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TECHNICAL NOTE

7WW/TN-80/002

SATELLITE DERIVED WINDS

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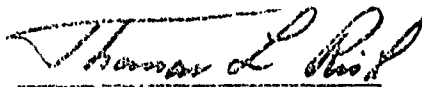


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PREFACE

Captain Heckman is a reserve officer assigned to 7WW/DON. He is a full-time meteorologist for the National Environmental Satellite Service (NESS) in Kansas City. The following was written and compiled by Capt Heckman during inactive duty training.

This Tech Note is the only known publication which identifies, all available satellite derived wind bulletins and provides complete and comprehensive decoding instructions for U.S., European, and Japanese data.

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SATELLITE DERIVED WINDS

1. INTRODUCTION. Forecasting winds over data-sparse areas of the globe is at best an inexact procedure. The best guidance available to most forecasters are numerical weather prediction (NWP) products. However, forecasters need to constantly check the accuracy of the forecast products. The accuracy of the forecast product is only as good as the quality of the observation data used to generate the forecast. If the input to the numerical model is poor quality data, subsequent forecast products will likewise be poor.

For many years the best data source available to check the accuracy of NWP products were AIREPs of upper level winds. These reports allowed forecasters to evaluate the quality of NWP products over well-traveled routes, but did little to aid the military forecaster briefing aircrews flying other than standard routes and altitudes. Now data are available to help alleviate this problem.

These new data are wind vectors developed from geostationary earth orbiting satellite (GOES) imagery. Several countries currently operate GOES systems, making possible many additional observations. This Tech Note is designed to introduce AWS forecasters to these data, give a brief description of the process used to derive these data, discuss their accuracy, give detailed instructions how to decode the satellite observation (SATOB) report, and suggest possible uses for the data.

2. GENERATION OF SATELLITE WIND VECTORS. Satellite wind vectors are made available by National Environmental Satellite Service (NESS) through the Satellite Wind Section (SWS) for low, middle, and high levels. The primary mission of SWS is twofold:

- Generate and quality control middle and high level wind vectors.
- Generate and quality control low level wind vectors and quality control NWP-generated low level vectors.

For further information see Green, et al. (1975) and Young (1975).

A completely objective computer algorithm has been designed for the generation of low level wind vectors. The process involves ingesting consecutive GOES images (a picture pair) into the computer, accurately defining the position of the two images relative to a surface feature, and then conducting several statistical tests. These tests measure numerous lag correlations between picture pairs, such as cloud displacement between two 30-minute interval images. After these complex processes are completed, the vectors are edited by SWS through a comparison with latest 850mb and surface analyses. SWS rejects about 10% of the vectors. The complete process is beyond the scope of the Tech Note. For a more detailed account of the procedures see Green, et al (1975).

SWS produces middle and high level vectors using the "manual method" which consists of the following steps:

a. Select cloud targets from a movie loop. Movie loops for both visual and IR data are available in 8 and 4km resolution. Typical loops consist of 5 images at 30 minutes intervals.

(1) The loop is fed through an overhead projector which focuses the image on a horizontal digitizing work area.

(2) A sheet of white paper is placed on the table and is used as a worksheet. By viewing the movie loop, meteorologists select potential cloud tracers and mark beginning and end points on the worksheet.

(3) Analysis times are currently 10, 16, and 22 GMT.

b. Determine cloud heights using the Man-Machine Interactive Processing System (MMIPS).

(1) IR data are ingested by the MMIPS computer to derive cloud top temperatures. Meteorologists work interactively with the computer to determine a representative cloud top temperature; they must determine the emissivity of the cloud so the proper temperatures are used. This step is important because many tracers are thin, allowing interference from the surface; that is, the sensed temperature is a combination of the cloud temperature and the temperature of the underlying surface. After this problem is addressed, a representative cloud temperature is processed by MMIPS; this is used to derive the height of the cloud tracer.

(2) Cloud tracer coordinates and estimated cloud temperatures are then digitized. Meteorologists identify the beginning and end points of cloud tracers on an X, Y coordinate board using a movable cursor. Meteorologists simultaneously enter the value of the cloud temperature.

