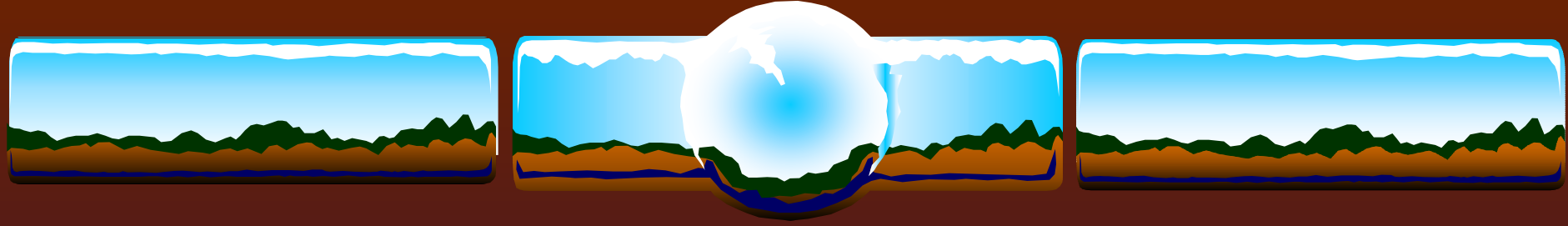
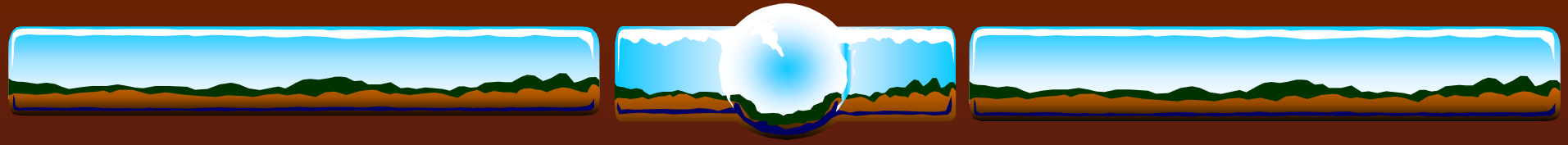


C-pr Umkehr Algorithm History and Current Status

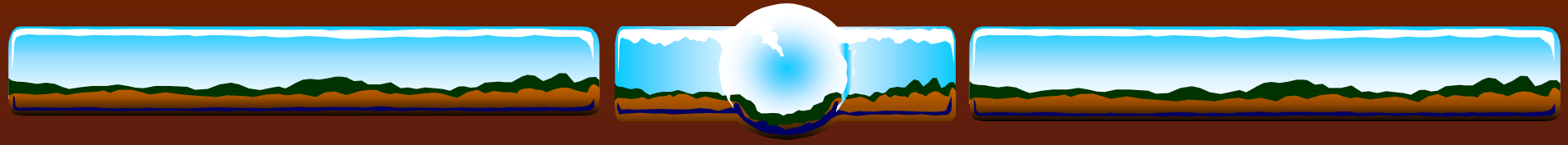
Irina Petropavlovskikh (NOAA/CIRES)

P. K. Bhartia (NASA/Goddard)



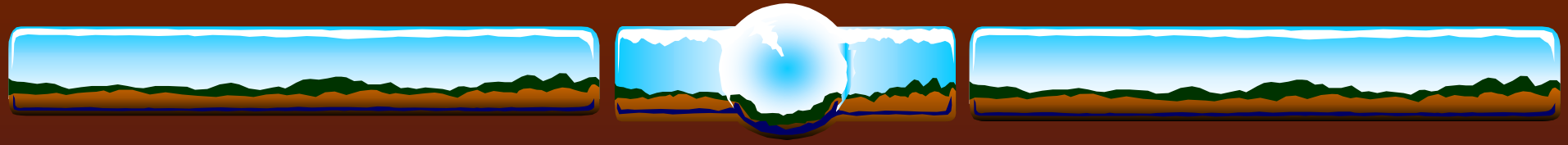
Ozone recovery as a result of actions taken under the Montreal Protocol

