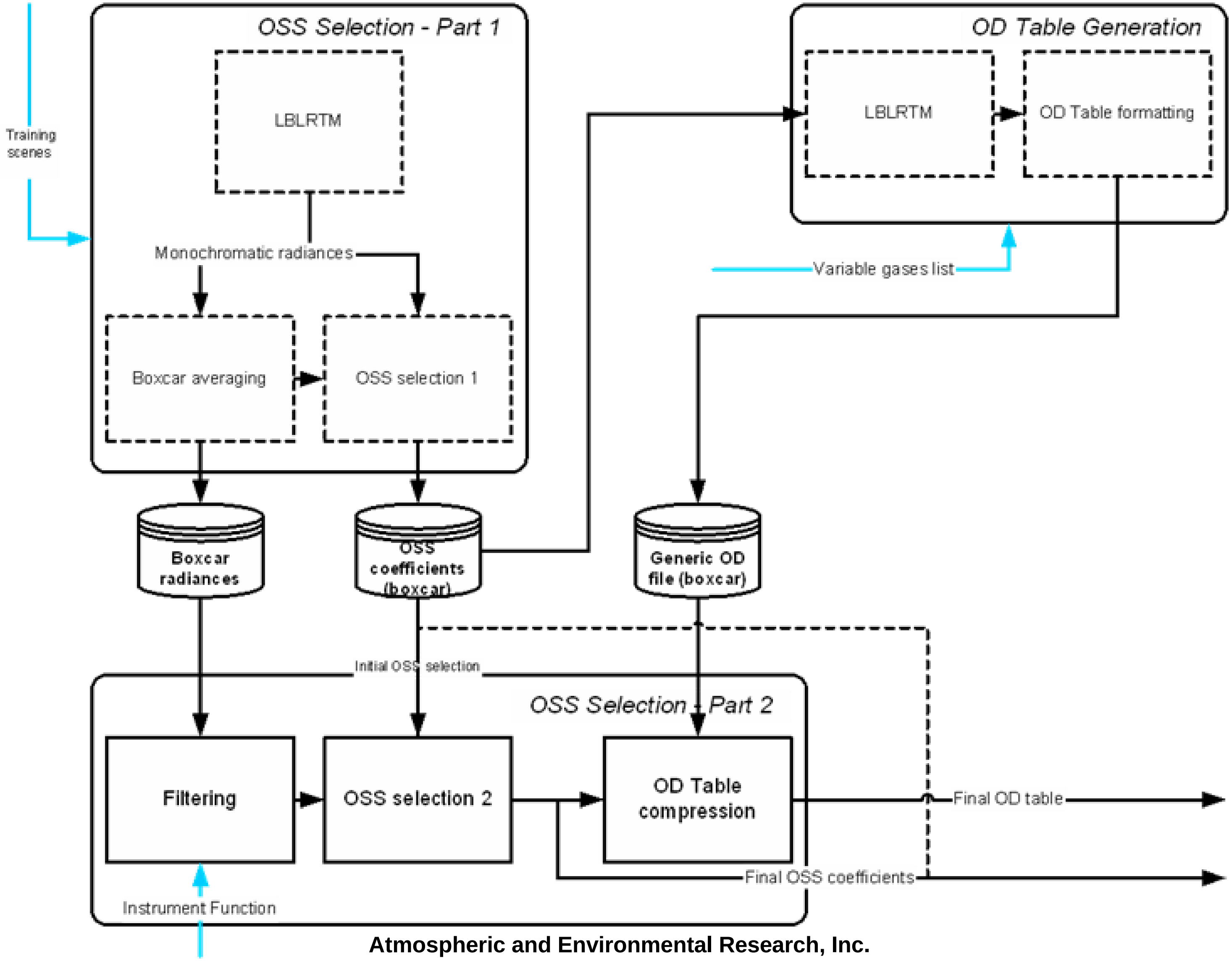
OSS S/W Transition to JCSDA

Status

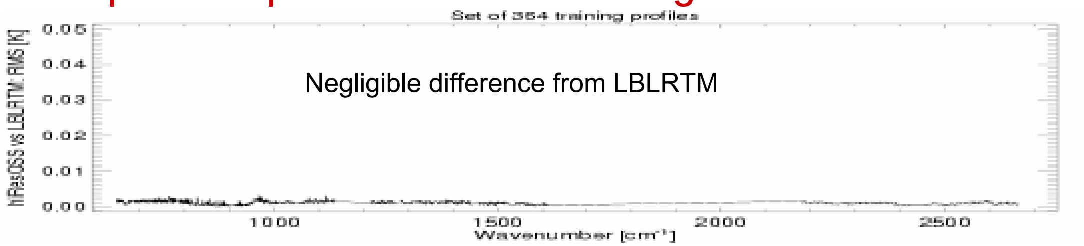
- MW and Infrared OSS training package delivered to NOAA
- New infrared capabilities (delivered before 06/01/07):
  - "First-guess" node selection from existing OSS files for (higher spectral resolution) instrument
    - Maximizes number of shared nodes between multiple instruments, i.e. minimizes size of input absorption look-up table (see Slide 10)
  - Generalized training
    - Accommodates clear and cloudy atmospheres
    - Applicable to ocean and land (including desert)
    - **Channel or EOF space**

OSS (IR) Parameter Generation S/W diagram



OSS RT models

- Fast MW + IR OSS RT models delivered
  - OSS specific features (CRTM compatibility?)
    - Node based RT
    - Surface/cloud properties specified on their own spectral grids
      - linearly interpolated in between hinge points
    - Fast linear approximation of spectral dependence of Planck function in IR (MW: see Final report)
    - Analytical Jacobians
    - Pressure interpolation of absorption coefficients ← *recently added*
      - reduces size of absorption look-up tables
      - RT directly performed on user-specified pressure grid
- OSS-HIRES model (training):
  - Generalized training requires scenes with different cloud types
    - Direct use of LBLRTM/CHARTS cumbersome when number of cloudy scenes is large
  - High spectral resolution (0.01 cm^{-1}) OSS model is used instead
    - Directly ingests LBLRTM optical depths instead of making use of absorption LUT's



Generalized training
(AIRS model performance)

Generalized training

- OSS-GEN (ocean/clear + cloudy)
  - *Generalized training applied across whole spectral domain (clear and cloudy)*
  - *Could be extended to include highly emissive land surfaces*
- OSS-GEN20 (land/clear + cloudy)
