

(2011 / 6 / 6 2010 / 12 /30)

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W.d/m²(6842 , 2307)

Study of Spatial Variation of Total Solar Radiation Falling on Horizontal Surface in Iraq

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ABSTRACT

Due to lack of studies concerning the spatial variation of total solar radiation falling on horizontal surface in Iraq , this give an importance to perform this research. A mathematical model was found in this study to estimate global solar radiation on plane surface as a

function of relative humidity, mean air temperature and sun shine ratio, the model give a high accuracy on application .

Figures concerning the spatial variation of total solar radiation were found during the winter, spring, summer and autum months by using 17 meteorological stations spread over the whole Iraq .

Mean monthly values of total solar radiation over Iraq were in the range of (2307, 6842) W.d/m² during the months of the year .

Annual spatial variation of total radiation in Iraq show a gradually increase of total solar radiation from the north toward the south of Iraq.

(Rensheng *et al.*,

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.(Muneer, 2004)

.(Tasdemirogin,1985 ; Hirunlabh *et al.*,1998)

(1991) (Bishop and Rossow)

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(Benjamin *et al.*, 2008)

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(2008-1980)

(1991-1974)

(2000-1980)

(1990-1971)

(1990-1971)

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(n/N)

(RH)

(T)

$$H = H_o [0.39 + 0.32(n/N) - 0.006(T)^{1/2} - 0.0014(RH)]$$

.(W.d/m²)

=H

.(W.d/m²)

= H_o

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(5,4,3,2,1)

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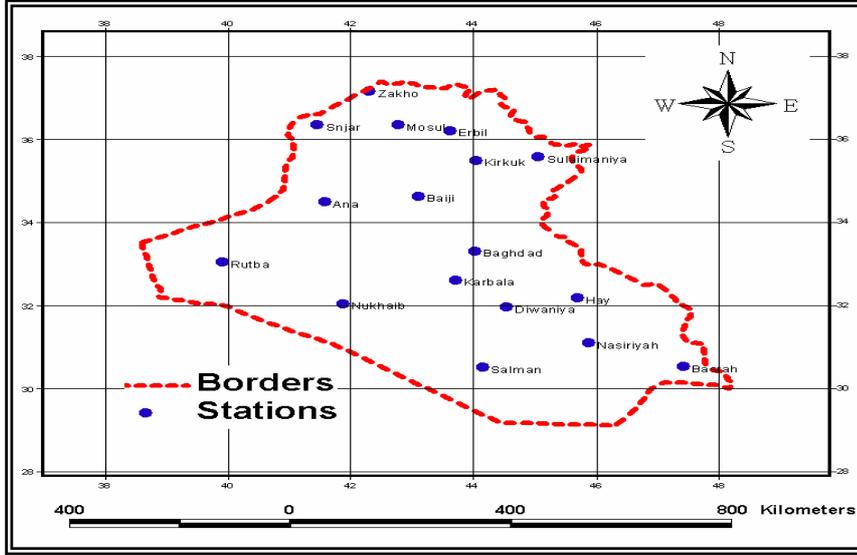
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W.d/m²(2200-1700)

W.d/m²(3200-2600)

W.d/m²(2400-1800)

-2200)

. (32°-34°)

W.d/m²(2800-2400)

W.d/m²(2500

W.d/m²(3600-3200)

(2800-2500)

.(32°)

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-3600)

W.d/m²(3100-2800)

W.d/m²

W.d/m²(3900

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(3)

30° 30'

37° 08'

(3)

(34°)

. W.d/m²(4100-3500)

(34°)

. W.d/m²(4700-4400)

(34°)

W.d/m²(5900-5400)

W.d/m²(5200-4500)

-6000)

W.d/m²(5500-5200)

W.d/m²(6300

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W.d/m²(5800-5500)

W.d/m²(6600

.(6500W.d/m²)

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(7200W.d/m²)

(6000W.d/m²)

W.d/m²(6500-6000)

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.W.d/m²(5900-5600)

.W.d/m²(5200-4600)

W.d/m²(5600-5200)

