DATA ASSIMILATION FOR EOS

AN INSTRUMENT WITHOUT FLIGHT HARDWARE

WHY DO WE CARE?

A PRIMER; VERSION 2

MODIS SCIENCE TEAM MEETING

MAY 1995

RICHARD B. ROOD
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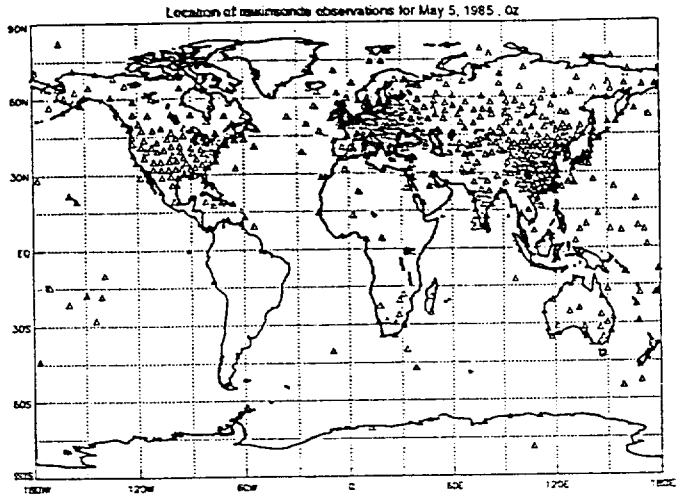
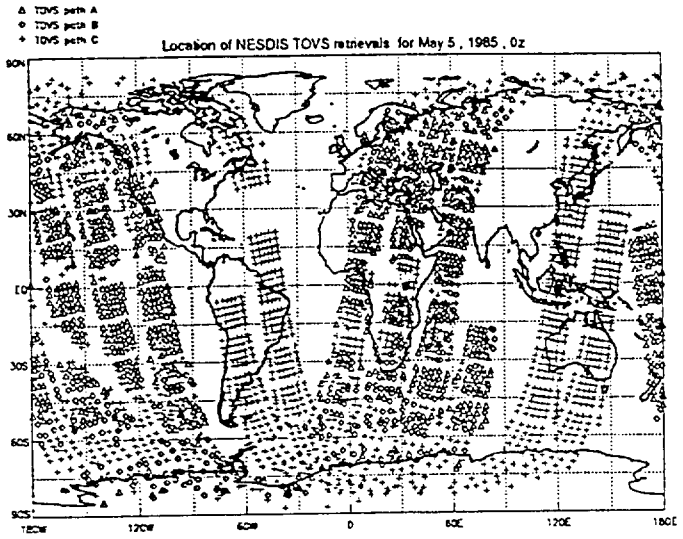
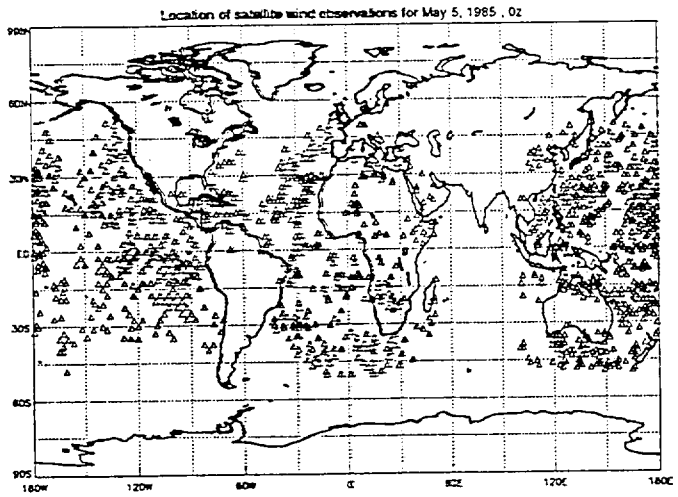
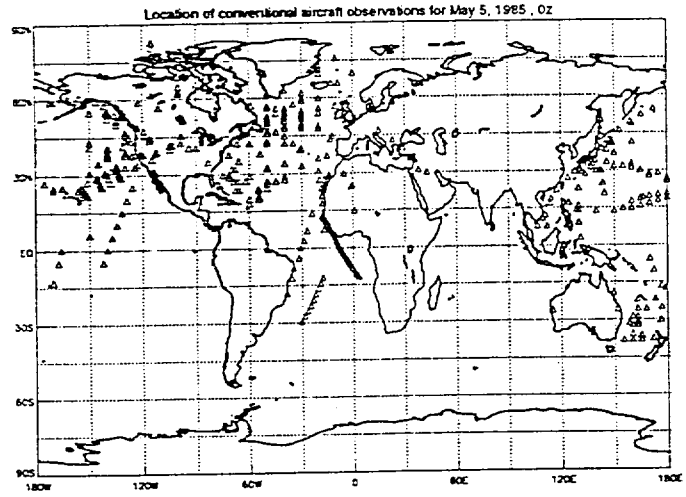
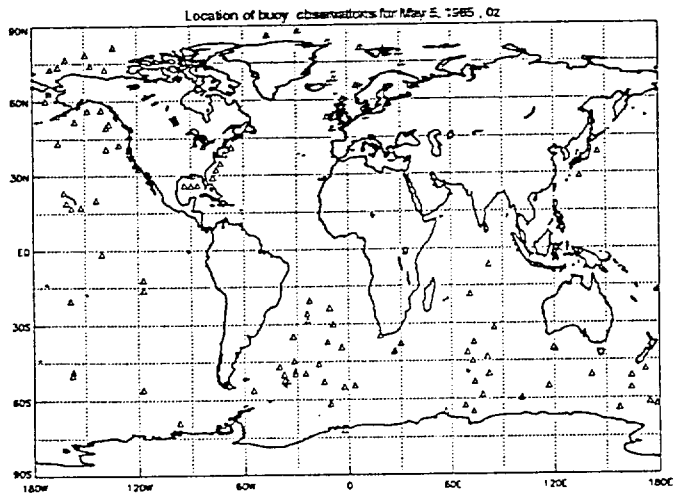
SCATTERED, "INCOMPLETE" OBSERVATIONS