  - *Surface emissivity assumed linear over contiguous 20 cm^{-1} intervals (needs to be verified with real data)*
  - *Generalized training applied independently to each interval*
    - May be best to separate surface sensitive channels and upper atmosphere sounding channels from surface sensitive channels in training (future work)

	AIRS - full channel set**			AIRS - 281 channel subset**		
	Localized	GEN20	GEN	Localized	GEN20	GEN
# channels	2378	2378	2378	281	281	281
# nodes	5340	2323	507	1809	993	328
N	**2.25**	**0.98**	**0.21**	**6.44**	**3.53**	**1.17**
N'	**9.84**	**35.60**	**203.63**	**11.75**	**30.53**	**238.43**

**** 0.05K nominal accuracy**

N = (total number of nodes) / (number of channels)
N' = number of nodes contributing to radiance computation in 1 channel (on average)

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AIRS timing improvements

- Two parts considered:
  - Part I: Computation of monochromatic radiances and Jacobians
  - Part II: Mapping of radiances and Jacobians from node-space to channel-space + transformation of atmospheric/surface parameters to EOF's
    - Part II timing depends on spectral measurement representation (e.g. channel space or EOF/node projection) and order of transformations – application dependent
- Example of speed gain with generalized training (1DVAR/full AIRS channel set + non-scattering RT)*

			Training	
# channels	Measurement space	Localized	GEN20	GEN
2378	Channel	**1****	1.35	2.02
2378	EOF/node projection	N.A.	1.5	6.2
281	Channel	4.48	5.96	6.77

*** Total (Part I and II) times based on 0.05K accuracy model and 314 atmospheric/surface parameters mapped into 63 EOF's**

**** Reference (used in past OPTRAN/OSS comparison)**

Memory requirements

- Old (from past OSS/OPTRAN comparison)*

	OPTRAN -V7 single, double precision	OPTRAN -compact double precision	**OSS**
AIRS	33 Mbytes, 66 Mbytes	5 Mbytes	**97 Mbytes**

