Update on Task Team 3 : Measurement Scheduling and Related Activities

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TT3 Scheduling - Objectives

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- to develop defensible, quantifiable, scientifically-sound guidance for GRUAN sites on measurement schedules and associated site requirements, in order to meet all GRUAN objectives including :

  - climate trend detection

  - satellite calibration/validation

  - studies of local meso-scale processes and events

- main information sources are from peer-reviewed literature, GRUAN documentation, and currently unpublished studies of which the group is aware. Some limited new analyses where critical gaps exist, using existing data sets.

Climate trend detection - How long does it take to reveal a trend?

- Many use the statistical approach discussed in Weatherhead et. al., JGR, 1998

$$Y = \mu + \omega T + N$$

μ constant term

ω trend

T time (months)

N noise

$$n^* \approx \left[\frac{3.3\, \sigma_N}{|\omega_0|} \sqrt{\frac{1+\phi}{1-\phi}} \right]^{2/3}$$

n^* the number of years

ω_0 trend magnitude

σ_N standard deviation

ϕ autocorrelation

Climate trend detection - How long does it take to reveal a trend?

- Alternative approach suggested by Leroy

Time taken for an estimated trend signal (m_{est}) to appear with a signal to noise ratio of s is given by :

$$\Delta t = \left[\frac{12s^2}{m_{est}^2} \sigma_{atm}^2 \tau_{atm} \right]^{\frac{1}{3}} \left[1 + \frac{\sigma_{meas}^2 \tau_{meas}}{\sigma_{atm}^2 \tau_{atm}} \right]^{\frac{1}{3}}$$

Where σ_{meas}^2 and σ_{atm}^2 are the measurement and atmospheric variance, and τ_{meas} and τ_{atm} are the measurement and atmospheric correlation times.

Leroy, Anderson and Ohring, J.Climate, pp 841-846, Feb 2008

Previous work – water vapour requirements

- Reinout Boers carried out an assessment of the requirements for UT water vapour trend determination, using the output of regional climate models as the base dataset.
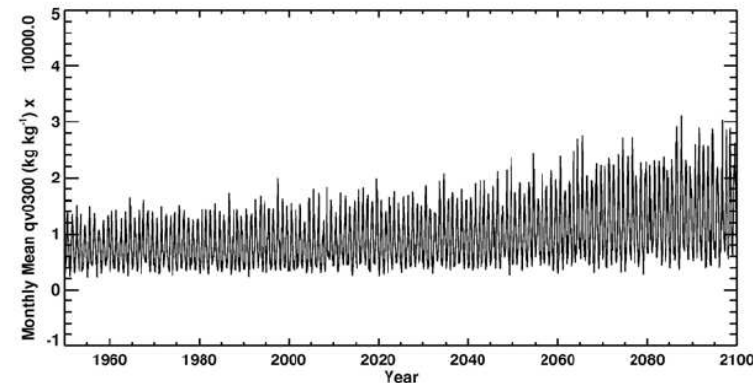
Time series of specific humidity at 300 hPa based on the r3 regional climate simulation

- The main conclusion for sampling was that, with a 10% measurement accuracy, it took 45 years of data at a 4 day sampling rate to determine an observed trend within 30% of the true trend.

- The potential of remote sensing to give a (much) higher data rate was highlighted.

Boers and van Meijgaard, GRL, 36, L19806, 2009

Recent work by Dave Whiteman

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- To assess trends using the Weatherhead et al., formulation requires quantifying the standard deviation and autocorrelation of noise due to natural atmospheric variability in water vapor

- Time series of measurements inherently comprised of a combination of natural variability and instrumental uncertainty

- Two datasets studied in attempt to separate these components
    - DOE/ARM radiosonde and lidar data

- Current idea is to estimate maximum likely instrumental contribution to time series noise
    - Based on analysis of radiosonde data, maximum likely noise contribution in the UT is ~25% so consider the effect of 25-50% instrumental uncertainties

