Paper Title: Man Made Deltas.

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SUPPLEMENTARY INFORMATION

Supplementary S1: Spatially-averaged linear progradation rate.

River deltas are tridimensional bodies composed by multiple sediment lobes whose geometry (shape, thickness and extent) is regulated mainly by the processes controlling sediment accumulation at the river mouth (see Supplementary Information S2), but reflect also the topography of the foundation surface. For this reason, in order to quantify the total volume of sediment stored in a delta, it would be ideal to have a full 3D view of each individual delta lobe and quantify changes in accumulation rates through time by comparing the size of each lobe in terms of decompacted sediment bulk during time-equivalent steps. Unfortunately, in coastal systems this full 3D view is far from being achieved because of the difficulties in carrying out high-resolution geophysical surveys across the land-sea border and obtaining long boreholes in delta plains.

Depending on these limitations, most assessments on delta growth throughout the world literature on deltas are given as averaged linear rates of progradation, derived by the distance between two successive dated delta fronts. Though practical in first approximation, this method has inevitably a number of limitations, as in deltas composed by multiple lobes receiving the exact same amount of sediment per unit of time, seaward lobe progradation primarily reflects the topography of the foundation surface (vertical accumulation vs. horizontal progradation). Variations in the topography of the foundation surface of a high stand delta reflect, typically, the specific coastal or marine environments that have been transgressed, and variably reworked, during phases of the previous sea level rise; few meters of differences can be depending on where transgressive barrier island or coastal sand ridges where preserved, compared to muddy lagoon or inlet deposits (h_1 and h_2 in Figure S1.1).

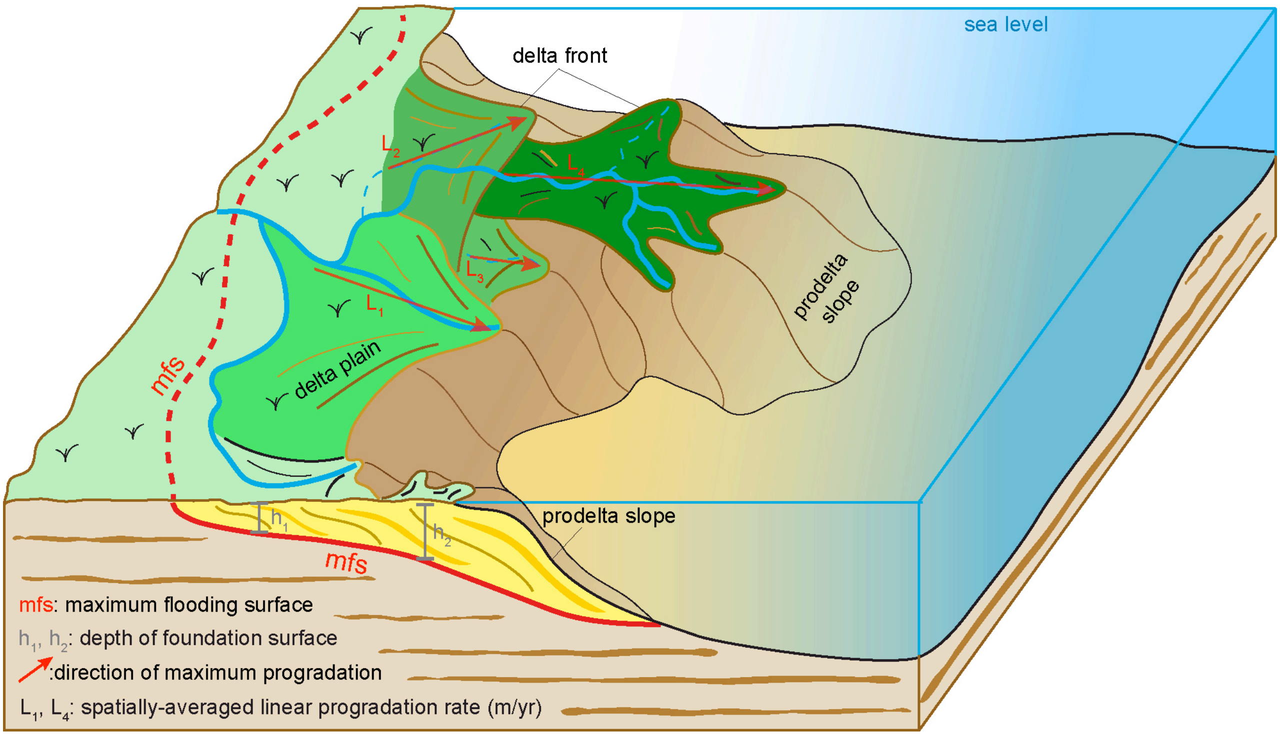

Figure S1.1. **Tridimensional view of delta outbuilding.** Spatially-averaged linear progradation rates are calculated along the maximum direction of progradation (L_1 to L_4, red arrows), and considering the seaward deepening of the foundation surface, i.e. the maximum flooding surface (h_1, h_2).

