Statistical Validation Assessment Model for Advanced Sounding Products


Hyperspectral Workshop Darmstadt
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Motivation Why Statistical?

- Sounding products errors must be in the form that can be utilized by the users - Regionally specific **Covariance** and **Bias**.
- Sounding occurs in turbulent atmosphere which is characterized statistically
- Retrievals are tuned statistically
Outline

• Methodology – Sounding and Validation are complimentary parts of remote sensing.
• Validation Assessment Model brief description.
• Practical example – IASI Level 2 Error Assessment and validation against radiosondes – Lindenberg campaign.
Remote Sensing and Validation by Correlative Measurements

C. D Rodgers, 2001
"Inverse Methods for Atmospheric Sounding, Theory and Practice"

"Validation of Atmospheric Sounders by Correlative Measurements"
Validation Issues

Why do We Need Validation Assessment Model

Why We Can NOT Use Correlative Data As Is

- Characteristic Difference – validated sounder and correlative measurements sample atmosphere differently.
- State Non-Coincidence – correlative measurements are at different time and location.

Validation Assessment Model reconciles the issues by modeling best linear estimate of the satellite measurements and assessing the errors

“Validation of Atmospheric Sounders by Correlative Measurements”
State Non-Coincidence

Correlation Between True States

No measurements involved at this point

\[
B_x(x_{\text{cor}} - \bar{x}_{\text{cor}}) = \text{Best estimate} = \text{Expected}\{x_{\text{sat}} - \bar{x}_{\text{sat}} | \text{given} x_{\text{cor}} - \bar{x}_{\text{cor}}\}
\]

State correlation matrix

\[
B_x = S_{x_{\text{sat}}x_{\text{cor}}} S^{-1}_{x_{\text{cor}}}
\]

State Non-Coincidence
Characteristic Difference

Correlation Between Measurements
(two different systems measure the same state)

\[
A_1(x - \bar{x}) = B_\hat{x} A_2(x - \bar{x}) + \xi_y
\]

Measurement Correlation Matrix

\[
B_\hat{x} = (A_1 S_x A_2^T)(A_2 S_x A_2^T)^{-1}
\]

Uncorrelated Characteristic Difference

Linearization a la Clive Rodgers

\[
\hat{x}_{1\text{mod}}(x) = \hat{x}_{1\text{mod}}(\bar{x}) + A_1(x - \bar{x})
\]

\[
\hat{x}_{2\text{mod}}(x) = \hat{x}_{2\text{mod}}(\bar{x}) + A_2(x - \bar{x})
\]

A – Averaging Kernel or Jacobian

\boxed{B_\hat{x} A_2(x - \bar{x}) = \text{Best fit to } A_1(x - \bar{x}) \text{ over ensemble with covariance } S_x}
IASI Validation Study

• **Validation Data Set** – radiosondes at Lindenberg (Germany, 52.21° N, 14.12° E, 112 m a.s.l). Dedicated launches 1 hour prior and at the overpass time; and synoptic times (0, 12, 6, and 18 UTC)

• **Validated parameters** – Atmospheric Temperature and Water Vapor Vertical Profiles.

• **Validated System** – IASI characterized by averaging kernels.

• **Validated Data Set** – EUMETSAT v. 4.3 retrievals; cloud clear; ±1° Lat. and Long. about Lindenberg
Averaging Kernels – Vertical Resolution

Temperature

Pressure (mb)

Sum of diagonals=14.18
Temperature Non-Coincidence Error
Free Troposphere

RMS Non-coincidence error
Temperature
Lindenberg site June - August 2007

RMS non-coincidence error
Averaged between 800 - 300 mb
Sodankyla, Lindenberg, and Southern Great Plane ARM

Space Dynamics Laboratory
Utah State University Research Foundation

www.spacedynamics.org
Temperature Retrieval Error and Bias
IASI – “True profile”

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**Graphs:**
- **x-axis:** Pressure (mb)
- **y-axis:** rms (K) and Bias (K)

**Legend:**
- Assessed Total Error
- Expected Total Error
- Temperature Variance ( sondes )

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**Title:**
Space Dynamics
Utah State University Research Foundation
Averaging Kernels – Vertical Resolution
Water Vapor

Sum of diagonals=10.14
Relative Humidity Non-Coincidence Error
Free Troposphere

RMS Non-coincidence error
Lindenberg site

RMS non-coincidence error
Averaged between 800 - 300 mb
Sodankyla, Lindenberg,
and Southern Great Plane ARM
Relative Humidity Retrieval Error and Bias
IASI – “True profile”

Assessed Total Error
Expected Total Error
RH Variance (sondes)

rms (% RH)
Bias (RH%)
Log(vmr) Retrieval Error and Bias
IASI -- “True profile”

Humidity Log(vmr)
IASI Retrievals Errors and Variance

Log(vmr) Retrieval
Bias against Radiosondes

Pressure (mb)

Total assessed error
Total expexted error
Log(vmr) variance (sondes)
Conclusions

• Temperature
  – Our Validation Assessment Model and radiosondes allow to account for non-coincidence error and finite vertical resolution of IASI and assess retrieval errors accurately: Expected and Assessed Errors are in good agreement.
  – Error variances/rms of a single FOV retrieval are $<1K$ between 800 – 300 mb with increase to $\sim1K$ in tropopause and $\sim2K$ at the surface – possible cause: wrong surface property and undetected clouds/haze.
  – Bias against radiosondes oscillates within $\pm0.5K$ between 950 – 100 mb.
Conclusions

• Water Vapor – RH
  – Estimated RH error variances/rms of a single FOV is higher than expected and in the free troposphere it is between 10 - 13 % RH
  – Possible causes may be:
    • Expected linear estimate of the error is not correct due to strong non-linearity of the retrieval
    • Spectroscopy knowledge is not accurate enough
    • Complex spatial structure of highly variable moisture field does not allow to assess retrieval errors accurately – WE DON’T HAVE GOOD VALIDATION SOURCE
  – Combination of techniques other than radiosondes, e. g. high accuracy airborne sounders (NAST-I) with drop-sondes, are needed for accurate RH retrieval error assessment.
This is THE END

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Thank You!!!