



The Australian Space Research Program - Platform Technologies for Space, Atmosphere & Climate -

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Co-authors/collaborators



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- **Bureau of Meteorology, Australia**
 - J. Le Marshall, Y. Kuleshov, B. Biadglgne
- **Curtin University of Technology, Australia**
 - P. Teunissen
- **University of New South Wales, Australia**
 - C. Rizos, S. Lim
- **Electro Optic Systems Space System, Australia**
 - J. Sang and C Smith
- **GPSat Systems Australia**
 - G. Hopper
- **Center for Space and Remote Sensing Research/NCU, Taiwan**
 - Y. Liou
- **NOAA World Data Centre of Meteorology, USA**
 - H. Diamond

- **The Australia Space Research Program (ASRP) scheme**
 - A new Australian government initiative
 - ASRP rationale, support and funding streams
 - Priorities of Australian National Space Policy
- **RMIT ASRP project – related to GNSS RO**
 - Key objectives/research tasks, anticipated research and outcomes
- **Current activities and results related to GNSS RO**
 - Key research collaboration/projects - Wide areas of engagement
 - Preliminary results
- **Conclusive remarks /discussion**
 - “further Big things” down the track



Australia Space Research Program Scheme



- **Rationale**
 - No government org coordinate space related activities
 - Senate inquiry – “lost in space”, defence, exploding space activities, etc.
- **\$50m initial investment for ASRP**
 - ~\$8.6m for the establishment of Australian Space Policy Unit (SPU)
 - \$40m allocated (\$10m for education, \$30m for research innovation)
- **Two streams**
 - Stream A education grants – \$200k – \$1m over 3 years (university lead plus at least one other collaborator)
 - Stream B research grants – \$1m-\$5m over 3 years (minimum of one research organisation and one company)
- **Requirements (4Cs + co-contribution)**
 - 50% cash/in-kind contributions sought from applicants
 - 4Cs approach → Credibility, Capacity, Collaboration, Communication
 - **International collaboration is encouraged**
- **A balance of investment across the nation and across disciplines**
- **Astronomy, Astrophysics & Cosmology – expressly ruled out**



Australian National Space policy



- **Personal position, navigation and timing (PNT) services, including**
 - Satellite Navigation, GPS enabled phones and mapping services like Google Earth are becoming increasingly central to personal navigation and planning
- **Commercial precision PNT services enable critical capabilities that underpin Australia's economic security, such as**
 - air and road transport of goods, precision agriculture, and
 - natural resource identification and management
- **Earth observation services help us understand climate change and monitor large-scale phenomena such as**
 - the El Niño, weather prediction, droughts, forest fires, and urban development, enabling long term Government and social planning
- **Satellite communications technologies, including broadband,**
 - enable Australian citizens and companies to conduct essential business and access critical services such as emergency transport.



- **Administered by the Federal Department of Industry, Innovation, Science and Research (DIISR)**
- **Independent panel used for the assessment**
- **Round based – four rounds**
 - 4 rounds – Dec 2009, May & Dec 2010, 2011 (allow re-submissions)
 - Funding concludes in June 2013
- **Not meant to be a one-off process**
 - This is a “scouting” / “fishing” process
 - A long-term plan to streamline the system
- **The 1st and 2nd rounds successful projects**
 - Dec 2009 deadline, outcomes announced on 26 Feb 2010 (1st round)
 - ✓ 3+1 successful out of ~40 applications
 - ✓ \$12M awarded to first recipients of new space research program
 - March 2010 deadline, outcomes announced in July 2010 (2nd round)
- **3rd round was open in Aug 2010**



Stream A – Space Education Development



- **Grants up to \$1 million**
- **Support student space projects & educational activities**
- **Student led and student focussed**
- **Applications from consortia comprising at least**
 - one university (lead applicant) and one other partner
 - other partners may include secondary schools, education insts, museums, CSIRO etc
- **Key objectives**
 - Strengthening education in the fundamental space-related sciences and disciplines, e.g. physics, mathematics, engineering, earth sciences, material sciences and relevant life sciences, social sciences and space law.
 - Providing opportunities for students to participate in Australia's space-related activities.
 - Enhancing knowledge, training, and skills development to encourage and support participation in Australia's space related workforce.
 - Developing linkages between Australian and international space-related education and training programs.



Stream B – Space Science & Innovation Project



- **Grants up to \$5 million**
- **Support space research and development projects**
- **Applications from consortia comprising at least:**
 - one university or research institution
 - one industry partner
- **International collaboration encouraged**
- **Key objectives**
 - Satellite-based services such as communications, position navigation and timing and earth observation
 - Space technology for sensors, instruments, satellites and vehicles
 - Space flights (e.g. launching and operating civil satellites)
 - Development of new technologies resulting from space related endeavours
 - Development of linkages and space related innovation projects



The 1st round successful projects



- **Dec 2009 deadline, outcomes announced on 26 Feb 2010**
 - 3+1 successful out of ~40 applications
 - \$12M awarded to first recipients of new space research program
- **Media Release by Senator the Hon Kim Carr on 26 Feb 2010**
 - Announcing the four successful projects today, Innovation Minister Senator Kim Carr praised the consortiums behind them for their smart approach to the program, which encourages applicants to assemble national and international teams with wide skills and experience.
 - “Only this week we saw evidence of the very real benefits that come from investing in world-class space science, with confirmation from NASA that it is building two new dishes at Australia’s Tidbinbilla facility, each worth US\$45 million”.
 - “The projects we are funding under the ASRP will promote new opportunities and new investment in Australian space science and the Australian space industry.
 - “Australia can be a serious player in the global space industry if we focus on niche areas that match our special capabilities. That is what these projects do.”



- **Platform Technologies for Space, Atmosphere and Climate (~\$7.5m, 50% cash)**
 - RMIT University, the Bureau of Meteorology (BoM), Curtin Univ of Technology (CUT), UNSW, Electro Optic Systems Space System (EOSSS), GPSat Systems Australia Pty Ltd,
 - National Central University (NCU)/(NSPO) Taiwan, NOAA's World Data Centre for Metrology (WDCM).

- **GRACE Follow-on Mission (\$4,673,001)**
 - ANU, CSIRO, EOS Space Systems Pty Ltd, Jet Propulsion Laboratory, Californian Institute of Technology, Max Planck Institute for Gravitational Physics (Albert Einstein Institute), National Measurement Institute