The spatially-averaged linear progradation rates given in Figure 2 of the main text are calculated along the direction of maximum progradation of each lobe (red arrows in Figure S1.1) considering lateral changes of delta width, approximating the tridimensional delta geometry to a trapezoidal pyramid confined by the maximum flooding surface (mfs) at the base, the subaerial delta plain at the top and the subaqueous prodelta slope seaward (see Fig. S1.2). The spatially-averaged linear progradation rates (L_1 to L_n) are quantified proportionally to the volume (or simplified to the areas, A_1 to A_n) between adjacent control points, such as dated delta fronts (red triangles), given the seaward deepening of the foundation surface (Fig. S1.2 and S1.3 to S1.6). In all four cases the seaward dip of the mfs is comprised between 0.02° and 0.06°, implying an even increasing thickness of the prodelta to maintain a constant progradation rate (1). The presence of an irregular foundation surface related to the morphology of older drowned coastal systems appears negligible in our calculation.

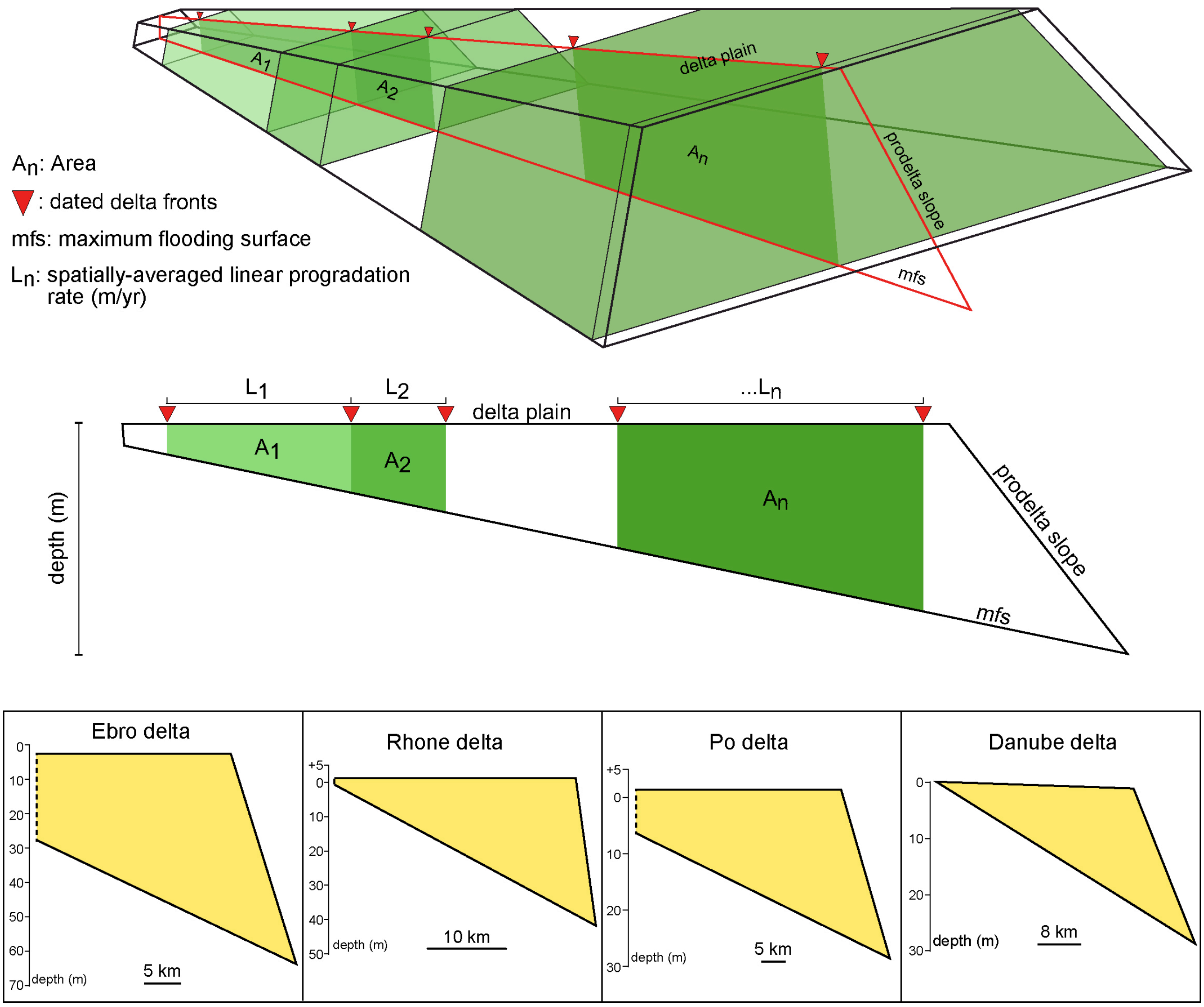

Figure S1.2. **From sediment volume to spatially-averaged linear delta progradation.** The spatially-averaged linear progradation rates (L_1 to L_n) are quantified proportionally to the areas (A_1 to A_n) subtended below adjacent dated delta fronts (red triangles), approximating the cross section of each delta to a triangle. This assumption in supported by the cross sections illustrated in Figures S1.3 to S1.6, derived from boreholes and seismic data.