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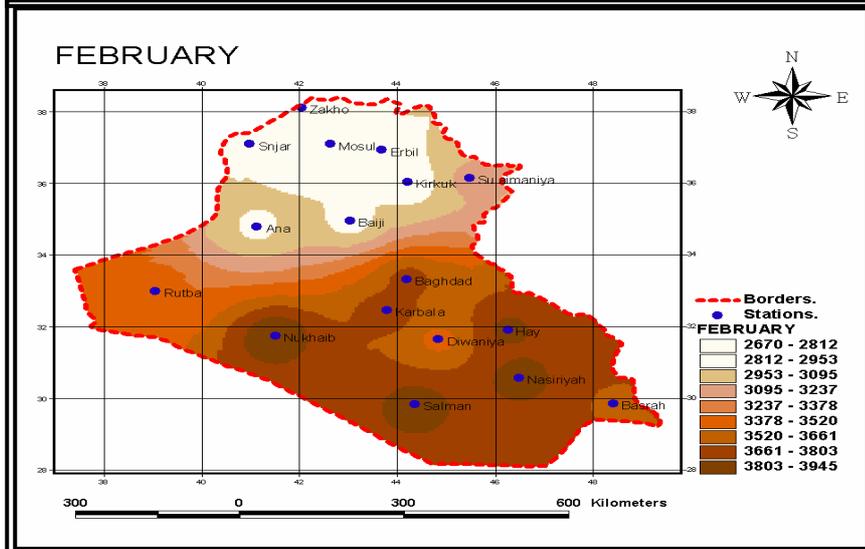
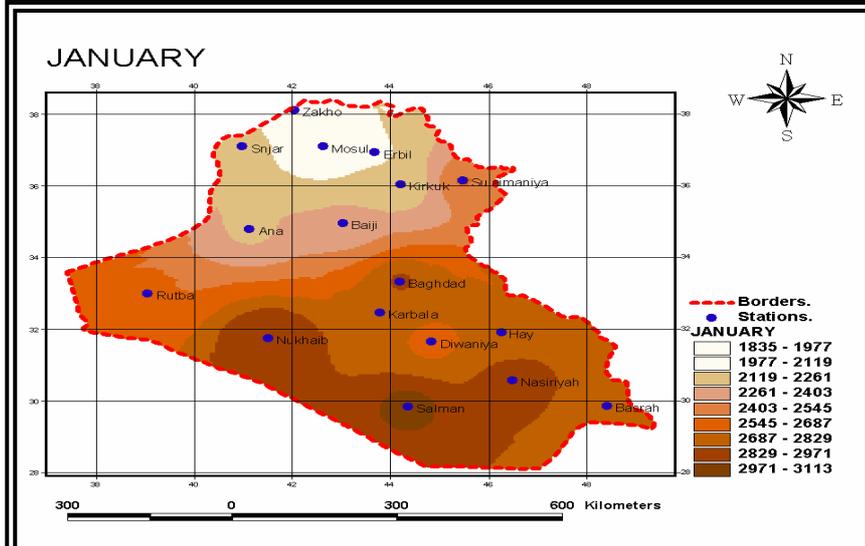
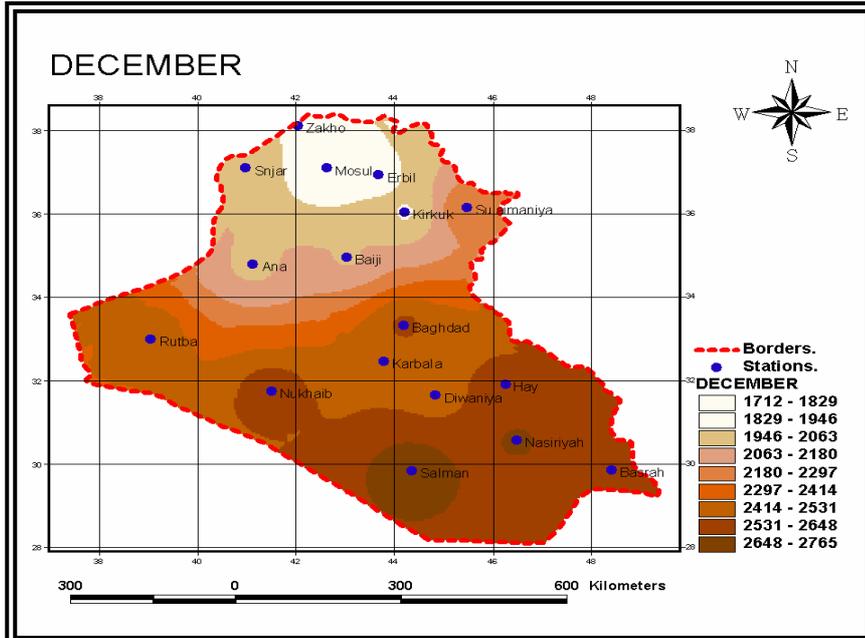
.W.d/m²(4100-3300)

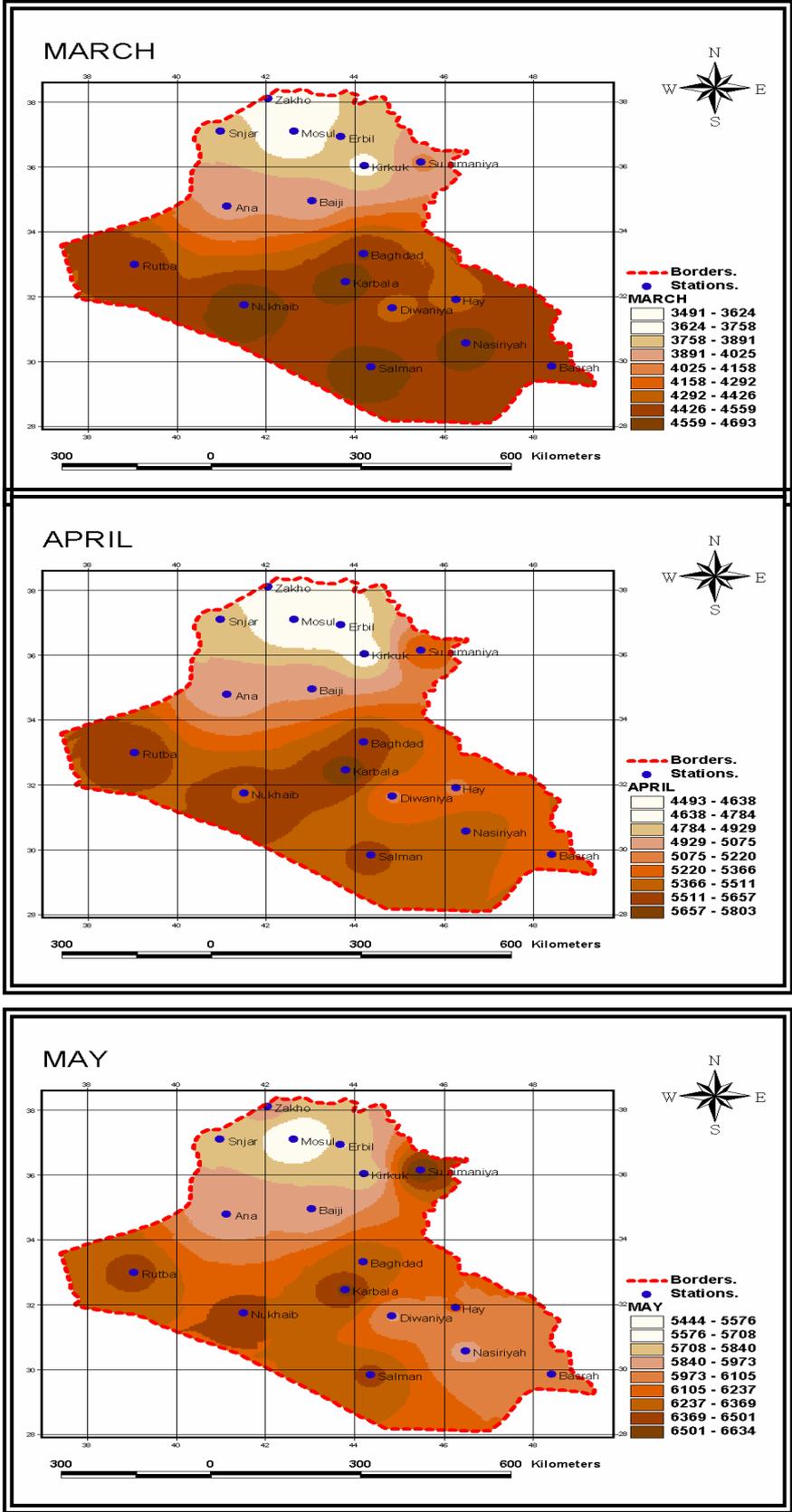
. W.d/m²(4450-4100)