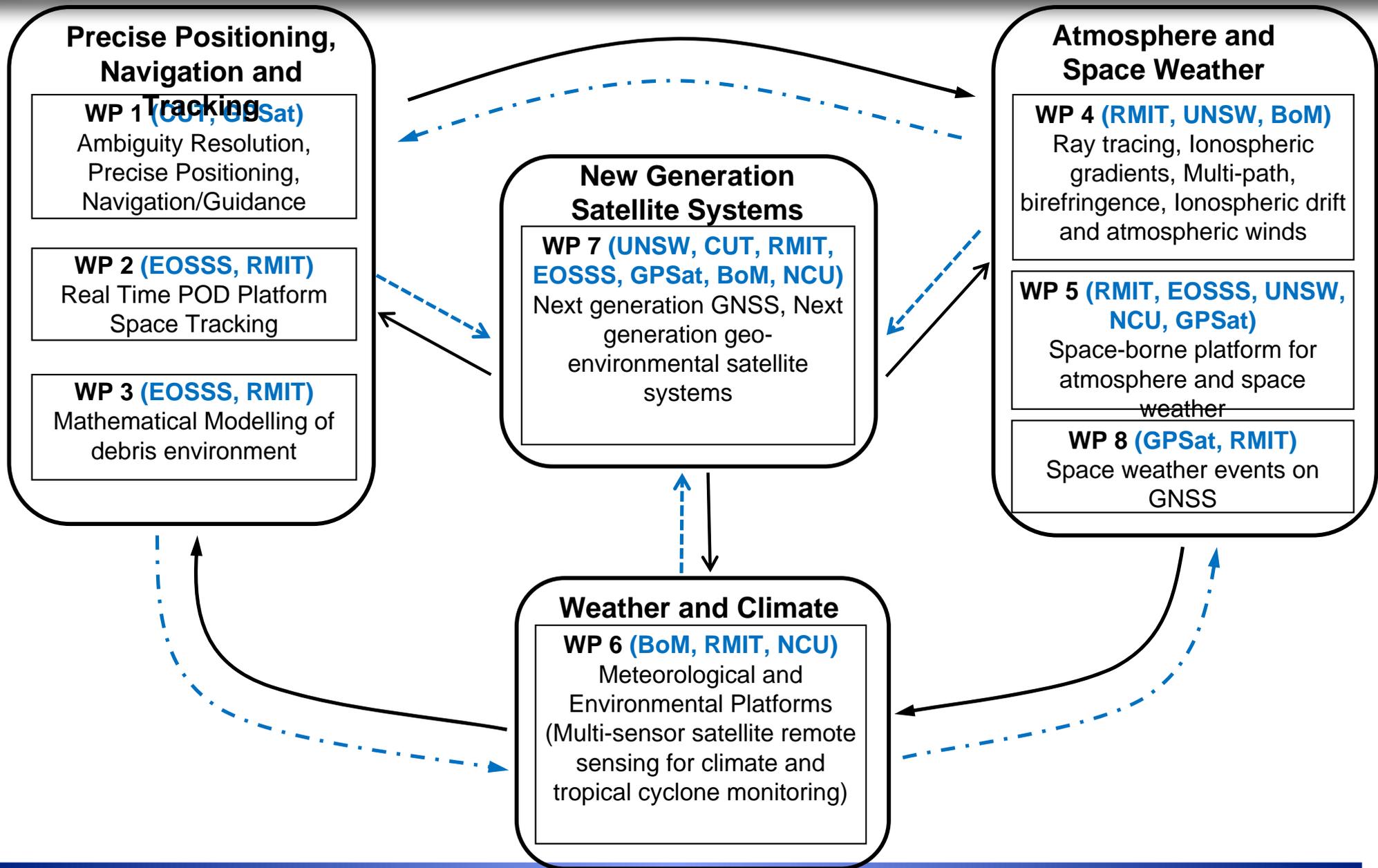
The RMIT ASRP project

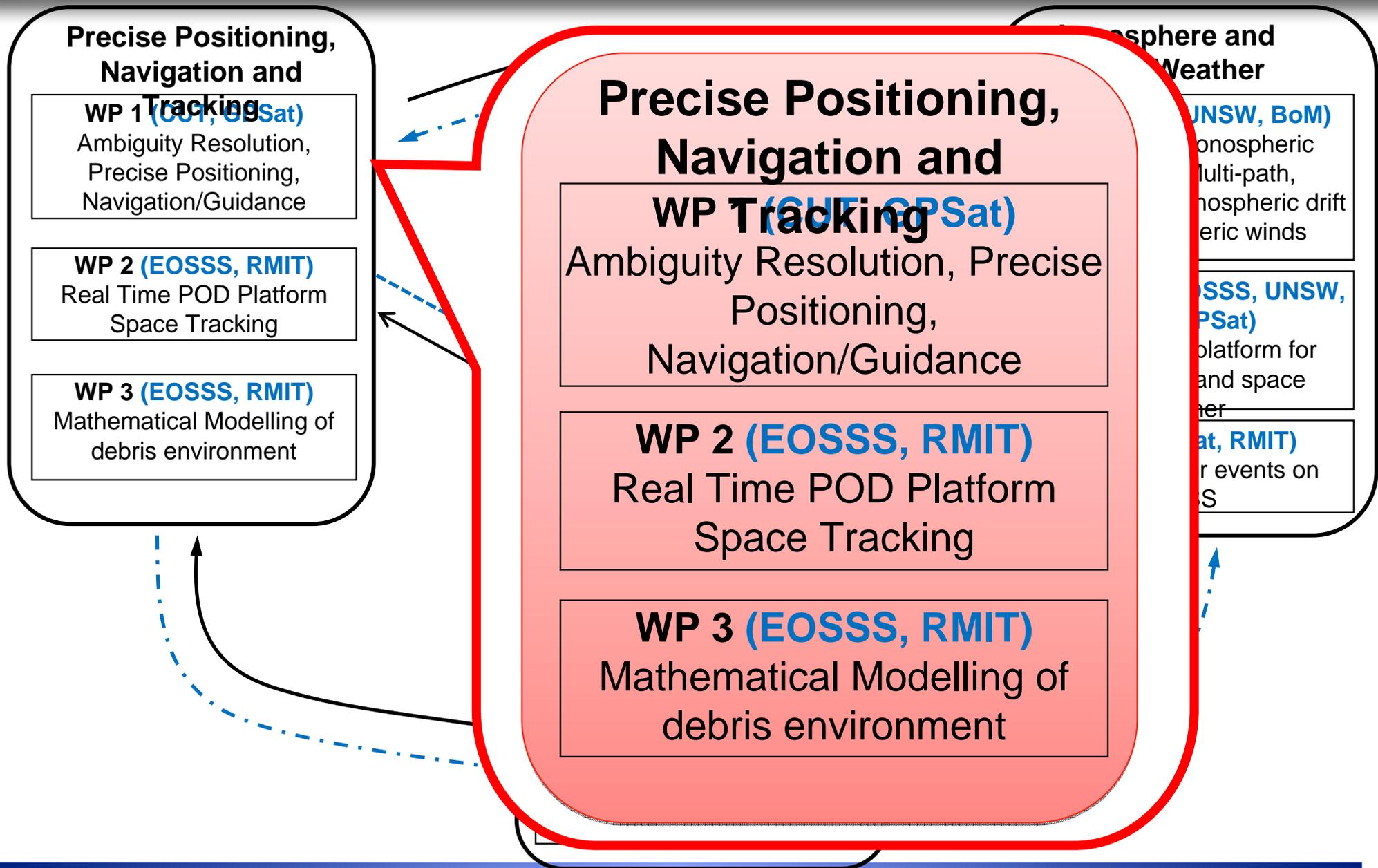


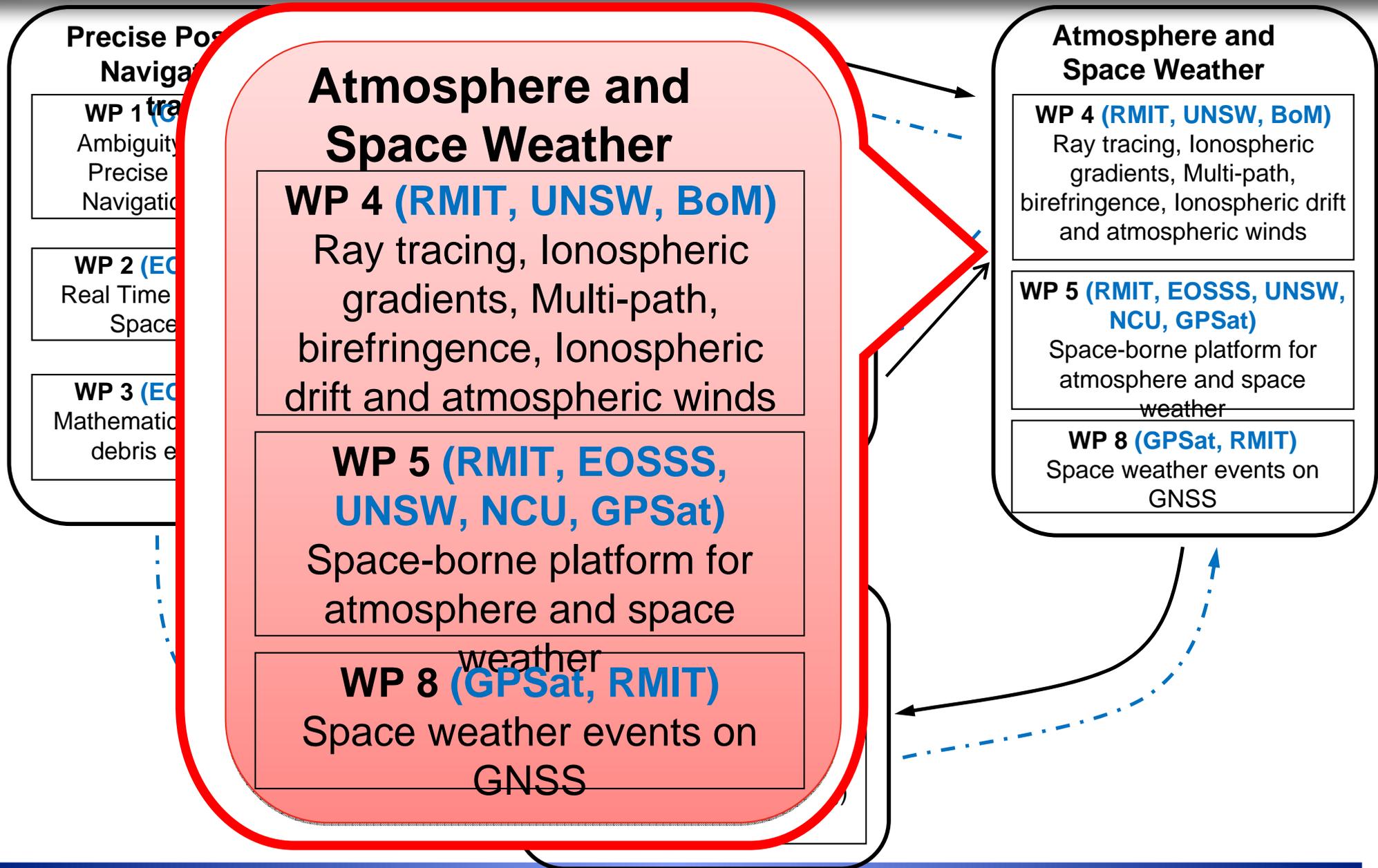
- **Platform Technologies for Space, Atmosphere and Climate**
 - \$7.5m (~50% cash, \$2.85m from DIISR directly)
 - Develop technologies for space research, including space/debris tracking and navigation, weather and climate monitoring, and atmospheric modelling.
 - make a significant contribution to our space industry, particularly in the satellite navigation, positioning and tracking; space tracking; meteorological services and space weather; and future planning, design, launch and operation of Australian micro and nano-satellite missions.
- **Consortium members**
 - Prof Kefei Zhang, RMIT University (Leading)
 - Prof Peter Teunnisen, CUT (Federation Fellow)
 - Prof Chris Rizos, HoS of SSI, UNSW (President of IAG)
 - Profs John Le Marshall / Y Kuleshov , Bureau of Meteorology
 - Drs Jizhang Sang / Craig Smith, Electro Optic Systems Space System
 - Mr Graeme Hopper, GPSat Systems Australia Pty Ltd
 - Prof Yue-an Liou, National Central University/Taiwan
 - Mr Howard Diamond, World Data Center for Meteorology/NOAA

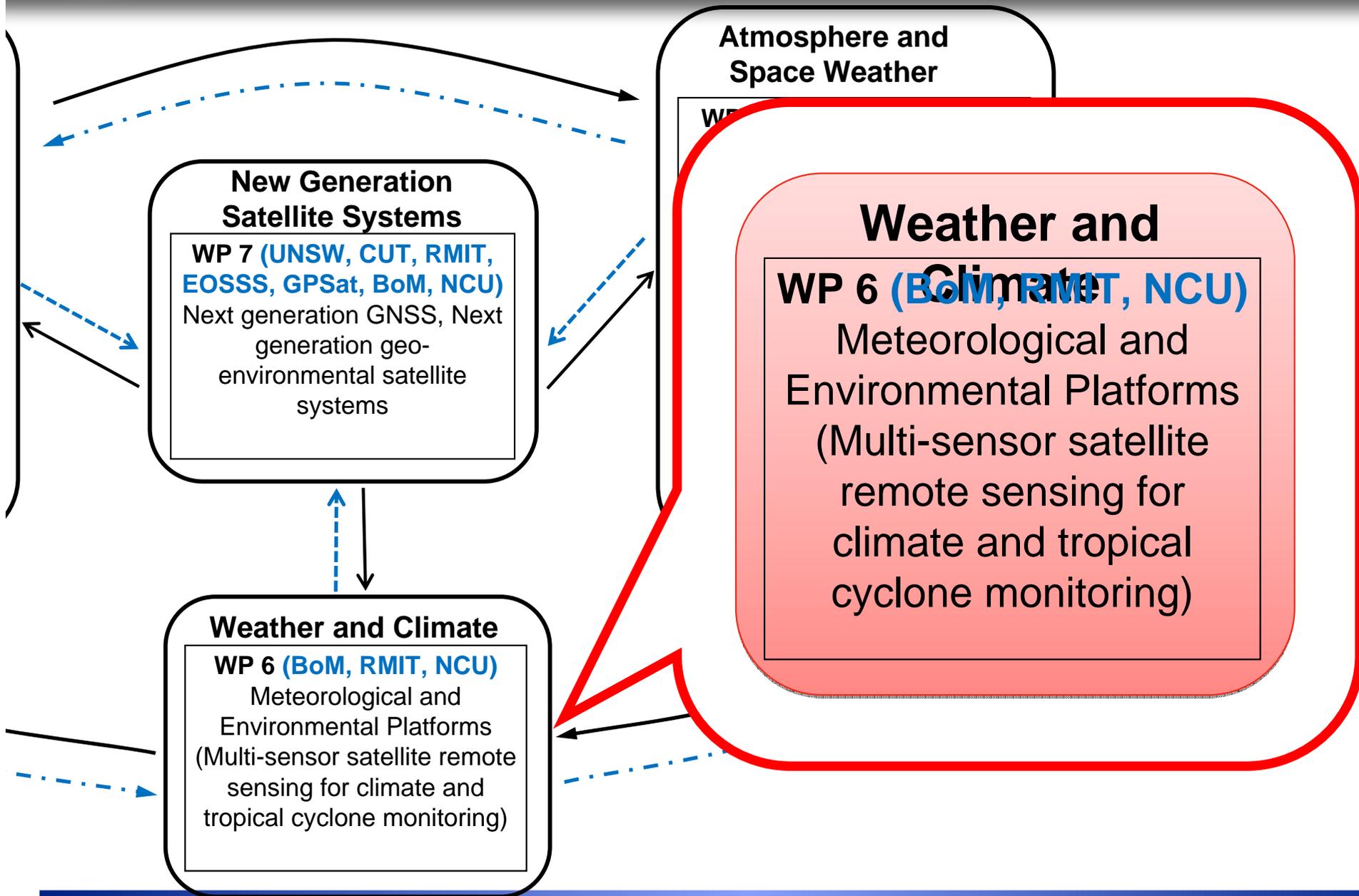
 - Domestic vs international: 6+2
 - HE, Gov, Industry: 3(+1)+1(+1)+2

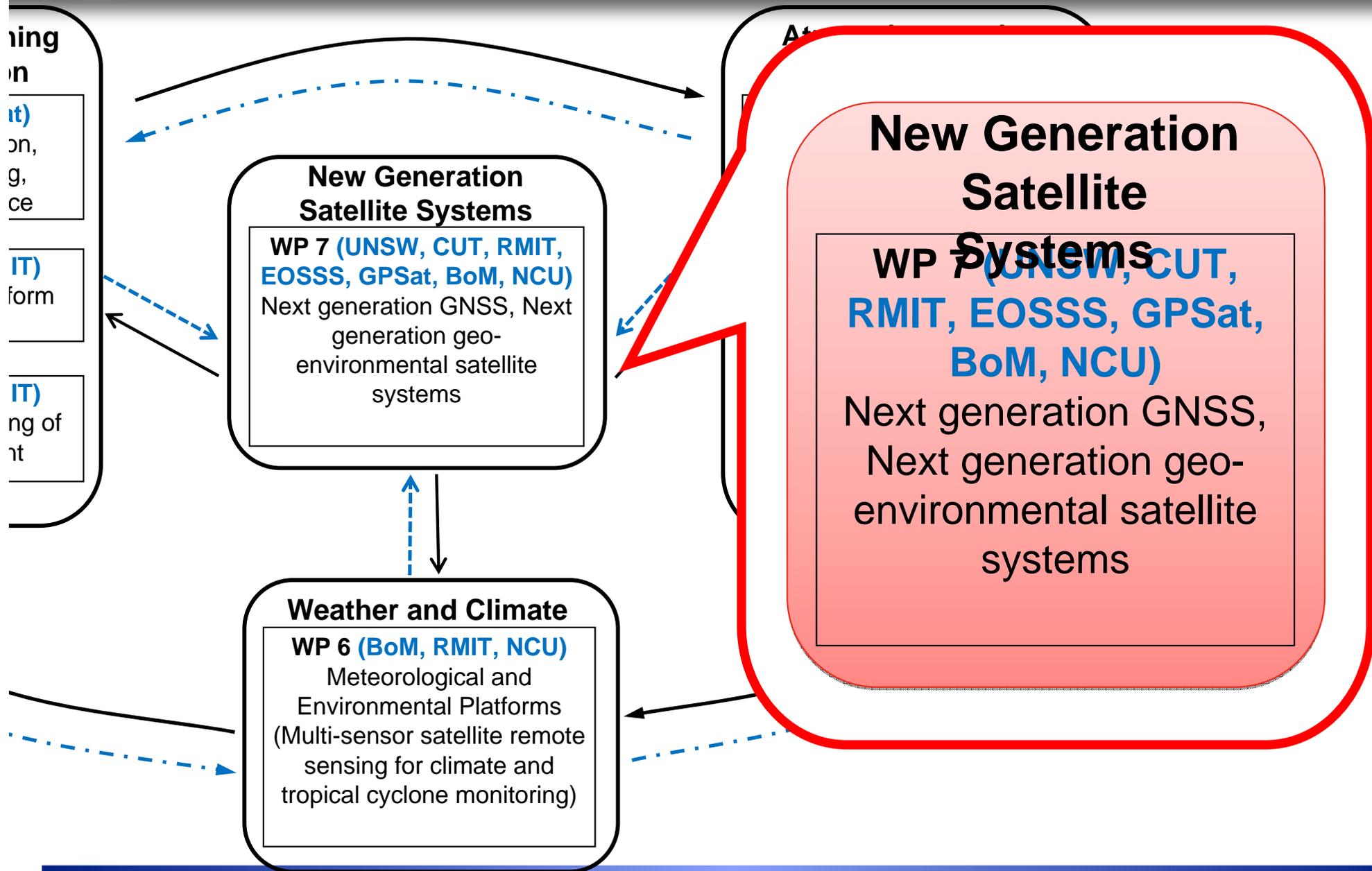














- **Satellite/space-based research**
- **System of systems**
- **Developments of platforms and platform technologies**
- **“Layer” by “layer”**
 - earth → air → atmosphere → satellite → space
- **Technology innovation and applications oriented**
- **Most important for Australia and southern hemisphere**