The following four figures highlight the role of the foundation surface (the maximum flooding surface, mfs) of each delta systems along one (or two perpendicular) cross sections, derived by boreholes and subsurface seismic data.

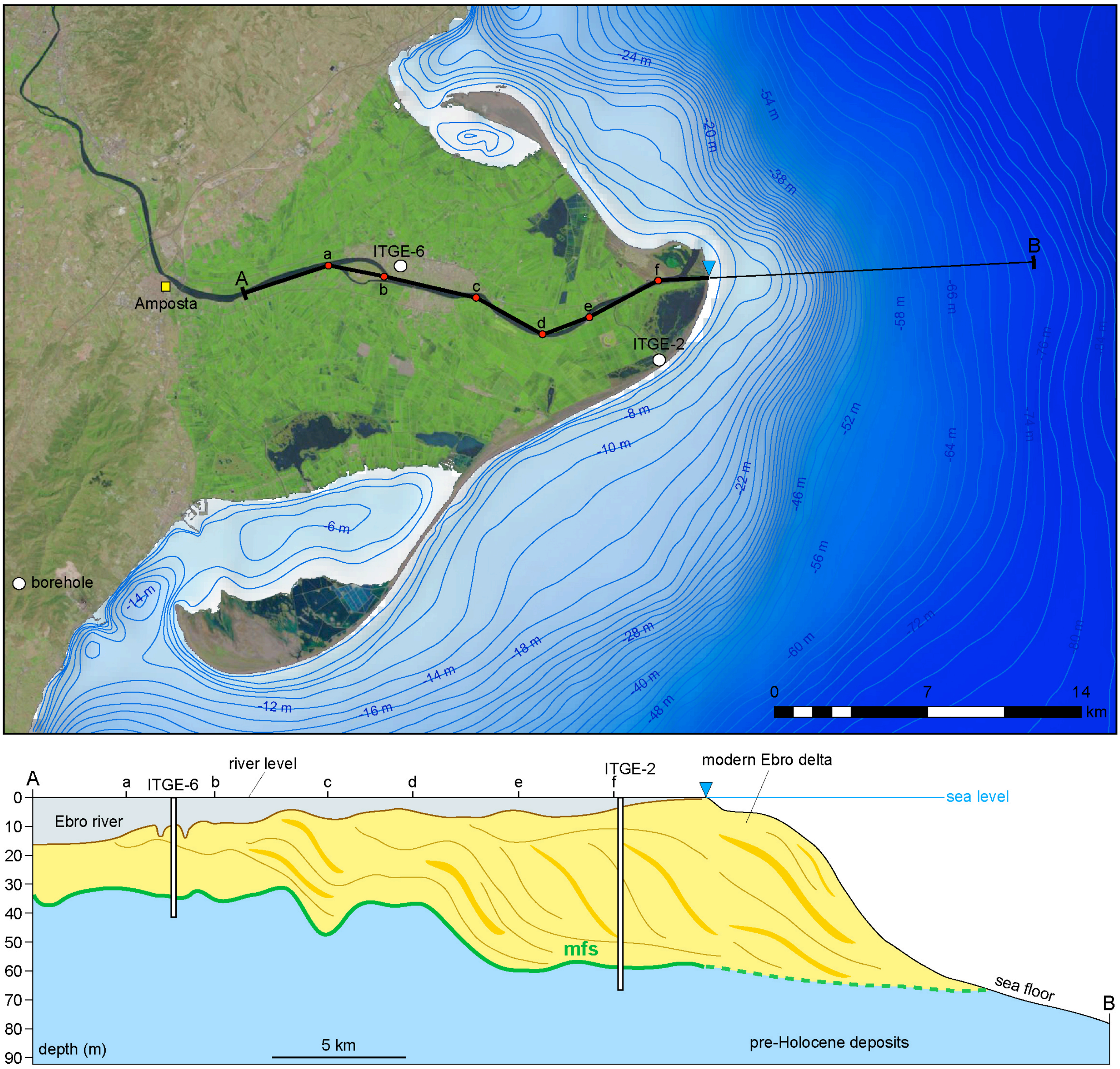

Figure S1.3. Stratigraphy of the Ebro delta. The line drowning is constructed along the direction of maximum progradation by integrating seismic data and the available time lines from boreholes (modified from 2 and 3; aerial view from the Landsat Archive and the Global Land Survey). Note that the foundation surface reflects the occurrence of drowned river valleys and coastal lithosomes. The location of Amposta, a marine harbor during Roman times, pre-dates the first main phase of delta growth.

