



AMERICAN METEOROLOGICAL SOCIETY

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Mr. Art Rangno
Sky Guide
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Dear Art:

Thank you very much for your interesting letter of January 6th. I agree with everything that you have said. Unfortunately, our profession seems to be getting into the same situation of over claiming and then having other people attack with global warming, as was the case with weather modification. I find this very depressing. Enclosed herewith is a talk I gave at the AMS Meeting of Probability and Statistics in Monterey last October. I was not going into detail on weather modification at that time, but merely trying to warn that we must be careful in the types of claims that we make to the press and the public when we are dealing with situations of very high natural variability in which we are trying to determine the effects of mans' activities.

Again, thanks so much for your letter.

Sincerely yours,

Joanne Simpson
Chief Scientist for Meteorology
Laboratory for Atmospheres

Enclosure

BANQUET TALK

OCTOBER 4, 1989

JOANNE SIMPSON, AMS PRESIDENT

THE WEATHER MODIFICATION PARADOX RISES AGAIN

A BANQUET SPEAKER SHOULD EITHER BE FUNNY OR CONTROVERSIAL. SINCE I ALWAYS FORGET THE PUNCH LINE OF JOKES, I DECIDED TO BE CONTROVERSIAL. FOR SOMEONE WHO WAS INVOLVED IN WEATHER MODIFICATION FOR A DECADE CONTROVERSY IS A WAY OF LIFE AND ONE HAS TO ENJOY IT TO SURVIVE.

MANY, IF NOT MOST, METEOROLOGISTS ARE RELIEVED THAT WEATHER MODIFICATION IN THE UNITED STATES HAS FALLEN TO AN ALMOST VANISHINGLY SMALL LEVEL OF ACTIVITY. THERE APPEARS TO BE A WIDESPREAD OPINION THAT DOING WEATHER MODIFICATION IS ABOUT AS DISREPUTABLE AND UNSCIENTIFIC AS SELLING SNAKE OIL. IRONICALLY, MANY DISTINGUISHED CLOUD PHYSICISTS EXPRESSED ACTUAL GLEE WHEN THE FLORIDA AREA CUMULUS EXPERIMENT WAS TERMINATED, WITH RESULTS THAT WERE STATISTICALLY INCONCLUSIVE. IN FACT, MANY SCIENTISTS AND MOST OF THE MEDIA CHOSE TO INTERPRET THIS OUTCOME AS UNSUCCESSFUL. I SAY IRONICALLY BECAUSE THE CLOUD PHYSICS COMMUNITY IS PAYING THE MOST IMMEDIATE HIGH

PRICE FOR THE DRASTIC CURTAILMENT OF WEATHER MODIFICATION RESEARCH - - BADLY NEEDED NEW OBSERVATIONAL DATA ON CLOUDS IS MUCH SLOWER AND HARDER TO COME BY THAN IN THE HEYDAY OF WEATHER MODIFICATION EXPERIMENTS.

BUT TWO ADDITIONAL, EQUALLY IMPORTANT LOSSES WERE CONSEQUENT ON THE DECLINE AND FALL OF WEATHER MODIFICATION. ONE IS THAT WE ARE NOT LEARNING FROM OUR MISTAKES IN ORDER TO COPE WITH SERIOUS FUTURE WATER SHORTAGES. MORE SUBTLE AND PERHAPS EVEN MORE IMPORTANT, THE ATMOSPHERIC SCIENCE COMMUNITY DID NOT TAKE A HARD LESSON FROM WHY WEATHER MODIFICATION APPARENTLY FAILED. LACKING THAT LESSON, OUR COMMUNITY HAS AGAIN STUMBLERD INTO THE WEATHER MODIFICATION PARADOX IN CONNECTION WITH GLOBAL WARMING - WHERE WE MAY BE DAMAGING OUR CREDIBILITY AGAIN FOR THE SAME BASIC REASON.

WHAT IS THE WEATHER MODIFICATION PARADOX? IT IS THE TENDENCY TO EXAGGERATE MAN-MADE ALTERATIONS IN THE ATMOSPHERE OWING TO THE GREAT DIFFICULTY IN DISTINGUISHING DEFINITELY BETWEEN NATURAL VARIABILITY IN THE SYSTEM AND ANTROPOGENIC EFFECTS - WHETHER THE PERCEIVED MAN-MADE CHANGE IS SMALL-SCALE RAIN PRODUCED BY INTENTIONAL CLOUD SEEDING OR WHETHER IT IS LONG-RANGE GLOBAL WARMING AS A BY-PRODUCT OF INDUSTRY AND AGRICULTURE.