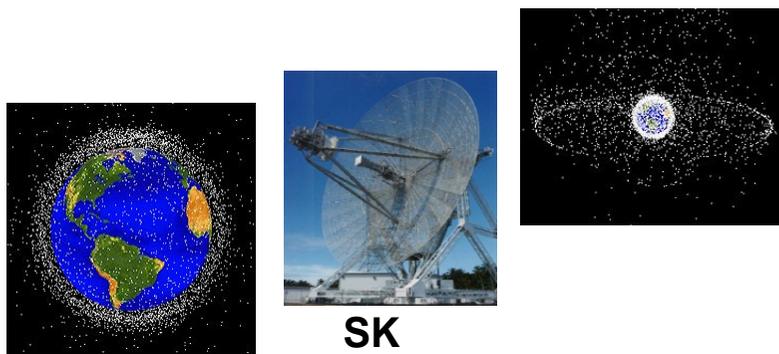
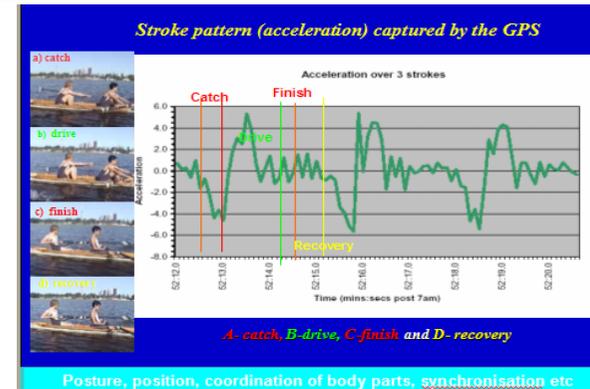
**The real voyage of discovery consists not in seeking new landscape,
but in having new eyes**

Marcel Proust (1871 - 1922)
a French novelist, critic and essayist



GNSS meteorology related activities conducted and preliminary results

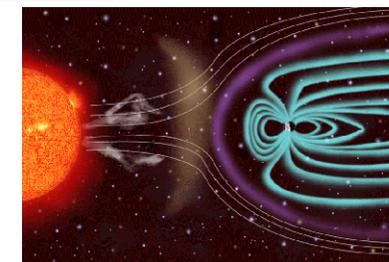
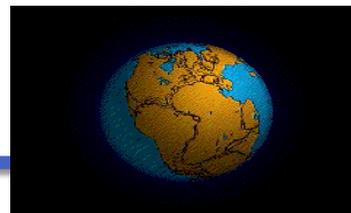
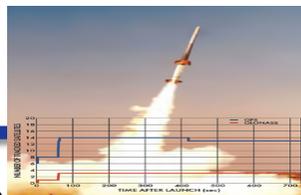
- **Smart people mobility & object tracking**
 - Miniaturised, high precision, GPS rower monitoring & coaching systems
 - Breakthrough in sport coaching & training
 - Indoor positioning/tracking
 - Robotic control in difficult environments
 - Intelligent Transportation Systems (ITS)



SK

- **GPS atmospheric modeling for**
 - precise positioning
 - space weather studies
 - Weather forecasting, climate change/monitoring, climatic hazards
 - Environment both space and earth

- **Space and debris tracking**
 - POD, in-space service,
 - debris surveillance & collision warning
 - SLR, SKA, VLBI

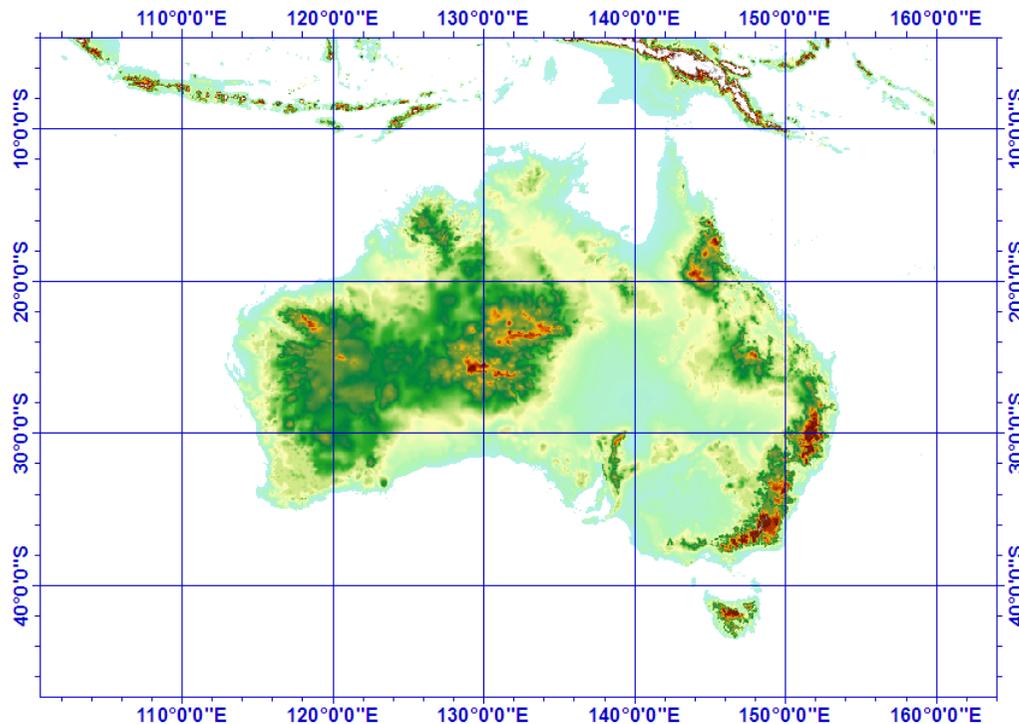


- **The collaboration between RMIT/BoM started in 2006**
 - GNSS considered as an emerging and enabling technology with a great potential
 - Drought/water storage problems in Western Australia
 - Tropical cyclone hazards
- **Lead to collaboration of GPS RO to look at the issues**
 - Climate monitoring / global warming
 - Weather forecast & climate monitoring e.g.
 - ✓ data assimilation process
 - ✓ GASP - [Australian Global Analysis & Prediction](#)
 - **New Australian mainframe machine**
 - Ideally in real-time
- **Funded through a number of initiatives**
 - Australia Research Council (ARC) (\$1.7m)
 - DIISR International Science Link (ISL) projects
 - ✓ Competitive Grant with USA and Taiwan (\$0.8m), JCSDA and CSRSR/NCU
 - ✓ Australia - China S&T Cooperation Special funds with GNSS Centre / Wuhan University



■ Distinct features

- Less populated
- Large landmass / territory
- Rich natural resources

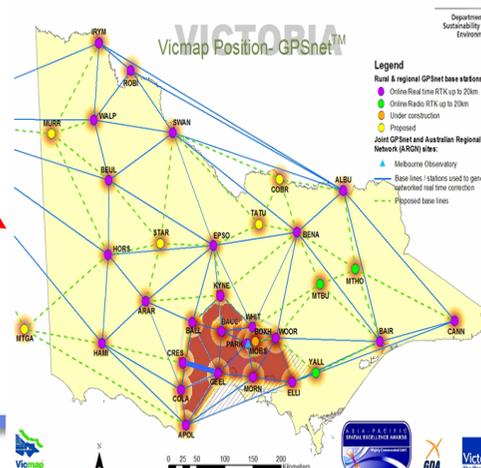
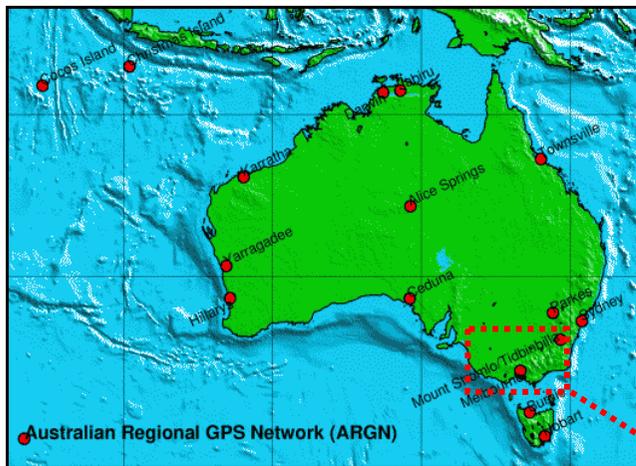


Geography

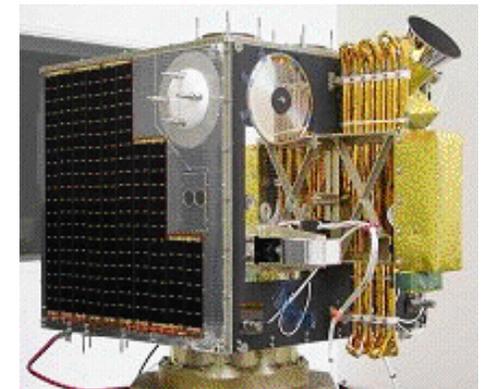
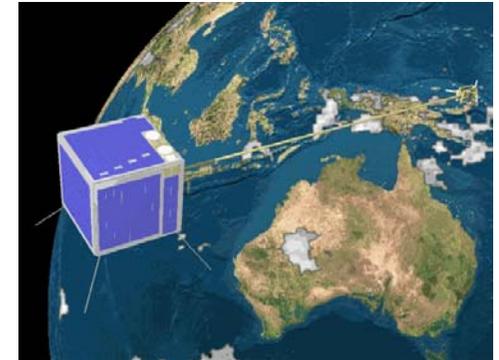
- Southern hemisphere
- Large island/continent
- Long coastline
- Large desert area
- Antarctica

Ground-based GPS CORS network

- Australian Regional GPS Network (ARGN) built in 1990s
- Regional GPSnet built since mid 1990s
- Recent Australian government initiative (NCRIS) to established “gridded” CORS across the country (*National Collaborative Research Infrastructure Strategy*)



- **FedSat – Federation Satellite**
 - The first Australian micro-satellite
 - A GPS receiver was onboard
- **The Australian made FedSat Microsatellite was launched into orbit on Dec 14th 2002 on board Japans HII-A launch vehicle.**
- **The FedSat spacecraft is a LEO,**
 - ~800 km altitude, microsatellite, measuring ~50 cm cubed and with a mass of 58 kg.
- **FedSat's payload**
 - experimental equipment used in conducting communications, space weather, remote sensing, engineering research and education/training.



