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A numerical Research on the Primary Scattering of the Sun's Ray in the High Atmosphere (II)

by Takao SATO

Nagasaki University

(Manuscript received Nov. 30, 1968)

Abstract

The author has investigated the primary scattering at 75 levels from 1 km to 38km height, the interval between neighboring two levels being 500m. Moreover the total solar energy is divided into twelve wavelength ranges, each of which has the partial energy equal to one twelfth of the total.

Let T_o be each level point above explained and draw a line passing through T_o and making an angle θ_1 with a line passing To and the earth's centre O. For convenience sake the line thus defined will be hereafter called θ_1 line. Let T_4 be the intersecting point of θ_1 line with the earth's surface or its atmospheric upper limit, and T_1, T_2, T_3 be three points which divide the line section between T_o and T_4 into four equal lengths. Hereafter the above five points will be called in general T_n. The author has researched and compared the primary scattering intensity which originates at T_n and reaches the level point To for 30°, 60° and 90° of the Sun's altitude h, determined each of two positions of the level point which take respectively max. and minimum value for each combination of the wavelength domains, θ_1, h, and Tn.

Introduction

When we elevate high and higher in the atmosphere, the blue sky becones dark and darker as a well known phenomenon. The scattering problem in the high atmosphere is not yet fully solved even if we restrict it in the primary scattering only. The author has adopted the earth's atmosphere of 40km thicness, composed of 4.10^5 numbers of concentric homogeneous spherical shell of 10cm thickness with its centre at the earth's center.

In the case of the primary scattering, the phase function has simple and rigorous expression with no ambiguity (Ref. 1).

1. The relation between the number of level point and its height

Let us now denote 1 km level above the ground by No. 1, and 38km by No. 75. As the thickness of the adjacent two levels is 500m, No. q corresponds to the height of $(q+1)/2$ in the unit of km. By this method we can know No.and the height of all level points up to 75.

2. Some explanations

a) Transmission coefficient in the high atmosphere. The discussion is the same as that explained in Ref. 2).

b) Extinction effect and twelve wavelength ranges. In this paper we have used the same values indicated in Table 1 in Ref. 3). Hence the detailed explanation may be here omitted. But we must explain the vaue of transmissivity for each λ_i corresponding to λ'_i in that Table i, e, the valu eof $P_{o\lambda}{}^{m/Mo}$ in Ref. 2), M_o being the total mass of vertical air column on a unit area from sea level to the upper atmospheric limit (i, e, 40km level) and $P_{o\lambda}$ corresponding to P_i in Table 1 in Ref. 3). The notation m is in this paper the sum of the mass traversed by the solar ray in reaching T_n from the upper atmospheric limit and that traversed by the primary scattered ray from Tn to To. m/Mo. is naturally positive. The author has caluculated and made a Table giving the value of $P_i^{m/Mo}$ for $m/Mo=0.01$, 0.02,……4.99, 5.00, and for larger than $5.00m/Mo$ is 5.05, 5.10, 5.15……… . This table is called P table.

The value of transmissivity for any traversed mass which is not given in P table may be approximated with permissible error by the value for the nearest m/Mo.

c) Relation between the value of θ'_1 and the height. The value of θ_1 of tangent from any level point to the earth's surface is specified by θ'_1.

This is larger than 85° for the height indicated by $q\leq47$, and smaller than 85° for $q\geq48$, so that we must introduce two different selections about θ_1 for the above two ranges of q, because this introduction is necessary to obtain the horizontal scattering intensity at the level point now in question in Ref. 4). We have in conclusion seiected for this purpose $\theta_1=0°$, 30°, 60°, 65°, 70°, 75°, 80°, $(85°+\theta'_1)/2$, θ'_1, $(90+\theta'_1)/2$, 90°, 95°, 100°, 105, 110°, 115°, 120°, 150°, 180° for $q\leq47$, and $q\geq48$ we have used 0°, 30°, 60°, 65°, 70°, 75°, 80°, $(80+\theta'_1)/2$, θ'_1, 85, 87.5, 90, 95, 100, 105, 110, 115, 120, 150, 180, arranged respectively in order of the magnitude.

The denser division near θ'_1 is attributed to the fact that the direction near the tangent has much influence on the evaluation of scattering intensity.

3. Numerical Research and Chart on the primary scattering

The author has calculated the Value (hereafter being denoted by S_1) of the primary scattering intensity received at each level point from a whole cone of one steradian with its axis at (θ_1, A) and ts vertex at the point in (1/12) $\frac{I_0}{D^2}$ unit in the partial wavelength domain, and in $\frac{I_0}{D^2}$ unit in the total domain. Here A is the azimuth of θ_1 line with respect to the vertical plane passing through the Sun's centre, I_0 the solar constant, D the distance of the earth from the Sun in Astronomical Unit. In this paper S_1 are graphically represented for θ_1 from 0° to 75°.

Let us take q the number of the level point as abscissa and S_1 as ordinate. The value of S_1 on the figure is the multiplication of the following three quantities: 10^{-n} (n being 2, 3 etc) on the ordinate line, the number given at the side of the line, 1/12. I_0/D^2 (or I_0/D^2) in the total domain, which is denoted by T in the figure). We must add the next explanation. (1), (2), ……(12) is the notation of the partial wavelength domain λ_1, λ_2…… λ_{12}.