2400 W.d/m²

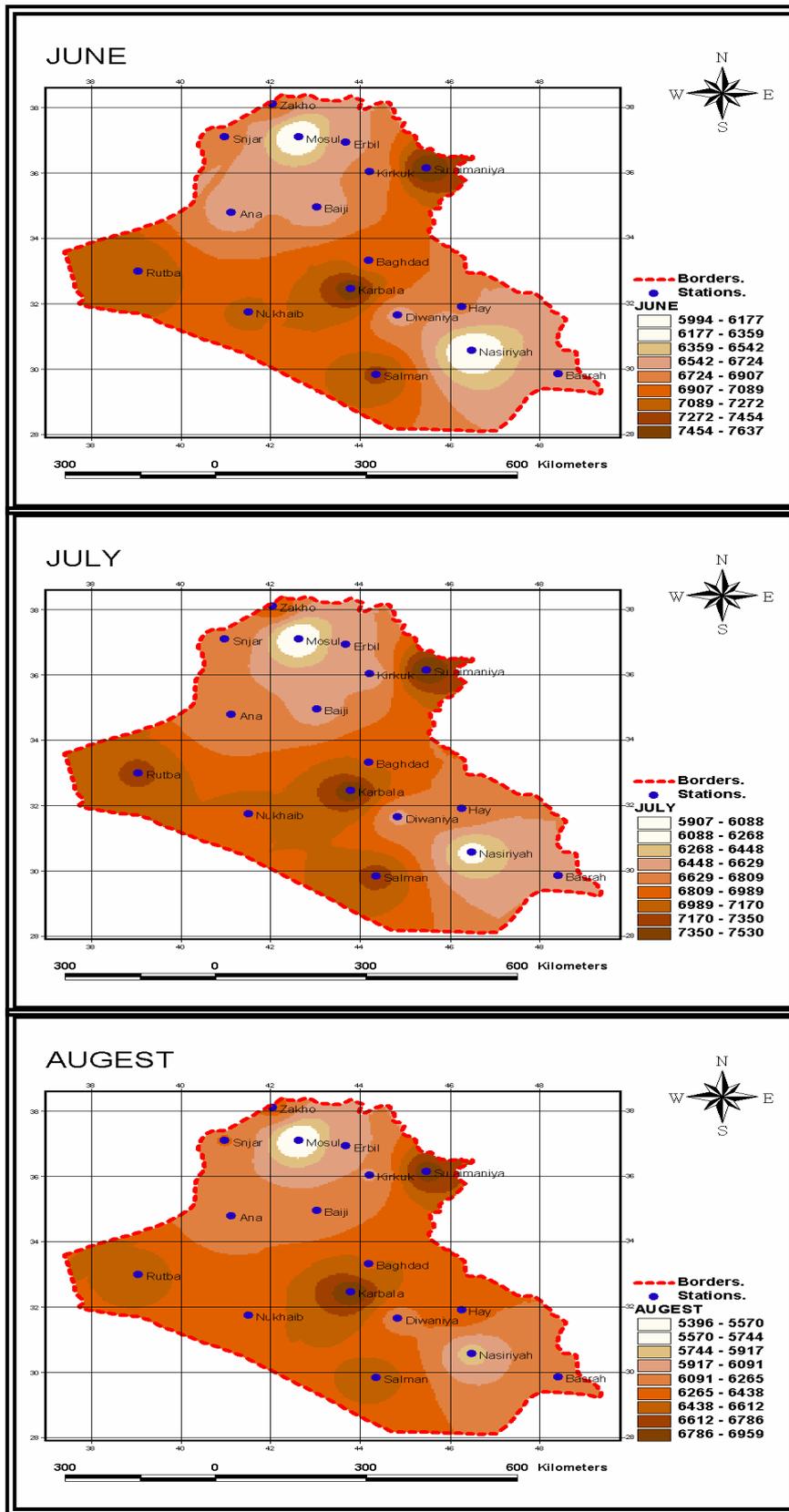
3400 W.d/m²

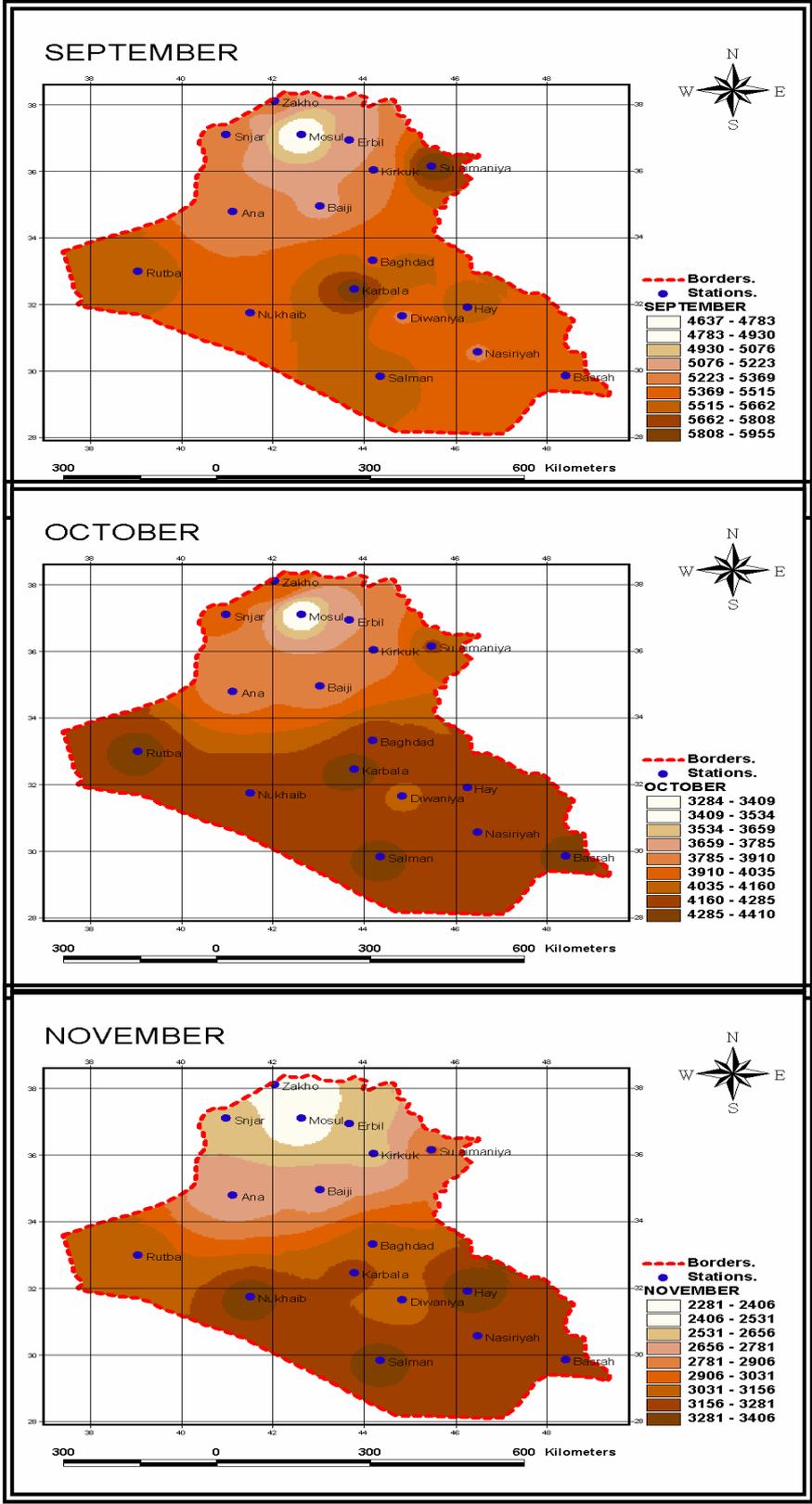
