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- main information sources are from peer-reviewed literature, GRUAN documentation, and currently unpublished studies of which the group is aware.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.

Update on TT3 activities

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- Published summary of ITS-9 presentation on Task Team and GATNDOR research activities :
  - *Sampling and measurement issues in establishing a climate reference upper air network ; T. Gardiner, F. Madonna, J. Wang, D. N. Whiteman, J. Dykema, A. Fassò, P. W. Thorne, and G. Bodeker; AIP Conf. Proc. 1552, pp. 1066-1071; doi:http://dx.doi.org/10.1063/1.4821422, 2013*
- Review of temperature measurement literature
- Temporal sampling – diurnal variability
- Lower stratospheric water vapour trends (Dave Whiteman's talk tomorrow afternoon)

Review of Temperature Measurement Requirements

- TG and a colleague at NPL (Dave Butterfield) have completed a review of the papers in this area, and use them to come up with a series of referenced recommendations – currently being reviewed as GRUAN Technical Note.
- 14 (+1) key papers identified to provided peer-reviewed evidence base for temperature measurement decisions.
- General focus on sonde measurements and long-term trend detection, although a number of the conclusions are more generally applicable.

Papers reviewed / summarised

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1. Causes of differing temperature trends in radiosonde upper air data sets, M Free & D Seidel, JGR, Vol 110, 2005
2. An Update of Observed Stratospheric Temperature Trends, W Randal et al, JGR, Vol 114, D02107, 2009
3. Comparison of Radiosonde and GCM Vertical Temperature Trend Profiles: Effects of Dataset Choice and Data Homogenization, J Lamzante & M Free, Journal of climate, Vol 21, 5417-5435, 15th October 2008
4. Measurement Requirements for Climate Monitoring of Upper-Air Temperature Derived from Reanalysis Data, D Seidel & M Free, Journal of Climate, Vol 19, 854 – 871, 1st March 2006.
5. Factor affecting the detection of trends: Statistical considerations and applications to environmental data, Weatherhead et al, JGR, Vol 113, No D14, 17149-17161, July 1998.
6. An assessment of three alternatives to linear trends for characterizing global atmospheric temperature changes, D Seidel and J Lanzante, JGR, Vol 109, D14108, doi:10.1029/2003JD004414.
7. Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products, F Immler et al, Atmospheric Measurement Techniques, Vol 3, 1217–1231, 2010.
8. Uncertainties in climate trends – Lessons from upper air temperature records, P Thorne et al, AMS, 1437 – 1442, 2005
9. Spatial sampling requirements for monitoring upper-air climate change with radiosondes, MP McCarthy, International Journal of Climatology, 985-993, vol 21, Aug 2008
10. Assessing bias and uncertainty in the HadAT adjusted radiosonde climate record, MP McCarthy, AMS, 817-832, 2008
11. Impact of missing sounding reports on mandatory levels and tropopause statistics: a case study, JC Antuna, Annales Geophysicae, 2445-2449, Vol 24, Issue 10, 2006.
12. A quantification of uncertainties in historical tropical tropospheric temperature trends from radiosondes, P Thorne et al, JGR, Vol 116, Article Number: D12116 , 2011
13. Separating signal and noise in atmospheric temperature changes: The importance of timescale, B Santer et al, JGR, VOL. 116, D22105, 2011
14. Critically Reassessing Tropospheric Temperature Trends from Radiosondes Using Realistic Validation Experiments, H. Titchner et al, Journal Of Climate, Vol 22, 465 – 485, Feb 2009
15. Observing systems Capability Analysis and Review Tool (OSCAR) – World Meteorological Organisation

Reported trends

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Source	Trend K.Decade^{-1}	Period	Location	Measurement	Comments
2	+0.2	1958 - 2005	LS	Sonde	Solar cycle
2	+0.5	1979-2005	LS	Sonde + MSU4 + SSU	Solar cycle
2	-0.2 to -0.4	1979 - 2007	LS	MSU4	
2	-0.5	1979 - 2007	LS	Sonde +MSU4	
2	-1.0	1957 – 2005	LS	Sonde	Large uncertainties in data 1958 – 1978 compromise the results.
2	-1.0 to -1.5	1979 - 2007	LS Antarctic	Sonde	Ozone hole during 1980s
2	-0.5	1979 – 2005	M	SSU	
2	-1.0 to -1.3	1979 - 2005	M – US	SSU	
2	-1.5	1979 – 2005	US	Lidar	
6	0.87 0.87 0.66	1900 - 2002	Surface	Slopped step Piecewise linear Linear	
6	0.32 0.52	1958 - 2001	T	Slopped steps Linear	Radiosonde
6	0.13	1979 - 2001	T	Linear Change dominated by inter-annual changes	Satellites Radiosonde s give 0.14
6	-1.82 -1.82 -1.90	1958 - 2001	S	Slopped step Linear Linear	Radiosonde Volcanic periods removed, linear give the best fit
6	-0.88 -1.13 -0.83 -0.99	1979 – 2001	S	Slopped step Linear Flat step Linear	Satellite Volcanic eruptions account for 94% of the cooling Volcanic activity removed

Differences in trend measurement techniques

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Source	Difference in trend K.Decade^{-1}	Period	Location	Measurement	Comments
1	-0.1	1979 - 1997	MT	Sonde – MSU2	
1	+0.16 to -0.31	1979 – 1997	LS	Sonde – MSU2	
1	0.071	1979 – 1997	200 mbar	Sonde -MSU2	Full and subsampled mean global trend
1	<0.05	1979 - 1997	50, 500 – 850 mbar	Sonde -MSU2	Full and subsampled mean global trend
1	0.02	1979 – 1997	MT	Sonde - MSU2	Due to temporal effects
1	0.2 0.1 <0.1	1979 – 1997	MT	Sonde	LKS vs HadRT 7 stations 8 stations 44 stations
3	Observed > modelled	1960 - 1999	T	Sonde x 2 – Modelled x 6	Homogeneity adjustments (sonde) improve agreement and correlation
3	Observed >> modelled	1960 - 1999	S	Sonde x 2 – Modelled x 6	Similar to troposphere, but sampling ozone depletion may cause problems in southern hemisphere
4	0 to 60%	1955 - 2005	T to S	Sonde	Analysis of the effects of precision, sampling time and frequency and measurement stability
5				Effect of autocorrelation, variability and measurement intervention on the detection of trends	

