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PROGRESS REPORT
30 NOVEMBER 1972

THE USE OF ERTS-1 SATELLITE DATA IN GREAT LAKES MESOMETEOROLOGICAL STUDIES

(GSFC ID UN 144 CONTRACT NAS5-21736)

Submitted by

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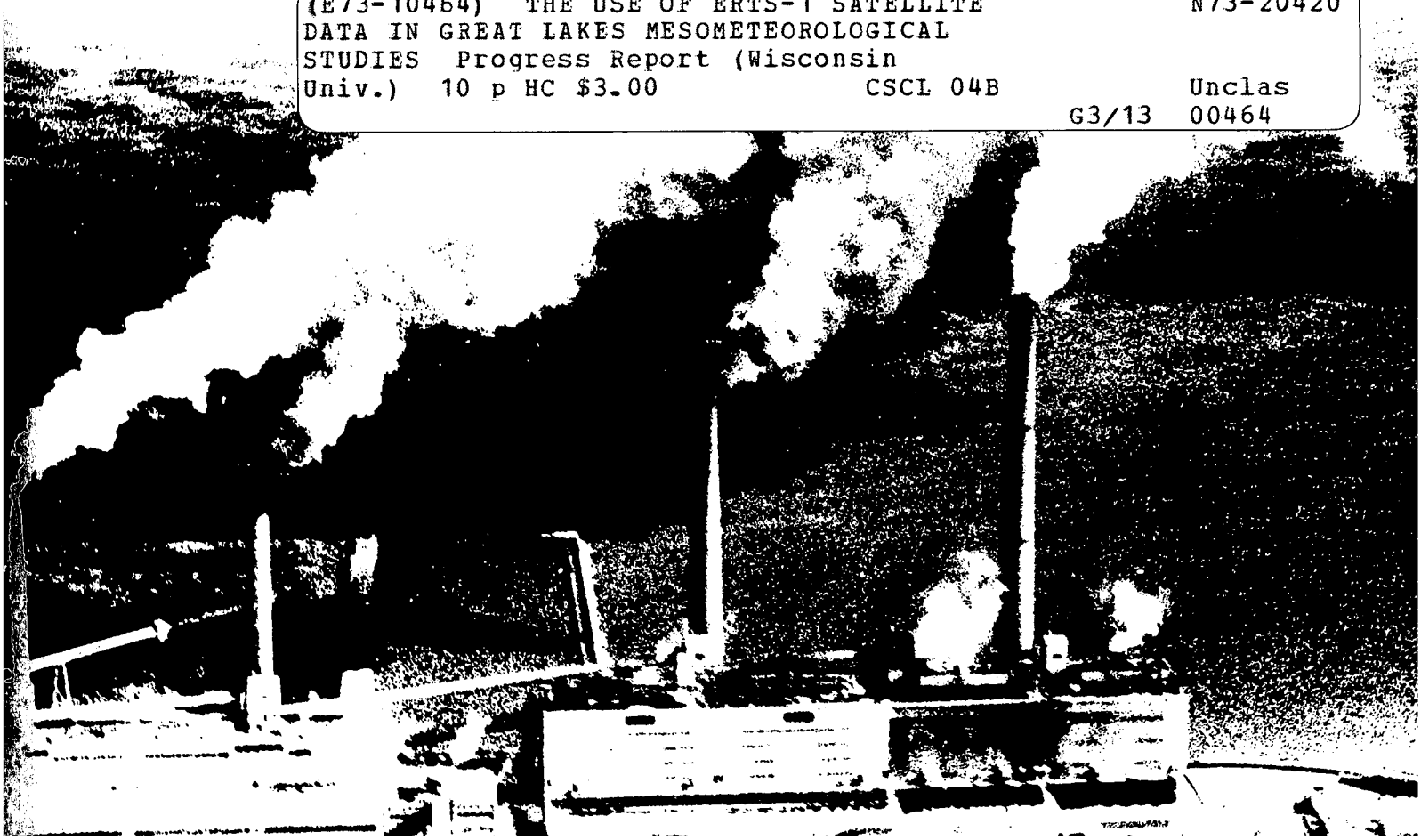

TYPE II PROGRESS REPORT: NOVEMBER 30, 1972

a. THE USE OF ERTS-1 SATELLITE DATA IN GREAT LAKES MESOMETEOROLOGICAL STUDIES

b. WALTER A. LYONS, GSFC ID UN 144 (Contract NAS5-21736)

c. PROBLEMS ENCOUNTERED:

The following is a summary of difficulties that have been encountered. They are not ranked in order of importance.

1. At exactly the time the first ERTS-1 data began arriving, the principal investigator transferred to a new unit within the University. This meant a total dismantling and reassembling of facilities, plus developing a new darkroom facility. This slowed down all work for the prior summer.