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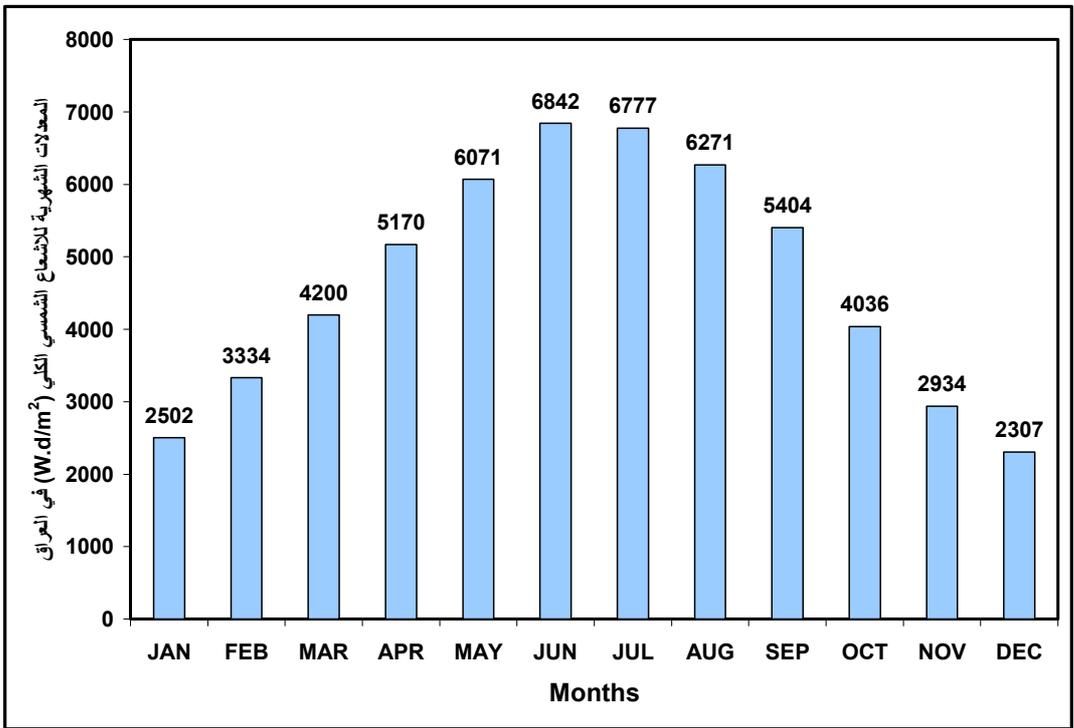
W.d/m²(3334 2502 2307) (

