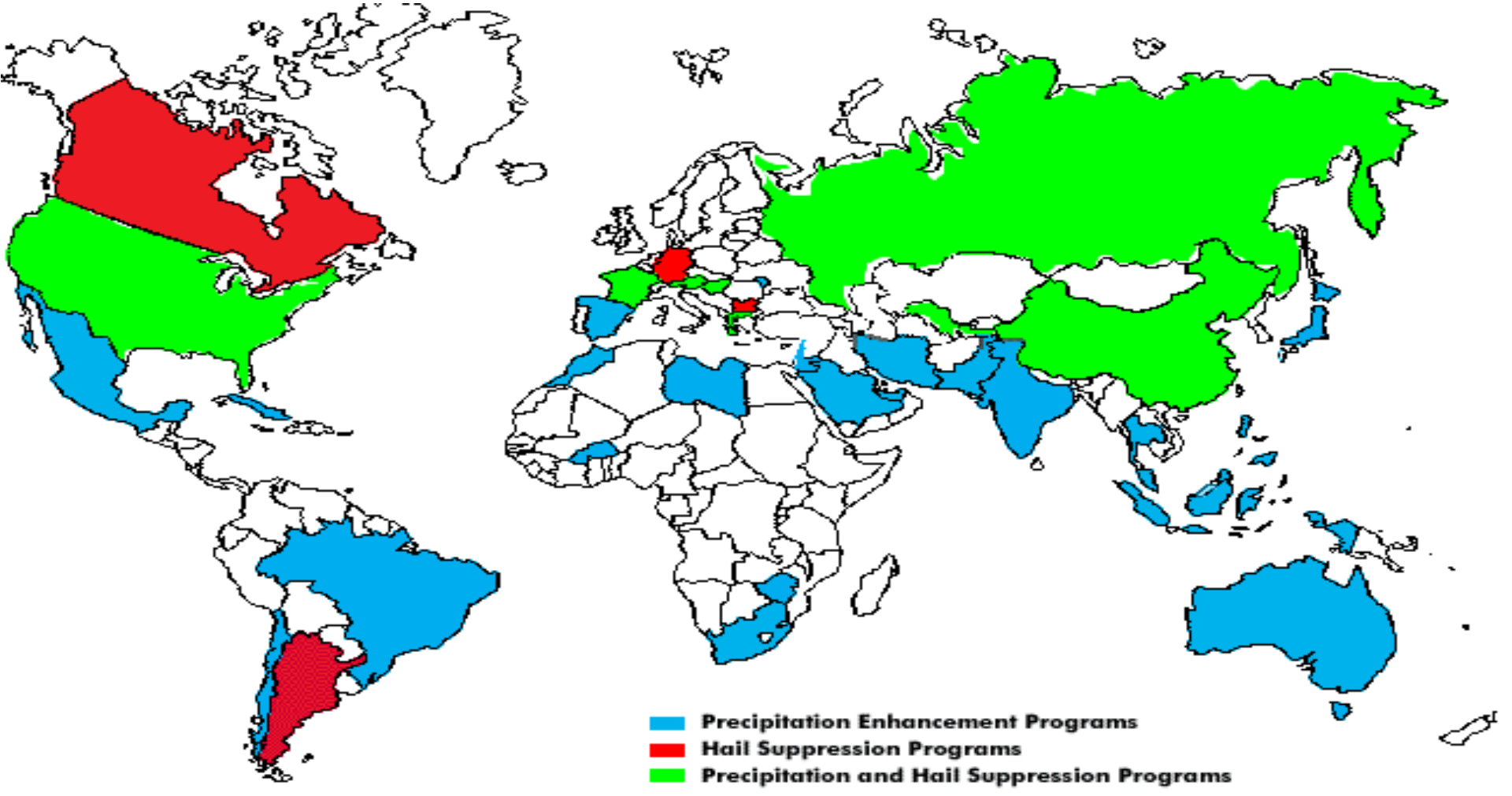
World Meteorological Organization
Weather • Climate • Water