- Total ozone record is difficult to use for detection (Shindell, 2001)
  - ozone recovery is related to ozone depleting substances
  - significant contribution from climate change effects
- Climate effect on stratospheric ozone depletion:
  - increased emission of greenhouse gases warms troposphere (water vapor),
  - increased content of water vapor in stratosphere (ozone depleting chemicals),
  - cooler temperatures in stratosphere (affects production)
- Layer 8 (40-45 km) is important for earlier detection of ozone recovery, it has minimal climate change interference
- There is a latitudinal difference in ozone recovery rates (Shindell, 2001)



Ground-based Zenith-Sky UV Instruments

- Traditional Dobson Umkehr
  - C-pair
  - -SZA: Summer: 60°-90°, Winter: 70˚ -90˚
  - polarization state unknown, algorithm assumes unpolarized measurements
- Automated Dobson Umkehr
  - A, C & D pairs
  - SZA: Summer: 60°-90°, Winter: 70˚ -90˚
  - polarization state same as for traditional Umkehr.
- Brewer Umkehr
  - 2 sets of 5 wavelengths
    (set 1: 306, 310, 313, 317, 319 nm, set 2: 317, 319, 323, 326, 329 nm)
  - selects parallel polarized light
  - 70°-90° SZA



Characteristics of Umkehr data

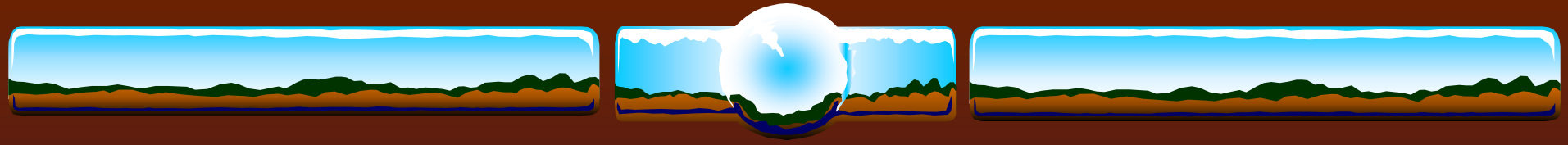
- Long historical record (back to 1957, some even earlier).
- SZA normalization removes (signal indep.) cal/ETC errors (also sfc albedo and part of trop aerosol effects).
- Stratospheric aerosol can induce large, but short-lived, errors.

Algorithm History

- UMK1992 (Mateer and DeLuisi, 1992)
  - TO dependent a priori
  - RT of the profile as Log O_3 in 16 layers
- REVUE (Bojkov, 2002)
  - Updated zonal a priori: seasonally dependent in all layers
  - Forward model corrections (altitude, temperature)
- UMK2004 (Petropavlovskikh, Bhartia, DeLuisi)
  - Fixed a priori (no TO dependence)
  - Further improved forward model (updated tables, standard profiles, λ-resolved intensity and convolution over band-pass, temperature and MS correction to N-values, no interpolation)
  - Updated inverse model (improved error analysis, linear solution)

Issues With UMK1992

- *A priori* is based on total ozone (derived from Dobson direct sun measurements).
  - therefore, inter-annual and long-term changes are driven both by AP and measurements- difficult to isolate.
  - trend in a given layer can be shifted to another layer.



Features of UMK2004 Algorithm

- A priori doesn't change from year-to-year
  - simplifies interpretation of trends
- Simple covariance matrix with relatively large diagonal terms and exponential inter-layer correlations.
  - makes averaging kernels more Gaussian
- Linear Jacobians (dN/dX insterad of DN/dlogX)
  - Improves PDFs (prob distribution fn.)
- Improved radiative transfer model.
  - reduces bias