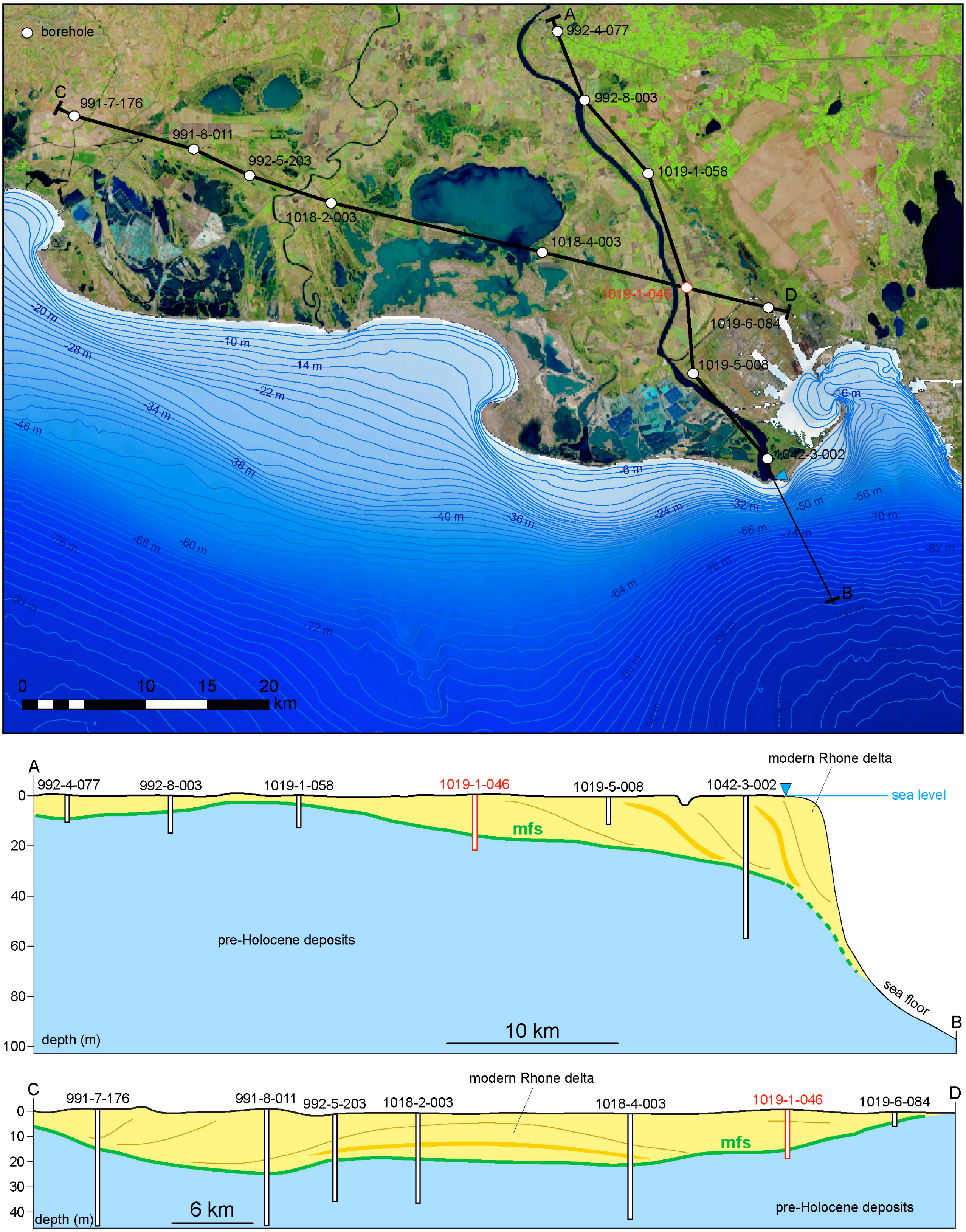

Figure S1.4. **Stratigraphy of the Rhone delta.** Cross sections along and across the main direction of delta advance (4; aerial view from the Landsat Archive and the Global Land Survey). Thickness exceeds 20 m only in the modern Rhone where foundation surface (mfs) becomes steeper. Foundation surface tilts seaward (section AB), while is almost convex up in cross section (section C-D). Tie point between the sections is in red (well 1019-1-046).