WMO Expert Committee on Weather Modification Research

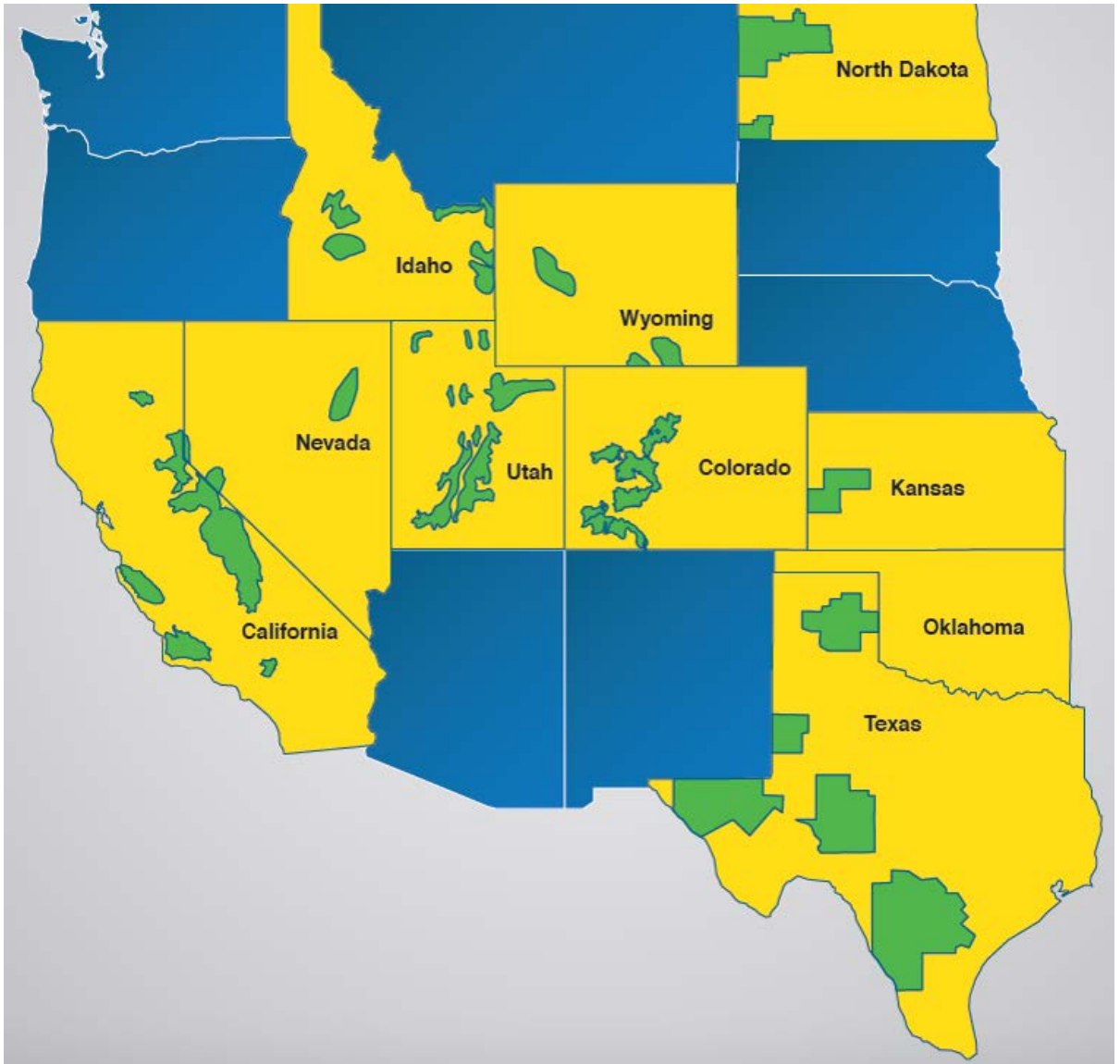
Chairman report

July 2013

Weather Modification Around the World
42 Countries with active cloud seeding programs



Cloud seeding programs in the USA
36 active weather modification programs



Activities since 2011

- Apart from 42 countries with active weather modification programs the committee provided advice to the following countries:
- Ecuador, Chile, Mexico, Costa Rica, Jordan, Iraq, Brazil, Kenya, Senegal, Qatar and Sultanate of Oman
- China by far has the largest investment in both operational programs and weather modification research programs. Every province except one has an active weather modification program in China.
- There are now several operational programs around the world that have conducted cloud seeding annually for more than 50 years without interruption. In the USA and Australia these programs are mostly supported by hydro-electric power companies.

Activities since 2011

- After China the USA, Thailand and India have the largest investment in operational weather modification programs. There are currently 36 active operational weather modification programs in at least nine states located in the western United States with often times multiple cloud seeding projects in the individual states(California, Nevada, Utah, Idaho, Wyoming, Colorado, North Dakota, Kansas and Texas).
- While funding for weather modification has increased over the past five years in the USA it is still well below the levels in the 1980's. India is currently one of the largest investors in weather modification research with a major multi-year program (CAIPEEX) conducted by the Indian Institute of Tropical Meteorology in Pune, India. Thailand is also embarking on a major research effort in this area.

Activities since 2011

- Two major research programs in weather modification to enhance snowpack are currently ongoing in the U.S. namely in Wyoming (Including modeling and field work in part funded by the National Science Foundation) and Idaho (modeling funded by Idaho Power). A smaller research project has been started in the State of Texas.
- Israel: These programs have generated extensive discussion in the scientific literature. Based on the extensive experience gained in the past, a new research experiment (Israel IV) of randomized orographic seeding that will start in the winter of 2013-14 will be conducted in the north of the country. Based on the recommendations of the WMO statement on whether modification, the experiment is designed and the results will be analyzed by independent prominent statisticians. Thus a complete separation will be achieved between experimental design, operations, data collection and analysis.