Sampling Issues

- Sampling twice daily, at 0000 and 1200 UTC, ensures that monthly statistics will be statistically significantly different from those based on four observations per day in only ~5% of the cases.
- Sampling once daily introduces biases in monthly mean temperatures.
- Large errors result from changing from 0000 to 1200 UTC observations (or vice versa).
- Twice-daily sampling must be done at least once every two days to ensure that monthly means are accurate to within 2 K.
- Sampling every two days, or every three days (but not every seven days), yields monthly means and standard deviations that are not significantly different from the true values at least 99.5% of the time.

Sampling Issues

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- The scheduling conclusions are :
  - Maintaining a constant time of observation is more important than maintaining daily observations for avoiding errors in temperature trend estimates.
  - Measurements should be made at least twice daily at 0000 and 1200 UTC to try and avoid bias in monthly means.
- In addition to scheduling, issues relating to temperature measurement uncertainty, change management and network requirements are also summarised.

Short-timescale sampling issues

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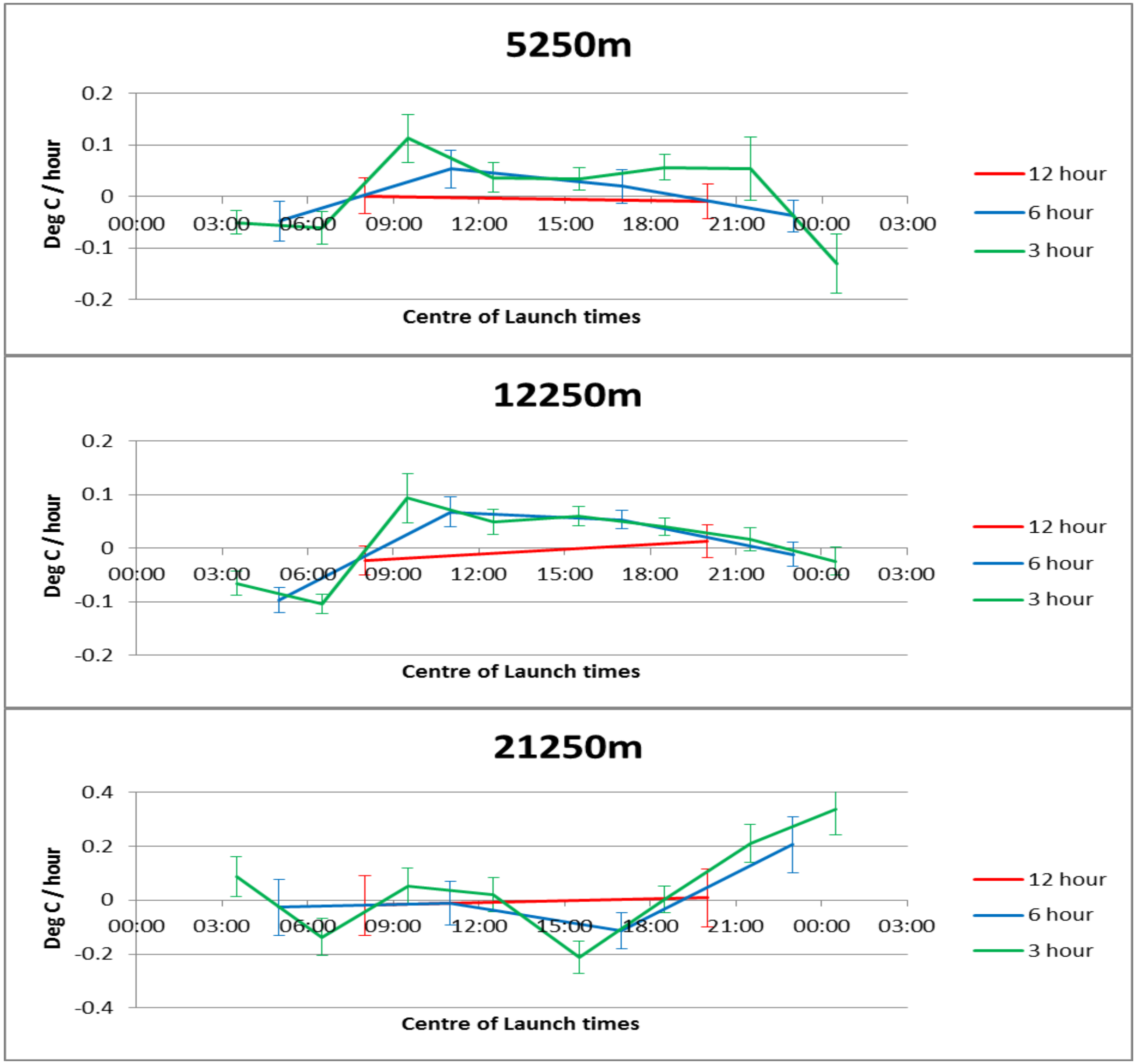
- Difficult / impossible to produce a fixed set of sampling guidelines given the wide potential range of short-timescale applications (for process studies and satellite validation).
- One option is to estimate the increased uncertainty due to non-simultaneous temperature measurements.
  - For example, what is the increased uncertainty in the temperature profile if a sonde result is used for a satellite overpass some time later ?
- This would enable an appropriate sampling strategy to be put in place for a given requirement / application.
- We have produced estimates of this from actual sonde datasets.