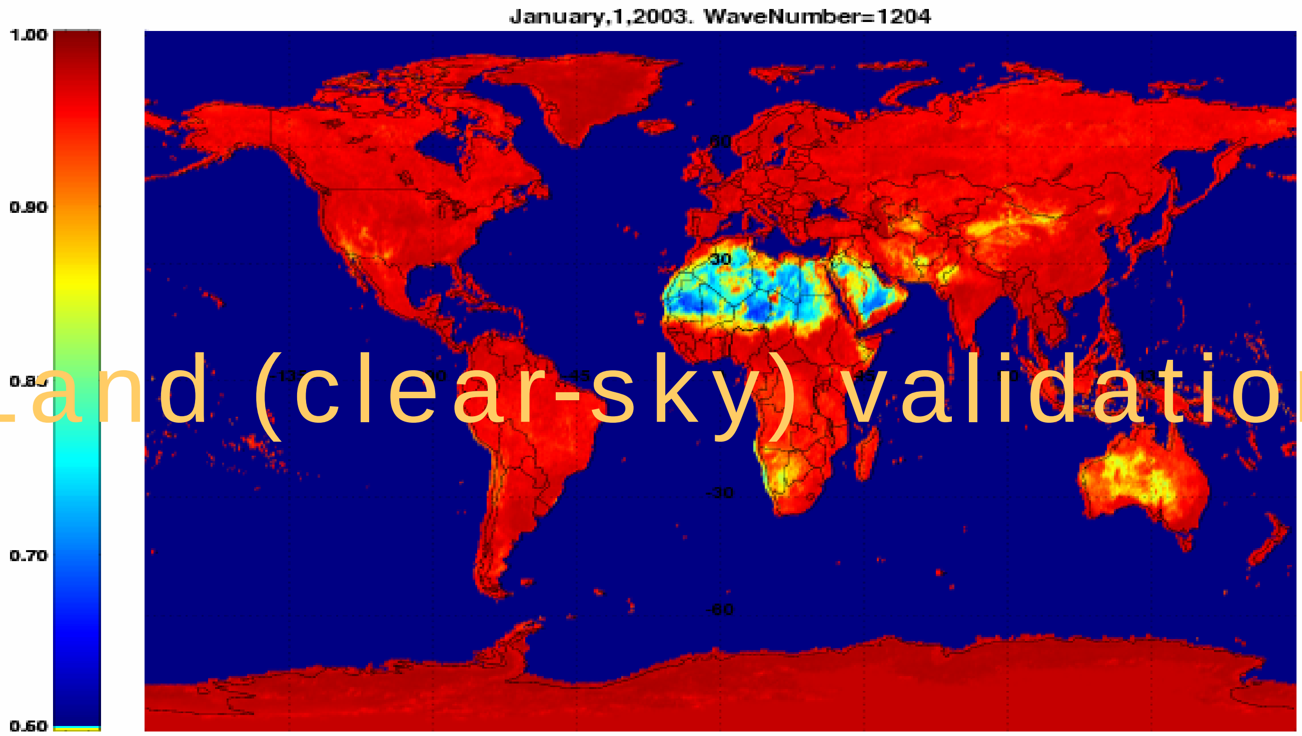
- New*

	AIRS - Full channel set			**AIRS - 281 channel subset**		
Training	**Localized**	**GEN20**	GEN	**Localized**	**GEN20**	GEN
Size (Mbytes)	**49**	**21**	5	**16**	**9**	3

*** 0.05K nominal accuracy**

- includes reduction by factor 2 in number of layer with pressure interpolation
- Multi-sensor applications:
  - OPTRAN: memory requirements increase proportionally with number of instruments/channels
  - OSS: marginal increase in storage requirements
    - AIRS look-up tables accommodates spectrally overlapping channels from ALL current operational sensors (including future CrIS)
    - Moderate size increase expected with IASI (higher spectral resolution)
    - Careful channel selection + information content (incl. apodized vs. non-apodized) trades required for optimal configuration

Land (clear-sky) validation



Simulating channel transmittance parameterization

- Previous OSS/OPTRAN comparisons focused on clear-sky/ocean (easy)
  - Need to simulate channel transmittance parameterization in order to compare accuracy of both RT approaches 1) over highly reflective surfaces and 2) in scattering atmospheres
- OSS-based simulation:
  - Compute space to level transmittance using OSS-HIRES