TO PROGRESS FURTHER HERE WE WILL HAVE TO LOOK MORE CLOSELY AT WHY IT WAS NOT POSSIBLE TO DEMONSTRATE POSITIVE EFFECTS OF CLOUD SEEDING ON RAINFALL - UNDER ALL CONDITIONS EXCEPT ONE. THE ONE EXCEPTION, WHICH SHOULD SERIOUSLY IMPACT OUR THINKING, IS THE 32-YEAR PROJECT IN ISRAEL. VIRTUALLY ALL METEOROLOGISTS , INCLUDING EVEN TOUGH-MINDED STATISTICIANS, AGREE THAT IN THE ISRAEL NORTH TARGET, RAIN WAS ENHANCED SIGNIFICANTLY BY SEEDING. WHY ARE WE ABLE TO SAY THAT? IS ISRAEL THE ONLY PLACE WHERE CLOUD SEEDING WORKS? OR IS IT THE ONLY PLACE WHERE IT HAS BEEN POSSIBLE TO REMOVE OR CORRECT FOR THE VARIABILITY IN NATURAL RAIN PROCESSES? I BELIEVE THAT THE LATTER IS THE CASE. I HAVE COME TO BELIEVE THAT IS WAS ACTUALLY UNFORTUNATE THAT CLASSICAL EXPERIMENT DESIGN WORKED IN ISRAEL. THAT SUCCESS ENCOURAGED US TO FOLLOW A "BLIND COPY" APPROACH TO CLOUD MODIFICATION. THE FAILURE OF THAT APPROACH WAS A MAIN REASON FOR THE DOWNFALL OF WEATHER MODIFICATION.

THIS CHAIN OF REASONING REQUIRES SOME EXPLANATION. MANY OF YOU REMEMBER THAT IN ISRAEL THE RAINFALL OCCURS IN SYNOPTIC SCALE WINTER STORMS. HENCE THE RAIN EXTENDS OVER A REGION LARGE ENOUGH TO ACCOMMODATE TWO AREAS WITH HIGHLY CORRELATED RAINFALL. FOR THIS REASON THE SEED/CONTROL DESIGN COULD BE APPLIED. ON EACH OPERATIONAL DAY, A SEED OR NO SEED DECISION IS RANDOMLY MADE FOR THE TARGET AND

A NEARBY AREA ACTS AS A CONTROL. THE BEAUTY OF THIS IS THAT THE CONTROL AREA SERVES TO SHOW WHAT THE RAINFALL IN THE SEEDED TARGET WOULD HAVE BEEN HAD IT NOT BEEN SEEDED. EVEN WITH THIS ADVANTAGE, THE ISRAEL NORTH TARGET EXPERIMENT REQUIRED TWO 6-YEAR PHASES, WITH NEARLY 400 CASES PER PHASE TO OBTAIN A POSITIVE SEEDING EFFECT ESTIMATE WHICH WAS HIGHLY STATISTICALLY SIGNIFICANT.

THE SUCCESS OF THE ISRAEL EXPERIMENT WAS A MAIN FACTOR LEADING US TO KNUCKLE UNDER TO DEMANDS THAT RIGIDLY CONTROLLED STATISTICAL EXPERIMENT DESIGNS BE APPLIED TO ATMOSPHERIC TARGET AREAS. THIS TYPE OF EXPERIMENTATION HAD BEEN SUCCESSFULLY APPLIED TO TESTING FERTILIZERS IN ADJACENT CORNFIELDS AND MEDICATIONS VERSUS PLACEBOS IN DOUBLE BLIND MEDICAL EXPERIMENTS. FUTILE EFFORTS WERE MADE TO FIND WELL CORRELATED CONTROL AREAS WHICH, TO MY KNOWLEDGE, HAVE NEVER BEEN FOUND EXCEPT IN ISRAEL, AND FAILING THOSE, TO TRY TO USE THE SAME TARGET AREA ON RANDOMLY SELECTED DIFFERENT DAYS, WHICH WAS WHERE THE FLORIDA EXPERIMENTS CAME TO GRIEF.