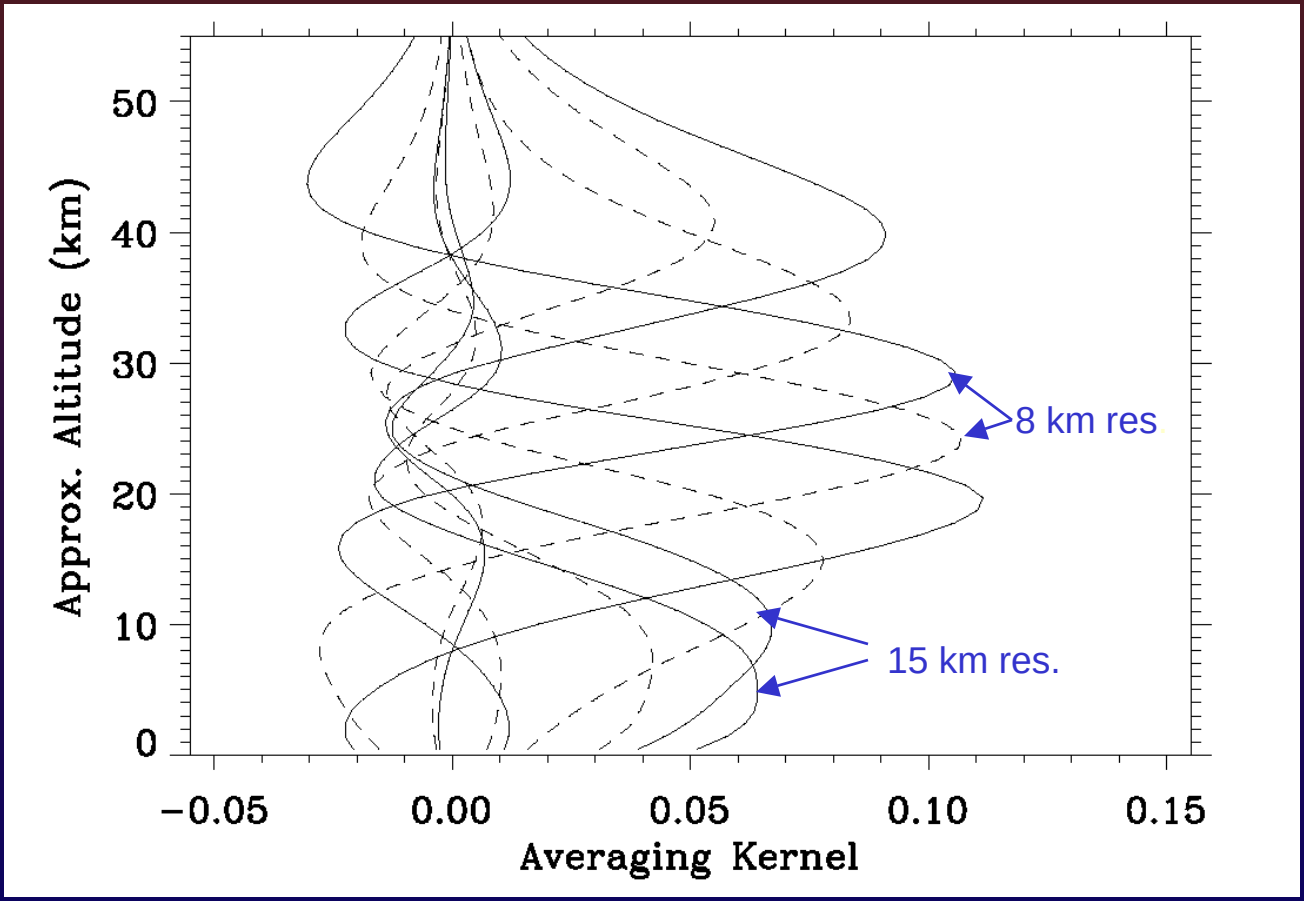
Information Content of Retrieved Profile

- **Averaging Kernel (W)**
  - Describes where the (fractional) changes seen in the retrieved profile at a given altitude are coming from

