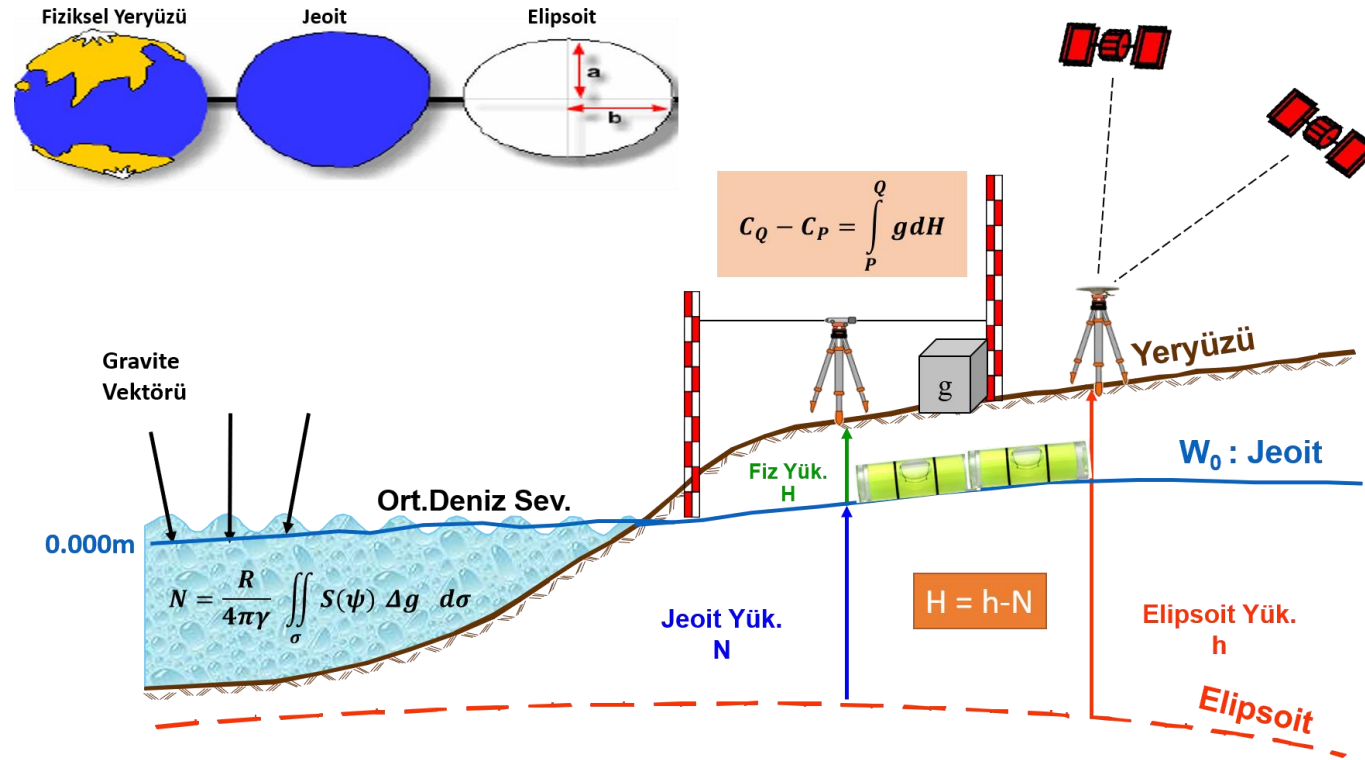


Türkiye Düşey Koordinat Referans Çerçevesi (Vertical Coordinate Reference Frame of Turkey)



Mehmet Simav, Ali İhsan Kurt, Ayhan Cingöz, İlyas Akpınar, Yunus Aytaç Akdoğan

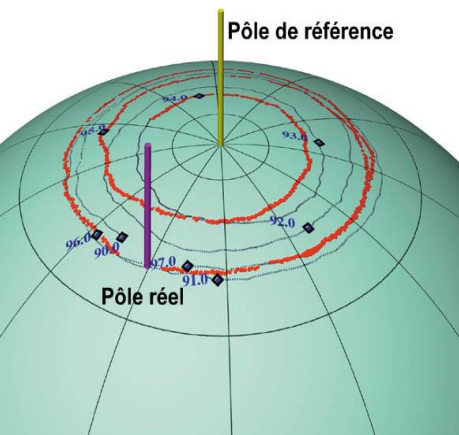
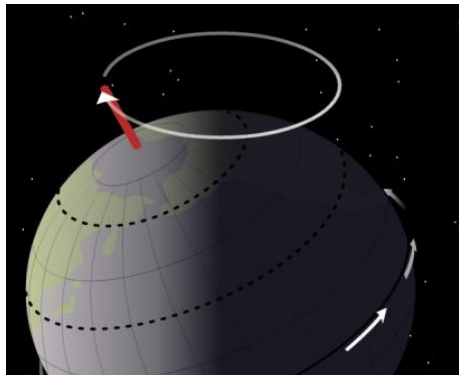
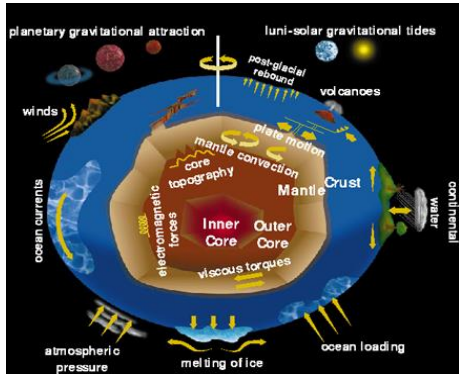


Harita Genel Müdürlüğü

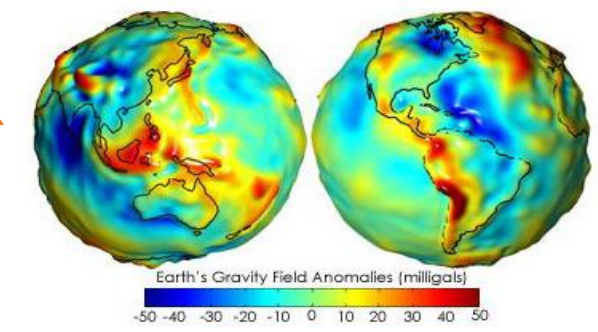
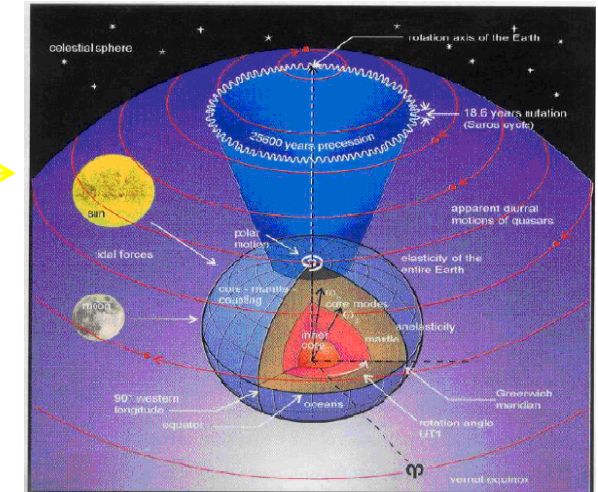
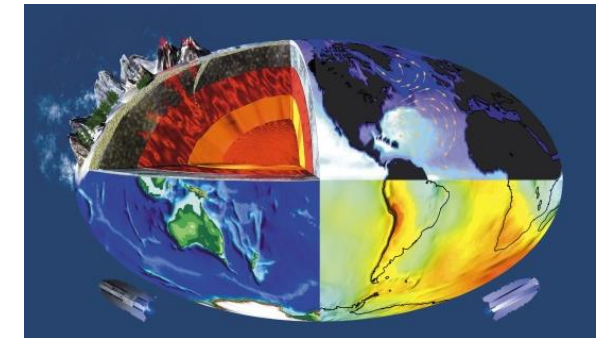
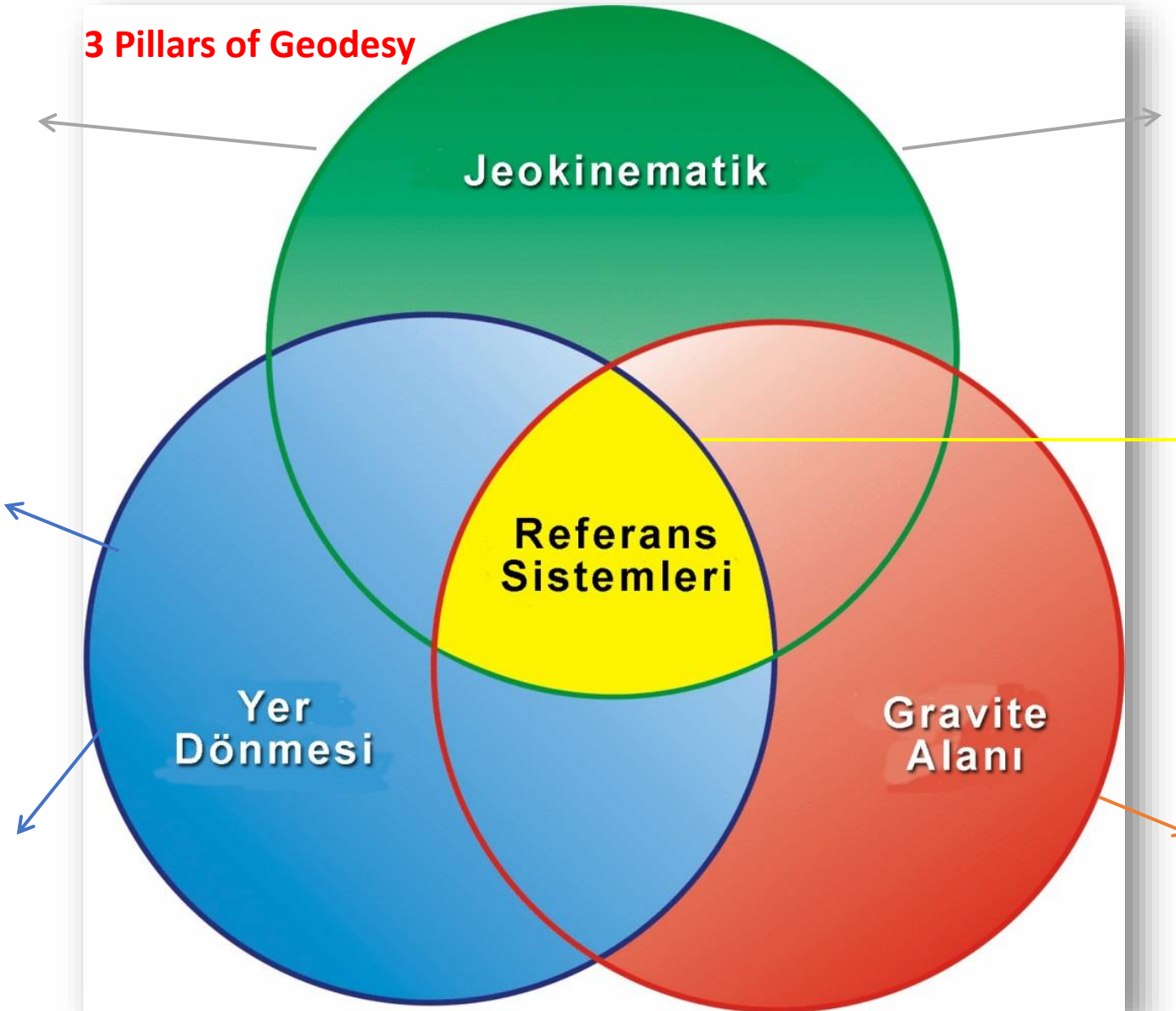