2. There is increasing evidence that much of the material requested has never arrived. Some packages took five weeks to be delivered, and the PI is discovering many images in the reports of others that we should have received, but did not.

3. Cataloging negatives has at times been extremely difficult inasmuch as the identifying numbers have been almost unreadable due to the extremely dense character of negatives supplied.

4. We were expecting to receive negatives, positives, and prints. However, we were later told we had our choice of either positives or prints. In selecting prints (for rapid inspection purposes), we are not now able to produce CIR color composites.

5. Much of the data analysis costs were to be borne by grants from other agencies. Cutbacks in once allocated funds have hurt, and thus considerably less money could be diverted (at least immediately) for analysis of exclusively ERTS data. We estimate that through other funds (grants, university, etc.) we have spent over $3,000 (not counting photographic technician labor) in equipping a new darkroom to handle ERTS data processing. Please note, this is a no-cost contract, but in reality, it costs plenty to do some of the intended tasks. As funds become available from other sources, the rate of analysis will accelerate.

6. Considerable time has been lost due to the extremely dense negatives, mainly in learning how to get a least useable prints. Also, we simply cannot afford to make prints of each negative received without the ordered print in order to see what we have gotten.

7. In the first four months of data reception, due mostly to quirks in the weather over imaged areas, very little data of any real interest was acquired. That situation, fortunately, has changed drastically in recent weeks.

8. Hopes for simultaneous aircraft and ERTS views of the same area were frustrated due to temporary legal and funding problems in instrumenting a Cessna 336. This problem is now about solved (see below).

9. The delayed launching of ERTS also preventing coordination with field studies of convective clouds during spring 1972 in the Milwaukee area.

10. Comparisons between ERTS images and those from conventional satellites have likewise been delayed due to the failure of another agency in delivering promised standard satellite photographs. This is now being remedied.

11. The proposed air pollution study around Toronto for the International Field Year on the Great Lakes (IFYGL) was never implemented due to a lack of funds.

12. Analysis of ERTS data in conjunction with meteorological data over Lake Ontario has been delayed due to the extreme time lag that has developed in the processing of IFYGL data by NOAA and others.

d. ACCOMPLISHMENTS:

The following items have been accomplished, listings not necessarily in order of importance.

1. We have extablished a new AIR POLLUTION ANALYSIS LABORATORY (APAL). This is atop a 200 foot building with a commanding view of the greater Milwaukee area. This permits photography of clouds and pollution sources (time lapse, telephoto, all-sky, etc.) in the area, co-ordinated with ERTS overflights. A nine station FM communications system being installed will allow for co-ordination with observers in boats, vehicles, aircraft, and on the ground during co-ordinated field studies. Standard meteorological data are being received and catalogued beginning in September, 1972, including NAFAX weather facsimile and Service A teletype. Mesoscale meteorological and pollution data are being collected from a nine station network throughout Milwaukee County. This network should be fully operational by May, 1973.

2. A photographic darkroom has been acquired and is now being equipped to handle many of the developing and printing tasks needed for ERTS data analysis. Included are enlargers, a color head, print washing tanks, air purifiers, large supply of 35 mm cameras and lenses, a highly versatile copy/animation stand etc.

3. Five all-sky time-lapse completely automatic camera systems now being used in the Lake Ontario IFYGL project are collecting some simultaneous views with ERTS overflights. Data are being catalogued and analysed. These cameras will be returned to Milwaukee in June, at which time they will be used in monitoring smog, clouds, contrails, etc.,

for upward looking views corresponding to ERTS.

4. The rather considerable volume of prints and negatives that have been received to date are now being catalogued. This has required the employment of a student helper (on other funds) but complete cataloguing should be achieved shortly.

5. Since many of the prints we were supposed to have gotten never arrived, we will attempt to make our own now that the darkroom is set up. Again, however, this entails considerable funds that must be gleaned from other sources.

6. An instrumented aircraft is now being readied for simultaneous underflights coordinated with ERTS. A twin engine Cessna 336 will be operated by UWM-APAL and the State of Wisconsin, Department of Natural Resources. The aircraft will be equipped to measure various meteorological, navigational and air pollution parameters. In addition, 35mm cameras will record ground, pollution and cloud scenes. Instrumentation includes, (1) TSI total mass monitor giving suspended particulate mass loadings, (2) a ROYCO two-channel particle counter (0.5 - 1.5 and 7 - 9 micrometer ranges), (3) SIGN-X SO_2 monitor, (4) temperature, (5) relative humidity, (6) true air speed, (7) pressure altitude, (8) two VOR channels, and (9) DME. All parameters are sampled 2.4 sec^{-1} in BCD format on 1/4" tape for later ground computer processing. Preliminary work has begun to modify twin 16mm time lapse scope cameras for aircraft use. The plane will allow us to photograph convective cloud patterns from heights up to 4000m MSL (using CIR film, filtered to match MSS bands 4, 5 and 7 combined). More importantly, we will soon have the capability to make profiles of suspended particulates from major point source plumes (from power plants and steel mills) and to relate these to brightness levels seen in the ERTS imagery. The first test flight is expected March, 1973.