Data sets studied

Launch site	Latitude	Longitude	Start	End	Launches per day	Sonde
Manus	2° 3' S	147° 25' E	24/09/2011	31/03/2012	8	RS92
Lindenberg	52° 12’ N	14° 7’ E	01/01/1999	31/12/2008	4	RS90
Lindenberg	52° 12’ N	14° 7’ E	01/01/2009	31/12/2012	4	RS92
Southern Great Plains	36° 36' N	97° 29' W	01/01/2006	31/12/2012	4	RS92

Capture of diurnal variability



Comparison of launch frequency

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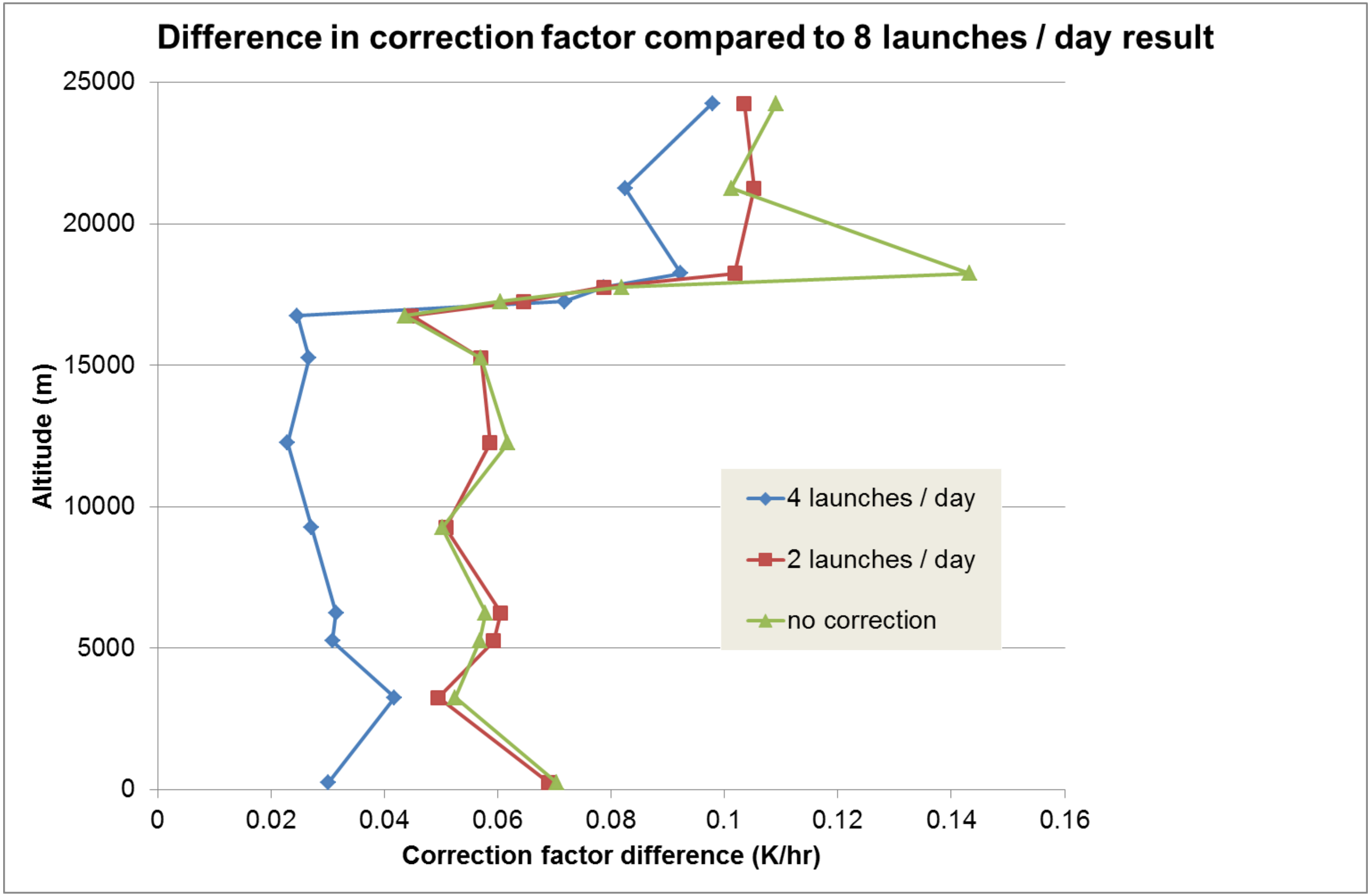