mehmet.simav@harita.gov.tr

Koordinat Referans Sistemi (Importance of Reference Systems)



3 Pillars of Geodesy

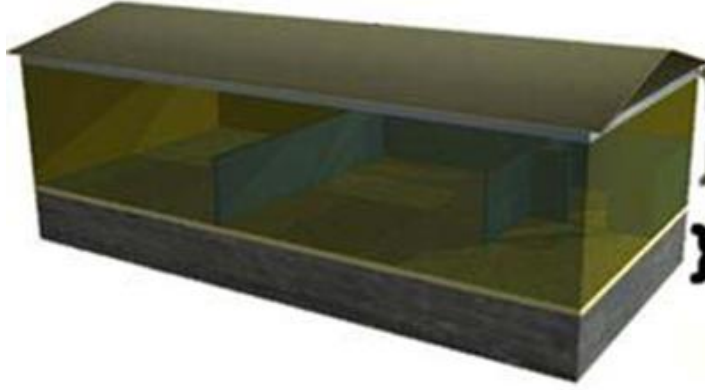


Koordinat Referans Sistemi (Importance of Reference Systems)

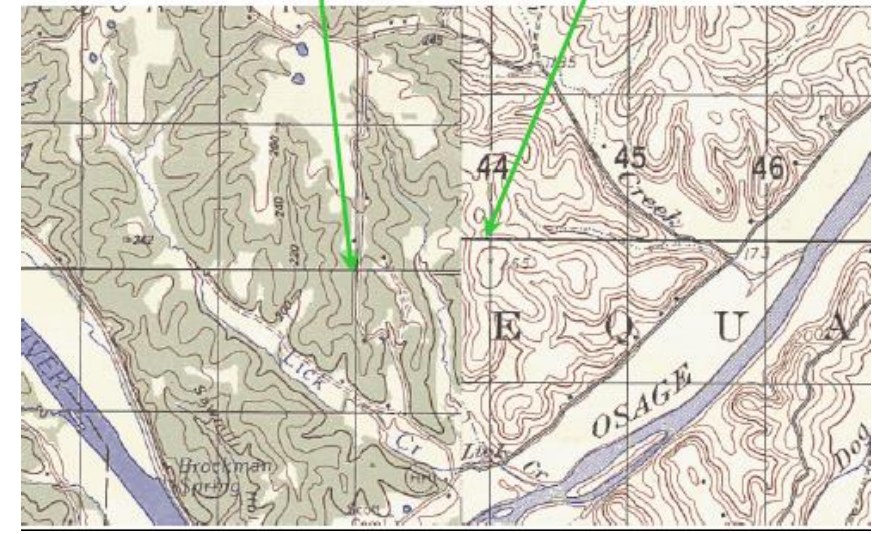
Mapping, GIS, Civil Engineering, Military ...



Harita-CBS-Etüt-Proje-Bilim, ...



Yollar
Arazi Kullanımı
Topoğrafya
Düsey Referans Sistemi
Yatay Referans Sistemi
Koordinat Referans Sistemi



Koordinat Referans Sistemi

(Definition & Elements of Coordinate Reference System)

ISO 19111 (2007): Geographic information — Spatial referencing by coordinates

ISO 19111 (2019): Geographic information — Referencing by coordinates

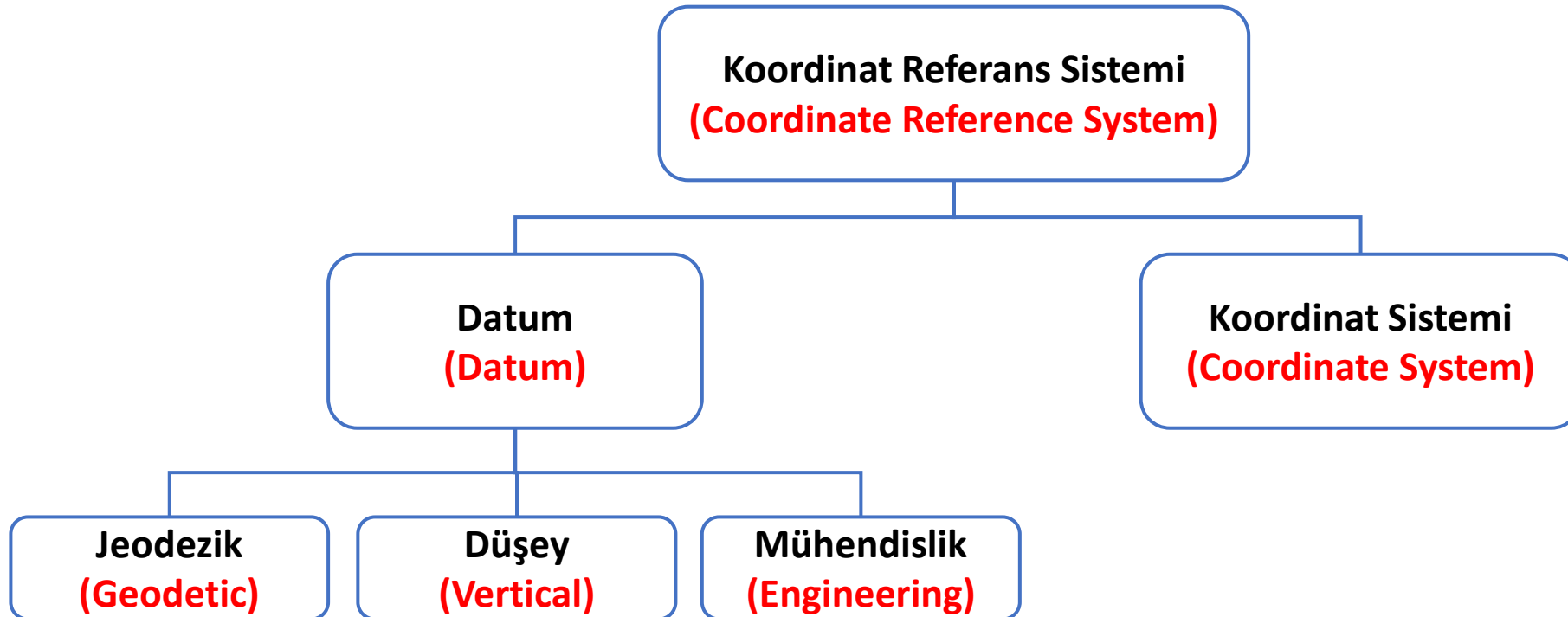


TÜRK STANDARDI
TURKISH STANDARD

TS EN ISO 19111/Coğrafi Bilgi - Koordinatlar ile Konumsal Referanslama

TS EN ISO 19111/A1

ICS 35.240.70



COĞRAFI BİLGİ - KOORDİNATLAR İLE KONUMSAL
REFERANSLAMA - TADİL 1

Geographic information - Referencing by coordinates -
Amendment 1

DüŖey Koordinat Referans Sistemi

(Vertical Coordinate Reference System)

DüŖey Koordinat Referans Sistemi

- Avrupa DüŖey KRS (European Vertical CRS)
- Türkiye DüŖey KRS (Turkish Vertical CRS)
-

DüŖey Datum (Vertical Datum)

- NAP (Normal Amsterdam Peil)
- Antalya Ortalama Deniz Seviyesi (Antalya Mean Sea Level)
- Kronstadt
- ...