(3) MMIPS then transforms these X, Y coordinates to earth located vectors. Additionally, MMIPS works interactively with NMC's massive data base to compare the MMIPS-derived cloud temperature and the current vertical temperature profile in the same region of the globe. The comparison yields a pressure level where the cloud temperature was measured. This level is rounded off to the nearest 10 mb.

c. Calculate wind vector for the derived cloud height using MMIPS. As with the low level winds, great efforts are made to insure the accuracy of the final product. Current analysis are used to edit all vectors before being released to the user community.

3. ACCURACY OF DATA. The term "accuracy" is misleading because to determine accuracy one would need to compare the information obtained against some established fact or ground truth. However, a ground truth regarding atmospheric motion does not exist - the true field of motion is an unknown. We now imply that we can determine this motion by tracking rawinsondes, radiosondes, or measuring the rate of rotation of an anemometer.

The most direct measurements of upper-level atmospheric motion are taken using radiosondes. Many studies undertaken to determine the accuracy of middle and high satellite winds have used radiosonde data as the comparative source, while ship reports and hourly observations were additional sources used to determine the accuracy of the low level vectors.

Results of early studies (Hubert and Whitney, 1971) revealed large differences between individual rawinsonde measurements and satellite derived wind vectors. Comparison of between rawin winds at 850mb and satellite wind vectors in a later study (Hubert and Whitney, 1974) showed that there was good agreement between the two sources when numerous satellite vectors and rawin measurements were used in a statistical "best fit analysis". The compatibility of these data sources therefore implied that the accuracy of the satellite derived winds are in good agreement with established accuracy of the rawinsonde derived winds. The main point is that although individual satellite vectors may deviate slightly from nearby radiosonde observations, one should not assume the satellite vectors are incorrect.

Results of the latest study (Hubert, 1976) revealed that approximately 68 percent of middle and high level satellite vectors deviated 15 knots or less from radiosondes, while low vectors deviated by approximately half this value. One of the results indicated that ... "the accuracy of most cloud vector (satellite derived) winds is about the same as that of Pibal observations, but a small portion (about 15%) contains significantly larger errors."

4. POSSIBLE USES OF THE DATA. In order to use the data, the data must be routinely received over teletype and plotted. Mission requirements will dictate ways to best use the data, but several suggested uses are given below. Instructions for decoding the satellite observation report and a sample bulletin are given in Appendices A and B.

Surface winds are available over many regions of the globe. Low level vectors can lead to a much better surface analysis, especially local analysis. Also, units supporting low level missions, such as Search and Rescue, can benefit by getting vectors in a more timely manner rather than "eyeballing" a wind or waiting on latest facsimile analysis.

Some of the uses of the high level wind vectors are given below.

- a. To augment the upper air analyses with satellite vectors.
- b. Blend satellite derived wind vectors with AIREPs to define the accuracy of NWP products, both in respect to forecast speeds as well as position of major synoptic features (troughs, ridges, pressure centers, etc.) defined by wind directions.
- c. Satellite derived winds would also make excellent aircrew briefing aids when incorporated into existing briefing tools.

REFERENCES

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- _____, 1976, "Wind Determination from Geostationary Satellites," Proceeding of the 19th COSPAR meeting, Keynote paper, C. 36.1, 1-6.
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APPENDIX A

SATELLITE WIND CODE

Satellite Observation (SATOBS) is a rather involved and extensive WMO code used to transmit data derived from GOES systems to worldwide users. We only need to use those sections dealing with satellite derived winds and temperatures. The general heading of this bulletin is TWXXii. An explanation of the code groups are given below. A sample bulletin and plot are given in Appendix B.

Section 1 - Header

The format for this section varies depending on the source of the data.