$$\delta \ln x_{retrieved} = A \delta \ln x_{truth}$$

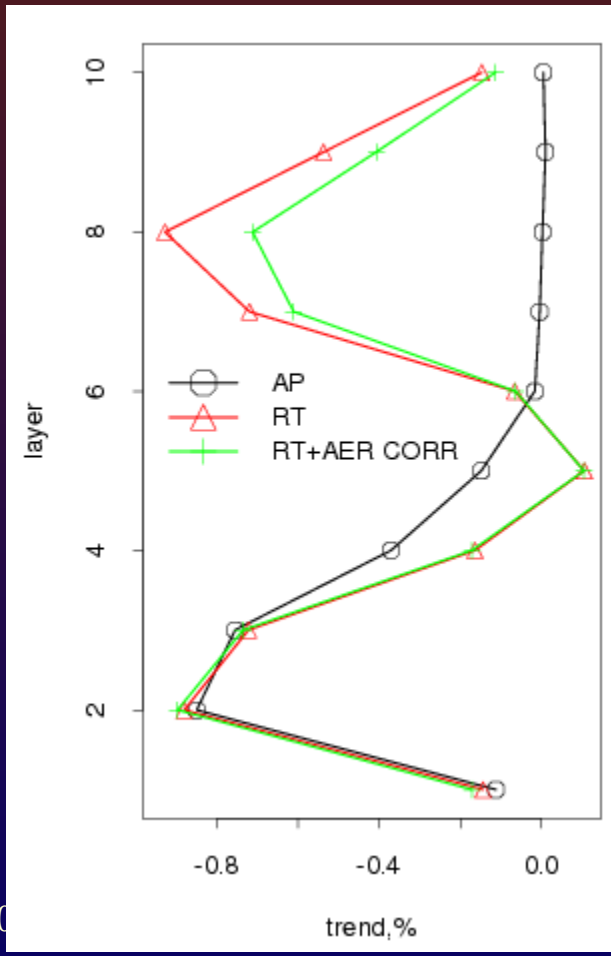
  - Ideally, A should be a set of Gaussian functions, producing no vertical shift between impulse and response. (Such shifts indicate that the changes observed at a given altitude represent changes from some other altitude.)
  - Width of A provides vertical resolution as a fn of altitude.