Koordinat Sistemi (Coordinate System)

- Gravite İliŖkili (gravity related)
 - Jeopotansiyel Sayı (geopotential number)
 - Ortometrik Yükseklik (orthometric height)
 - Normal Yükseklik (normal height)
 - ...
- Geometrik Yükseklik (geometric height)
-

Türkiye Düşey Koordinat Referans Sistemi

(Definition of Turkish Vertical Reference System)

$$C_{ANTALYA}^{ODS} = W_0 - W_{ANTALYA}^{ODS} = 0$$

$$C_Q - C_P = \int_P^Q gdH \approx \sum_{i=1}^n \frac{g_i + g_{i+1}}{2} \Delta H_i$$

$$H_P = \frac{C_P^{adj}}{\bar{g}_P} = \frac{C_P^{adj}}{g_P + 0.0424H_P}$$

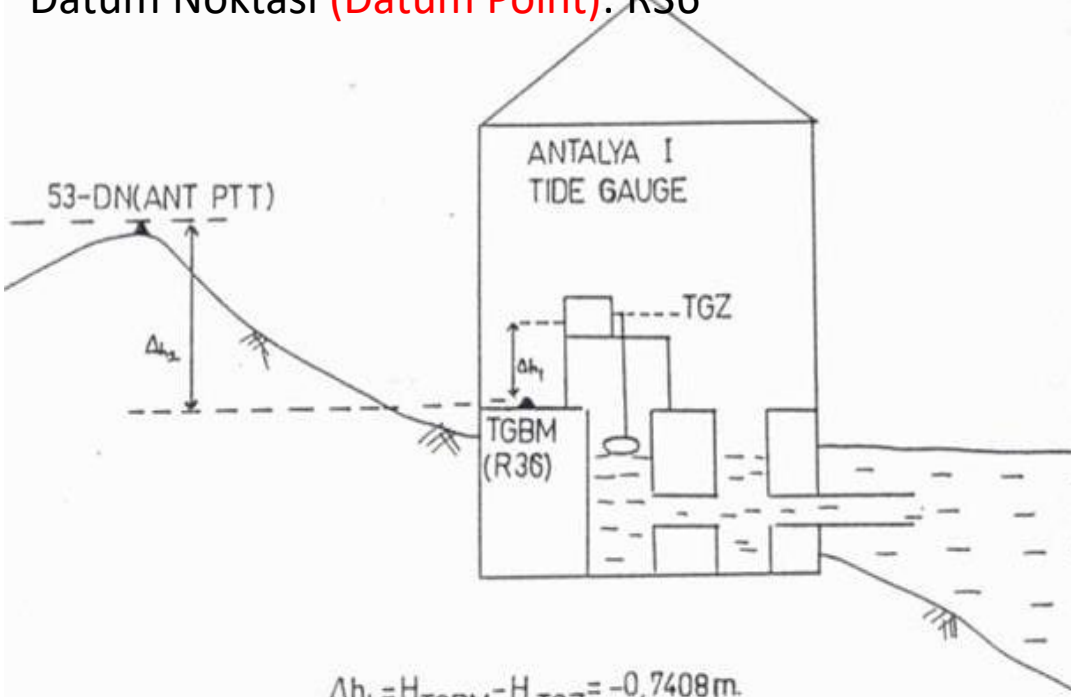
- Düşey datum eş potansiyelli bir yüzeydir ve Antalya Ortalama Deniz Seviyesi ile çakışır.
(the reference surface (vertical datum) is an equipotential surface of the Earth's gravity field which is the mean sea level of Antalya tide gauge)
- Yükseklik sistemi gravite ile ilişkilidir ve düşey bileşen noktalar arasındaki potansiyel farkıdır.
(Gravity-related height system. Vertical components are the geopotential differences between benchmarks - geopotential numbers)
- Helmert ortometrik yükseklik (Poincare-Prey indirgemesi).
(Helmert orthometric heights (Poincare-Prey reduction))

Türkiye Düşey Koordinat Referans Çerçevesi (Realization of Turkish Vertical Reference System)

Düşey Datum Gerçekleşimi (Realization):

Antalya 1936-1971 ortalama deniz seviyesi

Datum Noktası (Datum Point): R36



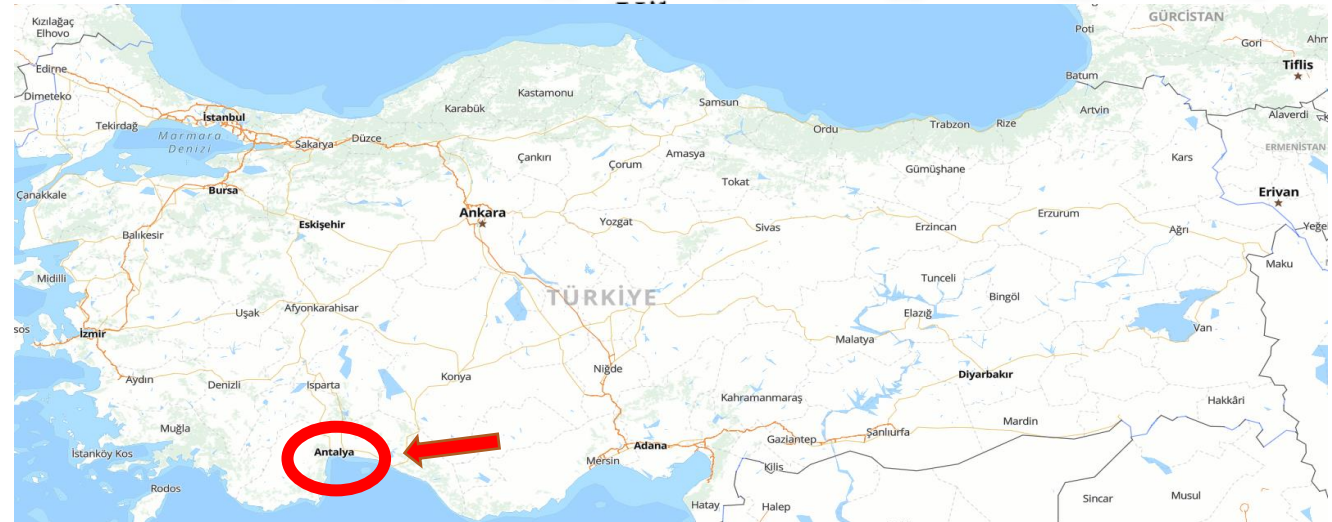
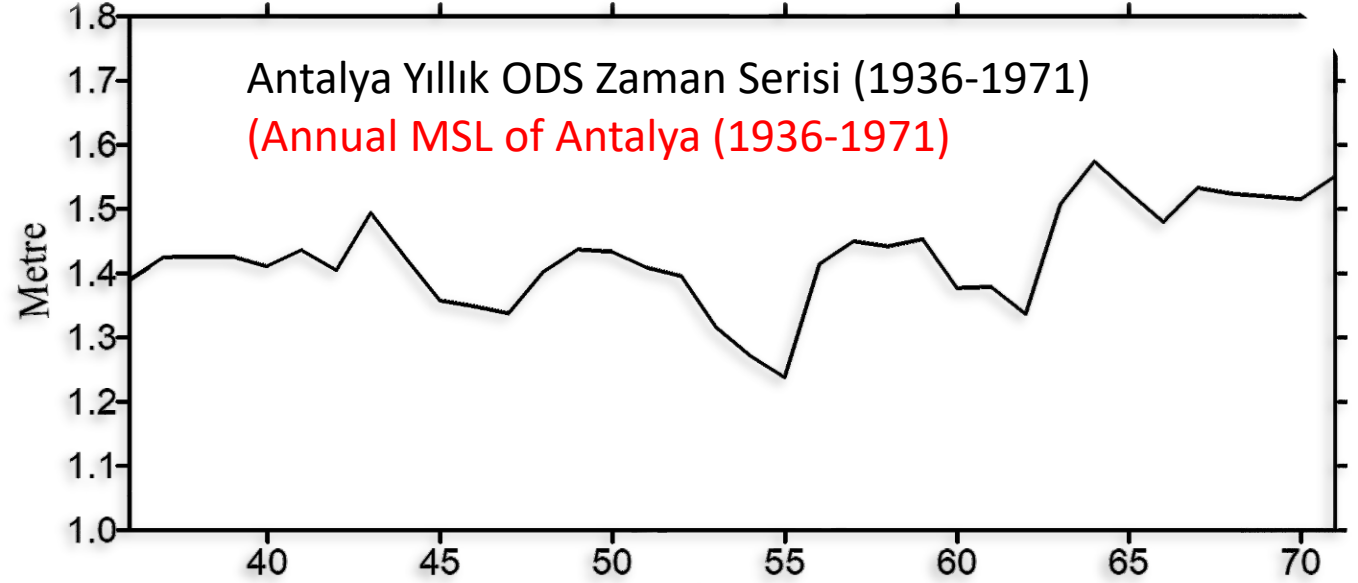
$$\Delta h_1 = H_{TGBM} - H_{TGZ} = -0,7408 \text{ m.}$$