Recent Scientific highlights

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- Breed, D., R. Rasmussen, B. Lawrence, B, Boe, T. Deshler, and C. Weeks, 2013: Evaluating winter orographic cloud seeding: Design of the Wyoming Weather Modification Pilot Project (WWMPP). Accepted for publication in *J. Appl. Meteor. Climatology.*
- Geerts, B., Q. Miao, Y. Yang, R. Rasmussen, and D. Breed, 2010: The impact of glaciogenic cloud seeding on snowfall from winter orographic clouds, *J. Atmos. Sci.,* **67,** 3286 – 3302.
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- Konwar M., Maheskumar R.S., Kulkarni J.R., Freud E., Goswami B.N., Rosenfeld D., Aerosol control on depth of warm rain in convective clouds, *Journal of Geophysical Research***, , 117**, July 2012, D13204, DOI:10.1029/2012JD01785, 1-10.
- Kulkarni J.R., Maheshkumar R.S., Morwal S.B., Padma kumari B., Konwar M., Deshpande C.G., Joshi R.R., Bhalwankar R.V., Pandithurai G., Safai P.D., Narkhedkar S.G., Dani K.K., Nath A., Nair Sathy, Sapre V.V., Puranik P.V., Kandalgaonkar S.S., Mujumdar V.R., Khaladkar R.M., Vijaykumar R., Prabha T.V., Goswami B.N., The Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX): overview and preliminary results (2012), *Curr. Sci.*, Vol.**102**, 2012, 413-425
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Recent Scientific highlights