Recent work by Dave Whiteman

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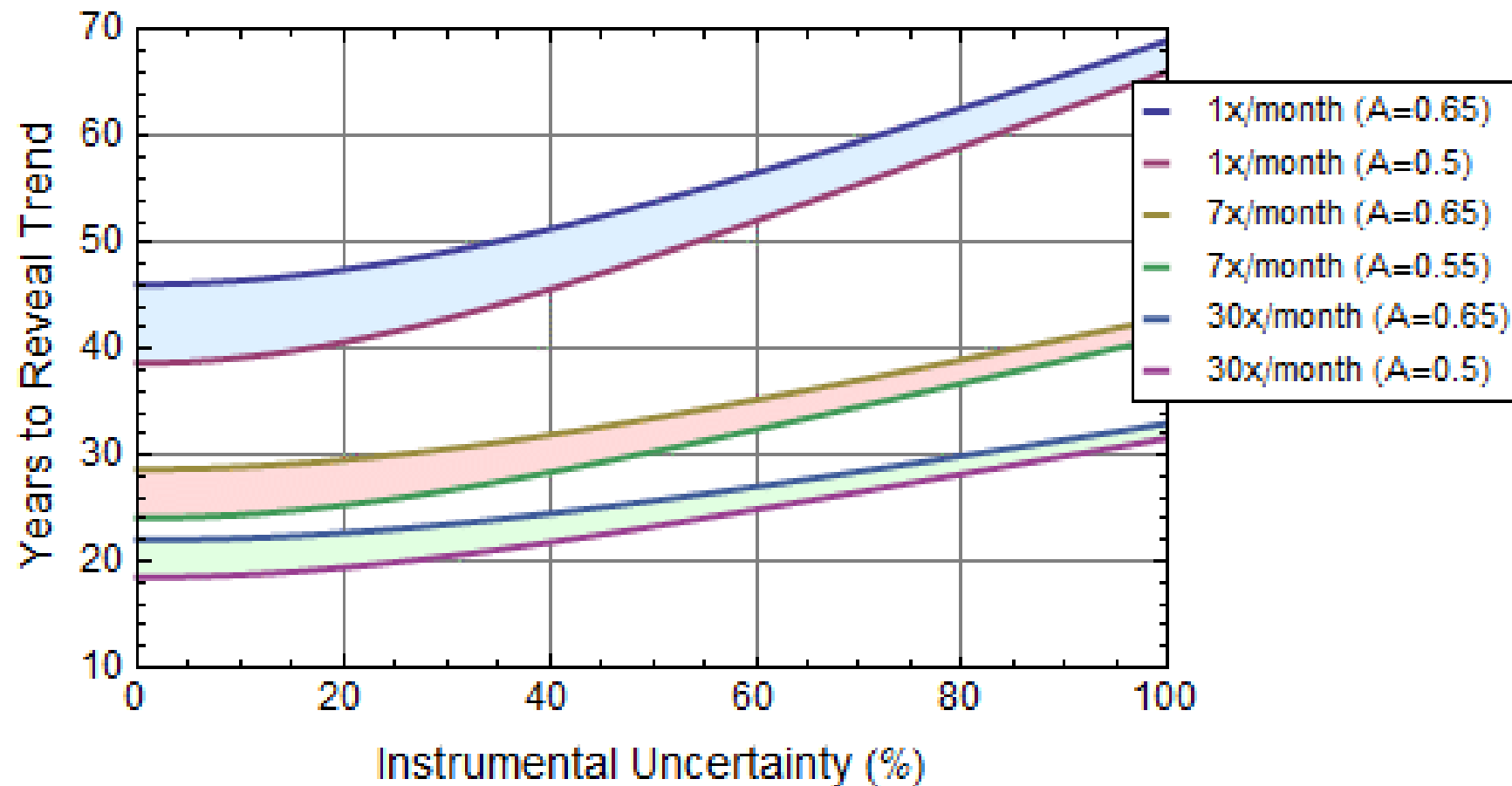
- Same conclusion as last year :

    Much more important to increase the frequency of measurement than to decrease the instrumental uncertainty

- NB: this conclusion pertains to trend monitoring in the UT. In the LS, variability is **much** lower and instrumental uncertainties will be much more important

- Further work to be done in radiosonde and lidar data analysis

- Desire to incorporate more realistic effects of gaps, recalibrations, etc into trend studies.

Alternative trend methodologies

- Can alternative methods for determining trends offer reduced trend uncertainties, and therefore shorter times to resolve them ?

- E.g. Dale Hurst's paper on stratospheric water trends over Boulder

- Uses a combination of measurement variability weighting and statistical outlier removal to reduce trend uncertainties,

- Able to determine significant quadratic trend behaviors over periods as short as 4 years.

- N.B. Method assumes negligible natural variability in comparison to the instrumental variability. So, works for L.S. water vapour, but wouldn't be immediately applicable in other cases.

Hurst et al, JGR, 116, D02306, 2011

Bootstrap re-sampled temperature trend analysis

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- Bootstrap resampling used for trend analysis of ten-year Lindenberg routine temperature sonde results.

- Method used because it can :

  - Model the data to take account of the inherent statistical variability.