$$\Delta h_2 = H_{53-DN} - H_{TGBM} = 35,218 \text{ m.}$$

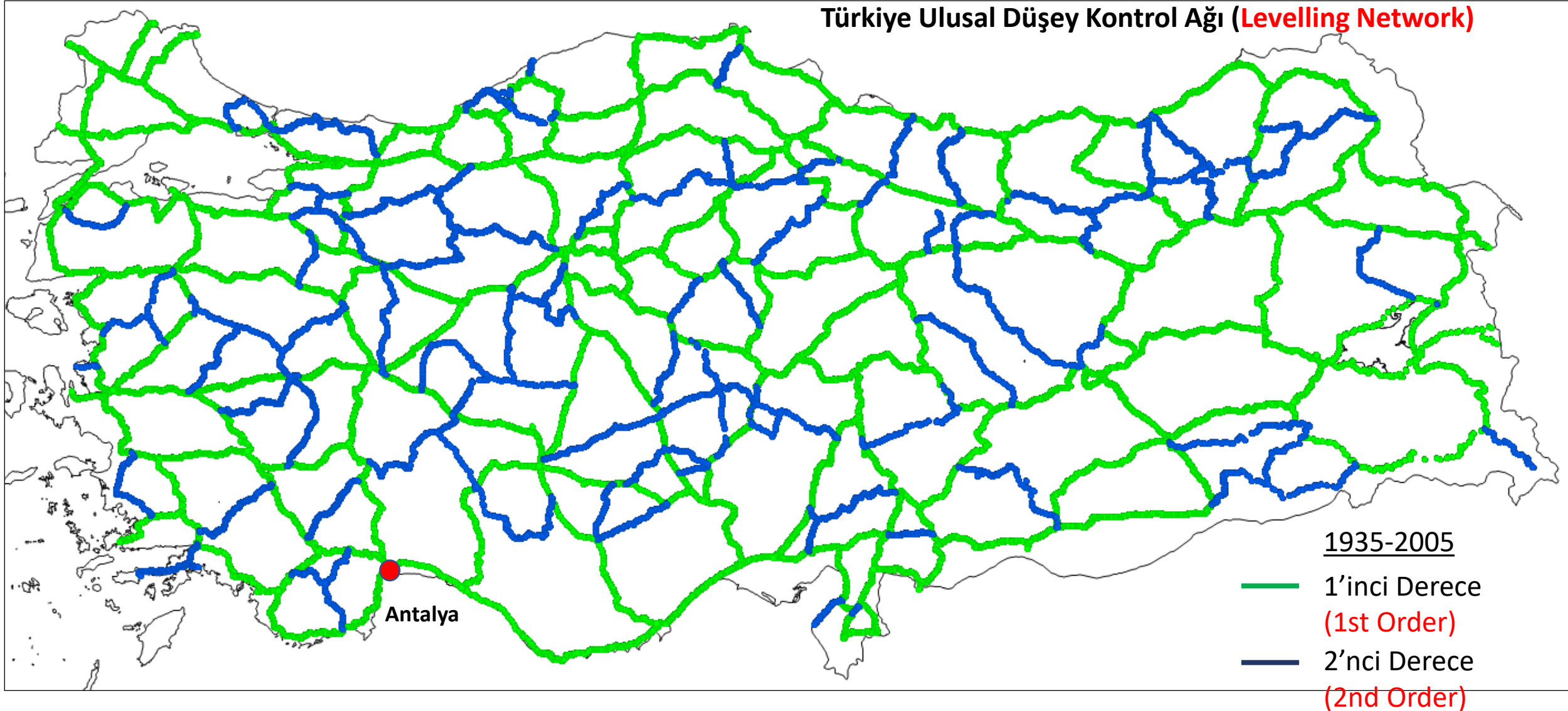
$$\Delta h_3 = H_{53-DN} - H_{85-2} = 35,7502 \text{ m.}$$

$$\Delta h_4 = H_{GPS} - H_{85-2} = 4,0303 \text{ m.}$$

$$H_{TGBM} - \text{MSL} = 1,42 \text{ m.}$$



Türkiye Düşey Koordinat Referans Çerçevesi (Realization of Turkish Vertical Reference System)

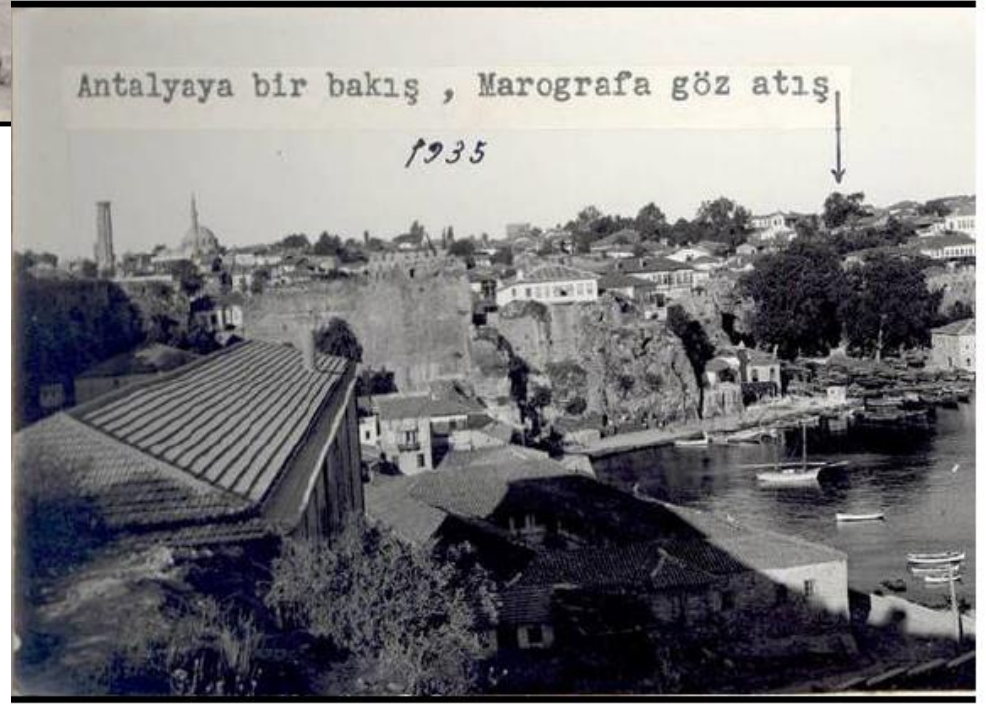
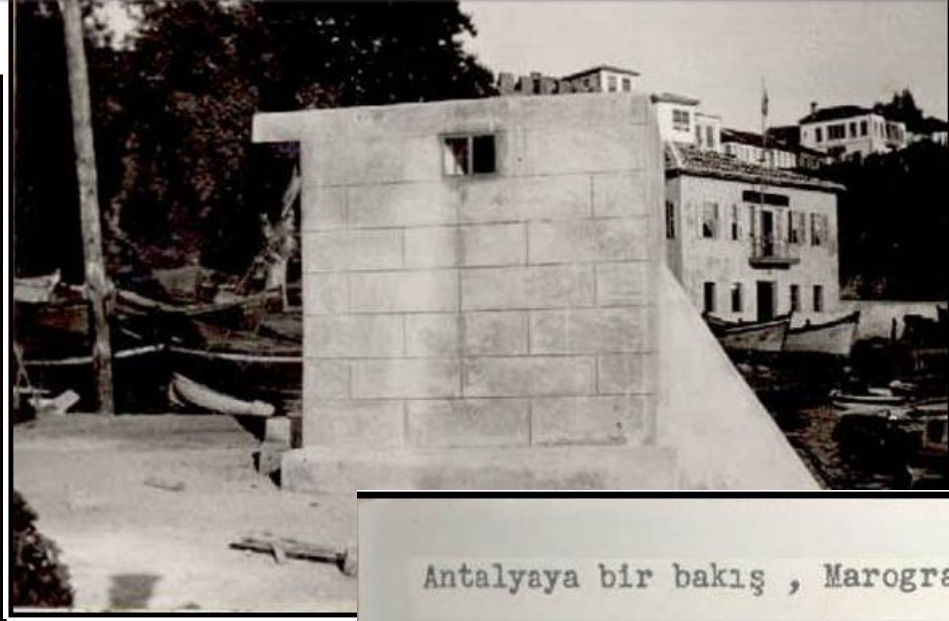


Türkiye Düşey Koordinat Referans Çerçevesi

(Realization of Turkish Vertical Reference System - Summary)

Referans Sistemi (Reference System)	Türkiye Düşey Referans Sistemi
Referans Çerçevesi (Reference Frame)	Türkiye Ulusal Düşey Kontrol Ağı-1999 (TUDKA-99)
Düşey Datum (Vertical Datum)	Antalya mareograf istasyonu, 1935-1971 dönemi ortalama deniz seviyesi
Datum Noktası (Datum Point)	R36 \rightarrow $H_{R36} = 1.4284$ m, $C_{R36} = 1.3997$ kgal.m, $g_{R36} = 9.7988393$ ms ⁻²
Gravite Datumu (Gravity Datum)	IGSN71 (The International Gravity Standardization Net 1971)
Yükseklik Sistemi (Coordinate System)	Gravite ilişkili - Helmert Ortometrik
Nivelman Periyot (Levelling Period)	1935-2005
Nokta Sayısı (Number of Benchmarks)	25,680 adet
Uzunluk (Length of Levelling Lines)	29,316 km
Düğüm Noktası Sayısı (# of Node Points)	274 adet
1'nci Derece Hat Sayısı (# 1st Order Lines)	158 adet (4 \sqrt{S} mm)
2'nci Derece Hat Sayısı (# 2nd Order Lines)	85 adet (8 \sqrt{S} mm)
Dengeleme Modeli (Adjustment)	$L + v = Ax$ $\rightarrow L$: Jeopotansiyel Sayı Farkları $\rightarrow \min(v^T P v)$ $P = \sigma_0^2 C_L^{-1}$ $\rightarrow P$: Noktalar arası mesafenin tersi ile orantılı
Uyuşumsuz Ölçü (Outlier Detection)	Data Snooping