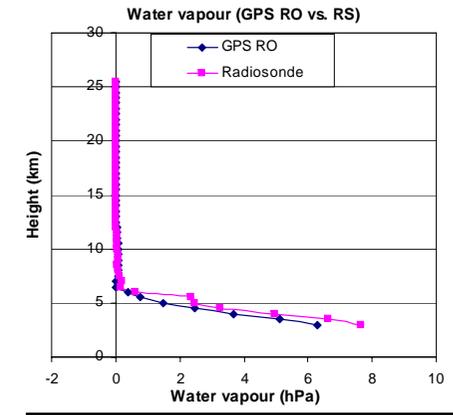
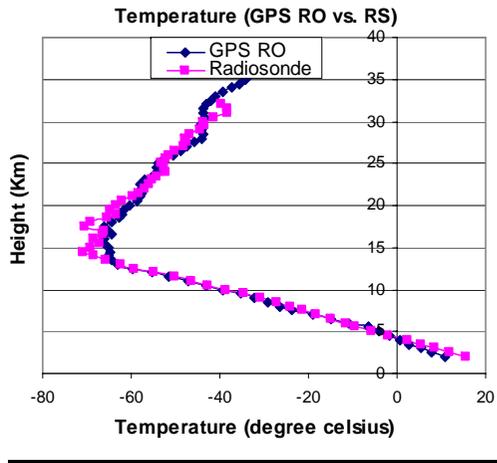
- **The feasibility and potential benefits of the GPS/GNSS RO technique to Australian weather and climate research and public services**
 - preliminary investigations carried out to investigate the stability, consistency, resolution and accuracy of the GPS RO technique
- **Key technologies, algorithms and software packages**
- **Impacts/contribution of Australian regional forecasts**
- **Antarctic climate change studies**



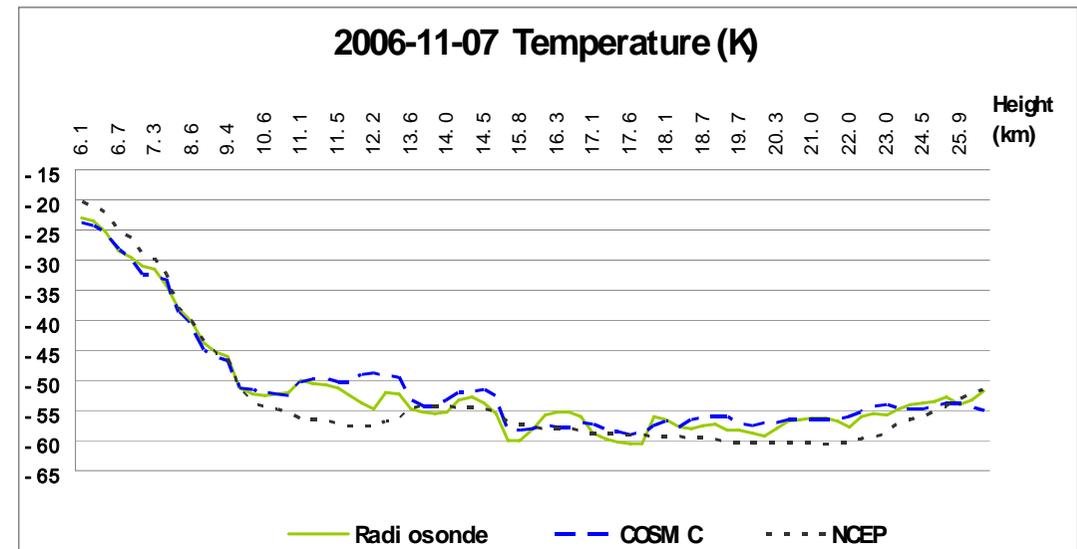
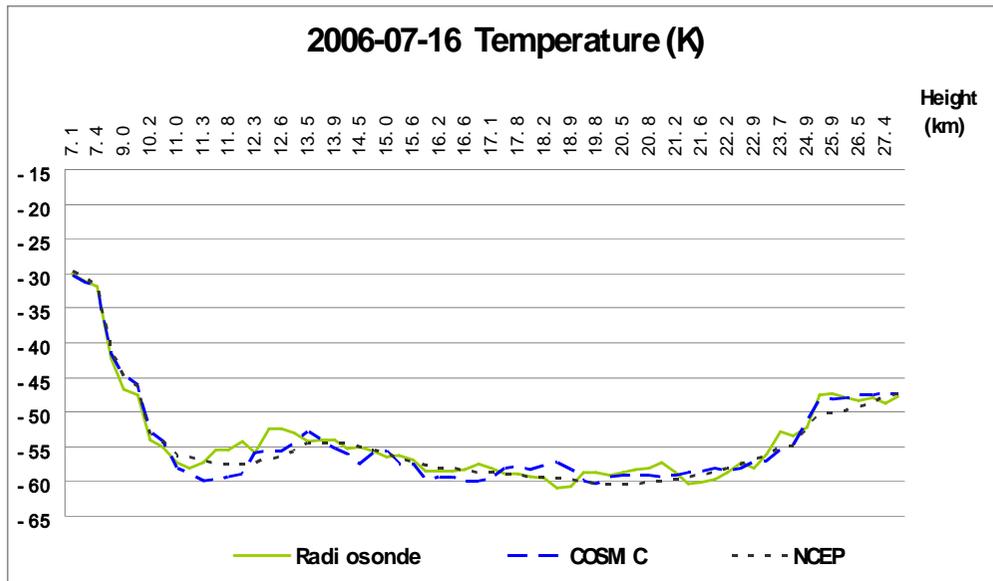
Recent RO research conducted



- **“Near” real-time WV retrieval using GPSnet CORS data in Victoria**
- **Comparisons between COSMIC/CHAMP, radiosonde & NCEP models**
 - 38 radiosonde stations in the Australian Region are used.
 - Stations chosen with different geographical features, i.e. land, ocean, low latitude, high latitude/polar regions etc.
- **Impact of variation collocation criteria on accuracy of deriving atmospheric parameters both spatially and temporally**
 - Spatial window – distance positions of RO and RS profiles and
 - Temporal window - time interval between the observations.
- **Antarctic climate change studies**
- **Positive impacts have been demonstrated (Le Marhsall et al., AMOJ, 2010)**



Perth
(CHAMP-RO)
Good general agreement

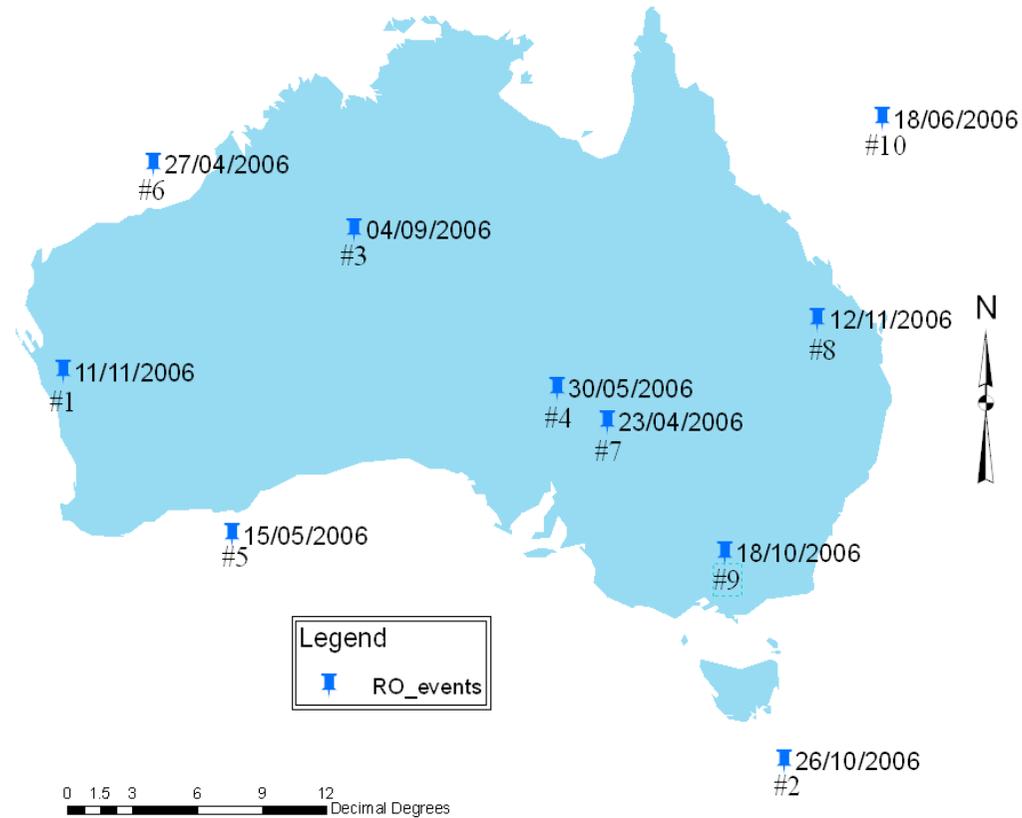


Date	Differences of temperature (degree)				Differences of pressure (mbar)			
	RS-RO		RO-NCEP		RS-RO		RO-NCEP	
	mean	STD	mean	STD	mean	STD	mean	STD
2006-7-16	-0.41	1.67	-0.11	1.44	0.72	0.43	1.09	0.59
2006-11-7	0.70	1.57	-1.09	2.14	-0.69	0.67	0.25	0.25

Date	Radiosonde (RS)			Radio Occultation (RO)			
	time	# of measurements	Location	time	# of measurements	Lon	Lat
2006-7-16	23:00	96	-37.67, 144.83	23:20	378	-36.73	143.35
2006-11-7	23:00	115	Melbourne Airport	21:15	374	-38.30	145.53

STD – standard deviation

The distribution of radio occultation events chosen (GPSRO-NWP)

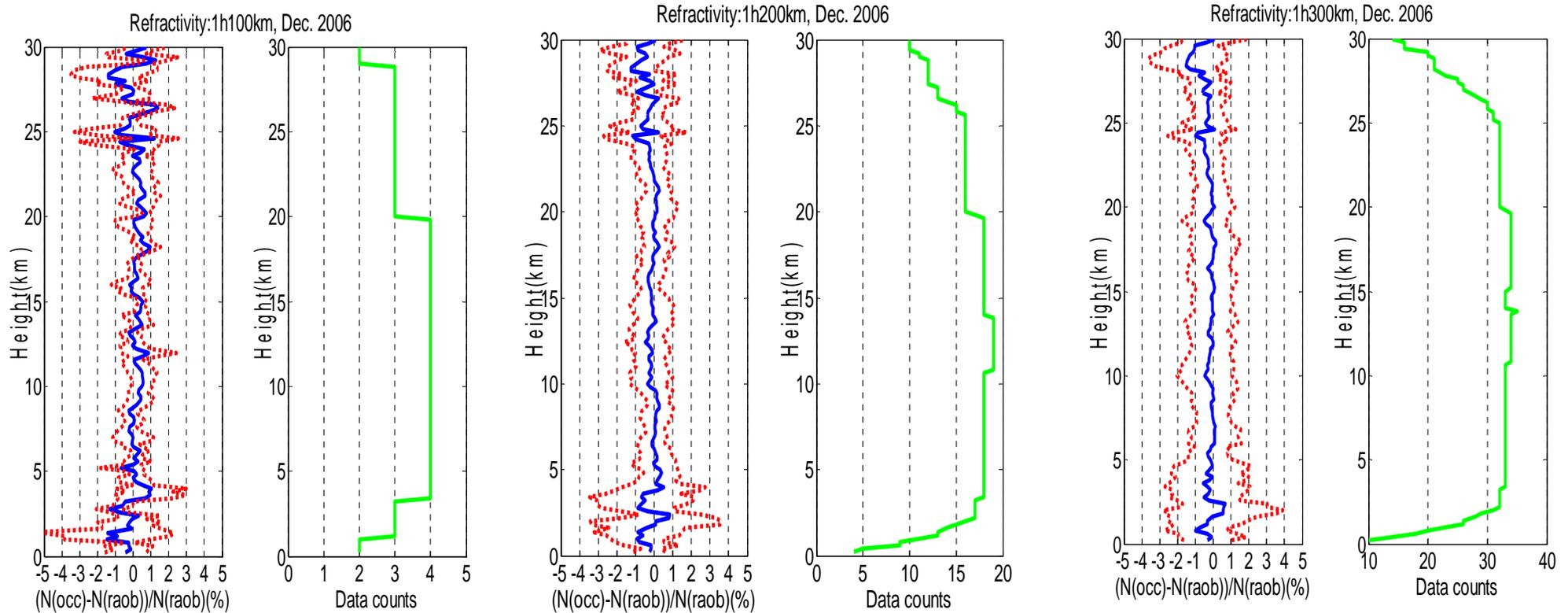


Test sites	Refractivity (index)		Temperature (K)		Pressure (mbar)		Water Vapor Pressure (mbar)	
	Mean Value	standard deviations	Mean Value	standard deviations	Mean Value	standard deviations	Mean Value	standard deviations
#1	-1.98	6.35	0.167	0.84	0.85	0.95	-0.47	1.42
#2	-1.32	3.13	0.487	0.87	0.63	0.45	-0.27	0.63
#3	-0.71	1.99	0.520	0.92	0.01	0.22	-0.14	0.44
#4	-0.50	1.70	0.320	0.75	0.41	0.35	-0.10	0.36
#5	-2.35	5.67	0.497	0.88	0.65	0.50	-0.53	1.25
#6	-2.07	3.26	0.812	1.37	0.44	0.17	-0.45	0.72
#7	-1.71	5.10	0.644	1.06	0.58	0.61	-0.37	1.08
#8	-1.39	3.18	-0.002	1.06	0.39	0.51	-0.31	0.72
#9	-2.43	5.57	-1.225	1.83	-2.17	1.11	-0.42	1.17
#10	-1.70	4.68	1.220	1.49	2.12	1.33	-0.43	1.04
Mean	-1.62	4.06	0.344	1.11	0.39	0.62	-0.35	0.88