C-pair Umkehr Averaging Kernels

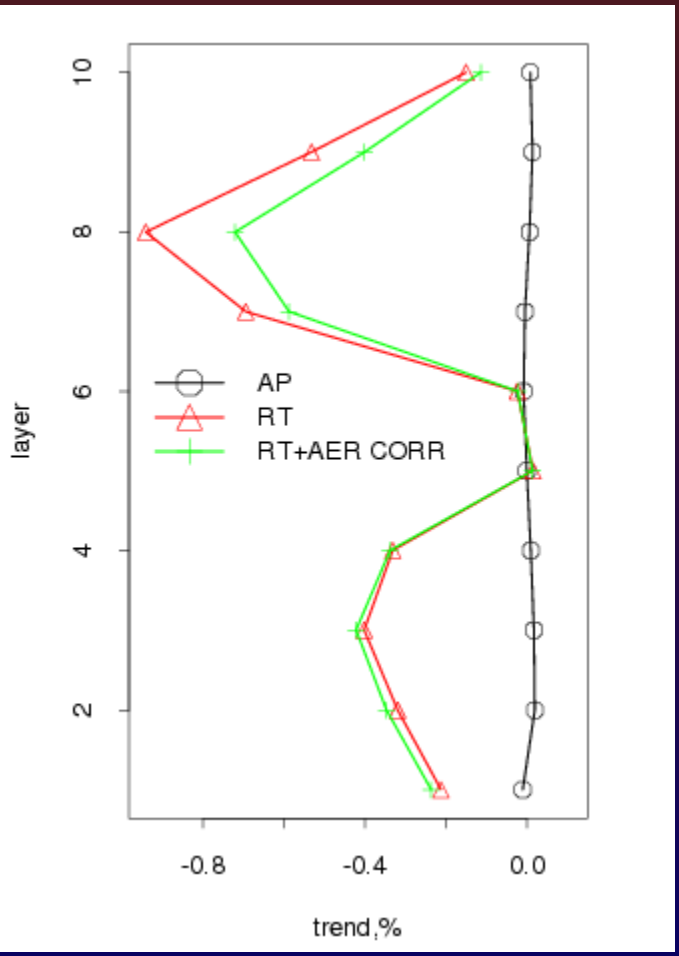


Effect of a priori on ozone trend, Boulder

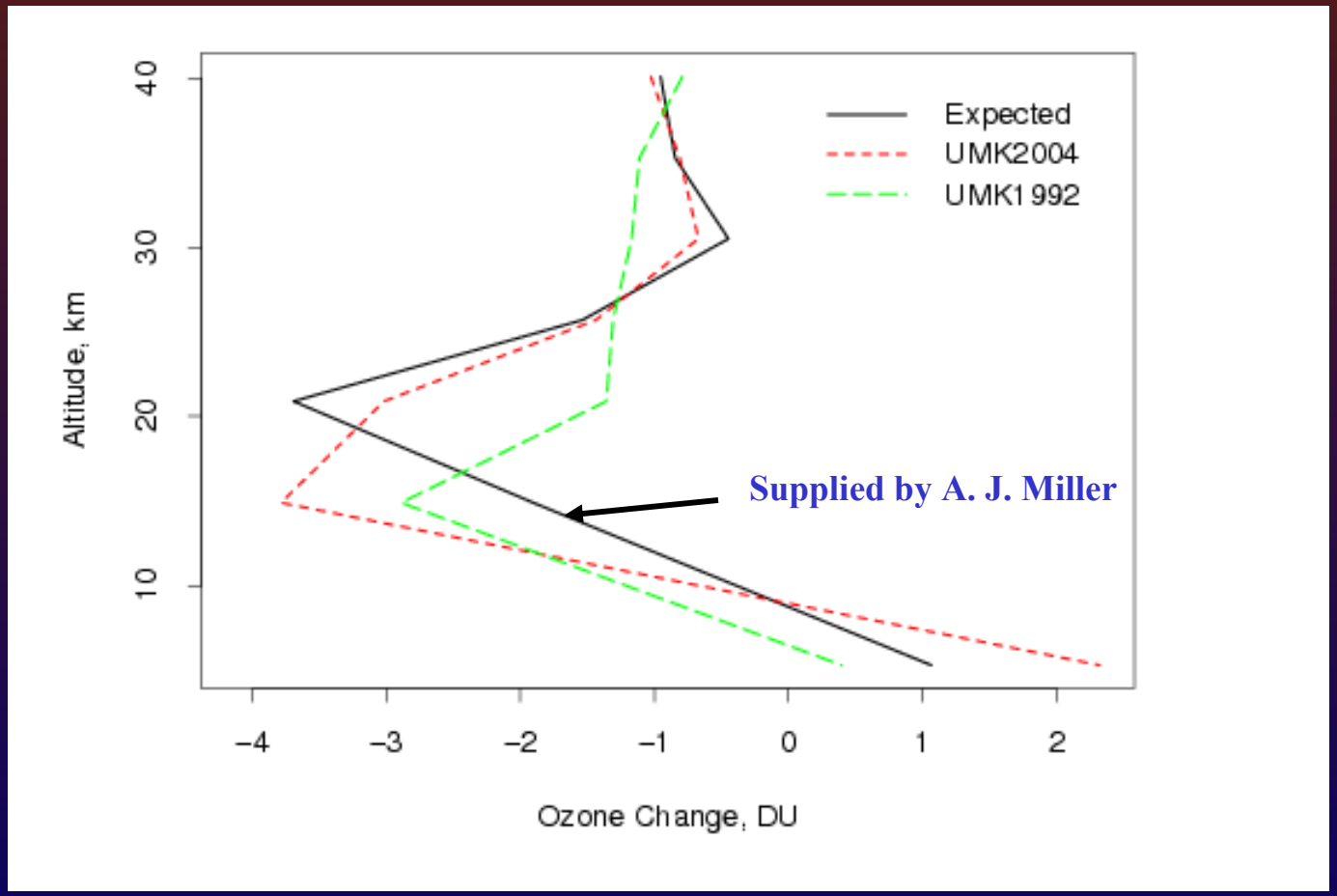
UMK1992