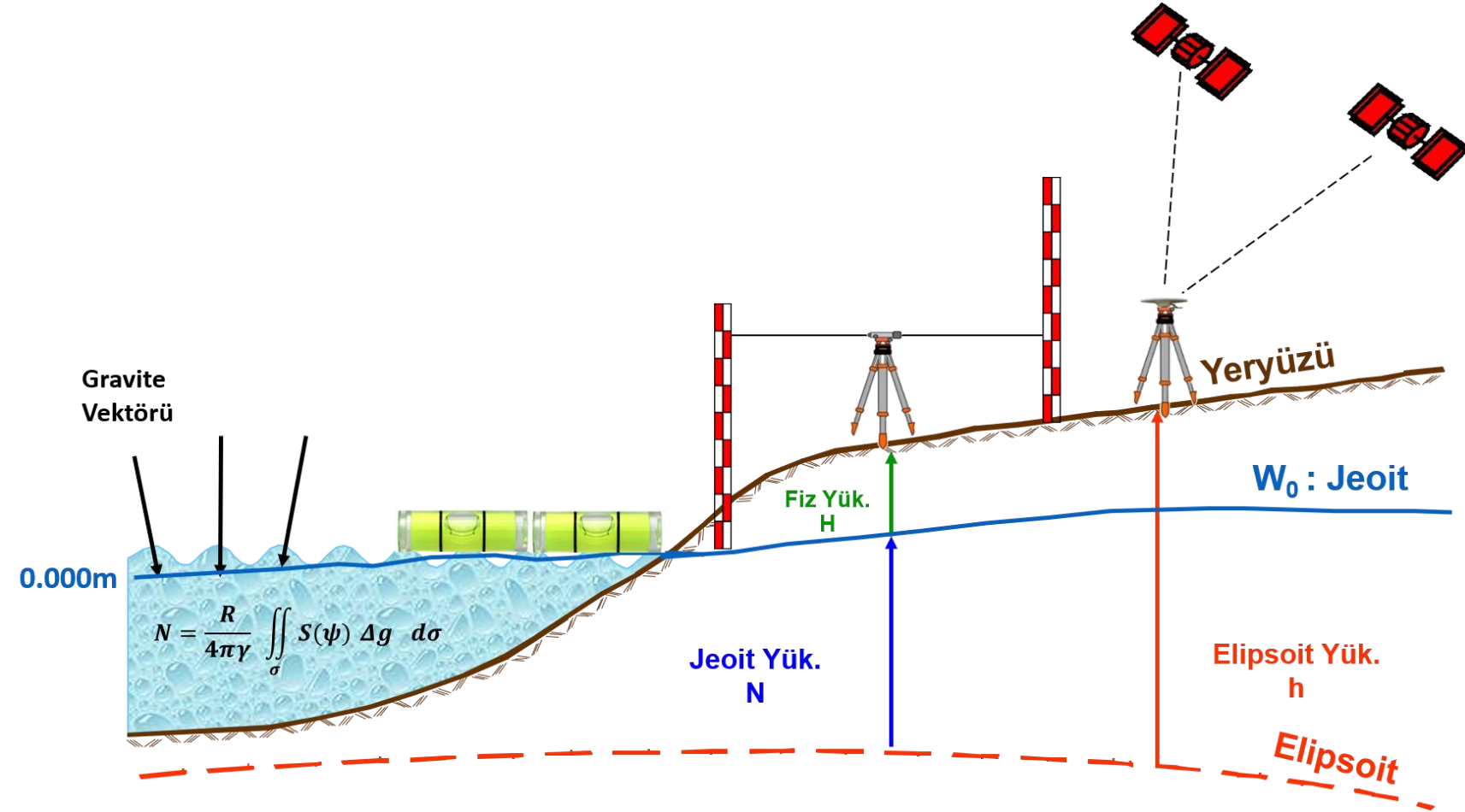
Türkiye Düşey Koordinat Referans Çerçevesi (Historical Photos from Antalya Tide Gauge)



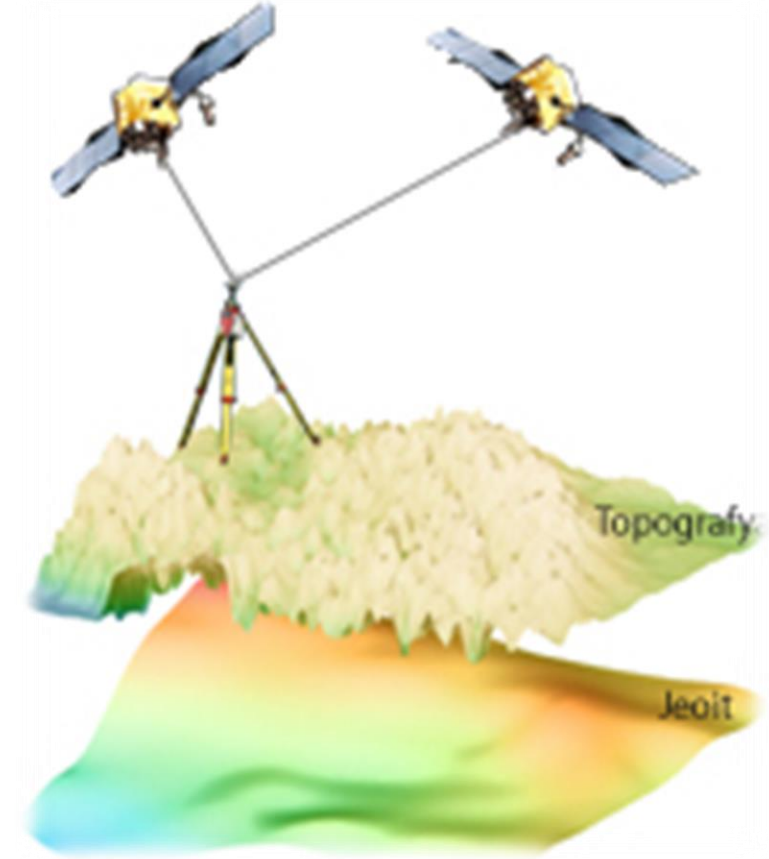
Türkiye Düşey Koordinat Referans Çerçevesi (Historical Photos from Levelling Measurements)



Türkiye Jeoit Modelleri (Geoid Models of Turkey)



$$H = h - N$$



Türkiye Jeoit Modelleri (Geoid Models of Turkey)



Türkiye Jeoit Modelleri (Geoid Models of Turkey)

	TG-99A	TG-03	THG-09	TG-20
Kestirim Tekniği (Method)	LSC	LSC	RCR - FFT	KTH-LSMSA
Yer Potansiyel Modeli (GGM)	GPM2-T1	EGM96	EGM08	GOCO06S
Yersel Gravite Ölçü (Point Gravity)	62,250	61,597	262,212	12,905 Yeni + 253,018 Tarihsel
Deniz Gravite Ölçüsü (Marine Gravity)	-	Uydu Altimetre	Uydu Altimetre	XGM2019e
Sayısal Yükseklik Modeli (DEM)	15'' x 15''	15'' x 15''	3'' x 3''	7.2'' x 7.2''
Dış Doğruluğu (Model Accuracy)	±10 cm	±9 cm	± 8.4 cm	± 1.3 cm – 6.3 cm

LSC : En Küçük Karelerle Kollokasyon

RCR-FFT : Kaldır Hesapla Yerine Koy – Hızlı Fourier Dönüşümü

KTH-LSMSA : Stokes Fonksiyonunun En Küçük Karelerle Modifikasyonu – İlave Düzeltmeler (KTH Yöntemi)

Avrupa Düşey Referans Sistemi ile Bağlantı (Connection to EVRF2007)

INSPIRE: Avrupa Parlamentosu ve Konseyinin 2007/2/EC sayılı direktifi

D2.8.I.1 INSPIRE Specification on Coordinate Reference Systems-Guidelines. INSPIRE Tematik Çalışma Grubu Koordinat Referans Sistemleri ve Coğrafi Grid Sistemleri



Avrupa Düşey Referans Sistemi ile Bağlantı



NR10



NR7



$$H_{\text{EVRF2007}} = H_{\text{TUDKA99}} + a_1$$

BM	H_{TUDKA99}	H_{EVRF2007}	a_1
NR10	48.2634	47.8574	-0.4060 ± 0.065
NR07	653.9477	653.5430	-0.4047 ± 0.068

$$a_1 = -0.405 \pm 0.067 \text{ m}$$

Avrupa Düşey Referans Sistemi ile Bağlantı

<http://crs.bkg.bund.de/>

CRSEU

Coordinate Reference Systems
in Europe



Information and Service System for European Coordinate Reference Systems

To get the information select a country in the list or click on the corresponding red dot in the map

Albania
Austria
Belarus
Belgium
Bosnia / Herceg.
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Gibraltar
Great Britain
Greece
Hungary
Iceland
Ireland



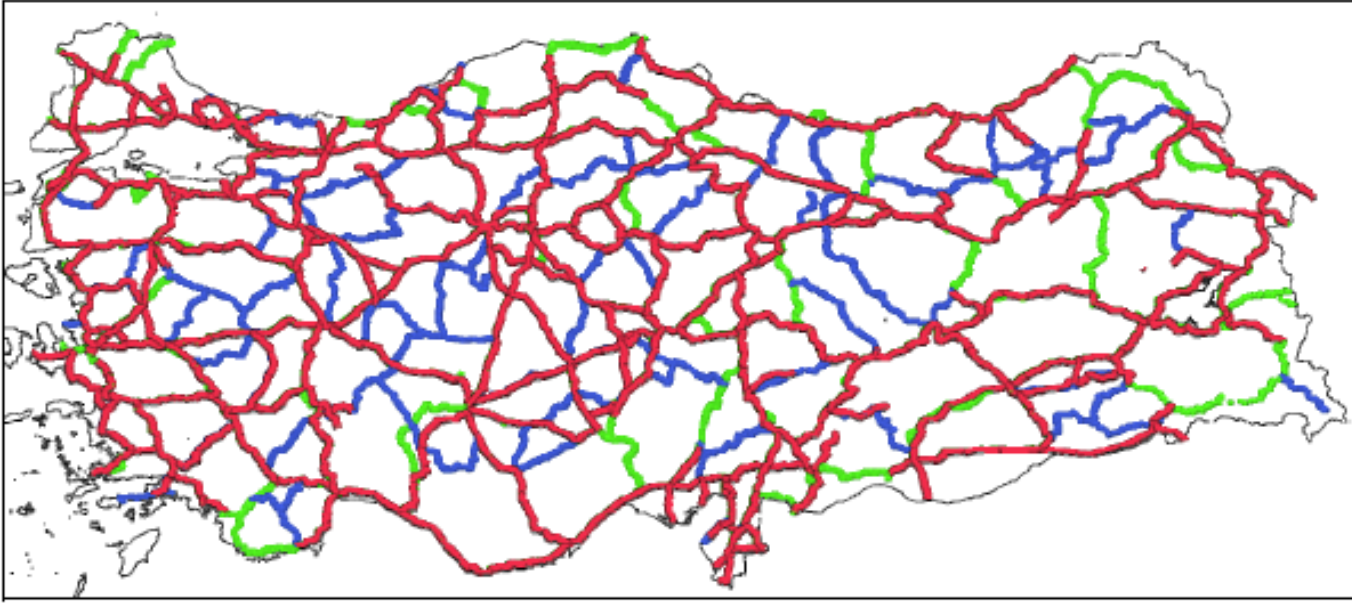
Italy
Latvia
Lithuania
Luxembourg
Malta
Netherlands
Macedonia
Northern Ireland
Norway
Poland
Portugal
Romania
Russia
Slovak Republic
Slovenia
Spain
Sweden
Switzerland
Turkey
Ukraine