7. APAL has now almost completed work on its multipurpose GLUMP Diffusion Model (Great Lakes UWM Mesometeorology Project). This regional air pollution prediction model takes in over 500 point and area sources for particulates and SO_2 in the Southeast Wisconsin Air Quality Control Region. It employs a steady-state Gaussian plume dispersion technique, which however, has been modified to accept (a) quasi-homogeneous atmosphere, (b) plume trapping, and (c) continous or dynamic shoreline fumigation. Vertical resolution is available in 15 layers for wind direction and speed, temperature, stability, classes,

and background levels. The movable, variable size 33 X 46 receptor grid is placed anywhere in the entire region. Plume rise from point sources is calculated. Thus with this model it will be possible to numerically simulate the downwind diffusion of plumes both from specific point and regional pollution sources. Thus the degradation in contrast often seen in MSS 4, which is probably related to heavy suspended particulate loadings from urbanized areas, can be related to predicted values. We hope at times to be able to detect the "smear" of smoke and haze downwind of Chicago-Gary and Milwaukee on ERTS images, and then relate them to predicted values. Surface measurements at the nine monitoring stations in Milwaukee will be used for verification, as will aircraft data.

e. SIGNIFICANT RESULTS

In the original proposal, it was hoped that ERTS could, with its extremely high resolution and multi-spectral capability, detect many meteorological phenomena occurring at the low end of the mesoscale motion spectrum (1 - 100km). This included convective cloud phenomena, internal wave patterns, air pollution, snow squalls, etc. As far as we are concerned, as meteorologists, ERTS has more than lived up to initial hopes. First-look inspection of images has produced a large number of truly remarkable finds. Some of the most significant are listed:

1. LAKE BREEZE FRONTS - Images of Lake Ontario during late summer have revealed several extremely good examples of lake breeze frontal cloud patterns. We are able to detect each individual cumulus cloud. This allows us to clearly mark the inland penetration of cooler lake air and its updrafts at the frontal convergence zone. Also obvious is the fact that we can now determine exactly what size indentation or bay in the shoreline produces detectable variations in the inland penetration. It has long been speculated that large cities should influence lake breeze penetrations, but images so far have not detected this. (Subdiscipline; 6. Meteorology, B. Air Surface Interactions)

2. SUSPENDED PARTICULATE PLUMES - The Chicago-Gary industrial complex contains several large point sources of suspended particulates in the 50,000 to 150,000 tons/year category. ERTS images have clearly been able to detect these, expecially when advecting in southwest flow over Lake Michigan. MSS 4 has the least contrast due to the large radiance of the underlying water. However in MSS 5 (and also 6) the plumes are easily detectable, extending for well over 50 nm downwind. We have every hope of being able to detect the plumes drifting to as far as Milwaukee during stable southeast flow this spring. Thus we will now be able to combine ERTS imaging, computer simulation and actual aircraft measurements in the study of inter-regional pollution transport, an item which is under great scrutiny at this time, both scientifically and politically speaking. (Subdiscipline; 7. Environment, A. Pollution)

3. INADVERTANT WEATHER MODIFICATION - It has long been suspected that anthropogenic condensation and ice nuclei from urban areas are responsible for downwind increases in precipitation from large cities. LaPorte, Indiana, 50 nm east of Gary, Indiana for 40 years has had abnormally high levels of precipitation, thunderstorms, and hail. Ice nuclei from steel mills has been a suspected cause. On 25 November 1972 ERTS obtained an image showing

cold southwest flow advecting these plumes over the relatively warm lake. The expected cumulus clouds did form ... but in a pattern of parallel streets emerging out of the individual plumes. This appears to be incontrovertible evidence of inadvertant weather modification. Clouds emerging from the plumes were brighter and larger, thus indicating a greater potential for precipitation. This lends greater credence to those theories relating the "LaPorte anomaly" to seeding from Chicago-Gary steel mills. (Subdiscipline; 6. Meteorology, C. Cloud Physics)

f. PRODUCTS

As of this time, data is still being collected, filed and analysed. However, an abstract entitled, "ERTS-1 Views the Great Lakes" has been accepted by the 16th Conference on Great Lakes Research, IAGLR, April, 1973, Sandusky, Ohio. A copy is enclosed.