- good agreements achieved in general
- red colored values indicate the top three largest differences found
- larger differences found for stations close to coastline, it appears higher humidity effects along coastline

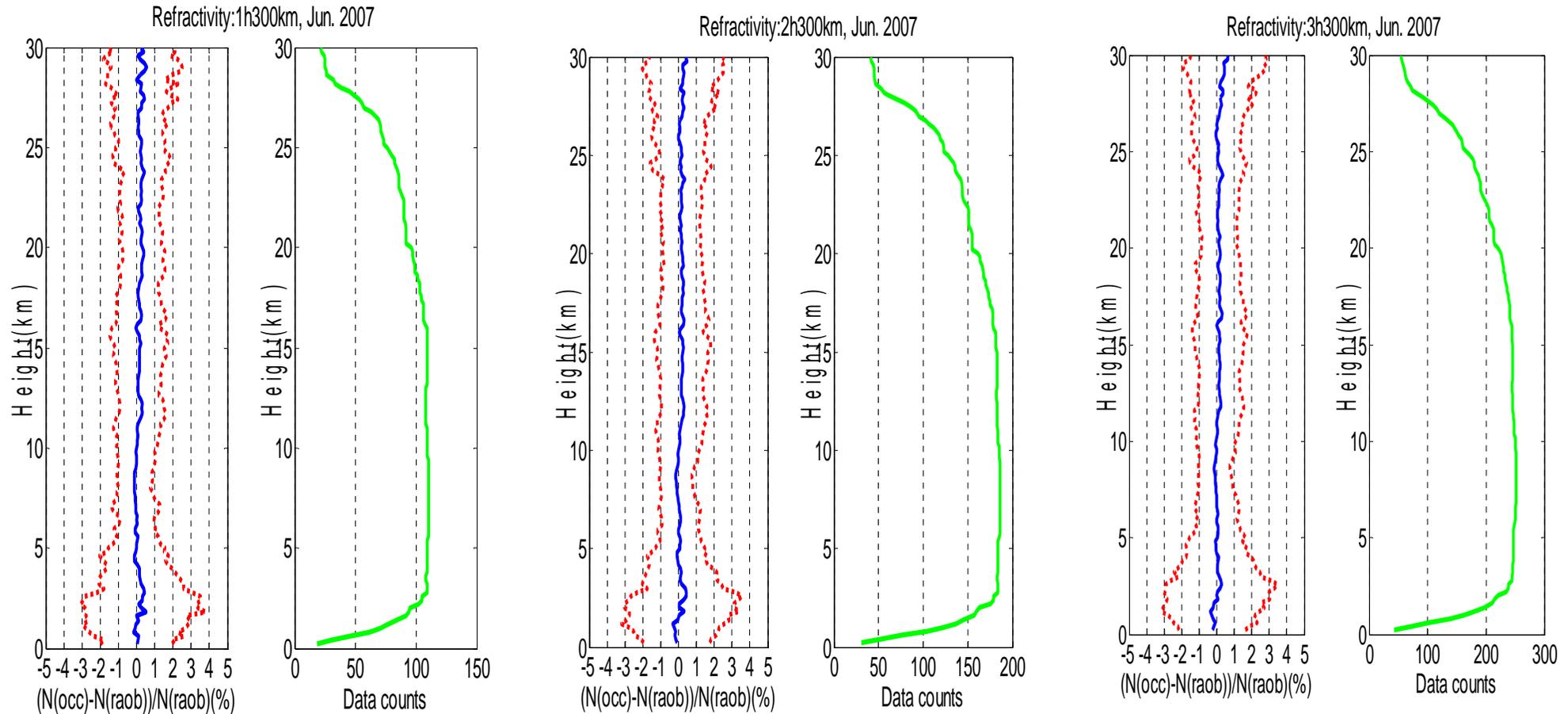
- **Comparison was made for two months**
 - Dec 2006 (austral summer) and June 2007 (austral winter).
- **In general, mean standard deviations of atmospheric parameters in June were greater than those in Dec,**
 - which indicates that greater humidity in winter in Australia may have some impact on the precision of COSMIC products.
- **Stricter collocation criteria do not necessarily result in smaller mean (fractional) differences of collocated atmospheric parameters,**
 - however it result in smaller mean STD of the differences.
- **Difference in atmospheric parameters was affected more by variation in distance than variation in time.**

Refractivity (Dec 2006)



Spatial variation on refractivity is more significant than that of time variation.

Refractivity (Jun 2007)



5~25km is altitude range with small mean difference and standard deviation

collocation criteria		100km			200km			300km		
		Number Ratio (%)	$\overline{\Delta N}$ (%)	$\overline{STD}_{\Delta N}$ (%)	Number Ratio (%)	$\overline{\Delta N}$ (%)	$\overline{STD}_{\Delta N}$ (%)	Number Ratio (%)	$\overline{\Delta N}$ (%)	$\overline{STD}_{\Delta N}$ (%)
1h	Dec. 2006	75	0.70	0.85	84	0.81	1.08	82	0.94	1.33
	Jun. 2007	78	0.87	1.12	78	0.98	1.37	81	1.05	1.46
2h	Dec. 2006	78	0.71	0.94	87	0.82	1.13	81	0.96	1.35
	Jun. 2007	89	0.95	1.26	81	0.98	1.39	82	1.05	1.47
3h	Dec. 2006	75	0.83	1.16	80	0.86	1.18	78	0.98	1.36
	Jun. 2007	81	0.98	1.33	81	1.01	1.43	80	1.06	1.49

Mean Absolute Fractional Differences and Mean STD of Refractivity between COSMIC RO and RS, Dec 2006 and June 2007 respectively

collocation criteria		100km			200km			300km		
		Number Ratio (%)	$ \overline{\Delta P} $ (%)	$\overline{STD}_{\Delta P}$ (%)	Number Ratio (%)	$ \overline{\Delta P} $ (%)	$\overline{STD}_{\Delta P}$ (%)	Number Ratio (%)	$ \overline{\Delta P} $ (%)	$\overline{STD}_{\Delta P}$ (%)
1h	Dec. 2006	100	0.57	0.64	95	0.68	0.88	96	0.75	0.92
	Jun. 2007	100	0.53	0.74	98	0.62	0.88	97	0.63	0.92
2h	Dec. 2006	94	0.62	0.71	95	0.69	0.88	96	0.73	0.90
	Jun. 2007	100	0.57	0.80	98	0.61	0.89	98	0.64	0.95
3h	Dec. 2006	93	0.60	0.69	94	0.68	0.85	95	0.74	0.91
	Jun. 2007	100	0.68	1.01	99	0.66	0.99	97	0.67	0.99

Mean Absolute Fractional Differences and mean STD of pressure between COSMIC RO and RS, Dec 2006 and June 2007 respectively

collocation criterias		100km			200km			300km		
		Number Ratio (%)	$ \overline{\Delta T} $ (K)	$\overline{STD}_{\Delta T}$ (K)	Number Ratio (%)	$ \overline{\Delta T} $ (K)	$\overline{STD}_{\Delta T}$ (K)	Number Ratio (%)	$ \overline{\Delta T} $ (K)	$\overline{STD}_{\Delta T}$ (K)
1h	Dec. 2006	100	1.31	1.51	100	1.28	1.62	97	1.46	1.89
	Jun. 2007	100	1.27	1.45	93	1.48	1.88	90	1.60	2.04
2h	Dec. 2006	100	1.18	1.58	97	1.34	1.78	96	1.53	1.97
	Jun. 2007	100	1.38	1.66	93	1.48	1.88	89	1.60	2.04
3h	Dec. 2006	100	1.31	1.69	97	1.40	1.80	94	1.59	2.02
	Jun. 2007	96	1.38	1.68	91	1.49	1.90	88	1.59	2.04

Mean Absolute Differences and Mean STD of Temperature between COSMIC RO and Radiosonde soundings, Dec 2006 and June 2007 respectively

- **Typical POD methods**
 - SLR (卫星激光测距)
 - PRARE (精密测距测速系统)
 - DORIS (卫星集成多普勒定轨和无线电定位系统)
 - GPS/GNSS (全球定位系统)
- **POD software platforms**
 - Current POD software platforms
 - ✓ GFZ , CSR , JPL
 - SHORDE-III using both geometry and dynamics methods
 - ✓ Ideal for applications, such as COSMIC
 - ✓ C/C++ and Fortran based
 - ✓ Collaborate with Shanghai Astronomical Observatory, CAS
- **Comparisons**

欢迎使用精密定轨软件

欢迎使用!

2008-11-20 激光检验结果

激光测距示意图

统计结果

总观测数: 231 均值 (cm): 8.17

总剔除数: 0 方差 (cm): 26.94

精密定轨 2008-12-3 15:20:53

GPS卫星跟踪低轨卫星示意图

精密定轨

数据检查

数据预处理

常规定轨

模糊度计算

模糊度解算

更新数据

更新钟差

更新观测数据

其它

格式转换

激光检验

退出程序

激光检验残差

测站号	观测时间	残差 (m)	高度
7237	54790.90961465	-0.0480	2
7237	54790.90963548	-0.0366	2
7237	54790.90965400	-0.0273	2
7237	54790.90965632	-0.0112	2
7237	54790.90967831	-0.0377	2
7237	54790.90968410	-0.0341	2
7237	54790.91001396	-0.0706	2
7237	54790.91001743	-0.0677	2
7237	54790.91004058	-0.0848	1
7237	54790.91004405	-0.1056	1
7237	54790.91005563	-0.0874	1

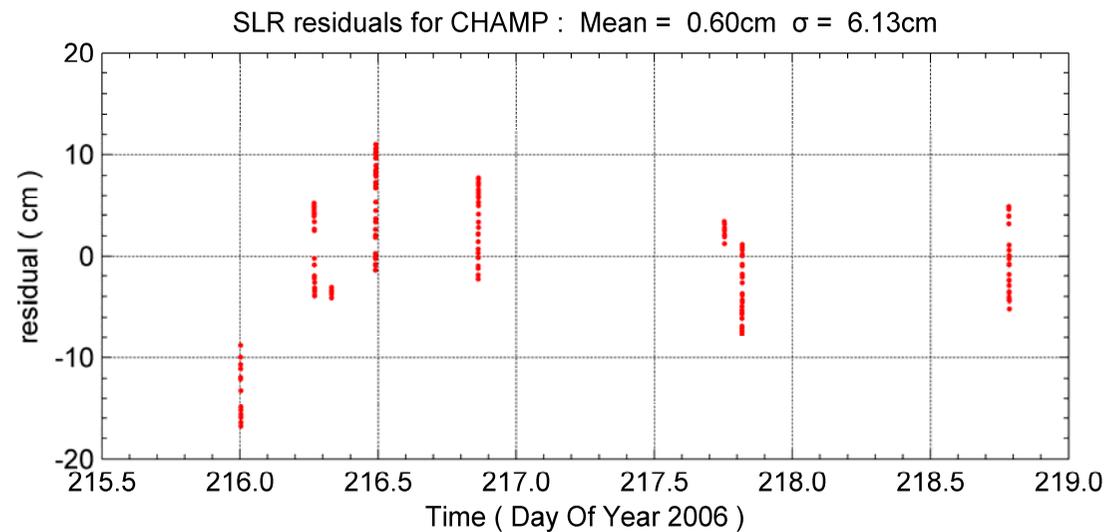
测站统计结果

测站号	测站名	均值 (cm)	方差 (cm)	观测个数
7237	长春	-6.33	2.13	98
7249	北京	18.86	31.47	133

- SHORDE, GFZ & UCAR for CHAMP satellite (external orbit overlap)**

date	Radial Pos[cm]		Along-track Pos[cm]		Cross-track Pos[cm]		3-D RSS Pos[cm]	
	(VEL:[mm/s])		(VEL:[mm/s])		(VEL:[mm/s])		(VEL:[mm/s])	
	GFZ	UCAR	GFZ	UCAR	GFZ	UCAR	GFZ	UCAR
216	5.5 (0.12)	---	11.7 (0.08)	---	6.5 (0.06)	---	14.5 (0.15)	---
217	4.1 (0.09)	6.5 (0.13)	9.0 (0.09)	10.1 (0.10)	6.2 (0.07)	4.5 (0.08)	11.5 (0.15)	12.8 (0.18)
218	4.1 (0.08)	6.5 (0.14)	7.9 (0.08)	9.2 (0.09)	4.8 (0.05)	4.9 (0.08)	9.8 (0.13)	12.3 (0.19)