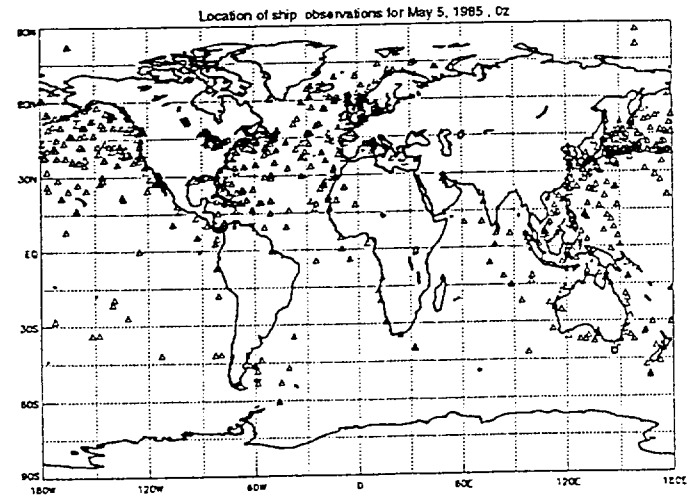


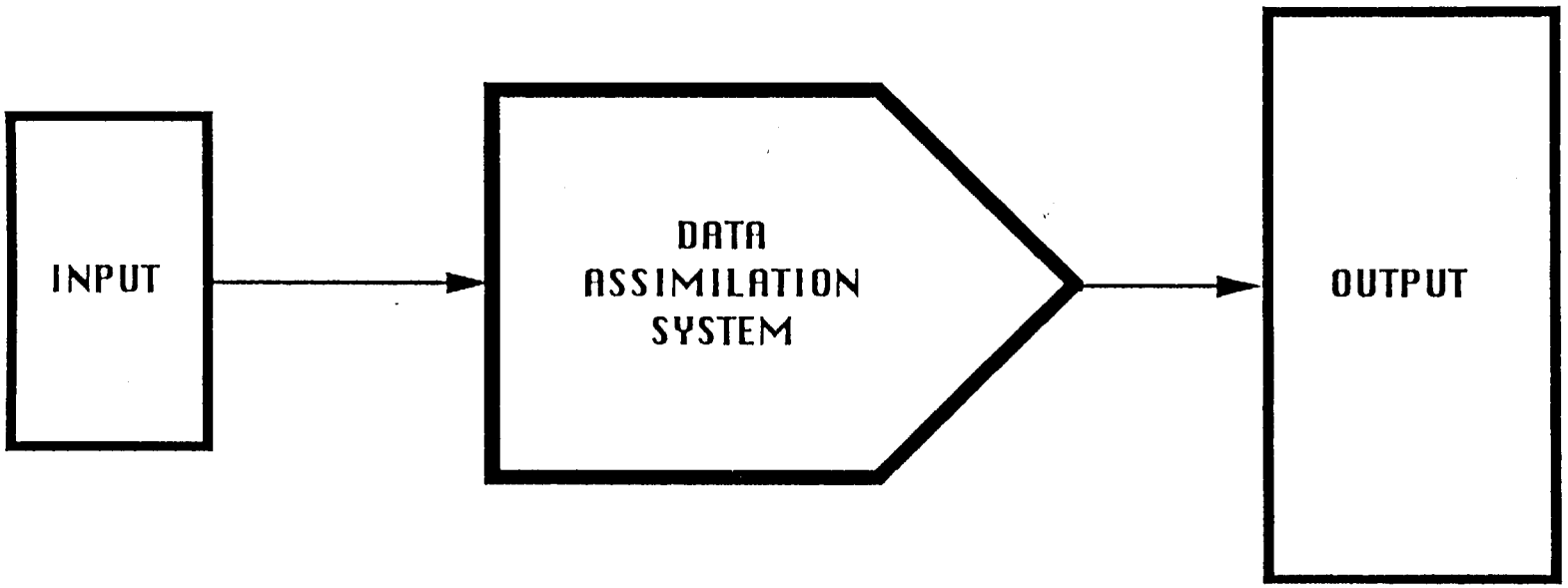




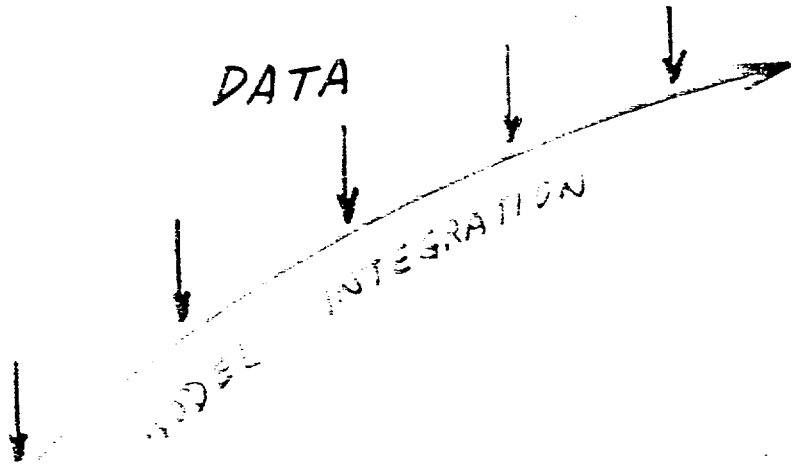







INPUT
DATA
ASSIMILATION
SYSTEM
OUTPUT

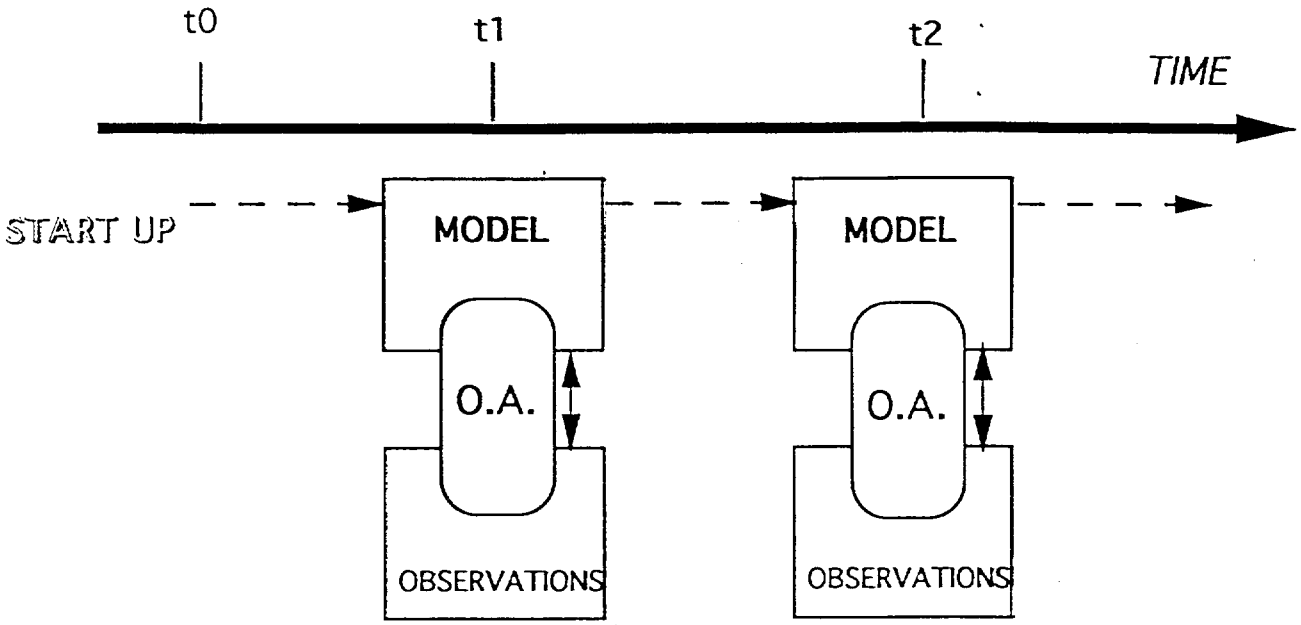
Insertion of Data into the Model



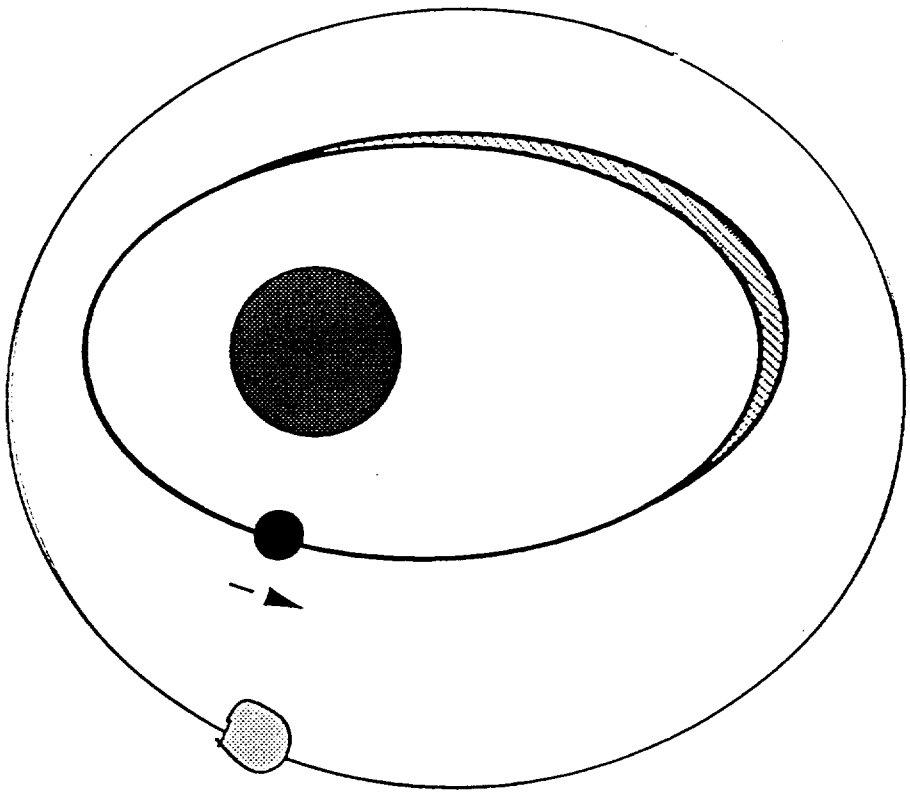
⇒ *a continuous AGCM integration with additional heat, momentum, moisture, and mass tendency terms updated every 6 h from observations*

$$\frac{\partial x}{\partial t} = \text{dynamics} + \text{physics} + \Delta x$$

Δx : Source/sink DERIVED FROM DATA

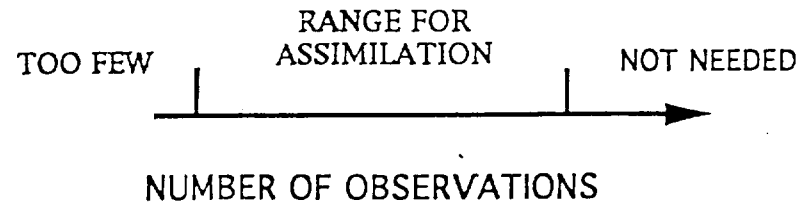


O. A. =OBJECTIVE ANALYSIS

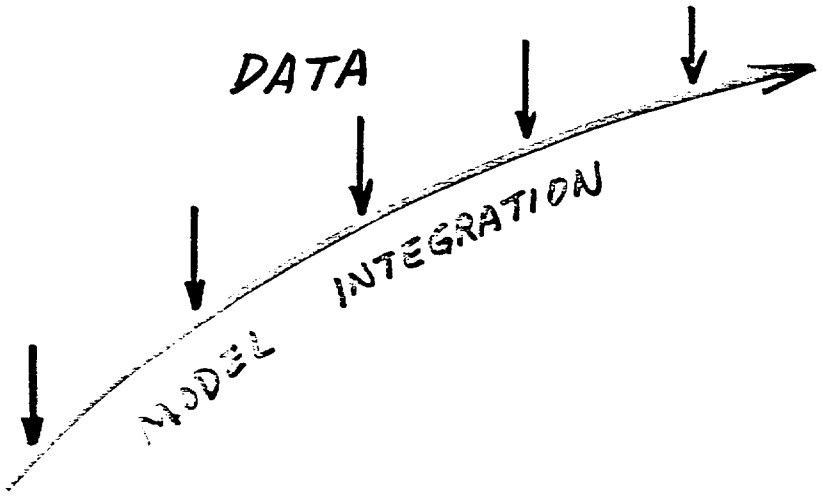


COMPONENTS

DYNAMIC SYSTEM
PREDICTIVE MODEL
OBSERVATIONS



Insertion of Data into the Model



⇒ *a continuous AGCM integration with additional heat, momentum, moisture, and mass tendency terms updated every 6 h from observations*

$$\frac{\partial x}{\partial t} = \text{dynamics} + \text{"physics"} + \Delta x$$

Δx = Source/sink DERIVED FROM DATA

dynamics = $V \bullet \nabla x$

$V = (u, v, w)$

$x =$ T, water vapor, ozone, etc.

as well as (u, v, w)

usually most observed part of the system

"physics" = solar radiative heating
infrared cooling
latent heat release
chemical sources and sinks
gravity wave breaking
turbulence
•••

"physics" often parameterized

WHAT IS THE "VALUE-ADDED" OF DATA ASSIMILATION?