- Manton, M. J., Warren, L., 2011: A confirmatory snowfall enhancement project in the Snowy Mountains of Australia. Part II: Primary and associated analyses. *Jour. of Appl. Meteor. and Climat*., **50**, 1448-1458.
- Nature, 2008: Change in the weather. *Nature*, **453**, 957958.
- Prabha T.V., Khain A., Maheshkumar R.S., Pandithurai G., Kulkarni J.R., Goswami B.N. (2011),Microphysics of Premonsoon and Monsoon Clouds as Seen from In Situ Measurements during the Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX), *J. Atm. Sc*., Vol.**68** , 2011, DOI: 10.1175/2011JAS3707.1, 1882-1901
- Tessendorf, S.A. and coauthors, 2012: The Queensland Cloud Seeding Research Program. *Bull. Amer. Meteor. Soc*iety, **93**, 1, 75-90.
- Tessendorf, S.A., C.E. Weeks, D. Axisa, and R.T. Bruintjes, 2013: Aerosol characteristics observed in southeast Queensland and implications for cloud microphysics. *J. Geophys. Res*., **118,** 1-14, doi:10.1002/jgrd.50274.
- Wilson, J. W., C. A. Knight, S. A. Tessendorf, C. Weeks, 2011: Polarimetric radar analysis of rain drop size variability in maritime and continental clouds, *JCAM,* **50**, 1970-1980.
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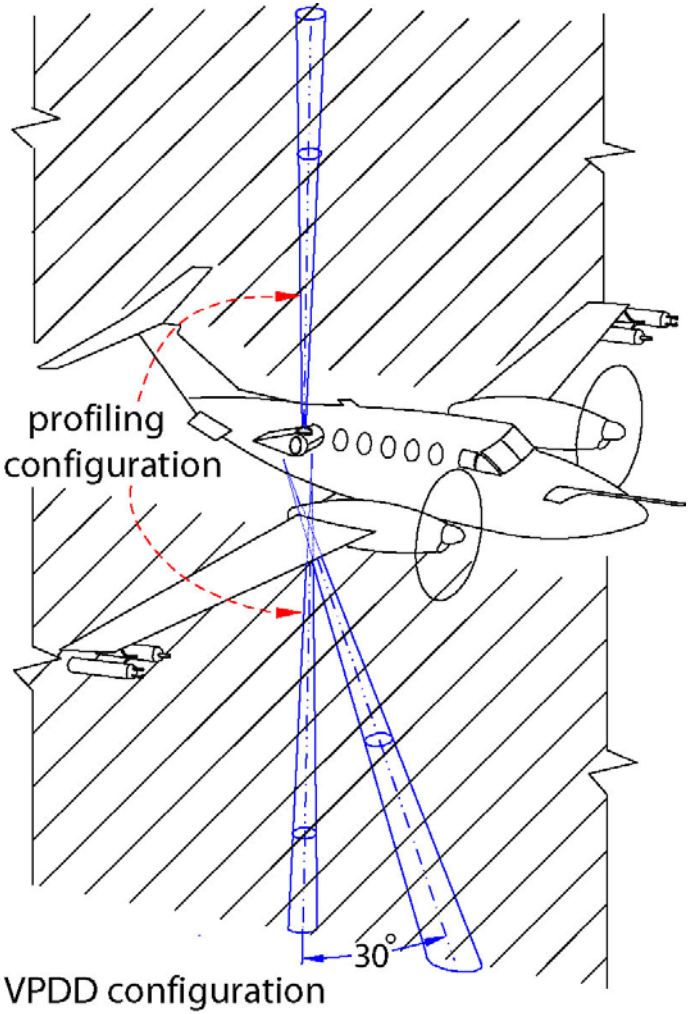
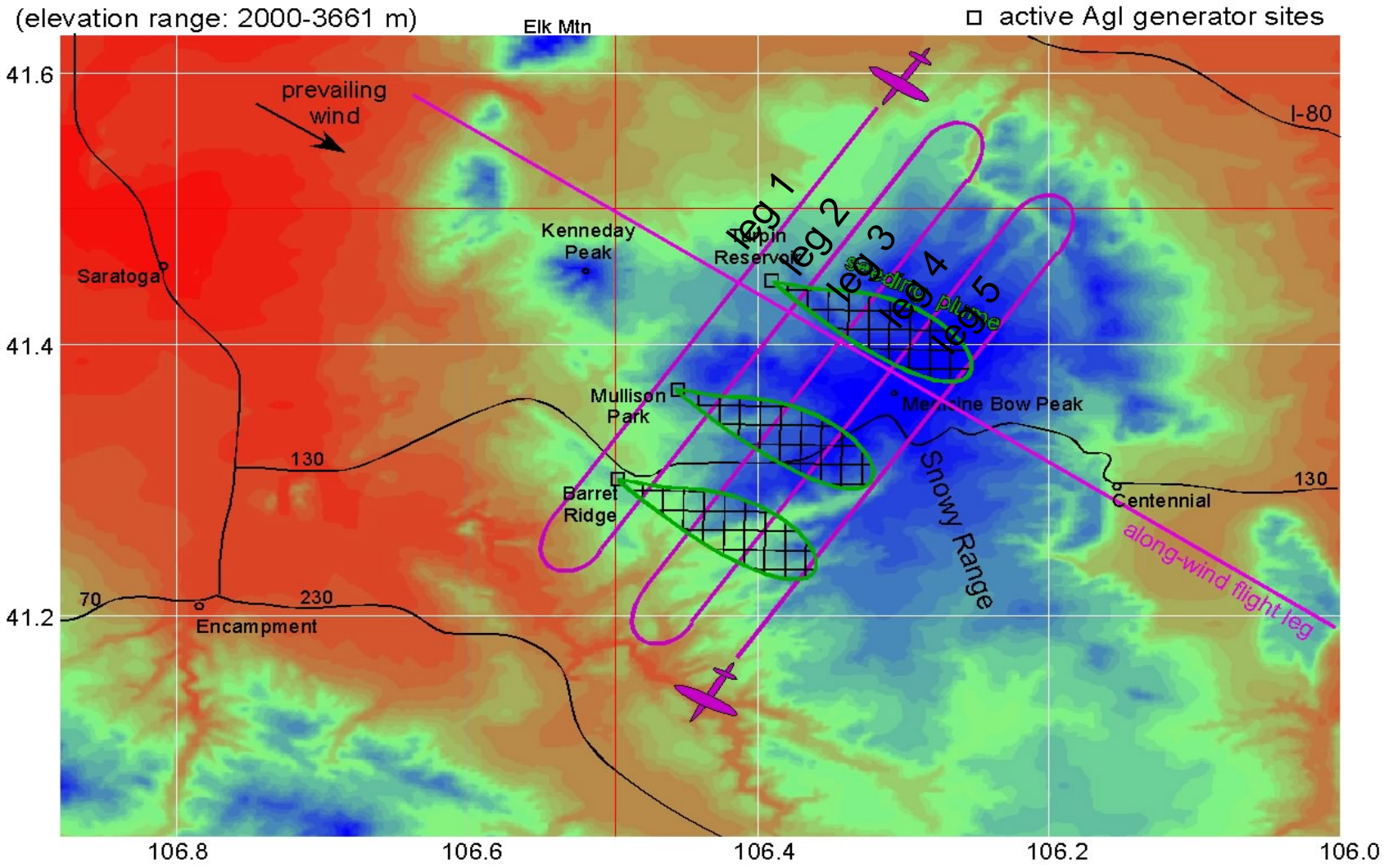
- Xue, L., S. Tessendorf, E. Nelson, R. Rasmussen, D. Breed, S. Parkinson, P. Holbrook, and D. Blestrud, 2013b: Implementation of a silver iodide cloud seeding parameterization in WRF. Part II: 3D simulations of actual seeding events and sensitivity tests. *J. Appl. Meteor. Climatol*., **52**, 1458- 1476.