W.d/m²(6071 5170 4200) ()

6777 6842) ()

() W.d/m²(6271

W.d/m²(2934 4036 5404)



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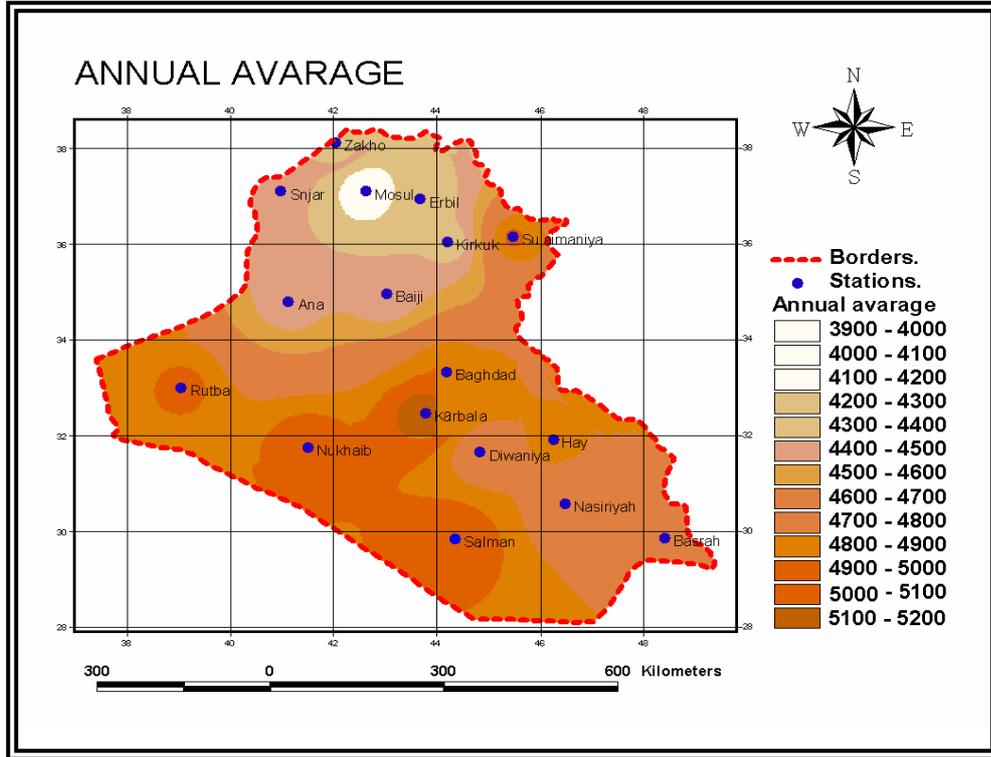
(3900

.(34°)

(4500 W.d/m²) W.d/m²)

W.d/m²(5000-4500)

.W.d/m²(5200-5000)



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$$H = Ho [0.39 + 0.32(n/N) - 0.006(T)^{1/2} - 0.0014(RH)]$$

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4200 3334 2502)

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. W.d/m²(2307 2934 4036 5404 6271 6777 6842 6071 5170

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|--------|--------------------------------|--------------------------|
| | W.d/m ² (4500-3900) | |
| -5000) | W.d/m ² (5000-4500) | |
| | | W.d/m ² (5200 |
| | 12 .(1989) | |
| | | .(1980) |

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.(W.d/m²)