1) ORGANIZES DATA

MODEL PROVIDES A "PHYSICALLY" AND "CHEMICALLY" CONSISTENT INTERPOLATOR

2) COMPLEMENTS DATA, FILLS IN UNOBSERVED REGIONS

MODEL PROPAGATES INFORMATION FROM DATA RICH TO DATA POOR REGIONS

3) SUPPLEMENTS DATA, PROVIDES UNOBSERVED QUANTITIES

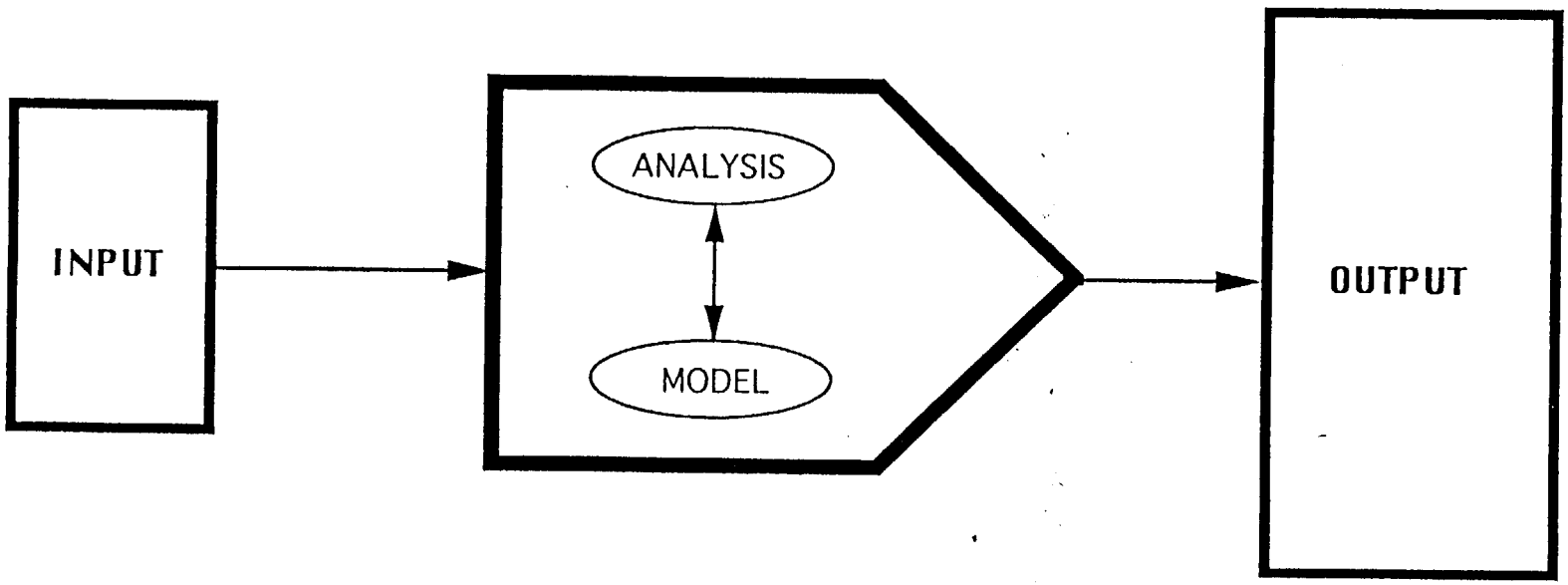
MODEL, ESPECIALLY THE PHYSICAL PARAMETERIZATIONS, PROVIDE ESTIMATES OF UNOBSERVED QUANTITIES