UW Cloud Radar

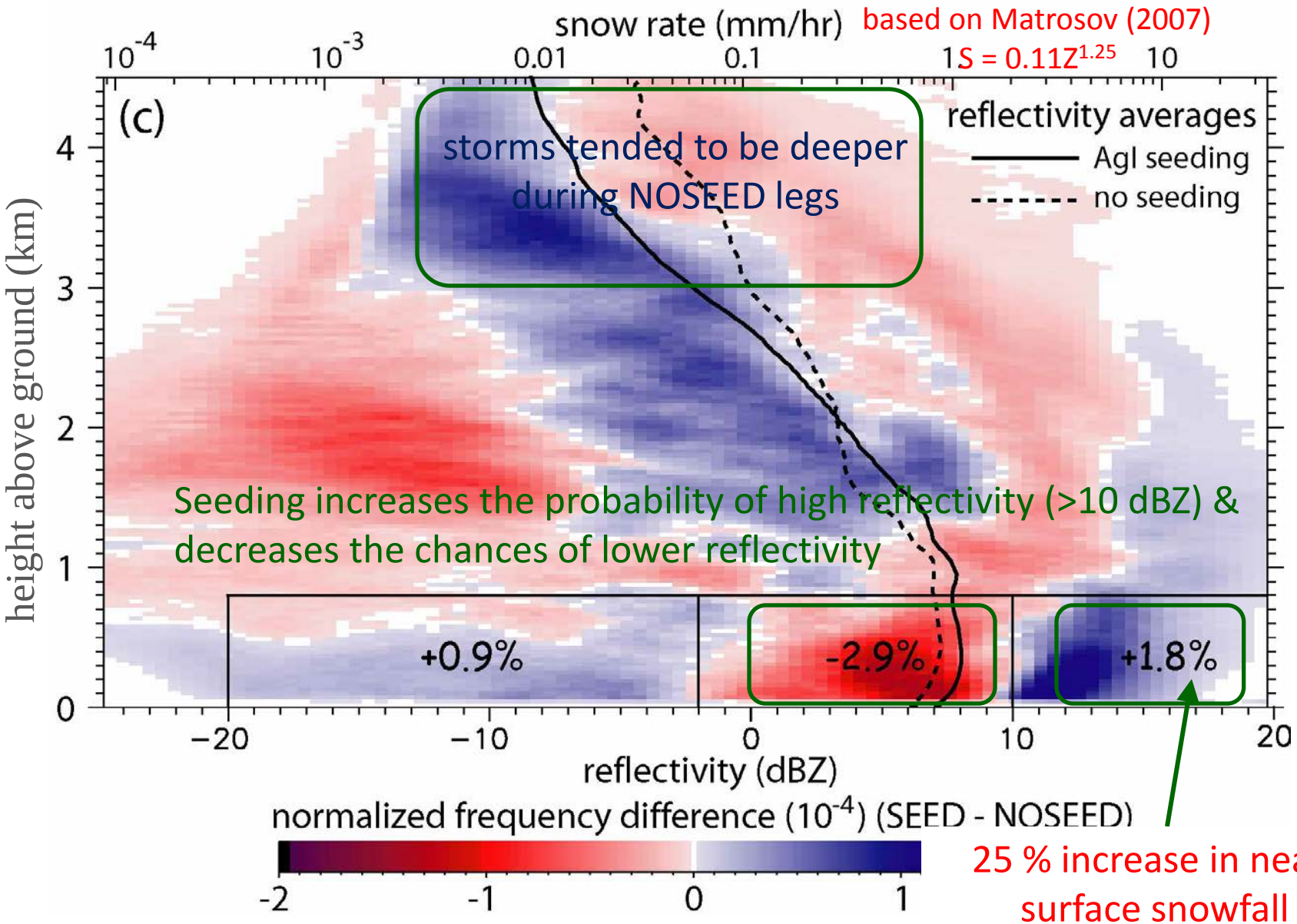
- 3 mm (95 GHz, W-band), dual-polarization
- pulse width: 250-500 ns
- max range: 3-10 km
- volume resolution @ 3 km range: < 40 m
- minimum detectable signal (@ 1 km): ~-30 dBZ
- Cloud droplets are much smaller than ice crystals, thus in a mixed-phase cloud, reflectivity is dominated by ice crystals.