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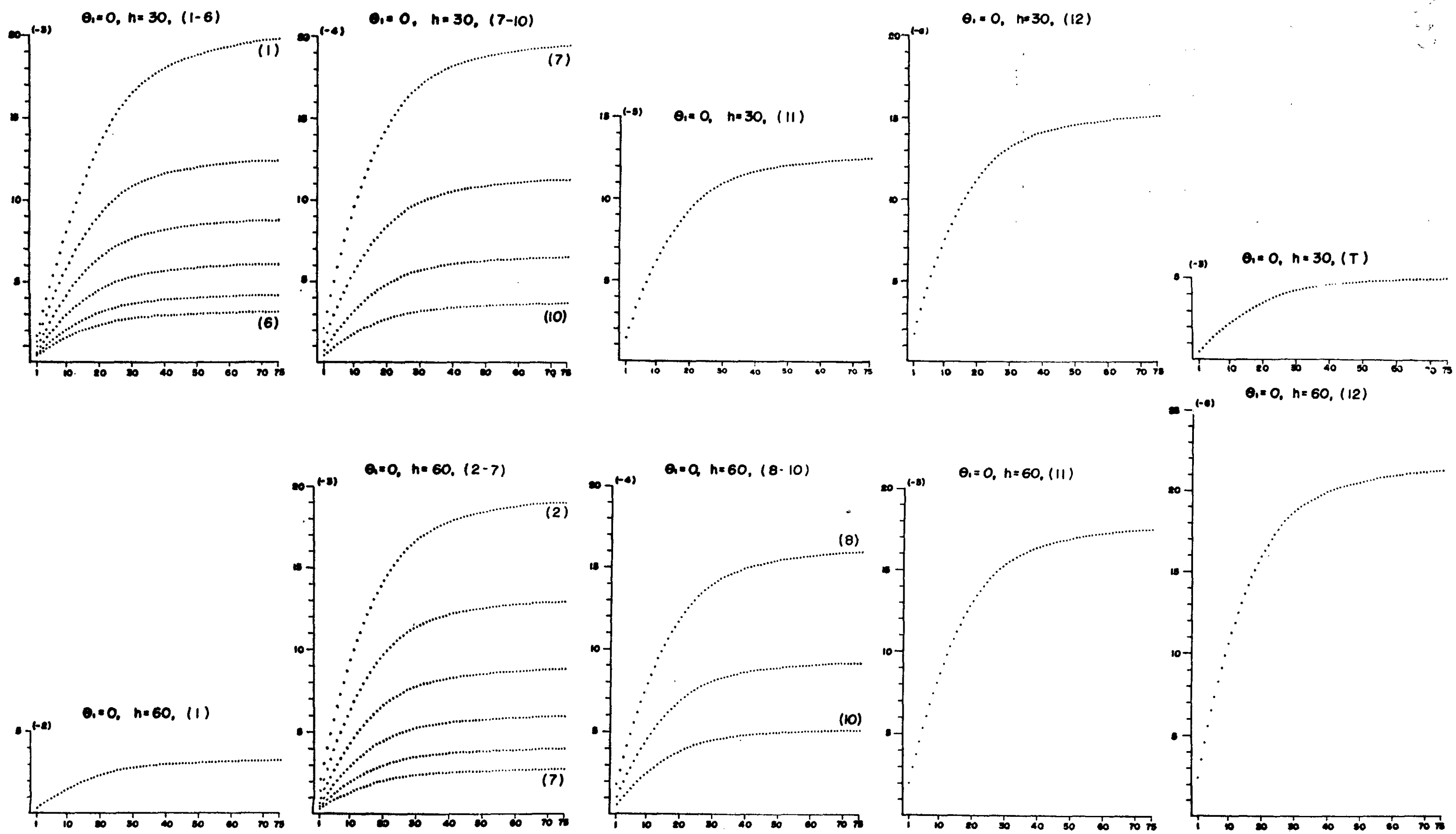
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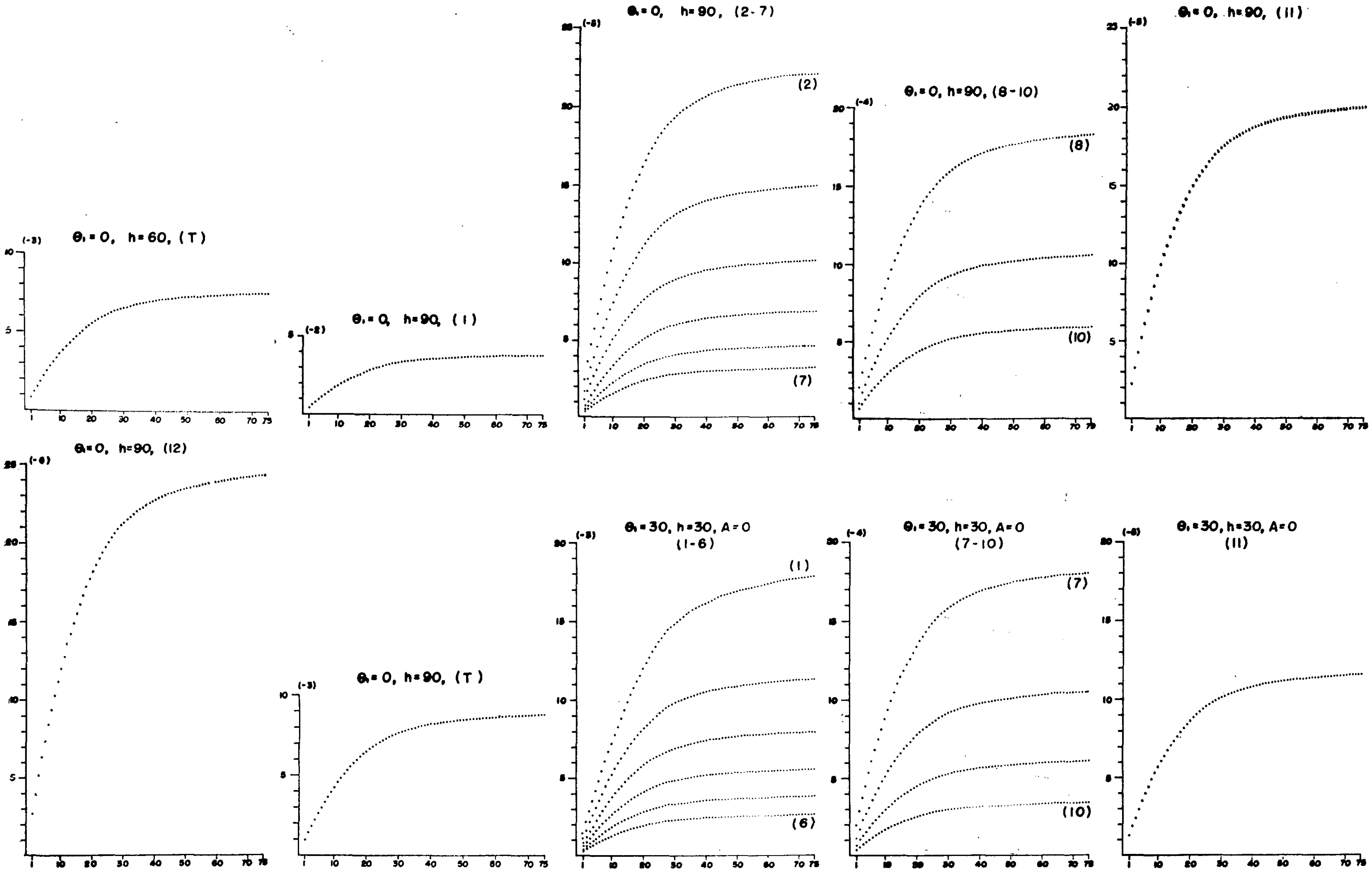