  - Take account of temporal cycles in the data in addition to underlying trends.

  - Enable confidence limits to be determined which require no assumptions to be made about the distributions of the measurement uncertainties

- Looked at effect of sonde launch time on trend results.

Example temperature trend results

Effect of launch time on temperature trend at 2.5 km

Effect of launch time on temperature trend at 5 km
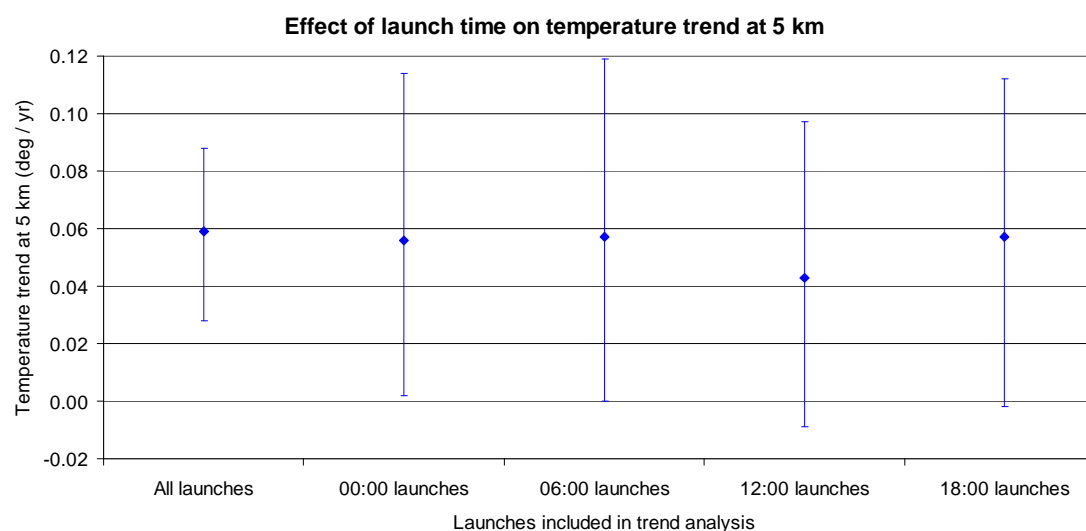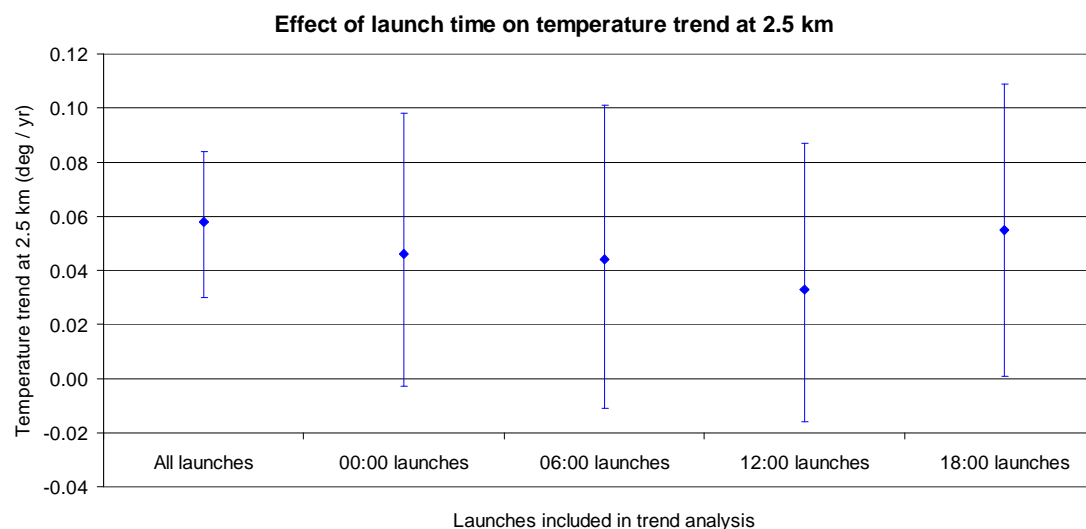
Satellite calibration / validation

- A key issue for satellite calibration, and any intercomparison between in-situ and remote sensing data is the combination of individual measurement uncertainties and the combined sampling uncertainties.

- Understanding how these combine is crucial in determining appropriate scheduling schemes.

- In many cases there will be spatial correlations in the data which will further complicate the issue, but tools do exist to address this.