4) QUALITY CONTROL OF OBSERVATIONS

MANIFOLD, SIMPLEST, MODEL PROVIDES ESTIMATE OR *FIRST GUESS* OF WHAT THE FIELD IS EXPECTED TO LOOK LIKE

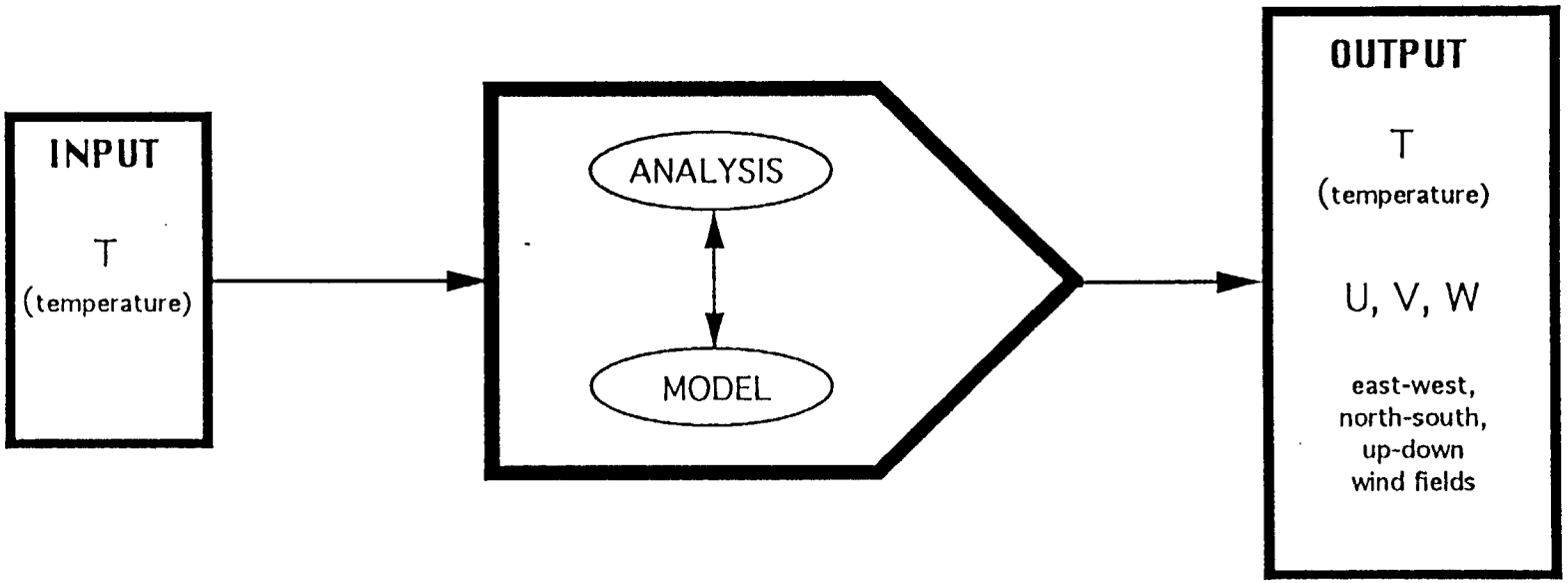
5) INSTRUMENT CALIBRATION

POTENTIALLY A POWERFUL APPLICATION, REQUIRES FORWARD MODELING OF FIRST GUESS FIELD


INPUT
ANALYSIS
MODEL
OUTPUT

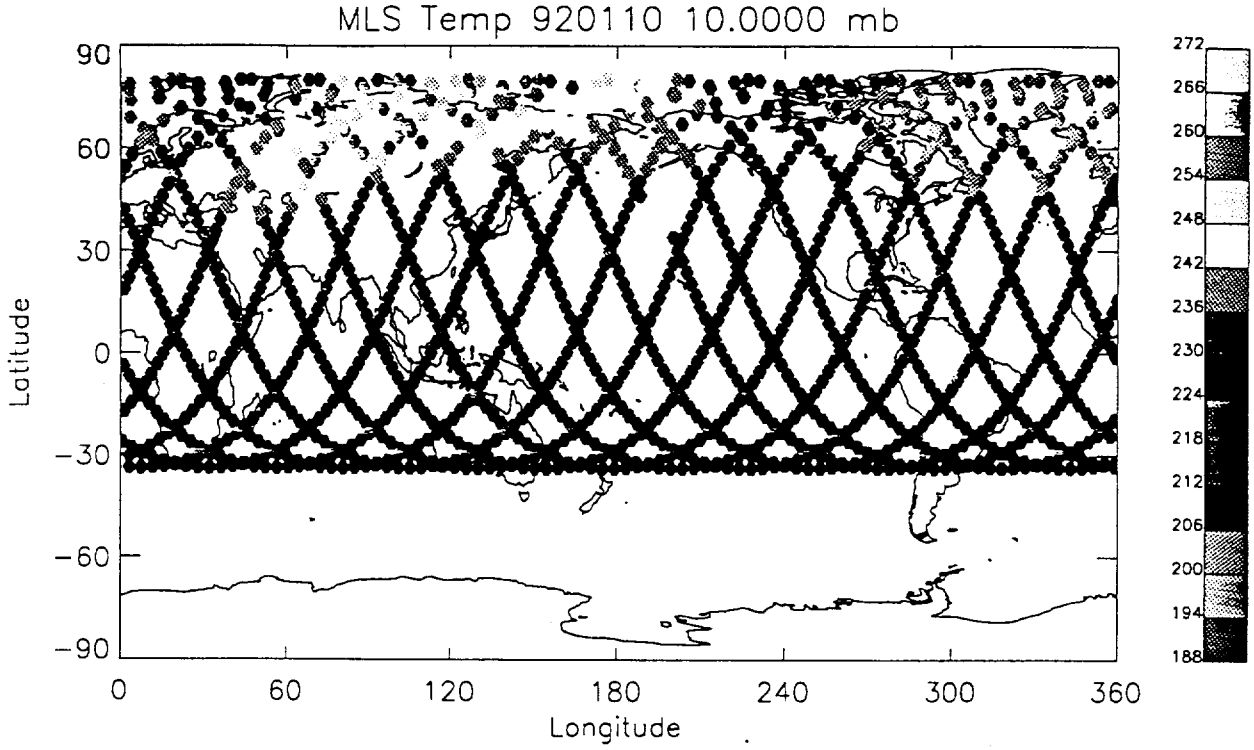
THINGS THAT THE MODEL BRINGS 1: UNOBSERVED QUANTITIES

(SIMPLE EXAMPLE IN THE STRATOSPHERE)



NOTE: FOR QUANTITY LIKE , T, THE MODEL IS A VERY SOPHISTICATED "MAPPER"