NOT BEING TOTALLY NAIVE, THE FLORIDA EXPERIMENTERS COLLECTED SEVERAL YEARS OF RADAR DATA FROM THE TARGET TO ESTIMATE THE NATURAL VARIABILITY AND, BASED ON THAT, CALCULATED THE NUMBER OF EXPERIMENTAL CASES REQUIRED TO PIN DOWN SMALL PERCENTAGE INCREASES AT SATISFACTORY SIGNIFICANCE

LEVELS. BUT DATA COLLECTION AND ANALYSIS IS COSTLY IN TIME AND MONEY AND A FEW YEARS OF DATA MAY OFTEN NOT CATCH THE EXTREME SITUATIONS. UNFORTUNATELY, THE FLORIDA SCIENTISTS SUCCUMBED TO THE MANAGEMENT'S INSISTENCE THAT THE PROJECT COULD ONLY BE SUPPORTED FOR THREE SEASONS, WITH A TOTAL OF 60 TEST CASES.

THE MANAGEMENT SHOULD HAVE BEEN TOLD TO GET LOST, AND SO SHOULD MOST OF THE STATISTICIANS. WE SHOULD HAVE GONE DOWN - TO UNEMPLOYMENT IF NECESSARY - TRYING TO FOLLOW OUR JUDGEMENT TO EXAMINE AND MODEL THE PHYSICAL LINKAGES IN VARIOUS PARTS OF THE RAIN PRODUCING SYSTEMS AND REJECTED THE TOTAL TARGET BLIND STATISTICAL APPROACH AS SUICIDAL. BUT THAT IS HINDSIGHT. ACTUALLY THERE WERE ENOUGH MEASUREMENTS AND MODELING OF INDIVIDUAL RAIN SYSTEMS MADE DURING THE FLORIDA PROJECT SO THAT OTHER SCIENTISTS LATER WERE ABLE TO SHOW FAIRLY CLEAR EVIDENCE OF EXPECTED SEEDING SIGNATURES AND POSITIVE SEEDING EFFECTS ON INDIVIDUAL CLOUD SYSTEMS. IN WEATHER MODIFICATION, IT WAS AND IS A TERRIBLE MISTAKE TO TREAT THE TARGET AS A BLACK BOX WITHOUT EXAMINING THE PHYSICAL INTERACTIONS WITHIN IT. MOREOVER, VIRTUALLY EVERYONE UNDERESTIMATED THE KILLING EFFECTS OF THE IMMENSE NATURAL VARIABILITY PRODUCED BY THE SCALE AND PROCESS INTERACTIONS.

THE WORST POSSIBLE APPROACH IN CLOUD MODIFICATION WAS TO LOOK AT HISTORICAL DATA IN THE SAME TARGET.

MANY CLOUD SEEDERS HAD SO LITTLE FINANCIAL SUPPORT THEY COULDN'T DO ANY MORE THAN THIS. OTHERS MAY HAVE BEEN OUT TO MAKE A FAST BUCK. IN ANY CASE, COUNTLESS PEOPLE CLAIMED SEEDING EFFECTS IN TARGETS WORLDWIDE BECAUSE THE RAIN WAS DIFFERENT DURING SELECTED HISTORICAL PERIODS FROM THAT MEASURED DURING THE SEEDED PERIOD. MANY OF THEM WERE DERIDED AS SNAKE OIL SALESMEN. NONE OF THIS ENHANCED THE CREDIBILITY OF THE ATMOSPHERIC SCIENCES. UNFORTUNATELY, I SEE SYMPTOMS INDICATING THAT CLIMATE EXPERTS MAY BE FALLING INTO SEVERAL VERSIONS OF THE WEATHER MODIFICATION PARADOX WHEN THEY WARN ABOUT GLOBAL WARMING DUE TO AN INCREASE IN THE GREENHOUSE EFFECT.