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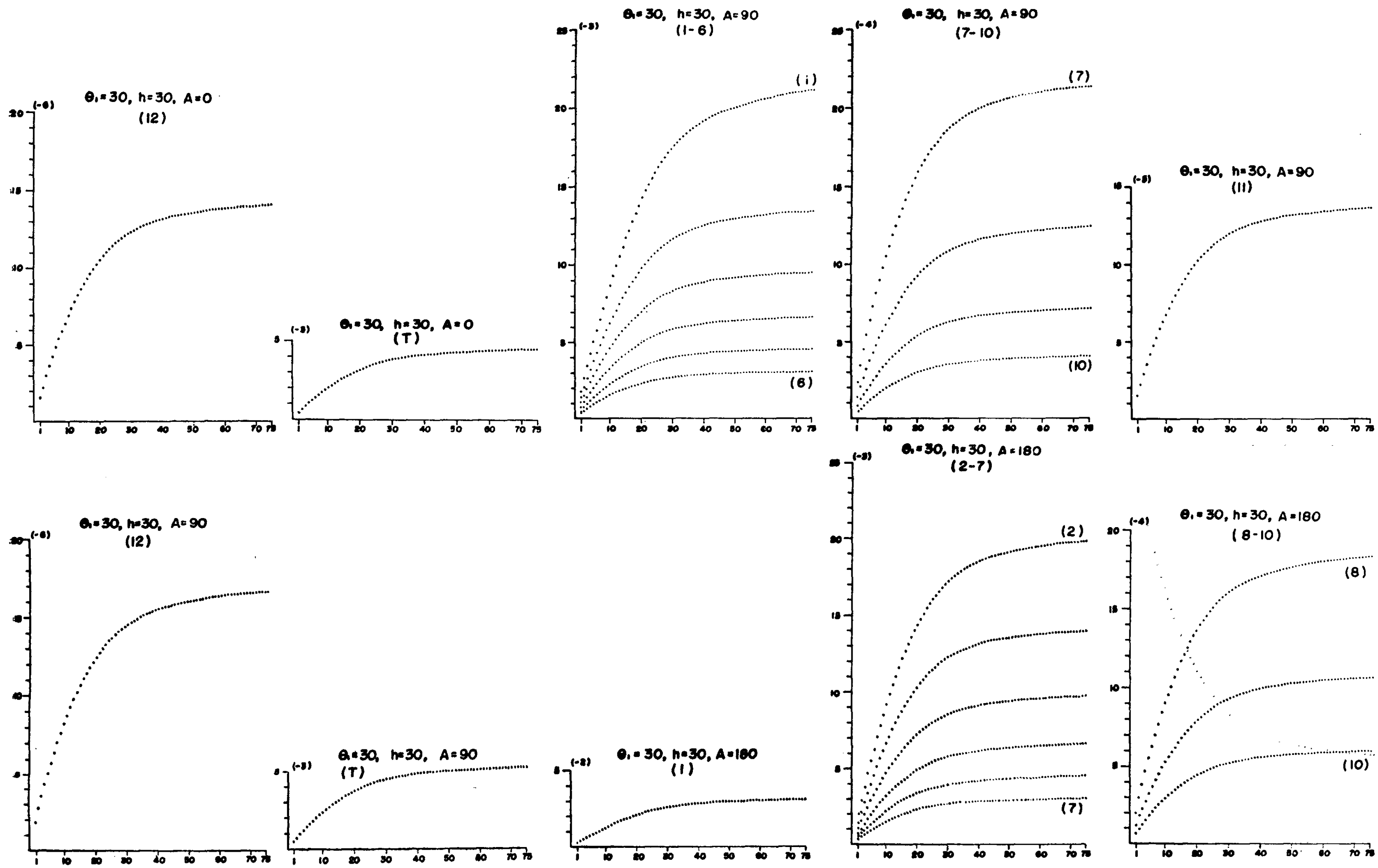
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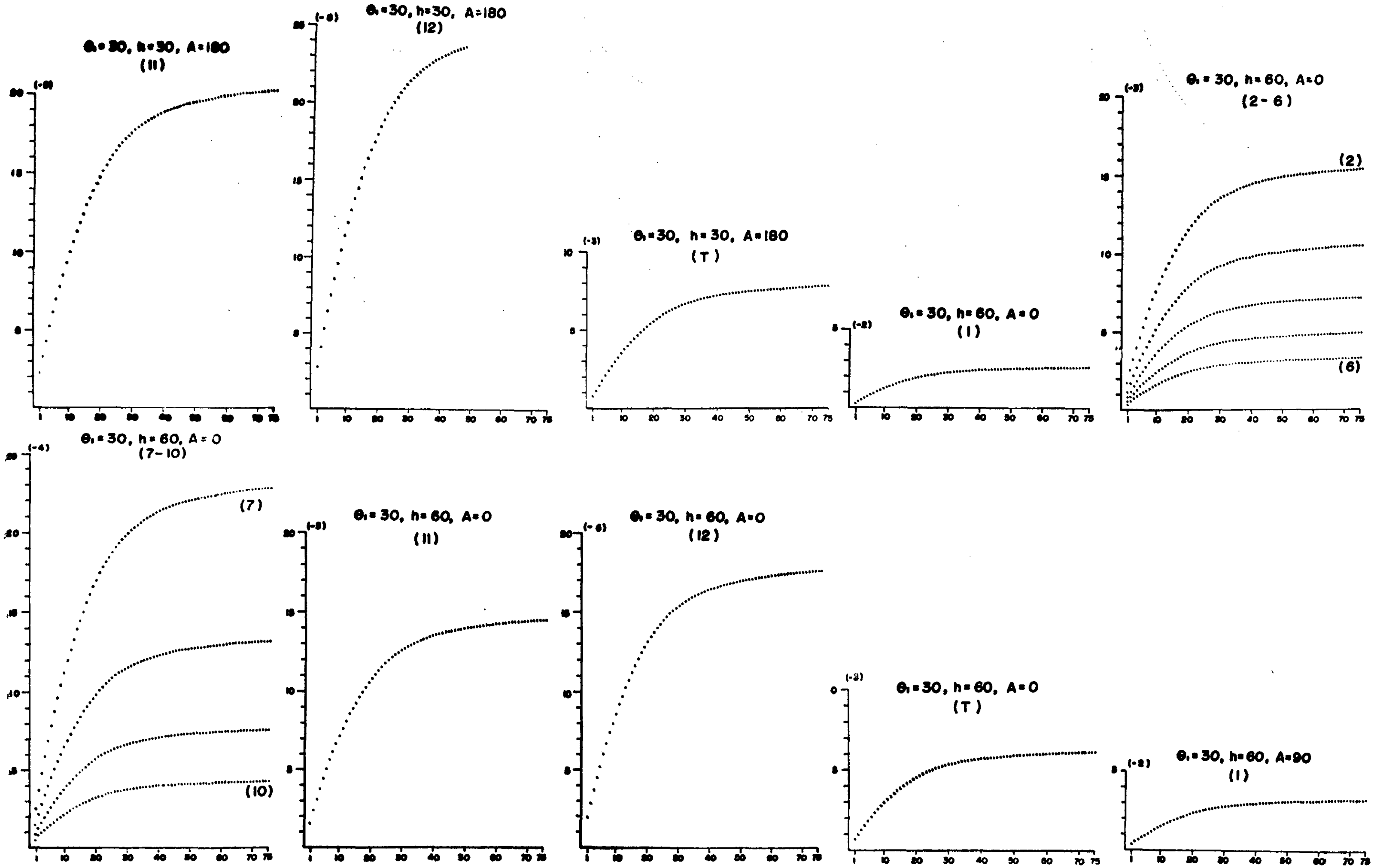
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