- PROPAGATES INFO TO UNOBSERVED REGIONS
- "PHYSICAL" INTERPOLATION
- ADDS DYNAMICAL MEMORY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Latitude
90
60
30
0
-30
-60
-90
0
60
120
180
240
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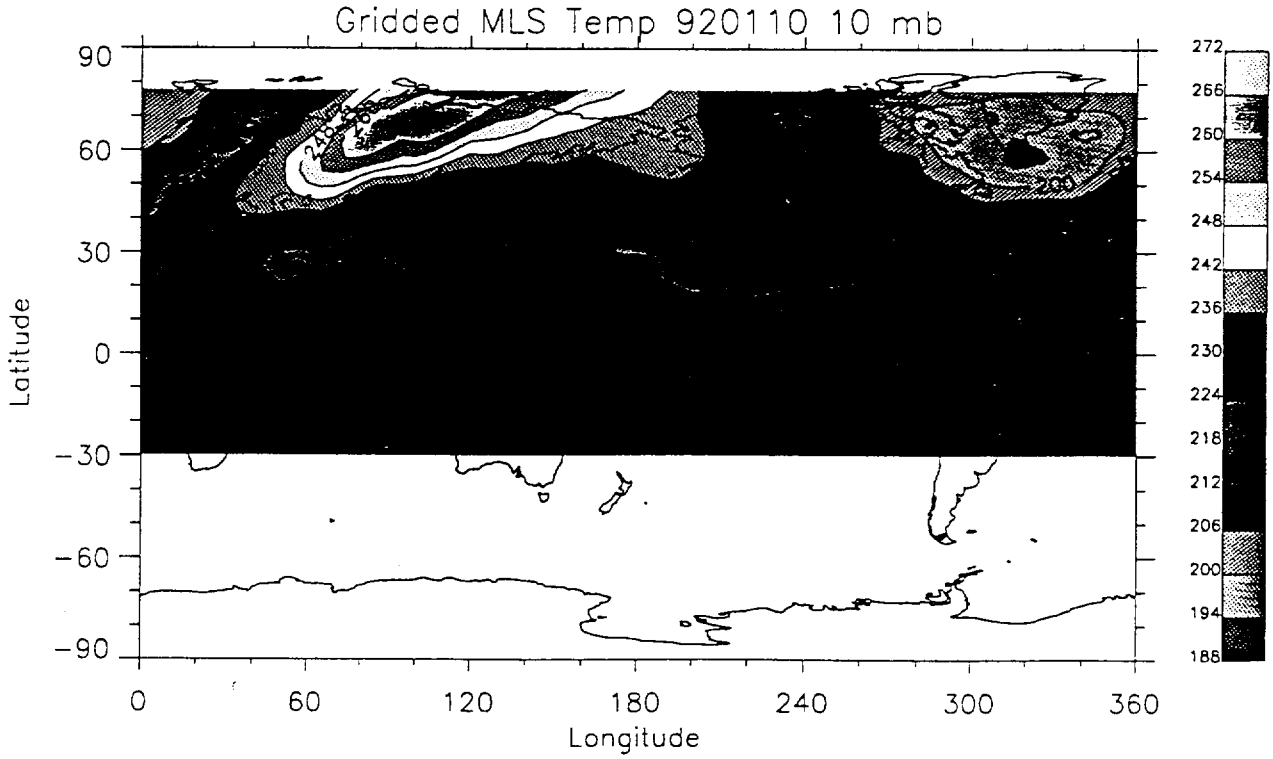
360
Longitude
272
266
260
254
248
242
236
230
224
218
212
206
200
194
188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Latitude
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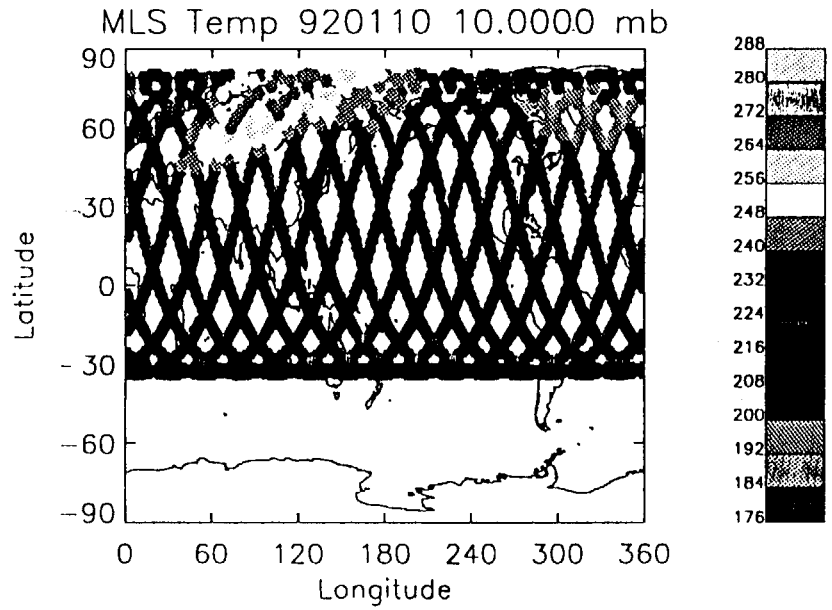
MLS Temp 920110 10.0000 mb
Latitude
Longitude
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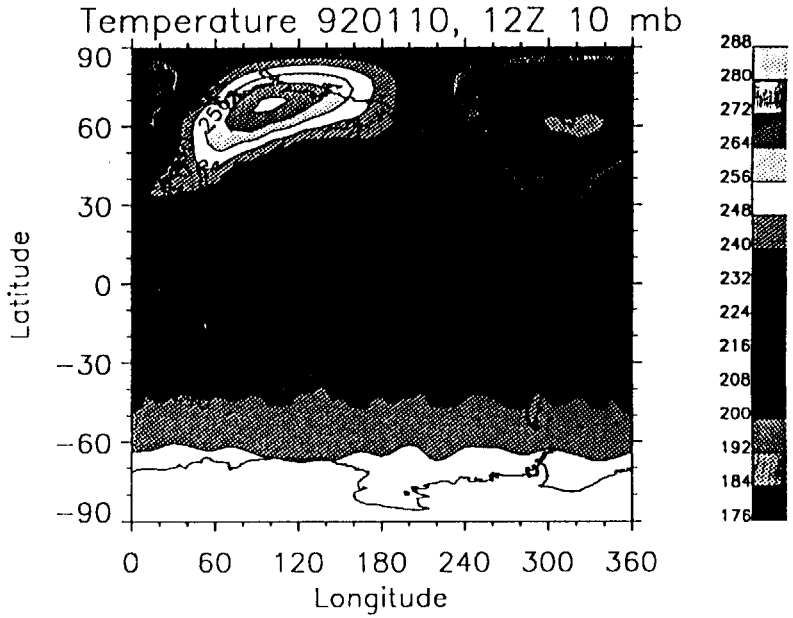
240
232
224
216
208
200
192
184
176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Latitude
Longitude
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60
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-30
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288
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264
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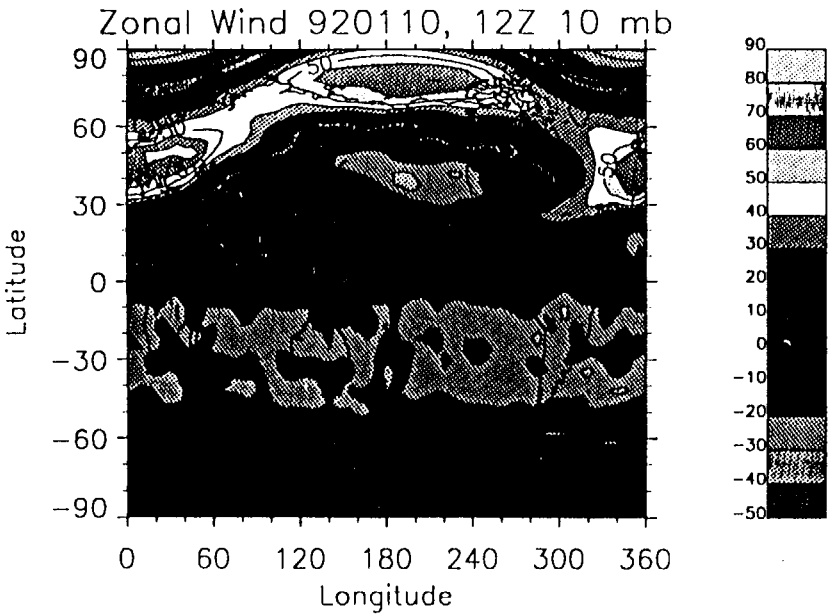
224
216
208
200
192
184
176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Longitude
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0
-30
-60
-90
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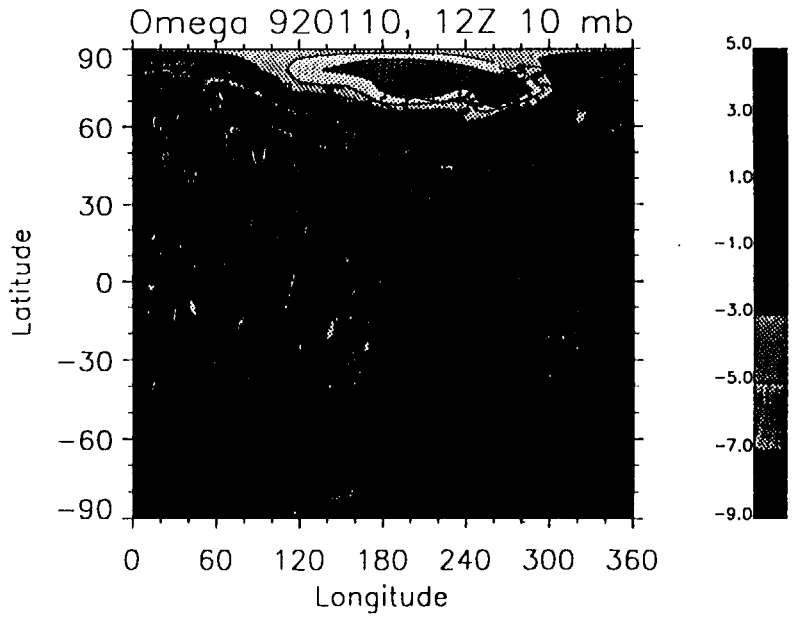
Omega 920110, 12Z 10 mb
Latitude
Longitude
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60
30
0
-30
-60
-90
0
60
120
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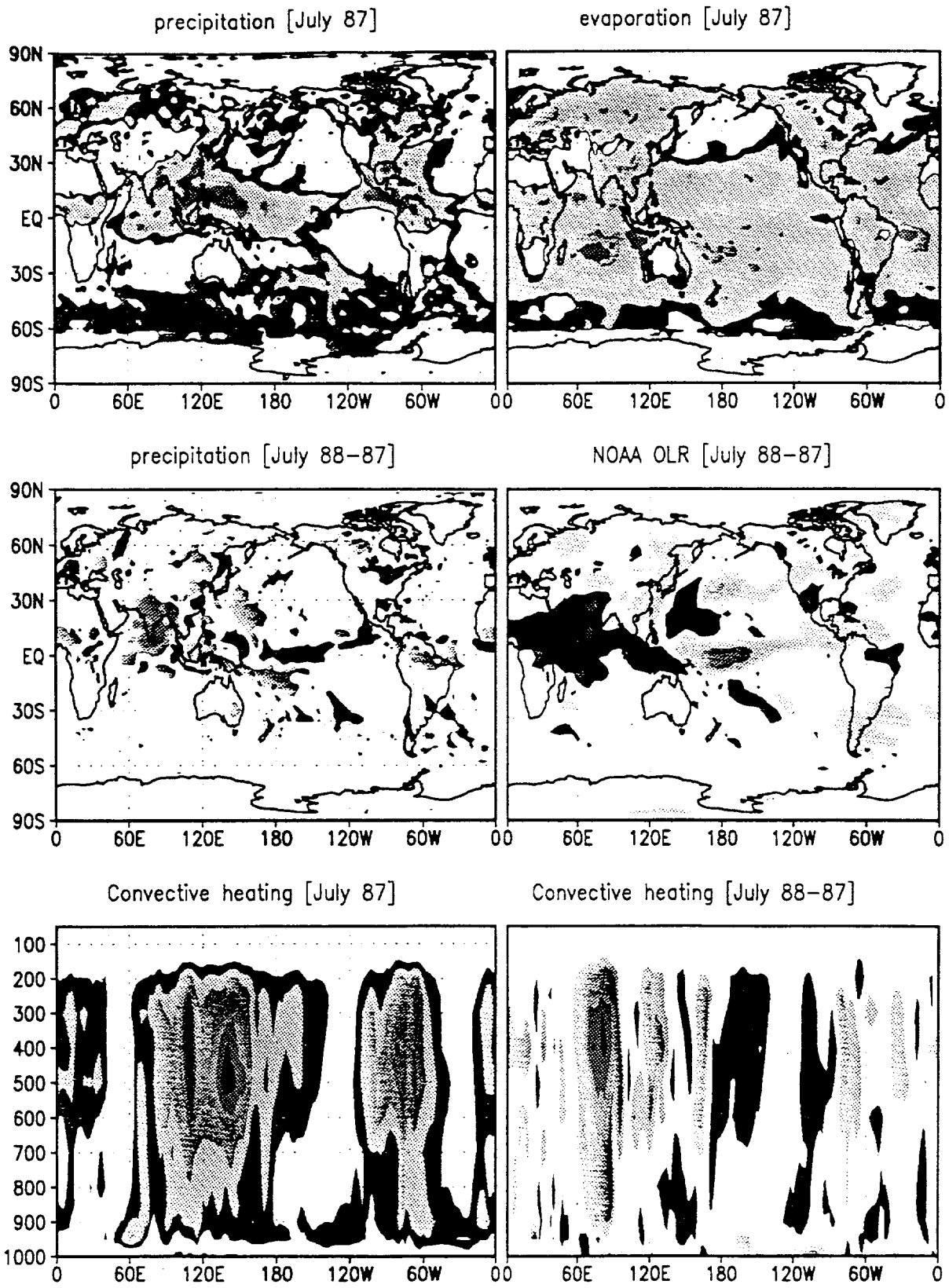
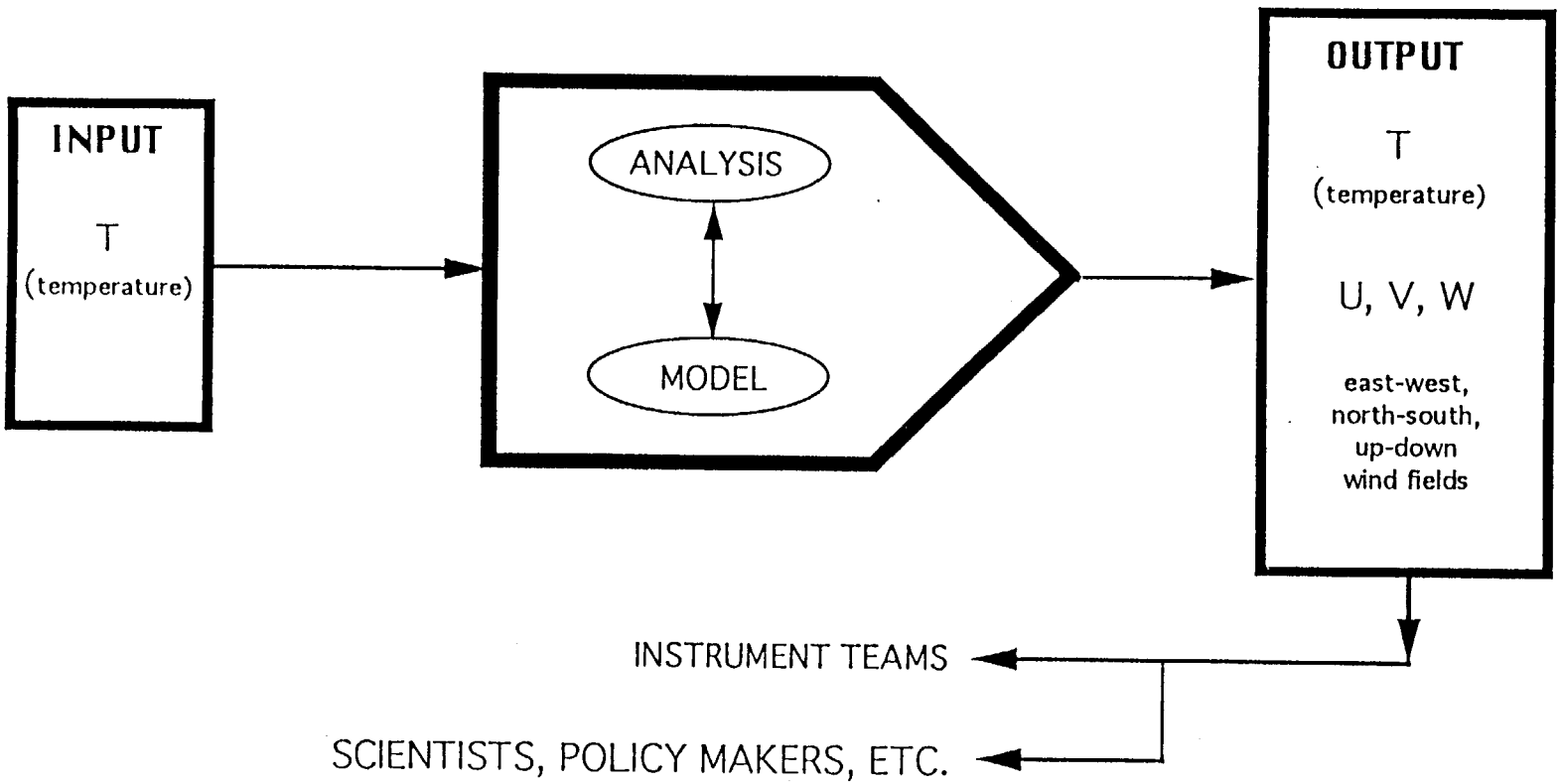
-1.0
-3.0
-5.0
-7.0
-9.0