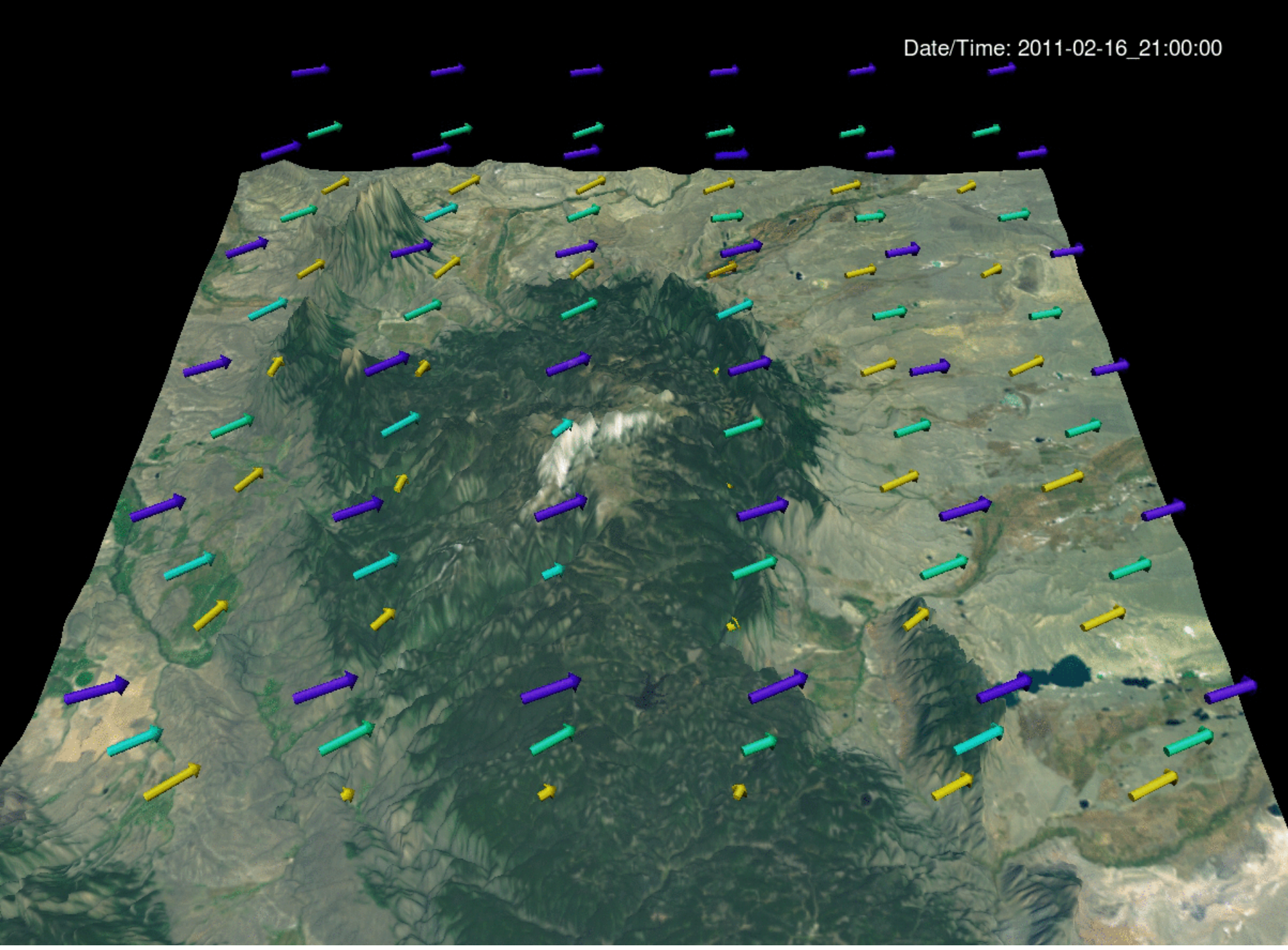
Fixed flight pattern, flown repeatedly
in each storm, both with and without AgI seeding,