ALL THE WELL-KNOWN CLIMATE MODELS ARE PREDICTING SUBSTANTIAL GLOBAL WARMING OVER THE NEXT FIFTY YEARS. THESE MODEL RESULTS HAVING BEEN MAKING HEADLINES. IN PARTICULAR, THEY MADE HEADLINES IN THE SUMMER OF 1988 WHEN MOST OF THIS COUNTRY WAS IN A SWELTERING DROUGHT. SEVERAL INCAUTIOUS MODELERS WENT SO FAR AS TO CLAIM THAT INCREASED GREENHOUSE WARMING IS ALREADY UPON US. IN MANY COMMUNITIES SERIOUS PLANS ARE UNDERWAY TO REDESIGN COASTAL CITIES IN RESPONSE TO EXPECTED MELTING OF THE POLAR ICE CAPS. ON CAPITOL HILL, SENATORS AND REPRESENTATIVES ARE PROPOSING BILL AFTER BILL TO COPE WITH GLOBAL CHANGE; COUNTLESS CONFERENCES AND COMMITTEES ARE BEING HELD TO DISCUSS HOW TO DEAL WITH IT AND MONEY IS FLOWING

INTO CLIMATE RESEARCH AS IT ONCE DID INTO WEATHER MODIFICATION.

I AM NOT SAYING THAT THIS IS ALL BAD. OF COURSE, WE HAVE TO BE DEEPLY CONCERNED ABOUT OUR GLOBAL ENVIRONMENT AND ITS HABITABILITY - ONE OF OUR MAJOR OBLIGATIONS IS TO ADVISE DECISION MAKERS ABOUT ATMOSPHERIC PROBLEMS. BUT WE ALSO HAVE TO RETAIN CREDIBILITY OR NO ONE WILL LISTEN WHEN WE ADVISE. ACTUALLY, WITH REGARD TO CLIMATE CHANGE, OUR KNOWLEDGE SITUATION IS FAR MORE ADVANCED THAN IT WAS IN THE DAYS OF WIDESPREAD WEATHER MODIFICATION. THERE ARE UNDISPUTED OBSERVATIONS THAT THE GREENHOUSE GASES IN THE ATMOSPHERE ARE INCREASING. PREDICTIONS OF GLOBAL WARMING ARE BASED ON NUMERICAL MODELS WHICH USE THE HYDRO-THERMODYNAMIC EQUATIONS DESCRIBING THE BEHAVIOR OF THE GLOBAL ATMOSPHERE, ALBEIT IN A NECESSARILY SIMPLIFIED MANNER. HEREIN LIES A MAJOR VULNERABILITY. NONE OF THE CLIMATE MODELS PROPERLY SIMULATE THE COUPLING BETWEEN THE ATMOSPHERE AND THE OCEANS, PARTICULARLY THE SLOWER RESPONDING LOWER OCEAN LAYERS. TO DO THAT REQUIRES AT LEAST MUCH GREATER COMPUTER CAPACITY THAN IS PRESENTLY AVAILABLE. THEN THERE IS ALSO THE PROBLEM OF CLOUDS -- WILL THEY RESPOND IN SUCH A WAY AS TO ACCELERATE OR TO COUNTERACT GLOBAL WARMING?

AS A METEOROLOGIST INVOLVED FOR MORE THAN 40 YEARS IN CLOUD STUDIES, I KNOW THAT WE ARE IN A VERY

CRUCIAL AND IMPORTANT STAGE WHEN IT IS BECOMING NECESSARY AND POSSIBLE TO COMBINE RADIATIVE, CHEMICAL, DYNAMICAL AND MICROPHYSICAL MODELS OF CLOUDS. WE NEED TO KNOW CLOUD RADIATIVE PROPERTIES BETTER TO USE THE NEW SATELLITE TOOLS TO EVALUATE PRECIPITATION AND THE GLOBAL ENERGY BUDGET. WE ALSO NEED THESE CLOUD CHARACTERISTICS TO UNDERSTAND HOW CLOUD RESPONSES WILL INTERACT WITH OTHER PROCESSES AFFECTING CLIMATE.

UNFORTUNATELY, THE DEMISE OF WEATHER MODIFICATION HAS SLOWED DOWN THE ACQUISITION OF CLOUD DATA, PARTICULARLY REGARDING THE ICE PHASE, WHICH IS BOTH POORLY DOCUMENTED AND VITALLY NEEDED TO PREDICT RADIATIVE RESPONSE. SO WE MUST MARCH FORWARD WITH CLOUD OBSERVATIONS UNDER THE FLAG OF GLOBAL CHANGE SINCE THE FLAG OF WEATHER MODIFICATION HAS FALLEN -- BUT THAT IS EASIER URGED THAN DONE.