Long-term data – diurnal variation

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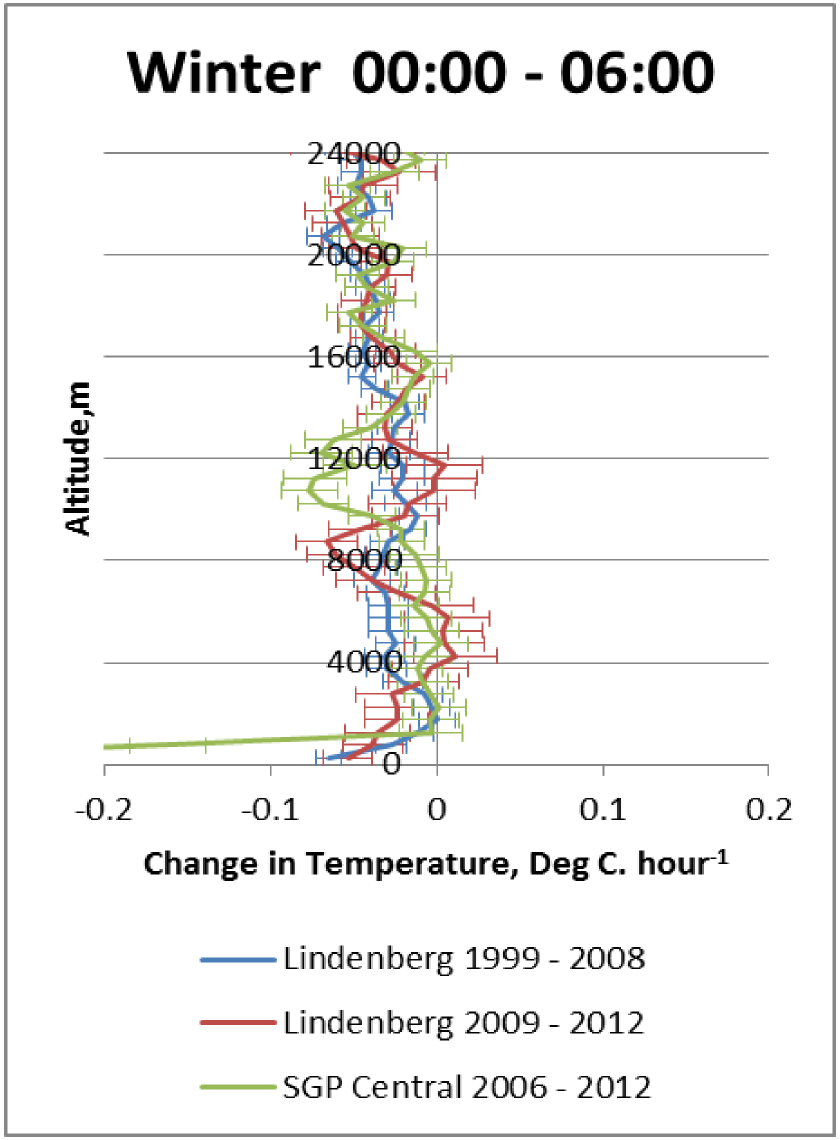