- With SLR**

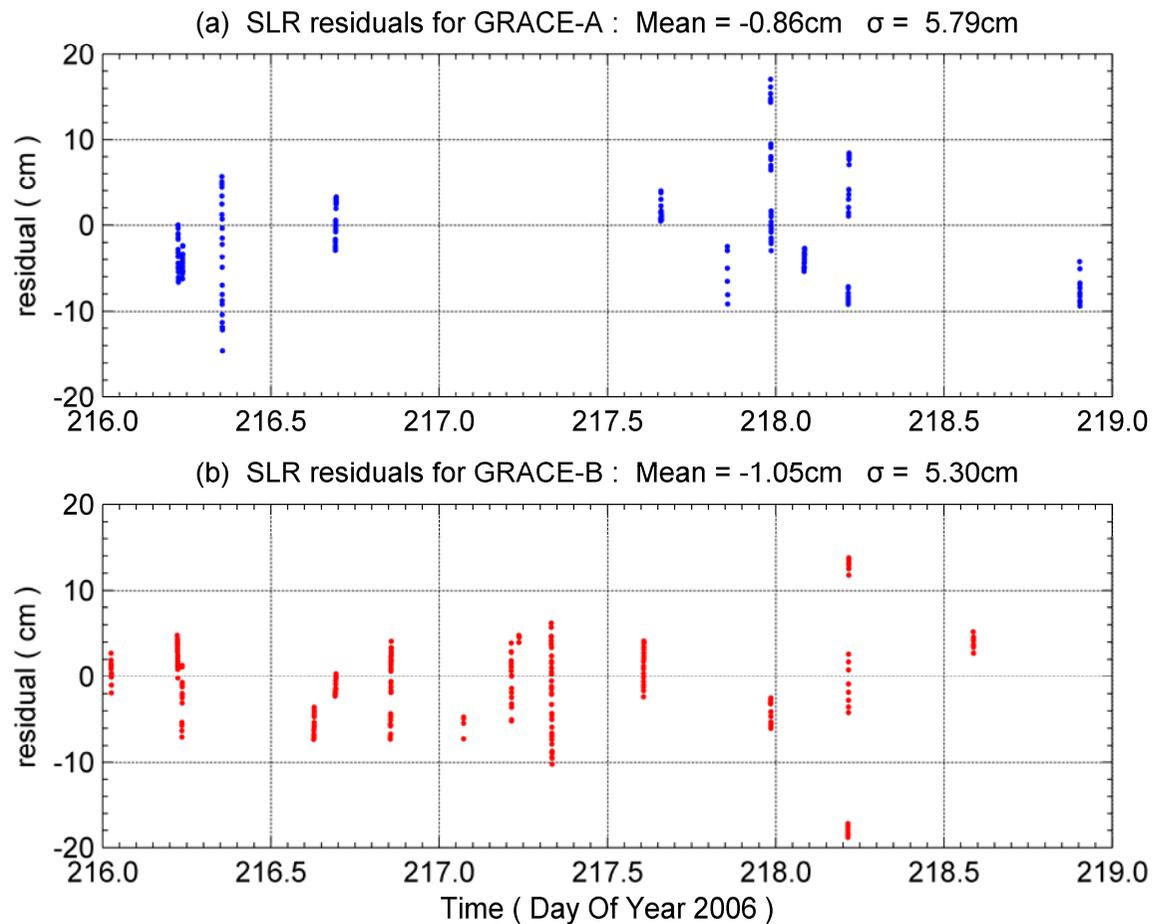


- **SHORDE and JPL for GRACE satellites (external orbit overlap)**

date	Radial Pos[cm]		Along-track Pos[cm]		Cross-track Pos[cm]		3D RSS Pos[cm]	
	(VEL:[mm/s])		(VEL:[mm/s])		(VEL:[mm/s])		(VEL:[mm/s])	
	GA	GB	GA	GB	GA	GB	GA	GB
216/2006	3.6 (0.07)	3.4 (0.07)	8.6 (0.04)	8.3 (0.04)	4.5 (0.06)	4.2 (0.06)	10.4 (0.10)	9.9 (0.10)
217/2006	3.4 (0.06)	3.0 (0.06)	8.1 (0.04)	7.9 (0.04)	5.7 (0.07)	4.7 (0.06)	10.5 (0.10)	9.7 (0.10)
218/2006	3.0 (0.06)	3.4 (0.06)	6.9 (0.04)	7.7 (0.04)	3.4 (0.05)	3.9 (0.05)	8.3 (0.09)	9.3 (0.09)

- **With SLR**

- With SLR (GRACE A+B)



- **SHORDE and NSPO/UCAR for COSMIC satellites (FM1 and FM2)**
- **CDDAC - The COSMIC Data Analysis and Archival (CDAAC)**

date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	11.4 (0.16)	14.6 (0.10)	13.7 (0.16)	21.5 (0.25)
2006-08-05/217	12.7 (0.40)	39.7 (0.14)	15.8 (0.18)	44.6 (0.47)
2006-08-06/218	9.4 (0.16)	14.9 (0.12)	12.1 (0.16)	21.5 (0.25)

date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	8.2 (0.14)	11.8 (0.09)	12.3 (0.10)	18.9 (0.19)
2006-08-05/217	9.8 (0.15)	16.6 (0.11)	9.7 (0.11)	21.6 (0.22)
2006-08-06/218	7.4 (0.14)	13.4 (0.09)	12.4 (0.11)	19.7 (0.20)

- **SHAO and CDDAC for COSMIC satellites (FM3 and FM4)**

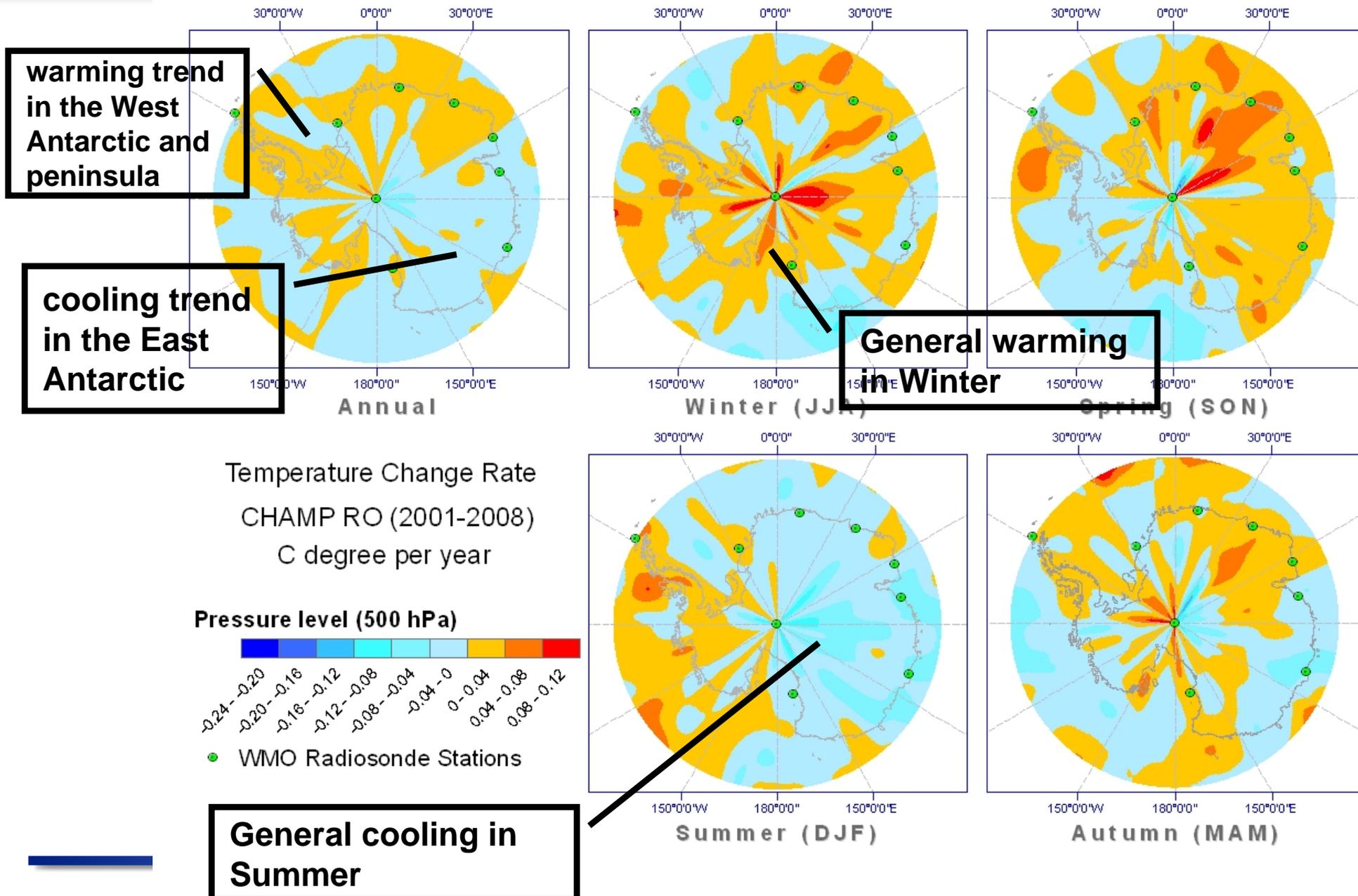
date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	8.2 (0.12)	11.6 (0.08)	15.3 (0.11)	20.9 (0.18)
2006-08-05/217	12.2 (0.18)	15.9 (0.08)	7.6 (0.11)	21.5 (0.23)
2006-08-06/218	8.4 (0.18)	16.4 (0.09)	11.2 (0.12)	21.7 (0.24)

date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	6.7 (0.14)	12.8 (0.08)	14.2 (0.15)	20.2 (0.22)
2006-08-05/217	8.9 (0.15)	13.2 (0.10)	15.3 (0.14)	22.2 (0.23)
2006-08-06/218	9.3 (0.12)	15.4 (0.12)	10.3 (0.14)	20.7 (0.22)

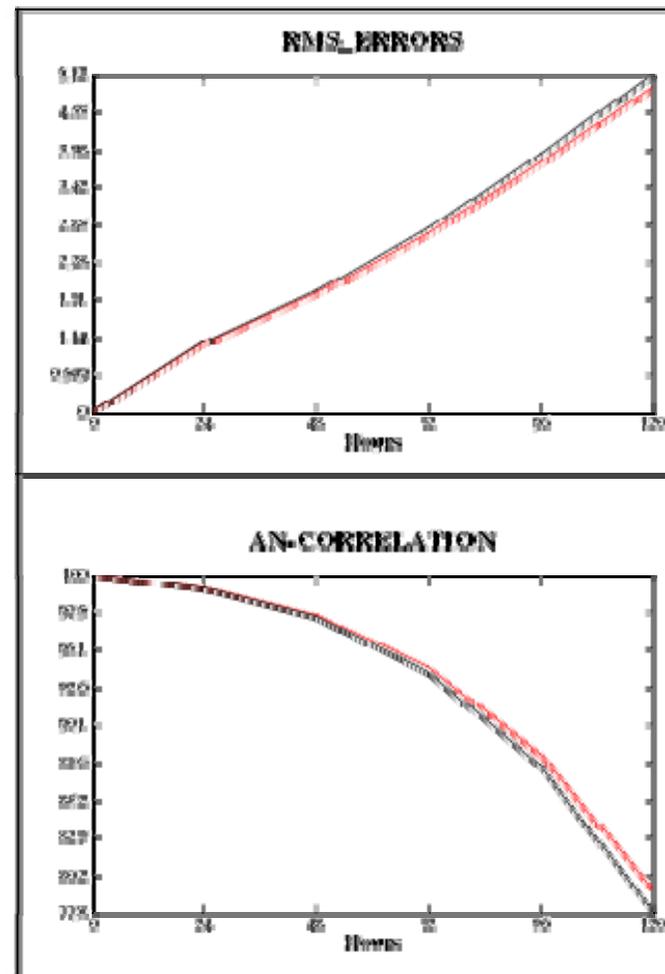
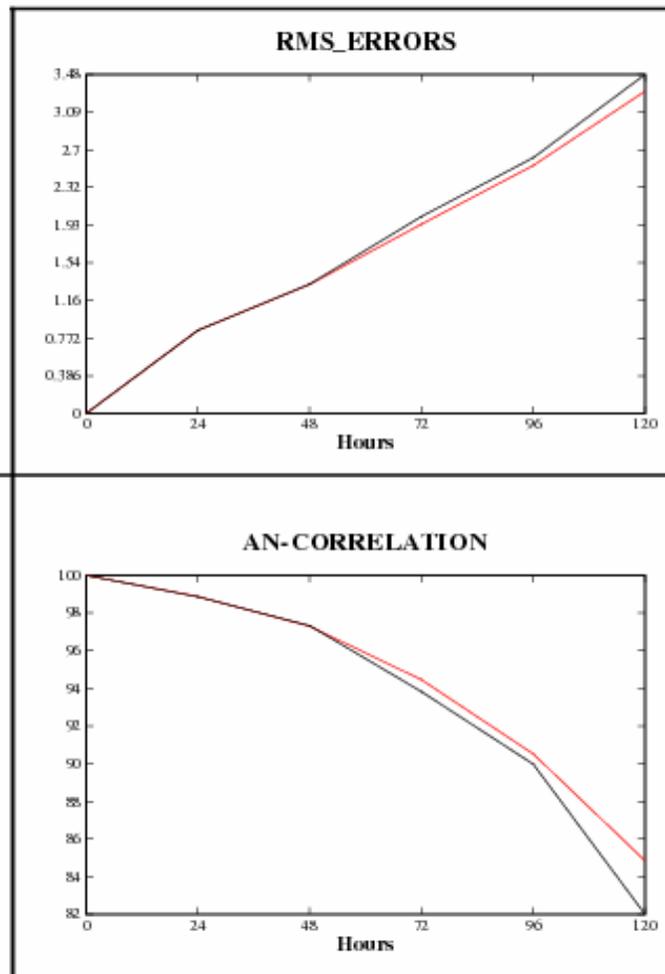
- **SHORDE and NSPO/UCAR for COSMIC satellites (FM5 and FM6)**