$$T_{0\to l} = \sum_j a_j T_{j,0\to l}$$

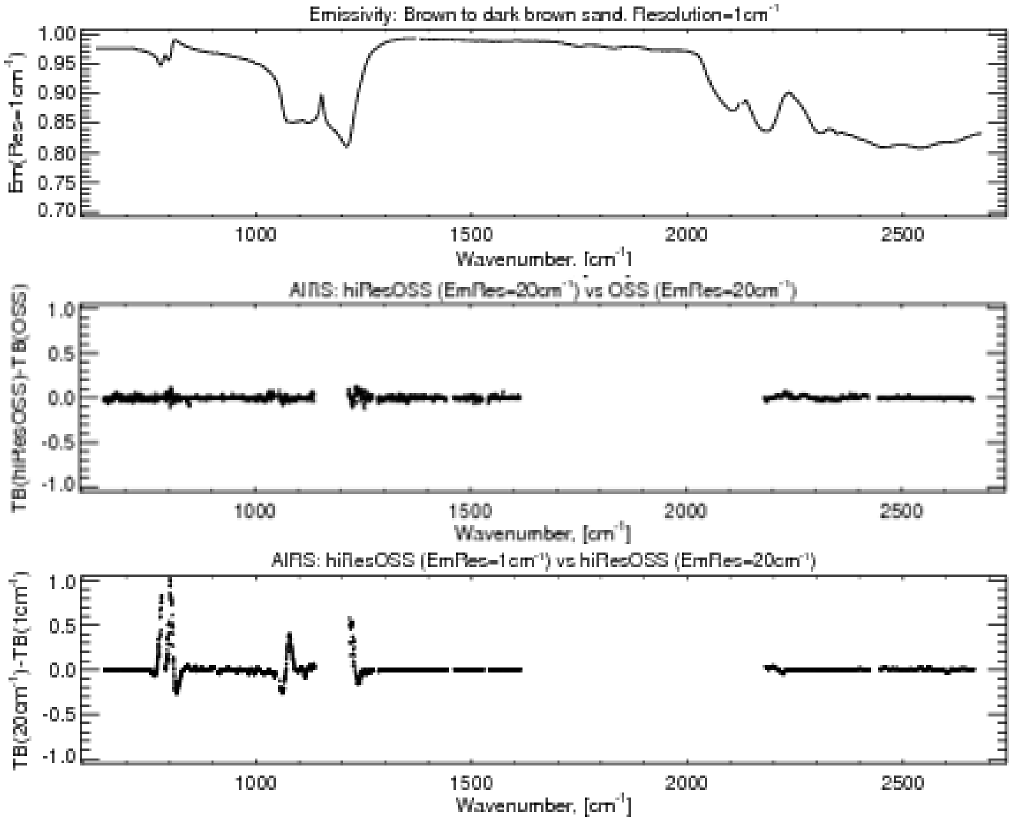
  - Compute effective layer OD for channel