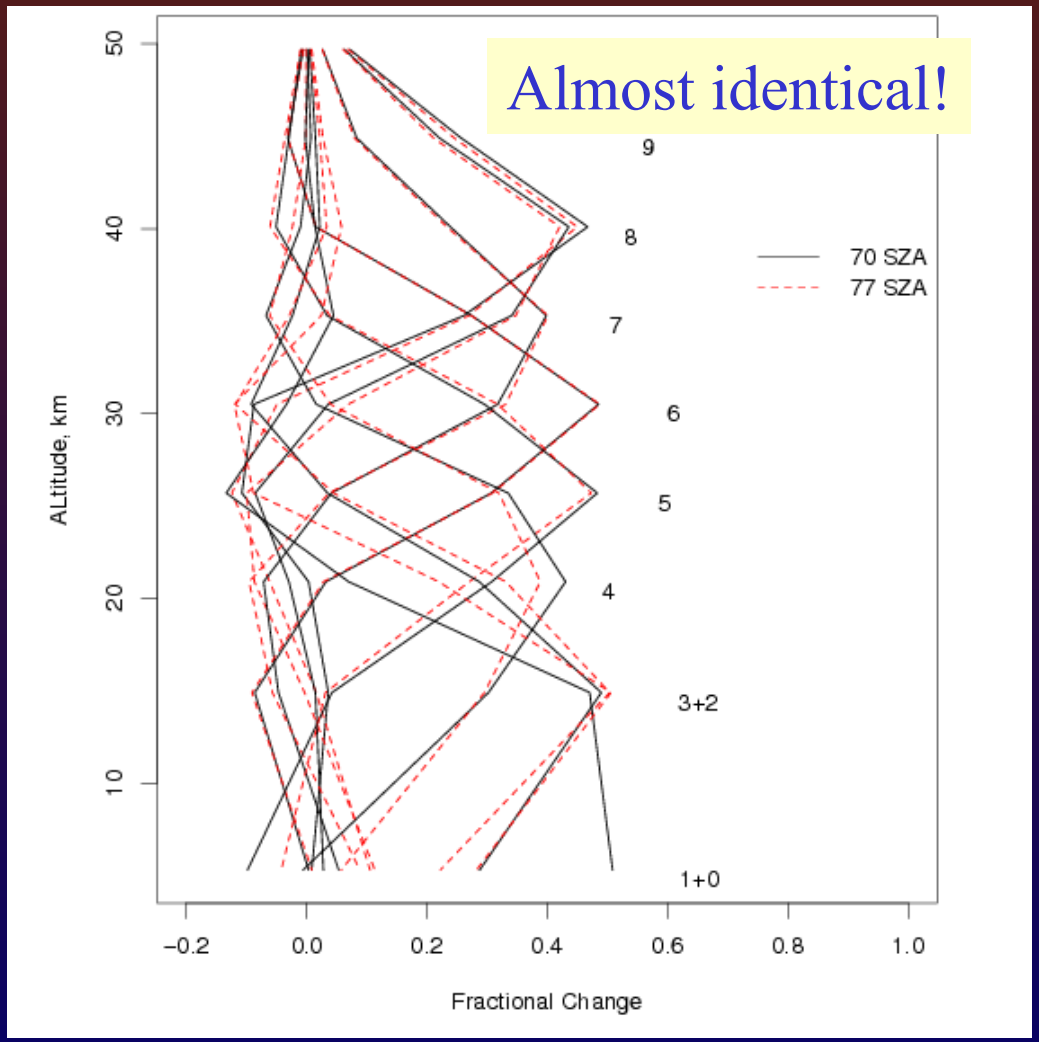
UMK2004



Effect of the algorithm on trend



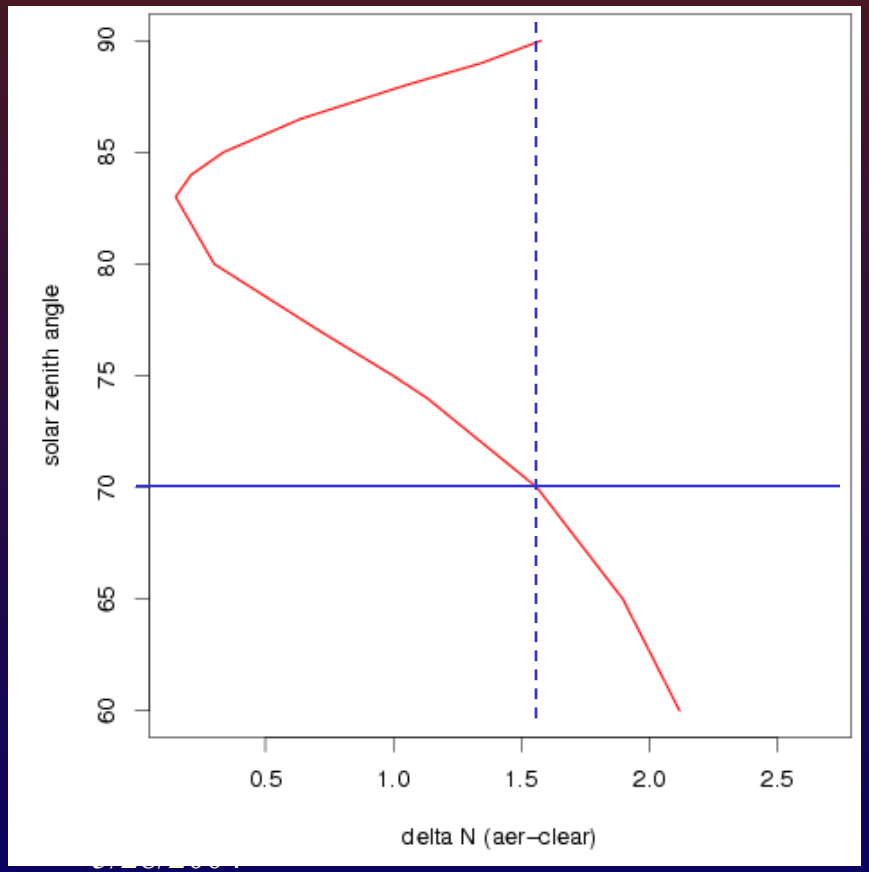
Effect of normalization (Boulder, RMSD %)