WCR reflectivity difference: SEED - NOSEED



entire legs, legs 2345, 7 days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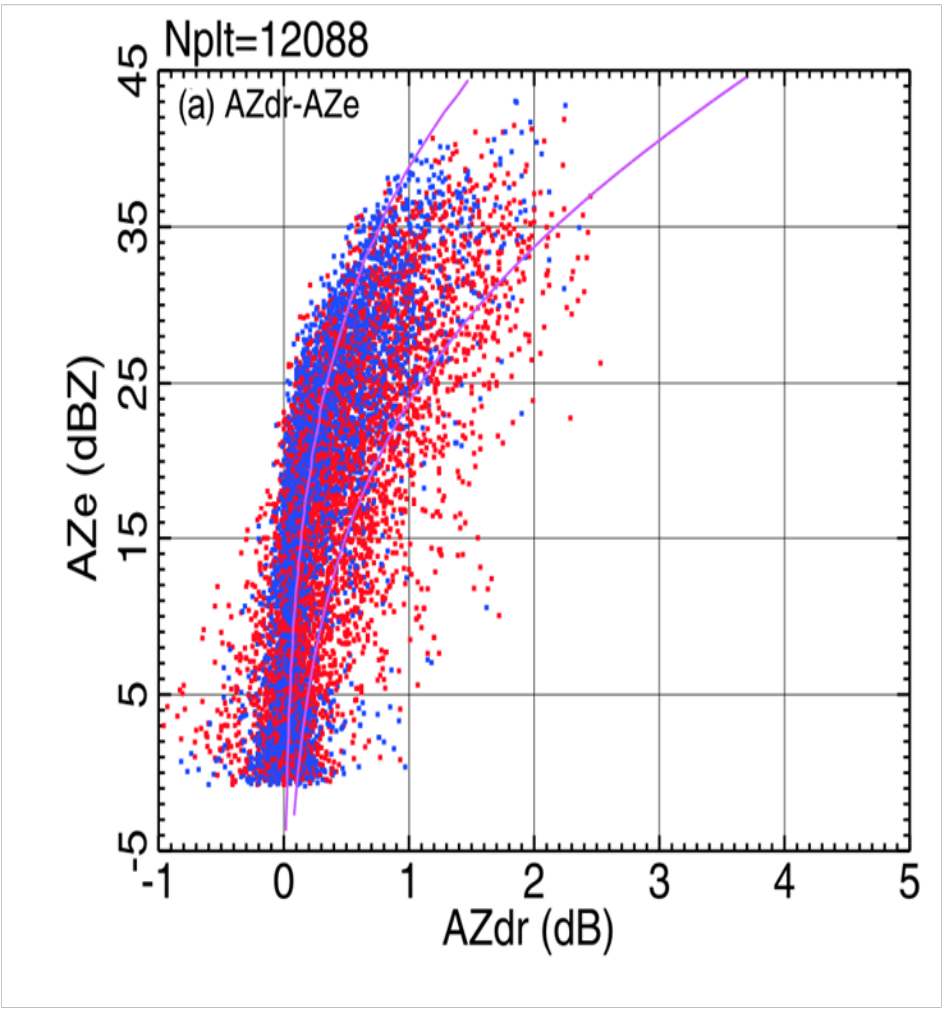
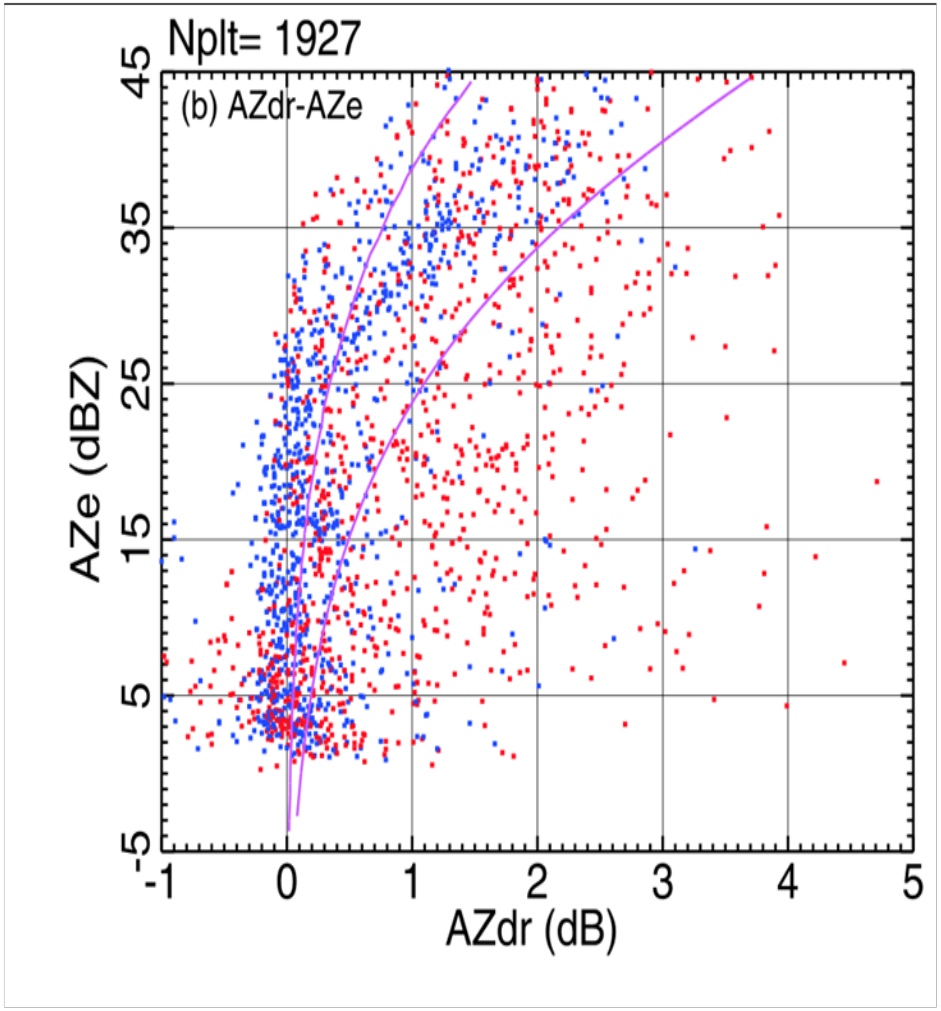
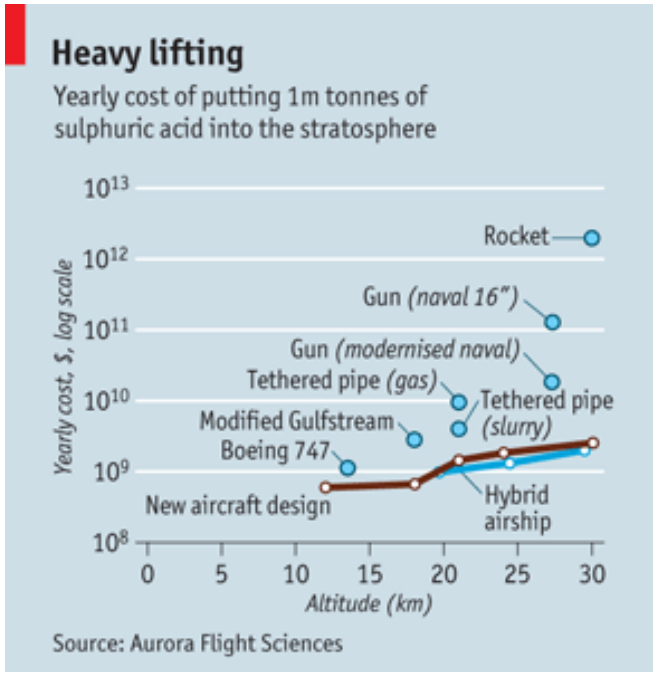
Continental versus maritime rain drop sizes (Wilson et al., 2012)