precipitation [July 87]
evaporation [July 87]
precipitation [July 88–87]
NOAA OLR [July 88–87]
Convective heating [July 87]
Convective heating [July 88–87]
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
100
200
300
400
500
600
700
800
900
1000

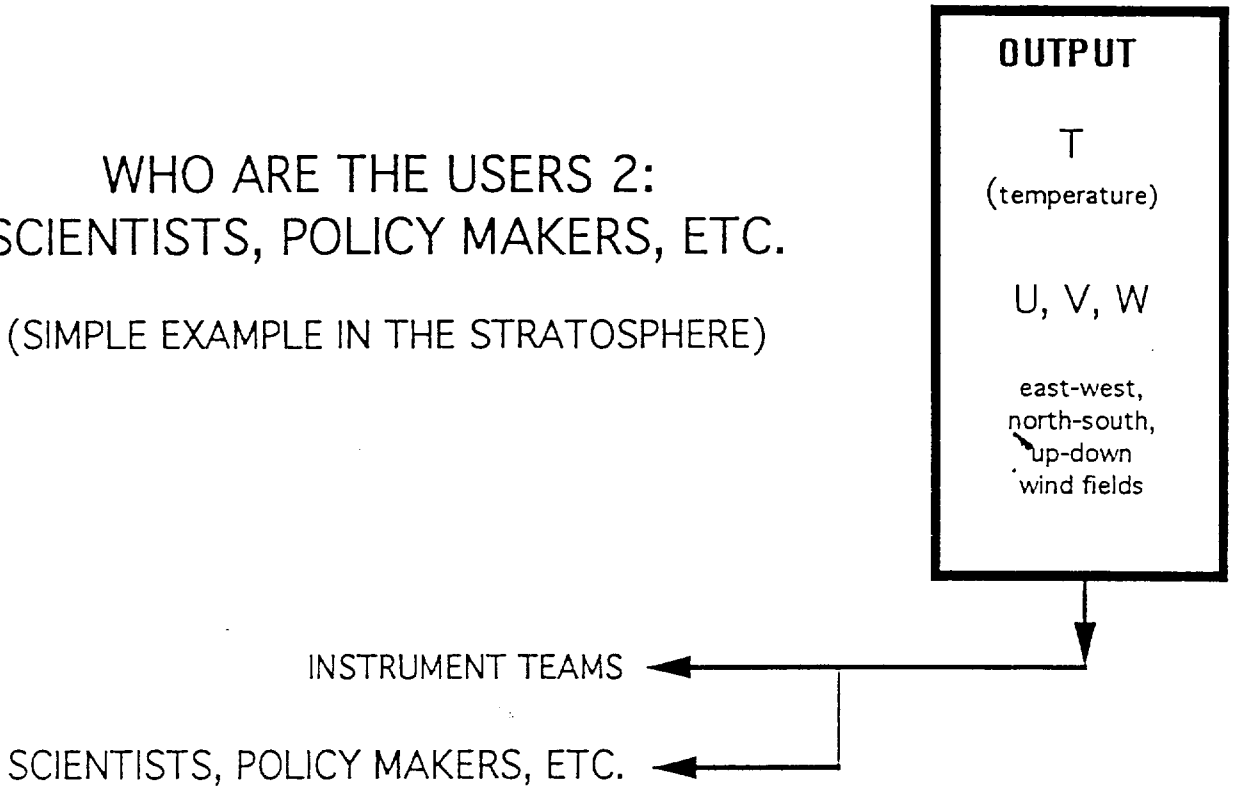
WHO ARE THE USERS 1: SCIENTISTS, POLICY MAKERS, ETC.

(SIMPLE EXAMPLE IN THE STRATOSPHERE)



WHO ARE THE USERS 2: SCIENTISTS, POLICY MAKERS, ETC.

(SIMPLE EXAMPLE IN THE STRATOSPHERE)



PROVIDE WINDS AND TEMPERATURES TO SCIENTISTS WHO PERFORM OZONE TRANSPORT EXPERIMENTS

IF "REMOVE" THE TRANSPORT VARIABILITY THEN CHEMISTRY CAN BE STUDIED MORE ACCURATELY

PROVIDE (U, V, W, T) TO FIELD EXPERIMENTS TO HELP PLAN AIRCRAFT FLIGHTS AND INTERPRET AIRCRAFT OBSERVATIONS

PROVIDE (U, V, W, T) TO SCIENTISTS PERFORMING ASSESSMENTS OF THE ENVIRONMENTAL IMPACT OF CIVIL AVIATION

REDUCE UNCERTAINTY OF TRANSPORT CALCULATION

AN EXAMPLE CUSTOMER: OZONE MODELER, ANNE DOUGLASS

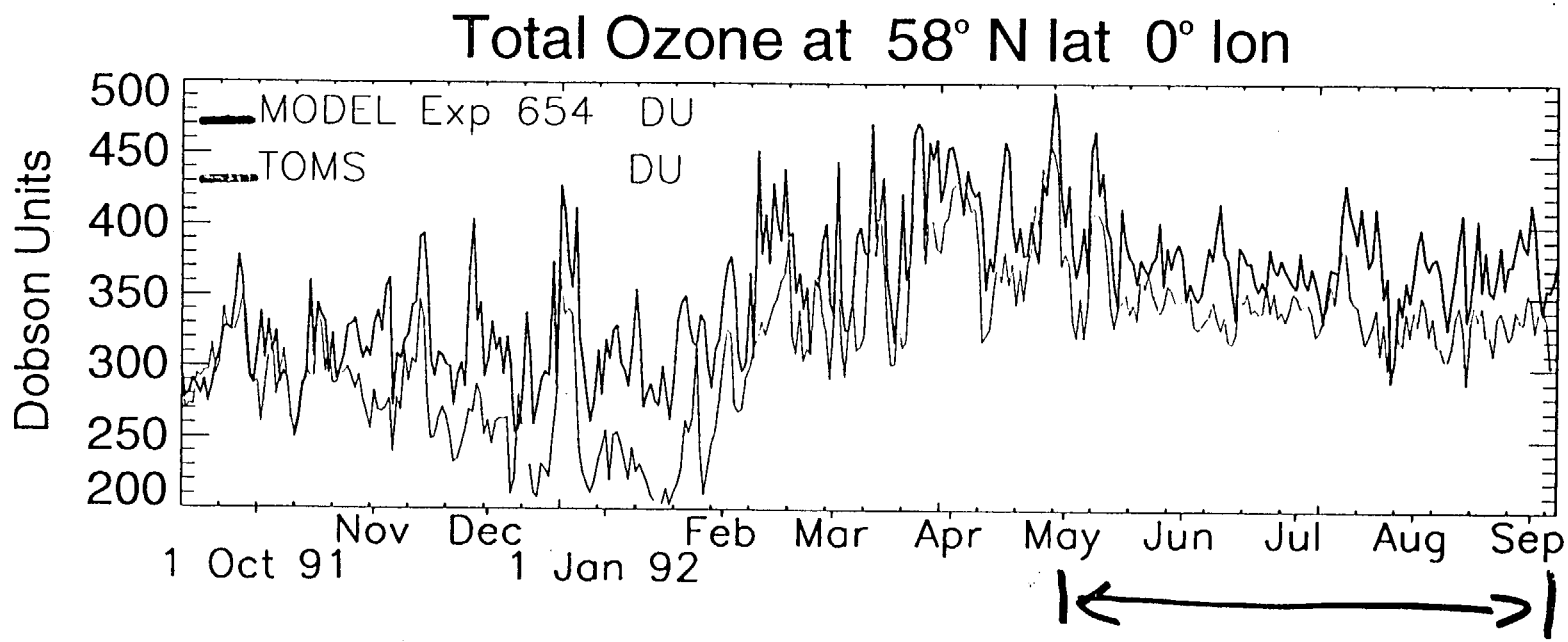
WE GIVE THE CUSTOMER V AND T AND THEY THEN USE