THE NATION AND THE WORLD CANNOT HOLD OFF ENTIRELY ON POLICY DECISIONS UNTIL CLIMATE MODELS HAVE OVERCOME THEIR PRESENTLY RECOGNIZED WEAKNESSES. I THINK THE BEST WE CAN RECOMMEND IS A FLEXIBLE POLICY BASED ON THE PRINCIPLE OF LEAST REGRET. THE PRINCIPLE OF LEAST REGRET CAN BE ADAPTED ROUGHLY THIS WAY: NAMELY 50 YEARS FROM NOW WOULD THE NATION REGRET IT LESS TO HAVE IGNORED THE WARMING PREDICTIONS BECAUSE OF THE UNCERTAINTIES IN THE MODELS, AND BY THAT TIME TO FIND THAT SUBSTANTIAL WARMING WITH ITS CONSEQUENCES HAS OVERTAKEN US - OR WOULD THE

CONSEQUENCES BE WORSE TO SPEND CONSIDERABLE PRECIOUS RESOURCES ON TRYING TO CHANGE INDUSTRIAL AND AGRICULTURAL PRACTICES SO AS TO RESTRICT EMISSIONS, WHILE THE MODELS, ON BEING IMPROVED BY ACCELERATED RESEARCH, COME OUT WITH REDUCED OR EVEN REVERSED PREDICTIONS OF GLOBAL WARMING AND ITS CONSEQUENCES?

BY REVERSED PREDICTIONS OF GLOBAL WARMING AND ITS CONSEQUENCES, I MEAN THAT CLOUD FEEDBACKS FROM THE INCREASE IN GREENHOUSE GASES COULD CONCEIVABLE LEAD TO COOLING RATHER THAN WARMING, AS MANY RESEARCHERS HAVE POINTED OUT. THIS IS NOT THE ONLY INTERACTION INTRACTABLE TO PRESENT MODELS. FOR EXAMPLE, AN EXPERT ON ANTARCTIC WEATHER POSTULATES THAT IF THE SOUTH POLAR AIR TEMPERATURES RISE THERE WILL BE MORE SNOWFALL AND THUS AN INCREASED ANTARCTIC ICE PACK, WITH CONSEQUENT LOWERING IN SEA LEVELS, RATHER THAN THE RISE EXPECTED AS THE ICE CAP IS SUPPOSED TO MELT. THIS ANTARTIC EXPERT WARNS THAT PRESENTLY THE AIR OVER ANTARCTICA IS TOO COLD FOR IT TO SNOW VERY MUCH! IN SUMMARY, WE MUST PLACE SOME CAVEATS ON HOW SERIOUSLY WE TAKE OUR CURRENT CLIMATE MODEL PREDICTIONS, ESPECIALLY SINCE THESE MODELS FAIL TO ADEQUATELY SIMULATE CLOUD AND PRECIPITATION PROCESSES..

CLEARLY, HOWEVER, THE 50 YEAR TIME JUMP I USED JUST NOW IS OVERSIMPLIFIED. A STEPWISE DECISION TREE WOULD BE MUCH BETTER. THE STEPWISE DECISION TREE WOULD

ALLOW FOR INCREMENTAL CHANGES IN POLICY AS
INCREMENTAL INFORMATION BECOMES AVAILABLE.

FOR EXAMPLE, IF WE USE OUR SCIENCE RESOURCES
PROPERLY, WE SHOULD KNOW A GREAT DEAL MORE ABOUT
THE RESPONSES OF CLOUDS AND PRECIPITATION TO AMBIENT
CHANGES BY THE YEAR 2000, AND, UNLESS WE AND OUR
FUNDING AGENCIES ARE INCREDIBLY DELINQUENT, WE
SHOULD KNOW BETTER HOW TO SIMULATE CLOUD PROCESSES
IN THE MODELS. THEREFORE, BY THE YEAR 2000, DECISION
MAKERS SHOULD BE ABLE TO RE-EXAMINE POLICY DECISIONS
USING PREDICTIONS FROM IMPROVED MODELS. BY THAT TIME,
WE METEOROLOGISTS SHOULD ALSO BE ABLE TO QUANTIFY
THE FRAILTIES OF THE MODELS TO ASSESS CONFIDENCE LEVELS
REGARDING THEIR PREDICTIONS.