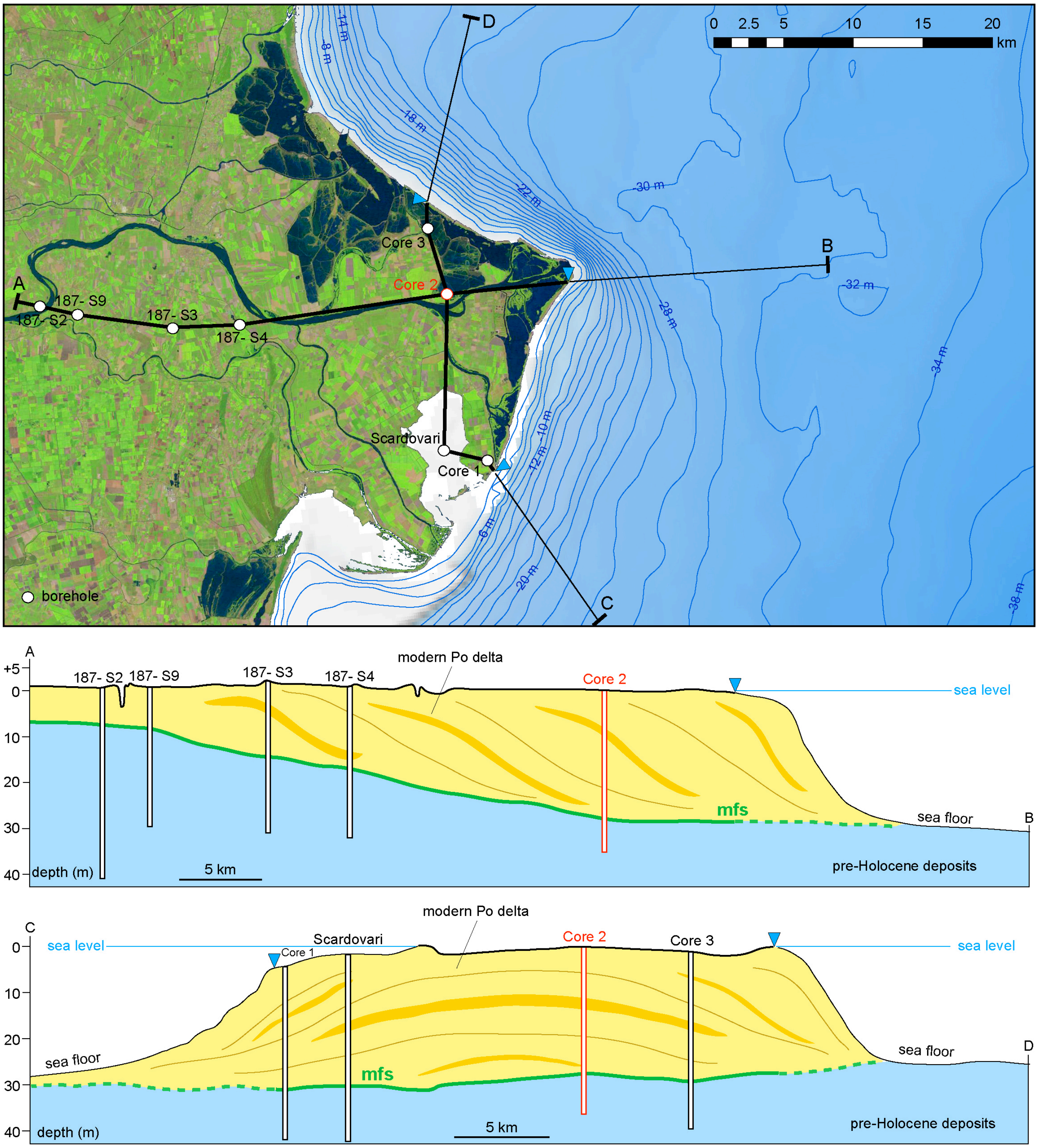

Figure S1.5. **Stratigraphy of the Po delta.** Cross sections along and across the maximum direction of construction of the Po delta (5 and 6; aerial view from the Landsat Archive and the Global Land Survey). Foundation surface tilts seaward (section AB), while is almost sub-horizontal (or slightly convex up) in cross section (section C-D). Modern deposits reach a thickness of about 30 m. Tie point between perpendicular sections is in red (well Core 2).