g. RECOMMENDATIONS

While our final checks have not yet been made, it appears we are not getting many of the requested products. Sometimes we get transparencies, sometimes prints, and sometimes both (as asked). It is possible that many items are being lost in the mails. Also we were never informed that we could not get both positive transparencies and prints. The change was just made. As a result, since we do need the prints for first-look inspection (the negatives are simply too dense), we are not able to make false-color composites (with the help of Dr. Robert Pease, University of California-Riverside). We cannot easily absorb the cost of making our own 70mm positives from the negatives.

h. CHANGES CONTEMPLATED

We would like to get (a) negative 70mm transparencies, (b) positive 70mm transparencies, and (c) 9.5 inch prints. If we can only get (b) or (c), we must continue with (c), however, as explained, this makes CIR image-production rather difficult.

6d. HYDROMETEOROLOGY

ERTS-1 VIEWS THE GREAT LAKES. Walter A. Lyons, Energetics Department and Center for Great Lakes Studies, and Steven R. Pease, Department of Geography, University of Wisconsin, Milwaukee.

With the launching of the Earth Resources Technology Satellite (ERTS-1) in July, 1972, a powerful new tool for studying mesoscale atmospheric phenomena associated with the Great Lakes has come on the scene. The satellite, in roughly a 500 nm orbit above the earth, takes 100 nm wide views of the same area every 18 days at about 0930 LST. Multi-Spectral Scanners (MSS) achieve better than a 200 m resolution in each of the 0.5-0.6, 0.6-0.7, 0.7-0.8, and 0.8-1.1 micrometer bands. A number of interesting findings have already been made.

It has been found possible to discriminate pollution patterns from large sources of suspended particulates. Plumes from major steel mill operations in the Chicago-Gary-Hammond area can be seen spreading in southwest flow over Lake Michigan for over 50 nm. The excellent background provided by water in the near infrared makes for optimum viewing. Conversely, over land even very dense smoke plumes become difficult to distinguish from terrain.

Comparison of same area viewed at different portions of the spectrum allows the detection and identification of cirritorm clouds. At shorter wavelengths (0.5-0.6 micrometers) cirrostratus layers might appear a total undercast. Yet in the near infrared (0.8-1.1) almost complete penetration to the underlying features is found. Denser clouds, such as altocumulus, stratus, cumulus, etc., do not exhibit this characteristic at all.

In a similar manner, views of the Toronto area under cloudless but hazy conditions, reveal the marked haze penetrating characteristics of the near infrared. Reconstructed color infrared views (made by combination of the three longer wavelength bands) reveal sharp ground features almost totally obscured by haze and pollutants in the "green" band (0.5-0.6 micrometers).

Snow cover is readily apparent in ERTS images. A localized record early season (October 18) lake snow squall in the south-Chicago and Hammond, Indiana region produced a well defined path through the metropolitan Chicago area. Though depth determination is difficult (maximum 4" in this case), such images can clearly reveal freshly deposited lake snow squall swaths as soon as the skies clear.

Summer lake phenomena, such as lake breeze fronts are ideally studied. Even the smallest cumulus elements are resolved. An all-shore Lake Breeze case over Lake Erie and Ontario shows the cloud-free zone extending almost uniformly inland from the shores around the perimeter of the lakes. Smaller lakes and reservoirs also show marked cloud suppression. Cloud streets on downwind shorelines show great similarity to laboratory studies of cold fluids advecting over heated plates.

Several sets of simultaneous views of cloud patterns from ERTS and the IFYGL all-sky cloud camera network are compared. These are helpful in showing the extremely high resolution of the satellite, as well as the horizontal viewing range with the lens-filter combination used.

EXHIBIT "C"

ERTS IMAGE DESCRIPTOR FORM

USER NAME Walter A. Lyons DATE 30 November 1973
USER ID UN 144
AGENCY University of Wisconsin-Milwaukee

PRODUCT ID (Include Band and Product)	Frequently Used Descriptors *				DESCRIPTORS
	Lk. Brze.	Contrail	Lake Snows		
1. 1070160415					Smoke
2. 107016041X					Altocumulus
3. 1028152905					Smoke
4. 102815290X					Bay-Head Bar
5. 1028152904					Cirrus
6. 102815290X	X				Cumulus
7. 1089160954		X			Cirrus, City
8. 102815293X	X				Cumulus
9. 1028152935					Smoke
10. 102815253X					Lee Wave
11. 1124160505					Smoke
12. 1124160504					Sediment, Metro Area
13. 100815171X		X			Cirrus
14. 108816041X			X		Cumulus
15. 109816043X			X		Cumulus

*For Descriptors which will occur frequently, write the descriptor terms in these column heading spaces now and use a check (✓) mark in the appropriate ID lines. (For other descriptors, write the term under the DESCRIPTORS column).

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