For US data the header is:

TWXXii KWBC YYGGgg
YYXX YYGG/ I₁I₂I₃//

Line 1: TWXXii KWBC YYGGgg

TW: designator for satellite derived winds

XX: geographical designator - XN for northern hemisphere
XS for southern hemisphere
XX for unspecified area

i: bulletin number in series, 1-9. Each bulletin can contain up to 90 wind vectors, so an entire series may contain 810 wind vectors.

i: global octant designator: 0 - northern hemisphere, 0-90W
1 - northern hemisphere, 90W-180W
2 - northern hemisphere, 180E-90E
3 - northern hemisphere, 90E-0
5 - southern hemisphere, 0-90W
6 - southern hemisphere, 90W-180W
7 - southern hemisphere, 180E-90E
8 - southern hemisphere, 90E-0

Example: TWXN20 designates the second bulletin in the series for wind vectors between 0-90°W in the northern hemisphere.

KWBC: transmission center of NMC/NESS.

YY: day of the year of satellite observation.

GG: hour of the day of transmission (GMT).

gg: minute of the hour of transmission.

Line 2: YYXX YYGG/ I₁I₂I₃//

YY: TOB designator.

XX: not used.

YY: day of month designator (51-81 (day of month + 50); indicates that wind speed is in knots).

GG: hour of the observation (GMT).

I₁I₂I₃: designator for country or international agency operating GOES systems from which data are obtained.

000 - European
100 - Japan
200 - USA
300 - USSR
400 - 900 - reserved

For European data, the header is slightly modified:

The standard header is:

TSXXii EESA YYGG gg
YYXX YYGG/ I₁I₂I₃//

TS: designator for geostationary satellite derived wind data.

XX: same as US data.

i: bulletin number in series, (1,2,3) for octants 0 and 5; 1+5 bulletin number in series (6,7,8) for octants 3 and 8.

i: global octant designator (same as US data).

Example: TSXN63 designates the first bulletin for wind vectors between 90E - 0° in the northern hemisphere.

EESA: transmission center of German communication system.

YYGGgg: same as US data.

YYXX: same as US data.

YY: day of month (01-31; indicates wind speed in meters per second). The rest is the same as US data.

For Japanese data, the header is also modified. The standard header for Japanese satellite wind data is:

TSXXii RJTD YYGGgg
YYXX YYGG/ I₁I₂I₃//

TSXX: same as European data.

ii: bulletin identifier for hemispheric wind data; 10-14 for northern hemisphere, octant 2; 15-19 for southern hemisphere, octant 7.

Example: TSXS16 designates the second bulletin for wind vectors between 180E-90E.

RJTD: transmission center for Japanese communications system.

The remainder is in the same format as US data.

Section 2 - Data for wind and cloud-top temperatures at specified pressure levels; designated by 222.

222 B₁B₂B₃nn U_{1a}U_{1o}U_{1a}U_{1o}/ P_cP_cT_cT_cT_a d d f f f P_cP_cT_cT_cT_a d d f f f etc.

The three digit designator, B₁B₂B₃, specifies the octant and a 10x10 degree latitude/longitude box within which a specified number (nn) of wind vectors are located. This provides a quick reference to where the data are located and allows the forecaster to quickly determine if any data are available in the area of interest. Figure 1 provides a visual indication of the location of 10x10 degree blocks for wind vector locations. The three numbers identify one of the blocks in the figure; e.g., 023 identifies a location in octant 0, in the 10x10° lat/lon block bounded by 20-30N and 30-40W. The breakdown of the remainder of the code identifies the location to the nearest degree and the wind data calculated for that point.