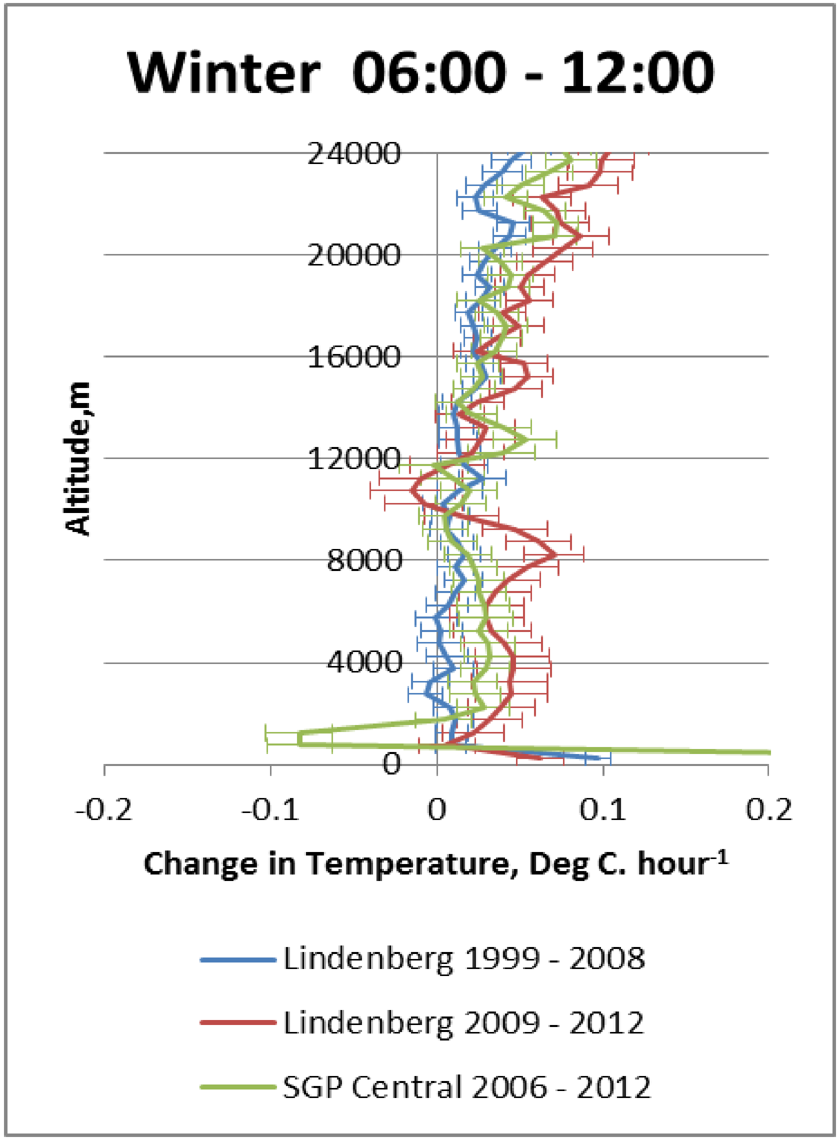
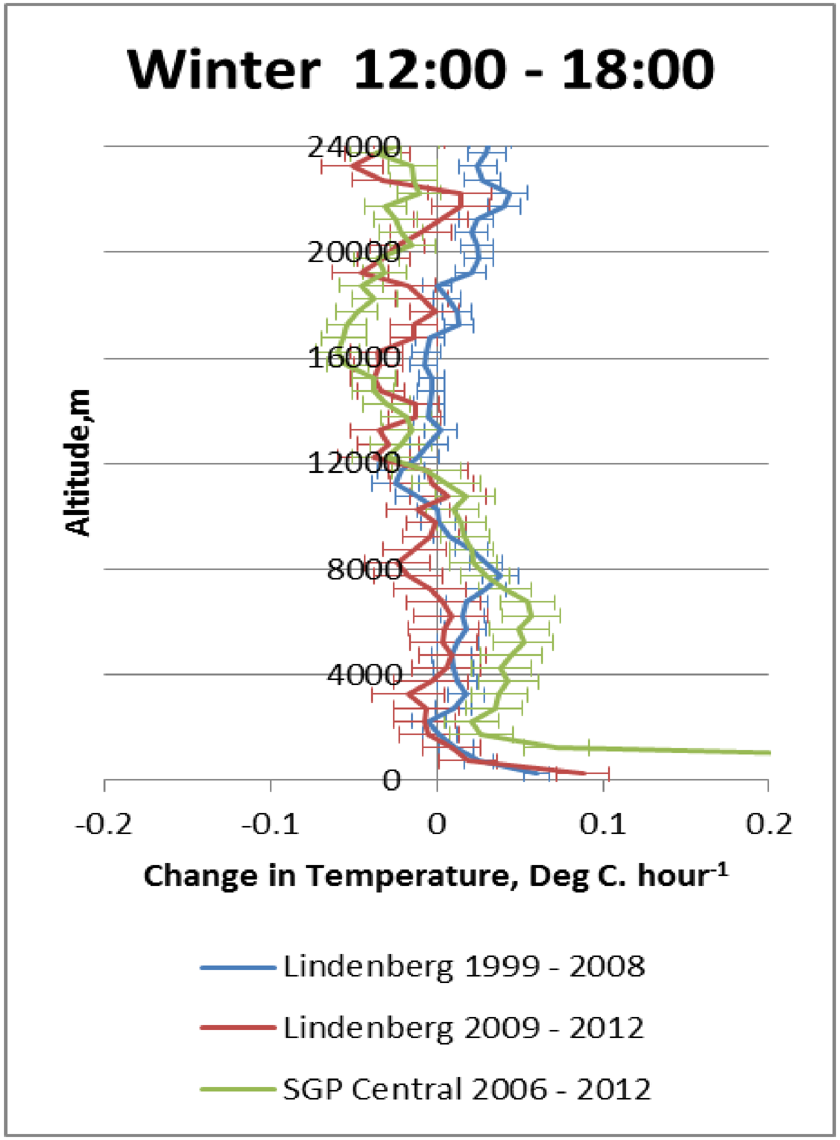
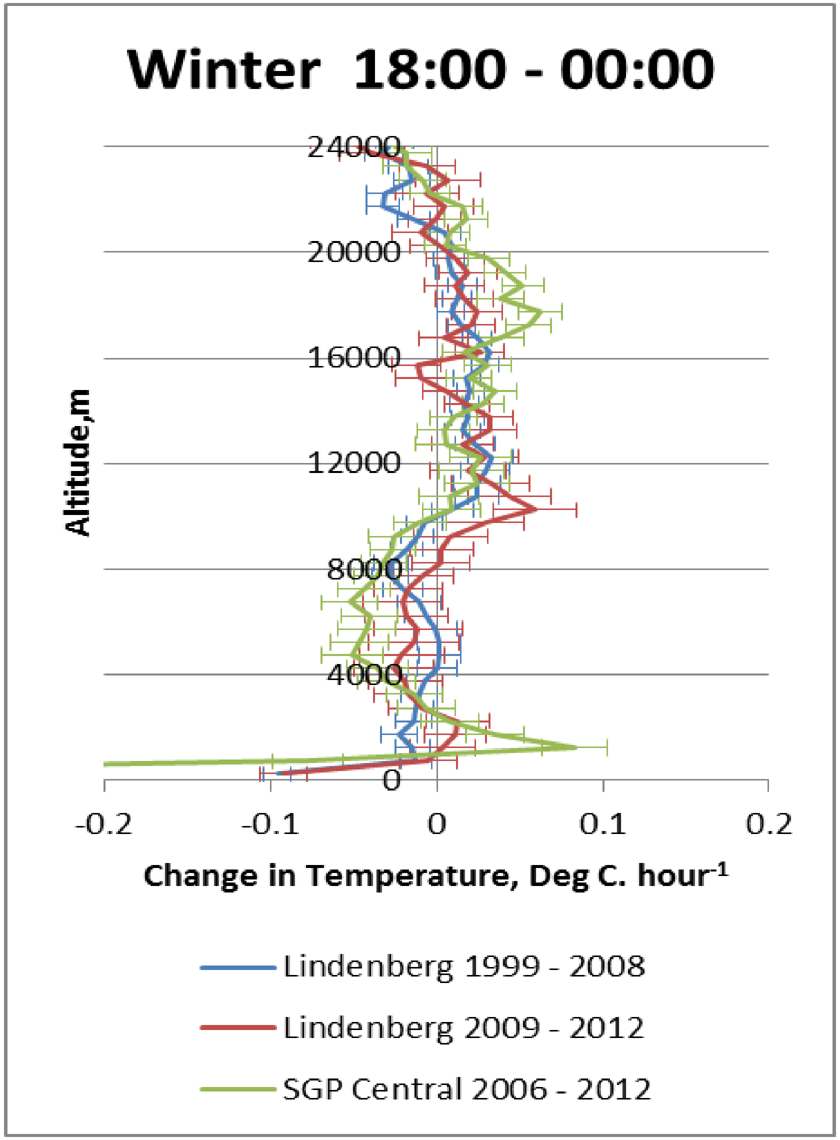