date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	8.5 (0.13)	13.0 (0.09)	12.1 (0.09)	19.7 (0.18)
2006-08-05/217	7.5 (0.10)	11.2 (0.08)	8.5 (0.08)	15.9 (0.15)
2006-08-06/218	8.8 (0.12)	15.1 (0.09)	10.9 (0.08)	20.6 (0.17)

date	Radial Pos[cm] (VEL:[mm/s])	Along-Track Pos[cm] (VEL:[mm/s])	Cross-Track Pos[cm] (VEL:[mm/s])	3-D RSS Pos[cm] (VEL:[mm/s])
2006-08-04/216	9.3 (0.13)	17.5 (0.11)	9.5 (0.17)	22.0 (0.24)
2006-08-05/217	8.1 (0.15)	13.0 (0.09)	10.2 (0.12)	18.5 (0.22)
2006-08-06/218	8.4 (0.17)	15.1 (0.09)	12.4 (0.14)	21.2 (0.24)



- RMS Errors and Anomaly Correlations at 500hPa (left) and 200hPa (right) geo-potential heights, without GPS RO data (black line) and with GPS RO data (red line).**





The Beneficial Impact of Radio Occultation Observations on Australian Region Forecasts

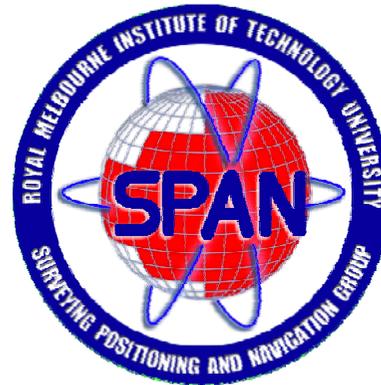


- **Study dataset**
 - RO profiles from COSMIC, MetOp and GRACE
 - from 26 February 2009 to 26 March 2009
- **Data assimilation**
 - Into global ACCESS (Australian Community Climate Earth System Simulator) system
 - Four dimensional variational assimilation (4DVAR) method to provide forecasts to five days ahead
 - Assimilate refractivity
- **Results**
 - the temperature accuracy of these forecasts has been compared to forecasts generated without the use of the radio occultation data
 - The forecasts using radio occultation data have been found to be improved in the lower, middle and upper troposphere
 - The potential to improve operational analysis and forecasting in the Australian Region
 - To assist in important tasks e.g. a regional reanalysis and climate monitoring.

- **A late comer, inter-disciplinary, inter-national team and preliminary research conducted,**
- **Exciting/promising results demonstrated**
- **Geographically “best” located for GNSS RO related**
 - research, applications, tracking, down/up link communication, ...
- **Strongly committed to the continuous effort in RO**
 - Australia is changing its mainframe machine by incorporating “near” real-time GNSS meteorology info
 - RT tasks about to commence on new super computer (SUN) before operational implementation
 - Continuous research in new environment in relation to generation of climate quality analysis
 - Space weather/cyclone, new mission, space debris etc.
 -

- **Satellite technologies provide a great platform for Earth obs and then enhance many studies such as meteorology, atmosphere and climatology**
- **RMIT + BoM are leading the GPS meteorology research team in Australia and a wide range of international collaboration established**
- **The ASRP project offers a great platform and more exciting opportunities for research and international collaboration**
- **New government has been elected and further stronger support expected**
 - Clearly, GNSS RO is “one of the key “BIG” things to go
 - – further extensive space/satellite related investment/endeavour expected
- **We are keen to extend our international collaboration horizon, exploit other space related opportunities of Australian involvement/contribution**

Thank you



Professor Kefei Zhang

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A journey of a thousand miles begins with a single step

By Confucius



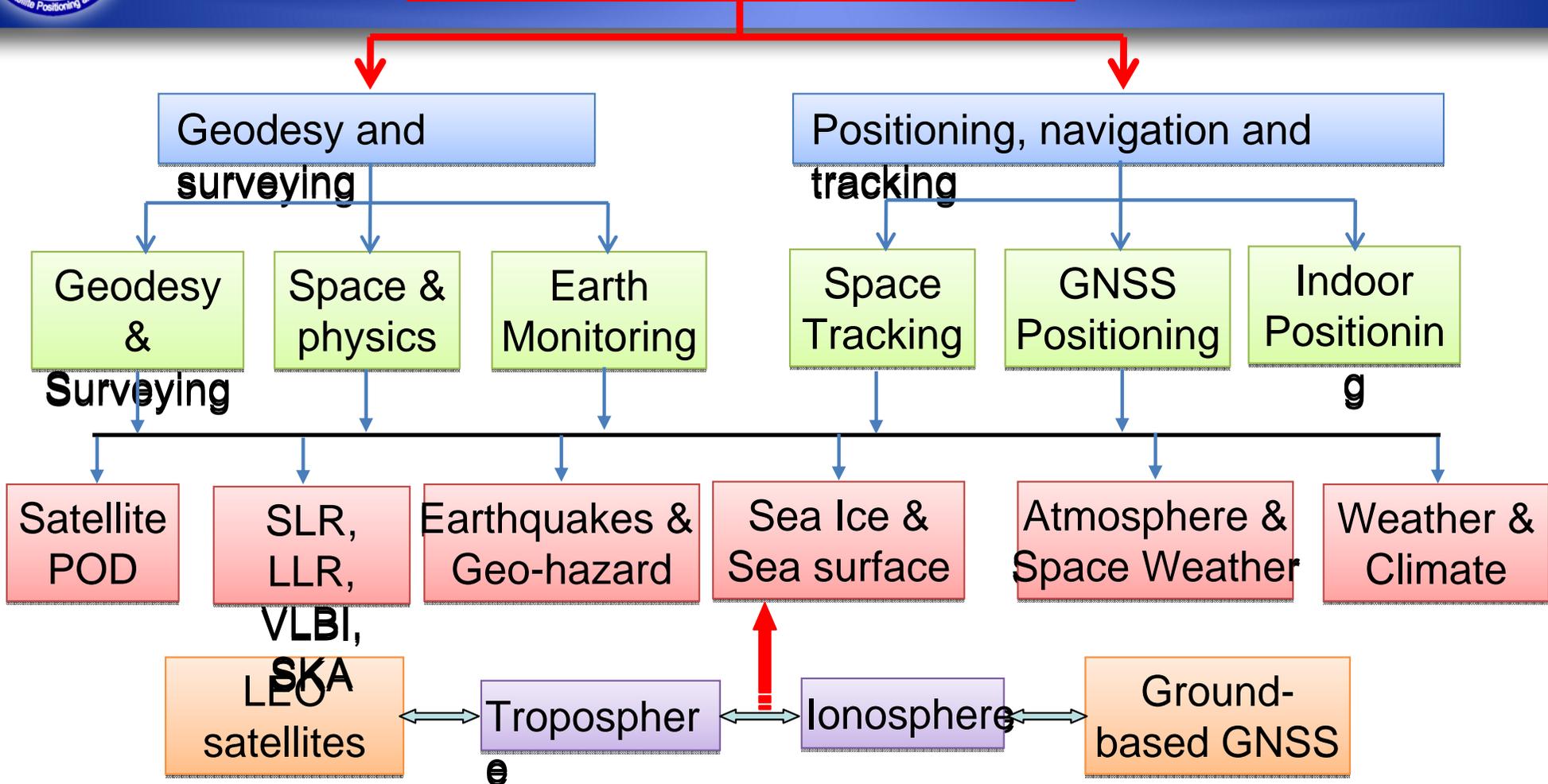
We are in the process of recruiting ...

- 8 postdoctoral research fellows (6@RMIT, 1@CUT, 1@UNSW)
- 1~2 executive/project manager(s)
- 3-5 PhD scholars
- 5+ visits of international collaborators /year

RMIT **official launch** is scheduled

- around 22 November
- All are welcome

Key research areas in SPAN



POD – precise orbit determination
 SLR – satellite laser ranging
 LLR – lunar laser ranging
 SA – satellite altimetry

LEO – low earth orbit
 GNSS – global navigation satellite systems
 VLBI – very long baseline interferometry
 GNSS – global navigation satellite systems

- **The world space industry size \$257 billion in 2008**
 - Australia has a limited share
- **Satellite navigation**
 - currently \$24 billion globally, \$70 billion by 2015
 - Market of GNSS-related derives – boasted \$240B by 2015
 - Australia has ~1% ???
- **The value of spatial information in Australia**
 - \$32 billion over 20 years (GNSS is a key technology)
- **Climate change and associated hazards**
 - e.g. drought, extreme heat, bushfires, storms, floods and tropical cyclones
 - \$1 billion / p.a. in Australia



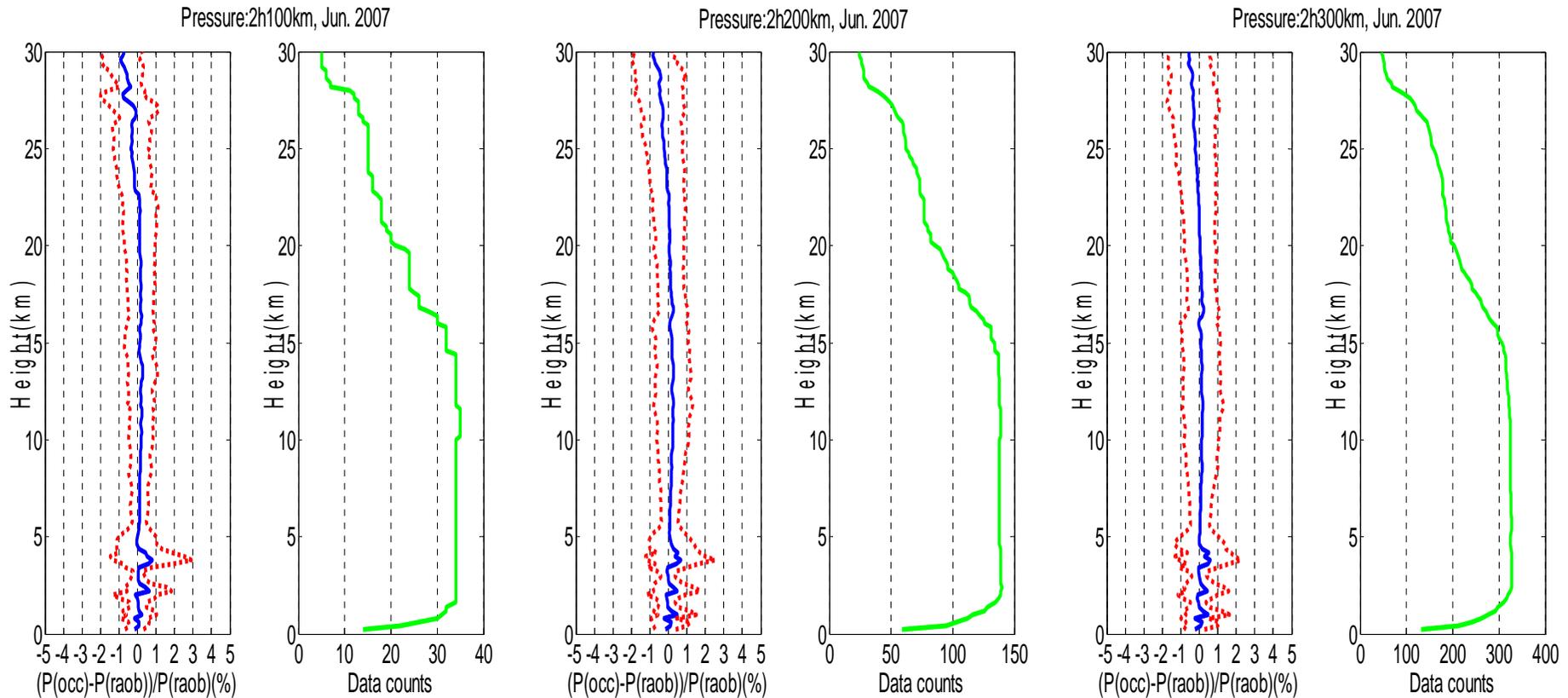
- **Pathways to Space: Empowering the Internet Generation**
 - a collaborative, hands-on program enabling year 10-12 students to plan space exploration projects using a living laboratory to simulate realistic scenarios and gain an understanding of space engineering challenges.
 - UNSW, The Univ of Sydney, the Powerhouse Museum & Cisco Systems Australia Pty Ltd
 - \$987,574