Position				
TR_ED50 / UTM	Datum ED50 with UTM Projection	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TR_ED50 / TR_TM	Datum ED50 in Transverse Mercator Projection with special Turkish parameters	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
TR_TUREF / TR_TM	Datum TUREF in Transverse Mercator Projection with special Turkish parameters	<input type="checkbox"/>	<input type="checkbox"/>	

Height				
TR_ANT / OH	orthometric heights referred to tide gauge Antalya	<input type="checkbox"/>	<input type="checkbox"/>	
TR_ANT / CP	geopotential numbers referred to tide gauge Antalya	<input type="checkbox"/>	<input type="checkbox"/>	

Selection of transformation version for CRS: TR_ANT / OH	
Transformation	Selection
TR_ANT / OH to EVRF2019zero	<input type="checkbox"/>
TR_ANT / OH to EVRF2019mean	<input type="checkbox"/>
TR_ANT / OH to EVRF2007	<input type="checkbox"/>

Yükseklik Sistemi Modernizasyonu (Height System Modernization)



— Genişletilmiş Yollar

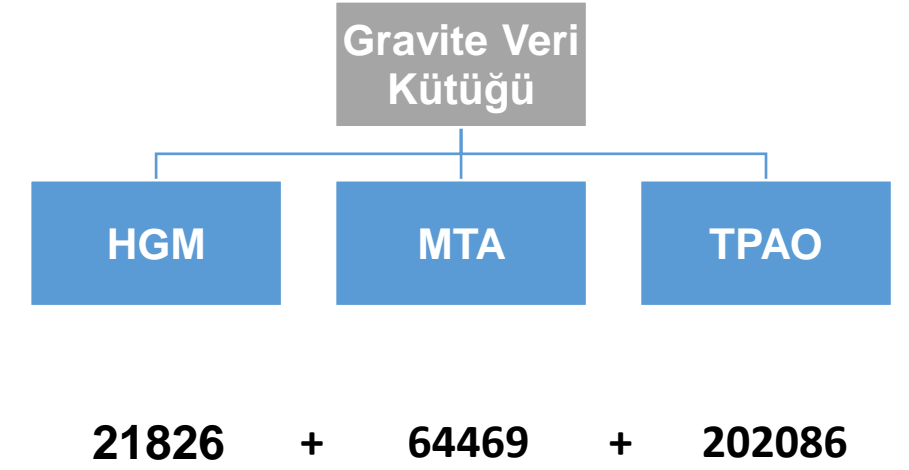
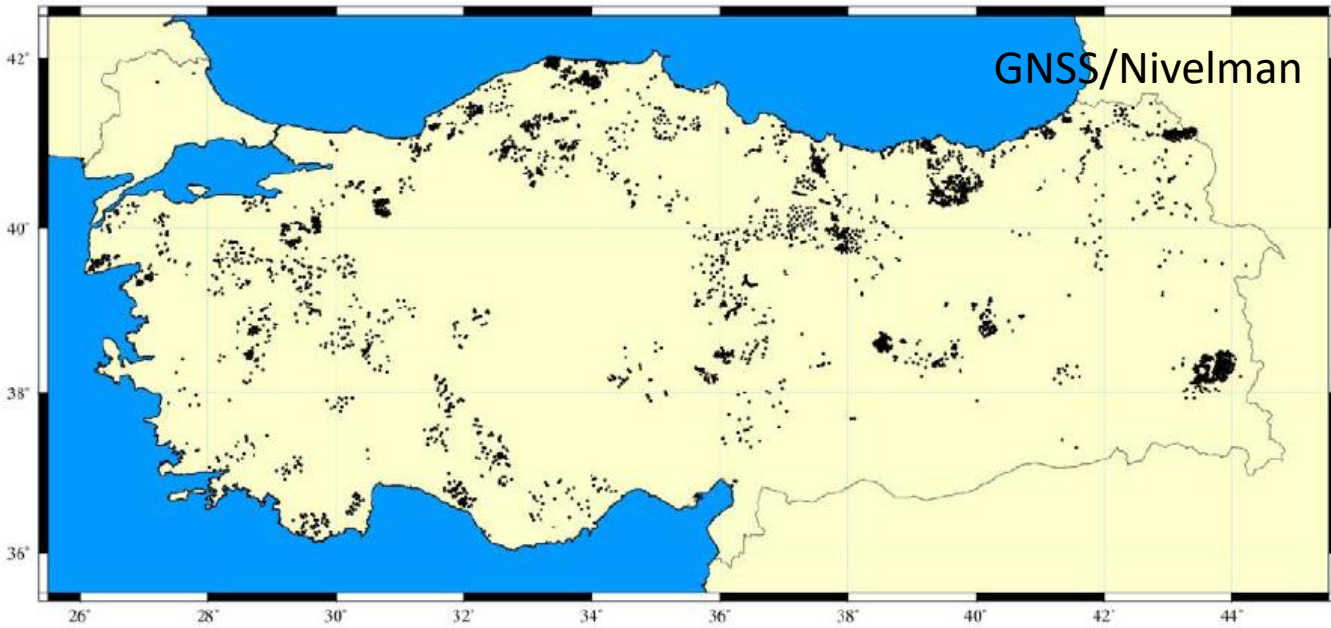
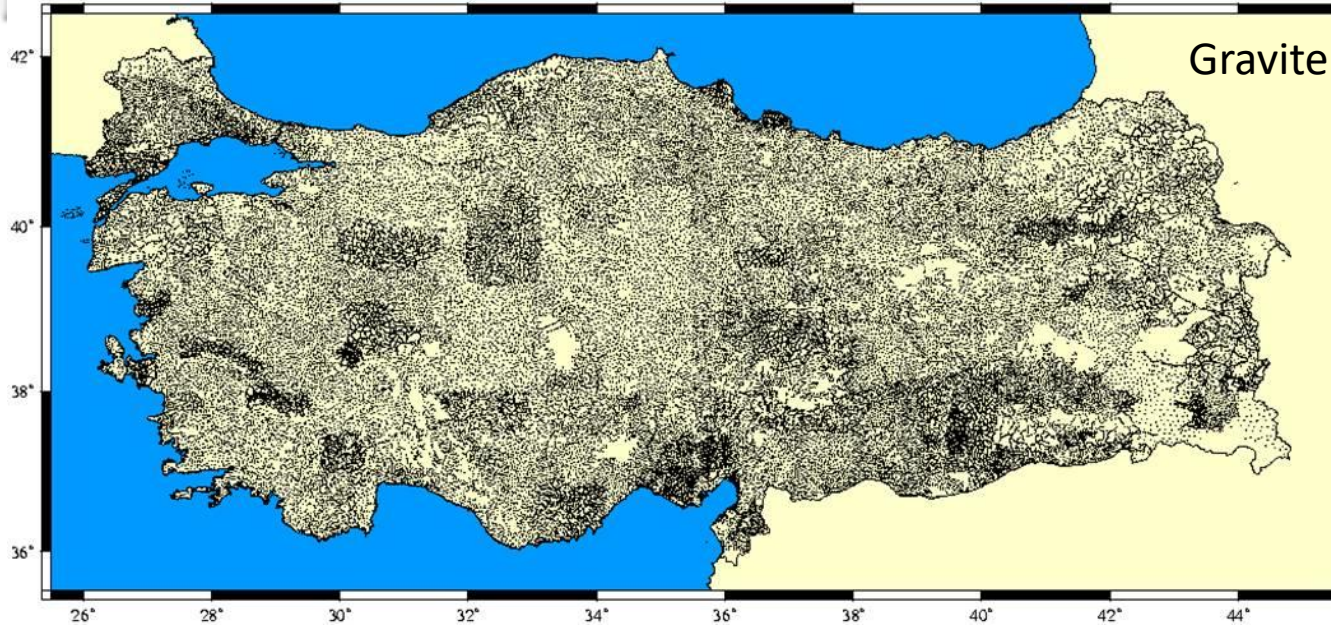
~%70 Tahribat (70% Destroyed due to road enlargements)



Jeodinamik, hidroloji vb. kaynaklı yer değiştirmeler
(Position changes due to geodynamics, hydrology, ...)