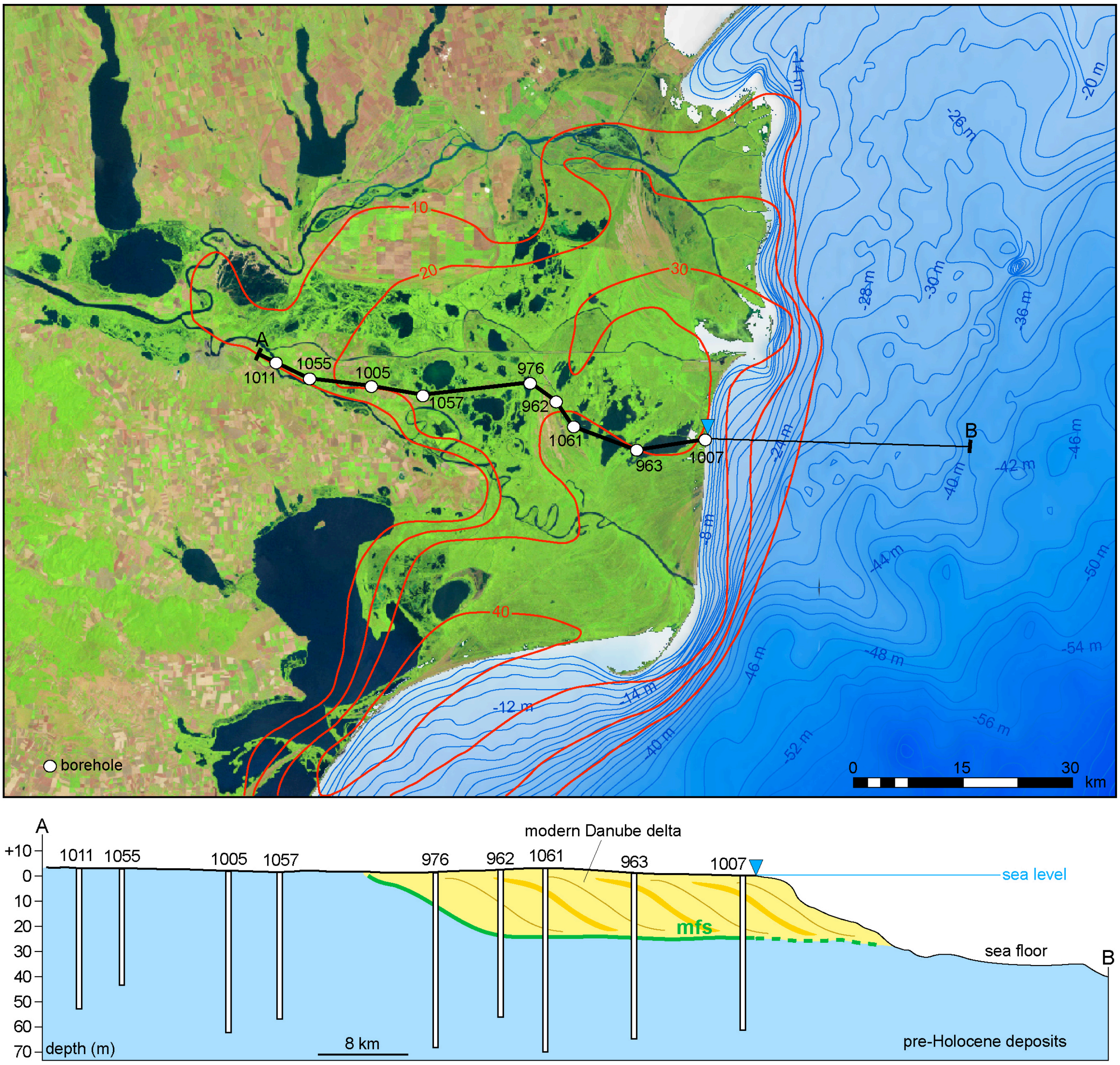

Figure S1.6. **Stratigraphy of the Danube delta.** Cross section along the main direction of delta advance (line drowning modified from 7, isopach contour of deltaic deposits from 8; aerial view from the Landsat Archive and the Global Land Survey).

Moreover, it is important to underline that the quantification of sediment accumulation rates from boreholes or outcrops, as well as for the linear progradation rates of delta lobes, is highly dependent on the length of the time window considered (9). The data presented in Figure 2 are organized using two different time scales, with shorter time steps for the last few centuries when delta progradation is best resolved chronologically. The increased sedimentation rate during the Little Ice Age reflects a real change compared to the preceding interval and is not ascribed to the "Sadler effect" because all the time windows considered are at the same century scale.

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Supplementary S2: Paleoenvironmental constraints.

The twilight zone between life and death of modern deltas reflects the interaction of allogenic and autogenic processes in controlling sediment delivery throughout the river system and storage at the river mouth. Four main parameters determine delta outbuilding:

1- Sediment flux to the coast, mainly controlled by the lithology and morphology of the catchments and by the sediment-transfer processes acting in it (including those driven by humans);
2- Climatic oscillations controlling river discharge, its magnitude and seasonality;
3- Relative sea level oscillations, controlling accommodation space, resulting from the convolution of tectonic subsidence, isostatic rebound, sediment compaction, eustatic oscillations;
4- Oceanography, controlling the energy and field orientation of marine of processes (storms, waves and tides).

In order to quantify the anthropic control on sediment production and, consequently, delta outbuilding it is necessary to take into account the "background" conditions related to climate, relative sea level oscillations and oceanography. While the role of sediment flux oscillations and climate are discussed in the main text, this paragraph is dedicated to possible changes of relative sea level and oceanographic regime during the formation of modern delta systems.

The role of fluvial system in storing sediments in their channel belts in response of perturbation in their equilibrium profile is not addressed in this paper; the results we provide regard only the deltas, the most seaward portion of the fluvial systems. Rivers can delay the signal of enhanced sediment supply to the coastal zone, reflecting perturbations in their drainage basins, by changing their fluvial pattern (1, 2), but this is under the resolution of the data presented (sub-millennial time scale): the result shows a synchronous relation between changes in catchment hydrology and delta outbuilding.

Relative sea level oscillations:

Relative sea level oscillations (RSL) can be quantified by the sum of several processes acting on global, regional and local scales. Here we refer to global processes, as glacial-interglacial eustatic oscillations; regional tectonic processes (i.e. tectonic subsidence, or uplift); local processes, such as sediment compaction, isostatic rebound and anthropically-generated subsidence.