$$\tau_l = -\log\left(\frac{T_{0\to l-1}}{T_{0\to l}}\right)$$

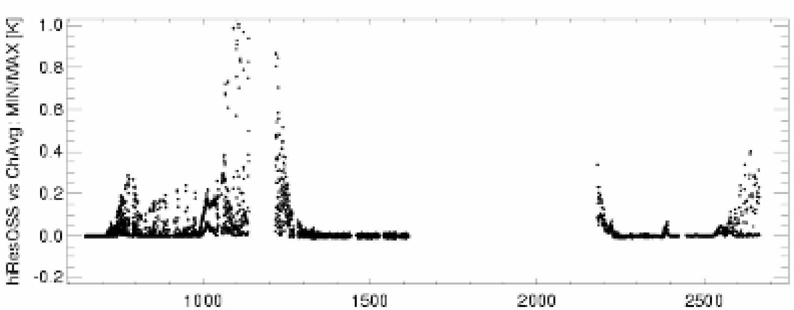
  - Perform monochromatic RT

OSS vs. channel-averaged Tx parameterization

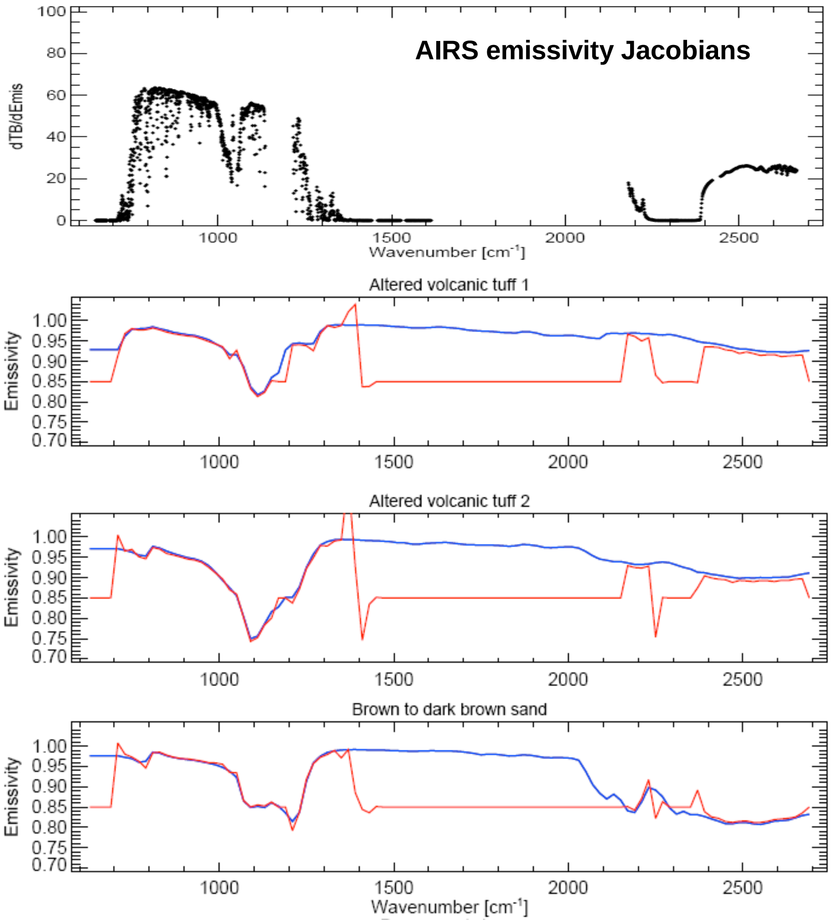
- Accurate handling of surface reflectivity
- Accuracy of generalized training (GEN20) over land limited by coarseness of emissivity grid (depend on information content of instrument)



Channel transmittance parameterization: error due to handling of surface reflectivity (brown to dark sand)



AIRS retrieval over non-vegetated surfaces

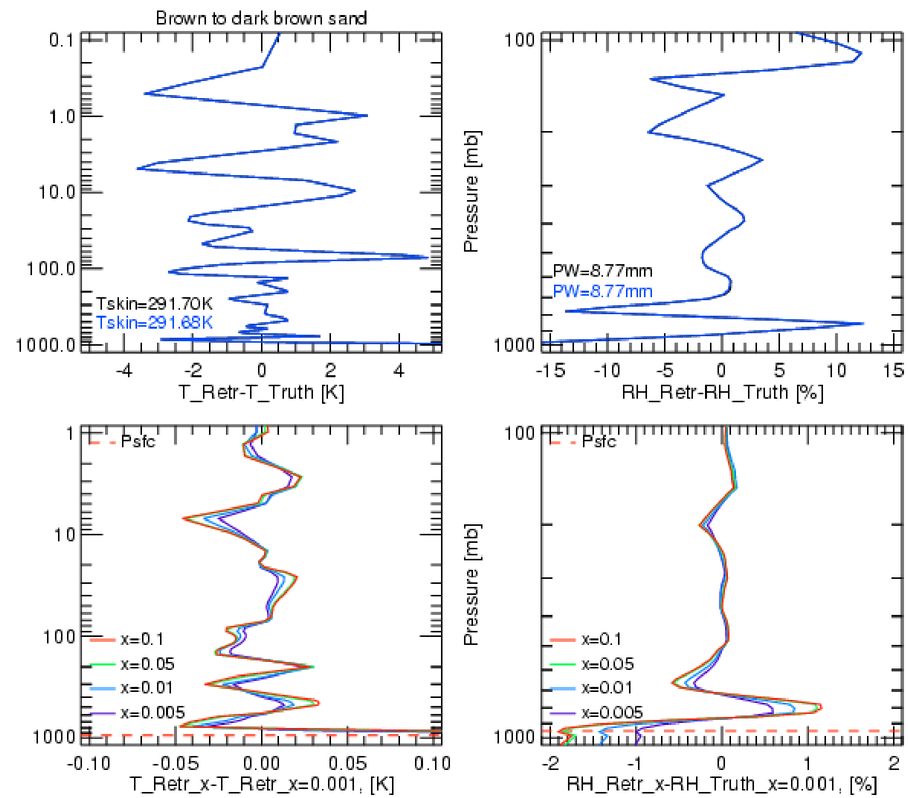


Retrieval emissivity grid: 20 cm^{-1}

Simulation:

20 cm^{-1} grid (black line)

1 cm^{-1} grid (blue line)