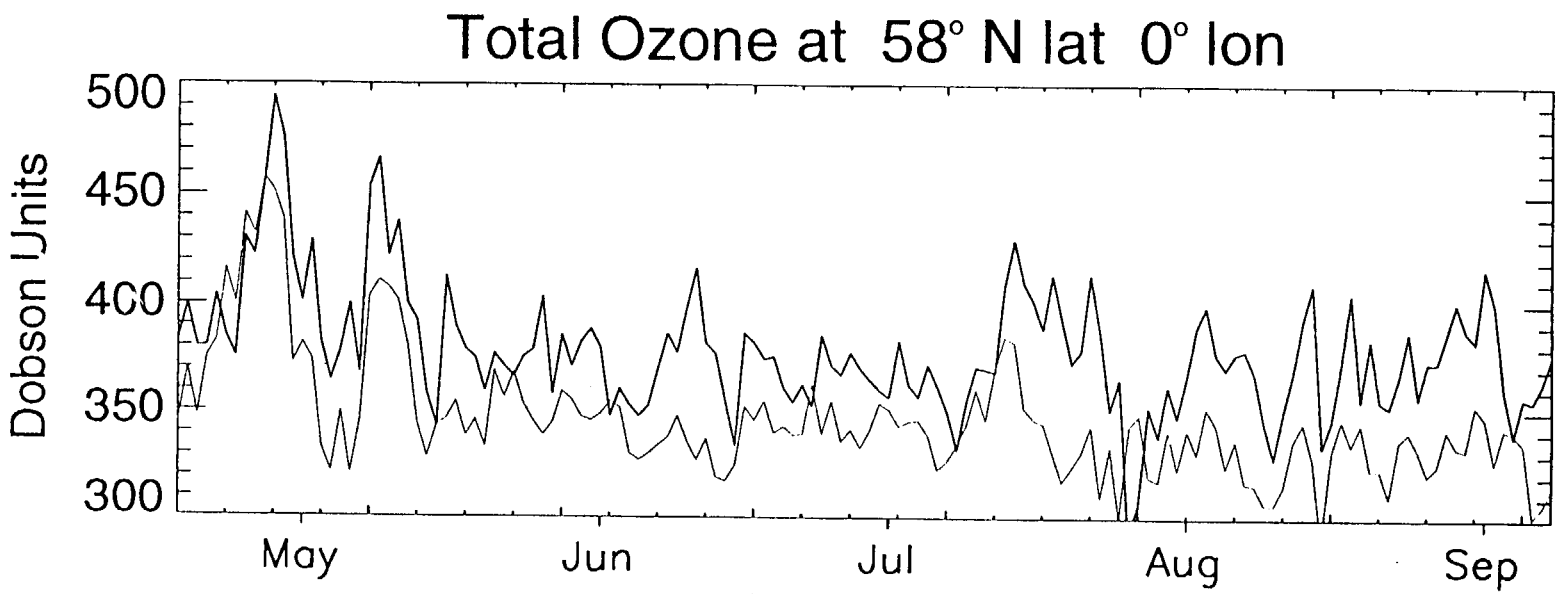
ASSIMILATION WINDS

TO

SIMULATE OZONE TRANSPORT

$$\frac{\partial O_3}{\partial t} = -V \bullet \nabla O_3 + P - LO_3$$


Total Ozone at 58° N lat 0° lon
Dobson Units
500
450
400
350
300
250
200
MODEL Exp 654 DU
TOMS DU
1 Oct 91
Nov
Dec
1 Jan 92
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep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500
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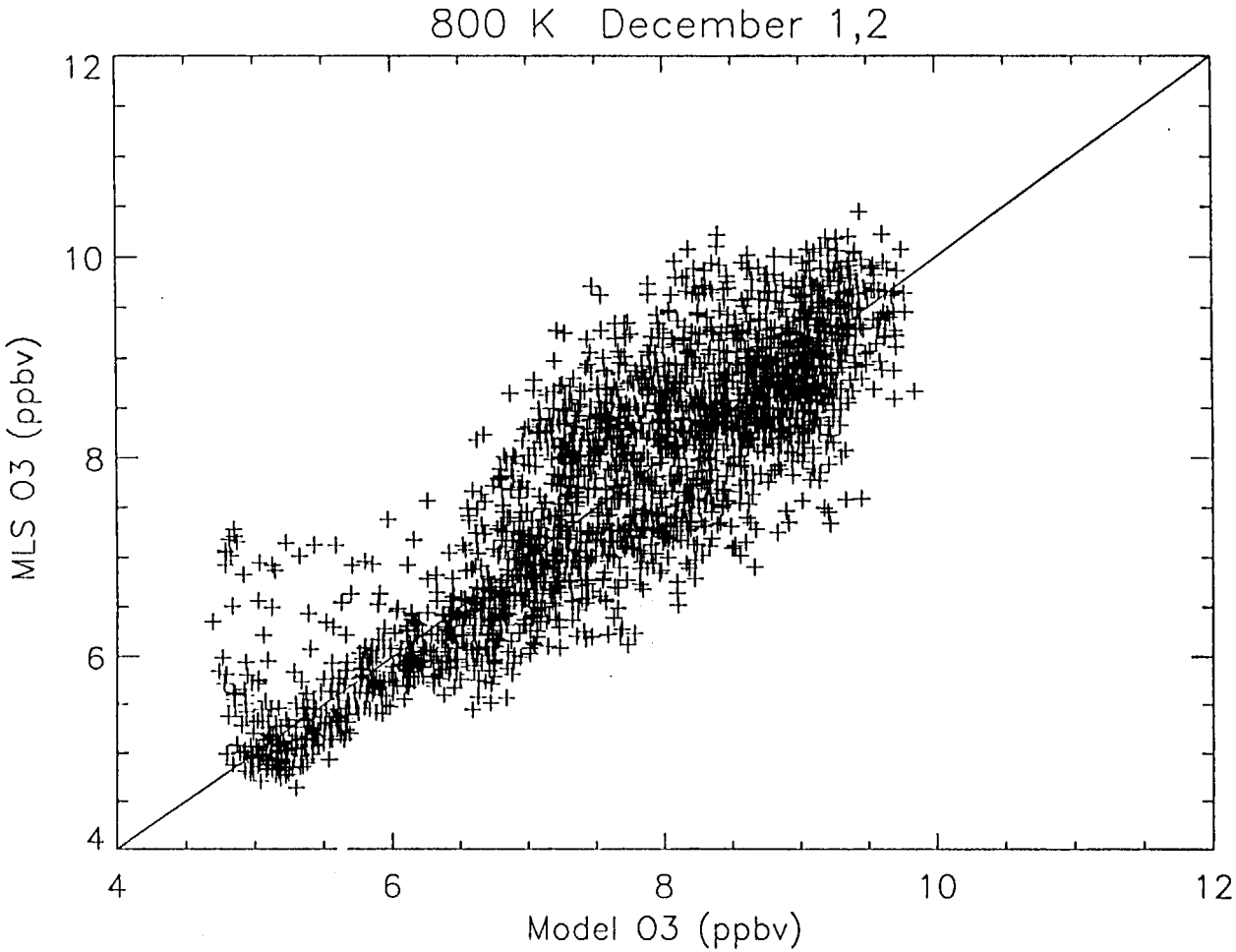


(183 GHz)

Slope = 0.95

WHO ARE THE USERS 3: INSTRUMENT TEAMS

(SIMPLE EXAMPLE IN THE STRATOSPHERE)

OUTPUT

T
(temperature)

U, V, W

east-west,
north-south,
up-down
wind fields

SCIENTISTS, POLICY MAKERS, ETC.

INSTRUMENT TEAMS

PROVIDE ANCILLARY DATA FOR RETRIEVALS
(E. G. T, O3, H2O, ETC.)