| Months Stations | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Zakho | 4668 | 6191 | 8014 | 9863 | 11085 | 11603 | 11361 | 10386 | 8787 | 6901 | 5146 | 4288 |
| Sinjar | 4814 | 6318 | 8113 | 9917 | 11097 | 11579 | 11359 | 10416 | 8864 | 7016 | 5285 | 4430 |
| Mosul | 4814 | 6318 | 8113 | 9917 | 11097 | 11579 | 11359 | 10416 | 8864 | 7016 | 5285 | 4430 |
| Erbil | 4830 | 6337 | 8128 | 9925 | 11097 | 11588 | 11358 | 10423 | 8875 | 7035 | 5303 | 4452 |
| Sulaimaniya | 4938 | 6519 | 8202 | 9965 | 11104 | 11577 | 11353 | 10447 | 8934 | 7122 | 5410 | 4561 |
| Kirkuk | 4952 | 6447 | 8211 | 9969 | 11105 | 11576 | 11353 | 10449 | 8941 | 7134 | 5423 | 4575 |
| Baiji | 5098 | 6578 | 8312 | 10022 | 11114 | 11560 | 11346 | 10480 | 9019 | 7251 | 5650 | 4723 |
| Ana | 5122 | 6599 | 8327 | 10030 | 11115 | 11558 | 11346 | 10485 | 9031 | 7269 | 5583 | 4747 |
| Baghdad | 5313 | 6769 | 8454 | 10094 | 11121 | 11532 | 11314 | 10519 | 9130 | 7420 | 5770 | 4942 |
| Rutba | 5364 | 6812 | 8488 | 10111 | 11123 | 11526 | 11326 | 10529 | 9155 | 7459 | 5819 | 4993 |
| Karbala | 5436 | 6876 | 8535 | 10133 | 11124 | 11516 | 11322 | 10541 | 9191 | 7515 | 5884 | 5066 |
| Hay | 5508 | 6939 | 8582 | 10156 | 11125 | 11505 | 11315 | 10553 | 9227 | 7572 | 5953 | 5140 |
| Nukhaib | 5530 | 6958 | 8596 | 10163 | 11124 | 11501 | 11313 | 10556 | 9237 | 7588 | 5975 | 5162 |
| Diwaniya | 5539 | 6967 | 8602 | 10166 | 11125 | 11500 | 11313 | 10558 | 9242 | 7595 | 5983 | 5171 |
| Nasiriya | 5695 | 7102 | 8701 | 10212 | 11124 | 11472 | 11296 | 10580 | 9316 | 7716 | 6135 | 5330 |
| Basrah | 5775 | 7172 | 8751 | 10235 | 11124 | 11460 | 11287 | 10592 | 9354 | 7776 | 6207 | 5411 |
| Salman | 5786 | 7181 | 8758 | 10238 | 11123 | 11457 | 11285 | 10593 | 9358 | 7784 | 6218 | 5423 |

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| Months Stations | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|----------------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Zakho | 9.72 | 10.67 | 11.76 | 12.98 | 13.99 | 14.54 | 14.33 | 13.48 | 12.33 | 11.15 | 10.06 | 9.47 |
| Sinjar | 9.79 | 10.71 | 11.77 | 12.95 | 13.93 | 14.46 | 14.26 | 13.43 | 12.32 | 11.18 | 10.12 | 9.54 |
| Mosul | 9.79 | 10.71 | 11.77 | 12.95 | 13.93 | 14.46 | 14.26 | 13.43 | 12.32 | 11.18 | 10.12 | 9.54 |
| Erbil | 9.80 | 10.72 | 11.77 | 12.95 | 13.92 | 14.45 | 14.25 | 13.43 | 12.32 | 11.18 | 10.13 | 9.56 |
| Sulaimaniya | 9.85 | 10.80 | 11.78 | 12.93 | 13.87 | 14.39 | 14.20 | 13.39 | 12.31 | 11.20 | 10.17 | 9.61 |
| Kirkuk | 9.86 | 10.75 | 11.78 | 12.92 | 13.87 | 14.39 | 14.19 | 13.39 | 12.31 | 11.21 | 10.18 | 9.62 |
| Baiji | 9.93 | 10.79 | 11.79 | 12.89 | 13.81 | 14.31 | 14.12 | 13.35 | 12.30 | 11.23 | 10.23 | 9.70 |
| Ana | 9.94 | 10.80 | 11.79 | 12.89 | 13.80 | 14.30 | 14.11 | 13.34 | 12.30 | 11.23 | 10.24 | 9.71 |
| Baghdad | 10.02 | 10.85 | 11.80 | 12.85 | 13.72 | 14.20 | 14.02 | 13.28 | 12.29 | 11.27 | 10.32 | 9.81 |
| Rutba | 10.05 | 10.86 | 11.80 | 12.84 | 13.70 | 14.17 | 13.99 | 13.27 | 12.28 | 11.27 | 10.34 | 9.84 |
| Karbala | 10.08 | 10.88 | 11.80 | 12.83 | 13.67 | 14.13 | 13.96 | 13.25 | 12.28 | 11.29 | 10.37 | 9.87 |
| Hay | 10.11 | 10.90 | 11.80 | 12.81 | 13.65 | 14.10 | 13.93 | 13.23 | 12.27 | 11.30 | 10.39 | 9.91 |
| Nukhaib | 10.12 | 10.90 | 11.81 | 12.81 | 13.64 | 14.09 | 13.92 | 13.22 | 12.27 | 11.30 | 10.40 | 9.92 |
| Diwaniya | 10.13 | 10.91 | 11.81 | 12.81 | 13.63 | 14.08 | 13.91 | 13.22 | 12.27 | 11.30 | 10.40 | 9.92 |
| Nasiriya | 10.19 | 10.95 | 11.81 | 12.78 | 13.57 | 14.00 | 13.84 | 13.17 | 12.26 | 11.33 | 10.46 | 10.00 |
| Basrah | 10.23 | 10.97 | 11.82 | 12.76 | 13.54 | 13.97 | 13.81 | 13.15 | 12.26 | 11.34 | 10.49 | 10.04 |
| Salman | 10.23 | 10.97 | 11.82 | 12.76 | 13.54 | 13.96 | 13.80 | 13.15 | 12.26 | 11.34 | 10.50 | 10.04 |

. (hrs)