WHILE IT IS NOT ENTIRELY CLEAR WHAT THE DECISION
MAKERS OF THE WORLD CAN AND SHOULD DO, I HOPE AT LEAST
THAT WE METEOROLOGISTS HAVE LEARNED SOME HARD
LESSONS. I HOPE THAT WE HAVE LEARNED ENOUGH FROM THE
HARM THAT WE AND OUR COLLEAGUES HAVE CAUSED OVER
THE YEARS BY EXAGGERATED CLAIMS AND EXAGGERATED
SCARE STORIES. I HOPE THAT WE WILL BE MORE CAUTIOUS IN
HOW WE EXPRESS OURSELVES, ESPECIALLY TO THE MEDIA --
THAT IS A DIFFICULT CHALLENGE, TO SAY THE LEAST.

ON A DEEPER AND MORE SUBTLE LEVEL, I WANT TO
CONCLUDE BY URGING THAT WE MAKE EVERY EFFORT TO
BECOME MORE KNOWLEDGABLE CONCERNING THE ENORMOUS
NATURAL VARIABILITY IN ATMOSPHERIC PROCESSES AND THAT

WE USE EVERY RESOURCE TO DOCUMENT THESE VARIABILITIES AND COMMUNICATE THEM TO THE PUBLIC.

IN THIS CONTEXT I WANT TO MAKE CLEAR THAT STATISTICIANS HAVE NOT ALWAYS BEEN OUR ENEMIES. WHILE A FEW STATISTICIANS DID HAVE A HARMFUL EFFECT IN STRAIGHT-JACKETING WEATHER MODIFICATION, THE PRESENT GENERATION WHO BEGAN WORKING WITH US IN THE SIXTIES AND SEVENTIES CAN BRING TO BEAR IMPORTANT TOOLS. THEY CAN HELP US GAIN INSIGHT INTO SYSTEMS IN WHICH A RATHER SMALL SIGNAL MUST BE DETECTED WITHIN A VERY HIGH AMPLITUDE NOISE LEVEL. I URGE THAT WE ENLIST THEIR HELP IN DOCUMENTING MAN'S ROLE IN CLIMATE CHANGE . I ALSO HOPE THAT METEOROLOGISTS WILL SEEK THEIR PARTNERSHIP IN A REVIVAL OF SOUNDLY BASED EXPERIMENTS ON RAIN ENHANCEMENT BY CLOUD MODIFICATION.

IN DISCUSSION ON WEATHER MODIFICATION:

POINT OUT THAT ONE OF THE MOST IMPORTANT FINDINGS IN WEATHER MODIFICATION EXPERIMENTS HAS BEEN THAT THE SAME TREATMENT HAS DIFFERENT EFFECTS UPON CLOUD PROCESSES AND RAINFALL DEPENDING UPON THE CONDITIONS IN WHICH THE CLOUDS ARE GROWING.

THIS WAS LEARNED RECENTLY IN THE ISRAEL PROJECT WHEN THE CLOUD RESPONSE IN THE SOUTHERN TARGET WAS FOUND TO BE NEGATIVE. THE NEGATIVE RESPONSE WAS PARTICULARLY PRONOUNCED ON SOUTHWEST WIND DAYS,

WHEN DESERT DUST PROVIDED EXCESS ICE NUCLEI IN THE CLOUDS.

IRONICALLY, THIS RECENTLY GAINED KNOWLEDGE SHOWED RETROSPECTIVELY THAT THE FAMOUS ISRAEL 1 EXPERIMENT WITH THE RANDOMIZED CROSSOVER DESIGN WAS SERIOUSLY FLAWED. AS MANY OF YOU RECALL, IN THAT EXPERIMENT THE TWO TARGETS WERE LOCATED SO THAT ONE TARGET WAS NORTH OF THE OTHER ONE. YOU CAN USE RANDOMIZED CROSSOVER ONLY WHEN THE TWO TARGET RESPOND PHYSICALLY IN THE SAME WAY TO SEEDING. IT HAS NOW BEEN FOUND BY RE-ANALYSIS THAT IN ISRAEL THE NORTH AND CENTRAL TARGETS DID NOT RESPOND THE SAME WAY. THE RESPONSE IN THE CENTRAL TARGET WAS LESS POSITIVE THAN THAT IN THE NORTH, PRESUMABLY FOR THE CLOUD MICROPHYSICAL REASON CITED ABOVE, ALTHOUGH THIS HYPOTHESIS HAS NOT YET BEEN PROVEN. EVEN SO, I WOULD BE PREPARED TO BET ANYONE A CASE OF BEER OR A STEAK DINNER THAT USEFULLY LARGE TARGETS SUITABLE FOR RANDOMIZED CROSSOVER CLOUD SEEDING WILL NOT BE FOUND ON THE LAND SURFACE OF THIS PLANET!