- DAO PRODUCT HAS MORE PARAMETERS THAN NMC
- DAO PRODUCT CAN BE 'TUNED' FOR INSTRUMENT
  (E.G. PARTICULAR SYNOPTIC TIME)

PROVIDE FIRST GUESS ESTIMATES OF FIELDS TO BE RETRIEVED

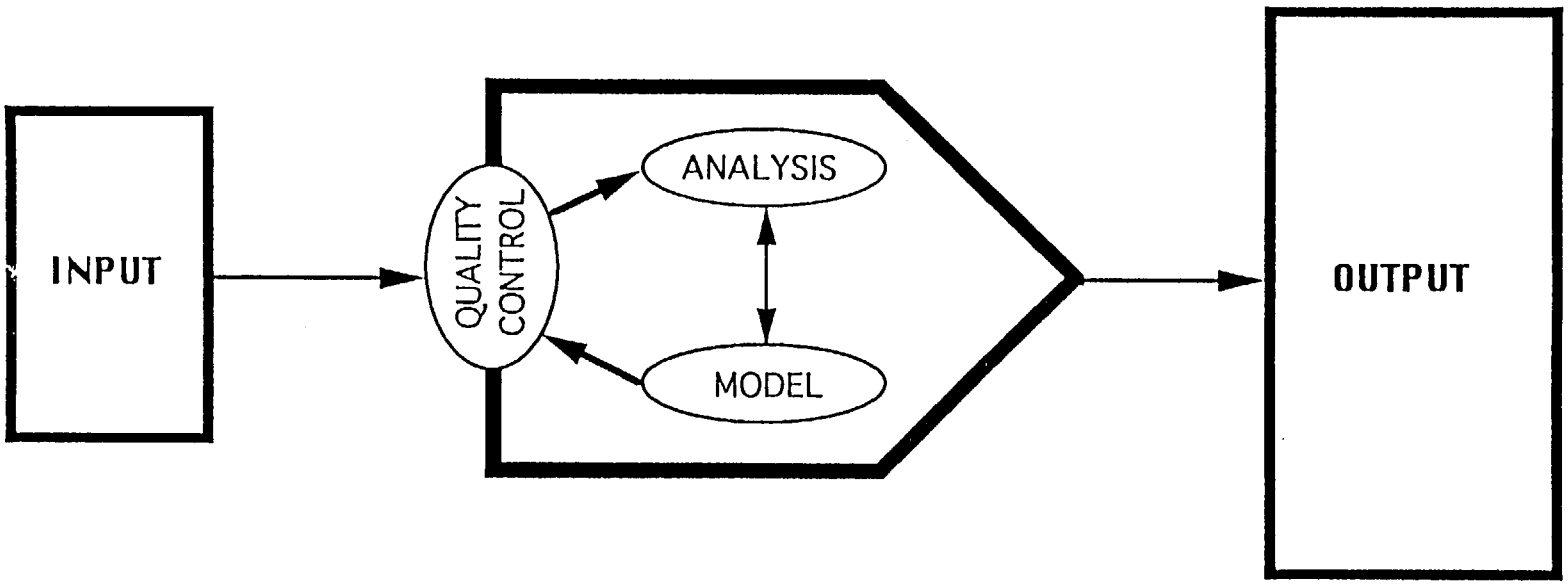
IF THE 'FORECAST' IS GOOD THEN THE 'FIRST GUESS'
TUNED FOR THE PARTICULAR SPACE-TIME LOCATION
CAN PROVIDE A SUPERIOR PRODUCT
(E.G. SUSSKIND'S TOVS PATHFINDER EFFORT)

PROVIDE QUALITY CONTROL INFORMATION

CHECK SUSPICIOUS DATA WITH ESTIMATES OF
EXPECTED VALUE

THROUGH RADIATIVE FORWARD MODEL PROVIDE ESTIMATES
OF WHAT THE INSTRUMENT SHOULD "SEE"

THINGS THAT THE MODEL BRINGS 2: QUALITY CONTROL



EVALUATION OF CURRENT CAPABILITIES

GOOD ----------> REASONABLE ----------> SHAMEFUL

WINDS MARINE SURFACE STRESS MARINE STRATUS

TEMPERATURE EVAPORATION PRECIPITATION WATER VAPOR

TROPICAL CLOUDS

AND LOTS OF THINGS WE ARE NOT DOING AT ALL YET.....

GROUND WETNESS

HOW DO WE IMPROVE?

- MORE DATA
- IMPROVE MODEL
- IMPROVE ANALYSIS

dynamics = $V \cdot \nabla x$

$V = (u, v, w)$

$x =$ T, water vapor, ozone, etc.

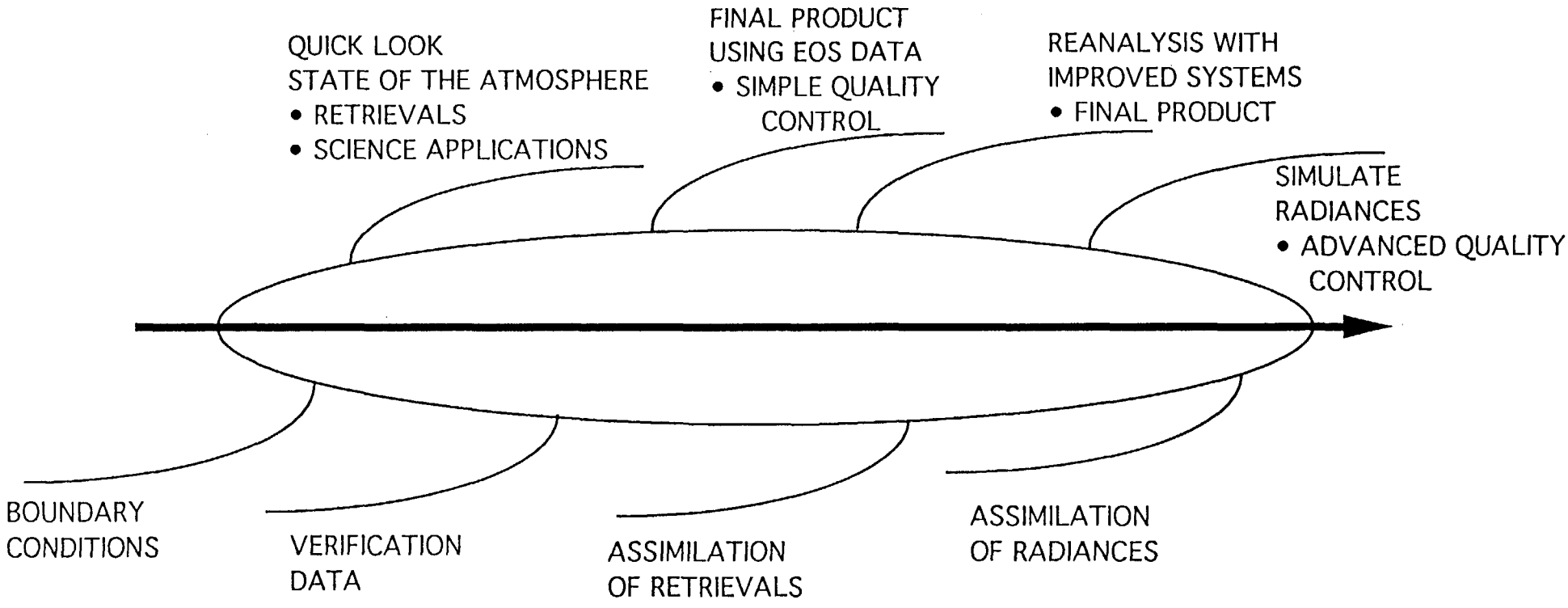
as well as (u, v, w)

usually most observed part of the system

"physics" = solar radiative heating
infrared cooling
latent heat release
chemical sources and sinks
gravity wave breaking
turbulence
• • •

Where ECS is Targeted

"physics" often parameterized


QUICK LOOK
STATE OF THE ATMOSPHERE
• RETRIEVALS
• SCIENCE APPLICATIONS
FINAL PRODUCT
USING EOS DATA
• SIMPLE QUALITY CONTROL
REANALYSIS WITH
IMPROVED SYSTEMS
• FINAL PRODUCT
SIMULATE
RADIANCES
• ADVANCED QUALITY CONTROL
BOUNDARY
CONDITIONS
VERIFICATION
DATA
ASSIMILATION
OF RETRIEVALS
ASSIMILATION
OF RADIANCES

SUMMARY: WHAT DOES DATA ASSIMILATION DO?

PROVIDES BEST ESTIMATE OF THE STATE OF THE SYSTEM

ALLOWS EXTRACTION OF MAXIMUM INFORMATION CONTENT FROM DATA

ALLOWS MORE QUANTITATIVE INTERPRETATION OF SATELLITE DATA

OPENS UP WHOLE NEW CAPABILITIES THROUGH ESTIMATES OF UNOBSERVED QUANTITIES

CRUCIAL FOR QUANTIFYING NATURAL VARIABILITY

PROVIDES A UNIFYING EFFECT

PRODUCTS USEFUL TO ALL DIRECTORATE, BROAD COMMUNITY

BRINGS TOGETHER COMPONENT MODELS FOR DATA-DRIVEN DEVELOPMENT