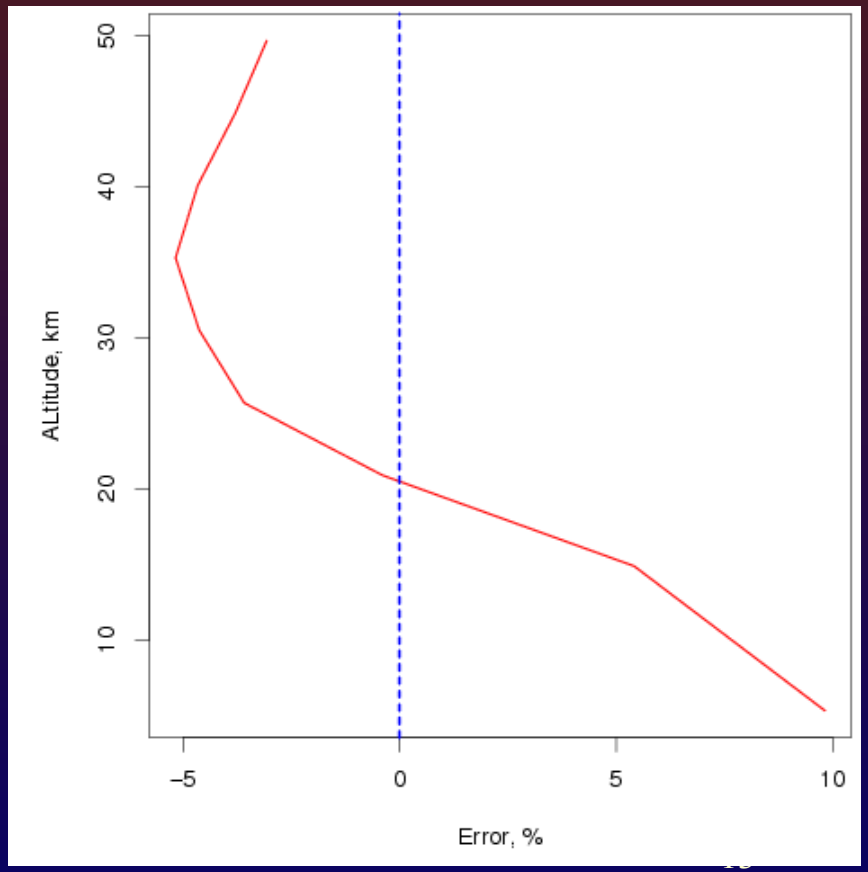
Layer	RT70	RT77
8+	7.7	8.5
8	8.4	9.4
7	6.9	7.7
6	6.5	6.6
5	7.3	7.1
4	13.6	11.9
2+3	20.2	19.6
0+1	20.4	14.0

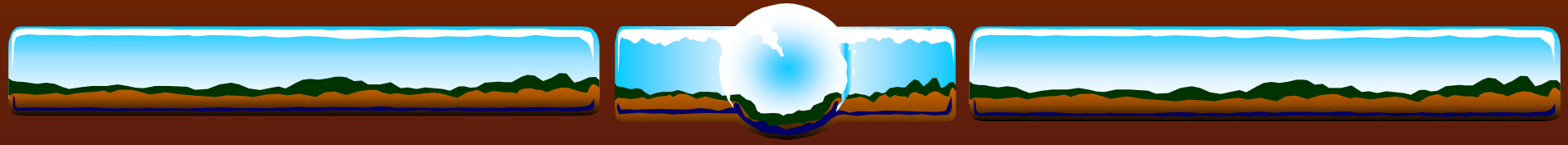
Effect of tropospheric aerosols (OD=0.3)