- Need to link into / learn from existing satellite validation activties

Profile Intercomparison Uncertainty

- In its simplest form, the error covariance of the difference between a reference instrument and the instrument being validated is

$$S_{diff} = S_{val} + S_{ref} + S_{coinc.} + S_{smooth,diff,}$$

where :

S_{val} is the measurement uncertainty covariance of the validation instrument

S_{ref} is the measurement uncertainty covariance of the reference instrument

$S_{coinc.}$ is due to the coincidence mismatch in space and time of the two measurements

$S_{smooth,diff,}$ is due to the smoothing error in the difference including the effect of mapping any *a piori* information onto the results

T. Von Clarmann, ACP, 6, 4311-4320, 2006

Profile Intercomparison

- Correlation between the reference and validation measurements (eg. through the use of the same *a prioi* infomation) and between the coincidence and smoothing covariances further complicate the issue.

- Despite this various quality metrics can be determined through χ^2 testing including

  - the significance of any bias in the comparison.

  - the consistency of the bias with the original estimates of the covariances.

  - determination of the precision of the comparison.

'Determining Optimal Spatial and Temporal Sampling Strategies for the GRUAN'

- Collaborative bid to the NOAA Climate Program from Carl Mears, Dave Whiteman, Tony Reale, Bomin Sun and Tom Gardiner

- Aim :

  to determine the effects of spatial and temporal sampling on our ability to both directly detect climate change and to provide absolutely calibrated synthetic radiances that can be used to provide absolute calibration information for satellite sensors.

- Even if not successful at this stage, useful in defining the scientific rationale, approach and objectives for a structured study in this area.

'Determining Optimal Spatial and Temporal Sampling Strategies for the GRUAN'

- Main elements of the proposal were :

  - investigation of sampling and scheduling issues using actual satellite / sonde matched datasets and theoretical simulations.

  - investigation of similar issues for climate trend detection, including sampling strategies and trend determination methodologies.

- In both cases, a key tool for these studies was the availability of a fine-scale mesoscale model dataset that properly captures the temporal and spatial variability of the atmosphere at GRUAN sites.

- By combining this dataset with different instrumental performances, sampling schedules, and predicted trend behaviours many questions on the measurement requirements and scheduling issues could be scientifically assessed.

Measurement Uncertainty

- In all of the preceding discussions it is key to have a complete understanding of the measurement uncertainties and uncertainty due to other effects (e.g.co-location).

- Information on this can come from a number of sources including :

  - Outputs from other Tasks Teams and GATNDOR

  - Results from sonde intercomparison campaign.

  - Work lead by Franz Immler on 'Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products'.

Immler et al, Atmos. Meas. Tech., 3, 1217-1231, 2010

Meteomet EMRP Project

- EMRP : European Metrology Research Project
    - Europe-wide research programme for National Measurement Institutes
    - Recent call on Environment topic for 3 year projects starting this summer
- One of the successful proposals was on 'Metrology for pressure, temperature, humidity and airspeed in the atmosphere' or Meteomet : Metrology for Meteorology.
- Large consortium lead by INRiM, Italy with 18 NMIs, 3 Universities and 29 collaborators including national meteorology organisations, universities, research institutes, associations and instrument companies

Meteomet Objectives

- 'Ensuring a defined traceability to the national standards for meteorological observations and climate data'
- Specific objectives include :
  - Definition of measurement protocols in accordance with WMO guidance.
  - Uncertainty evaluation for measurements of climate parameters.
  - Calibration of weather measurement stations and reference radiosondes.
  - Improved humidity sensors and calibration methods.
  - Robustness of the historical temperature measurement data.
  - Improved availability of traceable data and promote their use.
  - Improved communication and co-operation between scientific community.
  - Development and testing of novel instruments and facilities for ground based observations.
  - Improved laboratory and in-situ calibration procedures and best practice dissemination.

TT3 Discussion points

- Team Membership
  - Current membership includes expertise on remote instrumentation, satellite measurements and program management. Looking to extend this with expertise on trend determination and analysis.
  - Need to extend with representation from the sites and in-situ measurement expertise, and others.
- Task Team goals for 2011
  - GRUAN implementation plan sets out series of objectives including :

    'Quantitative assessment of in-situ (radiosonde) measurement frequency and scheduling impacts on trend and variability characterisation' [Winter 2010];

    'Assessment of the value and utility of satellite coincident in-situ and remote sensing measurements' [Summer 2011];

    'Final set of temporal sampling guidance for both in-situ and remote sensing instrumentation' [Winter 2011].
  - Need to agree what is key and realistic for the Task Team to achieve in the coming year.
- Awareness and linkage to other activities such as satellite validation campaigns, Meteomet project, etc.