Long-term data – diurnal variation





Long-term data – seasonal variation

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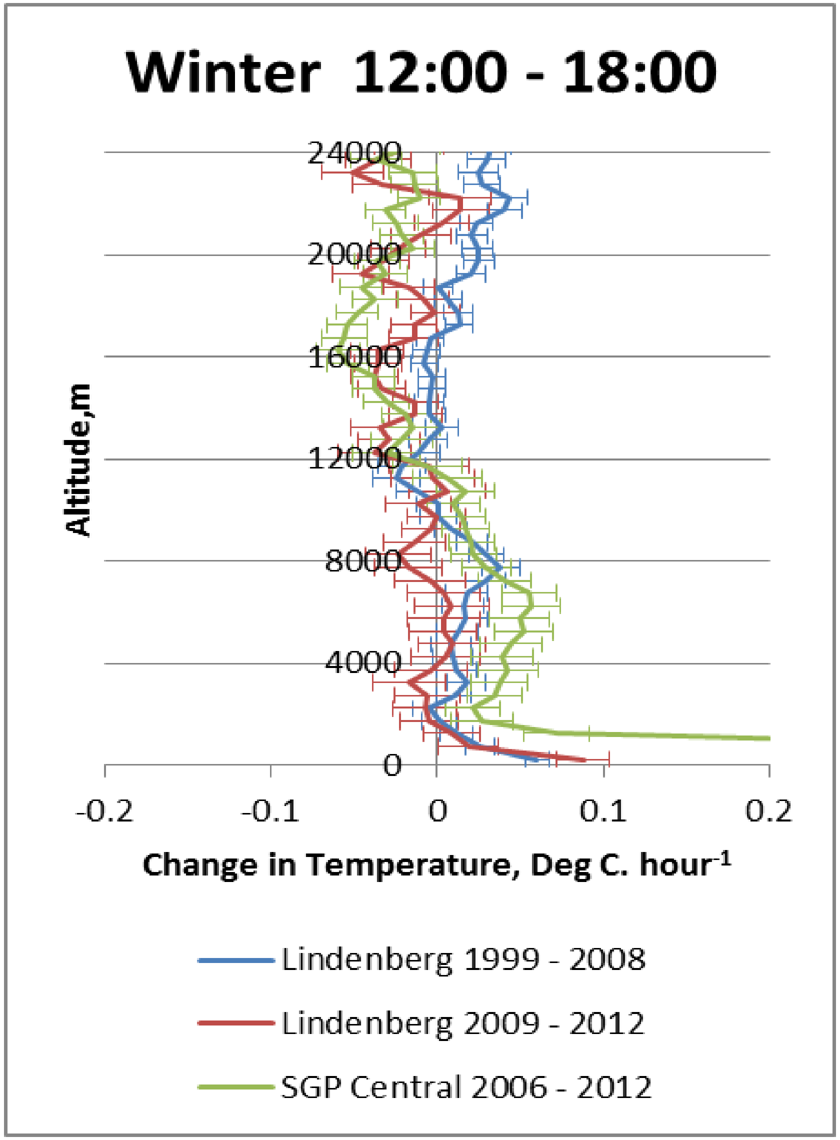