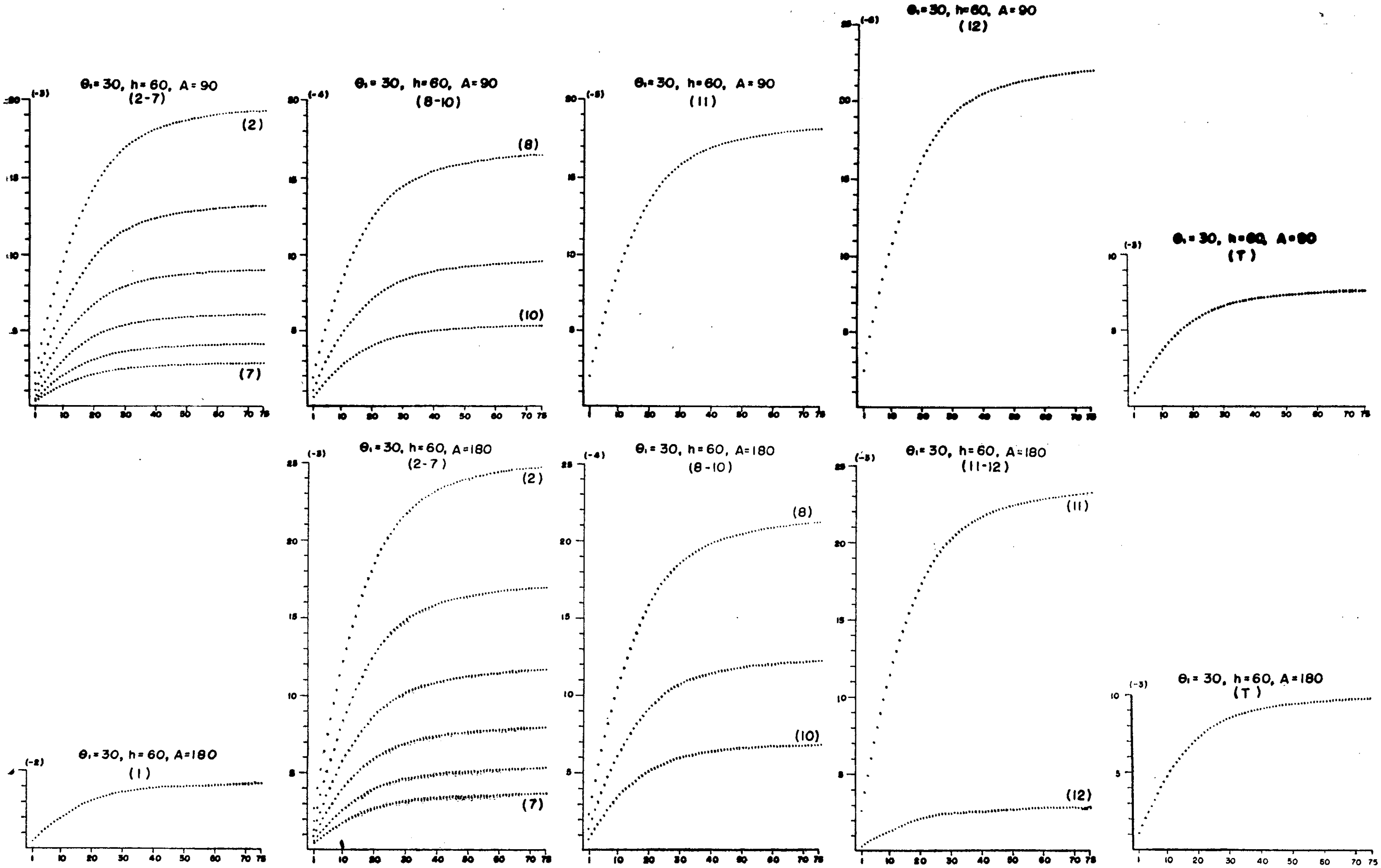
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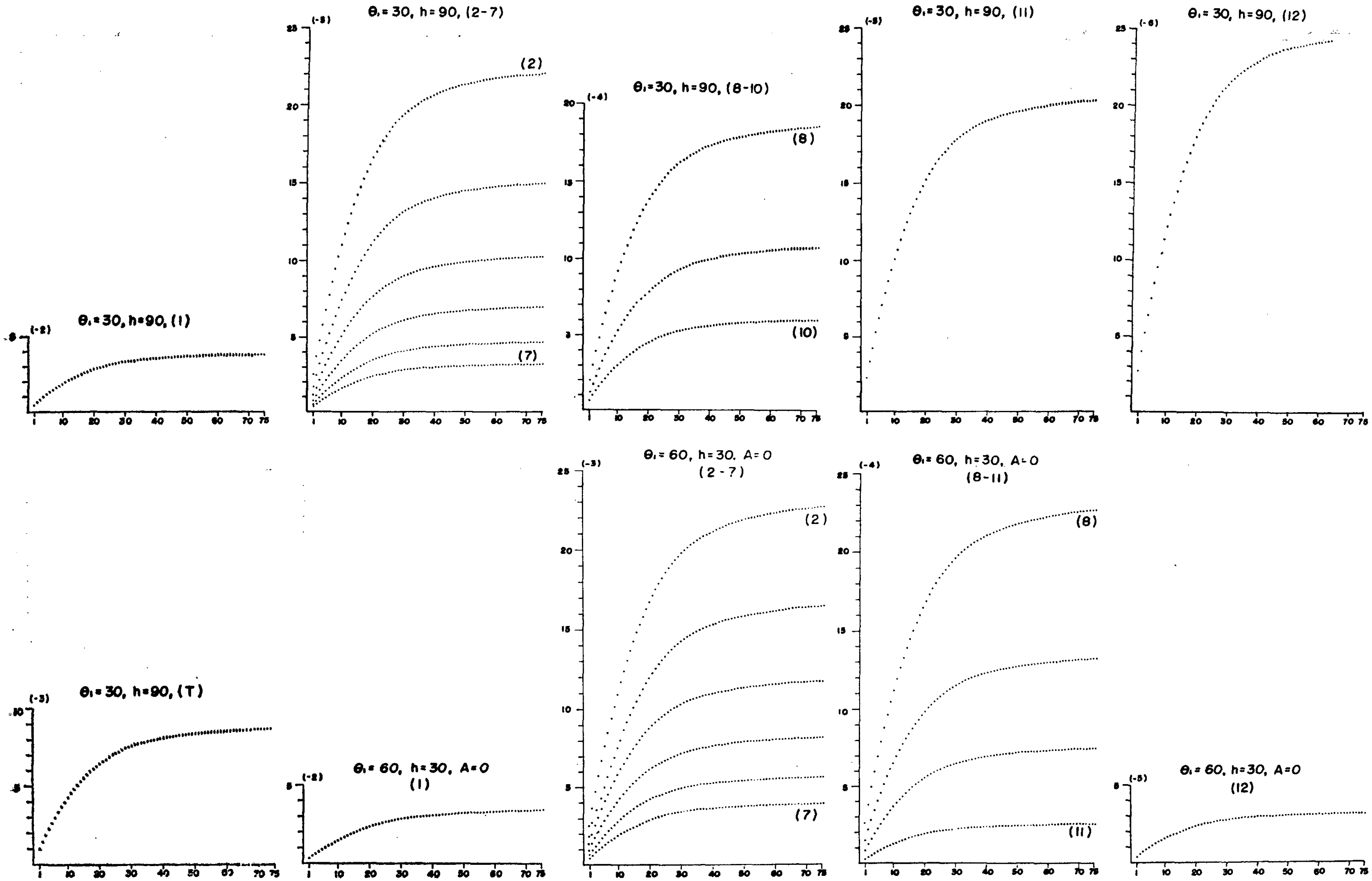
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