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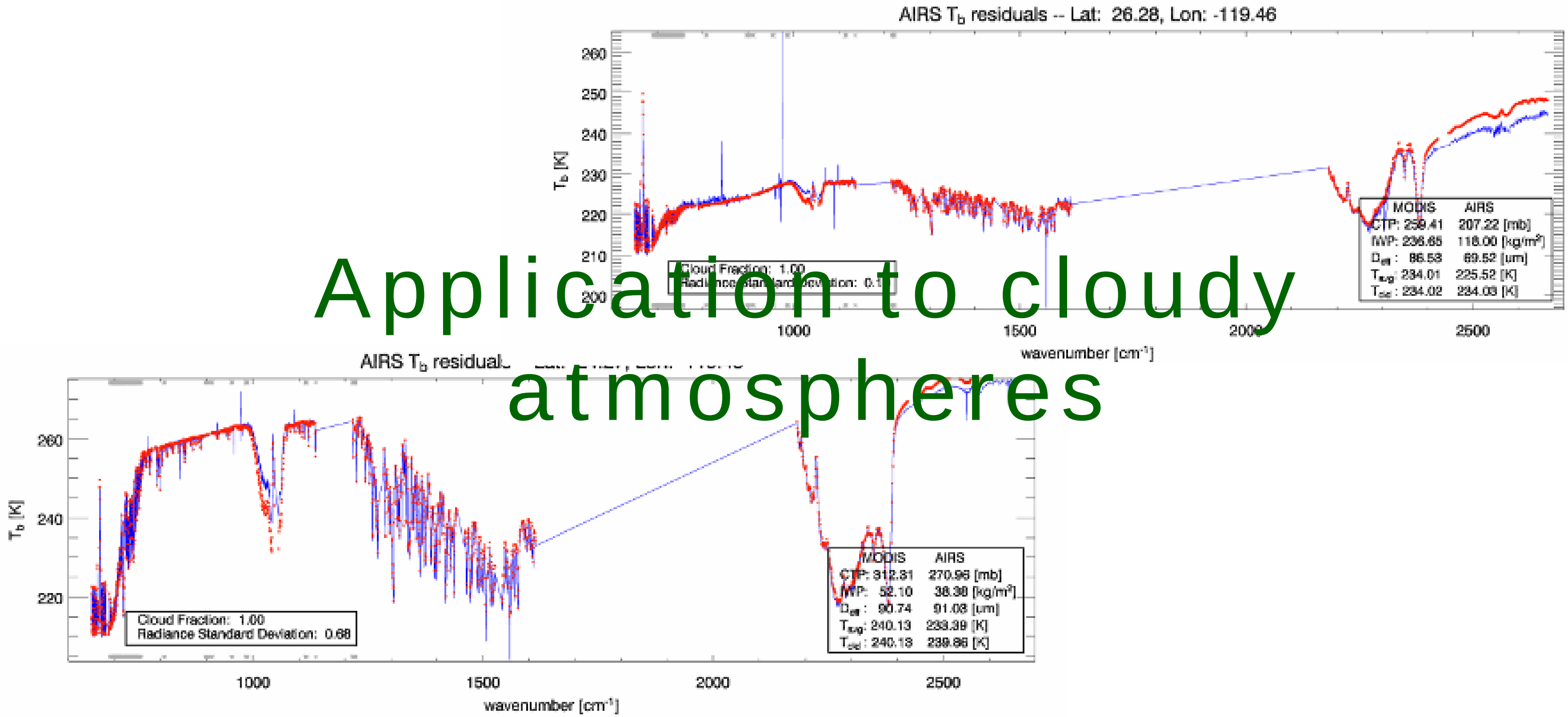
Application to cloudy atmospheres



Multiple scattering performance

- Execution time dominated by RT calculations (unless fast scattering parameterization is used)
  - Original OSS timing proportional to number of nodes
  - channel transmittance parameterizations: proportional to number of channels
  - Original OSS slower if average number of nodes per channel > 1**

**Does not take into account fact that scattering calculations can be avoided for some nodes (20-25% for AIRS)

Speeding up OSS scattering calculations

- Scattering calculations *may not* have to be performed for each node
  - Scattering correction may be predicted based on a few nodes only
- Approach tested with MODIS (worst case for OSS)

$$R_i = R_i^{noscatt} + \sum_{k \in S_i} C_{ik} \left(\tilde{R}_k - \tilde{R}_k^{noscatt} \right)$$