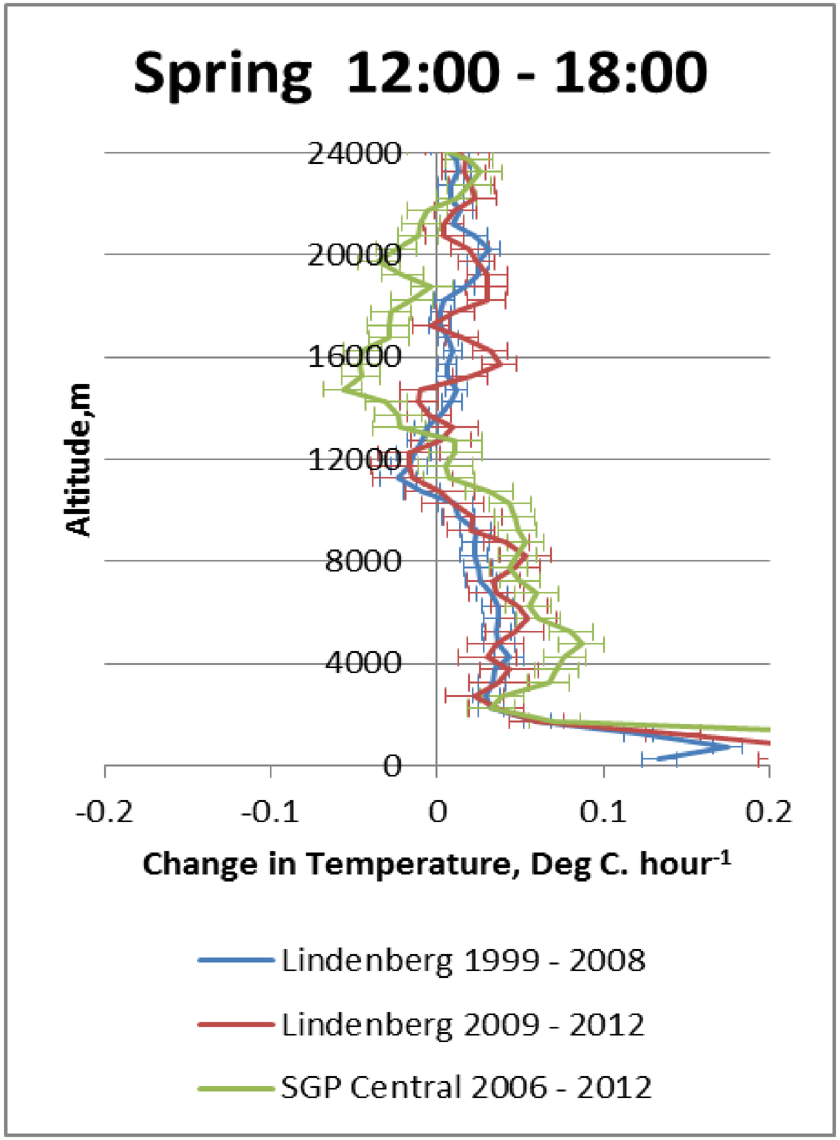
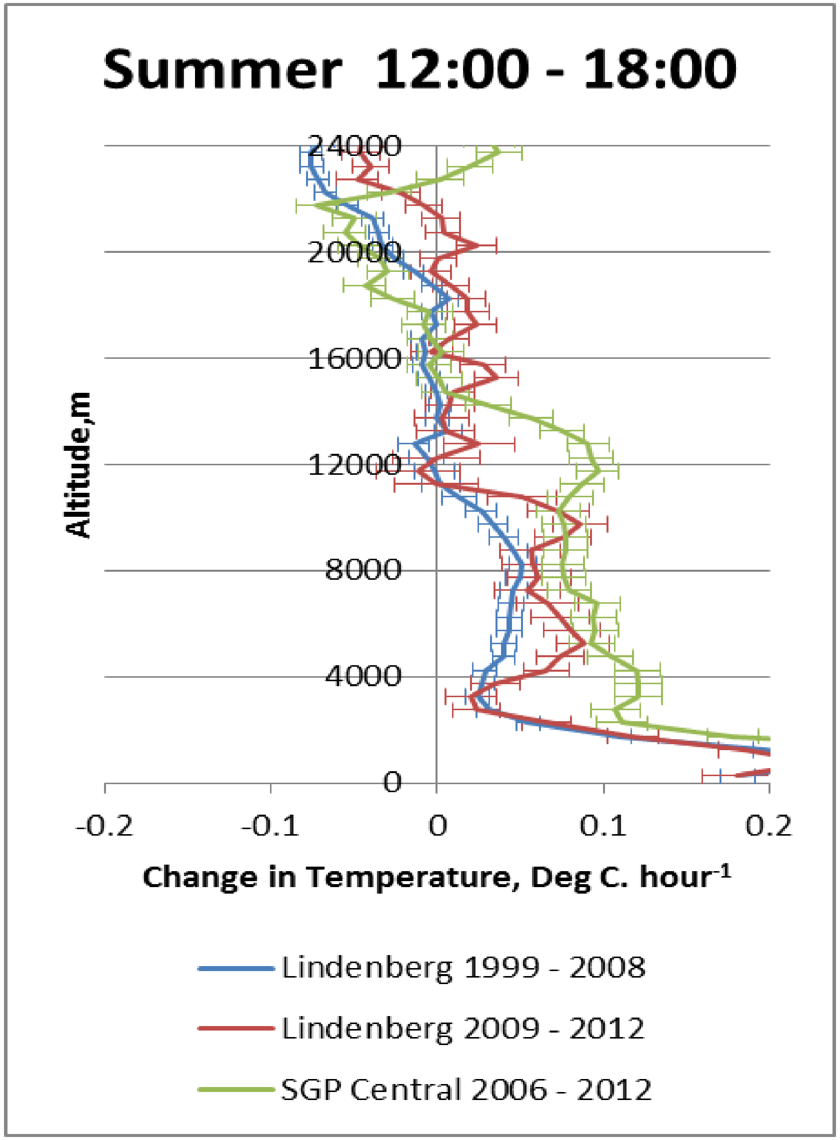
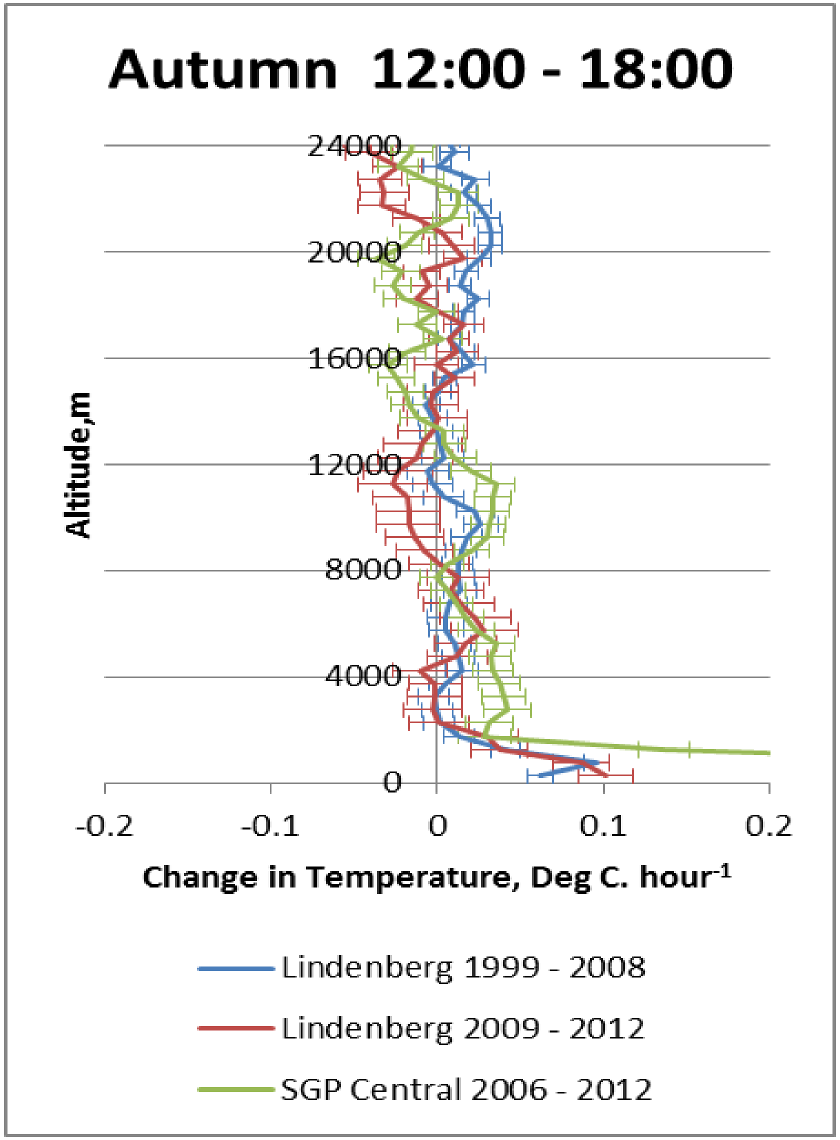