Yükseklik Sistemi Modernizasyonu (Height System Modernization)



Gravite : ~288.000

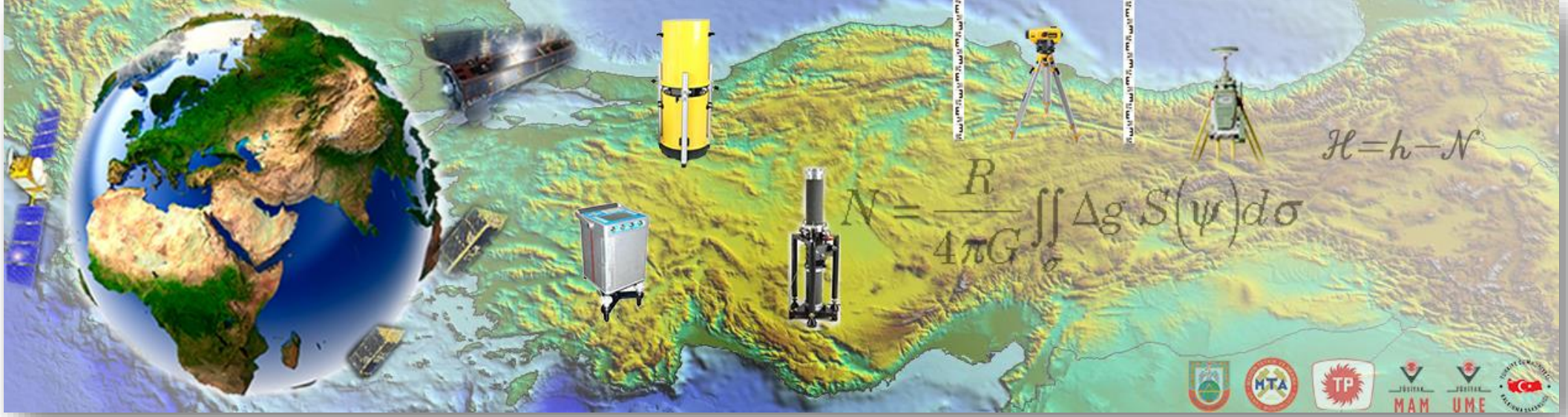
Gravite Aralık : ~ 3 - 5 km (Belirli bölgelerde boşluk)

GNSS/Nivelman : ~3000 (Çoğu kadastro çalışmalarından)

Tutarlılık : ???, Doğruluk : ??? Eş Zamanlı GNSS & Nivelman: ???

!! Problems in historical gravity and GPS/levelling data

Yükseklik Sistemi Modernizasyonu (Height System Modernization)



Türkiye Yükseklik Sisteminin Modernizasyonu ve Gravite Altyapısının İyileştirilmesi Projesi

2015-2020

(2015K090710)

Turkish Height System Modernization & Gravity Recovery Project



Yükseklik Sistemi Modernizasyonu (Height System Modernization)



Hrt.Gn.Md.lüğü



MTA Gn.Md.lüğü



TPAO Gn.Md.lüğü



TÜBİTAK MAM Bşk.lığı



TÜBİTAK UME Md.lüğü



T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı
(Kalkınma Bakanlığı/ Diğer Kamu Harcamaları - Sosyal Şehirleşme Sektörü)

- Kamu altyapı projesi
- 2015 – 2020 (5 yıl) (Duration)
- ~38.5 Milyon TL Bütçe (5 Kurum) (Budget)
- 10 İş Paketi (Work packages)
- Amaç: (Objectives)
 - Türkiye için yüksek çözünürlüklü ve doğruluklu jeoit modeli belirlemek (1-3 cm @ 1-3 km)
 - Gravite veri altyapısını iyileştirmek
- Çıktılar (Outputs)
 - Türkiye Jeoit Modeli-2020
 - Türkiye Gravite Standardizasyon Ağı (TRGRAV-Net)
 - Hava gravimetrisi sistemi
 - Motorize nivelman sistemi
 - Gravimetri laboratuvarı (TRGRAV-Lab)
 - Ulusal gravite veri tabanı ve web portalı (TRGRAV-Web)
 - Bağlı gravimetri indirgeme ve dengeleme yazılımı
 - Hava gravimetrisi analiz yazılımı

Yükseklik Sistemi Modernizasyonu (Height System Modernization)

Bağıl Gravimetri
(Relative Gravimetry)



Mutlak Gravimetri
(Absolute Gravimetry)



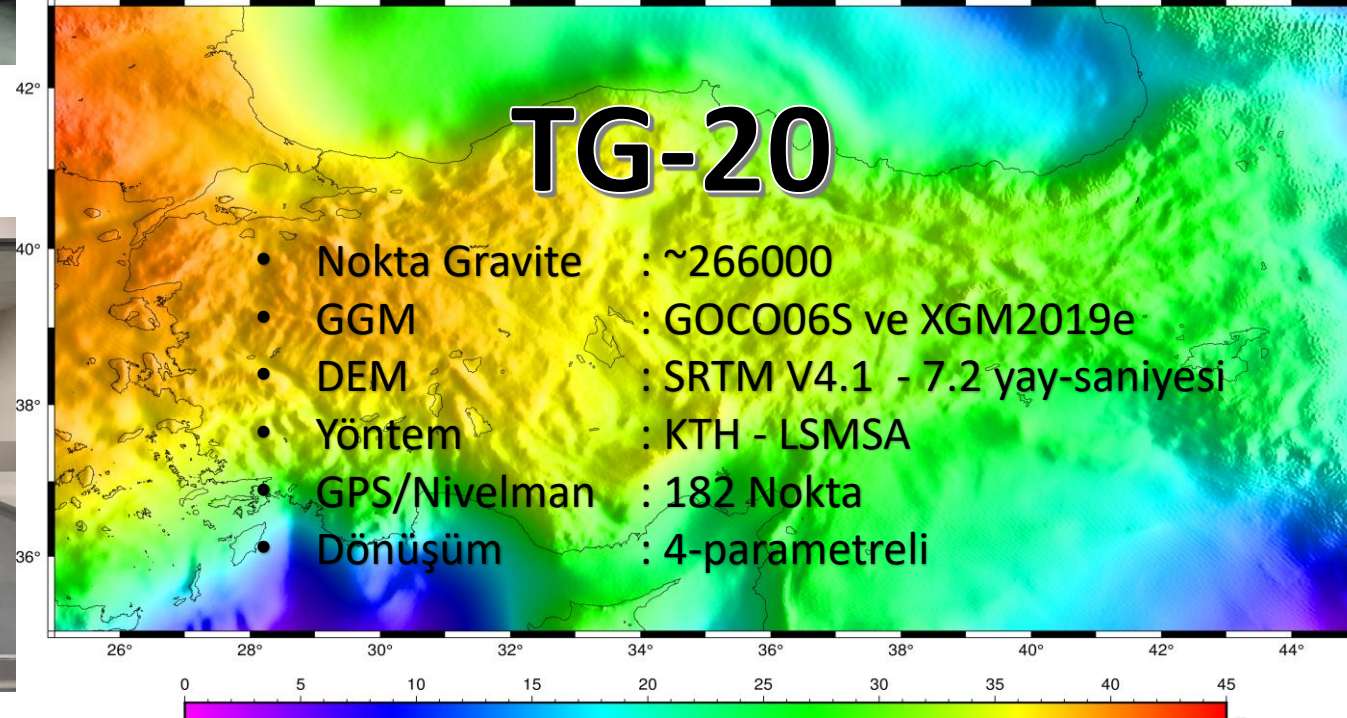
GNSS/Nivelman
(GNSS/Levelling)



Hava Gravimetri
(Airborne Gravimetry)



TRGRAV-LAB



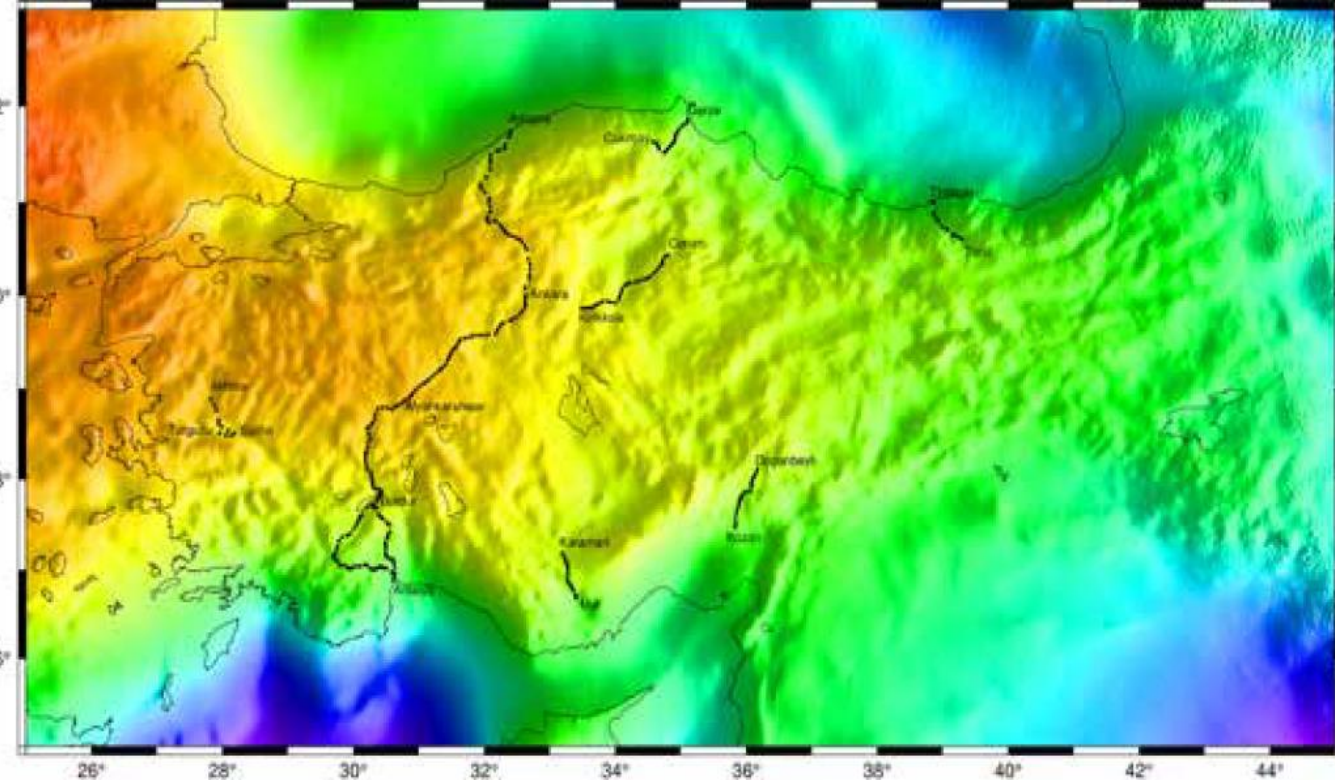
Mutlak Jeoit Testi (Absolute Geoid Test)

$$(N^{TG-20} \stackrel{?}{=} N^{GPS/niv})$$

7 Bağımsız Hat - 278 Nokta - Eş Zamanlı GNSS/Nivelman

(7 new levelling lines with 278 simultaneously measured GNSS points)