- Number of predictors can be tuned to control cloudy radiance accuracy

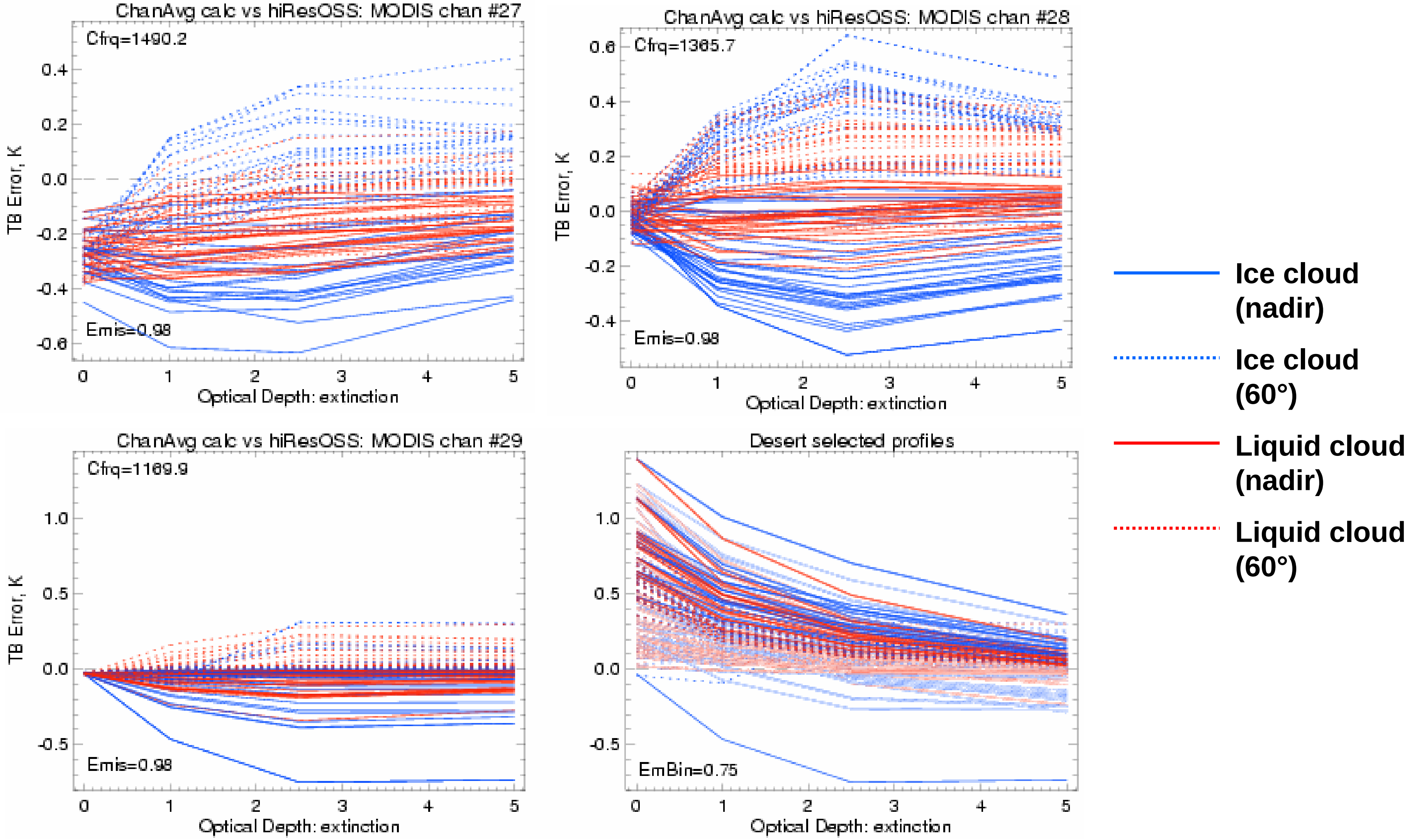
MODIS

Channel #	Wavenumber range (cm^{-1})	Number of Nodes	Number of Nodes	**Number of Predictors**
36	695.16 - 709.98	16	19	**1**
35	709.97 - 725.43	24	27	**1**
34	725.42 - 741.57	17	22	**2**
33	741.56 - 758.44	17	21	**2**
32	814.99 - 849.62	3	4	**1**
31	886.52 - 927.65	3	3	**1**
29	1149.42 - 1190.48	7	10	**2**
28	1337.79 - 1393.73	15	15	**2**
27	1450.32 - 1530.23	12	12	**2**
21	2604.16 - 2732.25	6	7	**3**
Channel average		12	14	**1.7**
		Clear Training	Cloudy Training	