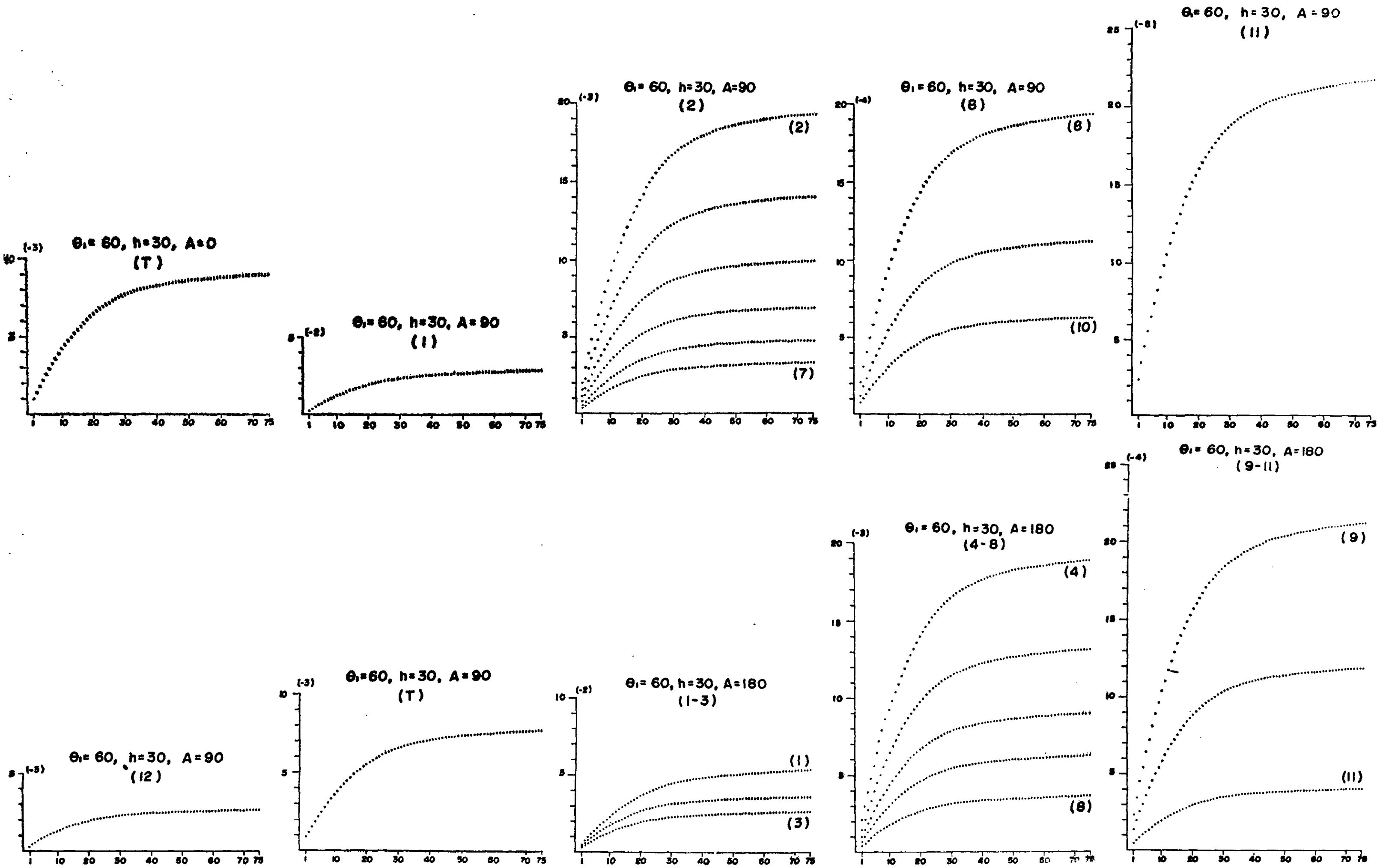
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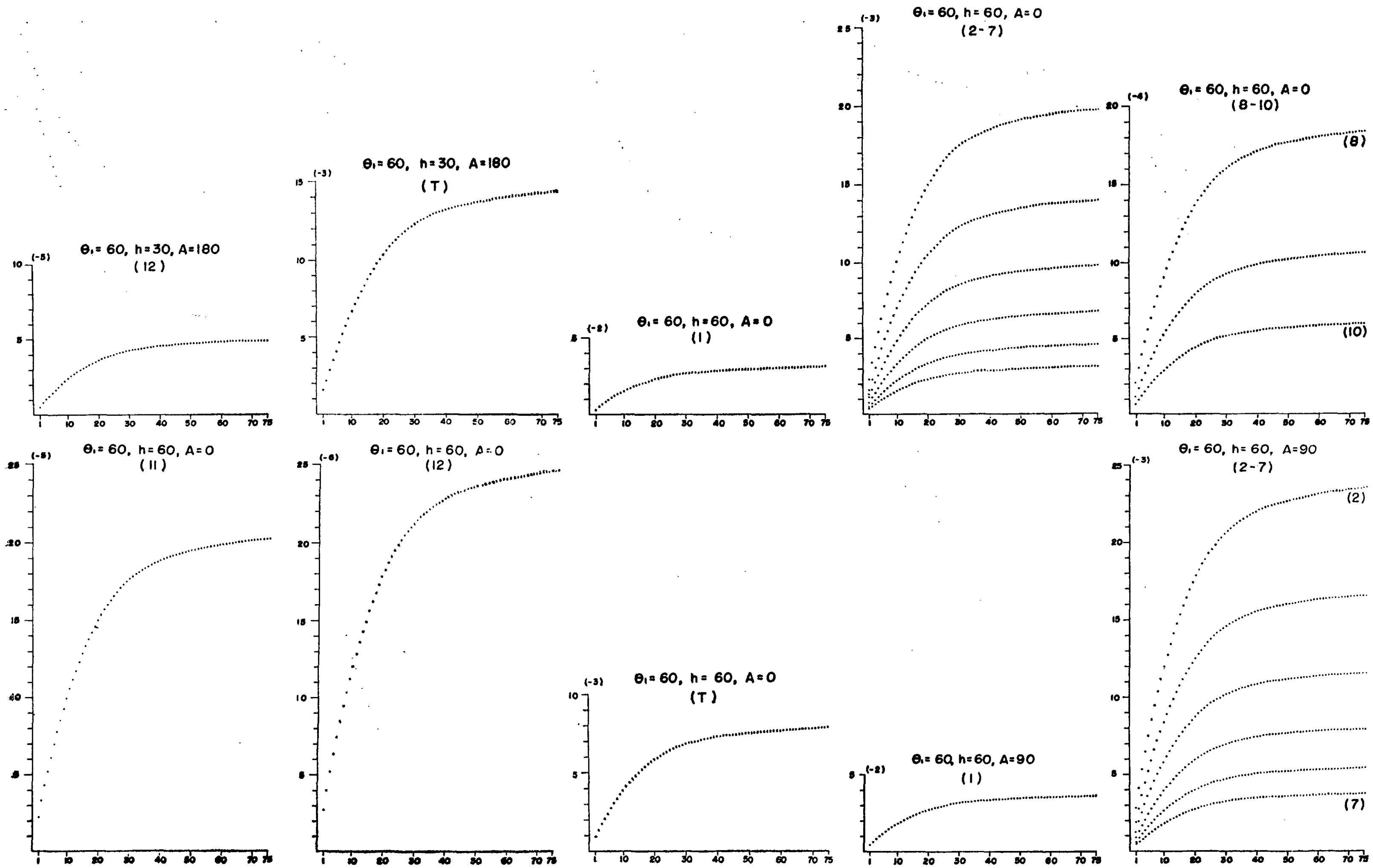
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