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| Months Stations | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|--------------------|-----|-----|-----|-----|------|------|------|------|------|-----|-----|-----|
| Zakho | 4.6 | 5.2 | 5.5 | 7.3 | 9.5 | 11.9 | 12.2 | 11.3 | 10.2 | 7.3 | 5.3 | 4.9 |
| Sinjar | 4.9 | 5.6 | 6.6 | 7.6 | 9.1 | 11.7 | 11.9 | 11.4 | 10.3 | 8.4 | 6.0 | 5.0 |
| Mosul | 4.7 | 5.6 | 6.8 | 7.9 | 9.9 | 12.2 | 11.9 | 11.3 | 10.3 | 8.1 | 6.4 | 4.6 |
| Erbil | 4.8 | 6.0 | 6.6 | 7.1 | 9.0 | 11.6 | 11.4 | 10.9 | 10.1 | 7.9 | 6.1 | 4.5 |
| Sulaimaniya | 5.1 | 5.4 | 5.9 | 7.6 | 9.8 | 12.0 | 12.1 | 11.7 | 10.4 | 8.0 | 6.2 | 5.2 |
| Kirkuk | 5.5 | 6.2 | 7.6 | 7.8 | 9.1 | 11.3 | 11.2 | 11.0 | 10.2 | 8.2 | 6.9 | 5.7 |
| Baiji | 5.4 | 5.8 | 7.1 | 7.9 | 9.5 | 11.4 | 11.5 | 11.1 | 10.1 | 8.0 | 6.5 | 5.3 |
| Ana | 5.4 | 5.8 | 7.2 | 7.9 | 9.4 | 11.5 | 11.6 | 11.2 | 10.2 | 8.0 | 6.5 | 5.3 |
| Baghdad | 6.1 | 7.2 | 8.0 | 8.7 | 10.2 | 12.1 | 11.9 | 11.5 | 10.1 | 8.3 | 7.1 | 6.1 |
| Rutba | 6.5 | 7.4 | 8.1 | 8.8 | 10.0 | 12.4 | 12.4 | 11.7 | 10.5 | 8.8 | 7.6 | 6.2 |
| Karbala | 6.1 | 7.2 | 8.0 | 8.4 | 9.5 | 11.4 | 11.5 | 11.1 | 10.2 | 8.3 | 7.2 | 6.1 |
| Hay | 6.3 | 8.2 | 7.8 | 8.5 | 10.1 | 11.6 | 11.8 | 11.4 | 10.6 | 8.7 | 8.2 | 6.2 |
| Nukhaib | 7.2 | 8.5 | 8.6 | 8.7 | 9.0 | 11.3 | 10.9 | 10.6 | 10.3 | 8.4 | 8.0 | 6.3 |
| Diwaniya | 6.4 | 7.3 | 8.0 | 8.4 | 9.5 | 11.6 | 11.6 | 11.3 | 10.3 | 8.5 | 7.3 | 6.5 |
| Nasiriya | 6.5 | 7.4 | 7.6 | 8.2 | 9.1 | 9.9 | 10.0 | 10.0 | 9.6 | 8.5 | 7.1 | 6.3 |
| Basrah | 6.6 | 7.7 | 7.9 | 8.5 | 9.7 | 11.5 | 11.1 | 10.9 | 10.3 | 8.9 | 7.6 | 6.7 |
| Salman | 6.8 | 7.7 | 8.0 | 9.0 | 9.5 | 11.7 | 11.7 | 11.3 | 10.1 | 8.2 | 7.3 | 6.3 |

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| Months Stations | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|--------------------|------|------|------|------|------|------|------|-------|------|------|-------|------|
| Zakho | 6.1 | 6.9 | 10.6 | 15.3 | 20.6 | 26.5 | 30.4 | 29.5 | 25.2 | 19.6 | 11.8 | 8.1 |
| Sinjar | 6.3 | 8.2 | 11.7 | 16.7 | 23.3 | 29.6 | 33.4 | 32.7 | 28.8 | 22.6 | 14.6 | 8.6 |
| Mosul | 7.0 | 8.6 | 12.6 | 17.9 | 24.7 | 30.8 | 34.5 | 33.7 | 28.5 | 22.4 | 13.7 | 9.0 |
| Erbil | 9.1 | 9.7 | 11.1 | 16.0 | 26.0 | 32.0 | 36.0 | 35.0 | 30.0 | 22.0 | 15.0 | 10.0 |
| Sulaimaniy | 9.8 | 10.7 | 15.1 | 22.1 | 28.4 | 38.8 | 39.3 | 38.4 | 35.3 | 26.7 | 18.3 | 11.3 |
| Kirkuk | 9.0 | 10.5 | 14.8 | 20.7 | 27.5 | 33.3 | 36.3 | 35.6 | 31.3 | 24.8 | 16.3 | 10.9 |
| Baiji | 9.4 | 11.0 | 15.0 | 24.5 | 27.7 | 32.2 | 35.4 | 34.5 | 30.6 | 24.2 | 16.5 | 11.2 |
| Ana | 7.7 | 9.6 | 13.6 | 20.3 | 25.9 | 30.6 | 33.5 | 32.9 | 28.5 | 22.0 | 14.8 | 9.7 |
| Baghdad | 9.4 | 12.0 | 16.1 | 23.0 | 28.9 | 32.7 | 35.1 | 34.4 | 30.5 | 24.4 | 16.3 | 11.1 |
| Rutba | 7.3 | 9.2 | 13.0 | 19.4 | 24.6 | 29.0 | 31.7 | 31.2 | 27.8 | 21.7 | 13.9 | 9.1 |
| Karbala | 10.2 | 12.7 | 17.6 | 24.2 | 29.9 | 34.2 | 36.7 | 35.9 | 32.2 | 25.6 | 17.4 | 11.9 |
| Hay | 11.5 | 13.2 | 17.8 | 24.4 | 30.2 | 34.6 | 36.7 | 36.05 | 33.1 | 27.1 | 19.15 | 13.0 |
| Nukhaib | 9.2 | 11.3 | 15.9 | 22.1 | 27.5 | 31.9 | 34.1 | 33.5 | 30.5 | 24.4 | 16.1 | 10.4 |
| Diwaniya | 11.2 | 13.5 | 18.4 | 24.8 | 30.5 | 34.3 | 36.1 | 35.5 | 32.2 | 26.6 | 18.3 | 13.0 |
| Nasiriya | 11.8 | 14.3 | 19.3 | 25.6 | 31.9 | 35.6 | 37.5 | 37.0 | 33.6 | 27.4 | 19.2 | 13.4 |
| Basrah | 12.3 | 14.6 | 19.4 | 26.1 | 32.4 | 36.1 | 37.8 | 37.2 | 33.6 | 27.8 | 19.8 | 14.0 |
| Salman | 11.2 | 13.5 | 18.3 | 25.6 | 31.1 | 34.9 | 37 | 34.7 | 33.5 | 28.3 | 20.4 | 11.4 |