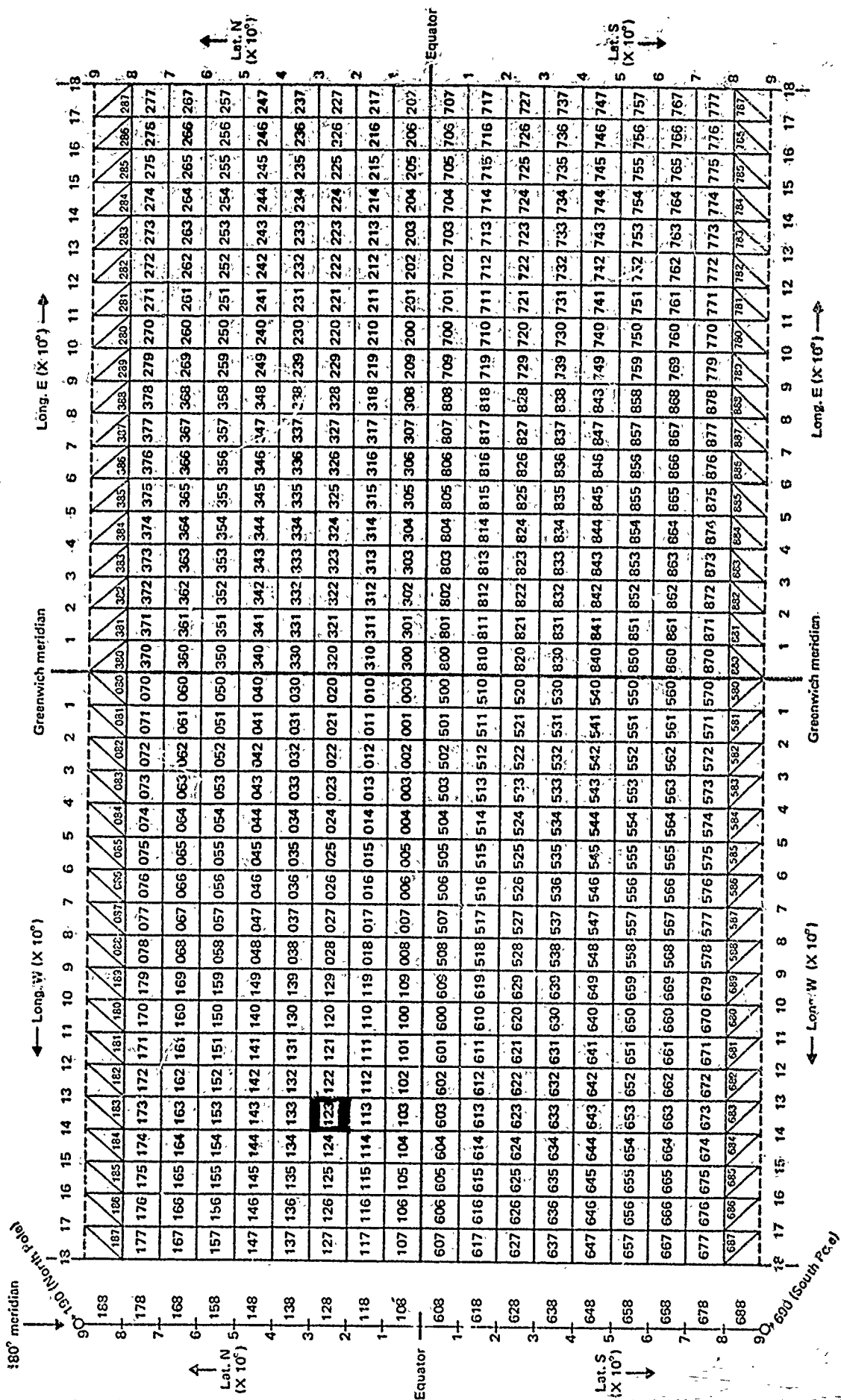
B₁: indicates the octant in which data are available.

B₂: latitude of 10x10° lat/lon box in which wind vectors are located, e.g.

0 - 0 to 10°N or S latitude, dependent on the octant.

1 - 10 to 20°N or S, dependent on octant, etc.

$B_1B_2B_3$ — Number designating a $10^\circ \times 10^\circ$ square in a geographical grid



B_3 : longitude of $10 \times 10^\circ$ lat/lon box in which wind vectors are located, e.g.

0 - 0 to 10° E or W or 100 to 110° E or W, dependent on the octant, etc.
1 - 10 to 20° E or W or 110 to 120° E or W, dependent on the octant, etc.

Example: 123 - $B_1 = 1$, identifies octant 1, between 90° W and 180° W in the northern hemisphere.

$B_2 = 2$, latitude lies between 20° and 30° N.

$B_3 = 3$, longitude lies between 130° and 140° W.