Long-term data – seasonal variation





Reduction in random uncertainty with repeat measurements

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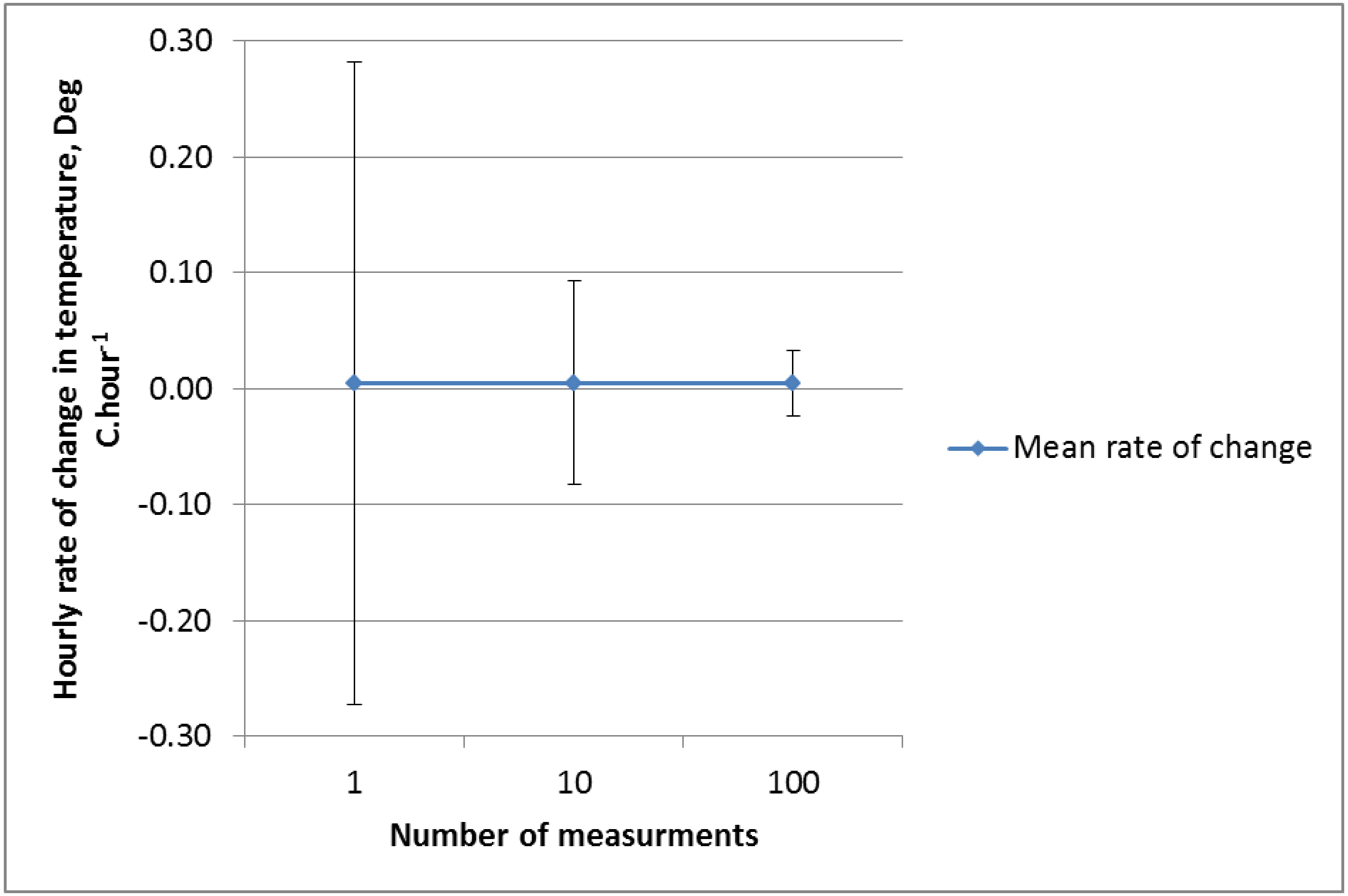

Temporal mis-match correction factors and uncertainties

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Rates of change (in K / hr) between 12:00 and 18:00

At Altitude of 5 km

	Spring	Summer	Autumn	Winter
Mean rate of change	0.036	0.040	0.010	0.013
Stdev (1 reading)	0.265	0.219	0.304	0.372
Stdev (10 readings)	0.084	0.069	0.096	0.118
Stdev (100 readings)	0.026	0.022	0.030	0.037

At Altitude of 10 km

	Spring	Summer	Autumn	Winter
Mean rate of change	0.011	0.027	0.023	0.000
Stdev (1 reading)	0.305	0.280	0.337	0.368
Stdev (10 readings)	0.097	0.088	0.107	0.116
Stdev (100 readings)	0.031	0.028	0.034	0.037

At Altitude of 15 km

	Spring	Summer	Autumn	Winter
Mean rate of change	0.006	-0.005	0.004	-0.003
Stdev (1 reading)	0.182	0.191	0.215	0.235
Stdev (10 readings)	0.058	0.060	0.068	0.074
Stdev (100 readings)	0.018	0.019	0.021	0.023

At Altitude of 20 km

	Spring	Summer	Autumn	Winter
Mean rate of change	0.031	-0.033	0.032	0.024
Stdev (1 reading)	0.199	0.175	0.202	0.270
Stdev (10 readings)	0.063	0.055	0.064	0.085
Stdev (100 readings)	0.020	0.017	0.020	0.027

Summary and next steps

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- 4 launches per day to capture diurnal variability
- Can use to predict temporal mis-match correction (and uncertainty) as function of altitude and season – where long term data is available.
- Draft paper prepared – hoping to submit to AMTD soon
- Have discussed with ECMWF options to use model data to extend to other sites having verified result at Lindenberg and SGP.
- Integration of GRUAN uncertainty information into recent Lindenberg dataset.
- Possible extension to water vapour measurements ?

Acknowledgements

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- Manus

  Data provided by NCAR/EOL under sponsorship of the National Science Foundation as one of the upper air data sets developed for the Dynamics of the Madden-Julian Oscillation (DYNAMO) 2011-2012 project. (http://data.eol.ucar.edu/)

- Southern Great Plains

  Data were obtained from the Atmospheric Radiation Measurement (ARM) Program sponsored by the U.S. Department of Energy, Office of Science, Office of Biological and Environmental Research, Climate and Environmental Sciences Division (www.arm.gov).

- Lindenberg

  Data provided by the Lindenberg Meteorological Observatory - Richard Aßmann Observatory of Deutscher Wetterdienst (http://www.dwd.de).