In the interval discussed in this paper (the last 2 thousand year), the eustatic contribute to RSL can be considered uniform and negligible (less than 0.5 m during the last 2 thousands of years, 3).

Regional processes, as tectonic movements related to the geodynamic setting, may provide additional accommodation space, but given the very slow rate of tectonic subsidence, require a longer time window compared to the interval of formation of modern deltas (few thousands of years).

Table 1 shows the values of tectonic subsidence for each delta and the geodynamic contest.

Delta system	Geodynamic setting	Tectonic subsidence	References
Ebro	Passive Margin	0 - 1.5 mm/yr	4, 5
Rhone	Passive Margin	0 - 0.2 mm/yr	6, 7
Po	Active Margin	1 - 2 mm/yr	8, 9
Danube	Passive Margin	1.5 - 1.8 mm/yr (local uplift +0.1mm/yr)	10 (11)

Local processes may be relevant in determining the total subsidence of a delta plain. By definition these values are highly variable in time and space, as they depend on the tridimensional nature of a deltaic system (especially in terms of lithology, thickness and water content). During the few last decades, local natural subsidence (LNS) was strongly enhanced by anthropic water and gas extraction, leading to subsidence rates hundreds of time grater than the natural background values. In table 2 we provide the LNS and the total local subsidence (TLS), taking into account all the processes mentioned above, highlighting also, where possible, the time window of interest.

Delta system	LNS	TLS	References
Ebro	2-4 mm/yr	6 mm/yr (1934-1965)	4, 5
Rhone	2-6 mm/yr	2-6 mm/yr	12
Po	1-10 mm/yr	250 mm/y (1951-1957) 180 mm/y (1958-1962) 33 mm/yr (1962-1967) 37 mm/yr (1967-1974) 16 - 23 mm/yr (1987-1993, Goro Area) 1-10 mm/yr (locally up to 20 mm/yr, 1992-2000)	9, 13
Danube		2-5 mm/yr	11

Oceanography:

The oceanographic regime of the Mediterranean and Black sea is the main driver for sediment dispersal, leading in recent times to generalized delta erosion. On the scale of the late Holocene, the intensity of marine processes, in term of waves and tides, could be considered uniform as primarily related to the size of the basin and to gravitational phenomena (14). Of course the generalized dearth of sediment supply to the coast over the last 100 yr confers to waves and coastal currents a greater relative efficacy in impeding or limiting the delta growth. When referring to storm power, which is primarily related to climate, Sorrel et al. (2012) highlights that during the mid to late

Holocene increased storm activity occurred with a period of about 1500 yr along the Atlantic French coasts, in phase with the internal ocean variability of the North Atlantic (15). The same periodicity (4500-3950, 3300-2400, 1900-1050, 600-250 yr cal BP, reported in Figure 3 in the Article) was observed at the scale of the Mediterranean Sea (16). Comparing those intervals with the timing of delta growth recognized in this paper (2250-1500 and 300-0 yr cal BP) it possible to note that delta progradation occurred both in intervals of high storm activity (Roman Empire) and low storm activity (the second half of the Little Ice Age), supporting the hypothesis that human forcing is the main driver for modern delta growth.

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Supplementary S3: Supplementary Information of Figure 1, 2, and 4.

Geomorphological reconstruction of the growth phases of the four deltas (summarized on the aerial views of Figure 1), their spatially-averaged linear progradation rates (Figure 2) and the suspended sediment load and water discharge for the last century (Figure 4) are obtained from the reference list reported below. The chronological constraints used to quantifying the spatially-averaged linear progradation rates of Figure 2 are derived from all the data provided by the literature reported below. In the case of contrasting chronologies for the same delta lobe in a given delta system, we refer to the most recent publication, under the assumption that dating techniques and awareness about the possible dating artefacts have greatly improved over the last two decades.

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Long-term fluvial discharges are derived from the Global Runoff Data Centre (GRDC, http://www.bafg.de/cln_031/nn_294622/GRDC/EN/Home/homepage__node.html?__nnn=true).

Supplementary S4: Delta plain evolution during the last 40 yr.

The impact of anthropic reservoirs, dams construction and river trunk excavation on land-sea sediment transport is reflected in the evolution of delta systems. By comparing Satellite images (derived from the Landsat Archive and the Global Land Survey (http://earthexplorer.usgs.gov) of the four largest southern European deltas, it is possible to quantify the amount of ground-loss or gain through GIS analyses for the interval 1972-2011. In the third column of Figure S4.1 the difference between the oldest and the youngest satellite images available for each deltas is reported, highlighting in blue newly formed subaerial terrains and in red eroded ones. In this way it is possible to estimate the amount of delta gain or loss at the delta front. The green arrows in Figure 4.1 denotes areas where the actual subaerial extent appears particularly difficult to determine, due to the occurrence of algal blooms (Chilia III, Danube Delta) or to artificially induced evaporation (Rhone Delta).