Therefore 123 describes the $10 \times 10^\circ$ latitude/longitude box that is located within.

20° N 130° W, 20° N 140° W

30° N 130° W, 30° N 140° W

This block is identified in Figure 1.

Note: The US operates two GOES systems, providing coverage from 49° N south to 49° S and from 20° W westerward to 170° E for octants 0, 1, 2, 5, 6, and 7. The European GOES provides winds for octants 0, 3, 5, and 8. Japanese GOES provides winds for octants 2 and 7.

nn: number of wind vectors available in box given by $B_1 B_2 B_3$.

If nn > 5, then four vectors are defined on line 1, vectors 5-8 are on line 2, etc.

$U_{1a} U_{1o} U_{2a} U_{2o}$: last digit of latitude and longitude where two wind vectors are located to the nearest degree; these must be used in conjunction with $B_1 B_2 B_3$.

Example: 1234 used in conjunction with example above, $B_1 B_2 B_3 = 123$.

vector 1 is located at 21° N 132° W.

vector 2 is located at 23° N 134° W.

Note: Two vector wind points are contained in this example.

$P_C P_C$: pressure level in tens of mb where cloud top temperature exists and where wind vector is observed. $P_C P_C$ is derived by converting cloud-top temperature to a pressure level using MMIPS.

$T_C T_C$: temperature ($^\circ$ C) at cloud top level. Value estimated from IR radiance data.

T_a : tenth of degrees C and designator of sign of $T_C T_C$. Odd integer - negative temperature; even integer - positive.

The code used is Code-Table 106 in FMH-4 or WMO Code 3931.

For US GOES data $T_a = 1$.

Code figure	Sign of temperature*	Temperature (tenths)
0	+	0.0 and 0.1
1	-	0.0 and 0.1
2	+	0.2 and 0.3
3	-	0.2 and 0.3
4	+	0.4 and 0.5
5	-	0.4 and 0.5
6	+	0.6 and 0.7
7	-	0.6 and 0.7
8	+	0.8 and 0.9
9	-	0.8 and 0.9

*Sign: + means above zero.
- means below zero.

ddfff: wind direction and speed in knots, where dd is in 5-degree increments.

If first f > 0 or f = 5, the speed > 100kts.

The European wind data are in meters per second; multiply speed values by 2 to convert to knots.

Section 3 - Wind data at estimated pressure levels.

333 B₁B₂B₃nn U_{1a}U_{1o}P_eP_e/ ddfff U_{1a}U_{1o}P_eP_e/ ddfff

B₁B₂B₃: same as in section 2.

nn: same as in section 2; there can be up to 5 wind vectors per line in this section.
If nn > 5, then 6th vector starts the new line.

U_{1a}U_{1o}: same as in section 2.

P_eP_e: estimated pressure level in tens of mb where cloud vector was observed at U_{1a}U_{1o}.

ddfff: same as in section 2.

A example of a complete bulletin is given below:

```
TWXX11 KWBC YYGGgg
YYXX YYGGg I1I2I3//
222 B1B2B3nn U1aU1oU1aU1o/ PcPcTcTcTa ddfff PcPcTcTcTa ddfff ....
333 B1B2B3nn U1aU1oPePe/ ddfff U1aU1oPePe/ ddfff ....
```

A sample TWXN bulletin for the eastern Pacific for 1000Z 8 Jan 79 and a plot of 900mb winds on the 00Z 850mb analysis are given in Appendix B. Note the winds plotted are located in the areas identified by block numbers 132-135, 142-145, 152-155 (ref Fig 1). Satellite winds are identified using the special notation to differentiate these from radiosonde winds.