Hat (Levelling Line)	Nokta Sayısı #	TG-20 σ [cm]	TG-03 σ [cm]
Antalya – Burdur - Amasra	176	2.8	11.1
Doğانبeyli – Kozan	18	1.8	2.9
Çakırçay – Gerze	17	1.9	4.1
Kırıkkale – Çorum	30	1.3	3.9
Akhisar - Salihli	11	1.3	2.2
Tirebolu - Torul	13	6.3	7.1
Karaman - Mut	13	1.2	3.0



Görelü Jeoit Testi (Relative Geoid Test)

$$\Delta H_{ij}^{Gidiş} \stackrel{?}{=} (\Delta h_{ij} - \Delta N_{ij}^{TG-20})^{Dönüş}$$

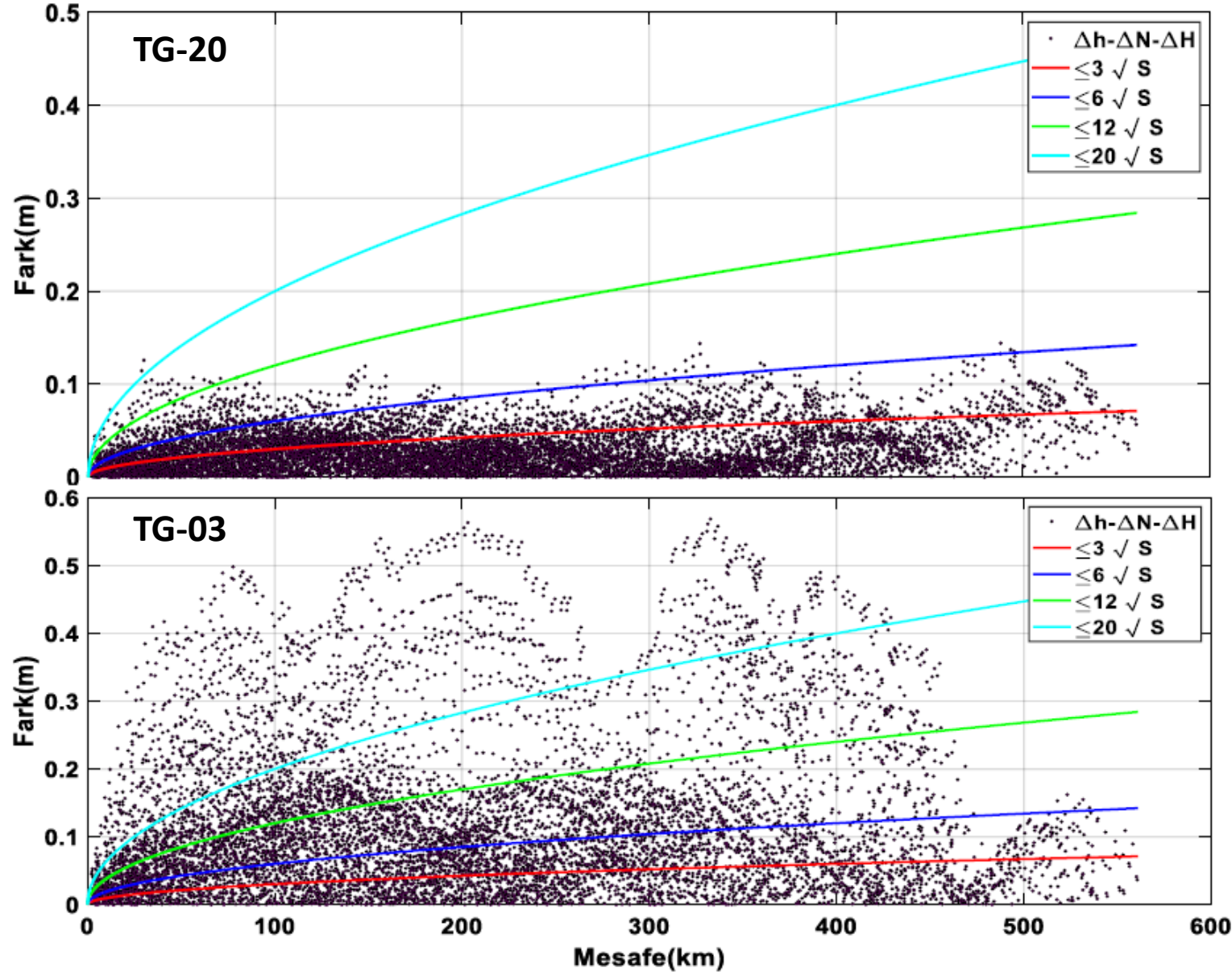
K (Kapanma)

$$\left| \Delta H_{ij}^{Gidiş} - (\Delta h_{ij} - \Delta N_{ij}^{TG-20})^{Dönüş} \right| \stackrel{?}{\leq} \begin{cases} 3 \sqrt{S_{ij}(km)} \\ 6 \sqrt{S_{ij}(km)} \\ 12 \sqrt{S_{ij}(km)} \\ 20 \sqrt{S_{ij}(km)} \end{cases}$$

K (Closure Error)

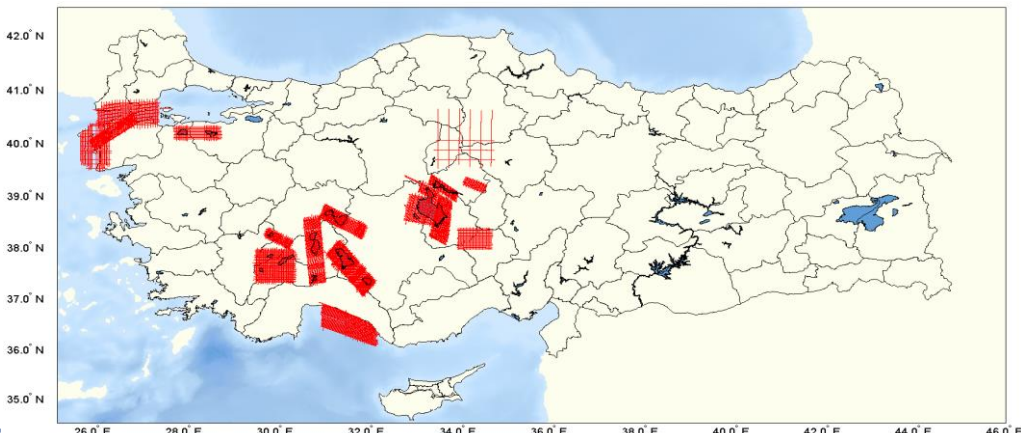
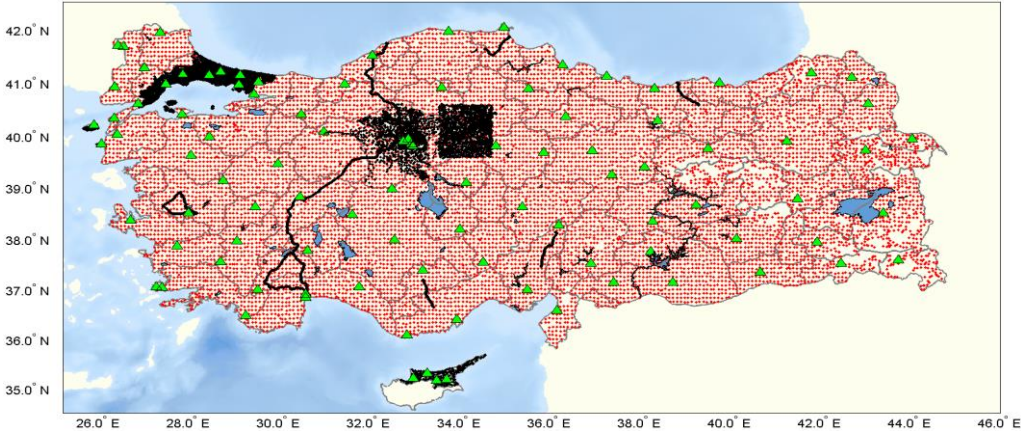
Toplam: 10970 Nokta Çifti (Aralık: ~5 – 550 km)

	TG-20	TG-03
$K \leq 3 \sqrt{S_{ij}(km)}$	7548 (%68.80)	2625 (%23.92)
$K \leq 6 \sqrt{S_{ij}(km)}$	10233 (%93.28)	4831 (%69.69)
$K \leq 12 \sqrt{S_{ij}(km)}$	10850 (%98.90)	7876 (%71.79)
$K \leq 20 \sqrt{S_{ij}(km)}$	10932 (%99.66)	9638 (%87.85)
$K > 20 \sqrt{S_{ij}(km)}$	20 (%0.18)	1332 (%12.15)



Yükseklik Sistemi Modernizasyonu Sonrası (After Project)

Yersel ve Hava Gravimetri Sıklaştırması (Densification)



Mobil Gravimetri (Mobile Gravimetry)



İş Birlikleri (Cooperation)

Harita Genel Müdürlüğü
Hacettepe Üniversitesi



- SANTİMETRE-ALTI BÖLGESEL JEOİT BELİRLEME
- KARA VE DENİZ PLATFORMLARI İÇİN MOBİL GRAVİMETRİ SİSTEMİ GELİŞTİRİLMESİ
- GRAVİTE DÜŞEY GRADYENT ALANI MODELLEME
- JEOİDİN GNSS/NİVELMAN İLE TESTİNDE ÇOKLU GNSS VE PPP KULLANIMI