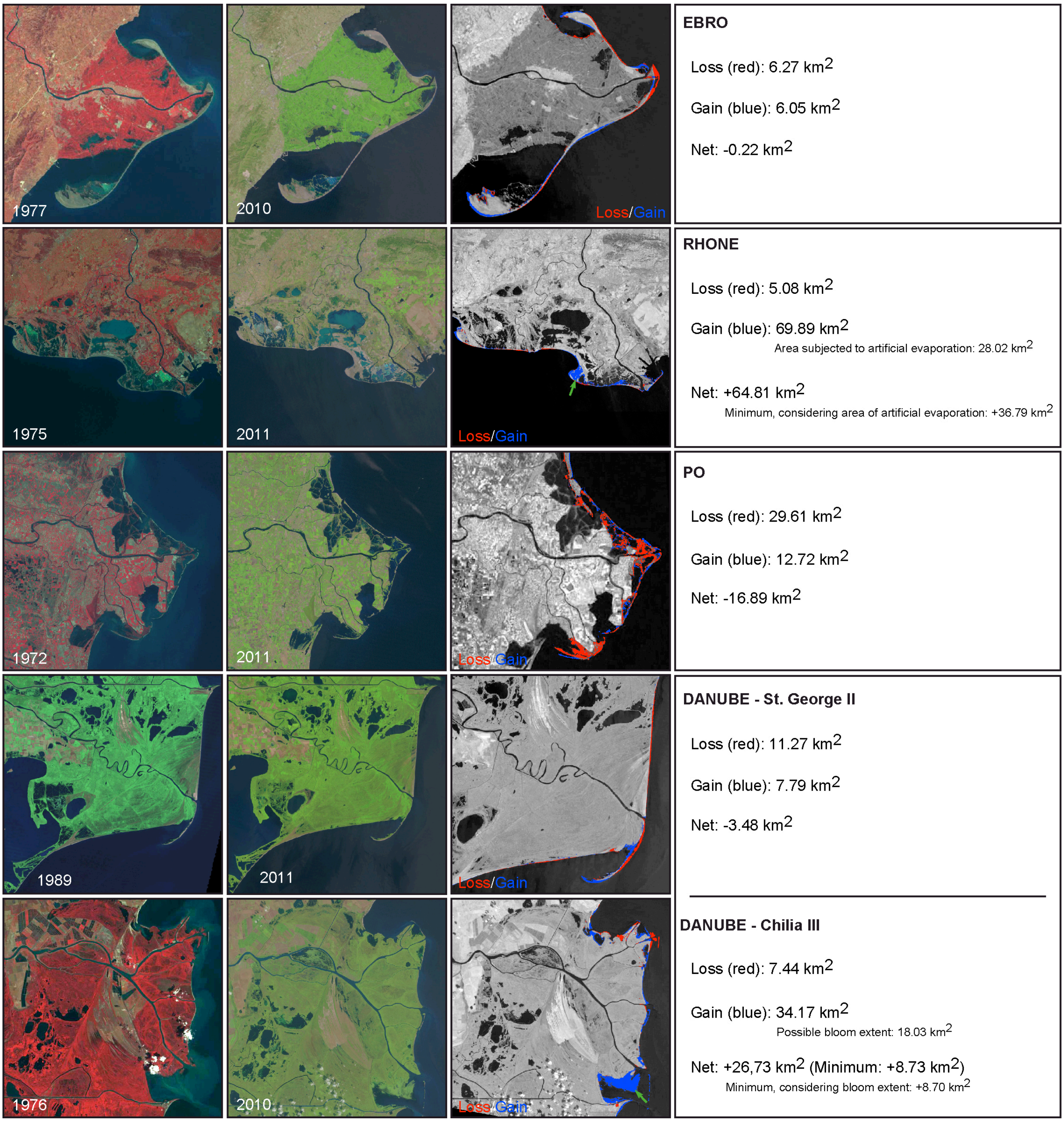

Figure S4.1. Loss/Gain area of delta front in the last 30 years. GIS supported analyses allow quantification of the amount of delta front areas that are lost (in red) or gained (in blue) in the last few decades for the main apparatuses of the four main northern Mediterranean and Black Sea deltas (aerial view from the Landsat Archive and the Global Land Survey).

Supplementary S5: Supplementary Information of Figure 1.

Digital elevation data are from the NASA Shutter Radar Topographic Mission (SRTM) with 3 arc second (90 m) resolution, available at http://srtm.csi.cgiar.org.

River drainage basins are from the "Global River Basins" of the WaterBase Project (http://www.waterbase.org/download_data.html).

Location and age of construction of European dams (see Figure 4) are form the Global Reservoir and Dam Database (GRanD), available at http://www.gwsp.org; see also the reference:

Lehner, B., Reidy Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., Döll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rödel, R., Sindorf, N., Wisser, D., 2011. High resolution mapping of the world's reservoirs and dams for sustainable river flow management. Frontiers in Ecology and the Environment, 9, 494-502.

Aerial pictures of the four largest southern Europe deltas are from the Landsat Archive and the Global Land Survey (http://earthexplorer.usgs.gov).