APPENDIX B
SAMPLE BULLETIN

TWXXN11 KWBC 081000

YYXX 5810/ 200//

222 10902 3148/ 57000 04014 58000 07514
 10602 7320/ 19541 30541 19541 28034
 11101 63/// 22471 27543
 11205 5978/ 23471 23572 22471 23087 9543/ 22471 23593 22471 24544
 70/// 23471 24048
 11302 9892/ 26431 30038 27431 26541
 11601 19/// 19541 29045
 11702 0623/ 19541 23543 19541 26044
 12102 5975/ 26431 25064 27431 26064
 12201 19/// 27431 26552
 12304 8947/ 29501 30083 28501 32583 3171/ 27431 25063 39431 28046
 12403 3825/ 20541 30062 22541 30566 75/// 22541 29583
 12503 7844/ 19541 25587 18541 27077 51/// 19541 27058
 12603 5774/ 27351 25094 22471 25100 87/// 20531 24134
 12701 91/// 52131 25049
 13201 88/// 26531 22076
 13301 31/// 26501 26572
 13402 3526/ 25501 28602 29501 30101
 13502 3974/ 18531 23155 23531 20617
 13601 12/// 18531 23642
 13702 1131/ 52131 24046 56131 25539
 14201 07/// 26531 18552
 14301 2125/ 24531 11536 22531 09025
 14401 83/// 43351 14528
 14501 24/// 26531 19092
 333 10903 8320/ 20519 5590/ 12507 3390/ 05005
 10005 5590/ 11512 5090/ 10517 3390/ 05005 0590/ 12007 0090/ 05017
 10106 8890/ 11011 8390/ 07015 5090/ 14015 3890/ 08023 3390/ 08019
 0090/ 11529
 10205 0090/ 11527 8390/ 09527 3890/ 06026 3390/ 10514 0590/ 12024
 10304 8890/ 09523 3890/ 08028 3390/ 08037 0090/ 09032
 10408 8890/ 09528 8390/ 09028 5590/ 11028 5090/ 09530 3890/ 11024
 3390/ 10033 0590/ 10535 0090/ 09528
 10506 8890/ 11029 8390/ 08028 5590/ 09524 5090/ 09027 0590/ 08032
 0090/ 09031
 10601 5090/ 09527

TWXXN21 KWBC 081000

YYXX 5810/ 200//

333 10706 8890/ 10506 5590/ 07523 3890/ 10510 3390/ 11026 0590/ 09522
 0090/ 09520
 10801 5090/ 09519
 11902 0020/ 22524 3390/ 07019
 11003 3890/ 06507 3390/ 07513 0590/ 10508
 11106 8890/ 07010 5090/ 06007 3890/ 08019 3390/ 10023 0590/ 05510
 0090/ 07515
 11201 0090/ 08017
 11301 0590/ 10010
 11403 3390/ 10533 0590/ 12528 0090/ 09526
 11507 8890/ 16511 5590/ 13525 5090/ 12018 3890/ 11521 3390/ 10523
 0590/ 09021 0090/ 10533
 11606 8890/ 21020 8390/ 21012 5090/ 14022 3390/ 15020 0590/ 11523
 0090/ 15011
 11703 8390/ 23516 5590/ 25507 5090/ 17510
 12902 3390/ 33507 0590/ 04506
 12001 7525/ 26081
 12101 5590/ 34016
 12202 5590/ 28516 0590/ 07018
 12302 3890/ 26020 3390/ 22016
 12403 8390/ 25038 3390/ 22025 0090/ 17516
 12501 0590/ 20010
 12605 5090/ 22035 3890/ 26035 3390/ 23531 0590/ 22013 0090/ 22023

12703 8390/ 27031 5590/ 27030 0090/ 24524
 12802 5090/ 28525 0090/ 26516
 13308 9450/ 28034 8050/ 24044 9050/ 23040 8890/ 28529 8390/ 25527
 5590/ 26038 5090/ 26027 0590/ 26026
 13401 5090/ 25020
 13503 8950/ 24045 9750/ 22039 8890/ 22533
 13607 7350/ 25037 8890/ 29518 8390/ 21518 5590/ 26527 3890/ 29033
 3390/ 25339 0590/ 27037
 13707 8890/ 29022 8390/ 32521 5590/ 29017 5090/ 29030 3890/ 29022
 0590/ 29021 0090/ 26529
 13802 5090/ 31524 0090/ 28524
 14201 5590/ 21028
 14302 5590/ 12022 0090/ 20521
 14503 1650/ 20536 3890/ 16520 0590/ 21032