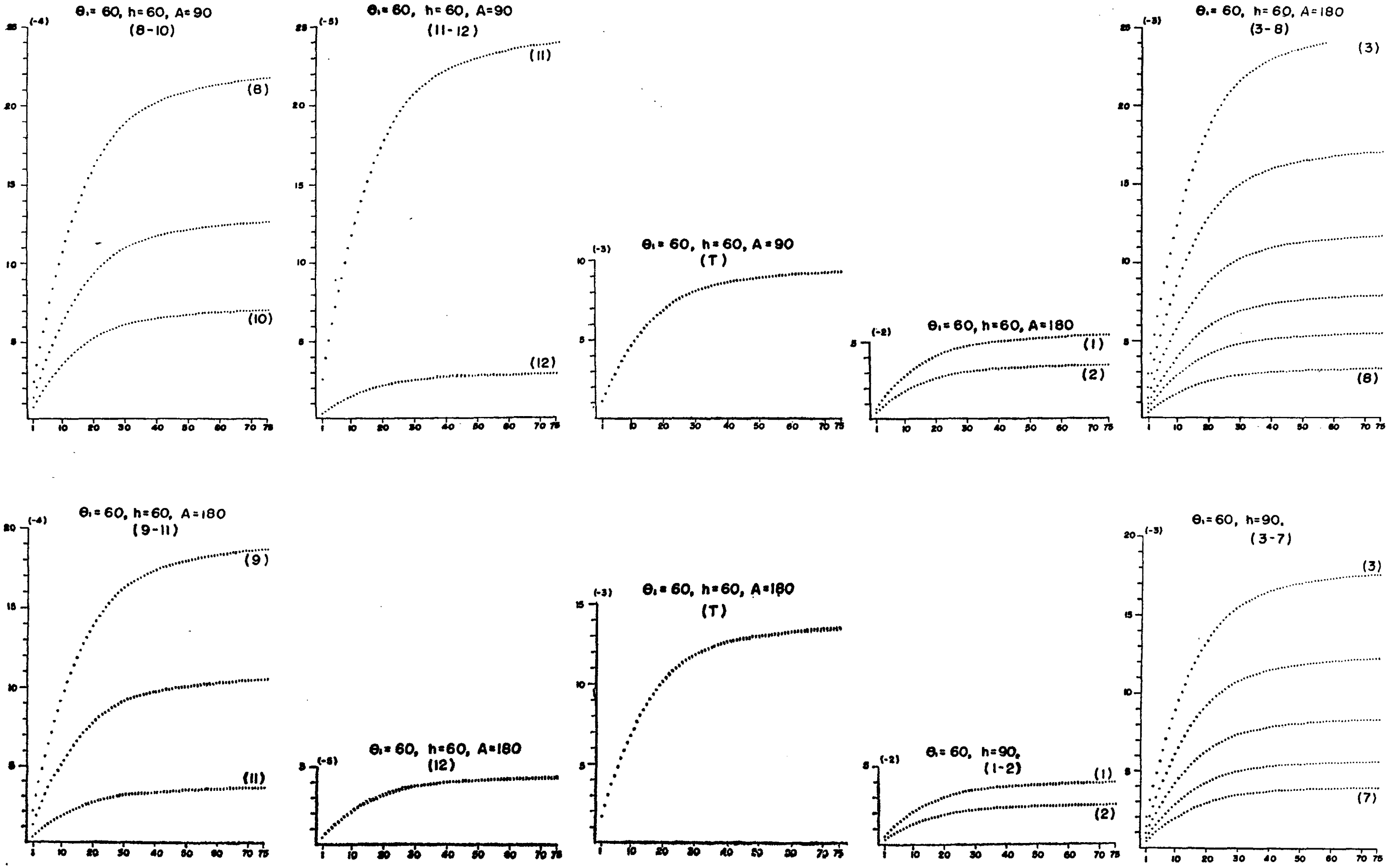
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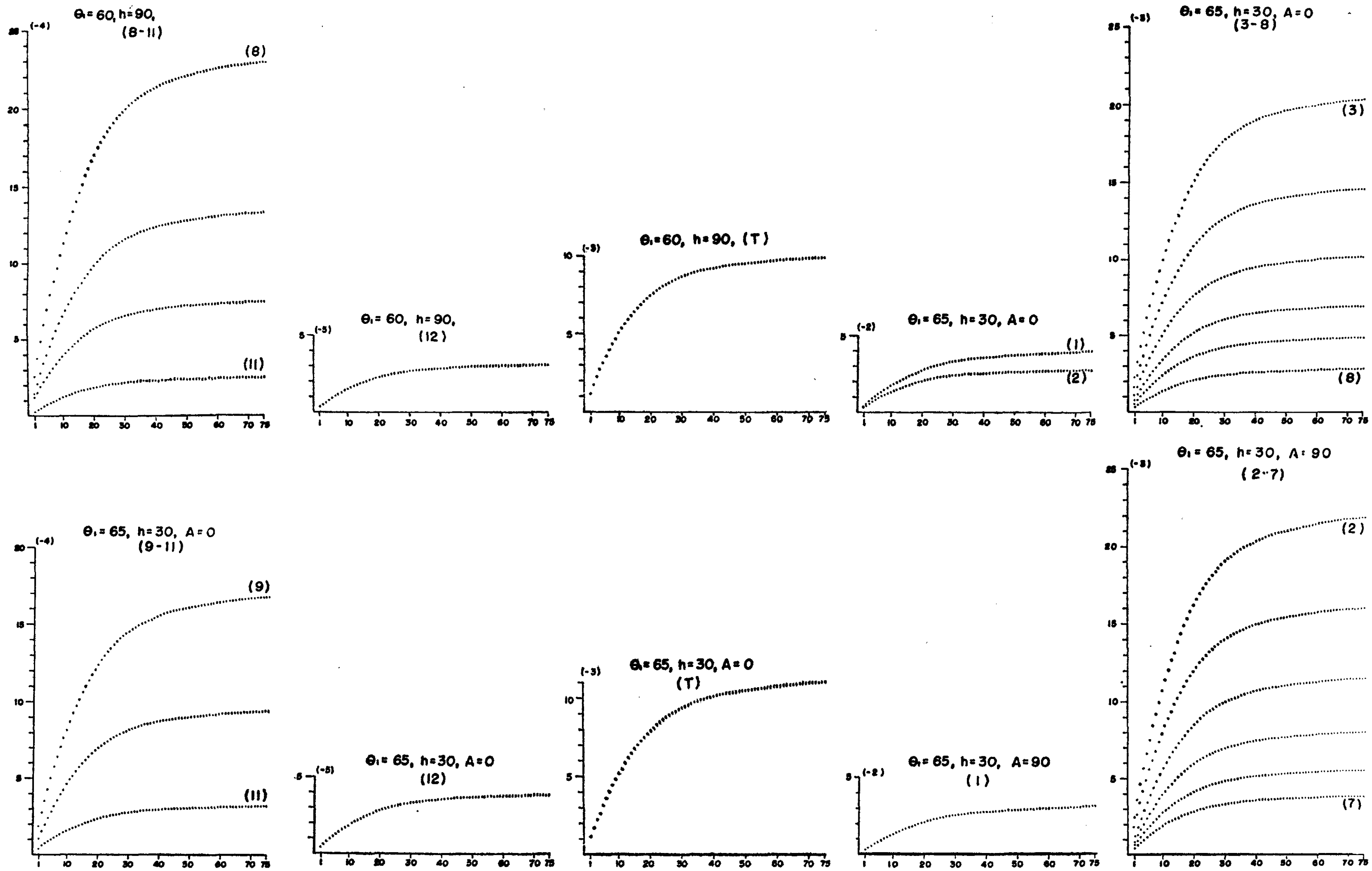
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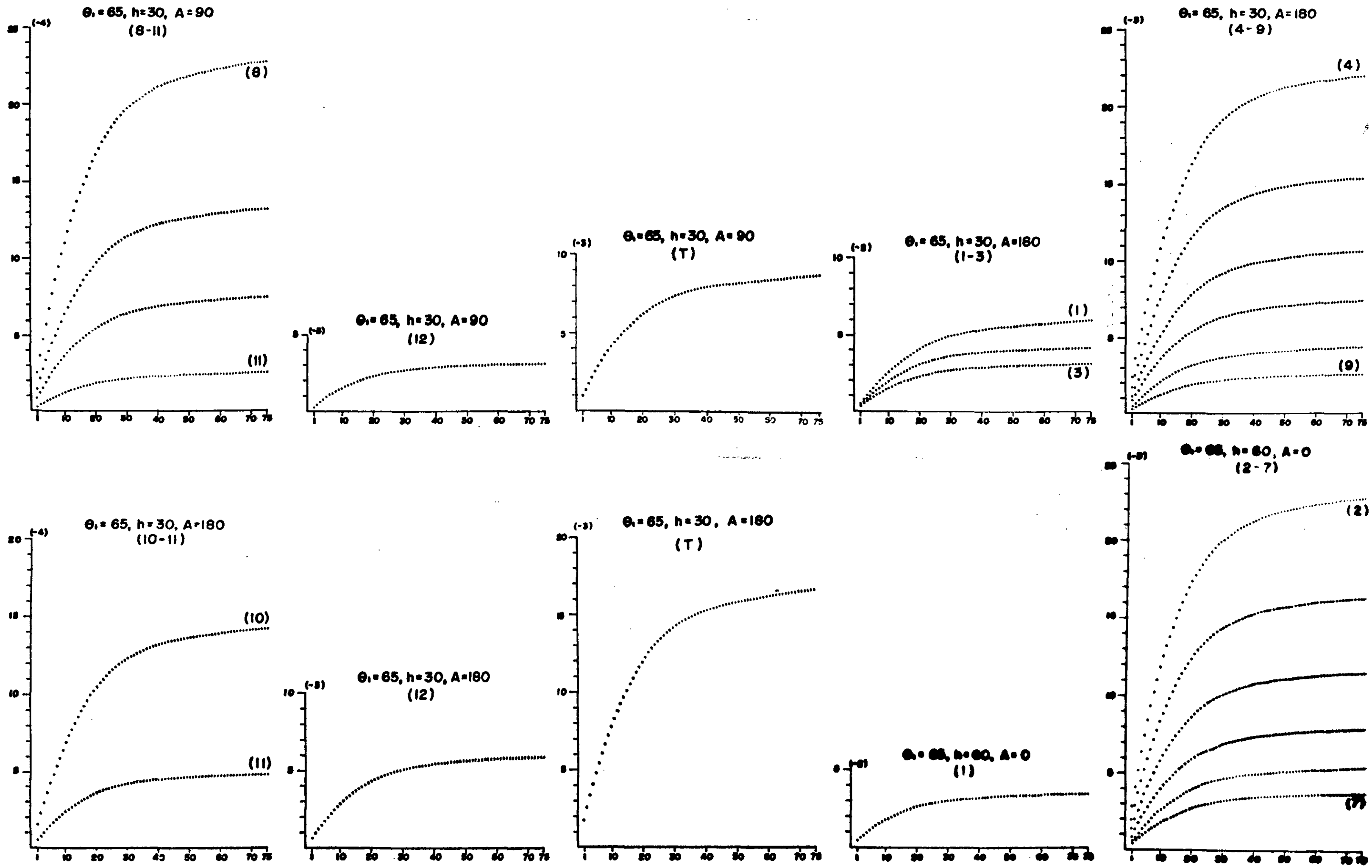