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| Months Stations | | | | | | | | | | | | |
|--------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| Zakho | 63 | 60 | 54 | 52 | 39 | 24 | 20 | 20 | 22 | 36 | 52 | 64 |
| Sinjar | 69 | 64 | 56 | 50 | 34 | 21 | 18 | 19 | 22 | 34 | 50 | 67 |
| Mosul | 79.7 | 73.8 | 67.5 | 61.3 | 42.9 | 27.6 | 25.1 | 26.4 | 31.3 | 45.9 | 64.5 | 78.2 |
| Erbil | 67 | 63 | 59 | 53 | 38 | 26 | 25 | 25 | 28 | 37 | 53 | 66 |
| Sulaimaniya | 72.4 | 66.4 | 61.5 | 53.1 | 38.6 | 22.7 | 19.8 | 21.8 | 23.5 | 39.5 | 60.8 | 71.3 |
| Kirkuk | 72.6 | 67.8 | 58.9 | 50.9 | 34.5 | 24.5 | 23 | 24.4 | 27.3 | 38.8 | 58.5 | 69.6 |
| Baiji | 79 | 73 | 61 | 48 | 38 | 29 | 27 | 28 | 32 | 46 | 65 | 78 |
| Ana | 80 | 72 | 59 | 45 | 33 | 27 | 24 | 26 | 31 | 45 | 63 | 78 |
| Baghdad | 72.1 | 60.2 | 50.8 | 41.7 | 31.8 | 25.2 | 24.7 | 27 | 31.9 | 42.4 | 57.9 | 69.6 |
| Rutba | 71.1 | 61.5 | 52.9 | 43.4 | 35 | 29.4 | 27.8 | 29.1 | 31.3 | 44.3 | 58.3 | 71 |
| Karbala | 75 | 62 | 53 | 43 | 34 | 29 | 30 | 32 | 36 | 46 | 62 | 74 |
| Hay | 74 | 65 | 56 | 46 | 33 | 26 | 25 | 25 | 29 | 41 | 60 | 72 |
| Nukhaib | 63.5 | 56.1 | 47.5 | 36.4 | 26.5 | 21.9 | 20.9 | 23.3 | 25.7 | 38.4 | 55.7 | 65.5 |
| Diwaniya | 69 | 60 | 51 | 42 | 32 | 27 | 27 | 30 | 33 | 41 | 57 | 67 |
| Nasiriya | 68.9 | 59.7 | 49.9 | 41.9 | 30.8 | 23.0 | 21.9 | 23.4 | 27.7 | 38.7 | 55.2 | 66.9 |
| Basrah | 69 | 59 | 51 | 41 | 29 | 23 | 23 | 25 | 28 | 40 | 55 | 67 |
| Salman | 60.4 | 50.6 | 38.4 | 27.1 | 24.2 | 16.8 | 14 | 13.7 | 18.1 | 24.6 | 37.8 | 57.1 |

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| المحطات | خطوط العرض | خطوط الطول | الإرتفاع (m) |
|-------------|------------|------------|--------------|
| Zakho | 37° 08' | 42° 41' | 442 |
| Sinjar | 36° 19' | 41° 50' | 538 |
| Mosul | 36° 19' | 43° 09' | 223 |
| Erbil | 36° 11' | 44° 00' | 420 |
| Sulaimaniya | 35° 33' | 45° 25' | 883 |
| Kirkuk | 35° 28' | 44° 25' | 331 |
| Baiji | 34° 36' | 43° 29' | 115 |
| Ana | 34° 28' | 41° 57' | 139 |
| Baghdad | 33° 18' | 44° 24' | 32 |
| Rutba | 33° 02' | 40° 17' | 630 |
| Karbala | 32° 36' | 44° 05' | 29 |
| Hay | 32° 10' | 46° 03' | 15 |
| Nukhaib | 32° 02' | 42° 15' | 305 |
| Diwaniya | 31° 57' | 44° 55' | 20 |
| Nasiriya | 31° 05' | 46° 14' | 3 |
| Basrah | 30° 31' | 47° 47' | 2 |
| Salman | 30° 30' | 44° 32' | 220 |