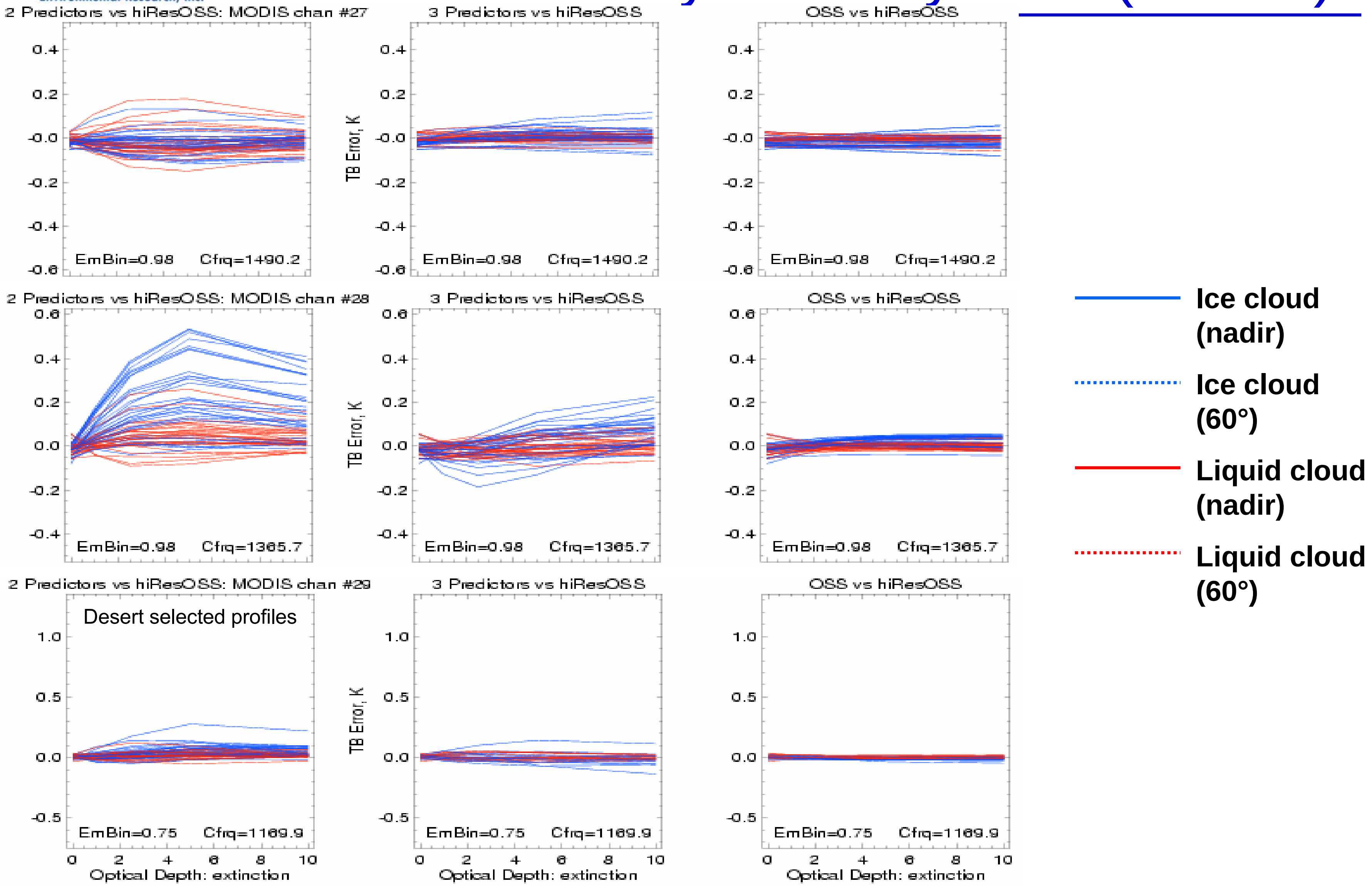
Localized training used

Generalized may require fewer predictors

Transmittance parameterization: accuracy in cloudy skies (MODIS)



OSS accuracy in cloudy skies (MODIS)



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Summary

- Complete OSS training capability for channel radiance (and/or EOF) modeling transferred to JCSDA
  - Generalized training offers significant improvements in memory requirements and speed
  - Finding optimal configuration for satellite data assimilation (e.g. EOF vs. channel-based retrieval, channel sub-setting, multi-sensor modeling) requires further trades
- Promising approach to accelerated scattering calculations in the IR (needs further testing with AIRS)
- Ongoing work under NOAA grant addresses improvements in MW and IR line-by-line models

Summary (cont.)

- AER plans:
  - Continue improving treatment of scattering
  - Test treatment of surface emissivity/reflectivity with real AIRS/IASI data
  - Handling of variability of minor species
  - Include solar
  - 4.3 μm NLTE
  - Address above trades
  - Continue validating and maintaining/upgrading OSS training