IN FLORIDA, THE DATA SHOWED LONG AGO THAT THE CLOUDS RESPONDED TO SEEDING DIFFERENTLY UNDER DIFFERENT CONDITIONS IN THE CASE OF INDIVIDUAL ISOLATED CLOUDS, MOST OF THE DIFFERENT RESPONSE COULD BE IDENTIFIED USING A SIMPLIFIED CLOUD MODEL AND A THERMODYNAMIC SOUNDING OF THE CLOUD ENVIRONMENT. HENCE THE POSITIVE RESULTS FROM SEEDING SINGLE CLOUDS

FOR DYNAMIC EFFECTS WAS STATISTICALLY SIGNIFICANT AND GENERALLY ACCEPTED AS VALID. IN FLORIDA, THE PROBLEM BECOMES FORMIDABLE WHEN A MESOSCALE TARGET AREA IS USED, IN WHICH THERE ARE MANY INTERACTING CLUSTERS OF CLOUDS AND NO WELL-CORRELATED CONTROL AREAS.

WHEN METEOROLOGISTS FIND DIFFERENT CLOUD RESPONSES TO TREATMENT UNDER DIFFERENT ATMOSPHERIC CONDITIONS, WE GET IN TROUBLE WITH STATISTICIANS WHO START RAISING PROBLEMS ABOUT "MULTIPLICITY". THEY SAY WE ARE STRATIFYING THE DATA AFTER THE FACT-AND IF YOU DO THIS ENOUGH DIFFERENT WAYS YOU CAN GET ANY RESULT YOU WANT FROM A MODIFICATION EXPERIMENT.

FURTHERMORE, IF YOU FIND, SAY, THAT SEEDING INCREASES THE RAINFALL WHEN THE WIND IS FROM THE NORTH WHERE THE AIR HAS COME OVER THE OCEAN, AND HAS A NEGATIVE EFFECT WHEN THE AIR COMES FROM THE DESERT SOUTH, YOU REDUCE YOUR NUMBER OF CASES TO THOSE ON WHICH ONLY NORTH WIND DAYS MAKE UP THE SAMPLE..ON A PRACTICAL BASIS, MODIFICATION BECOMES LESS COST EFFECTIVE IF IT APPLIES TO ONLY A FRACTION OF THE DAYS WITH AVAILABLE CLOUDS.

IN CONCLUSION, I BELIEVE THAT THE OLD WAY OF TESTING AN ENTIRE COMPLEX HYPHESIS AT ONCE IS MOST OFTEN MISTAKEN, AS USUALLY IS THE SEARCH FOR PREDICTORS FOR A WHOLE TARGET AREA. NO ONE CAN YET PREDICT THE DETAILS OF MESOSCALE EVENTS. INSTEAD, WHAT WE SHOULD BE DOING IS BUILDING UP PHYSICAL UNDERSTANDING. WE

NEED TO TEST EACH INDIVIDUAL LINK IN A HYPOTHESIS CHAIN BY MEASUREMENT AND MODELS. IF WE PROCEED THIS WAY AND HAVE TO REJECT A MODIFICATION HYPOTHESIS, WE PROBABLY HAVE LEARNED ENOUGH ABOUT THE CLOUDS TO JUSTIFY THE EXPERIMENT, WHILE THE OLD-FASHIONED BLIND OR BLACK BOX EXPERIMENTS FREQUENTLY SOWED MORE CONFUSION AND CONTROVERSY THAN ENLIGHTENMENT. THE SAME STEP-BY-STEP HYPOTHESIS TESTING SHOULD BE APPLICABLE TO GLOBAL WARMING ANALYSES, WHERE TURNING OFF THE "TREATMENT" IS ORDERS OF MAGNITUDE MORE DIFFICULT AND COSTLY THAN STOPPING CLOUD SEEDING.