- a) The designing, building, testing, installation, deployment and/or operation of hardware or systems developed:**
 - To be located in space
 - For the purpose of getting into or returning from space or
 - For the purpose of getting data or information to or from space

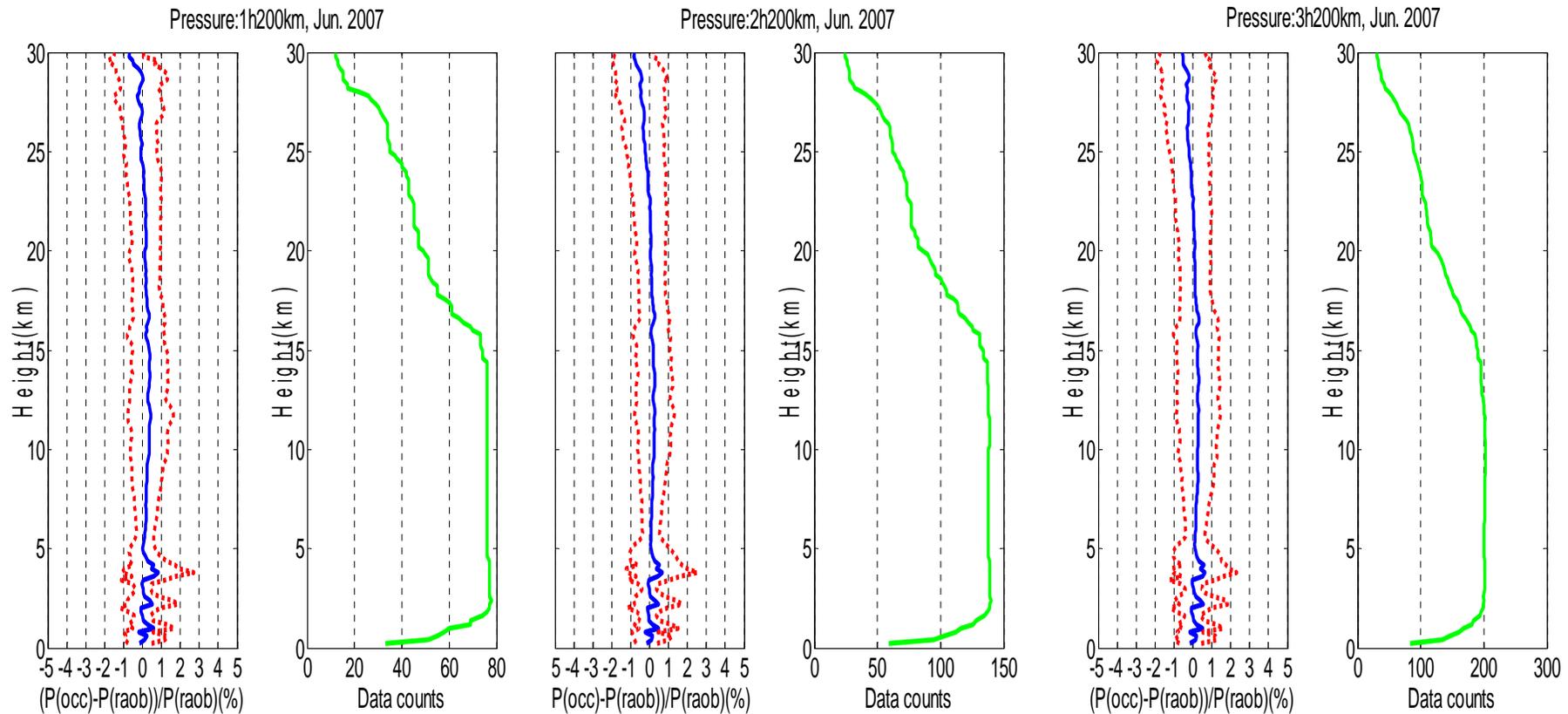
- b) The design, development, testing, installation and/or use of applications that require the operation of hardware or systems listed at (a)**

- c) Governance arrangements (such as legal, management and advisory structures) to support space hardware, systems or applications listed at (a) and (b) or**

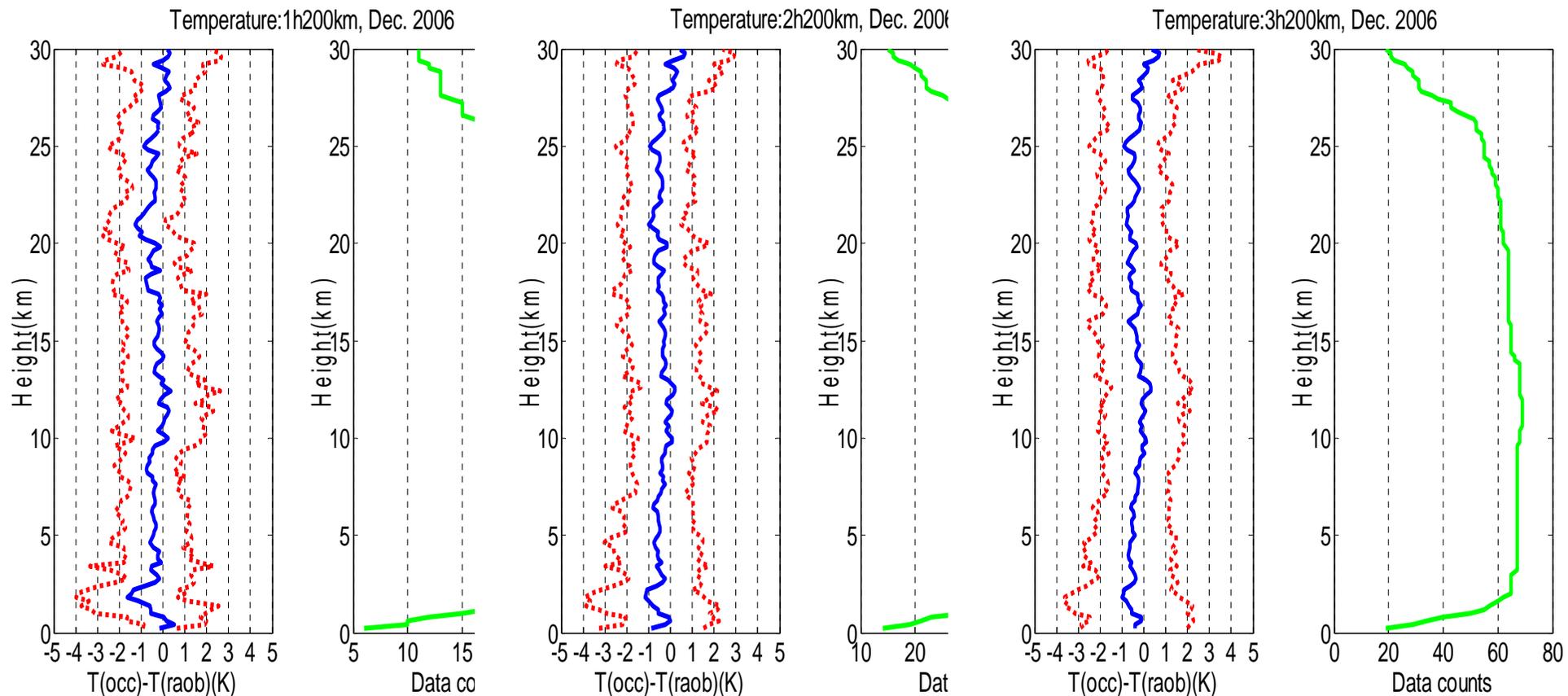
- d) Research into the environment in which space hardware or systems listed at (a) operate.**



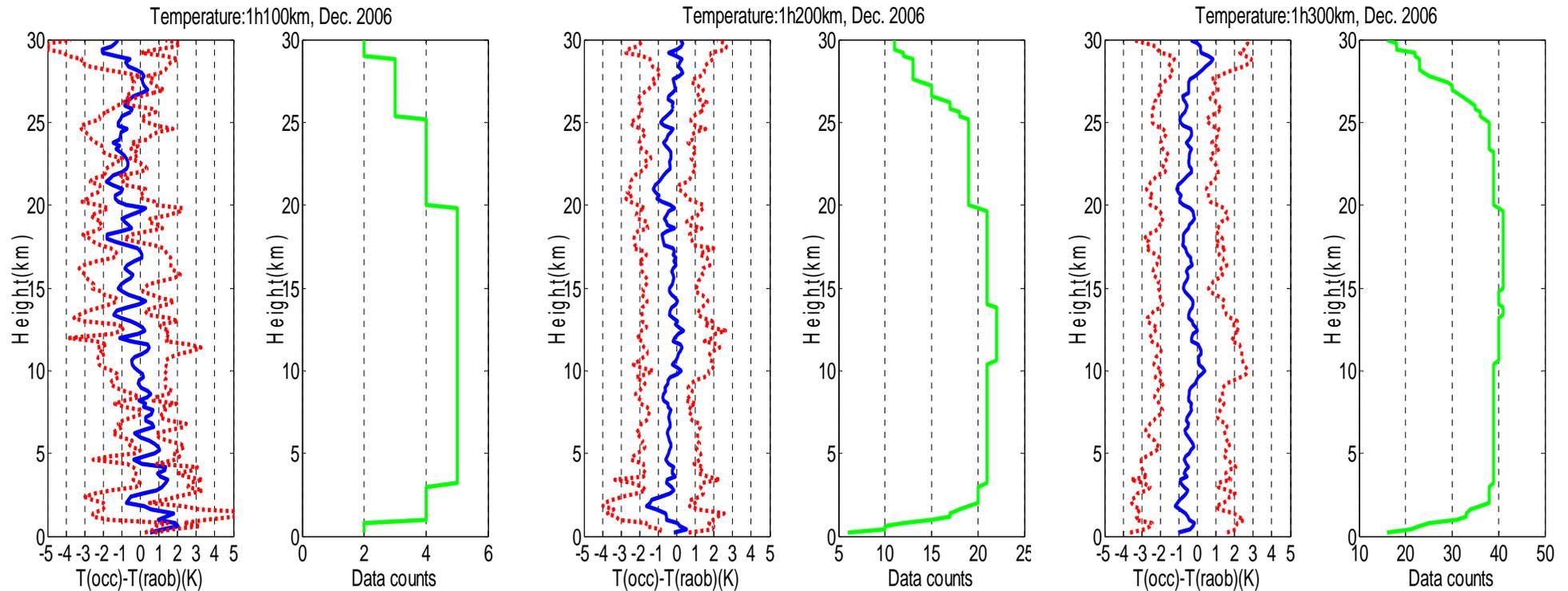
Spatial variation has larger impact on the results of pressure comparison than temporal variation.



- Fractional differences and STD of pressure were generally less than 1% in the middle to upper atmosphere for both months (i.e. 5km-25km)



- Mean difference of temperature was generally $< 1\text{K}$ and standard deviation was generally $< 2\text{K}$ in the middle to upper troposphere.
- In the lower troposphere, the standard deviation $> 3\%$.
- Systematic negative biases of temperature differences were found (e.g. in the whole altitude range of 0~30km for Dec 2006).



- Distance variation has larger impact on the results of temperature comparison than time interval variation