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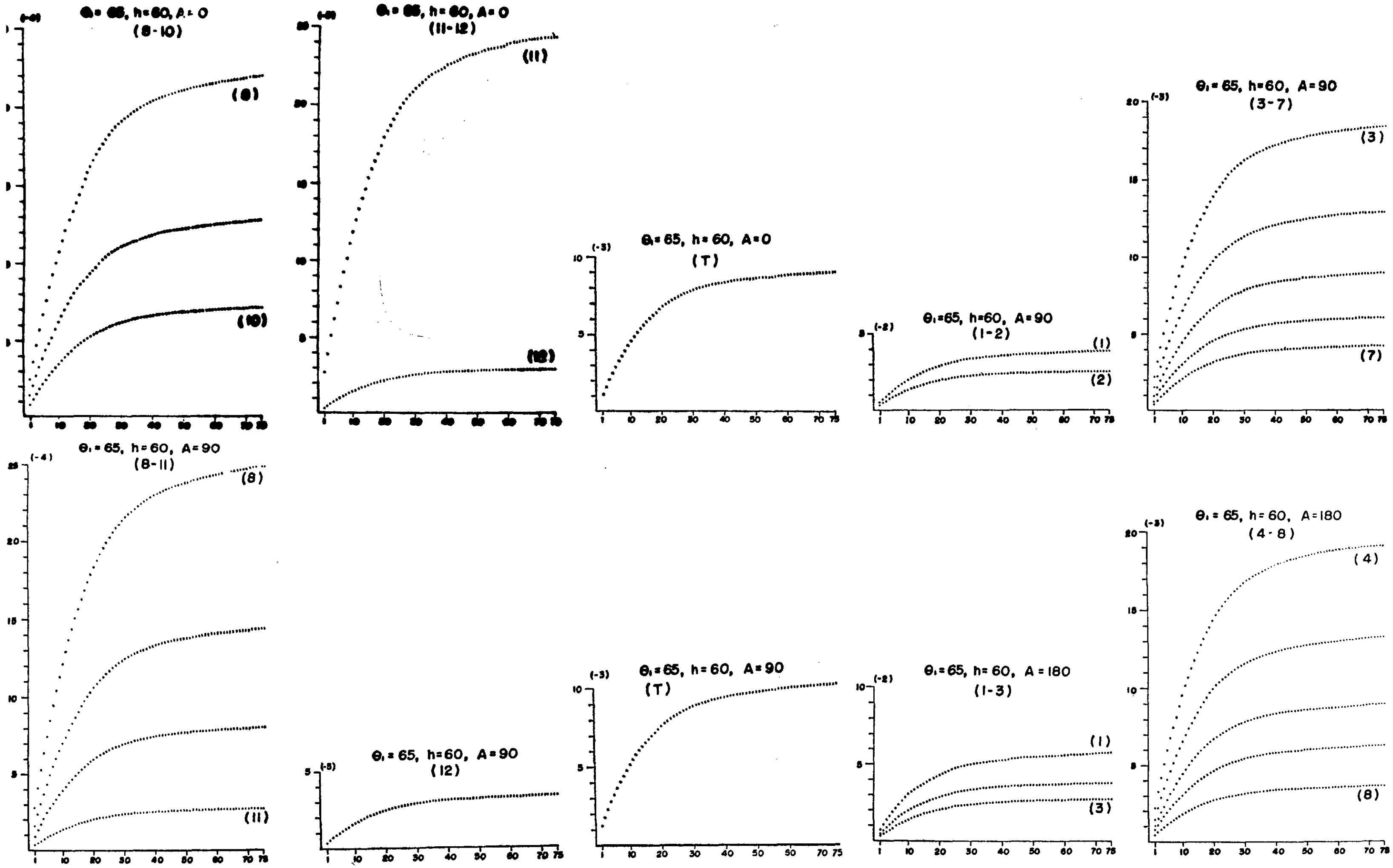
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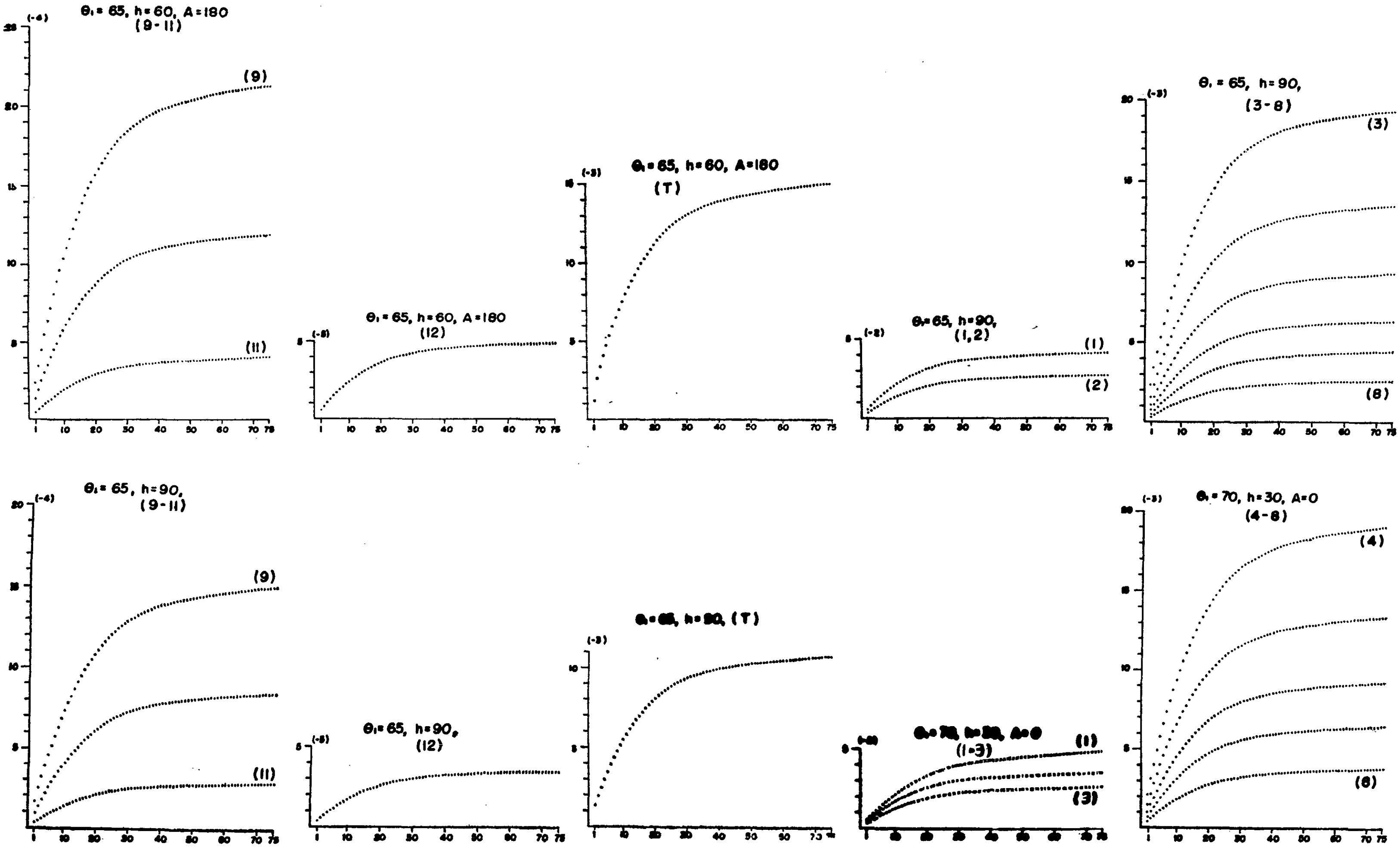