Geo-Engineering

- ICCP in IAMAS prepared a statement on Geo-engineering related to solar radiation management through clouds.
- National Academy of Sciences recently commissioned a study on Geo-engineering sponsored by CIA, NOAA and NASA focused on solar radiation management and carbone dioxide.
- AMS also in the process of developing a statement on Geo-engineering.



Geo-Engineering (ICCP Statement)

The International Commission on Clouds and Precipitation recommends:

- That further research is pursued to better understand the fundamental science and possible efficacy of radiation management climate engineering schemes.
- That climate engineering research be conducted in an open and independent manner that engages public participation, and is used to properly assess the potential risks involved.
- That research activities must include studies of the human impacts, ethics, legal and political impacts of climate engineering

Given the poor state of the current knowledge on clouds, aerosols, precipitation and their interactions, the ICCP does not support the implementation of climate engineering and does not expect that climate engineering can solve the global warming problem.

Geo-Engineering (NAS/NRC Study)

The study will:

1. Evaluate what is currently known about the science of several (3-4) selected example techniques, including potential risks and consequences (both intended and unintended), such as impacts, or lack thereof, on ocean acidification,
2. Describe what is known about the viability for implementation of the proposed techniques including technological and cost considerations,
3. Briefly explain other geoengineering technologies that have been proposed (beyond the selected examples), and
4. Identify future research needed to provide a credible scientific underpinning for future discussions.

The study will also discuss historical examples of related technologies (e.g., cloud seeding and other weather modification) for lessons that might be learned about societal reactions, examine what international agreements exist which may be relevant to the experimental testing or deployment of geoengineering technologies, and briefly explore potential societal and ethical considerations related to geoengineering.

Trust Fund

- Since 2010 the committee has been dependent on a WMO Trust Fund to support its activities. A request was sent to the Permanent Representatives of the WMO countries to request them to contribute to the fund. The reaction to this request has been extremely limited.
- Considering that weather modification activities in most countries are conducted outside the auspices of the Meteorological Services in separate government departments it is not surprising that very little response was received form the Permanent Representatives of members of WMO.
- This may call for a different approach to obtain funding for the Trust Fund supporting the committee work by directly identifying the entities that are involved in weather modification activities and then approaching them through the PR's.
- Currently working with NOAA and the U.S. PR to approach organizations involved in weather modification activities to obtain funding.
- Working with other committee members and WMO to approach similar organizations in other countries.
- Except for China all other Weather modification activities are operated outside Meteorological Services.
- Meteorological Services are are often asked to provide advice and most of the time refer to the WMO statements

Future Plans

- Committee meeting in China in October 2013 sponsored largely by CMA Training Center on Weather Modification
- Conduct a review of weather modification activities and science and publish as book or report.
- Request from AMS to potentially organize a combined WMO-AMS Weather Modification/Geo-engineering conference in 2015.
- Draft a recommendation on a potential statement on Geo-engineering