N-value change (aer-clear)



RT O3 change (aer-clear,%)

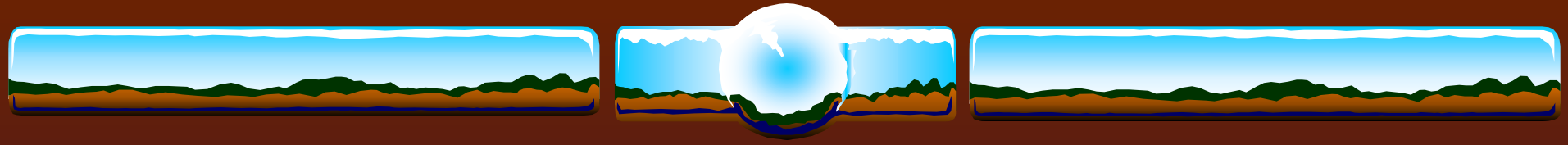




Summary

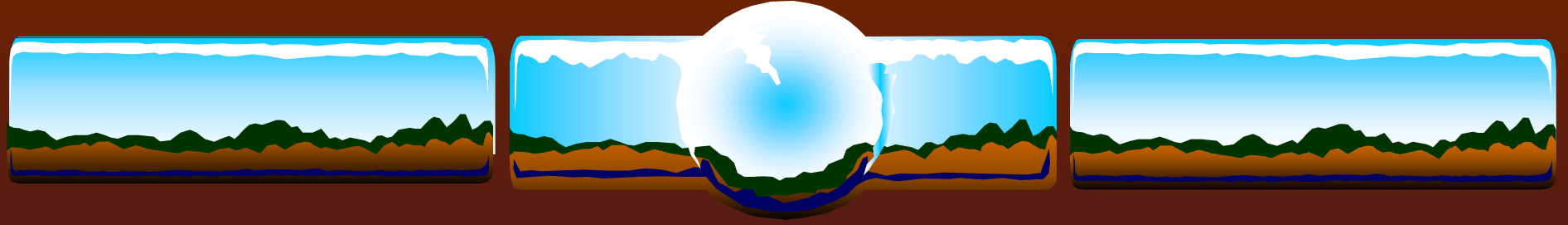
- UMK2004 is designed to capture the O_3 trend without algorithmic influences.
- It does better than UMK1992 in the lower layers.
- Information in layers 1-3 may be useful for tropospheric ozone assessment in tropics (measurements have to start at 60˚ SZA)
- Data collection can start as late as at 77˚ SZA (degraded information in troposphere) greatly reducing obs time in winter
- Aerosols may be responsible for the increased noise in the measurements at large SZAs, which can affect retrieved ozone (bias and noise)

The UMK2004 results are available at http://www.srrb.noaa.gov/research/umkehr



Recommendations.

- Process all available Umkehr data (from traditional Dobsons, Automated Dobsons, Single Brewers and Double Brewers) using the UMK2004 algorithm, make results available thru website
  - *Primary resp: Irina P. (Env. Canada will provide data).*
- Provide data processed from other algorithms, including UMK1992, to Irina P. for comparison
  - *Primary resp: Env Canada (for UMK 1992), committee members encouraged to contribute their data.*
- Based on the comparison decide whether to accept UMK2004 or go with something else.



Backup Slides

Effect of *A Priori* on Trend

From Inverse Methods for Atmos. Sounding by C. D. Rodgers eqn. 5.18

$$\hat{M} = A \bullet M_{truth} + (I - A) \bullet M_{apriori} + G \bullet (\bar{\varepsilon} - \varepsilon_0),$$

Where, $M = \dfrac{\bar{x} - \bar{x}_0}{\bar{x}_0}$ **is the mean monthly O_3 anomaly**

- **A (Averaging Kernel) filters out high vert. res. features from the true anomaly.**
- **Width of A can be reduced by increasing *a priori* cov, but only up to a point, after which G increases rapidly.**
- **2nd term inserts high res features from *a priori* into the retrieved profile, if the *a priori* varies from year-to-year.**
- **3rd term represents effect of monthly mean instrument drift on the retrieved profile.**