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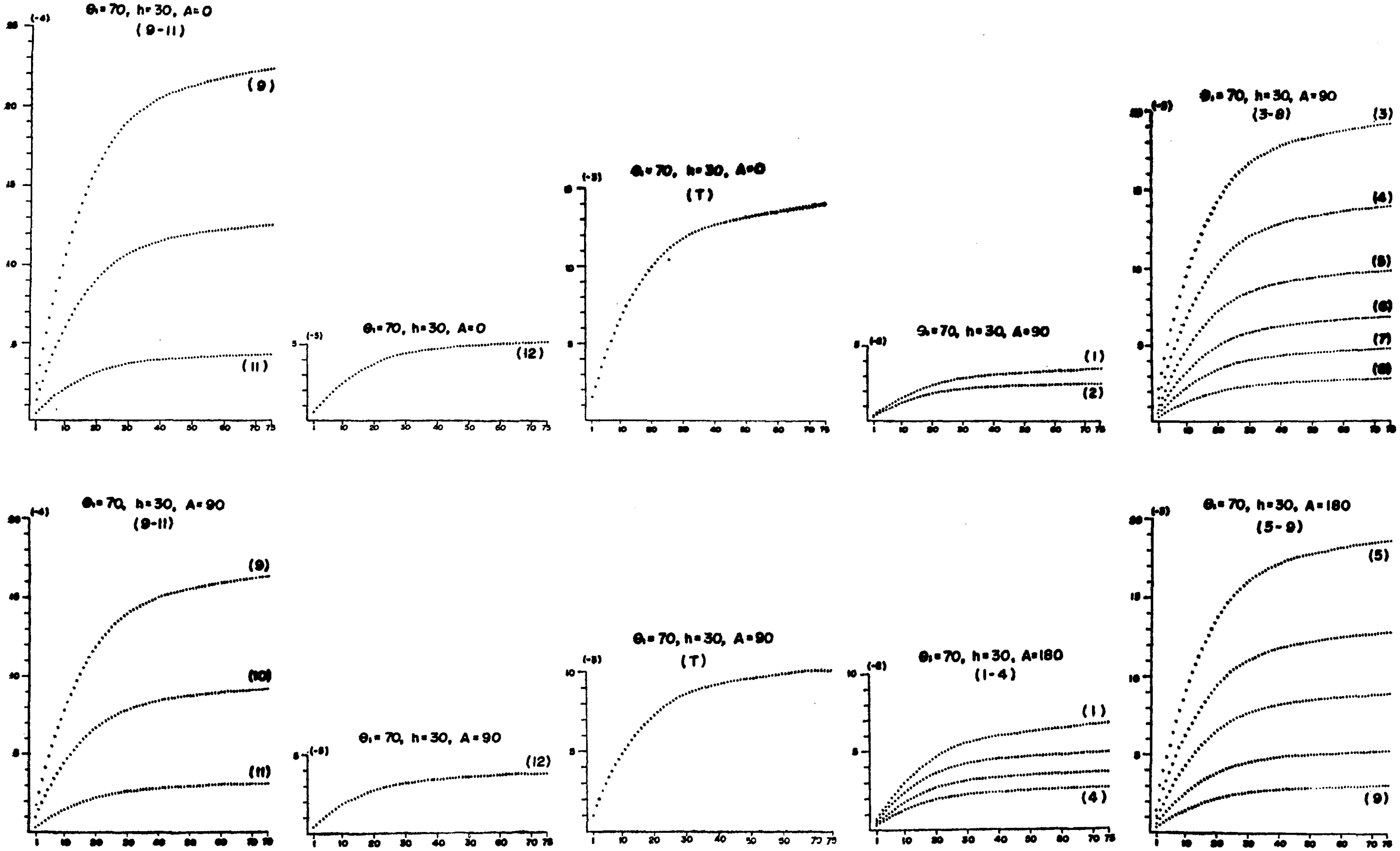
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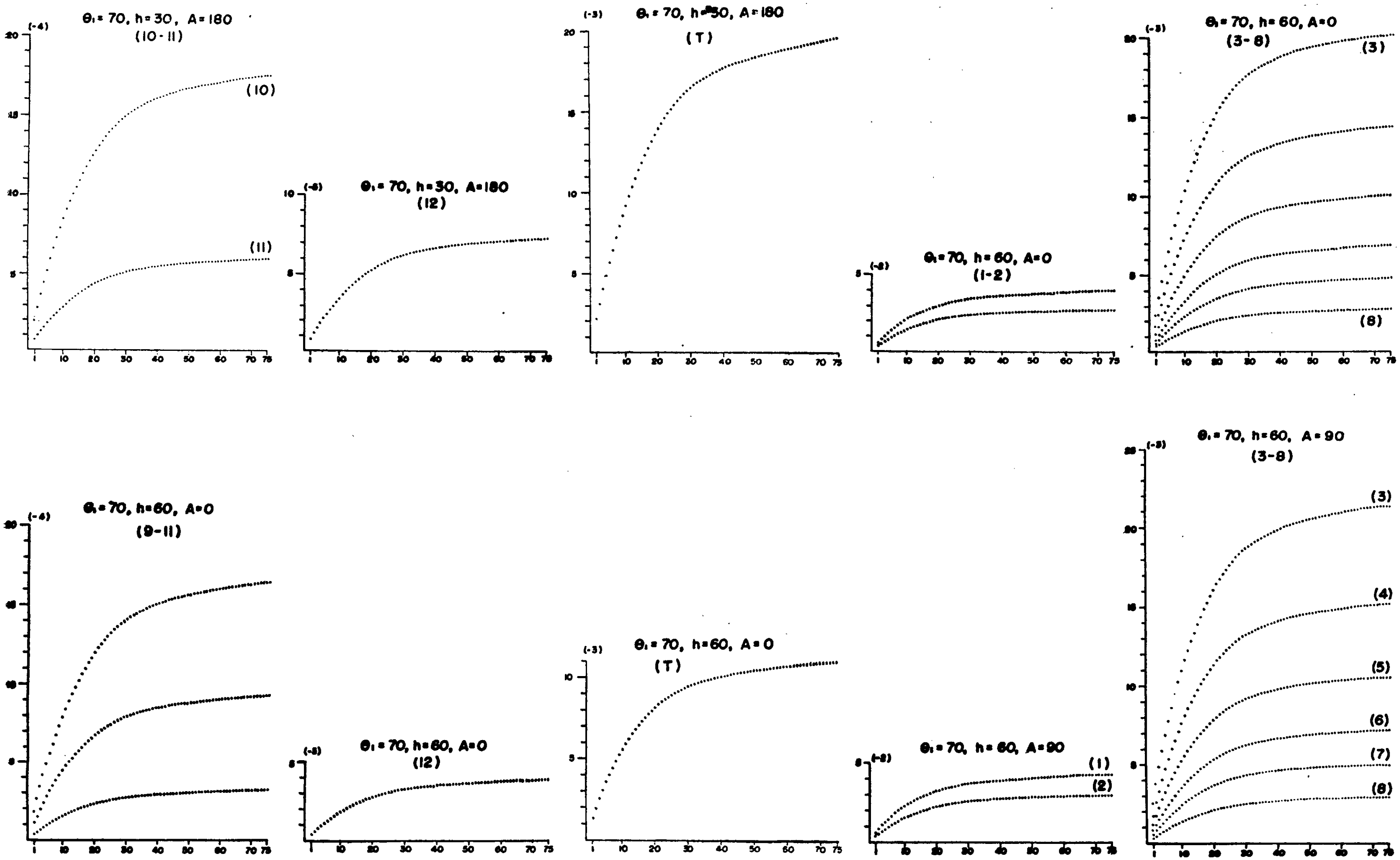
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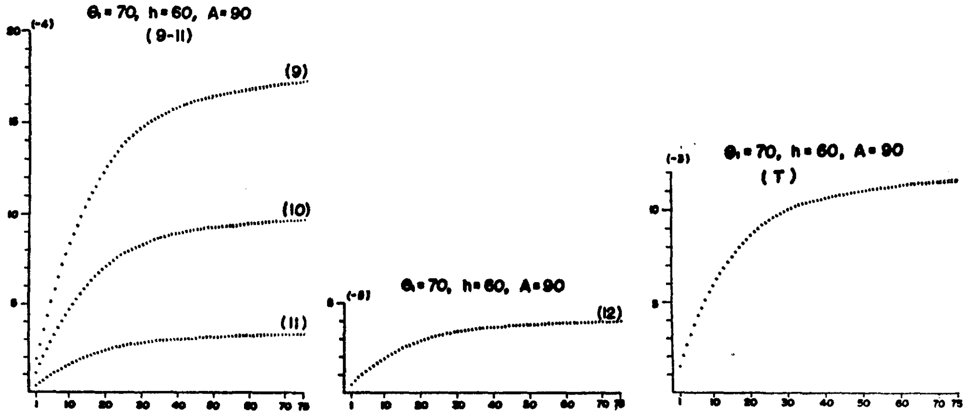
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